NSF International
Ann Arbor, Michigan

Product-Specific Test Plan
Adsorptive Media Process for the Removal of Arsenic
ADI International Inc.
ADI Pilot Test Unit No. 2002-09 with MEDIA G2®

Prepared by:

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

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Ann Arbor, Michigan

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The purpose of this Product-Specific Test Plan (PSTP) is to provide procedures for specific types of water treatment units to manufacturers wishing to participate in the EPA/NSF Environmental Technology Verification (ETV) Drinking Water Systems (DWS) Center. By participating in this ETV, manufacturers can have EPA and NSF verified third–party test data produced for their equipment from testing shaped by the manufacturers' performance claims. This verification program will serve to greatly accelerate the entrance of innovative water treatment technologies into the domestic and international marketplace, making cutting-edge water treatment technology widely available. This verification program could result in substantial savings in money and time to water purveyors and manufacturers, since this program may allow manufacturers to reduce or eliminate having to demonstrate product performance at every site considering a specific treatment technology.

In order to have a meaningful verification program, strict operation and testing protocol must be followed. This PSTP endeavors to provide these strict protocols. This PSTP was prepared through reference to the *EPA/NSF ETV Protocol for Equipment Verification Testing for Arsenic Removal* (April 2002), which includes the *EPA/NSF ETV Equipment Verification Testing Plan for Adsorptive Media Processes for the Removal of Arsenic* (Chapter 6), and has attempted to precisely follow the referenced sources. This document can be downloaded at the NSF/ETV web site: www.nsf.org/verification/verification.html and the EPA/ETV web site: www.epa.gov/etv. Paper copies of the Protocol and Test Plan are also available. They can be obtained by contacting NSF International at (734) 769-8010. One of the requirements of the ETV is that the verification testing be conducted by an independent party not associated with any manufacturing interest. The independent party is referred to as the Field Testing Organization (FTO). The FTO for this verification testing is Gannett Fleming, Inc. The verification testing is based upon the premise that the FTO designs a test plan with Data Quality Objectives (DQO) based upon the manufacturer's equipment performance objectives. The subsequent report provides a factual presentation of the test plan.

The treatment unit to be tested in this verification testing is ADI International Inc.'s Pilot Test Unit No. 2002-09 with MEDIA G2® Arsenic Removal Unit. It is the FTO's hope that this document will serve the interest of EPA, NSF, the manufacturing community and especially water purveyors.

Abbreviations and Acronyms

ADI	ADI International Inc.
ANOVA	Analysis of Variance
ANSI	American National Standards Institute
AWWA	American Water Works Association
AA	Activated Alumina
BET	Brunauer, Emmett and Teller
CA WET	California Waste Extraction Tests
cm	Centimeter
C	Degrees Celsius
C.U.	Platinum-Cobalt Color Units
D	Depth
DQO	Data Quality Objectives
EBCT	Empty Bed Contact Time
EPA	U. S. Environmental Protection Agency
ETV	Environmental Technology Verification
FAC	Free Available Chorine
°F	Degrees Fahrenheit
FRP	Fiberglass Reinforced Plastic
FTO	Field Testing Organization
g	Gram
gpd	Gallons per Day
gpm	Gallons per Minute
H	Height
HazMat	Hazardous Material
HDPE	High Density Polyethylene
HTWSA	Hilltown Township Water & Sewer Authority
ICR	Information Collection Rule
ISE	Ion Selective Electrode
L	Liter
Lb	Pound
LCD	Liquid Crystal Diode
LED	Liquid Emitting Diode
m	Meter
M	Mole
MCL	Maximum Contaminant Level
MCLG	Maximum Contaminant Level Goal
mg/L	Milligram per Liter
mL	Milliliter
mm	Millimeter
MDL	Method Detection Level
MSDS	Material Safety Data Sheets
N/A	Not Applicable
NA	Not Analyzed

Abbreviations and Acronyms (Contd)

ND	Not Detected
NEMA	National Electrical Manufacturers Association
NIST	National Institute of Standards and Technology
NPDES	National Pollution Discharge Elimination System
NR	Not Reported
NSF	NSF International (formerly known as National Sanitation Foundation)
NTU	Nephelometric Turbidity Units
O&M	Operation and Maintenance
OSHA	Occupational Safety and Health Administration
PA	Pennsylvania
PADEP	PA Department of Environmental Protection
ppb	Parts per Billion
PE	Performance Evaluation
PRV	Pressure Reducing Valve
PSM	Process Safety Management
psi	Pounds per Square Inch
PSTP	Product-Specific Test Plan
PVC	Poly Vinyl Chloride
QA	Quality Assurance
QC	Quality Control
QA/QC	Quality Assurance/Quality Control
QAPP	Quality Assurance Project Plan
RCRA	Resource and Recovery Act
RMP	Risk Management Plan
SM	*Standard Methods for the Examination of Water and Wastewater*
SOP	Standard Operating Procedure
SS	Stainless Steel
TBD	To Be Determined
TCLP	Toxicity Characteristic Leaching Procedure
TSTP	Technology Specific Test Plan
UPS	Uninterruptible Power Supply
µg/L	microgram per liter
W	Width

Gannett Fleming developed this PSTP for conducting an ETV of ADI International Inc.'s Pilot Test Unit No. 2002-09 with MEDIA G2® Arsenic Removal Unit. This PSTP describes equipment operation, verification and QA/QC procedures that follow the *EPA/ETV Protocol for Equipment Verification Testing for Arsenic Removal* which includes *Equipment Verification Testing Plan for Adsorptive Media Processes for the Removal of Arsenic* (Chapter 6).

This PSTP establishes that the ETV consists of a single 2-week (13 full days plus 8 hours) Integrity Verification Test, and an Adsorption Capacity Verification Test encompassing a period to arsenic break through (defined by ADI as greater than 5 ppb), a regeneration, and a relatively short period of testing following regeneration. Testing is to be conducted on water from Hilltown Township Water & Sewer Authority's (HTWSA) Well No. 1 located in Sellersville, PA. The following is included in this document:

- Characterization of Well No. 1 finished water.
- Test participants, roles and responsibilities, and lines of communication.
- Test schedule.
- Test design including water quality analyses, operating parameters, data collection and management, QA/QC plan and safety.
- Test plan reporting requirements, including data evaluation.

The manufacturer's statements of performance capabilities are the following:

"ADI Model No. 2002-09 arsenic treatment unit containing ADI's MEDIA G2® ferric hydroxide-based adsorptive media is capable of removing arsenic from a chlorinated feed water, containing an arsenic concentration of less than or equal to 20 ppb, when operated at an EBCT of 10 minutes and with an inlet pH of approximately 6.5, to an arsenic concentration of less than or equal to 5 ppb in the product water for a period of 8 months of continuous operation (24 hours per day) which is equivalent to over 33,000 ten minute bed volumes, without regeneration."

“ADI’s MEDIA G2® adsorptive media can be regenerated repeatedly in-situ, after being saturated with arsenic, such that an arsenic concentration of 5 ppb in the product water (described above) is not exceeded for a period of 30 months of continuous operation (24 hours per day) which is equivalent to over 130,000 ten minute volumes.”

“The liquid waste product from regeneration of MEDIA G2, when corrected to pH 6.0 to pH 6.5, will pass EPA’s TCLP.”

“ADI’s MEDIA G2 adsorptive media, at the end of the first 8 months of continuous operation, will pass EPA’s TCLP.”

“ADI’s MEDIA G2 adsorptive media, after its first use and after four regenerations, will pass EPA’s TCLP.”

"The total life of MEDIA G2 will be over 130,000 ten minute bed volumes, with four regenerations.”

The manufacturer's statements of performance capabilities were used to establish the data quality objectives for this test plan.

1.1 Purpose

The purpose of this PSTP is to provide procedures for ADI to participate in EPA/NSF ETV testing with their Model No. 2002-09 arsenic treatment unit containing ADI's MEDIA G2® media for arsenic removal. This verification program will serve to greatly accelerate innovative water treatment technologies, such as arsenic adsorptive media removal systems, into the domestic and international marketplace, making cutting edge water treatment technology widely available. This ETV could result in substantial savings in money and time to water purveyors and manufacturers, since this program may allow manufacturers to reduce or eliminate having to demonstrate product performance at every site considering adsorptive media technologies for arsenic removal.

1.2 Participation

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2.1 Verification Test Site Name and Location

The verification test site is Hilltown Township Water and Sewer Authority (HTWSA) Well Station No. 1 located off Brookside Drive in Hilltown Township, Bucks County, PA. Well Station No. 1 has a permitted capacity of 145 gpm and supplies a portion of the approximately 1,065 connections with a population served of 3,200. The frequency and duration of Well No. 1 pump operation depends on distribution system demand. Cumulative daily well pump run time ranges from 8 to 20 hours per day at a flow rate of 145 gpm.

HTWSA also has two other sources of supply, Well Nos. 2 and 5. Chlorine (sodium hypochlorite) and a sequestrant (Calciquest, a brand of polyphosphate sequestrant) are fed at all three well stations.

The MEDIA G2® arsenic adsorption media filter has been installed inside the Well Station No. 1 building. During this testing, a continuous flow of chlorinated water from the sample tap located on Well No.1 chlorine detention tank will be diverted to the MEDIA G2® arsenic adsorption media filter (normally water from this sample tap would also contain the sequestrant. HTWSA has agreed to terminate this chemical feed for the duration of the ETV, stating that it apparently has not provided significant improvement in water quality since the sequestrant feed program was initiated). The treated water from the arsenic adsorption media filter will be discharged (via the station floor drain) to an existing stormwater culvert. The backwash wastewater and regenerant wastewater (after collecting a sample of the regenerant wastewater for TCLP analysis) will be discharged to an existing sewer manhole adjacent to the building, at the request of the PADEP.

2.2 Verification Testing Organization and Participants

- ADI International, Inc. (ADI)
- Gannett Fleming, Inc.
- NSF International (NSF)
- Hilltown Township Water & Sewer Authority (HTWSA)
- Pennsylvania Department of Environmental Protection (PADEP)
- Bucks County Department of Health
- United States Environmental Protection Agency (EPA)
- TriMatrix Laboratories, Inc.

2.3 Roles and Responsibilities

Figure 2-1 presents the primary participants in the ETV and their organizational relationships.

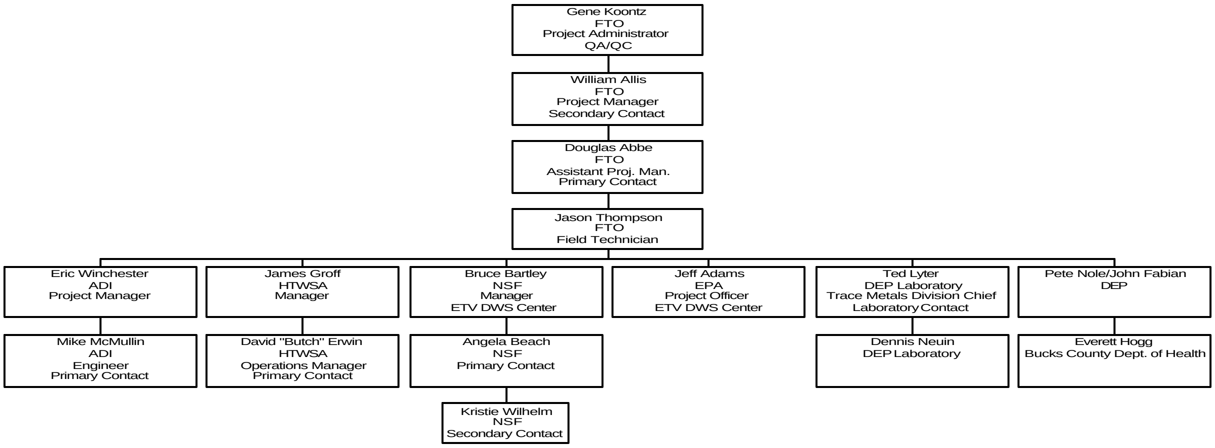


Figure 2-1. ADI International's Arsenic Adsorption Media ETV Organization Chart

2.3.1 Manufacturer

As the equipment manufacturer, ADI is responsible for installing their equipment and providing written and verbal instructions for its operation.

- A complete, installed arsenic adsorption media filter loaded with MEDIA G2® media has been provided and installed at Well Station No. 1 by ADI personnel for verification testing. Associated instrumentation, controls, and the operations manual for the pilot filter system are inserted in Appendix A. ADI customized the operations manual for the Hilltown Well No. 1 site; ADI tailors all of their operations manuals for site-specific conditions.

- ADI has provided technical support for the development of this PSTP for the arsenic adsorption media filter.

- ADI will provide technical assistance to Gannett Fleming during the operation and monitoring of their arsenic adsorption media filter.

- ADI has plumbed the arsenic adsorption media filter so that it will not drain when Well No. 1 is off line, or otherwise prevent any other condition from occurring that would either damage the system or render data generated by the system not reliable.

2.3.2 Field Testing Organization

As the FTO, Gannett Fleming is responsible for conducting verification testing of the arsenic adsorption media filter. As part of the verification testing, Gannett Fleming is responsible for:

- Defining the roles and responsibilities of appropriate verification testing participants.

- Providing needed logistical support, establishing a communications network, and scheduling and coordinating the activities of all verification testing participants.

- Verifying that the location selected as the test site has feed water quality consistent with the objectives of the verification testing.

- Managing, evaluating, interpreting and reporting on data generated by the verification testing.

- Preparing this PSTP for the verification testing.

- Overseeing and conducting the daily testing activities, collecting test samples and delivering those samples to the laboratories for analysis, tabulating and analyzing the test data, and preparing the final report.

2.3.3 NSF International

NSF International (NSF) is an independent, not-for-profit organization founded in 1944 for the purpose of developing standards and third-party conformity assessment services to government, manufacturers and consumers of products and systems related to public health, safety, and environmental quality.

NSF entered into an agreement on October 1, 2000 with the United States Environmental Protection Agency (EPA) to create a Drinking Water Systems (DWS) Center dedicated to technology verifications. NSF manages an Environmental Technology Verification (ETV) Program within the DWS Center for the purpose of providing independent performance evaluations of drinking water technologies. Evaluations are conducted using protocols developed with stakeholder involvement. Verified results of product evaluations presented in reports from ETV tests should accelerate a technology's entrance into the commercial marketplace.

The following are specific NSF roles and responsibilities.

- PSTP review to insure compliance with the general requirements of the *EPA/NSF ETV Protocol for Equipment Verification Testing for Arsenic Removal* and specific requirements of *EPA/NSF Equipment Verification Testing Plan for Adsorptive Media Processes for the Removal of Arsenic*
- Test audit to confirm testing follows the PSTP
- Interim and final report review including technical, format and QA/QC
- Analyzing the arsenic samples collected for laboratory analysis throughout the test

2.3.4 Hilltown Township Water & Sewer Authority

HTWSA manages and operates all of the municipal water and sewer facilities in Hilltown Township, which includes Well Station No. 1, the site of the ETV.

2.3.5 Pennsylvania Department of Environmental Protection (PADEP)

The PADEP's mission is to protect Pennsylvania's air, land and water from pollution and to provide for the health and safety of its citizens through a cleaner environment. The PADEP is the state agency largely responsible for administering Pennsylvania's environmental laws and regulations. Its responsibilities include: reducing air pollution; making sure Pennsylvania's drinking water is safe; protecting water quality in Pennsylvania's rivers and streams; making sure waste is handled properly; managing the Commonwealth's recycling programs and helping citizens prevent pollution and comply with the Commonwealth's environmental regulations. PADEP is committed to general environmental education and encouraging effective public involvement in setting environmental policy.

The roles and responsibilities of PADEP during this ETV include laboratory analyses for all of the water quality parameters that are scheduled to be conducted by an EPA-accredited and PADEP-certified laboratory, except arsenic. The PADEP is also responsible for reviewing the test plan and final report since this testing may also serve as a pilot study component of a water supply permit application for the installation of a full-scale version of this type of process at this site. Also, since the site is already a permitted public water supply, the PADEP needs to be involved with any modifications that may occur.

2.3.6 Bucks County Department of Health

The Bucks County Health Department supports the regional DEP office (Region 1 – Conshohocken)

2.3.7 United States Environmental Protection Agency (EPA)

EPA provides leadership in the nation's environmental science, research, education and assessment efforts. EPA works closely with other federal agencies, state and local governments, and Indian tribes to develop and enforce regulations under existing environmental laws. EPA is responsible for researching and setting national standards for a variety of environmental programs and delegates to states and tribes responsible for issuing permits, and monitoring and enforcing compliance. Where national standards are not met, EPA can issue sanctions and take other steps to assist the states and tribes in reaching the desired levels of environmental quality. The Agency also works with industries and all levels of government in a wide variety of voluntary pollution prevention programs and energy conservation efforts.

The following are specific EPA roles and responsibilities for this ETV:

- Technical review and QA oversight of the PSTP
- Final approval of lab methods other than those listed in the *NSF Protocol for Equipment Verification Testing for Arsenic Removal*
- Technical review of the final report

2.3.8 TriMatrix Laboratories, Inc.

TriMatrix Laboratories, Inc., located in Grand Rapids, Michigan, will be performing the Toxicity Characteristic Leaching Procedure (TCLP) and California Waste Extraction Tests (CA WET) on the regenerant wastewater and spent MEDIA G2® media.

2.4 Site Characteristics

Well Station No. 1 is housed within a masonry block building located off Brookside Drive in the Pleasant View housing development. The building is heated to a minimum temperature of 60º F. Two chemicals are normally fed at the well station, sodium hypochlorite for disinfection and polyphosphate for sequestration and corrosion control; however, the sequestrant will be discontinued during the ETV.

Well No. 1 operates intermittently depending on system demand. Operation of Well No. 1 is controlled through the HTWSA SCADA system, which is interconnected with Well Station Nos. 2 and 5, and the system's 1.0 million gallon finished water ground level storage tank. High and low water level sensors in the finished water storage tank, set at 78 feet and 71 feet, respectively, activate/deactivate the well pumps located at each well station. Booster pumps located in the distribution system increase the pressure to a constant 115 psi. Prior to the installation of the SCADA system, Well No. 1 operated off high and low pressure settings on the hydropneumatic tank located within Station No. 1. The hydropneumatic tank has since been converted to a chlorine detention tank; this tank no longer has any control features associated with the well pump.

Characterization of Well No. 1 raw and finished water quality is presented in Table 4-1.

Logistics of Pilot Filter Unit Supply, Discharges and Residuals

A portion of Well No. 1 chlorinated water will be used as the source water for the arsenic adsorption media unit verification testing. Water for the arsenic adsorption media will be "bled" continuously from the sample tap located on the chlorine detention tank.

