LAUNCH COMPLEX 39A, SWMU 008
OPERATIONS, MAINTENANCE, AND MONITORING REPORT
KENNEDY SPACE CENTER, FLORIDA

Prepared for:

National Aeronautics and Space Administration
Kennedy Space Center, Florida

April 2016
Revision 0

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FOR
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Prepared for:
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This report was prepared in accordance with sound professional practices. The figures, tables, and text have been reviewed and certified by a Professional Engineer registered in the State of Florida.

4/19/16

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EXECUTIVE SUMMARY

This Operations, Maintenance, and Monitoring Report (OMMR) presents the findings, observations, and results from Year 1 operation of the air sparging (AS) groundwater interim measure (IM) for High-Concentration Plumes (HCPs) and Low-Concentration Plumes (LCPs) within the perimeter fence line at Launch Complex 39A (LC39A) located at Kennedy Space Center (KSC), Florida. The objective of the LC39A groundwater IM is to actively decrease concentrations of trichloroethene (TCE), cis-1,2-dichloroethene (cDCE), and vinyl chloride (VC) in groundwater in the HCP and LCP within the pad perimeter fence line via AS to levels less than Florida Department of Environmental Protection (FDEP) Groundwater Cleanup Target Levels (GCTLs). The objective was developed because LC39A is currently being leased to Space Exploration Technologies (SpaceX), and the original IM for monitored natural attenuation (MNA) over an extended period of time was not suitable for future planned site use.

This OMMR presents system operations and maintenance (O&M) information from February 2015, when full-scale O&M began, through December 31, 2015, and performance monitoring results for quarterly groundwater sampling events conducted in May and September 2015 and January 2016. Additionally, air monitoring results from samples collected in May and September 2015 are presented in this report to provide evidence that operation of the AS system is not causing adverse effects for workers in the vicinity of the project site.

Based on the results to date, the AS system is operating as designed and is meeting the performance criteria and expected to meet the groundwater IM objective. Since the start of AS system operations at LC39A through the January 2016 groundwater sampling event, an overall 77-percent mass reduction of chemicals of concern (COC) has been achieved. Based on these results, team consensus was reached at the February 2016 KSC Remediation Team (KSCRT) meeting to continue IM operations and conduct routine O&M as presented in the Construction Completion Report (CCR) (NASA, 2015). Air flow in Zone C will be increased to address the increase in VC concentrations detected at well MW0017S since startup of the AS system, and flow will be decreased in Zone D due to the low groundwater COC concentrations observed in

this area. Air flow in Zone F will also be reduced due to the low VC groundwater concentrations observed in this area while increasing flow in Area E to balance the system. After the next annual groundwater sampling event, scheduled for September 2016, system data and performance monitoring data will be evaluated to make optimization recommendations as to whether any of the treatment zones can be shut down.

The performance monitoring network is also adequately constructed for assessment of IM performance at LC39A. At the February 2016 KSCRT meeting, team consensus was reached on the following performance monitoring optimization recommendations. Year 2 groundwater performance monitoring will proceed at the frequency presented in the CCR, which includes reducing the sampling frequency of the HCP wells from quarterly to semi-annual and continuing to monitor the LCP wells annually. However, monitoring well DBA-IW003I will no longer be included in the performance monitoring network based on consistently low concentrations of COCs and because another well in the monitoring program, MW0030I, is located nearby and will allow adequate monitoring of groundwater concentrations in the area. In addition, the following wells that have had previous detections of COCs but have not been sampled since 2012 will also be sampled during the next sampling event to gain a comprehensive view of groundwater conditions at the site:

- MW0012S
- MW0013S
- MW0016S
- MW0022I
- MW0024I
- MW0027S
- MW0029S

Team consensus was also reached to discontinue air monitoring based on the baseline, startup, and Year 1 performance monitoring air results. The next groundwater performance monitoring event is scheduled for June 2016.

ABBREVIATIONS AND ACRONYMS

ACGIH	American Conference of Governmental Industrial Hygienists
ADP	advanced data package
AS	air sparging
bls	below land surface
CCR	Construction Completion Report
cDCE	cis-1,2-dichloroethene
cfm	cubic foot per minute
COC	chemical of concern
DBA	Deluge Basin Area
DO	dissolved oxygen
DPT	direct-push technology
ECS	Environmental Control System
EE	Engineering Evaluation
EPA	United States Environmental Protection Agency
°F	degree Fahrenheit
FDEP	Florida Department of Environmental Protection
GCTL	Groundwater Cleanup Target Level
HCP	high-concentration plume
HFF	Hypergol Fuel Facility
HOF	Hypergol Oxidizer Facility
HVAC	Heating, Ventilation, and Air Conditioning
IDIQ	Indefinite Delivery Indefinite Quantity
IM	interim measure
IMWP	Interim Measures Work Plan
ISCTL	Industrial Soil Cleanup Target Level
IWP	Implementation Work Plan
KSC	Kennedy Space Center
KSCRT	Kennedy Space Center Remediation Team
LC39A	Launch Complex 39A

LCP	low-concentration plume
LSCTL	leachability Soil Cleanup Target Level
LUCIP	Land Use Control Implementation Plan
LOX	liquid oxygen
MNA	monitored natural attenuation
msl	mean sea level
NADC	Natural Attenuation Default Concentration
NASA	National Aeronautics and Space Administration
NAVD 88	North American Vertical Datum of 1988
O&M	operations and maintenance
OM&M	Operations, Maintenance, and Monitoring
OMMR	Operations, Maintenance, and Monitoring Report
ORP	oxidation-reduction potential
OSHA	Occupational Safety and Health Administration
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PEL	Permissible Exposure Limit
PRE	Preliminary Risk Evaluation
psig	pound per square inch gauge
RCRA	Resource Conservation and Recovery Act
RFI	Resource Conservation and Recovery Act Facility Investigation
RSCTL	Residential Soil Cleanup Target Level
SAP	Sampling and Analysis Plan
SCTL	Soil Cleanup Target Level
SpaceX	Space Exploration Technologies
SPLP	Synthetic Precipitation Leaching Procedure
STS	Space Transportation System
SVOC	semivolatile organic compound
SWMU	Solid Waste Management Unit
TCE	trichloroethene
tDCE	trans-1,2-dichloroethene

TLV	Threshold Limit Value
TRPH	total recoverable hydrocarbons
TWA	time-weighted average
µg/L	microgram per liter
VC	vinyl chloride
VOC	volatile organic compound

SECTION I
INTRODUCTION

This Operations, Maintenance, and Monitoring Report (OMMR) presents the findings, observations, and results from Year 1 operation of the air sparging (AS) groundwater interim measure (IM) for high-concentration plumes (HCPs) and low-concentration plumes (LCPs) within the perimeter fence line at Launch Complex 39A (LC39A) located at Kennedy Space Center (KSC), Florida (see Figures 1-1 and 1-2). The LC39A site has been designated Solid Waste Management Unit (SWMU) 008 under KSC's Resource Conservation and Recovery Act (RCRA) Corrective Action program. This document was prepared by Tetra Tech, Inc., for the National Aeronautics and Space Administration (NASA) under Indefinite Delivery Indefinite Quantity (IDIQ) Contract NNK12CA15B/NNK14CA23T, Task Order 9.

This OMMR presents system operations and maintenance (O&M) information from February 2015, when full-scale O&M began, through December 31, 2015, and presents performance monitoring results for sampling events conducted in May and September 2015 and January 2016.

1.1 BACKGROUND

LC39A is located at KSC, Florida, and includes approximately 170 acres, as shown on Figure 1-2. LC39A consists of former launch pad 39A, which supported Apollo Space Program and Space Transportation System (STS) operations from the mid-1960s until 2011. The complex is currently being leased by Space Exploration Technologies (SpaceX), and the site is being modified for future launch missions.

Several investigations and two soil remedial actions were completed within the fence line at LC39A prior to the groundwater IM that is being evaluated in this report. The LC39A site was entered into the Engineering Evaluation (EE) Multi-Step Process in 2013. The EE Multi-Step Process includes Site Characterization (Step 1), Remedial Alternatives Evaluation (Step 2), IM Work Plan (IMWP preparation (Step 3), and Performance Monitoring (Step 4), and the results of these steps are presented as advanced data packages (ADPs) at KSC Remediation Team

(KSCRT) Meetings. The prior investigations and remedial activities for the site are summarized in the following paragraphs.

1994: A Preliminary Assessment (EG&G, 1994) in 1994 focused on five areas of LC39A, including the Compressed Air Building, Environmental Control System (ECS) Area, Heating, Ventilation, and Air Conditioning (HVAC) Building, Hypergol Fuel Facility (HFF), and Hypergol Oxidizer Facility (HOF). Samples were collected from surface and shallow subsurface soil and groundwater, and surface water in drainage swales. Soil samples from the ECS Area and HVAC Building had metals and polycyclic aromatic hydrocarbon (PAH) contamination, and metals were detected in groundwater at concentrations less than Florida Department of Environmental Protection (FDEP) G-II standards and in surface water samples at concentrations greater than KSC screening levels.

1998 to 2000: A RCRA Facility Investigation (RFI) (NASA, 2000) was completed from 1998 to 2000 to characterize the nature and extent of contamination at LC39A. Soil, groundwater, drainage swale sediment, and drainage swale surface water samples were collected from within the fence line of LC39A and were analyzed for a full suite of analytical parameters including volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), metals, polychlorinated biphenyls (PCBs), pesticides, cyanide, and other miscellaneous parameters. Primary chemicals of concern (COCs) identified during this investigation in each media were as follows:

- Groundwater – VOCs, specifically chlorinated solvents, PAHs, phenols, and metals;
- Surface water – PAHs, metals, and pesticides;
- Soil – PCBs and PAHs; and
- Drainage swale soil – PAHs, PCBs, metals, and pesticides.

The results of the Preliminary Risk Evaluation (PRE) included in the RFI Report (NASA, 2000) indicated that unacceptable human health risks were associated with use of groundwater as a

source of drinking water, with exposure to soil under a residential land use scenario, and exposure to drainage swale soil under residential and industrial scenarios. An ecological risk assessment did not identify any ecological COCs for on-site soil, sediment, or surface water.

The RFI recommended an IM to remove soil and sediment in three areas of LC39A (Deluge Basin Area (DBA), ECS Area, and HVAC Building) with concentrations greater than FDEP Industrial Soil Cleanup Target Levels (ISCTLs), and the soil and sediment removal IM was completed in 2000 (NASA, 2001). Implementation of groundwater monitoring in the DBA and HOF areas and additional sampling of off-site surface water and drainage swale soil were recommended to evaluate degradation and potential of groundwater impacts in these areas.

