United States
Environmental Protection
Agency

EPA 542-R-14-004
June 25, 2104

ENVIRONMENTAL FOOTPRINT ANALYSIS OF STEAM ENHANCED EXTRACTION REMEDY

FORMER WILLIAMS AIR FORCE BASE, SITE ST012
MESA, AZ

FINAL REPORT
June 25, 2014

NOTICE

Work described herein was performed by Tetra Tech, Inc. (Tetra Tech) for the U.S. Environmental Protection Agency (EPA). Work conducted, including preparation of this report, was performed under Work Assignment #2-73 of EPA contract EP-W-07-078 with Tetra Tech. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

PREFACE

This report was prepared for the U.S. Environmental Protection Agency (EPA) Office of Superfund Remediation and Technology Innovation (OSRTI) and EPA Region 9. This report is available for download from EPA's Hazardous Waste Clean-Up Information (CLU-IN) Green Remediation webpage available at www.cluin.org/greenremediation.The authors of this report recognize that green remediation and the footprint analysis component of green remediation are developing practices, and comments and feedback on this report are welcome. Comments and feedback should be directed to Carlos Pachon (contact information below).

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LIST OF ACRONYMS

%	Percent
AFB	Air Force Base
ALT	Alternative
bgs	Below ground surface
BTU	British Thermal Units
Ccf	100 cubic feet
CHP	Combined heat and power
CO_2e	Carbon dioxide equivalent of global warming potential
cy	Cubic yards
CZ	Cobble Zone
°C	Degrees Celsius
EPA	U.S. Environmental Protection Agency
GAC	Granular activated carbon
GHG	Greenhouse gas
GPM	Gallons per minute
gptm	gallons per ton-mile (gptm)
GR	Green Remediation
HAP	Hazardous air pollutant
JP-4	Jet propellant grade 4
kWh	kilowatt hour
ISTT	In Situ thermal treatment
lbs	Pounds
LNAPL	Light non-aqueous phase liquid
LPZ	Lower Permeability Zone
LSZ	Lower Saturated Zone
MMBTU	Million British Thermal Units
MPE	Multiphase extraction
NAPL	Non-aqueous phase liquid
NG	Natural gas
NO_x	Nitrogen oxides
O&M	Operations and Maintenance
OSRTI	Office of Superfund Remediation and Technology Innovation
PM	Particulate matter
POTW	Publicly owned treatment works
REC	Renewable Energy Certificate
ROD	Record of Decision
PVC	Polyvinyl chloride
SEE	Steam enhanced extraction
SEFA	Spreadsheets for Environmental Footprint Analysis
SO_x	Sulfur oxides
SRP	Salt River Project
TTZ	Target treatment zone
UWBZ	Upper Water Bearing Zone

1.0 INTRODUCTION AND PURPOSE

1.1 Introduction

The U.S. Environmental Protection Agency (EPA) defines green remediation (GR) as the practice of considering all environmental effects of remedy implementation and incorporating options to minimize the environmental footprints of a cleanup. To this end, GR involves quantifying the environmental effects of a remedy and then taking steps to reduce negative environmental effects and enhance positive environmental effects, while meeting the regulatory requirements governing the remedy.

Two concepts are central to quantifying the environmental effects of a remedy. The first is to establish the environmental parameters that are to be quantified, and the second is to establish a straightforward methodology for quantifying those parameters. The term “footprint” refers to the quantification or measure of a specific environmental parameter. For example, the greenhouse gas (GHG) emissions footprint is the quantification or measure of carbon dioxide and other greenhouse gases emitted by a particular activity, facility, individual or remedy. The GHG emissions footprint is of interest because such emissions have been linked to environmental effects such as global warming and related climate change. The term “footprint” can be expanded to other environmental parameters such as energy use, water use, land use and air pollutant emissions. In addition, an environmental footprint can be local, regional or global. For example, the combustion of diesel fuel at a site will result in nitrogen oxide emissions (among other compounds) in the immediate vicinity of the site. Therefore, the most significant environmental effects from this nitrogen oxide may be near the site where it is most concentrated (a local effect). Contrastingly, diesel combustion at a site and diesel production at a refinery located far from the site will both emit carbon dioxide into the atmosphere. A pound of carbon dioxide emitted at the site or far from the site will have equal environmental effect with respect to global warming potential (a global effect).

Estimating the environmental footprints of remediation projects is becoming increasingly commonplace, as is the development of tools to assist with the effort. However, as yet there is no standardized process, set of parameters or accepted tool. Some projects focus on the GHG emissions footprint and omit other environmental parameters. Some projects limit the scope of the footprint analysis to fuel consumption and electricity use and omit contributions from the manufacture of materials or off-site services that are required for a remedy. In general, the objective of the footprint analysis is to identify the most significant contributors to a remedy’s footprints so that efforts to reduce the footprints can be targeted appropriately. The approach used in this footprint analysis focuses on the following environmental parameters: energy use, GHG emissions, air pollutant emissions, materials use, waste and water use. The approach (1) uses EPA’s Methodology for Understanding and Reducing a Project’s Environmental Footprint and (2) applies EPA’s Spreadsheets for Environmental Footprint Analysis (SEFA) tool.

1.2 Purpose

This GR study quantifies environmental footprint for an In-Situ Thermal Treatment (ISTT) remedy using Steam Enhanced Extraction (SEE) for Site ST012 located on the Former Williams Air Force Base (AFB) in Mesa, Arizona. The study estimates the footprint for a variety of parameters and attempts to consider the key contributors to each footprint. This study is not a formal life-cycle assessment that follows ISO Standards 14040 and 14044. Rather, it is a footprint analysis that borrows from life-cycle assessment principles. Like a life-cycle assessment, this study uses data from life-cycle inventory databases to convert energy usage, materials usage and various services associated with site remediation into the environmental footprints for that activity. Like life-cycle assessment, the environmental footprints associated with resource extraction through use and "end-of-life" treatment are considered. Unlike a formal life-cycle assessment, this study estimates environmental footprints but does not convert them into actual human or ecological impacts or effects (such as global warming or toxicity) through a formal impact assessment.

One of the objectives of this detailed analysis is to provide some of the information necessary to determine the level of detail that is merited for environmental footprint analysis of site remediation at Site ST012. The other primary objectives of this site-specific study are as follows:

- Evaluate the environmental footprint of the current ISTT design quantitatively for metrics such as the carbon dioxide equivalent of global warming potential (CO_2e), and evaluate potential qualitative impacts associated with the remedy.

- Compare the estimated environmental footprint for the current design to the estimated footprints for previous stages, such as the conceptual design and a scale-up from the previous pilot test.

- Identify how optimization and/or "good practices" from the pilot test stage through the current design stage have impacted the various types of environmental footprints at Site ST012, and highlight these "good practices."

This GR evaluation addresses only the ISTT portion of the remedy at Site ST012 and not the subsequent bioremediation portion that is planned after ISTT is completed. Additionally, this GR evaluation is based on data available during the design phase of the ISTT remedy; a follow-on GR evaluation using "actual" data can be conducted after the ISTT remedy is implemented. In support of the GR evaluation, a meeting with the site team took place on November 19, 2013, and included a visit to the site. This meeting allowed Tetra Tech to obtain additional information required for the GR evaluation.

1.3 Brief Site Background

As described in the Draft Design Report (AMEC, 2013), the former Williams AFB is located in Maricopa County and lies within the boundaries of the City of Mesa, AZ. The former Williams AFB was a flight-training base that was first activated in 1941. ST012 is the location of the former Liquid Fuels Storage Area where fuel storage and distribution operations involving aboveground and underground tanks and lines were conducted from 1941 until the fuel storage and distribution system was decommissioned in 1991. Equipment and structures relating to the fuel storage and transmission operations within ST012 have been removed. Soil and groundwater at ST012 have been affected by releases of fuels from the historic operations. Williams AFB was placed on the EPA National Priorities List in 1989. The base officially closed in 1993. The Air Force transferred the property (including ST012) to the Phoenix-Mesa Gateway Airport Authority in 2008.

An ISTT remedy for Site ST012 using a steam enhanced extraction (SEE) system is currently being designed. Key milestones in the design process include the following:

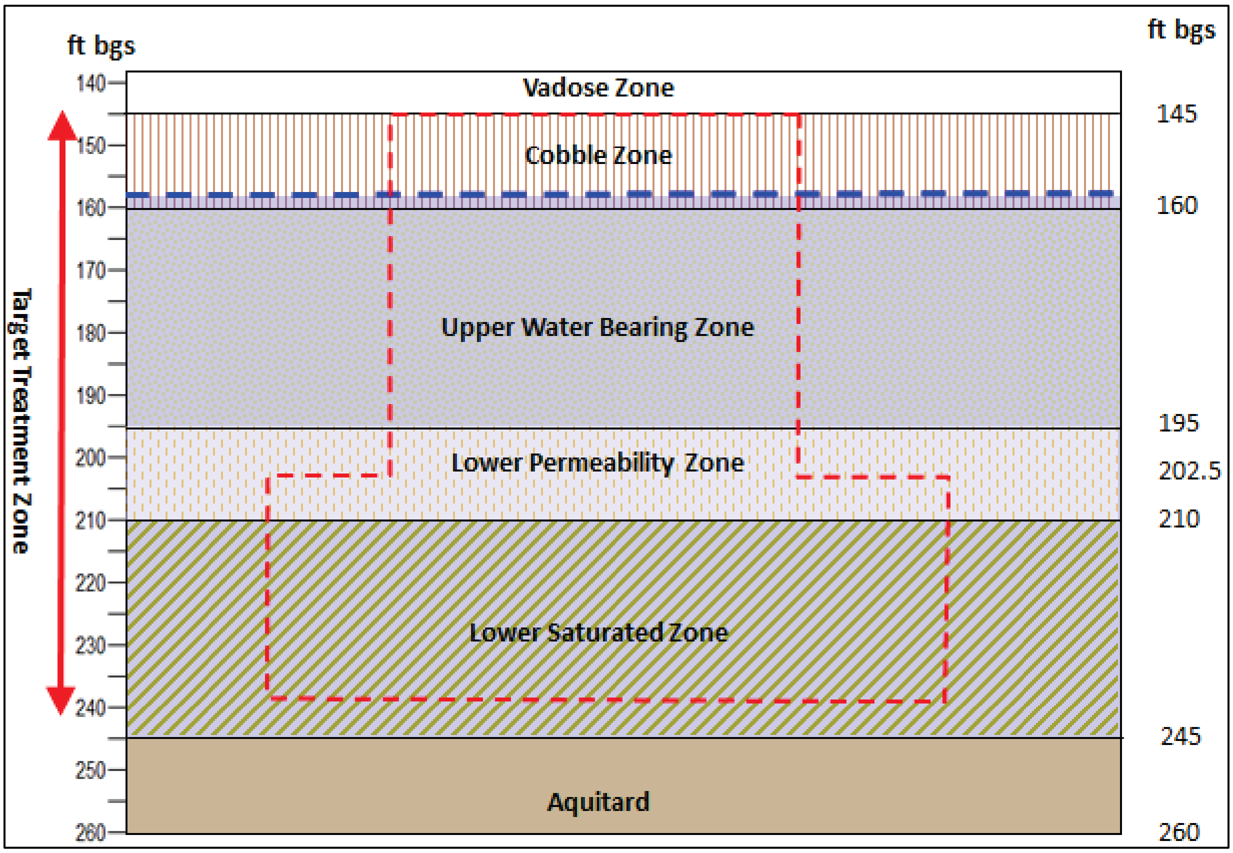
- ISTT pilot test activities performed 2008 to 2010
- Conceptual Design Report (TerraTherm, 2012)
- Draft Design Report (AMEC, 2013)

The SEE system is scheduled to begin operation in August 2014.

2.0 REMEDY OVERVIEW

2.1 Overview of Conceptual Site Model and Remedy Approach

Petroleum hydrocarbons are present at Site ST012 resulting from weathered jet propellant grade 4 (JP-4) and aviation gasoline spills. A simplified representation of the stratigraphic layers that comprise the Target Treatment Zone (TTZ) is provided below.



