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# Rocky Flats Site
# Annual Report of Site Surveillance and Maintenance Activities Calendar Year 2006

April 2007

U.S. Department of Energy

Office of Legacy Management

*Work Performed Under DOE Contract No. DE–AC01–02GJ79491*
*for the U.S. Department of Energy Office of Legacy Management.*
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Work Performed by S.M. Stoller Corporation under DOE Contract No. DE–AC01–02GJ79491
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Appendix E Chains of Custody for Present Landfill and Original Landfill Water Monitoring Locations

2006 Ecology Data for the Rocky Flats Site

End of current text

# Acronyms

| | |
|---|---|
| ac-ft | acre-feet |
| Ag | silver |
| ALF | Action Level Framework |
| Am | americium |
| ANOVA | Analysis of Variance |
| AOC | Area of Concern |
| AOI | analyte of interest |
| As | arsenic |
| Ba | barium |
| Be | beryllium |
| Bo | boron |
| BZ | Buffer Zone |
| CAD | Corrective Action Decision |
| Cd | cadmium |
| CDPHE | Colorado Department of Public Health and Environment |
| CERCLA | Comprehensive Environmental Response, Compensation & Liability Act – "Superfund" |
| CFR | *Code of Federal Regulations* |
| cfs | cubic feet per second |
| CNHP | Colorado Natural Heritage Program |
| COU | Central Operable Unit |
| Cr | chromium |
| CY | calendar year |
| D&D | decontamination and decommissioning |
| DCA | dichloroethane |
| DCE | dichloroethene |
| DER | Duplicate Error Ratio−calculated for real/duplicate radionuclide analyses |
| DOE | U.S. Department of Energy |
| DQA | data quality assessment |
| DQO | data quality objective |
| EPA | U.S. Environmental Protection Agency |
| ERP | *Emergency Response Plan for Rocky Flats Site Dams* |
| ESL | Environmental Sciences Laboratory |
| ETPTS | East Trenches Plume Treatment System |
| FC | Functional Channel |
| FY | fiscal year |
| g | gram |
| GIS | Geographic Information System |
| GPS | Global Positioning Systems |
| GWIS | ground water intercept system |
| HR ICP/MS | high resolution inductively-coupled plasma/mass spectrometry |
| HRC | Hydrogen Release Compound® |
| IA | Industrial Area |
| IDLH | Imminent Danger to Life and Health |
| IHSS | Individual Hazardous Substance Site |
| IMP | Integrated Monitoring Plan |

| | |
|---|---|
| IRA | Interim Remedial Action |
| ITS | Interceptor Trench System |
| K-H | Kaiser-Hill Company, LLC |
| LANL | Los Alamos National Laboratory |
| LCS | laboratory control sample |
| LM | Office of Legacy Management |
| $m^3$ | cubic meter |
| MDA | minimum detectable activity |
| MDL | method detection limit |
| µg/L | micrograms per liter |
| mg/L | milligrams per liter |
| ml | milliliter |
| Mn | manganese |
| mrem | millirem |
| MS | matrix spike |
| MSD | matrix spike duplicate |
| MSPTS | Mound Site Plume Treatment System |
| NA | not applicable |
| NSQ | Non-Sufficient Quantity |
| OBP | Oil Burn Pit |
| OLF | Original Landfill |
| OU | Operable Unit |
| PA | Protected Area |
| PARCC | precision, accuracy, representativeness, completeness, and comparability |
| PCE | tetrachloroethene |
| pCi/g | picocuries per gram |
| pCi/L | picocuries per liter |
| PLF | Present Landfill |
| PLFTS | Present Landfill Treatment System |
| POC | Point of Compliance |
| POE | Point of Evaluation |
| POU | Peripheral Operable Unit |
| ppb | parts per billion |
| Pu | plutonium |
| PU&D | Property Utilization and Disposal |
| QA | quality assurance |
| QC | quality control |
| RAO | Remedial Action Objective |
| RCRA | Resource Conservation and Recovery Act |
| RFCA | Rocky Flats Cleanup Agreement |
| RFETS | Rocky Flats Environmental Technology Site |
| RFLMA | *Rocky Flats Legacy Management Agreement* |
| RFP | Rocky Flats Plant |
| RFPO | Rocky Flats Project Office |
| RFS | Rocky Flats Site |
| RI/FS | Remedial Investigation/Feasibility Study |
| RMA | Rocky Mountain Arsenal |
| RMRS | Rocky Mountain Remediation Services |

| | |
|---|---|
| ROD | Record of Decision |
| RPD | relative percent difference |
| Se | selenium |
| SEEPro | Site Environmental Evaluation for Projects |
| SEP | Solar Evaporation Pond |
| SID | South Interceptor Ditch |
| S-K | Seasonal-Kendall |
| SOP | standard operating procedure |
| SPP | Solar Ponds Plume |
| SPPTS | Solar Ponds Plume Treatment System |
| SVOC | semivolatile organic compound |
| SWD | Soil and Water Database |
| TCE | trichloroethene |
| TIMS | thermal ionization mass spectrometry |
| Tl | thallium |
| TPU | Total Propagated Uncertainty |
| TSS | total suspended solids |
| U | uranium |
| UHSU | upper hydrostratigraphic unit |
| USFWS | U.S. Fish and Wildlife Services |
| V&V | validation and verification |
| VOC | volatile organic compound |
| WQP | Water Quality Parameter |
| WWTP | former Waste Water Treatment Plant |
| ZVI | zero-valent iron |

End of current text

# Executive Summary

This report covers the calendar year of 2006 (January 1 through December 31). The U.S. Department of Energy (DOE) Office of Legacy Management (LM) is responsible to implement the final response action selected in the Final Corrective Action Decision/Record of Decision (CAD/ROD) issued September 29, 2006, for the Rocky Flats Site (RFS). Prior to the CAD/ROD, cleanup and closure activities in accordance with the requirements of the Rocky Flats Cleanup Agreement (RFCA) were completed by the DOE Office of Environmental Management.

Under the CAD/ROD, two Operable Units (OUs) were established within the boundaries of the Rocky Flats property: the Peripheral OU (POU) and the Central OU (COU). The COU consolidates all areas of the site that require additional remedial/corrective actions, while also considering practicalities of future land management. The POU includes the remaining, generally unimpacted portions of the site, and surrounds the COU. The response action in the final CAD/ROD is no action for the POU, and institutional and physical controls with continued monitoring for the COU.

The Rocky Flats Legacy Management Agreement (RFLMA) will supersede RFCA. The purpose of RFLMA is to establish the regulatory framework for implementing the CAD/ROD final response action and ensuring that it remains protective of human health and the environment. As of December 31, 2006, the Draft RFLMA was issued for public review and comment prior to regulatory approval, but this report assumes the activities covered under this report will not significantly change in the final RFLMA.

Therefore, this report includes the results of surveillance and maintenance activities conducted under RFCA and subsequently conducted under the CAD/ROD and the Draft RFLMA. These surveillance and maintenance requirements include environmental monitoring; maintenance of the erosion controls, access controls (fences), landfill covers, dams, and ground water treatment systems; and operation of the ground water treatment systems.

This report includes all data evaluation as required by the 2006 RFCA Integrated Monitoring Plan, which underwent revision during this period (DOE 2006c, 2006d). For water monitoring, data evaluation is limited to those locations that remained after the CAD/ROD as part of the LM water-monitoring network.

Highlights of the monitoring, surveillance, and maintenance activities are as follows:

- Surface water flow volumes show expected reductions resulting from land configuration changes and removal of impervious surfaces. Surface water hydrologic data are summarized in Section 2.2.
- Surface-water monitoring at the Present Landfill Treatment System showed several analytes as periodically above applicable standards. These events have been discussed with the regulators and documented in contact records (Section 2.8).
- Point of Evaluation (POE) location GS10 continued to show reportable values for total uranium. Evaluation has suggested that these reportable values are a due to changes in hydrologic conditions resulting in ground water with naturally occurring uranium making up a larger proportion of streamflow at GS10. All other POEs and all other analytes at GS10 showed acceptable water quality for the entire year (Section 2.9).

- All surface-water Points of Compliance showed acceptable water quality for the entire year (Section 2.10).
- All other surface-water monitoring showed acceptable water quality (various subsections in Section 2).
- Ground water quality and flow at the RFS was generally consistent with previous years. Ground water contaminant plumes and ground water flow conditions are discussed in Section 3.
- Three of the four ground water treatment systems at the RFS underwent more intensive maintenance in 2006, including installation of automated instrumentation at the East Trenches Plume Treatment System and the Mound Site Plume Treatment System, media replacement at the Mound Site Plume Treatment System, and plumbing repairs at the Solar Ponds Plume Treatment System. These activities restored water treatment at the Mound and Solar Ponds systems, and allow enhanced maintenance and system performance at the Mound and East Trenches systems. Section 3 addresses these activities and water quality at the systems.
- The annual data quality assessment showed that the Site continues to collect high quality data sufficient for decision making (Section 4).
- Air quality monitoring was consistent with previous years and continued to show low emissions (Section 5).
- All required ecological data collection, analysis, and reporting was completed as scheduled (Section 6).
- Section 7 includes descriptions of Site operations and maintenance including inspections, issue resolution, facility upgrades, special projects, and significant events.

# 1.0 Introduction

As of the issuance of this report, the U.S. Department of Energy (DOE) Office of Legacy Management (LM) is responsible to implement the final response action selected in the Final Corrective Action Decision/Record of Decision (CAD/ROD) (EPA 2006) issued September 29, 2006, for the Rocky Flats Site. Prior to the CAD/ROD, cleanup and closure activities in accordance with the requirements of the Rocky Flats Cleanup Agreement (RFCA) (CDPHE et al. 1996) were completed by the DOE Office of Environmental Management. This report describes environmental monitoring, maintenance, and associated operations that were conducted during the period January 1 through December 31, 2006 (CY 2006).

Under the CAD/ROD, two Operable Units (OUs) were established within the boundaries of the Rocky Flats property: the Peripheral OU (POU) and the Central OU (COU). The COU consolidates all areas of the site that require additional remedial/corrective actions, while also considering practicalities of future land management. The POU includes the remaining, generally unimpacted portions of the site, and surrounds the COU. The response action in the final CAD/ROD is no action for the POU, and institutional and physical controls with continued monitoring for the COU.

The *Rocky Flats Legacy Management Agreement* (RFLMA) will supersede RFCA. The purpose of RFLMA is to establish the regulatory framework for implementing the CAD/ROD final response action and ensuring that it remains protective of human health and the environment. As of December 31, 2006, the Draft RFLMA was issued for public review and comment prior to regulatory approval, but this report assumes the activities covered under this report will not significantly change in the final RFLMA.[1]

Therefore, this report includes the results of surveillance, including water monitoring, and maintenance activities conducted under RFCA and subsequently conducted under the CAD/ROD and the Draft RFLMA. These surveillance and maintenance requirements include environmental monitoring; maintenance of the erosion controls, access controls (fences), landfill covers, dams, and ground water treatment systems; and operation of the ground water treatment systems.

This report includes all data evaluation as required by the 2006 RFCA Integrated Monitoring Plan (IMP), which underwent revision during this period (DOE 2006c, 2006d). For water monitoring, data evaluation is limited to those locations that remained after the CAD/ROD as part of the LM water-monitoring network. RFLMA requirements will replace the RFCA IMP.

## 1.1 Purpose and Scope

The purpose of this report is to inform the regulatory agencies and stakeholders regarding specified surveillance and maintenance activities being conducted at the Site, as required by RFCA and the CAD/ROD. DOE-LM is committed to periodic communications such as this report and through other means such as web-based tools and public meetings.

[1] RFLMA became effective March 14, 2007, and superseded RFCA. The monitoring, surveillance and maintenance activities for which quarterly, annual and 5 year review reports are issued are included in RFLMA Attachment 2, Legacy Management Requirements. These activities did not change from the draft to the final RFLMA.

Maintenance activities performed by LM in the fourth quarter of 2006 and routine monitoring performed during all of calendar year (CY) 2006 are addressed. This document also includes the fourth quarter of CY 2006 water-quality data (Appendix B.6) and evaluation, in lieu of a separate Fourth Quarter CY 2006 Report.

## 1.2 Background

Environmental monitoring during CY 2006 was conducted following the 2006 IMP (DOE 2006c, 2006d). Surveillance and maintenance activities in CY 2006 were conducted to meet the requirements of RFCA, including the IMP and requirements of RFCA accelerated action decision documents as further described in this Report. Surveillance and maintenance activities, including environmental monitoring, conducted in future periods will be performed according to the RFLMA (DOE 2007b).

# 2.0 Surface Water Monitoring

## 2.1 Introduction

This report presents the data collected to satisfy selected surface water monitoring objectives implemented at Rocky Flats in accordance with the RFCA (CDPHE et al. 1996) the fiscal year (FY) 2005 IMP Summary and Background Documents (Revision 1; K-H 2005d, 2005e), and the 2006 IMP Summary and Background Documents (DOE 2006c, 2006d). The IMP provides a framework for monitoring in support of closure activities at the Site. This framework includes implementation of a high-resolution surface water monitoring program that supports data-driven decisions determined by the IMP Data Quality Objectives (DQO) process. The surface water monitoring program provides:

- Detection of contaminants at Points of Compliance (POCs) in comparison to RFCA Standards in flows entering Stream Segment 4 and at the Site boundary;
- Detection of contaminants at Points of Evaluation (POEs) in comparison to RFCA Action Levels in flows entering Stream Segment 5 and the Site ponds;
- Monitoring of flows and contaminant levels in subdrainages upstream of POCs and POEs to facilitate the identification of contaminant sources;
- Monitoring to determine the short- and long-term effectiveness of the Present Landfill (PLF) and Original Landfill (OLF) remedies as related to surface water;
- Monitoring to confirm the proper functioning of the ground water treatment systems as related to surface water;
- Monitoring of indicator parameter values at various locations to determine correlations between indicator parameters and analytical water-quality measurements;
- Monitoring of nitrate in flows leaving the Site boundary;
- Monitoring of various surface water parameters at various locations on an ad hoc basis in support of special projects; and
- Monitoring for the safe and effective operation of the Site ponds.

This report provides a comprehensive and detailed summary of the surface water monitoring conducted at the Site, which fulfills the applicable requirements of the Site IMP. As such, this report is organized to follow the framework of the IMP, with each report section providing the objective-specific data evaluations. The 2006 IMP dictates the monitoring and data evaluation reported herein; the 2007 Annual Report will comply with RFLMA.

This report includes all data collected during CY 2006 for locations that remain after Closure as part of the DOE-LM surface water monitoring program. This surface water section includes:

- A description of the Site automated surface water monitoring program and monitoring network;
- A presentation of discharge and precipitation data summary statistics;
- A summary of selected analytical water-quality results;
- A loading analysis for radionuclides at POEs and POCs;

- Evaluations of analytical results as required by the Site IMP, organized by monitoring objective; and
- An appendix (CD-ROM) with hydrologic and water quality data.

### 2.1.1 Surface Water Monitoring Highlights: CY 2006

During CY 2006, the surface water monitoring network successfully fulfilled the targeted monitoring objectives as required by the Site IMP. During CY 2006, the network consisted of 15 gaging stations, 9 surface water grab sampling locations, 4 treatment system grab sampling locations, 8 precipitation gages, and 3 predischarge pond monitoring locations. During CY 2006, 139 samples composed of 2,898 individual grabs were collected at these locations.[2]

CY 2006 was significantly drier than average with approximately 9.18 inches of precipitation, which is 72 percent of average (12.78 inches; CY 1993−2005 average). The spring was significantly drier than average with March, April, and May being 36 percent of average. October was significantly wetter than average (226 percent of average), while April, May, and June were significantly drier than average (33 percent, 19 percent, and 40 percent of average, respectively). The largest events occurred on August 3, 2006 (0.82 inches), and July 9, 2006 (0.64 inches).[3] The largest 2-day total (1.42 inches) occurred on October 9−October 10, 2006. The highest peak flow rates for the year from the former Industrial Area (IA) were during the October 27, 2006, event (approximately 0.52 inches on wet soils following week of frequent precipitation). Peak flows for the year were 3.1 cubic feet per second (cfs) in North Walnut Creek (October 27, 2006) and 0.66 cfs in South Walnut Creek. The South Interceptor Ditch (SID) did not flow the entire year.

All water-quality data at the RFCA POCs were below the applicable standards during CY 2006. For the RFCA POEs, reportable values were observed at GS10 only (plutonium [Pu], americium [Am], and total uranium [U]). These reportable values for CY 2006 were addressed through multiple source evaluation letters from DOE to the regulators. These notifications are summarized in the 2006 Quarterly Reports (DOE 2006f, 2006g, 2007d).

### 2.1.2 Integrated Monitoring Plan for Surface Water

The Site surface water monitoring network is designed to meet the requirements documented in the Site IMP (DOE 2006c, 2006d), which groups all site surface water monitoring objectives into five primary categories: Site-Wide, IA (former), IA (former) Discharges to Ponds, Water Leaving the Site[4], and Off-Site. The seven IMP objectives evaluated in this report that are accomplished through surface water monitoring are described briefly below.[5] During CY 2006, the Site monitoring network included 15 gaging stations, 9 surface-water grab sampling

[2] Composite samples consist of multiple aliquotts ('grabs') of identical volume. Each grab is delivered by the automatic sampler to the composite container at each predetermined flow-volume or time interval.
[3] The precipitation gages used in the Automated Surface Water Monitoring Network are not heated due to the lack of AC power at the locations. As such, the gages do not accurately measure snowfall (as water equivalent).
[4] The 2006 IMP uses the term 'Site' as referring to the former RFETS area.
[5] The Imminent Danger to Life and Health (IDLH) decision rule (locations indicated in Table 2−1) requires the collection of hydrologic data to support the management of the Site ponds. This objective does not require any detailed data analysis. Therefore, this decision rule is not included in this report, however, hydrologic data are presented here for completeness.

locations, 4 treatment system grab sampling locations, 8 precipitation gages, and 3 predischarge pond monitoring locations to achieve these objectives. In some situations, a single location may serve multiple objectives. This report presents data evaluation only for those locations that were part of the monitoring network as of the end of CY 2006. Monitoring tasks and data collection, compilation, evaluation, and reporting for each objective included in this report are detailed in Sections 2.5 through 2.11. Figure 2–1 shows the monitoring network at the end of CY 2006.

The IMP used the DQO process to determine necessary and sufficient monitoring requirements. The process yielded multiple, data-driven, surface water monitoring objectives (called decision rules under the DQO process), a subset of which (seven) is presented in this report.

Four of the IMP automated surface water monitoring objectives are organized in a roughly upstream-to-downstream direction, beginning with performance monitoring and ending downstream at the POCs at Indiana Street (Figure 2–2). These monitoring objectives are summarized in the following paragraphs and are discussed in detail in Sections 2.8 through 2.11.

For the first of the upstream-to-downstream monitoring categories, the Site is required to evaluate surface water associated with individual accelerated actions within the COU. This performance monitoring (Section 2.8) is intended to evaluate surface water quality with respect to applicable surface-water standards.

For the next upstream-to-downstream monitoring category (Discharges to Ponds Objectives), the IMP requires the Site to identify and correct significant accidental or undetected releases of contaminants to the Site ponds. The POE (Section 2.9) objective monitors flows to the ponds at specific locations on North Walnut Creek, South Walnut Creek, and the SID. RFCA specifies POE monitoring for the upstream reaches of Site drainages (above the ponds) and specifies action levels for specific contaminants (Action Level Framework [ALF]).

The next category is Terminal Pond and Indiana Street Objectives. Predischarge monitoring (not evaluated in this report) is conducted in coordination with the State at the terminal ponds prior to planned discharges. The Site is also required to monitor at POC locations below the terminal ponds during discharges to subsequently compare analytical results to RFCA standards (Section 2.10). In addition, there are RFCA POCs that are located at Indiana Street for both Walnut and Woman Creeks. The Non-POC decision rule (Section 2.11) requires the Site to collect data for nitrate at the Walnut Creek POCs during pond discharges.

Some monitoring objectives do not fit into the upstream-to-downstream sequence and can be implemented at any location within the POU boundary.

For example, Imminent Danger to Life and Health monitoring provides information necessary for safe operation of the Site pond dams. This monitoring objective is not discussed in this document; however, the hydrologic data associated with this decision rule are presented in Section 2.2.

*Table 2−1. Matrix of Monitoring Locations and Supported IMP Decision Rules: CY 2006*

| | Supported Decision Rule | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Location Code** | **IDLH** | **Investigative** | **Ad Hoc** | **Indicator Parameter** | **Performance** | **POE** | **POC** | **Non-POC** | **Pre-discharge** | **Precip-itation** |
| GS01 | | | | ✓ | | | ✓ | | | ✓ |
| GS03 | | | | ✓ | | | ✓ | ✓ | | ✓ |
| GS05 | | ✓ | | | ✓ | | | | | ✓ |
| GS08 | ✓ | | | ✓ | | | ✓ | ✓ | | |
| GS10 | ✓ | | | ✓ | ✓* | ✓ | | | | |
| GS11 | ✓ | | | ✓ | | | ✓ | ✓ | | |
| GS12 | ✓ | | | | | | | | | |
| GS13 | ✓ | ✓ | | ✓ | ✓* | | | | | ✓ |
| GS31 | ✓ | | | ✓ | | | ✓ | | | |
| GS33 | | | ✓ | | | | | | | |
| GS51 | | ✓ | | ✓ | | | | | | |
| GS59 | | ✓ | | | ✓ | | | | | ✓ |
| SW018 | | ✓ | | ✓ | ✓* | | | | | |
| SW027 | ✓ | | | ✓ | | ✓ | | | | |
| SW093 | | | | ✓ | | ✓ | | | | |
| GWISINFNORTH | | | | | ✓ | | | | | |
| GWISINFSOUTH | | | | | ✓ | | | | | |
| PLFSEEPINF | | | | | ✓ | | | | | |
| PLFSYSEFF | | | | | ✓ | | | | | |
| PLFPONDEFF | | | | | ✓ | | | | | |
| POM2 | | | | | ✓* | | | | | |
| SPP DISCHARGE GALLERY | | | | | ✓* | | | | | |
| A3DM | ✓ | | | | | | | | | |
| A4DM | ✓ | | | | | | | | ✓ | |
| B5DM | ✓ | | | | | | | | ✓ | |
| C2DM | ✓ | | | | | | | | ✓ | |
| LFDM | ✓ | | | | | | | | | |
| RPTR | | | | | | | | | | ✓ |
| RPTR2 | | | | | | | | | | ✓ |
| RPTR3 | | | | | | | | | | ✓ |

Notes: Locations A3DM, A4DM, B5DM, C2DM, and LFDM are telemetry nodes collecting real-time pond level and piezometer data for the Imminent Danger to Life and Health (IDLH) decision rule. These data are not evaluated in this report.
* = evaluated under ground water monitoring

Investigative monitoring (see Section 2.7), is designed to evaluate upstream water quality when reportable water-quality values are observed at POEs and/or POCs, and can take place anywhere within the POU boundary. Unplanned, special-request monitoring activities are discussed as ad hoc monitoring in Section 2.5.

Indicator Parameter Monitoring for Assessment of Analytical Water-Quality Data (Section 2.6) provides the justification for the collection of general water-quality and quantity information to be used for various data assessments. Specifically, this objective outlines the current and expected uses of parameters such as total suspended solids (TSS) and flow rate.

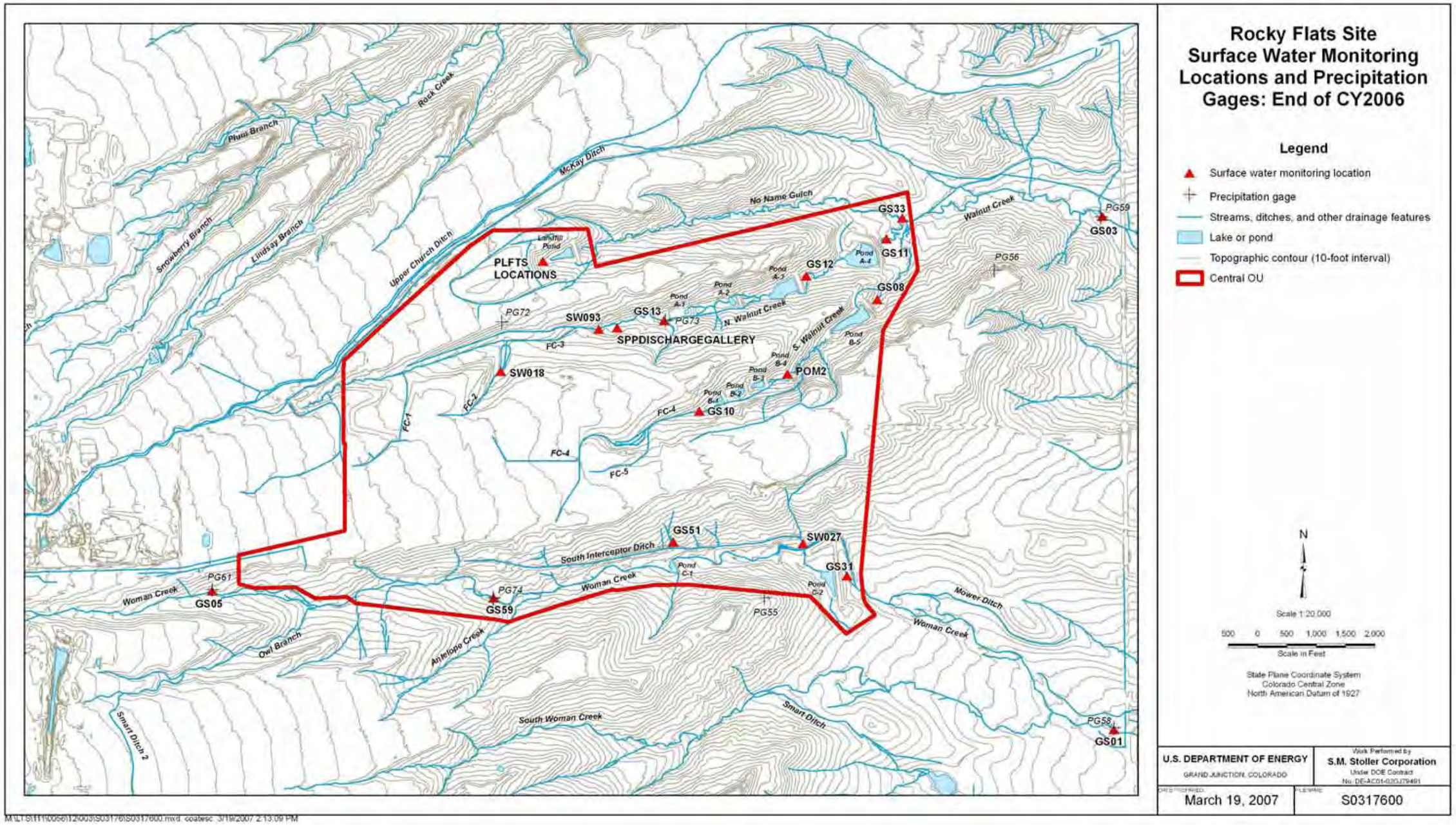


*Figure 2–1. Rocky Flats Site Surface Water Monitoring Locations and Precipitation Gages: End of CY 2006*

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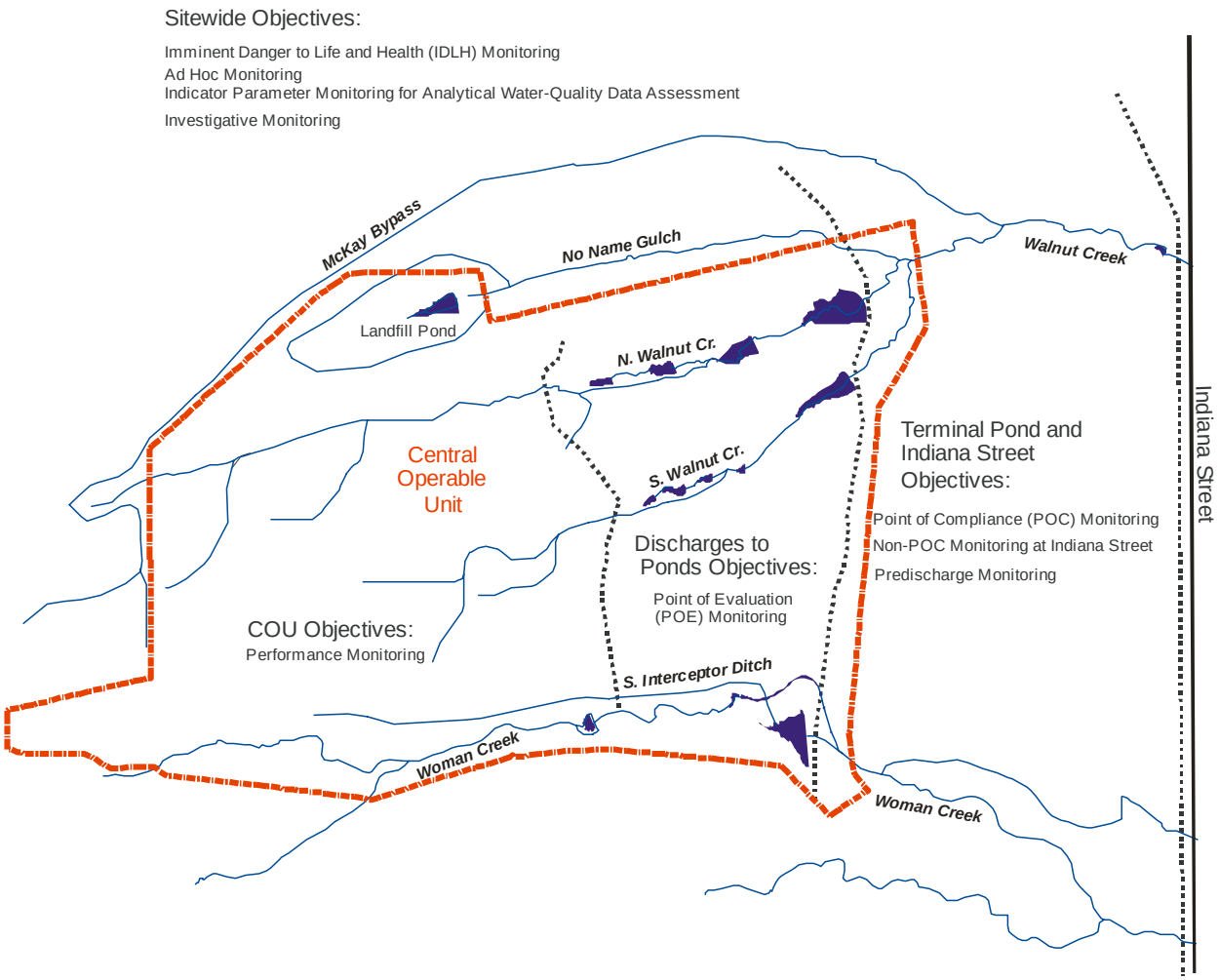


*Figure 2–2. Conceptual Model of Site Surface Water Monitoring Objectives*

### 2.1.3 Surface Water Hydrology

Streams and seeps at the Site are largely ephemeral, with stream reaches gaining or losing flow, depending on the season and precipitation amounts. Surface water flow across the Site is primarily from west to east, with three major drainages traversing the Site. Fourteen ponds (plus several small stock ponds) collect surface water runoff, although only 12 ponds are within the COU and maintained by DOE-LM. The Site drainages and ponds, including their respective pertinence to this report, are described below and shown on Figure 2–3.

The major stream drainages leading out of the POU, from north to south, are Rock Creek, Walnut Creek, and Woman Creek. North Walnut Creek flows through the A-Series Ponds and South Walnut Creek flows through the B-Series Ponds; both are tributaries to Walnut Creek.

#### 2.1.3.1 Walnut Creek

Walnut Creek receives surface water flow from the central third of the Site, including the majority of the COU. It consists of several tributaries: McKay Ditch, No Name Gulch, North

Walnut Creek, and South Walnut Creek. These tributaries join Walnut Creek upstream of the Site's eastern boundary (Indiana Street). East of Indiana Street, Walnut Creek flows through a diversion structure normally configured to divert flow to the Broomfield Diversion Ditch around Great Western Reservoir and into Big Dry Creek. The Walnut Creek tributaries, from north to south, are described below.

### *McKay Ditch*

The McKay Ditch was formerly a tributary to Walnut Creek within the Site boundaries but was diverted in July 1999 into a new pipeline to keep McKay Ditch water from commingling with Site water in Walnut Creek. Although no longer a contributor to Walnut Creek, the McKay Ditch drainage is described here to clarify water routing at the Site. The new configuration allows the City of Broomfield to transport water from the South Boulder Diversion Canal, across the northern portion of the POU and directly into Great Western Reservoir, without entering Walnut Creek. This configuration prevents commingling of McKay Ditch water with discharged water from the Site ponds. McKay Ditch (as well as both the McKay Bypass Canal and McKay Bypass Pipeline) are outside the COU; these features are not maintained by DOE-LM.

### *No Name Gulch*

This drainage is located downstream of the Landfill Pond. A surface water diversion ditch is constructed around the perimeter of the PLF to divert surface water runoff around the landfill to No Name Gulch. Effluent from the Present Landfill Treatment System (PLFTS) and runoff from the area surrounding the pond are the sole surface water sources to the Landfill Pond. The Landfill Pond is operated in a flow-through configuration, although the pool level often drops below the outlet works.

### *North Walnut Creek*

Runoff from the northern portion of the COU flows into this drainage, which has four ponds (Ponds A-1, A-2, A-3, and A-4). The combined capacity of the A-Series Ponds is approximately 197,000 cubic meters ($m^3$) (52 million gallons or 160 acre-feet [ac-ft]). In the normal operational configuration, Ponds A-1 and A-2 are bypassed and maintained for supplemental stormwater control and wetland habitat; evaporation or transfer controls water levels in these ponds. North Walnut Creek flow is diverted around Ponds A-1 and A-2 to Pond A-3 for retention. Pond A-3 is discharged in batches to the A-Series "terminal pond" Pond A-4. If routine discharge of retained water is warranted, Pond A-4 is isolated, sampled, and water is released if surface water quality criteria are met. Criteria for emergency discharge, regardless of pre-discharge pond sampling results, are detailed in the *Emergency Response Plan for Rocky Flats Site Dams* (ERP; DOE 2007a).

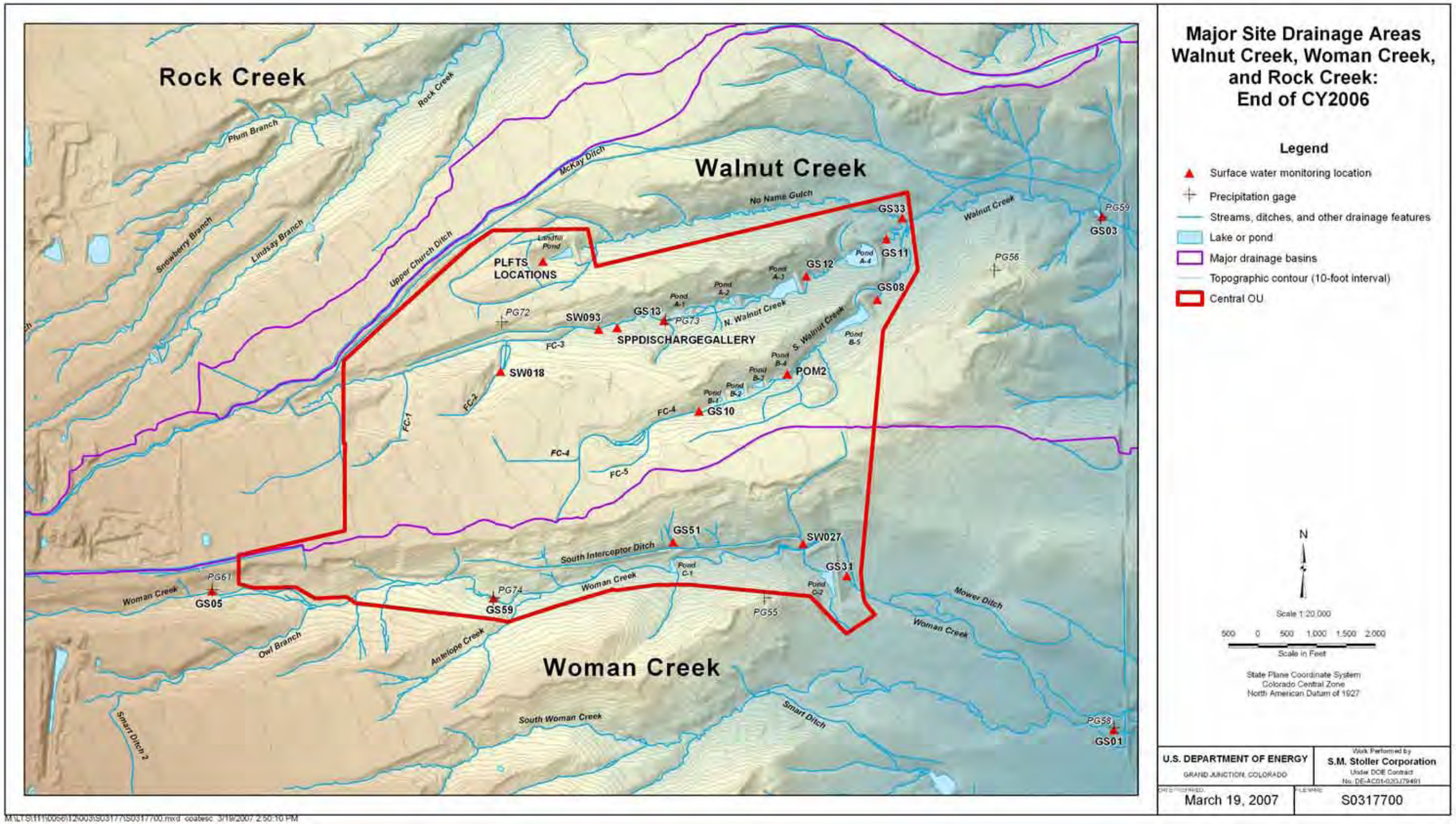


*Figure 2–3. Major Site Drainage Areas Walnut Creek, Woman Creek, and Rock Creek: End of CY 2006*

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***South Walnut Creek***

Runoff from the central portion of the COU flows into this drainage, which has five ponds (Ponds B-1, B-2, B-3, B-4, and B-5). The combined capacity of the South Walnut Creek B-Series Ponds is approximately 102,000 $m^3$ (27 million allons or 83 ac-ft). Ponds B-1, B-2, and B-3 are bypassed and maintained for supplemental stormwater control and wetland habitat; evaporation or transfer controls water levels in these ponds. South Walnut Creek flow is diverted around Ponds B-1, B-2, and B-3 and into Pond B-4, which flows directly into "terminal pond" Pond B-5. If routine discharge of retained water is warranted, Pond B-5 is sampled and water is released if surface water quality criteria are met. Criteria for emergency discharge, regardless of pre-discharge pond sampling results, are detailed in the ERP.

#### 2.1.3.2 Woman Creek

South of the COU is Woman Creek, which flows through Pond C-1 and off Site onto Refuge lands toward Indiana Street. The Woman Creek drainage basin extends eastward from the base of the foothills, near Coal Creek Canyon, to Standley Lake. In the current configuration, Woman Creek flows into the Woman Creek Reservoir located east of Indiana Street and upstream of Standley Lake, where the water is held until it is pump-transferred to Big Dry Creek by the City of Westminster.

***South Interceptor Ditch***

In the southern portion of the COU, and tributary to Woman Creek, is the SID drainage. Surface water runoff from the southern portion of the COU is captured by the SID, which flows from west to east into Pond C-2. If routine discharge of retained water is warranted, Pond C-2 is sampled and water is released to Woman Creek if surface water quality criteria are met. Criteria for emergency discharge, regardless of pre-discharge pond sampling results, are detailed in the ERP.

#### 2.1.3.3 Other Drainages

The third major drainage, other than Walnut and Woman Creeks, is Rock Creek. The Rock Creek drainage covers the northwestern portion of the former RFETS east-sloping alluvial plains to the west, several small stock ponds within the creek bed, and multiple steep gullies and stream channels to the east characterize the drainage channel. This entire basin is outside the COU.

Smart Ditch/South Woman Creek, located south of Woman Creek, is also completely outside the COU. The D-Series Ponds (D-1 and D-2) are located on Smart Ditch. This drainage and these ponds are not maintained by DOE-LM.

## 2.2 Hydrologic Data

The following section provides information on all automated surface water monitoring locations at the Site that operated during CY 2006. For locations with continuous flow measurement, graphical discharge summaries are provided. Numerical discharge values are included in the tables in Appendix A. The hydrologic routing diagram (as of December 31, 2006) for the locations included in this report is shown in Figure 2–4.

### 2.2.1 Data Presentation

#### 2.2.1.1 Flow Data Collection and Computation

Data obtained at a continuous surface water gaging station on a stream or conveyance, such as an irrigation ditch, consist of a continuous record of stage,[6] individual measurements of flow throughout a range of stages, and notations regarding factors that might affect the relation of stage to flow rate. These data, together with supplemental information such as climatological records, are used to compute daily mean discharges.

Continuous records of stage are obtained with electronic recorders that store stage values at selected time intervals or secondarily with radio-telemetry data-collection platforms that transmit near real-time data at selected time intervals to a central database for subsequent processing. Direct field measurements of flow are made with current meters, using methods adapted by the U.S. Geological Survey, or with flumes or weirs that are calibrated to provide a relation of observed stage to flow rate. These methods are described by Carter and Davidian (1968) and by Rantz (1982a, 1982b).

In computing flow records for non-standard flow-control devices, results of individual measurements are plotted against the corresponding stage, and stage-flow rate relation curves are constructed. From these curves, rating tables indicating the computed flow rate for any stage within the range of the measurements are prepared. For standard devices (e.g., flumes, weirs), rating tables indicating the flow rate for any stage within the range of the device are prepared based on the geometry of the device. If it is necessary to define extremes of flow outside the range of the device, the curves can be extended using (1) logarithmic plotting, (2) velocity-area studies, (3) results of indirect measurements of peak flow rate, such as slope-area or contracted-opening measurements, and computation of flow over dams or weirs, or (4) step-back-water techniques.

Daily mean discharges are computed by averaging the individual flow measurements using the stage-flow rate curves or tables. If the stage-flow rate relation is subject to change because of frequent or continual change in the physical features that form the control, the daily mean discharge is determined by the shifting-control method, in which correction factors based on the individual flow rate measurements and notes by the personnel making the measurements are applied to the gage heights before the flow rates are determined from the curves or tables. This shifting-control method also is used if the stage-flow rate relation is changed temporarily because of aquatic vegetation growth or debris on the control. For some gaging stations, formation of ice in the winter can obscure the stage-flow rate relations so that daily mean discharges need to be estimated from other information, such as temperature and precipitation records, notes of observations, and records for other gaging stations in the same or nearby basins for comparable periods.

[6] Stage is the water level (in units such as feet or meters) in a conveyance structure.

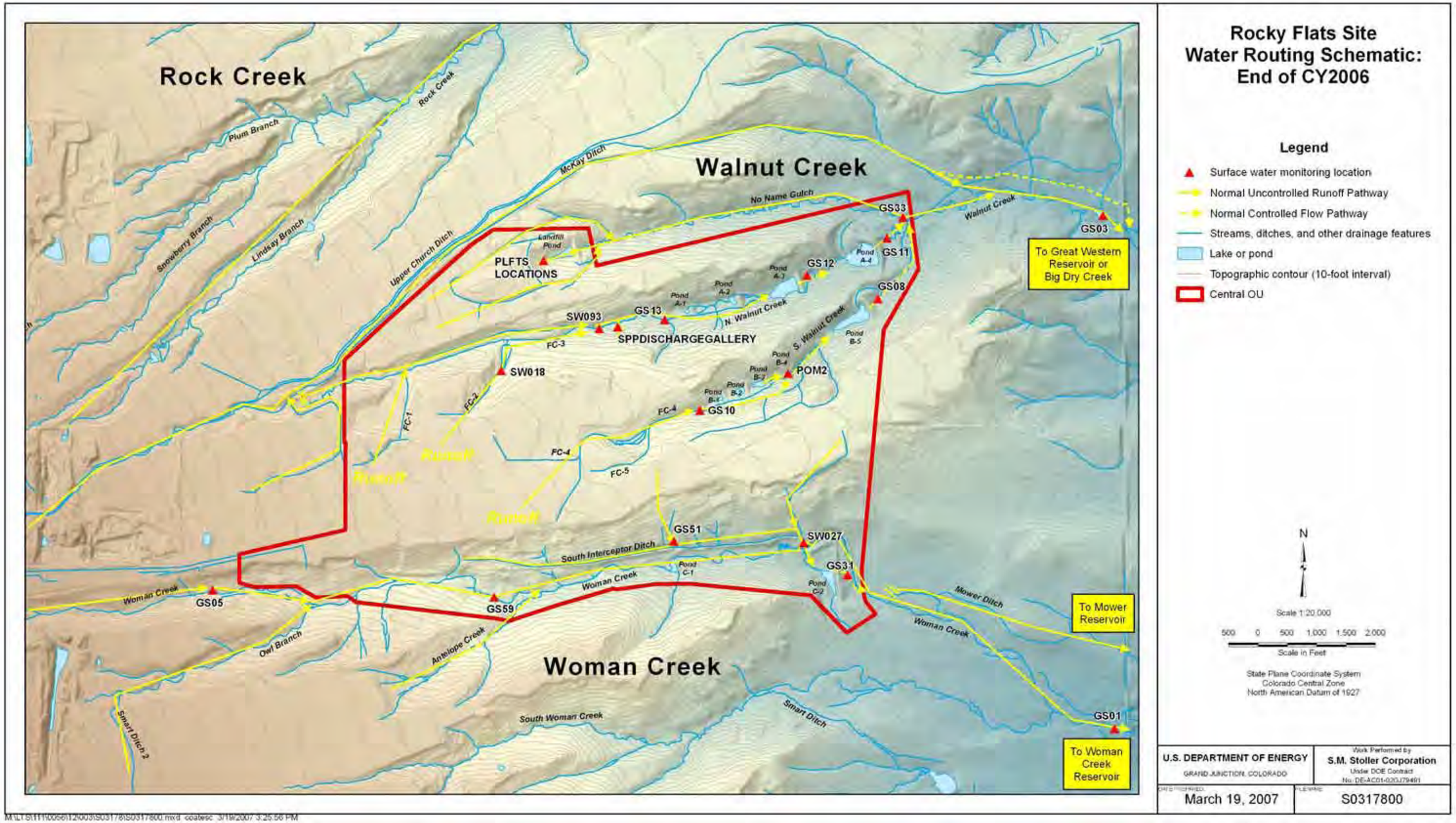


*Figure 2–4. Rocky Flats Site Water Routing Schematic: End of CY 2006*

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For most gaging stations, there may be periods when no gage-height record is obtained or the recorded gage height is faulty so that it cannot be used to compute daily mean discharge or contents. This record loss occurs when recording instruments malfunction or otherwise fail to operate properly, intakes are plugged, the stilling well is frozen, or for various other reasons. For such periods, the daily discharges are estimated from the recorded range in stage, previous or following record, field discharge measurements, climatological records, and comparison with other gaging-station records from the same or nearby basins. Information explaining how estimated daily discharge values are identified in gaging-station records is provided in the "Identifying Estimated Daily Discharge" section.

#### 2.2.1.2 Data Presentation

The information published for each continuous-record surface water gaging station consists of six parts: the station description; a map showing the drainage area for the station; a plot of the daily mean discharge for the calendar year(s); a table of daily mean discharge values for the calendar year with summary data; a tabular statistical summary of monthly mean discharge data for the calendar year; and a summary statistics table that includes statistical data of annual discharge and runoff. The tables are included in Appendix A, "Hydrologic Data," while the other information is presented below.

#### 2.2.1.3 Station Description

The station description provides, under various headings, descriptive information included gaging-station location, drainage area, period of record, and gage information. The following information is provided:

- Location—This entry provides the gaging-station state plane coordinates and geographic location. Gaging station state plane coordinates were obtained by geographic positioning system or digitized from site geographic information system (GIS) coverages.
- Drainage Area—This entry provides the drainage area (in acres) of the gaged basin. If, because of unusual natural conditions or artificial controls, some part of the basin does not contribute flow to the total flow measured at the gage, the noncontributing drainage area also is identified. Drainage area is usually measured using digital techniques and the most accurate maps available. Because the type of map available might vary from one drainage basin to another, the accuracy of digitized drainage areas also can vary. Drainage areas are updated as better maps become available. Some of the gaging stations included in this report measure stage and flow rate in channels that convey water to or from reservoirs or other features; these channels might have little or no contributing drainage area. Drainage areas in this report were provided by Site GIS coverages.[7]
- Period of Record—This entry provides the period for which the Site has been collecting records at the gage. This entry includes the month and year of the start of collection of hydrologic records by the Site and the words "to current year" if the records are to be continued into the following year.
- Gage—This entry provides the type of gage currently in use, and a condensed history of the types and locations of previous gages.

[7] Drainage area maps show Site configuration at the end of CY 2006.

#### 2.2.1.4 Daily Mean Discharge Values

The daily mean discharge values computed for each gaging station during a calendar year are listed in the body of the data tables in Appendix A. In the monthly "Flow Rate" summary part of the table, the line headed "Average" lists the average flow rate, in cubic feet per second, during the month; and the lines headed "Maximum" and "Minimum" list the maximum and minimum daily mean discharges for each month. Total discharge for the month also is expressed in cubic feet ("Cubic Feet"), gallons ("Gallons"), and acre-feet ("Acre-Feet"). The term "Partial Data" denotes a month with incomplete data.

#### 2.2.1.5 Summary Statistics

A section of the table titled "Annual Summaries For CY06" follows the monthly mean data section. This section provides a statistical summary of annual flow rates and discharge for the labeled calendar year. The applicable units are to the left of the table value. The term "PARTIAL DATA" denotes a year with incomplete data.

#### 2.2.1.6 Identifying Estimated Daily Discharge

Estimated daily discharges published in water-discharge tables and figures of this annual report are identified by *italicizing* individual daily values or through color coding in hydrographs. For periods of no data, a gap is shown on the hydrographs.

#### 2.2.1.7 Other Records Available

Information used in the preparation of the records in this report, such as discharge-measurement notes, gage-height records, and rating tables, are on file. Information on the availability of the unpublished information or on the published statistical analyses is available from personnel involved with data collection at the Site.

### 2.2.2 Discharge Data Summaries

#### 2.2.2.1 Site-Wide Discharge Summary

Discharge summaries for the two major Site drainages receiving flow from the COU (Walnut and Woman Creeks) are given in Figure 2–5 and Figure 2–6. Walnut Creek flows are measured at GS03 and Woman Creek flows are measured at GS01. Figure 2–7 shows the relative total CY 1997−2006 discharge volumes from the major Site drainages as measured at Site POEs and POCs. Through CY 2004, Walnut Creek discharged larger volumes than Woman Creek. As the Site progressed toward final closure in CY 2005,[8] volumes from Woman Creek exceeded volumes from Walnut Creek.

[8] The removal of impervious surfaces and the elimination of the Waste Water Treatment Plant (WWTP) significantly reduced contributions to Walnut Creek in CY 2005.

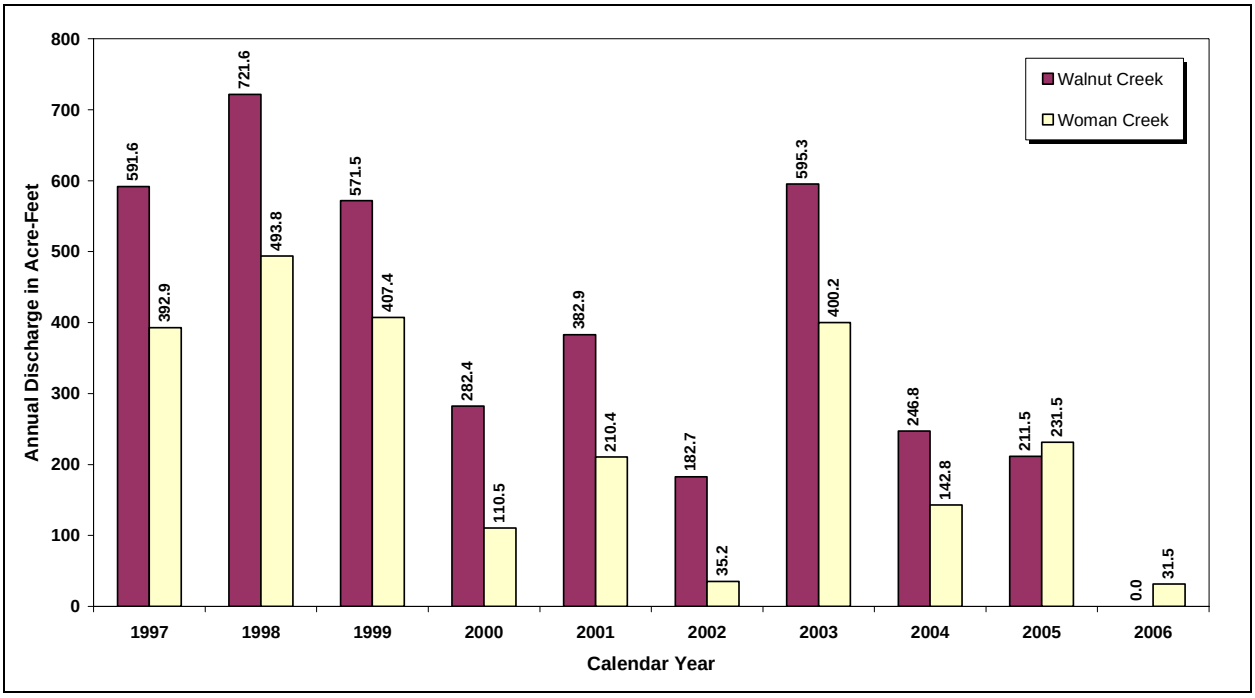



*Figure 2–5. Annual Discharge Summary from Major Site Drainages: CY 1997−2006*

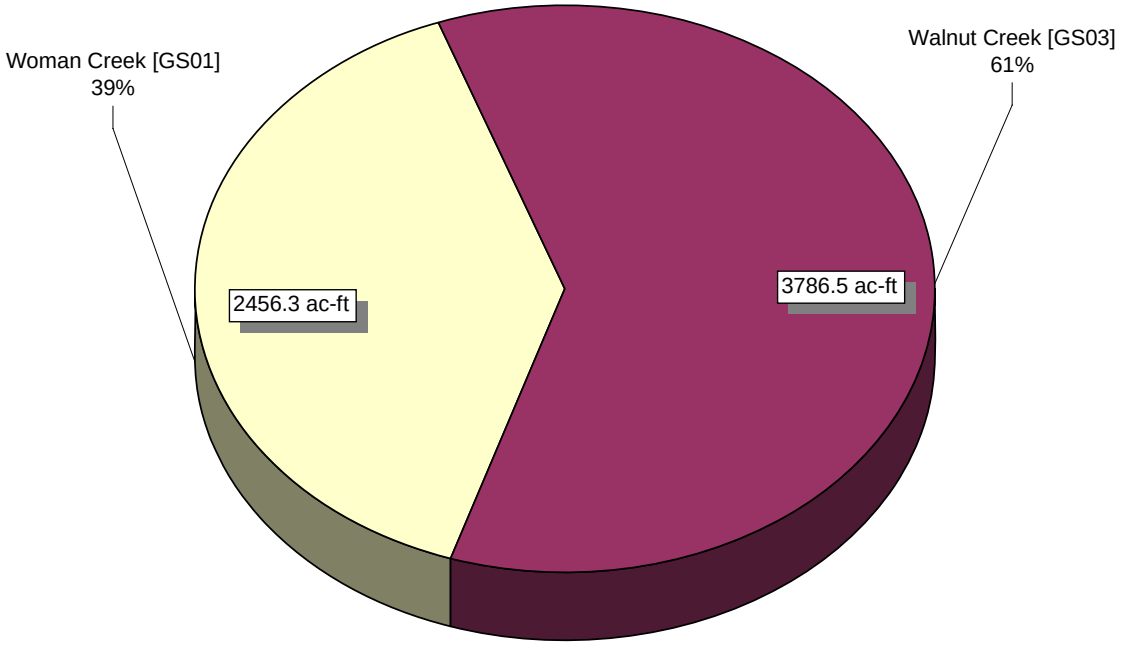
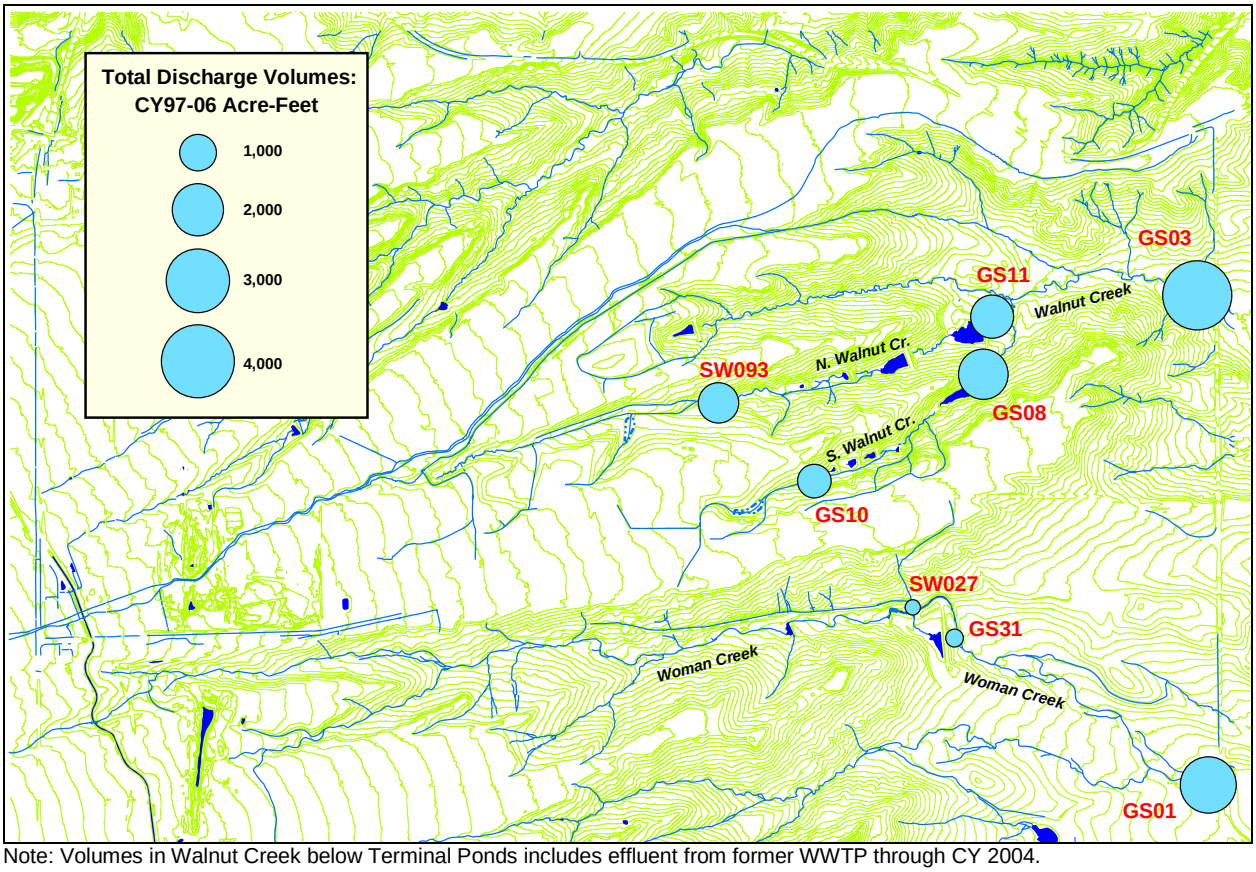



*Figure 2–6. Relative Total Discharge Summary from Major Site Drainages: CY 1997−2006*



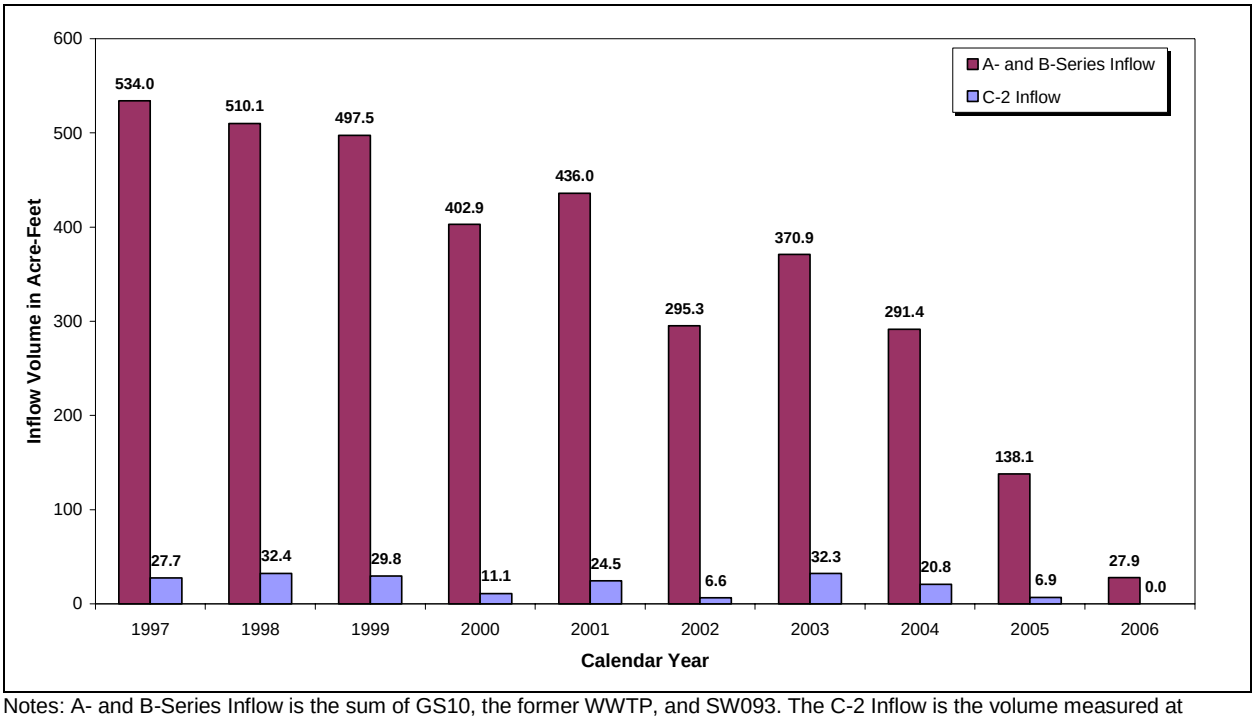

Note: Volumes in Walnut Creek below Terminal Ponds includes effluent from former WWTP through CY 2004.

*Figure 2–7. Map Showing Relative CY 1997−2006 Discharge Volumes for POEs and POCs*

### 2.2.2.2 Ponds Discharge Summary

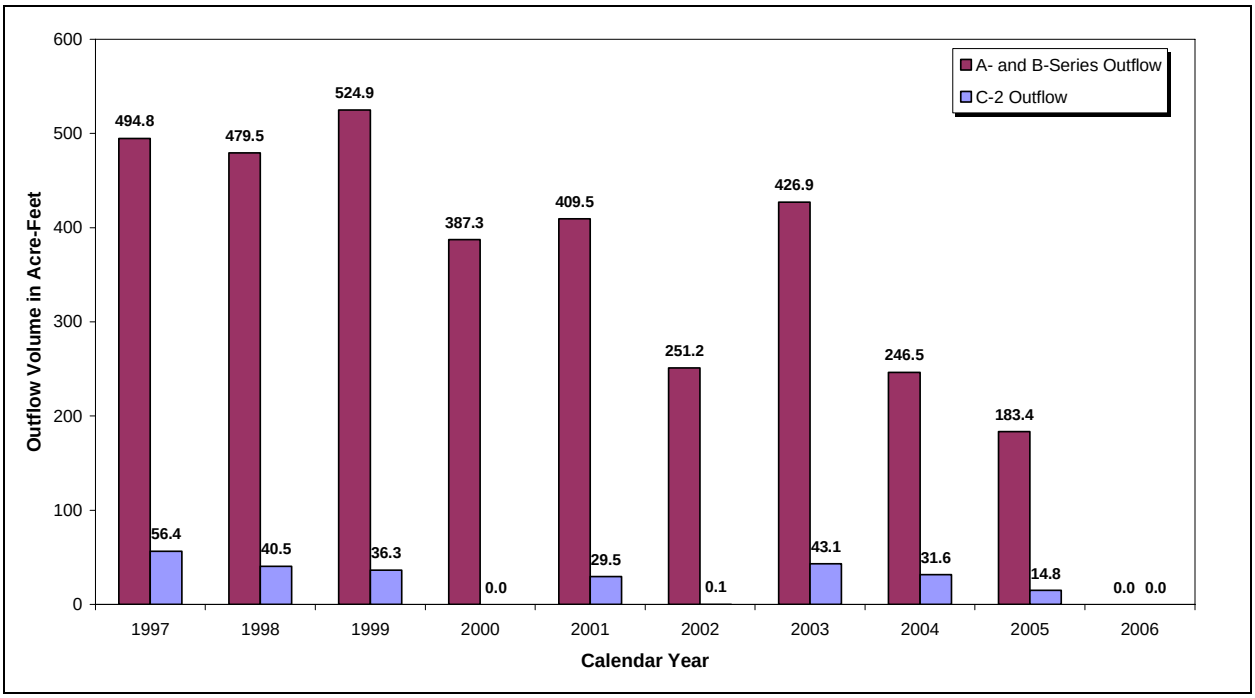
Figure 2–8 and Figure 2–9 show the annual ponds inflows and outflows, respectively. Due to the intermittent pump transfers of Pond B-5 water to Pond A-4, the volumes for the A- and B-Series Ponds are combined. Figure 2–10 shows the relative total CY 1997−2006 discharge volumes from the ponds (as measured at GS08, GS11, and GS31) and from the major drainages tributary to the ponds (as measured at GS10, SW027, SW091, SW093, and the former Waste Water Treatment Plant [WWTP] [995POE]).[9] Pond inflows do not necessarily equal outflows for any given year due to the storage of water in the ponds across water years, evaporative/seepage losses/gains, and local runoff to the ponds.

[9] The WWTP was removed from service on November 4, 2004.



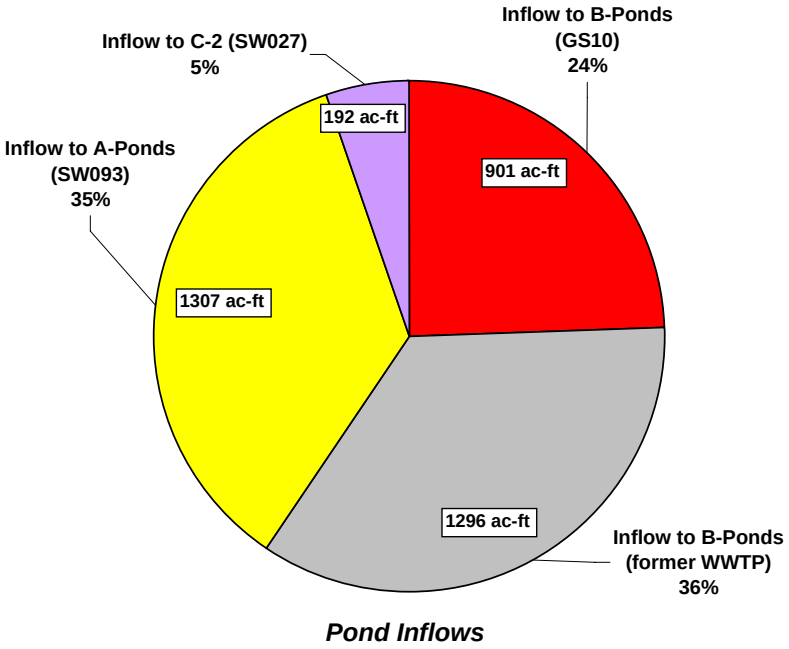

Notes: A- and B-Series Inflow is the sum of GS10, the former WWTP, and SW093. The C-2 Inflow is the volume measured at SW027.

*Figure 2–8. Pond Inflows: CY 1997−2006*

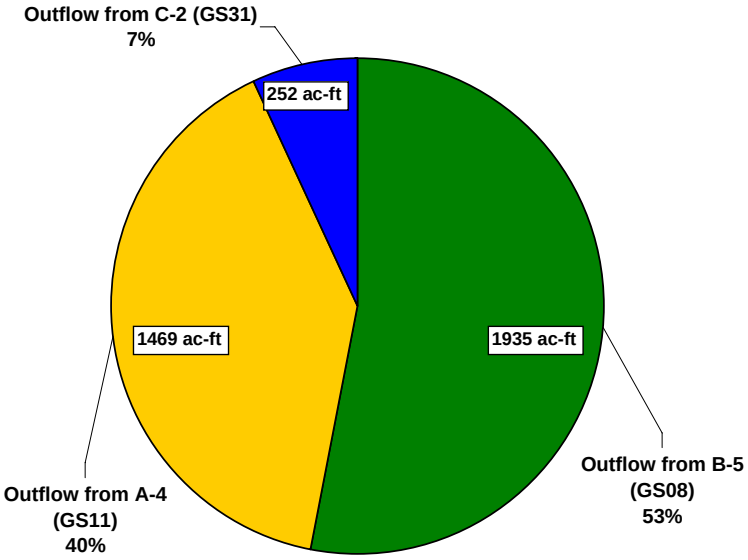



Notes: A- and B-Series Outflow is the sum of GS11 and GS08. The C-2 Outflow is the volume measured at GS31.

*Figure 2–9. Pond Outflows: CY 1997−2006*




***Pond Inflows***




***Pond Outflows***

*Figure 2–10. Relative Total Inflow and Outflow Volumes for Site Ponds: CY 1997−2006*

### 2.2.2.3 GS01: Woman Creek at Indiana Street

***Location***—Woman Creek 200 feet upstream of Indiana Street; State Plane: E2093820, N744894.

***Drainage Area***—The basin includes the Woman Creek drainage and southern portions of the COU; areas west of Highway 93 also contribute runoff (total drainage acreage undetermined).

***Period of Record***—September 16, 1991, to current year.

***Gage***—Water-stage recorder and 18-inch Parshall flume (flume is located just east of Indiana Street, sampling conducted on Site property); prior to March 24, 1998, flow measurement was at the onsite sampling location using a 9-inch Parshall flume.

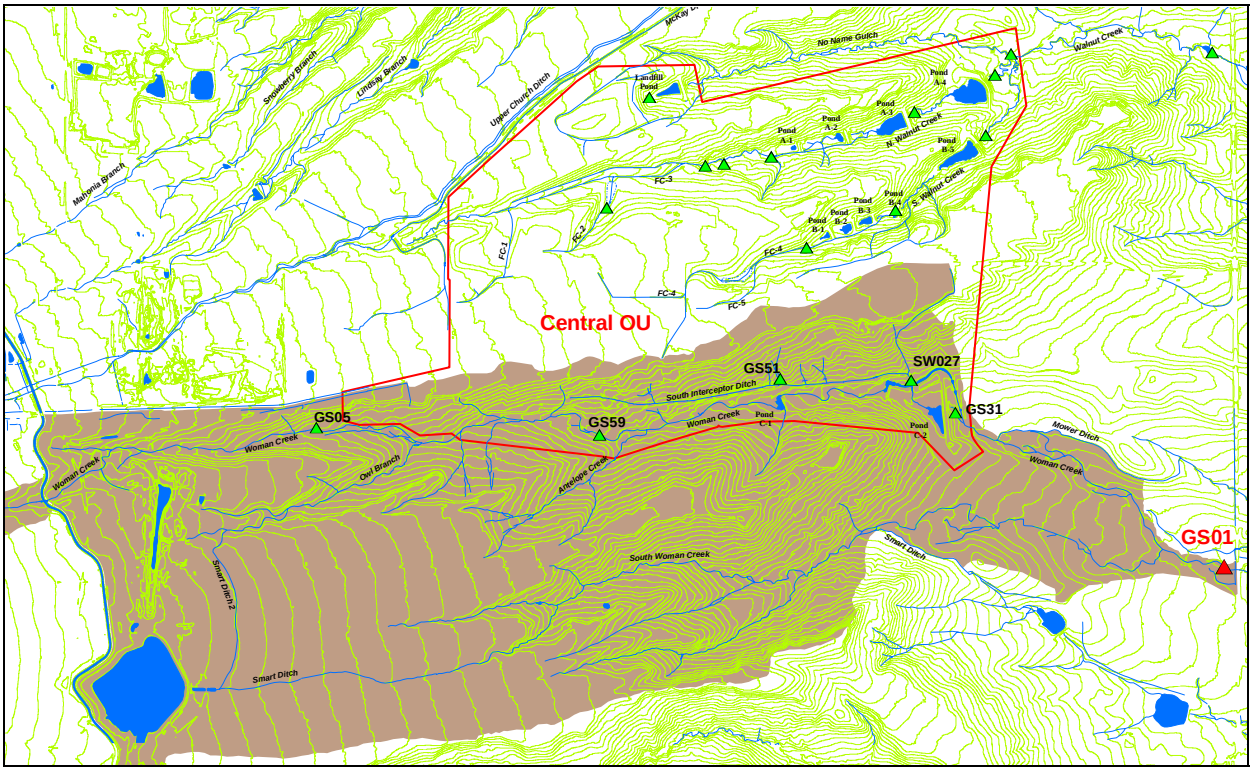



*Figure 2–11. Map Showing GS01 Drainage Area*

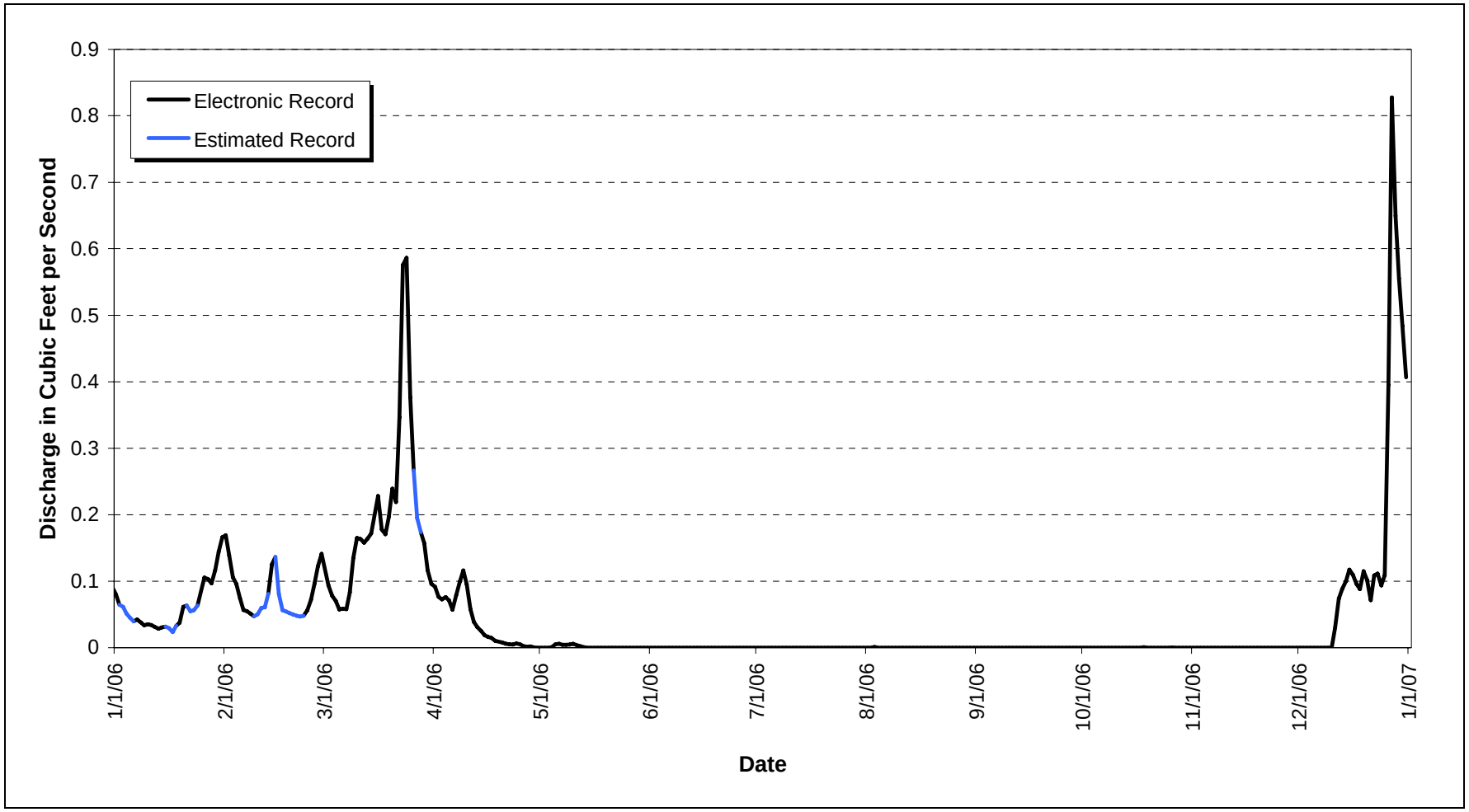



*Figure 2–12. CY 2006 Mean Daily Hydrograph at GS01: Woman Creek at Indiana Street*

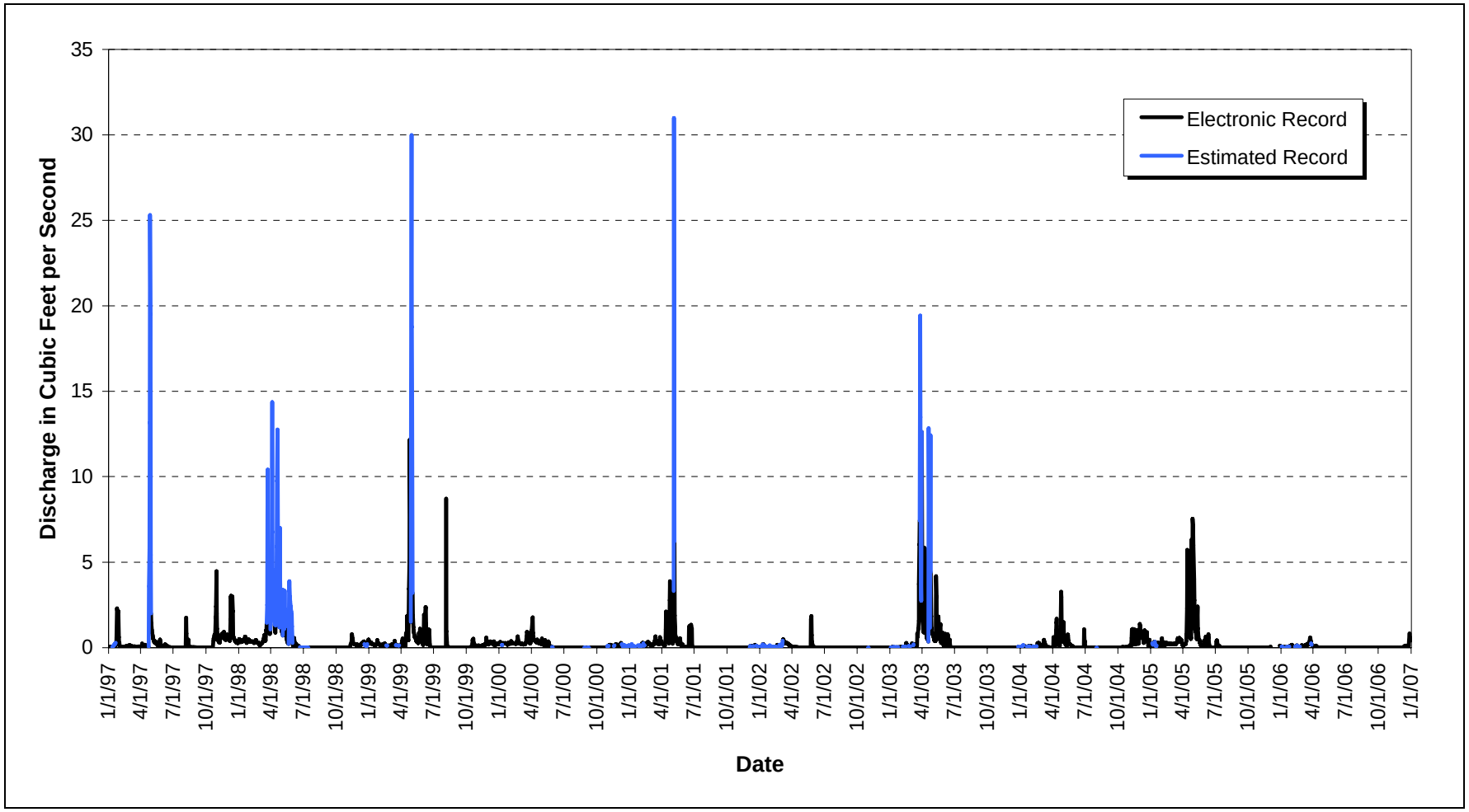



*Figure 2–13. CY 1997−2006 Mean Daily Hydrograph at GS01: Woman Creek at Indiana Street*

### 2.2.2.4 GS03: Walnut Creek at Indiana Street

***Location***—Walnut Creek at Flume Pond outlet upstream of Indiana Street; State Plane: E2093606, N753652.

***Drainage Area***—The basin includes the Walnut Creek drainage and the majority of the COU; areas west of Highway 93 also contribute runoff (total drainage acreage undetermined).

***Period of Record***—September 2, 1991, to current year.

***Gage***—Water-stage recorder and parallel 6-inch and 36-inch Parshall flumes prior to November 5, 2002. Rated stream section during flume construction (GS03T; November 5, 2002−February 12, 2003). Three-foot HL flume starting February 12, 2003.

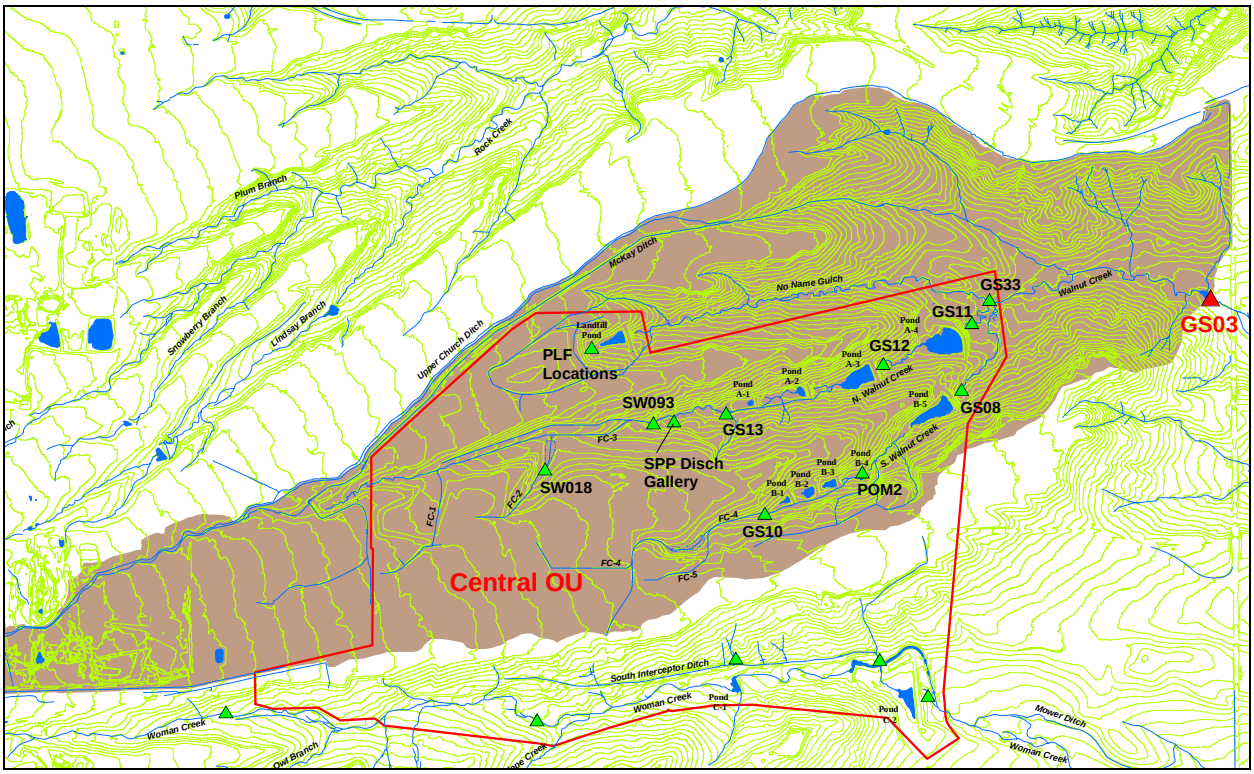



*Figure 2–14. Map Showing GS03 Drainage Area*

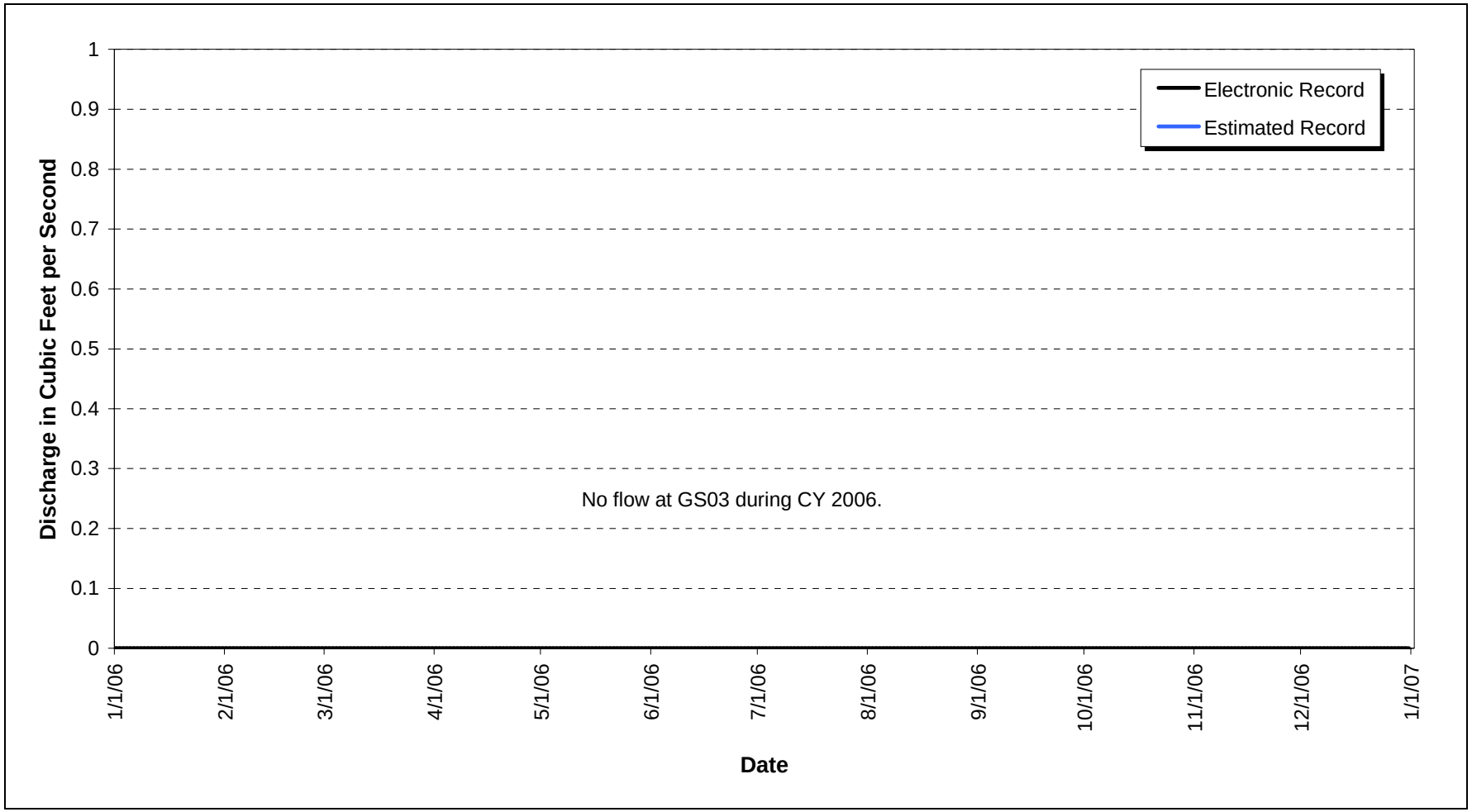



*Figure 2–15. CY 2006 Mean Daily Hydrograph at GS03: Walnut Creek at Indiana Street*

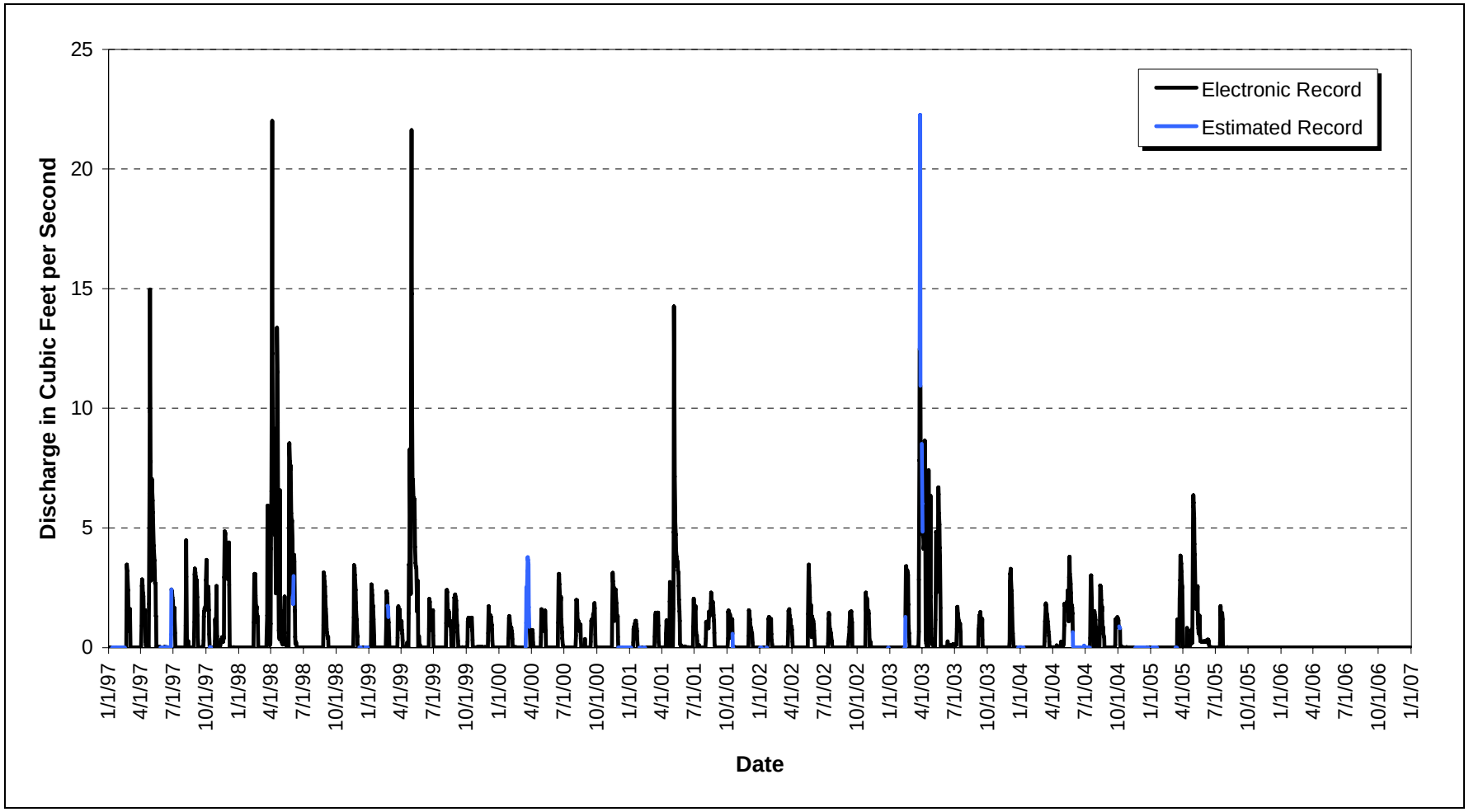



*Figure 2–16. CY 1997−2006 Mean Daily Hydrograph at GS03: Walnut Creek at Indiana Street*

2.2.2.5 GS05: Woman Creek at West Fenceline

***Location***—Woman Creek east of west Site boundary; State Plane: E2078428, N747260.

***Drainage Area***—The basin includes a portion of the Woman Creek drainage; areas west of Highway 93 also contribute runoff (total drainage acreage undetermined).

***Period of Record***—September 23, 1991, to current year.

***Gage***—Water-stage recorder and 9-inch Parshall flume with weir insert.

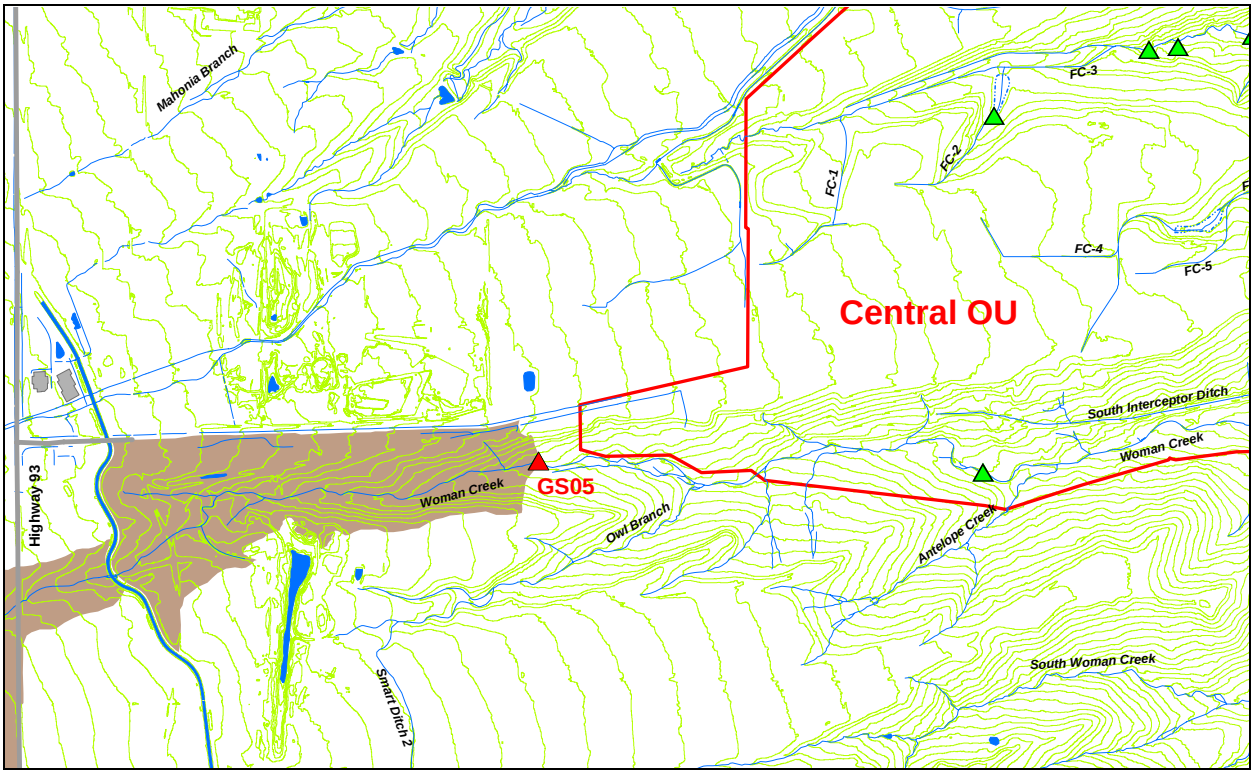



*Figure 2–17. Map Showing GS05 Drainage Area*

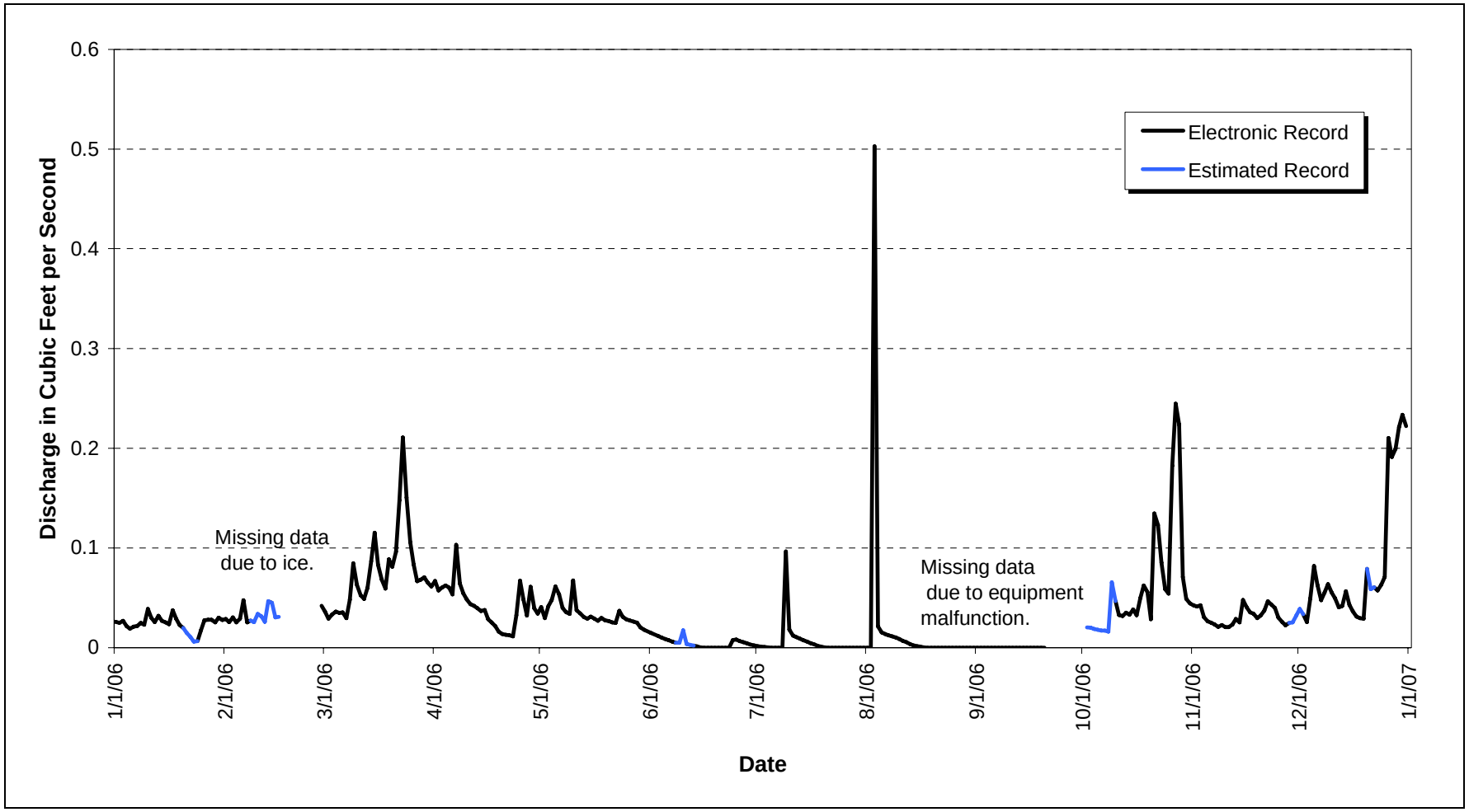



*Figure 2–18. CY 2006 Mean Daily Hydrograph at GS05: North Woman Creek at West Fenceline*

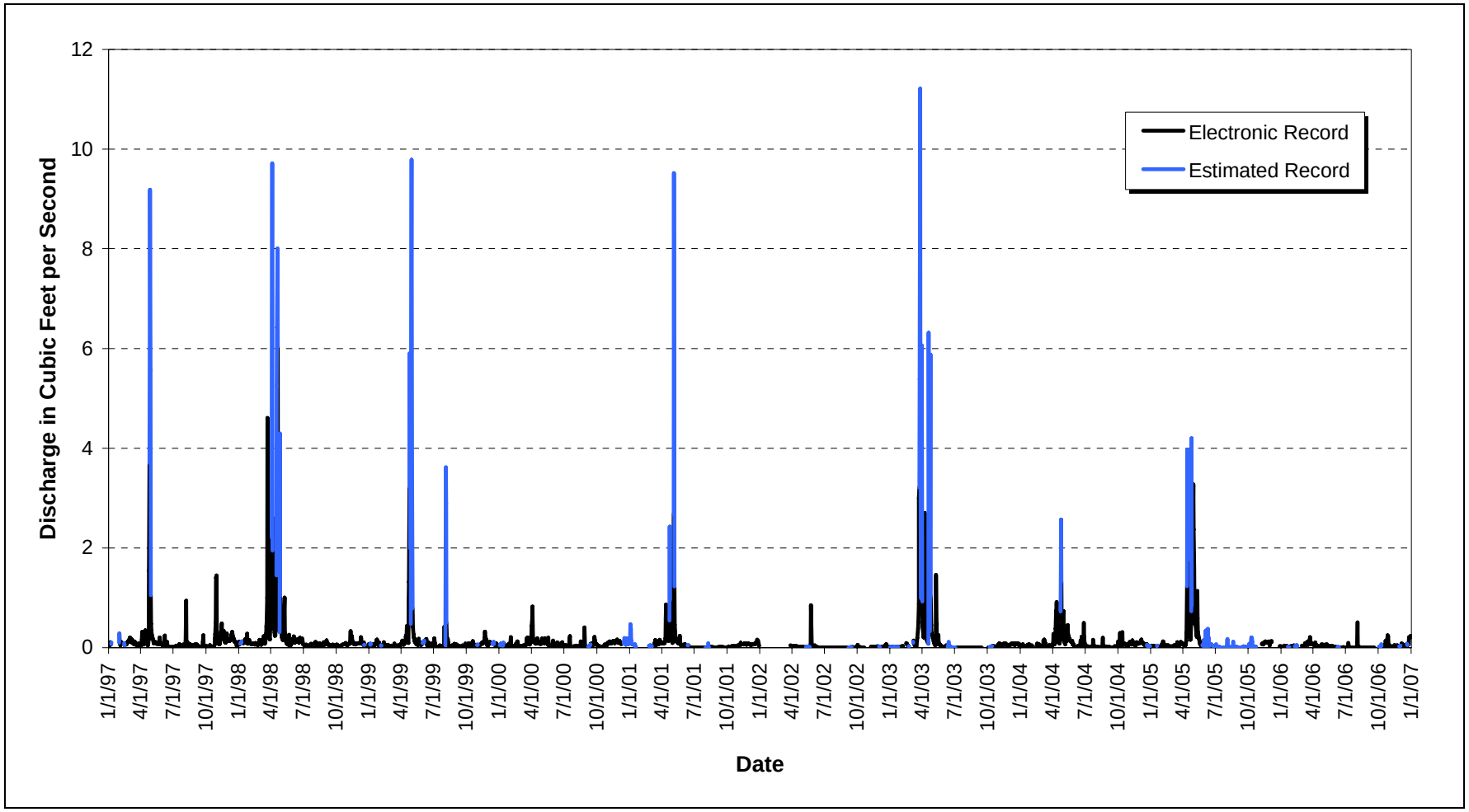



*Figure 2–19. CY 1997−2006 Mean Daily Hydrograph at GS05: North Woman Creek at West Fenceline*

### 2.2.2.6 GS08: South Walnut Creek at Pond B-5 Outlet

***Location***—South Walnut Creek at Pond B-5 outlet; State Plane: E2089779, N752234.

***Drainage Area***—The basin includes the South Walnut Creek drainage and central portions of the COU (total of 355.5 acres).

***Period of Record***—March 23, 1994, to current year.

***Gage***—Water-stage recorder and 24-inch Parshall flume.

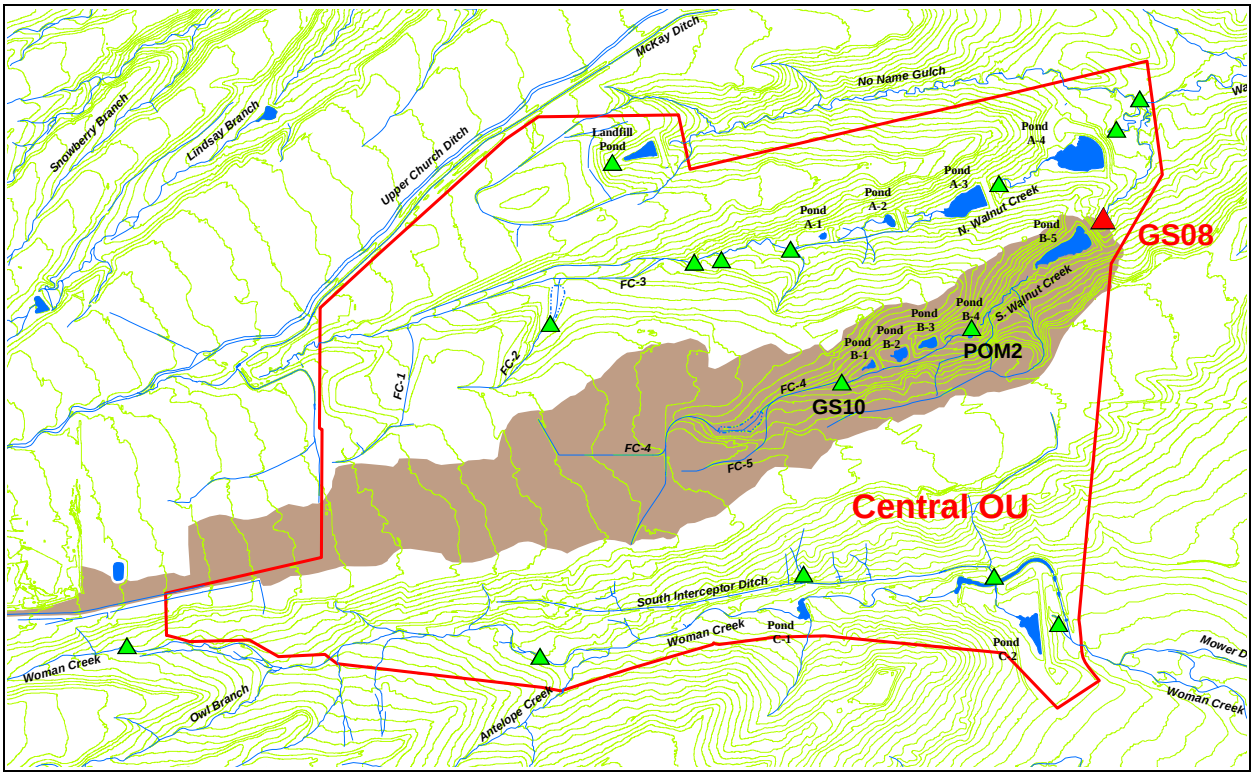



*Figure 2–20. Map Showing GS08 Drainage Area*

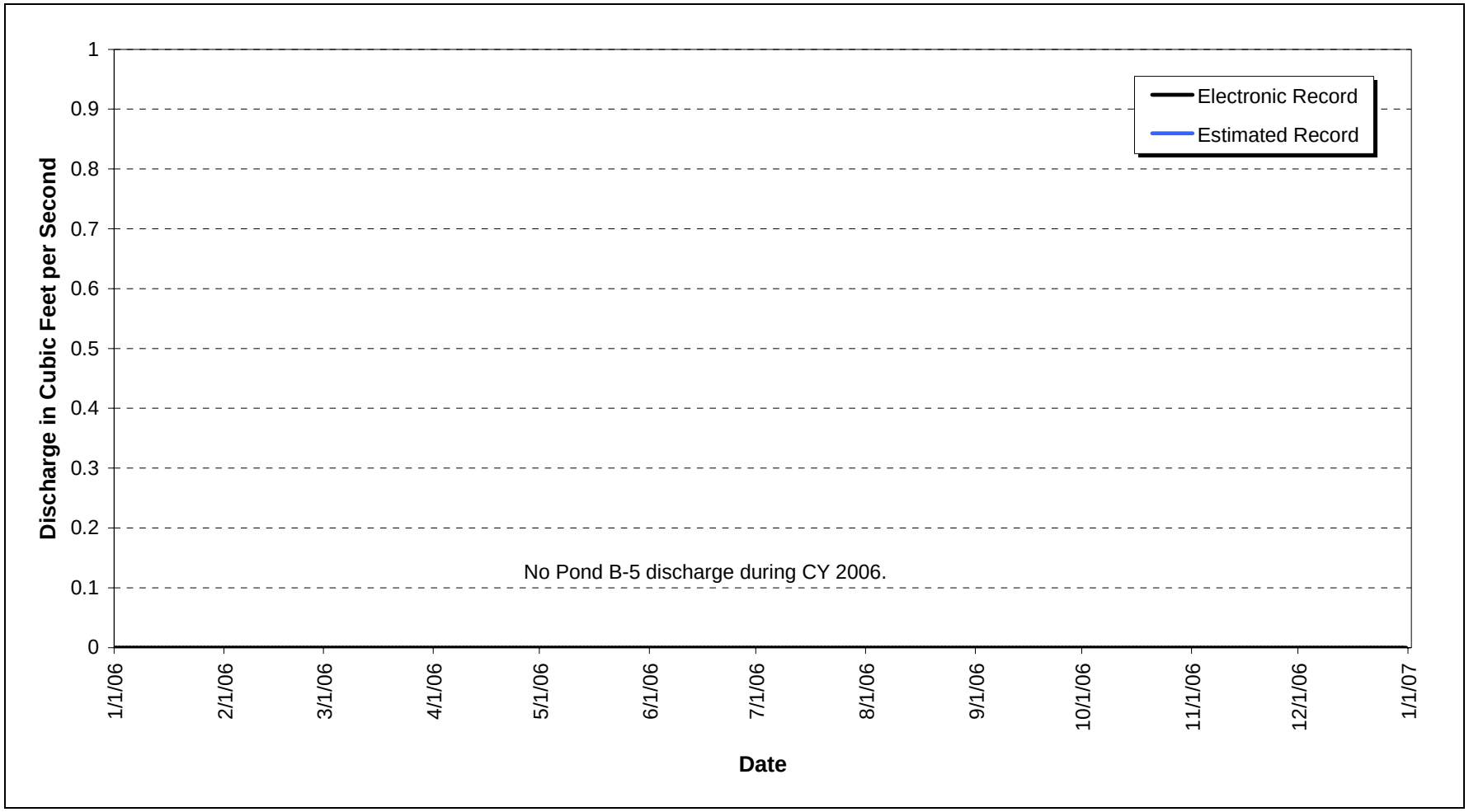



*Figure 2–21. CY 2006 Mean Daily Hydrograph at GS08: South Walnut Creek at Pond B-5 Outlet*

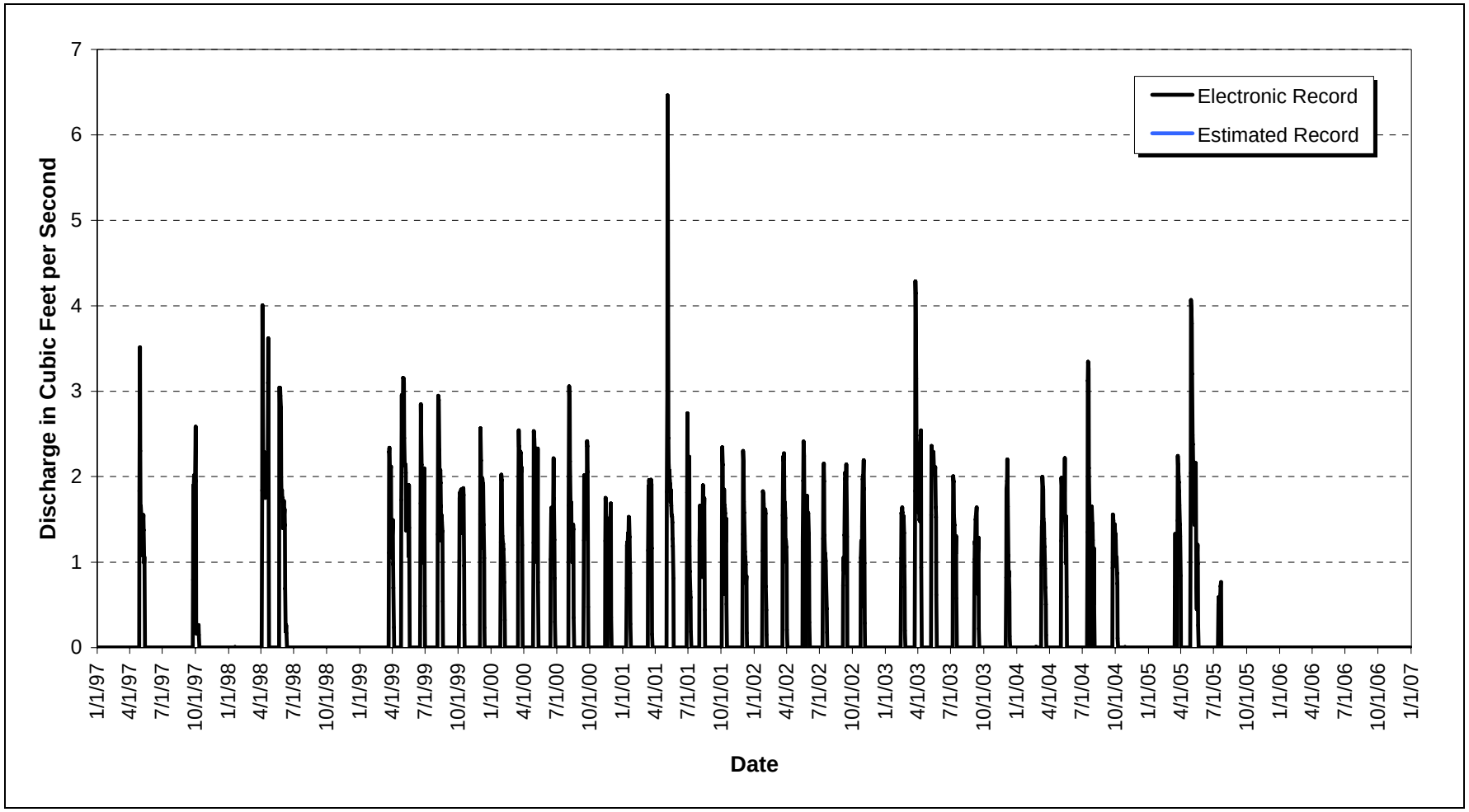



*Figure 2–22. CY 1997−2006 Mean Daily Hydrograph at GS08: South Walnut Creek at Pond B-5 Outlet*

2.2.2.7 GS10: South Walnut Creek at Pond B-1 Bypass

***Location***—South Walnut Creek above Pond B-1 Bypass; State Plane: E2086741, N750326.

***Drainage Area***—The basin includes the central portion of the COU (total of 250.4 acres).

***Period of Record***—April 1, 1993, to current year.

***Gage***—Water-stage recorder and 9-inch Parshall flume with weir insert.

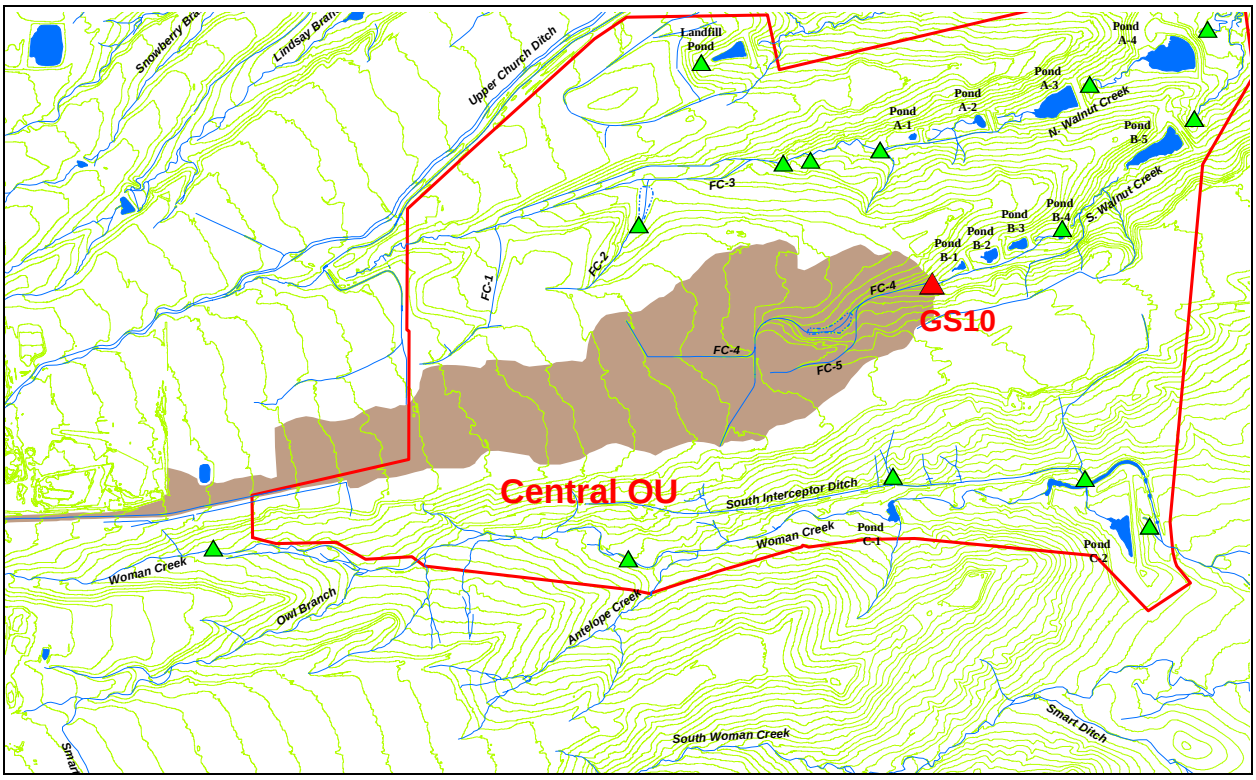



*Figure 2–23. Map Showing GS10 Drainage Area*

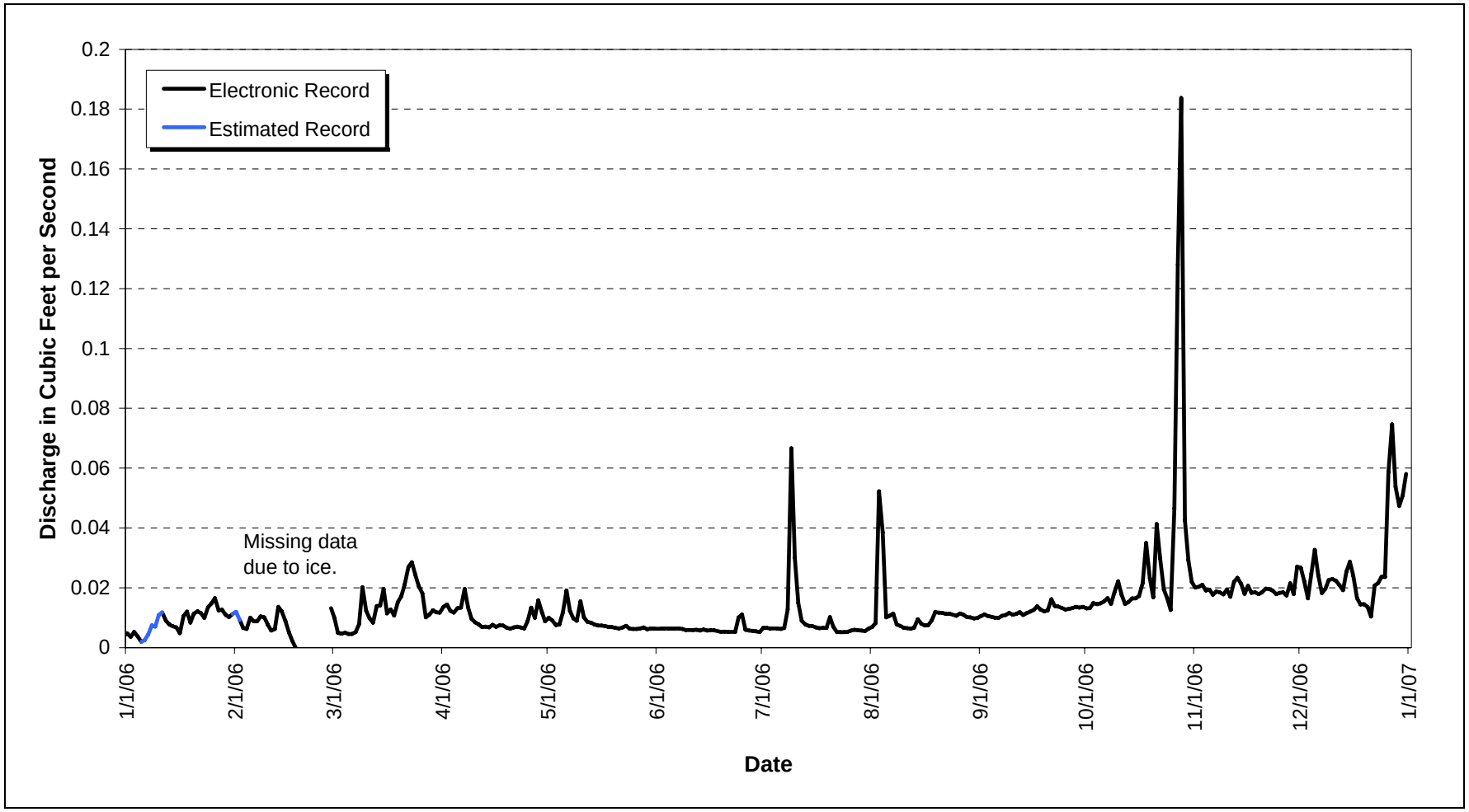



*Figure 2–24. CY 2006 Mean Daily Hydrograph at GS10: South Walnut Creek at Pond B-1 Bypass*

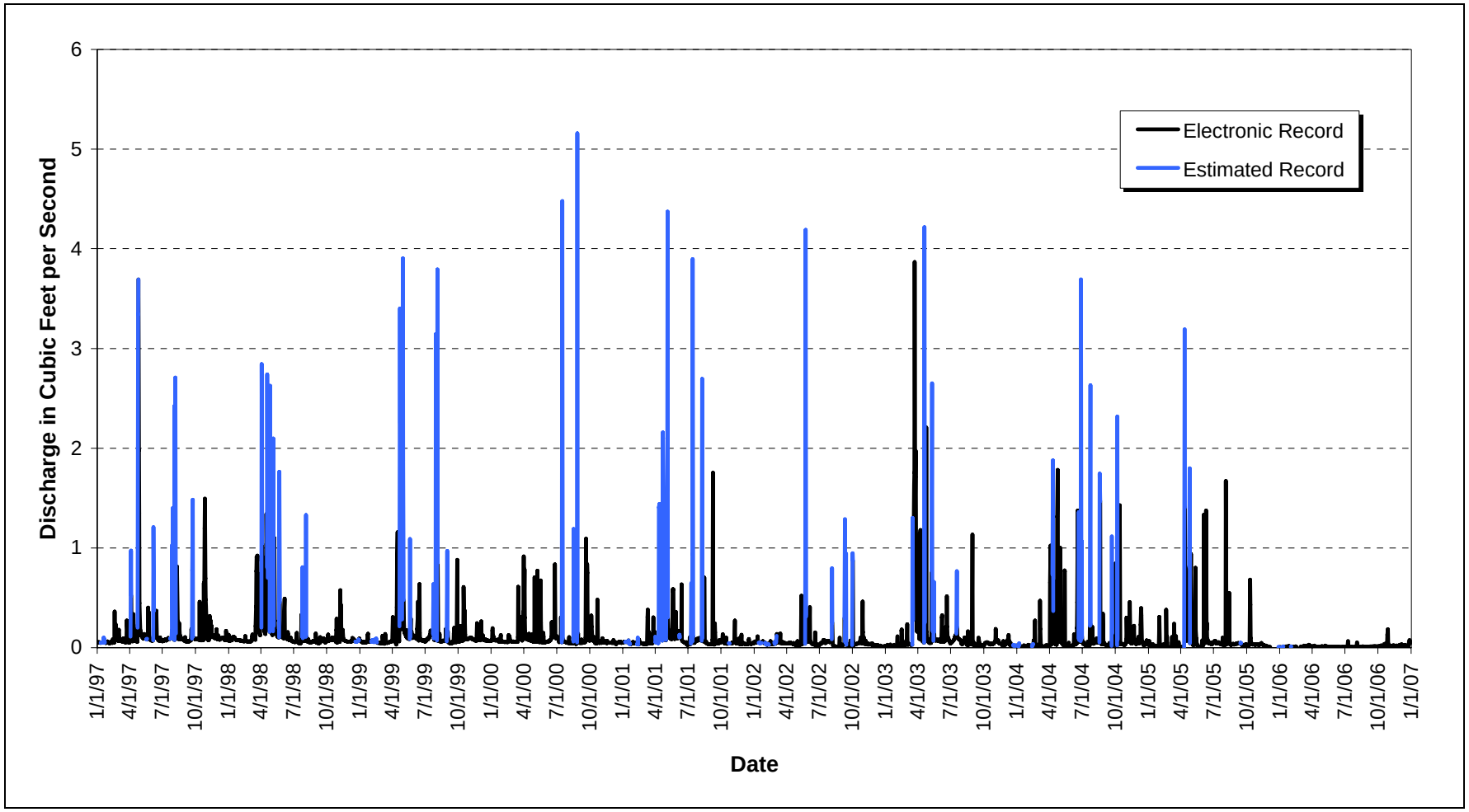



*Figure 2–25. CY 1997–2006 Mean Daily Hydrograph at GS10: South Walnut Creek at Pond B-1 Bypass*

2.2.2.8 GS11: North Walnut Creek at Pond A-4 Outlet

***Location***—North Walnut Creek at Pond A-4 outlet; State Plane: E2089934, N753267.

***Drainage Area***—The basin includes the North Walnut Creek drainage and northern portions of the COU (total of 367.5 acres).

***Period of Record***—May 12, 1992, to current year.

***Gage***—Water-stage recorder and 24-inch Parshall flume.

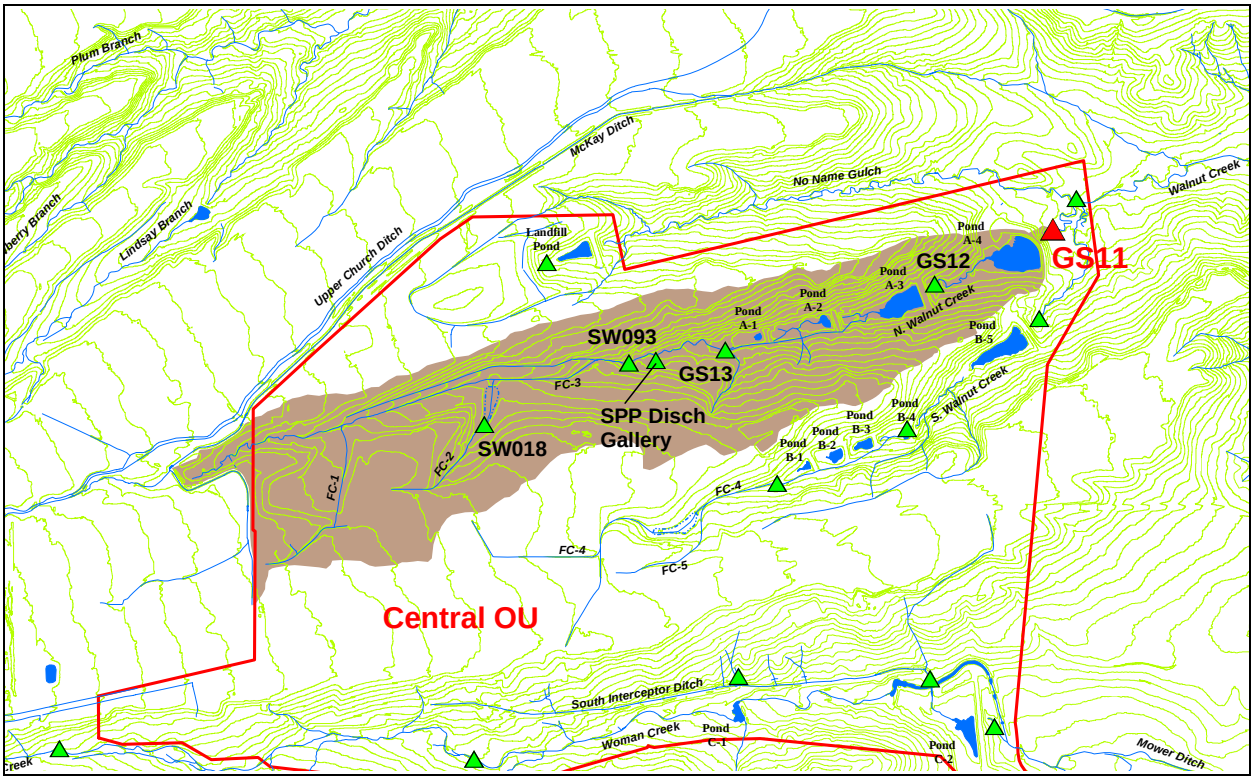



*Figure 2–26. Map Showing GS11 Drainage Area*

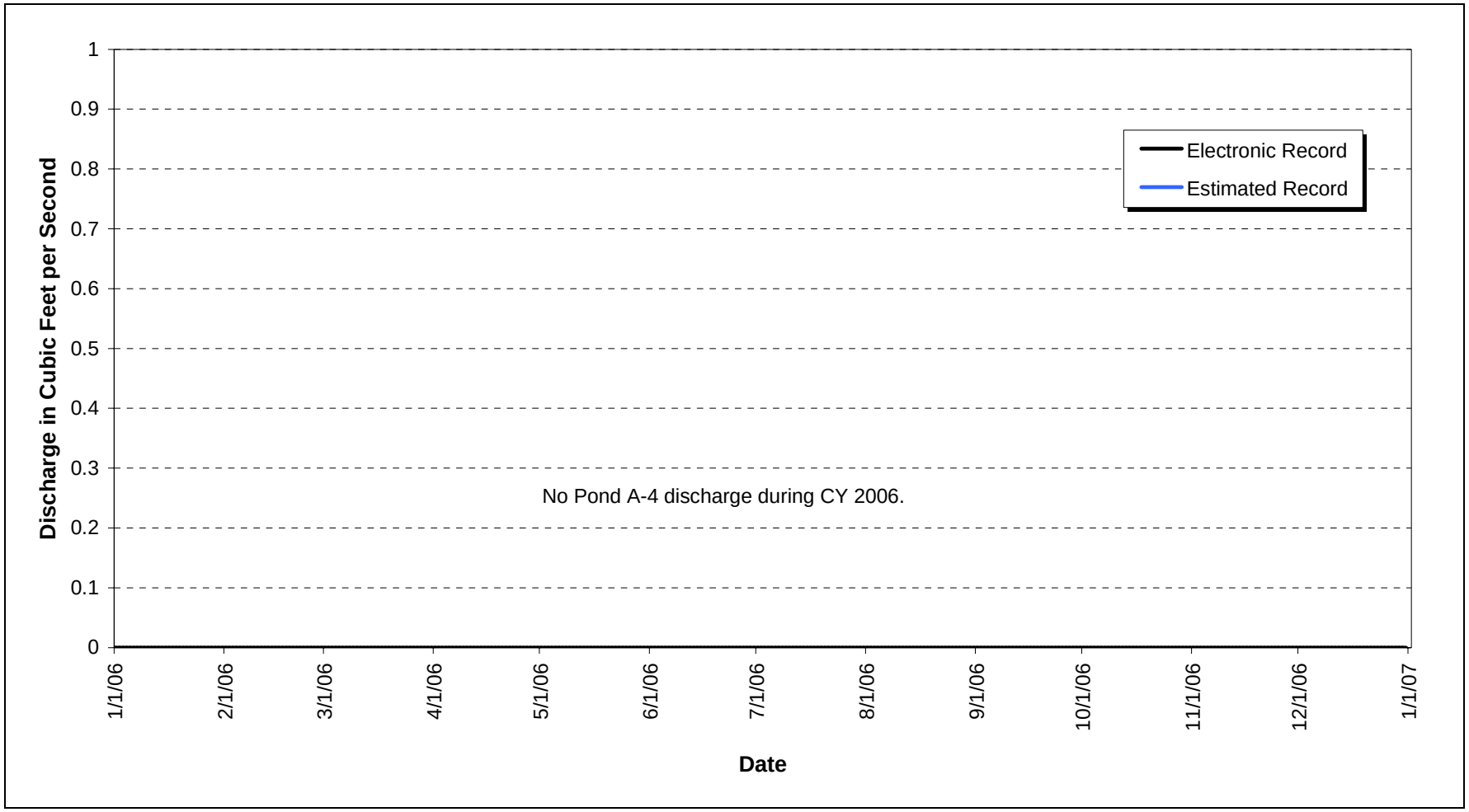



*Figure 2–27. CY 2006 Mean Daily Hydrograph at GS11: North Walnut Creek at Pond A-4 Outlet*

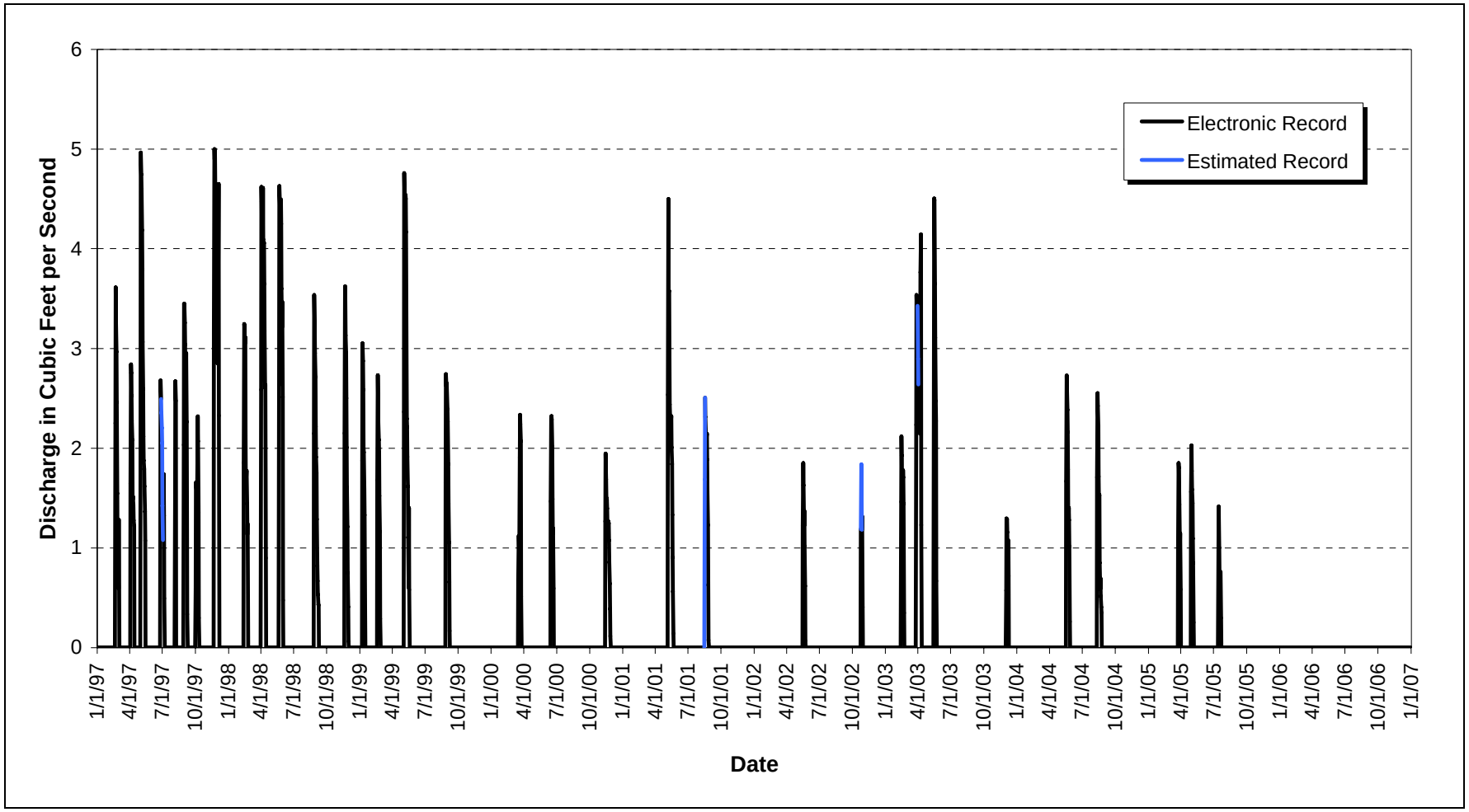



*Figure 2–28. CY 1997−2006 Mean Daily Hydrograph at GS11: North Walnut Creek at Pond A-4 Outlet*

2.2.2.9 GS12: North Walnut Creek at Pond A-3 Outlet

***Location***—North Walnut Creek at Pond A-3 outlet; State Plane: E2088569, N752633.

***Drainage Area***—The basin includes the North Walnut Creek drainage and northern portions of the COU (total of 334.2 acres).

***Period of Record***—May 13, 1992, to current year.

***Gage***—Water-stage recorder and 30-inch Parshall flume.

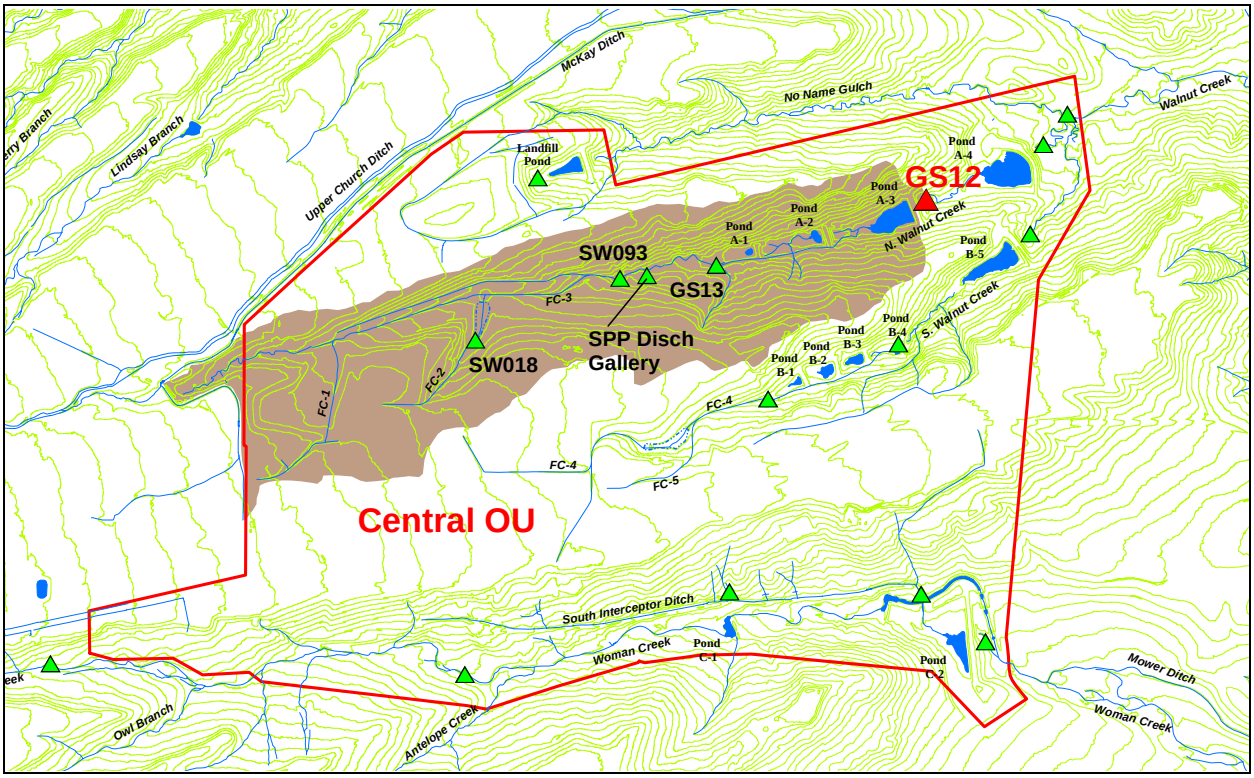



*Figure 2–29. Map Showing GS12 Drainage Area*

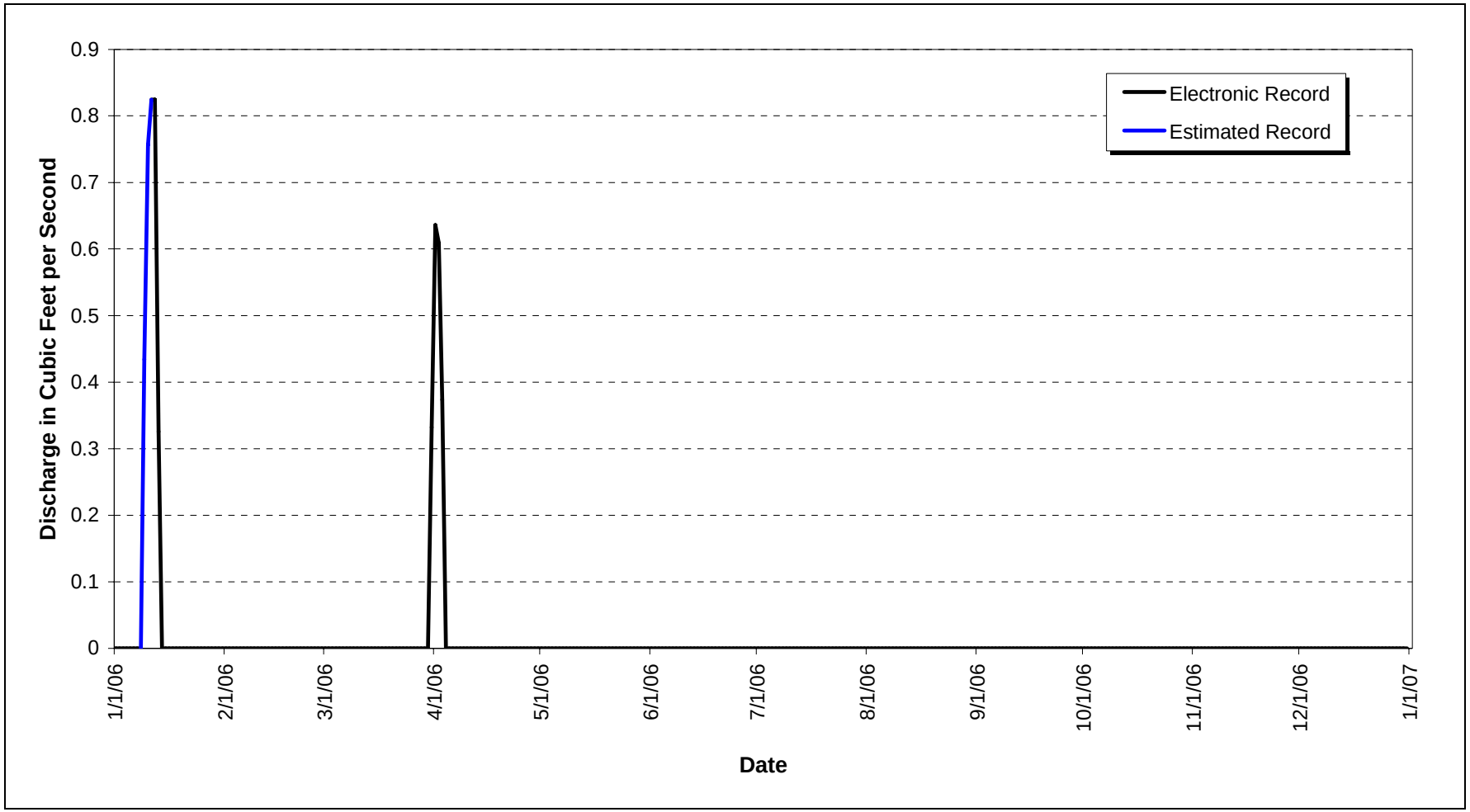



*Figure 2–30. CY 2006 Mean Daily Hydrograph at GS12: North Walnut Creek at Pond A-3 Outlet*

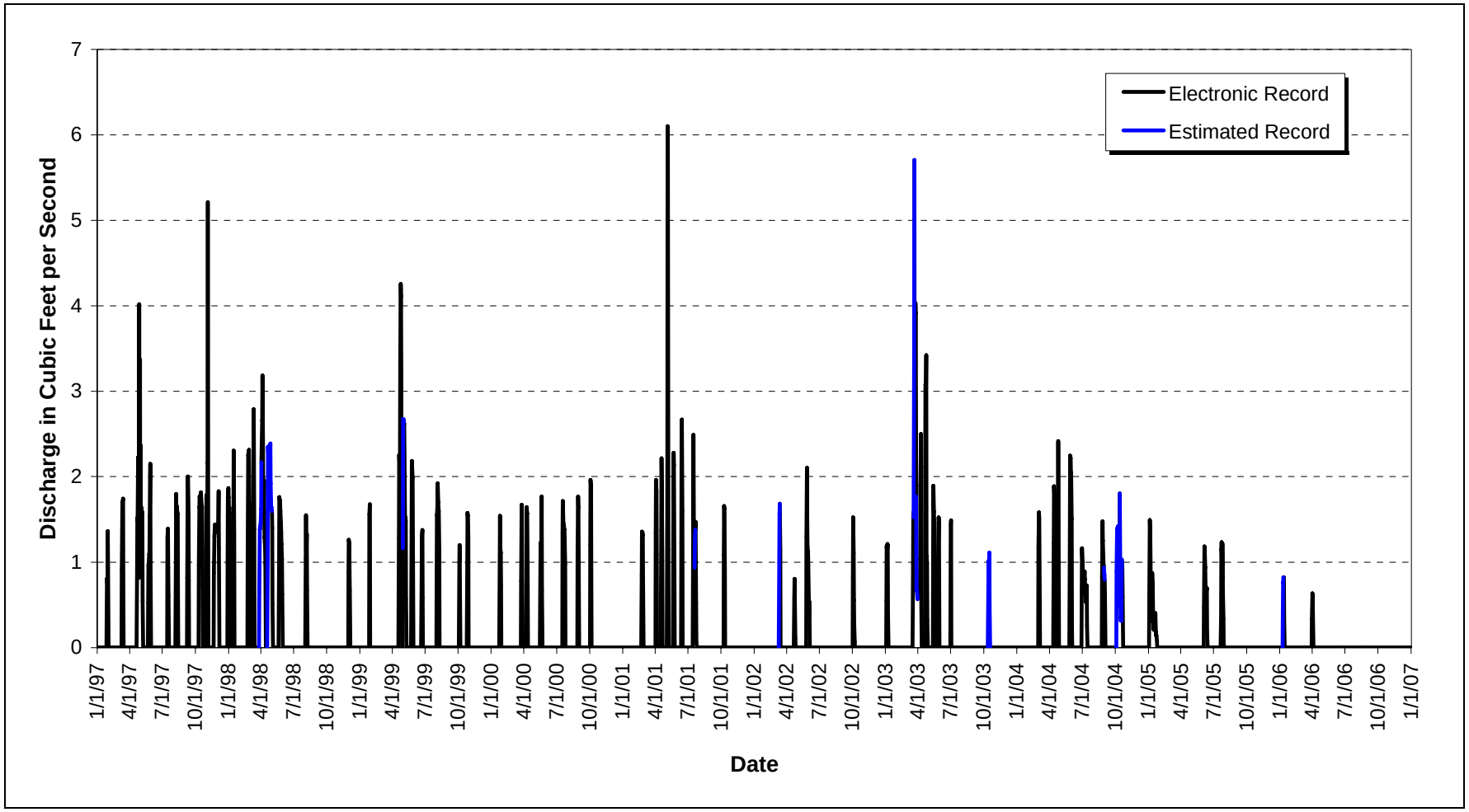



*Figure 2–31. CY 1997−2006 Mean Daily Hydrograph at GS12: North Walnut Creek at Pond A-3 Outlet*

2.2.2.10 GS13: North Walnut Creek above Pond A-1

***Location***—North Walnut Creek at A-1 Bypass; State Plane: E2086145, N751872.

***Drainage Area***—The basin includes the North Walnut Creek drainage and northwestern portions of the COU (total of 233.3 acres).

***Period of Record***—October 1, 2005, to current year.

***Gage***—Water-stage recorder and 6-inch Parshall flume.

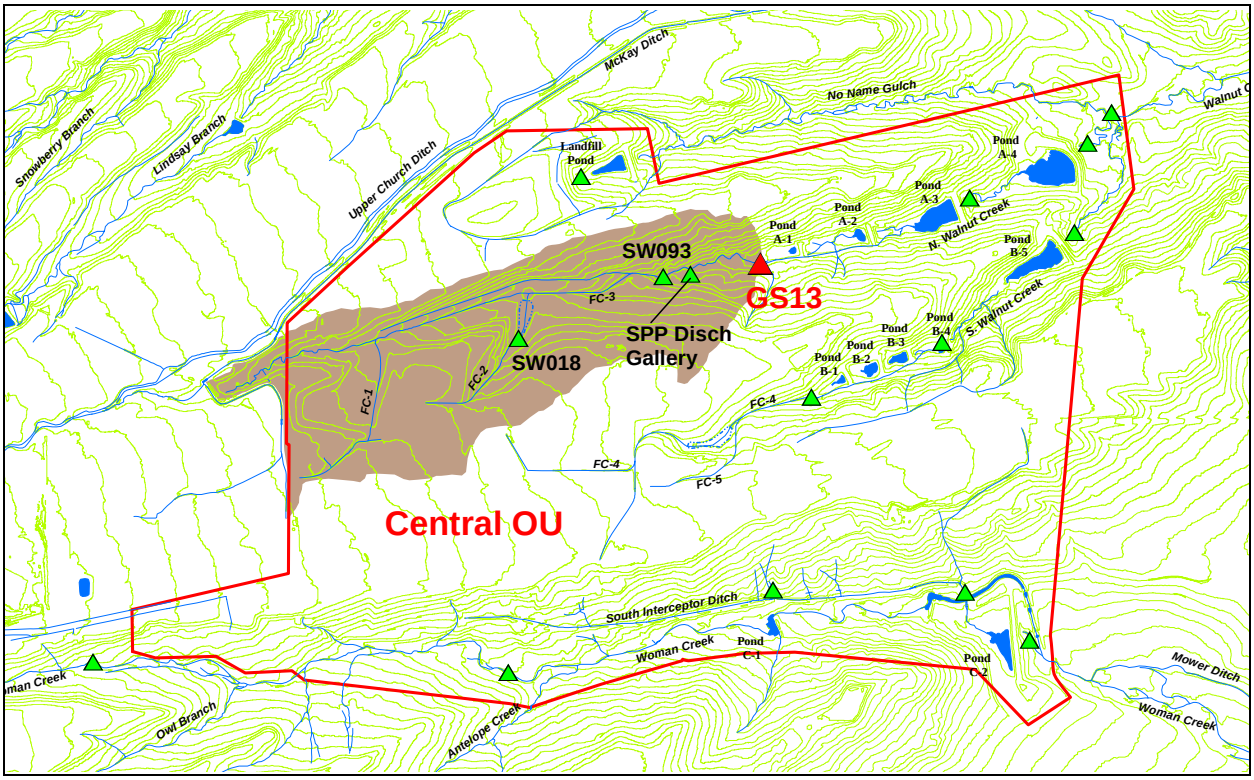



*Figure 2–32. Map Showing GS13 Drainage Area*

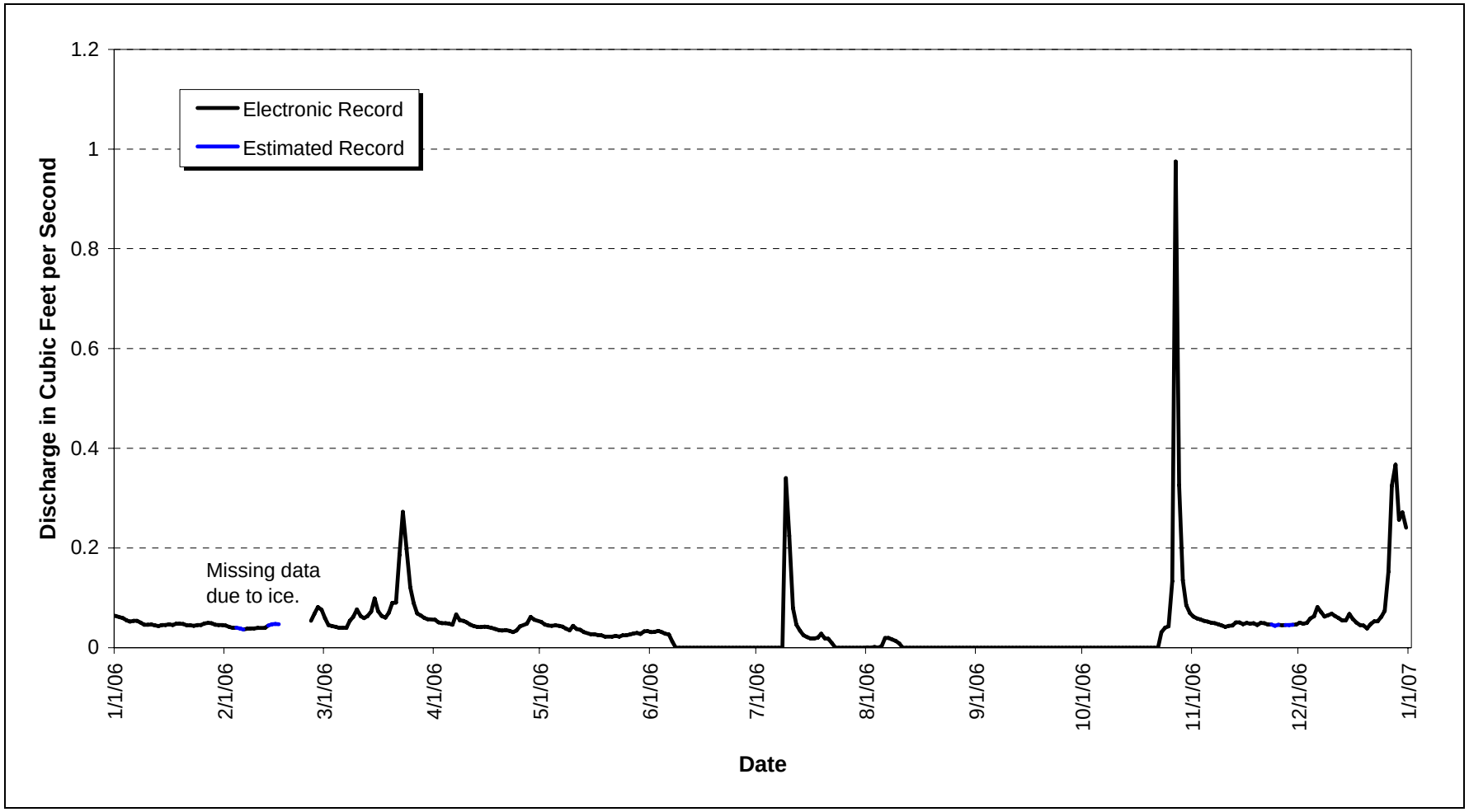



*Figure 2–33. CY 2006 Mean Daily Hydrograph at GS13: North Walnut Creek at Pond A-1 Bypass*

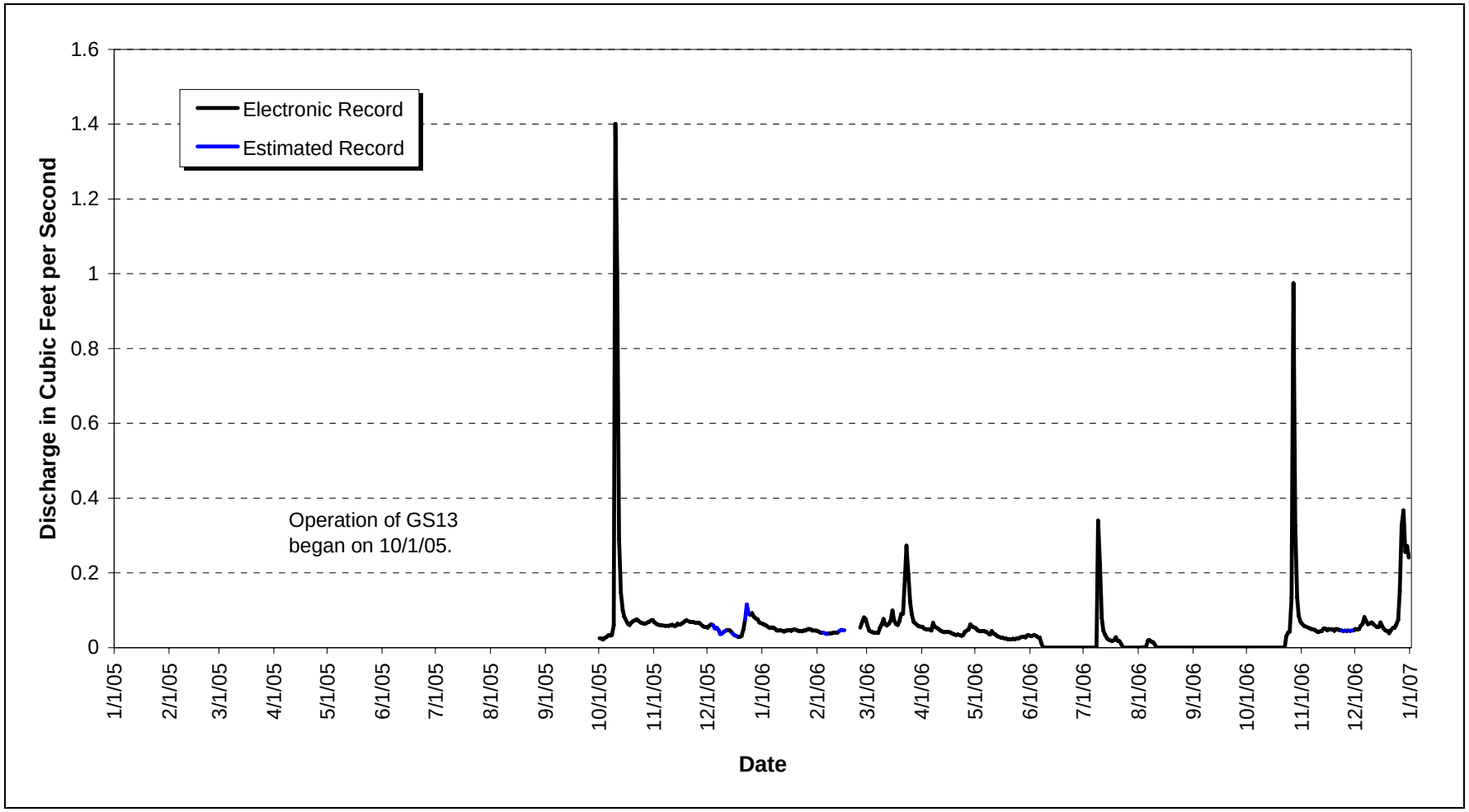



*Figure 2–34. CY 2005−2006 Mean Daily Hydrograph at GS13: North Walnut Creek at Pond A-1 Bypass*

2.2.2.11 GS31: Woman Creek at Pond C-2 Outlet

***Location***—Pond C-2 outlet; State Plane: E2089262, N747515.

***Drainage Area***—The basin includes a portion of the southern COU draining to the SID and the area surrounding Pond C-2 (total of 204.1 acres).

