Remedial Action Optimization Status Memorandum Revision 1 (12/12/2016)
Former Tronox Facility, Springfield, Missouri

This status memorandum summarizes the current status of the Remedial Action Optimization (RAO) activities for the former Tronox Facility in Springfield, Missouri (Facility or Site), and has been revised based on December 8, 2016 comments by the Missouri Department of Natural Resources (MoDNR) and the Missouri Division of Health & Senior Services (MDHSS). Specific activities performed and reported herein are based on Sections 5.1 through 5.3, 5.4.1, 5.4.2, 5.5, 5.6, and 5.7 of the RAO Work Plan. This memorandum summarizes findings, conclusions, and presents a path forward, and Figures 1.0 through 8.0 are provided for reference. This memorandum is a preliminary submittal in order to provide a status update to MoDNR and MDHSS, and conclusions presented in this memorandum may be updated based on new information. The Final RAO Report will be completed after the RAO activities are completed and all data and findings have been evaluated.

Proposed Springfield RAO Field Sampling and Analysis Next Steps Executive Summary

1. Delineate nature and extent of contamination in groundwater and evaluate the vapor intrusion pathway northeast of Facility
    - Identify shallow soil cover areas and verify depth to groundwater to target exposure investigation
    - Collect and analyze shallow groundwater/surface water from groundwater seepage
    - Install "fill-in" monitoring wells in key residential areas where plume extent is not defined
    - Evaluate groundwater data from new monitoring wells using the EPA vapor intrusion screening levels (VISL) calculator to identify locations where chemicals of concern (COCs) exceed the screening levels, thus warranting further evaluation of the vapor intrusion pathway. Perform additional VISL screening of additional groundwater analytical results
    - Collect and analyze ambient air samples from onsite (1 sample), background areas (2 samples), the residential neighborhood located directly to the north of the Facility (2 samples) and the residential neighborhood located to the northeast of the Facility (2 samples)
    - Install and sample shallow and deep soil vapor wells within the residential neighborhoods located directly to the north and northeast of the Facility. Soil vapor wells will be installed in the City of Springfield right-of-way (ROW).
    - For additional details, see the RAO Work Plan Addendum.

2. Determine additional UFZ or SFZ groundwater delineation needs in other areas
    - Coordinate step-out well locations with MDNR and property owners
        - Locations for further UFZ delineation are along the northeast Clifton Drainage outside of the residential area, pending discussion with MDNR
        - Further SFZ delineation would be off-site to the southwest of the Facility
    - Install up to four new monitoring wells at identified locations
        - UFZ locations may be along Kearney Street right-of-way for lateral plume delineation
        - An off-site SFZ well may be installed southwest of the Facility four southwest delineation of this lower hydrogeologic zone

3. Revise the August 18, 2016, Sampling and Analysis Plan, former Tronox Facility, Springfield, Missouri, and RCRA Post Closure Care Permit #MOD007129406 (RCRA Permit) as requested by MoDNR. This is anticipated to be submitted no later than Q3-2017 to allow collection and evaluation of sampling data from the new wells from two quarters.

- Perform quarterly sampling of new monitoring wells
- Evaluate appropriate monitoring wells for long-term monitoring
- Identify locations for periodic vapor intrusion monitoring
- Revise Sampling and Analysis Plan and RCRA Permit for revised monitoring issues

TarGOST and Geoprobe Boring Investigation

47 TarGOST borings were completed (please see Figure 1.0). TarGOST borings were completed on the Facility only, due to lack of access to off-site locations – eastern Greene County and southern BNSF property – during TarGOST availability.

- Pumping Center #1 (PC-1, northeast corner): 3 TarGOST with no detections (creosote is in bedrock)
- PC-2 (East border): 6 TarGOST, 2 detections near bedrock (13.9 feet below land surface [ft bls])
- PC-3 (site center): 5 TarGOST with no detections
- PC-4 (site west-center): 2 TarGOST with no detections
- PC-5 (pre-RCRA cell, site south center): 15 TarGOST (including western step-outs), with 10 detections including strongest site TarGOST responses between 4.5 – 8 ft bls.
- PC-7 (East side, BNSF property line): 4 TarGOST, 2 detections with apparent connection north with PC-5 detections
- PC-7 (Drip Track, former production area): 12 TarGOST, 1 detection at 13.4 ft bls

4 Geoprobe borings were completed as follow-up to TarGOST borings with soil samples collected at peak TarGOST responses (note: TarGOST responses are measured as percent of the reference emitter[RE], similar to a PID measurement relative to 100% isobutylene):

- SB-B (PC-2 near TG-47): at 13.9 feet (ft) below ground surface (bls) at 195% TarGOST RE, 17 polycyclic aromatic hydrocarbon (PAH) and 3 benzene, toluene, ethylbenzene, and xylene (BTEX) detections; 8 PAHs exceed EPA Region 3 Screening Levels for Industrial Soil (RSL-Industrial Soil)
- SB-B-2 (Greene County, east of SB-B): at 13 ft bls, 4 detections all below RSL-Industrial Soil
- SB-E (PC-5 near TG-20): at 8 ft bls at 409% TarGOST RE, 19 PAH and 4 BTEX detections, highest overall concentrations; 9 PAHs exceed RSL-Industrial Soil
- SB-F (PC-7, west former production area): at 13.4 ft bls at 225% TarGOST RE, 17 PAH and 4 BTEX detections; 7 PAHs exceed RSL-Industrial Soil
- Overall, chemical concentration patterns generally matched the TarGOST response strength

Preliminary Conclusions: TarGOST results, confirmed by laboratory analytical results, indicate that a large area of creosote appears present within, west, and south of the former pre-RCRA cell in the south-central Facility area at depths up to 8 ft bls. Soil borings and confirmation soil sampling is warranted to define the nature and extent of contamination in this area and to provide data for evaluating remedial options. The area east of PC-2 does not require additional investigation, since soil sample results there reported only 4 detections of COCs at concentrations well below RSL-Industrial Soil.

Source Area Surficial Soil Investigation

Three surface soil samples were collected from former source areas (Landfarm Area, Drip Track Area, and Black Tie Area) to determine whether or not COCs in soil exceeded the RSL-Industrial Soil. Locations are depicted on Figure 2.0.

- SS-1 (south side Drip Track Area near TG-34): at 1.5 ft bls 17 PAH and 4 BTEX detections; 4 PAHs exceed RSL-Industrial Soil levels

- SS-2 (Landfarm Area, south-central at highest historical concentration area): at 1.25 ft bls, 19 PAH and 4 BTEX detections, with 8 PAHs exceeding RSL-Industrial Soil
- SS-3 (Black Tie Area): two aliquots from 1.25 ft bls, 16 PAH and no BTEX detections, one PAH exceeds RSL-Industrial Soil (benzo[a]pyrene) by less than two times RSL
- Several PAHs exceed the RSL-Industrial Soil by one order of magnitude at SS-1. Several PAHs exceed the RSL-Industrial Soil by 2 to 3 orders of magnitude at SS-2.

Conclusions: Concentrations of PAHs in the Landfarm Area have remained elevated; therefore, continued maintenance of the surface cap is required to achieve the established remedial action objectives. Because soil in the Drip Track Area exceeds the RSL-Industrial Soil, additional investigation of the surficial zone is warranted to define nature and extent; collected data would be used to assess potential exposure risk.

New Upper Flow Zone Monitoring Wells

New Upper Flow Zone (UFZ) monitoring wells were installed on the Greene County Highway Department (GCHD) property located east of the Facility (East off-site GCHD), the residential area located southwest of the Facility, and the residential and Clifton Drainage area located northeast of the Facility. All wells were sampled for screening analysis of all Groundwater Protection Standards (GWPS) chemicals.

East Off-Site GCHD Monitoring Wells

Two new monitoring wells were installed on the GCHD property as depicted on Figure 3.0 (please see reference Index Figure).

SMW-77 (south location)
- Bedrock at 10 ft deep, weathered to 15 ft bls
- Total depth 40 ft bls
- No visual presence of creosote impacted soil, no odor, or no PID detections
- Constructed with 20 ft of screen from 20-40 ft bls. The well began producing water.
- Analytical results: 4 detections of PAHs and 2 VOCs, all below GWPS

SMW-78 (north location)
- Bedrock at 15 ft bls, weathered to 20 ft bls
- Diesel-like odor was observed at 15 ft bls (PID reading 28 parts per million [ppm])
- Total depth of 42 ft bls
- No indication of secondary porosity
- Constructed with 20 ft screen from 22 -42 ft bls. The well began producing water, with minor odor observed
- Analytical results: 9 detections of PAHs and 3 VOCs, one PAH above GWPS (phenanthrene).

Conclusions: No further delineation is warranted; however, it is recommended that these new monitoring wells be incorporated into the existing groundwater monitoring program, to include quarterly sampling for one year.

South and Southwest Off-Site BNSF and Residential Monitoring Wells

Two new monitoring wells were installed in City of Springfield ROW locations as depicted on Figure 4.0. Lack of BNSF access for drilling and obstacles from underground utilities prevented drilling the other proposed well locations as identified in the RAO Work Plan.

SMW-79 (north Drury Ave at Atlantic Street location)

- Bedrock at 17 ft bls, minimal weathering horizon
- Total depth 26 ft bls
- No visual presence of creosote impacted soil, no odor, or no PID detections
- Constructed with 7 ft of screen from 19-26 ft bls
- Well has remained dry and has not been sampled

SMW-83 (south location at W. Thoman and Drury Ave)

- Clay and weathered limestone fragments to 15 ft bls, competent bedrock to 20 ft bls
- Increased weathering was observed between 20-29 ft bls; total depth of well is 33.5 ft bls
- Constructed with 25 ft of screen from 8.5 -33.5 ft bls
- Well took several days to produce water and was sampled; 3 estimated PAH detections were reported with one (phenanthrene) slightly over its GWPS (0.2 ug/L vs 0.1 ug/L GWPS)

Preliminary Conclusions: Current results do not indicate an additional delineation need, since SMW-79 is dry and SMW-83 has only one PAH slightly above the GWPS. Additional groundwater sampling is needed to verify groundwater quality. Well SMW-60 located in the south BNSF yard was rehabilitated after damage by BNSF activities for use as a south delineation well, given the overall southward groundwater flow direction from the Facility. SMW-79 will continue to be monitored for presence of water and will be sampled if water appears.

Northeast Off-Site Residential and Clifton Drainage Area Monitoring Wells

Three new monitoring wells were installed in the City of Springfield ROW in the residential neighborhoods located to the northeast of the Facility (see Figures 3.0 and 5.0), and two new monitoring wells were installed further to the northeast along the Clifton Drainage on commercial property (Figure 5.0). Analytical results are summarized in Table 1.0.

SMW-80 (High St. ROW immediately northeast of the Facility corner, see Figure 3.0)

- Bedrock encountered at 12 ft deep, weathered to 24 ft bls
- Total depth of well is 27 ft bls
- Depth to water is 8.8 ft bls
- Creosote DNAPL was was observed in the weathered bedrock and groundwater. A strong creosote-like odor was also observed in both the drill cuttings and the groundwater.
- The well produces water.
- Constructed with 20 ft of screen from 7-27 ft bls.
- Sampled after DNAPL settled with results: 15 detections of PAHs and 4 VOCs, one VOC and 8 PAHs exceed GWPS. Naphthalene concentration is 11,000 ug/L. Well will be resampled to verify results.
- Conducted VISL evaluation of analytical results which showed that benzo(a)anthracene, benzene, ethylbenzene, and naphthalene calculated indoor air concentration exceed the residential carcinogenic exposure level, and naphthalene also exceeds the non-carcinogenic exposure level.

