1. INTRODUCTION

This report delineates the risk-based end state (RBES) vision for the Paducah Gaseous Diffusion Plant (PGDP) located in Paducah, Kentucky. It was prepared following the guidance contained in *Guidance for Developing Site-specific Risk-based End State Vision*, dated September 11, 2003, (DOE 2003a) and DOE Policy, DOE P 455.1, *Use of Risk-based End States* (DOE 2003b) as amended by clarification contained in a memorandum entitled "Risk Based End State Guidance Clarification" dated Dec. 23, 2003 (DOE 2003c). Once finalized, this report will provide information that can be used to establish clearly articulated and technically achievable cleanup goals for PGDP; serve as the primary tool for communicating the RBES for PGDP to the involved parties (i.e., stakeholders from the U.S. Department of Energy [DOE], the U.S. Environmental Protection Agency [EPA], the Commonwealth of Kentucky, and the public); and, using maps and figures, summarize the PGDP RBES so that any cleanup decisions made can be compared to the RBES and so that the variances between the RBES and the current PGDP cleanup strategy can be identified.

Objectives of the RBES Document

- Provide information to be used to establish clearly articulated and technically achievable cleanup goals.
- Present maps and figures that can be used ensure that cleanup decisions are consistent with the RBES.
- Provide a tool for communicating the RBES for PGDP to the involved parties.
- Summarize the PGDP RBES so that variance between it and the current cleanup strategy can be identified.

The RBES developed in this report will be used to establish clearly articulated and technically achievable goals that will be the focus of the continuing cleanup of PGDP. Using the RBES in this manner is consistent with the *Top to Bottom Review of the EM Program* (DOE 2002a), which recommended moving DOE's Environmental Management (EM) program to an accelerated, risk-based cleanup strategy and aligning the EM program so that its scope is consistent with an accelerated, risk-based cleanup and closure mission.

The RBES presented here is driven by the current and expected future land use for areas at and around PGDP and the exposures that may occur to receptors in these areas. The future land use presented is consistent with that established in several meetings held among the involved parties since the beginning of site cleanup. These descriptions of current and future land use are consistent with that discussed in the fiscal year (FY) 2004 revision of *Site Management Plan, Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, (SMP) (DOE 2003d) and in other remedial investigation (RI) and feasibility study (FS) reports (e.g., DOE 2001a, 2002b, 2003e, and 2003f). It should be recognized that attainment of the RBES will take longer than the 20 years commonly used as a planning horizon by local zoning boards for community changes due to the location and persistence of some contaminants and the uncertainty about the continued operation of the operating gaseous diffusion plant (GDP). Therefore, it is possible that the land uses used in this report will differ in the future resulting in the need to modify the RBES.

The exposures considered in formulating the RBES were derived consistent with EPA's risk assessment guidance documents (e.g., EPA 1989a, 1996a, and 2000a) and PGDP's risk methods document (DOE 2000). These exposures, which are documented in a series of conceptual site models (CSMs) in Chap. 4 of this report, are based on realistic scenarios that consider reasonable pathways of exposure, rational timeframes, and expected receptor populations.

The RBES report contains two important comparisons. These are a comparison between the current state and the RBES and a comparison between the RBES and the current cleanup baseline end state. (The current cleanup baseline end state or current planned end state is the state the site would achieve upon

executing the actions proposed in PGDP's current agreements and other planning documents.) The first of these comparisons is used to depict the risk reduction that would be achieved at the RBES. The second of these comparisons is used to identify variances between the RBES and current planned end state.

Although potential actions to address site problems are identified in the RBES report, this report is not a decision document. Once the RBES vision is developed, DOE will further evaluate the cleanup activities and the strategic approaches at PGDP to determine if it is appropriate to pursue changes in the PGDP baseline. Any decision to pursue changes to the baseline will include factors beyond those presented in the RBES report, including input from involved parties. If DOE ultimately decides to seek changes to the current compliance agreements, decisions, or statutory/regulatory requirements, then those changes will be made in accordance with applicable requirements and procedures.

