Test Plan

For

The Massachusetts Septic System Test Center

For Verification Testing
Of
F.R. Mahony Amphidrome™ Model "Single Family Unit"
Nutrient Reduction Technology

Prepared for
National Sanitation Foundation International
And
Environmental Technology Verification Program
of the
US Environmental Protection Agency

Prepared by
Newton Millham, Westport Water Resources
672 Drift Road
Westport, MA 02790

January 22, 2001

Executive Summary

This Test Plan is designed to verify nutrient reduction of the F.R. Mahony Amphidrome™ treatment technology under the US EPA Environmental Technologies Initiative Source Water Protection Program. The verification testing will be conducted by the Barnstable County Department of Health at the Massachusetts Septic System Test Center. During the testing, The F.R. Mahony Amphidrome™ technology will be loaded with influent wastewater from a sanitary sewer at the design hydraulic rate of 400 gpd.

The period of testing will consist of an eight-week startup period, and a twelve-month testing period incorporating five stress periods with varying stress conditions, simulating real household conditions.

Monitoring of nutrient reduction will be by measurements of constituents, which demand oxygen for treatment (BOD and CBOD), and nitrogen species (TKN, NH_4, NO_2, NO_3). Operational characteristics such as electric use, labor to perform maintenance, maintenance tasks, durability of the hardware, noise and odor production will be monitored.

The Plan includes a QAPP outlining the QA/QC measures incorporated into the Test Plan experimental design.

Deliverables from the monitoring will be in the form of sampling event reports, water quality data summary reports, an operation and maintenance report and a QC and analytical report.

Technology Description

The Amphidrome™ model "Single Family Unit " system is an example of a biologically aerated filter also known as a sequencing batch reactor.

The Amphidrome™ Process

The Amphidrome™ process is an advanced biological treatment that utilizes an attached growth culture. This process is designed for the removal of soluble organics, for nitrification and for denitrification to occur simultaneously, in a single reactor. Major components of the technology include: the anoxic/equalization tank; the Amphdrome™ reactor vessel; and the clear well.

The process begins operating in an aerobic mode and gradually progress to an anoxic mode. The process system is cyclical. A batch of wastewater passes from the anoxic/equalization tank through the granular biological filter into the clear well. Then, the batch of wastewater is pumped back from the clear well up through the filter, where it overflows into a trough that carries it back to the anoxic/equalization tank. These cycles are repeated multiple times, while the treatment is allowed to progress from aerobic to anoxic conditions within the filter. Once sufficient cycles have been repeated to insure the degree of treatment required, a batch of effluent is discharged.

The Amphidrome™ reactor consists of the following four items: underdrain, support gravel, filter media, and backwash trough. The underdrain, constructed of stainless steel, is located at the bottom of the Amphidrome™ reactor and provides support for the media and distribution of liquid into the reactor, during a reverse flow, or backwash. It is also designed as a manifold to distribute air evenly over the entire filter bottom during the aerobic portion of the cycle. While operating aerobically, air is pumped from above, into a common pipe at the center of the underdrain. The air enters the underdrain via a lateral distribution header, from there into channels that distribute the air evenly throughout the bottom of the reactor. As the air flows up through the media the bubbles are sheared by the sand forming finer and finer bubbles.

On top of the underdrain is approximately 18" of gravel. Several layers of different size gravel are used. Above the gravel there is a deep bed of coarse, round silica sand. The deep bed filter design employed in this manner is multi-functional. First, it functions as a filter to significantly reduce suspended solids. Second, it serves as a media to which an attached growth bacterial population can be maintained.

Biochemical Reactions

The following simplified reactions are typical of any biochemical reactor designed to remove soluble organic matter, (i.e. carbonaceous matter) and the inorganic nutrient nitrogen. However, in the Amphidrome™ process the goal is to promote all of the reactions simultaneously.

The equations governing the removal of soluble matter and ammonification are as follows:

1) $COHNS + O_2 + \text{nutrients} \Rightarrow CO_2 + NH_3 + C_5H_7O_2N + \text{other end products}$
(organic matter) (new cells)

2) $C_5H_7NO_2 + 5O_2 + \Rightarrow 5CO_2 + 2H_2O + NH_3 + \text{energy}$

Equation one accounts for the biodegradation of organic matters, including ammonification, and cell synthesis. Equation two represents the endogenous respiration of the biomass. The carbon source for cell synthesis is provided from an organic compound; therefore, the bacteria are heterotrophic. The equations also indicate that oxygen is required for both reactions to occur.

Nitrifying bacteria are autotrophic microorganisms that obtain their energy from the oxidation of nitrogen. Below are the two equations for nitrification.

3) $55NH_4^+ + 76O_2 + 109HCO_3^- \Rightarrow C_5H_7O_2N + 54NO_2^- + 57H_2O + 104H_2CO_3$

4) $400NO_2^- + NH_4^+ + 4H_2CO_3 + HCO_3^- + 195O_2 \Rightarrow C_5H_7O_2N + 3H_2O + 400NO_3^-$

Equation three describes the oxidation of ammonia to nitrite by the bacteria Nitrosomonas. Equations four describes the oxidation of nitrite to nitrate by the bacteria Nitrobacter. As the equations indicate both steps must occur in an aerobic environment.

The final step in the removal of nitrogen from the waste stream occurs when the nitrates produced in the nitrification process are converted to nitrogen gas by the process of denitrification, described below:

5) $NO_3^- + 2CH_3OH \Rightarrow 6NO_2^- + 2CO_2 + 4H_2O$

6) $6NO_2^- + 3CH_3OH \Rightarrow 3N_2 + 3CO_2 + 3H_2O + 6\ OH^-$

7) $6NO_3^- + 5CH_3OH \Rightarrow 5CO_2 + 3N_2 + 7H_2O + 6\ OH^-$

The above equations show methanol as the organic carbon source. However, in a single, family system methanol is not used. Denitirification is achieved by recycling nitrified wastewater back to the anoxic equalization tank to mix it with the incoming carbon load. The waste stream then flows through Amphidrome™ reactor under anoxic conditions. Therefore, for a single, family system, the above equations require a modification regarding the carbon source. However, pedagogical purpose the equations are correct. Equation five is an energy reaction in which nitrate is converted to nitrite. Equation six is also an energy equation for which nitrite is converted to nitrogen gas. The overall reaction is shown in equation seven.

In the Amphidrome™ process, the aerobic portion of the cycle is designed to promote the reactions indicated by equations 1 - 4. The purpose of the return cycles is to bring nitrified waste back to the anoxic/equalization tank where denitrification will be possible. However, in the anoxic equalization/tank the organic carbon source may be from the waste stream itself. The process is allowed to gradually progress from aerobic to anoxic within the Amphidrome™ reactor. When the reactor attains an anoxic mode then denitrification, as described in equation seven will occur in both the bioreactor and the anoxic/equalization tank.

ACRONYMS

BCDHE	Barnstable County Department of Health and the Environment
BOD_5	biochemical oxygen demand (five day)
$CBOD_5$	carbonaceous biochemical oxygen demand (five day)
COC	chain-of-custody
EPA	United States Environmental Protection Agency
ETV	Environmental Technology Verification Program
GAI	Groundwater Analytical Inc.
MA SSTC	Massachusetts Septic System Test Center
mg/L	milligrams per liter
NELAC	National Environmental Laboratory Accreditation Council
NIST	National Institute of Standards and Technology
NSF	NSF International
PQL	practical quantitation limit
QA	quality assurance
QAPP	quality assurance project plan
QC	quality control
RPD	relative percent difference
SOP	standard operating procedure
TKN	total Kjeldahl nitrogen

Table of Contents

1.0 Introduction

This Test Plan sets forth the experimental design, methods, measurements, Quality Assurance/Quality Control measures and reports which will be used the Barnstable County DeparTMent of Health and the Environment to test and verify the nutrient removal performance of the F.R. Mahony Amphidrome^{TM} wastewater treatment technology.

1.1 Background

1.1.1 Nutrient Reduction

Verification of residential wastewater treatment technologies under the ETV Source Water Protection Pilot's Protocol for Residential Nutrient Reduction Technologies is designed to verify the nutrient removal performance of residential wastewater treatment technologies. In addition, the removal of the oxygen-demanding contaminant load present in domestic wastewater by these technologies will be verified.

The reduction of nutrients in wastewater discharged within watersheds is desirable from two standpoints: first, reduction of watershed nitrogen inputs helps meet drinking-water quality standards for nitrate and nitrite; and second, the reduction of both nitrogen and phosphorus helps protect the water quality of receiving surface and ground waters from eutrophication and the consequent loss in ecological, commercial, recreational and aesthetic uses of these waters.

