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DEPARTMENT OF THE NAVY
CRANE DIVISION
NAVAL SURFACE WARFARE CENTER
300 HIGHWAY 361
CRANE, INDIANA 47522-5000

IN REPLY REFER TO
5090/S4.7.5
Ser RP3/5320

11 OCT 2005

U.S. Environmental Protection Agency, Region V
Waste, Pesticides, & Toxics Division
Waste Management Branch
Corrective Action Section
77 West Jackson Blvd.
Chicago, IL 60604

Dear Mr. Ramanauskas:

Crane Division, Naval Surface Warfare Center submits the responses to the U. S. EPA comments on the Corrective Measures Study (MCS) for Rockeye, Solid Waste Management Unit (SWMU) 10. Upon U. S. EPA approval of the comment responses, a final CMS will be submitted. The responses are presented as enclosure (1). The permit required Certification Statement is provided as enclosure (2).

If you require any further information, my point of contact is Mr. Thomas J. Brent, Code RP3-TB, at 812-854-6160, email thomas.brent@navy.mil.

Sincerely,

for JAMES M. HUNSICKER
Manager, Environmental Protection
By direction of the Commanding Officer

Enclosures: 1. Responses to Comments on the CMS for SWMU 10
2. Certification Statement

Copy to:
ADMINISTRATIVE RECORD
SOUTHNAVFACENGCOM (Code ES31) (w/o encl)
IDEM (Doug Griffin)
TTNUS (Ralph Basinski) (w/o encl)

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Christine D. Freeman

SIGNATURE

for Manager, Environmental Protection — 10/11/05

TITLE — DATE

ENCLOSURE

RESPONSE TO U.S. EPA COMMENTS DATED JULY 11, 2005, SEPTEMBER 7, 2005, AND SEPTEMBER 30, 2005 (E-MAIL) ON DRAFT RCRA CORRECTIVE MEASURES STUDY FOR SWMU 10 — ROCKEYE

**RESPONSE TO US EPA COMMENTS
DATED JULY 11, 2005, SEPTEMBER 7, 2005, AND SEPTEMBER 30, 2005 (E-MAIL) ON
DRAFT RCRA CORRECTIVE MEASURES STUDY REPORT
FOR SWMU 10 – ROCKEYE
NAVAL SURFACE WARFARE CENTER
CRANE, INDIANA**

Comments provided by the United States Environmental Protection Agency (US EPA) are shown in bold font. Responses following each comment are shown in regular font. Changes to Correctives Measures Study (CMS) Report text are italicized and enclosed in quotation marks.

1) In the Executive Summary (Remedial Alternatives), Alternative 2 states in the second to last sentence that there is "sufficient" available data to predict natural attenuation timeframe, while Alternative 3 states there is "insufficient" data available.

Response to Comment 1: The word "sufficient" was a typographical error; it should have been "insufficient."

The 5th sentence in the 1st paragraph of the Executive Summary, Subsection Remedial Alternatives, Alternative 2, has been revised as follows:

> *"Although currently available data is insufficient to accurately predict the timeframe required for natural attenuation to attain the Media Cleanup Standards (MCSs), preliminary estimations indicate that this timeframe would probably be somewhat greater than 100 years."*

2) Many figures identify multiple soil boring clusters taken in Areas A, B, C, D, etc. Were these taken as part of the recent RFI or historical USACE samples? There doesn't seem to be any data associated with these borings.

Response to Comment 2: All samples (i.e., groundwater, soil, sediment, etc.) used in the RFI Report including the preparation of the Human Health and Ecological Risk Assessments were collected in 2000/2001.

Soil borings collected for the RFI Report begin with the prefix "10SB." Soil borings collected during historical investigations, which were not including in the RFI Report of Human Health and Ecological Assessments, generally begin with the prefix "10-15-."

All historical sample locations are depicted on Figure 1-4. Figure 1-5 shows the sample locations collected during the 2000/2001 RFI sampling event as well as some historical soil borings.

Only the data from the 2000/2001 investigation was used in the RFI Reporting including the development of the Human Health and Ecological Risk Assessments. Therefore, no historical data summaries have been presented in the CMS Report.

For clarification, the 1st paragraph of Section 1.3.3.5 has been revised as follows:

> *The following is a brief description of the historical data collection activities conducted at SWMU 10. A tabular summary of the previous investigations completed for the site is presented in Table 1-1. Historical sample locations are shown in Figure 1-4. Locations of soil and groundwater samples collected in the 2000/2001, the latest phase of sampling as well as some historical borings, are shown in Figure 1-5."*

3) Section 3.2.2. states that there is no significant risk associated with sediment. Similarly, Section 3.3.5 states that chemicals in sediment are not found to present a significant risk. Table 2.6 shows risk to future child residents from ingestion of sediment (HI = 2.9).

Response to Comment 3: Section 7.6.1.4 of the RFI report states:

"Table 7-18 summarizes the COPC selection process for sediment at SWMU 10. Twelve sediment samples collocated with the surface water samples were collected during the investigation. No chemicals were eliminated from the quantitative risk assessment on the basis of background because appropriate upgradient locations could not (be) determined for SWMU 10.

The following chemicals were retained as COPCs in sediment:

- Inorganics - aluminum, arsenic, chromium (total), iron, manganese, and vanadium

These constituents were identified as COPCs in sediment because maximum concentrations exceeded US EPA Region 9 risk-based screening levels for residential soil, IDEM default closure levels for direct contact, and concentrations in the upgradient sample. The use of the US EPA Region 9 and IDEM risk-based concentrations for soil to evaluate chemical concentrations in sediment is conservative because these criteria were established assuming residential land use scenarios (e.g., routine daily contact with soils). However, it is anticipated that a human receptor would be exposed to the sediments in the streams and marshy areas of the site on a less frequent basis than is assumed for a typical residential exposure to soil. Consequently, the use of soil criteria for screening and risk estimation is likely to overestimate potential risks from exposure to sediment."

Based upon the above discussion from the RFI Report, the risk to receptors from sediment was considered to be insignificant.

No change to the CMS Report has been made in response to this comment.

4) Section 3.5.1 presents information on the explosives contaminant plume. How was the size of this plume determined? It appears that some of the boundaries were set arbitrarily as there is no groundwater data from many wells surrounding the "plume" (e.g., no data from wells 10C56,10-18, 10-21, 10C48P2, 10C48, 10-20, 10C29, 10C29P2, 10-19, 10C49,10C49P2). Similarly, how was the 100' diameter "hot-spot" determined?

This seems to have been arbitrarily set as well. The fact that this same information is presented in the "Assumptions" section of Appendix A implies that there is little supporting evidence for these boundary determinations. What about the RDX in well 10-02 (east of the SWMU)? Did the USACE RFI indicate a more widespread plume at the SWMU? A better discussion of the historical groundwater contamination/plume size compared to more recent data would be useful for additional perspective.

All RFI and historical groundwater data were used to map the area of the contaminant plume. These data are included in Appendix A. This plume area is shown in Figure A-1. The wells contained in the plume area include 10-07, 10-08, 10-17, 10-18, 10-21, 10C55, and 10C55P2 (seven wells total). These wells contain various concentrations of RDX, TNT, 4-amino-2,6-DNT, and 2-amino-4,6-DNT. The plume area is bordered by 12 monitoring wells that showed no detections of explosive compounds (10-19, 10-20, 10C29, 10C29P2, 10C33, 10C33P2, 10C48, 10C48P2, 10C49, 10C49P2, 10C56, and 10C57). These wells surrounding the plume were used to help define the shape and extent of the groundwater plume.

The groundwater in this plume appears to travel northeast parallel to the small ravine and eventually discharges into the ravine. The fact that explosives were not detected in wells 10C56 and 10C57 downgradient of the plume is evidence that the plume is most likely discharging to the ravine. Wells 10C60, 10-01, and 10-02 are located approximately 3,500 to 5,000 feet downstream of the plume (Figure A-2). These three wells also have historically had significant groundwater concentrations of RDX. Concentration-time graphs of RDX in wells 10-02 and 10C60 (see Appendix B) shown that the RDX concentrations have decreased over time and are now at or less than 10 µg/L. The RDX concentrations in well 10-01, however, are greater than 20 µg/L and do not appear to be decreasing over time (1983 through 1992). It is believed that RDX has been discharged directly to the ravine as surface water and/or has discharged to the ravine in the form of groundwater seepage between 1940 and the present. The RDX has traveled down the gully as surface water. Once the surface water in the gully migrated to the lower reaches, some of the surface water reenters the shallow groundwater system. This may be the reason that RDX was detected in the three wells located close to a mile downslope of the main plume area. It is not believed that the plume is continuous from the main plume area shown in Figure A-1 all the way eastward to wells 10-01 and 10-02.

The US ACE WES RFI Report (US ACE WES, 1995) reported that wells with mean concentration above the DL as follows: "...Ten wells had mean amounts of at least one explosive above the DL of 0.02 mg/l. All of the wells with amounts above DL were in the drainage way northeast and downslope of Rockeye. Referring to Plate 1, the wells with mean amounts of HMX, RDX, and TNT above DL were 10-07 and 10-08, 10-17 and 10-18, 10-21 (RDX only), 10C55 and 10C55P2, all atop the ridge, and 10C60, 10-01 and 10-02, downslope of Rockeye..." These ridge top wells are the same wells as used in the CMS discussion.

As noted in the SWMU 10 RFI (USACE, 1995), seven wells were identified on the top of the ridge as containing RDX or other explosive compounds. Time-concentration graphs for these seven wells are included in Appendix B. By visually observing these graphs, RDX concentrations in 10-07, 10-08, 10-17, 10-18, and 10C55P2 decreased over the time interval for which they were sampled. RDX concentrations in wells 10-21 and 10C55 appear to be relatively stable over time. RDX concentrations in none of the wells appear to have increased over time. Based on these graphs, the total mass of RDX in the plume and the overall size of the plume appear to have decreased slowly over time (between 1983 and 2001). RDX concentrations in 10-02 and 10C60 located east of SWMU 10 and next to the gully have also decreased over time; however, concentrations in 10-01 has remained relatively steady (see Appendix B). Overall, the wells located downslope of the plume are less affected by RDX now than they were in the 1980s and early 1990s

The following changes have been made in Appendix A to address these comments:

- Text in Appendix A has been expanded to include a discussion of how the plume area was defined and why wells 10-01, 10-02, and 10C60 are not considered to be part of the main plume area.

- The text in Appendix A has also been expanded to include a discussion of how the RDX plume size and concentrations have changed over time.

A new 2nd paragraph has been added to Section 3.5.1 as follows:

> *"The 'hot-spot' concept was not developed to accurately delineate particular areas of contamination outside of which groundwater quality meets the cleanup criteria. Instead, this concept was meant to identify and approximately size the two general areas within the contaminant plume that contain the highest levels of groundwater contamination and would therefore benefit the most from remedial action. Therefore, the centers of Hot-Spots Nos. 1 and 2 were selected as the two monitoring wells where the highest*

concentrations of explosives have been detected (337 µg/L at 10-17 for Hot-Spot No. 1 and 361 µg/L at 10C55 for Hot-Spot No. 2) and the approximate boundaries of these hot spots were delineated by assuming that they extend to the eastern edge of the plume on one side and halfway towards the nearest monitoring well where much lower explosives concentrations were detected (10-18 with 127 µg/L for Hot-Spot No. 1 and 10-21 with 66 µg/L for Hot-Spot No. 2) on the other side. For both hot-spots, this corresponds to a distance of approximately 100 feet and; therefore, it was decided to identify each hot-spot as a circular area with a 100-foot diameter."

Attachment 1 contains the revised Appendix A text, calculations, and figures.