1.1 ORGANIZATION OF THE REPORT

This report is presented in six chapters. Figure 1.1 is a diagram depicting the process used in the report's production. Chapter 1 presents some general information about the report, PGDP, and the status of cleanup at PGDP; Chaps. 2 through 4 present descriptions of the PGDP RBES in regional, site-specific, and hazard-specific contexts. Chapter 5 includes the variance report for the RBES and identifies any differences between the current cleanup baseline end state and the RBES. Finally, Chap. 6 includes the references used to prepare the report.

The information presented in Chaps. 2 through 4 consists primarily of a series of maps that depict the relationship between PGDP and its surroundings. These maps are intended to present and allow comparisons between current and future land use; depict hazards and risks to affected or potentially affected populations or receptors; serve as a planning tool for site management; facilitate communication of risks during discussions with stakeholders; allow tracking of expected and actual cleanup results; and serve as a communication tool for public meetings in regards to cleanup activities, current PGDP mission and requirements, and future land use. The maps follow a standardized hierarchical approach that depicts the PGDP RBES in regional, site, and hazard-specific contexts. The regional context maps are presented in Chap. 2. These maps show the relationship of PGDP to the surrounding region (i.e., surrounding counties) and include information about major watersheds (e.g., the Ohio River watershed), population centers, and other significant regional features. The site context maps are presented in Chap. 3. These maps depict the area immediately adjacent to PGDP, as well as the land inside the PGDP property boundaries. Finally, the hazard-specific context maps are presented in Chap. 4. These maps contain the greatest detail and depict the hazard areas (e.g., disposal cells, landfills, underground plumes, and burial grounds) at PGDP that pose potential hazards to human health and the environment. These hazard-specific context maps are presented in concert with a series of CSMs that depict how receptors are or may be exposed to contamination both currently and when the RBES for PGDP is attained.

Variances between the RBES and the current cleanup baseline end state (i.e., current planned end state) are presented in Chap. 5. These variances were identified through discussions with the involved parties, including regulators. In addition to narrative, the variances are depicted using a series of maps and CSMs that allow for comparisons between the RBES and the current planned end state. The format of these maps and CSMs matches those found in Chap. 4.

In addition to identifying the variances in Chap. 5, the potential impacts of the variances, the barriers to achieving the RBES, and recommendations on how to resolve the barriers also are presented. This information is to be used by DOE to determine whether to pursue changes to the current baseline.

1.2 SITE MISSION

In October 2003, PGDP reached its 51st anniversary of operation. Although originally one of three uranium enrichment plants in the U.S., as of 2002, only PGDP was operating. Currently, the United States Enrichment Corporation (USEC) operates the uranium enrichment plant at PGDP. This corporation was established on October 24, 1992, when the President signed the Energy Policy Act of 1992. The charter of USEC under this act is to provide profitable and competitive uranium enrichment services. USEC has leased the gaseous diffusion uranium enrichment production facilities from DOE since July 1, 1993, but DOE has retained the non-leased facilities and is responsible for the decontamination and decommissioning (D&D) and cleanup for environmental conditions that existed before July 1, 1993. It is currently anticipated that USEC will continue to operate the gaseous diffusion uranium enrichment production facilities through at least 2010.

In addition to the enrichment mission, PGDP has both a uranium conversion mission and an environmental cleanup mission. The uranium conversion mission involves the construction and operation of a facility that will convert depleted uranium hexafluoride (DUF_6) to less reactive uranium oxides. The contract to construct this facility was recently awarded and construction is expected to begin in 2004. Currently, it is anticipated that the conversion facility will operate for two or three decades.

The current DOE-EM cleanup mission at PGDP includes work under the Federal Facility Agreement (FFA), as well as some work outside of the FFA. The current portion of the cleanup mission under the FFA is to investigate and address existing environmental contamination and to D&D those facilities currently leased to USEC once the gaseous diffusion plant (GDP) ceases operation. The scope of these activities through 2019 is delineated in the FY 2004 SMP (DOE 2003d). This scope, which reflects investigation and cleanup of areas not impacted by the operating GDP, is to complete the following five strategic initiatives.