Technologies, which remove nutrients in on-site domestic wastewater, include the following types of biologically mediated technologies: aerobic trickling filters, aerobic submerged media filters, sand filters, peat filters, and soil absorption-based technologies. Removal of nutrients can also be accomplished chemically through the use of ion-exchange filters and chemical precipitation systems.

1.1.2 Verification Testing

The verification testing consists of the installation of a single residential wastewater treatment technology at the MA Septic System Test Center. The testing facility has a source of suitable domestic wastewater. The technologies will be dosed daily with wastewater at a rate of 100% of their rated capacity using a daily flow-pattern which mimics the generation of wastewater in a residence. An eight-week startup period will be followed by a twelve-month testing period.

Sampling frequency is monthly with additional five stress periods incorporating higher frequency sampling.

1.1.3 Testing Objectives

The testing objectives include the verification of the nutrient removals, removals of other oxygen-using contaminants and operational characteristics. Reduction in influent wastewater contaminants will be determined by laboratory analysis. Nutrient analytes include ammonia-N, nitrate-N, nitrite-N, and total Kjeldahl N. Other parameters to be measured include both CBOD and BOD, suspended solids, pH, temperature, alkalinity, and dissolved oxygen.

Testing will include the collection of operation and maintenance characteristics of the technology including the performance and reliability of technology components and the level of required operator maintenance. The test will identify and assess environmental inputs and outputs including chemical usage, energy usage, generation of byproducts or residuals, noise and odors.

1.1.4 Test Site Description

The Massachusetts Septic System Test Center is located at Otis Air National Guard Base, Bourne, MA. Domestic wastewater is supplied from a sanitary sewer serving Base residential housing and other military usage buildings. Average influent wastewater characteristics are as follows: BOD_5 = 181 mg/L, std. dev. = 61, n = 93; TSS = 159 mg/L, std. dev. = 59, n = 81; Total Nitrogen = 34.4 mg/L, std. dev. = 4.6, n = 61; alkalinity = 168 mg/L, std. dev. = 27.5, n = 58; pH = 7.37, std. dev.. = 0.13, n = 88. Influent wastewater is pumped to a central dosing channel at the rate of approximately 26,000 gallons per 18 hour daily cycle. Raw wastewater circulates through the dosing channel and excess wastewater, approximately 20,000 gallons, is returned by gravity to the sanitary sewer for treatment at the Base wastewater treatment plant. Within the dosing channel there are four circulation pumps which keep wastewater constantly flowing within the channel to ensure the suspension of solids and equal quality of wastewater at all points within the channel. Dosing is accomplished by individual pumps, one per technology, set in the dosing channel. Volumetric doses are controlled by a programmable logic controller, and occur in 15 equal dosing events of between 22 and 33 gallons per dose depending upon technology rated capacity.

1.1.5 Equipment Capabilities and Description

Bioreactor Configuration

The Amphidrome™ Model "Single Family Unit" is an example of a biologically aerated filter. The equipment consists of an microprocessor/control panel, an anoxic/equalization tank (volume, 1,500 gallons), the Amphidrome™ reactor vessel (volume, ~19 ft^3), and a clear well, (volume, 517 gallons). Process air and backwash air is supplied by a 1/3 hp 115 VAC air blower, recirculation is by a 1.5 hp 3 phase pump and discharge of treated effluent is by a 1.5 hp, 3 phase pump.

The Amphidrome™ Process

The Amphidrome™ process is an advanced biological treatment that utilizes an attached growth culture. This process is designed for the removal of soluble organics, for nitrification and for denitrification to occur simultaneously, in a single reactor. Major components of the technology include: the anoxic/equalization tank; the Amphdrome™ reactor vessel; and the clear well.

The process begins operating in an aerobic mode and gradually progress to an anoxic mode. The process system is cyclical. A batch of wastewater passes from the anoxic/equalization tank, through the granular biological filter into the clear well. Then, the batch of wastewater is pumped back from the clear well up through the filter, where it overflows into a trough that carries it back to the anoxic/equalization tank. These cycles are repeated multiple times, while the treatment is allowed to progress from aerobic to anoxic conditions within the filter. Once sufficient cycles have been repeated to insure the degree of treatment required, a batch of effluent is discharged.

The Amphidrome™ reactor consists of the following four items: underdrain, support gravel, filter media, and backwash trough. The working volume of the reactor is 18.84 ft^3, of which 12.56 ft^3 , is gravel and sand filter media; 6.28 ft^3 is transient liquid storage above the media column. The underdrain, constructed of stainless steel, is located at the bottom of the Amphidrome™ reactor and provides support for the media and distribution of liquid into the reactor, during a reverse flow, or backwash. It is also designed as a manifold to distribute air evenly over the entire filter bottom during the aerobic portion of the cycle. While operating aerobically, air is pumped from above by a 1/3 horsepower blower, into a common pipe at the center of the underdrain. The air enters the underdrain via a lateral distribution header, from there into channels that distribute the air evenly throughout the bottom of the reactor. As the air flows up through the media the bubbles are sheared by the sand forming finer and finer bubbles.

On top of the underdrain is approximately 18" of gravel. Several layers of different size gravel are used. Above the gravel there is a deep bed of coarse, round silica sand. The deep bed filter design employed in this manner is multi-functional. First, it functions as a filter to significantly reduce suspended solids. Second, it serves as a media to which an attached growth bacterial population can be maintained.

1.2 Critical Measurements

1.2.1 Critical measurement

For this test plan we define a critical measurement as a measurement whose absence would significantly lower the confidence in the data and would affect the ability to verify system performance. In the event data is lost or is deemed otherwise unacceptable, critical measurements must be repeated within a time period which would allow substitution so as not impair the final data set.

> Critical measurements of the verification plan fall into two categories: 1) measurement and characterization of the nutrient and other contaminant removal performance of the technologies; and 2) measurements and observations of technology operational characteristics.

1.2.2 Data Quality objectives

Data quality objectives for the first category in 1.2.1 above include the acquisition of sufficient correct analytical measurements of contaminant removal performance, in order to credibly characterize the long-term removal performance of the technology under varying climatic conditions.

The principal users of this data will be the technology vendor, F.R. Mahony, Inc. to gain regulatory approvals for use in marketing. Secondary users of this data will be the various state, regional and local approving and planning authorities in the United States. Likely secondary data users also will include system installation engineers and designers and consumers.

Data quality objectives for the second category 1.2.1 are the development of sufficient correct operational and environmental data about the technology to characterize the reliability, cost and environmental operational characteristics (i.e., noise and odor) of the technology. The principal users of this data are consumers and designers. Secondary users for the information are state, regional and local approving and planning authorities in the United States

1.2.3 Data quality indicator goals
Data quality indicator goals are to be met through the use of certified laboratories using EPA or Standard Methods with appropriate QA/QC for all off-site analyses. Field measurement data quality indicator goals are to be met through the use of Standard Methods and application of a QA/QC plan for the field testing.

1.2.4 Testing plan schedule
The testing plan schedule includes three phases: 1) a pre-installation communication between the verification organization, testing organization and the participating vendor, (F.R. Mahony, Inc.) and installation of the technology, already installed at the MA SSTC; 2) the start-up period of up to eight weeks wherein F.R. Mahony, Inc. is provided with time for the technology to come to a steady-state operational condition; F.R. Mahony has the option of indicating when the technology is ready to begin testing. 3) The twelve-month operational testing period. A detailed weekly schedule of the testing period is provided in Table 3 – 2.

1.2.5 Milestones
Milestones for the testing include: 1) the completion of start-up; 2) the completion of the startup period (up to eight weeks); 3) the completion of the twelve month testing period; and 4) the reporting of data.

2.0 Project Organization

U.S. Environmental Protection Agency (EPA):

Project Officer, ETV Source Water Protection Pilot: Ray Frederick, Urban Watershed Branch, Water Supply & Water Resources Division, NRMRL U.S. EPA, 2890 Woodbridge Ave., Edison, NJ 08837-3679 732-321-6627 frederick.ray@epa.gov

NSF International (NSF): P.O. Box 130140, Ann Arbor, MI 48113-0140 734-769-8010

Project Manager, ETV Source Water Protection Pilot: Tom Stevens 734-769-5347 stevenst@nsf.org

Project Coordinators, ETV Source Water Protection Pilot: Maren Roush 734-827-6821 mroush@nsf.org; Michelle Forcier, 734769-5277, forcier@nsf.org.

