Appendix B

Vegetation Management and Cover Performance

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B1.0 Introduction

This Appendix explores the state-of-the-science of conventional cover designs with respect to natural degradation processes, alternative designs, and opportunities to enhance long-term performance and reduce long-term maintenance costs.

Maintenance of disposal cell covers at DOE disposal sites can be costly. Cutting and spraying vegetation growing on covers has been a common practice because of concerns that plant roots will degrade their performance. The cost of herbicide spraying to control deep-rooted vegetation on covers has increased at many sites, and may continue to do so, as ecological conditions become more favorable for plant growth. However, replacement of the low-permeability radon barrier, because of natural degradation processes including root intrusion, could be even more expensive.

Fortunately, recent research indicates that plants may actually be a solution, not a problem. Without human intervention, ecological succession and soil development processes may effectively transform existing conventional covers, with low-permeability radon barriers, into water balance covers. A long-term management option may be to actually enhance this transformation process by anthropogenic means.

B2.0 Conventional Cover Performance

As with most conventional engineered covers for uranium mill tailings, the Gas Hills North cover design relies on a compacted soil layer (low-permeability radon barrier) to limit percolation flux and radon flux. Laboratory studies, field investigations, and other lines of evidence show that a few years after construction, permeabilities of compacted soil layers are typically several orders of magnitude greater than assumed or measured at the time of construction (Albright et al. 2004, Melchoir 1997, Waugh et al. 2007, Waugh et al. 2009, Benson et al. 2011a). The percolation rate into the tailings may also be much higher than anticipated, sometimes by several orders of magnitude (Albright et al. 2006a & 2006b, Waugh et al. 2007). Several reasons are cited:

- Unanticipated ecological consequences of designs that encourage plant and animal intrusion (Hakonson 1986, Suter et al. 1993, Bowerman and Redente 1998, Waugh et al. 1999),
- Compaction either dry or wet of optimum during construction (Benson et al. 1999),
- Desiccation cracking (Albrecht and Benson 2001),
- Differences between laboratory and field saturated hydraulic conductivities (Daniel 1984).
- Freeze-thaw cracking(Kim and Daniel 1992, Benson and Otlman 1993),
- Differential settlement (Jessberger and Stone 1991, Lagata 1992), and
- Retention of borrow soil structure (clods) during construction and pedogenesis (soil development processes) after construction (Benson et al. 2011a).

Deep-rooted plants began growing on conventional uranium mill tailings covers at several sites within a few years after construction (DOE 1992). Roots of woody plants were excavated and found to grow down into or through radon barriers at the Grand Junction, Colorado;

Lakeview, Oregon; Burrell, Pennsylvania; Durango, Colorado; Shiprock, New Mexico; and Tuba City, Arizona, disposal sites (DOE 1992, DOE 1999, Waugh et al. 2007). Taproots typically extended vertically through the riprap and bedding layers and then branched and spread laterally at the surface of the compacted soil barrier, following both the source of water and the path of least resistance to penetration and growth. Secondary and tertiary roots extended vertically into the compacted soil barrier, where they became fibrous root mats following cracks and soil structural planes.

In follow-up investigations of root intrusion, DOE evaluated the effects of plant roots and soil development on in situ soil hydraulic conductivity (K_s), a measure of permeability, for compacted soil layers at Burrell, Lakeview, Shiprock, and Tuba City using air-entry permeameters (Setphes et al. 1988). At Burrell, the mean K_s was 3.0×10^{-7} m/s where Japanese knotweed roots penetrated the radon barrier, and 2.9×10^{-9} m/s at locations with no plants (Waugh et al. 1999). The weighted-average K_s for the entire cover, calculated using the community leaf area index for Japanese knotweed, was 4.4×10^{-8} m/s. At Lakeview, the mean K_s for the radon barrier both with and without sagebrush and bitterbrush roots was 3.0×10^{-7} m/s (Waugh et al. 2007). The highest K_s occurred near the top of the compacted soil barrier; the lowest K_s occurred deeper in the barrier. The mean K_s in the top of the Shiprock radon barrier was 4.4×10^{-7} m/s (Glenn and Waugh 2001). Results were higher and more variable where tamarisk and Russian thistle were rooted in the radon barrier. The Shiprock radon barrier was nearly saturated, as measured monthly for 16 months at four locations using a neutron hydroprobe. At Tuba City, K_s of the radon barrier had a mean of 8.7×10^{-8} m/s and ranged from 9.8×10^{-11} to1.2×10^{-6} m/s. In all of the tests mentioned above, dyes indicated that water moved through macropore cracks in the soil structure of radon barriers.

Short-term changes in cover soil properties are not unique to disposal cells for uranium mill tailings. Exhumations of covers in the U.S. Environmental Protection Agency (EPA) Alternative Cover Assessment Program (ACAP) (Albright et al. 2004) show changes to saturated and unsaturated hydraulic properties after 4- to 8-years. Benson et al. (2011a) reported in-service K_s for storage and barrier layers between 7.5×10^{-8} and 6.0×10^{-6} m/s regardless of the initial K_s. Alterations in K_s occurred in all climates and for barrier and storage layers in all cover types. Wet-dry cycling appears to play a major role in altering K_s. Smaller changes in K_s occurred in storage and barrier layers constructed with soils that have lower clay content, soils that have a fines fraction with a greater proportion of silt-size particles, and soils compacted to lower dry unit weight. Benson et al. (2011a) reported that the porosity of most earthen storage and barrier layers evaluated in the ACAP study was between 0.35 and 0.45 when exhumed, and predicted that densely compacted soil layers in engineered covers would loosen over time and become more permeable.

B3.0 Water Balance Covers

In contrast with conventional low-permeability covers, DOE, EPA, and others have shown that water balance covers can be very effective at limiting percolation at arid and semiarid sites (Dwyer 2001, Albright et al. 2004, Scanlon et al. 2005a & 2005b, Waugh et al. 2009). For example, the average percolation rate from the water balance cover at the Monticello, Utah, Disposal Site has been approximately 0.6 mm/yr for more than a decade during which the average annual precipitation has been 358 mm/yr (Waugh et al. 2009).

Water balance covers consist of thick, fine-textured soil layers that store precipitation in the root zone where it can be removed seasonally by plants (Albright et al. 2010). Capillary barriers composed of coarse-textured sand and gravel placed below this soil "sponge" can enhance soil water-storage capacity and limit unsaturated flow (Nyhan et al. 1990, Ward and Gee 1997, Stormont and Morris 1998). Available water storage capacity has been defined as the difference between the total amount of water retained in a soil at field capacity (*upper limit*) and the amount of water remaining when the soil dries to the permanent wilting point for plants (*lower limit of extraction*) (Riche 1981). At the permanent wilting point, soil water tensions become too high for plants to remove more water. Water balance covers can be designed to accommodate changes in soil hydraulic properties caused by the environmental conditions that damage low-conductivity covers (Benson et al. 2011a).

The sustainability of water balance covers will depend, in part, on the establishment and resilience of a diverse plant community (Waugh et al. 1997). Changes in the plant community inhabiting a cover will influence soil water movement, evapotranspiration (ET) rates, and the water balance of a cover. However, plant community dynamics are complicated and effects are difficult to predict. Even in the absence of large-scale disturbances, seasonal and yearly variability in precipitation and temperature will cause changes in species abundance, diversity, biomass production, and soil water extraction rates on covers (Link et al. 1994). Investigations of natural analogs can provide insights as to how ecological processes may influence the sustainability of alternative covers (Waugh et al. 1994). Evidence from natural analogs can improve our understanding of (1) vegetation responses to climate change and disturbances, (2) effects of vegetation dynamics on ET, soil hydraulic conductivity, soil erosion, and animal burrowing, and (3) effects of soil development processes on water storage, hydraulic conductivity, and site ecology.