5) Referring to Section 4.2.2.3, Effectiveness, it is stated that preliminary modeling of explosives plume degradation time is presented in Appendix A. There is no such information in Appendix A.

Text and tables have been added to Appendix A which present an evaluation of the natural attenuation processes that are operating in the RDX plume area, the overall attenuation rate that is occurring in the plume, and the estimated length of time for natural attenuation before the maximum concentrations in the groundwater reach the MCS of 0.5 µg/L. Based on the current understanding of the plume, the estimated length of time for the RDX MCS to be attained is roughly 100 years. It is not known whether a significant source of RDX is still adsorbed to the soil and/or bedrock upgradient (south) of the plume area. Therefore, it is difficult to make a reliable estimate of time to cleanup relying solely on natural attenuation.

6) There appears to be an error in the "Retain?" column on page 2 of 3 for Table 4-1 under Equalization.

Response to Comment 6: Agreed. The "2" has been changed to "$Y^{(2)}$" to represent retained for the reason presented in footnote number 2.

7) Referring to page 3 of 3 for Table 4-1, why would Direct Discharge of extracted water to the Crane industrial wastewater treatment be unacceptable to the wastewater treatment facilities? How is explosives contaminated water from SWMU 10 (or other production/active areas) currently treated and why wouldn't it be feasible or acceptable to route low-level explosives contaminated extracted groundwater to that system?

Response to Comment 7: Current SWMU 10 operations include a pre-treatment carbon filter system (pre-treatment system) for filtering explosive from wastewater. The pre-treatment carbon filter system is located in Building 3044 and designed to batch approximately 40,000 gallons per day. The explosive containing wastewater is received from various locations throughout NSWC Crane. The explosive contaminated wastewater is typically received by tank truck and batched through the carbon filter system prior to discharge into the NSWC Crane sanitary water sewer system. The water currently being treated is relatively clean (i.e., low in suspended solid).

The proposed groundwater recovery system would generate approximately 7,200 gallons per day of additional wastewater for treatment by the pre-treatment system. The pre-treatment system is capable of filtering this additional wastewater but is not operated continuously and would require additional equipment (e.g., surge tank) to be able to accept and batch the extracted groundwater.

Upon review of the existing system and the requirements of the groundwater extraction system, indirect discharge of groundwater via the existing SWMU 10 pre-treatment system is not practical for the following reason:

1. Installation of approximately 1,500 feet of piping would be required to route the extracted groundwater from the two "Hot Spots" to Building 3044. This piping would be dedicated

to transferring extracted groundwater to the pre-treatment system. Additionally, this piping would be required to traverse a roadway and two railroad sidings. Most likely the piping routing would require the installation of a combination of above ground pipe racks and underground sleeved piping. The installation of the pipe racks and underground sleeved piping would disrupt of SWMU 10 operations.

2. To facilitate the batch operations of the pre-treatment filter system, a pumping system would need to be installed at the extraction wells as well as a surge/storage tank near Building 3044. The pumping system would require the installation of an electric power supply near the proposed location of the extraction system including but not limited to three phase power lines, transformer, motor control center (i.e., breaker room), etc.

3. The pre-treatment system operating costs are $0.20 per gallon ($1,440 per day). Additional costs would include maintenance costs associated for both the pre-treatment and extraction pumping systems as well as operating costs for the extraction pumping system.

4. As previously stated, the wastewater which is currently being treated in the pre-treatment system is relatively clean (i.e., low suspended solids). However, it is anticipated that the extracted groundwater will have sufficient suspended solid such as manganese and silt to create a fouling problem for the carbon filters. To minimize fouling, the groundwater would require treatment before being transferred to Building 3044 so that suspended solids are minimized. This would increase installation and operating costs for the extraction system.

5. Furthermore, it will be necessary to determine if the local discharge point to the sanitary sewer piping is adequately sized to accommodate the additional flow from the groundwater extraction system. If not, extensive modification to the sanitary sewer system would be required.

Finally, for any screening evaluation it is critical to consider the last word of the comment (i.e., practical). Based upon the aforementioned reasons, the extensive modifications and operating and maintenance costs associated with discharge to the existing sanitary sewer system, this option is "not practical."

No change has been made to the document in response to this comment.

8) Referring to Section 5.3.2., page 5-6: Isn't it estimated that Alternative 3 would attain MCS in less than 100 years? Section 6.2 states that Alternatives 1 and 2 would attain MCS within approximately 100 years, but an earlier prediction calculated 159 years.

Response to Comment 8: The model calculations for natural attenuation have been included in Appendix A of the CMS Report. These calculations indicate that natural attenuation will result in RDX concentrations below 0.5 µg/L in approximately 100 years. Therefore, Alternative 1 (no action) will achieve the MCS in approximately 100 years. Additionally, Alternative 2 (which includes monitoring to ensure that the plume size is not increasing and that the RDX concentration is not increasing with time) will also take approximately 100 years (i.e., no action monitoring will also take approximately 100 years).

Therefore, any active treatment will take less than 100 years. However, insufficient data exists to make an estimate of how the active treatment will impact the groundwater plume.

For consistency, the 4th sentence in the 1st paragraph of Section 5.3.2 has been revised as follows:

"However, preliminary estimations indicate that this impact should be significant and that Alternative 3 should attain MCS within somewhat less than 100 years."

9) When preparing the CMS for Rockeye, it would be good to provide the historical perspective which shows that most of the explosives contaminated soils based on the Army Corps studies was remediated via Interim Measure composting and the RFI looked at residual risks from the various media. The RFI does not seem to describe this. This is what was done, correct?

Response to Comment 9: The United States Army Corps of Engineers Waterways Experiment Station (USACE) Phase II Soils Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI) (USACE WES, 1998) recommended that additional soil sampling to be conducted near production building exhaust vents to determine the extent of explosives contamination near these buildings and other locations near the perimeter where explosives concentrations were higher. The recommendations for additional sampling at these locations were implemented as part of the Interim Measures (IM) pre-characterization sampling. The RFI investigation did not address theses areas. However, the confirmation sample data obtained during the IM was included in the RFI risk assessment. Therefore, the RFI considered residual risk as stated in the comment.

Further discussion of the IM associated with soils at SWMU 10 has been added. Section 1.3.3.3 has been revised as follows:

"Based on the results of the Phase II Soil Characterization, NSWC Crane evaluated SWMU 10 to determine if the area would be amenable to accelerated cleanup action, otherwise known as interim measure (IM). SWMU 10 was identified for IM cleanup because of explosive-contaminated surface soil.

"From March 1996 to June 1997, a 5½-acre bioremediation complex was constructed in the southwest quadrant of NSWC Crane near the Crane Landfill. Based upon the favorable results of pilot scale testing and full scale operations at SWMU 12 Mine Fill A and SWMU 13 Mine Fill B, the bioremediation occurred at SWMU 10.

"From November 2000 through July 2001 the following activities occurred at SWMU 10 near Building 2733 (Figure 1-4) (Toltest, 2002):

- *Collection and analysis of 96 initial site characterization samples from 34 grids of potentially-impacted soil. Sampling in each grid consisted of two composite samples and one grab sample. The composite samples were collected from a zero to 12 inched and from 24 to 36 inches.*
- *Of the 34 grids that were sampled, seven grids required excavation because the explosive content of the soils sampled exceeded industrial cleanup goals. Soil excavation was performed on the blast wall berm between Buildings 2733 and 2734 and adjacent to the west side of Building 2733.*
- *Approximately 1,300 tons of contaminated soil and approximately 20 tons of rock were excavated and then screened. During excavation, all oversized material was separated into soil clods that were mixed with gravel and large rock. The rejected soil that was mixed with gravel was re-screened several times to separate as much soil from the gravel as possible.*
- *Soil samples were collected from each grid during excavation activities to assist in determining the extent of excavation that was required. Field screening test kits were used to test the RDX levels for the in-process soil samples to provide quick field screening results. Post-excavation samples were collected following excavation and field screening to determine the levels of contaminants remaining in the soil. Twenty-two post-excavation samples, which included one composite and one grab sample from the base of each grid and one grab sample from each*

20 feet of the side wall, were collected to ensure that the soil contamination levels were below SWMU-specific cleanup goals.

- *Screened material was transported to the on-site Bioremediation Facility where treatment of the explosives-contaminated material through composting to degrade the explosive compounds to below the SWMU-specific cleanup goals occurred.*
- *At the on-site Bioremediation Facility, organic amendments, which serve as a food source for the microorganism, were mixed with the contaminated soil to form the compost windrows. The bioremediation resulted in a greater volume of compost being generated than the original volume of soil excavated.*
- *Confirmatory sampling of treated material to ensure that the cleanup goals were achieved included:*
  - *Fifteen samples plus quality control samples from each of the five windrows cross-sections for Windrows 203 through 208,*
  - *Twelve samples from each of the four cross section of Windrow 202, and*
  - *Three samples from the Control Windrow at one cress section.*
- *All treated materials met residential cleanup for explosives.*
- *Approximately 2,200 tons of treated soil compost was transported back to SWMU 10 for use as backfill in the excavation sites. Because composting generates more compost than the original soil excavated, after backfilling the excavations, it was necessary to convert the temporary storage area at SWMU 10 into a permanent placement area for the excess compost.*

"In summary, at SWMU 10, the IM work included the identification (e.g., soil adjacent to Building 2733 and the berm wall between Buildings 2733 and 2734), excavation, and bioremediation of explosives contaminated soils. All excavated soils were successfully treated at the Bioremediation Facility to levels below residential cleanup goals and returned to SWMU 10 for use as backfill. The confirmatory sampling was utilized in the RFI Report human health and ecological risk assessments (TtNUS, 2005)."

ATTACHMENT 1

DRAFT RCRA CORRECTIVE MEASURES STUDY FOR SWMU 10 — ROCKEYE

APPENDIX A — CONTAMINATED GROUNDWATER COMPUTATIONS

APPENDIX A

CONTAMINATED GROUNDWATER COMPUTATIONS

APPENDIX A

HYDROGEOLOGIC INFORMATION AND CALCULATIONS REGARDING CONTAMINATED GROUNDWATER PLUME AND NATURAL ATTENUATION

Shallow groundwater [less than 90 feet below ground surface (bgs)] on the northeast side of the Ordnance Renovation Complex (ORC) formerly known as the Rockeye Facility (SWMU 10) is contaminated with hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX), 2,4,6-trinitrotoluene (TNT), and other explosive compounds and degradation products. The main area of contamination is shown on Figures A-1, A-2, and A-3. In 2001, the highest concentration of RDX [240 micrograms per liter (µg/L)] was detected in monitoring well 10C55. The contamination also extends along the channel of the unnamed tributary of Sulphur Creek, which flows north and then eastward from SWMU 10. Monitoring wells 10C60, 10-01, and 10-02 are located along this channel and contain moderate levels of RDX (8.1 to 46 µg/L). Surface water in this gully also displayed low to moderate concentrations of RDX.

All RFI and historical groundwater data were used to map the area of the contaminant plume, as shown in Figure A-1. These data are included in Appendix A. The wells contained in the plume area include 10-07, 10-08, 10-17, 10-18, 10-21, 10C55, and 10C55P2 (seven wells total). These wells contain various concentrations of RDX, TNT, 4-amino-2,6-dinitrotoluene (4-amino-2,6-DNT), and 2-amino-4,6-dinitrotoluene (2-amino-4,6-DNT) (see Calculation Worksheet A-1). The plume area is bordered by 12 monitoring wells that showed no detections of explosive compounds (10-19, 10-20, 10C29, 10C29P2, 10C33, 10C33P2, 10C48, 10C48P2, 10C49, 10C49P2, 10C56, and 10C57, see Figure A-1). These wells surrounding the plume were used to help define the shape and extent of the groundwater plume.