Testing Organization (TO): Barnstable County Department of Health and the Environment (BCDHE); Superior Court House (P.O. Box 427), Barnstable MA 02630 508-375-6000

Project Manager: George Heufelder, Barnstable County Department of Health and the Environment (BCDHE), 508-375-6616, gheufeld@capecod.net

BCDHE Laboratory Manager: Thomas Bourne, Barnstable County Department of Health and the Environment (BCDHE) 508-375-6606 @capecod.net

Sub-contract Laboratory: Groundwater Analytical, Inc. (GWI) 228 Main St. Buzzards Bay, MA 02532

GAI Laboratory Manager: Eric Jensen; 508-759-4441

Facility Operations Manager: Sean Foss, Barnstable County Department of Health and the Environment (BCDHE), 508-563-6757, sfoss@capecod.net.

Project QA Officer: Thomas Bourne 508-375-6606

3.0 Experimental Design

3.1 Test Conditions

The F.R. Mahony Amphidrome™ Model "Single Family Unit" shall be assembled, installed and filled in accordance with the F.R. Mahony, Inc.'s specifications at the Massachusetts Septic System Test Center (MASSTC). F.R. Mahony, Inc. shall inspect the system for proper installation, and if no defects are detected and the system is determined to be structurally sound it shall be placed into operation in accordance with F.R. Mahony, Inc.'s 'start up procedures". If F.R. Mahony, Inc. does not provide a filling procedure, 2/3 of the system's capacity shall be filled with water and the remaining 1/3 shall be with residential wastewater.

When possible, electrical or mechanical defects shall be repaired to prevent evaluation delays. All repairs shall be recorded in the test log.

3.1.1 System Operation
The system shall be operated in accordance with F.R. Mahony, Inc.'s instructions. Routine service and maintenance of the system shall not be permitted during the performance and evaluation period unless specified in the O&M manual by F.R. Mahony, Inc.

3.1.2 Phases of Testing
The system shall undergo design loading of wastewater for a minimum of one (1) year following a maximum start-up period of eight (8) weeks. When the technology performance has stabilized during the start-up period, F.R. Mahony, Inc. shall advise the Testing Organization that the evaluation period can commence. This notice shall be in writing to the Verification Organization. The one-year evaluation period duration will allow for an assessment of the impact of seasonal variations on performance.

3.1.3 Influent Flow Pattern
The influent flow dosed to individual technologies will be through the use of timed pump operation and will conform to the following pattern as representative of a typical residence(s) scenario:

6 a.m. – 9 a.m.	approximately 33% of total daily flow in 5 doses
11 a.m. – 2 p.m.	approximately 27% of total daily flow in 4 doses
5 p.m. – 8 p.m.	approximately 40% of total daily flow in 6 doses

Total daily flow shall be within 100% ± 10% of the rated capacity of the technology (F.R. Mahony Amphidrome: 440 gallons per day) undergoing testing based on a thirty (30) day average with the exception of periods of stress testing described in Section 3.1.4. Influent dosing pumps are controlled by a programmable logic controller which permits timing of the fifteen individual doses to the second.

3.1.4 Stress Testing
One stress test shall be performed following every two months of normal operation during the technology evaluation, so that each of the five stress scenarios is addressed within the twelve (12) month evaluation period.

Stress testing shall involve the following simulations:

Wash-day stress
Working parent stress
Low-loading stress
Power/equipment failure stress
Vacation stress

Wash-day stress simulation shall consist of three (3) wash-days in a five (5) day period with each wash-day separated by a 24-hour period. During a wash-day, the technology shall receive the normal flow pattern (Section 3.1.3); however, during the course of the first two (2) dosing periods per day, the hydraulic loading shall include three (3) wash loads [three (3) wash cycles and six (6) rinse cycles]. The volume of washload flow to the technology will be standardized for all washloads (28 gallons). Common (readily available to consumers) detergent and non-chlorine bleach shall be added to each wash load at F.R. Mahony, Inc.'s recommended loading.

Working parent stress simulation shall consist of five (5) consecutive days when the technology is subjected to a flow pattern where approximately 40% of the total daily flow is received between 6 a.m. –

9 a.m. and approximately 60% of the total daily flow is received between 5 p.m. and 8 p.m., which shall include one (1) wash load [one (1) wash cycle and two (2) rinse cycles].

Low-loading stress simulation shall consist of testing the technology for 50% of the design flow loading for a period of 21 days. Approximately 35% of the total daily flow is received between 6 a.m. – 11 a.m., approximately 25% of the flow is received between 11 a.m. – 4 p.m., and approximately 40 % of the flow is received between 5 p.m. and 10 p.m.

Power/equipment failure stress simulation shall consist of a standard daily flow pattern until 8 p.m. on the day when the power/equipment failure stress is initiated. Power to the technology shall then be turned off at 9 p.m. and the flow pattern shall be discontinued for 48 hours. After the 48-hour period, power shall be restored and the technology shall receive approximately 60% of the total daily flow over a three (3) hour period which shall include one (1) wash load [one (1) wash cycle and two (2) rinse cycles].

Vacation stress simulation shall consist of a flow pattern where approximately 35% of the total daily flow is received between 6 a.m. and 9 a.m. and approximately 25% of the total daily flow is received between 11 a.m. and 2 p.m. on the day that the vacation stress is initiated. The flow pattern shall be discontinued for eight (8) consecutive days with power continuing to be supplied to the technology. Between 5 p.m. and 8 p.m. of the ninth day, the technology shall receive 60% of the total daily flow, which shall include three (3) wash loads [three (3) wash cycles and six (6) rinse cycles].

3.2 Sampling and monitoring points

3.2.1 Influent wastewater
Raw influent wastewater will be sampled from the dosing channel at a point near the technology dosing pump intake, at a point between four and six inches from the channel floor.

3.2.2 Intermediate Effluent (Not applicable for F.R. Mahony Amphidrome™)

3.2.3 Final effluent
Technology effluent shall be sampled from the distribution box downstream of the F.R. Mahony Amphidrome™ treatment unit at a point nearest the effluent discharge of the technology.

A grab sample will be withdrawn from the influent sampling point for the measurement of pH and temperature. An aliquot of the composite treated effluent sample will be drawn for analysis of Dissolved oxygen, pH and temperature. (Refer to Table 3-1).

TABLE 3–1
SAMPLING MATRIX

		SAMPLE LOCATION	SAMPLE LOCATION	
PARAMETER	**SAMPLE TYPE**	**INFLUENT**	**FINAL EFFLUENT**	**TESTING LOCATION**
BOD_5	24 Hour composite	√		Laboratory
$CBOD_5$	24 Hour composite		Composite of single daily effluent event	Laboratory
Suspended Solids	24 Hour composite	√	Composite of single daily effluent event	Laboratory
pH	Grab	√	Composite of single daily effluent event	Test Site
Temperature (°C)	Grab	√	Composite of single daily effluent event	Test Site
Alkalinity (as $CaCO_3$)	24 Hour composite	√	Composite of single daily effluent event	Laboratory
Dissolved Oxygen	Grab		Composite of single daily effluent event	Test Site

TKN (as N)	24 Hour composite	√	Composite of single daily effluent event	Laboratory
Ammonia (as N)	24 Hour composite	√	Composite of single daily effluent event	Laboratory
Total Nitrate (as N)	24 Hour composite		Composite of single daily effluent event	Laboratory
Total Nitrite (as N)	24 Hour composite		Composite of single daily effluent event	Laboratory

3.3 Sampling frequency and types

3.3.1 Sampling frequencies

Normal Monthly Frequency
Sampling frequency will be at a minimum of once per month. Additional samples will be taken in conjunction with the stress tests and final week as outlined in the following sections.

Stress Test Frequency
Samples shall be collected on the day each stress simulation is initiated and when approximately 50% of each stress test has been completed (Note: For the Vacation and Power/Equipment failure stresses, there is no 50% sampling). Beginning twenty-four (24) hours after the completion of wash-day, working-parent, low-loading, and vacation stress scenarios, samples shall be collected for six (6) consecutive days. Beginning forty-eight (48) hours after the completion of the power/equipment failure stress, samples shall be collected for five (5) consecutive days.

Final Week
Samples shall also be collected for five (5) consecutive days at the end of the yearlong evaluation period.

Table 3-2 shows a hypothetical sampling schedule based on the NSF/ETV Nutrient Reduction Protocol requirements.