An existing well station building floor drain will serve to collect treated water from the arsenic adsorption media filter. The treated water will be piped outside to an existing storm water culvert to avoid having to repump the water into the distribution system. The arsenic adsorption media filter backwash wastewater and regeneration wastewater (after collecting a sample of the regenerant wastewater for TCLP analysis) will be discharged to a sewer manhole via a garden hose that is routed through a louvered vent in the building.

Samples of spent media will be tested by TriMatrix Laboratories, Inc. at the conclusion of testing by the TCLP and the CA WET for determining the leaching potential. Spent media will be properly disposed in accordance with classification based on the results of the TCLP and CA WET, following the conclusion of the ETV. The disposal of media for manifesting purposes will be the responsibility of the manufacturer. The equipment used in this verification test will be packed up by Gannett Fleming after the testing is complete. ADI will make all shipping arrangements with a carrier.

3.1 Equipment Capabilities

3.1.1 Statement of Performance Capabilities

ADI has provided the following statements of performance capability:

"ADI Model No. 2002-09 arsenic treatment unit containing ADI's MEDIA G2® ferric hydroxide-based adsorptive media is capable of removing arsenic from a chlorinated feed water containing an arsenic concentration of less than or equal to 20 ppb, when operated at an EBCT of 10 minutes and with an inlet pH of approximately 6.5, to an arsenic concentration of less than or equal to 5 ppb in the product water for a period of 8 months of continuous operation (24 hours per day) which is equivalent to over 33,000 ten minute bed volumes, without regeneration."

"ADI's MEDIA G2® adsorptive media can be regenerated repeatedly in-situ, after being saturated with arsenic, such that an arsenic concentration of 5 ppb in the product water (described above) is not exceeded for a period of 30 months of operation which is equivalent to over 130,000 ten minute bed volumes."

"The liquid waste product from regeneration of MEDIA G2®, when corrected to pH 6.0 to pH 6.5, will pass EPA's TCLP."

"ADI's MEDIA G2® adsorptive media, at the end of the first 8 months of continuous operation, will pass EPA's TCLP."

"ADI's MEDIA G2® adsorptive media, after its first use and after four regenerations, will pass EPA's TCLP."

"The total life of MEDIA G2® will be over 130,000 ten minute bed volumes, with four regenerations."

These statements are provided for the purpose of shaping the data quality objectives (DQO) for this test plan.

3.2 Equipment Description

3.2.1 Basic Scientific and Engineering Concepts of Treatment

The conceptual treatment process for the arsenic adsorption media filter is based on passing arsenic-contaminated feed water through a bed of media that has a strong affinity for arsenic.

3.2.1.1 Generic Arsenic Adsorption Media Description[1]

Arsenic occurs in water in two valence states (As III and As V). The valence state can be modified by oxidation and reduction processes. The toxicology of arsenic varies depending upon its concentration and valence. Since the arsenic valence state can change while in aqueous solution, the objective of arsenic removal treatment is to remove all of the arsenic regardless of valence.

Adsorption is the physical attachment of the adsorbate (arsenic) to the surface of the adsorbent media grains. The removal capacity and effectiveness of the arsenic removal media is dependent on a number of factors, of which surface area is of primary importance. An adsorptive media's surface area is a function of its porosity. An adsorptive treatment media contains an extensive network of fine (small diameter) pores which extend throughout the body of a grain of media. The arsenic ion requires time to migrate into a pore within the grain of the adsorbent. As the surface area of each adsorbent grain becomes saturated with arsenic ions, the time required for additional adsorption becomes longer. Other factors that determine the capacity and effectiveness of adsorbent media are accessibility of the pore sites for arsenic ions, competing ions for pore sites, concentration of arsenic in the feed water, pH of the feed water, and flow characteristics of the feed water that convey the arsenic into the bed of adsorbent media. The concentration of raw water arsenic impacts media capacity for arsenic according to the following relationship: The higher the arsenic concentration, the higher the adsorptive driving force and the higher the arsenic capacity of the adsorptive media.

The adsorptive media is normally in a packed bed contained in a pressure vessel. The water to be treated typically flows in the downflow mode through the treatment bed. Gravity flow is feasible, but if pH adjustment is employed, gravity flow is not as effective because the pressure required to retain the carbon dioxide in solution does not occur under gravity flow conditions. Therefore, the free carbon dioxide is released resulting in the pH rising to higher than the desired level. As the feed water flows through the adsorptive media, the arsenic ions are adsorbed onto the available adsorption sites. As the water flows through the bed the arsenic concentration decreases until it is no longer detectable. As the feed water continues to flow through the treatment bed the media which comes in first contact with the feed water becomes saturated with arsenic ions. A treatment band then progresses through the treatment bed until breakthrough occurs. At that point, traces of arsenic appear in the treated water. As flow continues the

[1] From Chapter 6 – *Adsorptive Media Processes for the Removal of Arsenic* of the *EPA/NSF ETV Protocol for Equipment Verification Testing for Arsenic Removal*

treatment band progresses through the media until the bed is saturated; the arsenic concentration in the treated water is then the same as that in the feed water. Since the arsenic concentration in the treated water is the contaminant of concern, the arsenic concentration must be controlled to the desired level.

There are various methods of sequencing multiple treatment beds (parallel and/or series arrangements) which allow the entire (or almost the entire) adsorptive media capacity to be utilized. When the adsorptive media becomes saturated with arsenic ions it is removed from service for regeneration or disposal. Normally the economic feasibility of the adsorptive process requires reuse of the treatment media. This is accomplished by means of chemical regeneration requiring adjustment of pH (or other methods) to a level at which adsorptive conditions no longer exist. At these pH levels the adsorptive treatment media desorbs the adsorbate. The arsenic is released and flushed from the adsorptive media as a high concentration arsenic wastewater. Upon completion of regeneration, the pH of the media is adjusted to the desired treatment pH, at which point the media is reused for a subsequent treatment cycle. During a regeneration, some adsorptive media may be consumed (attrition); if that occurs, replacement adsorptive media should be added to the treatment bed. In small treatment systems and/or in treatment systems in which the arsenic concentration in the feed water is not excessively high, economic feasibility might dictate replacement of spent media in lieu of regeneration.

Historically the adsorptive media that has demonstrated the most cost effective, reliable performance has been granular activated alumina. Other adsorptive media such as bone char and synthetic bone char (tri-calcium phosphate) have also been employed, but have not performed as effectively as activated alumina.

Capacity

Capacities and performance of different adsorptive media do vary. Some types of adsorptive media may be capable of regeneration while others may not. Those adsorptive media that have regeneration capability also may vary in performance during subsequent treatment runs. The arsenic removal capacity diminishes until it is determined that adsorptive media replacement is required. Other types of adsorptive media experience attrition during each regeneration, requiring addition of makeup adsorptive media prior to commencement of the next arsenic removal treatment run. The latter type of adsorptive media may not experience reduction of arsenic removal capacity during subsequent treatment runs.

Intermittent Operation

In full-scale arsenic adsorptive media water treatment systems, operation may be intermittent. The smaller the system, the higher the probability that the operation of the treatment system will experience more frequent starts and stops. The performance of adsorptive media is not degraded when operated on an intermittent basis. In fact, the performance of the arsenic adsorption media exhibits a short period of improved performance during startup after a shutdown of the process. The reason for the improved performance is that arsenic ions adsorbed during continuous operation occupy adsorption sites that are most accessible. During process shutdown, the arsenic ions migrate from the most accessible adsorption sites to less accessible sites located deep in the pores of the media, thereby re-exposing the most accessible adsorption sites for reuse. At the time the treatment process restarts, the arsenic removal process exhibits increased capacity for a short period after which time the performance returns to the level occurring at the time of the treatment process shutdown.

3.2.1.2 MEDIA G2® Description

MEDIA G2® arsenic adsorption media consists of an inorganic, natural substrate upon which iron (ferric hydroxide) is chemically bonded. It is the iron that attracts the metallic ions in water and binds them to the substrate by chemisorption. Although it was developed specifically for adsorbing arsenic, MEDIA G2® will also adsorb iron, manganese, zinc, cadmium, lead and copper. The adsorption capacity for arsenic is about 500 µg to 2,500 µg of arsenic per gram of media, depending on operating pH and initial arsenic concentration in the raw water.

MEDIA G2® is an iron-based adsorption treatment technology for removing arsenic from water, specifically groundwater for potable use. The technology involves adsorption of arsenic onto a filter media (MEDIA G2®) as the water passes through the media. The arsenic adsorption filter pilot unit that will be used in this testing consists of one vessel containing MEDIA G2® adsorption media, and is operated in a downflow mode. As the media becomes saturated with arsenic, the concentration of arsenic in the treated water begins to increase. Before this concentration reaches the pre-determined maximum allowable contaminant level (breakthrough), the media is either replaced or regenerated on-site. ADI has stated that MEDIA G2® can be regenerated 4 to 5 times, with a loss in capacity of approximately 10% following each regeneration. Eventually it is more economical to replace the media rather than continue to regenerate do to cumulative loss in arsenic capacity.

Previous research and pilot tests have shown that MEDIA G2® systems work well in the pH range of 5.0 to 7.5, the lower the pH the better for extending the life of the media, i.e., its adsorption capacity increases with decreasing pH. However, for most applications it is desired to operate the system in the pH range of 6.5 to 6.8. After pH, the most critical parameter is the contact time in the adsorption vessels. This arsenic adsorption filter is sized for 10 minute EBCT (Empty Bed Contact Time).

MEDIA G2® is a registered trade mark of ADI International Inc and protected by US Patent No. 6,200,482. MEDIA G2® adsorption media is certified to ANSI/NSF Standard 61 for water treatment plant applications. Also, the performance of MEDIA G2® was verified under Canada's Environmental Technology Verification program in March 2001.

Table 3-1 below, and Table 5-2 present information specific to the MEDIA G2® arsenic adsorption media.

Table 3-1.
Manufacturing and Procedures Specific to ADI's MEDIA G2® Adsorptive Media

Item	Manufacturing/Procedures
Raw material used to make the adsorptive media	Calcined diatomite substrate and iron (ferric hydroxide)
Method of Manufacture	• Chemical processes: ferric hydroxide is chemically bonded to the calcined diatomite media (proprietary process) • Thermal processes: proprietary • Sizing/Screening methods: proprietary • Packaging methods: proprietary
Preconditioning Procedure	• Wetting requirements: a) Place media in filter vessel and backwash at a rate of 3.2 gpm for 30 to 60 minutes to remove fines. b) Rinse with acidified water (pH 4.0-5.0) at a filtration rate of 1.7 gpm until pH of the filter effluent water is reduced to 6.5. See ADI Operations Manual in Appendix A for further details • Waste: discharged to nearby sewer easement

Regeneration Procedure	• Backwash: See ADI Operations Manual, pages 3 and 4, in Appendix A. • Chemical process: Meter ~50 gallons of 1% caustic soda to the filter to regenerate the media, followed by neutralization of the media by feeding 0.5% sulfuric acid solution until a filter effluent pH of less than 7.0 occurs (but not less than 5.0) See ADI Operations Manual, pages 6 and 7, in Appendix A for additional details • Return to treatment mode: Rinse following acid neutralization until the pH of the effluent water is within one pH unit of the pilot feed water (ADI's target pH in the effluent water is approximately 6.5). Media is ready for normal operation following rinse. • Waste: See ADI Operations Manual, page A-5, for treatment and disposal of wastewater
Regeneration Results	• Adsorption media capacity: reduced by 10% with each regeneration. • Number of regenerations: MEDIA G2® reportedly can be regenerated 4 to 5 times in place. After this, it is more economical and practical to replace the media. • Waste: See ADI Operations Manual (page A-5) and the neutralization procedure of the spent regenerate wastewater in Appendix A for discussion on disposal of regenerants and spent media.

3.2.1.3 ADI's Arsenic Adsorption Media Test Unit Installation

ADI's filter installation at Hilltown in Well Station No. 1 is a pilot test unit, with a footprint of less than one square foot. The pilot unit has a capacity of only 1.7 gpm, although it is hydraulically configured and operated to simulate any size system which employs pressure filter vessels.

The depth of media in the pilot filter is about three feet and the diameter is 12 inches, which results in a hydraulic loading rate of 2.16 gpm/sf and an EBCT of 10.3 minutes. The hydraulic capacity of a full-scale system is determined by the size and number of vessels. Smaller systems would use vertical vessels. The larger systems (over 5 mgd) would use horizontal vessels.

The feed water is obtained from an existing tap on the well station chlorine detention tank, located within the building. The pressure at this location is a constant 115 psi. ADI has installed a pressure reducing valve (PRV) on the feed line to reduce pressure to the pilot filter unit to 50 psi.

An electric solenoid valve was installed on the line feeding the pilot filter unit to positively shut off the water flow to the unit in the event of a power outage at the station. The solenoid valve and chemical metering pumps will receive power from a constant 120 volt circuit. If there should be a loss of power, the solenoid valve will close, preventing the passage of water through the pilot filter unit without the addition of sulfuric acid preconditioning.

An electronic, battery-operated flow meter measures both the rate and cumulative flow to the test unit. Its stated accuracy is +/- 1% of full scale, or +/- 0.05 gpm. The meter measures both the feed water supply and backwash water supply to the test unit. Because backwash water for the test unit is supplied by the well, which contains arsenic, sampling for arsenic in treated water for verification purposes should wait at least one hour after forward flow is initiated.

HTWSA feeds sodium hypochlorite for disinfection to the raw water just upstream of the chlorine detention tank at a dose sufficient to produce a free chlorine residual of approximately 0.6 mg/L in the water entering the distribution system. ADI has stated that the target chlorine residual in the pilot unit effluent should be approximately the same as that entering the distribution system. (In the unforeseen event that the filter effluent chlorine residual should drop more than 15% below the target for a significant length of time, ADI's sodium hypochlorite feed system will be activated to boost the chlorine residual to a minimum of 0.6 mg/L; this is not anticipated to happen due to HTWSA's vigilant monitoring of their facilities, and the spare feed equipment they have on site). That portion of chlorinated water diverted to the pilot filter unit will be dosed with sulfuric acid to depress pH to approximately 6.5 as specified by ADI.

The test unit is supplied with two graduated chemical batch tanks and two metering pumps for feeding sulfuric acid, and either sodium hypochlorite or caustic soda. Since the well water will already be chlorinated prior to being diverted to the pilot filter unit, ADI's sodium hypochlorite feed system will serve as a spare, available for use in the event that HTWSA's chlorine feed system is out of service; it will also serve to meter caustic soda for the one scheduled regeneration. The metering pumps are intended to operate at a fixed rate. They will be plugged into electrical outlets that provide continuous power. The acid will be dosed to lower the pH from the approximate raw water pH of 7.2 to approximately 6.5. Periodic adjustment of pump speed may be required to stay close to the target pH in the filter effluent. Monitoring of sulfuric acid usage will be calculated daily from the volume changes in the batch tank. All chemicals will be metered into the pilot filter unit from diluted solutions. (See ADI's Operations Manual in Appendix A for an example preparation of sulfuric acid solution).

The filter is fitted with inlet and outlet pressure gages for measuring pressure drop through the media bed by calculating the difference between these two readings. The filter should be backwashed when the pressure drop reaches 10 psi, or following four weeks of continuous operation, whichever occurs first. Backwash events typically produce less than 0.5% solids in the backwash stream. A typical analysis of backwash water is included in ADI's Operations Manual in Appendix A. It should be noted that backwash water will always exhibit a reddish-orange color, even after hours of backwashing. This is normal, and the backwash period should not exceed the time given in the Operations Manual. After a backwash event, the filter is rinsed at the service flow rate for 15 minutes. During rinsing, the reddish-orange color will disappear within a few minutes.

Treated water for the test unit is discharged to the well station floor drain, which conveys the treated water to a stream culvert adjacent to the building. (The PADEP has given their permission for this discharge.) Treated water samples will be obtained at Sample Tap 3 (ST3), see Figures 3-1 and 3-2.

3.2.2 Filter System Components

The following equipment is provided by ADI specifically for the ETV and is not normally included with the arsenic adsorption media filter:

- Two chemical metering pumps, for metering sulfuric acid and a spare (either caustic acid or sodium hypochlorite)
- One solenoid valve to automatically isolate the filter unit in the event of a power outage (Well Station No. 1 does not have a back-up power supply)
- One electronic combination flow meter and totalizer for monitoring flow rate and accumulative production through the filter unit (totalizer resets to zero after 10,000 gallons and will not be used to record production)
- One mechanical totalizer meter
- Two chemical batch and feed tanks (sulfuric acid and a spare for either caustic soda or sodium hypochlorite)
- One pressure reducing valve to lower the chlorine detention tank discharge pressure from 115 psi to 50 psi for ease in regulating the flow through the test unit
- Two pressure gauges for measuring filter influent and effluent pressure and calculating pressure drop
- Eight ball valves for manual operations of the filter unit flows, including service, backwash, rinse, regeneration and sampling.

Physical Construction of Test Unit

The filter vessel is constructed of fiberglass, with a pressure rating of 125 psi. Rigid piping is Schedule 80 PVC. Flexible piping is reinforced, clear plastic tubing. Manually-operated valves are all PVC ball valves.

3.2.3 Photographs of Equipment

See Appendix C.

3.2.4 Drawing of Equipment

See Figures 3.1 and 3.2.