SMW-81 (W. Truman St. ROW, see Figure 5.0)

- Bedrock encountered at 10 ft bls, weathered to 22 ft bls with void horizons 14-19 and 21-22 ft bls
- Total depth of well is 27 ft bls
- Depth to water is 11.4 ft bls

- No significant PID detections, but minor odors observed in both the drill cuttings and the groundwater.
- Constructed with 20 ft of screen from 7-27 ft bls. Well began producing water.
- Analytical results: 17 detections of PAHs and 2 VOCs; 12 PAHs exceed GWPS
- Conducted VISL evaluation of analytical results which showed that benzo(a)anthracene calculated indoor air concentration exceeds the residential carcinogenic exposure level

SMW-82 (N. Clifton Ave ROW, immediately south of surface drainage, see Figure 5.0)

- Bedrock ledge at 6 ft bls, saturated clay below with weathered bedrock to 16 ft bls
- Drilling in shallow unconsolidated produced bubbling from cracks in concrete surface drainage with some sheen (controlled by absorbents)
- At depth, no significant PID readings or odor
- Drilled to 30 ft bls to verify no deeper secondary porosity; bentonite backfill with sand cap to 21 ft bls; constructed with 15 ft of screen from 6-21 ft bls.
- Total depth of well is 21 ft bls
- Depth to water is 3.2 ft bls average
- Abundant water produced; when purged for sampling, odor and minor sheen was observed.
- Analytical results: 17 detections of PAHs and 3 VOCs, 11 PAHs exceed GWPS
- Conducted VISL evaluation of analytical results which showed that ethylbenzene and naphthalene calculated indoor air concentrations exceed both carcinogenic and non-carcinogenic residential exposure levels

SMW-84 (Northeast Clifton Drainage, south Rite-Way Concrete property, see Figure 5.0)

- Bedrock at 12 ft bls, no significant near surface weathering
- Bedding plane voids/fracures from 45 to 55 ft bls with minor PID readings
- Drilled to 60 ft bls to verify no deeper secondary porosity; bentonite backfill with sand cap to 55 ft bls; constructed with 20 ft of screen from 35 -55 ft bls
- Total depth of well is 55 ft bls
- When purged for sampling, DNAPL globules and creosote odor were observed.
- Sampled after DNAPL settled, analytical results: 18 detections of PAHs and 4 VOCs, 11 PAHs exceed GWPS
- Conducted VISL evaluation of analytical results which showed that ethylbenzene and naphthalene calculated indoor air concentrations exceed residential carcinogenic exposure risk and naphthalene also exceeds the residential non-carcinogenic exposure level

SMW-85 (East extension of Clifton Drainage, east of surface ditch, Race Brothers property, see Figure 5.0)

- Bedrock at 10 ft bls
- No apparent fractures or voids; began producing water at 38 ft bls, minor PID readings
- Drilled to 57 ft bls; constructed with 20 ft of screen from 37 -57 ft bls
- Total depth of well is 57 ft bls
- When purged for sampling, a slight creosote-like odor was observed
- Analytical results: 14 detections of PAHs and no VOCs, 9 PAHs exceed GWPS

Figure 6.0 depicts a southwest to northeast cross-section from the northeast Facility corner to SMW-85 in the northeast Clifton Drainage area. The following is noted:

- Topography and bedrock surface both display elevation decrease to the northeast
- Upper weathered bedrock/karst features thin to the northeast, while karst features deepen in

the bedrock proceeding northeast

- DNAPL appears to follow the downward trend of secondary porosity (note occurrences in SMW-80 vs SMW-84, and RW-21 further to the north)
- Groundwater elevations decrease northeastward, with a significant drop past SMW-82. This is likely related to the deepening of karst features (also present at RW-21 to the north).
- The relatively high water level in SMW-82 may be related to the adjacent surface drainage
- During heavy precipitation and recharge, it may be possible for ground water to "back up" southward from the deeper karst system in the northeast. Sufficiently high recharge conditions could cause upward seepage in the area of the Clifton surface drainage in the residential area where conditions similar to SMW-82 exist

Preliminary Conclusions: Contaminant concentrations in groundwater exceeding GWPS are observed along inferred fracture lines following the northeast Clifton Drainage from the Facility. Delineating the nature and extent of contaminated groundwater and the potential for vapor intrusion within the residential areas located to the north and northeast of the Facility is warranted. These additional investigation activities are presented in the RAO Work Plan Addendum. It is recommended that these activities be prioritized.

VISL Evaluation of Groundwater for Vapor Inhalation Risk

The potential for vapor intrusion from off-gassing of UFZ groundwater was initially evaluated by inputting groundwater data from four new impacted wells, SMW-80, SMW-81, SMW-82, and SMW-84, into the EPA VISL calculator. The VISL calculator was used to assess for a residential exposure scenario for both carcinogenic (C) for $1x10^{-6}$ risk and non-carcinogenic (NC) Hazard Quotient=1 risk vapor intrusion standards for SMW-80, SMW-81, and SMW-82 in the residential neighborhood, and the same parameters for commercial exposure for SMW-84 which on industrial property. A memorandum of the findings of the VISL calculations with printouts of the VISL output is attached.

- Based on VISL parameter selection criteria, constituents automatically evaluated are: benzo(a)anthracene, benzene, ethylbenzene, naphthalene, toluene, and xylenes.
- Results show calculated exceedances for each well location:
    - SMW-80: Benzene, ethylbenzene, and naphthalene each exceed residential carcinogenic exposure levels, and naphthalene also exceeds the residential non-carcinogenic exposure level
    - SMW-81: Benzo(a)anthracene exceeds the residential carcinogenic exposure level
    - SMW-82: Naphthalene and ethylbenzene each exceed both carcinogenic and non-carcinogenic residential exposure levels
    - SMW-84: Ethylbenzene and naphthalene each exceed the residential carcinogenic exposure level, naphthalene also exceeds the residential non-carcinogenic exposure levels

Conclusions: Estimated screening levels indicate that groundwater contamination that extends into the residential areas northeast of the Facility has the potential for vapor intrusion exposure to residents. Per the RAO Work Plan, follow-up investigation of potential vapor intrusion exposure is warranted. Activities associated with this follow-up investigation are presented in the RAO Work Plan Addendum.

Secondary Flow Zone Monitoring Wells for Vertical and Horizontal Delineation

New Secondary Flow Zone (SFZ) monitoring wells were installed on-site to evaluate extent of SFZ impact between BMW-10R and BMW-5, downgradient of BMW-5 and BMW-10R, and vertically between the UFZ and SFZ. Wells were sampled for screening analysis of all GWPS chemicals.

SFZ Vertical Delineation Monitoring Wells

Two SFZ and two UFZ monitoring wells were installed as depicted on Figure 7.0 in the main facility area. Analytical results are summarized on Table 1.0.

BMW-12 (northeast of BMW-10R)

- Bedrock encountered at 18 ft deep, weathered to 20 ft bls
- Drilled and set surface casing to 35 ft bls, with abundant water production
- Drilled to 80 ft bls for initial monitoring; no visual, no odor, or PID indicators of impact
- 24 hrs later downhole video indicated multiple horizons of DNAPL entry between 37-75 ft bls, with minor DNAPL accumulating at the bottom
- Continued monitoring indicates slow DNAPL and water production; DNAPL is periodically bailed out
- Extensive vertical length of DNAPL entry horizons indicated potential vertical connection to upper SFZ, so decided to not drill well further and monitor for potential DNAPL recovery.
- Total depth of well is 80 ft bls

SMW-76 (northwest of BMW-10R, intended as downgradient SFZ delineation well)

- Bedrock encountered at 11 ft bls; water-producing void at 18-20 ft bls; creosote-like odor observed
- Drilled to 25 ft bls; constructed with 10 ft of 4-inch diameter screen from 15-25 ft bls; larger screen diameter was used to allow for future recovery options
- Total depth of well is 25ft bls
- Designated well as UFZ well for monitoring
- Analytical results: 17 detections of PAH and 2 BTEX, 11 PAHs exceed GWPS

BMW-13 (northwest of BMW-5, horizontal and vertical SFZ delineation well)

- Bedrock at 12 ft deep, weathered to 15 ft bls
- Drilled and set temporary surface casing to 30 ft bls, drilled bottom hole to 80 ft bls with no indications of impact.
- Limited water at 80 ft bls was sampled for screening analysis
- Analytical results at 80 ft: 9 PAH and 4 BTEX detections, 2 PAH exceed GWPS
- Downhole video showed no secondary porosity, and no DNAPL entry.
- Hole reamed out and casing set and grouted to 82 ft bls, bottom hole drilled to 180 ft bls
- Total depth of well is 180 ft bls
- Downhole video showed weathered secondary porosity zone 143 – 158 ft bls.
- Bottom hole low-flow sampled at 90, 150, 175 ft bls. Analytical results:
    - 90 ft: 11 PAH detections and 4 BTEX, 6 exceed GWPS
    - 150 ft: 11 PAH detections and 4 BTEX, 6 exceed GWPS (similar to 90 ft)
    - 175 ft: 11 PAH detections and 4 BTEX, 6 exceed GWPS (similar to 90 & 150 ft)

BMW-14 (northwest of SMW-76 and BMW-10R, horizontal SFZ delineation well)

- Bedrock at 19 ft bls, no moisture until 41 ft bls
- Drilled and cased to 80 ft bls; drilled bottom hole to 180 ft bls; no visual presence of creosote impacted soil, no odor, or no PID detections

- Total depth of well is 180 ft bls
- Water level at 67 ft bls; low-flow sampled at 107 ft bls
- Analytical results: 2 estimated BTEX detections, no GWPS exceedances

Preliminary Conclusions: Drilling observations, DNAPL occurrence at SMW-12 (and BMW-10R), and horizontal groundwater sampling indicates the potential for vertical migration of DNAPL between the UFZ and upper SFZ in the former production area. While BMW-13 has GWPS exceedances, impacted SFZ groundwater is delineated downgradient by existing well BMW-6. Similarly, BMW-14 delineates SFZ groundwater downgradient of BMW-10R. Southwestern delineation of BMW-10R is pending an access agreement with an off-site property owner. New UFZ well SMW-76 is impacted, and delineated to the south and southwest by PC-7 area wells, and new wells SMW-79 and SMW-83 to the south. It is recommended that SMW-12 remain as a deep UFZ/shallow SFZ monitoring well for potential DNAPL recovery; DNAPL monitoring and recovery is ongoing.

Next Steps for Evaluating the Vapor Intrusion Pathway

Details for evaluating the vapor intrusion pathway and next steps are presented in the RAO Work Plan Addendum.

As an additional aid in evaluating potential exposure in the area of the Facility, Figure 8.0 depicts area businesses and industries surrounding the Facility.

