Final
March 2012

Proposed Plan for Groundwater (Covering TNT Areas and Red Water Pond Areas)

Former Plum Brook Ordnance Works Sandusky, Ohio

US Army Corps of Engineers

FUDS Project No. G05OH001826

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March 26, 2012

U.S. Army Engineer District, Nashville
ATTN: CELRN-EC-E (Ms. Kathy McClanahan)
110 Ninth Avenue South, Room 682
U.S. Court House Annex
Nashville, Tennessee 37203

Submittal of the Final Proposed Plan for Groundwater
(Covering the TNT and Red Water Pond Areas)
Former Plum Brook Ordnance Works, Sandusky, Ohio
Contract No. W912DR-05-D-0026: Shaw Project Number 139788

Dear Ms. McClanahan:

In accordance with the requirements of Delivery Order No. DX16 of Contract No. W912QR-08-D-0013, Shaw is pleased to submit this Final Proposed Plan for Groundwater, Covering the TNT and Red Water Pond Areas, at the Former Plum Brook Ordnance Works located in Sandusky, Ohio.

Enclosed are four copies of this Proposed Plan for your records. Copies have also been sent as indicated to those on the attached distribution list. The 25 copies for Rick Meadows include those to be distributed to the public and kept at the library. This final document incorporates comments that were received during review.

Should you have any questions or require additional information regarding this submittal, please do not hesitate to contact me at (865) 694-7496.

Sincerely,

Steven T. Downey, PE, PMP
Project Manager

Enclosures

Distribution List

Name	Copies
U.S. Army Engineer District, Nashville ATTN: CELRN-EC-E (Ms. Kathy McClanahan) 110 Ninth Avenue South, Room 682 Annex Nashville, TN 37203	4
U.S. Army Engineer District, Huntington ATTN: CELRH-PM-PP-P (Mr. Rick Meadows) 502 Eighth Street Huntington, West Virginia 25701-2070	25 (CD provided)
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DISCIPLINE SIGN-OFF REVIEW

Client Name: U.S. Army Engineer District, Nashville; CELRN-EC-E

Project Description: Proposed Plan for Groundwater Covering TNT and Red Water Pond Areas
Former Plum Brook Ordnance Works, Sandusky, Ohio

Contract No. W912QR-08-D-0013

Delivery Order No. DX16

Project No. 139788

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NOTICE: By signature above, parties certify that the subject document has been prepared by and/or reviewed by them (as appropriate), that all review comments have been resolved, and that the document is ready for submittal.

Final
Proposed Plan for Groundwater
(Covering TNT Areas and Red Water Pond Areas)
Plum Brook Ordnance Works, Sandusky, Ohio
DERP-FUDS Project Number G05OH001826

Issued By U.S. Army Corps of Engineers
Huntington District

Prepared by Shaw Environmental, Inc.

March 2012

U.S. Army Corps of Engineers Announces Proposed Plan

This Proposed Plan identifies the Preferred Alternative of No Further Action as the remedy for contaminated groundwater associated with the former TNT Areas and Red Water Pond (RWP) Areas of the former Plum Brook Ordnance Works (PBOW), Sandusky, Ohio (Figure 1), and presents the rationale for this preference. The TNT Areas include the three former areas used to manufacture 2,4,6-trinitrotoluene (TNT): TNT Area A (TNTA), TNT Area B (TNTB), and TNT Area C (TNTC) (Figure 2). Ponds from the two RWP Areas, Pentolite Road Red Water Pond (PRRWP) and West Area Red Water Ponds (WARWP), received treated wastewater from the TNT areas. The Preferred Alternative for the TNT and RWP Areas groundwater, as well as the other alternatives described herein, addresses the human health risks associated with potential groundwater exposure pathways. Potential risks associated with direct exposure to soil and other environmental media will be or have been addressed in separate Proposed Plans for the respective TNT Areas and RWP Areas. Remedial actions specific for soil, described in those Proposed Plans, will represent the removal of potential sources of groundwater contamination.

U.S. Army environmental investigations and remediation at PBOW are administered under the Defense Environmental Restoration Program-Formerly Used Defense Sites (DERP-FUDS), as required for such sites by the Superfund Amendments and Reauthorization Act of 1986 (SARA). The U.S. Secretary of Defense delegated authority to the U.S. Army Corps of Engineers (USACE) to administer the DERP-FUDS program.

Comments can be directed to:

U.S. Army Corps of Engineers,
Huntington District
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The Proposed Plan is a document issued by the USACE Huntington District, the lead agency for environmental response actions at the PBOW, to fulfill public participation requirements. It was prepared in partnership with the Ohio Environmental Protection Agency (Ohio EPA). The Preferred Alternative may be modified based on any new information or comments received during this designated public comment period. Therefore, the public is encouraged to review and comment on all information presented in the Proposed Plan or Administrative Record file. As the lead agency, the USACE is charged with planning and implementing environmental investigations and remedial actions at PBOW associated with past U.S. Department of Defense (DoD) activities. The USACE Nashville District provides design support services for environmental investigations at PBOW and provides technical review. The USACE Huntington District provides overall project management of FUDS activities at PBOW for the Louisville District as well as acts as the contracting and oversight office for remedial actions. The USACE Louisville District is the project and program management office for all FUDS property in the USACE Great Lakes and Ohio River Division. The Ohio EPA provides regulatory review, comment, and oversight.

This Proposed Plan is issued to accomplish the following:

- Provide basic background information about the site
- Describe all remedial options considered
- Identify the Preferred Alternative for groundwater associated with the TNT and RWP Areas and explain reasons for the preference
- Solicit public review and comment on all alternatives
- Provide information on how the public can be involved in the remedy selection process.

The USACE, after consulting with the Ohio EPA, will select a final remedy for the TNT and RWP Areas groundwater after the public has had an opportunity to comment on this Proposed Plan and all comments received have been reviewed and considered. The comment period for the Proposed Plan is from March 29 through April 30, 2012, and the public meeting will be held at 6:30 p.m. on March 29 , 2012, at the Firelands Library, Firelands Campus of Bowling Green State University (BGSU), Huron, Ohio. The remedy selected for groundwater underlying the TNT and RWP Areas will be documented in a Decision Document.

DATES TO REMEMBER

Comment Period
March 29 through April 30, 2012

Public Meeting
6:30 p.m. March 29, 2012, at
Firelands Library - BGSU
Foundation Hall
One University Drive
Huron, Ohio

The USACE is issuing this Proposed Plan for public comment as part of its public participation responsibilities

consistent with Sections 117(a) and 113(k)(2)(B) of the Comprehensive Environmental Response Compensation, and Liability Act (CERCLA) of 1980, as amended by SARA and the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) under CERCLA Part 300.430(f)(2)&(3).

This Proposed Plan summarizes information presented in greater detail in documents contained in the Administrative Record (AR) file for TNTA, TNTB, TNTC, and the RWP Areas. Background documents for the TNT and RWP Areas are listed on Page 4 and can be found in the AR file. These background documents are referenced within this Proposed Plan and are the basis of most of the information summarized herein. The USACE and the Ohio EPA encourage the public to review these documents and the entire AR file to gain a more comprehensive understanding of the TNT and RWP Areas, the associated site activities, and the groundwater underlying these areas. The AR file, which contains information upon which the selection of the response action will be based, is maintained at the Huntington District Office, 502 Eighth Street, Huntington, West Virginia, 25701. The AR file can be viewed online at the USACE Huntington District Web site: http://www.lrh.usace.army.mil/projects/current/derp-fuds/pbow/documents.

The local Public Repository of the AR file is:

Firelands Library – BGSU
Foundation Hall
One University Drive
Huron, Ohio
Phone: 419-433-5560
Library hours vary throughout the year. Call for current hours. The AR file is maintained on compact discs; ask librarian at front desk for assistance.

Site Background

PBOW Description and History. PBOW is located approximately 4 miles south of Sandusky, Ohio, and 59 miles west of Cleveland (Figure 1). Although located primarily in Perkins and Oxford Townships, the eastern edge of the site extends into Huron and Milan Townships. PBOW is in general bounded on the north by Bogart Road, on the south by Mason Road, on the west by Patten Tract Road, and on the east by U.S. Highway 250. The area surrounding PBOW is mostly agricultural and residential (IT Corporation [IT], 2001).

The PBOW facility was built on property totaling 9,009 acres in early 1941 as a manufacturing plant for TNT, 2,4-dinitrotoluene (DNT), and pentolite (International Consultants Inc., 1995). Production of explosives at PBOW began in December 1941 and continued until 1945. It is

Primary Background Documents for the TNT Areas and Red Water Pond Areas Groundwater

Dames and Moore, Inc. (D&M), 1997a, ***Red Water Ponds, Focused Remedial Investigation, Final Report, Plum Brook Ordnance Works, Plum Brook Station/NASA, Sandusky, Ohio,*** prepared for U.S. Army Corps of Engineers, Nashville District/Huntington District, April.

Dames and Moore, Inc. (D&M), 1997b, ***Final Report, Sitewide Groundwater Investigation, Plum Brook Ordnance Works, Plum Brook Station/NASA, Sandusky, Ohio,*** prepared for U.S. Army Corps of Engineers, Nashville District/Huntington District, April.

Dames and Moore, Inc. (D&M), 1997c, ***TNT Areas Site Investigation, Final Report, Plum Brook Ordnance Works, Sandusky, Ohio,*** April.

International Consultants Inc., 1999, ***Community Relations Plan, Plum Brook Ordnance Works, Sandusky, Ohio,*** September.

International Consultants Inc., 1995, ***Site Management Plan, Plum Brook Ordnance Works, Sandusky, Ohio,*** September.

IT Corporation (IT), 2002, ***2001 Groundwater Remedial Investigation, Former Plum Brook Ordnance Works, Sandusky, Ohio***, March.

IT Corporation (IT), 2002, IT Corporation (IT), 2002, ***Final Red Water Pond Areas Focused Feasibility Study for Soils, Former Plum Brook Ordnance Works, Sandusky, Ohio***, December.

IT Corporation (IT), 2001, ***TNT Areas A and C Remedial Investigation, Volume 1, Report of Findings, Final, Former Plum Brook Ordnance Works, Sandusky, Ohio***, November.

IT Corporation (IT), 2000, ***Final Risk Assessment and Direct-Push Investigation of Red Water Pond Areas, Former Plum Brook Ordnance Works, Sandusky, Ohio, Volume 1***, August.

IT Corporation (IT), 1999, ***Summary Report, Site-Wide Groundwater Monitoring (1997-1998), Final, Former Plum Brook Ordnance Works, Sandusky, Ohio,*** June.

IT Corporation (IT), 1997, ***Site-Wide Groundwater Investigation Report, Plum Brook Ordnance Works, Sandusky, Ohio,*** September.

McTech Corp., 2009, ***Non-Time Critical Removal Action Report, Soil Excavation, Composting, and Disposal***, Plum Brook Ordnance Works, Pentolite Road Red Water Ponds, Sandusky, Ohio, April.

Morrison-Knudsen Ferguson Corporation, 1994, ***Site Inspection Report***, Plum Brook Station, Sandusky, Ohio, January.

Science Applications International Corporation, 1991, ***Plum Brook Station Preliminary Assessment,*** June.

Shaw Environmental, Inc. (Shaw), 2011, ***Feasibility Study Addendum for Groundwater, TNT and RWP Areas, Final, Sandusky, Ohio***, July.

Shaw Environmental, Inc. (Shaw), 2008, ***Final, Feasibility Study for Groundwater, TNT and RWP Areas, Sandusky, Ohio***, December.

Shaw Environmental, Inc. (Shaw), 2006, ***Baseline Human Health Risk Assessment of Groundwater, Final, Former Plum Brook Ordnance Works, Sandusky, Ohio***, September.

Shaw Environmental, Inc. (Shaw), 2005, ***2004 Groundwater Data Summary and Evaluation Report, Final, Former Plum Brook Ordnance Works, Sandusky, Ohio***, April.

Shaw Environmental, Inc. (Shaw), 2004, ***Ninth Quarterly (March 2004) Background Groundwater Report, Final, Former Plum Brook Ordnance Works, Sandusky, Ohio***, June.

Shaw Environmental, Inc. (Shaw), 2003, ***2002 Groundwater Data Summary and Evaluation Report, Former Plum Brook Ordnance Works, Sandusky, Ohio***, June.

U.S. Army Corps of Engineers (USACE), 2011, ***Decision Document for Soils, TNT Area A, Former Plum Brook Ordnance Works, Sandusky, Ohio***, (signed) July.

U.S. Army Corps of Engineers (USACE), 2009a, ***Decision Document for Soils, TNT Area B, Former Plum Brook Ordnance Works, Sandusky, Ohio***, September.

U.S. Army Corps of Engineers (USACE), 2009b, ***Decision Document for Soils and Sediment, TNT Area C, Former Plum Brook Ordnance Works, Sandusky, Ohio***, (signed) December.

U.S. Army Corps of Engineers (USACE), 2009, ***Interim Soil Removal Action Report, Excavation, Ex-Situ Bioremediation, and Disposal of Contaminated Soil, Pentolite Road Red Water Ponds, Plum Brook Ordnance Works, Sandusky, Ohio***, Huntington District, Huntington, West Virginia, March.

U.S. Army Corps of Engineers (USACE), 2003, ***Final Action Memorandum for Pentolite Road Red Water Pond Area Interim Removal Action at the Plum Brook Ordnance Works, Sandusky, Ohio***, Huntington District, Huntington, West Virginia, June.

estimated that more than 1 billion pounds of nitroaromatic explosives were manufactured during the 4-year operating period. The three TNT manufacturing areas were designated TNTA, TNTB, and TNTC. Twelve process lines were used in the manufacture of TNT: four lines at TNTA, three lines at TNTB, and five lines at TNTC. The PBOW facility also included infrastructure such as power plants and waste water treatment plants. The manufacturing areas consisted of widely scattered wood-frame buildings with asbestos and sheet metal coverings. These areas also included a series of buried and/or overhead flumes and pipes used to transport various liquids associated with the manufacturing process. Some of these waste liquids were transported to the PRRWP or WARWP, either prior to or subsequent to treatment.

After plant operations ceased, the manufacturing lines were decontaminated by the War Department in late 1945. During decontamination, all structures, equipment, and manufacturing debris were either removed and salvaged or removed and burned. After decontamination, the property was initially transferred to the Ordnance Department, then to the War Assets Administration after it was certified by the U.S. Army to be decontaminated. In 1949, PBOW was transferred to the General Services Administration (GSA). In 1955, the GSA completed further decontamination within the TNT manufacturing areas. This effort included removal of contaminated surface and subsurface soil around the building and wooden and ceramic waste disposal lines containing TNT. Thousands of pounds of TNT were discovered in catch basins; this TNT was removed and burned at the burning grounds.

Remedial investigations (RI) for environmental media other than groundwater were completed for TNTB and the PRRWP Area in 2000, and for TNTA and TNTC in 2003. As described in the "Scope and Role" section on page 15, Decision Documents have been signed for soil remediation at the three TNT areas, with remediation either completed (TNTB) or ongoing (TNTA and TNTC). Please note that the TNTC Decision Document also addresses contaminated sediment along a limited area of a drainage ditch. Remediation was also performed at the PRRWP Area as part of a non-time-critical removal action (NTCRA) completed in 2008, and additional remediation is anticipated for the PRRWP Area to address soil contamination that still remains at the site. It has been determined that no remediation was necessary at the WARWP Area (IT, 2002).

Two property use agreements were entered into by the National Advisory Committee of Aeronautics, the predecessor of the National Aeronautics and Space Administration (NASA), and the Army in 1956 and 1958, respectively. On March 15, 1963, NASA obtained accountability and custody for the remaining PBOW property, approximately 6,030 acres that had been under the accountability and custody of the Department of the Army. NASA performed

further decontamination efforts in the TNT Areas during 1964. The NASA decontamination process included removing contaminated surface soil above the drain tiles, flumes, etc.; destruction of buildings by fire; then removal of all soil, debris, sumps, and above-grade portions of concrete foundations. Portions of the concrete foundations located below grade were left buried, and some that had been previously slightly above grade were likewise buried. All materials, including the soil in those areas, were flashed; the area was then rough-graded. The decontamination process was also to have included the burning of nitroaromatic-filled flumes that were excavated (Dames & Moore, Inc. [D&M], 1997a).

NASA has operated and maintained PBOW since 1963, and the facility is currently the NASA Glenn Research Center, Plum Brook Station. NASA operates the former PBOW property as a space research facility in support of their John H. Glenn Research Center at Lewis Field, Cleveland, Ohio. Most of the aerospace testing facilities built in the 1960s at the site are presently on standby or inactive status. On April 18, 1978, NASA declared approximately 2,152 acres of PBOW as excess. The Perkins Township Board of Education acquired 46 acres of the excess acreage and uses this area as a bus transportation area. The GSA retains ownership of the remaining excess acreage and currently has a use agreement with the Ohio National Guard for 604 acres of this land. NASA presently controls approximately 6,400 acres. The details of land transactions are listed in the site management plan (International Consultants Inc., 1995).

Nitroaromatic compounds (i.e., explosives) are generally the contaminants in impacted TNT and RWP Areas groundwater that have resulted from past DoD activities. The presence of nitroaromatic groundwater contamination has resulted from spills on the surface; leaks from holding areas, flumes, and pipelines; and leaching from soils and materials that have infiltrated from process water associated with former manufacturing operations. Figure 3 is a generalized illustration of the source types and subsurface conditions at the TNT and RWP Areas.

It is emphasized that this Proposed Plan addresses contamination only in TNT and RWP Areas groundwater that has resulted from past DoD activities. However, it is recognized that the soil remedial actions conducted to mitigate potential risks associated with direct contact to soil contaminated primarily with nitroaromatic compounds at TNTB (Figure 4), the PRRWP Area (Figure 5), TNTC (Figure 6), and TNTA (Figure 7) will also remove potential sources of contamination to underlying groundwater . The following paragraphs briefly describe each of the former TNT areas, each of the RWP areas, and the groundwater underlying these areas.

TNTA Background. TNTA currently consists of an area of approximately 114 acres in the northeastern part of PBOW, with Columbus Avenue bisecting the site (Figure 2). Aboveground

features associated with past TNTA operations include roads, fire hydrants, water valves, railroad beds, and sections of former building pad foundations. Several below-ground features are also present: manholes, drains, and underground lines (indicated by aboveground water valves). NASA constructed its administration building on the east side of Columbus Avenue, in the central portion of TNTA. The NASA Administration Building and associated parking areas cover a small portion of the site and one of the former TNT process buildings. The remainder of TNTA is predominantly large, open areas of grasslands with less than 25 percent woodlands. TNTA is slightly hilly, generally increasing in elevation from southeast to northwest. Lindsley Ditch and smaller connecting ditches transect the site. The smaller ditches are dry during periods with little rainfall.

A Decision Document for TNTA soil remediation using alkaline hydrolysis and/or windrow composting and off-site disposal was signed in June 2011. This remedial action is based on human health and environmental risks associated with direct soil contact. Remediation for TNTA soils commenced in the fall of 2011.

TNTB Background. TNTB consists of an area of approximately 55 acres at the south-central portion of PBOW immediately north of West Scheid Road (Figure 2). Significant evidence of former PBOW facilities exists at TNTB in the form of roads, hydrants, aboveground water valves, and ditches. All buildings and structures associated with the manufacturing process have been demolished and removed. Two NASA facilities are present at the site and are currently active for research purposes: the Hypersonic Tunnel Facility (HTF) and Nitrogen Dewar Tanks. The HTF is located in the northwest portion of TNTB and consists of a single building, aboveground and underground piping and utilities, and paved parking areas. The Nitrogen Dewar Tanks are located in the center of TNTB, with aboveground piping and underground utilities leading to the northwest, toward HTF, and to the northeast, off site.

This area is relatively flat and is covered in old field and shrubby vegetation. The headwaters of Ransom Brook are located in the northwest portion of TNTB and are intermittent. Numerous drainage ditches within TNTB were dry during site visits and likely serve only as wet-weather conveyances.

A TNTB soil remedial action using windrow composting and off-site disposal was completed in December 2006 under a NTCRA. This remedial action was based on human health and environmental risks associated with direct soil contact.

TNTC Background. TNTC occupies approximately 119 acres of land in the western portion of PBOW, as shown on Figure 2. Several aboveground features are still evident at TNTC that indicate former PBOW facilities were present. These include roads, fire hydrants, water valves, a water valve control well, railroad beds, and former building pad foundations. Several below-ground features are also present: manholes, drains, and underground lines (indicated by aboveground water valves). There are no NASA buildings on the site, and NASA does not currently use the area. One building present on the site was constructed and used by the U.S. Environmental Protection Agency (USEPA) to perform noise abatement testing in the 1980s.