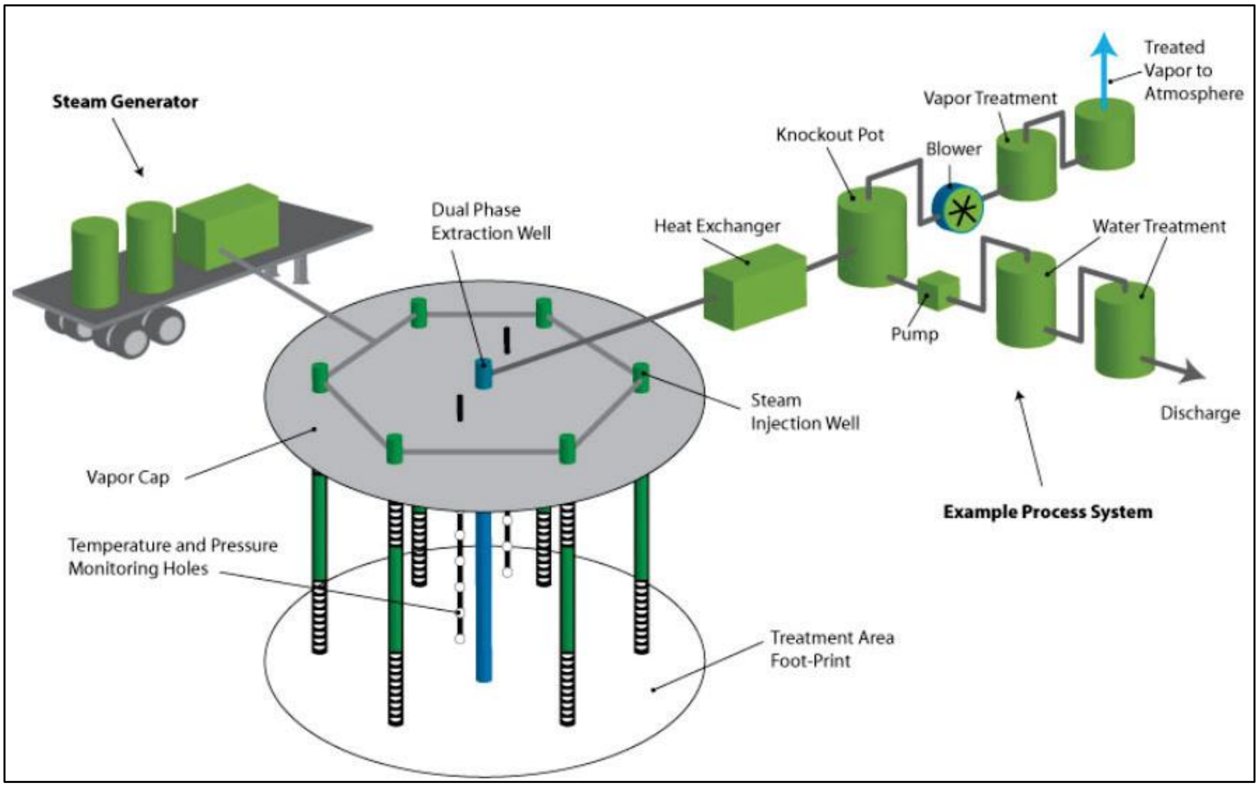
From Figure 3.2 of Appendix D in the Draft Design Report (AMEC, 2013). ft = feet; bgs = below ground surface.

The remedy includes implementation of SEE to thermally enhance light non-aqueous phase liquid (LNAPL) removal and reduce benzene concentrations in soil and groundwater. Three specific zones within ST012 are targeted for treatment:

- The Cobble Zone (CZ) with treatment depth of 145 to 160 feet below ground surface (bgs)
- The Upper Water Bearing Zone (UWBZ) with treatment depth from 160 to 195 feet bgs
- The Lower Saturated Zone (LSZ) with treatment depth of 210 to 240 feet bgs

A 15 foot thick Lower Permeability Zone (LPZ) is located between the UWBZ and the LSZ. Steam is not expected to directly heat the LPZ, but the LPZ will be heated indirectly by thermal conduction from the hot layers above and below it. The areal extent of the TTZ is large for an ISTT remedy, and varies by layer. In the current Draft Design (AMEC, 2013), the treatment areas for the CZ and UWBZ are identical (approximately 72,000 square feet) and the treatment area for the LSZ is larger (approximately 185,000 square feet). The ISTT treatment zone is limited by major streets to south and southeast, and a tank farm to the south. The size of the treatment areas increased between the Conceptual Design (TerraTherm, 2012) and the Draft Design Report (AMEC, 2013) based on a pre-design investigation.

A general schematic of the remedy approach is included in the Draft Design Report (AMEC, 2013) and is presented below.



From Figure 4.1 of Appendix D in Draft Design Report (AMEC, 2013)

SEE will be used to heat the TTZ to boiling temperatures between 100 and 140 degrees Celsius (°C), with the target treatment temperature increasing with depth bgs. The LNAPL will be made less viscous through SEE treatment and will be pushed by the steam injection toward the extraction wells for removal from the TTZ. The extracted fluids will be collected in a manifold piping system and conveyed to an on-site process treatment system which consists of condensation, phase separation and conditioning of the recovered weathered JP-4. The liquids separated from the recovered fuel will be treated on-site in an air stripper and subsequently polished using liquid carbon before being discharged to the sanitary sewer. Vapors will be extracted from the subsurface under vacuum and routed to a vapor treatment system consisting of multiple sequential treatment components to provide appropriate treatment and provide excess treatment capacity during peak loading. Primary vapor treatment will be provided by duplex thermal accelerators.

The thermal remedy is not expected to achieve cleanup standards in groundwater; rather it is expected to reduce groundwater concentrations for constituents of concern identified in the Record of Decision (ROD) (such as benzene) to an extent that subsequent bioremediation can achieve cleanup standards for those constituents in 10-20 years. Therefore, the decision to terminate steam injection will not be based on one specific, absolute criterion, but will be based on multiple criteria such as energy balance, rate of fuel recovery and temperature achieved.

Implementation of the full-scale remedy is expected in August 2014, and the Draft Design Report (AMEC, 2013) anticipates 422 days of total operation (332 days with steam and 90 days of extraction after steam is stopped). The current design estimates 100 days for mass removal (including pressure cycling) once the design temperature is achieved, based on the ISTT contractor's experience at previous sites.

2.2 Summary of Footprint-Related Remedy Items

Table 1 at the end of this report provides a summary of footprint-related remedy items based on the Conceptual Design Report (TerraTherm, 2012), and also indicates changes to those items based on the subsequent Draft Design Report (AMEC, 2013). The remedy items detailed in Table 1 are as follows:

- Injection wells
- Extraction wells - multiphase extraction (MPE)
- Vapor probes
- Temperature monitoring points
- Abandonment of wells
- Manifolds and pipe fittings
- Electricity use
- Natural gas usage
- Use of recovered JP-4
- Water use
- Water treatment at the publicly owned treatment works (POTW)
- Soil disposal
- Granular activated carbon (GAC)
- Off-site laboratory
- Transportation of materials
- Transportation of equipment
- Transportation of personnel

These data were entered in the EPA "Spreadsheets for Environmental Footprint Analysis" (SEFA) (EPA, 2013) tool to quantify specific footprints. Section 3.0 and Attachments 1 to 4 describe how these remedy items were addressed within the SEFA tool.

2.3 Discussion of ISTT Pilot Test (2008 to 2010)

A pilot test was conducted from 2008 to 2010 to assess well spacing and expected effectiveness of thermal treatment, using two injection wells in the center of a 70-foot radius circle, surrounded by six extraction well clusters. The pilot was useful for evaluating the screen intervals and well spacing needed for injections, but did not generate high enough temperatures to achieve effective remediation. As a result, subsequent design efforts have integrated plans to use much more steam to achieve the needed temperatures:

- The pilot test (2008-2010) had an average steam usage of 300 pounds (lbs) of steam per cubic yard (cy) of soil treated.

- The Conceptual Design Report (TerraTherm, 2012) included an estimate of 750 lbs of steam per cy of soil treated.

- The Draft Design Report (AMEC, 2013) included an estimate of 780 lbs of steam per cy of soil treated.

More than twice the amount of steam will be injected per cubic yard of soil in the full-scale application as compared to the pilot test. The more aggressive steam injection is anticipated to develop higher temperatures, provide more complete LNAPL displacement to extraction wells and create a longer and more effective vaporization period compared to the pilot test. Based on the pilot's lower steam use, a scale-up of the pilot test to a full-scale system would produce unrealistically low footprint results compared to SEFA results for the full-scale system using data from the Conceptual Design Report (TerraTherm, 2012) or the Draft Design Report (AMEC, 2013). Therefore, data for this study's SEFA analysis are drawn from the Conceptual Design Report and Draft Design Report.

3.0 FOOTPRINTING APPROACH AND RESULTS

3.1 Footprinting Approach

The EPA SEFA tool was used to organize the pertinent remedy information and quantify the following environmental footprints.

- Energy (million British thermal units [MMBTU])
- Total greenhouse gas (GHG) emissions (tons CO_2e)
- On-site nitrogen oxides (NOx) + sulfur oxides (SOx) + particulate matter (PM) (lbs)
- Total NOx + SOx + PM (lbs)
- On-site hazardous air pollutants (HAP) (lbs)
- Total HAPs (lbs)
- Refined material use (tons)
- Unrefined material use (tons)
- Waste (tons)
- Public water use (gallons)

Other aspects of environmental impacts were considered qualitatively.

Both the Conceptual Design Report (TerraTherm, 2012) and Draft Design Report (AMEC, 2013) were evaluated to illustrate how footprints can change as more information becomes available. For instance, a pre-design investigation conducted between the conceptual design and subsequent draft design increased the size of the TTZ, thus increasing the number of wells for injection and extraction and the amount of energy required to execute the remedy. At the same time, design improvements between the conceptual design and subsequent draft design incorporated efficiencies such as identifying existing wells that could be used in place of new injection or extraction wells. The SEFA tool was used to make calculations for quantitative footprints for four cases, as follows:

- Conceptual Design Report – “Base Case” (Recovered JP-4 Shipped Off-Site)
- Conceptual Design Report – “Alt 1” (Recovered JP-4 Used Within the Remedy)
- Draft Design Report – “Base Case” (Recovered JP-4 Shipped Off-Site)
- Draft Design Report – “Alt 1” (Recovered JP-4 Used Within the Remedy)

Attachments 1 through 4 provide the basis of the SEFA inputs for each of the four cases.

3.2 Summary of Quantitative Footprints – Overall Results

A summary of the overall quantitative footprints for each of the four cases is presented below.

Overall Quantitative Footprint Results

Metric	Conceptual Design (February 2012)		Draft Design (October 2013)		Units
	Base Case	Alt 1	Base Case	Alt 1	
Energy	662,738	461,976	837,999	581,230	MMBTU
Total GHG	48,395	34,190	61,021	42,852	Tons CO2e
On-site NOx+SOx+PM	40,239	223,569	44,632	313,072	Pounds
Total NOx+SOx+PM	401,106	364,327	549,671	502,628	Pounds
On-site HAPs	29	44	33	57	Pounds
Total HAPs	2,479	2,451	3,455	3,419	Pounds
Refined Material Use	550	550	367	367	Tons
Unrefined Material Use	44	44	32	32	Tons
Waste	693	693	465	465	Tons
Public Water Use	53,000,000	53,000,000	62,662,000	62,662,000	Gallons

GHG = greenhouse gas; NOx = nitrogen oxides; SOx = sulfur oxides, PM = particulate matter; HAPs = hazardous air pollutants; MMBTU = million British Thermal Units; CO_2e *= carbon dioxide equivalent of global warming potential.*

Observations from the overall results for these footprints include the following:

- For results based on both the Conceptual Design Report (TerraTherm, 2012) and the Draft Design Report (AMEC, 2013), there is a substantial reduction in energy and emissions footprints between the “Base Case” (recovered JP-4 shipped off-site) and “Alt 1” (recovered JP-4 used within the remedy). As detailed in Table 1, this is due to several factors:

    - Within the “Alt 1” scenarios, the natural gas usage is reduced by re-use of the recovered JP-4. The reduction in natural gas usage represents 95 to 99 percent of the difference between the “Base Case” and “Alt-1” results for energy and emissions footprints, depending on the metric. For “Alt 1,” some other fuel is still likely to be combusted off-site in place of the JP-4 not being recycled, but the footprint for that combustion is not considered to be part of the footprints of this remedy.

    - Within the “Alt 1” scenarios, the recovered JP-4 does not require transport to an off-site facility. This represents 1 to 5 percent of the difference between the “Base Case” and “Alt-1” results for energy and emissions footprints, depending on the metric.

  Note that in both cases, the same amount of JP-4 is ultimately combusted (off-site in the “Base Case” and on-site in “Alt-1”). Thus, the vast majority of the footprint reductions afforded by re-use of the recovered JP-4 within the remedy results from reducing the amount of natural gas needed for the remedy.

- Some of the footprints (such as total energy use, GHG emissions, total NOx+SOx+PM, emissions and water use) are higher for the calculations based on the draft design compared to the earlier conceptual design. This is primarily due to the increased area of the TTZ identified during the pre-design investigation (conducted after the conceptual design but before the draft design), which requires more steam and electricity. The increases for these footprints are slightly offset by optimization efforts (such as the option to re-use existing wells that was incorporated between the conceptual design and draft design). However, the dominant driver for these footprints are the steam and electricity requirements which increased between conceptual and draft design based on the associated increase in the TTZ area.

- On-site NOx+SOx+PM is much greater in the "Alt 1" scenarios than the base case, due primarily to much higher on-site NOx emissions from the on-site combustion of JP-4.

