DRAFT Phase III Remedial Action Plan
RTN 4-3024222
Former Bird Machine Company Site
Walpole, MA

Submitted to:

Baker Hughes Incorporated
Houston, TX

Submitted by:

AMEC Earth & Environmental, Inc.
Westford, Massachusetts

October 2011

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

LIST OF ACRONYMS

AMEC	AMEC Earth & Environmental, Inc.
AFCEE	Air Force Center for Engineering and the Environment
AUL	Activity and Use Limitation
bgs	below ground surface
BHI	Baker Hughes Inc.
BMC	Bird Machine Company
BWSC	Bureau of Waste Site Cleanup
bwt	below water table
CAM	Compendium of Analytical Methods
CMR	Code of Massachusetts Regulations
COC	Contaminants of Concern
CSA	Comprehensive Site Assessment
CSM	Conceptual Site Model
CY	cubic yard
dioxin	chlorinated dioxins and furans
DDA	Demolition Debris Area
EPC	Exposure Point Concentration
EPH	Extractable Petroleum Hydrocarbons
ft	feet
IRA	Immediate Response Action
ISI	Phase I Initial Site Investigation Report
K	hydraulic conductivity
LRA	Lead Release Area
LSP	Licensed Site Professional
MCP	Massachusetts Contingency Plan
MMCL	Massachusetts Maximum Contaminant Level for drinking water
mg/kg	milligrams per kilogram
NAPL	Non-aqueous phase liquid
ND	Not Detected by laboratory analysis
PAH	Polycyclic Aromatic Hydrocarbon
PCB	Polychlorinated Biphenyls
ppb	parts per billion (for groundwater, micrograms per liter)
RAM	Release Abatement Measure
RC	Reportable Concentration
RTN	Release Tracking Number
SRT	Sustainable Remediation Tool™ (AFCEE 2010)
SVOC	semivolatile organic compound
TCLP	Toxicity Characteristic Leaching Procedure
TEQ	toxic equivalent
UCL	upper concentration limit
USGS	U.S. Geological Survey
VOC	volatile organic compounds
VPH	volatile petroleum hydrocarbons
Weston	Weston Solutions, Inc.

EXECUTIVE SUMMARY

On behalf of Baker Hughes, Inc. (BHI), AMEC Earth and Environmental, Inc. (AMEC) completed this Phase III Remedial Action Plan (RAP) of the former Bird Machine Company (BMC) Site located in Walpole, Massachusetts. BHI is submitting this RAP pursuant to 310 CMR 40.0850 of the Massachusetts Contingency Plan (MCP). This RAP documents selection of a Remedial Action Alternative (RAA) which is a likely Permanent Solution for the Site, and evaluates the feasibility of achieving or approaching background levels of oil or hazardous material. A Permanent Solution will achieve a condition of No Significant Risk (NSR) for current and reasonably forseeable site uses.

The Site includes multiple RTNs due to the discovery of various releases at the property over a period of several years. Three separate exposure areas were identified and evaluated in the Draft Phase II Comprehensive Site Assessment (CSA) Report (AMEC 2011). Release Abatement Measures (RAMs) were conducted at several locations to reduce the mass and concentrations of contaminants at the Site. The CSA indicates that a condition of NSR exists for all areas of the Site except groundwater, where some monitoring well concentrations exceed drinking water criteria (Massachusetts Maximum Contaminant Levels or MMCLs). It is unlikely that groundwater at the Site will be used for drinking water, but the Site is within a Potential Drinking Water Source Area designated by the Town of Walpole (Walpole 2007). Considering this designation, groundwater at the Site is categorized as GW-1 under the MCP. Background information and remedial action objectives for the Site are summarized in Section 1 of this RAP.

Areas of groundwater contamination exceeding MMCLs have been identified for arsenic, chlorinated Volatile Organic Compounds (cVOCs), and 1,4-dichlorobenzene (DCB). Response actions and technologies to remove these contaminants have been evaluated and three RAAs have been identified that are reasonably likely to be feasible Permanent Solutions for the Site. These three RAAs are (1) Monitored Natural Attenuation (MNA) for all contaminants; (2) In-Situ Chemical Oxidation (ISCO) for organic contaminants and MNA for arsenic; and (3) Pump & Treat for organic contaminants and MNA for arsenic. A conceptual design of each alternative is provided in Section 2 of this RAP, including key components, a conceptual layout, treatment residuals or wastes requiring disposal, permit requirements, and a discussion of limitations, assumptions, and uncertainties.

A detailed evaluation of the three RAAs using eight criteria established under the MCP is provided in Section 3 of this RAP. The alternatives are compared and ranked based on estimates of their effectiveness, reliability, implementability, costs, risks, benefits, timeliness, and other impacts. Alternative 1 (MNA) received the highest rankings as indicated in Section 4, and has been selected for implementation in Phase IV. Alternative 1 is expected to provide a Permanent Solution that achieves a condition of NSR. MNA has already produced significant reductions in arsenic and cVOC concentrations at individual wells over the past four years of groundwater monitoring. Alternative 1 appears capable of achieving or approaching background for cVOCs -- which are expected to require the greatest reductions in groundwater concentrations – and for the other contaminants.

A schedule for activities leading up to and including Phase IV is provided in Section 5. Following public comment and a meeting to discuss this RAP, this document will be finalized, and design of the groundwater remedy will be initiated. Completion of construction is expected by June 2012, at which time operation of the remedy in Phase V will be initiated. The estimated timeframe for achieving a condition of NSR is 5-10 years from the start of operations.

1.0 SITE BACKGROUND AND REMEDIAL ACTION OBJECTIVES [310 CMR 40.0852 – 53]

AMEC completed this Phase III RAP of the former BMC Site located in Walpole, Massachusetts on behalf of BHI. This document is submitted pursuant to 310 CMR 40.0850 of the MCP. This RAP describes selection of a Remedial Action Alternative (RAA) which is a likely Permanent Solution for the Site, and evaluates the feasibility of achieving or approaching background levels of oil or hazardous material. The Site location is indicated in Figure 1, and following is general information pertaining to the MCP status.

Release Tracking Number (RTN):	RTN 4-3024222
Tier Classification:	Tier IB
Site Address:	100 Neponset Street Walpole, Massachusetts 02071-1037
Person Undertaking Response Actions:	Baker Process Inc. 2929 Allen Pkwy Ste 2100 Houston TX 77019-7111 Contact: Mr. Chris Clodfelter Phone: 713-439-8329
Licensed Site Professional:	Kim M. Henry, LSP (License # 7122) AMEC Earth & Environmental 2 Robbins Road Westford, Massachusetts 01886 Phone: 978-692-9090

A Tier 1B Permit Application was submitted to the Massachusetts Department of Environmental Protection (MassDEP) on 1/10/08, including a revised Tier Classification and updated Phase I information combining several linked sites under the subject RTN. Tier 1B permit #W204776 for this RTN was effective on 2/28/08. BHI submitted Notifications of Delay to MassDEP on 2/9/10 and 7/9/11 which described evaluations underway and a proposed schedule for completing the Phase II and Phase III reports. The Draft Phase II CSA Report was submitted to MassDEP and the public information repository on 7/15/11 (AMEC 2011).

This RAP is organized as follows:

- Section 1 – Site Background and Remedial Action Objectives
- Section 2 – Identification of Remedial Action Alternatives
- Section 3 – Detailed Evaluation of Remedial Action Alternatives
- Section 4 – Selection of a Remedial Action Alternative & Feasibility Evaluation
- Section 5 – Schedule for Phase IV
- Section 6 – Public Notification
- Section 7 – References

The following portions of Section 1 describe the Site and its release history, the investigations and response actions to date, risk assessment results, and remedial action objectives.

1.1 Disposal Site Description

The Site, defined in the MCP as the area where the release "has come to be located," is in the central portion of the 108-acre Property. The approximate universal transverse mercator coordinates for the Site are 4,664,600 North and 312,700 East (World Geodetic System 1984/North American Datum 1983), based on the United States Geological Survey (USGS) Franklin Quadrangle Map, 1987. The Site Location Map, Figure 1, shows the regional location of the Site. Access to the property and Site is obtained via Neponset Street as indicated in Figure 2. The Neponset River flows around the Site from the south to the northeast. Ruckaduck Pond is located to the west and was formerly used for water power, with dams maintaining an elevation several feet above the downstream river. An outlet from Ruckaduck Pond traverses the Site through an underground pipe, returning to the river on the east side (Outfall 2 on Figure 2). A number of storm drains on the Site also outlet to the Neponset River as shown on Figure 2.

As documented in the Phase II CSA, historical maps [including Sanborn Library, LLC Fire Insurance (Sanborn) Maps] were reviewed to determine the previous owner/operators of the property and the operations history. The Property appears to have been developed by 1832 with a "shingle mill" and two houses south of the Site, and a small pond in the present location of Ruckaduck Pond. A map dated 1852 indicates "Smith's Mill" and three houses in the same area. A map dated 1888 indicates the Walpole Emery Mill in the same area, and Old Colony Railroad in its present location along the western edge of the Site. Sanborn maps from 1918 indicate that a railroad spur and three "factory" buildings had been constructed, and an open channel or “tailrace” had been constructed downstream of one of the factory buildings to convey water used for powering machinery back to the Neponset River. The BMC reportedly started operations at the property in 1919.

The 1927 and 1944 Sanborn Fire Insurance Maps indicate larger industrial buildings at the property, including a machine shop, casting shed, lumber shed, assembling, welding shop, and office. A 1940 USGS Topographic Map contains more detailed topography in the vicinity of the Site, indicates the boundary of the Cedar Swamp, and shows Cedar Swamp Brook. Historical aerial photographs and facility plans from 1931 to 1978 indicate that the Neponset River was rerouted at different times to facilitate the expansion of buildings and the addition of new ones. The open tailrace channel was filled in and replaced with a buried 24-inch concrete pipe in 1966. The industrial buildings on the Property were expanded several times in the 1960s and 1970s.

BMC primarily manufactured and repaired industrial centrifuges on the Property. BHI acquired BMC in 1989. BMC became an operating unit within Baker Process, Inc., a wholly-owned subsidiary of Baker Hughes Incorporated. Baker Hughes Process Systems, Inc. is the present owner of the Property. Manufacturing operations at the Property were discontinued in 2004, and most buildings associated with the former BMC were demolished by 2008. There is typically one worker at the Property, a security guard. Current human receptors at the Site are limited to occasional trespassers. The Property is zoned Limited Manufacturing, which allows a wide range of commercial, institutional, and residential uses. The Property is also grandfathered for industrial use.

The area surrounding the property has a mixture of residential and recreational (undeveloped forests and wetlands) uses. There are 273 residences with an estimated 743 residents located within ½-mile of the Site (Weston, 2005). There are presently no inhabited houses or private water supply wells within 500 ft of the Site. There are no schools, daycare centers, playgrounds, or parks within 500 ft of the Site. The 1987 USGS Franklin quadrangle map depicts the Boyden School located approximately 0.35 mile southeast of the Property, and 0.5 miles southeast of the Site. The nearest public water supply wells are slightly over 1 mile northeast of the Site.

1.2 Release History and Response Actions

The Site includes multiple RTNs due to the discovery of various releases at the property during recent investigations. Timing of releases is not well known, and the Site was used for manufacturing from at least 1832 to 2004. The RTNs were linked together to facilitate administrative compliance with MCP requirements, and three separate exposure areas were identified and evaluated in the Phase II CSA Report (AMEC 2011). These three portions of the Site are the Manufacturing Building Area (MBA), the Lead Release Area 3 (LRA3), and the South Rail Spur (SRS), as indicated in Figure 2. Release Abatement Measures (RAMs) were conducted at several locations within MBA and LRA3 to reduce the mass and concentrations of contaminants at the Site. The CSA indicates that a condition of No Significant Risk (NSR) exists for all areas of the Site except groundwater within the MBA, where some monitoring well concentrations exceed drinking water criteria.

The remaining contamination at MBA includes metals (primarily antimony, barium, lead, nickel, and zinc) and EPH carbon range compounds in soil. The concentrations of metals and SVOCs have been reduced significantly by soil excavation RAMs. The remaining elevated concentrations in soil are under and around the former locations of manufacturing buildings. Groundwater sampling indicates elevated concentrations of arsenic and chlorinated Volatile Organic Compounds (cVOCs) in the area adjoining the river downgradient of the manufacturing buildings, petroleum hydrocarbons in a single well beneath the former buildings, and chlorobenzenes in a single well in the North Parking area. Concentrations in these areas exceed drinking water criteria. It is unlikely that groundwater at the Site will be used for drinking water, but the Site is within a Potential Drinking Water Source Area designated by the Town of Walpole (Walpole 2007). Considering this designation, groundwater at the Site is categorized as GW-1 under the MCP.

1.3 Hydrogeological Characteristics

The southeastern portion of the Site includes extensive sand and gravel fill, at depths of up to eight feet where the Neponset River was rerouted. The water table beneath the Site occurs approximately 3 to 5 feet (ft) below ground surface (bgs) in either fill or sand. Depth to bedrock is about 26 ft bgs near the eastern edge of the MBA and shallower to the west. The direction of groundwater flow in the shallow aquifer above bedrock is generally east toward the Neponset River or its associated wetlands. The water table in the areas adjacent to the River is less than 1 foot bgs. The horizontal direction of groundwater flow is toward the River from both sides. The vertical direction of flow is upward, discharging to the River, where measurements were available on the west riverbank. Vertical flow in the vicinity of Ruckaduck Pond is expected to be downward since the dam impounds surface water at an elevation above the water table.

Lateral groundwater seepage velocities in the sandy soils are estimated to be 0.1 – 0.9 feet per day in the MBA.

There appears to be considerable variation in groundwater flow direction depending on water table conditions in specific areas of the MBA. Groundwater elevations have been mapped for monitoring events in October 2006, July 2008, and April 2009, as shown in Figures 3-5. The October 26, 2006 event occurred when river flow was near the median long-term daily statistic, based on USGS hydrographs for the Neponset River discharge at the Norwood gauging station (the closest gauge to the Site). Therefore, Figure 3 likely represents typical fall seasonal conditions which are intermediate between summer and spring. The July 22-23, 2008 measurement occurred after several months of below-average river flow and immediately prior to a storm event, therefore the water table depicted in Figure 4 likely represents relatively dry low-flow conditions which may be expected during summer months. The April 15, 2009 event occurred after several months of near-average spring flows, therefore Figure 5 likely represents typical spring high-flow conditions. Note the significant changes in the water table surface between the three events, particularly in the southeast portion of the Site. Aside from precipitation and river flow, another difference between the events is that in 2006 the MBA buildings and pavement were still intact; in 2007 the buildings were demolished and some pavement removed resulting in the present Site conditions. Removal of the impervious structures may have affected infiltration patterns.

1.4 Contaminant Extent and Transport

The Neponset River appears to be a groundwater discharge area based on measured horizontal and vertical gradients around the Site, as indicated above. Groundwater contaminants from MBA have not been identified in monitoring wells east of the river. Sediment and surface water concentrations in the river suggest that the contaminant discharge from groundwater to the river has not resulted in increasing concentrations of contaminants in the river. A CSA completed for the river where it borders the Site found a condition of No Significant Risk for river receptors (Weston 2007).

The estimated areas of groundwater contamination exceeding MMCLs or background concentrations are indicated in Figure 6, and are discussed by contaminant in the subsections below. Each discussion considers the likely sources, concentration trends, and background levels if any. Figure 6 shows the estimated current extent of contamination, while older contamination that may no longer exist is discussed in the text.

The areas in Figure 6 include specific wells where Exposure Point Concentrations (EPCs) exceed the groundwater criteria. The EPCs are average concentrations over a period of one or more years, as indicated in the data tables provided for each analyte. The most recent data were used to calculate each EPC, while older data not included in the calculation are shown in the tables in italics. Non-detect (ND) results are shown in the tables in bold text at a concentration that is one-half the reporting limit.

USGS hydrographs for the Neponset River discharge at the Norwood gauging station (the closest gauge to the Site) are provided in Figure 7 for periods including groundwater sampling events during 2008 – 2011. Groundwater sampling occurred on 5/28/08, 7/22/08, 4/15/09, 12/7/09, 7/28/10, and 3/17/11. Note that several of these events have occurred at times of lower than normal river flow, such as May and July 2008, and July 2010. Sampling during low-flow periods may bias the groundwater results in several ways; for example due to changes in the depths of fill or aquifer materials exposed to groundwater, or less infiltration and groundwater flow through the Site. Potential impacts of these low-flow periods on the areas of contamination are discussed below.

1.4.1 Arsenic

Arsenic groundwater data, calculated EPCs, and the status of the monitoring wells where arsenic has exceeded background or the MMCL of 10 ppb are indicated in Table 1. The wells where arsenic exceeded the MMCL are all water table wells. Background levels of arsenic in groundwater appear to be in the range of 1-9 ppb considering detections in upgradient well MB-MW-368 (8.6 ppb) and wells MB-MW-360 (3.9 ppb) and -361 (0.8 ppb) located east of the Neponset River. For the purpose of Presumptive Certainty in achieving or approaching background, in accordance with MassDEP Policy WSC-04-160, it is assumed that the background level of arsenic is approached at a level of 5 ppb which is one-half of the GW-1 standard.

Arsenic concentrations in well LR-MW-122 decreased from 16 to 9.2 ppb in four sampling events between May 2008 and March 2011, excluding one anomalous result (75 ppb) from July 2010. LR-MW-122 is about 250 ft downgradient from the former Laboratory Building and a former fuel oil UST location (A09) that was excavated in 2008 during a RAM. Arsenic was not detected above background in the single soil sample from this excavation. Using a lateral seepage velocity of about 0.3 ft/day the estimated groundwater travel time between the RAM area and LR-MW-122 would be about two years, such that groundwater migrating from the RAM area around the time of excavation would have been expected to reach this well in early 2010. Therefore, it is possible that the anomalous arsenic detection in LR-MW-122 in July 2010 is related to soil disturbance that occurred during the 2008 RAM activity. It seems less likely the July 2010 result is related to the low river flow of that time, since similar low-flow conditions occurred in May 2008 but were not accompanied by an elevated arsenic concentration. Arsenic has not been detected in the adjacent deep well LR-MW-121. The extent of arsenic above the MMCL is estimated to extend upgradient to the vicinity of the former Laboratory Building as shown in Figure 6.

Table 1. Arsenic Exposure Point Concentrations in Groundwater (µg/L or ppb)

Well No.	Date	Result	EPC	Comment / Well Status
LR-MW-122	03/16/11	9.2	28.3	Existing Shallow Well adjacent to Neponset River; adjacent deep well LR-MW-121 has no arsenic detected
	07/26/10	75.4		
	12/07/09	12.4		
	04/15/09	16.1		
	05/28/08	*16.0*		
	06/06/07	*7.3*		
MB-GP-002	05/18/05	16.1	16.1	Shallow Well & Soil Removed in 2007 RAM
MB-MW-301	06/05/07	9.9	10.2	Shallow Well & Soil Removed in 2007 RAM
	08/15/06	8.6		
	06/23/06	12.0		
MB-MW-305	06/05/07	28.0	39.3	Shallow Well & Soil Removed in 2007 RAM
	08/15/06	51.0		
	06/23/06	39.0		

Results < GW-1 are shaded; data not used to calculate the EPC are in italics

A source of arsenic in the vicinity of Buildings 6 and 6A (MB-MW-301 and -305, and MB-GP-002) appears to have been eliminated by a soil excavation RAM conducted in December 2007, and arsenic above the MMCL no longer appears in this area. Monitoring well MB-MW-305 in this area had the highest levels of arsenic (39 – 51 ppb) in 2006, decreasing slightly before the RAM excavation in 2007. Arsenic soil concentrations were above background in the pre-excavation soil samples. MB-MW-301 was removed during the 2007 RAM activity, and the replacement well MB-MW-367 had an arsenic concentration of 6.4 ppb in July 2008 and ND in March 2011. MB-MW-305 and MB-GP-002 were removed during the same RAM activity, and the downgradient replacement well MB-MW-365 had an arsenic concentration of 1.5 ppb in July 2008 and ND in March 2011.

Arsenic is relatively persistent and unlikely to degrade in the natural environment. Arsenic is soluble and mobile in groundwater, more so under reducing geochemical conditions. Arsenic may sorb to aquifer sands in the area of groundwater contamination, but sudden desorption to groundwater would not be expected barring a significant change in geochemistry. Considering the source removal in 2007 and declining downgradient concentrations since then, it appears that the natural processes of dilution, dispersion, and sorption can be effective for reducing arsenic concentrations to below the MMCL of 10 ppb in the area of historic exceedances at LR-MW-122. The EPC for LR-MW-122 is expected to decline to below the MMCL and is likely to achieve or approach background levels by natural attenuation over a period of several years.

1.4.2 Chlorinated VOCs (cVOCs)

CVOC groundwater data, calculated EPCs, and the status of the monitoring wells where one or more cVOCs has exceeded MMCLs are indicated in Table 2. CVOCs are denser than water, and releases at the water table would be expected to migrate deeper in the aquifer. The wells with cVOC exceedances include water table wells, which are likely closest to the release area, and deep wells screened above bedrock which are likely downgradient from the release. These contaminants are not naturally occurring above current typical detection limits therefore the background for cVOCs is effectively no detectable level in groundwater.