Currently, TNTC consists mostly of early and late old field combined with shrubby thicket vegetation and is less than 10 percent wooded. The area is relatively hilly compared to other PBOW areas. Some wetland vegetation was found along TNTC drainage ditches and streams. During rain events, drainage from the ditches flows into any of three small streams that eventually flow to Pipe Creek, located northwest of TNTC. The areas east of TNTC are primarily old field and shrub, and to the southwest of TNTC are old field and early shrub thicket. The remaining areas bordering TNTC are primarily forested.

A Decision Document for TNTC soil and sediment remediation using alkaline hydrolysis and/or windrow composting and off-site disposal was signed in December 2009. This remedial action was based on human health and environmental risks associated with direct soil contact. The remedial action is ongoing.

PRRWP Area Background. The unlined pond received waste process water from Wastewater Treatment Plant No. 1 during PBOW operations via an elevated discharge pipe. This waste originated from the manufacture of TNT at TNTA and TNTB. The pond covered between 1 and 2 acres during plant operations. In 1977, retention dikes and sump pits were installed at the PRRWP Area in response to the observation of reddish-brown water in an adjacent surface ditch. In April and May 1977, approximately 60,000 gallons of the reddish-brown water were removed. The original basin was then backfilled so that the original pond area would be higher in elevation than the surrounding area; this was done to prevent ponding in the area of the original PRRWP footprint (D&M, 1997b).

A NTCRA was completed at PRRWP Area in September 2008 (McTech Corp., 2009) to remediate the area of a dark soil seam found to be associated with elevated TNT concentrations. In a subsequent investigation conducted outside of the NTCRA area, the presence of additional nitroaromatic soil contamination was identified. The contaminated soil outside of the NTCRA

area is being evaluated as part of an addendum to the RWP Areas focused feasibility study (FFS) for soil.

Currently, the PRRWP Area is covered in old field vegetation, scrub/shrub, and moderate forest, with isolated areas of standing water with emergent wetland vegetation. The approximately 0.6-acre NTCRA area was seeded in 2008 with Indian grass (*Sorghastrum nutans*), a native species. Seasonally ponded areas, which have been observed since the regrading activities, are present near the PRRWP but outside of the original PRRWP footprint. A drainage ditch, which has been observed as algae-covered and containing a few inches of flowing water, is located along the eastern edged of the PRRWP Area. No buildings are present, and the PRRWP Area is not used by NASA.

WARWP Area Background. The two unlined ponds received TNTC waste process water via an elevated discharge pipe from Wastewater Treatment Plant No. 2 during PBOW operations. The WARWP Area consisted of an "east pond" and a "west pond." Together, these ponds covered approximately 7 acres. The east pond contained water from the 1940s until the late 1970s, when the berm between the two ponds was breached by NASA to drain the eastern pond. At present, the east pond is typically dry, with the exception of localized water near the location of the former berm. The west pond has existed since the1940s. NASA reportedly disposed of some lime sludge immediately north of and within the west pond. The lime sludge originated from the reactor settling basins. This practice of lime sludge disposal was reportedly discontinued in 1973 (D&M, 1997a). The water within the west pond, combined with residual water in the east pond (near the former berm), comprises approximately 3.5 acres. The area adjacent to the pond is vegetated with mown grass, moderate forest, and late forest. The WARWP Area is not used by NASA, and no buildings are present.

Description of Groundwater Underlying the TNT and RWP Areas. Two groundwater units underlie the TNT and RWP Areas: an upper overburden/shale water-bearing unit and a deeper limestone unit. The overburden/shale water within the TNT and RWP Areas is isolated, discontinuous, and seasonally dependent, generally yielding a low and undependable volume of groundwater where it exists. A direct-push groundwater investigation undertaken in 2001 was discontinued because groundwater was not encountered in more than 80 percent of the borings. Additionally, groundwater from background wells in competent shale bedrock was found to have elevated concentrations of chloride, sulfate, iron, manganese, and total dissolved solids (TDS). Some of these concentrations, especially those of sulfate and TDS, were found at levels that far exceed the respective USEPA Office of Groundwater Secondary Drinking Water Regulations (SDWR) or health advisories (USEPA, 2011). The SDWRs are nonenforceable levels that are

based on aesthetic properties (e.g., taste, odor, color) or cosmetic effects (e.g., skin or tooth discoloration). The following bulleted items compare concentrations of these analytes in samples from off-site upgradient background shale unit groundwater wells to the respective Office of Drinking Water SDWRs or health advisories.

- Chloride – 50 percent of the background wells exceeded the chloride SDWR of 250 milligrams per liter or parts per million (ppm). The maximum background concentration (3,540 ppm) was 14 times higher than the SDWR.
- Sulfate – 11 percent of the background wells exceeded the sulfate SDWR of 250 ppm. The maximum background concentration (514 ppm) was approximately twice the SDWR.
- Iron – 32 percent of the background wells exceeded the iron SDWR of 300 ppm. The maximum background concentration (1,940 ppm) was approximately 5 times higher than the SDWR.
- Manganese – 61 percent of the background wells exceeded the manganese SDWR of 50 ppm. The maximum background concentration (728 ppm) was over 14 times higher than the SDWR.
- Sodium – 100 percent of the background wells exceeded the sodium health advisory level of 20 ppm. The maximum background concentration (1,390 ppm) was approximately 70 times higher than the sodium health advisory level. (Note that no SDWR exists for sodium.)
- TDS – 82 percent of the background wells exceeded the TDS SDWR of 500 ppm. The maximum background concentration (6,850 ppm) was nearly 14 times higher than the SDWR.

Based on naturally occurring high TDS and other analytes as described above, this groundwater unit is consistent with the USEPA guidelines for Class III nonpotable groundwater. Therefore, overburden/shale groundwater is not a suitable drinking water source based on yield and quality.

The limestone unit typically yields an adequate volume of groundwater for a drinking water source, but is regionally regarded by the Ohio Department of Natural Resources (1962) as being of low quality because of high mineral content. Naturally elevated concentrations of sulfate were observed in three limestone wells (in TNTA, TNTC, and the WARWP Area) and the off-gassing of hydrogen sulfide was observed in several wells. The maximum sulfate concentration (2,660 ppm) among these wells was over 10 times the SDWR of 250 ppm. Additionally, all limestone wells except one exhibited the presence of naturally occurring petroleum, and more than two-thirds of limestone groundwater samples were found to have benzene (a natural petroleum component) concentrations that exceed the drinking water standard (see Section 2.6 of the

groundwater feasibility study [FS]). The limestone groundwater within the TNT and RWP Areas also meets the USEPA guidelines for Class III nonpotable groundwater based on elevated concentrations of naturally occurring TDS, hydrogen sulfide, metals, and petroleum compounds. In summary, the limestone unit generally provides an adequate quantity of groundwater, but the natural quality of this water would fail drinking water standards. Therefore, groundwater from the limestone unit underlying the TNT and RWP Areas is nonpotable due to naturally poor quality that is unrelated to former site activities.

Site Characteristics

Field activities were conducted specifically to investigate environmental media at TNTA, TNTB, TNTC, and the RWP Areas, including soil, surface water, sediment, and groundwater. Even though this Proposed Plan addresses only groundwater, the sampling efforts for these other media are mentioned to provide an accurate context of the investigation history of the TNT and RWP sites. The analytical results and characteristics for media other than groundwater are not presented in this Proposed Plan.

A total of 135 direct-push overburden/shale groundwater samples had been planned for collection in 2001, 45 within each of the TNT areas. However, after 32 borings were installed in the three TNT areas, groundwater samples were collected from only 6 of these borings, as the other 26 borings lacked groundwater. Therefore, this sampling effort was abandoned due to a lack of groundwater.

The groundwater results are summarized for each of the TNT and RWP Areas in the paragraphs that follow. There were numerous detections of nitroaromatics in the overburden/shale groundwater, but because the groundwater within the overburden is discontinuous, no plumes were identified in this unit. For the overburden unit, the monitoring well and direct-push groundwater samples were evaluated separately. The direct-push groundwater samples, which are far less expensive and take far less time to collect, are used to determine the presence or absence of detectable levels of nitroaromatics but are not regarded as being of sufficient quality for quantitative analysis. However, the direct-push groundwater sampling results were used in the development of the GW-3 and GW-4 remedial alternatives which are described in the Summary of Remedial Alternatives section of this Proposed Plan.

In the limestone unit, the groundwater FS identified two nitroaromatics plumes. Each has relatively low concentrations. One is north of the PRRWP Area (Figure 8) and contains both 2,4-

DNT and 2,6-DNT. The other plume is in the vicinity of the WARWP Area (Figure 9) and is limited to 2,4-DNT only.

TNTA. Prior to the RI activities, one surface soil sample, two surface water samples, and two sediment samples were collected in 1993 in support of an initial site inspection (SI) completed in 1994. Thirty-six soil samples were collected during 1994 as reported in the 1997 site investigation report. With respect to groundwater, three overburden wells were sampled in 1993 and five were sampled in 1994, 1996, 1997, and 1998.

RI activities were conducted separately for TNTA soils (479 samples), surface water (8 samples), and sediment (10 samples) in 2000 and for site groundwater in October 2001 through April 2002 (semiannual sampling from 2 overburden wells and 2 bedrock wells). One of the overburden wells could not be sampled in 2001 because it was dry. The RI also evaluated five overburden well samples collected in 1997 and the five samples collected in 1998.

A total of 11 direct-push overburden groundwater samples were collected in 2000 and 2001; these also were used in the RI. A total of 45 temporary piezometer groundwater samples had been planned in 2001 for TNTA, but only 2 of these were collected due to a lack of groundwater in the overburden.

Two bedrock wells, one of which is located downgradient (BEDMW-17), were sampled in 1994, 1996, 1997, 1998, 2001 and 2002; the samples collected from these wells in 1997, 1998, 2001, and 2002 were used in the RI. A third bedrock well (TNTA-BEDGW-001) was installed and sampled in 2001 and was sampled again in 2002 as part of the RI.

The maximum detected nitroaromatics concentration among the TNTA overburden wells was 110 micrograms per liter or parts per billion (ppb) of TNT, which was detected in 27 percent of TNTA overburden well samples. TNT was detected at much higher concentrations in TNTA direct-push overburden groundwater samples, up to 32,400 ppb near Building 185. The soil in the vicinity of this direct-push sample is being remediated as part of the TNTA soil remedial action because of high soil concentrations of nitroaromatics. Based on sampling results from PBOW as well as other sites, analytical results from direct-push groundwater samples tend to be biased high for metals and nitroaromatics. This has been attributed both to the higher turbidity in direct-push groundwater samples as well as contamination from overlying soil being dragged down into the groundwater. For these reasons, direct-push groundwater samples are not regarded as being of adequate quality for quantitative evaluation of groundwater contamination.

The maximum detected nitroaromatics concentration among the TNTA limestone bedrock well samples was 3.6 ppb of 2,6-DNT, which was detected in only one of six TNTA bedrock groundwater samples. Note that TNT, detected in the overburden groundwater, was not detected in any of the TNTA bedrock wells.

TNTB. RI activities were conducted separately for TNTB soils (431 samples), surface water (2 samples), and sediment (5 samples) in 1998 and for site groundwater in October 2001 through August 2004 (semiannual sampling from 2 overburden wells and 4 bedrock wells). Two of these bedrock wells were installed in 2001. Two samples each of surface soil, surface water, and sediment were collected during 1993 in support of an SI completed in 1994, and 34 soil samples were collected in 1994 for the site investigation completed in 1997. Prior to the groundwater RI, the two overburden wells were sampled previously in 1993, 1994, 1996, 1997, and 1998, and the two bedrock wells were sampled previous to the RI in 1996, 1997, and 1998. The groundwater samples collected in 1997 and 1998 were also evaluated as part of the RI.

A total of 45 temporary piezometer groundwater samples had been planned in 2001 for TNTB. Groundwater samples were collected from only two of these piezometer locations because of a lack of groundwater in the overburden, and one of the samples had insufficient yield for complete analyses.

The maximum detected nitroaromatics concentration among the TNTB overburden wells was 680 ppb of TNT, which was detected in 80 percent of TNTA overburden well samples. TNT was not detected in TNTB direct-push overburden or in TNTB limestone bedrock groundwater samples.

TNTC. RI activities were conducted separately for TNTC soils (415 samples), surface water (10 samples), and sediment (15 samples) in 2000 and for site groundwater in October 2001 through April 2002. Two overburden wells were sampled in 2000, and three were sampled in 2002. Two bedrock wells were sampled in both 2001 and 2002. As part of the RI, nine samples were collected from temporary piezometers in 2000, and samples were collected from two additional temporary piezometers in 2001 (though 12 other TNTC piezometer locations were dry). Prior to the groundwater RI activities, five overburden wells were sampled in 1997 and 1998. One of the bedrock wells (BED-MW13) was also sampled in 1994, 1996, 1997, and 1998.

As part of the SI, one collocated surface water and sediment sample pair was collected in 1993 just downstream of the confluence of Pipe Creek and a small tributary running east to west in the northern portion of TNTC. Two TNTC soil samples were collected during the SI (Morrison-

Knudsen Ferguson Corporation, 1994), and 19 soil samples were collected in 1994 during the site investigation (D&M, 1997c).

Numerous temporary piezometer groundwater samples had been planned in 2001 for TNTC, but only two of these could be collected due to a lack of groundwater in the overburden.

The only nitroaromatic compound detected among the 15 TNTC overburden well samples was TNT at 0.61 ppb. TNT was detected at much higher concentrations in the TNTC direct-push overburden groundwater samples (up to 20,100 ppb), and 2,4-DNT was detected at an even higher concentration (37,600 ppb). These concentrations of TNT and 2,4-DNT were detected near Building 683. The soil in the vicinity of this direct-push sample is being remediated as part of the TNTC soil remedial action because of high soil concentrations of nitroaromatics. As mentioned in the discussion above for TNTA, the concentrations found in direct-push groundwater samples are commonly exaggerated due to a drag-down effect resulting from contamination in overlying soil. No nitroaromatic compounds were detected in TNTC bedrock groundwater.

RWP Areas. Focused RI sampling was performed in 1994. A total of 104 soil samples, 7 overburden groundwater samples, and 4 bedrock groundwater samples were collected from both RWP Areas; 5 surface water and 12 sediment samples were collected from the WARWP Area.

Additional soil, sediment, surface water, and groundwater sampling was conducted during a direct-push investigation conducted in 1998. In the PRRWP Area, 20 surface soil, 39 subsurface soil, 20 overburden groundwater, 4 surface water, and 4 sediment samples were collected from the PRRWP Area. This also included 19 surface soil, 37 subsurface soil, 14 overburden groundwater, 6 surface water, and 6 sediment samples collected from the WARWP Area. In addition to the samples collected during the focused RI and direct-push investigation, groundwater samples have been collected from overburden and bedrock monitoring wells associated with the two RWP Areas since 1997.

The maximum detected nitroaromatics concentration among the PRRWP Area overburden wells was 6,900 ppb of 1,3,5-trinitrobenzene, which was detected in 64 percent of the PRRWP Area. 1,3,5-Trinitrobenzene was detected in only 5 percent of the PRRWP Area direct-push samples, and at a much lower concentration (600 ppb) than in the overburden well samples; note that as stated above, the direct-push samples are not of adequate quality for quantitative analysis. 2,4-DNT was the nitroaromatic detected in the PRRWP direct-push groundwater samples at the highest concentration (9,200 ppb) and at the greatest frequency (62 percent); this compound was

detected at a maximum concentration in the overburden well samples at a maximum concentration of 4,100 ppb.

The maximum detected nitroaromatics concentration among the PRRWP Area limestone bedrock well samples was TNT at 1.6 ppb in well PB-BED-MW15. TNT was detected in two of six PRRWP Area bedrock groundwater samples. 2,4-DNT and 2,6-DNT were each detected at a concentration of 0.89 ppb in well PB-BED-MW15, and 2,4-DNT was also detected at a concentration of 1.5 ppb at the former abandoned well BED-MW27. Therefore, 2,4-DNT and 2,6-DNT in this area has been identified as a low-concentration plume in the limestone bedrock groundwater unit (Figure 8).

The maximum detected nitroaromatics concentration among the WARWP Area overburden wells was 55 ppb of 2,4-DNT, which was detected in 38 percent of the PRRWP Area. 1,3,5-trinitrobenzene, at a concentration of 680 ppb, had the highest concentration among the nitroaromatics in the direct-push overburden groundwater samples. As noted for TNTA and TNTC, direct-push groundwater samples are not regarded as being of sufficient quality for quantitative evaluation of contamination.

The maximum detected nitroaromatics concentration among the WARWP limestone bedrock well samples was that of 2,4-DNT at 19 ppb. TNT was detected in one of three other WARWP bedrock groundwater samples. This area is identified as a groundwater plume on Figure 9.

Scope and Role of the TNT and RWP Areas Groundwater

One of DoD's specific goals from the Defense Planning Guidance for DERP-FUDS is to reduce risk to human health and the environment through implementation of effective, legally compliant, and cost-effective response actions. To that end, the environmental investigation of PBOW has been divided into 16 areas of concern (AOC), also referred to as DERP-FUDS projects, to address the potential concerns presented by each area associated with former DoD activities. A separate close-out document is required for each of the 16 DERP-FUDS projects. This current Proposed Plan specifically addresses contamination in groundwater underlying TNTA, TNTB, TNTC, the PRRWP Area, and the WARWP Area only. The status for each of the other 15 DERP-FUDS sites is shown so that it can be seen how the current action fits into the scope of action at PBOW, including all completed, ongoing, and planned activities. This current Proposed Plan specifically addresses groundwater contamination in the TNT and RWP Areas only. Please note that groundwater associated with each active DERP-FUDS project (other than the RWP

Areas and the TNT Areas) will be addressed in the separate Decision Document specific to that DERP-FUDS project.

The 16 DERP-FUDS projects and their status are briefly identified in the following paragraphs. Please note that 6 of these 16 projects have been closed or have signed Decision Documents, as indicated.

TNT and RWP Areas Groundwater. A baseline human health risk assessment (BHHRA) of groundwater associated with the three former TNT Areas and two former RWP Areas was finalized in September 2006, and an FS for groundwater associated with these areas was finalized in December 2008. An addendum to the groundwater FS was finalized in July 2011 (Shaw Environmental, Inc. [Shaw], 2011). The groundwater associated with these five areas is expected to be addressed in a single Decision Document. Completion of this Proposed Plan is the next step in the process. Note that groundwater associated with each of the other active DERP-FUDS projects is expected to be addressed as part of the separate Decision Document specific to that DERP-FUDS project.

TNTA. An FFS for soils and sediment was completed in 2003. A Decision Document for TNTA soils was signed on June 22, 2011, and state concurrence was received on July 20, 2011. Remedial action for TNTA soils commenced in the fall of 2011.

TNTB. An FS for soils was completed in 2001. An Action Memorandum for a NTCRA regarding soils was presented to the public on March 28, 2002. The Action Memorandum was finalized in June 2003, and the removal action was completed in December 2006. The final report of the interim soil removal action was issued in 2007. A Proposed Plan recommending no further action was presented during a July 16, 2009 public meeting. No comments were provided during the subsequent public comment period. A no-further-action Decision Document was signed on September 23, 2009, and state concurrence was received on September 29, 2009. The project closeout report was signed on March 31, 2010.

TNTC. An FFS for soils and sediment was completed in 2003. A Proposed Plan was submitted in March 2009. A Decision Document was signed by DoD on December 7, 2009, and a concurrence letter, dated January 15, 2010, was received from the State of Ohio. Remedial action of TNTC soil and sediment is ongoing.

Red Water Pond Areas. An FFS for the Red Water Pond Areas soil was completed in December 2002. Remedial alternatives were developed and evaluated for PRRWP Area soil in

the FFS because the human health risks associated with PRRWP Area soil were determined to be unacceptable under unrestricted land use. Because human health and ecological risks for WARWP Area soil were determined to be within acceptable levels for unrestricted land use, it was not necessary to develop remedial alternatives for the WARWP Area soil. An Action Memorandum was presented to the public in September 2002 for a NTCRA regarding PRRWP Area soil. An interim removal action at the PRRWP Area began in January 2003 under the NTCRA. During the NTCRA soil removal, the need for additional soil sampling was recognized based on the discovery of a dark layer of contaminated soil. A windrow composting action was selected to remediate this soil under the NTCRA. Composting began in 2007 and was completed in September 2008. Post-NTCRA delineation sampling was performed in spring and summer 2009. Because of residual human health risks, additional delineation sampling was completed in November 2010. A soil delineation report and risk evaluation have been prepared in support of an addendum to the FFS, which is scheduled for completion in 2012.

Acid Areas 1, 2, and 3. The SIs of the three acid areas were completed in December 1998. An RI and risk assessments were completed for Acid Areas 2 and 3 in September 2006 and February 2008, respectively. These two areas are currently in the FS stage. The Acid Area 1 RI and risk assessments were completed July 2010. Additional delineation sampling was conducted in June and July 2011. FSs are planned for Acid Area 1 and for Acid Areas 2 and 3 in 2013.