- Other footprints (such as materials use and waste) are lower for the calculations based on the draft design compared to the earlier conceptual design. This is primarily due to optimization options identified between the conceptual design and draft design regarding (1) re-using existing wells when possible and (2) reducing the number of wells to be abandoned, which reduces the quantities of new well materials (steel, cement grout and sand) and also reduces the amount of soil cuttings requiring off-site disposal.

Section 3.3 provides additional findings regarding key contributors to specific footprints.

3.3 Key Footprint Contributors for Specific Footprints

In addition to reviewing the overall results for specific footprints (such as total energy use), it is instructive to develop an understanding of the relative contributions to those footprints from different aspects of the remedy. A summary of key contributors to specific footprints is summarized below.

Key Footprint Contributors – Energy Use

Total Energy Use (MMBTU)	**Conceptual Design (February 2012)**				**Draft Design (October 2013)**			
	Base Case		**Alt 1**		**Base Case**		**Alt 1**	
Construction	5,358	**0.8%**	5,358	**1.2%**	4,647	**0.6%**	4,647	**0.8%**
Abandoning Wells	1,565	**0.2%**	1,565	**0.3%**	212	**0.03%**	212	**0.04%**
O&M – Electricity	102,289	**15.4%**	102,289	**22.1%**	145,088	**17.3%**	145,088	**25.0%**
O&M – NG and JP-4	550,705	**83.1%**	349,942	**75.7%**	684,695	**81.7%**	427,926	**73.6%**
O&M – Other	1,990	**0.3%**	1,990	**0.4%**	2,533	**0.3%**	2,533	**0.4%**
Personnel Transport	831	**0.1%**	831	**0.2%**	825	**0.1%**	825	**0.1%**
Total	*662,738*	***100.0%***	*461,976*	***100.0%***	*837,999*	***100.0%***	*581,230*	***100.0%***

MMBTU = million British thermal units; O&M = operations and maintenance; NG = natural gas; JP-4 = jet propellant grade 4.

Key Footprint Contributors – Total GHG Emissions

Total GHG (Tons CO_2e)	Conceptual Design (February 2012)				Draft Design (October 2013)			
	Base Case		Alt 1		Base Case		Alt 1	
Construction	626	**1.3%**	626	**1.8%**	405	**0.7%**	405	**0.9%**
Abandoning Wells	203	**0.4%**	203	**0.6%**	22	**0.04%**	22	**0.05%**
O&M – Electricity	6,460	**13.3%**	6,460	**18.9%**	9,163	**15.0%**	9,163	**21.4%**
O&M – NG and JP-4	40,645	**84.0%**	26,440	**77.3%**	50,879	**83.4%**	32,711	**76.3%**
O&M – Other	393	**0.8%**	393	**1.1%**	484	**0.8%**	484	**1.1%**
Personnel Transport	67	**0.1%**	67	**0.2%**	67	**0.1%**	67	**0.16%**
Total	*48,395*	***100.0%***	*34,190*	***100.0%***	*61,021*	***100.0%***	*42,852*	***100.0%***

GHG = greenhouse gas; CO_2e = carbon dioxide equivalent of global warming potential; O&M = operations and maintenance; NG = natural gas; JP-4 = jet propellant grade 4.

Key Footprint Contributors – Total NOx + SOx + PM Emissions

Total NOx+SOx+PM (lbs)	Conceptual Design (February 2012)				Draft Design (October 2013)			
	Base Case		Alt 1		Base Case		Alt 1	
Construction	6,403	**1.6%**	6,403	**1.8%**	6,264	**1.1%**	6,264	**1.2%**
Abandoning Wells	2,085	**0.5%**	2,085	**0.6%**	320	**0.06%**	320	**0.06%**
O&M – Electricity	116,818	**29.1%**	116,818	**32.1%**	165,696	**30.1%**	165,696	**33.0%**
O&M – NG and JP-4	269,699	**67.2%**	232,920	**63.9%**	370,055	**67.3%**	323,012	**64.3%**
O&M – Other	5,143	**1.3%**	5,143	**1.4%**	6,386	**1.2%**	6,386	**1.3%**
Personnel Transport	957	**0.2%**	957	**0.3%**	951	**0.2%**	951	**0.2%**
Total	*401,106*	***100.0%***	*364,327*	***100.0%***	*549,671*	***100.0%***	*502,628*	***100.0%***

NOx = nitrogen oxides; SOx = sulfur oxides; PM = particulate matter; O&M = operations and maintenance; NG = natural gas; JP-4 = jet propellant grade 4.

Key Footprint Contributors – Total HAPs Emissions

Total HAPs (lbs)	Conceptual Design (February 2012)				Draft Design (October 4, 2013)			
	Base		Alt 1		Base		Alt 1	
Construction	42	**1.7%**	42	**1.7%**	34	**1.0%**	34	**1.0%**
Abandoning Wells	9	**0.4%**	9	**0.4%**	1	**0.03%**	1	**0.03%**
O&M – Electricity	2,320	**93.6%**	2,320	**94.7%**	3,290	**95.2%**	3,290	**96.2%**
O&M – NG and JP-4	81	**3.3%**	53	**2.2%**	102	**3.0%**	66	**1.9%**
O&M – Other	26	**1.0%**	26	**1.1%**	26	**0.8%**	26	**0.8%**
Personnel Transport	1	**0.04%**	1	**0.04%**	1	**0.03%**	1	**0.03%**
Total	*2,479*	***100.0%***	*2,451*	***100.0%***	*3,455*	***100.0%***	*3,419*	***100.0%***

HAPs = hazardous air pollutants; O&M = operations and maintenance; NG = natural gas; JP-4 = jet propellant grade 4.

Observations regarding the key contributors to specific footprints include the following:

- For total energy use, the combustion of natural gas and recovered JP-4 is the dominant contributor (approximately 74 to 83 percent), followed by electricity use (approximately 13 to 21 percent). Other energy use associated with well drilling equipment or transportation of personnel is small compared to the energy use associated with remedy O&M (that is primarily driven by steam production and treatment of vapors using natural gas and JP-4 fuels).

- The same key footprint contributors that drive the energy use footprint also drive GHG emissions and total NOx + SOx + PM emissions footprints. The percentage contributions for the key contributors to the GHG emissions are similar to those for energy use. However, electricity use provides a higher percentage of the total footprint for NOx + SOx + PM emissions than for the footprints for energy use or GHG emissions.

- For total HAPs emissions, the dominant contributor is electricity usage, which causes more than 90 percent of the HAPs emissions footprint. The next biggest contributor is the combustion of natural gas and recovered JP-4, but those represent less than 5 percent of the total.

Electricity use is a major contributor to the energy and emissions footprints. The site team provided the following information for the key components of electrical usage incorporated in the energy estimates for the Draft Design Report (AMEC, 2013):

- The steam injection system (boilers) accounts for approximately 4 percent of electricity usage.

- The extraction system (educator feed pumps) accounts for approximately 42 percent of electricity usage.

- The process system (vacuum blower, air stripper blower, thermal accelerators, treatment process pumps, cooling tower, and several other treatment process items) accounts for approximately 50 percent of electricity usage.

- Other utility items (load centers, air compressors) account for approximately 4 percent of electricity usage.

Contributors to other footprints are limited:

- Materials - The sole contributors accounted for are the drilling activities for injection wells, extraction wells, temperature monitoring points, and abandoning wells.

- Water Use - The sole contributor accounted for is the water use for steam production (for instance, well development water was considered negligible and was not quantified).

- Waste - The sole contributor accounted for is soil cuttings disposed of as non-hazardous waste.

Note that water sent to the POTW is not considered “waste” in the same manner as soil cuttings, but energy and emissions footprints for treatment at the POTW are included as part of the “O&M-Other” remedy category included in the tables above.

3.4 Non-Quantitative Items

As part of a GR evaluation, it is also appropriate to consider qualitative impacts caused by the remedy (positive or negative), in addition to the footprints that are quantified. The following are examples of qualitative considerations associated with this remedy:

- According to the Draft Design Report (AMEC, 2013), fugitive emissions will be prevented by maintaining negative pressures across most of the TTZ and keeping the existing shallow soil vapor extraction system operational. In addition, most vapor collection piping will be operated under a net negative pressure (until the inlet of the thermal accelerators), so that any minute leaks will result in vapors staying within the piping and not leaking out of the system. The control of fugitive emissions is part of the air “core element” in GR but it is not possible to quantify the benefits of these aspects of the design since there is no control system in place that quantifies it.

- There is no major improvement or degradation to ecosystems anticipated from this remedy.

- There is potential for a minor, short-term community impact with respect to disruption of traffic or parking patterns resulting from the remedy implementation. These are being addressed with a site management plan and community relations plan.

- There is potential for aesthetic impacts from dust during remedy construction, and that is being addressed with a dust control plan.

- There is no plan to use renewable energy as part of the remedy, which is consistent with the short-term nature of this remediation technology.

Some of these items (such as traffic and dust management) are not mentioned in the Conceptual Design Report (TerraTherm, 2012) but are addressed in the subsequent and more detailed Draft Design Report (AMEC, 2013). This is similar to the quantitative aspects of a GR evaluation, where latter phases of design have the benefit of additional information and detail.

4.0 GREEN REMEDIATION "OPTIMIZATION" AND "BEST PRACTICES" HIGHLIGHTED FOR THIS APPLICATION OF SEE

The design and planned implementation of ISTT using SEE at Site ST012 includes many examples of optimization or best practices that support GR. Examples include the following:

- Consideration of using heat exchange to recover energy from the extraction zone for steam generation
- Steam injection optimization
- Re-use of treated water as part of the remedy where practical
- Re-use of equipment from the pilot test where feasible
- Use of alternative fuels and catalytic converters
- Inclusion of fugitive emissions capture as part of the design
- Consideration of "greener" options for electricity mix or purchase of Renewable Energy Certificates (RECs)

Information on these best practices is included below. Another practice that was considered but could not be applied for this specific application of ISTT using SEE was cogeneration (combined heat and power [CHP]). The site team determined that CHP was not feasible for this project given high initial investment required for CHP and the short-term nature of the remedy (the steam equipment will be rented, and CHP is not common in rental equipment). Instead, the site team designed boilers (and thermal accelerators) that operate using gas, diesel and recovered product to allow for reduced overall energy use and emissions (by using recovered JP-4 on-site for these aspects of the remedy).

4.1 Consideration of Using of Heat Exchange to Recover Energy from the Extraction Zone for Steam Generation

During the site visit meeting on November 19, 2013, TerraTherm indicated that energy recovered from heat exchange associated with treatment of vapors and liquids (removed from the ground at high temperatures) was being considered to help heat the water for steam generation. This approach would reduce the energy use required for steam generation, resulting in reduced emissions of GHG and priority pollutants (such as NOx, SOx and PM). The amount of energy potentially afforded by this recovery option was not quantified in the Draft Design Report (October 4, 2013), and ultimately this was not implemented due to site-specific cost-benefit analysis, but recapture of heat for beneficial use is a general "best practice" for ISTT remedies.

4.2 Steam Injection Optimization

The design of the ISTT remedy using SEE incorporates optimization of the steam injection in several ways, including the following:

- Based on results from temperature modeling and monitoring, adjustments will be made to the steam injection over time by zone. The injection of steam into three different vertical zones is more complex than most steam remedies, because there are more opportunities for heat leakage that could be represented inaccurately in the model. Thus, adjustments to the design should be expected throughout the operating period of the remedy.

- Early injection of steam in the lower zone will provide "pre-heating" for the zone above.

- After the breakthrough of steam to the extraction wells, the use of pressure cycling will enhance recovery and reduce the required amount of steam injection.

- Wells can be used for either injection or extraction, and therefore, well use can change as the remedy progresses. A well initially planned for extraction can be used for injection if that adds efficiency to the remedy, and vice versa.

During the site visit meeting on November 19, 2013, the site team indicated that there is no real way to know how much steam use reduction is achieved by such optimization, but suggested it could be on the order of 25 to 50 percent. If it is assumed that such optimization practices cut steam usage and time of steam application on the order of 25 to 50 percent, and utilities required for steam production represents the greatest contributor to the energy and emissions footprints, then this optimization achieves a correspondingly significant reduction for the overall remedy.

4.3 Re-Use of Treated Water as Part of the Remedy Where Practical

Some of the treated water will be re-used as circulation water for the extraction pumps which are self-cleaning, inductor-type "mud pumps." The re-use of this treated water within the remedy is a "best practice." The draft design estimates that the remaining 235 gallons per minute (gpm) will be treated and discharged. The site team believes that after the water goes through the POTW, it is infiltrated back into the aquifer such that there is no net resource lost regionally. The site team indicated it considered options for treating this water for subsequent re-use within the remedy (such as making steam in the boiler), but the treatment process would be too costly to justify.

4.4 Re-Use of Equipment from the Previous Pilot Test Where Feasible

Some equipment from the previous pilot test is being re-used in the full-scale implementation of the remedy including wells and a cooling tower. However, much of the equipment from the pilot test could not be re-used because it is not compatible with the full-scale design or is not of appropriate size.

