N00210.AR.001383
NSTC GREAT LAKES
5090.3a

CORRECTIVE ACTION PLAN BUILDING 1600A OLD GAS STATION NS GREAT LAKES IL
2/1/2000
TOLTEST, INC

89

CORRECTIVE ACTION PLAN
BUILDING 1600A (OLD GAS STATION)
GREAT LAKES, ILLINOIS

ENVIRONMENTAL JOB ORDER CONTRACT (EJOC)
CONTRACT NO. N68950-96-D-0052
DELIVERY ORDER NO. 0054

FOR

Department of the Navy
Naval Training Center (NTC) – Environmental Department
Building 1-A, 201 Decatur Avenue
Great Lakes, Illinois 60088-5600

SUBMITTED

FEBRUARY 2000
TOLTEST PROJECT NO. 37755.01

TOLTEST, INC.
1915 N. 12TH STREET
P.O. BOX 2186
TOLEDO, OHIO 43603
(419) 241-7175
FAX (419) 321-6259

CORRECTIVE ACTION PLAN
BUILDING 1600A (OLD GAS STATION)
GREAT LAKES, ILLINOIS

ENVIRONMENTAL JOB ORDER CONTRACT (EJOC)
CONTRACT NO. N68950-96-D-0052
DELIVERY ORDER NO. 0054

FOR

Department of the Navy
Naval Training Center (NTC) – Environmental Department
Building 1-A, 201 Decatur Avenue
Great Lakes, Illinois 60088-5600

SUBMITTED

FEBRUARY 2000
TOLTEST PROJECT NO. 37755.01

TOLTEST, INC.
1915 N. 12TH STREET
P.O. BOX 2186
TOLEDO, OHIO 43603
(419) 241-7175
FAX (419) 321-6259

The Agency is authorized to require this information under Section 4 and Title XVI of the Environmental Protection Act (415 ILCS 5/4, 5/57 - 57.17). Failure to disclose this information may result in a civil penalty of not to exceed $50,000.00 for the violation and an additional civil penalty of not to exceed $10,000.00 for each day during which the violation continues (415 ILCS 5/42). Any person who knowingly makes a false material statement or representation in any label, manifest, record, report, permit, or license, or other document filed, maintained or used for the purpose of compliance with Title XVI commits a Class 4 felony. Any second or subsequent offense after conviction hereunder is a Class 3 felony (415 ILCS 5/57.17). This form has been approved by the Forms Management Center.

Underground Storage Tank Owner/Operator:

Please indicate below the type of plan/report that is being submitted to the Agency at this time. This form must be attached to all plans and reports submitted to the Agency pursuant to 35 Ill. Adm. Code 732 and 415 ILCS 5/57-57.17. Please check all that apply.

20 Day Certification _____

45 Day Report _____

Free Product Removal Report _____

	Initial Submittal	Amended Submittal
Site Classification Plan		
Site Classification Plan Budget		
Site Classification Completion Report		
Groundwater Monitoring Plan (Low Priority)		
Groundwater Monitoring Plan Budget (Low Priority)		
Groundwater Monitoring Results (Low Priority)		
Professional Engineer Certification (Low Priority)		
Corrective Action Plan (High Priority)	X	
Corrective Action Plan Budget (High Priority)		
Corrective Action Completion Report (High Priority)		
Professional Engineer Certification (High Priority)		
Corrective Action Completion Report (35 IAC Section 732.300(b), 732.400(b) or (c)		
Professional Engineer Certification (35 IAC Section 732.300(b), 732.400(b) or (c)		

I certify under penalty of law that this document was prepared by me or under my direction or supervision. This information is to the best of my belief and knowledge, true, accurate and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine for knowing violations.

Owner Department of the Navy

Name: Mark Schultz

Title: Director, NTC, GL Env. Dept.

Signature: Mark Schultz

Date: 2-18-00

Operator Same as Owner

Name: _____

Title: _____

Signature: _____

Date: _____

The Agency is authorized to require this information under Section 4 and Title XVI of the Environmental Protection Act (415 ILCS 5/4, 5/57 – 57.17). Failure to disclose this information may result in civil penalty of not to exceed $50,000.00 for the violation and an additional civil penalty of not to exceed $10,000,000 for each day during which the violation continues (415 ILCS 5/43). Any person who knowingly makes a false material statement or representation in any label, manifest, record, permit, or license, or other document filed, maintained or used for the purpose of compliance with Title XVI commits a Class 4 felony. Any second or subsequent offense after conviction hereunder is a Class 3 felony (415 ILCS 5/57.17). This form has been approved by the Forms Management Center.

Illinois Environmental Protection Agency
Leaking Underground Storage Tank Program
Corrective Action Plan

A. Site Identification

IEMA Incident # (6 digit): 971739 IEPA Generator # (10 digit): 0971255004

Site Name: United States Navy, Great Lakes Training Center

Site Address (Not a P.O. Box): Building 1600A, Ray Street

City: Great Lakes County: Lake

B. Site Information

1. Will the owner/operator seek reimbursement from the Underground Storage Tank Fund? Yes___ No X

2. If yes, is the budget attached? Yes___ No X

3. Is this an amended plan? Yes___ No X

4. Identify the material released: gasoline and diesel fuel

5. This Corrective Action Plan is being submitted pursuant to:

   a. 35 Ill. Adm. Code 731.166:

      i. A release of petroleum from a UST was reported to IEMA prior to September 13, 1993 and the owner/operator has NOT elected to Proceed under Title XVI of the Environmental Protection Act. _____

      ii. The material released was not petroleum. _____

   b. 35 Ill. Adm. Code 732.404:

      i. A groundwater quality standard or objective for any applicable indicator contaminant has been exceeded at the property boundary line or 200 feet from the leaking UST. X

      ii. The leaking UST system is within the setback zone or regulated Recharge area of a potable water supply well. _____

iii. There is evidence that migration of petroleum or petroleum vapors may threaten human health or human safety. _____

iv. Class III Special Resource Groundwater exists within 200 feet of the site. _____

v. A surface body of water has been adversely affected by the presence of a visible sheen or free product layer. _____

c. 35 Illinois Administrative Code Section 732.312 _____

C. Proposed Methods of Remediation

1. Soil - Heritage Environmental Services, Inc. (HES) removed impacted soil from the leak source in 1998. Subsurface soils within the identified plume are impacted due to the migration of dissolved gasoline and diesel constituents. An in-situ biosparge technique has been designated for this site which will remediate soils and groundwater concurrently. In-situ treatment allows soil to be treated without being excavated or transported, which results in significant cost savings. Due to the logistics of this site and the extent of contamination, excavation is not a feasible option for soil remediation.

2. Groundwater - The impacted groundwater will be treated in situ utilizing two directionally-drilled horizontal wells to deliver oxygen to the subsurface to enhance naturally-occurring bioactivity. Injecting air into the groundwater at fairly low rates can dramatically increase biological activity associated with the natural degradation of organic compounds. Biosparging through horizontal wells into the saturated zone is an efficient process that is typically more economical than SVE or conventional air sparging.

D. Soil and Groundwater Investigation Results

1. Description of investigation activities performed to define the extent of soil and/or groundwater contamination

HES submitted a LUST 45-Day/Site Classification Completion Report and LUST Investigation/Remediation Report to IEPA dated May 8, 1998. The HES report includes UST closure activities, piping removal, impacted soils removal, and soil boring activities. On September 17, 1997, RW Collins removed three USTs in September 1997. Two (2) 10,000-gallon gasoline tanks and one (1) 6,000 gallon diesel tank were removed. HES mobilized to the site on September 25, 1997 to remove the distribution piping and to excavate the petroleum contaminated soils within the immediate area of the former USTs. Approximately 800 cubic yards of impacted soil from the former UST excavation and dispenser pipeline area were transported to the Navy Fire Fighting Training Area for bioremediation.

Following the over-excavation efforts, a total of 35 Geoprobe® soil borings were advanced at the site to collect soil samples. In addition, four piezometers were installed for the collection of groundwater samples. The soil and groundwater plumes were defined using analytical results from a mobile field laboratory and a conventional analytical laboratory. A correlation between the results was not performed, as soil samples from the same horizon were not typically analyzed by both techniques, and the field lab did not test for polynuclear aromatics (PNAs). The site was designated as high priority because the plumes extend to adjacent properties and the soil is impacted at approximately 250 feet from the source. HES determined that the soil plume is larger than the groundwater plume; this was confirmed by subsequent sampling activities performed by TolTest. Appendix A contains figures from the HES report.

Benzene is the indicator contaminant. It was detected offsite in soil borings within the Elgin Joliet and Eastern (EJ&E) Railway property, directly to the east of the subject property, and further to the east at (Navy-owned) Spaulding Street industrial facilities. With the exception of benzene, the soil and groundwater laboratory analytical results from the HES investigation indicate petroleum constituents are below the IEPA Tier 1 Site Remediation Objectives for the ingestion, inhalation and migration to groundwater routes of exposure for Residential property use.

The mobile field gas chromatograph (GC) analysis conducted by HES on soil samples did indicate exceedences of Tier 1 levels for ingestion/migration to Class I Groundwater remediation objectives as follows: at IPS 7 (for toluene, ethylbenzene & xylenes), IPS 8 (toluene) IPS 14 (ethylbenzene) and nine other locations (for benzene only). The plume as defined by HES was further investigated prior to the development of this CAP.

TolTest developed a Work Plan to confirm plume dimensions and to obtain hydrogeological information to develop a design for this CAP. The Work Plan, dated June 1999 was discussed with the IEPA with the objectives of the investigation clearly defined. TolTest mobilized to the site in October 1999. Drilling activities consisted of installing 11 soil borings and six monitoring wells at locations around the perimeter and within the identified subsurface plume. A Geoprobe® rig was used to install four small-diameter soil borings (one-inch diameter) approximately 15 to 20 feet west of the railroad tracks in the vicinity of HES soil boring B17. Direct push samplers with sample liners were used to collect samples for visual inspections and soil classification, with attention to the possible occurrence of free product. Total depth of the Geoprobe® soil borings is estimated to be approximately 12 to 15 feet. A temporary one-inch diameter PVC screen was placed in the Geoprobe® borings and visually inspected for any accumulation of free product with a small diameter Teflon bailer. Upon completion of sampling and inspections, the small diameter soil borings were backfilled with bentonite. Since no free product was encountered, no recovery well was installed.

A truck-mounted drill rig was utilized to advance the six large diameter soil borings. Figure 1 (Appendix H) depicts the locations of the soil borings/monitoring wells. The borings were advanced at least five feet into the apparent water table. Total depth is estimated to be approximately 12 to 15 feet. Soil samples were obtained continuously in soil borings utilizing 4¼" inside diameter (ID) hollow-stem auger methods. Standard penetration tests

(ASTM D1586) were performed utilizing 2" outside diameter split spoon sampler driven by a 140-pound drop hammer. The soils were classified on boring logs indicating lithologic descriptions and Unified Soil Classified System descriptions, degree of sorting, sedimentary contacts, PID readings, etc. All soil cuttings were placed in 55-gallon drums for disposal.

Monitoring wells were constructed of 2-inch ID, schedule 40 flush joint PVC risers and screens. Ten feet of 0.010 slot screen and a sufficient length of riser were placed in each boring. The screened interval was installed as to intersect the apparent water table and to allow for potential seasonal fluctuations. Each well screen was surrounded by a quartz sand filter pack with a bentonite seal, the remainder of the annulus was back-filled with a cement/bentonite slurry. Well covers were flush-mounted and cemented in place over the well casing.

To help assess the apparent groundwater gradient, exact water level measurements were made. Each monitoring well was surveyed by a registered land surveyor to a United States Geological Survey (USGS) common site datum to a reference mark on the top of casing to the nearest 0.01 foot to determine relative elevations of the groundwater. After the wells were developed and allowed to reach static equilibrium, water levels were taken with an electric water level indicator to an accuracy of 0.01 feet. From these measurements, groundwater contour map (see Figure 4, Appendix H) was constructed and the groundwater gradient and flow direction was assessed. The direction of groundwater flow as documented by TolTest, to the east, with a gradient of approximately 0.01, is generally consistent with the gradient described in the HES report of 1998. Table 1 summarizes groundwater measurements. Appendix B contains the survey data.