Reservoir No. 2 Burning Grounds. The RI began in 2004, and the site characterization report was issued in January 2006. Human health and ecological risk assessments were completed in February 2010. Further delineation sampling was performed in October 2010, and a draft FS was submitted in July 2011. The final FS was completed in October 2011. A proposed plan is currently being prepared and is scheduled for completion in 2012.

Additional Burning Grounds. A preliminary assessment (PA) was performed in 1991. This project includes five burning ground areas. NASA has agreed to take full responsibility for three of these (Taylor Road, Snake Road, and Fox Road Burning Grounds). The other two (G-8 and "Additional" Burning Grounds) require further records research review. Based on this records review, responsibility for these areas will be established.

Waste Water Treatment Plant Nos. 1 and 3. A limited site investigation was completed in July 2000. The RI report is scheduled for completion in 2012. These will include the associated wood-stave waste water sewer lines from TNTA and TNTB to Waste Water Treatment Plant No. 1. The former Waste Water Treatment Plant No. 3 neutral waste storage tank, which was used by NASA as the K-Site control building, is scheduled for demolition by NASA in 2012.

Waste Water Treatment Plant No. 2. A PA performed in 1991 found a potential for contamination of soil, surface water, sediment, and groundwater with acetone, pentaerythritol, and tetraerythritol tetranitrate. An SI was performed in 1997. An RI and FS were recently funded, which include the associated TNTC to Waste Water Treatment Plant No. 2 sewer lines and the steel sewer lines. Fieldwork for the RI was begun in May 2011 and is expected to be completed in 2013.

Power House Ash Pit No. 2. A PA was performed in 1991. A final site characterization report and risk assessment reports were submitted in September 2010. Additional soil sampling was conducted in July 2011 for an RI and risk assessment addenda. A contract has been awarded for a Proposed Plan and Decision Document.

Ash Pits Nos. 1 and 3. A limited site investigation performed in July 2000 resulted in the recommendation that further investigation be performed. A contract for an RI was awarded in June 2008, and fieldwork began in December 2008. A site characterization report and risk assessments were submitted in 2011 for Ash Pit No. 1, and the site characterization report and risk assessments for Ash Pit No. 3 are anticipated for completion in 2012. Completion of an RI report and a proposed plan are scheduled for 2014.

TNT Loading Areas. A limited site investigation was completed in July 2000. The site was recommended for no further action, and closeout was achieved with state concurrence in September 2006.

Pentolite Area Waste Lagoon. A limited site investigation was completed. The project was closed out in September 2006 with no further action; the state of Ohio concurred.

Lower Toluene Tanks. A limited site investigation was completed in July 2000. The project was closed out in September 2006 with no further action; the State of Ohio concurred.

Garage Maintenance Area. A limited SI was completed for the Locomotive Building Area in July 2000 that resulted in the recommendations to proceed with further investigation. The Locomotive Building Area is in the eastern portion of the Garage Maintenance Area. A final site characterization report was submitted for the Locomotive Building Area in September 2010, and the final risk assessment reports were submitted in December 2010. Fieldwork for the Sellite Area and Unloading Area RI began in June 2011 and is expected to be completed in May 2012.

Preparation of an RI report that includes these two portions of the Garage Maintenance Area is scheduled for 2013.

Soil Actions. The soil actions undertaken at the PRRWP Area, TNTA, TNTB, and TNTC and the proposed action at Reservoir No. 2 Burning Grounds are being implemented by the USACE under DERP-FUDS. To date, no other removal actions or response actions have been recommended.

Summary of Potential Site Risks

A BHHRA was performed for TNTA, TNTB, TNTC, PRRWP Area, and WARWP Area groundwater. Although ecological risk assessments were performed for each of the TNT and RWP Areas, no complete ecological exposure pathway was identified for any of these areas with respect to groundwater. Therefore, no ecological risks or hazards have been identified for groundwater underlying the TNT and RWP Areas.

The BHHRA identified no current human exposure to groundwater either on site or in adjacent areas off site. However, as agreed by the PBOW Project Delivery Team, it was assumed for purposes of the BHHRA that limestone bedrock groundwater underlying the TNT and RWP Areas may be developed as a source of potable water at some time in the future. Although this limestone unit would provide an adequate quantity of groundwater, the quality of this water would fail drinking water standards due to the presence of naturally occurring compounds that is unrelated to former site activities. Therefore, groundwater from the limestone unit underlying the TNT and RWP Areas is regarded as nonpotable, despite the assumption made in the BHHRA that it would be developed as a drinking water source. The assumption of potability for the limestone bedrock groundwater was made in the BHHRA because the state maintained that this assumption should be made under baseline conditions where no prior use restrictions are in place and the water unit could provide adequate yield. The BHHRA evaluated the overburden/shale groundwater only qualitatively because of undependable yield and naturally low quality.

The following exposure scenarios were evaluated in the BHHRA with respect to future use of the limestone bedrock groundwater (exposure routes shown in parentheses):

- On-site worker (ingestion, dermal contact with water)
- On-site resident (ingestion, dermal contact with water, inhalation [volatile compounds only])

- Off-site resident at downgradient property boundary (ingestion, dermal contact with water, inhalation [volatile compounds only]).

Risks were evaluated for these receptors based on current groundwater concentrations and modeled future groundwater concentrations. The modeling was performed using a site-specific concentration, leaching, and groundwater flow information to determine potential future limestone bedrock concentrations which may result from current concentrations of TNT, 2,4-DNT, and 2,6-DNT in the soil and overburden groundwater (Shaw, 2008). Note that the output of the groundwater model is considered to be conservative (i.e., biased high), likely resulting in overestimates of potential future groundwater concentrations. Because there is no current exposure to groundwater, there are no current risks associated with groundwater. Figure 10 depicts the groundwater exposure pathways evaluated for each receptor in the BHHRA.

The incremental lifetime cancer risks (ILCR) that could result from a reasonable maximum exposure to potential carcinogenic (cancer-causing) chemicals detected in groundwater associated with TNTA, TNTB, TNTC, the PRRWP Area, and the WARWP Area were determined under each human receptor scenario. The ILCR is the "extra risk" that cancer will develop at some point in an exposed individual solely because of exposure to the pertinent chemicals. In this case, the ILCR is associated with chemicals in the site groundwater that are resultant from DoD activities. This extra cancer risk does not include the baseline cancer risk statistically incurred by a member of the general population, whether or not he is exposed to the PBOW site groundwater. The ILCR from each chemical and exposure pathway (e.g., ingestion of groundwater as tap water, dermal exposure to groundwater, inhalation of vapors from household water) were summed to calculate the combined ILCRs to the individual receptors. The NCP states that acceptable exposure levels are generally concentrations that represent an excess upper bound lifetime cancer risk (or ILCR) to an individual between 1×10^{-6} (1 in 1,000,000) and 1×10^{-4} (1 in 10,000). The Ohio EPA considers total ILCR values greater than 1×10^{-5} (1 in 100,000) in an environmental medium to be unacceptable. Please note that the baseline risk for the general U.S. population of developing cancer is approximately 40 percent (4 in 10). As an illustration, if an individual is assumed to have exactly a 40 percent chance (400,000 in 1,000,000) of developing cancer without a specific exposure, an additional exposure at an ILCR of 1×10^{-5} (1 in 100,000, or 10 in 1,000,000) would result in an overall cancer risk of 400,010 in 1,000,000.

Noncancer human health effects are evaluated differently than are cancer risks because the nature of noncancer effects generally assumes a "threshold level" below which adverse health

effects are regarded as unlikely to occur. As stated in the NCP, acceptable exposure levels for systemic toxicants (i.e., noncancer effects) are represented by concentration levels to which a human population may be exposed without adverse effect during a lifetime or part of a lifetime, incorporating an adequate margin of safety. Consistent with USEPA risk assessment guidance, the estimated exposure levels of DoD-related chemicals were mathematically compared to threshold-level-based chronic reference doses to derive a hazard index (HI). These chronic reference doses are generally USEPA-verified acceptable lifetime exposure rates that represent the acceptable exposure levels described in the NCP. An HI value greater than 1 indicates a possible concern for potential adverse health effects; HI values equal to or less than 1 indicate that adverse health effects are unlikely for any exposed individual. The overall ILCR and HI values for each receptor, based separately on site-related chemicals, non-site-related chemicals, and modeled off-site concentrations, are summarized in Table 1. "Site-related" chemicals refers to those which are related to former DoD activities at PBOW, and "non-site-related" chemicals are those which are associated with background levels or are otherwise not related to former DoD activities at PBOW. The relative percentages of site-related cancer risks and noncancer hazards compared to non-site-related cancer risks and noncancer hazards are presented in Table 2.

Groundwater at each of the five AOCs and downgradient locations along the PBOW facility boundary would exceed the Ohio EPA 1×10^{-5} cancer risk goal and/or the HI index goal of 1, based on cancer risks and noncancer hazards associated with a combination of naturally occurring chemicals and site-related contaminants. These exceedances of the criteria were found under either a hypothetical future residential exposure scenario or a future on-site worker scenario. Also, these exceedances were found for both current groundwater concentrations and future modeled concentrations. Please note that future concentrations were modeled for site-related contaminants only; it is assumed that naturally occurring, non-site-related chemicals will have the same concentrations and associated risks/hazards in the future as they do currently.

At the downgradient areas and at each AOC, except the WARWP Area, the non-site-related chemicals of potential concern dominate both the cancer risk and noncancer hazards. However, even at the WARWP Area, residential and worker ILCR values associated with non-site-related arsenic exceed the 1×10^{-5} cancer risk goal. The following classes of chemicals identified in the groundwater BHHRA are dominant with respect to cancer risk and/or noncancer hazard for the five AOCs and the downgradient areas; site-related and non-site-related (i.e., naturally occurring) are specifically noted as such:

- TNTA – Naturally occurring petroleum-related organic compounds
- TNTB – Naturally occurring inorganics and naturally occurring petroleum-related organic compounds
- TNTC – Naturally occurring petroleum-related organic compounds
- PRRWP Area – Naturally occurring petroleum-related organic compounds
- WARWP Area – Site-related nitroaromatics and naturally occurring arsenic
- Downgradient – Naturally occurring petroleum-related organic compounds.

Because of the presence of naturally occurring contaminants, use of the limestone groundwater from any of AOCs or downgradient areas as a potable source would result in cancer risks and/or noncancer hazards that would exceed the target HI goal of 1 and/or the Ohio EPA 1×10^{-5} cancer risk goal.

The following conclusions regarding cancer risks and noncancer hazards are drawn from the BHHRA results and uncertainty evaluation for groundwater underlying TNTA, TNTB, TNTC, the PRRWP Area, the WARWP Area, and the downgradient PBOW boundary. These conclusions are also presented on Tables 1 and 2.

TNTA Conclusions

- ***Current Site-Related Risks Using Measured Concentrations.*** Using current measured concentrations, site-related risks/hazards associated with residential use of TNTA groundwater (ILCR=4×10^{-5}; HI=2) would exceed the 1×10^{-5} Ohio EPA target cancer risk goal and the target HI goal, but those associated with on-site worker use (ILCR=1×10^{-5}; HI=0.2) would not. Site-related cancer risks associated with the TNTA on-site resident and worker, based on current concentrations, are within the NCP acceptable range (1×10^{-6} to 1×10^{-4}). For each receptor, the site-related risks/hazards account for 4 percent or less of the total; for TNTA, non-site-related chemicals account for 96 percent or more of the total risks/hazards.

- ***Future Site-Related Risks Using Modeled Concentrations.*** Using modeled future concentrations that include modeled future potential impact from overburden groundwater, site-related risks/hazards associated with residential use of TNTA groundwater (ILCR=5×10^{-4}; HI=4) would exceed the 1×10^{-5} Ohio EPA target cancer risk goal and the target HI goal. Likewise, the cancer risk for the worker (1×10^{-4}) would exceed the Ohio EPA goal, but the worker HI (0.5) would not. Assuming future modeled concentrations, site-related cancer risks associated with the TNTA on-site resident exceed the NCP acceptable range; site-related cancer risks associated with the worker are at the upper limit of the NCP acceptable range (1×10^{-6} to 1×10^{-4}).

- ***Non-Site-Related Risks.*** The naturally occurring, non-site-related cancer risks associated with residential use (ILCR=2×10^{-3}) and worker use (ILCR=2×10^{-4}) indicate unacceptable cancer risks for the resident with respect to both the Ohio EPA (1×10^{-5}) cancer risk goal and NCP acceptable risk range (1×10^{-6} to 1×10^{-4}). Also, the noncancer HI values for the resident (HI=345) and for the worker (HI=10) exceed the target HI goal of 1. These ILCR and HI values clearly indicate unacceptable risks and hazards associated with naturally occurring, non-site-related chemicals under a residential or worker use scenario. For each receptor, the non-site-related risks/hazards account for 96 percent or more of the total.

TNTB Conclusions

- ***Current Site-Related Risks Using Measured Concentrations.*** The groundwater BHHRA identified no site-related chemicals of potential concern in the TNTB limestone groundwater unit. Cancer risks and noncancer hazards associated with site-related chemicals in TNTB groundwater, based on measured concentrations, are considered negligible.

- ***Future Site-Related Risks Using Modeled Concentrations.*** Using modeled future concentrations that include modeled future potential impact from overburden groundwater, site-related cancer risks (ILCR=2×10^{-5}) for the resident would slightly exceed the Ohio EPA target cancer risk goal, but would be well within the NCP acceptable range. The site-related cancer risk estimate for the worker (ILCR=6×10^{-6}) would meet the Ohio EPA target cancer risk goal. Noncancer hazards for the resident (HI=0.1) and worker (HI=0.02) based on modeled concentrations would meet the target goal of 1.

- ***Non-Site-Related Risks.*** The naturally occurring, non-site-related cancer risks associated with residential use (ILCR=3×10^{-4}) and worker use (ILCR=7×10^{-5}) indicate unacceptable cancer risks with respect to the Ohio EPA (ILCR=1×10^{-5}) cancer risk goal. The cancer risk for the resident also exceeds the NCP acceptable range. The noncancer HI value for the resident (18) exceeds the target HI goal of 1, whereas the HI value for the worker (0.8) does not. The ILCR and HI values clearly indicate unacceptable risks and hazards associated with naturally occurring, non-site-related chemicals under a residential use scenario.

TNTC Conclusions

- ***Current Site-Related Risks Using Measured Concentrations.*** The groundwater BHHRA identified no site-related chemicals of potential concern for the TNTC limestone groundwater unit. Cancer risks and noncancer hazards associated with site-related chemicals in TNTC groundwater, based on measured concentrations, are considered negligible.

- ***Future Site-Related Risks Using Modeled Concentrations.*** Using modeled future concentrations that include modeled future potential impact from overburden

groundwater, site-related risks/hazards associated with residential use of TNTC groundwater (ILCR=2×10^{-3}; HI=8) would exceed 1×10^{-5} Ohio EPA target cancer risk goal and the target HI goal. Likewise, the cancer risk for the worker (ILCR=4×10^{-4}) would exceed the Ohio EPA goal for cancer risk, but the worker HI (1) would not exceed the target HI threshold of 1. Assuming future modeled concentrations, site-related cancer risks associated with both the TNTC on-site resident and worker exceed the NCP acceptable range.

- ***Non-Site-Related Risks.*** The naturally occurring, non-site-related cancer risks associated with residential use (ILCR=1×10^{-3}) and worker use (ILCR=9×10^{-5}) indicate unacceptable cancer risks for the resident with respect to the Ohio EPA (ILCR=1×10^{-5}) cancer risk goal. The ILCR associated with naturally occurring, non-site-related chemicals for the resident also exceeds the NCP acceptable risk range. The non-site-related noncancer HI value for the resident (65) exceeds the target HI goal of 1; that of the worker equals this goal. These ILCR and HI values clearly indicate unacceptable risks and hazards associated with naturally occurring, non-site-related chemicals under a residential use scenario.

PRRWP Conclusions

- ***Current Site-Related Risks Using Measured Concentrations.*** Using current concentrations, site-related cancer risks associated with residential use of PRRWP Area groundwater (ILCR=2×10^{-5}) would exceed the 1×10^{-5} Ohio EPA target cancer risk goal, but the noncancer hazard (HI=0.6) would meet the target HI goal. The residential cancer risk would be within the NCP acceptable range. Site-related cancer risks associated with on-site worker use of groundwater (ILCR=4×10^{-6}) would meet the Ohio EPA cancer risk goal, and noncancer hazards (HI=0.07) for the worker would meet the noncancer target HI of 1. For each receptor, the site-related risks/hazards account for less than 1 percent or less of the total; for PRRWP groundwater, non-site-related chemicals account for more than 99 percent of the total risks/hazards.

- ***Future Site-Related Risks Using Modeled Concentrations.*** Using modeled future concentrations that include modeled future potential impact from overburden groundwater, site-related risks associated with residential use of PRRWP Area groundwater (ILCR=2×10^{-4}) would exceed the 1×10^{-5} Ohio EPA target cancer risk goal; the target noncancer hazard (HI=0.7) would meet the target HI goal of 1. Likewise, the cancer risk for the worker (4×10^{-5}) would exceed the Ohio EPA goal, and the worker HI (0.1) would not exceed the target goal of 1. Assuming future modeled concentrations, site-related cancer risks associated with the PRRWP Area on-site resident exceed the NCP acceptable range; site-related cancer risks associated with the worker are within the NCP acceptable range.

- ***Non-Site-Related Risks.*** The naturally occurring, non-site-related cancer risks associated with residential use (ILCR=7×10^{-3}) and worker use (ILCR=5×10^{-4}) indicate unacceptable cancer risks with respect to the Ohio EPA (1×10^{-5}) cancer risk goal. Also, the residential and worker cancer risks associated with exposure to non-

site-related chemicals in groundwater exceed the NCP acceptable risk range. The noncancer HI values for both the resident (234) and the worker (15) exceed the target HI goal of 1. These ILCR and HI values clearly indicate unacceptable risks and/or hazards associated with naturally occurring, non-site-related chemicals under a residential or worker use scenario. For each receptor, the non-site-related risks/hazards account for more than 99 percent of the total.

WARWP Conclusions

- ***Current Site-Related Risks Using Measured Concentrations.*** Using current measured concentrations, site-related cancer risks associated with residential use of WARWP Area groundwater (ILCR=2×10^{-4}) would exceed the 1×10^{-5} Ohio EPA target cancer risk goal, and the noncancer hazard (HI=59) would exceed the target HI goal. The residential cancer risk would also exceed the NCP acceptable range. Site-related cancer risks associated with on-site worker use of groundwater (ILCR=6×10^{-5}) would exceed the Ohio EPA cancer risk goal but would be within the NCP acceptable range. Noncancer hazards (HI=9) for the worker would exceed the noncancer target HI of 1. For each receptor, the site-related cancer risks account for approximately 53 percent of the total WARWP cancer risks, and site-related hazards account for approximately 93 percent of total WARWP hazards.

- ***Future Site-Related Risks Using Modeled Concentrations.*** Using modeled future concentrations that include modeled future potential impact from overburden groundwater, site-related risks associated with residential use of WARWP Area groundwater (ILCR=2×10^{-4}) would exceed the 1×10^{-5} Ohio EPA target cancer risk goal; the target noncancer hazard (HI=0.6) would meet the target HI goal of 1. Similarly, the cancer risk for the worker (4×10^{-5}) would exceed the Ohio EPA goal, and the worker HI (=0.09) meets the target goal of 1. Assuming future modeled concentrations, site-related cancer risks associated with the PRRWP Area on-site resident exceed the NCP acceptable range; site-related cancer risks associated with the worker are within the NCP acceptable range.

- ***Non-Site-Related Risks.*** The naturally occurring, non-site-related cancer risks associated with residential use (ILCR=2×10^{-4}) and worker use (ILCR=5×10^{-5}) indicate unacceptable cancer risks with respect to the Ohio EPA (1×10^{-5}) cancer risk goal. Also, the residential cancer risks associated with exposure to non-site-related chemicals in groundwater exceed the NCP acceptable risk range. The noncancer HI value for the resident (4) exceeds the target HI goal of 1, but that of the on-site worker (0.6) does not. These ILCR and HI values clearly indicate unacceptable risks and hazards associated with naturally occurring, non-site-related chemicals under a residential use scenario.

Downgradient Property Conclusions

- ***Current Site-Related Risks Using Measured Concentrations.*** Using current measured concentrations from all downgradient areas nearest the property boundary,

site-related risks/hazards associated with residential use of downgradient groundwater, the ILCR (ILCR=3×10^{-5}) would exceed the 1×10^{-5} Ohio EPA target cancer risk goal but would be within the NCP acceptable risk range. The hazard index (HI=0.4) would meet the target HI goal.