3.3.2 Sample types
Composite Samples
Composite samples are to be drawn using automated samplers at the influent sample collection point cited in Section 3.2.1 and Table 3.1. An automated sampler will be programmed to draw equal volume of sample from the influent waste stream at the same frequency, number (15) and timing as influent wastewater doses to the relevant technology. Samples taken in this manner will therefore be flow proportional. Initiation of individual automated sampler events will be offset or delayed to correspond to the passage of a flow pulse through the relevant sample collection point.

The Amphidrome™ discharges effluent into a distribution box once per day at the end of the treatment cycle (at ~05:00) via a two-inch diameter pressure line. A sampling manifold will be attached to this discharge point. The manifold will be constructed of 2-inch diameter plastic pipe formed into an inverted "u" that conducts the flow upward and then downward to discharge. A 2-inch plastic ball valve will be placed on the end of the sampling manifold to provide variable hydraulic head and control the subsample rate. A ¼-inch hole will be drilled and tapped into the horizontal section of the "u", and a ¼" nylon barbed tubing connector will be threaded into the tapped hole. A short section of clear flexible tubing will be placed onto the short section to conduct sample to the 3-gallon Nalgene sample bottle. The 2-inch ball valve will be manipulated to provide sufficient flow through the sample line to obtain between 6 and 8 litres of sample during the discharge cycle.

Grab Samples
Grab samples for pH and temperature will be obtained from the influent wastewater stream at the location of the automated sampler intake. Samples for the measurement of pH, temperature and dissolved oxygen in the final technology effluent will be obtained as aliquots of the final technology discharge composite sample.

QC Samples
QC samples shall be taken at the rate one field sample split per sampling event for the monthly samples. Samples will be split in the field by drawing all sub-samples from the composite container. During stress test sampling field sample splits shall be taken at least once per stress event.

Raw sample retention
Sample remaining in the bulk composite sample containers shall be retained at 4 degrees Celsius for 24 hours following field sampling. In the event of transportation or laboratory sample loss, this retained sample may provide additional sub-sample volume for analysis.

3.4 Sampling strategy and procedures

3.4.1 Sampling Site Selection Rationale

Influent wastewater
The influent sampling site selection rationale is based upon the layout of the dosing channel at the MASSTC facility. Raw wastewater enters the sixty-six foot long dosing channel via two pipes midway between the channel end and the channel outlet. Dosing pumps for individual technologies are located in-line along the dosing channel. The Influent wastewater sampling site will be located close to the F.R. Mahony Amphidrome™ dosing pump to ensure a representative sample of wastewater is obtained.

Intermediate Technology Effluent (Not Required by F.R. Mahony Amphidrome™)

F.R. Mahony Amphidrome™ Effluent
For the F.R. Mahony Amphidrome™ effluent, the sampling site will be located at the end of the normal (2" diameter) effluent pipe of the F.R. Mahony Amphidrome™ where it enters a distribution box.

3.4.2 Sample Type Selection Rationale
Selection of the types of samples, grab or composite is dictated by the ETV SWPP Nutrient Reduction Protocol for which this plan is intended. The selection of composite samples for the majority of parameters reflects the tendency of a composite sample to provide a more representative sample in the face of the established daily variability of influent wastewater strength and character and is a compromise with sample holding time restrictions. In contrast, grab samples for pH, temperature and dissolved oxygen are parameters best measured from fresh sample obtainable as a grab.

For details concerning the acquisition of composite and grab samples please refer to the MA Test Center SOPS (Attachment I, vers.2; Section 1)

3.4.3 Sample Frequency Selection Rationale
Selection of the frequencies of sampling has been established by the ETV SWPP Nutrient Reduction Protocol. Samples shall be collected at a minimum interval of once per month at all sampling locations (See Table 3-2).

Table 3 – 2

Sampling Schedule

Startup Period (up to 8 weeks): Samples shall be collected once during week 3, 5, 6, and 7.

Testing Period:

Week 1-8:	Samples shall be collected once per month
Week 9:	**Wash Day stress** initiated on day 1 of Week 9. Samples shall be collected on day 1, day 3, day 6 and day 7 of Week 9.
Week 10:	Samples shall be collected on day 1 through 4 of week 10.
Week 11-17	Samples shall be collected once per month
Week 18	**Working Parent stress** initiated on Day 1 of week 18. Samples will be collected on Day 1, Day 3 and Day 6 and 7 of Week 18.
Week 19	Samples will be collected on Day 1 through day 4 of Week 19.
Week 20-27	Samples shall be collected once per month.
Week 28	**Low-loading Stress** initiated on Day 1 of Week 28. Samples will be collected on Day 1 of Week 28.

Week 29-30	Samples will be collected on Day 4 of Week 29.
Week 31	Samples will be collected on Day 1 though 6 of Week 31.
Week 32-38	Samples shall be collected once per month.
Week 39	**Power/equipment Failure stress** initiated on Day 1 of Week 39. Samples will be collected on Day 6 and Day 7 of Week 39.
Week 40	Samples will be collected on Day 1 through 3 of Week 40.
Week 41-47	Samples shall be collected once per month.
Week 48	**Vacation Stress** initiated on Day 1 of Week 48. Samples will be taken on Day 1 of Week 48.
Week 49	Samples shall be collected on Day 4 through 7 of Week 49.
Week 50	Samples shall be collected on Day 1 of Week 50.
Week 51	No sample will be taken this week.
Week 52	Samples shall be collected on Day 1 through Day 5 of Week 52.

Table 3- 3
Test Specific Target Parameter Table

Operational Venue	Measurement	Target Analytes	Critical	Non-Critical
	Type	Analyte or Measure		
Influent Wastewater	Chemical Analysis	BOD5	X	
		pH		X
		Alkalinity	X	
		TKN	X	
		Ammonia (as N)	X	
	Assay	Suspended Solids	X	
	Physical	Temperature		X
		Volume	X	
Final Effluent	Chemical Analysis	CBOD5	X	
		pH		X
		Alkalinity	X	
		TKN	X	
		Ammonia (as N)	X	
		Orthophosphate (as P)	X	
		Dissolved Oxygen		X
	Assay	Suspended Solids	X	
	Physical	Temperature		X
Byproducts/ Residues	Assay	TSS	X	
		VSS		X
	Physical	Volumetric	X	
Environmental	Assay	Noise		X
		Odor		X
Operation & Maintenance	Physical	Kilowatt usage	X	
		Chemical Usage	X	
Monthly Alarms test		Alarm light and Buzzer		X
Electrical Components		Failure/Bearings/Deterioration of control/junction boxes		X
Structural integrity		Operator Observation		X

3.5 Evaluation of Verification Objectives

3.5.1 Evaluation of Nitrogen Removal Data
Laboratory analytical data will be evaluated for acceptance based on the data falling within QA/QC limits as reported by BCDHE and GAI laboratories and outlined in relevant laboratory SOP's (Attachments II and III).

The data produced by the field analytical measures at the MA SSTC testing facility will be evaluated as falling within acceptable QA/QC limits for those measures as outlined in the MA SSTC SOP (Attachment I, vers.2). Measurements of influent flow and volumetric use of technology process chemicals will be evaluated for acceptance on the basis of meeting the stated QA/QC objectives for those measures as outlined in the MA SSSTC SOP.

Observations of the F.R. Mahony Amphidrome ™ operational characteristics, environmental characteristics and measures, and alarm tests will be evaluated on the basis of these measures compliance with the relevant QA/QC requirements for recording observations, electric use and alarm tests.

3.6 Safety and hygiene plan
The MA SSTC safety plan is attached. The BCDHE laboratory has a health and safety plan on file and available upon request.

4 Field Operation Procedures

4.1 Method to establish steady state
F.R. Mahony, Inc. will advise the BCDHE when the technology is ready for commencement of evaluation. Alternately, the F.R. Mahony, Inc. may indicate the parameter values that indicate the system is ready. As noted in the protocols, this period does not extend beyond 8 weeks, but may, at F.R. Mahony, Inc.'s prerogative, be shorter.

4.2 Site Specific Factors affecting sampling monitoring procedures. Refer to MA SSTC SOP (Attachment I, vers.2, Section 1) for sampling strategy.

4.3 Site preparation needed prior to sampling monitoring (Please refer to MA SSTC SOP (Attachment I, vers.2) for sampling strategy and sampler setup.

4.3.1 Distribution box sampling point. The effluent sampling point is the existing distribution box located downstream of the F.R. Mahony Amphidrome™ technology clear well. There is a retainer for the 3-gallon Nalgene sample bottle installed within the distribution box.