Table 1
Groundwater Measurements
Building 1600A, GLNTC, Illinois
(measurements obtained 12/16/99)

Well No.	TOC Elevation (NGVD 1929)	Depth to Water (ft)	Static Water Elevation (NGVD 1929)
MW-1	663.22	4.61	658.61
MW-2	663.33	6.08	657.25
MW-3	662.80	6.11	656.69
MW-4	660.73	5.38	655.35
MW-5	659.51	4.91	654.60
MW-6	658.73	4.14	654.59

Slug tests were conducted on the six monitoring wells to calculate the hydraulic conductivity of the uppermost water-bearing zone. This test entailed rapidly displacing a volume of water with a PVC bailer and measuring the rate of recharge towards static levels. Changes in water levels were measured by a pressure transducer and recorded by a programmable hydraulic monitor. The method developed by Bouwer and Rice (1976)

was used for calculating the hydraulic conductivity. Table 2 is a summary of the hydraulic conductivities from the slug test results. Appendix C contains plots and data of the slug tests using the computer program *Aquifer Test for Windows, version 2.55*, developed by Waterloo Hydrogeologic, Inc.

Table 2
Hydraulic Conductivity
Building 1600A, GLNTC, Illinois

Location	Hydraulic Conductivity	
	(cm/sec)	(ft/min)
MW-1	7.62×10^{-4}	1.50×10^{-3}
MW-2	4.21×10^{-4}	8.26×10^{-4}
MW-3	3.08×10^{-3}	6.06×10^{-3}
MW-4	5.39×10^{-3}	1.06×10^{-2}
MW-5	3.37×10^{-4}	6.63×10^{-4}
MW-6	4.80×10^{-4}	9.45×10^{-4}
Average	1.75×10^{-3}	3.43×10^{-3}

Based on the slug tests, the site's groundwater classification is a Class I per 35 IAC 620 since the hydraulic conductivity is greater than 1.00×10^{-4}. The average hydraulic conductivity measurements indicate the site is conducive to remediation by biosparge technology.

2. Analytical results and cleanup objectives in tabular format

Contaminants of concern, based on gasoline and diesel sources, are benzene, toluene, ethylbenzene, and xylenes (BTEX), methyl tertiary butyl ether (MTBE), PNAs, total lead and synthetic precipitate leaching procedure (SPLP) lead. IEPA has recently become concerned about MTBE contamination in groundwater at sites with gasoline releases because of recent case histories. Cleanup objectives for MTBE have not been set by USEPA or IEPA as the health risks have not been quantified. The USEPA has an advisory objective goal of 20 to 40 mg/L, but it is not enforceable at this time, as carcinogenic studies have not been performed.

The cleanup objectives for groundwater will be per 35 IAC part 742, Appendix B, Table E: Tier 1 Groundwater Remediation Objectives for the Groundwater Component of the Groundwater Ingestion Route for Class I Groundwater. The cleanup objectives for soil will be 35 IAC Part 742, Appendix B: Table A: Tier 1 Soil Remediation Objectives for Residential Properties, Soil Component of the Groundwater Ingestion Exposure Route Values for Class I Groundwater. It will be preferable to the Navy if Tier I residential objectives can be met through remediation of this site as no land use controls would be required. If the Tier I residential standards cannot be met, Industrial-Commercial standards would be acceptable to the Navy because these standards are consistent with the current land use. Any required land use controls would be established in cooperation between the Navy, IEPA, and the off site land owner.

The following Table 3 summarizes groundwater analytical results and Table 4 summarizes soil analytical results from TolTest's investigation. Appendix D contains summaries of the 1997 analytical results from the HES report. The TolTest results indicate the plumes have not changed in size. The fact that the soil plume is bigger than the groundwater plume is attributed to active microbial populations in the silty sands between the clay layers both above and below the groundwater plume.

Table 3
Groundwater Analyses
Building 1600A, GLNTC, Illinois

Target Analyte	"Groundwater Remediation Objective"	Analytical Results from Groundwater Samples					
	Class I (mg/L)	MW-1 (mg/L)	MW-2 (mg/L)	MW-3 (mg/L)	MW-4 (mg/L)	MW-5 (mg/L)	MW-6 (mg/L)
Benzene	0.005	<0.001	0.453	<0.001	0.691	0.0248	<0.001
Toluene	1.0	<0.001	0.407	<0.001	0.761	0.00779	<0.001
Ethylbenzene	0.7	<0.001	1.320	<0.001	0.243	<0.001	<0.001
Xylenes	10.0	<0.003	1.100	<0.003	1.680	0.00575	<0.003
MTBE	*	<0.001	<0.002	<0.001	<0.001	0.0192	<0.001
Acenaphthene	0.42	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Anthracene	2.1	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Benzo(a)anthracene	0.00013	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Benzo(b)fluoranthene	0.00018	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Benzo(k)fluoranthene	0.00017	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Benzo(a)pyrene	0.0002	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Chrysene	0.0015	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Dibenzo(a,h)anthracene	0.0003	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Fluoranthene	0.28	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Fluorene	0.28	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Indeno(1,2,3-c-d)pyrene	0.00043	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Naphthalene	0.025	<0.005	0.0562	<0.005	<0.005	<0.005	<0.005
Pyrene	0.21	<0.0025	<0.0025	<0.0025	<0.0025	<0.0025	<0.0025
Lead	0.0075	0.020	<0.001	0.002	NA	NA	NA

Notes:
1. Shaded areas presents analyses greater than cleanup objectives as per 35 IAC Part 742, Appendix B: Table E: Tier 1 Groundwater Remediation Objectives for the Groundwater Component of the Groundwater Ingestion Route for Class I Groundwater.
2. Groundwater samples collected on October 28, 1999 (MW-1 thru MW-5) and December 16, 1999 (MW-6).
3. Samples were analyzed as follows: BTEX/MTBE (Method 5035/8021), PNAs (Method 8270), lead (Method 7421)

Table 4
Soil Analyses
Building 1600A, GLNTC, Illinois

Target Analyte	"Soil Component of the Ground water Ingestion Exposure Route Values" Class I	"Exposure Route Specific Values For Soil" Residential		Analytical Results from Soil Borings					
		Ingestion	Inhalation	MW1-03 (4-6")	MW2-03 (4-6')	MW3-04 (6-8')	MW4-05 (8-10')	MW5-05 (8-10')	MW6-06 (10-12')
	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
Benzene	0.03	22	0.8	<0.005	0.116	<0.005	0.023	0.039	<0.005
Toluene	12	16,000	650	<0.005	<0.005	<0.005	0.044	<0.005	0.031
Ethylbenzene	13	7,800	400	<0.005	<0.005	<0.005	0.031	<0.005	<0.005
Xylenes	150	160,000	410	<0.015	<0.015	<0.015	0.969	<0.015	<0.015
MTBE	*	*	*	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Acenaphthene	570	4,700	*	<0.300	<0.300	<0.300	<0.300	<0.300	<0.300
Anthracene	12,000	23,000	*	<0.250	<0.250	<0.250	<0.250	<0.250	<0.250
Benzo(a)anthracene	2	0.9	*	<0.150	<0.150	<0.150	<0.150	<0.150	<0.150
Benzo(b)fluoranthene	5	0.9	*	<0.150	<0.150	<0.150	<0.150	<0.150	<0.150
Benzo(k)fluoranthene	49	9	*	<0.300	<0.300	<0.300	<0.300	<0.300	<0.300
Benzo(a)pyrene	8	0.9	*	<0.150	<0.150	<0.150	<0.150	<0.150	<0.150
Chrysene	160	88	*	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100
Dibenzo(a,h)anthracene	2	0.9	*	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100
Fluoranthene	4,300	3,100	*	<0.300	<0.300	<0.300	<0.300	<0.300	<0.300
Fluorene	560	3,100	*	<0.250	<0.250	<0.250	<0.250	<0.250	<0.250
Indeno(1,2,3-c-d)pyrene	14	0.9	*	<0.250	<0.250	<0.250	<0.250	<0.250	<0.250
Naphthalene	84	3,100	*	<0.300	6.990	<0.300	<0.300	<0.300	<0.300
Pyrene	4,200	2,300	*	<0.300	<0.300	<0.300	<0.300	<0.300	<0.300
Lead (soil in mg/kg)	*	400	*	6.60	7.38	15.20	NA	NA	NA
Lead (SPLP in mg/l)	0.0075	*	*	0.020	0.038	0.027	NA	NA	NA

Notes:
1. Indicates no toxicity criteria available on 35 IAC Part 742, Appendix B: Table A: Tier 1 Soil Remediation Objectives for Residential Properties
2. Shaded areas present analyses greater than cleanup objectives.
3. NA – Location not analyzed for constituent.
4. Soil samples collected on October 19-20, 1999 (MW-1 thru MW-5) and December 7, 1999 (MW-6).
5. Samples were analyzed as follows: BTEX/MTBE (Method 5035/8021), PNAs (Method 8270), SPLP lead (Method 1312/7421)

3. **Laboratory reports.** Copies of the laboratory test reports are included in Appendix E.

4. **Boring logs.** Copies of the boring logs are included in Appendix F.

5. **Monitoring well logs.** Copies of the monitoring well logs are included in Appendix G.

6. **Site maps.** Figures of the following are presented in Appendix H:

   Figure 1 – Site Map
   Figure 2 – Estimated Extent of Groundwater Contamination
   Figure 3 – Estimated Extent of Soil Contamination
   Figure 4 – Groundwater Contour Map
   Figure 5 – Site Cross Sections
   Figure 6 – Proposed Well Locations
   Figure 7 – Proposed Horizontal Well (cross section)

E. Technical Information – Corrective Action Plan

1. A discussion of how the corrective action plan shall remediate each of the criteria which caused the site to be classified as High Priority

The site was classified as high priority in the HES report because contamination was detected off-site, beneath the EJ&E Railway property. In addition, the soil plume extends in excess of 200 feet from the source. Corrective actions will mitigate the migration and reduce concentration of the plume to less than action levels.

2. Engineering design specifications, diagrams, calculations, manufacturer's specifications, system analyses, site maps, etc.

Two parallel horizontal wells are proposed for the biosparge conceptual design to remediate this site to Tier 1 cleanup objectives. IEPA representatives met with TolTest and US Navy representatives on January 11, 2000 to discuss the feasibility of horizontal wells, and the necessity for extensive computer simulation prior to finalizing the screen size(s), screen length, compressed air injection rates, radii of influence and other engineering variables. Therefore, engineering design specifications, diagrams, calculations, manufacturer's specifications, system analyses, and site maps will be submitted after the IEPA and Navy approve the conceptual design as provided in this CAP.

Soils excavation is not feasible due to the extent of the plume, overhead and below ground utilities, and active rail freight line. Air sparging (AS) with soil vapor extraction (SVE) was considered early in the evaluation of in situ cleanup methods for the site but were rejected because of limitations on where vertical wells could be installed due to the presence of utilities and the rail lines on the site. Based on case histories of specifically designed

horizontal well biosparge projects, SVE is not necessary or conducive to expediting clean up of this site.

Discussions on possible conventional and alternative technologies follow below. Most information pertaining to alternative technologies was obtained from the Technology Innovation Office of the U.S. Environmental Protection Agency web site at URL address http://clu-in.org/remed1.htm. This web site is an interactive document: *Federal Remediation, Technologies Roundtable, Remediation Technologies Screening Matrix and Reference Guide, Version 3.0.*

Conventional pumping - Groundwater pumping systems, consisting of appropriate recovery wells for groundwater extraction, remove contaminants that are dissolved in the water for treatment at the surface. One or more recovery wells are installed in a contaminated plume of groundwater. Water is pumped to the surface where it is treated by standard water treatment operations. The recovery well network is generally designed to capture water from the center (high concentration area) of the plume for rapid mass removal and from the leading edge of the plume to minimize plume spread. The design can be based on standard groundwater models. Simplicity of concept and flexibility in meeting various cleanup objectives (many different contaminant types, balanced optimization based on mass reduction and plume spread, etc.) are significant strengths of groundwater pump and treat, and this technology will continue to be an important tool in cleanup activities.

This technology is relatively mature with many years of operating experience and post operational evaluations complete. The treated water must be disposed to an outfall or to reinjection wells. This requires additional energy and expense. Long-term costs (labor, energy/consumables, and monitoring) are a substantial portion of this conventional technology.

Advantages

- This technology is simple to design and operate, uses standard equipment available from many sources, and treats all types of dissolved contamination.
- It allows flexibility in meeting various cleanup goals (e.g., mass reduction versus plume spread).
- It can be implemented quickly.

Disadvantages

- Treats "clean water" from the aquifer that is drawn into the cone of depression.
- Generation of substantial amounts of secondary waste water.
- High energy costs for pumping and moving large volumes of water.
- Indiscriminate removal of all ground water components.
- Slow progress toward terminal regulatory goals due to technical limitations typically lasting several years.