The source(s) of cVOCs in groundwater appear to include solvent releases in the central and southeast portions of the MBA based on groundwater monitoring results. Detected concentrations of cVOCs exceeded MMCLs in one or more rounds of sampling at shallow (water table) well MB-MW-301, and at deep wells LR-MW-129, MB-MW-362, and MB-MW-374. The cVOCs that exceeded criteria included tetrachloroethylene (aka perchloroethylene, or PCE), trichloroethylene (TCE), and vinyl chloride (VC). MMCLs for PCE and TCE are 5 ppb, and for VC the standard is 2 ppb. For the purpose of Presumptive Certainty in achieving or approaching background, in accordance with MassDEP Policy WSC-04-160, it is assumed that background levels of cVOCs are approached at one-half of the GW-1 standards (2.5 ppb for PCE or TCE, 1 ppb for VC). Dichloroethene (DCE) isomers were also detected in most of these wells at levels below MMCLs (70-100 ppb). Detections of cVOCs and possible sources and transport pathways are described in the following paragraphs.

MB-MW-301 was located near the northeast corner of Building 6 prior to removal of this well during a December 2007 soil excavation RAM. PCE concentrations in MB-MW-301 were in the range of 10 ppb prior to the RAM soil removal. After the RAM and demolition of the MBA buildings in 2007, MB-MW-367 was installed nearby to replace MB-MW-301. MB-MW-367 did not have PCE detected during monitoring from the start of sampling in July 2008 through the most recent sampling in July 2010. Neither MB-MW-301 nor MB-MW-367 had TCE or VC detected. The lack of detections in MB-MW-367 suggests that the source of cVOCs in the area of these shallow wells is no longer present.

Table 2. cVOC Exposure Point Concentrations in Groundwater (µg/L or ppb)

Well No.	Analyte	Date	Result	EPC	Comment / Well Status
MB-MW-301	PCE	06/05/07	9.7	8.2	Shallow Well & Soil Removed in 2007 RAM
		08/15/06	4.8		
		06/23/06	10.0		
LR-MW-129	PCE	03/17/11	**2.5**	30.7	Existing Deep Well adjacent to Neponset River and downgradient of MB-MW-301 and -374. Adjacent shallow well LR-MW-124 has no cVOCs detected.
		05/28/08	5.2		
		11/16/07	15.0		
		06/22/07	100.0		
	TCE	03/16/11	**2.5**	21.8	
		05/28/08	2.7		
		11/16/07	11.0		
		06/22/07	71.0		
	VC	03/16/11	**1.0**	4.1	
		05/28/08	1.5		
		11/16/07	3.1		
		06/22/07	11.0		
MB-MW-362	PCE	03/17/11	39.0	83.0	Existing Deep Well adjacent to Neponset River and downgradient of southeast corner of the Site. Adjacent shallow well MB-MW-363 has no cVOCs detected.
		07/27/10	110.0		
		12/07/09	120.0		
		04/15/09	63.0		
	TCE	03/17/11	15.0	35.5	
		07/27/10	43.0		
		12/07/09	45.0		
		04/15/09	39.0		
	VC	03/17/11	3.3	7.2	
		07/27/10	11.0		
		12/07/09	9.9		
		04/15/09	4.5		
MB-MW-374	PCE	03/17/11	42.0	17.2	Existing Deep Well downgradient of southeast corner of the Site; upgradient shallow well RA-MW-013 had PCE detected < MCL/GW-1.
		07/28/10	6.9		
		12/07/09	6.7		
		04/15/09	13.0		
	TCE	03/17/11	10.0	5.5	
		07/28/10	**2.5**		
		12/07/09	2.9		
		04/15/09	6.6		
	VC	03/17/11	**1.0**	2.1	
		07/28/10	2.5		
		12/07/09	3.3		
		04/15/09	1.5		

Results < GW-1 are shaded; ND (1/2 RL) are in **bold**; data not used to calculate the EPC are in *italics*

Shallow (LR-MW-124) and deep (LR-MW-129) wells were installed in 2006 downgradient of the MBA buildings and adjacent to the 2005 RAM excavations on the west bank of the Neponset River. No cVOCs were detected in the shallow well LR-MW-124 during sampling between 2006 and 2008. Concentrations of cVOCs (PCE, TCE, DCE, & VC) in the deep well LR-MW-129 declined consistently from the start of sampling in June 2007, and were not detected in the most recent sample in March 2011. These wells appear to be downgradient from the cVOC detections in MB-MW-301 described above, and also from detections in MB-MW-374 described below.

MB-MW-362 (deep) and -363 (shallow) were installed in 2008 along the west bank of the Neponset River and southeast of the detections in LR-MW-129. These wells appear to be downgradient of the southeastern portion of the MBA. No cVOCs were detected in the shallow well MB-MW-363 in a sample collected in 2008. Concentrations of cVOCs in the deep well MB-MW-362 generally increased from the start of sampling in July 2008 until July 2010, then declined in the most recent sample in March 2011. Cis-1,2-DCE was also detected consistently but at levels (11-31 ppb) below the MMCL. The recent decline in cVOCs at MB-MW-362 may indicate that the upgradient source of contamination is dissipating. Two shallow water table wells, LR-MW-106 and MB-MW-375, are located in the upgradient area. LR-MW-106 had no cVOCs detected in monitoring between 2006 and 2008, and MB-MW-375 had no cVOCs detected in 2009 and 2010.

Deep well MB-MW-374 was installed in 2008 at a location west of former Building 7E and north of former Building 23. PCE ranged from 6.7 to 13 ppb in 2009 – 2010, but increased to 42 ppb in the March 2011 sample. TCE was also highest (10 ppb) in the most recent sample, after declining from 6.6 ppb to non-detect in the preceding two years. VC was not detected in the most recent sample, after detections of up to 3.3 ppb in the preceding two years. Cis-1,2-DCE was detected in samples from 2009 and 2011 (4.0-6.1 ppb), and trans-1,2-DCE was detected once at a trace level. The nearest well in the upgradient direction is water table well RA-MW-13, which had PCE (but no other cVOCs) detected in 2006-2007 at levels of 2.4-4.5 ppb. RA-MW-013 was removed in 2007 in conjunction with building demolition activities. The recent increase in cVOCs at MB-MW-374 suggests that an intermittent upgradient source of contamination is present. The groundwater flow path distance between MB-MW-374 and the Neponset River is about 300 feet. Assuming a lateral seepage velocity of about 0.3 ft/day, the estimated groundwater travel time between the MB-MW-374 and LR-MW-129 would be about 2.7 years.

The cVOC results for the MBA groundwater sampling suggest that PCE was released to the water table near MB-MW-301 in the center of the MBA and possibly at other locations near the center of the MBA, upgradient of wells LR-MW-129, MB-MW-362, and MB-MW-374. Groundwater flow directions may vary considerably in this portion of the MBA with seasonal fluctuations in precipitation and river flow, as described in Section 1.3. The cVOC source in the vicinity of MB-MW-301 appears to be reduced or eliminated based on results from MB-MW-367 and LR-MW-129, and this source may have been located in soil that was removed during the 2007 RAM excavation. The most recent sample results for LR-MW-129 are approaching background, although the EPCs still exceed MMCLs. The source of cVOCs upgradient from MB-MW-362 may be dissipating based on the latest sample result which shows the lowest detections to date. The recent increase in cVOCs in MB-MW-374 indicates that an intermittent source of contamination may still be present upgradient from this well. The extent of cVOCs above the MMCLs is conservatively estimated in Figure 6 to extend as far upgradient as the historic manufacturing buildings that were located in the southern part of the MBA.

PCE and TCE are relatively mobile and degradable in the natural environment. The presence of DCE and VC suggests that natural biodegradation is occurring at the Site. Other natural attenuation processes including dilution, dispersion, and volatilization are likely significant at the Site, and sorption to a lesser extent. The cVOCs in pure form are denser than water and are expected to sink below the water table as they dissolve. If the release is large enough, a separate phase (undissolved) mass of source material may accumulate near the bottom of the aquifer within the soil matrix or on the bedrock surface and gradually dissolve into groundwater. This may be the case upgradient of deep wells MB-MW-362 and -374. The cVOCs have not been detected in shallow/deep wells MB-MW-360/-361 located near the east riverbank. The Neponset River appears to be a groundwater discharge area for the Site, and cVOCs in groundwater are expected to enter the river and be diluted to ND levels at the point of discharge. A CSA completed for the river where it borders the Site found a condition of No Significant Risk for river receptors (Weston 2007).

1.4.3 Petroleum Hydrocarbons

Groundwater data for Polycyclic Aromatic Hydrocarbons (PAH) and Extractable Petroleum Hydrocarbons (EPH), including calculated EPCs and the status of the monitoring wells where one or more analytes has exceeded GW-1 criteria, are indicated in Table 3. GW-1 standards are relevant drinking water criteria for the compounds in Table 3 because MMCLs are not published for these compounds. PAH contaminants are not naturally occurring above current typical detection limits therefore the background is effectively no detectable level in groundwater. GW-1 criteria are 20 ppb for acenaphthene, 40 ppb for phenanthrene, and 200 ppb for EPH C11-C22 aromatics. Petroleum hydrocarbons and acenaphthene are listed as degradable or non-persistent contaminants for the purpose of Presumptive Certainty in achieving or approaching background, in accordance with MassDEP Policy WSC-04-160. Phenanthrene is not listed in the policy as either persistent or degradable, and it is assumed that background levels of phenanthrene are approached at one-half of the GW-1 standards.

Table 3. PAH & EPH Exposure Point Concentrations in Groundwater (µg/L or ppb)

Well No.	Analyte	Date	Result	EPC	Comment / Well Status
MB-MW-366	Acenaphthene	03/18/11	**2.5**	10.1	Existing Shallow Well downgradient of MB-MW-301 and in the area of removed buildings and 2007 RAM excavations.
		07/26/10	32.0		
		12/07/09	3.3		
		04/15/09	2.5		
		07/22/08	*41.0*		
	Phenanthrene	03/18/11	**2.5**	14.5	
		07/26/10	49.0		
		12/07/09	5.3		
		04/15/09	1.0		
		07/22/08	*2.9*		
	EPH C11-C22	03/18/11	**25.0**	25.0	
		07/26/10	**25.0**		
		12/07/09	**25.0**		
		04/15/09	**25.0**		
		07/22/08	*410.0*		
MB-MW-301	EPH C11-C22	06/05/07	1025.0	631.7	Shallow Well removed in 2007 RAM
		08/15/06	150.0		
		06/23/06	720.0		

Results < GW-1 are shaded; ND (1/2 RL) are in **bold**; data not used to calculate the EPC are in *italics*

Concentrations of acenaphthene, phenanthrene, and EPH (C11-C22 aromatics, adjusted) have exceeded criteria for MB-MW-366, though the current EPCs for this well are below the criteria. The samples with exceedances in MB-MW-366 were collected in July 2010 (acenaphthene and phenanthrene) and July 2008 (acenaphthene and EPH). These PAHs and EPH have been detected in other wells at lower concentrations in the area east and downgradient of MB-MW-366 (LR-MW-122 and -124). MB-MW-366 was installed in 2008 following RAM soil removal in the area of Building 7C.

MB-MW-301 was located upgradient from MB-MW-366 near the northeast corner of Building 6 prior to its removal during a December 2007 soil excavation RAM. After the RAM and demolition of the MBA buildings in 2007, MB-MW-367 was installed nearby to replace MB-MW-301. MB-MW-367 did not have PAHs or EPH detected during monitoring from the start of sampling in July 2008 through the most recent sampling in July 2010.

The exceedances of the EPH GW-1 standard in MB-MW-301 in 2006-2007 are consistent with the significant detections of these compounds in soil beneath the Manufacturing Buildings. Soil containing EPH and PAHs was the focus of RAM excavations performed in 2007. The results for replacement well MB-MW-367 and downgradient well MB-MW-366 indicate that the source of EPH and PAHs was largely removed in the 2007 RAM, and groundwater concentrations are gradually declining below GW-1 standards and approaching background. The detections of PAHs above standards in July 2010, and of acenaphthene and EPH above standards in July 2008, occurred during times of relatively low flow in the Neponset River. Assuming the water table at the Site is similarly lower and groundwater flow velocities are falling, it is possible that these results reflect less dilution of residual contamination sorbed to aquifer soils.

PAHs and higher molecular weight EPH are relatively insoluble, sorb to soil, and are slowly transported in groundwater, but biodegradation is expected to be a significant attenuation pathway. Considering the remedial actions, groundwater monitoring results, and contaminant transport pathways, there does not appear to be a consistent area of groundwater EPCs exceeding GW-1 criteria for PAH/EPH.

1.4.4 Chlorobenzenes

Groundwater data for 1,2,4-trichlorobenzene (TCB) and 1,4-dichlorobenzene (DCB), including calculated EPCs for the monitoring well where these analytes have exceeded MMCLs, are indicated in Table 4. These contaminants are not naturally occurring above current typical detection limits therefore the background is effectively no detectable level in groundwater. MMCLs are 5 ppb for DCB and 70 ppb for TCB. For the purpose of Presumptive Certainty in achieving or approaching background, in accordance with MassDEP Policy WSC-04-160, it is assumed that background levels of DCB/TCB are approached at one-half of the GW-1 standards; these levels are 2.5 ppb for DCB and 35 ppb for TCB.

NP-MW-601 is the only monitoring well with recent MMCL exceedances for the chlorobenzenes. TCB was detected in one other well at the MBA, SL-MW-012 (1.4 ppb in December 2007) which is downgradient of NP-MW-601 near the Neponset River. DCB has not been detected downgradient of NP-MW-601. Sporadic DCB detections below the MMCL were identified to the south, in OS-MW-03 and MB-MW-366 near the northern edge of the manufacturing buildings and in LR-MW-121, -122, and -123 along the river. Based on groundwater flow directions, these DCB detections to the south are unlikely to be unrelated to the exceedances in NP-MW-601. NB-MW-601 and LR-MW-121 are screened below the water table in the deepest part of the saturated zone, while the other wells with chlorobenzene detections are shallow wells.

Higher concentrations of DCB were detected at CP-MW-102 in 1992 during investigation of the Cart Path area along the north side of Ruckaduck Pond. A Waiver Completion Statement was filed for this area in 1993 based on the Phase II investigation results (Balsam 1993). DCB (1,4 and other isomers) were detected at levels up to 105 ppb, and TCB at levels up to 12.8 ppb in CP-MW-102. This shallow well was located within the original source area and was eventually decommissioned after several years of no measureable water level. Bedrock in the Cart Path area was found to be very shallow, about 5-18 ft bgs based on refusals and coring at one drilling location. Approximately 1,843 tons of contaminated soil and wastes were removed from the Cart Path area in 1991. The area appears to be upgradient from NP-MW-601.

Concentrations of TCB and DCB in NP-MW-601 appeared to increase steadily from the start of monitoring in June 2006 until the end of 2007, then declined in 2008 and early 2009. After that, concentrations in the 2010-2011 results increased to the earlier levels. Building 20, located 120 ft upgradient from NP-MW-601, was demolished in 2007. Building 20 and/or the historic Cart Path area may be sources of the chlorobenzenes detected in NP-MW-601. Although current EPCs are below MMCLs, this may change with continued monitoring considering recent results for DCB. Considering these recent DCB results above the MMCLs, a tentative area of exceedance is indicated around NP-MW-601 in Figure 6, extending to near historic the Cart Path area.

Table 4. TCB & DCB Exposure Point Concentrations in Groundwater (µg/L or ppb)

Well No.	Analyte	Date	Result	EPC	Comment / Well Status
NP-MW-601	TCB	03/17/11	68.0	38.4	Existing Deep Well downgradient of the Cart Path (RTN 4-3002469) and a historic building demolished in 2007.
		07/28/10	68.0		
		12/07/09	**2.5**		
		04/15/09	15.0		
		07/22/08	*24.0*		
		12/11/07	*75.0*		
		06/07/07	*50.0*		
		08/16/06	*39.0*		
		06/27/06	*26.0*		
	DCB	03/17/11	5.2	4.6	
		07/28/10	5.3		
		12/07/09	6.4		
		04/15/09	1.5		
		07/22/08	*2.5*		
		12/11/07	*6.3*		
		06/07/07	*5.4*		
		08/16/06	*5.3*		
		06/27/06	*5.1*		

Results < GW-1 are shaded; ND (1/2 RL) are in **bold**; data not used to calculate the EPC are in *italics*

Chlorobenzenes are moderately mobile and degradable in the natural environment. Biodegradation appears to occur faster under aerobic vs. anaerobic conditions. The presence of DCB (an anaerobic degradation intermediate of TCB) and corresponding trends in TCB and DCB levels suggest that natural biodegradation is occurring at the Site. Other natural attenuation processes including dilution, dispersion, and volatilization are likely significant at the Site, and sorption to a lesser extent. TCB is denser than water and would be expected to sink below the water table as it enters the aquifer. The Neponset River appears to be a groundwater discharge area for the Site, and chlorobenzenes in groundwater are expected to enter the river and be diluted to ND levels at the point of discharge. The “background” level of chlorobenzenes is ND; these levels have already been achieved in some wells near the Neponset River. Background may be achieved elsewhere with continued natural attenuation, though this is less likely if concentrations near MB-MW-601 do not decline significantly.

1.5 Remedial Objectives

The site remedial objective is to achieve a Permanent Solution in accordance with the MCP, including public response activities throughout this process. The requirements for a Permanent Solution include the following:

1. Achieve a condition of No Significant Risk (NSR) for current and reasonably foreseeable future site uses in accordance with 310 CMR 40.0000. NSR has been achieved at the Site except for groundwater which may be a potential source of drinking water, as described above. A condition of NSR for groundwater can be achieved when EPCs are below GW-1 criteria, or if concentrations achieve any background levels that are above GW-1 criteria.
2. Eliminate or control any source of oil and/or hazardous material which is resulting or is likely to result in an increase in concentrations in an environmental medium, as specified in 310 CMR 40.1003(5).
3. To the extent practicable, reduce levels of site contaminants to those that achieve or approach background.

Achieving these objectives will require elimination of any significant sources of groundwater contaminants. Source control has occurred at the Site through soil excavation RAMs in the areas in and upgradient from arsenic and some cVOC groundwater contamination. The RAM around Building 6/6A, upgradient from arsenic detected in LR-MW-122, included soil having arsenic above background levels. The RAM around Building 7A/7C and LRA2, upgradient from cVOCs detected in LR-MW-129, included soil with metals and oily contamination but was not known to contain cVOCs.

Sources of groundwater contamination have not been specifically identified upgradient from MB-MW-362 and -374, or NP-MW-601. All above-ground structures and below-ground tanks in these areas have been removed as of early 2008, and it is possible that these structures included source materials; also the historic Cart Path area is a potential source of the contaminants identified in NP-MW-601. Remedial Action Alternatives for groundwater will include additional soil and groundwater investigations as needed to confirm that any source that is likely to result in increasing concentrations of contaminants is controlled or eliminated.

2.0 IDENTIFICATION OF REMEDIAL ACTION ALTERNATIVES [310 CMR 40.0855-6]

The objective of this section is to identify Remedial Action Alternatives (RAA) for containment and/or treatment of groundwater impacted by historic releases from the MBA. The identification of RAA includes an initial screening to identify those remedial technologies which are reasonably likely to be feasible, based on the oil and hazardous material present, media contaminated, and site characteristics. The RAA are likely to be feasible if:

- The technologies to be employed by the alternative are reasonably likely to achieve a Permanent or Temporary Solution; and

- Individuals with the expertise needed to effectively implement available solutions would be available, regardless of arrangements for securing their services (310 CMR 40.0856).

A Temporary Solution means any measure or combination of measures which will, when implemented, eliminate any substantial hazard which is presented by a disposal site or by any oil and/or hazardous material at or from such site in the environment until a Permanent Solution is achieved.

The process leading to the development of RAAs involves the following steps:

1. Development of general response actions - The general response actions identified for the Site are intended to address the containment, removal, treatment, and/or disposal of groundwater impacted by metals, chlorobenzenes, and chlorinated VOCs.
2. Selection of technologies and process options - The specific technologies and process options that may be used to implement a response action are evaluated, and the most feasible options are retained for further consideration.
3. Development of RAAs - The technologies and process options that were retained for further consideration in Step 2 are selectively combined to form RAAs that would be likely to meet the remedial objectives.

The Step 1 general response actions are presented in Subsection 2.1. The Step 2 identification and screening of remedial technologies and process options are presented in Subsection 2.2. The Step 3 development of RAAs is presented in Subsection 2.3. A detailed evaluation of the RAAs developed in this section is provided in Section 3 in accordance with 310 CMR 40.0857 and 40.0858.

2.1 General Response Actions

The general response actions to remediate dissolved contaminants in groundwater include:

- Containment
- Treatment
- Disposal

2.2 Technology Screening and Evaluation

Remedial action technologies must perform the general response action identified for the specific medium and must satisfy the appropriate remedial objectives. Numerous process options may exist within a specific technology type. Technology types refer to general categories of technologies, such as in situ treatment or off-site disposal. Technology process options are specific processes within each technology type. Process options may be similar in action to one another, or may be quite different in the manner in which they accomplish similar results.