***Period of Record***—October 1, 1996, to current year.

***Gage***—Water-stage recorder and 24-inch Parshall flume.

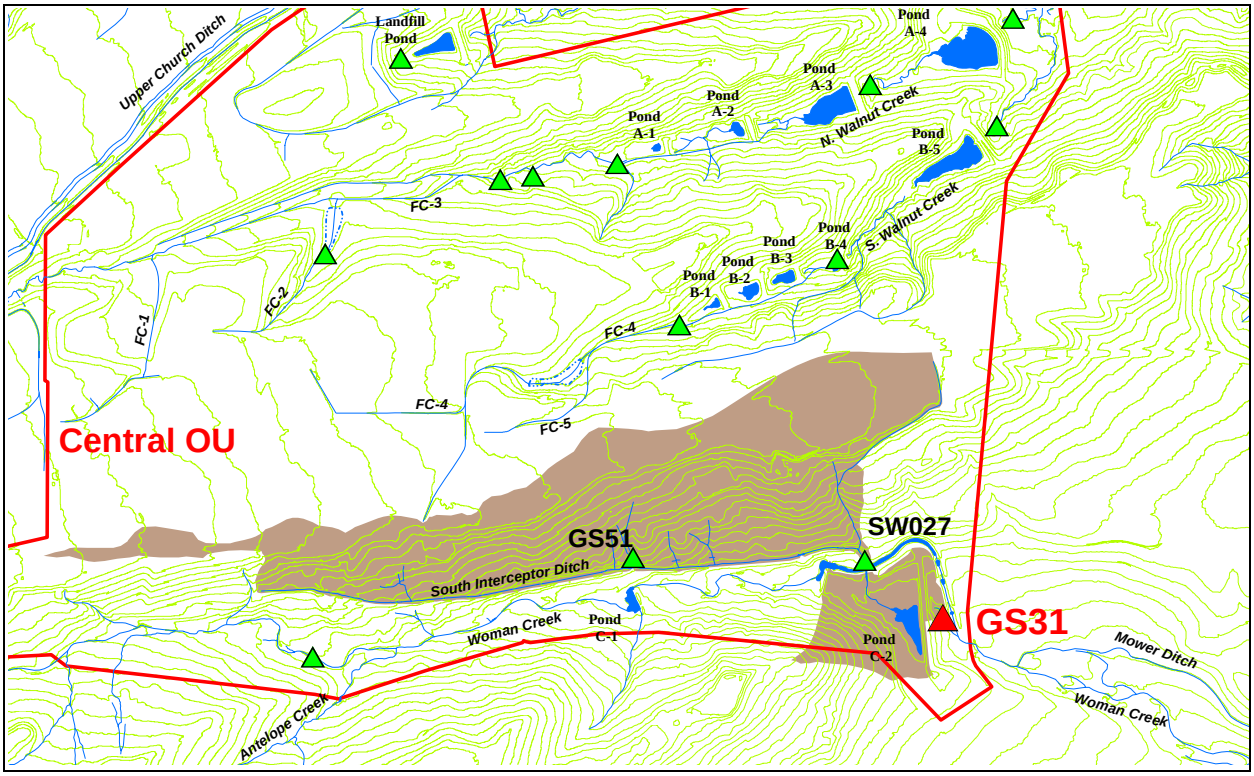



*Figure 2–35. Map Showing GS31 Drainage Area*

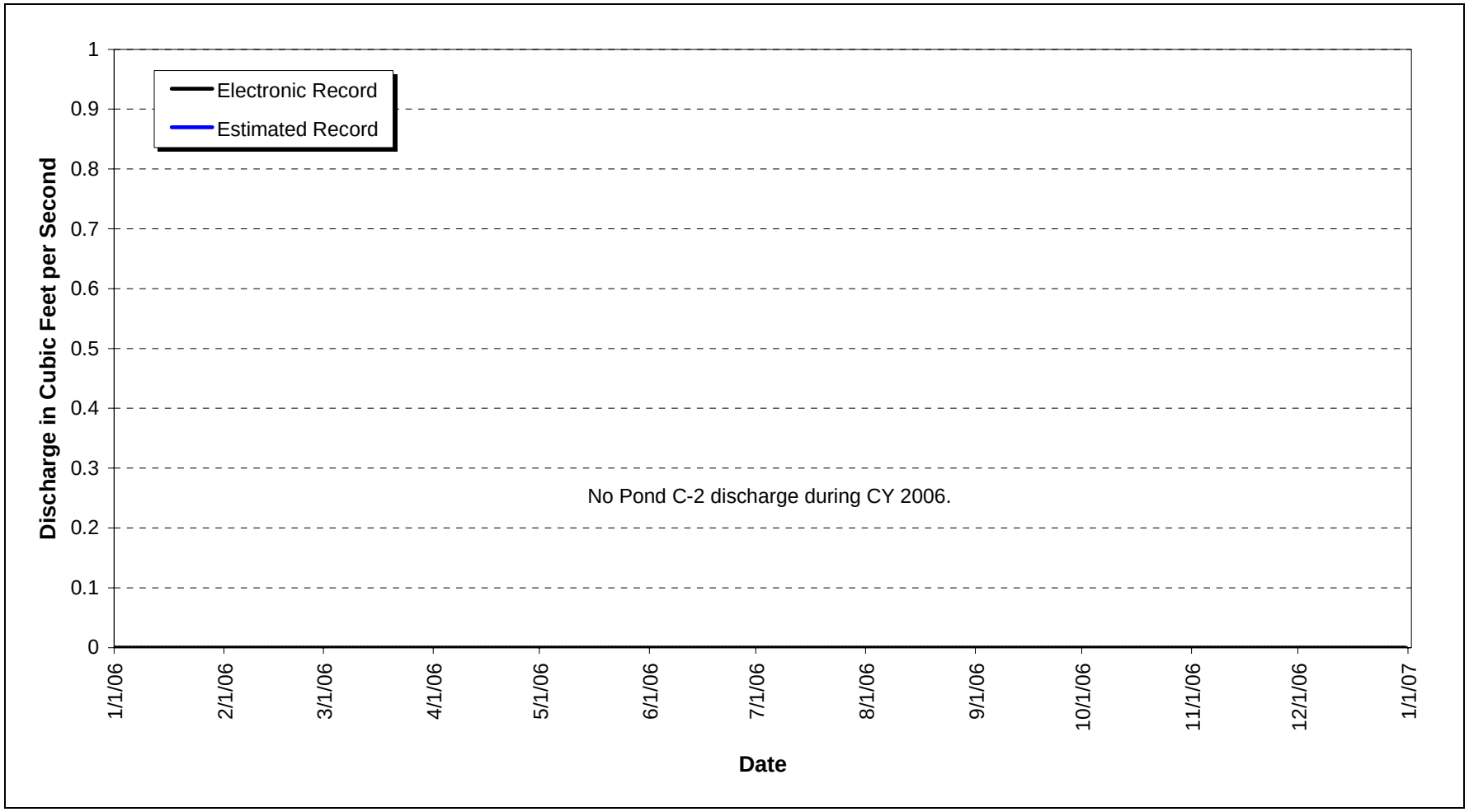



*Figure 2–36. CY 2006 Mean Daily Hydrograph at GS31: Woman Creek at Pond C-2 Outlet*

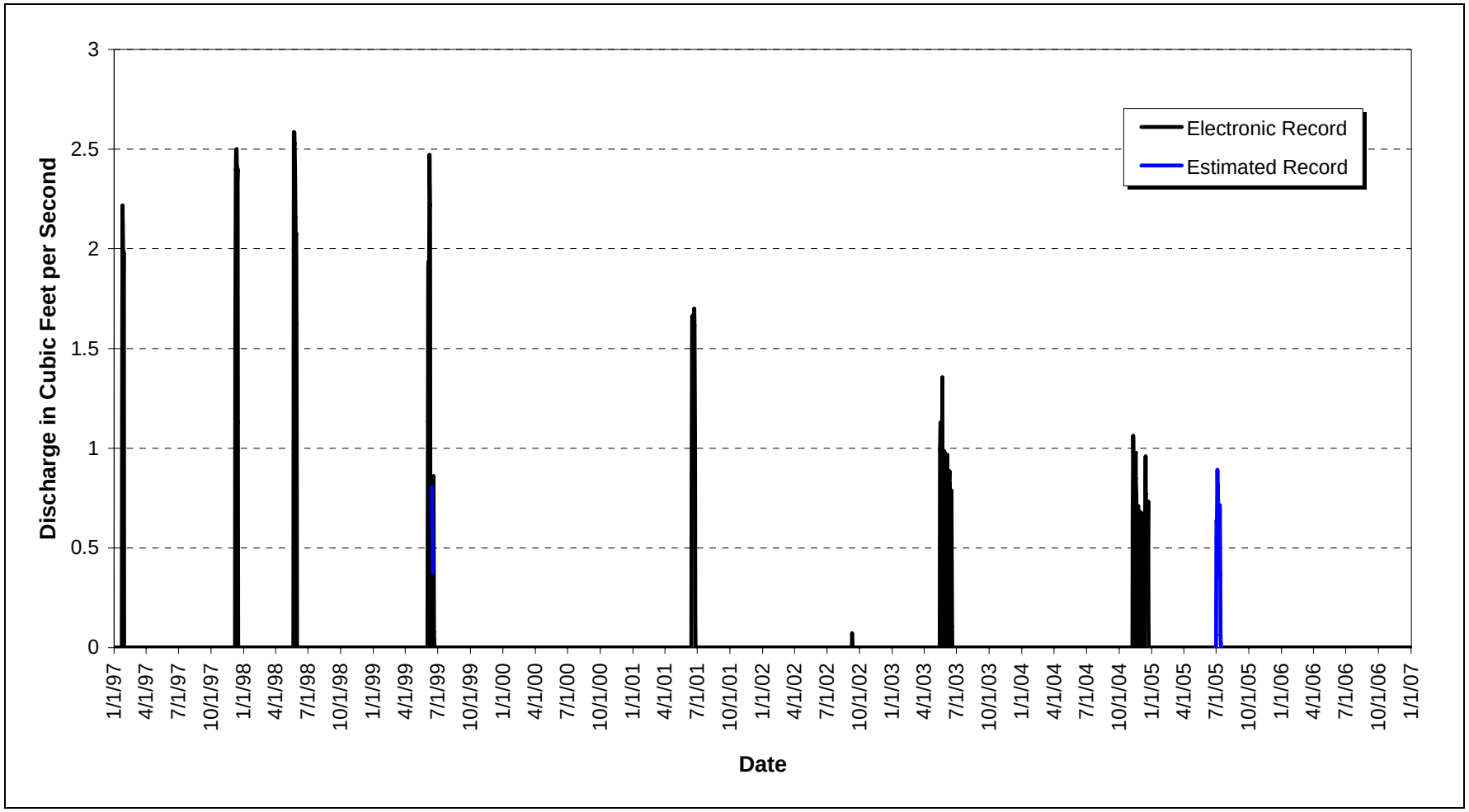



*Figure 2–37. CY 1997−2006 Mean Daily Hydrograph at GS31: Woman Creek at Pond C-2 Outlet*

2.2.2.12 GS33: No Name Gulch at Walnut Creek

***Location***—No Name Gulch at Walnut Creek; State Plane: E2090209, N753621.

***Drainage Area***—The basin is the No Name Gulch drainage (total of 295.3 acres).

***Period of Record***—September 16, 1997, to current year.

***Gage***—Water-stage recorder and 9.5-inch Parshall flume.

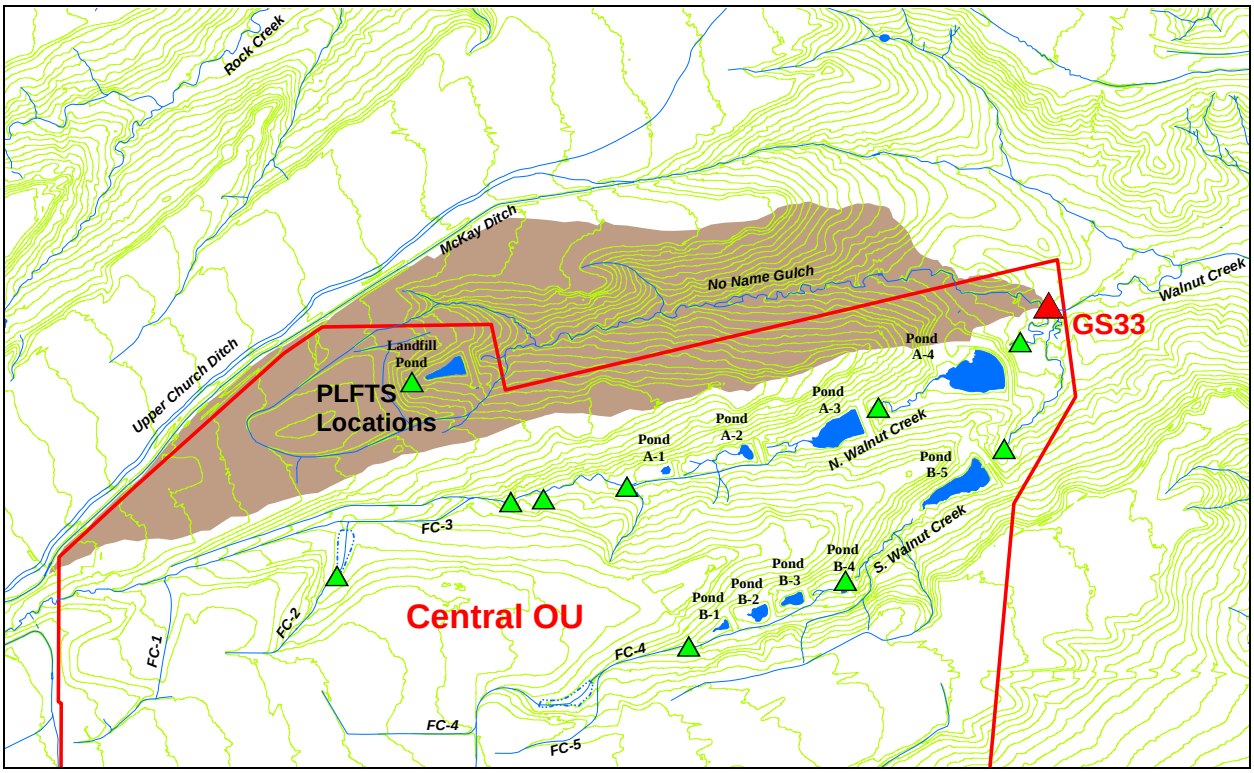



*Figure 2–38. Map Showing GS33 Drainage Area*

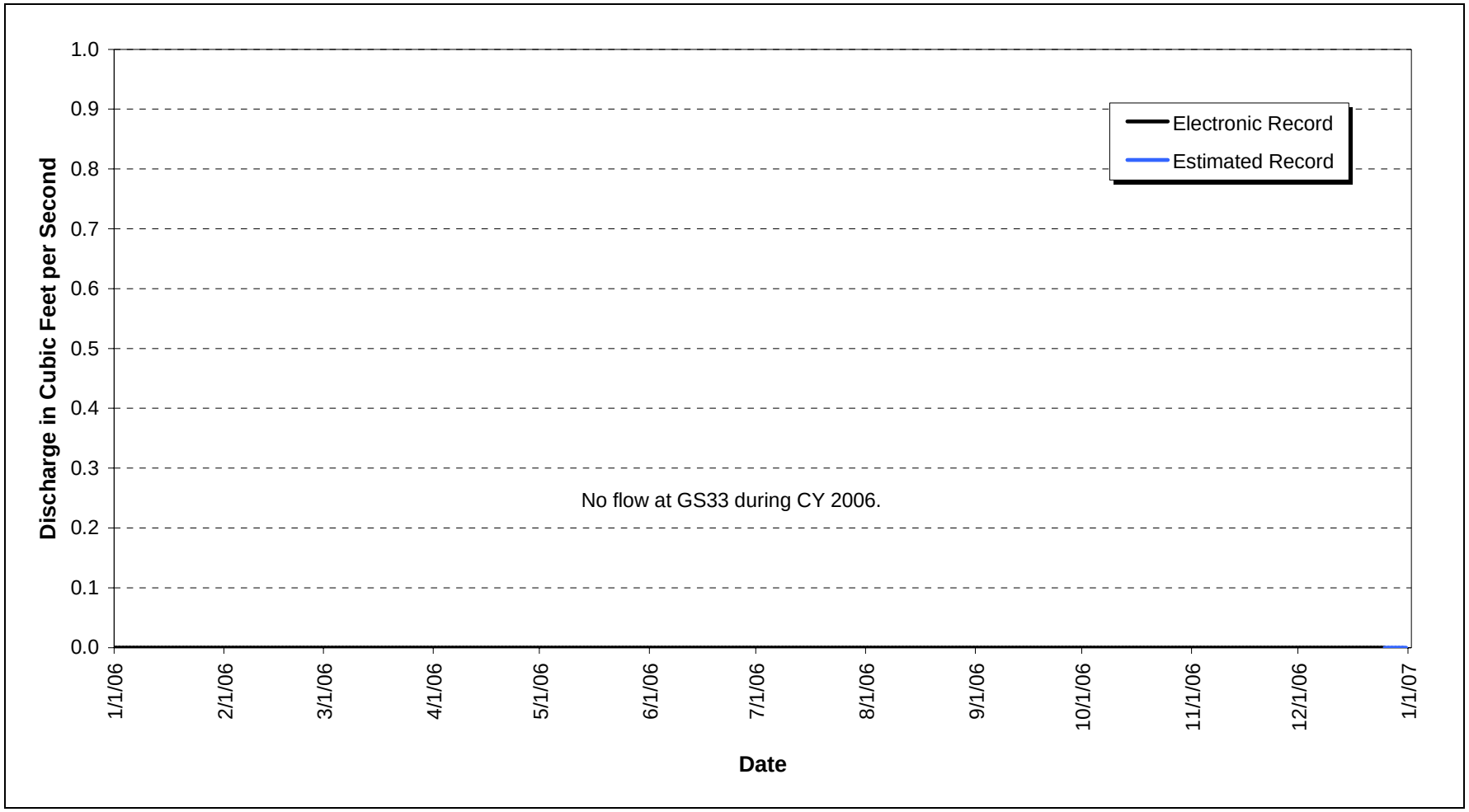



*Figure 2–39. CY 2006 Mean Daily Hydrograph at GS33: No Name Gulch at Walnut Creek*

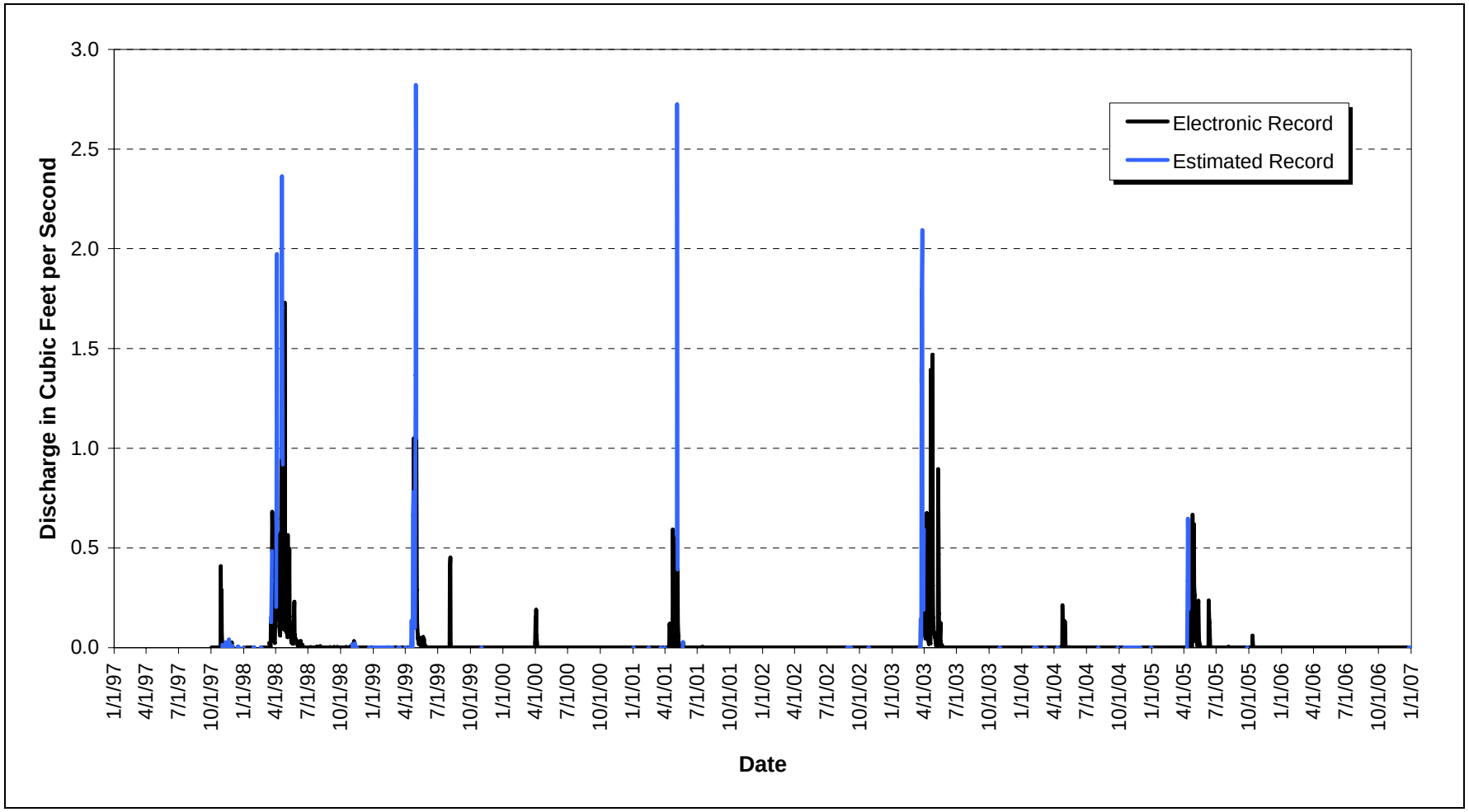



*Figure 2–40. CY 1997−2006 Mean Daily Hydrograph at GS33: No Name Gulch at Walnut Creek*

2.2.2.13 GS51: Ditch South of 903 Pad

***Location***—Ditch south of 903 Pad; State Plane: E2086295, N748107.

***Drainage Area***—The basin includes an area south and west of the former 903 Pad (total of 16.0 acres).

***Period of Record***—August 13, 2001, to current year.

***Gage***—Water-stage recorder and 0.75-foot H-flume.

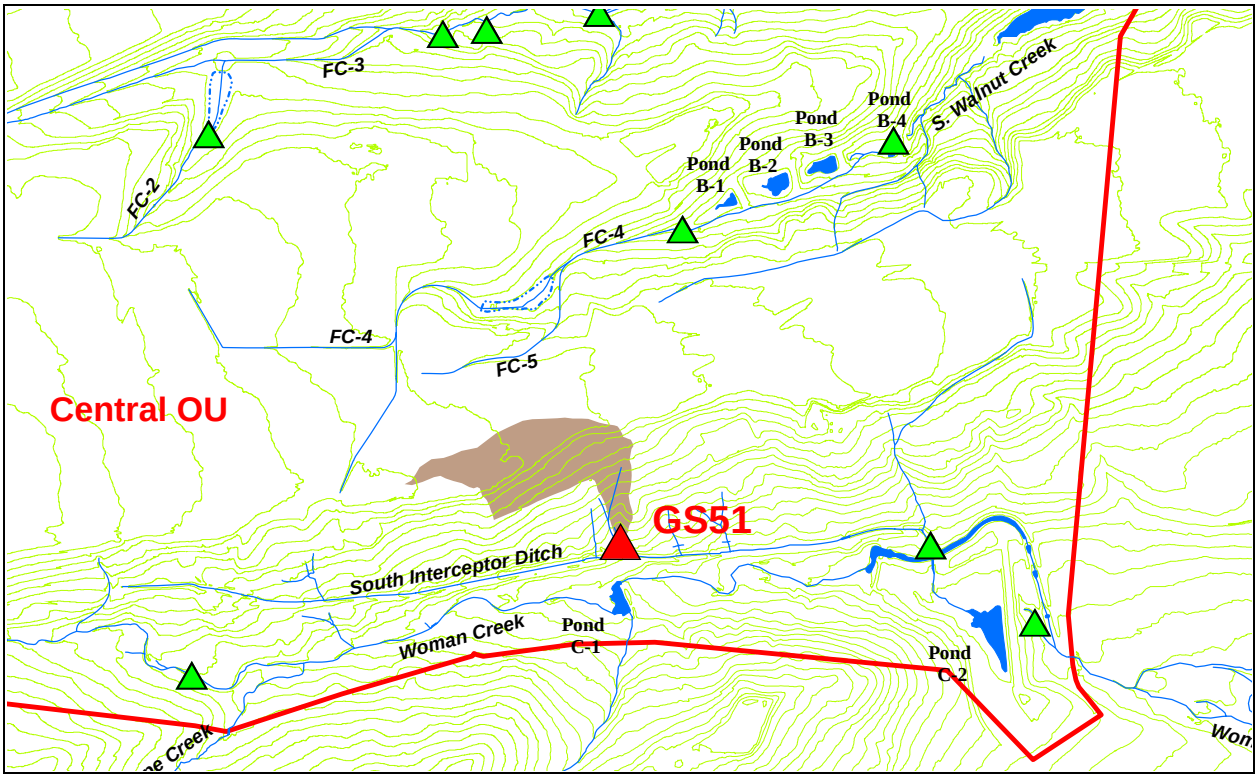



*Figure 2–41. Map Showing GS51 Drainage Area*

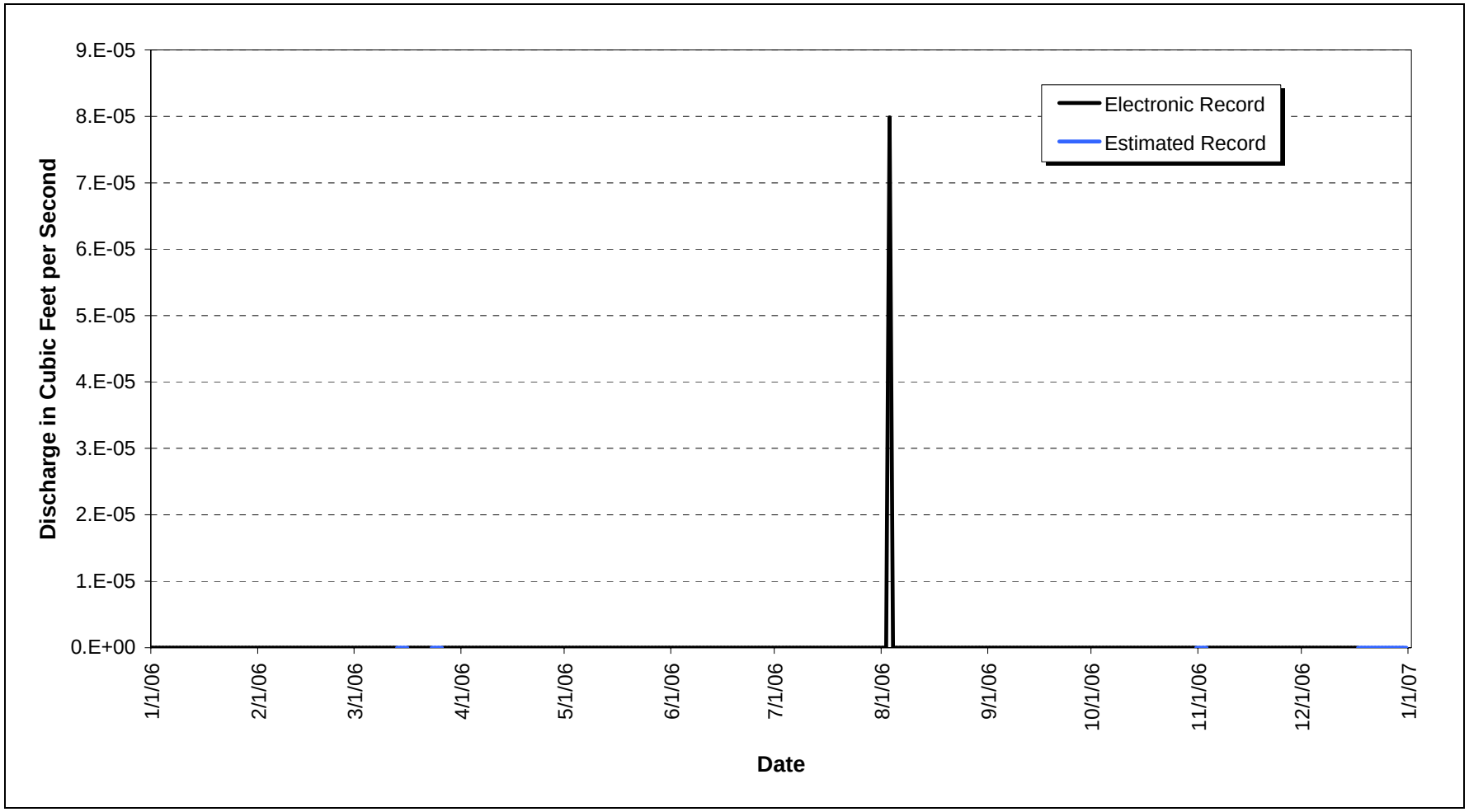



*Figure 2–42. CY 2006 Mean Daily Hydrograph at GS51: Ditch South of 903 Pad*

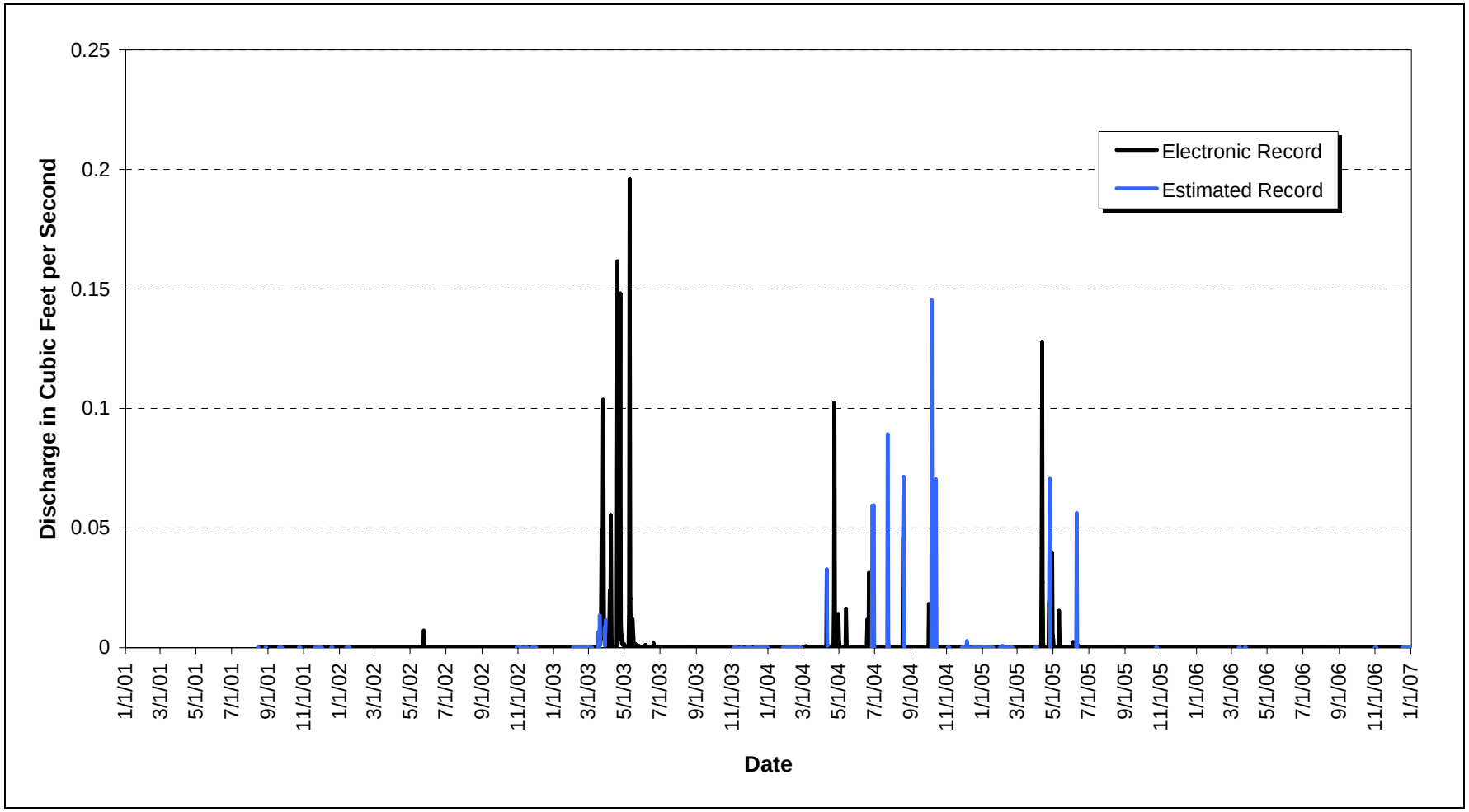



*Figure 2–43. CY 2001−2006 Mean Daily Hydrograph at GS51: Ditch South of 903 Pad*

2.2.2.14 GS59: Woman Creek Upstream of Antelope Springs Confluence

***Location***—Woman Creek 900 feet upstream of Antelope Springs confluence; State Plane: E2083231, N747137.

***Drainage Area***—The basin includes upstream reaches of the Woman Creek; areas west of Highway 93 also contribute runoff (total drainage acreage undetermined).

***Period of Record***—November 20, 2002, to current year.

***Gage***—Water-stage recorder and 1.5-foot Parshall flume.

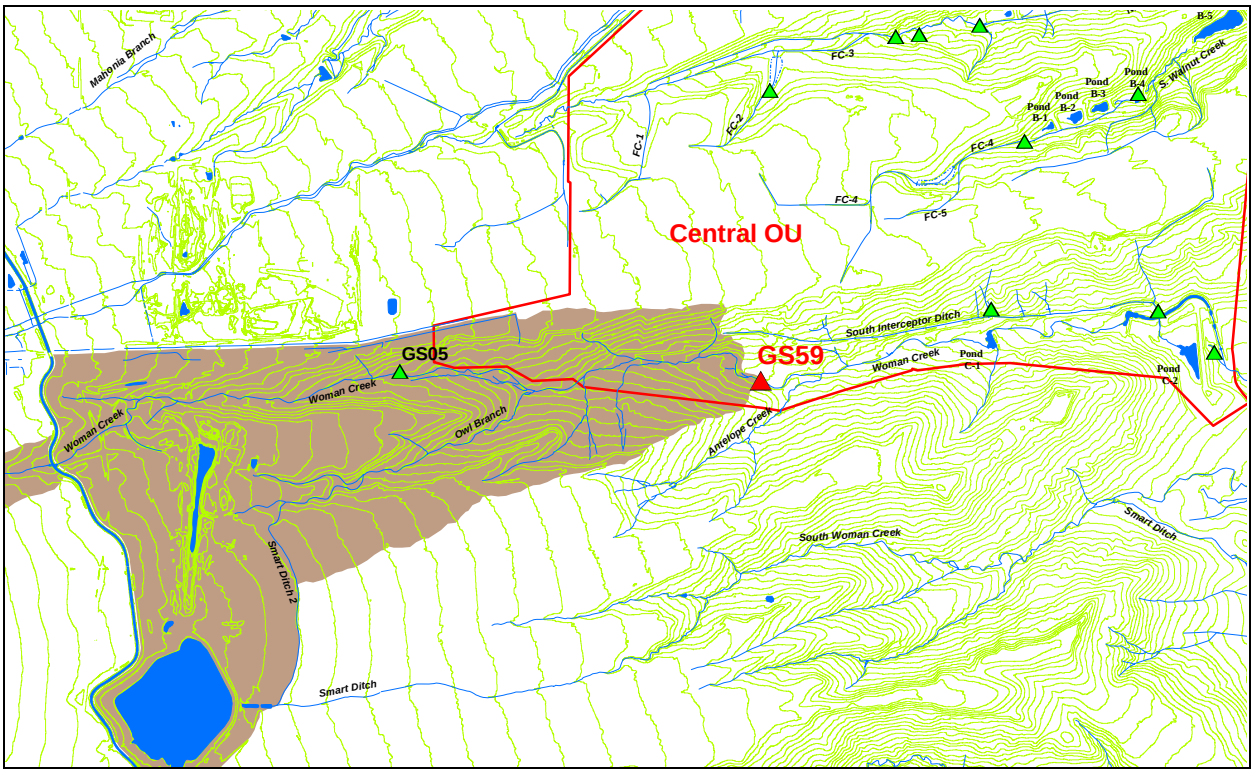



*Figure 2–44. Map Showing GS59 Drainage Area*

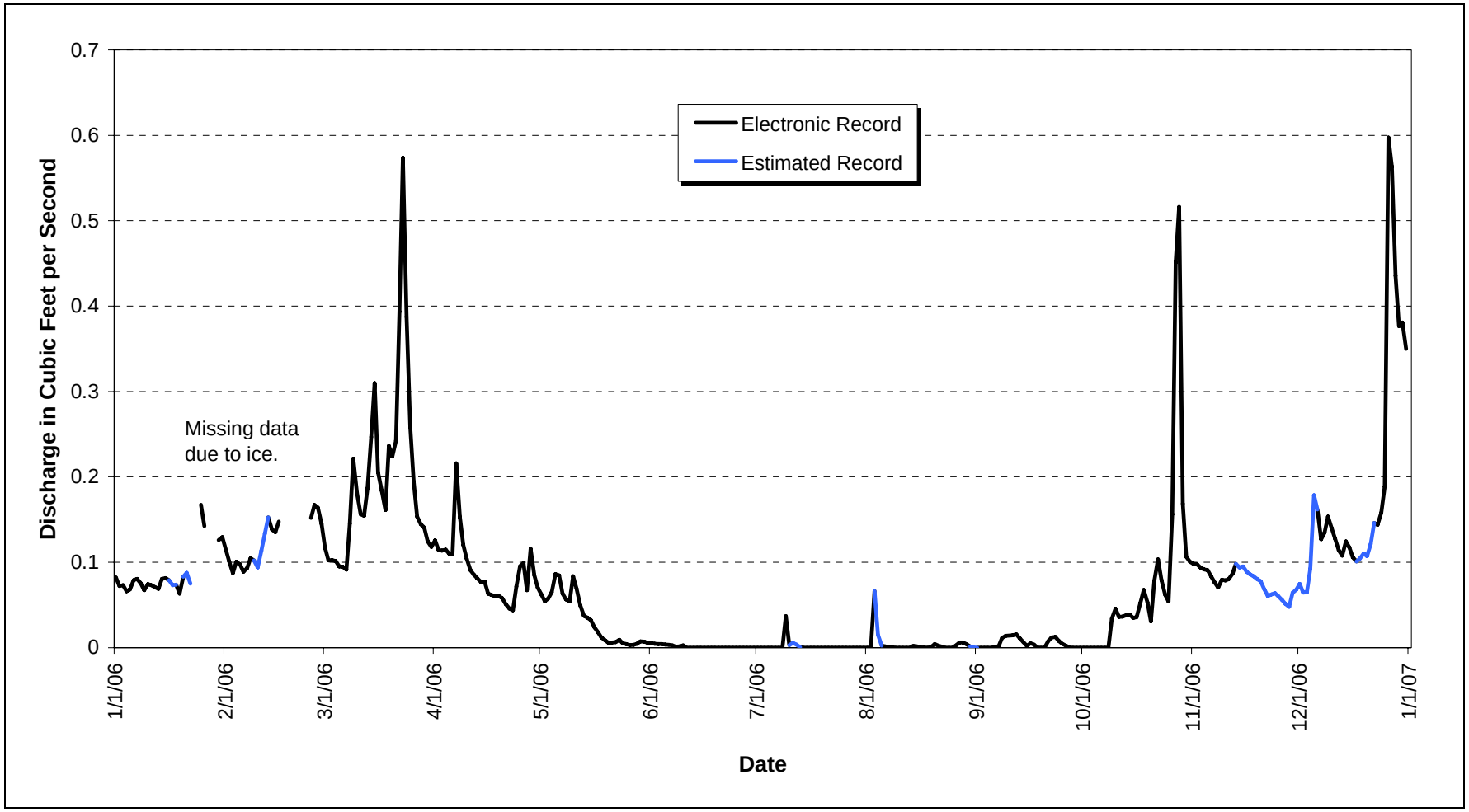



*Figure 2–45. CY 2006 Mean Daily Hydrograph at GS59: Woman Creek Upstream of Antelope Springs Confluence*

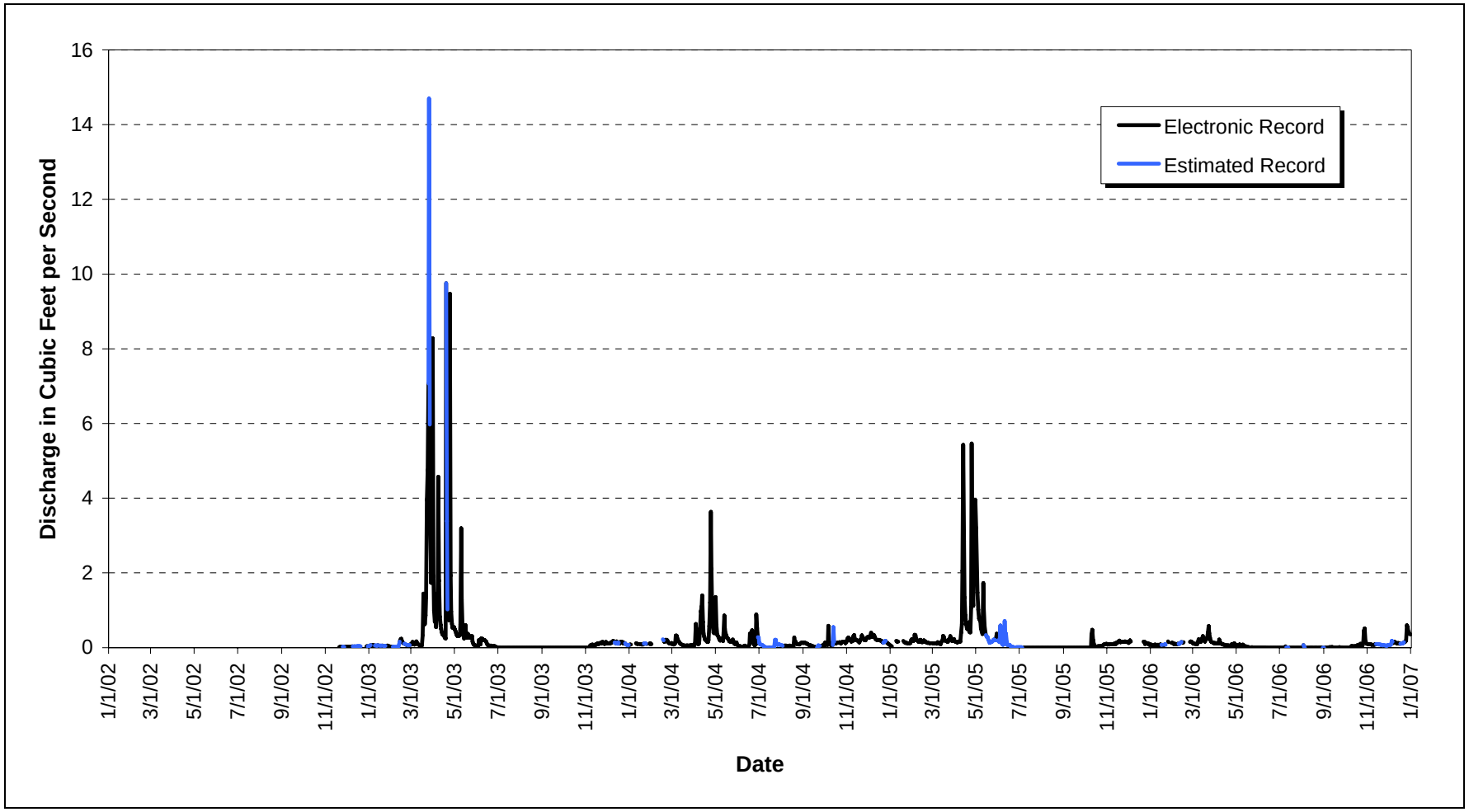



*Figure 2–46. CY 2002−2006 Mean Daily Hydrograph at GS59: Woman Creek Upstream of Antelope Springs Confluence*

2.2.2.15 SW018: Functional Channel (FC) 2 at FC-2 Wetland

***Location***—FC-2 drainage just upstream of FC-2 wetland; State Plane: E2083351, N751006.

***Drainage Area***—The basin includes FC-2 areas tributary to North Walnut Creek (total of 42.4 acres).

***Period of Record***—October 10, 2003, to current year.

***Gage***—Water-stage recorder and 1-foot Parshall flume through September 12, 2006. One-foot H flume installed on September 13, 2006.

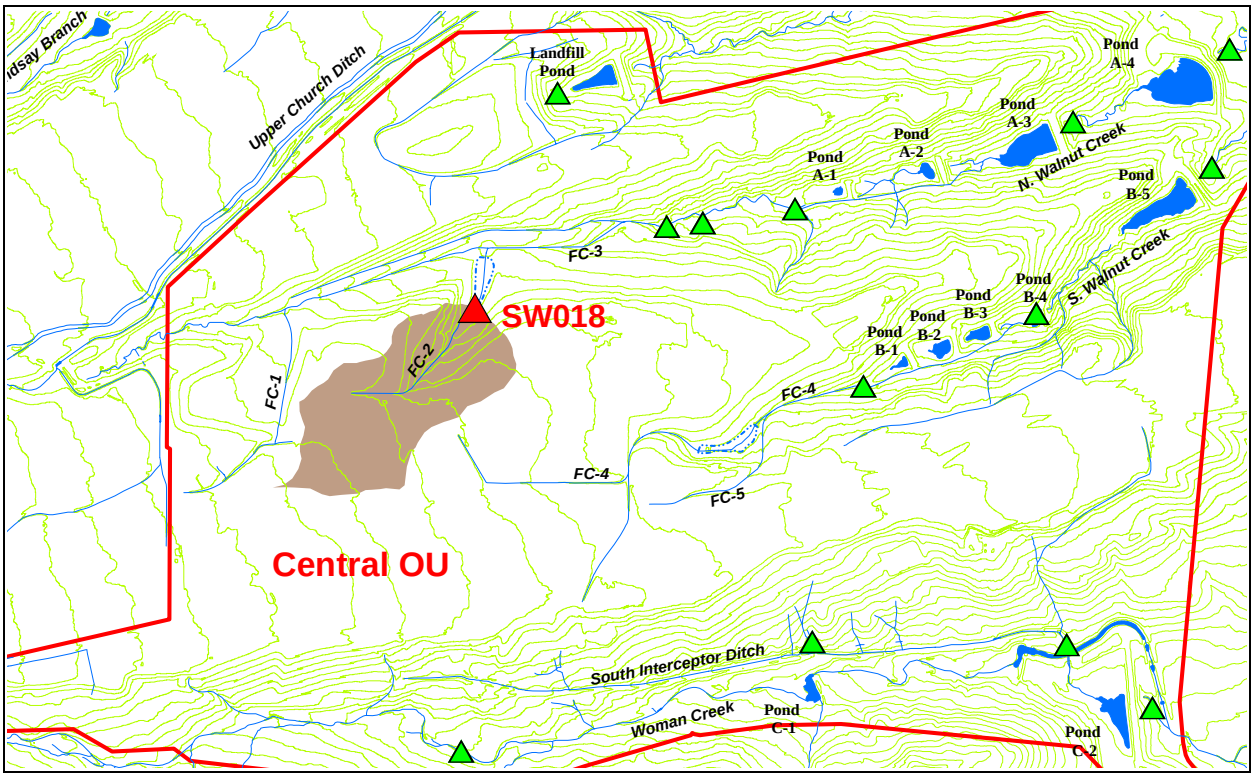



*Figure 2–47. Map Showing SW018 Drainage Area*

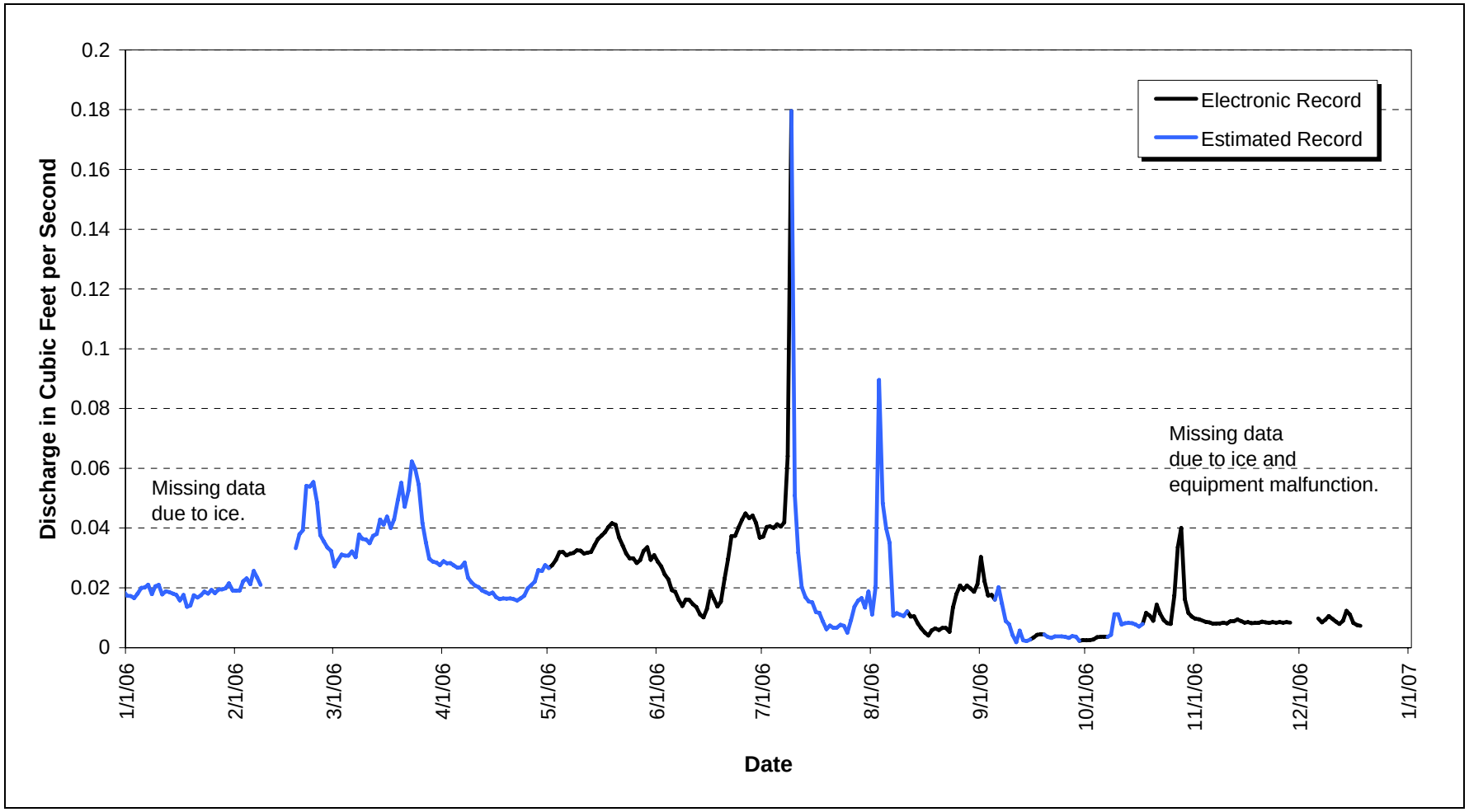



*Figure 2–48. CY 2006 Mean Daily Hydrograph at SW018: FC-2 at FC-2 Wetland*

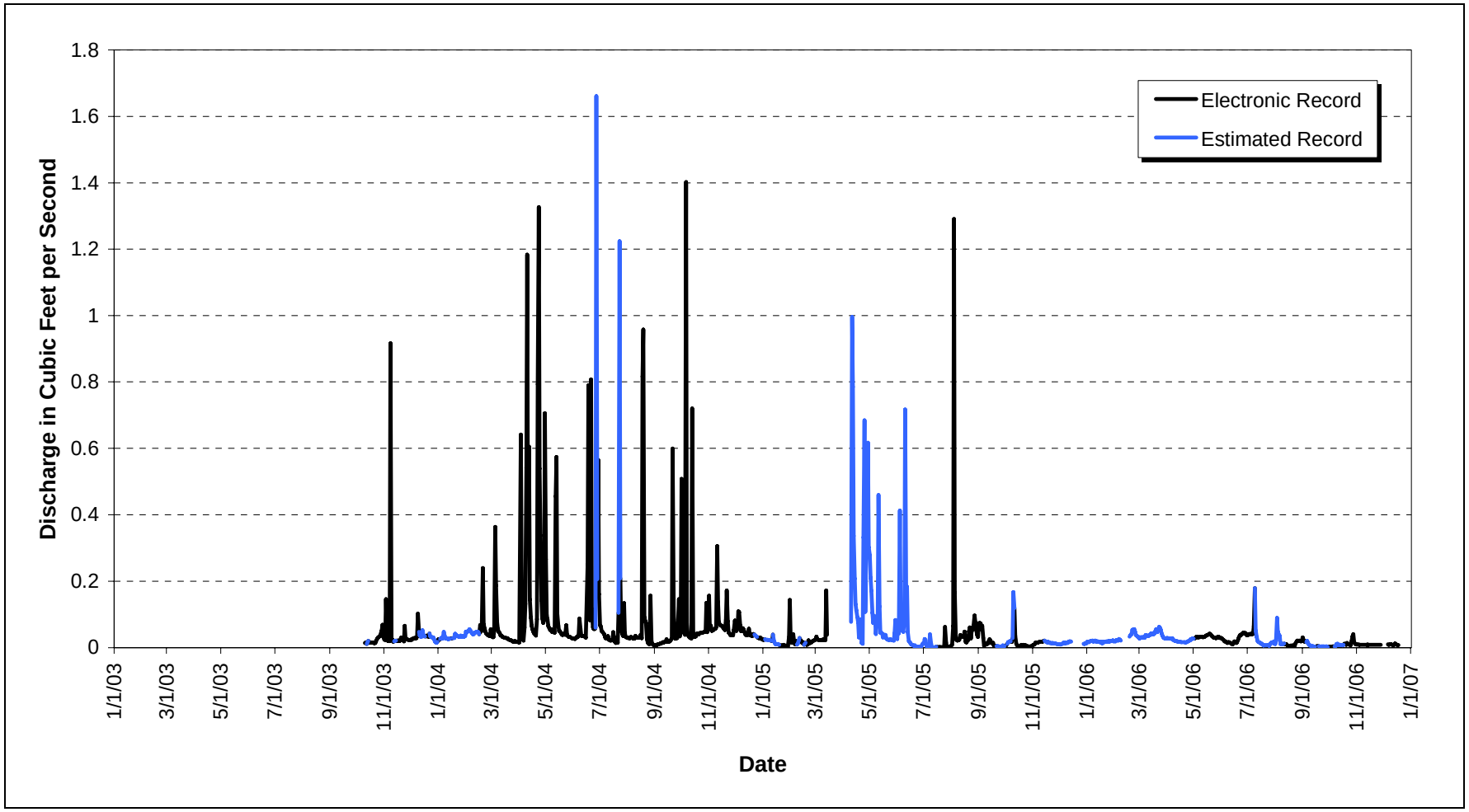



*Figure 2–49. CY 2003−2006 Mean Daily Hydrograph at SW018: FC-2 at FC-2 Wetland*

2.2.2.16 SW027: SID at Pond C-2

***Location***—East end of SID at Pond C-2; State Plane: E2088515, N748067.

***Drainage Area***—The basin includes a portion of the southern COU drained by the SID (total of 177.6 acres).

***Period of Record***—September 11, 1991, to current year.

***Gage***—Water-stage recorder and dual, parallel 120° V-notch weirs.

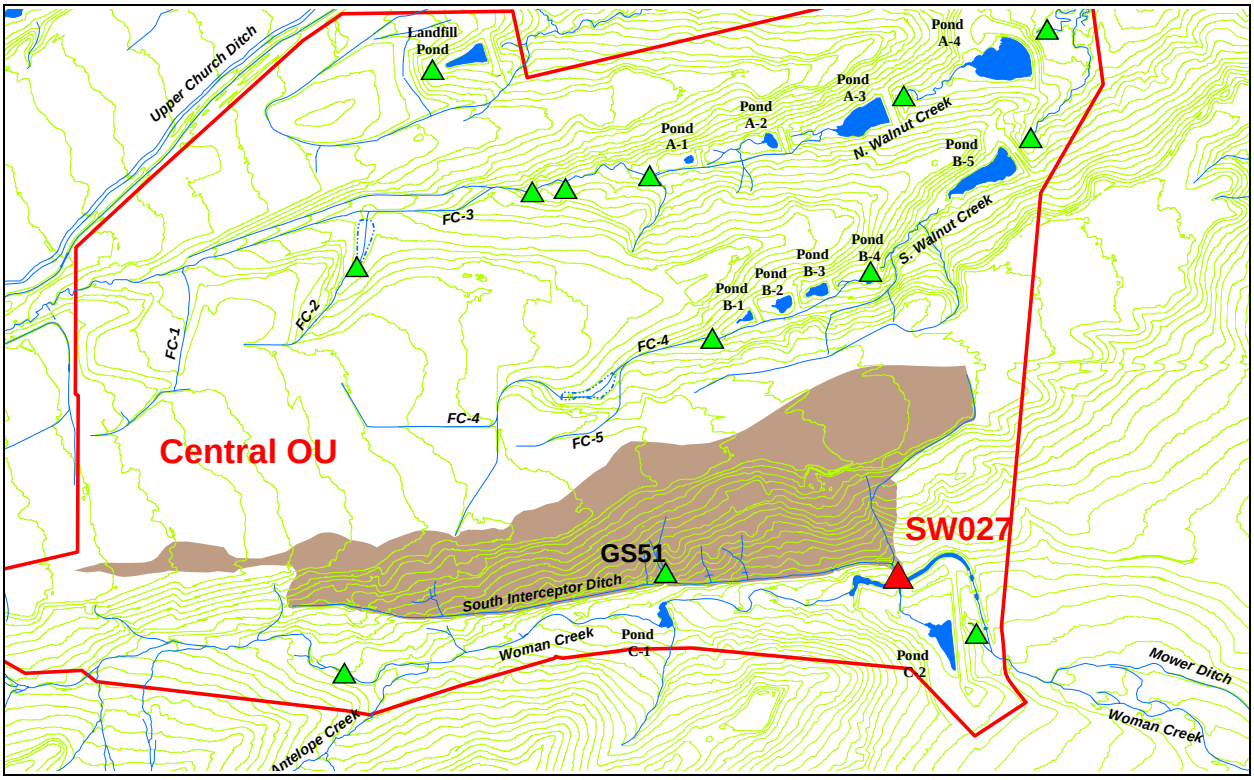



*Figure 2–50. Map Showing SW027 Drainage Area*

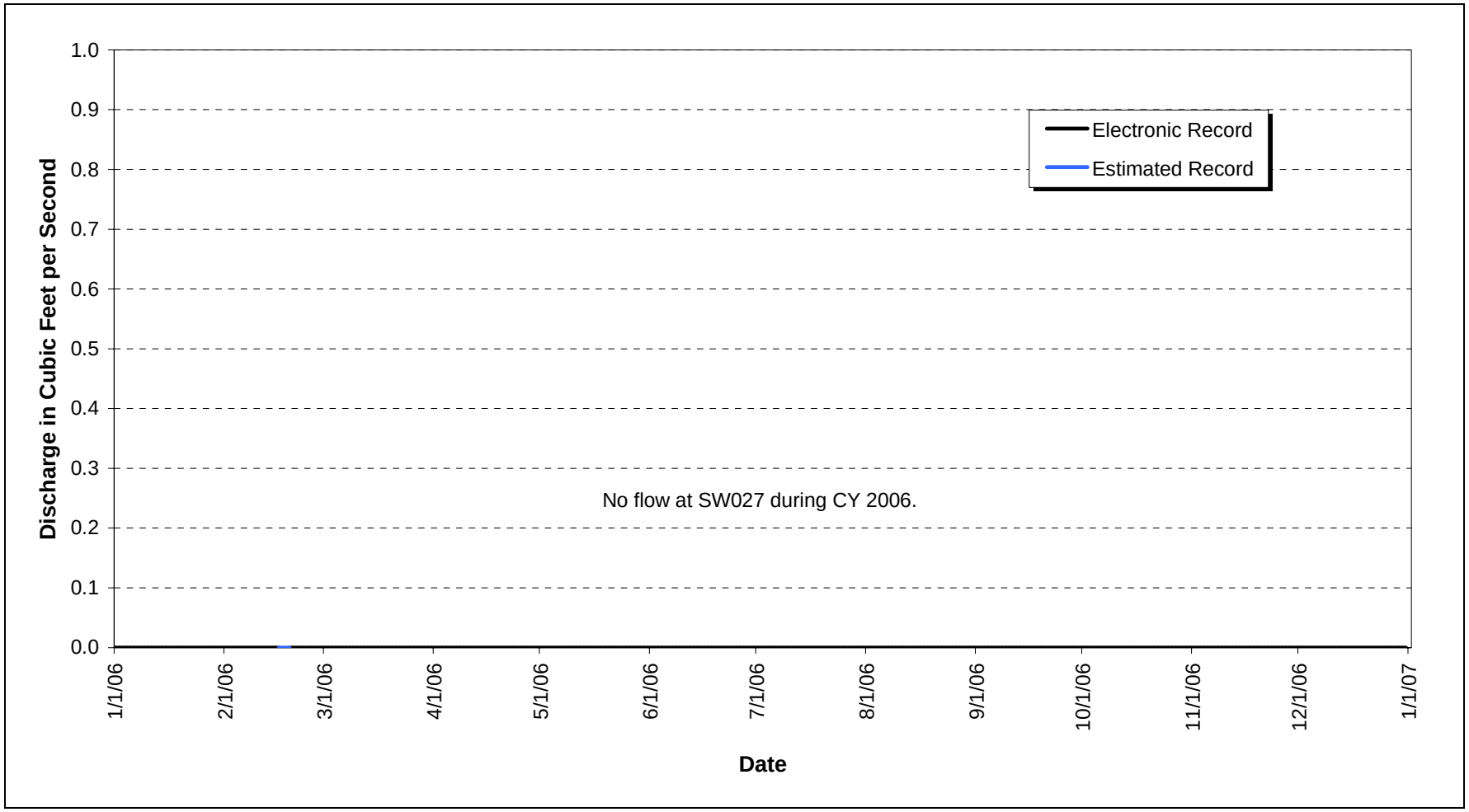



*Figure 2–51. CY 2006 Mean Daily Hydrograph at SW027: SID at Pond C-2*

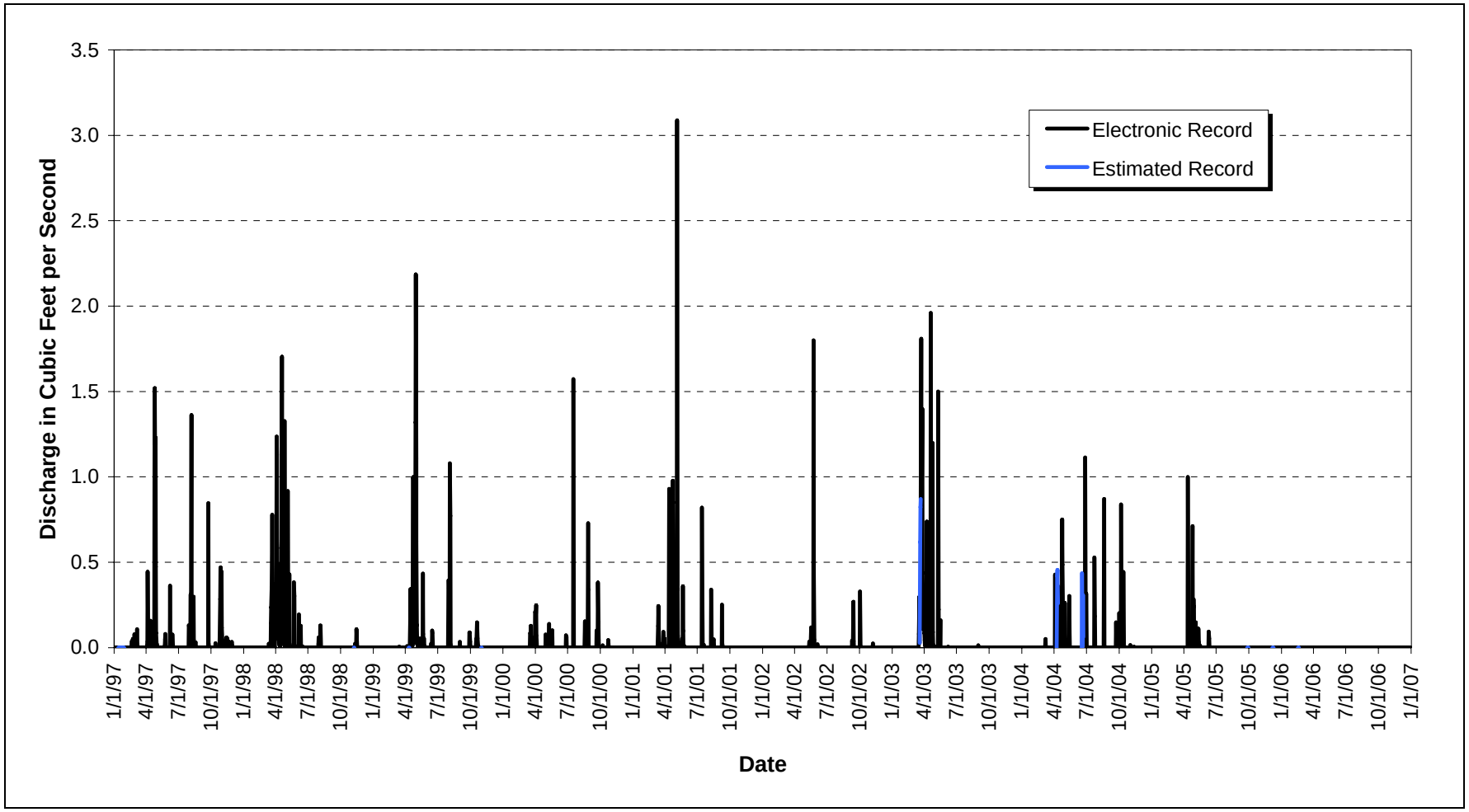



*Figure 2–52. CY 1997−2006 Mean Daily Hydrograph at SW027: SID at Pond C-2*

2.2.2.17 SW093: North Walnut Creek 1,300 feet Upstream of Pond A-1 Bypass

***Location***—North Walnut Creek 1,300 feet above Pond A-1 Bypass; State Plane: E2085026, N751720.

***Drainage Area***—The basin includes the northwestern portion of the COU drained by FC-3 (total of 192.5 acres).

***Period of Record***—September 11, 1991, to current year.

***Gage***—Water-stage recorder and 36-inch suppressed, rectangular, sharp-crested weir to January 27, 2003; rated stream section during new flume construction (SW093T; January 27, 2003−May 29, 2003). Three-foot H flume starting May 29, 2003.

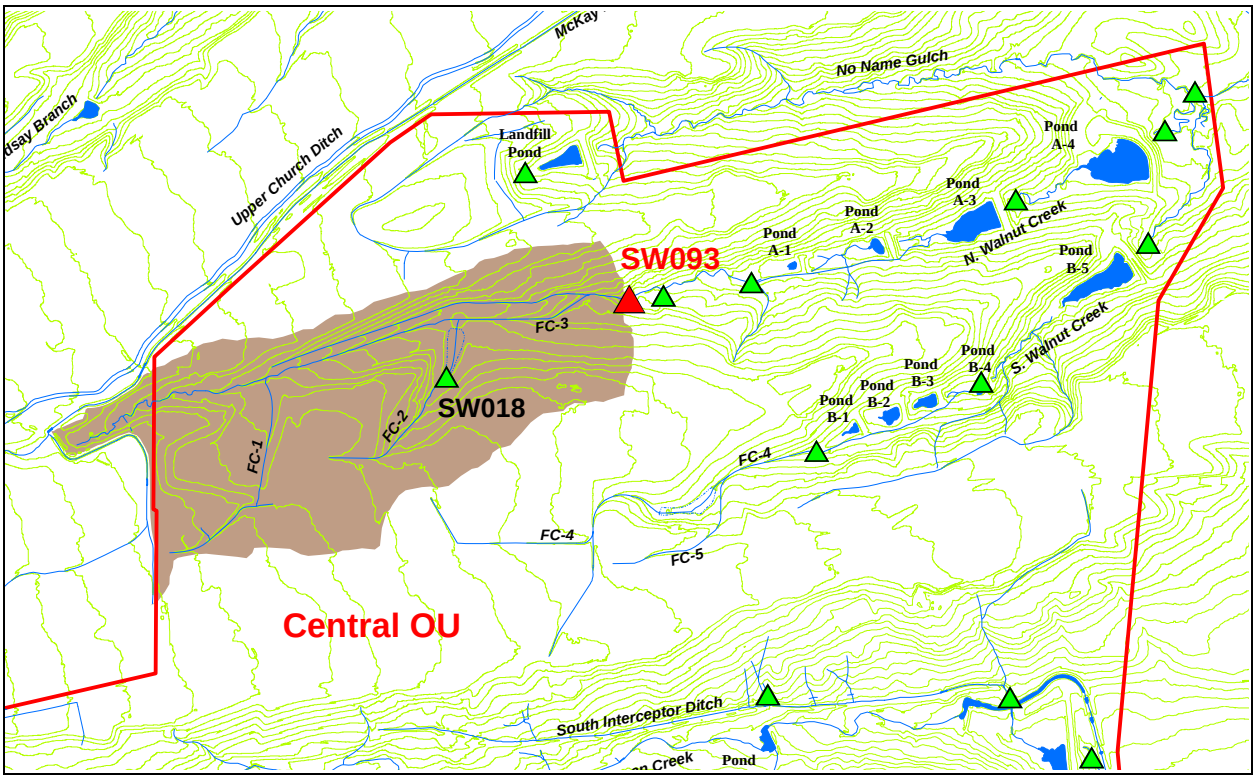



*Figure 2–53. Map Showing SW093 Drainage Area*

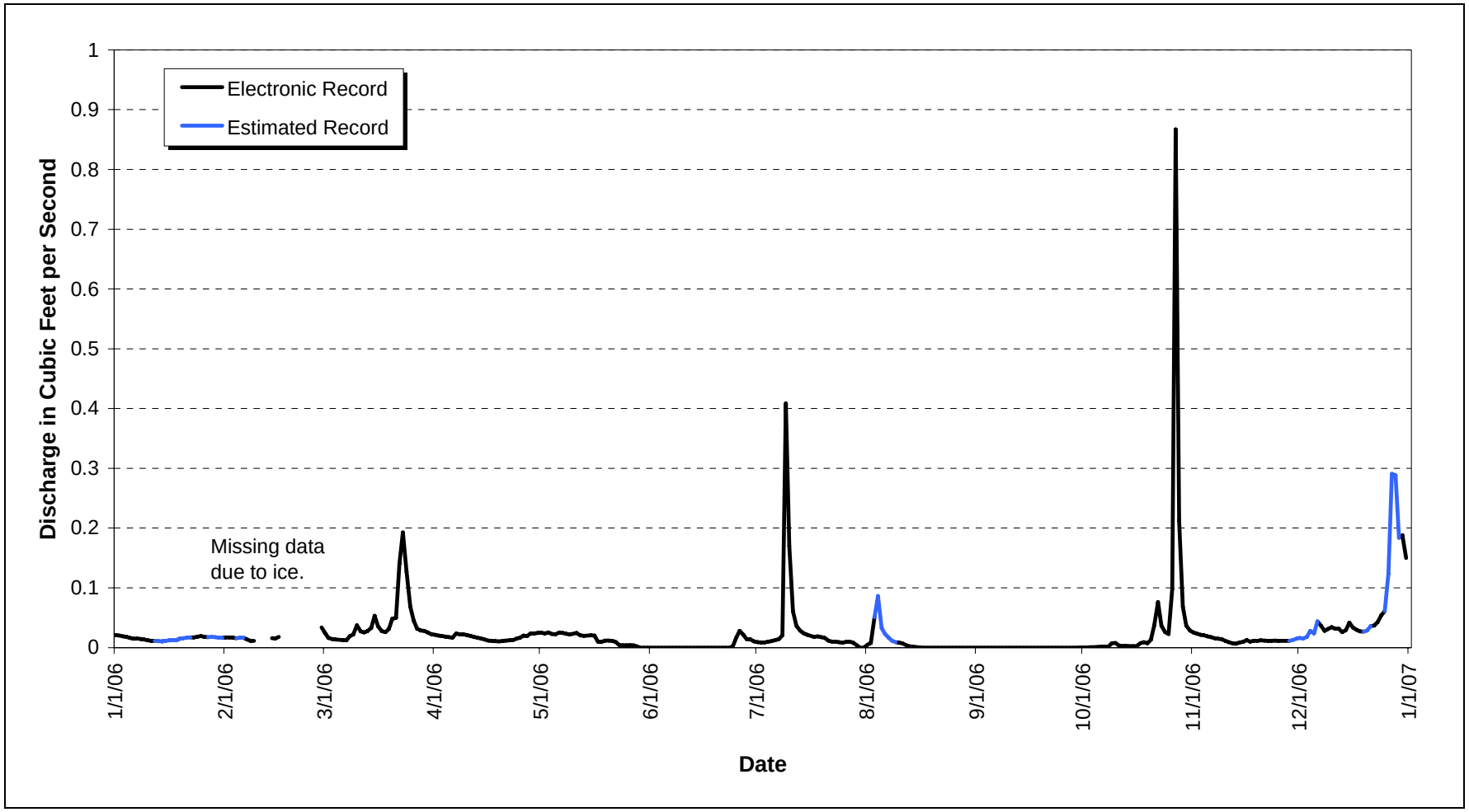



*Figure 2–54. CY 2006 Mean Daily Hydrograph at SW093: North Walnut Creek Upstream of Pond A-1 Bypass*

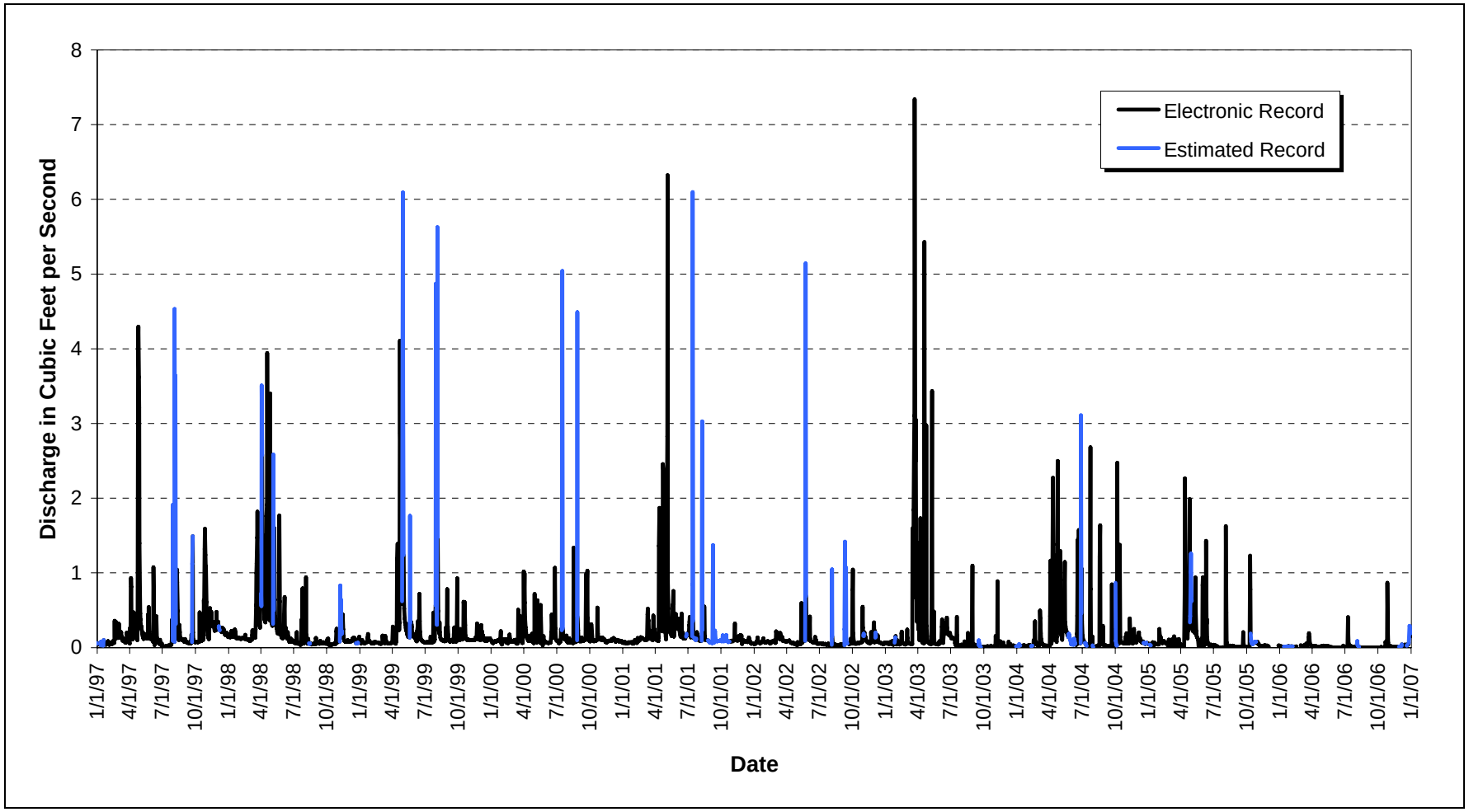



*Figure 2–55. CY 1997−2006 Mean Daily Hydrograph at SW093: North Walnut Creek Upstream of Pond A-1 Bypass*

### 2.2.3 Precipitation Data

During CY 2006, eight precipitation gages were operated as part of the automated surface water monitoring network. The locations employ tipping-bucket rain gages generally mounted at ground level. Precipitation totals are logged on 5- and/or 15-minute intervals. The gages are not heated and will not accurately record equivalent precipitation for all snowfall events. The following sections present several figures summarizing the precipitation data collected for CY 1997−2006.

*Table 2−2. Monitoring Network Precipitation Gage Information*

| Location Code [Surface Water Gage] | Easting [State Plane] | Northing [State Plane] | Period of Operation |
|---|---|---|---|
| PG55 [NA] | 2087857.63 | 747141.16 | 7/19/94−current year |
| PG56 [NA] | 2091790.63 | 752716.35 | 7/18/94−current year |
| PG58 [GS01] | 2093835.22 | 744921.16 | 10/11/96−current year |
| PG59 [GS03] | 2093598.99 | 753629.51 | 4/1/96−current year |
| PG61 [GS05] | 2078432.10 | 747285.45 | 4/1/96−current year |
| PG72 [NA] | 2083387.82 | 751851.00 | 6/7/05−current year |
| PG73 [GS13] | 2086169.70 | 751862.47 | 9/27/05−current year |
| PG74 [GS59] | 2083249.49 | 747158.98 | 9/5/06−current year |

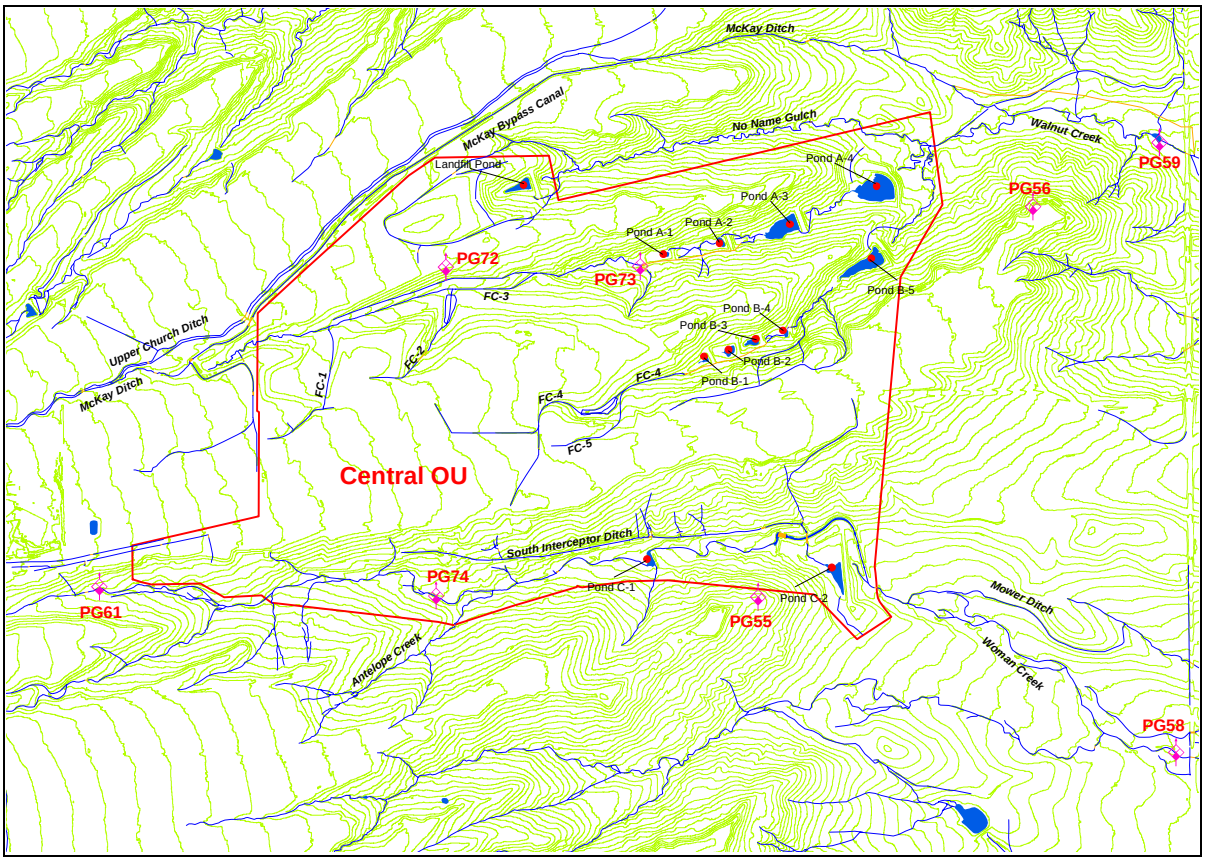
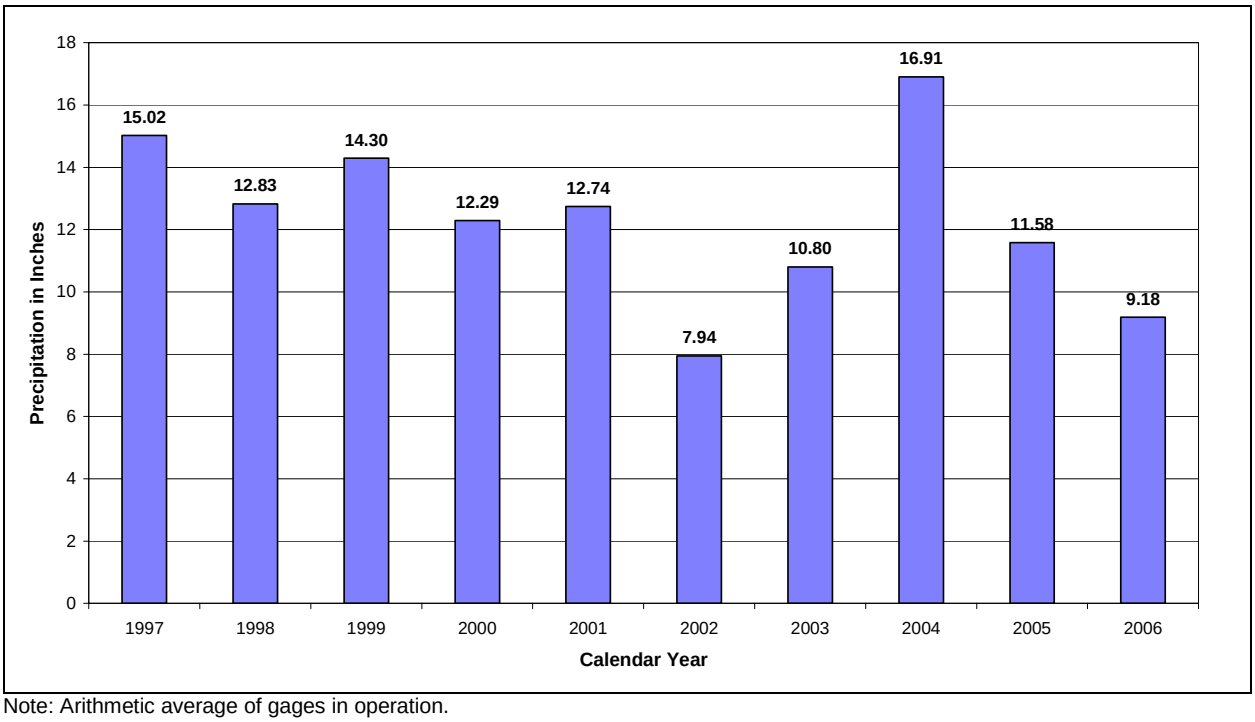


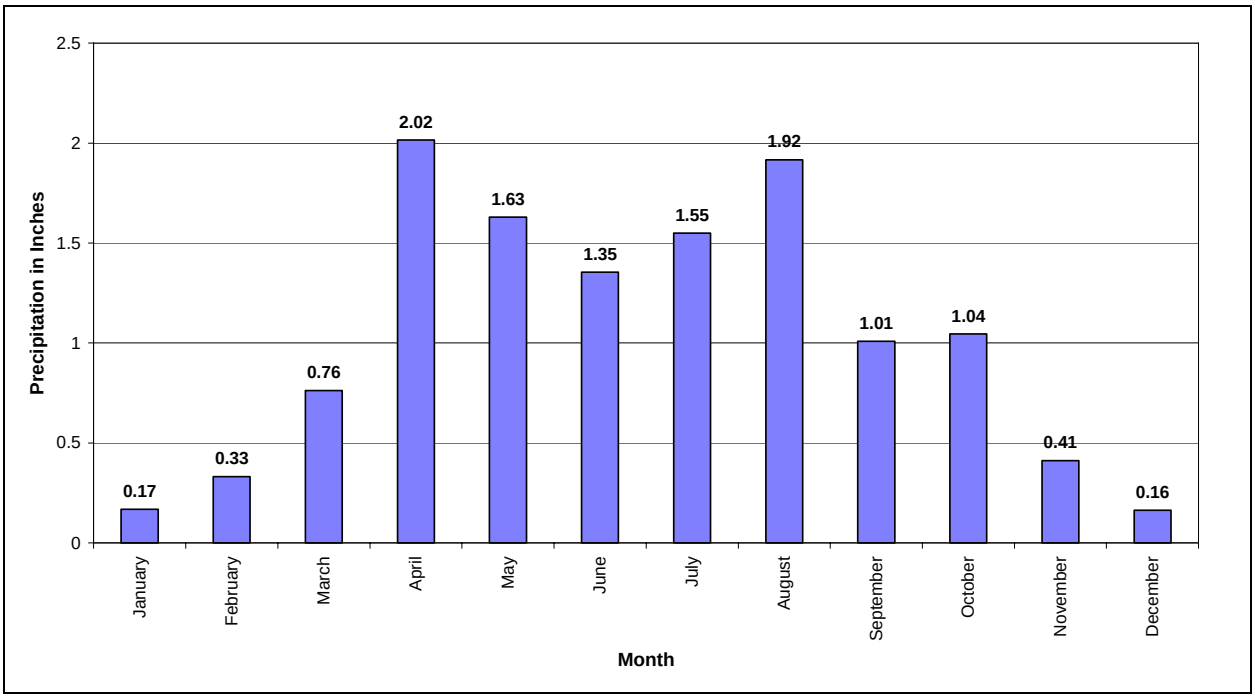

*Figure 2–56. Map of Site Precipitation Gages: CY 2006*

### 2.2.3.1 CY 1997–2006 Summary



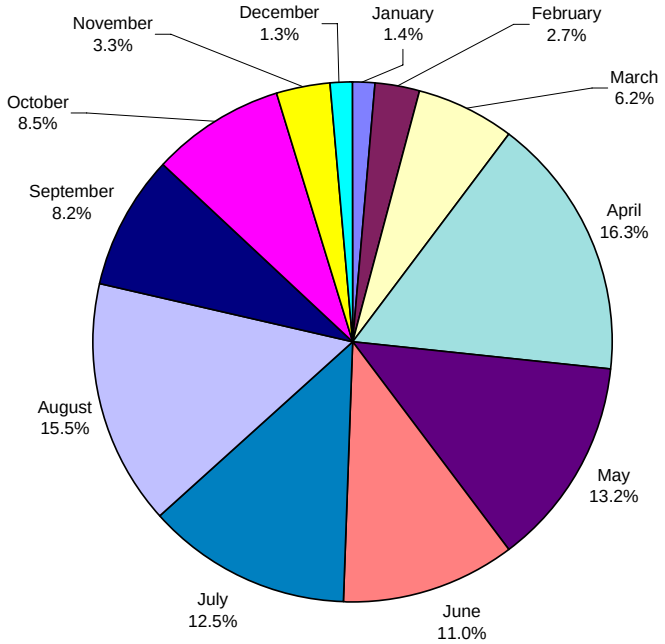

Note: Arithmetic average of gages in operation.

*Figure 2–57. Annual Total Precipitation for CY 1997–2006*




Note: Arithmetic average of gages in operation.

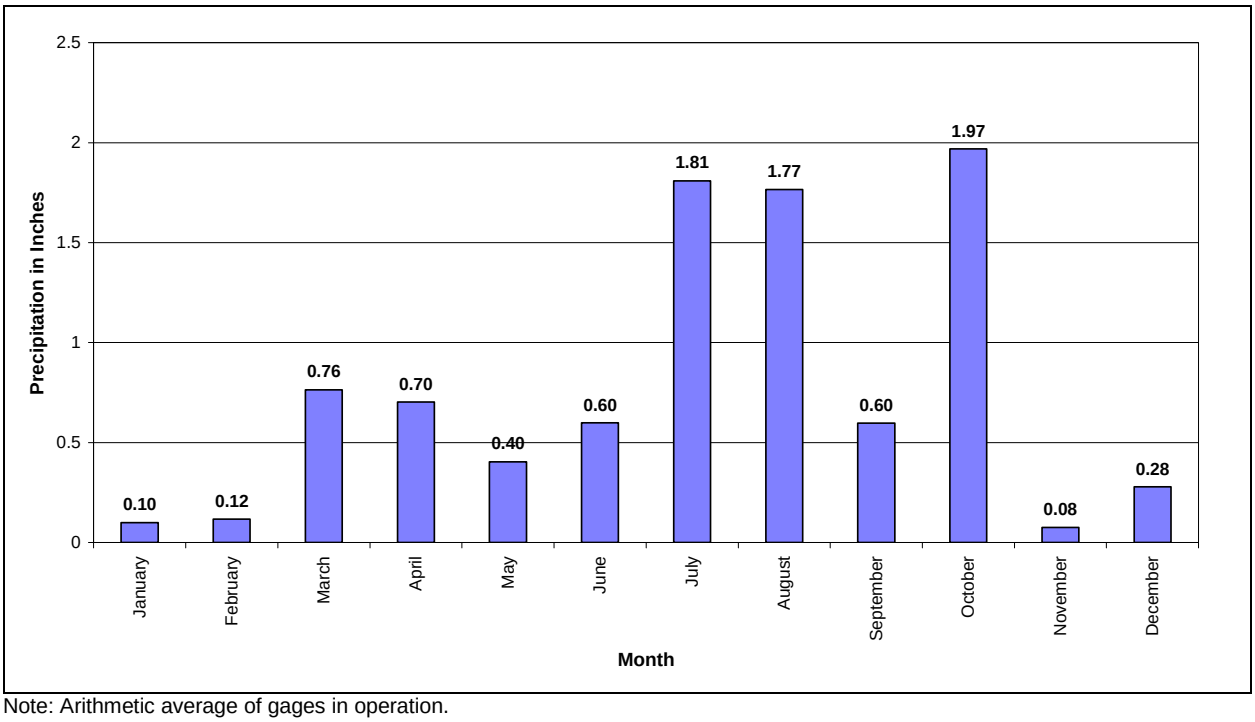
*Figure 2–58. Average Monthly Precipitation for CY 1997–2006*




Note: Arithmetic average of gages in operation.

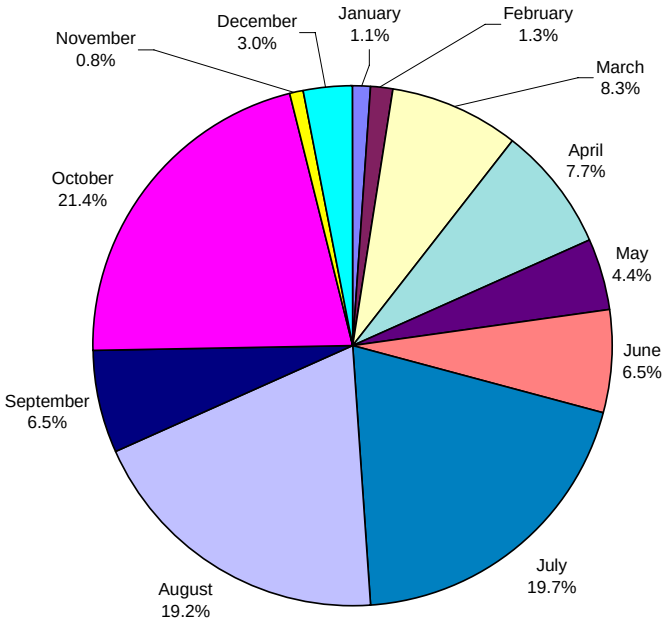
*Figure 2–59. Relative Monthly Precipitation Totals for CY 1997–2006*

### 2.2.3.2 CY 2006 Summary



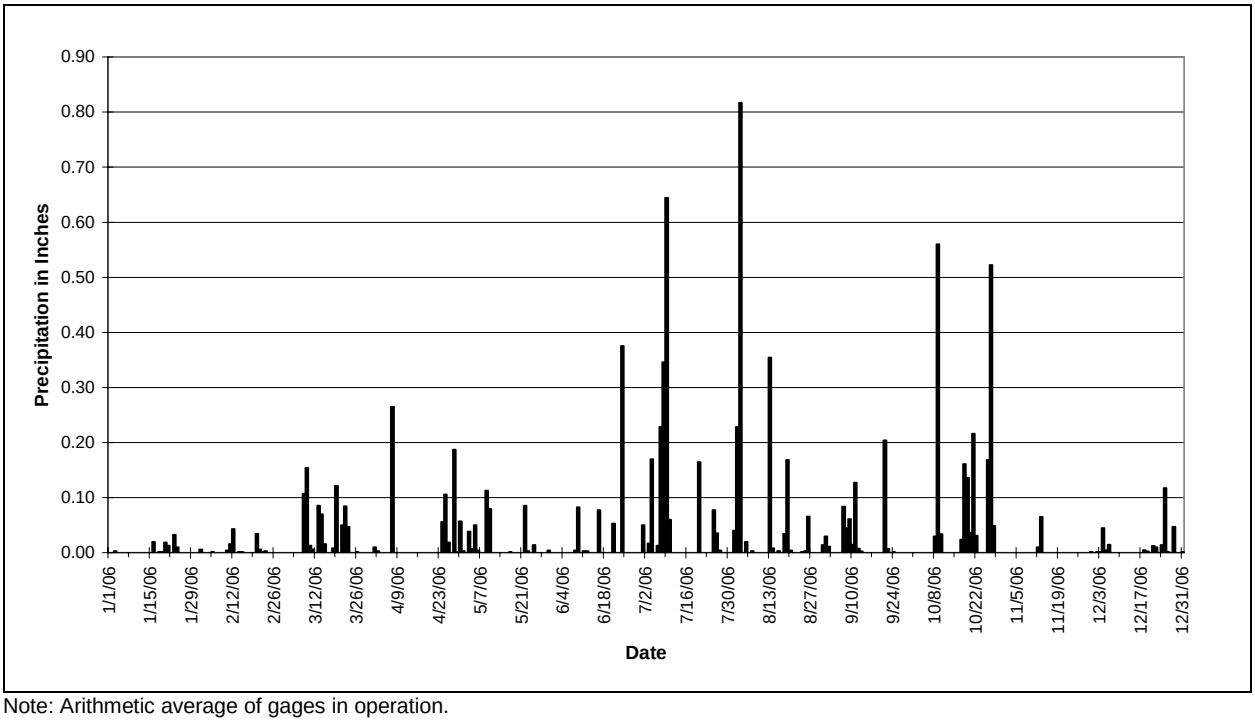

Note: Arithmetic average of gages in operation.

*Figure 2–60. Monthly Precipitation for CY 2006*




Note: Arithmetic average of gages in operation.

*Figure 2–61. Relative Monthly Precipitation Volumes for CY 2006*




Note: Arithmetic average of gages in operation.

*Figure 2–62. Daily Precipitation Totals for CY 2006*

## 2.3 Water-Quality Summaries

This section presents water-quality summaries for selected analytes for the period January 1, 1997, through December 31, 2006 (CY 1997–2006), for the locations operational in CY 2006. Radionuclides summarized in Section 2.3.1 include Pu, Am,[10] and total U. Additionally, the POE metals (total beryllium [Be], dissolved cadmium [Cd], total chromium [Cr], and dissolved silver [Ag]) are summarized in Section 2.3.2. Many additional analyses are also performed based on the specific monitoring objective. The results and evaluation for these additional analytes are presented in Sections 2.6 through 2.11 by monitoring objective.

### 2.3.1 Radionuclides

The following summaries include all results that were not rejected through the validation process.[11] Data are generally presented to decimal places as reported by the laboratories. Accuracy should not be inferred; minimum detectable concentrations/activities and analytical error are often greater than the precision presented. When a negative radionuclide result (e.g., −0.002 picocuries per liter [pCi/L]) is reported by the laboratory due to blank correction, then a value of 0.0 pCi/L is used for calculation purposes. When a sample has a corresponding field duplicate, the value used in calculations is the arithmetic average of the ‘real’ and ‘duplicate’ values.[12] When a sample has multiple ‘real’ analyses (e.g., Site requested ‘reruns’),

[10] In this report, ‘plutonium’ or ‘Pu’ refers to Pu-239,240 and ‘americium’ or ‘Am’ refers to Am-241.
[11] Summaries do not include supplemental grab samples from GS13 that were collected to assess modifications to the Solar Ponds Plume Treatment System (SPPTS); only routine continuous flow-paced samples are included.
[12] Arithmetic averaging of radionuclide pairs is performed only when the duplicate error ratio (DER) is less than 1.5. If the DER is greater than or equal to 1.5, then the radionuclide results are determined to be non-representative.

the value used in calculations is the arithmetic average of the multiple 'real' analyses. Total U activity is calculated by summing the activities for the analyzed isotopes (U-233,234 + U-235 + U-238).

The Pu/Am ratio is calculated for each sample by dividing the Pu result by the corresponding Am result. Ratios are only calculated for samples where *both* the Pu and Am results are greater than 0.015 pCi/L (generally the minimum detectable activity [MDA] for Pu and Am analyses) to exclude ratios for very low results with high relative error.

The U-233,234/U-238 ratio is calculated for each sample by dividing the U-233,234 result by the corresponding U-238 result. Ratios are only calculated for samples where *both* the U-233,234 and U-238 results are greater than 0.025 pCi/L (generally the MDA for these isotope analyses) to exclude ratios for very low results with high relative error. The U-233,234/U-238 ratios can only be used to qualitatively infer the characteristics of the U in surface water. In the past, ground water and surface water samples from select locations have been sent to Los Alamos National Laboratory (LANL) for high resolution inductively-coupled plasma/mass spectrometry (HR ICP/MS) and/or thermal ionization mass spectrometry (TIMS) analyses. These analyses measure mass ratios of four U isotopes (masses 234, 235, 236, and 238) and are detailed in the reports titled *Uranium in Surface Soil, Surface Water, and Groundwater at the Rocky Flats Environmental Technology Site* (K-H 2004f), and in the *Interim Measure/Interim Remedial Action for Groundwater at the Rocky Flats Environmental Technology Site* (K-H 2005c). Isotopic ratios provide a signature that indicates whether the source of U is natural, anthropogenic (man-made), or mixed. The results to date indicate that the ground water and surface water locations at Rocky Flats display a predominately natural signature.

Each table includes only those locations where samples were collected that were analyzed for the referenced analyte. Maps are also included showing monitoring locations and the corresponding median values of the referenced parameter. Only locations that had four or more individual results are mapped.

Table 2−4 and Figure 2–64 show that post-closure median Pu activities for all locations are well below 0.15 pCi/L.[13]

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These results are not used for the calculation of summary statistics. A more thorough discussion of data management is given in Appendix B.1, "Analytical Data Evaluation Methods."

[13] The Pu, Am, and total U standards / action levels noted in this section apply only to POE (GS10, SW027, and SW093; Section 2.9) and POC (GS01, GS03, GS08, GS11, and GS31; Section 2.10) 30-day or 12-month rolling averages. Comparisons of standards / action levels to other locations are noted in this section for reference only. POEs and POCs are highlighted in **bold** in the tables.

*Table 2−3. Summary Statistics for Pu-239,240 Analytical Results in CY 1997−October 13, 2005*

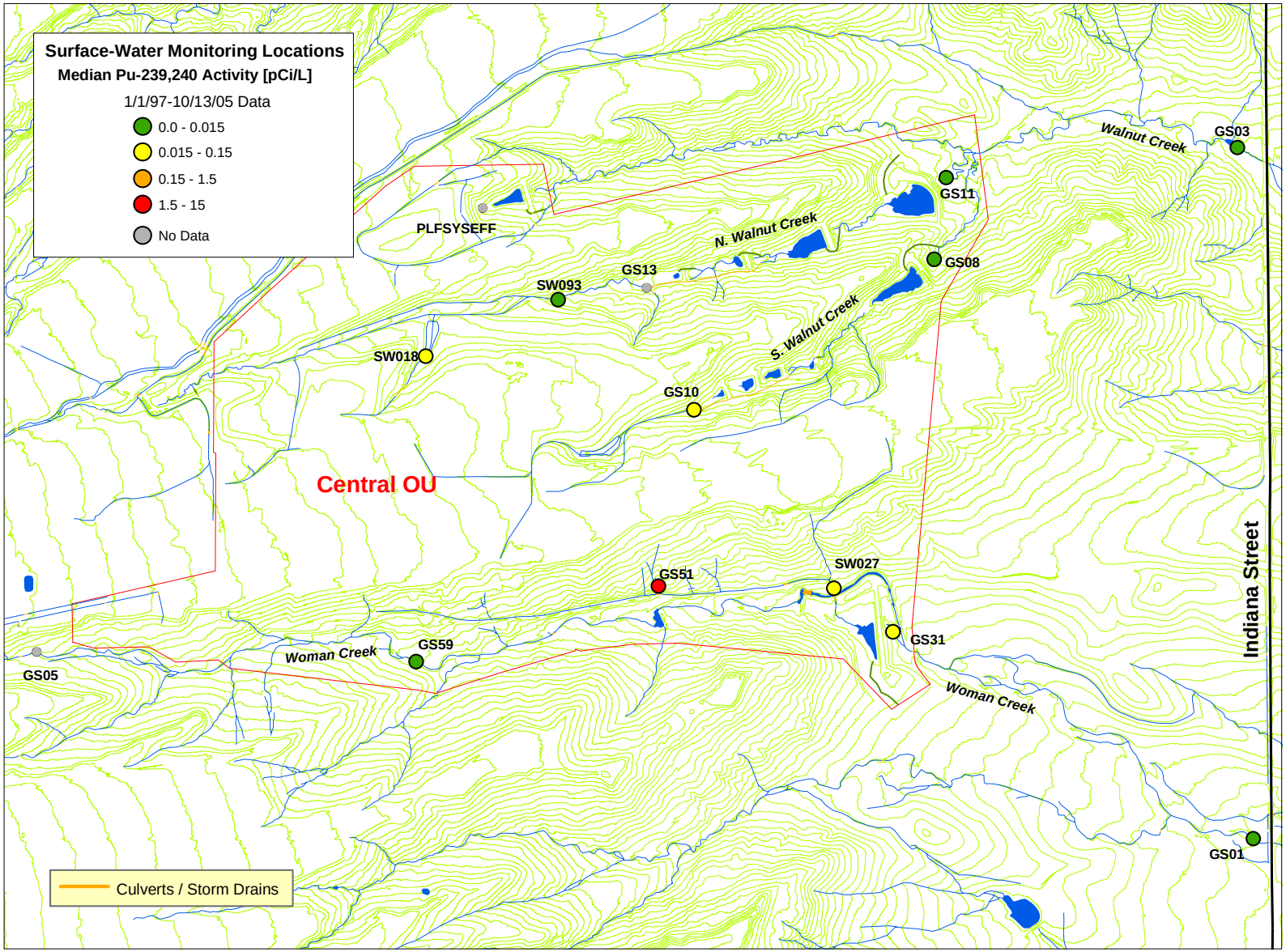
| Location | Samples (N) | Median (pCi/L) | 85th Percentile (pCi/L) | Maximum (pCi/L) |
|---|---|---|---|---|
| **GS01** | **165** | **0.002** | **0.008** | **0.024** |
| **GS03** | **257** | **0.005** | **0.016** | **0.220** |
| GS05 | NA | NA | NA | NA |
| **GS08** | **118** | **0.004** | **0.013** | **0.864** |
| **GS10** | **266** | **0.054** | **0.207** | **2.27** |
| **GS11** | **89** | **0.002** | **0.009** | **0.070** |
| GS13 | NA | NA | NA | NA |
| **GS31** | **26** | **0.017** | **0.094** | **0.348** |
| GS51 | 27 | 3.97 | 8.41 | 99.7 |
| GS59 | 30 | 0.000 | 0.004 | 0.020 |
| PLFSYSEFF | NA | NA | NA | NA |
| SW018 | 33 | 0.017 | 0.043 | 0.197 |
| **SW027** | **71** | **0.049** | **0.199** | **13.2** |
| **SW093** | **284** | **0.010** | **0.063** | **4.18** |

Notes: NA = Analyte not sampled
Bold-face type = POC or POE

*Table 2−4. Post-Closure Summary Statistics for Pu-239,240 Analytical Results (October 13, 2005−December 31, 2006)*

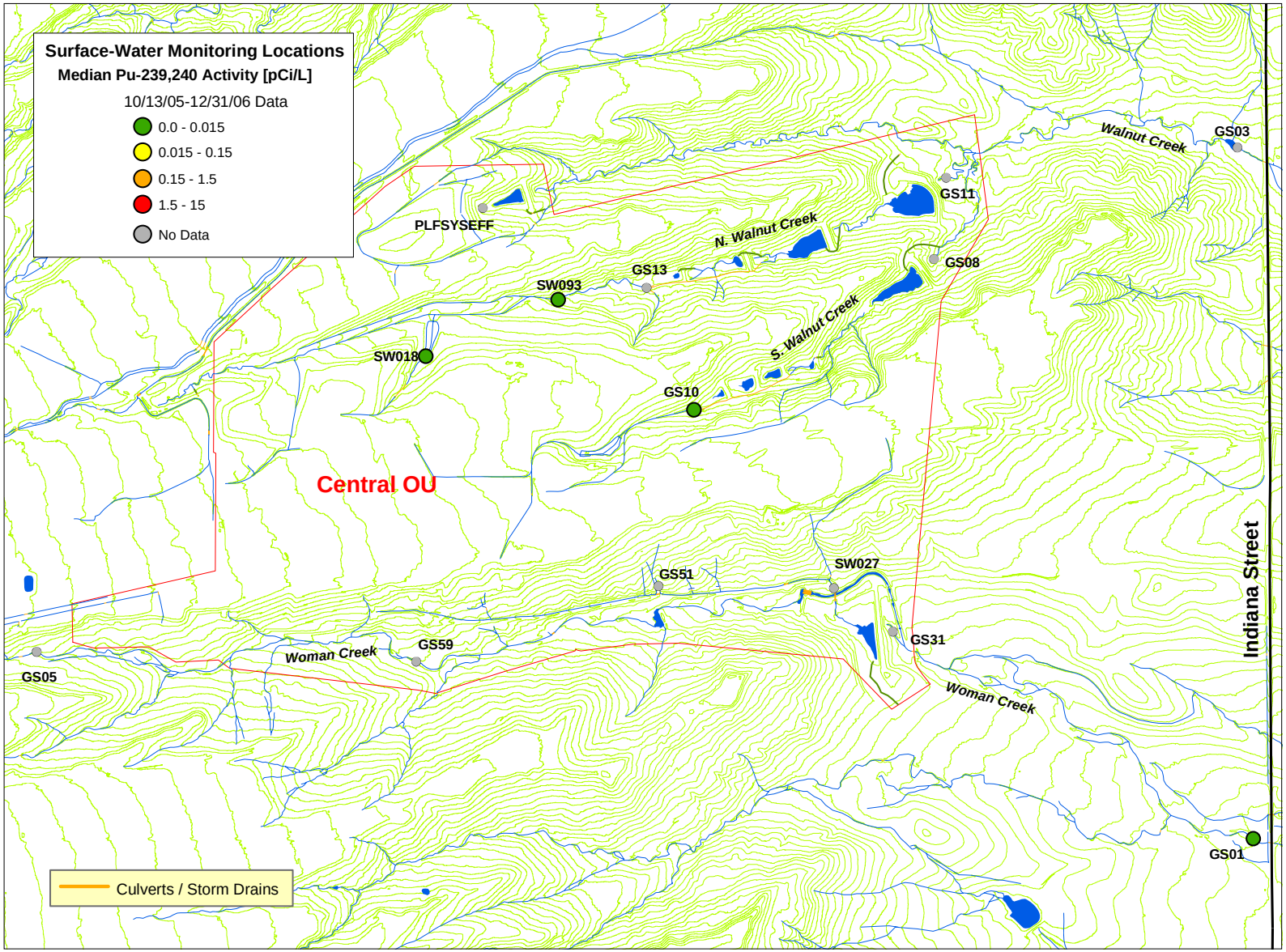
| Location | Samples (N) | Median (pCi/L) | 85th Percentile (pCi/L) | Maximum (pCi/L) |
|---|---|---|---|---|
| **GS01** | **10** | **0.000** | **0.007** | **0.008** |
| **GS03** | * | * | * | * |
| GS05 | NA | NA | NA | NA |
| **GS08** | * | * | * | * |
| **GS10** | **19** | **0.009** | **0.020** | **0.060** |
| **GS11** | * | * | * | * |
| GS13 | NA | NA | NA | NA |
| **GS31** | * | * | * | * |
| GS51 | 1 | 1.05 | 1.05 | 1.05 |
| GS59 | NA | NA | NA | NA |
| PLFSYSEFF | NA | NA | NA | NA |
| SW018 | 10 | 0.003 | 0.016 | 0.026 |
| **SW027** | * | * | * | * |
| **SW093** | **17** | **0.004** | **0.021** | **0.025** |

Notes: * = No post-closure results through CY 2006
NA = Analyte not sampled
Bold-face type = POC or POE




Note: Only locations with four or more results are mapped.

*Figure 2–63. Map Showing Median Pu-239,240 Activities for CY 1997–October 13, 2005*




Note: Only locations with four or more results are mapped.

*Figure 2–64. Map Showing Post-Closure Median Pu-239,240 Activities*

Table 2−6 and Figure 2–66 show that post-closure median Am activities for all locations are well below 0.15 pCi/L.

*Table 2−5. Summary Statistics for Am-241 Analytical Results in CY 1997−October 13, 2005*

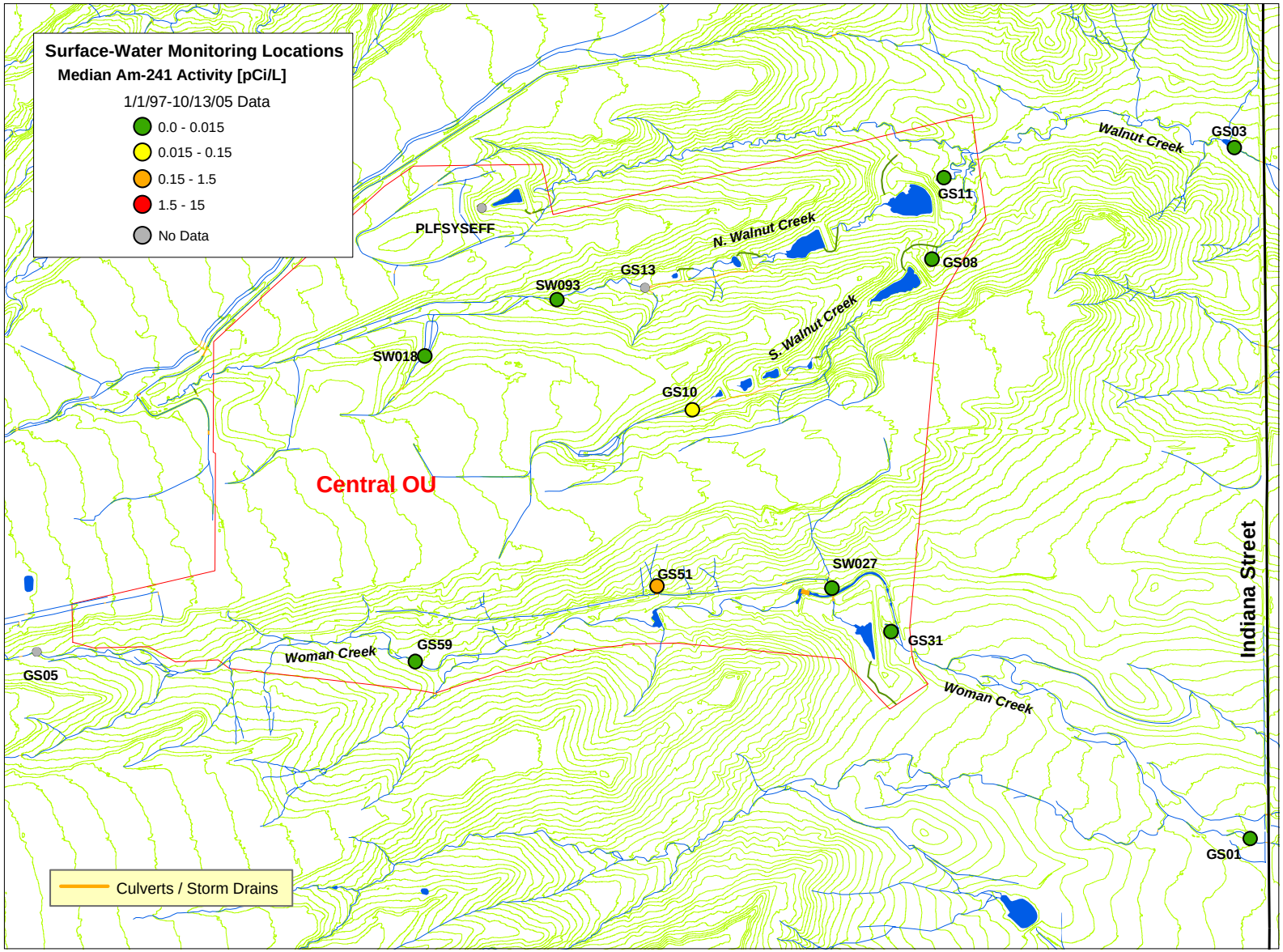
| Location | Samples (N) | Median (pCi/L) | 85th Percentile (pCi/L) | Maximum (pCi/L) |
|---|---|---|---|---|
| GS01 | **164** | **0.001** | **0.008** | **0.054** |
| **GS03** | **258** | **0.006** | **0.018** | **0.066** |
| GS05 | NA | NA | NA | NA |
| **GS08** | **118** | **0.006** | **0.015** | **0.275** |
| **GS10** | **259** | **0.057** | **0.193** | **8.39** |
| **GS11** | **88** | **0.003** | **0.010** | **0.047** |
| GS13 | NA | NA | NA | NA |
| **GS31** | **26** | **0.009** | **0.020** | **0.116** |
| GS51 | 25 | 0.807 | 1.76 | 3.41 |
| GS59 | 30 | 0.001 | 0.004 | 0.015 |
| PLFSYSEFF | NA | NA | NA | NA |
| SW018 | 34 | 0.008 | 0.024 | 0.091 |
| **SW027** | **71** | **0.009** | **0.045** | **2.33** |
| **SW093** | **279** | **0.012** | **0.052** | **14.1** |

Notes: NA = Analyte not sampled
Bold-face type = POC or POE

*Table 2−6. Post-Closure Summary Statistics for Am-241 Analytical Results (October 13, 2005−December 31, 2006)*

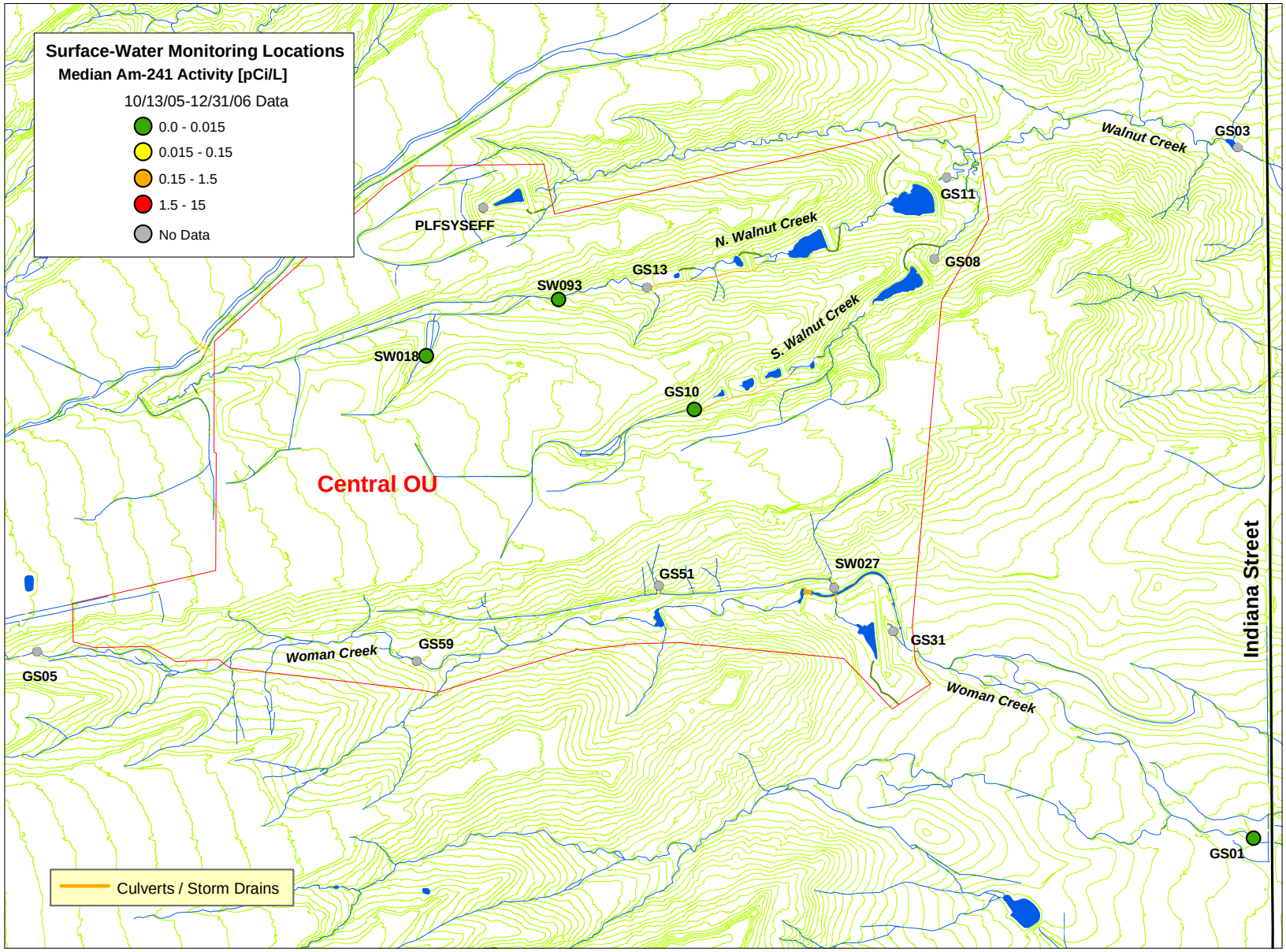
| Location | Samples (N) | Median (pCi/L) | 85th Percentile (pCi/L) | Maximum (pCi/L) |
|---|---|---|---|---|
| **GS01** | **10** | **0.005** | **0.012** | **0.057** |
| **GS03** | * | * | * | * |
| GS05 | NA | NA | NA | NA |
| **GS08** | * | * | * | * |
| **GS10** | **19** | **0.008** | **0.028** | **0.047** |
| **GS11** | * | * | * | * |
| GS13 | NA | NA | NA | NA |
| **GS31** | * | * | * | * |
| GS51 | 1 | 0.209 | 0.209 | 0.209 |
| GS59 | NA | NA | NA | NA |
| PLFSYSEFF | NA | NA | NA | NA |
| SW018 | 10 | 0.002 | 0.011 | 0.016 |
| **SW027** | * | * | * | * |
| **SW093** | **17** | **0.000** | **0.017** | **0.026** |

Notes: * = No post-closure results through CY 2006
NA = Analyte not sampled
Bold-face type = POC or POE




Note: Only locations with four or more results are mapped.

*Figure 2–65. Map Showing Median Am-241 Activities for CY 1997–October 13, 2005*




Note: Only locations with four or more results are mapped.

*Figure 2–66. Map Showing Post-Closure Median Am-241 Activities*

Table 2−8 and Figure 2–68 show that post-closure median total U activities for most locations are below the action level of 10 pCi/L (11 pCi/L for Woman Creek). Recent data from GS10 and GS13 show total U levels in excess of 10 pCi/L. U activities at GS13 are known to be directly affected by ground water associated with the Solar Ponds Plume (SPP). The measurements at GS10 are likely due to contributions of naturally occurring U in ground water and hydrologic changes at GS10. As impervious areas were removed at the Site (reducing direct runoff during precipitation events), contributions to the creek from ground water with naturally occurring U represented a larger portion of the streamflow monitored at GS10. Without direct runoff contributions to mix with the ground water U contributions, samples from GS10 began to reflect the naturally occurring ground water U concentrations (often significantly greater than the surface water action level).

*Table 2−7. Summary Statistics for Total Uranium Analytical Results in CY 1997−October 13, 2005*

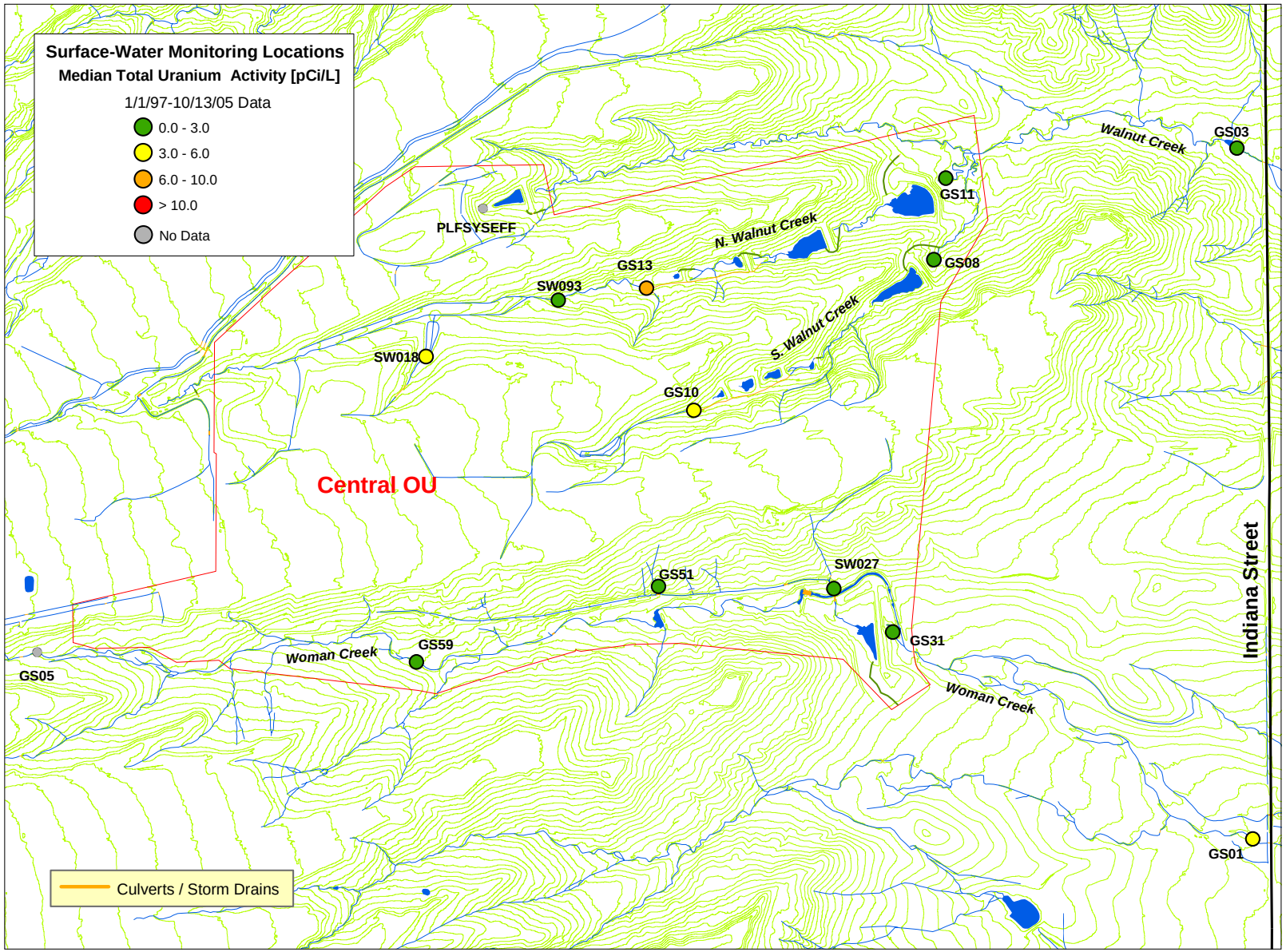
| Location | Samples (N) | Median (pCi/L) | 85th Percentile (pCi/L) | Maximum (pCi/L) |
|---|---|---|---|---|
| **GS01** | **53** | **3.26** | **5.10** | **9.35** |
| **GS03** | **78** | **1.75** | **3.25** | **5.43** |
| GS05 | NA | NA | NA | NA |
| **GS08** | **118** | **1.32** | **2.23** | **6.87** |
| **GS10** | **266** | **3.23** | **5.04** | **14.0** |
| **GS11** | **89** | **2.10** | **3.08** | **4.06** |
| GS13 | 56 | 8.44 | 12.9 | 23.5 |
| **GS31** | **26** | **2.21** | **2.68** | **4.07** |
| GS51 | 26 | 1.07 | 1.83 | 2.76 |
| GS59 | 31 | 0.762 | 1.24 | 3.87 |
| PLFSYSEFF | NA | NA | NA | NA |
| SW018 | 33 | 3.87 | 5.43 | 7.94 |
| **SW027** | **71** | **1.32** | **2.92** | **4.48** |
| **SW093** | **284** | **2.72** | **4.16** | **7.33** |

Notes: NA = Analyte not sampled
Bold-face type = POC or POE

*Table 2−8. Post-Closure Summary Statistics for Total Uranium Analytical Results (October 13, 2005−December 31, 2006)*

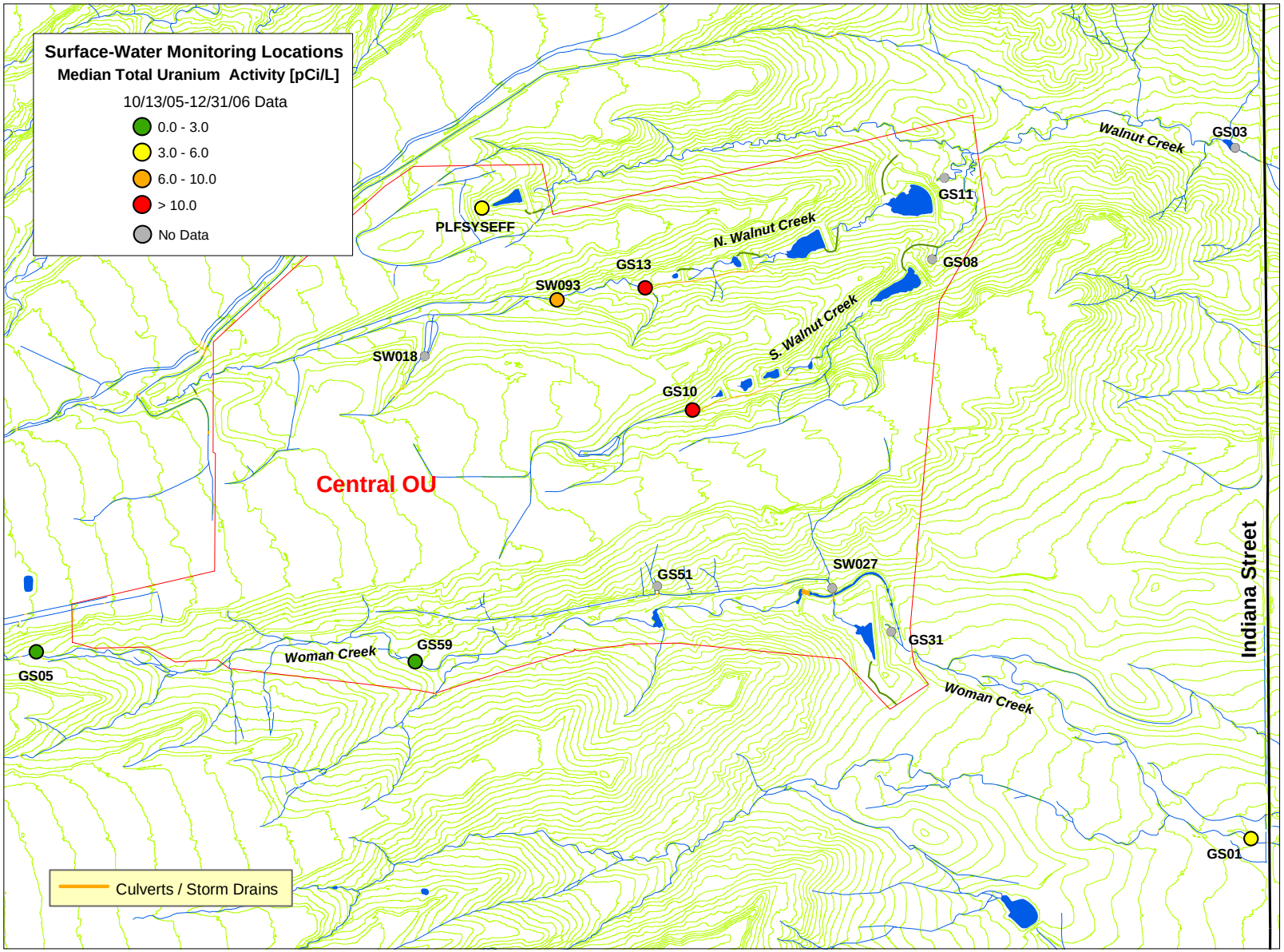
| Location | Samples (N) | Median (pCi/L) | 85th Percentile (pCi/L) | Maximum (pCi/L) |
|---|---|---|---|---|
| **GS01** | **10** | **4.92** | **5.80** | **7.53** |
| **GS03** | * | * | * | * |
| GS05 | 7 | 0.64 | 0.86 | 2.35 |
| **GS08** | * | * | * | * |
| **GS10** | **19** | **10.7** | **17.0** | **24.5** |
| **GS11** | * | * | * | * |
| GS13 | 9 | 15.6 | 18.9 | 21.6 |
| **GS31** | * | * | * | * |
| GS51 | NA | NA | NA | NA |
| GS59 | 6 | 2.11 | 4.36 | 5.65 |
| PLFSYSEFF | 5 | 5.53 | 7.88 | 8.43 |
| SW018 | NA | NA | NA | NA |
| **SW027** | * | * | * | * |
| **SW093** | **17** | **6.23** | **8.00** | **10.2** |

Notes: * = No post-closure results through CY 2006
NA = Analyte not sampled
Bold-face type = POC or POE




Note: Only locations with four or more results are mapped.

*Figure 2–67. Map Showing Median Total Uranium Activities for CY 1997–October 13, 2005*




Note: Only locations with four or more results are mapped.

*Figure 2–68. Map Showing Post-Closure Median Total Uranium Activities*

Table 2−9 and Table 2−10 list the average Pu/Am activity ratios for locations where samples are analyzed for Pu and Am. A ratio greater than one indicates Pu activity in excess of Am activity. Conversely, a ratio less than one indicates Am activity in excess of Pu activity. Generally, Pu activities are greater than Am activities in surface water at the Site. Very few post-closure Pu/Am data pairs satisfying the MDA criteria are available, and a post-closure map is not presented.

*Table 2−9. Average Pu/Am Ratios for Analytical Results in CY 1997−October 13, 2005*

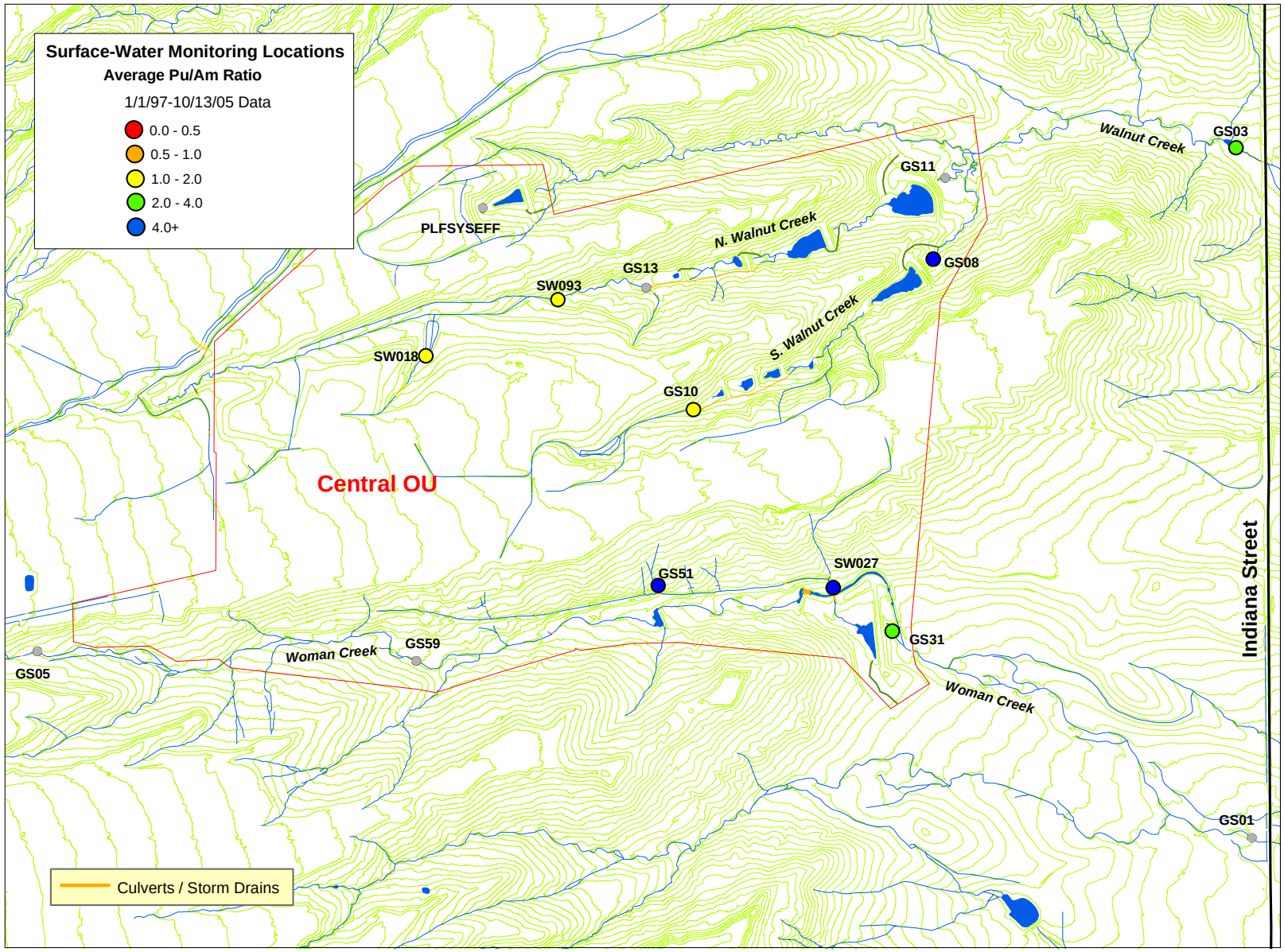
| Location | Samples (N)[a] | Average Pu/Am Ratio |
|---|---|---|
| **GS01** | **1** | **1.5** |
| **GS03** | **14** | **2.1** |
| GS05 | NA | NA |
| **GS08** | **5** | **8.9** |
| **GS10** | **196** | **1.3** |
| **GS11** | ***** | ***** |
| GS13 | NA | NA |
| **GS31** | **4** | **3.9** |
| GS51 | 24 | 4.6 |
| GS59 | * | * |
| PLFSYSEFF | NA | NA |
| SW018 | 9 | 1.8 |
| **SW027** | **26** | **4.9** |
| **SW093** | **95** | **1.8** |

[a]Number of samples where both Pu and Am were greater than 0.015 pCi/L
*No results greater than 0.015 pCi/L
Bold-face type = POC or POE
NA = Analyte not sampled

*Table 2−10. Post-Closure Average Pu/Am Ratios for Analytical Results (October 13, 2005−December 31, 2006)*

| Location | Samples (N)[a] | Average Pu/Am Ratio |
|---|---|---|
| **GS01** | ***** | ***** |
| **GS03** | ***** | ***** |
| GS05 | NA | NA |
| **GS08** | ***** | ***** |
| **GS10** | **2** | **1.9** |
| **GS11** | ***** | ***** |
| GS13 | NA | NA |
| **GS31** | ***** | ***** |
| GS51 | 1 | 5.0 |
| GS59 | NA | NA |
| PLFSYSEFF | NA | NA |
| SW018 | * | * |
| **SW027** | ***** | ***** |
| **SW093** | **1** | **0.8** |

[a]Number of samples where both Pu and Am were greater than 0.015 pCi/L
*No results greater than 0.015 pCi/L
Bold-face type = POC or POE
NA = Analyte not sampled




Note: Only locations with four or more results are mapped.

*Figure 2–69. Map Showing Average Pu/Am Ratios for CY 1997–October 13, 2005*

Naturally occurring U generally shows a U-233,234/U-238 activity ratio of approximately one. The U-233,234/U-238 activity ratios at Site surface water monitoring locations may be used as an indication of the existence of U with 'unnatural' ratios. Although this evaluation does not deal systematically with analytical counting errors, Table 2−11, Table 2−12, Figure 2–70, and Figure 2–71 are presented here for reference.

In the past, Site ground water and surface water samples from select locations have been sent to LANL for HR ICP/MS and/or TIMS analyses as discussed previously. The results indicate that ground water and surface-water at the Site display a predominately natural signature.

*Table 2−11. Average U-233,234/U-238 Ratios for Analytical Results in CY 1997−October 13, 2005*

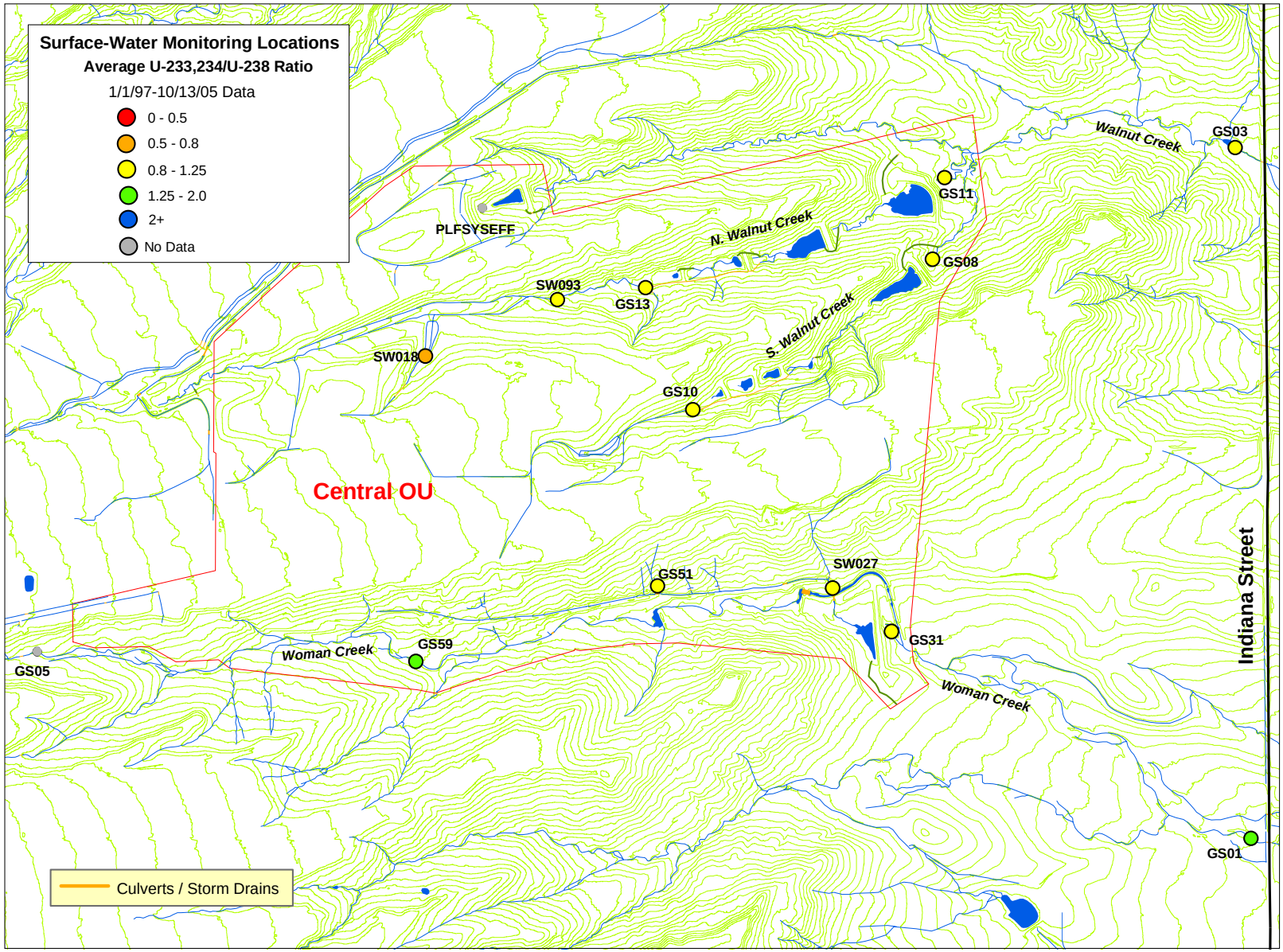
| Location | Samples (N)[a] | Average U-233,234/U-238 Ratio |
|---|---|---|
| **GS01** | **53** | **1.3** |
| **GS03** | **78** | **1.2** |
| GS05 | NA | NA |
| **GS08** | **118** | **1.1** |
| **GS10** | **266** | **1.1** |
| **GS11** | **89** | **1.0** |
| GS13 | 56 | 1.1 |
| **GS31** | **26** | **0.9** |
| GS51 | 26 | 1.0 |
| GS59 | 31 | 1.3 |
| PLFSYSEFF | NA | NA |
| SW018 | 33 | 0.6 |
| **SW027** | **71** | **0.8** |
| **SW093** | **284** | **1.0** |

[a]Number of samples where both U-233,234 and U-238 were greater than 0.025 pCi/L
Bold-face type = POC or POE
NA = Analyte not sampled

*Table 2−12. Post-Closure Average U-233,234/U-238 Ratios for Analytical Results (October 13, 2005−December 31, 2006)*

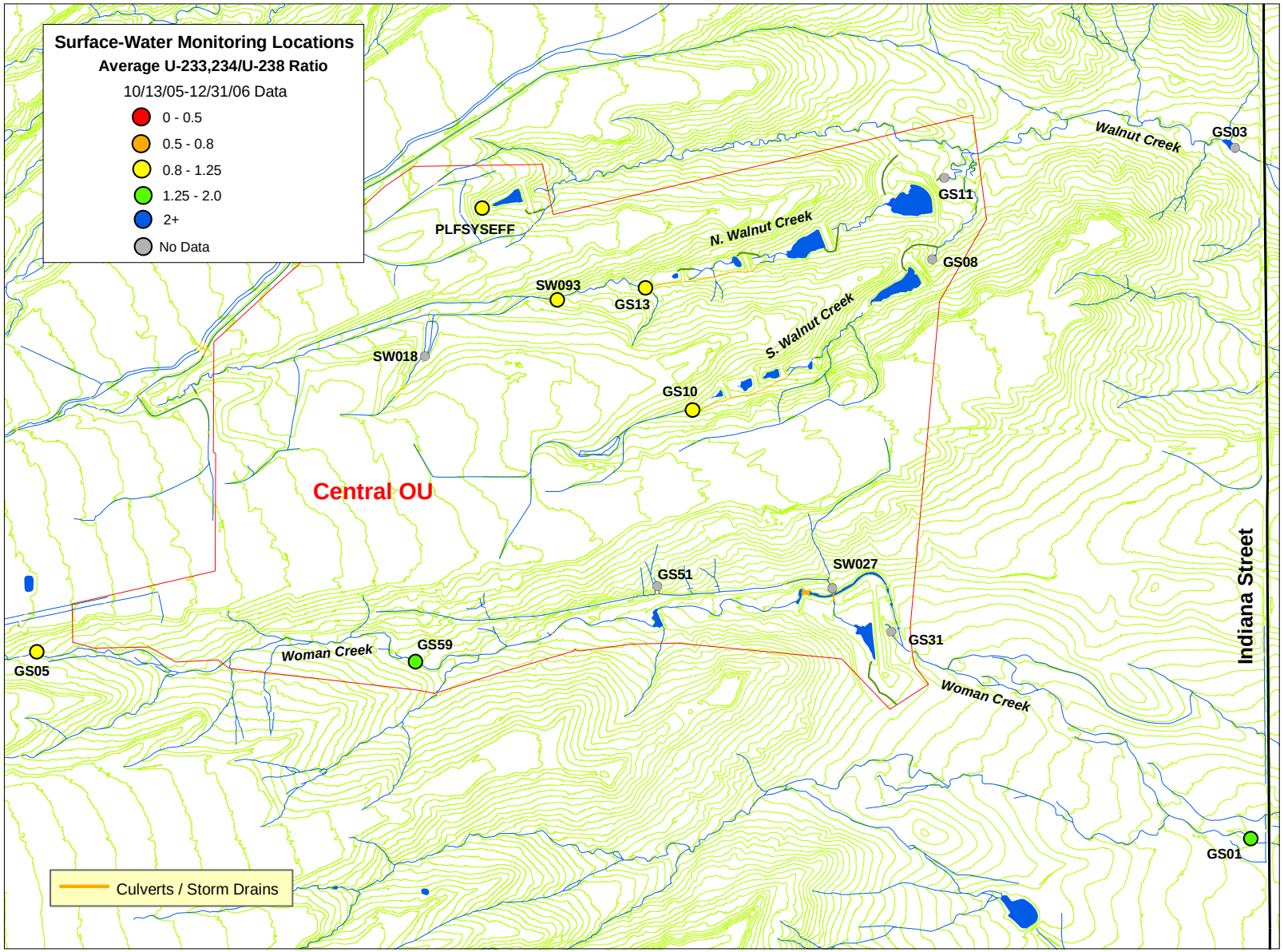
| Location | Samples (N)[a] | Average U-233,234/U-238 Ratio |
|---|---|---|
| **GS01** | **10** | **1.3** |
| **GS03** | * | * |
| GS05 | 7 | 1.2 |
| **GS08** | * | * |
| **GS10** | **19** | **1.1** |
| **GS11** | * | * |
| GS13 | 9 | 1.1 |
| **GS31** | * | * |
| GS51 | NA | NA |
| GS59 | 6 | 1.4 |
| PLFSYSEFF | 5 | 1.2 |
| SW018 | NA | NA |
| **SW027** | * | * |
| **SW093** | **17** | **1.2** |

[a]Number of samples where both U-233,234 and U-238 were greater than 0.025 pCi/L
Bold-face type = POC or POE
NA = Analyte not sampled




Note: Only locations with four or more results are mapped.

*Figure 2–70. Map Showing Average U-233,234/U-238 Ratios for CY 1997–October 13, 2005*




Note: Only locations with four or more results are mapped.

*Figure 2–71. Map Showing Post-Closure Average U-233,234/U-238 Ratios*

### 2.3.2 POE Metals

The following summaries include all results that were not rejected through the validation process. Data are generally presented to decimal places as reported by the laboratories. Accuracy should not be inferred; minimum detectable concentrations/activities and analytical error are often greater than the precision presented. When an 'undetect' is returned from the lab for metals analyses, then one-half the detection limit is used for calculation purposes. When a sample has a corresponding field duplicate, the value used in calculations is the arithmetic average of the 'real' value and the 'duplicate'.[14] When a sample has multiple 'real' analyses (Site requested 'reruns'), the value used in calculations is the arithmetic average of the multiple 'real' analyses.

*Table 2−13. Summary Statistics for POE Metals Results from GS10 in CY 1997−October 13, 2005*

| Analyte | Samples (N) | Undetect | Median (µg/L) | 85th Percentile (µg/L) | Maximum (µg/L) |
|---|---|---|---|---|---|
| Total Be | 263 | 32.3% | 0.12 | 0.63 | 3.40 |
| Dissolved Cd | 259 | 59.1% | 0.05 | 0.15 | 1.00 |
| Total Cr | 264 | 13.3% | 2.40 | 9.72 | 80.10 |
| Dissolved Ag | 258 | 88.8% | 0.11 | 0.18 | 1.10 |

*Table 2−14. Post-Closure Summary Statistics for POE Metals Results from GS10 (October 13, 2005−December 31, 2006)*

| Analyte | Samples (N) | Undetect | Median (µg/L) | 85th Percentile (µg/L) | Maximum (µg/L) |
|---|---|---|---|---|---|
| Total Be | 19 | 100.0% | 0.50 | 0.50 | 0.50 |
| Dissolved Cd | 19 | 100.0% | 0.05 | 0.05 | 0.14 |
| Total Cr | 19 | 78.9% | 0.50 | 1.59 | 2.20 |
| Dissolved Ag | 19 | 100.0% | 0.10 | 0.10 | 0.10 |

*Table 2−15. Summary Statistics for POE Metals Results from SW027 in CY 1997−October 13, 2005*

| Analyte | Samples (N) | Undetect | Median (µg/L) | 85th Percentile (µg/L) | Maximum (µg/L) |
|---|---|---|---|---|---|
| Total Be | 70 | 45.7% | 0.09 | 0.41 | 1.30 |
| Dissolved Cd | 70 | 68.6% | 0.05 | 0.13 | 0.70 |
| Total Cr | 70 | 8.6% | 1.70 | 4.03 | 31.2 |
| Dissolved Ag | 68 | 85.3% | 0.12 | 0.24 | 0.72 |

[14] Arithmetic averaging of metal pairs is performed only when the relative percent difference (RPD) is less than 100 percent. If the RPD is greater than or equal to 100 percent, then the metal results are determined to be non-representative. The results are then not used for the calculation of summary statistics.

*Table 2−16. Post-Closure Summary Statistics for POE Metals Results from SW027 (October 13, 2005−December 31, 2006)*

| Analyte | Samples (N) | Undetect | Median (µg/L) | 85th Percentile (µg/L) | Maximum (µg/L) |
|---|---|---|---|---|---|
| Total Be | 0 | NA | NA | NA | NA |
| Dissolved Cd | 0 | NA | NA | NA | NA |
| Total Cr | 0 | NA | NA | NA | NA |
| Dissolved Ag | 0 | NA | NA | NA | NA |

Notes: NA = not applicable

*Table 2−17. Summary Statistics for POE Metals Results from SW093 in CY 1997−October 13, 2005*

| Analyte | Samples (N) | Undetect | Median (µg/L) | 85th Percentile (µg/L) | Maximum (µg/L) |
|---|---|---|---|---|---|
| Total Be | 284 | 35.2% | 0.11 | 0.55 | 2.10 |
| Dissolved Cd | 284 | 68.7% | 0.05 | 0.14 | 2.20 |
| Total Cr | 283 | 16.3% | 2.00 | 7.40 | 34.90 |
| Dissolved Ag | 280 | 89.6% | 0.10 | 0.18 | 1.03 |

*Table 2−18. Post-Closure Summary Statistics for POE Metals Results from SW093 (October 13, 2005−December 31, 2006)*

| Analyte | Samples (N) | Undetect | Median (µg/L) | 85th Percentile (µg/L) | Maximum (µg/L) |
|---|---|---|---|---|---|
| Total Be | 17 | 100.0% | 0.50 | 0.50 | 0.50 |
| Dissolved Cd | 17 | 94.1% | 0.05 | 0.05 | 0.11 |
| Total Cr | 17 | 64.7% | 0.50 | 1.46 | 1.90 |
| Dissolved Ag | 17 | 100.0% | 0.10 | 0.10 | 0.10 |

## 2.4 Loading Analysis

This section provides a summary of radionuclide loads (Am, Pu, and total U) for RFCA POEs and POCs. These locations collect continuous flow paced composite samples for laboratory analysis. The nature of the continuous sampling during all flow conditions allows for more accurate load estimations compared to storm-event or grab sampling.

This loading analysis should not be confused with demonstration of compliance at POCs and POEs. Compliance is demonstrated based on water activity (essentially concentration in pCi/L) in comparison to applicable surface water standards (sees Sections 2.9 and 2.10). This loading analysis is presented to show the changes in the transport of Pu, Am, and U following Site closure. These changes in load, in conjunction with the successful demonstration of compliance, can be used to support conclusions regarding the success and continued performance of the remedy.

To calculate load, the activity for each composite sample (pCi/L) is multiplied by the corresponding stream discharge (L) during the composite sample period, to yield the load (pCi).

The total pCi value is then converted to micrograms (µg) using the conversion factors in Table 2−19.[15] A detailed description of the method for load estimation is given in Appendix B1.[16]

The Pu-239,240 conversion factor was derived from Table 2.7.2-2 in the April 1980 *Final Environmental Impact Statement (Final Statement to ERDA 1545-D)*, Rocky Flats Plant (RFP) Site.

The conversion factors for Am-241, U-233,234, U-235, and U-238 were taken from the *Code of Federal Regulations* (CFR), Title 40, Chapter I, Part 302.4, Appendix B, October 7, 2000.[17]

*Table 2−19. Activity to Mass Conversion Factors for Pu, Am, and U Isotopes*

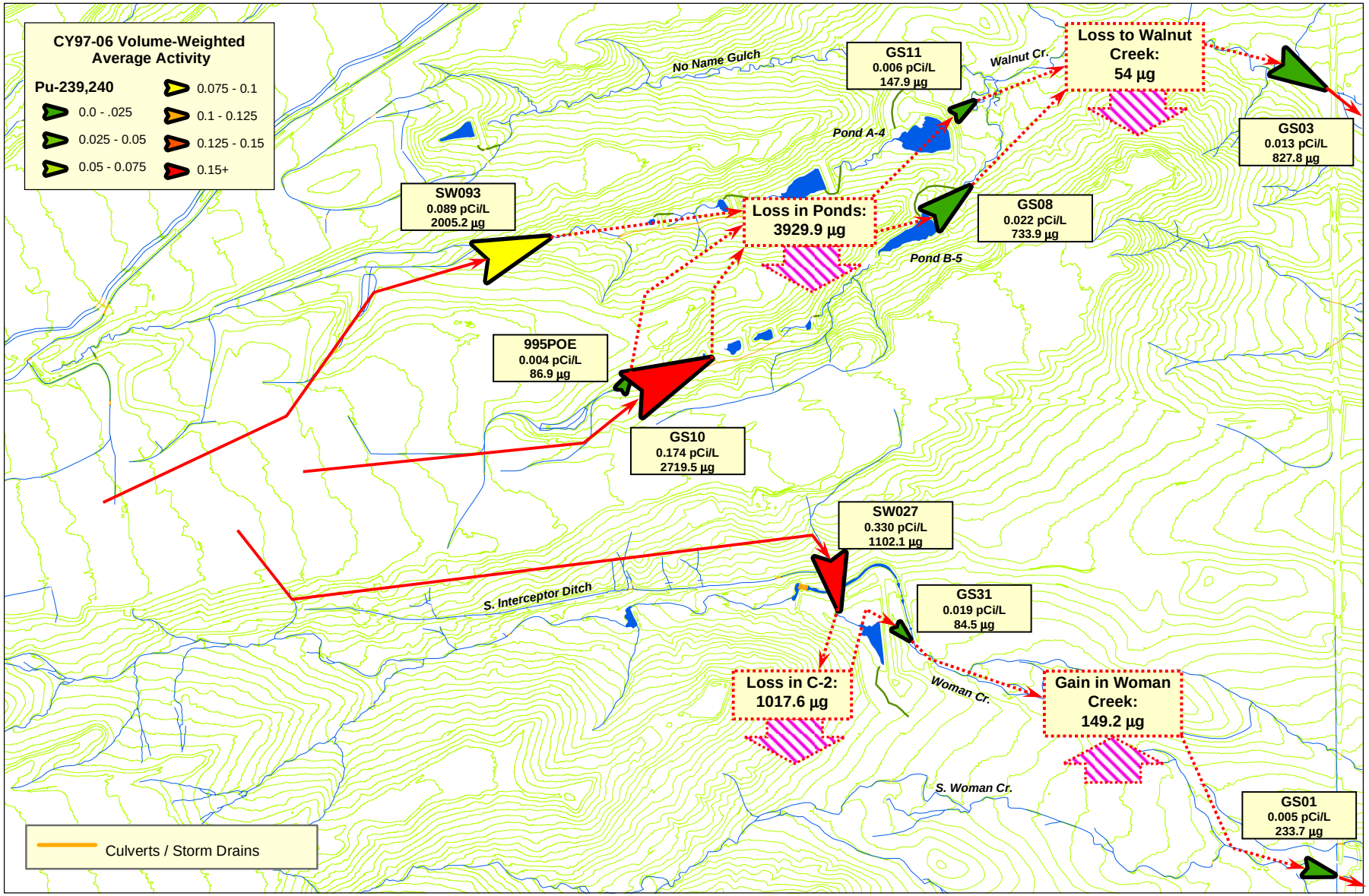
| Analyte | Mass/Activity (g/Ci) |
|---|---|
| Pu-239,240 | 14.085 |
| Am-241 | 0.292 |
| U-233,234 | 1.6 E+02 |
| U-235 | 4.63 E+05 |
| U-238 | 2.98 E+06 |

### 2.4.1 Site-Wide

This section summarizes the calculated overall Pu and Am loads for selected locations. Total uranium data collection began at GS01 and GS03 just prior to CY 2003, as such only CY 2003−2006 data are shown. The following points are noted:

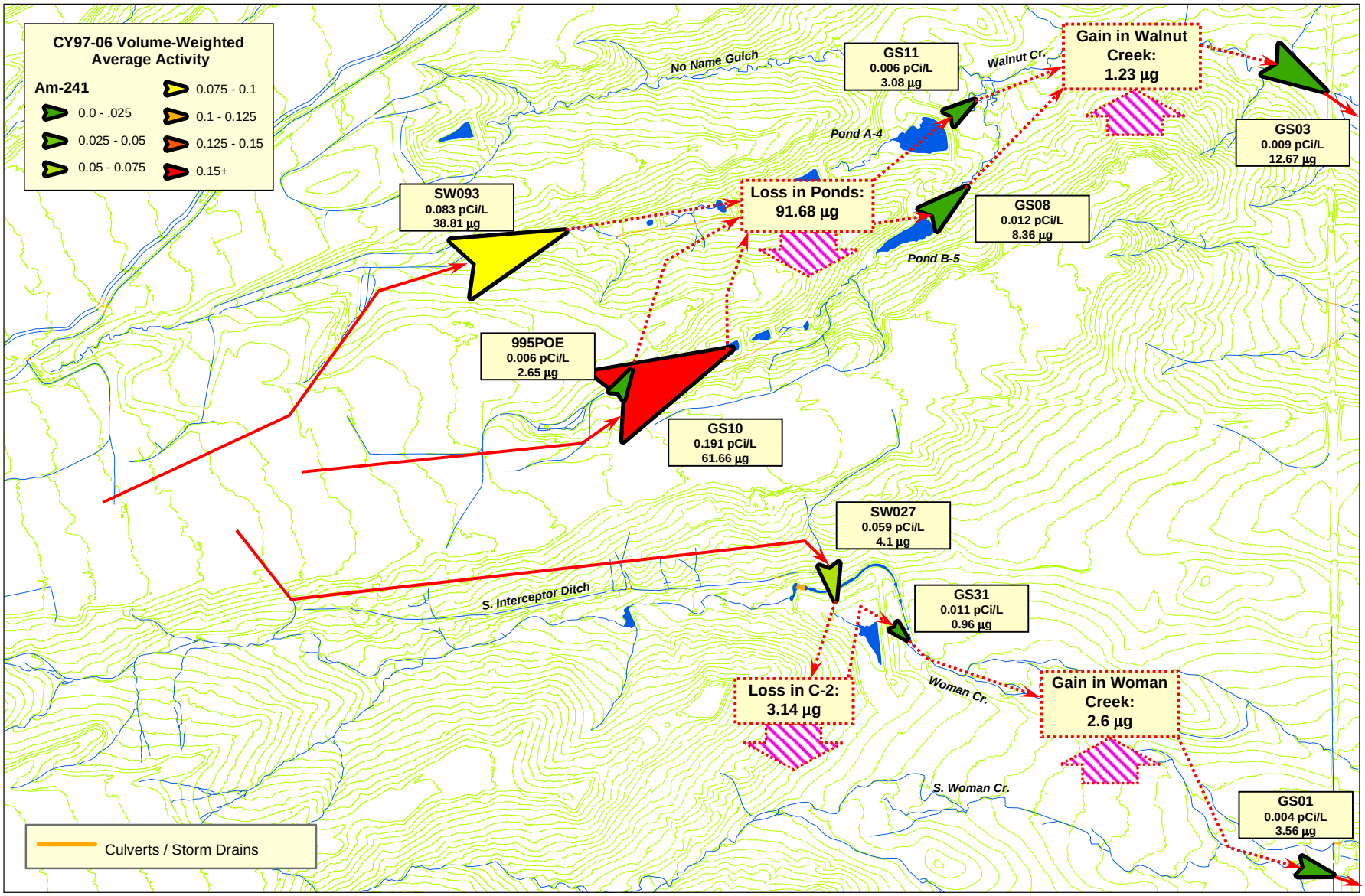
- For lower Walnut Creek, Figure 2–72 shows that there is a calculated Pu loss between the terminal ponds and GS03. For lower Woman Creek, however, there is a calculated gain in Pu load between Pond C-2 and GS01. This is likely due to transport of diffuse, low-level Pu contamination in the much larger flow volumes measured at GS01 (2,456 ac-ft at GS01; 252 ac-ft at GS31). The volume-weighted average Pu activity of 0.005 pCi/L at GS01 is significantly below the standard of 0.15 pCi/L.
- For lower Walnut Creek, Figure 2–73 shows that there is a calculated Am gain between the terminal ponds and GS03. For lower Woman Creek, there is a larger calculated gain in Am load between Pond C-2 and GS01. This is likely due to transport of diffuse, low-level Am contamination in the much larger flow volumes measured at GS01. The volume-weighted Am activity of 0.004 pCi/L at GS01 is significantly below the standard of 0.15 pCi/L.
- For lower Walnut Creek, Figure 2–74 shows that there is a calculated U[18] gain between the terminal ponds and GS03. For lower Woman Creek, however, there is a much larger gain in U load between Pond C-2 and GS01. This is likely due to naturally occurring U in the much larger flow volumes measured at GS01 (since 2003, 805 ac-ft at GS01; 89 ac-ft at GS31).[19] The volume-weighted total U activity of 2.15 pCi/L at GS01 is significantly below the standard of 11 pCi/L.

[15] In the following tables and plots, values are rounded for presentation.
[16] Data are generally presented at varying precision for presentation. Accuracy should not be inferred; both analytical and flow measurement error have not been quantified in this report.
[17] The U-234 conversion factor was used to represent U-233,234 due to the small relative abundance of U-233.
[18] Total U is calculated as the sum of individual isotopes: U-233.234 + U-235 + U-238.
[19] For the CY 2003−2006 period.



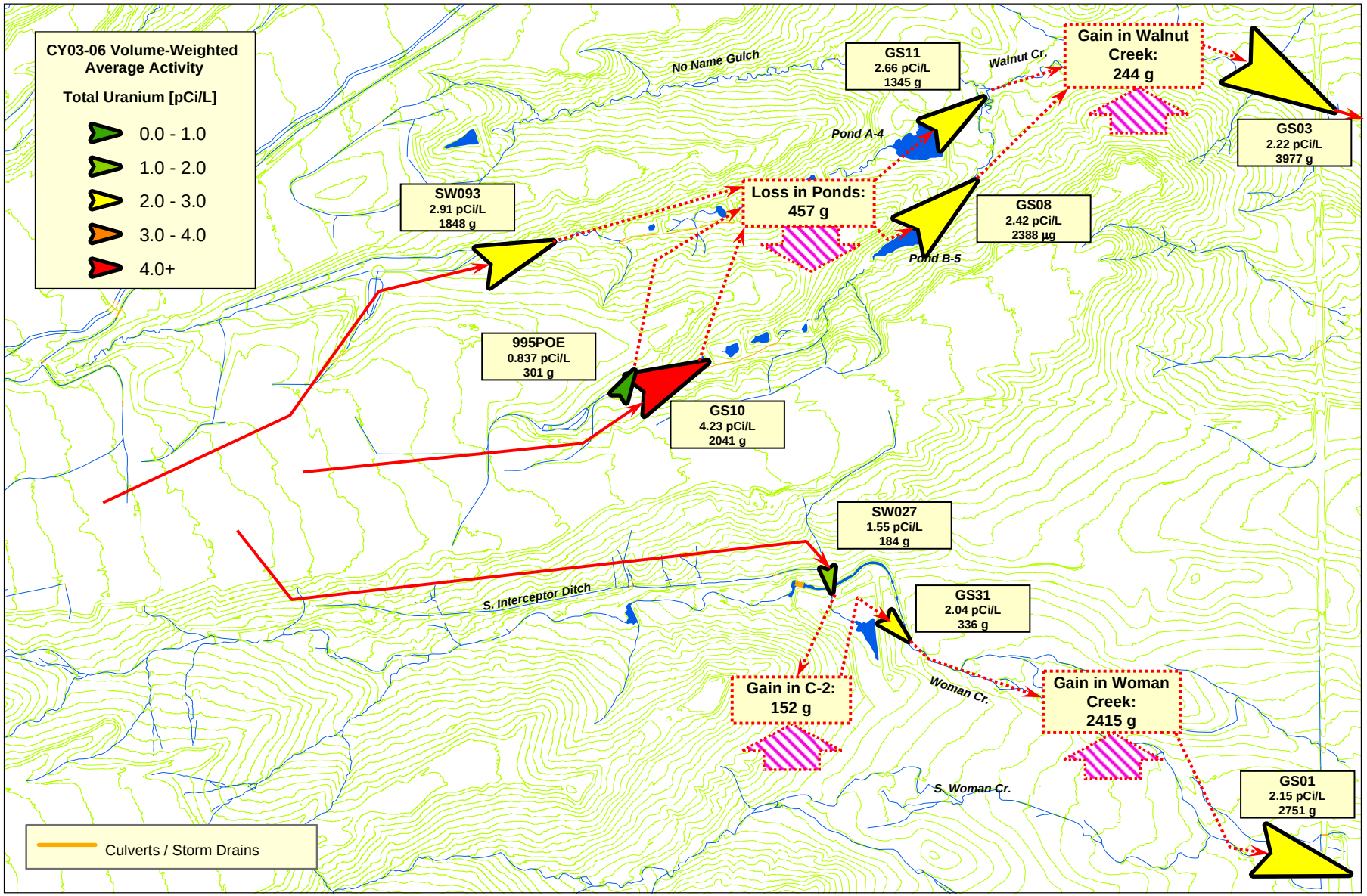

Note: Location symbols are displayed proportional to calculated load and shaded according to activity ranges in legend.

*Figure 2–72. Relative Pu Loading Schematic: CY 1997–2006*




Note: Location symbols are displayed proportional to calculated load and shaded according to activity ranges in legend.

*Figure 2–73. Relative Am Loading Schematic: CY 1997–2006*




Note: Location symbols are displayed proportional to calculated load and shaded according to activity ranges in legend.

*Figure 2–74. Relative Total Uranium Loading Schematic: CY 2003−2006*

### 2.4.2 Fenceline Points of Compliance

This section summarizes the calculated offsite Pu and Am loads from Walnut and Woman Creeks. The following points are noted:

- Walnut Creek accounts for 78 percent of both the Pu (Figure 2–77) and Am (Figure 2–79) loads at Indiana Street. The fact that Walnut Creek only accounts for 61 percent of the combined Walnut and Woman Creek flow volumes (Section 2.2.2.1) shows that the activities in Walnut Creek are somewhat higher than Woman Creek.
- Both Pu and Am loads have decreased in recent years as Site closure activities have reduced discharge volumes and eliminated source terms (Figure 2–75).
- U analysis at both GS01 and GS03 began just prior to CY 2003. Walnut Creek accounts for 78 percent of the total U (Figure 2–81) load at Indiana Street for CY 2003−2005 (57 percent of the flow volume).

*Table 2−20. Offsite Pu and Am Loads from Walnut and Woman Creeks: CY 1997–2006*

| Calendar Year | Pu-239,240 (µg) | | | Am-241 (µg) | | |
|---|---|---|---|---|---|---|
| | Walnut Creek | Woman Creek | Site Total | Walnut Creek | Woman Creek | Site Total |
| 1997 | 262.4 | 47.9 | 310.3 | 2.99 | 0.40 | 3.39 |
| 1998 | 172.2 | 55.4 | 227.6 | 2.66 | 0.99 | 3.65 |
| 1999 | 150.2 | 56.7 | 206.9 | 1.83 | 0.75 | 2.57 |
| 2000 | 26.0 | 6.1 | 32.1 | 0.74 | 0.18 | 0.92 |
| 2001 | 58.6 | 22.4 | 81.0 | 0.63 | 0.30 | 0.93 |
| 2002 | 37.4 | 0.8 | 38.2 | 0.37 | 0.03 | 0.40 |
| 2003 | 57.6 | 25.9 | 83.5 | 1.07 | 0.34 | 1.41 |
| 2004 | 33.1 | 4.7 | 37.8 | 0.70 | 0.15 | 0.86 |
| 2005 | 30.3 | 12.5 | 42.8 | 1.67 | 0.30 | 1.97 |
| 2006 | 0.0 | 1.4 | 1.4 | 0.0 | 0.13 | 0.13 |
| **Total** | 827.8 | 233.7 | 1,061.5 | 12.67 | 3.56 | 16.23 |

Note: During CY 1997, flows from Woman Creek were routinely diverted to Mower Ditch for subsequent monitoring at GS02. Therefore, the load calculated for Woman Creek at Indiana Street (GS01) includes the water that was measured at GS02. The estimated load diverted to GS02 is calculated by multiplying the CY 1997 volume-weighted activities at GS01 by the streamflow volume measured at GS02, and converting for units. This diverted load is then added to the calculated load at GS01 to obtain the total CY 1997 load at GS01. For subsequent water years, the Mower diversion structure has been upgraded and configured to prevent Woman Creek flows from entering the Mower Ditch.

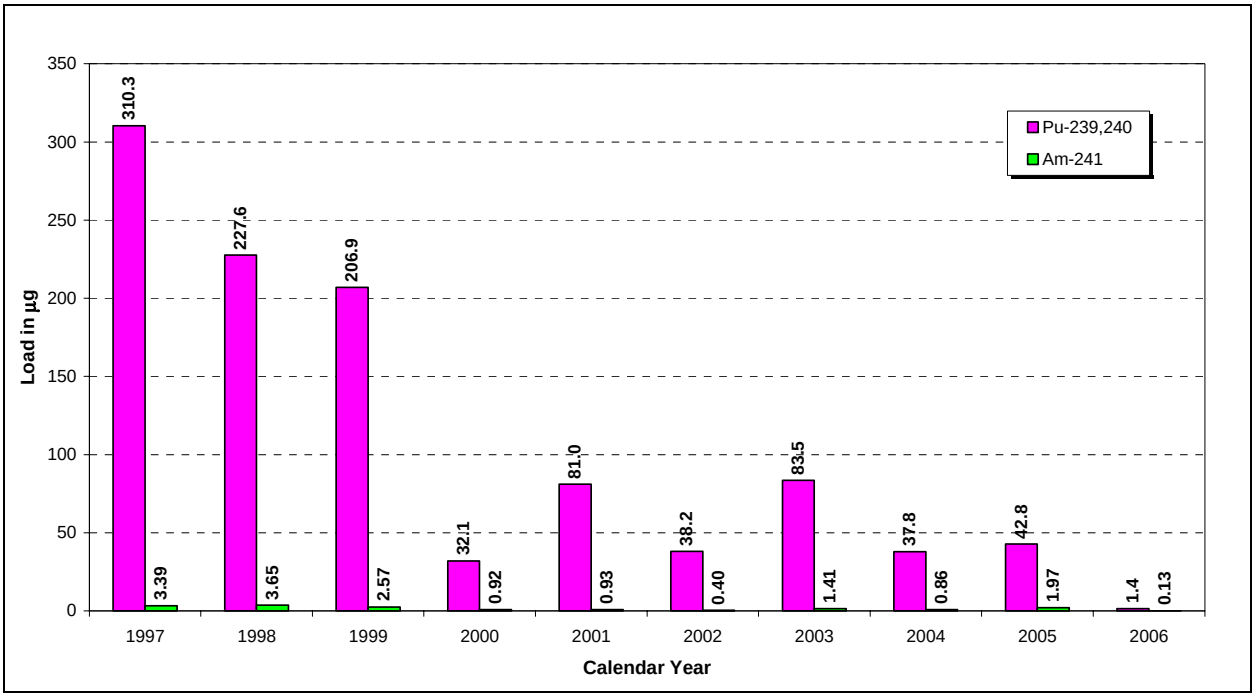



*Figure 2–75. Combined Annual Pu and Am Loads from Walnut and Woman Creeks: CY 1997–2006*

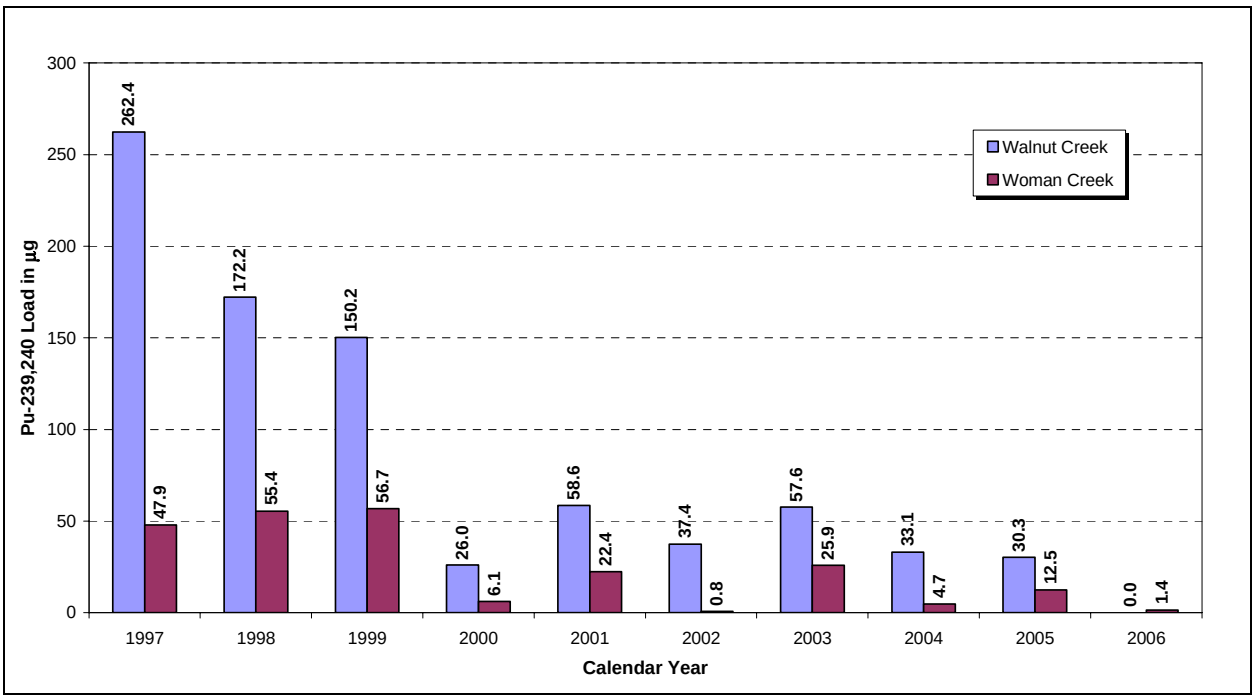



*Figure 2–76. Annual Pu Loads from Walnut and Woman Creeks: CY 1997–2006*

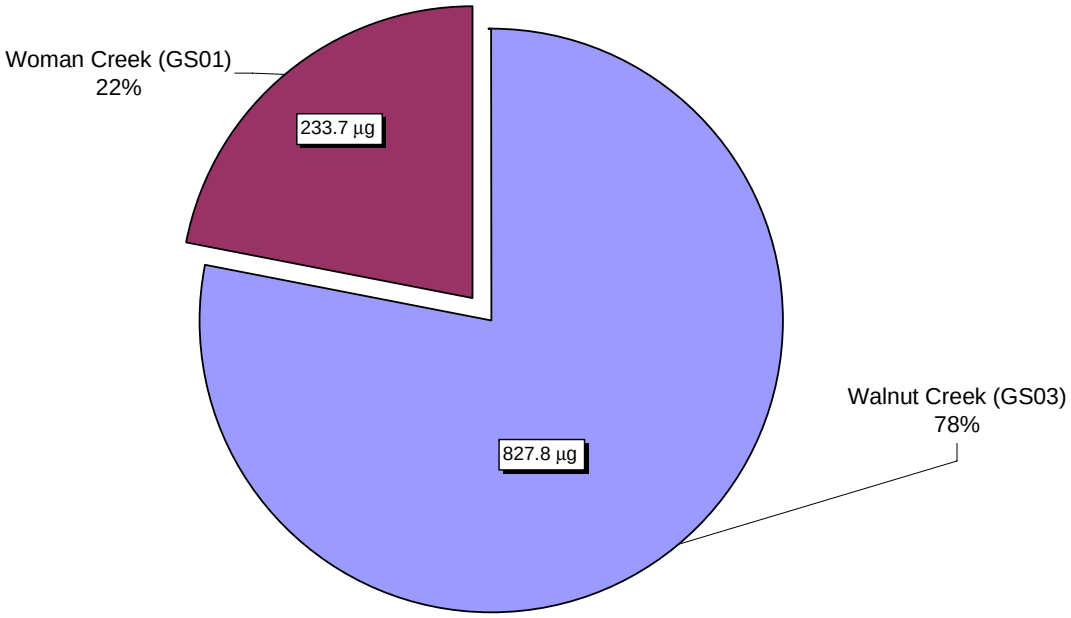



*Figure 2–77. Relative Pu Load Totals from Walnut and Woman Creeks: CY 1997–2006*

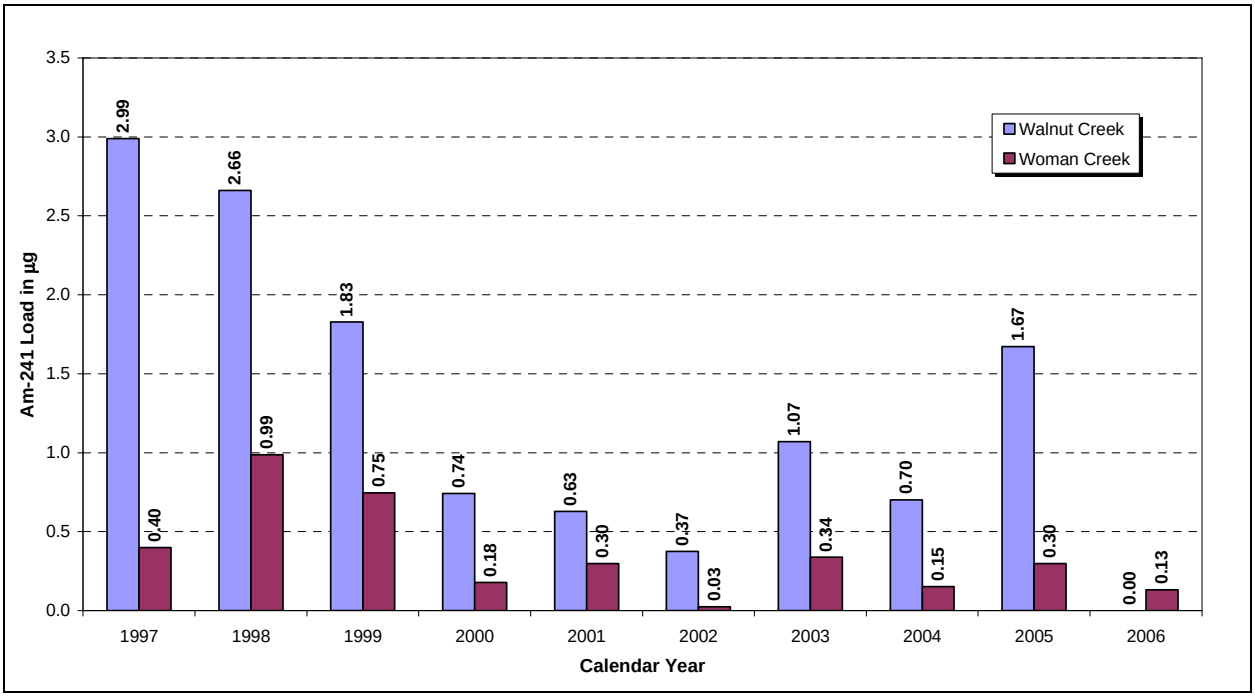



*Figure 2–78. Annual Am Loads from Walnut and Woman Creeks: CY 1997–2006*

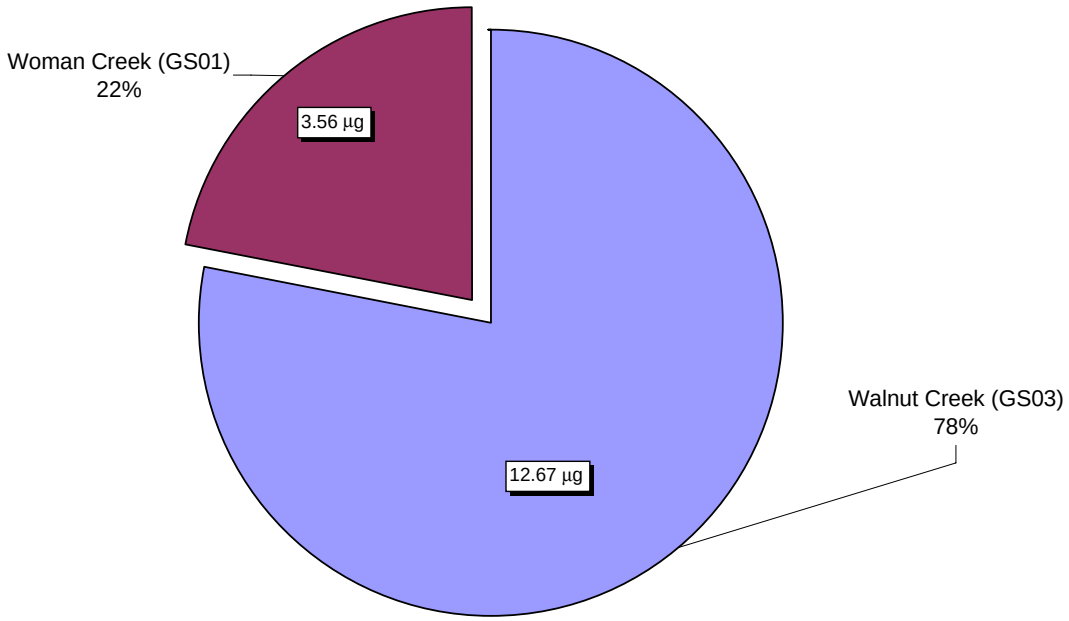



*Figure 2–79. Relative Am Load Totals from Walnut and Woman Creeks: CY 1997–2006*

*Table 2−21. Total Uranium Loads from Walnut and Woman Creeks: CY 2003−2006*

| Calendar Year | Total Uranium (g) | |
|---|---|---|
| | **Walnut Creek** | **Woman Creek** |
| 2003 | 1,751 | 790 |
| 2004 | 744 | 808 |
| 2005 | 1,482 | 918 |
| 2006 | 0<br>No flow | 235 |
| **Total** | 3,977 | 2,751 |

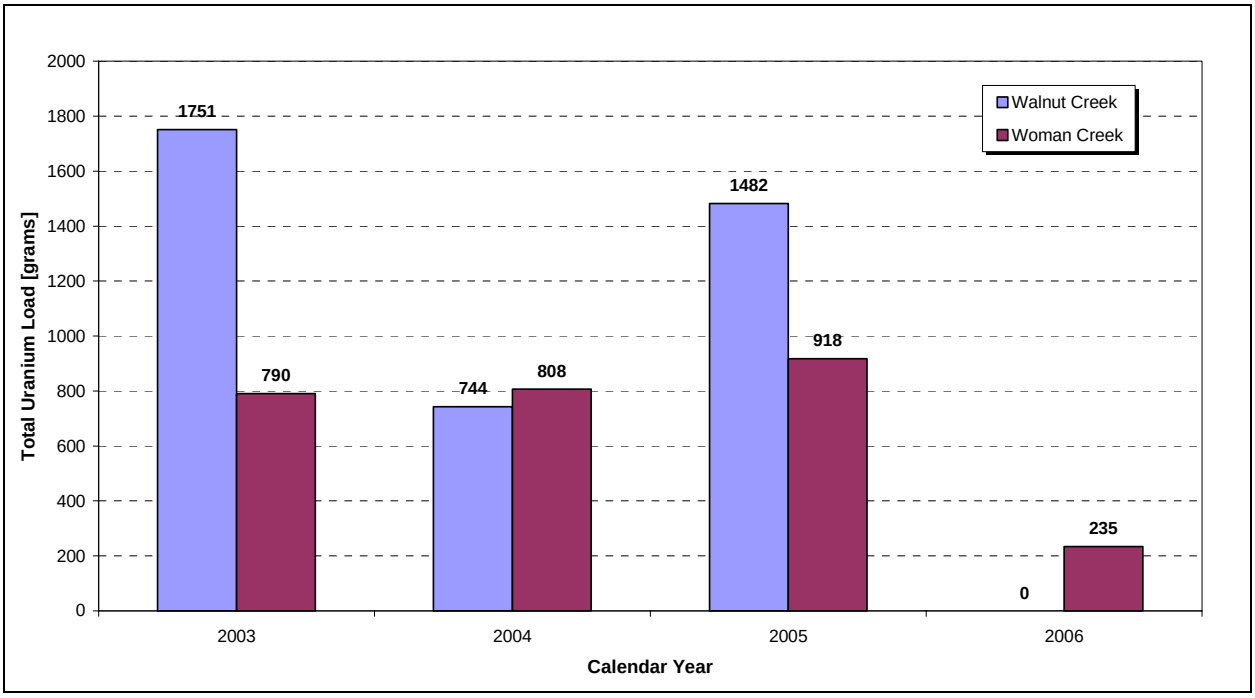



*Figure 2–80. Annual Total Uranium Loads from Walnut and Woman Creeks: CY 2003–2006*

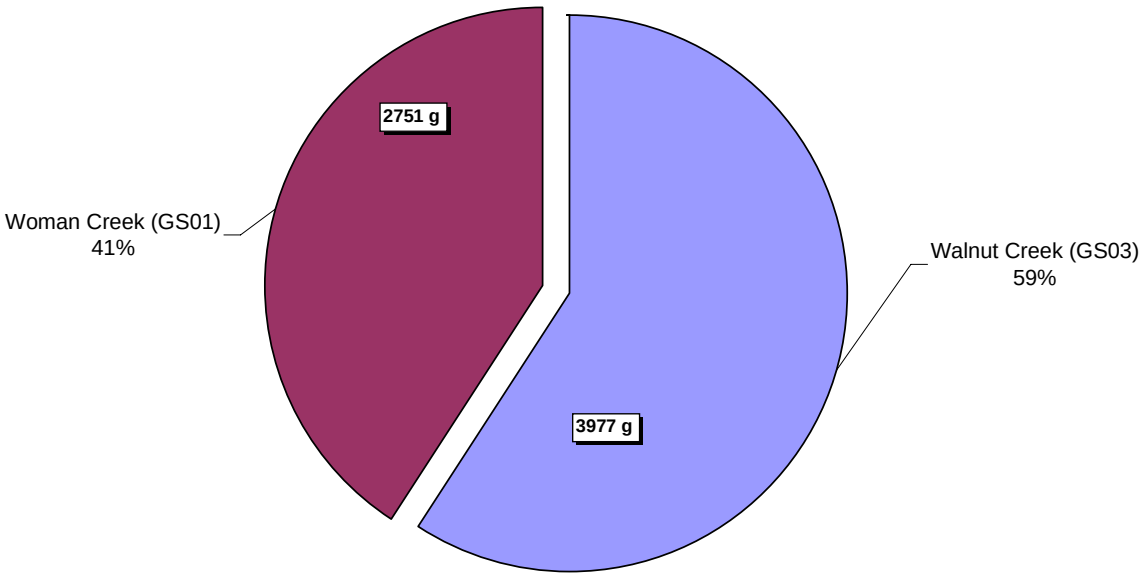



*Figure 2–81. Relative Total Uranium Load from Walnut and Woman Creeks: CY 2003−2006*

### 2.4.3 Walnut Creek (POC GS03)

This section summarizes the calculated Pu and Am loads in Walnut Creek at GS03 (Walnut and Indiana Street), GS08 (Pond B-5), and GS11 (Pond A-4). Total U data collection began at GS03 on November 5, 2002, as such only CY 2003−2006 data are shown. The following points are noted:

- Annual Pu and Am loads vary by up to two orders of magnitude year to year (Figure 2–83 and Figure 2–85). The significant annual variability in Pu and Am loads is likely due to the very low measured activities and the inherent analytical error at such low levels.
- Pu and Am loads appear to be decreasing at GS03 (Figure 2–82). The slight increase in Am loads at GS03 during CY 2005 is due to increased Am contributions to the A-Series Ponds related to the decontamination and decommissioning (D&D) of B771. Treatment of Pond A-4 water was successful in reducing Am levels well below the applicable standard (0.15 pCi/L), but the Am activity of the discharged water was somewhat higher than normal. Pond B-5 also showed some increased Am activity due to temporarily increased Am load associated with solids transport resulting from the construction of FC-4. These slightly higher Am activities were subsequently measured at GS03.
- Pu and Am loads from Pond B-5 are significantly greater than loads from Pond A-4 (Table 2−22 and Table 2−23), a result of both higher activities and larger discharge volumes prior to Closure.
- Total Pu loads from Ponds A-4 and B-5 for the entire period of 1997 through 2006 are marginally greater than the loads at GS03 (Table 2−22 and Figure 2–84), indicating a small net loss of load to the Walnut Creek streambed below Ponds A-4 and B-5.
- Total Am loads from Ponds A-4 and B-5 for the entire period of 1997 through 2006 are marginally less than the loads at GS03 (Table 2−23 and Figure 2–86), indicating a small net gain of load (11 percent) from tributaries and the Walnut Creek streambed below Ponds A-4 and B-5.
- Total CY 2003−2006 U loads from Ponds A-4 and B-5 are less than the loads at GS03 (Figure 2–88), indicating a small net gain of load from tributaries and the Walnut Creek streambed below Ponds A-4 and B-5.