B4.0 Cover Enhancement Studies

An ongoing DOE research project is testing methods to accelerate and enhance natural processes that are effectively transforming existing conventional covers, which rely on low-permeability compacted soil layers, into water balance covers, that store water in soil and release it as soil evaporation and plant transpiration (Benson et al. 2011b). The goal is to accommodate ecological processes and, thereby, sustain a high level of performance while reducing long-term maintenance costs.

DOE is also investigating potential effects of root intrusion and soil development on radon flux in compacted soil layers and biouptake of contaminants.

B5.0 References

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Appendix C

Field Photograph Log

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Field Photograph Log

Site: Purpose of Visit:

Date of Visit: Photo Type: (film and/or digital)

Photo File Name	Film Frame No.	Azimuth	Field Inspection Photo No.	Trip Report PL No.	Post on Web (Y/N)	Photo Caption

Lead Inspector: Assistant Inspector:
Remarks:
Electronic File Location:

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Appendix D

Initial Site Inspection Checklist

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Inspection Checklist: Gas Hills North

Date of This Revision: ______________
Last Annual Inspection: ______________
Inspectors: ______________ and ______________

Next Annual Inspection (Planned): ______________

No.	Item	Issue	Action
1	Access	Access is from the BLM road directly south of the site.	None.
2	Specific site surveillance features	See attached list.	Inspect. Identify maintenance requirements.
3	Impoundments and associated drainage structures	Tailings and solution ponds were stabilized in-place within constructed impoundments that are protected from surface runoff by a series of drainage structures.	Check integrity of impoundments; look for slumping, settling, and erosion damage. Check functionality of drainage structures.
4	Rock mulch	The surfaces of the tailings impoundments and solution ponds have been covered with rock mulch to control wind and water erosion.	Inspect impoundment cover and note condition of rock mulch and evidence of displacement.
5	Riprap	Certain areas have been armored with riprap for erosion protection.	Inspect riprap; note evidence of rock displacement, rock degradation, hydraulic scour, or bank cutting.
6	Site perimeter and balance of site	The area between the tailings impoundments and solution ponds have been contoured and revegetated. Specific site surveillance features were installed in this area.	Check integrity of the area between tailings impoundments and solution ponds, site boundary, boundary monuments, site entrance and perimeter signs, and site marker.
7	Outlying Areas	Check land use 0.25 mile beyond site boundary for changes and developments. Check for domestic wells installed.	Status ownership and land use adjacent to the site.

Checklist of Site-Specific Surveillance Features: <u>Gas Hills North</u>

Feature	Comment
Access Road	Dirt road. Verify road is passable (provide maintenance on ROW, as needed).
Entrance Gate	Total: 2
Entrance and Perimeter Signs	Total: 15
Boundary Monuments	Total: 17 (3 are witness corners)
Site Marker	Total: 1
Monitor Wells	Total: 5 Background Well (Wind River Aquifer) T1–6 POC Well (Wind River Aquifer) T1–12 POC Wells (Fraser Draw Alluvial Aquifer) AL–1, AL–7 POE Well (Fraser Draw Alluvial Aquifer) AL–6

Appendix E

Time-Concentration Plots of Historical Groundwater Monitoring Data from the Gas Hills North, Wyoming, Disposal Site

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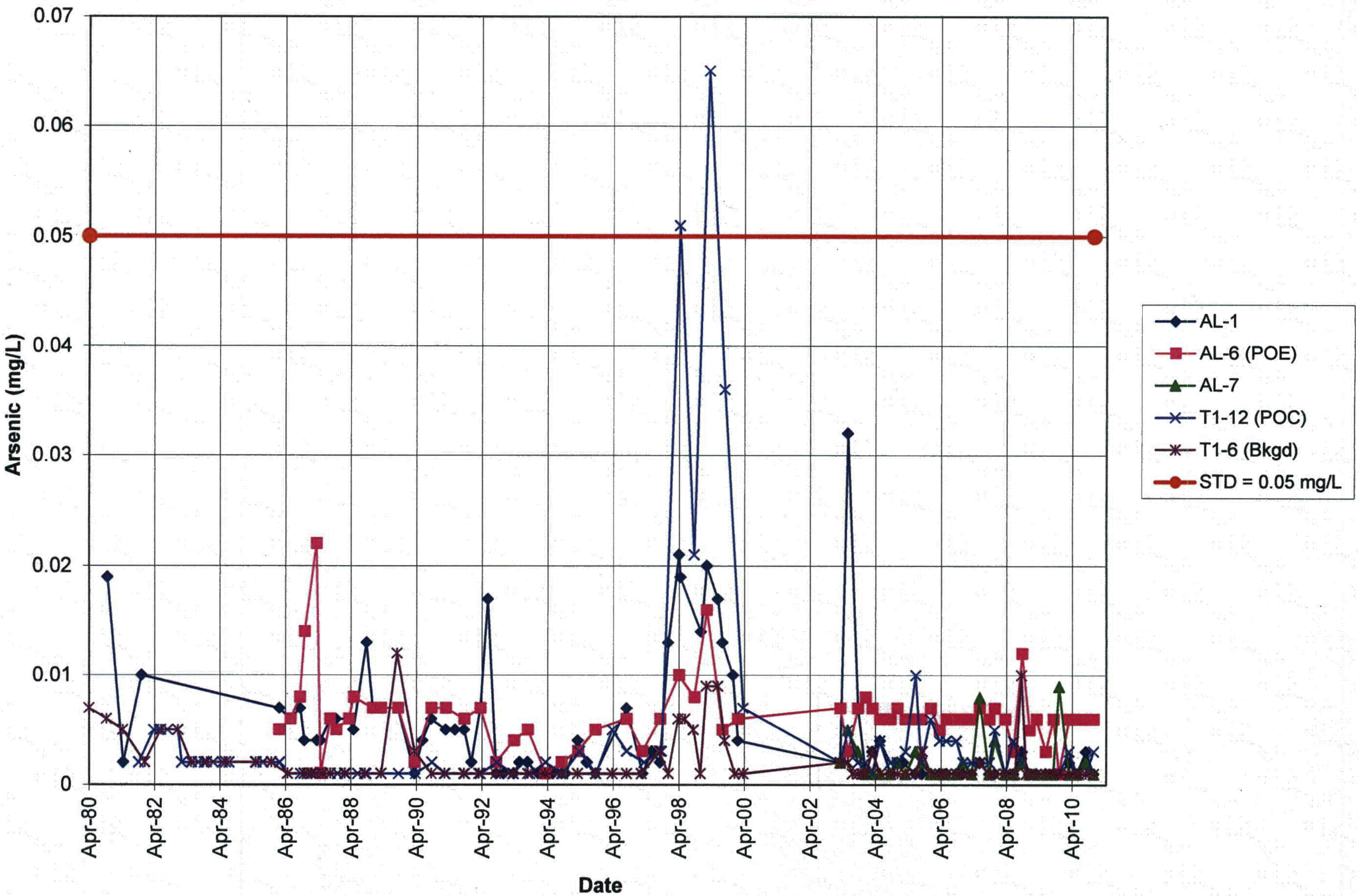

Figure E–1. Time-Concentration Plots of Arsenic in the Groundwater at the Gas Hills North, Wyoming, Disposal Site