A range of potentially applicable treatment technologies and process options were reviewed and selectively reduced by screening the technologies and process options with respect to technical implementability while considering site-specific conditions. The list of technologies was developed based on available information from other sites, and on a review of technical publications, conference proceedings, EPA publications and databases, and current vendor information. The technologies retained after the screening process were further evaluated on the basis of achieving remedial objectives using the following guidelines:

- Description: The technology process option is described along with a brief discussion of its potential application.
- Technical Considerations: The technical reliability (technology development, performance, and safety) and implementability of the process option, with respect to site and waste characteristics, were evaluated.
- Recommendation: A recommendation is made to retain or eliminate the process option from further consideration based on the criteria previously described.

Table 5 provides the results of this evaluation for the technologies considered feasible for the site. Based on this initial evaluation, the following technologies have been selected for development of RAAs:

- Monitored Natural Attenuation (MNA);
- In Situ Chemical Oxidation (ISCO); and
- Ex-Situ Groundwater Treatment (Pump & Treat).

Each of these technologies has the potential to treat and remove dissolved contaminants in Site groundwater. Other technologies were ruled out either because they are not applicable to the current conditions at the Site, or they were otherwise judged less likely to succeed. Air Sparging/SVE was ruled out based on a higher difficulty of implementation compared to other in situ technologies having similar costs, such as ISCO. Enhanced Bioremediation may be included as a contingent remedy for MNA of organics (see Section 2.3.1), but as a primary alternative it does not have significant advantages over ISCO. A Permeable Reactive Wall was ruled out based on a relatively high cost and longer treatment time compared to other alternatives.

2.3 Assembly of Remedial Alternatives

The remedial technologies retained in Table 5 were used to develop three RAAs that are reasonably likely to be feasible Permanent or Temporary Solutions for the Site. These three RAAs are (1) MNA for all contaminants; (2) ISCO for organic contaminants and MNA for arsenic; and (3) Pump & Treat for organic contaminants and MNA for arsenic. A conceptual design of each alternative is described in the following subsections. The description includes key components, a conceptual layout, treatment residuals or wastes requiring disposal, permit requirements, and a discussion of limitations, assumptions, and uncertainties for each alternative. The cost estimates provided herein have an accuracy of at best +50% / -30% and are meant for comparative purposes only. The actual costs depend on many factors that will be further refined during pre-design activities.

Costs and other conceptual design information were calculated using AFCEE's Sustainable Remediation Tool™ (SRT) for the separate arsenic, PCE, and DCB areas of contamination shown in Figure 6 (AFCEE 2010). SRT annual costs were adjusted to calculate a present worth for each alternative using a 7% discount rate. The present worth costs for the three alternatives are summarized in Table 6. Input and output information for SRT is summarized below, and provided in Appendix C.

2.3.1 Alternative 1 – Monitored Natural Attenuation

Monitored Natural Attenuation (MNA) consists of active monitoring of natural processes to ensure attainment of cleanup goals. Natural processes that affect contaminant transport include dilution, dispersion, and sorption for all contaminants, and also biodegradation and volatilization for organic contaminants. Considering the age of the release and the presence of PCE and TCB breakdown products in groundwater at the site, natural biodegradation appears to be occurring for PCE and TCB. Natural attenuation may achieve GW-1 standards for arsenic in the short term considering arsenic concentrations have declined to about this level in the most recent samples, and for other contaminants over a longer period.

As detailed in the OSWER Directive (USEPA 1999) and adopted by MassDEP in their draft policy WSC #02-500 (2002), fundamental components of any MNA remedy include source control, prevention of plume migration, extensive long-term performance monitoring, and contingency remedies. The application of these components to the Site contaminants is discussed in the subsections that follow.

2.3.1.1 Source Control

Source control has occurred at the Site through soil excavation RAMs in the areas in and upgradient from arsenic and some cVOC groundwater contamination, as described in Section 1. Implementation of MNA would include additional soil and groundwater sampling to confirm that source control has occurred for all groundwater contaminants.

2.3.1.2 Plume Control

Plumes of groundwater contamination are expected to discharge to the Neponset River along the eastern edge of the Site. The river serves as a hydraulic barrier preventing offsite migration of contaminated groundwater. Groundwater contaminants from MBA have not been identified in monitoring wells east of the river. Sediment and surface water concentrations in the river suggest that the contaminant discharge from groundwater to the river has not had measureable impacts, and a condition of No Significant Risk was found to apply to the river (Weston 2007).

2.3.1.3 Performance Monitoring

Performance monitoring would be used to assess the time required to reach GW-1 Standards at the Site using MNA and to periodically reassess the remedial strategy. The alternative would include installation of groundwater monitoring wells to supplement the existing well network. A conceptual layout of new and existing wells to be monitored in each of the three areas is illustrated in Figure 8. The groundwater samples would be analyzed for the constituents of concern, as well as parameters used to demonstrate that natural attenuation is occurring within the plumes. A preliminary list of potential monitoring parameters is provided in Table 7.

Details of the performance monitoring system, including the data needs and evaluation methods, would be developed during implementation of the selected RAA in accordance with Phase IV requirements under 310 CMR 40.0870. For the purpose of this evaluation it is assumed that quarterly monitoring may extend as long as 10 years. The duration and frequency of monitoring could be adjusted based on interim results as the program progressed.

2.3.1.4 Contingency Remedy

A contingency remedy would be implemented if MNA does not progress in an effective or timely manner as determined by performance monitoring. A typical contingency remedy for MNA of organic contaminants would involve intervention to enhance existing biodegradation, for example by injection of microbial nutrients into the plume. A decision matrix for contingent remedies and any data needed for design or execution would be included in the plans to be developed and implemented in Phase IV.

Any solid wastes generated from well installation would be evaluated prior to removal and disposed of in accordance with the MCP. Purge water from monitoring well development would be contained and tested prior to discharge or hauling off-site. No other wastes would be generated for implementation of MNA. This alternative may require quarterly access to the site by two or more persons for a period of 2-3 days over 10 years, including operation of a portable generator for powering sampling equipment.

The estimated capital costs of MNA, including the first year of monitoring, are $130,000 to $390,000 per area depending on the numbers of wells to be installed for each area. Annual monitoring costs are $15,000 - $23,000 per area and are assumed to continue for nine years after the first year, resulting in a total present worth cost of $1.0 million (M) for the Site.

2.3.2 Alternative 2 – ISCO / MNA

In Situ Chemical Oxidation (ISCO) consists of injecting or otherwise distributing liquid oxidants into the aquifer, in some cases with other chemicals that function as catalysts. The oxidants chemically break down organic chemicals upon contact to inert materials such as carbon dioxide, water; and with the chlorinated compounds, inorganic chloride. For this Site, chlorobenzenes and cVOCs are particularly susceptible to chemical oxidation. ISCO would not be effective for arsenic; MNA could be used in this RAA for the arsenic plume, similar to what was discussed for Alternative 1.

Several oxidants have been used on similar constituents to date, but most commercial applications have used hydrogen peroxide, potassium permanganate or sodium permanganate in the saturated zone. Because of the variety of compounds on Site that may require remediation, the oxidant(s) and any catalysts used should be further evaluated in a pre-design study. It is assumed for this RAP that sodium permanganate will be used to oxidize the chlorinated plume and sodium persulfate activated by sodium hydroxide will be used for the chlorobenzene plume. Additional field investigation and testing would also need to be conducted to determine existing background oxygen demand within the soils for actual dosing and amount of oxidant required to remediate the constituents.

A conceptual layout of monitoring points and areas of treatment is illustrated in Figure 9. The injection points would be 1-inch PVC and screened at varying depths to control the vertical location of the dose administered. Dose amounts and injection sites would be designed to optimize treatment while preventing discharge of oxidant to the river. SRT estimates 530 injection points for the PCE plume and 190 for the DCB plume, based on a spacing of 20 feet. Installation of the remedial system would entail well installation, well development, and on-site plumbing of the ISCO components. Remediation equipment would be brought on-site for an injection cycle (a few weeks) and removed once the cycle is complete. Annual Operation and Maintenance (O&M) of the treatment system would not be required since the system will only be on-site during injection events. It is expected that 1 to 2 injection cycles, over a period of 1-3 years, may be needed to remediate the areas of contamination based on typical times for treatment and subsequent performance monitoring.

The alternative would include installation of groundwater monitoring wells to supplement the existing well network. Prior to, during, and after injection activities, the injection area and nearby monitoring wells would be monitored. A sampling round would be conducted one to two months after the injection to calculate consumption of the oxidant and whether another injection would be necessary. Details of the performance monitoring system, including the data needs and evaluation methods, would be developed during implementation of the selected RAA in accordance with Phase IV requirements under 310 CMR 40.0870. Monitoring and reporting would meet the requirements for Remedial Additives under 310 CMR 40.0040.

Any solid wastes generated from well installation would be evaluated prior to removal and disposed of in accordance with the MCP. Purge water from monitoring well development would be contained and tested prior to discharge or hauling off-site. No other wastes would be generated for implementation of ISCO. This alternative may require quarterly access to the site by two or more persons for a period of 2-3 days for monitoring, and also for 1-2 weeks per year for injections, over a period of two years. Personnel would operate a portable generator for powering sampling and injection equipment.

MNA for arsenic would proceed as described for Alternative 1, with installation and monitoring of groundwater wells to supplement the existing network. ISCO and MNA would be conducted in different areas of the aquifer since the organic and arsenic plumes do not appear to overlap. ISCO would be conducted to avoid movement of oxidant into the arsenic plume, since a temporary change in geochemistry could immobilize arsenic and slow the MNA process.

The estimated capital costs of ISCO are $2.4M for the DCB plume and $6.6M for the PCE plume. These costs are based on a single injection event for each area. Quarterly monitoring costs for DCB and PCE were assumed to be the same as for Alternative 1 and to occur for three years. A total present worth cost of $9.3M is estimated for the Site.

2.3.3 Alternative 3 – Pump & Treat / MNA

Pump and treat involves extracting impacted groundwater via one or more pumping wells and subsequently treating the water prior to discharge. The pumping well configuration (i.e., the number and location of wells) and construction (e.g., casing diameter, screen length, and screen placement) are dependent on site-specific characteristics and regulatory requirements. Site considerations include local geology and hydrogeology, the type of contaminants present, the extent of contamination in groundwater, site accessibility, and site operations.

Once the groundwater is extracted, a treatment technology appropriate for the type and amount of impacted groundwater would be used to treat the groundwater before discharge. Carbon adsorption using liquid phase granular activated carbon (GAC) as the absorbent material is a proven treatment technology for groundwater containing organic compounds. During the carbon adsorption process, water flows through columns packed with adsorbent carbon material. Soluble compounds are attracted to the surfaces of the GAC and are removed from water by adsorption. Once the GAC surfaces are covered with compounds, the adsorption capacity of the GAC is exhausted and the carbon must be replaced and sent off-site for regeneration or disposal. GAC is not a viable treatment technology for arsenic or vinyl chloride. MNA could be used in this RAA for the arsenic plume, similar to what was discussed for Alternative 2. Vinyl chloride levels in the cVOC plume appear to be very low, and this compound would be expected to volatilize into the ambient air such that the discharge from the treatment plant would not have detectable levels of VC.

Treated groundwater would be discharged to the Neponset River. The NPDES Program regulates this type of activity and is implemented by the USEPA. It is anticipated that a NPDES Permit Exclusion would be obtained for the pump and treat alternative. Under permit exclusion requirements, it is typically necessary to collect and analyze influent and effluent samples from the treatment system. Sampling requirements are based on the compounds being treated, and a specific sampling schedule would be conducted in accordance with the NPDES Permit Exclusion. Sampling frequency is anticipated to be every 2 days during the first 2 weeks of operation, and would likely be reduced to monthly sampling as system operation progressed.

A conceptual layout of a pump & treat system is illustrated in Figure 10. The conceptual design includes:

- Installation and development of groundwater extraction wells (including pumps) that capture flow from the contamination areas. A total groundwater extraction rate of 4-10 gallons per minute (gpm) per plume, using 3-7 wells per plume, is estimated by SRT based on plume sizes and general aquifer characteristics.
- Installation of subsurface piping from extraction wells to a treatment system enclosure at a central location on the Site.
- Installation, plumbing, and wiring of treatment system components including:
    - Influent/equalization tank prior to treatment.
    - A pre-treatment filter to remove insoluble metals (e.g., calcium, magnesium, manganese, and iron) and total suspended solids, as their presence in groundwater could potentially interfere with treatment system operation.
    - GAC treatment consisting of two vessels in series (primary and secondary). Treatment system piping would be designed to minimize downtime during GAC change-outs.
- Discharge of the treated water to the Neponset River.

Performance monitoring would be used to assess the time required to reach remedial objectives and to periodically reassess the remedial strategy. The alternative would include installation of groundwater monitoring wells to supplement the existing well network. Details of the performance monitoring system, including the data needs and evaluation methods, would be developed during implementation of the selected RAA in accordance with Phase IV requirements under 310 CMR 40.0870. For the purpose of this evaluation it is assumed that quarterly monitoring may extend as long as eight years. The duration and frequency of monitoring could be adjusted based on interim results as the program progressed.

Any solid wastes generated from system installation would be evaluated prior to removal and disposed of in accordance with the MCP. Purge water from monitoring well development would be contained and tested prior to discharge or hauling off-site. Spent GAC would be sent off-site for regeneration or disposal. This alternative may require quarterly access to the site by two or more persons for a period of 2-3 days for monitoring over a period of eight years.

The treatment plant would be designed for continuous remote operation with electronic notification of alarm conditions to offsite operators. Breakthrough in the primary vessel would require operators to shift vessel positions such that the secondary vessel becomes the primary unit and vice versa, until the secondary unit can be changed out. Spent GAC would be regenerated or disposed of off-site.

MNA for arsenic would proceed as described for Alternative 1 or 2, with installation and monitoring of groundwater wells to supplement the existing network. Pump & Treat and MNA would be conducted in different areas of the aquifer since the organic and arsenic plumes do not appear to overlap.

The estimated capital and O&M costs of Pump & Treat for the DCB plume are $1.7M and $270,000, respectively. The estimated capital and O&M costs for the PCE plume are $2.1M and $280,000, respectively. Alternative 3 assumes that the same treatment system could be applied to both plumes, and the estimated capital costs that include this system would be less than the sum of these separate SRT estimates. Assuming a 40% reduction in the sum of the capital costs, a total present worth cost of $5.8M is estimated for the Site.

3.0 DETAILED EVALUATION OF REMEDIAL ACTION ALTERNATIVES [310 CMR 40.0857-58]

A detailed evaluation of the remedial action alternatives identified in Section 2.0 is required by the MCP at 310 CMR 40.0857. The detailed evaluation compares the RAAs using the eight criteria described in 310 CMR 40.0858, which provides a basis for the selection of the remedial action alternative:

- **Effectiveness** in achieving a Permanent or Temporary Solution and reducing levels of untreated oil and hazardous material at the Site to concentrations that achieve or approach background;
- **Short and long term reliability**, including remedial success and waste management;
- **Implementability**, taking into consideration technical complexity, disruption of facility operations, availability of necessary services and materials;
- **Costs**, considering implementation, operation, permitting, and environmental restoration;
- **Risks** to health, safety, public welfare, and the environment, considering implementation, waste handling, and residual contaminants;
- **Benefits**, considering restoration, reuse, avoidance of relocation and lost value of the Site;
- **Timeliness** in achieving of a level of No Significant Risk as described in 310 CMR 40.0900; and
- **Relative effects upon non-pecuniary interests**, such as aesthetic values.

The MCP evaluation criteria are presented in the subsections that follow. Each of the RAAs from Section 2.0 is ranked on a scale of 1 to 3 for each criteria, with the most favorable ranking being a 3 and the least favorable being a 1. These rankings will be combined to aid in selection of the final remedy in Section 4.

3.1 Effectiveness

This criterion requires a comparative evaluation of the RAAs in terms of:

(a) achieving a Permanent or Temporary Solution under 310 CMR 40.1000;
(b) reusing, recycling, destroying, detoxifying, or treating oil and hazardous material at the disposal site; and
(c) reducing levels of untreated oil and hazardous material at the site to concentrations that achieve or approach background.

All three RAAs appear to be capable of achieving a Permanent Solution and a condition of NSR by reduction of groundwater concentrations to GW-1 standards. As indicated in Section 1.3.1, source removal and MNA appears to have reduced arsenic concentrations in groundwater to around the GW-1 criteria of 10 ppb based on recent measurements. The exposure point concentration for DCB is also around the level of GW-1 criteria at the location of the highest detections, as indicated in Section 1.3.4. The cVOC detections in the southeast portion of MBA appear to represent the greatest challenge to achieving NSR based on exceedances of up to eight times the GW-1 standards in the latest sample results for PCE. However, these three RAAs include processes which are expected to remove or destroy the cVOC contaminants as described in Section 2, and it appears likely that a condition of NSR can be achieved.

Alternatives 1 (MNA) and 2 (ISCO/MNA) would not reuse or recycle contaminants, but organic contaminants would be destroyed, detoxified, and treated by natural or engineered processes. Alternative 3 (P&T/MNA) would not reuse, recycle, destroy, or detoxify contaminants, but organic contaminants would be transferred to other media to remove them from the Site.

All three RAAs would likely achieve background for arsenic and DCB, and may approach background (one-half the Method 1 groundwater standards) for cVOCs. Achieving or approaching background would require reductions in groundwater concentrations of about 50% for arsenic, 50% for DCB, and almost 95% for PCE. These levels of reductions are typically achievable by the RAAs under consideration, though at differing rates which will affect the duration of remedial activities (see Section 3.7).

Considering these comparisons, the three RAAs are ranked equally (“2”) for the Effectiveness criterion.

3.2 Short and Long Term Reliability

This criterion requires a comparative evaluation of the RAAs in terms of:

(a) the degree of certainty that the alternative will be successful; and
(b) the effectiveness of any measures required to manage residues or remaining wastes or control emissions or discharges to the environment.

Alternative 1 (MNA) may be less certain to achieve remediation goals compared to Alternatives 2 (ISCO/MNA) and 3 (P&T/MNA), since Alternative 1 relies primarily on natural processes which are usually less predictable than engineered remedies. Alternatives 1 and 2 would not result in any residues, wastes, emissions, or discharges to the environment that would require disposal. Alternative 3 would result in a solid waste residue and air emissions due to transfer of contaminants to other media. Measures to manage these materials and emissions are available and are typically effective.

Considering these comparisons, Alternative 1 is ranked “2” and the other RAAs are ranked “3” for the Reliability criterion.

3.3 Implementability

This criterion requires a comparative evaluation of the RAAs in terms of:

(a) technical complexity of the alternative;

(b) where applicable, the integration of the alternative with existing facility operations and other current or potential remedial actions;
(c) any necessary monitoring, operations, maintenance or site access requirements or limitations;
(d) the availability of necessary services, materials, equipment, or specialists;
(e) the availability, capacity and location of necessary off-site treatment, storage and disposal facilities; and
(f) whether the alternative meets regulatory requirements for any likely approvals, permits or licenses required by the Department, or other state, federal or local agencies.

Alternative 1 is the least technically complex, Alternative 2 is more complex, and Alternative 3 is the most complex, based on the types of remediation systems and their operating requirements. All three RRAs are relatively easily integrated with existing remedies and site operations. All three alternatives would require similar levels of groundwater monitoring to ensure that performance standards are met. Alternatives 1 and 2 do not require off-site treatment capacity; Alternative 3 requires such capacity for spent carbon media and aquifer solids, and the capacity is expected to be available. Alternatives 1 and 2 do not require permits to operate; Alternative 3 requires a discharge permit or permit exclusion.

Considering these comparisons, Alternative 1 is ranked “3”, Alternative 2 is ranked “2”, and Alternative 3 is ranked “1” for the Implementability criterion.

3.4 Costs

This criterion requires a comparative evaluation of the RAAs in terms of:

(a) costs of implementing the alternative, including without limitation: design, construction, equipment, site preparation, labor, permits, disposal, operation, maintenance and monitoring costs;
(b) costs of environmental restoration, potential damages to natural resources, including consideration of impacts to surface waters, wetlands, wildlife, fish and shellfish habitat; and
(c) the relative consumption of energy resources in the operation of the alternatives, and externalities associated with the use of those resources.

Present worth costs were estimated for each alternative in Section 2, including all of the above factors. The estimated costs of Alternatives 1, 2, and 3 were \$1.0M, \$9.3M, and \$5.8M respectively. The cost rankings of Alternatives 1, 2, and 3 are “3”, “1”, and “2” respectively.

3.5 Risks

This criterion requires a comparative evaluation of the RAAs in terms of:

(a) the short-term on-site and off-site risks posed during implementation of the alternative associated with any excavation, transport, disposal, containment, construction, operation or maintenance activities, or discharges to the environment from remedial systems;
(b) on-site and off-site risks posed over the period of time required for the alternative to attain applicable remedial standards, including risks associated with ongoing transport,

disposal, containment, operation or maintenance activities, or discharges from remedial systems; and

(c) the potential risk of harm to health, safety, public welfare or the environment posed to human or environmental receptors by any oil and/or hazardous material remaining at the disposal site after the completion of the remedial action.