*Table 2−22. Pu Loads at GS03, GS08, and GS11: CY 1997–2006*

| Calendar Year | Pu-239,240 (µg) | | | |
|---|---|---|---|---|
| | **Pond A-4 (GS11)** | **Pond B-5 (GS08)** | **Walnut Creek Terminal Ponds Total** | **POC GS03** |
| 1997 | 59.2 | 8.8 | 68.0 | 262.4 |
| 1998 | 20.0 | 22.4 | 42.4 | 172.2 |
| 1999 | 23.8 | 261.4 | 285.2 | 150.2 |
| 2000 | 28.4 | 244.6 | 273.0 | 26.0 |
| 2001 | 4.7 | 32.3 | 37.0 | 58.6 |
| 2002 | 0.1 | 7.8 | 7.9 | 37.4 |
| 2003 | 7.3 | 111.5 | 118.8 | 57.6 |
| 2004 | 2.2 | 27.1 | 29.3 | 33.1 |
| 2005 | 2.2 | 17.9 | 20.1 | 30.3 |
| 2006 | 0.0;<br>No A-4 discharge | 0.0;<br>No B-5 discharge | 0.0 | 0.0<br>No flow |
| **Total** | 147.9 | 733.9 | 881.8 | 827.8 |

Notes: NA = not applicable

*Table 2−23. Am Loads at GS03, GS08, and GS11: CY 1997–2006*

| Calendar Year | Am-241 (µg) | | | |
|---|---|---|---|---|
| | **Pond A-4 (GS11)** | **Pond B-5 (GS08)** | **Walnut Creek Terminal Ponds Total** | **POC GS03** |
| 1997 | 0.70 | 0.25 | 0.95 | 2.99 |
| 1998 | 1.25 | 0.35 | 1.60 | 2.66 |
| 1999 | 0.20 | 1.81 | 2.01 | 1.83 |
| 2000 | 0.02 | 3.14 | 3.16 | 0.74 |
| 2001 | 0.11 | 0.46 | 0.57 | 0.63 |
| 2002 | 0.04 | 0.25 | 0.29 | 0.37 |
| 2003 | 0.18 | 0.54 | 0.72 | 1.07 |
| 2004 | 0.14 | 0.58 | 0.73 | 0.70 |
| 2005 | 0.43 | 0.97 | 1.39 | 1.67 |
| 2006 | 0.0<br>No A-4 discharge | 0.0;<br>No B-5 discharge | 0.00 | 0.0<br>No flow |
| **Total** | 3.08 | 8.36 | 11.44 | 12.67 |

Notes: NA = not applicable

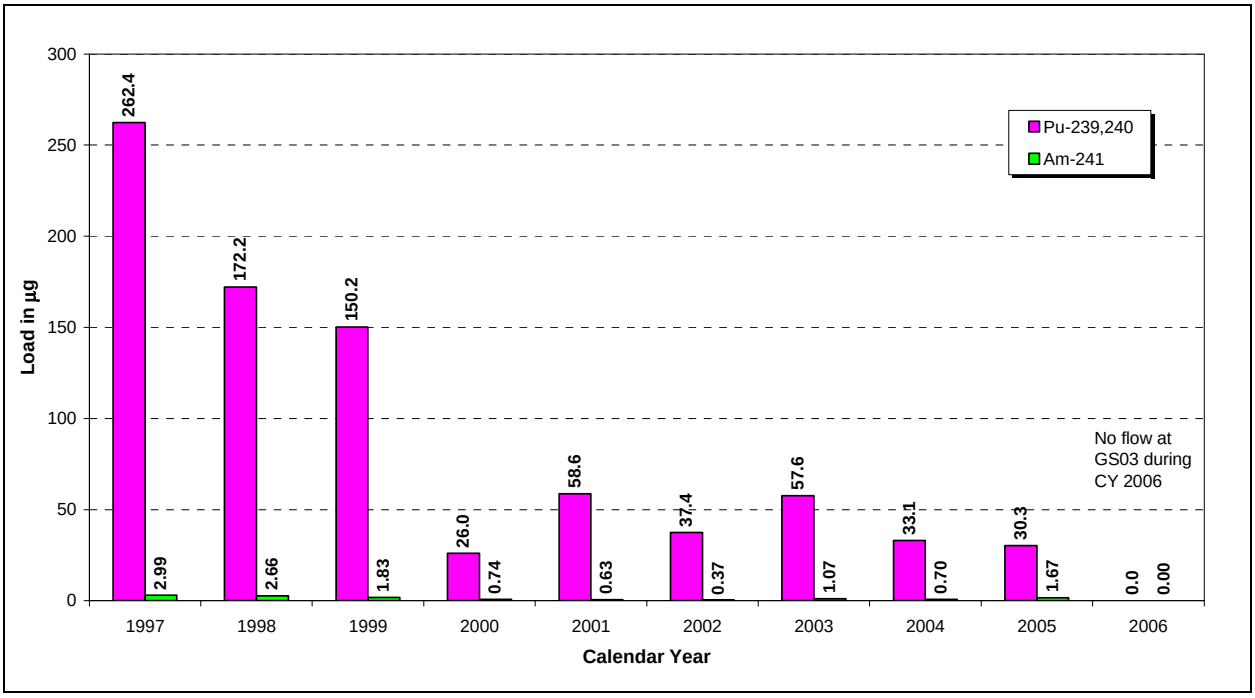



*Figure 2–82. Annual Pu and Am Loads at GS03: CY 1997–2006*

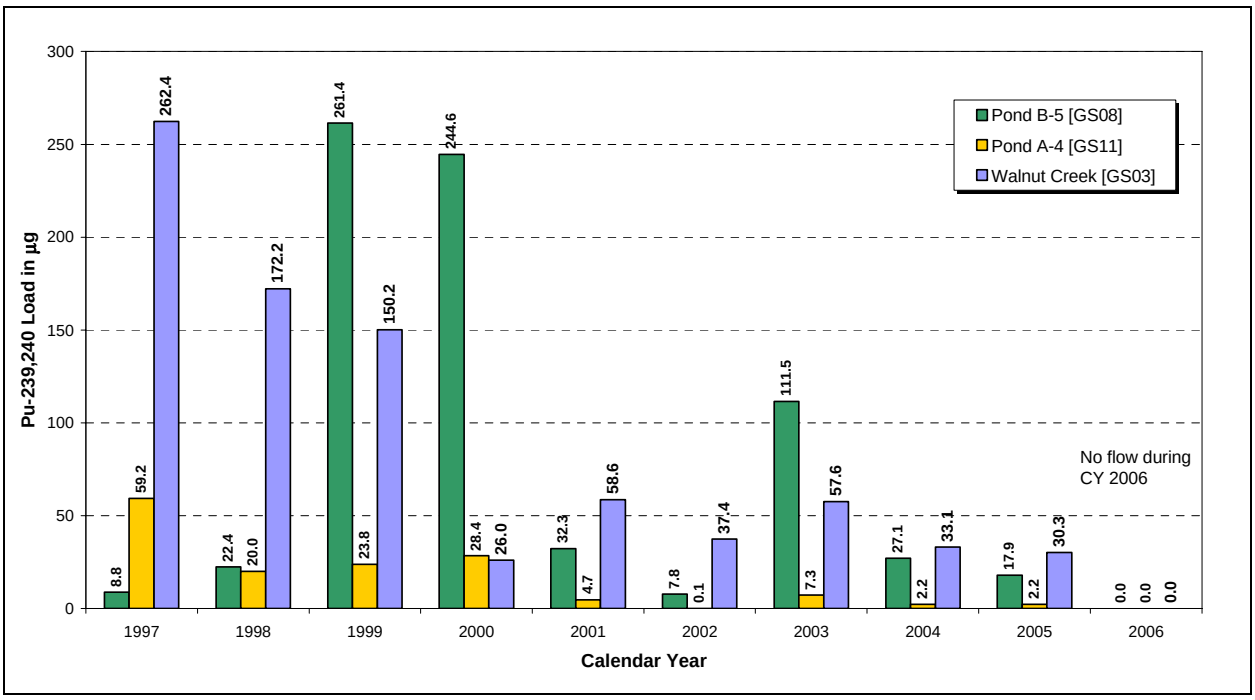



*Figure 2–83. Annual Pu Loads at GS03, GS08, and GS11: CY 1997–2006*

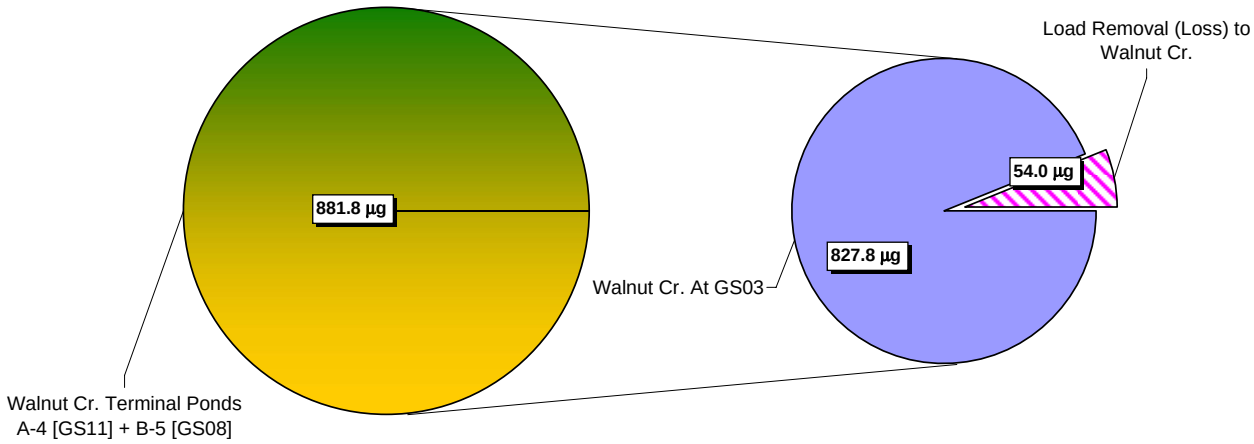



*Figure 2–84. Relative Pu Load Totals at GS03, GS08, and GS11: CY 1997–2006*

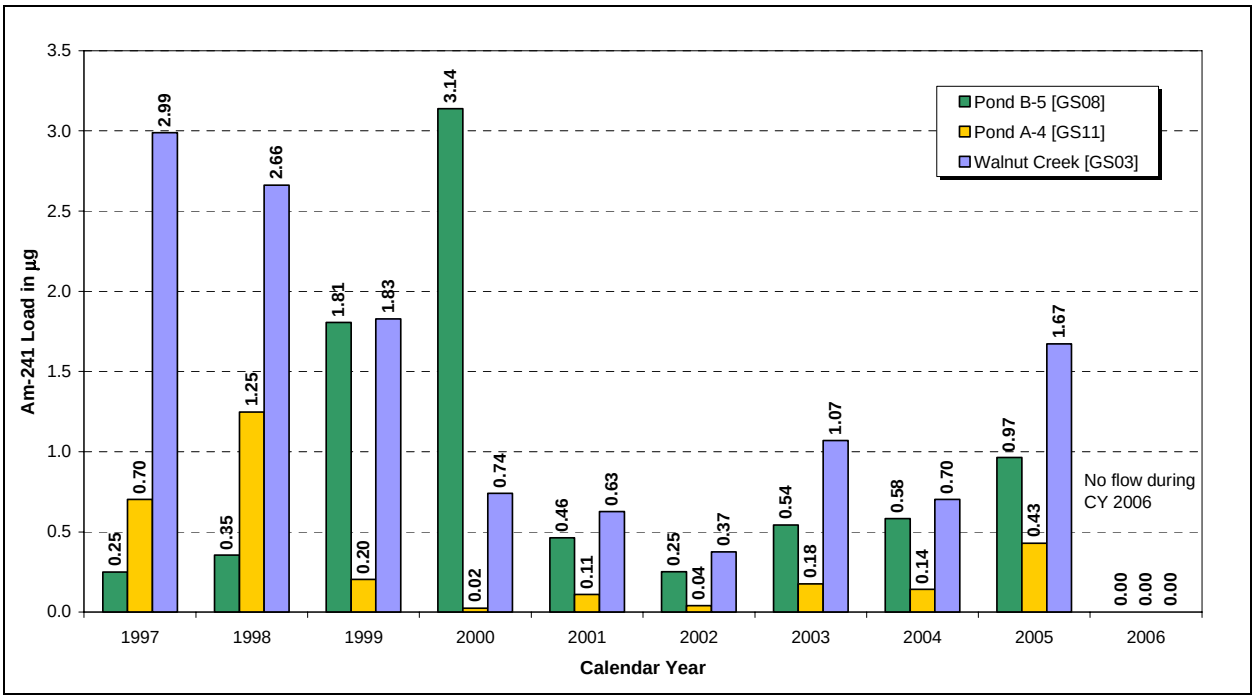



*Figure 2–85. Annual Am Loads at GS03, GS08, and GS11: CY 1997–2006*

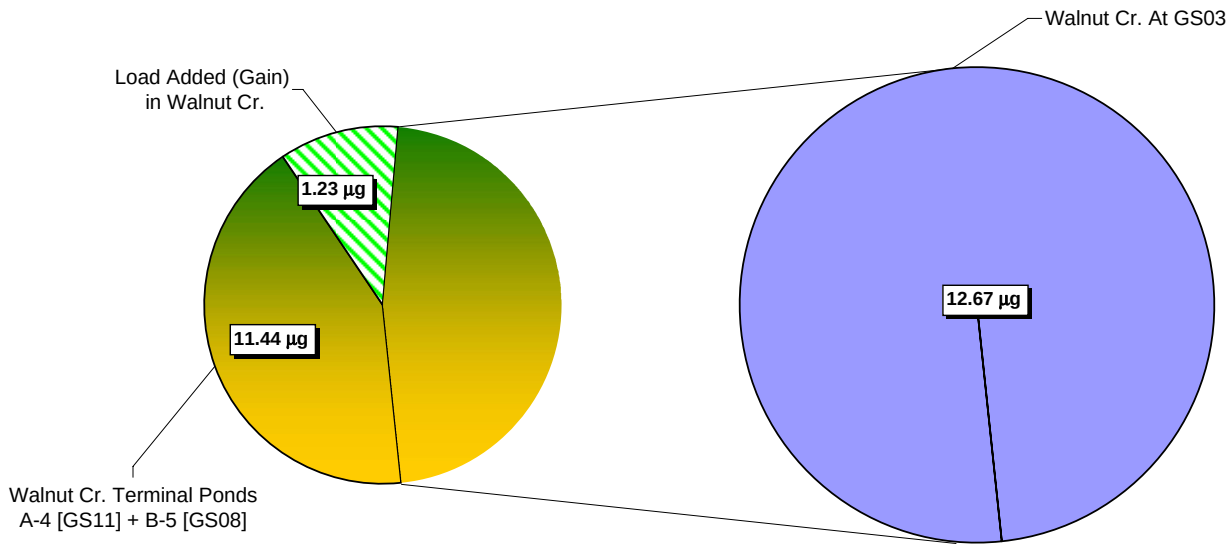



*Figure 2–86. Relative Am Load Totals at GS03, GS08, and GS11: CY 1997–2006*

*Table 2−24. Total Uranium Loads at GS03, GS08, and GS11: CY 2003−2006*

| Calendar Year | Total Uranium (g) | | | |
|---|---|---|---|---|
| | **Pond A-4 (GS11)** | **Pond B-5 (GS08)** | **Walnut Creek Terminal Ponds Total** | **POC GS03** |
| 2003 | 865 | 610 | 1,474 | 1,751 |
| 2004 | 316 | 390 | 705 | 744 |
| 2005 | 165 | 1,389 | 1,554 | 1,482 |
| 2006 | 0;<br>No A-4 discharge | 0;<br>No B-5 discharge | 0 | 0<br>No flow |
| **Total** | 1,345 | 2,388 | 3,733 | 3,977 |

Notes: NA = not applicable

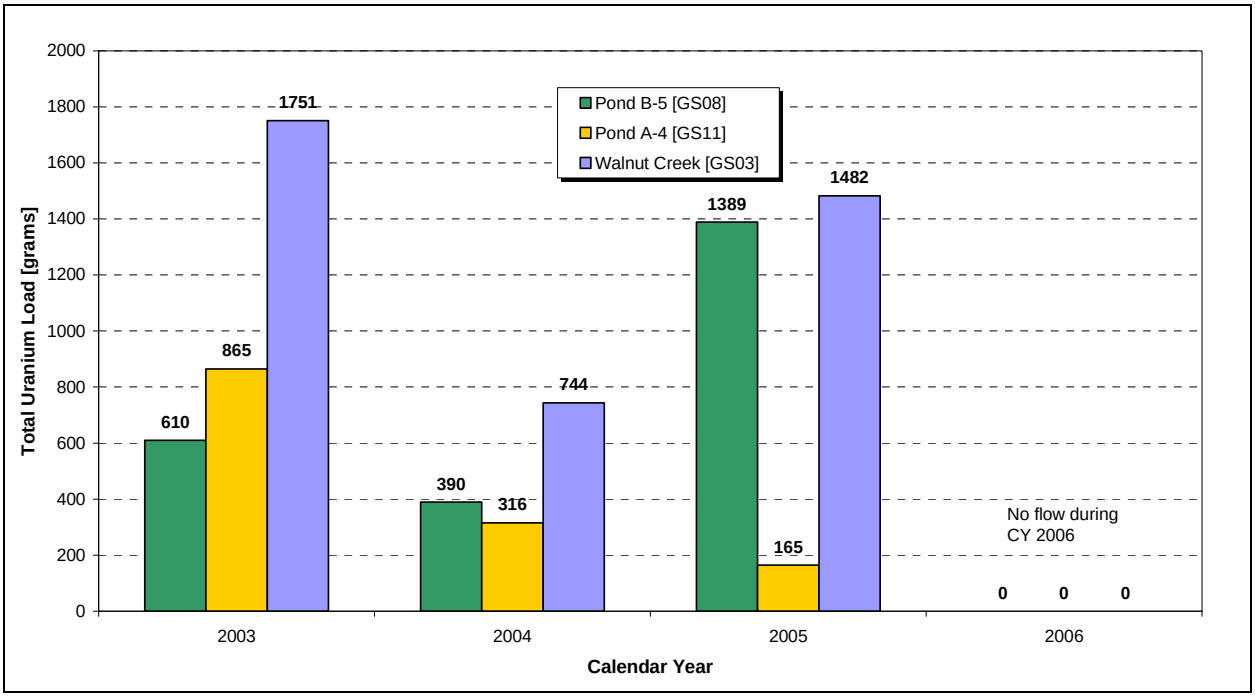



*Figure 2–87. Annual Total Uranium Loads at GS03, GS08, and GS11: CY 2003−2006*

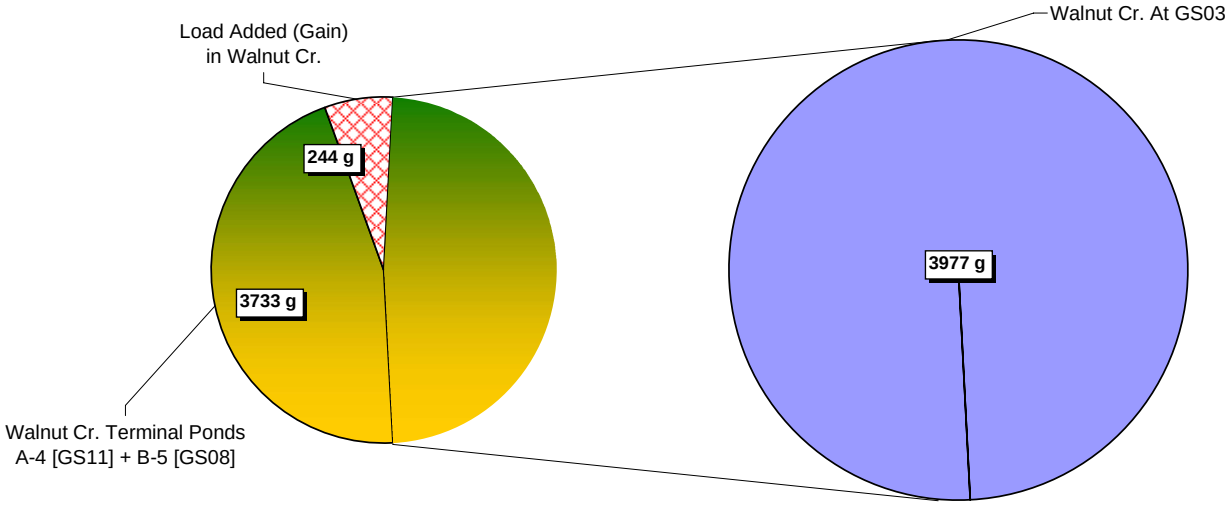



*Figure 2–88. Relative Total Uranium Load Totals at GS03, GS08, and GS11: CY 2003−2006*

### 2.4.4 Woman Creek (POC GS01)

This section summarizes the calculated Pu and Am loads in Woman Creek at GS01 (Woman Creek at Indiana Street) and GS31 (Pond C-2). Total U data collection began at GS01 on February 3, 2003, as such only CY 2003−2006 data are shown. The following points are noted:

- Annual Pu and Am loads generally vary by up to two orders of magnitude year to year (Figure 2–90 and Figure 2–92). The significant annual variability in Pu and Am loads is likely due to the very low measured activities and the inherent analytical error at such low levels.
- Pu and Am loads appear to be decreasing at GS01 (Figure 2–89).
- Total Pu loads from Pond C-2 are less than the loads at GS01 (Table 2−25 and Figure 2–91), indicating a gain of load from the Woman Creek drainage.
- Total Am loads from Pond C-2 are less than the loads at GS01 (Table 2−26 and Figure 2–93), indicating a gain of load from the Woman Creek drainage.
- Total CY 2003−2006 U load from Pond C-2 is less than the load at GS01 (Table 2−27 and Figure 2–95), indicating a gain of load from naturally occurring U in the Woman Creek drainage.

*Table 2−25. Pu Loads at GS01 and GS31: CY 1997–2006*

| Calendar Year | Pu-239,240 (µg) | |
|---|---|---|
| | Pond C-2 (GS31) | POC GS01 |
| 1997 | 16.7 | 47.9 |
| 1998 | 2.2 | 55.4 |
| 1999 | 26.9 | 56.7 |
| 2000 | 0.0;<br>No C-2 discharge | 6.1 |
| 2001 | 11.0 | 22.4 |
| 2002 | 0.2 | 0.8 |
| 2003 | 11.0 | 25.9 |
| 2004 | 11.5 | 4.7 |
| 2005 | 5.0 | 12.5 |
| 2006 | 0.0;<br>No C-2 discharge | 1.4 |
| **Total** | 84.5 | 233.7 |

Note: During CY 1997 (through September 30, 1997), flows from Woman Creek were routinely diverted to Mower Ditch for subsequent monitoring at GS02 (discontinued location). Therefore, the load calculated for Woman Creek at Indiana Street (GS01) includes the water that was measured at GS02. The estimated load diverted to GS02 is calculated by multiplying the CY 1997 volume-weighted activities at GS01 by the streamflow volume measured at GS02, and converting for units. This diverted load is then added to the calculated load at GS01 to obtain the total CY 1997 load at GS01. For subsequent water years, the Mower diversion structure has been upgraded and configured to prevent Woman Creek flows from entering the Mower Ditch.
NA = not applicable

*Table 2−26. Am Loads at GS01 and GS31: CY 1997–2006*

| Calendar Year | Am-241 (µg) | |
|---|---|---|
| | Pond C-2 (GS31) | POC GS01 |
| 1997 | 0.17 | 0.40 |
| 1998 | 0.27 | 0.99 |
| 1999 | 0.13 | 0.75 |
| 2000 | 0.00;<br>No C-2 discharge | 0.18 |
| 2001 | 0.14 | 0.30 |
| 2002 | <0.01 | 0.03 |
| 2003 | 0.09 | 0.34 |
| 2004 | 0.11 | 0.15 |
| 2005 | 0.04 | 0.30 |
| 2006 | 0.0;<br>No C-2 discharge | 0.13 |
| **Total** | 0.96 | 3.56 |

Note: During CY 1997 (through September 30, 1997), flows from Woman Creek were routinely diverted to Mower Ditch for subsequent monitoring at GS02 (discontinued location). Therefore, the load calculated for Woman Creek at Indiana Street (GS01) includes the water that was measured at GS02. The estimated load diverted to GS02 is calculated by multiplying the CY 1997 volume-weighted activities at GS01 by the streamflow volume measured at GS02, and converting for units. This diverted load is then added to the calculated load at GS01 to obtain the total CY 1997 load at GS01. For subsequent water years, the Mower diversion structure has been upgraded and configured to prevent Woman Creek flows from entering the Mower Ditch.
Notes: NA = not applicable

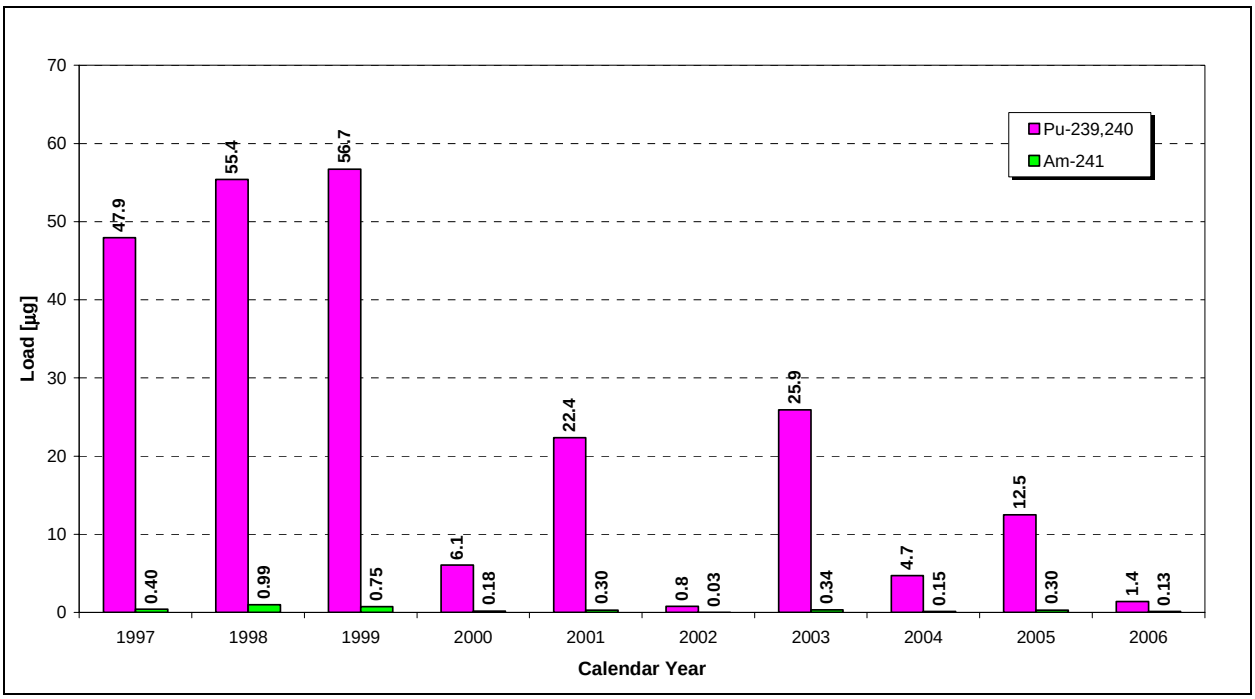



*Figure 2–89. Annual Pu and Am Loads at GS01: CY 1997–2006*

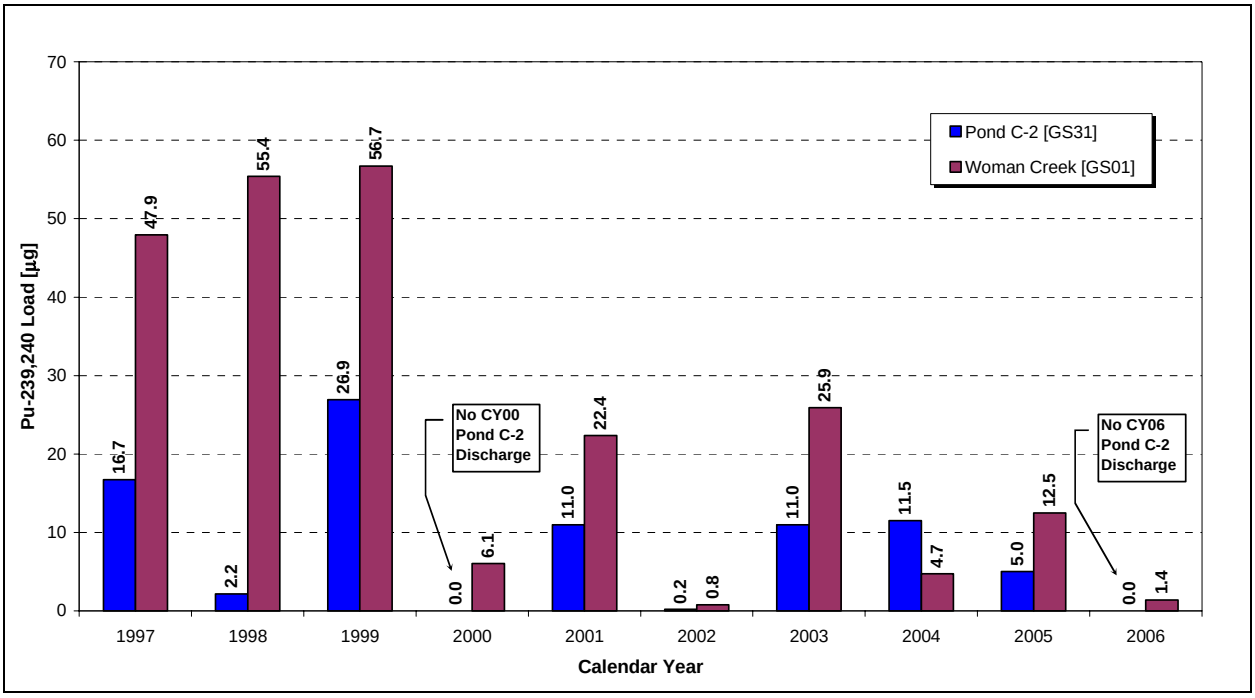



*Figure 2–90. Annual Pu Loads at GS01 and GS31: CY 1997–2006*

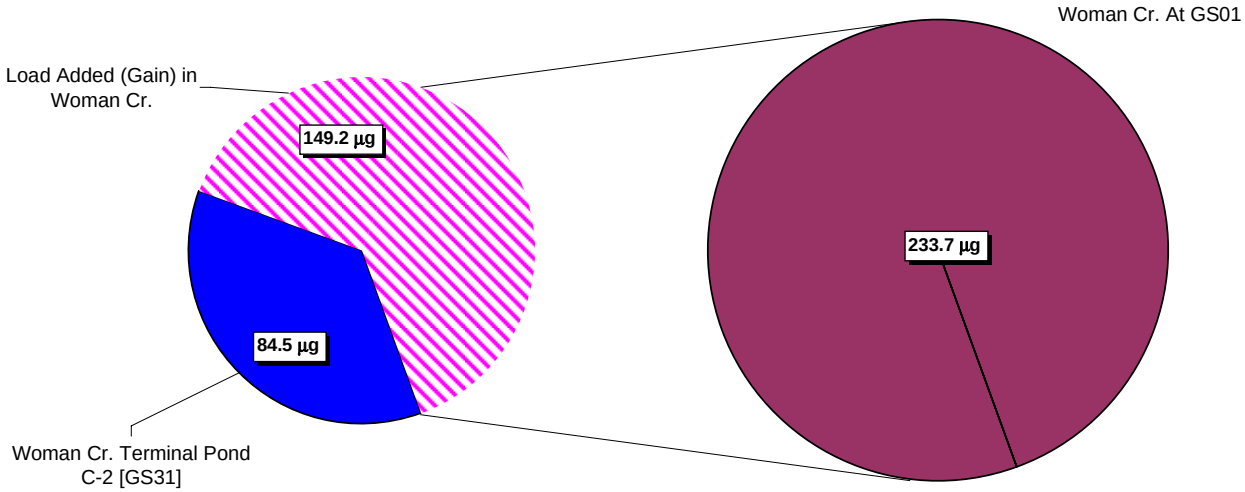



*Figure 2–91. Relative Pu Load Totals at GS01 and GS31: CY 1997–2006*

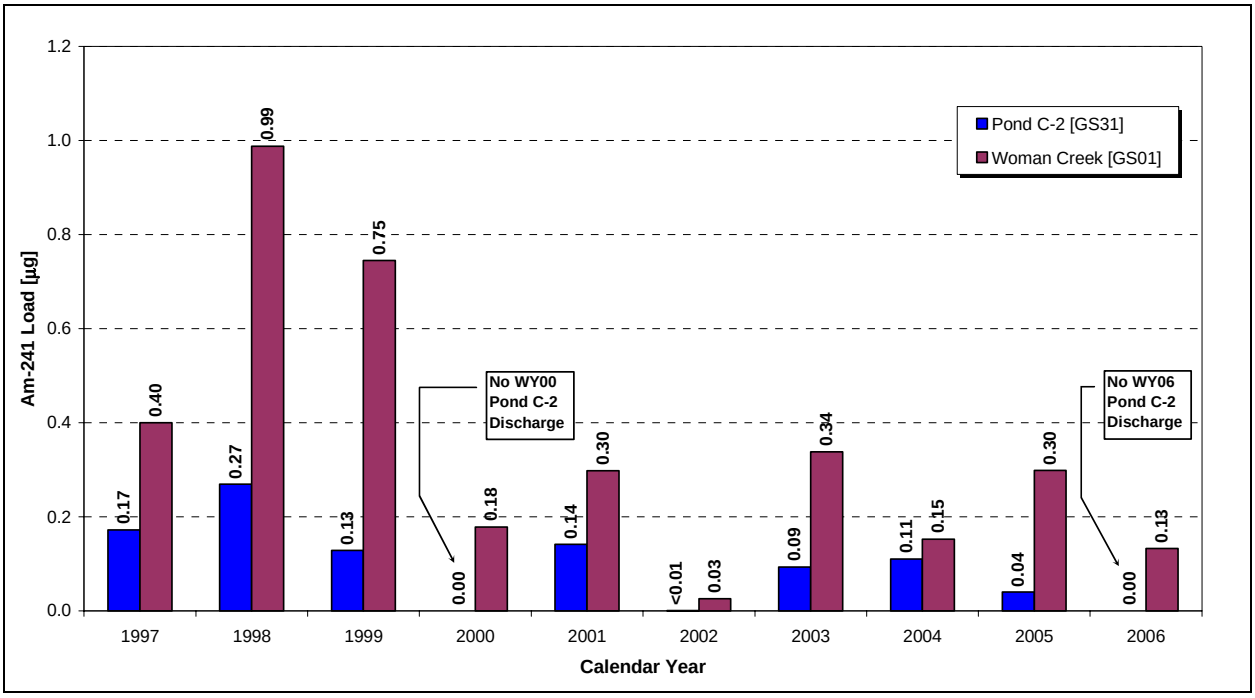



*Figure 2–92. Annual Am Loads at GS01 and GS31: CY 1997–2006*

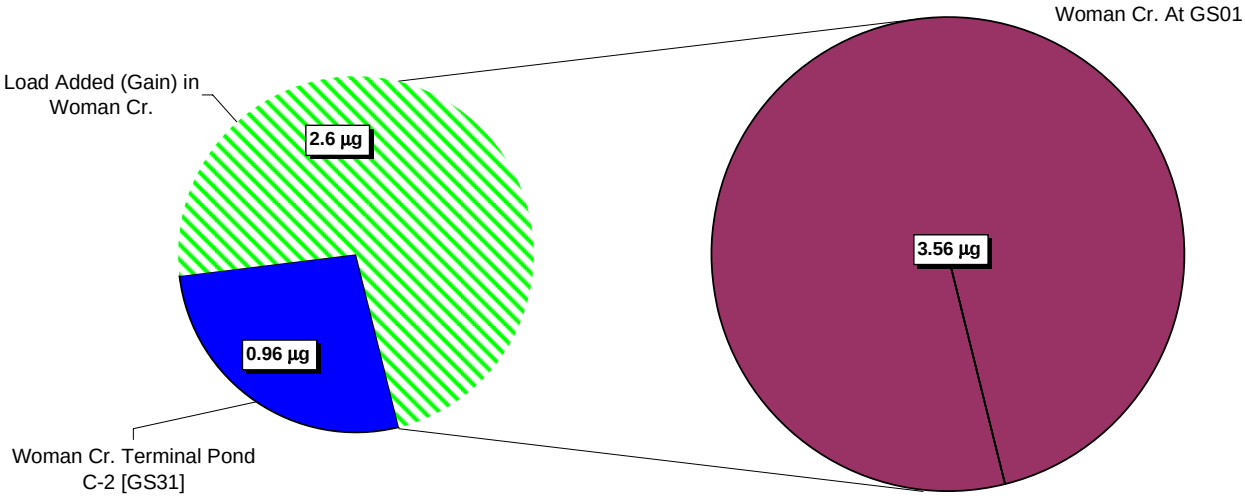



*Figure 2–93. Relative Am Load Totals at GS01 and GS31: CY 1997–2006*

*Table 2−27. Total Uranium Loads at GS01 and GS31: CY 2003−2006*

| Calendar Year | Total Uranium (g) | |
|---|---|---|
| | Pond C-2 (GS31) | POC GS01 |
| 2003 | 129 | 790 |
| 2004 | 92 | 808 |
| 2005 | 115 | 918 |
| 2006 | 0;<br>No C-2 discharge | 235 |
| **Total** | 336 | 2,751 |

Notes: NA = not applicable

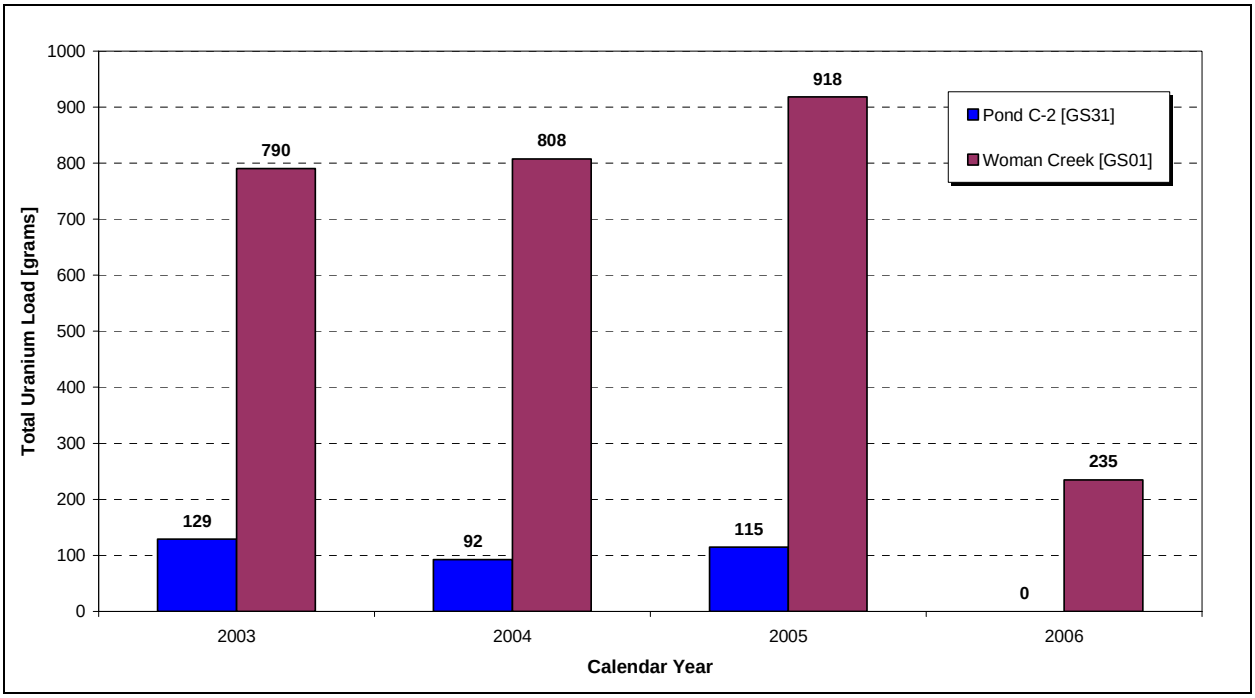



*Figure 2–94. Annual Total Uranium Loads at GS01 and GS31: CY 2003−2006*

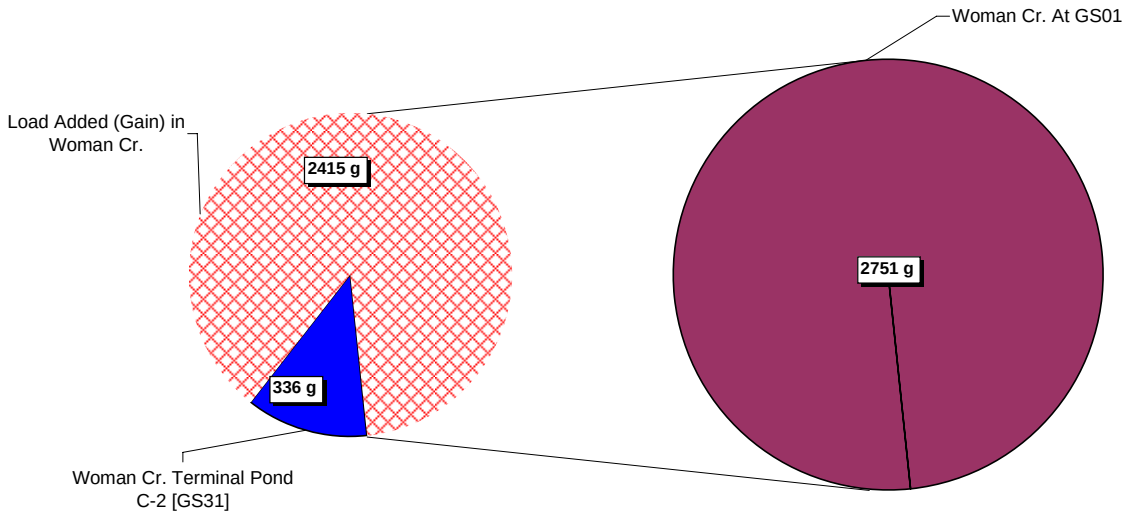



*Figure 2–95. Relative Total Uranium Load Totals at GS01 and GS31: CY 2003−2006*

### 2.4.5 Terminal Ponds

This section summarizes the calculated Pu, Am, and total U loads from terminal Ponds A-4, B-5, and C-2. The following points are noted:

- Annual Pu and Am loads vary significantly year to year (Figure 2–96 and Figure 2–98).
- A general reduction in Pu and Am loads is noted (Figure 2–96 and Figure 2–98).
- Pond B-5 accounts for a majority (76 percent) of the Pu load from the terminal ponds (Figure 2–97).
- Pond B-5 accounts for a majority (67 percent) of the Am load from the terminal ponds (Figure 2–99).
- Pond A-4 accounts for a slim majority (46 percent) of the total U loads from the terminal ponds (Figure 2–101).

*Table 2−28. Pu and Am Loads from Terminal Ponds A-4, B-5, and C-2: CY 1997–2006*

| Calendar Year | Pu-239,240 (µg) | | | Am-241 (µg) | | |
|---|---|---|---|---|---|---|
| | Pond A-4 (GS11) | Pond B-5 (GS08) | Pond C-2 (GS31) | Pond A-4 (GS11) | Pond B-5 (GS08) | Pond C-2 (GS31) |
| 1997 | 59.2 | 8.8 | 16.7 | 0.70 | 0.25 | 0.17 |
| 1998 | 20.0 | 22.4 | 2.2 | 1.25 | 0.35 | 0.27 |
| 1999 | 23.8 | 261.4 | 26.9 | 0.20 | 1.81 | 0.13 |
| 2000 | 28.4 | 244.6 | 0.0; No C-2 discharge | 0.02 | 3.14 | 0.00; No C-2 discharge |
| 2001 | 4.7 | 32.3 | 11.0 | 0.11 | 0.46 | 0.14 |
| 2002 | 0.1 | 7.8 | 0.2 | 0.04 | 0.25 | <0.01 |
| 2003 | 7.3 | 111.5 | 11.0 | 0.18 | 0.54 | 0.09 |
| 2004 | 2.2 | 27.1 | 11.5 | 0.14 | 0.58 | 0.11 |
| 2005 | 2.2 | 17.9 | 5.0 | 0.43 | 0.97 | 0.04 |
| 2006 | 0.0; No A-4 discharge | 0.0; No B-5 discharge | 0.0; No C-2 discharge | 0.00; No A-4 discharge | 0.00; No B-5 discharge | 0.0; No C-2 discharge |
| **Total** | 147.9 | 733.9 | 84.5 | 3.08 | 8.36 | 0.96 |

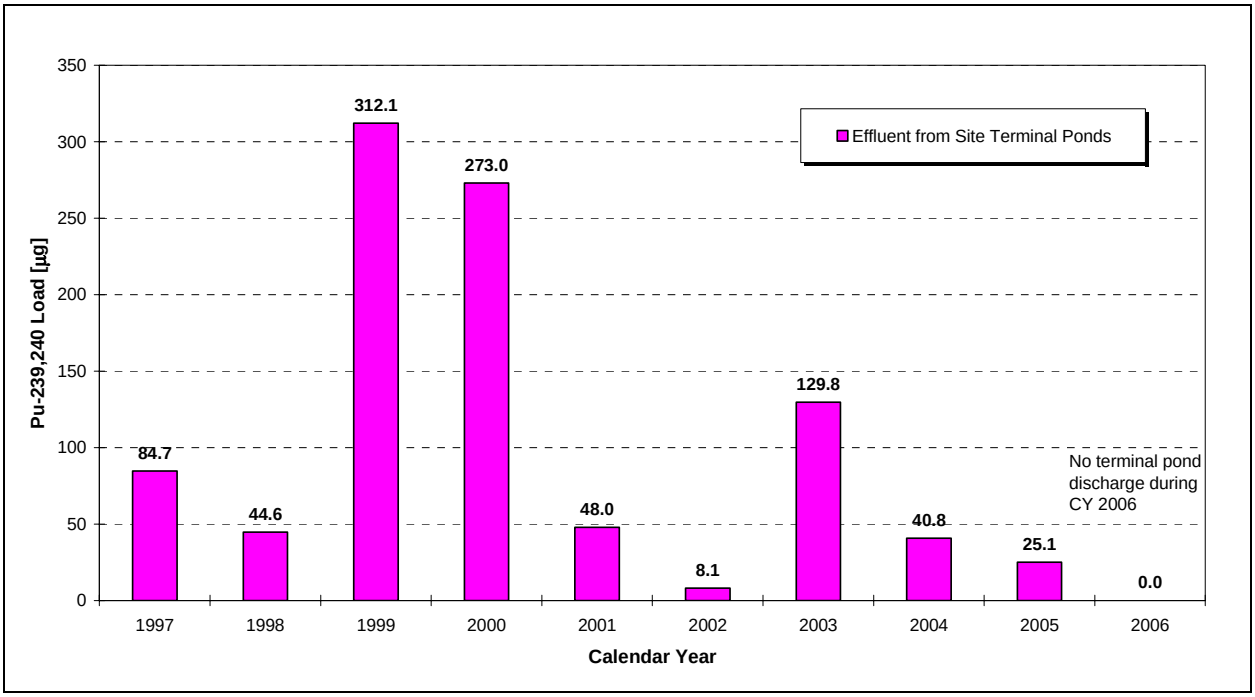



*Figure 2–96. Annual Pu Loads from Terminal Ponds A-4, B-5, and C-2: CY 1997–2006*

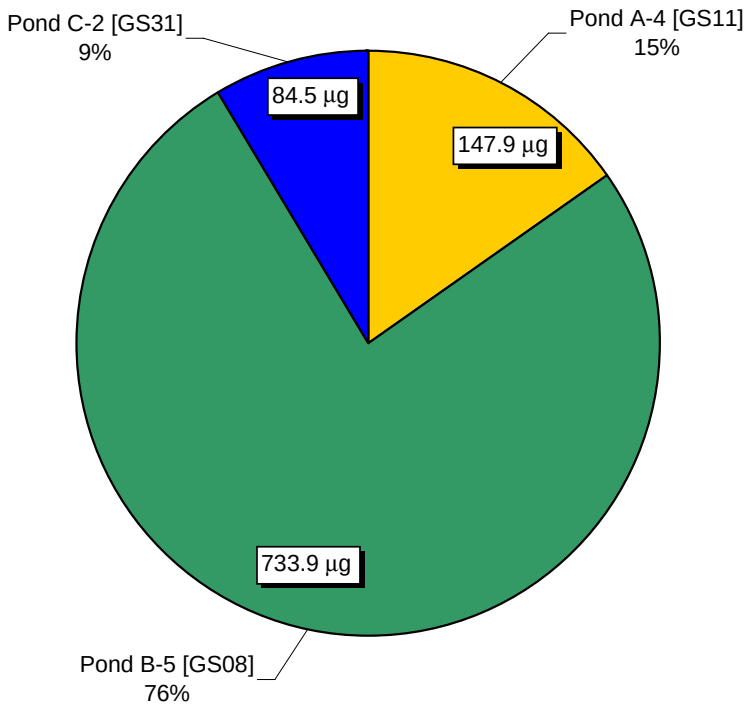



*Figure 2–97. Relative Pu Load Totals from Terminal Ponds A-4, B-5, and C-2: CY 1997–2006*

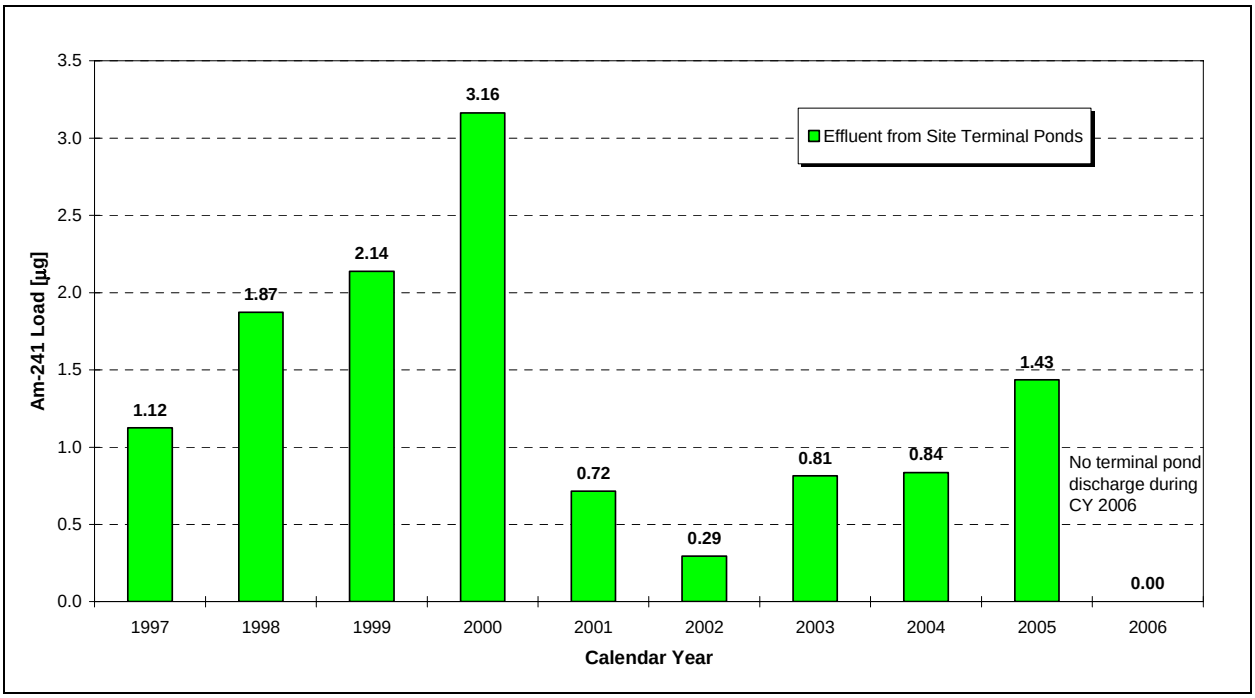



*Figure 2–98. Annual Am Loads from Terminal Ponds A-4, B-5, and C-2: CY 1997–2006*

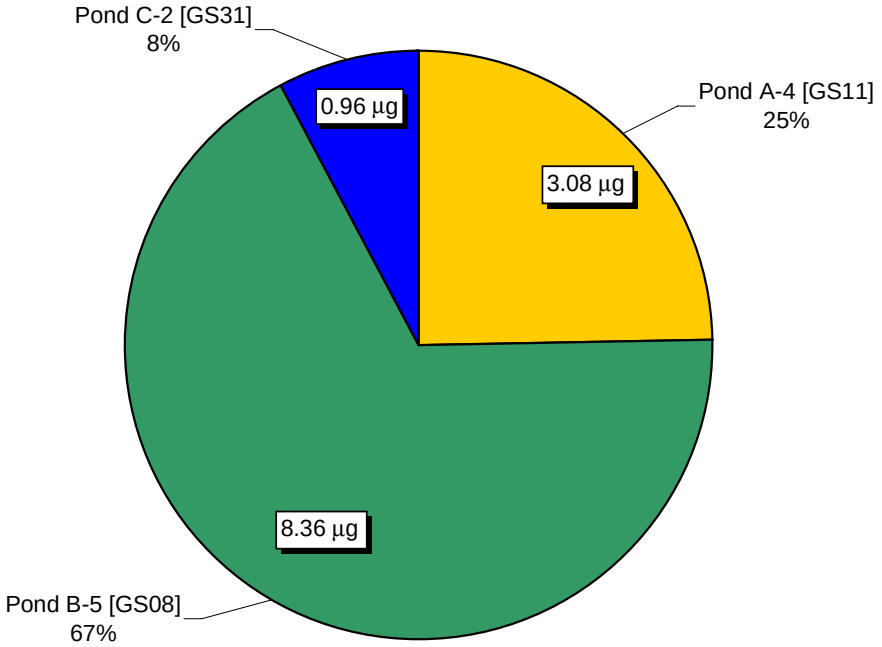



*Figure 2–99. Relative Am Load Totals from Terminal Ponds A-4, B-5, and C-2: CY 1997–2006*

*Table 2−29. Total Uranium Loads from Terminal Ponds A-4, B-5, and C-2: CY 1997–2006*

| Calendar Year | Total Uranium (g) | | |
|---|---|---|---|
| | **Pond A-4 (GS11)** | **Pond B-5 (GS08)** | **Pond C-2 (GS31)** |
| 1997 | 1,365 | 252 | 231 |
| 1998 | 1,301 | 620 | 216 |
| 1999 | 633 | 809 | 189 |
| 2000 | 386 | 465 | 0;<br>No C-2 discharge |
| 2001 | 564 | 639 | 67 |
| 2002 | 132 | 258 | 1 |
| 2003 | 865 | 610 | 129 |
| 2004 | 316 | 390 | 92 |
| 2005 | 165 | 1,389 | 115 |
| 2006 | 0;<br>No A-4 discharge | 0;<br>No B-5 discharge | 0;<br>No C-2 discharge |
| **Total** | 5,727 | 5,432 | 1,039 |

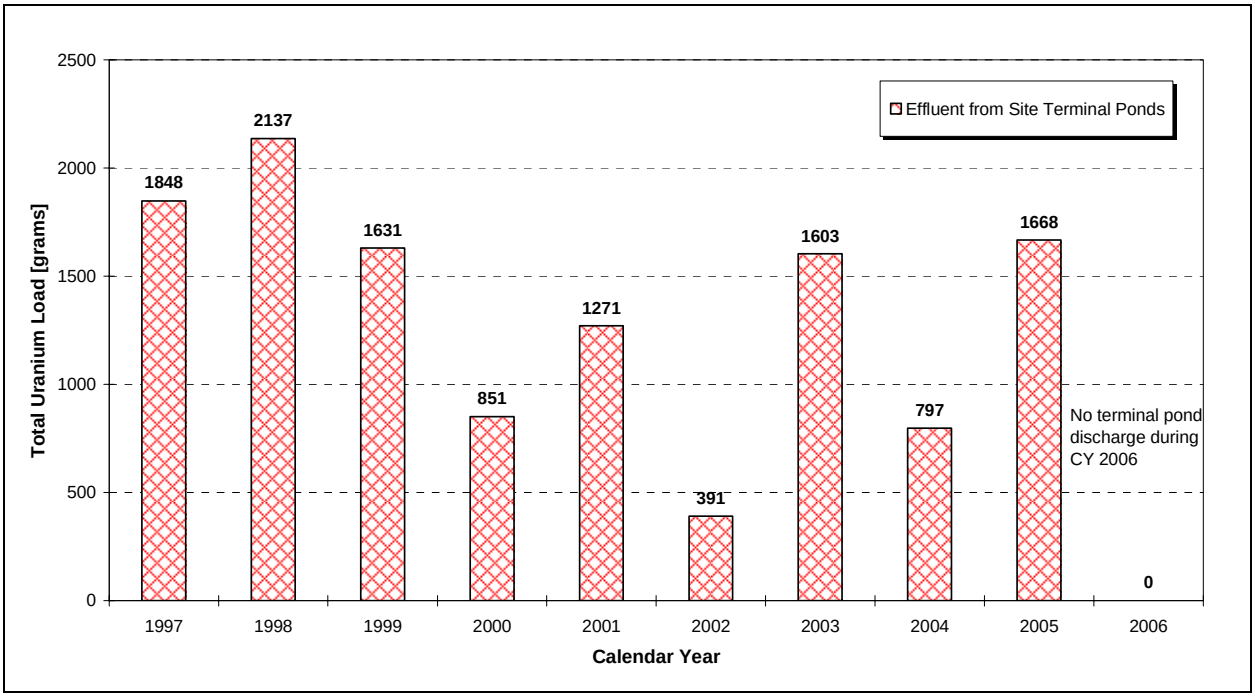



*Figure 2–100. Annual Total Uranium Loads from Terminal Ponds A-4, B-5, and C-2: CY 1997–2006*

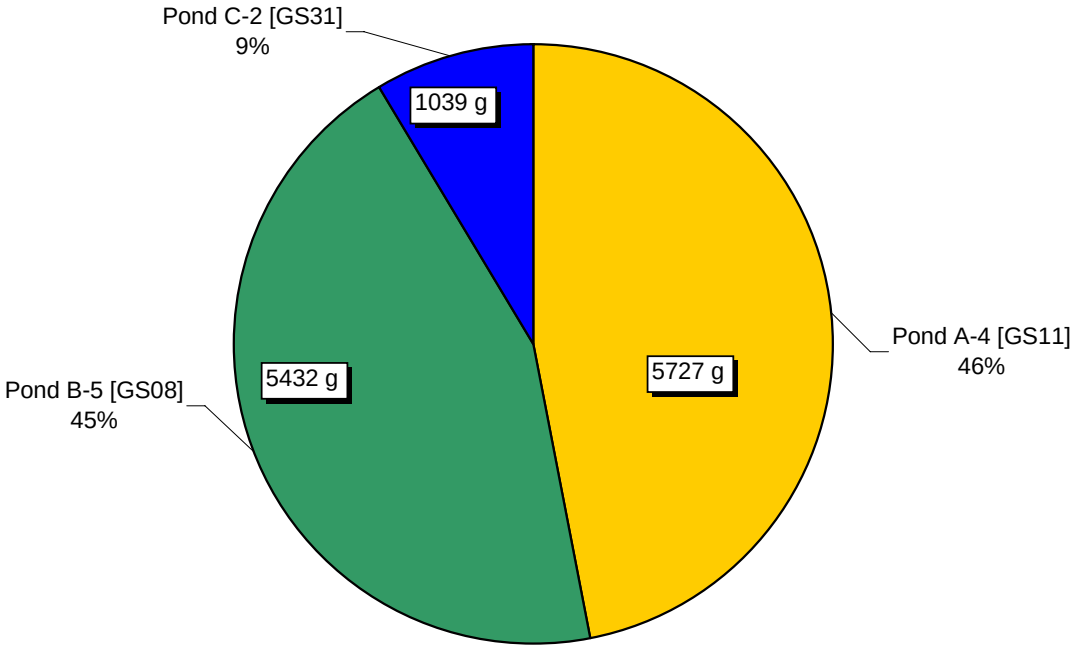



*Figure 2–101. Relative Total Uranium Load from Terminal Ponds A-4, B-5, and C-2: CY 1997–2006*

### 2.4.5.1 A- and B-Series Ponds (POCs GS08 and GS11)

This section summarizes the calculated Pu, Am, and total U loads for the A- and B-Series Ponds. Since water transfers occur between ponds, the load analysis below is performed for both pond series combined. The influent load sources are GS10 and the former WWTP (South Walnut), and SW093 (North Walnut). The effluent loads are GS08 (Pond B-5 outlet) and GS11 (Pond A-4 outlet). The following points are noted:

- Table 2−30 shows GS10 with the highest influent Pu load.
- A significant increase in Pu loads to the ponds is noted during CY 2004 due to increased solids transport resulting from active building demolition and soil disturbance (Figure 2–102). With the enhanced implementation of erosion controls, revegetation, and soil stabilization, a significant reduction is noted for CY 2005−2006.
- Table 2−31 shows GS10 with the highest influent Am load.
- A measurable increase in Am loads to the ponds is noted during both CY 2005. This increase was partly due to increased solids transport resulting from active building demolition and soil disturbance (Figure 2–104). Increased Am loads at SW093 were primarily due to contributions from B771 D&D during the July 2004 through November 2004 period. The pathway causing these increased loads was eliminated in December 2004.
- Annual Pu and Am loads vary significantly year to year (Figure 2–102 and Figure 2–104) primarily due to hydrologic and solids transport variation.
- Figure 2–106 shows GS10 with the highest influent total U activity, while SW093 shows the highest total U load (due to larger flow volumes at SW093).
- Figure 2–106 shows GS11 with the highest effluent total U activity and load.

*Table 2−30. Pu Load Summary for the A- and B-Series Ponds: CY 1997–2006*

| Calendar Year | Pu-239,240 (µg) | | | | |
|---|---|---|---|---|---|
| | Influent (WWTP) | Influent (GS10) | Influent (SW093) | Effluent (GS08) | Effluent (GS11) |
| 1997 | 11.2 | 576.0 | 164.2 | 8.8 | 59.2 |
| 1998 | 13.4 | 328.6 | 69.1 | 22.4 | 20.0 |
| 1999 | 19.4 | 307.9 | 127.8 | 261.4 | 23.8 |
| 2000 | 17.4 | 326.2 | 87.4 | 244.6 | 28.4 |
| 2001 | 11.3 | 141.4 | 44.4 | 32.3 | 4.7 |
| 2002 | 8.3 | 59.3 | 9.6 | 7.8 | 0.1 |
| 2003 | 3.8 | 207.2 | 140.1 | 111.5 | 7.3 |
| 2004 | 2.1 | 523.3 | 1,330.9 | 27.1 | 2.2 |
| 2005 | 0.0 WWTP removed | 247.1 | 29.2 | 17.9 | 2.2 |
| 2006 | 0.0 WWTP removed | 2.3 | 2.5 | 0.0; No B-5 discharge | 0.0; No A-4 discharge |
| **Total** | 86.9 | 2,719.5 | 2,005.2 | 733.9 | 147.9 |

Notes: NA = not applicable

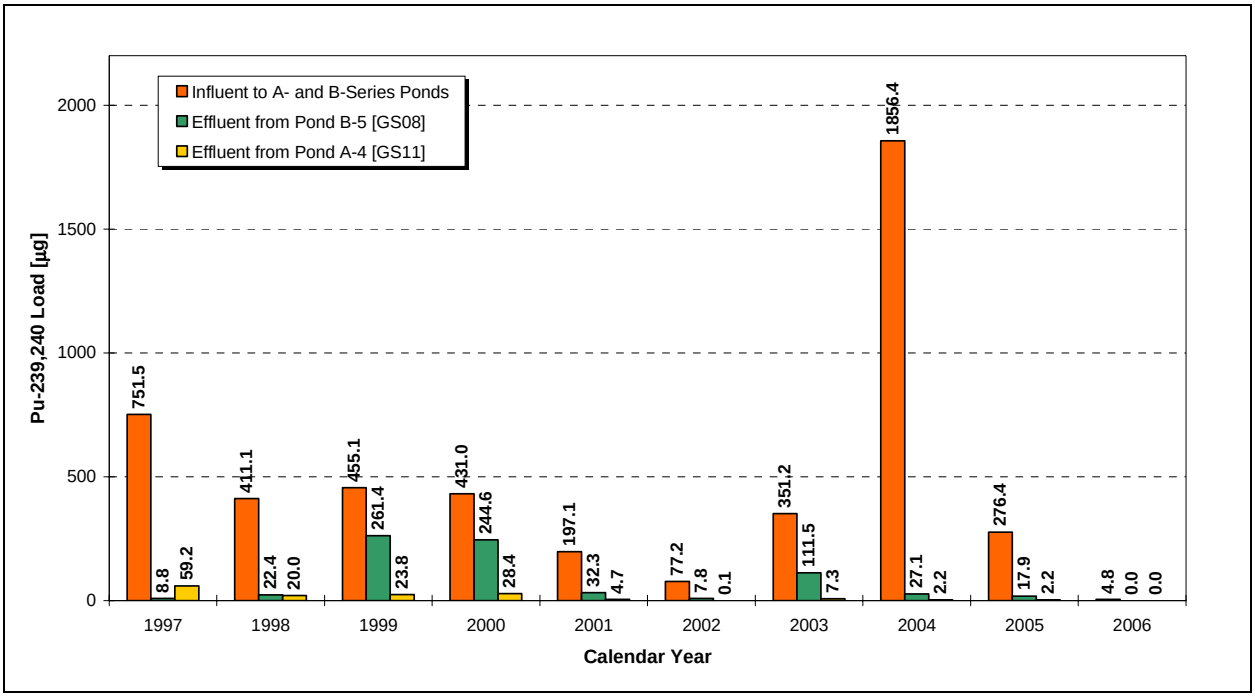



*Figure 2–102. Annual Pu Loads for the A- and B-Series Ponds: CY 1997–2006*

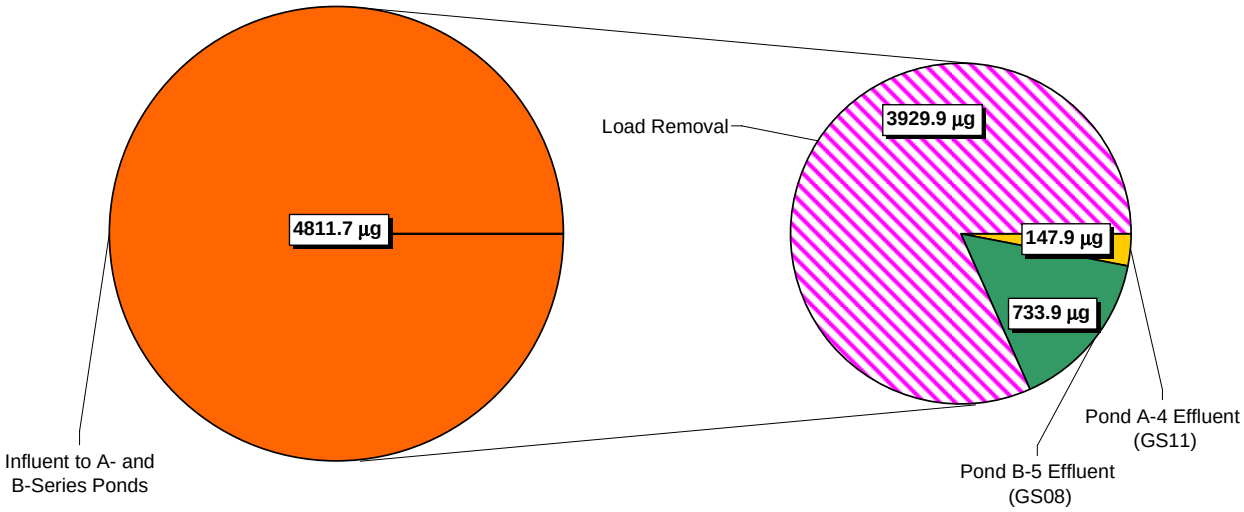



*Figure 2–103. Relative Pu Load Totals for the A- and B-Series Terminal Ponds: CY 1997–2006*

*Table 2−31. Am Load Summary for the A- and B-Series Ponds: CY 1997–2006*

| Calendar Year | Am-241 (µg) | | | | |
|---|---|---|---|---|---|
| | Influent (WWTP) | Influent (GS10) | Influent (SW093) | Effluent (GS08) | Effluent (GS11) |
| 1997 | 0.64 | 12.20 | 2.24 | 0.25 | 0.70 |
| 1998 | 0.32 | 4.69 | 1.30 | 0.35 | 1.25 |
| 1999 | 0.11 | 12.55 | 1.73 | 1.81 | 0.20 |
| 2000 | 0.29 | 14.57 | 0.98 | 3.14 | 0.02 |
| 2001 | 0.32 | 2.75 | 0.65 | 0.46 | 0.11 |
| 2002 | 0.20 | 1.76 | 0.52 | 0.25 | 0.04 |
| 2003 | 0.52 | 4.44 | 2.05 | 0.54 | 0.18 |
| 2004 | 0.25 | 4.68 | 28.48 | 0.58 | 0.14 |
| 2005 | 0.00 WWTP removed | 3.98 | 0.82 | 0.97 | 0.43 |
| 2006 | 0.00 WWTP removed | 0.04 | 0.02 | 0.00; No B-5 discharge | 0.00; No A-4 discharge |
| **Total** | 2.65 | 61.66 | 38.81 | 8.36 | 3.08 |

Notes: NA = not applicable

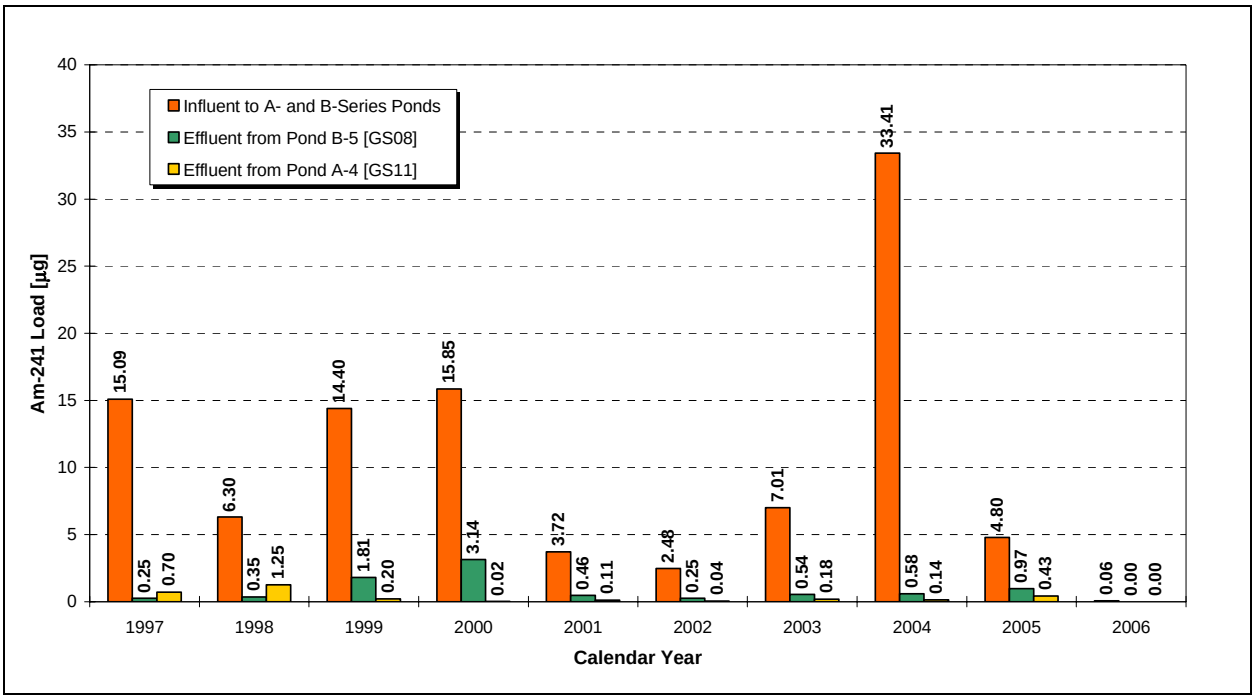



*Figure 2–104. Annual Am Loads for the A- and B-Series Ponds: CY 1997–2006*

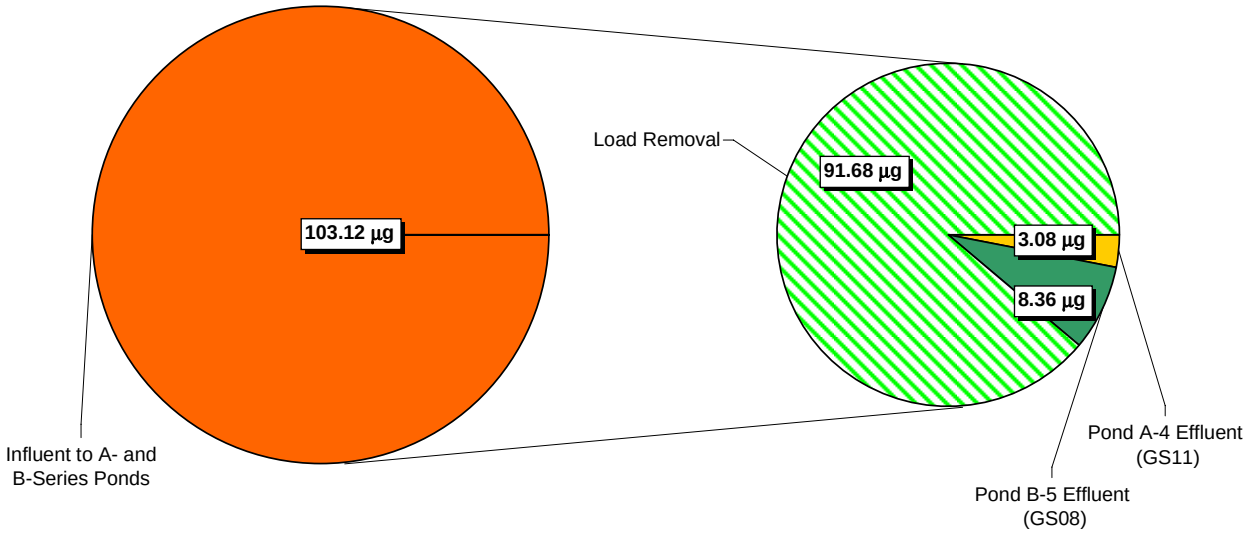
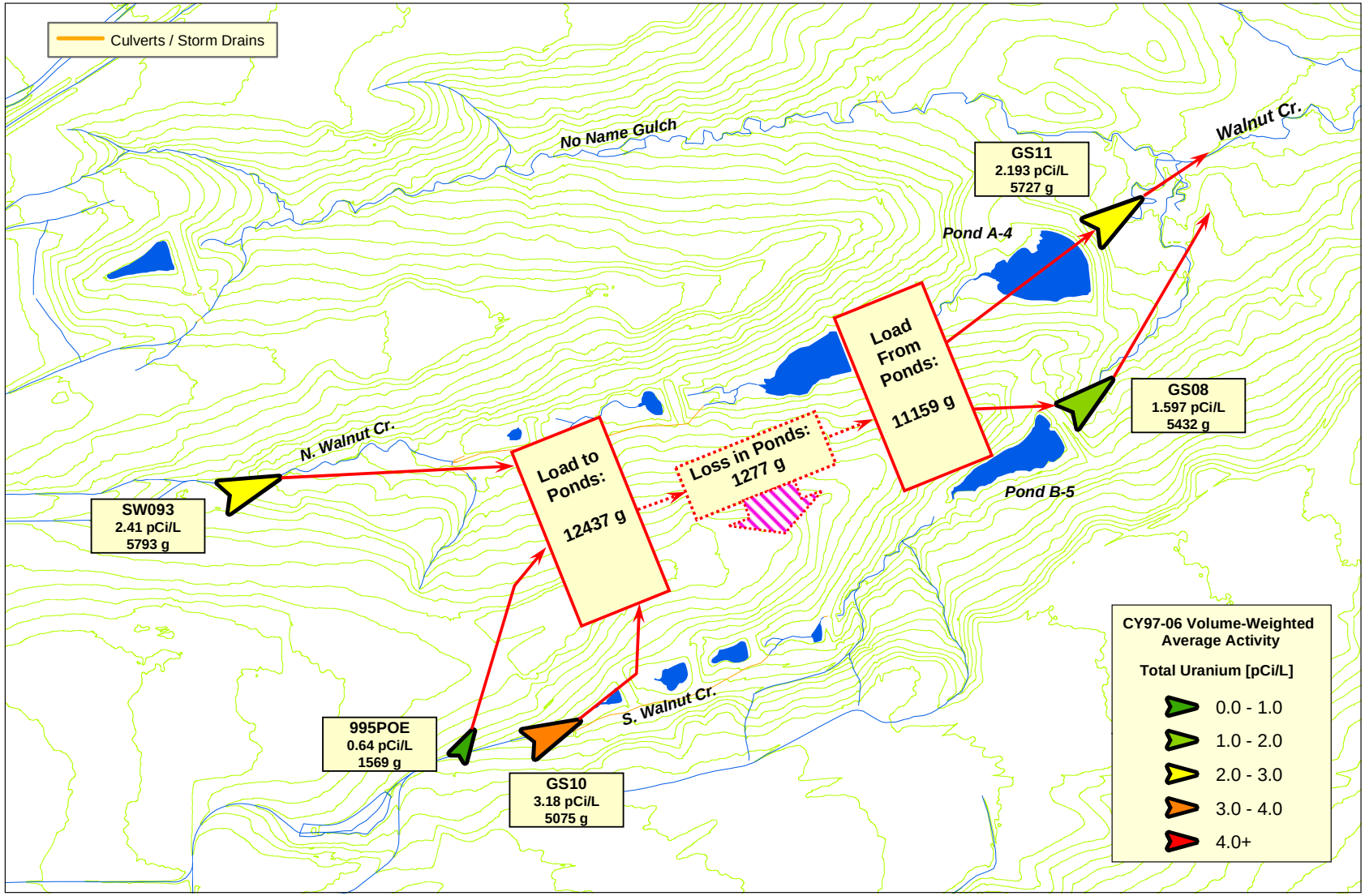



*Figure 2–105. Relative Am Load Totals for the A- and B-Series Ponds: CY 1997–2006*




Note: Location symbols are displayed proportional to calculated load and shaded according to activity ranges in legend.

*Figure 2–106. Relative Total Uranium Loading Schematic for the A- and B-Series Ponds: CY 1997–2006*

*Table 2−32. Total Uranium Load Summary for the A- and B-Series Ponds: CY 1997–2006*

| Calendar Year | Total Uranium (g) | | | | |
|---|---|---|---|---|---|
| | Influent (WWTP) | Influent (GS10) | Influent (SW093) | Effluent (GS08) | Effluent (GS11) |
| 1997 | 257 | 637 | 853 | 252 | 1,365 |
| 1998 | 467 | 631 | 797 | 620 | 1,301 |
| 1999 | 121 | 589 | 714 | 809 | 633 |
| 2000 | 103 | 379 | 485 | 465 | 386 |
| 2001 | 259 | 519 | 646 | 639 | 564 |
| 2002 | 61 | 279 | 450 | 258 | 132 |
| 2003 | 161 | 501 | 568 | 610 | 865 |
| 2004 | 139 | 430 | 575 | 390 | 316 |
| 2005 | 0 WWTP removed | 879 | 534 | 1,389 | 165 |
| 2006 | 0 WWTP removed | 230 | 171 | 0; No B-5 discharge | 0; No A-4 discharge |
| **Total** | 1,569 | 5,075 | 5,793 | 5,432 | 5,727 |

Notes: NA = not applicable

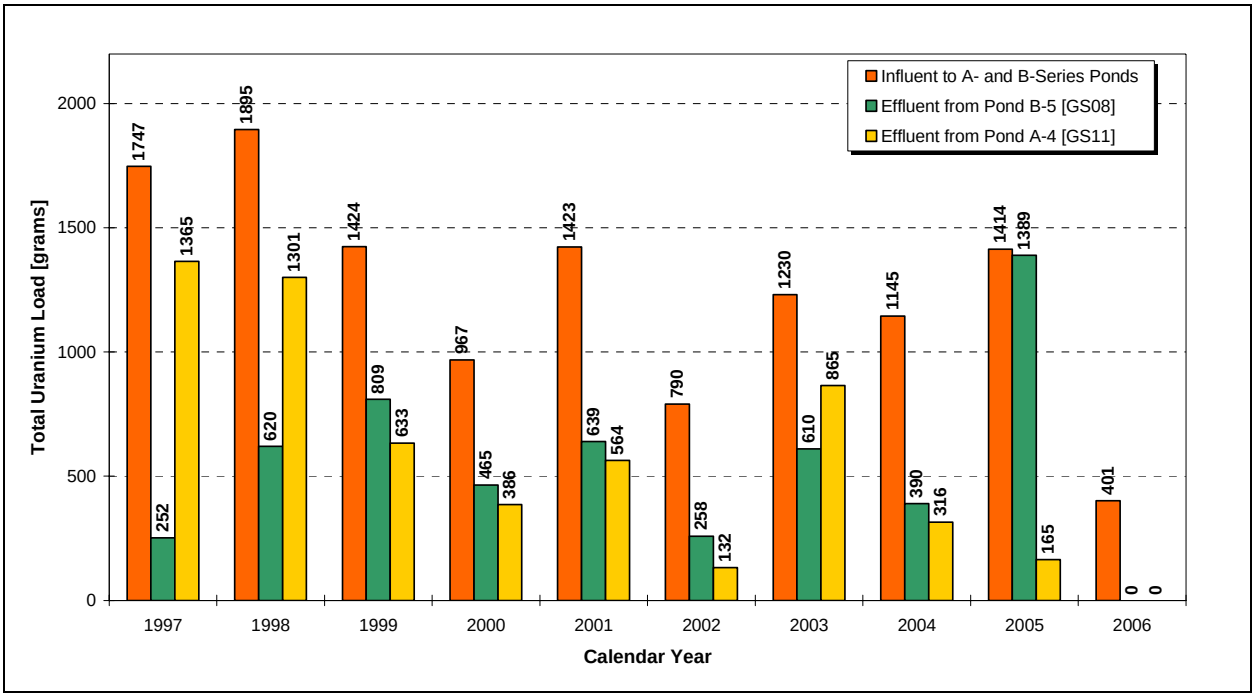



*Figure 2–107. Annual Total Uranium Loads for the A- and B-Series Ponds: CY 1997–2006*

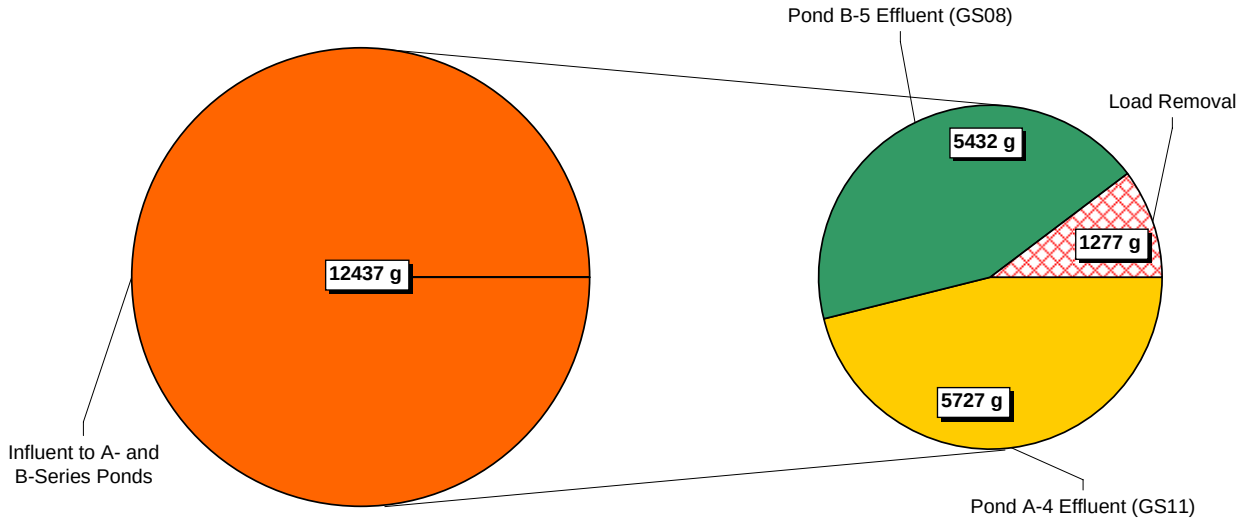



*Figure 2–108. Relative Total Uranium Load Totals for the A- and B-Series Ponds: CY 1997–2006*

### 2.4.5.2 Pond C-2 (POC GS31)

This section summarizes the calculated Pu, Am, and total U loads for Pond C-2. The influent load source is SW027 (SID at Pond C-2 inlet). The effluent loads are calculated at GS31 (Pond C-2 outlet). The following points are noted:

- Annual Pu and Am loads vary significantly year to year (Figure 2–109 and Figure 2–111). A significant increase in both Pu and Am loads to Pond C-2 is noted during CY 2004 due to increased solids transport from extensive soil disturbance in the drainage associated with the 903 Pad/Lip accelerated actions. With the enhanced implementation of erosion controls, revegetation, and soil stabilization, a significant reduction is noted for CY 2005 (no flow in the SID or Pond C-2 discharge in CY 2006).
- Annual total U loads also vary significantly year to year (Figure 2–114).
- There is a measurable total U load gain in Pond C-2 (Figure 2–113). This is likely due to ground water seepage to Pond C-2 with naturally occurring U.

*Table 2−33. Pu Load Summary for Terminal Pond C-2: CY 1997–2006*

| Calendar Year | Pu-239,240 (µg) | |
|---|---|---|
| | Influent (SW027) | Effluent (GS31) |
| 1997 | 17.4 | 16.7 |
| 1998 | 87.7 | 2.2 |
| 1999 | 34.3 | 26.9 |
| 2000 | 67.2 | 0.0;<br>No C-2 discharge |
| 2001 | 10.7 | 11.0 |
| 2002 | 0.3 | 0.2 |
| 2003 | 45.1 | 11.0 |
| 2004 | 820.8 | 11.5 |
| 2005 | 18.6 | 5.0 |
| 2006 | 0.0;<br>No flow | 0.0;<br>No C-2 discharge |
| **Total** | 1,102.1 | 84.5 |

Notes: NA = not applicable

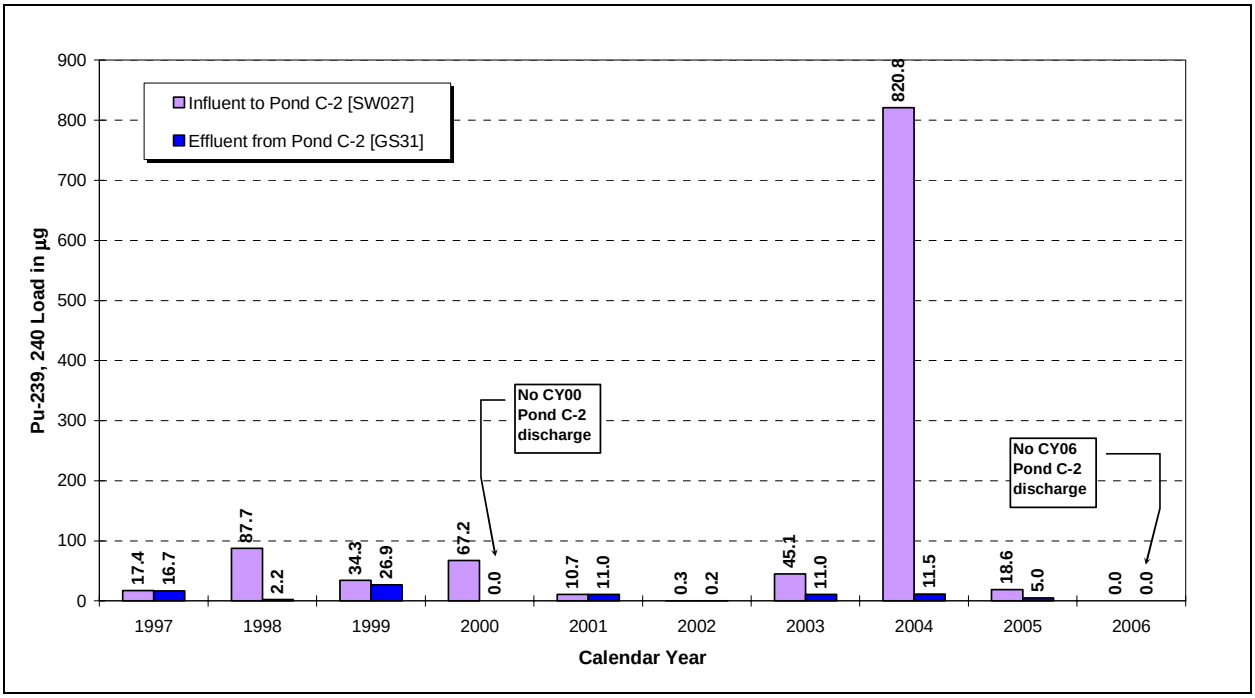



*Figure 2–109. Annual Pu Loads for Pond C-2: CY 1997–2006*

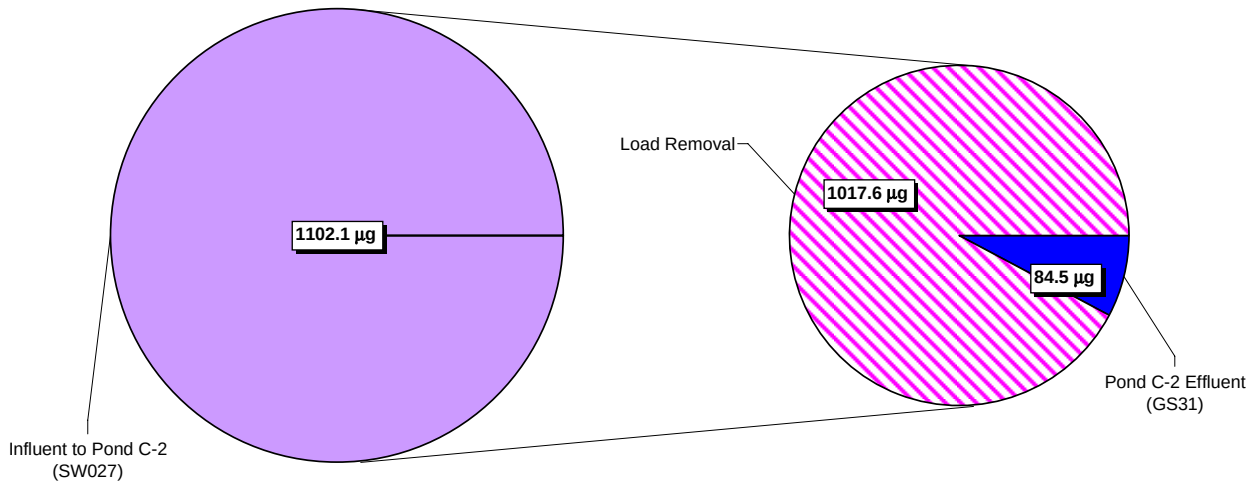



*Figure 2–110. Relative Pu Load Totals for Pond C-2: CY 1997–2006*

*Table 2−34. Am Load Summary for Terminal Pond C-2: CY 1997–2006*

| Calendar Year | Am-241 (µg) | |
|---|---|---|
| | **Influent (SW027)** | **Effluent (GS31)** |
| 1997 | 0.08 | 0.17 |
| 1998 | 0.25 | 0.27 |
| 1999 | 0.20 | 0.13 |
| 2000 | 0.24 | 0.00;<br>No C-2 discharge |
| 2001 | 0.05 | 0.14 |
| 2002 | 0.00 | <0.01 |
| 2003 | 0.12 | 0.09 |
| 2004 | 3.09 | 0.11 |
| 2005 | 0.05 | 0.04 |
| 2006 | 0.00;<br>No flow | 0.00;<br>No C-2 discharge |
| **Total** | 4.10 | 0.96 |

Notes: NA = not applicable

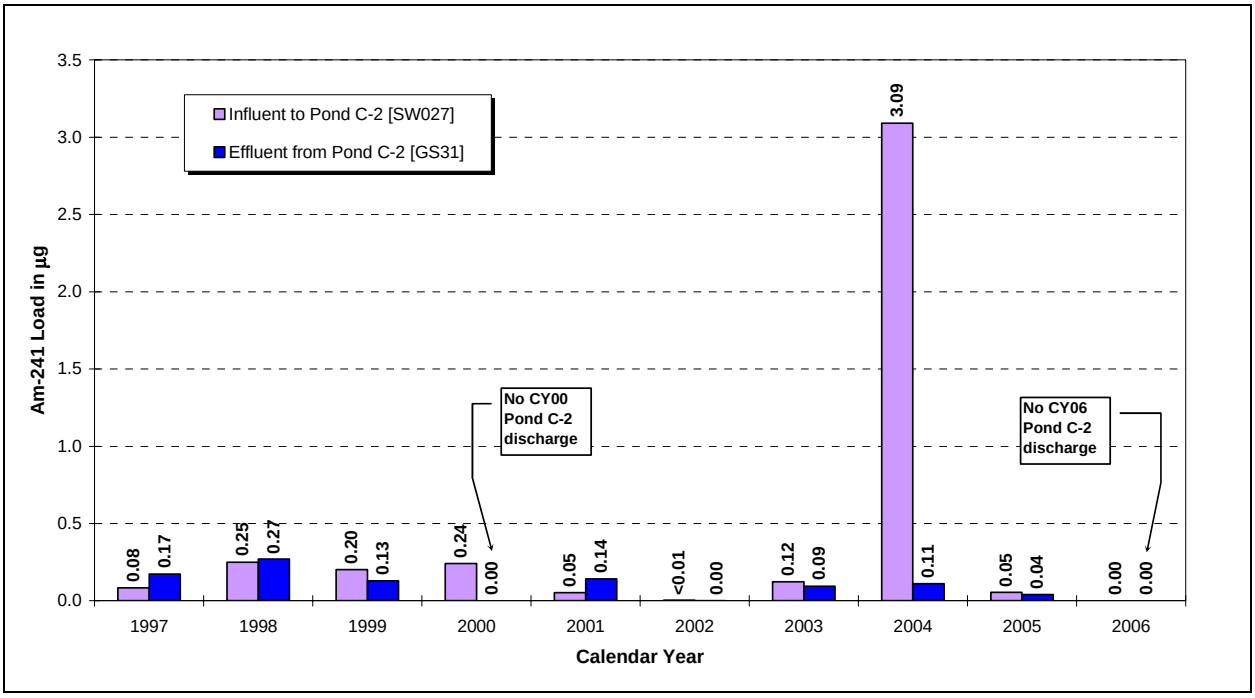



*Figure 2–111. Annual Am Loads for Pond C-2: CY 1997–2006*

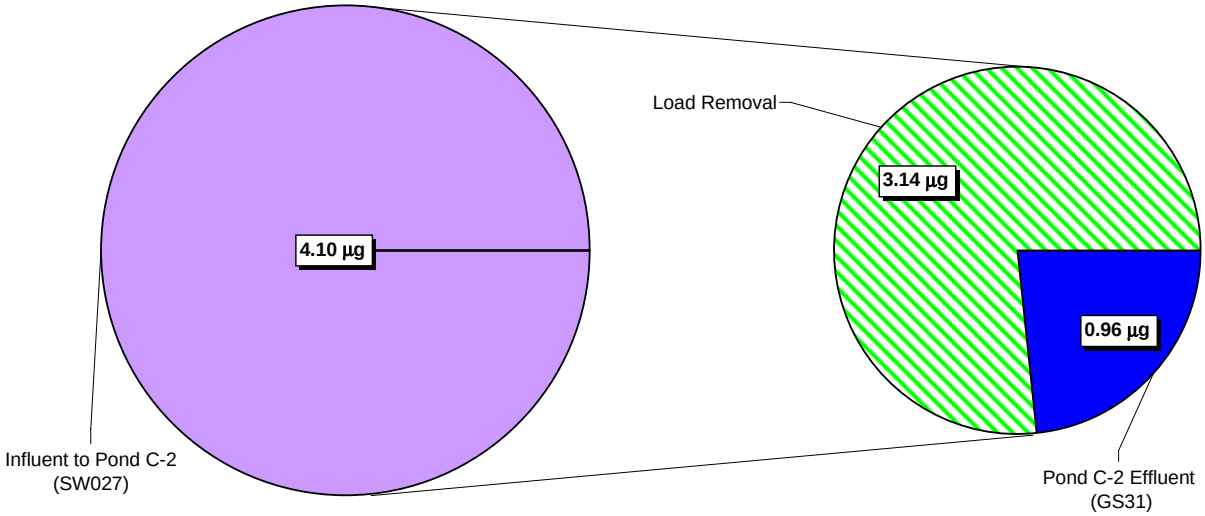
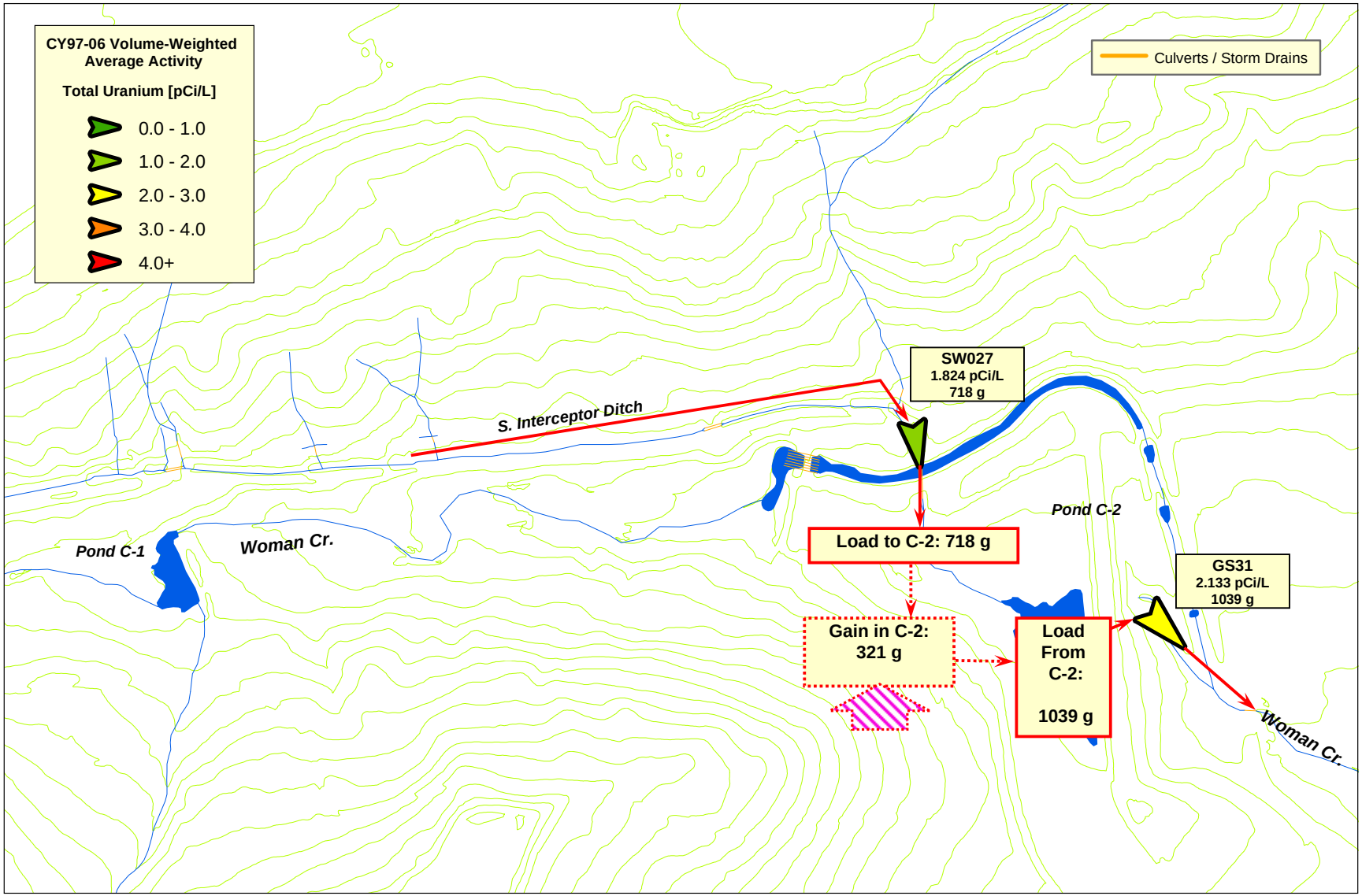



*Figure 2–112. Relative Am Load Totals for Pond C-2: CY 1997–2006*

*Table 2−35. Total Uranium Load Summary for Terminal Pond C-2: CY 1997–2006*

| Calendar Year | Total Uranium (g) | |
|---|---|---|
| | Influent (SW027) | Effluent (GS31) |
| 1997 | 84 | 231 |
| 1998 | 239 | 216 |
| 1999 | 116 | 189 |
| 2000 | 22 | 0.00;<br>No C-2 discharge |
| 2001 | 66 | 67 |
| 2002 | 7 | 1 |
| 2003 | 111 | 129 |
| 2004 | 40 | 92 |
| 2005 | 33 | 115 |
| 2006 | 0;<br>No flow | 0;<br>No C-2 discharge |
| **Total** | 718 | 1,039 |

Notes: NA = not applicable




Note: Location symbols are displayed proportional to calculated load and shaded according to activity ranges in legend.

*Figure 2–113. Relative Total Uranium Loading Schematic for Pond C-2: CY 1997–2006*

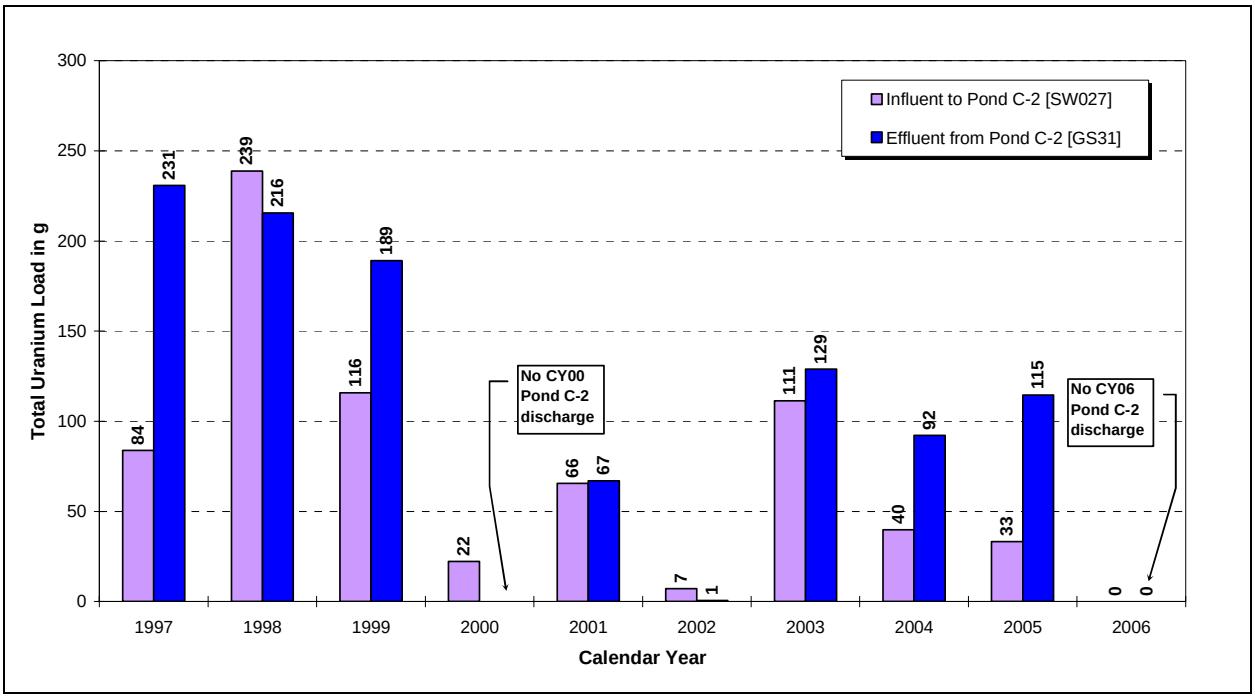



*Figure 2–114. Annual Total Uranium Loads for Pond C-2: CY 1997–2006*

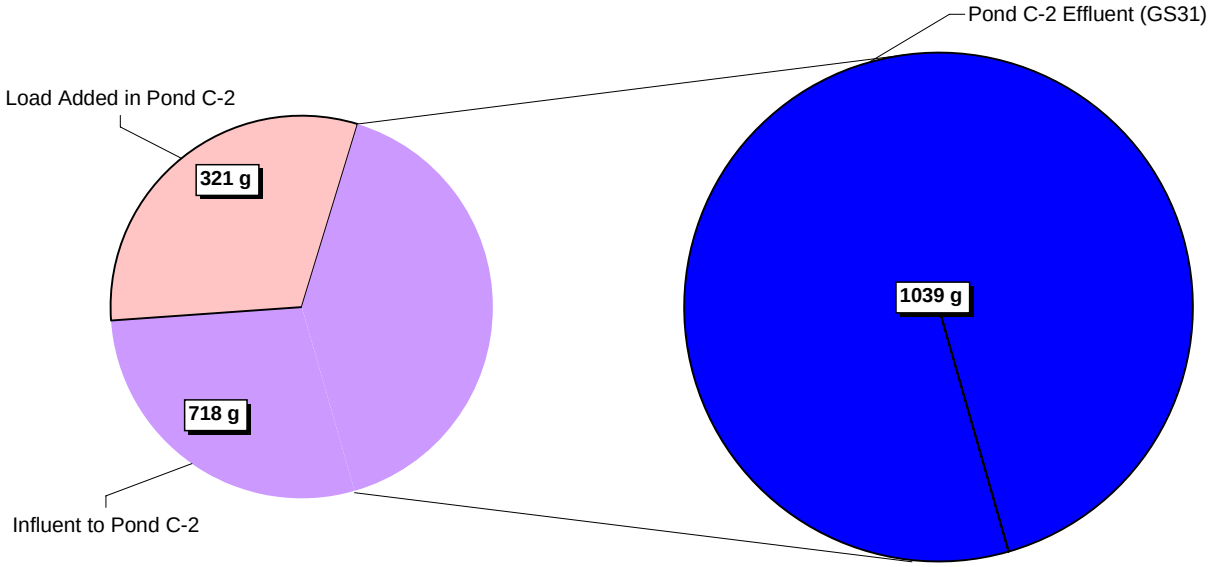



*Figure 2–115. Relative Total Uranium Load Totals for Pond C-2: CY 1997–2006*

### 2.4.6 RFCA Points of Evaluation

#### 2.4.6.1 Major COU Drainages

This section summarizes the calculated Pu, Am, and total U loads for the three major COU drainages: North Walnut Creek (SW093), South Walnut Creek (GS10 and the former WWTP), and the SID (SW027). The following points are noted:

- Total Pu load varies year to year and shows a significant increase in CY 2004 due to extensive soil disturbance (Figure 2–116). With the enhanced implementation of erosion controls, revegetation, and soil stabilization, a significant reduction is noted for CY 2005−2006.
- Total Am load also varies year to year and shows a measurable increase in CY 2004 due to soil disturbance and contributions from the B771 area (Figure 2–118). Data from SW093 in CY 2005 (Figure 2–123) clearly show that the B771 pathway elimination was successful.
- South Walnut Creek accounts for a majority (47 percent) of the Pu load from the COU (Figure 2–117). Of the South Walnut Creek Pu load, GS10 accounts for 97 percent while the former WWTP accounts for the remaining 3 percent.
- South Walnut Creek accounts for a majority (60 percent) of the Am load from the IA (Figure 2–119). Of the South Walnut Creek Am load, GS10 accounts for 96 percent while the former WWTP accounts for the remaining 4 percent.
- Annual total U loads are fairly consistent year to year (Figure 2–124). The load reduction in CY 2006 is due to flow volume reduction, and not a decrease in U activity.
- Total U loads are fairly evenly divided (44 percent−51 percent) between North and South Walnut Creeks (Figure 2–125).

*Table 2−36. Central OU Pu and Am Loads: CY 1997–2006*

| Calendar Year | Pu-239,240 (µg) | | | | Am-241 (µg) | | | |
|---|---|---|---|---|---|---|---|---|
| | North Walnut Creek (SW093) | South Walnut Creek (GS10) | South Walnut Creek (WWTP) | SID (SW027) | North Walnut Creek (SW093) | South Walnut Creek (GS10) | South Walnut Creek (WWTP) | SID (SW027) |
| 1997 | 164.2 | 576.0 | 11.2 | 17.4 | 2.24 | 12.20 | 0.64 | 0.08 |
| 1998 | 69.1 | 328.6 | 13.4 | 87.7 | 1.30 | 4.69 | 0.32 | 0.25 |
| 1999 | 127.8 | 307.9 | 19.4 | 34.3 | 1.73 | 12.55 | 0.11 | 0.20 |
| 2000 | 87.4 | 326.2 | 17.4 | 67.2 | 0.98 | 14.57 | 0.29 | 0.24 |
| 2001 | 44.4 | 141.4 | 11.3 | 10.7 | 0.65 | 2.75 | 0.32 | 0.05 |
| 2002 | 9.6 | 59.3 | 8.3 | 0.3 | 0.52 | 1.76 | 0.20 | 0.00 |
| 2003 | 140.1 | 207.2 | 3.8 | 45.1 | 2.05 | 4.44 | 0.52 | 0.12 |
| 2004 | 1,330.9 | 523.3 | 2.1 | 820.8 | 28.48 | 4.68 | 0.25 | 3.09 |
| 2005 | 29.2 | 247.1 | 0.0; WWTP removed | 18.6 | 0.82 | 3.98 | 0.00; WWTP removed | 0.05 |
| 2006 | 2.5 | 2.3 | 0.0; WWTP removed | 0.0; No flow | 0.02 | 0.04 | 0.00; WWTP removed | 0.00; No flow |
| **Total** | 2,005.2 | 2,719.5 | 86.9 | 1,102.1 | 38.81 | 61.66 | 2.65 | 4.10 |

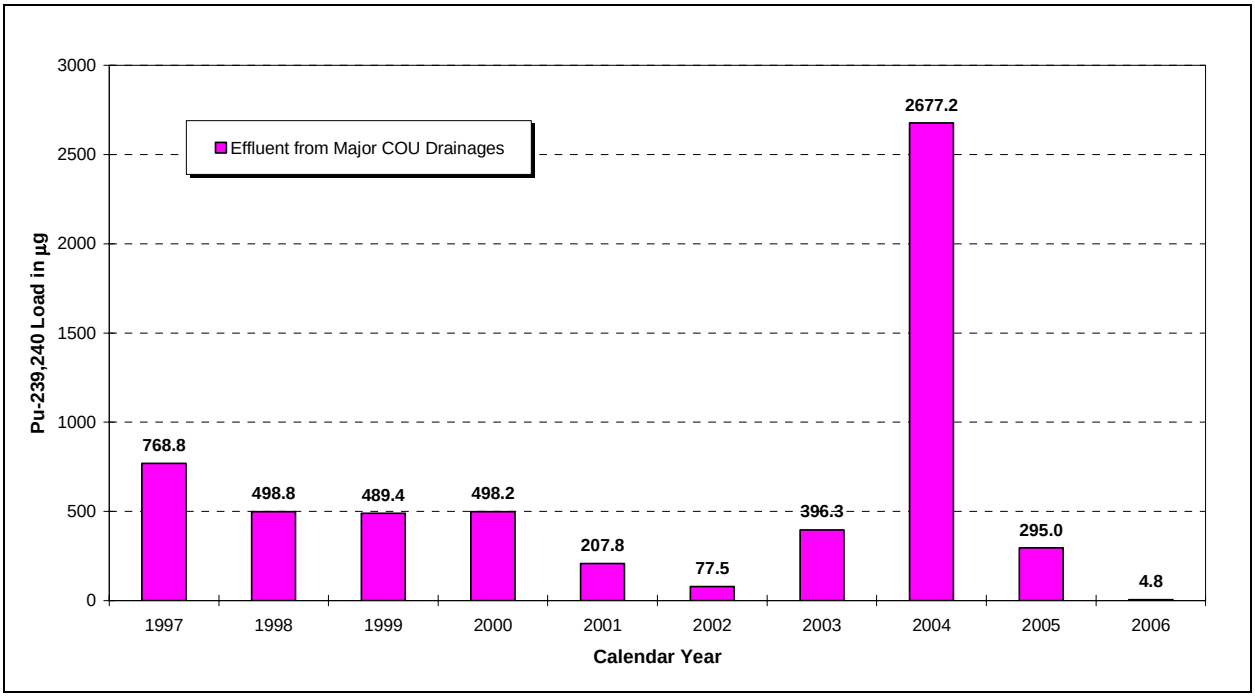



*Figure 2–116. Combined Annual Pu Loads from Major COU Drainages and WWTP: CY 1997–2006*

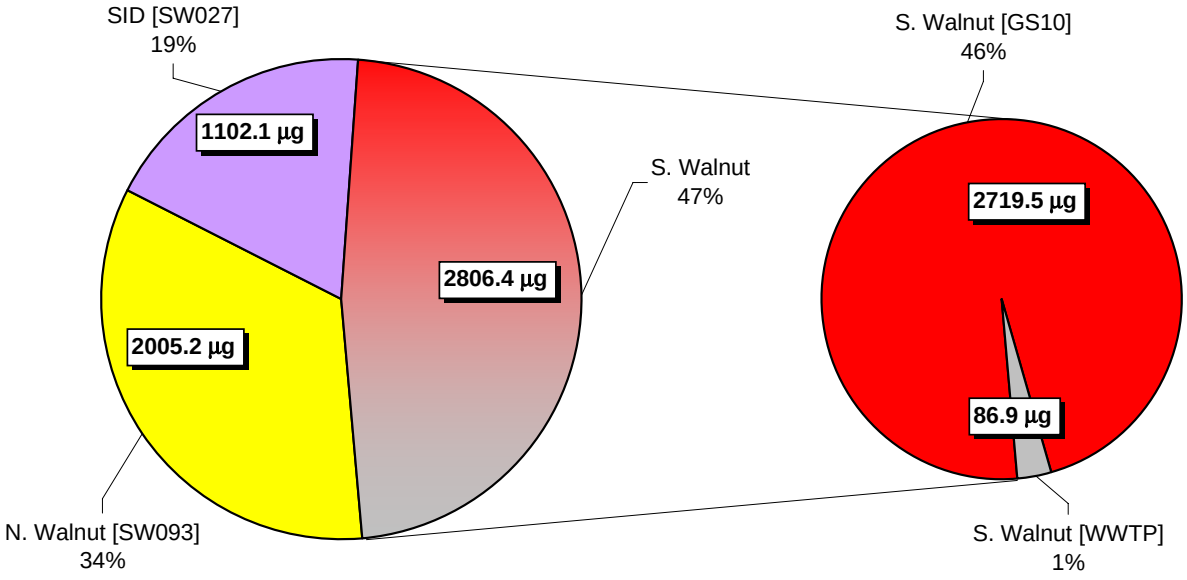



*Figure 2–117. Relative Pu Load Totals from Major COU Drainages and WWTP: CY 1997–2006*

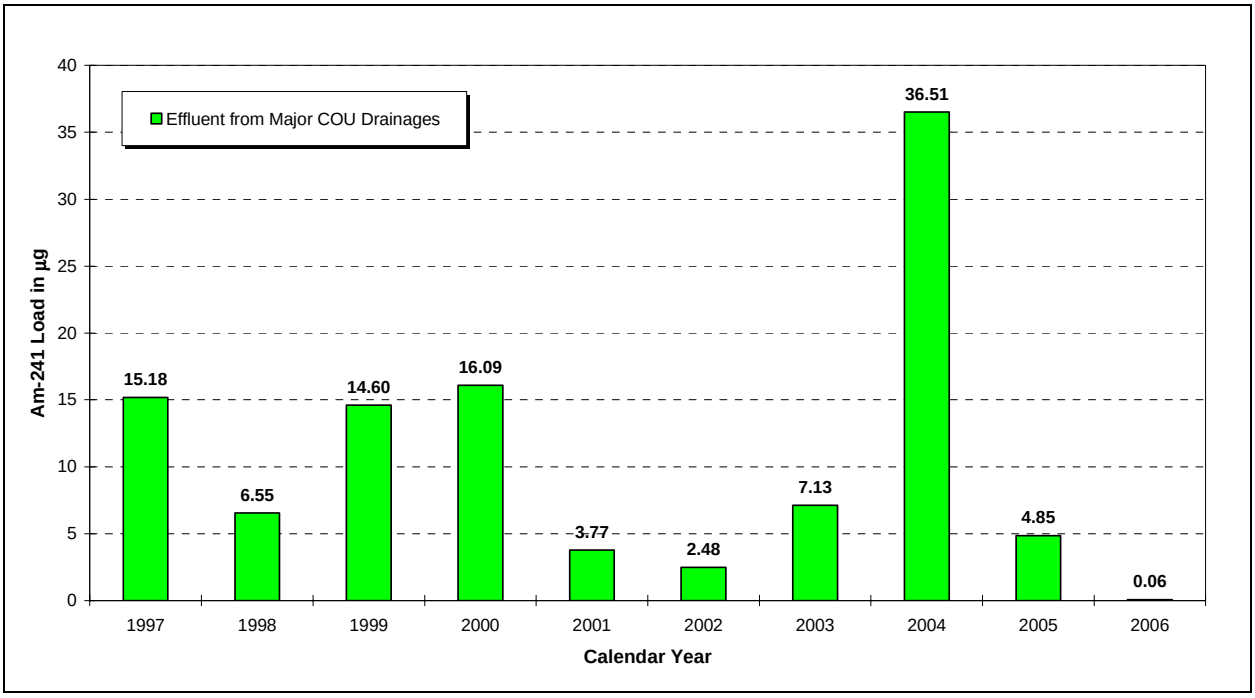



*Figure 2–118. Annual Am Loads from Major COU Drainages and WWTP: CY 1997–2006*

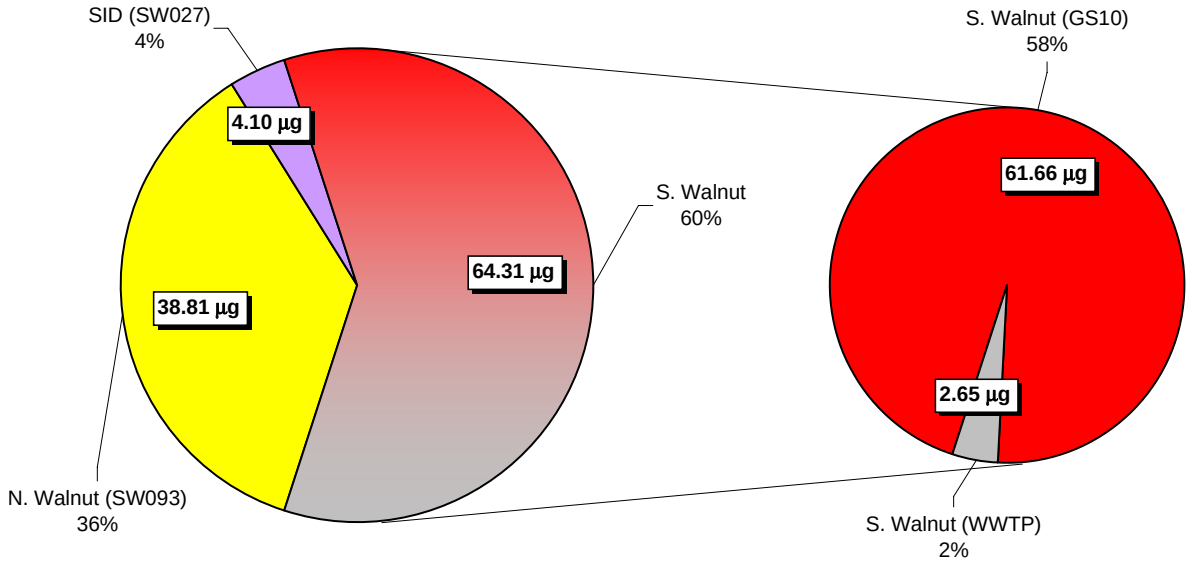



*Figure 2–119. Relative Am Load Totals from Major COU Drainages and WWTP: CY 1997–2006*

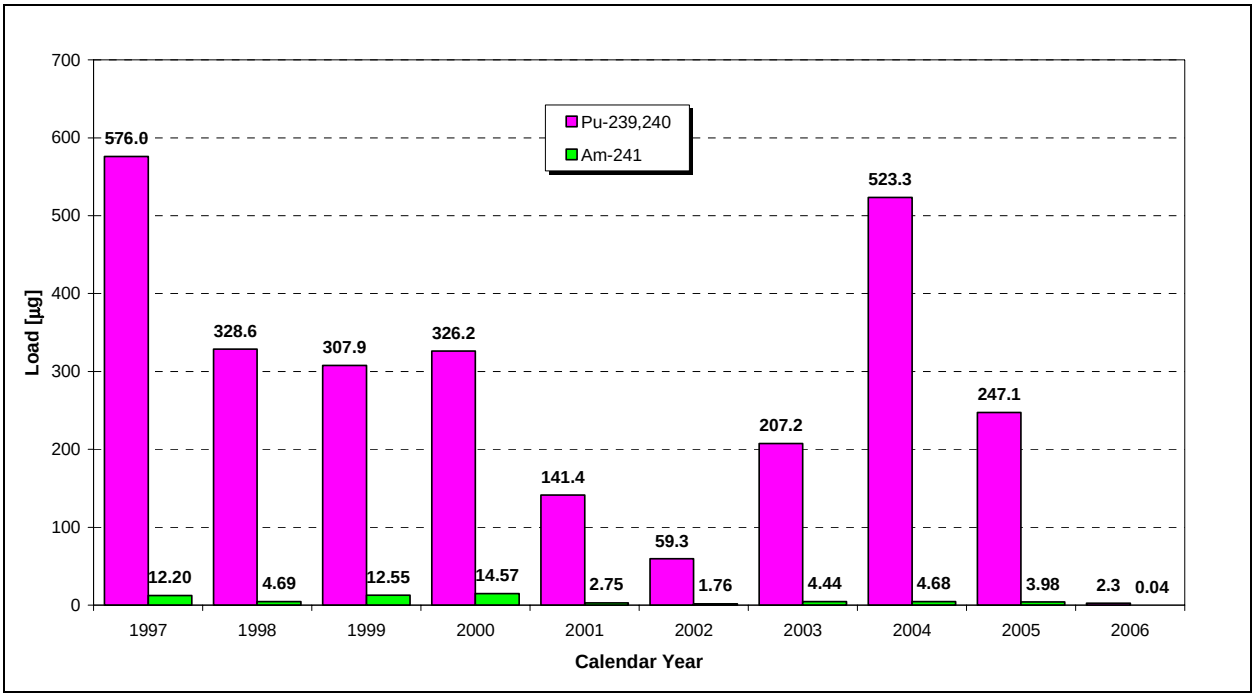



*Figure 2–120. Annual Pu and Am Loads at GS10: CY 1997–2006*

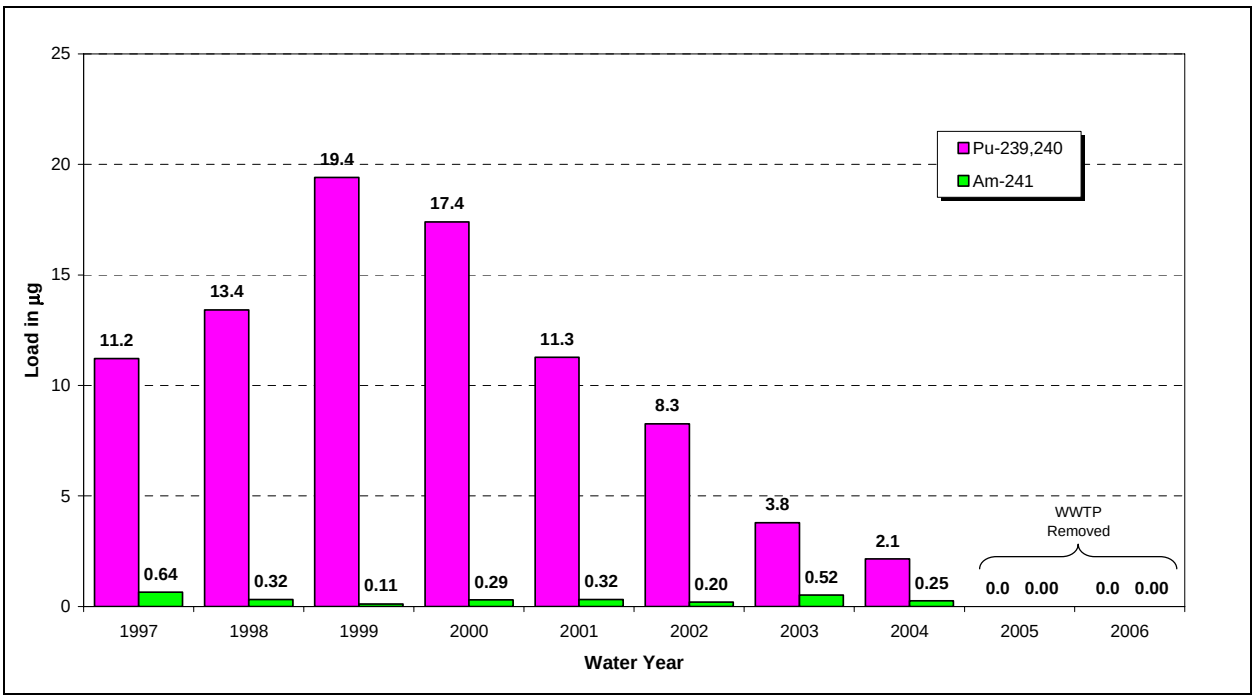



*Figure 2–121. Annual Pu and Am Loads at the WWTP: CY 1997–2006*

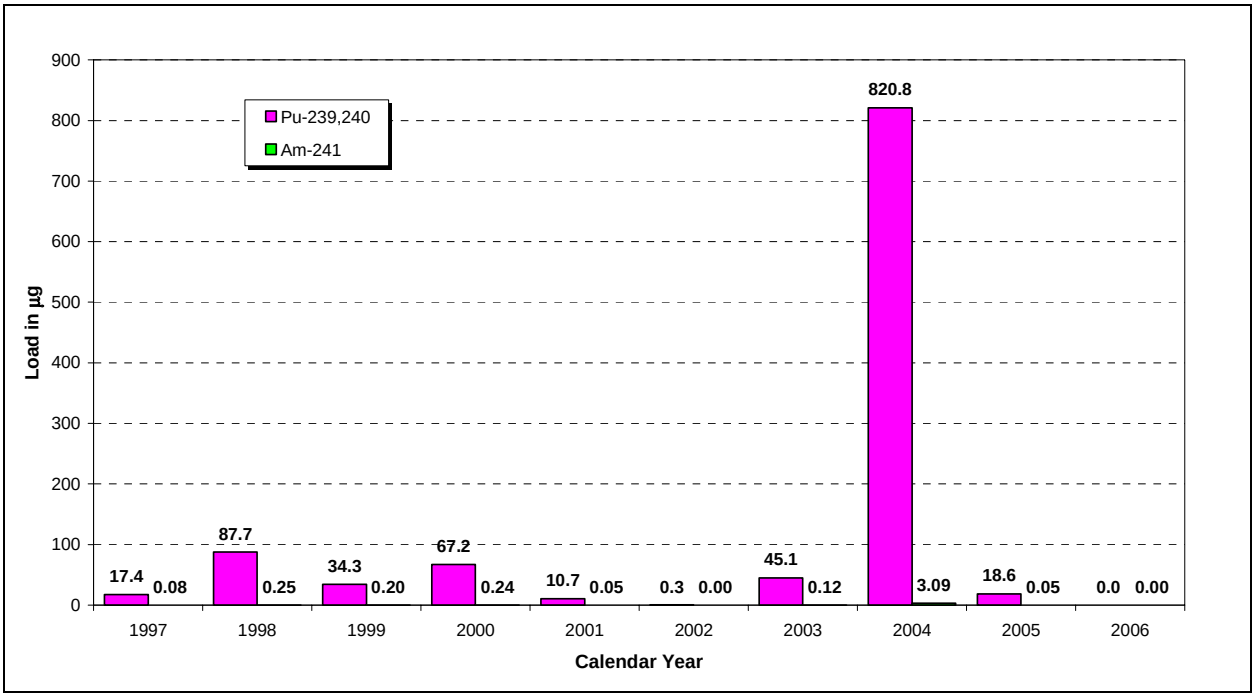



*Figure 2–122. Annual Pu and Am Loads at SW027: CY 1997–2006*

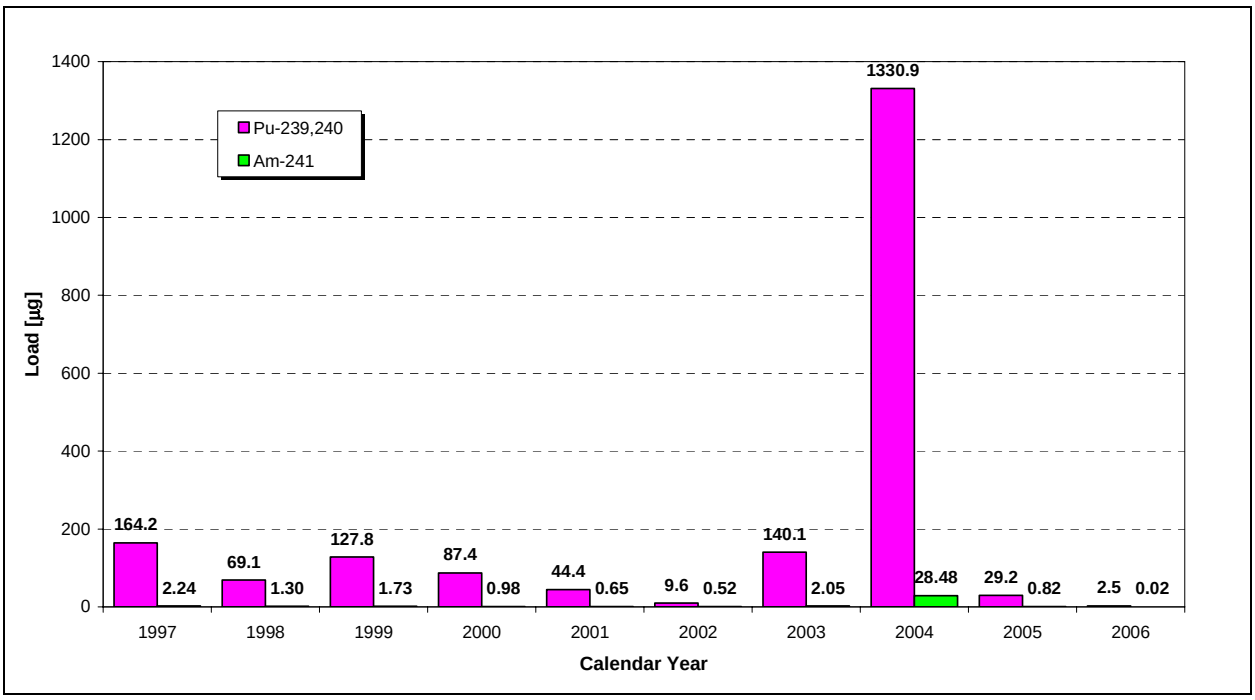



*Figure 2–123. Annual Pu and Am Loads at SW093: CY 1997–2006*

*Table 2−37. COU Total Uranium Loads: CY 1997–2006*

| Calendar Year | Total Uranium (g) | | | |
|---|---|---|---|---|
| | North Walnut Creek (SW093) | South Walnut Creek (GS10) | South Walnut Creek (WWTP) | SID (SW027) |
| 1997 | 853 | 637 | 257 | 84 |
| 1998 | 797 | 631 | 467 | 239 |
| 1999 | 714 | 589 | 121 | 116 |
| 2000 | 485 | 379 | 103 | 22 |
| 2001 | 646 | 519 | 259 | 66 |
| 2002 | 450 | 279 | 61 | 7 |
| 2003 | 568 | 501 | 161 | 111 |
| 2004 | 575 | 430 | 139 | 40 |
| 2005 | 534 | 879 | 0; WWTP removed | 33 |
| 2006 | 171 | 230 | 0; WWTP removed | 0; No flow |
| **Total** | 5,793 | 5,075 | 1569 | 718 |

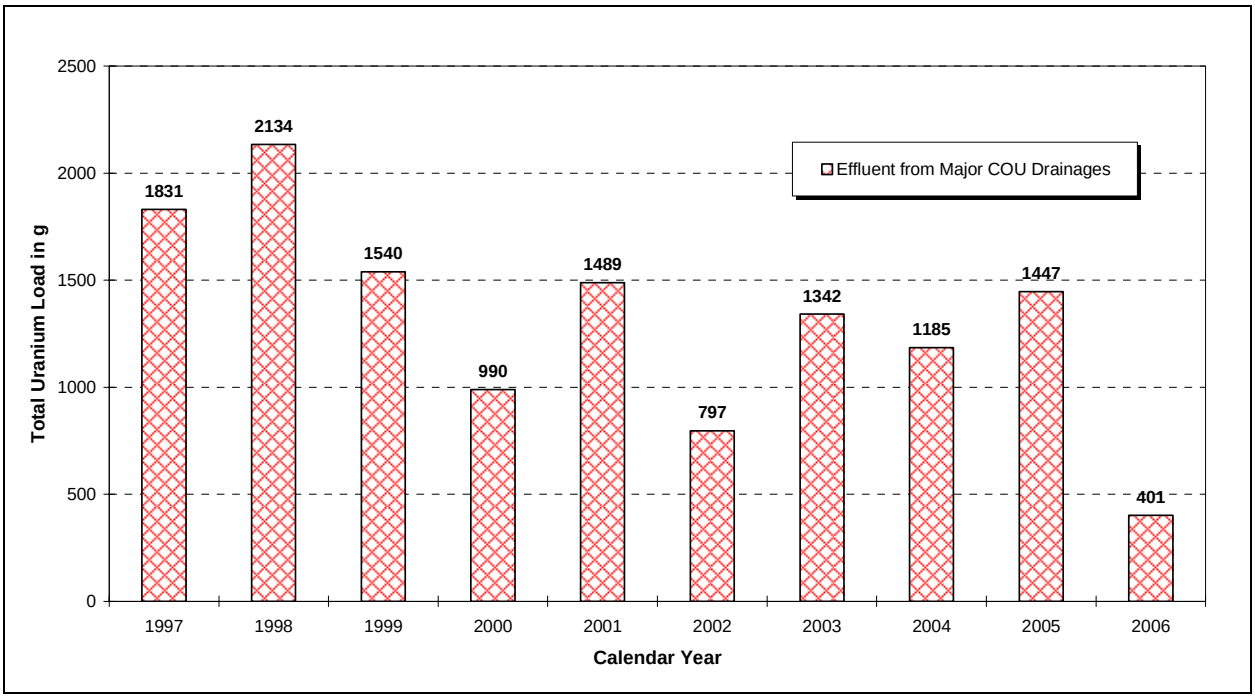



*Figure 2–124. Annual Total Uranium Loads from Major COU Drainages and Former WWTP: CY 1997–2006*

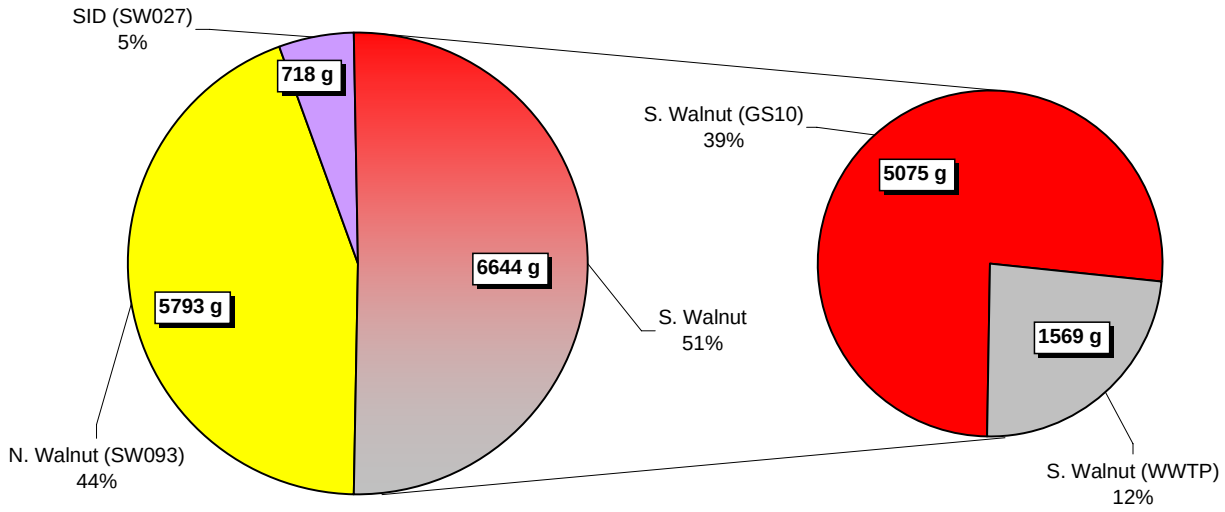



*Figure 2–125. Relative Total Uranium Load Totals from Major COU Drainages and Former WWTP: CY 1997–2006*

## 2.5 Ad Hoc Monitoring

The Site often monitors surface waters on an ad hoc basis for a variety of reasons. This monitoring may be requested by DOE, cities, and agencies. It is anticipated that various parties will continue to request ad hoc monitoring in the future. This monitoring will not always require sample analyses. In some cases, only flow or continuously recorded water-quality monitoring will be needed. Examples of situations that may warrant ad hoc monitoring include:

- Major precipitation events that disrupt routine pond predischarge monitoring and discharge schedules;
- Community assurance monitoring at the request of downstream cities and DOE;
- Unanticipated changes in regulatory permits, agreements, or funding;
- Special projects;
- Anticipated but unfunded changes in permits or agreements; and
- Construction projects.

The ad hoc monitoring details in Section 2.5.1 are based on the automated ad hoc monitoring performed in CY 2006.

### 2.5.1 Data Types, Frequency, and Collection Protocols

The type of data collected depends exclusively on the predetermined intent of the specific ad hoc monitoring location. The collected data can then be processed to provide decision support or input to a technical analysis. In most cases, flow is the primary data collected.

### 2.5.2 CY 2006 Monitoring Scope

Table 2−38 lists the ad hoc monitoring location that was operational during CY 2006. Figure 2–126 shows the location of this monitoring station.

*Table 2−38. Ad Hoc Monitoring Locations*

| Location Code | Location | Primary Flow Measurement Device | Telemetry | Notes |
|---|---|---|---|---|
| GS33 | No Name Gulch at confluence with Walnut Creek | 9.5-inch Parshall Flume | Yes | Flow data collection for determination of No Name Gulch contributions to Walnut Creek |

Note: Only locations specifically installed in support of an ad hoc project are shown.

*Table 2−39. Ad Hoc Field Data Collection: Parameters and Frequency*

| Location Code | Discharge |
|---|---|
| GS33 | 15-min continuous |

Note: Only locations specifically installed in support of an ad hoc project are shown.

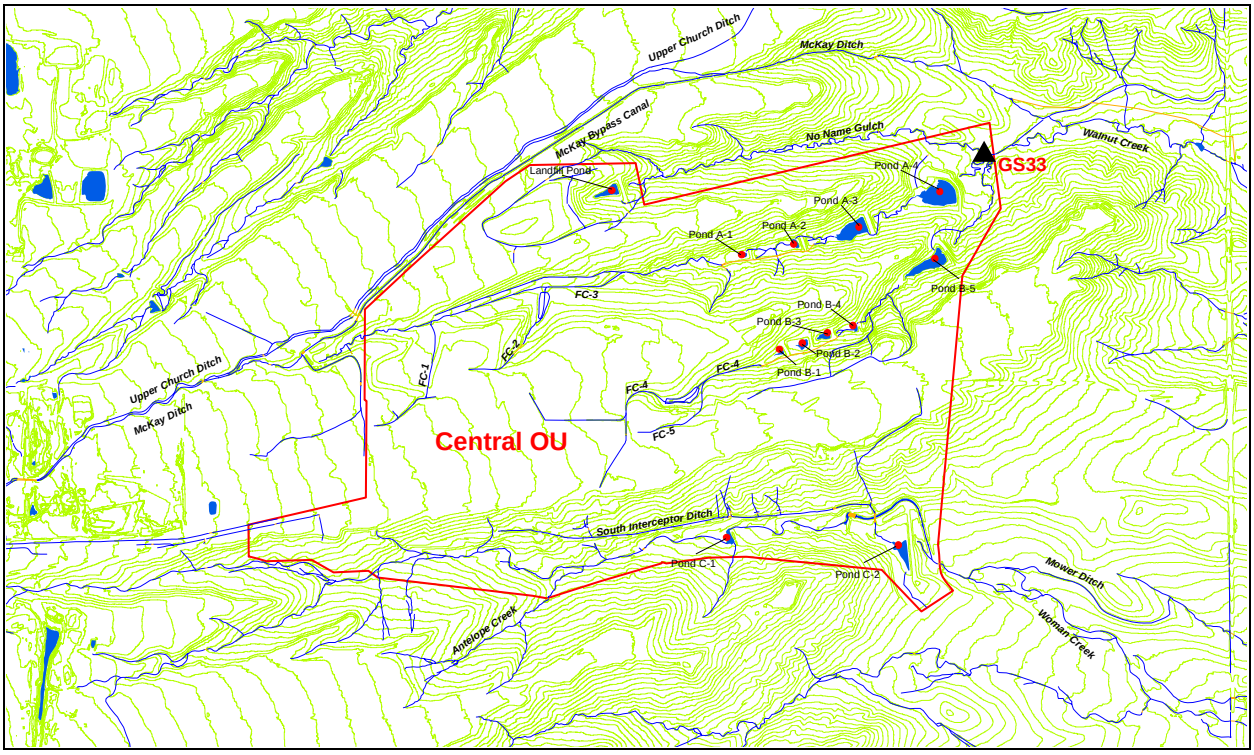



*Figure 2–126. CY 2006 Ad Hoc Monitoring Locations*

### 2.5.3 Data Evaluation

2.5.3.1 Flow Measurement Locations

Monitoring location GS33 was operated to specifically collect flow data to determine No Name Gulch contributions to Walnut Creek. Flow data from this location are presented in Section 2.2.2.12.

## 2.6 Indicator Parameter Monitoring for Assessment of Analytical Water-Quality Data

This objective provides the justification for the collection of general water-quality and quantity information to be used for various data assessments. Specifically, this objective outlines the current and expected uses of parameters such as TSS and flow rate.

This monitoring objective is intended to establish relationships between analytical measurements of constituents such as radionuclides and metals with selected indicator parameters, such as TSS, precipitation, and flow rate. The determination of these relationships may support evaluation of erosion control measures, design of land configuration options, pond operations, evaluation of radionuclide transport, assessment of statistically significant changes in water quality, and management decision making. Table 2−42 provides a listing of data uses for this monitoring objective.

For this report, data evaluation is limited to selected monitoring locations that were part of the network during CY 2006 and measuring surface-water flow from the COU (see Figure 2–127).

### 2.6.1 Data Types, Frequency, and Collection Protocols

To evaluate the relationship between TSS and analytical constituents,[20] TSS would ideally be analyzed for all samples collected at the locations covered by the other decision rules in this report. However, sampling protocols (continuous flow paced) often result in composite samples that are collected over periods exceeding the 7-day hold time for TSS analyses. Therefore, TSS cannot be analyzed for all composite samples but are analyzed whenever hold time requirements are met.

To evaluate the relationship between precipitation and analytical constituents, precipitation is currently monitored at multiple locations across the Site. The distribution of precipitation gages allows for the calculation of precipitation for any drainage area tributary to each monitoring location. Each of these locations is equipped with a continuously recording precipitation gauge. Because these gauges are not heated, precipitation in the form of snow may be underreported.

To evaluate the relationship between flow rate and analytical constituents, flow is currently measured at all automated monitoring locations across the Site. Each of these locations is equipped with continuously-recording flow-measurement instrumentation.

[20] The term ‘analytical constituents’ is used here to refer to constituents measured for samples collected as defined by the other decision rules in this report.

This decision rule does not limit the data uses to those given in Table 2−42. Relationships can be determined for any data combinations as required. For example, relationships between flow and precipitation, precipitation and TSS, etc., may be useful depending on the specific data evaluation.

### 2.6.2 CY 2006 Monitoring Scope

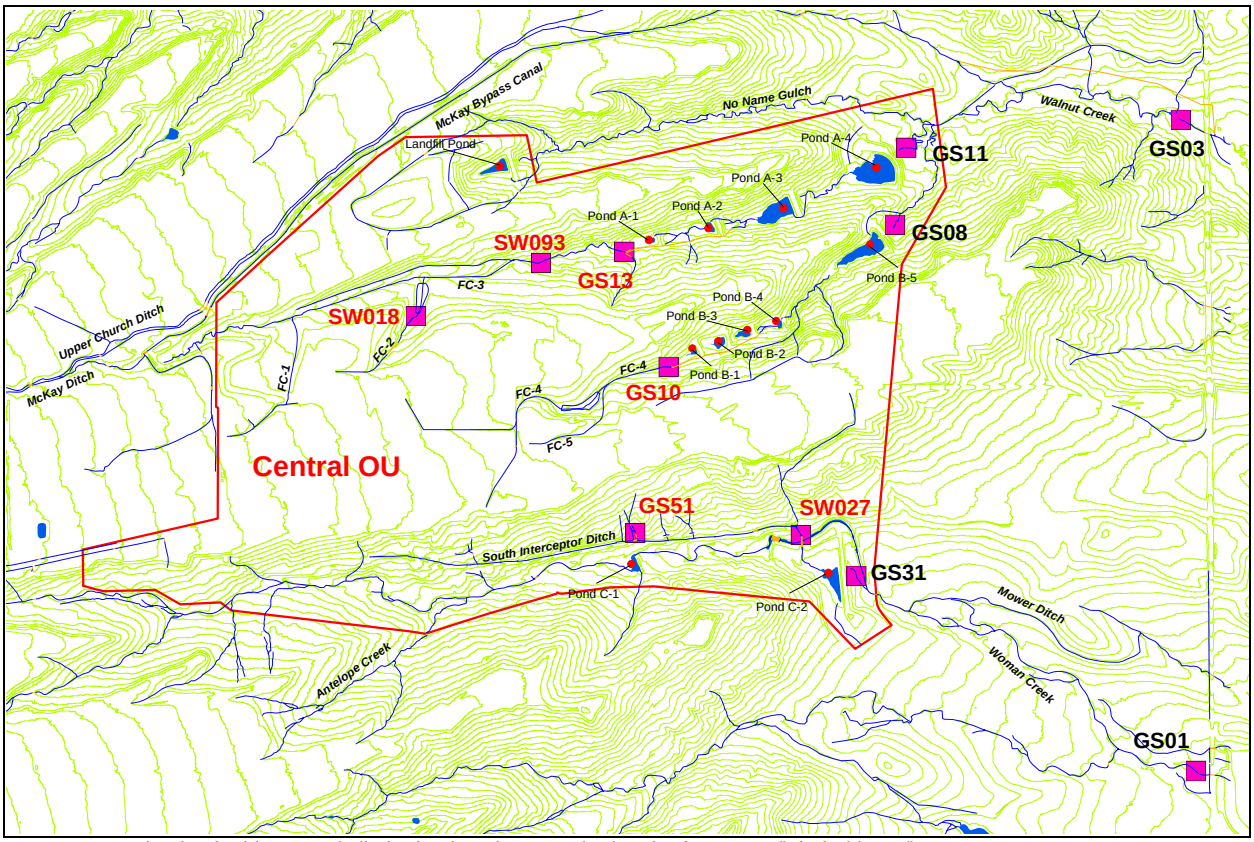
The following tables detail the Indicator Parameter monitoring scope for CY 2006. Figure 2–127 shows the Indicator Parameter monitoring locations.

*Table 2−40. Indicator Parameter Field Data Collection: Parameters and Frequency*

| Parameter | Frequency | Monitoring Location(s) |
|---|---|---|
| Flow rate | 5-min continuous | All locations where feasible |
| Precipitation | 5-min continuous | 13 locations site-wide |
| Flow volume | Derived from flow rate for any selected time period | All locations where feasible |

*Table 2−41. Indicator Parameter Analytical Data Collection: Analytes and Frequency*

| Analyte | Frequency | Monitoring Location(s) |
|---|---|---|
| Actinides | Determined by applicable monitoring objective | All locations as applicable |
| TSS | Determined by applicable monitoring objective; all samples that meet TSS hold time limits | All locations as applicable |




Note: Data evaluation in this report is limited to locations monitoring the former IA (labeled in red).

*Figure 2–127. CY 2006 Indicator Parameter Monitoring Locations*

Table 2−42 lists the data evaluations included in this section. Evaluation is limited to locations GS10, GS13, GS51, SW018, SW027, and SW093.

*Table 2−42. Data Evaluation for Indicator Parameter Monitoring for Analytical Water-Quality Assessment*

| Data Use | Required Parameters | Description |
|---|---|---|
| Correlation of Actinides with TSS | Actinides, TSS | Use of TSS measurements to predict actinide concentrations |
| Correlation of Actinides with Flow Rate | Actinides, flow rate | Use of flow rate measurements to predict actinides concentrations |
| Correlation of TSS with Flow Rate | TSS, flow rate | Use of flow rate measurements to predict TSS concentrations |

### 2.6.2.1 Correlation of Actinides with TSS

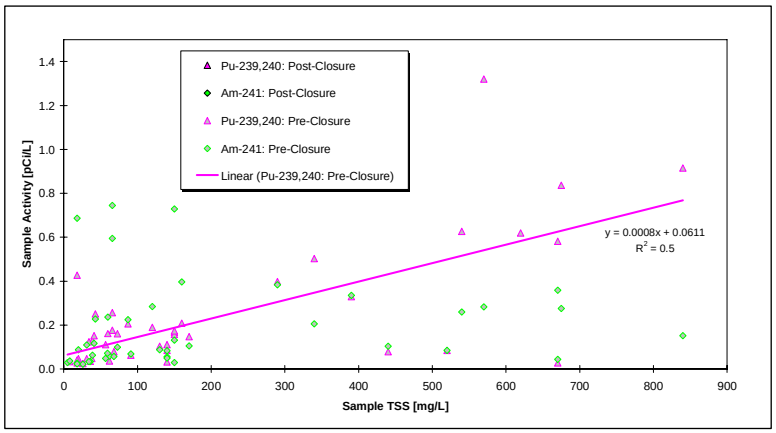
Since Pu and Am are transported in surface water in association with particulate matter (measured as TSS), a relationship between activity and TSS could be used as an indicator of Pu and Am transport. This section evaluates the variation of composite sample Pu and Am activity with the corresponding TSS concentration. Plots are presented for selected locations where both

Pu and Am data are collected with TSS. Data in plots are further separated by pre- and post-closure periods.

The sample Pu and Am activities are the values obtained through laboratory analysis given in pCi/L. Only Pu and Am values greater than the MDA (generally 0.015 pCi/L) are included.[21] The sample TSS is the value obtained through laboratory analysis given in milligrams per liter (mg/L). TSS analysis is only performed for composite samples that are collected over a period of less than the TSS hold time (7 days). Consequently, not all samples collected at the locations below were analyzed for TSS. Only TSS values greater than the detection limit (generally 5 mg/L) are included.

Only locations that had greater than two data pairs are plotted. As such, plots are not presented for location SW018.

### *Location GS10*

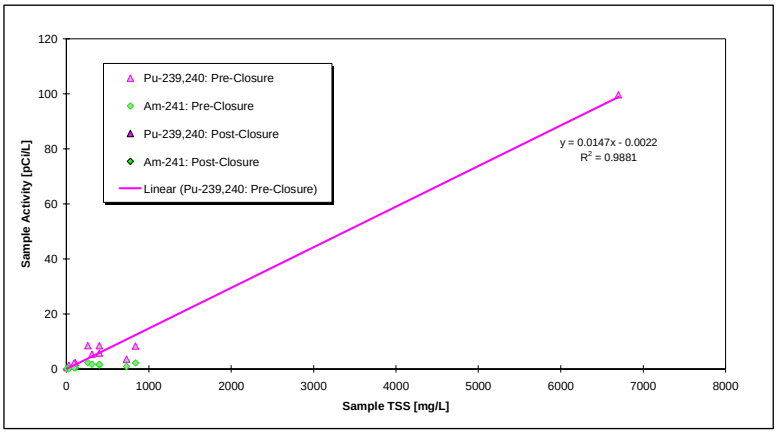



GS10 shows a fair trend between increasing Pu and increasing TSS. However, no trend is evident between Am and TSS. This lack of correlation may be caused by the variability of contamination levels throughout the drainage and the possible existence of localized Am source areas prior to Site Closure.

Note: No post-closure results through CY 2006 that met the MDA criteria.

*Figure 2–128. Variation of Pu and Am with TSS at GS10*

### *Location GS51*



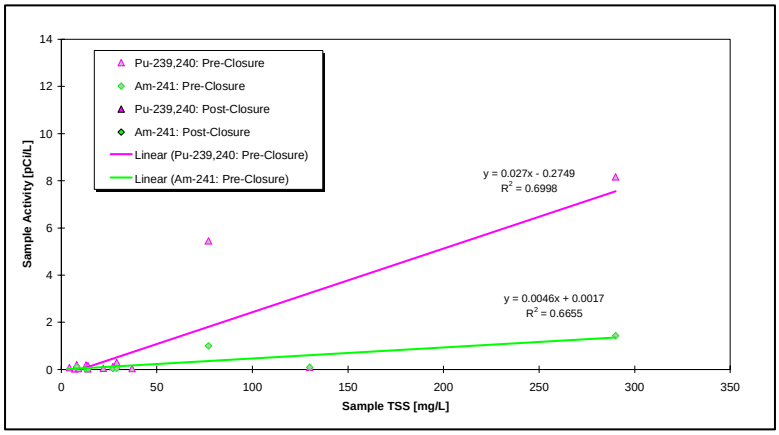

GS51 shows a strong correlation between increasing Pu activity and increasing TSS. The correlation is strongly influenced by a very high TSS value collected during the 903 Pad/Lip accelerated actions. No statistically significant correlation is noted for Am (the Am result associated with the highest TSS value was rejected by data validation).

Note: No post-closure TSS results through CY 2006.

*Figure 2–129. Variation of Pu and Am with TSS at GS51*

[21] Data are generally presented at varying precision for clarity. Accuracy should not be inferred; both analytical and flow measurement error have not been quantified in this section.

### *Location SW027*

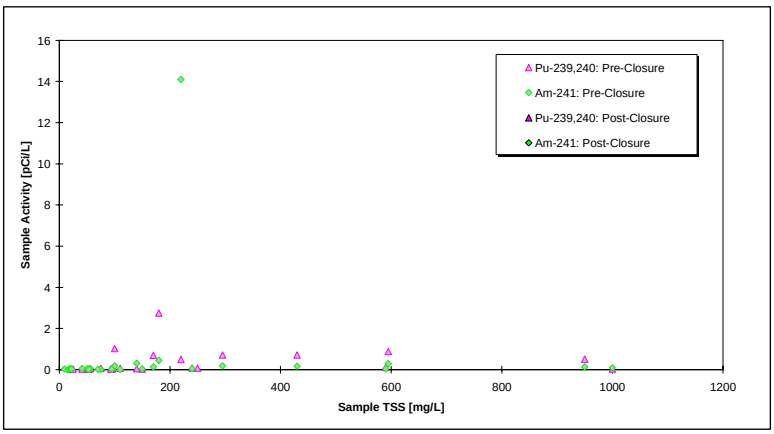



SW027 shows fair correlations between activity and TSS, but are highly influenced by single points.

Note: No post-closure TSS results through CY 2006.

*Figure 2–130. Variation of Pu and Am with TSS at SW027*

### *Location SW093*




SW093 shows no statistically significant correlation between activity and TSS.

Note: No post-closure TSS results through CY 2006 that met the MDA criteria.

*Figure 2–131. Variation of Pu and Am with TSS at SW093*

### 2.6.2.2 Correlation of Radionuclides with Flow Rate

Since Pu and Am are transported in surface water in association with particulate matter, and assuming that higher flow rates tend to transport more sediment, a relationship between activity and flow rate could be used as an indicator of Pu and Am transport. This section evaluates the variation of composite sample Pu and Am activity with the corresponding average flow rate. Plots are presented for selected locations where both Pu and Am data are collected with flow measurement. Data in plots are further separated by pre- and post-closure periods.

The sample Pu and Am activities are the values obtained through laboratory analysis given in pCi/L. Only Pu and Am values greater than the MDA (generally 0.015 pCi/L) are included. [22]

[22] Data are generally presented at varying precision for clarity. Accuracy should not be inferred; both analytical and flow measurement error have not been quantified in this section.

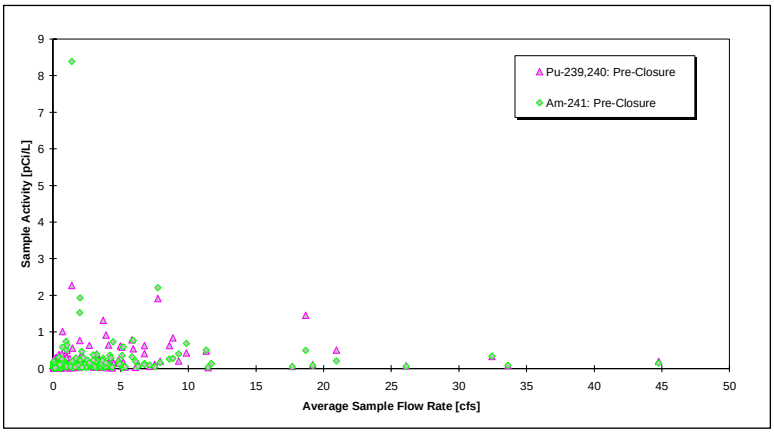
Plots are also presented showing the variability of total U with flow rate. Plots are presented for all locations where U data are collected with flow measurement. The sample total U activity is the sum of the isotopic values obtained through laboratory analysis given in pCi/L (U-233,234 + U-235 + U-238).

The average composite-sample period flow rate (cfs) is calculated as follows:

1. The date and time of each grab sample comprising the composite is obtained from the monitoring instrumentation.
2. The corresponding flow value for each grab sample is interpolated from the 15-minute interval flow data. Some samples may not have flow values due to equipment failures and periodic winter icing conditions.
3. Since each grab sample is of the same volume (200 milliliters [ml]), the interpolated flow values are arithmetically averaged to obtain the applicable flow for the entire composite sampling period.

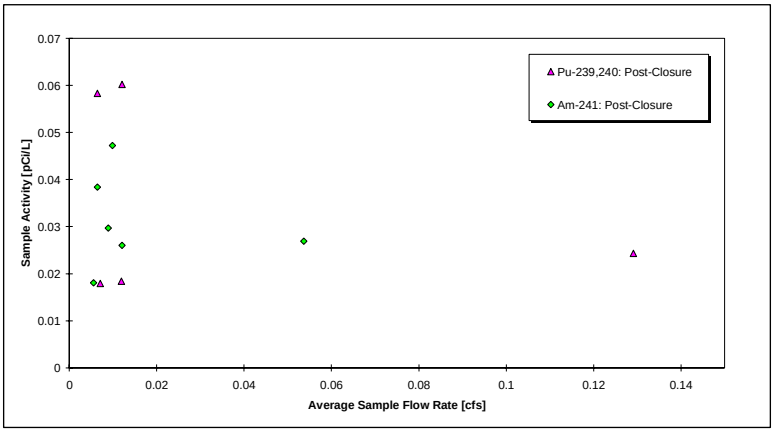
It should be noted that many locations were temporarily influenced by closure activities that resulted in large areas of disturbed soils susceptible to transport as TSS. Any Pu and Am that may be associated with these soils would then also be subject to increased transport for the given flow rate. Only locations that had greater than two data pairs are plotted. As such, post-closure plots are not presented for location SW018.

### *Location GS10*



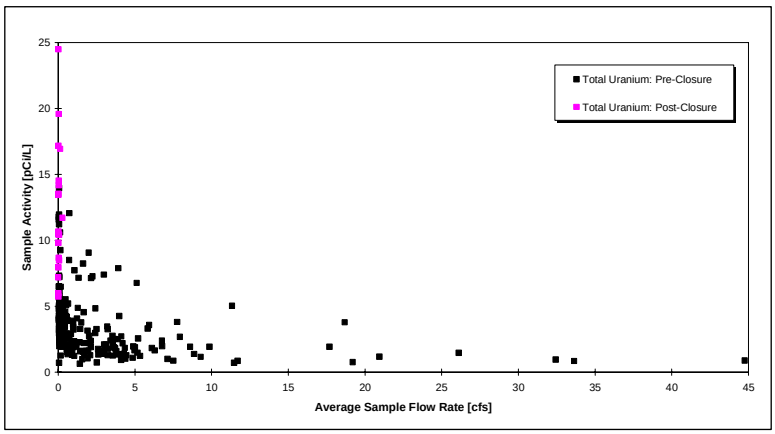

GS10 shows no statistically significant correlation between Pu and Am activity with flow rate using pre-closure data.

*Figure 2–132. Variation of Pu and Am with Flow Rate at GS10: Pre-Closure*




GS10 also shows no statistically significant correlation between Pu and Am activity with flow rate using post-closure data.

*Figure 2–133. Variation of Pu and Am with Flow Rate at GS10: Post-Closure*

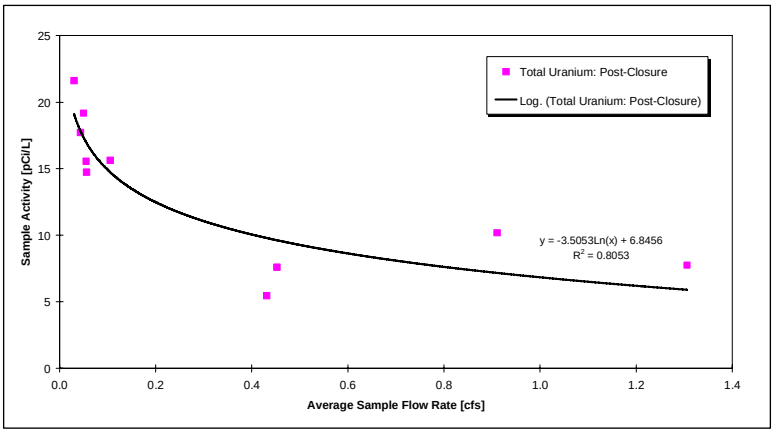



GS10 shows a visual trend between decreasing U activity and increasing flow rate. Baseflow at GS10 is sustained by ground water seepage to the creek. Naturally occurring U is associated with these flows. Therefore, the decrease in U activity at higher flow rates is likely caused by dilution from stormwater runoff. The highest activities are associated with the lowest flows.

The post-closure results clearly show this trend, as runoff rates have been significantly reduced.

*Figure 2–134. Variation of Total Uranium with Flow Rate at GS10*

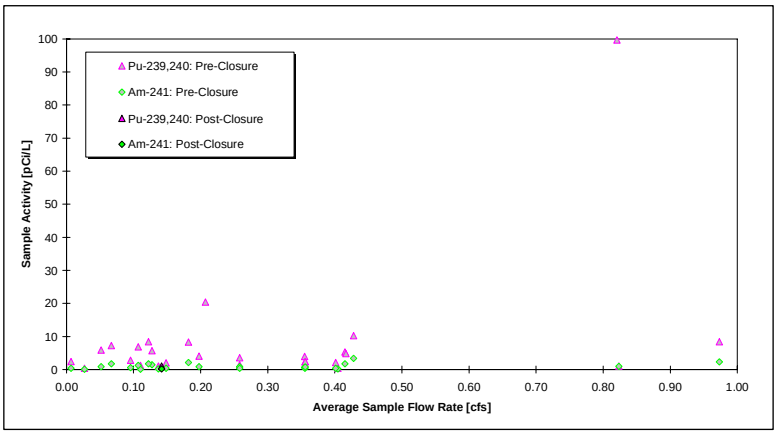
## *Location GS13*




GS13 shows a good correlation between decreasing U activity and increasing flow rate. Baseflow at GS13 is sustained by ground water seepage and treated discharge from the Solar Ponds Plume Treatment System (SPPTS). U is associated with these flows. Therefore, the decrease in U activity at higher flow rates is likely caused by dilution from stormwater runoff.

*Figure 2–135. Variation of Total Uranium with Flow Rate at GS13*

## *Location GS51*

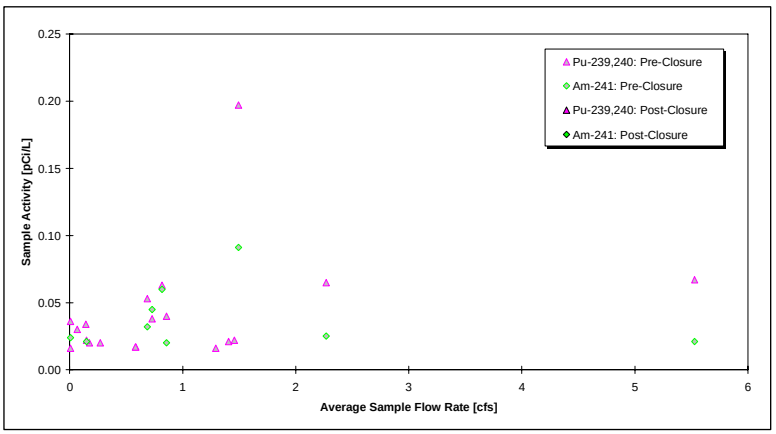



GS51 shows no statistically significant correlation between Pu and Am activity with flow rate.