- ***Future Site-Related Risks Using Modeled Concentrations for Areas Downgradient of TNTA and the WARWP Area.*** Using modeled future concentrations of locations downgradient from TNTA, the cancer risk (ILCR=4×10^{-7}) meets the Ohio EPA goal of 1×10^{-5}. Similarly, the future model-based concentrations of locations downgradient from the WARWP Area yield a cancer risk value (1×10^{-6}) that meets the Ohio EPA goal of 1×10^{-5}. The noncancer hazards for these two downgradient areas (HI values of 0.002 and 0.006, respectively) meet the target HI value of 1.

- ***Future Site-Related Risks Using Modeled Concentrations for the Area Downgradient of TNTB, TNTC, and the PRRWP.*** Using modeled future concentrations of locations downgradient from TNTB, TNTC, and the PRRWP Area, the resultant predicted cancer risk (ILCR=2×10^{-5}) slightly exceeds the Ohio EPA goal of 1×10^{-5} but is within the NCP acceptable range. The noncancer hazard (HI=0.08) meets the target goal of 1. It is noted that the modeled concentrations and the resultant ILCR values are likely to be overestimates of future conditions.

- ***Non-Site-Related Risks.*** Using current measured concentrations, the naturally occurring, non-site-related cancer risks associated with residential use of groundwater from all downgradient areas nearest the property boundary is 4×10^{-4}, which exceeds both the Ohio EPA goal and the NCP acceptable range. Similarly, the noncancer hazards associated with naturally occurring chemicals at the property boundary (HI=99) exceed the target HI of 1. These ILCR and HI values clearly indicate unacceptable risks and hazards associated with naturally occurring, non-site-related chemicals under a residential use scenario.

Remedial Action Objectives

The following remedial action objectives (RAO) were developed in the FS for groundwater associated with the TNT and RWP Areas:

- Prevent on-site human exposure to groundwater containing contaminants of concern (COC) at concentrations that exceed remedial goals (RG).

- Prevent human exposure to downgradient off-site groundwater containing COCs at concentrations that exceed RGs.

The RGs are presented in Table 3. The RGs were developed in the FS as either promulgated Safe Drinking Water Act maximum contaminant levels or are risk-based values. Maximum

contaminant levels are USEPA-enforceable levels for public water supplies. Risk-based RGs are calculated for chemicals that do not have maximum contaminant levels. These risk-based RGs were designed based on site-specific concentrations such that the cumulative cancer risk (i.e., ILCR) associated with household use of this water as tap water would not result in a cumulative cancer risk that exceeds the Ohio EPA cancer goal of 1×10^{-5} or the target cumulative noncancer hazard of 1. The Ohio EPA has maintained a 1×10^{-5} ILCR as a target cancer risk goal for all PBOW sites, which is consistent with Ohio EPA policy. This goal represents the logarithmic midpoint of the NCP acceptable range of 1×10^{-6} to 1×10^{-4} for incremental lifetime cancer risk (USEPA, 1990), which is recognized by the Army. The noncancer RGs were derived so that the sum of the noncancer effects of those chemicals that affect the same target organ does not exceed the target HI goal of 1. The maximum contaminant level-based RGs would be applicable or relevant and appropriate requirements (ARAR) if this water were regarded as potable. (Please see the "Evaluation of the Alternatives" section on page 32 for further information on ARARs.) A given RG may be exceeded and the groundwater may still meet the intent of the RAOs, so long as the PBOW criteria for cumulative cancer risk (i.e., 1×10^{-5}) and cumulative noncancer hazard (HI=1) are met with respect to the COCs.

Table 3 includes two lists of COCs and the corresponding RGs. The first is for the limestone bedrock groundwater COCs. These RGs also apply to the overburden shale/groundwater under the two active technology-based remedial alternatives, GW-3 and GW-4 (described under the Summary of the Remedial Alternatives in the section that follows). The second list is for additional COCs that would also be targeted for remediation under Remedial Alternative GW-4, where it is assumed that the overburden/shale groundwater may be used as a potable source.

Summary of the Remedial Alternatives

The following five remedial alternatives were developed and evaluated in the FS for contaminated groundwater at PBOW:

- ***Alternative GW-1:*** No further action
- ***Alternative GW-2:*** Groundwater monitoring, monitored natural attenuation, and institutional controls
- ***Alternative GW-3:*** In situ enhanced bioremediation (ISEB)/pump and treat (P&T) for mitigation/protection of the limestone bedrock groundwater, groundwater monitoring, and institutional controls

- ***Alternative GW-4:*** ISEB/P&T for mitigation/protection of the overburden/shale and limestone bedrock groundwater, groundwater monitoring, and institutional controls.

- ***Alternative GW-5:*** Groundwater monitoring and/or institutional controls.

As agreed by the Project Delivery Team, these alternatives represent a broad range of remedial alternatives that allow the project risk managers to assess the relative cost effectiveness of different remedial strategies that employ varying degrees of active remediation, as well as no further action.

Alternative GW-1 is the NCP-required no-further-action alternative. Under Alternative GW-1, no further action would be performed to remediate or monitor groundwater or to ensure that administrative controls such as groundwater use restrictions were maintained at the TNT and RWP Areas.

Alternatives GW-2 through GW-5 are regarded as action-based because they include monitoring, institutional controls, and/or active remediation. Each of these four action-based alternatives includes a 5-year review, at which point the monitoring program and the effectiveness of the remedy are evaluated. Changes in the remedy may be recommended during the 5-year review. Prior to implementation, any changes would be documented in the Administrative Record as appropriate, depending on the nature of the change (letter to the Administrative Record, Explanation of Significant Differences, or Decision Document Amendment).

Alternatives GW-2 through GW-4 include groundwater monitoring and institutional controls. Each of these alternatives employs the installation of an estimated 29 new wells in the limestone bedrock and the sampling of these and other monitoring wells. It was estimated in the FS for costing purposes that a total of 33 wells would be sampled under Alternatives GW-2 through GW-4 for 30 years. Alternatives GW-3 and GW-4 also include additional overburden wells as presented in the descriptions of the alternatives that follow. Alternative GW-5 was developed to monitor the downgradient PBOW property boundary and may include the installation of 15 monitoring wells near the downgradient boundary, where it was assumed that monitoring may occur for 30 years. Please note that the actual monitoring regime, including the number of wells, sampling frequency, and sampling duration, would be developed by the USACE, considering input from the Ohio EPA, when a long-term monitoring program is developed.

Institutional controls would also be included in action-based Alternatives GW-2 through GW-4 to prevent human exposure to groundwater COCs, prohibiting the use of groundwater until the

RGs were met. The groundwater use restrictions would prevent use of all groundwater in contaminated areas. These use restrictions would be in place as long as the concentrations of COCs were greater than the RGs. These land-use controls consist of legal mechanisms that would be designed to control exposure to chemicals in groundwater and may include deed notices, well drilling prohibitions, and zoning restrictions. Alternative GW-5 could include institutional controls as well, but may include monitoring only.

The implementation of land-use controls to prohibit use of groundwater underlying property within the PBOW facility boundary would require the agreement of the GSA and NASA. A land-use control implementation plan would be required to implement and enforce the specific groundwater use prohibitions. Based on groundwater modeling, it is possible that the RGs would not be met within 150 years. However, the groundwater model did not include natural attenuation associated with the highly reducing conditions in the limestone bedrock groundwater unit. Thus, it is likely that RGs would be met in less time than predicted by the model. For costing purposes, it is assumed that RGs would be met within the limestone groundwater unit in 30 years, which is generally used as a default upper-limit duration for monitoring.

Alternative GW-1 – No Further Action

A no-further-action alternative is carried forward as a baseline for comparison. Under this alternative, no further remedial action, monitoring, or institutional controls would be conducted specifically for contaminated groundwater at the site. Note that completed (TNTB [Figure 4]), ongoing (PRRWP Area [Figure 5] and TNTC [Figure 6]), and planned soil remedial actions (TNTA [Figure 7]) represent source removal actions with respect to protection of groundwater. Decontamination efforts, beginning in 1945, were also completed that removed potential groundwater sources. Therefore, GW-1 is a no-further-action alternative rather than a no-action alternative.

The following estimated costs and durations are associated with Alternative GW-1:

Capital Cost:	*$0 M*
Present Worth Total Operation/Maintenance Costs:	*$0 M*
Present Worth Total Cost:	*$0 M*
Present Worth Total Cost with 50% Contingency:	*$0 M*
Total Cost in 2012 Dollars with 50% Contingency:	*$0M*
Time to Implement:	*1 Year*
Time to Achieve RAOs:	*(not applicable: see note below)*

Note: The RAOs are currently met because there are no complete exposure pathways to contaminated on-site groundwater and contamination has not been observed in off-site

groundwater. The water is not used nor will it reasonably be used in the foreseeable future because of its naturally low quality associated with petroleum hydrocarbons and constituents (e.g., benzene, xylenes), hydrogen sulfide, and inorganics.

Alternative GW-2: Groundwater Monitoring, Monitored Natural Attenuation, and Institutional Controls

This alternative would include no active remedial action to reduce the concentration of COCs in groundwater. Alternative GW-2 would include a monitored natural attenuation component as part of the long-term monitoring program described previously for Alternatives GW-2 through GW-4. The objective of this monitored natural attenuation component is to collect and evaluate the potential for natural attenuation to be occurring in the limestone bedrock to complement the other long-term monitoring data showing spatial and temporal changes in the extent of contamination. As described previously, Alternative GW-2 would also include institutional controls.

The following estimated costs and durations are associated with Alternative GW-2:

Capital Cost:	*$0.73 M*
Present Worth Total Operation/Maintenance Costs:	*$1.5 M*
Present Worth Total Cost:	*$2.2 M*
Present Worth Total Cost with 50% Contingency:	*$3.3 M*
Total Cost in 2012 Dollars with 50% Contingency:	*$4.3M*
Time to Implement:	*1 Year*
Time to Achieve RAOs:	*(not applicable: see note below)*

Note: The RAOs are currently met because there are no complete exposure pathways to contaminated on-site groundwater and contamination has not been observed in off-site groundwater. The water is not used nor will it reasonably be used in the foreseeable future because of its naturally low quality associated with petroleum hydrocarbons and constituents (e.g., benzene, xylenes), hydrogen sulfide, and inorganics.

Alternative GW-3: In Situ Enhanced Bioremediation/Pump and Treat for Mitigation/Protection of the Limestone Bedrock Groundwater, Groundwater Monitoring, and Institutional Controls

In addition to long-term monitoring and institutional controls, Alternative GW-3 would include active remediation. ISEB would be used within the overburden and weathered shale aquifer to reduce the concentrations of COCs to RGs within 12 targeted areas of the overburden/shale unit. These 12 areas would require an estimated 4,600 injection points and 1.03 million pounds of emulsified vegetable oil. The targeted areas are shown on Figures 11 through 15 for the three TNT Areas and two RWP Areas. The objective of this component is to protect the underlying

limestone bedrock aquifer from contamination in the overburden/weathered shale zone. Restoration of the entire overburden/shale aquifer to drinking water quality is not an objective.

P&T would be used within the 2,4-DNT plumes in the limestone aquifer in the WARWP and PRRWP Areas (Figures 10 and 9, respectively). Five recovery wells would be installed in the PRRWP Area at a total flow rate of 10.5 gallons per minute, and three wells would be installed in the WARWP Area at a total flow rate of 6.0 gallons per minute. The objective of this component is to reduce the concentrations of COCs to RGs in the limestone groundwater unit.

The following estimated costs and durations are associated with Alternative GW-3.

Capital Cost:	*$9.3 M*
Present Worth Total Operation/Maintenance Costs:	*$4.7 M*
Present Worth Total Cost:	*$13.9 M*
Present Worth Total Cost with 50% Contingency:	*$20.9 M*
Total Cost in 2012 Dollars with 50% Contingency:	*$24.2M*
Time to Implement:	*1 Year*
Time to Achieve RAOs:	*(not applicable: see note below)*

Note: The RAOs are currently met because there are no complete exposure pathways to contaminated on-site groundwater and contamination has not been observed in off-site groundwater. The water is not used nor will it reasonably be used in the foreseeable future because of its naturally low quality associated with petroleum hydrocarbons and constituents (e.g., benzene, xylenes), hydrogen sulfide, and inorganics.

Alternative GW-4: ISEB/P&T for Mitigation/Protection of the Overburden/Shale and Limestone Bedrock Groundwater, Groundwater Monitoring, and Institutional Controls

Alternative GW-4 uses the same components as Alternative GW-3. This alternative differs from GW-3 in that the goal of GW-4 is to restore all overburden/shale groundwater, in addition to limestone groundwater, to RGs. Therefore, instead of selecting 12 targeted areas to implement ISEB in the overburden/shale, ISEB would be implemented in 27 target areas. These 27 areas would require an estimated 8,200 injection points and 1.91 million pounds of emulsified oil. The targeted areas are shown on Figures 11 through 15 for the three TNT Areas and 2 RWP Areas. The P&T component of GW-4 is the same as that for GW-3.

The following estimated costs and durations are associated with Alternative GW-4:

Capital Cost:	*$12.8 M*
Present Worth Total Operation/Maintenance Costs:	*$4.7 M*
Present Worth Total Cost:	*$17.6 M*
Present Worth Total Cost with 50% Contingency:	*$26.4 M*

Total Cost in 2012 Dollars with 50% Contingency:	*$29.6 M*
Time to Implement:	*1 Year*
Time to Achieve RAOs:	*(not applicable: see note below)*

Note: The RAOs are currently met because there are no complete exposure pathways to contaminated on-site groundwater and contamination has not been observed in off-site groundwater. The water is not used nor will it reasonably be used in the foreseeable future because of its naturally low quality associated with petroleum hydrocarbons and constituents (e.g., benzene, xylenes), hydrogen sulfide, and inorganics.

Alternative GW-5: Groundwater Monitoring and/or Institutional Controls

Alternative GW-5 protects human health and the environment. The alternative provides an additional measure to prevent human exposure in comparison to Alternative GW-1 by establishing groundwater-use restrictions to prevent exposure to contaminated groundwater on site. Groundwater monitoring would protect the surrounding community by monitoring and evaluating the potential for contamination to migrate off site.

The following estimated costs and durations are associated with Alternative GW-5:

Groundwater Monitoring Only

Capital Cost:	*$0.35 M*
Present Worth Total Operation/Maintenance Costs:	*$0.36 M*
Present Worth Total Cost:	*$0.71M*
Present Worth Total Cost with 50% Contingency:	*$1.1 M*
Total Cost in 2012 Dollars with 50% Contingency:	*$1.4 M*
Time to Implement:	*1 Year*
Time to Achieve RAOs:	*(not applicable: see note below)*

Note: The RAOs are currently met because there are no complete exposure pathways to contaminated on-site groundwater and contamination has not been observed in off-site groundwater.

Institutional Controls Only

Capital Cost:	*$0.03 M*
Present Worth Total Operation/Maintenance Costs:	*$0.21 M*
Present Worth Total Cost:	*$0.24 M*
Present Worth Total Cost with 50% Contingency:	*$0.36 M*
Total Cost in 2012 Dollars with 50% Contingency:	*$0.54 M*
Time to Implement:	*1 Year*
Time to Achieve RAOs:	*(not applicable: see note below)*

Note: The RAOs are currently met because there are no complete exposure pathways to contaminated on-site groundwater and contamination has not been observed in off-site

groundwater. The water is not used nor will it reasonably be used in the foreseeable future because of its naturally low quality associated with petroleum hydrocarbons and constituents (e.g., benzene, xylenes), hydrogen sulfide, and inorganics.

Evaluation of the Alternatives

Each of the remedial alternatives was evaluated with respect to the following nine criteria, as required by the NCP at 40 Code of Federal Regulations 300.430 (e)(9)(iii). Criteria 1 and 2 are the threshold criteria, which must be met; criteria 3 through 7 are the primary balancing criteria; and criteria 8 and 9 are the modifying criteria.

Threshold Criteria

1. Overall Protectiveness of Human Health and the Environment
2. Compliance with ARARs

Primary Balancing Criteria

3. Long-term Effectiveness and Permanence
4. Reduction of Toxicity, Mobility, or Volume of Contaminants through Treatment
5. Short-Term Effectiveness
6. Implementability
7. Cost

Modifying Criteria

8. State Support/Agency Acceptance
9. Community Acceptance.

The threshold criteria are requirements that a remedial alternative must meet to be eligible for selection. The five primary balancing criteria are used to determine the trade-offs between alternatives. The modifying criteria are public and state acceptance. Although the public and state have had opportunity for input throughout the RI/FS process, these criteria are not finalized until the public comment period on the Proposed Plan.

Threshold Criteria. All of the alternatives meet the threshold criteria for protection for human health and the environment and compliance with ARARs. The groundwater at the five AOCs is not currently used, nor is it a potential source of drinking water because the quality of the groundwater in both the overburden/shale and limestone units renders it as Class III nonpotable groundwater (refer to the Description of Groundwater Underlying the TNT and RWP Areas beginning on page 9 of this Proposed Plan). No COCs have been detected in off-site downgradient groundwater, and groundwater contamination does not present a threat to off-site downgradient groundwater. Municipal water, the only source of drinking water in the vicinity of

PBOW, is readily available both on site and near the site boundary. This municipal water does not originate from groundwater. Contaminated groundwater does not present a threat to ecological receptors or other environmental media, because impacted groundwater does not discharge to surface water. Groundwater within the overburden/shale is discontinuous, seasonally dependent, and as mentioned, of poor natural quality.

A survey of current off-site use of groundwater was conducted by the USACE. The results of the survey indicated that, while private wells were present in downgradient areas, they are not used for potable water. Thus, the naturally poor water quality and limited yield in the overburden/shale and naturally poor water quality in the limestone in effect deter use as a potable source for drinking water. This results in an incomplete exposure pathway for off-site groundwater.

The combination of strongly reducing conditions and naturally occurring organic carbon in the limestone bedrock may be contributing to the microbial degradation and transformation of nitroaromatic compounds. These conditions should prevent concentrations of COCs in the overburden/shale from contributing to downgradient bedrock groundwater contamination. Available groundwater analytical data indicate that site-related contamination is limited to on-site areas.

Alternative GW-5 provides an additional measure to prevent groundwater exposure by implementing, either separately or in combination, institutional controls and groundwater monitoring. Alternative GW-2 includes these measures and also evaluates capacity of the limestone bedrock to naturally attenuate COCs that may migrate from the overburden/weathered shale. Groundwater use restrictions would prevent the use of on-site groundwater. Groundwater monitoring would be used to monitor and further evaluate limestone bedrock groundwater quality. Alternatives GW-3 and GW-4 would implement active groundwater remediation. The objective of groundwater remediation under Alternative GW-3 is to reduce the concentrations of COCs in the limestone bedrock groundwater to RGs. The objective of groundwater remediation under Alternative GW-4 is to reduce the concentrations of COCs in the overburden/shale and the limestone bedrock to RGs. Both GW-3 and GW-4 would generate appreciable greenhouse gases associated with the pump-and-treat system.

No unacceptable ecological risks are presented by groundwater contamination at the site, and no ARARs have been identified for any of the remedial alternatives.

Primary Balancing Criteria. Alternatives GW-3 and GW-4 would meet the preference for treatment technologies that result in a reduction in toxicity, mobility, or volume. Both of these alternatives rely on treatment technologies. The other three alternatives do not include treatment. However, it should be noted that the soil remedial actions completed at TNTB, the ongoing actions at the PRRWP Area and TNTC, and those being implemented for TNTA involve treatment of the potential ongoing groundwater contamination sources within these areas. These remedial actions for soil are implicitly associated with each of the five groundwater alternatives.

The short-term effectiveness of each of the five alternatives would be virtually equal. There would be no risks to the community associated with the implementation of any of these five alternatives. Workers would be protected in the implementation of Alternatives GW-3 and GW-4 through a remedial action safety and health plan. Alternative GW-1 would require the least effort and time. The technological components of GW-3 and GW- 4 (i.e., ISEB and P&T) are proven and readily implementable.

The cost differential among the five alternatives is considerable, spanning an order of magnitude. Even among the four action-based alternatives, costs may span over two orders of magnitude. The costs of these alternatives from least to most expensive are as follows:

- Alternative GW-1 – $0.00M
- Alternative GW-5 (institutional controls component only) – $0.036M
- Alternative GW-5 (monitoring component only) – $0.25M
- Alternative GW-2 – $1.7M
- Alternative GW-3 – $13.2M
- Alternative GW-4 – $16.9M.

Modifying Criteria. The two modifying criteria, state acceptance and public acceptance, are not fully evaluated until the Responsiveness Summary of the Decision Document is complete. The evaluation in the Responsiveness Summary is based on state and public comment during the public meeting and during the public comment period. Note that, depending on feedback from the state and/or public during the public comment period, it is possible that the selected remedy in the Record of Decision may differ substantially from the preferred remedy presented in the Proposed Plan.