1) Groundwater Operable Unit (GWOU) Strategic Initiative – This strategic initiative includes investigation, baseline risk assessment (BRA), evaluation of removal/remedial actions, and selection and implementation of actions necessary to achieve protection of human health from exposure to groundwater contamination that could result in unacceptable risk. The projects associated with implementation of this strategy are those for the C-400 Building and other sources to the three major solvent plumes at PGDP (e.g., the C-747-C Oil Landfarm, C-749 Uranium Burial Ground, and C-747 Contaminated Burial Yard); the Northwest and Northeast Plumes; the Southwest Plume; and the C-746-S and T Landfills. The completion date for this initiative is 2010.

2) Surface Water OU (SWOU) Strategic Initiative – This strategic initiative includes the investigation, BRA, evaluation of removal/remedial actions, and selection and implementation of actions necessary to achieve protection of human health and the environment from exposure to contamination in "hot spots" associated with the following areas: internal plant ditches; outfall ditches; and Sections 3, 4, and 5 of the North-South Diversion Ditch (NSDD). In addition, the initiative includes evaluation of the need for additional sediment-control measures at PGDP and evaluation and potential implementation of actions for legacy releases associated with the PGDP storm sewer system and Bayou and Little Bayou Creeks. The completion date for this initiative is 2017.

3) Burial Grounds OU (BGOU) Strategic Initiative – This strategic initiative includes investigation, BRA, evaluation of remedial alternatives, and selection and implementation of actions necessary to protect human health and the environment from exposure to contamination found at eight burial grounds and additional disposal areas that might exist beneath scrapyards. The completion date for this initiative is 2019.

4) D&D OU Strategic Initiative – This strategic initiative includes a phased investigation and evaluation and implementation of removal actions for two major inactive process facilities and 15 smaller inactive facilities. The completion date for this initiative is 2017. This initiative does not include the D&D of the GDP facilities currently leased to USEC. These facilities will undergo D&D after the GDP ceases operation.

5) Surface Soils OU (SSOU) Strategic Initiative – This strategic initiative includes the investigation, BRA, evaluation of removal alternatives, and selection and implementation of actions necessary to achieve protection of human health and the environment from exposure to contamination in "hot spots" associated with soils underlying scrapyards, outside DOE Material Storage Areas (DMSAs), and plant areas not impacted by either the uranium enrichment or conversion missions. The completion date for this initiative is 2017.

In addition to actions related to the five strategic initiatives discussed above, the FFA portion of the DOE-EM mission includes cleanup of areas impacted by the uranium enrichment and conversion missions. The scope of this cleanup will include D&D of the GDP followed by the Comprehensive Site OU (CSOU). The CSOU will include the investigation, BRA, evaluation of remedial alternatives, and selection and implementation of actions necessary to achieve protection of human health and the environment. While the planning associated with the scope of the CSOU will begin six months before GPD shutdown, the RBES and current planned end state to be achieved by the CSOU is discussed in this report. The completion date for the CSOU is uncertain due to the lease status of the GDP.

The portions of the DOE-EM mission not included in the FFA include characterization and appropriate disposal of legacy waste and materials found in DMSAs and continuation of waste management. The scope of the legacy waste activities is to characterize, treat, and dispose of approximately 33,000 containers of DOE waste currently in storage at PGDP. The scope of the DMSA activities is to characterize, place in proper storage, treat, and dispose of excess materials found in 160 DMSAs.

The scope of the ongoing waste management activities is to characterize and properly disposition any newly generated waste and to operate the C-746-U Sanitary Landfill and other landfills, if any additional landfills are constructed during PGDP cleanup and GDP D&D. (The RBES does consider the potential construction of a Comprehensive Environmental Response, Compensation, and Liability Act [CERCLA] Cell to be used for on-site disposal of materials derived from D&D of the GDP.) Waste management's mission will continue until site cleanup is complete, including that portion of the cleanup that is under the CSOU.