The groundwater in this plume appears to travel northeast parallel to the small ravine and eventually discharges into the ravine. The fact that explosives were not detected in wells 10C56 and 10C57 downgradient of the plume is evidence that the plume is most likely discharging to the ravine. Wells 10C60, 10-01, and 10-02 are located approximately 3,500 to 5,000 feet downstream of the plume (see Figure 1-4). These three wells also have historically had significant groundwater concentrations of RDX. Concentration-time graphs of RDX in wells 10-02 and 10C60 (see Appendix B) shown that the RDX concentrations have decreased over time and are now at or less than 10 µg/L. The RDX concentrations in well 10-01, however, are greater than 20 µg/L and do not appear to be decreasing over time (1983 through 1992). It is believed that RDX has been discharged directly to the ravine as surface water and/or has discharged to the ravine in the form of groundwater seepage between 1940 and the present. The RDX has traveled down the gully as surface water. Once the surface water in the gully migrated to the lower reaches, some of the surface water reenters the shallow groundwater system. This may be the reason that RDX was detected in the three wells located close to a mile downslope of the main plume area. As stated above, explosive compounds have not been detected in monitoring wells 10C56 and 10C57 on the northeastern side the plume. Hence, the plume is not considered to be continuous between the main plume area shown in Figure A-1 and wells 10-01, 10-02, and 10C60 located along the gully to the east of SWMU 10..

The contaminated plume area shown on Figures A-1, A-2, and A-3 is found primarily in sandstones and siltstones that lie between 740 and 810 feet above mean sea level (msl). The ground surface in this area ranges from about 760 to 820 feet msl. The area of primary groundwater contamination (150,000 ft^2) is calculated in Figure A-2. Information regarding the average estimated porosity, hydraulic conductivity, and hydraulic gradients used in the calculations are presented in Calculation Worksheets A-1 and A-2. The best estimate of linear groundwater velocity in the contaminated area is about 0.2 ft/day, or 73 ft/year. Based on the

hydraulic properties presented in Calculation Worksheet A-2, the ambient flow rate through the contaminated portion of the aquifer [0.39 gallons per minute (gpm)]..

Under ambient flow conditions, the contaminated plume area will clean up in about 85 years due to natural attenuation.

Because of the large amount of variation in the lateral extent of thicknesses of the lithologic units; the large variability in the fracture densities and apertures, porosity, hydraulic conductivity, and other hydraulic properties; the uncertainty regarding fraction of organic carbon (f_{oc}) in the rock; and uncertainties in other parameters which affect the groundwater flow and contaminant transport at the site, the data and calculations presented in this Appendix should be viewed as rough approximations of the conditions that currently exist at the site, and how the groundwater system (including contaminants) might react in the future. To be conservative, it is believed that the groundwater plume containing explosive compounds will reach 0.5 µg/L in 100 to 150 years due to natural attenuation and flushing.

Graphs of RDX concentrations measured over time are included in Appendix B for the 10 monitoring wells where RDX has been detected. Note that the graphs are log concentrations versus time. As shown on these graphs, RDX is decreasing in seven of the ten wells: 10-02, 10-07, 10-08, 10-17, 10-18, 10C55P2, and 10C60. In the other three wells (10-01, 10-21, and 10C55), the RDX concentrations appear to be relatively stable over time. Overall, it is believed that the total mass of RDX in the plume is decreasing over time and the size of the plume is shrinking.

TABLE A-1

HISTORICAL AND RF INVESTIGATION RDX SAMPLE DATA
SWMU 10 - ROCKEYE
NSWC CRANE
CRANE, INDIANA

Results (µg/L)	Validated (Yes/No)	Sample Number	Sample Date
100 U	N	10-01 (83a) (03/02/83)	3/2/1983
100 U	N	10-01 (83b) (08/02/83)	8/2/1983
77	N	10-01 (84a) (02/03/84)	2/3/1984
31	N	10-01 (84b) (06/14/84)	6/14/1984
24	N	10-01 (85) (01/16/85)	1/16/1985
60	N	10-01 (86) (02/07/86)	2/7/1986
23.4	N	10-01 (89) (04/26/89)	4/26/1989
20 U	N	10-01 (91a) (03/16/91)	3/16/1991
56	N	10-01 (92a) (01/09/92)	1/9/1992
46	N	10-01 (92b) (05/14/92)	5/14/1992
10-02			
100 U	N	10-02 (83a) (03/02/83)	3/2/1983
255	N	10-02 (83b) (08/02/83)	8/2/1983
110	N	10-02 (84a) (02/03/84)	2/3/1984
92	N	10-02 (84b) (06/14/84)	6/14/1984
70	N	10-02 (85) (01/16/85)	1/16/1985
17	N	10-02 (86) (02/09/86)	2/9/1986
13.3	N	10-02 (89) (04/26/89)	4/26/1989
20 U	N	10-02 (91a) (03/16/91)	3/16/1991
34	N	10-02 (92a) (01/09/92)	1/9/1992
44	N	10-02 (92b) (05/14/92)	5/14/1992
4.9	Y	10GW0201	1/6/2001
8.1	Y	10GW0201-D	1/6/2001
10-03			
20 U	N	10-03 (83b) (07/12/83)	7/12/1983
10 U	N	10-03 (85) (01/16/85)	1/16/1985
10 U	N	10-03 (86) (02/09/86)	2/9/1986
20 U	N	10-03 (91a) (03/16/91)	3/16/1991
20 U	N	10-03 (92a) (01/09/92)	1/9/1992
20 U	N	10-03 (92b) (05/14/92)	5/14/1992
0.7 U	Y	10GW0301	1/18/2001
10-04			
20 U	N	10-04 (83b) (07/12/83)	7/12/1983
10 U	N	10-04 (85) (01/16/85)	1/16/1985
10 U	N	10-04 (86) (02/09/86)	2/9/1986
5 U	N	10-04 (89) (04/26/89)	4/26/1989
20 U	N	10-04 (91a) (03/16/91)	3/16/1991
20 U	N	10-04 (91b) (06/01/91)	6/1/1991
20 U	N	10-04 (92a) (01/09/92)	1/9/1992
20 U	N	10-04 (92b) (05/14/92)	5/14/1992

TABLE A-1

HISTORICAL AND RF INVESTIGATION RDX SAMPLE DATA
SWMU 10 - ROCKEYE
NSWC CRANE
CRANE, INDIANA

Results (µg/L)	Validated (Yes/No)	Sample Number	Sample Date
10-05			
20 U	N	10-05 (83b) (07/12/83)	7/12/1983
10 U	N	10-05 (85) (01/16/85)	1/16/1985
10 U	N	10-05 (86) (02/09/86)	2/9/1986
20 U	N	10-05 (91a) (03/16/91)	3/16/1991
20 U	N	10-05 (92a) (01/09/92)	1/9/1992
20 U	N	10-05 (92b) (05/14/92)	5/14/1992
20 U	N	10-06 (83b) (07/12/83)	7/12/1983
10-06			
10 U	N	10-06 (85) (01/30/85)	1/30/1985
10 U	N	10-06 (86) (02/09/86)	2/9/1986
20 U	N	10-06 (91a) (03/16/91)	3/16/1991
20 U	N	10-06 (91b) (06/01/91)	6/1/1991
20 U	N	10-06 (92a) (01/09/92)	1/9/1992
20 U	N	10-06 (92b) (05/14/92)	5/14/1992
10-07			
180	N	10-07 (83b) (07/27/83)	7/27/1983
260	N	10-07 (83c) (09/06/83)	9/6/1983
72	N	10-07 (85) (01/30/85)	1/30/1985
370	N	10-07 (86) (02/09/86)	2/9/1986
83	N	10-07 (89) (04/26/89)	4/26/1989
22	N	10-07 (91a) (03/16/91)	3/16/1991
32	N	10-07 (91b) (06/01/91)	6/1/1991
35	N	10-07 (92a) (01/09/92)	1/9/1992
82	N	10-07 (92b) (05/14/92)	5/14/1992
10 U	N	10-07	
10-08			
150	N	10-08 (83b) (07/27/83)	7/27/1983
62	N	10-08 (83c) (09/06/83)	9/6/1983
113	N	10-08 (85) (01/30/85)	1/30/1985
240	N	10-08 (86) (02/09/86)	2/9/1986
33.8	N	10-08 (89) (04/26/89)	4/26/1989
22	N	10-08 (91a) (03/16/91)	3/16/1991
134	N	10-08 (91b) (06/01/91)	6/1/1991
41	N	10-08 (92a) (01/09/92)	1/9/1992
135	N	10-08 (92b) (05/14/92)	5/14/1992
140	N	10-08	

TABLE A-1

HISTORICAL AND RF INVESTIGATION RDX SAMPLE DATA
SWMU 10 - ROCKEYE
NSWC CRANE
CRANE, INDIANA

Results (µg/L)	Validated (Yes/No)	Sample Number	Sample Date
10-09			
120	N	10-09 (83b) (07/27/83)	7/27/1983
10 U	N	10-09 (83c) (09/06/83)	9/6/1983
10 U	N	10-09 (86) (02/09/86)	2/9/1986
5 U	N	10-09 (89) (04/26/89)	4/26/1989
20 U	N	10-09 (91a) (03/16/91)	3/16/1991
20 U	N	10-09 (91b) (06/01/91)	6/1/1991
20 U	N	10-09 (92a) (01/09/92)	1/9/1992
20 U	N	10-09 (92b) (05/14/92)	5/14/1992
10 U	N	10-09	
10-10			
20 U	N	10-10 (83b) (07/27/83)	7/27/1983
10 U	N	10-10 (83c) (09/06/83)	9/6/1983
10 U	N	10-10 (85) (01/16/85)	1/16/1985
10 U	N	10-10 (86) (02/09/86)	2/9/1986
20 U	N	10-10 (91a) (03/16/91)	3/16/1991
20 U	N	10-10 (91b) (06/01/91)	6/1/1991
20 U	N	10-10 (92a) (01/09/92)	1/9/1992
20 U	N	10-10 (92b) (05/14/92)	5/14/1992
10 U	N	10-10	
10-11			
10 U	N	10-11 (83c) (09/06/83)	9/6/1983
10 U	N	10-11 (85) (01/30/85)	1/30/1985
10 U	N	10-11 (86) (02/09/86)	2/9/1986
20 U	N	10-11 (91a) (03/16/91)	3/16/1991
20 U	N	10-11 (92a) (01/09/92)	1/9/1992
20 U	N	10-11 (92b) (05/14/92)	5/14/1992
10-12			
10 U	N	10-12 (83c) (09/06/83)	9/6/1983
10 U	N	10-12 (85) (01/30/85)	1/30/1985
10 U	N	10-12 (86) (02/09/86)	2/9/1986
10-13			
10 U	N	10-13 (83c) (09/06/83)	9/6/1983
10 U	N	10-13 (85) (01/16/85)	1/16/1985
10 U	N	10-13 (86) (02/09/86)	2/9/1986
20 U	N	10-13 (91a) (03/16/91)	3/16/1991
20 U	N	10-13 (92a) (01/09/92)	1/9/1992
20 U	N	10-13 (92b) (05/14/92)	5/14/1992
10-14			
10 U	N	10-14 (83c) (09/06/83)	9/6/1983