4.5 Use of Alternative Fuels and Catalytic Converters

During the site visit meeting on November 19, 2013, the well driller was observed to be using ultra-low sulfur diesel or catalytic converters. The fuel use from drilling represents a very minor contributor to the overall remedy footprints, but nevertheless this approach is a “best practice” that was represented in the quantitative footprints presented in Section 3.

4.6 Inclusion of Fugitive Emissions Capture as Part of the Design

As discussed in Section 3.4, according to the Draft Design Report (AMEC, 2013), fugitive emissions will be prevented by maintaining negative pressures across most of the TTZ and keeping the existing shallow soil vapor extraction system operational. In addition, most vapor collection piping will be operated under a net negative pressure (until the inlet of the thermal accelerators), to allow for the capture of vapor from minute leaks into the piping, not out of the system. The control of fugitive emissions is a “best practice” associated with the air “core element” in GR.

4.7 Consideration of “Greener” Options for Electricity Mix or Purchase of RECs

The electricity for this project is purchased from the Salt River Project (SRP). The site team indicated that although the SRP service territory is open to competitive electricity suppliers, there are currently no competitive electricity suppliers certified by the Arizona Corporation Commission. Thus, SRP is currently the sole option. The site team has determined that purchase of RECs is available through SRP under a pilot program. Conceptually, purchase of RECS supports development of renewable energy projects and can be considered to offset footprints accordingly. The utility offers RECs (wind), currently priced at $1.39 per 100 kWh, and has offered longer term programs for solar power. To date, the site contractor has not pursued the purchase of RECs because such purchases were not part of the negotiated contract with the Air Force. Therefore, there has been some consideration of energy mix and purchase of RECs for this project, but there are no possible actions to be taken in those regards at this time.

5.0 REFERENCES

AMEC. 2013. ”Draft Remedial Design and Remedial Action Work Plan for Operable Unit 2, Revised Groundwater Remedy, Site ST012.” October 4.

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EPA. 2012b. “eGRID2012 Version 1.0 Year 2009 Summary Tables.” April. Accessed in January 2014 at: http://www.epa.gov/cleanenergy/documents/egridzips/eGRID2012V1_0_year09_SummaryTables.pdf.

EPA. 2013. “Spreadsheets for Environmental Footprint Analysis (SEFA).” January 28. Accessed in January 2014 at: http://www.clu-in.org/greenremediation/methodology/.

TerraTherm, Inc. 2012. “Conceptual Design Report, In Situ Thermal Treatment Project, Former Williams Air Force Base, Site ST012.” February.

TABLES

Table 1.
Footprint-Related Remedy Items from the
Conceptual Design Report and Draft Design Report

Item	Conceptual Design Report (TerraTherm, 2012)	*__Changes__* Included in Draft Remedial Design (AMEC, 2013)
Injection Wells	• Cobble zone (6 injection wells) o Casing to 145 feet (ft) (6*145 = 870 linear ft) o Screen 145 to 160 ft (6*15 = 90 linear ft) • Upper Water Bearing Zone (UWBZ) (10 injection wells) o Casing to 170 ft (10*170 = 1700 linear ft) o Screen 170 to 195 ft (10*25 = 250 linear ft) • Lower Saturated Zone (LSZ) (15 injection wells) o Casing to 210 ft (15*210 = 3150 linear ft) o Screen 210 to 245 ft (15*35 = 525 linear ft) • Casings are steel, screens are stainless steel • Additional construction materials include sand and cement grout • Report indicates “4 to 6 inch wells,” use estimate for pounds of materials and cuttings, per linear foot, for 6 inch wells from Exhibit 3.6 (EPA, 2012a) • Assume diesel for drilling equipment • Consider development water de minimis for footprinting	• Cobble zone: no change (6 injection wells) • UWBZ: 2 of the 10 are existing wells and do not require new drilling, so will drill 8 new wells • LSZ: Increase from 15 to 18 wells, but 6 of the 18 are existing wells and do not require new drilling, so will drill 12 new wells • Chose biodiesel to represent ultra-low sulfur diesel for drilling equipment since it is a cleaner fuel choice than using diesel and SEFA does not have an option for ultra-low sulfur diesel (note: this assumption is based on observation of ultra-low sulfur diesel and catalytic converters during site visit)

Table 1.
Footprint-Related Remedy Items from the Conceptual Design Report and Draft Design Report

Item	Conceptual Design Report (TerraTherm, 2012)	***Changes*** **Included in Draft Remedial Design (AMEC, 2013)**
Extraction Wells-Multiphase Extraction (MPE)	• Cobble zone (11 MPE wells) ○ Casing to 145 ft (11*145 = 1595 linear ft) ○ Screen 145 to 160 ft (11*15 = 165 linear ft) • UWBZ zone (13 MPE wells) ○ Casing to 170 ft (13*170 = 2210 linear ft) ○ Screen 170 to 195 ft (13*25 = 325 linear ft) • LSZ zone (21 MPE wells) ○ Casing to 210 ft (21*210 = 4410 linear ft) ○ Screen 210 to 245 ft (21*35 = 735 linear ft) • Casings are steel, screens are stainless steel • Additional construction materials include sand and cement grout • Report indicates “4 to 6 inch wells”, use estimate for pounds of materials and cuttings, per linear foot, for 6 inch wells from Exhibit 3.6 (EPA, 2012a) • Assume diesel for drilling equipment • Consider development water de minimis for footprinting	• Cobble zone: increase in number of MPE wells from 11 to 13 • UWBZ: 6 of the 13 wells are existing and do not require new drilling, so will drill 7 new wells. Of the new wells, 5 are being installed at location of overdrilled wells. The report lists 14 “extraction wells,” but 1 of the 14 is “vapor probes” and that is discussed below as a separate item. • LSZ: Increase from 21 to 24 wells, but 11 of the 24 wells are existing and do not require new drilling, so will drill 13 new wells. Of the new wells, 1 is being installed at location of an overdrilled well. • Chose biodiesel to represent ultra-low sulfur diesel for drilling equipment since it is a cleaner fuel choice than using diesel and SEFA does not have an option for ultra-low sulfur diesel (note: this assumption is based on observation of ultra-low sulfur diesel and catalytic converters during site visit) • For new wells installed at locations of overdrilled wells, only count well cuttings once (not for overdrilling and then for drilling)
Vapor Probes	• None discussed in report so not included	• Only one location, being installed at location of an overdrilled well, only count well cuttings once (not for overdrilling and then for drilling) • Footprint for one vapor probe location considered de minimis

Table 1.
Footprint-Related Remedy Items from the
Conceptual Design Report and Draft Design Report

Item	Conceptual Design Report (TerraTherm, 2012)	*Changes* Included in Draft Remedial Design (AMEC, 2013)
Temperature Monitoring Points	• Report says at least 15 temperature monitoring points to be installed to bottom of target treatment zone (TTZ), assume 15 X 245 ft = 3675 linear feet • Assume steel casing and grout, use estimate for pounds of materials and cuttings, per linear foot, for 2 inch wells from Exhibit 3.6 (EPA, 2012a)	• Increase number of temperature monitoring points from 15 to 17 ○ 16 of the 17 are in the LSZ, assume 245 ft, 1 of the 17 will be to 195 ft per Drawing C106 ○ Total length (16*245) + (1*160) = 4080 linear feet, use same assumption for well and boring size • 12 of the 17 being installed at location of an overdrilled well, only count well cuttings once (not for overdrilling and then for drilling) • Chose biodiesel to represent ultra-low sulfur diesel for drilling equipment since it is a cleaner fuel choice than using diesel and SEFA does not have an option for ultra-low sulfur diesel (note: this assumption is based on observation of ultra-low sulfur diesel and catalytic converters during site visit)

Table 1.
Footprint-Related Remedy Items from the Conceptual Design Report and Draft Design Report

Item	Conceptual Design Report (TerraTherm, 2012)	*Changes* Included in Draft Remedial Design (AMEC, 2013)
Abandon Wells	• Based on Appendix A of the report, assume 109 vertical wells to abandon. Some have depth and material (steel or polyvinyl chloride [PVC]) indicated, some do not. For simplicity, assume average depth per well is 200 ft, and assume unknown material types are evenly split between steel and PVC, there would be 75 steel and 34 PVC. o Assume steel wells require a backhoe to dig down 5 feet to cut off top of casing, and then wells are filled with cement grout assuming 4-inch wells o Assume PVC wells overdrilled with hollow stem auger for a 8-inch boring consistent with a 4-inch finished well, with associated cuttings as waste, and filled with cement grout • Based on Section 7.4 of the Report, two horizontal wells installed in the LSZ will also be abandoned. Based on other site information, assume these are steel wells that will be cement grouted in place, and assume 6-inch wells with total of 1,400 linear feet to be filled with cement grout	• Based on Section 4.2.1.2 and Appendix G of the report, assume 25 vertical wells to abandon, of which 19 then have new wells or temperature monitoring points installed such that for those 19 the drilling is accounted for. Of the remaining six that are being abandoned, based on Appendix G there would be 4 PVC and 2 steel. For simplicity, assume average depth per well is 200 ft. o Assume steel wells require a backhoe to dig down 5 feet to cut off top of casing, and then wells are filled with cement grout assuming 4-inch wells o Assume PVC wells overdrilled with hollow stem auger for a 8-inch boring consistent with a 4-inch finished well, with associated cuttings as waste, and filled with cement grout • Based on Section 7.4 of the Report, two horizontal wells installed in the LSZ will also be abandoned. These are steel wells that will be cement grouted in place; assume 6-inch wells with total of 1,400 linear feet to be filled with cement grout
Manifolds and Pipe Fittings	• As a simplification, assume the following: o Estimate an average distance of 150 ft from wellhead to steam or treatment infrastructure o 76 total injection and extraction wells, assume 76 * 150 ft = 11,400 linear ft of 4-inch steel piping o Disregard materials for pipe supports and disregard equipment for installing the pipe	• Use same simplifying assumptions except use different number of wells o 84 total injection and extraction wells, assume 84 * 150 ft = 12,600 linear ft of 4-inch steel piping
Electricity Use	• Table 6.1 of Report indicates 7,997,000 kilowatt hour (kWh) of electricity usage	• Table 5.8 of Report indicates 11,343,000 kWh of electricity usage

Table 1.
Footprint-Related Remedy Items from the
Conceptual Design Report and Draft Design Report

Item	Conceptual Design Report (TerraTherm, 2012)	***Changes*** Included in Draft Remedial Design (AMEC, 2013)
Natural Gas Usage	• Table 6.1 of the Report indicates 350,000 MMBTU of natural gas usage, assuming no recovered JP-4 is used to offset natural gas usage for steam generation and/or vapor treatment ○ For "Base Case," assume no JP-4 is used to offset natural gas usage ○ For "Alt-1," based on Section 6.5 of the Report, assume 10,250,000 pounds (lbs) of JP-4 is recovered and is used to offset 190,000 MMBTU of natural gas usage ○ The amount of natural gas offset is based on Section 6.5 of the Report, which indicates JP-4 has an estimated heat content of 18,500 BTU/lb	• The Report does not specifically indicate natural gas usage; site team suggests scaling value from the Conceptual Design Report (TerraTherm, 2012) based on steam usage estimate, which is 319,357,000 lbs in the "draft design" and 280,000,000 lbs in the "conceptual design." 350,000 MMBTU * 319,357,000 / 280,000,000 = 400,000 MMBTU of natural gas usage, assuming no recovered JP-4 is used to offset natural gas usage for steam generation and/or vapor treatment ○ For "Base Case," assume no JP-4 is used to offset natural gas usage. ○ For "Alt-1," assume 13,140,000 lbs of JP-4 is recovered and is used to offset 243,000 MMBTU of natural gas usage. ○ The amount of natural gas offset is based on Section 6.5 of the Conceptual Design Report which indicates JP-4 has an estimated heat content of 18,500 BTU/lb.