Natural Attenuation – Since target contaminants for natural attenuation are nonhalogenated VOCs, SVOCs, and fuel hydrocarbons, this site is a candidate for natural attenuation. For natural attenuation, natural subsurface processes -- such as dilution, volatilization, biodegradation, adsorption, and chemical reactions with subsurface materials -- are allowed to reduce contaminant concentrations to acceptable levels. Natural attenuation is not a technology per se.

Consideration of this option requires modeling and evaluation of contaminant degradation rates and pathways. The primary objective of site modeling is to demonstrate that natural processes of contaminant degradation will reduce contaminant concentrations below regulatory standards before potential exposure pathways are completed. In addition, sampling and sample analysis must be conducted throughout the process to confirm that degradation is proceeding at rates consistent with meeting cleanup objectives. Where contaminants are expected to remain in place over long periods of time, waivers and institutional controls must be obtained.

Advantages

- Lower costs than most active remedial alternatives.
- Minimal disturbance to the site operations.

Disadvantages

- Some migration of constituents may occur; not suitable if receptors might be affected.
- Long period of time required to remediate heavier petroleum products.
- Longer period of time may be required to mitigate contamination than for active remedial measures.
- May not always achieve the desired cleanup levels within a reasonable length of time.

Biosparging - The Proposed Technology for Building 1600A. Injecting air into the groundwater at fairly low rates can dramatically increase biological activity associated with the natural degradation of organic compounds. This procedure, called biosparging in the saturated zone, is an efficient process that is typically more economical than SVE or conventional AS. Since flow rates are low, blowers and associated operating costs are less, and there is no need to treat collected contaminant-laden soil gas. In large plume areas, or in locations under buildings or pavements, horizontal wells are very cost effective and efficient for injecting air and controlling vapor migration.

Two basic criteria must be satisfied for successful biosparging. First, air must be able to pass through the soil in sufficient quantities to maintain aerobic conditions; second, natural hydrocarbon-degrading microorganisms must be present in concentrations large enough to obtain reasonable biodegradation rates. Results of the heterotrophic plate count, used to determine how many microorganisms are in a given sample, indicated the percentage of organisms exhibiting the ability to degrade BTEX and MTBE exceeds

the minimum requirements for bioremediation. Once active biosparging is initiated, the number of microorganisms will increase many-fold.

Computer modeling, utilizing proprietary software SPARGE© by Integrity Engineering, Inc. is used to specify design parameters such as the number and density of the wells, sparging rate, well slot size and spacing, well diameter, equipment, and required operating conditions.

Construction of the entry and exit pits for the proposed two horizontal wells will begin immediately upon mobilization. Each pit location will be prepared by excavating approximately a four-foot by four-foot area to approximately one foot in depth. The pits will be subsequently finished with a concrete pad and manhole for access to the well on one end and finished with a concrete pad, blower, heat exchanger, control, and small shed to house the blower equipment on the opposite end.

Figure 6, Proposed Well Locations, and Figure 7, Proposed Horizontal Well (cross section) depicts where the wells will be installed. Horizontal wells are installed by pushing a drill string with the hydraulics of a horizontal drill rig. Electronics behind the head of the drill bit transmit its location to the surface, where a receiver picks up the signal. A plate on the drill bit is used to guide the path of the drill string to the desired depth (bottom of the sand layer). Once the drill string is guided down to the desired depth, horizontally under the plume, and back up to the surface at the exit pit, a reamer is attached to the drill string after the drill head is removed. Engineered well screen and casing (four-inch diameter HDPE piping) is attached to the reamer and the drill string is pulled back to the entry point. Once placed, the well is developed to remove fines. Development water will be containerized, sampled, and properly disposed. Appendix I contains a conceptual process design of a biosparge system.

Advantages

- Readily available equipment; easy installation.
- Implemented with minimal disturbance to site operations.
- Short treatment times, 6 months to 2 years under optimal conditions.
- Is cost competitive.
- Enhances the effectiveness of air sparging for treating a wider range of petroleum hydrocarbons.
- In large plume areas, or in locations under railroad tracks and/or pavements, horizontal vapor extraction wells are very cost effective and efficient for controlling vapor migration.
- Requires no removal, treatment, storage, or discharge of groundwater.
- Low air injection rates minimize potential need for vapor capture and treatment.
- This technology does not require expensive equipment and can be left unattended for long periods of time.
- Typically, only periodic maintenance monitoring is conducted.

Disadvantages

- Can only be used in environments where biosparging is suitable (*e.g.*, no nearby subsurface confined spaces).
- Some interactions among complex chemical, physical, and biological processes are not well understood.
- Monitoring of off-gases at the soil surface may be required.

3. A list of sampling parameters and corresponding cleanup objectives

Contaminants of concern include BTEX, MTBE, PNAs, lead and SPLP lead per 35 IAC Section 732.310 (b) and (c) since historically, the USTs contained leaded gasoline and diesel fuel. MTBE recently became a concern with the IEPA regarding groundwater contamination and will soon be added to the list of LUST regulations. Corresponding cleanup objectives are listed in Tables 3 and 4 for groundwater and soils respectively.

4. The basis for determining sampling parameters and cleanup objectives

The basis for determining sampling parameters and cleanup objectives is 35 IAC Part 740 and 35 IAC Part 620 since the site's groundwater classification is Class I.

5. Media sampling plan to verify completion of remediation

Groundwater will be sampled from monitoring wells to ascertain when cleanup objectives have been met. Samples will be collected quarterly or until cleanup objectives are met. Closure sampling will be conducted after the monitoring wells in the plume exhibit concentrations below detection levels for BTEX for two consecutive quarters. Closure sampling will consist of existing wells and from soil from three new Geoprobe® holes in the plume for the contaminants of concern.

6. A discussion of the proposed system(s) effectiveness in remediating the contaminated soil and/or groundwater

Biosparging technology stimulates the natural in situ biodegradation of petroleum hydrocarbons in soil by providing oxygen to existing soil microorganisms using low air flow rates to provide only enough oxygen to sustain microbial activity. Oxygen is commonly supplied through direct air injection into residual contamination. In addition to degradation of adsorbed fuel residuals, volatile compounds are biodegraded as vapors move slowly through biologically active soil. Biosparging differs from air sparging which achieves physical removal of contaminants by operating at a higher volumetric flow rate.

The use of horizontal wells is more efficient and effective than vertical wells. To ensure the effectiveness of the conceptual design, and prior to the development of specifications, modeling will be performed to determine the number of horizontal wells, sparge flow rates and blower size, and minimum time to clear the well of groundwater and achieve steady-state sparge injection conditions.

7. A description and results of bench/pilot studies

Soil samples from five borings (MW-1, MW-2, MW-3, MW-4, and MW-5) were submitted to BioRemedial Technologies, Inc., Hermitage, Pennsylvania. Aliquots of the samples were used in tests designed to determine the feasibility of utilizing a biologically based technology for remediation. The laboratory report is included as Appendix J. Results of the heterotrophic plate count indicated the following:

- The percentage of organisms exhibiting the ability to degrade BTEX and MTBE exceeds the minimum requirements for bioremediation.
- Some of the microorganisms prefer the contaminant as a food source.
- Microbial degradation of the contaminants of interest is a viable option for remediation at the site.

A soil sample from MW-6 was not submitted since this soil boring was installed at a later date. It was determined after review of the microbial results that a sample from this location would not add to the general microbial assessment of the site.

8. Itemized cost estimates of alternative versus conventional technologies.

Itemized costs are not provided with this submittal because the Navy is not seeking state reimbursement from the Underground Storage Tank Fund. It is appropriate, however, to emphasize that the proposed innovative technology has been estimated to be 80% more cost effective than pump and treat technology with vertical wells, and 50% more cost effective than air sparge technology. These cost estimates were provided by a design professional, (Louis D. Fournier, Ph.D.) with horizontal well experience on 200 petroleum contamination sites over the past 10 years (where the lithology was conducive to horizontal well application).

9. For alternative technologies the following must be provided:

a. A demonstration that the proposed technology has a substantial likelihood of achieving compliance with all applicable regulations and all corrective action remediation objectives necessary to comply with the Environmental Protection Act and the regulations and to protect human health and the environment. Due to the complexity of the plume, (multiple property owners, active freight rail line, and overhead and below ground utilities) institutional controls are not desirable for this site. The Navy prefers to meet Tier I residential objectives. If the Tier I residential objectives cannot be met, Industrial-Commercial standards would be acceptable to the Navy because these standards are consistent with the current land use. The proposed biosparging alternative technology has been proven with over 200 case histories. It is cost effective as documented in the presentation to the IEPA and Navy on January 11, 2000 by Louis Fournier, Ph.D. Dr. Fournier is a member of the National Ground Water Association's Horizontal Well Technical Committee and the Editor of Horizontal Well News.

b. A demonstration that the proposed technology will not adversely affect human health or the environment. Biosparging introduces low air flow rates, typically 0.5 scfm per foot of well screen through a horizontal well. At such low flow rates, vapors have been shown not to be a problem at the surface, and the plume does not spread due to the injection of air into the subsurface. Monitoring points are already established to demonstrate that the plume remains contained during the biosparge treatment, which is expected to completely reduce contaminants of concern to concentrations below the Tier 1 levels within one to three years. Existing monitoring wells MW-1, MW-2, MW-3, MW-4, MW-5, and MW-6 will be used to measure system effectiveness. Two additional wells, approximately 50 feet north and south of MW-4, respectively, will be installed to more accurately measure system performance.

Additional evidence that the proposed technology will not adversely affect human health or the environment includes that the site is located in an urban environment surrounded by industrial property. Also, the site consists of an active freight rail line. There are no nearby residential structures, schools, or ecologically sensitive areas.

c. Copies of all Agency permits necessary to authorize the use of the alternative technology. No IEPA permits are necessary.

d. Results of the monitoring program implemented to determine whether the proposed technology will achieve compliance with the applicable regulations and remediation objectives. Results will be provided with periodic monitoring reports and in the Corrective Action Completion Report as per 35 IAC Part 732.

F. Signatures

I certify under penalty of law that this plan, supporting documents and all attachments were prepared under my direction or supervision. To the best of my knowledge and belief, this plan, supporting documents and all attachments are true, accurate and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Owner

Name: Department of the Navy
Mark Shultz, by order of the Commanding Officer
Title: Director, NTC GL Env. Dept.
Address: Bldg 1-A, 201 Decatur Avenue
Great Lakes, IL 60088
Phone: (847) 688-5999 x 40
Signature: Mark Shultz
Date: 2-18-06

Operator

Name: Same as the Owner
Title: _____
Address: _____
_____
Phone: _____
Signature: _____
Date: _____

Consultant

Firm: TolTest, Inc.

Contact: Robert R. Beckwith, CPG

Title: Principal Hydrogeologist

Address: 1915 N. 12th Street
Toledo, Ohio 43606

Phone: (419) 241-7175

Signature: Robert R Beckwith

Date: 2/16/00

CORRECTIVE ACTION PLAN SUPPLEMENT
BUILDING 1600A (OLD GAS STATION)
GREAT LAKES, ILLINOIS

ENVIRONMENTAL JOB ORDER CONTRACT (EJOC)
CONTRACT NO. N68950-96-D-0052
DELIVERY ORDER NO. 0099

FOR

Department of the Navy
Naval Training Center (NTC) – Environmental Department
Building 1-A, 201 Decatur Avenue
Great Lakes, Illinois 60088-5600

SUBMITTED

AUGUST 2000
TOLTEST PROJECT NO. 37755.02

TOLTEST, INC.
1915 N. 12TH STREET
P.O. BOX 2186
TOLEDO, OHIO 43603
(419) 241-7175
FAX (419) 321-6259

TOLTEST, INC.

TOLTEST, INC.

To be the preferred and trusted partner of our clients and associates . . . **PERIOD!**

August 28, 2000 TolTest No. 37755.02

Christopher Bartku
Environmental Engineer
Environmental Department, Code N453B
201 Decatur Avenue
Great Lakes, Illinois 60088-5600

RE: Corrective Action Plan Supplement
Building 1600A, Great Lakes, Illinois
IEMA Incident #971739

Dear Mr. Bartku:

The purpose of this letter is to submit supplemental engineering information to the Corrective Action Plan (CAP) dated February 2000. This information fulfills CAP requirements for Section E. *Technical Information – Corrective Action Plan*, paragraph 2 - *Engineering design specifications, diagrams, calculations, manufacturer's specifications, system analyses, site maps, etc.* The CAP stated the necessity for computer simulation prior to finalizing the screen size(s), screen length, compressed air injection rates, radii of influence and other engineering variables, and would be submitted at a later time.

