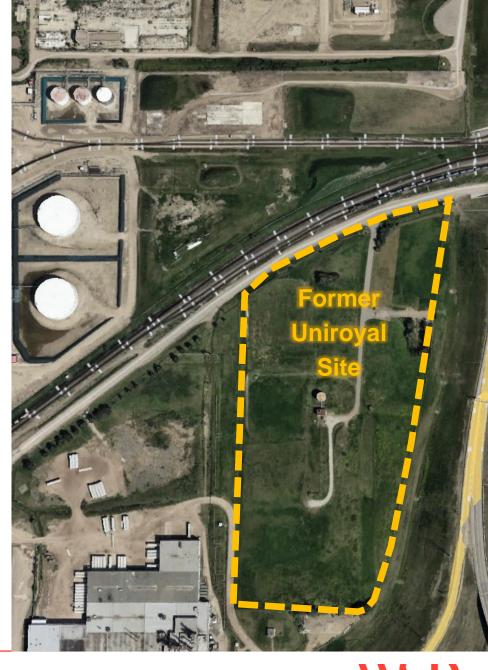
Transition to Monitored Natural Attenuation After 30 Years of Pump and Treat at the Former Uniroyal Site in Edmonton, Alberta

Joe A. Ricker, P.E. Senior Technical Principal WSP USA Inc. Joseph.ricker@wsp.com Hadley Stamm
Environmental and Remediation
LANXESS
Hadley.stamm@lanxess.com



Site Background

- Chemical manufacturing: 1961 1983
 - > Chlorophenoxy herbicides
 - Chlorophenolic wood preservatives
- Groundwater remediation system
 - > Commenced 1984
 - > 7 extraction wells in upper zone
 - > year-round operation: 1984 2003
 - > Seasonal operation: 2003-2014
 - > Trial shutdown in 2014
 - Transition from pump & treat to MNA





Constituents Evaluated

- Initial Evaluation 2014
 - > 2,4-dichlorophenoxyacetic acid (2,4-D)
 - > 2,4,5-trichlorophenoxyacetic acid (2,4,5-T)
 - > total phenolics
- Updated Evaluation 2024
 - > 2-methyl-4-chlorophenoxyacetic acid (MCPA)
 - pentachlorophenol (PCP)
 - > 2,3,4,6-tetrachlorophenol
 - > 2,4,6-trichlorophenol
 - > 2,4-dichlorophenol





Groundwater Plume Analytics® Tools

Ricker Method® Plume Stability Analysis

- Published in Groundwater Monitoring & Remediation, 2008

Spatial Change Indicator™

- US Patent No. 10,400,583

Remediation System Benefit Analysis (RSBA®)

- US Patent No. 9,299,038

Monitoring&Remediation

A Practical Method to Evaluate Ground Water Contaminant Plume Stability

by Joseph A. Ricker

Abstract

Evaluating plume stability is important for the evaluation of natural attenuation of dissolved chemicals in ground water. When characterizing ground water contaminant plumes, there are numerous methods for evaluating concentration isopleth maps are typically developed to evaluate temporal changes in the plume boundaries, and plume stability is often assessed by conducting trend analyses for individual monitoring wells. However, it is becoming more important to understand and effectively communicate the nature of the entire plume in terms of its stability (i.e., is the plume growing, shrinking, or stable?). This article presents a method for evaluating plume stability using innovative techniques to calculate and assess historical trends in various plume characteristics, including area, average concentration, contaminant mass, and center of mass. Contaminant distribution isopleths are developed for several sampling events, and the characteristics mentioned previously are calculated for each event using numerical methods and engineering principles. A statistical trend analysis is then performed on the calculated values to assess the plume stability. The methodology presented here has been used at various contaminated sites to effectively evaluate the stability of contaminant plumes comprising tetrachloroethene, carbon tetrachloride, pentachlorophenol, creosote, naphthalene, benzene, and chlordane. Although other methods for assessing contaminant plume stability exist, this method has been shown to be efficient, reliable, and applicable to any site with an established monitoring well network and multiple years of analytical data.

Introduction

Evaluating plume stability is important for the evaluation of natural attenuation of dissolved chemicals in ground water. U.S. EPA (1998) states that the primary line of evidence in evaluating natural attenuation is historical ground water chemistry data that demonstrate a clear and meaningful trend of decreasing contaminant mass and/or concentration over time at appropriate monitoring or sampling points. When characterizing ground water contaminant plumes, there are numerous methods for evaluating concentration data.

Wiedemeier et al. (2000) discussed common approaches for evaluating plume stability using both graphical and statistical techniques. Graphical methods include the following: (1) the preparation of contaminant concentration isopleth maps; (2) plotting concentration data vs. time for individual monitoring wells; and (3) plotting concentration data vs. distance downgradient for several monitoring wells. Common statistical methods for evaluation of

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temporal and spatial trends include regression analysis (U.S. EPA 2006), the Mann-Whitney *U*-test (Mann and Whitney 1947), and the Mann-Kendall test (U.S. EPA 2006: Gilbert 1987).

Graphical plume stability analysis by comparing isopleth maps over time can provide compelling visual evidence for natural attenuation. However, a comparison of apparent plume size over time does not always provide a complete analysis. Consider, for example, the case of a plume that discharges to a surface water body, or a plume geometry that is persistent over time. In this case, the plume area would remain relatively unchanged, whereas the overall plume average concentration and mass may be decreasing. The change in plume mass would not be necsearily reflected in the visual analysis of isopleth maps. However, a quantitative analysis of changes in overall plume concentration and mass would provide a better understanding of the plume stability.

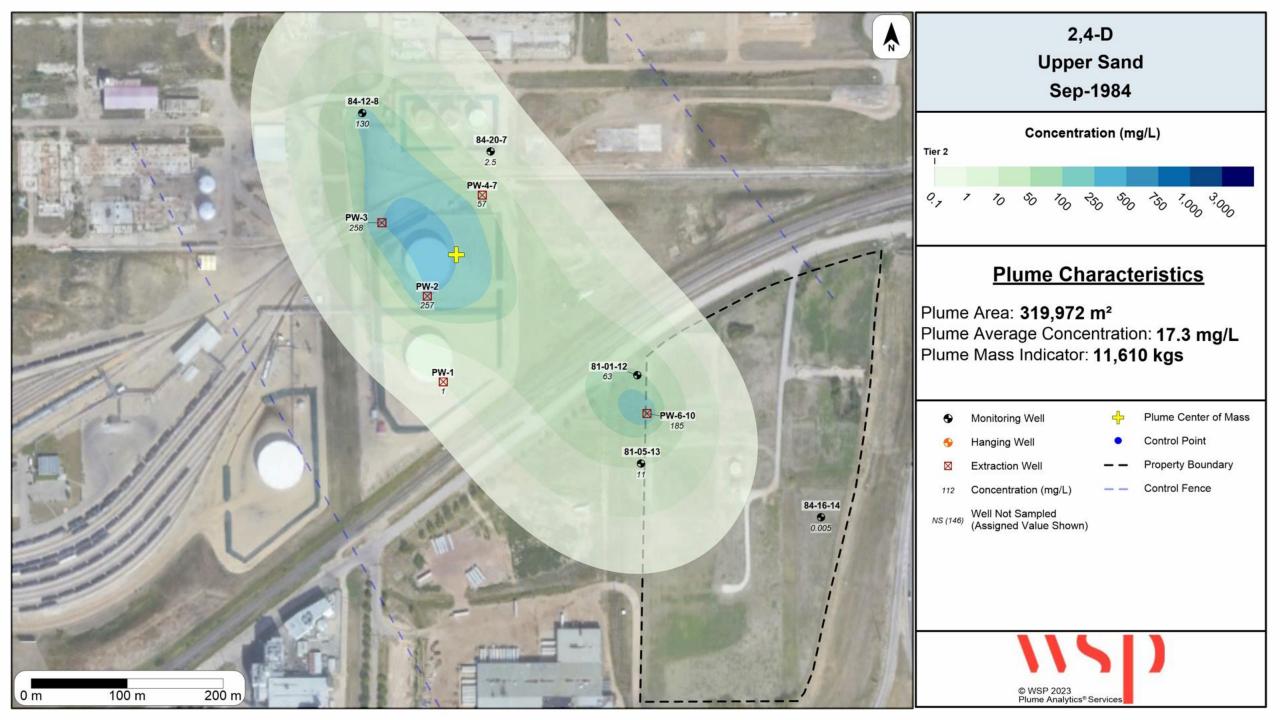
A common approach for evaluating plume stability is the use of statistical analysis techniques for single-well data. However, chemical concentration trends at individual monitoring wells may show different trends. For example, at a given site, there may be wells exhibiting decreasing

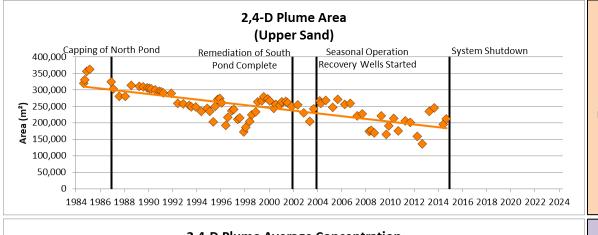
Ground Water Monitoring & Remediation 28, no. 4/ Fall 2008/pages 85-94



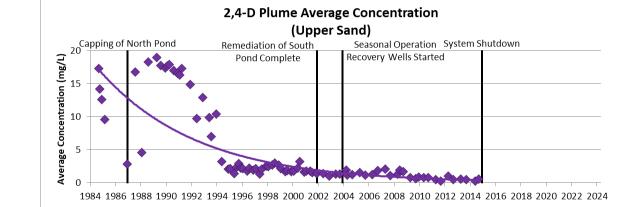
Groundwater Plume Analytics® Services

Upper Sand 2,4,5-T Phenolics **MCPA** PCP 2,4,6-2,3,4,6-Tetrachlorophenol Trichlorophenol 2,4-Dichlorophenol



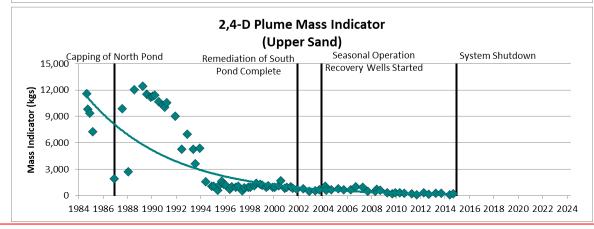


Decreasing Trend Mann-Kendall: >99% Confidence Regression: >99% Confidence



Sep-1984 to Sep-2014

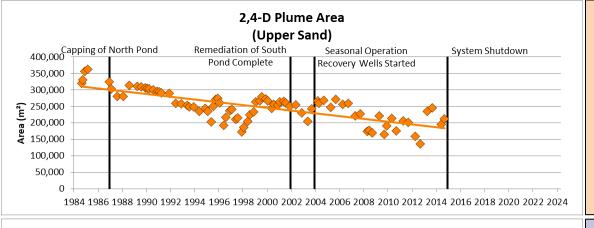
Decreasing Trend Mann-Kendall: >99% Confidence Regression: >99% Confidence