Table 1.
Footprint-Related Remedy Items from the
Conceptual Design Report and Draft Design Report

<table>
<tr><th>Item</th><th>Conceptual Design Report
(TerraTherm, 2012)</th><th><u>Changes</u> Included in Draft Remedial Design
(AMEC, 2013)</th></tr>
<tr><td>Use of Recovered JP-4</td><td>• Table 6.1 of the Report indicates 1,383,000 gallons of JP-4 is expected to be recovered, and Section 6.4 indicates 10,250,000 lbs of JP-4 is expected to be recovered. This is approximately 7.41 pounds per gallon.
○ For “Base Case” assume 10,250,000 lbs of JP4 is combusted offsite as fuel, and also requires transportation to a recycling facility
○ For “Alt-1” assume 10,250,000 lbs of JP-4 is combusted on-site and therefore, does not require transportation to a recycling facility. Conceptually, an additional 10,250,000 lbs of JP-4 or some other fuel is also assumed to still be combusted off-site in place of the JP-4 not being recycled, but the footprint for that combustion is not considered to be part of the footprint of this remedy</td><td>• Section 3.3 in Appendix D of the Report states “The system is designed to treat a maximum of approximately 2,000,000 gallons (13,140,000 lbs) of non-aqueous phase liquid (NAPL).” This is approximately 6.57 pounds per gallon.
○ For “Base Case” assume 13,140,000 lbs of JP4 is combusted offsite as fuel, and also requires transportation to a recycling facility
○ For “Alt-1” assume 13,140,000 lbs of JP-4 is combusted on-site and therefore, does not require transportation to a recycling facility. Conceptually, an additional 13,140,000 lbs of JP-4 or some other fuel is also assumed to still be combusted off-site in place of the JP-4 not being recycled, but the footprint for that combustion is not considered to be part of the footprint of this remedy</td></tr>
<tr><td>Water Use</td><td>• Table 6.1 of the Report indicates 53,000,000 gallons of fresh water will be used for cooling tower make-up and steam generation.</td><td>• Table 5.10 in Appendix D of Report indicates 62,662,000 gallons of fresh water will be used for cooling tower make-up and steam generation.</td></tr>
<tr><td>Water Treatment at Publicly Owned Treatment Works (POTW)</td><td>• Table 6.1 of the Report indicates 80,000,000 gallons of water will be discharged to the POTW.</td><td>• Table 6.1 of Report indicates 110,250,000 gallons of water will be discharged to the POTW.</td></tr>
</table>

Table 1.
Footprint-Related Remedy Items from the
Conceptual Design Report and Draft Design Report

Item	**Conceptual Design Report (TerraTherm, 2012)**	***Changes* Included in Draft Remedial Design (AMEC, 2013)**
Soil Disposal	• Drill cuttings for the following (details described above): ○ 31 injection wells ○ 45 extraction wells ○ 15 temperature monitoring points ○ 34 abandoned PVC wells • Assume all waste transported on a ton mile basis. Details regarding quantities provided in waste transport/disposal section of Attachment A. Materials transported include soil cuttings for wells, temperature monitoring points and well abandonment	• Drill cuttings for the following (details described above): ○ 26 injection wells newly drilled ○ 33 extraction wells newly drilled ○ 1 vapor probe newly drilled ○ 17 temperature monitoring points ○ 4 abandoned PVC wells where new wells or temperature monitoring points listed above are not being installed (23 PVC wells being abandoned minus 19 of those where a new well or temperature monitoring point is being installed) • Similar approach for transportation (ton mile basis) but quantities change due to different number of wells, temperature monitoring points, well abandonments and the addition of one vapor probe location
Granular activated carbon (GAC)	• For polishing water treated by air stripper prior to discharge to POTW. Assume 20,000 lbs of virgin GAC	• No change. This is consistent with Section 5.10.10 of Appendix D of the Report which includes four 5,000-pound vessels, and indicates carbon may not be required throughout, so no carbon changes assumed.
Off-Site Lab	• Assumed to be minor and not included	• Assumed to be minor and not included
Transportation of Materials	• Assume all materials transported on a ton mile basis. Details regarding quantities are provided in materials section of Attachment A. Materials transported include the following: ○ Sand, cement (grout), steel and stainless steel for wells, temperature monitoring points and well abandonment ○ GAC ○ JP-4 sent off-site (for base case)	• Similar approach (ton mile basis), but quantities change due to different number of wells, temperature monitoring points, well abandonments and the addition of one vapor probe location, as well as the JP-4 quantity (for base case)

Table 1.
Footprint-Related Remedy Items from the
Conceptual Design Report and Draft Design Report

Item	Conceptual Design Report (TerraTherm, 2012)	*Changes* Included in Draft Remedial Design (AMEC, 2013)
Transportation of Equipment	• Assume all drilling equipment is transported on a per trip basis (to and from site assuming rig is driven) • Assume backhoe for abandoning steel wells is transported on a flatbed on a per trip basis (two round trips) • Details for trips are provided in the transport of materials and equipment section of Attachment A	• Similar approach (per trip basis for drill equipment and backhoe) but increase number of drill rigs from 3 to 5.
Transportation of Personnel	• Included rough estimates for the following types of travel: ○ Transportation of personnel during construction (drillers and contractors) ○ Operators during operation ○ Monthly meetings (air and ground transport) • Assumed quantities provided in transport for personnel section of Attachment A • Assume 402 days of operation	• Total operation period changes from 402 days to 422 days

Attachment 1:

Tables Detailing SEFA Input Based on Conceptual Design Report – "Base Case" (Recovered JP-4 Shipped Off-Site)

Attachment 1:
Tables Detailing SEFA Input Based on Conceptual Design Report – "Base Case"
(Recovered JP-4 Shipped Off-Site)

Table 1-A: Fuel Use for Equipment: Conceptual Design

Item for Footprint Evaluation	Source of Information and/or Comments	SEFA Input - Conceptual Design
Equipment used for the construction of the In-Situ Thermal Treatment (ISTT) system: • Installation of 31 steam injection wells	• Conceptual Design Report (TerraTherm, 2012) - Page 14 & 15 ○ 6 steam injection wells in Cobble Zone, 10 inches (in) Upper Water Bearing Zone (UWBZ), and 15 in Lower Saturated Zone (LSZ) • Injection wells in Cobble Zone = 145 feet (ft) of casing + 15 ft of screen each = 160 ft x 6 = 960 linear ft • Injection wells in UWBZ = 170 ft of casing + 25 ft of screen each = 195 ft x 10 = 1950 linear feet • Injection wells in LSZ = 210 ft of casing + 35 ft of screen each = 245 ft x 15 = 3675 linear feet • Air rotary drilling 6585 feet at 200 linear feet per day (EPA, 2012a) takes 32.925, 8-hour days = 263 hours of use	*On-Site Equipment Use, etc.* Selected: "Drilling – large rig", 500 horsepower (HP), 75% load factor, Diesel fuel, 263 hours operated 4931.25 Gallons of Fuel Used *WAFB_ConceptDesign-Base_energy.xlsx → Const. – New Wells → Row 31*
Equipment used for the construction of the ISTT system: • Installation of 45 multi-phase extraction (MPE) wells	• Conceptual Design Report, February 2012 - Page 14 & 16 ○ 11 MPE wells in Cobble Zone, 13 in Upper Water Bearing Zone (UWBZ), and 21 in Lower Saturated Zone (LSZ) • MPE wells in Cobble Zone = 145 ft of casing + 15ft of screen each = 160 ft x 11 = 1760 linear feet • MPE wells in UWBZ = 170 ft of casing + 25 ft of screen each = 195 ft x 13 = 2535 linear feet • MPE wells in LSZ = 210 ft casing + 35 ft of screen each = 245 ft x 21 = 5145 linear feet • Air rotary drilling 9440 feet at 200 linear feet per day (EPA, 2012a) takes 47.2, 8-hour days = 378 hours of use	*On-Site Equipment Use, etc.* Selected: "Drilling – large rig", 500 HP, 75% load factor, Diesel fuel, 378 hours operated 7087.5 Gallons of Fuel Used *WAFB_ConceptDesign-Base_energy.xlsx → Const. – New Wells → Row 32*
Equipment used for the construction of the ISTT system: • Installation of 15 temperature monitoring points	• Conceptual Design Report, February 2012 - Page 14 & 17 ○ "At least fifteen temperature monitoring points will be installed to the bottom of the TTZ across the Site." • Temp. Monitoring Points = 245 ft x 15 = 3675 linear feet • Air rotary drilling 3675 feet at 200 linear feet per day (EPA, 2012a) takes 18.375, 8-hour days = 147 hours of use	*On-Site Equipment Use, etc.* Selected: "Drilling – large rig", 500 HP, 75% load factor, Diesel fuel, 147 hours operated 2756.25 Gallons of Fuel Used *WAFB_ConceptDesign-Base_energy.xlsx → Const. – Temp Points → Row 31*

EPA (2012a) refers to "Methodology for Understanding and Reducing a Project's Environmental Footprint, February 2012"

Item for Footprint Evaluation	Source of Information and/or Comments	SEFA Input - Conceptual Design
Equipment used for the abandonment of PVC wells: • Use of drill rig to overdrill 34 PVC wells	• Conceptual Design Report, February 2012 - Appendix A ○ Based on Appendix A, assume 109 vertical wells to be abandoned ○ Only PVC wells require overdrilling, of which we assume there are 34 • For simplicity assume average depth of wells is 200 feet • 34 wells at 200 feet = 6800 of drilling required to abandon wells • Air rotary drilling 6800 feet at 200 linear feet per day (EPA, 2012a) takes 34, 8-hour days = 272 hours of use	*On-Site Equipment Use, etc.* Selected: "Drilling – large rig", 500 HP, 75% load factor, Diesel fuel, 272 hours operated 5100 Gallons of Fuel Used *WAFB_ConceptDesign-Base_energy.xlsx → Abandoning → Row 31*
Equipment used for the abandonment of Steel wells: • Use of backhoe to dig down to remove top of casing for 75 steel wells	• Conceptual Design Report, February 2012 - Appendix A ○ Based on Appendix A, assume 109 vertical wells to be abandoned ○ Only Steel wells require use of backhoe down to 5 feet, of which we assume there are 75 • For simplicity assume it takes a backhoe 2 hours at each well to dig 5 feet • 75 wells at 2 hours each of backhoe use = 150 hours of backhoe use	*On-Site Equipment Use, etc.* Selected: "Backhoe", 100 HP, 75% load factor, Diesel fuel, 150 hours operated 562.5 Gallons of Fuel Used *WAFB_ConceptDesign-Base_energy.xlsx → Abandoning → Row 32*

EPA (2012a) refers to "Methodology for Understanding and Reducing a Project's Environmental Footprint, February 2012"

Table 1-B: Materials Use: Conceptual Design

Item for Footprint Evaluation	Source of Information and/or Comments	SEFA Input - Conceptual Design
Construction of 31 Injection Wells • Steel for casing	• Conceptual Design Report, February 2012 - Page 15 & 17 ○ "Injection and extraction wells will be constructed of 4 inch (") to 6" stainless steel screens and carbon steel risers." Assume 6" casing • 18.97 pounds (lbs) of steel casing per foot of 6" well (EPA, 2012a) • 18.97 lbs per foot x 5720 total feet of casing = 108508 lbs of steel	*Material Use and Trans.* Selected: "Steel" Input: 108,508 lbs *WAFB_ConceptDesign-Base_energy.xlsx → Const. – New Wells → Row 67*
Construction of 31 Injection Wells • Sand for annulus	• Conceptual Design Report, February 2012 - Page 15 ○ Wells to have sandpack for entire screened interval plus 2 feet of additional sand above screen • 39 lbs of sand for annulus per foot of 6" well (EPA, 2012a) • 39 lbs per foot x (865 feet of screen + (2 feet of additional sand x 31 wells)) = 36153 lbs of sand	*Material Use and Trans.* Selected: "Gravel/sand/clay" Input: 36,153 lbs *WAFB_ConceptDesign-Base_energy.xlsx → Const. – New Wells → Row 68*
Construction of 31 Injection Wells • Grout for annulus	• Conceptual Design Report, February 2012 - Page 15 ○ Wells to be grouted for entire length of well casing minus the 2 feet of sand above screen • 25 lbs of grout for annulus per foot of 6" well (EPA, 2012a) • 25 lbs per foot x (5720 total feet of casing – 2 feet per well x 31 wells) = 141450 lbs of cement	*Material Use and Trans.* Selected: "Cement" Input: 141,450 lbs *WAFB_ConceptDesign-Base_energy.xlsx → Const. – New Wells → Row 69*
Construction of 31 Injection Wells • Stainless steel for screens	• Conceptual Design Report, February 2012 - Page 15 & 17 ○ "Injection and extraction wells will be constructed of 4" to 6" stainless steel screens and carbon steel risers." Assume 6" screens • 4.8 lbs of stainless steel screen per foot of 6" well (EPA, 2012a) • 4.8 lbs per foot x 865 total feet of screen = 4152 lbs of stainless steel	*Material Use and Trans.* Selected: "Stainless Steel" Input: 4,152 lbs *WAFB_ConceptDesign-Base_energy.xlsx → Const. – New Wells → Row 70*

EPA (2012a) refers to "Methodology for Understanding and Reducing a Project's Environmental Footprint, February 2012"