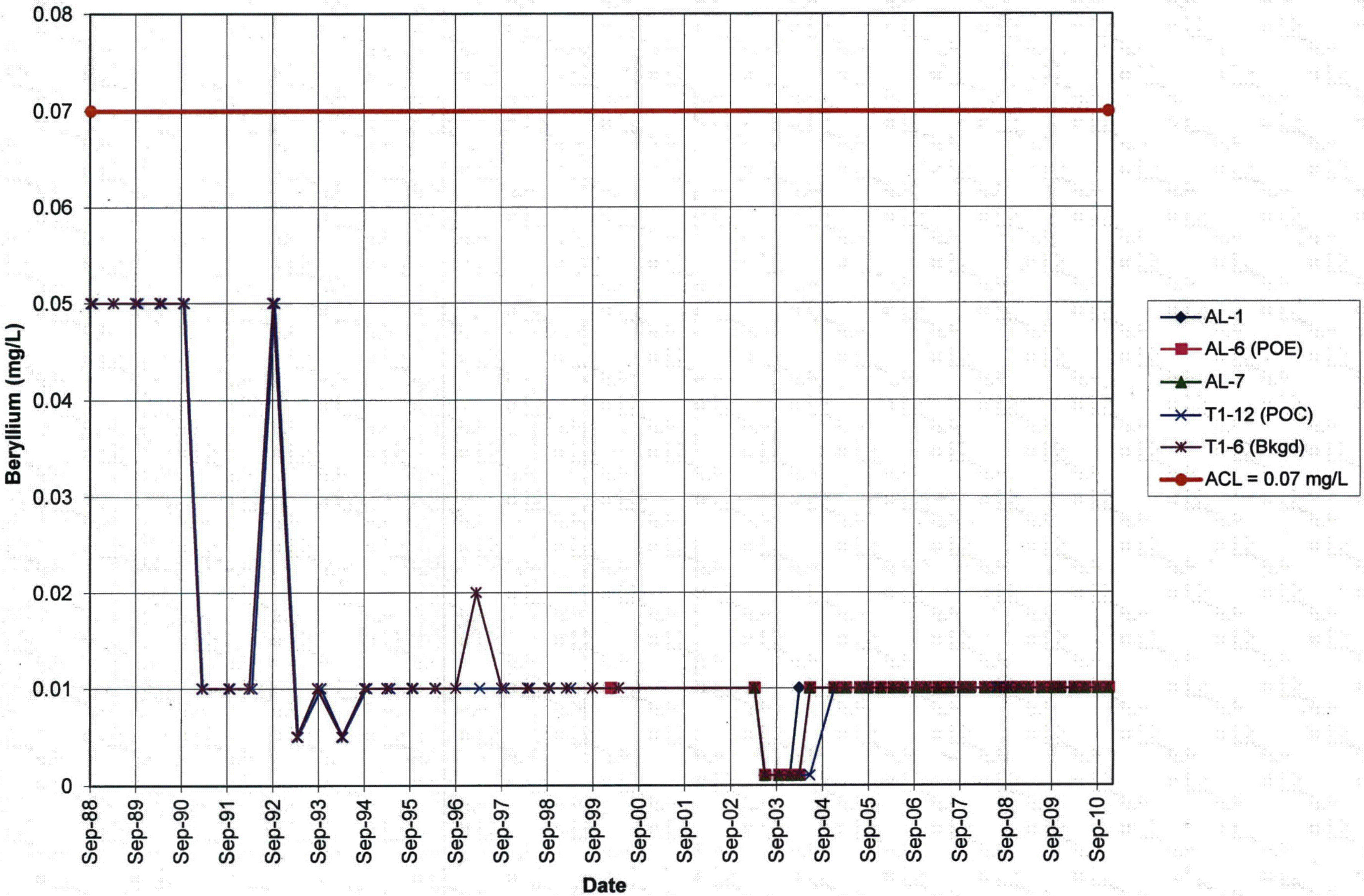

Figure E–2. Time-Concentration Plots of Beryllium in the Groundwater at the Gas Hills North, Wyoming, Disposal Site

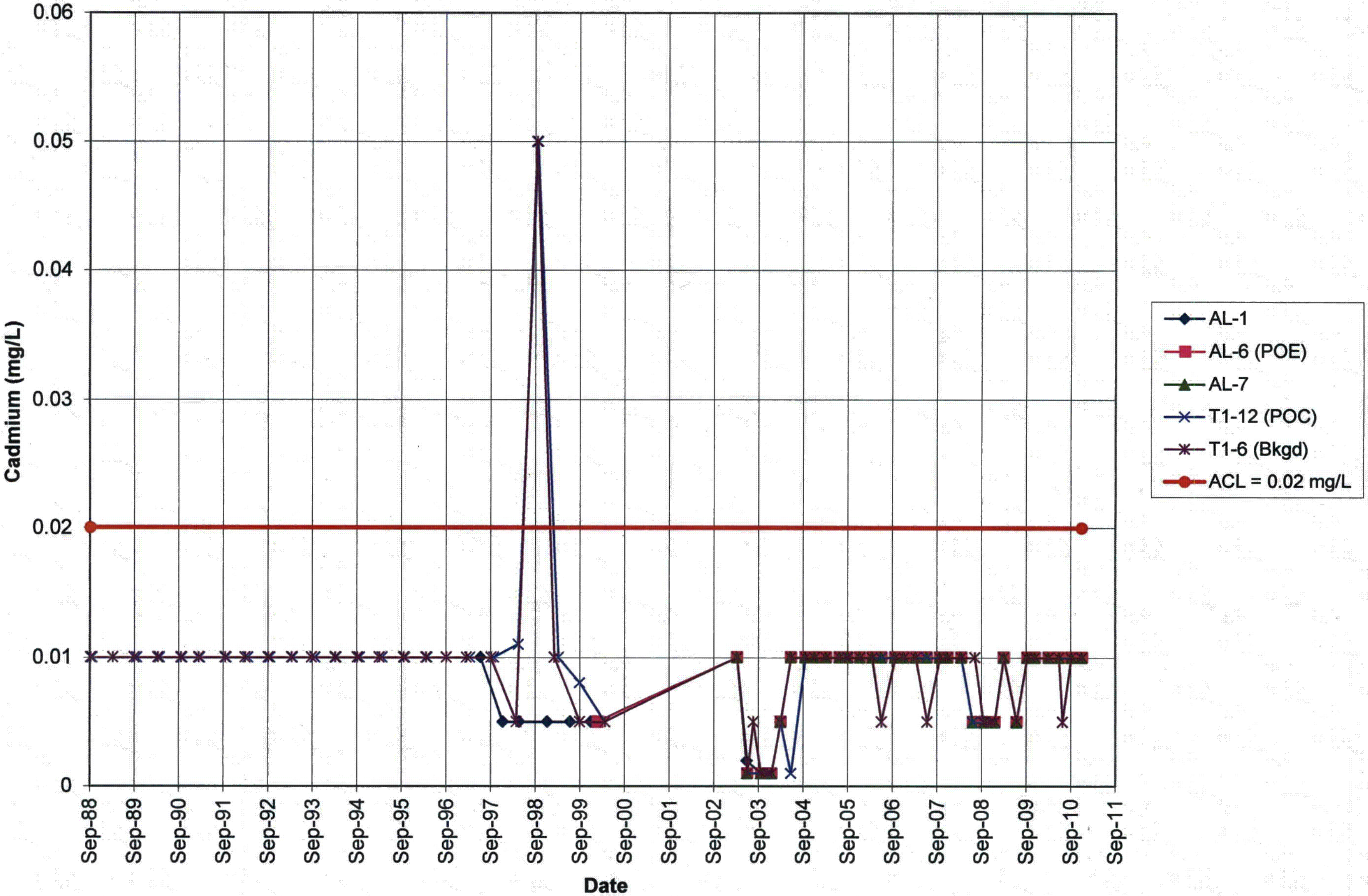

Figure E–3. Time-Concentration Plots of Cadmium in the Groundwater at the Gas Hills North, Wyoming, Disposal Site