1.3 STATUS OF CLEANUP PROGRAM

In response to the discovery of trichloroethene (TCE) and technetium-99 (^{99}Tc) in residential wells north of PGDP in 1988, DOE immediately provided a temporary alternate water supply to affected residences and sampled all surrounding residential wells. Following this initial response, DOE and EPA entered into an Administrative Consent Order (ACO) that required monitoring residential wells potentially affected by contamination, providing alternative drinking water to residents with contaminated wells, and investigating the nature and extent of off-site contamination.

The ACO activities delineated two off-site groundwater contamination plumes, referred to as the Northwest and Northeast Plumes; identified several potential on-site source areas requiring additional investigation; and resulted in several interim activities. Upon signature of the FFA in February 1998, the FFA parties declared the ACO requirements satisfied and terminated the ACO because the remaining cleanup would be continued under the authority of the FFA. A series of RI/FSs was conducted under the FFA, including completing the evaluation of all major contaminant sources impacting groundwater and surface water. In accordance with the ACO and FFA investigations, DOE implemented actions that focused

on reducing potential risks associated with off-site contamination. Examples of the significant actions initiated and completed to date include the following.

- Extended municipal water lines as a permanent source of drinking water to affected residents to eliminate exposure to contaminated groundwater (1995).
- Constructed and implemented groundwater treatment systems for both the Northwest and Northeast Plumes to reduce contaminant migration (1995 and 1997, respectively).
- Imposed institutional controls (fencing and posting) to restrict public access to contaminated areas in certain outfall ditches and surface water areas (1993).
- Constructed hard-piping to reroute surface runoff around highly contaminated portions of the NSDD to reduce potential migration of surface contamination (1995).
- Removed and disposed of "drum mountain," a contaminated scrap pile potentially contributing to surface water contamination to eliminate potential direct-contact risks to plant workers and reduce off-site migration (2000).
- Excavated soil with high concentrations of polychlorinated biphenyls (PCBs) in certain on-site areas to reduce off-site migration and potential direct-contact risks to plant workers (1998).
- Applied *in situ* treatment of TCE-contaminated soils at the cylinder drop test site using innovative technology (i.e., the LASAGNA™ technology) to eliminate a potential source of groundwater contamination (2002).
- Removed petroleum-contaminated soil from Solid Waste Management Unit (SWMU) 193 to eliminate a potential source of groundwater contamination (2002).
- Completed installation of a sediment control basin to control the potential migration of contamination during the scrap metal removal action and initiated removal and disposal of approximately 54,000 tons of scrap metal to eliminate potential direct contact risks to plant workers and a source of surface water contamination (2002).
- Completed hard-piping and initiated installation of a detection basin and excavation of the on-site portions of the NSDD, which will remove a source of potential direct-contact risk to plant workers and surface water contamination (2003).

Appendix 1 of the FY 2004 SMP (DOE 2003d) contains a summary of the status of all actions taken to date that have been documented through a Record of Decision (ROD) or Action Memorandum. More detailed information on the status of each OU is available in the FFA Semi-Annual Progress Report (DOE 2003g). In addition to the completed actions, DOE has an ongoing integrated environmental monitoring program that assesses contaminant effects and depicts trends in effects over time. Results from this program are reported in the Annual PGDP Environmental Reports (DOE 2002c).

The aforementioned response actions are steps in reducing site risks. While no known imminent threats currently exist, as verified by conclusions in the Agency for Toxic Substances and Disease Registry's Health Assessment (ATSDR 2002), and in a report from the Commonwealth of Kentucky entitled *Report of the Commonwealth of Kentucky's Task Force Examining State Regulatory Issues at the Paducah Gaseous Diffusion Plant* (KY 2000), several major challenges remain at PGDP. These challenges, depicted in Fig. 1.2 and discussed in more detail in Chap. 4, include, in summary, legacy waste, DMSAs, PCBs and radionuclides in creeks and soils, off-site organic compound plumes, burial grounds, and on-site sources of groundwater contamination. Primary contaminants associated with these challenges are chlorinated solvents (primarily TCE and its breakdown products), PCBs, polynuclear aromatic hydrocarbon (PAHs) compounds, several metals (antimony, arsenic, cadmium, chromium, and lead),

^{99}Tc, and uranium isotopes (^{234}U, ^{235}U, and ^{238}U). A complete list of the significant contaminants of potential concern at PGDP taken from completed BRAs is in Table 1.1.