The single post-closure result shows low Pu activity in relation to the flow rate suggesting that remedial actions and erosion control measures have been effective.

*Figure 2–136. Variation of Pu and Am with Flow Rate at GS51*

## *Location SW018*

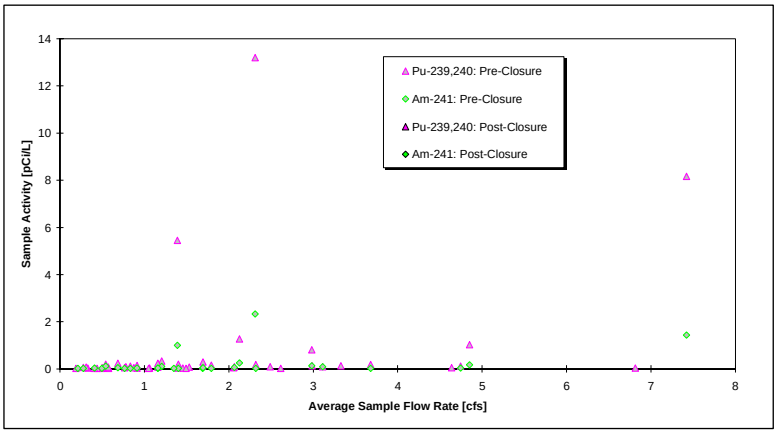



SW018 shows no statistically significant correlation between Pu and Am activity with flow rate using pre-Closure data.

Note: Less than three post-closure results greater than the MDA through CY 2006.

*Figure 2–137. Variation of Pu and Am with Flow Rate at SW018*

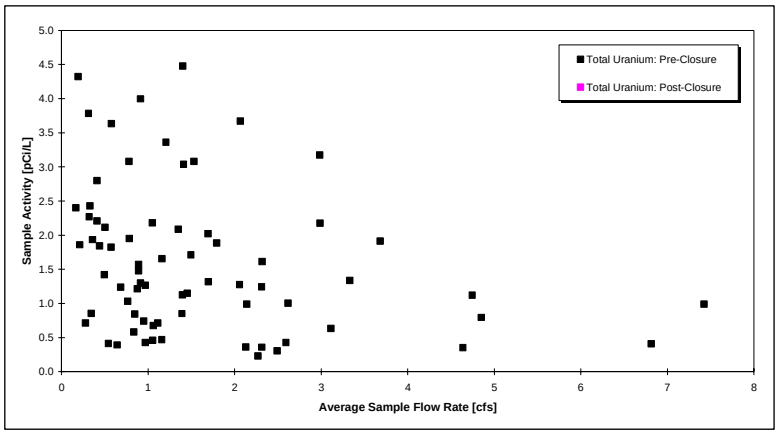
## *Location SW027*




SW027 shows no statistically significant correlation between Pu and Am activity with flow rate.

Note: No post-closure results through CY 2006.

*Figure 2–138. Variation of Pu and Am with Flow Rate at SW027*

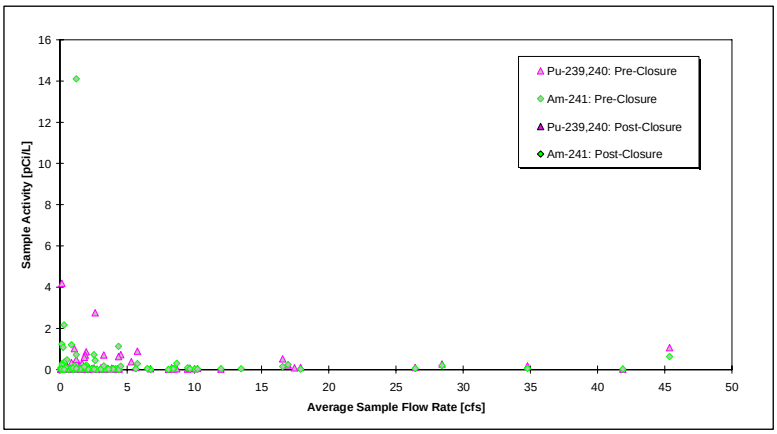



SW027 shows no statistically significant correlation between U activity and flow rate.

Note: No post-closure results through CY 2006.

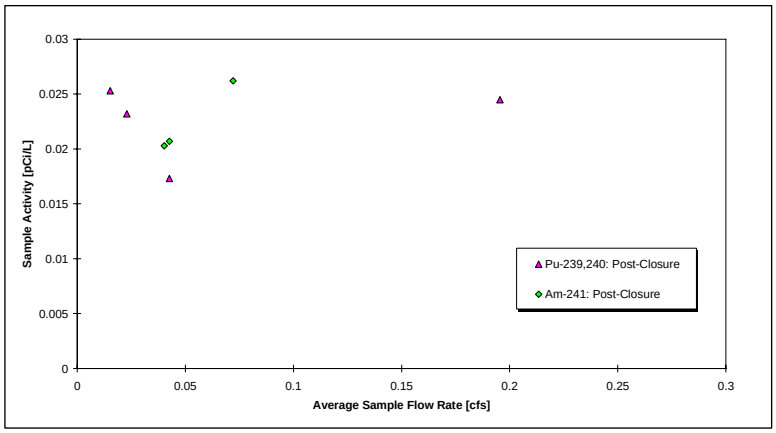
*Figure 2–139. Variation of Total Uranium with Flow Rate at SW027*

## *Location SW093*



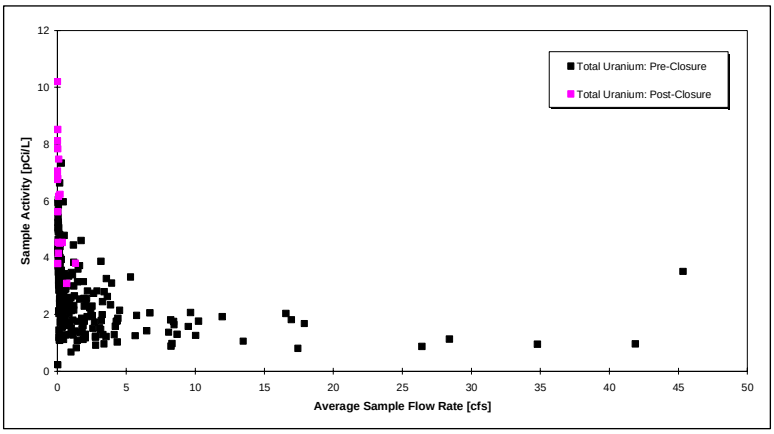

SW093 shows no statistically significant correlation between Pu and Am activity with flow rate using pre-closure data.

*Figure 2–140. Variation of Pu and Am with Flow Rate at SW093: Pre-Closure*




SW093 shows no statistically significant correlation between Pu and Am activity with flow rate using post-closure data.

*Figure 2–141. Variation of Pu and Am with Flow Rate at SW093: Post-Closure*




SW093 shows a visual trend between decreasing U activity and increasing flow rate. Baseflow at SW093 is sustained by ground water seepage to the creek. Naturally occurring U is associated with these flows. Therefore, the decrease in U activity at higher flow rates is likely caused by dilution from stormwater runoff.

The post-closure results clearly show this trend, as runoff rates have been significantly reduced.

*Figure 2–142. Variation of Total Uranium with Flow Rate at SW093*

### 2.6.2.3 Correlation of TSS with Flow Rate

Since many contaminants are transported in surface water in association with particulate matter (measured as TSS), if a relationship between TSS and flow rate could be established, then flow could be used as an indicator of contaminant transport. This section evaluates the variation of composite sample TSS with the corresponding average flow rate. Plots are presented for selected locations where both flow and TSS data are collected.

The sample TSS is the value obtained through laboratory analysis given in mg/L. TSS analysis is only performed for composite samples that are collected over a period of less than the TSS hold time (7 days). Consequently, not all samples collected at the locations evaluated were analyzed for TSS. Only TSS values greater than the detection limit (generally 5 mg/L) are included.[23]

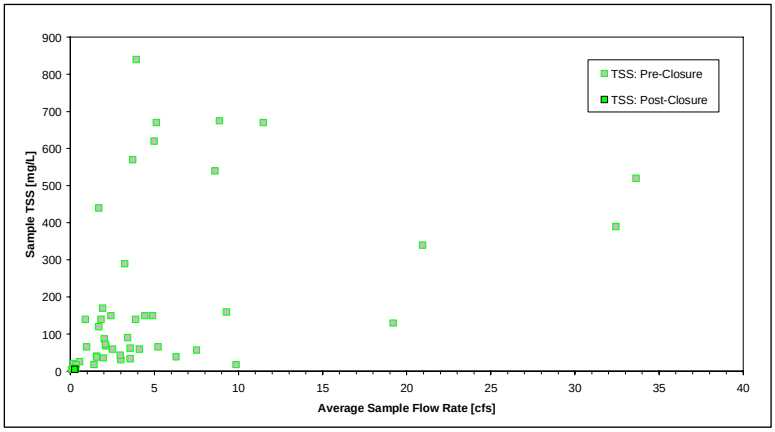
The average composite sample period flow rate (cfs) is calculated as follows:

1. The date and time of each grab sample comprising the composite is obtained from the monitoring instrumentation.
2. The corresponding flow value for each grab sample is interpolated from the 15-minute interval flow data. Some TSS samples may not have flow values due to equipment failures and poor flow data due to winter icing conditions.
3. Since each grab sample is of the same volume (200 ml for flow-paced composites and generally 1 liter for storm-event composites), the interpolated flow values are arithmetically averaged to obtain the applicable flow for the entire composite sampling period.

It should be noted that many locations were significantly influenced by closure activities that resulted in large areas of disturbed soils susceptible to transport as TSS. This increased transport of soil would result in increased TSS for the given flow rate.

[23] Data are generally presented at varying precision for clarity. Accuracy should not be inferred; both analytical and flow measurement error have not been quantified in this section.

## *Location GS10*

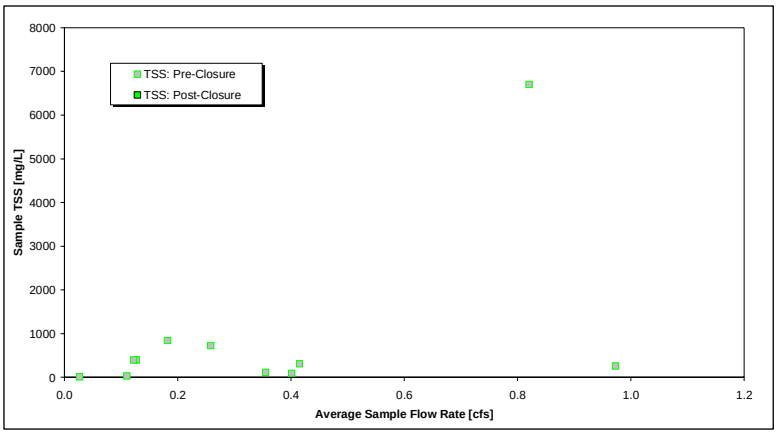



GS10 shows no statistically significant correlation between TSS and flow rate. GS10 had previously shown a fair correlation between increasing TSS and increasing flow rate. This loss of correlation is due to high TSS at relatively low flow rates caused by extensive 2004−2005 soil disturbances in the GS10 drainage.

Note: Only one post-closure result through CY 2006.

*Figure 2–143. Variation of TSS with Flow Rate at GS10*

## *Location GS51*

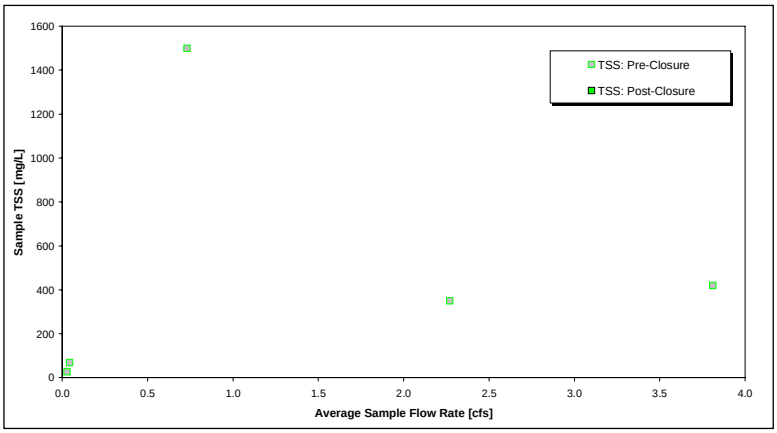



GS51 shows no statistically significant correlation between TSS and flow rate.

Note: No post-closure results through CY 2006.

*Figure 2–144. Variation of TSS with Flow Rate at GS51*

## *Location SW018*

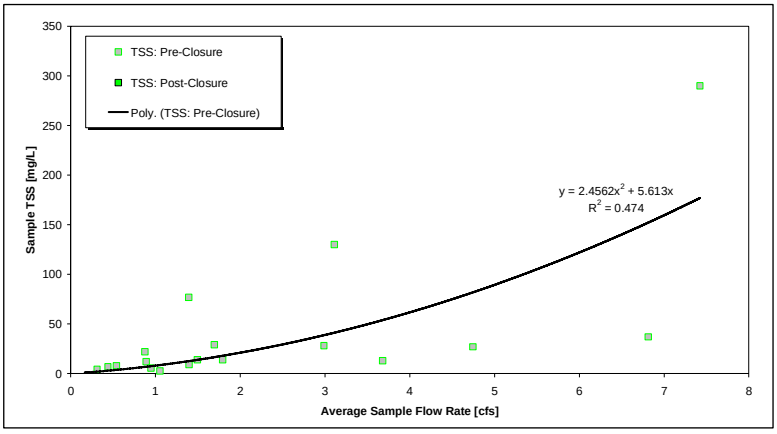



SW018 shows no statistically significant correlation between TSS and flow rate.

Note: No post-closure results through CY 2006.

*Figure 2–145. Variation of TSS with Flow Rate at SW018*

### *Location SW027*

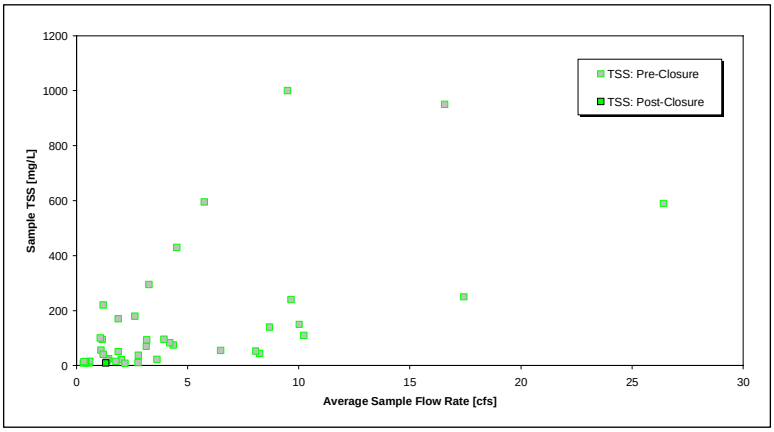



SW027 shows a weak correlation between increasing TSS and increasing flow rate.

Note: No post-closure results through CY 2006.

*Figure 2–146. Variation of TSS with Flow Rate at SW027*

### *Location SW093*




SW093 shows no statistically significant correlation between TSS and flow rate.

Note: Only one post-closure result through CY 2006.

*Figure 2–147. Variation of TSS with Flow Rate at SW093*

## 2.7 Investigative Monitoring

When reportable water-quality measurements are detected by surface water monitoring at POEs or POCs, additional monitoring may be required to identify[24] the source and evaluate for mitigating action pursuant to RFCA through the consultative process. This Investigative Monitoring objective is intended to provide upstream water-quality information should reportable water-quality values be detected at RFCA POEs or POCs. This group of upstream monitoring locations have been installed prior to any active source evaluation. Data collection is generally limited to POE and POC analytes of interest (AOIs) and is intended to be discontinued once acceptable water quality has been demonstrated at POEs and POCs for an extended period.

[24] Note that the term "identify" is used here to mean "locate." Characterization is also implied.

### 2.7.1 Data Types, Frequency, and Collection Protocols

Data collection upstream of POEs and POCs is not limited to the locations below. The Site may also elect to collect data using other methods, subject to the characteristics of the reportable water-quality values and through the applicable consultative process.

#### 2.7.1.1 Data Types and Frequencies

The following types of data could also be collected at the Site at specific frequencies:

- Continuous flow data at 15-minute intervals;
- Continuous flow-paced composite samples at location-specific frequencies;
- Isotopic U analytical results from GS05, GS13, and GS59; and
- Isotopic Pu, Am, and TSS analytical results from GS51 and SW018.

Data collection is currently limited to monitoring locations GS05 and GS59 on Woman Creek, GS13 and SW018 on North Walnut Creek, and GS51 on areas tributary to the SID. Flow data and composite samples are collected continuously using automated equipment.

### 2.7.2 CY 2006 Monitoring Scope

*Table 2−43. Investigative Monitoring Locations*

| Location Code | Location | Primary Flow Measurement Device | Telemetry |
|---|---|---|---|
| GS05 | North Woman Creek at West Site Boundary | 9-inch Parshall Flume with weir insert | Yes |
| GS13 | North Walnut Creek above Pond A-1 | 6-inch Parshall Flume | Yes |
| GS51 | Ditch along abandoned road south of former 903 Pad just upstream of SID | 0.75-foot H-Flume | Yes |
| GS59 | Woman Creek 900 feet upstream of Antelope Springs confluence | 1.5-foot Parshall Flume | Yes |
| SW018 | FC-2 at FC-2 Wetland | 1-foot Parshall Flume through September 12, 2006;<br>1-foot H flume installed September 13, 2006 | Yes |

*Table 2−44. Investigative Field Data Collection: Parameters and Frequency*

| Location Code | Flow |
|---|---|
| GS05 | 15-min continuous |
| GS13 | 15-min continuous |
| GS51 | 15-min continuous |
| GS59 | 15-min continuous |
| SW018 | 15-min continuous |

Note: All locations collect 5- and 15-minute flow data.

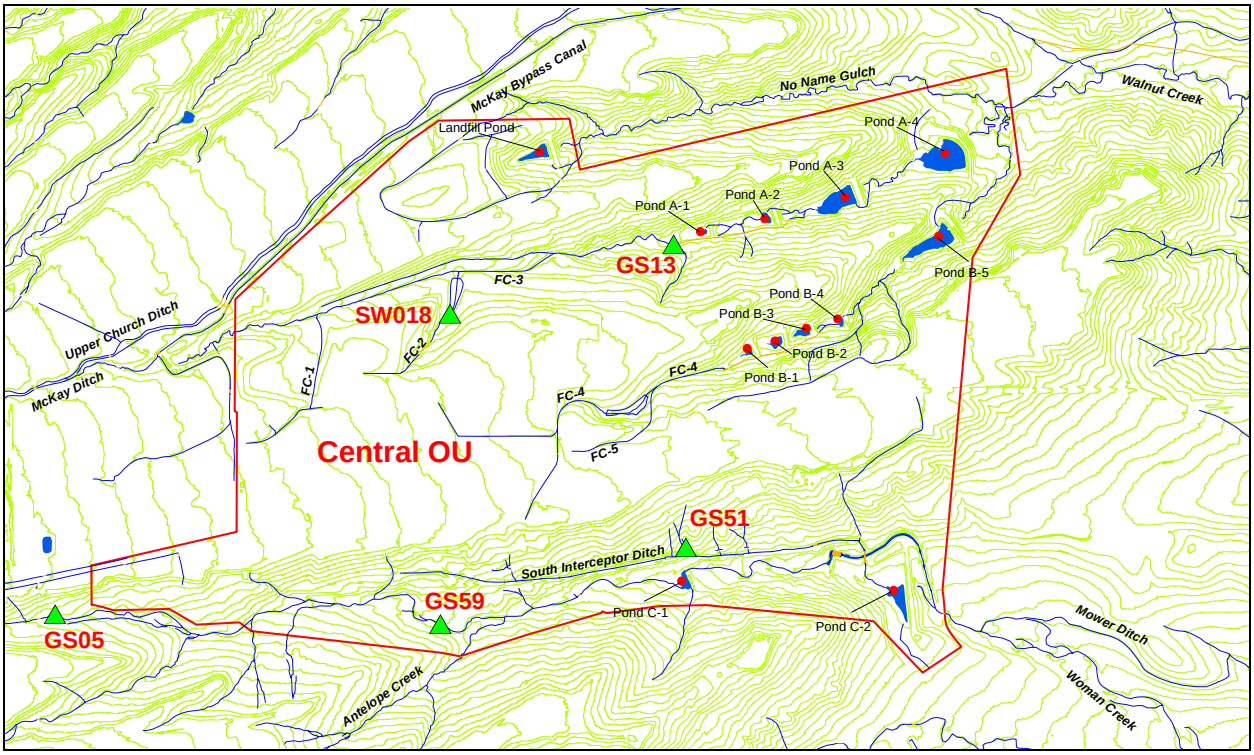



*Figure 2–148. CY 2006 Investigative Monitoring Locations*

*Table 2−45. Investigative Sample Collection Protocols*

| Location Code | Frequency: CY 2006 Actual (Target) | Type[a] |
|---|---|---|
| GS05 | 6 (8 per year) | Continuous flow-paced composites |
| GS13 | 8 (8 per year) | Continuous flow-paced composites |
| GS51 | 1 (8 per year) | Continuous flow-paced composites |
| GS59 | 6 (8 per year) | Continuous flow-paced composites |
| SW018 | 7 (8 per year) | Continuous flow-paced composites |

[a]Sample types are defined in Appendix B.

*Table 2−46. Investigative Analytical Targets (Analyses per Year)*

| Location Code | Pu and Am CY 2006 Actual (Target) | Uranium CY 2006 Actual (Target) | TSS CY 2006 Actual (Target) |
|---|---|---|---|
| GS05 | NA | 6 (8) | NA |
| GS13 | NA | 8 (8) | NA |
| GS51 | 1 (8) | NA | 0 (8) |
| GS59 | NA | 6 (8) | NA |
| SW018 | 7 (8) | NA | 0 (8) |

Notes: NA = analyte not collected

### 2.7.3 Data Evaluation

This Investigative Monitoring objective is intended to provide upstream water-quality information should reportable water-quality values be detected at RFCA POEs or POCs. Data evaluation at Investigative Monitoring locations is selected to aid in a specific source evaluation. These evaluations include, but are not limited to, loading, fate and transport, correlations and trending, and other statistical evaluation. The DQO decision rule is:

**IF** Reportable water quality values are observed at a POE or POC (see Sections 2.9 and 2.10) for the applicable RFCA AOIs—
**THEN** Investigative monitoring data from an appropriate upstream location may be used to evaluate the reportable POE or POC values, subject to the consultative process.

**IF** No reportable water quality values are observed at a specific POE or POC for the applicable RFCA AOIs for a period of 1 full year—
**THEN** Analysis of the collected sample(s) from the appropriate tributary upstream location(s) may be suspended; samples will continue to be collected and held for a period of 6 months for potential analysis should reportable water quality values subsequently be observed at a POE or POC (subject to the consultative process).

**IF** No reportable water quality values are observed at a specific POE or POC for the applicable RFCA AOIs for a period of 5 consecutive years—
**THEN** Sample collection from the appropriate tributary upstream location(s) may be terminated; the ability to resume upstream sampling at these locations, or any other appropriate location, will be maintained should subsequent reportable water-quality values be observed at a POE or POC (subject to the consultative process).

Reportable water-quality values were observed only at POE GS10 during CY 2006. A source evaluation update for GS10 is given in Section 2.9.3.1. No reportable values were observed at all other POEs and POCs during CY 2006. Analytical data for Investigative Monitoring during the 4th quarter are provided in the appendices; previous data have been presented in previous quarterly reports.

## 2.8 Performance Monitoring

### 2.8.1 Present Landfill Treatment System

This surface water-monitoring objective is intended to determine the short- and long-term effectiveness of the remedy. These requirements were initially identified in the *Final Interim Measures/Interim Remedial Action (IM/IRA) for IHSS 114 and RCRA Closure of the RFETS Present Landfill*, "Appendix B: Post-Accelerated Action Monitoring and Long-Term Surveillance and Monitoring Considerations" (DOE 2004), and finalized in the *Present Landfill Monitoring and Maintenance Plan and Post-Closure Plan* (PLF M&M Plan; DOE 2006b) including institutional controls, inspection and maintenance, and environmental monitoring.

As part of PLF closure, a passive seep interception and treatment system (the PLFTS) has been installed to treat landfill seep water and ground water intercept system (GWIS) water. There are three sources of influent to the PLFTS: two GWIS pipes and the PLF seep. Effluent from the

PLFTS eventually flows to the Landfill Pond. This section presents the monitoring data for PLFTS influent and effluent as well as the Landfill Pond if the PLFTS effluent exceeds surface water standards. Details regarding surface water monitoring for the PLFTS can be found in the PLF M&M Plan.

As required by the PLF M&M Plan and detailed in the IMP, PLFTS monitoring requirements will consist of quarterly sampling until the upcoming Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) 5-year review is complete (August 2007). A validated exceedance of a PLFTS effluent limit will trigger monthly monitoring for 3 consecutive months. Continued exceedances during the 3-month period will trigger consultation between the RFCA parties to determine whether a change in the remedy is required, additional parameters need to be analyzed, or a different sampling frequency is desired. Continued exceedances will also trigger sampling of the Landfill Pond for those constituent standards that were exceeded in the PLFTS effluent. If surface water standards are exceeded in the pond, RFCA parties will be consulted to determine if further sampling is required, if the water in the pond can flow through the outlet, or if another water management strategy should be applied.

The GWIS influent (if any) to the PLFTS will also be sampled. The water will be sampled quarterly for 1 year, and the analytical results will be evaluated by the RFCA parties.

PLFTS sampling locations, data collection protocols, and analyte suites are given in Table 2−47.

*Table 2−47. Sampling Locations for PLFTS*

| Location Code | Location Description | Routine Data Collection | Analytes |
|---|---|---|---|
| GWISINFNORTH | Northern GWIS influent to the treatment system | Quarterly grab samples | VOCs, isotopic uranium, total and dissolved metals, nitrate/nitrite, total mercury |
| GWISINFSOUTH | Southern GWIS influent to the treatment system | Quarterly grab samples | VOCs, isotopic uranium, total and dissolved metals, nitrate/nitrite, total mercury |
| PLFSEEPINF | Landfill seep influent to the treatment system | Quarterly grab samples; instantaneous flow rate at sample event | VOCs, isotopic uranium, total and dissolved metals, total mercury |
| PLFSYSEFF | Effluent from the treatment system | Quarterly grab samples | VOCs, isotopic uranium, total and dissolved metals, SVOCs, total mercury |
| PLFPONDEFF | East Landfill pond at the downstream (east) end | As needed; triggered by decision rule | As needed; determined by decision rule |

Note: Flow at the seep influent is measured using a 'bucket-and-stopwatch' method

Analytical methodologies and reporting limits, data reporting procedures, laboratory quality assurance/quality control (QA/QC) procedures, and laboratory data validation and contractor validation procedures are conducted in accordance with U.S. Environmental Protection Agency (EPA)-approved methods. Samples are submitted to an EPA-approved analytical laboratory for some or all of the following analysis methods:

- SW-846 Method 8260B—Volatile organic compounds (VOCs)
- SW-846 Method 6010B—Metals (total and dissolved)

- SW-846 Method 7470A—Mercury (total)
- SW-846 Method 8270C—Semivolatile organic compounds (SVOCs)
- Alpha Spectrometry—Isotopic uranium
- EPA-600 / 4-79-020 Method 353.2—Nitrate/nitrite

This objective is intended to evaluate water quality for the inflows to the PLFTS. Monitoring of the PLFTS effluent is intended to demonstrate compliance with surface water standards.

Generally, analytical data evaluation is performed quarterly as data become available. Analytical data from the GWIS (GWISINFNORTH and GWISINFSOUTH) and seep (PLFSEEPINF) influent sources are routinely reported to the RFCA parties. GWIS sampling results will be reviewed by the RFCA parties after 1 year to determine if further sampling is required. The DQO decision rule for the PLFTS effluent (PLFSYSEFF) is as follows:

**IF** Quarterly effluent (PLFSYSEFF) results are greater than surface water standards listed in the RFCA, Attachment 5, Table 1—
**THEN** Sampling frequency will be increased to monthly for 3 consecutive months (increased sampling, other than the routine quarterly sampling, will be limited to the constituents that triggered the increased sampling frequency).

**IF** Monthly effluent results continue to be greater than surface water standards listed in the RFCA, Attachment 5, Table 1 for 3 consecutive months—
**THEN** Notify the RFCA parties and sample the Landfill Pond for the constituents that were greater than the surface water standards during monthly sampling—
**ELSE** Discontinue monthly sampling for the constituents that were less than the surface water standards.

**IF** Landfill Pond sampling results are greater than surface water standards listed in the RFCA, Attachment 5, Table 1—
**THEN** Consult the RFCA parties to determine if further sampling is required, or if another water management strategy should be applied (Additional action)—
**ELSE** Continue routine quarterly sampling for the constituents that were sampled in the Landfill Pond.

#### 2.8.1.1 Data Evaluation

Analytical results for the treatment system effluent (PLFSYSEFF) are compared to the appropriate surface water standards listed in RFCA Attachment 5, Table 1. The following list details analytes that were greater than the applicable surface water standard during CY 2006, triggering monthly sampling:

- Phenenthrene
- Antimony (Sb) (total)
- Arsenic (As) (total)
- Barium (Ba) (total)
- Boron (Bo) (total)

- Cd (dissolved)
- Manganese (Mn)
- Selenium (Se)
- Ag (dissolved)
- Thallium (Tl) (total)

The following list details analytes that were greater than the applicable surface water standard for 3 consecutive months during CY 2006, triggering consultation and Landfill Pond sampling:

- As (total)
- Bo (total)
- Mn (total)

Contact records detailing the resolution for each of the above analytes have been generated based on consultation with the regulators. These contact records can be accessed on the Rocky Flats web page at the LM website (http://www.lm.doe.gov/land/sites/co/rocky_flats/rocky.htm).

### 2.8.2 Original Landfill

This surface water-monitoring objective is intended to determine the short- and long-term effectiveness of the OLF remedy as related to surface water. These requirements were initially identified in the *Final Interim Measure/Interim Remedial Action for the Original Landfill*, Appendix B: "Post-Accelerated Action Monitoring and Long-Term Surveillance and Monitoring Considerations" (DOE 2005a), and finalized in the *Final Landfill Monitoring and Maintenance Plan, Rocky Flats Environmental Technology Site, Original Landfill* (OLF M&M Plan; DOE 2006a), including institutional controls, inspection and maintenance, and environmental monitoring.

Details regarding surface water monitoring for the OLF can be found in the OLF M&M Plan. As part of OLF closure, surface water will be monitored at both upgradient and downgradient locations in Woman Creek (locations GS05 and GS59, respectively). Applicable surface water standards are listed in RFCA, Attachment 5, Table 1.

As detailed in the IMP, monitoring requirements will consist of quarterly monitoring until the current CERCLA 5-year review is completed in fall 2007. A validated exceedance of an effluent limit will trigger monthly monitoring for 3 consecutive months. Continued exceedances during the 3-month period will trigger consultation between the RFCA parties to determine whether a change in the remedy is required, additional parameters need to be analyzed, or a different sampling frequency is required.

OLF sampling locations, data collection protocols, and analyte suites are given in Table 2−48.

*Table 2−48. Sampling Locations for OLF*

| Location Code | Location Description | Routine Data Collection | Analytes |
|---|---|---|---|
| GS05 [upgradient] | Woman Creek at west fenceline | Quarterly grab samples | VOCs, isotopic uranium, total and dissolved metals, total mercury |
| GS59 [downgradient] | Woman Creek 800 feet downstream of the OLF | Quarterly grab samples | VOCs, isotopic uranium, total and dissolved metals, total mercury |

Notes: Flow is measured at 15-minute intervals as part of the Investigative monitoring objective; isotopic U, dissolved metals, and total metals are currently collected as continuous flow-paced composites using automated samplers, also as part of Investigative monitoring

Analytical methodologies and reporting limits, data reporting procedures, laboratory QA/QC procedures, and laboratory data validation and contractor validation procedures are conducted in accordance with EPA-approved methods. Samples are submitted to an EPA-approved analytical laboratory for the following analysis methods:

- SW-846 Method 8260B—VOCs
- SW-846 Method 6010B—Metals (total and dissolved)
- SW-846 Method 7470A—Mercury (total)
- Alpha Spectrometry—Isotopic U

This objective is intended to evaluate water quality in Woman Creek by monitoring both upstream and downstream of the OLF. Monitoring is intended to demonstrate compliance with surface water standards.

Generally, analytical data evaluation is performed quarterly as data become available. The surface water DQO decision rule for the OLF is as follows:

**IF** Quarterly mean concentrations at downstream location GS59 are greater than surface water standards listed in the RFCA, Attachment 5, Table 1,
**AND** Quarterly mean concentrations at downstream location GS59 are greater than quarterly mean concentrations at upstream location GS05—
**THEN** Sampling frequency will be increased to monthly for 3 consecutive months for the constituents that were greater than the surface water standards during quarterly sampling.

**IF** Quarterly mean concentrations for monthly sampling at downstream location GS59 are greater than surface water standards listed in the RFCA, Attachment 5, Table 1,
**AND** Quarterly mean concentrations for monthly sampling at downstream location GS59 are greater than quarterly mean concentrations for monthly sampling at upstream location GS05—
**THEN** Consult the RFCA parties to determine whether a change in the remedy is required, additional parameters need to be analyzed, or a different sampling frequency is required—
**ELSE** Discontinue monthly sampling.

#### 2.8.2.1 Data Evaluation

Analytical results for GS59 and GS05 are compared to the appropriate surface water standards listed in RFCA Attachment 5, Table 1. The following list details analytes that were greater than the applicable surface water standard during CY 2006, triggering monthly sampling:

- As (total)
- Tl (total)

Neither of the above analytes were greater than the applicable standard for three consecutive samples during CY 2006.

## 2.9 Point of Evaluation Monitoring

This monitoring objective deals with POE monitoring for adherence with the RFCA ALF. Responses to reportable values relative to action levels at POEs are different than the responses associated with contaminated runoff before it reaches Segment 5 or after it enters Segment 4. Monitoring upgradient of Segment 5 is designed to detect new contaminant sources upstream of the ponds. Downstream, Segment 4 is monitored at POCs to protect designated uses, ecology, and public health.

Past data collected during active closure resulted in reportable values for Pu, Am, and total U under the RFCA action level criteria at the designated POEs. Such reportable values have required source evaluation and the development of a mitigation plan, when appropriate. These reportable values have caused the Site to perform special monitoring tailored to the specific source evaluation and take action upstream of Segment 5 to protect Segment 5 from contaminant sources that caused the reportable values.

### 2.9.1 Data Types, Frequency, and Collection Protocols

The analytical decision inputs are those analytes specified as the Segment 5 AOIs per Table 2−49, as sampled at the POEs for Stream Segment 5. RFCA provides specific criteria for regulated contaminants for the main stream channels of Segment 5. In developing the IMP, the DQOs identified a subset of contaminants that are of sufficient interest to warrant monitoring under ALF.

Segment 5 includes North and South Walnut Creek downstream to the terminal ponds, and the SID downstream to Pond C-2. Monitoring is performed for Stream Segment 5 only as represented by POEs SW093, SW027, and GS10 (see Figure 2–149).

Sampling for AOIs at POEs is performed by collecting continuous flow-paced composite samples. The recommended monitoring design specified in the IMP is to take samples for CY 2006 as specified in Table 2−53 and Table 2−54. The intent is to take no less than one sample per quarter and no more than four composite samples per month from each of the three monitoring locations.

Table 2−54 presents the approximate location-specific number of samples per month based on recommendations by statisticians at Pacific Northwest National Laboratory that worked with the

DQO working group. There are both practical and statistical advantages to this sample allocation design. Averaging a larger number of samples is more expensive, but it protects the Site from regulatory action in response to a spurious, nonrepresentative monitoring result. With the final closure of the Site in October 2005, targeted sample collection has been somewhat reduced to account for smaller expected flow volumes.

There are secondary advantages to this monitoring plan. A larger number of samples allows for estimates of variability that can be used to refine the monitoring plan over time. The monitoring program specified in the IMP is a technically defensible approach that represents a compromise between a statistical design, a design based on professional judgment, and a design based on budgetary constraints. This design is expected to generate data that are representative of contaminant levels and loads.

*Table 2−49. RFCA POE AOIs*

| | | |
|---|---|---|
| **Radionuclides** | Total Pu-239,240 | Known carcinogen. Known past measurements have exceeded RFCA Action Levels. This provides reasonable cause to expect future measurements in excess of RFCA Action Levels. |
| | Total U-233,234, U-235, U-238 | Known renal toxicity. Past measurements provide reasonable cause to expect future measurements in excess of RFCA Action Levels. |
| | Total Am-241 | Known carcinogen. Known past measurements have exceeded RFCA Action Levels. This provides reasonable cause to expect future measurements in excess of RFCA Action Levels. |
| **Metals** | Total Be | Known to cause berylliosis in susceptible individuals when exposed by inhalation. May also cause contact dermatitis. Will be monitored as an indicator of releases from process and waste storage areas. |
| | Total Cr | Physiological and dermal toxicity. High level of regulatory concern due, in part to the chromic acid incident of 1989. Low levels can cause significant ecological damage. |
| | Dissolved Ag | Highly toxic to fish at low levels if chronic. State of Colorado has temporarily removed its stream standard for silver, while under study. The study has been completed, and the standard will be reinstated at the next triennial review of South Platte stream standards, if not before. Used at Rocky Flats only for photographic development. Routinely accepted by Publicly Owned Treatment Works as municipal waste, but discharge is regulated. May be removed from this list later, if data do not support concern. |
| | Dissolved Cd | Highly toxic to fish at low levels if chronic. Known human carcinogen (prostate cancer) and depletes physiologic calcium. Used at Rocky Flats in plating processes. Monitoring data for the Interceptor Trench System (ITS) and the proposed discharge of untreated ITS waters into Walnut Creek provide reasonable cause to expect future releases in excess of RFCA Action Levels. |
| | Hardness | Required to evaluate metals analyses, due to its effect on solubility of these metals. |
| **Real Time Monitoring** | Flow | Required to detect flow events, pace automated samplers, evaluate contaminant loads, and plan pond operations and discharges. Affects nearly every decision rule, and is the most commonly discussed attribute of Rocky Flats surface waters. |

### 2.9.2 CY 2006 Monitoring Scope

*Table 2−50. POE Monitoring Locations*

| Location Code | Location | Primary Flow Measurement Device | Telemetry |
|---|---|---|---|
| GS10 | South Walnut Creek upstream from the Pond B-1 Bypass | 9-inch Parshall Flume; weir insert installed February 1, 2006 | Yes |
| SW027 | SID just upstream of Pond C-2 | Dual Parallel 120° V-Notch Weirs | Yes |
| SW093 | North Walnut Creek 1,300 feet upstream from the Pond A-1 Bypass | 36-inch Suppressed Rectangular Sharp-Crested Weir; 3-foot H-Flume installed May 29, 2003 | Yes |

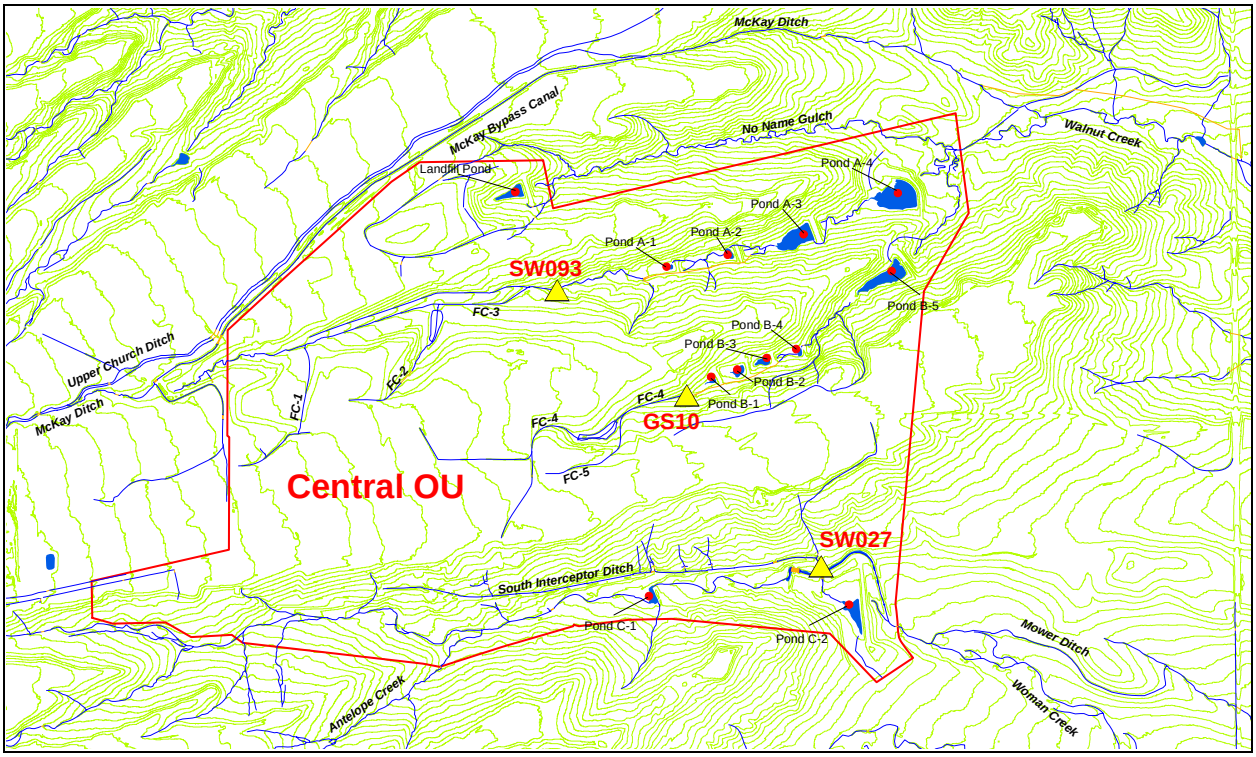



*Figure 2–149. CY 2006 Point of Evaluation Monitoring Locations*

*Table 2−51. POE Field Data Collection: Parameters and Frequency*

| Location Code | Flow |
|---|---|
| GS10 | 15-min continuous |
| SW027 | 15-min continuous |
| SW093 | 15-min continuous |

Note: All locations collect 5- and 15-minute flow data.

*Table 2−52. POE Sample Collection Protocols*

| Location Code | Frequency[a]: CY 2006 Actual (Target) | Type[b] |
|---|---|---|
| GS10 | 17 (21 per year) | Continuous flow-paced composites |
| SW027 | 0 (10 per year) | Continuous flow-paced composites |
| SW093 | 16 (21 per year) | Continuous flow-paced composites |

[a]Sample frequency distribution during the year for SW093, GS10, and SW027 (POEs) is given in Table 2−54.
[b]Sample types are defined in Appendix B.

*Table 2−53. POE Analytical Targets (Analyses per Year)*

| Location Code | Dissolved Ag, Total Be, Dissolved Cd, Total Cr CY 2006 Actual (Target) | Hardness CY 2006 Actual (Target) | Pu, U, and Am CY 2006 Actual (Target) |
|---|---|---|---|
| GS10 | 17 (21) | 17 (21) | 17 (21) |
| SW027 | 0 (10) | 0 (10) | 0 (10) |
| SW093 | 16 (21) | 16 (21) | 16 (21) |

*Table 2−54. POE Target Sample Distribution*

| Month | SW093: CY 2006 Actual (Target) | GS10: CY 2006 Actual (Target) | SW027: CY 2006 Actual (Target) | Totals: CY 2006 Actual (Target) |
|---|---|---|---|---|
| Jan 2006 | 1 (1) | 1 (1) | 0 (0) | 2 (2) |
| Feb 2006 | 1 (1) | 1 (0) | 0 (0) | 2 (1) |
| Mar 2006 | 2 (2) | 1 (2) | 0 (1) | 3 (5) |
| Apr 2006 | 2 (4) | 1 (4) | 0 (3) | 3 (11) |
| May 2006 | 2 (3) | 2 (3) | 0 (2) | 4 (8) |
| Jun 2006 | 0 (2) | 2 (2) | 0 (1) | 2 (5) |
| Jul 2006 | 2 (1) | 3 (2) | 0 (0) | 5 (3) |
| Aug 2006 | 1 (2) | 2 (2) | 0 (1) | 3 (5) |
| Sep 2006 | 0 (1) | 0 (1) | 0 (0) | 0 (2) |
| Oct 2006 | 2 (2) | 3 (2) | 0 (1) | 5 (5) |
| Nov 2006 | 2 (1) | 1 (1) | 0 (1) | 3 (3) |
| Dec 2006 | 1 (1) | 0 (1) | 0 (0) | 1 (2) |
| **Totals** | **16 (21)** | **17 (21)** | **0 (10)** | **33 (52)** |

### 2.9.3 Data Evaluation

Sampling for AOIs at POEs is performed by collecting continuous flow-paced composite samples. The AOIs are evaluated using 12-month rolling averages[25] or the 85th percentile of

[25] The 12-month rolling average for the last day of a particular month is calculated as a volume-weighted average of a "window" of time containing the previous 12 months. Each 12-month "window" includes daily discharge volumes (measured at the location with a flow meter) and daily activities (from the sample carboy in place at the end of that day). Therefore, there are twelve 12-month rolling averages for a given calendar year. Days with no flow or no analytical result, either due to failed laboratory analysis, Non-Sufficient Quantity (NSQ) for analysis, or excessive DER, are not included. When no discharge has occurred in the last 12 months, no 12-month rolling average is reported.

30-day moving averages[26] for the preceding calendar year, as specified in the IMP. Total Pu, Am, and U are evaluated using volume-weighted 12-month rolling averages. Total Be and Cr, and dissolved Ag and Cd are evaluated using the 85th percentile of 30-day moving averages for the preceding calendar year.

Generally, analytical data evaluation is performed as preliminary data become available. If an initial qualitative screening indicates that an analytical result is higher than the action level for a particular AOI, then the compliance values are calculated immediately upon receipt of the preliminary result. The desired evaluation frequency is semimonthly, within 1 week of the 15th and last day of any given month. The DQO decision rule is:

**IF** The volume-weighted 12-month rolling average for any radionuclide AOI, as represented by samples from the specified RFCA POEs (GS10, SW027, and SW093), exceeds the appropriate RFCA action level (Table 2−56)—

**THEN** The Site must notify EPA and the Colorado Department of Public Health and Environment (CDPHE), evaluate for source location, and implement mitigating action[27] if appropriate.[28]

**IF** The 85th percentile of the volume-weighted 30-day moving averages of a given calendar year for any metals AOI, as represented by samples from the specified RFCA POEs (GS10, SW027, and SW093) exceeds the appropriate RFCA action level—

**THEN** The Site must notify EPA and CDPHE, evaluate for source location, and implement mitigating action[27] if appropriate.[28]

*Table 2−55. POE Monitoring Analytical Data Evaluation*

| Location Code | Evaluation Type[a] |
|---|---|
| GS10 | Radionuclides: 12-Month Rolling Averages; Loading Analysis<br>Metals: 85th Percentile of 30-Day Averages for Calendar Year |
| SW027 | Radionuclides: 12-Month Rolling Averages; Loading Analysis<br>Metals: 85th Percentile of 30-Day Averages for Calendar Year |
| SW093 | Radionuclides: 12-Month Rolling Averages; Loading Analysis<br>Metals: 85th Percentile of 30-Day Averages for Calendar Year |

[a]Details on the evaluation of analytical results are given in Appendix B.1. Loading analysis for POEs is given in Section 2.4.

[26] The 30-day average for a particular day is calculated as a volume-weighted average of a 'window' of time containing the previous 30-days which had flow. Each day has its own discharge volume (measured at the location with a flow meter) and concentration (analytical result from the sample in place at the end of that day). Therefore, there are 365 30-day moving average values for a location that flows all year (366 values in a leap year). At locations that have intermittent flows, 30-day averages are reported as averages of the previous 30 days of greater than zero flow. Days with no flow or no analytical result, either due to failed laboratory analysis, NSQ for analysis, or excessive RPD, are not included. When no discharge has occurred in the last 30 days, no 30-day average average is reported.

[27] Mitigating action may include, but not be limited to, the following examples: (1) immediate action to halt a discharge or contain a spill; or (2) use of upstream monitoring data to seek out and mitigate upstream contaminant sources.

[28] RFCA may actually specify consequences for an exceedance of any action level (not just those for AOIs) at any location within the segment (not just at the consensus monitoring points). This decision rule presents the consensus decision rule that drives our monitoring activities. It is an implementation, rather than a reiteration, of RFCA.

*Table 2−56. POE Monitoring RFCA Action Levels*

| Analyte | Action Level |
|---|---|
| Am-241 | 0.15 pCi/L |
| Pu-239,240 | 0.15 pCi/L |
| Total Uranium | 10 pCi/L (GS10 and SW093); 11 pCi/L (SW027) |
| Total Be | 4 µg/L |
| Dissolved Cd | 1.5 µg/L |
| Total Cr | 50 µg/L |
| Dissolved Ag | 0.6 µg/L |

Note: The above action levels only apply to calculated compliance values (see Table 2−55)

The following sections include summary tables and plots showing the applicable compliance values and annual volume-weighted averages for the POE analytes.

The following evaluations include all results that were not rejected through the verification and validation process. Data are generally presented to decimal places as reported by the laboratories. Accuracy should not be inferred; minimum detectable concentrations/activities and analytical error are often greater than the precision presented. When a sample has a corresponding field duplicate, the value used in calculations is the arithmetic average of the 'real' and the 'duplicate' values. When a sample has multiple 'real' analyses (Site requested 'reruns'), the value used in calculations is the arithmetic average of the multiple 'real' analyses.[29] Total U is calculated by summing the activities for the analyzed isotopes (U-233,234 + U-235 + U-238).

The methods used for the evaluations are given in Appendix B.1.

#### 2.9.3.1 Location GS10

Monitoring location GS10 is located on South Walnut Creek just upstream of the B-Series Ponds. Figure 2–23 shows the drainage area for GS10. The central portion of the COU contributes flow to GS10 through FC-4 and FC-5.

Table 2−57 shows that many of the annual average Pu and Am activities were greater than 0.15 pCi/L during active Site closure, with measurable increases in CY 2004−2005. Source evaluation for POE GS10 identified runoff from the 903 Pad area as the primary contributor of Pu and Am load in CY 2004. Source evaluation in CY 2005 for POE GS10 identified solids transport resulting from the construction of FC-4 and closure actions in the 700 Area as the primary contributor of Pu and Am load in CY 2005. With the completion of the FCs, implementation of enhanced erosion controls, revegetation, and soil stabilization, transport of Pu and Am approaching the action level has been virtually eliminated.

Prior to the Site's declaration of physical completion on October 13, 2005, demonstration of compliance for Pu-239,240 and Am-241 concentrations at RFCA POEs used calculated 30-day average values. Subsequent to the declaration of physical completion, compliance for Pu and Am

[29] Averaging of real/duplicate and first analysis/reanalsis data pairs is subject to the DER and RPD criteria as appropriate.

at POEs is demonstrated using the 12-month rolling average calculation for the last day of each month, per the 2006 IMP.

Based on results using the 12-month rolling average method (Figure 2–150), the Site notified the regulators that reportable Pu and Am values had been observed at GS10 in CY 2005. This notification was triggered by the transition from the 30-day to the 12-month reporting window, and was provided for information only. All of the analytical results causing the reportable 12-month rolling averages occurred prior to June 11, 2005. Since source evaluation letters/reports have been previously completed for those results, no additional action is warranted at this time. Pu and Am were no longer reportable as of February 28, 2006, and April 30, 2006, respectively.

Figure 2–151 shows that the 12-month rolling averages for total U required reporting during CY 2006. A source evaluation update for total U at GS10 is given below.

*Table 2−57. Annual Volume-Weighted Average Radionuclide Activities at GS10 in CY 1997−2006*

| Calendar Year | Volume-Weighted Average Activity (pCi/L) | | |
|---|---|---|---|
| | Am-241 | Pu-239,240 | Total Uranium |
| 1997 | 0.266 | 0.260 | 2.78 |
| 1998 | 0.109 | 0.158 | 3.06 |
| 1999 | 0.274 | 0.139 | 2.49 |
| 2000 | 0.421 | 0.195 | 2.23 |
| 2001 | 0.075 | 0.080 | 2.91 |
| 2002 | 0.087 | 0.061 | 2.88 |
| 2003 | 0.117 | 0.113 | 2.68 |
| 2004 | 0.136 | 0.314 | 2.48 |
| 2005 | 0.185 | 0.238 | 8.27 |
| 2006 | 0.010 | 0.014 | 13.4 |
| Total (CY 1997−2006) | 0.191 | 0.174 | 3.18 |

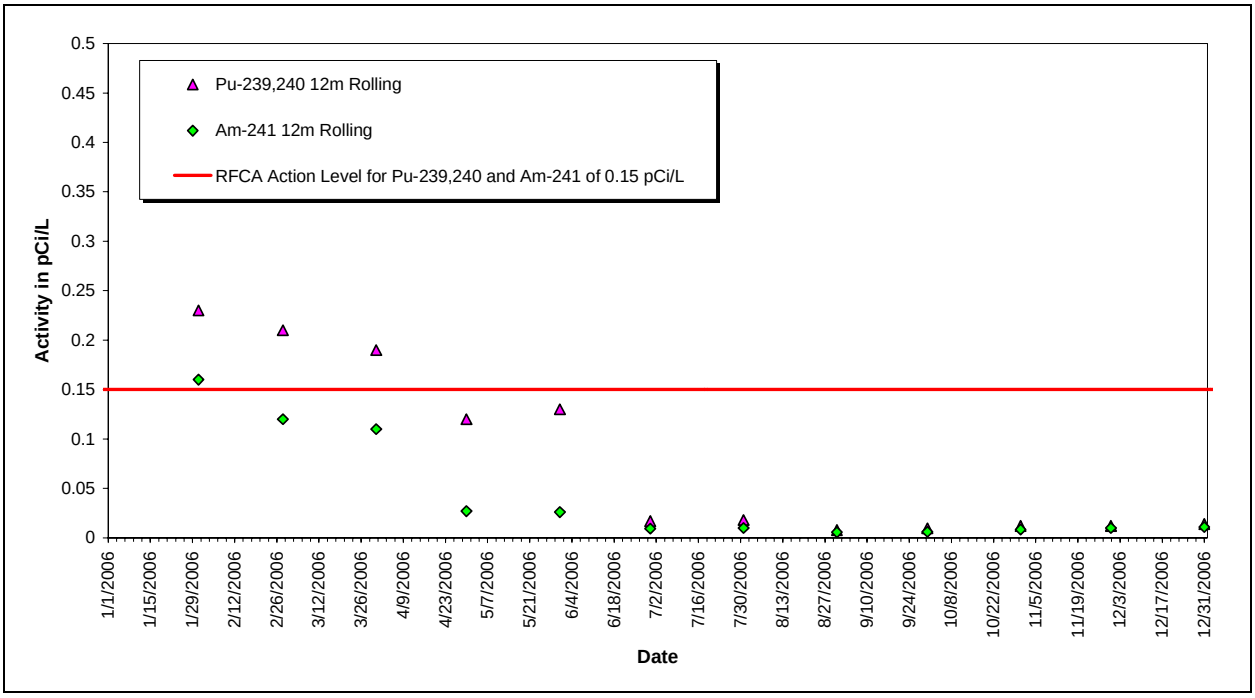



*Figure 2–150. Pu and Am Compliance Values at GS10: CY 2006*

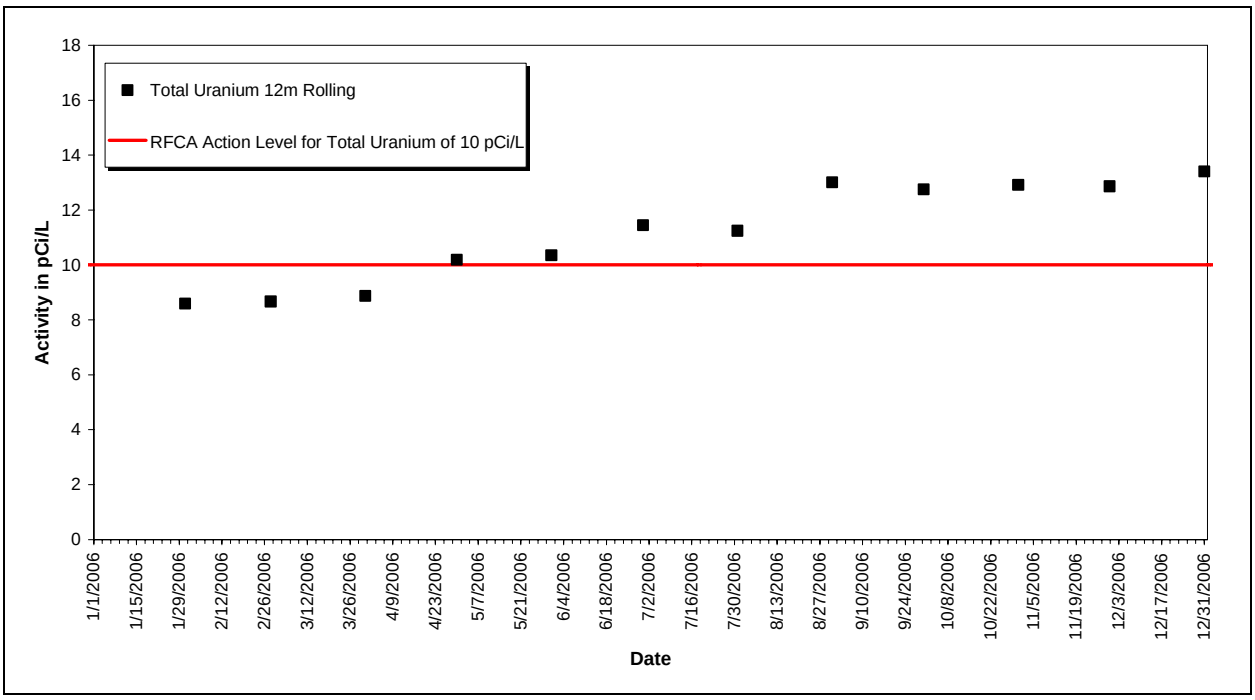



*Figure 2–151. Total Uranium Compliance Values at GS10: CY 2006*

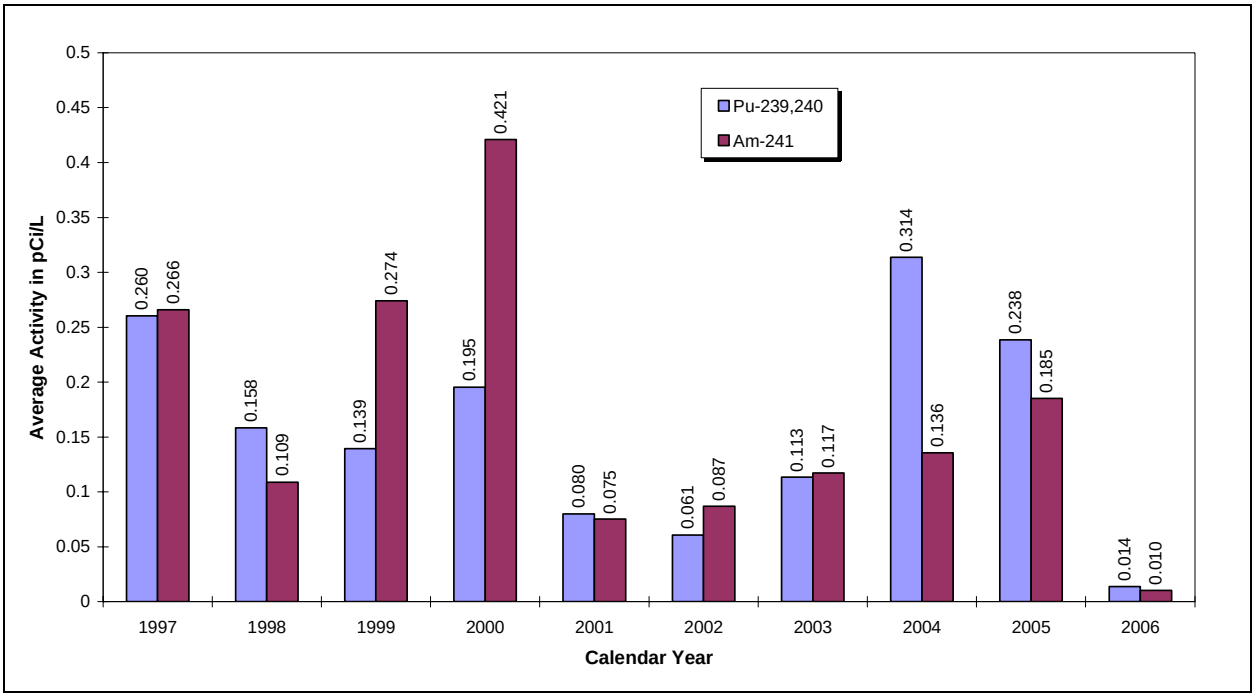



*Figure 2–152. Annual Volume-Weighted Average Pu and Am Activities at GS10: CY 1997−2006*

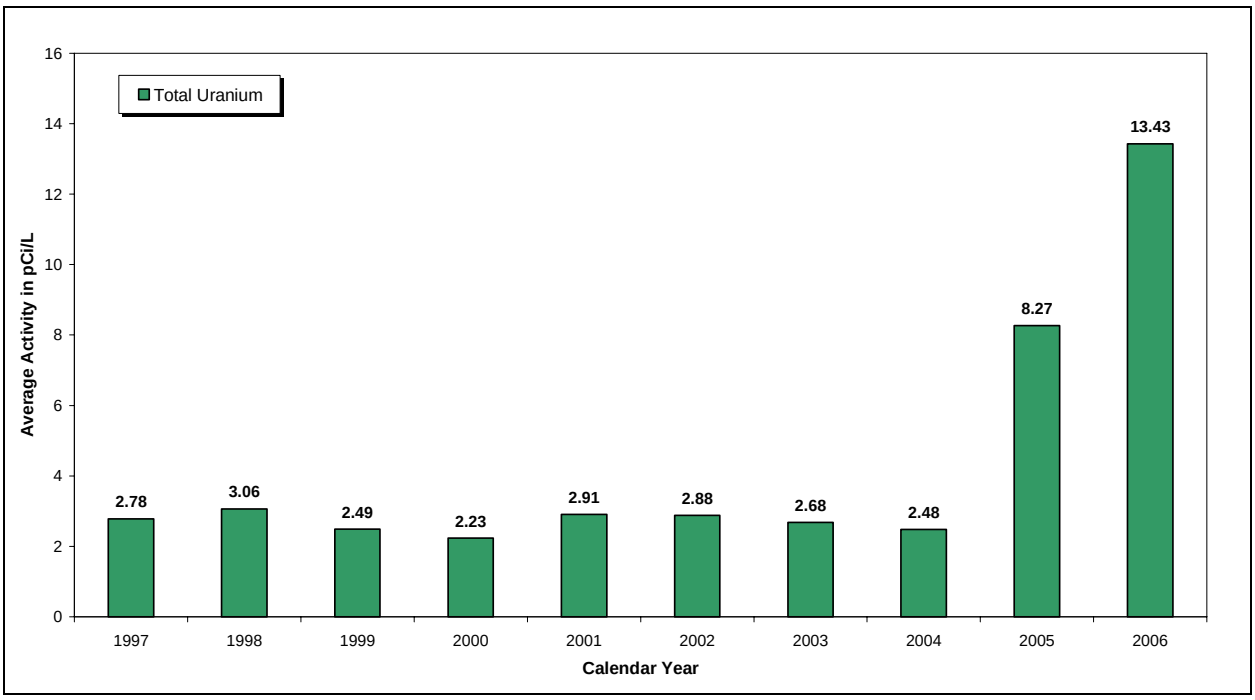



*Figure 2–153. Annual Volume-Weighted Average Total Uranium Activities at GS10: CY 1997−2006*

Table 2−58 shows that all of the annual average metals concentrations were less than the action level. Additionally, the long-term metals averages (CY 1997−2006) were less than the action levels.

Figure 2–154 shows that none of the compliance values were reportable for Be, Cd, or Ag during CY 2006.

*Table 2−58. Annual Volume-Weighted Average Hardness and Metals Concentrations at GS10 in CY 1997−2006*

| Calendar Year | Volume-Weighted Average Concentration (µg/L) | | | | |
|---|---|---|---|---|---|
| | Hardness [mg/L] | Total Be | Dissolved Cd | Total Cr | Dissolved Ag |
| 1997 | 138 | 0.50 | 0.09 | 4.05 | 0.11 |
| 1998 | 162 | 0.15 | 0.13 | 3.32 | 0.20 |
| 1999 | 139 | 0.16 | 0.07 | 4.08 | 0.15 |
| 2000 | 181 | 0.21 | 0.11 | 3.65 | 0.11 |
| 2001 | 222 | 0.32 | 0.11 | 5.95 | 0.11 |
| 2002 | 277 | 0.24 | 0.09 | 5.38 | 0.10 |
| 2003 | 228 | 0.22 | 0.10 | 6.91 | 0.12 |
| 2004 | 227 | 0.60 | 0.10 | 13.15 | 0.13 |
| 2005 | 401 | 0.88 | 0.06 | 17.49 | 0.15 |
| 2006 | 604 | 0.50 | 0.05 | 0.74 | 0.10 |
| Total (CY 1997−2006) | 207 | 0.34 | 0.10 | 6.38 | 0.13 |

Note: Hardness units mg/L.

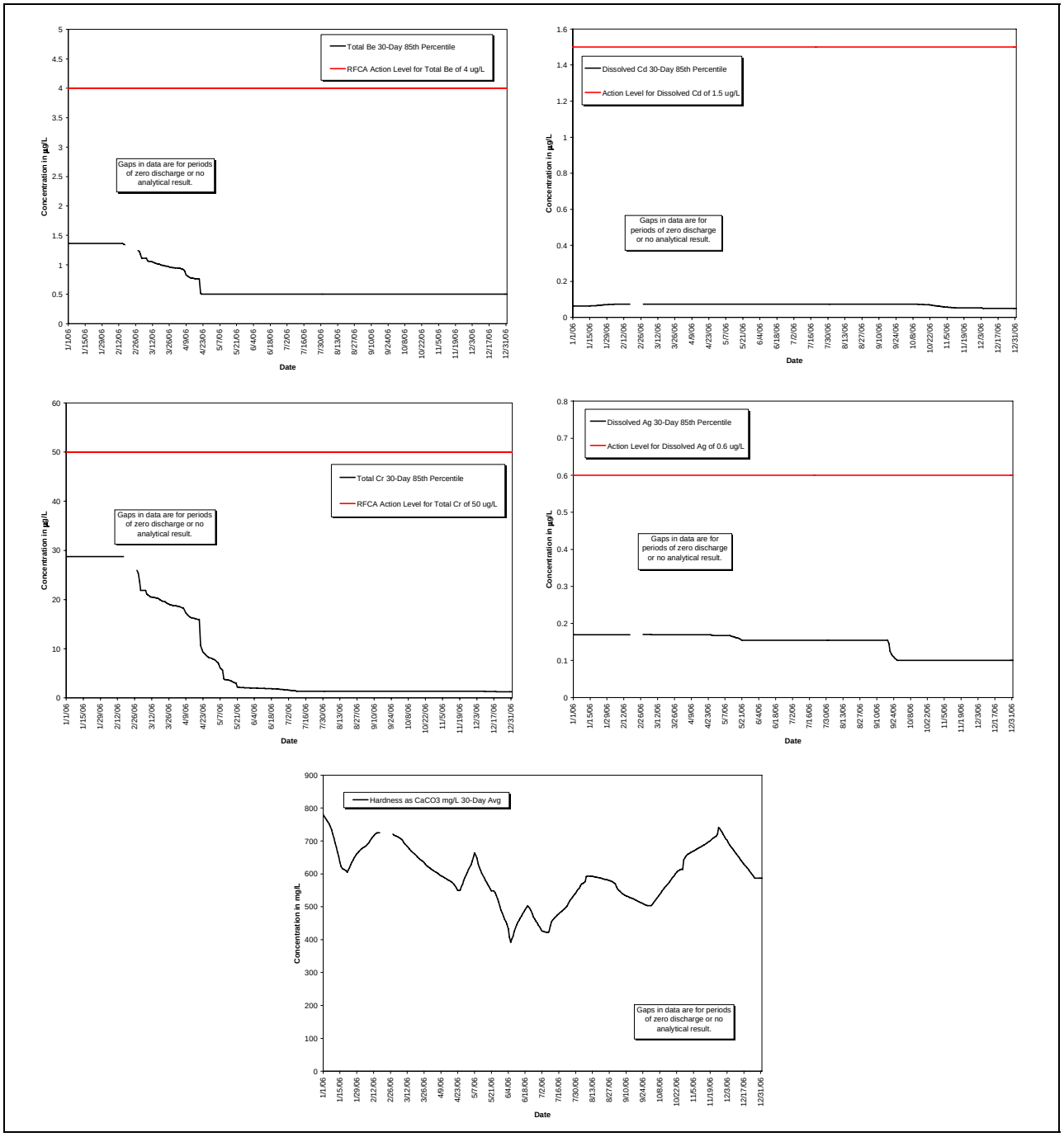



*Figure 2–154. Metals Compliance Values and Hardness Concentrations at GS10: CY 2006*

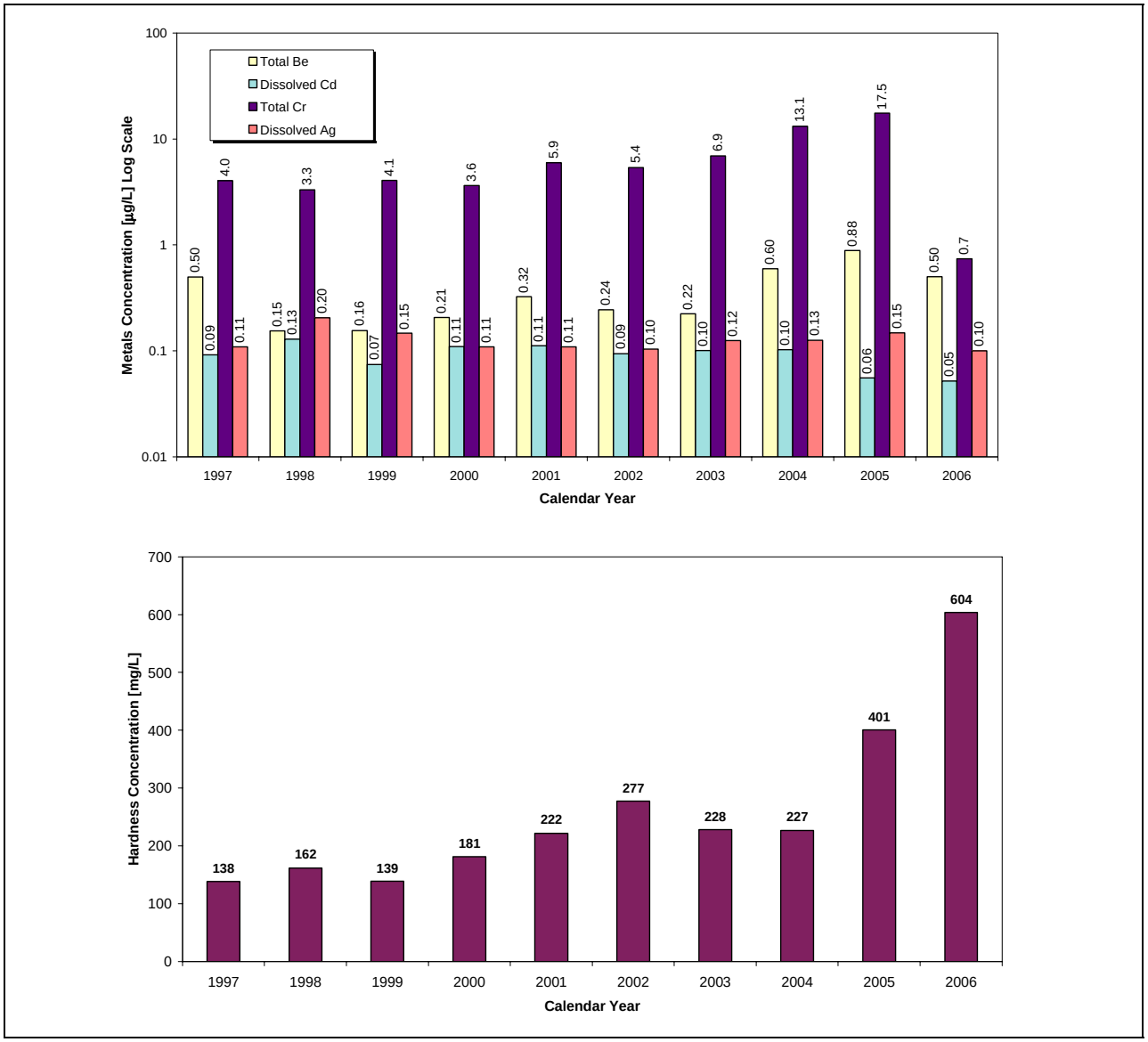



*Figure 2–155. Annual Volume-Weighted Average Metals and Hardness Concentrations at GS10: CY 1997−2006*

### *Summary of Recent Reportable 12-Month Rolling Total Uranium Values at RFCA Point of Evaluation GS10*

This section addresses the Site's July 13, 2006, notification of observed reportable concentrations of uranium in surface water at RFCA POE surface water monitoring location GS10, which is located in South Walnut Creek upstream of Pond B-1 in the Walnut Creek basin (Figure 2–149). Reportable U levels continue to be observed at GS10. The Site continues to evaluate, in coordination with the regulators, the measured U concentrations at GS10.

DOE first became aware of the reportable 12-month rolling averages when all U sample results were validated on July 6, 2006. To meet the RFCA commitment, DOE transmitted notification to EPA and CDPHE within the 15-day reporting period, which ended July 21, 2006. In addition,

RFCA requires that DOE, within 30 days of gaining knowledge of the reportable results, submit to EPA and CDPHE a source evaluation plan addressing reportable values. The July 13, 2006, notification letter served as both the comprehensive notice and the plan for that source evaluation, based on consideration for other evaluative work already performed in this drainage.

The characteristics of the current reportable period for U at GS10 are consistent with those for the previous reportable period during the summer of 2005. DOE provided notice for that reportable period on August 16, 2005 (05-DOE-00522).

The calculated 12-month rolling average for total U triggered the reporting requirements under RFCA Attachment 5, Section 2.4 (B) for April 30 through December 31, 2006 (for details, see Table 2−59). All data used in the calculation of the 12-month rolling average have been validated. The end of the reportable period will be determined by subsequent data. Recent analytical results are listed in Table 2−60.

*Table 2−59. Reportable 12-Month Rolling Average Values for RFCA POE Monitoring Location GS10*

| Analyte | Dates of Reportable Values | Range of 12-Month Rolling Average Values (pCi/L) |
|---|---|---|
| Total Uranium | 4/30/06−to be determined | 10.19−13.41 |

The RFCA action level for total U in Walnut Creek is 10 pCi/L

*Table 2−60. Recent Analytical Results for Composite Samples Collected at GS10*

| Composite Sample Start Date | Total Uranium Analytical Result (pCi/L) |
|---|---|
| 7/3/2006 | 8.47 |
| 7/10/2006 | 10.44 |
| 7/27/2006 | 10.41 |
| 8/10/2006 | 9.82 |
| 8/30/2006 | 5.74 |
| 10/2/2006 | 8.66 |
| 10/24/2006 | 11.71 |
| 10/28/2006 | 14.17 |
| 11/27/2006 | 16.94 |

This evaluation for South Walnut Creek monitoring station GS10 covers data received through March 12, 2007. Laboratory analyses for two composite samples collected for the periods January 10−February 8, 2007, and February 8−March 2, 2007, have not been completed. The composite sample, started on March 2, 2007, is still in progress. The following are included in this assessment:

- Evaluation of ongoing automated surface water monitoring at GS10;
- Estimation of U loads at GS10; and
- Evaluation of water-quality trends and correlations at GS10.

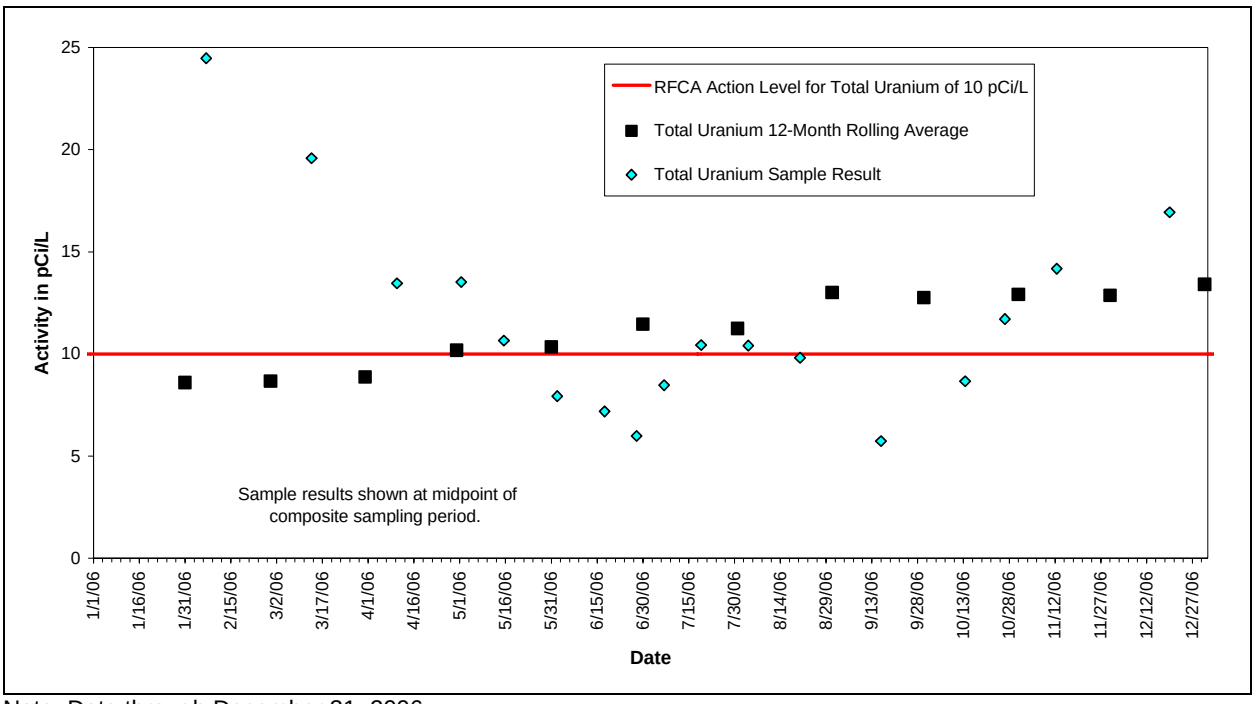
## Downstream Water Quality Monitoring

Water flowing through GS10 also passes through the lower B-Series Ponds (Ponds B-4 and B-5) and South Walnut Creek before leaving the Site. RFCA POCs GS08 (Pond B-5 outlet) and GS03 (Walnut Creek at Indiana Street) again monitor this water during Pond B-5 discharges.

Pond B-5 was predischarge sampled on February 28, 2007. Total U concentration for that sample was 7.82 pCi/L. Pond B-5 was direct-discharged through the outlet to South Walnut Creek through POC GS08 starting on March 1, 2007, and ending on March 13, 2007. During the discharge period, six composite samples were collected at both POC GS08 and POC GS03.

## GS10 Monitoring Results

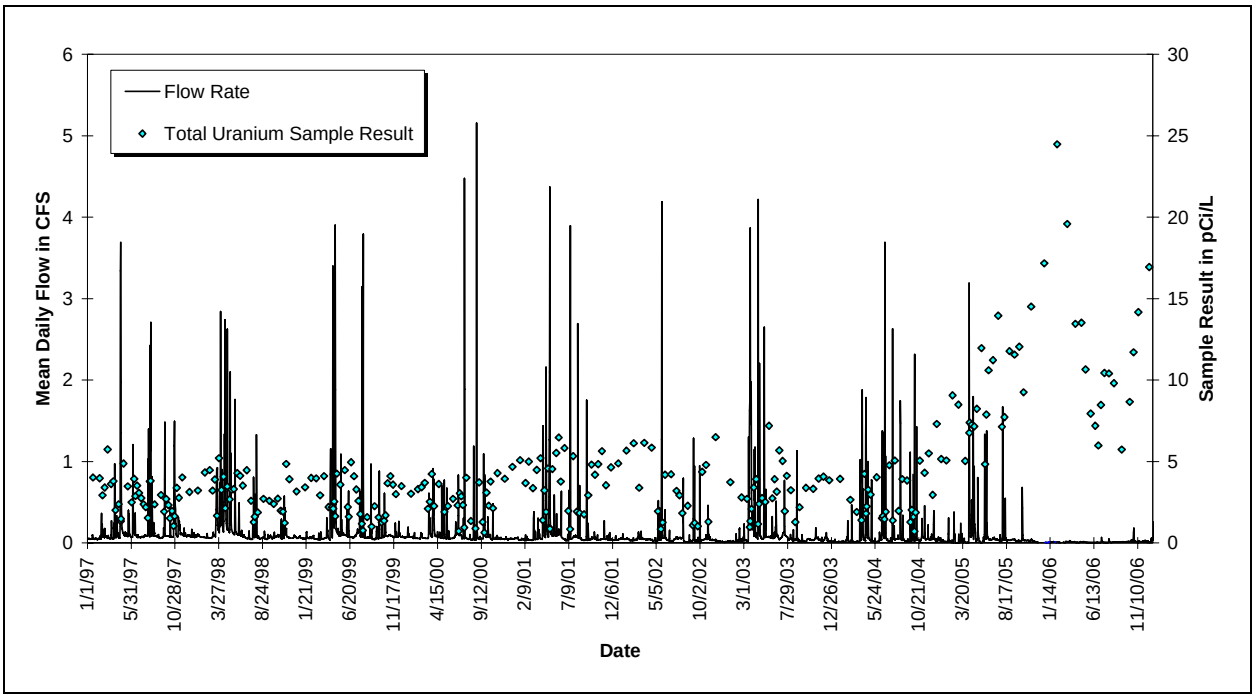
As specified in the IMP, the Site currently evaluates 12-month rolling average values for selected radionuclides at POE surface water monitoring locations. Prior to the Site declaration of physical completion (October 13, 2005), demonstration of compliance for total U concentrations at RFCA POEs used calculated 30-day average values. Subsequent to the declaration of physical completion, compliance for total U at POEs is demonstrated using the agreed upon 12-month rolling average calculation for the last day of each month. Results for recent 12-month rolling average values using available data at GS10 are summarized in Table 2−59. Figure 2–156 shows the calculated compliance values and the individual sample results at GS10 for the previous calendar year period.




Note: Data through December 31, 2006

*Figure 2–156. POE Monitoring Station GS10: Compliance Values and Individual Sample Results for Total Uranium (January 1, 2006−December 31, 2006)*

All analytical results for the composite samples collected during the period of reportable values have been validated. A review of historical GS10 monitoring data shows that these results are measurably higher than those for previous years (Figure 2–157). More recent U results suggest a possible return to near previously observed levels. The significant reduction in runoff following Site closure can also be clearly seen in Figure 2–157.




Note: Data through December 31, 2006

*Figure 2–157. POE Monitoring Station GS10: Hydrograph and Individual Sample Results for Total Uranium (January 1, 1997−December 31, 2006)*

## Data Summary and Analysis

The following data evaluation for GS10 includes all surface water data available as of March 12, 2007. Monitoring data were extracted from the former Soil and Water Database (SWD) or the current Site Environmental Evaluation for Projects (SEEPro) database. The following list describes the environmental data compilation process:

- Individual sample result values are calculated as arithmetic averages of real and field duplicate results when both results are from the same sampling event;[30]
- When available, Site-requested laboratory reruns are averaged with initial runs for the same sampling event;
- Laboratory duplicate and replicate QC results are not used;
- When negative values for actinide measurement are returned from the laboratories due to blank correction, 0.0 pCi/L is used in the calculations;

[30] Radionuclide data pairs are averaged when the DER is less than 1.5; sample pairs with DER ratios in excess of 1.5 are not used due to inferred lack of confidence in either result.

- Only total radionuclide measurements are used; and
- Data that did not pass validation (rejected data) are not used.

***Verification and Validation of Surface Water Analytical Results***

Prior to Site closure, all surface water isotopic data are either verified or validated, based on criteria determined by the Kaiser-Hill Analytical Services Division, or at the special request of the requestor. Approximately 75 percent of all isotopic data are verified and the remaining 25 percent are validated. Validation is typically determined randomly for each subcontracted laboratory, based on the specific analytical suites. This random validation selection may or may not routinely include POE or POC locations. However, when reportable values are observed, all analytical results used in the calculations receive formal validation.

Under current LM procedures, all data are validated prior to being loaded to the SEEPro database.

***High Resolution Inductively Coupled Mass Spectrometry (HR ICP/MS) and Thermal Ionization Mass Spectrometry (TIMS) Analyses***

Prior to Site closure, ground water and surface water samples from select locations were sent to LANL for HR ICP/MS and/or TIMS analyses. These analytical methods measure mass ratios of four U isotopes (masses 234, 235, 236, and 238). Isotopic ratios provide a signature that indicates whether and the extent to which the source of U is natural or anthropogenic (man-made).

In August 2005, South Walnut Creek surface water samples from SW056, SW141, and GS10, and ground water samples from upgradient wells (91305, 99305, 91203, and 99405) were evaluated using HR ICP/MS and TIMS. The results indicate that, although concentrations of U vary widely, all the ground water and surface water locations produce water samples with a predominantly natural U isotopic signature. Location GS10, however, displayed a higher percentage of anthropogenic U than the other locations. Concentrations of U in ground water samples collected in August 2005 from wells located upstream of GS10 vary from less than 5 micrograms per liter (μg/L) at well 91203 (with a 93.4 percent natural U isotopic signature) to nearly 400 μg/L at well 99405 (with an isotopic signature that is 99.9 percent natural U; a previous sample from the original well at this location, 99401, produced a sample with a concentration of just over 650 μg/L U that was 100 percent natural).

The results of all the HR ICP/MS and TIMS analyses are summarized in a report titled "Quantitative Evaluation of Mixture Components in RFETS Uranium Isotopic Analyses: Development & Verification/Validation of Calculations using an Excel Spreadsheet" by Dr. David R. Janecky, LANL (March 2006; included as Attachment 3 to Section 8 of the Remedial Investigation/Feasibility Study published in June 2006). This report provides a summary of the HR ICP/MS and TIMS results and calculations of U isotopic mixtures (mixtures between natural and anthropogenic [enriched and depleted] U). Dr. Janecky's analysis concludes that the U at GS10 is dominated by natural U, with a lesser amount of depleted and minimal enriched U. An earlier sample analyzed by LANL, collected in May 2002, shows a generally similar isotopic signature, although the relative fraction of anthropogenic U is smaller as shown in Table 2−61.

*Table 2−61. Uranium Concentrations and Isotopic Signatures from Samples Collected at GS10 as Reported by LANL*

| Date | Concentration, µg/L | % Depleted | % Enriched | % Natural |
|---|---|---|---|---|
| 5/1/2002 | 9.6 | 22.1 | 0.04 | 77.8 |
| 8/11/2005 | 13.2 | 36.2 | 0.10 | 63.7 |

Source: Data are from RI/FS Section 8, Attachment 3, and have been normalized to 100 percent.

The samples from GS10 summarized in Table 2−61 illustrate the isotopic variability of the mixture of direct runoff and ground water that contributes to surface water flow at this location. Over longer periods, this variability may have a greater influence on the characteristics of the U in surface water, both concentration and signature. To fully understand this variability, additional U data as they relate to the appropriate water-quality action level would need to be evaluated.

### *Total Uranium at GS10: Data Summary*

Figure 2–158 shows the volume-weighted average annual activity-concentrations (concentration in surface water expressed as activity per unit volume) for total U at GS10 during CY 1997−2006. A measurable increase in concentration is noted starting in 2005.

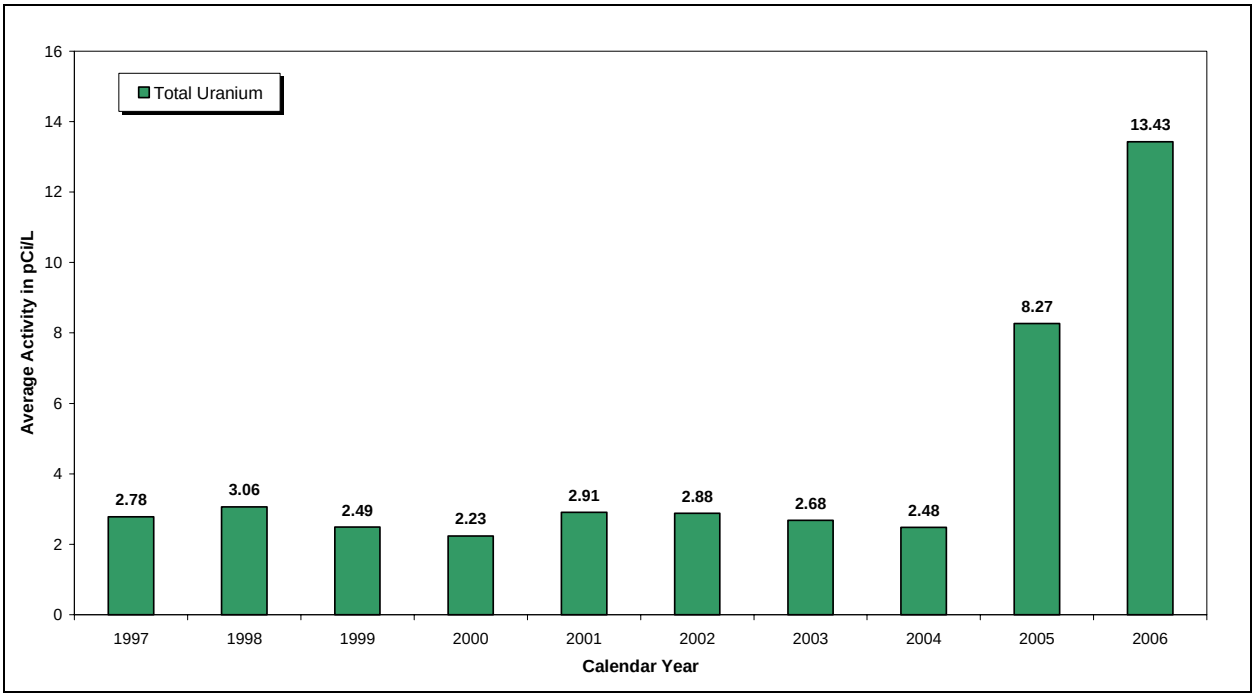



*Figure 2–158. Average Annual Total Uranium Concentrations at GS10: 1997−2006*

Annual total U loads (mass) for GS10 in grams are plotted in Figure 2–159 to show long-term loading at GS10. For 1997−2006, the activity-concentration for each flow-paced composite sample is multiplied by the associated discharge volume to get pCi, then converted to grams and totaled annually. Although reportable compliance values were observed during the 2005−2006

period, and concentrations in Figure 2–158 show a measurable increase, the loads for 2005−2006 are within historical ranges, and measurably lower in CY 2006. This further suggests that the recently observed increased U concentrations at GS10 may be a result of changing hydrologic conditions, and not significant increases in the quantity of U reaching the creek.

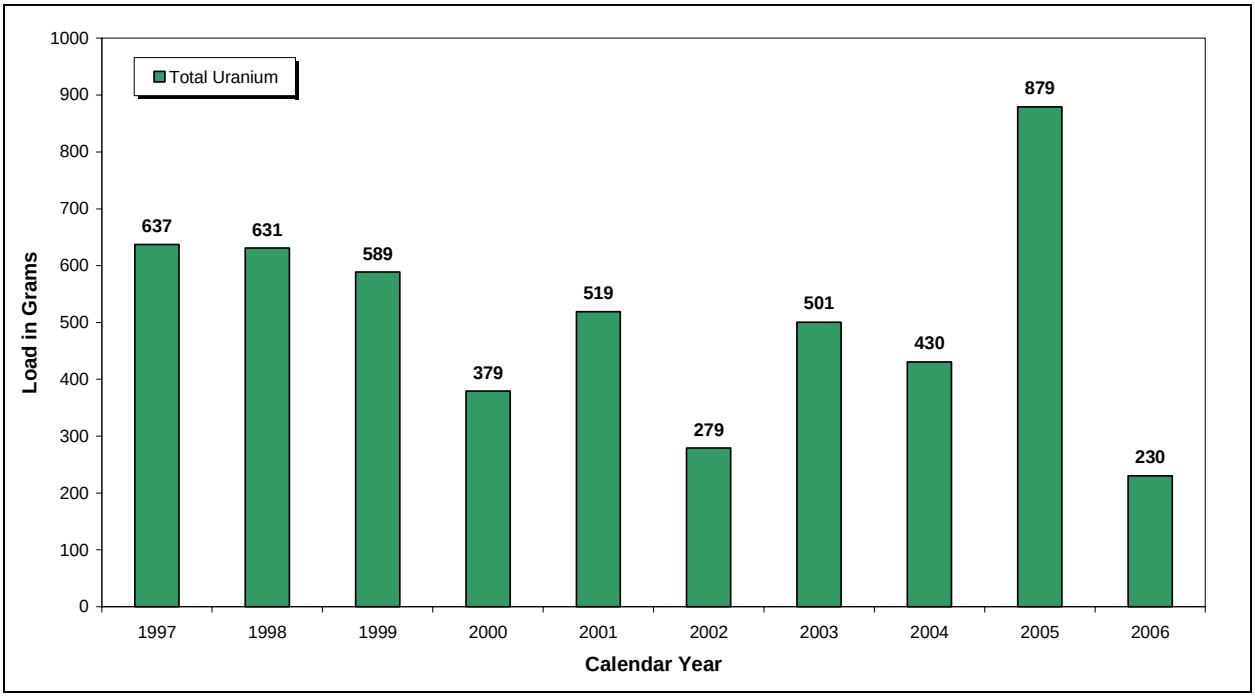



*Figure 2–159. Annual Total Uranium Loads at GS10: 1997−2006*

Figure 2–160 shows that the higher U concentrations are associated with lower flow rates, during periods of extended baseflow sustained by ground water contributions.[31] As the area of impervious surfaces in the GS10 drainage was reduced by Site closure (i.e., removal of buildings, asphalt, and concrete), direct runoff to GS10 was also reduced. Similarly, removal of Site infrastructure likely resulted in reduced baseflow contributions from domestic and sanitary water leakage.[32] Therefore, ground water contributions to the creek over the same period comprised an increasing portion of the flows monitored at GS10. Ground water data from monitoring wells located near South Walnut Creek show naturally occurring U in concentrations that are considerably higher than the surface water action level. Without the attenuation of U from ground water sources by direct runoff and infrastructure leakage, increases in surface water U concentrations would be expected. More recent U data at GS10 show a noticeable decrease (Figure 2–156 and Figure 2–157). At this time it is unclear if this represents a seasonal variation of U in surface water (as has been observed at other locations at the Site), or the return of the hydrologic conditions in South Walnut Creek to a state of equilibrium following Site closure.[33]

[31] These ground water contributions occur as localized or distributed seeps to the streambed.
[32] Leaks from domestic and sanitary lines are presumed to have lower U concentrations than natural ground water sources.
[33] As a result of Site closure, increased infiltration and the use of substantial quantities of dust suppression water can reasonably be assumed to have affected, at least temporarily, the rate at which ground water is reaching the creek.

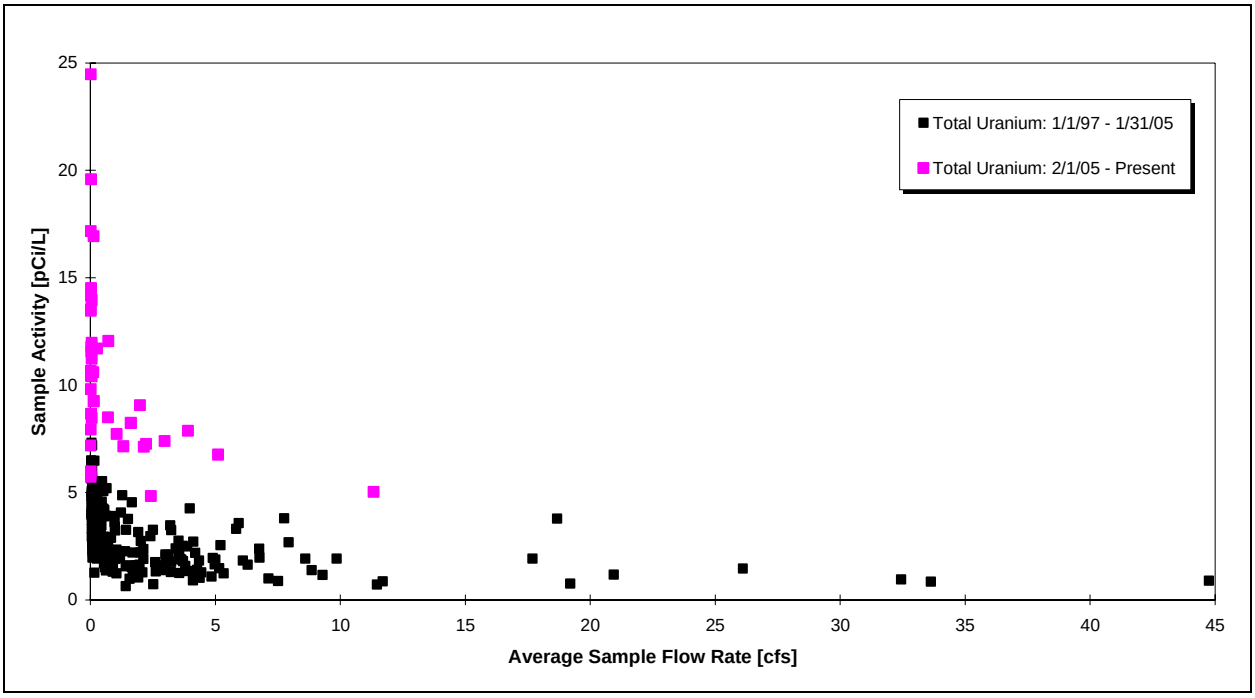



*Figure 2–160. Variation of Total Uranium Concentration with Flow Rate at GS10: 1997−2006*

Hardness is collected for all composite samples at GS10 to support metals evaluation.

Figure 2–161 shows individual sample results for hardness plotted with flow rate. A measurable increase in hardness is noted during the recent period of reduced flow rates and increased U concentrations (see Figure 2–157).[34] Since ground water generally shows higher hardness than surface water runoff, these data further suggest an increase in the proportion of ground water in flows at GS10.

[34] The measurably higher hardness concentrations starting in 2001 have been attributed to changes in the deicing products used at Rocky Flats during the winter of 2000−2001.

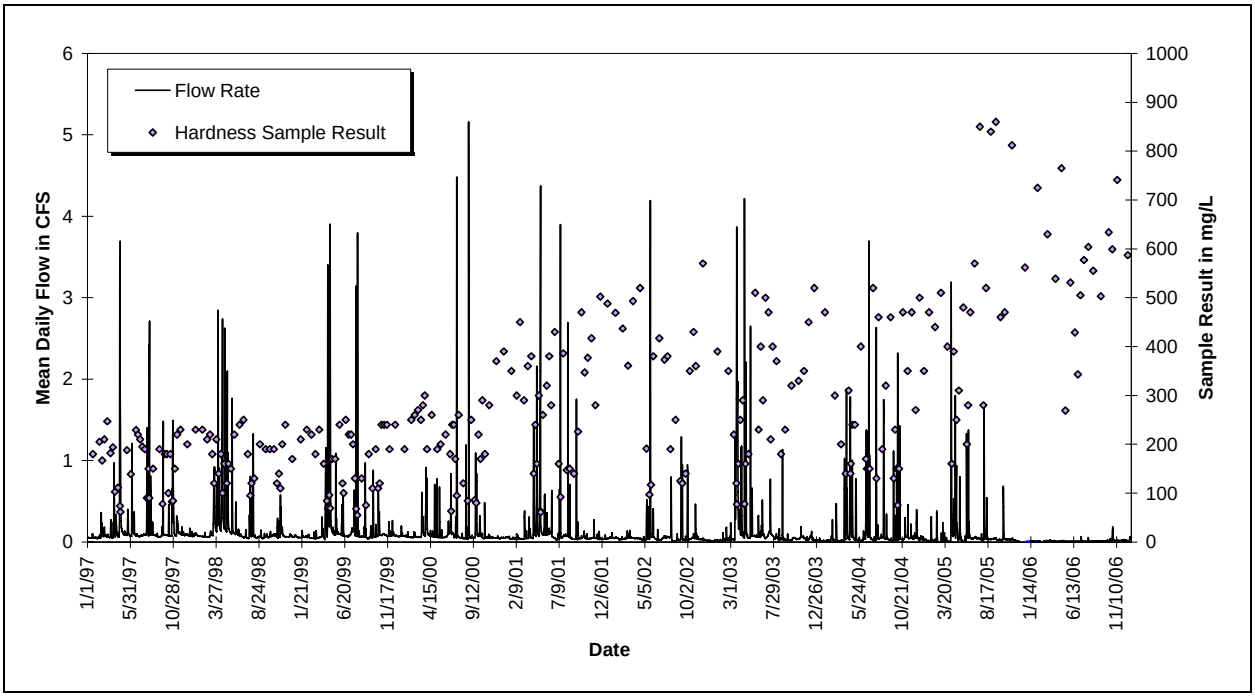



*Figure 2–161. POE Monitoring Station GS10: Hydrograph and Individual Sample Results for Hardness (January 1, 1997−December 31, 2006)*

## Summary and Conclusions

Based on the above evaluation, Site personnel conclude that the recent U activities at GS10 are likely a result of changing hydrologic conditions (particularly the increasing ground water component in surface water flows at GS10, relative to conditions that prevailed prior to Site closure), and that no specific remedial action(s) is indicated at this time. The data do not suggest a previously unknown localized source(s) of contamination that warrants targeted remediation. The current conclusions are summarized below:

- Data collected from all terminal pond and fenceline POCs remain below reporting thresholds for all monitored analytes.
- Recent HR ICP/MS and TIMS analyses for both ground water and surface water samples collected upstream of GS10 all show a predominantly natural U signature. While the two analyses of surface water from GS10 indicate the existence of some depleted U, the normal variability of direct runoff and ground water flow would be expected to strongly influence the U characteristics, both concentration and signature, over longer periods. To fully understand this variability, additional U data as they relate to the appropriate water-quality action level would need to be evaluated.
- Ground water data within South Walnut Creek show naturally occurring U activities considerably higher than the surface water action level. Baseflow at GS10 is sustained by ground water expressions in the form of both localized seeps and distributed flow to the streambed.
- Surface water data from GS10 show that the higher U concentrations are associated with lower flow rates, during periods of extended baseflow sustained by ground water

contributions. As the amount of impervious surface at the Site was reduced, direct runoff to GS10 was also reduced. Similarly, removal of Site infrastructure likely resulted in reduced baseflow contributions from domestic and sanitary water leakage. Therefore, ground water contributions to South Walnut Creek now make up a larger portion of the flows monitored at GS10. Without the attenuation of U ground water sources by direct runoff and infrastructure leakage, increases in surface water U concentrations would be expected.

#### 2.9.3.2 Location SW027

Monitoring location SW027 is located at the end of the SID at the inlet to Pond C-2. Figure 2–50 shows the drainage area for SW027. The southern portion of the COU contributes flow to SW027 through the SID.

Table 2−62 shows that the majority of the annual average Pu and Am activities were less than 0.15 pCi/L. The increased CY 2000 Pu activity was the result of a single sample (May 11−July 17, 2000, 1.03 pCi/L). The significant increase in CY 2004 was the result of increased solids transport from disturbed areas associated with the 903 Pad/Lip accelerated actions. In response, the Site aggressively enhanced the pre-existing erosion control program to further reduce the transport of suspended solids from disturbed areas. With the completion of the 903 Pad/Lip actions, implementation of enhanced erosion controls, revegetation, and soil stabilization, transport of Pu and Am approaching the action level has been virtually eliminated. The total U average activities are well below 11 pCi/L.

Figure 2–162 shows no reportable 12-month rolling averages for Pu and Am during CY 2006. Figure 2–163 shows that the 12-month rolling average for total U was below the action level for all of CY 2006.

*Table 2−62. Annual Volume-Weighted Average Radionuclide Activities at SW027 in CY 1997−2006*

| Calendar Year | Volume-Weighted Average Activity (pCi/L) | | |
|---|---|---|---|
| | Am-241 | Pu-239,240 | Total U |
| 1997 | 0.008 | 0.036 | 1.484 |
| 1998 | 0.021 | 0.156 | 3.445 |
| 1999 | 0.019 | 0.066 | 1.897 |
| 2000 | 0.060 | 0.348 | 1.100 |
| 2001 | 0.006 | 0.025 | 1.327 |
| 2002 | 0.001 | 0.003 | 0.531 |
| 2003 | 0.011 | 0.080 | 1.701 |
| 2004 | 0.413 | 2.273 | 1.050 |
| 2005 | 0.022 | 0.156 | 2.341 |
| 2006 | NA<br>No flow | NA<br>No flow | NA<br>No flow |
| Total (CY 1997−2006) | 0.059 | 0.330 | 1.82 |

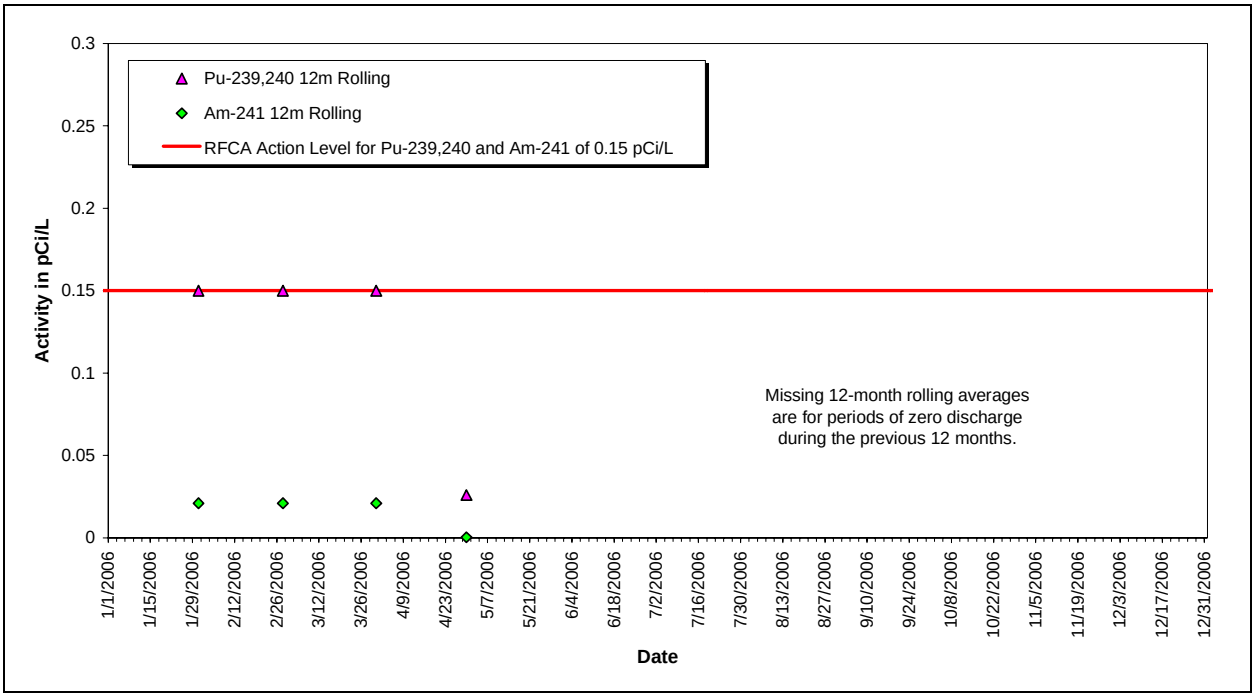



*Figure 2–162. Pu and Am Compliance Values at SW027: CY 2006*

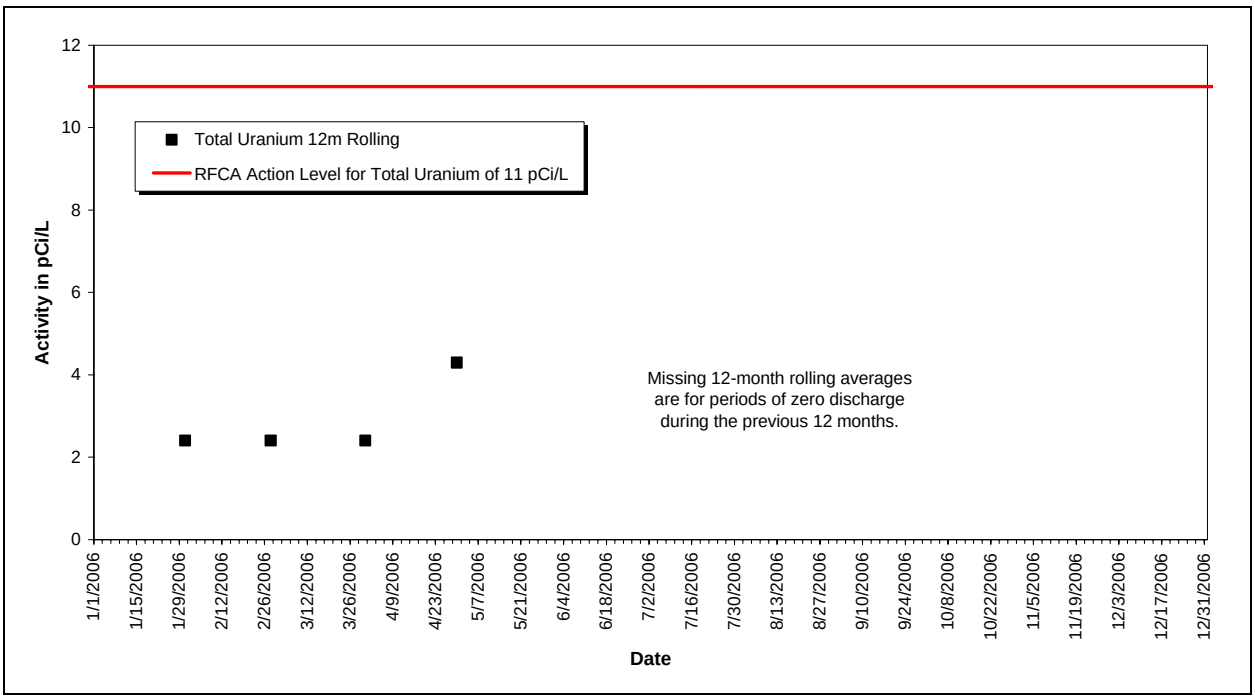



*Figure 2–163. Total Uranium Compliance Values at SW027: CY 2006*

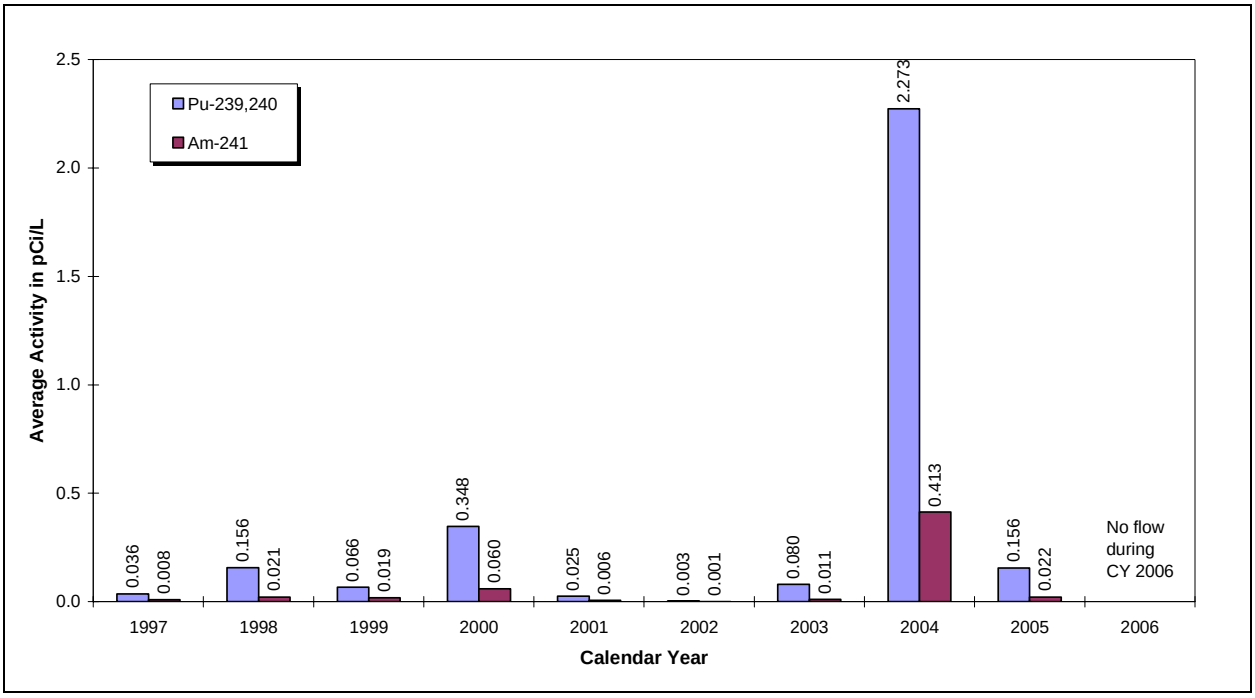



*Figure 2–164. Annual Volume-Weighted Average Pu and Am Activities at SW027: CY 1997–2006*

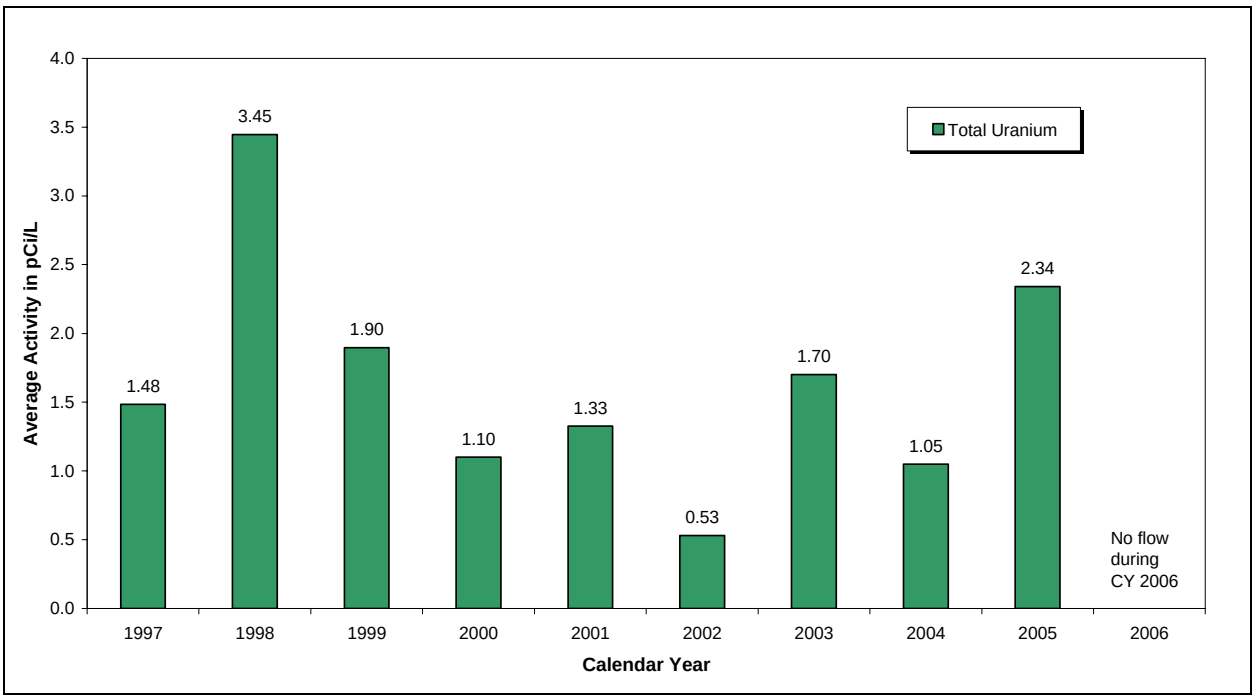



*Figure 2–165. Annual Volume-Weighted Average Total Uranium Activities at SW027: CY 1997–2006*

Table 2−63 shows that all of the annual average metals concentrations were less than the action level. Additionally, the long-term metals averages (CY 1997−2006) were less than the action levels.

Since there was no flow at SW027 during CY 2006, no 30-day average metals concentrations are calculated. Therefore, compliance plots are not presented.

*Table 2−63. Annual Volume-Weighted Average Hardness and Metals Concentrations at SW027 in CY 1997−2006*

| Calendar Year | Volume-Weighted Average Concentration (µg/L) | | | | |
|---|---|---|---|---|---|
| | Hardness [mg/L] | Total Be | Dissolved Cd | Total Cr | Dissolved Ag |
| 1997 | 112 | 0.44 | 0.09 | 1.71 | 0.10 |
| 1998 | 152 | 0.14 | 0.15 | 0.91 | 0.21 |
| 1999 | 111 | 0.03 | 0.10 | 1.55 | 0.24 |
| 2000 | 150 | 0.27 | 0.05 | 4.14 | 0.09 |
| 2001 | 145 | 0.23 | 0.07 | 1.82 | 0.12 |
| 2002 | 114 | 0.12 | 0.05 | 2.88 | 0.11 |
| 2003 | 148 | 0.06 | 0.06 | 1.75 | 0.15 |
| 2004 | 133 | 0.32 | 0.06 | 7.36 | 0.19 |
| 2005 | 236 | 0.08 | 0.07 | 2.03 | 0.19 |
| 2006 | NA<br>No flow | NA<br>No flow | NA<br>No flow | NA<br>No flow | NA<br>No flow |
| Total (CY 1997−2006) | 138 | 0.19 | 0.09 | 2.37 | 0.17 |

Note: Hardness units mg/L

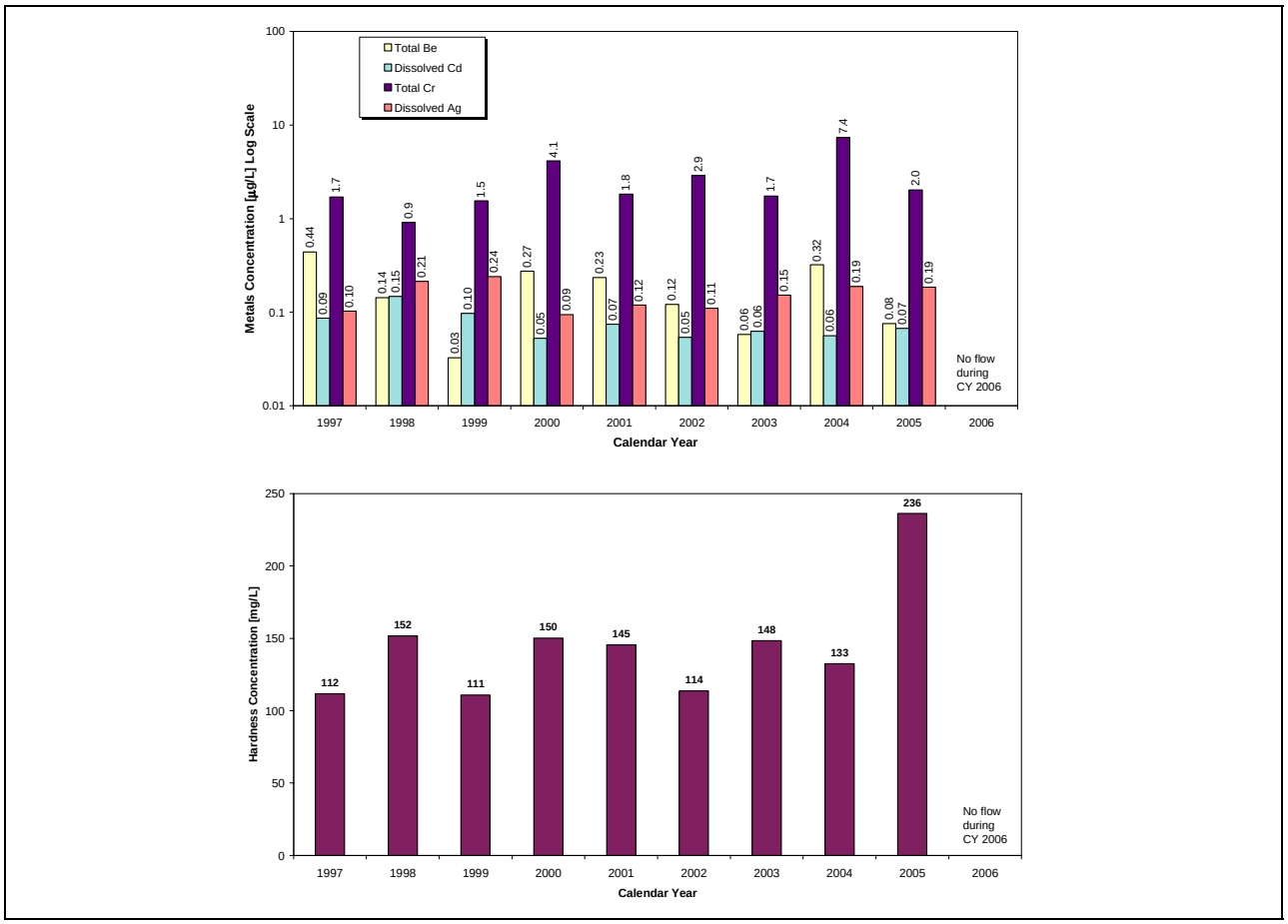



*Figure 2–166. Annual Volume-Weighted Average Metals and Hardness Concentrations at SW027: CY 1997–2006*

### 2.9.3.3 Location SW093

Monitoring location SW093 is located on North Walnut Creek 1,300 feet upstream of the A-Series Ponds. Figure 2–53 shows the drainage area for SW093. The northern portion of the COU contributes flow to SW093 through FC-2 and FC-3.

Table 2−64 shows a significant increase in Pu and Am activities during CY 2004. The Pu, and a portion of the Am, increase in CY 2004 was attributed to increased solids transport from disturbed areas, especially the B779 area. In response, the Site aggressively enhanced the pre-existing erosion control program to further reduce the transport of suspended solids from disturbed areas. The Am increase in CY 2004 was attributed to dust suppression water flows from the former B771 footing drain. In response, the Site disrupted the drain and eliminated the pathway in December 2004. The cause of the CY 2005 reportable Pu values (Figure 2–167) was the construction of FC-2/3 resulting in temporarily increased solids transport. With the completion of the FCs, elimination of the B771 pathway, implementation of enhanced erosion controls, revegetation, and soil stabilization, transport of Pu and Am approaching the action level has been virtually eliminated. The total U average activities are below the 10 pCi/L action level.

Figure 2–167 shows no reportable 12-month rolling averages for Pu and Am during CY 2006. Figure 2–168 shows that the 12-month rolling average for total U was below the action level for all of CY 2006.

*Table 2−64. Annual Volume-Weighted Average Radionuclide Activities at SW093 in CY 1997−2006*

| Calendar Year | Volume-Weighted Average Activity (pCi/L) | | |
|---|---|---|---|
| | Am-241 | Pu-239,240 | Total Uranium |
| 1997 | 0.035 | 0.052 | 2.38 |
| 1998 | 0.020 | 0.022 | 2.26 |
| 1999 | 0.025 | 0.038 | 1.95 |
| 2000 | 0.022 | 0.040 | 2.06 |
| 2001 | 0.011 | 0.015 | 2.14 |
| 2002 | 0.017 | 0.006 | 2.67 |
| 2003 | 0.039 | 0.056 | 2.34 |
| 2004 | 0.622 | 0.603 | 2.50 |
| 2005 | 0.029 | 0.022 | 3.97 |
| 2006 | 0.004 | 0.008 | 5.93 |
| Total (CY 1997−2006) | 0.083 | 0.089 | 2.41 |

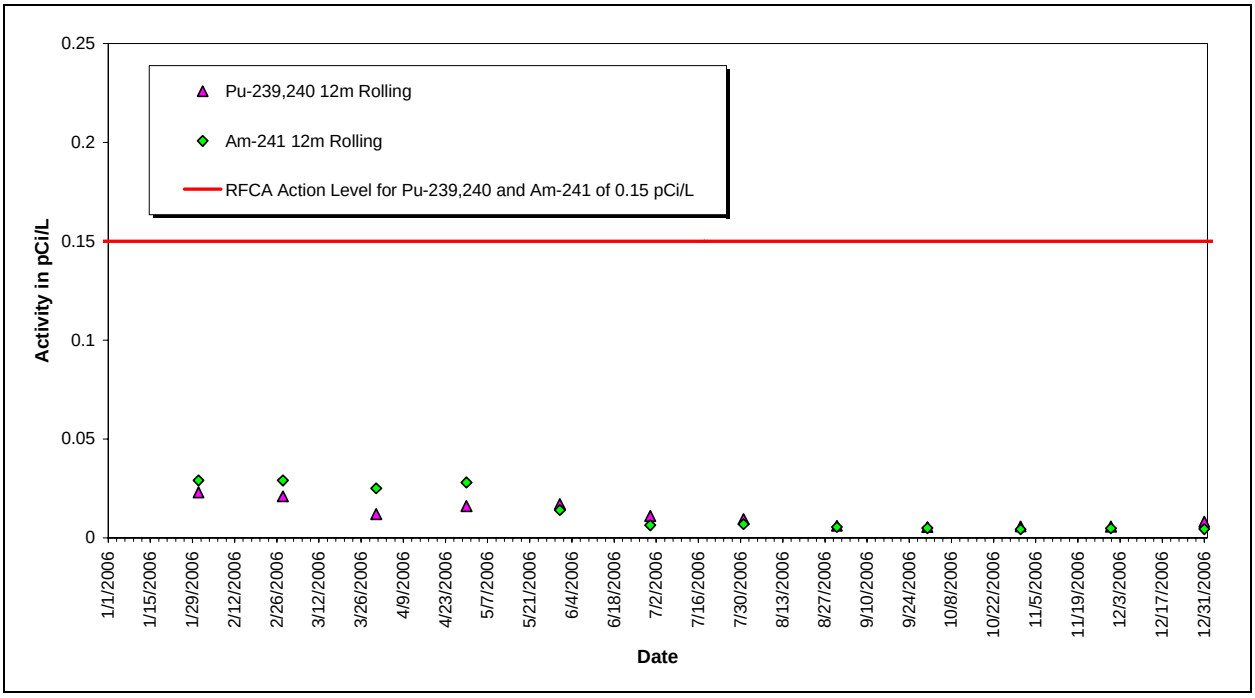



*Figure 2–167. Pu and Am Compliance Values at SW093: CY 2006*

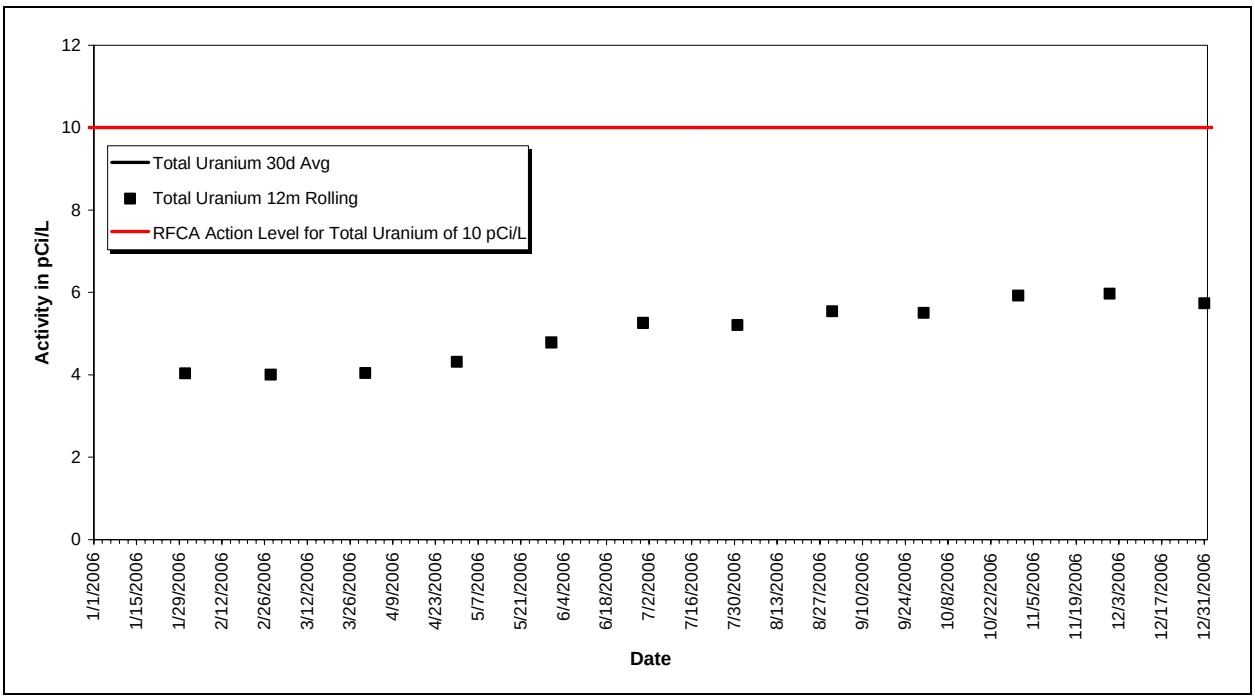



*Figure 2–168. Total Uranium Compliance Values at SW093: CY 2006*

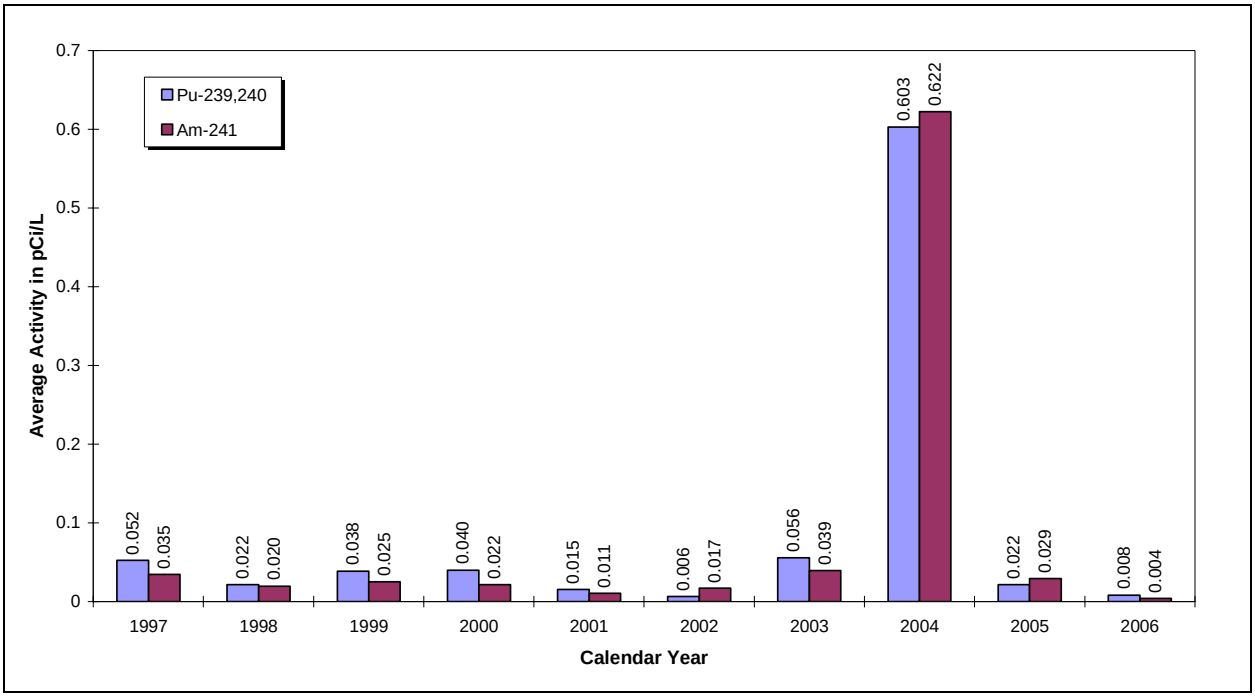



*Figure 2–169. Annual Volume-Weighted Average Pu and Am Activities at SW093: CY 1997–2006*

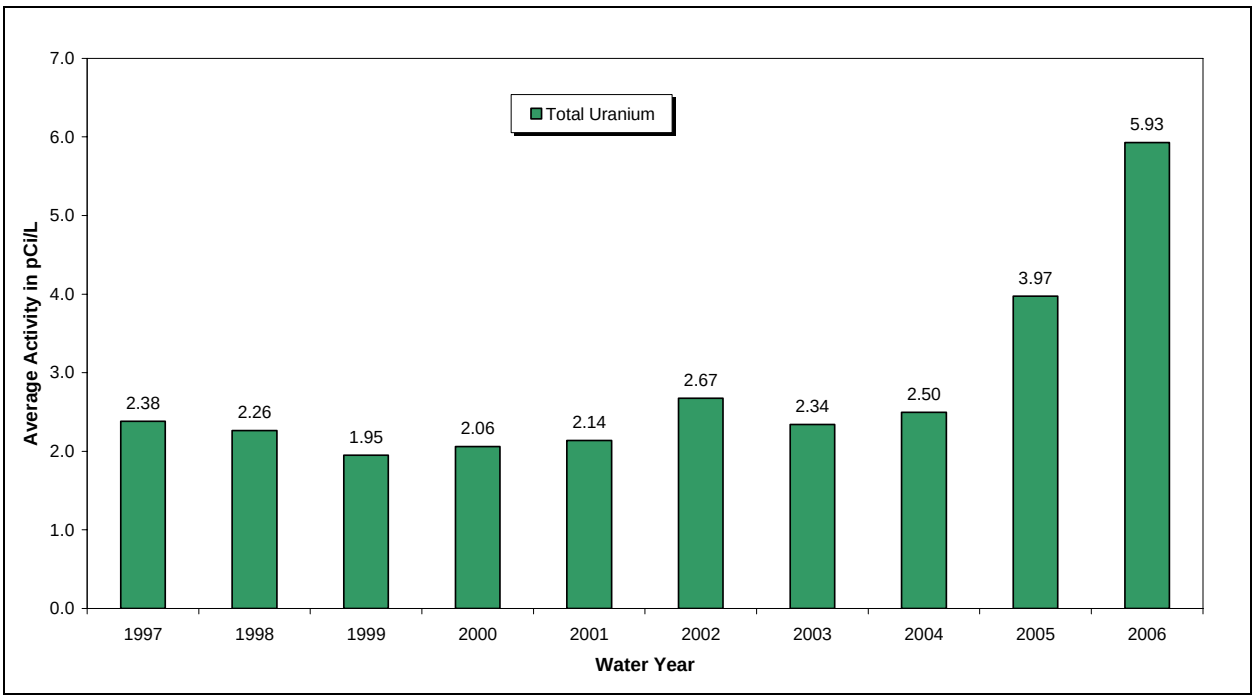



*Figure 2–170. Annual Volume-Weighted Average Total Uranium Activities at SW093: CY 1997–2006*

Table 2−65 shows that all of the annual average metals concentrations were less than the action level. Additionally, the long-term metals averages (CY 1997−2006) were less than the action levels.

Figure 2–171 shows that none of the compliance values for metals were reportable during CY 2006.

*Table 2−65. Annual Volume-Weighted Average Hardness and Metals Concentrations at SW093 in CY 1997−2006*

| Calendar Year | Volume-Weighted Average Concentration (µg/L) | | | | |
|---|---|---|---|---|---|
| | Hardness [mg/L] | Total Be | Dissolved Cd | Total Cr | Dissolved Ag |
| 1997 | 168 | 0.43 | 0.07 | 2.36 | 0.12 |
| 1998 | 184 | 0.14 | 0.23 | 2.22 | 0.22 |
| 1999 | 152 | 0.20 | 0.13 | 5.08 | 0.16 |
| 2000 | 231 | 0.21 | 0.08 | 3.94 | 0.11 |
| 2001 | 247 | 0.36 | 0.07 | 6.49 | 0.11 |
| 2002 | 365 | 0.30 | 0.08 | 5.95 | 0.11 |
| 2003 | 257 | 0.29 | 0.09 | 6.88 | 0.16 |
| 2004 | 315 | 0.57 | 0.09 | 12.05 | 0.12 |
| 2005 | 337 | 0.11 | 0.05 | 1.92 | 0.11 |
| 2006 | 564 | 0.50 | 0.05 | 0.82 | 0.10 |
| Total (CY 1997−2006) | 237 | 0.30 | 0.11 | 5.06 | 0.14 |

Note: Hardness units mg/L.

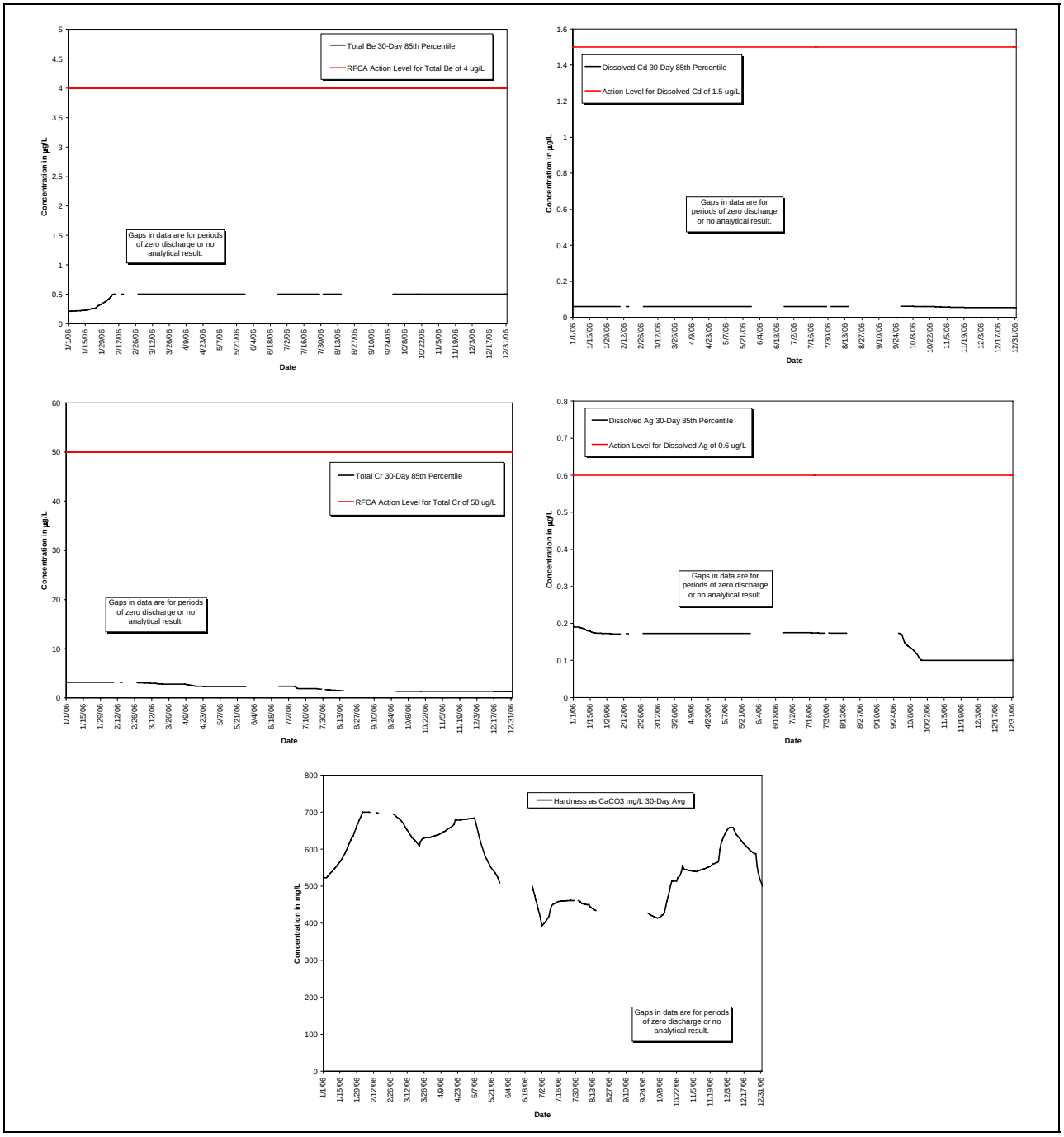



*Figure 2–171. Metals Compliance Values and Hardness Concentrations at SW093: CY 2006*

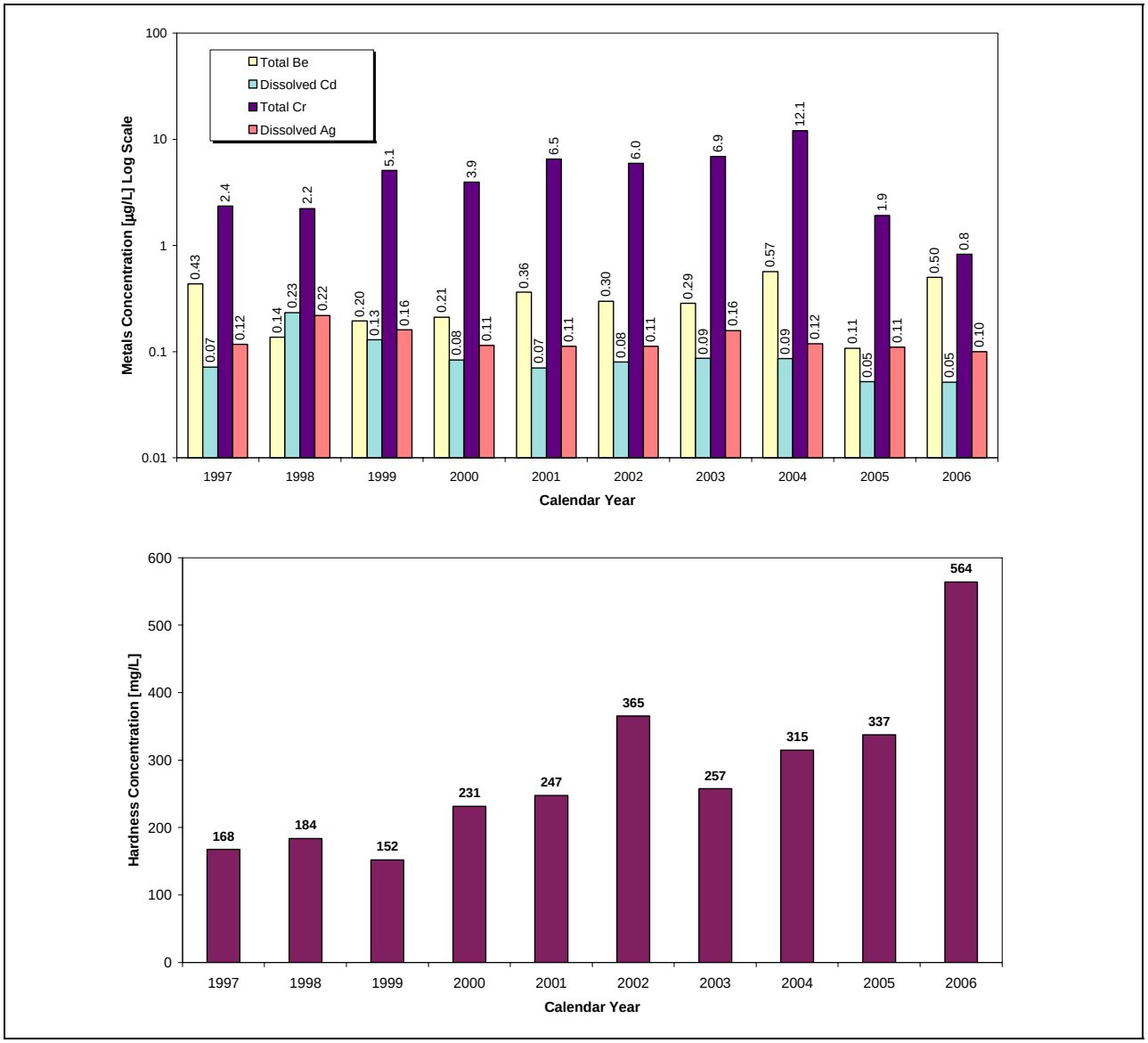



*Figure 2–172. Annual Volume-Weighted Average Metals and Hardness Concentrations at SW093: CY 1997–2006*

## 2.10 Point of Compliance Monitoring

RFCA provides specific standards for Walnut and Woman Creeks below the terminal ponds. These criteria and the responses to them are different than the criteria and actions associated with POEs. This section deals only with monitoring discharges at the terminal pond POCs and the additional POCs at Indiana Street. Terminal pond discharges are monitored by POCs GS08, GS11, and GS31 (Ponds B-5, A-4, and C-2, respectively). Walnut Creek is monitored at Indiana Street by POC GS03. Woman Creek is monitored at Indiana Street by POC GS01. These locations are shown on Figure 2–173.

With the completion of the Woman Creek Reservoir, located just east of Indiana Street and operated by the city of Westminster, all Woman Creek flows are detained in cells of the reservoir

until the water quality has been assured by monitoring Woman Creek at Indiana Street. There is concern that solely monitoring Pond C-2 discharge does not adequately demonstrate that all water crossing Indiana Street via Woman Creek meets standards. All Woman Creek water, either combined with Pond C-2 discharge or flowing in the absence of any Pond C-2 water, enters the Woman Creek Reservoir. This is the basis for setting an additional RFCA POC for Woman Creek at Indiana Street (GS01) for those radiologic contaminants that could be directly attributable to the Site (i.e., not naturally occurring).

For Walnut Creek, a similar POC, GS03, has been established on Walnut Creek and Indiana Street. As with Woman Creek, it is possible that contaminated overland runoff or PLF drainage may enter Walnut Creek below the terminal pond monitoring points (GS08 and GS11), yet upstream of Indiana Street.

### 2.10.1 Data Types, Frequency, and Collection Protocols

The analytical decision inputs are those analytes specified as the POC AOIs (Table 2−66), as sampled at the POCs. POC monitoring is limited to locations GS01, GS03, GS08, GS11, and GS31.

Sampling for AOIs at POCs is performed by collecting continuous flow-paced composite samples. The recommended monitoring design detailed in the IMP is to take samples for CY 2006 as specified in Table 2−69 and Table 2−70. Flow-paced monitoring is maintained at all times for all five POCs, although no samples are anticipated from terminal pond locations except during planned pond discharges.

Historically, terminal pond discharges occurred on average once per year for Pond C-2 and nine times per year for Ponds A-4 and B-5 combined. Since the DQO process originally targeted three composite samples per discharge, and taking into consideration the reduction in runoff due to closure land configuration modifications, the terminal pond POCs target is 20 composite samples to be collected annually.

For CY 2006 planning purposes for Walnut Creek, eight samples were to be collected from Pond A-4, and seven from Pond B-5, targeting the collection of 15 composite samples (see Table 2−70).

The source(s) of the water sampled at the Indiana Street POCs (GS01 and GS03) must be determined prior to sample planning at these locations. Monitoring at GS01 and GS03 calls for samples to be segregated based on water origin (natural creek flows or terminal pond discharges commingled with natural flows).

POC GS01 targets five samples during each Pond C-2 discharge; storm runoff and baseflow samples are based on average annual volumes. During storm runoff and baseflow, the target at GS01 is 29 samples per year (frequency based on expected discharge), with a maximum of four samples during any one month (see Table 2−70). GS03 targets 15 samples during Pond A-4 and Pond B-5 discharges (GS03 collects the same number of composite samples as the terminal pond POCs for each discharge). During storm runoff and baseflow periods between pond discharges, GS03 targets two composite samples every 15 days. The goal is to have at least two analytical

results for any 30-day period for averaging purposes. The Site may combine samples of the same flow pacing to reduce analytical costs and avoid samples of non-sufficient quantity for analysis.

*Table 2−66. RFCA POC AOIs*

| | | |
|---|---|---|
| **Radionuclides:** | Total Pu-239,240 | Known carcinogen. Known past measurements have exceeded RFCA Standards. This provides reasonable cause to expect future measurements in excess of RFCA Standards. |
| | Total Am-241 | Known carcinogen. Known past measurements have exceeded RFCA Standards. This provides reasonable cause to expect future measurements in excess of RFCA Standards. |
| | Total U-233,234; U-235; U-238 | Known renal toxicity. Past measurements provide reasonable cause to expect future measurements in excess of RFCA Standards. |
| **Real Time Monitoring:** | Flow | Required to detect flow events, pace automatic samplers, evaluate contaminant loads, and plan pond operations and discharges. Affects nearly every decision rule, and is the most commonly discussed attribute of Site surface waters. |

## 2.10.2 CY 2006 Monitoring Scope

*Table 2−67. POC Monitoring Locations*

| Location Code | Location | Primary Flow Measurement Device | Telemetry |
|---|---|---|---|
| GS11 | Pond A-4 outlet works | 24-inch Parshall Flume | Yes |
| GS08 | Pond B-5 outlet works | 24-inch Parshall Flume | Yes |
| GS31 | Pond C-2 outlet works | 24-inch Parshall Flume | Yes |
| GS03 | Walnut Creek and Indiana Street | 6-inch and 36-inch Parallel Parshall Flumes; 3-foot HL-Flume installed February 12, 2003 | Yes |
| GS01 | Woman Creek and Indiana Street | 9-inch Parshall Flume; 18-inch Parshall flume starting on March 25, 1999 | Yes |

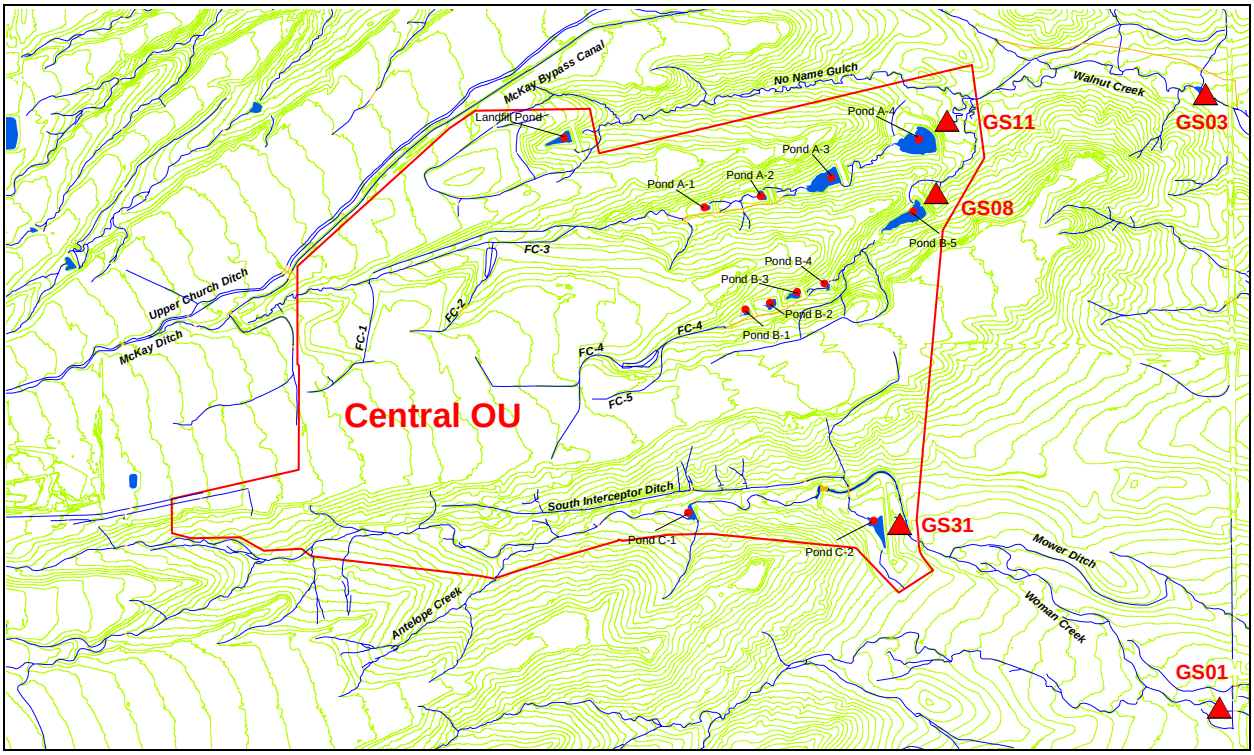



*Figure 2–173. CY 2006 Point of Compliance Monitoring Locations*

*Table 2−68. POC Field Data Collection: Parameters and Frequency*

| Location Code | Parameter Flow |
|---|---|
| GS01 | 15-min continuous |
| GS03 | 15-min continuous |
| GS08 | 15-min continuous |
| GS11 | 15-min continuous |
| GS31 | 15-min continuous |

Note: All locations collect both 5- and 15-minute interval flow data.

*Table 2−69. POC Sample Collection Protocols*

| Location Code | Frequency: CY 2006 Actual (Target) | Type[a] |
|---|---|---|
| GS01 | 9 (29 per year) | Continuous flow-paced composites |
| GS03 | 0 (36 per year) | Continuous flow-paced composites |
| GS08 | 0 (7 per year) | Continuous flow-paced composites |
| GS11 | 0 (8 per year) | Continuous flow-paced composites |
| GS31 | 0 (5 per year) | Continuous flow-paced composites |

[a]Sample types are defined in Appendix B.

*Table 2−70. POC Target Sample Distribution*

| Time Period | Pond: CY 2006 Actual (Target) | | | Walnut Creek at Indiana Street [GS03]: | Woman Creek at Indiana Street [GS01]: | Total Number of Samples: |
|---|---|---|---|---|---|---|
| | A-4 [GS11] | B-5 [GS08] | C-2 [GS31] | CY 2006 Actual (Target) | CY 2006 Actual (Target) | CY 2006 Actual (Target) |
| During Discharge | 0 (8) | 0 (7) | 0 (5) | 0 (15) | 0 (5) | 0 (40) |
| **Storm and Baseflow[c]** | | | | | | |
| January 2006 | NA | NA | NA | 0 (2) | 1 (2) | 1 (4) |
| February 2006 | NA | NA | NA | 0 (2) | 3 (2) | 3 (4) |
| March 2006 | NA | NA | NA | 0 (2) | 3 (4) | 3 (6) |
| April 2006 | NA | NA | NA | 0 (3) | 1 (4) | 1 (7) |
| May 2006 | NA | NA | NA | 0 (1) | 0 (4) | 0 (5) |
| June 2006 | NA | NA | NA | 0 (3) | 0 (1) | 0 (4) |
| July 2006 | NA | NA | NA | 0 (2) | 0 (1) | 0 (3) |
| August 2006 | NA | NA | NA | 0 (2) | 0 (1) | 0 (3) |
| September 2006 | NA | NA | NA | 0 (2) | 0 (1) | 0 (3) |
| October 2006 | NA | NA | NA | 0 (1) | 0 (1) | 0 (2) |
| November 2006 | NA | NA | NA | 0 (1) | 0 (1) | 0 (2) |
| December 2006 | NA | NA | NA | 0 (0) | 1 (2) | 1 (2) |
| Annual Totals | 0 (8) | 0 (7) | 0 (5) | 0 (36) | 9 (29) | 9 (85) |

Notes: NA = not applicable

*Table 2−71. POC Analytical Targets (Analyses per Year)*

| Location Code | TSS[a]: CY 2006 Actual (Target) | Pu, U, Am: CY 2006 Actual (Target) |
|---|---|---|
| GS01 | 1 (24) | 9 (28) |
| GS03 | 0 (21) | 0 (36) |
| GS08 | NA | 0 (7) |
| GS11 | NA | 0 (8) |
| GS31 | NA | 0 (5) |

[a]Ideally, TSS would be analyzed for all runoff samples collected at the Indiana Street locations. However, continuous flow-paced sampling protocols often result in composite samples which are collected over periods exceeding the 7-day hold time for TSS analyses. Therefore, TSS cannot be analyzed for all continuous flow-paced composite samples, but will be analyzed when possible.
NA = analyte not collected

### 2.10.3 Data Evaluation

Sampling for AOIs at POCs is performed by collecting continuous flow-paced composite samples. These AOIs are evaluated using volume-weighted 30-day or 12-month rolling averages, as specified in the IMP. Prior to final Site closure (October 13, 2005), total Pu, Am, and U were evaluated using volume-weighted 30-day moving averages at all POCs.[35] After October 13, 2005, total Pu, Am, and U are evaluated using volume-weighted 30-day averages at the Indiana Street POCs and 12-month rolling averages[36] at the terminal pond POCs.

Generally, analytical data evaluation is performed as data become available. If an initial qualitative screening indicates that an analytical result is higher than the standard for a particular AOI, then the compliance values are calculated immediately. If the compliance values are reportable, then validation is requested for all data packages used in the calculation. The desired evaluation frequency is semimonthly, within 1 week of the 15th and last day of any given month. RFCA requires that the DOE Rocky Flats Project Office (RFPO) inform regulators within 15 days of DOE-RFPO gaining knowledge (not just a suspicion) that an exceedance (verified) has (actually) occurred. The DQO decision rule is:

**IF** The volume-weighted 30-day (Indiana Street POCs) or 12-month rolling (Terminal Pond POCs) average for any AOI in Stream Segment 4, as represented by samples from the specified RFCA POCs (i.e., Terminal Pond discharges and Indiana Street) exceeds the appropriate RFCA standard (Table 2−73)—

**THEN** The Site must:

- Notify EPA, CDPHE, and either Broomfield or Westminster, whichever is affected;
- Submit a plan and schedule to evaluate for source location, and implement mitigating action if appropriate; and
- The Site may receive a notice of violation.

[35] The 30-day average for a particular day is calculated as a volume-weighted average of a ‘window’ of time containing the previous 30 days which had both flow and an analytical result. Each day has its own discharge volume (measured at the location with a flow meter) and activity (analytical result from the sample in place at the end of that day). Therefore, there are 365 30-day moving averages for a location which flows all year (366 in a leap year). At locations which monitor pond discharges or have intermittent flows, 30-day averages are calculated as averages of the previous 30 days of greater than zero flow. For days where no activity is available, either due to failed lab analysis, excessive DER, or NSQ for analysis, no 30-day average is reported.

[36] The 12-month rolling average for the last day of a particular month is calculated as a volume-weighted average of a “window” of time containing the previous 12 months. Each 12-month “window” includes daily discharge volumes (measured at the location with a flow meter) and daily activities (from the sample carboy in place at the end of that day). Therefore, there are twelve 12-month rolling averages for a given calendar year. Days with no flow or no analytical result, either due to failed laboratory analysis, NSQ for analysis, or excessive DER, are not included in the calculation. When no discharge has occurred in the last 12 months, no 12-month rolling average is reported.

*Table 2−72. POC Monitoring Analytical Data Evaluation*

| Location Code | Evaluation Type[a] |
|---|---|
| GS01 | 30-Day Volume-Weighted Moving Averages; Loading Analysis |
| GS03 | 30-Day Volume-Weighted Moving Averages; Loading Analysis |
| GS08 | 12-Month Rolling Averages; Loading Analysis |
| GS11 | 12-Month Rolling Averages; Loading Analysis |
| GS31 | 12-Month Rolling Averages; Loading Analysis |

[a]Details on the evaluation of analytical results are given in Appendix B.1: Data Evaluation Methods. Loading analysis for POCs is given in Section 2.4.

*Table 2−73. POC Monitoring RFCA Standards*

| Analyte | Standard |
|---|---|
| Am-241 | 0.15 pCi/L |
| Pu-239,240 | 0.15 pCi/L |
| Total U | 10 pCi/L (Walnut Creek); 11 pCi/L (Woman Creek) |

Note: The above standards only apply to 30-day and 12-month rolling average values. Comparisons to other values are provided for reference only.

The following sections include summary tables and plots showing the 30-day averages, periodic volume-weighted averages, and 12-month rolling averages for the POC analytes.

The following evaluations include all results that were not rejected through the verification and validation process. Data are generally presented to decimal places as reported by the laboratories. Accuracy should not be inferred; minimum detectable concentrations/activities and analytical error are often greater than the precision presented. When a sample has a corresponding field duplicate, the value used in calculations is the arithmetic average of the 'real' and the 'duplicate' values. When a sample has multiple 'real' analyses (Site requested 'reruns'), the value used in calculations is the arithmetic average of the multiple 'real' analyses. Total U is calculated by summing the activities for the analyzed isotopes (U-233,234 + U-235 + U-238). The methods used for the evaluations are given in Appendix B.1. The loading analysis for the POCs is presented in Section 2.4.

#### 2.10.3.1 Location GS01

Monitoring location GS01 is located on Woman Creek at Indiana Street. Figure 2–11 shows the drainage area for GS01. The Woman Creek headwaters, the southern portion of the COU, and Pond C-2 contribute flow to GS01.

Table 2−74 shows that all of the annual average Pu and Am activities were well below the 0.15 pCi/L standard. Additionally, the long-term Pu and Am averages (CY 1997−2006) are well below the 0.15 pCi/L standard. The average total U activities are all well below the 11 pCi/L standard. Figure 2–174 through Figure 2–177 show no occurrences of reportable values.[37]

[37] Collection of U data at POCs GS01 and GS03 began in CY 2003.

*Table 2−74. Annual Volume-Weighted Average Radionuclide Activities at GS01 in CY 1997−2006*

| Calendar Year | Volume-Weighted Average Activity (pCi/L) | | |
|---|---|---|---|
| | **Am-241** | **Pu-239,240** | **Total U** |
| 1997 | 0.003 | 0.007 | NA |
| 1998 | 0.006 | 0.006 | NA |
| 1999 | 0.005 | 0.008 | NA |
| 2000 | 0.004 | 0.003 | NA |
| 2001 | 0.004 | 0.006 | NA |
| 2002 | 0.002 | 0.001 | NA |
| 2003 | 0.002 | 0.004 | 1.24 |
| 2004 | 0.003 | 0.002 | 3.56 |
| 2005 | 0.004 | 0.003 | 2.50 |
| 2006 | 0.012 | 0.003 | 4.76 |
| Total (CY 1997−2006) | 0.004 | 0.005 | 2.15 |

Notes: NA = analyte not collected; collection of total U data began on February 3, 2003.

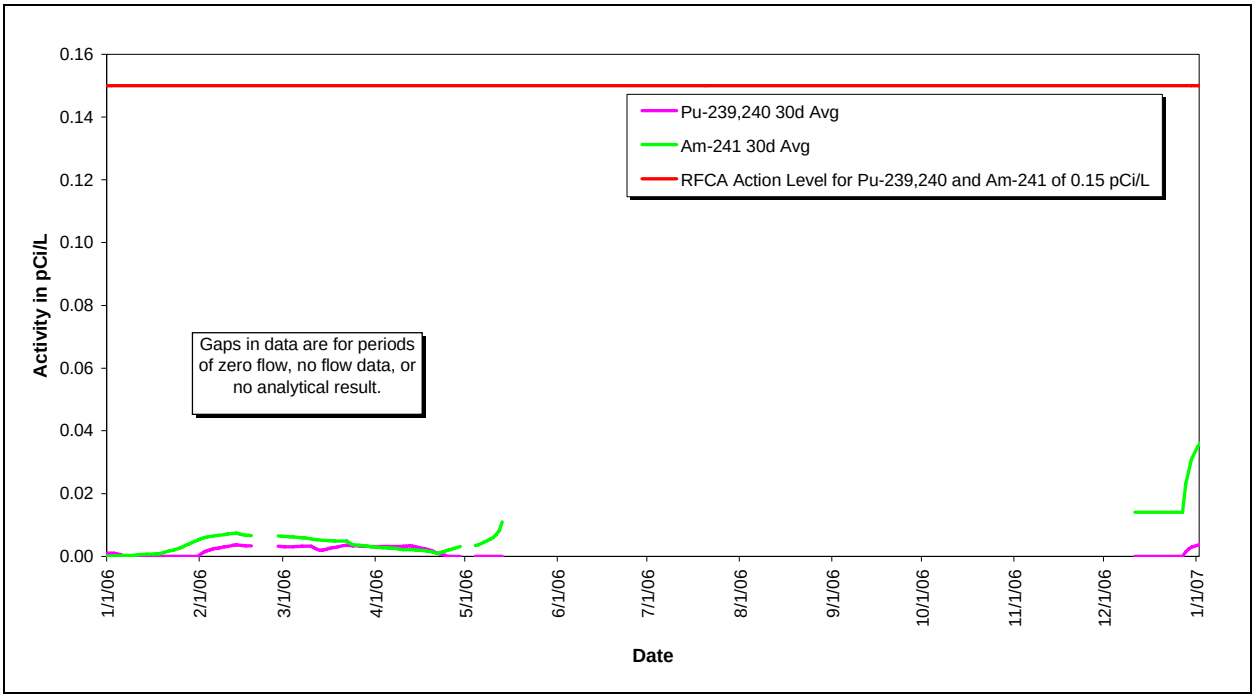



*Figure 2–174. Pu and Am Compliance Values at GS01: CY 2006*

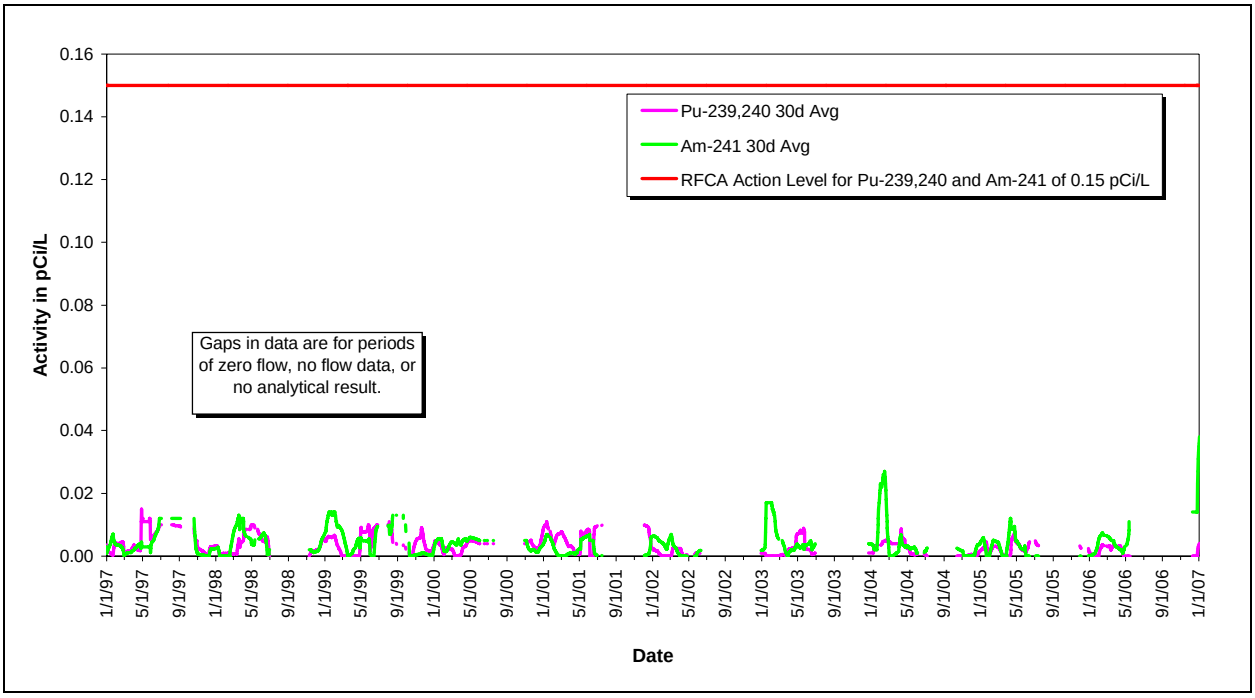



*Figure 2–175. Volume-Weighted 30-Day Average Pu and Am Activities at GS01: CY 1997–2006*

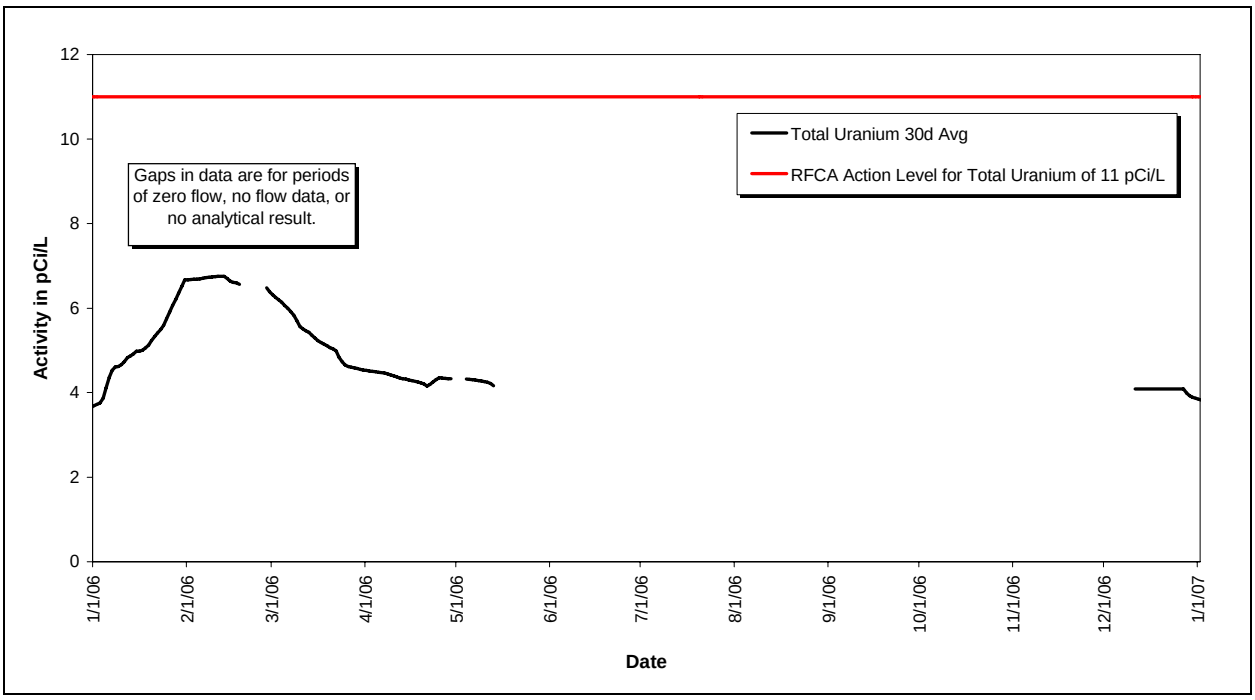



*Figure 2–176. Total Uranium Compliance Values at GS01: CY 2006*

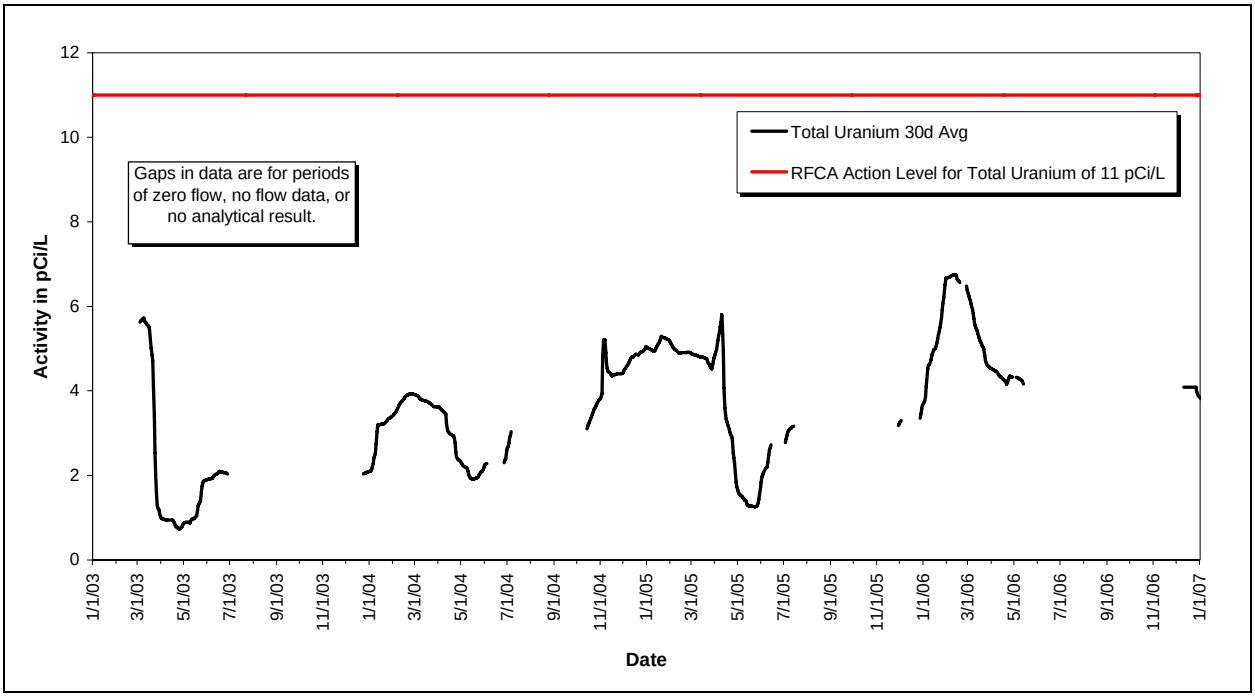



*Figure 2–177. Volume-Weighted 30-Day Average Total Uranium Activities at GS01: CY 2003−2006*

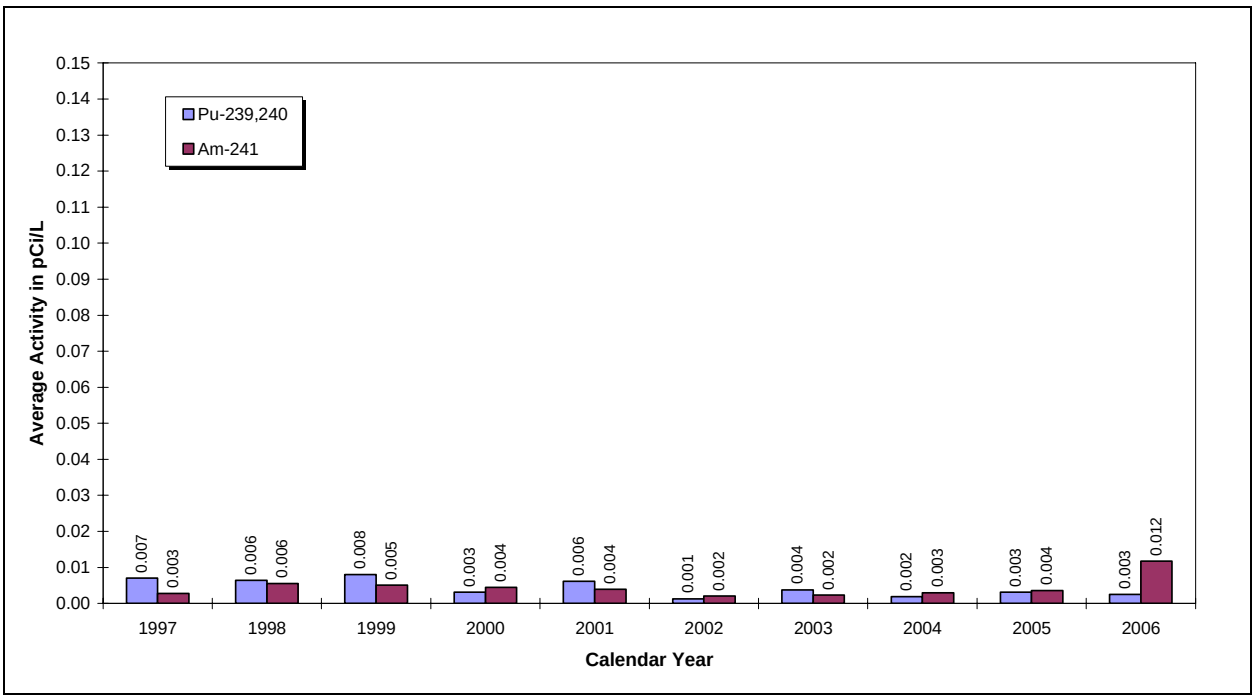



*Figure 2–178. Annual Volume-Weighted Average Pu and Am Activities at GS01: CY 1997–2006*

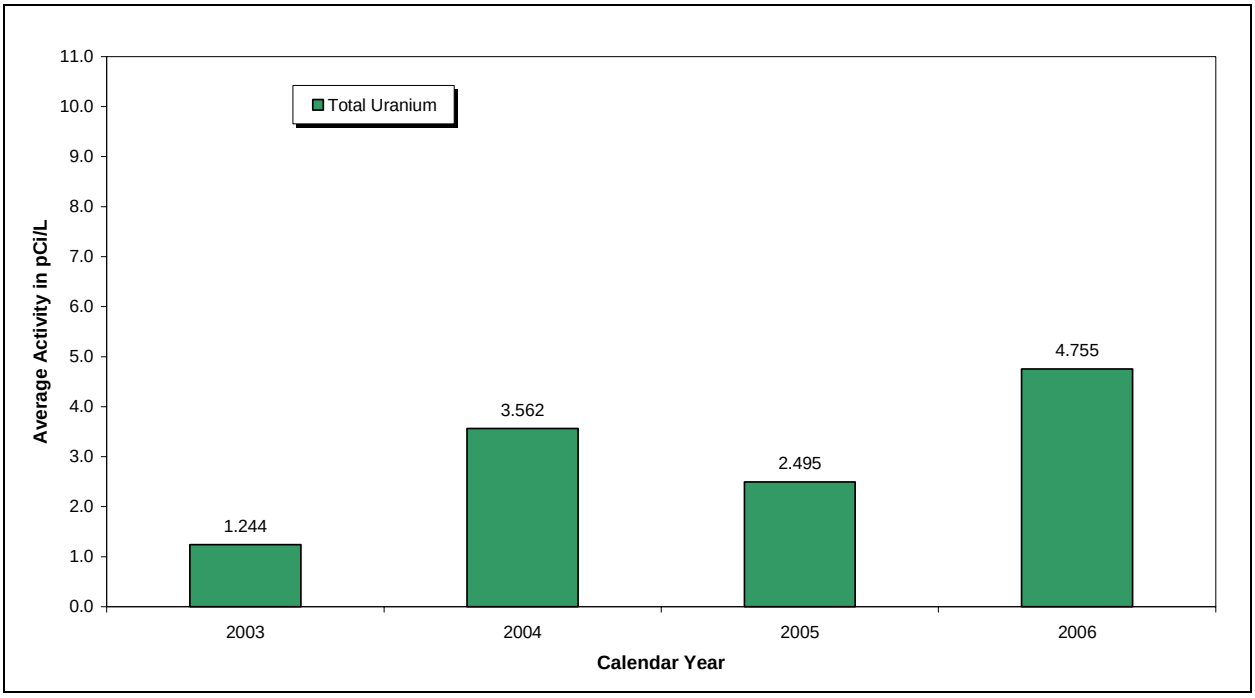



*Figure 2–179. Annual Volume-Weighted Average Total Uranium Activities at GS01: CY 2003–2006*

### 2.10.3.2 Location GS03

Monitoring location GS03 is located on Walnut Creek at Indiana Street. Figure 2–14 shows the drainage area for GS03. The Walnut Creek headwaters, the majority of the COU, Pond A-4, and Pond B-5 contribute flow to GS03.