Table 1.0 - INITIAL GROUNDWATER ANALYTICAL DATA - NEW RAO MONITORING WELLS

Former Tronox Facility, Springfield, MO

Analyte	Units	GWPS	SMW-76		SMW-77		SMW-78		SMW-80		SMW-81		SMW-82		SMW-83	
			Results	MDL	Results	MDL	Results	MDL	Results	MDL	Results	MDL	Results	MDL	Results	MDL
Acenaphthene	ug/l	1200	150	1	0.16 J	0.11	1.0	0.10	370	2	320	1	470	1.0	N.D.	0.1
Acenaphthylene	ug/l	0.1	6	0.1	N.D.	0.11	N.D.	0.10	18	0.1	3	0.1	1.9	0.10	N.D.	0.1
Anthracene	ug/l	9600	16	0.1	N.D.	0.11	0.70	0.10	14	0.1	61	0.1	22	0.10	N.D.	0.1
Benzo(a)anthracene	ug/l	0.1	36	0.1	N.D.	0.11	N.D.	0.10	0.5	0.1	68	0.1	9.8	0.10	N.D.	0.1
Benzo(a)pyrene	ug/l	0.2	17	0.1	N.D.	0.11	N.D.	0.10	N.D.	0.1	23	0.1	2.6	0.10	N.D.	0.1
Benzo(b)fluoranthene	ug/l	0.1	25	0.1	N.D.	0.11	N.D.	0.10	0.1 J	0.1	33	0.1	5.4	0.10	N.D.	0.1
Benzo(k)fluoranthene	ug/l	0.1	11	0.1	N.D.	0.11	N.D.	0.10	N.D.	0.1	13	0.1	2.1	0.10	N.D.	0.1
2-Chlorophenol	ug/l	0.5	N.D.	0.5	N.D.	0.54	N.D.	0.51	N.D.	0.5	N.D.	0.5	N.D.	0.52	N.D.	0.5
Chrysene	ug/l	0.1	26	0.1	N.D.	0.11	N.D.	0.10	0.4 J	0.1	47	0.1	7.2	0.10	N.D.	0.1
Dibenz(a,h)anthracene	ug/l	0.1	2	0.1	N.D.	0.11	N.D.	0.10	N.D.	0.1	2	0.1	0.32 J	0.10	N.D.	0.1
Dibenzofuran	ug/l	7.9	100	0.5	N.D.	0.54	0.90 J	0.51	270	10	220	5	290	5.2	N.D.	0.5
2,4-Dimethylphenol	ug/l	540	N.D.	0.5	N.D.	0.54	N.D.	0.51	2	0.5	N.D.	0.5	N.D.	0.52	N.D.	0.5
2,4-Dinitrophenol	ug/l	70	N.D.	10	N.D.	11	N.D.	10	N.D.	10	N.D.	10	N.D.	10	N.D.	10
Fluoranthene	ug/l	300	170	1	0.69	0.11	0.15 J	0.10	23	0.1	400	1	83	0.10	0.2 J	0.1
Fluorene	ug/l	1300	100	1	0.15 J	0.11	2.6	0.10	230	2	350	1	300	1.0	N.D.	0.1
Indeno(1,2,3-cd)pyrene	ug/l	0.1	6	0.1	N.D.	0.11	N.D.	0.10	N.D.	0.1	6	0.1	1.3	0.10	N.D.	0.1
2-Methylnaphthalene	ug/l	36	11	0.1	N.D.	0.11	0.28 J	0.10	630	2	43	0.1	470	1.0	N.D.	0.1
Naphthalene	ug/l	20	67	0.1	0.14 J	0.11	0.54	0.10	11,000	20	4	0.1	3,900	10	N.D.	0.1
Phenanthrene	ug/l	0.1	110	1	N.D.	0.11	1.6	0.10	210	2	950	1	390	1.0	0.2 J	0.1
Phenol	ug/l	300	N.D.	0.5	N.D.	0.54	N.D.	0.51	0.5 J	0.5	N.D.	0.5	N.D.	0.52	N.D.	0.5
2-Picoline	ug/l		N.D.	2	N.D.	2.2	N.D.	2.0	N.D.	2	N.D.	2	N.D.	2.1	N.D.	2
Pyrene	ug/l	960	100	1	0.48 J	0.11	0.29 J	0.10	11	0.1	240	1	47	0.10	0.3 J	0.1
Benzene	ug/l	5	N.D.	0.2	0.3 J	0.2	0.6 J	0.2	10	0.2	N.D.	0.2	N.D.	1.0	N.D.	0.2
Ethylbenzene	ug/l	700	1.7	0.2	N.D.	0.2	N.D.	0.2	94	0.2	0.7 J	0.2	13	1.0	N.D.	0.2
Toluene	ug/l	1000	N.D.	0.2	0.4 J	0.2	1 J	0.2	47	0.2	N.D.	0.2	2.6 J	1.0	N.D.	0.2
Total Xylenes	ug/l	10000	3.8	0.2	N.D.	0.2	0.8 J	0.2	310	0.2	2.7	0.2	38	1.0	N.D.	0.2

Notes: **GWPS** = Groundwater Protection Standards

Yellow Highlight = GWPS exceedances

MDL = Minimum Detection Limit

Table 1.0 - INITIAL GROUNDWATER ANALYTICAL DATA - NEW RAO MONITORING WELLS

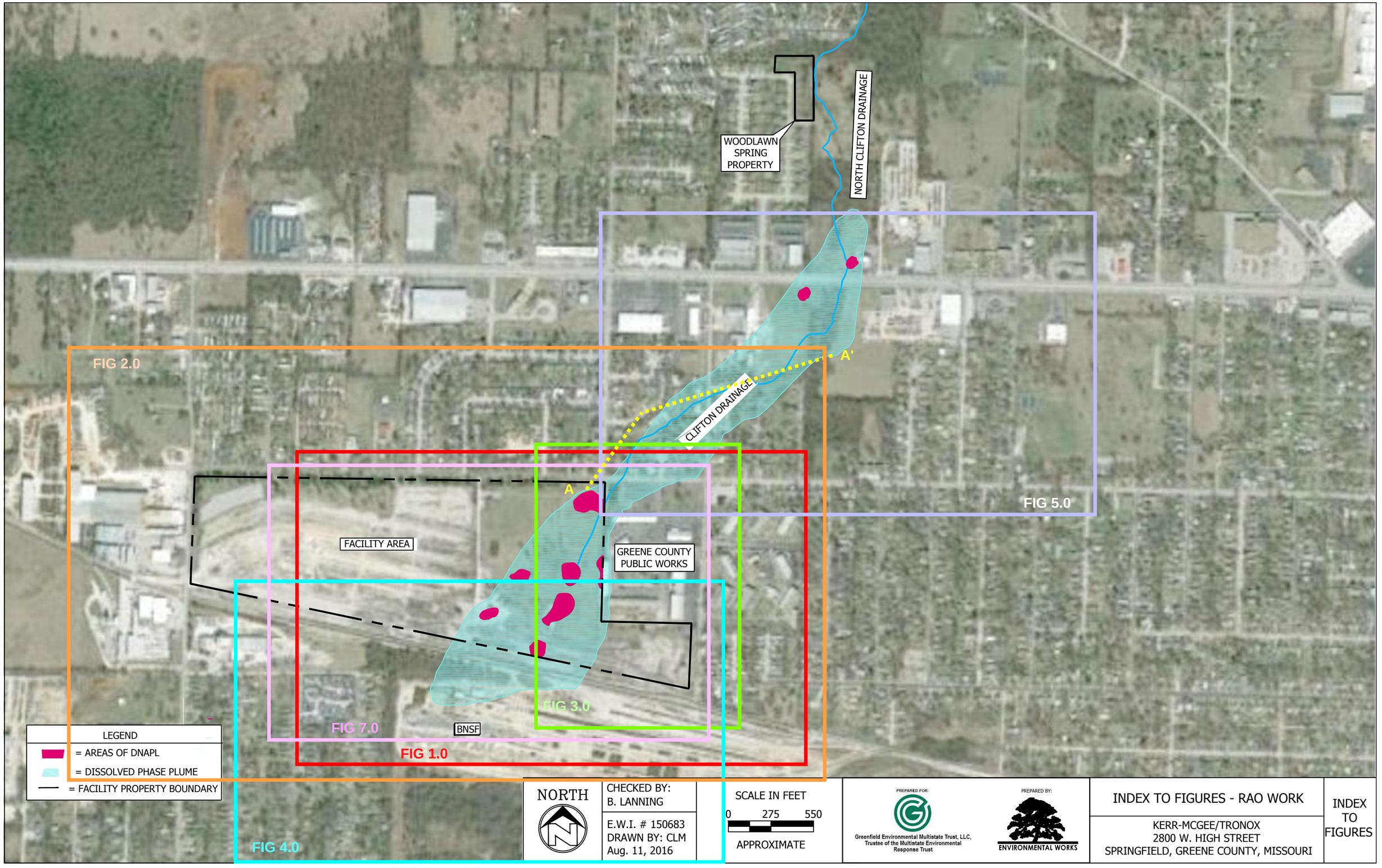
Former Tronox Facility, Springfield, MO

Analyte	Units	GWPS	SMW-84		SMW-85		BMW-13					BMW-14	
			Results	MDL	Results	MDL	80-ft	MDL	90-ft	150-ft	175-ft	MDL	107-ft	MDL
Acenaphthene	ug/l	1200	410	1	37	1	0.4 J	0.1	93	58	48	0.1	N.D.	0.11
Acenaphthylene	ug/l	0.1	3	0.1	1 J	1	N.D.	0.1	4	3	2	0.1	N.D.	0.11
Anthracene	ug/l	9600	17	0.1	5 J	1	N.D.	0.1	N.D.	N.D.	N.D.	0.1	N.D.	0.11
Benzo(a)anthracene	ug/l	0.1	2	0.1	6	1	N.D.	0.1	N.D.	N.D.	N.D.	0.1	N.D.	0.11
Benzo(a)pyrene	ug/l	0.2	0.5 J	0.1	6	1	N.D.	0.1	N.D.	N.D.	N.D.	0.1	N.D.	0.11
Benzo(b)fluoranthene	ug/l	0.1	0.7	0.1	9	1	N.D.	0.1	N.D.	N.D.	N.D.	0.1	N.D.	0.11
Benzo(k)fluoranthene	ug/l	0.1	0.3 J	0.1	4 J	1	N.D.	0.1	N.D.	N.D.	N.D.	0.1	N.D.	0.11
2-Chlorophenol	ug/l	0.5	N.D.	0.5	N.D.	5	N.D.	0.5	N.D.	N.D.	N.D.	0.5	N.D.	0.54
Chrysene	ug/l	0.1	1	0.1	5	1	N.D.	0.1	N.D.	N.D.	N.D.	0.1	N.D.	0.11
Dibenz(a,h)anthracene	ug/l	0.1	N.D.	0.1	N.D.	1	N.D.	0.1	N.D.	N.D.	N.D.	0.1	N.D.	0.11
Dibenzofuran	ug/l	7.9	290	5	24	5	N.D.	0.5	91	57	47	0.5	N.D.	0.54
2,4-Dimethylphenol	ug/l	540	1	0.5	N.D.	5	1	0.5	6	8	6	0.5	N.D.	0.54
2,4-Dinitrophenol	ug/l	70	N.D.	10	N.D.	100	N.D.	10	N.D.	N.D.	N.D.	10	N.D.	11
Fluoranthene	ug/l	300	28	0.1	42	1	0.1 J	0.1	4	3	2	0.1	N.D.	0.11
Fluorene	ug/l	1300	230	1	32	1	0.7	0.1	41	26	22	0.1	N.D.	0.11
Indeno(1,2,3-cd)pyrene	ug/l	0.1	0.1 J	0.1	3 J	1	N.D.	0.1	N.D.	N.D.	N.D.	0.1	N.D.	0.11
2-Methylnaphthalene	ug/l	36	540	1	N.D.	1	1	0.1	330	200	160	1	N.D.	0.11
Naphthalene	ug/l	20	5000	5	N.D.	1	58	0.1	6,400	4,000	3,400	10	N.D.	0.11
Phenanthrene	ug/l	0.1	240	1	32	1	0.6	0.1	54	36	27	0.1	N.D.	0.11
Phenol	ug/l	300	1	0.5	N.D.	5	3	0.5	N.D.	N.D.	N.D.	0.5	N.D.	0.54
2-Picoline	ug/l		N.D.	2	N.D.	20	N.D.	2	5 J	5 J	5 J	2	N.D.	2.2
Pyrene	ug/l	960	14	0.1	26	1	0.1 J	0.1	2	2	1	0.1	N.D.	0.11
Benzene	ug/l	5	0.5 J	0.2	N.D.	0.2	1.9	0.2	180	160	150	2.0	0.2 J	0.2
Ethylbenzene	ug/l	700	20	0.2	N.D.	0.2	1.0	0.2	73	51	42	2.0	N.D.	0.2
Toluene	ug/l	1000	5	0.2	N.D.	0.2	2.9	0.2	190	150	130	2.0	0.4 J	0.2
Total Xylenes	ug/l	10000	82	0.2	N.D.	0.2	3.3	0.2	290	200	170	2.0	N.D.	0.2