3.2.5 Data plate

A data plate has been installed on the arsenic adsorption media test unit which provides the following information:

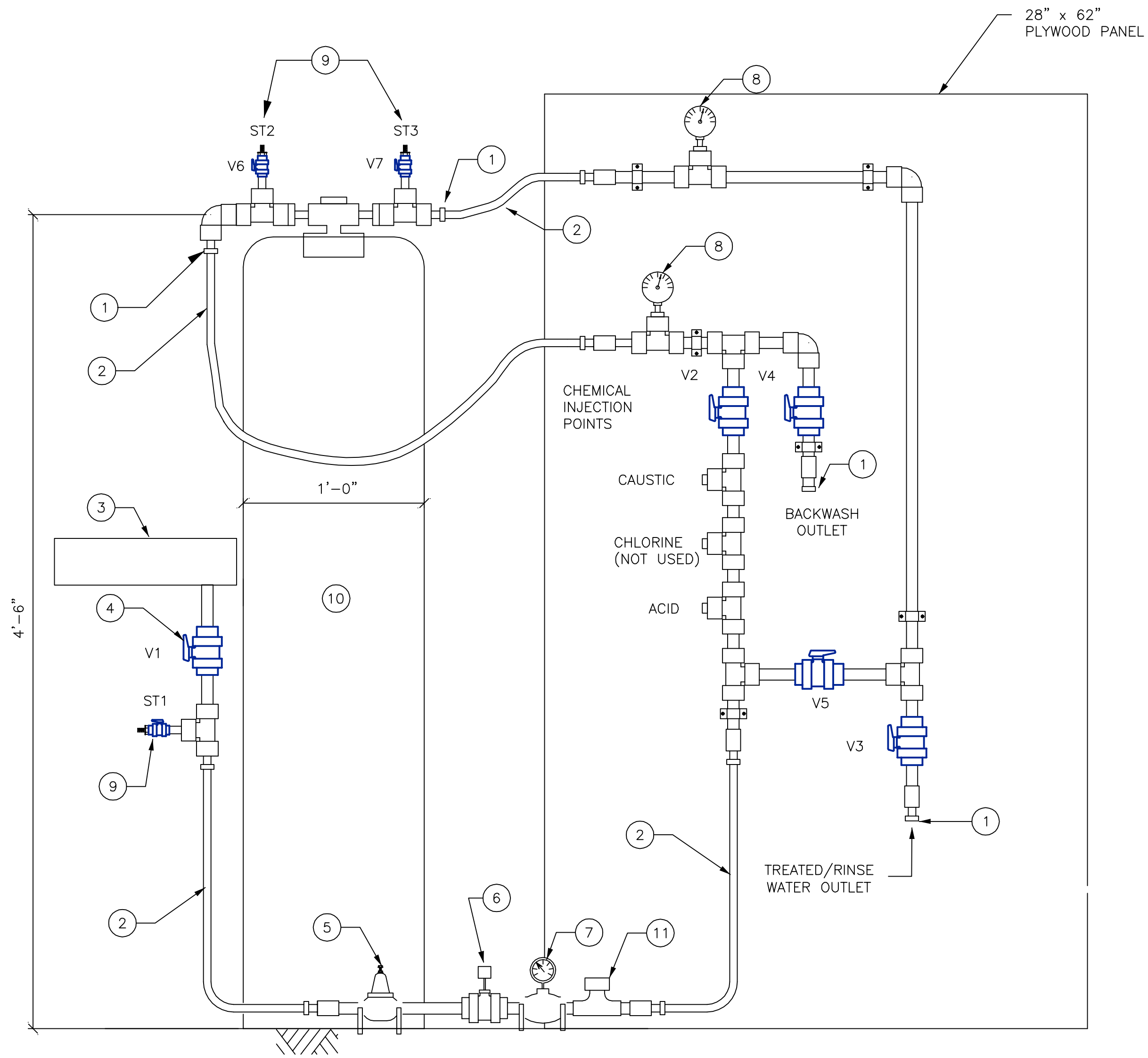
Equipment name: MEDIA G2® Arsenic Removal Unit
Model No.: 2002-09
Electrical Requirements: 120V, 60Hz for powering chemical metering pumps and solenoid valve.

Maximum pressure: 125 psi.

Manufacturer's Name and Address:
ADI International
1133 Regent Street
Suite 300
Fredericton, NB E3B 3Z2
Canada

Additional Information:
Serial Number: N/A
Service flow: 1.7gpm, continuous or start/stop
Unit installed for NSF and EPA Environmental Technology Verification Program.
Call 506-452-9000 for more information.

Warning and Caution Statements:
Testing in progress, please do not disturb.
This unit is designed to operate with minimum and maximum inlet pressures of 30 psi, and 125 psi, respectively.



KEYNOTES

1. GARDEN HOSE ADAPTER
2. FLEXIBLE TUBING
3. HYDROPNEUMATIC TANK
4. EXISTING CONNECTION/VALVE
5. PRESSURE REDUCING VALVE
6. 2 WAY NORMALLY CLOSED SOLENOID VALVE
7. FLOW TOTALIZER
8. PRESSURE GAUGE
9. SAMPLE TAP
10. FILTER VESSEL
11. FLOW METER / TOTALIZER

OPERATION			
VALVES	NORMAL	BACKWASH	RINSE
V1	O	O	O
V2	O	C	O
V3	O	C	O
V4	C	O	C
V5	C	C	C
O – OPEN C – CLOSED			

No.	Revision	Ckd. By	Date

Subconsultant

Project No.

PRELIMINARY

Const. North

Drawn By: JLB

Dwg. Standards Ckd. By:

Designed By: JKH

Date Printed

Dwg. Design Ckd. By:

ADI® International Inc.
Design–Build, Turn–Key Packag
and Project Management

1133 Regent Street, suite 300
Fredericton, New Brunswick, Canada

Project Title: HILLTOWN ARSENIC PILOT

Dwg. Title: GENERAL ARRANGEMENT

Project No.: 7000–222.1

Dwg. No.: FIG–02

Rev. No.: 1

Scale

This drawing is not to be scaled

FIGURE 3–1. SCHEMATIC OF MEDIA G2® ARSENIC REMOVAL PILOT UNIT AT HILLTOWN TOWNSHIP WATER & SEWER AUTHORITY WELL NO. 1 FACILITY

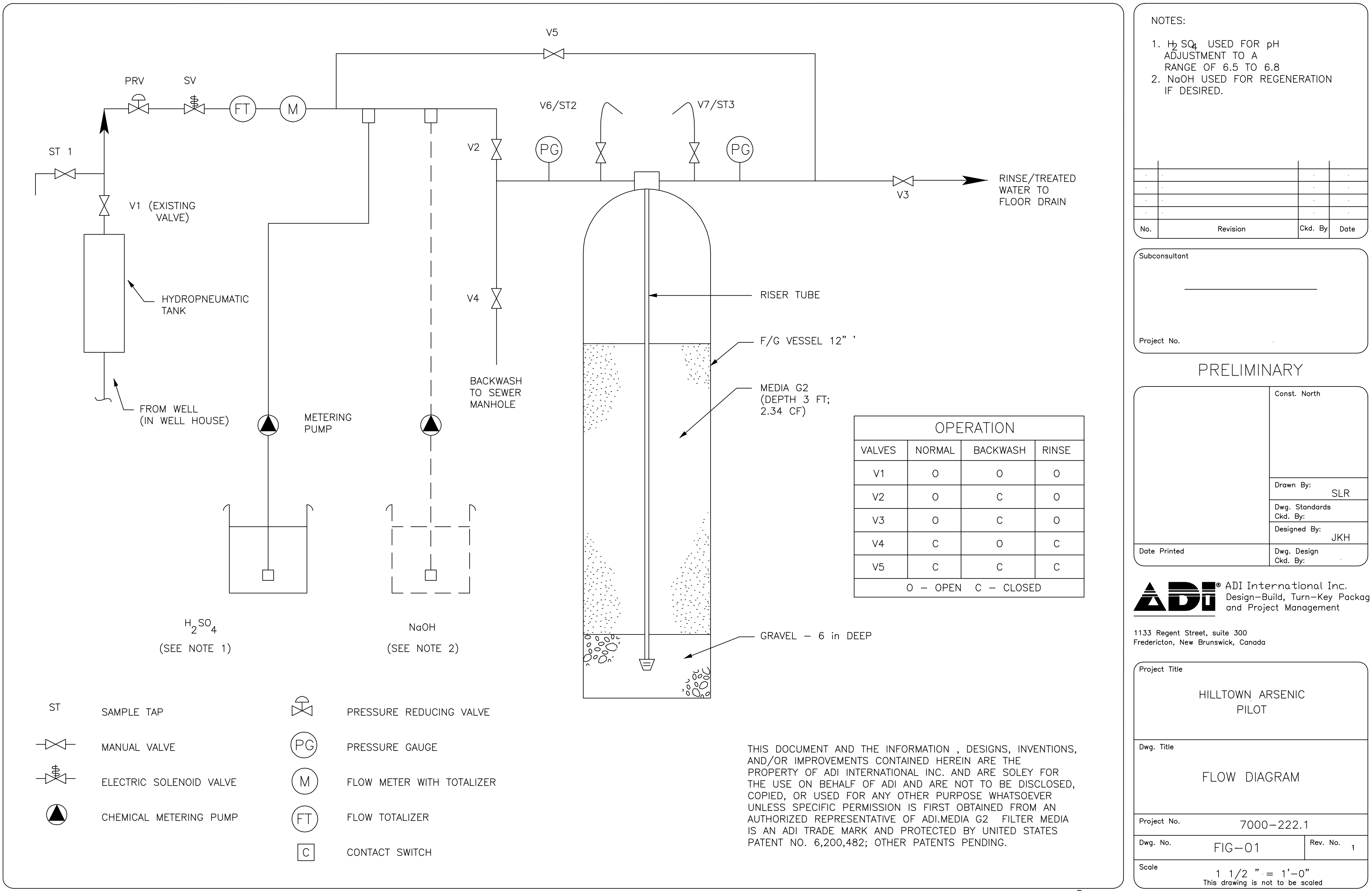


FIGURE 3-2. SCHEMATIC OF MEDIA G2® ARSENIC REMOVAL PILOT PLANT AT HILLTOWN TOWNSHIP WATER & SEWER AUTHORITY WELL NO. 1 FACILITY

3.2.6 Principles of Operation

This modular filter system consists of one pressurized filter vessel designed for operation in the downflow mode. The filter does not require electricity to operate, although appurtenances do require electricity. The filter system can operate either intermittently or continuously at the service flow rate of 1.7 gpm. Specific operating criteria are used to determine when a backwash should be conducted, which are four weeks of operation or a pressure drop across the filter of 10 psi, whichever comes first. Backwash is manually initiated and operated.

The cumulative flow and the flow rate through the filter unit will be monitored with one accessory electronic flow meter and one mechanical totalizer meter, each located on the feed side of the unit prior to the sulfuric acid injection point. The flow meter will also monitor backwash, rinse and regeneration water flow rates. Flow rate will be throttled with a non-integral PVC ball valve located on the treated water side of the filter unit. The collection of backwash and rinse wastewaters for volume determination and water quality analyses will occur once a month during the Adsorption Capacity Test. The collection of regeneration wastewater for volume determination and water quality analyses will occur at the end of the adsorption capacity test.

The difference in feed water and treated water pressure readings will provide loss of head across the filter unit.

Grab samples for on-site and laboratory analyses will be collected from a raw water sample tap on the well discharge pipe prior to chlorine addition (not shown on Figure 3.1), at a sample tap prior to sulfuric acid addition (ST1), at the feed water sample tap (ST2) located immediately upstream of the pilot filter unit, and from the treated water sample tap (ST3), located downstream of the pilot filter unit. Samples from these taps will be collected following the opening of their respective valves and a flush period of around five seconds.

As arsenic-contaminated feed water passes down through the filter unit containing MEDIA G2® arsenic adsorption media, the arsenic concentration will decline until it is no longer detectable. As the upper portion of the adsorption media becomes saturated, the treatment band progresses downward until all adsorptive capacity is used.

3.2.7 Operator Requirements

The pilot filter unit will operate continuously using the chlorinated well water bled from the chlorine detention tank. Operator attention during the capacity verification test will mainly consist of monitoring the equipment, conducting process water quality analyses, refilling chemical tank(s) and to confirm operation in accordance with this PSTP. The well will be monitored for at least the required minimum of 2 hours per day.

The system must be backwashed manually following four weeks of operation or a pressure drop of 10 psi, whichever comes first. Operator initiation is required. The operator will also manually re-initiate service operation of the filter following a backwash period.

Eventually spent MEDIA G2® media must be regenerated, when arsenic is first detected in the filter effluent at a level of 5.0 µg/L. Following regeneration, the pilot unit will be operated for a minimum of four weeks. The media will be removed from the pilot filter unit following the first regeneration and four additional weeks of operation.

Data will be generated that will represent the trend of the actual volume of water treated by the MEDIA G2® media, and the resultant treated water arsenic concentrations.

3.2.8 Required Consumables

- MEDIA G2® media: approximately 2.3 cubic feet, or 109 pounds (uncompacted), replaced following four regenerations
- Sulfuric Acid: 15 gallon carboy of 94% H_2SO_4 - frequency of replacement is site-specific; will be determined at HTWSA's Well Station No. 1 from monitoring chemical usage
- Sodium Hypochlorite: will be calculated based on chlorine dose required to achieve ADI's target free chlorine residual (if needed)
- Caustic Soda: will only be fed for one regeneration, quantity used will be recorded
- Electricity: power consumption for the metering pumps and solenoid valve

3.2.9 Rates of Waste Production

Backwash

Approximately 60 gallons of backwash wastewater and approximately 25 gallons of rinse wastewater are generated following every four weeks of continuous operation or following 10 psi pressure drop, whichever comes first. The backwash wastewater will be discharged to a sanitary sewer manhole located adjacent to the well station, as requested by the PADEP. The rinse wastewater will be discharged to a stream culvert.

Regeneration

Regeneration produces approximately 50 gallons of regenerant wastewater. A portion of this regenerant wastewater will be collected for TCLP analysis. In addition, wastewater is generated following regeneration due to rinsing of the filter bed until the treated water is within one pH unit of the feed water. Both of these wastewaters will be discharged to the sanitary sewer.

When the MEDIA G2® media is eventually removed, following the first regeneration and four (4) weeks of additional operation, it must be disposed in a manner that complies with all state and federal regulations for ultimate waste disposal. ADI has stated that spent MEDIA G2® media is suitable for disposing in a landfill. In order to confirm this claim, the Gannett Fleming field technician will sample a portion of the spent media at the conclusion of the Adsorption Capacity Verification Testing for laboratory TCLP, plus CA WET. The field technician will follow the media sampling protocol presented in Table 3-2.

Table 3-2.
Sampling Protocol for MEDIA G2® Adsorptive Media

Occurrence	Prerequisite Procedure	Media Sampling Procedure
Once, following arsenic breakthrough in the Adsorption Capacity Verification Test, including one regeneration and four weeks of additional testing	ADI's Procedure for Media Replacement in Appendix D	Core one sample from filter vessel using a 1.5 inch diameter, 4 foot long thin-walled copper tube; collect in a plastic bag, shake vigorously and divide into equal sample volumes and collect in sealed plastic bags for delivery to laboratory for TCLP and CA WET.

3.2.10 Equipment Performance Range

ADI has stated that their MEDIA G2® arsenic adsorption media system requires specific water quality conditions to minimize interference from other ions and to maximize arsenic removal. The maximum system pressure is presented on Table 5-1 as the filter tank material rating of 125 psi.

3.2.11 Applications of Equipment

Based on many lab and pilot-scale tests, and experience with ten full-scale installations, the following can be stated regarding interferences to MEDIA G2®:

- Adsorption capacity is not affected by chloride and sulfate ions at concentrations up to 250 mg/L.
- MEDIA G2® does not adsorb silica when the operating pH is at or below 7.2.
- The presence of naturally occurring iron and manganese concentrations up to 2.0 mg/L and 0.8 mg/L, respectively, may enhance performance of MEDIA G2® for arsenic removal, but more frequent backwashing may be required due to increased pressure drop. Both iron and manganese will be reduced to well below the MCLs.
- MEDIA G2® does not remove fluoride by any measure.
- Chlorine and ozone, when used as oxidants or for disinfection, reportedly have no effect on the integrity of MEDIA G2®. ADI has stated that preoxidation is necessary where a portion of the arsenic exists as As III; oxidation converts As III to As V, which is more easily removed by MEDIA G2. (ADI prefers chlorine residual within the filter bed). As to whether an oxidant will improve the performance of MEDIA G2 directly, there is no available data.

- MEDIA G2® will remove both As III and As V with preoxidation.
- Adsorption media is appropriate for groundwater not under the influence of surface water.
- Although MEDIA G2® has performed effectively over a pH range of 5.0 to 7.5 in previous applications, the optimal pH range for most applications is 6.5 to 6.8.
- The manufacturer states that the process is appropriate for "smaller" systems. It is also appropriate for "larger" systems of up to 5.0 mgd.

Table 3-3 below presents a relative comparison of adsorption media to other arsenic removal technologies.

Table 3-3.
Relative Comparisons to Other Arsenic Removal Technologies

Arsenic Removal Process	Equipment Cost	Water Loss	Chemical Requirements	Ease of Operations
Adsorption Media	low	very low	none to moderate	simple to moderate
Ion Exchange	moderate	high	high	moderate
Coagulation/Media Filtration	moderate	low/moderate	moderate	moderate
Coagulation/Microfiltration	high	high	high	high
Reverse Osmosis or Nanofiltration	very high	very high	moderate	moderate

Arsenic Removal Process	Labor Requirements	Power	Hazardous Residuals	Interference from Competing Ions
Adsorption Media	low to moderate	low	low to moderate	low to moderate
Ion Exchange	low to moderate	moderate	high	moderate to high
Coagulation/Media Filtration	moderate to high	high	high	low to moderate
Coagulation/Microfiltration	moderate to high	high	high	low to moderate
Reverse Osmosis or Nanofiltration	moderate	very high	high	low

3.2.12 Licensing Requirements Associated with Equipment Operation

States generally require a specific grade of waterworks operator permit in order to operate a filter process on a public water supply. However, this requirement does not apply for the ETV since all of the treated water will be discharged to waste.

In Pennsylvania, to operate a full-scale version of this treatment technology for the HTWSA public drinking water supply, a D9 license will be required. The "D" refers to a capacity of 0.1 mgd or less, and the "9" refers to inorganics removal.

3.2.13 Known Limitations of Equipment

Chloride and sulfate ions greater than 250 mg/L may reduce MEDIA G2® capacity for arsenic. Iron exceeding 2.0 mg/L and manganese exceeding 0.8 mg/L may result in an excessive rate of headloss across the filter bed. If the feed water pH is greater than 7.2, silica may be adsorbed onto MEDIA G2®, interfering with arsenic adsorption. If a chlorine residual is not maintained through the media bed, MEDIA G2® may be less effective at removing arsenic.

4.1 Objectives

The objectives of this verification testing are in the following areas:

- Produce data to meet the Data Quality Objectives (DQO) shaped by the manufacturer's performance objectives;
- Present data on the impact of variations in feed water quality such as turbidity, arsenic, pH, silica, iron, and manganese on equipment performance;
- Identify the logistical, human and economic resources necessary to operate the equipment;
- Determine the reliability, ruggedness, cost, range of usefulness, and ease of operations; and
- Evaluate the restoration in treatment effectiveness of the pilot unit following a regeneration.