Table 2−75 shows that all of the annual average Pu and Am activities were well below the 0.15 pCi/L standard. Additionally, the long-term Pu and Am averages (CY 1997−2006) are well below the 0.15 pCi/L standard. The average total U activities are all well below the 10 pCi/L standard.

There was no flow at GS03 during CY 2006. Therefore, compliance plots for CY 2006 are not presented. Figure 2–180 and Figure 2–181 show no occurrences of reportable values during CY 1997−2006. The slight increase in CY 2005 Am activities is due to the discharge of treated Pond A-4 water with Am activities slightly higher than normal.

*Table 2−75. Annual Volume-Weighted Average Radionuclide Activities at GS03 in CY 1997−2006*

| Calendar Year | Volume-Weighted Average Activity (pCi/L) | | |
|---|---|---|---|
| | **Am-241** | **Pu-239,240** | **Total U** |
| 1997 | 0.014 | 0.026 | NA |
| 1998 | 0.010 | 0.014 | NA |
| 1999 | 0.009 | 0.015 | NA |
| 2000 | 0.007 | 0.005 | NA |
| 2001 | 0.005 | 0.009 | NA |
| 2002 | 0.006 | 0.012 | NA |
| 2003 | 0.005 | 0.006 | 1.79 |
| 2004 | 0.008 | 0.008 | 1.76 |
| 2005 | 0.022 | 0.008 | 3.95 |
| 2006 | NA<br>No flow | NA<br>No flow | NA<br>No flow |
| Total (CY 1997−2006) | 0.009 | 0.013 | 2.22 |

Notes: NA = analyte not collected; collection of total U data began on November 5, 2002.

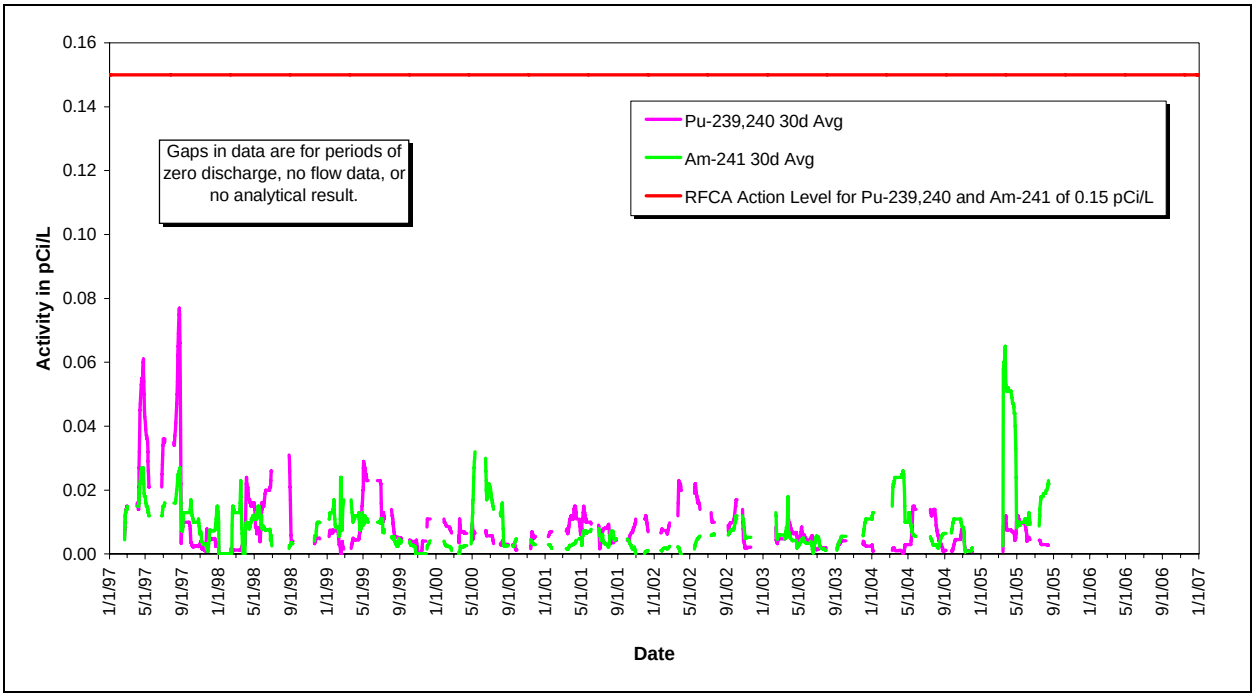



*Figure 2–180. Volume-Weighted 30-Day Average Pu and Am Activities at GS03: CY 1997–2006*

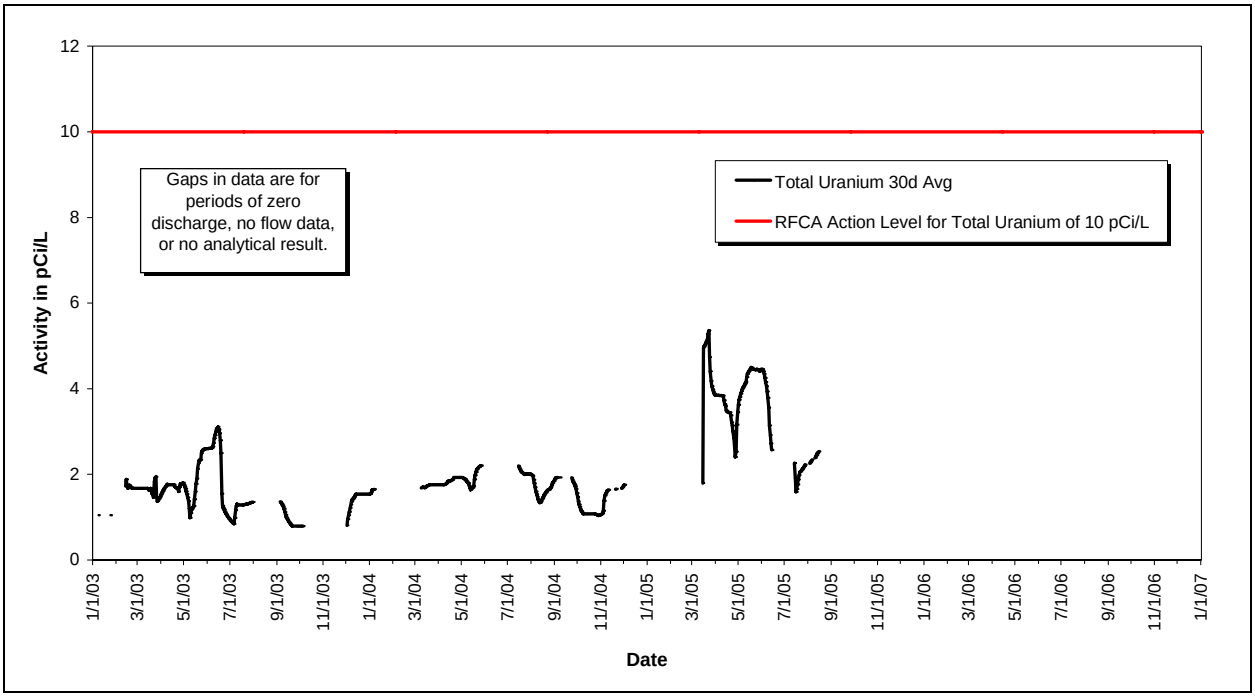



*Figure 2–181. Volume-Weighted 30-Day Average Total Uranium Activities at GS03: CY 2003−2006*

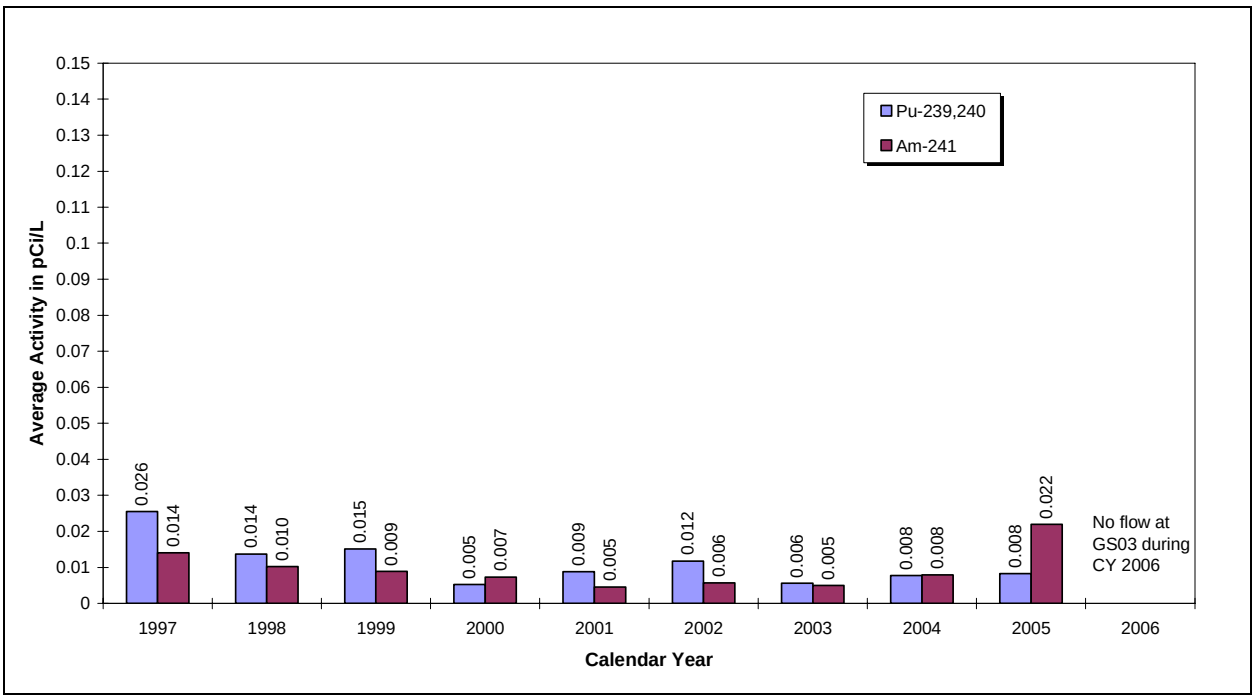



*Figure 2–182. Annual Volume-Weighted Average Pu and Am Activities at GS03: CY 1997–2006*

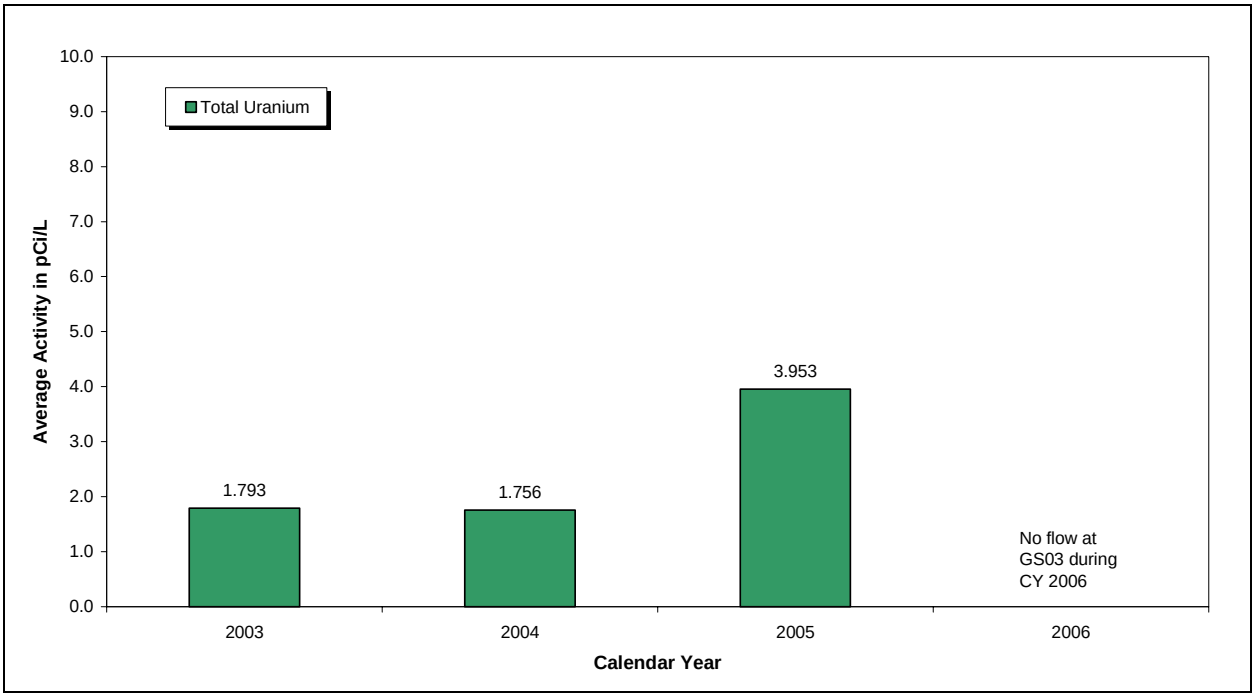



*Figure 2–183. Annual Volume-Weighted Average Total Uranium Activities at GS03: CY 2003–2006*

### 2.10.3.3 Location GS08

Monitoring location GS08 is located on South Walnut Creek at the outlet of Pond B-5. Figure 2–20 shows the drainage area for GS08. The central portion of the COU contributes flow to GS08.

Table 2−76 shows that all of the annual average Pu and Am activities were below the 0.15 pCi/L standard. Additionally, the long-term Pu and Am averages (CY 1997−2006) are well below the 0.15 pCi/L standard. The average U activities are all well below the 10 pCi/L standard.

Figure 2–184 and Figure 2–185 show no occurrences of reportable values during CY 2006.

*Table 2−76. Annual Volume-Weighted Average Radionuclide Activities at GS08 in CY 1997−2006*

| Calendar Year | Volume-Weighted Average Activity (pCi/L) | | |
|---|---|---|---|
| | **Am-241** | **Pu-239,240** | **Total U** |
| 1997 | 0.008 | 0.006 | 1.69 |
| 1998 | 0.006 | 0.008 | 2.33 |
| 1999 | 0.015 | 0.046 | 1.38 |
| 2000 | 0.029 | 0.047 | 0.93 |
| 2001 | 0.004 | 0.006 | 1.24 |
| 2002 | 0.003 | 0.002 | 0.68 |
| 2003 | 0.006 | 0.026 | 1.37 |
| 2004 | 0.009 | 0.009 | 1.24 |
| 2005 | 0.021 | 0.008 | 6.11 |
| 2006 | NA<br>No B-5 discharge | NA<br>No B-5 discharge | NA<br>No B-5 discharge |
| Total (CY 1997−2006) | 0.012 | 0.022 | 1.60 |

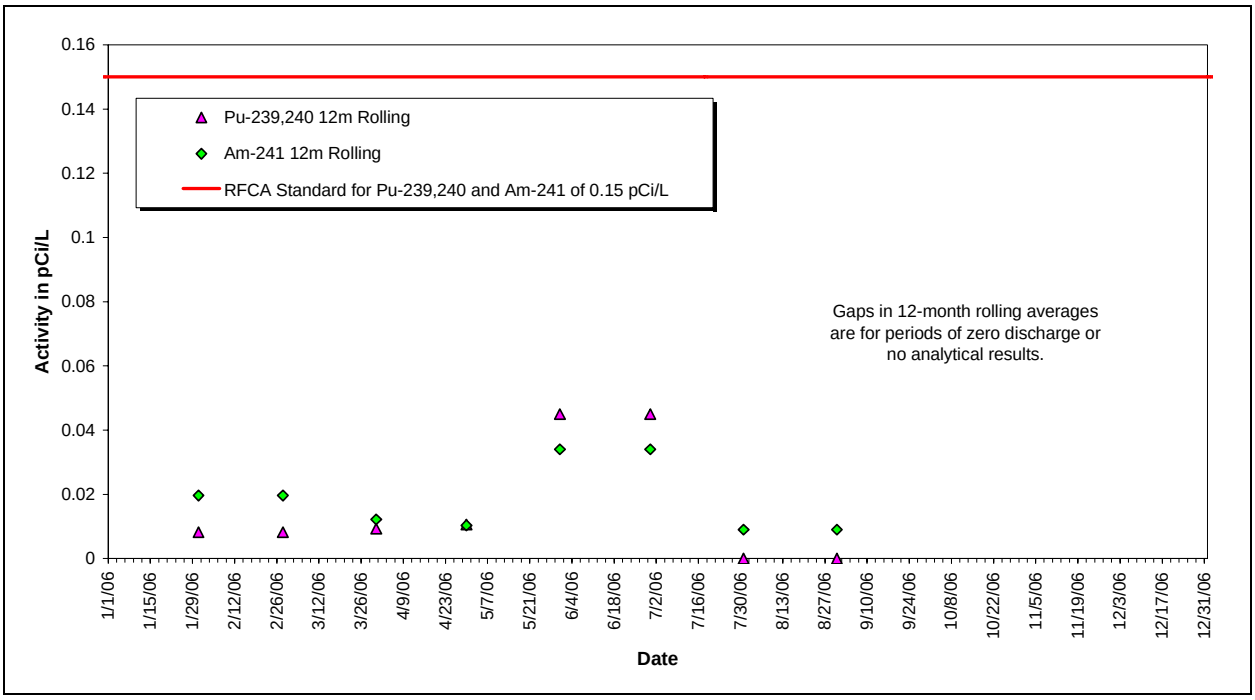



*Figure 2–184. Pu and Am Compliance Values at GS08: CY 2006*

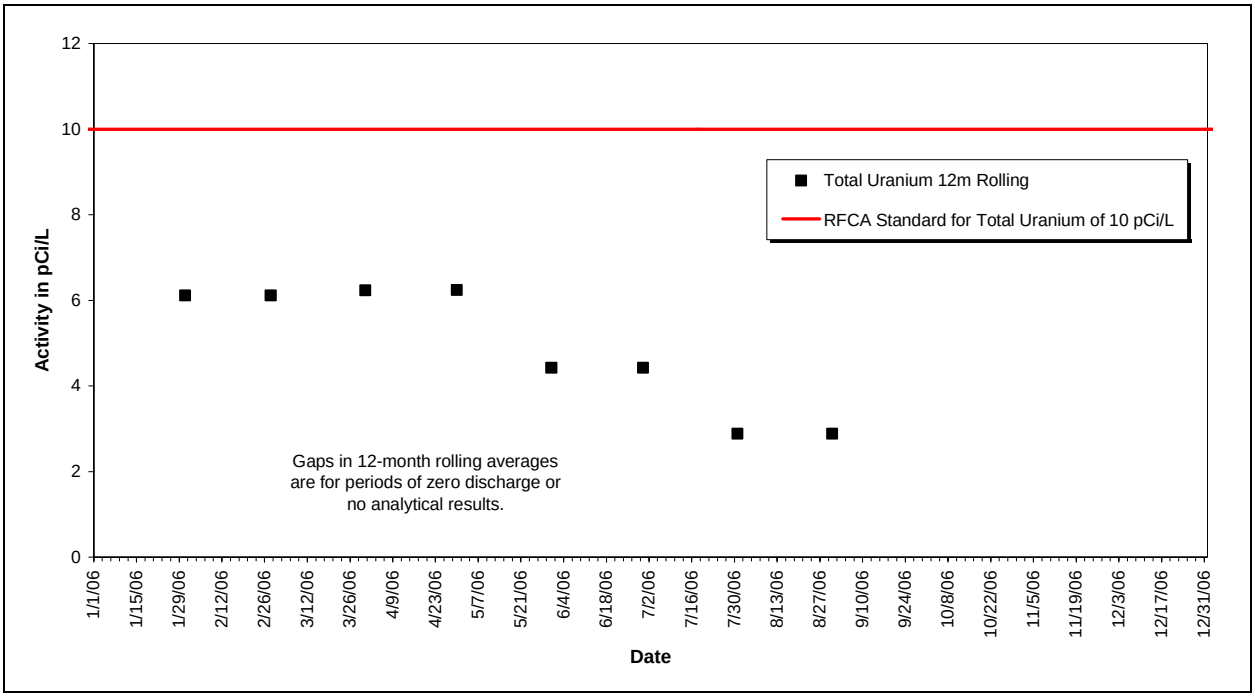



*Figure 2–185. Total Uranium Compliance Values at GS08: CY 2006*

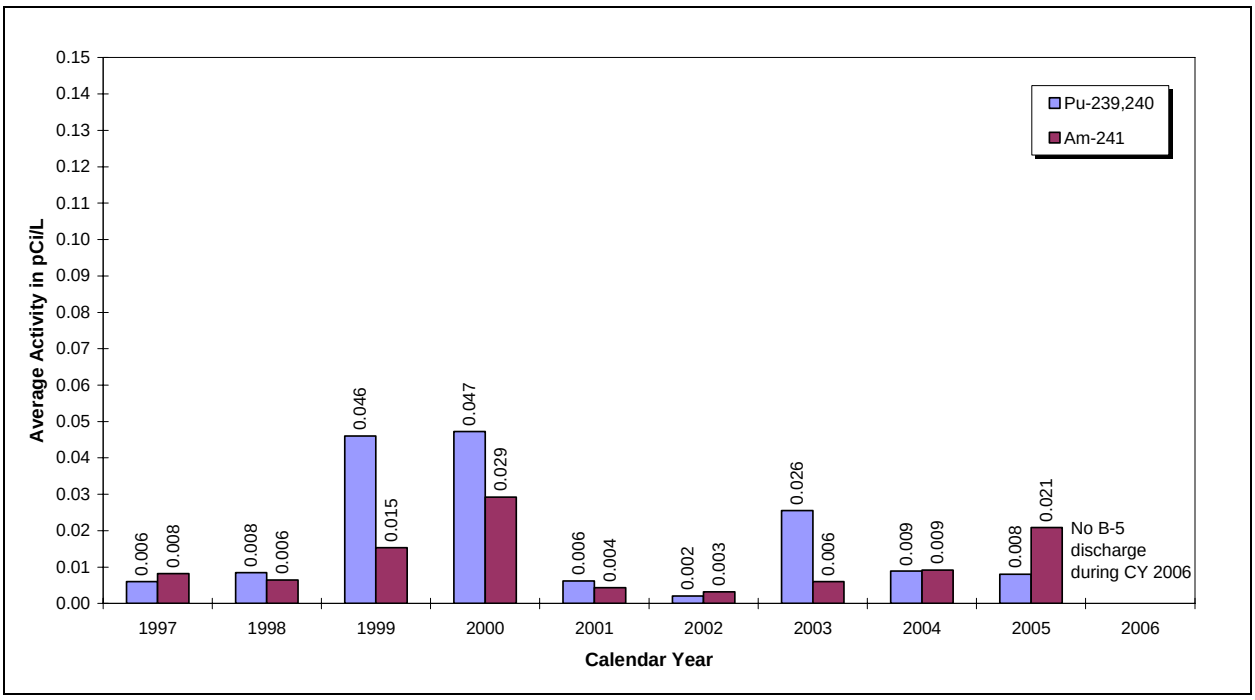



*Figure 2–186. Annual Volume-Weighted Average Pu and Am Activities at GS08: CY 1997–2006*

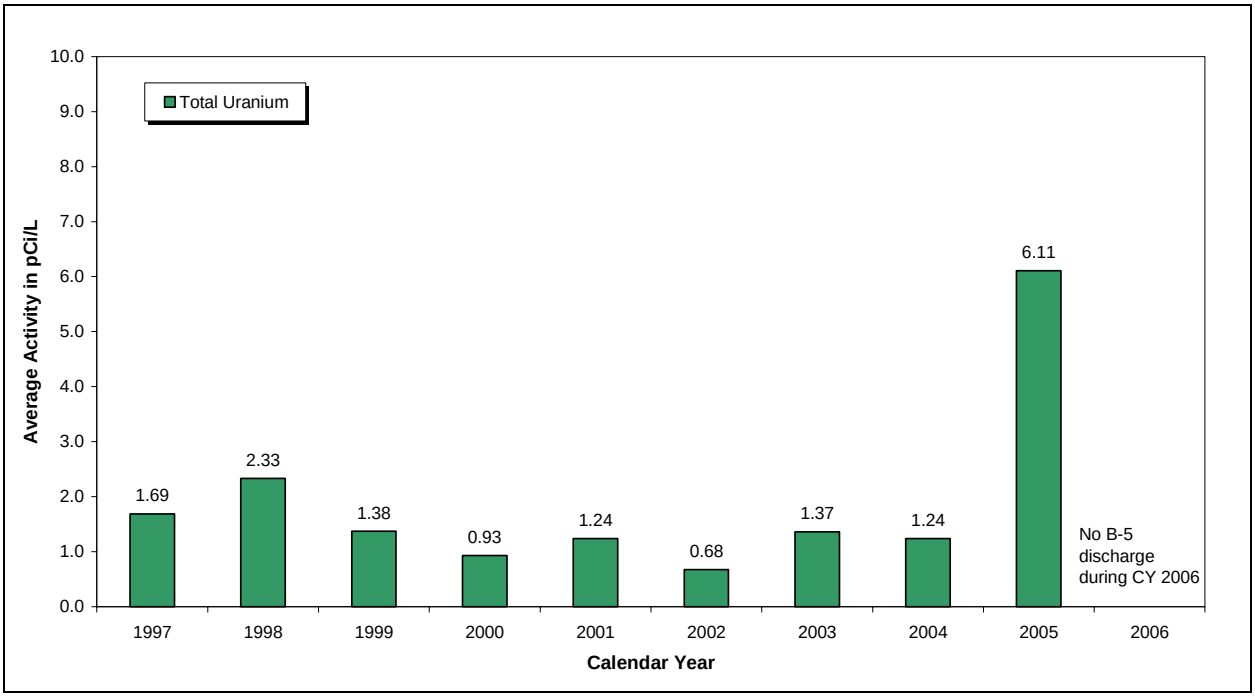



*Figure 2–187. Annual Volume-Weighted Average Total Uranium Activities at GS08: CY 1997–2006*

### 2.10.3.4 Location GS11

Monitoring location GS11 is located on North Walnut Creek at the outlet of Pond A-4. Figure 2–26 shows the drainage area for GS11. The northern portion of the COU contributes flow to GS11.

Table 2−77 shows that all of the annual average Pu and Am activities were well below the 0.15 pCi/L standard. Additionally, the long-term Pu and Am averages (CY 1997−2006) are well below the 0.15 pCi/L standard. The average U activities are all well below the 10 pCi/L standard.

Figure 2–188 and Figure 2–189 show no occurrences of reportable values during CY 2006.

*Table 2−77. Annual Volume-Weighted Average Radionuclide Activities at GS11 in CY 1997−2006*

| Calendar Year | Volume-Weighted Average Activity (pCi/L) | | |
|---|---|---|---|
| | **Am-241** | **Pu-239,240** | **Total U** |
| 1997 | 0.005 | 0.008 | 1.82 |
| 1998 | 0.011 | 0.004 | 2.18 |
| 1999 | 0.003 | 0.007 | 1.76 |
| 2000 | 0.001 | 0.018 | 2.45 |
| 2001 | 0.003 | 0.002 | 2.89 |
| 2002 | 0.003 | 0.000 | 2.29 |
| 2003 | 0.003 | 0.002 | 2.91 |
| 2004 | 0.006 | 0.002 | 2.71 |
| 2005 | 0.022 | 0.002 | 1.78 |
| 2006 | NA<br>No A-4 discharge | NA<br>No A-4 discharge | NA<br>No A-4 discharge |
| Total (CY 1997−2006) | 0.006 | 0.006 | 2.19 |

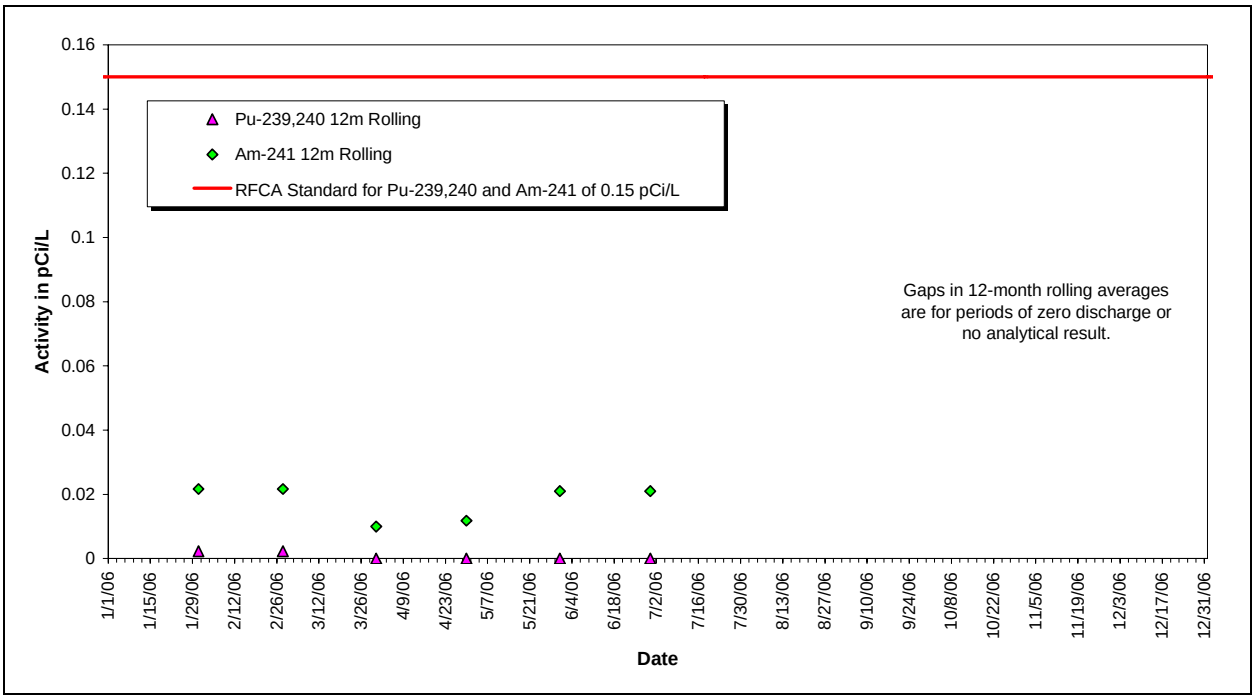



*Figure 2–188. Pu and Am Compliance Values at GS11: CY 2006*

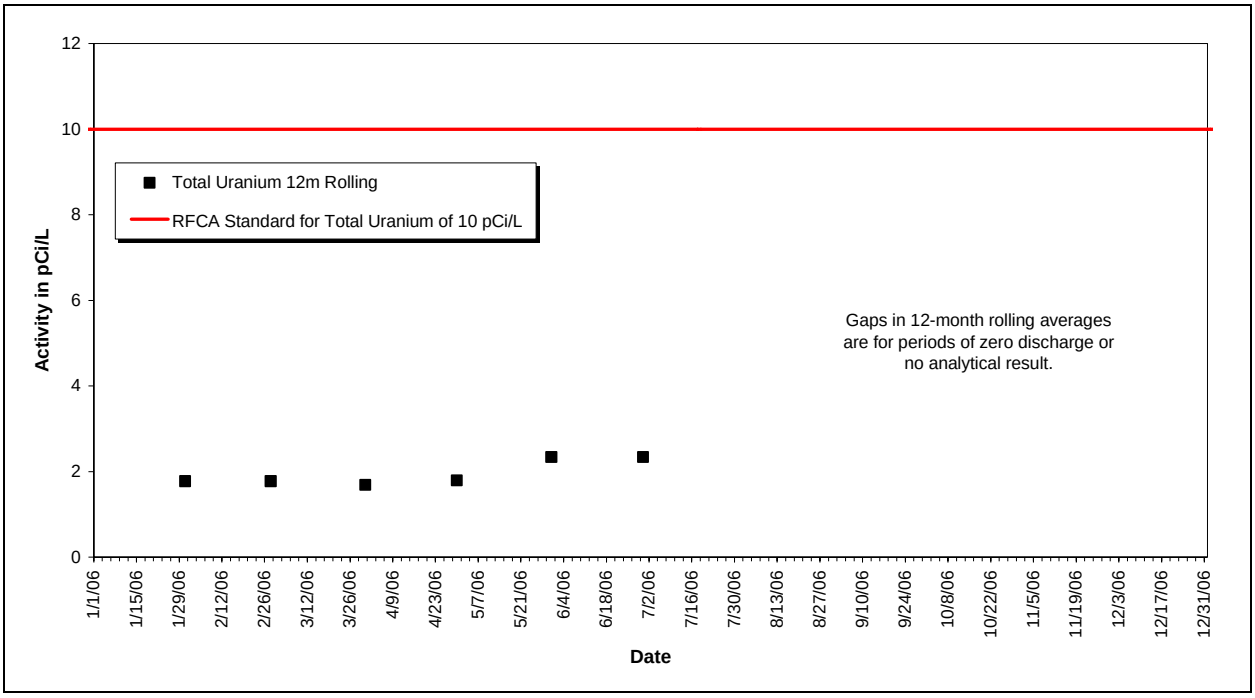



*Figure 2–189. Total Uranium Compliance Values at GS11: CY 2006*

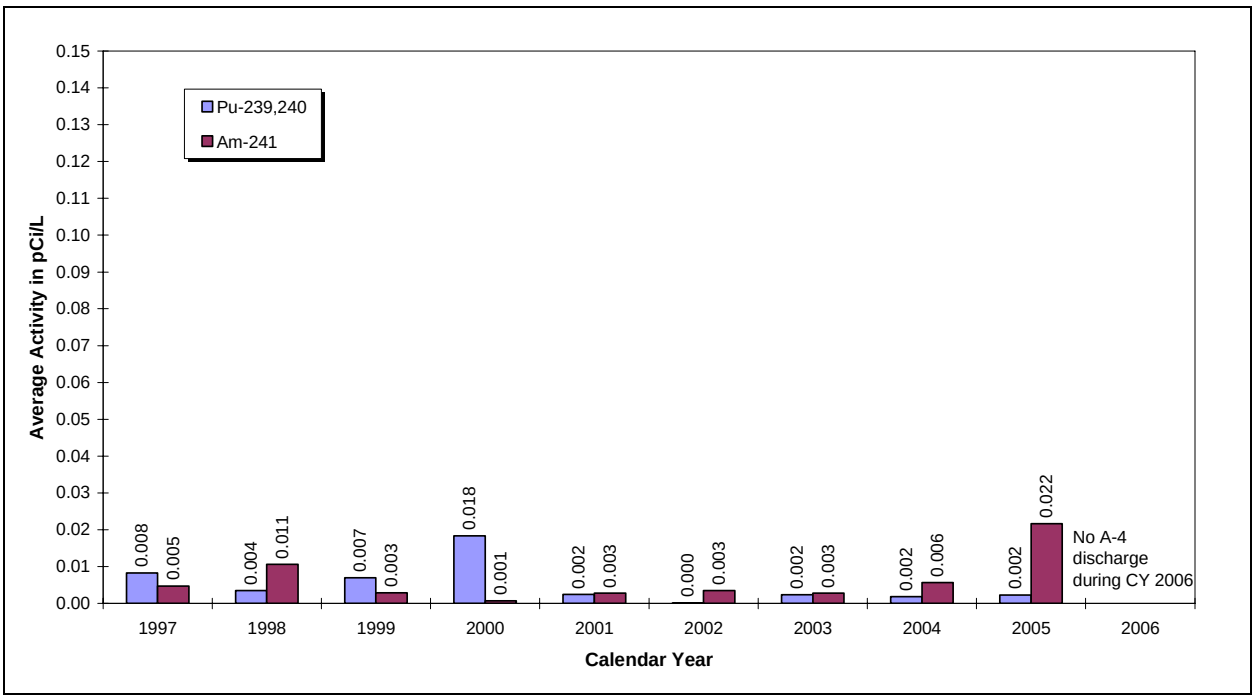



*Figure 2–190. Annual Volume-Weighted Average Pu and Am Activities at GS11: CY 1997–2006*

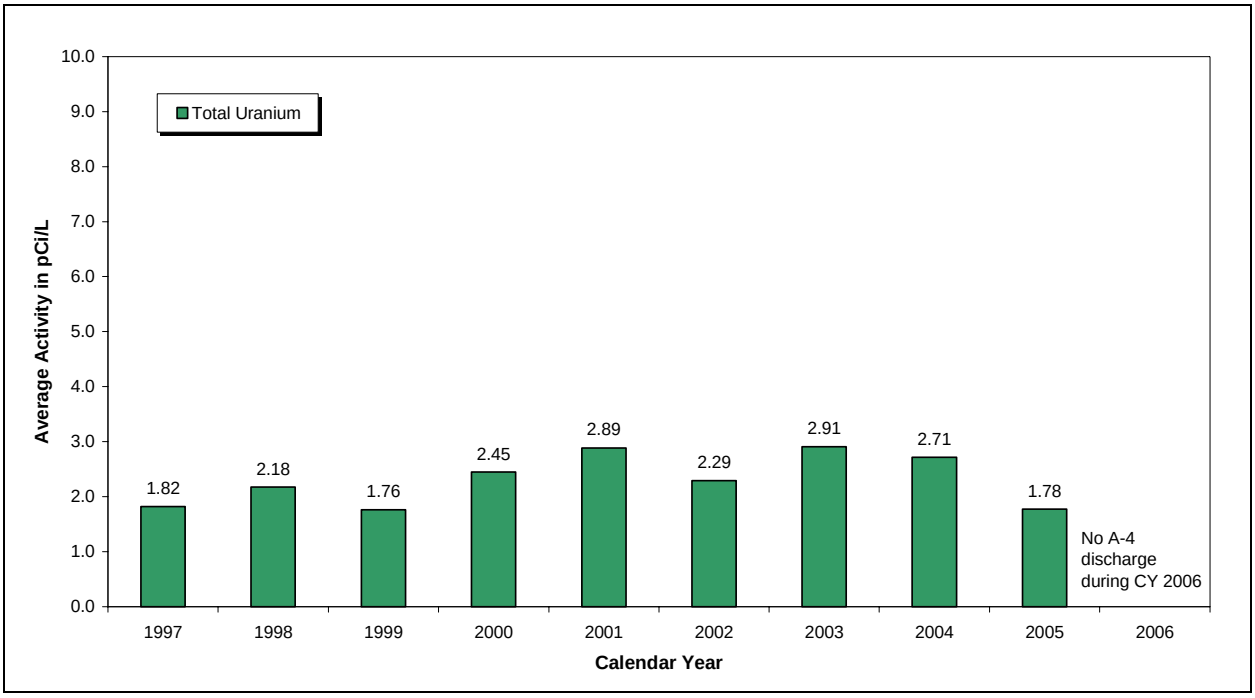



*Figure 2–191. Annual Volume-Weighted Average Total Uranium Activities at GS11: CY 1997–2006*

### 2.10.3.5 Location GS31

Monitoring location GS31 is located on Woman Creek at the outlet of Pond C-2. Figure 2–35 shows the drainage area for GS31. The southern portion of the COU contributes flow to GS31.

Table 2−78 shows that all of the annual average Pu and Am activities were below the 0.15 pCi/L standard. Additionally, the long-term Pu and Am averages (CY 1997−2006) are below the 0.15 pCi/L standard. The average U activities are all well below the 11 pCi/L standard.

Figure 2–192 and Figure 2–193 show no occurrences of reportable values during CY 2006.

*Table 2−78. Annual Volume-Weighted Average Radionuclide Activities at GS31 in CY 1997−2006*

| Calendar Year | Volume-Weighted Average Activity (pCi/L) | | |
|---|---|---|---|
| | **Am-241** | **Pu-239,240** | **Total U** |
| 1997 | 0.008 | 0.017 | 2.10 |
| 1998 | 0.018 | 0.003 | 2.53 |
| 1999 | 0.010 | 0.043 | 2.70 |
| 2000 | NA<br>No C-2 discharge | NA<br>No C-2 discharge | NA<br>No C-2 discharge |
| 2001 | 0.013 | 0.021 | 1.25 |
| 2002 | 0.015 | 0.089 | 2.43 |
| 2003 | 0.006 | 0.015 | 1.62 |
| 2004 | 0.010 | 0.021 | 1.65 |
| 2005 | 0.008 | 0.020 | 4.07 |
| 2006 | NA<br>No C-2 discharge | NA<br>No C-2 discharge | NA<br>No C-2 discharge |
| Total (CY 1997−2006) | 0.011 | 0.019 | 2.13 |

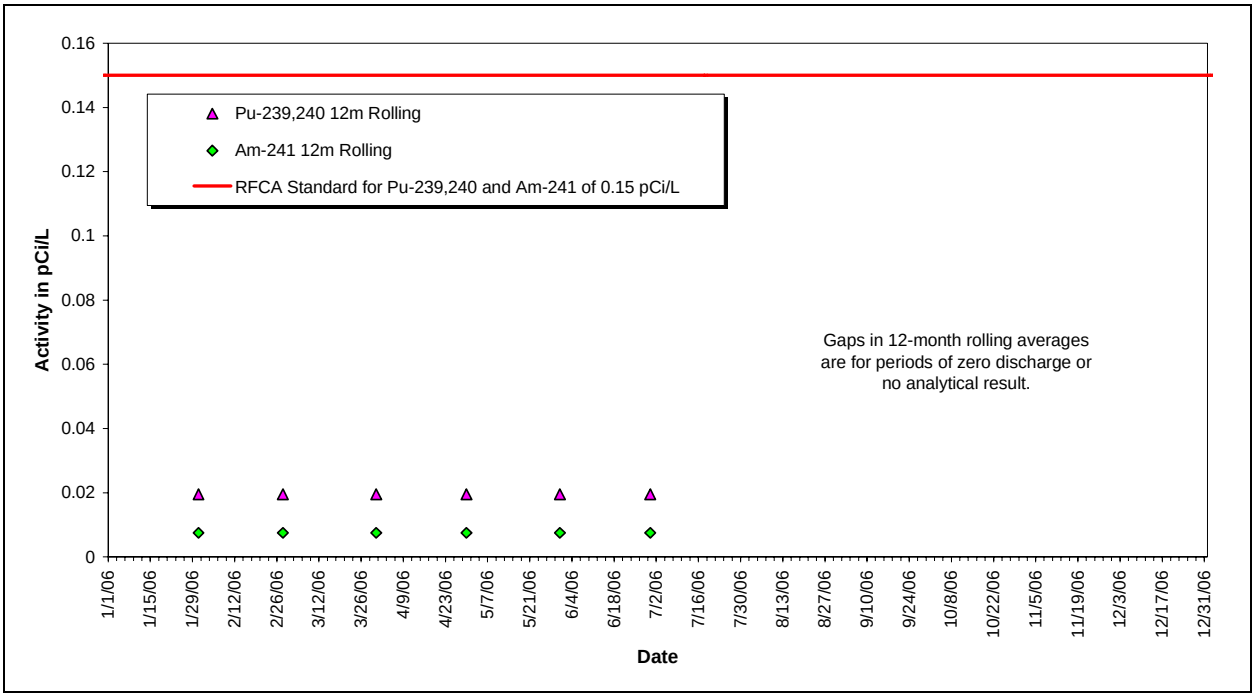



*Figure 2–192. Pu and Am Compliance Values at GS31: CY 2006*

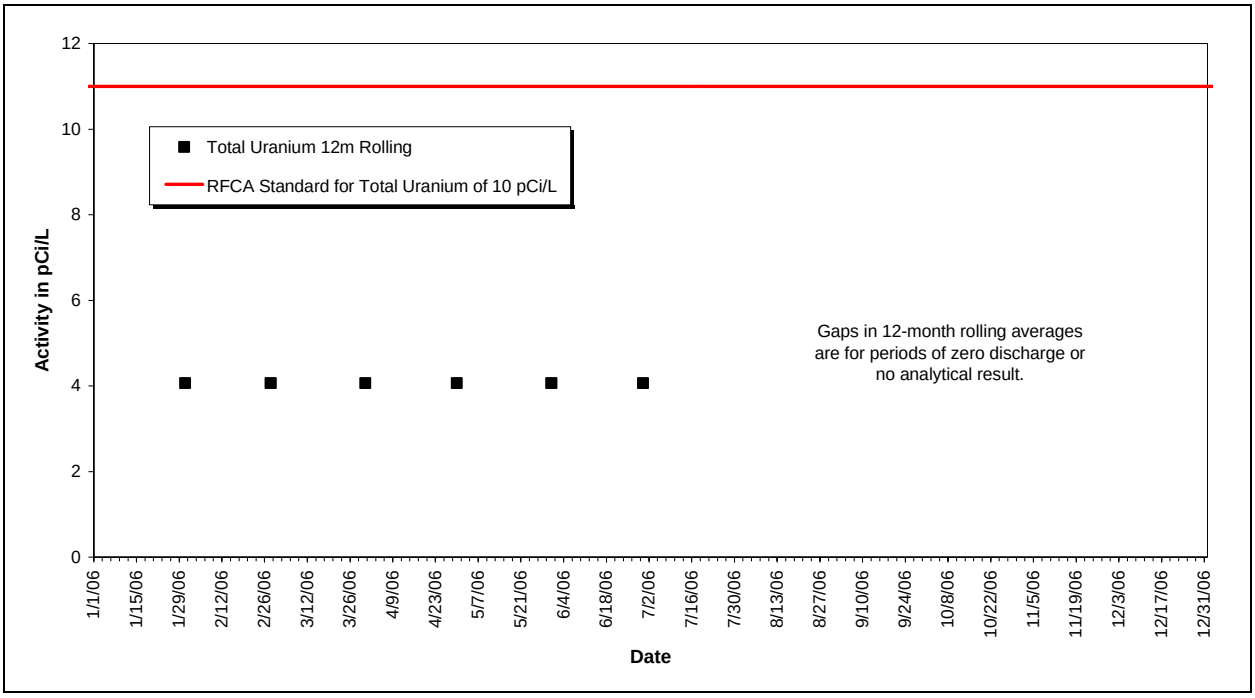



*Figure 2–193. Total Uranium Compliance Values at GS31: CY 2006*

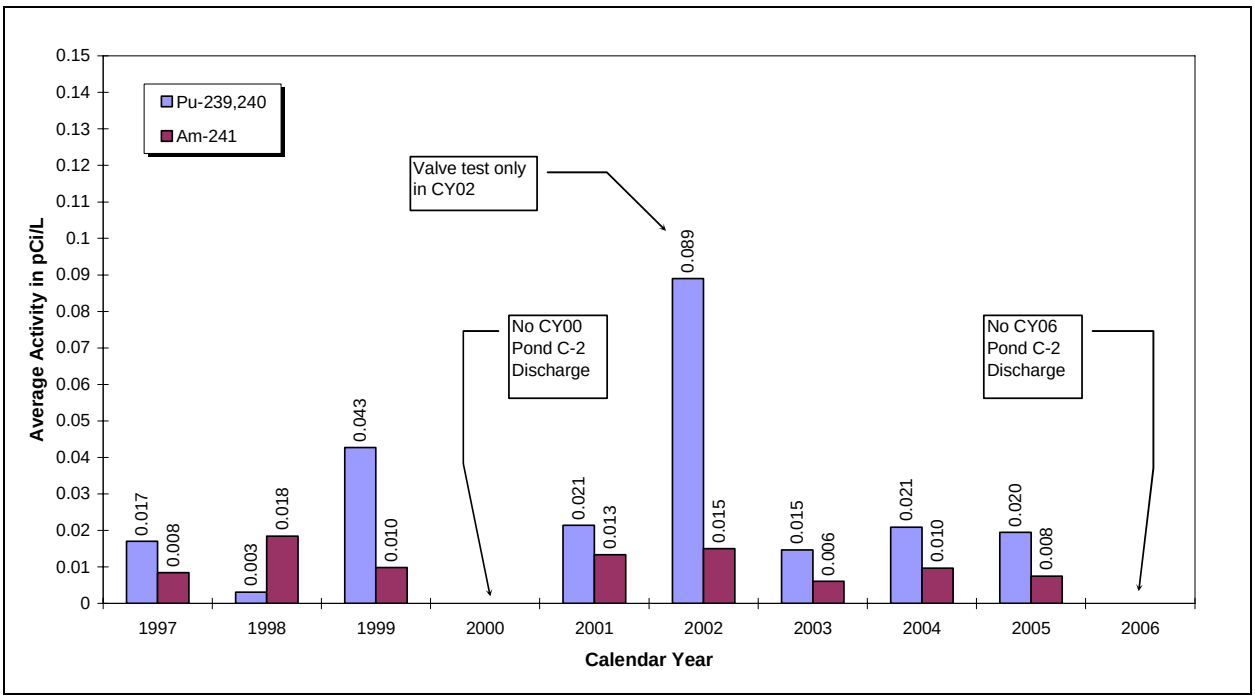



*Figure 2–194. Annual Volume-Weighted Average Pu and Am Activities at GS31: CY 1997–2006*

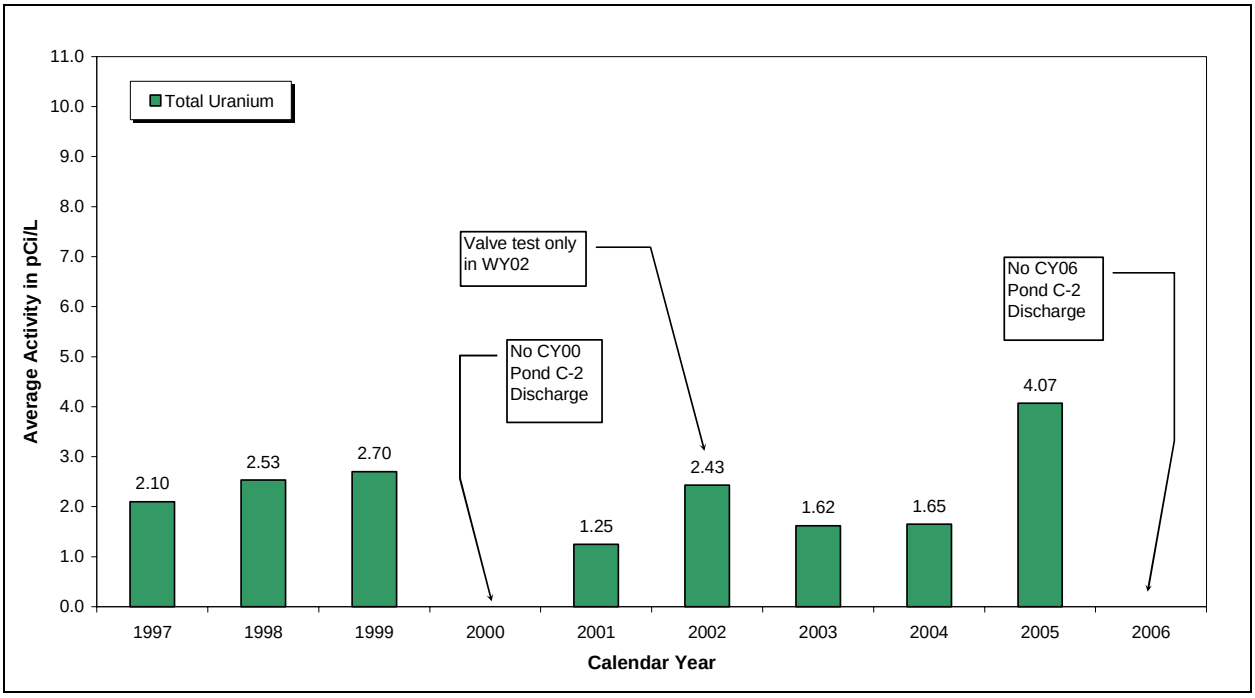



*Figure 2–195. Annual Volume-Weighted Average Total Uranium Activities at GS31: CY 1997–2006*

## 2.11 Non-POC Monitoring in Walnut Creek

The monitoring described in this section is intended to evaluate nitrate concentrations in Walnut Creek during terminal pond discharges.

### 2.11.1 Data Types, Frequency, and Collection Protocols

Nitrate analysis in lower Walnut Creek will be performed for the same pond discharge samples collected under the POC monitoring objective (Section 2.10). Annual sample collection targets for the Walnut Creek POCs are given in Table 2−70.

Non-POC nitrate monitoring will be confined to samples taken during the terminal pond discharges at GS11, GS08, and GS03 (Table 2−79).

#### 2.11.1.1 Data Types and Frequencies

The following types of data could also be collected at the Site at specific frequencies:

- Nitrate, as sampled for at the Walnut Creek Non-POC locations GS03, GS08, and GS11 during terminal pond discharges only;
- Source of the water sampled. Monitoring at Indiana Street Non-POC location GS03 calls for samples to be segregated based on water origin (natural creek flows or terminal pond discharges commingled with natural flows);
- Samples collected will be continuous flow-paced composites; and
- Flow-paced monitoring is maintained at all times for the Non-POC locations.

#### 2.11.1.2 Boundaries

The two types of boundaries are as follows:

- Spatial: Data collection is limited to Non-POC monitoring locations GS03, GS08, and GS11; and
- Temporal: Data are collected continuously, during terminal pond discharges only, using automated equipment.

### 2.11.2 CY 2006 Monitoring Scope

*Table 2−79. Non-POC Monitoring Locations*

| Location Code | Location | Primary Flow Measurement Device | Telemetry |
|---|---|---|---|
| GS03 | Walnut Creek and Indiana Street | 6-inch and 36-inch Parallel Parshall Flumes; 3-foot HL-Flume installed February 12, 2003 | Yes |
| GS11 | Pond A-4 outlet works | 24-inch Parshall Flume | Yes |
| GS08 | Pond B-5 outlet works | 24-inch Parshall Flume | Yes |

*Table 2−80. Non-POC Field Data Collection: Parameters and Frequency*

| Location Code | Parameter Flow |
|---|---|
| GS03 | 15-min continuous |
| GS08 | 15-min continuous |
| GS11 | 15-min continuous |

Note: All locations collect both 5- and 15-minute interval flow data.

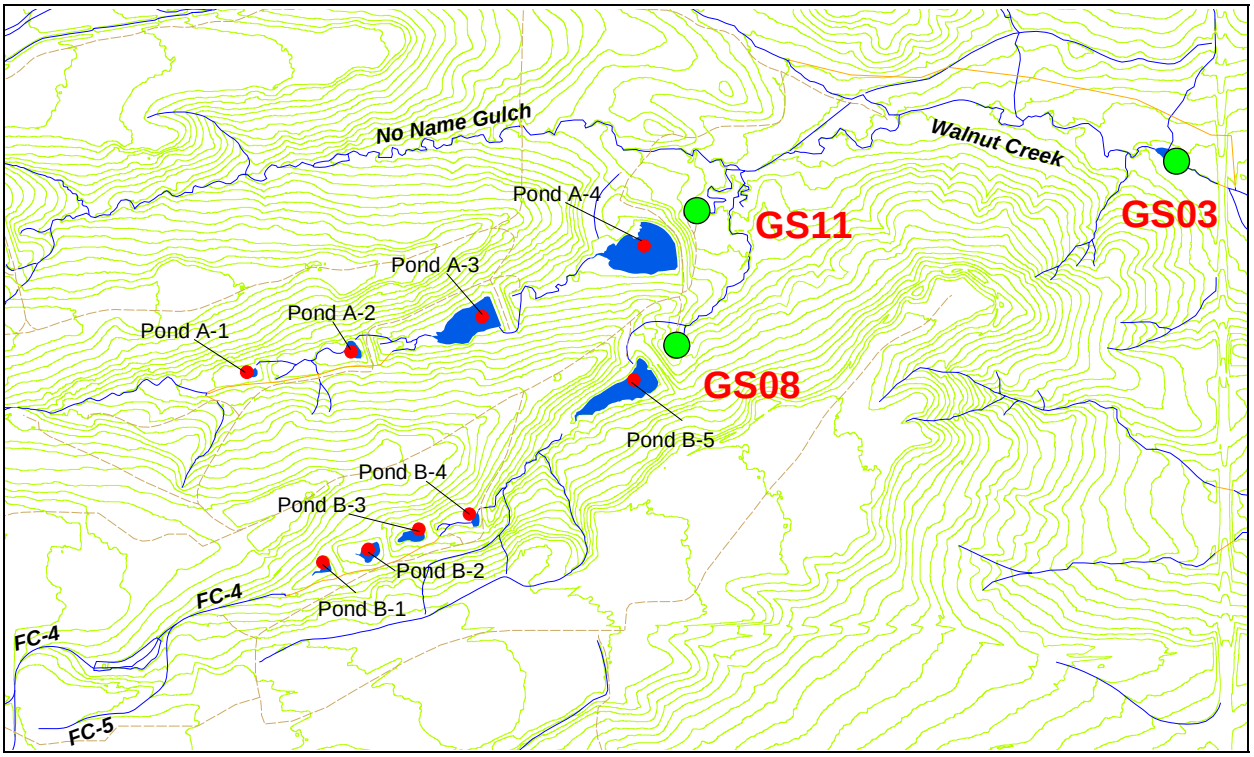



*Figure 2–196. CY 2006 Non-POC Monitoring Locations*

*Table 2−81. Non-POC Sample Collection Protocols*

| Location Code | Frequency: CY 2006 Actual (Target) | Type[a] |
|---|---|---|
| GS03 | 0 (15 per year[a]) | Continuous flow-paced composites |
| GS08 | 0 (7 per year[a]) | Continuous flow-paced composites |
| GS11 | 0 (8 per year[a]) | Continuous flow-paced composites |

[a]Sample types are defined in Appendix B.

### 2.11.3 Data Evaluation

Sampling for nitrate at the Non-POC locations is performed by collecting continuous flow-paced composite samples during pond discharges. Nitrate will be evaluated using the 85th percentile of the 30-day averages for a calendar year at GS03 and 12-month rolling averages at GS08 and GS11.

Generally, analytical data evaluation is performed as data become available. If an initial qualitative screening indicates that an analytical result is higher than the standard, then the compliance values are calculated immediately. If the compliance values are reportable, then validation is requested for all data packages used in the calculation. The desired evaluation frequency is semimonthly, within 1 week of the 15th and last day of any given month. RFCA requires that DOE-RFPO inform regulators within 15 days of DOE-RFPO gaining knowledge (not just a suspicion) that an exceedance (verified) has (actually) occurred. The DQO decision rule is:

**IF** The volume-weighted 12-month rolling average for nitrate, as represented by samples from the specified terminal pond Non-POC monitoring locations (GS08 and GS11), exceeds the appropriate RFCA standard—

**THEN** The Site must notify EPA and CDPHE within 15 days of DOE-RFPO gaining knowledge that an exceedance (verified) has occurred to initiate the consultative process.

**IF** The 85th percentile of the volume-weighted 30-day moving averages of a given calendar year for nitrate, as represented by samples from Non-POC monitoring location GS03 exceeds the appropriate RFCA standard—

**THEN** The Site must notify EPA and CDPHE within 15 days of DOE-RFPO gaining knowledge that an exceedance (verified) has occurred to initiate the consultative process.

*Table 2−82. POC Monitoring Analytical Data Evaluation*

| Location Code | Evaluation Type[a] |
|---|---|
| GS03 | 85th Percentile of 30-Day Averages for Calendar Year |
| GS08 | 12-Month Rolling Averages |
| GS11 | 12-Month Rolling Averages |

[a]Details on the evaluation of analytical results are given in Appendix B.1: Data Evaluation Methods

*Table 2−83. POC Monitoring RFCA Standards*

| Analyte | Standard |
|---|---|
| Nitrate | 10 mg/L |

Note: The above standard only applies to 30-day and 12-month rolling average values. Comparisons to other values are provided for reference only.
The Site analyzes samples for nitrate+nitrite as N, and conservatively compares the results to the nitrate standard.

No terminal pond discharges occurred during CY 2006. Therefore, no data were collected and no evaluation is presented in this report.

# 3.0 Ground Water Monitoring

This section discusses ground water monitoring and presents interpretations resulting from these activities in 2006. Section 3.1 presents an overview of routine monitoring activities. Section 3.2 summarizes nonroutine monitoring activities. Discussion and interpretation of the results of ground water monitoring are provided in Section 3.3, which focuses on the water quality and flow at the more notable ground water contaminant plumes at the Site and the water quality and maintenance at the ground water treatment systems associated with contaminant plumes. The PLF and OLF are addressed in Section 3.4. Section 3.5 summarizes some of the ground water-affecting activities and events that took place, as well as selected studies performed on Site ground water. References are included in Section 8.0.

Appendix B.3 includes previously published Seasonal-Kendall (S-K) trend plots from the second quarterly report for 2006 (DOE 2006g) as well as these plots for the fourth quarterly report. Appendix A.3 contains water level data from 2006, and Appendix A.4 contains corresponding hydrographs.

Ground water was monitored in 2006 in accordance with the 2006 IMP (DOE 2006c, 2006d). The 2006 IMP dictates the monitoring and data evaluation reported herein; the 2007 Annual Report will comply with RFLMA.

The ground water section of this 2006 Annual Report is written with two primary objectives:

1. Provide summary discussion and interpretation of ground water results obtained in 2006 from IMP locations; and
2. Incorporate additional content that may be most relevant to long-term monitoring objectives at the Site.

Upon acceptance of RFLMA, the monitoring will be performed under Attachment 2 to that document (DOE 2007b).

In keeping with the annual report for 2005 (DOE 2006e), references to the Site and to the subject of ground water monitoring will honor the name (e.g., RFP, RFETS, and RFS) and form of the term (ground water vs. groundwater) used in each reference cited.

Note also that discussions of ground water analytical data are focused on the IMP-defined data set, which contains data from January 1, 2000, to the end of the reporting period—in this case, through December 31, 2006. In addition, unless otherwise noted these discussions consider only results from “Field” samples (previously referred to as “REAL” samples in the SWD)—not field duplicates or laboratory duplicates, for example—and data that are rejected or not validated are excluded. Those seeking additional detail in the analytical data are referred to previously published documents, such as the quarterly reports (DOE 2006f, 2006g, 2007d) and Appendix B.6.

## 3.1 Routine Ground Water Monitoring Activities of 2006

Routine activities of the ground water monitoring program in 2006 included sample collection, water level measurement, and well maintenance (particularly the development or redevelopment of monitoring wells).

The program also performed special, nonroutine monitoring discussed in Section 3.2 to support various objectives. Analytical data and other information generated via routine and nonroutine sampling have been reported in the corresponding quarterly reports (DOE 2006f, 2006g, 2007d) and Appendix B.6.

The network of monitoring wells did not change during 2006 (i.e., no additional wells were monitored, and none were removed from the network). However, physical conditions at one well did degrade over the course of the year. Monitoring at well 45605, installed within a slump block that developed over the course of the year south of former B991, was accelerated in order to collect more data before the well no longer functions. The slump is addressed in more detail in Section 3.5.1.

The ground water closure network devised by the IMP (K-H 2005d, DOE 2006c) is subdivided and categorized as shown in Table 3−1. A summary of additional modifications, as initially recommended by the Water Working Group and subsequently incorporated in Attachment 2 of RFLMA (DOE 2007b), is presented in Table 3−2. Upon acceptance and implementation of these recommendations, the well network would be reduced in size by roughly 20 percent.

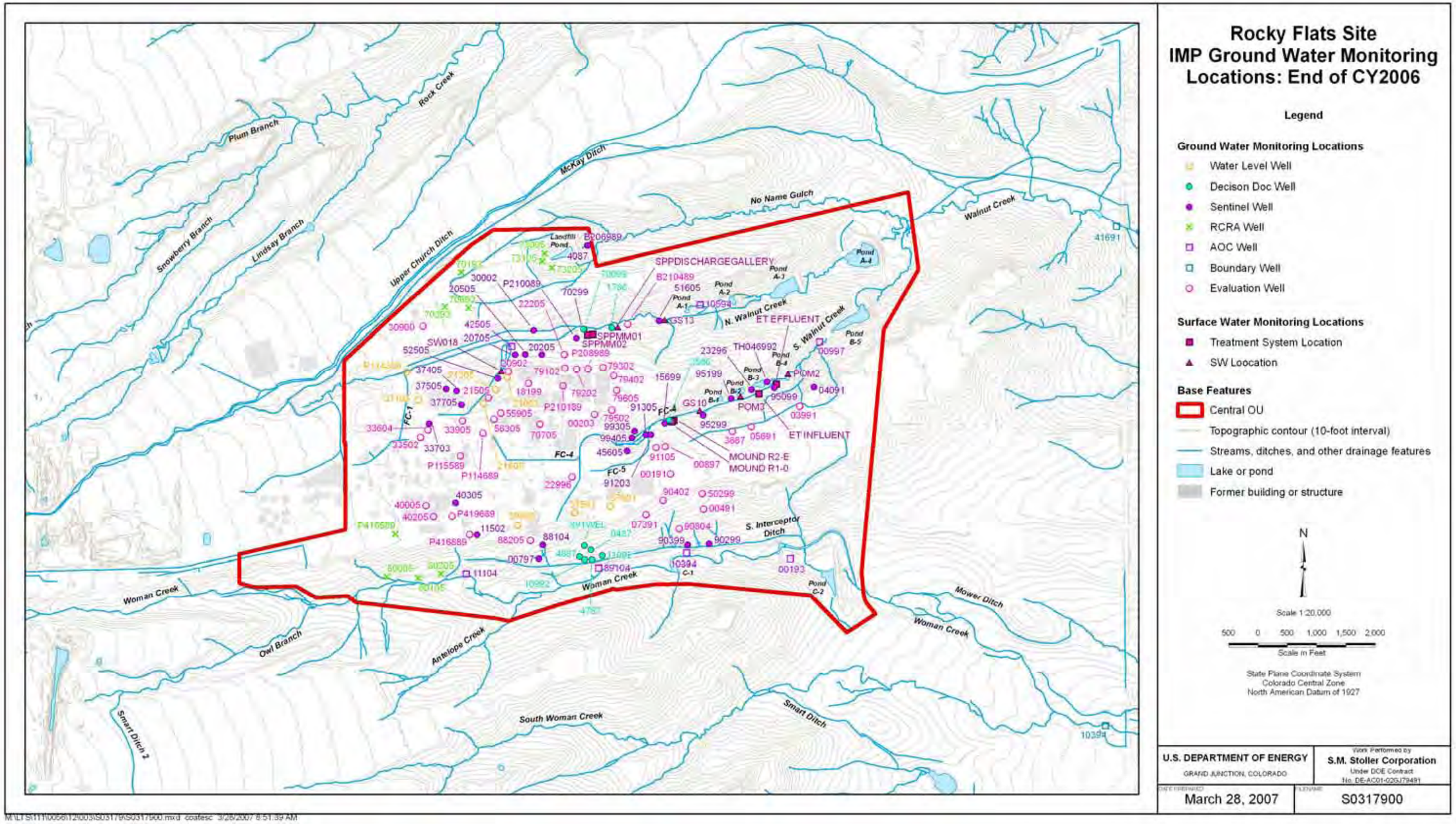



*Figure 3−1. Rocky Flats Site IMP Ground Water Monitoring Locations: End of CY 2006*

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*Table 3−1. IMP Classifications for the 2006 Ground Water Monitoring Network (K-H 2006c)*

| Well Classification | General Objective | Number of Wells | Monitoring Frequency |
|---|---|---|---|
| AOC | Monitor ground water quality and water levels in a drainage downgradient of a contaminant plume or group of plumes | 7 | Semiannual (2x/year) |
| Boundary | Monitor ground water quality and water levels in Woman Creek and Walnut Creek drainages at eastern (downgradient) Site boundary | 2 | Annual (1x/year) |
| Sentinel | Monitor ground water quality and water levels near contaminant plume edges and in drainages | 32 | Semiannual (2x/year) |
| Evaluation | Monitor ground water quality and water levels in or near contaminant source areas and in the former Industrial Area | 40 | Biennial (1x/every 2 years) |
| RCRA | Monitor ground water quality and water levels upgradient and downgradient of the PLF and the OLF | 10 | Quarterly (4x/year) |
| Decision Doc | Monitor ground water quality and/or water levels in accordance with published decision documents | 9 | Varies |
| Water Level | Monitor ground water levels (not water quality) in areas lacking coverage or of special interest | 26 | Semiannual (2x/year) |
| Treatment System[a] | Monitor quality of ground water treatment system influent, effluent, and downgradient surface water | 10 | Semiannual (2x/year) |
| Surface Water Support[a] | Monitor quality of surface water downgradient of contaminant plume | 2 | Semiannual (2x/year) |

[a]Treatment System and Surface Water Support locations are not monitoring wells but are included for completeness.
Note: AOC = Area of Concern, RCRA = Resource Conservation and Recovery Act, Decision Doc = Decision Document.

*Table 3−2. Additional Proposed Modifications to the Monitoring Network*

| Well / Location | Area | Current IMP Classification | Suggested Disposition |
|---|---|---|---|
| 0487 | OU1 | Decision Document | Abandon |
| 1786 | SPPTS | Decision Document | Abandon |
| 3586 | MSPTS | Decision Document | Abandon |
| 4787 | OU1 | Decision Document | Abandon |
| 4887 | OU1 | Decision Document | Abandon |
| 10992 | OU1 | Decision Document | Abandon |
| 11092 | OU1 | Decision Document | Abandon |
| 15199 | MSPTS | Water Level | Abandon |
| 15299 | MSPTS | Water Level | Abandon |
| 15399 | MSPTS | Water Level | Abandon |
| 15499 | MSPTS | Water Level | Abandon |
| 15599 | MSPTS | Water Level | Abandon |
| 15799 | MSPTS | Water Level | Abandon |
| 16199 | MSPTS | Water Level | Declassify |
| 16299 | MSPTS | Water Level | Declassify |
| 16399 | MSPTS | Water Level | Declassify |
| 16499 | MSPTS | Water Level | Declassify |
| 16599 | MSPTS | Water Level | Declassify |
| 70299 | SPPTS | Decision Document | Abandon[a] |
| 70799 | SPPTS | Water Level | Declassify |
| 70899 | SPPTS | Water Level | Declassify |
| 70999 | SPPTS | Water Level | Declassify |
| 71099 | SPPTS | Water Level | Declassify |
| 95699 | ETPTS | Water Level | Declassify |
| 95799 | ETPTS | Water Level | Declassify |
| 95899 | ETPTS | Water Level | Declassify |
| SPPMM02 | SPPTS | Treatment System | Replace with SPIN[b] |
| 891WEL (replaces 891COLWEL) | OU1 | Decision Document | Reclassify as Evaluation well (biennial, rather than quarterly) |
| 51605 (replaces 1386) | SPPTS | Sentinel | Reclassify as Evaluation well (biennial, rather than semiannual) |

Notes: Except as noted, these are recommended by the Water Working Group during development of the 2005 IMP.
[a]Well 70299 and well 70099 were both considered for retention or abandonment. The Working Group recommended one be retained; well 70299 was ultimately selected. However, data evaluations indicate well 70099 responds more quickly to changes in water quality, and may be the best candidate for retention; therefore, well 70099 is proposed for retention and 70299 abandonment as indicated above.
[b](Not discussed during IMP development) SPPMM02 is intended to represent system influent. However, location SPIN more accurately represents this water, as it is the well in which the pump is located. The decision document predates installation of that well, and specifies influent sampling at nearby piezometer 71099 (a.k.a. SPPMM02).
OU1 = Operable Unit 1 (881 Hillside); SPPTS = Solar Ponds Plume Treatment System; MSPTS = Mound Site Plume Treatment System; ETPTS = East Trenches Plume Treatment System.
Declassify = remove from routine monitoring and eliminate monitoring requirements, but retain for troubleshooting purposes.

Table 3−3 presents the 2006 schedule for routine sample collection, a subset of which are summarized in Table 3−4 as those scheduled samples that were not successfully collected (e.g., due to dry conditions.) Corresponding analytical results are published in the associated quarterly reports (DOE 2006f, 2006g, 2007d) and Appendix B.6.

*Table 3−3. Summary of Scheduled Routine Ground Water Sampling in CY 2006 (by Quarter)*

| Location | | Analytes | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **ID** | **IMP Class** | **VOC** | **U** | **Nitrate** | **Metals** | **Pu/Am** | **α/β** | **SVOC** |
| 0487 | DD | 1,2,3,4 | | | | | | |
| 1786 | DD | | 2,4 | 2,4 | | | | |
| 3586 | DD | 2,4 | 2,4 | | | 2,4 | 2,4 | |
| 3687 | E | 2 | | | | | | |
| 4087 | S | 2,4 | 2,4 | 2,4 | | | | |
| 4787 | DD | 2,4 | | | | | | |
| 4887 | DD | 2,4 | | | | | | |
| 00191 | E | 2 | | | | | | |
| 00193 | AOC | 2,4 | 2,4 | | | | | |
| 00203 | E | 2 | 2 | 2 | | | | |
| 00491 | E | 2 | | | | | | |
| 00797 | S | 2,4 | 2,4 | | | | | |
| 00897 | E | 2 | | | | | | |
| 00997 | AOC | 2,4 | 2,4 | 2,4 | | | | |
| 03991 | E | 2 | | | | | | |
| 04091 | S | 2,4 | | | | | | |
| 05691 | E | 2 | | | | | | |
| 07391 | E | 2 | 2 | | | | | |
| 10304 | AOC | 2,4 | 2,4 | 2,4 | | | | |
| 10394 | B | 2 | 2 | 2 | | | | |
| 10594 | AOC | 2,4 | 2,4 | 2,4 | | | | |
| 10992 | DD | 2,4 | | | | | | |
| 11092 | DD | 2,4 | | | | | | |
| 11104 | AOC | 2,4 | 2,4 | | | | | |
| 11502 | S | 2,4 | 2,4 | | | | | |
| 15699 | S | 2,4 | | | | | | |
| 18199 | E | 2 | | | | | | |
| 20205 | S | 2,4 | 2,4 | | | 2,4 | | |
| 20505 | S | 2,4 | 2,4 | | | 2,4 | | |
| 20705 | S | 2,4 | 2,4 | 2,4 | | 2,4 | | |
| 20902 | E | 2 | | | | | | |
| 21505 | E | 2 | | | | | | |
| 22205 | E | 2 | 2 | 2 | | | | |
| 22996 | E | 2 | 2 | | | | | |
| 23296 | S | 2,4 | 2,4 | | | | | |
| 30002 | S | 2,4 | | | | | | |
| 30900 | E | 2 | | | | | | |
| 33502 | E | 2 | | | | | | |
| 33604 | E | 2 | | | | | | |
| 33703 | S | 2,4 | | | | | | |
| 33905 | E | 2 | | | | | | |
| 37405 | S | 2,4 | 2,4 | 2,4 | | 2,4 | | |
| 37505 | S | 2,4 | 2,4 | 2,4 | | | | |
| 37705 | S | 2,4 | 2,4 | 2,4 | | 2,4 | | |
| 40005 | E | 2 | 2 | | | | | |
| 40205 | E | 2 | 2 | | | | | |

*Table 3−3 (continued). Summary of Scheduled Routine Ground Water Sampling in CY 2006 (by Quarter)*

| Location | | Analytes | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **ID** | **IMP Class** | **VOC** | **U** | **Nitrate** | **Metals** | **Pu/Am** | ***α/β*** | **SVOC** |
| 40305 | S | 2,4 | 2,4 | | | | | |
| 41691 | B | 2 | 2 | 2 | | | | |
| 42505 | AOC | 2,4 | | | | | | |
| 45605 | S | 2,4 | | | | | | |
| 50299 | E | 2 | | | | | | |
| 51605 | S | | 2,4 | 2,4 | | | | |
| 52505 | S | 2,4 | | | | | | |
| 55905 | E | 2 | 2 | 2 | | | | |
| 56305 | E | 2 | 2 | 2 | | | | |
| 70099 | DD | | 2,4 | 2,4 | | | | |
| 70193 | RCRA | 1,2,3,4 | | | 1,2,3,4 | | | |
| 70299 | S | | 2,4 | 2,4 | | | | |
| 70393 | RCRA | 1,2,3,4 | | | 1,2,3,4 | | | |
| 70693 | RCRA | 1,2,3,4 | | | 1,2,3,4 | | | |
| 70705 | E | 2 | 2 | | | | | |
| 73005 | RCRA | 1,2,3,4 | | | 1,2,3,4 | | | |
| 73105 | RCRA | 1,2,3,4 | | | 1,2,3,4 | | | |
| 73205 | RCRA | 1,2,3,4 | | | 1,2,3,4 | | | |
| 79102 | E | 2 | 2 | 2 | | | | |
| 79202 | E | 2 | 2 | 2 | | | | |
| 79302 | E | | 2 | 2 | | | | |
| 79402 | E | | 2 | 2 | | | | |
| 79502 | E | | 2 | 2 | | | | |
| 79605 | E | | 2 | 2 | | | | |
| 80005 | RCRA | 1,2,3,4 | | | 1,2,3,4 | | | 1,2,3,4 |
| 80105 | RCRA | 1,2,3,4 | | | 1,2,3,4 | | | 1,2,3,4 |
| 80205 | RCRA | 1,2,3,4 | | | 1,2,3,4 | | | 1,2,3,4 |
| 88104 | S | 2,4 | 2,4 | | | | | |
| 88205 | E | 2 | 2 | | | | | |
| 89104 | AOC | 2,4 | | | | | | |
| 891WEL | DD | 1,2,3,4 | | | | | | |
| 90299 | S | 2,4 | | | | | | |
| 90399 | S | 2,4 | | | | | | |
| 90402 | E | 2 | | | | | | |
| 90804 | E | 2 | | | | | | |
| 91105 | E | 2 | | | | | | |
| 91203 | S | 2,4 | | | | | | |
| 91305 | S | 2,4 | 2,4 | 2,4 | | | | |
| 95099 | S | 2,4 | | | | | | |
| 95199 | S | 2,4 | | | | | | |
| 95299 | S | 2,4 | | | | | | |
| 99305 | S | 2,4 | 2,4 | 2,4 | | | | |
| 99405 | S | 2,4 | 2,4 | 2,4 | | | | |
| B206989 | S | 2,4 | 2,4 | 2,4 | | | | |
| B210489 | E | | 2 | 2 | | | | |
| P114689 | E | 2 | | | | | | |
| P115589 | E | 2 | | | | | | |
| P208989 | E | 2 | 2 | 2 | | | | |

*Table 3−3 (continued). Summary of Scheduled Routine Ground Water Sampling in CY 2006 (by Quarter)*

| Location | | Analytes | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **ID** | **IMP Class** | **VOC** | **U** | **Nitrate** | **Metals** | **Pu/Am** | **α/β** | **SVOC** |
| P210089 | S | 2,4 | 2,4 | 2,4 | | | | |
| P210189 | E | 2 | 2 | 2 | | | | |
| P416589 | RCRA | 1,2,3,4 | | | 1,2,3,4 | | | 1,2,3,4 |
| P416889 | E | 2 | 2 | | | | | |
| P419689 | E | 2 | 2 | | | | | |
| TH046992 | S | 2,4 | | | | | | |
| MOUND R1-0 | TS | 2,4 | 2,4 | | | 2,4 | 2,4 | |
| MOUND R2-E | TS | 2,4 | 2,4 | | | 2,4 | 2,4 | |
| GS10 | TS | 2,4 | | | | | | |
| ET INFLUENT | TS | 2,4 | | | | | | |
| ET EFFLUENT | TS | 2,4 | | | | | | |
| POM2 | TS | 2,4 | | | | | | |
| SPPMM02 | TS | | 2,4 | 2,4 | | | | |
| SPPMM01 | TS | | 2,4 | 2,4 | | | | |
| SPP DIS GAL | TS | | 2,4 | 2,4 | | | | |
| GS13 | TS | | 2,4 | 2,4 | | | | |
| POM3 | SS | 2,4 | | | | | | |
| SW018 | SS | 2,4 | | | | | | |

**Notes:**
ID = Identification (name) of well/sampling location
IMP = Integrated Monitoring Plan
IMP classifications: AOC = Area of Concern; B = Boundary; S = Sentinel; E = Evaluation; DD = Decision Document; RCRA = Resource Conservation and Recovery Act; TS = Treatment System; SS = Surface Water Support.
2 (or other numeral) = Analyte requested; if blank, analyte not requested

*Table 3−4. Summary of Samples Not Successfully Collected*

| Location | | Analytes | | | | | | |
|---|---|---|---|---|---|---|---|---|
| ID | IMP Class | VOC | U | Nitrate | Metals | Pu/Am | α/β | SVOC |
| 4087 | S | 2,4 | 2,4 | 2,4 | | | | |
| 4787 | DD | 2,4 | | | | | | |
| 4887 | DD | 2,4 | | | | | | |
| 04091 | S | 4 | | | | | | |
| 07391 | E | | 2[a] | | | | | |
| 11092 | DD | 2,4 | | | | | | |
| 73005 | RCRA | 3 | | | 3 | | | |
| 88104 | S | | 4 | | | | | |
| 90299 | S | 2 | | | | | | |
| 95199 | S | 4 | | | | | | |
| 95299 | S | 2,4 | | | | | | |
| P416589 | RCRA | | | | 3 | | | |
| SPPMM02 | TS | | 4 | 4 | | | | |
| GS13 | TS | | | 2 | | | | |
| POM3[b] | SS | 2,4 | | | | | | |

**Notes:**
[a]Analyte successfully collected in 3rd quarter.
[b]Location is to be sampled in coordination with CDPHE, who did not request sampling in 2006.
Most unsuccessful attempts to collect samples were due to dry conditions.
ID = Identification (name) of well/sampling location
IMP = Integrated Monitoring Plan
IMP classifications: AOC = Area of Concern; B = Boundary; S = Sentinel; E = Evaluation; DD = Decision Document; RCRA = Resource Conservation and Recovery Act; TS = Treatment System; SS = Surface Water Support.
2 (or other numeral) = Analyte requested during the quarter indicated by the numeral, but not successfully collected; if blank, analyte not requested.

## 3.2 Nonroutine Ground Water Monitoring Activities of 2006

Nonroutine ground water monitoring was performed in 2006 in support of several data needs:

- Confirmatory sampling
- Accelerated sampling
- Investigative sampling

Confirmatory samples were collected in 2006 from Boundary well 41601. The nitrate concentration in a sample from this well (located at the intersection of Walnut Creek and Indiana Street) was reported at 470 mg/L, which is several orders of magnitude higher than normal (it is typically much less than 1 mg/L). The concentration reported for the confirmatory sample, 0.024 mg/L (B-qualified—there was nitrate present in the blank), confirmed the 470 mg/L result to be an outlier. Therefore, that datapoint will not be used in water quality assessments at well 41691.

Accelerated sampling may be performed if a data need is urgent, or if there is reason to believe the location to be sampled will be inaccessible during its normally scheduled sampling. The latter was the case at well 45605, which is installed within the active slump that is associated with former French drain outfall location SW056, south of former B991. This slump was first identified in January 2006 (DOE 2006f, 2006g, 2007d). As the slump developed over the course

of the year, the condition of the well grew increasingly precarious. Sampling of the well was accelerated to enable the collection of additional water quality data should the well no longer function.

Investigative sampling may be performed when additional data needs are identified that will not be satisfied by the routine monitoring schedule. In 2006, this was most clearly applicable to the Solar Ponds Plume Treatment System (SPPTS). Water quality data collected after a valve adjustment in May 2005 showed elevated nitrate in the system effluent. Subsequent valve adjustments were made, and samples collected to track their effects on effluent water quality. While improved, nitrate treatment was still inadequate and additional measures were taken. Nonroutine samples were collected throughout these efforts to evaluate their effects on effluent water quality in general and nitrate concentrations in particular. The topic of the SPPTS is discussed in greater detail in Sections 3.3.2.3 and 3.5.2.

Another application of investigative sampling was the continuation of the no-purge sampling evaluation begun in late 2005 (see DOE 2006e for additional discussion). This topic is addressed in Section 3.5.2.

All Evaluation wells were scheduled for sampling in the second quarter of 2006. In some cases this could be considered nonroutine, as these wells are routinely sampled every other year and most had been sampled in 2005. However, in this case sampling of Evaluation wells in 2006 is considered routine sampling, and is summarized in Table 3−3 of Section 3.1. The full set of Evaluation wells was sampled (along with the other wells) to meet two objectives:

- The results would represent the first comprehensive post-closure analytical data set for ground water (i.e., all Site wells scheduled for analytical sampling would be represented); and
- Sampling all Evaluation wells together effectively resets their schedules so that in the future they will all be sampled together, in the same quarter of the same year.

## 3.3 Description of Current Ground Water at the RFS

This section presents a summary evaluation of ground water quality and flow at the RFS during 2006. Ground water quality is addressed first, followed by interpretations of ground water flow. Included in the discussion of water quality are descriptions of the behavior of and any notable activities at the ground water treatment systems during 2006.

### 3.3.1 Trend Plots

Numerous statistical trend plots were constructed using analytical data collected from Sentinel wells as a part of this report and for the report on the second quarter (DOE 2006g). These are presented in Appendix B.3. Plots were also constructed for locations associated with the SPPTS, and are discussed separately in Section 3.3.2.3.

The Sanitas™ software package (version 8.6; NIC 2005) was used for statistical calculations, including the construction of trend plots. (This is noted for the purpose of completeness only; this report does not make any software recommendations.) For simplicity, because the fundamental objective of Sentinel wells is to monitor plume edges and ahead of plumes, and

because no interwell statistics were planned (only intrawell assessment of the trend of an analyte over time at each given well), all wells were assigned downgradient positions.

Trends were calculated and plotted using the S-K statistical method, as recommended for Rocky Flats ground water data (K-H 2004e) and in accordance with the IMP (DOE 2006c). Trends were only plotted for selected VOCs, nitrate, and U. Of the VOCs, those analytes represented by numerous detections above the RFCA action level were included in trend calculations. For U, isotopic data from a given date at a given well were converted to mass and then summed to provide the "total" U concentration.

There were many instances in the database of multiple U results on the same date at the same well (representing any or all of the following: isotopic analysis providing results in activity units, isotopic analysis providing results in mass units, total U analysis via a metals analytical method, total U via a total U analytical method, filtered sample, unfiltered sample). Before trends were calculated, these were winnowed to a single result on each given date. Factors that were evaluated in selecting the result for statistical use included:

- Filtration status;
- Validation qualifier(s);
- Lab qualifier(s); and
- Other U results from the well.

Because most samples were filtered, where both sample results were provided the filtered result was preferred for reasons of consistency. Similarly, where two very different results were presented, that most similar to other results from the well was retained. When the results were assigned different lab or validation qualifiers, that with the qualifier indicating it to be most representative was selected. (For example, if one result was assigned a lab qualifier and the other had no qualifier, and the validation on both was the same, the unqualified result was retained.) For the remaining instances of multiple results, the higher value was typically selected unless professional judgment did not support this decision.

Data from original wells were grouped with those from replacement wells to form a data set on which the statistics were based. This may prove to be inappropriate. As more data are collected, the populations from original and replacement wells may prove to be discontinuous, suggesting data from the original well(s) be removed from statistical assessments of the ground water data. This determination will be made as the post-closure data set gets large enough to allow such an evaluation. Therefore, it should be stressed that trends calculated for these wells may be misleading in that they may be strongly affected by well replacement, as opposed to reflecting only ground water geochemistry and hydrology.

The IMP (DOE 2006c) instructs that nondetects be replaced by zeroes when performing statistical assessments. However, to calculate trends the data cannot contain zeroes. Therefore, instead of zeroes, nondetects were replaced with a value of 0.001. The Sanitas™ program generally incorporates nondetects in calculations at one-half the listed value, which in this case would be 0.0005. Likewise, the program cannot perform the necessary statistical calculations if negative numbers are included in the results, as is occasionally the case with results for U isotopes and other radionuclides. Following conversion of isotopic activities to masses and

summation, the resulting sum was on a few occasions negative; these results were also replaced with 0.001.

No data replacements were made for some questionable results that warrant additional inspection prior to any conclusions being made. In particular, this applies to results for methylene chloride that are B-qualified, signifying the presence of blank contamination. As this compound is a commonly used laboratory solvent, B-qualified results should be carefully reviewed alongside corresponding detection limits, concentrations in the blanks, and other relevant data before basing any decisions on them. However, as shown by the S-K trend plots none of the methylene chloride trends are increasing with a 95 percent level of significance.

Table 3−5 summarizes the results of the S-K trend plots. Refer to Appendix B.3 for the plots and associated summary information, and Figure 3−1 for well locations. Significant trends are discussed later in this section in the context of their respective ground water contaminant plumes.

Additional data will be collected to further refine the trend plots. Given that the bulk of the data at all locations listed was collected before the Site was closed and in many cases is from wells that have since been replaced, some change in slope is to be expected as the hydrologic and geochemical systems stabilize. For a cross-walk of original and replacement wells, refer to the IMP (DOE 2006c: Appendix B, Table B-4).

### 3.3.2 Ground Water Plumes with Treatment Systems

Ground water quality data were obtained for all monitored areas in 2006. Analytical data have been published in quarterly reports issued for 2006 (DOE 2006f, 2006g, 2007d), plus Appendix B.6, and will not be duplicated here. Appendix B.3 includes the S-K trend plots that were contained within those documents and S-K trend plots for 4CQ06.

Ground water quality at the Site was largely consistent in 2006 with data reported in prior years. Ground water plumes that were identified and characterized through the decades of pre-closure ground water monitoring at the Site do not appear to have been greatly affected during 2006 by the closure of the Site. This is to be expected; 2006 was a relatively dry year, and additional time will be required for the ground water regime to equilibrate to post-closure conditions.

Although obvious, it is worth stressing that the reduction in size and density of the ground water monitoring network compared to that operating prior to Site closure does not permit the assessment of small-scale changes in plume configuration, nor in many other local-scale attributes. This is consistent with the vision and design of the closure network, which was never intended to provide the level of detail afforded by the extremely dense well network existing in past years.

This section describes the general ground water quality in various areas of interest across the Site. Descriptions of activities and conditions in 2006 at the three ground water contaminant plume treatment systems are also provided. Refer to previously published quarterly reports (DOE 2006f, 2006g, 2007d) and Appendix B.6 for any data that may be of special interest.

*Table 3−5. Summary of Seasonal Kendall Trend Calculations for Sentinel Wells*

| Well | General Location | Analyte | Trend | Significant at 95%? |
|---|---|---|---|---|
| **00797** | **B881** | **U** | **Increasing** | **Yes** |
| 4087 | East of PLF | U | Decreasing | No |
| **04091** | **East Trenches Plume** | **Carbon tetrachloride** | **Decreasing** | **Yes** |
| 04091 | East Trenches Plume | Methylene chloride | No slope | No |
| 04091 | East Trenches Plume | PCE | Decreasing | No |
| 15699 | MSPTS | 1,1-DCE | Decreasing | No |
| 15699 | MSPTS | Chloroform | Decreasing | No |
| **15699** | **MSPTS** | **Methylene chloride** | **Decreasing** | **Yes** |
| 15699 | MSPTS | PCE | Decreasing | No |
| 15699 | MSPTS | TCE | Decreasing | No |
| 15699 | MSPTS | Vinyl chloride | No slope | No |
| 20705 | B771 | Cis-1,2-DCE | Increasing | No |
| 20705 | B771 | TCE | No slope | No |
| **20705** | **B771** | **U** | **Increasing** | **Yes** |
| **23296** | **ETPTS** | **Carbon tetrachloride** | **Decreasing** | **Yes** |
| **23296** | **ETPTS** | **Chloroform** | **Decreasing** | **Yes** |
| **23296** | **ETPTS** | **Cis-1,2-DCE** | **Increasing** | **Yes** |
| **23296** | **ETPTS** | **Methylene chloride** | **Decreasing** | **Yes** |
| **23296** | **ETPTS** | **PCE** | **Decreasing** | **Yes** |
| 23296 | ETPTS | TCE | Decreasing | No |
| 37705 | B371 | Nitrate | Increasing | No |
| **40305** | **B444** | **Methylene chloride** | **No slope** | **Yes** |
| **40305** | **B444** | **TCE** | **Decreasing** | **Yes** |
| **51605** | **North Walnut Creek** | **U** | **Increasing** | **Yes** |
| **70299** | **SPPTS** | **Nitrate** | **Decreasing** | **Yes** |
| **88104** | **B881** | **U** | **Decreasing** | **Yes** |
| 90299 | 903 Pad/Ryan's Pit Plume | Carbon tetrachloride | Decreasing | No |
| 90299 | 903 Pad/Ryan's Pit Plume | PCE | No slope | No |
| **90299** | **903 Pad/Ryan's Pit Plume** | **TCE** | **Decreasing** | **Yes** |
| 90399 | 903 Pad/Ryan's Pit Plume | Carbon tetrachloride | Decreasing | No |
| 90399 | 903 Pad/Ryan's Pit Plume | Methylene chloride | No slope | No |
| 95099 | ETPTS | Carbon tetrachloride | No slope | No |
| **95099** | **ETPTS** | **Chloroform** | **No slope** | **Yes** |
| **95099** | **ETPTS** | **Methylene chloride** | **No slope** | **Yes** |
| 95199 | ETPTS | Cis-1,2-DCE | Decreasing | No |
| **95199** | **ETPTS** | **Methylene chloride** | **No slope** | **Yes** |
| 99305 | B991 | 1,1-DCE | No slope | No |
| 99305 | B991 | Cis-1,2-DCE | Increasing | No |
| 99305 | B991 | PCE | Increasing | No |
| 99305 | B991 | Vinyl chloride | No slope | No |
| 99305 | B991 | U | Increasing | No |
| 99405 | B991 | PCE | No slope | No |
| 99405 | B991 | TCE | No slope | No |
| 99405 | B991 | U | Decreasing | No |
| B206989 | East of PLF | Carbon tetrachloride | No slope | No |
| B206989 | East of PLF | Chloroform | No slope | No |

Notes:
Trends are listed if there is an 80% statistical significance; any decisions that may be made would be based on trends having a 95% significance.
Bold entries designate those trends having a 95% significance.

#### 3.3.2.1 Mound Plume and Treatment System

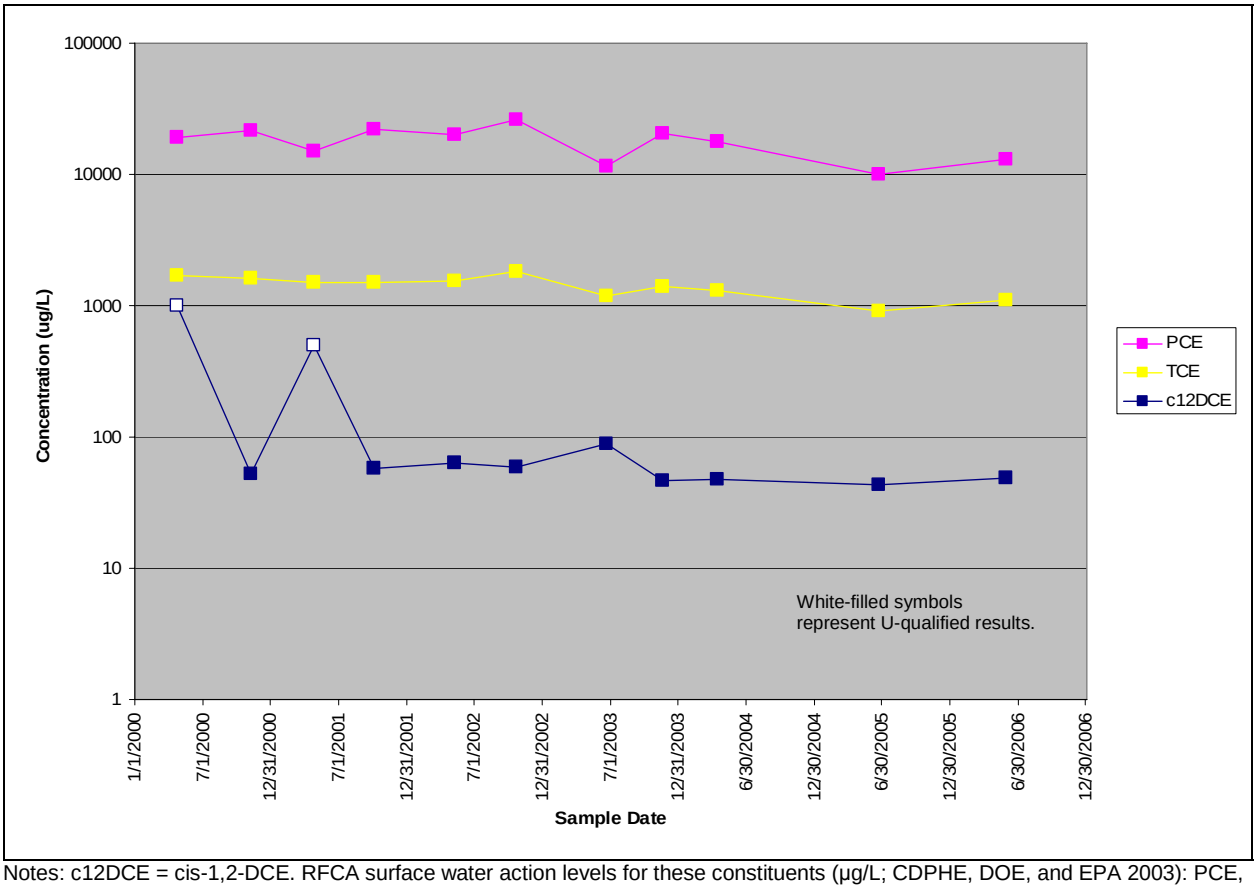
The Mound Plume (a.k.a. Mound Site Plume) is located north of the former 903 Pad. The source of the plume is a former drum storage area ("the Mound") that was in use in the 1950s. Some of the drums leaked, creating a ground water contaminant plume extending northward toward South Walnut Creek. The drums were removed in 1970, and contaminated soils were removed in 1997. The following paragraphs describe the plume and treatment system installed to address the ground water contamination.

***Mound Plume***

The Mound Plume is characterized by elevated concentrations of tetrachloroethene (PCE) and trichloroethene (TCE). The source area is very near Oil Burn Pit (OBP) #2, source of another VOC plume, which is discussed separately below.

The ground water sample collected from Evaluation well 00897 in 2006 contained concentrations of VOCs that were generally consistent with previous data. These results continue to support a possible (and modest) decrease in concentrations, as suggested in the 2005 Annual Report (DOE 2006e). However, the aerobic conditions in ground water here and elsewhere across the Site hamper more rapid biodegradation of the parent products (PCE and TCE). Figure 3−2 displays concentrations of PCE, TCE, and cis-1,2- dichloroethene (DCE) in ground water samples from well 00897. PCE in this well has ranged 11,500 μg/L to 26,000 μg/L from 2000 through 2004; in a sample collected in May 2006 it was reported at 13,000 μg/L. TCE has ranged from 1,170 μg/L to 1,800 μg/L over the same period, and in the May 2006 sample it was reported at 1,100 μg/L. Cis-1,2-DCE was reported at a concentration of 49 μg/L (estimated) in May 2006, from a range of 47.2−89.1 μg/L (estimated) over the same period. Additional data will be required to confirm any decreasing trend, but such a long-term pattern is expected following the source excavation in 1997.

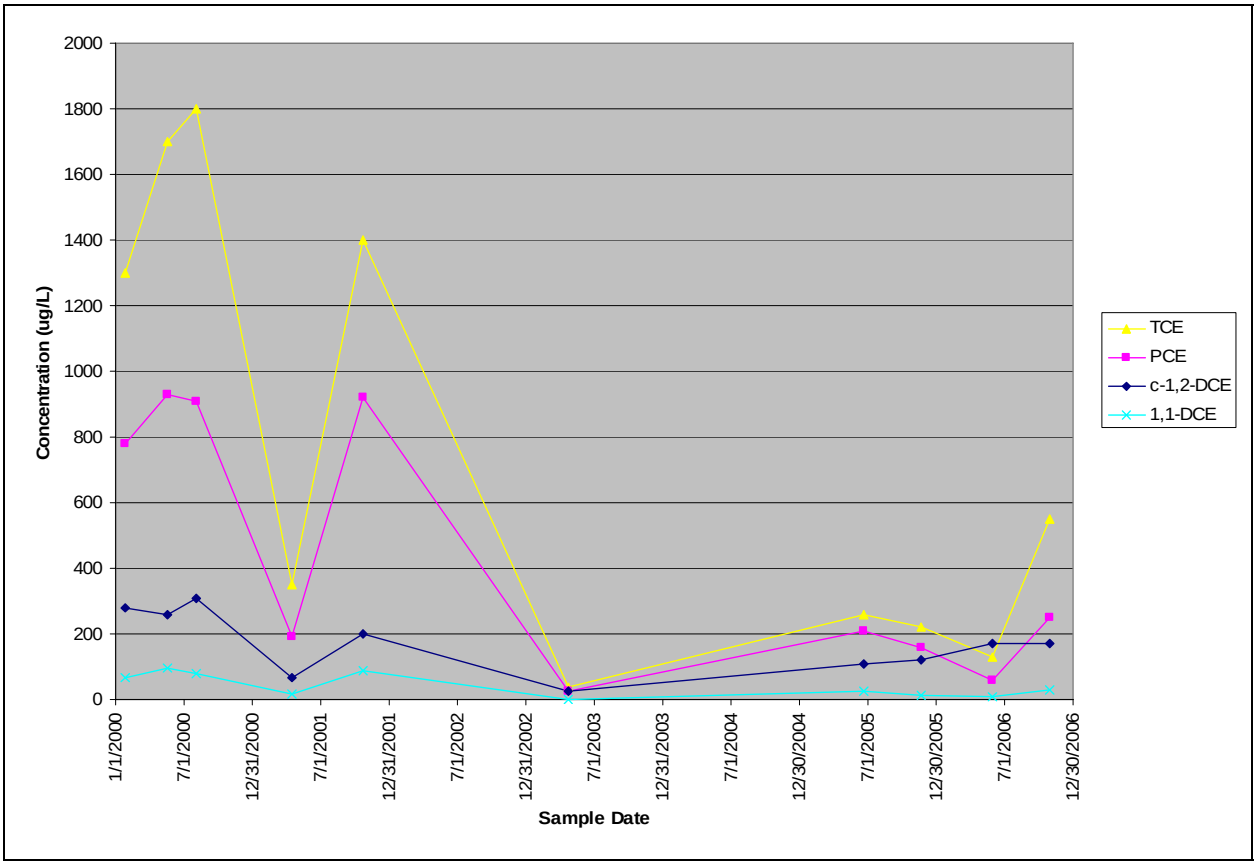
Downgradient of this source-area well, the plume is monitored by Sentinel well 15699 and Decision Document well 3586, but the Mound Site Plume Treatment System (MSPTS) intercept trench collects Mound plume ground water and diverts it to the treatment cells upgradient of these wells. Ground water at wells 15699 and 3586 is therefore physically separated from the main body of the plume. VOCs were detected in ground water samples from well 15699 during 2006, and primarily included PCE and its degradation byproducts, TCE, cis-1,2-DCE, and 1,1-DCE, as well as low concentrations of vinyl chloride. Well 3586 reported only very low concentrations of 1,1-dichloroethane (DCA) and cis- and trans-1,2-DCE.




Notes: c12DCE = cis-1,2-DCE. RFCA surface water action levels for these constituents (µg/L; CDPHE, DOE, and EPA 2003): PCE, 5; TCE, 5; cis-1,2-DCE, 70. In addition to the nondetects (U-qualified results), several other results were qualified (D, DB, J, DJ), but are not shown differently for the sake of simplicity. Note logarithmic concentration scale.

*Figure 3−2. Concentrations of PCE, TCE, and cis-1,2-DCE in Well 00897*

Figure 3−3 displays concentrations of PCE, TCE, cis-1,2-DCE, and 1,1-DCE in samples from well 15699. (Refer to DOE 2006f, 2006g, 2007d, and Appendix B.6 for additional analytical data.) Clearly evident in this figure is the strong correlation among concentrations of these constituents, with the relative concentration of each mirroring its position in the degradation pathway of PCE. With successive dechlorination, PCE is transformed to TCE and then to cis-1,2-DCE and 1,1-DCE (K-H 2004a). With more active biodegradation of chlorinated solvents in the Mound Plume, one would expect to see a relative increase of daughter products and a corresponding decrease in concentrations of parent products. Instead, the lock-step pattern of these constituent concentrations indicates a low rate of biodegradation over the time period displayed. This is consistent with conclusions made in previous studies of biodegradation in this area (e.g., K-H 2004a) and as noted in the discussion above regarding well 00897.




Notes: RFCA surface water action levels for these constituents (µg/L; CDPHE, DOE, and EPA 2003): PCE, 5; TCE, 5; cis-1,2-DCE, 70; and 1,1-DCE, 7. Several results are qualified (J, D, or in one case, U), but are not shown differently for the sake of simplicity.

*Figure 3−3. VOCs in Samples from Sentinel Well 15699*

S-K trend plots for well 15699 (see Appendix B.3, as well as Section 3.3.1 and Table 3−5) show a statistically significant (95 percent) decreasing trend for methylene chloride in well 15699. However, this is an artificial conclusion, as all data reported since 2001 have been nondetects.

### *Mound Site Plume Treatment System*

The MSPTS was the first ground water intercept/treatment system to incorporate zero-valent iron (ZVI) installed at the Site, and is actually among the first of its type in the world. This work was completed in 1998.

Routine maintenance activities performed at the MSPTS in 2006 included weekly raking of the media and inspection of influent and effluent flow conditions, and calibration of the flow monitoring instrumentation. Raking is performed to break up the crust that develops on the surface of the media. In July and August of 2006, due to the development of a much thicker oxidized crust on the surface of the ZVI, reduction in media permeability, and increasing concentrations of VOCs in system effluent (DOE 2006e), the ZVI media was replaced.

Media replacement was made difficult by the fact that the media in the west (upgradient) cell had become bound into a solid mass by the iron oxyhydroxides and other precipitates that had formed. Heavy equipment was required to break up and remove the spent media, and the process

took several weeks; Figure 3−4 includes photographs showing the replacement activity in progress.

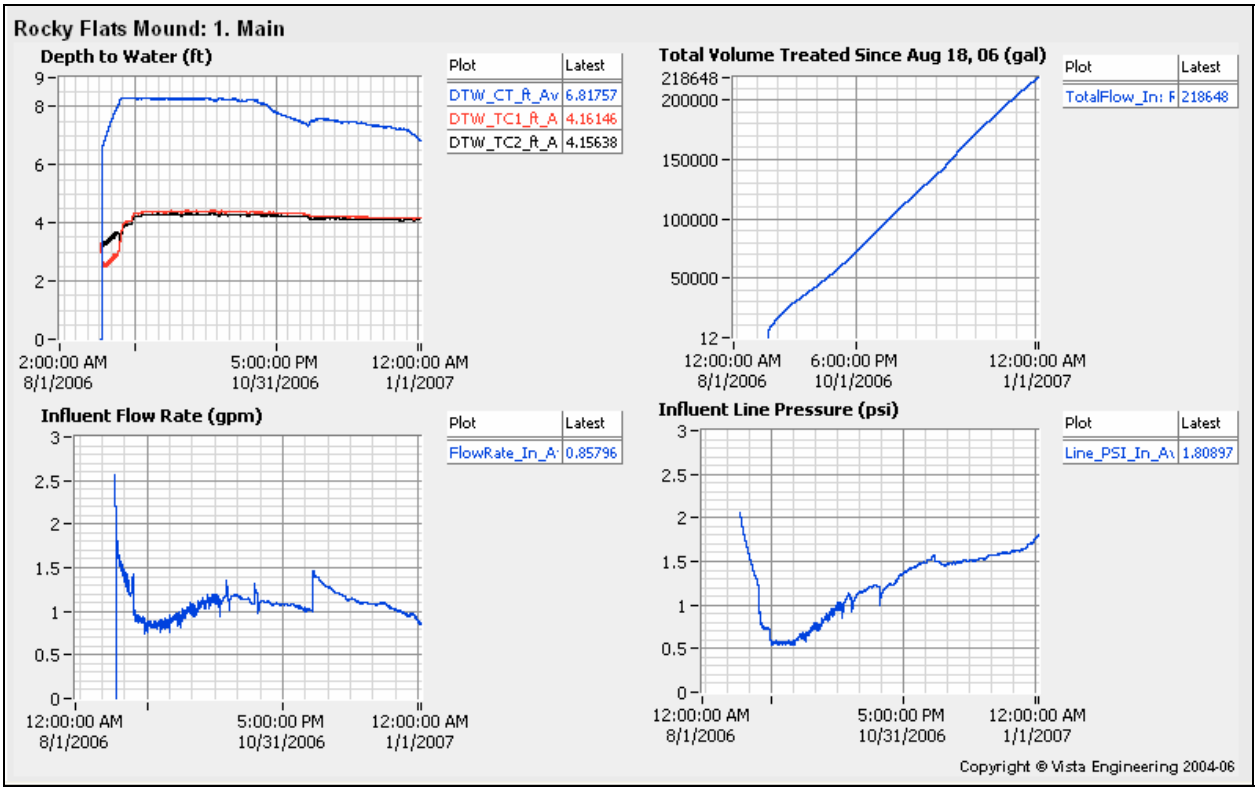
While the heavy equipment was present, additional automated instrumentation was installed at the MSPTS to support maintenance and operation of this system. Depth to water in the intercept trench and both cells is now measured, as are the influent flow rate and line pressure and the volume of water treated. Instruments are controlled and all plumbing is now routed through a small vault situated between the two treatment cells. (A similar instrumentation vault was installed earlier at the East Trenches Plume Treatment System [ETPTS], as discussed below.) Data from these instruments are accessed via the internet and are used to monitor and enhance the performance of the system.

Figure 3−5 summarizes data from this instrumentation since it was activated on August 18, 2006, through the end of 2006.

In addition to these instrumentation upgrades, the plumbing at the treatment cells was upgraded to afford an upflow condition within each cell (i.e., such that the influent water would move upward through the media and exit at the top of the cell, rather than moving downward through the media). Flow direction was not changed to upflow, but this configuration may be used in the future if there are indications that it would extend the life of the media and/or enhance treatment of the water.

Left: Using a backhoe to break up the solidified ZVI media. Right: Once broken up, the media had to be hand-loaded into the backhoe bucket; additional safety requirements included harness and man-lift, ventilation hoses, and personal protective equipment.

*Figure 3−4. Media Replacement at the MSPTS*




Notes: Upper left graph: DTW = depth to water in feet below measuring point. CT = collection (intercept) trench, TC1 and TC2 = treatment cells 1 (west) and 2 (east), respectively. Upper right graph: gal = gallons. Lower left graph: gpm = gallons per minute. Lower right graph: psi = pounds per square inch measured in the line feeding cell 1.

*Figure 3−5. Data Display From Automated Instrumentation Installed at the MSPTS*

Prior to the media replacement and installation of the instrumentation vault, the MSPTS exfiltration gallery was replaced. The original exfiltration line had been buried during the final Site regrading activities and construction of FC-4 in this area, and water was not discharging properly. The old line was removed and replaced with a new line that discharges to a gravel bed near FC-4; cleanout ports were also installed to allow the line to be maintained.

Flow rates through the system have remained well above pre-2005 levels following the addition of the flow through the corridor remaining after the removal of the 72-inch storm drain that was present along the west side of the MSPTS. (For additional background, see the 2005 Annual Report, DOE 2006e.) The total volume of water treated by the MSPTS during 2006 was approximately 430,000 gallons. This is about 20 percent less than that reported in 2005 (506,000 gallons), but is still approximately five times the volumes treated in 2003 and 2004 (82,000 and 86,000 gallons, respectively). The decrease relative to 2005 was anticipated and discussed in the 2005 Annual Report (DOE 2006e), and is likely due to the combined effects of the loss of Site contributions (e.g., dust suppression and leaking water supply) and the fact that 2006 was a dry year. It should also be noted that the MSPTS was shut down during the media replacement activity in July and August; during that period, water was stored within the intercept trench but some subsurface leakage would be expected.

Some VOCs were detected in MSPTS treated effluent in 2005 (DOE 2006e) and 2006, in part leading to the replacement of the media as discussed above. The main constituents detected in the effluent were PCE, TCE, and cis-1,2-DCE, results for which are summarized in Table 3−6.

Concentrations were increasing until the media was replaced in August, which restored water treatment. Refer to the quarterly reports (DOE 2006f, 2006g, 2007d) and Appendix B.6 for additional water quality data from the MSPTS.

*Table 3−6. Selected VOC Data from MSPTS Influent and Effluent*

| Sample Date | Analyte | MSPTS Influent | MSPTS Effluent |
|---|---|---|---|
| 1/27/2000 | DCE | 57 | 1 |
| | PCE | 120 | 0.1(J) |
| | TCE | 150 | 1(U) |
| 2/8/2000 | DCE | 59 | 2 |
| | PCE | 96 | 1(U) |
| | TCE | 140 | 1(U) |
| 3/7/2000* | DCE | 62 | 2 |
| | PCE | 100 | 1(U) |
| | TCE | 160 | 1(U) |
| 4/26/2000 | DCE | 61 | 4 |
| | PCE | 110 | 1(U) |
| | TCE | 140 | 1(U) |
| 5/15/2000 | DCE | 42(D) | 3 |
| | PCE | 68(D) | 1(U) |
| | TCE | 87(D) | 1(U) |
| 6/14/2000 | DCE | 42 | 1 |
| | PCE | 130 | 1(U) |
| | TCE | 150 | 1(U) |
| 7/19/2000 | DCE | 42 | 2 |
| | PCE | 64 | 1(U) |
| | TCE | 79 | 1(U) |
| 8/16/2000 | DCE | 39 | 1(J) |
| | PCE | 100 | 1(U) |
| | TCE | 140 | 1(U) |
| 9/13/2000 | DCE | 32.1 | 0.74 |
| | PCE | 65.3 | 0.5(U) |
| | TCE | 99.9 | 0.5(U) |
| 10/25/2000 | DCE | 37.3 | 0.69 |
| | PCE | 68.7 | 0.33(J) |
| | TCE | 104 | 0.5(U) |
| 4/19/2001 | DCE | 38(D) | 3 |
| | PCE | 44(D) | 1(U) |
| | TCE | 76(D) | 1(U) |
| 10/25/2001 | DCE | 23 | 0.9(J) |
| | PCE | 50 | 1(U) |
| | TCE | 74 | 1(U) |
| 4/25/2002 | DCE | 24 | 1.8 |
| | PCE | 41 | 1(U) |
| | TCE | 76 | 1(U) |
| 10/21/2002 | DCE | 11.3 | 1(U) |
| | PCE | 33.6 | 1(U) |
| | TCE | 46.8 | 1(U) |
| 4/17/2003 | DCE | 23 | 4.4 |
| | PCE | 31 | 0.38(J) |
| | TCE | 38 | 0.31(J) |
| 12/1/2003 | DCE | 9 | 1 |
| | PCE | 22.6 | 1(U) |
| | TCE | 31.4 | 1(U) |
| 6/9/2004 | DCE | 6.98 | 1(U) |
| | PCE | 21.5 | 1(U) |
| | TCE | 28.3 | 1(U) |
| 10/20/2004 | DCE | 5.59 | 0.83(J) |
| | PCE | 25.7 | 0.72(J) |
| | TCE | 29.4 | 2.74 |
| 6/21/2005 | DCE | 3.93 | 2.04 |
| | PCE | 29.1 | 1.66 |
| | TCE | 34.9 | 1.28 |
| 11/18/2005 | DCE | 20 | 6.3 |
| | PCE | 81 | 4.5 |
| | TCE | 90 | 1.6 |
| 4/25/2006 | DCE | 920 | 390 |
| | PCE | 150 | 5.7 |
| | TCE | 150 | 7.6 |
| 6/5/2006 | DCE | 2040(D) | 793(D) |
| | PCE | 125(D) | 3 |
| | TCE | 158(D) | 4.6 |
| 10/5/2006 | DCE | 6580(D) | 0.78(J) |
| | PCE | 87.2 | 1(U) |
| | TCE | 93.7 | 1(U) |

Results are in µg/L. DCE = cis-1,2-dichloroethene; PCE = tetrachloroethene; TCE = trichloroethene; RFCA action levels in µg/L for these constituents are 70, 5, and 5 respectively (CDPHE, DOE, and EPA 2003). Lab qualifiers: D = analysis was performed at a dilution; J = result is estimated below the sample quantitation limit; U = analyte not detected. * Effluent sample was collected the next day, March 8 2000. Formal sampling location names are Mound R1-0 (influent) and Mound R2-E (effluent).

Data for samples of MSPTS influent (Table 3−6) show the influence of the modifications made upgradient of the system. As reported in the 2005 Annual Report (DOE 2006e) and mentioned

above, the preferential pathway formed by the corridor that once hosted a 72-inch storm drain was tied into the MSPTS ground water intercept trench. This pathway now transports water from the OBP #2 source area to the MSPTS. The source area was remediated prior to Site closure and Hydrogen Release Compound® (HRC) was added to the backfill, enhancing the natural degradation of residual VOCs. This is the most likely reason for the sharp increase in the daughter product, cis-1,2-DCE, and the smaller increases in parent products such as PCE, TCE, and other VOCs (see DOE 2006f, 2006g, 2007d, and Appendix B.6) in MSPTS influent.

Two grab samples were collected in 2006 (one each in May and October) at the performance monitoring location for the MSPTS, surface water station GS10. As in 2005, results include detections of VOCs, but none exceed the corresponding surface water surface water action levels. More importantly, concentrations appear to be decreasing since the MSPTS media was replaced in August. VOCs detected in the May sample include 1,1-DCA (8.5 µg/L), cis-1,2-DCE (39 µg/L), and TCE (0.47 µg/L, J-qualified, estimated). VOCs detected in the October sample include 1,1-DCA (1.8 µg/L) and cis-1,2-DCE (0.19 µg/L, J-qualified, estimated). Collection of samples for the analysis of VOCs at this location began in 2005. As additional data are available, it will be possible to calculate trends of any VOCs that may be consistently detected at GS10.

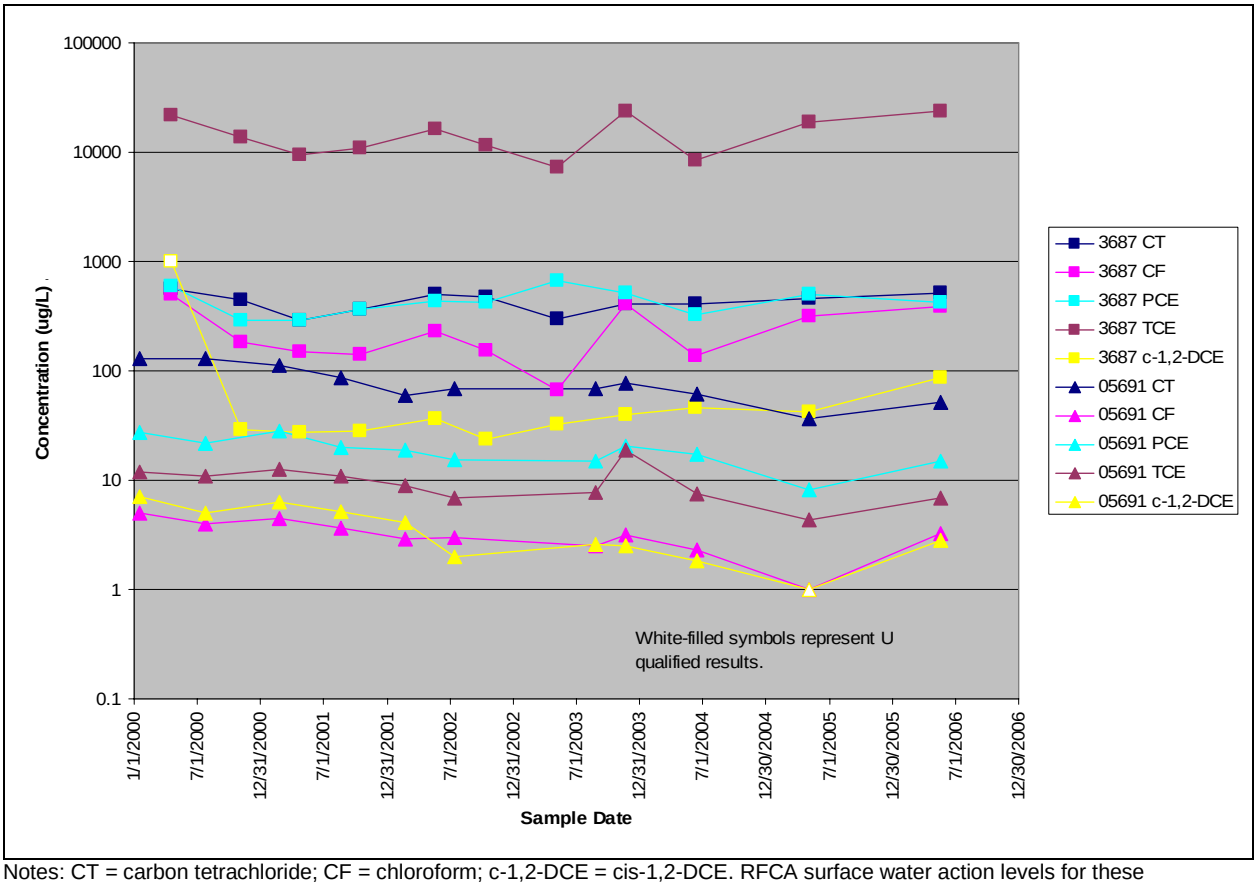
#### 3.3.2.2 East Trenches Plume and Treatment System

The East Trenches Plume is an area of contamination named after several disposal trenches that contribute VOCs to ground water. These trenches are located on the pediment south of South Walnut Creek, in former OU 2. The source of this plume is Trenches T-3 and T-4, which were remediated in 1996. In addition, a portion of the 903 Pad Plume flows toward the northeast and joins the East Trenches Plume. The following paragraphs describe the plume and treatment system installed to address this contamination.

***East Trenches Plume***

Evaluation wells 3687 and 05691 monitor the source areas of the East Trenches Plume, Trenches T-3 and T-4, respectively. More distal portions of the plume are monitored by Evaluation well 03991 and Sentinel well 04091 to the east-northeast, and Area of Concern (AOC) well 00997 at the mouth of Pond B-5 in the South Walnut Creek drainage. Sentinel wells 95099, 95199, 95299, 23296, and TH046991 monitor the ETPTS, which was installed in 1999 to collect and treat contaminated ground water of the East Trenches Plume as it migrates toward the B-Ponds and South Walnut Creek.

Source-area Evaluation wells 3687 and 05691 produce samples with elevated concentrations of VOCs of the PCE and carbon tetrachloride families. The VOC present in the highest concentrations in ground water samples from well 3687 is TCE, while samples from 05691 are highest in carbon tetrachloride. Figure 3−6 provides a summary display of the most prevalent VOCs in these two wells, using a logarithmic concentration scale to better illustrate results for lower-concentration constituents.



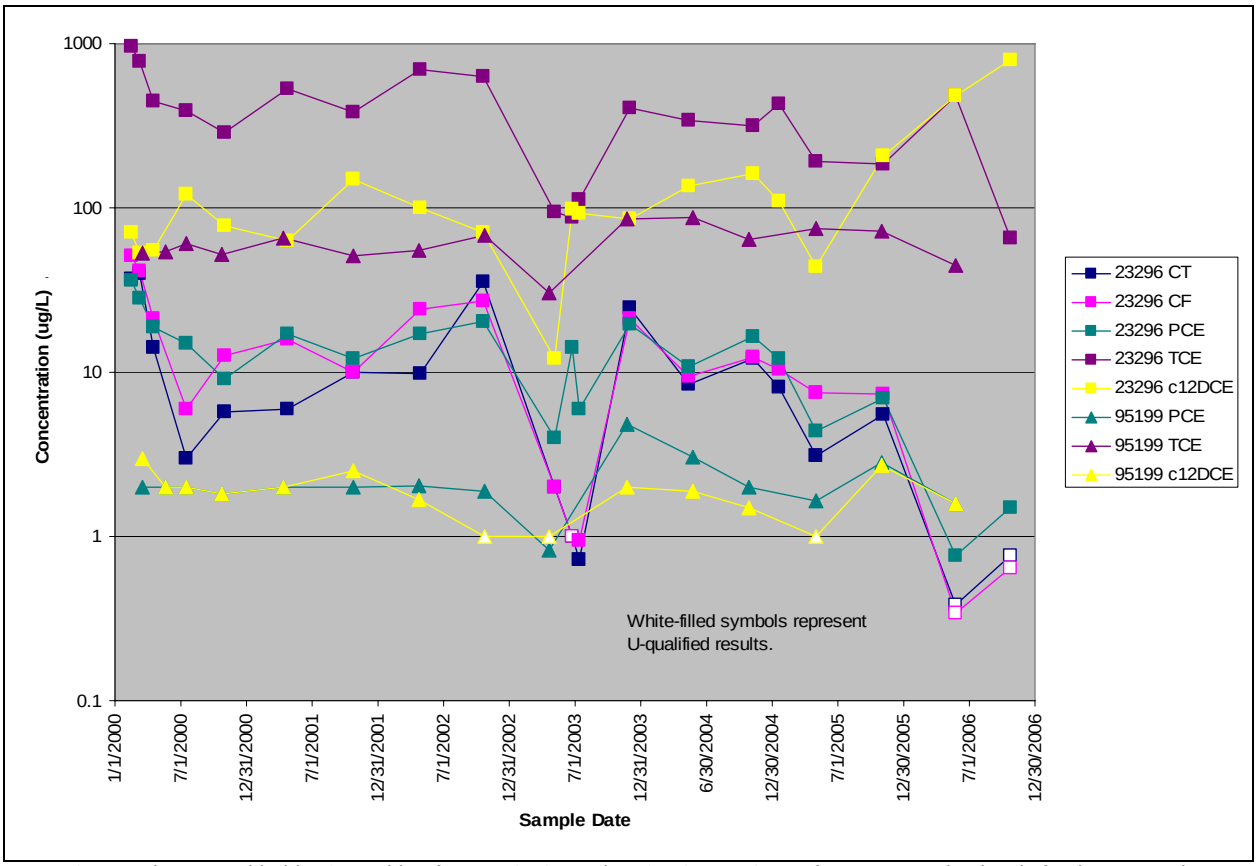

Notes: CT = carbon tetrachloride; CF = chloroform; c-1,2-DCE = cis-1,2-DCE. RFCA surface water action levels for these constituents (µg/L; CDPHE, DOE, and EPA 2003): CT, 5; CF, 5.7; cis-1,2-DCE, 70. In addition to the nondetects (U-qualified results), several other results were qualified (D, E, J), but are not shown differently for the sake of simplicity. Note logarithmic concentration scale.

*Figure 3−6. Primary VOCs in Samples from East Trenches Plume Source-Area Evaluation Wells 3687 and 05691*

As indicated by Figure 3−6, concentrations of VOCs in samples from well 3687 do not appear to be changing appreciably. Concentrations in well 05691 may be exhibiting a modest decrease, although the sample collected in 2006 shows several VOCs at higher concentrations than in one or more prior samples. Apparent decreases or increases in concentrations will be evaluated as more post-closure data are available.

Wells monitoring the downgradient portion and edges of the East Trenches Plume include Sentinel wells 23296, 95099, 95199, 95299, and TH046992. With the exception of wells 95099 and TH046992, each is physically separated from the main body of the East Trenches Plume by the ETPTS ground water intercept trench.

Analytical data for these wells in 2006 were generally consistent with those from recent years. (Well TH046992 is represented by few data, as it was added to the network in 2005.) Of these wells, samples from 23296 contain the highest concentrations of VOCs. Figure 3−7 displays VOCs most commonly detected in these wells at concentrations exceeding the corresponding RFCA action level. Refer to Appendix B.3 for S-K trend plots.




Notes: CT = carbon tetrachloride; CF = chloroform; c12DCE = cis-1,2-DCE. RFCA surface water action levels for these constituents (µg/L; CDPHE, DOE, and EPA 2003): CT, 5; CF, 5.7; cis-1,2-DCE, 70. In addition to the nondetects (U-qualified results), several other results were qualified (D, J), but are not shown differently for the sake of simplicity. Note logarithmic concentration scale.

*Figure 3−7. Most Commonly Detected VOCs in Sentinel Wells Downgradient of the ETPTS*

S-K trend plots (Appendix B.3, and summarized above in Section 3.3.1 and Table 3−5) indicate 95 percent significant trends for several constituents monitored in the East Trenches Plume wells. Well 23296 is represented by significant trends for carbon tetrachloride (decreasing), chloroform (decreasing), cis-1,2-DCE (increasing), methylene chloride (decreasing), PCE (decreasing), and TCE (decreasing). These trends suggest the source removal actions are affecting concentrations of VOCs as desired; the increasing trend in cis-1,2-DCE suggests ongoing degradation of parent compounds.

Wells 95099 and 95199 also are represented by significant trends, although in each case the trend is no slope: chloroform and methylene chloride at well 95099, and methylene chloride at well 95199. However, these trends are artificial: all of the data since 2001 for methylene chloride have been nondetects, and almost all data for chloroform are nondetects, with the exceptions being J-qualified (estimates) and the highest such detection estimated at 0.3 µg/L.

In the distal portions of the plume, well 04091 shows a statistically-significant (95 percent significance) decreasing trend in carbon tetrachloride concentrations (Table 3−5).

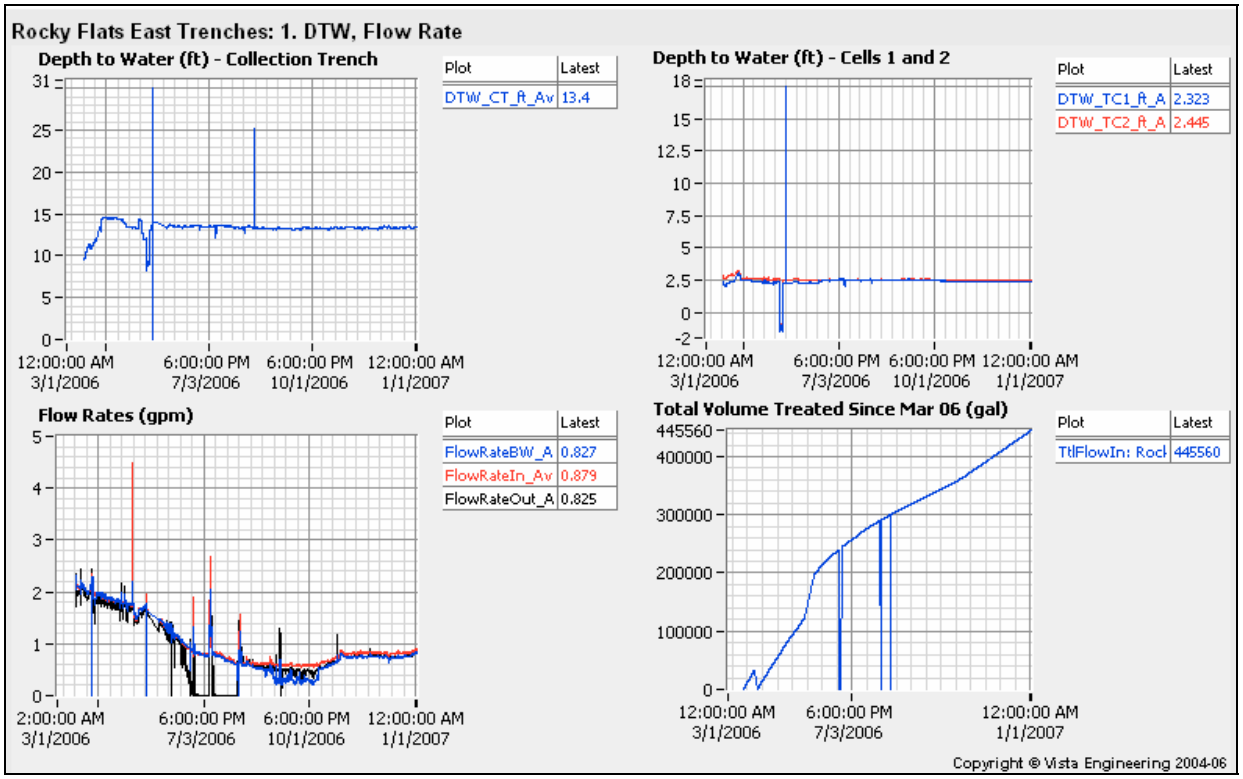
### *East Trenches Plume Treatment System*

The ETPTS was installed in 1999. Its design is very similar to that of the MSPTS. However, the intercept trench for the ETPTS is 1,200 feet long, compared to the 220 foot long MSPTS trench. The longer trench is required to intercept the broader East Trenches Plume as it flows toward South Walnut Creek and the B-Ponds.

The ETPTS treated approximately 675,000 gallons of water in 2006. This is significantly less than in recent years; it is about 38 percent of the total flow in 2005 (1.8 million gallons). In 2003, 2.1 million gallons were treated, and in 2004, 1.5 million gallons were treated. This decrease in flow suggests a large combined effect from the dry year and loss of artificial contributions; indeed, adjacent Ponds B-1, B-2, B-3, and B-4 were dry or nearly so for much of the spring, summer, and fall of 2006.

For the first several years following its installation, the ETPTS functioned well. However, frequent intensive maintenance (including media replacement) was required beginning in 2003. The media in both cells was replaced in September−October 2003, partially replaced in both cells in May 2004, partially removed in December 2004, and completely replaced in September 2005. Other more intensive maintenance work at the ETPTS in recent years has included using heavy equipment to break up the crusted iron, flushing the media with acid to restore flow, and performing plumbing repairs and upgrades.

Routine maintenance at the ETPTS in 2006 included weekly raking of the media, inspection of influent and effluent flow conditions, and calibration of the flow monitoring instrumentation. Automated instrumentation was installed in March 2006 to enhance maintenance and operation of the system. This was reported in more detail in the 2005 Annual Report (DOE 2006e) and in the corresponding quarterly report (DOE 2006f), and those details will not be reiterated here. Briefly, the instrumentation and associated vault are similar to that installed at the MSPTS, as described above, and include measurement of water depth in the intercept trench (collection trench) and both cells, and flow rates. Figure 3−8 provides the summary display of data collected from the installation of the instrumentation vault through the end of 2006; occasional spikes and other discontinuities in the data represent periods of troubleshooting and instrumentation correction.




Notes: Upper left graph: DTW = depth to water in feet below measuring point. CT = collection (intercept) trench.
Upper right graph: DTW = depth to water in feet below measuring point. TC1 and TC2 = treatment cells 1 and 2, respectively. Lower left graph: gpm = gallons per minute, BW = between cells, In = influent, Out = effluent. Lower right graph: gal = gallons.

*Figure 3−8. Data Display From Automated Instrumentation Installed at the ETPTS*

In addition to these instrumentation upgrades, the plumbing at the treatment cells was upgraded to afford an upflow condition within each cell (i.e., such that the influent water would move upward through the media and exit at the top of the cell, rather than moving downward through the media) and the discharge line was replaced. Flow direction was not changed to upflow, but this configuration may be used in the future if there are indications that it would extend the life of the media and/or enhance treatment of the water. Also, the discharge line was replaced because the original line did not present sufficient gradient, causing water to frequently back up into the effluent manhole.

The ETPTS treatment of ground water in 2006 was improved with respect to much of its history. The system was sampled twice: once in May, and once in October. VOCs detected in the effluent on both occasions included 1,1-DCA (1 µg/L in May, and estimated—J-qualified—0.45 µg/L in October), cis-1,2-DCE (27 µg/L and estimated 4.3 µg/L), PCE (4.1 µg/L and estimated 0.85 µg/L), and TCE (2.8 µg/L and estimated 0.18 µg/L). These recent results can be compared with earlier data in Table 3−7; refer to quarterly reports (DOE 2006f, 2006g, 2007d) and Appendix B.6 for additional data from 2006.

*Table 3−7. Summary of Recent VOC Data from ETPTS Influent and Effluent*

| DATE | 1,1-DCE | | Carbon Tetrachloride | | Chloroform | | cis-1,2-DCE | | Methylene Chloride | | PCE | | TCE | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Influent | Effluent | Influent | Effluent | Influent | Effluent | Influent | Effluent | Influent | Effluent | Influent | Effluent | Influent | Effluent |
| 1/28/04 | 5 | 1(U) | 130 | 1(U) | 71 | 1.1 | 40 | 9.5 | 5(U) | 20 | 290 | 0.93(J) | 2300 | 1.8 |
| 2/25/04 | 4.8(J) | 1(U) | 150 | 1(U) | 71 | 1.4 | 40 | 10 | 2.7(JB) | 19(B) | 270 | 1.1 | 2400 | 2.5 |
| 3/22/04 | 4.8(J) | 1(U) | 180 | 1(U) | 71 | 1 | 39 | 9.7 | 2.6(U) | 21 | 270 | 1.2 | 2400 | 1.8 |
| 5/26/04 | 2.93 | 1(U) | 216 | 1(U) | 65.1 | 1(U) | 28 | 11.5 | 1(U) | 17 | 618(D) | 3.38 | 5510(D) | 6.36 |
| 6/22/04 | 3.2(J) | 1(U) | 130 | 1(U) | 59 | 1(U) | 29 | 8 | 6.7(JB) | 14(B) | 240 | 1.9 | 1900 | 1.8 |
| 7/29/04 | 3.3 | 1(U) | 142(D) | 1(U) | 54.1 | 1(U) | 29.4 | 7.7 | 2.3 | 14.1(U) | 354(D) | 1.8 | 1960(D) | 0.69(J) |
| 8/19/04 | 1.6 | 1(U) | 68.1 | 1(U) | 26.6 | 1(U) | 13.3 | 7.4 | 1(U) | 13.7 | 137(D) | 1.2 | 774(D) | 0.55(J) |
| 10/20/04 | 4.21 | 1(U) | 160 | 1(U) | 72.9 | 2.56 | 32.6 | 11.3 | 1(U) | 15.6 | 230(D) | 2.13 | 1170(D) | 1.91 |
| 5/12/05 | 5.09 | 1.59 | 131 | 1(U) | 66 | 22.2 | 30.4 | 36.4 | 1(U) | 14.6 | 256(D) | 21.9 | 2280(D) | 33.1 |
| 6/7/05 | 5.1(J) | 1.1 | 160 | 1(U) | 81 | 30 | 33 | 44 | 10(U) | 22(B) | 340 | 36 | 3300 | 66 |
| 11/2/05 | 50(U) | 1.6 | 151 | 1(U) | 74.8 | 0.73(J) | 50.7 | 39.6 | 250(U) | 18.2 | 350 | 1(U) | 2500 | 4.4 |
| 5/17/06 | 6.1(J) | 0.39(J) | 170 | 0.23(U) | 75(J) | 1.9(U) | 46 | 27 | 0.32(U) | 32 | 280 | 4.1 | 2800 | 2.8 |
| 10/31/06 | 3.9(J) | 0.14(U) | 120(J) | 0.19(U) | 75(J) | 0.16(U) | 40(J) | 4.3(J) | 6.4(U) | 0.32(U) | 290(J) | 0.85(J) | 2100(J) | 0.18(J) |

Notes: Results are in µg/L. Parenthetical values represent data qualifiers: D = analysis was performed at a dilution; J = result is estimated; U = analyte not detected at concentration shown; B = analyte was detected in the sample and method blank. RFCA action levels in µg/L (CDPHE, DOE, and EPA 2003): 1,1-DCE, 7 µg/L; carbon tetrachloride, 5 µg/L; chloroform, 5.7 µg/L; cis-1,2-DCE, 70 µg/L; methylene chloride, 4.7 µg/L; PCE, 5 µg/L; TCE, 5 µg/L.

The performance monitoring location for the ETPTS is POM2, which is located in Pond B-4. Sampling in support of the ETPTS began at this location in 2005. Grab samples were collected from POM2 in May and November 2006. There were no validated detections of VOCs in either sample.

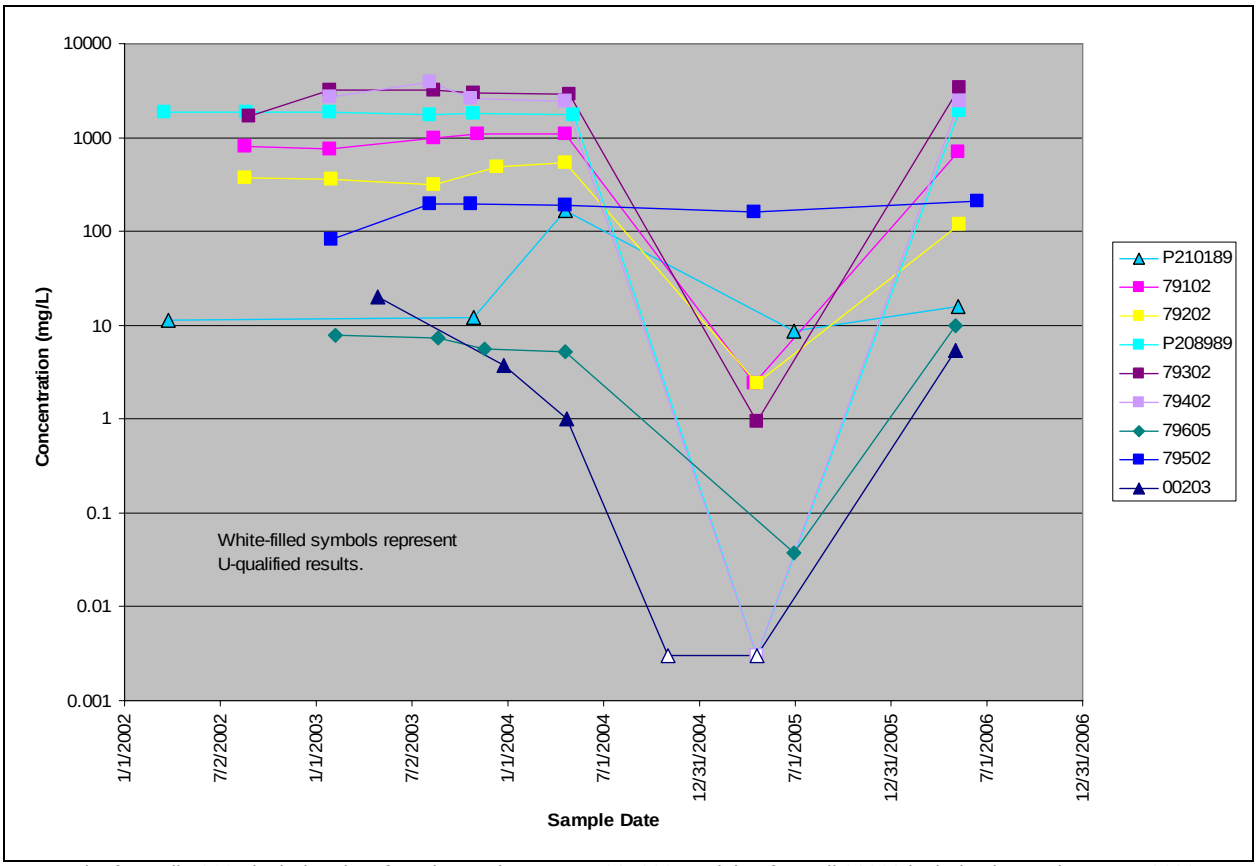
### 3.3.2.3 Solar Ponds Plume and Treatment System

The SPP is an area of elevated nitrate and U concentrations in ground water. (Note: The analytical data report concentrations of nitrate/nitrite as N; this is referred to herein simply as nitrate.) The former Solar Evaporation Ponds (SEPs), which were located on the pediment in the northeastern portion of the former IA, were the source of this contamination. Liquid wastes generated during production were stored in these ponds. Leaks that occurred over the years are the source of the ground water plume. The following paragraphs describe the plume, the treatment system installed to address this contamination, and work performed in 2006 on the system. Discussion of special investigations of the system is provided in Section 3.5.2.

***Solar Ponds Plume***

Ground water in the SEP area is contaminated with nitrate and U. The westernmost portion of this area, generally coinciding with the location of former Pond 207-C, also is contaminated with VOCs.

Concentrations of nitrate in the main body of the plume in 2006 were consistent with results prior to 2005, confirming that some of the data reported in 2005 were anomalous and not representative (see DOE 2006e). Figure 3−9 provides summary nitrate data for recent years for ground water samples from the Evaluation wells surrounding the SEPs.



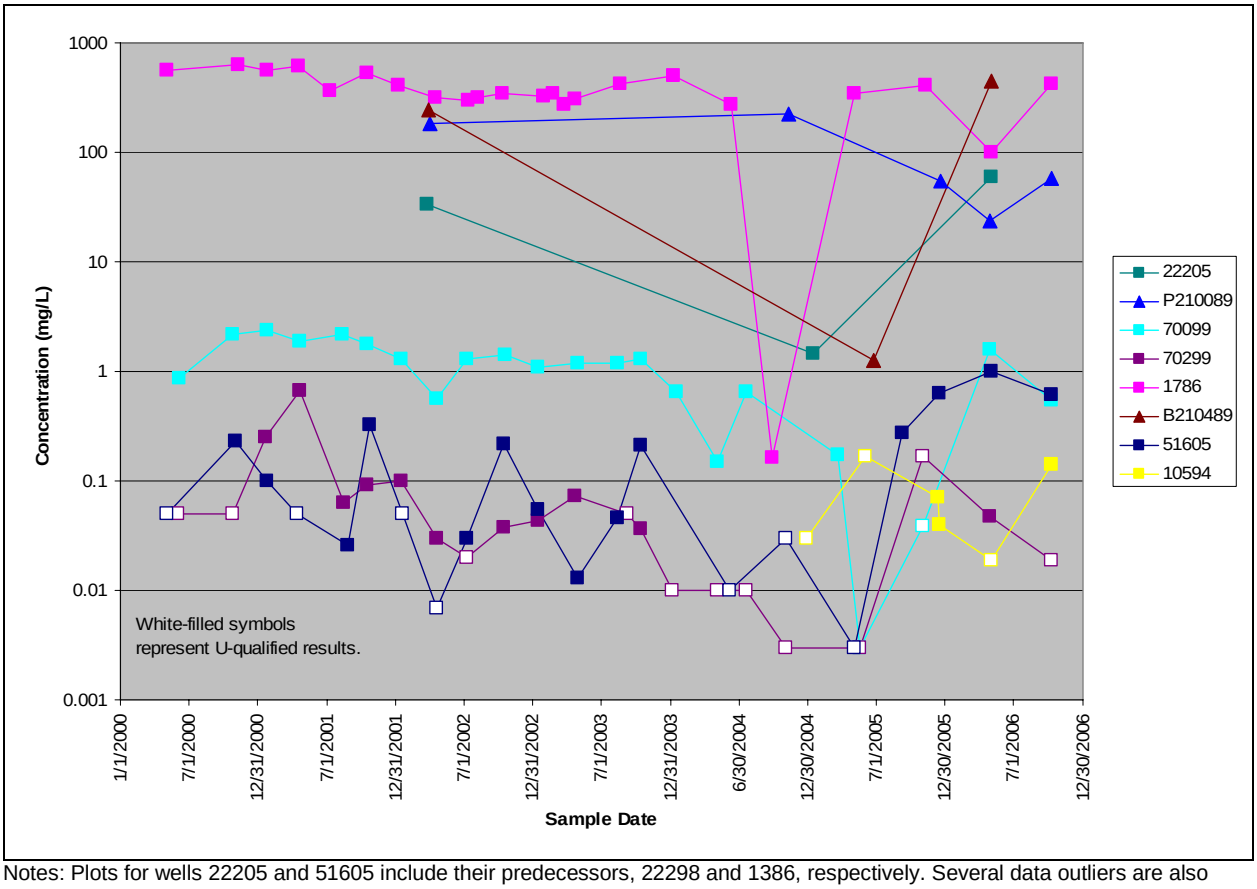

Notes: Plot for well 79605 includes data from its predecessor, P207989; and that for well 00203 includes its predecessor, 00297. Atypically-low results in 2005 represent data outliers. RFCA surface water action level for nitrate (mg/L; CDPHE, DOE, and EPA 2003) is 100 in the area of the Solar Ponds Plume. In addition to the nondetects (U-qualified results), several other results were qualified (B), but are not shown differently for the sake of simplicity. Note logarithmic concentration scale.

*Figure 3−9. Concentrations of Nitrate in Ground Water Samples From the Solar Ponds Plume Source Area*

Nitrate behaves fairly conservatively—it flows readily with ground water, and is not attenuated as much as many other constituents. In addition, the contaminant source is no longer active and vegetation has been established, which would act to reduce residual concentrations of nitrate. Although concentrations of nitrate appear relatively stable over the past several years, suggesting this contamination will not be flushed rapidly from the area, as revegetation efforts are rewarded the removal of nitrate may accelerate.

Concentrations of nitrate farther from the source area also appear relatively stable, as shown below in Figure 3−10. Worth noting are the differences between paired wells 70099 and 70299, with the former showing higher concentrations of nitrate than the latter. This is because well 70099 screens unconsolidated materials while 70299 screens the weathered bedrock, which is a less-permeable claystone. Both appear to be outside the nitrate plume, and were installed in 1999 to evaluate bypass of the SPPTS around the western end of the intercept trench. Also worth noting is the statistically-significant (95 percent) decreasing trend for nitrate at well 70299. This trend is artificial, however, as almost all results since 2003 have been nondetects. (See Appendix B.3 for the S-K trend plots, which are also summarized above in Section 3.3.1 and Table 3−5.) Figure 3−10 confirms that AOC well 10594 and Sentinel well 51605 are both

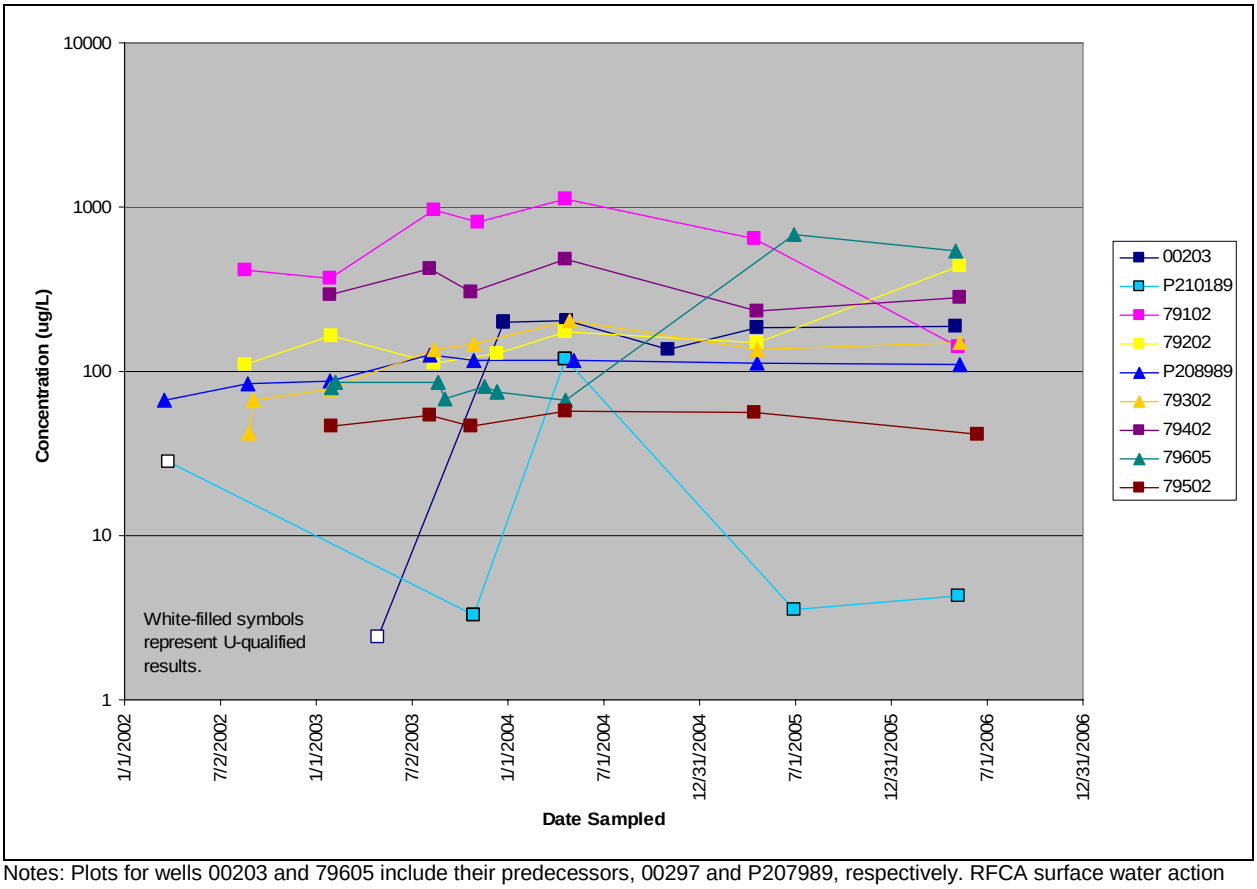
outside the nitrate plume. (Note: Data shown for well 51605 include its predecessor, 1386, which was replaced by 51605 beginning with the September 2005 data.) Wells within the plume include those closer to the source area (22205 and P210089) and those closest to the former Interceptor Trench Pump House and current SPP Discharge Gallery (1786 and B210489).




Notes: Plots for wells 22205 and 51605 include their predecessors, 22298 and 1386, respectively. Several data outliers are also obvious on the graph. RFCA surface water action level for nitrate (mg/L; CDPHE, DOE, and EPA 2003) is 100 in the area of the Solar Ponds Plume. In addition to the nondetects (U-qualified results), several other results were qualified (B, J), but are not shown differently for the sake of simplicity. Note logarithmic concentration scale.

*Figure 3−10. Concentrations of Nitrate in Ground Water Samples Downgradient of the Solar Ponds Plume Source Area*

As with those for nitrate, U concentrations around the former SEPs are generally consistent with past years. Figure 3−11 provides a display of results for total U in the source area. (When preparing the plots for U, data were managed as described in Section 3.3.1.) This figure shows the concentration of U at 79605 increasing significantly between 2004 and 2005; this coincides with the replacement of original well P207989 (results from which represent the first part of the plot for 79605) and its replacement by well 79605 due to the inadvertent destruction of the former well during closure of the Site. The replacement well is about 5 feet from the original well; perhaps more importantly, it is just over 5 feet deeper, allowing it to collect more of the ground water within the weathered bedrock. This may account for the difference in U concentrations between original well P207989 and replacement well 79605.




Notes: Plots for wells 00203 and 79605 include their predecessors, 00297 and P207989, respectively. RFCA surface water action level for total U in Walnut Creek (pCi/L; CDPHE, DOE, and EPA 2003) is 10, which converts (assuming natural U) to approximately 15 µg/L. In addition to the nondetects (U-qualified results), several other results were qualified (B, E, N), but are not shown differently for the sake of simplicity. Note logarithmic concentration scale.

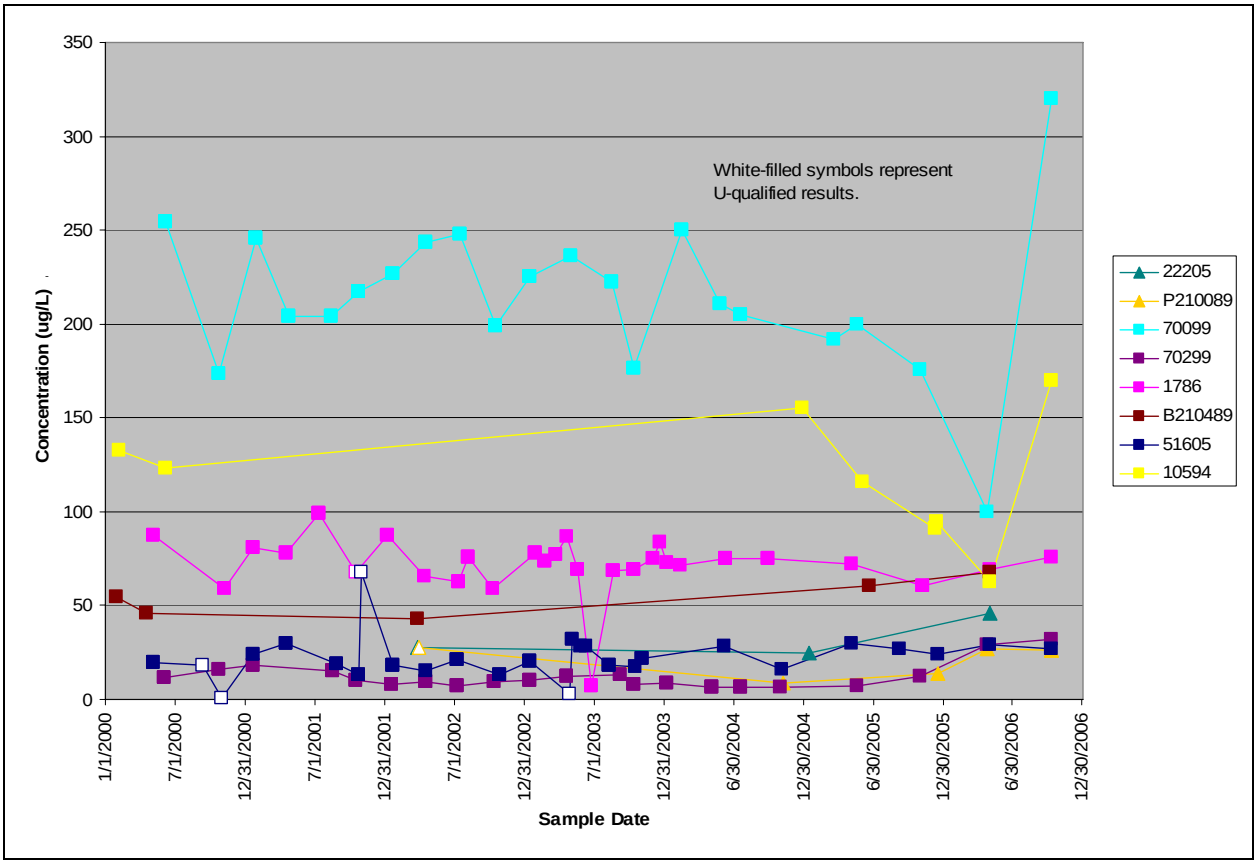
*Figure 3−11. Concentrations of Uranium in Ground Water Samples From the Solar Ponds Plume Source Area*

A similar mechanism may be responsible for the apparent increase in concentrations at well 00203. This well replaced shallower well 00297, which was continually dry and not suitable for long-term monitoring; the original well only produced the first sample represented on Figure 3−11.

The reason for the higher-concentration result in April 2004 at well P210189 is not known. This result may represent an anomaly or error, or it may be related to closure activities in the area. Concentrations of U after that sample have been consistently low, between 3 µg/L and 4.3 µg/L; the sample preceding the April 2004 event was reported as a nondetect at 28 µg/L.

Concentrations of U in downgradient wells are also generally consistent with previous results (Figure 3−12). The main exceptions are seen at wells 70099 and 10594. The former well, located at the northwest end of the SPPTS ground water intercept trench, is represented by two anomalous results in 2006: one, from a sample collected in April, is the lowest concentration in the period of record, while the next sample, collected in October, reported the highest concentration. The data from well 10594, located between Ponds A-1 and A-2, appear to confirm these results from well 70099; both wells appear to show a short period of declining concentrations followed by a sharp increase at the end of 2006. However, other wells in the area,

including several located between wells 70099 and 10594, do not confirm such a pattern although several display moderate increases in U through 2006. Factors that may have contributed to this pattern include the flooding of several wells (70099, 70299, and P210089) during final grading and construction of Functional Channel 3 immediately prior to closure; and the storage of untreated ground water within the SPPTS intercept trench during system repairs performed in August-September 2006. In addition, interpretation of the time series plot for well 10594 is made more difficult by the fact that this well is represented by fewer data points than most others. Because this well and well 70099 are clearly not strongly impacted by the nitrate plume and have been determined to monitor naturally occurring U (K-H 2004f), the variations in U concentrations are most likely of natural origin and/or reflect some measure of laboratory uncertainty.

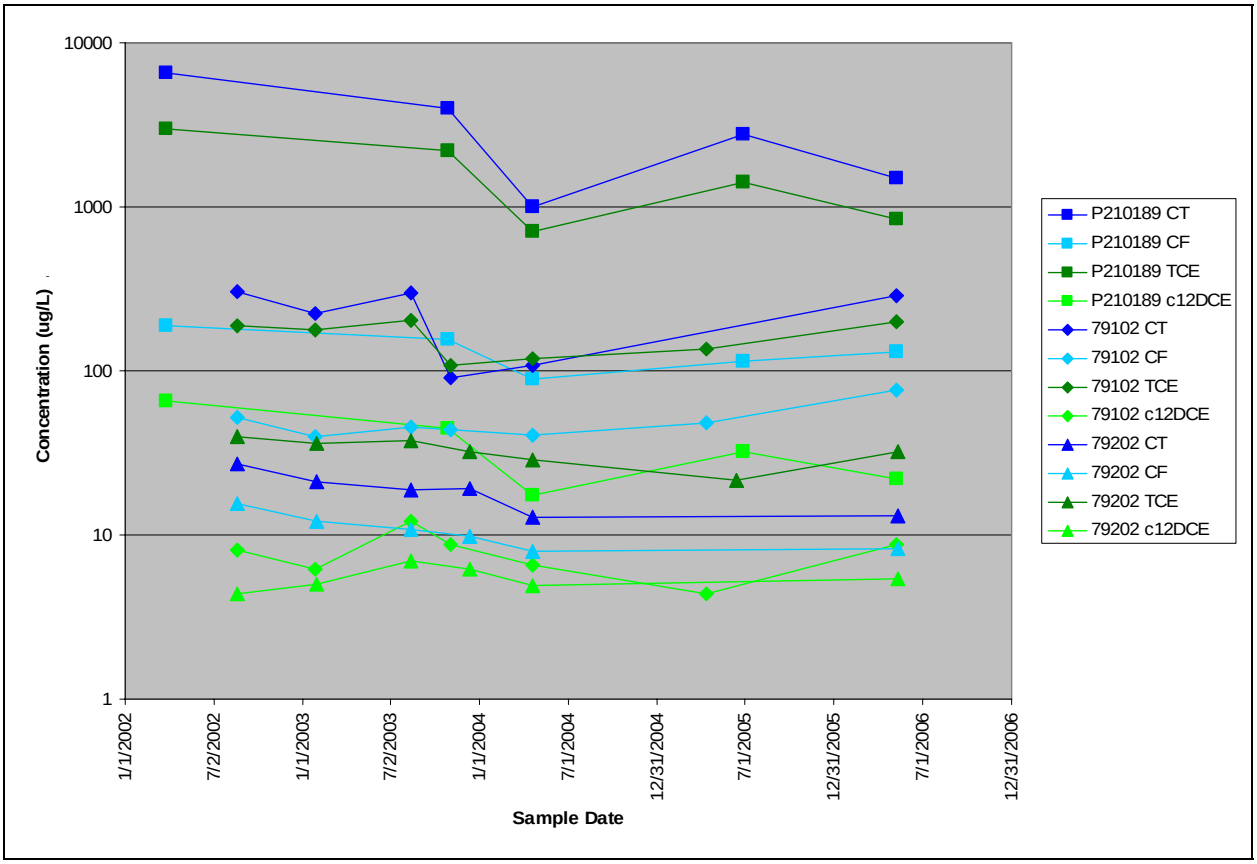



NOTES: Plots for wells 22205 and 51605 include their predecessors, 22298 and 1386, respectively. Several data outliers are also obvious on the graph. RFCA surface water action level for total U in Walnut Creek (pCi/L; CDPHE, DOE, and EPA 2003) is 10, which converts (assuming natural U) to approximately 15 µg/L. In addition to the nondetects (U-qualified results), several other results were qualified (B, J, N, *), but are not shown differently for the sake of simplicity.

*Figure 3−12. Concentrations of Uranium in Ground Water Downgradient of the SPP Source Area*

The S-K trend plot for well 51605 indicates a statistically-significant (95 percent) increasing trend for U at this location. Again, data for this well includes those for the original well, 1386. More importantly, concentrations of U remain well below the U threshold defined in the IMP (DOE 2006c). See Appendix B.3 for the S-K trend plots, which are also summarized above in Section 3.3.1 and Table 3−5.

The main constituents of the VOC plume in the western SEP area are carbon tetrachloride and TCE, with lesser concentrations of their daughter products (primarily chloroform and cis-1,2-DCE) and PCE. The highest concentrations of carbon tetrachloride and TCE are reported in samples from well P210189. The location of wells 79102 and 79202 were selected in part to monitor for VOCs from this plume. Concentrations of these constituents in samples collected from these wells during 2006 are generally consistent with those reported in previous years' samples. Downgradient Evaluation well 22205 reported no detections of these constituents except for low detections in 2003 of PCE (2.17 µg/L) and TCE (30.4 µg/L) that were not confirmed in subsequent samples. Downgradient Sentinel well P210089 also shows no detections of these constituents. Figure 3−13 summarizes concentrations of the major constituents of this plume. PCE is omitted because detections have been under 10 µg/L.




NOTES: CT = carbon tetrachloride, CF = chloroform, c12DCE = cis-1,2-DCE. RFCA surface water action levels for these constituents (µg/L; CDPHE, DOE, and EPA 2003): CT, 5; CF, 5.7; TCE, 5; cis-1,2-DCE, 70. In addition to the nondetects (U-qualified results), several other results were qualified (D, J), but are not shown differently for the sake of simplicity. Note logarithmic concentration scale.

*Figure 3−13. Concentrations of Primary VOCs in SEP-Area VOC Plume*

As shown in Figure 3−13, concentrations of VOCs in this plume have not changed substantially over the past several years with the possible exception of decreasing concentrations in the source-area well P210189.

### *Solar Ponds Plume Treatment System*

Like the ETPTS, the SPPTS was installed in 1999. In basic design terms, the system is very similar to the MSPTS and ETPTS, with an intercept trench (1,100 feet long) and two treatment cells. However, unlike the ETPTS and MSPTS, this system is designed to treat water with elevated concentrations of nitrate and U. As such, the treatment media in the SPPTS differs from that in the VOC-treating MSPTS and ETPTS. The treatment media in the SPPTS consists of ZVI and organic material (sawdust).