Notes: **GWPS** = Groundwater Protection Standard

Yellow Highlight = GWPS exceedances

MDL = Minimum Detection Limit



NORTH

CHECKED BY: B. LANNING

E.W.I. # 150683
DRAWN BY: CLM
Aug. 11, 2016

SCALE IN FEET
0 275 550
APPROXIMATE

PREPARED FOR: Greenfield Environmental Multistate Trust, LLC, Trustee of the Multistate Environmental Response Trust

PREPARED BY: ENVIRONMENTAL WORKS

INDEX TO FIGURES - RAO WORK

KERR-MCGEE/TRONOX
2800 W. HIGH STREET
SPRINGFIELD, GREENE COUNTY, MISSOURI

INDEX TO FIGURES

High Street

N. Clifton Ave

APPROXIMATE PROPERTY BOUNDARY

PC-1
PC-2
PC-3
PC-4
PC-5
PC-6
PC-7

TG-1 TG-2 TG-3 TG-4 TG-5 TG-6 TG-7 TG-8 TG-9 TG-10 TG-11 TG-12 TG-13 TG-14 TG-15 TG-16 TG-17 TG-18 TG-19 TG-20 TG-21 TG-22 TG-23 TG-24 TG-25 TG-26 TG-27 TG-28 TG-29 TG-30 TG-31 TG-32 TG-33 TG-34 TG-35 TG-36 TG-37 TG-38 TG-39 TG-40 TG-41 TG-42 TG-43 TG-44 TG-45 TG-46 TG-47

SB-B SB-B-2 SB-E SB-F

SB-F Geoprobe Boring

LEGEND

Targost Creosote hit

Targost-no Creosote

= PROPOSED SOIL BORING LOCATION

= FORMER IMPOUNDMENTS

= TARGOST INFERRED CREOSOTE EXTENT

= GROUNDWATER DIVIDE

= FORMER PRODUCTION AREA

PC-5 = PUMPING CENTER

NORTH

CHECKED BY: B. LANNING

E.W.I. # 150683
DRAWN BY: CLM
Aug. 11, 2016

SCALE IN FEET
0 100 200
APPROXIMATE

PREPARED FOR:
Greenfield Environmental Multistate Trust, LLC, Trustee of the Multistate Environmental Response Trust

PREPARED BY:
ENVIRONMENTAL WORKS

TARGOST AND GEOPROBE CHECK BORINGS

KERR-MCGEE SPRINGFIELD
2800 W. HIGH STREET
SPRINGFIELD, GREENE COUNTY, MISSOURI

FIGURE
1.0

NORTH

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EWI #150683
DRAWN BY: CLM
Aug. 17, 2016

SCALE IN FEET
0 150 300
APPROXIMATE

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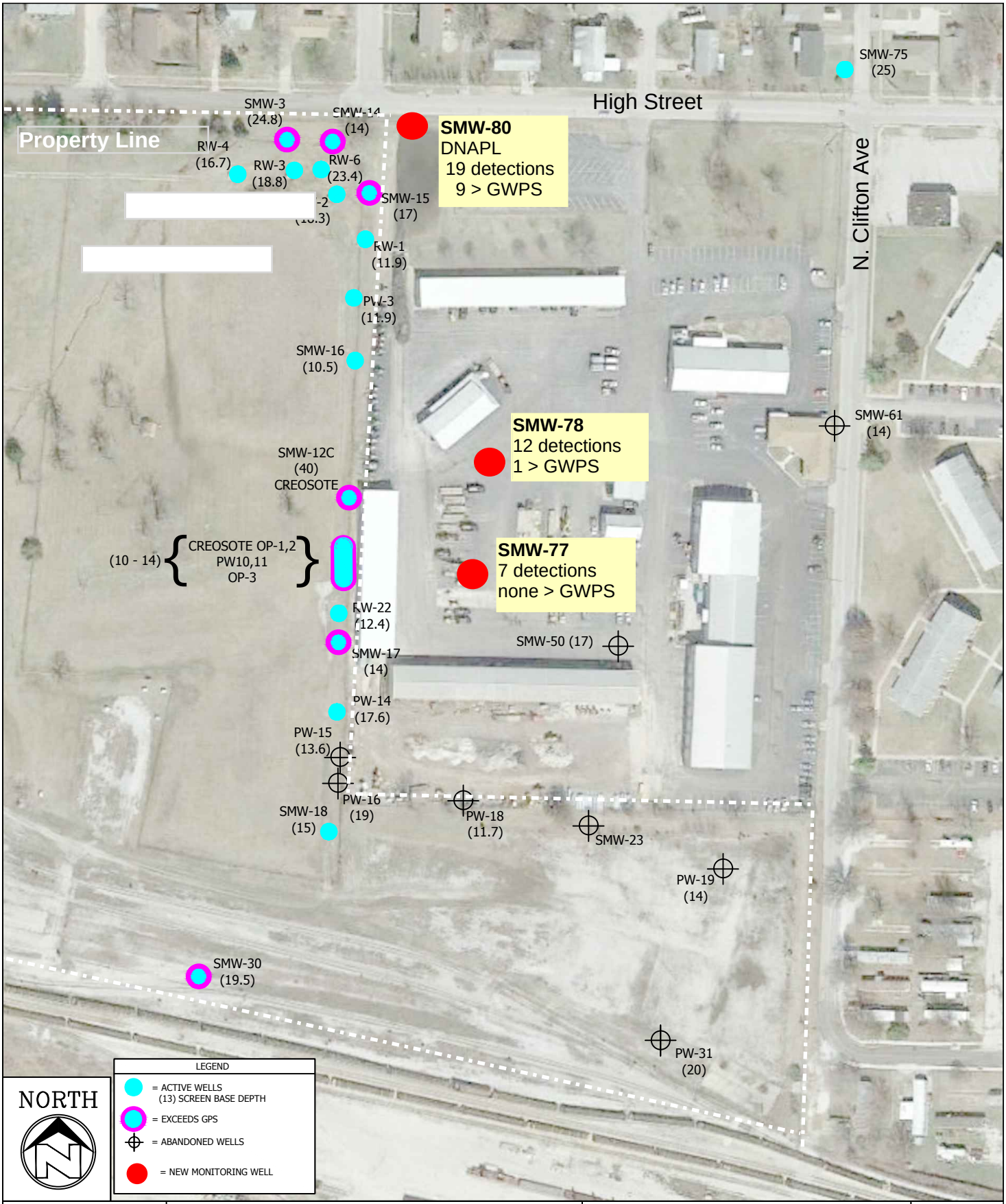
PREPARED BY:
ENVIRONMENTAL WORKS

SURFICIAL SOIL BORINGS

FORMER TRONOX FACILITY
2800 WEST HIGH ST.
SPRINGFIELD, GREENE COUNTY, MISSOURI

FIGURE
2.0



SCALE (FEET)
0 1000 2000

EWI# 150683
DRAWN BY: CLM
Aug. 11, 2016

PREPARED FOR:
Greenfield Environmental Multistate Trust, LLC, Trustee of the Multistate Environmental Response Trust

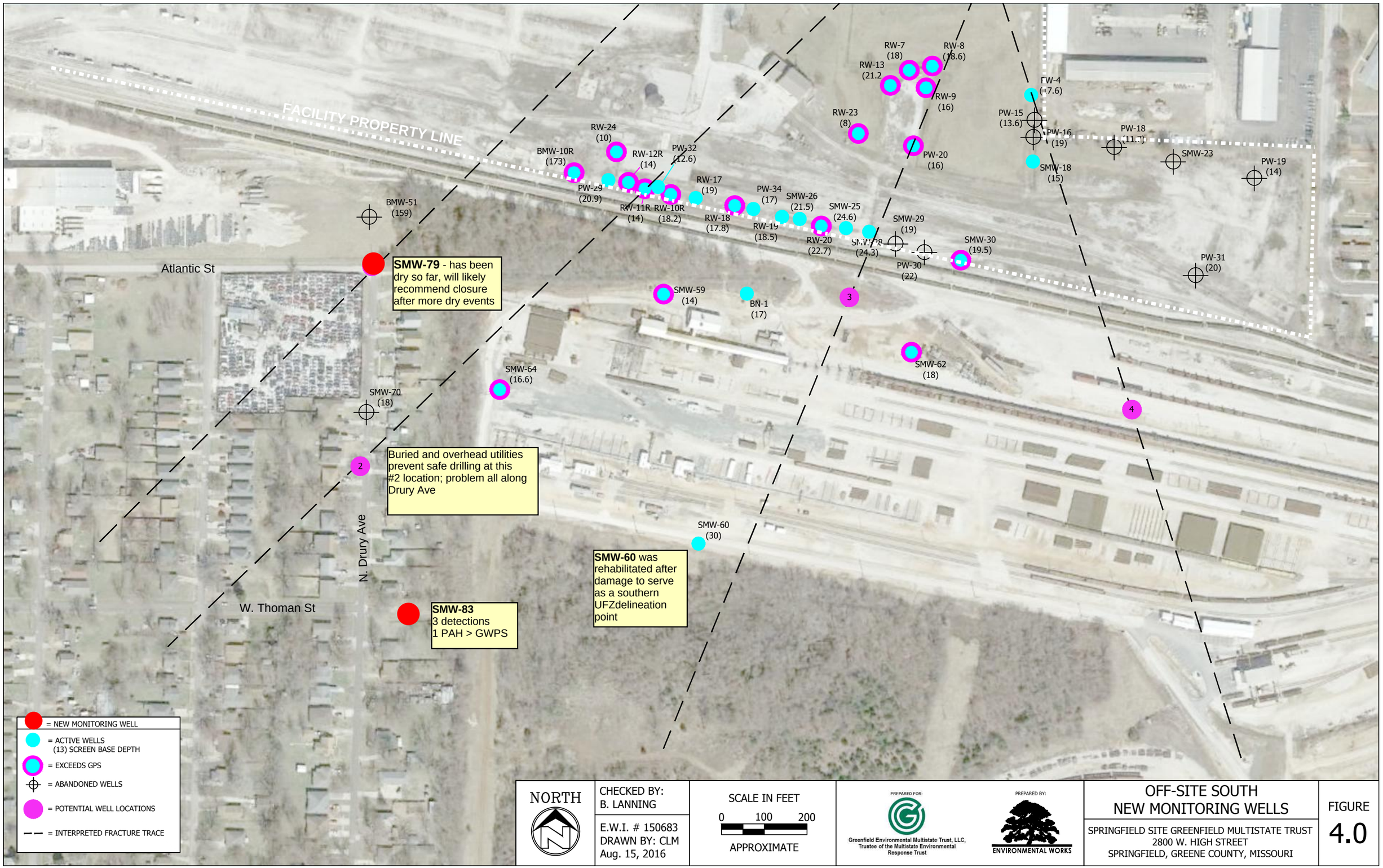
PREPARED BY:
ENVIRONMENTAL WORKS

OFF-SITE EAST NEW MONITORING WELLS

SPRINGFIELD SITE GREENFIELD MULTISTATE TRUST
2800 W. HIGH STREET
SPRINGFIELD, GREENE COUNTY, MISSOURI

FIGURE
3.0

PRELIMINARY - SUBJECT TO REVISION



NORTH

CHECKED BY: B. LANNING

E.W.I. # 150683
DRAWN BY: CLM
Aug. 15, 2016

SCALE IN FEET
0 100 200
APPROXIMATE

PREPARED FOR:
Greenfield Environmental Multistate Trust, LLC, Trustee of the Multistate Environmental Response Trust