2003: An RFI Addendum was completed in 2003 to address regulatory comments received on the RFI Report, including a request that additional groundwater investigations be conducted for the DBA and HOF areas along with a third area located outside the pad perimeter fence line and downgradient of the liquid oxygen (LOX) area (NASA, 2003). The FDEP Division of Waste Management concurred that, for remediation purposes, groundwater at LC39A should be considered as Class G-III (non-potable).

Based on the results of the RFI Addendum, metals, PAHs, and phenols were eliminated as COCs in groundwater at LC39A. A chlorinated solvent plume was identified in groundwater downgradient of the LOX area outside the pad perimeter fence line, but the source of the plume was unknown.

2012: Upon completion of the STS Program in 2011, a Re-Assessment Investigation was completed in 2012 to provide a baseline delineation of contamination in groundwater, soil, and drainage swale soil within the fence line of LC39A (NASA, 2012). Field activities included advancement of four soil lithology borings, collection and analysis of 3,400 groundwater samples via direct-push technology (DPT) from 655 locations to maximum depths of 60 feet below land surface (bls), installation and sampling of 21 monitoring wells, and collection and analysis of 786 soil and drainage swale soil samples from 761 locations.

The Re-Assessment Investigation identified two groundwater plumes with concentrations of COCs greater than FDEP Groundwater Cleanup Target Levels (GCTLs) within the fence line of LC39A. The groundwater plumes are located in the northern and northwestern quadrants of LC39A. The primary contaminants in the northwest plume are trichloroethene (TCE), cis-1,2-dichloroethene (cDCE), and vinyl chloride (VC). The primary contaminant in the north plume is VC. The total area of the LCPs at the site, defined by groundwater concentrations less than FDEP Natural Attenuation Default Concentrations (NADCs) but greater than GCTLs, is 7.6 acres, and the total area of the HCPs at the site, defined by groundwater concentrations exceeding NADCs, is 0.72 acre. The maximum depth of the LCP is 40 feet bls, and the maximum depth of the HCP is 30 feet bls.

The Re-Assessment also identified metals (arsenic, barium, copper, thallium, nickel, and lead), total recoverable hydrocarbons (TRPH), carcinogenic PAHs, and PCBs in soil at concentrations greater than Residential Soil Cleanup Target Levels (RSCTLs) in 43 separate areas within the fence line of LC39A and PCBs and carcinogenic PAHs in soil at concentrations greater than ISCTLs in seven separate areas within the fence line at LC39A. Although a few exceedances of leachability Soil Cleanup Target Levels (LSCTLs) were identified in soil at the site, Synthetic Precipitation Leaching Procedure (SPLP) analysis results were less than GCTLs, indicating that leachability is not an issue at this site. A residential IMWP, which recommended excavation of soil with concentrations greater than RSCTLs, was prepared and included in the Re-Assessment Investigation Report (NASA, 2012). An interim Land Use Control Implementation Plan (LUCIP) for LC39A was prepared to limit exposures to soil and groundwater with concentrations exceeding Soil Cleanup Target Levels (SCTLs) and GCTLs, respectively, and included in the Re-Assessment Investigation Report.

2013: Following completion of the 2012 Re-Assessment Investigation, LC39A was transitioned into the KSC EE Multi-Step Process. The Site Characterization ADP, presented to the KSCRT in May 2013, included delineation of groundwater inside the fence line of LC39A to FDEP GCTLs. The Remedial Alternatives Evaluation ADP, presented at the November 2013 KSCRT meeting, included a summary of previous investigations, COCs and media of concern, cleanup criteria, and development and screening of groundwater IM alternatives. The recommended

alternative in the Remedial Alternatives Evaluation ADP was monitored natural attenuation (MNA) in the HCP and LCP. The LC39A complex was not being used at the time of the decision, but the recommendation included a provision that if site use changed and unrestricted use of site groundwater was desired, the most aggressive option, AS in the HCP and LCP, would be implemented. Since that time, SpaceX entered into a lease for use of the complex, so AS in the HCP and LCP was selected for IMWP development.

The IMWP ADP for the HCPs and LCPs portions of the northwest and north plumes at LC39A were presented at the December 2013 KSCRT meeting and provided details of the proposed IM, a modified version of AS in the HCP and LCP. Instead of 40-foot well spacing between AS wells, 50-foot well spacing was used in the LCPs where VC concentrations were greater than 10 micrograms per liter (µg/L), and 60-foot spacing was used in the LCPs where VC concentrations were less than 10 µg/L. The final IMWP (NASA, 2013), including the ADP and supplemental information, was submitted for regulatory approval at the December 2013 KSCRT meeting, and FDEP approved the IMWP at the December 2013 meeting (Meeting Minute 1312-M09, Decision 1312-D15).

2014: The Implementation Work Plan (IWP) (NASA, 2014) for the groundwater IM was completed in 2014. Construction of the AS system for the groundwater IM and excavation of soil for the soil IM were initiated in 2014. Soil sampling activities to delineate dioxin/furan soil contamination and confirm excavation areas were completed along with the collection of baseline groundwater samples in December 2014.

2015: The groundwater IM described in the IWP was implemented in 2015. System startup activities began in January 2015, and full-scale AS operations began on February 18, 2015. The overall AS well array includes 122 AS wells in six treatment zones (Zones A to F) determined based on the lateral and vertical extents of the VOC plumes. The design flow rate for each AS well is 5 cubic foot per minute (cfm). The AS system includes a 50-horsepower rotary screw air compressor, integrated refrigerated air dryer, coalescing and particulate filters with an oil-water separator, 120-gallon receiver tank, manifold, and telemetry. Electrical service is provided

through a 150-amp electrical service feeder from an existing 480-volt/150-amp breaker from a panelboard in Building J8-1553. The layout of the AS system is illustrated on Figure 1-3.

Soil IM field activities were completed in spring 2015. Based on pre-excavation confirmation soil sampling results, the total number of soil areas excavated was reduced to 37. A total of 10,791 tons, equating to a soil volume of 7,061 cubic yards, of non-hazardous soil were excavated from LC39A in 37 areas covering a total of approximately 127,000 square feet. Excavation depths varied from 0.5 to 4 feet bls. Several areas were excavated to below the water table.

1.2 PURPOSE

The purpose of this OMMR is to summarize groundwater IM activities conducted since the start of full-scale O&M in February 2015 and to present performance monitoring results for groundwater sampling events conducted in May and September 2015 and January 2016. Additionally, this report provides recommendations for future groundwater IM activities at LC39A. Detailed information about AS system startup and initial O&M activities were provided in the July 2015 Construction Completion Report (CCR) (NASA, 2015).

1.3 INTERIM MEASURE OBJECTIVE

The objective of the LC39A groundwater IM is to actively decrease concentrations of TCE, cDCE, and VC in groundwater in the HCP and LCP within the pad perimeter fence line via AS to levels less than GCTLs. The objective was developed because LC39A is currently being leased to SpaceX, and the original IM for MNA over an extended period of time was not suitable for planned site use. Based on the performance of the AS IM, AS operations may be modified, as appropriate, to achieve the IM objective.

1.4 REPORT ORGANIZATION

Section 1: Introduction – Provides a brief overview of the report and site background information and discusses the objective of the IM.

Section 2: System Operation, Maintenance, and Monitoring – Details efforts associated with O&M of the system since the start of full-scale O&M in February 2015.

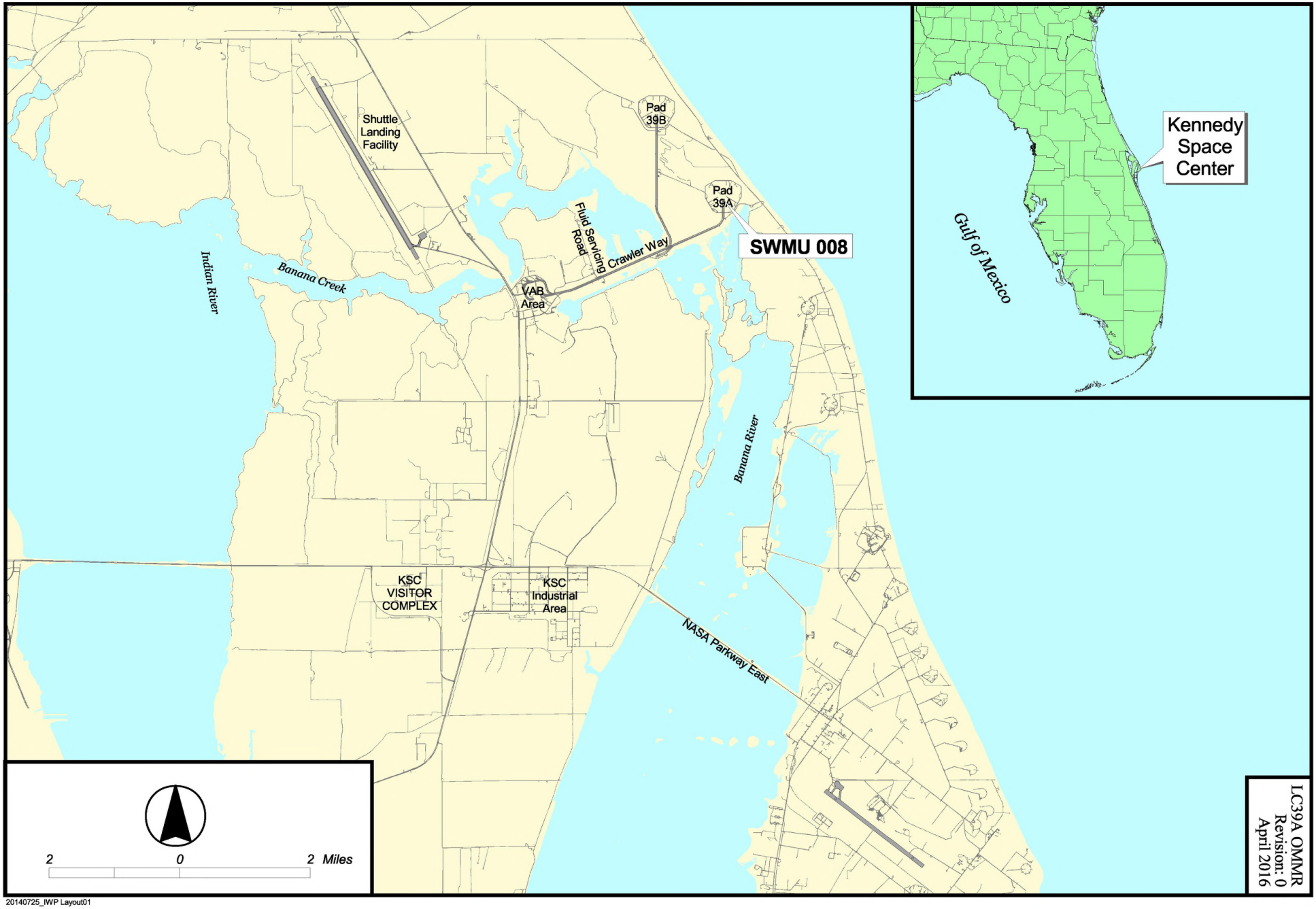
Section 3: Performance Monitoring – Summarizes the results of performance monitoring conducted in May and September 2015 and January 2016.