Alternative 3 involves the highest short-term risks since it requires the greatest amount of construction for remediation systems. Alternative 3 also involves some ongoing risk with O&M of the treatment system and periodic handling of spent sorbent media and aquifer solids. Alternative 1 involves the lowest level of risks due to minimal construction and O&M requirements, and Alternative 2 risks are intermediate. Risks associated with any remaining contamination are similar for all three RAAs considering that their effectiveness in achieving NSR is expected to be similar.

Considering these comparisons, the Risk rankings of Alternatives 1, 2, and 3 are “3”, “2”, and “1” respectively.

3.6 Benefits

This criterion requires a comparative evaluation of the RAAs in terms of:

(a) the benefit of restoring natural resources;
(b) providing for the productive reuse of the site;
(c) the avoided costs of relocating people, businesses, or providing alternative water supplies; and
(d) the avoided lost value of the site.

The three alternatives are expected to have similar effectiveness in reducing groundwater concentrations to GW-1 standards, and levels approaching background. All three RAAs are ranked “2” for the Benefits criterion.

3.7 Timeliness

This criterion requires a comparative evaluation of the RAAs in terms of timeliness in eliminating any uncontrolled sources of oil and/or hazardous material and achieving of a level of No Significant Risk (NSR). Considering current levels of arsenic and chlorobenzenes around the levels of GW-1 standards, achieving a condition of NSR would likely require the most time for cVOCs in groundwater. Alternative 1 (MNA) is expected to take the longest (5-10 years) to achieve remediation goals due to reliance on natural groundwater flow gradients and contaminant degradation mechanisms. Natural attenuation appears to have reduced PCE concentrations at LR-MW-129 from 100 ppb to ND in a period of four years. Alternative 2 (ISCO/MNA) is expected to achieve NSR quickest (2-4 years) for organic contaminants considering the in-situ delivery of oxidant for treatment throughout the contaminant plume. Alternative 3 (P&T/MNA) may achieve NSR for organic contaminants within an intermediate timeframe considering the ability to remove contaminants at multiple locations throughout the plume but limitations on mass transfer rates between aquifer materials and groundwater.

Considering these comparisons, the Timeliness rankings of Alternatives 1, 2, and 3 are “1”, “3”, and “2” respectively.

3.8 Relative effects upon non-pecuniary interests

This criterion requires a comparative evaluation of the RAAs in terms of non-pecuniary interests, such as aesthetic values. Alternatives 1 and 2 are expected to have no impact on the Site aesthetic values, since neither alternative would result in any above-ground infrastructure. Alternative 3 would have a minimal impact associated with a small above-ground treatment system. All three RAAs are ranked “2” for this criterion.

4.0 SELECTION OF AN RAA & FEASIBILITY EVALUATION [310 CMR 40.0859-60]

A Remedial Action Alternative is selected in this section based on the detailed evaluation presented in Section 3. The sums of the comparative rankings in Section 3 are 18 for Alternative 1, 17 for Alternative 2, and 15 for Alternative 3, assuming an equal weighting for each of the eight evaluation categories, as indicated in Table 8. These sums suggest that Alternative 1 is more feasible than Alternative 2, and both are more feasible than Alternative 3.

The three alternatives had the same relative rankings for the Effectiveness, Benefits, and Non-Pecuniary criteria. Alternative 1 was ranked highest for Implementability, Cost, and Risks, and was ranked lowest for Timeliness. Alternative 2 was ranked highest for Timeliness and co-ranked highest (with Alternative 3) for Reliability, and was ranked lowest for Cost. Alternative 3 was co-ranked highest for Reliability, was ranked between the others for Cost, and was ranked lowest for Implementability and Risks.

Considering these rankings Alternative 1 is selected as the most feasible RAA. Alternative 1 (MNA) is a Permanent Solution that appears likely to achieve a condition of NSR. MNA has already produced significant reductions in arsenic and cVOC concentrations at individual wells over the past four years of groundwater monitoring. Alternative 1 appears capable of achieving or approaching background for cVOCs -- which are expected to require the greatest reductions in groundwater concentrations – and the other contaminants. Since the selected RAA is a Permanent Solution and it appears feasible to achieve or approach background, no demonstration of infeasibility is made in accordance with 310 CMR 40.0860.

5.0 SCHEDULE FOR PHASE IV [310 CMR 40.0861(2)(I)]

The public comment period for this RAP is presently expected to occur in October 2011 as indicated below. In accordance with the MCP and the PIP, the public may request extension of the comment period. Phase IV activities, which include design and construction of the selected RAA, will begin once all public comments on the RAP have been addressed and the RAP has been finalized. Following is the projected schedule for Phase IV and the activities leading up to it:

- 09/30/11 submit Draft Phase III RAP and public comment period begins
- 10/25/11 conduct public meeting for the Draft Phase III RAP
- 10/31/11 public comment period ends for the Draft Phase III RAP
- 12/16/11 submit Final Phase III RAP; begin Phase IV Implementation of the Selected Remedial Action Alternative
- 02/14/12 submit Draft Phase IV Remedy Implementation Plan (RIP) and public comment period begins
- 02/28/12 conduct public meeting for the Draft Phase IV RIP
- 03/06/12 public comment period ends for the Draft Phase IV RIP
- 04/06/12 submit Final Phase IV RIP
- 06/01/12 complete remedy construction and submit Final Inspection Report & Phase IV Completion Statement; begin Phase V Operation, Maintenance, and Monitoring (OMM)

The estimated timeframe for achieving a condition of NSR is 5-10 years from the expected 2012 start of implementation, as indicated in Section 3.7.

6.0 PUBLIC NOTIFICATION

Public notification letters are required at the completion of each phase of the MCP process, pursuant to 310 CMR 40.1403(3)(e). Copies of letters to the Chief Municipal Officer and Board of Heath, notifying them of the findings and conclusions of the Phase III Remedial Action Plan, are provided in Appendix A. This Phase III Remedial Action Plan will be submitted electronically through eDEP, the MassDEP's Online Filing System, after public comment and final revisions. A copy of transmittal form BWSC-108 will be provided in Appendix B in final paper copies of the document.

7.0 REFERENCES

AFCEE 2010. Sustainable Remediation Tool, May 2010. http://www.afcee.af.mil/resources/technologytransfer/programsandinitiatives/sustainableremediation/srt/index.asp

AMEC 2011. Phase II Comprehensive Site Assessment Report for RTN 4-3024222, Former Bird Machine Company Site. Prepared by AMEC Earth & Environmental Inc. for Baker Hughes Inc. Draft, June XX 2011.

USEPA 1999. Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites. OSWER Directive 9200.4-17P. April 21, 1999.

Walpole 2007. Letter from John Spillane, Chairman, Town of Walpole Board of Water & Sewer Commissioners, to Dina Kuykendall, BHI. October 25, 2007.

Weston 2005. Phase I Initial Site Investigation Report for RTN 3-0024222, Bird Machine Company Manufacturing Building Area. Prepared by Weston Solutions Inc. for Baker Process Inc. September 14, 2005.

Weston 2007. Phase II Comprehensive Site Assessment for Release of Hydrocarbons to the Neponset River Site, RTN 4-3023575. Prepared by Weston Solutions Inc. for Baker Process Inc. January 25, 2007.

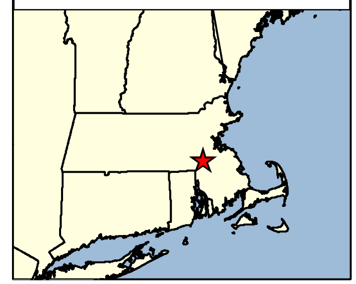
FIGURE 1

SITE LOCATION MAP

Bird Machine Inc. Company

100 Neponset Street
Walpole, MA

Location of Site



Source: Topo quad provided by National Geographic TOPO! Series: 2008

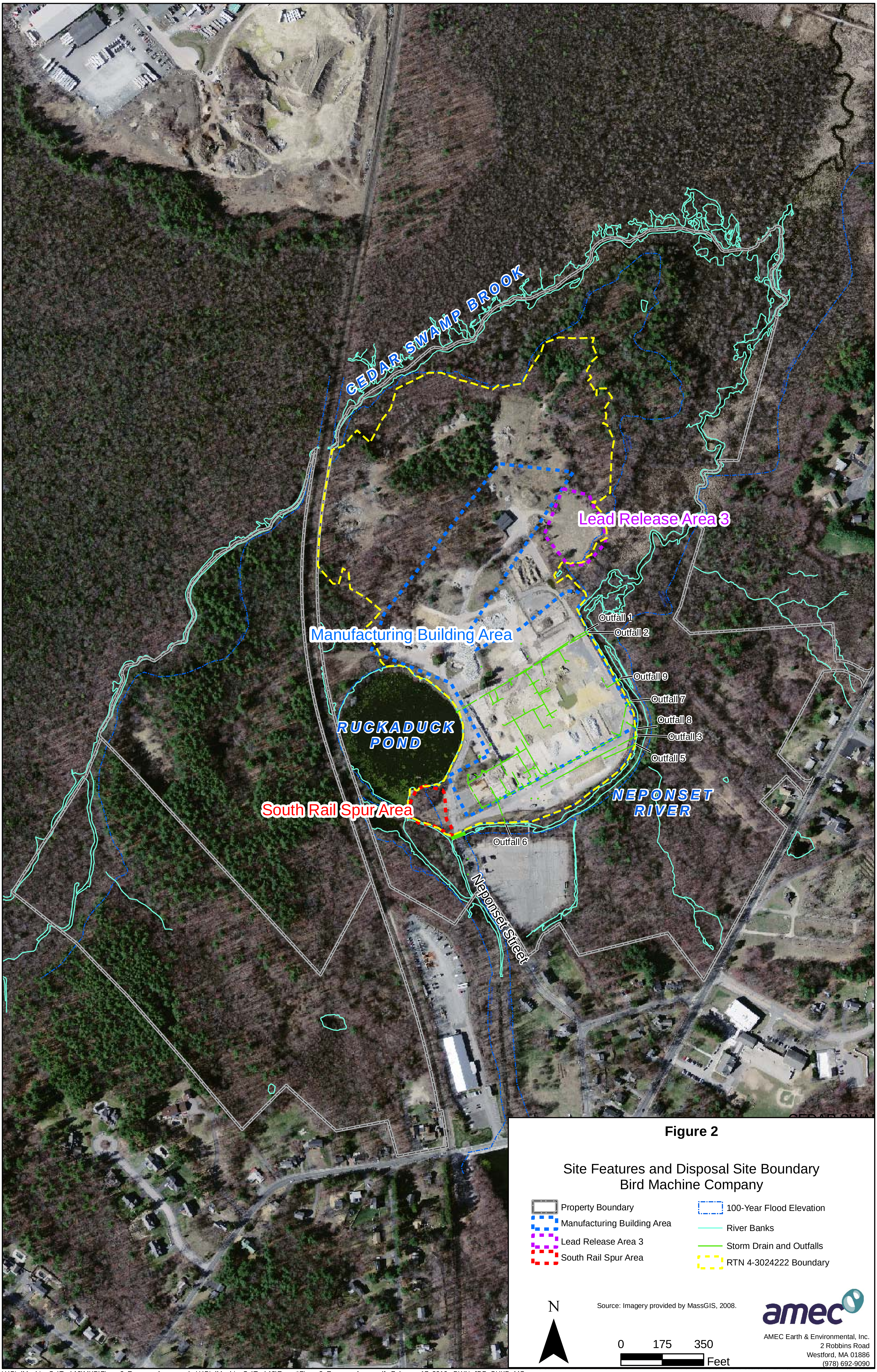
0 2,000 Feet

amec

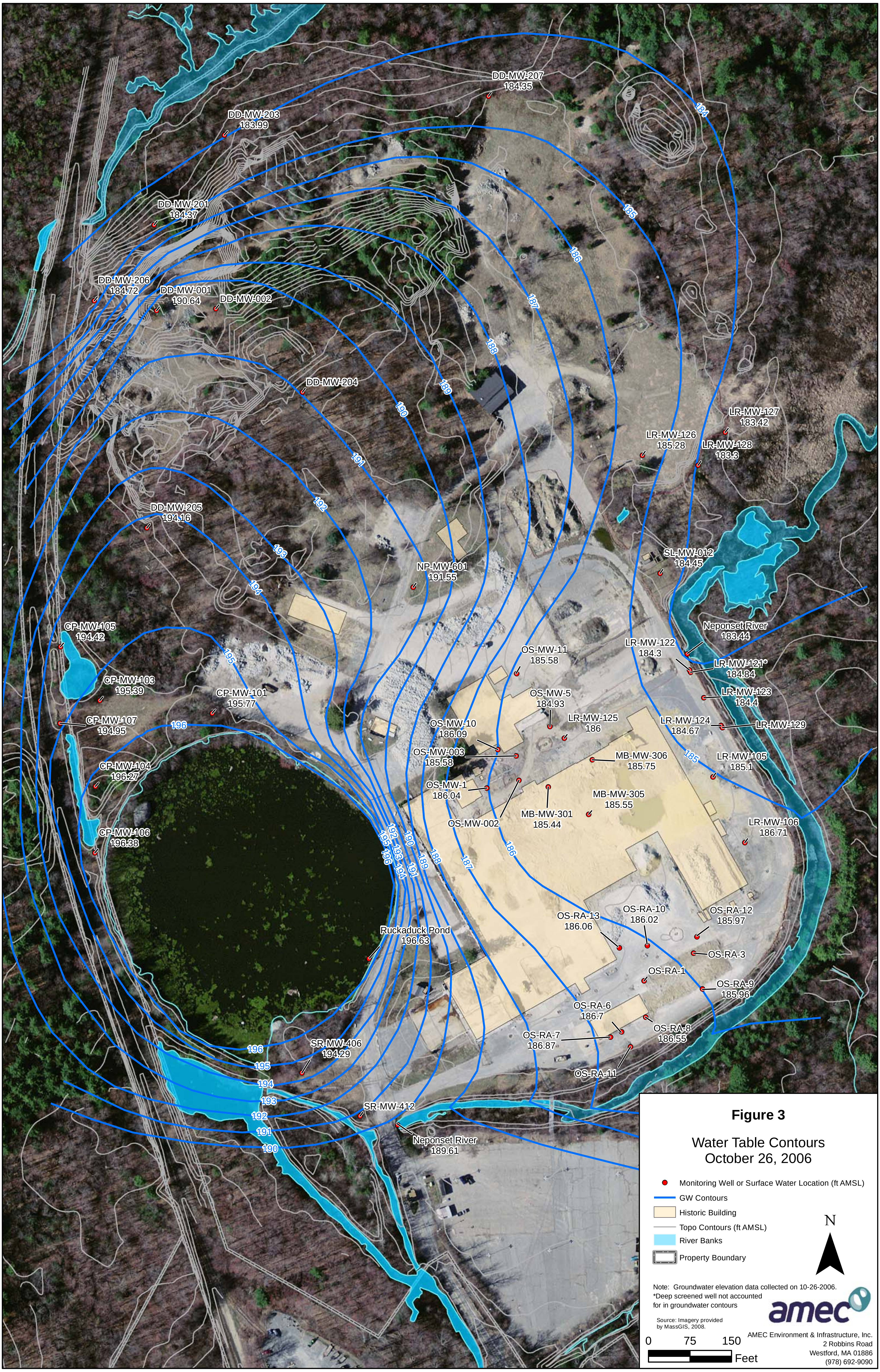
AMEC Earth & Environmental, Inc.
2 Robbins Road
Westford, MA 01886
(978) 692-9090

N

H:\BirdMachineCo\Task12\MXD\SiteMap.mxd H:\BirdMachineCo\Task12\Export\SiteMap.pdf February 15, 2011 DWN: JDP CHKD: KW



H:\BirdMachineCo\Task12\MXD\Figure2_ExposureAreas.mxd H:\BirdMachineCo\Task12\Export\Figure2_ExposureAreas.pdf February 17, 2010 DWN: JDP CHKD: MG



H:\BirdMachineCo\Task15\MXD\Figure3.mxd September 28, 2011 DWN: alisa.churchill CHKD: AKN

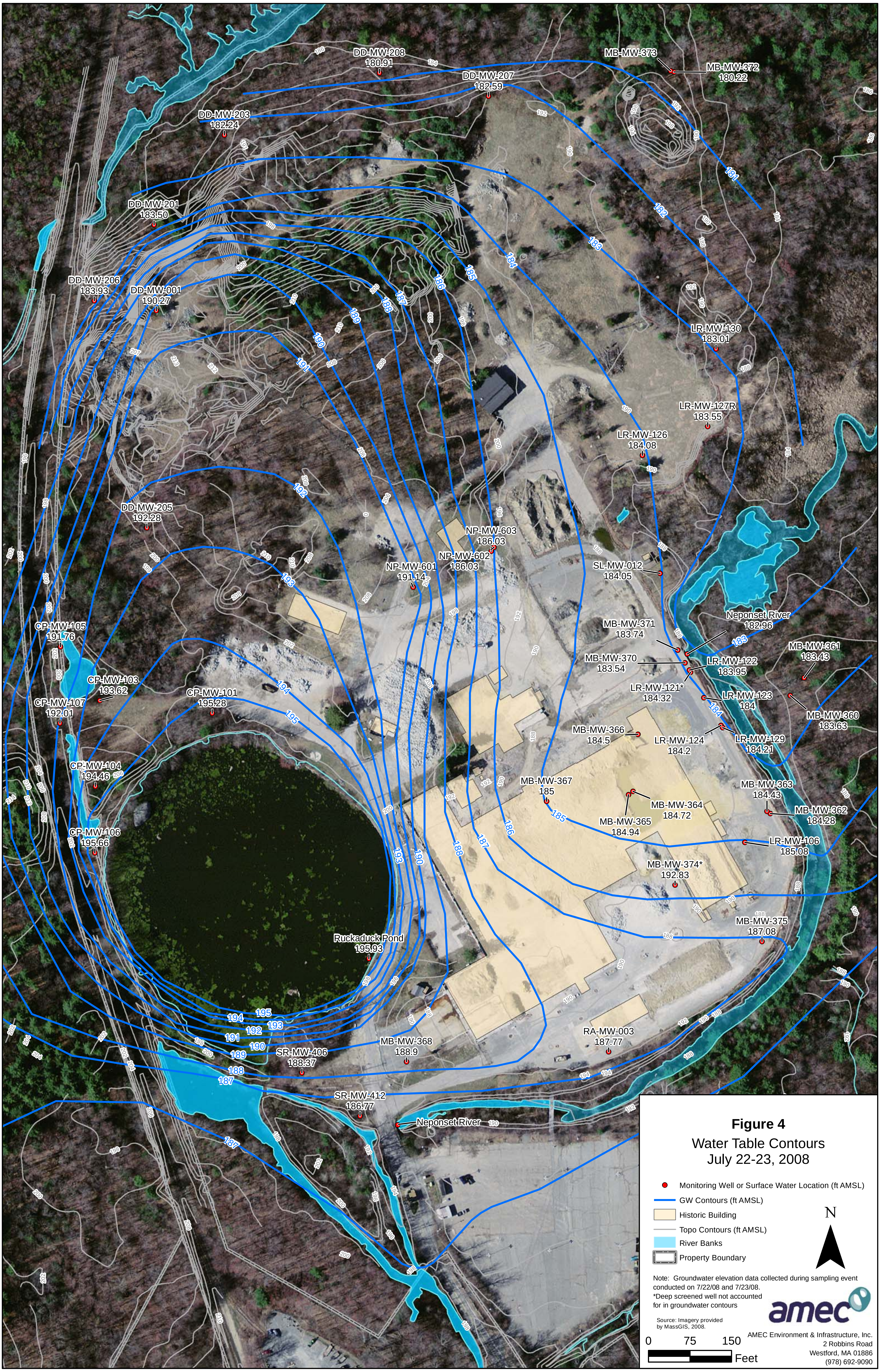


Figure 4
Water Table Contours
July 22-23, 2008

H:\BirdMachineCo\Task15\MXD\Figure4.mxd September 28, 2011 DWN: alisa.churchill CHKD: JDP