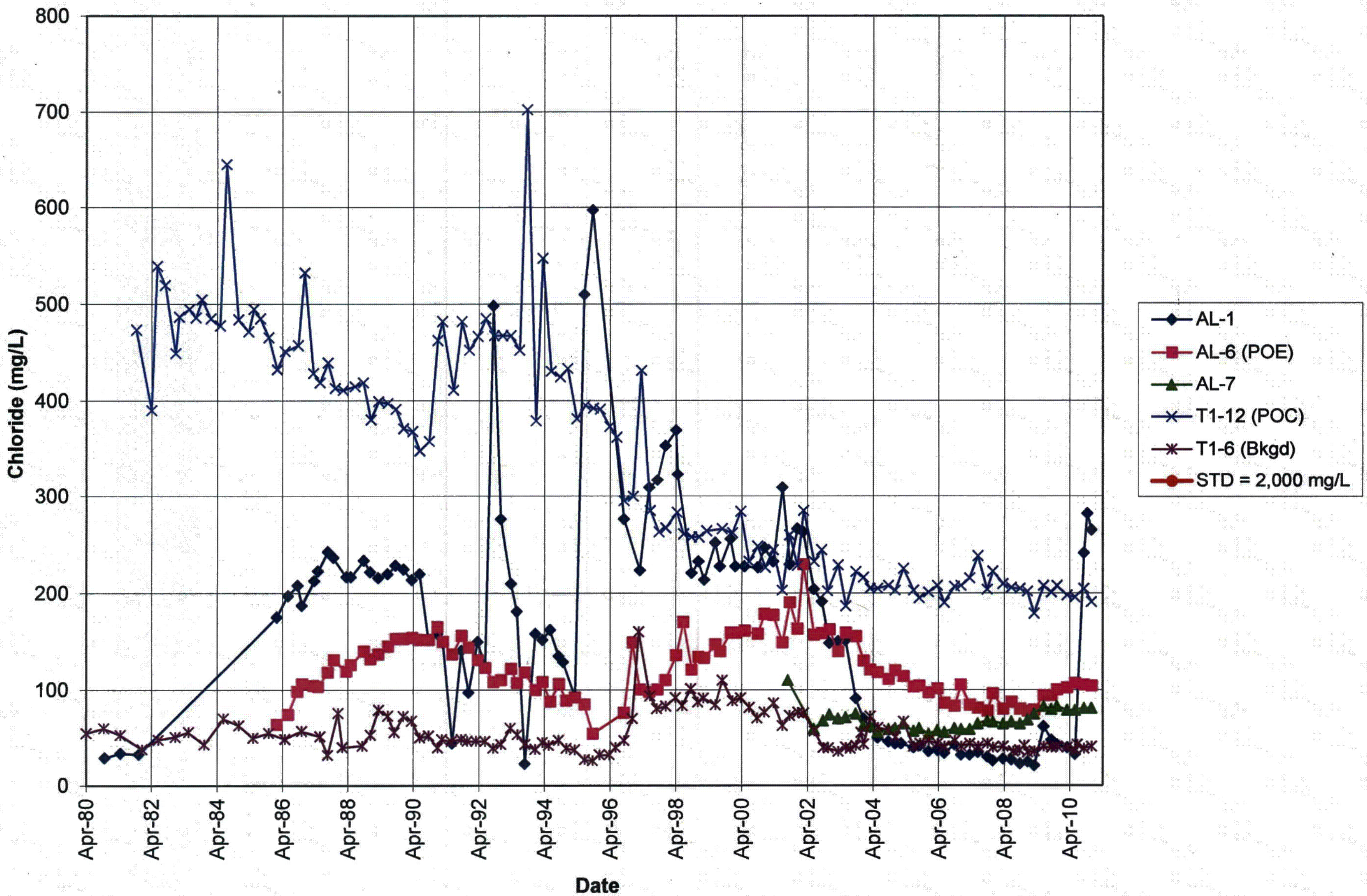

Figure E–4. Time-Concentration Plots of Chloride in the Groundwater at the Gas Hills North, Wyoming, Disposal Site

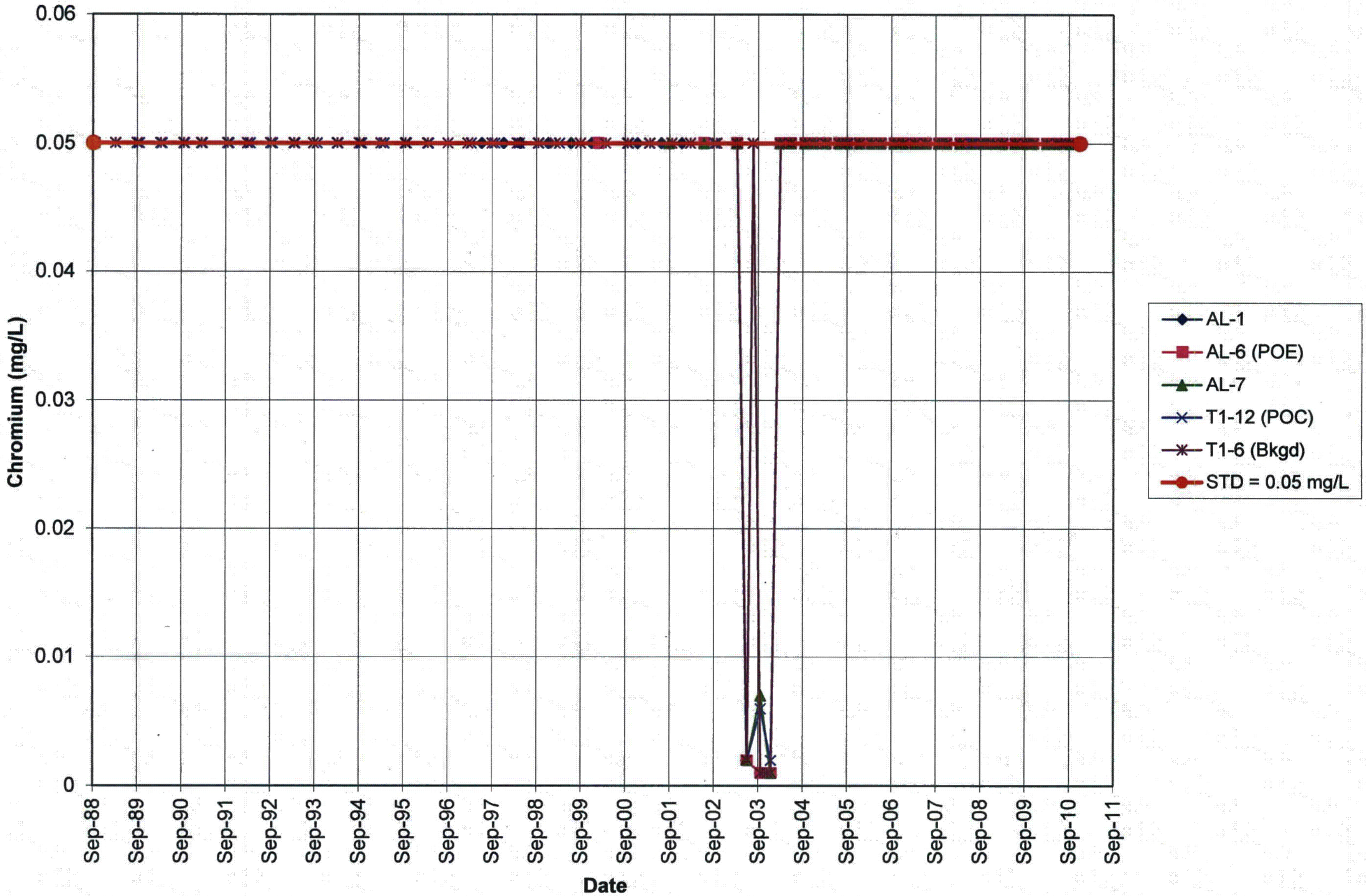

Figure E–5. Time-Concentration Plots of Chromium in the Groundwater at the Gas Hills North, Wyoming, Disposal Site