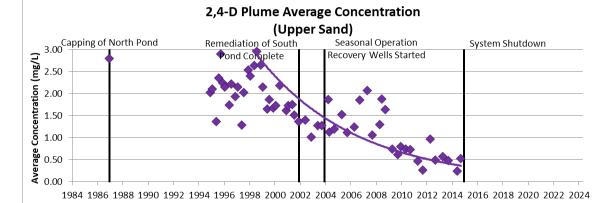
Sep-1984 to Sep-2014

Decreasing Trend Mann-Kendall: >99% Confidence Regression: >99% Confidence



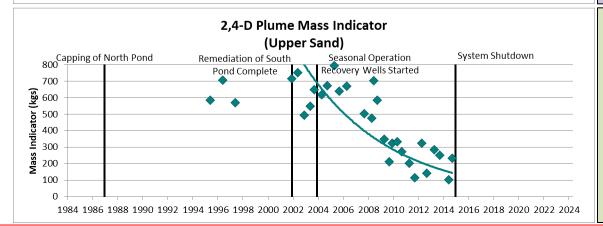


Decreasing Trend Mann-Kendall: >99% Confidence Regression: >99% Confidence



Sep-1984 to Sep-2014

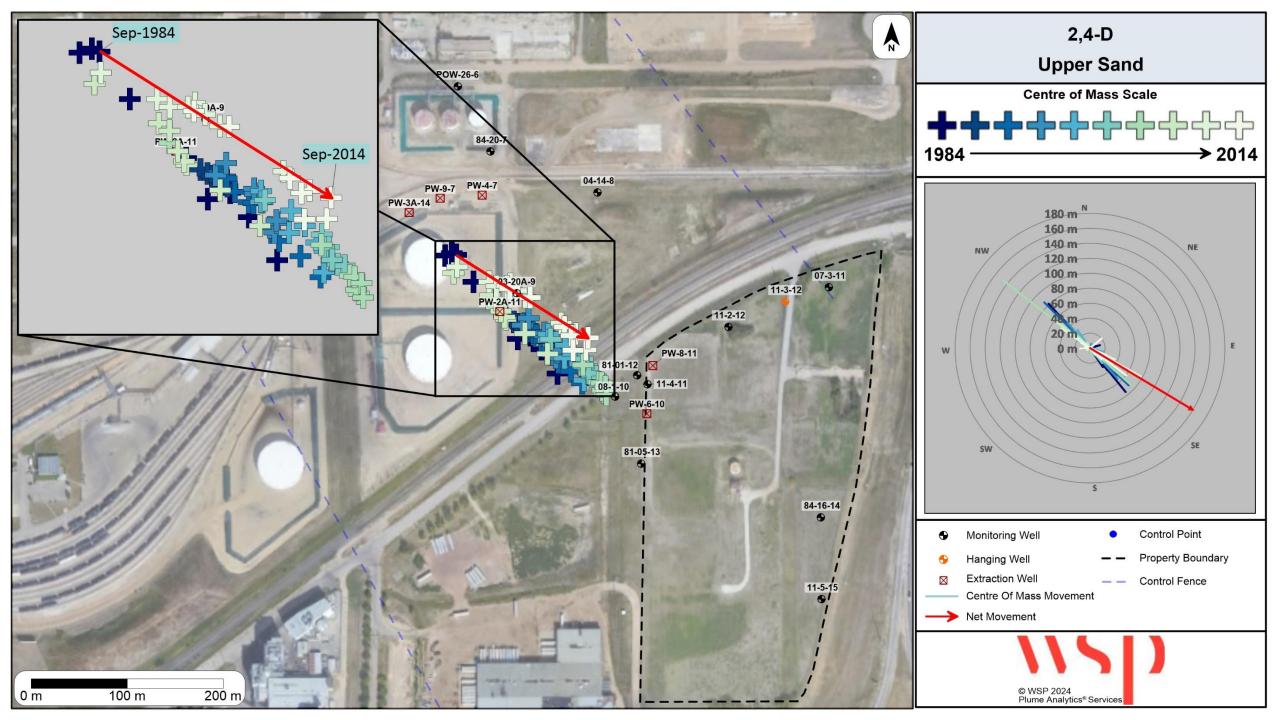
Decreasing Trend
Mann-Kendall: >99% Confidence
Regression: >99% Confidence

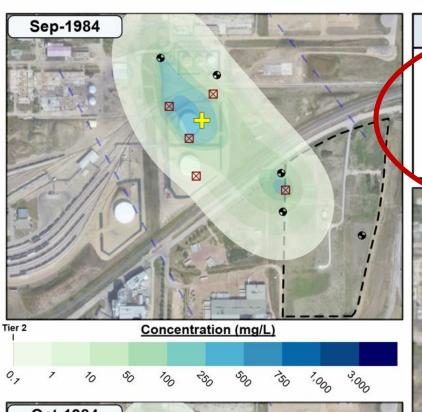


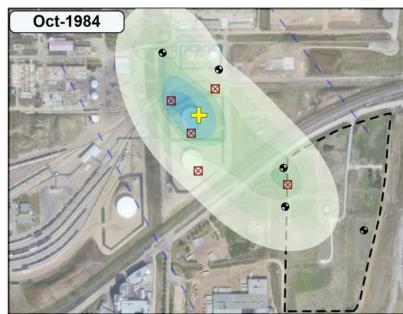
Sep-1984 to Sep-2014

Decreasing Trend Mann-Kendall: >99% Confidence Regression: >99% Confidence









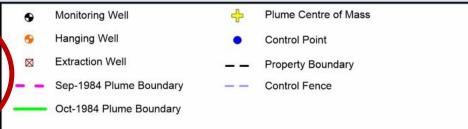


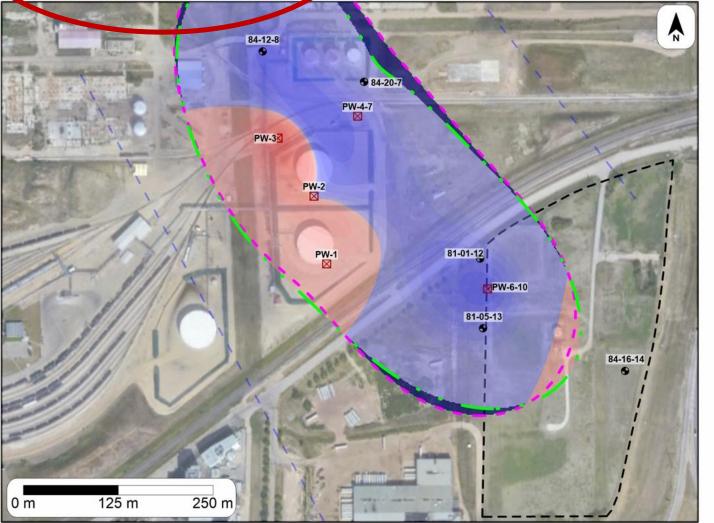
Plume Characteristics

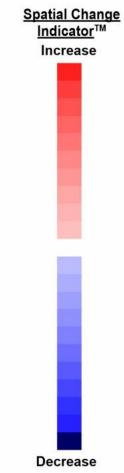
Area: 3% Increase

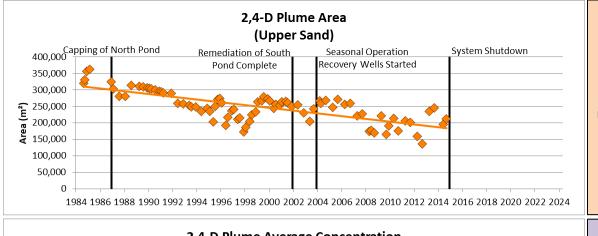
Average Concentration: 18% Decrease

Mass Indicator: 15% Decrease
Mass Increase: 575 kgs Increase
Mass Decrease: 2,339 kgs Decrease

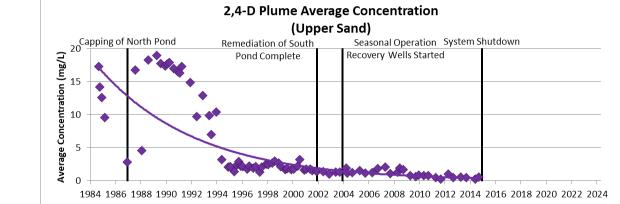






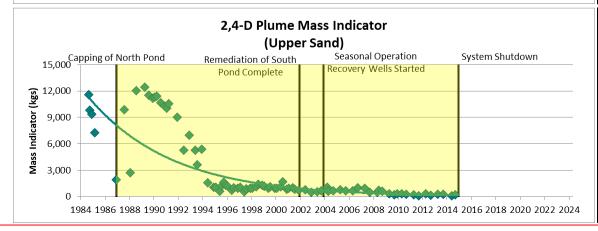


Decreasing Trend Mann-Kendall: >99% Confidence Regression: >99% Confidence



Sep-1984 to Sep-2014

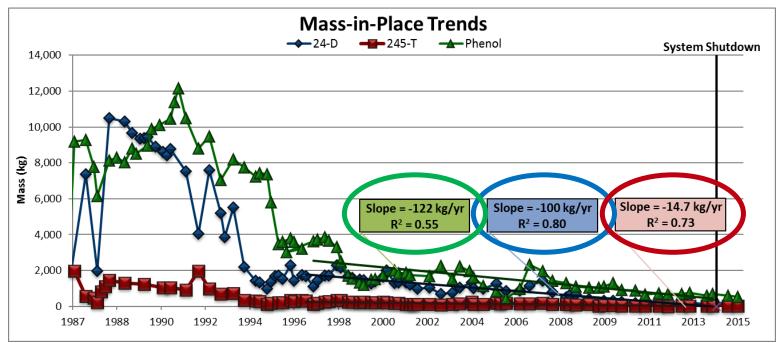
Decreasing Trend
Mann-Kendall: >99% Confidence
Regression: >99% Confidence

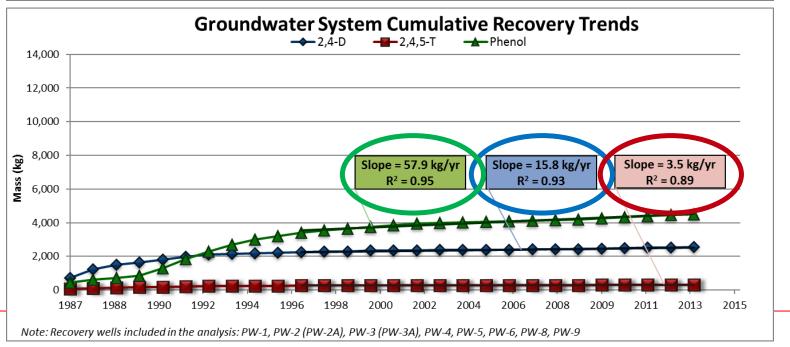


Sep-1984 to Sep-2014

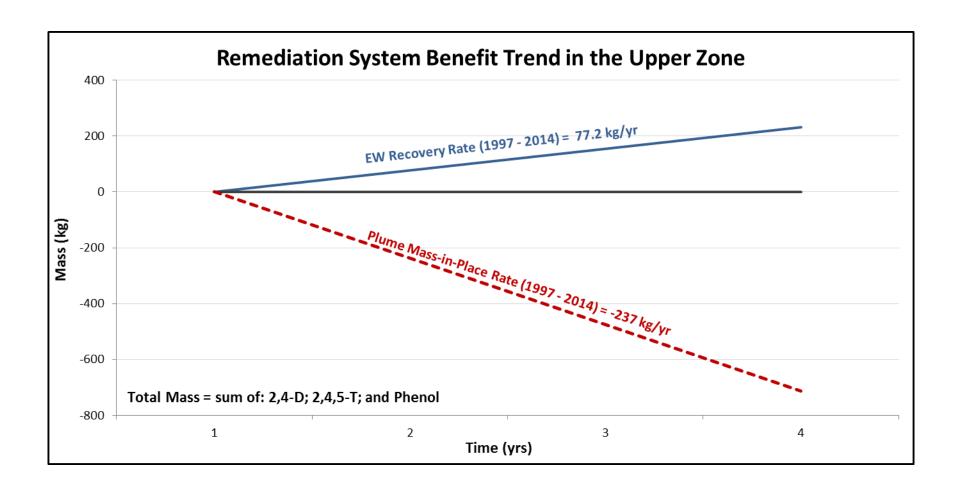
Decreasing Trend Mann-Kendall: >99% Confidence Regression: >99% Confidence