Section 4: Conclusions and Recommendations – Provides a summary of the activities conducted in support of the groundwater IM and presents recommendations for future activities at LC39A based on the results of the IM and associated monitoring.

Section 5: References – Provides a listing of the references cited in this report.

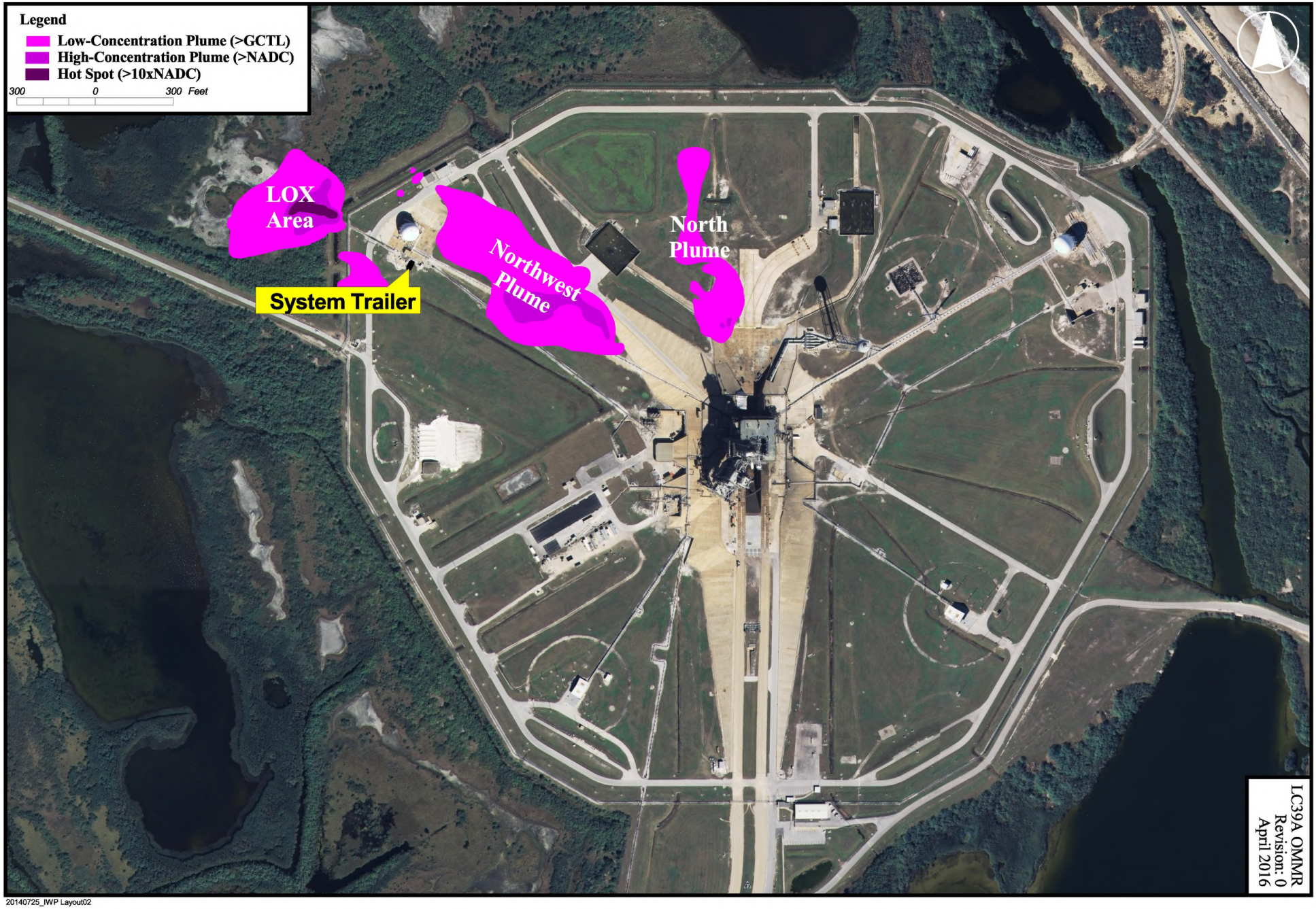
FIGURE 1-1 LOCATION OF KENNEDY SPACE CENTER AND SWMU 008

SWMU 008, KENNEDY SPACE CENTER, FLORIDA



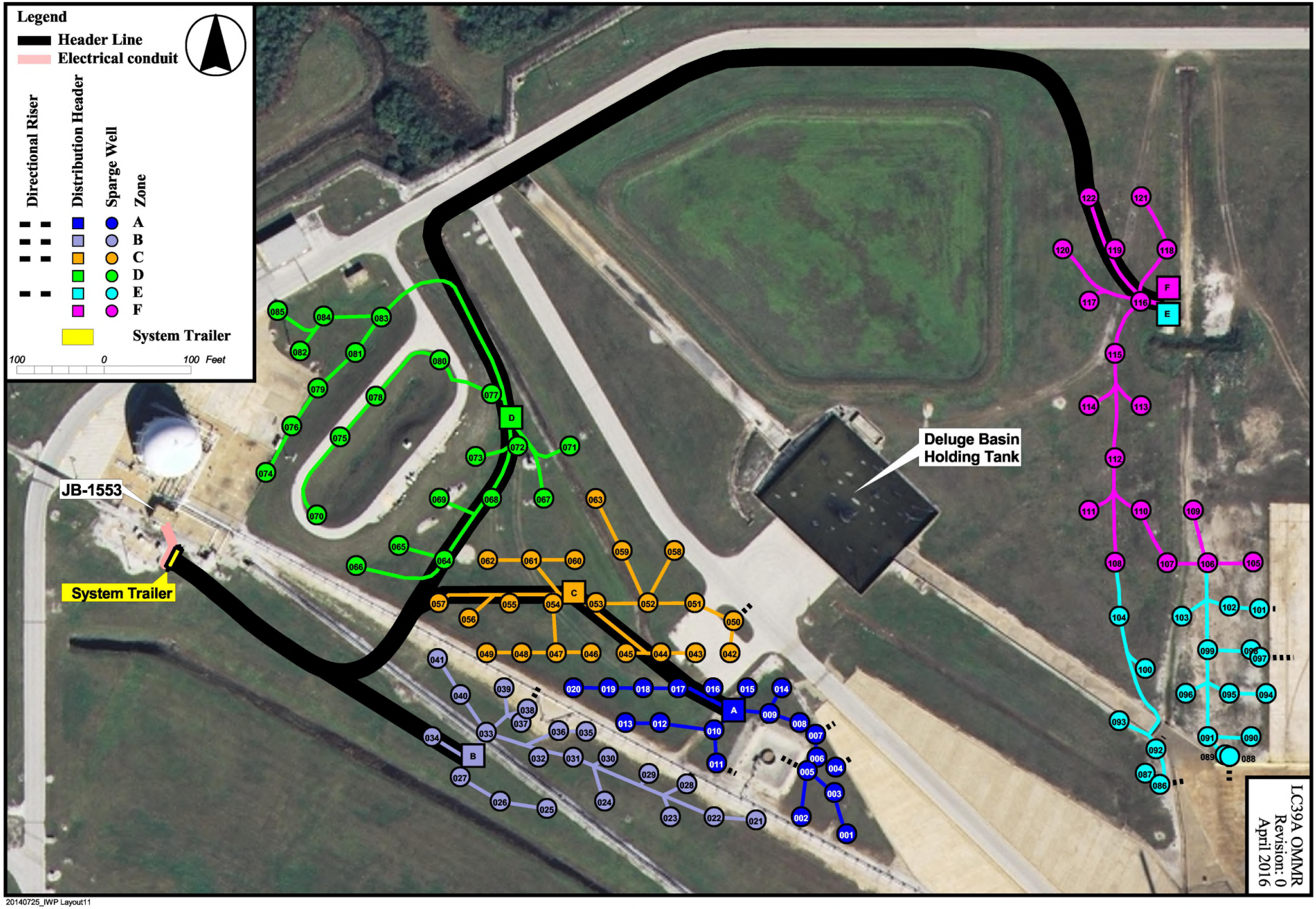
20140725_IWP Layout01

FIGURE 1-2 SITE PLAN
SWMU 008, KENNEDY SPACE CENTER, FLORIDA



20140725_IWP Layout02

FIGURE 1-3 AIR SPARGING SYSTEM WELL AND PIPING LAYOUT MAP
SWMU 008, KENNEDY SPACE CENTER, FLORIDA



20140725_IWP Layout11

SECTION II

SYSTEM OPERATION, MAINTENANCE, AND MONITORING

This section identifies the activities conducted and results obtained during full-scale AS system O&M activities. Detailed information about system startup, prove-out, and initial operations and O&M activities are provided in the CCR (NASA, 2015).

2.1 OPERATION

System startup testing was conducted from January 20 to February 17, 2015, and full-scale AS operations began on February 18, 2015. No significant issues requiring repair of equipment have occurred since the start of full-scale operations. The system was shut down or partially shut down for groundwater sampling events, sporadic system alarms (e.g., high humidity or high/low temperature), and when AS wells and trenches were being installed in the adjacent LOX Area (Figure 1-2) during system expansion activities. The dates of long shutdowns include a total system shutdown from May 13 to 27, 2015, and September 8 to 16, 2015, for groundwater performance monitoring sampling events and a partial system shutdown from December 1 to 31, 2015, when four manifold zones (C, D, E, and F) were shut off due to water bubbling in wells that were impacting system expansion activities in the LOX Area. The following table presents the planned and actual operational hours for Year 1 of system operations.

Component	Planned Hours[1]	Operational Hours (Year 1)	Operational vs. Planned
Total Runtime	8,304	7,412	89%
Zone A	2,768	3,054	110%
Zone B	2,768	2,917	105%
Zone C	2,768	2,328	84%
Zone D	2,768	2,423	88%
Zone E	2,768	2,228	80%
Zone F	2,768	2,314	84%

[1] Planned hours based on expected cycle times from system start-up date through December 31, 2015.

2.2 REMOTE MONITORING

The system was evaluated via site visits and monitoring data recorded hourly and transmitted through a telemetry system. These operational data, including run-time, flow, and pressure readings for each AS zone, are provided in Appendix A. During the O&M period, each pair of treatment zones (A and B, C and D, and E and F) were designed to operate for 8 hours per day with a cycling approach as described in the CCR (NASA, 2015). Air flow rates in all AS wells ranged from 3.5 to 4.5 cfm, which is slightly less than the design criterion presented in the IMWP of 5 cfm per well. AS well pressures ranged from 15 to 25 pounds per square inch gauge (psig) which is within the design criteria.