Item for Footprint Evaluation	Source of Information and/or Comments	SEFA Input - Conceptual Design
Construction of 45 Extraction (MPE) Wells • Steel for casing	• Conceptual Design Report, February 2012 - Page 16 & 17 ○ "Injection and extraction wells will be constructed of 4" to 6" stainless steel screens and carbon steel risers." Assume 6" casing • 18.97 lbs of steel casing per foot of 6" well (EPA, 2012a) • 18.97 lbs per foot x 8215 total feet of casing = 155839 lbs of steel	*Material Use and Trans.* Selected: "Steel" Input: 155,839 lbs *WAFB_ConceptDesign-Base_energy.xlsx* → *Const. – New Wells* → *Row 71*
Construction of 45 MPE Wells • Sand for annulus	• Conceptual Design Report, February 2012 - Page 16 ○ Wells to have sandpack for entire screened interval plus 2 feet of additional sand above screen • 39 lbs of sand for annulus per foot of 6" well (EPA, 2012a) • 39 lbs per foot x (1225 feet of screen + (2 feet of additional sand x 45 wells)) = 51285 lbs of sand	*Material Use and Trans.* Selected: "Gravel/sand/clay" Input: 51,285 lbs *WAFB_ConceptDesign-Base_energy.xlsx* → *Const. – New Wells* → *Row 72*
Construction of 45 MPE Wells • Grout for annulus	• Conceptual Design Report, February 2012 - Page 16 ○ Wells to be grouted for entire length of well casing minus the 2 feet of sand above screen • 25 lbs of grout for annulus per foot of 6" well (EPA, 2012a) • 25 lbs per foot x (8215 total feet of casing - 2 feet per well x 45 wells)= 203125 lbs of cement	*Material Use and Trans.* Selected: "Cement" Input: 20,3125 lbs *WAFB_ConceptDesign-Base_energy.xlsx* → *Const. – New Wells* → *Row 73*
Construction of 45 MPE Wells • Stainless steel for screens	• Conceptual Design Report, February 2012 - Page 16 & 17 ○ "Injection and extraction wells will be constructed of 4" to 6" stainless steel screens and carbon steel risers." Assume 6" screens • 4.8 lbs of stainless steel screen per foot of 6" well (EPA, 2012a) • 4.8 lbs per foot x 1225 total feet of screen = 5880 lbs of stainless steel	*Material Use and Trans.* Selected: "Stainless Steel" Input: 5,880 lbs *WAFB_ConceptDesign-Base_energy.xlsx* → *Const. – New Wells* → *Row 74*
Connection Piping • Steel for connecting wells to treatment	• Conceptual Design Report, February 2012 - Page 13 ○ Assuming an average of 150 feet from well head to treatment with 4" steel piping • 10.79 lbs of steel per foot of 4" diameter piping (EPA, 2012a) • 10.79 lbs per foot x (150 feet x 76 injection and extraction wells total) = 123006 lbs of steel	*Material Use and Trans.* Selected: "Steel" Input: 123,006 lbs *WAFB_ConceptDesign-Base_energy.xlsx* → *Const. – New Wells* → *Row 75*

EPA (2012a) refers to "Methodology for Understanding and Reducing a Project's Environmental Footprint, February 2012"

Item for Footprint Evaluation	Source of Information and/or Comments	SEFA Input - Conceptual Design
Initial GAC material Use	• Tetra Tech (TT) professional judgment: Initial GAC required for treatment system will be approximately 10 tons.	*Material Use and Trans.* Selected: "Virgin GAC (coal based)" Input: 20,000 lbs *WAFB_ConceptDesign-Base_energy.xlsx → O&M - Other → Row 68*
Construction of 15 Temperature Monitoring Points • Steel for casing	• Conceptual Design Report, February 2012 - Page 14 & 17 ○ "At least fifteen temperature monitoring points will be installed to the bottom of the TTZ across the Site." • 3.65 lbs of steel casing per foot of 2" well (EPA, 2012a) • 3.65 lbs per foot x (15 temp. monitoring points x 245 feet each) = 13413.75 lbs of steel	*Material Use and Trans.* Selected: "Steel" Input: 13,414 lbs *WAFB_ConceptDesign-Base_energy.xlsx → Const. – Temp Points → Row 67*
Construction of 15 Temperature Monitoring Points • Grout for annulus	• Conceptual Design Report, February 2012 - Page 14 & 17 ○ "At least fifteen temperature monitoring points will be installed to the bottom of the TTZ across the Site." • 13 lbs of grout for annulus per foot of 2" well (EPA, 2012a) • 13 lbs per foot x (15 temp. monitoring points x 245 feet each) = 47775 lbs of cement	*Material Use and Trans.* Selected: "Cement" Input: 47,775 lbs *WAFB_ConceptDesign-Base_energy.xlsx → Const. – Temp Points → Row 68*
Abandonment of PVC wells: • Grout for filling overdrilled, abandoned PVC wells	• For 34 PVC wells that required overdrilling to be abandoned, assume 8-inch boring is used to removed wells • Using material calculations for 8" well (interior diameter of 8") - 25 lbs of grout per foot to abandon 8" borehole (EPA, 2012a) • 25 lbs of grout per foot x 200 feet x 34 wells = 170000 lbs of cement	*Material Use and Trans.* Selected: "Cement" Input: 170,000 lbs *WAFB_ConceptDesign-Base_energy.xlsx → Abandoning → Row 67*

EPA (2012a) refers to "Methodology for Understanding and Reducing a Project's Environmental Footprint, February 2012"

Item for Footprint Evaluation	Source of Information and/or Comments	SEFA Input - Conceptual Design
Abandonment of Steel wells: • Grout for filling 4-inch steel wells	• For 75 - 4" steel wells, cut off top 5 feet and fill remaining 195 feet with grout • 6 lbs of grout per foot to abandon 4-inch well (EPA, 2012a) • 6 lbs of grout per foot x 195 feet x 75 wells = 87750 lbs of cement	*Material Use and Trans.* Selected: "Cement" Input: 87750 lbs *WAFB_ConceptDesign-Base_energy.xlsx → Abandoning → Row 68*
Abandonment of Horizontal wells: • Grout for filling 6-inch steel wells	• For 6" Steel horizontal wells, assume 1400 linear feet total are to be filled with cement grout • 14 lbs of grout per foot to abandon 6"well (EPA, 2012a) • 14 lbs of grout per foot x 1400 feet = 19600 lbs of cement	*Material Use and Trans.* Selected: "Cement" Input: 19600 lbs *WAFB_ConceptDesign-Base_energy.xlsx → Abandoning → Row 69*

Table 1-C: Transport for Materials and Equipment: Conceptual Design

Item for Footprint Evaluation	Source of Information and/or Comments	SEFA Input - Conceptual Design
Transportation of drilling equipment for installation of new wells, temperature monitoring points, and well abandoning • Air rotary drill rig	• TT estimates that 3 air rotary rigs will be used on the Site during construction process. • TT assumes that transportation for each rig will consist of the rig driving itself to the Site and driving off-site once construction is complete, for one roundtrip. • TT assumes a distance of 100 miles roundtrip to site.	*On-Site Equipment Use, etc.* Input: 1 roundtrips, 100 miles, Diesel 16.7 Gallons of Fuel Used each Input for each drill rig (3 times total) *WAFB_ConceptDesign-Base_energy.xlsx → Const. – New Wells → Row 31* *Plus* *WAFB_ConceptDesign-Base_energy.xlsx → Const. – Temp Points → Row 31* *Plus* *WAFB_ConceptDesign-Base_energy.xlsx → Abandoning → Row 31*

EPA (2012a) refers to "Methodology for Understanding and Reducing a Project's Environmental Footprint, February 2012"

Item for Footprint Evaluation	Source of Information and/or Comments	SEFA Input - Conceptual Design
Transportation of backhoe for abandonment of steel wells • Backhoe	• TT estimates that 1 backhoe will be used on the Site for abandoning steel wells. • TT assumes that backhoe will be transported to site on flatbed truck, consisting of 2 roundtrips to site. • TT assumes a distance of 100 miles roundtrip to site.	*On-Site Equipment Use, etc.* Input: 2 roundtrips, 100 miles, Diesel 33.3 Gallons of Fuel Used *WAFB_ConceptDesign-Base_energy.xlsx → Abandoning → Row 32*
Transportation of materials used in construction • All materials	• Professional judgment: The footprint for transportation of all construction materials should be quantified based on truck freight transport, in terms of gallons per ton-mile (gptm). • Weight for transportation of sand, cement, steel, stainless steel and GAC are equal to the amounts calculated in the Material Use section. • TT assumes 50 miles of transport to site for all materials.	*Material Use and Transportation* <u>For all materials</u> Input: 50 miles for transport Selected: Truck freight (gptm) for Mode of Transport, Diesel for Fuel Type Make this selection for all construction materials in Const. – New Wells, Const. – Temp Points, and Abandoning tabs 861.4 Gallons of Fuel Used Total for all Materials *WAFB_ConceptDesign-Base_energy.xlsx → Const. – New Wells → Row 67 thru 75* *Plus* *WAFB_ConceptDesign-Base_energy.xlsx → Const. – Temp Points → Row 67 & 68* *Plus* *WAFB_ConceptDesign-Base_energy.xlsx → Abandoning → Row 67 – 69* *Plus* *WAFB_ConceptDesign-Base_energy.xlsx → O&M - Other → Row 68*

EPA (2012a) refers to "Methodology for Understanding and Reducing a Project's Environmental Footprint, February 2012"

Item for Footprint Evaluation	Source of Information and/or Comments	SEFA Input - Conceptual Design
Transportation of JP4 off site to fuel recycler	• For base case, assume no recovered JP4 is used on site and all recovered JP4 is sent to recycler and will be combusted. • Amount of JP4 for transportation is given in Fuel Use for Operation table. • TT assumes 50 miles of transport to offsite recycler.	*Material Use and Transportation* Input: 50 miles for transport Selected: Truck freight (gptm) for Mode of Transport, Diesel for Fuel Type 7,431.2 Gallons of Fuel Used *WAFB_ConceptDesign-Base_energy.xlsx → O&M – JP4 Base → Row 67*

Table 1-D: Waste Transport/Disposal: Conceptual Design

Item for Footprint Evaluation	Source of Information and/or Comments	Input Values to SEFA - Concept
Disposal of drill cuttings in landfill • Cuttings from injection and extraction wells	• 61 lbs of drill cuttings for disposal per foot of 6" well (EPA, 2012a) • 6585 feet of drilling for injection wells + 9440 feet of drilling for extraction wells = 16025 feet total • 16025 feet of drilling x 61 lbs of cuttings per foot = 977525 lbs of cutting for disposal / 2000 lbs per ton = 488.7625 tons of cuttings for disposal • TT professional judgment: The footprint for transportation of all disposal to landfill should be quantified based on truck freight transport, in terms of gallons per ton-mile. • Transport to landfill is assumed to be 50 miles.	*Waste Transport and Disposal* Selected: Non-hazardous waste landfill Input: 488.7625 tons, 50 miles of transport Selected Truck freight (gptm), Diesel 708.7 Gallons of Fuel Used *WAFB_ConceptDesign-Base_energy.xlsx → Const. – New Wells → Row 89*

EPA (2012a) refers to "Methodology for Understanding and Reducing a Project's Environmental Footprint, February 2012"

Item for Footprint Evaluation	Source of Information and/or Comments	Input Values to SEFA - Concept
Disposal of drill cuttings in landfill • Cuttings from temperature monitoring point installation	• 39 lbs of drill cuttings for disposal per foot of 4" well (EPA, 2012a) • 3675 feet of drilling for temperature monitoring point installation • 3675 feet of drilling x 39 lbs of cuttings per foot = 143325 lbs of cutting for disposal / 2000 lbs per ton = 71.6625 tons of cuttings for disposal • TT professional judgment: The footprint for transportation of all disposal to landfill should be quantified based on truck freight transport, in terms of gallons per ton-mile. • Transport to landfill is assumed to be 50 miles.	*Waste Transport and Disposal* Selected: Non-hazardous waste landfill Input: 71.6625 tons, 50 miles of transport Selected Truck freight (gptm), Diesel 103.9 Gallons of Fuel Used *WAFB_ConceptDesign-Base_energy.xlsx → Const. – Temp Points → Row 89*
Disposal of drill cuttings in landfill • Cuttings from overdrilling of PVC wells to be abandoned	• 39 lbs of drill cuttings for disposal per foot of 4" well (EPA, 2012a) • 34 PVC wells x 200 feet each = 6800 feet of drilling for abandonment • 6800 feet of drilling x 39 lbs of cuttings per foot = 265200 lbs of cutting for disposal / 2000 lbs per ton = 132.6 tons of cuttings for disposal • TT professional judgment: The footprint for transportation of all disposal to landfill should be quantified based on truck freight transport, in terms of gallons per ton-mile. • Transport to landfill is assumed to be 50 miles.	*Waste Transport and Disposal* Selected: Non-hazardous waste landfill Input: 132.6 tons, 50 miles of transport Selected Truck freight (gptm), Diesel 192.3 Gallons of Fuel Used *WAFB_ConceptDesign-Base_energy.xlsx → Abandoning → Row 89*
Treated water discharge to POTW	• Conceptual Design Report, February 2012 - Page 28 ○ "An estimated 80,000,000 gallons of water will be extracted and treated during the thermal implementation."	*Waste Transport and Disposal* Selected: POTW Input: 80,000 Gallons x 1000 *WAFB_ConceptDesign-Base_energy.xlsx → O&M – Operating Costs → Row 89*

EPA (2012a) refers to "Methodology for Understanding and Reducing a Project's Environmental Footprint, February 2012"