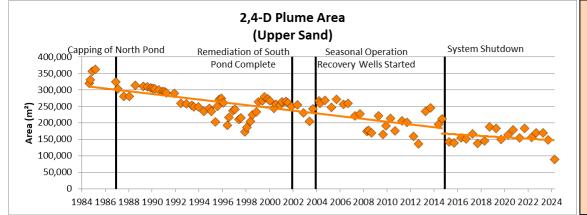








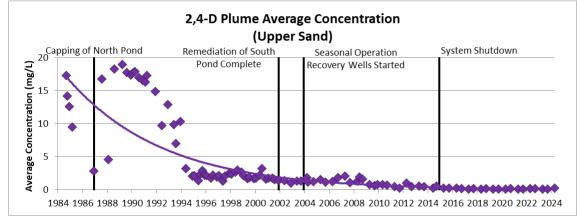




Decreasing Trend
Mann-Kendall: >99% Confidence
Regression: >99% Confidence

Sep-2014 to May-2024

Stable/No Trend Mann-Kendall: 56% Confidence Regression: 68% Confidence

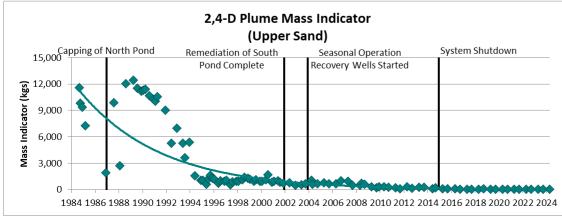


Sep-1984 to Sep-2014

Decreasing Trend
Mann-Kendall: >99% Confidence
Regression: >99% Confidence

Sep-2014 to May-2024

Decreasing Trend
Mann-Kendall: 99% Confidence
Regression: 99% Confidence



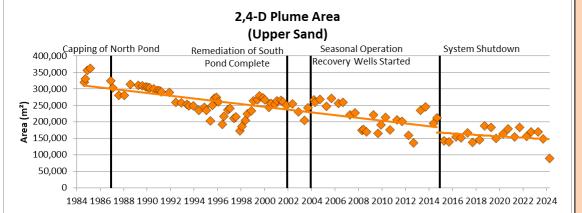
Sep-1984 to Sep-2014

Decreasing Trend
Mann-Kendall: >99% Confidence
Regression: >99% Confidence

Sep-2014 to May-2024

Decreasing Trend Mann-Kendall: 99% Confidence Regression: 99% Confidence

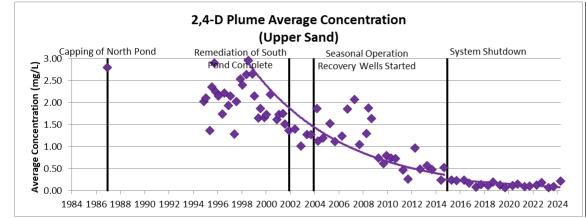




Decreasing Trend
Mann-Kendall: >99% Confidence
Regression: >99% Confidence

Sep-2014 to May-2024

Stable/No Trend Mann-Kendall: 56% Confidence Regression: 68% Confidence

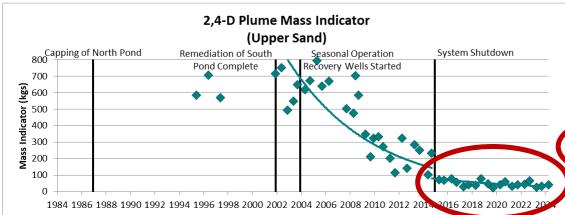


Sep-1984 to Sep-2014

Decreasing Trend
Mann-Kendall: >99% Confidence
Regression: >99% Confidence

Sep-2014 to May-2024

Decreasing Trend
Mann-Kendall: 99% Confidence
Regression: 99% Confidence



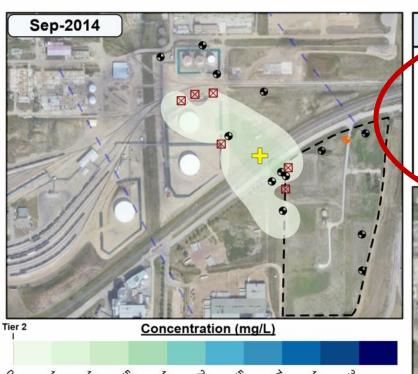
Sep-1984 to Sep-2014

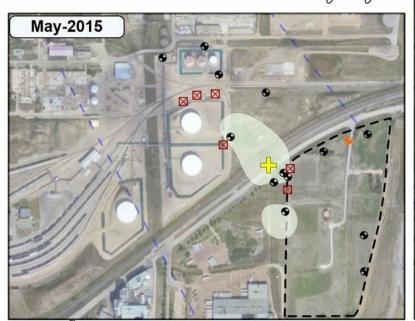
Decreasing Trend Mann-Kendall: >99% Confidence Regression: >99% Confidence

Sep-2014 to May-2024

Decreasing Trend Mann-Kendall: 99% Confidence Regression: 99% Confidence







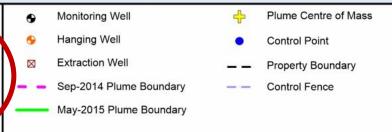
2,4-D Upper Sand Spatial Changes Sep-2014 vs May-2015

Plume Characteristics

Area: 33% Decrease

Average Concentration: 54% Decrease

Mass Indicator: 69% Decrease
Mass Increase: 0.27 kgs Increase
Mass Decrease: 162 kgs Decrease