Summary of the Preferred Alternative

Alternative GW-1, No Further Action, is selected as the preferred alternative for groundwater associated with the TNT Areas and RWP Areas. The USACE recommends that no further action specific to TNT and RWP Areas groundwater be taken.

Alternative GW-1 meets the "protectiveness of human health" threshold criterion because no complete groundwater pathway currently exists or is expected to exist into the future. GW-1 also meets the "compliance with ARARs" criterion because no ARARs have been identified for TNT or RWP Area groundwater. Please note that the removal of contaminated soil at the three TNT Areas and the PRRWP Area also represents a contamination source removal with respect to groundwater. Thus, even though these areas of soil contamination are being remediated based on risks associated with direct soil contact rather than as a source of potential groundwater contamination, this no-further-action alternative implicitly includes the separate soil actions completed and ongoing at these sites.

Based on an evaluation using the primary balancing criteria, Alternative GW-1 was selected over the other alternatives because it is far less expensive than these alternatives. None of the four action-based alternatives would provide any tangible benefit based on the following observations:

- The quality of both the overburden/shale and limestone bedrock groundwater is low due to naturally occurring chemicals and renders this water Class III nonpotable.
- For limestone bedrock groundwater underlying each of the TNT and RWP Areas except the WARWP, the human health risks/hazards associated with naturally occurring, non-site-related chemicals are much higher than those associated with site-related chemicals.
- The overburden/shale groundwater unit is of a very low and seasonally dependent yield.
- Municipal tap water, rather than groundwater, is used by NASA as well as all residences in the area.

If the TNT/RWP Areas groundwater were used for potable purposes, the human health risks associated solely with naturally occurring chemicals in groundwater would exceed the NCP acceptable range and would exceed the risks associated with site-related contaminants. Therefore, no regulatory justification exists to perform any further remedial action (including monitoring or institutional controls) with respect to the TNT and RWP Areas groundwater.

The USACE expects Alternative GW-1 to satisfy the following statutory requirements of CERCLA Section 121(b): (1) be protective of human health and the environment; (2) comply with ARARs; and (3) be cost effective. The Preferred Alternative is subject to change after the public comment period as the result of input by the state or the public. This change would be reflected in the TNT and RWP Areas Decision Document. The comment providing the basis for such change would be recorded in the Responsiveness Summary of the Decision Document.

Community Participation

A level of community relations activities that is consistent with CERCLA, SARA, and the NCP is required for DERP-FUDS projects. The objective of the community relations program at PBOW is to provide a mechanism for the communication and exchange of information among Army agencies, government agencies, and residents of local communities and those adjacent to Plum Brook downgradient from PBOW. In January 1997, a Restoration Advisory Board composed of local citizens with varying backgrounds, along with members from the USACE, NASA, and the Ohio EPA, was established to promote a two-way dialog to keep local citizens informed about site progress and to allow them the opportunity to provide input to DERP-FUDS project decisions. The USACE and Restoration Advisory Board follow the community relations plan, which was developed in 1999 and is updated each year.

In compliance with CERCLA (Section 113), the USACE has developed the AR file to provide documentation as to how and why decisions specific to the remediation of the site are made. The AR file contains these final documents as well as all others for the PBOW site. Currently, these final documents are located in the AR file at the USACE Huntington District Office (Huntington, West Virginia) and at the Public Repository located at the BGSU Firelands Library (Huron, Ohio). All documents are available for public viewing at the Firelands Library, at the USACE Huntington District Office, and at the following Web site: http://www.lrh.usace.army.mil/projects/current/derp-fuds/pbow/documents.

References *(in addition to the list of PBOW documents presented on Page 4)*

Ohio Department of Natural Resources, 1962, ***Availability of Underground Water, Pickerel—Pipe Creek Area***.

U.S. Environmental Protection Agency (USEPA), 2011, ***2011 Edition of the Drinking Water Standards and Health Advisories***, Office of Water, Washington, D.C., January, EPA 820-R-11-002.

ACRONYMS AND ABBREVIATIONS

ACRONYMS AND ABBREVIATIONS

Common acronyms and abbreviations used in this Proposed Plan are defined below:

AOC	area of concern
AR	Administrative Record
ARAR	applicable or relevant and appropriate requirement
BGSU	Bowling Green State University
BHHRA	baseline human health risk assessment
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act (also referred to as "Superfund")
COC	contaminant of concern
D&M	Dames & Moore, Inc.
DERP-FUDS	Defense Environmental Restoration Program-Formerly Used Defense Sites
DNT	dinitrotoluene
DoD	U.S. Department of Defense
FFS	focused feasibility study
FS	feasibility study
GSA	General Services Administration
HI	hazard index
HTF	Hypersonic Tunnel Facility
ILCR	incremental lifetime cancer risk
ISEB	in situ enhanced bioremediation
IT	IT Corporation
NASA	National Aeronautics and Space Administration
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NTCRA	non-time-critical removal action
Ohio EPA	Ohio Environmental Protection Agency
P&T	pump and treat
PA	preliminary assessment
PBOW	Plum Brook Ordnance Works
ppb	parts per billion
ppm	parts per million
PRRWP	Pentolite Road Red Water Pond
RAO	remedial action objective
RG	remedial goal
RI	remedial investigation
RWP	Red Water Pond
SARA	Superfund Amendments and Reauthorization Act of 1986
SDWR	Secondary Drinking Water Regulation
Shaw	Shaw Environmental, Inc.
SI	site inspection
TDS	total dissolved solids
TNT	2,4,6-trinitrotoluene
TNTA	TNT Area A
TNTB	TNT Area B
TNTC	TNT Area C
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
WARWP	West Area Red Water Pond

TABLES

Table 1

Summary of Total Hazard Index and Total Cancer Risk from Site-Related Chemicals and Naturally Occuring Chemicals
TNT Areas and Red Water Pond Areas
Plum Brook Ordnance Works, Sandusky, Ohio

	Site-Related (Measured Conc)[a]		Site-Related (Modeled Future Conc)[b]		Nonsite-Related, Naturally Occuring (Measured Conc)[a]	
PBOW Site and Receptors	Total HI[c]	Total ILCR[d]	Total HI	Total ILCR	Total HI	Total ILCR
TNTA						
Resident	***2***	*4.E-05*	***4***	***5.E-04***	***345***	***2.E-03***
Worker	0.2	1.E-05	0.5	1.E-04	***10***	***2.E-04***
TNTB						
Resident	NA[e]	NA[e]	0.1	*2.E-05*	***18***	***3.E-04***
Worker	NA[e]	NA[e]	0.02	6.E-06	0.8	*7.E-05*
TNTC						
Resident	NA[e]	NA[e]	***8***	***2.E-03***	***65***	***1.E-03***
Worker	NA[e]	NA[e]	1	***4.E-04***	1	*9.E-05*
PRRWP Area						
Resident	0.6	*2.E-05*	0.7	***2.E-04***	***234***	***7.E-03***
Worker	0.07	4.E-06	0.1	*4.E-05*	***15***	***5.E-04***
WARWP Area						
Resident	***59***	***2.E-04***	0.6	***2.E-04***	***4***	***2.E-04***
Worker	***9***	*6.E-05*	0.09	*4.E-05*	0.6	*5.E-05*
Downgradient Areas[f]						
Resident	0.4	*3.E-05*	NA[g]	NA[g]	***99***	***4.E-04***
Areas Downgradient from TNTA						
Resident	NA[h]	NA[h]	0.002	4.E-07	NA[h]	NA[h]
Areas Downgradient from TNTB, TNTC, and PRRWP Area						
Resident	NA[h]	NA[h]	0.08	*2.E-05*	NA[h]	NA[h]
Areas Downgradient from WARWP Area						
Resident	NA[h]	NA[h]	0.006	1.E-06	NA[h]	NA[h]

[a]Based on measured groundwater concentrations.
[b]Based on modeled potential future groundwater concentrations.
[c]The hazard index (HI) is a measure of noncancer hazard for an exposed individual.
[d]The incremental lifetime cancer risk (ILCR) is the estimated extra cancer risk which an individual encounters based on exposure to a site.
[e]Not applicable because no site-related chemicals of potential concern were identified in limestone bedrock groundwater in the risk assessment (Shaw, 2006).
[f]Downgradient HI and ILCR values based on measured groundwater concentrations combined all downgradient locations, using the highest concentrations among these.
[g]Not applicable because separate downgradient areas were evaluated for the HI and ILCR using the modeled concentrations.
[h]Not applicable because separate downgradient areas were not evaluated for the HI and ILCR using the measured concentrations. Please refer to footnote f.

Notes:
1. HI values equal to or less than 1 are unlikely to result in adverse noncancer human health effects for any member of the exposed population and are regarded as acceptable.
2. ILCR values equal to or less than 1E-5 (1 in 100,000) are generally regarded by the Ohio Environmental Protection Agency (OEPA) as acceptable.
3. The NCP identifies ILCR values less than 1E-6 (1 in 1,000,000) as negligible, and ILCR values of 1E-6 (1 in 1,000,000) through 1E-4 (1 in 10,000) are within the NCP acceptable range. It is noted that the average lifetime cancer risk of the general U.S. population is approximately 40,000 in 100,000.
4. *Italics* (non-bolded) apply only to cancer risks and indicate that the value exceeds the the 1E-5 value that is regarded as acceptable by the OEPA.
5. ***Bold intalics*** indicates that the noncancer hazard is unacceptable, or that the cancer risk value exceeds the NCP acceptable range (1E-6 to 1E-4).

Table 2

Percentage Comparison of Noncancer Hazards and Cancer Risks of Site-Related and Naturally Occuring Chemicals
TNT Areas and Red Water Pond Areas
Plum Brook Ordnance Works, Sandusky, Ohio

	Percent of Non-Cancer Hazard[a]		Percent of Cancer Risk[b]	
PBOW Site and Receptors	Site-Related[c]	Non-Site-Related[d]	Site-Related[c]	Non-Site-Related[d]
TNTA				
Resident	***0.6%***	***99.4%***	*1.7%*	***98.3%***
Worker	1.5%	***98.5%***	4.0%	***96.0%***
TNTB				
Resident	0%	***100%***	0.0%	***100.0%***
Worker	0%	100%	0.0%	*100.0%*
TNTC				
Resident	0%	***100%***	0.0%	***100.0%***
Worker	0%	100%	0.0%	*100.0%*
PRRWP Area				
Resident	0.3%	***99.7%***	*0.3%*	***99.7%***
Worker	0.4%	***99.6%***	0.8%	***99.2%***
WARWP Area				
Resident	***93.3%***	***6.7%***	***53.3%***	***46.7%***
Worker	***93.1%***	6.9%	*53.4%*	*46.6%*
Downgradient Areas[e]				
Resident	0.4%	***99.6%***	*7.5%*	***92.5%***

[a]Refer to Table 1 for actual noncancer hazard index values that are based on measured groundwater concentrations. Percentages for site-related and non-site-related hazards add up to 100 percent for each receptor associated with each site.

[b]Refer to Table 1 for actual incremental lifetime cancer risk values that are based on measured groundwater concentrations. Percentages for site-related and non-site-related risks add up to 100 percent for each receptor associated with each site.

[c]Site-related refers to those contaminants of concern that are related to former Department of Defense (DoD) activities.

[d]Non-site-related refers to those chemicals that were evaluated in the baseline human health risk assessment (BHHRA) but are associated with natural conditions or are otherwise unrelated to former DoD activities.

[e]Downgradient noncancer hazards and cancer risks are based on measured groundwater concentrations combining all downgradient locations, using the highest concentrations among these.

Notes:
1. *Italics* (non-bolded) apply only to cancer risks and indicate that the value exceeds the the cancer risk goal (1E-5) that is regarded as acceptable by the Ohio Environmental Protection Agency.
2. ***Bold intalics*** indicate that the noncancer hazard is unacceptable, or that the cancer risk value exceeds the NCP acceptable range (1E-6 to 1E-4).

Table 3

Remedial Goals for Groundwater
TNT and Red Water Pond Areas
Former Plum Brook Ordnance Works, Sandusky, Ohio

Chemicals of Concern for Limestone Bedrock Groundwater[a]	Remedial Goal (µg/L)
2,4,6-Trinitrobenzene	*3*
2,4-Dinitrotoluene	*0.5*
2,6-Dinitrotoluene	*0.5*
2-Amino-4,6-dinitrotoluene	*1*
4-Amino-2,6-dinitrotoluene	*1*
2-Nitrotoluene	*0.6*
4-Nitrotoluene	*4*
Nitrobenzene	*0.5*
4,6-Dinitro-2-methylphenol	2
3-Nitroaniline	2
Nitrate[b]	10,000
Chemicals of Concern for Overburden/Shale Groundwater[c]	**Remedial Goal (µg/L)**
2,4,6-Trinitrobenzene	*3*
2,4-Dinitrotoluene	*0.5*
2,6-Dinitrotoluene	*0.5*
2-Amino-4,6-dinitrotoluene	*1*
4-Amino-2,6-dinitrotoluene	*1*
2-Nitrotoluene	*0.6*
4-Nitrotoluene	*4*
Nitrobenzene	*0.5*
4,6-Dinitro-2-methylphenol	2
3-Nitroaniline	2
Nitrate[b]	10,000
1,3,5-Trinitrobenzene	109
1,3-Dinitrobenzene	0.4
3-Nitrotoluene	122
2,4-Dinitrophenol	7.3
4-Nitrophenol	4.9
Dibenzofuran	1.2
Fluorene	24
Toluene[b]	1,000

Notes: µg/L = Micrograms per liter; RG = Remedial goal.

[a] Remedial Goal (RG) for the limestone bedrock chemicals of concern (COC) were derived based on back-calculations from the groundwater risk assessment (Shaw, 2006) as described in Section 3.4 of the FS, except as noted.

[b] RG equals the maximum contaminant level (MCL) for drinking water (EPA, 2011).

[c] Overburden/shale RGs in the following list for 2,4,6-trinitrotoluene through nitrate are the same as the limestone bedrock RGs listed above. RGs for the additonal overburden/shale groundwater COCs 1,3,5-trinitrobenzene through fluorene are the risk-based concentrations found in the risk assessment (Shaw, 2006). The overburden/shale groundwateris targeted only for the active technology-based alternatives (i.e., GW-3 and GW-4).

FIGURES

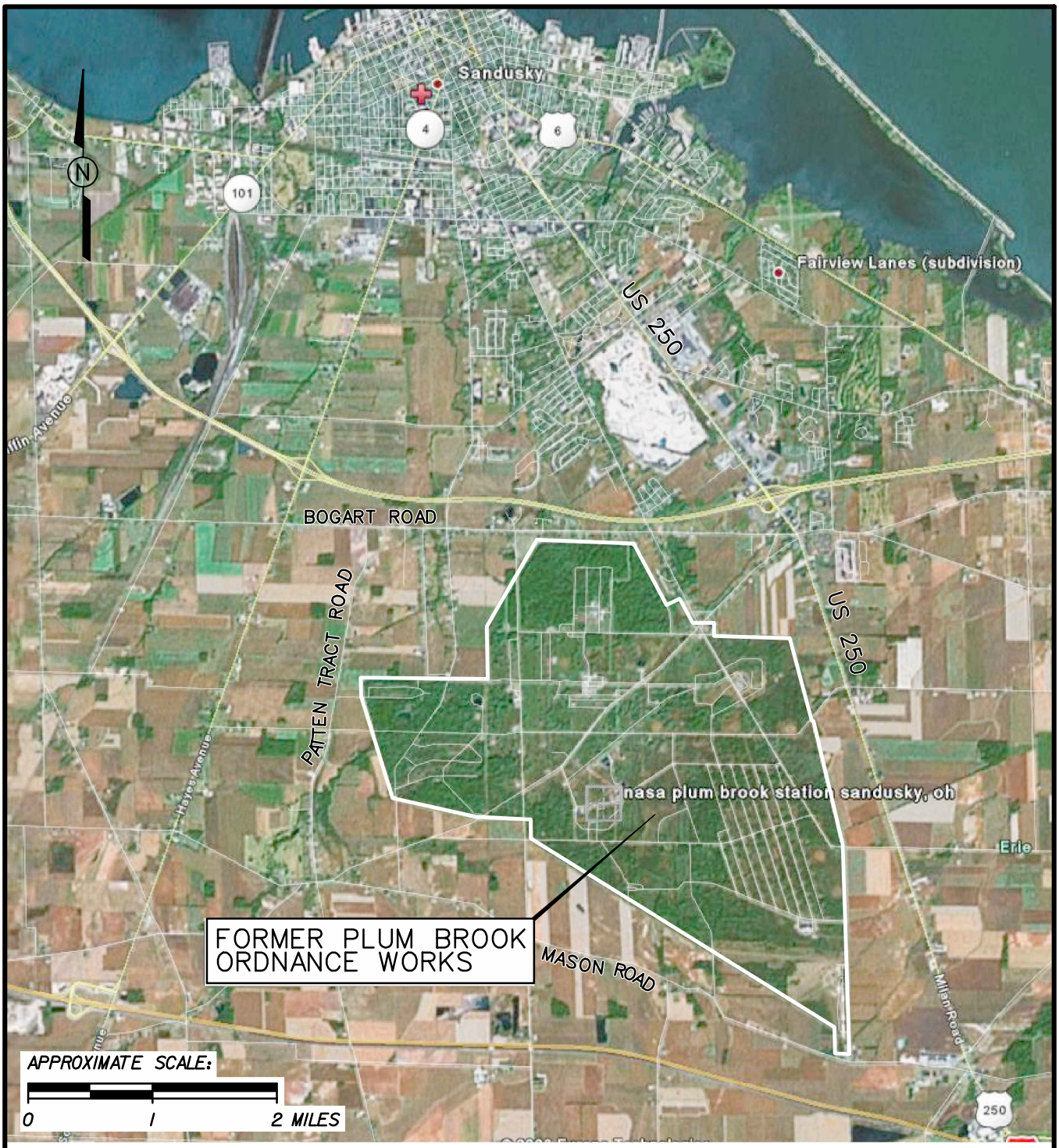

FIGURE 1
PBOW VICINITY MAP

PROPOSED PLAN FOR GROUNDWATER
TNT AREAS AND RED WATER POND AREAS
FORMER PLUM BROOK ORDNANCE WORKS
NASA PLUM BROOK STATION
SANDUSKY, OHIO

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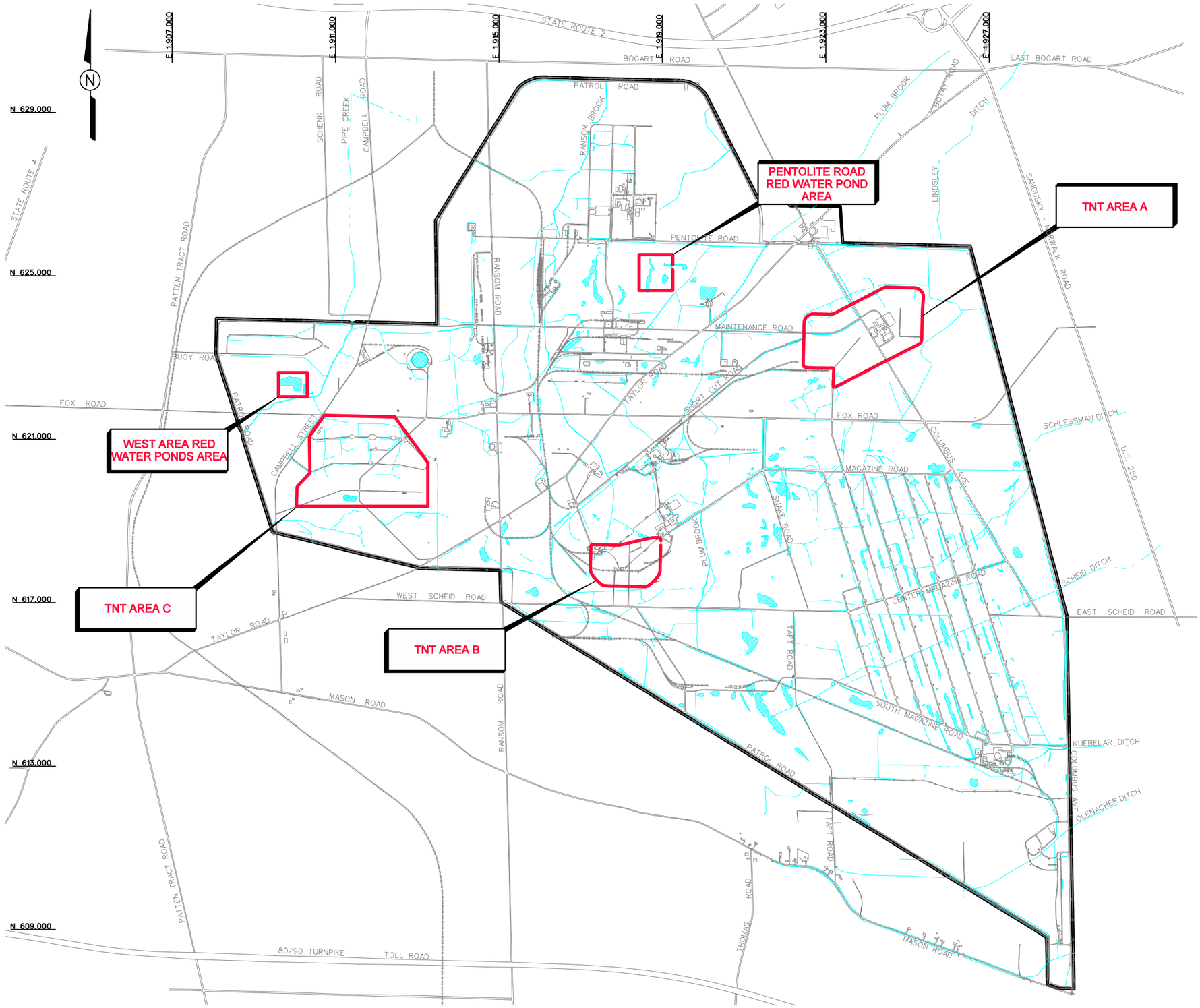