STAR Environmental, Inc. (STAR) completed their computer simulation and presented their findings in a report titled *Layout and Design of a Two-Well Horizontal Well Remediation System.* The STAR report is attached as Appendix A. Once STAR submitted their designs, TolTest completed a Process Flow Diagram and Piping and Instrumentation Diagram, which is attached as Appendix B. Carbonair Environmental Systems was selected as the equipment vendor. Carbonair submitted their system modeling and drawings, list of proposed equipment and cut sheets, and control package description, and is attached as Appendix C.

We will keep you informed as the two equipment skids are completed and are ready for shipment to the site. If you have any questions, please do not hesitate to call at (419) 241-0170.

Sincerely,
TolTest, Inc.

Robert R. Beckwith, PG
Principal Hydrogeologist

Cc: Ronald Stewart (Illinois EPA)

attachments

APPENDIX A

STAR Environmental, Inc.
Layout and Design of a Two-Well Horizontal Well Remediation System

TOLTEST, INC.

STAR Environmental, Inc.

10 Wilmington-West Chester Pike • Chadds Ford, PA 19317
Phone: 610-558-2121 • Fax: 610-558-2112
E-mail: starcompany@erols.com

Layout and Design of a Two-Well Horizontal Well Remediation System for the Naval Training Center, Great Lakes, Illinois

(Delivery Order 0099)

Prepared For:

United States Navy

Great Lakes Naval Training Center
Great Lakes, Illinois

&

TolTest, Inc.

1915 North 12th Street
Toledo, OH 43624

Prepared By:

Louis B. Fournier, Ph.D.
Principal Scientist/President

June 19, 2000

"Strategies & Technologies for Assessment & Remediation"

Table of Contents

Section	Page
Introduction	1
Discussion	4
Modeling Results	6
Flow Requirements	7
Uniformity of Air Flow from Wells	15
Screen Alternatives	15
Conclusion	20

List of Tables

Table	Title	Page
1	Design Parameters and Constraints for Navy Wells	8
2	Navy Well Slot Designs	17

List of Figures

Figure	Title	Page
1	Proposed Well Locations	2
2	Horizontal Well Cross-Section	3
3	Internal Well Pressure	9
4	Internal Well Pressure (Narrow Range)	10
5	Air Sparged per Foot Screen (ACFM)	11
6	Air Sparged per Foot Screen (SCFM)	12
7	Cumulative Air Sparged (SCFM)	13
8	Internal Well Air Velocity (FPM)	14
9	Circumferencial Slotting	18
10	Longitudinal Slotting	19

INTRODUCTION

TolTest, Inc. ("TolTest" herein) and STAR Environmental, Inc. ("STAR" herein) are working together to design and install two identical directionally-drilled biosparge wells to remediate petroleum hydrocarbon contamination at a site at the United States Navy Great Lakes Naval Training Center (Great Lakes, Illinois). The plume runs between Buildings 1506 and 1712 as shown in Figure 1 and is generally contained within a sandy zone between a lower confining clay layer and an upper clayey fill layer as shown in Figure 2. Two identically-designed biosparge wells will be installed at 10 feet below grade as illustrated in these figures. The exact length of these wells has yet to be determined, but will be approximately 430' long with 230' of screen, 100' of header (i.e., the distance from the equipment compound to the screen) and 100' of tail (i.e., the distance from the screen to the distal end of the well.) Drilling of these wells has been contracted to Longbore, Inc. of Houston, Texas, a firm which specializes in the installation of directionally-drilled horizontal wells. TolTest will provide over-all project management, civil engineering support, electrical engineering and installation for power drops to blower compounds, and on-going project operation and maintenance support (O&M). STAR will provide the design of the horizontal wells, custom-slotted well materials, conceptual design of blower equipment, oversight of well installation, assistance with system start-up, and on-going project consulting. The purpose of the present report is to provide required well designs.

Figure 1

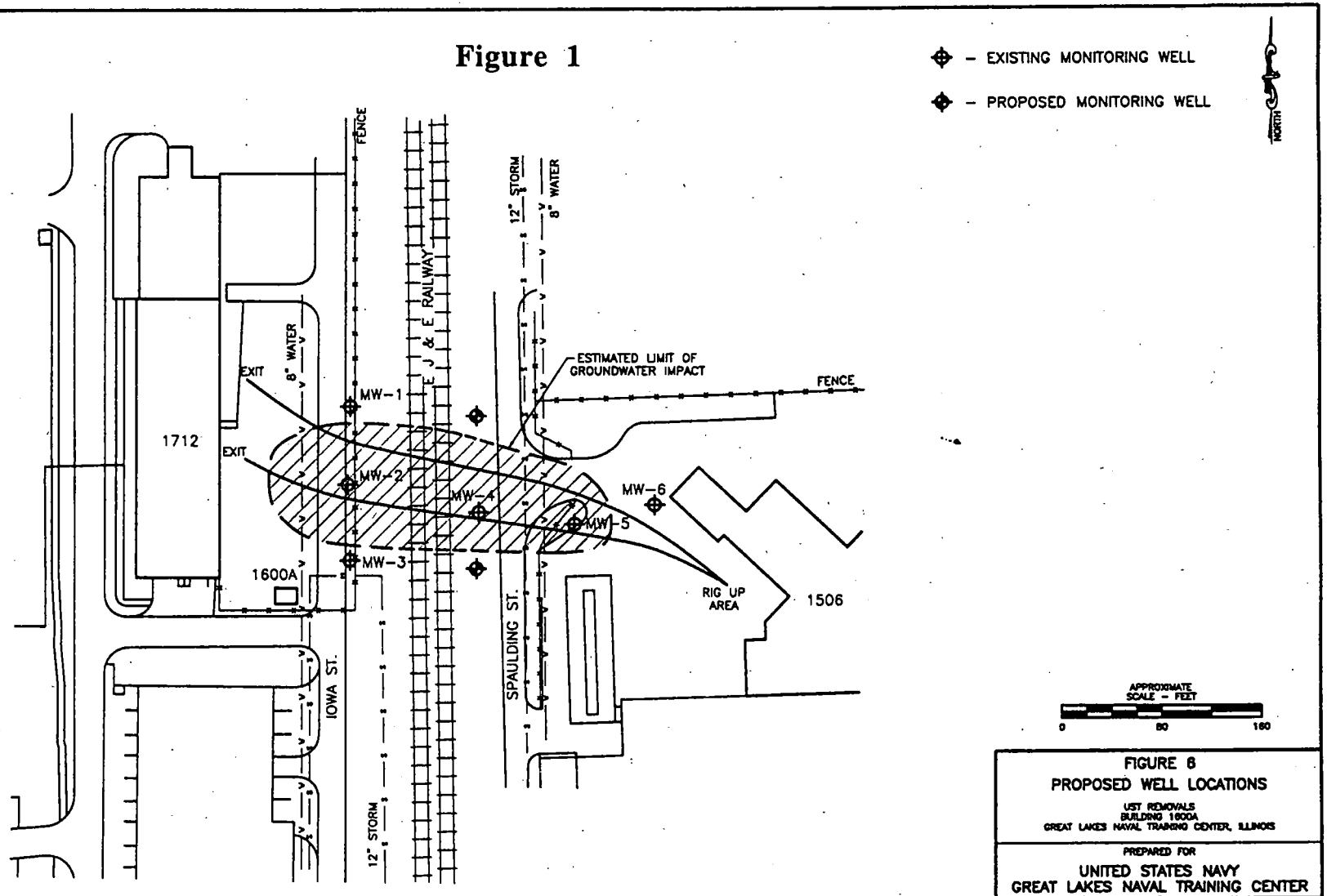
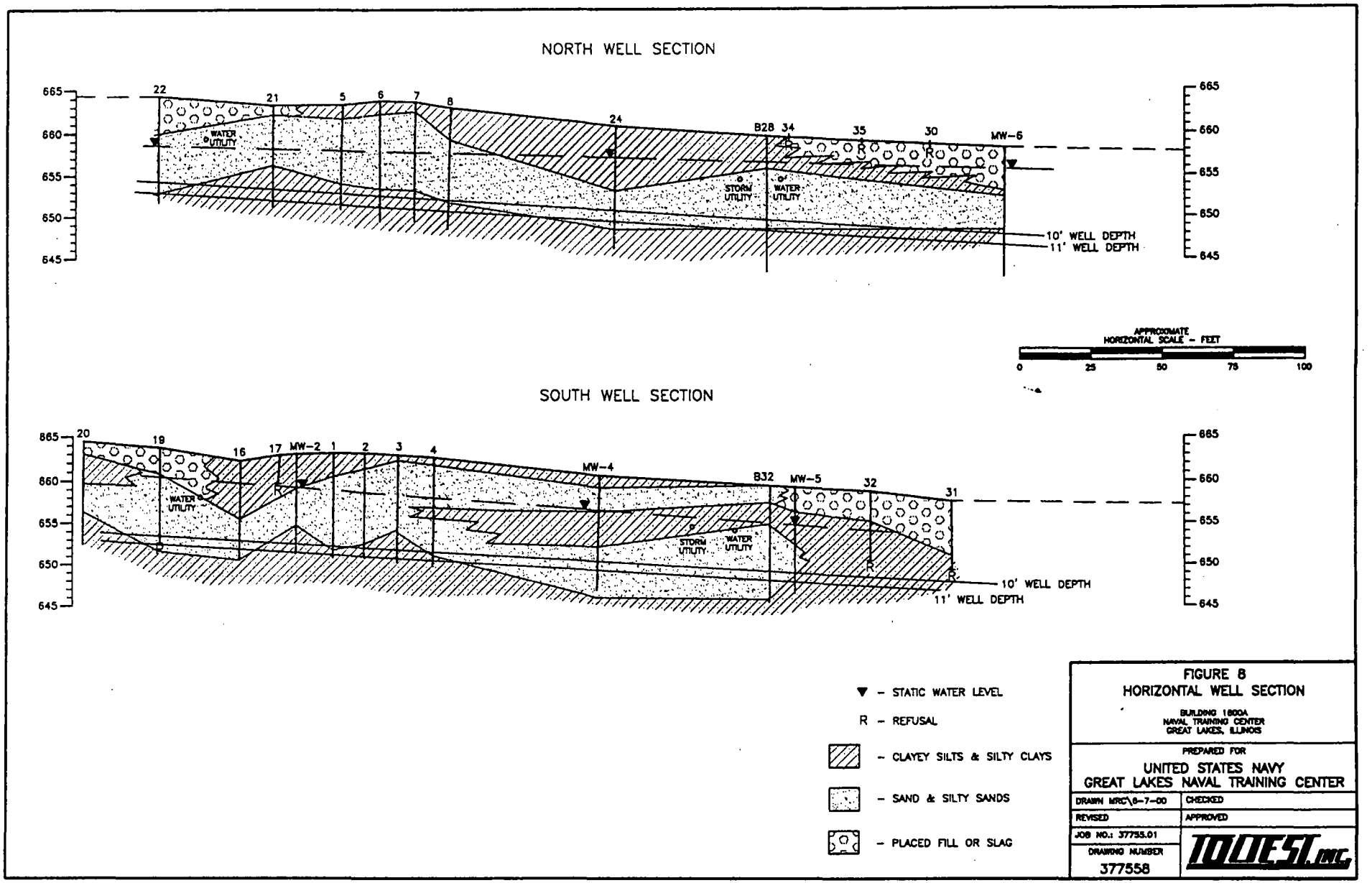


FIGURE 6
PROPOSED WELL LOCATIONS
UST REMOVALS
BUILDING 1600A
GREAT LAKES NAVAL TRAINING CENTER, ILLINOIS

PREPARED FOR
UNITED STATES NAVY
GREAT LAKES NAVAL TRAINING CENTER

DRAWN MRC\5-25-00	CHECKED
REVISED	APPROVED
JOB NO.: 37785.01	
DRAWING NUMBER 377556	TOLTEST INC.