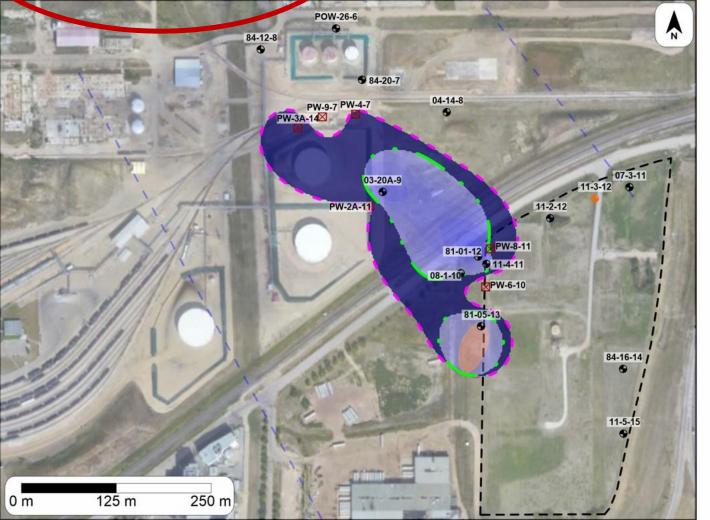


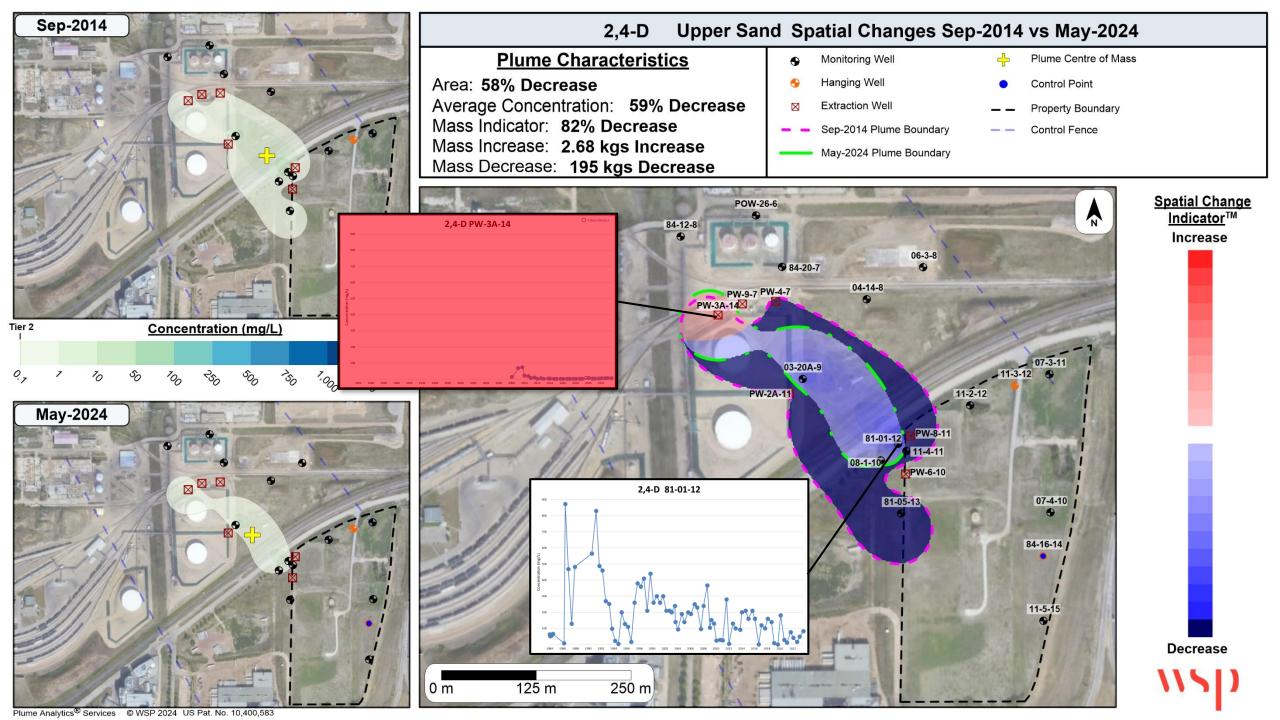
Spatial Change

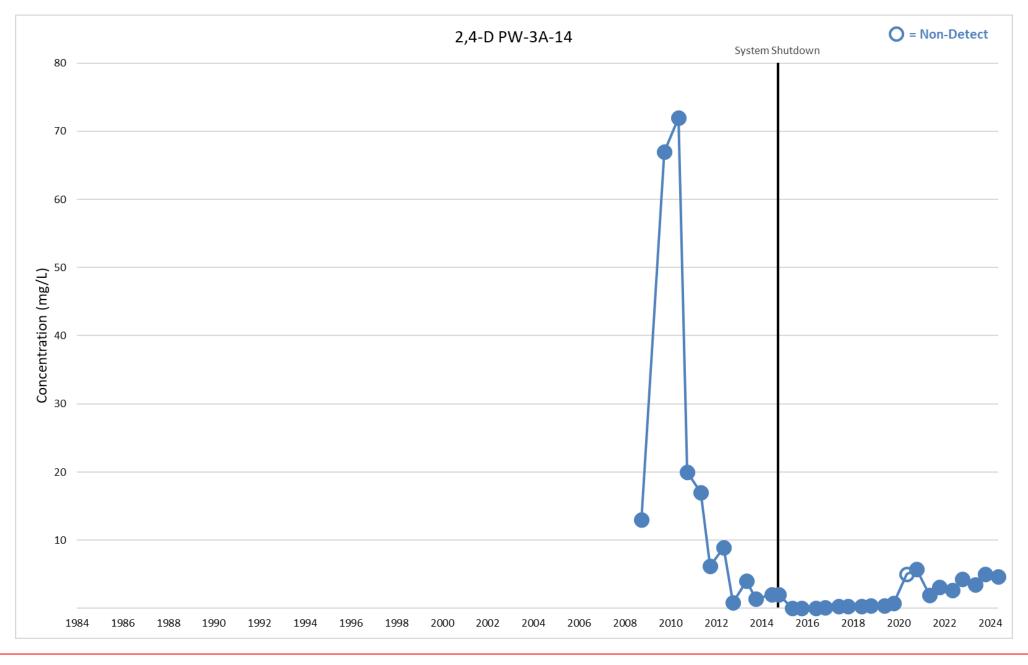
Indicator™

Increase

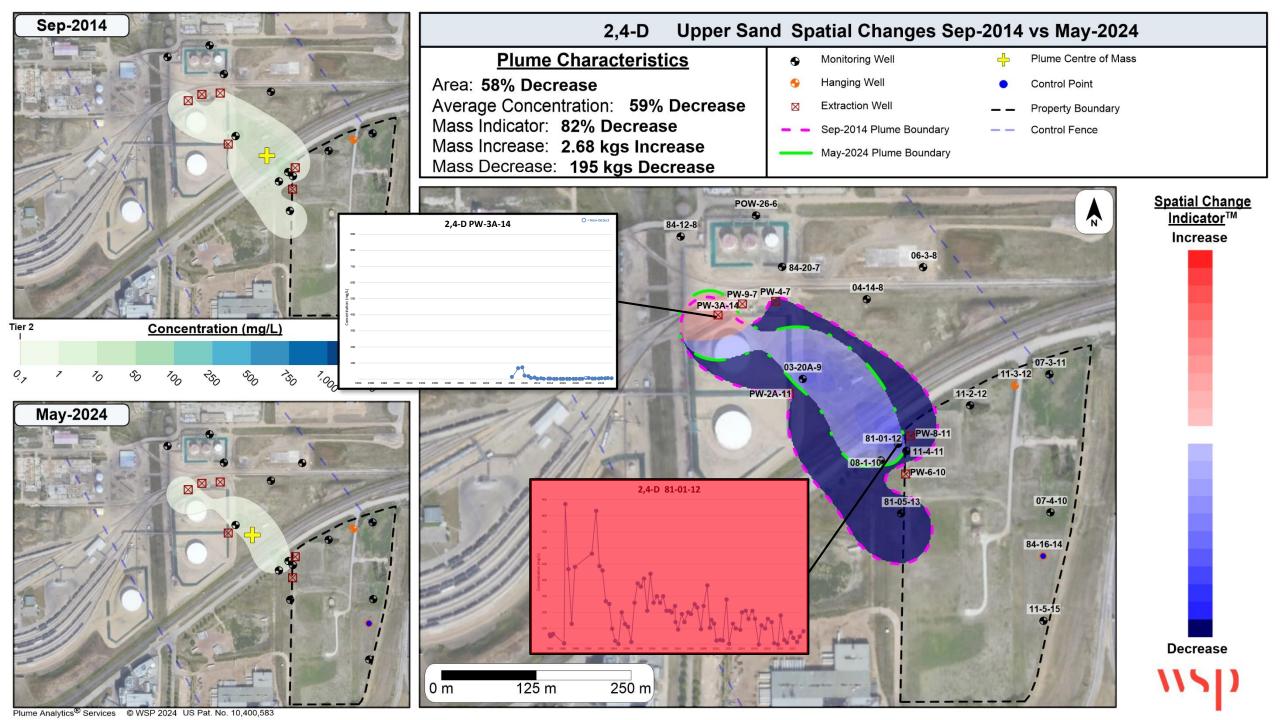
Decrease

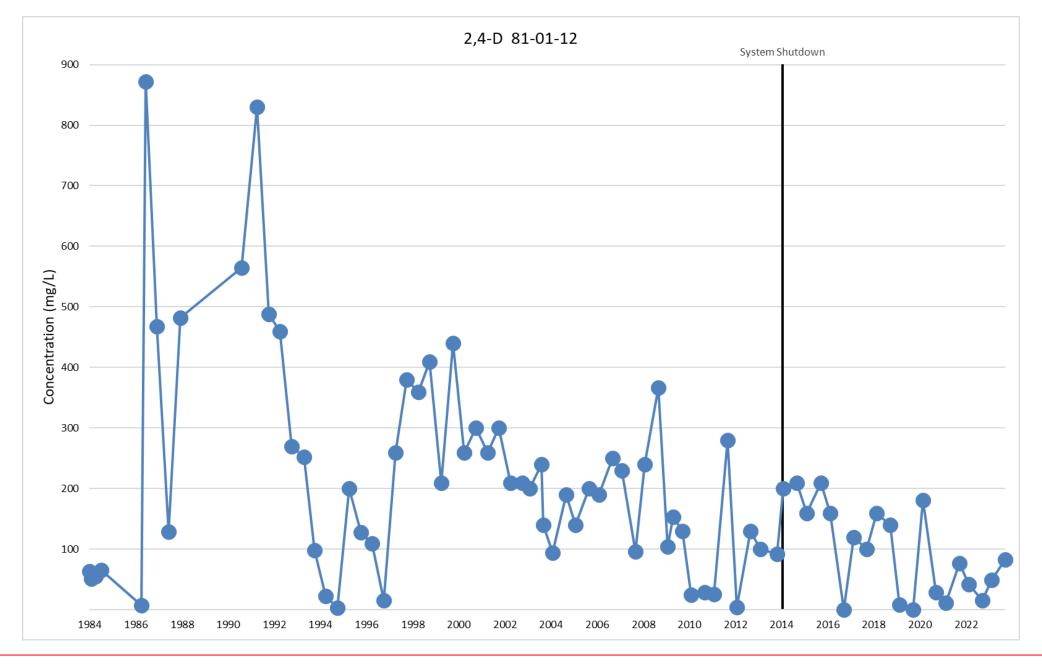






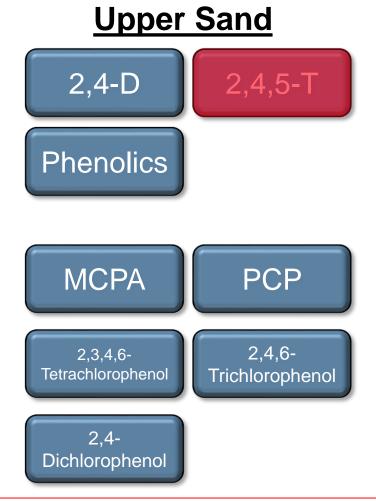




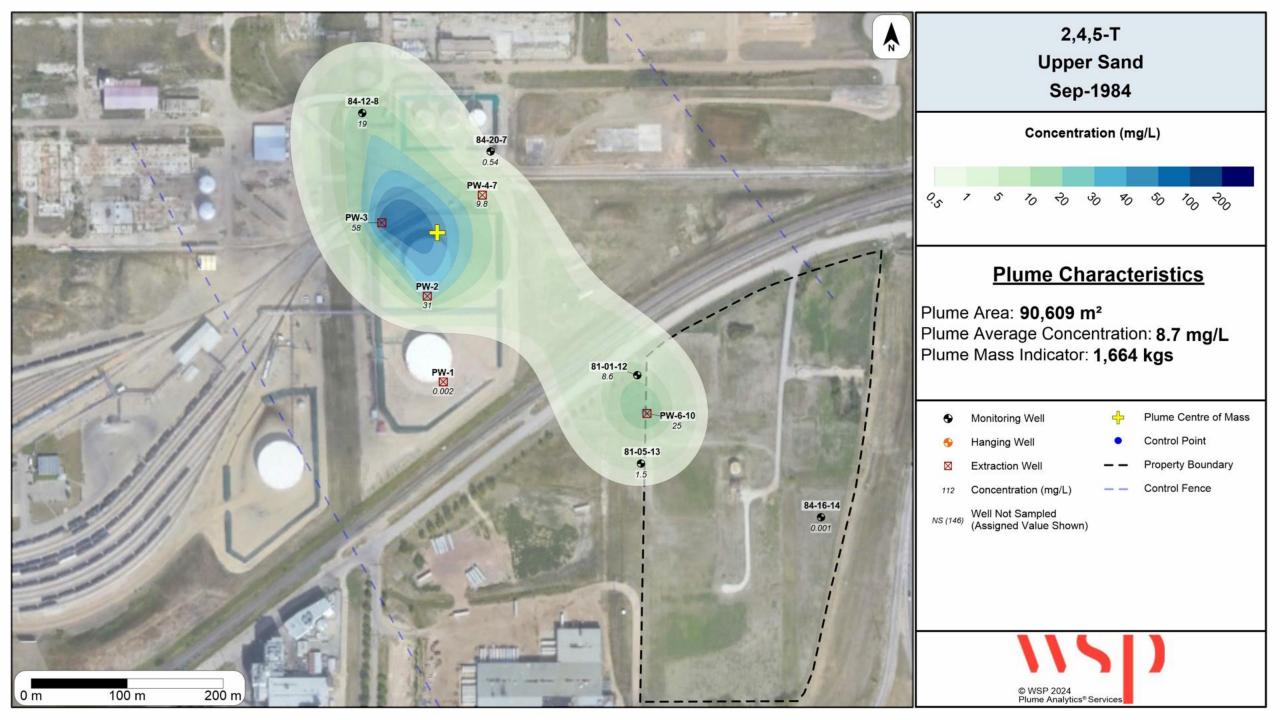


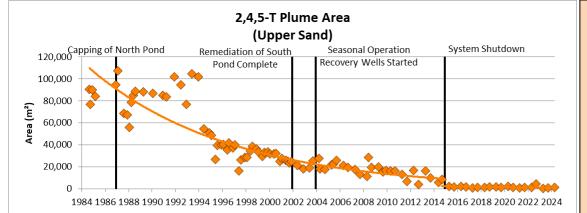


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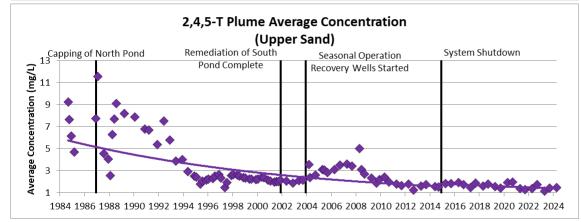