TABLE A-1

HISTORICAL AND RF INVESTIGATION RDX SAMPLE DATA
SWMU 10 - ROCKEYE
NSWC CRANE
CRANE, INDIANA

Results (µg/L)	Validated (Yes/No)	Sample Number	Sample Date
10-14B			
10 U	N	10-14B (86) (02/09/86)	2/9/1986
20 U	N	10-14B (91a) (03/16/91)	3/16/1991
20 U	N	10-14B (91b) (06/01/91)	6/1/1991
20 U	N	10-14B (92a) (01/09/92)	1/9/1992
20 U	N	10-14B (92b) (05/14/92)	5/14/1992
10 U	N	10-14B	
10-15			
10 U	N	10-15 (83c) (09/06/83)	9/6/1983
10 U	N	10-15 (85) (01/30/85)	1/30/1985
10 U	N	10-15 (86) (02/09/86)	2/9/1986
20 U	N	10-15 (91a) (03/16/91)	3/16/1991
20 U	N	10-15 (92a) (01/09/92)	1/9/1992
20 U	N	10-15 (92b) (05/14/92)	5/14/1992
10-16			
10 U	N	10-16 (83c) (09/21/83)	9/21/1983
10 U	N	10-16 (85) (01/30/85)	1/30/1985
10 U	N	10-16 (86) (02/09/86)	2/9/1986
20 U	N	10-16 (91a) (03/16/91)	3/16/1991
20 U	N	10-16 (91b) (06/01/91)	6/1/1991
20 U	N	10-16 (92a) (01/09/92)	1/9/1992
20 U	N	10-16 (92b) (05/14/92)	5/14/1992
1.7 U	Y	10GW1601	1/21/2001
10-17			
14	N	10-17 (85) (01/30/85)	1/30/1985
8200	N	10-17 (86) (02/09/86)	2/9/1986
1370	N	10-17 (89) (04/26/89)	4/26/1989
806	N	10-17 (91a) (03/16/91)	3/16/1991
632	N	10-17 (91b) (06/01/91)	6/1/1991
422	N	10-17 (92a) (01/09/92)	1/9/1992
618	N	10-17 (92b) (05/14/92)	5/14/1992
33	Y	10GW1701	1/23/2001
7200 U	N	10-17-0983c	
10-18			
6190	N	10-18 (85) (01/30/85)	1/30/1985
69	N	10-18 (86) (02/09/86)	2/9/1986
83	N	10-18 (89) (04/26/89)	4/26/1989
43	N	10-18 (91a) (03/16/91)	3/16/1991
20 U	N	10-18 (91b) (06/01/91)	6/1/1991
20 U	N	10-18 (92a) (01/09/92)	1/9/1992
37	N	10-18 (92b) (05/14/92)	5/14/1992
26	N	10-18-0983c	

TABLE A-1

HISTORICAL AND RF INVESTIGATION RDX SAMPLE DATA
SWMU 10 - ROCKEYE
NSWC CRANE
CRANE, INDIANA

Results (µg/L)	Validated (Yes/No)	Sample Number	Sample Date
10-19			
25	N	10-19 (83c) (09/21/83)	9/21/1983
26	N	10-19 (85) (01/30/85)	1/30/1985
10 U	N	10-19 (86) (02/09/86)	2/9/1986
5 U	N	10-19 (89) (04/26/89)	4/26/1989
20 U	N	10-19 (91a) (03/16/91)	3/16/1991
20 U	N	10-19 (91b) (06/01/91)	6/1/1991
20 U	N	10-19 (92a) (01/09/92)	1/9/1992
20 U	N	10-19 (92b) (05/14/92)	5/14/1992
10 U	N	10-19	
10-20			
10	N	10-20 (83c) (09/21/83)	9/21/1983
10 U	N	10-20 (85) (01/30/85)	1/30/1985
10 U	N	10-20 (86) (02/09/86)	2/9/1986
5 U	N	10-20 (89) (04/26/89)	4/26/1989
20 U	N	10-20 (91a) (03/16/91)	3/16/1991
20 U	N	10-20 (91b) (06/01/91)	6/1/1991
20 U	N	10-20 (92a) (01/09/92)	1/9/1992
20 U	N	10-20 (92b) (05/14/92)	5/14/1992
10-21			
10 U	N	10-21 (83c) (09/21/83)	9/21/1983
10 U	N	10-21 (85) (01/30/85)	1/30/1985
10 U	N	10-21 (86) (02/09/86)	2/9/1986
23	N	10-21 (91a) (03/16/91)	3/16/1991
20 U	N	10-21 (91b) (06/01/91)	6/1/1991
12 J	N	10-21 (92a) (01/09/92)	1/9/1992
26	N	10-21 (92b) (05/14/92)	5/14/1992
10-22			
10 U	N	10-22 (83c) (09/21/83)	9/21/1983
10 U	N	10-22 (85) (01/16/85)	1/16/1985
10 U	N	10-22 (86) (02/09/86)	2/9/1986
20 U	N	10-22 (91a) (03/16/91)	3/16/1991
20 U	N	10-22 (92b) (05/14/92)	5/14/1992
10C23			
5 U	N	10C23-042689	4/26/1989
20 U	N	10C23 (91a) (03/16/91)	3/16/1991
20 U	N	10C23 (91b) (06/01/91)	6/1/1991
20 U	N	10C23 (92a) (01/09/92)	1/9/1992
20 U	N	10C23 (92b) (05/14/92)	5/14/1992
20 U	N	10C24 (91a) (03/16/91)	3/16/1991
20 U	N	10C24 (91b) (06/01/91)	6/1/1991
20 U	N	10C24 (92a) (01/09/92)	1/9/1992
20 U	N	10C24 (92b) (05/14/92)	5/14/1992

TABLE A-1

HISTORICAL AND RF INVESTIGATION RDX SAMPLE DATA
SWMU 10 - ROCKEYE
NSWC CRANE
CRANE, INDIANA

Results (µg/L)	Validated (Yes/No)	Sample Number	Sample Date
10C24P2			
20 U	N	10C24P2 (91a) (03/16/91)	3/16/1991
20 U	N	10C24P2 (91b) (06/01/91)	6/1/1991
20 U	N	10C24P2 (92b) (05/14/92)	5/14/1992
5 U	N	10C24P3-042689	4/26/1989
20 U	N	10C24P3 (91a) (03/16/91)	3/16/1991
20 U	N	10C24P3 (91b) (06/01/91)	6/1/1991
20 U	N	10C24P3 (92a) (01/09/92)	1/9/1992
20 U	N	10C24P3 (92b) (05/14/92)	5/14/1992
10C25			
5 U	N	10C25-042689	4/26/1989
20 U	N	10C25 (91a) (03/16/91)	3/16/1991
20 U	N	10C25 (91b) (06/01/91)	6/1/1991
20 U	N	10C25 (92a) (01/09/92)	1/9/1992
20 U	N	10C25 (92b) (05/14/92)	5/14/1992
10C25P2			
5 U	N	10C25P2-042689	4/26/1989
20 U	N	10C25P2 (91a) (03/16/91)	3/16/1991
20 U	N	10C25P2 (91b) (06/01/91)	6/1/1991
20 U	N	10C25P2 (92a) (01/09/92)	1/9/1992
20 U	N	10C25P2 (92b) (05/14/92)	5/14/1992
20 U	N	10C25P3 (91a) (03/16/91)	3/16/1991
20 U	N	10C25P3 (91b) (06/01/91)	6/1/1991
20 U	N	10C25P3 (92a) (01/09/92)	1/9/1992
20 U	N	10C25P3 (92b) (05/14/92)	5/14/1992
10C26			
20 U	N	10C26 (91a) (03/16/91)	3/16/1991
20 U	N	10C26 (92a) (01/09/92)	1/9/1992
20 U	N	10C26 (92b) (05/14/92)	5/14/1992
10C26P2			
20 U	N	10C26P2 (91a) (03/16/91)	3/16/1991
20 U	N	10C26P2 (92a) (01/09/92)	1/9/1992
20 U	N	10C26P2 (92b) (05/14/92)	5/14/1992
5 U	N	10C26P3 (89) (04/26/89)	4/26/1989
20 U	N	10C26P3 (91a) (03/16/91)	3/16/1991
20 U	N	10C26P3 (92a) (01/09/92)	1/9/1992
20 U	N	10C26P3 (92b) (05/14/92)	5/14/1992
10C27			
20 U	N	10C27 (91a) (03/16/91)	3/16/1991
20 U	N	10C27 (91b) (06/01/91)	6/1/1991
20 U	N	10C27 (92a) (01/09/92)	1/9/1992
20 U	N	10C27 (92b) (05/14/92)	5/14/1992

TABLE A-1

HISTORICAL AND RF INVESTIGATION RDX SAMPLE DATA
SWMU 10 - ROCKEYE
NSWC CRANE
CRANE, INDIANA

Results (µg/L)	Validated (Yes/No)	Sample Number	Sample Date
10C27P2			
5 U	N	10C27P2 (89) (04/26/89)	4/26/1989
20 U	N	10C27P2 (91a) (03/16/91)	3/16/1991
20 U	N	10C27P2 (91b) (06/01/91)	6/1/1991
20 U	N	10C27P2 (92a) (01/09/92)	1/9/1992
10C28			
5 U	N	10C28-042689	4/26/1989
20 U	N	10C28 (91a) (03/16/91)	3/16/1991
20 U	N	10C28 (91b) (06/01/91)	6/1/1991
20 U	N	10C28 (92a) (01/09/92)	1/9/1992
20 U	N	10C28 (92b) (05/14/92)	5/14/1992
10C28P2			
5 U	N	10C28P2 (89) (04/26/89)	4/26/1989
20 U	N	10C28P2 (91a) (03/16/91)	3/16/1991
20 U	N	10C28P2 (91b) (06/01/91)	6/1/1991
20 U	N	10C28P2 (92a) (01/09/92)	1/9/1992
20 U	N	10C28P2 (92b) (05/14/92)	5/14/1992
10C29			
5 U	N	10C29-042689	4/26/1989
20 U	N	10C29 (91a) (03/16/91)	3/16/1991
20 U	N	10C29 (91b) (06/01/91)	6/1/1991
20 U	N	10C29 (92a) (01/09/92)	1/9/1992
20 U	N	10C29 (92b) (05/14/92)	5/14/1992
10C29P2			
5 U	N	10C29P2 (89) (04/26/89)	4/26/1989
20 U	N	10C29P2 (91a) (03/16/91)	3/16/1991
20 U	N	10C29P2 (91b) (06/01/91)	6/1/1991
20 U	N	10C29P2 (92a) (01/09/92)	1/9/1992
20 U	N	10C29P2 (92b) (05/14/92)	5/14/1992
10C30			
5 U	N	10C30 (89) (04/26/89)	4/26/1989
20 U	N	10C30 (91a) (03/16/91)	3/16/1991
20 U	N	10C30 (92a) (01/09/92)	1/9/1992
20 U	N	10C30 (92b) (05/14/92)	5/14/1992
10C30P2			
5 U	N	10C30P2 (89) (04/26/89)	4/26/1989
20 U	N	10C30P2 (91a) (03/16/91)	3/16/1991
20 U	N	10C30P2 (92a) (01/09/92)	1/9/1992
20 U	N	10C30P2 (92b) (05/14/92)	5/14/1992