4.2 Equipment Characteristics

4.2.1 Qualitative Factors

The equipment will, as much as is feasible, be operated in such a way as to maintain its operating parameters within the manufacturer's recommendations. The operating range for pH is a critical parameter for arsenic adsorption efficiency. Contact time is also a critical parameter for arsenic adsorption efficiency and is dependent on maintaining flow within the design range. The nature and frequency of the changes required to maintain the operating conditions will be used in the qualitative evaluation of the equipment.

Frequent and significant adjustments will indicate relatively lower reliability and higher susceptibility to environmental conditions, and also the degree of operator experience that may be required. The effect of operator experience on the treatment results will be evaluated.

The modular nature of the filter components, similar to a residential ion exchange water softener, makes equipment installation easy and straightforward. The equipment can be installed by a qualified plumber. This also makes the equipment easy to move and reinstall at another location. The filter unit is freestanding, requiring only a level surface capable of supporting 135 pounds, and maintenance of ambient temperature above 40°F.

4.2.2 Quantitative Factors

The following factors will be quantified for site specific conditions based upon data collected during this testing program:

- Rate of media exhaustion
- Quantity of sulfuric acid
- Quantity of sodium hypochlorite
- Quantity of caustic soda
- Frequency of media replacement
- Backwash and rinse water quantity and quality
- Backwash and rinse duration and frequency
- Regenerant water quantity and quality
- Regeneration duration and frequency
- Estimated labor hours for operation and maintenance
- Chemical tank batching frequency and volume

These quantitative factors will be used as an initial benchmark to assess equipment performance and develop operation and maintenance costs.

4.3 Water Quality Considerations

4.3.1 Raw and Treated Water Quality

Well No. 1 raw and finished water quality is presented on Table 4-1. The raw water is generally of relatively poor quality for a groundwater supply; arsenic and manganese concentrations exceed their promulgated and existing maximum contaminant levels (MCL), respectively. The water is relatively high in total and calcium hardness. Sulfate levels are moderately high in this supply, although less than the level stated by ADI as a potential limiting factor for MEDIA G2's capacity for arsenic. A relatively high conductivity level, due in a major part to the levels of hardness and sulfates, indicates a high level of dissolved ions. Silica concentrations are relatively high and, according to ADI, could be an interference to MEDIA G2 arsenic adsorption on the media if the feed water pH is not maintained below 7.2.

The finished water quality presented in Table 4-1 was collected with the sequestrant added prior to distribution to minimize manganese precipitation; the manganese is at a level where it could create aesthetic problems for consumers if allowed to "plate out". HTWSA has agreed to terminate the addition of the sequestrant for the duration of the ETV, stating that it apparently has not provided significant improvement in water quality since the sequestrant feed program was initiated. Finished water quality from Well No. 1 tends to have high levels of hardness and alkalinity and a pH in the slightly alkaline range. Arsenic is approximately double the promulgated MCL of 10 µg/L.

The one finished water analysis for turbidity was relatively high for a groundwater supply. Since the two raw water samples were very low in turbidity, and assuming that the finished water analysis is valid, the finished water turbidity is likely due to oxidation of manganese.

Table 4-1.
HTWSA Well No. 1 Water Quality Data

Parameter	Well No. 1 Raw Water Quality		Well No. 1 Finished Water Quality[2]
All results as µg/L unless noted otherwise.			
Parameter	***Sample #1[1]***	***Sample#2[1]***	
Samples Collected by RPC Laboratory - September 2002			
Al	<1	<1	
Sb	<0.1	<0.1	
As	14	18	
Ba	42	237	
Be	<0.1	<0.1	
Bi	<1	<1	
B	887	174	
Cd	<0.1	<0.1	
Ca	86400	57500	
Cr	<1	<1	
Co	<0.1	<0.1	
Cu	<1	6	
Fe	<20	<20	
Pb	<0.1	0.7	
Li	17.3	9.7	
Mg	7760	26300	
Mn	58	52	
Mo	3.2	1.9	
Ni	2	2	
K	760	740	
Ru	0.6	0.6	
Se	<1	<1	
Ag	<0.1	<0.1	
Na	23100	14300	
Sr	3020	1840	
Te	<0.1	0.1	
Tl	<0.1	<0.1	
Sn	<0.1	<0.1	
U	0.2	1.9	
V	<1	<1	
Zn	22	98	
NH_3 (mg/L as N)	<0.05	<0.05	
pH (units)	7.1	7.1	
Alkalinity (mg/L as $CaCO_3$)	166	183	
Chloride (mg/L)	31.4	21.5	
SO_4 (mg/L)	94.0	69.0	
NO_3, NO_2 (mg/L as N)	<0.05	<0.05	
o-PO_4 (mg/L as P)	<0.01	<0.01	
r-Silica (mg/L as SiO_2)	28.9	22.6	

Table 4-1. continued
HTWSA Well No. 1 Water Quality Data

Parameter	Well No. 1 Raw Water Quality	Well No. 1 Finished Water Quality[(2)]
T.O.C. (mg/L)	1.2	1.0
Turbidity (NTU)	0.1	0.1
Conductivity (µmhos/cm)	565	517
Samples collected by PADEP – April and June 2003		
pH	---	7.3
Color	---	< 5
Alkalinity (mg/L as $CaCO_3$)	---	168
Arsenic, Total (µg/L)	19.2 to 21.6	18.6
Turbidity (NTU)	---	2.4
TDS (mg/L)	---	468
Hardness, Total (mg/L as $CaCO_3$)	---	241
Calcium, Total (mg/L)	---	84
Magnesium, Total (mg/L)	---	7.6
Iron, Total (mg/L)	---	0.11
Manganese, Total (mg/L)	---	0.10
TOC (mg/L)	---	0.5 to 0.7
Sulfate, Total (mg/L)	---	85 to 91
Sulfide, Total (mg/L)	---	<0.10
Silica, Total (mg/L)	---	23.5 to 30.2
Phosphate, Total (mg/L)	---	0.02 to 1.1
Vanadium, Total (mg/L)	---	<20

(1) Results of testing by RPC Laboratory of Fredericton, New Brunswick conducted on two raw water samples (prior to any chemical addition) collected from Well No. 1 by HTWSA in September 2002 and sent to ADI.
(2) Contain both chlorine and sequestrant.

4.4 Recording Data

The following information will be recorded on-site and listed on Tables 5-4, 5-5, 5-7 and 5-11:

- Experimental run number
- Water type [raw, feed (prior to and after sulfuric acid addition), treated]
- Wastewater type (backwash, rinse, regenerant)
- Hours of operation (since previous monitoring period) and total hours
- Feed water flow rate
- Feed water total production
- Feed water pressure
- Treated water pressure
- Feed water temperature
- Treated water temperature
- Raw, feed and treated water turbidity

- Raw, feed (prior to and after sulfuric acid addition), and treated water pH
- Raw, feed (prior to and after sulfuric acid addition), and treated water chlorine residual
- Raw, feed and treated water arsenic concentration (qualitatively with field test kit)
- Raw, feed and treated calcium, magnesium, and hardness
- Raw, feed and treated alkalinity
- Raw, feed, and treated fluoride
- Occurrence of a backwash
- Backwash water flow rate
- Backwash duration
- Total volume of backwash wastewater
- Rinse water flow rate
- Rinse duration
- Total volume of rinse water
- Occurrence of a regeneration
- Regeneration water flow rate
- Regeneration duration
- Total volume of regenerant water
- Sodium hypochlorite metering pump rate (if used)
- Sodium hypochlorite dose (if used)
- Sodium hypochlorite tank level (if used)
- Sulfuric acid metering pump rate
- Sulfuric acid dose
- Sulfuric acid tank level
- Caustic soda metering pump rate (during regeneration)
- Caustic soda dose (during regeneration)
- Caustic soda drum level (during regeneration)

4.5 Recording Statistical Uncertainty for Assorted Water Quality Parameters

For the analytical data obtained during verification testing, 95% confidence intervals will be calculated by Gannett Fleming for arsenic data and for all other water quality data where the sample set contains eight or more values.

The consistency and precision of water quality data can be evaluated with the use of the confidence interval. A confidence interval describes a population range in which any individual population measurement may exist with a specified percent confidence. The following formula will be employed for confidence interval calculation:

$$\text{Confidence interval} = \overline{X} \pm t_{n-1,\ 1-\frac{\alpha}{2}} \left(S / \sqrt{n} \right)$$

Where: $\overline{X}$ is the sample mean;
S is the sample standard deviation;
n is the number of independent measures included in the data set;
t is the Student's t distribution value with n-1 degrees of freedom;
 is the significance level, defined for 95% confidence as: 1 - 0.95 = 0.05.

According to the 95% confidence interval approach, the á term is defined to have the value of 0.05, thus simplifying the equation for the 95% confidence interval in the following manner:

$$95\% \text{ confidence interval} = \overline{X} \pm t_{n-1,\,0.975}\left(S / \sqrt{n}\right)$$

Results of these calculations will be expressed as the sample mean plus or minus the width of the confidence interval.

pH statistics will be calculated on a log basis.

4.6 Verification Testing Schedule

Verification testing activities include equipment set up and shakedown, equipment integrity and adsorptive capacity verification tests, and water quality sampling and analysis. The test schedule will be developed to encompass all of these activities.

The test is tentatively scheduled to begin in July 2003. The integrity and adsorptive capacity verification tests will be initiated simultaneously. The integrity verification test will run for a 2-week (13 full days plus 8 hours) period. The adsorptive capacity verification test will run until 5 ppb of arsenic is detected in the treated water. ADI has estimated that the media can treat 561,000 gallons of Well No. 1 feed water to an arsenic concentration less than or equal to 5 ppb, providing that the EBCT is maintained at 10 minutes with a feed water pH of approximately 6.5. At a 1.7 gpm process flow rate and 24 hours per day of operation, this equates to 229 days of operation.

5.1 Equipment Operations and Design

The *EPA/NSF ETV Testing Plan Adsorptive Media Processes for the Removal of Arsenic* specifies the procedures that will be used to ensure the accurate documentation of both equipment performance and treated water quality. Strict adherence to these procedures will result in definition of verifiable performance of equipment.

Design aspects of the water treatment process equipment will be shared with interested regulatory officials.

5.1.1 Design Criteria

The following table presents design criteria for the arsenic adsorption process and appurtenances.

Table 5-1.
Equipment Design Criteria

Model No. 2002 Pilot Unit MEDIA G2®	
No. of Filter Units	1
Filter Tank Dimensions	
Diameter (ID)	12 inches
Height (vessel only)	54 inches
Mode of Operation	downflow
Operating Capacity & Service Flow Rate	1.7 gpm
Hydraulic Loading Rate	2.16 gpm/sf
EBCT at 1.7 gpm	10.3 minutes
Operating pH	~ 6.5
Initial pressure drop (clean media bed)	2 psi
Operating differential pressure range	8 psi
Filter Media	
Depth	35.4 inches
Freeboard above media	12.6 inches
Volume	~2.3 cu. ft., or ~17 gal (uncompacted)
Weight	109 lbs. (based on 47 lbs/ft^3) Note: 109 lbs. of media was weighed on-site by ADI prior to installation into the filter vessel

Table 5-1. (continued)
Equipment Design Criteria

	Support gravel layer	6 inches
	Media expansion during backwash	See backwash expansion curve in Appendix A, Operations Manual - Appendix B
Filter Tank Material		Fiberglass rated @ 125 psi
Control		Manual
Backwash		
	Frequency criteria	Pressure drop of 10 psi, or every four weeks, which ever occurs first.
	Flow Rate	3.2 gpm, or 4.1 gpm/sf
	Duration	15 minutes
Rinse		
	Flow Rate	1.7 gpm
	Duration	~15 minutes (until rinse water is clear)
Regeneration		
	Flow Rate	1.2 gpm (forward flow)
	Caustic Soda Feed Rate	Rate that will allow a 1% solution to enter the pilot unit
	Caustic Soda Feed Duration	Time required to feed 3 bed volumes of 1% solution
	Neutralization	
	Sulfuric Acid Feed Rate	Rate that will allow a 0.5% solution to enter the pilot unit
	Sulfuric Acid Feed Duration	Time required to reduce the pH of the effluent below 7.0 (ENSURE THAT THE pH DOES NOT DROP BELOW 5.0)

Table 5-1. (continued)
Equipment Design Criteria

Rinse	1.7 gpm
Flow Rate	Time required for pH of the
Duration	effluent water to be within one unit of the pH of the influent water
Pressure Gauges	
Manufacturer	Lyn Car
Pressure Range	0-100 psi
Accuracy	±0.5%
Totalizer Meter	
Manufacturer	Neptune Trident
Type	positive displacement
Series	T10
Flow Meter	
Manufacturer	Blue-White Industries, Ltd
Type	Electronic-impeller
Model	F2000/RTSB-50P2-GM2
Range	0.5 to 5.0 gpm
Accuracy & repeatedly	± 1% of full scale
Power supply	4 AA batteries or AC transformer
Size	0.5 inch
Enclosure	NEMA 4X
Feed Water Throttling Valve	
Manufacturer	Hayward Industrial Products, Inc.
Type	Ball valve
Material of Construction	PVC
Size	0.75 inch
Control	Manual

Table 5-1. (continued)
Equipment Design Criteria

Pressure Reducing Valve	
Manufacturer	Conbraco Industries Inc
Model No.	36C
Series	200
Static set pressure	50 psig
Adjustable pressure range	25 to 75 psig
Size	0.75 inch
Solenoid Valve	
Manufacturer	Hayward Industrial Products Inc.
Type	PVC True Union
Maximum Service Pressure	120 psig
Size	0.75 inch
Power requirement	1.6 amps; 20V/AC; 50/60 Hz; 19 watts
Chemical Feed Tanks	
Number	2
Manufacturer	ACO Container Systems
Type	graduated - poly
Volume	100 liter
Dimensions	
Diameter	20 inch
Height	30 inch
Chemical Metering Pumps	
Sulfuric Acid	
Manufacturer	Prominent Fluid Controls
Series	beta/4
Series No.	7-BT4A1601PPE200BDO
Type	Electronic solenoid diaphragm pump
Capacity @ Max Pressure	1.1 L/hr
Max Pressure	253 psig
Capacity @ ½Max Pressure	1.4 L/hr
1/2 Max Pressure	126 psig
Capacity @ Static Set Pressure	~1.7 L/hr
Power Requirement	0.7 amps/115 V/50 –60 Hz
Spare (for caustic soda or sodium hypochlorite)	
Manufacturer	Prominent Fluid Controls
Series	gamma/L
Series No.	GALa 1602NPB900UD
Type	Electronic solenoid diaphragm pump

Table 5-1. (continued)
Equipment Design Criteria

Capacity @ Max Pressure	1.4 L/hr
Max Pressure	253 psig
Capacity @ ½Max Pressure	1.7 L/hr
1/2 Max Pressure	126 psig
Capacity @ Static Set Pressure	~2.6 L/hr
Power Requirement	0.7 amps/100-230 V/50-60 Hz

5.1.2 Arsenic Adsorption Media

A typical breakthrough curve for feed arsenic at 200 ppb is shown in Appendix A, Operations Manual – Appendix B. Table 5-2 presents specifications for the arsenic adsorption media being tested.

Table 5-2.
ADI's MEDIA G2® Media Specifications

Chemical Constituents	
Base material	Mined calcined diatomite graded
Processed	and coated with ferric hydroxide
Iron, % by weight	5 to 30
Physical Properties	
Bulk Density	47 lbs/cu ft
Hardness	210 lb/sq in
Attrition	no data available
Voids	no data available
Pore Size	no data available
Pore volume	no data available
Abrasion loss	no data available
Moisture (weight)	no data available
Sieve sizes, US sieve series	no data available
Particle Size	no data available
Effective Size	0.32 mm
Uniformity Coefficient	1.8 to 2.0
Arsenic adsorption capacity	800 µg arsenic per gram of media
Ionic Preference Series	no data available

Approvals:

- Certified to NSF/ANSI 61 (See Appendix B)
- TCLP (see Appendix B)

MEDIA G2® MSDS:

- See Appendix F

5.1.3 Field Test Equipment

Table 5-3 presents the analytical and calibration equipment that will be used on-site.

Table 5-3.
Field Analytical and Calibration Equipment

Equipment	Manufacturer/Model/Specs
Turbidimeter	Hach Model 2100P Portable Ratio™ Optical System (meets or exceeds USEPA method 180.1 criteria)
pH/ISE Meter	Orion Model 290A Meter with Triode pH Electrode Model 91-578N (resolution 0.1/0.01/0.001, accuracy ± 0.005); and Fluoride Combination Electrode Model 96-09 (reproducibility ± 2%)
Thermometer	Miller & Weber (range 0-32°C; NIST traceable)
Arsenic Field Test Kit	Industrial Test Systems (ITS), Inc. Model QUICK Low Range II (optimum accuracy below 6 ppb)
Colorimeter	Hach Model DR/850; wavelength range 520, 610 nm; wavelength accuracy ±1 nm
Dead weight pressure gauge tester	Amthor Testing Instrument Co. Inc. (Type No. 460; range 0-6000 psi)
Burettes for analytical titrations	50 mL capacity with 0.1 mL subdivisions and 1000 mL reagent reservoir
Stopwatch and "bucket"	Digital stopwatch and 2.0 L graduated cylinder with 10 mL increments for rotameter and totalizer meter calibration checks. Fifty gallon container for backwash wastewater flow calibration

5.2 Communications, Documentation, Logistics, and Equipment

It is Gannett Fleming's responsibility to coordinate communication between all verification testing participants.

All field activities will be thoroughly documented using the following forms of record:

- Field Logbook
- Field Data Sheets
- Photographs
- Laboratory Chain-of-Custody Forms, Submission Sheets, and Reports
- Laptop Computer

Gannett Fleming will be responsible for maintaining all field documentation. A bound field logbook will be used to record all water treatment equipment operating data. Each page will be sequentially numbered and labeled with the project name and number. Completed pages will be signed and dated by the individual responsible for the entries. Errors will have one line drawn through them and this line will be initialed and dated.

All photographs will be inserted in the field logbook. The time, date, direction, subject of the photograph and identity of the photographer will be included with each entry. Any deviations from the approved final PSTP will be thoroughly documented in the field logbook at the time of inspection and in the verification report.

Laboratory submission forms will accompany all samples shipped to the PADEP and NSF Laboratories. Copies of laboratory submission forms or chain-of-custody forms for all samples will be provided at the time of the QA/QC inspection and included in the verification reports.

5.3 Equipment Operation and Water Quality Sampling for Verification Testing

The field activities will conform to requirements provided in this PSTP that were developed and approved for the verification testing to be conducted. The sampling and sample analyses that occur during this verification testing program will be performed according to the procedures detailed by Gannett Fleming in this PSTP.