LEGEND:

- AREA OF CONCERN
- POND
- CREEK, DITCH, CONVEYANCE
- RAILROAD
- PBOW BOUNDARY

NOTES:

1. COORDINATES ARE OHIO STATE PLANE COORDINATE SYSTEM, 3401 OHIO NORTH, NAD83.

SCALE:

0 500 1000 FEET

FIGURE 2
LOCATION MAP

PROPOSED PLAN FOR GROUNDWATER
TNT AREAS AND RED WATER POND AREAS
FORMER PLUM BROOK ORDNANCE WORKS
NASA PLUM BROOK STATION
SANDUSKY, OHIO

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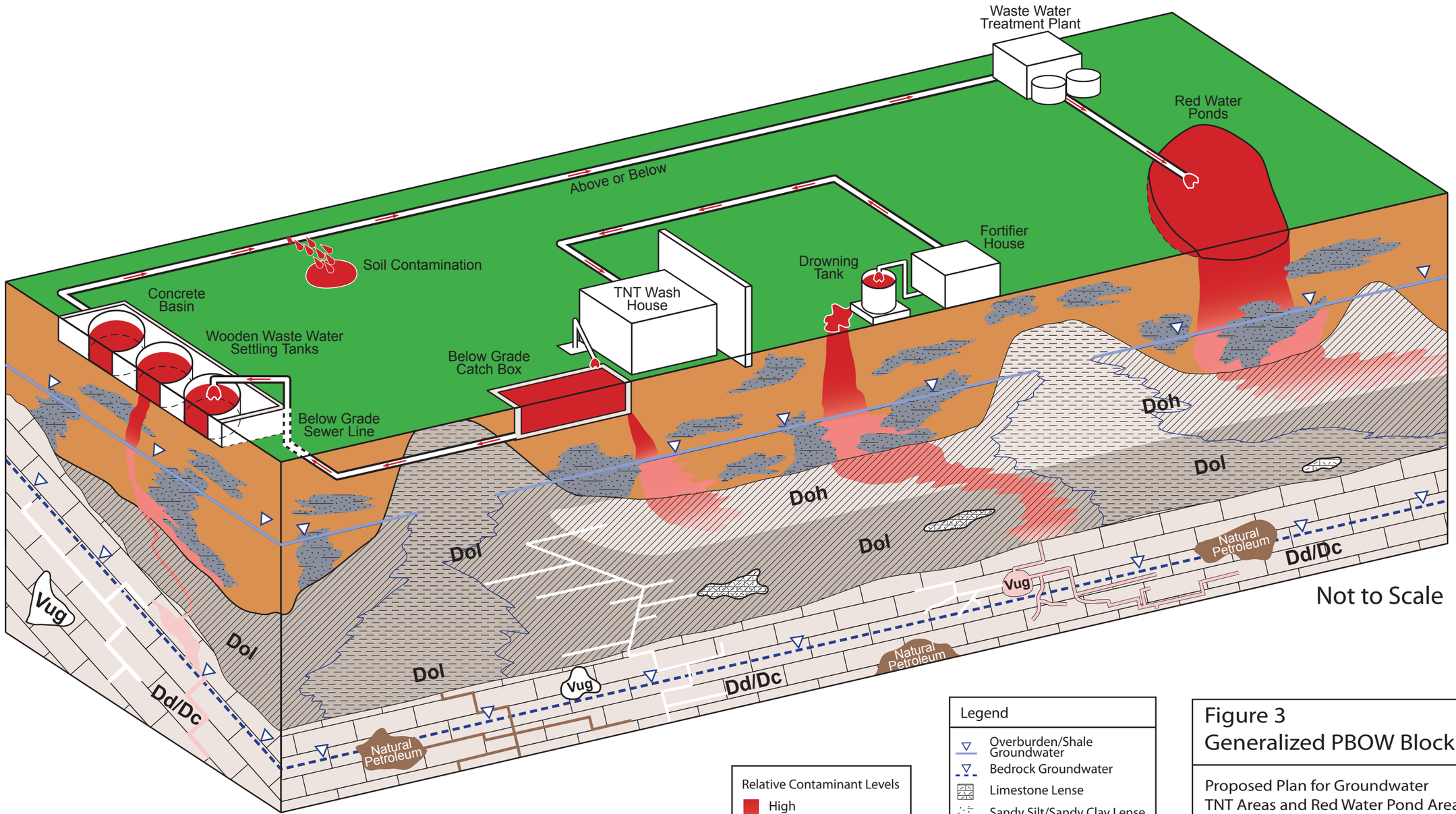

Relative Contaminant Levels

High

Low

Legend

- Overburden/Shale Groundwater
- Bedrock Groundwater
- Limestone Lense
- Sandy Silt/Sandy Clay Lense
- Silt/Clay/Shale Fragments
- Weathered Shale

Doh - Ohio Shale
Dol - Olentangy Shale
(Prout and Olentangy Shale Members)
Dd- Delaware Limestone
Dc- Columbus Limestone

Figure 3
Generalized PBOW Block Diagram

Proposed Plan for Groundwater
TNT Areas and Red Water Pond Areas
Former Plum Brook Ordnance Works
Sandusky, Ohio

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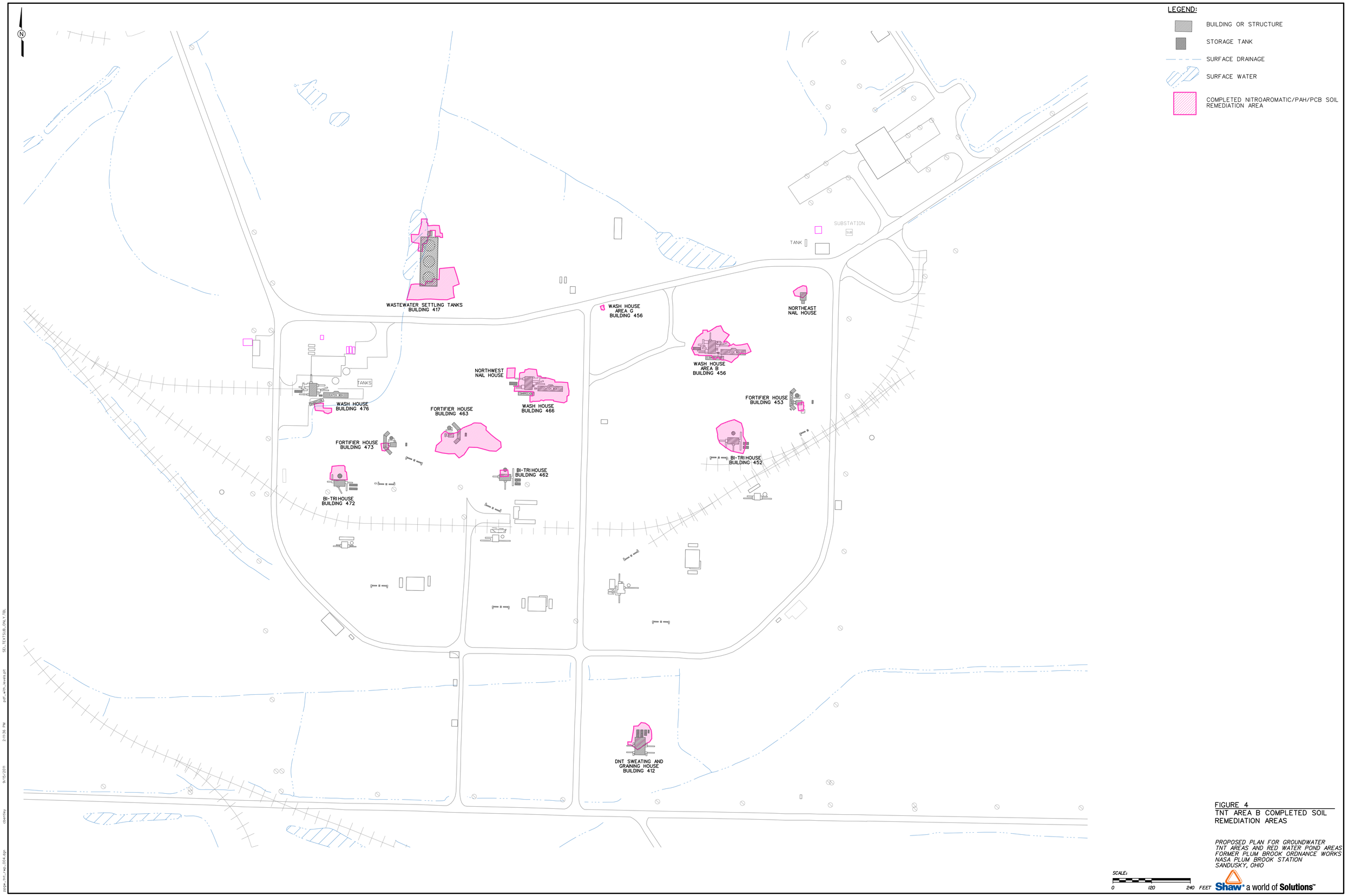

FIGURE 4
TNT AREA B COMPLETED SOIL REMEDIATION AREAS

PROPOSED PLAN FOR GROUNDWATER
TNT AREAS AND RED WATER POND AREAS
FORMER PLUM BROOK ORDNANCE WORKS
NASA PLUM BROOK STATION
SANDUSKY, OHIO

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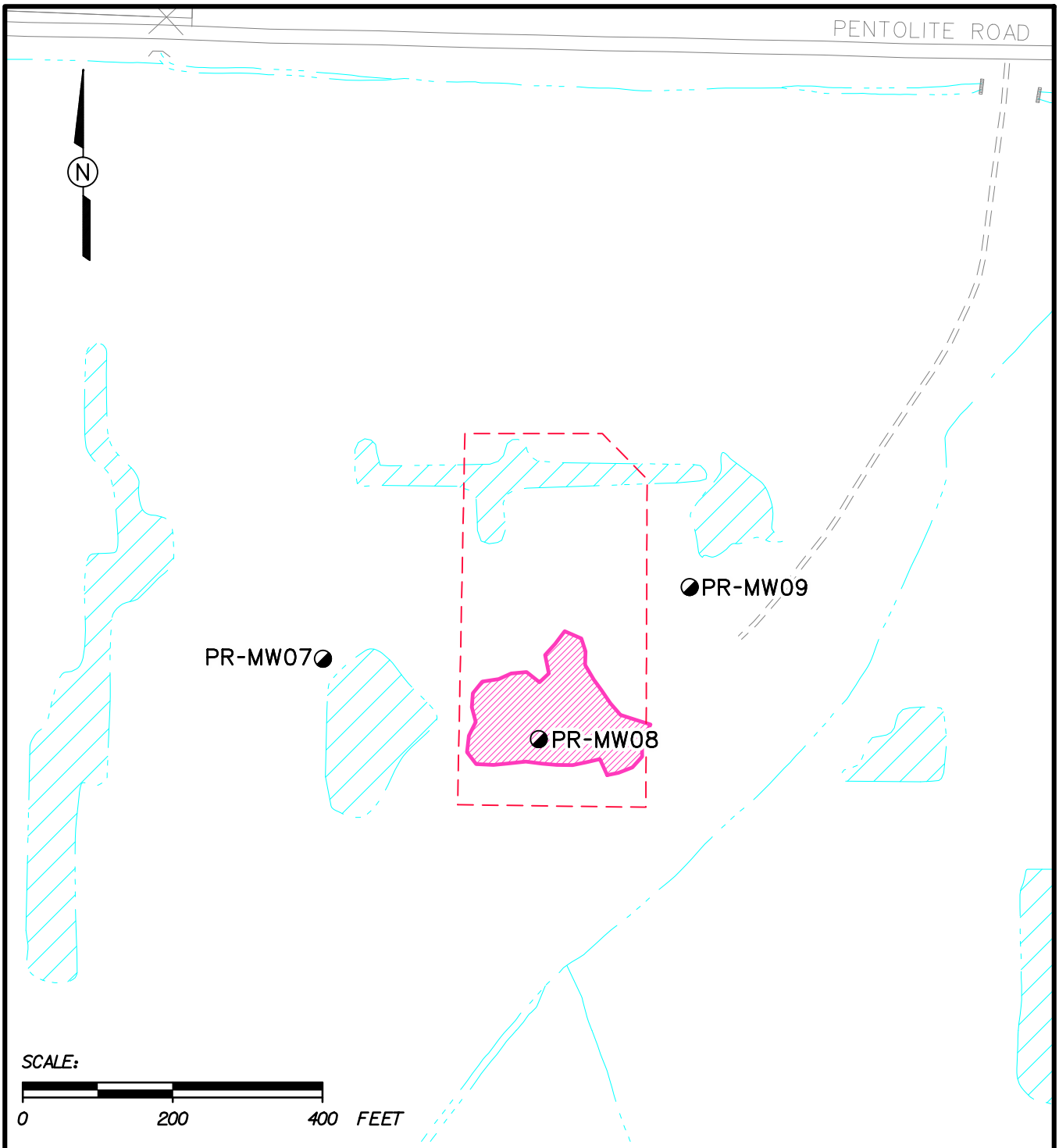

LEGEND

- APPROXIMATE HISTORICAL LOCATION OF POND
- CREEK, DITCH, CONVEYANCE
- POND, SURFACE WATER
- OVERBURDEN/SHALE MONITORING WELL LOCATION
- COMPLETED NONTIME CRITICAL REMOVAL ACTION TNT SOIL REMEDIATION AREA

FIGURE 5

PENTOLITE ROAD RED WATER POND AREA COMPLETED SOIL REMEDIATION AREA

PROPOSED PLAN FOR GROUNDWATER
TNT AREAS AND RED WATER POND AREAS
FORMER PLUM BROOK ORDNANCE WORKS
NASA PLUM BROOK STATION
SANDUSKY, OHIO

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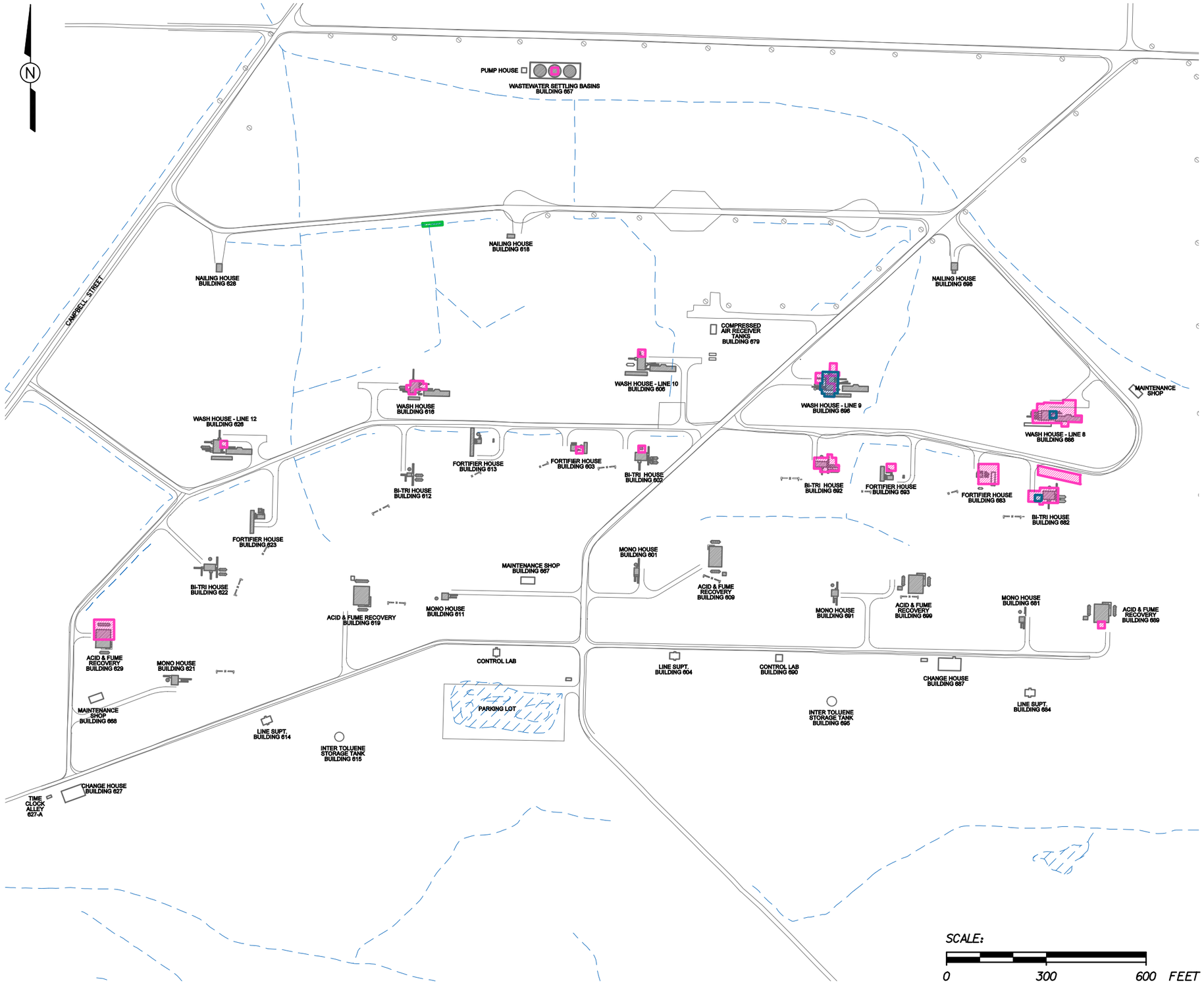

LEGEND:

- FORMER BUILDING OR STRUCTURE
- FORMER STORAGE TANK
- ESTIMATED NITROAROMATIC/PAH SOIL REMEDIATION AREA
- ESTIMATED LEAD/PCB SOIL REMEDIATION AREA
- ESTIMATED NITROAROMATIC SEDIMENT REMEDIATION AREA

SCALE:

0 300 600 FEET

FIGURE 6
AREAS OF CONTAMINATED SOIL TO BE REMEDIATED TNT AREA C

PROPOSED PLAN FOR GROUNDWATER
TNT AREAS AND RED WATER POND AREAS
FORMER PLUM BROOK ORDNANCE WORKS
NASA PLUM BROOK STATION
SANDUSKY, OHIO