Decreasing Trend
Mann-Kendall: >99% Confidence
Regression: >99% Confidence

Sep-2014 to May-2024

Decreasing Trend Mann-Kendall: 99% Confidence Regression: 97% Confidence

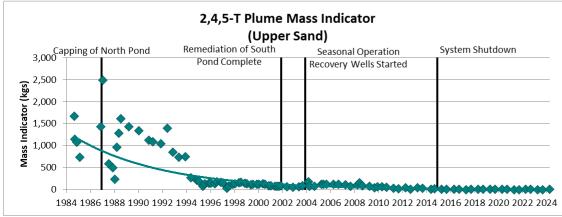


Sep-1984 to Sep-2014

Decreasing Trend Mann-Kendall: >99% Confidence Regression: >99% Confidence

Sep-2014 to May-2024

Decreasing Trend
Mann-Kendall: 98% Confidence
Regression: 99% Confidence



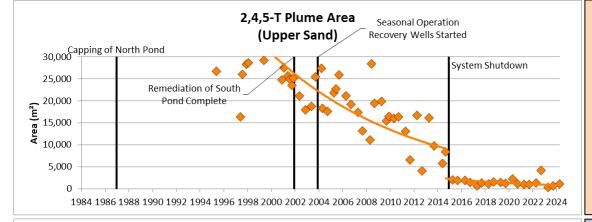
Sep-1984 to Sep-2014

Decreasing Trend Mann-Kendall: >99% Confidence Regression: >99% Confidence

Sep-2014 to May-2024

Decreasing Trend Mann-Kendall: >99% Confidence Regression: 99% Confidence

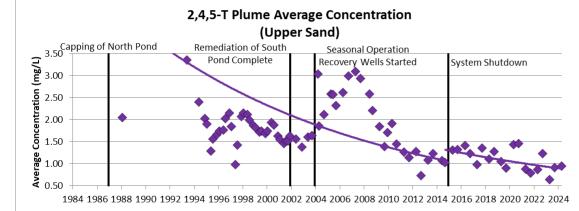




Decreasing Trend
Mann-Kendall: >99% Confidence
Regression: >99% Confidence

Sep-2014 to May-2024

Decreasing Trend Mann-Kendall: 99% Confidence Regression: 97% Confidence

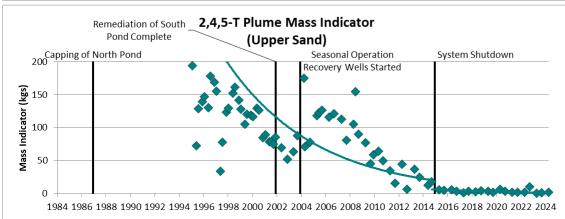


Sep-1984 to Sep-2014

Decreasing Trend
Mann-Kendall: >99% Confidence
Regression: >99% Confidence

Sep-2014 to May-2024

Decreasing Trend
Mann-Kendall: 98% Confidence
Regression: 99% Confidence



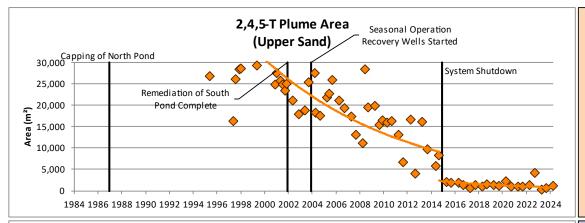
Sep-1984 to Sep-2014

Decreasing Trend
Mann-Kendall: >99% Confidence
Regression: >99% Confidence

Sep-2014 to May-2024

Decreasing Trend Mann-Kendall: >99% Confidence Regression: 99% Confidence



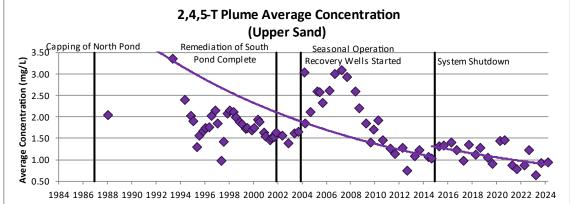


Decreasing Trend Mann-Kendall: >99% Confidence

Regression: >99% Confidence

Sep-2014 to May-2024

Decreasing Trend Mann-Kendall: 99% Confidence Regression: 97% Confidence

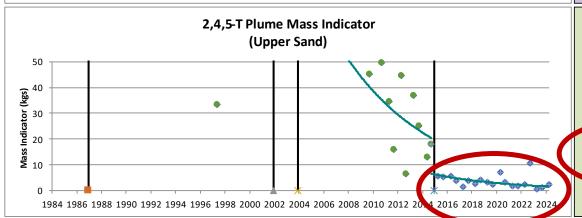


Sep-1984 to Sep-2014

Decreasing Trend Mann-Kendall: >99% Confidence Regression: >99% Confidence

Sep-2014 to May-2024

Decreasing Trend Mann-Kendall: 98% Confidence Regression: 99% Confidence

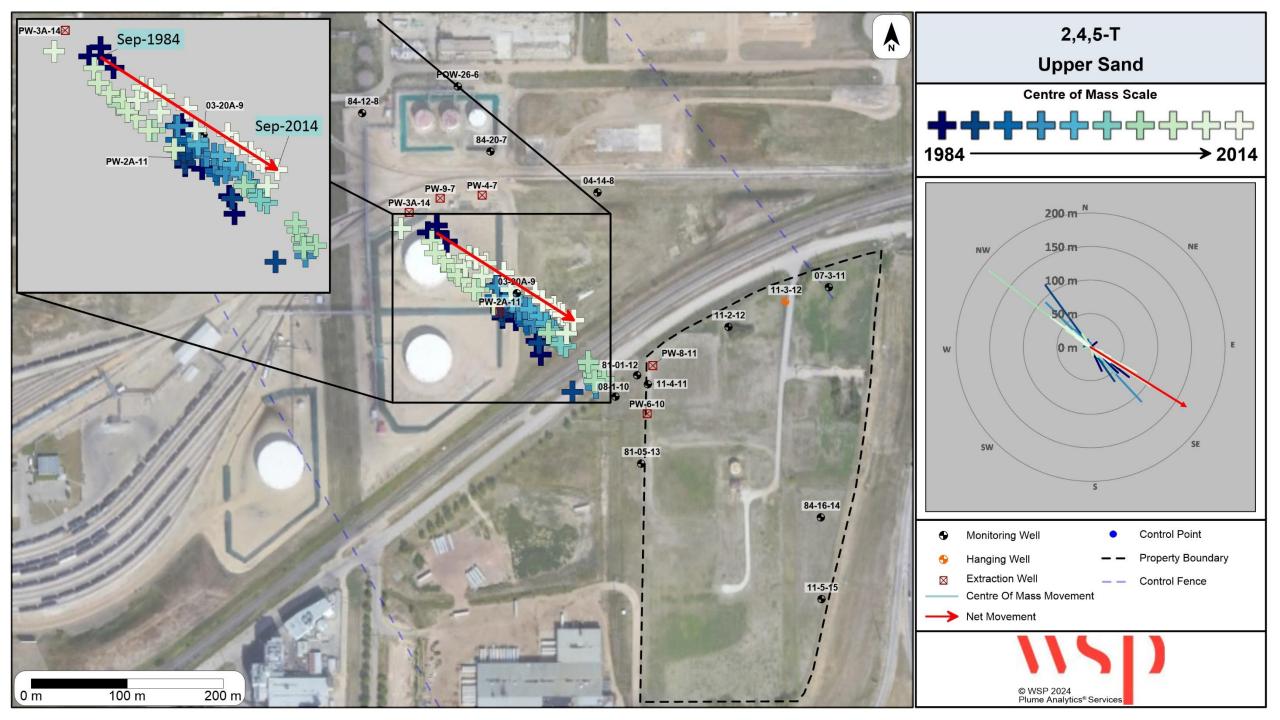


Sep-1984 to Sep-2014

Decreasing Trend Mann-Kendall: >99% Confidence Regression: >99% Confidence

sep-2014 to May-2024

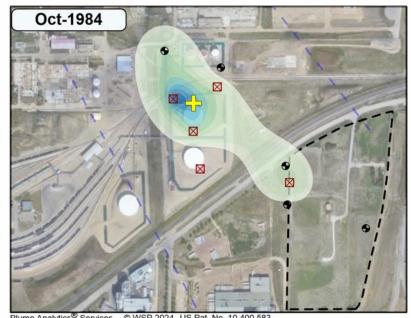
Decreasing Trend Mann-Kendall: >99% Confidence Regression: 99% Confidence



Sep-1984

Concentration (mg/L)





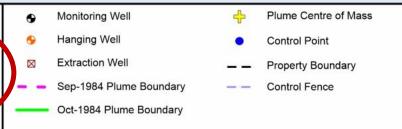
2,4.5-T Upper Sand Spatial Changes Sep-1984 vs Oct-1984

Plume Characteristics

Area: 15% Decrease

Average Concentration: 18% Decrease

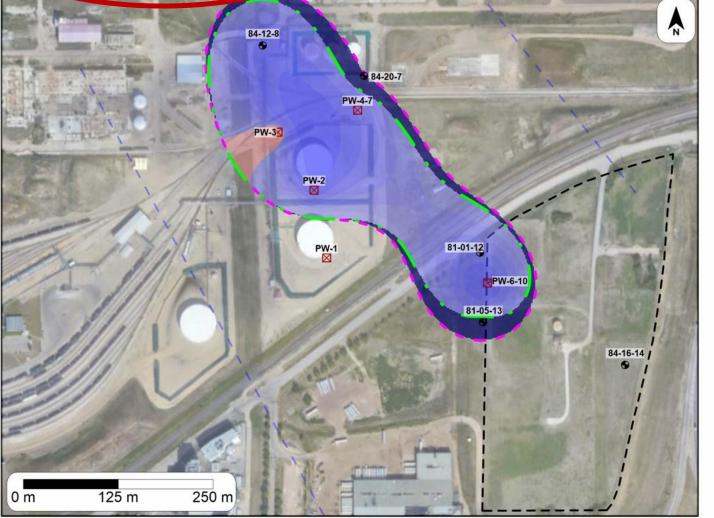
Mass Indicator: 31% Decrease
Mass Increase: 1.78 kgs Increase
Mass Decrease: 515 kgs Decrease



Spatial Change Indicator™

Increase

Decrease



Sep-2014

Concentration (mg/L) O₅ 7 5 70 70 70 80 80 50 700 700



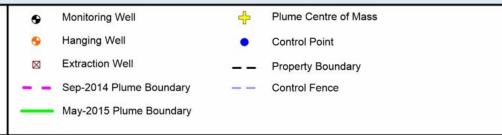
2,4,5-T Upper Sand Spatial Changes Sep-2014 vs May-2015

Plume Characteristics

Area: 76% Decrease

Average Concentration: 27% Increase

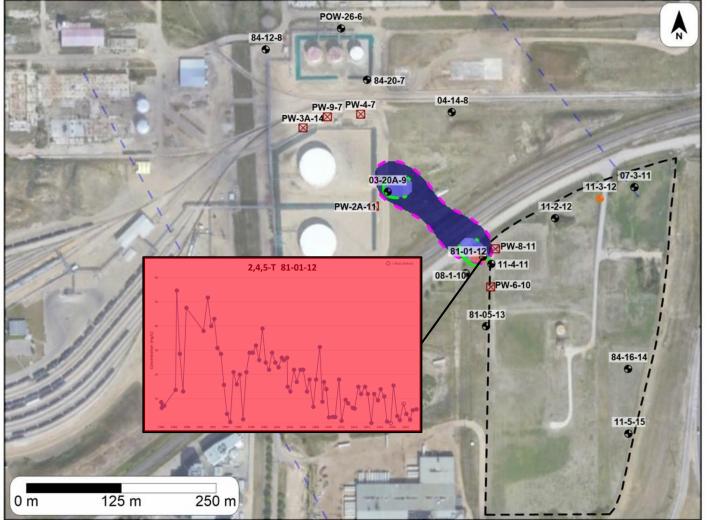
Mass Indicator: 69% Decrease
Mass Increase: 0.91 kgs Increase
Mass Decrease: 13.3 kgs Decrease

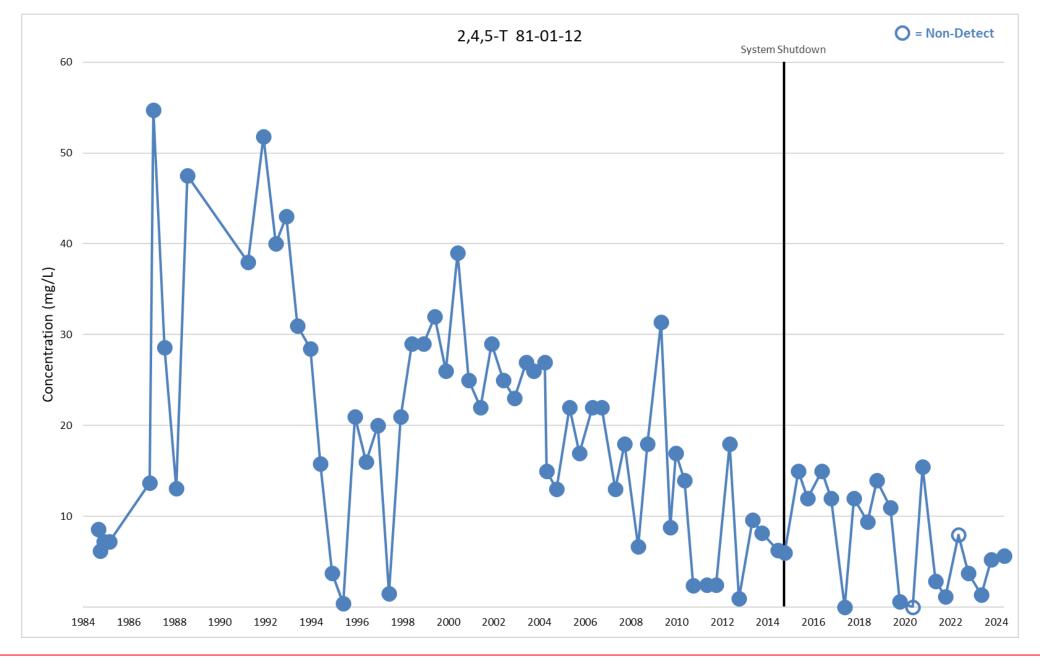


Spatial Change

Indicator™ Increase

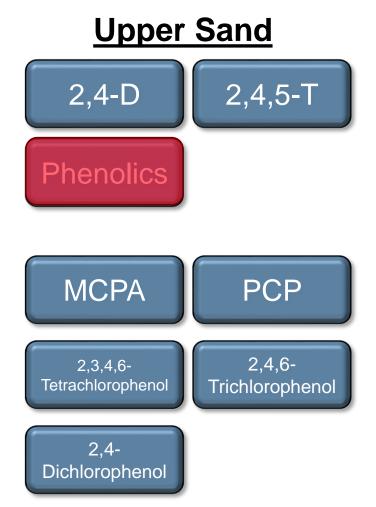
Decrease

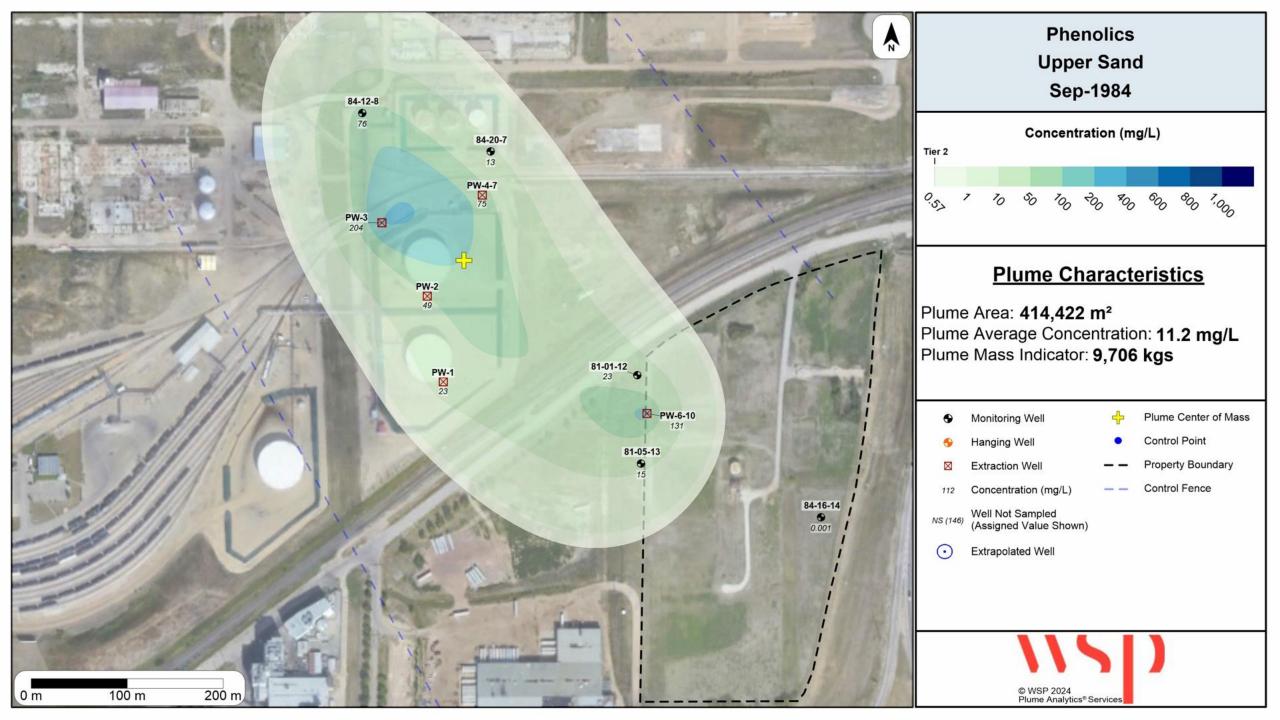


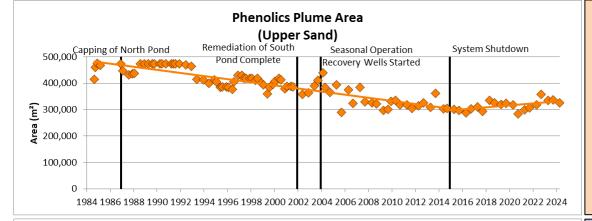




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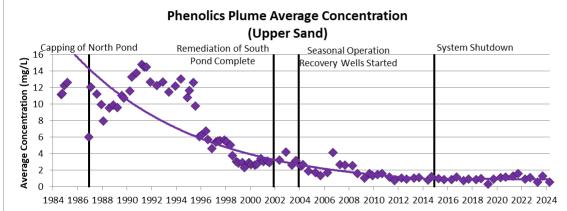