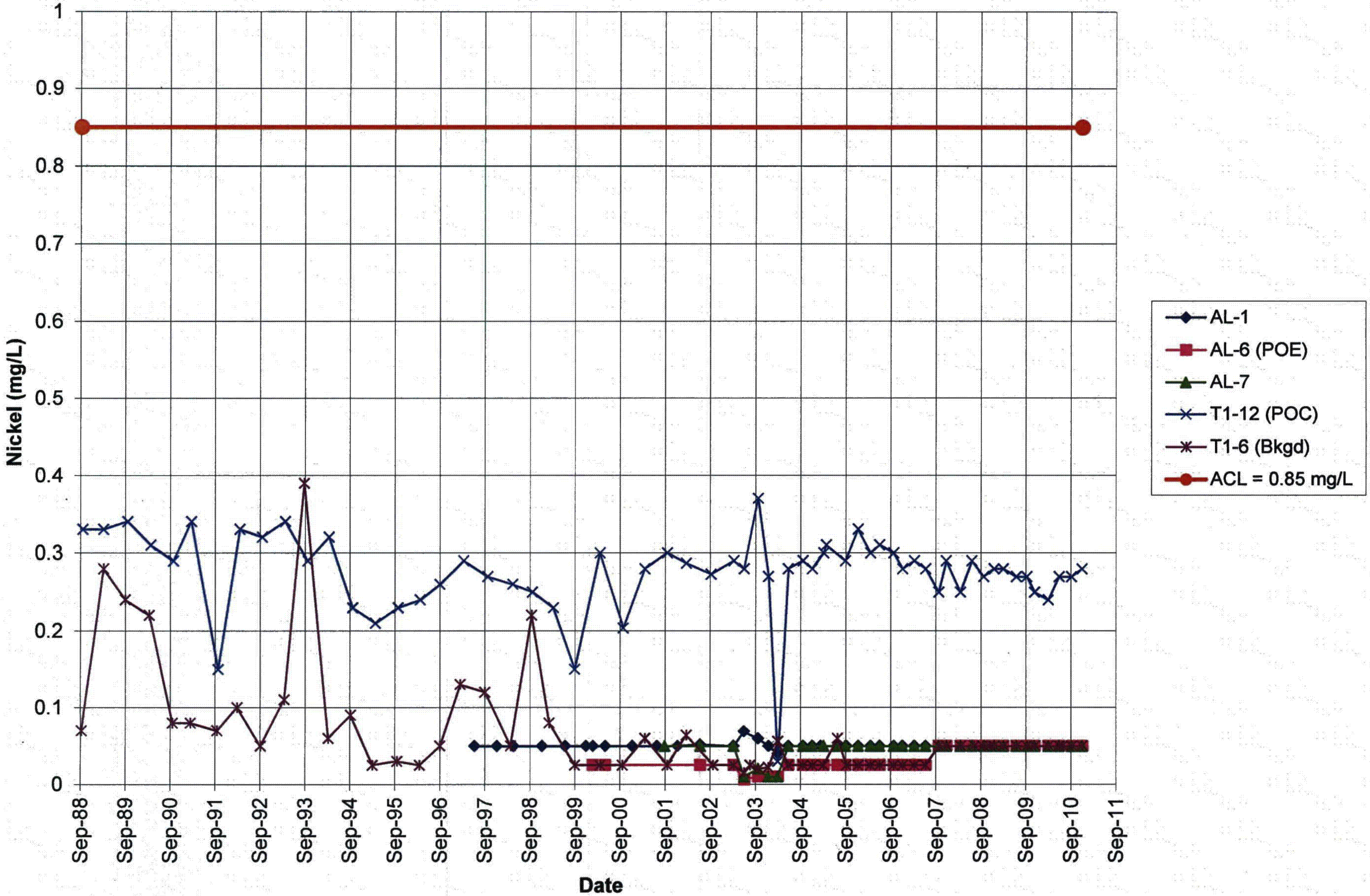

Figure E–6. Time-Concentration Plots of Nickel in the Groundwater at the Gas Hills North, Wyoming, Disposal Site

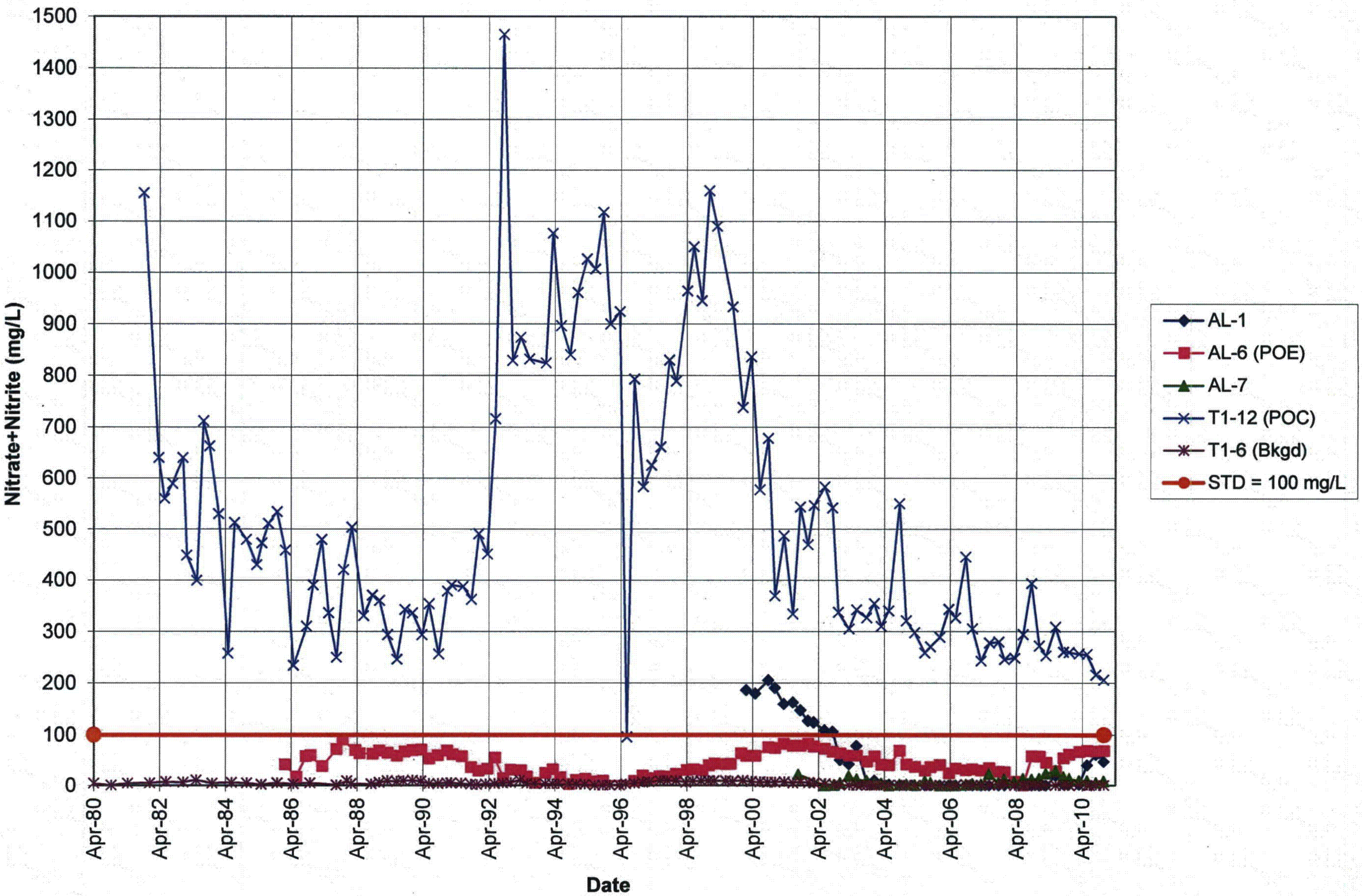

Figure E–7. Time-Concentration Plots of Nitrate+Nitrite in the Groundwater at the Gas Hills North, Wyoming, Disposal Site