TABLE A-1

HISTORICAL AND RF INVESTIGATION RDX SAMPLE DATA
SWMU 10 - ROCKEYE
NSWC CRANE
CRANE, INDIANA

Results (µg/L)	Validated (Yes/No)	Sample Number	Sample Date
10C31			
5 U	N	10C31 (89) (04/26/89)	4/26/1989
20 U	N	10C31 (91a) (03/16/91)	3/16/1991
20 U	N	10C31 (91b) (06/01/91)	6/1/1991
20 U	N	10C31 (92a) (01/09/92)	1/9/1992
20 U	N	10C31 (92b) (05/14/92)	5/14/1992
0.7 U	Y	10GWC3101	1/8/2001
10C31P3			
5 U	N	10C31P3 (89) (04/26/89)	4/26/1989
20 U	N	10C31P3 (91a) (03/16/91)	3/16/1991
20 U	N	10C31P3 (91b) (06/01/91)	6/1/1991
20 U	N	10C31P3 (92a) (01/09/92)	1/9/1992
1.2 U	Y	10GWC31P301	1/22/2001
10C32			
5 U	N	10C32 (89) (04/26/89)	4/26/1989
20 U	N	10C32 (91a) (03/16/91)	3/16/1991
20 U	N	10C32 (91b) (06/01/91)	6/1/1991
20 U	N	10C32 (92a) (01/09/92)	1/9/1992
20 U	N	10C32 (92b) (05/14/92)	5/14/1992
10C32P2			
20 U	N	10C32P2 (91a) (03/16/91)	3/16/1991
20 U	N	10C32P2 (91b) (06/01/91)	6/1/1991
20 U	N	10C32P2 (92a) (01/09/92)	1/9/1992
20 U	N	10C32P2 (92b) (05/14/92)	5/14/1992
5 U	N	10C32P3 (89) (04/26/89)	4/26/1989
20 U	N	10C32P3 (91a) (03/16/91)	3/16/1991
20 U	N	10C32P3 (91b) (06/01/91)	6/1/1991
20 U	N	10C32P3 (92a) (01/09/92)	1/9/1992
20 U	N	10C32P3 (92b) (05/14/92)	5/14/1992
10C33			
5 U	N	10C33 (89) (04/26/89)	4/26/1989
20 U	N	10C33 (91a) (03/16/91)	3/16/1991
20 U	N	10C33 (91b) (06/01/91)	6/1/1991
20 U	N	10C33 (92a) (01/09/92)	1/9/1992
20 U	N	10C33 (92b) (05/14/92)	5/14/1992
0.43 U	Y	10GWC3301	1/20/2001
10C33P2			
5 U	N	10C33P2 (89) (04/26/89)	4/26/1989
20 U	N	10C33P2 (91a) (03/16/91)	3/16/1991
20 U	N	10C33P2 (91b) (06/01/91)	6/1/1991
20 U	N	10C33P2 (92a) (01/09/92)	1/9/1992
20 U	N	10C33P2 (92b) (05/14/92)	5/14/1992
0.58 U	Y	10GWC33P201	1/20/2001

TABLE A-1

HISTORICAL AND RF INVESTIGATION RDX SAMPLE DATA
SWMU 10 - ROCKEYE
NSWC CRANE
CRANE, INDIANA

Results (µg/L)	Validated (Yes/No)	Sample Number	Sample Date
10C34			
5 U	N	10C34 (89) (04/26/89)	4/26/1989
20 U	N	10C34 (91a) (03/16/91)	3/16/1991
20 U	N	10C34 (91b) (06/01/91)	6/1/1991
20 U	N	10C34 (92a) (01/09/92)	1/9/1992
20 U	N	10C34 (92b) (05/14/92)	5/14/1992
10C34P2			
5 U	N	10C34P2 (89) (04/26/89)	4/26/1989
20 U	N	10C34P2 (91a) (03/16/91)	3/16/1991
20 U	N	10C34P2 (91b) (06/01/91)	6/1/1991
20 U	N	10C34P2 (92a) (01/09/92)	1/9/1992
20 U	N	10C34P2 (92b) (05/14/92)	5/14/1992
10C34P3			
5 U	N	10C34P3 (89) (04/26/89)	4/26/1989
20 U	N	10C34P3 (91a) (03/16/91)	3/16/1991
20 U	N	10C34P3 (91b) (06/01/91)	6/1/1991
20 U	N	10C34P3 (92a) (01/09/92)	1/9/1992
20 U	N	10C34P3 (92b) (05/14/92)	5/14/1992
10C35			
5 U	N	10C35 (89) (04/26/89)	4/26/1989
20 U	N	10C35 (91a) (03/16/91)	3/16/1991
20 U	N	10C35 (91b) (06/01/91)	6/1/1991
6 J	N	10C35 (92a) (01/09/92)	1/9/1992
20 U	N	10C35 (92b) (05/14/92)	5/14/1992
0.49 U	Y	10GWC3501	1/21/2001
10C35P2			
20 U	N	10C35P2 (91a) (03/16/91)	3/16/1991
20 U	N	10C35P2 (91b) (06/01/91)	6/1/1991
20.8 U	N	10C35P2 (92a) (01/09/92)	1/9/1992
20 U	N	10C35P2 (92b) (05/14/92)	5/14/1992
0.52 U	Y	10GWC35P201	1/21/2001
5 U	N	10C35P3 (89) (04/26/89)	4/26/1989
20 U	N	10C35P3 (91a) (03/16/91)	3/16/1991
20 U	N	10C35P3 (91b) (06/01/91)	6/1/1991
20 U	N	10C35P3 (92a) (01/09/92)	1/9/1992
20 U	N	10C35P3 (92b) (05/14/92)	5/14/1992
10C36			
20 U	N	10C36 (91a) (03/16/91)	3/16/1991
20 U	N	10C36 (91b) (06/01/91)	6/1/1991
20 U	N	10C36 (92a) (01/09/92)	1/9/1992
20 U	N	10C36 (92b) (05/14/92)	5/14/1992

TABLE A-1

HISTORICAL AND RF INVESTIGATION RDX SAMPLE DATA
SWMU 10 - ROCKEYE
NSWC CRANE
CRANE, INDIANA

Results (µg/L)	Validated (Yes/No)	Sample Number	Sample Date
10C36P2			
5 U	N	10C36P2 (89) (04/26/89)	4/26/1989
20 U	N	10C36P2 (91a) (03/16/91)	3/16/1991
20 U	N	10C36P2 (91b) (06/01/91)	6/1/1991
20 U	N	10C36P2 (92a) (01/09/92)	1/9/1992
20 U	N	10C36P2 (92b) (05/14/92)	5/14/1992
10C36P3			
5 U	N	10C36P3 (89) (04/26/89)	4/26/1989
20 U	N	10C36P3 (91a) (03/16/91)	3/16/1991
20 U	N	10C36P3 (91b) (06/01/91)	6/1/1991
20 U	N	10C36P3 (92a) (01/09/92)	1/9/1992
20 U	N	10C36P3 (92b) (05/14/92)	5/14/1992
10C37			
5 U	N	10C37 (89) (04/26/89)	4/26/1989
18 J	N	10C37 (91a) (03/16/91)	3/16/1991
20 U	N	10C37 (91b) (06/01/91)	6/1/1991
20 U	N	10C37 (92a) (01/09/92)	1/9/1992
20 U	N	10C37 (92b) (05/14/92)	5/14/1992
0.68 U	Y	10GWC3701	1/19/2001
10C37P2			
20 U	N	10C37P2 (91a) (03/16/91)	3/16/1991
20 U	N	10C37P2 (91b) (06/01/91)	6/1/1991
20 U	N	10C37P2 (92a) (01/09/92)	1/9/1992
20 U	N	10C37P2 (92b) (05/14/92)	5/14/1992
10C37P3			
5 U	N	10C37P3 (89) (04/26/89)	4/26/1989
20 U	N	10C37P3 (91a) (03/16/91)	3/16/1991
20 U	N	10C37P3 (91b) (06/01/91)	6/1/1991
20 U	N	10C37P3 (92a) (01/09/92)	1/9/1992
20 U	N	10C37P3 (92b) (05/14/92)	5/14/1992
0.29 U	Y	10GWC37P301	1/6/2001
10C38			
5 U	N	10C38 (89) (04/26/89)	4/26/1989
20 U	N	10C38 (91a) (03/16/91)	3/16/1991
20 U	N	10C38 (91b) (06/01/91)	6/1/1991
20 U	N	10C38 (92a) (01/09/92)	1/9/1992
20 U	N	10C38 (92b) (05/14/92)	5/14/1992
10C39			
5 U	N	10C39 (89) (04/26/89)	4/26/1989
20 U	N	10C39 (91a) (03/16/91)	3/16/1991
20 U	N	10C39 (91b) (06/01/91)	6/1/1991
20 U	N	10C39 (92a) (01/09/92)	1/9/1992
20 U	N	10C39 (92b) (05/14/92)	5/14/1992

TABLE A-1

HISTORICAL AND RF INVESTIGATION RDX SAMPLE DATA
SWMU 10 - ROCKEYE
NSWC CRANE
CRANE, INDIANA

Results (µg/L)	Validated (Yes/No)	Sample Number	Sample Date
10C39P2			
5 U	N	10C39P2 (89) (04/26/89)	4/26/1989
20 U	N	10C39P2 (91a) (03/16/91)	3/16/1991
20 U	N	10C39P2 (91b) (06/01/91)	6/1/1991
20 U	N	10C39P2 (92a) (01/09/92)	1/9/1992
20 U	N	10C39P2 (92b) (05/14/92)	5/14/1992
10C40			
5 U	N	10C40 (89) (04/26/89)	4/26/1989
20 U	N	10C40 (91a) (03/16/91)	3/16/1991
10C40P2			
5 U	N	10C40P2 (89) (04/26/89)	4/26/1989
20 U	N	10C40P2 (91a) (03/16/91)	3/16/1991
20 U	N	10C40P2 (91b) (06/01/91)	6/1/1991
20 U	N	10C40P2 (92a) (01/09/92)	1/9/1992
20 U	N	10C40P2 (92b) (05/14/92)	5/14/1992
5 U	N	10C40P4 (89) (04/26/89)	4/26/1989
20 U	N	10C40P4 (91a) (03/16/91)	3/16/1991
20 U	N	10C40P4 (91b) (06/01/91)	6/1/1991
20 U	N	10C40P4 (92a) (01/09/92)	1/9/1992
20 U	N	10C40P4 (92b) (05/14/92)	5/14/1992
10C41			
5 U	N	10C41 (89) (04/26/89)	4/26/1989
20 U	N	10C41 (91a) (03/16/91)	3/16/1991
20 U	N	10C41 (91b) (06/01/91)	6/1/1991
20 U	N	10C41 (92a) (01/09/92)	1/9/1992
20 U	N	10C41 (92b) (05/14/92)	5/14/1992
0.61 U	Y	10GWC4101	1/9/2001
10C41P3			
5 U	N	10C41P3 (89) (04/26/89)	4/26/1989
20 U	N	10C41P3 (91a) (03/16/91)	3/16/1991
20 U	N	10C41P3 (91b) (06/01/91)	6/1/1991
20 U	N	10C41P3 (92a) (01/09/92)	1/9/1992
20 U	N	10C41P3 (92b) (05/14/92)	5/14/1992
0.49 U	Y	10GWC41P301	1/9/2001
10C42			
5 U	N	10C42 (89) (04/26/89)	4/26/1989
20 U	N	10C42 (91a) (03/16/91)	3/16/1991
20 U	N	10C42 (91b) (06/01/91)	6/1/1991
20 U	N	10C42 (92a) (01/09/92)	1/9/1992
20 U	N	10C42 (92b) (05/14/92)	5/14/1992