4.4 Monitoring procedures for the MA Test Center are incorporated within the MA Test Center SOP (Attachment I, vers.2, Section 1). Set-up, programming and calibration of the automated samplers for composite sampling are discussed in detail in that section. Splitting of composite samples at the MA SSTC is also discussed in detail in Section 2 of Attachment I, vers.2. Labeling of samples, chain of custody and sample transport are discussed in Section 2 of Attachment I, vers.2.

4.5 Collection of representative samples is ensured through the use of an automated, composite sampler to collect all major influent samples except pH, Temperature and dissolved oxygen, which are more appropriately measured with grab samples. Programming of the automated sampler is to be synchronized with influent dosing events, and ensures that samples collected are flow-proportional. Sample volumes delivered by the automated sampler are self-calibrated by the sampler and calibrated by hand on a monthly basis and recorded in the Field Log as per MASSTC SOPS, Attachment I, vers.2, Section 1.3. The continuous collection of a small sample from the treated effluent discharge cycle will ensure that the composite sample will be representative of the full discharge volume.

Shaking of composite containers prior to pouring sub-samples into containers for transport to BCDHE and GAI laboratories ensures that sub-samples are representative of the original composite sample. (Refer to MA SSTC SOP Attachment I, vers.2; Section 2).

4.6 Split samples
Split sample frequency and methods are discussed in Sections 2.1-2.5 of MA SSTC SOP, Attachment I, vers.2.

4.7 Sample containers, volumes and holding times
Sample containers, volumes and holding times are shown in Table 4 – 1 and are discussed in detail in Attachment I, vers.2, Section 2. Sample preservation is discussed in Section 2.0, MA SSTC SOP, Attachment I, vers.2.

4.8 Sample labeling, transport and archiving
Samples will be labeled with the standard BCDHE adhesive label. Information required to complete this label includes the following items of information: (Dummy data in parenthesis)

Barnstable County Department of Health and the Environment, Barnstable, MA 508-362-2511 Ext 337
Sample Client: (NSF)
Sample Date: (1/1/01)
Time of Collection: (09:15)
Location: (MA SSTC)
Sampling ID: (F.R. Mahony Influent) (F.R. Mahony Effluent)
Collected by: (S.F.., G.H.)

Preservative: (Ice, H2SO4)
Analysis Requested (BOD, CBOD, NO2, NH4, TKN, TSS, PO4, TP, alkalinity)

Sample Transport
BCDHE personnel will transport samples to the BCDHE laboratory via automobile. The samples will be in coolers packed with ice to maintain the temperature of all transported samples at 4^o C. Sub-sample containers to be analyzed at the GAI laboratory will be transported from BCDHE laboratory to GAI in GAI vehicle by GAI personnel. Travel time to BCDHE is approximately 40 minutes. Travel time from BCDHE to GAI is approximately 45 minutes.

Sample Archiving
The remaining sample of raw composite will be retained for 24 hours at 4^oC at the MA SSTC facility.

Table 4–1
Sample Holding Time Requirements

Analyte	Sample Location	Container	Holding Time
BOD_5	Influent	250 ml Nalgene	48 hr.
$CBOD_5$	Effluent	1 liter Nalgene	48 hr
Suspended Solids	Influent	250 ml Nalgene	7 days
Suspended Solids	Effluent	1 liter Nalgene	24 hr
pH	All	250 ml sample cup	[1]
Temperature	All	250 ml sample cup	[1]
Alkalinity	All	250 ml Nalgene	6 hr
Dissolved oxygen	Effluent	250 ml sample cup	[1]
TKN[2]	All	250 ml acidified bottle	24 hr
Ammonia[2]	All	250 ml acidified bottle	24 hr
Total Nitrate/Nitrite	Effluent	250 ml Nalgene	24 hr

1. pH, Temperature and D.O. will be measured immediately following recovery of sample at MA SSTC field location.
2. TKN and Ammonia use a common pre-acidified bottle for all locations.

5 Analytical procedures

5.1 Water quality methods
Water quality parameters and analytical methods are listed in Table 5-1.

Table 5-1
Water Quality Analytical Methods

Parameter	Facility	Acceptance Criteria	Acceptance Criteria	Standard Method
		Duplicates (%)	Spikes (%)	
BOD_5	BCDHE Laboratory	80-120	N/A	Method #5210 B*
$CBOD_5$	BCDHE Laboratory	80-120	N/A	Method #5210 B
Suspended Solids	BCDHE Laboratory	80-120	N/A	Method #2540 D
pH	On-site	90-110	N/A	Method #423
Temperature (^oC)	On-site	90-110	N/A	Method #2550
Alkalinity	BCDHE Laboratory	80-120	N/A	Method #2320
Dissolved Oxygen	On-site	80-120	N/A	Method #4500
TKN (as N)	GAI Laboratory	80-120	80-120	EPA 351.4**
Ammonia (as N)	BCDHE Laboratory	80-120	80-120	EPA 350.1
Total Nitrite (as N)	BCDHE Laboratory	90-110	60-140	EPA 353.3
Total Nitrate (as N)	BCDHE Laboratory	90-110	60-140	EPA 353.3

*Standard Methods for the Examination of Water and Wastewater, APHA, 19th ed., (1995).
**Methods for Chemical Analysis of Water and Wastes, US EPA, EPA-600/4-790-20, Revised (1983) and Methods for the Determination of Inorganic Substances in Environmental Samples, US EPA, EPA/600/R-93/100, (1993).

5.2 Methods listed in Table 5-1 are approved for the analysis wastewater and effluent.

5.2.1 Reporting Units
Reporting units are listed in Table 6–1

5.3 Calibrated measurements

5.3.1 BCDHE Calibrations
Calibration procedures for analytes measured at the BCDHE facility in Table 5-1 are contained in the Barnstable County Department of Health Laboratory Standard Operating Procedures available at BCDHE.

5.3.2 GAI QA/QC
Summaries of QA/QC procedures for analytes to be measured by Groundwater Analytical, Inc. are attached as Attachment III. A detailed QA/QC procedure is available at GAI.

5.3.3 MA SSTC QA/QC
Calibration procedures for pH and dissolved oxygen are included in the MA SSTC SOP Section 2.5, Attachment I, vers.2.

5.4 Other Measurements
5.4.1 Influent wastewater
Measurement of operational facility and technology parameters other than those listed in Tables 5-1, include volume of influent wastewater dosed to the F.R. Mahony Amphidrome™ technology and will include electric use, chemical use, and by-product volumes and characteristics.

5.4.2 Electric Use
Electrical use as recorded by the dedicated electric meter serving the F.R. Mahony Amphidrome™ will be recorded biweekly in the Field Log by BCDHE personnel. The meter's manufacturer and model number and any claimed accuracy for the meter will be noted in the Field Log. Following the end of the testing period the electric meter will be returned to the manufacturer for calibration and the calibration data will be entered in the Field Log.

5.4.3 Chemical Use
For this ETV testing, the F.R. Mahony Amphidrome™ does not add process chemicals to achieve treatment**.**

5.4.4 Environmental Considerations
Noise
Noise levels associated with mechanical equipment (particularly compressors and blowers) shall be verified during the evaluation period. A decibel meter shall be used to measure the noise level associated with the technology. Measurements shall be taken one meter from the source(s) at one and a half meters above the ground, at 90° intervals in four (4) directions. Any mitigation measures for noise control provided by the F.R. Mahony, Inc. shall be noted. Noise levels shall be measured once during the evaluation, approximately one month after completion of start-up period. The meter shall be calibrated prior to use, either at the Test Facility or by the lessor. Meter readings shall be recorded in the Field Log. Repeated or duplicate measurements at each quadrant shall be made to account for variations in ambient sound levels. Duplicated measurements shall be expressed as the geometric mean of the measurements. Noise measurements shall be made at times of the day when ambient noise levels are at there lowest, for example on a weekend morning and when wind speed is at a minimum and during times when there are no Air Base flight operations.

Odors
Monthly observations shall be made by the Testing Organization during the evaluation period with respect to odors generated by the F.R. Mahony Amphidrome™ technology. The observation shall be qualitative and shall include odor strength (intensity) and type (attribute). Intensity shall be as non-detectable; barely detectable; moderate; and strong. Observations shall be made during periods of low wind velocity (<10 knots) and will be made standing upright at a distance of three (3) feet from the treatment unit, at 90° intervals in four (4) directions. All observations shall be by the same BCDHE employee.

If the treatment system is buried, covered or otherwise has odor containment, the means of ventilating the compartment(s), including any odor treatment systems shall be noted in the Field Log.