Figure 2


NORTH WELL SECTION
665
660
655
650
645
22
21
5
6
7
8
24
B28
34
35
30
MW-6
WATER UTILITY
STORM UTILITY
WATER UTILITY
10' WELL DEPTH
11' WELL DEPTH
APPROXIMATE HORIZONTAL SCALE - FEET
0
25
50
75
100
SOUTH WELL SECTION
865
860
655
650
645
20
19
16
17
MW-2
1
2
3
4
MW-4
B32
MW-5
32
31
WATER UTILITY
STORM UTILITY
WATER UTILITY
10' WELL DEPTH
11' WELL DEPTH
▼ - STATIC WATER LEVEL
R - REFUSAL
- CLAYEY SILTS & SILTY CLAYS
- SAND & SILTY SANDS
- PLACED FILL OR SLAG
FIGURE 8
HORIZONTAL WELL SECTION
BUILDING 1600A
NAVAL TRAINING CENTER
GREAT LAKES, ILLINOIS
PREPARED FOR
UNITED STATES NAVY
GREAT LAKES NAVAL TRAINING CENTER
DRAWN MRC\6-7-00
CHECKED
REVISED
APPROVED
JOB NO.: 37755.01
DRAWING NUMBER
377558
TOLTEST INC.

DISCUSSION

The principals at STAR were the first persons to install and utilize directionally-drilled horizontal wells for subsurface remediation and have conceptualized, designed, installed, and/or operated over 200 horizontal well systems since 1989. In addition, the company has developed over a dozen highly specialized, fluid-mechanics-based computer programs for the design of air sparge, biosparge, groundwater withdrawal, steam injection, water injection, and related purposes. These computer programs are reiterative, based on the laws of conservation of mass and energy, and have been field-proven in dozens of projects. These programs provide highly-accurate information on the slot size and spacing, well diameter, operational requirements, and other parameters required to achieve desired performance with any horizontal (or vertical) well in any formation, with any contaminant distribution, and regardless of stratigraphy.

In addition, STAR provides a variety of services related to horizontal wells and horizontal well remediation including:

- Preparation of well and motive equipment specifications and designs.
- Turn-key well installation, drilling oversight, and performance verification.
- Custom-slotted well materials (STAR-Well®) to meet computer-determined requirements.
- Cetco biodegradable and specialty drilling fluids.
- Drilling rigs and crews.
- Equipment fabrication and installation.
- Well maintenance.
- Post-installation consulting.

For the present effort, STAR was asked to assist in the conceptual design, engineering design, associated modeling, and preparation of design specifications for contracting for two horizontal biosparge remediation wells by performing the following:

- Review of existing supplied project documents as required to develop conceptual design parameters for sparge wells.

- Provide conceptual design and modify based on discussion with TolTest project management.
- Perform required modeling using Sparger® software, modifying conceptual design of the wells based on modeling results (both location and well design specifications).
- Assist in the review and edit of technical specifications for drilling contractor bid documents.
- Provide technical support during well installation.
- Assist with development and oversight of startup and pilot testing procedures.

To determine the correct well orientation at the site, TolTest performed a GeoProbe® study of the two proposed drill paths. The results of that study are illustrated in Figure 2. An evaluation of this information concluded that the wells could be installed at either 10' or 11' below grade. Of these two, the 10' depth appeared to offer the greatest interaction with the sandy saturated zone.

With wells 10' below grade, it is expected from historic records and site survey(s) that there will be nominally 8' of groundwater on top of the screened intervals. However, there may be times that the more water is present, representing a greater hydraustatic head, and times that the zone may be virtually dry. It was concluded that the wells would be designed to perform with a nominal head of 8' of water but with capabilities of operating with 10' of water or more. Conversely, it was decided that if the sand zone should run dry during periods of draught, the use of the wells will be discontinued. At other times, blower equipment should be fitted with either manual or automatic (or semi-automatic) capability to adjust operation to reflect site conditions.

Normally, as part of the Conceptual Design Report, STAR provides engineering operating specifications for the horizontal well system. For the present effort, it has been determined that others will provide engineering support for equipment design and procurement. Hence, the current report is limited to providing information related to the design of the horizontal wells proper including slot size and spacing, required well diameter, suggested materials-of-construction, pressure requirements, and flow requirements.

Modeling Results

Sparger® is the newest computer software modeling program developed by STAR. It, like previous proprietary programs, is based on fluid dynamics equations pertinent to the flow of air and other gases through conduit and into porous media. Each of these programs are based on the conservation of mass and energy as a primary requirement. Programs are available for all remediation technologies including air sparging, biosparging, groundwater pump-and-treat, water injection, soil vapor extraction, and steam injection. These are the first such programs known to be available within the environmental industry.

Figures 3, 4, 5, 6, 7 and 8 summarize the best well design for this project as determined using the Sparger® computer program. From these figures and the data used to generate them, the following comments can be offered:

- Based on a specified screen length of 230' in each of the two wells, the best screen design is as follows:
  - ◊ Wells fabricated using 4" diameter SDR-11 HDPE.
  - ◊ Screen inside well percent open area = 0.344%.
  - ◊ For 4" diameter SDR-11 HDPE, the inside diameter is 3.633". Hence the total inside circumference is 11.41 sq. in. and the required inside well open space is 0.4712 sq. in. per foot of screen.
  - ◊ Only 1 slot zone is required to achieve uniformity of air sparging down the length of the screened interval.
- A pressure of 6 psig <u>at the well header</u> will produce a pressure of 5.9735 psig at the proximal end of the screen (first slot) and 5.9701 psig on the distal end (last slot) of the screen.
- Equipment must be designed to deliver 6 psig at the well header.
  - ◊ The general industry practice of "over-sizing" blowers will result in different slot requirements to produce uniformity of air flow and frequent shut-downs of blower equipment due to "over-capacity" within the well.
  - ◊ A blower, rather than a compressor, will perform in this application.

- ◊ The blower must be sized to reflect pressure drops due to heat exchanger, elbows, instruments, etc.
- ◊ Provision must be made for straight runs of HDPE post-heat exchanger to accommodate flow measurement device requirements for installation.
- ◊ The heat exchanger must protect HDPE (140 deg. F. melting point).
- ◊ An acoustical enclosure around the blower and/or acoustical housing must be included in the equipment specification so as to protect neighboring facilities and personnel.
- ◊ The equipment must be designed to allow proper start-up of the systems.

- Horizontal wells are normally grouted and cemented at their ends consistent with vertical well practices.
- The step-back distance on each end of the horizontal wells shown in Figures 1 and 2 are expected to be approximately 93'. A value of 100' was used in these modeling efforts to reflect additional well length above-ground between the well exit and the blower compound.

Flow Requirements

STAR defines air sparge wells to operate at 1 SCFM per foot of screen and biosparge wells to operate at 0.5 SCFM per foot of screen. The intent of air sparge wells is to physically volatilize contaminants; the intent of biosparge wells is to introduce oxygen for *in situ* bioremediation. Commonly, regulatory agencies require that a soil vapor extraction system be used with air sparge wells to capture, contain, and treat physically evolved vapors. Contrarily, regulators have not required the use of SVE systems when the goal is *in situ* bioremediation. At 0.5 SCFM, each of the two wells planned for this project must be operated at a total of 115 SCFM (i.e., 1/2 of the total screen length of 230' each).

It should be noted that it is possible to design air sparge and biosparge wells with lower volumetric flow rates from those specified above. Such wells are easier to design but generally do not produce the minimum volumetric air flow required to achieve reasonable distances-of-influence. Hence, the use of lower flow rates is not suggested.

Table 1

Design Parameters and Constraints for Navy Wells

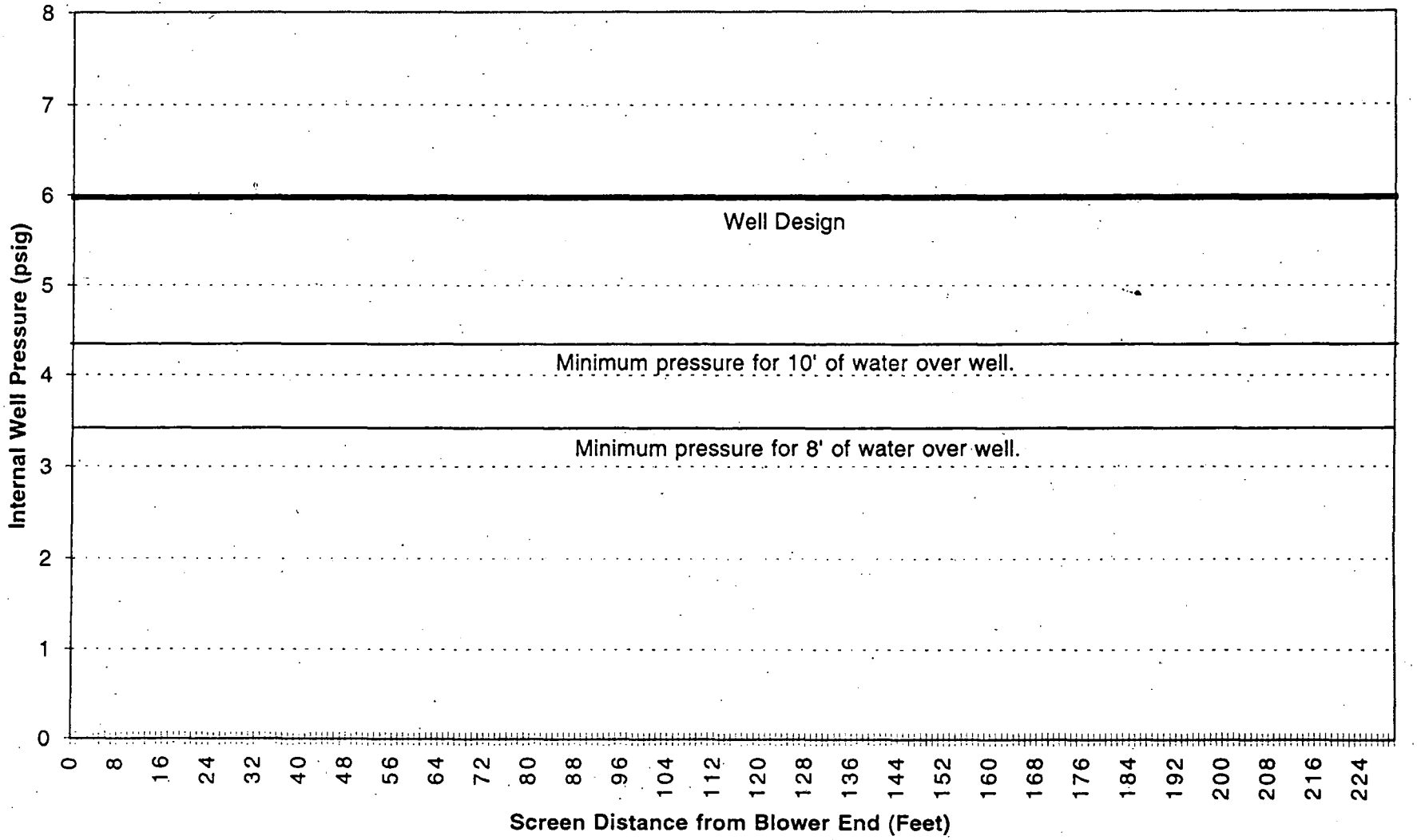
Design Parameter	Specified Value
Total Well Length	430 feet (approximate)
Screened Interval Length	230 feet
Well Material	SDR-11, HDPE
Well Size	3.633" I.D./4.500" O.D.
Well Header Length	100 feet
Target Flow Rate	115 SCFM
Stratigraphy	Homogeneous Sand
Air Permeability	120 Darcy
Ambient Air Temperature	90 deg. F
Well Depth Below Grade	10 feet (uniform)
Height of Water Above Well	8 feet (nominal)
Air Distribution Target	Uniformity of Discharge (± 10% Average Flow Maximum)

Inside pipe area for 1' pipe segment = 136.96 sq. in.