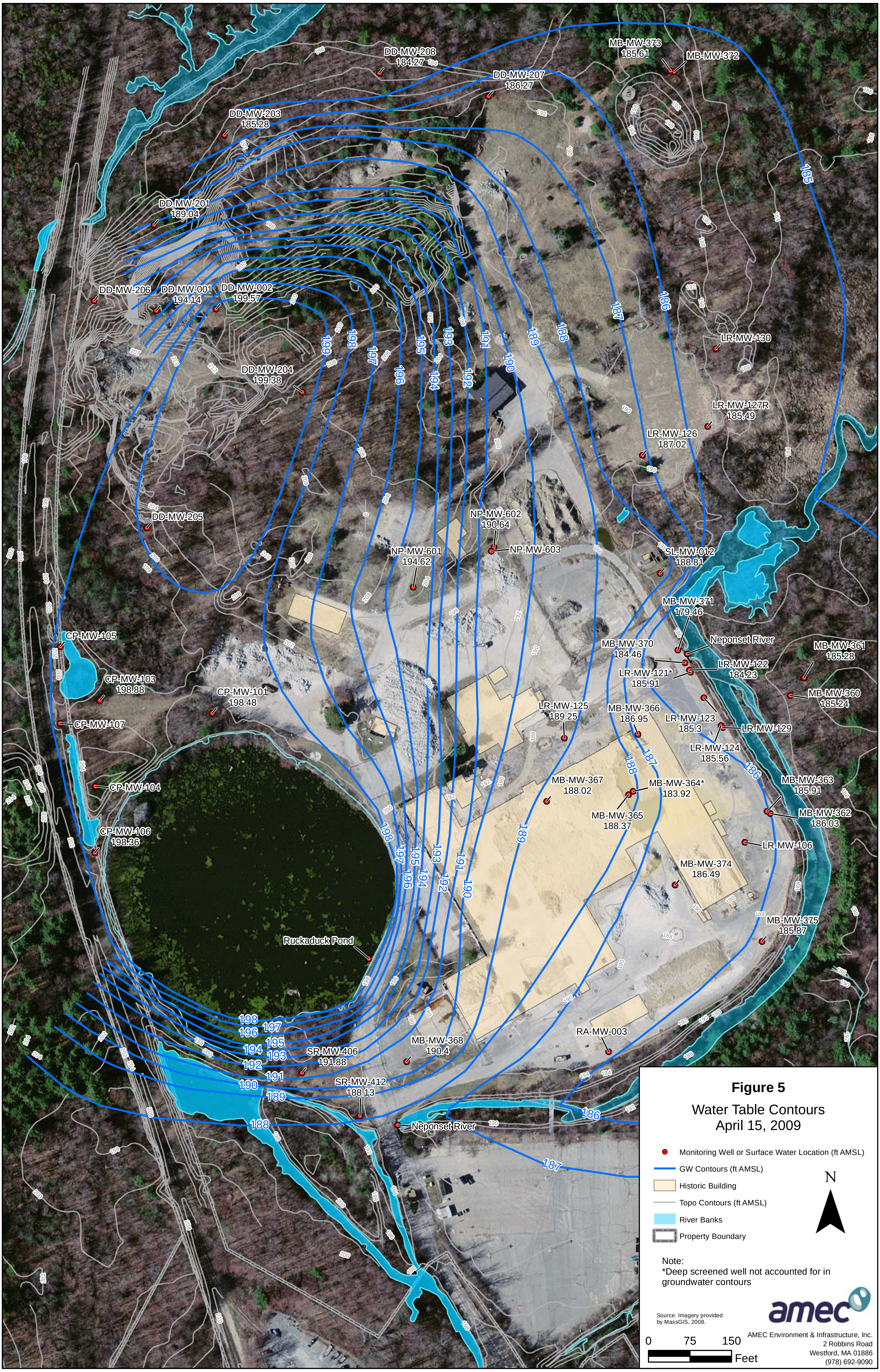
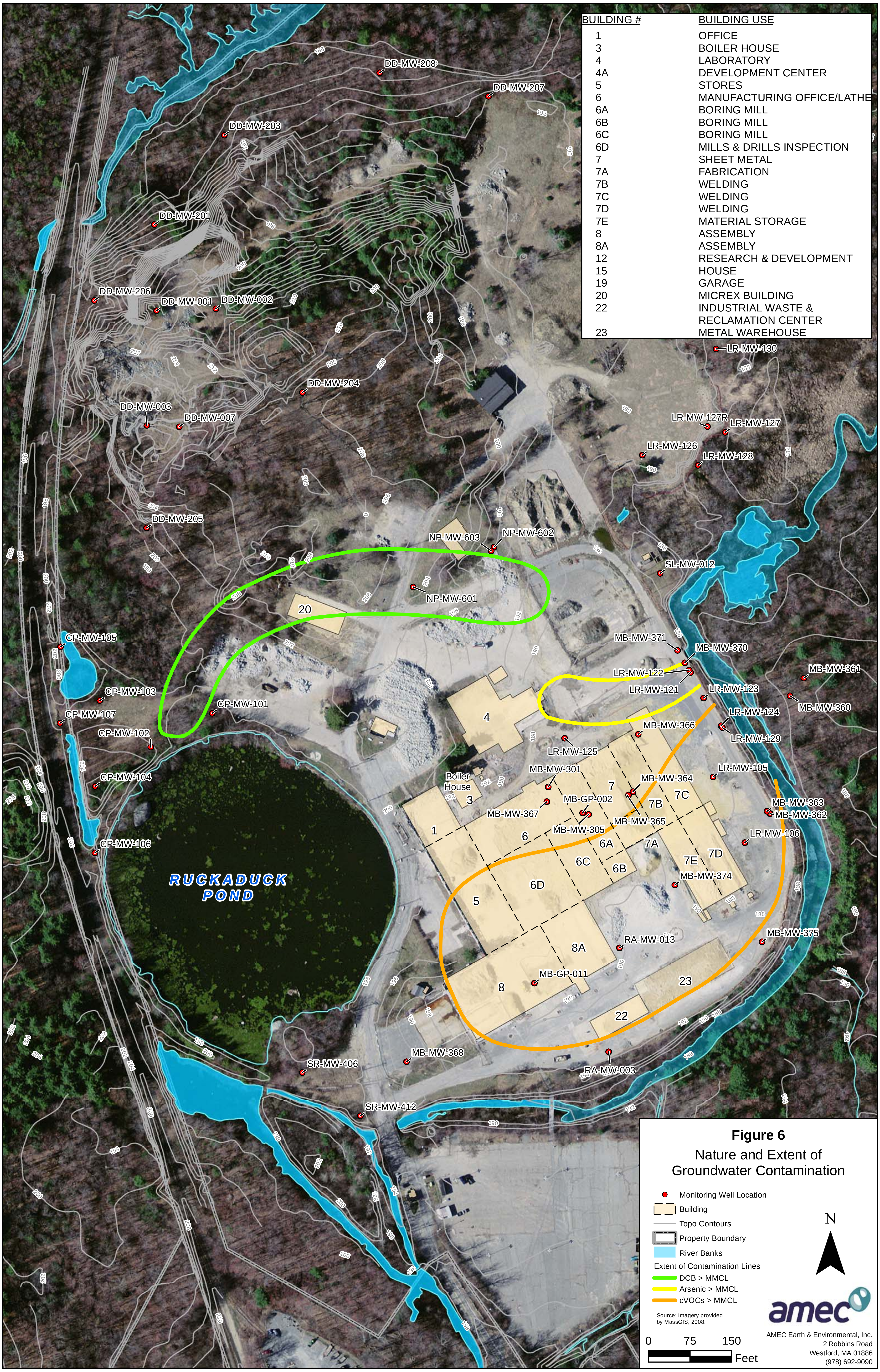


Figure 5
Water Table Contours
April 15, 2009

H:\BirdMachineCo\Task15\MXD\Figure5.mxd September 28, 2011 DWN: alisa.churchill CHKD: JDP



H:\BirdMachineCo\Task15\MXD\Figure6.mxd September 29, 2011 DWN: alisa.churchill CHKD: JDP

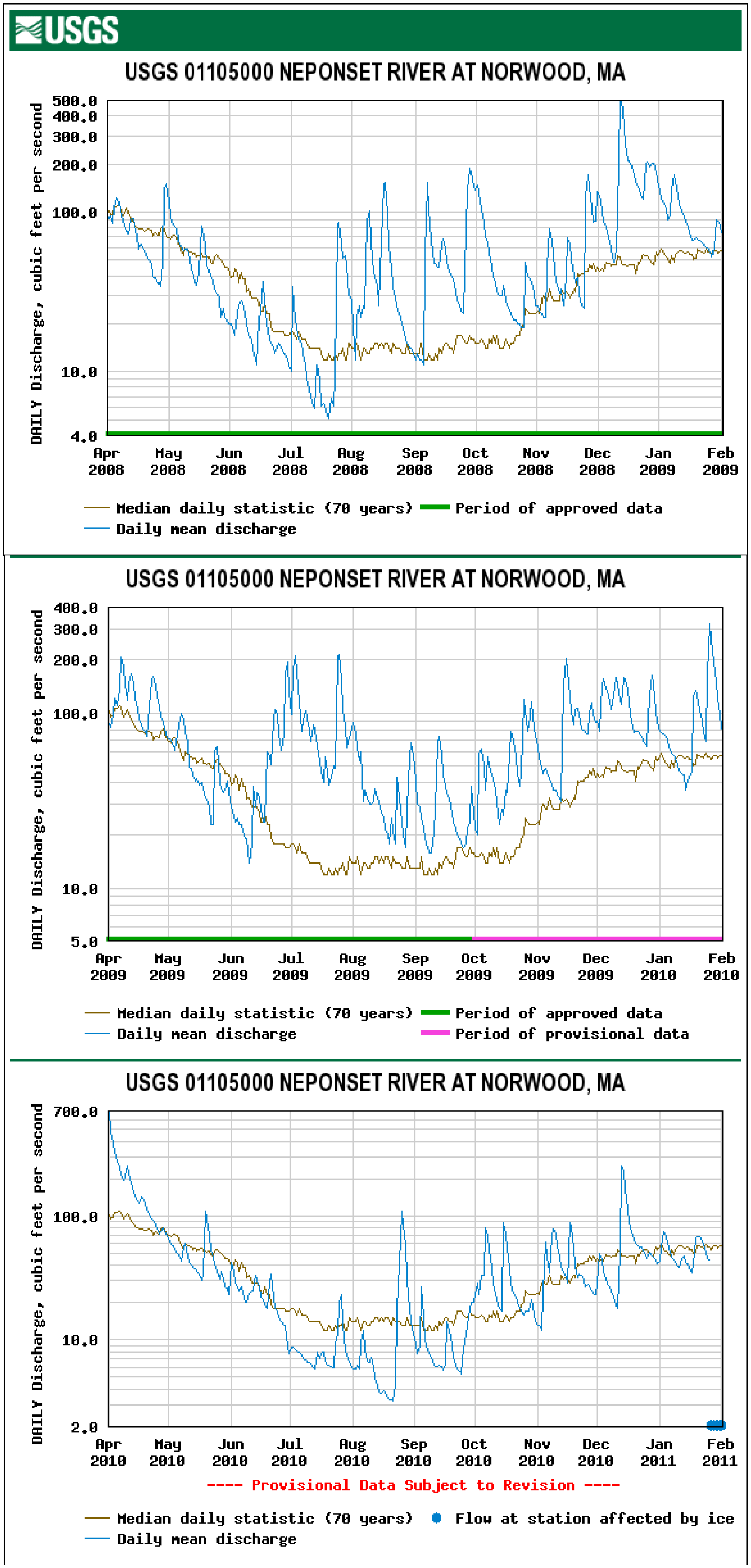
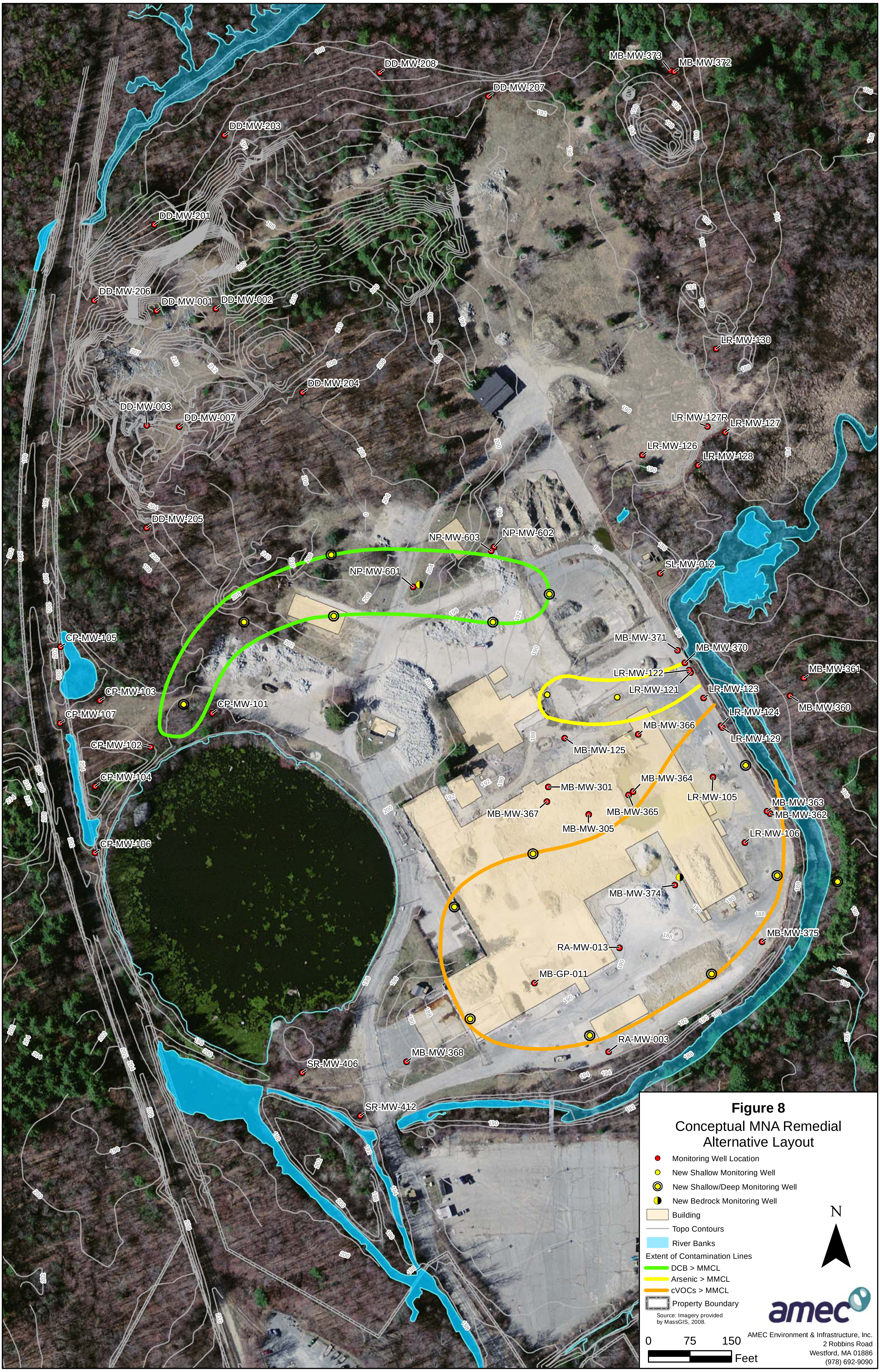
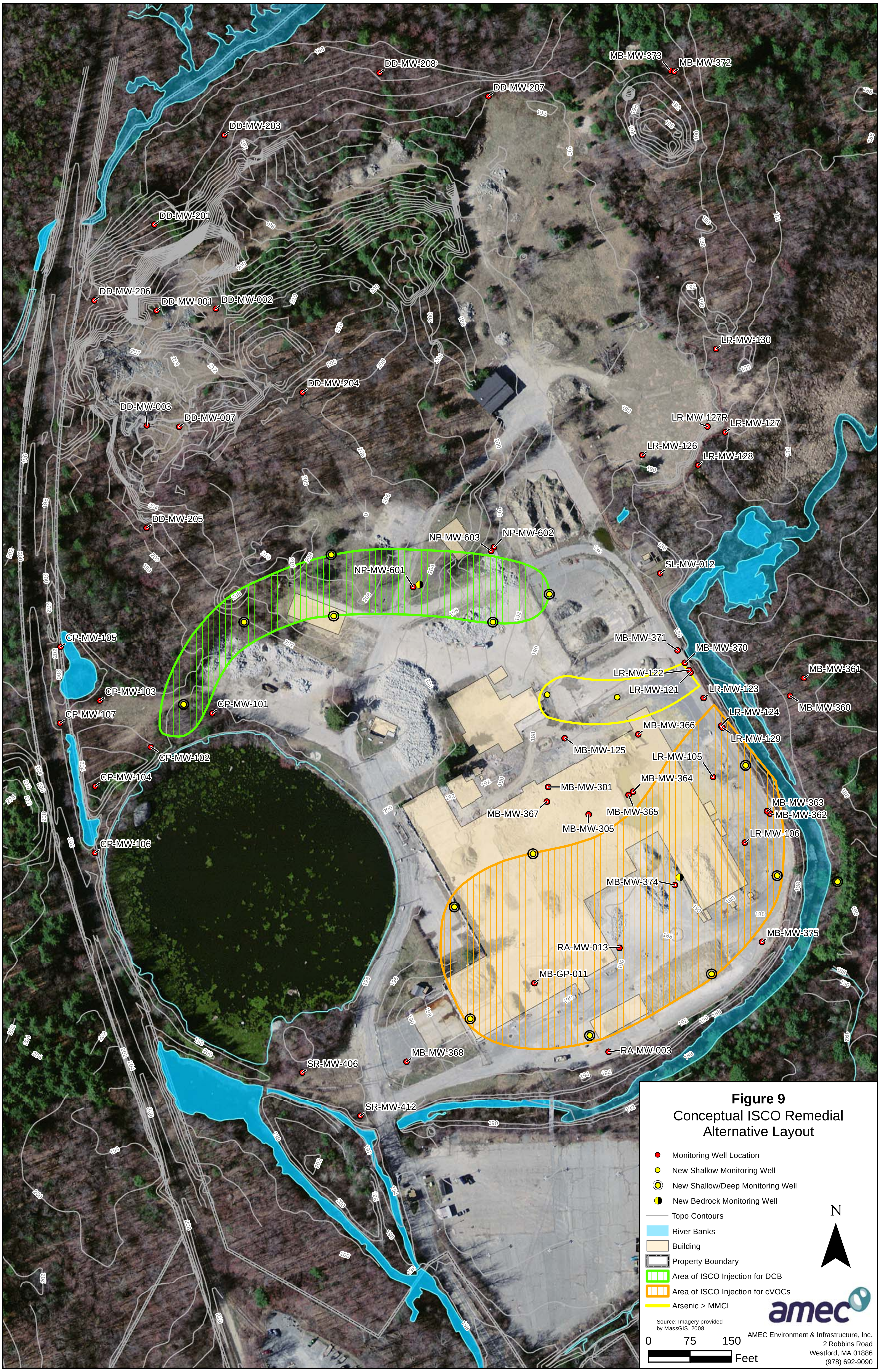


Figure 7. USGS Hydrographs for Neponset River



H:\BirdMachineCo\Task15\MXD\Figure8.mxd September 29, 2011 DWN: alisa.churchill CHKD: JDP



H:\BirdMachineCo\Task15\MXD\Figure9.mxd September 29, 2011 DWN: alisa.churchill CHKD: JDP

Figure 10
Conceptual Pump & Treat
Remedial Alternative Layout
Monitoring Well Location
New Shallow Monitoring Well
New Shallow/Deep Monitoring Well
New Bedrock Monitoring Well
Extraction Well
Topo Contours
River Banks
Building
Property Boundary
Extent of Contamination Lines
DCB > MMCL
Arsenic > MMCL
cVOCs > MMCL
Source: Imagery provided
by MassGIS, 2008.
0 75 150
Feet
N
amec
AMEC Environment & Infrastructure, Inc.
2 Robbins Road
Westford, MA 01886
(978) 692-9090
Treatment System Enclosure
DD-MW-208
DD-MW-207
DD-MW-203
DD-MW-201
DD-MW-206
DD-MW-001
DD-MW-002
DD-MW-204
DD-MW-003
DD-MW-007
DD-MW-205
MB-MW-373
MB-MW-372
LR-MW-130
LR-MW-127R
LR-MW-127
LR-MW-126
LR-MW-128
NP-MW-603
NP-MW-602
NP-MW-601
SL-MW-012
CP-MW-105
CP-MW-103
CP-MW-107
CP-MW-101
CP-MW-102
CP-MW-104
CP-MW-106
MB-MW-371
MB-MW-370
LR-MW-122
LR-MW-121
LR-MW-123
MB-MW-361
MB-MW-360
MB-MW-366
LR-MW-124
MB-MW-125
LR-MW-129
MB-MW-364
LR-MW-105
MB-MW-301
MB-MW-367
MB-MW-365
MB-MW-305
MB-MW-363
MB-MW-362
LR-MW-106
MB-MW-374
MB-MW-375
RA-MW-013
MB-GP-011
RA-MW-003
MB-MW-368
SR-MW-406
SR-MW-412