Decreasing Trend
Mann-Kendall: >99% Confidence
Regression: >99% Confidence

Sep-2014 to May-2024

Increasing Trend Mann-Kendall: 99% Confidence Regression: 99% Confidence

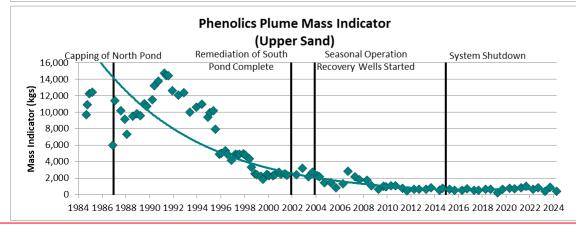


Sep-1984 to Sep-2014

Decreasing Trend
Mann-Kendall: >99% Confidence
Regression: >99% Confidence

Sep-2014 to May-2024

Stable/No Trend
Mann-Kendall: 73% Confidence
Regression: 18% Confidence



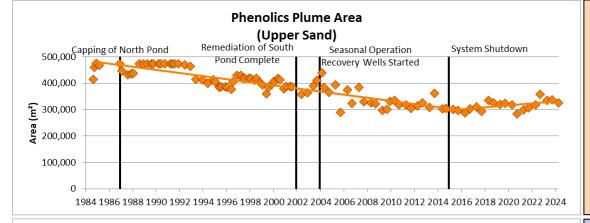
Sep-1984 to Sep-2014

Decreasing Trend Mann-Kendall: >99% Confidence Regression: >99% Confidence

Sep-2014 to May-2024

No Trend Mann-Kendall: 81% Confidence Regression: 40% Confidence

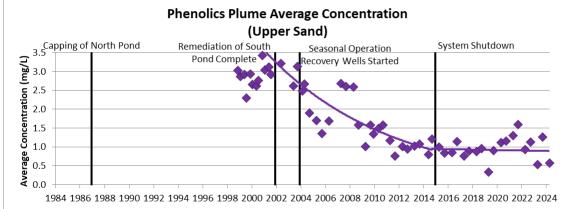




Decreasing Trend
Mann-Kendall: >99% Confidence
Regression: >99% Confidence

Sep-2014 to May-2024

Increasing Trend
Mann-Kendall: 99% Confidence
Regression: 99% Confidence

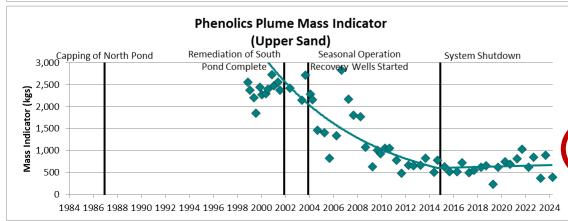


Sep-1984 to Sep-2014

Decreasing Trend
Mann-Kendall: >99% Confidence
Regression: >99% Confidence

Sep-2014 to May-2024

Stable/No Trend Mann-Kendall: 73% Confidence Regression: 18% Confidence



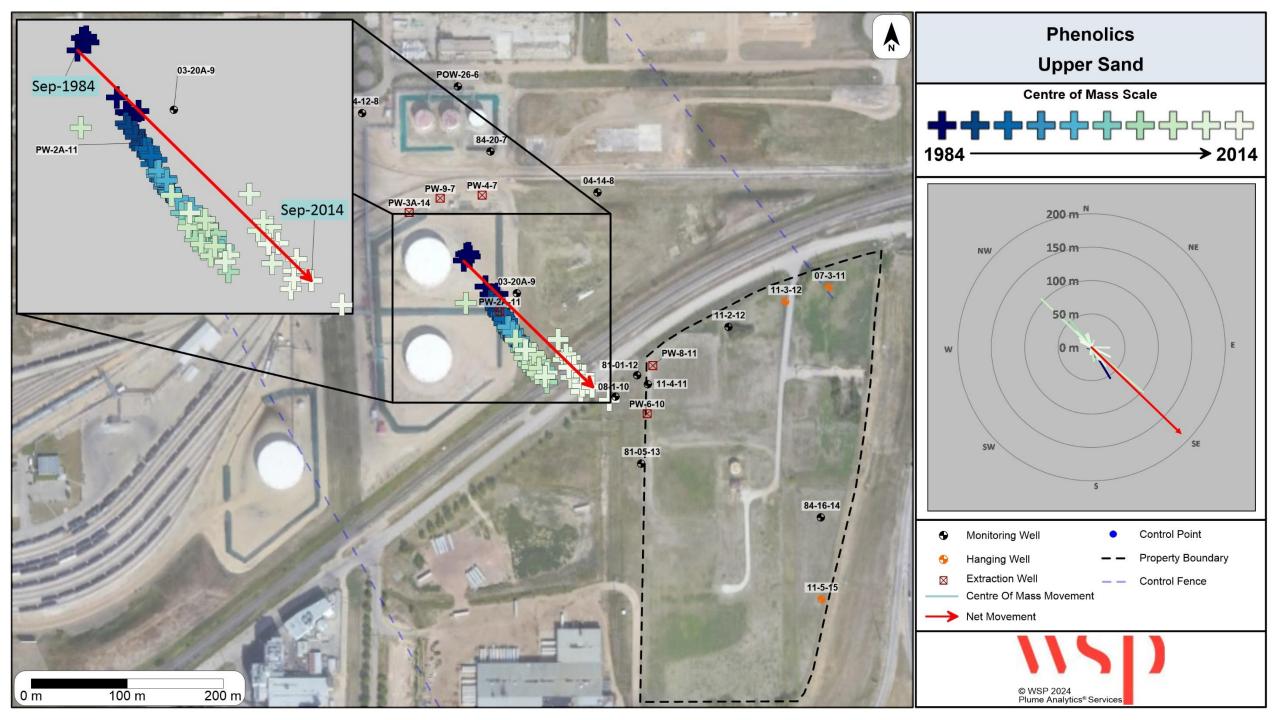
Sep-1984 to Sep-2014

Decreasing Trend
Mann-Kendall: >99% Confidence
Regression: >00% Confidence

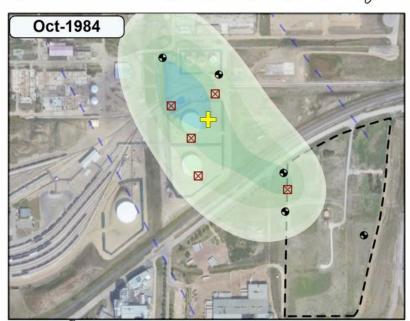
Sep-2014 to May-2024

No Trend Mann-Kendall: 81% Confidence Regression: 40% Confidence





Sep-1984 Concentration (mg/L)



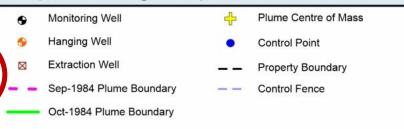
Phenolics Upper Sand Spatial Changes Sep-1984 vs Oct-1984

Plume Characteristics

Area: 11% Increase

Average Concentration: 1% Increase

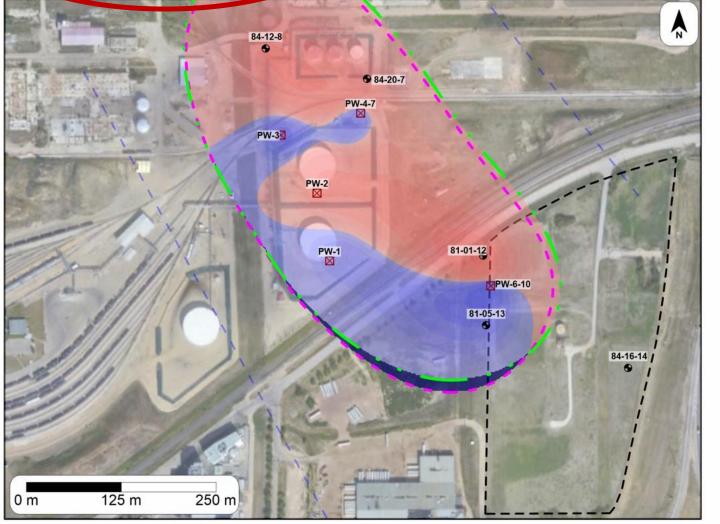
Mass Indicator: 12% Increase
Mass Increase: 1,601 kgs Increase
Mass Decrease: 405 kgs Decrease



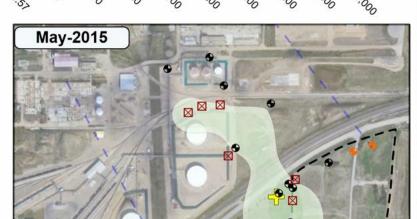
Spatial Change Indicator™

Increase

Decrease



Sep-2014 Concentration (mg/L)



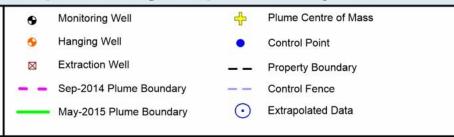
Phenolics Upper Sand Spatial Changes Sep-2014 vs May-2015