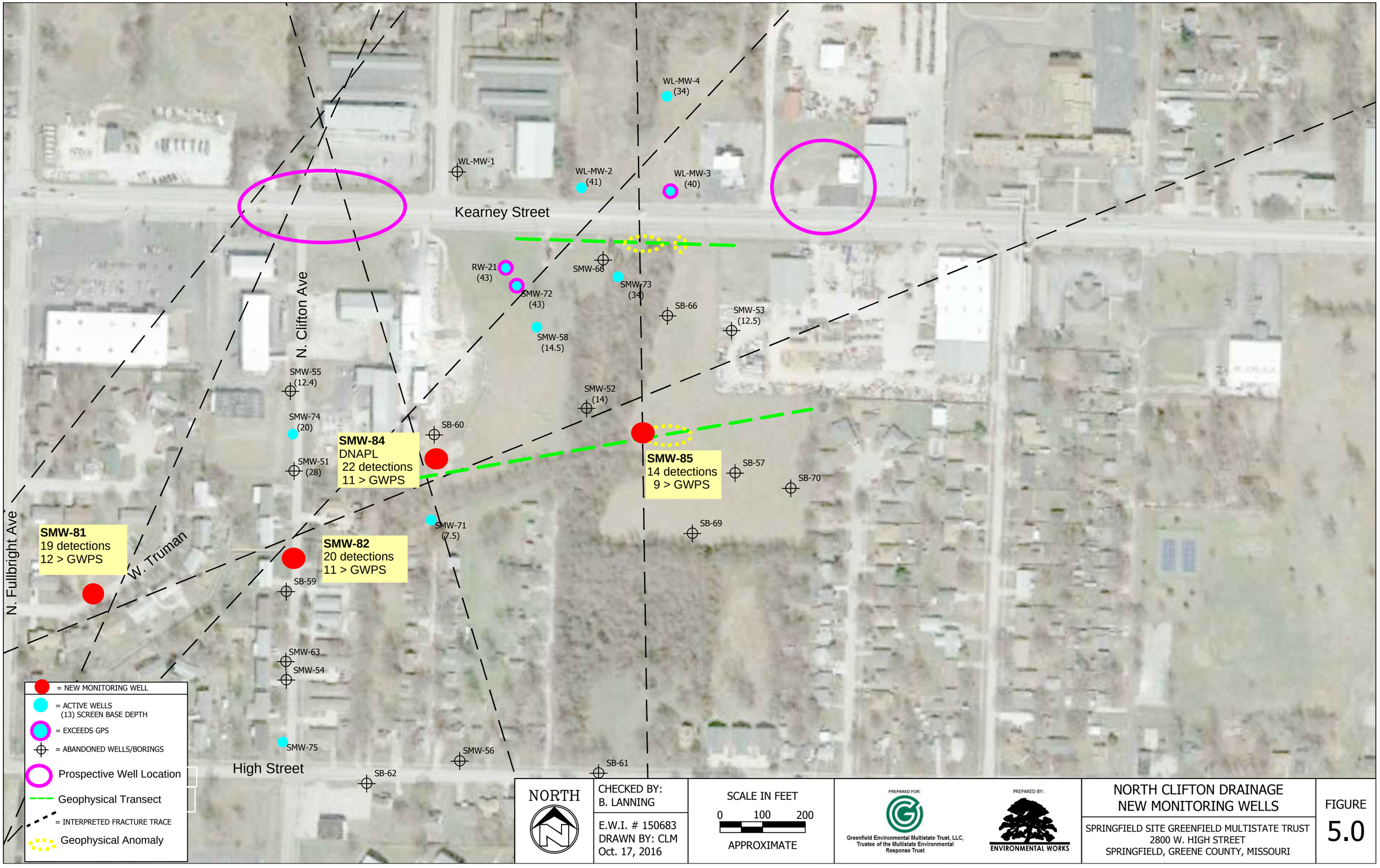
PREPARED BY:
ENVIRONMENTAL WORKS

OFF-SITE SOUTH NEW MONITORING WELLS

SPRINGFIELD SITE GREENFIELD MULTISTATE TRUST
2800 W. HIGH STREET
SPRINGFIELD, GREENE COUNTY, MISSOURI

FIGURE
4.0

PRELIMINARY - SUBJECT TO REVISION



NORTH

CHECKED BY: B. LANNING

E.W.I. # 150683
DRAWN BY: CLM
Oct. 17, 2016

SCALE IN FEET
0 100 200
APPROXIMATE

PREPARED FOR:
Greenfield Environmental Multistate Trust, LLC, Trustee of the Multistate Environmental Response Trust

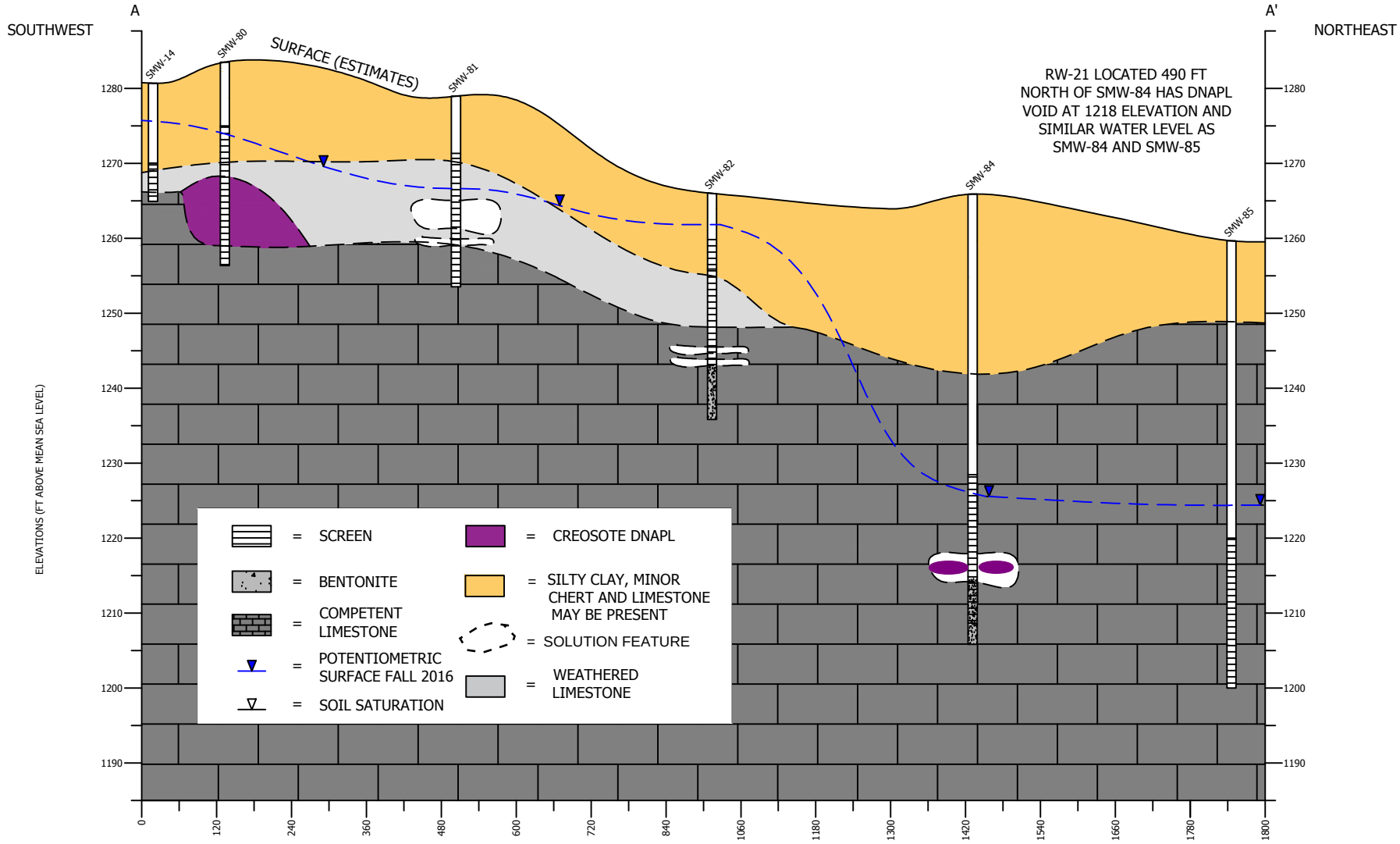
PREPARED BY:
ENVIRONMENTAL WORKS

NORTH CLIFTON DRAINAGE NEW MONITORING WELLS

SPRINGFIELD SITE GREENFIELD MULTISTATE TRUST
2800 W. HIGH STREET
SPRINGFIELD, GREENE COUNTY, MISSOURI

FIGURE
5.0

PRELIMINARY - SUBJECT TO REVISION



NORTH

CHECKED BY: B. LANNING

E.W.I. # 150683
DRAWN BY: JWP
Nov. 21, 2016

HORIZONTAL SCALE IN FEET
0 60 120

APPROXIMATE

VERTICAL SCALE IN FEET
0 5 10

PREPARED FOR:

Greenfield Environmental Multistate Trust, LLC, Trustee of the Multistate Environmental Response Trust

ENVIRONMENTAL WORKS

CROSS SECTION (A-A')

KERR - MCGEE / TRONO X
2800 WEST HIGH ST.
SPRINGFIELD, GREENE COUNTY, MISSOURI

FIGURE
6.0

PRELIMINARY - SUBJECT TO REVISION

High Street

BMW-6

BMW-3

BMW-2

BMW-8

BMW-1

BMW-7

BMW-13
11 detections
napthalene,
phenanthrene
> GWPS

BMW-5

BMW-9

BMW-14
2 detections
none > GWPS

BMW-11

SMW-76 - impacted
19 detections
11 > GWPS
Original SFZ step-out
location for BMW-10R

BMW-10R

BMW-10

BMW-12
80 ft - DNAPL
Intended to be
BMW deeper well

BMW-51

Planned southwest
SFZ delineation
well; awaiting
off-site access

FACILITY PROPERTY LINE

BNSF RAILWAY YARD

LEGEND

- = ACTIVE SFZ WELLS
- = ABANDONED SFZ WELLS
- = AREA OF NEW SFZ HORIZONTAL DELINEATION WELL
- = NEW MONITORING WELL

NORTH

CHECKED BY:
B. LANNING

E.W.I. # 150683
DRAWN BY: CLM
Aug. 11, 2016

SCALE IN FEET
0 90 180
APPROXIMATE

PREPARED FOR:
Greenfield Environmental Multistate Trust, LLC,
Trustee of the Multistate Environmental
Response Trust