TABLE A-1

HISTORICAL AND RF INVESTIGATION RDX SAMPLE DATA
SWMU 10 - ROCKEYE
NSWC CRANE
CRANE, INDIANA

Results (µg/L)	Validated (Yes/No)	Sample Number	Sample Date
10C42P2			
5 U	N	10C42P2 (89) (04/26/89)	4/26/1989
20 U	N	10C42P2 (91a) (03/16/91)	3/16/1991
20 U	N	10C42P2 (91b) (06/01/91)	6/1/1991
20 U	N	10C42P2 (92a) (01/09/92)	1/9/1992
20 U	N	10C42P2 (92b) (05/14/92)	5/14/1992
10C43			
5 U	N	10C43-042689	4/26/1989
20 U	N	10C43 (91a) (03/16/91)	3/16/1991
20 U	N	10C43 (91b) (06/01/91)	6/1/1991
20 U	N	10C43 (92a) (01/09/92)	1/9/1992
20 U	N	10C43 (92b) (05/14/92)	5/14/1992
10C43P2			
20 U	N	10C43P2 (91a) (03/16/91)	3/16/1991
20 U	N	10C43P2 (91b) (06/01/91)	6/1/1991
20 U	N	10C43P2 (92a) (01/09/92)	1/9/1992
20 U	N	10C43P2 (92b) (05/14/92)	5/14/1992
5 U	N	10C43P3 (89) (04/26/89)	4/26/1989
20 U	N	10C43P3 (91a) (03/16/91)	3/16/1991
20 U	N	10C43P3 (91b) (06/01/91)	6/1/1991
20 U	N	10C43P3 (92a) (01/09/92)	1/9/1992
20 U	N	10C43P3 (92b) (05/14/92)	5/14/1992
10C44			
20 U	N	10C44 (91a) (03/16/91)	3/16/1991
20 U	N	10C44 (91b) (06/01/91)	6/1/1991
20 U	N	10C44 (92a) (01/09/92)	1/9/1992
20 U	N	10C44 (92b) (05/14/92)	5/14/1992
20 U	N	10C44P2 (91a) (03/16/91)	3/16/1991
20 U	N	10C44P2 (92a) (01/09/92)	1/9/1992
20 U	N	10C44P2 (92b) (05/14/92)	5/14/1992
10C45			
20 U	N	10C45 (91a) (03/16/91)	3/16/1991
20 U	N	10C45 (92a) (01/09/92)	1/9/1992
20 U	N	10C45 (92b) (05/14/92)	5/14/1992
10C45P2			
20 U	N	10C45P2 (91a) (03/16/91)	3/16/1991
20 U	N	10C45P2 (92a) (01/09/92)	1/9/1992
20 U	N	10C45P2 (92b) (05/14/92)	5/14/1992
10C46			
20 U	N	10C46 (91a) (03/16/91)	3/16/1991
20 U	N	10C46 (92a) (01/09/92)	1/9/1992
20 U	N	10C46 (92b) (05/14/92)	5/14/1992
20 U	N	10C46P2 (91a) (03/16/91)	3/16/1991
20 U	N	10C46P2 (92a) (01/09/92)	1/9/1992
20 U	N	10C46P2 (92b) (05/14/92)	5/14/1992

TABLE A-1

HISTORICAL AND RF INVESTIGATION RDX SAMPLE DATA
SWMU 10 - ROCKEYE
NSWC CRANE
CRANE, INDIANA

Results (µg/L)	Validated (Yes/No)	Sample Number	Sample Date
10C46P3			
20 U	N	10C46P3 (91a) (03/16/91)	3/16/1991
20 U	N	10C46P3 (92a) (01/09/92)	1/9/1992
20 U	N	10C46P3 (92b) (05/14/92)	5/14/1992
10C47			
20 U	N	10C47 (91a) (03/16/91)	3/16/1991
20 U	N	10C47 (92a) (01/09/92)	1/9/1992
20 U	N	10C47 (92b) (05/14/92)	5/14/1992
10C47P2			
20 U	N	10C47P2 (91a) (03/16/91)	3/16/1991
20 U	N	10C47P2 (92a) (01/09/92)	1/9/1992
20 U	N	10C47P2 (92b) (05/14/92)	5/14/1992
10C48			
20 U	N	10C48 (91a) (03/16/91)	3/16/1991
20 U	N	10C48 (91b) (06/01/91)	6/1/1991
20 U	N	10C48 (92a) (01/09/92)	1/9/1992
20 U	N	10C48 (92b) (05/14/92)	5/14/1992
10C48P2			
20 U	N	10C48P2 (91a) (03/16/91)	3/16/1991
20 U	N	10C48P2 (91b) (06/01/91)	6/1/1991
20 U	N	10C48P2 (92a) (01/09/92)	1/9/1992
20 U	N	10C48P2 (92b) (05/14/92)	5/14/1992
10C49			
20 U	N	10C49 (91a) (03/16/91)	3/16/1991
20 U	N	10C49 (91b) (06/01/91)	6/1/1991
20 U	N	10C49 (92a) (01/09/92)	1/9/1992
20 U	N	10C49 (92b) (05/14/92)	5/14/1992
10C49P2			
20 U	N	10C49P2 (91a) (03/16/91)	3/16/1991
20 U	N	10C49P2 (91b) (06/01/91)	6/1/1991
20 U	N	10C49P2 (92a) (01/09/92)	1/9/1992
20 U	N	10C49P2 (92b) (05/14/92)	5/14/1992
10C50			
20 U	N	10C50 (91a) (03/16/91)	3/16/1991
20 U	N	10C50 (91b) (06/01/91)	6/1/1991
20 U	N	10C50 (92a) (01/09/92)	1/9/1992
20 U	N	10C50 (92b) (05/14/92)	5/14/1992
10C51			
20 U	N	10C51 (91a) (03/16/91)	3/16/1991
20 U	N	10C51 (91b) (06/01/91)	6/1/1991
20 U	N	10C51 (92a) (01/09/92)	1/9/1992
20 U	N	10C51 (92b) (05/14/92)	5/14/1992

TABLE A-1

HISTORICAL AND RF INVESTIGATION RDX SAMPLE DATA
SWMU 10 - ROCKEYE
NSWC CRANE
CRANE, INDIANA

Results (µg/L)	Validated (Yes/No)	Sample Number	Sample Date
10C52			
20 U	N	10C52 (91a) (03/16/91)	3/16/1991
20 U	N	10C52 (92a) (01/09/92)	1/9/1992
20 U	N	10C52 (92b) (05/14/92)	5/14/1992
0.9 U	Y	10GWC5201	1/18/2001
10C53			
20 U	N	10C53 (91a) (03/16/91)	3/16/1991
20 U	N	10C53 (91b) (06/01/91)	6/1/1991
20 U	N	10C53 (92a) (01/09/92)	1/9/1992
20 U	N	10C53 (92b) (05/14/92)	5/14/1992
10C53P2			
20 U	N	10C53P2 (91a) (03/16/91)	3/16/1991
20 U	N	10C53P2 (91b) (06/01/91)	6/1/1991
20 U	N	10C53P2 (92a) (01/09/92)	1/9/1992
20 U	N	10C53P2 (92b) (05/14/92)	5/14/1992
10C54			
20 U	N	10C54 (91a) (03/16/91)	3/16/1991
20 U	N	10C54 (91b) (06/01/91)	6/1/1991
20 U	N	10C54 (92a) (01/09/92)	1/9/1992
20 U	N	10C54 (92b) (05/14/92)	5/14/1992
10C55			
548	N	10C55 (91a) (03/16/91)	3/16/1991
244	N	10C55 (91b) (06/01/91)	6/1/1991
278	N	10C55 (92a) (01/09/92)	1/9/1992
160	N	10C55 (92b) (05/14/92)	5/14/1992
240	Y	10GWC5501	1/21/2001
240	Y	10GWC5501-D	1/21/2001
10C55P2			
88	N	10C55P2 (91a) (03/16/91)	3/16/1991
115	N	10C55P2 (91b) (06/01/91)	6/1/1991
116	N	10C55P2 (92a) (01/09/92)	1/9/1992
94	N	10C55P2 (92b) (05/14/92)	5/14/1992
21	Y	10GWC55P201	1/22/2001
10C56			
20 U	N	10C56 (91a) (03/16/91)	3/16/1991
20 U	N	10C56 (91b) (06/01/91)	6/1/1991
20 U	N	10C56 (92a) (01/09/92)	1/9/1992
20 U	N	10C56 (92b) (05/14/92)	5/14/1992
10C57			
20 U	N	10C57 (91a) (03/16/91)	3/16/1991
20 U	N	10C57 (92a) (01/09/92)	1/9/1992
20 U	N	10C57 (92b) (05/14/92)	5/14/1992
0.64 U	Y	10GWC5701	1/24/2001

TABLE A-1

HISTORICAL AND RF INVESTIGATION RDX SAMPLE DATA
SWMU 10 - ROCKEYE
NSWC CRANE
CRANE, INDIANA

Results (µg/L)	Validated (Yes/No)	Sample	
		Number	Date
10C60			
51	N	10C60 (91a) (03/16/91)	3/16/1991
12 J	N	10C60 (92a) (01/09/92)	1/9/1992
20 U	N	10C60 (92b) (05/14/92)	5/14/1992
10C61			
20 U	N	10C61 (91a) (03/16/91)	3/16/1991
20 U	N	10C61 (92a) (01/09/92)	1/9/1992
20 U	N	10C61 (92b) (05/14/92)	5/14/1992

1.0 ASSUMPTIONS

The following assumptions are made based upon results of field investigations:

- As illustrated on attached Figures A-1 and A-2, there is a groundwater contaminant plume at SWMU 10 with elevated concentrations of explosives.
- The explosives plume is approximately 900 feet long by 170 feet wide, extending in a north to northeast direction from the vicinity of Building 2739 to monitoring wells 10C56 and 10C57.
- Within that plume, two circular areas approximately 100 feet in diameter are centered around monitoring well cluster 10C55/10C55P2 and monitoring well 10-17, where the highest concentrations of explosives have been detected. These circular areas have been designated as "Hot-Spot" No. 1 and "Hot-Spot" No. 2, respectively (Figure A-2).
- The thickness of contaminated groundwater is estimated at approximately 25 ft.

2.0 EXPLOSIVES PLUME SURFACE AREA, THICKNESS, AND VOLUME

2.1 Explosives Plume Surface Area

As illustrated on attached Figure A-3 the surface area of the explosives plume is estimated at approximately 150,000 ft^2.

2.2 Explosives Plume Thickness

As stated in the assumptions the thickness of contaminated groundwater is estimated at approximately 25 ft. Groundwater surface elevation is approximately 5 ft below ground surface (bgs).

2.3 Explosives Plume Volume

Groundwater in the explosives plume area occurs in bedrock with a porosity ranging from 0.03 to 0.15, with an average of 0.10. Therefore, the estimated volume of contaminated groundwater in the explosives plume can be computed as follows:

150,000 ft^2 x 25 ft x 0.10 = 375,000 ft^3 or 2,805,000 gallons

3.0 COCS QUANTITIES COMPUTATIONS

The quantities of COCs within the explosives plume groundwater can be computed based upon the volume of contaminated groundwater and the average concentrations of these COCs in that area. Average concentrations are assumed to be the mathematical average of the historical concentrations detected in samples collected from monitoring wells located within the explosives plume.

Average concentrations (in µg/L) of COCs in the explosives plume groundwater are computed in the table below. Analytical results shown on this table are those for samples collected at the indicated date that corresponds to the latest sampling.

COC	10-07 (5/14/92)	10-08 (5/14/92)	10-17 (1/23/01)	10-18 (5/14/92)	10-21 (5/14/92)	10C55 (1/21/01)	10C55P2 (1/22/01)	Average
Explosives (µg/L)								
RDX	82	140	33	37	26	240	21	83
TNT	9 J	60	26	20 U	20 U	56 J	5.8 J	25
2A-DNT	NA	NA	20	NA	NA	2.8	7.2	10
4A-DNT	NA	NA	18	NA	NA	3.7	18	13
HMX	119	98	240	70	20 U	59	91	98
Inorganics (µg/L)								
Iron	448	308	286	77	10,100	612	100 U	1,697
Manganese	471	296	299	442	468	336	15 U	331

NOTES

NA Not analyzed

J Estimated value

U Not detected at the indicated analytical detection limit. Half of the detected value was used for estimating the average concentration.