Another difference between the SPPTS and the other two systems is that the water collected in the intercept trench is pumped into the treatment cells. This is accomplished using a solar-charged, battery-powered pump system. This component of the SPPTS, together with the collection well (or "sump") that houses the pump and is installed within the trench, was added in 2002. The system was initially designed to take advantage of gravity by situating the treatment cells near the bottom of the North Walnut Creek drainage, and routing intercepted ground water down the hill from the intercept trench to those cells. However, concerns about Preble's meadow jumping mouse habitat in this area of North Walnut Creek caused the cells to be relocated and placed adjacent to the intercept trench. This required water to accumulate in the intercept trench to a depth of about 11 feet before it would flow into the higher-elevation treatment cells. Such a configuration was found to be unrealistic, and the pump system was installed in the fall of 2002.

Routine maintenance activities at the SPPTS were conducted throughout 2006, and include weekly inspection of the solar/battery system that powers the pump, operation of the pump, and influent and effluent flow conditions. In addition, the flow monitoring instrumentation was calibrated periodically.

System performance was satisfactory until spring 2005. Prior to that time, the system reduced nitrate and U concentrations as designed. But in spring 2005, water backed up in the system due to clogging of the gravel/ZVI media in downgradient Cell 2. The valves were reconfigured to bypass this cell. Concentrations of nitrate following this change showed no treatment. The media in Cell 2 was changed in September 2005, just prior to Site closure. U treatment resumed, but nitrate treatment was still insufficient.

In 2006, an iterative strategy for correcting the nitrate problem was developed. The valve positions were checked and found to be one issue: only two of the five valves were accessible. These were reconfigured to support series flow, resulting in a slight decrease in system effluent nitrate concentrations, but the positions of the other three valves could not be confirmed.

At the end of March 2006, heavy equipment was used to excavate and restore access to the other three valves. All valves were then reconfigured to series flow (through both cells in sequence). Field screening samples were collected frequently (2x-5x/month) to evaluate the effects of ongoing efforts to restore treatment. Nitrate concentrations in system effluent began to decrease sharply, but this decrease was inconsistent. Although effluent concentrations of nitrate continued to decrease somewhat, in the summer of 2007 it was determined that the system should be excavated to expose the treatment media and influent distribution lines.

In August 2007, heavy equipment was used to remove the approximately 12 feet of overburden (soil and wood chips) from the top of the media in the SPPTS. The last portion of the excavation

was performed by hand to avoid damaging the plumbing and media. It was found that the influent distribution gallery within nitrate-treating Cell 1 had separated from its feed line because that connection was not designed to account for settling of the sawdust/ZVI media. Additional excavation outside the cells revealed all valves to be leaking, several lines to be broken, and several penetrations through the cell walls to be unsealed, allowing water to flow freely into or out of the cells in an uncontrolled fashion. Finally, it was found that the influent line from the pump was kinked and the original line from the trench had not been capped when the pump was installed; this allowed pumped influent water to either flow into the treatment cells or cycle back into the collection well. A break in that original line also allowed pumped influent to leak into the surrounding soil rather than recirculate back into the collection well or flow to the system. The cumulative effects of these conditions would be reduced treatment effectiveness and efficiency, and reduced flow through the system due to increased system bypass. Figure 3−14 includes photographs of some of the components.

Upper left: looking down into western Cell 1 at the influent distribution gallery. Upper right: distribution gallery (gray pipes, white elbow, pipe fragment) is detached from the main influent port (the pipe in the side of the wall). The pipe extending upwards and having white tubing inside it is the west cell influent vent riser. Lower left: leaking valve feeding main influent port to Cell 1; break in T-pipe; standing water in lower left corner of photo from break in pipe and from leaking valve; kinked influent line from the pump installed in the collection well enters at 45-degree angle "Y" connection from upper right and joins the original influent line from the intercept trench (the other branch of the "Y"), allowing pumped influent to recirculate back into trench. Lower right: same location as lower left photo, but after repairs: new valves; capped line from trench prevents recirculation of water from pumped collection well back to trench; replaced cracked T-pipe; stabilized influent line. Note amount of settling indicated by original line from trench (on right), which had lined up with the valve and main influent port to Cell 1 when the system was installed in 1999, but has since settled with the intercept trench backfill. Stresses from this and other settling caused some of the problems corrected in 2006.

*Figure 3−14. Photographs from SPPTS Investigation and Repair*

Plumbing components were repaired or replaced as follows:

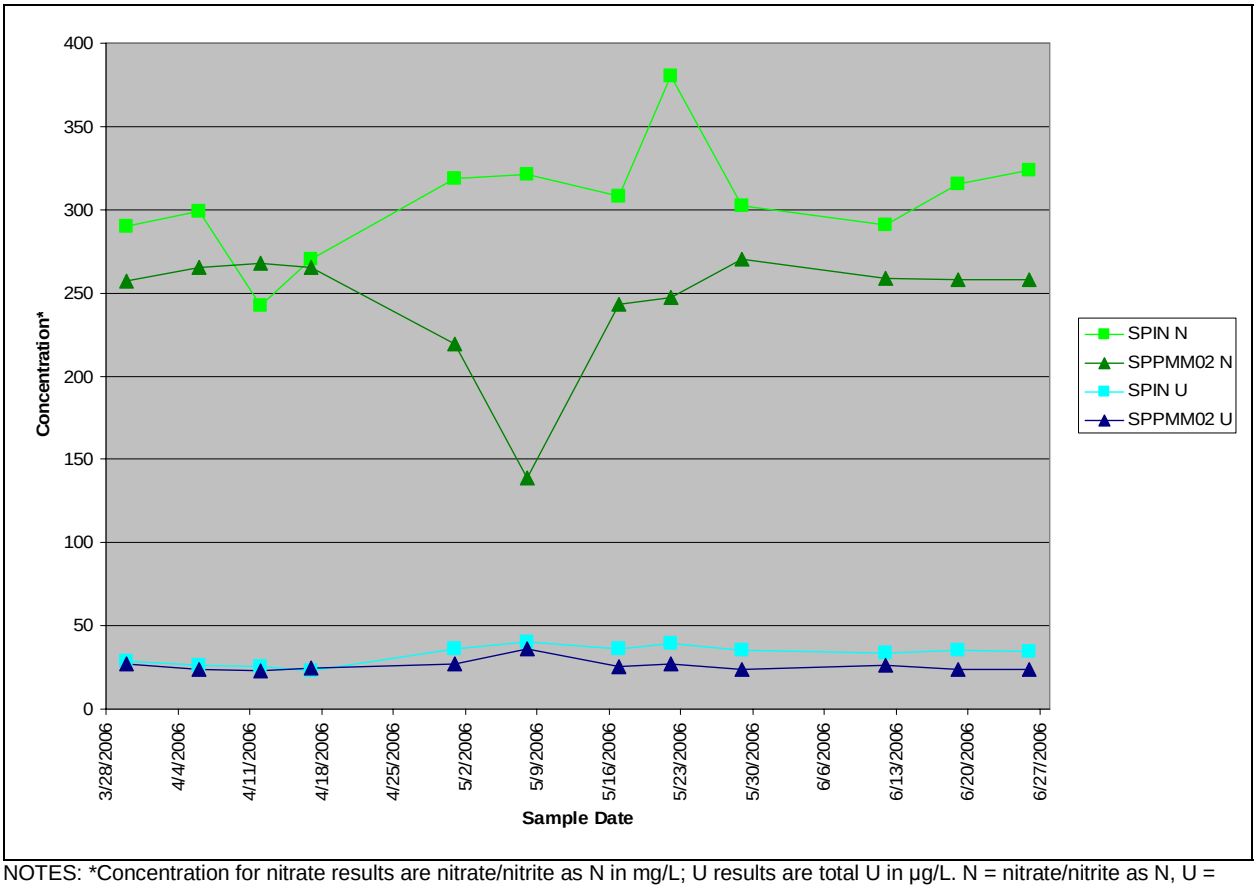
- Truncated original influent line to prevent recirculation and address broken line
- Replaced main influent line "Y"
- Stabilized influent line from collection well pump to prevent further kinking
- Replaced all valves with new valves
- Replaced distribution gallery and used flexible hose to allow settling
- Sealed penetrations through cell walls
- Reconnected west cell effluent vent riser
- Stabilized all vent risers.

The sawdust media was found to be acceptable for continued use and was not replaced.

As a part of these evaluations, differences in water quality between the traditional influent location and the actual influent were characterized. When the system was first installed, influent water quality was approximated via samples from a piezometer located near the deepest part of the ground water intercept trench. In 2002, the collection well was installed and water was pumped from there into the system. This latter location is approximately 10 yards from the traditional location and, by definition, represents true system influent. However, influent samples continued to be collected at the original location (known as both piezometer 71099 and sample location SPPMM02) because the decision document for the SPPTS (DOE 1999b) specified this as the monitoring location for influent. The Site Corrective Action Decision/Record of Decision (CAD/ROD) and post-closure agreement would afford a convenient opportunity to replace this pseudo-influent location with the real influent location. Samples were collected at both locations. The true influent, as represented by samples collected from the collection well (which has been given the location name SPIN), has been found to contain water with concentrations of nitrate and U that are significantly higher than in samples collected from the traditional location, SPPMM02. On average, this difference is approximately 20 percent. Figure 3−15 illustrates these differences.

Following these repairs, flow through the system was resumed. Samples collected following repairs indicate nitrate treatment was restored, and concentrations of nitrate in system effluent returned to typical levels (generally below 1 mg/L as N).

Concentrations at the SPP Discharge Gallery were not significantly affected by the repairs, except for a short-duration decrease when the system was put back in operation immediately following the repairs. (This is thought to be a result of the sudden influx of higher-than-normal flows of treated water, causing dilution of the water discharged at this location. After flows returned to normal, concentrations at this location increased again.)

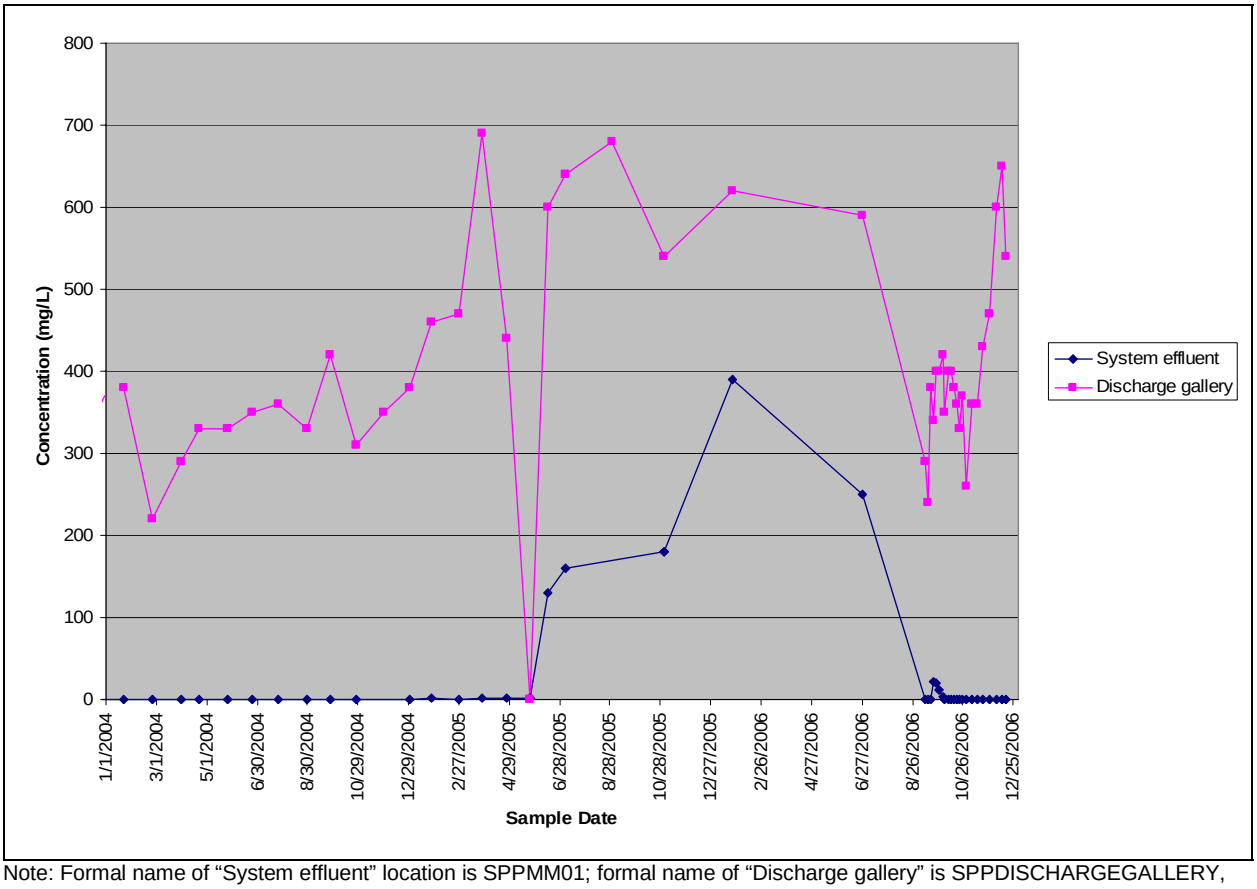



NOTES: *Concentration for nitrate results are nitrate/nitrite as N in mg/L; U results are total U in µg/L. N = nitrate/nitrite as N, U = total U. All results are from field screening samples analyzed by the Environmental Sciences Laboratory in Grand Junction, CO, which is operated by S.M. Stoller Corp. for DOE-LM.

*Figure 3−15. Nitrate and Uranium in Water Samples from the Traditional SPPTS influent Sampling Location, SPPMM02, vs. Actual Influent Collected from SPIN*

The effects of the initial valve reconfiguration and the repairs described above are shown using analytical data provided by contract laboratories (as opposed to field screening samples) on Figure 3−16.

In addition to this and the routine maintenance, treatability studies were begun at the SPPTS. This effort is discussed in Section 3.5.

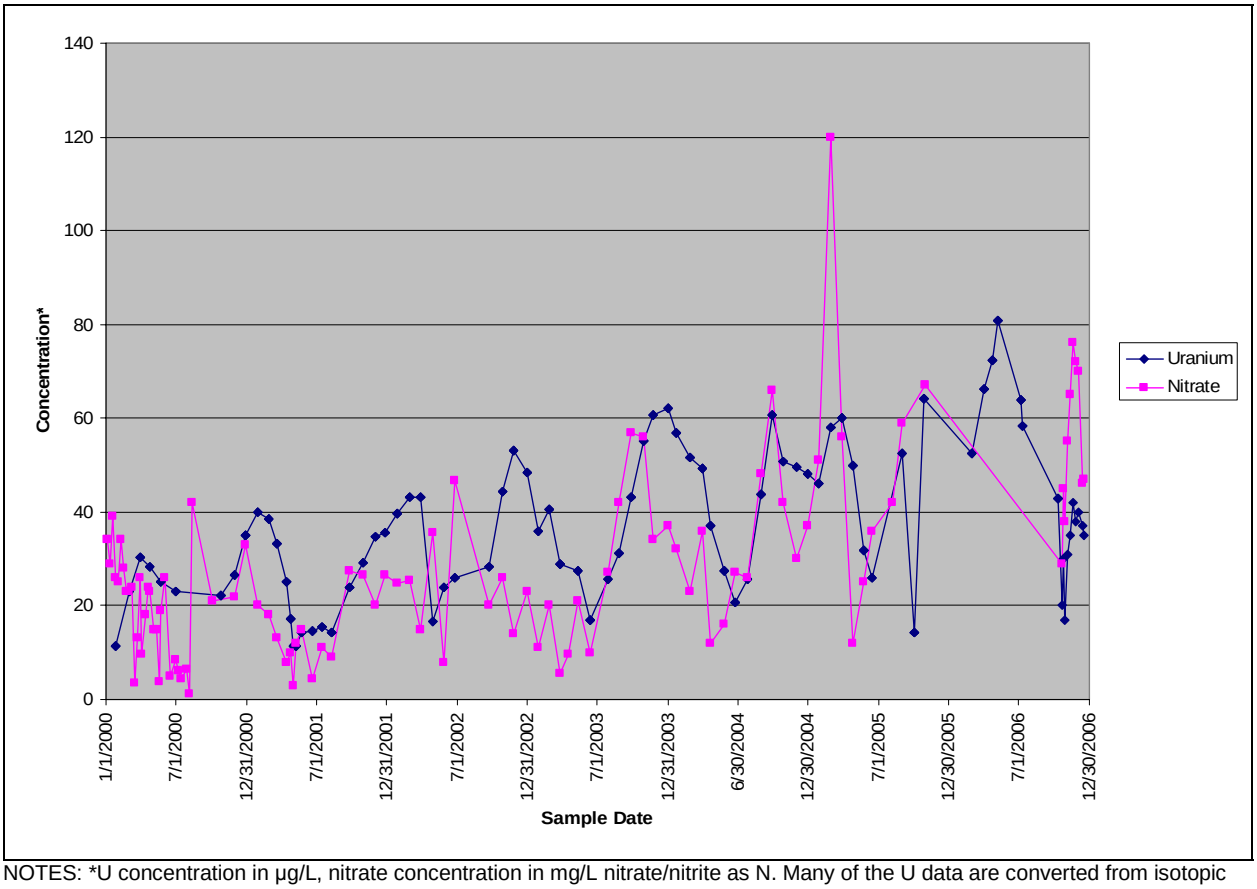



Note: Formal name of "System effluent" location is SPPMM01; formal name of "Discharge gallery" is SPPDISCHARGEGALLERY, but has been reported using that name, SPP Discharge Gallery, SPP DisGal, and other permutations. Many of the lowest-concentration effluent results are nondetects (U-qualified) but are not shown as such for simplicity.

*Figure 3−16. Concentrations of Nitrate in SPPTS Effluent and Discharge Water*

Water quality at the performance monitoring location for the SPPTS, GS13, is generally consistent with previous data. Concentrations of nitrate are below the Temporary Modification stipulated in the RFCA (CDPHE, DOE, and EPA 2003). Even so, the trend of nitrate concentrations at this surface water location is increasing (see S-K trend plot for GS13 in Appendix B.3). One factor is that the water exiting the SPPTS at the SPP Discharge Gallery began to take a shortcut directly to North Walnut Creek rather than flow along its designed path. This condition was corrected in 2006 by restoring the flow to its intended path, and should result in decreasing nitrate concentrations at GS13.

The historic pattern of U concentrations—higher in the winter, lower in the summer—suggests the relative contributions of runoff and ground water discharge to North Walnut Creek. Now that impermeable surfaces such as parking lots, roads, and buildings have been removed, the amount of runoff has decreased sharply. Ground water now comprises a larger fraction of the surface water than in years past. At GS13, this may result in some smoothing of the pattern shown on Figure 3−17, and a generally higher average U concentration.




NOTES: *U concentration in µg/L, nitrate concentration in mg/L nitrate/nitrite as N. Many of the U data are converted from isotopic activities to mass units, as described in the text.

*Figure 3−17. Uranium and Nitrate at SPPTS Performance Location GS13.*

S-K trend plots were constructed for locations at the SPPTS including the traditional influent location (SPPMM02, a.k.a. piezometer 71099), effluent (SPPMM01), discharge gallery, and GS13. These are provided in Appendix B.3. Summarizing, the trend for all four locations is increasing for nitrate at a 95 percent level of confidence, and for three of the four locations for U at the same level of confidence. U is not increasing at the 95 percent level of confidence at location SPPMM02.

Visual examination of the trend plots (Appendix B.3) illustrates the significance of the most recent data in determining the slope of the trends at SPPMM02. Those slopes are estimated at 0.1309 for U, and 0.03326 for nitrate—both extremely gentle increases and very close to no slope. These statistical evaluations underscore the importance of the repairs that were performed in 2006 to the SPPTS. As additional data are collected, the trends should decrease to zero slope at SPPMM01. And as discussed above, if the anticipated increases in U concentrations at GS13 hold true, the increasing trend at that location will continue until steady-state conditions have been reached. This applies equally to nitrate, since it too is in the ground water in this area at an elevated concentration.

Refer to the quarterly reports (DOE 2006f, 2006g, 2007d) and Appendix B.6 for additional analytical data from SPPTS monitoring locations.

The SPPTS treated approximately 251,000 gallons in 2006. This is generally consistent with volumes treated since the system was modified with the addition of the pump. In 2003, the system treated 340,000 gallons, in 2004 it treated 230,000 gallons, and in 2005 it treated 140,000 gallons. Repairs made in August−September 2006 will act to increase flow through the system, since these repairs included fixing numerous leaks. However, the general decrease in flow that may result because of the removal of previous Site contributions could counteract this.

### 3.3.3 Other Plumes

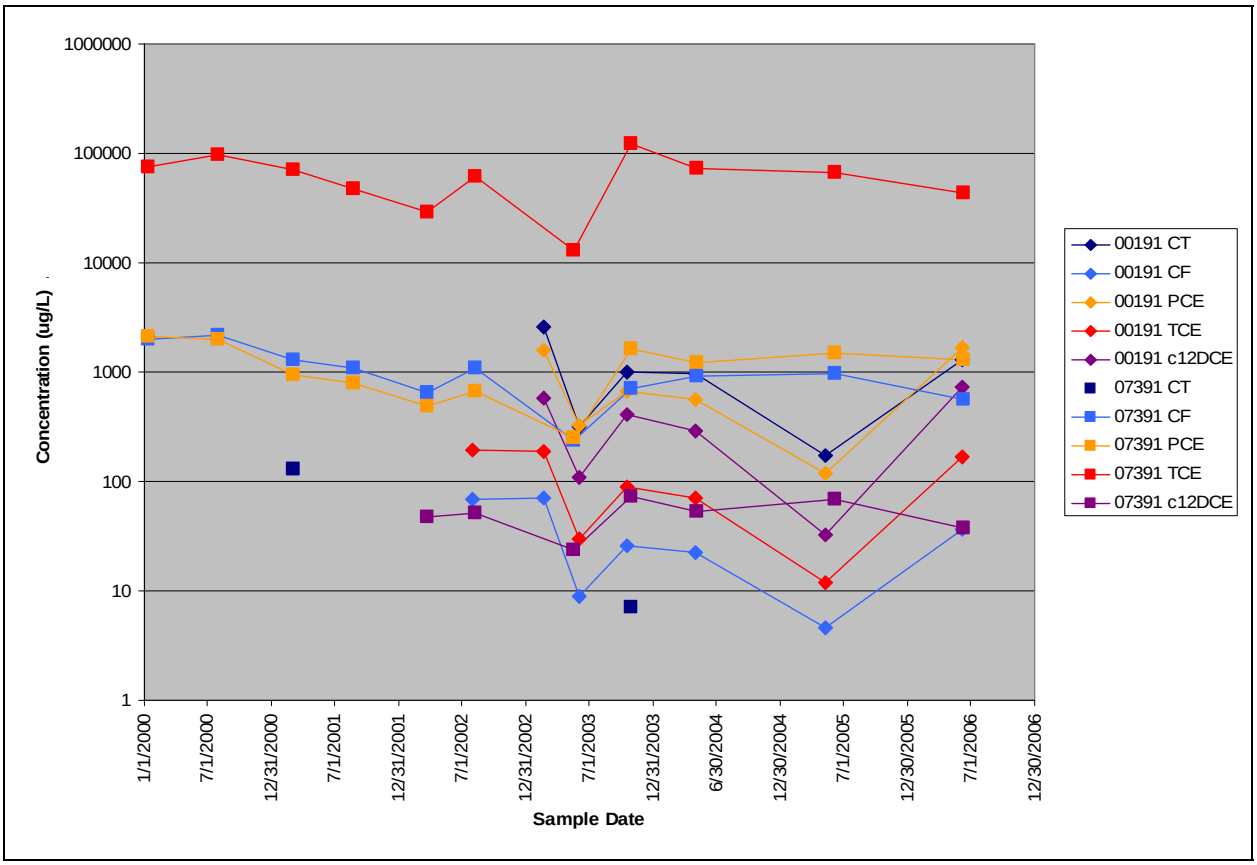
In accordance with the IMP, several other ground water contaminant plumes were monitored during 2006. These include the 903 Pad/Ryan's Pit Plume, the collection of small plumes collectively referred to as the IA Plume (and often discussed, as in this report, in terms of the South and North IA Plume), the Vinyl Chloride Plume (or OBP #1 Plume) located south of former B371, the OBP#2 Plume located immediately west of the Mound Plume, the Individual Hazardous Substance Site(s) (IHSS) 118.1 Plume located north-northwest of former B776, the Property Utilization and Disposal (PU&D) Yard Plume, and the OU1 Plume.

#### 3.3.3.1 903 Pad/Ryan's Pit Plume

The 903 Pad/Ryan's Pit Plume was monitored in 2006 via several wells distributed within and at the margins of the plume. This plume bifurcates, with one portion flowing toward the southeast and Woman Creek, and the other flowing toward the northeast and joining the East Trenches Plume. The northeastern branch is not discussed here; refer to the text on the East Trenches Plume above.

Water quality within the southeastern portion of the 903 Pad/Ryan's Pit Plume appears consistent with that reported in previous years. AOC well 10304, located south of the SID and just east of Pond C-1, monitors for VOCs that may be reaching the Woman Creek drainage from this plume. None of the 903 Pad/Ryan's Pit Plume VOC constituents were detected; only a J-qualified detection of acetone (3.9 µg/L), a common lab contaminant, and a detection of styrene (1 µg/L) were reported. The RFCA Attachment 5 (CDPHE, DOE, and EPA 2003) action levels for these constituents in surface water are 3,650 µg/L and 100 µg /L, respectively.

This plume is also monitored by downgradient Sentinel wells 90299 and 90399, source-area Evaluation wells 00191 (just east of the former 903 Pad) and 07391 (just south of the former Ryan's Pit), and in-plume Evaluation wells 90402, 50299, 00491, and 90804. These wells show contamination consistent with the source constituents, with the 903 Pad source being enriched in carbon tetrachloride relative to the PCE-TCE chain of compounds, though concentrations of PCE approach those of carbon tetrachloride. Conversely, ground water contaminated by Ryan's Pit contains much more TCE relative to carbon tetrachloride, which is frequently not detected. (Detection of carbon tetrachloride in well 07391 is hampered by interference from other compounds present at high concentrations, requiring samples be diluted significantly prior to analysis; as a result, detection limits reported for carbon tetrachloride have been as high as 5,000 µg/L since 2000.) Figure 3−18 shows time-series plots of carbon tetrachloride and its daughter product, chloroform, as well as PCE and its daughter products TCE and cis-1,2-DCE. Note that some daughter products, particularly TCE, were heavily used during production at the Site and therefore do not always represent true "daughter products."




NOTES: CT = carbon tetrachloride, CF = chloroform, c12DCE = cis-1,2-DCE. Of the CT data from well 07391 since 1/12000, only two results are detections, the other ten are nondetects. Both detections are shown. RFCA surface water action levels for these constituents (µg/L; CDPHE, DOE, and EPA 2003): CT, 5; CF, 5.7; PCE, 5; TCE, 5; cis-1,2-DCE, 70. Not shown are U-qualified data for CT from well 07391, as discussed, nor U-qualified data for c12DCE from well 07391 that precede the first 2002 data point shown for this constituent at this location. Several other results were qualified (D, E, J), but are not shown differently for the sake of simplicity. Note logarithmic concentration scale.

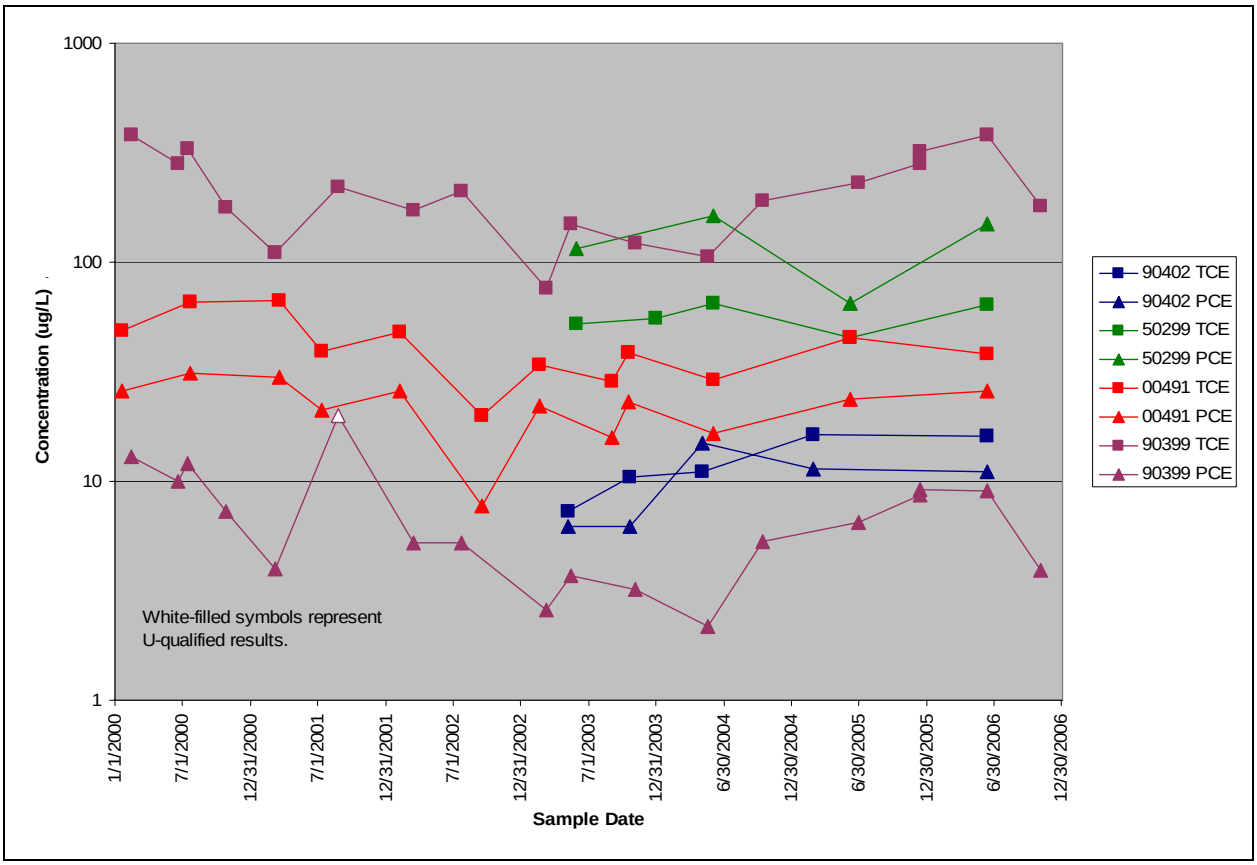
*Figure 3−18. Concentrations of VOCs in Source-Area Wells 00191 (903 Pad) and 07391 (Ryan's Pit)*

As is evident on Figure 3−18, the relative concentrations of different VOCs in the 903 Pad and Ryan's Pit source areas are different. Constituent concentrations measured in samples from well 00191 vary uniformly from one sample to the next, and show the 903 Pad contaminants to be marked by higher concentrations of carbon tetrachloride than TCE. This is the opposite of conditions at Ryan's Pit. Over time, the HRC application prior to Site closure should be manifested in decreasing concentrations of parent compounds and increasing concentrations of daughter products at source-area wells.

Concentrations in 2006 were generally consistent with previous data, though results from well 00191 in May 2005 had suggested a decrease that has not been confirmed by the 2006 data. In addition, the S-K trend plot for well 90299 shows a statistically-significant (95 percent) decreasing trend in TCE concentrations (which are consistently below 5 µg/L) at that well. See Appendix B.3 for the S-K trend plots, which are also summarized above in Section 3.3.1 and Table 3−5.

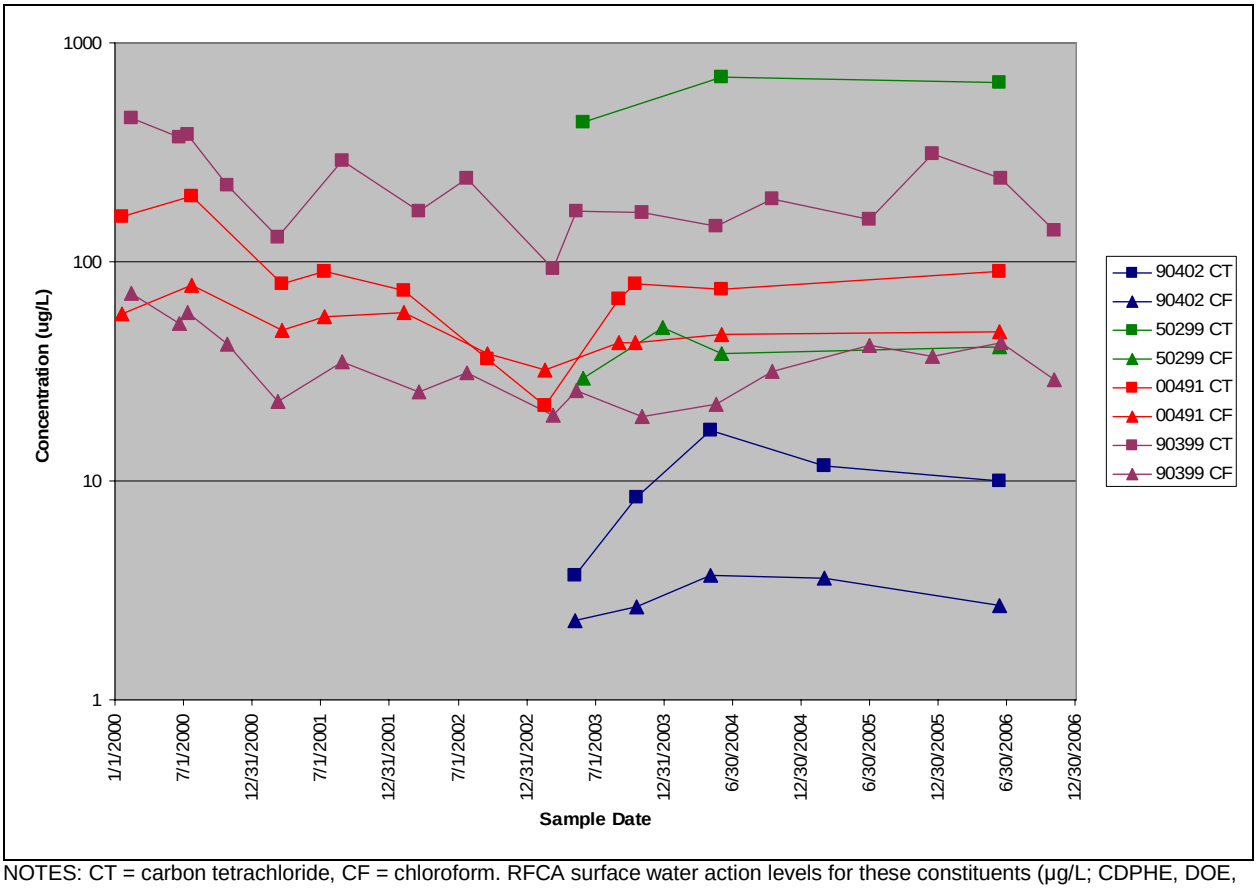
Similar plots of concentrations in downgradient wells, focusing on carbon tetrachloride, chloroform, PCE, and TCE, are presented in Figure 3−19 and Figure 3−20. As with samples

from source-area wells, concentrations of the different VOCs at each well are seen to vary uniformly from one sample to the next. The distribution of PCE and TCE in samples from well 90399 suggest a significant contribution from the Ryan's Pit source area (as represented by the contaminant distribution seen in time series plots for well 07391; see Figure 3−18), given the higher concentration of TCE relative to PCE at Ryan's Pit. Biodegradation of the PCE to TCE may also be contributing to the higher TCE concentrations, but previous reports suggest this mechanism would be of minor importance (K-H 2004a).




NOTES: RFCA surface water action levels for these constituents (µg/L; CDPHE, DOE, and EPA 2003): TCE, 5; PCE, 5. In addition to the nondetects (U-qualified results), several other results were qualified (D, J), but are not shown differently for the sake of simplicity. Note logarithmic concentration scale.

*Figure 3−19. PCE and TCE in Downgradient 903 Pad/Ryan's Pit Plume Wells*




NOTES: CT = carbon tetrachloride, CF = chloroform. RFCA surface water action levels for these constituents (µg/L; CDPHE, DOE, and EPA 2003): CT, 5; CF, 5.7. In addition to the nondetects (U-qualified results), several other results were qualified (D), but are not shown differently for the sake of simplicity. Note logarithmic concentration scale.

*Figure 3−20. Carbon Tetrachloride and Chloroform in Downgradient 903 Pad/Ryan's Pit Plume Wells*

As noted in the 2005 Annual Report (DOE 2006e), HRC was emplaced in the subsurface in the 903 pad and Ryan's Pit source areas. The effects of this are not yet evident in samples from the source-area wells.

Refer to the quarterly reports (e.g., DOE 2006f, 2006g, 2007d) and Appendix B.6 for analytical data.

### 3.3.3.2 IA Plume

The IA Plume is actually a collection of several small VOC plumes grouped together for convenience and, in some cases, because of uncertainties regarding specific sources.

The South IA Plume is monitored by AOC well 11104. This well, sampled during the second and fourth quarters of 2006, showed very low, J-qualified (estimated) results for acetone, a common lab solvent, and 1,3-dichlorobenzene. In addition, concentrations of U, samples for which are collected because of proximity of the OLF and former B444, were well below the U threshold in the IMP (DOE 2006c).

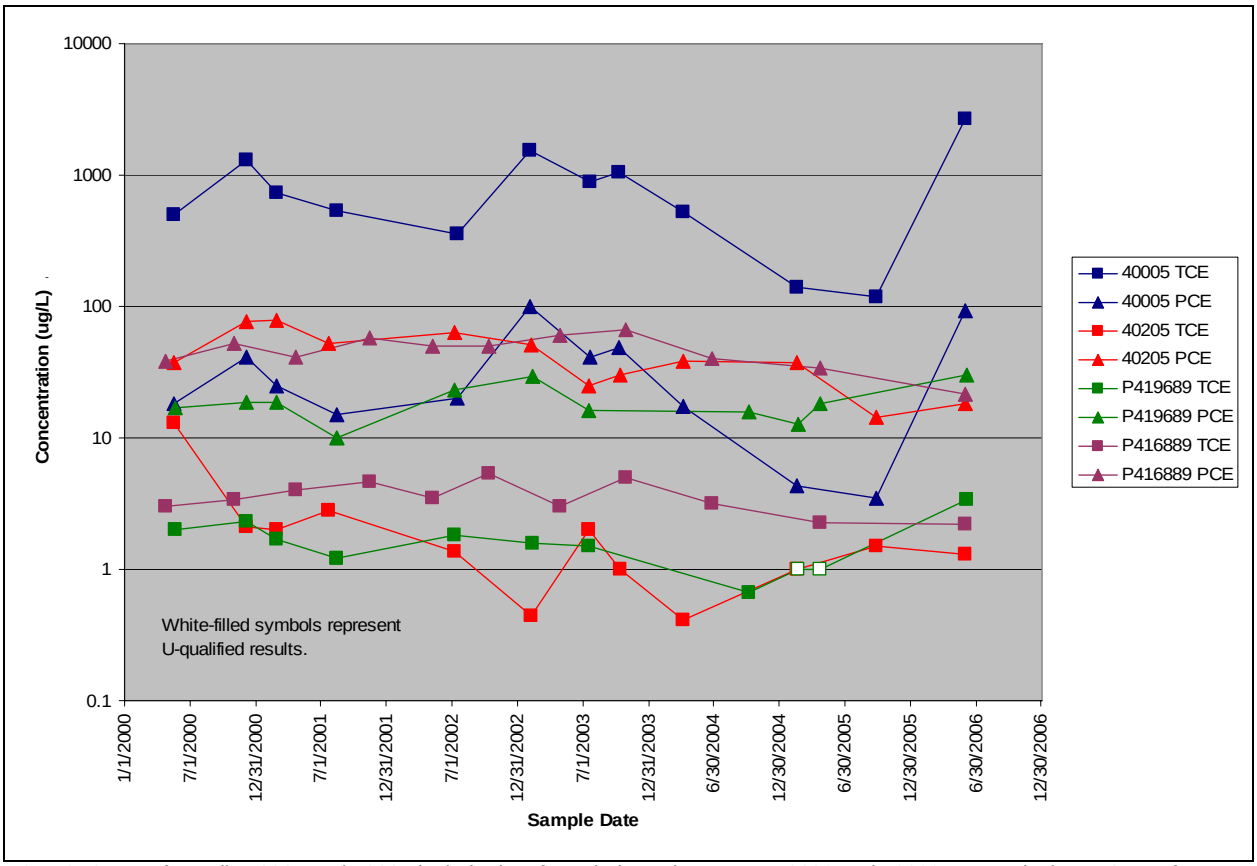
Upgradient of well 11104, wells monitoring the South IA Plume include Sentinel wells 11502 and 40305, and Evaluation wells 40005, 40205, P419689, and P416889. While results from samples collected in 2006 from the Sentinel wells indicate little change, those from the Evaluation wells vary more sharply. Each of the three Evaluation wells surrounding the former B444 complex, 40005, 40205, and P419689, show increases in PCE and TCE concentration in 2006 (Figure 3−21). The only exception is TCE at well 40205. Compared with samples collected most recently, these increases vary in magnitude from just a few parts per billion (ppb; e.g., TCE at well P419689 increased from nondetect to 3.4 μg/L) to over 2,500 ppb (TCE at well 40005 increased from 117 μg/L to 2,650 μg/L). The sharpest increases are seen at well 40005, located immediately west of the former B444 complex and traditionally producing ground water samples with the highest concentrations of VOCs of all B444 wells. A short distance downgradient, well P416889 shows slight decreases in PCE and TCE concentrations; nearby Sentinel well 11502 (not shown on Figure 3−21) produced samples with lower concentrations of PCE and TCE that also show a slight decrease compared to samples collected in 2005. These data may be indicative of the effects of the removal of impermeable surfaces (pavement and buildings) from this area, together with the disruption of the foundation and storm drains here and the waning effects of dilution and flushing from dust suppression water applied during B444 closure. Analytical data from future samples may show continued increasing concentrations at well 40005 in particular as the water applied during closure of the B444 facility moves out of the area, the ground water receives direct recharge, and geochemical conditions stabilize.

Also evident on Figure 3−21 is the different contaminant distribution at well 40005 as compared to the other wells. At 40005, concentrations of TCE are significantly greater than those of PCE; the opposite is true at wells 40205 and P419689. Refer to K-H (2002b) for additional discussion on possible historical influences at well 40005.

The S-K trend plots for well 40305 are notable, as statistically-significant (95 percent) trends are calculated for TCE (decreasing) and methylene chloride (no slope). However, both are artificial trends: there has been no detection of either compound reported since 2001. See Appendix B.3 for the S-K trend plots, which are also summarized above in Section 3.3.1 and Table 3−5.

The North IA Plume is monitored by AOC well 42505. This well was sampled twice in 2006, and reported no confirmed detections of VOCs.

This area is also monitored by numerous other wells (Figure 3−1). Analyses of samples from well 55905, located on the north side of former B559, show concentrations of carbon tetrachloride have declined following the elevated result in 2005 (from 120 μg/L in 2005 to 65 μg/L in 2006). Concentrations of this constituent in nearby well 56305 (located on the west side of former B559) also decreased somewhat from 136 μg/L to 110 μg/L over the same period. Other VOCs (such as PCE and TCE) have decreased in concentration at well 55905, but are still above their pre-closure averages in well 56305. Again, all of this is probably related to factors such as the removal of impermeable surfaces and gradually stabilizing hydrological and geochemical conditions.

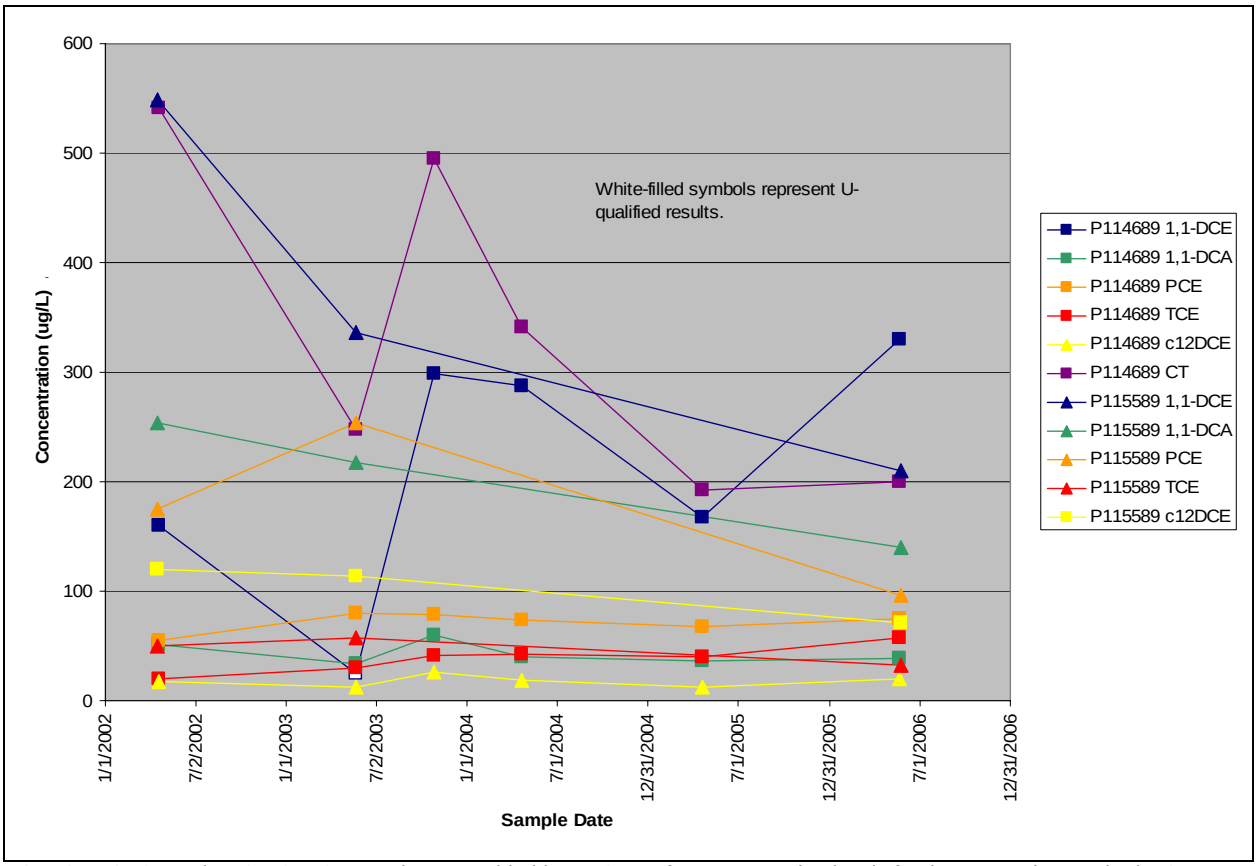



NOTES: Curves for wells 40005 and 40205 include data from their predecessors, 40099 and 40299, respectively. RFCA surface water action levels for these constituents (µg/L; CDPHE, DOE, and EPA 2003): PCE, 5; TCE, 5. In addition to the nondetects (U-qualified results), several other results were qualified (J, E, D), but are not shown differently for the sake of simplicity. Note logarithmic concentration scale.

*Figure 3−21. PCE and TCE in South IA Plume/B444 Wells*

Ground water samples collected in 2005 from well 70705, located on the east side of former B707, indicated a sharp increase in carbon tetrachloride concentration. This has not continued through 2006; this constituent was most often not detected in the original well, 00200, from 2000 through 2003 (highest concentration: 1.4 µg/L in November 2000). It was then reported at a concentration of 163 µg/L in the sample collected from replacement well 70705 in September 2005. The sample collected in 2006 reported a concentration of carbon tetrachloride of 2 µg/L.

Farther west, concentrations of VOCs in wells P114689 and P115589 are either consistent with past ranges or are declining, with two notable exceptions. Concentrations of TCE in ground water from well P114689 appear to be steadily increasing. In addition, concentrations of 1,1-DCE have also increased here, as shown in Figure 3−22. This compound is a common breakdown product of 1,1,1-TCA, PCE, TCE, and 1,2-DCE. None of these is present at levels similar to that of 1,1-DCE. At well P115589, concentrations of 1,1-DCE appear to be decreasing, as are concentrations of PCE, TCE, and other VOCs.




NOTES: c12DCE = cis-1,2-DCE, CT = carbon tetrachloride. RFCA surface water action levels for these constituents (µg/L; CDPHE, DOE, and EPA 2003): 1,1-DCE, 7; 1,1-DCA, 3650; cis-1,2-DCE, 70; PCE, 5; TCE, 5. In addition to the nondetects (U-qualified results), several other results were qualified (D), but are not shown differently for the sake of simplicity.

*Figure 3−22. Concentrations of VOCs in IA Wells P114689 and P115589*

Collectively, these changes in North IA Plume ground water may indicate mobilization of residual contamination that had been stationary due to the presence of impermeable surfaces (pavement, buildings) in this area. Removal of those surfaces and subsequent direct recharge of the ground water through precipitation (and prior to closure, dust suppression water as well), coupled with the general disturbance and loosening of the ground surface, will act to increase the mobility of VOC contamination from residual sources. Ground water quality in this area will continue to be monitored and assessed in case these conditions begin to pose a potential threat to downgradient surface water.

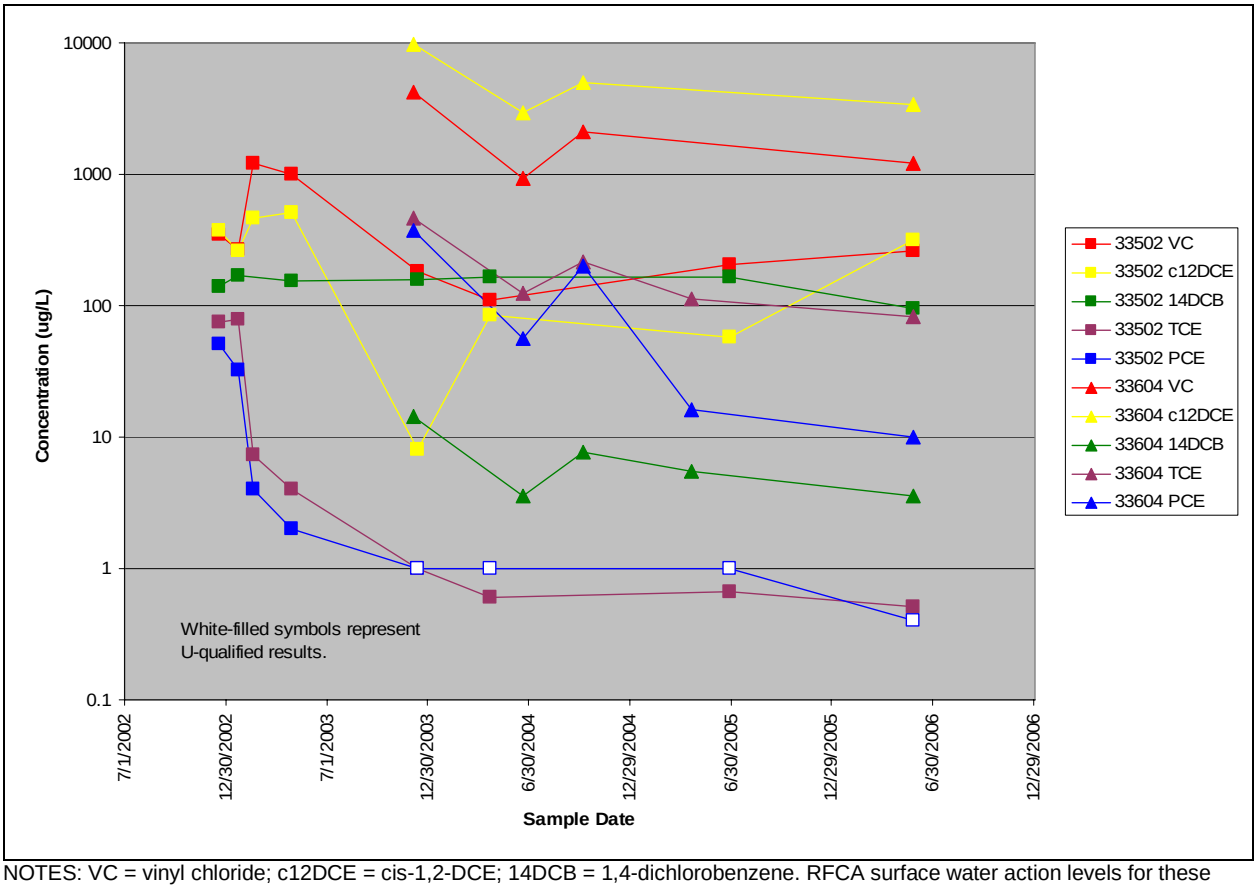
### 3.3.3.3 Vinyl Chloride Plume

The vinyl chloride plume emanates from OBP#1 and/or the metal disposal/ destruction sites (former IHSSs 134N and 134S). These source areas are on the margin of a valley that was buried during construction of B371 and became the site of the Portal 2 parking lots, among other facilities; the plume resides within that buried valley. Although vinyl chloride was historically detected in many locations at the Site (one study reports vinyl chloride was detected in 44 of 620 wells; K-H 2004d), the only location at which it is present in such elevated concentrations is this plume. Elevated concentrations of vinyl chloride have been reported in Evaluation wells 33502

and 33604 (as well as the latter's predecessor, 33603). The highest concentration reported has been 4,190 µg/L (well 33603, December 4, 2003). These two wells monitor the source area of this plume. Vinyl chloride was detected in Sentinel well 33703, located just over 100 feet immediately north of well 33604, in a sample collected in May 2006, but was not detected in the next sample nor has it been detected prior to that May sample.

Well 33502 is one location at which strong evidence for biodegradation has been found (K-H 2004a), which may explain both the high concentrations of vinyl chloride as well as the extremely limited aerial extent over which it has been observed. This biodegradation is probably a result of the slowly decomposing organic matter remaining from the vegetation that once grew within the valley. This would consume oxygen, providing an anaerobic environment suitable for reductive dechlorination of the chlorinated solvents most commonly found at RFS. Another breakdown product that is present at higher levels in samples from the source area is cis-1,2-DCE.

Parent compounds, such as PCE and TCE, are present in the ground water in this area but at relatively lower concentrations compared with that of vinyl chloride. Reported in the tens to hundreds of µg/L are VOCs including PCE and TCE at well 33604 and 1,4-dichlorobenzene at well 33502. These compounds are displayed via a time series plot in Figure 3−23. As is evident on that figure, the concentrations of vinyl chloride and cis-1,2-DCE in ground water samples collected from well 33502 increased in 2006 (from 207 µg/L to 260 µg/L and from 57.5 µg/L to 320 µg/L, respectively), while concentrations of other compounds are seen to decrease here and in well 33604. This could represent normal variability, or it may indicate continued degradation of parent compounds with a concomitant increase in the concentrations of these daughter products. The decreasing concentrations of PCE and TCE do support continuing biodegradation.




NOTES: VC = vinyl chloride; c12DCE = cis-1,2-DCE; 14DCB = 1,4-dichlorobenzene. RFCA surface water action levels for these constituents (µg/L; CDPHE, DOE, and EPA 2003): VC, 2; cis-1,2-DCE, 70; 1,4-DCB, 75; PCE, 5; TCE, 5. In addition to the nondetects (U-qualified results), several other results were qualified (J, D), but are not shown differently for the sake of simplicity. Note logarithmic concentration scale. Plots for well 33604 include data from its predecessor, 33603.

*Figure 3−23. VOCs Present in the Vinyl Chloride Plume Source Area*

### 3.3.3.4 OBP#2 Plume

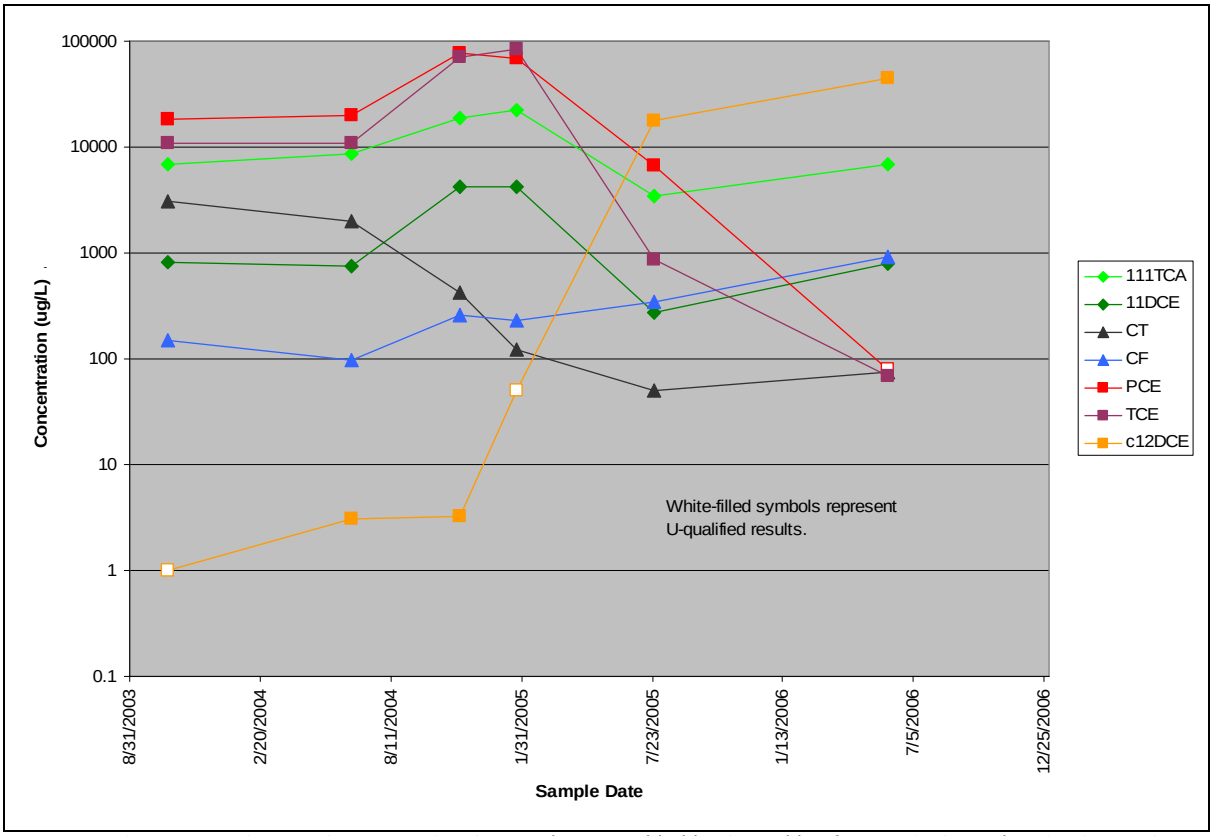
OBP#2 was located at the southeast corner of the former Protected Area (PA) fence just west of the Mound source area. Because of the security infrastructure, ground water monitoring in this location was not feasible until the PA was eliminated. Ground water and soil were subsequently sampled and elevated concentrations of VOCs from OBP#2 were observed.

Ground water in the source area of OBP#2 was first monitored by well 91103. Due to the elevated concentrations of VOCs reported in samples from this well and resulting concerns about the integrity of the PVC of which this well was constructed, stainless-steel replacement well 91104 was installed 10 feet from the original well. Excavation of the source area required abandonment of well 91104, as it was within the excavation boundary. Well 91105 was installed following completion of source removal activities, and is located a few feet downgradient of the downgradient edge of the source removal excavation, just under 75 feet north-northeast from the location of former well 91104. HRC was added to the excavation backfill (K-H 2005b). As a result of the source removal, enhancement of biodegradation, and ultimate location of the replacement well, water quality in samples from well 91105 is not expected to closely resemble that in samples from former wells 91103 and 91104.

Adjacent to the OBP#2 source area was a 72-inch storm drain that potentially acted as a preferential ground water pathway from the source area to South Walnut Creek. As a part of its removal, a trench was cut and backfilled with gravel to divert ground water from the storm drain corridor to the MSPTS intercept trench (K-H 2005b).

The ground water contaminant plume from OBP#2 flows generally northward toward South Woman Creek/FC-4. Previous work has shown the majority of this plume is captured by the MSPTS intercept trench (K-H 2005a), and this behavior was enhanced by the installation of the gravel drain downgradient of the OBP#2 source area (K-H 2005b).

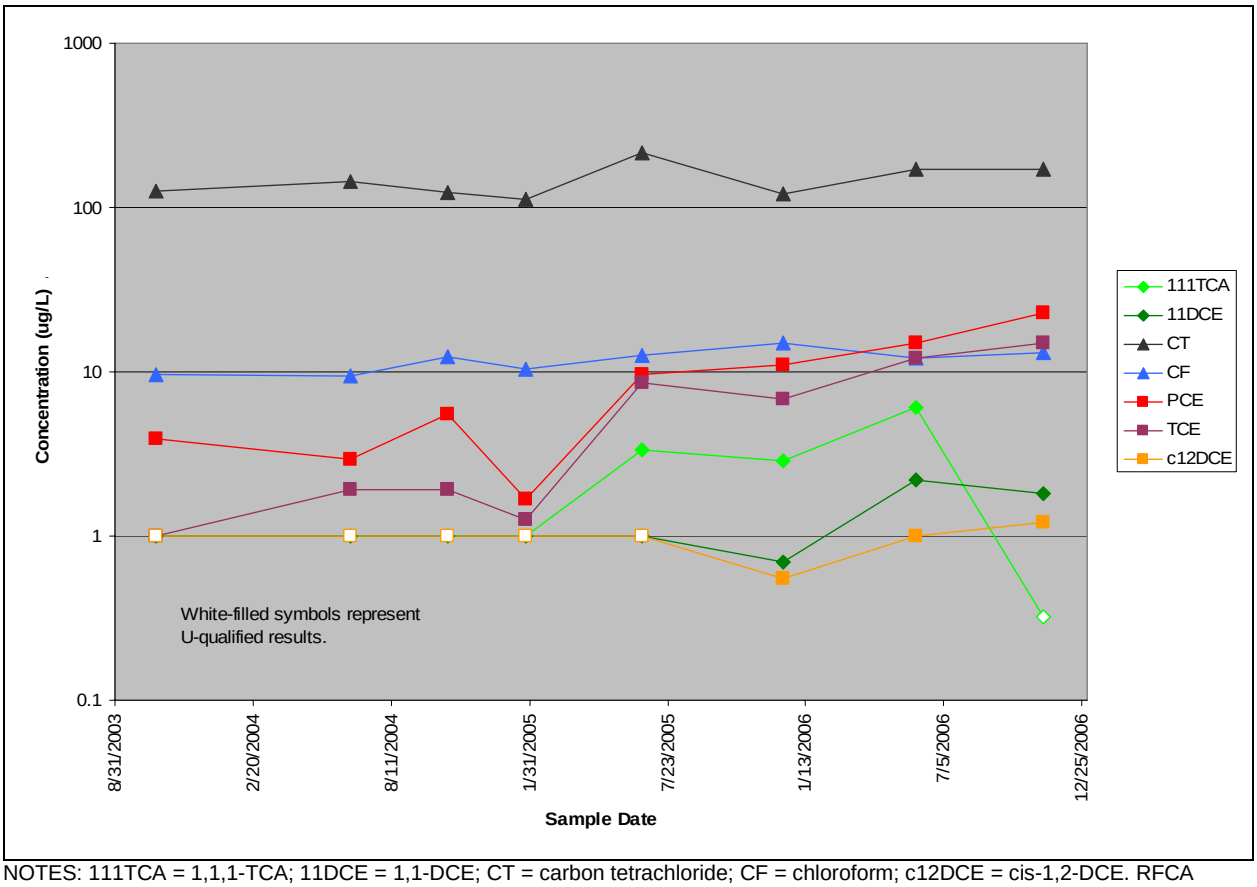
The main VOCs present in ground water samples from the OBP#2 source area are displayed on the time-series plot on Figure 3−24. Evident on this figure are several patterns. First, concentrations of 1,1,1-TCA and its daughter product, 1,1-DCE, vary in concert with one another. This suggests minimal degradation of either compound. Second, concentrations of carbon tetrachloride are generally decreasing, while those of its daughter product chloroform are increasing. This suggests ongoing degradation of the parent product to form additional chloroform. Finally, a similar but stronger pattern is evident with parent products PCE and TCE, both of which are degrading to cis-1,2-DCE, with a corresponding decrease in PCE and TCE concentrations and concomitant increase in cis-1,2-DCE concentrations.




Notes: 111TCA = 1,1,1-TCA; 11DCE = 1,1-DCE; CT = carbon tetrachloride; CF = chloroform; c12DCE = cis-1,2-DCE. RFCA surface water action levels for these constituents (µg/L; CDPHE, DOE, and EPA 2003): 1,1,1-TCA, 200; 1,1-DCE, 7; CT, 5; CF, 5.7; cis-1,2-DCE, 70; PCE, 5; TCE, 5. In addition to the nondetects (U-qualified results), several other results were qualified (J, D), but are not shown differently for the sake of simplicity. Original well 91103 provided samples through June 21, 2004; replacement well 91104 provided subsequent samples through January 26, 2005; and replacement well 91105 provided the balance of the samples. More simply put, the first two samples are from 91103, the middle two are from 91104, and the last two samples shown are from 91105. Note logarithmic scale for concentrations.

*Figure 3−24. Concentrations of VOCs in OBP#2 Source Area Well 91105*

The same compounds are displayed on Figure 3−25, which is based upon ground water analytical data from well 91203, located north of the OBP#2 source area (Figure 3−1). Samples from this well show relatively uniform concentrations of carbon tetrachloride and chloroform, concentrations of PCE and TCE that tend to vary in tandem with one another, and low to nondetect concentrations of cis-1,2-DCE, 1,1,1-TCA, and 1,1-DCE. These patterns suggest ground water at well 91203 is not strongly impacted by the OBP#2 source area, although the mid-2005 increases in VOC concentrations may be related to source removal activities completed April 1, 2005, and/or to water from the 700 Area that was routed across the surface here in March 2005. Several years of additional data will be needed to evaluate the potential for a hydrologic and geochemical connection, because physical changes to the area as a result of Site closure have been significant and it may take years before the hydrologic system equilibrates. In summary, the contamination observed in samples from well 91203 may have originally come from OBP#2, but how current ground water flow paths are affected by the now-removed storm drain and its replacement gravel drain, the proximity of FC-5, the many changes to the land surface to create and then remove the PA berm, and so forth will require additional data to determine.




NOTES: 111TCA = 1,1,1-TCA; 11DCE = 1,1-DCE; CT = carbon tetrachloride; CF = chloroform; c12DCE = cis-1,2-DCE. RFCA surface water action levels for these constituents (µg/L; CDPHE, DOE, and EPA 2003): 1,1,1-TCA, 200; 1,1-DCE, 7; CT, 5; CF, 5.7; cis-1,2-DCE, 70; PCE, 5; TCE, 5. In addition to the nondetects (U-qualified results), several other results were qualified (J, D), but are not shown differently for the sake of simplicity. Note logarithmic scale for concentrations.

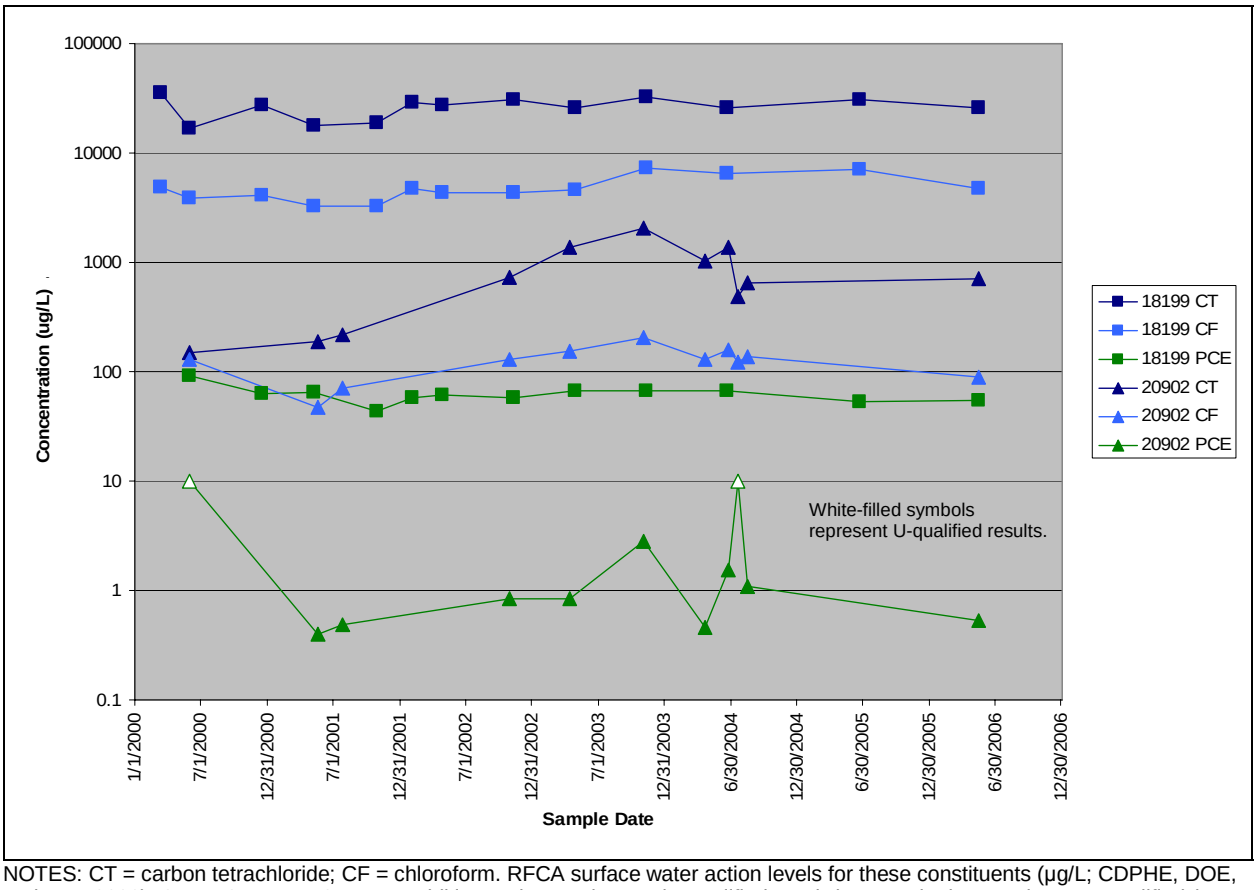
*Figure 3−25. Concentrations of OBP#2 VOCs in Downgradient Well 91203*

Data from well 91305, located west of well 91203, suggest the OBP#2 source area does not contribute to ground water monitored by well 91305, though cis-1,2-DCE and vinyl chloride have been reported in samples from well 91305.

### 3.3.3.5 IHSS 118.1 (Carbon Tetrachloride) Plume

The area referred to as the former IHSS 118.1 is the source of a carbon tetrachloride plume. In late 2004, the dense, non-aqueous phase liquid (DNAPL) source material was removed along with an adjacent subsurface tank group referred to as B730. HRC was added to the backfill material to enhance the biodegradation of residual contamination.

Evaluation well 18199 is located on the north of the former IHSS, roughly 80−90 feet north-northwest of the area in which free-phase carbon tetrachloride was present and perhaps 30 feet north of the source-removal excavation boundaries. Concentrations of carbon tetrachloride, chloroform, PCE, and other VOCs from this well in May 2006 are similar to those reported in prior years. To the northwest, well 20902 has also been impacted by IHSS 118.1. Time-series plots are presented in Figure 3−26.




NOTES: CT = carbon tetrachloride; CF = chloroform. RFCA surface water action levels for these constituents (µg/L; CDPHE, DOE, and EPA 2003): CT, 5; CF, 5.7; PCE, 5. In addition to the nondetects (U-qualified results), several other results were qualified (J, D, E), but are not shown differently for the sake of simplicity. Plots for well 20902 include data from its predecessor, 20998. Note logarithmic scale for concentrations.

*Figure 3−26. Concentrations of Primary IHSS 118.1 VOCs in Source Area and Downgradient Wells*

Concentrations of methylene chloride, another breakdown product of carbon tetrachloride, are also reported in samples from well 18199 but are not shown in Figure 3−26 because of the frequent B qualifiers (indicating laboratory contamination from this common lab solvent). Also not shown are TCE concentrations because of their elevated detection limits and frequent U qualifiers (not detected at the indicated detection limit).

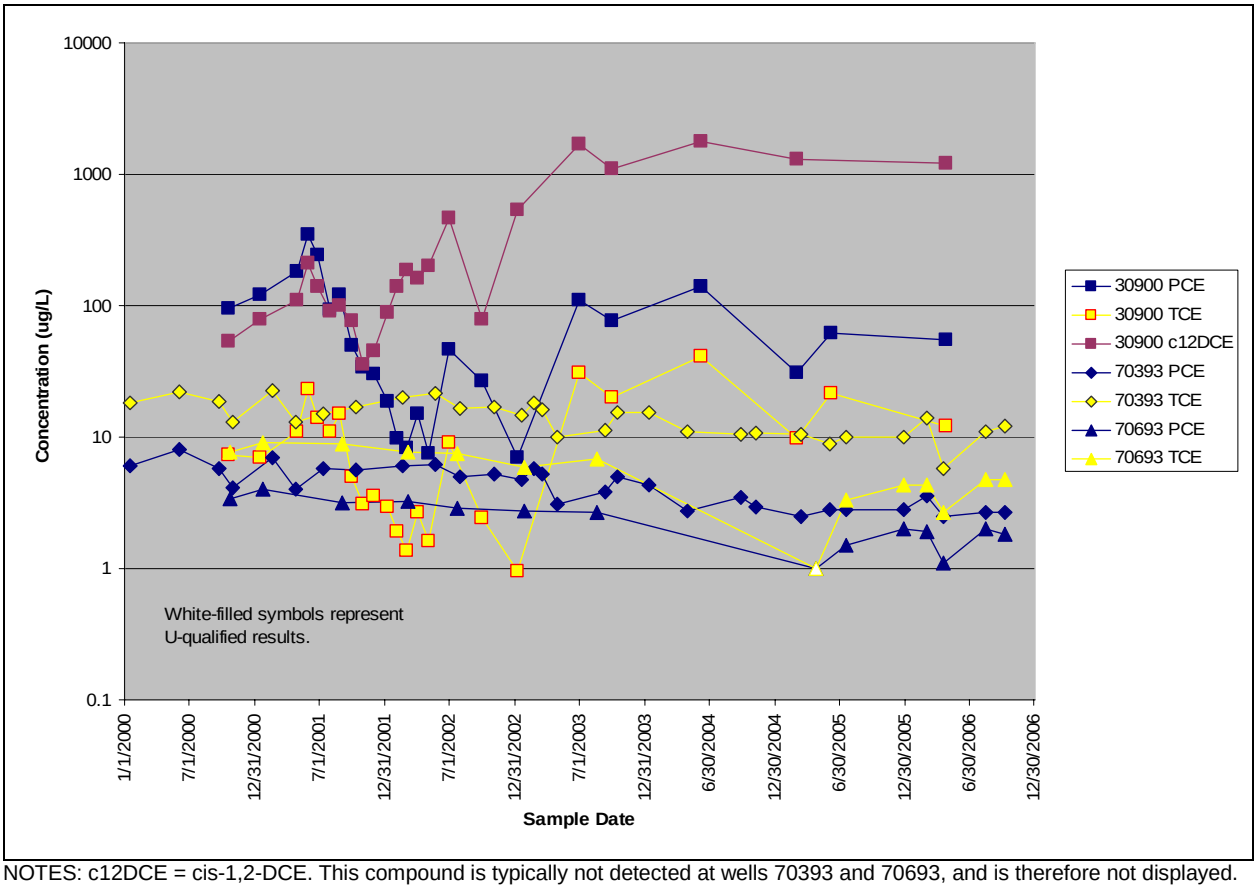
Concentrations of carbon tetrachloride and PCE in samples from source-area well 18199 would be expected to decrease, and those of chloroform increase, following enhancement of biodegradation related to the application of HRC in the backfill following source removal activities. This is not evident on Figure 3−26, but will continue to be assessed. Water quality data from wells 20705, 20505, and 20205 will also continue to be assessed to determine whether a more northerly flow path is established; such a path is not indicated by data collected in 2006. However, S-K trend calculations indicate a statistically-significant (95 percent) increasing trend in U concentrations at well 20705. Even so, the highest results are an order of magnitude lower than the U threshold defined in the IMP (DOE 2006c). See Appendix B.3 for the S-K trend plots, which are also summarized above in Section 3.3.1 and Table 3−5.

#### 3.3.3.6 PU&D Yard Plume

The PU&D Yard Plume is an area of ground water with low concentrations of primarily PCE-family VOCs. This area was the site of the first HRC application performed at RFS, which took the form of a treatability study performed in early 2001 (K-H 2001, 2002a; see K-H 2005a for final detailed information from this study). This plume is monitored by Evaluation well 30900 in the source area and Sentinel well 30002 to the east, at the margin of North Walnut Creek. In addition, PLF Resource Conservation and Recovery Act (RCRA) wells 70393 and 70693 monitor the northern edge of this plume.

Concentrations of PCE, TCE, and cis-1,2-DCE in samples from source-area well 30900 suggest steady-state conditions have been reached in the source area. All three compounds show a leveling off of concentrations, and data from 2006 indicate there is little or no additional degradation of parent PCE and TCE to cis-1,2-DCE resulting from the application of HRC in 2001. Reductive dechlorination of cis-1,2-DCE results in vinyl chloride and/or 1,2-DCA (K-H 2004a), but with the exception of one result of 0.21 μg/L vinyl chloride in July 2001, neither of these constituents have been detected in samples collected from well 30900. This suggests either incomplete degradation of PCE or an alternative dechlorination pathway. Given the limited effective lifetime of HRC and the oxygenated ground water here, this is not surprising.

Concentrations of PCE and TCE in ground water samples from downgradient PLF RCRA wells 70393 and 70693 do not show the same fluctuations as are evident in samples from well 30900 (Figure 3−27). Instead, samples from these RCRA wells continue to show a slight decline in concentrations, apparently unaffected by events in the source area of the PU&D Yard Plume. Cis-1,2-DCE is rarely detected at these locations, with those few detections qualified as estimated and reported at below 1 μg/L.




NOTES: c12DCE = cis-1,2-DCE. This compound is typically not detected at wells 70393 and 70693, and is therefore not displayed. RFCA surface water action levels for these constituents (µg/L; CDPHE, DOE, and EPA 2003): cis-1,2-DCE, 70; PCE, 5; TCE, 5. In addition to the nondetects (U-qualified results), several other results were qualified (J, E, D), but are not shown differently for the sake of simplicity. Note logarithmic scale for concentrations.

*Figure 3−27. Concentrations of Primary PU&D Yard Plume VOCs in Source Area and Downgradient Wells*

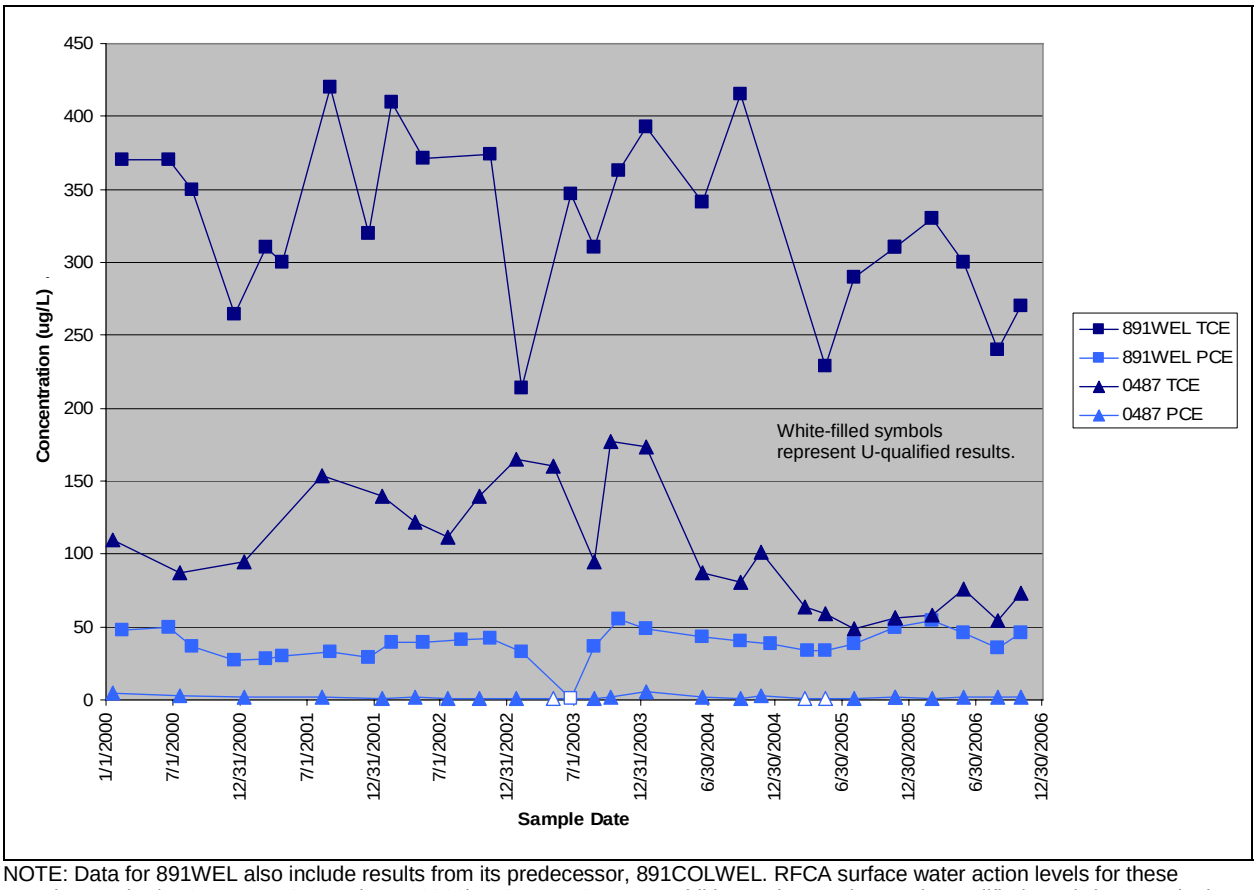
In addition to the analytes displayed on Figure 3−27, as discussed in the 2005 Annual Report (DOE 2006e) well 30900 reports elevated concentrations of two non-chlorinated constituents that are rare or absent in ground water at the Site: acetone ($C_3H_6O$) and 2-butanone (a.k.a. methyl ethyl ketone, $C_4H_8O$). Samples collected in 2006 showed a decrease in 2-butanone (from 1,900 µg/L in March 2005 to 880 µg/L in April 2006) and an increase in acetone (from 1,000 µg/L to 1,100 µg/L over the same time period). Both of these chemicals are common laboratory contaminants, but the concentrations reported for ground water samples from well 30900 are far above what would be normal for lab contamination of a sample. Both constituents are readily degraded in the environment (Hazardous Substances Databank). Neither of these analytes are detected in ground water samples from wells 70393 and 70693, but the samples collected from Sentinel well 30002 in November 2005 and in April 2006 reported acetone detections (estimated, J-qualified 3.2 µg/L and 120 µg/L, respectively). The October 2006 sample did not contain a confirmed detection of acetone.

### 3.3.3.7 OU1 Plume

The OU1 Plume is located on the 881 Hillside, immediately south of the former IA. Its source area, former IHSS 119.1, was a drum and scrap metal storage area. Throughout 2006 this plume

was monitored according to the OU1 CAD/ROD (DOE 2001), which specifies six wells be monitored. Two, Decision Document wells 891COLWEL (now 891WEL) and 0487, are monitored quarterly; the other four (Decision Document wells 4787, 4887, 10992, 11092) are monitored semiannually.

Concentrations of TCE (the constituent of most interest in this plume) in ground water at the OU1 Plume did not change markedly through 2006. Analytical results are displayed on Figure 3−28 for TCE and PCE in source-area well 891WEL (including its predecessor, 891COLWEL) and well 0487, which is located about 135 feet downgradient. TCE was not detected in ground water samples from AOC well 89104, but estimated detections of acetone (62 µg/L) and methylene chloride (0.46 µg/L, also B-qualified, indicating blank contamination) were reported here.




NOTE: Data for 891WEL also include results from its predecessor, 891COLWEL. RFCA surface water action levels for these constituents (µg/L; CDPHE, DOE, and EPA 2003): PCE, 5; TCE, 5. In addition to the nondetects (U-qualified results), several other results were qualified (J, D), but are not shown differently for the sake of simplicity.

*Figure 3−28. OU1 Plume VOCs*

### 3.3.3.8 Other Areas

Although not marked by plumes, other areas warrant mention either because associated wells have produced samples with concentration trends having a 95 percent significance (as calculated including results from the fourth quarter of 2006) or because they may be of interest. These are summarized below.

- Former B881: Well 88104 shows a decreasing trend in U, while well 00797 shows an increasing trend in U. Concentrations at 88104, located immediately southeast of the building, are typically at least twice as high as at 00797. Concentrations at both locations are well below the U threshold in the IMP (DOE 2006c).
- Former SW056: Well 45605 is installed within what is now a slump block south of former B991 to monitor ground water that previously exited the hillside via a pipe outlet identified as SW056. (See Section 3.5.1 for additional discussion on the historical context of SW056 and the slump.) Following removal of the pipe and backfilling with HRC, the monitoring well was installed. Whereas the surface water samples from SW056 reported the presence of parent compounds such as PCE and TCE (most recently—July 2005—in the 20−40 µg/L range), samples from the well have continued to report no detections of these constituents. However, detections of vinyl chloride are reported, as well as higher concentrations of cis-1,2-DCE. Both compounds were also reported at SW056, but vinyl chloride was present at higher concentrations (most recently to approximately 12 µg/L in SW056, and an estimated concentration of 0.97 µg/L from 45605) and cis-1,2-DCE was at lower concentrations (most recently approximately 110 µg/L at SW056 and 300 µg/L at 45605). Concentrations of the latter compound have increased through 2006, suggesting continued degradation of parent compounds upgradient of the well.

### 3.3.4 Ground Water Flow

This section provides summary discussion of ground water elevation and flow characteristics. Ground water elevation data are discussed first, through the construction and interpretation of potentiometric surface maps and hydrographs. Ground water flow characteristics are then assessed, including calculated flow velocities.

Discussions of conditions at the PLF and OLF are presented separately in Section 3.4.

#### 3.3.4.1 Ground Water Elevations

Ground water elevation data were collected at the start of the second and fourth quarters of 2006. (Water level data are included in Appendix A.3.) These data were plotted and hand-contoured to create potentiometric surface maps.

The potentiometric surface maps for 2006 are the first to use new topographic data representing the post-closure land surface. These data were received in early 2007, and are based on an aerial survey performed in the summer of 2006.

The potentiometric surface map for the second quarter of 2006 is included as Figure 3−29, and that for the fourth quarter of 2006 is included as Figure 3−30. Both of these maps are based on water level measurements collected manually from all wells then scheduled and available for measurement. All wells are screened within the upper hydrostratigraphic unit (UHSU) at Rocky Flats, which comprises the unconsolidated surficial materials (e.g., Rocky Flats Alluvium, hillslope colluvium, valley-fill alluvium, and artificial fill—all of which are often loosely referred to as “alluvium”) and underlying weathered bedrock (most often the Cretaceous-aged Laramie Formation, but in some areas also or instead the Cretaceous-aged Arapahoe Formation). While these two components of the UHSU are in hydraulic communication, a well screened

entirely within the weathered bedrock may reflect different water levels from an adjacent well screened only in the alluvium.

Seep areas are also posted on both potentiometric surface maps; these are from the 1995 Hydrogeologic Characterization Report (EG&G 1995b). As such, given the removal of the water supply system and associated reduction in the amount of water available to the Site, as well as the cessation in the 1990s of remaining spray evaporation practices, this depiction of seep areas is almost certainly no longer accurate. However, it remains the best available map of seeps at the Site.

As is obvious from a comparison of the potentiometric surface maps for 2006 (Figure 3−29 and Figure 3−30) against those issued in pre-closure years (e.g., K-H 2004b, 2004c), the level of detail afforded by the closure network is sharply reduced relative to the network monitored in past years. Previous potentiometric surface maps were based on the data from hundreds of monitoring wells across the Site, while those for 2006 are based on many fewer locations focused on the former IA and adjacent areas of interest.

Several locations on each map are labeled as having been dry at the time of measurement, indicating areas that are unsaturated. Unsaturated areas are evident each year, but are less notable now for two reasons: First and foremost, the monitoring network in 2006 was much more streamlined than in most prior years. This results in more widely-distributed data and a lower resolution when constructing the maps, affecting both the water level contours as well as the size of dry areas. Second, many of the wells in the network are replacement wells that are better-designed and constructed than their predecessors. (Many of the previous wells did not penetrate deeply enough into the UHSU, whereas replacements typically extend well into the weathered bedrock.)

In annual reports for years prior to 2004, actual dry areas were mapped based on corresponding groups of dry wells. This is no longer feasible due to the limitations of the current network (nor is it a particularly important or meaningful objective), and only the wells themselves are shown as being dry. Despite the fact that many of the wells in the current network are improved in many ways over their predecessors, the apparent indication of wetter conditions must be considered in terms of the reduced well coverage before reaching any conclusions regarding larger-scale conditions. Wells are shown as dry if they are either dry or only contain water below the base of the screened interval (a condition that has been historically referred to at RFS as “technically dry,” because the water within the casing below the screen is stagnant and may not reflect the actual water level).

Unsaturated areas are the result of limited ground water. This condition may be caused by reduced recharge from precipitation (i.e., droughts, such as that in 2002) or reductions in the contributions from other sources. These may include such sources as dust suppression or irrigation water, unlined ditches, and water lines and other subsurface utilities that can leak water or convey ground water along their corridors. These sources were removed during Site closure and were no longer present in 2006, but their effects may continue to be expressed for several years as residual “artificial” water (i.e., from such sources as leaking water supply lines and dust suppression) moves through the system. Changes in the extent of saturation can also come about from changes in ground surface configuration (e.g., addition/removal of impervious surfaces, modification of surface water runoff), but none of the work done in 2006 would have had such an effect.

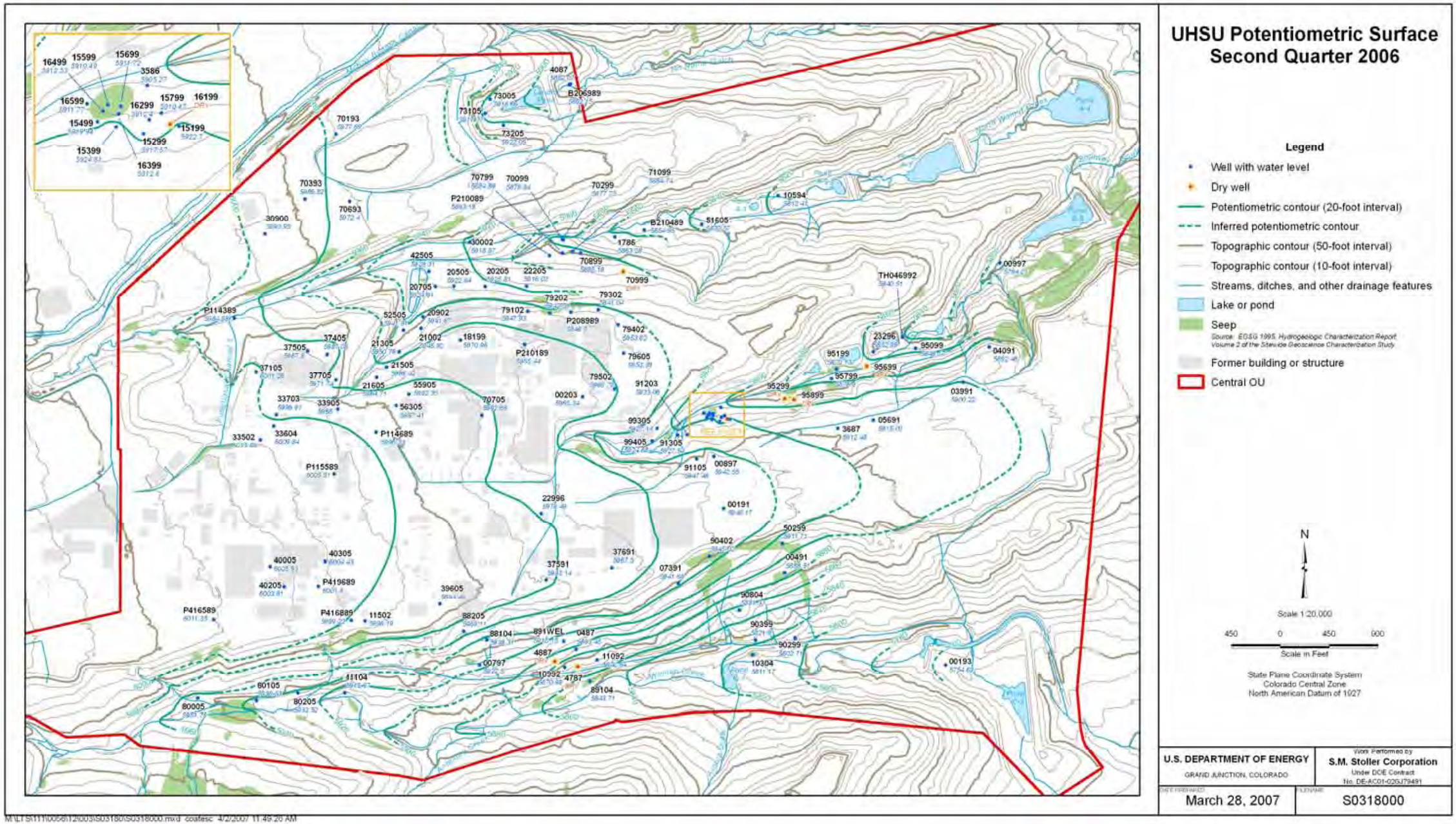



*Figure 3−29. UHSU Potentiometric Contours: Second Quarter 2006*

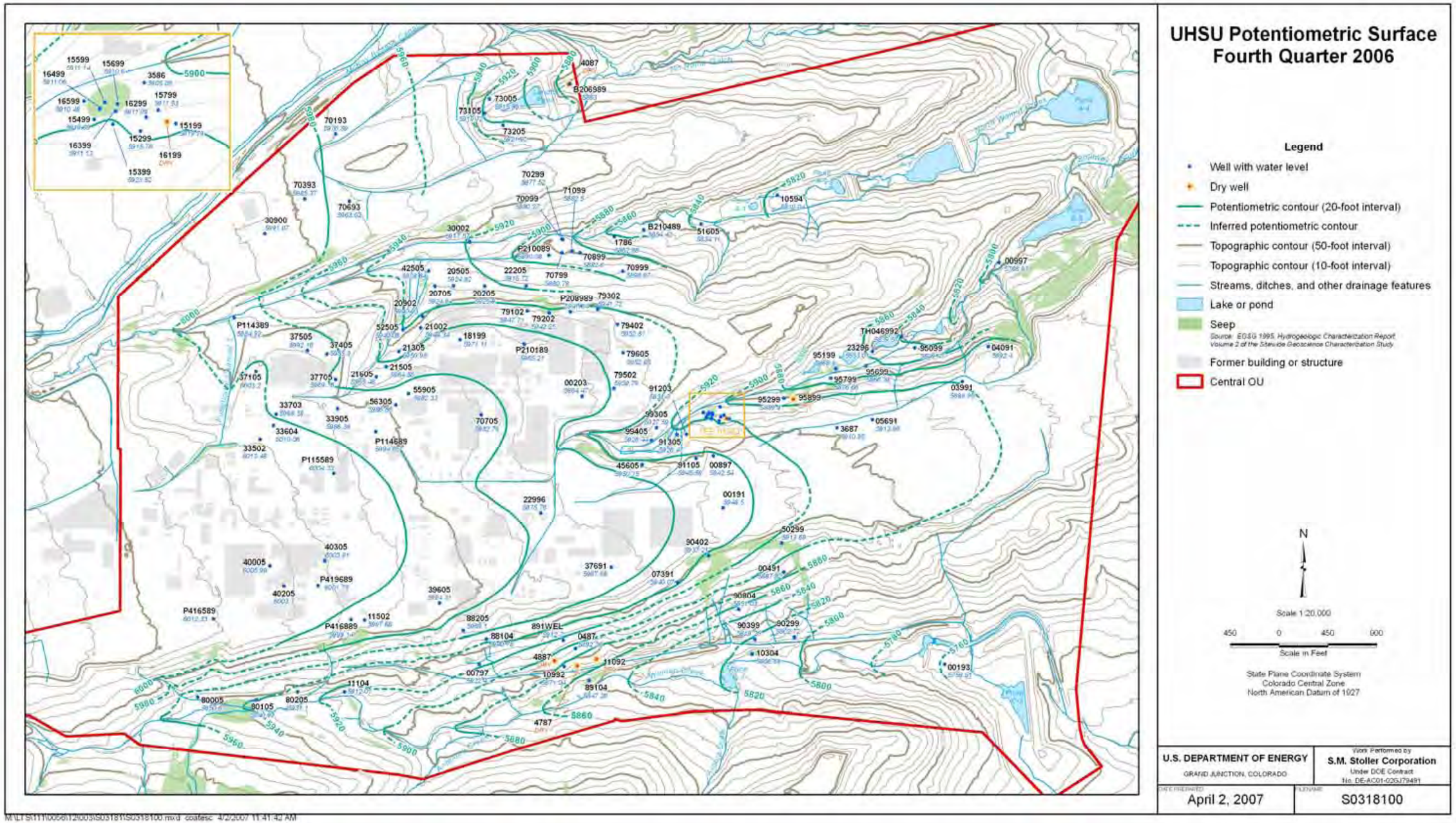



*Figure 3−30. UHSU Potentiometric Contours: Fourth Quarter 2006*

Precipitation in 2006 was recorded at eight locations across the Site. Table 3−8 summarizes precipitation totals for recent calendar years, and serves as evidence of the dry conditions of 2006. Note that the amount shown for 2003 incorporates March data from the Site's 61-meter meteorology tower, which included a heated precipitation gauge that recorded precipitation from the multi-foot March 2003 snowstorm more accurately than the unheated gauges operated by the Water Programs Group. See Section 2 of this report for additional discussion of precipitation.

*Table 3−8. Calendar Year Precipitation Totals at the Site*

| Calendar Year | Total Precipitation (inches) |
|---|---|
| 1993 | 12.27* |
| 1994 | 10.64 |
| 1995 | 16.49* |
| 1996 | 12.36 |
| 1997 | 15.02* |
| 1998 | 12.83* |
| 1999 | 14.30 |
| 2000 | 12.29 |
| 2001 | 12.74* |
| 2002 | 7.94 |
| 2003 | 12.35 |
| 2004 | 16.91 |
| 2005 | 11.58 |
| 2006 | 9.18 |

Notes: Total precipitation listed is an average of all precipitation gauges operating that year at the Site. In 2006, this was 8 gauges. *Value corrected from that included in 2005 Annual Report. Correction factors were 0.01 to 0.03 inches.

Unsaturated areas in 2006 are similar to those depicted in previous years, if well coverage and design are taken into account. Unsaturated areas in both the second and fourth quarters of 2006 include areas of the OU1 Plume and each of the three ground water treatment systems. These locations are typically dry; all four are controlled to a large extent by the ground water intercept trenches they are installed within or adjacent to. (At the OU1 Plume, it is the defunct French drain that is nearby.) Ground water flow directions are also generally consistent with previous years, as estimated from the potentiometric surface maps (Figure 3−29 and Figure 3−30).

Water levels are generally higher in the second quarter than the fourth quarter. This is typical, and reflects seasonal patterns. Both maps indicate the importance to ground water flow of the buried drainage south of former B371, which exerts an influence on water levels in wells in the area south and east of that facility. Where B371 used to represent a local "low" in the water table as a result of its foundation drains, the maps indicate the ground water has equilibrated in the area and it now appears to resemble ground water in the other hillsides. A similar scenario also appears to be the case in the B883/B881 area, as the edge and side of that hill appear to reflect no further effect of the now-disrupted subsurface drains. (This is also supported by hydrographs, discussed below.) Even so, it bears repeating that the well network is not designed to reveal such small-scale changes.

### *Hydrographs*

Hydrographs were prepared and are included in Appendix A.4, and groups of hydrographs are discussed here. This section should be read while also viewing the referenced hydrographs to enable greater understanding; without the hydrographs, much of the following detailed discussion will appear meaningless.

The hydrographs combine original and replacement wells under the assumption that the corresponding data are continuous. (As additional data are collected, this may prove to be a faulty assumption at some locations, and the corresponding water level data and/or analytical data may no longer be pooled.) Differences in well construction and geology from original to replacement wells are evident on many of the hydrographs. Regarding geological differences, it is important to note that in some locations the bedrock contact is exceptionally subtle, which can lead to the selection of different depths for this contact even in geological materials that are essentially identical from the original to replacement location.

Water level data used for the hydrographs (Appendix A.3) include routine water level measurements as well as pre-sampling and specially-requested measurements. This allows a more comprehensive assessment of the hydrogeology screened by the well, as in many cases it offers information on well recharge that would be omitted if only routine water level measurements were posted. Water level elevations were calculated from the recorded depth to water and the elevation of the top of the well casing. Where a well was found to be dry, the water level posted on the hydrograph is equivalent to the elevation of the bottom of the well casing, as calculated from the measured total length of the well casing during its installation. Also posted as dry are measurements of water levels within the blank sump at the base of most wells.

Hydrographs for wells monitoring contaminant plumes in the eastern portion of the former IA and adjacent areas, including the OBP#2 Plume, Mound Site Plume, 903 Pad/Ryan's Pit Plume, and East Trenches Plume, will be discussed together due to their geographic proximity, similar hydrogeologic setting, and commingling contamination. Ground water from the OBP#2 Plume and Mound Site Plume is captured and treated by the MSPTS. In the source areas, the hydrograph for well 91105 (OBP#2) shows a fairly flat curve, while that for downgradient well 91203 shows a sharply higher water level in the spring of 2005. This was discussed in the 2005 Annual Report (DOE 2006e) and relates to pumping of water from the 700 Area across the surface just upgradient of this well. The water level in 91203 remains high throughout 2006, suggesting that the flow of ground water within the former storm drain corridor, which is routed to the MSPTS intercept trench, reduces evapotranspiration at well 91203; as is evident from the ground water quality discussions above, contaminants at that well do not support a direct contribution of ground water from the storm drain corridor, assuming ground water within that corridor reflects OBP#2 contamination. Well 00897, which monitors the Mound source area, shows ground water levels have decreased since closure but not greatly, and appear to have leveled off in 2006.

Wells 07391 and 00191 are closest to their source areas, Ryan's Pit and the 903 Pad, respectively. Hydrographs for these wells are very similar if the effects of sampling at 07391 are ignored. Following Site closure, ground water elevations at well 00191 have leveled off, but at 07391 it appears more variable. The hydrograph for well 90402, located generally between the former two wells, is also similar. Post-closure water levels are more closely related to those at

07391 than at 00191, which may relate to the mechanism causing the 903 Plume to bifurcate, with one portion flowing southeast toward Woman Creek during wetter times and the other flowing northeast to join with the East Trenches Plume. Well 00191 is located near the point at which these two lobes diverge. Farther down the hillside are wells 50299, 00491, 90804, and 90399. The hydrograph for well 90399, located adjacent to the SID, shows some similarity to the curve for well 07391. However, the hydrograph for well 50299, located closest to the top of the pediment, does not resemble any of the other curves. Located adjacent to an area that has been mapped as a seep, this well appears to receive a strong localized contribution, and therefore does not reflect the larger-scale pattern evident in other wells. This also applies at well 90804, which monitors a detachment plane beneath a slump block between well 50299 and the SID; the water level in this well is very consistent and shows no seasonal or closure-related influences.
Well 00491, located near 50299, presents a water level curve that is impacted by sampling and extended dry periods. The latter portion of the curve, since the St. Patrick's Day 2003 blizzard, resembles that from wells 07391 and 00191; the 2006 data are most similar to those from well 07391. Generally speaking, these patterns indicate there are definite seasonal influences in the source areas and hillside monitoring locations except at those monitoring localized features, such as the seep near 50299 and the slump at 90804. The effects of closure on ground water elevations in this area so far appear minimal.

Wells 3687, 05691, 03991, and 04091 monitor the East Trenches Plume and are located, respectively, in the T-3 and T-4 source areas and along the distal edge of the plume. The water level curves displayed on hydrographs for wells 3687, 05691, and 03991 are very similar, reflecting the same increases and decreases in water level. There may be some seasonal component to their curves, but this is not certain because the relative high water levels occur in late summer to fall months only during odd-numbered years. Well 04091, located farther to the east, does not reflect this pattern: water levels here are very consistent and the curve is essentially flat.

The hydrographs for several wells in the vicinity of the MSPTS, most notably 15399 but also including 91203 and 15199 (and less so wells 15299, 15499, 15599, 15699, and 3586), display increasing water levels beginning in early 2005, most typically in March. This timing coincides with the routing of 700 Area water through a temporary ditch cut across the ground just upgradient of the MSPTS, and the diversion of water to the MSPTS intercept trench from the corridor formed by a storm drain, as discussed previously. This latter change continues to affect the hydrograph for well 15399 particularly strongly, with the water level in 2006 typically very close to the former top of casing. (Many of these wells were extended just prior to closure due to the addition of several feet of fill.) This condition is evident in the field as well, with the ground surface at 15399 typically moist to saturated. Conversely, well 91105, located immediately downgradient of the OBP#2 source area excavation, does not reflect this pattern, indicating it is upgradient of the impact. Also in the MSPTS area, well 15799 is just beyond the eastern end of the ground water intercept trench. This well typically has been dry since its installation, but data collected in 2006 indicate rising ground water levels here. This is likely affected, at least in part, by removal of the nearby infrastructure (North Perimeter Road, Central Ave. Ditch) and increased infiltration, but perhaps more importantly the additional water routed to the intercept trench may be sufficient to saturate this eastern end of the trench and affect water levels in nearby well 15799.

Hydrographs for wells around former B771 show the overlapping effects of several changes. Removal of the foundation drains would be expected to cause rising water levels, but removal of the water supply system and dust suppression water applied during closure activities would have an opposite effect. The net result is varied. Well 18199, located upgradient of B771 but downgradient of former IHSS 118.1, would have been strongly affected by the pumping (ground water removal) during IHSS 118.1 source removal and the application of dust suppression water during B776/777 closure. The hydrograph for this well shows a slow decrease in ground water elevations following source removal and cessation of the application of dust suppression fluids. The water level in 2006 appears to be stabilizing about two to four feet below its previous average, though that average was strongly influenced by Site activities as suggested by the hydrograph's large range. Downgradient of B771, well 20705 also shows a slightly lower average water level in 2006 than prior to closure, but the water level curve for this well lacks the larger variations evident in the upgradient well. This is also the case at well 20205, located farther to the east near former Bowman's Pond. Between these two is well 20505, which the hydrograph indicates was strongly affected by the changes brought during Site closure. Water levels at this location have been rebounding since spring 2005; this may be related to removal of the storm and foundation drains that previously either emptied to the Bowman's Pond area or were routed to the west and north via subsurface drains.

Hydrographs for wells monitoring the former B371/374 complex (37105, 37405, 37505, and 37705, plus more distal P114389) each shows a very different pattern from the others. Ground water around this facility was formerly controlled very strongly by a pair of foundation drains, one around the building's basement and one around its sub-basement. The most consistent element in hydrographs from the first three wells listed—located on the west and north of B371/374—is a drop in water levels immediately following Site closure. This would relate to ground water filling the previously-dry subsurface following disruption of the foundation drains. Of these three wells, it is least obvious at 37105, consistent with its location upgradient of the complex, and most strongly indicated by the water levels in well 37505, located downgradient of B371. The amount of this decline ranges from about 4 feet at well 37105 to about 25 feet at well 37505. The hydrograph for well 37405 is complicated in that it indicates a broader, two-step decrease similar to that at upgradient well 37105. Water levels in all three wells rebounded. Well 37705, located near where the foundation drains for the two subsurface portions of the buildings came together, shows an increase in water level following closure, and then a decrease to a level more consistent with pre-closure conditions. However, the original well, 37701, was located almost 200 feet northeast of replacement well 37705, which may require their respective data pools to be considered separately. This topic will continue to be assessed as more analytical and hydrological data are collected. Finally, well P114389, located northwest of the B371/374 complex and at the mouth of FC-1, presents a hydrograph that shows very little change from pre-closure water levels. A slight decline is present at a time coinciding with Site closure, but otherwise the water levels are consistent with earlier data.

Ground water around the unnamed drainage between former B771 and B371 is monitored by several wells. Well 20902 is located adjacent to a former B771 foundation drain outfall. The hydrograph for this well indicates decreasing water levels since Site closure and the cessation of dust suppression activities. Conversely, nearby well 21002 shows little change over the years, because it is not as near or strongly influenced by foundation drains or dust suppression and closure activities. Other wells in this area include 21305, 21505, 21605, and 33905. Each of these locations shows a drop in water levels correlating with the timing of Site closure, followed

by either a rebound (partial, as in the case of wells 21305 and especially 21605, or complete, as in the case of 21505) or static conditions (well 33905). The seep at well 21605 and the subsurface conditions it represents probably influence the three rebounding water levels, but well 33905 is farther upgradient and is unaffected by these localized conditions.

Well 33905 also monitors the northeast end of the buried drainage present south of B371, which is also monitored by wells 33502, 33604, and 33703. (These three wells monitor the vinyl chloride plume.) Wells 33502 and 33604 maintain very stable water levels, showing little or no influence by Site closure. Water levels in wells 33703 and 33905 show similar patterns through closure, then the former well begins a gradual rebound while the latter, as noted above, remains fairly stable.

In the central portion of the former IA, hydrographs for wells P114689 and P115589 both indicate water levels that are not dramatically affected by Site closure. Water levels at the former well, located between former B551 Warehouse and B559, are within their historic range. The water level at P115589, located on the western edge of the former Warehouse, shows a slight decline in water levels that may have begun as early as 2003. Wells 55905 ad 56305 both monitor former B559, and also show minimal effects from closure, with 2006 water levels falling generally within their former ranges. However, well 70705, located on the east side of former B707, shows a significant increase in water levels that may be related to the disruption of the foundation drain at that building.

Farther south, at former B444, hydrographs from wells 40005, 40205, and 40305 show smooth water level curves with little or no response to Site closure. The foundation drain for this complex was not extensive, and its disruption appears to have had little effect on water levels. In addition, the predecessor wells all produced ground water readily, suggesting the drain system did not have a very strong effect on water levels prior to closure. The hydrograph for nearby well P419689, however, does reflect a drop in water levels coinciding with closure—and immediately following an increase that is likely related to the dust suppression water applied during demolition and closure of B444. Hydrographs for wells 11502 and P416889, both located farther southeast of B444, also show an increase that may be related to dust suppression activities, but the decline in water levels following closure is not indicated here. Possible factors in the declining water levels at well P419689 include removal of two small drainages near the well prior to closure, and the removal of the subsurface water lines that were present here.

Hydrographs for wells in the former 800 Area clearly show the impacts of closure on ground water levels in this area. The predecessor to well 88205 (well 5187) used to be in a parking lot on the south side of B881, and was strongly affected by the foundation drain system. Following disruption of that system, water levels at this location have risen dramatically—an increase of nearly 20 feet is apparent on the hydrograph. Nearby well 88104 also shows a significant increase of just over 10 feet. This latter well is separated from the original well by over 100 feet, but the pattern is probably representative of this area. On the pediment surface in the 800 Area, well 39605 is closest to former B881. The hydrograph for this well appears to show closure exerted little or no effect on ground water elevations in this area. Its predecessor, well 39691, was often dry, a condition which was previously thought to be due to the presence of the B881 foundation drain a short distance downgradient (east) of the well. However, the deeper replacement well suggests these conditions may have been natural and water levels here were not strongly affected by the drain. The lack of a strong influence on water levels at downgradient

well 00797 is also apparent in the hydrograph from that well; a similar apparent lack of closure-related change is shown at 881 Hillside wells 891WEL (which is represented by few data), 0487, 4787, 4887, 10992, and 11092. In the 891 Yard area, well 37591, located near the former B891 water treatment facility, shows a water level drop of just over 10 feet since closure. This well was also located adjacent to a water line, which may have influenced water levels here. Farther east, well 37691 at the south end of the former 904 Pad shows a water level increase of about two feet since closure, possibly related to the removal of the impermeable surfaces represented by the many paved surfaces that previously diverted precipitation and limited local recharge.

The hydrographs indicate that water levels in the source area of the SPP are relatively stable. Downgradient to the north, the water level in well 22205 appears to be leveling off at a lower elevation than prior to closure, possibly affected by the dry climate in 2006. Conversely, ground water in well P210089 is leveling off higher than its pre-closure elevation, possibly because the drainage that used to transport surface water adjacent to the well is gone, allowing this water to infiltrate. Alluvial well 70099 and weathered bedrock well 70299 show little change with respect to earlier data. The hydrograph for well 70299 is remarkably uniform, while that for 70099 may indicate a slight increase in water levels.

At former B991, hydrographs for wells 99305 and 99405 suggest ground water in this area is also stabilizing. Water level curves at both wells appear to be influenced by sampling. Ground water levels at well 99305 (located near the northeast edge of the former building) show little impact from Site closure, and are fairly steady at what would have been near the top of the range for this location prior to closure. Ground water at well 99405, which was located in what was the loading dock area on the southeast corner of the building, has been rising since approximately June 2005. This coincides with construction of the future FC-4 wetland area; not surprisingly, the constructed wetland area adjacent to this well has caused its water level to rise. The 2-inch well diameters of 99305 and 99405 show reduced effects of sampling, as compared to the original one-inch-diameter wells.

The hydrograph for Evaluation well 30900, located in the PU&D Yard source area, shows an extremely well-developed, cyclical recharge pattern. Water levels are higher in late second quarter—June—of each year, with the March 2003 blizzard contributing to the rise that year. But the increase in 2006 is very muted, which is consistent with the very dry conditions that spring and summer. This pattern is also evident on the hydrograph for well 70393, located nearby on the upgradient (west) side of the PLF.

Wells monitoring drainages display interesting patterns. Ground water in the North Walnut Creek drainage is monitored by, from upgradient to downgradient, wells P114389, 52505, 42505, 30002, 1786, B210489, 51605, 10594, and 41691 (the last of which is at the Walnut Creek/Indiana Street intersection). Similarities can be seen among the hydrographs for many of these wells. The most upstream of these, P114389, 52505, and 42505, show very similar patterns with clear seasonal influences; the lattermost well is represented by minimal data and slow initial ground water production. Well 30002 presents a different water level curve that appears to be affected seasonally but also by sampling and the dust suppression measures employed during removal of the North Perimeter Road and associated paved areas, including former Portal 3. Since closure, water levels in this well have decreased smoothly, and appear to be stabilizing within its former (pre-dust suppression) range. Skipping wells whose water levels are strongly affected by the SPPTS, the next well downgradient is 1786. The water level curves at 1786 and

next-downgradient well B210489 are similar, and appear more similar to the wells farther upgradient than to nearer well 30002. This may be expected, since well 30002 was isolated from the bulk of the surface water flow prior to closure, as it was routed through culverts from former Portal 3 to just west of well 1786. In addition, well 30002 is influenced by ground water discharging to the North Walnut Creek drainage from the pediment to the north (which hosts the PU&D Yard and PLF) while the others reflect ground water discharging to the drainage from the south (the location of the IA). The hydrograph for well 51605, located near the inlet to Pond A-1, shows the effects of seasonal influences, sampling, and slow initial ground water production in the replacement well (51605; the original well was 1386). The water level curve here is much like the other upgradient wells except 30002, and is also very similar to that for next-downgradient well 10594, located between Ponds A-1 and A-2. The hydrograph for well 10594 displays limited data, and also appears affected by sampling, but the overall behavior is very similar to that at well 51605 on the upstream side of Pond A-1. This suggests that, as would be expected, the water levels in both wells adjacent to Pond A-1 may be strongly influenced by the pond. Finally, well 41691 shows the recharge to ground water downgradient of the terminal ponds that has been provided by pond discharges. Since the last discharge in May 2005, the hydrograph for well 41691 shows a steady decline in water levels.

The South Walnut Creek drainage is monitored by, from upgradient to downgradient, wells 99405, 91305, 23296, TH046992, 00997, and 41691. (As with the discussion on North Walnut Creek, wells most strongly influenced by the ground water intercept trench—in South Walnut Creek, it is the ETPTS—are not included in this discussion.) Unlike the hydrographs for wells monitoring North Walnut Creek, there is not much similarity in those monitoring South Walnut Creek. The most upgradient well, 99405, is strongly affected through mid-2005 by closure of former B991 and construction of FC-4. Nearby well 91305 is slightly less than 60 feet southeast of the location of original well 2187, which was adjacent to a wetland just east of B991. The hydrograph for this well shows a very flat curve, with a slight increase in water level in the replacement well compared to the original well. The flatness of this curve is completely dissimilar to the curve for well 99405, which reflects adjacent closure activities. Farther down the South Walnut Creek drainage, the hydrograph for well 23296, located between Ponds B-2 and B-3, is also fairly uniform but appears to show seasonal recharge, the effects of sampling, and as expected, the adjacent ponds. Well TH046992, installed as a dam piezometer for the Pond B-3 dam, has a very flat curve similar to that for well 91305. Although Pond B-3 was dry or nearly so for much of 2006, the hydrograph for well TH046992 reflects only a very small decline in water levels. The hydrographs for well 00997, located at the inlet to Pond B-5, and 41691, located at Walnut Creek and Indiana Street, are very similar in that they reflect pond discharge and a decreasing water level since closure.

The Woman Creek drainage is monitored by, from upgradient to downgradient, wells 80005, 80105, 80205, 11104, 89104, 10304, 00193, and 10394. Only the last of these, which is located at the Woman Creek and Indiana Street intersection, has plentiful water level data. More data will be needed from the other wells to enable clear patterns to be distinguished. The first three of these are downgradient of the OLF, and monitor ground water entering the drainage from the OLF and pediment to the north. As such, their hydrographs are strongly influenced by water moving within the constructed buttress at the base of the OLF. The hydrographs for these three wells are all fairly smooth, but also show they monitor different ground water regimes. The curve for well 80005 is very uniform, while that for 80105 shows a period of lower water levels following Site closure and that for 80205 shows an increase in water levels following closure.

Each well is, therefore, influenced somewhat by different ground water sources. Farther downgradient, well 11104 presents a hydrograph with a decrease in water levels coinciding with Site closure, followed by a rapid rebound to pre-closure levels. With additional data, the hydrograph for this well may reveal the expected strong seasonal component. Ground water monitored by well 89104 appears to have been rebounding since this well was first monitored in early 2005. The hydrograph for well 10304, located just east of Pond C-1, is most similar to that for well 11104. Well 00193 presents a water level curve that shows a steep drop coinciding with Site closure, followed by a steady rebound through 2006. The hydrograph for Boundary well 10394 shows a very strong seasonal pattern, with the well either dry or nearly so during dry months.

#### 3.3.4.2 Ground Water Flow Characteristics

Ground water flow directions and velocities in 2006 are generally consistent with those reported in 2005. As previously noted, the main changes following Site closure are seen at B371, where disruption of the foundation drain system has caused this area to no longer act as a ground water sink. Water levels in this area appear to have equilibrated across the B371 pediment, although they do and will continue to reflect the presence of the buried drainage to the south (Figure 3−29 and Figure 3−30). The disruption of foundation drains will also influence flow paths at B771 and B883/881, for example.

Flow directions, water level data, geological information, and completed well designs and locations support the selection of several well pairs for the calculation of linear ground water flow velocities, also referred to as seepage velocities. Using the potentiometric surface maps, a pair of wells is potentially useful if a line drawn between them is perpendicular (or nearly so) to the potentiometric contour lines between the two wells, and there are no intervening drainages or artificial ground water control structures such as the ground water intercept trenches that are a component of each of the treatment systems.

Well pairs selected for use in this Report are the same as those selected in 2005 plus one pair at the OLF (which is discussed at greater length in Section 3.4).

The seepage velocity ($v$) may be calculated using the Darcy equation:

$$v = \left(K/n\right)\left(dh/dl\right)$$

where

$K$ = hydraulic conductivity
$n$ = effective porosity
$dh/dl$ = hydraulic gradient.

This calculation is most sensitive to the hydraulic gradient and value of K used, because for all calculations of v in this report a consistent porosity of 0.1 is used. This is consistent with previous Annual RFCA Groundwater Monitoring Reports.

The hydraulic gradient was calculated from water level measurements performed in the 2nd and 4th quarters of 2006. Results of this calculation typically differ slightly when using data from one quarter vs. that from another, but the differences are typically not large.

Calculated seepage velocities are only useful as estimates. These velocities are most often used to estimate the travel time of conservative (non-reactive) constituents. Reactive constituents will tend to migrate more slowly than the calculated velocity. It is important to note that these calculated velocities do not take into account properties such as sorption and chemical reactions (e.g., precipitation, biodegradation, volatilization) that can strongly influence the migration rate of ground water contaminants.

For each well pair, the hydraulic conductivity, K, selected for this calculation was based on the predominant lithologic unit comprising the flow path between the two wells. This is based on the core logs for the respective wells and the published geology (EG&G 1995a), plus information from the hydrographs (i.e., whether ground water is typically restricted to the bedrock or extends into surficial materials). If more than one lithology was represented between the wells, an average K was calculated from that for each of the two lithologies. Similarly, if the water was present within different geologic materials from one season to another, these differences were accounted for via the use of corresponding hydraulic conductivities. K values used for these calculations are from EG&G (1995b), Table G-2, with subsequently modified values for Rocky Flats Alluvium (Qrf) and valley-fill alluvium (RMRS 2000; Safe Sites 2001, 2002).

One factor that cannot be accounted for without additional aquifer test data, and which may cause significant error in estimated seepage velocities, is the presence of artificial fill in many portions of the former IA. The K for Qrf is used because the source of the fill was typically various areas of the Rocky Flats Alluvium. However, it is unlikely that the backfilled alluvium is as well-packed as the original deposits, resulting in a higher effective porosity and K. Where well pairs cross former buildings that were backfilled with concrete rubble and alluvium, the effective porosity and K values will be higher still. For this report, well pairs crossing areas of sufficiently thick backfill deposits use the K for Qrf rather than that for the original lithology, under the assumption that the entire area of backfill/regrading has a hydraulic conductivity closer to that of the Rocky Flats Alluvium than to a lower-permeability unit.

An example well pair may serve to illustrate some of the related difficulties. Well 18199 is located between former B776 and B771. It screens Qrf and sandstone of the Arapahoe Formation (the “Number One Sandstone;” EG&G 1995a). Ground water in this area previously flowed toward the west as a result of the B771 foundation drain system. Following disruption of this drain, ground water flow will be more northerly, potentially through the rubble- and alluvium-backfilled subsurface remnants of B771. Well 20505 was selected as the downgradient well in this well pair. This well screens artificial fill, clays, claystone, and silty claystone. The transect from 18199 to 20505 is mostly occupied by the artificial fill of the B771 closure, and that fill is essentially reworked alluvium. Therefore, an average hydraulic conductivity of the Arapahoe Formation No. 1 Sandstone and Qrf is used to calculate the seepage velocity between this well pair.

As noted above, these calculated velocities are based in part on data displayed on the hydrographs: where water is shown above the bedrock contact, hydraulic conductivities for the unconsolidated surficial material (e.g., Qrf or Qc) are selected for this calculation. If the hydrographs show water is typically restricted to the bedrock, the K value for the generalized bedrock type is selected. Note that the extreme variability of bedrock lithologies (i.e., from

claystone to silty claystone to clayey siltstone to siltstone) is often reflected in core from the screened interval of a given well, but a single K value is selected to represent the well.

Table 3−9 presents the results of the calculation of seepage velocities. Refer to Figure 3−1 for the respective locations of the wells. Estimated velocities range from 17 feet per year (from well P210189 to 79102 in the SEP area) to 600 feet per year (from well 18199 to 20505 in the B771 area). The time to traverse the distance between each well in a well pair ranges from about 10 months (from well 18199 to 20505) to 74 years (from well 40305 at B444 to well 22996 at B886). These velocities are comparable to those calculated prior to Site closure (e.g., see K-H 2004b).

*Table 3−9. Calculated Flow Velocities for 2006*

| Well pair | Area | 2006 quarter | Geological unit | WL elevation, well 1 | WL elevation, well 2 | dh (ft) | dl (ft) | dh/dl (hydraulic gradient) | K (cm/s) | v (ft/yr) | Time to traverse transect (yrs) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| P115589-P114689 | North IA | 2 | Qrf | 6005.51 | 5996.33 | 9.18 | 550.14 | 0.017 | 4.18E-04 | 72.17 | 7.62 |
| P115589-P114689 | North IA | 4 | Qrf | 6004.33 | 5994.85 | 9.48 | 550.14 | 0.017 | 4.18E-04 | 74.53 | 7.38 |
| P114689-56305 | North IA/ B559 | 2 | Qrf | 5996.33 | 5987.41 | 8.92 | 304.74 | 0.029 | 4.18E-04 | 126.59 | 2.41 |
| P114689-56305 | North IA/ B559 | 4 | Qrf | 5994.85 | 5986.86 | 7.99 | 304.74 | 0.026 | 4.18E-04 | 113.39 | 2.69 |
| 56305-21605 | B559 | 2 | Qrf/Qc | 5987.41 | 5964.71 | 22.7 | 319.61 | 0.071 | 2.56E-04 | 187.86 | 1.70 |
| 56305-21605 | B559 | 4 | Qrf/Qc | 5986.86 | 5965.48 | 21.38 | 319.61 | 0.067 | 2.56E-04 | 176.94 | 1.81 |
| 18199-20505 | B771 | 2 | Qrf/ KaNo.1ss | 5970.96 | 5922.84 | 48.12 | 500.43 | 0.096 | 6.03E-04 | 599.92 | 0.83 |
| 18199-20505 | B771 | 4 | Qrf/ KaNo.1ss | 5971.11 | 5924.92 | 46.19 | 500.43 | 0.092 | 6.03E-04 | 575.85 | 0.87 |
| P416589-80105 | OLF | 2 | Qrf/KaKlclst | 6011.35 | 5938.53 | 72.82 | 846.63 | 0.086 | 2.09E-04 | 186.38 | 4.54 |
| P416589-80105 | OLF | 4 | Qrf | 6012.33 | 5940.99 | 71.34 | 846.63 | 0.084 | 4.18E-04 | 364.42 | 2.32 |
| 40305-39605 | South IA | 2 | Qrf/KaKlslt | 6004.43 | 5994.49 | 9.94 | 1126.39 | 0.009 | 2.23E-04 | 20.40 | 55.22 |
| 40305-39605 | South IA | 4 | Qrf/KaKlslt | 6003.91 | 5994.31 | 9.6 | 1126.39 | 0.009 | 2.23E-04 | 19.70 | 57.18 |
| 40005-P419689 | South IA | 2 | Qrf | 6005.93 | 6001.8 | 4.13 | 478.87 | 0.009 | 4.18E-04 | 37.30 | 12.84 |
| 40005-P419689 | South IA | 4 | Qrf | 6005.99 | 6001.75 | 4.24 | 478.87 | 0.009 | 4.18E-04 | 38.29 | 12.51 |
| P419689-11502 | South IA | 2 | Qrf | 6001.8 | 5998.19 | 3.61 | 535.27 | 0.007 | 4.18E-04 | 29.17 | 18.35 |
| P419689-11502 | South IA | 4 | Qrf | 6001.75 | 5997.66 | 4.09 | 535.27 | 0.008 | 4.18E-04 | 33.05 | 16.20 |
| 40305-22996 | South IA/ 800 Area | 2 | Qrf/KaKlclst * | 6004.43 | 5978.49 | 25.94 | 2037.05 | 0.013 | 2.09E-04 | 27.59 | 73.82 |
| 40305-22996 | South IA/ 800 Area | 4 | Qrf/KaKlclst * | 6003.91 | 5975.76 | 28.15 | 2037.05 | 0.014 | 2.09E-04 | 29.95 | 68.03 |
| 88205-00797 | 881 Hillside | 2 | Qrf/Qc | 5969.11 | 5922.5 | 46.61 | 343.12 | 0.136 | 2.56E-04 | 359.31 | 0.95 |
| 88205-00797 | 881 Hillside | 4 | Qrf/Qc | 5969.1 | 5922.4 | 46.7 | 343.12 | 0.136 | 2.56E-04 | 360.00 | 0.95 |
| 00191-00491 | 903 Pad-Lip | 2 | Qrf/KaKlclst | 5948.17 | 5888.51 | 59.66 | 816.98 | 0.073 | 2.09E-04 | 158.24 | 5.16 |
| 00191-00491 | 903 Pad-Lip | 4 | Qrf/KaKlclst | 5948.5 | 5887.82 | 60.68 | 816.98 | 0.074 | 2.09E-04 | 160.95 | 5.08 |
| 00491-90399 | 903 Hillside | 2 | Qc/KaKlclst | 5888.51 | 5821.80 | 66.71 | 676.30 | 0.099 | 4.71E-05 | 48.06 | 14.07 |

*Table 3−9 (continued). Calculated Flow Velocities for 2006*

| Well pair | Area | 2006 quarter | Geological unit | WL elevation, well 1 | WL elevation, well 2 | dh (ft) | dl (ft) | dh/dl (hydraulic gradient) | K (cm/s) | v (ft/yr) | Time to traverse transect (yrs) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 00491-90399 | 903 Hillside | 4 | Qc/KaKlclst | 5887.82 | 5819.26 | 68.56 | 676.30 | 0.101 | 4.71E-05 | 49.39 | 13.69 |
| 07391-10304 | Ryan's Pit/ Woman Ck. | 2 | Qc | 5941.68 | 5811.17 | 130.51 | 948.74 | 0.138 | 9.33E-05 | 132.79 | 7.14 |
| 07391-10304 | Ryan's Pit/ Woman Ck. | 4 | Qc/KaKlclst | 5940.07 | 5808.69 | 131.38 | 948.74 | 0.138 | 4.71E-05 | 67.47 | 14.06 |
| 91105-91203 | Oil Burn Pit #2 | 2 | Qrf/KaKlslt | 5947.48 | 5933.06 | 14.42 | 242.17 | 0.060 | 2.23E-04 | 137.63 | 1.76 |
| 91105-91203 | Oil Burn Pit #2 | 4 | Qrf/KaKlslt | 5945.59 | 5931.3 | 14.29 | 242.17 | 0.059 | 2.23E-04 | 136.39 | 1.78 |
| 91105-15499 | Oil Burn Pit #2 | 2 | Qrf/Qc | 5947.48 | 5919.94 | 27.54 | 392.19 | 0.070 | 2.56E-04 | 185.74 | 2.11 |
| 91105-15499 | Oil Burn Pit #2 | 4 | Qrf/Qc | 5945.59 | 5919.69 | 25.9 | 392.19 | 0.066 | 2.56E-04 | 174.68 | 2.25 |
| 91105-15399 | Oil Burn Pit #2 | 2 | Qrf/Qc | 5947.48 | 5924.81 | 22.67 | 394.09 | 0.058 | 2.56E-04 | 152.16 | 2.59 |
| 91105-15399 | Oil Burn Pit #2 | 4 | Qrf/Qc | 5945.59 | 5923.52 | 22.07 | 394.09 | 0.056 | 2.56E-04 | 148.13 | 2.66 |
| 00897-15499 | Mound | 2 | KaKlslt/Qc | 5942.55 | 5919.94 | 22.61 | 366.17 | 0.062 | 6.11E-05 | 39.00 | 9.39 |
| 00897-15499 | Mound | 4 | KaKlslt/Qc | 5942.54 | 5919.69 | 22.85 | 366.17 | 0.062 | 6.11E-05 | 39.42 | 9.29 |
| 00897-15399 | Mound | 2 | KaKlslt/Qc | 5942.55 | 5924.81 | 17.74 | 347.49 | 0.051 | 6.11E-05 | 32.25 | 10.78 |
| 00897-15399 | Mound | 4 | KaKlslt/Qc | 5942.54 | 5923.52 | 19.02 | 347.49 | 0.055 | 6.11E-05 | 34.57 | 10.05 |
| P210189-79102 | SEPs | 2 | KaKlslt | 5965.44 | 5947.93 | 17.51 | 301.98 | 0.058 | 2.88E-05 | 17.28 | 17.48 |
| P210189-79102 | SEPs | 4 | KaKlslt | 5965.21 | 5947.71 | 17.5 | 301.98 | 0.058 | 2.88E-05 | 17.27 | 17.49 |
| 79102-22205 | North of SEPs | 2 | KaKlslt | 5947.93 | 5916.02 | 31.91 | 235.62 | 0.135 | 2.88E-05 | 40.36 | 5.84 |
| 79102-22205 | North of SEPs | 4 | KaKlslt | 5947.71 | 5915.72 | 31.99 | 235.62 | 0.136 | 2.88E-05 | 40.46 | 5.82 |
| 79502-99305 | SEPs/B991 | 2 | KaKlslt/Qrf | 5960.79 | 5927.14 | 33.65 | 532.37 | 0.063 | 2.23E-04 | 146.10 | 3.64 |
| 79502-99305 | SEPs/B991 | 4 | KaKlslt/Qrf | 5959.79 | 5927.59 | 32.2 | 532.37 | 0.060 | 2.23E-04 | 139.80 | 3.81 |
| 70393-70693 | PU&D/PLF | 2 | Qrf | 5986.82 | 5972.4 | 14.42 | 410.48 | 0.035 | 4.18E-04 | 151.93 | 2.70 |
| 70393-70693 | PU&D/PLF | 4 | Qrf | 5985.37 | 5963.02 | 22.35 | 410.48 | 0.054 | 4.18E-04 | 235.48 | 1.74 |
| 30900-30002 | PU&D/ N. Walnut Ck. | 2 | Qrf/KaKlclst | 5993.95 | 5918.87 | 75.08 | 1890.74 | 0.040 | 2.09E-04 | 86.05 | 21.97 |
| 30900-30002 | PU&D/ N. Walnut Ck. | 4 | Qrf/KaKlclst | 5991.07 | 5917.57 | 73.5 | 1890.74 | 0.039 | 2.09E-04 | 84.24 | 22.45 |

Notes:
WL = water level; dh (ft) = difference in height, in feet; dl (ft) = distance between wells, in feet; cm/s = centimeters per second; v (ft/yr) = velocity in feet per year; yrs = years.
Qrf = Rocky Flats Alluvium; Qc = colluvium; KaNo.1ss = Arapahoe Formation "No. 1 Sandstone"; KaKlclst = undifferentiated Arapahoe/Laramie Formation claystone; KaKlslt = undifferentiated Arapahoe/Laramie Formation siltstone.
*Bedrock lithology estimated due to incomplete core log for well 22996.

Flow across the former IA is calculated for several well pairs (Table 3−9). The travel time from well P115589 to P114689 and then to 56399 and into the drainage at 21605 can be estimated by summing the individual calculated travel times. The result is approximately 11 to 12 years. In the southern IA, flow from well 40305 to 39605, or from 40305 to 22996, is calculated to take approximately 55 or 70 years, respectively.

Flow across the former B444 is estimated using wells 40005 and P419689. The travel time here is estimated at 12.5 to 13 years. This is based on the K for Rocky Flats Alluvium. However, although the former building was backfilled with that material, this is an example of the scenario discussed above in which the backfill would almost certainly have a significantly higher K. If the value of K is an order of magnitude higher, the seepage velocity increases from about 37 feet per year to nearly 360 feet per year, and the travel time is reduced from almost 13 years to less than 1.5 years. This illustrates the sensitivity of this calculating to the value of K used, and also highlights the uncertainty when calculating travel times across areas of artificial fill (such as B444 now represents). Refer to Section 3.3.3.2 and Figure 3−21 for information and discussion of the VOCs in ground water in this area.

Table 3−9 includes calculated travel times for several alternate flow paths. Ground water from the OBP#2 source area, as monitored by well 91105, is captured and treated at the MSPTS, and therefore well pairs 91105-15399 and 91105-15499 are included. Both are included because ground water elevations vary by 4 to 5 feet between the two downgradient wells, affecting the calculated gradient. Even so, the difference is only 6 months or less in total calculated travel time from the source-area well to the MSPTS well, ranging from just over 2 years to just over 2 ½ years. Alternatively, in case the OBP#2 ground water flow path does have more of a westerly component, well pair 91105-91203 is included; the calculated travel time between the wells in this pair is slightly less than 2 years. As discussed in the section on the OBP#2 Plume (Section 3.3.3.4), there have been so many changes in this area that their effects on contaminant transport are still unclear, and more data will be needed before conclusions can be drawn. However, in this specific case (91105-91203) the calculated travel times are probably not applicable, because ground water is presumably captured by the preferential pathway formed by the corridor remaining from the 72-inch storm drain. This feature has been tied into the MSPTS ground water intercept trench, and contaminants measured in MSPTS influent as well as the volume of influent (see Section 3.3.2.1) have increased significantly since that corridor was redirected into the trench. This suggests that OBP#2 water is being transported by this feature. Such a conclusion is also supported by flow data presented in the 2005 report (DOE 2006e).

Alternate paths are also provided for Mound plume well pairs 00897-15399 and 00897-15499, with a difference of up to 1.5 years in calculated travel time. For the former path, the calculated travel time is 10 to 11 years; for the latter path, the travel time is just over 9 years. In either case, this travel time suggests the effects of remediation of the Mound source area (which was completed in 1997) may soon be apparent in Mound Plume ground water that is captured and treated by the MSPTS. However, the addition of OBP#2 ground water could mask this. Most importantly, given that VOC concentrations in samples from source-area well 00897 are not rapidly decreasing, it may be many years before the effects of the Mound remediation is evident at the MSPTS.

Seepage velocities were also calculated for monitoring wells in the 903 Pad/Ryan's Pit Plume area. Two flow paths were selected, based in part on previous work (K-H 2004a). One, from Evaluation wells 00191 to 00491, may not be realistic, as ground water from well 00191 more likely migrates northeastward toward the East Trenches Plume as suggested by the contaminant distributions (Section 3.3.3.1). Even so, as a well more directly upgradient from 00491 but still near the 903 Pad VOC source area would have a similar water level elevation to that of 00191, this calculation is still useful. The results of this calculated travel time, approximately five years,

suggest that the effects of the 903 Pad and Lip remediation and HRC applications will not be reflected in ground water samples collected from well 00491 for at least several years. The second leg of this flow path, down the hillside from Evaluation well 00491 to Sentinel well 90399 at the SID, is calculated to take approximately 14 years. Therefore, effects of the remediation and HRC application would probably not be apparent in VOC data from the latter well for at least 20 years, even under the most conservative flow conditions (i.e., ignoring the effects of contaminant retardation).

The second flow path selected in this area includes Ryan's Pit source-area Evaluation well 07391 and Woman Creek AOC well 10304. The flow between these was considered to be within the hillslope colluvium during the second quarter and within the bedrock for part of the travel path during the fourth quarter of 2006, based on the hydrograph for well 07391. These calculated seepage velocities are approximately 7 years to 14 years, respectively. Because Ryan's Pit VOCs are not detected at well 10304, currently no effect from the HRC application near well 07391 is anticipated at the AOC well.

Table 3−9 indicates that if the 18199-20505 pathway is appropriate, the latter well could have begun to report detections of carbon tetrachloride and chloroform in 2006. This was not the case. This pathway is reasonable, but given the intervening presence of a disrupted foundation drain and its corridor, the backfilled building, and backfilled/disrupted subsurface utility corridors on the north side of former B771, the ground water may be diverted in another direction. Note that in 2006 none of these downgradient wells—not 20205, 20505, or 20705—reported detections of carbon tetrachloride or chloroform, the most notable contaminants from IHSS 118.1.

In the former SEP area, travel times were calculated for wells monitoring the VOC plume here as well as for a potential southeastern route for nitrate contamination. Well P210189 reports the highest concentrations of VOCs in this area; the calculated travel time from it to well 79102 is about 17.5 years. The latter well has also reported elevated concentrations of VOCs; the calculated travel time for ground water to flow from this well to well 22205 is approximately 6 years. Well 22205 has yet to report consistent detections of VOCs, despite the fact that well 79102 has produced samples with elevated concentrations of VOCs since its installation in 2002 and it is fairly safe to assume ground water at 79102's location contained VOCs for at least several years before the well was installed. This is empirical evidence against the common practice of assuming a calculated travel time for ground water applies equally to VOCs. The calculated travel time across a potential southeastern flow path, from well 79502 to 99305, is nearly 4 years. Because nitrate contamination is not evident at well 99305, such a flow path is probably unlikely.

Also arguing against the liberal application of calculated ground water travel times to contaminants is the calculated travel time from PU&D source area well 30900 to well 30002 in North Walnut Creek. This travel time is estimated at approximately 22 years. However, the PU&D Yard Plume source has probably been present for at least 20 or 30 years, which may be indicative of the retardation that affects VOCs compared to pure ground water.

## 3.4 Ground Water Monitoring at the Present Landfill and Original Landfill in 2006

This section presents the evaluation of the CY 2006 ground water quality data for the PLF, previously known as OU7; and the OLF, previously OU5.

### 3.4.1 Present Landfill

The PLF is located in the former Buffer Zone (BZ) just north of the former IA. It served as a solid waste disposal facility for the RFP/RFETS and has not been operational since 1998. Including the Landfill Pond, it occupies approximately 44 acres at the western end of the No Name Gulch drainage. The PLF underwent RCRA closure and an engineered RCRA-compliant cover was constructed as a part of the PLF and Site closure. These activities were performed and completed during 2005. Since that time, routine monitoring and maintenance have been the focus at the PLF. Refer to K-H (2004) for details on closure of the PLF.

The Annual RCRA Groundwater Monitoring Reports for RFETS (DOE, 1990, 1991a, 1992, 1993, 1994, 1995, 1996) describe ground water data for 1989 through 1995 at the PLF. The Phase I RCRA Facility Investigation/Remedial Investigation Work Plan for Operable Unit 7: Present Sanitary Landfill (DOE 1991b) presents additional information. Subsequent ground water monitoring activities were conducted under RFCA during CY 1996, 1997, 1998, and 1999, and are presented in annual Present Sanitary Landfill Groundwater Monitoring Reports (DOE 1998, 1999a, 2000). From 1999 through 2003, the annual data assessment for the PLF has been included in the Annual RFCA Groundwater Monitoring Reports (Safe Sites 2001, 2002; K-H 2004c). The 2004 information is presented in the Fourth Quarter RFCA Groundwater Monitoring Report for Calendar Year 2004 (URS 2005), and that for 2005 is in the 2005 Annual Report (DOE 2006e). Additional background information regarding the PLF is presented in the OLF Interim Measure/Interim Remedial Action (IM/IRA) for IHSS 114 and RCRA Closure of the PLF (DOE 2004).

Ground water monitoring requirements at the PLF were consistent over the course of the year, and are outlined in the 2006 IMP (DOE 2006c). Figure 3−1 displays the ground water monitoring network at the PLF. Monitoring performed in 2006 is summarized in Table 3−10.

The RCRA monitoring network at the PLF comprises three upgradient and three downgradient wells. A year of quarterly analytical data (i.e., four sets of quarterly samples) are required to determine the baseline, and the same quantity of data are needed to perform the statistical analyses. This 2006 report represents the first annual report to present these analyses for the post-closure network, due to these data requirements.

*Table 3−10. RCRA Ground Water Sampling Performed in 2006 at the PLF*

| Well | Location | Q1 | Q2 | Q3 | Q4 |
|---|---|---|---|---|---|
| 70193 | Upgradient | V, M | V, M | V, M | V, M |
| 70393 | Upgradient | V, M | V, M | V, M | V, M |
| 70693 | Upgradient | V, M | V, M | V, M | V, M |
| 73005 | Downgradient | V, M | V, M | D | V, M |
| 73105 | Downgradient | V, M | V, M | V, M | V, M |
| 73205 | Downgradient | V, M | V, M | V, M | V, M |

Notes:
Q = quarter.
V = VOCs, M = metals (which includes U), D = dry or insufficient water to complete the analytes listed.
Only RCRA wells supporting the PLF are listed; other wells in the area (such as Sentinel and Evaluation wells) are omitted because they are not a part of the RCRA monitoring network.

Statistical evaluation of the analytical data from the PLF was performed using all non-rejected data for upgradient and downgradient RCRA wells. An interwell comparison was made (i.e., comparing upgradient wells against downgradient wells) in accordance with the PLF M&M Plan (DOE 2006b), using the Analysis of Variance (ANOVA) procedure as run using the Sanitas™ software package. Non-parametric ANOVA was required for most analytes, but a few were represented by normally-distributed data and were analyzed using parametric ANOVA. U data were all converted to mass units, and negative values were replaced with 0.001 to abide by software limitations, as discussed in Section 3.3.1. Results of the ANOVA analyses are provided in Appendix B.3 and summarized below.

No VOCs were found to be present in downgradient wells at statistically higher concentrations than in upgradient wells. However, the concentrations of several metals are statistically higher in samples from downgradient wells compared to those from upgradient wells. These results are summarized in Table 3−11. Most importantly, of those constituents present at statistically significant higher concentrations in downgradient wells than in upgradient wells, none exceed the highest of the RFCA surface water action level, PQL, or Temporary Modification specified in the RFCA Attachment 5 (CDPHE, DOE, and EPA 2003). Monitoring will continue and future metals data will be assessed for statistical trend in these downgradient wells; due to data limitations, this is currently not feasible.

*Table 3−11. Results of Ground Water ANOVA at the Present Landfill*

| Analyte | 73005 | 73105 | 73205 | Comments |
|---|---|---|---|---|
| Antimony | x | x | x | |
| Arsenic | x | x | x | |
| Barium | | x | | |
| Beryllium | | x | x | |
| Boron | x | x | x | |
| Cadmium | x | | | |
| Chromium | | x | x | |
| Copper | x | x | x | |
| Lead | x | x | x | |
| Lithium | -- | x | x | Insufficient data for statistical evaluation at 73005 |
| Manganese | | x | x | |
| Molybdenum | -- | x | x | Insufficient data for statistical evaluation at 73005 |
| Nickel | | | x | |
| Selenium | x | | x | |
| Silver | x | x | x | |
| Strontium | -- | x | x | Insufficient data for statistical evaluation at 73005 |
| Thallium | x | x | x | |
| Tin | -- | x | x | Insufficient data for statistical evaluation at 73005 |
| Uranium | -- | x | x | Insufficient data for statistical evaluation at 73005 |

Note: x = analyte is present in ground water at a statistically significant higher concentration in the indicated downgradient well compared to upgradient wells. -- = see comment.

Ground water quality at the PLF is impacted on the upgradient side by VOCs from the PU&D Yard Plume. Data from 2006 from downgradient RCRA wells show several VOCs were detected in downgradient ground water. Validated detections are summarized in Table 3−12, but again, no VOCs show a statistically-significant increase in concentration from upgradient to downgradient wells.

Ground water flow at the PLF is strongly affected by the GWIS, which diverts ground water flow around the perimeter of the PLF rather than through the wastes. The GWIS includes a slurry wall and perforated drain around the upgradient and side-gradient perimeter of the PLF, and acts to isolate ground water within the PLF from that outside the PLF. (Refer to the previously-published reports referenced earlier in this section for more detail on the GWIS and related discussions.) Previous RCRA and Groundwater Annual Reports have confirmed the effectiveness of this isolation. Because the GWIS is located between the upgradient PLF RCRA wells and the downgradient PLF RCRA wells, estimating seepage velocities as discussed in Section 3.3.4 between those sets of wells is not appropriate.

*Table 3−12. VOCs detected in 2006 in Downgradient Wells at the Present Landfill*

| Well | Sample Date | Analyte | Result | Units | Lab Qualifier |
|---|---|---|---|---|---|
| 73005 | 4/19/2006 | Acetone | 6.9 | µg/L | J |
| 73105 | 10/10/2006 | 1,3-Dichlorobenzene | 0.65 | µg/L | J |
| 73105 | 4/19/2006 | Acetone | 3.9 | µg/L | J |
| 73105 | 3/6/2006 | Chloroform | 0.45 | µg/L | J |
| 73105 | 4/19/2006 | Chloroform | 0.3 | µg/L | J |
| 73105 | 3/6/2006 | Chloromethane | 0.43 | µg/L | J |
| 73105 | 8/30/2006 | m,p-Xylene | 2.4 | µg/L | |
| 73105 | 4/19/2006 | Toluene | 0.49 | µg/L | J |
| 73105 | 8/30/2006 | Toluene | 0.63 | µg/L | J |
| 73205 | 4/19/2006 | Acetone | 60 | µg/L | |
| 73205 | 3/6/2006 | Chloromethane | 0.65 | µg/L | J |
| 73205 | 4/19/2006 | Toluene | 0.7 | µg/L | J |

Note: J = analyte detected, result is estimated.
No validation qualifiers were attached to these results.

### 3.4.2 Original Landfill

The OLF is located within the former IA OU south to southwest of the former 400 Area, between former Cactus Ave. on the north and Woman Creek on the south. The OLF operated as a dump from the 1950s until 1968, when the PLF was opened.

Activities to close the OLF were completed in 2005. Closure included abandoning wells, removing debris, regrading the ground surface, and adding a soil cover. Refer to K-H (2005b) for details on closure of the OLF.

During negotiations to close the OLF, RCRA was identified as an applicable or relevant and appropriate requirement for the facility. As a result of these negotiations, four wells were identified to monitor the OLF, three of which were installed in 2005.

Ground water monitoring requirements at the OLF were consistent over the course of the year, and are outlined in the 2006 IMP (DOE 2006c). Figure 3−1 displays the ground water monitoring network at the OLF. Monitoring performed in 2006 is summarized in Table 3−13.

*Table 3−13. RCRA Ground Water Sampling Performed in 2006 at the OLF*

| Well | Location | Q1 | Q2 | Q3 | Q4 |
|---|---|---|---|---|---|
| P416589 | Upgradient | V, M, S | V, M, S | V, M, S | V, M, S |
| 80005 | Downgradient | V, M, S | V, M, S | V, M, S | V, M, S |
| 80105 | Downgradient | V, M, S | V, M, S | V, M, S | V, M, S |
| 80205 | Downgradient | V, M, S | V, M, S | V, M, S | V, M, S |

Notes:
Q = quarter.
V = VOCs, M = metals (which includes U), S = semivolatile organic compounds.
Only RCRA wells supporting the PLF are listed; other wells in the area (such as Sentinel and Evaluation wells) are omitted because they are not a part of the RCRA monitoring network.

The RCRA monitoring network at the OLF comprises one upgradient and three downgradient wells. A year of quarterly analytical data (i.e., four sets of quarterly samples) are required to determine the baseline, and the same quantity of data are needed to perform the upgradient-downgradient statistical comparisons. This 2006 report represents the first annual report to present these analyses for the post-closure network, due to these data requirements.

In addition to monitoring and evaluating these wells similar to RCRA wells (i.e., on a quarterly basis, and evaluating the resulting analytical data via upgradient-downgradient comparisons), the three downgradient wells are also monitored and evaluated in the manner of Sentinel wells at the RFS. Specifically, data from these wells are statistically evaluated using 85th percentile concentrations to compare against surface water standards, and data trends are constructed as warranted to determine a need for action. This type of evaluation requires a minimum of eight data points for each well-analyte combination, in accordance with the IMP, and cannot yet be performed for the OLF wells due to data insufficiency. It is anticipated that the Sentinel well evaluation method will be feasible for the 2007 annual report.

Statistical evaluation of the analytical data from the OLF was performed using all non-rejected data for upgradient and downgradient RCRA wells. An interwell comparison was made (i.e., comparing the upgradient well against downgradient wells) in accordance with the OLF M&M Plan (DOE 2006a), using the ANOVA procedure as run using the Sanitas™ software package. As at the PLF, non-parametric ANOVA was required for most analytes. U data were all converted to mass units, and negative values were replaced with 0.001 to abide by software limitations, as described in Section 3.3.1. Results of the ANOVA analyses are provided in Appendix B.3 and summarized below.

No VOCs were found to be present in downgradient wells at statistically higher concentrations than in upgradient wells. However, the concentrations of several metals are statistically higher in samples from downgradient wells compared to those from upgradient wells. These results are summarized in Table 3−14. Of those constituents present at statistically-significant higher concentrations in downgradient wells than in upgradient wells, only U exceeds the highest of the RFCA surface water action level, PQL, or Temporary Modification specified in the RFCA Attachment 5 (CDPHE, DOE, and EPA 2003). This is to be expected, given the typically higher concentrations of U in ground water relative to surface water. The concentrations do not exceed the U threshold in the IMP (DOE 2006c). Natural U concentrations are seen to vary dramatically over very short distances in other areas (e.g., from well 99305 to well 99405), so the fact that U is higher in well 80205 than the other wells is not necessarily indicative of contamination. However, special analytical methods (high-resolution ICP/MS or TIMS) will be employed in 2007 to determine whether the ground water here is affected by anthropogenic U.

*Table 3−14. Results of Ground Water ANOVA at the Original Landfill*

| Analyte | 80005 | 80105 | 80205 |
|---|---|---|---|
| Boron | x | x | x |
| Lithium | x | x | x |
| Manganese | | x | |
| Strontium | | x | x |
| Uranium | | | x |

Note: x = analyte is present in ground water at a statistically significant higher concentration in the indicated downgradient well compared to upgradient wells.

Data reported in 2006 from downgradient RCRA wells at the OLF show several VOCs were detected in downgradient ground water, though again not at statistically higher concentrations than in the upgradient well. Validated detections are summarized in Table 3−15.

*Table 3−15. VOCs Detected in 2006 in Downgradient Wells at the Original Landfill*

| Well | Sample Date | Analyte | Result | Units | Lab Qualifier |
|---|---|---|---|---|---|
| 80105 | 2/28/06 | Bis(2-ethylhexyl) phthalate | 3.8 | µg/L | J |
| 80105 | 8/31/06 | m,p-Xylene | 2.4 | µg/L | |
| 80205 | 6/5/06 | 1,2,4-Trichlorobenzene | 0.34 | µg/L | JB |

Note: J = analyte detected, result is estimated. B = chemical detected in method blank.
No validation qualifiers were attached to these results.

Bis(2-ethylhexyl) phthalate and m,p-xylene are also reported in samples collected in 2006 from upgradient well P416589.

Ground water flow at the OLF is not affected by controls such as the GWIS at the PLF. Ground water flows beneath the pediment surface north of the OLF in a general west to east direction. As it nears the southern edge of the pediment, ground water is diverted to a more south-southeasterly direction. This latter flow direction applies to ground water moving through the OLF.

Ground water flow velocities were calculated (see Section 3.3.4 and Table 3−9) for OLF well pair P416589 (the upgradient well) and 80105 (the middle downgradient well). The resulting estimates for the travel time from the upgradient to downgradient well range from just over 2 years when ground water is present within the surficial materials (i.e., the “alluvium”), and approximately 4 ½ years when it is within the claystone bedrock screened by the upgradient well. Both of these calculations were performed because during the second quarter of 2006, the ground water in the upgradient well was below the bedrock contact (with the bedrock at this location defined as claystone); in the fourth quarter, it was within the Rocky Flats Alluvium. Because the cover on the landfill is reworked Rocky Flats Alluvium, which almost certainly has a higher hydraulic conductivity, these travel times may be overestimations for pure water, though any contaminants that may be present would likely be retarded significantly.

Seeps are also present at the OLF, and have been observed in this area for decades (as well as being suggested on aerial photographs taken before the RFP came into existence). Additional discussion of these seeps is provided in Section 7.3.2.

## 3.5 Other Issues Related to Rocky Flats Ground Water in 2006

This section summarizes some of the more notable events, activities, and conditions related to ground water at the RFS in 2006.

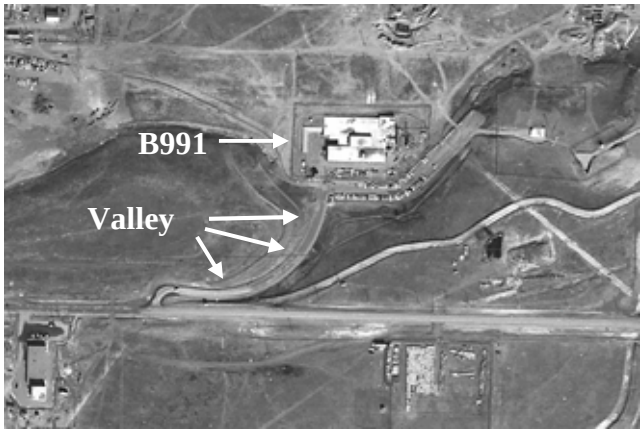
### 3.5.1 Slump South of B991

During expansion and development of the PA in the late 1970s-early 1980s, a valley south of former B991 was filled to provide a uniform surface that would be easier to monitor for security

purposes. A French drain was installed at the base of the up to 30 feet of fill to stabilize the artificial hillside that was constructed in the former valley, and the drain was equipped with an outfall that was later given the identification SW056. Water samples collected from the outfall showed elevated concentrations of VOCs, including PCE, TCE, cis-1,2-DCE, and vinyl chloride. The source of these VOCs is thought to be the IA Plume, as the corridor in which the French drain resides overlaps many other utility corridors that extend into various regions of the former IA. As a part of Site closure it was necessary to address this outfall, as water flowed directly from it into the future FC-4 wetland. The action that was agreed upon by the closure contractor, DOE, and the regulators was to remove the outfall portion of the drain, interrupt the east-west portion of the drain, and backfill the interrupted portion with lower-permeability materials (cement grout) and HRC. One additional requirement was to install a monitoring well immediately downgradient (north) of the east-west drain and upgradient (west) of the point at which that drain had been interrupted. That well is 45605 (Figure 3−1).

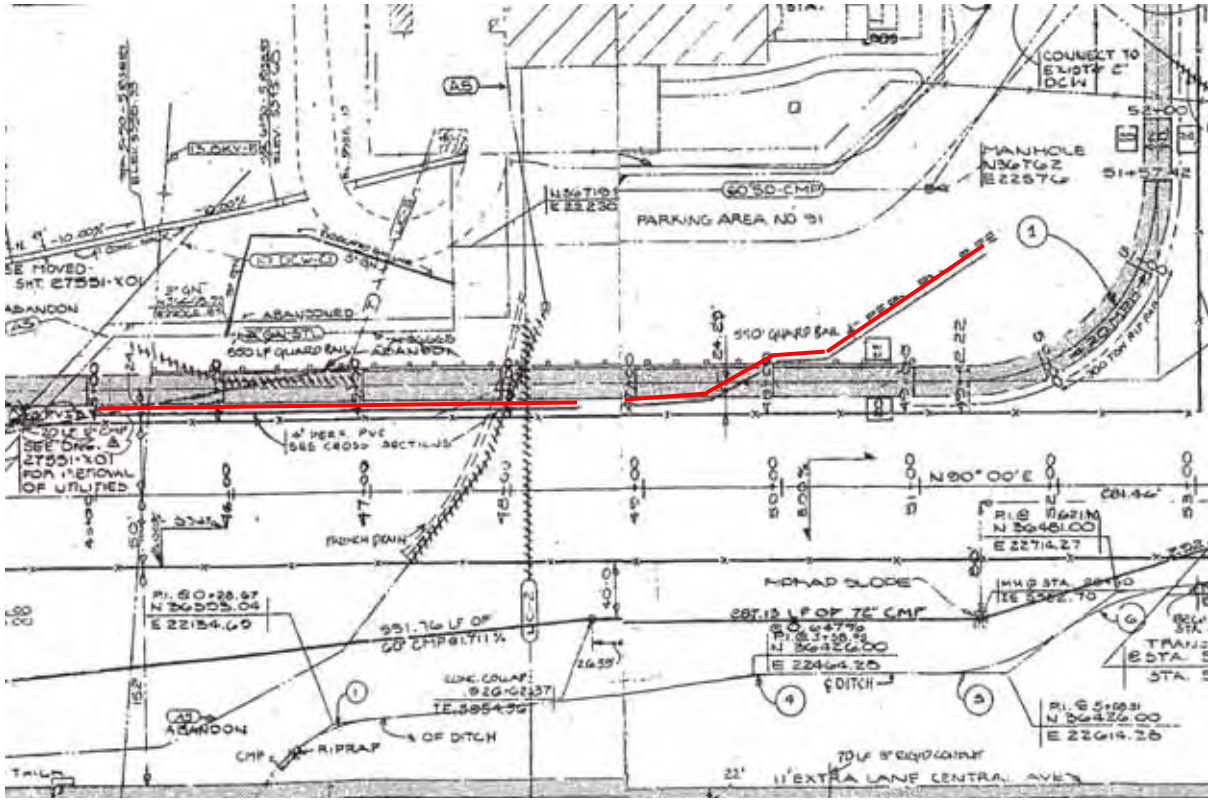
Because the drain outfall has been removed, water that is collected by the remaining portion of the French drain to the west has no defined outlet. This has allowed the collected ground water to saturate the artificial hillside, causing it to become destabilized. Slumping was first apparent in early January 2006 when small cracks were observed across the surface of the ground where the excavation formed to remove the outfall and interrupt the drain had been backfilled. These cracks broadened, extended, and multiplied throughout the year, accompanied by increasing horizontal and vertical displacement. Through discussions with the regulators, a resolution has been devised. Because protecting the integrity of this hillside is not necessary to protect the remedy itself, the slump is being allowed to continue to develop. When movement stops or is sufficiently reduced to allow it, the hillside will be regraded and seeded to address safety and aesthetic concerns. (This will not be done until movement is complete or has slowed enough to limit the need for repeated grading efforts.) If necessary, the well will be replaced after regrading has been completed.

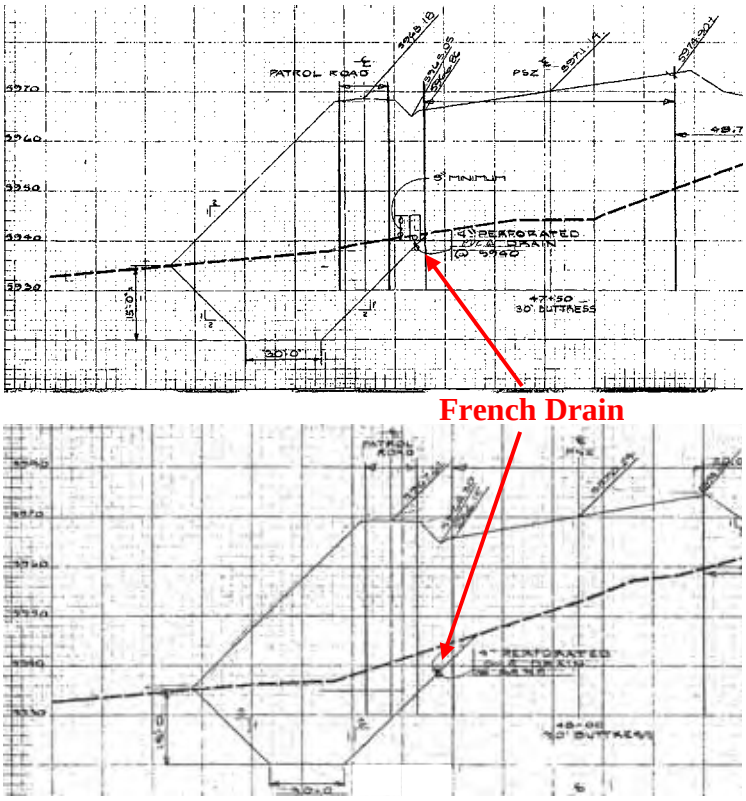
The figures below provide a summary of the history and development of this slump.



Top left: Water issuing from pipe at SW056. This pipe was removed during closure, eliminating the outlet for water collected by the French drain. Top right: Former B991 and the valley that was filled to enhance security in the late 1970s. Photo taken in the late 1960s; also evident is OBP#2 (dark patch to right of valley) and active storage at 903 Pad (lower right, below OBP#2). Bottom: Same area in 1988, after security upgrades that filled the valley. Approximate axis of valley is indicated.

*Figure 3−31. Historic Photographs of SW056 and Associated Area*




Top drawing: Two merged "as-built" drawings showing utilities in the area generally south of B991, the southwest corner of which is at the top of the drawing and is shown with hatching. To enhance its visibility, the French drain is highlighted with a red line that is slightly offset from the actual drain; the drain's construction is described on the drawing as 4-inch perforated PVC. Note drawing inaccuracies: The outfall (SW056) was not present at the indicated point (far right end of drain, near circled number 1), but was instead just south of the word "Area" in "Parking Area No 91"; and the French drain was presumably continuous and did not have the short gap that is shown. (The faint vertical line at the right edge of this gap is where the two drawings are merged.) Bottom two drawings: "As-built" cross-section drawings (nos. 47.50 and 48.00) of the constructed hillside in the vicinity of SW056, showing the drain to have been installed approximately 28 to 30 feet below the surface of the Patrol Road that was placed on top of the hillside. Heavy dashed line indicates former ground surface.

*Figure 3−32. "As-built" Drawings of French Drain and Constructed Hillside*

Top photo: Conditions on June 6, 2005. The constructed hillside is the area covered with green grass. Future FC-4 wetland is at its base, and SW056 is located as shown, just left of the line of willows on the valley floor. The site of former B991 is across FC-4 from the hillside and SW056, on the center-right edge of the photo. FC-5 (the line of gray rip-rap) enters from the left and joins FC-4 near the center of the photograph. Site closure activities are still in progress at this time, as indicated by the presence of heavy equipment and former B891 in the background. Bottom photos: Ground surface on January 12, 2006, showing developing fractures. Well 45605 is visible in the lower right photo.

*Figure 3−33. Photographs of Hillside and Ground Surface Prior to Slump Development*

Top photo: Panoramic shot of slump from B991 hillside on May 10, 2006. Person is faintly visible near base of constructed hillside in left portion of photo; the brown, sparsely-vegetated swath across which this person is walking is the extent of the excavation formed to remove the SW056 pipe and interrupt the French drain. The concrete pad for monitoring well 45605 is visible as a light spot at the top right corner of this area of sparse vegetation. Maximum vertical displacement at main fracture on this date was approximately 12 ft. Middle photo: Future FC-4 wetland and area of uplift caused by rotational slumping; as the ground surface above and to the right (south) moves downward, the floor of the wetland against that hillside moves up and out (toward the north). The area where the approximately 5 ft. 4 in.-tall person is standing used to be even with the floor of FC-4, as was evident from water stains on the erosion matting covering the ground surface; the line of willows shown on the top photo of Figure 3−33 extend from the floor of the future wetland across the uplifted area just past the person in the photo. Well 45605 is visible at top right; the orientation of the surface protection for this well is clearly no longer vertical. Bottom photo: Slump on February 13, 2007. Maximum displacement at main fracture on this date was approximately 16 ft. Displacement along other fractures north (in the direction of the valley floor) of the main fracture also increased through 2006.

*Figure 3−34. Photographs of Slump During Development*

### 3.5.2 SPPTS Investigations

Section 3.3.2.3 summarizes investigations performed at the SPPTS and the results of those investigations. This section will not reiterate that discussion, but will instead summarize the data that were gathered during the water quality component of these investigations and the treatability study that followed.

The investigations of the SPPTS generally included physical and chemical components. The physical components involved assessment of valve configurations (which led to the use of heavy equipment to restore access to the valves) and the condition of the media and plumbing (which led to extensive plumbing repairs). The chemical component included sampling of various points on the system to determine the effects of the physical activities.

Water samples were collected from numerous locations at the SPPTS. Included were the traditional influent sampling location (SPPMM02, a.k.a. piezometer 71099), the actual influent location (SPIN, the collection well from which the pump delivers water to the treatment cells), the effluent location (SPPMM01), and the discharge gallery (SPP Discharge Gallery). In addition, several points within the treatment cells were sampled by inserting tubing in the vent risers associated with cell influent and cell effluent pipes. Sampled locations included the west cell (Cell 1) influent, west cell effluent (later assigned the identification SPWEF), east cell (Cell 2) influent (later assigned the identification SPEIN), and east cell effluent.

Samples were shipped to the Environmental Sciences Laboratory (ESL) in Grand Junction, Colorado, which is operated for DOE-LM by the S.M. Stoller Corp. As such, the data are used as "field screening data" to evaluate general trends and effectiveness, with confirmatory samples collected and shipped to a contract laboratory when needed.

The results generated by the ESL are provided in Table 3−16.

A treatability study was also performed at the SPPTS. The objective of this study was to determine if a simpler, more efficient, and less management-intensive system could be designed.

A study facility (a modified, enclosed utility trailer) was stationed at the SPPTS. Solar panels were erected and used to recharge batteries that drove the equipment. Untreated influent was pumped through four columns and effluent concentrations of nitrate were measured. The columns compared different substrates: two were pea gravel, and two were engineered, high surface-area plastic packing beads. All four were inoculated with denitrifying bacteria, and the influent directed to one column of each type of substrate was augmented with ethanol, the carbon source evaluated as a nutrient for the bacteria.