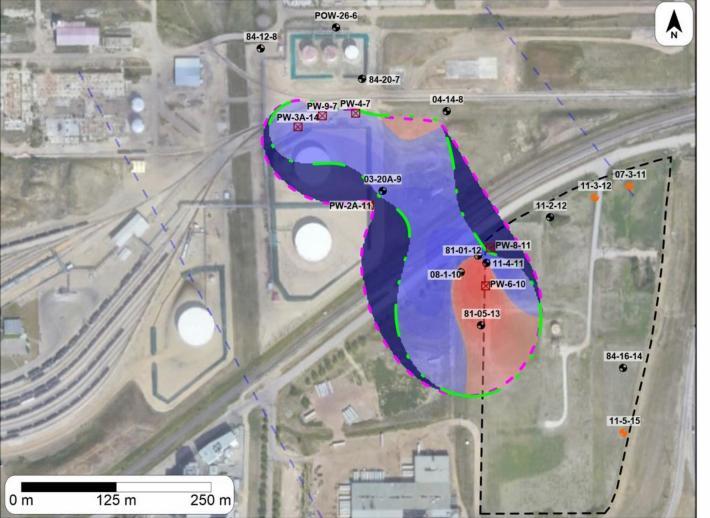
Plume Characteristics

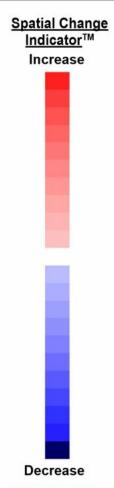
Area: 1% Decrease

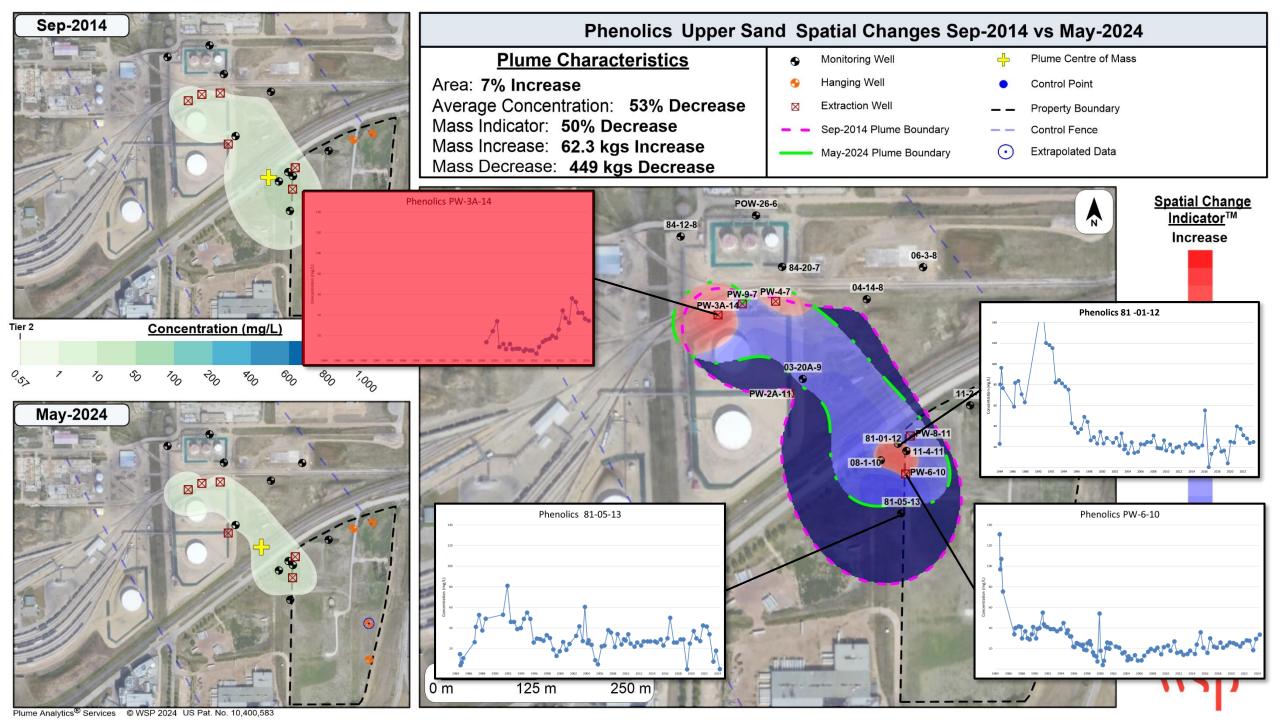
Average Concentration: 18% Decrease

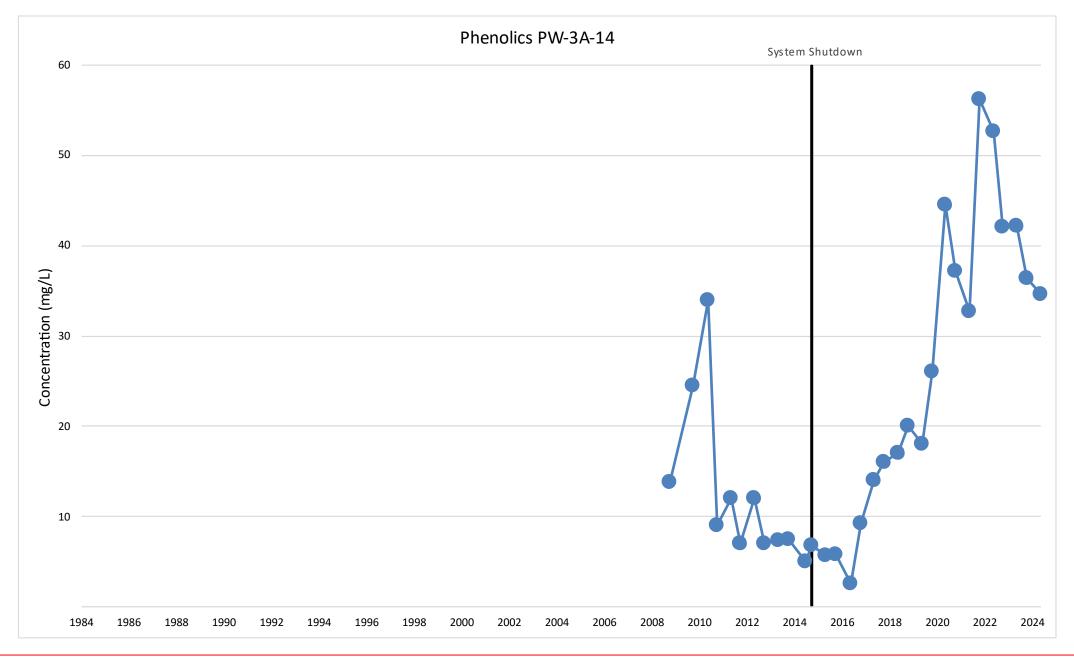
Mass Indicator: 19% Decrease
Mass Increase: 77.1 kgs Increase
Mass Decrease: 223 kgs Decrease