Quantities (in pounds) of COCs in the explosives plume groundwater can be calculated according to the following formula:

$$\text{Quantity} = (2{,}805{,}200 \text{ gallons}) \times (8.34 \text{ lb/gal}) \times (\text{average } \mu\text{g/L concentration}) \times (10^{-9})$$

Accordingly, estimated quantities of COCs in the explosives plume groundwater are as follows:

COC	Quantity (pounds)
Explosives	
RDX	1.94
TNT	0.58
2A-DNT	0.23
4A-DNT	0.30
HMX	2.29
Total Explosives	5.36
Inorganics	
Iron	39.70
Manganese	7.74
Total Inorganics	47.44

Project:	**NSWC Crane, SWMU 10 CMS**	**Project No.:**	**N4267**
Subject:	**SWMU 10 CMS - Calculations for Groundwater Flow and Natural Attenuation**		
By:	JPS	**Date:**	8/24/2005
Checked:		**Date:**	

Project/Design Objective:

Characterize groundwater flow system in plume area and calculate flushing rates and time to naturally attenuate plume. The desired cleanup level for RDX in groundwater is 0.5 ug/L.

Basis of Calculations: (Input cells yellow, blue automatically calculated)

Groundwater Plume Information

Plume Width (W):	150	ft.
Plume Thickness (P_T):	25	ft.
Plume Area (P_A):	150,000	ft^2
Volume of Groundwater in Plume (= P_T * P_A * n):	375,000	ft^3
Avg Hydraulic Conductivity, Plume Area (Hydr-c_{avg}):	1	ft/day

Aquifer Characteristics

Thickness (B):	25	ft
Avg. Hydraulic Conductivity (K):	1	ft/day
Transmissivity (T = B * K):	25	ft^2/day
Porosity (n):	0.1	
Storativity (S):	0.1	
Fractional Organic Carbon Content (foc) *:	0.0005	
Flow Gradient (i):	0.02	

Contaminant Characteristics

Contaminant A Representative gw conc.:	RDX	100	µg/L
Koc, Contaminant A:		150	
Kd, Contaminant A (= T * Koc):		0.075	
Half-life, Contaminant A:		20	years
Target Cleanup Level, Contaminant A:		0.5	ug/L

Estimated Flow Rate of Contaminated Groundwater (through plane normal to flow direction)

Q: = T * i * W

Q: = 75.00 ft^3/day, or 0.39 gpm

All groundwater/soil contaminant concentrations are in consistent units, i.e., mg/L & mg/kg, or µg/L & µg/kg.

* for contaminants that partition between soil and water through mechanisms other than adsoption onto organic carbon, i.e., metals, the compound's K_d is input directly into the K_{OC} entry cell, with f_{OC} then set to 1. For fractured bedrock, reduce the f_{OC} by 1-2 orders of magnitude to adjust for typical low fracture porosity and resulting high model-perceived mass of aquifer material in contact with water.

This spreadsheet calculates flushing rates and cleanup times for a groundwater flow system that consists of up to 3 groundwater "flow units". Flow units are discrete portions of the aquifer that have unique properties, i.e., higher or lower average hydraulic conductivity, porosity, or specific gravity relative to other portions of the aquifer, higher/lower contaminant concentrations, and/or different organic carbon contents. The spreadsheet factors in different flushing rates for discrete portions of the aquifer based on the differences in the physical/chemical characteristics of the flow units. First-order contaminant decay/degradation processes can also be factored into the cleanup rate prediction through the optional use of contaminant half-life data.

Groundwater Flow Unit Physical/Chemical Data

Flow Unit 1 (U1)		Flow Unit 2 (U2)		Flow Unit 3 (U3)	
Cw_{01}	100.000	Cw_{02}	100.000	Cw_{03}	100.000
n	0.100	n	0.100	n	0.100
S_G	2.650	S_G	2.650	S_G	2.650
f_{OC}*	0.0005	f_{OC}*	0.0005	f_{OC}*	0.0005
K_d	0.075	K_d	0.075	K_d	0.075
M_W	10.000	M_W	10.000	M_W	10.000
C_S	7.500	C_S	7.500	C_S	7.500
M_S	17.888	M_S	17.888	M_S	17.888
M_T	27.888	M_T	27.888	M_T	27.888
M_S/M_T	0.6414	M_S/M_T	0.6414	M_S/M_T	0.6414

Cw_{0N} = Initial contaminant concentration in groundwater flow unit N

Groundwater Flow Unit Hydrogeologic Characteristics

Avg. K, ft/d highest to lowest	Relative average K, K_U	Fraction of aquifer volume, FV_U	Fraction of total flow, FQ_U	Flow unit number, U
1	1.000	0.333	0.333	1
1	1.000	0.334	0.334	2
1	1.000	0.333	0.333	3

Pore Volumes and Pore Volume Removal Rates

Groundwater discharge rate, gpm	Groundwater discharge rate, ft^3/day, Q_T	Total volume occupied by plume, ft^3, PV_T
0.39	75.00	4,375,000

Discharge rate, Unit 1 ft^3/day, Q_1	Discharge rate, Unit 2 ft^3/day, Q_2	Discharge rate, Unit 3 ft^3/day, Q_3	Plume pore Vol., Unit 1 ft^3, PV_1	Plume pore Vol., Unit 2 ft^3, PV_2	Plume pore Vol., Unit 3 ft^3, PV_3	Time for 1 PV flush, Unit 1, days, t_1	Time for 1 PV flush, Unit 2, days, t_2	Time for 1 PV flush, Unit 3, days, t_3
24.98	25.03	24.98	145687.5	146125	145687.5	5831.28	5837.12	5831.28

Contaminant Half-Life Data

Does contaminant have a decay half-life (yes/no):	yes	If yes, half-life (days):	7300
1st order decay coefficient (k):	0.000095		

Average Pumped/Discharged and Residual Plume Concentrations Over Time

Target Cleanup Concentration :		0.5	ug/L	
Time period	Time span, days, t	Avg pumped GW conc.	Avg residual GW conc.	Time span, years
0	0	0	**100**	0
0.1	583.13	90.507	**90.507**	1.60
0.15	874.69	86.104	**86.104**	2.39
0.2	1166.26	81.915	**81.915**	3.19
0.3	1749.39	74.139	**74.139**	4.79
0.4	2332.51	67.101	**67.101**	6.39
0.5	2915.64	60.731	**60.731**	7.98
0.7	4081.90	49.747	**49.747**	11.18
0.9	5248.16	40.751	**40.751**	14.37
1.2	6997.54	30.212	**30.212**	19.16
1.5	8746.93	22.399	**22.399**	23.95
1.8	10496.31	16.606	**16.606**	28.74
2.1	12245.70	12.312	**12.312**	33.53
2.5	14578.21	8.261	**8.261**	39.91
3	17493.85	5.017	**5.017**	47.90
3.5	20409.50	3.047	**3.047**	55.88
4	23325.14	1.850	**1.850**	63.86
5	29156.42	0.682	**0.682**	79.83
6	34987.71	0.252	**0.252**	95.79
8	46650.28	0.034	**0.034**	127.72
10	58312.85	0.005	**0.005**	159.65
5.2	30322.68	0.559	**0.559**	83.02
5.3	30905.81	0.506	**0.506**	84.62
5.31	30964.12	0.501	**0.501**	84.78
5.32	31022.44	0.496	**0.496**	84.93
5.33	31080.75	0.491	**0.491**	85.09

Adjust the initial time period to auto-adjust the following 19 time periods and obtain the desired range in concentrations.

The last 5 time periods can be modified to more precisely determine the time required to meet a specific residual concentration.

Natural GW flow rate = W * P_T * Hydr-c_{avg} * i * (7.48 gal/ft^3)/[(24 hrs/day) * (60 min/hr)]
Natural GW flow rate through the plume area = 0.39 gpm,
Calculated time estimate for RDX to naturally attenuate = 85 years

Based on the conditions calculated above, the projected time for RDX in the plume area to naturally attenuate is approximately 85 years. However, because of uncertainties in site geology, hydrogeology, contaminant source, and contaminant behaviour in the plume area, a suitable safety factor should be included in the estimate. Based on the degree of confidence in the site data, and best scientific judgement, the time for natural attenuation to reduce RDX to a cleanup goal of 0.5 ug/L is more conservatively estimated to be 100 - 150 years.

Time conservatively estimated for RDX to naturally attenuate = 100 - 150 years

Average RDX concentration in groundwater @ time T = $[Cw_{01} \times (M_S/M_T)_1^{1/1} \times FQ_1 + Cw_{02} \times (M_S/M_T)_2^{1/2} \times FQ_2 + Cw_{03} \times (M_S/M_T)_3^{1/3} \times FQ_3] \times 2.718^{-kt}$

where FQ_1, FQ_2, FQ_3 = Fraction of total flow per day from each groundwater flow unit.

Number of pore volumes (PVs) required to reach a target groundwater concentration Cw_x: PVs = log (Cw_x/Cw_0) / log (M_S/M_T), for each groundwater flow unit

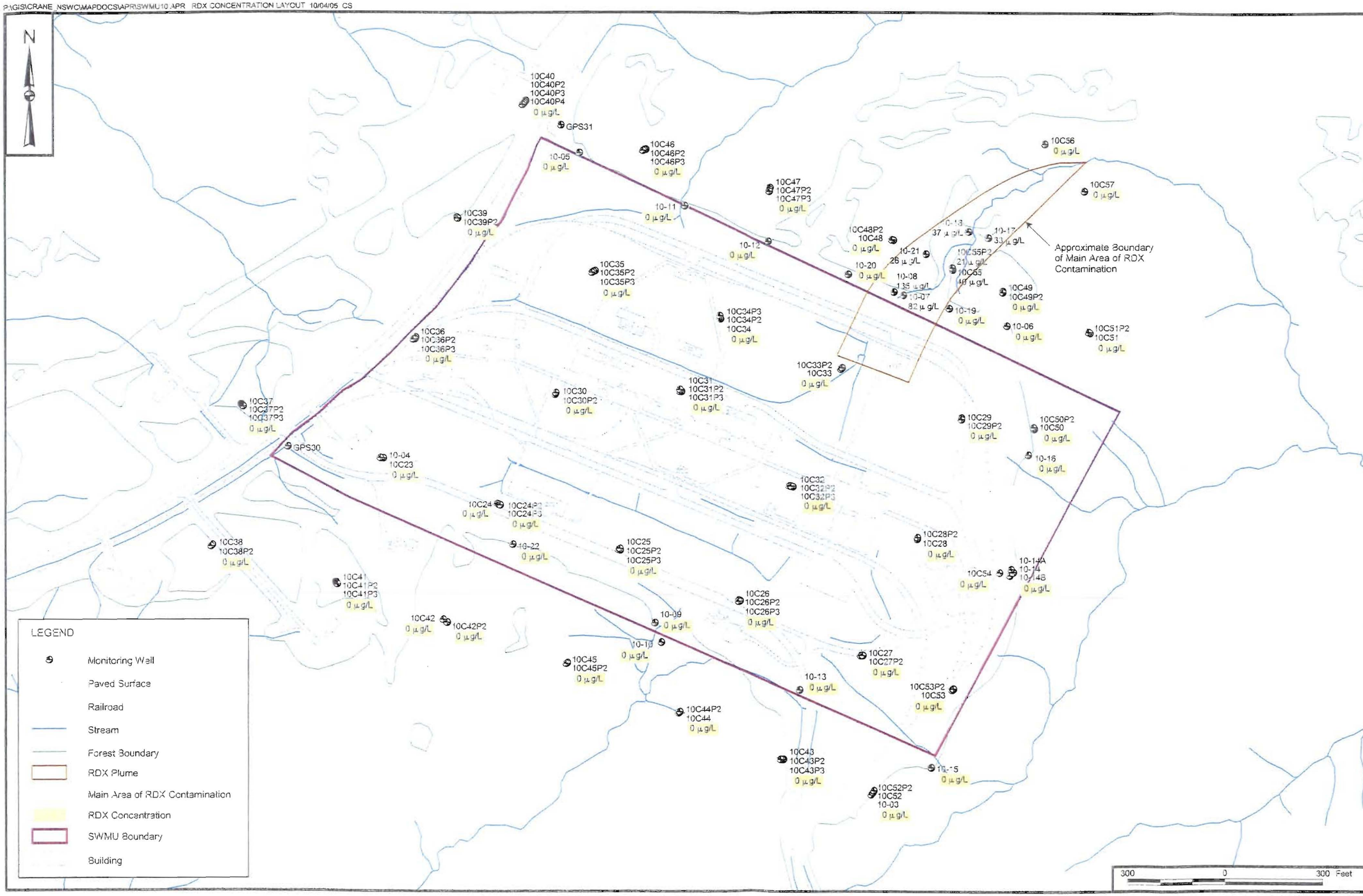
Contaminant Partitioning Formulas :