5.4.5 Mechanical Components
Performance and reliability of the mechanical components such as compressors or blowers, mixers, and chemical and wastewater pumps equipment shall be observed and documented during the test period. This will include the recording in the Field Log of equipment failure rates, replacement rates, and the existence and use of duplicate or standby equipment.

Alarms
During the evaluation period, any alarm systems associated with the technology shall be operationally tested and verified at least once per month. Alarms which are activated by floats and which are accessible shall be operated by lifting floats to activate. Responses of the alarms (Does the alarm sound or not?) to testing shall be recorded in the Field Log. Alarms which are activated by sensors generally have a test circuit which can be activated to test and these alarms responses will be recorded in the Field Log.

5.4.6 Electrical/Instrumentation Components
Electrical components, particularly those that might be adversely affected by the corrosive aTMosphere of a wastewater treatment process, and instrumentation and alarm systems shall be monitored for performance and durability during the course of verification testing. Observations of physical deterioration shall be noted in the Field Log. Electrical equipment failure rates, replacement rates, and the existence and use of duplicate or standby equipment shall be noted and recorded in the Field Log.

5.4.7 Residuals and Byproducts
Byproducts or residuals, when generated, may include septage, sludge. The quantity and quality of residuals generated during the evaluation process shall be recorded in the Field Log. Measurement of

sludge depth shall be made twice during the testing period once after six months and once in the final month of testing. A coring sludge measurement tool (Core Pro) shall be used to estimate the depth of sludge/solids in the 1,500 gallon process/anoxic tank. Measurement of the sludge depth shall be repeated at three locations within the septic tank area accessible to each of the two access manholes. A measurement of sludge/residual depth in the F.R. Mahony Amphidrome™ clear well will be made at the end of the testing period. (Note: The bottom of the reactor vessel is not accessible without removing the treatment media and the stainless steel screen, so measurement in this vessel is not contemplated.) The sludge measurement tool will be inserted in the F.R. Mahony unit's central riser and a measurement of sludge in the bottom of the clear well tank recorded in the Field Log.
Samples of sludge shall be recovered from the Core Pro during the final measurement period (Month 14) by emptying the probe contents into a clean, sterile container and sending the sample to the BCDHE laboratory for water content, VSS and TSS analysis.

In the event residuals/solids are removed as a matter of regular operation and maintenance of the F.R. Mahony technology, the volume, mass and other characteristics of the byproducts or residuals (such as TSS, VSS, water content.) shall be recorded in the Field Log.

6.0 Quality Assurance Project Plan

6.1 QA/QC Objectives

The QA/QC objective of this plan are to ensure that strict methods and procedures are followed during this verification so that the data obtained from the testing are valid for use for the NSF ETV Nutrient Reduction Protocols. The other QA/QC objective is to ensure that the conditions under which data are obtained will be properly recorded so as to be directly linked to the data, should a question arise as to its validity.

6.2 Quality Control Indicators

6.2.1 Precision

Precision is defined as the degree of mutual agreement relative to individual measurements of a particular sample. As such, Precision provides an estimate of random error. Precision is evaluated using analysis of field or matrix spiked duplicates. Method precision is demonstrated through the reproducibility of the analytical results. Relative percent difference (RPD) may be used to evaluate Precision by the following formula:

$$RPD=[(C_1- C_2) \div ((C_1 + C_2)/2)] \times 100\%$$

Where:

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

Please refer to Table 6-1 for field and laboratory methods for determination of precision.

6.2.2 Accuracy

For water quality analyses, accuracy is defined as the difference between the measured or calculated sample result and the true value for the sample. The closer the numerical value of the measurement comes to the true value or actual concentration, the more accurate the measurement. Loss of accuracy can be caused by errors in standards preparation, equipment calibrations, interferences, and systematic or carryover contamination from one sample to the next.

Analytical accuracy may be expressed as the percent recovery of a compound or element that has been added to a sample at known concentrations prior to analysis. The following equation is used to calculate percent recovery:

$$\text{Percent Recovery} = (A_r-A_o)/A_f \times 100\%$$

Where:

A_r= Total amount detected in spiked sample
A_o= Amount detected in unspiked sample
A_f= Spike amount added to sample.

Analytical Accuracy

Analytical accuracy is ensured by following individual analytical method SOPs. Execution of random spiking procedures for specific target constituents is summarized in the GAI QA/QC Summary (Attachment III) and BCDHE method QA Plan and method SOPs (Attachment II). Please refer to Table 6-1 for analytical method accuracy.

Field Sample Accuracy

Accuracy will be ensured for analyses conducted at the MA SSTC facility by use of calibration standards and calibration procedures outlined in the MA SSTC SOP Section 2.6 (Attachment I, vers.2,).

Field process systems accuracy

Accuracy of influent dosing volumes and any chemical feed volumes measured during the test is ensured by regular calibration of dosing pump deliver, chemical feed pump delivery (MA SSTC SOP, Section 2; Attachment I, vers.2).

Table 6 – 1
Methodology for Measurement of Precision and accuracy

Parameter	Precision	Accuracy
BOD_5 (Report to the nearest 1 mg/l)	One sample per sample event or 10% of sample batch.	Refer to BCDHE laboratory SOP
$CBOD_5$ (Report to the nearest 1 mg/l)	One sample per sample event or 10% of sample batch.	Refer to BCDHE laboratory SOP
Suspended Solids (Report to the nearest 1 mg/l)	One sample per sample event or 10% of sample batch.	Refer to BCDHE laboratory SOP
Alkalinity (Report to the nearest 1 mg/l)	One sample per sample event or 10% of sample batch.	Refer to BCDHE laboratory SOP
TKN (Report to the nearest 0.1 mg/l)	One sample per sample event or 10% of sample batch.	Refer to GAI laboratory QA/QC summary
Ammonia (Report to the nearest 0.1 mg/l)	One sample per sample event or 10% of sample batch.	Refer to BCDHE laboratory SOP
Total Nitrate/Nitrite (Report to the nearest 0.1 mg/l)	One sample per sample event or 10% of sample batch.	Refer to BCDHE laboratory SOP
pH (report to nearest 0.1 pH unit)	One sample per sample event or 10% of sample batch.	Daily 3-point calibration with certified pH buffers in range of measurements (4.0-10.0)
Temperature (report to nearest 0.1oC)	One sample per sample event or 10% of sample batch.	Quarterly verification against BCDHE Laboratory's NIST thermometer.
Dissolved Oxygen (report to nearest 0.5 mg/l)	One sample per sample event or 10% of sample batch.	Daily calibration to internal standard and reference to table of saturation values.

For equipment operating parameters, accuracy refers to the difference between the reported operating condition and the actual operating condition. For operating data, accuracy entails collecting a sufficient quantity of data during operation to be able to detect a change in system operations.

Influent dosing flow rate

Assurance of the accuracy of influent flow rate to the technology is documented by MA SSTC SOP (Attachment I, vers.2, Section 8).

Electrical usage
Accuracy of electrical usage measurement will be assured by regular biweekly recording of meter readings. Accuracy of the meter itself as claimed by the meter manufacturer. shall be noted along with model number and serial number of meter. Following the end of the testing period the electric meter will be returned to the manufacturer for calibration and the calibration data will be entered in the Field Log.

Chemical Usage
Chemical use is not applicable to the F.R. Mahony Amphidrome™, as no process chemicals will be added to the treatment process.

6.2.3 Environmental Considerations

Noise
The sound meter for measurement of noise levels will be calibrated prior to use by the rental firm or meter manufacturer and calibration information noted in the Field Log. Accuracy will be ensured by conforming to ANSI/NSFI Std 40 protocols for noise measurement (Refer to Section 5.4.3 above).

Odor
Use of the term accuracy is not appropriate for a qualitative measurement instrument (the human nose). However, the consistency of measurement of the monthly observations of odors will be ensured by use of consistent location of measurement instrument (the human nose), consistency on odor description or type, odor intensity and the measurement timing(Refer to Section 5.4.3 above for method of observations).

6.2.4 Representativeness

Representativeness is the degree to which data accurately and precisely represent a characteristic of a population, parameter variations at a sampling point, a process condition, or an environmental condition

Analytical procedures
Representativeness of laboratory procedures will be ensured by proper handling, storage and analysis of samples so that the material reflects the material collected as accurately as possible.

Field samples
The representativeness of field samples is generally assessed by the collection of field duplicates covering the range of concentrations for the particular parameter of interest encountered in this verification Test Plan. Field sample representativeness is ensured by the use of composite sample for influent and effluent samples.