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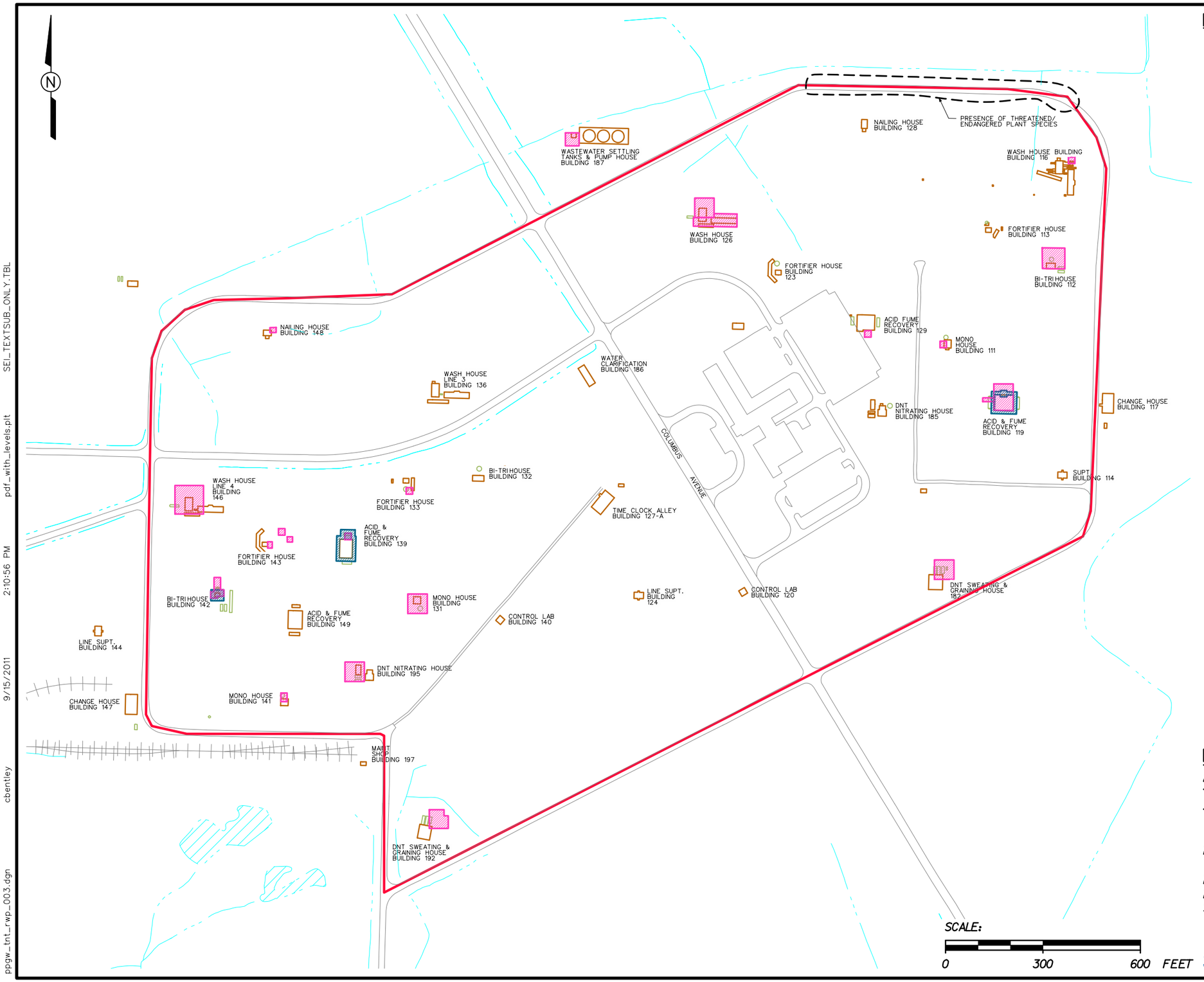

LEGEND:

- AREA OF CONCERN
- BUILDING OR STRUCTURE
- STORAGE TANK
- ESTIMATED NITROAROMATIC REMEDIATION AREA
- ESTIMATED LEAD/PCB REMEDIATION AREA
- PRESENCE OF THREATENED/ ENDANGERED PLANT SPECIES

FIGURE 7
AREAS OF CONTAMINATED SOIL TO BE REMEDIATED
TNT AREA A

PROPOSED PLAN FOR GROUNDWATER
TNT AREAS AND RED WATER POND AREAS
FORMER PLUM BROOK ORDNANCE WORKS
NASA PLUM BROOK STATION
SANDUSKY, OHIO

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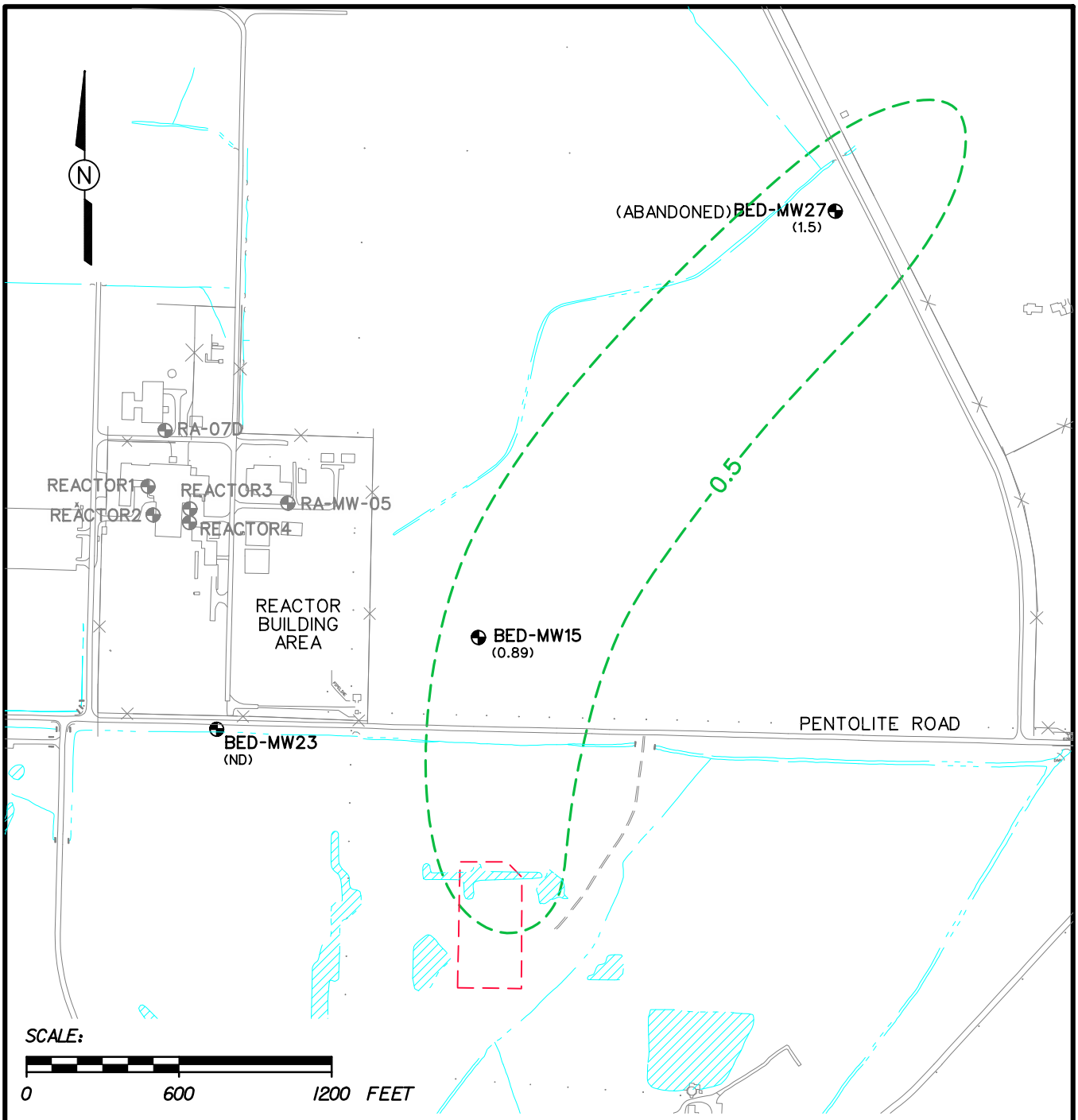

LEGEND:

- BUILDINGS
- APPROXIMATE HISTORICAL LOCATION OF POND
- SURFACE DRAINAGE
- SURFACE WATER
- BEDROCK MONITORING WELL LOCATION
- (1.5) 2,4-DNT CONCENTRATION (ug/L)
- 0.5 2,4-DNT CONTOUR (ug/L) (DASHED WHERE INFERRED)
- (ND) NOT DETECTED

FIGURE 8

LIMESTONE BEDROCK GROUNDWATER 2,4-DNT/2,6-DNT PLUME PENTOLITE ROAD RED WATER POND AREA

PROPOSED PLAN FOR GROUNDWATER
TNT AREAS AND RED WATER POND AREAS
FORMER PLUM BROOK ORDNANCE WORKS
NASA PLUM BROOK STATION
SANDUSKY, OHIO

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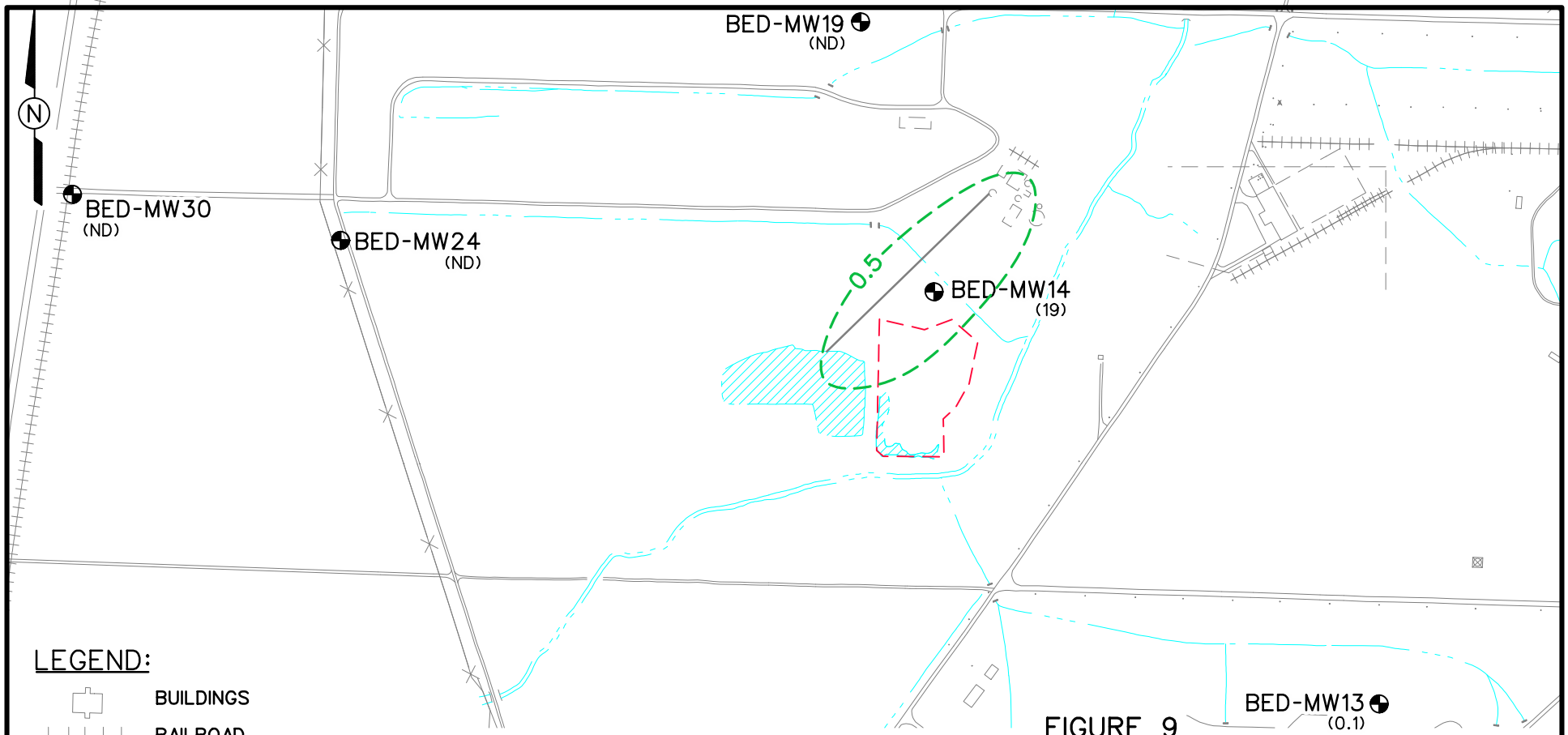

LEGEND:

- BUILDINGS
- RAILROAD
- APPROXIMATE HISTORICAL LOCATION OF POND
- SURFACE DRAINAGE
- SURFACE WATER
- BEDROCK MONITORING WELL LOCATION
- (1.5) 2,4-DNT CONCENTRATION (ug/L)
- 0.5 2,4-DNT CONTOUR (ug/L) (DASHED WHERE INFERRED)
- (ND) NOT DETECTED

SCALE:

0 600 1200 FEET

FIGURE 9

LIMESTONE BEDROCK GROUNDWATER 2,4-DNT PLUME WEST AREA RED WATER PONDS AREA

PROPOSED PLAN FOR GROUNDWATER
TNT AREAS AND RED WATER POND AREAS
FORMER PLUM BROOK ORDNANCE WORKS
NASA PLUM BROOK STATION
SANDUSKY, OHIO

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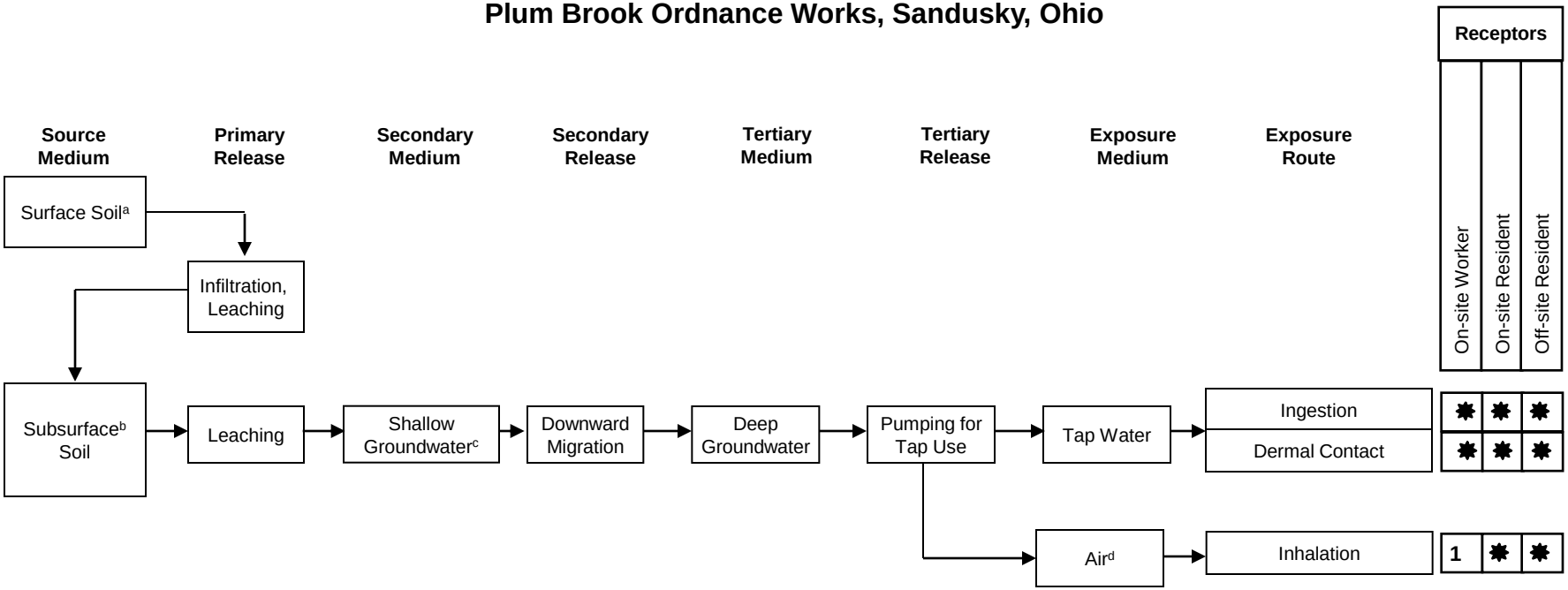
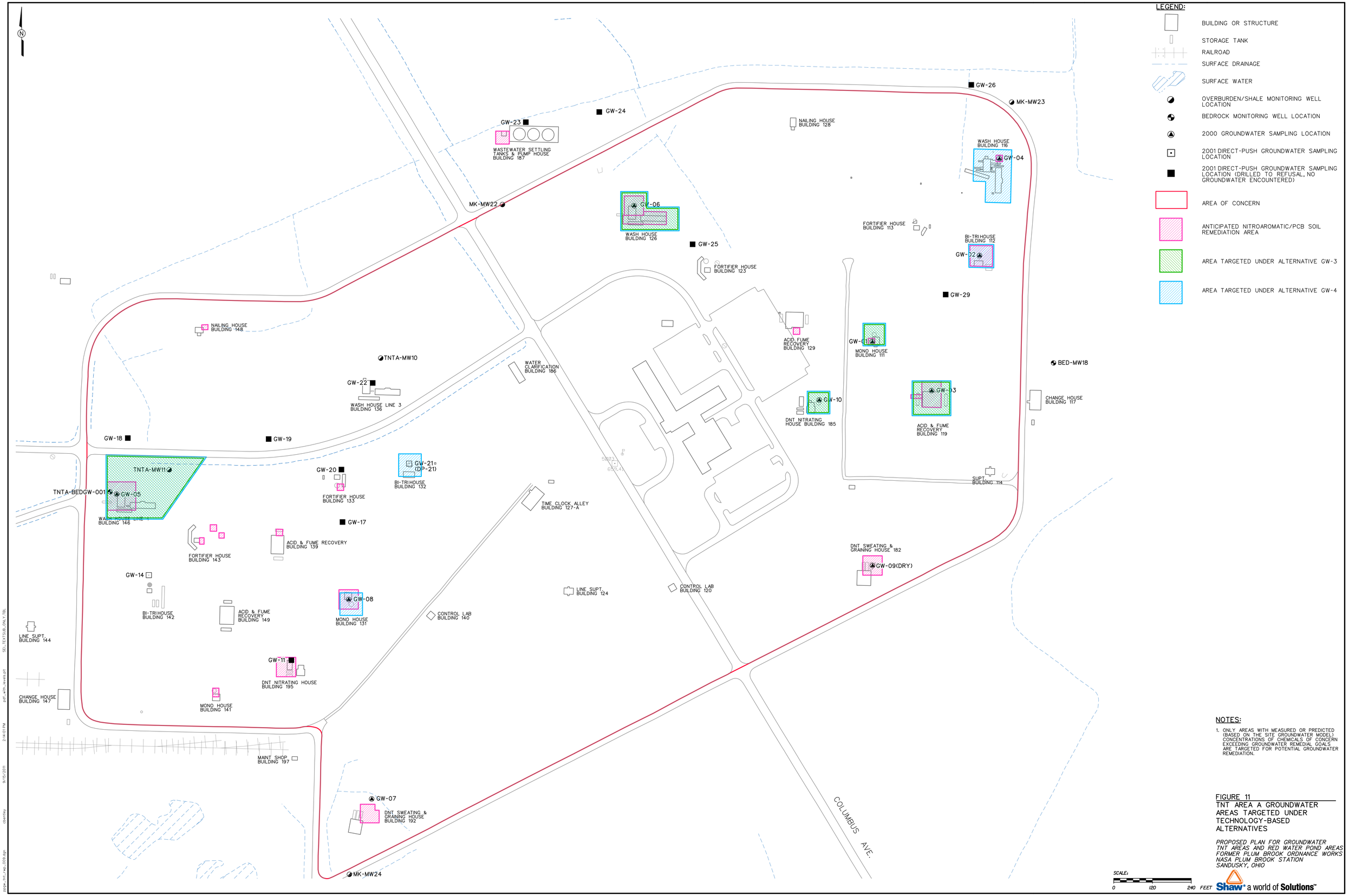
Figure 10

Human Health Conceptual Site Exposure Model for Groundwater
TNT Areas and Red Water Pond Areas
Plum Brook Ordnance Works, Sandusky, Ohio



✸ = Complete exposure route quantified in the groundwater risk assessment.
1 = Although theoretically complete, the large dilution factor of ambient air obviates the need to quantify this pathway.

[a] Contaminated from surface spills and leak.
[b] Contaminated from subsurface leaks and holding areas, as well as leaching.
[c] Shallow groundwater is isolated and seasonally dependent. It does not provide sufficient yield for use as tap water and was evaluated only qualitatively in the risk assessment.
[d] Volatilized into air during use of tap water.



NOTES:

1. ONLY AREAS WITH MEASURED OR PREDICTED (BASED ON THE SITE GROUNDWATER MODEL) CONCENTRATIONS OF CHEMICALS OF CONCERN EXCEEDING GROUNDWATER REMEDIAL GOALS ARE TARGETED FOR POTENTIAL GROUNDWATER REMEDIATION.