Figure 3

TolTest Navy Project

Internal Well Pressure



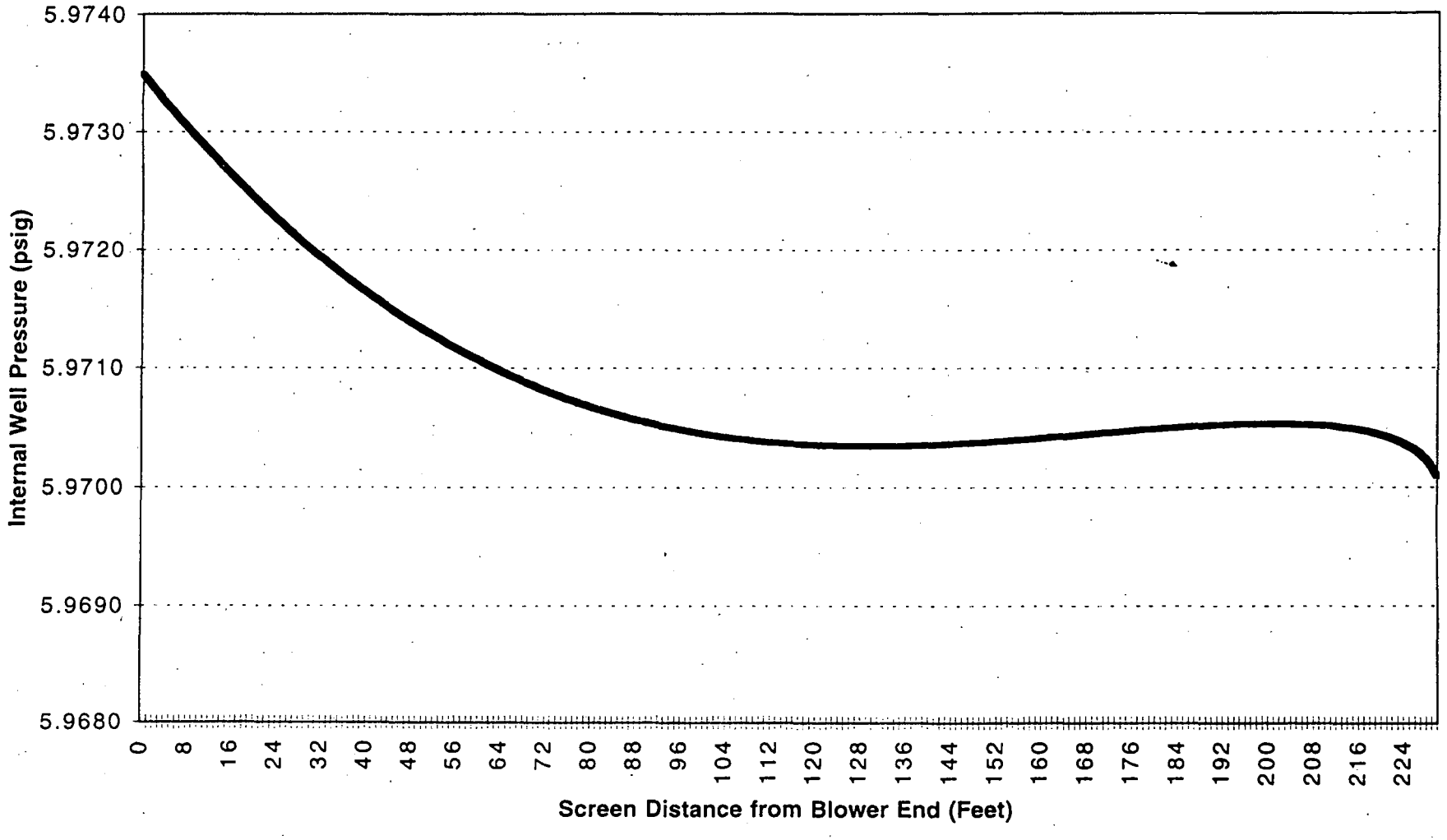
(c) STAR Environmental, Inc., 2000. Graph prepared using SpargerTM computer modeling program.

4" x 230' screen at 115 scfm.

Figure 4

TolTest Navy Project

Internal Well Pressure (Narrow Range)



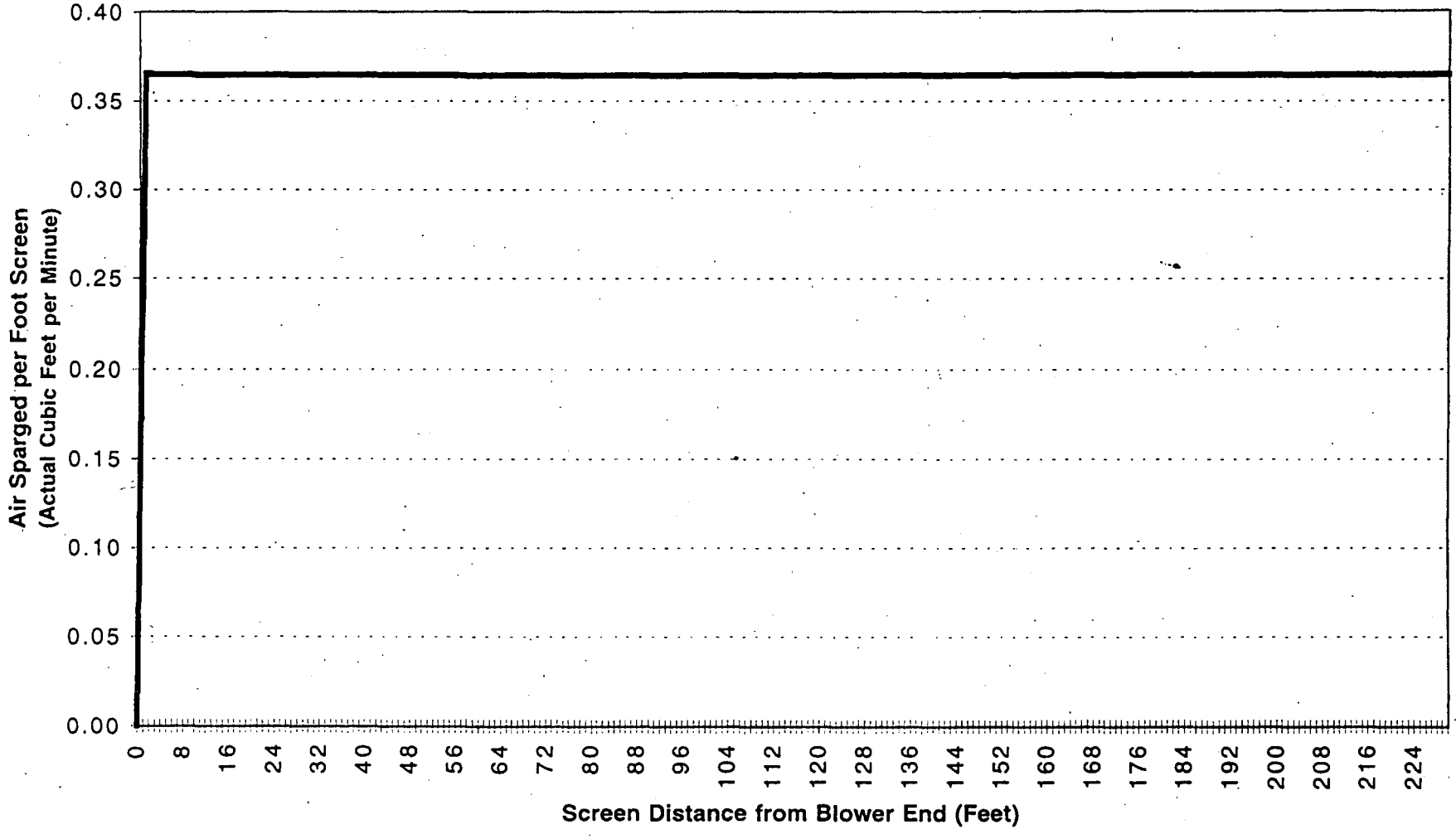
(c) STAR Environmental, Inc., 2000. Graph prepared using SpargerTM computer modeling program.

4" x 230' screen at 115 scfm.

Figure 5

TolTest Navy Project

Air Sparged per Foot Screen (ACFM)



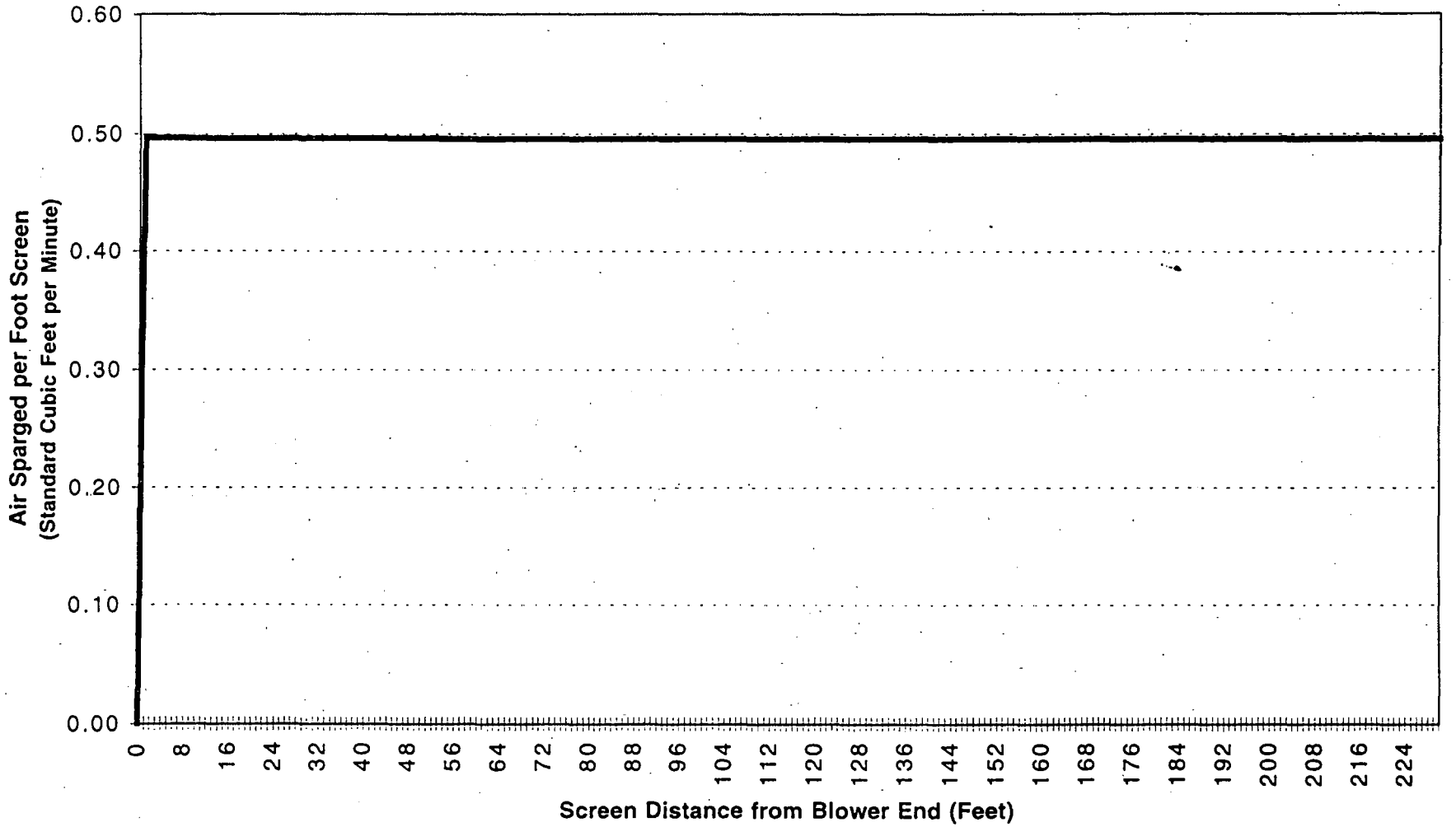
(c) STAR Environmental, Inc., 2000. Graphed with SpargerTM computer modeling program.

4" x 230 screen at 115 scfm.