Table 1-E: Transport for Personnel: Conceptual Design

Item for Footprint Evaluation	**Source of Information and/or Comments**	**SEFA Input - Conceptual Design**
Personnel transportation during construction • Drill rig operators	• TT estimated 2 person crew per air rotary rig, 3 rigs total. • TT estimated 20 miles roundtrip for site labor to travel to site. • 19700 linear feet total for drilling of injection wells, extraction wells, and temp monitoring points • 6800 linear feet total for over drilling of PVC wells for abandonment • 26500 feet / 200 feet per day / 3 rigs operating at a time = 44 days drillers are on site	*Labor, Mobilizations, Mileage, and Fuel* Input: 6 Drillers during construction, 6 crew, 44 days, 8 hours per day, 264 trips, 20 miles roundtrip Selected: Car, Gasoline 220 Gallons of Fuel Used *WAFB_ConceptDesign-Base_energy.xlsx → Const. – Personnel Transport → Row 16*
Personnel transportation during construction • Contractors	• TT estimated 6 person crew during drilling and other construction for estimated 120 days. • TT estimated 20 miles roundtrip for site labor to travel to site.	*Labor, Mobilizations, Mileage, and Fuel* Input: 6 Contractors during construction, 6 crew, 120 days, 8 hours per day, 720 trips, 20 miles roundtrip Selected: Car, Gasoline 600 Gallons of Fuel Used *WAFB_ConceptDesign-Base_energy.xlsx → Const. – Personnel Transport → Row 17*
Permanent operator transportation during O&M period	• Conceptual Design Report, February 2012 - Page 28 ○ 402 days of pre-heating, steam injection, and post-treatment • TT estimated 20 miles roundtrip for site labor to travel to site.	*Labor, Mobilizations, Mileage, and Fuel* Input: 2 Permanent Operators, 2 crew, 402 days, 8 hours per day, 804 trips, 20 miles roundtrip Selected: Car, Gasoline 670 Gallons of Fuel Used *WAFB_ConceptDesign-Base_energy.xlsx → O&M – Operator Travel→ Row 16*

EPA (2012a) refers to "Methodology for Understanding and Reducing a Project's Environmental Footprint, February 2012"

Item for Footprint Evaluation	Source of Information and/or Comments	SEFA Input - Conceptual Design
Other support personnel transportation during O&M period	• TT estimated 2 additional support staff on site for 100 days during operation. • TT estimated 20 miles roundtrip for site labor to travel to site.	*Labor, Mobilizations, Mileage, and Fuel* Input: 2 support personnel, 2 crew, 100 days, 8 hours per day, 200 trips, 20 miles roundtrip Selected: Car, Gasoline 167 Gallons of Fuel Used *WAFB_ConceptDesign-Base_energy.xlsx → O&M – Operator Travel → Row 17*
Personnel transportation for monthly meetings • Air travel for meeting	• TT estimated 4 personnel need to travel by air for meetings. • Assume 18 meetings over period of construction and O&M. • Traveling 2000 miles roundtrip by airplane	*Labor, Mobilizations, Mileage, and Fuel* Input: Travel for meetings - Air, 4 crew, 18 days, 8 hours per day, 72 trips, 2000 miles roundtrip Selected: Airplane, Diesel 3,200 Gallons of Fuel Used *WAFB_ConceptDesign-Base_energy.xlsx → O&M – Meeting Travel → Row 16*
Personnel transportation for monthly meetings • Travel by car for meetings	• TT estimated 8 personnel need to travel by car for meetings. • Assume 18 meetings over period of construction and O&M • Traveling 100 miles roundtrip by car	*Labor, Mobilizations, Mileage, and Fuel* Input: Travel for meetings - Ground, 8 crew, 18 days, 8 hours per day, 144 trips, 100 miles roundtrip Selected: Car, Gasoline 600 Gallons of Fuel Used *WAFB_ConceptDesign-Base_energy.xlsx → O&M – Meeting Travel → Row 17*

EPA (2012a) refers to "Methodology for Understanding and Reducing a Project's Environmental Footprint, February 2012"

Table 1-F: Electricity Use: Conceptual Design

Item for Footprint Evaluation	Source of Information and/or Comments	SEFA Input - Conceptual Design
Electricity use for ISTT system – O&M	• Conceptual Design Report, February 2012 - Page 25 & 28 ○ "The ISTT system will require an estimated 1,000-1,500 kVa power feed to the Site to power the steam generation and effluent treatment systems." ○ Utility usage estimated to be 7,997,000 kWh	*On-Site Electricity Use* Input: 7,997,000 7,997,000 kWh, Energy Used *WAFB_ConceptDesign-Base_energy.xlsx → O&M - Elec → Row 59*

EPA (2012a) refers to "Methodology for Understanding and Reducing a Project's Environmental Footprint, February 2012"

Table 1-G: Fuel Use for Operating: Conceptual Design

Item for Footprint Evaluation	Source of Information and/or Comments	SEFA Input - Conceptual Design
Natural Gas use for ISTT system – O&M	• Conceptual Design Report, February 2012 - Page 28 ○ "Approx. 70 MMBTU/hr of natural gas for use as fuel for steam generation and for thermal oxidation." ○ Gas usage estimated to be 350,000 MMBTU total • 350,000 MMBTU = $3.5x10^{11}$ BTUs • 1 ccf = 100 cubic feet = 103,000 BTUs	*On-Site Natural Gas Use* Input: 350,000,000,000 BTUs, 3,398,058 ccf *WAFB_ConceptDesign-Base_energy.xlsx → O&M – Natural Gas → Row 48*
Recovered JP4 combusted off-site – O&M	• Conceptual Design Report, February 2012 - Page 28 ○ Recovered fuel = 1,383,000 gallons • For base case, assume no recovered JP4 is used on site and all recovered JP4 is sent to recycler and will be combusted. JP4 combustion will be included in this remedy's footprint as if it was combusted on site.	*Material Use* Selected: JP4 Combustion (JP4 Combustion is a user defined input for Activity #1. See Table J for details regarding input) Input: 1,383,000 gallons *WAFB_ConceptDesign-Base_energy.xlsx → O&M – JP4 Base → Row 67*

EPA (2012a) refers to "Methodology for Understanding and Reducing a Project's Environmental Footprint, February 2012"

Table 1-H: Water Use: Conceptual Design

Item for Footprint Evaluation	Source of Information and/or Comments	SEFA Input - Conceptual Design
Public Water use for cooling tower and creation of steam	• Conceptual Design Report, February 2012 - Page 28 ○ "Approx. 150 gpm of fresh water for cooling tower make-up and steam generation." ○ Fresh water usage estimated to be 53,000,000 gallons total	*Material Use* Selected: Public Water Input: 53,000 gallons x 1000 *WAFB_ConceptDesign-Base_energy.xlsx → O&M – Operating Costs→ Row 67*

EPA (2012a) refers to "Methodology for Understanding and Reducing a Project's Environmental Footprint, February 2012"

Table 1-I: eGRID Subregion AZNM—WECC Southwest, 2009 Characteristics

Electricity Source	Fuel Mix %
Nonrenewable Resource	
Coal	38.5979
Oil	0.0598
Gas	35.6808
Other Fossil	0.0013
Nuclear	16.4726
Other Unknown / Purchased Fuel	0.0000
Nonrenewable Total	90.8124
Renewable Resource	
Wind	0.5008
Solar	0.1012
Geothermal	2.1789
Biomass	0.3166
Hydro	6.0901
Renewable Total	9.1876

Source: EPA eGRID 2012 files,
http://www.epa.gov/cleanenergy/energy-resources/egrid/index.html

Table 1-J: User defined input for combustion of JP4 – Conceptual Design

Footprint for combustion of JP4 (per gallon)*		
Tons per Gal	0.0037057**	tons
Energy	0.1315	MMBTU/unit
CO2e	21.05	lbs/unit
NOx	0.14	lbs/unit
SOx	0.00495	lbs/unit
PM	0.00197	lbs/unit
Air Toxics	0.0000221	lbs/unit

* *Based on the assumption that the footprint for combustion of JP4 is equivalent to 50% of the footprint for combustion of gasoline plus 50% of the footprint for combustion of diesel.*

** *Weight per unit for JP4 is based on values provided in the Conceptual Design Report that indicate recovered JP4 will be 1,383,000 gallons and 10,250,000 pounds.*

Attachment 2:

Tables Detailing SEFA Input Based on Conceptual Design Report – "Alt 1" (Recovered JP-4 Used Within the Remedy)

"Alt 1" specifies a different use of the recovered JP-4 fuel. In the "Base Case," the recovered JP-4 is shipped off-site and subsequently combusted as fuel. In "Alt 1,"the recovered JP-4 is used on site and offsets some of the natural gas required (and the transportation of JP-4 offsite is eliminated). The only differences in SEFA input relative to the "Base Case" using information from the Conceptual Design Report are the following:

Table 2-C: Transport for Materials and Equipment: Conceptual Design

Item for Footprint Evaluation	Source of Information and/or Comments	SEFA Input - Conceptual Design
Transportation of JP4 off site to fuel recycler	• JP4 Transport off site is eliminated	NO INPUT

Table 2-G: Fuel Use for Operating: Conceptual Design

Item for Footprint Evaluation	Source of Information and/or Comments	SEFA Input - Conceptual Design
Natural Gas use for ISTT system – O&M	• Conceptual Design Report, February 2012 - Page 28 ○ Recovered JP4 = 1,383,000 gallons ○ Original Natural Gas use = 350,000 MMBTUs • Assume that 10,250,000 lbs of JP-4 is recovered and is used to offset 190,000 MMBTUs of Natural Gas • Natural Gas consumption for Alternative 1 = 350,000 MMBTUs – 190,000 MMBTUs = 160,000 MMBTUs of Natural Gas • 160,000 MMBTUs = 1553398 ccf	*On-Site Natural Gas Use* Input: 160,000,000,000 BTUs, 1553398 ccf *WAFB_ConceptDesign-Alt1_energy.xlsx → O&M – Natural Gas → Row 48*

Attachment 2:
Tables Detailing SEFA Input Based on Conceptual Design Report – "Alt 1"
(Recovered JP-4 Used Within the Remedy)

Item for Footprint Evaluation	**Source of Information and/or Comments**	**SEFA Input - Conceptual Design**
Recovered JP4 use for Steam or Oxidizer – O&M	• Conceptual Design Report, February 2012 - Page 28 o Recovered fuel = 1,383,000 gallons • For alternative case assume all recovered JP4 is used on site and no transportation for JP4 is required	*On-Site: Other forms of on-site conventional energy use* Define: JP4 Combustion as Other form of on-site conventional energy use #1 (Row 39 of User Defined Factors tab) (See Table J for details regarding input) Input: 1,383,000 gallons *WAFB_ConceptDesign-Alt1_energy.xlsx → O&M – JP4 Alt1 → Row 101*

Attachment 3:

Tables Detailing SEFA Input Based on Draft Design Report – "Base Case" (Recovered JP-4 Shipped Off-Site)

Attachment 3:
Tables Detailing SEFA Input Based on Draft Design Report – "Base Case"
(Recovered JP-4 Shipped Off-Site)

Table 3-A: Fuel Use for Equipment: Draft Design

Item for Footprint Evaluation	Source of Information and/or Comments	SEFA Input - Draft Design
Equipment used for the construction of the ISTT system: • Installation of 26 newly drilled steam injection wells	• Draft Design Report, October 4, 2013 – Appendix G, Page 1-2 ○ 6 newly installed steam injection wells in Cobble Zone, 8 newly installed in Upper Water Bearing Zone (UWBZ), and 12 newly installed in Lower Saturated Zone (LSZ) • Injection wells in Cobble Zone = 145 ft of casing + 15ft of screen each = 160 ft x 6 = 960 linear feet • Injection wells in UWBZ = 170 ft of casing + 25 ft of screen each = 195 ft x 8 = 1560 linear feet • Injection wells in LSZ = 210 ft of casing + 35 ft of screen each = 245 ft x 12 = 2940 linear feet • Air rotary drilling and sonic (both large rigs) 5460 feet at 200 linear feet per day (EPA, 2012a) takes 27.3, 8-hour days = 218 hours of use • Assume biodiesel based on observation of ultra-low sulfur diesel use and catalytic converters for drill rigs during site visit (SEFA has no option for ultra-low sulfur diesel)	*On-Site Equipment Use, etc.* Selected: "Drilling – large rig", 500 horsepower (HP), 75% load factor, BioDiesel fuel, 218 hours operated 4,496.25 Gallons of Fuel Used *WAFB_DraftDesign-Base_energy.xlsx → Const. – New Wells → Row 31*
Equipment used for the construction of the ISTT system: • Installation of 33 newly drilled multi-phase extraction (MPE) wells	• Draft Design Report, October 4, 2013 – Appendix G, Page 1-2 ○ 13 newly installed MPE wells in Cobble Zone, 7 newly installed in Upper Water Bearing Zone (UWBZ), and 13 newly installed in Lower Saturated Zone (LSZ) • MPE wells in Cobble Zone = 145 ft of casing + 15ft of screen each = 160 ft x 13 = 2080 linear feet • MPE wells in UWBZ = 170 ft of casing + 25 ft of screen each = 195 ft x 7 = 1365 linear feet • MPE wells in LSZ = 210 ft casing + 35 ft of screen each = 245 ft x 13 = 3185 linear feet • Air rotary drilling and sonic (both large rigs) 6630 feet at 200 linear feet per day (EPA, 2012a) takes 33.15, 8-hour days = 265 hours of use. • Assume biodiesel based on observation of ultra-low sulfur diesel use and catalytic converters for drill rigs during site visit (SEFA has no option for ultra-low sulfur diesel)	*On-Site Equipment Use, etc.* Selected: "Drilling – large rig", 500 HP, 75% load factor, BioDiesel fuel, 265 hours operated 5,465.625 Gallons of Fuel Used *WAFB_DraftDesign-Base_energy.xlsx → Const. – New Wells → Row 32*