2.3 SITE VISITS

System evaluation site visits were conducted weekly for the first month of operation and then monthly at a minimum thereafter. Additional visits were made when Tetra Tech personnel were conducting system evaluation visits for remediation systems at nearby sites. During monthly system evaluation site visits, the following activities were performed:

- Balancing individual sparging well flows within each manifold zone;
- Inspection of flow meters, transmitters, and AS system components for leakage and excessive vibration, noise, or abnormal temperatures;
- Inspection of the AS wells, air compressor, heat exchanger, and air and coalescing filters;
- Inspection of oil levels and lubrication;
- Inspection of the condensate treatment system and refrigerated air dryer;
- Assessment of differential pressures across filtration units and process equipment;
- Observing system operational data, including at a minimum flow rates and pressures, and comparing data to design conditions and previous operating data;
- Repairing and cleaning equipment as needed; and
- Housekeeping.

2.4 MAINTENANCE ACTIVITIES

Routine maintenance and inspection activities were conducted while the system was operating, and maintenance was executed in a manner that minimized emergencies or unscheduled shutdowns. The only significant maintenance activity conducted during the reporting period was routine draining of the condensate treatment system in October 2015.

2.5 EVALUATION

During operation of the AS system, no significant issues requiring unscheduled maintenance or repair of equipment occurred. The system was only shut down for sampling events, sporadic system alarms, and during the installation of AS wells and trenches in the LOX Area as part of the LC39A system expansion. AS well flow rates and pressures are within design criteria.

SECTION III
PERFORMANCE MONITORING

3.1 GROUNDWATER SAMPLING

Groundwater sampling activities from May 2015 through January 2016 were conducted in accordance with the IWP (NASA, 2014), KSC Sampling and Analysis Plan (SAP) for the RCRA Corrective Action Program at KSC (NASA, 2011), and FDEP Standard Operating Procedure FS 2200 (2008). The results of baseline sampling, conducted in December 2014 prior to startup of the AS system in January 2015, were reported in the CCR submitted in July 2015.

Peristaltic pumps were used for purging and sampling, and samples for VOC analysis were collected using the "soda-straw" technique. Samples collected in May and September 2015 were submitted to ALS Environmental of Jacksonville, Florida, and samples collected in January 2016 were submitted to Test America Laboratories of Tampa, Florida, for analysis of VOCs via Method SW-846 8260B. Monitoring well locations and Year 1 sampling frequency are shown on Figure 3-1, and a performance monitoring summary is provided in Table 3-1.

Three performance monitoring events have been conducted since the startup of the full-scale AS system in February 2015. In May 2015 and January 2016, six wells were sampled, and in September 2015, 18 wells were sampled (see Table 3-1). The September 2015 event included sampling of the same wells as during the baseline event in December 2014 and one additional monitoring well, MW0020I, added to the quarterly performance monitoring program in April 2015 based on baseline sampling results in nearby wells (Meeting Minute 1504-M7, Decision 1504-D31).

3.2 FIELD MEASUREMENTS

Temperature, pH, conductivity, turbidity, dissolved oxygen (DO), and oxidation-reduction potential (ORP) were measured and recorded in the field at each well sampled during performance monitoring events (see sample log sheets in Appendix B). Water levels were

measured at all of the 18 LC39A performance monitoring wells prior to each sampling event. Water level measurements and associated groundwater elevations are presented in Table 3-2.

3.3 GROUNDWATER ANALYTICAL RESULTS

Performance monitoring results were used to evaluate the effectiveness of the AS IM in reducing VOC concentrations in groundwater based on comparisons to the results of baseline sampling completed in December 2014. For wells sampled as part of performance monitoring, summaries of TCE, cDCE, trans-1,2-dichloroethene (tDCE), and VC results for the baseline (December 2014) and three performance monitoring events (May and September 2015 and January 2016) are presented in Table 3-3. Figure 3-2 includes all available TCE, cDCE, tDCE, and VC results for performance monitoring wells. Although tDCE does not exceed the GCTL and is not a COC for the site, it is included on tables and figures because it is a degradation product of TCE. Groundwater sample log sheets are provided in Appendix B, and laboratory analytical reports from the performance monitoring events are provided in Appendix C. Results for the three quarterly performance monitoring events conducted during this reporting period are discussed in the subsections below.

3.3.1 MAY 2015. During the first post-startup sampling event in May 2015, groundwater samples were collected from six wells located in the HCPs, including MW0021S, MW0020I, MW0018S, MW0017S, MW0017I in the northwest HCP plume and MW0028I in the north HCP plume. The selected wells for the sampling event were identified in the CCR (NASA, 2015) as to be sampled quarterly.

With the exception of MW0017S, concentrations of TCE, cDCE, tDCE, and VC in May 2015 were generally less than or similar to concentrations detected during baseline sampling. In MW0017S, VC concentrations increased from 1.3 µg/L during the baseline sampling event to 68 µg/L in May 2015. Concentrations of TCE, cDCE, and tDCE also increased in this well but remained less than the GCTLs. VC was the only chemical with concentrations greater than the GCTL, which was observed in five of the six wells sampled in May 2015. The maximum VC concentration was 68 µg/L (MW0017S).

3.3.2 SEPTEMBER 2015. During the September 2015 sampling event, groundwater samples were collected from 18 monitoring wells located in the HCPs and LCPs, as identified in the CCR (NASA, 2015) as wells to be sampled annually. In September 2015, 12 wells in the northwest plume were sampled, including the five HCP wells sampled in May 2015 and seven LCP wells (MW0023S, MW0019S, MW0031I, MW0032I, MW0015I, and MW0014I). Six wells were sampled in the north plume, including MW0028I sampled in May 2015 and MW0026S, MW0025S, IW0003S, IW0003I, and MW0030I. In general, concentrations of TCE, cDCE, and tDCE in these wells decreased from the levels detected during baseline sampling and the previous sampling event and were less than GCTLs. VC was the only chemical detected in September 2015 at concentrations greater than the GCTL. VC was detected in 8 of 18 wells at concentrations ranging from 0.36 to 78 µg/L, and concentrations were greater than the GCTL in 7 of the 18 wells sampled in September 2015.

Concentrations of VC decreased from the levels detected during baseline sampling and previous sampling event in the majority of the wells sampled. The most notable decrease was at MW0020I located in the HCP of the northwest plume, where VC concentrations decreased from 59 µg/L in May 2015 to 4.9 µg/L in September 2015. VC concentrations increased from levels detected during baseline sampling in two wells, MW0025S and MW0023S. VC concentrations in MW0023S increased from 2.9 µg/L during baseline sampling to 15 µg/L in September 2015. In MW0025S, VC was not detected during baseline sampling but was detected at 1.9 µg/L, greater than the GCTL, in September 2015. At MW0017S, where VC concentrations increased significantly from the baseline event to May 2015 (1.3 to 68 µg/L), the VC concentration increased again in September 2015 to 78 µg/L.

3.3.3 JANUARY 2016. During the January 2016 sampling event, six groundwater samples were collected from the same wells sampled during the first quarterly event in May 2015. VC was the only chemical detected in January 2016 at concentrations greater than the GCTL. VC was detected in three of the six wells sampled in January 2016, with a maximum concentration of 69 µg/L (MW0017S), and all detected concentrations exceeded the GCTL.

VC concentrations in January 2016 were similar to or less than concentrations during the previous sampling event (September 2015) in five of the six wells sampled. At MW0020I, there was a slight increase in VC concentrations from 4.9 µg/L in September 2015 to 6.2 µg/L during the January 2016 event. This well was not sampled during the baseline sampling event because it was added to the performance monitoring plan in 2015; however, the overall trend in VC concentrations at this well is downward, from the historical maximum concentration of 273 µg/L in September 2012 to 59 µg/L in May 2015 and to 6.2 in January 2016 (see Figure 3-2). VC concentrations at MW0017S, which increased significantly from 1.3 µg/L during the baseline sampling event to 78 µg/L in September 2015, remained similar to previous results at a concentration of 69 µg/L in January 2016.

3.3.4 PERFORMANCE RESULTS SUMMARY

Within the treatment areas, the original mass of TCE, cDCE, and VC estimated to be present within dissolved and absorbed phases was approximately 8.9 pounds. Tetra Tech used data from the six wells included in the quarterly sampling events (MW17S, MW17I, MW18S, MW20I, MW21S, and MW28I) to calculate the total molar concentrations of COCs (including tDCE) at each well during each sampling event. The total of the molar concentrations (∑µM) of each COC and the total molar concentrations for all COCs are shown in the table below. Using these data, it is estimated that since the start of full-scale AS system operations in February 2015 through the January 2016 groundwater sampling event, there has been a 77-percent reduction in the mass of groundwater COCs, equating to a total of 6.9 pounds of contaminant mass removed.

	09/2012	**05/2015 (1st Event)**	**09/2015 (2nd Event)**	**01/2016 (3rd Event)**	**Mass Reduction**
∑µM - TCE	9.539	3.317	1.879	1.515	84%
∑µM - cDCE	0.188	0.026	0.010	0.018	91%
∑µM - tDCE	3.882	0.860	0.378	0.224	94%
∑µM - VC	0.111	0.144	0.083	0.041	63%
∑µM	5.358	2.288	1.408	1.232	77%

3.4 AIR MONITORING ANALYTICAL RESULTS

Air monitoring results were used to provide evidence that operation of the AS system was not causing adverse effects for workers in the vicinity of the project site. To ensure worker safety, air monitoring results were compared to Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PEL) and American Council of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLVs). Summa canisters were deployed for the collection of 8-hour time-weighted average (TWA) samples, and the samples were submitted to ALS of Simi Valley, California, for analysis of VOCs via United States Environmental Protection Agency (EPA) Method TO-15.

Baseline air monitoring samples and startup air monitoring samples were collected prior to the start of system operation and during system startup activities in 2015; these results were presented in the CCR (NASA, 2015). Performance air monitoring samples were collected from one location in the HCP near the Zone A distribution manifold on June 1, 2015, and September 29, 2015. TCE, cDCE, tDCE, and VC were not detected in the these samples. The air sample chain-of-custody form is provided in Appendix C along with the laboratory analytical results.