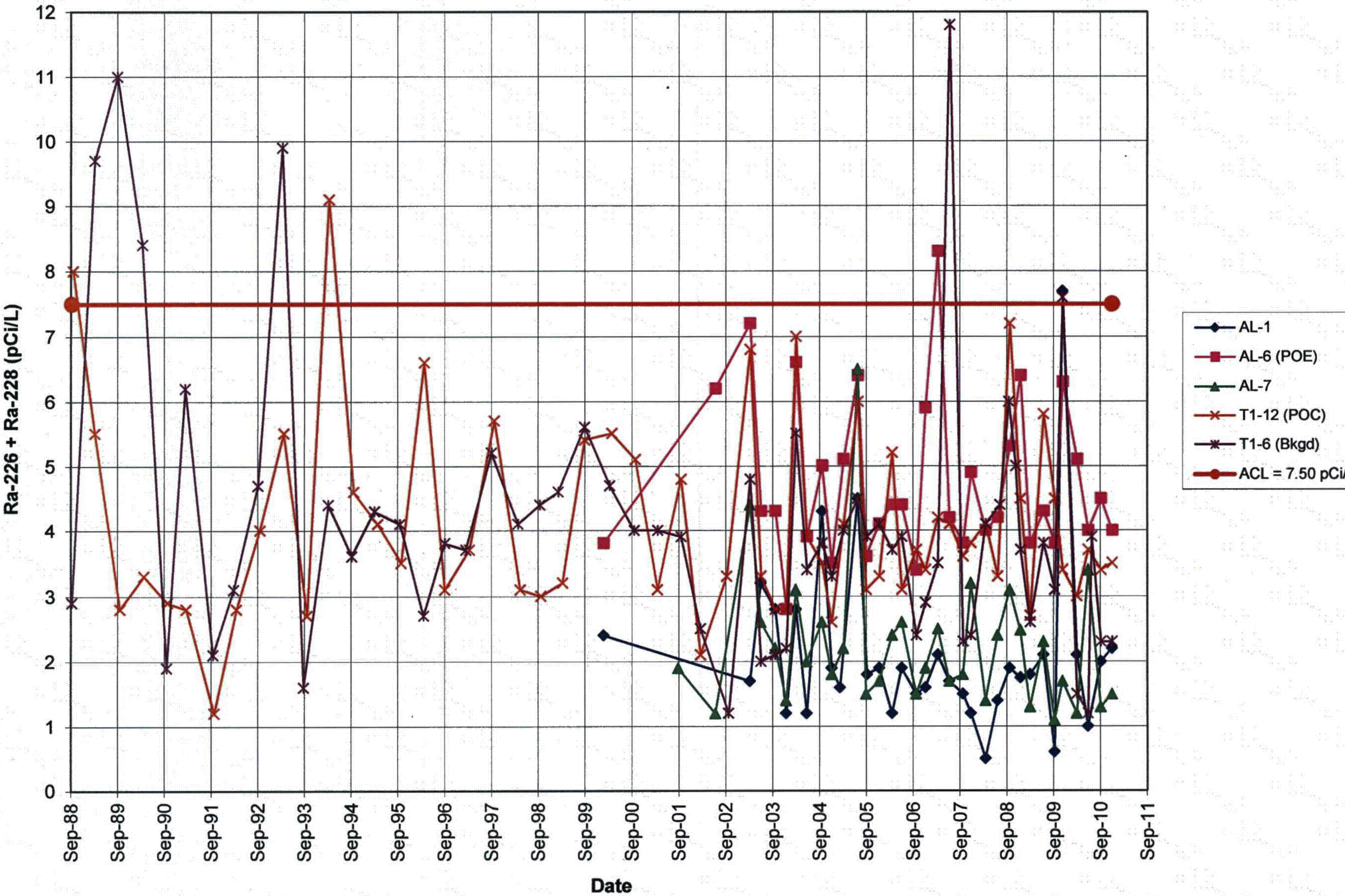

Figure E–8. Time-Concentration Plots of Ra-226+Ra-228 in the Groundwater at the Gas Hills North, Wyoming, Disposal Site

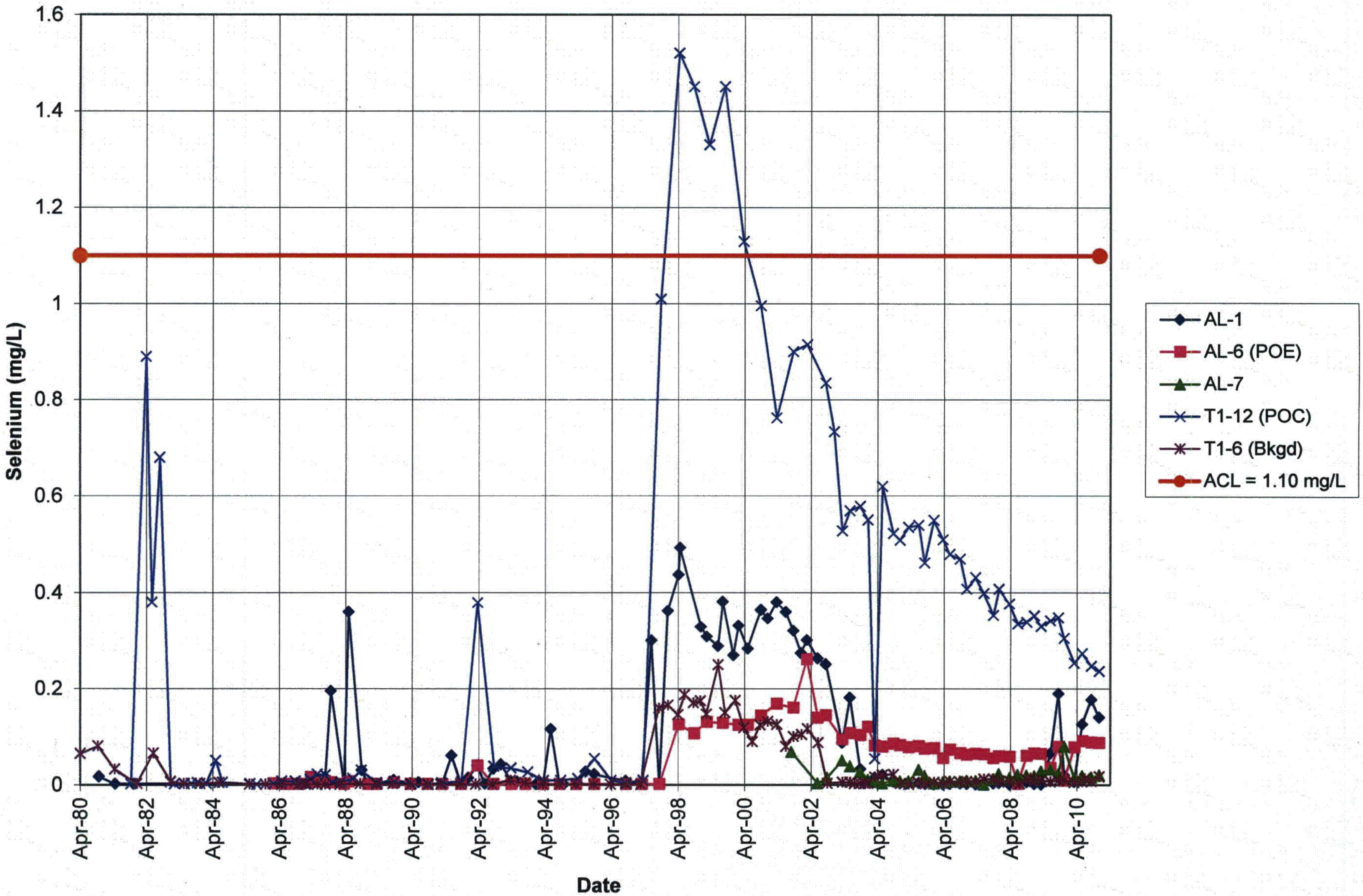

Figure E–9. Time-Concentration Plots of Selenium in the Groundwater at the Gas Hills North, Wyoming, Disposal Site