Table 5
Screening of Remedial Technologies

Option	Description	Advantages	Disadvantages	Relative Cost	Likely Feasible and achieve a level of NSR?
Monitored Natural Attenuation *(In-situ)*	Contaminants naturally diminish over time. Regular groundwater monitoring to observe progress.	• Minimal above ground construction • Requires no removal, treatment, storage, or discharge of groundwater	• Typically moderate or longer treatment times.	Low	Yes
Air Sparging with Soil Vapor Extraction (SVE) *(In-situ)*	Air is injected below the water table to mobilize contaminants into the vapor phase. Volatile contaminants are collected above water table via SVE for treatment.	• Minimal above ground construction • Requires no removal, treatment, storage, or discharge of groundwater • Typically short treatment times, <3 years under optimal conditions	• Not effective for arsenic • Vapor extraction may be difficult due to shallow water table and presence of heterogeneous fill materials	Medium	Possibly for organics
Enhanced Bioremediation *(In-situ)*	Microorganisms break down organic contaminants using them as a food source. Degradation is enhanced by injection of oxygen and/or nutrients into the contaminated zone.	• Minimal above ground construction • Requires no removal, treatment, storage, or discharge of groundwater	• Not effective for arsenic	Medium	Yes for organics

Option	Description	Advantages	Disadvantages	Relative Cost	Likely Feasible and achieve a level of NSR?
In-situ Chemical Oxidation (ISCO) *(In-situ)*	Injection of chemical reagents and amendments into groundwater at different depths to oxidize organic contaminants.	• Minimal above ground construction • Requires no removal, treatment, storage, or discharge of groundwater • Typically short treatment times, <3 years under optimal conditions	• Not effective for arsenic	Medium	Yes for organics
Permeable Reactive Wall *(In-situ)*	A Permeable Reactive Wall is installed across the flow path of a plume, and contaminants are treated or immobilized as the groundwater flows through the wall.	• Once installed, requires no removal, treatment, storage, or discharge of groundwater	• Typically moderate or longer treatment times • Installation requires significant construction • Less feasible for a wide groundwater discharge area	High	No
Pump and Treat *(Ex-situ)*	Contaminated groundwater is pumped from wells and treated aboveground using a treatment train to remove contaminants, then discharged.	• Minimal above ground construction	• Treatment/disposal of groundwater necessary; permits required • Effectiveness typically decreases over time due to mass transfer limitations	High	Yes

Table 6. Summary of Estimated Costs for Groundwater Remedies

Alternative	Contaminant	Technology	Capital Cost (1)	Annual O&M	Duration (yr)	Present Worth (2)
1	Arsenic	MNA	$ 130,000	$ 15,000	9	$ 227,725
1	PCE	MNA	$ 390,000	$ 23,000	9	$ 539,845
1	DCB	MNA	$ 160,000	$ 17,000	9	$ 270,755
					Alternative 1 Total	$ 1,038,325
2	Arsenic	MNA	$ 130,000	$ 15,000	9	$ 227,725
2	PCE	ISCO	$ 6,600,000	$ 23,000	3	$ 6,660,352
2	DCB	ISCO	$ 2,400,000	$ 17,000	3	$ 2,444,608
					Alternative 2 Total	$ 9,332,685
3	Arsenic	MNA	$ 130,000	$ 15,000	9	$ 227,725
3	PCE	P&T	$ 2,100,000	$ 340,000	7	$ 3,932,260
3	DCB	P&T	$ 1,700,000	$ 270,000	7	$ 3,155,030
					Alternative 3 Total (3)	$ 5,795,015

Notes & Abbreviations:

MNA = Monitored Natural Attenuation

ISCO = In Situ Chemical Oxidation

P&T = Pump and Treat

(1) Capital and O&M Costs are from AFCEE 2010; inputs and outputs are attached in Appendix C

(2) Present Worth Costs are calculated using a 7% discount rate

(3) The sum of P&T Capital Costs is reduced 40% to account for a single P&T treatment system

Table 7
Proposed Groundwater Sampling Analytical Methods

Parameters	Field/Laboratory	MCP SW-846 Method
Contaminants of Concern		
Arsenic	Laboratory	Metals 6010B, 7000
Chlorobenzene	Laboratory	Volatile 8260B, 8021B
Chlorinated VOCs	Laboratory	Volatile 8260B, 8021B
Natural Attenuation Parameters		
Dissolved Oxygen	Field	Meter
pH	Field	Meter
Temperature	Field	Meter
Conductivity	Field	Meter
Nitrate [NO_3^-]	Laboratory	IC Method E300
Ferrous iron [Fe(II)]	Field	Hach 8146 test-kit
Sulfate [$SO_4^=$]	Laboratory	IC Method E300
Hydrogen sulfide [H_2S]	Field	Color disk, Methylene Blue method; Hach 2238-01 test-kit
Methane [CH_4]	Laboratory	Kampbell et al. (1989) or SW-846 Method 3810 Modified
Alkalinity	Field	Hach AL AP MG-L test-kit
ORP	Field	Meter

Table 8. Remedial Alternative Scoring Summary

Remedial Alternative	Score									
	Effectiveness	Short- and Long-Term Reliability	Implementability	Costs	Risks	Benefits	Timeliness	Non-Pecuniary Interests	Total Score	Estimated Cost (in Millions)
1. MNA for all contaminants	2	2	3	3	3	2	1	2	18	$ 1.0
2. ISCO for organics and MNA for arsenic	2	3	2	1	2	2	3	2	17	$ 9.3
3. P&T for organics and MNA for arsenic	2	3	1	2	1	2	2	2	15	$ 5.8

Appendix A – Public Notification Letters

1. Draft RAP Transmittal Letter dated 10/6/11 including PIP Mailing List Notice of Document Availability, Public Comment Period, and date of upcoming Public Meeting

2. Final RAP Transmittal Letter including PIP Mailing List Notice of Document Availability (to be included in final document)

October 6, 2011

Mr. Gerard Martin
Massachusetts Department of Environmental Protection
Southeast Regional Office
Bureau of Waste Site Cleanup
20 Riverside Drive, Lakeville, Massachusetts 02347

Dear Mr. Martin:

Re: Public Comment Draft
Phase III Remedial Action Plan
100 Neponset Street
Walpole, Massachusetts
RTN 4-3024222

On behalf of Baker Hughes, Inc. (Baker Hughes), AMEC Earth and Environmental (AMEC) is providing this Public Comment Draft of the Phase III Remedial Action Plan (RAP) for the Bird Machine Company Site, Release Tracking Number (RTN) 4-3024222, which is located at 100 Neponset Street in Walpole, Massachusetts. The RAP describes and evaluates remedies for areas of groundwater contamination that were identified in the July 2011 Public Comment Draft of the Phase II Comprehensive Site Assessment (CSA) for this RTN. A response to public comments on the CSA is being prepared and will be provided shortly.

The public comment period for the Draft RAP will begin on October 6, 2011and will extend through October 28, 2011. Comments can be submitted to Chris Clodfelter of Baker Hughes at the following address:

Chris Clodfelter
Senior HS&E Specialist
Baker Hughes Incorporated
2929 Allen Parkway
Suite 2100
Houston, Texas 77019-2118
Office: 713.439.8329 | Fax: 713.439.8383

Copies of the Draft RAP will be available at the MassDEP Southeast Regional Office (File Review Telephone Number: 508-946-2718) and at the Walpole Public Library (Telephone Number: 508-660-7341). A copy of the executive summary of the Draft RAP, which summarizes the findings and conclusions presented in the document, is attached to this letter. A copy of this letter including the summary is being sent via US Mail to the Public Involvement Plan (PIP) Mailing List for the Site.

Baker Hughes will present a summary of the Draft RAP and be available to answer questions at a public meeting tentatively scheduled for Tuesday October 25, 2011. Please contact me if you have any questions regarding the Public Involvement process for this document.

Sincerely,

Kim M. Henry
LSP No. 7122

cc:

Mr. Michael Boynton, Walpole Town Administrator
Ms. Robin Chapell, Walpole Health Agent
Ms. Landis Hershey, Walpole Conservation Agent
Ms. Deborah Burke, Key Petitioner
Public Involvement Plan Mailing List

Enclosure:

Draft Phase III RAP Executive Summary

AMEC Earth & Environmental, Inc.
2 Robbins Road
Westford, MA 01886
Tel +(978) 692-9090
Fax +(978) 692-6633

COPY OF DRAFT PHASE III RAP - EXECUTIVE SUMMARY

On behalf of Baker Hughes, Inc. (BHI), AMEC Earth and Environmental, Inc. (AMEC) completed this Phase III Remedial Action Plan (RAP) of the former Bird Machine Company (BMC) Site located in Walpole, Massachusetts. BHI is submitting this RAP pursuant to 310 CMR 40.0850 of the Massachusetts Contingency Plan (MCP). This RAP documents selection of a Remedial Action Alternative (RAA) which is a likely Permanent Solution for the Site, and evaluates the feasibility of achieving or approaching background levels of oil or hazardous material. A Permanent Solution will achieve a condition of No Significant Risk (NSR) for current and reasonably forseeable site uses.

The Site includes multiple RTNs due to the discovery of various releases at the property over a period of several years. Three separate exposure areas were identified and evaluated in the Draft Phase II Comprehensive Site Assessment (CSA) Report (AMEC 2011). Release Abatement Measures (RAMs) were conducted at several locations to reduce the mass and concentrations of contaminants at the Site. The CSA indicates that a condition of NSR exists for all areas of the Site except groundwater, where some monitoring well concentrations exceed drinking water criteria (Massachusetts Maximum Contaminant Levels or MMCLs). It is unlikely that groundwater at the Site will be used for drinking water, but the Site is within a Potential Drinking Water Source Area designated by the Town of Walpole (Walpole 2007). Considering this designation, groundwater at the Site is categorized as GW-1 under the MCP. Background information and remedial action objectives for the Site are summarized in Section 1 of this RAP.

Areas of groundwater contamination exceeding MMCLs have been identified for arsenic, chlorinated Volatile Organic Compounds (cVOCs), and 1,4-dichlorobenzene (DCB). Response actions and technologies to remove these contaminants have been evaluated and three RAAs have been identified that are reasonably likely to be feasible Permanent Solutions for the Site. These three RAAs are (1) Monitored Natural Attenuation (MNA) for all contaminants; (2) In-Situ Chemical Oxidation (ISCO) for organic contaminants and MNA for arsenic; and (3) Pump & Treat for organic contaminants and MNA for arsenic. A conceptual design of each alternative is provided in Section 2 of this RAP, including key components, a conceptual layout, treatment residuals or wastes requiring disposal, permit requirements, and a discussion of limitations, assumptions, and uncertainties.

A detailed evaluation of the three RAAs using eight criteria established under the MCP is provided in Section 3 of this RAP. The alternatives are compared and ranked based on estimates of their effectiveness, reliability, implementability, costs, risks, benefits, timeliness, and other impacts. Alternative 1 (MNA) received the highest rankings as indicated in Section 4, and has been selected for implementation in Phase IV. Alternative 1 is expected to provide a Permanent Solution that achieves a condition of NSR. MNA has already produced significant reductions in arsenic and cVOC concentrations at individual wells over the past four years of groundwater monitoring. Alternative 1 appears capable of achieving or approaching background for cVOCs -- which are expected to require the greatest reductions in groundwater concentrations – and for the other contaminants.

A schedule for activities leading up to and including Phase IV is provided in Section 5. Following public comment and a meeting to discuss this RAP, this document will be finalized, and design of the groundwater remedy will be initiated. Completion of construction is expected by June 2012, at which time operation of the remedy in Phase V will be initiated. The estimated timeframe for achieving a condition of NSR is 5-10 years from the start of operations.

Appendix B – BWSC Transmittal Form 108

(to be included in final hardcopy document)

Appendix C – Input and Output Data for AFCEE Sustainable Remediation Tool

1. Arsenic Plume GW Input and MNA Output (3 pp)
2. DCB Plume GW Input and MNA, ISCO, and P&T Outputs (7 pp)
3. PCE Plume GW Input and MNA, ISCO, and P&T Outputs (7 pp)

GROUNDWATER INPUT

Arsenic plume
Bird Machine, Walpole MA

Instructions:
= Enter your data here. Click button to the right of the cell for help.
= Use this default value or override with your own.
= Calculated value. You cannot change this.

Paste Tier 2 Ex | Restore Defaults | Clear GW Inputs

Recommended flow:
You are here
Input → Next: Choose Technologies
- [x] Pump & Treat
- [x] Enhanced Bioremediation
- [x] In Situ Chemical Oxidation
- [x] PRB
- [x] LTM / MNA

>>
→ Results

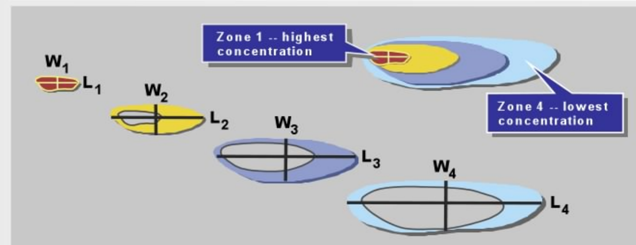
Dimensions & Concentrations (Zone 1 & 2 reqd)

	Zone 1	Zone 2	Zone 3	Zone 4	
Width	75	100			ft
Length	300	400			ft
Area of "doughnut"	22,500	17,500	0	0	ft^2

Contaminant Class: CVOCs — (•) ug/L ( ) mg/L

	Zone 1	Zone 2	Zone 3	Zone 4
Conc Low	5	1		
Conc High	10	5		
Representative zone concentration	7.1	2.2	0	0

Depth to Water	5	ft
Depth to Top of Formation	25	ft
Thickness of Water-bearing Unit	10	ft
Aquifer Media	Sand (well graded)	
Hydraulic Conductivity	0.01	cm/s — 0.01 cm/s
Hydraulic Gradient	0.003	-
Porosity	0.25	
Groundwater seepage velocity	120	ft/year



Calculate natural resource service? ( ) Yes (•) No

LTM / MNA - TIER 2
Arsenic plume
Bird Machine, Walpole MA
CAPITAL and O&M

Instructions:
= Enter your data here. Click button to the right of the cell for help.
= Use this default value or override with your own.
= Calculated value. You cannot change this.

Restore Defaults

Recommended flow:
Main → Input → Technology Design (Pump & Treat, Enhanced Bioremediation, In Situ Chemical Oxidation, PRB, LTM / MNA) → Results

Design for Managing Groundwater

Airline miles flown by project team (total miles for all travelers)	0	miles over proj lifetime
Average Distance Traveled by Site Workers per one-way trip	50	miles one-way
Trips by Site Workers during construction	10	# over project lifetime
Trips by Site Workers after construction (not including sampling)	10	# over project lifetime

Tier 2: Change Calculated Values (dark gray cells)

Number of monitoring wells	2	#
Length of piping, per well	20	ft
Number of characterization (baseline) sampling events	1.	#
Number of sampling events in the first year	4.	#
Number of sampling events per year in subsequent years	4.	#/year
Duration	10.	years
Number of samples collected per sampling event	8	#/event

Plume Calculation Method: ks / Enter Directly

Source zone point decay rate constant (k_s) 0.23 1/year

	Original Plume		Plume After Project	
Plume Area	0.92	acres	0.	acres
Plume Length	400.	feet	1.1	feet
Plume Volume	0.73	mil gals	0.	mil gals
Dissolved Mass	0.014	kg	0.	kg

Materials and Consumable Amounts Used for Metrics

PVC	81.	lbs
Diesel	12.8	gal
Gasoline (Capital)	100.	gal
Gasoline (O&M)	310.	gal

Technology Cost

Capital	130,000.	$
O&M	150,000.	$ over project

Project-specific Metrics (Add & Subtract/Offsets)

Yes / No

Additional Technology Cost		$
Total Energy Consumed		Megajoules
CO_2 Emissions to Atmosphere		tons CO_2
Safety / Accident Risk		lost hours

Design Calculations - LTM / MNA

Number of monitoring wells (entered above)	2.	#
Number of characterization (baseline) sampling events	1.	#
Number of sampling events in the first year	4.	#
Number of sampling events per year in subsequent years	4.	#/year
Duration	10.	years

Restore Defaults (Detail Section)

Materials and Consumable Calculations - LTM / MNA

Length of PVC per well (entered above)	20.	ft
Conversion factor	2.03	lbs/ft
PVC	81.	lbs

Amount of PVC: Length of PVC per well * number of wells * conversion to get weight.

Linear feet for drilling	40.	ft
Drilling rate	100.	ft/day
Drilling fuel consumption rate	32.	gal/day
Fuel for drilling	12.8	gal
Total fuel (diesel)	12.8	gal

Amount of diesel is based on the amount of fuel for drilling.

All diesel is assumed to be in Capital phase.

Jet fuel use rate per passenger	0.0000097	gal/mi
Weight of passenger + luggage	200.	lbs
Total air miles (all passengers; entered above)	0.	miles
Jet fuel (Capital)	0.	gal
Jet fuel (O&M)	0.	gal

Total jet fuel: Jet fuel use rate * weight * air miles input above.

Jet fuel is distributed as 50% in Capital phase and 50% in O&M phase.

Vehicle mileage (travel)	15.	mpg
Miles traveled (Capital)	1,500.	miles
Miles traveled (O&M)	4,600.	miles
Gasoline (Capital)	100.	gal
Gasoline (O&M)	310.	gal
Total fuel (gasoline + jet fuel) Capital	100.	gal
Total fuel (gasoline + jet fuel) O&M	310.	gal

Capital Phase: Average distance traveled by site workers per one way trip x 2 x (Number of trips by site workers during construction + Number of characterization sampling events + Number of sampling events in first year) *O&M Phase*: Average distance traveled by site workers per one way trip x 2 x (Number of trips by site workers after construction + (Number of sampling events in subsequent years x (Duration - 1))
Totals reflected in summary screen. Capital costs are assumed to be incurred within the first year.

Metrics - Basic Calculations

Technology Cost

Technology Cost (Capital)	130,000.	$
Technology Cost (O&M)	150,000.	$

Technology cost is based on the well installation depth and characterization plus first year sampling (capital) and the number of subsequent sampling events (O&M). The cost equations were developed from RACER.

Energy Cost - Energy usage can be modified in Materials and Consumables (above). Update costs on Conversion tab.

Safety/Accident Risk

Hours worked (Capital)	150.	hrs
Hours worked (O&M)	270.	hrs
Total hours worked	420	hrs
Vehicle speed	40.	mph
Injuries per hour	2.74E-09	injuries/hr
Vehicle miles traveled (Capital)	1,500.	hrs

Safety/Accident Risk: (Statistical number of injuries from time worked + injuries from miles traveled) * lost hours per injury.

Vehicle miles traveled (O&M)	4,600.	*hrs*
Total vehicle miles traveled	6,100.	*miles*
Injuries per mile	9.10E-07	*injuries/mi*
Lost hours per injury	48.	*hrs/injury*
Safety/Accident Risk	0.27	*lost hours*

GROUNDWATER INPUT

DCB plume
Bird Machine, Walpole MA

Dimensions & Concentrations (Zone 1 & 2 reqd)

	Zone 1	Zone 2	Zone 3	Zone 4	
Width	100	150			ft
Length	600	800			ft
Area of "doughnut"	60,000	60,000	0	0	ft^2

Contaminant Class: CVOCs — ug/L (selected) / mg/L

	Zone 1	Zone 2	Zone 3	Zone 4
Conc Low	5	1		
Conc High	10	5		
Representative zone concentration	7.1	2.2	0	0

Depth to Water	5	ft
Depth to Top of Formation	25	ft
Thickness of Water-bearing Unit	10	ft
Aquifer Media	Sand (well graded)	
Hydraulic Conductivity	0.01 cm/s	0.01 cm/s
Hydraulic Gradient	0.003	-
Porosity	0.25	
Groundwater seepage velocity	120	ft/year

Calculate natural resource service? Yes / No (selected)

Instructions:

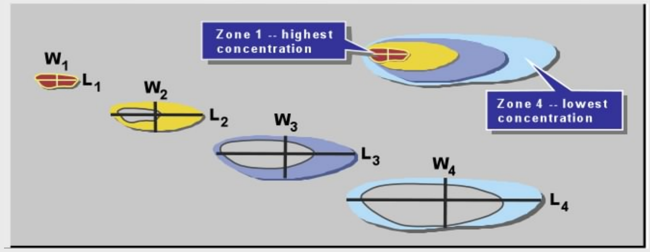
= Enter your data here. Click button to the right of the cell for help.
= Use this default value or override with your own.
= Calculated value. You cannot change this.

Paste Tier 2 Ex | Restore Defaults | Clear GW Inputs

Recommended flow:

You are here → Input → Next: Choose Technologies → Results

- [x] Pump & Treat
- [x] Enhanced Bioremediation
- [x] In Situ Chemical Oxidation
- [x] PRB
- [x] LTM / MNA



LTM / MNA - TIER 2
DCB plume
Bird Machine, Walpole MA
CAPITAL and O&M

Instructions:
= Enter your data here. Click button to the right of the cell for help.
= Use this default value or override with your own.
= Calculated value. You cannot change this.