Table 3-1. Year 1 Performance Monitoring Summary

Well ID (39A-)	Screened Interval (ft bls)	HCP/LCP	Baseline Dec. 2014	May 2015	Sept. 2015	Jan. 2016	Analytes	
							VOCs	Field Parameters
Northwest Plume								
21ST-MW0023S	15-20	LCP	✔		✔		✔	✔
21ST-MW0023I	30-35	LCP	✔		✔		✔	✔
21ST-MW0021S	15-20	HCP	✔	✔	✔	✔	✔	✔
21ST-MW0020I(1)	23-28	HCP		✔	✔	✔	✔	✔
21ST-MW0018S	13-18	HCP	✔	✔	✔	✔	✔	✔
21ST-MW0017S	14-19	HCP	✔	✔	✔	✔	✔	✔
21ST-MW0017I	30-35	HCP	✔	✔	✔	✔	✔	✔
21ST-MW0019S	15-20	LCP	✔		✔		✔	✔
21ST-MW0031I	23-28	LCP	✔		✔		✔	✔
21ST-MW0032I	23-28	LCP	✔		✔		✔	✔
21ST-MW0015I	36-41	LCP	✔		✔		✔	✔
21ST-MW0014I	22-27	LCP	✔		✔		✔	✔
North Plume								
21ST-MW0028I	22-27	HCP	✔	✔	✔	✔	✔	✔
21ST-MW0026S	15-20	LCP	✔		✔		✔	✔
21ST-MW0025S	12-17	LCP	✔		✔		✔	✔
DBA-IW0003S	7-17	LCP	✔		✔		✔	✔
DBA-IW0003I	33-37	LCP	✔		✔		✔	✔
21ST-MW0030I	20-25	LCP	✔		✔		✔	✔

1 MW0020I was added to the performance monitoring program in April 2015 based on baseline sampling results in nearby wells.

ft bls - feet below land surface.

HCP - High-concentration plume.

LCP - Low-concentration plume.

VOCs - Volatile organic compounds.

Field parameters - dissolved oxygen, pH, oxidation-reduction potential, water level, temperature, and conductivity.

Table 3-2. Water Level Measurements and Groundwater Elevations

Well ID	Ground Surface Elevation (feet NAVD 88)	T.O.C. Elevation (feet NAVD 88)	12/13/14 - 12/15/14		5/22/15		9/14/15 - 9/15/15		1/04/16	
			Depth to Water (feet below T.O.C.)	Groundwater Elevation (feet NAVD 88)	Depth to Water (feet below T.O.C.)	Groundwater Elevation (feet NAVD 88)	Depth to Water (feet below T.O.C.)	Groundwater Elevation (feet NAVD 88)	Depth to Water (feet below T.O.C.)	Groundwater Elevation (feet NAVD 88)
21ST-MW0014I	6.53	6.19	5.06	1.13	5.88	0.31	5.85	0.34	5.90	0.29
21ST-MW0015I	16.39	16.03	14.90	1.13	15.67	0.36	15.70	0.33	15.70	0.33
21ST-MW0017I	6.67	6.31	5.01	1.30	5.91	0.40	5.82	0.49	5.86	0.45
21ST-MW0017S	6.69	6.39	5.05	1.34	5.98	0.41	5.95	0.44	5.63	0.76
21ST-MW0018S	5.16	5.06	3.63	1.43	4.65	0.41	4.65	0.41	4.65	0.41
21ST-MW0019S	6.11	5.90	4.50	1.40	5.55	0.35	5.50	0.40	5.60	0.30
21ST-MW0020I	5.01	4.69	NM	NM	3.74	0.95	4.20	0.49	4.22	0.47
21ST-MW0021S	5.10	4.90	3.10	1.80	4.44	0.46	4.20	0.70	4.90	0.00
21ST-MW0023I	7.39	7.21	5.25	1.96	6.59	0.62	6.60	0.61	6.63	0.58
21ST-MW0023S	7.32	7.09	5.12	1.97	6.52	0.57	6.30	0.79	6.55	0.54
21ST-MW0025S	4.57	4.42	2.57	1.85	NM	NM	3.45	0.97	3.10	1.32
21ST-MW0026S	4.84	4.68	2.48	2.20	3.83	0.85	3.50	1.18	4.18	0.50
21ST-MW0028I	4.38	4.31	1.98	2.33	3.38	0.93	3.00	1.31	3.73	0.58
21ST-MW0030I	4.93	4.78	3.53	1.25	4.38	0.40	4.30	0.48	4.33	0.45
21ST-MW0031I	4.76	4.77	3.50	1.27	4.38	0.39	4.30	0.47	4.36	0.41
21ST-MW0032I	4.22	4.32	3.05	1.27	3.96	0.36	3.89	0.43	3.95	0.37
DBA-IW0003I	NM	4.59	3.30	1.29	4.15	0.44	4.00	0.59	4.33	0.26
DBA-IW0003S	NM	4.77	3.10	1.67	4.15	0.62	4.00	0.77	4.35	0.42

T.O.C. - Top of casing.
NM - Not measured.
NAVD88 - North American Vertical Datum of 1988.

Table 3-3. Performance Monitoring Groundwater Results for TCE, cDCE, tDCE, and VC

Well	Baseline-December 2014				May 2015				September 2015				January 2016			
	TCE	cDCE	tDCE	VC	TCE	cDCE	tDCE	VC	TCE	cDCE	tDCE	VC	TCE	cDCE	tDCE	VC
FDEP GCTL	**3**	**70**	**100**	**1**	**3**	**70**	**100**	**1**	**3**	**70**	**100**	**1**	**3**	**70**	**100**	**1**
Northwest Plume - HCP																
39A-21ST-MW0017S	0.16 U	0.36 U	0.12 U	**1.3**	**0.53 I**	**7**	**3.2**	**68**	**0.5 I**	**7.2**	**3**	**78**	**0.65 I**	**6.7**	**4**	**69**
39A-21ST-MW0017I	0.16 U	**0.84 J**	**1.7**	0.22 U	1 U	**0.76 I**	**0.93 I**	1 U	0.36 U	**0.65 I**	**0.74 I**	0.36 U	0.61 U	0.65 U	0.67 U	0.71 U
39A-21ST-MW0018S	**16**	**22**	0.12 U	**2.7**	**1.9**	**7.5**	**1.3**	**3.5**	**0.83 I**	**2.6**	**0.43 I**	0.36 U	**1.7**	**2.1**	0.67 U	0.71 U
39A-21ST-MW0020I	NS	NS	NS	NS	**0.94 I**	**4.8**	**6.4**	**59**	0.36 U	**4.9**	**2.9**	**4.9**	0.61 U	**6.7**	0.67 U	**6.2**
39A-21ST-MW0021S	0.16 U	**29**	**0.19 J**	**0.88 J**	1 U	**57**	**1.5**	**2.5**	0.36 U	**17**	**0.54 I**	0.36 U	0.61 U	**2.8**	0.67 U	0.71 U
Northwest Plume - LCP																
39A-21ST-MW0014I	0.16 U	**1.1**	**3.2**	**3.7**	NS	NS	NS	NS	0.36 U	**0.89 I**	**2.5**	**0.36**	NS	NS	NS	NS
39A-21ST-MW0015I	0.16 U	**1.2**	**1.7**	**1.7**	NS	NS	NS	NS	0.36 U	**0.77 I**	**1.4**	0.36 U	NS	NS	NS	NS
39A-21ST-MW0019S	0.16 U	**7.3**	**0.28 J**	**7.6**	NS	NS	NS	NS	0.36 U	**6.6**	**0.45 I**	**8.9**	NS	NS	NS	NS
39A-21ST-MW0023S	**5.1**	**4.7**	0.12 U	**2.9**	NS	NS	NS	NS	0.36 U	**4.5**	**0.63 I**	**15**	NS	NS	NS	NS
39A-21ST-MW0023I	0.16 U	**0.46 J**	**0.8 J**	0.22 U	NS	NS	NS	NS	0.36 U	**0.53 I**	**1.1**	0.36 U	NS	NS	NS	NS
39A-21ST-MW0031I	0.16 U	**0.51 J**	**0.86 J**	**1.7**	NS	NS	NS	NS	0.36 U	**0.39 I**	**0.45 I**	0.36 U	NS	NS	NS	NS
39A-21ST-MW0032I	**4.7**	**1.7**	**1.5**	**7.3**	NS	NS	NS	NS	0.36 U	**0.63 I**	**0.51 I**	0.36 U	NS	NS	NS	NS
North Plume - HCP																
39A-21ST-MW0028I	0.16 U	**5.3**	**0.33 J**	**11**	1 U	**6.3**	**0.61 I**	**10**	0.36 U	**4.3**	**0.47 I**	**5.1**	0.61 U	**3.4**	0.67 U	**1.8**
North Plume - LCP																
39A-21ST-MW0025S	0.16 U	**0.48 J**	**0.12 J**	0.22 U	NS	NS	NS	NS	0.36 U	**1.7**	**1**	**1.9**	NS	NS	NS	NS
39A-21ST-MW0026S	0.16 U	**2.3**	**1**	**21**	NS	NS	NS	NS	0.36 U	**3.3**	**0.79 I**	**11**	NS	NS	NS	NS
39A-21ST-MW0030I	0.16 U	**9.1**	**0.42 J**	**6.8**	NS	NS	NS	NS	0.36 U	**8**	**0.56 I**	0.36 U	NS	NS	NS	NS
39A-DBA-IW0003I	0.16 U	0.36 U	0.12 U	0.22 U	NS	NS	NS	NS	0.36 U	0.36 U	**0.32 I**	0.36 U	NS	NS	NS	NS
39A-DBA-IW0003S	0.16 U	0.36 U	0.12 U	0.22 U	NS	NS	NS	NS	0.36 U	0.36 U	0.19 U	0.36 U	NS	NS	NS	NS

Concentrations in µg/L.
FDEP GCTL = Florida Department of Environmental Protection Groundwter Cleanup Target Level.
TCE = Trichloroethene.
tDCE = trans-1,2-Dichloroethene.
cDCE = cis-1,2-Dichloroethene.
VC = Vinyl chloride.
Shading indicates GCTL exceedence, TCE = 3 µg/L, cDCE = 70 µg/L, tDCE = 100 µg/L, and VC = 1 µg/L.
J = Estimated concentration.
U = Not detected at or above MDL (associated value).
I = Value is between the laboratory method detection limit and the laboratory practical quantitation limit.
NS = Not sampled.