M_W	=	$C_W \times n$
C_S	=	$K_{OC} \times f_{OC} \times C_W$, or, $K_d \times C_W$
K_d	=	$K_{OC} \times f_{OC}$, or, C_S/C_W
M_S	=	$S_G \times (1-n) \times C_S$
M_T	=	$M_W + M_S$
Cw_x	=	$[Cw_i](M_S/M_T)^x$

where:

Cw_i	=	initial contaminant concentration in groundwater
n	=	aquifer porosity
S_G	=	specific gravity of aquifer solids (default value = 2.65)
M_W	=	mass of contaminants per unit volume of aquifer water
C_S	=	contaminant concentration on aquifer solids
Cw_x	=	Pore water concentration after x number of pore volume exchanges
M_S	=	mass of contaminants per unit volume of aquifer solids
M_T	=	total mass of contaminants per unit volume of aquifer
K_{OC}	=	organic carbon partition coefficient
f_{OC}	=	fractional organic carbon content of solids
K_c	=	soil/water distribution coefficient

P:\GIS\CRANE_NSWC\MAPDOCS\APR\SWMU10.APR RDX CONCENTRATION LAYOUT 10/04/05 CS



CONTRACT NO. N4267

APPROVED BY ___ DATE ___

APPROVED BY ___ DATE ___

DRAWING NO. FIGURE A - 1

REV 0

RDX CONCENTRATION
CMS REPORT FOR SWMU 10 - ROCKEYE
NSWC CRANE
CRANE, INDIANA

NAVFAC

DRAWN BY C. FOSTER DATE 11/11/04

CHECKED BY V. PLACHY DATE 11/29/04

COST/SCHED-AREA

SCALE AS NOTED

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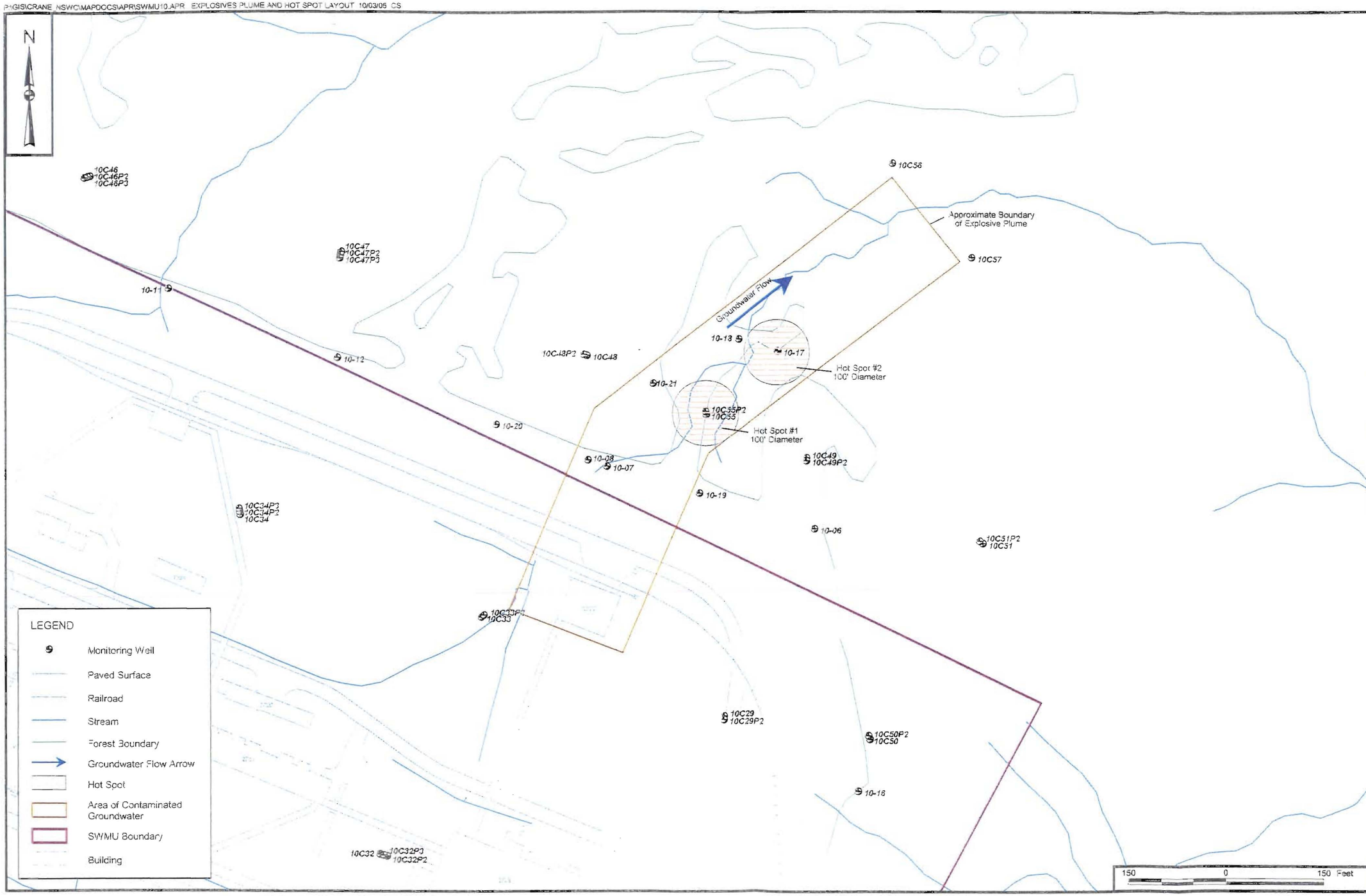


CONTRACT NO. N4267

APPROVED BY — DATE

APPROVED BY — DATE

DRAWING NO. FIGURE A - 2

REV 0

SWMU 10 EXPLOSIVES PLUME AND "HOT SPOTS"
CMS REPORT FOR SWMU 10 - ROCKEYE
NSWC CRANE
CRANE, INDIANA

NAVFAC

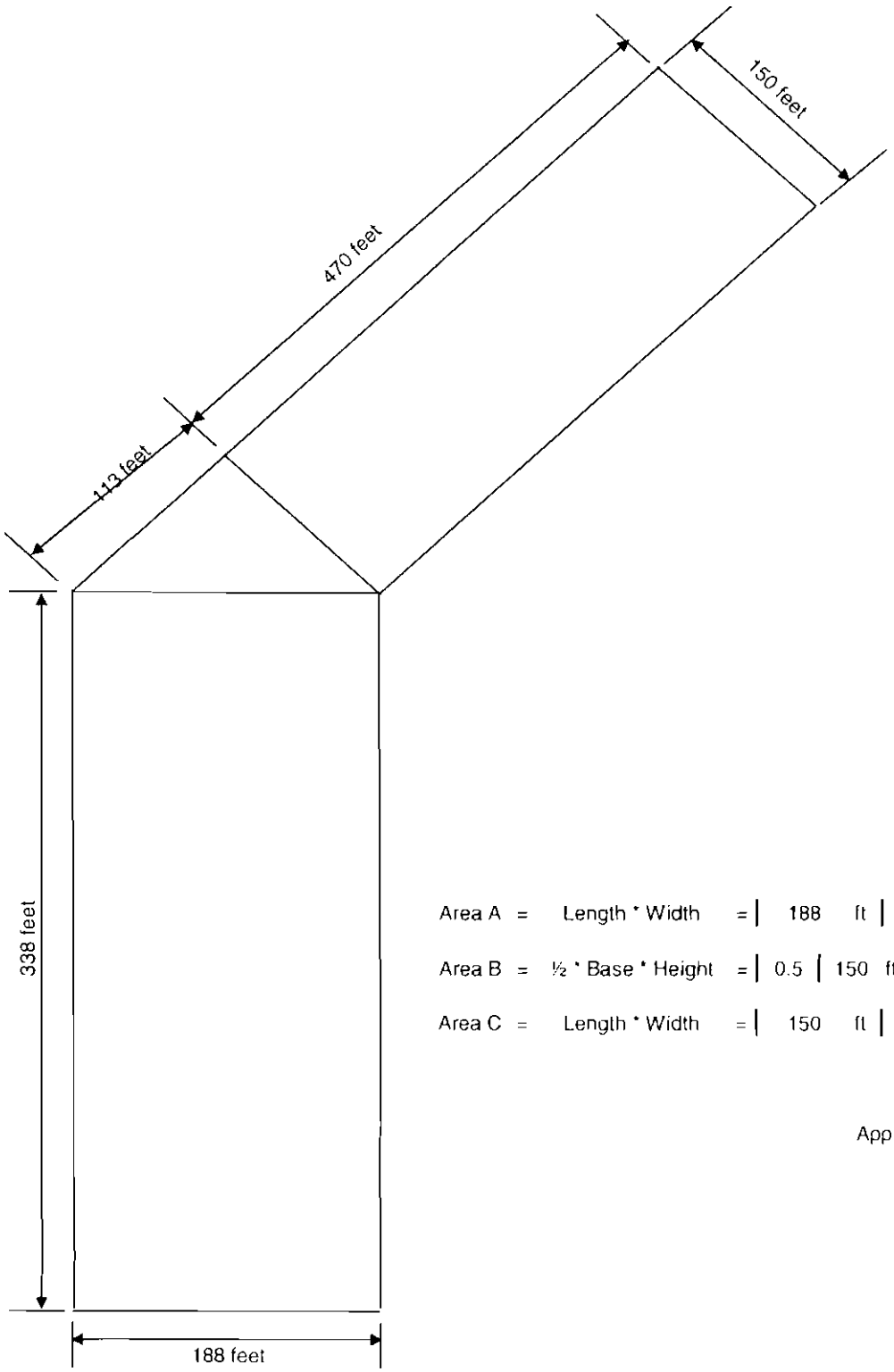
DRAWN BY C. FOSTER — DATE 02/25/05

CHECKED BY V. PLACHY — DATE 02/25/05

COST/SCHED-AREA

SCALE AS NOTED

FIGURE A-3
AREA CALCULATIONS FOR RDX-CONTAMINATED GROUNDWATER
CMS REPORT FOR SWMU 10 - ROCKEYE
NSWC CRANE
CRANE, INDIANA



Area A	=	Length * Width	=	188	ft	338	ft	=	63,544	ft^2
Area B	=	½ * Base * Height	=	0.5	150 ft	113	ft	=	8,475	ft^2
Area C	=	Length * Width	=	150	ft	470	ft	=	70,500	ft^2
							Total Area	=	142,519	ft^2
							Approxmimately	≅	150,000	ft^2