Figure 6

TolTest Navy Project

Air Sparged per Foot Screen (SCFM)



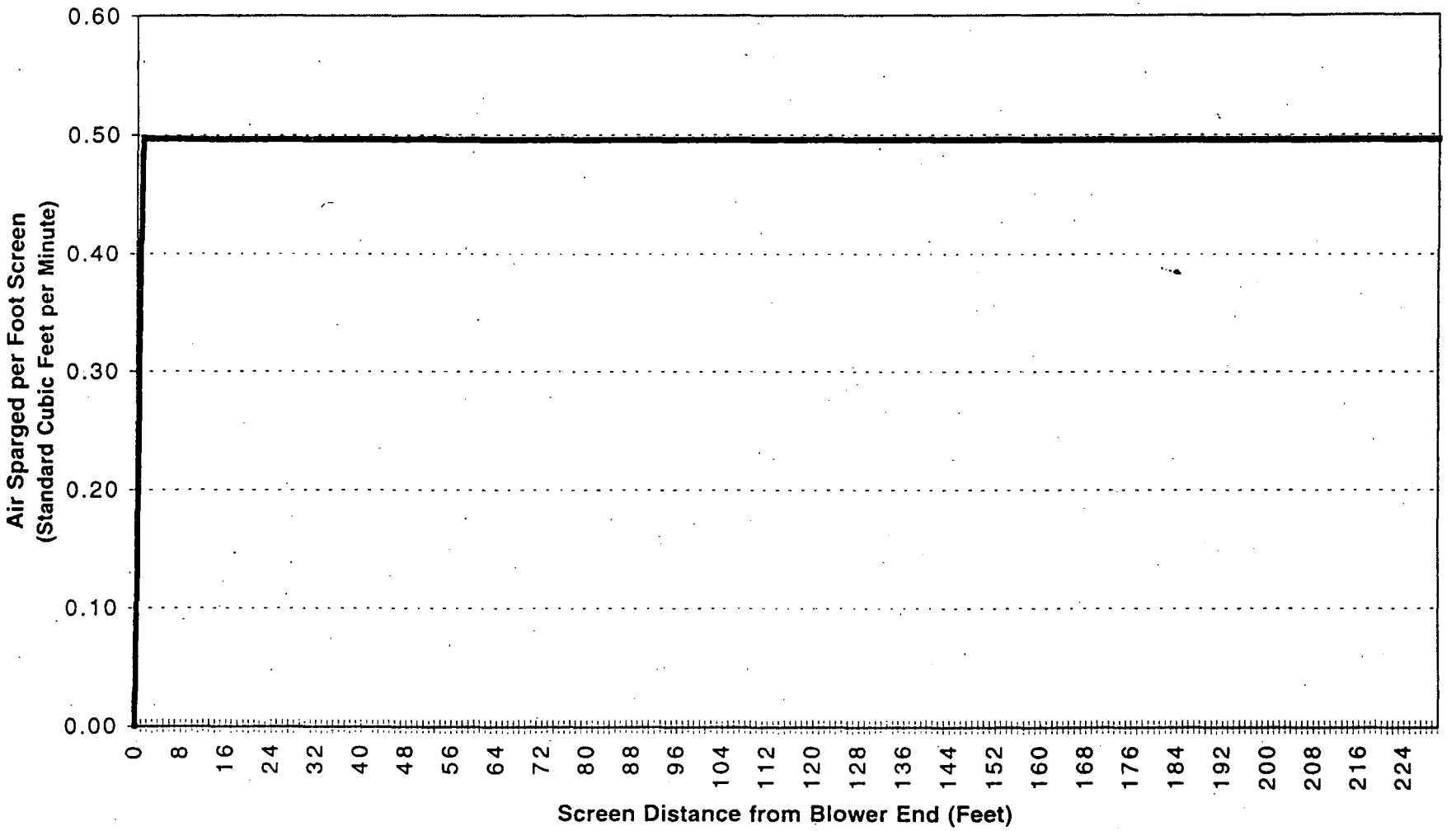
(c) STAR Environmental, Inc., 2000. Graphed with SpargerTM computer modeling program.

4" x 230' screen at 115 scfm.

Figure 6

TolTest Navy Project

Air Sparged per Foot Screen (SCFM)



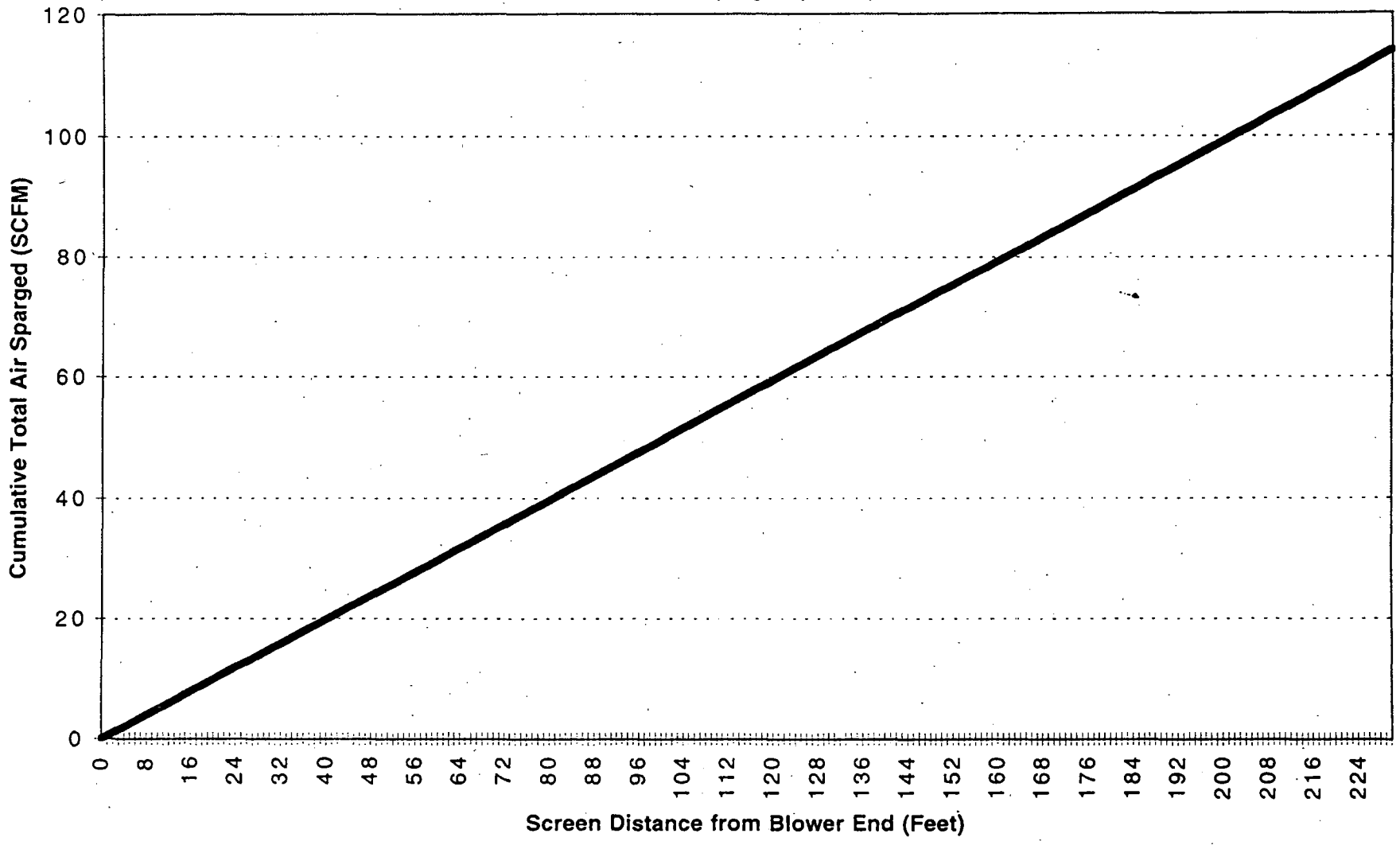
(c) STAR Environmental, Inc., 2000. Graphed with SpargerTM computer modeling program.

4" x 230' screen at 115 scfm.

Figure 7

TolTest Navy Project

Cumulative Air Sparged (SCFM)



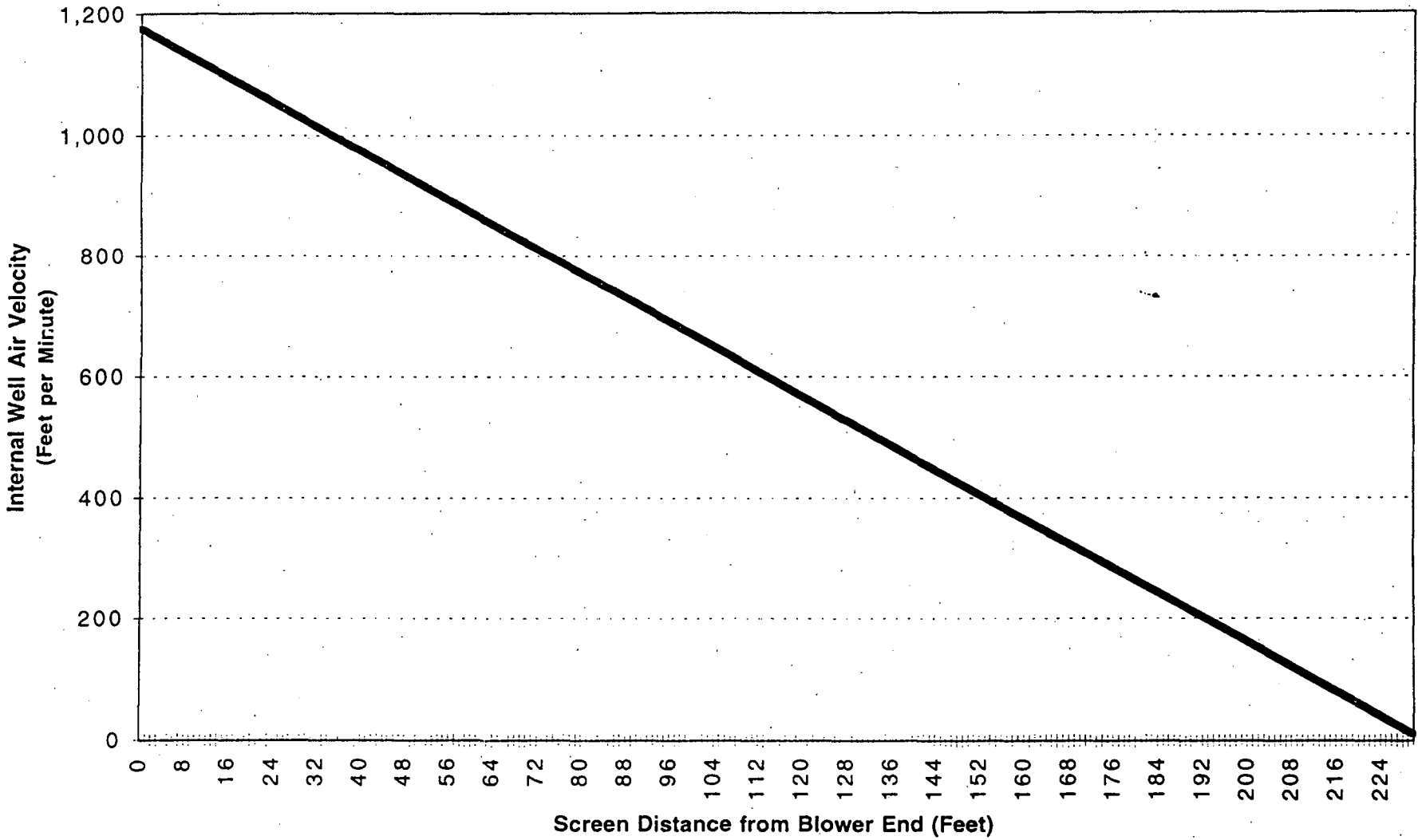
(c) STAR Environmental, Inc., 2000. Graphed with SpargerTM computer modeling program.

4" x 230' screen at 115 scfm.

Figure 8

TolTest Navy Project

Internal Well Air Velocity (FPM)



(c) STAR Environmental, Inc., 2000. Graphed with SpargerTM computer modeling program.

4" x 230' screen at 115 scfm.

Uniformity of Air Flow from Wells

STAR defines the uniformity of air flow from wells in terms of "% Skew" or "% Linearity":

- *Skew* is defined to be the difference between the volumetric air flow at the first slot and the last slot divided by the value at the first slot. *Percent Skew* is this value times 100.
- *Linearity* is defined as 100 minus *Skew*. *Percent Linearity* is this value times 100.

For the present wells, the results from the Sparger® computer program give the flow at the first slot as 0.4964 SCFM and at the last slot as 0.4955 SCFM. The difference between these is 0.0009 SCFM. Thus the % Skew for these wells is 0.18%. Conversely, the linearity of flow down the well screen (under the conditions specified) is 99.8%. This is reflected in Figures 3 - 6.

Screen Alternatives

4"-diameter, SDR-11, HDPE well materials can be slotted with either circumferencial slotting (the slotting arrangement most often used with vertical wells) or longitudinal slotting. The latter is about 20% more expensive than the former but offers greater tensile strength during pull-back. On the other hand, conventionally-slotted (i.e., circumferentially-slotted) well materials have had ample pull-back strength for most applications and would be expected to perform well in this particular project. Table 2 provides the required slotting dimensions for each of these alternatives.

The decrease of pull-back strength with slotting is directly proportional to the amount of circular area removed during slotting. Since a greater amount is removed from the outside perimeter than the inside of the pipe with circumferencial slotting, it is a fairly complicated calculation to determine the exact reduction in pull-back strength. A common practice is to approximate this reduction based on the average of the outside diameter and the inside diameter. This average diameter is multiplied by pi to obtain an average circumference for the pipe being used. For SDR-11 HDPE, the average of the outside diameter (4.50") and the inside diameter (3.633") is 4.0665". Thus, the "average"

Uniformity of Air Flow from Wells

STAR defines the uniformity of air flow from wells in terms of "% Skew" or "% Linearity":

- *Skew* is defined to be the difference between the volumetric air flow at the first slot and the last slot divided by the value at the first slot. *Percent Skew* is this value times 100.
- *Linearity* is defined as 100 minus *Skew*. *Percent Linearity* is this value times 100.