6.2.5 Completeness

Start-up period completeness

Analytical results completeness
(No startup period data are required by the Test Protocols for technology removal performance.)

Influent volumetric measurements
Influent flow data completeness shall be determined as 85% of the total number of dosing days being valid and acceptable.

Electric Use
Electric use completeness shall be determined as 83% of the biweekly meter readings.

Twelve-Month Sampling Period

Sampling
Completeness of sampling for **monthly samples** shall be determined as 83% of valid sampling data from the monthly tests.
Completeness of sampling for **stress tests** will be determined as 83% valid sampling data from each of the stress tests.

Analytical results completeness
Analytical results completeness will be determined as 90% of samples delivered to the BCDHE and GAI laboratories shall be valid and acceptable.

6.2.5 Comparability
Comparability of data for both GAI and BCDHE laboratories is ensured by the regular laboratory certification program of the MA Department of Environmental Protection. Comparability will also be addressed by sending duplicate samples to an independent Certified Laboratory (QA laboratory).

6.3 Sampling equipment calibration and frequency

6.3.1 Automated Sampler calibration:

Calibration is accomplished using a subroutine in the regular sampler program. At the prompt for sample calibration in the routine place a graduated cylinder in the refrigerated sample compartment and place the delivery tube end in the cylinder. Note the volume and respond to the program requests for this information. The program will automatically adjust the pumping time to deliver the correct volume. The program will prompt for a recheck of the volume with the new volumetric data you have entered. Re-check the volume delivered as necessary and complete the program steps.

Checks on the sample collection method for the Amphidrome™ technology effluent line will be carried out monthly, one to three days prior to a sample date. The check will consist of installing the sampler manifold and collecting a sample during the regular discharge period of the technology. The amount of liquid collected will be noted in the Field Log. If the amount of liquid exceeds the capacity of the sampling container, an adjustment to the ball valve to reduce pressure in the discharge line will be made to ensure collection of sample throughout the discharge cycle without exceeding the volume of the sample container.

6.3.2 Calibration Frequency

The sampler shall be calibrated monthly to ensure that equal samples are drawn and that sufficient sample volume is drawn for the necessary analysis sub-samples. The amount normally drawn for each of the 15 samples is between 450 and 550 milliliters. This provides a total composite sample of between 6.75 and 8.25 liters.

6.4 Water Quality and Operational control Checks

6.4.1 Water Quality Data
Spiked samples for each method will be analyzed at the rate outlined in the BCDHE SOP and QA Plan (Attachment II) and GAI QA Summary (Attachment III).

Method blanks will be analyzed at the rate outlined in the BCDHE SOP and QA Plan (Attachment II) and GAI QA Summary (Attachment III).

Travel blanks will be provided to the BCDHE and GAI laboratories twice during the sample period.

Performance evaluation samples will be analyzed under the MA Department of Environmental laboratory certification program at the rate of twice per annum.

6.4.2 Quality control for equipment operation
Laboratory analytical instruments shall be checked for accuracy based upon the SOP and QA plans for the GAI and BCDHE laboratories (Attachments II and III).

All analytical and sampling equipment at the MA SSTC will be maintained and calibrated by MA SSTC and BCDHE personnel according to the manufacturer's instructions and according to the MA SSTC SOP (Attachment I, vers.2).

6.5 Maintenance of Chain of Custody

6.5.1 COC Forms
Chain of custody forms (COC) shall be filled out in triplicate prior to sample transportation. If the person transporting the samples is not the field sampler, the chain of custody form should indicate the transfer of samples. Retain a copy of the COC for records.

Samples will be transported from MA SSTC to Barnstable County Health laboratory in coolers packed with ice, immediately following completion of sample collection. Travel time to Barnstable County Health should be less than one hour.

Samples to be subcontracted to the Groundwater Analytical laboratory will be included in the chain of custody to the BCDHE laboratory. Subcontract samples will be picked up from the BCDHE laboratory and transported by Groundwater Analytical courier. Subcontract samples will be transported from Barnstable County Health laboratory to the GAI laboratory in coolers packed with ice held at 4^{o}C. Travel time to GAI laboratory is approximately 45 minutes. A separate chain of custody will be created and accompany subcontract samples to the GAI laboratory.

BCDHE personnel in charge of sample intake and transfer to GAI laboratory shall maintain the chain of custody for subcontracted samples and retain a copy of the chain of custody for project records.

6.5.2 Cooler receipts
Cooler receipts will be part of the chain of custody forms. The receipt will include the observed condition of samples and the cooler temperature.

6.6 Acceptance Criteria

Analytical acceptance criteria for QA objectives for each matrix are listed in Table 5-1. The criteria are contained in the Barnstable County DeparTMent of Health Laboratory Standard Operating Procedures (SOP) available upon request. Calibration procedures for analytes measured at the Groundwater Analytical, Inc. facility are summarized in Attachment III. Acceptance criteria for pH, temperature and dissolved oxygen are discussed in MA SSTC SOP, Section 2.6, Attachment I, vers.2.

6.6.1 Criteria for acceptance of Operational Facility Parameters
Influent wastewater dose volumes are calibrated weekly with a bucket test. Acceptance criteria for the measurements shall be that the 30-day average volume of the wastewater delivered to the technology shall be within 100% +/- 10% of the systems rated hydraulic capacity. An exception to this volume shall be during the Low Flow Stress Test when the 21-day average volumes accepted will be 100%+/- 10% of the daily reduced flow (50% of normal daily flow volume). For purposes of calculating the 21-day average volume, only the 21 days of the Low Flow Stress period are to be included.

6.6.2 Criteria for acceptance of technology operational parameters
Electrical use is manually recorded from the dedicated electric meter and criteria are the meter reading, and pertinent Field Log notations (date, time recorder's name). Accuracy of the meter as claimed by the manufacturer shall be noted in the Field Log. The meter shall be returned to the manufacturer for recalibration following the end of the Test Period and the recalibration results entered in the Field Log.

6.7 Assessment of additional QA Objectives (mass balance)

The use of a mass balance approach to removal performance is not contemplated at this time.

6.8 Corrective Action Plan

6.8.1 Analytical methods
Corrective actions for analytical methods (listed in Table 5-1) performed at the BCDHE and GAI laboratories are outlined in the BCDHE SOP and in the GAI QA summary (Attachments II and III). When analytical parameters fall outside of the relevant acceptance criteria, corrective action will be taken to rerun samples. Such actions may include: re-analysis of sample and standards; re-analysis with appropriate fresh reagents and standards. Corrective action may also take the form of measures to prevent future occurrence of the problem. Any problems with analysis will be noted in the relevant laboratory log book and corrective actions taken will also be recorded in the laboratory log book..

6.8.2 Sample Collection, Handling and Field Measures
Corrective actions for field sampling and field analytical procedures at MA SSTC are included in the MA SSTC SOP(Attachment I, vers.2, Sections 1.4, and below)and in the performance evaluation audits outlined in Section 9 below. Whenever necessary or appropriate, shortcomings in the execution of this test plan revealed by audits will be corrected

Sample Collection
Nonconformance of sample collection with procedures in this Test Plan and the MA SSTC SOPS will be noted in the Field Log. Likewise any corrective action taken will be recorded in the Field Log. Nonconformance can include: automated sampler malfunction due to electrical fault; improperly programmed sampler controller; failure to initiate sampler program; movement of suction line and loss of suction. (Refer to MASSTC SOP vers. 2, Section 1.4).

Sample Handling
Nonconformance with sample handling and transport will be recorded in the Field Log and any corrective action taken recorded in the Field Log.

Field Analytical Measurement
Nonconformance with field measures refers to measurement of Temperature, pH, and Dissolved Oxygen made ate the MA Septic System Test Center. Measurements, which fall outside of the acceptance criteria for these analyses, will be noted in the Field Log. Corrective action shall be taken and noted in the Field Log.

For pH, corrective actions can include: measurements with the pH meter which appear to be anomalous can be repeated; buffers can be checked between measurements; sample duplicates are run at the prescribed rate in this document; the meter can be recalibrated, or recalibrated with fresh buffers, and the sample(s) reanalyzed.

Temperature is measured with a separate thermistor probe, and subsequently measured with a second thermistor on the pH probe. Corrective actions may include remeasurement of temperature.