If unanticipated or unusual situations are encountered that may alter the plans for equipment operation, water quality sampling, or data quality, Gannett Fleming will discuss the situation and plan modifications with the NSF technical lead and the PADEP. Any deviations from the approved final PSTP will be documented.

During routine operation, the following will be documented daily:

- The number of hours the arsenic adsorption media filter is operated.

- The number of hour(s) the operator was working at tasks at the well station related to the operation of the arsenic adsorption media filter.
- Description of tasks performed during the arsenic adsorption media filter operation.

5.4 Task 1: System Integrity Verification Testing

5.4.1 Introduction

During Task 1, Gannett Fleming will evaluate the reliability of equipment operation under the environmental and hydraulic conditions at the HTWSA Well Station No. 1 site, and determine whether performance objectives stated in Section 5.5.2 can be achieved for arsenic removal at the design operating parameters for the arsenic adsorption media system. The adsorption media filter will be operated for integrity testing purposes within the operational range presented in the equipment design criteria and the manufacturer's statement of performance capabilities.

5.4.2 Experimental Objectives

- Establish equipment operational reliability under field conditions.
- Document feed water quality relative to the maximum arsenic value of 20 ppb stated in performance objective.
- Collect operational and water quality data under field conditions that can be related to the operating time, throughput and water quality objectives stated by the manufacturer.

5.4.3 Work Plan

- A platform scale was used by the vendor to weigh the media prior to installation into the filter vessel. The weight of the media is reported on Table 5-1.
- Protocol for start-up:
  a) Place media in filter vessel and backwash at a rate of 4 to 5 gpm/sf for 15 to 30 minutes to remove fines,
  b) Rinse with acidified water (pH 4.0 to 5.0) at the normal service rate until the pH of filter outlet water is reduced to less than 7.0 (See Appendix A, Operation Manual pages 1 to 4, for further details).
- Monitoring and on-site data collection schedule is presented on Table 5-4.
- A minimum of two hours of continuous operation per day will be witnessed by the Gannett Fleming field technician.
- Grab samples for on-site and laboratory analyses will be collected based on the sampling schedule presented on Table 5-5. The raw, ST1, feed (ST2) and treated (ST3) water sample taps will be flushed for at least five seconds prior to sample collection.
- A sampling plan for arsenic that includes the Integrity Verification Test is presented on Table 5-8.

- Seven days of the daily raw, feed and treated water samples will be collected to speciate arsenic during the Integrity Test, as specified in Table 5-8. The protocol for arsenic speciation is presented in Appendix G.
- Daily and weekly samples collected for on-site analysis will be analyzed immediately after collection. Sample collection and handling procedures will follow *Standard Methods* 3010 B.
- Daily and weekly samples for laboratory analysis will be collected during the 2-hour period of monitoring. All of the samples will be collected by the Gannett Fleming field technician, in appropriate sample bottles prepared with preservatives, as required, that are specific to the analytical methods to be used. Additionally, the samples will be stored and shipped in accordance with appropriate procedures and holding times, as specified by the PADEP and NSF laboratories. A water quality sampling protocol for laboratory analyses describing volumes, preservation, holding times and laboratory sample identification for each water quality parameter is presented on Table 5-14. The methods to be used by the laboratories for the scheduled analytical procedures are presented on Table 5-5, and described in Task 5, Quality Assurance/Quality Control.
- At least one backwash will occur during the System Integrity Verification Test, which will be manually initiated by the field engineer. Backwash water flow rate, duration, and volume will be monitored volumetrically and recorded. Water quality of the backwash wastewater will be analyzed as listed on Table 5-9.

5.4.4 Analytical Schedule

- Operational Data Collection
  - Feed water production will be monitored twice per day at the mechanical totalizer meter, located on the feed water pipe.
  - Feed water flow rate will be monitored twice per day and adjusted, as needed, with the flow meter and ball valve located on the feed water pipe. Flow rate will be recorded twice per day, before and after adjustment. Flow rate will be set at 1.7 gpm ±0.1 gpm.
  - Feed water pressure will be monitored and recorded twice per day at the pressure gauge located on the feed water pipe. Minimum and maximum operating pressures for the filter vessel are 30 psi and 125 psi, respectively. A PRV should maintain the feed water pressure at a constant 50 psi.
  - Treated water pressure will be monitored and recorded twice per day at the pressure gauge located on the treated water pipe. This will be performed at the same time as the feed water pressure measurement. The difference between these measurements will represent pressure drop through the pilot filter unit.
  - The sulfuric acid chemical batch tank level will be checked and recorded daily (see Table 5-6). The tank will be refilled as needed, with the time and quantity of refill noted.

- The sulfuric acid metering pump feed rate will be monitored and adjusted based on the draw down in the batch tank to maintain ADI's goal of sustaining the pH as close as possible to 6.5 in the feed (ST2) and treated (ST3) water.

Table 5-4.
On-site Equipment Operating Parameter Monitoring and Data Collection Schedule

Parameter	Monitoring Frequency	Monitoring Method
Feed water production	Check & record twice per day	Feed water totalizer meter
Feed water flow rate	Check & record twice per day (adjust when 5% above or below target; record before and after adjustment)	Feed water flow meter
Feed water pressure	Check & record twice per day	Feed water pressure gauge
Treated water pressure	Check & record twice per day	Treated water pressure gauge
Chemical feed: tank volume and pump metering rate	Check & record once per day	Measure with measuring tape depth of chemical remaining and, as required, quantity of chemical refill
Chemicals used	As needed	Record name of chemical, supplier, commercial strength, dilution used for making batch solution

- Water Quality Data Collection
  - The water quality of the raw water, feed water (both prior to and after sulfuric acid addition), and treated water will be characterized by analysis of the water quality parameters listed on Table 5-5.
  - Samples will be collected during the 2-hour monitoring period
  - All "on-site analyses" will be analyzed on-site.
  - The water quality analyses presented on Table 5-5 are conducted to provide state drinking water regulatory agencies with background data on the quality of the raw water being treated, and the quality of the feed and treated water.

Table 5-5.
Water Quality Sampling Schedule - System Integrity Verification Testing

Parameter	Sampling Frequency	Test Streams to be Sampled	Standard Method[1]	EPA Method	Hach Method
On-Site Analyses					
Arsenic	[2]	Raw Water, Adsorptive Media Feed & Treated Water	(See Appendix H)		
pH	Twice Daily	Raw Water, ST1[3], Adsorptive Media Feed & Treated Water	4500-H^+ B	--	--
Temperature	Daily	Adsorptive Media Feed & Treated Water	2550 B	--	--
Turbidity	Daily	Raw Water, ST1[3], Adsorptive Media Feed & Treated Water	2130 B	--	--
Alkalinity	Daily	Raw Water, Adsorptive Media Feed & Treated Water	--	--	8221
Calc ium	Weekly	Raw Water, Adsorptive Media Feed & Treated Water	--	--	8222
Magnesium	Weekly	Raw Water, Adsorptive Media Feed & Treated Water	--	--	Calculated (8226-8222)
Hardness	Weekly	Raw Water, Adsorptive Media Feed & Treated Water	--	--	8226
Fluoride	Daily	Raw Water[4], Adsorptive Media Feed & Treated Water	4500-F^- C	--	--
FAC	Twice Daily	Raw Water, ST1[3], Adsorptive Media Feed & Treated Water	--	--	8021
Laboratory Analyses					
Arsenic[5]	Daily	Raw Water, Adsorptive Media Feed & Treated Water	--	200.8	--
Silica	Daily	Raw Water[4], Adsorptive Media Feed & Treated Water	--	200.7	--
Aluminum	Daily	Raw Water[4], Adsorptive Media Feed & Treated Water	--	200.7	--
Iron	Daily	Raw Water[4], Adsorptive Media Feed[6] & Treated Water	--	200.7	--
Manganese	Daily	Raw Water[4], Adsorptive Media Feed[6] & Treated Water	--	200.7	--
Chloride	Weekly	Raw Water, Adsorptive Media Feed & Treated Water	--	300.0	--
Sulfate	Weekly	Raw Water, Adsorptive Media Feed & Treated Water	--	300.0	--
Sodium	Weekly	Raw Water, Adsorptive Media Feed & Treated Water	--	200.7	--
Total Phosphorus	Weekly	Raw Water, Adsorptive Media Feed & Treated Water	--	365.1	--

(1) APHA, AWWA and WPCF (1995). *Standard Methods for Examination of Water and Wastewater*. 19th ed. Washington, D.C. APHA
(2) See Table 5.8. Arsenic field test kit will be used for periodic qualitative arsenic checks.
(3) A sample will be collected once per day from ST1, the sample tap located on the chlorinated water, prior to sulfuric acid addition.
(4) The raw water will be collected and analyzed weekly.
(5) The NSF International laboratory will perform laboratory arsenic analyses. The PADEP Laboratory will analyze all other laboratory analyses during the Integrity Test.
(6) Feed water will be checked for the soluble fractions of iron and manganese in addition to the total concentrations of these metals, requiring filtration through 0.22 µm filter paper.

5.4.5 *Evaluation Criteria and Minimum Reporting Requirements*

- Operational performance evaluation
  - A table and time series plot will be produced to present all raw water, feed water and treated water arsenic laboratory data from the System Integrity Verification testing. The System Integrity Verification testing demonstrates the initial ability of the adsorptive media to remove the feed water arsenic concentration to below detectable levels in the treated water.
- Feed water flow rate
  - A table of feed water flow rates will be tabulated.
- Backwash waste stream flow rates
  - A table of backwash and rinse water waste stream flow rates will be tabulated
- A plot of feed water and treated water pressures and system pressure drop will be presented. This information can be used to infer power requirements in systems that will pump directly through the unit. No direct measurement of power is possible, since the system does not require electricity (other than the small amperage demand placed by the chemical metering pumps and solenoid valve).

TABLE 5-6.
SYSTEM INTEGRITY VERIFICATION TEST: CHEMICAL CONSUMPTION DATA REPORT (1)

MANUFACTURER: ADI International **PRODUCT NAME:** MEDIA G2 **MODEL NO.:** ADI Pilot Test Unit No. 2002-09

ADSORPTIVE MEDIA MANUFACTURER'S CHEMICAL CONSUMPTION OBJECTIVE: ______________________ ______________________

SULFURIC ACID: ______Gal/1000 gal Trtd
CAUSTIC SODA: ______Gal/1000 gal Trtd

Event	Date	Time	Flow Meter Flow Rate (gpm)	Water Production Totalizer Meter (gallons x 1000)	Water Production Incremental Volume(2) (gallons x 1000)	Sulfuric Acid Remaining (gallons)	Sulfuric Acid Consumed (gallons)	Sulfuric Acid Batch Tank Refilled (gallons)	Caustic Soda Batch Tank (gallons)	Caustic Soda Batch Tank Consumed (gallons)	Chemical Usage Total (gallons)

(1) Data entered on this report provides information which yields chemical consumption per thousand gallons of treated water.
This in turn is to be converted to a cost of each chemical per thousand gallons of treated water.
(2) Totalizer Meter Reading (n) - Totalizer Meter Reading (n-1) in 1000 gallons

5.5 Task 2: Adsorptive Capacity Verification Testing

5.5.1 Introduction

The objectives of this task are to produce quality operational and water quality data up through and including what ADI has defined as the breakthrough arsenic level for their arsenic adsorption system. The performance of the adsorptive media is a function of the feed water quality, contact time, rest time and type of adsorptive media used. Arsenic breakthrough is highly dependent on the concentration and adsorptive characteristics (isotherm) of the arsenic to be treated by the adsorptive media. Design and empty bed contact time (EBCT) will help define the performance of a given media for a given feed water quality.

A tabulation of physical properties of the MEDIA G2® arsenic adsorption media is presented on Table 5-2.

Adsorption capacity verification testing will be performed one time to arsenic breakthrough, defined by ADI as 5 µg/L, for the MEDIA G2® arsenic adsorption media system using the feed water from HTWSA's Well No. 1. Following breakthrough, MEDIA G2® will be regenerated and returned to operations for a minimum of four (4) weeks of continuous operations.

Regeneration will be accomplished by first performing a brief backwash of the pilot unit, followed by chemical regeneration of MEDIA G2® by passing three (3) bed volumes (50 gallons total) of 1% caustic soda through the bed. Subsequently the bed will be neutralized with a 0.5% sulfuric acid solution. It is estimated that the entire regeneration process will take approximately one hour. Details of the regeneration procedure are provided in Section 6.0 of ADI's Operations Manual (see Appendix A)

Table 5-7.
Water Quality Sampling Schedule - Media Adsorption Capacity Verification Testing

Adsorption Capacity Verification Testing Parameter	Sampling Frequency	Test Streams to be Sampled	Standard Method(1)	EPA Method	Hach Method
On-Site Analyses					
Arsenic	(2)	Adsorptive Media Feed & Treated Water	(See Appendix H)		
pH(3)	Daily	Raw Water, ST1(4), Adsorptive Media Feed & Treated Water	4500-H^+ B	--	--
Temperature(3)	Daily	Adsorptive Media Feed & Treated Water	2550 B	--	--
Turbidity(3)	Daily	Raw Water, ST1(3), Adsorptive Media Feed & Treated Water	2130 B	--	--
Alkalinity	3/Week	Raw Water, Adsorptive Media Feed & Treated Water	--	--	8221
Calcium	Weekly	Adsorptive Media Feed & Treated Water	--	--	8222
Magnesium	Weekly	Adsorptive Media Feed & Treated Water	--	--	Calculated (8226-8222)
Hardness	Weekly	Adsorptive Media Feed & Treated Water	--	--	8226
Fluoride	Weekly(7)	Adsorptive Media Feed & Treated Water	4500-F^- C	--	--
FAC(3)	Daily	ST1(4), Adsorptive Media Feed & Treated Water	--	--	8021
Laboratory Analyses					
Arsenic(5)	Weekly(6)	Raw Water, Adsorptive Media Feed & Treated Water	--	200.8	--
Silica	Weekly(7)	Adsorptive Media Feed & Treated Water	--	200.7	--
Aluminum	Weekly(7)	Adsorptive Media Feed & Treated Water	--	200.7	--
Iron	Weekly	Adsorptive Media Feed & Treated Water	--	200.7	--
Manganese	Weekly	Adsorptive Media Feed & Treated Water	--	200.7	--
Chloride	Weekly	Adsorptive Media Feed & Treated Water	--	300.0	--
Sulfate	Weekly	Adsorptive Media Feed & Treated Water	--	300.0	--
Sodium	Weekly	Adsorptive Media Feed & Treated Water	--	200.7	--
Total Phosphorus	Weekly	Adsorptive Media Feed & Treated Water	--	365.1	--
TCLP(8)	Once	Spent MEDIA G2® Adsorptive Media	--	SW-846 EPA 1311	--
CA WET(8)	Once	Spent MEDIA G2® Adsorptive Media	(See Appendix E)		

(1) APHA, AWWA and WPCF (1995). *Standard Methods for Examination of Water and Wastewater*. 19th ed. Washington, D.C. APHA.
(2) Arsenic field test kit will be used for periodic qualitative arsenic checks as specified in Table 5-8.
(3) Gannett Fleming will be on-site TBD days per week to collect data. Each day that the FTO is not on-site, a representative from the HTWSA will be gathering the data and recording it in the logbook.
(4) A sample will be collected three times per week from ST1, the sample tap located on the chlorinated water, prior to sulfuric acid addition. Less frequent sampling (e.g. once per week) of this parameter will occur if data collected daily during Task 1 show that the concentration of the parameter does not fluctuate or is not at a higher or lower concentration than expected.
(5) The NSF International laboratory will perform laboratory arsenic analyses. The PADEP Laboratory will analyze all other laboratory analyses during the Capacity Test.
(6) See arsenic sampling plan on Table 5-8.
(7) More frequent sampling of this parameter will occur if data collected daily during Task 1 show that the concentration of the parameter fluctuates or is at a higher concentration than expected. A higher frequency of this parameter will also be considered during the last two months of sample collection.
(8) TriMatrix Laboratories, Inc. will perform the TCLP and CA WET.

Table 5-8.
Arsenic Sampling Plan

Laboratory Analyses

Test Period	Sample Sources	Sample Frequency	Sampling Period	No. of Days Samples Speciated(1)	Hold Samples	Total No. Analyses
Integrity Verification	raw, feed, treated	daily	13 days 8 hours	7	none	84
Adsorption Capacity Verification	raw(2), feed, treated	weekly	first 6 months(1)	monthly(3)	none	84
Adsorption Capacity Verification	raw (2), feed, treated	daily	final 2 months(1)	monthly(3)	12 per week	72
Post Regeneration Verification	raw(2), feed, treated	3x/week(4); weekly	one 4 week period	1x(3)	N/A	19
***On-site Qualitative Analyses*(5)**						
Integrity Verification	feed, treated	weekly	13 days 8 hours	N/A	N/A	4
Adsorption Capacity Verification	feed, treated	weekly	first 6 months(1)	N/A	N/A	48
Adsorption Capacity Verification	feed, treated	3x per week	final 2 months(1)	N/A	N/A	48
Post Regeneration Verification	feed, treated	weekly	one 4 week period	N/A	N/A	8

(1) Based on ADI's estimate of 8 months of continuous (24 hour per day) operations with a feed water arsenic level of 20 ppb or less, inlet pH of 6.5 to 6.8, and 10 minute EBCT producing a filtrate with an arsenic level of 5 ppb or less.
(2) Monthly sampling, if after the results of daily sampling during the integrity test indicate that raw and feed total arsenic levels do not vary significantly.
(3) This is considered the minimum number of samples speciated; if arsenic results not anticipated should occur, such as premature breakthrough or significant variatio n in feed arsenic level, more frequent arsenic speciation will occur.
(4) For the first week, weekly thereafter.
(5) Method procedure presented in Appendix H.

Table 5-9.
Backwash and Rinse Wastewater Monitoring, Sampling and Analyses

Parameter	Backwash and Rinse Wastewater Monitoring or Sample Type	Frequency	Method
Flow Rate	yes	every backwash	"bucket"[(2)] & stopwatch
Volume	yes	every backwash	graduated container[(2)]
Duration	yes	every backwash	stopwatch
Turbidity	grab[(1)]	monthly	SM 2130-B
pH	grab[(1)]	monthly	SM 4500-H^+
Arsenic	grab[(1)]	monthly	EPA 200.8
Manganese	grab[(1)]	monthly	EPA 200.7
Iron	grab[(1)]	monthly	EPA 200.7
Aluminum	grab[(1)]	monthly	EPA 200.7
Sodium	grab[(1)]	monthly	EPA 200.7
Alkalinity	grab[(1)]	monthly	Hach 8221
FAC	grab[(1)]	monthly	Hach 8021

(1) Grab samples will be collected from a continuously mixed batch tank using a 2-liter beaker. All wastewaters will be collected in a 50-gallon container.
(2) The "bucket" will be a 50 -gallon container for calibrating backwash and rinse flow rates. Increments in liters will be marked on the sides of this container based on incrementally filling the container beforehand with a 2 liter graduated cylinder.