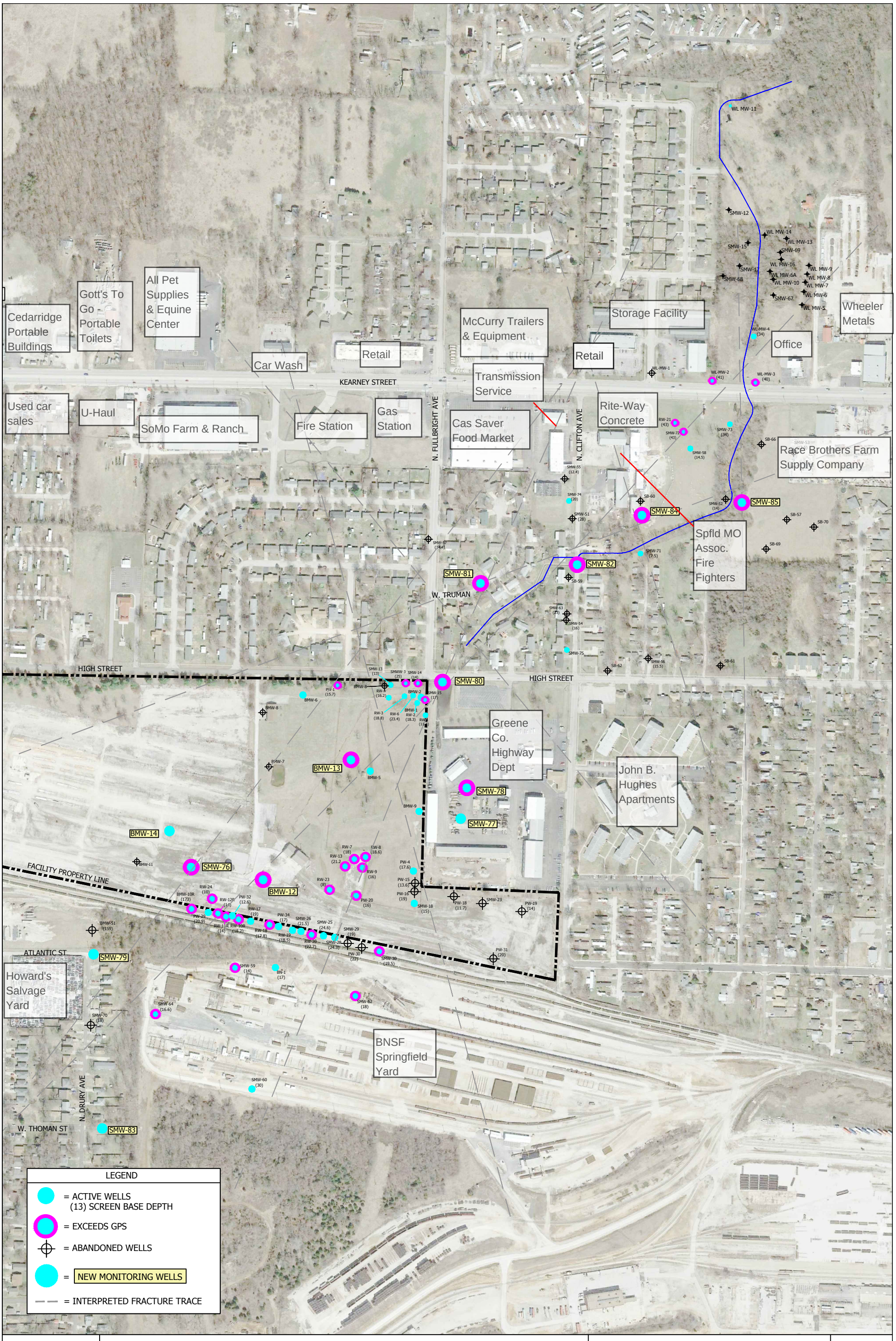
PREPARED BY:
ENVIRONMENTAL WORKS

NEW WELLS FOR SFZ VERTICAL AND HORIZONTAL DELINEATION

SPRINGFIELD SITE GREENFIELD MULTISTATE TRUST
2800 W. HIGH STREET
SPRINGFIELD, GREENE COUNTY, MISSOURI

FIGURE
7.0

PRELIMINARY - SUBJECT TO REVISION



CHECKED BY:
B. LANNING

E.W.I. # 150683
DRAWN BY: JWP
Dec. 9, 2016

NORTH

PREPARED FOR:
Greenfield Environmental Multistate Trust, LLC,
Trustee of the Multistate Environmental Response Trust

PREPARED BY:
ENVIRONMENTAL WORKS

0 250 500

AREA AROUND FACILITY

SPRINGFIELD SITE - GREENFIELD MULTISTATE TRUST
2800 W. HIGH STREET
SPRINGFIELD, GREENE COUNTY, MISSOURI

FIGURE
8.0

PRELIMINARY - SUBJECT TO REVISION

VISL Screening for Inhalation Risk from New Monitoring Well Groundwater
Former Tronox Facility, Springfield, Missouri

Groundwater analytical results from the screening samples taken from new off-site wells were input to the U.S. EPA Vapor Intrusion Screening Level (VISL) software as an initial screening of vapor intrusion risk in the residential areas near the Facility. The only data for the new off-site wells thus far are the screening samples that were obtained after the wells were built. Contaminants of concern (COCs) for the facility were selected in VISL, and six of them were chosen for evaluation based on their physical properties. Of the Springfield facility COCs, six (benzo[a]anthracene, benzene, ethylbenzene, naphthalene, toluene, and xylenes) are physically capable of creating vapor intrusion (VI) risks, *and* have toxicity data available to assess health risks. It is important to keep in mind that for some COCs toxicity data for indoor air is not available, even though it is volatile enough to make it to the breathing zone, as is the case with 2-methylnaphthalene. Other standard input parameters the VISL used to forward-calculate VI risk based on analytical groundwater data were:

- Exposure Scenario – Residential
- Target Risk for Carcinogens (TCR) - $1x10^{-6}$
- Target Hazard Quotient for Non-Carcinogens (THQ) – 1
- Average Groundwater Temperature (T_{GW}) – 25^{o} C

Based on data from the 2H16 sampling event, groundwater temperatures range from approximately 20^{o} C to 25^{o} C. Sensitivity analysis reveals that health risk (Cancer Risk [CR] and Hazard Quotient [HQ]) and groundwater temperature are directly related. If T_{GW} increases, so does CR and HQ for each COC. The maximum T_{GW} of 25^{o} C was used in the risk screening to be conservative.

New off-site upper flow zone (UFZ) wells considered for this evaluation are SMW-79, SMW-80, SMW-81, SMW-82, SMW-83, SMW-84, and SMW-85. SMW-84 and SMW-85 are on industrial/commercial properties, but the wells are very close to residential areas so the groundwater data obtained from the wells will be screened using the residential scenario. A summary of VISL evaluation and results is given below. The VISL printouts are included as attachments.

- SMW-79
    - This well has been dry since it was installed, so no analytical data exist.
- SMW-80
    - Visual NAPL (creosote) was observed while drilling this well. After settling, a groundwater sample was carefully collected and analyzed, with data input to the VISL with the following results:
    - Benzene: CR = 6.3E-06 > Target CR 1E-06
    - Ethylbenzene CR = 2.7E-05 > Target CR 1E-06
    - Naphthalene CR = 2.4E-03 > Target CR 1E-06; HQ = 630 > THQ = 1
- SMW-81
    - Benz[a]anthracene: CR = 3.6E-06 > Target CR = 1E-06
    - Acute toxicity data for benzo[a]anthracene is not available, so VISL did not calculate a hazard quotient (HQ) for this COC.
    - All other COCs passed the risk screening (CR<TCR and HQ<THQ)

- SMW-82
    - Naphthalene: CR = 8.5E-04 > TCR = 1E-06; HQ = 2.2E+01 > THQ = 1
        - *Naphthalene exceeded the TCR by 2 orders of magnitude, and the THQ by 1 order of magnitude.*
    - Ethylbenzene: CR = 3.7E-06 > TCR = 1E-06
    - All other COCs passed the risk screening (CR<TCR and HQ<THQ).

- SMW-83
    - Groundwater analytical data from this well have no detections applicable to VISL.

- SMW-84
    - Visual NAPL (creosote) was observed while drilling this well. After settling, a groundwater sample was carefully collected and analyzed, with data input to the VISL with the following results:
    - Ethylbenzene CR = 5.7E-06 > Target CR 1E-06
    - Naphthalene CR = 1.1E-03 > Target CR 1E-06; HQ = 29 > THQ = 1

Recommendation for Groundwater Vapor Intrusion Risk Potential: Estimated indoor air concentrations calculated by VISL screening from input groundwater data exceed residential risk levels at these locations:

- SMW-80 on High Street
- SMW-81 on W. Truman Street
- SMW-82 on N. Clifton Ave
- SMW-84 on Rite-way Concrete commercial property

This indicates that groundwater contamination that extends into the residential areas northeast of the facility has the potential for vapor intrusion exposure to residents. A plan of action to further assess this potential is warranted. Per the RAO Work Plan Addendum, this will involve installation of soil vapor monitoring points near the wells that exceeded the screening levels, and collection of soil vapor data for direct comparison of vapor concentrations to the action levels.

Environmental Works, Inc. will coordinate installing shallow and deep soil vapor monitoring points in the right-of-ways near the subject SMW wells per the RAO Work Plan Addendum. We have contacted Eurofins Laboratory to confirm the appropriate sampling and analytical method(s) for the analytes identified by the VISL evaluation, and are coordinating with the Multistate Trust as to plans and schedule.

EPA-OLEM VAPOR INTRUSION ASSESSMENT
Groundwater Concentration to Indoor Air Concentration (GWC-IAC) Calculator Version 3.5.1 (May 2016 RSLs)

Parameter	Symbol	Value	Instructions
Exposure Scenario	Scenario	Residential	Select residential or commercial scenario from pull down list
Target Risk for Carcinogens	TCR	1.00E-06	Enter target risk for carcinogens (for comparison to the calculated VI carcinogenic risk in column F)
Target Hazard Quotient for Non-Carcinogens	THQ	1	Enter target hazard quotient for non-carcinogens (for comparison to the calculated VI hazard in column G)
Average Groundwater Temperature (°C)	Tgw	25	Enter average of the stabilized groundwater temperature to correct Henry's Law Constant for groundwater target concentrations

CAS	Chemical Name	Site Groundwater Concentration Cgw (ug/L)	Calculated Indoor Air Concentration Cia (ug/m^3)	VI Carcinogenic Risk CR	VI Hazard HQ	Inhalation Unit Risk IUR (ug/m^3)$^{-1}$	IUR Source*	Reference Concentration RfC (mg/m^3)	RFC Source*	Mutagenic Indicator i
56-55-3	Benz[a]anthracene	5.0E-01	2.45E-04	2.7E-08	No RfC	1.10E-04	CA			Mut
71-43-2	Benzene	1.0E+01	2.27E+00	**6.3E-06**	7.3E-02	7.80E-06	I	3.00E-02	I	
100-41-4	Ethylbenzene	9.4E+01	3.03E+01	**2.7E-05**	2.9E-02	2.50E-06	CA	1.00E+00	I	
91-20-3	Naphthalene	1.1E+04	1.98E+02	**2.4E-03**	**6.3E+01**	3.40E-05	CA	3.00E-03	I	
108-88-3	Toluene	4.7E+01	1.28E+01	No IUR	2.4E-03			5.00E+00	I	
1330-20-7	Xylenes	3.1E+02	8.40E+01	No IUR	8.1E-01			1.00E-01	I	

Notes:

(1) **Inhalation Pathway Exposure Parameters (RME):**

Exposure Scenario	Units	Residential Symbol	Residential Value	Commercial Symbol	Commercial Value	Selected (based on scenario) Symbol	Selected (based on scenario) Value
Averaging time for carcinogens	(yrs)	ATc_R_GW	70	ATc_C_GW	70	ATc_GW	70
Averaging time for non-carcinogens	(yrs)	ATnc_R_GW	26	ATnc_C_GW	25	Atnc_GW	26
Exposure duration	(yrs)	ED_R_GW	26	ED_C_GW	25	ED_GW	26
Exposure frequency	(days/yr)	EF_R_GW	350	EF_C_GW	250	EF_GW	350
Exposure time	(hr/day)	ET_R_GW	24	ET_C_GW	8	ET_GW	24

(2) **Generic Attenuation Factors:**

Source Medium of Vapors	Residential Symbol	Residential Value	Commercial Symbol	Commercial Value	Selected (based on scenario) Symbol	Selected (based on scenario) Value
Groundwater (-)	AFgw_R_GW	0.001	AFgw_C_GW	0.001	AFgw_GW	0.001
Sub-Slab and Exterior Soil Gas (-)	AFss_R_GW	0.03	AFss_C_GW	0.03	AFss_GW	0.03

(3) **Formulas**

Cia, target = MIN(Cia,c; Cia,nc)
Cia,c (ug/m3) = TCR x ATc x (365 days/yr) x (24 hrs/day) / (ED x EF x ET x IUR)
Cia,nc (ug/m3) = THQ x ATnc x (365 days/yr) x (24 hrs/day) x RfC x (1000 ug/mg) / (ED x EF x ET)

(4) **Special Case Chemicals**

Trichloroethylene	Residential Symbol	Residential Value	Commercial Symbol	Commercial Value	Selected (based on scenario) Symbol	Selected (based on scenario) Value
	mIURTCE_R_GW	1.00E-06	mIURTCE_C_GW	0.00E+00	mIURTCE_GW	1.00E-06
	IURTCE_R_GW	3.10E-06	IURTCE_C_GW	4.10E-06	IURTCE_GW	3.10E-06

Mutagenic Chemicals — The exposure durations and age-dependent adjustment factors for mutagenic-mode-of-action are listed in the table below:

Note: This section applies to trichloroethylene and other mutagenic chemicals, but not to vinyl chloride.