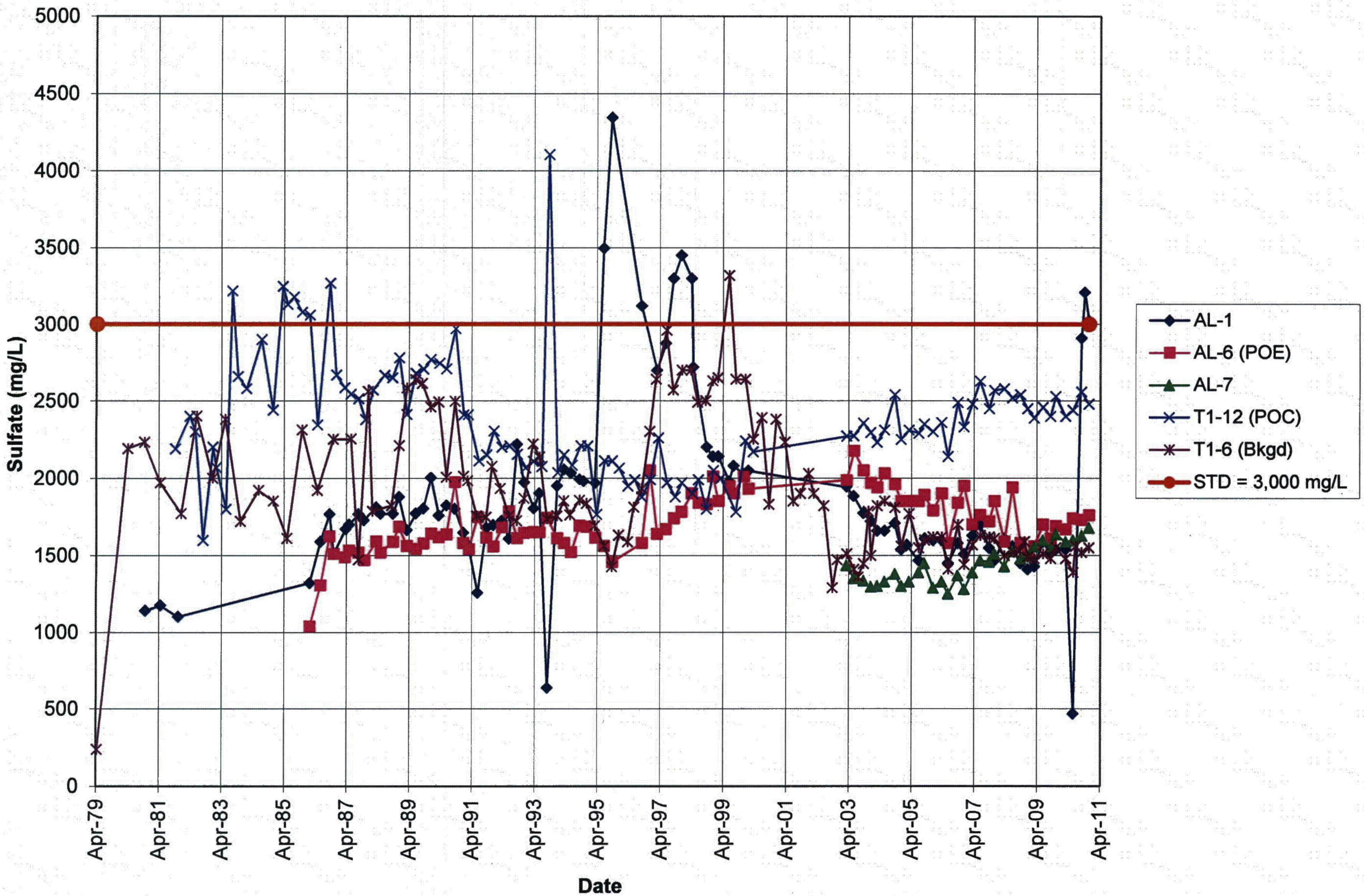

Figure E–10. Time-Concentration Plots of Sulfate in the Groundwater at the Gas Hills North, Wyoming, Disposal Site

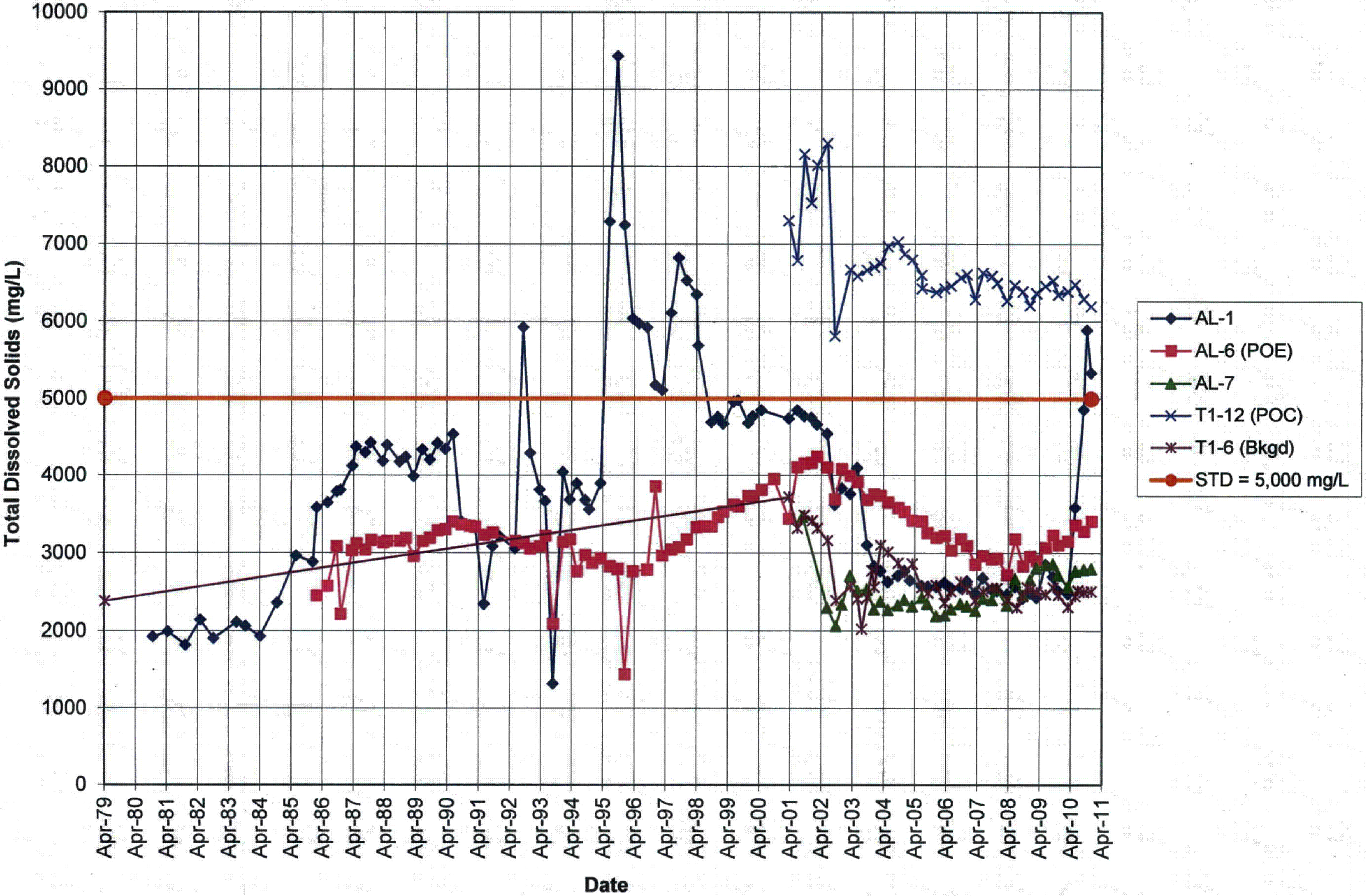

Figure E–11. Time-Concentration Plots of Total Dissolved Solids in the Groundwater at the Gas Hills North, Wyoming, Disposal Site