5.5.2 Experimental Objectives

The experimental objective is to provide quality operating and water quality data relative to ADI's process performance objective.

Gannett Fleming has identified the following manufacturer's process performance objectives based on bench-scale testing of water from HTWSA Well No. 1:

“ADI Model No. 2002-09 arsenic treatment unit containing ADI’s MEDIA G2® ferric hydroxide-based adsorptive media is capable of removing arsenic from a chlorinated feed water, containing an arsenic concentration of less than or equal to 20 ppb, when operated at an EBCT of 10 minutes and with an inlet pH of approximately 6.5, to an arsenic concentration of less than or equal to 5 ppb in the product water for a period of 8 months of continuous operation which is equivalent to over 33,000 ten minute bed volumes, without regeneration.”

“ADI’s MEDIA G2® adsorptive media can be regenerated repeatedly in-situ, after being saturated with arsenic, such that an arsenic concentration of 5 ppb in the product water (described above) is not exceeded for a period of 30 months of continuous operation which is equivalent to over 130,000 ten minute volumes.”

“The liquid waste product from regeneration of MEDIA G2®, when corrected to pH 6.0 to pH 6.5, will pass EPA’s TCLP.”

“ADI’s MEDIA G2® adsorptive media, at the end of the first 8 months of continuous operation, will pass EPA’s TCLP.”

“ADI’s MEDIA G2® adsorptive media, after its first use and after four regenerations, will pass EPA’s TCLP.”

“The total life of MEDIA G2® will be over 130,000 ten minute bed volumes, with four regenerations.”

The water quality and performance objectives are based upon continuous operation of the equipment, 24 hours per day, and an anticipated total throughput of greater than 561,000 gallons. The design flow rate is 1.7 gpm ± 0.1 gpm.

5.5.3 Work Plan

The measured feed water arsenic concentration during verification testing must average within 10% of the amount stated in the manufacturers' performance objective.

- Equipment Operation

  Task 2 Adsorption Capacity Verification Testing will begin simultaneously with Task 1 System Integrity Verification Testing. The operating conditions will be as stated under 5.4.3 Work Plan for Task 1: System Integrity Verification Testing.

5.5.4 *Analytical Schedule*

- Operational Data Collection
  - Feed water production will be monitored twice per day at the mechanical totalizer meter, located on the feed water pipe.
  - Feed water flow rate will be monitored twice per day and adjusted, as needed, with the flow meter and ball valve located on the feed water pipe. Flow rate will be recorded twice per day, before and after adjustment. Flow rate will be set at 1.7 gpm ±0.1 gpm.
  - Feed water pressure will be monitored and recorded twice per day at the pressure gauge located on the feed water pipe. Minimum and maximum operating pressures for the filter vessel are 30 psi and 125 psi, respectively. A PRV should maintain the feed water pressure at a constant 50 psi.
  - Treated water pressure will be monitored and recorded twice per day at the pressure gauge located on the treated water pipe. This will be performed at the same time as the feed water pressure measurement. The difference between these measurements will represent pressure drop through the pilot filter unit.
  - The sulfuric acid chemical batch tank level will be checked and recorded daily (see Table 5-6). The tank will be refilled as needed, with the time and quantity of refill noted.
  - The sulfuric acid metering pump feed rate will be monitored and adjusted based on the draw down in the batch tank to maintain ADI's goal of sustaining the pH of approximately 6.5 in the feed (ST2) and treated (ST3) water.

- Sample Holding

  As indicated on Table 5-8, as the media approaches 70% of its predicted capacity, samples for laboratory arsenic will be collected on a daily basis and held (approximately 2 weeks) pending the results of the weekly arsenic samples. This will be done in the event that arsenic breakthrough is missed with the weekly sampling. If a breakthrough should happen to be missed, the hold samples will be submitted for analysis. The first detection of arsenic using the field test kit, at a level of 2 ppb or higher in the treated water (and all previous treated water lab results for arsenic were non-detects) will also trigger sample collection for laboratory arsenic analysis and/or submittal of any recently collected samples being held for future arsenic analysis.

  Fluoride, silica, and aluminum samples will be collected weekly, at a minimum, during Task 2. More frequent sampling of a parameter will occur if data collected daily during Task 1 shows that the concentration of the parameter fluctuates or is at a higher concentration than expected. A higher frequency of these parameters, including alkalinity, will also be considered during the last 2 months of sample collection.

- Water Quality Data Collection
  The water quality of the raw water; adsorptive media feed and treated water (pre and post regeneration); backwash wastewater; rinse wastewater; and regeneration wastewater will be characterized by the analysis of the water quality parameters listed in Tables 5-7, 5-9, 5-11 and 5-12. The sampling frequency is described in Tables 5-7, 5-8, 5-9, 5-11 and 5-12. This frequency is intended to provide sufficient water quality data to effectively characterize the breakthrough profile of arsenic, to develop representative backwash and regenerant wastewater quality profiles, and to produce quality operational and water quality data for a minimum of four weeks of continuous operation following regeneration of the media. The exact sampling interval and duration will depend on the length of the verification testing. If breakthrough does not occur by the estimated time of 8 months, the verification test and sampling plan will continue until breakthrough occurs.

  Grab samples of backwash, rinse and regenerant wastewaters will be collected for the water quality analyses at the frequency presented on Table 5-9 and 5-12. The wastewaters will be collected separately; each will be mixed to maintain a relatively homogenous suspension during sample collection. As stated in Section 2.4, the liquid waste from regeneration will be analyzed, including TCLP analysis, and discharged to a sewer manhole.

- Arsenic Speciation
  The minimum arsenic speciation frequency is presented on Table 5-8. If arsenic is detected in a treated water laboratory analysis, follow-up samples of raw, feed and treated water will be speciated for arsenic. In addition, if the arsenic field test detects arsenic in the treated water, than the next sample collected for laboratory arsenic analysis will be speciated.

- Spent Media Analysis
  - TCLP and CA WET will be performed on spent MEDIA G2® media, as described in Section 3.2.9 and Appendix E. The physical condition of the spent media will be noted and reported. TCLP will be performed on the media after the one-month post-regeneration period, not before regeneration as stated in the manufacturer's performance objectives.
  - A 1.5-inch thin-walled copper tube 4 feet in length will be used to core one sample of spent MEDIA G2® adsorption media from the filter vessel. The ADI procedure for media replacement in Appendix D will be followed (with the exception of emptying the media into the bucket) to gain access to the media contained in the filter vessel, and to decant the water out of the vessel. Following decant, the copper tube will be used to obtain a core sample through the entire depth of the media. The cored sample will be discharged into a large plastic bag. The bag will be vigorously shaken to provide a homogenous media sample. The media sample will subsequently be unloaded onto a flat surface (cardboard, perhaps) and divided into two samples of roughly equal volume. Each sample will be collected in a separate sample bag and marked with

appropriate information indicating its source and required laboratory tracking information. One sample will be used for TCLP. The second sample will be used for CA WET.

  - o A media gradation analysis will be performed on the spent MEDIA G2® media and compared to the gradation analysis of new media, to determine the extent of media physical degradation, if any.

5.5.5 Evaluation Criteria and Minimum Reporting Requirements

- Record of Arsenic Removal
  - o An arsenic breakthrough curve showing adsorptive media treated water concentrations versus bed volumes treated will be plotted. Feed water arsenic concentrations will be included on the same plot.
  - o A spreadsheet table (Table 5-10) will tabulate on-site arsenic (qualitative) feed water concentrations and calculate the average feed water arsenic concentration.
  - o The performance objective for treated water volume and water quality will be represented on the plot.
- Process Control
  - o Adsorptive media feed water and treated water arsenic (qualitative), pH, FAC, pressure, water production, and flow rate will be recorded on Table 5-10, which will be used to calculate incremental feed and treated water production, differential pressure, and cumulative arsenic removed. Included will be the adsorptive media feed water average, standard deviation and percent standard deviation for each parameter.
- Record of Chemical Consumption
  - o Gallon(s) of chemicals consumed per 1,000 gallons of treated water will be calculated from data entered into the spreadsheet presented on Table 5-6. The calculated data will aid in generating operating costs for the treatment system.

TABLE 5-10.
ADSORPTION MEDIA CAPACITY VERIFICATION TEST: DATA REPORT

MANUFACTURER: ADI International Inc.
ADSORPTIVE MEDIA: MEDIA G2®
PRODUCT NAME: MEDIA G2®
RATED CAPACITY: 1328 g of arsenic per liter of MEDIA G2
MODEL NO.: ADI Pilot Test Unit No. 2002-09

Date	Time	Flow Meter Flow Rate (gpm)	Feed Water Production: Totalizer Meter (gallons)	Feed Water Production: Incremental Volume (gallons)	Feed Pressure (psig)	Treated Pressure (psig)	Differential Pressure (psig)	Raw pH	Feed pH (ST1)	Feed pH (ST2)	Treated pH (ST3)	Raw FAC Residual (mg/L)	Feed FAC Residual (ST1) (mg/L)	Feed FAC Residual (ST2) (mg/L)	Treated FAC Residual (ST3) (mg/L)	Qualitative Arsenic Analyses: Feed Arsenic (ST2) (mg/L)	Qualitative Arsenic Analyses: Treated Arsenic (ST3) (mg/L)	Qualitative Arsenic Analyses: Arsenic Removed (mg/L)	Qualitative Arsenic Analyses: Cumulative Arsenic Removed (mg)
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Table 5-11.
Water Quality Sampling Schedule – Post Regeneration Media Verification Testing

Post Regeneration Media Verification Testing Parameter	Sampling Frequency	Test Streams to be Sampled	Standard Method(1)	EPA Method	Hach Method
On-Site Analyses					
Arsenic	(2)	Adsorptive Media Feed & Treated Water	(See Appendix H)		
pH(3)	Daily(8)	Raw Water, ST1(4), Adsorptive Media Feed & Treated Water	4500-H^+ B	--	--
Temperature (3)	Daily	Adsorptive Media Feed & Treated Water	2550 B	--	--
Turbidity(3)	Daily	Raw Water, ST1(3), Adsorptive Media Feed & Treated Water	2130 B	--	--
Alkalinity	3/Week	Raw Water, Adsorptive Media Feed & Treated Water	--	--	8221
Calcium	3/Week(5)	Adsorptive Media Feed & Treated Water	--	--	8222
Magnesium	3/Week(5)	Adsorptive Media Feed & Treated Water	--	--	Calculated (8226-8222)
Hardness	3/Week(5)	Adsorptive Media Feed & Treated Water	--	--	8226
Fluoride	3/Week(5)	Adsorptive Media Feed & Treated Water	4500-F^- C	--	--
FAC	Daily	ST1(4), Adsorptive Media Feed & Treated Water	--	--	8021
Laboratory Analyses					
Arsenic (5)	3/Week(6)(7)	Raw Water, Adsorptive Media Feed & Treated Water	--	200.8	--
Silica	3/Week(6)	Adsorptive Media Feed & Treated Water	--	200.7	--
Aluminum	3/Week(6)	Adsorptive Media Feed & Treated Water	--	200.7	--
Iron	3/Week(6)(8)	Adsorptive Media Feed & Treated Water	--	200.7	--
Manganese	3/Week(6)	Adsorptive Media Feed & Treated Water	--	200.7	--
Chloride	3/Week(6)	Adsorptive Media Feed & Treated Water	--	300.0	--
Sulfate	3/Week(6)	Adsorptive Media Feed & Treated Water	--	300.0	--
Sodium	3/Week(6)	Adsorptive Media Feed & Treated Water	--	200.7	--
Total Phosphorus	3/Week(6)	Adsorptive Media Feed & Treated Water	--	365.1	--

(1) APHA, AWWA and WPCF (1995). *Standard Methods for Examination of Water and Wastewater*. 19th ed. Washington, D.C. APHA.
(2) Arsenic field test kit will be used for periodic qualitative arsenic checks as specified in Table 5-8.
(3) Gannett Fleming will be on-site TBD days per week to collect data. Each day that the FTO is not on-site, a representative from the HTWSA will be gathering the data and recording it in the logbook.
(4) A sample will be collected three times per week from ST1, the sample tap located on the chlorinated water, prior to sulfuric acid addition. Less frequent sampling (e.g. once per week) of this parameter will occur if data collected daily during Task 1 and Task 2 (prior to regeneration) show that the concentration of the parameter does not fluctuate or is not at a higher or lower concentration than expected.
(5) The NSF International laboratory will perform laboratory arsenic analyses. The PADEP Laboratory will analyze all other laboratory analyses during the Post Regeneration Test.
(6) During the first week following regeneration, followed by weekly sampling thereafter
(7) See arsenic sampling plan on Table 5-8.
(8) Samples will be collected 3x during the first 12 hours following regeneration

Table 5-12.
Regeneration Wastewater Monitoring, Sampling and Analyses

Parameter	Backwash, Rinse and Regeneration Wastewater Monitoring or Sample Type	Frequency	Method
Flow Rate	yes	1x	"bucket"(4) & stopwatch
Volume	yes	1x	graduated container(2)
Duration	yes	1x	Stopwatch
Volume of Caustic Soda	yes	1x	graduated container(2)
Volume of Sulfuric Acid	yes	1x	graduated container(2)
Turbidity	grab(1)	1x	SM 2130-B
pH	grab(2)	1x	SM 4500-H^+
Arsenic	grab(3)	1x	EPA 200.8
Manganese	grab(1)	1x	EPA 200.7
Iron	grab(1)(3)	1x	EPA 200.7
Aluminum	grab(1)(3)	1x	EPA 200.7
Sodium	grab(1)	1x	EPA 200.7
Alkalinity	grab(1)	1x	Hach 8221
FAC	grab(1)	1x	Hach 8021
TCLP(5)	grab(1)	1x	SW-846? EPA 1311

(1) Grab samples will be collected from a continuously mixed batch tank using a 2-liter beaker. All wastewaters will be collected in a 50-gallon container.
(2) Samples for pH analysis will be collected every 5 minutes during the regeneration rinse to evaluate the efficiency of media pH adjustment, and to assure that the media is conditioned to within the pH “window” specified by ADI.
(3) Samples for laboratory analysis of arsenic, iron and aluminum will be collected every 10 minutes during the regeneration and rinse to evaluate the efficiency of regeneration.
(4) The "bucket" will be a 50 -gallon containers for calibrating backwash, rinse and regeneration flow rates, and the volume of caustic soda fed Increments in liters will be marked on the sides of this container based on incrementally filling the container beforehand with a 2 liter graduated cylinder.
(5) TCLP will be performed on the regenerant wastewater only. For liquid wastes (i.e., those containing less than 0.5% dry solid material), the waste, after filtration through a 0.6 to 0.8 µm glass fiber filter, is defined as the TCLP extract.

5.6 Task 3: Documentation of Operating Conditions and Treatment Equipment Performance

5.6.1 Introduction

During each day of verification testing, arsenic adsorption media filter operating conditions will be documented, including the rate of pressure drop. The volumetric flow rate through adsorptive media is a critical parameter, and must be monitored and documented. Adsorptive media performance is affected by the EBCT, which varies directly with the volumetric flow rate through the vessel.

5.6.2 Experimental Objectives

The objective of this task is to accurately and fully document the operating conditions and performance of the equipment.

The task will be performed in conjunction with both the System Integrity Verification Testing and the Adsorption Capacity Verification Testing.

5.6.3 Work Plan

During each day of verification testing for both System Integrity Testing and Adsorption Capacity Testing, treatment equipment operating parameters will be monitored and recorded on a routine basis. This will include a complete description of all applicable data. Table 5-10 will be used to record applicable operating data.

A complete description of the treatment process will be given on volume and detention time for the rated flow. Data on the adsorptive media will be provided and will include EBCT, depth, effective size and uniformity coefficient. The type and source of adsorptive media used will also be stated.

5.6.4 Schedule

Table 5-13 presents the schedule for observing and recording equipment operation and performance data. The schedule applies to both System Integrity Verification Testing and Adsorption Capacity Verification Testing.

Table 5-13.
Schedule for Observing and Recording Equipment Operation and Performance Data

Operational Parameter	Action[1]
Feed water flow rate	Check and record in logbook twice per day, adjust when >5% above or below target. Record before and after adjustment.
Filter unit feed water and treated water pressures	Record in logbook initial clean bed feed water and treated water pressure at the start of the run, and thereafter record twice per day.
Tasks performed during equipment operation	Record in logbook tasks performed on a daily basis.
Number of hours per day operator attends to all tasks related to the treatment process	Record number of hours required by operator to accomplish all tasks.
Totalizer Meter Reading	Record totalizer meter readings twice daily.

(1) During the Capacity Test, a representative of the HTWSA will record the operational data for the days when the Gannett Fleming field technician is not onsite.

5.6.5 Evaluation Criteria

Where applicable, the data developed from this task will be presented relative to ADI's statements of performance objectives.

An objective evaluation of the difficulty of operations will be based on assessment of time required for process monitoring and hydraulic control.

5.7 Task 4: Data Management

5.7.1 Introduction

The data management system that will be used in this verification involves the use of computer spreadsheet software and manual recording of system operating parameters.

5.7.2 Experimental Objectives

The objective of this task is to establish a viable structure for the recording and transmission of field testing data by Gannett Fleming, such that NSF receives sufficient and reliable data for verification purposes.

5.7.3 Work Plan

The following outline is for data handling and data verification by Gannett Fleming:

The Gannett Fleming field technician or other field-testing operator will record operating and water quality data and calculations by hand, in a laboratory notebook.

- Daily measurements will be recorded on specially prepared data log sheets.
- The logbook will be permanently bound with consecutively numbered pages.
- The logbook will indicate the starting and ending dates that apply to entries in the logbook.
- All pages will have appropriate headings to avoid entry omissions.
- All logbook entries will be made in black water-insoluble ink.
- All corrections in the logbook will be made by placing one line through the erroneous information and initialed by the field-testing operator
- Pilot operating logs will include a description of the adsorptive media equipment, description of test run(s), names of visitor(s), description of any problems or issues, etc; such descriptions will be provided in addition to experimental calculations and other items.