For the present wells, the results from the Sparger® computer program give the flow at the first slot as 0.4964 SCFM and at the last slot as 0.4955 SCFM. The difference between these is 0.0009 SCFM. Thus the % Skew for these wells is 0.18%. Conversely, the linearity of flow down the well screen (under the conditions specified) is 99.8%. This is reflected in Figures 3 - 6.

Screen Alternatives

4"-diameter, SDR-11, HDPE well materials can be slotted with either circumferencial slotting (the slotting arrangement most often used with vertical wells) or longitudinal slotting. The latter is about 20% more expensive than the former but offers greater tensile strength during pull-back. On the other hand, conventionally-slotted (i.e., circumferentially-slotted) well materials have had ample pull-back strength for most applications and would be expected to perform well in this particular project. Table 2 provides the required slotting dimensions for each of these alternatives.

The decrease of pull-back strength with slotting is directly proportional to the amount of circular area removed during slotting. Since a greater amount is removed from the outside perimeter than the inside of the pipe with circumferencial slotting, it is a fairly complicated calculation to determine the exact reduction in pull-back strength. A common practice is to approximate this reduction based on the average of the outside diameter and the inside diameter. This average diameter is multiplied by pi to obtain an average circumference for the pipe being used. For SDR-11 HDPE, the average of the outside diameter (4.50") and the inside diameter (3.633") is 4.0665". Thus, the "average"

circumference of this well material is 12.775 inches. This "average" diameter is often used in pull-back strength reduction calculations.

An alternative method of calculating pull-back strength reduction is to base the calculation on the inside diameter and inside circumference of the well rather than an average diameter and circumference. An inside diameter of 3.633" gives an inside-well circumference of 11.413396".

Figure 9 illustrates circumferencial slotting using HDPE and a circular saw blade. Figure 10 illustrates longitudinal slotting using HDPE and a circular saw blade.

While mathematical computations will show that longitudinally-slotted wells will have greater tensile or pull-back strength than conventionally-slotted wells, this increase and the increased cost of procuring longitudinally slotted wells are not warranted for the wells for the present project. Conventionally-slotted wells up to about 1000' long and less than about 25' below grade have ample pull-back strength.

Table 2

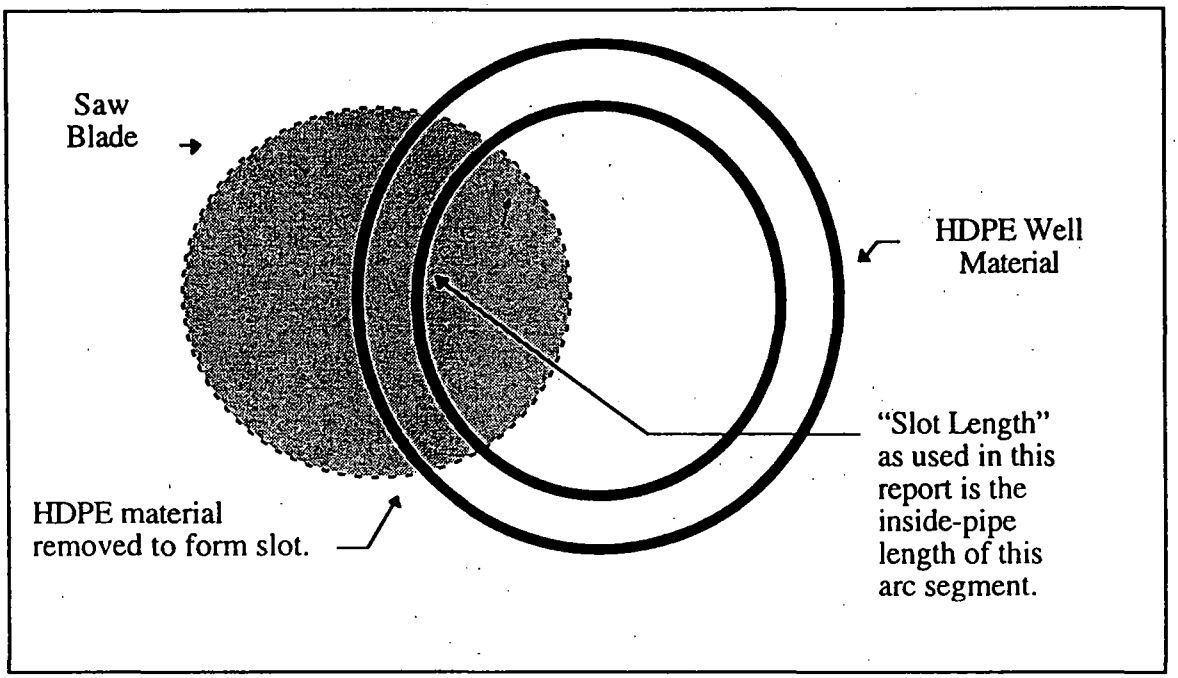
Navy Well Slot Designs

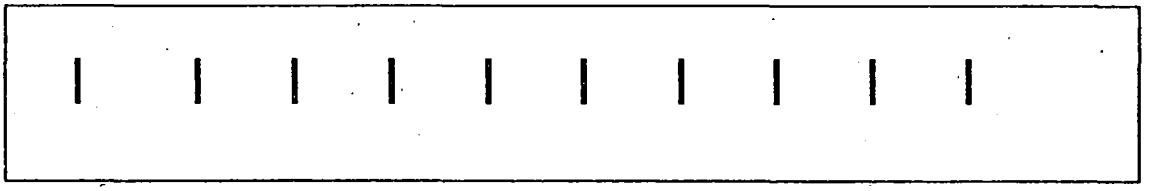
Design Parameter	Circumferencial Slots	Longitudinal Slots
Zone Length	0 to 230 feet	0 to 230 feet
Slot Width	0.020"	0.020"
Slot I.D. Length	1.178"	1.4725"
Number of rows	2	8
Number of slots/row-foot	10	2
ID Open Area/ft. screen	0.4712 sq. in.	0.4712 sq. in.
Percent Open Area	0.344	0.344

Inside-Pipe Nominal Slot Lengths = 1 3/16-inch for Circumferencial Slots and 1 15/32-inch for Longitudinal Slots.

Figure 9

Circumferencial Slotting

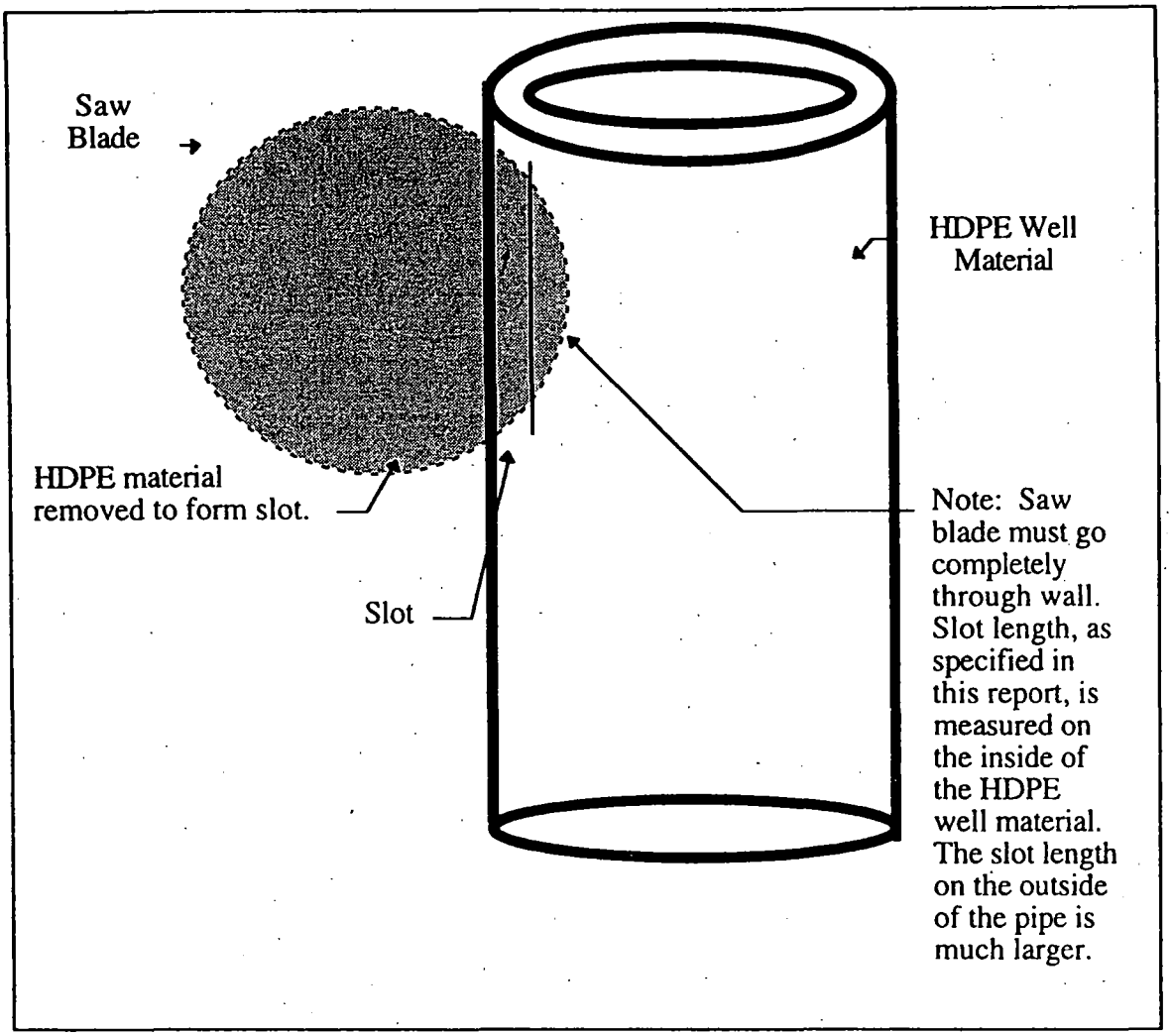


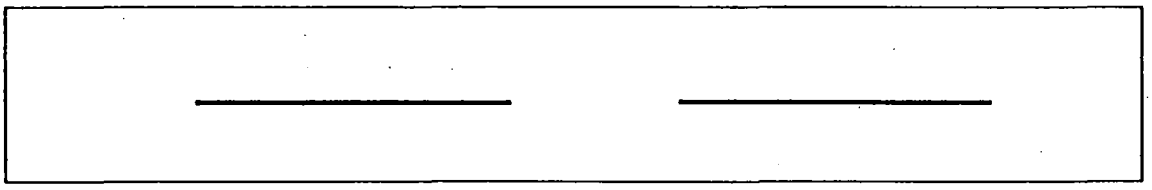


1 foot segment of well material. Single row of *circumferencial* slots illustrated. 10 slots per row shown.

Figure 10

Longitudinal Slotting





1 foot segment of well material showing a single row of two *longitudinal* slots.

CONCLUSION

As a result of the present effort, it was determined that the desired well material (nominal SDR-11 HDPE) could be acceptably utilized for the well and header. This conclusion is based upon the fluid dynamics consideration of the material (at the site specified) being capable of delivering the specified compressed air (in total and incrementally per foot of screen) without excessive pressure loss. The conclusion, however, does not encompass whether the material can be inserted into the subsurface during pull-back to meet the required radii-of-curvature needed to place the well where desired and at depth.

It was additionally determined that the best well performance would be realized by using a single propagation of well slots (defined as "zone") over the screened interval's full length. This single zone screen design is applied over the screen distance from 0 feet to 230 feet. The single screen design will achieve acceptably uniform sparge air flow over the entire length of the screen. Internal pressure degradation and increasingly-lesser flow discharge with distance will result with any slot design employed. With the slot pattern specified, this change is minimal for these well materials and for the present project.

Circumferencial slotting is recommended for the wells for this project. The required inside-well percent open area is 0.344 for 4" diameter SDR-11 HDPE piping. This is equivalent to 0.4712 sq. in. open area per foot of well material (as measured on the inside of the well). Table 2 provides one possible design. The final design must be determined after consultation with the slotter.

APPENDIX B

Groundwater Treatment System Drawing Package

TOLTEST, INC.