Table 3-4. Year 2 Performance Monitoring Plan

Well ID (39A-)	Screen Interval, feet bls	HCP/ LCP	Year 2 Frequency	Analytes	
				VOCs	Field Parameters
Northwest Plume					
21ST-MW0023S	15-20	LCP	Annually	✔	✔
21ST-MW0023I	30-35	LCP	Annually	✔	✔
21ST-MW0021S	15-20	HCP	Semi-Annually	✔	✔
21ST-MW0020I	23-28	HCP	Semi-Annually	✔	✔
21ST-MW0018S	13-18	HCP	Semi-Annually	✔	✔
21ST-MW0017S	14-19	HCP	Semi-Annually	✔	✔
21ST-MW0017I	30-35	HCP	Semi-Annually	✔	✔
21ST-MW0019S	15-20	LCP	Annually	✔	✔
21ST-MW0031I	23-28	LCP	Annually	✔	✔
21ST-MW0032I	23-28	LCP	Annually	✔	✔
21ST-MW0015I	36-41	LCP	Annually	✔	✔
21ST-MW0014I	22-27	LCP	Annually	✔	✔
21ST-MW0016S	15-20	N/A	Once [1]	✔	✔
21ST-MW0022I	23-28	N/A	Once [1]	✔	✔
North Plume					
21ST-MW0028I	22-27	HCP	Semi-Annually	✔	✔
21ST-MW0026S	15-20	LCP	Annually	✔	✔
21ST-MW0025S	12-17	LCP	Annually	✔	✔
DBA-IW0003S	7-17	LCP	Annually	✔	✔
21ST-MW0030I	20-25	LCP	Annually	✔	✔
21ST-MW0024I	20-25	N/A	Once [1]	✔	✔
21ST-MW0027S	12-17	N/A	Once [1]	✔	✔
21ST-MW0029S	12-17	N/A	Once [1]	✔	✔
Other [1]					
21ST-MW0012S	12-17	N/A	Once [1]	✔	✔
21ST-MW0013S	12-17	N/A	Once [1]	✔	✔

1 Wells located outside the north and northwest plumes.
2 Well will be sampled once during the semi-annual event to gain a comprehensive view of groundwater conditions at the site.
Field parameters - dissolved oxygen, pH, oxidation-reduction potential, water level, temperature, and conductivity.
ft bls - feet below land surface.
HCP - High-concentration plume.
LCP - Low-concentration plume.
N/A - Not applicable.
VOCs - Volatile organic compounds.

FIGURE 3-1 YEAR 1 PERFORMANCE MONITORING LAYOUT
SWMU 008, KENNEDY SPACE CENTER, FLORIDA

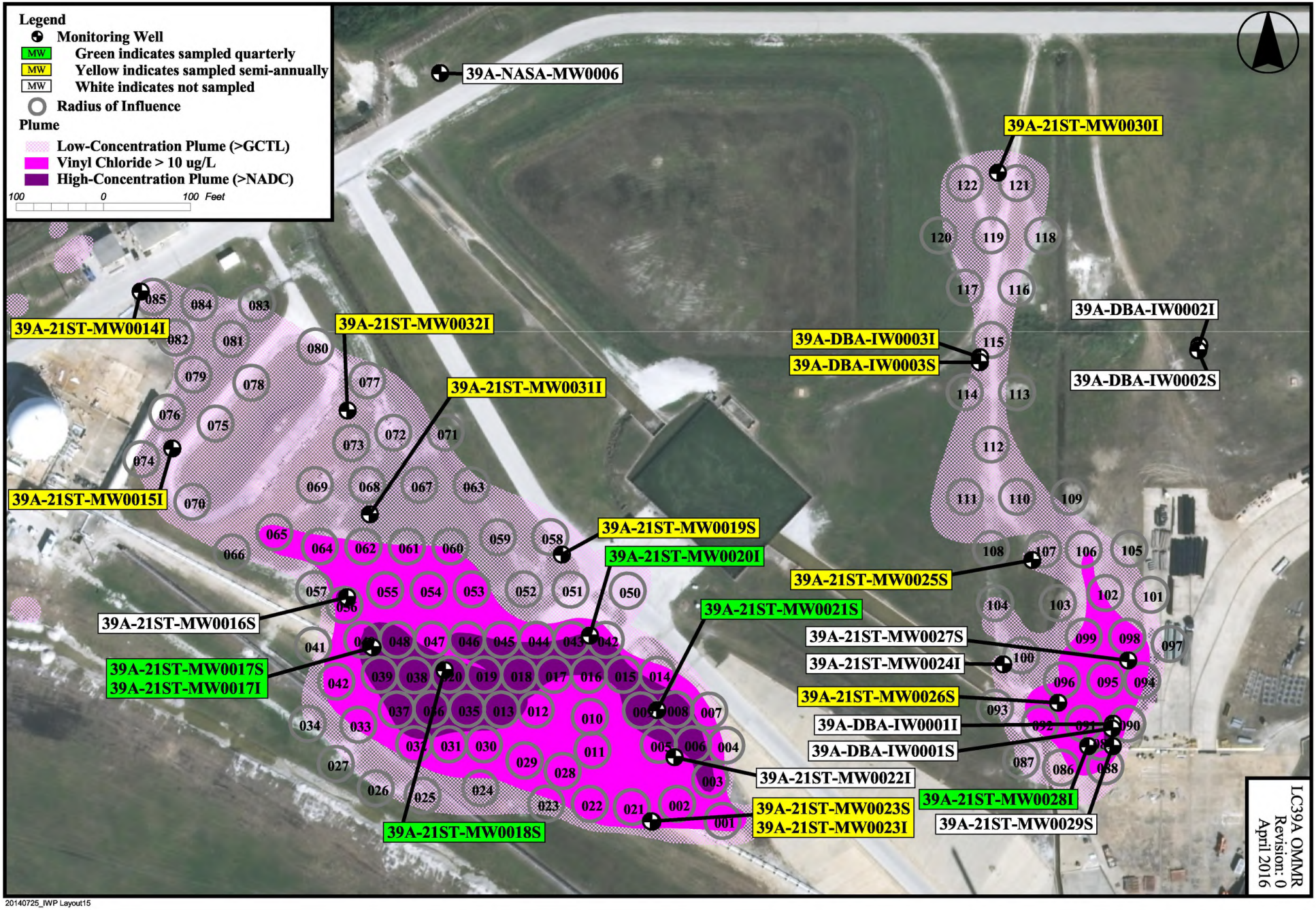


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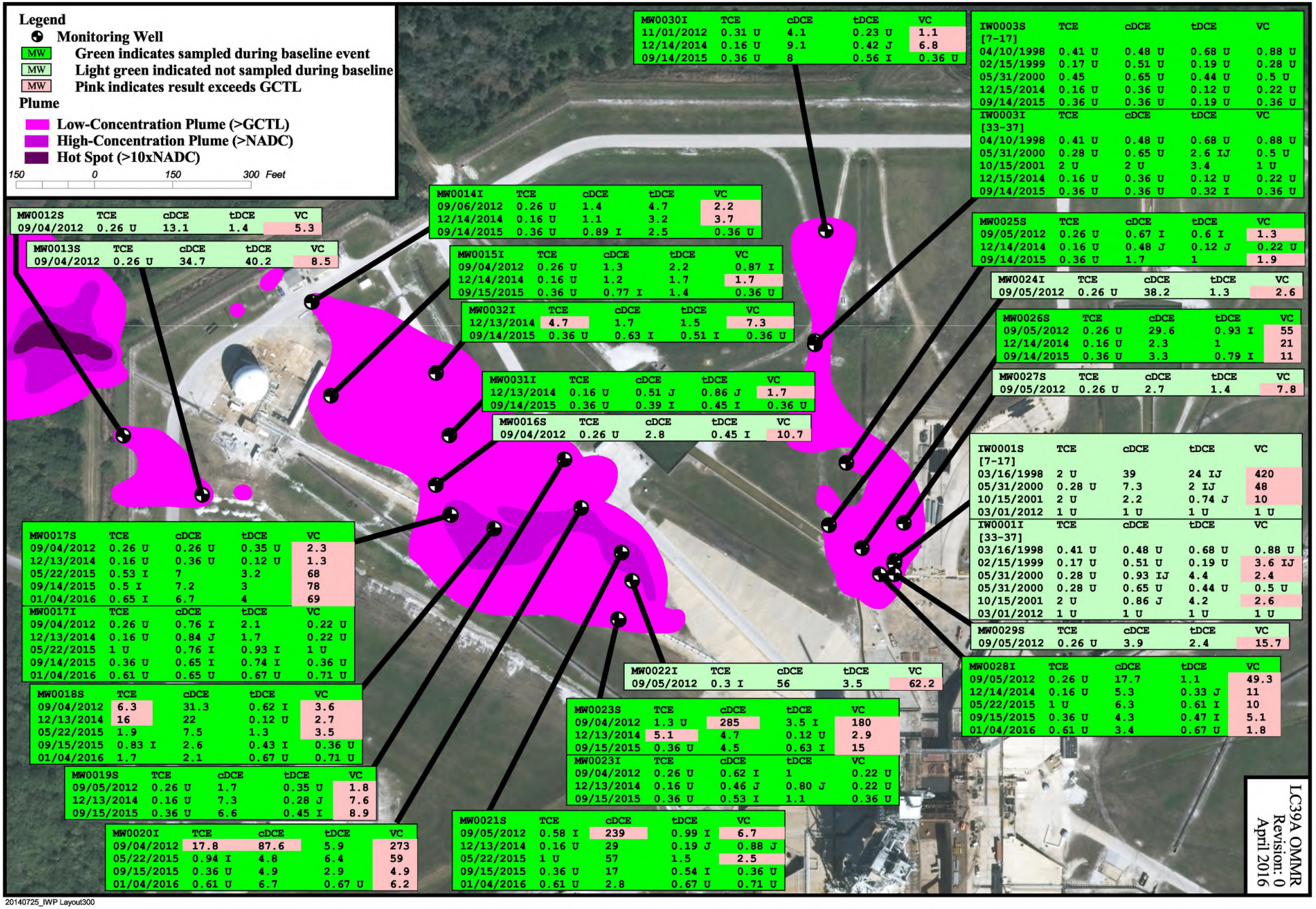
FIGURE 3-2 PERFORMANCE MONITORING RESULTS
SWMU 008, KENNEDY SPACE CENTER, FLORIDA



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SECTION IV

CONCLUSIONS AND RECOMMENDATIONS

Based on system and performance monitoring data from the first year of operation, the AS system is operating as designed and is meeting the performance criteria and is expected to meet the groundwater IM objective. The performance monitoring network is adequately constructed for assessment of AS IM performance.

At the February 2016 KSCRT meeting, team consensus was reached to continue IM operations and conduct routine OM&M as presented in the CCR (Meeting Minute 1602-M12, Decisions 1602-D34 to D37). Air flow in Zone C will be increased to address the increase in VC concentrations detected at well MW0017S since startup of the AS system, and flow will be decreased in Zone D due to the low groundwater COC concentrations observed in this area. Air flow in Zone F will also be reduced due to the low VC groundwater concentrations observed in this area while increasing flow in Area E to balance the system. After the next annual groundwater sampling event, scheduled for September 2016, system data and performance monitoring data will be evaluated to make optimization recommendations as to whether any of the treatment zones can be shut down.