Restore Defaults

Recommended flow:
Main → Input → Technology Design (Pump & Treat, Enhanced Bioremediation, In Situ Chemical Oxidation, PRB, LTM / MNA) >> → Results

Design for Managing Groundwater

Airline miles flown by project team (total miles for all travelers)	0	miles over proj lifetime
Average Distance Traveled by Site Workers per one-way trip	50	miles one-way
Trips by Site Workers during construction	10	# over project lifetime
Trips by Site Workers after construction (not including sampling)	10	# over project lifetime

Tier 2: Change Calculated Values (dark gray cells)

Number of monitoring wells	7	#
Length of piping, per well	40	ft
Number of characterization (baseline) sampling events	1.	#
Number of sampling events in the first year	4.	#
Number of sampling events per year in subsequent years	4.	#/year
Duration	10.	years
Number of samples collected per sampling event	7	#/event

Plume Calculation Method: ks / Enter Directly

Source zone point decay rate constant (k_s)	0.23	1/year

	Original Plume		Plume After Project	
Plume Area	2.8	acres	0.	acres
Plume Length	800.	feet	2.2	feet
Plume Volume	2.2	mil gals	0.	mil gals
Dissolved Mass	0.039	kg	0.	kg

Materials and Consumable Amounts Used for Metrics

PVC	570.	lbs
Diesel	89.6	gal
Gasoline (Capital)	100.	gal
Gasoline (O&M)	310.	gal

Technology Cost

Capital	160,000.	$
O&M	170,000.	$ over project

Project-specific Metrics (Add & Subtract/Offsets)

Yes / No

Additional Technology Cost		$
Total Energy Consumed		Megajoules
CO_2 Emissions to Atmosphere		tons CO_2
Safety / Accident Risk		lost hours

Design Calculations - LTM / MNA

Number of monitoring wells (entered above)	7.	#
Number of characterization (baseline) sampling events	1.	#
Number of sampling events in the first year	4.	#
Number of sampling events per year in subsequent years	4.	#/year
Duration	10.	years

Restore Defaults (Detail Section)

Materials and Consumable Calculations - LTM / MNA

Length of PVC per well (entered above)	40.	ft	Amount of PVC: Length of PVC per well * number of wells * conversion to get weight.
Conversion factor	2.03	lbs/ft	
PVC	570.	lbs	
Linear feet for drilling	280.	ft	Amount of diesel is based on the amount of fuel for drilling.
Drilling rate	100.	ft/day	
Drilling fuel consumption rate	32.	gal/day	
Fuel for drilling	89.6	gal	
Total fuel (diesel)	89.6	gal	All diesel is assumed to be in Capital phase.
Jet fuel use rate per passenger	0.0000097	gal/mi	Total jet fuel: Jet fuel use rate * weight * air miles input above.
Weight of passenger + luggage	200.	lbs	
Total air miles (all passengers; entered above)	0.	miles	
Jet fuel (Capital)	0.	gal	Jet fuel is distributed as 50% in Capital phase and 50% in O&M phase.
Jet fuel (O&M)	0.	gal	
Vehicle mileage (travel)	15.	mpg	*Capital Phase*: Average distance traveled by site workers per one way trip x 2 x (Number of trips by site workers during construction + Number of characterization sampling events + Number of sampling events in first year) *O&M Phase*: Average distance traveled by site workers per one way trip x 2 x (Number of trips by site workers after construction + (Number of sampling events in subsequent years x (Duration - 1))
Miles traveled (Capital)	1,500.	miles	
Miles traveled (O&M)	4,600.	miles	
Gasoline (Capital)	100.	gal	
Gasoline (O&M)	310.	gal	
Total fuel (gasoline + jet fuel) Capital	100.	gal	Totals reflected in summary screen. Capital costs are assumed to be incurred within the first year.
Total fuel (gasoline + jet fuel) O&M	310.	gal	

Metrics - Basic Calculations

Technology Cost

Technology Cost (Capital)	160,000.	$	Technology cost is based on the well installation depth and characterization plus first year sampling (capital) and the number of subsequent sampling events (O&M). The cost equations were developed from RACER.
Technology Cost (O&M)	170,000.	$	

Energy Cost - Energy usage can be modified in Materials and Consumables (above). Update costs on Conversion tab.

Safety/Accident Risk

Hours worked (Capital)	200.	hrs	
Hours worked (O&M)	630.	hrs	
Total hours worked	830	hrs	
Vehicle speed	40.	mph	
Injuries per hour	2.74E-09	injuries/hr	Safety/Accident Risk: (Statistical number of injuries from time worked + injuries from miles traveled) * lost hours per injury.
Vehicle miles traveled (Capital)	1,500.	hrs	

Vehicle miles traveled (O&M)	4,600.	*hrs*
Total vehicle miles traveled	6,100.	*miles*
Injuries per mile	9.10E-07	*injuries/mi*
Lost hours per injury	48.	*hrs/injury*
Safety/Accident Risk	0.27	*lost hours*

IN SITU CHEMICAL OXIDATION - TIER 2
DCB plume
Bird Machine, Walpole MA
CAPITAL and O&M

Instructions:
= Enter your data here. Click button to the right of the cell for help.
= Use this default value or override with your own.
= Calculated value. You cannot change this.
Restore Defaults

Recommended flow: Main → Input → Technology Design (Pump & Treat; Enhanced Bioremediation; In Situ Chemical Oxidation; PRB; LTM / MNA) >> → Results
You are here

Design for Managing Groundwater

Airline miles flown by project team (total miles for all travelers)	0	*miles over proj lifetime*
Average Distance Traveled by Site Workers per one-way trip	50	*miles one-way*
Trips by Site Workers during construction	20	*# over project lifetime*
Trips by Site Workers after construction	0	*# over project lifetime*
Treat Source Only or Source + Plume?	Source Only	
Treatment frequency	Once	
Length of pipe, per well	20.	*ft*
Number of injection points	191.	*#*
Natural Oxygen Demand	Average	*g/kg*

Tier 2: Change Calculated Values (dark gray cells)

	Original Plume		After Project	
Plume Area	2.8	*acres*	0.23	*acres*
Plume Length	800.	*feet*	200.	*feet*
Plume Volume	2.2	*mil gals*	0.	*mil gals*
Dissolved Mass	0.039	*kg*	0.0089	*kg*

Materials and Consumable Amounts used for Metrics

PVC	7,800.	*lbs*
Oxidant	120,000.	*lbs*
Gasoline (Capital)	134.	*gal*
Diesel	450.	*gal*

Technology Cost

Capital	2,400,000.	*$*

Project-specific Metrics (Add & Subtract/Offsets)
Yes No

Design Calculations - In Situ Chemical Oxidation

Restore Defaults (Detail Section)

Area for treatment	60,000.	*ft2*	
Thickness of water-bearing unit	10.	*ft*	Assumes that thickness of contaminated interval is equal to thickness of water-bearing unit.
Injection well spacing	20.	*ft*	
Number of injection points	191.	*#*	
Volume to treat	600,000.	*ft3*	Volume to treat is total volume (does not consider porosity).
Soil bulk density	100.	*lb/ft3*	Default value is based on aquifer media selected on InputGW tab.
Natural oxygen demand	2.	*g/kg*	Default values: Low (0.2 g/kg); Average (2.0 g/kg); High (20 g/kg)
Mass of oxidant (Initial event)	54,000,000.	*g*	
Mass of oxidant (Initial event)	120,000.	*lbs*	
Mass of oxidant (Subsequent events)	0.	*lbs per event*	If more than 1 treatment is selected above, the calculation assumes two add'l events using half the amount of initial oxidant for each subsequent event.
Total mass of oxidant	120,000.	*lbs total*	

Materials and Consumable Calculations - In Situ Chemical Oxidation

Length of PVC per well	20.	*ft*	Entered above.
Number of injection points	191.	*#*	Entered above.
Conversion factor	2.03	*lbs/ft*	
PVC (Capital)	7,800.	*lbs*	Length of PVC (ft) * number of injection points * PVC conversion factor (lbs PVC per foot).
Linear feet for drilling	3,820.	*ft*	Length of PVC per well * number of injection points.
Drilling rate	100.	*ft/day*	
Drilling fuel consumption	10.	*gal/day*	
Fuel for drilling (diesel)	382.	*gal*	Linear feet for drilling divided by drilling rate, multiplied by fuel consumption rate.
Oxidant load delivery capacity	10,000.	*lbs per truck load*	
Number of loads for oxidant	12.	*#*	Total mass of oxidant (shown above), divided by load delivery capacity.
Distance to oxidant supplier	50.	*miles one-way*	
Total miles driven for oxidant	1,200.	*miles two-way*	Number of loads * distance * 2.
Vehicle mileage (transportation for oxidant delivery)	17.6	*mpg*	
Fuel for heavy trucks (transportation; diesel)	68.	*gal*	Total miles driven for oxidant divided by vehicle mileage.
Fuel for drilling + bringing oxidant to site	450.	*gal*	

Jet fuel use rate per passenger	0.0000097	*gal/mi*	Total jet fuel: Jet fuel use rate* weight * air miles input above.
Weight of passenger + luggage	200.	*lbs*	
Total air miles (all passengers; input above)	0.	*miles*	
Total jet fuel	0.	*gal*	
Vehicle Mileage (travel)	15.	*mpg*	Total gasoline: (Construction + Post construction trips) * 2 * distance from office to site / vehicle mileage. Note that travel is lumped into Capital phase, but this value does include reinjections.
Miles traveled (Capital)	2,000.	*miles*	
Gasoline	134.	*gal*	
Total fuel (gasoline + jet fuel)	134.	*gal*	

Metrics - Baseline calculations (These calculations do not include Project-specific, direct additions / subtractions)

Technology Cost

Volume for treatment	22,000.	*cu yd*	
Unit cost	94.	*$/cu yd*	
Cost	2,400,000.	*$*	Volume for treatment multiplied by unit cost. Assumes all costs occur in first year (capital). For NOD demand of "Average" or "High", $2.50/lb * oxidant is added.

Energy Cost - Energy usage can be modified in Materials and Consumables (above). Update costs on Conversion tab.

Safety/Accident Risk

Hours worked	15,000.	*hrs*	Safety/Accident Risk: (Statistical number of injuries from time worked + injuries from miles traveled) * lost hours per injury.
Injuries per hour	2.74E-09	*injuries/hr*	
Additional injuries per hour due to oxidant risk	1.65E-05	*injuries/hr*	Default value of 1.65 x 10^{-5} injuries per hour worked is based on 2007 Bureau of Labor statistics (3.3 injuries per 200,000 hours worked for chemical manufacturing workers).
Vehicle speed	40.	*mph*	
Hours for travel (post-construction/site visit)	0.	*hrs*	
Total vehicle miles traveled	2,000.	*miles*	
Injuries per mile	9.10E-07	*injuries/mi*	
Lost hours per injury	48.	*hrs/injury*	
Safety/Accident risk	12.	*lost hours*	

PUMP AND TREAT - TIER 2

DCB plume
Bird Machine, Walpole MA
CAPITAL and O&M

Instructions:
= Enter your data here. Click button to the right of the cell for help.
= Use this default value or override with your own.
= Calculated value. You cannot change this.

Restore Defaults

Recommended flow:
Main → Input → Technology Design (You are here): Pump & Treat, Enhanced Bioremediation, In Situ Chemical Oxidation, PRB, LTM / MNA → Results

Design for Managing Groundwater

Airline miles flown by project team (total miles for all travelers)	0	miles over proj lifetime
Average Distance Traveled by Site Workers per one-way trip	50	miles one-way
Trips by Site Workers during construction	40	# over project lifetime
Trips by Site Workers after construction	260	# over project lifetime
Remediation Design (Purpose)	Remediation	
Duration (must be <100 years)	8	years
Total pumping rate	8.4	gpm
Number of wells	3.	#
Length of manifold	1,500.	ft
Treatment Method	Activated Carbon	
Beginning Plume Mass	0.079	kg
Ending Plume Mass	0.0002	kg

Tier 2: Change Calculated Values (dark gray boxes)

	Original Plume		After Project	
Plume Area	2.8	acres	0.029	acres
Plume Length	800.	feet	83.	feet
Plume Volume	4.5	million gallons	0.048	mil gals
Dissolved Mass	0.079	kg	0.0002	kg

Materials and Consumable Amounts Used for Metrics

PVC	3,200.	lbs
Steel	870.	lbs
Activated carbon	0.27	lbs
Electricity	1,500.	kWh
Diesel (Capital)	65.	gal
Diesel (O&M)	20.	gal
Gasoline (Capital)	267.	gal
Gasoline (O&M)	1,734.	gal
Natural gas	0.0018	mcf

Technology Cost

Capital	1,700,000.	$
O&M	2,160,000.	$ over project

Project-specific Metrics (Add & Subtract/Offsets)? Yes No

Design Calculations - Pump & Treat

Total pumping rate - Containment	-	gpm	Containment pumping rate (capture zone equation): Maximum plume width * Hydraulic conductivity * Aquifer thickness * Gradient * 2 * unit conversions.
Plume volume	600,000.	ft3	Remediation pumping rate (assumes 1 pore volume per year): Total plume volume for all zones * unit conversions.
Total pumping rate - Remediation	8.5	gpm	
Total pumping rate - initial estimate	8.5	gpm	
Number of wells per acre	1		
Plume area	2.8	acres	
Number of wells	3.	#	Number of wells: Number of wells per acre * Number of acres
Per well pump rate	2.8333	gpm	Initial estimated total pump rate / number of wells
Adjusted per well pump rate	2.8	gpm	Adjust for pump sizes
Adjusted total pump rate	8.4	gpm	Re-calculated based on number of wells * adjusted per well pump rate
Length of manifold	1,500.	ft	Length of PVC for manifold: Total length of each zone + Number of wells * Maximum plume width / 4
Treatment method	Activated Carbon		Treatment method entered above. If maximum concentrations is less than 1 mg/L, then activated carbon is the default value. Otherwise, air stripper is selected. This default value can be modified in the summary above.
Beginning plume mass	0.079	kg	Beginning plume mass: The sum of each zone of Area of Doughnut * Aquifer thickness & porosity * representative concentration * unit conversions.
Operating time	8,320.	hrs/yr	Operating time: the hours per year the system is in operation.
Pore volumes recovered	7.5	#	Pore volumes recovered: Pump rate * Duration * unit conversions / original plume volume. This factor is used to calculate the concentration reduction factor (CRF): If pore volumes recovered < 3, CRF = (-0.2195* PVr) + 1. If pore volumes recovered >=3, CRF = 1.3367 * PVr ^(-1.2424). Minimum CRF = 0.05. For Containment systems, CRF = 1.
Concentration reduction factor	0.11		
Adjusted CRF	0.11		
Ending plume mass	0.0002	kg	Ending plume mass: See PlumeCalcs worksheet for calculation based on original plume dimensions and CRF. For Containment systems, the starting and ending mass is assumed to be the same.

Materials and Consumable Calculations - Pump & Treat

Length of PVC per well	25.	ft	Length of PVC per well: default value is depth to groundwater + aquifer thickness.
Additional PVC pipe	0.	ft	Additional PVC pipe: optional amount of PVC in the Pump and Treat system.
Length of PVC for manifold (from above)	1,500.	ft	
Conversion factor	2.03	lbs/ft	
PVC	3,200.	lbs	Amount of PVC: [PVC per well * number of wells + additional PVC pipe + PVC for manifold] * conversion factor. This value is calculated for Capital or both Capital and O&M projects.
Length of Steel Pipe per well	10.	ft/well	Length of steel pipe per well includes well screen.
Conversion factor	10.79	lbs/ft	Conversion factor for weight of steel pipe.
Other steel per well	50.	lbs	Other steel per well includes equipment such as pumps.
Other steel (system-wide, eg, treatment system)	400.	lbs	Other steel for system includes weight of air stripper or carbon tanks.
Steel	870.	lbs	Amount of steel: [Steel pipe per well * number of wells * conversion factor + Other steel per well * number of wells + other system components]. This value is calculated for Capital or both Capital and O&M projects.
Operating time	8,320.	hrs/yr	Amount of activated carbon, if required by treatment system, is based on average concentration in recovered groundwater (a function of pump rate, operating time and duration), and contaminant-specific parameters from Dobbs and Cohen, 1980. This value is calculated for O&M and both Capital and O&M projects.
Average concentration	0.0006	mg/L	
K parameter	28.		
1/n parameter	0.62		
Activated carbon	0.27	lbs	
Power requirements	0.022	kW per hr	Amount of electricity over project lifetime: Power requirements * Operating time in hours / year * Duration (input above). This value is calculated for O&M and both Capital and O&M
Operating time	8,320.	hrs/yr	
Electricity	1,500.	kWh	

Linear feet for trenching	1,500.	*ft*	Amount of diesel is based on the amount of fuel for trenching plus drilling. Diesel is calculated for Capital and both Capital and O&M projects.
Trenching rate	300.	*ft/hr*	
Trenching fuel consumption rate	6.25	*gal/hr*	
Fuel for trenching	31.	*gal*	
Linear feet for drilling	105.	*ft*	
Drilling rate	100.	*ft/day*	
Drilling fuel consumption rate	32.	*gal/day*	
Fuel for drilling	34.	*gal*	
Total fuel (diesel; capital phase)	65.	*gal*	
Vehicle mileage (transportation for activated carbon disposal)	5.	*mpg*	Diesel for O&M is calculated based on transport for activated carbon.
Miles traveled for activated carbon disposal (O&M)	100.	*miles (project total)*	
Diesel (O&M phase)	20.	*gal*	
Jet fuel use rate per passenger	0.0000097	*gal/mi*	Total jet fuel: Jet fuel use rate * weight * air miles input above. The default calculation assumes 50% is used in capital, and 50% used in O&M phases.
Weight of passenger + luggage	200.	*lbs*	
Total air miles (all passengers; input above)	0.	*miles*	
Jet fuel (capital phase)	0.	*gal*	
Jet fuel (O&M phase)	0.	*gal*	
Vehicle mileage (travel)	15.	*mpg*	
Miles traveled (capital)	4,000.	*miles*	
Gasoline (capital)	267.	*gal*	
Vehicle mileage (travel)	15.	*mpg*	
Miles traveled (O&M)	26,000.	*miles*	
Gasoline (O&M phase)	1,734.	*gal*	
Total fuel (gasoline + jet fuel) - Capital phase	267.	*gal*	
Total fuel (gasoline + jet fuel) - O&M phase	1,734.	*gal*	
Natural gas requirements for PT/Therm Ox			
Operation Time	8,320.	*hrs/yr*	If treatment method is Air Stripper/Therm Ox, amount of natural gas: Natural gas flow rate * Duration (input above) * Operation time in hours per year * unit conversions.
Natural gas flow rate	2.21	*scfm*	
Natural gas for Therm Ox	0.	*mcf*	
Natural gas requirements for Activated Carbon regeneration			
Conversion factor	7,000.	*btu/lb activated carbon*	If treatment method is Activated Carbon, amount of natural gas: Amount of activated carbon (calculated above) * conversion factor.
Natural gas for activated carbon	0.0018	*mcf*	
Natural gas used for metrics (Therm Ox or Activated Carbon)	0.0018	*mcf*	Natural gas is used in metrics calculations for O&M and both Capital and O&M projects.

Metrics - Baseline Calculations

Technology Cost

Volume recovered	4,200.	*1,000 gal/yr*	Capital and O&M Costs are based on site data from USEPA 2001. Capital cost = [277189 * Volume ^ (-0.781)] * Volume. Annual O&M cost = [40500 * Volume ^ (-0.7706)] * Volume.
Technology Cost (Capital)	1,700,000.	*$*	
Technology Cost (O&M)	270,000.	*$/year*	
Technology Cost (O&M)	2,160,000.	*$ over project*	

Energy Cost - Modify usage in Materials and Consumables (above). Update costs on Conversion tab.

Safety/Accident Risk

Hours worked (Capital)	11,000.	*hrs*	Safety/Accident Risk: (Statistical number of injuries from time worked + injuries from miles traveled) * lost hours per injury.
Vehicle speed	40.	*mph*	
Hours worked (O&M)	17,000.	*hrs*	
Total hours worked	28,000.	*hrs*	
Injuries per hour	2.74E-09	*injuries/hr*	
Vehicle miles traveled (Capital)	4,000.	*miles*	
Vehicle miles traveled (O&M)	26,000.	*miles*	
Total vehicle miles traveled	30,000.	*miles*	
Injuries per mile	9.10E-07	*injuries/mi*	
Lost hours per injury	48.	*hrs/injury*	
Safety/Accident Risk	1.3	*lost hours*	

GROUNDWATER INPUT

PCE plume
Bird Machine, Walpole MA

Dimensions & Concentrations (Zone 1 & 2 reqd)

	Zone 1	Zone 2	Zone 3	Zone 4	
Width	300	400			ft
Length	550	700			ft
Area of "doughnut"	165,000	115,000	0	0	ft^2
Contaminant Class	CVOCs		ug/L	mg/L	
Conc Low	40	1			
Conc High	120	40			
Representative zone concentration	69	6.3	0	0	

Depth to Water	5	ft
Depth to Top of Formation	25	ft
Thickness of Water-bearing Unit	10	ft
Aquifer Media	Sand (well graded)	
Hydraulic Conductivity	0.01 cm/s	0.01 cm/s
Hydraulic Gradient	0.003	-
Porosity	0.25	
Groundwater seepage velocity	120	ft/year

Calculate natural resource service? Yes No

Instructions:

= Enter your data here. Click button to the right of the cell for help.

= Use this default value or override with your own.

= Calculated value. You cannot change this.