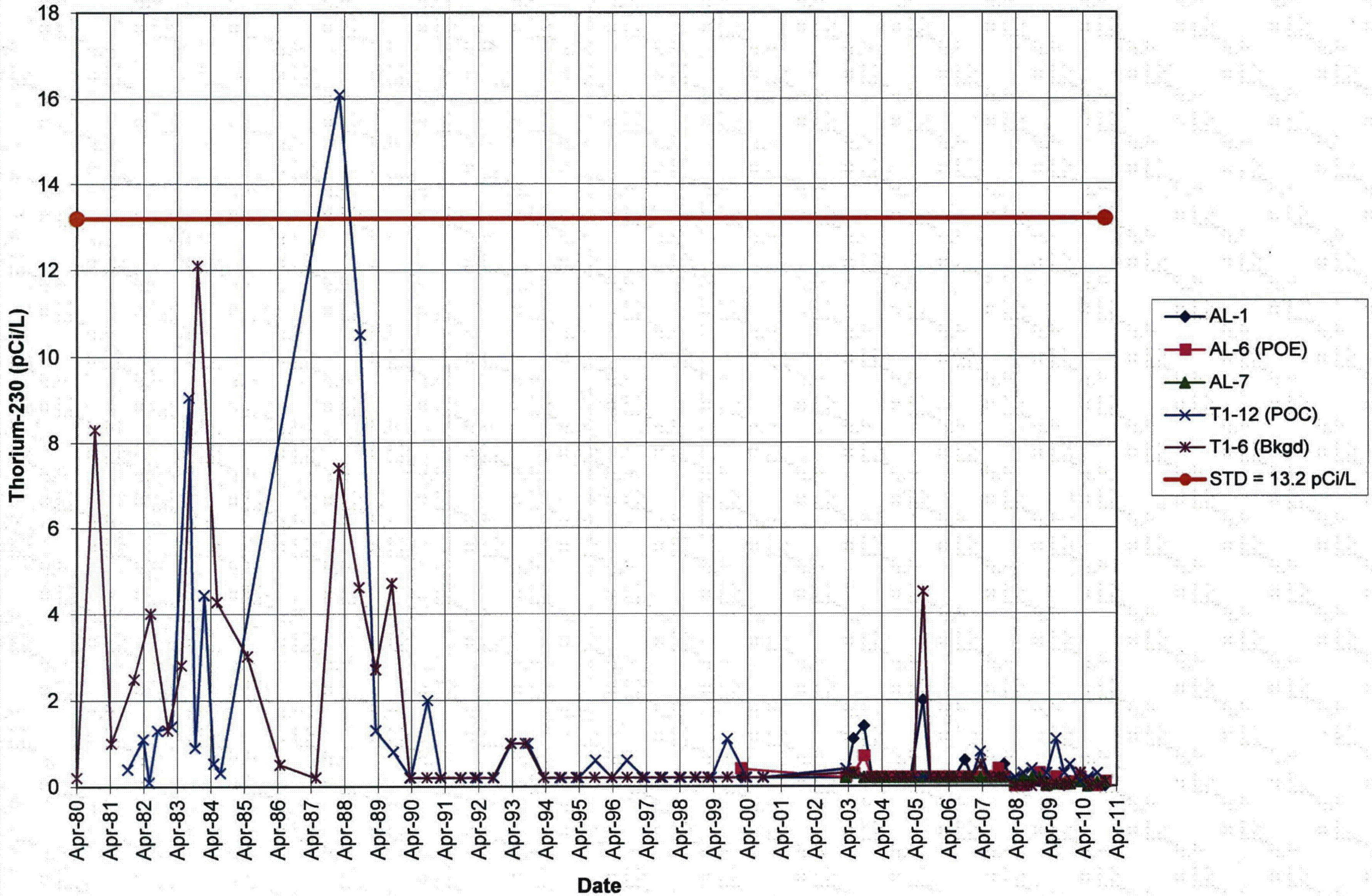

Figure E–12. Time-Concentration Plots of Thorium-230 in the Groundwater at the Gas Hills North, Wyoming, Disposal Site

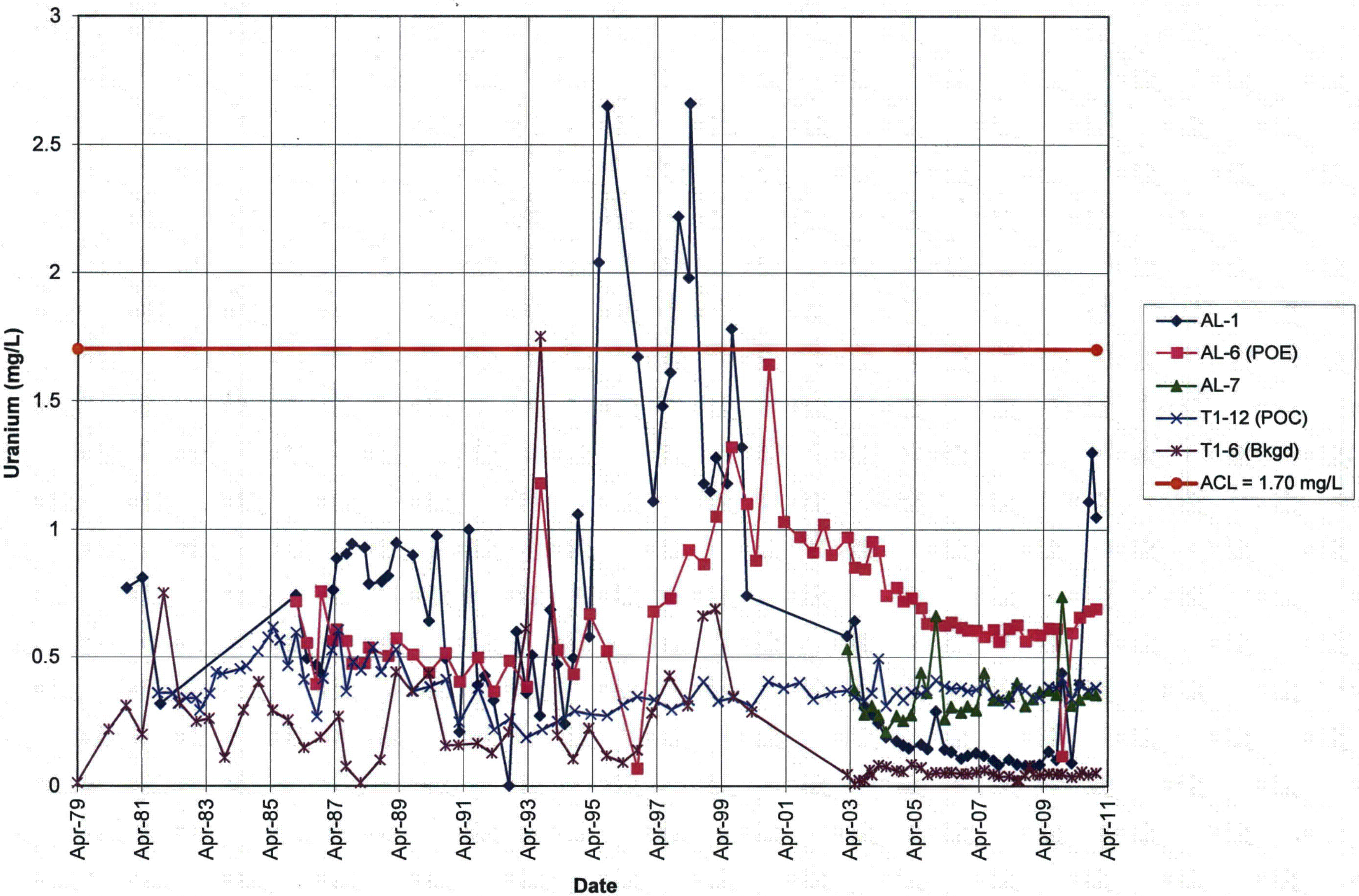

Figure E–13. Time-Concentration Plots of Uranium in the Groundwater at the Gas Hills North, Wyoming, Disposal Site

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Supplemental Information

NRC Acceptance Documentation

This documentation was added following acceptance of this Long-Term Surveillance Plan by the U.S. Nuclear Regulatory Commission

(to be inserted upon receipt)

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