The original logbook will be stored on site. The original logbook will be photocopied at least once per week and copies forwarded to the project engineer of Gannett Fleming. This protocol will not only ease referencing the original data, but offer protection of the original record of results.

The database for this verification-testing program will be set up in the form of custom-designed spreadsheets. The spreadsheets will be capable of storing and manipulating each monitored water quality and operational parameter from each task, each sampling location, and each sampling time. All data from the laboratory notebooks and data log sheets will be entered into the appropriate spreadsheets. The Gannett Fleming field technician will conduct data entry offsite. All recorded calculations will also be checked at this time. Following data entry, the spreadsheet will be printed out and another individual will check the printout against the handwritten data sheet. Any corrections will be noted on the hard copies and corrected on the screen, and then a corrected version of the spreadsheet will be printed out. The field technician or supervisor performing the entry or verification step will initial each step of the verification process.

Each experiment (e.g. each test run, defined by a regeneration) will be assigned a run number that will then be tied to the data from the experiment through each step of data entry and analysis. As samples are collected and sent to the PADEP and NSF Laboratories, the data will be tracked by use of a system of run numbers. Data from the PADEP and NSF Laboratories will be received and reviewed by the Gannett Fleming field technician. This data will be entered into the data spreadsheets, corrected, as needed and verified in the same manner as the field data.

5.8 Task 5: Quality Assurance/Quality Control (QA/QC)

5.8.1 Introduction

Quality assurance and quality control for the operation of the arsenic adsorption media filter and the measured water quality parameters will be maintained during the verification-testing program.

5.8.2 Experimental Objectives

The objective of this task is to maintain strict QA/QC methods and procedures during this verification. Maintenance of strict QA/QC procedures is important in that if a question arises when analyzing or interpreting data collected for the arsenic adsorption media filter, it will be possible to verify exact conditions at the time of testing.

5.8.3 Work Plan

Equipment flow rates will be verified and verification recorded on a routine basis. A routine daily walk-through during testing will be established to verify that each piece of equipment or instrumentation is operating properly. The items listed below are in addition to any specified checks outlined in the analytical methods.

It is extremely important that system flow rates are maintained at set values and monitored frequently. Doing so allows a constant and known EBCT to be maintained in the adsorptive media. Adsorptive media performance is directly affected by the EBCT, which in turn is proportional to the volumetric flow rate through the media. Therefore, an important QA/QC objective will be the maintenance of a constant volumetric flow rate through the adsorptive media by frequent monitoring and documentation. Documentation will include an average and standard deviation of recorded flow rates through the adsorptive media.

- Weekly QA/QC Verifications
  - In-line flow meter (clean any fouling buildup as needed, and verify flow rate volumetrically)
  - In-line totalizer meter (clean any foulant buildup as needed and verify production rate volumetrically)
  - Tubing (verify good condition of all tubing and connections, replace as necessary)
  - Calculate change in chemical tank volumes for weekly time of filter operation to confirm calibration of each metering pump

5.8.4 Analytical Methods

The analytical methods utilized in this study for on-site and laboratory monitoring of a raw water, and adsorptive media feed and treated water quality are described in the section below.

- **Arsenic**

  Arsenic analyses will be performed in the NSF Laboratory using EPA Method 200.8. These analyses are the most critical for the entire ETV test program. Minimum analytical turnaround time is required to achieve optimum process control. This method requires that ultra-pure (optimum) grade nitric acid must be used, not reagent grade, to avoid the trace amounts of arsenic that can be present in reagent grade nitric acid.

  Arsenic analyses will also be performed on-site for qualitative purposes using the Model QUICK Low Range II field test kit from Industrial Test Systems (ITS), Inc. The arsenic field test kit has an optimum accuracy below 6 ppb and has a reaction time of less than 15 minutes. The complete method procedure is presented in Appendix H.

- **pH**

  Analyses for pH will be performed on-site according to Standard Method 4500-H^+ B (Electrometric Method). A three-point calibration of the pH meter used in this study will be performed once per day when the instrument is in use. Certified pH buffers 4.0, 7.0, and 10.0 will be used. The pH electrode will be stored in the appropriate solution defined in the instrument manual.

- **Chlorine, Free Available**

  Analyses for free available chlorine (FAC) will be performed on-site using Hach Method 8021 (DPD Photometric Method)

- **Alkalinity**

  Analyses for alkalinity will be performed on-site using Hach Method 8221(Buret Titration Method).

- **Fluoride**

  Analyses for fluoride will be performed on-site according to Standard Method 4500-F^- C (Ion-Selective Electrode Method).

- **Chloride**

  Analyses for chloride will be performed in the PADEP Lab according to EPA Method 300.0.

- **Sulfate**

  Analyses for sulfate will be performed in the PADEP Lab according to EPA Method 300.0.

- **Silica**
  Analyses for silica will be performed in the PADEP Lab according to EPA Method 200.7.

- **Sodium**
  Analyses for sodium will be performed in the PADEP Lab according to EPA Method 200.7.

- **Aluminum**
  Analyses for aluminum will be performed in the PADEP Lab according to EPA Method 200.7.

- **Total Phosphorus**
  Analyses for phosphate will be performed in the PADEP Lab according to EPA Method 365.1.

- **Calcium**
  Analyses for calcium will be performed on-site using Hach Method 8222 (Buret Method) with 0.020 N titrant.

- **Hardness**
  Analyses for hardness will be performed on-site using Hach Method 8226 (ManVer 2 Buret Titration) with 0.020 N titrant.

- **Magnesium**
  Magnesium will be calculated by subtracting the Calcium result (Hach Method 8222) from the Hardness result (Hach Method 8226).

- **Iron**
  Analyses for iron will be performed in the PADEP Lab using EPA Method 200.7.

- **Manganese**
  Analyses for manganese will be performed in the PADEP Lab using EPA Method 200.7.

- **Turbidity**
  Turbidity analyses will be performed on-site according to Standard Method 2130 B using a portable turbidimeter.

- **Temperature**
  Temperature will be analyzed on-site according to Standard Method 2550 B.

- **TCLP**
  Toxicity Characteristic Leaching Procedures will be performed on the regenerant wastewater and spent MEDIA G2® media by TriMatrix Laboratories, Inc. using

SW-846 and EPA Method 1311. TriMatrix Laboratories, Inc. will use Method SW-846 6010B for As, Ba, Cd, Cr, Cu, Ni, Pb, Se, Ag, and Zn; and Method SW-846 7470A for Hg.

- **CA WET**
  California Waste Extraction Test will be performed on spent MEDIA G2® media by TriMatrix Laboratories, Inc. using the procedure and metal analysis methods presented in Appendix E. TriMatrix Laboratories, Inc. will use Method SW-846 6010B for As, Ba, Cd, Cr, Cu, Ni, Pb, Se, Ag, and Zn; and Method SW-846 7470A for Hg.

5.8.5 Samples Shipped Offsite for Analysis

Samples for inorganic analysis including chloride, sodium, sulfate, silica, aluminum, total phosphorus, iron, and manganese by the PADEP Laboratory, will be collected and preserved in accordance with *Standard Methods* 3010 B, paying particular attention to the sources of contamination as outlined in *Standard Methods* 3010 C. The samples will be kept cool, in the range of 2º to 8ºC immediately upon collection, shipped in a cooler, and maintained at a temperature of 2º to 8ºC. The samples collected for analysis by the PADEP Laboratory will be dropped off at the Bucks County Department of Health located in the Neshaminy Manor Center in Doylestown. The Bucks County Department of Health routinely ships water samples to the PADEP Laboratory on a daily basis, Monday through Thursday. Any samples collected Friday through Sunday will be kept refrigerated until they can be shipped on Monday. The laboratory will keep the samples at approximately 2º to 8ºC until initiation of analysis. The samples collected for arsenic analysis by the NSF Laboratory will be shipped by Gannett Fleming at the determined frequencies, without being preserved or packed in ice, as per NSF instructions. The PADEP and NSF laboratories will process the samples for analysis (i.e. log in the samples) within 24 hours of receiving the samples. Table 5-14 presents the sampling protocol that will be followed during the ETV.

5.8.6 Tests and Data Specific to Adsorptive Media Type Evaluated

ADI's MEDIA G2® adsorptive media used for this testing is described by data on the adsorptive media type, characteristics, and tests, listed in Tables 3-1 and 5-2.

5.9 Operations and Maintenance

The following are recommendations for criteria to be included in the Operation and Maintenance (O&M) Manual for adsorptive media removal of arsenic, as described in the Technology Specific Test Plan (TSTP) within the ETV Protocol. Gannett Fleming will review ADI's Operations Manual and will report on the applicability of the manual in the final report from the verification test.

5.9.1 Operations

ADI provided a customized Operations Manual (which includes installation instructions) that provides information needed to operate the equipment at the HTWSA Well No. 1 site. The Operations Manual is included in Appendix A.

Gannett Fleming has discussed the following issues with ADI and has received all of the equipment information needed to proceed with testing:

- Monitoring of Preconditioning of Adsorptive Media
  - Utilizing the manufacturer's procedure specific for MEDIA G2® adsorptive media, including backwashing new media at a specified flow rate to remove fines.
  - Backwash parameters (flow rate and time)
  - Rinse water flow rate and time
  - Rinse with sulfuric acid addition to a designated pH depression in the feed water and treated water
  - Volume of wastewater
  - Wastewater disposal requirements
- Monitoring Operations
  - Use of an arsenic field test kit for the purpose of monitoring feed and treated arsenic levels.
  - Feed water flow rate and production
  - Feed water pressure
  - Treated water pressure
  - Maintenance and operator labor requirements
  - Spare parts requirements
- Chemical Additions
  - ADI has provided instructions for chemical addition (sulfuric acid only) and monitoring requirements
- Operability

  During verification testing and during compilation of process operating data, attention will be given to the arsenic adsorption media filter operability aspects. Among the factors that will be considered are:
  - Fluctuation of flow rates, as well as the frequency at which flow adjustment is needed.
  - Ease of adjusting the flow rate when it is outside the design range.
- Adsorptive Media Replacement and Disposal Procedure, and Wastewater Disposal Procedure
  - Media replacement procedure.
  - Contacting the state regulatory agency, acknowledging the volumes and nature of wastewater residue from the preconditioning of the media, backwash wastewater, regeneration wastewater and spent media for the purpose of determining the appropriate disposal methods and permitting requirements.

5.9.2 Maintenance

ADI will provide readily understood information on the required or recommended maintenance schedule for each piece of operating equipment including, but not limited to:

- manual ball valves
- solenoid valve
- pressure reducing valve

- on-line measuring instruments
- chemical metering pumps

ADI will provide readily understood information on the required or recommended maintenance schedule for non-mechanical or non-electrical equipment including, but not limited to:

- adsorptive media vessel
- feed lines

Gannett Fleming will comment on the quality of this information in the final report.

Table 5-14.
Water Quality Sampling Protocol

					DEP Sample ID Protocol – Sample Submission Sheet						NSF Test Tracking ID	
					Sequence Number[1]							
Parameter	Sample Bottle	Sample Volume	Sample Preservation	Sample Hold Time	Feed	Treated	SAC No.[1]	Bottle Cap ID[1]	Collector No.[1]	Date/Time Collected	Integrity	Capacity
Laboratory												
Aluminum, Silica, Sodium, Iron & Manganese	125 mL HDPE	125 mL	Nitric Acid to pH <2.0; iced	6 months	101	102	109	M	1749	✔	I	II
Arsenic	125 mL Trace clean	100 mL	Nitric Acid to pH<2.0	6 months	NA	NA	NA	NA	NA		I	II
Sulfate & Chloride	500 mL HDPE	250 mL	iced	28 days	201	202	109	N/A	1749	✔	I	II
Total Phosphorus	125 mL HDPE	100 mL	Sulfuric Acid to pH <2.0; iced	28 days	201	202	109	P	1749	✔	I	II
TCLP & CaWET	Plastic Bag	N/A	N/A	N/A	N/A	N/A	NA	N/A	1749	✔	N/A	II

SAC: Standard Analysis Code

[1] Information also required on sample bottle.

6.0 Quality Assurance Project Plan (QAPP)

The QAPP for this verification testing specifies procedures that will be used to ensure data quality and integrity. Careful adherence to these procedures will ensure that data generated from this verification testing will provide sound analytical results that can serve as the basis for the performance verification.

6.1 Purpose and Scope

The purpose of this section is to outline steps that will be taken by Gannett Fleming and by the PADEP and NSF laboratories to ensure that data resulting from this verification testing is of known quality and that a sufficient number of critical measurements are taken.

6.2 Quality Assurance Responsibilities

Several individuals will be responsible for monitoring equipment-operating parameters, and for sampling and analysis QA/QC throughout the verification testing. Primary responsibility for ensuring that equipment operations, sampling and analysis activities comply with the QA/QC requirements of this PSTP rests with Gannett Fleming.

QA/QC activities for the PADEP and NSF laboratories that will analyze samples sent off-site will be the responsibility of the respective supervisors of these analytical laboratories. If problems arise or any data appears unusual, they will be thoroughly documented and corrective actions will be implemented as specified in this section. The QA/QC measurements made by the PADEP and NSF laboratories are dependent on the analytical methods being used.

The PADEP and NSF Laboratories will provide copies of the raw data (run logs, bench sheets) to Gannett Fleming on a monthly basis (or more frequently as decided by the PADEP and NSF laboratories). Copies of the emailed results and QA/QC summaries from the PADEP laboratories sent to Gannett Fleming, as results are available, will also be copied to NSF. Final laboratory reports with all results will be sent to Gannett Fleming, as they are complete. NSF will review the raw data records within the final report for compliance with QC requirements and check, at a minimum, 10% of the data against the reported results (emails and/or final lab reports).

PADEP and the NSF laboratories will retain and will not discard the arsenic and metals samples until NSF notifies PADEP and the NSF laboratories that the data is valid and the samples can be discarded. NSF will provide written release for samples via email to the designated PADEP and NSF laboratory representatives. Samples with short holding times can be discarded by the PADEP laboratory using their normal procedures.

This procedure will reduce the risk that data quality problems could jeopardize the test program. If problems are detected, PADEP and the NSF laboratories will be notified immediately and will take appropriate corrective action. This procedure does not release PADEP or the NSF laboratories from having the primary responsibility to produce analytical results that meet the QA requirements and follow the specified EPA procedures.

6.3 Data Quality Indicators

The data obtained during the verification testing must be of sound quality for conclusions to be drawn on the equipment. For all measurement and monitoring activities conducted for equipment verification, NSF and EPA require that data quality parameters be established based on the proposed end uses of the data. Data quality parameters include four indicators of data quality: representativeness, accuracy, precision, and statistical uncertainty.

Treatment results generated by the equipment and by the laboratory analyses must be verifiable for the purposes of this program to be fulfilled. High quality, well-documented analytical laboratory results are essential for meeting the purpose and objectives of this verification testing. Therefore, the following indicators of data quality will be closely evaluated to determine the performance of the equipment when measured against data generated by the analytical laboratory.

6.3.1 Representativeness

Representativeness refers to the degree to which the data accurately and precisely represent the conditions or characteristics of the parameter represented by the data. In this verification testing, representativeness will be ensured by executing consistent sample collection protocol, including sample locations, timing of sample collection, sampling procedures, sample preservation, sample packaging, and sample shipping. Representativeness also will be ensured by using each method at its optimum capability to provide results that represent the most accurate and precise measurement it is capable of achieving. For equipment-operating data, representativeness entails collecting a sufficient quantity of data during operation to be able to detect a change in operations. For most water treatment processes involving arsenic removal, detecting a +/- 10% change in an operating parameter (i.e., pressure drop, pressure) is sufficient.

6.3.2 Accuracy

The definition of accuracy depends on the context, and is defined as the following:

- Water quality analyses – difference between a sample result and the reference or true value for the sample. Loss of accuracy can be caused by:
    - errors in standards preparation
    - equipment out of calibration
    - loss of target analyte in the extraction process
    - chemical interferences
    - systematic or carryover of contamination from one sample to the next
- Arsenic speciation resin columns QA check – each lot of the arsenic speciation resin will be checked once against samples with known concentrations of As III and As V by the person who will be performing the speciation procedure onsite. This QC check will assure that the resin was properly prepared, and the laboratory is performing as expected, and is being used correctly. The samples will be sent to the NSF Laboratory after speciation to analyze for arsenic.
- pH QA - checks will consist of conducting a 3-point calibration of the pH meter daily using certified pH buffers 4.0, 7.0 and 10.0. If the accuracy of the pH electrode falls outside 95% to 105%, the electrode will be rehabilitated according to manufacturer's recommendations, or discarded.

- Chlorine QA – a standard known to contain approximately 4.0 mg/L as FAC.
- Temperature QA checks - readings will be made using a thermometer in accordance with Standard Methods 2550. The thermometer will have a scale marked for every 0.1°C. Since the thermometer used will be a NIST-traceable certified reference thermometer, calibration will not be required.
- Turbidimeter QA checks - the portable turbidimeter will be calibrated according to the manufacturer's instructions on a weekly basis using primary turbidity standards. Secondary standards will be used daily to verify the primary standard calibration. A performance evaluation sample will be analyzed prior to the start of testing.
- Hach test kits – split samples will be collected during the first two days of Task 1 for the parameters that will be measured onsite by the Hach test kits, including alkalinity, calcium, and hardness. One sample for each parameter will be delivered to the PADEP Laboratory for analysis. These split samples will determine if there are any interferences present in the water affecting the results of the Hach methods. If the difference of each result from the Hach method and the PADEP laboratory falls outside of 30%, then the source of the discrepancy will be determined and the use of the Hach test kits will be reevaluated.

Accuracy of analytical readings is measured through the use of spiked samples, that is, a known quantity of a target analyte is added to a sample. The percent recovery is calculated as a measure of the accuracy. Acceptance limits for percent recovery are analyte and concentration specific. Tables 6-1 and 6-2 present the frequency and the acceptable accuracy limits for the laboratory and on-site spiked samples, respectively.

Table 6-1.
Laboratory Water Quality Indicators

Parameter	Lab Spike Frequency	Acceptable Accuracy (% Recovery)	Lab Duplicate Frequency	Acceptable Precision[(1)]
Arsenic	10%	± 30	10%	± 30%
Iron	10%	± 30	10%	± 30%
Manganese	10%	± 30	10%	± 30%
Aluminum	10%	± 30	10%	± 30%
Sodium	10%	± 30	10%	± 30%
Silica	10%	± 30	10%	± 30%
Chloride	10%	± 20	10%	± 11%
Sulfate	10%	± 20	10%	± 11%
Total Phosphorus	10%	± 10	10%	± 30%

(1) All precision limits are based on Relative Percent Standard Deviation as shown in Section 6.3.3. For all laboratory duplicate analyses, the first analysis is considered the sample and that result is reported. The duplicate analysis is used for calculating precision per Section 6.3.3.