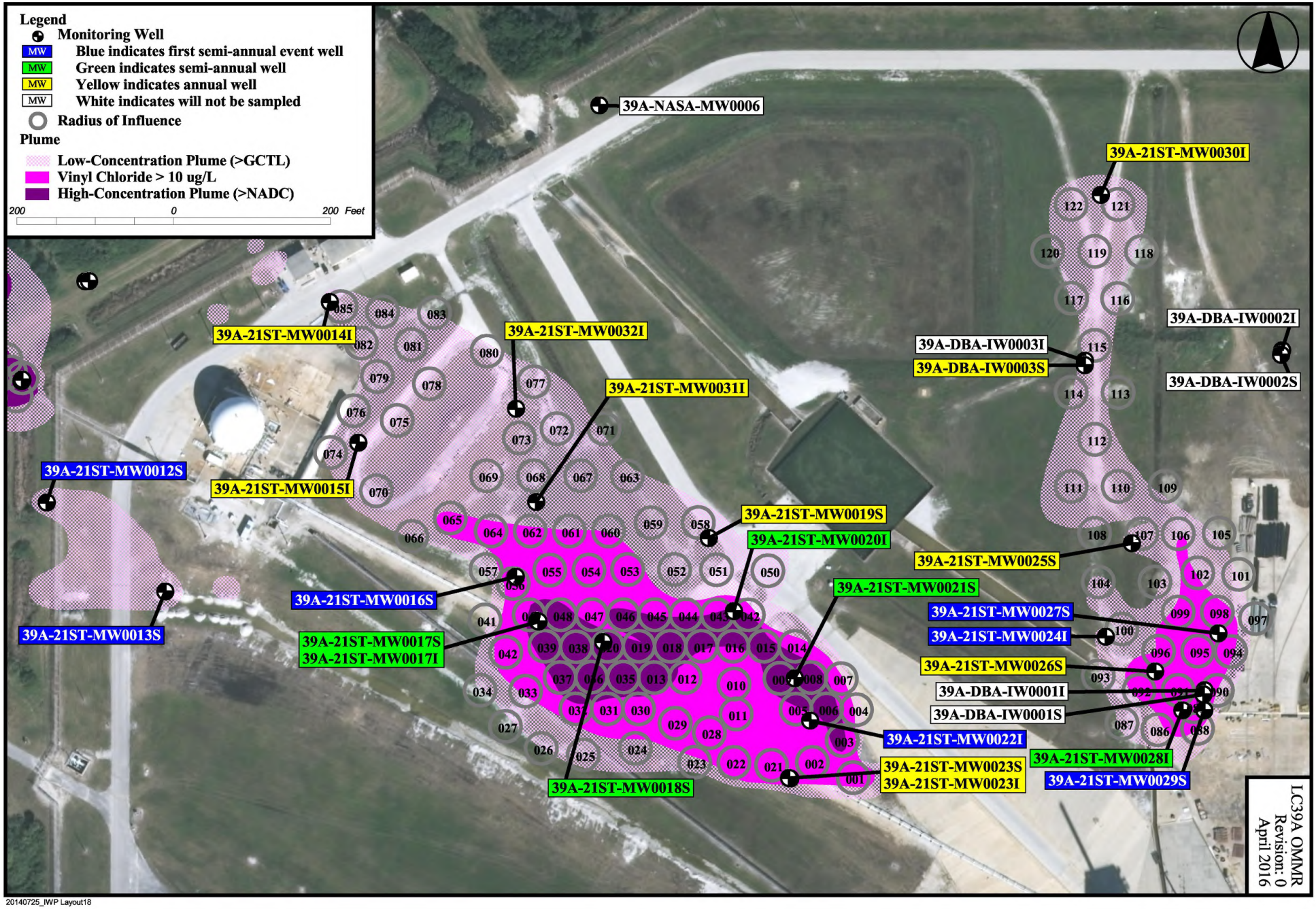
Also at the February 2016 KSCRT meeting, team consensus was reached on the following performance monitoring optimization recommendations. Year 2 groundwater performance monitoring will proceed at the frequency presented in the CCR, which includes reducing the sampling frequency of the HCP wells from quarterly to semi-annual and continuing to monitor the LCP wells annually (Table 3-4 and Figure 4-1). However, monitoring well DBA-IW003I will no longer be included in the performance monitoring network based on consistently low concentrations of COCs and because another well in the monitoring program, MW0030I, is located nearby and will allow adequate monitoring of groundwater concentrations in the area (Meeting Minute 1602-M12, Decisions 1602-D34 to D37). In addition, the following wells that have had previous detections of COCs but have not been sampled since 2012 will also be

sampled during the next sampling event to gain a comprehensive view of groundwater conditions at the site:

- MW0012S
- MW0013S
- MW0016S
- MW0022I
- MW0024I
- MW0027S
- MW0029S

Team consensus was also reached to discontinue air monitoring based on the baseline, startup, and Year 1 performance monitoring air results. The next groundwater performance monitoring event is the semi-annual event scheduled for June 2016.