Paste Tier 2 Ex

Restore Defaults

Clear GW Inputs

Recommended flow:

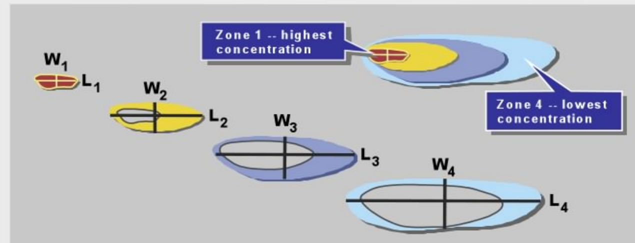
You are here

Input

Next: Choose Technologies
- ☑ Pump & Treat
- ☑ Enhanced Bioremediation
- ☑ In Situ Chemical Oxidation
- ☑ PRB
- ☑ LTM / MNA

>>

Results



LTM / MNA - TIER 2
PCE plume
Bird Machine, Walpole MA
CAPITAL and O&M

Instructions:
= Enter your data here. Click button to the right of the cell for help.
= Use this default value or override with your own.
= Calculated value. You cannot change this.

Restore Defaults

Design for Managing Groundwater

Airline miles flown by project team (total miles for all travelers)	0	miles over proj lifetime
Average Distance Traveled by Site Workers per one-way trip	50	miles one-way
Trips by Site Workers during construction	10	# over project lifetime
Trips by Site Workers after construction (not including sampling)	10	# over project lifetime

Tier 2: Change Calculated Values (dark gray cells)

Number of monitoring wells	9	#
Length of piping, per well	40	ft
Number of characterization (baseline) sampling events	1.	#
Number of sampling events in the first year	4.	#
Number of sampling events per year in subsequent years	4.	#/year
Duration	10.	years
Number of samples collected per sampling event	21	#/event

Plume Calculation Method: ks / Enter Directly

Source zone point decay rate constant (k_s)	0.23	1/year

	Original Plume		Plume After Project	
Plume Area	6.4	acres	4.8	acres
Plume Length	700.	feet	610.	feet
Plume Volume	5.1	mil gals	3.9	mil gals
Dissolved Mass	0.86	kg	0.052	kg

Recommended flow:
Main → Input → Technology Design (Pump & Treat, Enhanced Bioremediation, In Situ Chemical Oxidation, PRB, LTM / MNA) >> → Results

Materials and Consumable Amounts Used for Metrics

PVC	730.	lbs
Diesel	115.2	gal
Gasoline (Capital)	100.	gal
Gasoline (O&M)	310.	gal

Technology Cost

Capital	390,000.	$
O&M	230,000.	$ over project

Project-specific Metrics (Add & Subtract/Offsets)

Yes / No

Additional Technology Cost		$
Total Energy Consumed		Megajoules
CO_2 Emissions to Atmosphere		tons CO_2
Safety / Accident Risk		lost hours

Design Calculations - LTM / MNA

Number of monitoring wells (entered above)	9.	#
Number of characterization (baseline) sampling events	1.	#
Number of sampling events in the first year	4.	#
Number of sampling events per year in subsequent years	4.	#/year
Duration	10.	years

Restore Defaults (Detail Section)

Materials and Consumable Calculations - LTM / MNA

Length of PVC per well (entered above)	40.	ft
Conversion factor	2.03	lbs/ft
PVC	730.	lbs

Amount of PVC: Length of PVC per well * number of wells * conversion to get weight.

Linear feet for drilling	360.	ft
Drilling rate	100.	ft/day
Drilling fuel consumption rate	32.	gal/day
Fuel for drilling	115.2	gal
Total fuel (diesel)	115.2	gal

Amount of diesel is based on the amount of fuel for drilling.

All diesel is assumed to be in Capital phase.

Jet fuel use rate per passenger	0.0000097	gal/mi
Weight of passenger + luggage	200.	lbs
Total air miles (all passengers; entered above)	0.	miles
Jet fuel (Capital)	0.	gal
Jet fuel (O&M)	0.	gal

Total jet fuel: Jet fuel use rate * weight * air miles input above.

Jet fuel is distributed as 50% in Capital phase and 50% in O&M phase.

Vehicle mileage (travel)	15.	mpg
Miles traveled (Capital)	1,500.	miles
Miles traveled (O&M)	4,600.	miles
Gasoline (Capital)	100.	gal
Gasoline (O&M)	310.	gal
Total fuel (gasoline + jet fuel) Capital	100.	gal
Total fuel (gasoline + jet fuel) O&M	310.	gal

Capital Phase: Average distance traveled by site workers per one way trip x 2 x (Number of trips by site workers during construction + Number of characterization sampling events + Number of sampling events in first year) *O&M Phase*: Average distance traveled by site workers per one way trip x 2 x (Number of trips by site workers after construction + (Number of sampling events in subsequent years x (Duration - 1))

Totals reflected in summary screen. Capital costs are assumed to be incurred within the first year.

Metrics - Basic Calculations

Technology Cost

Technology Cost (Capital)	390,000.	$
Technology Cost (O&M)	230,000.	$

Technology cost is based on the well installation depth and characterization plus first year sampling (capital) and the number of subsequent sampling events (O&M). The cost equations were developed from RACER.

Energy Cost - Energy usage can be modified in Materials and Consumables (above). Update costs on Conversion tab.

Safety/Accident Risk

Hours worked (Capital)	220.	hrs
Hours worked (O&M)	770.	hrs
Total hours worked	990	hrs
Vehicle speed	40.	mph
Injuries per hour	2.74E-09	injuries/hr
Vehicle miles traveled (Capital)	1,500.	hrs

Safety/Accident Risk: (Statistical number of injuries from time worked + injuries from miles traveled) * lost hours per injury.

Vehicle miles traveled (O&M)	4,600.	*hrs*
Total vehicle miles traveled	6,100.	*miles*
Injuries per mile	9.10E-07	*injuries/mi*
Lost hours per injury	48.	*hrs/injury*
Safety/Accident Risk	0.27	*lost hours*

IN SITU CHEMICAL OXIDATION - TIER 2
PCE plume
Bird Machine, Walpole MA
CAPITAL and O&M

Instructions:
= Enter your data here. Click button to the right of the cell for help.
= Use this default value or override with your own.
= Calculated value. You cannot change this.
Restore Defaults

Recommended flow:
Main → Input → Technology Design: Pump & Treat; Enhanced Bioremediation; In Situ Chemical Oxidation; PRB; LTM / MNA → Results
You are here

Design for Managing Groundwater

Airline miles flown by project team (total miles for all travelers)	0	miles over proj lifetime
Average Distance Traveled by Site Workers per one-way trip	50	miles one-way
Trips by Site Workers during construction	20	# over project lifetime
Trips by Site Workers after construction	0	# over project lifetime
Treat Source Only or Source + Plume?	Source Only	
Treatment frequency	Once	
Length of pipe, per well	25.	ft
Number of injection points	526.	#
Natural Oxygen Demand	Average	g/kg

Tier 2: Change Calculated Values (dark gray cells)

	Original Plume		After Project	
Plume Area	6.4	acres	0.35	acres
Plume Length	700.	feet	150.	feet
Plume Volume	5.1	mil gals	0.	mil gals
Dissolved Mass	0.86	kg	0.055	kg

Materials and Consumable Amounts used for Metrics

PVC	27,000.	lbs
Oxidant	330,000.	lbs
Gasoline (Capital)	134.	gal
Diesel	1,500.	gal

Technology Cost

Capital	6,600,000.	$

Project-specific Metrics (Add & Subtract/Offsets)

Yes No

Design Calculations - In Situ Chemical Oxidation

Restore Defaults (Detail Section)

Area for treatment	165,000.	ft2	
Thickness of water-bearing unit	10.	ft	Assumes that thickness of contaminated interval is equal to thickness of water-bearing unit.
Injection well spacing	20.	ft	
Number of injection points	526.	#	
Volume to treat	1,650,000.	ft3	Volume to treat is total volume (does not consider porosity).
Soil bulk density	100.	lb/ft3	Default value is based on aquifer media selected on InputGW tab.
Natural oxygen demand	2.	g/kg	Default values: Low (0.2 g/kg); Average (2.0 g/kg); High (20 g/kg)
Mass of oxidant (Initial event)	150,000,000.	g	
Mass of oxidant (Initial event)	330,000.	lbs	
Mass of oxidant (Subsequent events)	0.	lbs per event	If more than 1 treatment is selected above, the calculation assumes two add'l events using half the amount of initial oxidant for each subsequent event.
Total mass of oxidant	330,000.	lbs total	

Materials and Consumable Calculations - In Situ Chemical Oxidation

Length of PVC per well	25.	ft	Entered above.
Number of injection points	526.	#	Entered above.
Conversion factor	2.03	lbs/ft	
PVC (Capital)	27,000.	lbs	Length of PVC (ft) * number of injection points * PVC conversion factor (lbs PVC per foot).
Linear feet for drilling	13,150.	ft	Length of PVC per well * number of injection points.
Drilling rate	100.	ft/day	
Drilling fuel consumption	10.	gal/day	
Fuel for drilling (diesel)	1,315.	gal	Linear feet for drilling divided by drilling rate, multiplied by fuel consumption rate.
Oxidant load delivery capacity	10,000.	lbs per truck load	
Number of loads for oxidant	33.	#	Total mass of oxidant (shown above), divided by load delivery capacity.
Distance to oxidant supplier	50.	miles one-way	
Total miles driven for oxidant	3,300.	miles two-way	Number of loads * distance * 2.
Vehicle mileage (transportation for oxidant delivery)	17.6	mpg	
Fuel for heavy trucks (transportation; diesel)	190.	gal	Total miles driven for oxidant divided by vehicle mileage.
Fuel for drilling + bringing oxidant to site	1,500.	gal	

Jet fuel use rate per passenger	0.0000097	*gal/mi*	Total jet fuel: Jet fuel use rate* weight * air miles input above.
Weight of passenger + luggage	200.	*lbs*	
Total air miles (all passengers; input above)	0.	*miles*	
Total jet fuel	0.	*gal*	

Vehicle Mileage (travel)	15.	*mpg*	Total gasoline: (Construction + Post construction trips) * 2 * distance from office to site / vehicle mileage. Note that travel is lumped into Capital phase, but this value does include reinjections.
Miles traveled (Capital)	2,000.	*miles*	
Gasoline	134.	*gal*	
Total fuel (gasoline + jet fuel)	134.	*gal*	

Metrics - Baseline calculations (These calculations do <u>not</u> include Project-specific, direct additions / subtractions)

Technology Cost

Volume for treatment	61,000.	*cu yd*	
Unit cost	94.	*$/cu yd*	
Cost	6,600,000.	*$*	Volume for treatment multiplied by unit cost. Assumes all costs occur in first year (capital). For NOD demand of "Average" or "High", $2.50/lb * oxidant is added.

Energy Cost - Energy usage can be modified in Materials and Consumables (above). Update costs on Conversion tab.

Safety/Accident Risk

Hours worked	41,000.	*hrs*	Safety/Accident Risk: (Statistical number of injuries from time worked + injuries from miles traveled) * lost hours per injury.
Injuries per hour	2.74E-09	*injuries/hr*	
Additional injuries per hour due to oxidant risk	1.65E-05	*injuries/hr*	Default value of 1.65 x 10^{-5} injuries per hour worked is based on 2007 Bureau of Labor statistics (3.3 injuries per 200,000 hours worked for chemical manufacturing workers).
Vehicle speed	40.	*mph*	
Hours for travel (post-construction/site visit)	0.	*hrs*	
Total vehicle miles traveled	2,000.	*miles*	
Injuries per mile	9.10E-07	*injuries/mi*	
Lost hours per injury	48.	*hrs/injury*	
Safety/Accident risk	33.	*lost hours*	

Instructions:

= Enter your data here. Click button to the right of the cell for help.
= Use this default value or override with your own.
= Calculated value. You cannot change this.

Restore Defaults

PUMP AND TREAT - TIER 2
PCE plume
Bird Machine, Walpole MA
CAPITAL and O&M

Recommended flow:
Main → Input → Technology Design → Results
You are here
Pump & Treat
Enhanced Bioremediation
In Situ Chemical Oxidation
PRB
LTM / MNA
>>

Design for Managing Groundwater

Airline miles flown by project team (total miles for all travelers)	0	miles over proj lifetime
Average Distance Traveled by Site Workers per one-way trip	50	miles one-way
Trips by Site Workers during construction	40	# over project lifetime
Trips by Site Workers after construction	260	# over project lifetime
Remediation Design (Purpose)	Remediation	
Duration (must be <100 years)	8	years
Total pumping rate	20.3	gpm
Number of wells	7.	#
Length of manifold	2,000.	ft
Treatment Method	Activated Carbon	
Beginning Plume Mass	1.7	kg
Ending Plume Mass	0.11	kg

Tier 2: Change Calculated Values (dark gray boxes)

	Original Plume		After Project	
Plume Area	6.4	acres	4.9	acres
Plume Length	700.	feet	610.	feet
Plume Volume	10.	million gallons	8.	mil gals
Dissolved Mass	1.7	kg	0.11	kg

Materials and Consumable Amounts Used for Metrics

PVC	4,400.	lbs
Steel	1,500.	lbs
Activated carbon	1.5	lbs
Electricity	3,500.	kWh
Diesel (Capital)	120.	gal
Diesel (O&M)	20.	gal
Gasoline (Capital)	267.	gal
Gasoline (O&M)	1,734.	gal
Natural gas	0.01	mcf

Technology Cost

Capital	2,100,000.	$
O&M	2,720,000.	$ over project

Project-specific Metrics (Add & Subtract/Offsets)? Yes No

Design Calculations - Pump & Treat

Total pumping rate - Containment	-	gpm	Containment pumping rate (capture zone equation): Maximum plume width * Hydraulic conductivity * Aquifer thickness * Gradient * 2 * unit conversions.
Plume volume	1,400,000.	ft3	Remediation pumping rate (assumes 1 pore volume per year): Total plume volume for all zones * unit conversions.
Total pumping rate - Remediation	20.	gpm	
Total pumping rate - initial estimate	20.	gpm	
Number of wells per acre	1		
Plume area	6.4	acres	
Number of wells	7.	#	Number of wells: Number of wells per acre * Number of acres
Per well pump rate	2.8571	gpm	Initial estimated total pump rate / number of wells
Adjusted per well pump rate	2.9	gpm	Adjust for pump sizes
Adjusted total pump rate	20.3	gpm	Re-calculated based on number of wells * adjusted per well pump rate
Length of manifold	2,000.	ft	Length of PVC for manifold: Total length of each zone + Number of wells * Maximum plume width / 4
Treatment method	Activated Carbon		Treatment method entered above. If maximum concentrations is less than 1 mg/L, then activated carbon is the default value. Otherwise, air stripper is selected. This default value can be modified in the summary above.
Beginning plume mass	1.7	kg	Beginning plume mass: The sum of each zone of Area of Doughnut * Aquifer thickness & porosity * representative concentration * unit conversions.
Operating time	8,320.	hrs/yr	Operating time: the hours per year the system is in operation.
Pore volumes recovered	7.7	#	Pore volumes recovered: Pump rate * Duration * unit conversions / original plume volume. This factor is used to calculate the concentration reduction factor (CRF): If pore volumes recovered < 3, CRF = (-0.2195* PVr) + 1. If pore volumes recovered >=3, CRF = 1.3367 * PVr ^(-1.2424). Minimum CRF = 0.05. For Containment systems, CRF = 1.
Concentration reduction factor	0.11		
Adjusted CRF	0.11		
Ending plume mass	0.11	kg	Ending plume mass: See PlumeCalcs worksheet for calculation based on original plume dimensions and CRF. For Containment systems, the starting and ending mass is assumed to be the same.

Materials and Consumable Calculations - Pump & Treat

Length of PVC per well	25.	ft	Length of PVC per well: default value is depth to groundwater + aquifer thickness.
Additional PVC pipe	0.	ft	Additional PVC pipe: optional amount of PVC in the Pump and Treat system.
Length of PVC for manifold (from above)	2,000.	ft	
Conversion factor	2.03	lbs/ft	
PVC	4,400.	lbs	Amount of PVC: [PVC per well * number of wells + additional PVC pipe + PVC for manifold] * conversion factor. This value is calculated for Capital or both Capital and O&M projects.
Length of Steel Pipe per well	10.	ft/well	Length of steel pipe per well includes well screen.
Conversion factor	10.79	lbs/ft	Conversion factor for weight of steel pipe.
Other steel per well	50.	lbs	Other steel per well includes equipment such as pumps.
Other steel (system-wide, eg, treatment system)	400.	lbs	Other steel for system includes weight of air stripper or carbon tanks.
Steel	1,500.	lbs	Amount of steel: [Steel pipe per well * number of wells * conversion factor + Other steel per well * number of wells + other system components]. This value is calculated for Capital or both Capital and O&M projects.
Operating time	8,320.	hrs/yr	Amount of activated carbon, if required by treatment system, is based on average concentration in recovered groundwater (a function of pump rate, operating time and duration), and contaminant-specific parameters from Dobbs and Cohen, 1980. This value is calculated for O&M and both Capital and O&M projects.
Average concentration	0.0052	mg/L	
K parameter	28.		
1/n parameter	0.62		
Activated carbon	1.5	lbs	
Power requirements	0.053	kW per hr	Amount of electricity over project lifetime: Power requirements * Operating time in hours / year * Duration (input above). This value is calculated for O&M and both Capital and O&M
Operating time	8,320.	hrs/yr	
Electricity	3,500.	kWh	

Linear feet for trenching	2,000.	ft	Amount of diesel is based on the amount of fuel for trenching plus drilling. Diesel is calculated for Capital and both Capital and O&M projects.
Trenching rate	300.	ft/hr	
Trenching fuel consumption rate	6.25	gal/hr	
Fuel for trenching	42.	gal	
Linear feet for drilling	245.	ft	
Drilling rate	100.	ft/day	
Drilling fuel consumption rate	32.	gal/day	
Fuel for drilling	78.	gal	
Total fuel (diesel; capital phase)	120.	gal	
Vehicle mileage (transportation for activated carbon disposal)	5.	mpg	Diesel for O&M is calculated based on transport for activated carbon.
Miles traveled for activated carbon disposal (O&M)	100.	miles (project total)	
Diesel (O&M phase)	20.	gal	
Jet fuel use rate per passenger	0.0000097	gal/mi	Total jet fuel: Jet fuel use rate * weight * air miles input above. The default calculation assumes 50% is used in capital, and 50% used in O&M phases.
Weight of passenger + luggage	200.	lbs	
Total air miles (all passengers; input above)	0.	miles	
Jet fuel (capital phase)	0.	gal	
Jet fuel (O&M phase)	0.	gal	
Vehicle mileage (travel)	15.	mpg	
Miles traveled (capital)	4,000.	miles	
Gasoline (capital)	267.	gal	
Vehicle mileage (travel)	15.	mpg	
Miles traveled (O&M)	26,000.	miles	
Gasoline (O&M phase)	1,734.	gal	
Total fuel (gasoline + jet fuel) - Capital phase	267.	gal	
Total fuel (gasoline + jet fuel) - O&M phase	1,734.	gal	
Natural gas requirements for PT/Therm Ox			
Operation Time	8,320.	hrs/yr	If treatment method is Air Stripper/Therm Ox, amount of natural gas: Natural gas flow rate * Duration (input above) * Operation time in hours per year * unit conversions.
Natural gas flow rate	2.21	scfm	
Natural gas for Therm Ox	0.	mcf	
Natural gas requirements for Activated Carbon regeneration			
Conversion factor	7,000.	btu/lb activated carbon	If treatment method is Activated Carbon, amount of natural gas: Amount of activated carbon (calculated above) * conversion factor.
Natural gas for activated carbon	0.01	mcf	
Natural gas used for metrics (Therm Ox or Activated Carbon)	0.01	mcf	Natural gas is used in metrics calculations for O&M and both Capital and O&M projects.

Metrics - Baseline Calculations

Technology Cost

Volume recovered	10,000.	1,000 gal/yr	Capital and O&M Costs are based on site data from USEPA 2001. Capital cost = [277189 * Volume ^ (-0.781)] * Volume. Annual O&M cost = [40500 * Volume ^ (-0.7706)] * Volume.
Technology Cost (Capital)	2,100,000.	$	
Technology Cost (O&M)	340,000.	$/year	
Technology Cost (O&M)	2,720,000.	$ over project	

Energy Cost - Modify usage in Materials and Consumables (above). Update costs on Conversion tab.

Safety/Accident Risk

Hours worked (Capital)	14,000.	hrs	Safety/Accident Risk: (Statistical number of injuries from time worked + injuries from miles traveled) * lost hours per injury.
Vehicle speed	40.	mph	
Hours worked (O&M)	20,000.	hrs	
Total hours worked	34,000.	hrs	
Injuries per hour	2.74E-09	injuries/hr	
Vehicle miles traveled (Capital)	4,000.	miles	
Vehicle miles traveled (O&M)	26,000.	miles	
Total vehicle miles traveled	30,000.	miles	
Injuries per mile	9.10E-07	injuries/mi	
Lost hours per injury	48.	hrs/injury	
Safety/Accident Risk	1.3	lost hours	