*Table 3−16. Field Screening Results From the SPPTS*

| Sample Location | Sample Date | pH (field) | U (µg/L, ESL) | U (µg/L, CL) | Alkalinity (mg/L as $CaCO_3$; ESL) | Nitrate as N (mg/L; field) | Nitrate as N (mg/L; IC; ESL) | Nitrate as N (mg/L; CL) | Ammonia as N (mg/L; ESL) | Total Iron (mg/L; field) | TOC (mg/L; ESL) | N-BaRT (cfu/mL; ESL) | Nitrite as N (mg/L; ESL) | pH (ESL) | Total Iron (mg/L; flame) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SPPMM02 | 1/19/2006 | | 29.02 | | | | | | | | | | | | |
| SPPMM02 | 1/23/2006 | | | 36 | | | 272 | 220 | 1 (U) | | | | | | |
| SPPMM02 | 2/8/2006 | | 31.5 | | | | 270 | | | | | | | | |
| SPPMM02 | 2/28/2006 | | 26.2 | | | | 264 | | | | | | | | |
| SPPMM02 | 3/28/2006 | | 39.3 | | 320 | | 274 | | | | 17.2 | | | | |
| SPPMM02 | 3/30/2006 | 6.86 | 27.3 | | 370 | 286 | 257 | | | 1.02 | 5.3 | | | | |
| SPPMM02 | 4/6/2006 | | 23.6 | | | | 265 | | | | | | | | |
| SPPMM02 | 4/12/2006 | | 23.3 | | | | 268 | | | | | | | | |
| SPPMM02 | 4/17/2006 | | 24.6 | | | | 265 | | | | | | | | |
| SPPMM02 | 5/1/2006 | | 27.2 | | | | 219 | | | | | | | | |
| SPPMM02 | 5/8/2006 | | 36.3 | | | | 139 | | | | | | | | |
| SPPMM02 | 5/17/2006 | | 25.4 | | | | 243 | | | | | | | | |
| SPPMM02 | 5/22/2006 | | 27.3 | | | | 247 | | | | | | | | |
| SPPMM02 | 5/29/2006 | | 24.1 | | | | 270 | | | | | | | | |
| SPPMM02 | 6/12/2006 | | 26.4 | | | | 259 | | | | | | | | |
| SPPMM02 | 6/19/2006 | | 23.9 | | | | 258 | | | | | | | | |
| SPPMM02 | 6/26/2006 | | 23.9 | | | | 258 | | | | | | | | |
| SPPMM01 | 1/19/2006 | | 0.92 | | | | | | | | | | | | |
| SPPMM01 | 1/23/2006 | | | 1.5 | | | 460 | 390 | 19 | | | | | | |
| SPPMM01 | 2/8/2006 | | 15.8 | | | | 435 | | | | | | | | |
| SPPMM01 | 2/28/2006 | | 37.3 | | | | 331 | | | | | | | | |
| SPPMM01 | 3/28/2006 | | 19.9 | | 150 | | 328 | | | | 4.6 | | | | |
| SPPMM01 | 3/30/2006 | 7.59 | 2.63 | | 60 | 324 | 304 | | | 0.12 | 3.8 | | | | |
| SPPMM01 | 4/6/2006 | | 2.76 | | | | 266 | | | | | | | | |
| SPPMM01 | 4/12/2006 | | 0.22 | | | | 280 | | | | | | | | |
| SPPMM01 | 4/17/2006 | | 0.1 | | | | 224 | | | | | | | | |
| SPPMM01 | 5/1/2006 | | 2.6 | | | | 341 | | | | | | | | |
| SPPMM01 | 5/8/2006 | | 2.5 | | | | 296 | | | | | | | | |
| SPPMM01 | 5/17/2006 | | 0.2 | | | | 263 | | | | | | | | |
| SPPMM01 | 5/22/2006 | | 0.6 | | | | 271 | | | | | | | | |
| SPPMM01 | 5/29/2006 | | 4.8 | | | | 244 | | | | | | | | |
| SPPMM01 | 6/12/2006 | | 5.2 | | | | 293 | | | | | | | | |

*Table 3−16 (continued). Field Screening Results From the SPPTS*

| Sample Location | Sample Date | pH (field) | U (µg/L, ESL) | U (µg/L, CL) | Alkalinity (mg/L as CaCO3; ESL) | Nitrate as N (mg/L; field) | Nitrate as N (mg/L; IC; ESL) | Nitrate as N (mg/L; CL) | Ammonia as N (mg/L; ESL) | Total Iron (mg/L; field) | TOC (mg/L; ESL) | N-BaRT (cfu/mL; ESL) | Nitrite as N (mg/L; ESL) | pH (ESL) | Total Iron (mg/L; flame) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SPPMM01 | 6/19/2006 | | 5.6 | | | | 275 | | | | | | | | |
| SPPMM01 | 6/26/2006 | | 4.6 | | | | 252 | | | | | | | | |
| SPPMM01 | 7/11/2006 | | 1.4 | | 130 | | 209 | | 25 | | 7.6 | | 1.48 | 6.57 | 0.01 |
| SPPMM01 | 7/17/2006 | | 4.8 | | | | 159 | | 20 | | 9.8 | | 0.96 | | 3.27 |
| SPPMM01 | 7/25/2006 | | 1.9 | | | | 126 | | 30 | | 12.7 | | 1.47 | | 0.11 |
| SPPMM01 | 10/26/2006 | | | | | | | | 21 | | | | | | |
| SPP D. G. | 1/19/2006 | | 40.4 | | | | 673 | | 4 | | | | | | |
| SPP D. G. | 7/11/2006 | | 46.7 | | 240 | | 581 | | 3 | | 8.1 | | 0.474 | 6.56 | 0.01 (U) |
| SPP D. G. | 7/17/2006 | | 55.6 | | | | 556 | | 1 | | 11.5 | | 0.735 | | 0.1 |
| SPP D. G. | 7/25/2006 | | 48.9 | | | | 533 | | 3 | | 7 | | 0.305 | | 0.11 |
| SPP D. G. | 10/26/2006 | | | | | | | | 5 | | | | | | |
| SPIN | 3/30/2006 | 6.65 | 29.1 | | 400 | 300 | 290 | | | 0 | 6.1 | 1000 | | | |
| SPIN | 4/6/2006 | | 26.4 | | | | 299 | | | | | | | | |
| SPIN | 4/12/2006 | | 25.2 | | | | 242 | | | | | | | | |
| SPIN | 4/17/2006 | | 23.3 | | | | 270 | | | | | | | | |
| SPIN | 5/1/2006 | | 36.2 | | | | 319 | | | | | | | | |
| SPIN | 5/8/2006 | | 40.4 | | | | 321 | | | | | | | | |
| SPIN | 5/17/2006 | | 36.5 | | | | 308 | | | | | | | | |
| SPIN | 5/22/2006 | | 39.4 | | | | 380 | | | | | | | | |
| SPIN | 5/29/2006 | | 35.5 | | | | 302 | | | | | | | | |
| SPIN | 6/12/2006 | | 33.6 | | | | 291 | | | | | | | | |
| SPIN | 6/19/2006 | | 35.1 | | | | 315 | | | | | | | | |
| SPIN | 6/26/2006 | | 34.6 | | | | 324 | | | | | | | | |
| SPIN | 7/11/2006 | | 41.5 | | 290 | | 329 | | 1 (U) | | 8.6 | | 0.02 | 6.69 | 0.24 |
| SPIN | 7/17/2006 | | 43 | | | | 338 | | 1 (U) | | 14.9 | | 0.011 | | 1.54 |
| SPIN | 7/25/2006 | | 37.1 | | | | 304 | | 1 (U) | | 16 | | 0.01 | | 0.32 |
| SPIN | 10/26/2006 | | | | | | | | 1 (U) | | | | | | |

*Table 3−16 (continued). Field Screening Results From the SPPTS*

| Sample Location | Sample Date | pH (field) | U (µg/L, ESL) | U (µg/L, CL) | Alkalinity (mg/L as CaCO3; ESL) | Nitrate as N (mg/L; field) | Nitrate as N (mg/L; IC; ESL) | Nitrate as N (mg/L; CL) | Ammonia as N (mg/L; ESL) | Total Iron (mg/L; field) | TOC (mg/L; ESL) | N-BaRT (cfu/mL; ESL) | Nitrite as N (mg/L; ESL) | pH (ESL) | Total Iron (mg/L; flame) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SPPTS W.C. in. | 3/30/2006 | 6.57 | 29.3 | | 400 | 246 | 244 | | | 0.08 | 12.2 | 1000 | | | |
| SPPTS W.C. ef. | 3/30/2006 | 6.56 | 36 | | 510 | 274 | 272 | | | 0.63 | 10.8 | 10000 | | | |
| SPPTS W.C. ef. | 7/11/2006 | | 36 | | 470 | | 286 | | 1 (U) | | 12.3 | | 0.067 | 6.44 | 9.55 |
| SPPTS W.C. ef. | 7/17/2006 | | 11.7 | | | | 14 | | 1 (U) | | 21 | | 0.022 | | 4.8 |
| SPPTS W.C. ef. | 7/25/2006 | | 8.1 | | | | 0.25 | | 1 (U) | | 22 | | 0.005 (U) | | 33.9 |
| SPPTS W.C. ef. | 10/26/2006 | | | | | | | | 1 (U) | | | | | | |
| SPPTS E.C. in. | 3/30/2006 | 6.84 | 42.9 | | 320 | 325 | 343 | | | 0 | 11.2 | | | | |
| SPPTS E.C. in. | 7/11/2006 | | 28.9 | | 220 | | 245 | | 7 | | 11.1 | | 2.49 | 6.49 | 0.92 |
| SPPTS E.C. in. | 7/17/2006 | | 24 | | | | 149 | | 1 (U) | | 22 | | 0.012 | | 0.81 |
| SPPTS E.C. in. | 7/25/2006 | | 21.7 | | | | 146 | | 1 (U) | | 6.4 | | 0.005 (U) | | 15.2 |
| SPPTS E.C. in. | 10/26/2006 | | | | | | | | 1 | | | | | | |
| SPPTS E.C. ef. | 3/30/2006 | 8.45 | 2.99 | | 40 | 323 | 321 | | | 0.1 | 4 | 10000 | | | |
| GS13 | 5/1/2006 | | 19.7 | | | | 76 | | | | | | | | |
| GS13 | 5/8/2006 | | 21.3 | | | | 74 | | | | | | | | |
| GS13 | 5/17/2006 | | 19.8 | | | | 66 | | | | | | | | |
| GS13 | 5/22/2006 | | 22.4 | | | | 63 | | | | | | | | |
| GS13 | 5/29/2006 | | 26.4 | | | | 55 | | | | | | | | |
| GS13 | 6/12/2006 | | 32.6 | | | | 58 | | | | | | | | |
| GS13 | 10/26/2006 | | | | | | | | 1 (U) | | | | | | |

NOTES:
field = field measurement; ESL = Environmental Sciences Laboratory measurement; CL = Contract Laboratory measurement.
U = uranium, ammonia = total ammonia; TOC = total organic carbon, N-BaRT: "N" signifies denitrifying bacteria, BaRT = biological activity reaction test; N = nitrogen;
µg/L = micrograms per liter; mg/L = milligrams per liter; cfu/mL = colony forming units per milliliter.
$CaCO_3$ = calcium carbonate; IC = ion chromatography; flame = flame atomic absorption spectrometry.
D.G. = Discharge Gallery; W.C. in. = west cell influent; W.C. ef. = west cell effluent; E.C. in. = east cell influent; E.C. ef. = east cell effluent.
(U) = analyte not detected at indicated level.

Unfortunately, the studies experienced difficulties that led to their discontinuation before they could be completed. After several weeks of operation, it was apparent that the columns were not behaving as expected because negligible nitrate removal was occurring. Tracer tests were performed and revealed that instead of the 8-hour designed residence time, water was short-circuiting through the columns in as little as 10 minutes. The studies were paused and possible alternatives were considered.

The study apparatus was then re-engineered for batch-mode operation, in which influent would be pumped into the columns, then the columns would be sealed for 8 hours, then water would be exchanged and later another 8-hour batch test would be run. Shortly after this solution was devised and put in place, an extended period of very cold temperatures caused the columns and their water jackets to freeze. (Influent was also circulated through large barrels in which the columns were replaced; this was done to stabilize temperatures. For freeze protection, due to the limited power available only a low-wattage light bulb could be used; it was placed within the insulated study facility and connected to a timer that activated it during the colder night-time hours.) Because of these continuing difficulties, the studies were halted for additional reconsideration.

Due to winter weather, it was decided to forego completion of the current studies and use information they provided to design new, larger studies. Those study designs will be finalized and the studies will be performed in spring and summer 2007.

The report on the aborted studies is attached as Appendix D.

### 3.5.3 Seeps

Several seeps were observed over the course of 2005 that warrant special mention. Those present on the OLF are discussed separately (refer to Section 7.3.2).

A seep was observed at the northeastern end of the fractures associated with the slump at former SW056 (see Section 3.5.1). Standing water was visible inside a fracture during an inspection of the slump on August 2, 2006. This inspection followed a precipitation event, however, so it was not certain whether the water was seepage or precipitation. Subsequent inspections showed it to be seepage.

The location in which this seep is present has long been marked by lush vegetation (willows and thick grass). Close inspection of aerial photographs from 1937 and 1951 show even more lush vegetation at that time, which precedes development of the RFP. Therefore, the appearance of this seep would seem to represent a condition that was normal prior to the existence of the Site, as opposed to a “new” seep.

Another seep was observed in the fall of 2006 on the hillside forming the eastern margin of the FC-1 basin, near the southwest corner of the former B371/374 complex. The ground at the seep is covered with railroad ballast (dark gray, angular gravel), and it appeared the seep might be issuing from this deposit. At the time the seep was observed, a large puddle was present south of former B371, east of and topographically higher than the location of the seep.

Aerial photos of the area taken during B371/374 closure were examined. It was found that the ballast and seep occur at the western end of the former rail line that was used to transport demolition/closure debris from the Site, and the puddles that had been present were overlying part of the former rail line. It was therefore concluded that the railroad ballast was covered with backfill but not removed or extensively disrupted during final closure and regrading efforts in this area, and this subsurface deposit of gravel acts to drain accumulated surface water toward FC-1, where it issues as the seep that was observed.

### 3.5.4 No-Purge Sampling

After DOE-LM accepted control of the Site, a study was begun to determine the feasibility of using different sampling methods at wells that typically go dry during the pre-sampling purge. This purging activity is intended to remove stagnant, non-representative water from a well so that the sample represents fresh ground water. However, by purging extremely low-producing wells, often there is insufficient recharge to collect a sample within the allotted time (for VOCs, this is 48 hours after purging). DOE-LM and some other entities have on occasion employed a "no-purge" sampling technique at such wells, and the no-purge method has been reported to be applicable to carefully selected fuel-hydrocarbon sites (Newell et al. 2000). (See also WSPA 1996, and Barcelona 1997 for additional discussion of this technique.) In this use of the term "no purge," samples are collected from water initially present within the well casing, rather than purging that water and collecting the recharge (if any); this latter process is the traditional sampling method at Rocky Flats.

Parallel sampling at the Site was attempted in the fourth quarter of 2005 at six wells, and in the second and fourth quarters of 2006 in up to eight wells. These specific wells were selected because they often fail to recover during sampling. The intent was to collect a sample using the no-purge method, then purge the well and collect a second sample (termed the purge sample in this discussion). In most cases, the analytical suite was VOCs, but metals and/or nitrate were included at some locations. The goal of this effort is to evaluate whether a transition to no-purge sampling for low-producing wells would be acceptable from the perspective of data usability and representativeness.

Many of the wells selected for this study did not provide adequate water to meet the study objectives. In some cases (e.g., wells 4787 and 4887) they were dry and provided no samples; in other cases, they provided the no-purge sample but not the purge sample. Further complication resulted from the need to return to some wells at a later date to collect the purge samples, because recharge was so slow. The resulting temporal gap between samples ranged from 1 day to over 6 weeks. Such a long period between samples clearly raises the question of whether both such samples can be considered to represent the same ground water.

Analytical results of these samples were assembled. Only paired samples were included in the assessment; if a well did not produce both the no-purge and purge samples, analytical data for the event were eliminated from consideration.

Table 3−17 provides a summary of analytical data from this study.

*Table 3−17. Comparison of Analytical Results From Samples Collected Using No-Purge and Purge Sampling Methods*

| Well | Sample Date | Analyte Name | Result | Units | Lab Qualifier |
|---|---|---|---|---|---|
| 00797-NP | 12/12/2005 | Trichloroethene | 0.58 | µg/L | J |
| 00797-P | 12/14/2005 | Trichloroethene | 0.2 | µg/L | U |
| 00797-NP | 12/12/2005 | Uranium | 26 | µg/L | J |
| 00797-P | 12/14/2005 | Uranium | 25 | µg/L | J |
| 10594-NP | 12/12/2005 | Methylene chloride | 0.1 | µg/L | U |
| 10594-P | 12/14/2005 | Methylene chloride | 0.41 | µg/L | J |
| 10594-NP | 12/12/2005 | Nitrate + Nitrite as Nitrogen | 0.07 | mg/L | |
| 10594-P | 12/14/2005 | Nitrate + Nitrite as Nitrogen | 0.04 | mg/L | B |
| 10594-NP | 12/12/2005 | Trichloroethene | 0.51 | µg/L | J |
| 10594-P | 12/14/2005 | Trichloroethene | 0.2 | µg/L | U |
| 10594-NP | 12/12/2005 | Uranium | 91 | µg/L | J |
| 10594-P | 12/14/2005 | Uranium | 95 | µg/L | J |
| 90399-NP | 12/12/2005 | 1,1,1-Trichloroethane | 0.15 | µg/L | U |
| 90399-P | 12/13/2005 | 1,1,1-Trichloroethane | 0.17 | µg/L | J |
| 90399-NP | 12/12/2005 | 1,1-Dichloroethene | 1.3 | µg/L | |
| 90399-P | 12/13/2005 | 1,1-Dichloroethene | 1.3 | µg/L | |
| 90399-NP | 12/12/2005 | Carbon tetrachloride | 250 | µg/L | D |
| 90399-P | 12/13/2005 | Carbon tetrachloride | 310 | µg/L | D |
| 90399-NP | 12/12/2005 | Chloroform | 29 | µg/L | D |
| 90399-P | 12/13/2005 | Chloroform | 37 | µg/L | |
| 90399-NP | 12/12/2005 | cis-1,2-Dichloroethene | 3.8 | µg/L | |
| 90399-P | 12/13/2005 | cis-1,2-Dichloroethene | 3.3 | µg/L | |
| 90399-NP | 12/12/2005 | Methylene chloride | 0.1 | µg/L | U |
| 90399-P | 12/13/2005 | Methylene chloride | 0.44 | µg/L | J |
| 90399-NP | 12/12/2005 | Tetrachloroethene | 8.6 | µg/L | |
| 90399-P | 12/13/2005 | Tetrachloroethene | 9.2 | µg/L | |
| 90399-NP | 12/12/2005 | Trichloroethene | 280 | µg/L | D |
| 90399-P | 12/13/2005 | Trichloroethene | 320 | µg/L | D |
| 10992-NP | 5/31/2006 | Acetone | 1.9 | µg/L | U |
| 10992-P | 5/31/2006 | Acetone | 99 | µg/L | |
| 10992-NP | 5/31/2006 | Methylene chloride | 0.32 | µg/L | U |
| 10992-P | 5/31/2006 | Methylene chloride | 0.46 | µg/L | JB |
| 21505-NP | 5/24/2006 | 1,1-Dichloroethane | 1.2 | µg/L | |
| 21505-P | 5/24/2006 | 1,1-Dichloroethane | 0.6 | µg/L | J |
| 21505-NP | 5/24/2006 | 1,1-Dichloroethene | 1.5 | µg/L | |
| 21505-P | 5/24/2006 | 1,1-Dichloroethene | 0.6 | µg/L | J |
| 21505-NP | 5/24/2006 | Acetone | 1.9 | µg/L | U |
| 21505-P | 5/24/2006 | Acetone | 6.4 | µg/L | J |
| 21505-NP | 5/24/2006 | cis-1,2-Dichloroethene | 3.2 | µg/L | |
| 21505-P | 5/24/2006 | cis-1,2-Dichloroethene | 1.5 | µg/L | |
| 21505-NP | 5/24/2006 | Tetrachloroethene | 4.6 | µg/L | |
| 21505-P | 5/24/2006 | Tetrachloroethene | 1.3 | µg/L | |
| 21505-NP | 5/24/2006 | Toluene | 0.17 | µg/L | J |
| 21505-P | 5/24/2006 | Toluene | 0.17 | µg/L | U |
| 21505-NP | 5/24/2006 | Trichloroethene | 25 | µg/L | |
| 21505-P | 5/24/2006 | Trichloroethene | 8.9 | µg/L | |
| 73005-NP | 10/10/2006 | 1,3-Dichlorobenzene | 2.1 | µg/L | |

*Table 3−17 (continued). Comparison of Analytical Results From Samples Collected Using No-Purge and Purge Sampling Method*

| Well | Sample Date | Analyte Name | Result | Units | Lab Qualifier |
|---|---|---|---|---|---|
| 73005-P | 10/11/2006 | 1,3-Dichlorobenzene | 0.16 | µg/L | U |
| 73005-NP | 10/10/2006 | Aluminum | 18 | µg/L | U |
| 73005-P | 11/28/2006 | Aluminum | 95.2 | µg/L | B |
| 73005-NP | 10/10/2006 | Arsenic | 4.4 | µg/L | U |
| 73005-P | 11/28/2006 | Arsenic | 7.1 | µg/L | B |
| 73005-NP | 10/10/2006 | Barium | 100 | µg/L | |
| 73005-P | 11/28/2006 | Barium | 97 | µg/L | B |
| 73005-NP | 10/10/2006 | Boron | 29 | µg/L | B |
| 73005-P | 11/28/2006 | Boron | 39.5 | µg/L | |
| 73005-NP | 10/10/2006 | Cadmium | 0.45 | µg/L | U |
| 73005-P | 11/28/2006 | Cadmium | 1.8 | µg/L | B |
| 73005-NP | 10/10/2006 | Cobalt | 1.2 | µg/L | B |
| 73005-P | 11/28/2006 | Cobalt | 1 | µg/L | U |
| 73005-NP | 10/10/2006 | Lithium | 84 | µg/L | |
| 73005-P | 11/28/2006 | Lithium | 85.5 | µg/L | B |
| 73005-NP | 10/10/2006 | Manganese | 14 | µg/L | |
| 73005-P | 11/28/2006 | Manganese | 18.3 | µg/L | |
| 73005-NP | 10/10/2006 | Selenium | 10 | µg/L | B |
| 73005-P | 11/28/2006 | Selenium | 6 | µg/L | U |
| 73005-NP | 10/10/2006 | Strontium | 750 | µg/L | |
| 73005-P | 11/28/2006 | Strontium | 895 | µg/L | |
| 73005-NP | 10/10/2006 | Thallium | 4.9 | µg/L | U |
| 73005-P | 11/28/2006 | Thallium | 14.7 | µg/L | B |
| 73005-NP | 10/10/2006 | Uranium | 16 | µg/L | B |
| 73005-P | 11/28/2006 | Uranium | 52.3 | µg/L | J |
| 73005-NP | 10/10/2006 | Zinc | 6.4 | µg/L | B |
| 73005-P | 11/28/2006 | Zinc | 6.8 | µg/L | B |
| 90399-NP | 6/13/2006 | 1,1-Dichloroethene | 1 | µg/L | |
| 90399-P | 6/13/2006 | 1,1-Dichloroethene | 1.2 | µg/L | |
| 90399-NP | 11/1/2006 | 1,1-Dichloroethene | 0.34 | µg/L | J |
| 90399-P | 11/2/2006 | 1,1-Dichloroethene | 0.76 | µg/L | J |
| 90399-NP | 6/13/2006 | Acetone | 5.6 | µg/L | J |
| 90399-P | 6/13/2006 | Acetone | 2.7 | µg/L | J |
| 90399-NP | 6/13/2006 | Carbon tetrachloride | 210 | µg/L | |
| 90399-P | 6/13/2006 | Carbon tetrachloride | 240 | µg/L | |
| 90399-NP | 11/1/2006 | Carbon tetrachloride | 120 | µg/L | |
| 90399-P | 11/2/2006 | Carbon tetrachloride | 140 | µg/L | |
| 90399-NP | 6/13/2006 | Chloroform | 39 | µg/L | |
| 90399-P | 6/13/2006 | Chloroform | 43 | µg/L | |
| 90399-NP | 11/1/2006 | Chloroform | 28 | µg/L | |
| 90399-P | 11/2/2006 | Chloroform | 29 | µg/L | |
| 90399-NP | 6/13/2006 | cis-1,2-Dichloroethene | 3.8 | µg/L | |
| 90399-P | 6/13/2006 | cis-1,2-Dichloroethene | 4.4 | µg/L | |
| 90399-NP | 11/1/2006 | cis-1,2-Dichloroethene | 2.4 | µg/L | |
| 90399-P | 11/2/2006 | cis-1,2-Dichloroethene | 2.5 | µg/L | |
| 90399-NP | 11/1/2006 | Styrene | 1.2 | µg/L | |
| 90399-P | 11/2/2006 | Styrene | 1.1 | µg/L | |

*Table 3−17 (continued). Comparison of Analytical Results From Samples Collected Using No-Purge and Purge Sampling Method*

| Well | Sample Date | Analyte Name | Result | Units | Lab Qualifier |
|---|---|---|---|---|---|
| 90399-NP | 6/13/2006 | Tetrachloroethene | 8.2 | µg/L | |
| 90399-P | 6/13/2006 | Tetrachloroethene | 9.1 | µg/L | |
| 90399-NP | 11/1/2006 | Tetrachloroethene | 3.5 | µg/L | |
| 90399-P | 11/2/2006 | Tetrachloroethene | 3.9 | µg/L | |
| 90399-NP | 6/13/2006 | Trichloroethene | 350 | µg/L | |
| 90399-P | 6/13/2006 | Trichloroethene | 380 | µg/L | |
| 90399-NP | 11/1/2006 | Trichloroethene | 170 | µg/L | |
| 90399-P | 11/2/2006 | Trichloroethene | 180 | µg/L | |
| 90402-NP | 6/12/2006 | 1,1-Dichloroethene | 0.27 | µg/L | J |
| 90402-P | 6/12/2006 | 1,1-Dichloroethene | 0.24 | µg/L | J |
| 90402-NP | 6/12/2006 | Acetone | 5.1 | µg/L | J |
| 90402-P | 6/12/2006 | Acetone | 2.4 | µg/L | J |
| 90402-NP | 6/12/2006 | Carbon tetrachloride | 10 | µg/L | |
| 90402-P | 6/12/2006 | Carbon tetrachloride | 10 | µg/L | |
| 90402-NP | 6/12/2006 | Chloroform | 2.7 | µg/L | |
| 90402-P | 6/12/2006 | Chloroform | 2.7 | µg/L | |
| 90402-NP | 6/12/2006 | cis-1,2-Dichloroethene | 0.24 | µg/L | J |
| 90402-P | 6/12/2006 | cis-1,2-Dichloroethene | 0.16 | µg/L | J |
| 90402-NP | 6/12/2006 | Tetrachloroethene | 9.7 | µg/L | |
| 90402-P | 6/12/2006 | Tetrachloroethene | 11 | µg/L | |
| 90402-NP | 6/12/2006 | Trichloroethene | 17 | µg/L | |
| 90402-P | 6/12/2006 | Trichloroethene | 16 | µg/L | |
| B206989-NP | 10/10/2006 | Nitrate + Nitrite as Nitrogen | 36 | mg/L | |
| B206989-P | 10/10/2006 | Nitrate + Nitrite as Nitrogen | 35 | mg/L | |
| B206989-NP | 10/10/2006 | Uranium | 110 | µg/L | |
| B206989-P | 10/10/2006 | Uranium | 120 | µg/L | |

NOTES: Well numbers have –P or –NP suffices attached; -P refers to the purge sample, -NP refers to no-purge samples. Qualifiers: J = estimated; U = analyte not detected; B = analyte detected in blank; D = analysis run at a dilution.

Results gathered during this evaluation were first examined and results for analytes that were not detected in either sample were removed from the data set. The final data set was then assessed statistically using both the ANOVA and Mann-Whitney methods. An interwell comparison was made. No-purge data were assigned upgradient and purge downgradient positions. Both statistical methods found insufficient data to form a conclusion for many analytes, which is not surprising given the maximum possible size of the pool of data was only three samples for each analyte/method/well combination (one each for the three quarters in which samples were collected using both methods).

While the overall results of the study to date are inconclusive, preliminary results for several analytes suggest there is no statistical difference between samples collected using no-purge vs. purge methods. (See Appendix B.3 for the results of this assessment.) However, because the results are not conclusive and because of the significant temporal gap between some samples, this study will be continued into 2007 in an attempt to collect enough data to support a technically-based decision on whether to use no-purge sampling methods at selected poor-producing wells.

End of current text

# 4.0 Water Monitoring: Validation and Data Quality Assessment

Data validation and verification (V&V) during CY 2006 was performed by LM personnel at the Grand Junction Office. Data quality assessment (DQA) is performed by personnel at the Site. The following section distinguishes DQA from data validation, and discusses the technical basis, equations, and criteria used for DQA of water.

## 4.1 General Discussion

Data validation is the principal means of assessing the usability of water analytical data. Validation also improves overall data quality by allowing the laboratory coordinator to closely monitor laboratory performance and to provide feedback to each laboratory regarding its ability to produce quality data that meets subcontract requirements. The laboratory coordinator may also use the results of data validation to direct analytical work to laboratories that demonstrate superior performance by generating timely, high quality analytical data for the Site.

Data validation is a rigorous data review performed by the laboratory coordinator or designee on all of the water analytical data generated by the Site. Additionally, the Site lead may request a secondary detailed validation on a case-by-case basis. Data validation is currently performed as specified in Stoller procedure *Environmental Procedures Catalog* (STO 6), "Standard Practice for Validation of Laboratory Data," GT-9(P). This procedure is based on the following EPA documents:

- U.S. Environmental Protection Agency, July 2002, USEPA Contract Laboratory Program National Functional Guidelines for Inorganic Data Review, EPA540/R-01/008.
- U.S. Environmental Protection Agency, October 1999, USEPA Contract Laboratory Program National Functional Guidelines for Organic Data Review, EPA540/R-99/008.
- U.S. Environmental Protection Agency, June 2001, USEPA Contract Laboratory Program National Functional Guidelines for Low Concentration Organic Data Review, EPA540/R-01/006.
- U.S. Environmental Protection Agency Office of Environmental Management, April 1997, Evaluation of Radiochemical Data Usability, ES/ER/MS-5.

All water analytical data collected by the Site are considered valid unless data validation identifies analytical problems that require the data to be qualified. When it is necessary to qualify individual data records, standard qualifier codes (alphanumeric validation codes) are applied. Integer "reason codes" often accompany these validation codes, enabling the data user to determine why the results were qualified.

Common data qualifiers used by LM are defined below. Refer to *Environmental Procedures Catalog* (STO 6), "Standard Practice for Validation of Laboratory Data," GT-9(P) for formal definitions.

- U The material was analyzed for but was not detected. The associated numerical value is the sample quantitation limit.
- J The associated numerical value is an estimated quantity.

- R The data are unusable (compound may or may not be present). Re-sampling and reanalysis are necessary for verification.
- N Presumptive evidence of the presence of the material.
- NJ Presumptive evidence of the presence of the material at an estimated quantity.
- UJ The material was analyzed for but was not detected. The sample quantitation limit is an estimated value.

Data validation includes the evaluation of laboratory QC data such as method blanks, laboratory control samples (LCS), and spike recoveries. Adherence to sample and extract holding times, standard analytical methods, contractual requirements, and proper documentation are also verified.

Although DQA and data validation examine some of the same QC data, they do so from different perspectives. DQA (in this report) looks at the overall quality of an entire year of water data, in contrast to validation, which looks at the analytical details of individual data packages. data validation focuses on laboratory performance, while DQA focuses on interpretation of data describing QC samples that originated in the field, such as “field duplicate” samples and “equipment rinsate” samples.

In contrast to data validation, the DQA performed by personnel at the Site, does not assign data qualifiers to individual analytical results or data packages. DQA is a second level of QA intended to be a general assessment of how well the water data-collection program is operating. The DQA is performed by evaluating water quality data in terms of the precision, accuracy, representativeness, completeness, and comparability (PARCC) parameters.

## 4.2 PARCC Parameters

Use of the PARCC parameters for DQA has been promoted by EPA guidance documents. Accuracy and precision are quantitative measures. Representativeness and comparability are qualitative measures. Completeness is a combination of both quantitative and qualitative measures.

Site personnel evaluate the PARCC parameters by following guidelines published in the following QC documents.

- RMRS, 1998, Procedure for Evaluation of Data for Usability.
- RMRS, 2000, Quality Assurance Program Plan for the Automated Surface-Water Monitoring Program. RF/RMRS-2000-013, Revision 0, March 2000.
- RMRS, 2001, Quality Assurance Program Plan for the Groundwater Monitoring Program Rocky Flats Environmental Technology Site.

The following subsections discuss the PARCC parameters and the types of data available to assess them.

### 4.2.1 Criteria for Precision

The precision of a measurement is an expression of the mutual agreement between duplicate measurements of the same property taken under similar conditions. Precision can be expressed quantitatively by the relative percent difference (RPD) between real and field duplicate samples for metals, VOCs, polychlorinated biphenyls and water quality parameters (WQPs) as defined by the following equation:

$$RPD = \frac{|(S - D)|}{(S + D)/2} * 100$$

where: S = Concentration of analyte in Real Sample
D = Concentration of analyte in Duplicate Sample
Undetects are not included

The Site uses the "Duplicate Error Ratio" (DER) to quantify the precision of radionuclide activity data:

$$DER = \frac{|(S - D)|}{\sqrt{\left[(TPU_S)^2 + (TPU_D)^2\right]}}$$

where: $TPU_S$ = Total Propagated Uncertainty of the Sample
$TPU_D$ = Total Propagated Uncertainty of the Duplicate
S = Sample Result
D = Duplicate (or Lab Replicate) Result

Because TPU is seldom reported with radionuclide activity data, the two-sigma error or random counting error has been substituted for TPU in the U, Am, and Pu calculations made for this report.

The Site QC criterion for water RPDs is that individual RPDs should be ≤30 percent. The analogous criterion for DERs is to be ≤1.96. The overall goal for the water data set is to have 85 percent of the RPD and DER values comply with the QC criteria.

### 4.2.2 Criteria for Accuracy

Accuracy is the degree of agreement for a measurement with an accepted reference or true value and is a measure of the bias in a system. The closer the measurement is to the true value, the more accurate the measurement. The Site validation process is the principal means for evaluating the accuracy of analytical results.

Because the Site V&V process compares the actual analytical methods used by each laboratory to the contract-required analytical methods, the Site does not repeat this evaluation.

Matrix spike (MS) and matrix spike duplicate (MSD) recoveries are reported by the analytical laboratories for most non-radionuclide analytical suites. Criteria for acceptable MS recoveries vary between laboratories, depending on the analyte, and the analytical method. The Site criterion for acceptable MS results ranges from 75 to 125 percent recovery.

LCS recoveries for radionuclides are often available for water-quality data. Laboratories in practice will commonly accept LCS values in the range of 70−130 percent. LCS percent recoveries between the 70−130 percent laboratory range and the 75−125 percent QC range required by the Site laboratory contracts are examined by data validators for acceptability on an analyte-by-analyte basis. The Site criterion for acceptable LCS recoveries ranges from 75 to 125 percent recovery.

Because some laboratories reported LCS results in pCi/L, while others calculated percent recovery, the Site uses the "relative bias" reporting criterion. The relative bias criterion is defined in the BOA by the following formula (see Page J-6 of the National BOA, Section 2.3.2.5):

$$\text{Relative Bias} = (\text{Observed} - \text{Known}) / \text{Known}$$

where: Observed = measured activity of LCS standard (pCi/L)
Known = known activity of LCS standard (pCi/L)

Acceptable values for relative bias results range from –0.25 to +0.25.

### 4.2.3 Criteria for Representativeness

Representativeness in DQA is limited to an evaluation of whether analytical results for field samples are truly representative of environmental concentrations, or whether they may have been influenced by the introduction of contamination during collection and handling. The potential introduction of contamination is commonly evaluated by examination of the analytical results for equipment rinsates.

Equipment rinsates are used to assess the efficacy of the decontamination process used to clean water sampling equipment. Analytes detected in rinsate samples indicate possible cross-contamination between environmental samples. Rinsates are samples of volatile-free "distilled" water that have been poured over or through decontaminated sampling equipment and subsequently handled in the same manner as environmental samples. For flow-paced composite samples that are collected over time in carboys, a location-specific "rinse carboy" is prepared using distilled water. This carboy is treated the same as other surface-water samples from that location, and analyzed for the same parameters. Analytical data from these rinse carboys are used to assess how well the carboys were cleaned between field deployments and to determine if contamination was introduced during sample preparation.

Although rinsates are used specifically as indicators of cross-contamination from improper decontamination of equipment, they are carried through the entire sampling, shipping, and laboratory process. Therefore, they are good indicators of potential contamination introduced during any of these steps.

### 4.2.4 Criteria for Completeness

A qualitative measure of completeness is the rate of successful sampling. The DQA verifies that all planned samples were collected, unless insufficient water was available for sampling. The completeness goal for successful sampling is the collection of at least 90 percent of the planned samples. However, the availability of water is outside the control of the Site. If all required stations were visited, sampling completeness is considered acceptable.

Completeness as a quantitative measure of data quality may be expressed as the percentage of valid or acceptable data obtained from a measurement system. The Site tracks analytical laboratory performance through both the shipment of samples to the laboratory and the receipt of data from the laboratory. The also evaluates data completeness on the following formula:

$$Completeness = DP_u = \frac{DP_t - DP_n}{DP_t} * 100$$

where: $DP_u$ = Percentage of usable data points
$DP_t$ = Total number of data points
$DP_n$ = Non-usable (rejected) data points

The completeness criterion is having $\geq$ 90 percent valid samples.

### 4.2.5 Criteria for Comparability

Comparability is a qualitative parameter. Consistency in the acquisition, handling, and analysis of samples is necessary for comparing results. Samples are collected in accordance with Site standard operating procedures (SOPs), transported per Site SOPs and U.S. Department of Transportation shipping regulations, and analyzed using standard EPA, or nationally recognized analytical methods. This helps to ensure comparability of results with other analyses performed in a similar manner.

The laboratory coordinator or designee verifies that laboratory analyses are performed according to the standard protocols specified by the Site subcontract to each laboratory. Therefore, the analytical results should be comparable to data produced by similar methods.

## 4.3 Water DQA Results CY 2006

During CY 2006, 119 locations were sampled one or more times. This resulted in a total of 399 water samples collected.[38] During CY 2006, 1,099 bottles of water were submitted to analytical laboratories for analysis. The following table breaks this data down by sample type.

*Table 4−1. CY 2006 Sample Type Breakdown*

| | Unique Water Samples | Unique Bottle Codes |
|---|---|---|
| **Primary samples (REALs)** | 383 | 988 |
| **Field duplicates (DUPs)** | 16 | 54 |
| **Rinsates (RNSs)** | 12 | 57 |
| **Totals** | 411 | 1099 |

Data used to evaluate the PARCC parameters are included in the available CY 2006 analytical data generated by the laboratories. These include analyses of field duplicate and rinsate QC samples submitted to the laboratory, and laboratory generated QA/QC samples such as LCS. The DQA of these analyses is discussed below by each PARCC parameter.

[38] This is the sum of real and duplicate samples for unique sampling events.

### 4.3.1 Precision During CY 2006

DERs are indicators of precision for radionuclide analyses. The QC criterion for precision requires that individual DER values should be ≤1.96, and overall the data set should have ≥85 percent compliance with the criterion. Appendix Table B-1 is a tabulation of the DER values for CY 2006 radionuclide analyses. The table has been sorted by the DER parameter so that the range of values is apparent. The DER range is from 0.01 to 1.63.

Table 4−2 summarizes the DER findings of Table B-1 and indicates if the 85 percent goal has been met. Overall, 100 percent of the DER data are in compliance with the criterion, indicating excellent precision for radionuclide analyses.

*Table 4−2. Summary of Duplicate Error Ratio Values*

| Analyte Group | Total Number of DER Results | Number of Unacceptable Results DER>1.96 | Number of Acceptable Results | Percentage Acceptable | Goal Met |
|---|---|---|---|---|---|
| Radionuclides | 27 | 0 | 27 | 100% | Yes |

RPD between real and field duplicate sample results is an indicator of precision for non-radionuclide analyses. Individual RPD values should be ≤30 percent and at least 85 percent of the RPDs should comply with the criterion. Appendix Table B-2 tabulates RPD values and is sorted first by analyte suite, then by RPD, in order to highlight the RPD range of each suite. RPD values ranged from 0.0 percent to 98.18 percent for metals, 0.66 percent to 2.67 percent for WQPs, and 0.0 percent to 70.79 percent for VOCs/SVOCs.

Table 4−3 summarizes the RPD findings of Table B-2 and indicates if the 85 percent goal has been met. During CY 2006, the RPD goal was met for metals and for all analyte groups. Overall, the non-radionuclide data had 93.3 percent acceptable RPDs, and therefore exceeded the 85 percent goal.

*Table 4−3. Summary of RPD Values*

| Analyte Group | Total Number of RPD Results | Number of Unacceptable Results RPD>30% | Number of Acceptable Results | Percentage Acceptable | Goal Met |
|---|---|---|---|---|---|
| Metals | 8 | 1 | 9 | 88.9 | Yes |
| WQP | 4 | 0 | 4 | 100 | Yes |
| VOC/SVOC | 33 | 2 | 31 | 93.9 | Yes |
| Totals | 45 | 3 | 42 | 93.3 | Yes (overall) |

### 4.3.2 Accuracy During CY 2006

MS recoveries provide another measure of accuracy. Appendix Table B-3 displays recoveries for 479 MS and MSD analytical records for metals, VOCs/SVOCs, and WQPs. This data is summarized in Table 4−4. All individual suites, except for WQP, met the goal with greater than

90 percent of their spike recoveries falling in the acceptable range. Overall, across all analytical suites, the percentage of acceptable MS/MSD results was 96.5 percent.

*Table 4−4. Summary of MS and MSD Recovery Data*

| Analyte Group | Total Number of MS & MSD Results | Number of Low Results Below 75% | Number of High Results Above 125% | Number Acceptable | Percentage Acceptable | Goal Met |
|---|---|---|---|---|---|---|
| Metals | 302 | 0 | 0 | 302 | 100.0 | Yes |
| WQP | 47 | 12 | 0 | 35 | 74.5 | No |
| VOC/SVOC | 130 | 4 | 1 | 125 | 96.2 | Yes |
| Totals | 479 | 16 | 1 | 462 | 96.5 | Yes (overall) |

Appendix Table B-4 contains 33 relative bias values for LCSs. These are used by the Site to evaluate the accuracy of radionuclide analyses. The QC criterion for the acceptable range of relative bias values is from –0.25 to +0.25. During the CY 2006, the bias ranged from −0.123 to +0.140. All of the data met the QC criterion.

LCS results for non-radionuclide suites were available for metals, VOCs/SVOCs, and WQPs (including anions). These LCS recoveries are tabulated in Appendix Table B-5, which is sorted by analyte group, then by percent recovery. There are 260 LCS data records for metals. All of the LCS recoveries for metals fell in the range 82.4 percent to 120.4 percent and were within the 75 percent to 125 percent acceptable QC range. There are 153 LCS data records for VOCs/SVOCs. LCS recoveries for VOCs/SVOCs fell between 28 percent and 120 percent. Thirty-six records are outside the 75 percent to 125 percent acceptable QC range (76.5 percent acceptable). There are 52 LCS data records for WQPs. LCS recoveries for WQPs fell between 90 percent and 110 percent and were all acceptable. Overall for non-radionuclides, 92.3 percent of the LCS recoveries indicate that CY 2006 water analytical data for metals, VOCs/SVOCs, and WQPs are of high accuracy.

Another aspect of accuracy is “rejected data.” Out of 12,413 analytical records representing reals, duplicates and rinsates during CY 2006, eight records were rejected (R qualified) during data V&V. Another way to state this is that 99.9 percent of the analytical data collected during the year were considered to be valid and usable. Appendix Table B-6 lists the eight rejected records.

### 4.3.3 Representativeness During CY 2006

As defined earlier, representativeness is an evaluation of the sampling procedure for its ability to reflect the true concentrations of contaminants in water. Equipment rinsate samples ( and ‘rinse carboys’) are used by the Site to determine whether there is introduced contamination from improper or incomplete decontamination of the sampling equipment.

During CY 2006 a total of 739 rinsate analytical records were generated for metals, radionuclides, VOCs/SVOCs, and WQPs. The majority of these records lack evidence of contamination. The remaining 62 records are tabulated in Appendix Table B-7. Four of these are B-qualified inorganic data which constitute only weak evidence of contamination. The “B” qualifier for inorganics indicates that the concentrations are above the instrument detection limit,

but below the method detection limit. Thirty records are J-qualified indicating an estimated quantification/result. Three of these are B-qualified organic data which constitute only weak evidence of contamination. The “B” qualifier for organics indicates that the analyte was also found in the method blank.

Only 25 records (3 percent; at the top of Table B-7) provide substantial evidence of inadequate decontamination of a sample carboy or equipment. Overall, there is very little evidence of introduced contamination during CY 2006 water sampling and/or shipping activities. Most of the 739 rinsate records appear to be clean. Therefore, water quality data for the year are judged to be representative of the actual water concentrations.

Because all required sampling locations were visited, and the samples that could be collected were analyzed, analyses for the year are judged to be representative with respect to spatial coverage.

### 4.3.4 Completeness During CY 2006

If sufficient water is available for sampling, the goal is to have ≥90 percent successful sampling of all required locations. However, the availability of water is beyond the control of the samplers. Surface water monitoring during CY 2006 targeted sampling at 20 surface water sampling locations. In actuality, samples were collected at each of the 14 sites and were submitted to the laboratory for analysis; six locations were dry for the entire year. Ground water monitoring during CY 2005 targeted sampling at 100 wells. In actuality, samples were collected at 96 wells and were submitted to the laboratory for analysis; four locations were dry for the entire year. Treatment system monitoring during CY 2006 targeted sampling at six locations. In actuality, samples were collected at all six locations and were submitted to the laboratory for analysis. Therefore the sampling success rates for surface water, ground water, and treatment systems were 70 percent, 98 percent, and 100 percent, respectively.

V&V completeness is summarized in Table 4−5. This table compiles by analyte group, the total number of data points for reals, duplicates and rinsate samples. It then subtracts rejected data points, and subtracts points that lack validation qualifiers. The result is the net number of usable validated or verified data points, and this is expressed as percent usable data, or percent V&V completeness. The QC goal for completeness is ≥90 percent.

*Table 4−5. Summary of Validation and Verification Data Completeness*

| Analyte Group | Number of Data Points | Number of Unvalidated Points | Number Rejected | Net Usable Points | Percent Completeness | Goal Met |
|---|---|---|---|---|---|---|
| Metals | 1,163 | 0 | 0 | 1.163 | 100.0 | Yes |
| Radionuclides | 418 | 0 | 0 | 418 | 100.0 | Yes |
| WQP | 191 | 0 | 0 | 191 | 100.0 | Yes |
| VOC/SVOC | 10,641 | 0 | 8 | 10,633 | 99.9 | Yes |
| | | | | | | |
| | **Sum of Number of Data Points** | **Sum of Number of Unvalidated Points** | **Sum of Number Rejected** | **Sum of Net Usable Points** | **Overall Completeness** | **Goal Met** |
| **Totals** | **12,413** | **0** | **8** | **12,405** | **99.9** | **Yes** |

Validation completeness for all suites exceeded 99.9 percent and exceeded the completeness goal. Therefore, from the perspective of V&V completeness, the CY 2006 water data are acceptable.

Another measure of completeness is that an adequate number of QC samples (field duplicates and equipment rinsates) must be collected to meet QC requirements. The recommended frequency for collecting duplicate samples is one duplicate (DUP) per 20 or fewer primary (REAL) water samples. In other words, duplicates should be collected at a 5 percent or greater frequency per REAL sample. Like duplicates, rinsate samples (RNS) are also to be collected at a 5 percent or greater rate.

The sample collection frequencies of REAL, DUP, and RNS samples are tabulated by analyte group in Table 4−6. The ratios of REAL/DUP samples shown in Table 4−6 meet water program QC goals with one DUP per 15.0 REALs. Across all analyte suites and samples collected during the year, the overall frequency of duplicates was 6.68 percent, exceeding program goals (≥5 percent).

The ratios of REAL/ RNS samples in Table 4−6 also meet program QC goals with one rinsate per 14.8 REALs. Overall, across all suites and samples collected during the year, the rinsate collection frequency was 6.75 percent, exceeding program goals (≥5).

*Table 4−6. Summary of Field Quality Control Samples and Data Records*

| Analyte Group | Number of Locations Sampled for REALs | Number of Locations Sampled for DUPs | Ratio REALs/ DUPs (Goal <20) | Ratio REALs/ RNSs (Goal <20) | Number REAL Records | Number DUP Records | Number RNS Records | Total Records |
|---|---|---|---|---|---|---|---|---|
| Metals | 77 | 9 | 22.5 | 18.6 | 1,059 | 47 | 57 | 1,163 |
| Radionuclides | 19 | 4 | 13.6 | 14.6 | 366 | 27 | 25 | 418 |
| WQP | 42 | 5 | 29.8 | 29.8 | 179 | 6 | 6 | 191 |
| VOC/SVOC | 99 | 9 | 14.3 | 14.3 | 9,339 | 651 | 651 | 10,641 |
| **Totals** | | | **15.0** | **14.8** | **10,943** | **731** | **739** | **12,413** |
| **Percentages** | | | | | | **6.68%** | **6.75%** | |

### 4.3.5 Comparability During CY 2006

No significant changes were made to water sampling or analytical procedures during CY 2006. Therefore, the analytical data generated during the year should be generally comparable to corresponding analyses from previous years.

End of current text

# 5.0 Air Monitoring

## 5.1 Introduction

Air monitoring and emissions assessments have been performed at the Site since the Site began operations in the early 1950s. The Site has historically been subject to 40 CFR 61, Subpart H which specifies radionuclide air emissions limitations and monitoring requirements for DOE facilities. However, following decommissioning and environmental restoration activities pursuant to the RFCA (CDPHE et al, 1996), completed in Fall 2005, the remaining DOE-retained lands are no longer a "facility" as defined in 40 CFR 61.91(b); consequently, 40 CFR 61, Subpart H, no longer applies.

Compliance with the 10-millirem (mrem) standard had been determined by comparing environmental radionuclide air concentration measurements at specified air monitoring locations around the perimeter of the former BZ with the "Concentration Levels for Environmental Compliance" listed in Table 2 of Appendix E to 40 CFR 61. Compliance is demonstrated when each measured radionuclide air concentration is less than its corresponding compliance level in Table 2 and when the fractional sum of all radionuclides is less than one. In the period since September 2005, the air concentrations have been compared to the same benchmarks as a matter of comparison to a historical threshold. For the annual period from October 2005 to September 2006, the maximum contribution from any single isotope was less than 0.8 percent of the corresponding concentration level for environmental compliance and the fractional sum of all radionuclides was less than 1.5 percent of the allowable annual dose rate at the sampler with the highest fractional sum (sampler S-132). The average dose rate measured in CY 2006 was 0.82 percent of the 10 mrem standard, compared to the dose rate in CY 2005 of 2.75 percent of the standard for the 9 months of active demolition and other physical completion activities. CY 2005, as a whole averaged 2.27 percent of the standard.

In CY 2006, airborne radionuclides were dominated by U isotopes. This has been observed generally in previous years, the isotopes being almost entirely of natural origin. Across all compliance samplers, U isotopes characteristic of naturally occurring U contributed an average of 94 percent of the dose rate.

In October 2006, following a year of continuous monthly sampling and observation, routine analysis of air monitoring filters has been suspended at all three sampling locations. The samples from two of the locations (S-136 and S-138) are still collected on a continuous monthly sampling schedule, but are archived pending review of site activities and identification of possible soil disturbances that are potentially able to cause significant air emissions. During the past year, except for U, the measured isotopes were generally below their detection limits and not measurable. In the absence of large-scale soil disturbances, potential air emissions from the site would be expected to remain near or below their detection limit in the samples and would not be measured.

## 5.2 CY 2006 Air Emissions Source Description

Potential air-emitting activities involving radioactive materials at the Site during CY 2006 were quite limited. The most significant activities involve minor dirt-road regrading and construction, excavation at the SPPTS to perform adjustments and maintenance, and driving on these same

roads to perform various surveillance activities and minor Site maintenance. In addition, on March 2, 2006, a grass fire in the former BZ caused significant smoke emissions, with some potential to increase radionuclide air emissions due to particles that may have been attached to the leaves of plants and due also the removal of surface vegetation that protects the soil surface from wind erosion. Surface soil emissions are the prominent source of air emissions from the Site, and result from nonpoint, diffuse sources, including mechanical and natural disturbances of contaminated soil and debris. The remaining minor radionuclide air emission potential is the result of residual contamination from past radioactive material spills and other releases. All of these sources have been reduced to low levels with no extensive areas in excess of 50 pCi/g in soils near the surface. In addition to these contaminants, the soils on and around the Site contain quantities of naturally occurring radionuclides.

## 5.3 Air Monitoring for Radionuclides

This section describes the routine air monitoring performed at the Site since October 2005.

Historically, the Site demonstrated compliance with the 10-mrem public dose standard in 40 CFR 61, Subpart H, through emission measurement or estimation and dispersion modeling of Site emissions to determine the dose to the most impacted off-Site resident. Beginning with CY 1998, the Site transitioned to an approved alternative compliance demonstration method based on environmental measurements (ambient air sampling), as allowed by 40 CFR 61.93(b)(5). The monitoring conducted in CY 2006 conformed to that same methodology but is no longer used to demonstrate compliance.

### 5.3.1 Description of Sampling Network

The Site operated a network of three high-volume, size-fractionating ambient air samplers located at the perimeter of the site, one to the west on Highway 93 and two along Indiana Street. The sampling network is shown in Figure 5–1.

The two locations on Indiana Street (S-136 and S-138) are downwind of the Site under prevailing higher speed winds and in locations where typically the highest potential dose would be expected to occur from wind-eroded Site sources, based on modeling using representative meteorological conditions. These two downwind locations are those that would be appropriate to measure Site emissions based on the alternative compliance demonstration guidance given in EPA's *Guidance on Implementing the Radionuclide NESHAPs* (EPA 1991) under conditions of continuous fugitive dust emissions as are anticipated. The third location to the west of the Site (S-132) is predominantly upwind and is known to not be representative of Site emissions alone due to a significant contribution of natural U and its progeny from wide-spread sand and gravel mining operations immediately east and southeast of the sampling location. During periods of daytime upslope wind conditions impacts have been historically observed at this location from intense soil disturbance activities at the Site.

The ambient air samplers continuously collect both fine and coarse particulate matter fractions on filters and removable impactor surfaces that were exchanged and analyzed on a monthly schedule through September 2006. The samples were analyzed for the Pu, Am, and U isotopes that represent most of the radioactive materials handled at or residing on the Site. These isotopes account for all materials that have the potential to contribute 10 percent or more of the dose to the public.

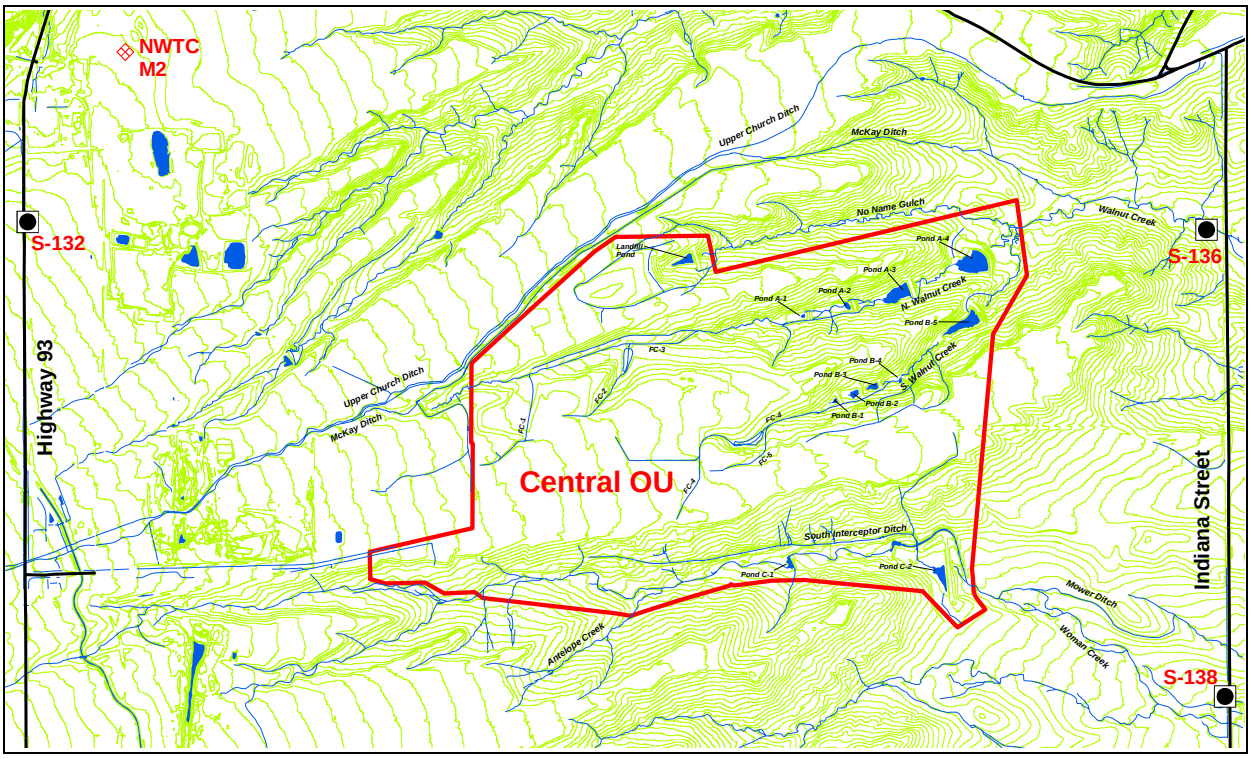



*Figure 5–1. CY 2006 Air Sampling Network*

### 5.3.2 Sampling Network Measurements in CY 2006

Filters from the sampling network were generally exchanged monthly through September 2006, then analyzed for Pu-239/240, Am-241, U-233/234, U-235, and U-238 on a regular submittal schedule. In April 2006, the filters from March were submitted for expedited analysis due to the grass fire that occurred in the former BZ. Other than that event, all filters were exchanged and analyzed on a prescribed schedule.

Average isotopic concentrations have been calculated at each sampler location from monthly measurements of isotopic activity on the filters and impactor pads, and from sample volume data. The average isotopic concentrations averaged over the period from October 2005 through September 2006 are shown in Table 5−1 for each sampler location. The results can be compared to the allowable concentrations of those same isotopes, if no other is present, or to the fractional sum of isotopes when a mixture is present as at the Site.

*Table 5−1. Annually Averaged Isotopic Concentrations at Sampling Network Locations for the Period from October 2005 through September 2006*

| Sampler and Time Period | Am-241 (pCi/m$^3$) | Pu-239/240 (pCi/m$^3$) | U-233/234 (pCi/m$^3$) | U-235 (pCi/m$^3$) | U-238 (pCi/m$^3$) | Fractional Sum |
|---|---|---|---|---|---|---|
| S-132: 10/05-9/06 | 2.5E-07 | 6.4E-07 | 3.0E-05 | 1.5E-06 | 2.8E-05 | 8E-03 |
| S-136: 10/05-9/06 | 5.8E-07 | 2.8E-07 | 1.4E-05 | 1.1E-06 | 1.6E-05 | 4E-03 |
| S-138: 10/05-9/06 | -7.4E-08 | 2.7E-07 | 1.6E-05 | 8.9E-07 | 1.8E-05 | 4E-03 |
| **Compliance Level (pCi/m$^3$)[a]** | **1.9E-03** | **2.0E-03** | **7.7E-03** | **7.1E-03** | **8.3E-03** | **1** |

[a]Compliance levels are listed for each isotope in Table 2 of Appendix E to 40 CFR 61.
Notes:
Am = Americium
Ci/m$^3$ = Curies per cubic meter; 1 Ci = 3.7 x $10^{10}$ Becquerel (Bq)
E# = x $10^{\#}$
Pu = Plutonium
U = Uranium

The *fractional sum* has been calculated for each sampler location by dividing each September 2005 through September 2006 isotopic concentration by that isotope's corresponding *compliance level* as listed in Table 2 of Appendix E to 40 CFR 61, then summing the fractions.

Table 5−2 lists the annually averaged concentrations of the individual isotopes. Both the fine particle concentrations (inhalable fraction) and the total airborne concentrations are listed. The total concentration is used for reporting dose consequences even though this is likely to result in a relatively large overestimate of the potential dose rate. The table shows that the fine concentration of each isotope is less that the total by a noticeable margin, except possibly when measurement error is most dominant. Results for Am and Pu were below detection limits in almost all samples.

*Table 5−2. Annual Average Ambient Radionuclide Concentrations*

| Location | Analyte | Approximate Annual Average Concentration[a] | |
|---|---|---|---|
| | | Fine Concentration (pCi/m$^3$) | Total Concentration (pCi/m$^3$) |
| S-132 | Am-241 | -8.01E-08[b] | 2.48E-07 |
| | Pu-239/240 | 3.21E-07 | 6.41E-07 |
| | U-233/234 | 1.30E-05 | 2.96E-05 |
| | U-235 | 7.48E-07 | 1.54E-06 |
| | U-238 | 1.27E-05 | 2.82E-05 |
| S-136 | Am-241 | -1.14E-07[b] | 5.79E-07 |
| | Pu-239/240 | 6.86E-08 | 2.79E-07 |
| | U-233/234 | 6.77E-06 | 1.38E-05 |
| | U-235 | 6.41E-07 | 1.06E-06 |
| | U-238 | 8.93E-06 | 1.59E-05 |
| S-138 | Am-241 | 2.49E-07 | -7.37E-08[b] |
| | Pu-239/240 | -8.28E-08[b] | 2.73E-07 |
| | U-233/234 | 8.06E-06 | 1.64E-05 |
| | U-235 | 2.98E-07 | 8.92E-07 |
| | U-238 | 1.03E-05 | 1.82E-05 |

Notes: [a]Average Concentrations for Am are estimated due to loss of fine filters in March.
[b]A negative result indicates analytical results similar to the variability in the blank filter value (i.e., very low non-detectable results)

### 5.3.3 Implications of the Air Monitoring Results

As reported in Section 1.3.2 of this report, the annually averaged concentrations of Pu-239/240, Am-241, U-233/234, U-235, and U-238 measured at the air sampling network have been compared to the compliance levels listed in Table 2 of Appendix E to 40 CFR 61. The maximum average concentration of each isotope, as shown in Table 5−1, ranges from 0.03 percent (Am and Pu) to less than 0.4 percent (U-234 and U-238) of the corresponding concentrations listed in Table 2 of Appendix E to 40 CFR 61. In addition, the fractional sum of all isotopes at the sampler location showing the highest concentrations in the 12-month period (October 2005−September 2006) was determined to be approximately 0.008. This corresponds to an annual dose of 0.08 mrem, or 0.8 percent of the 10-mrem standard. Had the Site been subject to 40 CFR 61, subpart H during the reporting period, it would have demonstrated compliance with the standards of that regulation.

Figure 5–2 shows monthly monitoring results for the period from October 2005 through September 2006 at the three sampling locations. The total airborne concentrations of radionuclides are presented as percentages of the allowable dose rate prescribed under 40 CFR 61, Subpart H for all isotopes combined. The total height of each bar in Figure 5–2 is the fractional sum of isotope concentrations expressed as a percentage. Sampler locations have been shown in Figure 5–1.

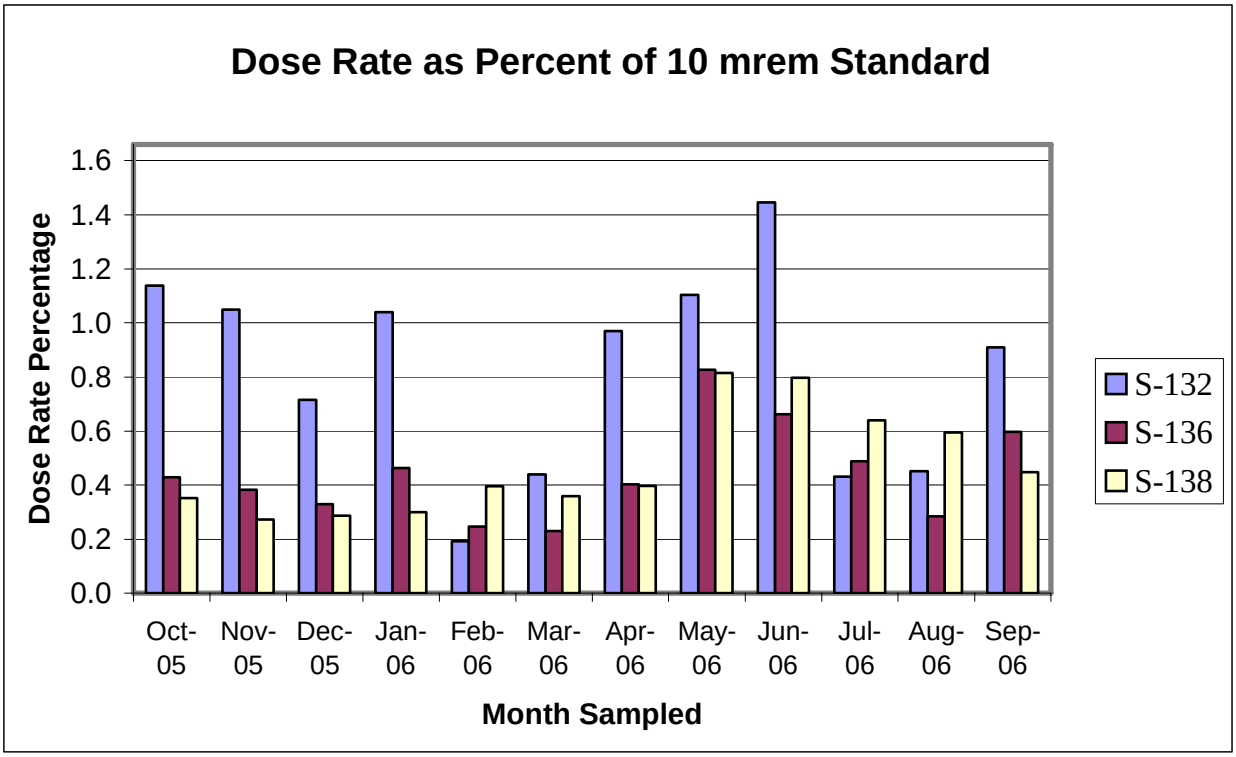



*Figure 5–2. Dose Rate Estimated from Environmental Measurements of Airborne Radionuclides Sampled from October 2005 through September 2006, by Month*

During this reporting period, the maximum measured radionuclide levels occurred to the west-northwest of the Site, at sampler S-132. This is the same sampler that had the highest measured annual-averaged radionuclide concentrations in 1998, 1999, 2000, 2001, and 2002. (In 2003 and 2004, sampler S-254, located across open space north of the Site along a dirt road that has seen increased traffic volumes due to local development, had the highest measured radionuclide concentrations among the compliance samplers being used at that time. In 2005, while active, sampler S-254 still showed higher measured concentrations of U than any other compliance sampler, most likely related to local dust sources combined with naturally occurring U isotopes in the soils in this part of the Front Range. Samples from that location, S-254, were not representative of Rocky Flats emissions.) The highest overall location in 2005 is not estimated, since the compliance network was not active for the entire year.

Naturally occurring U isotopes were the greatest contributors to airborne radionuclide levels at all monitoring locations in CY 2006. The monthly contribution of U-233/234 and U-238 activity ranged from 51 percent to approximately 100 percent of the measured dose rate, and for the year contributed around 94 percent of the dose rate.

The implications of the grass fire that occurred on April 2, 2006, were analyzed and presented in some detail at the time immediately following that event and are not presented in this annual report. The basic conclusion from that analysis, including the results of both modeling and sampling, was that the increase in airborne radionuclide emissions from the area involved was negligible and not detectable in the sampling network.

Table 5−2 also presents the annually averaged measured concentrations of Pu-239/240 and Am-241 at the three sampling locations. These two isotopes, the major constituents of the weapons-grade Pu processed at the Site, were reported by the laboratory at activities less than the required laboratory detection limit in nearly all samples. The laboratory-required detection limits were specified to assure that these isotopes would be measurable at airborne concentrations less than 1 percent of the Appendix E, Table 2 limits.

The estimated dose rate for this reporting period at the sampling location indicating the highest dose rate can be compared with the 10-mrem dose limit and with data from prior years. Figure 5–3 shows these results. As noted previously, the annually averaged dose rate at the critical receptor location in the current reporting period is 0.82 percent of the standard, based on the 12-month average. The results for all years are presented as a percentage of the 10 mrem dose limit.

The progressive increase in emissions over the 8-year period prior to physical completion was consistent with the continually increasing levels of soil disturbance and demolition activity occurring over the same period. The rapidly reduced emissions evident in the results for the CY 2006 reporting period demonstrate the effects of the reduced activities and diminished sources on the Site following its closure.

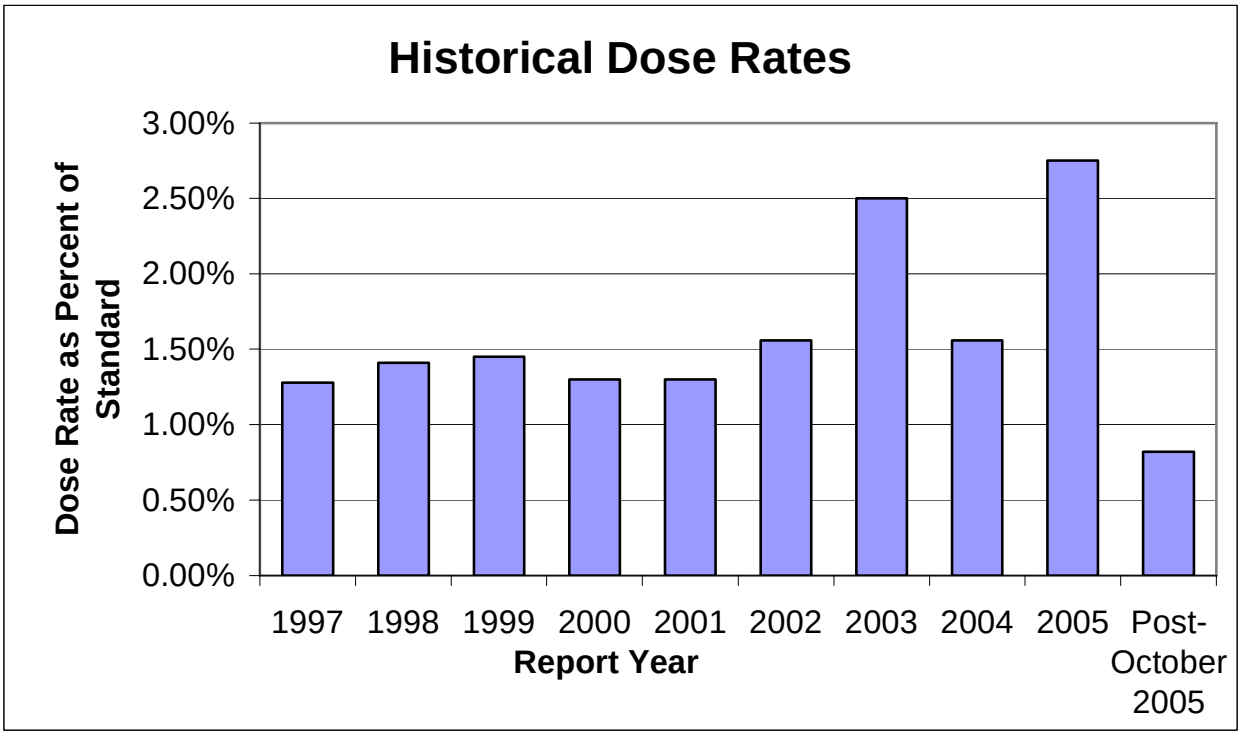



*Figure 5–3. Annually Averaged Concentrations as a Fraction of the 10 mrem Standard for the Years Leading to Site Closure*

End of current text

# 6.0 Ecological Monitoring

## 6.1 Introduction

The Ecology Group conducts ecological monitoring of the Site's ecological resources to ensure regulatory compliance and to preserve, protect, and manage those resources. Ecological monitoring is an integral aspect of determining whether the management objectives and goals for the natural resources at the Site are being achieved. This report summarizes the results of the ecological monitoring that was conducted at the Site during 2006.

At an elevation of approximately 6,000 feet, the Site contains a unique ecotonal mixture of mountain and prairie plant species resulting from the topography of the area and its proximity to the mountain front. The POU (formerly known as the BZ), the area surrounding COU (the general area where the old IA was once located), is one of the largest remaining undeveloped tracts of its kind along the Colorado Piedmont. A number of plant communities present at the Site have been identified as increasingly rare and unique by the Colorado Natural Heritage Program (CNHP; CNHP 1994, 1995). These communities include the xeric tallgrass prairie, tall upland shrubland, wetlands, and Great Plains riparian woodland communities. Small inclusions of a number of other increasingly rare plant communities are also found on the Site. Many of these communities support populations of increasingly rare animals as well, including the federally protected Preble's meadow jumping mouse, and other uncommon species such as the grasshopper sparrow, loggerhead shrike, Merriam's shrew, black crowned night heron, hops blue butterfly, and Arogos skipper.

A brief summary of the highlights from the 2006 field season is found below. Full detailed summaries and analyses for each field monitoring effort are presented as stand-alone reports on the accompanying Ecology CD-ROM.

## 6.2 Vegetation Monitoring

### 6.2.1 High Value Vegetation Monitoring

The Site is located along the Front Range of Colorado in an ecotonal position between the Great Plains and Rocky Mountains. As a result it contains plant species common to both physiographic regions. Several plant communities have been identified by the CNHP as containing significant or rare ecological resources at both the local and regional scale (CNHP 1994, 1995). These high-value plant communities (xeric tallgrass prairie, tall upland shrubland, selected wetlands, and Great Plains riparian woodland) are monitored to assess their status and condition.

Objectives of the high-value vegetation monitoring in 2006 were to qualitatively:

- Identify new plant records found at the Site during the field season.
- Evaluate the populations of known rare plants at the Site,
- Identify and document infestations of selected noxious weeds,
- Document the locations where herbicide applications were conducted.

#### 6.2.1.1 Site Flora

The complete list of plant species known to occur at the Site as of the end of 2006 is found in Appendix A on the CD-ROMs. As a result of the 2006 fieldwork, a total of four new records of vascular plant species for the Site flora are reported. None of these species are noxious weeds. Many were found growing in newly revegetated areas. The new plant species[39] occurring at the Site are described in Table 6−1.

*Table 6−1. New Plant Species at Rocky Flats*

| Family | Scientific Name | Speccode | Common Name |
|---|---|---|---|
| Poaceae | *Leptochloa fasicularis* (Lam.) A. Gray | LEFA1 | Bearded Sprangletop |
| Juncaginaceae | *Triglochin maritima* L. | TRMA1 | Arrowgrass |
| Caryophyllaceae | *Spurgularia media* (L.) Presl. | SPME1 | Sand Spurrey |
| Poaceae | *Chloris virgata* Sw. | CHVI2 | Showy Chloris |

Voucher specimens of these species will be deposited at the University of Colorado Herbarium in Boulder, Colorado.

#### 6.2.1.2 Rare-Plant Monitoring

Four plant species that occur at the Site are listed as rare and imperiled in Colorado by CNHP (CNHP 1999). The presence of these species underscores the significance of the ecological resources found at the Site and its value in the regional landscape. Populations of mountain-loving sedge (*Carex oreocharis*), forktip three-awn (*Aristida basiramea*), carrionflower greenbriar (*Smilax herbacea* ssp. *lasioneuron*), and dwarf wild indigo (*Amorpha nana*) are known to occur at the Site.

Populations of all four species were visited during 2006 and qualitative observations were made of each species. The carrionflower greenbriar was less abundant in 2006 than past observations have recorded, most likely due to the drought. The species occurs in isolated patches beneath the tall upland shrublands in the main branch of Rock Creek and requires abundant moisture. Old stems from previous years and a few new stems from 2006 (one male plant was in flower) were observed. The lack of moisture probably accounts for the fewer stems observed in 2006, since nothing else has occurred at these locations that might have had an impact on it.

The dwarf wild indigo continues to consist of a single small shrub in the Rock Creek drainage. The plant was observed as it was leafing out and prior to flowering in 2006. A total of 10 stems were counted coming up from the base. It appears to continue to do well in its isolated location in Rock Creek as the only population known at the Site.

Mountain loving sedge occurs predominantly along the north edges of the pediment tops in the Rock Creek drainage. At one location, the herbicide Plateau® had been applied in the area for control of jointed goatgrass (*Aegilops cylindrica*) in 2005 and there was some minor effects

[39] Plant nomenclature follows that of GPFA (1986), Weber (1976), and Weber (1990), in that order of determination when feasible. Species were verified at the University of Colorado Herbarium in Boulder, Colorado (COLO).

observed on the plants in 2006 (small amount of chlorosis on leaf tips). But the plants had flowered and otherwise appeared unaffected by the management actions. Because Plateau® is used for control of some monocot (graminoid) species at the Site it is worth noting this effect and future weed control efforts should minimize the use of this herbicide where this sedge species is present. Other populations outside where the herbicide had been applied appeared to be doing well and many of these had flowered in 2006.

Forktip three-awn was observed at several locations at the Site in late fall 2006. The drought in 2006 had apparently reduced the overall abundance to some degree and fewer plants appeared to have flowered. But given that the plant is an annual, it is not unexpected to see such a response to drought. Other annual plants observed on the prairie at the Site responded in a similar fashion in 2006.

The annual plant counts of the forktip three-awn were continued in 2006 at the locations where seeding of forktip three-awn was done in the south POU in 2001 and 2002. In fall 2001, seed collected from the original known location of forktip three-awn at the Site was sown by hand into two 1 meter square plots (approximately 100 seeds per plot). During 2002, additional seed (approximately 400 seeds) was collected at large new population discovered along North Walnut Creek, west of the COU in 2001. This seed was sown in four 1 meter square plots near where the seeding trials had been conducted in 2001. Approximately 100 seeds were placed in each plot in fall 2002. Table 6−2 shows the number of plants that have been counted annually, in and adjacent to the plots since the project was begun. In 2006, a large decrease in the number of plants in the plots was observed, most likely due to the drought conditions. It is expected that when normal precipitation returns the abundance of the plants in the plots will increase again. In general however, the seeding study has shown that the species germinates and grows readily under Site conditions that mimic where it has been found growing naturally at the Site.

*Table 6−2. Forktip Three-Awn Establishment Summary*

| Year | Plot | | | | | | Total # | Precipitation (in) |
|---|---|---|---|---|---|---|---|---|
| | 2001-NW | 2001-SE | 2002-1 | 2002-2 | 2002-3 | 2002-4 | | |
| 2002 | 25 | 28 | NA | NA | NA | NA | 53 | 7.85 |
| 2003 | 15 | 28 | 85 | 20 | 15 | 27 | 190 | 11.95 |
| 2004 | 7 | 54 | 136 | 13 | 21 | 34 | 265 | 18.71 |
| 2005 | 13 | 98 | 198 | 18 | 30 | 33 | 390 | 13.51 |
| 2006 | 3 | 8 | 15 | 0 | 0 | 9 | 35 | 6 |

Notes: Values are the number of plants that had germinated and grown during that year.
Plot name = Year - Plot ID
Precipitation data = March to September for each year.

### 6.2.1.3 Weed Mapping and Weed Control

Resource management is an important concern at the Site with a goal to protect and sustain the native ecological resources that make the Site so unique along the Front Range. One of the challenges at the Site is to manage the ecological resources with a limited set of methods available as management tools. Currently most efforts focus on the control or eradication of the weed species themselves with little emphasis on trying to improve conditions for the desired native species. Two of the key tools for grassland management, fire and grazing, are not

currently allowed or planned for use at the Site in the near future. As a result, management of the ecological resources is largely limited to controlling the noxious weeds themselves. The Comprehensive Conservation Plan (USFWS 2005) developed by the U.S. Fish and Wildlife Service (USFWS) for management of the Rocky Flats National Wildlife Refuge, has identified the full range of Integrated Pest Management tools for use at the refuge for controlling weeds. This includes administrative, cultural, biological (including grazing), mechanical (including prescribed fire), and chemical as viable tools for controlling noxious weeds and ecosystem management. As part of the Site transfers to USFWS in 2007, there may be a greater opportunity for some of these other resource management tools to be used.

As part of the data collection needed for good stewardship of the natural resources at the Site, mapped locations of noxious weeds are useful for helping to determine where control actions may be needed. The 2006 weed distribution maps for diffuse knapweed (*Centaurea diffusa*) and dalmatian toadflax (*Linaria dalmatica*) are shown in Figure 6–1 and Figure 6–2, respectively. Table 6−3 contains the estimated total acreage and acreage-by-density categories for each species, based on the 2006 maps. Table 6−4 shows the annual total infested acreages for diffuse knapweed and dalmatian toadflax from 1997 to 2006. [NOTE: Most of the large increases in infestation acreages from 1997 to 1998 were a result of the time of year in which mapping was conducted. Mapping in 1997 was conducted in August for each of the species. Beginning in 1998, weed mapping was conducted for each species when that species was in flower and/or most visible. Therefore, the higher visibility of the species at the time of mapping allowed more accurate estimates of their infestation levels from 1998 through 2006.] The total acreage of the Site is approximately 6,500 acres (K-H 1997). It should be noted that the acreage values are only approximate and should not be interpreted as exact areas. It is possible that unmapped infestations are present as well.

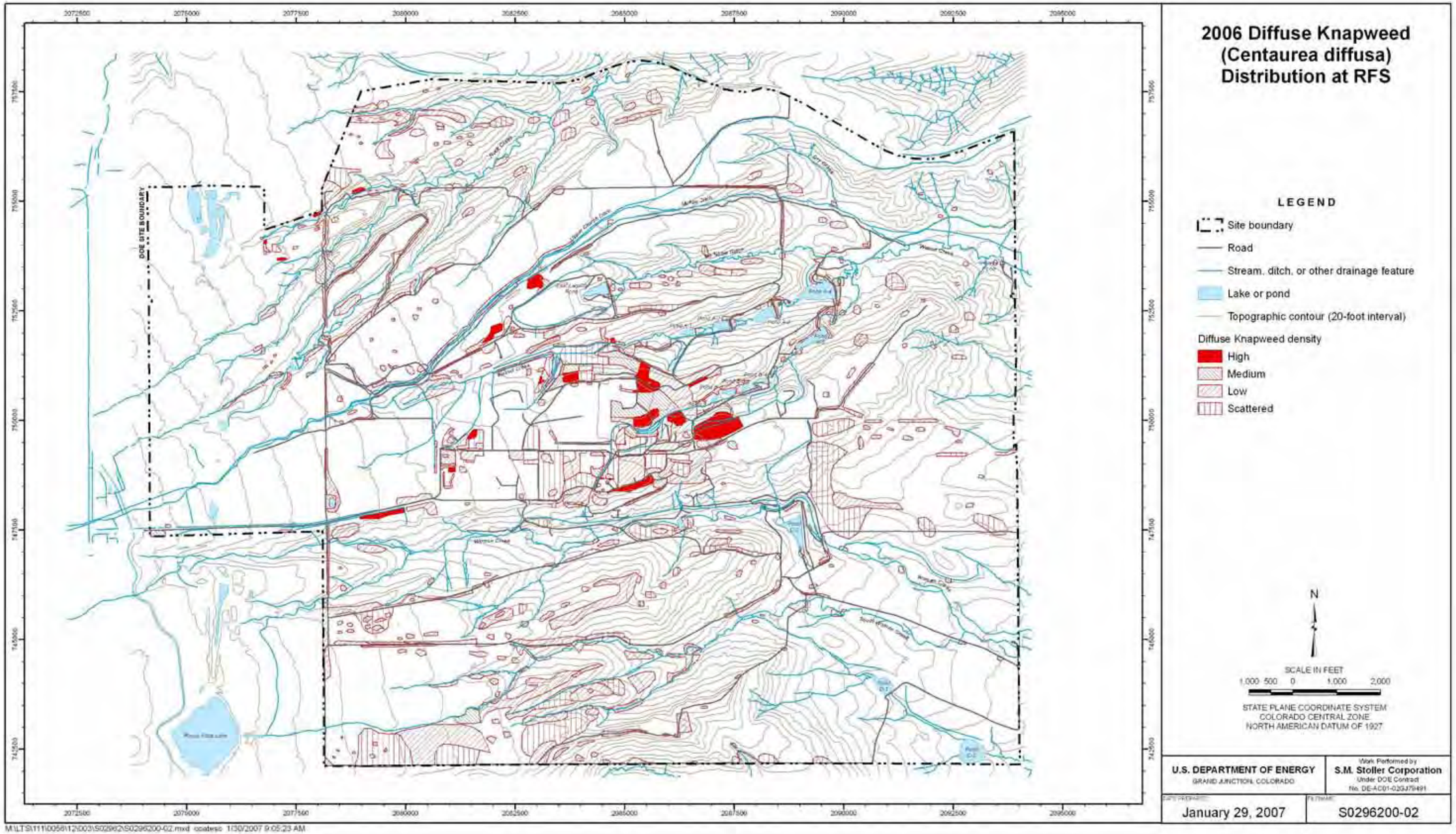



*Figure 6–1. 2006 Diffuse Knapweed (*Centaurea diffusa*) Distribution at RFS*

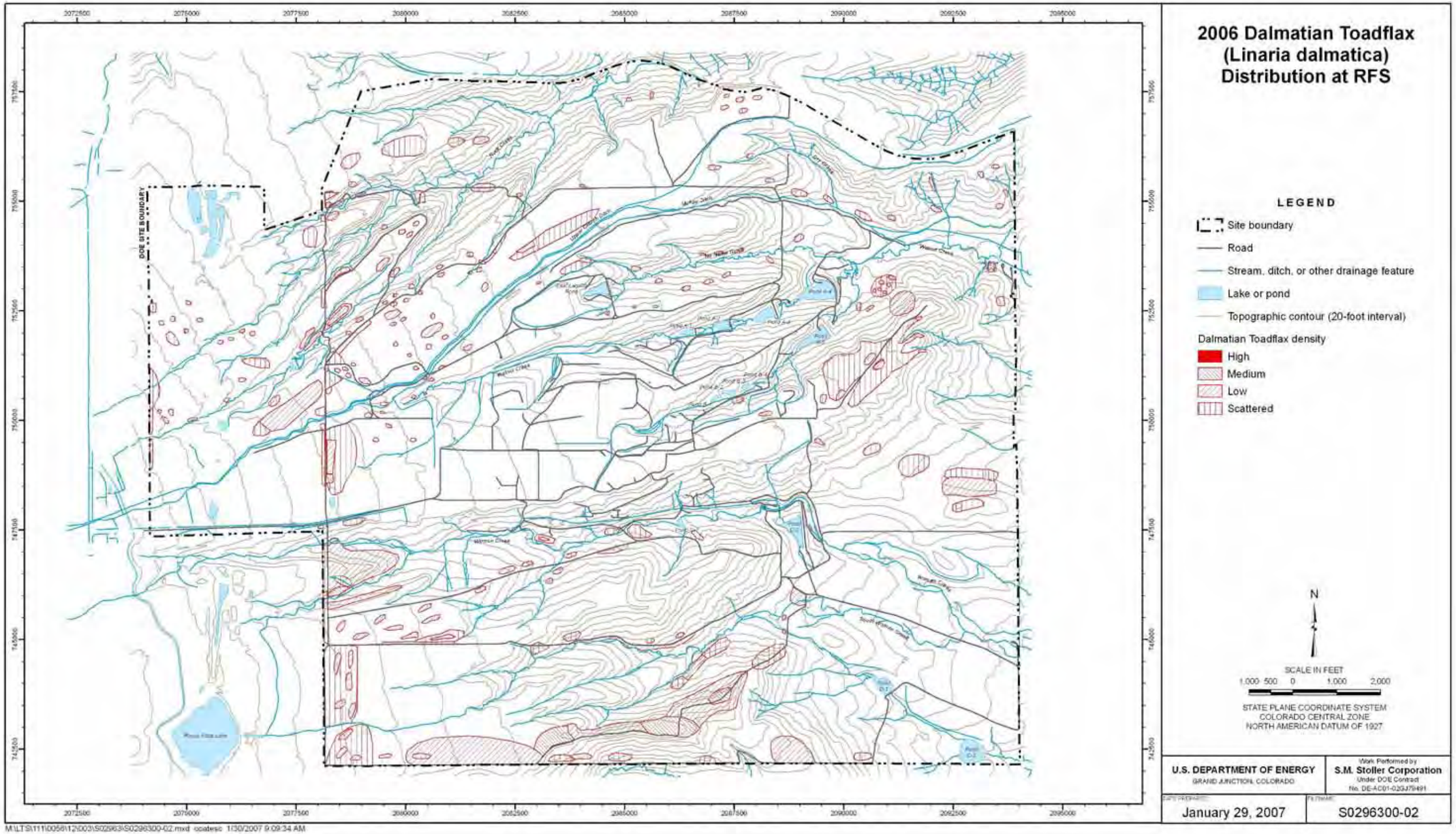



*Figure 6–2. 2006 Dalmatian Toadflax (*Linaria dalmatica*) Distribution at RFS*

*Table 6−3. 2006 Estimated Weed Infestation Acreage Summary for the Rocky Flats Site*

| Common Name | 2006 Acreage | | | | |
|---|---|---|---|---|---|
| | Site Total | Density Level | | | |
| | | High | Medium | Low | Scattered |
| Diffuse Knapweed | 800 | 38 | 95 | 367 | 300 |
| Dalmatian Toadflax | 467 | 0 | 25 | 193 | 249 |

Notes: All values are approximate acreages.
See text for density level descriptions.

*Table 6−4. Comparison of 1997−2006 Weed Infestation Extents at the Rocky Flats Site*

| Weed Species | Year | Site Total | Density Level | | | |
|---|---|---|---|---|---|---|
| | | | High | Medium | Low | Scattered |
| Diffuse Knapweed | 1997 | 2678 | 696 | 893 | 658 | 431 |
| | 1998 | 2913 | 761 | 778 | 987 | 388 |
| | 1999 | 2295 | 466 | 613 | 873 | 343 |
| | 2000 | 2223 | 510 | 531 | 771 | 412 |
| | 2001 | 1957 | 381 | 525 | 674 | 377 |
| | 2002 | 1093 | 165 | 344 | 368 | 215 |
| | 2003 | 2127 | 182 | 512 | 857 | 576 |
| | 2004[a] | 2259 | 77 | 390 | 1187 | 605 |
| | 2005[a] | 2158 | 29 | 296 | 902 | 931 |
| | 2006[a] | 800 | 38 | 95 | 367 | 300 |
| Dalmatian Toadflax | 1997 | 422 | 135 | 205 | 82 | 0 |
| | 1998 | 1934 | 313 | 273 | 989 | 359 |
| | 1999 | 2507 | 341 | 389 | 1240 | 537 |
| | 2002 | 1264 | 5 | 69 | 281 | 909 |
| | 2003 | 2897 | 109 | 388 | 1563 | 837 |
| | 2004 | 2858 | 77 | 450 | 1559 | 772 |
| | 2005[a] | 3085 | 24 | 169 | 1400 | 1492 |
| | 2006[a] | 467 | 0 | 25 | 193 | 249 |

[a]Acreages do not include Centennial Mine area as it has in previous years. It was not mapped due to the expansion of the mine and/or lack of access and visibility of the mine area.
Notes: All values are approximate acreages.
See text for density level descriptions.

In 2006, diffuse knapweed was observed on approximately 800 acres at various levels of infestation. This is down considerably from previous years that have averaged 2,000+ acres per year. Dalmatian toadflax was mapped on approximately 467 acres at the Site in 2006. This is huge decrease from the 3,085 acres present in 2005. Considerable annual variation in the number of infested acres for each species listed in Table 6−4 exists due to annual climatic differences and past herbicide applications. Most of the reductions for each species from 1998 or 1999 through 2002 were due to the large-scale aerial herbicide applications. In 2002, some of the decreases seen for each species were also a result of the drought that year. That drought caused many species, native species and noxious weeds alike, to either remain dormant or to not germinate that year. However, in 2003 there was a large increase in the number of infested acres due to the above average snowfall received in March 2003 that caused a large germination of annual species' seed from the seedbank and growth of dormant perennial plants. This resulted in nearly

twice the number of acres infested with diffuse knapweed and dalmatian toadflax in 2003 compared to 2002. Increased precipitation in 2004 and 2005 also probably accounts for the continued high number of infested acres in 2004. The huge decline in the abundance of both of these species in 2006 is likely due to the drought conditions experienced at the Site throughout the winter, spring, and summer of 2006. Many other species at the Site remained dormant and/or did not germinate in 2006.

During 2006, a total of approximately 401 acres were treated with herbicides using ground applications. Figure 6–3 and Figure 6–4 show the locations where herbicide applications were made in 2006. Table 6−5 lists the herbicides and application rates applied at each location. [Note: At several locations multiple herbicides are listed for a location. This does not mean that each herbicide was used across that entire location. Rather depending on site-specific characteristics (target weed species, the locations of water bodies, soil types, and the professional judgment of the licensed herbicide applicator), different herbicides were used within that location to provide the control needed.] Locations (GIS Ref ID column in Table 6−5) up to number 67 were treated in the spring and early summer of 2006, while the locations from number 68 and upward were treated in the fall. The fall applications were made to control the rosettes that were already present for some species and as a pre-emergent application for other species. In previous years herbicide applications have not been made in Preble's mouse habitat because of restrictions placed on the Site by USFWS. A document was prepared and consultation was conducted with USFWS on the use of herbicide applications for weed control in Preble's mouse habitat during the winter/spring of 2005/2006. Approval for the use of selected herbicides in Preble's mouse habitat was received in April 2006. Several locations in Preble's habitat were targeted for applications to control such species as Dame's rocket (*Hesperis matronalis*), Canada thistle (*Cirsium arvense*), and diffuse knapweed.

A new herbicide that became available in 2006, Milestone (active ingredient = aminopyralid), was used to treat several areas at the Site. The low application rate, low environmental impact status, and yet high effectiveness on many species we have at the Site has made this herbicide a very good tool in our toolbox. The fact that it can be sprayed to the waters edge also makes this a good tool for controlling Canada thistle and other weedy species that are often common around the ponds and wetland edges. Previously near water these species have been much more difficult, if not impossible to control with other methods. Observations of the treated areas in 2006 have shown that the Milestone has done a very good job in controlling the species that were targeted with it.

The effectiveness of biocontrol insects that have been released at the Site continues to be monitored. The results from the biocontrol study on diffuse knapweed are reported in another section of the annual report. Additional biocontrols will be released as they become available. Collections from established populations at the Site will be made and moved to other infestations at the Site where control is needed, as feasible.

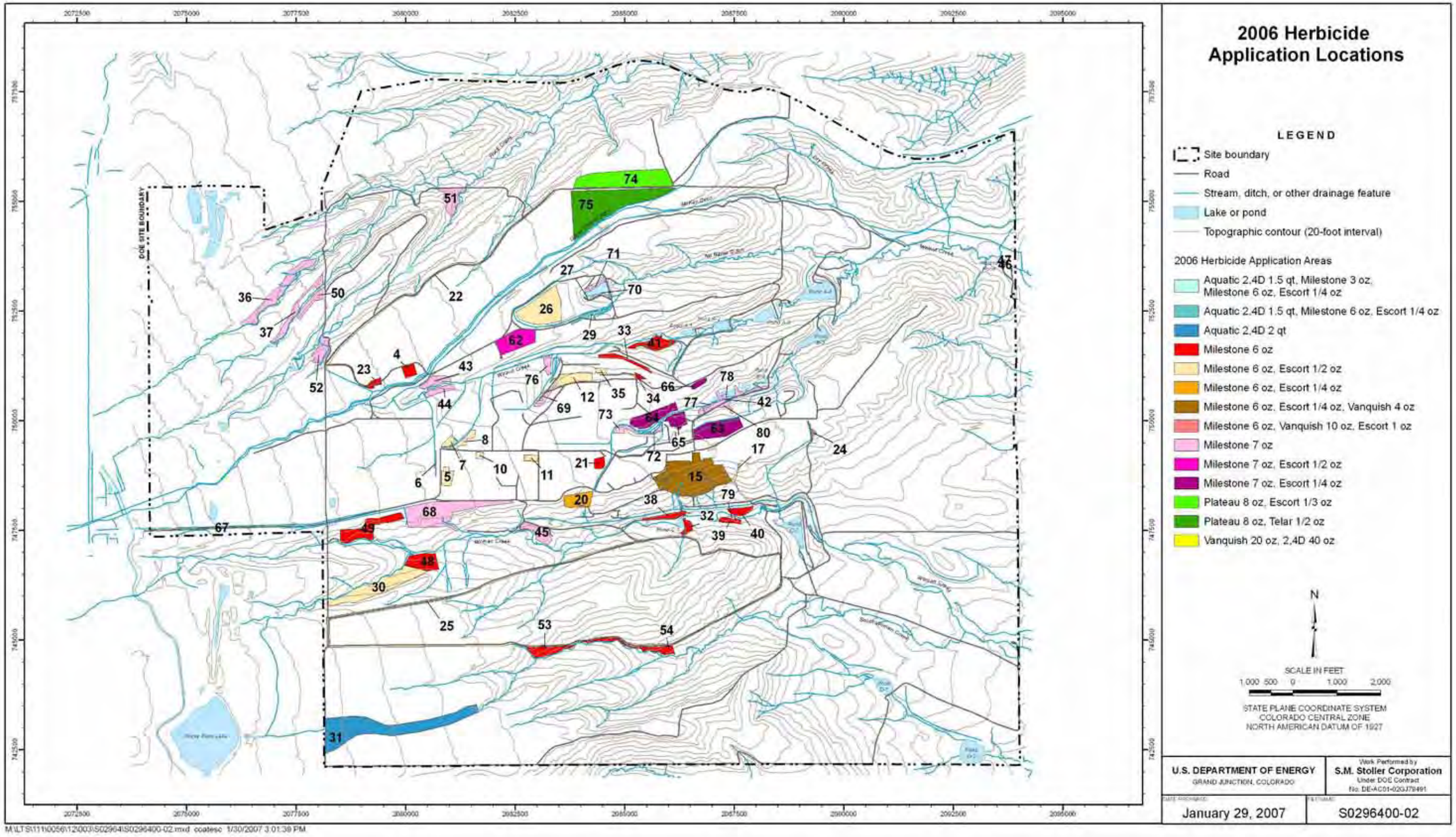



*Figure 6–3. 2006 Herbicide Application Locations*

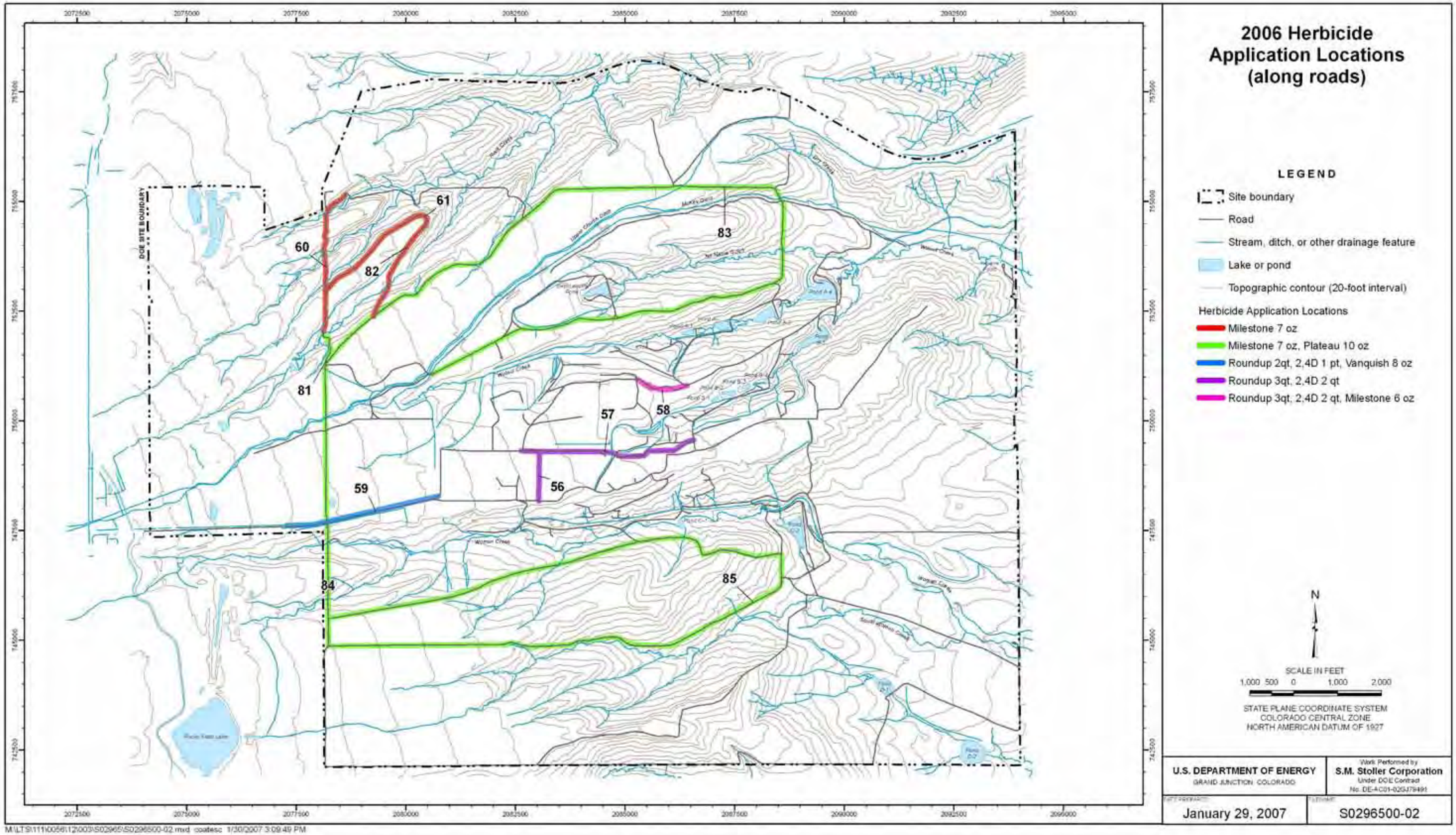



*Figure 6–4. 2006 Herbicide Application Locations (along roads)*

*Table 6−5. 2006 Weed Control Location Summary*

| GIS Ref ID | Acres Treated | Herbicide/Application Rate | Application Method |
|---|---|---|---|
| 4 | 1.70 | Milestone 6 oz | ATV |
| 5 | 2.20 | Milestone 6 oz, Escort 1/2 oz | ATV |
| 6 | 0.25 | Milestone 6 oz, Escort 1/2 oz | ATV |
| 7 | 1.20 | Milestone 6 oz, Escort 1/2 oz | ATV |
| 8 | 1.70 | Milestone 6 oz, Escort 1/2 oz | ATV |
| 10 | 0.50 | Milestone 6 oz, Escort 1/2 oz | ATV |
| 11 | 1.00 | Milestone 6 oz, Escort 1/2 oz | ATV |
| 12 | 5.00 | Milestone 6 oz, Escort 1/2 oz | ATV |
| 15 | 28.00 | Milestone 6 oz, Escort 1/4 oz, Vanquish 4 oz | ATV |
| 17 | 1.00 | Milestone 6 oz, Escort 1/2 oz | ATV |
| 20 | 4.00 | Milestone 6 oz, Escort 1/4 oz | ATV |
| 21 | 1.25 | Milestone 6 oz | ATV |
| 22 | 10.00 | Milestone 6 oz, Escort 1/2 oz | Truck |
| 23 | 2.00 | Milestone 6 oz | ATV |
| 24 | 0.40 | Milestone 6 oz, Vanquish 10 oz, Escort 1 oz | ATV |
| 25 | 23.00 | Milestone 6 oz, Escort 1/2 oz | Truck |
| 26 | 12.00 | Milestone 6 oz, Escort 1/2 oz | ATV |
| 27 | 2.25 | Aquatic 2,4D 1.5 qt, Milestone 3 oz, Milestone 6 oz, Escort 1/4 oz | ATV |
| 29 | 3.00 | Aquatic 2,4D 2 qt, Milestone 6 oz, Escort 1/4 oz | ATV |
| 30 | 11.50 | Milestone 6 oz, Escort 1/2 oz | ATV |
| 31 | 24.00 | Aquatic 2,4D 2 qt | ATV |
| 32 | 1.50 | Milestone 6 oz | ATV |
| 33 | 3.00 | Milestone 6 oz | ATV |
| 34 | 1.00 | Milestone 6 oz | ATV |
| 35 | 1.50 | Milestone 6 oz, Escort 1/2 oz | ATV |
| 36 | 6.00 | Milestone 7 oz | ATV |
| 37 | 4.00 | Milestone 7 oz | ATV |
| 38 | 2.75 | Milestone 6 oz | ATV |
| 39 | 1.25 | Milestone 6 oz | ATV |
| 40 | 2.00 | Milestone 6 oz | ATV |
| 41 | 5.00 | Milestone 6 oz | ATV |
| 42 | 5.00 | Milestone 7 oz | ATV |
| 43 | 3.25 | Milestone 7 oz | ATV |
| 44 | 2.50 | Milestone 7 oz | ATV |
| 45 | 4.00 | Milestone 7 oz | ATV |
| 46 | 0.30 | Milestone 7 oz | ATV |
| 47 | 0.20 | Milestone 7 oz | ATV |
| 48 | 5.50 | Milestone 6 oz | ATV |
| 49 | 8.50 | Milestone 6 oz | ATV |
| 50 | 2.50 | Milestone 7 oz | ATV |
| 51 | 4.75 | Milestone 7 oz | ATV |
| 52 | 3.50 | Milestone 7 oz | ATV |
| 53 | 4.00 | Milestone 6 oz | ATV |
| 54 | 4.00 | Milestone 6 oz | ATV |
| 56 | 0.50 | Roundup 3 qt, 2,4D 2 qt | ATV |
| 57 | 1.50 | Roundup 3 qt, 2,4D 2 qt | ATV |
| 58 | 0.50 | Roundup 3 qt, 2,4D 2 qt, Milestone 6 oz | ATV |

*Table 6−5 (continued). 2006 Weed Control Location Summary*

| GIS Ref ID | Acres Treated | Herbicide/Application Rate | Application Method |
|---|---|---|---|
| 59 | 3.50 | Roundup 2 qt, 2,4D 1 pt, Vanquish 8 oz | ATV |
| 60 | 3.25 | Milestone 7 oz | ATV |
| 61 | 5.75 | Milestone 7 oz | ATV |
| 62 | 9.00 | Milestone 7 oz, Escort 1/2 oz | ATV |
| 63 | 9.00 | Milestone 7 oz, Escort 1/4 oz | ATV |
| 64 | 7.50 | Milestone 7 oz, Escort 1/4 oz | ATV |
| 65 | 3.00 | Milestone 7 oz, Escort 1/4 oz | ATV |
| 66 | 1.00 | Milestone 7 oz, Escort 1/4 oz | ATV |
| 67 | 3.00 | Vanquish 20 oz, 2,4D 40 oz | ATV |
| 68 | 17.00 | Milestone 7 oz | ATV, Backpack |
| 69 | 1.50 | Milestone 7 oz | ATV |
| 70 | 1.50 | Milestone 7 oz | ATV, Backpack |
| 71 | 1.00 | Milestone 7 oz | ATV, Backpack |
| 72 | 1.00 | Milestone 7 oz | ATV |
| 73 | 1.50 | Milestone 7 oz | ATV |
| 74 | 18.00 | Plateau 8 oz, Escort 1/3 oz | ATV |
| 75 | 27.00 | Plateau 8 oz, Telar 1/2 oz | ATV |
| 76 | 2.00 | Milestone 7 oz | ATV |
| 77 | 0.75 | Milestone 7 oz | ATV |
| 78 | 0.75 | Milestone 7 oz | ATV |
| 79 | 0.25 | Milestone 7 oz | ATV |
| 80 | 2.50 | Milestone 7 oz | ATV |
| 81 | 9.00 | Milestone 7 oz, Plateau 10 oz | Truck |
| 82 | 8.50 | Milestone 7 oz, Plateau 10 oz | Truck |
| 83 | 22.00 | Milestone 7 oz, Plateau 10 oz | Truck |
| 84 | 4.50 | Milestone 7 oz, Plateau 10 oz | Truck |
| 85 | 23.00 | Milestone 7 oz, Plateau 10 oz | Truck |
| Total Acres Sprayed in 2006 | 401.20 | | |

Note: At several locations multiple herbicides are listed for a location. This does not mean that each herbicide was used across that entire location. Rather depending on site-specific characteristics (target weed species, the locations of water bodies, soil types, and the professional judgment of the licensed herbicide applicator), different herbicides were used within that location to provide the control needed.

### 6.2.2 Dalmatian Toadflax Monitoring

Dalmatian toadflax is a noxious weed that has invaded hundreds of acres across the Site and is a problem throughout much of the Front Range of Colorado. The species is an escaped ornamental plant from Europe. Dalmatian toadflax is listed as a List “B” species under the Colorado Noxious Weed Act (CNWA 2006). This means it is established in the state and statewide eradication is not possible. The species is well adapted to arid environments and has a deep, extensive root system. The deep root system, waxy leaves, and high seed production make the species difficult to control. The species is a significant problem for ecological resource management because of its ability to replace native plant species and degrade the quality of the land for wildlife or grazing.

A three-phase study was conducted to evaluate the effectiveness of Tordon 22K® alone (applied at two different application rates [1 pint/acre and 1 quart/acre]) and Tordon 22K® (1 quart/acre) plus Telar® (1 ounce/acre) on dalmatian toadflax density. The study was conducted using a control plot and treatment plots. The three phases were initiated over a three year period while the same control plot was used for all three phases.

From 2003 through 2005, dalmatian toadflax density in the control plot increased from 75.2 stems per square meter (stems/$m^2$) to 126.1 stems/$m^2$ (Figure 6–5). Some of the increase may have been due to the above average precipitation received in 2004 and 2005 (November to June precipitation; average [1992−2005] = 10.24 inches, 2004 = 13.08 inches, 2005 = 12.58 inches). In 2006, dalmatian toadflax density in the control plot dropped to only 56.5 stems/$m^2$ (Figure 6–5). This was likely in response to the below average precipitation received (November to June precipitation; 2006 = 4.98 inches).

In the Phase I study, looking at the effect of an application of 1 pint of Tordon 22K®/acre, dalmatian toadflax densities dropped annually from 72 stems/$m^2$ in 2003 to 28.4 stems/$m^2$ in 2005 (Figure 6–5). In 2006, the continued effect of the herbicide, plus the drought resulted in only 7.2 stems/$m^2$. In the Phase II study, dalmatian toadflax densities dropped from 64.8 stems/$m^2$ in 2004 to 23.7 stems/$m^2$ in 2005 in response to a single application of Tordon 22K® at 1 quart/acre (Figure 6–5). In 2006, the continued effect of the herbicide, plus the drought resulted in only 12.1 stems/$m^2$. In the Phase III study, dalmatian toadflax densities dropped from 117.0 stems/$m^2$ in 2005 to only 9.9 stems/$m^2$ in 2006.

Excluding the 2006 drought effects, both the Phase I and Phase II studies (2003−2005 data) have shown that the herbicide applications have had a substantial impact on dalmatian toadflax density. Stem densities were reduced by 61 percent and 63 percent in the Phase I and Phase II studies, respectively, while densities continued to increase during the same timeframe in the control plot (increase of 68 percent). In 2006, adding in the effect of the drought, plus the residual herbicide effects, the dalmatian toadflax densities have been reduced by 90 percent and 81 percent in the Phase I and Phase II studies, respectively. In the Phase III study, the herbicide effects plus drought effects have reduced the dalmatian toadflax density by more than 91 percent in a single year. Based on this information alone and given the small differences in results between the different treatments, a single application of Tordon 22K® at a rate of 1 pint per acre is just as effective as the higher application rates of the other two treatments. It is also evident that drought has a substantial effect on dalmatian toadflax density. The effect of the drought alone on the control plot reduced dalmatian toadflax density from 126.1 stems/$m^2$ in 2005 to 56.5 stems/$m^2$ in 2006 (a reduction of 55 percent).

Although the drought complicates the interpretation of the results, because the drought alone also reduces dalmatian toadflax densities, the fact that the drought occurred across all three treatments equally, at least somewhat negates its effect. A different analysis was done to try and take into account the effect of the drought on the study results. If 55 percent of the dalmatian toadflax density reduction from 2005 to 2006 is attributable to the drought (based on the control), then only 20 percent or 5.7 stems/$m^2$ of the stem reduction at the Phase I study from 2005−2006 is attributable to the continued effect of the herbicide. This amount combined with the reductions that occurred from 2003 to 2005, means a reduction from 72 stems/ $m^2$ in 2003 to 22.7 stems/$m^2$ in 2006 (68 percent reduction in stem density) is attributable to the herbicide effects at the Phase I study. Thus the application of 1 pint of Tordon 22K® per acre reduced dalmatian toadflax

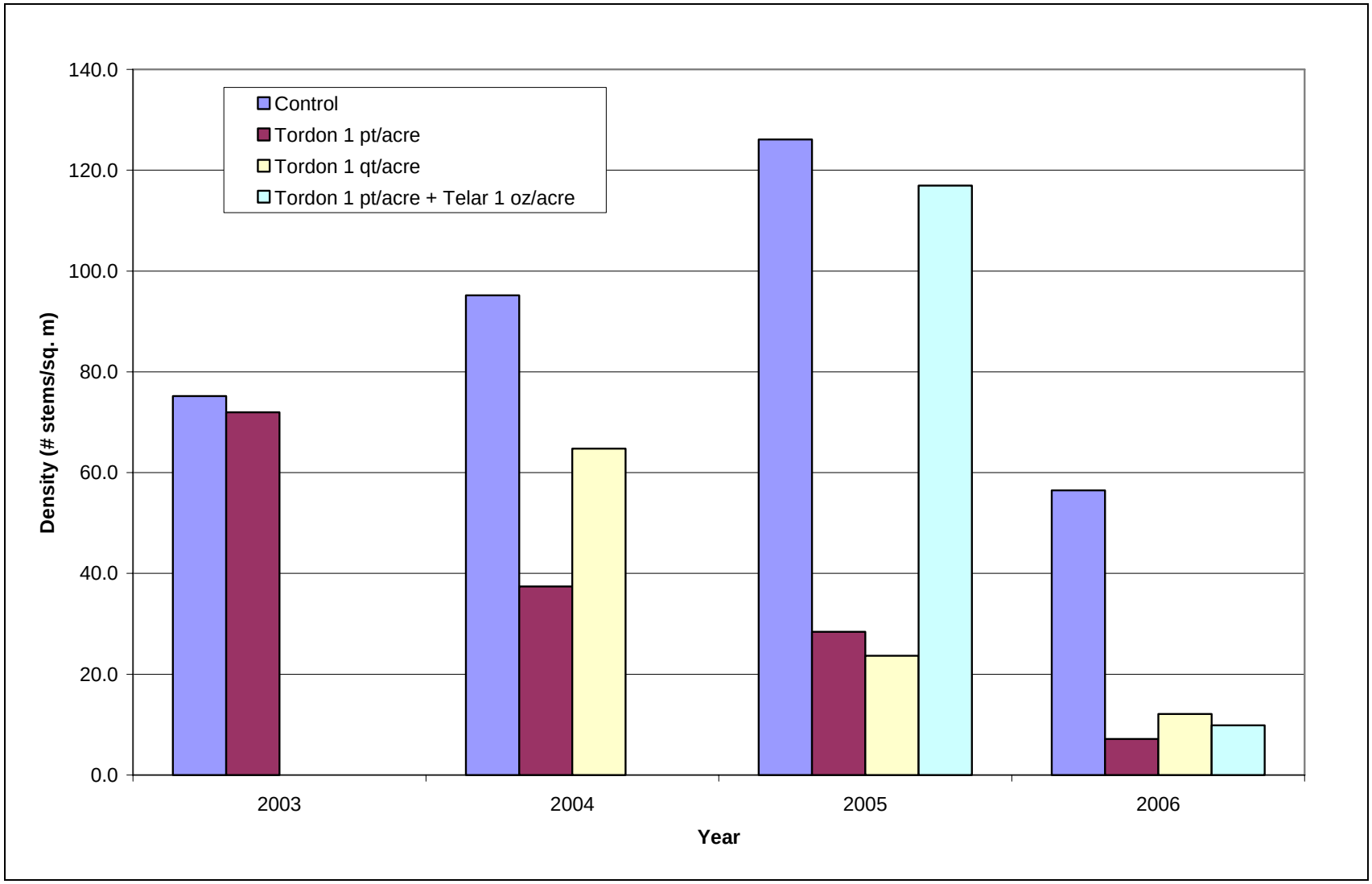



*Figure 6–5. Dalmatian Toadflax Stem Density Response to Herbicide Applications*

density by 68 percent. At the Phase II study, none of the reduction in stem density from 2005−2006 was attributable to the herbicide because the percentage change at the Phase II locations was less than 55 percent during this time frame. Thus an overall stem density reduction of 63 percent is attributable to an application of 1 quart of Tordon 22K® for the Phase II study. For the Phase III study, if the 55 percent reduction in stem density attributable to drought is removed, only 36 percent or 42 stems/$m^2$ of the stem density reduction observed in 2006 is attributable to the herbicide application of Tordon 22K® plus Telar®. Based on this analysis, it is apparent that a single application of Tordon 22K® at a rate of 1 pint per acre is more effective at reducing dalmatian toadflax density than the other two treatments. This would also be more cost effective and have less potential environmental side-effects.

The final conclusion is that using either type of data analysis, the results are the same. A single application of Tordon 22K® at a rate of 1 pint per acre just as effective at reducing dalmatian toadflax density as the other two treatments.

### 6.2.3 Revegetation Monitoring

As part of the cleanup and closure of the Site, the buildings, roads, and other infrastructure in the COU were removed. Approximately 650 acres were disturbed during cleanup activities that were completed in fall 2005. Revegetation of the disturbed areas was conducted to prevent erosion and sedimentation of the Site streams and to meet water quality standards. Re-establishment of native plant species is desirable to benefit wildlife and the future of the Site as a National Wildlife Refuge. As part of the revegetation process, monitoring is conducted to determine whether success criteria, as stated in the Revegetation Plan (DOE 2005c) are being met as well as to determine whether management of these resources are needed. The objective of the revegetation monitoring in 2006 was to assess the status of the revegetation efforts at selected locations.

Semi-quantitative revegetation monitoring was conducted during summer in 2006 to evaluate the establishment of vegetation at revegetation locations across the Site. The monitoring methodology provided in the Revegetation Plan was used with some modification. The revegetation areas were divided into “units” or areas based on geographic features (i.e., roads, streams) or previous building areas (i.e., 700 Area, 400 Area). A total of 25 revegetation units were sampled (Figure 6–6). Within each revegetation unit, sample locations were randomly generated in the GIS and then located on the ground using a global positioning system (GPS) for monitoring. Quadrats (0.5 $m^2$; 50 cm $\times$ 100 cm) were used to sample the vegetation. Dependent on the size of the area, the number of quadrats sampled in each area varied from 10 to 30 quadrats. A total of 480 quadrats were sampled in 2006. Table 6−6 lists the number of quadrats sampled in each unit. At each quadrat, both species richness and species cover were sampled.

*Table 6−6. 2006 Revegetation Location Sample Sizes*

| Location | Number of Quadrats Sampled |
|---|---|
| A1 | 30 |
| A2 | 30 |
| A3 | 10 |
| A4 | 30 |
| A5 | 30 |
| A6 | 10 |
| A7 | 30 |
| A8 | 10 |
| A9 | 30 |
| A10 | 10 |
| A11 | 30 |
| A12 | 30 |
| A13 | 10 |
| A14 | 10 |
| A15 | 15 |
| A16 | 10 |
| A17 | 10 |
| A18 | 10 |
| A19 | 15 |
| A20 | 10 |
| A21 | 30 |
| A22 | 30 |
| A23 | 10 |
| A24 | 10 |
| A25 | 30 |
| Total | 480 |

Species richness across all sampled revegetation units is presented in Table 6−7. Species richness in 2006 at the revegetation units ranged from a low of nine species in unit A10 to 39 species at unit A22. The wide range of in the number of species present in each revegetation unit is attributable to a number of factors including: how long ago the area was revegetated, the size of the unit, the number of quadrats sampled in the unit, and what management actions (i.e., weed control) have been conducted in the area. A total of 13 seeded graminoid species had established and were growing at some or all locations in 2006 (shaded rows in Table 6−7). Two species, western wheatgrass (*Agropyron smithii*) and slender wheatgrass (*Agropyron caninum = Agropyron trachycaulum*) were established at all 25 locations. As would be expected in a revegetation project many other early successional species were growing at most of the areas. Kochia (*Kochia scoparia*), Russian thistle (*Salsola iberica*), wild lettuce (*Lactuca serriola*), yellow sweet clover (*Melilotus officinalis*), and hoary vervain (*Verbena bracteata*) were among the more common. These will largely disappear on their own over the next couple of years as the seeded species begin to fill in more. Several noxious weeds also occurred in the revegetation areas. The most common of these were diffuse knapweed, fillaree (*Eurodium cicutarium*), and downy brome (*Bromus tectorum*). Weed management will be conducted as needed to keep noxious weed populations down in the revegetation areas, so that the desired seeded species can establish more quickly and help compete with the weeds.

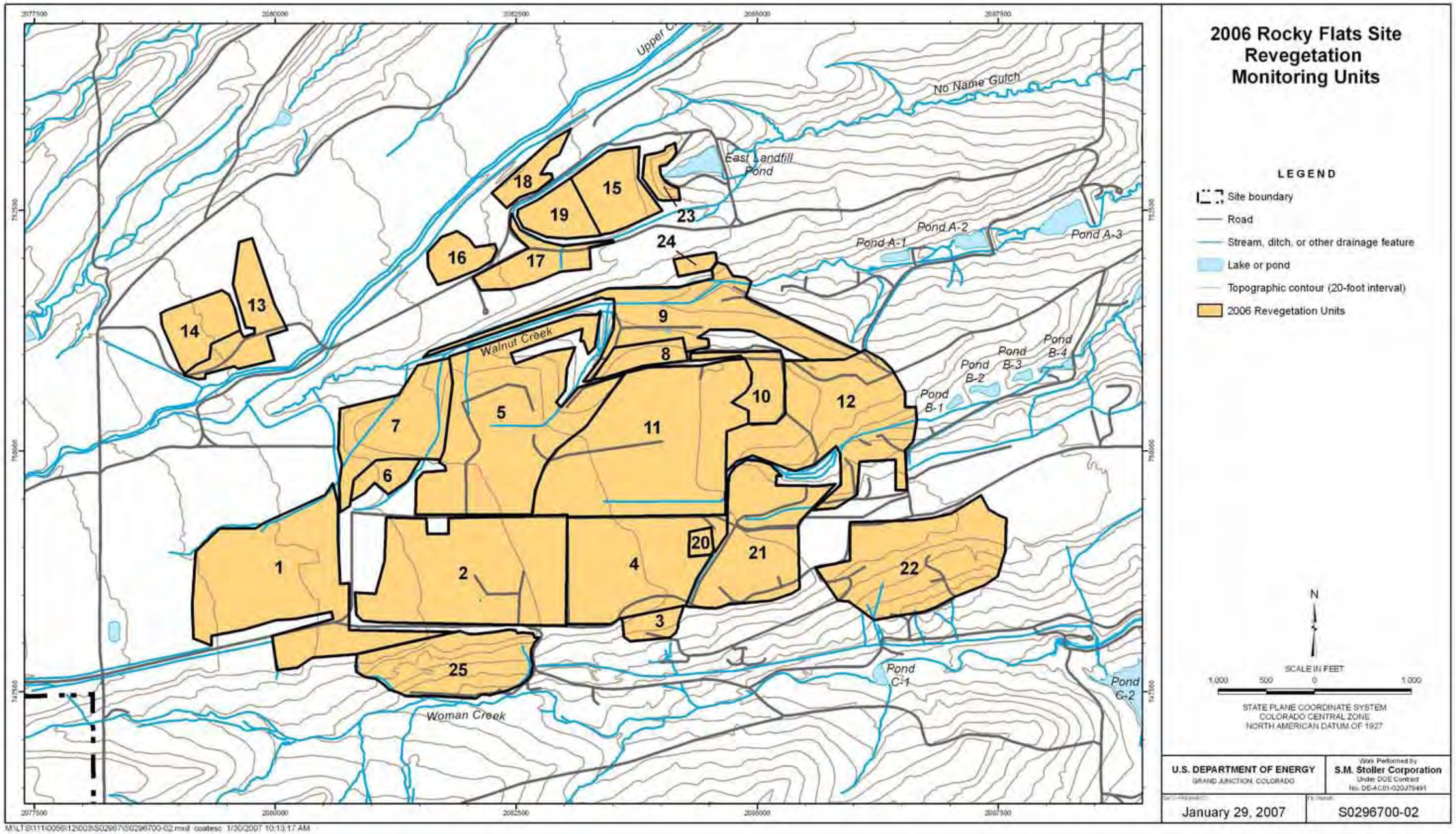



*Figure 6–6. 2006 Rocky Flats Site Revegetation Monitoring Units*

*Table 6−7. Species Richness Summary at Locations A1−A25*

| Family | Scientific Name | Speccode | Native | Noxious Weed | A1 | A2 | A3 | A4 | A5 | A6 | A7 | A8 | A9 | A10 | A11 | A12 | A13 | A14 | A15 | A16 | A17 | A18 | A19 | A20 | A21 | A22 | A23 | A24 | A25 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AMARANTHACEAE | Amaranthus albus L. | AMAL2 | N | | | | | | | | | | | | | | X | | | | | | | | | | | | |
| ASCLEPIADACEAE | Asclepias speciosa Torr. | ASSP1 | Y | | | | | | | | | | | | | | | | | | | | | | | X | | | |
| ASTERACEAE | Ambrosia artemisiifolia L. | AMAR1 | Y | | X | | | X | | | | | | | | | | | | | X | X | | | X | | | | |
| ASTERACEAE | Ambrosia psilostachya DC. | AMPS1 | Y | | | | | | | | | | X | | X | | | | | | X | | | X | X | X | X | | |
| ASTERACEAE | Artemisia campestris L. ssp. caudata (Michx.) Hall & Clem. | ARCA1 | Y | | | | | | | | | | | | | | | | | X | | | | X | | | | | |
| ASTERACEAE | Artemisia frigida Willd. | ARFR1 | Y | | | | | | | | | | | | | | | | | | | | | X | | | | | |
| ASTERACEAE | Aster porteri Gray | ASPO1 | Y | | | | | | | | | X | | | | | | | X | | | | | | | | | | |
| ASTERACEAE | Carduus nutans L. ssp. macrolepis (Peterm.) Kazmi | CANU1 | N | X | | | | X | | | | | | | | X | | | | | | | | | | X | | | |
| ASTERACEAE | Centaurea diffusa Lam. | CEDI1 | N | X | X | X | X | X | X | X | X | X | X | | X | X | X | X | X | X | X | X | X | X | X | X | X | | X |
| ASTERACEAE | Chrysanthemum leucanthemum L. | CHLE1 | N | X | | | | | | | | | | | | | | | | | | X | | | | | | | |
| ASTERACEAE | Chrysopsis fulcrata Greene | CHFU1 | Y | | | | | | | | | | | | | | | | | | | | | | | X | | | |
| ASTERACEAE | Cirsium arvense (L.) Scop. | CIAR1 | N | X | | | | X | | | | | X | | | X | | | | | | | | | X | X | | | X |
| ASTERACEAE | Conyza canadensis (L.) Cronq. | COCA1 | Y | | | | | | | | | | | | | | | | X | | X | | | | | | X | | |
| ASTERACEAE | Dyssodia papposa (Vent) Hitchc. | DYPA1 | N | | | | | | | | | | | | | | | | | X | X | X | | | | | | | |
| ASTERACEAE | Erigeron divergens T. & G. | ERDI1 | Y | | | | | | | | | | | | | | | | | | | | | | | X | | | |
| ASTERACEAE | Grindelia squarrosa (Pursh.) Dun. | GRSQ1 | Y | | X | | X | X | | | | X | X | | | X | | | X | | X | | X | X | X | X | X | | |
| ASTERACEAE | Helianthus annuus L. | HEAN1 | Y | | X | | | | | | | | X | | | X | | | | X | X | | | | X | | | | |
| ASTERACEAE | Lactuca serriola L. | LASE1 | N | | X | X | X | X | X | X | | X | X | | X | X | X | | X | X | X | X | X | | X | X | X | | X |
| ASTERACEAE | Liatris punctata Hook. | LIPU1 | Y | | | | | | | | | | | | | | | X | | | | | | | | | | | |
| ASTERACEAE | Scorzonera laciniata L. | SCLA1 | N | | X | | | | | | | | | | | | | | | | | | | X | X | | | | |
| ASTERACEAE | Sonchus arvensis L. ssp. uglinosus (Bieb.) Nyman | SOAR2 | N | | X | | | | X | | | | | | | | | | | | | | | | | | | | |
| ASTERACEAE | Taraxacum officinale Weber | TAOF1 | N | | | | | | | | | | | | | X | | | X | | | | X | X | | | | | |
| ASTERACEAE | Thelesperma megapotanicum (Spreng.) O. Ktze. | THME1 | Y | | | | | | | | | | | | | | | | | | | | | X | | | | | |
| ASTERACEAE | Tragopogon dubius Scop. | TRDU1 | N | | X | | | X | | | | X | X | | | X | | | | | X | X | X | X | X | X | | X | |
| BORAGINACEAE | Onosmodium molle Michx. var. occidentale (Mack.) Johnst. | ONMO1 | Y | | | | | | | | | | | | | | | | | | | | | | | X | | | |
| BRASSICACEAE | Alyssum alyssoides (L.) L. | ALAL1 | N | | | | | | | | | | | | | | | | | | | | | X | X | | | | |
| BRASSICACEAE | Alyssum minus (L.) Rothmaler var. micranthus (C. A. Mey.) Dudley | ALMI1 | N | | X | | X | X | X | X | | X | | | X | X | X | | | X | X | | | X | | X | | | X |
| BRASSICACEAE | Erysimum capitatum (Nutt.) DC. | ERCA2 | Y | | | | | | | | X | | | | | | | | | | | | | | | | | | |
| BRASSICACEAE | Lepidium campestre (L.) R. Br. | LECA1 | N | | X | | | | | | | X | | | | | X | | X | | | | X | | | | X | | |
| BRASSICACEAE | Lesquerella montana (A. Gray) Wats. | LEMO1 | Y | | | | | | | | X | | | | | | | | | | | | | | | | | | |
| BRASSICACEAE | Sisymbrium altissimum L. | SIAL1 | N | | X | | | | | | | | | | | | | | | | | | | | | | | | |
| CHENOPODIACEAE | Chenopodium album L. | CHAL1 | N | | X | | | | | | X | | | | | | X | | | | | X | | | X | | | | |
| CHENOPODIACEAE | Chenopodium fremontii S. Wats. | CHFR1 | Y | | X | | | | X | | | | | | | | | | | | | | | | X | | | | |
| CHENOPODIACEAE | Chenopodium leptophyllum Nutt. ex Moq. | CHLE2 | Y | | | | | | | | X | | | | | | | | | | | | | | | | | | |
| CHENOPODIACEAE | Kochia scoparia (L.) Schrad. | KOSC1 | N | | X | X | X | X | X | X | X | | X | | X | X | X | | | X | X | | | | X | X | | | X |
| CHENOPODIACEAE | Salsola iberica Senn. & Pau. | SAIB1 | N | | X | X | | X | X | | X | | X | | X | X | X | | | X | X | | | | X | X | | | X |
| CONVOLVULACEAE | Convolvulus arvensis L. | COAR1 | N | X | X | | X | X | | X | X | | | | | X | | | | | | X | X | X | X | X | | | |
| EUPHORBIACEAE | Euphorbia serpyllifolia Pers. | EUSE1 | Y | | | | | | | | | | | | | | X | | | | X | X | | | | X | | | |
| FABACEAE | Astragalus canadensis L. | ASCA1 | Y | | | | | X | | | | X | | | | | | | | | | | | | | | | | |
| FABACEAE | Medicago lupulina L. | MELU1 | N | | | | | X | | | | | | | | | | | | | | | | | | | | | |
| FABACEAE | Medicago sativa L. ssp. sativa | MESA1 | N | | | | | | | | | | | | | X | | | | | | | | | | | | | |
| FABACEAE | Melilotus alba Medic. | MEAL1 | N | | | | | | | X | | | X | | | X | | | | | | | X | | X | | | | |
| FABACEAE | Melilotus officinalis (L.) Pall. | MEOF1 | N | | X | X | X | X | X | X | X | X | X | | X | X | X | | X | X | X | X | X | X | X | X | | | X |
| FABACEAE | Psoralea tenuiflora Pursh. | PSTE1 | Y | | | | | | | | | | | | | | | | | | | | | | | X | | | |
| GERANIACEAE | Erodium cicutarium (L.) L'Her. | ERCI1 | N | X | X | X | X | X | X | X | X | | | | X | X | X | | | X | X | X | X | X | X | X | | | X |
| LAMIACEAE | Marrubium vulgare L. | MAVU1 | N | | | | | | | | | | | | | X | | | | | X | | | | | | | | |
| LINACEAE | Linum perenne L. var. lewisii (Pursh.) Eat. & Wright | LIPE1 | Y | | | | | | | | | | | | | | | | | | | | | X | | X | | | |

*Table 6−7 (continued). Species Richness Summary at Locations A1−A25*

| Family | Scientific Name | Speccode | Native | Noxious Weed | A1 | A2 | A3 | A4 | A5 | A6 | A7 | A8 | A9 | A10 | A11 | A12 | A13 | A14 | A15 | A16 | A17 | A18 | A19 | A20 | A21 | A22 | A23 | A24 | A25 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MALVACEAE | Sphaeralcea coccinea (Pursh.) Rydb. | SPCO1 | Y | | | | | | | | | | | | | | | | | | | | | | | X | | | |
| NYCTAGINACEAE | Mirabilis linearis (Pursh.) Heimerl | MILI1 | Y | | | | | | | | | X | | | | | | | | | | | | | | | | | |
| PLANTAGINACE | Plantago lanceolata L. | PLLA1 | N | | X | | | X | | X | | | | | | | | | | | | | X | | X | X | | | |
| PLANTAGINACE | Plantago patagonica Jacq. | PLPA1 | Y | | | | | X | | | | | | | | | | | | X | | X | | | | | | | |
| POACEAE | Aegilops cylindrica Host | AECY1 | N | X | | | | | | | | | | | | | | | | | | | | | | X | | | X |
| POACEAE | Agropyron caninum (L.) Beauv. ssp. majus (Vasey) C. L. Hitchc. | AGCA1 | Y | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| POACEAE | Agropyron cristatum (L.) Gaertn. | AGCR1 | N | | | | | | | | | | | | | X | | | | | | | | | X | | | | |
| POACEAE | Agropyron dasystachyum (Hook.) Scribn. | AGDA1 | Y | | | | | X | | | | | | X | | | | | | | X | | | | | | | | |
| POACEAE | Agropyron intermedium (Host) Beauv. | AGIN1 | N | | | | | | | | | | | | | X | | | | X | | | | | | | | X | |
| POACEAE | Agropyron smithii Rydb. | AGSM1 | Y | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| POACEAE | Andropogon gerardii Vitman | ANGE1 | Y | | | | | X | | | X | | | | | | | X | X | | X | X | X | | X | X | | | |
| POACEAE | Andropogon scoparius Michx. | ANSC1 | Y | | | | | | | | | | | | | | | X | X | | | | X | | | | | | |
| POACEAE | Bouteloua curtipendula (Michx.) Torr. | BOCU1 | Y | | X | | | X | X | X | | X | X | X | | X | | X | X | X | X | X | X | | X | X | X | X | X |
| POACEAE | Bouteloua gracilis (H. B. K.) Lag ex Griffiths | BOGR1 | Y | | | X | | X | | X | X | X | X | X | X | X | X | X | X | X | X | X | | X | X | X | X | X | X |
| POACEAE | Bromus inermis Leyss. ssp. inermis | BRIN1 | N | | | | | | | X | | | X | X | | X | | X | | | | | | X | X | X | | | |
| POACEAE | Bromus japonicus Thunb. ex Murr. | BRJA1 | N | | X | | X | | | | | | X | | | | | | | X | | | X | X | | X | | | |
| POACEAE | Bromus tectorum L. | BRTE1 | N | X | | X | | X | | X | X | | X | X | | X | X | X | X | X | X | | X | X | X | X | | X | X |
| POACEAE | Buchloe dactyloides (Nutt.) Engelm. | BUDA1 | Y | | | | X | X | | X | | X | | X | | | | X | X | | X | X | X | | X | X | | X | |
| POACEAE | Digitaria sanguinalis (L.) Scop. | DISA1 | N | | | | | | | | | | | | | | | | | X | | | | | | | | | |
| POACEAE | Echinochloa crusgallii (L.) Beauv. | ECCR1 | N | | X | | | | | | | | | | | | | | | | | | | | | | | | |
| POACEAE | Elymus canadensis L. | ELCA1 | Y | | | | | | | X | X | | | | | | | | | | | | | | | | | | |
| POACEAE | Festuca pratensis Huds. | FEPR1 | N | | | | | | | | | | | | | | | X | | | | | X | | | X | | | |
| POACEAE | Hordeum jubatum L. | HOJU1 | Y | | | | | | | X | | | X | | | | X | | | | | | X | | X | | | | |
| POACEAE | Hordeum pusillum Nutt. | HOPU1 | Y | | | | | | X | | | | | | | | | | | | | | | | | | | | |
| POACEAE | Koeleria pyramidata (Lam.) Beauv. | KOPY1 | Y | | | | | | | | | | | | | | | | | | X | | X | | | | | | |
| POACEAE | Muhlenbergia montana (Nutt.) Hitchc. | MUMO1 | Y | | | | | | | | | | | | | | | X | | | | | | | | | | | |
| POACEAE | Poa compressa L. | POCO1 | N | | X | | | | | X | | X | | | | | | | X | | | | X | X | | | | | |
| POACEAE | Poa pratensis L. | POPR1 | N | | | | | | | | | | X | | | | | | | | | | | X | X | | | | |
| POACEAE | Setaria viridis (L.) Beauv. | SEVI1 | N | | X | | | | X | X | | | | | | | | | | | X | | | | | | | | |
| POACEAE | Sorghastrum nutans (L.) Nash | SONU1 | Y | | | | | | | X | | | | X | | | | X | | | X | | | | | | | | |
| POACEAE | Sporobolus asper (Michx.) Kunth | SPAS1 | Y | | | | | | | | | | | | | | | | | | | | | | | X | | X | |
| POACEAE | Sporobolus cryptandrus (Torr.) A. Gray | SPCR1 | Y | | | | | | | | | | | | | | | X | | | X | X | | | | | | | |
| POACEAE | Stipa comata Trin. & Rupr. | STCO1 | Y | | | | | | | | | | | | | | | | | | | | | X | | | | | |
| POACEAE | Stipa viridula Trin. | STVI1 | Y | | | | | | | | | | | | | | | | | | | | | | | X | | X | |
| POACEAE | Triticum aestivum L. | TRAE1 | N | | X | X | | | X | | X | | X | | X | | X | | | X | | | | | | X | | | X |
| POLYGONACEAE | Polygonum arenastrum Jord. ex Bor. | POAR1 | N | | X | X | | X | X | | X | | X | | X | X | X | | | X | | | | | X | | | | |
| POLYGONACEAE | Polygonum persicaria L. | POPE2 | N | | X | | | | | | | | | | | | | | | | | | | | | | | | |
| POLYGONACEAE | Rumex crispus L. | RUCR1 | N | | | | | | | | | | | | | X | | | | | | | | | | | | | |
| SANTALACEAE | Comandra umbellata (L.) Nutt. | COUM1 | Y | | | | | | | | | | | | | | | | X | | | | | | | | | | |
| SCROPHULARIACEAE | Linaria dalmatica (L.) Mill. | LIDA1 | N | X | | | | | | | | X | | | | | | | | | | | | | | X | | | |
| SCROPHULARIACEAE | Verbascum thapsus L. | VETH1 | N | X | | | | | | | | | | | | | | | | | X | | X | | | X | | | |
| SOLANACEAE | Solanum rostratum Dun. | SORO1 | Y | | | | | | | | X | | | | | | | | | | | | | | | | | | |
| VERBENACEAE | Verbena bracteata Lag. & Rodr. | VEBR1 | Y | | X | X | X | X | X | | X | X | | | X | X | | | X | X | X | X | X | | X | X | | | |
| | Unknown species | UNKN | | | | | | | | X | | | | | | | X | | | | X | X | | X | | | | | |
| | | Total Number of Species | | | 30 | 13 | 13 | 27 | 17 | 22 | 20 | 18 | 22 | 9 | 14 | 28 | 19 | 15 | 19 | 22 | 31 | 21 | 25 | 25 | 32 | 39 | 10 | 10 | 15 |

Shaded species are those that were seeded.

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Slightly different seed mixes were used at the different locations depending on the year they were seeded and the slope position. One of the success criteria in the Revegetation Plan (DOE 2005c) states that at least 50 percent of the seeded species must be present in an area for it to be considered successful. Table 6−8 lists the location, number of seeded species, number of species present at the location, and percentage present at the location in 2006. Fifteen locations had 50 percent or more seeded species present in 2006 and have thus meet this success criterion. The drought conditions experienced during 2006 may have limited the amount of germination of seeded species at the other locations. When normal precipitation returns it is expected that additional species should germinate and establish at the locations.

*Table 6−8. Number of Seeded Species Present in 2006 Summary*

| Location | # Species Seeded at Location | # Seeded Species Present in 2006 | % Seeded Species Present in 2006 |
|---|---|---|---|
| A1 | 11 | 3 | 27 |
| A2 | 11 | 3 | 27 |
| A3 | 7 | 3 | 43 |
| A4 | 11 | 7 | 64 |
| A5 | 11 | 3 | 27 |
| A6 | 11 | 7 | 64 |
| A7 | 12 | 5 | 42 |
| A8 | 7 | 5 | 71 |
| A9 | 7 | 4 | 57 |
| A10 | 14 | 7 | 50 |
| A11 | 11 | 3 | 27 |
| A12 | 12 | 4 | 33 |
| A13 | 11 | 3 | 27 |
| A14 | 14 | 9 | 64 |
| A15 | 13 | 7 | 54 |
| A16 | 11 | 4 | 36 |
| A17 | 11 | 10 | 91 |
| A18 | 11 | 7 | 64 |
| A19 | 13 | 7 | 54 |
| A20 | 14 | 3 | 21 |
| A21 | 11 | 6 | 55 |
| A22 | 12 | 7 | 58 |
| A23 | 7 | 4 | 57 |
| A24 | 10 | 6 | 60 |
| A25 | 7 | 4 | 57 |

Note: Shaded locations pass success criteria in 2006.

Ground cover protection from rock, litter, and current year live vegetation varied from 40 percent to over 100 percent at the revegetation locations in 2006 (Table 6−9). The occasional values over 100 percent are a result of the cover class system used for estimating cover which estimates cover values into a range and uses the midpoint of the cover class for analysis. Another success criterion outlined in the Revegetation Plan (DOE 2005c), states a minimum of 70 percent total ground cover comprised of litter cover, current year live vegetation basal cover, and rock cover is to be present to help prevent erosion. Fourteen locations met this criteria in 2006. At each of the locations most of the cover came from rock. In time the dominant ground cover will shift

from rock to litter as dead plant matter falls to the ground at the end of each growing season and builds up over time, covering and protecting the soil even more.

*Table 6−9. 2006 Rock, Litter, and Basal Vegetation Cover Summary*

| Location | Basal Veg Cover | Rock Cover | Litter Cover | Total Ground Cover |
|---|---|---|---|---|
| A1 | 3.7 | 54.2 | 7.8 | 65.6 |
| A2 | 2.3 | 52.6 | 14.8 | 69.6 |
| A3 | 2.5 | 8.8 | 72.3 | 83.5 |
| A4 | 2.9 | 38.8 | 37.0 | 78.8 |
| A5 | 2.8 | 43.7 | 5.3 | 51.8 |
| A6 | 6.3 | 29.8 | 25.0 | 61.0 |
| A7 | 2.3 | 47.7 | 6.0 | 55.9 |
| A8 | 3.8 | 18.0 | 79.5 | 101.3 |
| A9 | 2.8 | 27.0 | 9.7 | 39.5 |
| A10 | 6.3 | 7.5 | 66.3 | 80.0 |
| A11 | 2.5 | 43.8 | 12.7 | 58.9 |
| A12 | 5.1 | 20.3 | 15.8 | 41.1 |
| A13 | 2.5 | 47.8 | 25.0 | 75.3 |
| A14 | 10.0 | 33.0 | 7.3 | 50.3 |
| A15 | 2.5 | 21.0 | 75.2 | 98.7 |
| A16 | 2.5 | 54.5 | 19.8 | 76.8 |
| A17 | 2.5 | 57.3 | 18.3 | 78.0 |
| A18 | 2.5 | 47.8 | 12.3 | 62.5 |
| A19 | 3.3 | 13.3 | 79.0 | 95.7 |
| A20 | 2.5 | 3.3 | 71.3 | 77.0 |
| A21 | 2.3 | 35.0 | 28.8 | 66.1 |
| A22 | 5.8 | 17.9 | 50.7 | 74.4 |
| A23 | 2.5 | 9.8 | 90.0 | 102.3 |
| A24 | 15.0 | 2.8 | 85.8 | 103.5 |
| A25 | 3.1 | 11.3 | 85.0 | 99.3 |

Notes: All values are percentages.
Some values exceed 100% because of the use of cover class midpoints for data collection and analyses.
Shaded locations pass success criteria in 2006.

A third success criterion outlined in the Revegetation Plan (DOE 2005c), states that a minimum of 30 percent relative cover of desired species must be present and a forth criterion states that no single species comprise more than 45 percent of the total relative cover. Table 6−10 through Table 6−14 summarize the foliar cover data by location for 2006. The shaded row titled Total Native Cover represents the percentage of desired species at each location. The relative cover values at individual locations that are higher than 30 percent are shaded, indicating these locations have met this success criterion.

Total relative vegetation cover of desired (native) species was greater than 30 percent at 19 of the 25 locations in 2006. Only two of the 25 revegetation locations had a single species that comprised greater than 45 percent of the relative cover at the location, A10 and A19. At each of these locations 49 percent of the cover came from slender wheatgrass, one of the early successional seeded native species. Thus all locations except A10 and A19 met this latter success criterion. The dominant species across all sites in 2006 were slender wheatgrass, western wheatgrass, wheat (*Triticum aestivum*), kochia, and yellow sweetclover.

*Table 6−10. Species Foliar Cover Summary at Locations A1−A5*

| Scientific Name | Speccode | Growth Form | Native | Cool/ Warm Season | Noxious Weed | A1 | | A2 | | A3 | | A4 | | A5 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Absolute Cover (%) | Relative Cover (%) | Absolute Cover (%) | Relative Cover (%) | Absolute Cover (%) | Relative Cover (%) | Absolute Cover (%) | Relative Cover (%) | Absolute Cover (%) | Relative Cover (%) |
| Alyssum alyssoides (L.) L. | ALAL1 | F | N | | | | | | | | | | | | |
| Alyssum minus (L.) Rothmaler var. micranthus (C. A. Mey.) Dudley | ALMI1 | F | N | | | 0.8 | 2.2 | | | 0.3 | 0.8 | 0.1 | 0.2 | 0.1 | 0.5 |
| Amaranthus albus L. | AMAL2 | F | N | | | | | | | | | | | | |
| Carduus nutans L. ssp. macrolepis (Peterm.) Kazmi | CANU1 | F | N | | X | | | | | | | 0.1 | 0.2 | | |
| Centaurea diffusa Lam. | CEDI1 | F | N | | X | 0.2 | 0.4 | 0.1 | 0.5 | 9.3 | 31.1 | 2.8 | 8.1 | 0.1 | 0.5 |
| Chenopodium album L. | CHAL1 | F | N | | | 0.7 | 1.8 | | | | | | | | |
| Chrysanthemum leucanthemum L. | CHLE1 | F | N | | X | | | | | | | | | | |
| Cirsium arvense (L.) Scop. | CIAR1 | F | N | | X | | | | | | | 0.6 | 1.7 | | |
| Convolvulus arvensis L. | COAR1 | F | N | | X | 0.1 | 0.2 | | | 0.3 | 0.8 | 0.8 | 2.2 | | |
| Dyssodia papposa (Vent) Hitchc. | DYPA1 | F | N | | | | | | | | | | | | |
| Erodium cicutarium (L.) L'Her. | ERCI1 | F | N | | X | 1.8 | 4.9 | 0.3 | 1.4 | 0.3 | 0.8 | 0.8 | 2.2 | 0.6 | 3.2 |
| Kochia scoparia (L.) Schrad. | KOSC1 | F | N | | | 4.0 | 10.8 | 3.9 | 22.2 | 2.5 | 8.4 | 6.5 | 19.1 | 4.3 | 23.9 |
| Lactuca serriola L. | LASE1 | F | N | | | 1.5 | 4.0 | 0.3 | 1.4 | 0.5 | 1.7 | 0.6 | 1.7 | 0.6 | 3.2 |
| Lepidium campestre (L.) R. Br. | LECA1 | F | N | | | 0.1 | 0.2 | | | | | | | | |
| Linaria dalmatica (L.) Mill. | LIDA1 | F | N | | X | | | | | | | | | | |
| Marrubium vulgare L. | MAVU1 | F | N | | | | | | | | | | | | |
| Melilotus alba Medic. | MEAL1 | F | N | | | | | | | | | | | | |
| Medicago lupulina L. | MELU1 | F | N | | | | | | | | | 1.1 | 3.2 | | |
| Melilotus officinalis (L.) Pall. | MEOF1 | F | N | | | 1.7 | 4.5 | 0.8 | 4.2 | 0.8 | 2.5 | 0.8 | 2.5 | 2.5 | 13.8 |
| Medicago sativa L. ssp. sativa | MESA1 | F | N | | | | | | | | | | | | |
| Plantago lanceolata L. | PLLA1 | F | N | | | 0.3 | 0.7 | | | | | 0.2 | 0.5 | | |
| Polygonum arenastrum Jord. ex Bor. | POAR1 | F | N | | | 4.3 | 11.5 | 0.7 | 3.8 | | | 1.1 | 3.2 | 0.8 | 4.6 |
| Polygonum persicaria L. | POPE2 | F | N | | | 0.1 | 0.2 | | | | | | | | |
| Rumex crispus L. | RUCR1 | F | N | | | | | | | | | | | | |
| Salsola iberica Senn. & Pau. | SAIB1 | F | N | | | 3.7 | 9.9 | 0.2 | 0.9 | | | 0.1 | 0.2 | 0.9 | 5.0 |
| Scorzonera laciniata L. | SCLA1 | F | N | | | 0.3 | 0.7 | | | | | | | | |
| Sisymbrium altissimum L. | SIAL1 | F | N | | | 0.2 | 0.4 | | | | | | | | |
| Sonchus arvensis L. ssp. uglinosus (Bieb.) Nyman | SOAR2 | F | N | | | 0.1 | 0.2 | | | | | | | 0.1 | 0.5 |
| Taraxacum officinale Weber | TAOF1 | F | N | | | | | | | | | | | | |
| Tragopogon dubius Scop. | TRDU1 | F | N | | | 0.2 | 0.4 | | | | | 0.2 | 0.5 | | |
| Verbascum thapsus L. | VETH1 | F | N | | X | | | | | | | | | | |
| Ambrosia artemisiifolia L. | AMAR1 | F | Y | | | 1.2 | 3.1 | | | | | 0.1 | 0.2 | | |
| Ambrosia psilostachya DC. | AMPS1 | F | Y | | | | | | | | | | | | |
| Artemisia campestris L. ssp. caudata (Michx.) Hall & Clem. | ARCA1 | F | Y | | | | | | | | | | | | |
| Artemisia frigida Willd. | ARFR1 | F | Y | | | | | | | | | | | | |
| Astragalus canadensis L. | ASCA1 | F | Y | | | | | | | | | 0.5 | 1.5 | | |
| Aster porteri Gray | ASPO1 | F | Y | | | | | | | | | | | | |
| Asclepias speciosa Torr. | ASSP1 | F | Y | | | | | | | | | | | | |
| Chenopodium fremontii S. Wats. | CHFR1 | F | Y | | | 0.1 | 0.2 | | | | | | | 0.1 | 0.5 |
| Chrysopsis fulcrata Greene | CHFU1 | F | Y | | | | | | | | | | | | |
| Chenopodium leptophyllum Nutt. ex Moq. | CHLE2 | F | Y | | | | | | | | | | | | |
| Conyza canadensis (L.) Cronq. | COCA1 | F | Y | | | | | | | | | | | | |
| Comandra umbellata (L.) Nutt. | COUM1 | F | Y | | | | | | | | | | | | |

*Table 6−10 (continued). Species Foliar Cover Summary at Locations A1−A5*

| Scientific Name | Speccode | Growth Form | Native | Cool/ Warm Season | Noxious Weed | A1 | | A2 | | A3 | | A4 | | A5 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Absolute Cover (%) | Relative Cover (%) | Absolute Cover (%) | Relative Cover (%) | Absolute Cover (%) | Relative Cover (%) | Absolute Cover (%) | Relative Cover (%) | Absolute Cover (%) | Relative Cover (%) |
| Erysimum capitatum (Nutt.) DC. | ERCA2 | F | Y | | | | | | | | | | | | |
| Erigeron divergens T. & G. | ERDI1 | F | Y | | | | | | | | | | | | |
| Euphorbia serpyllifolia Pers. | EUSE1 | F | Y | | | | | | | | | | | | |
| Grindelia squarrosa (Pursh.) Dun. | GRSQ1 | F | Y | | | 0.8 | 2.2 | | | 0.5 | 1.7 | 0.3 | 0.7 | | |
| Helianthus annuus L. | HEAN1 | F | Y | | | 0.1 | 0.2 | | | | | | | | |
| Lesquerella montana (A. Gray) Wats. | LEMO1 | F | Y | | | | | | | | | | | | |
| Linum perenne L. var. lewisii (Pursh.) Eat. & Wright | LIPE1 | F | Y | | | | | | | | | | | | |
| Liatris punctata Hook. | LIPU1 | F | Y | | | | | | | | | | | | |
| Mirabilis linearis (Pursh.) Heimerl | MILI1 | F | Y | | | | | | | | | | | | |
| Onosmodium molle Michx. var. occidentale (Mack.) Johnst. | ONMO1 | F | Y | | | | | | | | | | | | |
| Plantago patagonica Jacq. | PLPA1 | F | Y | | | | | | | | | 0.1 | 0.2 | | |
| Psoralea tenuiflora Pursh. | PSTE1 | F | Y | | | | | | | | | | | | |
| Solanum rostratum Dun. | SORO1 | F | Y | | | | | | | | | | | | |
| Sphaeralcea coccinea (Pursh.) Rydb. | SPCO1 | F | Y | | | | | | | | | | | | |
| Thelesperma megapotanicum (Spreng.) O. Ktze. | THME1 | F | Y | | | | | | | | | | | | |
| Verbena bracteata Lag. & Rodr. | VEBR1 | F | Y | | | 0.1 | 0.2 | 0.1 | 0.5 | 0.3 | 0.8 | 0.8 | 2.2 | 0.2 | 0.9 |
| Aegilops cylindrica Host | AECY1 | G | N | C | X | | | | | | | | | | |
| Agropyron cristatum (L.) Gaertn. | AGCR1 | G | N | C | | | | | | | | | | | |
| Agropyron intermedium (Host) Beauv. | AGIN1 | G | N | C | | | | | | | | | | | |
| Bromus inermis Leyss. ssp. inermis | BRIN1 | G | N | C | | | | | | | | | | | |
| Bromus japonicus Thunb. ex Murr. | BRJA1 | G | N | C | | 0.2 | 0.4 | | | 0.3 | 0.8 | | | | |
| Bromus tectorum L. | BRTE1 | G | N | C | X | | | 0.2 | 0.9 | | | 0.8 | 2.5 | | |
| Festuca pratensis Huds. | FEPR1 | G | N | C | | | | | | | | | | | |
| Poa compressa L. | POCO1 | G | N | C | | 0.2 | 0.4 | | | | | | | | |
| Poa pratensis L. | POPR1 | G | N | C | | | | | | | | | | | |
| Triticum aestivum L. | TRAE1 | G | N | C | | 7.8 | 20.9 | 7.2 | 40.6 | | | | | 3.6 | 19.7 |
| Digitaria sanguinalis (L.) Scop. | DISA1 | G | N | W | | | | | | | | | | | |
| Echinochloa crusgallii (L.) Beauv. | ECCR1 | G | N | W | | 0.2 | 0.4 | | | | | | | | |
| Setaria viridis (L.) Beauv. | SEVI1 | G | N | W | | 0.1 | 0.2 | | | | | | | 0.1 | 0.5 |
| Agropyron caninum (L.) Beauv. ssp. majus (Vasey) C. L. Hitchc. | AGCA1 | G | Y | C | | 5.6 | 15.1 | 2.5 | 14.2 | 11.0 | 37.0 | 8.4 | 24.8 | 3.1 | 17.0 |
| Agropyron dasystachyum (Hook.) Scribn. | AGDA1 | G | Y | C | | | | | | | | 1.3 | 3.7 | | |
| Agropyron smithii Rydb. | AGSM1 | G | Y | C | | 1.0 | 2.7 | 1.5 | 8.5 | 1.8 | 5.9 | 2.9 | 8.6 | 1.0 | 5.5 |
| Elymus canadensis L. | ELCA1 | G | Y | C | | | | | | | | | | | |
| Hordeum jubatum L. | HOJU1 | G | Y | C | | | | | | | | | | | |
| Hordeum pusillum Nutt. | HOPU1 | G | Y | C | | | | | | | | | | 0.1 | 0.5 |
| Koeleria pyramidata (Lam.) Beauv. | KOPY1 | G | Y | C | | | | | | | | | | | |
| Stipa comata Trin. & Rupr. | STCO1 | G | Y | C | | | | | | | | | | | |
| Stipa viridula Trin. | STVI1 | G | Y | C | | | | | | | | | | | |
| Andropogon gerardii Vitman | ANGE1 | G | Y | W | | | | | | | | 0.1 | 0.2 | | |
| Andropogon scoparius Michx. | ANSC1 | G | Y | W | | | | | | | | | | | |
| Bouteloua curtipendula (Michx.) Torr. | BOCU1 | G | Y | W | | 0.2 | 0.4 | | | | | 1.4 | 4.2 | 0.1 | 0.5 |
| Bouteloua gracilis (H. B. K.) Lag ex Griffiths | BOGR1 | G | Y | W | | | | 0.2 | 0.9 | | | 1.8 | 5.1 | | |
| Buchloe dactyloides (Nutt.) Engelm. | BUDA1 | G | Y | W | | | | | | 2.3 | 7.6 | 0.2 | 0.5 | | |
| Muhlenbergia montana (Nutt.) Hitchc. | MUMO1 | G | Y | W | | | | | | | | | | | |

*Table 6−10 (continued). Species Foliar Cover Summary at Locations A1−A5*

| Scientific Name | Speccode | Growth Form | Native | Cool/ Warm Season | Noxious Weed | A1 | | A2 | | A3 | | A4 | | A5 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Absolute Cover (%) | Relative Cover (%) | Absolute Cover (%) | Relative Cover (%) | Absolute Cover (%) | Relative Cover (%) | Absolute Cover (%) | Relative Cover (%) | Absolute Cover (%) | Relative Cover (%) |
| Sorghastrum nutans (L.) Nash | SONU1 | G | Y | W | | | | | | | | | | | |
| Sporobolus asper (Michx.) Kunth | SPAS1 | G | Y | W | | | | | | | | | | | |
| Sporobolus cryptandrus (Torr.) A. Gray | SPCR1 | G | Y | W | | | | | | | | | | | |
| Unknown species | UNKN | | | | | | | | | | | | | | |
| Total Foliar Cover | | | | | | 37.1 | 100.0 | 17.7 | 100.0 | 29.8 | 100.0 | 34.0 | 100.0 | 18.2 | 100.0 |
| Total Forb Cover | | | | | | 22.0 | 59.3 | 6.2 | 34.9 | 14.5 | 48.7 | 17.2 | 50.5 | 10.3 | 56.4 |
| Total Non-Native Forb Cover | | | | | | 19.8 | 53.3 | 6.1 | 34.4 | 13.8 | 46.2 | 15.5 | 45.6 | 10.0 | 55.0 |
| Total Native Forb Cover | | | | | | 2.3 | 6.1 | 0.1 | 0.5 | 0.8 | 2.5 | 1.7 | 4.9 | 0.3 | 1.4 |
| Total Graminoid Cover | | | | | | 15.1 | 40.7 | 11.5 | 65.1 | 15.3 | 51.3 | 16.8 | 49.5 | 7.9 | 43.6 |
| Total Non-Native Graminoid Cover | | | | | | 8.3 | 22.5 | 7.3 | 41.5 | 0.3 | 0.8 | 0.8 | 2.5 | 3.7 | 20.2 |
| Total Native Graminoid Cover | | | | | | 6.8 | 18.2 | 4.2 | 23.6 | 15.0 | 50.4 | 16.0 | 47.1 | 4.3 | 23.4 |
| Total Native Cover | | | | | | 9.0 | 24.3 | 4.3 | 24.1 | 15.8 | 52.9 | 17.7 | 52.0 | 4.5 | 24.8 |
| Total Non-Native Cover | | | | | | 28.1 | 75.7 | 13.4 | 75.9 | 14.0 | 47.1 | 16.3 | 48.0 | 13.7 | 75.2 |
| Total Warm-Season Graminoid Cover | | | | | | 0.4 | 1.1 | 0.2 | 0.9 | 2.3 | 7.6 | 3.4 | 10.0 | 0.2 | 0.9 |
| Total Cool-Season Graminoid Cover | | | | | | 14.7 | 39.6 | 11.3 | 64.2 | 13.0 | 43.7 | 13.4 | 39.5 | 7.7 | 42.7 |
| Total Noxious Weed Cover | | | | | | 2.1 | 5.6 | 0.5 | 2.8 | 9.8 | 32.8 | 5.8 | 16.9 | 0.7 | 3.7 |

Absolute Cover = The percentage of the number of hits on a species out of the total number of hits possible.
Relative Cover = The percentage of the number of hits on a species out of the total number of vegetation hits.
Native Categories: Y = Native, N = Non-Native
Growth Form Categories: F = Forb, G = Graminoid
Cool/Warm Season Categories: C = Cool-Season Graminoid, W = Warm-Season Graminoid
Noxious Weed Category: X = Noxious Weed (listed on May 2006 Colorado State Noxious Weed List)
Shaded cells indicate success criteria were met in 2006.

*Table 6−11. Species Foliar Cover Summary at Locations A6−A10*

| Scientific Name | Speccode | Growth Form | Native | Cool/ Warm Season | Noxious Weed | A6 | | A7 | | A8 | | A9 | | A10 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Absolute Cover (%) | Relative Cover (%) | Absolute Cover (%) | Relative Cover (%) | Absolute Cover (%) | Relative Cover (%) | Absolute Cover (%) | Relative Cover (%) | Absolute Cover (%) | Relative Cover (%) |
| Alyssum alyssoides (L.) L. | ALAL1 | F | N | | | | | | | | | | | | |
| Alyssum minus (L.) Rothmaler var. micranthus (C. A. Mey.) Dudley | ALMI1 | F | N | | | 0.3 | 0.6 | | | 0.3 | 0.5 | | | | |
| Amaranthus albus L. | AMAL2 | F | N | | | | | | | | | | | | |
| Carduus nutans L. ssp. macrolepis (Peterm.) Kazmi | CANU1 | F | N | | X | | | | | | | | | | |
| Centaurea diffusa Lam. | CEDI1 | F | N | | X | 0.3 | 0.6 | 0.5 | 5.3 | 4.8 | 9.7 | 1.8 | 10.4 | | |
| Chenopodium album L. | CHAL1 | F | N | | | | | 0.1 | 0.9 | | | | | | |
| Chrysanthemum leucanthemum L. | CHLE1 | F | N | | X | | | | | | | | | | |
| Cirsium arvense (L.) Scop. | CIAR1 | F | N | | X | | | | | | | 0.5 | 2.8 | | |
| Convolvulus arvensis L. | COAR1 | F | N | | X | 1.5 | 3.7 | 0.1 | 0.9 | | | | | | |
| Dyssodia papposa (Vent) Hitchc. | DYPA1 | F | N | | | | | | | | | | | | |
| Erodium cicutarium (L.) L'Her. | ERCI1 | F | N | | X | 0.5 | 1.2 | 1.3 | 14.0 | | | | | | |
| Kochia scoparia (L.) Schrad. | KOSC1 | F | N | | | 5.3 | 12.8 | 0.1 | 0.9 | | | 2.3 | 12.8 | | |
| Lactuca serriola L. | LASE1 | F | N | | | 0.3 | 0.6 | | | 0.3 | 0.5 | 1.3 | 7.1 | | |
| Lepidium campestre (L.) R. Br. | LECA1 | F | N | | | | | | | 0.5 | 1.0 | | | | |
| Linaria dalmatica (L.) Mill. | LIDA1 | F | N | | X | | | | | 1.8 | 3.6 | | | | |
| Marrubium vulgare L. | MAVU1 | F | N | | | | | | | | | | | | |
| Melilotus alba Medic. | MEAL1 | F | N | | | 1.5 | 3.7 | | | | | 0.1 | 0.5 | | |
| Medicago lupulina L. | MELU1 | F | N | | | | | | | | | | | | |
| Melilotus officinalis (L.) Pall. | MEOF1 | F | N | | | 0.8 | 1.8 | 0.8 | 7.9 | 1.8 | 3.6 | 3.7 | 20.9 | | |
| Medicago sativa L. ssp. sativa | MESA1 | F | N | | | | | | | | | | | | |
| Plantago lanceolata L. | PLLA1 | F | N | | | 0.3 | 0.6 | | | | | | | | |
| Polygonum arenastrum Jord. ex Bor. | POAR1 | F | N | | | | | 0.1 | 0.9 | | | 0.1 | 0.5 | | |
| Polygonum persicaria L. | POPE2 | F | N | | | | | | | | | | | | |
| Rumex crispus L. | RUCR1 | F | N | | | | | | | | | | | | |
| Salsola iberica Senn. & Pau. | SAIB1 | F | N | | | | | 0.1 | 0.9 | | | 0.8 | 4.7 | | |
| Scorzonera laciniata L. | SCLA1 | F | N | | | | | | | | | | | | |
| Sisymbrium altissimum L. | SIAL1 | F | N | | | | | | | | | | | | |
| Sonchus arvensis L. ssp. uglinosus (Bieb.) Nyman | SOAR2 | F | N | | | | | | | | | | | | |
| Taraxacum officinale Weber | TAOF1 | F | N | | | | | | | | | | | | |
| Tragopogon dubius Scop. | TRDU1 | F | N | | | | | | | 0.3 | 0.5 | 0.2 | 0.9 | | |
| Verbascum thapsus L. | VETH1 | F | N | | X | | | | | | | | | | |
| Ambrosia artemisiifolia L. | AMAR1 | F | Y | | | | | | | | | | | | |
| Ambrosia psilostachya DC. | AMPS1 | F | Y | | | | | | | | | 0.1 | 0.5 | | |
| Artemisia campestris L. ssp. caudata (Michx.) Hall & Clem. | ARCA1 | F | Y | | | | | | | | | | | | |
| Artemisia frigida Willd. | ARFR1 | F | Y | | | | | | | | | | | | |
| Astragalus canadensis L. | ASCA1 | F | Y | | | | | | | 0.3 | 0.5 | | | | |
| Aster porteri Gray | ASPO1 | F | Y | | | | | | | 0.5 | 1.0 | | | | |
| Asclepias speciosa Torr. | ASSP1 | F | Y | | | | | | | | | | | | |
| Chenopodium fremontii S. Wats. | CHFR1 | F | Y | | | | | | | | | | | | |
| Chrysopsis fulcrata Greene | CHFU1 | F | Y | | | | | | | | | | | | |
| Chenopodium leptophyllum Nutt. ex Moq. | CHLE2 | F | Y | | | | | 0.5 | 5.3 | | | | | | |
| Conyza canadensis (L.) Cronq. | COCA1 | F | Y | | | | | | | | | | | | |
| Comandra umbellata (L.) Nutt. | COUM1 | F | Y | | | | | | | | | | | | |

*Table 6−11 (continued). Species Foliar Cover Summary at Locations A6−A10*

| Scientific Name | Speccode | Growth Form | Native | Cool/ Warm Season | Noxious Weed | A6 | | A7 | | A8 | | A9 | | A10 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Absolute Cover (%) | Relative Cover (%) | Absolute Cover (%) | Relative Cover (%) | Absolute Cover (%) | Relative Cover (%) | Absolute Cover (%) | Relative Cover (%) | Absolute Cover (%) | Relative Cover (%) |
| Erysimum capitatum (Nutt.) DC. | ERCA2 | F | Y | | | | | 0.1 | 0.9 | | | | | | |
| Erigeron divergens T. & G. | ERDI1 | F | Y | | | | | | | | | | | | |
| Euphorbia serpyllifolia Pers. | EUSE1 | F | Y | | | | | | | | | | | | |
| Grindelia squarrosa (Pursh.) Dun. | GRSQ1 | F | Y | | | | | | | 7.0 | 14.3 | 0.6 | 3.3 | | |
| Helianthus annuus L. | HEAN1 | F | Y | | | | | | | | | 0.2 | 0.9 | | |
| Lesquerella montana (A. Gray) Wats. | LEMO1 | F | Y | | | | | 0.1 | 0.9 | | | | | | |
| Linum perenne L. var. lewisii (Pursh.) Eat. & Wright | LIPE1 | F | Y | | | | | | | | | | | | |
| Liatris punctata Hook. | LIPU1 | F | Y | | | | | | | | | | | | |
| Mirabilis linearis (Pursh.) Heimerl | MILI1 | F | Y | | | | | | | 0.3 | 0.5 | | | | |
| Onosmodium molle Michx. var. occidentale (Mack.) Johnst. | ONMO1 | F | Y | | | | | | | | | | | | |
| Plantago patagonica Jacq. | PLPA1 | F | Y | | | | | | | | | | | | |
| Psoralea tenuiflora Pursh. | PSTE1 | F | Y | | | | | | | | | | | | |
| Solanum rostratum Dun. | SORO1 | F | Y | | | | | 0.5 | 5.3 | | | | | | |
| Sphaeralcea coccinea (Pursh.) Rydb. | SPCO1 | F | Y | | | | | | | | | | | | |
| Thelesperma megapotanicum (Spreng.) O. Ktze. | THME1 | F | Y | | | | | | | | | | | | |
| Verbena bracteata Lag. & Rodr. | VEBR1 | F | Y | | | | | 0.6 | 6.1 | 0.3 | 0.5 | | | | |
| Aegilops cylindrica Host | AECY1 | G | N | C | X | | | | | | | | | | |
| Agropyron cristatum (L.) Gaertn. | AGCR1 | G | N | C | | | | | | | | | | | |
| Agropyron intermedium (Host) Beauv. | AGIN1 | G | N | C | | | | | | | | | | | |
| Bromus inermis Leyss. ssp. inermis | BRIN1 | G | N | C | | 5.5 | 13.4 | | | | | 0.2 | 0.9 | 2.0 | 3.9 |
| Bromus japonicus Thunb. ex Murr. | BRJA1 | G | N | C | | | | | | | | 0.1 | 0.5 | | |
| Bromus tectorum L. | BRTE1 | G | N | C | X | 0.3 | 0.6 | 0.3 | 2.6 | | | 0.1 | 0.5 | 0.5 | 1.0 |
| Festuca pratensis Huds. | FEPR1 | G | N | C | | | | | | | | | | | |
| Poa compressa L. | POCO1 | G | N | C | | 0.5 | 1.2 | | | 2.3 | 4.6 | | | | |
| Poa pratensis L. | POPR1 | G | N | C | | | | | | | | 0.1 | 0.5 | | |
| Triticum aestivum L. | TRAE1 | G | N | C | | | | 1.3 | 13.2 | | | 0.4 | 2.4 | | |
| Digitaria sanguinalis (L.) Scop. | DISA1 | G | N | W | | | | | | | | | | | |
| Echinochloa crusgallii (L.) Beauv. | ECCR1 | G | N | W | | | | | | | | | | | |
| Setaria viridis (L.) Beauv. | SEVI1 | G | N | W | | 0.5 | 1.2 | | | | | | | | |
| Agropyron caninum (L.) Beauv. ssp. majus (Vasey) C. L. Hitchc. | AGCA1 | G | Y | C | | 13.3 | 32.3 | 2.3 | 23.7 | 20.3 | 41.3 | 2.8 | 15.6 | 25.0 | 48.5 |
| Agropyron dasystachyum (Hook.) Scribn. | AGDA1 | G | Y | C | | | | | | | | | | 1.5 | 2.9 |
| Agropyron smithii Rydb. | AGSM1 | G | Y | C | | 2.5 | 6.1 | 0.6 | 6.1 | 5.3 | 10.7 | 1.6 | 9.0 | 14.0 | 27.2 |
| Elymus canadensis L. | ELCA1 | G | Y | C | | 0.3 | 0.6 | 0.3 | 2.6 | | | | | | |
| Hordeum jubatum L. | HOJU1 | G | Y | C | | 0.5 | 1.2 | | | | | 0.1 | 0.5 | | |
| Hordeum pusillum Nutt. | HOPU1 | G | Y | C | | | | | | | | | | | |
| Koeleria pyramidata (Lam.) Beauv. | KOPY1 | G | Y | C | | | | | | | | | | | |
| Stipa comata Trin. & Rupr. | STCO1 | G | Y | C | | | | | | | | | | | |
| Stipa viridula Trin. | STVI1 | G | Y | C | | | | | | | | | | | |
| Andropogon gerardii Vitman | ANGE1 | G | Y | W | | | | 0.1 | 0.9 | | | | | | |
| Andropogon scoparius Michx. | ANSC1 | G | Y | W | | | | | | | | | | | |
| Bouteloua curtipendula (Michx.) Torr. | BOCU1 | G | Y | W | | 1.8 | 4.3 | | | 0.5 | 1.0 | 0.4 | 2.4 | 0.5 | 1.0 |
| Bouteloua gracilis (H. B. K.) Lag ex Griffiths | BOGR1 | G | Y | W | | 3.3 | 7.9 | 0.1 | 0.9 | 1.3 | 2.6 | 0.4 | 2.4 | 1.5 | 2.9 |
| Buchloe dactyloides (Nutt.) Engelm. | BUDA1 | G | Y | W | | 1.8 | 4.3 | | | 1.8 | 3.6 | | | 3.5 | 6.8 |
| Muhlenbergia montana (Nutt.) Hitchc. | MUMO1 | G | Y | W | | | | | | | | | | | |

*Table 6−11 (continued). Species Foliar Cover Summary at Locations A6−A10*

| Scientific Name | Speccode | Growth Form | Native | Cool/ Warm Season | Noxious Weed | A6 | | A7 | | A8 | | A9 | | A10 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Absolute Cover (%) | Relative Cover (%) | Absolute Cover (%) | Relative Cover (%) | Absolute Cover (%) | Relative Cover (%) | Absolute Cover (%) | Relative Cover (%) | Absolute Cover (%) | Relative Cover (%) |
| Sorghastrum nutans (L.) Nash | SONU1 | G | Y | W | | 0.3 | 0.6 | | | | | | | 3.0 | 5.8 |
| Sporobolus asper (Michx.) Kunth | SPAS1 | G | Y | W | | | | | | | | | | | |
| Sporobolus cryptandrus (Torr.) A. Gray | SPCR1 | G | Y | W | | | | | | | | | | | |
| Unknown species | UNKN | | | | | 0.3 | 0.6 | | | | | | | | |
| Total Foliar Cover | | | | | | 41.0 | 100.0 | 9.5 | 100.0 | 49.0 | 100.0 | 17.6 | 100.0 | 51.5 | 100.0 |
| Total Forb Cover | | | | | | 10.5 | 25.6 | 4.8 | 50.0 | 17.8 | 36.2 | 11.5 | 65.4 | 0.0 | 0.0 |
| Total Non-Native Forb Cover | | | | | | 10.5 | 25.6 | 3.0 | 31.6 | 9.5 | 19.4 | 10.7 | 60.7 | 0.0 | 0.0 |
| Total Native Forb Cover | | | | | | 0.0 | 0.0 | 1.8 | 18.4 | 8.3 | 16.8 | 0.8 | 4.7 | 0.0 | 0.0 |
| Total Graminoid Cover | | | | | | 30.3 | 73.8 | 4.8 | 50.0 | 31.3 | 63.8 | 6.1 | 34.6 | 51.5 | 100.0 |
| Total Non-Native Graminoid Cover | | | | | | 6.8 | 16.5 | 1.5 | 15.8 | 2.3 | 4.6 | 0.8 | 4.7 | 2.5 | 4.9 |
| Total Native Graminoid Cover | | | | | | 23.5 | 57.3 | 3.3 | 34.2 | 29.0 | 59.2 | 5.3 | 29.9 | 49.0 | 95.1 |
| Total Native Cover | | | | | | 23.5 | 57.3 | 5.0 | 52.6 | 37.3 | 76.0 | 6.1 | 34.6 | 49.0 | 95.1 |
| Total Non-Native Cover | | | | | | 17.3 | 42.1 | 4.5 | 47.4 | 11.8 | 24.0 | 11.5 | 65.4 | 2.5 | 4.9 |
| Total Warm-Season Graminoid Cover | | | | | | 7.5 | 18.3 | 0.2 | 1.8 | 3.5 | 7.1 | 0.8 | 4.7 | 8.5 | 16.5 |
| Total Cool-Season Graminoid Cover | | | | | | 22.8 | 55.5 | 4.6 | 48.2 | 27.8 | 56.6 | 5.3 | 29.9 | 43.0 | 83.5 |
| Total Noxious Weed Cover | | | | | | 2.5 | 6.1 | 2.2 | 22.8 | 6.5 | 13.3 | 2.4 | 13.7 | 0.5 | 1.0 |

Absolute Cover = The percentage of the number of hits on a species out of the total number of hits possible.
Relative Cover = The percentage of the number of hits on a species out of the total number of vegetation hits.
Native Categories: Y = Native, N = Non-Native
Growth Form Categories: F = Forb, G = Graminoid
Cool/Warm Season Categories: C = Cool-Season Graminoid, W = Warm-Season Graminoid
Noxious Weed Category: X = Noxious Weed (listed on May 2006 Colorado State Noxious Weed List)
Shaded cells indicate success criteria were met in 2006.