FIGURE 4-1 YEAR 2 PERFORMANCE MONITORING LAYOUT
SWMU 008, KENNEDY SPACE CENTER, FLORIDA



20140725_IWP Layout18

SECTION V

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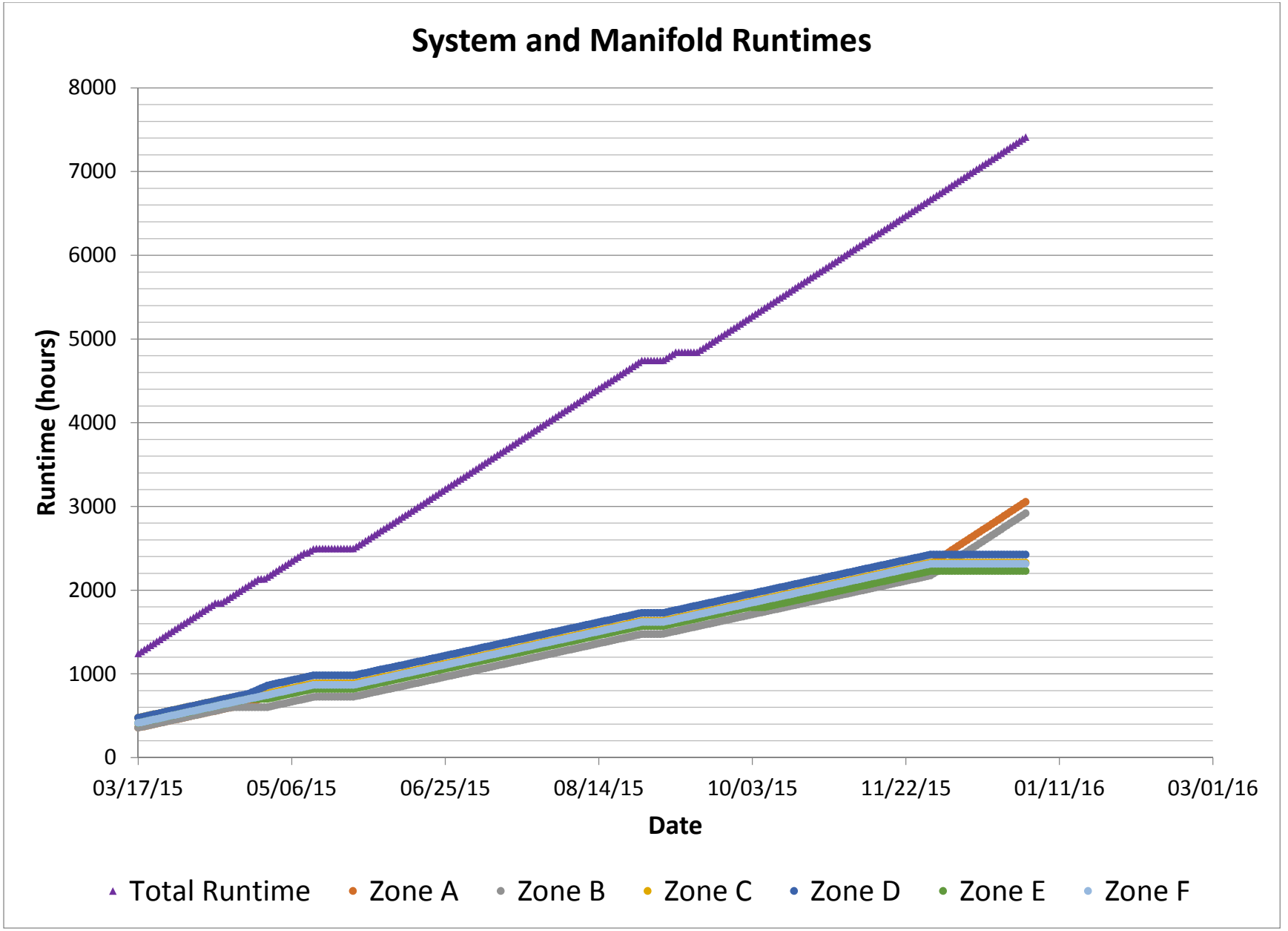
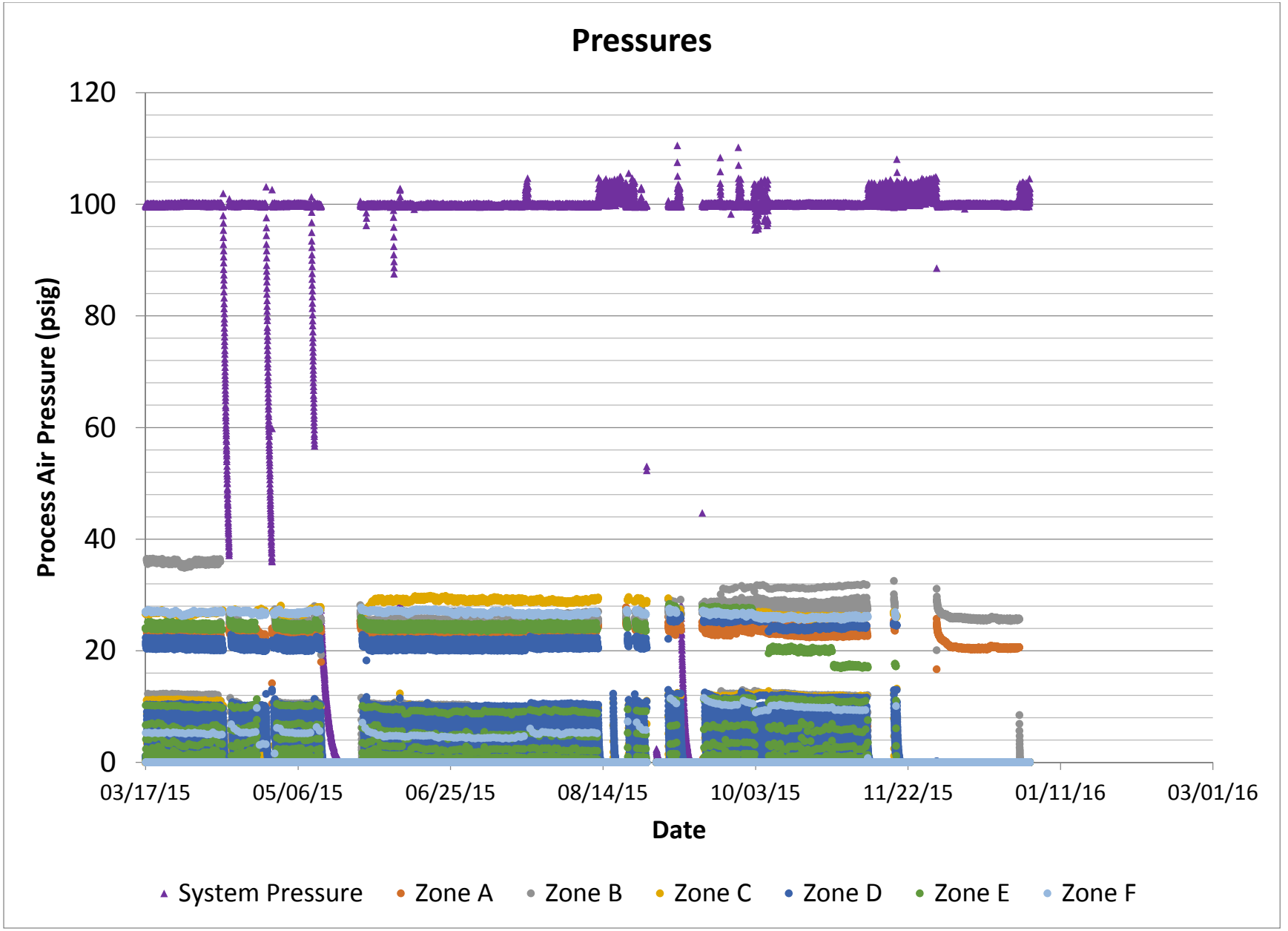
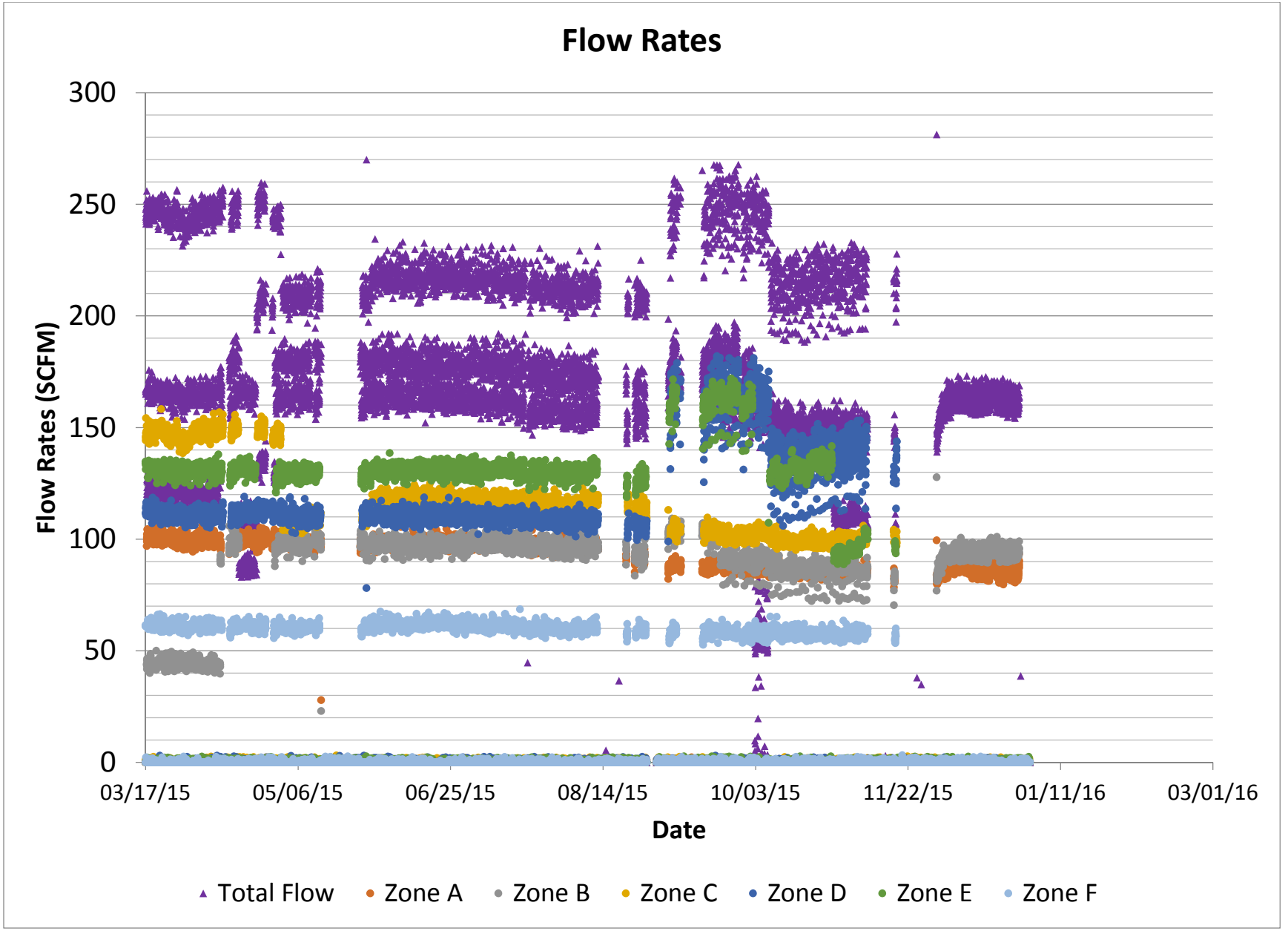
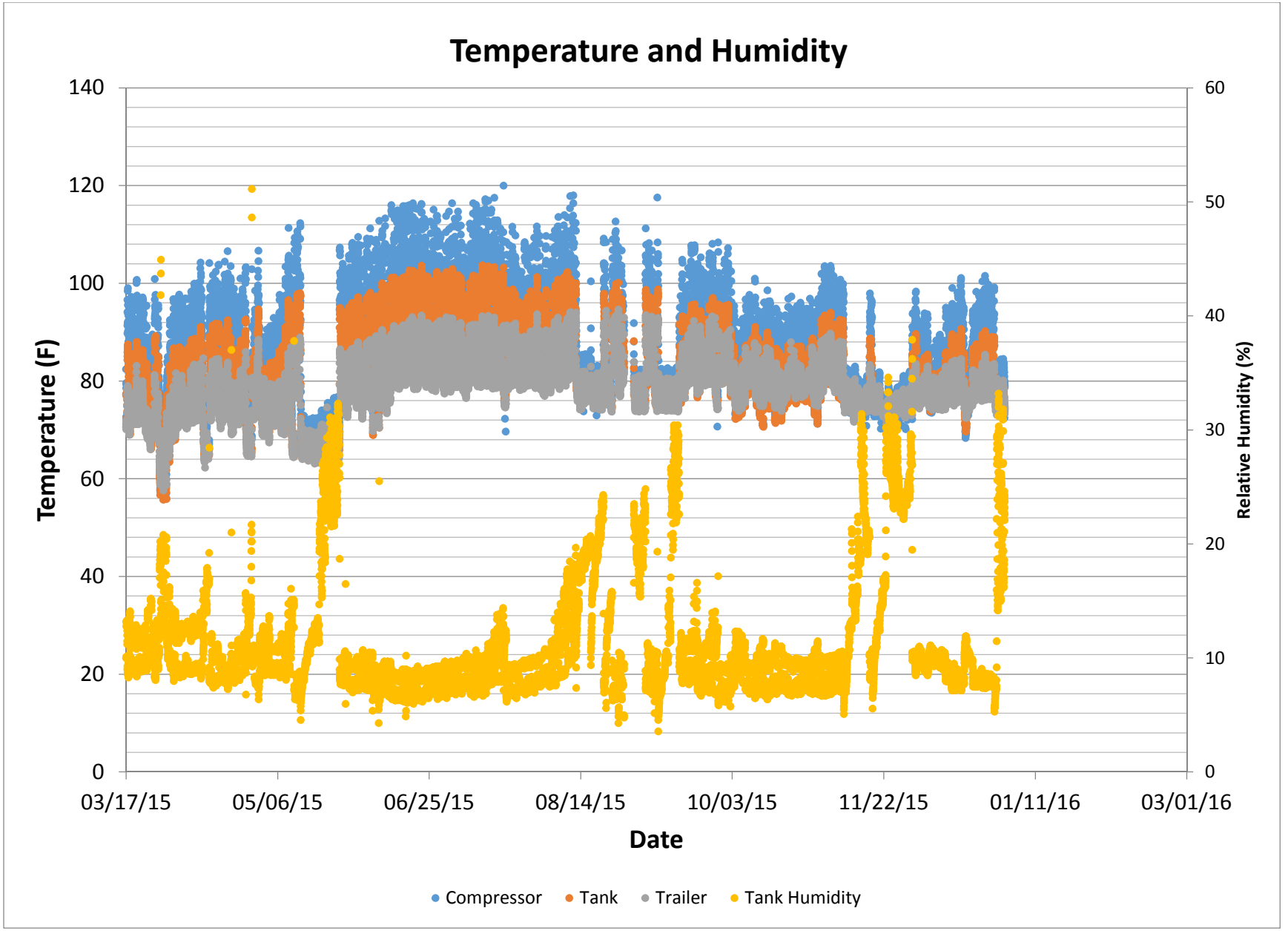
APPENDIX A

SYSTEM OPERATING DATA


System and Manifold Runtimes
Runtime (hours)
8000
7000
6000
5000
4000
3000
2000
1000
0
03/17/15
05/06/15
06/25/15
08/14/15
10/03/15
11/22/15
01/11/16
03/01/16
Date
Total Runtime
Zone A
Zone B
Zone C
Zone D
Zone E
Zone F


Pressures
Process Air Pressure (psig)
120
100
80
60
40
20
0
03/17/15
05/06/15
06/25/15
08/14/15
10/03/15
11/22/15
01/11/16
03/01/16
Date
System Pressure
Zone A
Zone B
Zone C
Zone D
Zone E
Zone F


Flow Rates
Flow Rates (SCFM)
300
250
200
150
100
50
0
03/17/15
05/06/15
06/25/15
08/14/15
10/03/15
11/22/15
01/11/16
03/01/16
Date
Total Flow
Zone A
Zone B
Zone C
Zone D
Zone E
Zone F


Temperature and Humidity
Temperature (F)
Relative Humidity (%)
Date
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120
100
80
60
40
20
0
60
50
40
30
20
10
0
03/17/15
05/06/15
06/25/15
08/14/15
10/03/15
11/22/15
01/11/16
03/01/16
Compressor
Tank
Trailer
Tank Humidity

APPENDIX B

SAMPLE LOG SHEETS

APPENDIX C

LABORATORY DATA