Age Cohort	Exposure Duration	Age-dependent adjustment factor
0 - 2 years	2	10
2 - 6 years	4	3
6 - 16 years	10	3
16 - 26 years	10	1

Mutagenic-mode-of-action (MMOA) adjustment factor 72 — This factor is used in the equations for mutagenic chemicals.

Vinyl Chloride — See the Navigation Guide equation for Cia,c for vinyl chloride.

Notation:
I = IRIS: EPA Integrated Risk Information System (IRIS). Available online at: http://www.epa.gov/iris/subst/index.html
P = PPRTV. EPA Provisional Peer Reviewed Toxicity Values (PPRTVs). Available online at: http://hhpprtv.ornl.gov/pprtv.shtml
A = Agency for Toxic Substances and Disease Registry (ATSDR) Minimum Risk Levels (MRLs). Available online at: http://www.atsdr.cdc.gov/mrls/index.html
CA = California Environmental Protection Agency/Office of Environmental Health Hazard Assessment assessments. Available online at: http://www.oehha.ca.gov/risk/ChemicalDB/index.asp
H = HEAST. EPA Superfund Health Effects Assessment Summary Tables (HEAST) database. Available online at: http://epa-heast.ornl.gov/heast.shtml
S = See RSL User Guide, Section 5
X = PPRTV Appendix

EPA-OLEM VAPOR INTRUSION ASSESSMENT

Groundwater Concentration to Indoor Air Concentration (GWC-IAC) Calculator Version 3.5.1 (May 2016 RSLs)

Parameter	Symbol	Value	Instructions
Exposure Scenario	Scenario	Residential	Select residential or commercial scenario from pull down list
Target Risk for Carcinogens	TCR	1.00E-06	Enter target risk for carcinogens (for comparison to the calculated VI carcinogenic risk in column F)
Target Hazard Quotient for Non-Carcinogens	THQ	1	Enter target hazard quotient for non-carcinogens (for comparison to the calculated VI hazard in column G)
Average Groundwater Temperature (^oC)	Tgw	25	Enter average of the stabilized groundwater temperature to correct Henry's Law Constant for groundwater target concentrations

CAS	Chemical Name	Site Groundwater Concentration Cgw (ug/L)	Calculated Indoor Air Concentration Cia (ug/m^3)	VI Carcinogenic Risk CR	VI Hazard HQ	Inhalation Unit Risk IUR ($(ug/m^3)^{-1}$)	IUR Source*	Reference Concentration RfC (mg/m^3)	RFC Source*	Mutagenic Indicator i

Mut = Chemical acts according to the mutagenic-mode-of-action, special exposure parameters apply (see footnote (4) above).
VC = Special exposure equation for vinyl chloride applies (see Navigation Guide for equation).
TCE = Special mutagenic and non-mutagenic IURs for trichloroethylene apply (see footnote (4) above).
Yellow highlighting indicates site-specific parameters that may be edited by the user.
Blue highlighting indicates exposure factors that are based on Risk Assessment Guidance for Superfund (RAGS) or EPA vapor intrusion guidance, which generally should not be changed.
Pink highlighting indicates VI carcinogenic risk greater than the target risk for carcinogens (TCR) or VI Hazard greater than or equal to the target hazard quotient for non-carcinogens (THQ).

EPA-OLEM VAPOR INTRUSION ASSESSMENT
Groundwater Concentration to Indoor Air Concentration (GWC-IAC) Calculator Version 3.5.1 (May 2016 RSLs)

Parameter	Symbol	Value	Instructions
Exposure Scenario	Scenario	Residential	Select residential or commercial scenario from pull down list
Target Risk for Carcinogens	TCR	1.00E-06	Enter target risk for carcinogens (for comparison to the calculated VI carcinogenic risk in column F)
Target Hazard Quotient for Non-Carcinogens	THQ	1	Enter target hazard quotient for non-carcinogens (for comparison to the calculated VI hazard in column G)
Average Groundwater Temperature (°C)	Tgw	25	Enter average of the stabilized groundwater temperature to correct Henry's Law Constant for groundwater target concentrations

CAS	Chemical Name	Site Groundwater Concentration Cgw (ug/L)	Calculated Indoor Air Concentration Cia (ug/m^3)	VI Carcinogenic Risk CR	VI Hazard HQ	Inhalation Unit Risk IUR (ug/m^3)$^{-1}$	IUR Source*	Reference Concentration RfC (mg/m^3)	RFC Source*	Mutagenic Indicator i
56-55-3	Benz[a]anthracene	6.8E+01	3.34E-02	**3.6E-06**	No RfC	1.10E-04	CA			Mut
71-43-2	Benzene	1.0E-01	2.27E-02	6.3E-08	7.3E-04	7.80E-06	I	3.00E-02	I	
100-41-4	Ethylbenzene	7.0E-01	2.26E-01	2.0E-07	2.2E-04	2.50E-06	CA	1.00E+00	I	
91-20-3	Naphthalene	4.0E+00	7.20E-02	8.7E-07	2.3E-02	3.40E-05	CA	3.00E-03	I	
108-88-3	Toluene	1.0E-01	2.71E-02	No IUR	5.2E-06			5.00E+00	I	
1330-20-7	Xylenes	2.7E+00	7.32E-01	No IUR	7.0E-03			1.00E-01	I	

Notes:

(1) **Inhalation Pathway Exposure Parameters (RME):**

Exposure Scenario	Units	Residential Symbol	Residential Value	Commercial Symbol	Commercial Value	Selected (based on scenario) Symbol	Selected (based on scenario) Value
Averaging time for carcinogens	(yrs)	ATc_R_GW	70	ATc_C_GW	70	ATc_GW	70
Averaging time for non-carcinogens	(yrs)	ATnc_R_GW	26	ATnc_C_GW	25	Atnc_GW	26
Exposure duration	(yrs)	ED_R_GW	26	ED_C_GW	25	ED_GW	26
Exposure frequency	(days/yr)	EF_R_GW	350	EF_C_GW	250	EF_GW	350
Exposure time	(hr/day)	ET_R_GW	24	ET_C_GW	8	ET_GW	24

(2) **Generic Attenuation Factors:**

Source Medium of Vapors	Residential Symbol	Residential Value	Commercial Symbol	Commercial Value	Selected (based on scenario) Symbol	Selected (based on scenario) Value
Groundwater (-)	AFgw_R_GW	0.001	AFgw_C_GW	0.001	AFgw_GW	0.001
Sub-Slab and Exterior Soil Gas (-)	AFss_R_GW	0.03	AFss_C_GW	0.03	AFss_GW	0.03

(3) **Formulas**
Cia, target = MIN(Cia,c; Cia,nc)
Cia,c (ug/m3) = TCR x ATc x (365 days/yr) x (24 hrs/day) / (ED x EF x ET x IUR)
Cia,nc (ug/m3) = THQ x ATnc x (365 days/yr) x (24 hrs/day) x RfC x (1000 ug/mg) / (ED x EF x ET)

(4) **Special Case Chemicals**

Trichloroethylene	Residential Symbol	Residential Value	Commercial Symbol	Commercial Value	Selected (based on scenario) Symbol	Selected (based on scenario) Value
mIURTCE_R_GW		1.00E-06	mIURTCE_C_GW	0.00E+00	mIURTCE_GW	1.00E-06
IURTCE_R_GW		3.10E-06	IURTCE_C_GW	4.10E-06	IURTCE_GW	3.10E-06

Mutagenic Chemicals — The exposure durations and age-dependent adjustment factors for mutagenic-mode-of-action are listed in the table below:

Note: This section applies to trichloroethylene and other mutagenic chemicals, but not to vinyl chloride.

Age Cohort	Exposure Duration	Age-dependent adjustment factor
0 - 2 years	2	10
2 - 6 years	4	3
6 - 16 years	10	3
16 - 26 years	10	1

Mutagenic-mode-of-action (MMOA) adjustment factor 72 — This factor is used in the equations for mutagenic chemicals.

Vinyl Chloride — See the Navigation Guide equation for Cia,c for vinyl chloride.

Notation:
I = IRIS: EPA Integrated Risk Information System (IRIS). Available online at: http://www.epa.gov/iris/subst/index.html
P = PPRTV. EPA Provisional Peer Reviewed Toxicity Values (PPRTVs). Available online at: http://hhpprtv.ornl.gov/pprtv.shtml
A = Agency for Toxic Substances and Disease Registry (ATSDR) Minimum Risk Levels (MRLs). Available online at: http://www.atsdr.cdc.gov/mrls/index.html
CA = California Environmental Protection Agency/Office of Environmental Health Hazard Assessment assessments. Available online at: http://www.oehha.ca.gov/risk/ChemicalDB/index.asp
H = HEAST. EPA Superfund Health Effects Assessment Summary Tables (HEAST) database. Available online at: http://epa-heast.ornl.gov/heast.shtml
S = See RSL User Guide, Section 5
X = PPRTV Appendix
Mut = Chemical acts according to the mutagenic-mode-of-action, special exposure parameters apply (see footnote (4) above).
VC = Special exposure equation for vinyl chloride applies (see Navigation Guide for equation).
TCE = Special mutagenic and non-mutagenic IURs for trichloroethylene apply (see footnote (4) above).
Yellow highlighting indicates site-specific parameters that may be edited by the user.
Blue highlighting indicates exposure factors that are based on Risk Assessment Guidance for Superfund (RAGS) or EPA vapor intrusion guidance, which generally should not be changed.
Pink highlighting indicates VI carcinogenic risk greater than the target risk for carcinogens (TCR) or VI Hazard greater than or equal to the target hazard quotient for non-carcinogens (THQ).