The calibration procedures for the analyses of samples for parameters shown in Table 6-1 will be as follows:

A calibration check standard is analyzed at a frequency of 10% with acceptable criteria of ±15% for arsenic and ±10% for iron, manganese, aluminum and silica. A calibration check standard is analyzed at a frequency of 10% with acceptable criteria of ±10% for sodium, chloride, sulfate, and total phosphorus. If a spiked sample is not within acceptable criteria, the sample and spike are either reanalyzed or re-spiked and re-analyzed. If still not within acceptable criteria, a comment is placed on the report indicating possible matrix interference. The same procedure applies to duplicates. A comment in that case may be that the sample may not be homogenous. If a calibration check standard does not meet the acceptable criteria, the samples following the last acceptable calibration check standard must be reanalyzed.

Table 6-2.
On-site Water Quality Indicators

Parameter	On-site Spike Frequency	Acceptable Accuracy (% Recovery)	On-site Duplicate Frequency	Acceptable Precision[1]
Alkalinity	10%	± 30	10%	± 30%
Calcium	10%	± 30	10%	± 30%
Hardness	10%	± 30	10%	± 30%
Fluoride	10%	± 30	10%	± 30%
FAC	10%	± 30	10%	± 30%
Turbidity	--	--	10%	± 30%
pH	--	--	10%	± 30%
Temperature	--	--	10%	± 30%

(1) All precision limits are based on Relative Percent Standard Deviation as shown in Section 6.3.3. For all on-site duplicate analyses, the first analysis is considered the sample and that result is reported. The duplicate analysis is used for calculating precision per Section 6.3.3.

On-site analyses for pH, temperature, chlorine and turbidity do not lend themselves to spike samples and percent recovery or blank analyses. Turbidity accuracy will be documented by analysis of a performance evaluation (PE) sample at the beginning of the testing protocol. The acceptable limits for the analysis of the PE samples for the on-site parameters are presented on Table 6-5. Accuracy for pH, chlorine and temperature will be assured by calibration procedures previously described.

- Equipment operating parameters – difference between the reported operating condition and the actual operating condition.
  - Water flow – difference between the reported flow indicated by a flow meter and the flow as actually measured on the basis of known volumes of water and carefully defined times as practiced in hydraulics laboratories or water meter calibration shops. The "bucket and stopwatch" technique will be used to determine the accuracy of the accessory flow meter and totalizer meter.
  - Pressure measurement – accuracy will be determined by using a dead weight pressure tester to check the calibration of the pressure gauges.

Meters and gauges will be checked at the frequencies presented on Table 6-3 for accuracy, and when proven to be dependable over time, the time interval between accuracy checks will be increased. Inaccurate pressure gauges and meters will be replaced.

Table 6-3.
Field Instrument Calibration Schedule

Instrument	Calibration Method	Frequency	Acceptable Accuracy
Pressure Gauges	dead weight calibration tester	biannual	± 10%
Flow Meter	volumetric "bucket & stop watch"	weekly	± 10%
Totalizer Meter	volumetric "bucket & stop watch"	weekly	± 1.5%
Portable Turbidimeter	secondary turbidity standards primary turbidity standards	daily weekly	PE sample
Portable pH/ISE Meter with Combination pH/ Temperature Electrode	three-point calibration using 4.0, 7.0 and 10.0 buffers	daily	± 5%
Portable Colorimeter	approximate 4.0 mg/L chlorine standard	daily(3)	±25%
Thermometer (NIST-traceable)	calibration not required(1)	N/A	
Portable pH/ISE Meter with Fluoride Ion Selective Electrode	0.2 mg/L fluoride standard and 2.0 mg/L fluoride standard(2)	daily	± 2%

(1) Copy of NIST-traceable certification in Appendix I.

(2) The standards used will depend on the concentration of fluoride detected; the analytical method recommends that the standards used to calibrate the meter bracket the measured concentration, with the upper range standard greater than the low range standard by a factor of at least ten; a blank will also be checked.

(3) A daily check will be performed both with a blank and the 4.0 mg/L chlorine standard.

6.3.3 Precision

Precision refers to the degree of mutual agreement among individual measurements and provides an estimate of random error. Analytical precision is a measure of how far an individual measurement may be from the mean of replicate measurements. The standard deviation and the relative standard deviation recorded from sample analyses will be reported as a means to quantify sample precision. The percent relative standard deviation will be calculated in the following manner:

$$\text{Percent Relative Standard Deviation} = S(100) / X_{average}$$

where: S = standard deviation
$X_{average}$ = the arithmetic mean of the recovery values

Standard Deviation is calculated as follows:

$$\text{Standard Deviation} = \sqrt{\sum_{i=1}^{n} \frac{(Xi - X)^2}{n - 1}}$$

where: X_i = the individual recovery values
X = the arithmetic mean of the recovery values
n = the number of determinations

For acceptable analytical precision under the verification testing program, the percent relative standard deviation for drinking water samples must be less than 30%.

Tables 6-1 and 6-2 present the frequency of laboratory and on-site duplicates, respectively, and the acceptable percent relative standard deviation for each analyte.

6.3.4 Statistical Uncertainty

Statistical uncertainty of the water quality parameters analyzed will be evaluated through calculation of the 95% confidence interval around the sample mean. Description of the confidence interval calculation is provided in Section 4.5 – Recording Statistical Uncertainty.

6.4 Quality Control Checks

This section describes the QC requirements that apply to both the treatment equipment and the on-site water quality analyses. It also describes the corrective action to be taken if the QC parameters fall outside of the evaluation criteria. The quality control checks provide a means of measuring the quality of data produced.

6.4.1 Quality Control for Equipment Operation

This section explains the methods that will be used to check the accuracy of equipment operating parameters and the frequency with which these quality control checks will be made. If the quality of the equipment operating data cannot be verified, then the water quality analytical results may be of no value. Because water cannot be treated if equipment is not operating, obtaining valid equipment operating data is a prime concern for verification testing.

6.4.2 Water Quality Data

After treatment equipment is being operated and water is being treated, the results of the treatment are interpreted in terms of water quality. Therefore the quality of water sample analytical results is just as important as the quality of the equipment operating data.

- **Duplicate Samples.** Duplicate samples must be analyzed to determine the precision of analysis. Duplicate samples will be collected and analyzed for all laboratory analyses for every ninth sample collected. One sample will be collected and subsequently split into two aliquots, representing the regular sample and the duplicate sample. Each aliquot will comply with all of the sampling requirements presented on Table 5-12. The frequency of field duplicate sampling and the estimated total number of duplicates is presented on Table 6-4.

- **Method Blanks.** Method blanks will be used to evaluate analytical method-induced contamination, which may cause false positive results. The PADEP and NSF laboratories will produce and analyze method blanks for each laboratory method used in this ETV. The frequency of method blank analyses required is presented on Table 6-4.
- **Travel Blanks.** Travel blanks will be provided by Gannett Fleming to the analytical laboratory to evaluate travel-related contamination. Travel blanks will be provided for every sample shipment to the respective laboratory. The frequency of sending trip blanks to the laboratories is presented on Table 6-4.

Table 6-4. Schedule of Field Duplicates, Method Blanks and Trip Blanks for Laboratory Analyses

	Field Duplicates (1)		Method Blanks	Travel Blanks
Parameter	Frequency	Total Number	Frequency	Frequency
Arsenic	1/10	Max 22(2)	1/Analytical Batch	1/trip
Chloride	1/10	6	1/Analytical Batch	1/trip
Sulfate	1/10	6	1/Analytical Batch	1/trip
Silica	1/10	Max 45(2)	1/Analytical Batch	1/trip
Aluminum	1/10	Max 45(2)	1/Analytical Batch	1/trip
Iron	1/10	6	1/Analytical Batch	1/trip
Manganese	1/10	6	1/Analytical Batch	1/trip
Sodium	1/10	6	1/Analytical Batch	1/trip
Phosphorus	1/10	6	1/Analytical Batch	1/trip

(1) All field duplicates will begin the first week of the Integrity Test.
(2) May be significantly less if hold samples are not analyzed.

- **Performance Evaluation Samples for Water Quality Testing.** Performance evaluation samples are samples of known concentration prepared by an independent PE lab and provided as unknowns to an analyst to evaluate his or her analytical performance. Analyses of laboratory PE samples will be conducted before verification testing. The control limits for the PE samples will be used to evaluate the field analytical method performance.

  A PE sample comes with statistics that have been derived from the analysis of the sample by a number of laboratories using EPA-approved methods. These statistics include a true value of the PE sample, a mean of the laboratory results obtained from the analysis of the PE sample, and an acceptance range for sample values. The field laboratory, PADEP and NSF laboratories are expected to provide results from the analysis of the PE samples that meet the performance objectives of the verification testing.

  PE sample results for the PADEP Laboratory are included in Appendix J. PE checks will be performed prior to initiation of verification testing for all of the on-site parameters listed in Table 6-5.

Table 6-5.
PE Samples for On-site Analyses[1]

Parameter	Acceptance Limits
pH	7.25– 8.86
Turbidity, NTU	0.445– 0.895
Alkalinity, mg/L	38.9– 46.2
Calcium, mg/L	38.3 – 49.0
Arsenic, ug/L[2]	86.9-111
Total Hardness, mg/L	159- 215
Fluoride, mg/L	1.47 – 1.79
FAC, mg/L	0.422-0.718

(1) Analyses of PE samples will be conducted prior to the initiation of verification testing. Objective is to provide results from the analysis of the PE samples that are within the acceptance range included with the specific PE samples provided by the laboratory certified to provide PE samples.
(2) Performed using the arsenic field test kit.

6.5 Data Reduction, Validation, and Reporting

To maintain good data quality, specific procedures will be followed during data reduction, validation, and reporting. These procedures are detailed below.

6.5.1 Data Reduction

Data reduction refers to the process of converting the raw results from the equipment into concentration or other data in a form to be used in the comparison. The purpose of this step is to provide quality data that will be presented in a form that is useful for all stakeholders. This data will be obtained from logbooks, instrument outputs, and computer outputs.

6.5.2 Data Validation

There are two types of data validation that need to be addressed, field data and laboratory data.

For the field data (including data collected from the field laboratory):

- The field technician will verify the correctness of data acquisition and reduction;
- The field team supervisor or another technical person will review calculations and inspect laboratory logbooks and data sheets to verify accuracy of data recording and sampling;
- Calibration and QC data will be examined by the field technician and the field team supervisor;
- Project managers will verify that all instrument systems are in control and that QA objectives for accuracy, precision, and method detection limits have been met.

For the laboratory data:

- Calibration and QC data will be examined by the individual analysts and the laboratory supervisor;

- Laboratory managers will verify that all instrument systems are in control and that QA objectives for accuracy, precision, and method detection limits have been met. Method detection limits are presented on Table 6-6.

Table 6-6.
Method Detection Limits (MDL) and Laboratory Reporting Limits

	Analytical Method	MDL (mg/L)	Laboratory Report Limit (mg/L)
Arsenic	EPA 200.8	0.002	0.002
Aluminum	EPA 200.7	0.081	0.200
Iron	EPA 200.7	0.008	0.020
Manganese	EPA 200.7	0.007	0.010
Sodium	EPA 200.7	0.097	0.2
Silica	EPA 200.7	0.038	1.07
Chloride	EPA 300.0	0.230	0.50
Sulfate	EPA 300.0	0.076	1.00
Phosphorus	EPA 365.1	0.002	0.010

Analytical outlier data are defined as those QC data lying outside a specific QC objective window for precision and accuracy for a given analytical method. Should QC data be outside of control limits:

- The analytical laboratory or field team supervisor will investigate the cause of the problem.
- If the problem involves an analytical problem, the sample will be reanalyzed.
- If the problem can be attributed to the sample matrix, the result will be flagged with a data qualifier.
- The data qualifier will be included and explained in the final analytical report.

6.5.3 Data Reporting

This section contains a list of the water quality and equipment operation data to be reported. The data tabulation will list the results for raw, feed water and treated water quality analyses and equipment operating data. All QC information such as calibrations, blanks and reference samples will be included in an appendix. All raw analytical data will also be reported in an appendix. All data will be reported in hardcopy and electronically in a spreadsheet on a regular basis to NSF for QA review, included in database format.

The PADEP and NSF laboratories will provide copies of the raw data (run logs, bench sheets) to Gannett Fleming on a monthly basis (or more frequently as decided by the PADEP and NSF laboratories). Copies of the emailed results and QA/QC summaries from the PADEP laboratories sent to Gannett Fleming, as results are available, will also be copied to NSF. Final laboratory reports with all results will be sent to Gannett Fleming, as they are complete. NSF will review the raw data records within the final report for compliance with QC requirements and check, at a minimum, 10% of the data against the reported results (emails and/or final lab reports).

The PADEP and NSF laboratories will retain and will not discard the arsenic and metals samples until NSF notifies the PADEP and NSF laboratories that the data is valid and the samples can be discarded. NSF will provide written release for samples via email to the designated PADEP and the NSF laboratory representatives. Samples with short holding times can be discarded by the PADEP laboratory using their normal procedures.

This procedure will reduce the risk that data quality problems could jeopardize the test program. If problems are detected, the PADEP and the NSF laboratories will be notified immediately and will take the appropriate corrective action. This procedure does not release the PADEP and NSF laboratories from having the primary responsibility to produce analytical results that meet the QA requirements and follow the specified EPA procedures.

6.6 System Inspections

System inspections and audits for sampling activities and field operations will be conducted as specified by the ETV Testing Plan *Adsorptive Media Processes for the Removal of Arsenic*. NSF will conduct an audit of the test and the Gannett Fleming QA officer will perform quarterly on-site inspections and audits, as presented on Table 6-7, to determine if this PSTP is being implemented as intended. The Gannett Fleming QA officer will also conduct an on-site inspection during the first two weeks of operation. Separate inspection reports will be completed after the inspections and provided to the participating parties.

6.7 Reports

6.7.1 Status Reports

Gannett Fleming will prepare periodic reports to pertinent parties such as ADI, NSF, PADEP, and the utility where testing is done. These reports will discuss project progress, problems and associated corrective actions, and future scheduled activities associated with the verification testing. When problems occur, ADI and Gannett Fleming project managers will discuss them and estimate the type and degree of impact, and describe the corrective actions taken to mitigate the impact and to prevent a recurrence of the problems. The frequency, format, and content of these reports are outlined below.

- Frequency:
  - Weekly during integrity testing
  - Monthly during adsorption capacity testing
- Format:
  - Excel spreadsheet data tables with status report memo
- Content:
  - Water quality tables
  - Production data

6.7.2 *Inspection Reports*

Any QA inspections that take place in the field or at the analytical laboratory while the verification testing is being conducted will be formally reported by Gannett Fleming to NSF and ADI.

Table 6-7.
Field Testing Organization QA Officer Inspections and Audits of Test Site and Laboratory

Frequency Test Site/ Laboratory	Report
quarterly[1]	Any procedures that are not consistent with PSTP requirements are noted and subsequently reported to NSF in memo form.

[1] In addition to the inspection conducted during the first two weeks of operation.

6.8 Corrective Action

If, during the course of the verification testing, established equipment operation acceptance limits are exceeded, Gannett Fleming will require that corrective action be implemented. Acceptance limits are discussed in the appropriate sections of this document. If corrective action is necessary, Gannett Fleming will document the required action, the party responsible and the results of the action. Any suspect data gathered during or before the implementation of the corrective action will be discarded.

7.1 Data Management and Analysis

All operational and analytical data will be gathered and included in the Final ETV Report. The data will consist of results of analyses and measurements that are detailed in the Tasks section of this PSTP. The data will be entered into computer spreadsheets and submitted in electronic and hard copies. In addition, all QA/QC summary forms, field notebooks, and photographs will be provided.

7.2 Report of Equipment Testing

The test report will be issued in two phases. An initial report will be issued after the Integrity Verification Test. This report will be supplemented at the conclusion of the Capacity Verification Test. The report will be issued in draft form for review prior to final publication.

Gannett Fleming will prepare the reports.
The reports will consist of:

- Introduction
- Forward (Phase 1)
- Introduction (Phase 1)
- Description and Identification of Product Tested (Phase 1)
- Procedures and Methods Used in Testing (Phase 1)
- Results and Discussion (Phase 1 – Integrity, Phase 2 – Capacity)
- References
- QA/QC Results (Phases 1 and 2)
- Each piece of data or information identified for collection in the *ETV Testing Plan for Adsorptive Media Processes for the Removal of Arsenic* (Phases 1 and 2)
- Laboratory raw data and validated data (hard copy and electronic spreadsheets) (Phases 1 and 2)
- Field notebooks (Phases 1 and 2)
- Photographs (Phase 1)
- Results from the use of other field analytical methods (Phases 1 and 2)

This report will be prepared in Microsoft Word® with data and graphics presented using Microsoft Excel® spreadsheets.

8.1 Hazardous Chemicals

The hazardous chemicals that will be stored on-site during this verification testing are sulfuric acid, sodium hypochlorite, caustic soda, plus the reagents required for the on-site analyses. Latex gloves and eye protection will be available for the operator. MSDS for caustic soda and sulfuric acid will be posted inside Well Station No. 1.

8.2 Conformance to Electrical Codes

All equipment electrical connections will comply with appropriate electrical codes. This consists of bench-top analytical equipment, chemical metering pumps and the solenoid valve located on the feed water pipe.

8.3 Ventilation of Hazardous Gasses

Sodium hypochlorite tends to off-gas, particularly at the higher concentrations typically used at water treatment plants. However, if necessary, sodium hypochlorite will be diluted to a batch solution used for metering and feed that is at a concentration that is stable, with a very low tendency to off-gas. The drum containing the neat sodium hypochlorite will be kept sealed to prevent off-gassing.

8.4 HTWSA Well Station No. 1 Facility

The test equipment and on-site analytical equipment will be housed within the existing Well Station No. 1 Facility. Prior to starting the test, the Gannett Fleming field technician will become familiar with the facilities via training provided by the HTWSA operations manager. This training will include:

- A facility tour
- Presentation of the Well Station No. 1 O&M manual
- A review of the electrical facilities
- Specific operating instructions to start and stop Well No. 1
- A presentation of emergency contact information and people to be contacted
- Location of MSDS sheets