*Table 6−12. Species Foliar Cover Summary at Locations A11−A15*

| Scientific Name | Speccode | Growth Form | Native | Cool/ Warm Season | Noxious Weed | A11 | | A12 | | A13 | | A14 | | A15 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Absolute Cover (%) | Relative Cover (%) | Absolute Cover (%) | Relative Cover (%) | Absolute Cover (%) | Relative Cover (%) | Absolute Cover (%) | Relative Cover (%) | Absolute Cover (%) | Relative Cover (%) |
| Alyssum alyssoides (L.) L. | ALAL1 | F | N | | | | | | | | | | | | |
| Alyssum minus (L.) Rothmaler var. micranthus (C. A. Mey.) Dudley | ALMI1 | F | N | | | 0.5 | 2.2 | 0.3 | 0.8 | 0.3 | 0.7 | | | | |
| Amaranthus albus L. | AMAL2 | F | N | | | | | | | 0.3 | 0.7 | | | | |
| Carduus nutans L. ssp. macrolepis (Peterm.) Kazmi | CANU1 | F | N | | X | | | 0.1 | 0.3 | | | | | | |
| Centaurea diffusa Lam. | CEDI1 | F | N | | X | 0.1 | 0.4 | 8.8 | 28.1 | 0.8 | 2.1 | 5.3 | 12.0 | 1.0 | 2.6 |
| Chenopodium album L. | CHAL1 | F | N | | | | | | | 3.5 | 9.9 | | | | |
| Chrysanthemum leucanthemum L. | CHLE1 | F | N | | X | | | | | | | | | | |
| Cirsium arvense (L.) Scop. | CIAR1 | F | N | | X | | | 0.2 | 0.6 | | | | | | |
| Convolvulus arvensis L. | COAR1 | F | N | | X | | | 1.1 | 3.6 | | | | | | |
| Dyssodia papposa (Vent) Hitchc. | DYPA1 | F | N | | | | | | | | | | | | |
| Erodium cicutarium (L.) L'Her. | ERCI1 | F | N | | X | 0.6 | 2.6 | 0.1 | 0.3 | 0.3 | 0.7 | | | | |
| Kochia scoparia (L.) Schrad. | KOSC1 | F | N | | | 9.0 | 39.9 | 2.8 | 8.8 | 3.3 | 9.2 | | | | |
| Lactuca serriola L. | LASE1 | F | N | | | 0.1 | 0.4 | 1.5 | 4.7 | 1.8 | 4.9 | | | 0.5 | 1.3 |
| Lepidium campestre (L.) R. Br. | LECA1 | F | N | | | | | | | 0.3 | 0.7 | | | 0.2 | 0.4 |
| Linaria dalmatica (L.) Mill. | LIDA1 | F | N | | X | | | | | | | | | | |
| Marrubium vulgare L. | MAVU1 | F | N | | | | | 0.1 | 0.3 | | | | | | |
| Melilotus alba Medic. | MEAL1 | F | N | | | | | 1.4 | 4.4 | | | | | | |
| Medicago lupulina L. | MELU1 | F | N | | | | | | | | | | | | |
| Melilotus officinalis (L.) Pall. | MEOF1 | F | N | | | 3.1 | 13.7 | 5.3 | 17.1 | 0.5 | 1.4 | | | 1.3 | 3.5 |
| Medicago sativa L. ssp. sativa | MESA1 | F | N | | | | | 0.1 | 0.3 | | | | | | |
| Plantago lanceolata L. | PLLA1 | F | N | | | | | | | | | | | | |
| Polygonum arenastrum Jord. ex Bor. | POAR1 | F | N | | | 0.8 | 3.3 | 0.3 | 0.8 | 0.5 | 1.4 | | | | |
| Polygonum persicaria L. | POPE2 | F | N | | | | | | | | | | | | |
| Rumex crispus L. | RUCR1 | F | N | | | | | 0.5 | 1.7 | | | | | | |
| Salsola iberica Senn. & Pau. | SAIB1 | F | N | | | 1.4 | 6.3 | 0.9 | 2.8 | 1.8 | 4.9 | | | | |
| Scorzonera laciniata L. | SCLA1 | F | N | | | | | | | | | | | | |
| Sisymbrium altissimum L. | SIAL1 | F | N | | | | | | | | | | | | |
| Sonchus arvensis L. ssp. uglinosus (Bieb.) Nyman | SOAR2 | F | N | | | | | | | | | | | | |
| Taraxacum officinale Weber | TAOF1 | F | N | | | | | 0.1 | 0.3 | | | | | 0.2 | 0.4 |
| Tragopogon dubius Scop. | TRDU1 | F | N | | | | | 0.2 | 0.6 | | | | | | |
| Verbascum thapsus L. | VETH1 | F | N | | X | | | | | | | | | | |
| Ambrosia artemisiifolia L. | AMAR1 | F | Y | | | | | | | | | | | | |
| Ambrosia psilostachya DC. | AMPS1 | F | Y | | | 0.1 | 0.4 | | | | | | | | |
| Artemisia campestris L. ssp. caudata (Michx.) Hall & Clem. | ARCA1 | F | Y | | | | | | | | | | | | |
| Artemisia frigida Willd. | ARFR1 | F | Y | | | | | | | | | | | | |
| Astragalus canadensis L. | ASCA1 | F | Y | | | | | | | | | | | | |
| Aster porteri Gray | ASPO1 | F | Y | | | | | | | | | | | 0.2 | 0.4 |
| Asclepias speciosa Torr. | ASSP1 | F | Y | | | | | | | | | | | | |
| Chenopodium fremontii S. Wats. | CHFR1 | F | Y | | | | | | | | | | | | |
| Chrysopsis fulcrata Greene | CHFU1 | F | Y | | | | | | | | | | | | |
| Chenopodium leptophyllum Nutt. ex Moq. | CHLE2 | F | Y | | | | | | | | | | | | |
| Conyza canadensis (L.) Cronq. | COCA1 | F | Y | | | | | | | | | | | 0.5 | 1.3 |

*Table 6−12 (continued). Species Foliar Cover Summary at Locations A11−A15*

| Scientific Name | Speccode | Growth Form | Native | Cool/ Warm Season | Noxious Weed | A11 | | A12 | | A13 | | A14 | | A15 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Absolute Cover (%) | Relative Cover (%) | Absolute Cover (%) | Relative Cover (%) | Absolute Cover (%) | Relative Cover (%) | Absolute Cover (%) | Relative Cover (%) | Absolute Cover (%) | Relative Cover (%) |
| Comandra umbellata (L.) Nutt. | COUM1 | F | Y | | | | | | | | | | | 0.2 | 0.4 |
| Erysimum capitatum (Nutt.) DC. | ERCA2 | F | Y | | | | | | | | | | | | |
| Erigeron divergens T. & G. | ERDI1 | F | Y | | | | | | | | | | | | |
| Euphorbia serpyllifolia Pers. | EUSE1 | F | Y | | | | | | | 0.5 | 1.4 | | | | |
| Grindelia squarrosa (Pursh.) Dun. | GRSQ1 | F | Y | | | | | 0.1 | 0.3 | | | | | 0.2 | 0.4 |
| Helianthus annuus L. | HEAN1 | F | Y | | | | | 0.1 | 0.3 | | | | | | |
| Lesquerella montana (A. Gray) Wats. | LEMO1 | F | Y | | | | | | | | | | | | |
| Linum perenne L. var. lewisii (Pursh.) Eat. & Wright | LIPE1 | F | Y | | | | | | | | | | | | |
| Liatris punctata Hook. | LIPU1 | F | Y | | | | | | | | | 0.3 | 0.6 | | |
| Mirabilis linearis (Pursh.) Heimerl | MILI1 | F | Y | | | | | | | | | | | | |
| Onosmodium molle Michx. var. occidentale (Mack.) Johnst. | ONMO1 | F | Y | | | | | | | | | | | | |
| Plantago patagonica Jacq. | PLPA1 | F | Y | | | | | | | | | | | | |
| Psoralea tenuiflora Pursh. | PSTE1 | F | Y | | | | | | | | | | | | |
| Solanum rostratum Dun. | SORO1 | F | Y | | | | | | | | | | | | |
| Sphaeralcea coccinea (Pursh.) Rydb. | SPCO1 | F | Y | | | | | | | | | | | | |
| Thelesperma megapotanicum (Spreng.) O. Ktze. | THME1 | F | Y | | | | | | | | | | | | |
| Verbena bracteata Lag. & Rodr. | VEBR1 | F | Y | | | 0.3 | 1.5 | 1.6 | 5.2 | | | | | 2.3 | 6.1 |
| Aegilops cylindrica Host | AECY1 | G | N | C | X | | | | | | | | | | |
| Agropyron cristatum (L.) Gaertn. | AGCR1 | G | N | C | | | | 0.2 | 0.6 | | | | | | |
| Agropyron intermedium (Host) Beauv. | AGIN1 | G | N | C | | | | 0.1 | 0.3 | | | | | | |
| Bromus inermis Leyss. ssp. inermis | BRIN1 | G | N | C | | | | 0.2 | 0.6 | | | 0.3 | 0.6 | | |
| Bromus japonicus Thunb. ex Murr. | BRJA1 | G | N | C | | | | | | | | | | | |
| Bromus tectorum L. | BRTE1 | G | N | C | X | | | 0.1 | 0.3 | 0.5 | 1.4 | 0.3 | 0.6 | 0.2 | 0.4 |
| Festuca pratensis Huds. | FEPR1 | G | N | C | | | | | | | | 1.5 | 3.4 | | |
| Poa compressa L. | POCO1 | G | N | C | | | | | | | | | | 0.2 | 0.4 |
| Poa pratensis L. | POPR1 | G | N | C | | | | | | | | | | | |
| Triticum aestivum L. | TRAE1 | G | N | C | | 5.3 | 23.2 | | | 7.3 | 20.4 | | | | |
| Digitaria sanguinalis (L.) Scop. | DISA1 | G | N | W | | | | | | | | | | | |
| Echinochloa crusgallii (L.) Beauv. | ECCR1 | G | N | W | | | | | | | | | | | |
| Setaria viridis (L.) Beauv. | SEVI1 | G | N | W | | | | | | | | | | | |
| Agropyron caninum (L.) Beauv. ssp. majus (Vasey) C. L. Hitchc. | AGCA1 | G | Y | C | | 0.8 | 3.7 | 1.7 | 5.5 | 7.0 | 19.7 | 12.0 | 27.4 | 14.7 | 38.6 |
| Agropyron dasystachyum (Hook.) Scribn. | AGDA1 | G | Y | C | | | | | | | | | | | |
| Agropyron smithii Rydb. | AGSM1 | G | Y | C | | 0.5 | 2.2 | 2.2 | 6.9 | 4.0 | 11.3 | 0.3 | 0.6 | 2.2 | 5.7 |
| Elymus canadensis L. | ELCA1 | G | Y | C | | | | | | | | | | | |
| Hordeum jubatum L. | HOJU1 | G | Y | C | | | | | | 1.5 | 4.2 | | | | |
| Hordeum pusillum Nutt. | HOPU1 | G | Y | C | | | | | | | | | | | |
| Koeleria pyramidata (Lam.) Beauv. | KOPY1 | G | Y | C | | | | | | | | | | | |
| Stipa comata Trin. & Rupr. | STCO1 | G | Y | C | | | | | | | | | | | |
| Stipa viridula Trin. | STVI1 | G | Y | C | | | | | | | | | | | |
| Andropogon gerardii Vitman | ANGE1 | G | Y | W | | | | | | | | 1.5 | 3.4 | 5.5 | 14.5 |
| Andropogon scoparius Michx. | ANSC1 | G | Y | W | | | | | | | | 0.8 | 1.7 | 0.2 | 0.4 |
| Bouteloua curtipendula (Michx.) Torr. | BOCU1 | G | Y | W | | | | 0.1 | 0.3 | | | 9.3 | 21.1 | 6.2 | 16.2 |
| Bouteloua gracilis (H. B. K.) Lag ex Griffiths | BOGR1 | G | Y | W | | 0.1 | 0.4 | 1.5 | 4.7 | 0.3 | 0.7 | 3.5 | 8.0 | 0.5 | 1.3 |
| Buchloe dactyloides (Nutt.) Engelm. | BUDA1 | G | Y | W | | | | | | | | 5.8 | 13.1 | 2.0 | 5.3 |

*Table 6−12 (continued). Species Foliar Cover Summary at Locations A11−A15*

| Scientific Name | Speccode | Growth Form | Native | Cool/ Warm Season | Noxious Weed | A11 | | A12 | | A13 | | A14 | | A15 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Absolute Cover (%) | Relative Cover (%) | Absolute Cover (%) | Relative Cover (%) | Absolute Cover (%) | Relative Cover (%) | Absolute Cover (%) | Relative Cover (%) | Absolute Cover (%) | Relative Cover (%) |
| Muhlenbergia montana (Nutt.) Hitchc. | MUMO1 | G | Y | W | | | | | | | | 1.5 | 3.4 | | |
| Sorghastrum nutans (L.) Nash | SONU1 | G | Y | W | | | | | | | | 1.5 | 3.4 | | |
| Sporobolus asper (Michx.) Kunth | SPAS1 | G | Y | W | | | | | | | | | | | |
| Sporobolus cryptandrus (Torr.) A. Gray | SPCR1 | G | Y | W | | | | | | | | 0.3 | 0.6 | | |
| Unknown species | UNKN | | | | | | | | | 1.5 | 4.2 | | | | |
| Total Foliar Cover | | | | | | 22.6 | 100.0 | 31.3 | 100.0 | 35.5 | 100.0 | 43.8 | 100.0 | 38.0 | 100.0 |
| Total Forb Cover | | | | | | 15.9 | 70.5 | 25.3 | 81.0 | 13.5 | 38.0 | 5.5 | 12.6 | 6.5 | 17.1 |
| Total Non-Native Forb Cover | | | | | | 15.5 | 68.6 | 23.5 | 75.2 | 13.0 | 36.6 | 5.3 | 12.0 | 3.2 | 8.3 |
| Total Native Forb Cover | | | | | | 0.4 | 1.8 | 1.8 | 5.8 | 0.5 | 1.4 | 0.3 | 0.6 | 3.3 | 8.8 |
| Total Graminoid Cover | | | | | | 6.7 | 29.5 | 5.9 | 19.0 | 20.5 | 57.7 | 38.3 | 87.4 | 31.5 | 82.9 |
| Total Non-Native Graminoid Cover | | | | | | 5.3 | 23.2 | 0.5 | 1.7 | 7.8 | 21.8 | 2.0 | 4.6 | 0.3 | 0.9 |
| Total Native Graminoid Cover | | | | | | 1.4 | 6.3 | 5.4 | 17.4 | 12.8 | 35.9 | 36.3 | 82.9 | 31.2 | 82.0 |
| Total Native Cover | | | | | | 1.8 | 8.1 | 7.2 | 23.1 | 13.3 | 37.3 | 36.5 | 83.4 | 34.5 | 90.8 |
| Total Non-Native Cover | | | | | | 20.8 | 91.9 | 24.1 | 76.9 | 20.8 | 58.5 | 7.3 | 16.6 | 3.5 | 9.2 |
| Total Warm-Season Graminoid Cover | | | | | | 0.1 | 0.4 | 1.6 | 5.0 | 0.3 | 0.7 | 24.0 | 54.9 | 14.3 | 37.7 |
| Total Cool-Season Graminoid Cover | | | | | | 6.6 | 29.2 | 4.4 | 14.0 | 20.3 | 57.0 | 14.3 | 32.6 | 17.2 | 45.2 |
| Total Noxious Weed Cover | | | | | | 0.7 | 3.0 | 10.3 | 33.1 | 1.5 | 4.2 | 5.5 | 12.6 | 1.2 | 3.1 |

Absolute Cover = The percentage of the number of hits on a species out of the total number of hits possible.
Relative Cover = The percentage of the number of hits on a species out of the total number of vegetation hits.
Native Categories: Y = Native, N = Non-Native
Growth Form Categories: F = Forb, G = Graminoid
Cool/Warm Season Categories: C = Cool-Season Graminoid, W = Warm-Season Graminoid
Noxious Weed Category: X = Noxious Weed (listed on May 2006 Colorado State Noxious Weed List)
Shaded cells indicate success criteria were met in 2006.

*Table 6−13. Species Foliar Cover Summary at Locations A16−A20*

| Scientific Name | Speccode | Growth Form | Native | Cool/ Warm Season | Noxious Weed | A16 | | A17 | | A18 | | A19 | | A20 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Absolute Cover (%) | Relative Cover (%) | Absolute Cover (%) | Relative Cover (%) | Absolute Cover (%) | Relative Cover (%) | Absolute Cover (%) | Relative Cover (%) | Absolute Cover (%) | Relative Cover (%) |
| Alyssum alyssoides (L.) L. | ALAL1 | F | N | | | | | | | | | | | 0.3 | 0.5 |
| Alyssum minus (L.) Rothmaler var. micranthus (C. A. Mey.) Dudley | ALMI1 | F | N | | | 2.5 | 4.8 | 0.5 | 1.0 | | | | | 1.5 | 2.8 |
| Amaranthus albus L. | AMAL2 | F | N | | | | | | | | | | | | |
| Carduus nutans L. ssp. macrolepis (Peterm.) Kazmi | CANU1 | F | N | | X | | | | | | | | | | |
| Centaurea diffusa Lam. | CEDI1 | F | N | | X | 3.5 | 6.8 | 0.3 | 0.5 | 1.5 | 3.9 | 1.2 | 2.7 | 2.0 | 3.7 |
| Chenopodium album L. | CHAL1 | F | N | | | | | | | 0.3 | 0.7 | | | | |
| Chrysanthemum leucanthemum L. | CHLE1 | F | N | | X | | | | | 0.3 | 0.7 | | | | |
| Cirsium arvense (L.) Scop. | CIAR1 | F | N | | X | | | | | | | | | | |
| Convolvulus arvensis L. | COAR1 | F | N | | X | | | | | 0.5 | 1.3 | 0.2 | 0.4 | 1.0 | 1.8 |
| Dyssodia papposa (Vent) Hitchc. | DYPA1 | F | N | | | 0.8 | 1.4 | 0.8 | 1.5 | 0.3 | 0.7 | | | | |
| Erodium cicutarium (L.) L'Her. | ERCI1 | F | N | | X | 6.3 | 12.1 | 7.0 | 14.4 | 2.0 | 5.3 | 1.3 | 3.1 | 0.5 | 0.9 |
| Kochia scoparia (L.) Schrad. | KOSC1 | F | N | | | 0.3 | 0.5 | 0.8 | 1.5 | | | | | | |
| Lactuca serriola L. | LASE1 | F | N | | | 3.8 | 7.2 | 0.5 | 1.0 | 0.3 | 0.7 | 0.8 | 1.9 | | |
| Lepidium campestre (L.) R. Br. | LECA1 | F | N | | | | | | | | | 0.2 | 0.4 | | |
| Linaria dalmatica (L.) Mill. | LIDA1 | F | N | | X | | | | | | | | | | |
| Marrubium vulgare L. | MAVU1 | F | N | | | | | 0.3 | 0.5 | | | | | | |
| Melilotus alba Medic. | MEAL1 | F | N | | | | | | | | | 0.2 | 0.4 | | |
| Medicago lupulina L. | MELU1 | F | N | | | | | | | | | | | | |
| Melilotus officinalis (L.) Pall. | MEOF1 | F | N | | | 11.8 | 22.7 | 3.3 | 6.7 | 7.8 | 20.4 | 1.3 | 3.1 | 0.3 | 0.5 |
| Medicago sativa L. ssp. sativa | MESA1 | F | N | | | | | | | | | | | | |
| Plantago lanceolata L. | PLLA1 | F | N | | | | | | | | | 0.2 | 0.4 | | |
| Polygonum arenastrum Jord. ex Bor. | POAR1 | F | N | | | 1.5 | 2.9 | | | | | | | | |
| Polygonum persicaria L. | POPE2 | F | N | | | | | | | | | | | | |
| Rumex crispus L. | RUCR1 | F | N | | | | | | | | | | | | |
| Salsola iberica Senn. & Pau. | SAIB1 | F | N | | | 4.5 | 8.7 | 1.0 | 2.1 | | | | | | |
| Scorzonera laciniata L. | SCLA1 | F | N | | | | | | | | | | | 0.3 | 0.5 |
| Sisymbrium altissimum L. | SIAL1 | F | N | | | | | | | | | | | | |
| Sonchus arvensis L. ssp. uglinosus (Bieb.) Nyman | SOAR2 | F | N | | | | | | | | | | | | |
| Taraxacum officinale Weber | TAOF1 | F | N | | | | | | | | | 0.2 | 0.4 | 0.3 | 0.5 |
| Tragopogon dubius Scop. | TRDU1 | F | N | | | | | 1.5 | 3.1 | 0.3 | 0.7 | 0.2 | 0.4 | 0.5 | 0.9 |
| Verbascum thapsus L. | VETH1 | F | N | | X | | | 1.8 | 3.6 | | | 0.3 | 0.8 | | |
| Ambrosia artemisiifolia L. | AMAR1 | F | Y | | | | | 1.5 | 3.1 | 0.3 | 0.7 | | | | |
| Ambrosia psilostachya DC. | AMPS1 | F | Y | | | | | 0.3 | 0.5 | | | | | 9.3 | 17.1 |
| Artemisia campestris L. ssp. caudata (Michx.) Hall & Clem. | ARCA1 | F | Y | | | 0.3 | 0.5 | | | | | | | 0.3 | 0.5 |
| Artemisia frigida Willd. | ARFR1 | F | Y | | | | | | | | | | | 1.8 | 3.2 |
| Astragalus canadensis L. | ASCA1 | F | Y | | | | | | | | | | | | |
| Aster porteri Gray | ASPO1 | F | Y | | | | | | | | | | | | |
| Asclepias speciosa Torr. | ASSP1 | F | Y | | | | | | | | | | | | |
| Chenopodium fremontii S. Wats. | CHFR1 | F | Y | | | | | | | | | | | | |
| Chrysopsis fulcrata Greene | CHFU1 | F | Y | | | | | | | | | | | | |
| Chenopodium leptophyllum Nutt. ex Moq. | CHLE2 | F | Y | | | | | | | | | | | | |
| Conyza canadensis (L.) Cronq. | COCA1 | F | Y | | | | | 0.3 | 0.5 | | | | | | |

*Table 6−13 (continued). Species Foliar Cover Summary at Locations A16−A20*

| Scientific Name | Speccode | Growth Form | Native | Cool/ Warm Season | Noxious Weed | A16 | | A17 | | A18 | | A19 | | A20 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Absolute Cover (%) | Relative Cover (%) | Absolute Cover (%) | Relative Cover (%) | Absolute Cover (%) | Relative Cover (%) | Absolute Cover (%) | Relative Cover (%) | Absolute Cover (%) | Relative Cover (%) |
| Comandra umbellata (L.) Nutt. | COUM1 | F | Y | | | | | | | | | | | | |
| Erysimum capitatum (Nutt.) DC. | ERCA2 | F | Y | | | | | | | | | | | | |
| Erigeron divergens T. & G. | ERDI1 | F | Y | | | | | | | | | | | | |
| Euphorbia serpyllifolia Pers. | EUSE1 | F | Y | | | | | 0.3 | 0.5 | 0.3 | 0.7 | | | | |
| Grindelia squarrosa (Pursh.) Dun. | GRSQ1 | F | Y | | | | | 0.3 | 0.5 | | | 0.5 | 1.2 | 0.3 | 0.5 |
| Helianthus annuus L. | HEAN1 | F | Y | | | 1.5 | 2.9 | 1.8 | 3.6 | | | | | | |
| Lesquerella montana (A. Gray) Wats. | LEMO1 | F | Y | | | | | | | | | | | | |
| Linum perenne L. var. lewisii (Pursh.) Eat. & Wright | LIPE1 | F | Y | | | | | | | | | | | 8.5 | 15.7 |
| Liatris punctata Hook. | LIPU1 | F | Y | | | | | | | | | | | | |
| Mirabilis linearis (Pursh.) Heimerl | MILI1 | F | Y | | | | | | | | | | | | |
| Onosmodium molle Michx. var. occidentale (Mack.) Johnst. | ONMO1 | F | Y | | | | | | | | | | | | |
| Plantago patagonica Jacq. | PLPA1 | F | Y | | | 0.3 | 0.5 | | | 0.3 | 0.7 | | | | |
| Psoralea tenuiflora Pursh. | PSTE1 | F | Y | | | | | | | | | | | | |
| Solanum rostratum Dun. | SORO1 | F | Y | | | | | | | | | | | | |
| Sphaeralcea coccinea (Pursh.) Rydb. | SPCO1 | F | Y | | | | | | | | | | | | |
| Thelesperma megapotanicum (Spreng.) O. Ktze. | THME1 | F | Y | | | | | | | | | | | 0.3 | 0.5 |
| Verbena bracteata Lag. & Rodr. | VEBR1 | F | Y | | | 1.5 | 2.9 | 4.3 | 8.8 | 8.3 | 21.7 | 4.7 | 10.9 | | |
| Aegilops cylindrica Host | AECY1 | G | N | C | X | | | | | | | | | | |
| Agropyron cristatum (L.) Gaertn. | AGCR1 | G | N | C | | | | | | | | | | | |
| Agropyron intermedium (Host) Beauv. | AGIN1 | G | N | C | | 0.3 | 0.5 | | | | | | | | |
| Bromus inermis Leyss. ssp. inermis | BRIN1 | G | N | C | | | | | | | | | | 2.3 | 4.1 |
| Bromus japonicus Thunb. ex Murr. | BRJA1 | G | N | C | | 0.3 | 0.5 | | | | | 0.2 | 0.4 | 0.3 | 0.5 |
| Bromus tectorum L. | BRTE1 | G | N | C | X | 1.0 | 1.9 | 1.8 | 3.6 | | | 0.2 | 0.4 | 0.5 | 0.9 |
| Festuca pratensis Huds. | FEPR1 | G | N | C | | | | | | | | 1.3 | 3.1 | | |
| Poa compressa L. | POCO1 | G | N | C | | | | | | | | 0.7 | 1.6 | 1.8 | 3.2 |
| Poa pratensis L. | POPR1 | G | N | C | | | | | | | | | | 0.3 | 0.5 |
| Triticum aestivum L. | TRAE1 | G | N | C | | 5.8 | 11.1 | | | | | | | | |
| Digitaria sanguinalis (L.) Scop. | DISA1 | G | N | W | | 0.3 | 0.5 | | | | | | | | |
| Echinochloa crusgallii (L.) Beauv. | ECCR1 | G | N | W | | | | | | | | | | | |
| Setaria viridis (L.) Beauv. | SEVI1 | G | N | W | | | | 2.3 | 4.6 | | | | | | |
| Agropyron caninum (L.) Beauv. ssp. majus (Vasey) C. L. Hitchc. | AGCA1 | G | Y | C | | 2.8 | 5.3 | 4.3 | 8.8 | 5.8 | 15.1 | 21.2 | 49.2 | 1.8 | 3.2 |
| Agropyron dasystachyum (Hook.) Scribn. | AGDA1 | G | Y | C | | | | 1.5 | 3.1 | | | | | | |
| Agropyron smithii Rydb. | AGSM1 | G | Y | C | | 1.5 | 2.9 | 2.3 | 4.6 | 2.5 | 6.6 | 3.0 | 7.0 | 12.3 | 22.6 |
| Elymus canadensis L. | ELCA1 | G | Y | C | | | | | | | | | | | |
| Hordeum jubatum L. | HOJU1 | G | Y | C | | | | | | | | 0.2 | 0.4 | | |
| Hordeum pusillum Nutt. | HOPU1 | G | Y | C | | | | | | | | | | | |
| Koeleria pyramidata (Lam.) Beauv. | KOPY1 | G | Y | C | | | | 0.3 | 0.5 | | | 0.2 | 0.4 | | |
| Stipa comata Trin. & Rupr. | STCO1 | G | Y | C | | | | | | | | | | 0.3 | 0.5 |
| Stipa viridula Trin. | STVI1 | G | Y | C | | | | | | | | | | | |
| Andropogon gerardii Vitman | ANGE1 | G | Y | W | | | | 0.8 | 1.5 | 2.3 | 5.9 | 3.0 | 7.0 | | |
| Andropogon scoparius Michx. | ANSC1 | G | Y | W | | | | | | | | 0.2 | 0.4 | | |
| Bouteloua curtipendula (Michx.) Torr. | BOCU1 | G | Y | W | | 1.5 | 2.9 | 3.8 | 7.7 | 0.8 | 2.0 | 0.7 | 1.6 | | |
| Bouteloua gracilis (H. B. K.) Lag ex Griffiths | BOGR1 | G | Y | W | | 0.3 | 0.5 | 2.8 | 5.7 | 3.5 | 9.2 | | | 6.8 | 12.4 |
| Buchloe dactyloides (Nutt.) Engelm. | BUDA1 | G | Y | W | | | | 2.3 | 4.6 | 0.8 | 2.0 | 1.2 | 2.7 | | |

*Table 6−13 (continued). Species Foliar Cover Summary at Locations A16−A20*

| Scientific Name | Speccode | Growth Form | Native | Cool/ Warm Season | Noxious Weed | A16 | | A17 | | A18 | | A19 | | A20 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Absolute Cover (%) | Relative Cover (%) | Absolute Cover (%) | Relative Cover (%) | Absolute Cover (%) | Relative Cover (%) | Absolute Cover (%) | Relative Cover (%) | Absolute Cover (%) | Relative Cover (%) |
| Muhlenbergia montana (Nutt.) Hitchc. | MUMO1 | G | Y | W | | | | | | | | | | | |
| Sorghastrum nutans (L.) Nash | SONU1 | G | Y | W | | | | 0.3 | 0.5 | | | | | | |
| Sporobolus asper (Michx.) Kunth | SPAS1 | G | Y | W | | | | | | | | | | | |
| Sporobolus cryptandrus (Torr.) A. Gray | SPCR1 | G | Y | W | | | | 0.3 | 0.5 | 0.3 | 0.7 | | | | |
| Unknown species | UNKN | | | | | | | 0.3 | 0.5 | 0.3 | 0.7 | | | 1.5 | 2.8 |
| Total Foliar Cover | | | | | | 51.8 | 100.0 | 48.5 | 100.0 | 38.0 | 100.0 | 43.0 | 100.0 | 54.3 | 100.0 |
| Total Forb Cover | | | | | | 38.3 | 73.9 | 26.0 | 53.6 | 22.0 | 57.9 | 11.2 | 26.0 | 26.8 | 49.3 |
| Total Non-Native Forb Cover | | | | | | 34.8 | 67.1 | 17.5 | 36.1 | 13.0 | 34.2 | 6.0 | 14.0 | 6.5 | 12.0 |
| Total Native Forb Cover | | | | | | 3.5 | 6.8 | 8.5 | 17.5 | 9.0 | 23.7 | 5.2 | 12.0 | 20.3 | 37.3 |
| Total Graminoid Cover | | | | | | 13.5 | 26.1 | 22.3 | 45.9 | 15.8 | 41.4 | 31.8 | 74.0 | 26.0 | 47.9 |
| Total Non-Native Graminoid Cover | | | | | | 7.5 | 14.5 | 4.0 | 8.2 | 0.0 | 0.0 | 2.3 | 5.4 | 5.0 | 9.2 |
| Total Native Graminoid Cover | | | | | | 6.0 | 11.6 | 18.3 | 37.6 | 15.8 | 41.4 | 29.5 | 68.6 | 21.0 | 38.7 |
| Total Native Cover | | | | | | 9.5 | 18.4 | 26.8 | 55.2 | 24.8 | 65.1 | 34.7 | 80.6 | 41.3 | 76.0 |
| Total Non-Native Cover | | | | | | 42.3 | 81.6 | 21.5 | 44.3 | 13.0 | 34.2 | 8.3 | 19.4 | 11.5 | 21.2 |
| Total Warm-Season Graminoid Cover | | | | | | 2.0 | 3.9 | 12.3 | 25.3 | 7.5 | 19.7 | 5.0 | 11.6 | 6.8 | 12.4 |
| Total Cool-Season Graminoid Cover | | | | | | 11.5 | 22.2 | 10.0 | 20.6 | 8.3 | 21.7 | 26.8 | 62.4 | 19.3 | 35.5 |
| Total Noxious Weed Cover | | | | | | 10.8 | 20.8 | 10.8 | 22.2 | 4.3 | 11.2 | 3.2 | 7.4 | 4.0 | 7.4 |

Absolute Cover = The percentage of the number of hits on a species out of the total number of hits possible.
Relative Cover = The percentage of the number of hits on a species out of the total number of vegetation hits.
Native Categories: Y = Native, N = Non-Native
Growth Form Categories: F = Forb, G = Graminoid
Cool/Warm Season Categories: C = Cool-Season Graminoid, W = Warm-Season Graminoid
Noxious Weed Category: X = Noxious Weed (listed on May 2006 Colorado State Noxious Weed List)
Shaded cells indicate success criteria were met in 2006.

*Table 6−14. Species Foliar Cover Summary at Locations A21−A25*

| Scientific Name | Speccode | Growth Form | Native | Cool/ Warm Season | Noxious Weed | A21 | | A22 | | A23 | | A24 | | A25 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Absolute Cover (%) | Relative Cover (%) | Absolute Cover (%) | Relative Cover (%) | Absolute Cover (%) | Relative Cover (%) | Absolute Cover (%) | Relative Cover (%) | Absolute Cover (%) | Relative Cover (%) |
| Alyssum alyssoides (L.) L. | ALAL1 | F | N | | | 0.1 | 0.2 | | | | | | | | |
| Alyssum minus (L.) Rothmaler var. micranthus (C. A. Mey.) Dudley | ALMI1 | F | N | | | | | 0.2 | 0.4 | | | | | 0.2 | 0.8 |
| Amaranthus albus L. | AMAL2 | F | N | | | | | | | | | | | | |
| Carduus nutans L. ssp. macrolepis (Peterm.) Kazmi | CANU1 | F | N | | X | | | 0.1 | 0.2 | | | | | | |
| Centaurea diffusa Lam. | CEDI1 | F | N | | X | 1.8 | 4.1 | 2.8 | 6.5 | 0.5 | 1.9 | | | 1.0 | 5.0 |
| Chenopodium album L. | CHAL1 | F | N | | | 0.1 | 0.2 | | | | | | | | |
| Chrysanthemum leucanthemum L. | CHLE1 | F | N | | X | | | | | | | | | | |
| Cirsium arvense (L.) Scop. | CIAR1 | F | N | | X | 2.3 | 5.2 | 4.3 | 9.9 | | | | | 0.1 | 0.4 |
| Convolvulus arvensis L. | COAR1 | F | N | | X | 2.7 | 6.2 | 0.8 | 1.7 | | | | | | |
| Dyssodia papposa (Vent) Hitchc. | DYPA1 | F | N | | | | | | | | | | | | |
| Erodium cicutarium (L.) L'Her. | ERCI1 | F | N | | X | 1.3 | 3.1 | 0.1 | 0.2 | | | | | 0.6 | 2.9 |
| Kochia scoparia (L.) Schrad. | KOSC1 | F | N | | | 5.5 | 12.7 | 0.2 | 0.4 | | | | | 0.7 | 3.3 |
| Lactuca serriola L. | LASE1 | F | N | | | 2.8 | 6.6 | 0.8 | 1.7 | 1.8 | 6.6 | | | 1.6 | 7.9 |
| Lepidium campestre (L.) R. Br. | LECA1 | F | N | | | | | | | 0.5 | 1.9 | | | | |
| Linaria dalmatica (L.) Mill. | LIDA1 | F | N | | X | | | 0.1 | 0.2 | | | | | | |
| Marrubium vulgare L. | MAVU1 | F | N | | | | | | | | | | | | |
| Melilotus alba Medic. | MEAL1 | F | N | | | 2.5 | 5.8 | | | | | | | | |
| Medicago lupulina L. | MELU1 | F | N | | | | | | | | | | | | |
| Melilotus officinalis (L.) Pall. | MEOF1 | F | N | | | 5.6 | 12.9 | 3.1 | 7.1 | | | | | 1.3 | 6.2 |
| Medicago sativa L. ssp. sativa | MESA1 | F | N | | | | | | | | | | | | |
| Plantago lanceolata L. | PLLA1 | F | N | | | 0.1 | 0.2 | 0.1 | 0.2 | | | | | | |
| Polygonum arenastrum Jord. ex Bor. | POAR1 | F | N | | | 0.3 | 0.6 | | | | | | | | |
| Polygonum persicaria L. | POPE2 | F | N | | | | | | | | | | | | |
| Rumex crispus L. | RUCR1 | F | N | | | | | | | | | | | | |
| Salsola iberica Senn. & Pau. | SAIB1 | F | N | | | 0.5 | 1.2 | 0.3 | 0.6 | | | | | 0.7 | 3.3 |
| Scorzonera laciniata L. | SCLA1 | F | N | | | 0.1 | 0.2 | | | | | | | | |
| Sisymbrium altissimum L. | SIAL1 | F | N | | | | | | | | | | | | |
| Sonchus arvensis L. ssp. uglinosus (Bieb.) Nyman | SOAR2 | F | N | | | | | | | | | | | | |
| Taraxacum officinale Weber | TAOF1 | F | N | | | | | | | | | | | | |
| Tragopogon dubius Scop. | TRDU1 | F | N | | | 0.1 | 0.2 | 0.2 | 0.4 | | | 0.3 | 0.4 | | |
| Verbascum thapsus L. | VETH1 | F | N | | X | | | 0.8 | 1.7 | | | | | | |
| Ambrosia artemisiifolia L. | AMAR1 | F | Y | | | 0.1 | 0.2 | | | | | | | | |
| Ambrosia psilostachya DC. | AMPS1 | F | Y | | | 0.7 | 1.5 | 0.1 | 0.2 | 1.8 | 6.6 | | | | |
| Artemisia campestris L. ssp. caudata (Michx.) Hall & Clem. | ARCA1 | F | Y | | | | | | | | | | | | |
| Artemisia frigida Willd. | ARFR1 | F | Y | | | | | | | | | | | | |
| Astragalus canadensis L. | ASCA1 | F | Y | | | | | | | | | | | | |
| Aster porteri Gray | ASPO1 | F | Y | | | | | | | | | | | | |
| Asclepias speciosa Torr. | ASSP1 | F | Y | | | | | 0.2 | 0.4 | | | | | | |
| Chenopodium fremontii S. Wats. | CHFR1 | F | Y | | | 0.1 | 0.2 | | | | | | | | |
| Chrysopsis fulcrata Greene | CHFU1 | F | Y | | | | | 0.5 | 1.1 | | | | | | |
| Chenopodium leptophyllum Nutt. ex Moq. | CHLE2 | F | Y | | | | | | | | | | | | |
| Conyza canadensis (L.) Cronq. | COCA1 | F | Y | | | | | | | 0.3 | 0.9 | | | | |

*Table 6−14 (continued). Species Foliar Cover Summary at Locations A21−A25*

| Scientific Name | Speccode | Growth Form | Native | Cool/ Warm Season | Noxious Weed | A21 | | A22 | | A23 | | A24 | | A25 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Absolute Cover (%) | Relative Cover (%) | Absolute Cover (%) | Relative Cover (%) | Absolute Cover (%) | Relative Cover (%) | Absolute Cover (%) | Relative Cover (%) | Absolute Cover (%) | Relative Cover (%) |
| Comandra umbellata (L.) Nutt. | COUM1 | F | Y | | | | | | | | | | | | |
| Erysimum capitatum (Nutt.) DC. | ERCA2 | F | Y | | | | | | | | | | | | |
| Erigeron divergens T. & G. | ERDI1 | F | Y | | | | | 0.1 | 0.2 | | | | | | |
| Euphorbia serpyllifolia Pers. | EUSE1 | F | Y | | | | | 0.1 | 0.2 | | | | | | |
| Grindelia squarrosa (Pursh.) Dun. | GRSQ1 | F | Y | | | 0.6 | 1.4 | 0.7 | 1.5 | 1.5 | 5.7 | | | | |
| Helianthus annuus L. | HEAN1 | F | Y | | | 0.5 | 1.2 | | | | | | | | |
| Lesquerella montana (A. Gray) Wats. | LEMO1 | F | Y | | | | | | | | | | | | |
| Linum perenne L. var. lewisii (Pursh.) Eat. & Wright | LIPE1 | F | Y | | | | | 0.2 | 0.4 | | | | | | |
| Liatris punctata Hook. | LIPU1 | F | Y | | | | | | | | | | | | |
| Mirabilis linearis (Pursh.) Heimerl | MILI1 | F | Y | | | | | | | | | | | | |
| Onosmodium molle Michx. var. occidentale (Mack.) Johnst. | ONMO1 | F | Y | | | | | 0.1 | 0.2 | | | | | | |
| Plantago patagonica Jacq. | PLPA1 | F | Y | | | | | | | | | | | | |
| Psoralea tenuiflora Pursh. | PSTE1 | F | Y | | | | | 0.6 | 1.3 | | | | | | |
| Solanum rostratum Dun. | SORO1 | F | Y | | | | | | | | | | | | |
| Sphaeralcea coccinea (Pursh.) Rydb. | SPCO1 | F | Y | | | | | 0.5 | 1.1 | | | | | | |
| Thelesperma megapotanicum (Spreng.) O. Ktze. | THME1 | F | Y | | | | | | | | | | | | |
| Verbena bracteata Lag. & Rodr. | VEBR1 | F | Y | | | 0.3 | 0.6 | 0.6 | 1.3 | | | | | | |
| Aegilops cylindrica Host | AECY1 | G | N | C | X | | | 0.1 | 0.2 | | | | | 0.6 | 2.9 |
| Agropyron cristatum (L.) Gaertn. | AGCR1 | G | N | C | | 0.1 | 0.2 | | | | | | | | |
| Agropyron intermedium (Host) Beauv. | AGIN1 | G | N | C | | | | | | | | 9.3 | 13.5 | | |
| Bromus inermis Leyss. ssp. inermis | BRIN1 | G | N | C | | 0.3 | 0.6 | 2.7 | 6.1 | | | | | | |
| Bromus japonicus Thunb. ex Murr. | BRJA1 | G | N | C | | | | 0.3 | 0.8 | | | | | | |
| Bromus tectorum L. | BRTE1 | G | N | C | X | 0.2 | 0.4 | 1.0 | 2.3 | | | 15.5 | 22.6 | 0.7 | 3.3 |
| Festuca pratensis Huds. | FEPR1 | G | N | C | | | | 0.1 | 0.2 | | | | | | |
| Poa compressa L. | POCO1 | G | N | C | | | | | | | | | | | |
| Poa pratensis L. | POPR1 | G | N | C | | 0.1 | 0.2 | | | | | | | | |
| Triticum aestivum L. | TRAE1 | G | N | C | | | | 0.1 | 0.2 | | | | | 2.6 | 12.8 |
| Digitaria sanguinalis (L.) Scop. | DISA1 | G | N | W | | | | | | | | | | | |
| Echinochloa crusgallii (L.) Beauv. | ECCR1 | G | N | W | | | | | | | | | | | |
| Setaria viridis (L.) Beauv. | SEVI1 | G | N | W | | | | | | | | | | | |
| Agropyron caninum (L.) Beauv. ssp. majus (Vasey) C. L. Hitchc. | AGCA1 | G | Y | C | | 8.9 | 20.7 | 9.0 | 20.7 | 7.8 | 29.2 | 0.3 | 0.4 | 6.4 | 31.8 |
| Agropyron dasystachyum (Hook.) Scribn. | AGDA1 | G | Y | C | | | | | | | | | | | |
| Agropyron smithii Rydb. | AGSM1 | G | Y | C | | 1.8 | 4.2 | 2.4 | 5.5 | 6.5 | 24.5 | 15.3 | 22.3 | 3.2 | 15.7 |
| Elymus canadensis L. | ELCA1 | G | Y | C | | | | | | | | | | | |
| Hordeum jubatum L. | HOJU1 | G | Y | C | | 0.1 | 0.2 | | | | | | | | |
| Hordeum pusillum Nutt. | HOPU1 | G | Y | C | | | | | | | | | | | |
| Koeleria pyramidata (Lam.) Beauv. | KOPY1 | G | Y | C | | | | | | | | | | | |
| Stipa comata Trin. & Rupr. | STCO1 | G | Y | C | | | | | | | | | | | |
| Stipa viridula Trin. | STVI1 | G | Y | C | | | | 0.5 | 1.1 | | | 20.5 | 29.9 | | |
| Andropogon gerardii Vitman | ANGE1 | G | Y | W | | 0.3 | 0.6 | 0.6 | 1.3 | | | | | | |
| Andropogon scoparius Michx. | ANSC1 | G | Y | W | | | | | | | | | | | |
| Bouteloua curtipendula (Michx.) Torr. | BOCU1 | G | Y | W | | 2.2 | 5.0 | 4.8 | 10.9 | 3.0 | 11.3 | 0.3 | 0.4 | 0.5 | 2.5 |
| Bouteloua gracilis (H. B. K.) Lag ex Griffiths | BOGR1 | G | Y | W | | 0.9 | 2.1 | 0.7 | 1.5 | 3.0 | 11.3 | 1.5 | 2.2 | 0.3 | 1.2 |
| Buchloe dactyloides (Nutt.) Engelm. | BUDA1 | G | Y | W | | 0.7 | 1.5 | 2.3 | 5.2 | | | 2.0 | 2.9 | | |

*Table 6−14 (continued). Species Foliar Cover Summary at Locations A21−A25*

| Scientific Name | Speccode | Growth Form | Native | Cool/ Warm Season | Noxious Weed | A21 | | A22 | | A23 | | A24 | | A25 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Absolute Cover (%) | Relative Cover (%) | Absolute Cover (%) | Relative Cover (%) | Absolute Cover (%) | Relative Cover (%) | Absolute Cover (%) | Relative Cover (%) | Absolute Cover (%) | Relative Cover (%) |
| Muhlenbergia montana (Nutt.) Hitchc. | MUMO1 | G | Y | W | | | | | | | | | | | |
| Sorghastrum nutans (L.) Nash | SONU1 | G | Y | W | | | | | | | | | | | |
| Sporobolus asper (Michx.) Kunth | SPAS1 | G | Y | W | | | | 2.1 | 4.8 | | | 3.8 | 5.5 | | |
| Sporobolus cryptandrus (Torr.) A. Gray | SPCR1 | G | Y | W | | | | | | | | | | | |
| Unknown species | UNKN | | | | | | | | | | | | | | |
| Total Foliar Cover | | | | | | 43.2 | 100.0 | 43.6 | 100.0 | 26.5 | 100.0 | 68.5 | 100.0 | 20.2 | 100.0 |
| Total Forb Cover | | | | | | 27.8 | 64.3 | 17.1 | 39.2 | 6.3 | 23.6 | 0.3 | 0.4 | 6.0 | 29.8 |
| Total Non-Native Forb Cover | | | | | | 25.6 | 59.3 | 13.6 | 31.2 | 2.8 | 10.4 | 0.3 | 0.4 | 6.0 | 29.8 |
| Total Native Forb Cover | | | | | | 2.2 | 5.0 | 3.5 | 8.0 | 3.5 | 13.2 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total Graminoid Cover | | | | | | 15.4 | 35.7 | 26.5 | 60.8 | 20.3 | 76.4 | 68.3 | 99.6 | 14.2 | 70.2 |
| Total Non-Native Graminoid Cover | | | | | | 0.6 | 1.4 | 4.3 | 9.8 | 0.0 | 0.0 | 24.8 | 36.1 | 3.8 | 19.0 |
| Total Native Graminoid Cover | | | | | | 14.8 | 34.4 | 22.3 | 51.1 | 20.3 | 76.4 | 43.5 | 63.5 | 10.3 | 51.2 |
| Total Native Cover | | | | | | 17.0 | 39.4 | 25.8 | 59.1 | 23.8 | 89.6 | 43.5 | 63.5 | 10.3 | 51.2 |
| Total Non-Native Cover | | | | | | 26.2 | 60.6 | 17.8 | 40.9 | 2.8 | 10.4 | 25.0 | 36.5 | 9.8 | 48.8 |
| Total Warm-Season Graminoid Cover | | | | | | 4.0 | 9.3 | 10.3 | 23.7 | 6.0 | 22.6 | 7.5 | 10.9 | 0.8 | 3.7 |
| Total Cool-Season Graminoid Cover | | | | | | 11.4 | 26.4 | 16.2 | 37.1 | 14.3 | 53.8 | 60.8 | 88.7 | 13.4 | 66.5 |
| Total Noxious Weed Cover | | | | | | 8.2 | 18.9 | 10.0 | 22.9 | 0.5 | 1.9 | 15.5 | 22.6 | 2.9 | 14.5 |

Absolute Cover = The percentage of the number of hits on a species out of the total number of hits possible.
Relative Cover = The percentage of the number of hits on a species out of the total number of vegetation hits.
Native Categories: Y = Native, N = Non-Native
Growth Form Categories: F = Forb, G = Graminoid
Cool/Warm Season Categories: C = Cool-Season Graminoid, W = Warm-Season Graminoid
Noxious Weed Category: X = Noxious Weed (listed on May 2006 Colorado State Noxious Weed List)
Shaded cells indicate success criteria were met in 2006.

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Table 6−15 presents a summary of the pass/fail criteria for each revegetation location monitored in 2006. Eight of the locations passed all four criteria in 2006. It is not unexpected that most failed at this point in time, as it often takes 5 or 6 years to establish a good stand of vegetation. It should also be remembered that the success criteria listed in the Revegetation Plan are an initial set of criteria established primarily for erosion protection. As stated in the Revegetation Plan, these "...criteria are provided as initial guidance; however, common sense combined with scientific data will need to be applied to final evaluations to determine whether further management actions are required at specific locations" (DOE 2005c). It should also be noted that the success criteria listed in the Revegetation Plan were taken from the Rocky Mountain Arsenal (RMA) National Wildlife Refuge Habitat Restoration Plan (USFWS 1999) and are the criteria that is used at the RMA. So although some of the areas passed each of the criteria listed in the Revegetation Plan, this does not mean that the vegetation has established to a desirable level at these locations as of 2006. Some of the revegetation locations may require some reseeding and weed control also. The drought experienced in 2006 also limited the amount of vegetation growth observed this year. Normal precipitation amounts should result in increased vegetation growth in future years. Proactive management of the revegetation areas is critical to success. These data provide useful information for making management decisions and provide documentation of the successional changes at the revegetation locations that can then be used to help improve revegetation techniques at the Site.

### 6.2.4 Present Landfill/Original Landfill Monitoring

As part of the cleanup and closure of the Site, two landfills were covered using different types for covers. At the PLF, a RCRA Subtitle C-compliant cover was constructed to protect the underlying waste. At the OLF, a 2-foot-thick soil cover was placed over the waste material. Both areas were seeded with native plant species to provide a vegetation cover on each landfill. As part of the revegetation process, monitoring is conducted to evaluate the status of the vegetation. The Rocky Flats, Colorado, Site Revegetation Plan (Revegetation Plan; DOE 2005c) provides initial success criteria for revegetation areas at the Site. As stated in the plan the success criteria contained in the Revegetation Plan are simply initial guidance and may be modified using professional judgment, scientific data, and common sense to determine whether the vegetation establishment at a given location is acceptable for the specific location(s). This report summarizes the revegetation monitoring results for data collected at the PLF and OLF during 2006.

Semi-quantitative revegetation monitoring was conducted during late summer to evaluate the establishment of vegetation at the PLF and OLF in 2006. The PLF was divided into three revegetation sampling units, two on the cover and one on the east face (Figure 6–7). The OLF was sampled as one unit (Figure 6–7). Within each revegetation unit, sample locations were randomly generated in the GIS and then located on the ground using a GPS for monitoring. Quadrats (0.5 m2; 50 cm × 100 cm) were used to sample the vegetation. A total of 15 quadrats were sampled on each half of the cover at the PLF, with an additional 10 quadrats sampled on the east face of the PLF. The top of the cover was roughly split in half because the eastern and western areas differed somewhat in the soil materials that were placed on each half. So the sampling was designed to see if there was a difference in the vegetation. The OLF had a total of 30 quadrats sampled across the face of the cover. At each quadrat, both species richness and species cover were sampled.

*Table 6−15. Success Criteria Summary for Revegetation Locations in 2006*

| Location | Minimum of 50% of Seeded Species Present | 70% Ground Cover of Litter, Rock, and Vegetation | 30% Relative Cover of Desired Species | No Single Species With >45% Relative Cover | Overall Pass/Fail |
|---|---|---|---|---|---|
| A1 | Fail | Fail | Fail | Pass | Fail |
| A2 | Fail | Fail | Fail | Pass | Fail |
| A3 | Fail | Pass | Pass | Pass | Fail |
| A4 | Pass | Pass | Pass | Pass | Pass |
| A5 | Fail | Fail | Fail | Pass | Fail |
| A6 | Pass | Fail | Pass | Pass | Fail |
| A7 | Fail | Fail | Pass | Pass | Fail |
| A8 | Pass | Pass | Pass | Pass | Pass |
| A9 | Fail | Fail | Pass | Pass | Fail |
| A10 | Pass | Pass | Pass | Fail | Fail |
| A11 | Fail | Fail | Fail | Pass | Fail |
| A12 | Fail | Fail | Fail | Pass | Fail |
| A13 | Fail | Pass | Pass | Pass | Fail |
| A14 | Pass | Fail | Pass | Pass | Fail |
| A15 | Pass | Pass | Pass | Pass | Pass |
| A16 | Fail | Pass | Fail | Pass | Fail |
| A17 | Pass | Pass | Pass | Pass | Pass |
| A18 | Pass | Fail | Pass | Pass | Fail |
| A19 | Pass | Pass | Pass | Fail | Fail |
| A20 | Fail | Pass | Pass | Pass | Fail |
| A21 | Pass | Fail | Pass | Pass | Fail |
| A22 | Pass | Pass | Pass | Pass | Pass |
| A23 | Pass | Pass | Pass | Pass | Pass |
| A24 | Pass | Pass | Pass | Pass | Pass |
| A25 | Pass | Pass | Pass | Pass | Pass |

Notes: Shaded locations pass success criteria in 2006.

Species richness in 2006 at both the PLF and OLF is presented in Table 6−16. Total species richness at the PLF was 35 species in 2006, while the OLF had 15 species. Much of this is related to the fact that 2006 was the second growing season for the PLF, while 2006 was really the first growing season for the OLF since the projects were completed. Additionally, the drought in 2006 limited germination and establishment on the south-facing OLF. At the PLF, a total of eight seed species were present in 2006. Table 6−17 lists the species that were seeded at each landfill. At the OLF, a total of four seeded species were present in 2006. One of the success criteria in the Revegetation Plan (DOE 2005c) states that at least 50 percent of the seeded species must be present in an area for it to be considered successful. Table 6−18 lists the location, number of seeded species, number of species present at the location, and percentage present at each location in 2006. All four sampled areas on the landfills met this criteria in 2006.

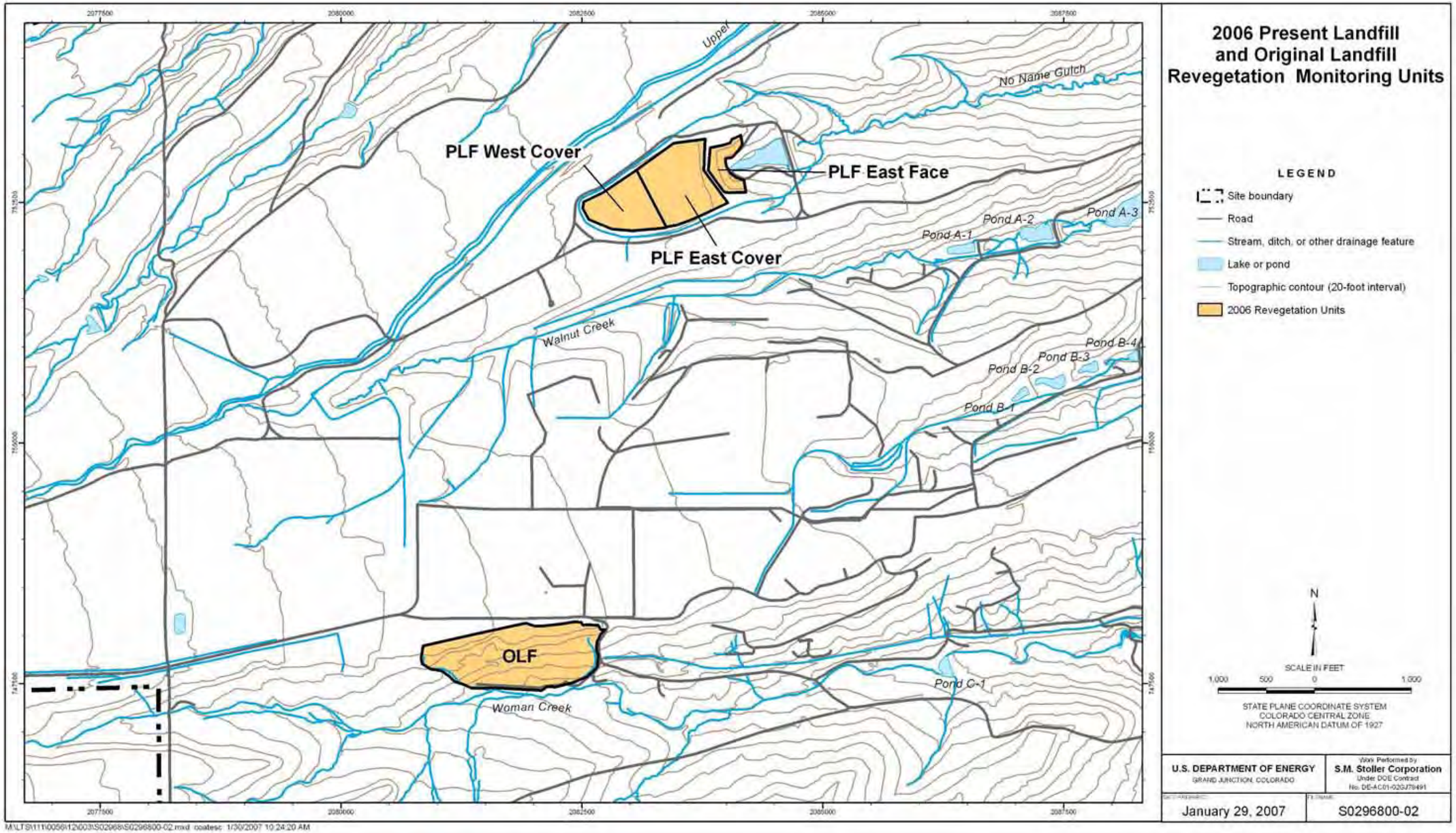


*Figure 6–7. 2006 Present Landfill and Original Landfill Revegetation Monitoring Units*

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*Table 6−16. 2006 Species Richness Summary at the PLF and OLF*

| Family | Scientific Name | Speccode | Native | Noxious Weed | PLF East Cover | PLF West Cover | PLF East Face | OLF |
|---|---|---|---|---|---|---|---|---|
| ASTERACEAE | Ambrosia psilostachya DC. | AMPS1 | Y | | | | X | |
| ASTERACEAE | Aster porteri Gray | ASPO1 | Y | | X | | | |
| ASTERACEAE | Carduus nutans L. ssp. macrolepis (Peterm.) Kazmi | CANU1 | N | X | | | | |
| ASTERACEAE | Centaurea diffusa Lam. | CEDI1 | N | X | X | X | X | X |
| ASTERACEAE | Chrysanthemum leucanthemum L. | CHLE1 | N | X | | | | |
| ASTERACEAE | Cirsium arvense (L.) Scop. | CIAR1 | N | X | | | | X |
| ASTERACEAE | Conyza canadensis (L.) Cronq. | COCA1 | Y | | X | | X | |
| ASTERACEAE | Grindelia squarrosa (Pursh.) Dun. | GRSQ1 | Y | | X | X | X | |
| ASTERACEAE | Lactuca serriola L. | LASE1 | N | | X | X | X | X |
| ASTERACEAE | Taraxacum officinale Weber | TAOF1 | N | | X | X | | |
| ASTERACEAE | Tragopogon dubius Scop. | TRDU1 | N | | | X | | |
| BRASSICACEAE | Alyssum minus (L.) Rothmaler var. micranthus (C. A. Mey.) Dudley | ALMI1 | N | | | | | X |
| BRASSICACEAE | Lepidium campestre (L.) R. Br. | LECA1 | N | | X | X | X | |
| CHENOPODIACEAE | Kochia scoparia (L.) Schrad. | KOSC1 | N | | | | | X |
| CHENOPODIACEAE | Salsola iberica Senn. & Pau. | SAIB1 | N | | | | | X |
| CONVOLVULACEAE | Convolvulus arvensis L. | COAR1 | N | X | | X | | |
| FABACEAE | Melilotus alba Medic. | MEAL1 | N | | | X | | |
| FABACEAE | Melilotus officinalis (L.) Pall. | MEOF1 | N | | X | X | | X |
| GERANIACEAE | Erodium cicutarium (L.) L'Her. | ERCI1 | N | X | | X | | X |
| PLANTAGINACE | Plantago lanceolata L. | PLLA1 | N | | | X | | |
| POACEAE | Aegilops cylindrica Host | AECY1 | N | X | | | | X |
| POACEAE | Agropyron caninum (L.) Beauv. ssp. majus (Vasey) C. L. Hitchc. | AGCA1 | Y | | X | X | X | X |
| POACEAE | Agropyron smithii Rydb. | AGSM1 | Y | | X | X | X | X |
| POACEAE | Andropogon gerardii Vitman | ANGE1 | Y | | X | X | | |
| POACEAE | Andropogon scoparius Michx. | ANSC1 | Y | | X | X | | |
| POACEAE | Bouteloua curtipendula (Michx.) Torr. | BOCU1 | Y | | X | X | X | X |
| POACEAE | Bouteloua gracilis (H. B. K.) Lag ex Griffiths | BOGR1 | Y | | X | | X | X |
| POACEAE | Bromus japonicus Thunb. ex Murr. | BRJA1 | N | | | X | | |

*Table 6−16 (continued). 2006 Species Richness Summary at the PLF and OLF*

| Family | Scientific Name | Speccode | Native | Noxious Weed | PLF East Cover | PLF West Cover | PLF East Face | OLF |
|---|---|---|---|---|---|---|---|---|
| POACEAE | Bromus tectorum L. | BRTE1 | N | X | X | X | | X |
| POACEAE | Buchloe dactyloides (Nutt.) Engelm. | BUDA1 | Y | | X | X | | |
| POACEAE | Festuca pratensis Huds. | FEPR1 | N | | | X | | |
| POACEAE | Hordeum jubatum L. | HOJU1 | Y | | | X | | |
| POACEAE | Koeleria pyramidata (Lam.) Beauv. | KOPY1 | Y | | | X | | |
| POACEAE | Poa compressa L. | POCO1 | N | | X | X | | |
| POACEAE | Triticum aestivum L. | TRAE1 | N | | | | | X |
| SANTALACEAE | Comandra umbellata (L.) Nutt. | COUM1 | Y | | X | | | |
| SCROPHULARIACEAE | Linaria dalmatica (L.) Mill. | LIDA1 | N | X | | | | |
| SCROPHULARIACEAE | Verbascum thapsus L. | VETH1 | N | X | | X | | |
| VERBENACEAE | Verbena bracteata Lag. & Rodr. | VEBR1 | Y | | X | X | | |
| | Unknown species | UNKN | | | | | | |
| | | Total Number of Species | | | 19 | 25 | 10 | 15 |
| | | Grand Total | | | 35 | | 15 | |

*Table 6−17. Seeded Species By Location*

| Family<br>Graminoids | Scientific Name | PLF | OLF |
|---|---|---|---|
| POACEAE | Agropyron caninum | X | X |
| POACEAE | Agropyron dasystachum | X | X |
| POACEAE | Agropyron lanceolatus | X | |
| POACEAE | Agropyron smithii | X | X |
| POACEAE | Andropogon gerardii | X | |
| POACEAE | Andropogon scoparius | | |
| POACEAE | Bouteloua curtipendula | X | X |
| POACEAE | Bouteloua gracilis | X | X |
| POACEAE | Buchloe dactyloides | X | X |
| POACEAE | Koleria pyrimidata | X | |
| POACEAE | Poa canbyi | X | |
| POACEAE | Sorghastrum nutans | X | |
| POACEAE | Sporobolus cryptandrus | X | |
| POACEAE | Stipa viridula | X | X |
| | Total # Species Seeded | 13 | 7 |

*Table 6−18. Number of Seeded Species Present in 2006 Summary*

| Location | # Species Seeded at Location | # Seeded Species Present in 2006 | % Seeded Species Present in 2006 |
|---|---|---|---|
| PLF East Cover | 13 | 7 | 54 |
| PLF West Cover | 13 | 7 | 54 |
| PLF East Face | 7 | 4 | 57 |
| OLF | 7 | 4 | 57 |

Notes: Shaded locations pass success criteria in 2006.

Ground cover protection from rock, litter, and current year live vegetation was above 95 percent at both the PLF and OLF (Table 6−19). The occasional value over 100 percent is a result of the cover class system used for estimating cover which estimates cover values into a range and uses the midpoint of the cover class for analysis. Another success criterion outlined in the Revegetation Plan (DOE 2005c), states a minimum of 70 percent total ground cover comprised of litter cover, current year live vegetation basal cover, and rock cover is to be present to help prevent erosion. At each of the locations on the PLF and OLF most of the ground cover came from litter, which at this time represents the erosion matting. In time the litter cover will continue to remain the dominant ground cover but it will come from dead plant material that is matted down, rather from the erosion matting. The bottom line is that at both locations there is substantial protection on the soil surface to prevent erosion.

*Table 6−19. 2006 Rock, Litter, and Basal Vegetation Cover Summary*

| Location | Basal Veg Cover | Rock Cover | Litter Cover | Total Ground Cover |
|---|---|---|---|---|
| PLF East Cover | 2.5 | 21.0 | 75.2 | 98.7 |
| PLF West Cover | 3.3 | 13.3 | 79.0 | 95.7 |
| PLF East Face | 2.5 | 9.8 | 90.0 | 102.3 |
| OLF | 3.1 | 11.3 | 85.0 | 99.3 |

Notes: All values are percentages.
Some values exceed 100% because of the use of cover class midpoints for data collection and analyses.
Shaded locations pass success criteria in 2006.

A third success criterion outlined in the Revegetation Plan (DOE 2005c), states that a minimum of 30 percent relative cover of desired species must be present and a forth criterion states that no single species comprise more than 45 percent of the total relative cover. Table 6−20 summarizes the foliar cover data for the PLF and OLF by location for 2006. The shaded row titled Total Native Cover represents the percentage of desired species at each location. The relative cover values at individual locations that are higher than 30 percent are shaded, indicating these locations have met this success criterion. This criteria was met at both the PLF and OLF in 2006. Based on actual absolute cover, however, the total actual amount of vegetation cover would have only met at the East and West PLF cover locations with approximately 35 percent cover at each area. The East Face of the PLF and the OLF still had much lower vegetation cover present on them in 2006. The dominant species on the cover of the PLF were slender wheatgrass, side-oats grama (*Bouteloua curtipendula*), big bluestem (*Andropogon gerardii*), and western wheatgrass. The East Face of the PLF was dominated by slender wheatgrass, western wheatgrass, side-oats grama, and blue grama (*Bouteloua gracilis*). Weed cover from forbs on the PLF was not very high in 2006 because most of the top had been treated with Milestone (aminopyralid) in spring of 2006 to keep the weeds down to allow for better establishment of the graminoids. On the OLF, the dominant species were slender wheatgrass, western wheatgrass, and wheat. The relative cover of slender wheatgrass on the West PLF area was above the 45 percent value for a single species. Otherwise no other species comprised greater than 45 percent of the relative cover at either the PLF or OLF.

*Table 6−20. 2006 Species Foliar Cover Summary at the PLF and OLF*

| Scientific Name | Speccode | Growth Form | Native | Cool/ Warm Season | Noxious Weed | PLF East Cover | | PLF West Cover | | PLF East Face | | OLF | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Absolute Cover (%) | Relative Cover (%) | Absolute Cover (%) | Relative Cover (%) | Absolute Cover (%) | Relative Cover (%) | Absolute Cover (%) | Relative Cover (%) |
| Alyssum minus (L.) Rothmaler var. micranthus (C. A. Mey.) Dudley | ALMI1 | F | N | | | | | | | | | 0.2 | 0.8 |
| Centaurea diffusa Lam. | CEDI1 | F | N | | X | 1.0 | 2.6 | 1.2 | 2.7 | 0.5 | 1.9 | 1.0 | 5.0 |
| Cirsium arvense (L.) Scop. | CIAR1 | F | N | | X | | | | | | | 0.1 | 0.4 |
| Convolvulus arvensis L. | COAR1 | F | N | | X | | | 0.2 | 0.4 | | | | |
| Erodium cicutarium (L.) L'Her. | ERCI1 | F | N | | X | | | 1.3 | 3.1 | | | 0.6 | 2.9 |
| Kochia scoparia (L.) Schrad. | KOSC1 | F | N | | | | | | | | | 0.7 | 3.3 |
| Lactuca serriola L. | LASE1 | F | N | | | 0.5 | 1.3 | 0.8 | 1.9 | 1.8 | 6.6 | 1.6 | 7.9 |
| Lepidium campestre (L.) R. Br. | LECA1 | F | N | | | 0.2 | 0.4 | 0.2 | 0.4 | 0.5 | 1.9 | | |
| Melilotus alba Medic. | MEAL1 | F | N | | | | | 0.2 | 0.4 | | | | |
| Melilotus officinalis (L.) Pall. | MEOF1 | F | N | | | 1.3 | 3.5 | 1.3 | 3.1 | | | 1.3 | 6.2 |
| Plantago lanceolata L. | PLLA1 | F | N | | | | | 0.2 | 0.4 | | | | |
| Salsola iberica Senn. & Pau. | SAIB1 | F | N | | | | | | | | | 0.7 | 3.3 |
| Taraxacum officinale Weber | TAOF1 | F | N | | | 0.2 | 0.4 | 0.2 | 0.4 | | | | |
| Tragopogon dubius Scop. | TRDU1 | F | N | | | | | 0.2 | 0.4 | | | | |
| Verbascum thapsus L. | VETH1 | F | N | | X | | | 0.3 | 0.8 | | | | |
| Ambrosia psilostachya DC. | AMPS1 | F | Y | | | | | | | 1.8 | 6.6 | | |
| Aster porteri Gray | ASPO1 | F | Y | | | 0.2 | 0.4 | | | | | | |
| Conyza canadensis (L.) Cronq. | COCA1 | F | Y | | | 0.5 | 1.3 | | | 0.3 | 0.9 | | |
| Comandra umbellata (L.) Nutt. | COUM1 | F | Y | | | 0.2 | 0.4 | | | | | | |
| Grindelia squarrosa (Pursh.) Dun. | GRSQ1 | F | Y | | | 0.2 | 0.4 | 0.5 | 1.2 | 1.5 | 5.7 | | |
| Verbena bracteata Lag. & Rodr. | VEBR1 | F | Y | | | 2.3 | 6.1 | 4.7 | 10.9 | | | | |
| Aegilops cylindrica Host | AECY1 | G | N | C | X | | | | | | | 0.6 | 2.9 |
| Bromus japonicus Thunb. ex Murr. | BRJA1 | G | N | C | | | | 0.2 | 0.4 | | | | |
| Bromus tectorum L. | BRTE1 | G | N | C | X | 0.2 | 0.4 | 0.2 | 0.4 | | | 0.7 | 3.3 |
| Festuca pratensis Huds. | FEPR1 | G | N | C | | | | 1.3 | 3.1 | | | | |
| Poa compressa L. | POCO1 | G | N | C | | 0.2 | 0.4 | 0.7 | 1.6 | | | | |
| Triticum aestivum L. | TRAE1 | G | N | C | | | | | | | | 2.6 | 12.8 |
| Agropyron caninum (L.) Beauv. ssp. majus (Vasey) C. L. Hitchc. | AGCA1 | G | Y | C | | 14.7 | 38.6 | 21.2 | 49.2 | 7.8 | 29.2 | 6.4 | 31.8 |
| Agropyron smithii Rydb. | AGSM1 | G | Y | C | | 2.2 | 5.7 | 3.0 | 7.0 | 6.5 | 24.5 | 3.2 | 15.7 |
| Hordeum jubatum L. | HOJU1 | G | Y | C | | | | 0.2 | 0.4 | | | | |
| Koeleria pyramidata (Lam.) Beauv. | KOPY1 | G | Y | C | | | | 0.2 | 0.4 | | | | |
| Andropogon gerardii Vitman | ANGE1 | G | Y | W | | 5.5 | 14.5 | 3.0 | 7.0 | | | | |
| Andropogon scoparius Michx. | ANSC1 | G | Y | W | | 0.2 | 0.4 | 0.2 | 0.4 | | | | |
| Bouteloua curtipendula (Michx.) Torr. | BOCU1 | G | Y | W | | 6.2 | 16.2 | 0.7 | 1.6 | 3.0 | 11.3 | 0.5 | 2.5 |
| Bouteloua gracilis (H. B. K.) Lag ex Griffiths | BOGR1 | G | Y | W | | 0.5 | 1.3 | | | 3.0 | 11.3 | 0.3 | 1.2 |
| Buchloe dactyloides (Nutt.) Engelm. | BUDA1 | G | Y | W | | 2.0 | 5.3 | 1.2 | 2.7 | | | | |
| Total Foliar Cover | | | | | | 38.0 | 100.0 | 43.0 | 100.0 | 26.5 | 100.0 | 20.2 | 100.0 |
| Total Forb Cover | | | | | | 6.5 | 17.1 | 11.2 | 26.0 | 6.3 | 23.6 | 6.0 | 29.8 |
| Total Non-Native Forb Cover | | | | | | 3.2 | 8.3 | 6.0 | 14.0 | 2.8 | 10.4 | 6.0 | 29.8 |
| Total Native Forb Cover | | | | | | 3.3 | 8.8 | 5.2 | 12.0 | 3.5 | 13.2 | 0.0 | 0.0 |
| Total Graminoid Cover | | | | | | 31.5 | 82.9 | 31.8 | 74.0 | 20.3 | 76.4 | 14.2 | 70.2 |
| Total Non-Native Graminoid Cover | | | | | | 0.3 | 0.9 | 2.3 | 5.4 | 0.0 | 0.0 | 3.8 | 19.0 |
| Total Native Graminoid Cover | | | | | | 31.2 | 82.0 | 29.5 | 68.6 | 20.3 | 76.4 | 10.3 | 51.2 |

*Table 6−20 (continued). 2006 Species Foliar Cover Summary at the PLF and OLF*

| Scientific Name | Speccode | Growth Form | Native | Cool/ Warm Season | Noxious Weed | PLF East Cover | | PLF West Cover | | PLF East Face | | OLF | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Absolute Cover (%) | Relative Cover (%) | Absolute Cover (%) | Relative Cover (%) | Absolute Cover (%) | Relative Cover (%) | Absolute Cover (%) | Relative Cover (%) |
| Total Native Cover | | | | | | 34.5 | 90.8 | 34.7 | 80.6 | 23.8 | 89.6 | 10.3 | 51.2 |
| Total Non-Native Cover | | | | | | 3.5 | 9.2 | 8.3 | 19.4 | 2.8 | 10.4 | 9.8 | 48.8 |
| Total Warm-Season Graminoid Cover | | | | | | 14.3 | 37.7 | 5.0 | 11.6 | 6.0 | 22.6 | 0.8 | 3.7 |
| Total Cool-Season Graminoid Cover | | | | | | 17.2 | 45.2 | 26.8 | 62.4 | 14.3 | 53.8 | 13.4 | 66.5 |
| Total Noxious Weed Cover | | | | | | 1.2 | 3.1 | 3.2 | 7.4 | 0.5 | 1.9 | 2.9 | 14.5 |

Absolute Cover = The percentage of the number of hits on a species out of the total number of hits possible.
Relative Cover = The percentage of the number of hits on a species out of the total number of vegetation hits.
Native Categories: Y = Native, N = Non-Native
Growth Form Categories: F = Forb, G = Graminoid
Cool/Warm Season Categories: C = Cool-Season Graminoid, W = Warm-Season Graminoid
Noxious Weed Category: X = Noxious Weed (listed on May 2006 Colorado State Noxious Weed List)
Shaded cells indicate success criteria were met in 2006.

Table 6−21 presents a summary of the pass/fail criteria for each revegetation areas at the PLF and OLF monitored in 2006. Three of the four locations passed all four criteria in 2006. The only area that did not pass was the East Face of the PLF which had greater than 45 percent cover of slender wheatgrass. An important issue to keep in mind when considering success criteria are that the criteria listed in the Revegetation Plan are an initial set of criteria established primarily for erosion protection. As stated in the Revegetation Plan, these "...criteria are provided as initial guidance; however, common sense combined with scientific data will need to be applied to final evaluations to determine whether further management actions are required at specific locations" (DOE 2005c). It should also be noted that the success criteria listed in the Revegetation Plan were taken from the RMA National Wildlife Refuge Habitat Restoration Plan (USFWS 1999) and are the criteria that is used at the RMA. So although three of the areas passed each of the criteria listed in the Revegetation Plan, this does not mean that the vegetation has established to a desirable level at either landfill as of 2006. Continued management and monitoring to promote a long-term, sustainable, vegetation cover on both landfills will continue to be pursued. A good healthy stand of vegetation is desirable on both landfills to protect the covers and provide good erosion control. Proactive management of the revegetation areas is critical to success. These data provide useful information for making management decisions and provide documentation of the successional changes at the revegetation locations that can then also be used to help improve revegetation techniques at the Site.

*Table 6−21. Success Criteria Summary for Revegetation Locations in 2006*

| Location | Minimum of 50% of Seeded Species Present | 70% Ground Cover of Litter, Rock, and Vegetation | 30% Relative Cover of Desired Species | No Single Species With >45% Relative Cover | Overall Pass/Fail |
|---|---|---|---|---|---|
| PLF East Cover | Pass | Pass | Pass | Pass | Pass |
| PLF West Cover | Pass | Pass | Pass | Fail | Fail |
| PLF East Face | Pass | Pass | Pass | Pass | Pass |
| OLF | Pass | Pass | Pass | Pass | Pass |

Notes: Shaded locations pass success criteria in 2006.

### 6.2.5 Diffuse Knapweed Biological Control Monitoring

Diffuse knapweed is one of the noxious weeds at the Site. A variety of control methods have been used to control diffuse knapweed at the Site, including biological, mechanical, and chemical control methods. Biological control measures are low cost, have a low impact to surrounding habitat and non-target vegetation, and may provide long lasting effects. The effectiveness of biological controls measured for 6 years on diffuse knapweed populations at the Site is evaluated in this report.

Various species of biological control insects have been released on Site for control of diffuse knapweed, including the Lesser knapweed flower weevil (*Larinus minutus*), Blunt knapweed flower weevil (*L. obtusus*), Banded gall fly (*Urophora affinis*), and UV knapweed seed head fly (*U. quadrifasciata*), all of which cause damage to the seeds of the knapweed. The other diffuse knapweed biocontrol insects that have been released and documented on Site (*Cyphocleonus achates* and *Sphenoptera yugoslavica)* cause damage to either roots or stems of the plant.

Objectives of the study include:

- Evaluate changes in pre and post-treatment diffuse knapweed cover and density at the release locations through time.
- Document visually, through photo monitoring, changes in diffuse knapweed populations at the release locations.
- Using flowerhead and seed counts, evaluate biocontrol insect impacts on diffuse knapweed seed production.

Figure 6–8 shows the release locations of the *L. minutus* weevils. The biocontrol insects at release sites one through five were released in 2001. Insects at release site six were released in 2002. Release location number five (label shown in grey on Figure 6–8) was removed from the study in 2004 because the area was treated with herbicides. Location LM6 was established in 2002, therefore, there are no cover or density data prior to 2002 for this location. When making comparisons between years for the density and cover data, the mean includes data from all locations sampled during a specific year.

The overall mean cover of diffuse knapweed plants at the five locations sampled in 2006 was 0.6 percent. For years 2001 through 2005 the mean cover for all locations sampled in that specific year was 21.4 percent, 12.7 percent, 15.4 percent, 13.0 percent and 12.8 percent, respectively (Table 6−22). Cover for 2006 was significantly lower than 2001 and 2003 ($p = 0.009$). Percent cover of diffuse knapweed decreased in 2006 at all locations from the previous years 2001 to 2005 (Figure 6–9). There was no significant difference found when comparing the 2006 cover results between the five biocontrol locations.

*Table 6−22. Average Percent Cover of Diffuse Knapweed at Biocontrol Release Locations (2001−2006)*

| Location | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 |
|---|---|---|---|---|---|---|
| LM1 | 33.5 | 15.9 | 12.7 | 14.1 | 11.7 | 0 |
| LM2 | 19.4 | 6.0 | 19.2 | 11.7 | 6.8 | 1.5 |
| LM3 | 21.6 | 12.3 | 9.2 | 1.8 | 3.3 | 0.3 |
| LM4 | 26.1 | 10.4 | 22.0 | 23.8 | 32.1 | 1.2 |
| LM5 | 6.3 | 14.5 | 24.1 | N/A | N/A | N/A |
| LM6 | N/A | 17.1 | 5.4 | 13.8 | 10.1 | 0 |
| Mean | 21.4 | 12.7 | 15.4 | 13.0 | 12.8 | 0.6 |

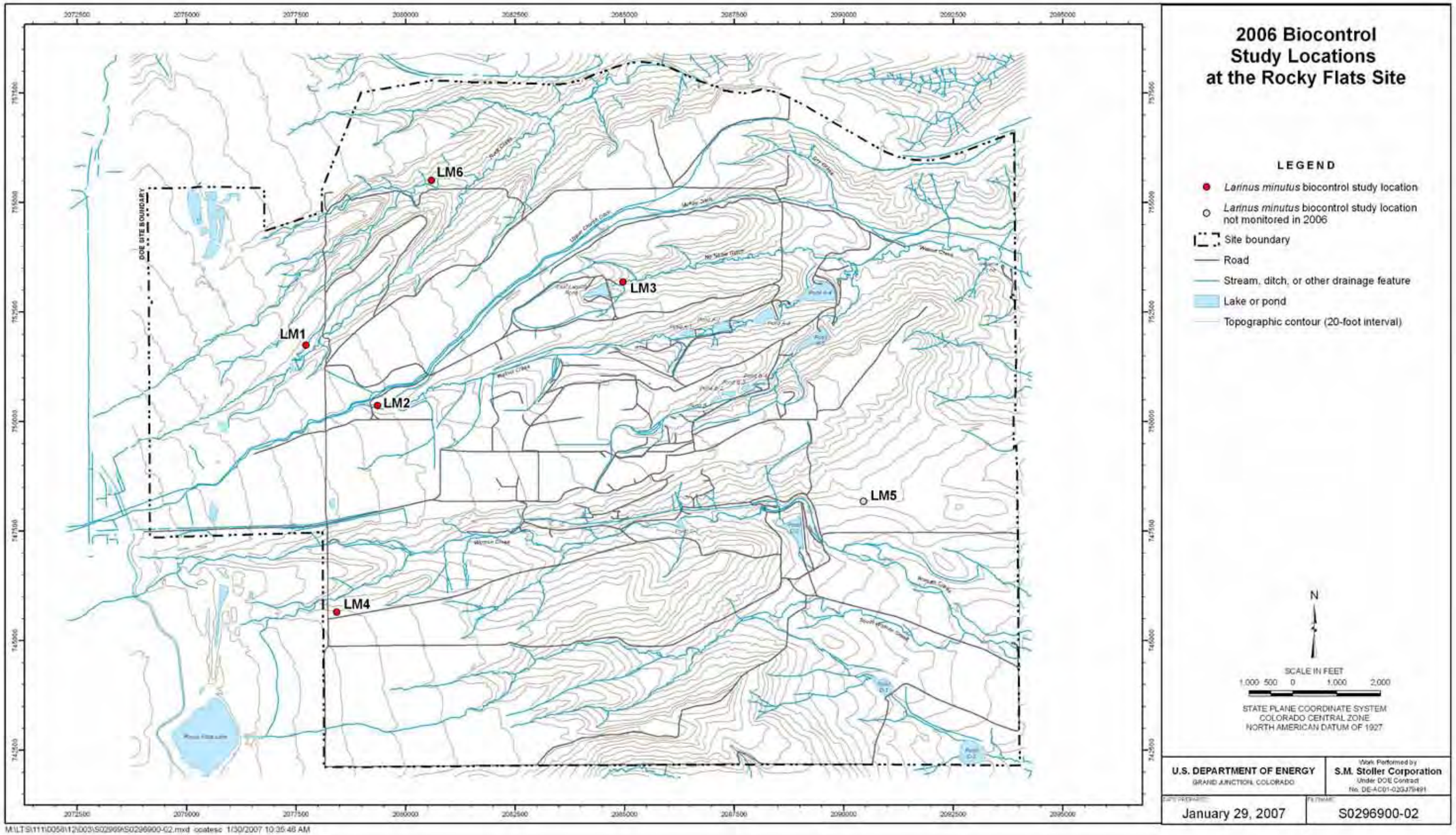


*Figure 6–8. 2006 Biocontrol Study Locations at the Rocky Flats Site*

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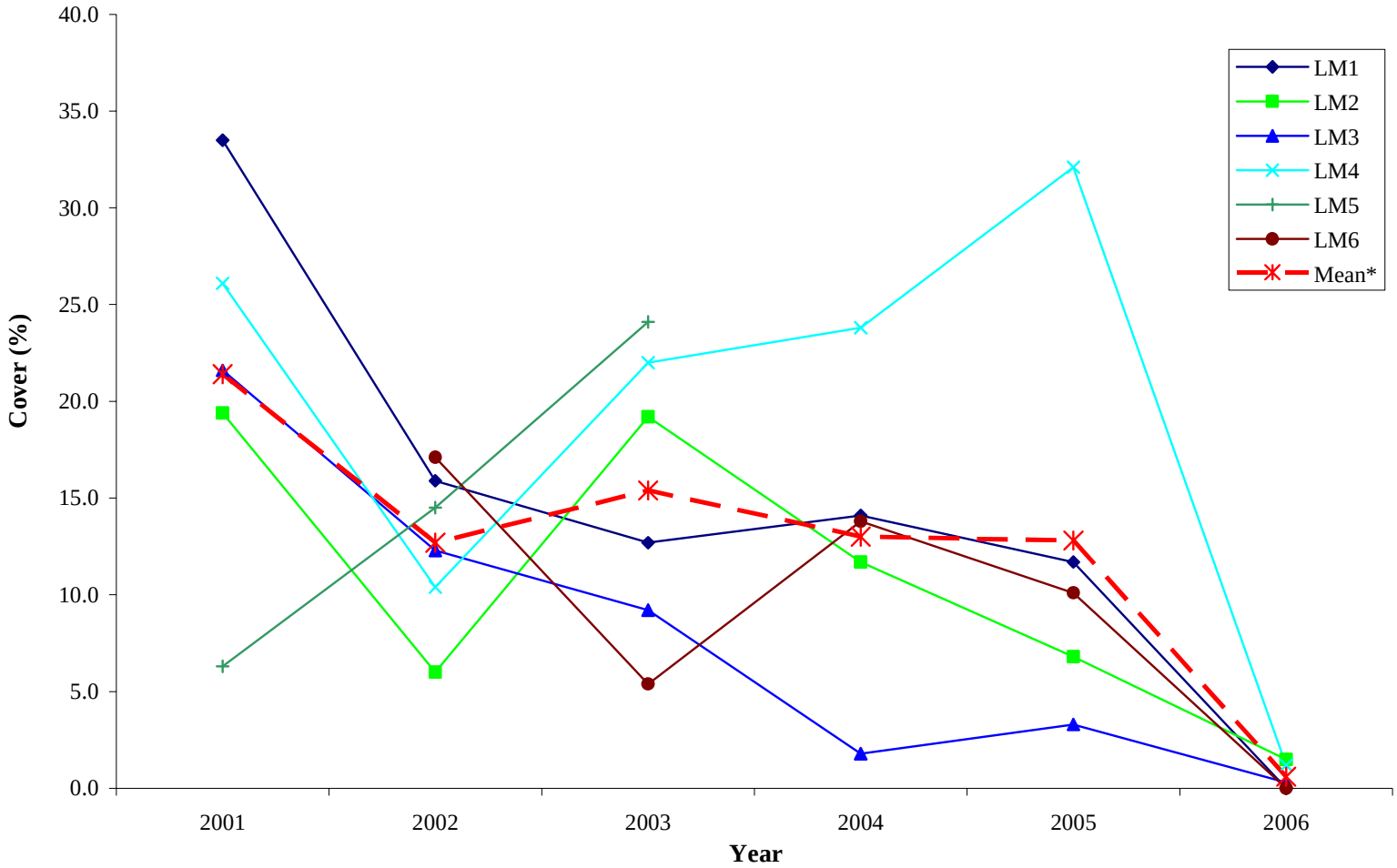



*The mean includes data from all locations sampled during a specific year.

*Figure 6–9. Diffuse Knapweed Cover at Biocontrol Release Locations (2001−2006)*

The overall mean density of diffuse knapweed plants at the five locations sampled in 2006 was 0.6 plants per square meter. From 2001 through 2005, the mean density for all locations sampled in each specific year was 9.1, 7.1, 3.0, 4.9 and 12.2 plants per square meter respectively (Table 6−23). Density was significantly lower in 2006 than in 2005 ($p = 0.012$). In 2006, the overall mean density was the lowest it had been since the initiation of the study.

*Table 6−23. Average Density (plants/m$^2$) of Diffuse Knapweed Plants at Biocontrol Release Locations (2001−2006)*

| Location | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 |
|---|---|---|---|---|---|---|
| LM1 | 15.8 | 7.8 | 4.6 | 6.0 | 7.8 | 0 |
| LM2 | 14.5 | 3.9 | 5.0 | 4.3 | 7.3 | 0.8 |
| LM3 | 4.4 | 8.0 | 1.2 | 0.5 | 1.5 | 0.3 |
| LM4 | 9.5 | 3.3 | 4.5 | 8.9 | 27.5 | 1.8 |
| LM5 | 1.1 | 6.8 | 2.4 | N/A | N/A | N/A |
| LM6 | N/A | 12.6 | 0.5 | 4.6 | 16.8 | 0 |
| Mean | 9.1 | 7.1 | 3.0 | 4.9 | 12.2 | 0.6 |

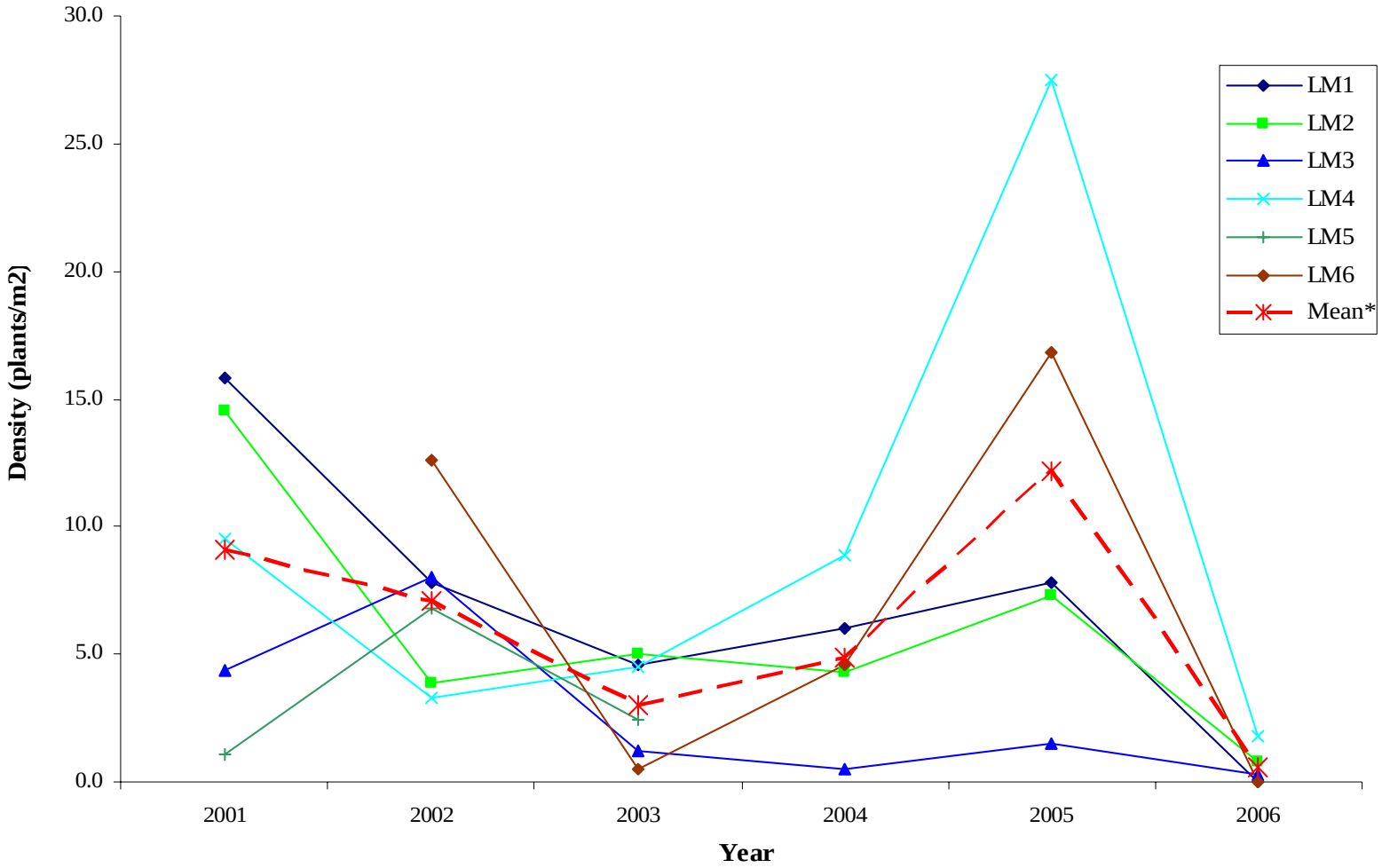
In past years, the density data have fluctuated (with the density at some sample locations increasing, while at others decreasing). In 2005 densities at all individual locations increased from 2004, but decreased again in 2006 (Figure 6–10). Comparing only the 2006 density results between the five locations, there were no significant differences found.

#### 6.2.5.1 Flowerhead Counts

The mean number of flowerheads per plant at all five locations monitored in 2006 was 169 flowerheads per plant. From 2001 through 2005, the mean number of flowerheads per plant has been 153, 135, 288, 454, and 251, respectively (Table 6−24). The mean number of flowerheads per plant doubled from 2002 to 2003 (statistically significant increase, $p = 0.002$), then increased again from 2003 to 2004 (no statistical significance). The year 2004 was significantly higher in flowerhead counts compared to 2001 and 2002 ($p = 0.002$). In 2005, the mean number of flowerheads per plant decreased to about half the number in 2004 (statistically significant decrease, $p = 0.040$). The mean number of flowerheads per plant in 2006 was slightly higher than at the beginning of the study in 2001, but less than 2003 through 2005 (Figure 6–11). Between locations in 2006, location LM2 had significantly higher flowerhead counts compared to LM1, LM3, and LM6 ($p < 0.001$).

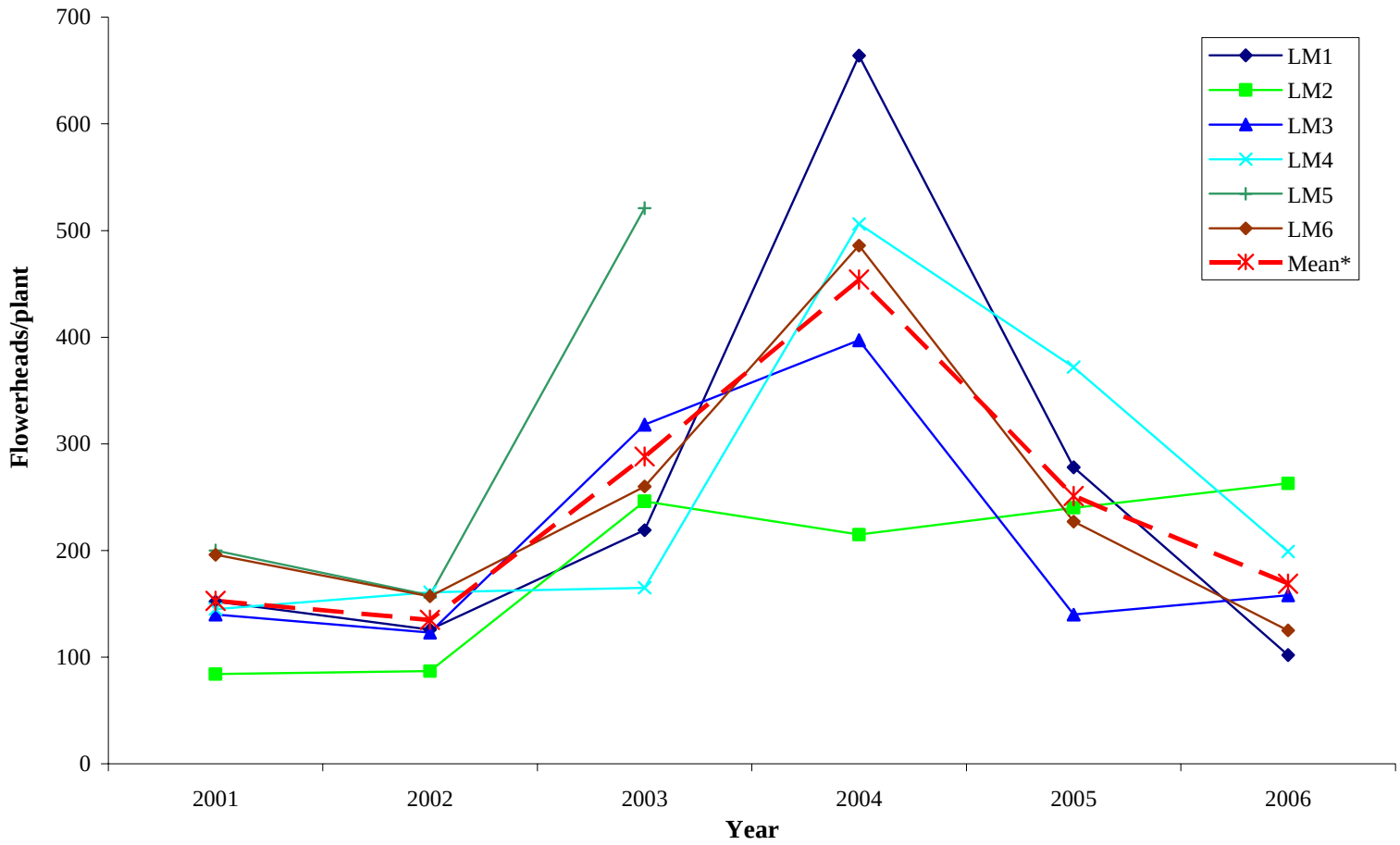
*Table 6−24. The Average Number of Flowerheads per Plant at Biocontrol Release Locations (2001−2006)*

| Location | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 |
|---|---|---|---|---|---|---|
| LM1 | 152 | 126 | 219 | 664 | 278 | 102 |
| LM2 | 84 | 87 | 246 | 215 | 240 | 263 |
| LM3 | 140 | 123 | 318 | 397 | 140 | 158 |
| LM4 | 145 | 161 | 165 | 506 | 372 | 199 |
| LM5 | 200 | 158 | 521 | N/A | N/A | N/A |
| LM6 | 196 | 157 | 260 | 486 | 227 | 125 |
| Mean | 153 | 135 | 288 | 454 | 251 | 169 |




*The mean includes data from all locations sampled during a specific year.

*Figure 6–10. Diffuse Knapweed Density at Biocontrol Release Locations (2001−2006)*




*The mean includes data from all locations sampled during a specific year.

*Figure 6–11. Average Number of Diffuse Knapweed Flowerheads per Plant at Biocontrol Release Locations (2001−2006)*

### 6.2.5.2 Seed Counts/ Insect Evidence

The average number of seeds per flowerhead (of the 500 flowerheads examined) across all five locations monitored in 2006 was 4.5 seeds per flowerhead, which is the highest number since seeds counts were initiated in 2002. From 2002 through 2005 the mean number of seeds per flowerhead was 0.91, 0.55, 3.08, and 0.58, respectively (Table 6−25, Figure 6–12). Seed production per flowerhead was significantly higher in 2006 ($p < 0.001$) compared to all the other years in which seed counts were performed. There was no significant difference in number of seeds per flowerhead between locations for 2006.

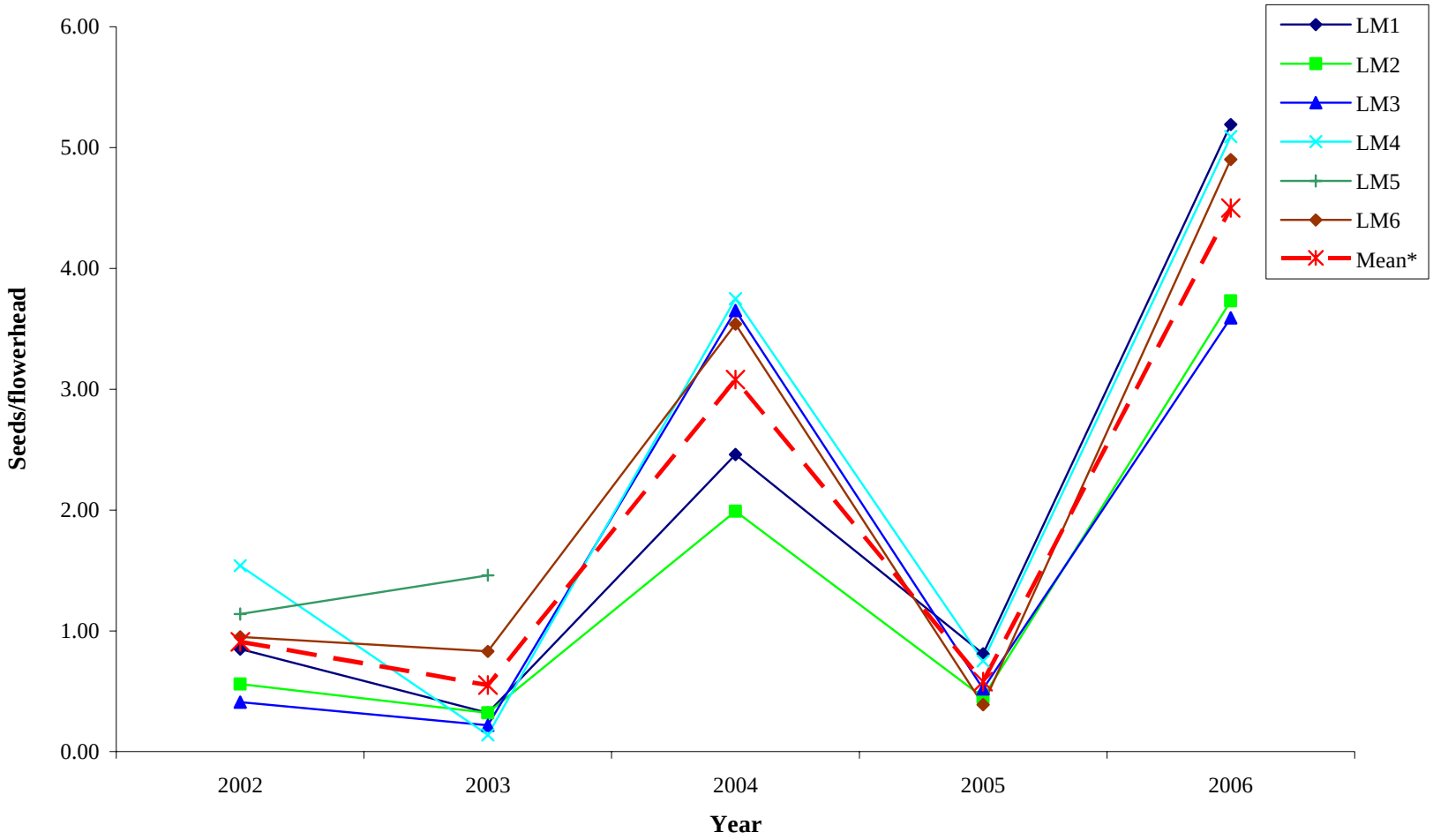
*Table 6−25. The Average Number of Seeds per Flowerhead (out of 500 flowerheads examined) at Biocontrol Release Locations (2002−2006)*

| Location | 2002 | 2003 | 2004 | 2005 | 2006 |
|---|---|---|---|---|---|
| LM1 | 0.85 | 0.32 | 2.46 | 0.81 | 5.19 |
| LM2 | 0.56 | 0.32 | 1.99 | 0.45 | 3.73 |
| LM3 | 0.41 | 0.22 | 3.65 | 0.52 | 3.59 |
| LM4 | 1.54 | 0.14 | 3.75 | 0.75 | 5.09 |
| LM5 | 1.14 | 1.46 | N/A | N/A | N/A |
| LM6 | 0.95 | 0.83 | 3.54 | 0.39 | 4.9 |
| Mean | 0.91 | 0.55 | 3.08 | 0.58 | 4.50 |

In 2006, the percent of flowerheads with evidence of insect damage was 19 percent (97 flowerheads out of 500 total). This is down from a high of 93 percent observed in 2003 (Table 6−26), which was significantly higher ($p < 0.001$) that year compared to the years 2002−2005. Percent of flowerheads with insect damage was significantly lower ($p < 0.001$) in 2006 compared to all the other years of the study (Figure 6–13).

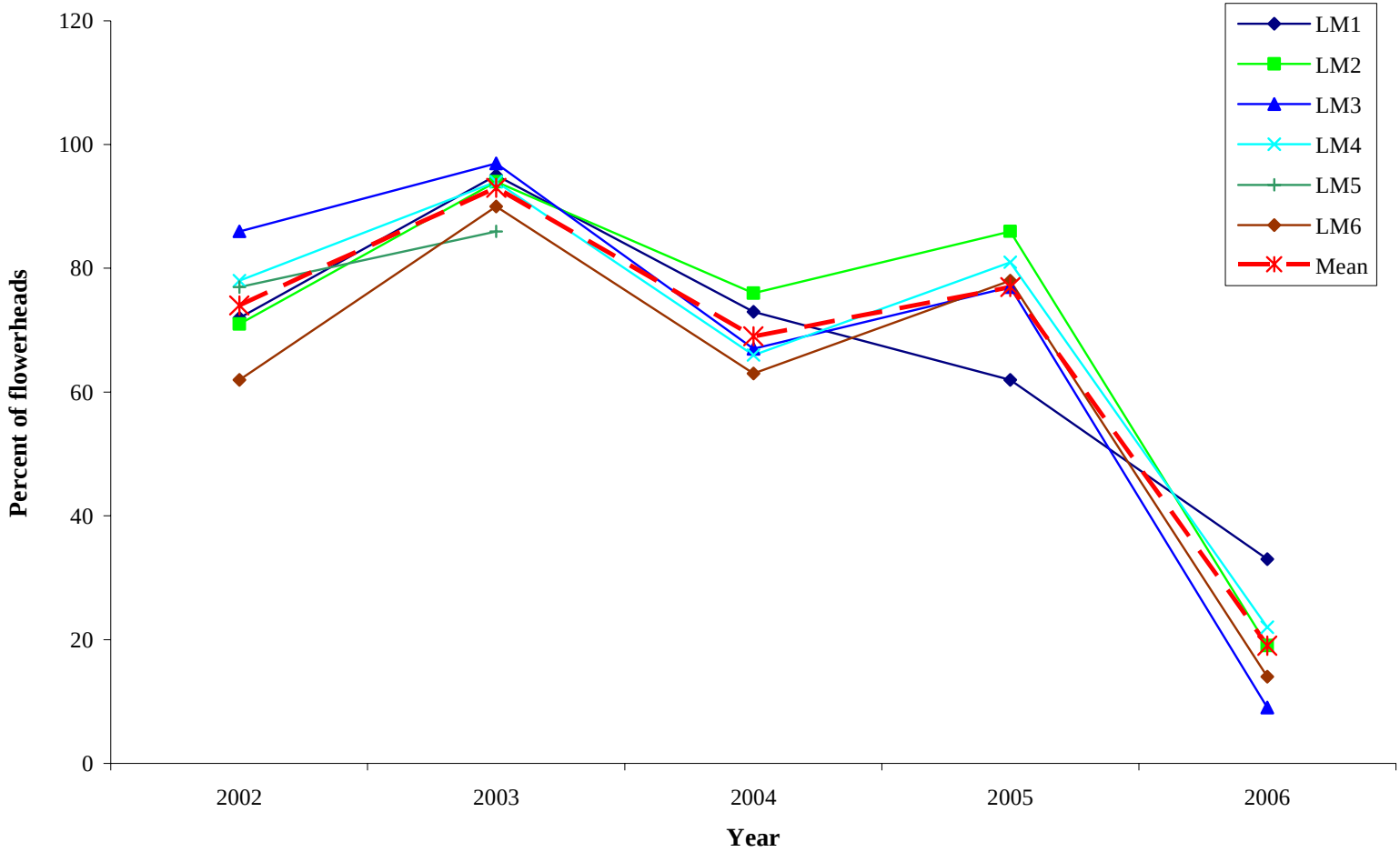
*Table 6−26. Percent of Flowerheads (out of 500 flowerheads examined) with Evidence of Insect Damage at Biocontrol Release Locations (2002−2006)*

| Location | 2002 | 2003 | 2004 | 2005 | 2006 |
|---|---|---|---|---|---|
| LM1 | 72 | 95 | 73 | 62 | 33 |
| LM2 | 71 | 94 | 76 | 86 | 19 |
| LM3 | 86 | 97 | 67 | 77 | 9 |
| LM4 | 78 | 94 | 66 | 81 | 22 |
| LM5 | 77 | 86 | N/A | N/A | N/A |
| LM6 | 62 | 90 | 63 | 78 | 14 |
| Mean | 74 | 93 | 69 | 77 | 19 |




*The mean includes data from all locations sampled during a specific year.

*Figure 6–12. Average Number of Diffuse Knapweed Seeds per Flowerhead at Biocontrol Release Locations (2002−2006)*




*The mean includes data from all locations sampled during a specific year.

*Figure 6–13. Percent of Diffuse Knapweed Flowerheads with Evidence of Insect Damage at Biocontrol Release Locations (2002−2006)*

The average number of seeds per flowerhead for flowerheads with insect evidence and for flowerheads without insect evidence was also calculated (Table 6−27). In all 5 years, the overall number of seeds per flowerhead and flowerheads with insect damage, was statistically lower than for those showing no insect damage (2002 = $p<0.05$, 2003 through 2006 $p<0.001$).

*Table 6−27. The Average Number of Seeds per Flowerhead (out of 500 flowerheads examined) at all Five Release Locations, calculated for the following categories: all flowerheads, flowers with evidence of insect damage, and flowerheads with evidence of no insect damage (2002−2006)*

| Year | Mean # seeds (all) | Mean # seeds (w/evidence) | Mean # seeds (no evidence) |
|---|---|---|---|
| 2002 | 0.91 | 0.37 | 2.48 |
| 2003 | 0.55 | 0.14 | 5.66 |
| 2004 | 3.08 | 1.10 | 7.49 |
| 2005 | 0.58 | 0.21 | 1.82 |
| 2006 | 4.5 | 2.65 | 4.95 |

Table 6−28 shows the overall percentages of flowerheads in the following categories: no evidence of biocontrol insects, evidence of *Larinus* spp., evidence of *U. affinis*, evidence of *U. quadrifasciata*, and evidence of an unknown insect between the years 2004−2006. Evidence of multiple insect species damage to a flowerhead was found in three flowerheads in 2004 and eight flowerheads in 2005.

*Table 6−28. The Percent of Flowerheads (out of 500 examined) at all Five Release Locations with the following flowerhead damage: no evidence of insect damage, evidence of* Larinus *spp., evidence of* U. affinis*, evidence of* U. quadrifasciata*, and evidence of an unknown insect (2004−2006)*

| Year | No evidence | *Larinus* spp. | *U. affinis* | *U. quadrifasciata* | Unknown insect |
|---|---|---|---|---|---|
| 2004* | 31 | 36 | 11 | 12 | 11 |
| 2005* | 23 | 27 | 16 | 5 | 31 |
| 2006 | 80 | 3 | 3 | 12 | 2 |

Notes: *The total percentages sum to a slightly higher number than 100, due to the overrepresentation of three flowerheads in 2004 and eight flowerheads in 2005 that showed evidence of damage from multiple insects.

In 2004, the percent of flowerheads with evidence of the two species of *Urophera* and an unknown insect were about the same with about 11−12 percent each. Flowerheads with evidence of *Larinus* damage had the highest percentage, with 36 percent, and the remaining 31 percent of flowerheads showed no evidence of any biocontrol insect (out of 500 flowerheads collected). In 2005, the number of flowerheads with no evidence of biocontrol damage declined to 23 percent, as did the percentage of flowerheads with *Larinus* evidence (27 percent) and *U. quadrufasciata* evidence (5 percent). The only increases in percentages were in flowerheads with evidence of *U. affinis*, from 11 percent to 16 percent, and in flowerheads with evidence of an unknown insect. The increase in unknown insect percentage was the largest change of all categories, a three-fold increase from 11 percent in 2004 to 31 percent in 2005. In 2006 flowerheads with no insect evidence increased to 80 percent and *Larinus* and *U. affinis* evidence dropped to only 3 percent each. Unknown insect evidence was just 2 percent. These percentages were the lowest for those insect categories thus far during the study. Evidence of *U. quadrifasciata* increased to the 2004 level of 12 percent (Figure 6–14).

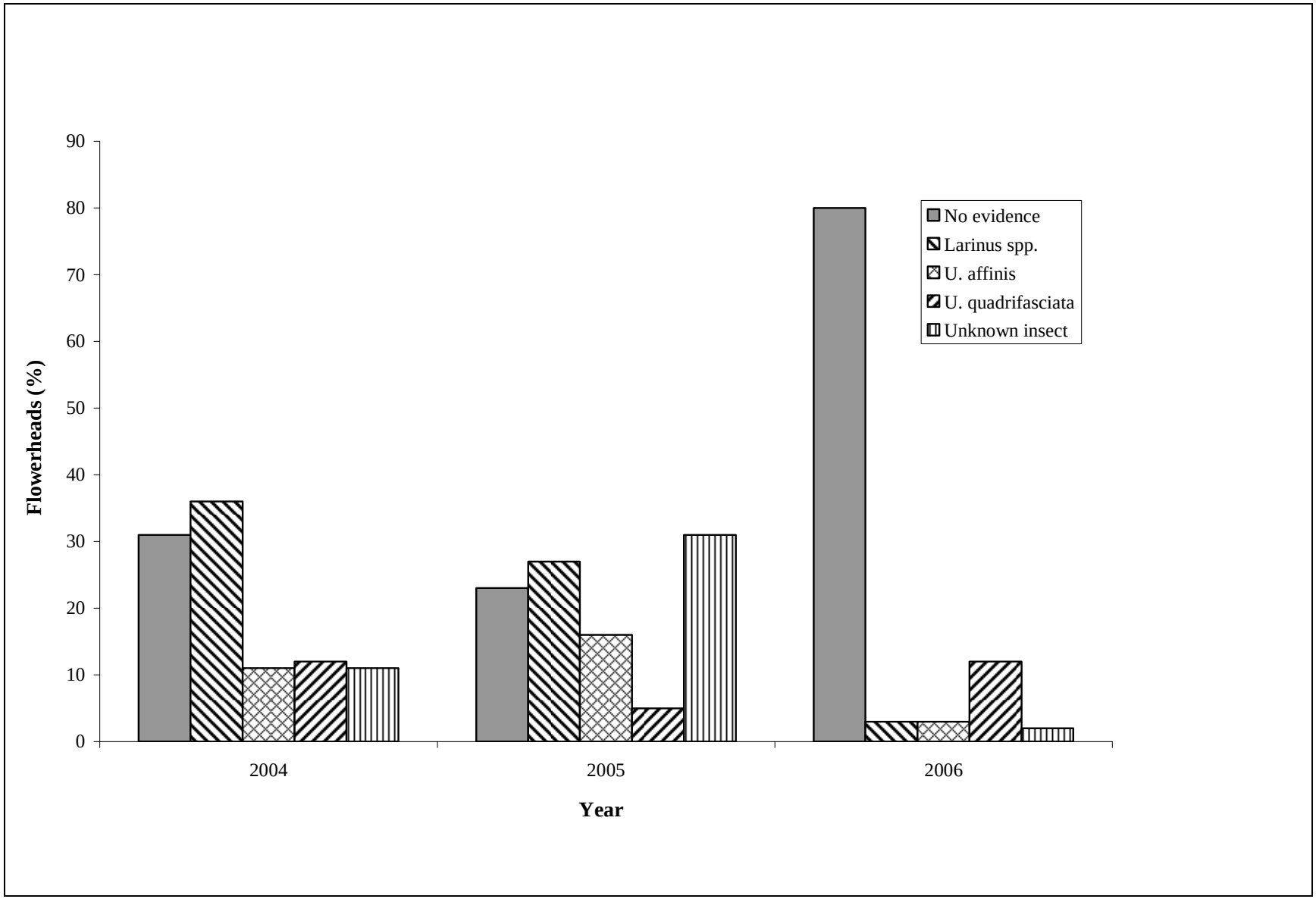


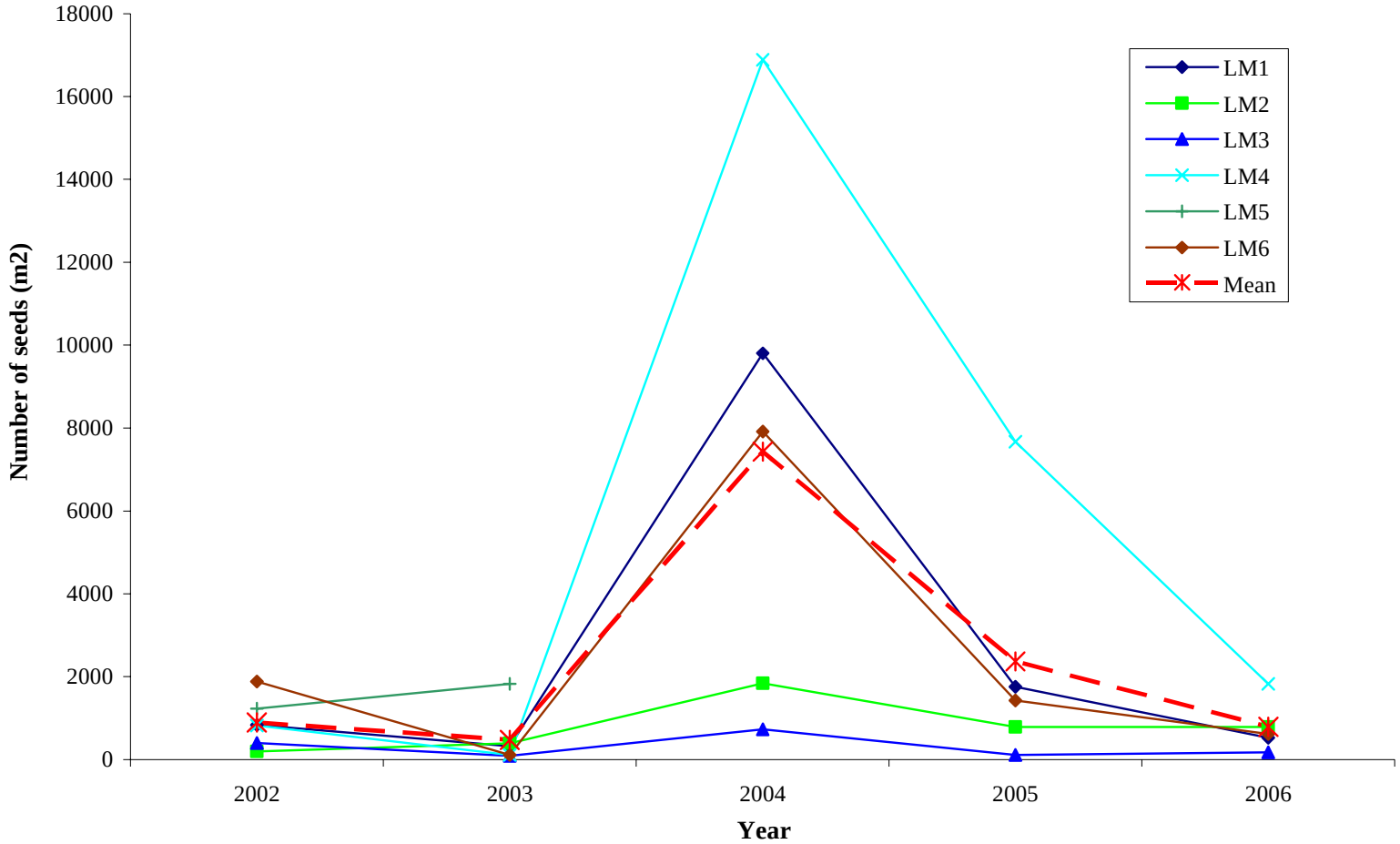

*Figure 6–14. Percent of Diffuse Knapweed Flowerheads Divided into Insect Damage Categories at Biocontrol Release Locations (2004−2006)*

### 6.2.5.3 Total Seed Production

Using knapweed plant density, the average number of flowerheads per plant and the average number of seeds per flowerhead, diffuse knapweed seed production per square meter was calculated (Table 6−29). From 2002 to 2003, the average seed production decreased from 892 to 473 seeds/$m^2$. The overall seed production then increased to 7,433 seeds/$m^2$, an almost 16-fold increase in 2004. In 2005, the overall seed production once again decreased to 2,363 seeds/$m^2$, still several times higher than the seed production at the time when the study began. In 2006 the overall seed production decreased to 784 seeds/$m^2$ (Figure 6–15). The data show large within site and annual variation in total seed production. As a result, only the increase in the grand mean from 2003 to 2004 is statistically significant ($p = 0.027$).

*Table 6−29. The Average Number of Diffuse Knapweed Seeds per Square Meter at Biocontrol Release Locations (2002−2006)*

| Location | 2002 | 2003 | 2004 | 2005 | 2006 |
|---|---|---|---|---|---|
| LM1 | 835 | 322 | 9801 | 1756 | 529 |
| LM2 | 191 | 394 | 1840 | 788 | 785 |
| LM3 | 403 | 84 | 725 | 109 | 170 |
| LM4 | 820 | 104 | 16888 | 7673 | 1823 |
| LM5 | 1226 | 1827 | N/A | N/A | N/A |
| LM6 | 1879 | 108 | 7914 | 1427 | 613 |
| Mean | 892 | 473 | 7433 | 2363 | 784 |




*The mean includes data from all locations sampled during a specific year.

*Figure 6–15. Average Number of Diffuse Knapweed Seeds per Square Meter at Biocontrol Release Locations (2002−2006)*

#### 6.2.5.4 Discussion and Summary

In general, the average cover of diffuse knapweed has declined at the release locations since the *L. minutus* were released. The greatest decline occurred initially the year after the releases were made and in 2006. Diffuse knapweed density also declined initially, but has not followed the pattern of the cover. Instead it began increasing in 2004 and continued to rise in 2005 to the point where it was above the level of when the study began. In 2006 both density along with cover declined to the lowest levels during the study.

There appears to be a correlation of the diffuse knapweed density data with the previous year's precipitation (November to October; Figure 6–16). Diffuse knapweed is a winter annual, often germinating in the fall, overwintering as a rosette, then bolting and flowering the following summer. In years with higher moisture, greater numbers of seeds germinate in the fall and survive through the following summer to be counted as adult plants (density counts are based only on the adults). Likewise, years with lower moisture show the opposite effect of decreased germination and density. From 2002−2003 density decreased with lower precipitation (11.99 inches and 13.16 inches, respectively), compared to 15.34 inches in 2001. In 2004 and 2005 precipitation increased to 22.83 inches and 19.35 inches, respectively, and knapweed density increased. In 2006 precipitation decreased to 10.65 inches and diffuse knapweed density once again decreased.

A comparison of cover versus precipitation suggests that cover generally follows the precipitation amounts for the same year (i.e., cover is higher with higher precipitation and vice-versa; Figure 6–16). This pattern was not maintained in 2004 and 2005, when cover did not increase with additional precipitation. In 2006 however, cover decreased once again with a decrease in precipitation.

One possible explanation for the 2004 and 2005 cover results was that the abundance of biocontrol insects had reached a level where they were starting to impact the diffuse knapweed plants. Not only do *Larinus* weevils destroy seed in the larval form, but they also forage on leaves and stems of the plant as adults. *Cyphocleonus achates* and *S. yugoslavica* are two other biocontrol insects that stress knapweed plants by affecting the root systems. In 2006 precipitation may have played a greater role in the decrease of cover and density than the biocontrol insects.

Flowerhead counts from 2002−2006 also appear to correlate well with annual precipitation received. With increased precipitation the number of flowerheads produced per plant increased and vice-versa (Figure 6–17). From 2002−2005 the number of seeds produced per flowerhead also followed precipitation amounts, for both flowerheads with and without insect damage. Then in 2006 overall seed production increased and was significantly higher compared to all the other years of the study (Figure 6–16).

Even though for 2006 the seed production results do not coincide with the results of other studies regarding seed production and precipitation (Seastedt et al. 2003, 2005 and Schirman 1981), the increase in seed production may be due to the lower percent of flowerheads with insect damage. In 2006, the percentage of flowerheads with insect damage was significantly lower when compared to flowerheads with insect damage for all other years. The average number of seeds found in flowerheads with insect damage in 2006 was the highest number for the study. In addition, evidence of *Larinus* spp., *U. affinis* and unknown insects in flowerheads were lower in 2006 than for other years (Figure 6–18).

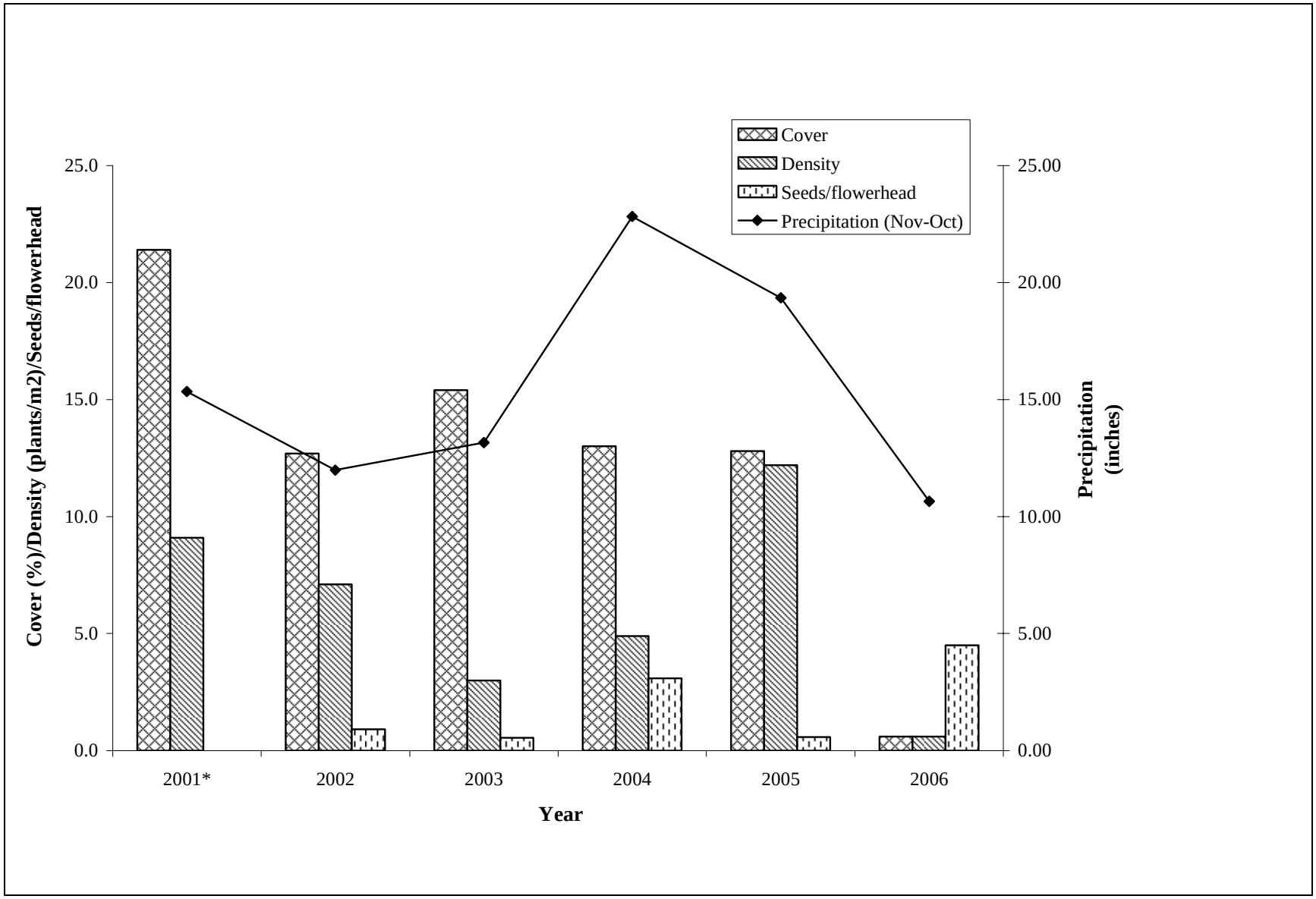



*Figure 6–16. Rocky Flats Precipitation versus Diffuse Knapweed Cover, Density, and Number of Seeds/Flowerhead (2001−2006)*

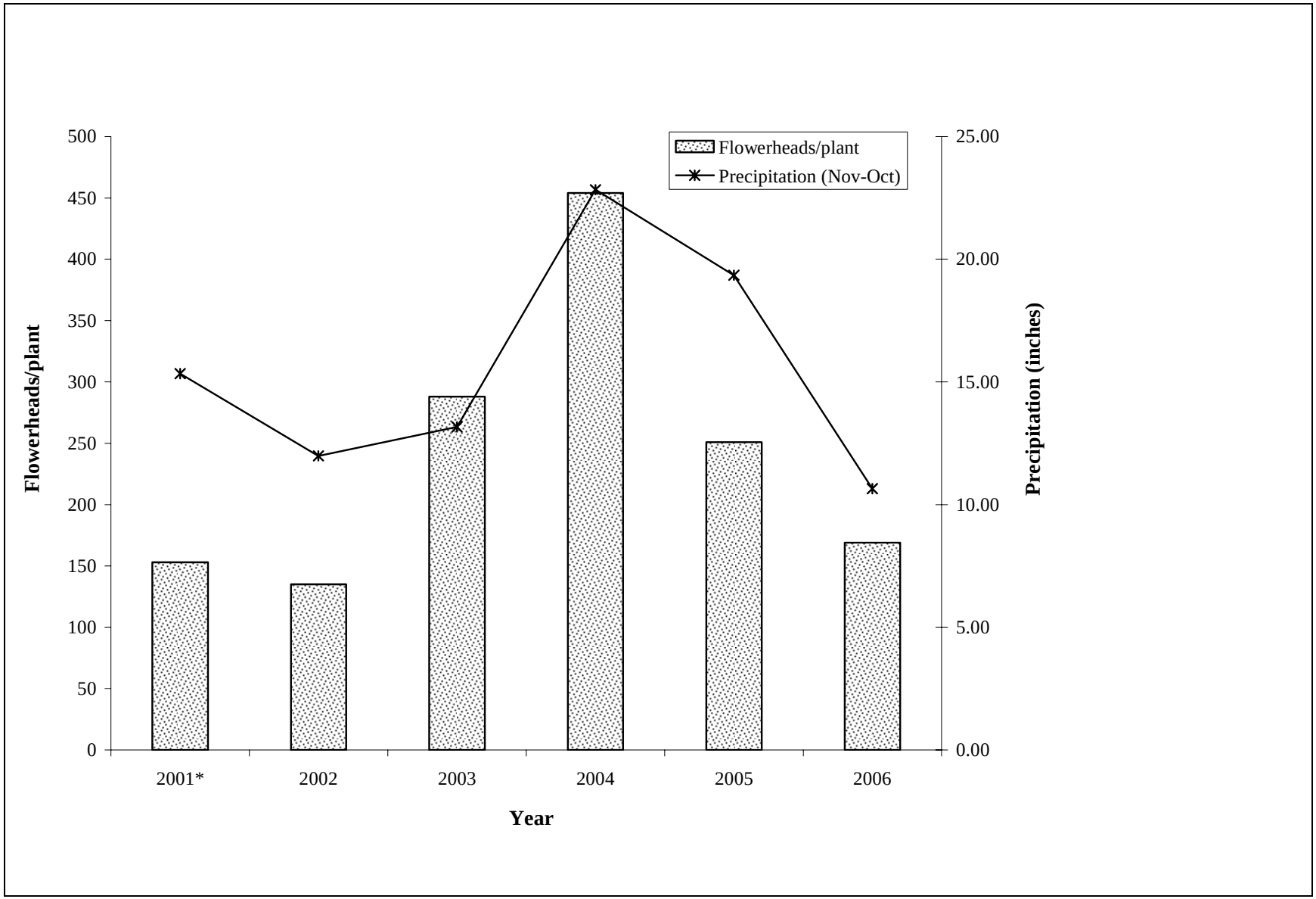



*Figure 6–17. Rocky Flats Precipitation and Mean Number of Flowerheads/Plant of Diffuse Knapweed at Biocontrol Release Locations (2001−2006)*

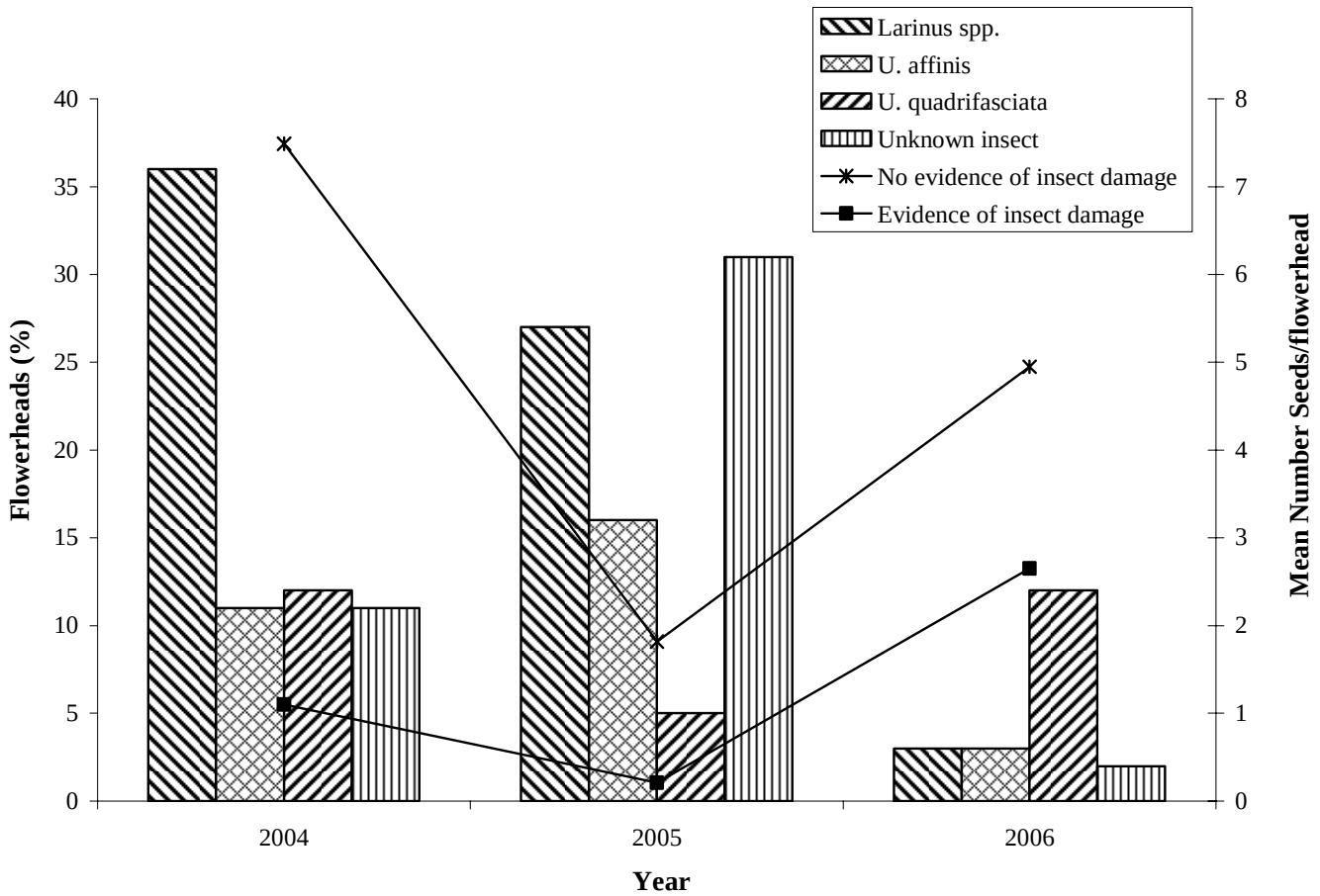



*Figure 6–18. Percent of Diffuse Knapweed Flowerheads Divided into Insect Damage Categories and Mean Number of Seeds/Flowerhead with and without Insect Damage at Biocontrol Release Locations (2004−2006)*

Seastedt et al. 2005 found that when *Larinus* weevil abundance is high, seed production is low, but when *Larinus* weevil abundance is moderate to low, seed production can vary from low to high. Also, *Larinus* weevils appear to lay few eggs in stressed plants, which could have been the case for 2006 as the November−October precipitation was the lowest since the study began.

Despite the fact that seed production per flowerhead was significantly higher in 2006 than in any other year, the average number of seeds per square meter was the second lowest during the study.

It typically takes 4−6 years after initial releases for the population levels of biocontrol insects to reach levels where they begin to have some effect on the target species populations. While the reduction in seed production is not as great as the biocontrol release study to the north of the Site on Boulder County Open Space land (Seastedt et al. 2003), the data show that the biocontrol insects appear to be having an affect on reducing knapweed cover and overall seed production at the Rocky Flats release locations as well.

The fact that the biocontrol insects have had some effectiveness in reducing the seed production of the diffuse knapweed at the Site is an important step towards controlling this annual species which reproduces by seed. The use of biocontrol insects alone will not likely completely control diffuse knapweed at the Site or most locations along the Front Range where it is problematic. However, biocontrol insects are one of several control methods for invasive species that can be used in conjunction with other control methods, or when other methods are inappropriate or not feasible.

## 6.3 Wildlife Monitoring

Wildlife monitoring has been conducted as part of the on-going ecological monitoring at the Site since the early 1990's. The frog vocalization survey was conducted on May 2, 2006.

### 6.3.1 Frog Vocalization Monitoring

Although occasional frog observations were noted while conducting general wildlife monitoring in the past, there were no specific attempts to monitor frog populations until 1998. Even though an annual presence/absence record for amphibians was being established as a part of general wildlife monitoring, the lack of a specific methodology precluded the ability to effectively track population abundance or distribution of these species at the Site. In an effort to better track amphibian populations and use that information as an indicator for detecting changes in the health of aquatic ecosystems, a systematic and recognized monitoring program was initiated that was based on nationally recognized protocol for monitoring frogs. Amphibians are an important group to track because their semi-aquatic nature makes them particularly sensitive to aquatic impacts (Blaustein and Wake 1995). The boreal chorus frog (*Pseudacris triseriatus)* was chosen as the best candidate at the Site for vocalization monitoring and can also serve as an indicator species for tracking general amphibian population abundance onsite.

In 2006, 20 locations were sampled for species presence/absence and population abundance on May 2, 2006 (Figure 6–19). Boreal chorus frogs were recorded at 11 of the 20 (55 percent) sample locations surveyed in 2006 (Table 6−30). Figure 6–20 shows the frequency of the different vocalization indices at all 20 locations sampled in 2006. Four of the locations (20 percent) sampled had full choruses of frogs calling (vocalization index 3). Four locations (20 percent) had multiple individuals calling with overlaps between the calls (vocalization index 2). Three locations (15 percent) had a vocalization index of 1, where individuals could be counted but the calls were not overlapping. The remaining nine locations (45 percent) had no frogs calling (vocalization index 0).

*Table 6−30. Frog Vocalization Summary 1999−2006*

| Site Number | 1999 | 2000 | 2001 | 2003 | 2004 | 2005 | 2006 |
|---|---|---|---|---|---|---|---|
| 1 | 3 | 2 | 1 | 1 | 3 | 3 | 1 |
| 2 | 3 | 2 | 3 | 2 | 2 | 3 | 2 |
| 4 | 3 | 2 | 3 | 0 | 1 | 1 | 0 |
| 5 | 3 | 3 | 3 | 0 | 3 | 3 | 0 |
| 6 | 3 | 2 | 2 | 2 | 3 | 3 | 0 |
| 7 | 3 | 2 | 3 | 0 | 3 | 3 | 3 |
| 8 | 3 | 3 | 2 | 0 | 3 | 3 | 3 |
| 9 | 2 | 2 | 2 | 0 | 1 | 1 | 1 |
| 10 | 3 | 3 | 3 | 3 | 3 | 3 | 0 |
| 11 | 3 | 1 | 3 | 1 | 3 | 2 | 2 |
| 12 | 0 | 3 | 1 | 2 | 3 | 3 | 3 |
| 13 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| 14 | 3 | 3 | 3 | 2 | 3 | 3 | 2 |
| 15 | 0 | 2 | 2 | 3 | 0 | 3 | 0 |
| 16 | 0 | 1 | 3 | 1 | 0 | 0 | 0 |
| 17 | 0 | 0 | 1 | 0 | 2 | 1 | 0 |
| 18 | 3 | 2 | 1 | 2 | 3 | 3 | 1 |
| 19 | 2 | 3 | 2 | 1 | 0 | 3 | 0 |
| 20 | 2 | 3 | 3 | 0 | 3 | 3 | 2 |
| 21 | 0 | 1 | 1 | 0 | 0 | 0 | 0 |
| Mean Vocalization Index | 2.1 | 2.2 | 2.3 | 1.2 | 2.1 | 2.4 | 1.2 |
| Grand Mean (1999−2006) | 1.9 | | | | | | |

Notes: Values are vocalization indices.

On the evening when sampling was conducted in 2006, the average water and air temperature ($^{o}$C) was 16$^{o}$ and 16$^{o}$, respectively. No precipitation occurred on the day when sampling was conducted and the mean cloud cover was approximately 89 percent.

Table 6−30 and Figure 6–20 show the 2006 results in comparison to the data collected since 1999. The 1998 data is not shown because of the different sample locations used in 1998. The 2006 vocalization results tied for the lowest of all the years sampled thus far. The mean vocalization index in 2006 was 1.2 versus the annual mean of 1.9 (1999−2006; Table 6−30). Because the boreal chorus frog requires water to mate and lay eggs in, the overall abundance of the frogs at the Site appears be related to how much water is available at the Site during the

spring. From the available monitoring data, frogs were least abundant in 2003, the year after the drought in 2002 (Table 6−30, no data was collected in 2002). In 2004 and 2005, abundant precipitation resulted in higher abundances of vocalizations. However, during the fall and winter of 2005−2006, drought conditions were experienced again at the Site which left few locations with standing pools of water available for breeding in spring 2006. Additionally, many of the ponds at the Site were drained in midsummer 2005 for sediment sampling. The lack of precipitation after they were drained resulted in little to no water present at many of these locations. Although the 2006 data shows decline in the boreal chorus frog abundance at the Site, at this point there is no reason to assume it is nothing more than a normal perturbation resulting from the lack of water.

## 6.4 Summary

The Ecology Program at the Rocky Flats Site conducts monitoring of the ecological resources to ensure regulatory compliance and to preserve, protect, and manage those resources. Data from 2006 continue to substantiate the presence of increasingly rare ecological resources that are rapidly disappearing along the Front Range of Colorado due to development and urbanization. Proactive management of the natural resources is critical to the long-term sustainability of the ecosystems at the Site. Noxious weeds continue to be a top priority as does the revegetation of the COU. The monitoring results continue to provide useful information to assist in management activities. Full detailed summaries and analyses for each field monitoring effort are presented as stand-alone reports on the accompanying CD-ROMs.

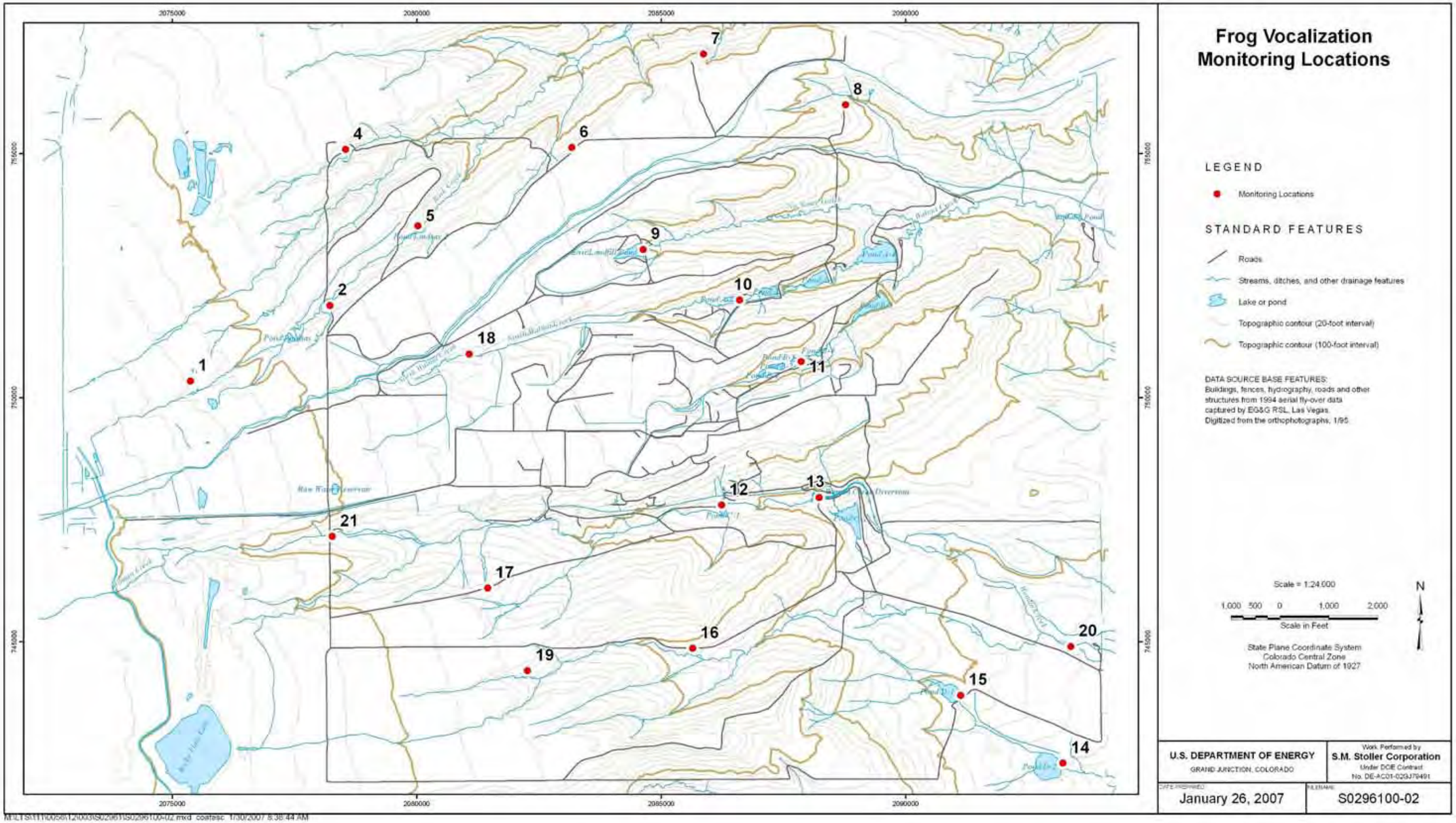



*Figure 6–19. Frog Vocalization Monitoring Locations*

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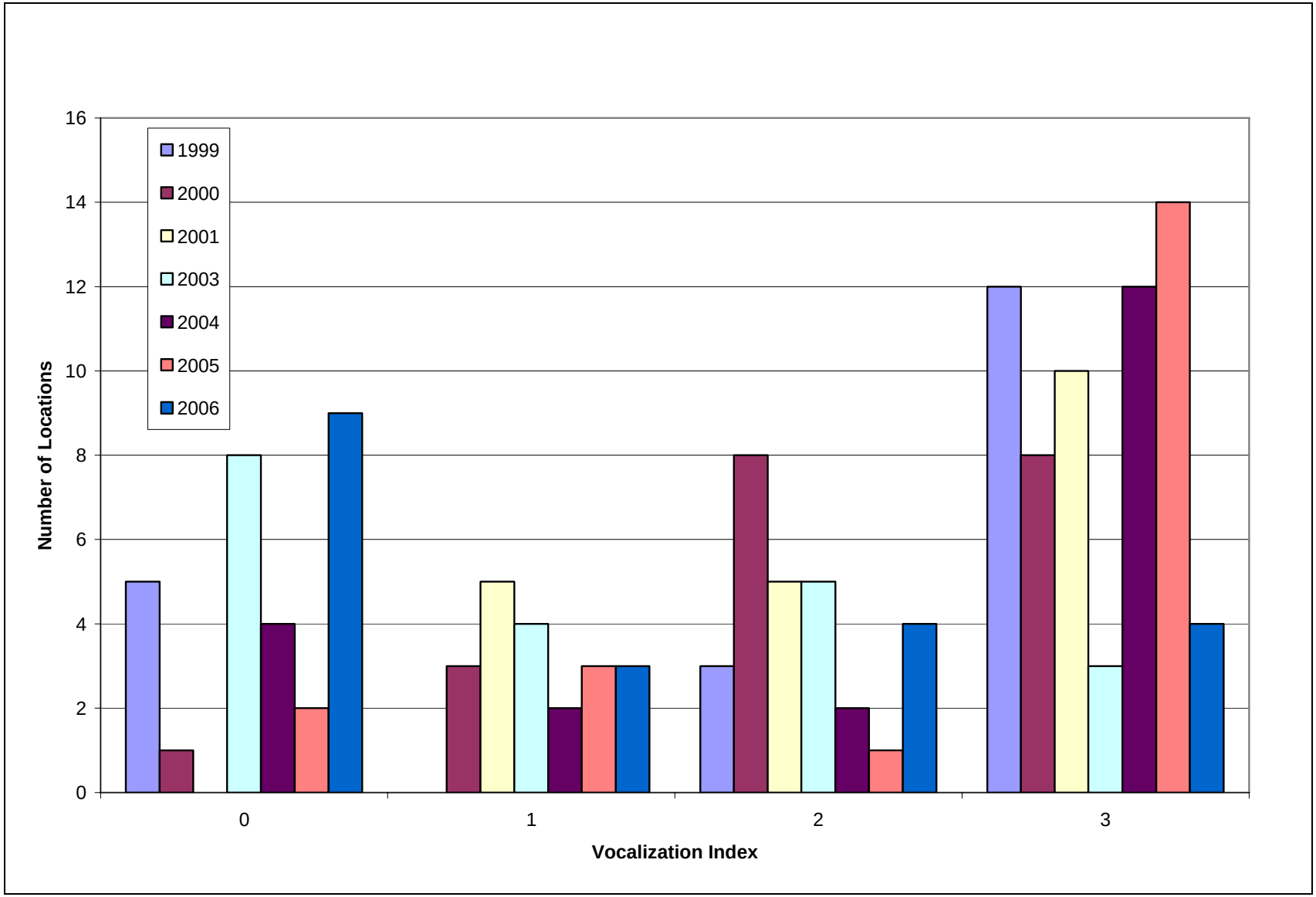


*Figure 6–20. Frog Vocalization Summary*

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# 7.0 Site Operations and Maintenance

## 7.1 Pond Operations

Twelve constructed ponds collect and manage surface water runoff at the Site. The ponds are grouped together in series based on the drainage in which they are located, with the A-Series Ponds in North Walnut Creek, the B-Series Ponds in South Walnut Creek, the C-Series Ponds in Woman Creek, and the Landfill Pond in No Name Gulch. Ponds A-4, B-5, and C-2 are referred to as "terminal ponds," because they are the farthest downstream ponds in their respective drainages, and the ponds from which water is discharged off the Site. Off-site discharges of water from the terminal ponds are currently performed using a batch release method. The location of the ponds and drainage features are given in Figure 2–1.

During CY 2006, the Site performed no terminal pond discharges. Pond A-3 was discharged to Pond A-4 twice in CY 2006 (Table 7−1). For habitat enhancement, water was periodically allowed to enter Pond B-1 from S. Walnut Creek, and Ponds A-1 and A-2 from North Walnut Creek. As of December 31, 2006, Ponds A-3, A-4, B-5, C-2, and the Landfill Pond were holding a total of approximately 12.1 million gallons (12.2 percent of total capacity).

*Table 7−1. CY 2006 Pond Water Transfers*

| Transfer | Dates | Volume (million gallons) |
|---|---|---|
| Pond A-3 to A-4 (outlet works) | 1/9−1/13/06 | 2.04 |
| Pond A-3 to A-4 (outlet works) | 3/31−4/3/06 | 1.26 |

Monthly routine dam inspections, pond level measurements, and piezometer measurements were performed as scheduled during the year. Semiannual movement monument surveys and inclinometer readings were also performed as scheduled; nothing unusual was noted. Annual dam mowing was completed in July and August. The annual Federal Energy Regulatory Commission dam inspection was completed in August. Upgrades to automated instrumentation and staff gages were completed for all ponds during the year.

## 7.2 Passive Ground Water Treatment Systems

Routine maintenance by LM personnel was begun in late October 2005. Prior to that, these activities were performed by K-H. The system-specific summaries below focus on tasks performed by LM. Details regarding monitoring, maintenance, and operation of the MSPTS, ETPTS, and SPPTS are presented in Section 3.3.2.

## 7.3 Landfills

The general approach for the PLF and OLF monitoring and inspections, along with the results of those inspections, is shown below.

### 7.3.1 Present Landfill

The PLF consists of approximately 22 acres of an engineered RCRA Subtitle C-compliant cover over a former sanitary/construction debris landfill. The cover was completed in May 2005. A diversion channel surrounds the landfill and diverts storm water runoff away from the landfill to No Name Gulch. The landfill has a passive seep interception and treatment system, installed to treat landfill seep water and GWIS water, that discharges into the Landfill Pond. A gas extraction system is also built into the landfill and allows subsurface gas to vent to the atmosphere. The landfill final construction site conditions will be used as a baseline for comparisons made during site inspections.

The inspections of the PLF in CY 2006 were initially conducted quarterly. Monthly inspections were initiated in June consistent with the requirements contained in the most recent Monitoring and Maintenance plan released in May 2006 (DOE 2006b). It is anticipated that after the first year, the inspection frequency may be reduced to quarterly for an additional 4 years. The inspection program will be evaluated at the next CERCLA review scheduled for 2007. The findings and observations of the inspections are presented in the Quarterly and Annual Reports, which will be submitted to EPA and CDPHE. Inspections and monitoring tasks are addressed in Appendix A of the *Final IM/IRA for IHSS 114 and RCRA Closure of the RFETS Present Landfill* (DOE 2004), and include ground water and surface water monitoring (see Section 2.8.1 and Section 3.4.1), monitoring subsidence/consolidation, slope stability, soil cover, vegetation, stormwater management structures, and erosion in surrounding features so that corrective actions can be taken in a timely manner.

#### 7.3.1.1 Inspection Results

Eight inspections were performed at the PLF in CY 2006. The inspection process followed the format and protocol established in the *Present Landfill Monitoring and Maintenance Plan and Post-Closure Plan, Rocky Flats Environmental Technology Site* (DOE 2006b). No significant problems were observed during these inspections. Refer to the inspection forms accompanying this document (Appendix C) for additional information.

Monitoring of surface water and ground water is covered in those respective sections of this report.

#### 7.3.1.2 Settlement Monuments

In late July the settlement monument locations proposed in the PLF Monitoring and Maintenance Plan were field surveyed to correspond to the exact locations used in the waste settlement calculations. Installation of the settlement monuments at the PLF began August 7. Progress was slow because the soil was very rocky and highly compacted. The work was stopped while the installation method was re-visited. After consultation with DOE-LM, DOE Office of Environmental Management, the landfill design engineer, and the settlement monument design engineer, an agreement was reached to use a backhoe to perform the first stage of excavation for the remaining eight monuments on the top of the landfill. Once the bio-barrier was reached the excavation was completed manually. The six monuments on the east face of the landfill required manual excavation due to the steep slope.

Installation of the settlement monuments at the PLF was completed the fourth week of August. Revegetation of the excavation areas was completed by RF LM personnel. The initial quarterly surveying of the settlement monuments was performed in December.

### 7.3.2 Original Landfill

The OLF consists of approximately 20 acres of an engineered cover over a former solid sanitary and construction debris landfill. The cover was completed in August 2005. The final cover consists of a 2-foot-thick Rocky Flats Alluvium soil cover that was constructed over both a regraded surface and a buttress fill. The original surface was regraded to provide a consistent slope. A 20-foot-high, 1,000-foot-long soil mass buttress fill was placed at the toe of the landfill. Erosion is controlled by a series of diversion berms that carry storm runoff away from the cover in lined channels. In addition, the soil cover was covered with both straw mulch and a spray-on erosion control medium called "Flexterra." A perimeter channel collects runoff from the diversion berms and carries it away from the landfill.

The inspections of the OLF in CY 2006 were initially conducted quarterly. Monthly inspections were initiated in June consistent with the requirements contained in the most recent Monitoring and Maintenance plan released in February 2006 (DOE 2006a). It is anticipated that after the first year, the inspection frequency may be reduced to quarterly for an additional 4 years. The inspection program will be evaluated at the next CERCLA review scheduled for 2007. The findings and observations of the site inspections are presented in the Quarterly and Annual Reports, which will be submitted to EPA and CDPHE. Inspections and monitoring tasks are addressed in Appendix B of the Final IM/IRA for the OLF (DOE 2005a), and include ground water and surface water monitoring (see Section 2.8.2 and Section 3.4.2), monitoring subsidence/consolidation, slope stability, soil cover, vegetation, stormwater management structures, and erosion in surrounding features so that corrective actions can be taken in a timely manner.

#### 7.3.2.1 Inspection Results

Eight inspections were performed at the OLF in CY 2006. The inspection process followed the format and protocol established in the *Final Landfill Monitoring and Maintenance Plan, Rocky Flats Environmental Technology Site, Original Landfill* (DOE 2006a). No significant problems were observed during these inspections. Refer to the inspection forms accompanying this document for additional information.

#### 7.3.2.2 Seeps

***Seep #7***

An area of saturated soil was observed in the area above Seep #7 in December 2005. K-H personnel were contacted to investigate the problem. K-H asked LM personnel to hand dig several "potholes" in one area of subsidence near the lower end of the seep collection system. Two potholes were made, one to a depth of about 4.5 feet and the other to a depth of about 2.5 feet. Neither pothole exposed the drain collection system.

A more extensive investigation of the OLF Seep #7 “burrito drain” was conducted May 23. Three perpendicular trenches were dug with a backhoe at the lower, middle, and upper sections of the drain. No obvious problems were seen with the function of the drain at these locations. Water was observed moving through the rock interior of the drain as designed. No sediment build-up or tearing of the geo-textile fabric was observed in the three locations inspected. The shallow depression above the lower footprint of the drain was believed to be caused by settling of the soil due to insufficient compaction during construction. Following the inspection, the area was leveled with a backhoe and compacted with a vibrator attachment on the end of the backhoe boom. The contractor returned to the landfill on May 24 to re-seed the impacted area, install erosion matting, and repair minor ruts left in the west drainage ditch by the backhoe during ingress and egress to Seep #7.

***Seep #4***

In July a shallow trench was dug approximately half the length of Diversion Berm #3 to drain areas of standing water at Seep #4 to the west perimeter ditch. All the current wet soil areas associated with suspected seeps on the OLF were surveyed using the field GPS instrument to provide a snapshot of the status of the seep areas on the landfill cover. The GPS information will be used to track seep/wet area locations over time. Photographs were taken of each location as well.

Seeps #4 and #7 at the OLF were evaluated again September 7. Both seeps still showed areas of active ground water seepage that is being drained by Diversion Berm #3. A French Drain system was designed that could be used (when or if required) to assist drainage of these wet areas off the landfill to the west perimeter ditch.

## 7.4 General Site M&O

The Site will be managed and maintained to protect the remediation activities that have taken place in the closure of the Site. Assessment of the Site will be performed on both a scheduled and continuous basis. Highlights of the routine and nonroutine maintenance and operation is shown below.

### 7.4.1 Plainview Fire Fighting Support

Rocky Flats LM supported efforts to fight the January 11 Plainview fire located just west of the Rocky Flats Site by allowing firefighters to fill their pumper trucks from the Rocky Flats Raw Water pond. The fire burned more than 2,700 acres of grassland, but never crossed Highway 93 to threaten the Site. Firefighters were very appreciative of the support from Rocky Flats and for allowing them access to a water source in such close proximity to the fire.

### 7.4.2 Rocky Flats Fire

A grass fire April 2 burned approximately 850 acres on the northeast corner of the POU/COU. The source of the fire was an arc from a faulty contact and broken conductor on an electrical power pole. Fire crews responded within eight minutes and called multiple agencies for mutual aid due to the wind driven, rapid spread of fire and the proximity to other jurisdictions. Eight emergency response agencies, including Broomfield, Westminster, and Boulder, responded.

Extensive local media coverage focused on the threat to nearby homes and generally left the Rocky Flats Site out of the spotlight.

Firefighters entered the Site and surrounding areas and lit numerous backfires to control the spread of the fire. The Westminster Emergency Response agencies also implemented a precautionary evacuation of the Walnut Creek subdivision in case the fire continued to spread toward Westminster. The fire was contained within approximately three hours and completely extinguished by 8:00 p.m. that evening.

The fire was limited to former POU/COU lands and never reached any erosion controls or recently re-vegetated areas, with the exception of one temporary road that was being re-vegetated. One surface water monitoring station (GS08 located below Pond B-5), was destroyed by the fire. The station was replaced before any water was discharged from Pond B-5. Several other water-monitoring stations suffered minimal damage that did not affect operability. No damage was found to any ground water monitoring wells. Fences damaged by firefighters cutting locks and fencing to access the Site and fallen power poles were repaired. Signage on the perimeter fence along Indiana Avenue and Highway 128 was replaced where needed.

Several permanent photo-monitoring locations were established in and around the wildfire location to document the ecological effects of the fire. Initial photos were taken shortly following the fire, and will be retaken throughout the growing season.

### 7.4.3 Rocky Flats Site Road Upgrades

Several dirt roads in the area of the COU were in poor repair, and during times of high precipitation were nearly impassible. To maintain access to all sections of the Site for surveillance and maintenance work, the worst of the problem areas on these roads were improved. Depending on the specific problem being addressed, the improvements included road base, geotextile fabric, rock water crossings, and surfactant.

The road improvements started August 7. Although the work started out well, several areas were identified that required preliminary work to support the road upgrades. Specific problem areas included a sinkhole likely related to a former sanitary sewer manhole, an area in the COU with chronically-wet soil, and an abandoned culvert. Culverts were installed across FC-4 to support a new east-west road traversing the COU. Surfactant was applied September 8. The subcontractor rolled and compacted the roads one final time on September 11 prior to de-mobilizing the equipment.

The subcontractor returned the week of September 25 to perform a second phase of upgrades to several additional roads at the Site. Road base was used to upgrade access roads in the former IA and to construct work pads around the ETPTS and the MSPTS. This second phase of work was completed October 3 when the surfactant was applied.

### 7.4.4 Erosion Control

The existing erosion controls are maintained and repaired to protect the bare soil areas until the vegetation can stabilize the soil. Assessing the erosion control is especially important following high wind events which are common at the Site. Reestablishment of the vegetation in the

disturbed areas was assessed during the growing season. Areas lacking sufficient vegetative cover were reseeded to assure adequate establishment of the native vegetation in these areas.

Maintenance of the Site erosion control required effort throughout CY 2006, but especially during the windy months of January and February. Erosion control matting required replacement of the stakes and/or wire spikes originally used to secure the matting. In areas of very rocky soil, a common characteristic of Rocky Flats alluvium, staking was ineffective and large rocks and cobles were used to secure the matting. During the 2nd quarter of CY 2006 a subcontractor was hired to assist with erosion control efforts in some larger areas near the B-series ponds. The work was initiated the first week of May, with reseeding performed prior to the installation of the erosion matting.

Erosion wattles were also loosened and displaced by the wind, and required restaking. In areas where the soil allowed, the original stakes were replaced with longer stakes to allow deeper penetration of the stake in the soil to better hold the wattle.

Several high-precipitation rain events occurred during the summer, which initiated investigations of the Site to assess potential erosion or other damage. In late June a heavy rainfall event occurred that required erosion control repairs in early July on the hillside east of FC-5 where previous rainfall events had eroded soil along the wattles. Wattles on the hillside were repositioned so they were placed along a contour line rather than running almost parallel with the direction of water flow (as originally installed). Old wattle materials were placed in the eroded cuts to stop any further soil erosion and facilitate these areas filling with sediment. The eroded cuts along the edge of the riprap area of FC-5 were filled with riprap to minimize further downcutting. Additional erosion control repairs were made in FC-1 where wattles had been placed previously.

Approximately 2 inches of rain fell at the site July 7 (based on National Renewable Energy Laboratory data). Erosion control surveys were conducted July 10 to evaluate any problems. Observations were also made of the areas repaired the week of July 3. No problems were observed.

Throughout the fall and winter months the field crew replaced erosion controls in several areas, including sensitive areas where the new roads were constructed. Wattles that had been destroyed or blown out of place were repaired/replaced on the OLF and on the hillside south of FC-4 (east of the SW056 slump). Water bars were dug to divert any heavy runoff into FC-5. Erosion control matting was added to several areas that appeared to be potentially prone to erosion based on summer storm events. Overseeding and erosion matting replacement was completed at the PLF, the OLF, the former Building 371 area, the hillside east of FC-5, and south of the FC-4 area.

### 7.4.5 Aerial Survey

A contract to perform aerial photography and a topographic survey of the Rocky Flats Site and former BZ was awarded during the second quarter of CY 2006. The survey was needed to support vegetation studies with high-resolution aerial photographs as well as provide updated topographical maps of the DOE retained lands. Additional aerial photographs of the Site were requested for public relations use. Establishment of ground control coordinates, specified to facilitate integration of previous aerial surveys with the new survey, was performed the week of

June 19. A clear day was required for good quality aerial photography and mapping, and was completed June 27. The completed photographs and topographic maps were due from the subcontractor August 31, but were delayed due to problems converting the vertical datum from NAVD88 to NGVD27 to allow existing Rocky Flats date to be integrated with the new orthophotos and topographic maps.

### 7.4.6 Site Access Control

The security of the Site is assessed on a continuous basis. The perimeter fence is maintained and replaced as required. Excess or unnecessary gates in the perimeter fence were removed and replaced with fence to reduce the number of access points to the Site.

In January and February general upgrades were made to the east perimeter fence. Posts were installed and wire replaced and/or repaired as necessary to make the fence intact. Although the fence is nearing the end of its useable life, it is still functional for maintaining a barrier to Site access from Indiana Street.

In March an SUV slid off Indiana Street and rolled over the east perimeter fence. Emergency response crews cut through the fence just south of the accident to allow access for rescue operations. Both areas of damage to the perimeter fence were repaired as the tow truck was removing the vehicle.

In March the fence just south of the west gate was damaged by a vehicle that apparently could not make a complete stop before contacting the fence. Repairs were minor, and required a new "T" post and re-stretching of the lower two strands of barbed wire.

In addition to routine maintenance in CY 2006, fence repairs performed by the Rocky Flats staff included a new gate that was built and secured on the sawmill road, repairs to the adjacent fence near this gate, and repairs to the gate near the McCaslin-Hwy 128 intersection.

A subcontractor was employed in early May to do a thorough repair of the east perimeter fence along Indiana Street. The repairs involved replacement of broken and/or missing fence posts, replacement and re-tensioning of the barbed wire in sections of fence found to be in poor condition, reattachment of the wire to the posts, and installation of additional fence stays.

On the night of May 5 a vehicle hit the west gate. One of the wooden gate posts and a short section of wire fence was damaged. The gate chain and locks were moved to the former K-H gate located approximately 300 feet east to maintain security of the Site. The fencing subcontractor employed to repair the east perimeter fence repaired the gate post and re-hung the gate. New signs that read "Dead End" and "Road Closed" were placed at the west gate to help inform individuals that they are on the west access road to the Site, and not on a continuous roadway. Additional barricades were also added to the fence line on either side of the west gate.

In August a statement of work was issued for a subcontract to support Site fencing needs. The statement of work included scope for assistance in making minor adjustments to the COU fence location, construction of the COU fence, and for future fence repairs (as needed) after the initial fence construction is complete. The minor adjustments to the fence location were performed in early October. The construction of the COU fence was started November 6. The fence

construction work progressed well through November and December until the first of several heavy snow storms hit the Site on December 20, causing the construction to be halted until snow cleared enough to resume work in 2007.

### 7.4.7 Site Surveillance

A contract for Site surveillance was awarded in CY 2006, with surveillance initiated April 19. The surveillance is performed during times when the field sampling crew is not normally in the field. These times include coverage evenings during the week, and continuous coverage Thursday evening through Monday morning.

During CY 2006 the subcontract surveillance personnel reported the use of illegal fireworks north of the Site, ands were the first to discover and report the vehicle damage to the west gate. They also made numerous contacts with drivers of vehicles stopped near the Site, and were visible by passing motorists while stationed at their observation stations, possibly preventing unauthorized access through the heightened public awareness of their presence.

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