Dissolved oxygen problems can include excessive drift during measurement; excessive temperature shift during measurement; and failure to agitate probe sufficiently during measurement. When problems with measurement occur corrective actions include: remeasurement; recalibration of the meter and probe; replacement of meter batteries with fresh; and replacement of probe membrane. Measurements, which fall outside of the acceptance criteria for these analyses, will be noted in the Field Log. Corrective action shall be taken and noted in the Field Log.

6.9 Sample Cross contamination preventive measures

Composite sample containers shall be uniquely labeled with plastic tags attached with plastic wire ties, which identify the technology, and sample location. Composite sample bottles are thus dedicated to a single technology and sampling point throughout the testing period. In the field facility, to minimize cross contamination while processing analytical sub-samples and during field analytical measurements, samples will be processed beginning with the most highly treated effluent, then intermediate effluent and last the wastewater influent.

6.10 QA management structure

6.10.1 QA Manager
Thomas Bourne
Director, Water Quality Testing Laboratory
Barnstable County Department of Health and the Environment
Superior Court Bldg.
Barnstable, MA 02640
508-375-6606

Responsibilities: QA Manager, Laboratory Director, Sample custody transfer between BCDHE and GAI lab
Qualifications: Ph.D., chemistry. BCDHE Water quality lab director, 1993-present.

6.10.2 Project Participants

George Heufelder
Project Manager
Barnstable County Department of Health and the Environment
Superior Court Bldg.
Barnstable, MA 02640
508-375-6616

Responsibilities: Overall Project Management, Data reduction, Report preparation, sample transport
Qualifications: M.A., Biology; Environmental Programs Director, BCDHE, 1988-present

Sean Foss
MA Septic System Test Facility Operator
Barnstable County Department of Health and the Environment
Superior Court Bldg.
Barnstable, Ma 02640
508-563-6757

Responsibilities: Operation of MA Septic Test Facility and wastewater dosing to technology, Sample Collection, Sample Custody, Sample Field chemical, physical and process (O&M) measurements, Data entry, Data reduction, reporting.

Qualifications: B.S. Zoology; Environmental Specialist BCDHE 1997-present.

7.0 Reports and other deliverables

Table 7-1
Data Reporting Table

Parameter	Reporting Units	Matrix			Method
		Influent	Intermediate*	Effluent	
BOD_5	Milligrams/liter	X			Floppy Disk Paper Table
$CBOD_5$	Milligrams/liter		X	X	Floppy Disk Paper Table
Suspended Solids	Milligrams/liter	X	X	X	Floppy Disk Paper Table
pH	pH units	X	X	X	Floppy Disk Paper Table
Temperature	Degrees C.	X	X	X	Floppy Disk Paper Table
Alkalinity	Milligrams/liter ($CaCO_3$)	X	X	X	Floppy Disk Paper Table
Dissolved Oxygen	Milligrams/liter		X	X	Floppy Disk Paper Table
TKN	Milligrams/liter	X	X	X	Floppy Disk Paper Table
Ammonia as N	Milligrams/liter	X	X	X	Floppy Disk Paper Table
Total Nitrite as N	Milligrams/liter		X	X	Floppy Disk Paper Table
Total Nitrate as N	Milligrams/liter		X	X	Floppy Disk Paper Table
Influent Wastewater	Gallons per day	X			Floppy Disk Paper Table

* Not apllicable to Amphidrome verification.

7.1 Deliverables

The following are deliverables from BCDHE to NSFI:

7.1.1 Sampling Report

A Sampling Report of each sampling event during the evaluation period following all sampling activities. This report will consist of a brief summary of the major actions performed, any problems encountered since the previous report, and corrective actions taken to correct problems. This information will be kept in project files along with the COC forms and the Field Log documenting the sampling activities.

7.1.2 Data Summary Report

A Data Summary Report consisting of tabulated summaries of the data including startup data will be provided by BCDHE to the Verification Organization in both electronic and hard copy format. The summaries will show the sample identifiers, the analyses performed, and the measured concentration or effects, including all relevant qualifiers and validation flags. A brief narrative statement on the overall data quality and quantity will also accompany the tabulated summaries. The BCDHE Project Manager will coordinate with the laboratory project manager to define the format of these data summary reports. All data summary reports shall also be forwarded to the Verification Organization Project Manager following review by the BCDHE Project Manager.

7.1.3 Operation and Maintenance Report

An Operation and Maintenance Report will be provided by BCDHE Project Manager or MA Test Facility Operator of the operation and maintenance activities, which were performed during the verification testing period. The report will consist of a summary of the recommended operation and maintenance activities for the technology and any additional operation or maintenance tasks that were required during the test period. This report shall clearly delineate when the F.R. Mahony, Inc. provided technical assistance to the Testing Organization.

The Operation and Maintenance Report will also comment upon the F.R. Mahony O&M manual as it relates to the 12-month operation and maintenance record of the F.R. Mahony technology. Comments could include: maintenance needed but not covered by the manual; clarification of the F.R. Mahony O&M language, etc.

7.1.4 Quality Control and Analytical Report
A Quality Control and Analytical Report will be used to address the quality control practices employed during the project. The report will also summarize the problems identified in the sampling reports, which are likely to impact the quality of the data. The report will include:

1) The project description, including report organization and background information

2) Summaries of the sampling procedures sample packaging, sample transportation, and decontamination procedures at the MA Test Center.

3) A summary of the GAI and BCDHE laboratory analytical methods, detection limits, quality control activities, deviations from planned activities, and a summary of the data quality for each analysis and matrix.

4) An assessment of the sampling and analyses techniques, an evaluation of the data quality of each parameter, and an evaluation of the usability of the data.

5) A summary of any field or analytical procedures that could be changed or modified to better characterize the raw influent and treated effluent in future evaluations.

6) An overall discussion of the quality of the environmental data collected during the evaluation and whether or not it meets the project objectives.

7) Identification of the QA samples which were split and sent to the GAI and BCDHE laboratories and to the QA laboratory.

8) All cooler receipt and COC forms associated with the required sample results.

9) A laboratory case narrative to be included in the results if nonconformance or other evaluation events affect the sample results.

10) The portion of the primary field sample results and associated batch QC results, which conform to the QA samples submitted to the QA laboratory.

7.2 Data Reduction

7.2.1 BCDHE Laboratory
Data reduction procedures for the BCDHE laboratory analysis of parameters are contained in the SOPS (Attachment II) for each analyte/parameter.

7.2.2 GAI laboratory
Data reduction procedures for the GAI laboratory analysis of parameters are contained in the SOPS (Attachment III) for each analyte/parameter.

7.2.3 MA SSTC
The MA Test Center Operator will do data reduction for influent flow calculations. The daily wastewater flow into the technology will be derived and reduced based on the procedures outlined in the MA Test Center SOPS included as Attachment I, vers.2.

8 Assessments

8.1 Audits at MA SSTC
MA SSTC will conduct audits of dosing pump calibrations, sampling and sample processing on a quarterly basis. For audits, a checklist of operations performed will be created.

8.1.1 Dosing pumps
For the dosing pump calibrations the checklist will include calibration equipment set-up procedures, calibration procedure, and logging of calibration results.

8.1.2 Sampling
For sampling the audit checklist will include composite container preparation, installation and retrieval, sampler calibration check, and sampler programming.

8.1.3 Sample Processing
For sample processing the audit checklist will include the setup, calibration and measurement of pH and D.O. meters, the measurement of temperature, the splitting of the composite sample into sub-sample containers, use of the COC, and sample preservation and transport.

8.1.4 Responsible personnel
Personnel who are responsible for the above audits are George Heufelder, BCDHE and Sean Foss, BCDHE. Audits will be kept on file for reference by NSF.

8.2 Audits at BCDHE laboratory
BCDHE laboratory audits are regularly conducted by BCDHE personnel for each analytical method in the Test Plan. Audits will be conducted by Thomas Bourne, BCDHE.

8.3 Waste Management Plan
Liquid Waste
Liquid waste generated by the Testing Organization consists of: raw wastewater and process effluent from sample collection; 2% dilute bleach (sodium hypochlorite); and small volumes of pH and conductivity standards. These are disposed of into the sink and toilet drains at the test site. The effluent enters the facility sewer system to be treated at the Air National Guard wastewater treatment plant. Liquid waste generated by the Testing Organization does not enter or mix with the Test Facility influent wastewater.

Solid waste
Solid waste generated at the testing Organization consists of paper and cardboard and other packaging materials. Disposal of these wastes is to the Upper Cape Regional Solid waste transfer plant. Residuals left in the F.R. Mahony process/anoxic tank clear well are mixed (liquified) and pumped into the Test Facility sewer to be treated at the Air National Guard wastewater treatment plant.