FIGURE 11
TNT AREA A GROUNDWATER AREAS TARGETED UNDER TECHNOLOGY-BASED ALTERNATIVES

PROPOSED PLAN FOR GROUNDWATER
TNT AREAS AND RED WATER POND AREAS
FORMER PLUM BROOK ORDNANCE WORKS
NASA PLUM BROOK STATION
SANDUSKY, OHIO

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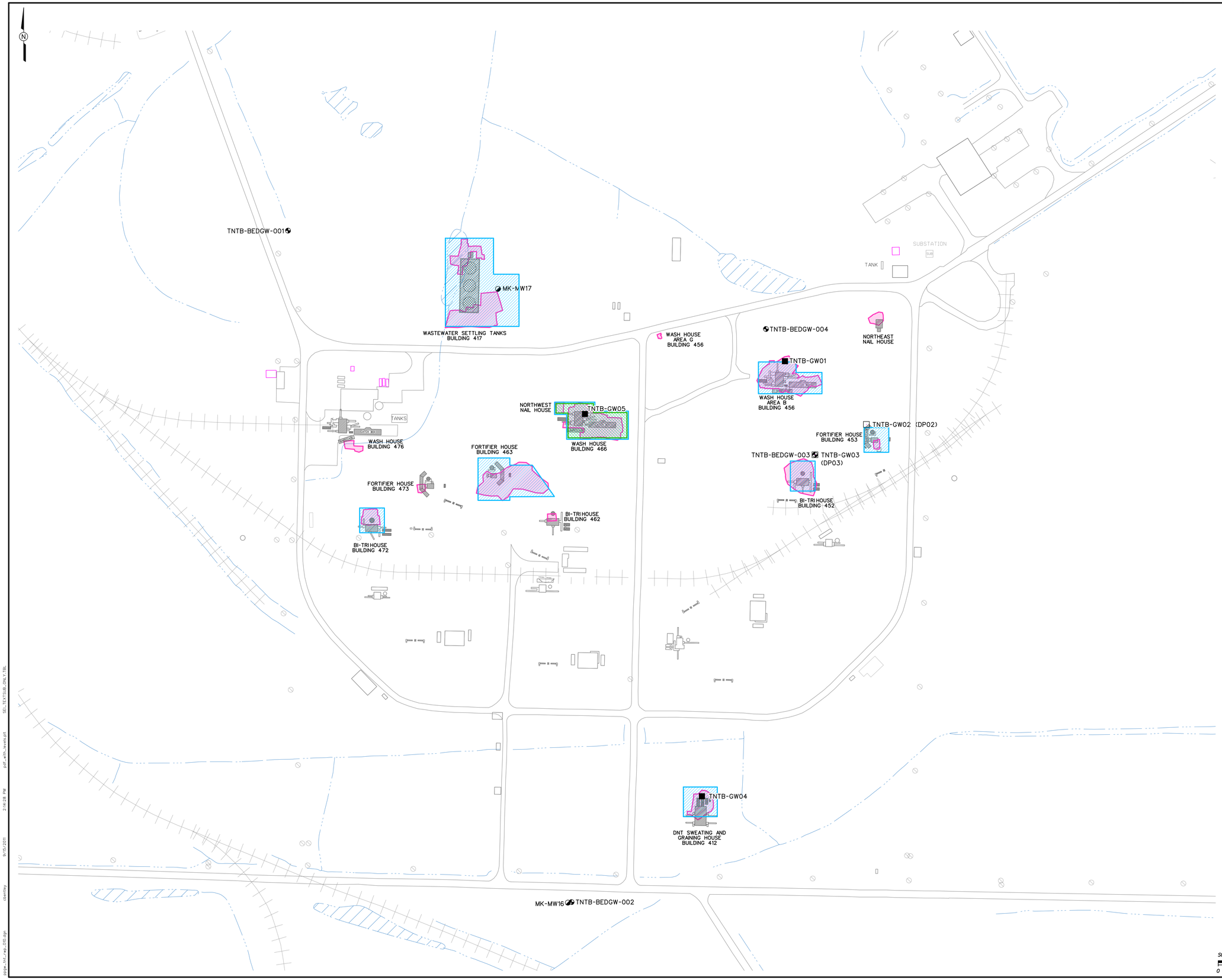

LEGEND:

- BUILDING OR STRUCTURE
- STORAGE TANK
- SURFACE DRAINAGE
- SURFACE WATER
- OVERBURDEN/SHALE MONITORING WELL LOCATION
- BEDROCK MONITORING WELL LOCATION
- 2000 GROUNDWATER SAMPLING LOCATION
- 2001 DIRECT-PUSH GROUNDWATER SAMPLING LOCATION
- 2001 DIRECT-PUSH GROUNDWATER SAMPLING LOCATION (DRILLED TO REFUSAL, NO GROUNDWATER ENCOUNTERED)
- COMPLETED NITROAROMATIC/PAH/PCB SOIL REMEDIATION AREA
- AREA TARGETED UNDER ALTERNATIVE GW-3
- AREA TARGETED UNDER ALTERNATIVE GW-3

NOTES:

1. ONLY AREAS WITH MEASURED OR PREDICTED (BASED ON THE SITE GROUNDWATER MODEL) CONCENTRATIONS OF CHEMICALS OF CONCERN EXCEEDING GROUNDWATER REMEDIAL GOALS ARE TARGETED FOR POTENTIAL GROUNDWATER REMEDIATION.

FIGURE 12
TNT AREA B GROUNDWATER AREAS TARGETED UNDER TECHNOLOGY-BASED ALTERNATIVES

PROPOSED PLAN FOR GROUNDWATER
TNT AREAS AND RED WATER POND AREAS
FORMER PLUM BROOK ORDNANCE WORKS
NASA PLUM BROOK STATION
SANDUSKY, OHIO

SCALE:
0 120 240 FEET

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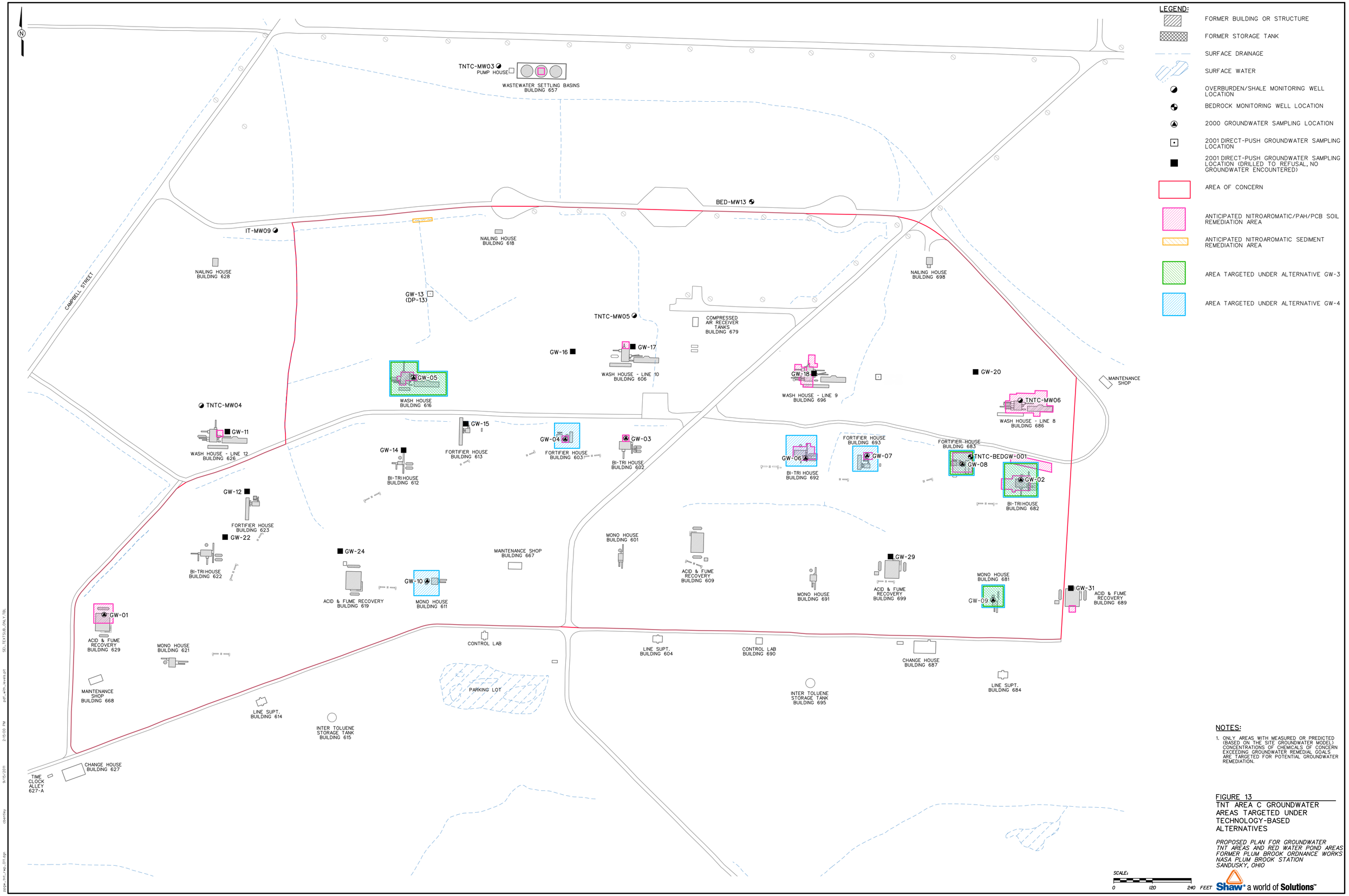

NOTES:

1. ONLY AREAS WITH MEASURED OR PREDICTED (BASED ON THE SITE GROUNDWATER MODEL) CONCENTRATIONS OF CHEMICALS OF CONCERN EXCEEDING GROUNDWATER REMEDIAL GOALS ARE TARGETED FOR POTENTIAL GROUNDWATER REMEDIATION.

FIGURE 13
TNT AREA C GROUNDWATER AREAS TARGETED UNDER TECHNOLOGY-BASED ALTERNATIVES

PROPOSED PLAN FOR GROUNDWATER
TNT AREAS AND RED WATER POND AREAS
FORMER PLUM BROOK ORDNANCE WORKS
NASA PLUM BROOK STATION
SANDUSKY, OHIO

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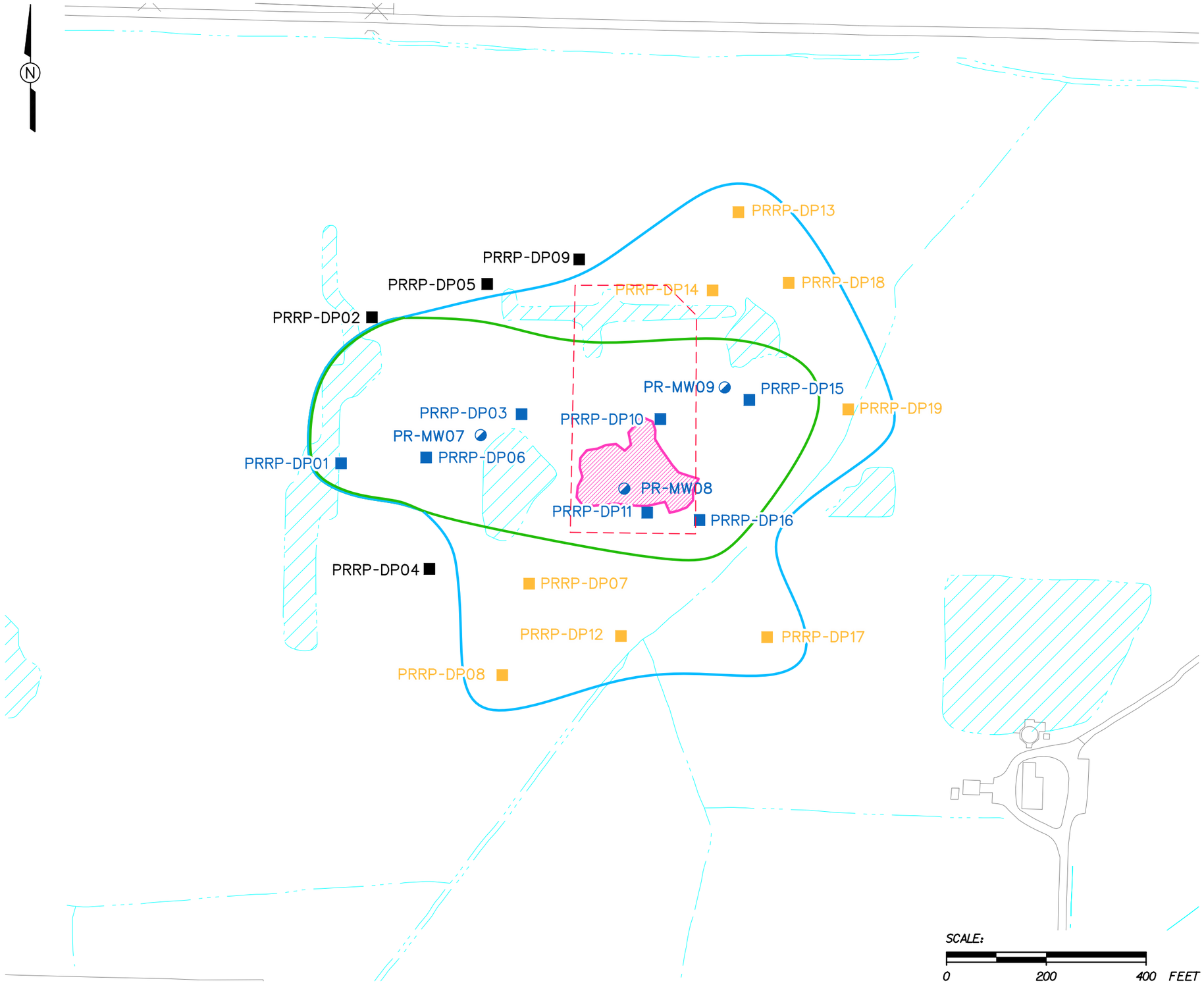

LEGEND:

- BUILDINGS
- APPROXIMATE HISTORICAL LOCATION OF POND
- SURFACE DRAINAGE
- SURFACE WATER
- OVERBURDEN/SHALE MONITORING WELL LOCATION
- DIRECT-PUSH GROUNDWATER SAMPLING LOCATION
- COMPLETED NONTIME CRITICAL REMOVAL ACTION TNT SOIL REMEDIATION AREA
- AREA TARGETED UNDER ALTERNATIVE GW-3
- AREA TARGETED UNDER ALTERNATIVE GW-4
- SAMPLE EXCEEDS AT LEAST ONE RG, AND 40 ug/L TOTAL COCs
- SAMPLE EXCEEDS AT LEAST ONE RG, BUT TOTAL COCs ARE LESS THAN 20 ug/L
- ALL COCs ARE LESS THAN RGs

NOTES:

1. ALL CONCENTRATIONS ARE IN MICROGRAMS PER LITER (ug/L).
2. RG = REMEDIAL GOAL.
3. COC = CHEMICAL OF CONCERN.
4. POTENTIAL REMEDIATION AREAS DETERMINED USING CONCENTRATION DATA AND SITE GROUNDWATER MODEL.

FIGURE 14

PENTOLITE ROAD RED WATER POND GROUNDWATER AREAS TARGETED UNDER TECHNOLOGY-BASED ALTERNATIVES

PROPOSED PLAN FOR GROUNDWATER TNT AREAS AND RED WATER POND AREAS FORMER PLUM BROOK ORDNANCE WORKS NASA PLUM BROOK STATION SANDUSKY, OHIO

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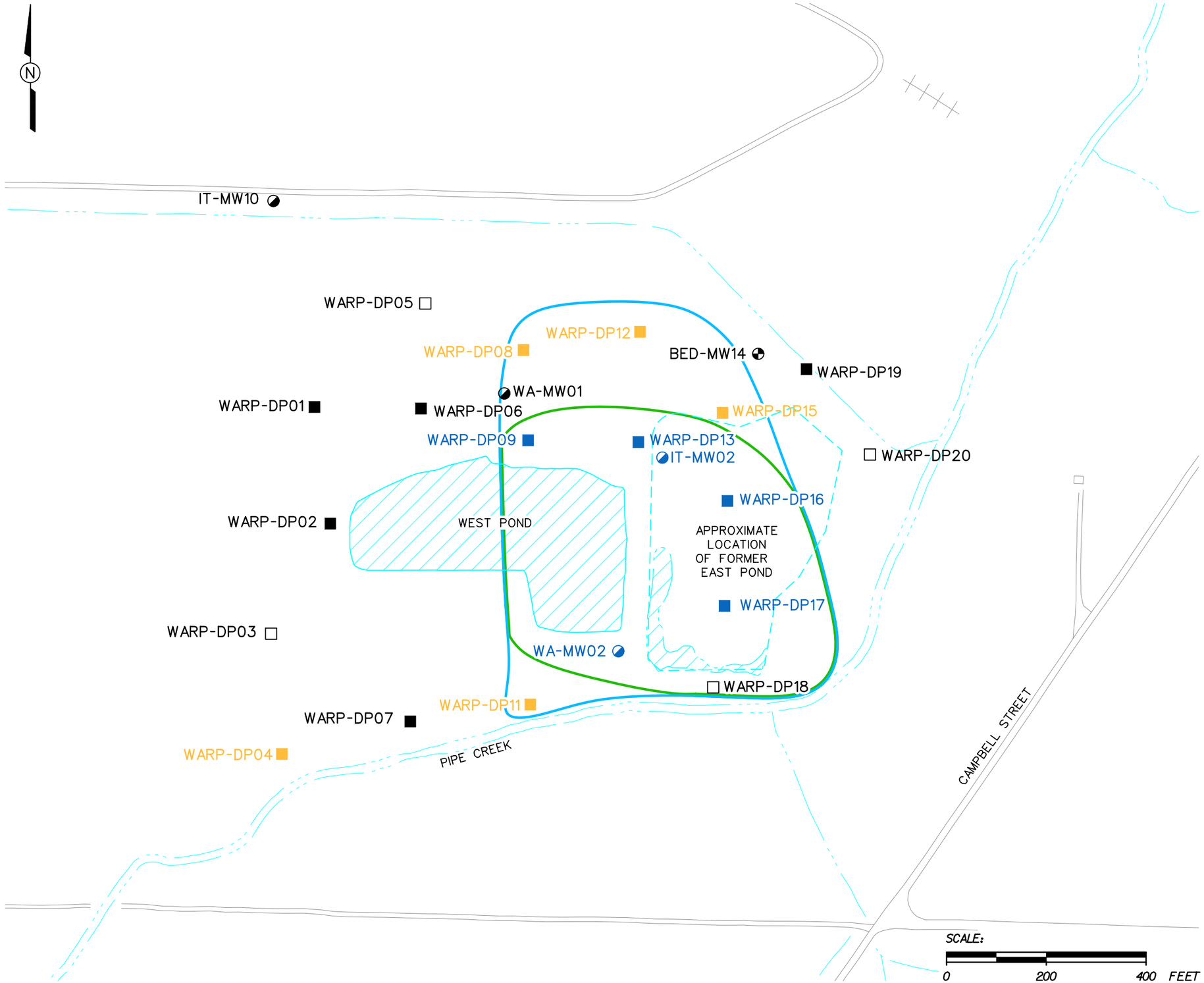

LEGEND:

- SURFACE WATER
- SURFACE DRAINAGE
- UNPAVED ROADS/DRIVES
- PAVED ROADS
- OVERBURDEN/SHALE MONITORING WELL LOCATION
- BEDROCK MONITORING WELL LOCATION
- DIRECT-PUSH GROUNDWATER SAMPLING LOCATION
- PLANNED DIRECT-PUSH GROUNDWATER SAMPLING LOCATION (INSUFFICIENT YIELD TO COLLECT SAMPLE)
- AREA TARGETED UNDER ALTERNATIVE GW-3
- AREA TARGETED UNDER ALTERNATIVE GW-4
- SAMPLE EXCEEDS AT LEAST ONE RG, AND 80 ug/L TOTAL COCs
- SAMPLE EXCEEDS AT LEAST ONE RG, BUT TOTAL COCs ARE LESS THAN 20 ug/L
- ALL COCs ARE LESS THAN RGs

NOTES:

1. ALL CONCENTRATIONS ARE IN MICROGRAMS PER LITER (ug/L).
2. RG = REMEDIAL GOAL.
3. COC = CHEMICAL OF CONCERN.
4. POTENTIAL REMEDIATION AREAS DETERMINED USING CONCENTRATION DATA AND SITE GROUNDWATER MODEL.
5. AT WARP-DP04, ONLY 3-NITROANILINE (3.2 ug/L) EXCEED THE RG (2 ug/L). THIS SINGLE MARGINAL EXCEEDANCE WOULD NOT CONNOTE A HUMAN HEALTH THREAT.

FIGURE 15

WEST AREA RED WATER PONDS AREA GROUNDWATER AREAS TARGETED UNDER TECHNOLOGY-BASED ALTERNATIVES

PROPOSED PLAN FOR GROUNDWATER
TNT AREAS AND RED WATER POND AREAS
FORMER PLUM BROOK ORDNANCE WORKS
NASA PLUM BROOK STATION
SANDUSKY, OHIO

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