Table 1.1. Significant contaminants of potential concern at PGDP[a]

Metals/Inorganic Chemicals	Organic Compounds	Radionuclides
Antimony	Acrylonitrile	Americium-241
Arsenic	Benzene	Cesium-137
Beryllium	***Carbon tetrachloride***	Cobalt-60
Cadmium	***Chloroform***	Neptunium-237
Chromium III	***1,1-Dichloroethene***	Plutonium-238
Chromium VI	***1,2-Dichloroethene (mixed)***	Plutonium-239
Copper	***trans-1,2-Dichloroethene***	Plutonium-240
Iron	***cis-1,2-Dichloroethene***	Radium-226
Lead	Ethylbenzene	Radon-222
Manganese	Pyrene	Stontium-90
Mercury	Tetrachloroethene	***Technetium-99***
Molybdenum	***Trichloroethene***	Thorium-228
Nickel	Dioxins/Furans	Thorium-230
Selenium	***Polynuclear aromatic hydrocarbons***	Thorium-232
Silver	***Polychlorinated biphenyls***	***Uranium-234***
Thallium	***Vinyl chloride***	***Uranium-235***
Uranium	Xylenes	***Uranium-238***
Vanadium		
Zinc		

Primary contaminants associated with site challenges are highlighted in bold, italic font.

[a]This list of chemicals, compounds, and radionuclides was compiled from the results of baseline risk assessments performed at PGDP between 1990 and 2000 (e.g., DOE 1996a, 1996b, 1997a, 1998a, 1999a, 1999b, 2000b, 2000c, and 2001a).

1.4 GOAL OF PGDP CLEANUP STRATEGY

The goal of the PGDP cleanup strategy is to maximize the use of on- and off-site locations consistent with current and reasonably anticipated future use patterns. This end state goal was derived considering current and past land use, existing lease commitments, future missions at PGDP, the nature of site contamination, and input from involved parties.

To achieve the goal, specific site cleanup objectives were established. These objectives serve as the guiding principles used when developing more detailed remedial action objectives (RAOs) that focus on specific OU problems. The cleanup objectives were developed considering current and reasonable anticipated future land use, exposure pathways, and potentially affected receptors. These cleanup objectives are as follows:

Definition of Risk-Based End States

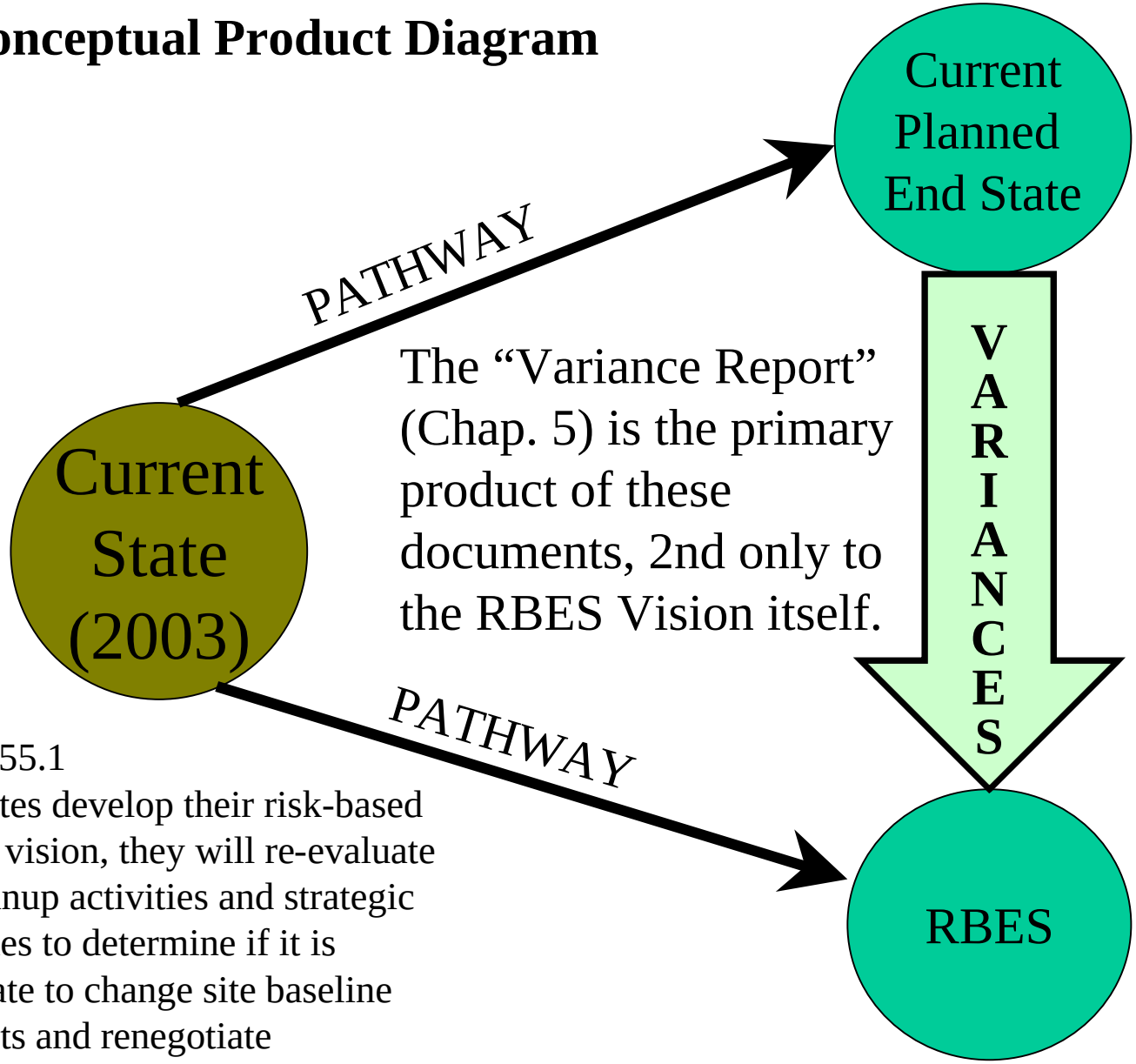
Risk-based end states are representations of site conditions and associated information that reflect the planned future use of the property and are appropriately protective of human health and the environment consistent with that use. They form the basis for the exposure scenarios developed in baseline risk assessments that help establish remediation levels (RLs) used to develop remedial alternatives in feasibility studies.

- Protect residential receptors from exposure to contaminated groundwater in areas off DOE property;
- Protect recreational users from exposure to contaminated surface water, sediments, and biota in areas outside the main PGDP security fence;

- Protect industrial workers from exposure to waste and contaminated soils and sediments in areas inside the security fence.

Under each of these objectives, protectiveness to human receptors is defined either in terms of chemical-specific applicable or relevant and appropriate requirements (ARARs) or in terms of calculated risk-based concentrations consistent with the National Contingency Plan (NCP) (i.e., the implementing regulations of CERCLA). The ARARs used are compiled as appropriate when response action decisions are made. The risk-based concentrations also are calculated when the response action decision is made and, for human health, are based on an excess upper-bound lifetime cancer risk between 10^{-6} and 10^{-4} for known or suspected carcinogens and a hazard index of 1 for systemic toxicants. For non-human receptors, the risk-based concentrations are estimates of concentrations of substances present in the environmental media that will protect ecological receptors at the site (DOE 2000a).

Conceptual Product Diagram



DOE P 455.1
"Once Sites develop their risk-based end state vision, they will re-evaluate their cleanup activities and strategic approaches to determine if it is appropriate to change site baseline documents and renegotiate agreements."