EPA-OLEM VAPOR INTRUSION ASSESSMENT
Groundwater Concentration to Indoor Air Concentration (GWC-IAC) Calculator Version 3.5.1 (May 2016 RSLs)

Parameter	Symbol	Value	Instructions
Exposure Scenario	Scenario	Residential	Select residential or commercial scenario from pull down list
Target Risk for Carcinogens	TCR	1.00E-06	Enter target risk for carcinogens (for comparison to the calculated VI carcinogenic risk in column F)
Target Hazard Quotient for Non-Carcinogens	THQ	1	Enter target hazard quotient for non-carcinogens (for comparison to the calculated VI hazard in column G)
Average Groundwater Temperature (°C)	Tgw	25	Enter average of the stabilized groundwater temperature to correct Henry's Law Constant for groundwater target concentrations

CAS	Chemical Name	Site Groundwater Concentration Cgw (ug/L)	Calculated Indoor Air Concentration Cia (ug/m^3)	VI Carcinogenic Risk CR	VI Hazard HQ	Inhalation Unit Risk IUR ($(ug/m^3)^{-1}$)	IUR Source*	Reference Concentration RfC (mg/m^3)	RFC Source*	Mutagenic Indicator i
56-55-3	Benz[a]anthracene	9.8E+00	4.81E-03	5.2E-07	No RfC	1.10E-04	CA			Mut
71-43-2	Benzene	5.0E-01	1.13E-01	3.2E-07	3.6E-03	7.80E-06	I	3.00E-02	I	
100-41-4	Ethylbenzene	1.3E+01	4.19E+00	**3.7E-06**	4.0E-03	2.50E-06	CA	1.00E+00	I	
91-20-3	Naphthalene	3.9E+03	7.02E+01	**8.5E-04**	**2.2E+01**	3.40E-05	CA	3.00E-03	I	
108-88-3	Toluene	2.6E+00	7.06E-01	No IUR	1.4E-04			5.00E+00	I	
1330-20-7	Xylenes	3.8E+01	1.03E+01	No IUR	9.9E-02			1.00E-01	I	

Notes:

(1) **Inhalation Pathway Exposure Parameters (RME):**

Exposure Scenario	Units	Residential Symbol	Residential Value	Commercial Symbol	Commercial Value	Selected (based on scenario) Symbol	Selected (based on scenario) Value
Averaging time for carcinogens	(yrs)	ATc_R_GW	70	ATc_C_GW	70	ATc_GW	70
Averaging time for non-carcinogens	(yrs)	ATnc_R_GW	26	ATnc_C_GW	25	Atnc_GW	26
Exposure duration	(yrs)	ED_R_GW	26	ED_C_GW	25	ED_GW	26
Exposure frequency	(days/yr)	EF_R_GW	350	EF_C_GW	250	EF_GW	350
Exposure time	(hr/day)	ET_R_GW	24	ET_C_GW	8	ET_GW	24

(2) **Generic Attenuation Factors:**

Source Medium of Vapors	Residential Symbol	Residential Value	Commercial Symbol	Commercial Value	Selected (based on scenario) Symbol	Selected (based on scenario) Value
Groundwater (-)	AFgw_R_GW	0.001	AFgw_C_GW	0.001	AFgw_GW	0.001
Sub-Slab and Exterior Soil Gas (-)	AFss_R_GW	0.03	AFss_C_GW	0.03	AFss_GW	0.03

(3) **Formulas**

Cia, target = MIN(Cia,c; Cia,nc)
Cia,c (ug/m3) = TCR x ATc x (365 days/yr) x (24 hrs/day) / (ED x EF x ET x IUR)
Cia,nc (ug/m3) = THQ x ATnc x (365 days/yr) x (24 hrs/day) x RfC x (1000 ug/mg) / (ED x EF x ET)

(4) **Special Case Chemicals**

Trichloroethylene	Residential Symbol	Residential Value	Commercial Symbol	Commercial Value	Selected (based on scenario) Symbol	Selected (based on scenario) Value
	mIURTCE_R_GW	1.00E-06	mIURTCE_C_GW	0.00E+00	mIURTCE_GW	1.00E-06
	IURTCE_R_GW	3.10E-06	IURTCE_C_GW	4.10E-06	IURTCE_GW	3.10E-06

Mutagenic Chemicals — The exposure durations and age-dependent adjustment factors for mutagenic-mode-of-action are listed in the table below:

Note: This section applies to trichloroethylene and other mutagenic chemicals, but not to vinyl chloride.

Age Cohort	Exposure Duration	Age-dependent adjustment factor
0 - 2 years	2	10
2 - 6 years	4	3
6 - 16 years	10	3
16 - 26 years	10	1

Mutagenic-mode-of-action (MMOA) adjustment factor 72 — This factor is used in the equations for mutagenic chemicals.

Vinyl Chloride — See the Navigation Guide equation for Cia,c for vinyl chloride.

Notation:
I = IRIS: EPA Integrated Risk Information System (IRIS). Available online at: http://www.epa.gov/iris/subst/index.html
P = PPRTV. EPA Provisional Peer Reviewed Toxicity Values (PPRTVs). Available online at: http://hhpprtv.ornl.gov/pprtv.shtml
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CA = California Environmental Protection Agency/Office of Environmental Health Hazard Assessment assessments. Available online at: http://www.oehha.ca.gov/risk/ChemicalDB/index.asp
H = HEAST. EPA Superfund Health Effects Assessment Summary Tables (HEAST) database. Available online at: http://epa-heast.ornl.gov/heast.shtml
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EPA-OLEM VAPOR INTRUSION ASSESSMENT

Groundwater Concentration to Indoor Air Concentration (GWC-IAC) Calculator Version 3.5.1 (May 2016 RSLs)

Parameter	Symbol	Value	Instructions
Exposure Scenario	Scenario	Residential	Select residential or commercial scenario from pull down list
Target Risk for Carcinogens	TCR	1.00E-06	Enter target risk for carcinogens (for comparison to the calculated VI carcinogenic risk in column F)
Target Hazard Quotient for Non-Carcinogens	THQ	1	Enter target hazard quotient for non-carcinogens (for comparison to the calculated VI hazard in column G)
Average Groundwater Temperature (^{o}C)	Tgw	25	Enter average of the stabilized groundwater temperature to correct Henry's Law Constant for groundwater target concentrations

CAS	Chemical Name	Site Groundwater Concentration Cgw (ug/L)	Calculated Indoor Air Concentration Cia (ug/m^3)	VI Carcinogenic Risk CR	VI Hazard HQ	Inhalation Unit Risk IUR ($(ug/m^3)^{-1}$)	IUR Source*	Reference Concentration RfC (mg/m^3)	RFC Source*	Mutagenic Indicator i

Mut = Chemical acts according to the mutagenic-mode-of-action, special exposure parameters apply (see footnote (4) above).
VC = Special exposure equation for vinyl chloride applies (see Navigation Guide for equation).
TCE = Special mutagenic and non-mutagenic IURs for trichloroethylene apply (see footnote (4) above).
Yellow highlighting indicates site-specific parameters that may be edited by the user.
Blue highlighting indicates exposure factors that are based on Risk Assessment Guidance for Superfund (RAGS) or EPA vapor intrusion guidance, which generally should not be changed.
Pink highlighting indicates VI carcinogenic risk greater than the target risk for carcinogens (TCR) or VI Hazard greater than or equal to the target hazard quotient for non-carcinogens (THQ).

EPA-OLEM VAPOR INTRUSION ASSESSMENT
Groundwater Concentration to Indoor Air Concentration (GWC-IAC) Calculator Version 3.5.1 (May 2016 RSLs)

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CAS	Chemical Name	Site Groundwater Concentration Cgw (ug/L)	Calculated Indoor Air Concentration Cia (ug/m^3)	VI Carcinogenic Risk CR	VI Hazard HQ	Inhalation Unit Risk IUR (ug/m^3)$^{-1}$	IUR Source*	Reference Concentration RfC (mg/m^3)	RFC Source*	Mutagenic Indicator i
56-55-3	Benz[a]anthracene	2.0E+00	9.81E-04	1.1E-07	No RfC	1.10E-04	CA			Mut
71-43-2	Benzene	5.0E-01	1.13E-01	3.2E-07	3.6E-03	7.80E-06	I	3.00E-02	I	
100-41-4	Ethylbenzene	2.0E+01	6.44E+00	**5.7E-06**	6.2E-03	2.50E-06	CA	1.00E+00	I	
91-20-3	Naphthalene	5.0E+03	8.99E+01	**1.1E-03**	**2.9E+01**	3.40E-05	CA	3.00E-03	I	
108-88-3	Toluene	5.0E+00	1.36E+00	No IUR	2.6E-04			5.00E+00	I	
1330-20-7	Xylenes	8.2E+01	2.22E+01	No IUR	2.1E-01			1.00E-01	I	

Notes:

(1) **Inhalation Pathway Exposure Parameters (RME):**

Exposure Scenario	Units	Residential Symbol	Residential Value	Commercial Symbol	Commercial Value	Selected (based on scenario) Symbol	Selected (based on scenario) Value
Averaging time for carcinogens	(yrs)	ATc_R_GW	70	ATc_C_GW	70	ATc_GW	70
Averaging time for non-carcinogens	(yrs)	ATnc_R_GW	26	ATnc_C_GW	25	Atnc_GW	26
Exposure duration	(yrs)	ED_R_GW	26	ED_C_GW	25	ED_GW	26
Exposure frequency	(days/yr)	EF_R_GW	350	EF_C_GW	250	EF_GW	350
Exposure time	(hr/day)	ET_R_GW	24	ET_C_GW	8	ET_GW	24

(2) **Generic Attenuation Factors:**

Source Medium of Vapors	Residential Symbol	Residential Value	Commercial Symbol	Commercial Value	Selected (based on scenario) Symbol	Selected (based on scenario) Value
Groundwater (-)	AFgw_R_GW	0.001	AFgw_C_GW	0.001	AFgw_GW	0.001
Sub-Slab and Exterior Soil Gas (-)	AFss_R_GW	0.03	AFss_C_GW	0.03	AFss_GW	0.03

(3) **Formulas**

Cia, target = MIN(Cia,c; Cia,nc)
Cia,c (ug/m3) = TCR x ATc x (365 days/yr) x (24 hrs/day) / (ED x EF x ET x IUR)
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(4) **Special Case Chemicals**

Trichloroethylene	Residential Symbol	Residential Value	Commercial Symbol	Commercial Value	Selected (based on scenario) Symbol	Selected (based on scenario) Value
	mIURTCE_R_GW	1.00E-06	mIURTCE_C_GW	0.00E+00	mIURTCE_GW	1.00E-06
	IURTCE_R_GW	3.10E-06	IURTCE_C_GW	4.10E-06	IURTCE_GW	3.10E-06

Mutagenic Chemicals — The exposure durations and age-dependent adjustment factors for mutagenic-mode-of-action are listed in the table below:

Note: This section applies to trichloroethylene and other mutagenic chemicals, but not to vinyl chloride.

Age Cohort	Exposure Duration	Age-dependent adjustment factor
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2 - 6 years	4	3
6 - 16 years	10	3
16 - 26 years	10	1

Mutagenic-mode-of-action (MMOA) adjustment factor 72 — This factor is used in the equations for mutagenic chemicals.

Vinyl Chloride — See the Navigation Guide equation for Cia,c for vinyl chloride.

Notation:
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A = Agency for Toxic Substances and Disease Registry (ATSDR) Minimum Risk Levels (MRLs). Available online at: http://www.atsdr.cdc.gov/mrls/index.html
CA = California Environmental Protection Agency/Office of Environmental Health Hazard Assessment assessments. Available online at: http://www.oehha.ca.gov/risk/ChemicalDB/index.asp
H = HEAST. EPA Superfund Health Effects Assessment Summary Tables (HEAST) database. Available online at: http://epa-heast.ornl.gov/heast.shtml
S = See RSL User Guide, Section 5
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EPA-OLEM VAPOR INTRUSION ASSESSMENT

Groundwater Concentration to Indoor Air Concentration (GWC-IAC) Calculator Version 3.5.1 (May 2016 RSLs)

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Exposure Scenario	Scenario	Residential	Select residential or commercial scenario from pull down list
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CAS	Chemical Name	Site Groundwater Concentration Cgw (ug/L)	Calculated Indoor Air Concentration Cia (ug/m^3)	VI Carcinogenic Risk CR	VI Hazard HQ	Inhalation Unit Risk IUR ($(ug/m^3)^{-1}$)	IUR Source*	Reference Concentration RfC (mg/m^3)	RFC Source*	Mutagenic Indicator i

Mut = Chemical acts according to the mutagenic-mode-of-action, special exposure parameters apply (see footnote (4) above).
VC = Special exposure equation for vinyl chloride applies (see Navigation Guide for equation).
TCE = Special mutagenic and non-mutagenic IURs for trichloroethylene apply (see footnote (4) above).
Yellow highlighting indicates site-specific parameters that may be edited by the user.
Blue highlighting indicates exposure factors that are based on Risk Assessment Guidance for Superfund (RAGS) or EPA vapor intrusion guidance, which generally should not be changed.
Pink highlighting indicates VI carcinogenic risk greater than the target risk for carcinogens (TCR) or VI Hazard greater than or equal to the target hazard quotient for non-carcinogens (THQ).