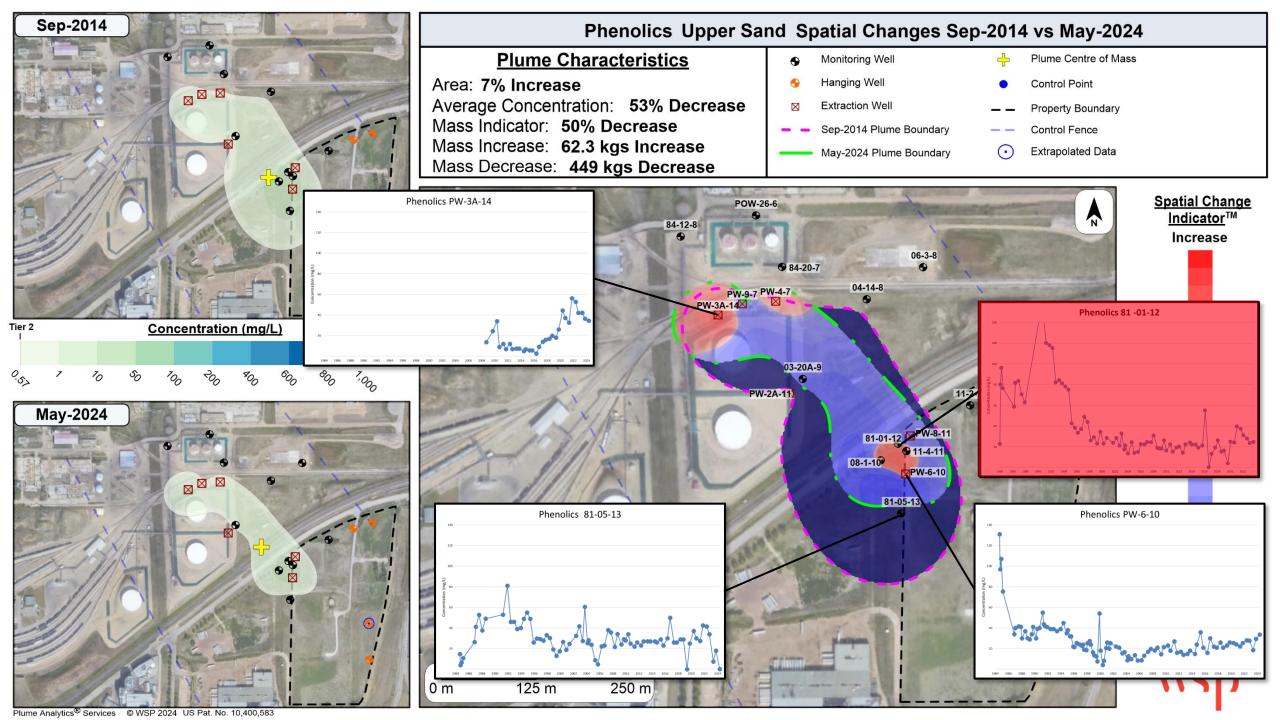


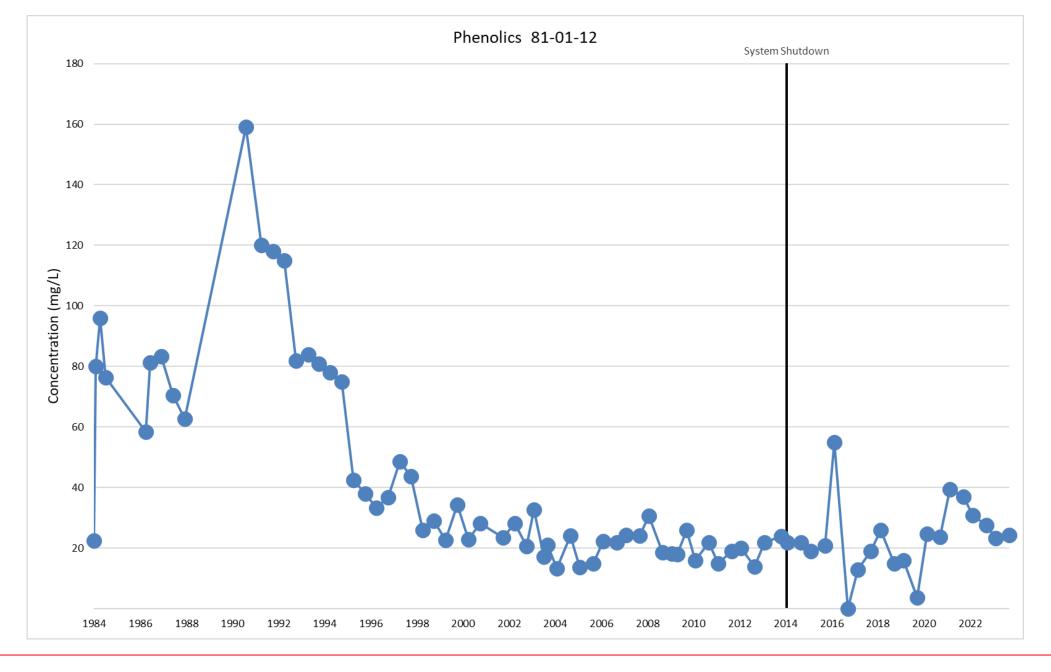




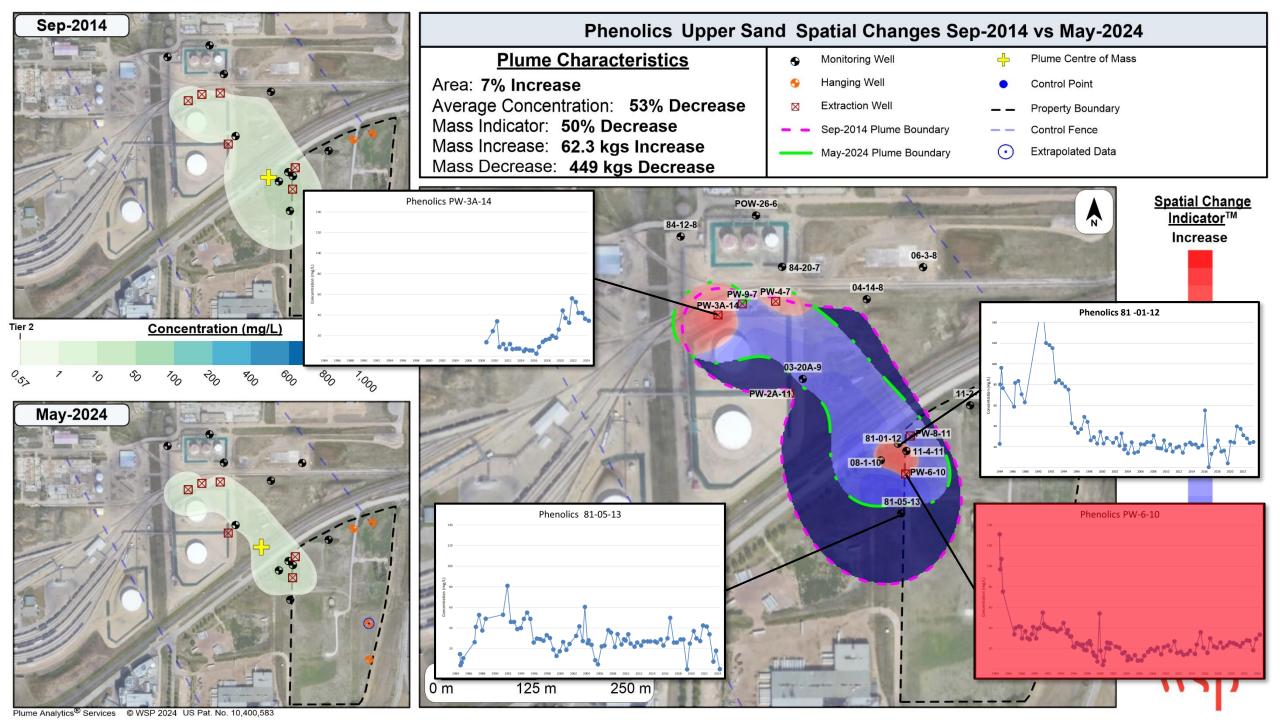


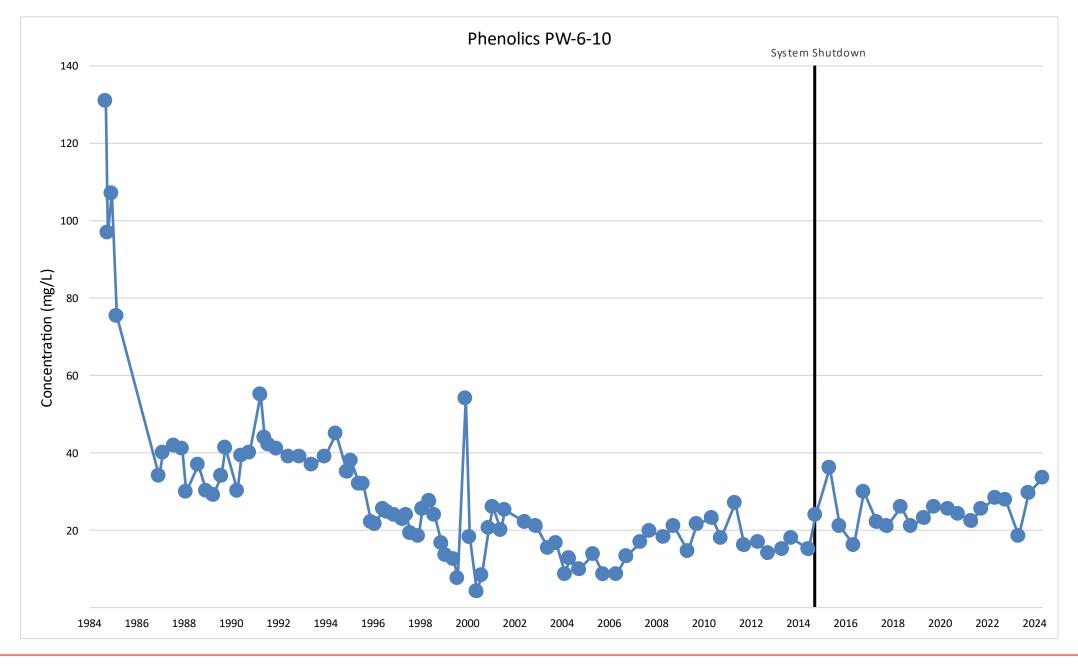






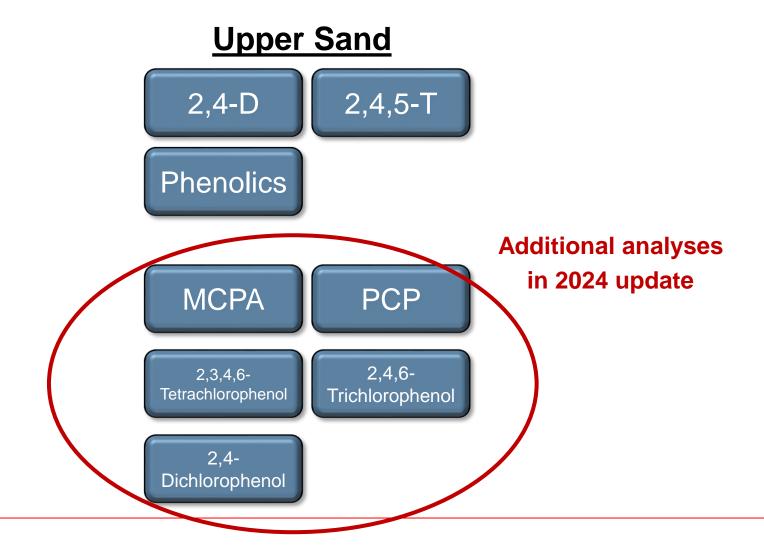






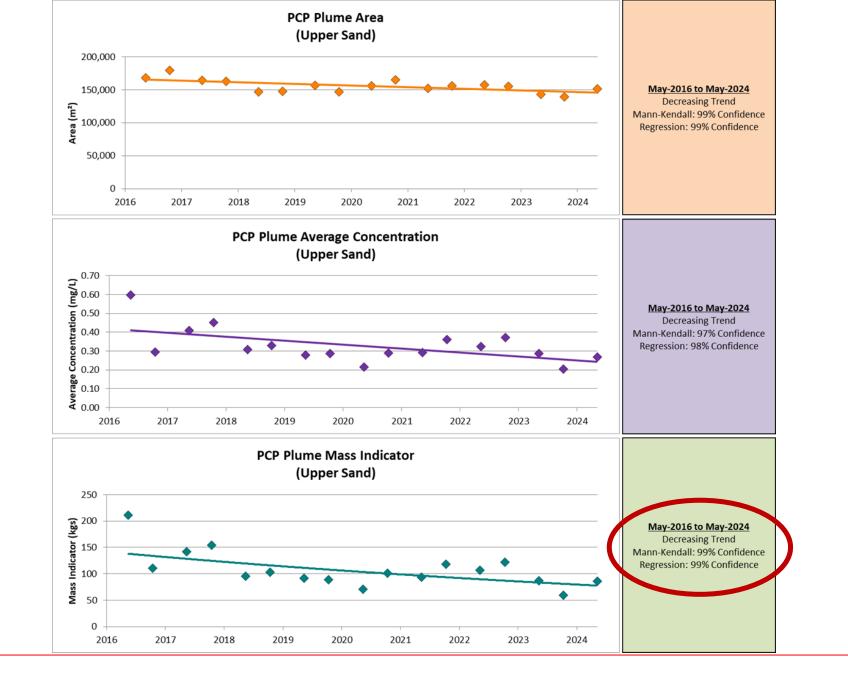


Groundwater Plume Analytics® Services

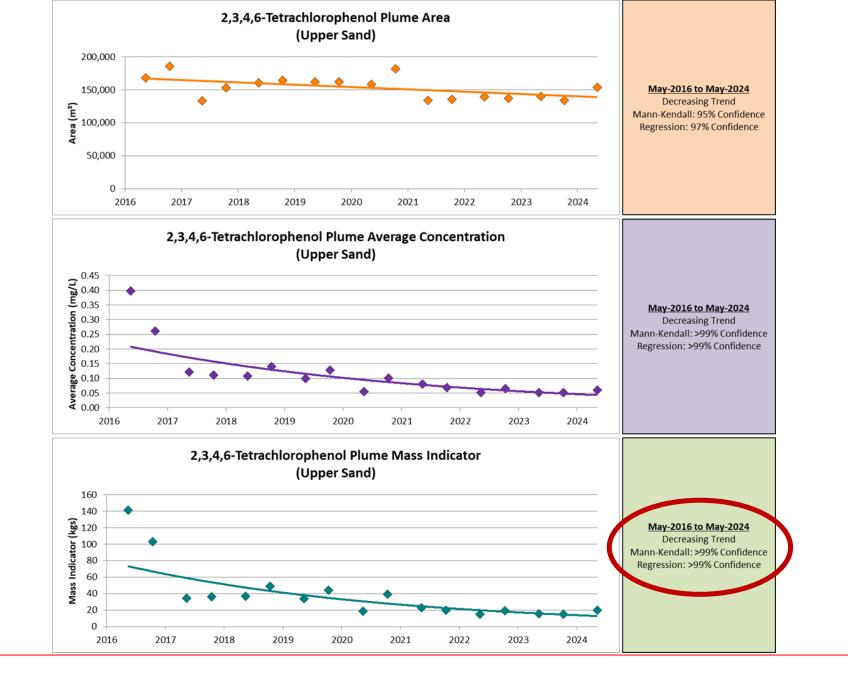




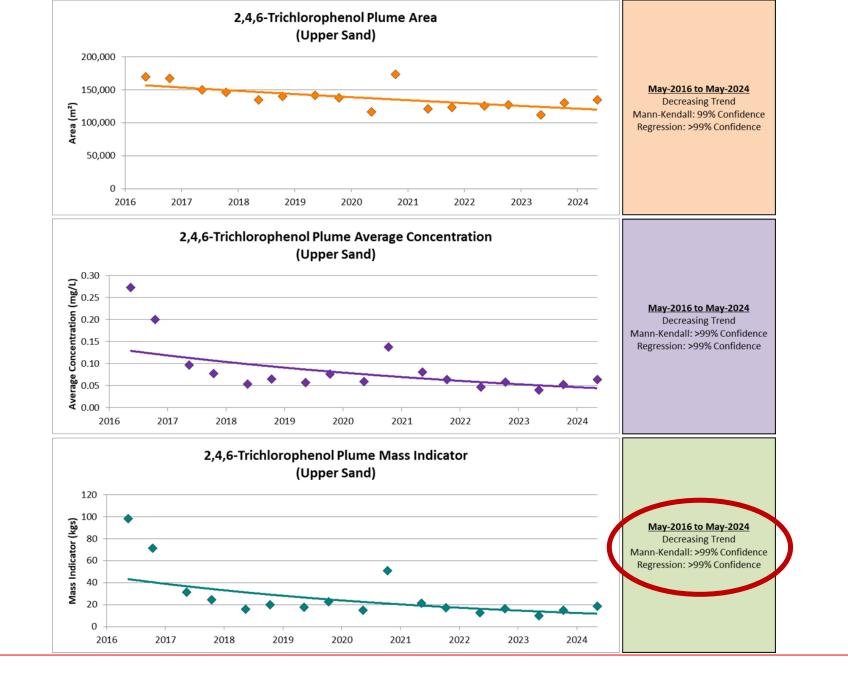




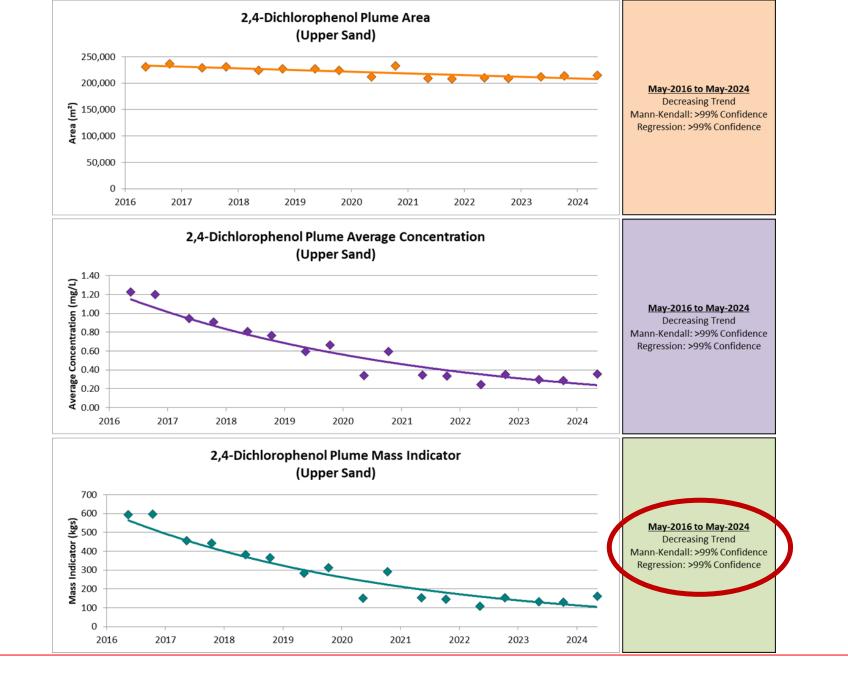




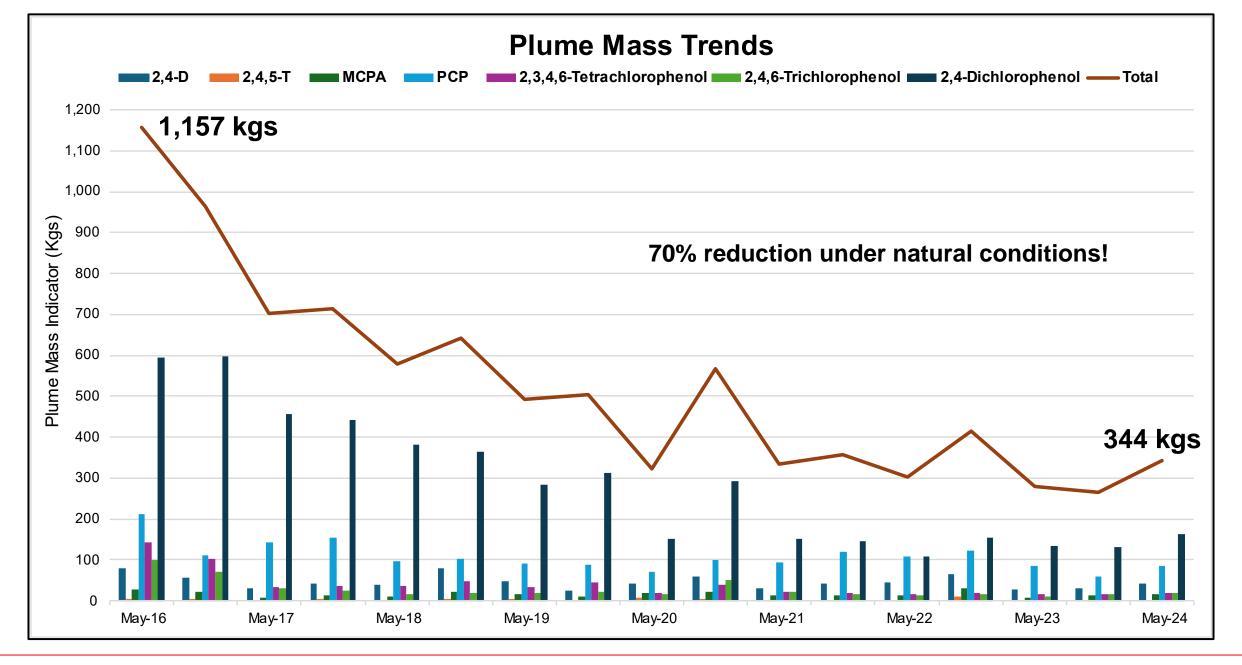
















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