Fig. 1.1 Conceptual product diagram for the RBES report

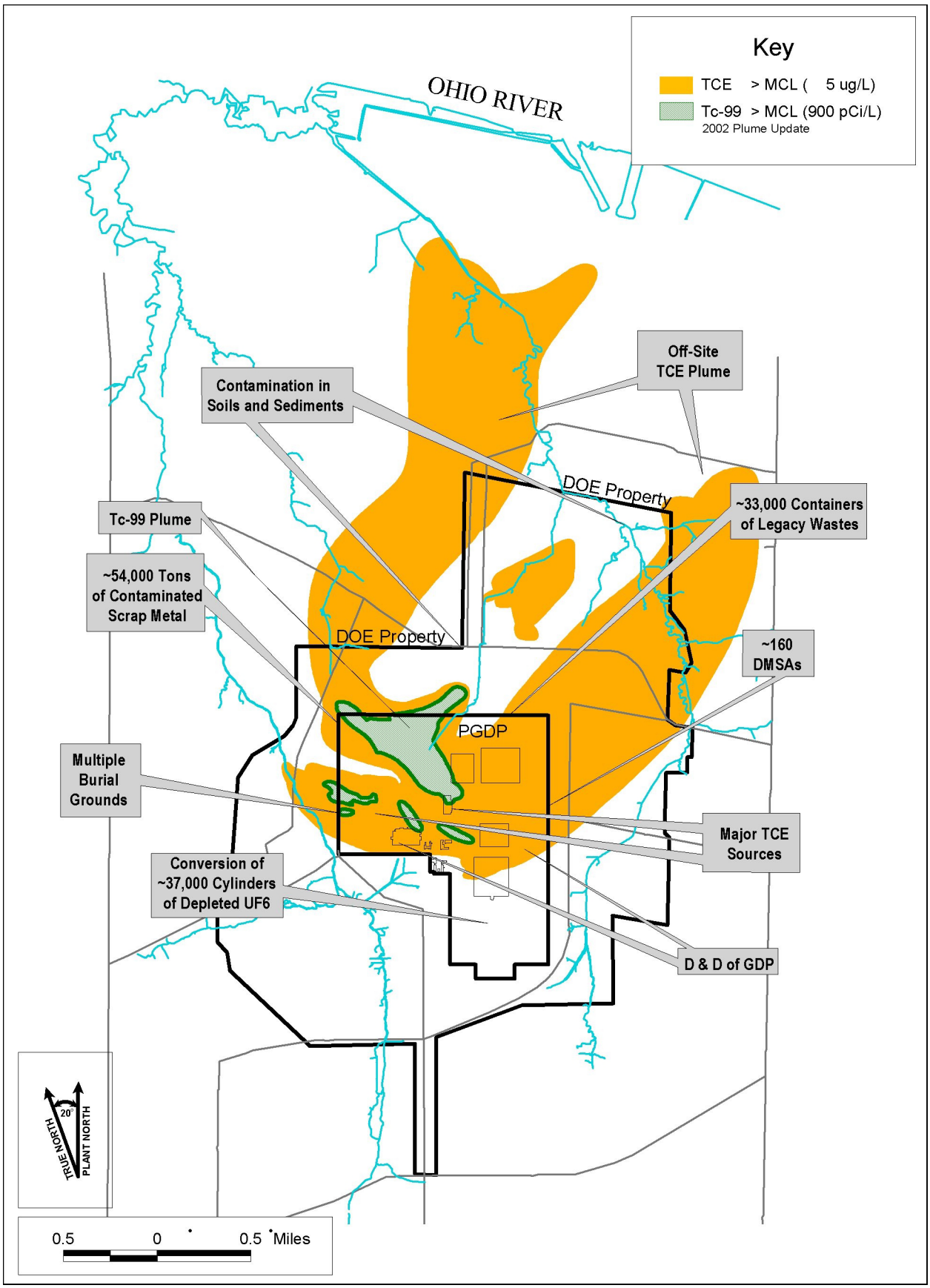


Fig. 1.2. Major cleanup challenges at the PGDP.