EPA (2012a) refers to" Methodology for Understanding and Reducing a Project's Environmental Footprint, February 2012"

Attachment 3:
Tables Detailing SEFA Input Based on Draft Design Report – "Base Case"
(Recovered JP-4 Shipped Off-Site)

Item for Footprint Evaluation	Source of Information and/or Comments	SEFA Input - Draft Design
Equipment used for the construction of the ISTT system: • Installation of 17 temperature monitoring points • 16 to 245 ft • 1 to 195 ft	• Draft Design Report, October 4, 2013 – Appendix G, Page 3 ○ "5 New Probes and 12 from Well to be Abandoned" • Temp. Monitoring Points = ((16 temp. monitoring points x 245 feet) + (1 temp. monitoring points x 195 feet)) = 4115 linear feet • Air rotary drilling and sonic (both large rigs) 4115 feet at 200 linear feet per day (EPA, 2012a) takes 20.575, 8-hour days = 165 hours of use. • Assume biodiesel based on observation of ultra-low sulfur diesel use and catalytic converters for drill rigs during site visit (SEFA has no option for ultra-low sulfur diesel)	*On-Site Equipment Use, etc.* Selected: "Drilling – large rig", 500 HP, 75% load factor, BioDiesel fuel, 165 hours operated 3,403.125 Gallons of Fuel Used *WAFB_DraftDesign-Base_energy.xlsx → Const. – Temp Points → Row 31*
Equipment used for the abandonment of PVC wells: • Use of drill rig to overdrill 4 PVC wells (others accounted for in new wells or probes)	• Draft Design Report, October 4, 2013 – Appendix G, Page 3 ○ Only PVC wells require overdrilling, of which we assume there are 4 • For simplicity assume average depth of wells is 200 feet • 4 wells at 200 feet = 800 of drilling required to abandon wells • Sonic drilling 800 feet at 200 linear feet per day (EPA, 2012a) takes 4 days, 8-hour days = 32 hours of use. • Assume biodiesel based on observation of ultra-low sulfur diesel use and catalytic converters for drill rigs during site visit (SEFA has no option for ultra-low sulfur diesel)	*On-Site Equipment Use, etc.* Selected: "Drilling – large rig", 500 HP, 75% load factor, BioDiesel fuel, 32 hours operated 660 Gallons of Fuel Used *WAFB_DraftDesign-Base_energy.xlsx → Abandoning → Row 31*
Equipment used for the abandonment of Steel wells: • Use of backhoe to dig down to remove top of casing for 2 steel wells	• Draft Design Report, October 4, 2013 – Appendix G, Page 3 ○ Only Steel wells require use of backhoe down to 5 feet, of which we assume there are 2 • For simplicity assume it takes a backhoe 2 hours at each well to dig 5 feet • 2 wells at 2 hours each of backhoe use = 4 hours of backhoe use	*On-Site Equipment Use, etc.* Selected: "Backhoe", 100 HP, 75% load factor, Diesel fuel, 4 hours operated 15 Gallons of Fuel Used *WAFB_DraftDesign-Base_energy.xlsx → Abandoning → Row 32*

EPA (2012a) refers to" Methodology for Understanding and Reducing a Project's Environmental Footprint, February 2012"

Table 3-B: Materials Use: Draft Design

Item for Footprint Evaluation	Source of Information and/or Comments	SEFA Input - Draft Design
Construction of 26 Newly Drilled Injection Wells • Steel for casing	• Draft Design Report, October 4, 2013 – Appendix D, Page 33 ○ Injection and extraction wells will be constructed of 6" steel pipe to surface. • 18.97 lbs of steel casing per foot of 6" well (EPA, 2012a) • 18.97 lbs per foot x 4750 total feet of casing = 90108 lbs of steel	*Material Use and Trans.* Selected: "Steel" Input: 90,108 lbs *WAFB_DraftDesign-Base_energy.xlsx → Const. – New Wells → Row 67*
Construction of 26 Newly Drilled Injection Wells • Sand for annulus	• Draft Design Report, October 4, 2013 – Appendix D, Page 33 ○ Wells to have sandpack for entire screened interval plus 2 feet of additional sand above screen. • 39 lbs of sand for annulus per foot of 6" well (EPA, 2012a) • 39 lbs per foot x (710 feet of screen + (2 feet of additional sand x 26 wells)) = 29718 lbs of sand	*Material Use and Trans.* Selected: "Gravel/sand/clay" Input: 29,718 lbs *WAFB_DraftDesign-Base_energy.xlsx → Const. – New Wells → Row 68*
Construction of 26 Newly Drilled Injection Wells • Grout for annulus	• Draft Design Report, October 4, 2013 – Appendix D, Page 33 ○ Wells to be grouted for entire length of well casing minus the 2 feet of sand above screen. • 25 lbs of grout for annulus per foot of 6" well (EPA, 2012a) • 25 lbs per foot x (4750 total feet of casing – 2 feet per well x 26 wells) = 117450 lbs of cement	*Material Use and Trans.* Selected: "Cement" Input: 117,450 lbs *WAFB_DraftDesign-Base_energy.xlsx → Const. – New Wells → Row 69*
Construction of 26 Newly Drilled Injection Wells • Stainless steel for screens	• Draft Design Report, October 4, 2013 – Appendix D, Page 33 ○ Injection and extraction wells will be constructed of 6" stainless steel screen. • 4.8 lbs of stainless steel screen per foot of 6" well (EPA, 2012a) • 4.8 lbs per foot x 710 total feet of screen = 3408 lbs of stainless steel	*Material Use and Trans.* Selected: "Stainless Steel" Input: 3,408 lbs *WAFB_DraftDesign-Base_energy.xlsx → Const. – New Wells → Row 70*

EPA (2012a) refers to" Methodology for Understanding and Reducing a Project's Environmental Footprint, February 2012"

Item for Footprint Evaluation	Source of Information and/or Comments	SEFA Input - Draft Design
Construction of 33 Newly Drilled Extraction (MPE) Wells • Steel for casing	• Draft Design Report, October 4, 2013 – Appendix D, Page 33 ○ Injection and extraction wells will be constructed of 6" steel pipe to surface. • 18.97 lbs of steel casing per foot of 6" well (EPA, 2012a) • 18.97 lbs per foot x 5805 total feet of casing = 110121 lbs of steel	*Material Use and Trans.* Selected: "Steel" Input: 110,121 lbs *WAFB_DraftDesign-Base_energy.xlsx → Const. – New Wells → Row 71*
Construction of 33 Newly Drilled • Sand for annulus	• Draft Design Report, October 4, 2013 – Appendix D, Page 33 ○ Wells to have sandpack for entire screened interval plus 2 feet of additional sand above screen. • 39 lbs of sand for annulus per foot of 6" well (EPA, 2012a) • 39 lbs per foot x (825 feet of screen + (2 feet of additional sand x 33 wells)) = 34749 lbs of sand	*Material Use and Trans.* Selected: "Gravel/sand/clay" Input: 34,749 lbs *WAFB_DraftDesign-Base_energy.xlsx → Const. – New Wells → Row 72*
Construction of 33 Newly Drilled • Grout for annulus	• Draft Design Report, October 4, 2013 – Appendix D, Page 33 ○ Wells to be grouted for entire length of well casing minus the 2 feet of sand above screen. • 25 lbs of grout for annulus per foot of 6" well (EPA, 2012a) • 25 lbs per foot x (5805 total feet of casing - 2 feet per well x 33 wells)= 143475 lbs of cement	*Material Use and Trans.* Selected: "Cement" Input: 143,475 lbs *WAFB_DraftDesign-Base_energy.xlsx → Const. – New Wells → Row 73*
Construction of 33 Newly Drilled • Stainless steel for screens	• Draft Design Report, October 4, 2013 – Appendix D, Page 33 ○ Injection and extraction wells will be constructed of 6" stainless steel screen. • 4.8 lbs of stainless steel screen per foot of 6" well (EPA, 2012a) • 4.8 lbs per foot x 825 total feet of screen = 3960 lbs of stainless steel	*Material Use and Trans.* Selected: "Stainless Steel" Input: 3,960 lbs *WAFB_DraftDesign-Base_energy.xlsx → Const. – New Wells → Row 74*
Connection Piping • Steel for connecting wells to treatment	• Draft Design Report, October 4, 2013 – Figure 3-3 ○ Assuming an average of 150 feet from well head to treatment with 4" steel piping • 10.79 lbs of steel per foot of 4" diameter piping (EPA, 2012a) • 10.79 lbs per foot x (150 feet x 84 total injection and extraction wells total) = 135954 lbs of steel	*Material Use and Trans.* Selected: "Steel" Input: 135,954 lbs *WAFB_DraftDesign-Base_energy.xlsx → Const. – New Wells → Row 75*

EPA (2012a) refers to" Methodology for Understanding and Reducing a Project's Environmental Footprint, February 2012"

Item for Footprint Evaluation	Source of Information and/or Comments	SEFA Input - Draft Design
Initial GAC material Use	• TT professional judgment: Initial GAC required for treatment system will be approximately 10 tons.	*Material Use and Trans.* Selected: "Virgin GAC (coal based)" Input: 20,000 lbs *WAFB_DraftDesign-Base_energy.xlsx → O&M - Other → Row 68*
Construction of 17 Temperature Monitoring Points • Steel for casing • 16 to 245 ft • 1 to 195 ft	• Draft Design Report, October 4, 2013 – Appendix D, Page 32 & 34 ○ 17 temperature monitoring strings installed to lower limit of TTZ • 3.65 lbs of steel casing per foot of 2" well (EPA, 2012a) • 3.65 lbs per foot x ((16 temp. monitoring points x 245 feet) + (1 temp. monitoring points x 195 feet)) = 15020 lbs of steel	*Material Use and Trans.* Selected: "Steel" Input: 15,020 lbs *WAFB_DraftDesign-Base_energy.xlsx → Const. – Temp Points → Row 67*
Construction of 17 Temperature Monitoring Points • Grout for annulus • 16 to 245 ft • 1 to 195 ft	• Draft Design Report, October 4, 2013 – Appendix D, Page 32 & 34 ○ 17 temperature monitoring strings installed to lower limit of TTZ • 13 lbs of grout for annulus per foot of 2" well (EPA, 2012a) • 13 lbs per foot x ((16 temp. monitoring points x 245 feet) + (1 temp. monitoring points x 195 feet)) = 53495 lbs of cement	*Material Use and Trans.* Selected: "Cement" Input: 53,495 lbs *WAFB_DraftDesign-Base_energy.xlsx → Const. – Temp Points → Row 68*
Abandonment of PVC wells: • Grout for filling overdrilled, abandoned PVC wells	• Draft Design Report, October 4, 2013 – Appendix G, Page 3 • For 4 PVC wells that required overdrilling to be abandoned, assume 8-inch boring is used to removed wells • Using material calculations for 8" well (interior diameter of 8") - 25 lbs of grout per foot to abandon 8" borehole (EPA, 2012a) • 25 lbs of grout per foot x 200 feet x 4 wells = 20000 lbs of cement	*Material Use and Trans.* Selected: "Cement" Input: 20,000 lbs *WAFB_DraftDesign-Base_energy.xlsx → Abandoning → Row 67*

EPA (2012a) refers to" Methodology for Understanding and Reducing a Project's Environmental Footprint, February 2012"

Attachment 3:
Tables Detailing SEFA Input Based on Draft Design Report – "Base Case"
(Recovered JP-4 Shipped Off-Site)

Item for Footprint Evaluation	Source of Information and/or Comments	SEFA Input - Draft Design
Abandonment of Steel wells: • Grout for filling 4" steel wells	• Draft Design Report, October 4, 2013 – Appendix G, Page 3 • For 2 - 4" steel wells, cut off top 5 feet and fill remaining 195 feet with grout • 6 lbs of grout per foot to abandon 4"well (EPA, 2012a) • 6 lbs of grout per foot x 195 feet x 2 wells = 2340 lbs of cement	*Material Use and Trans.* Selected: "Cement" Input: 2,340 lbs *WAFB_DraftDesign-Base_energy.xlsx → Abandoning → Row 68*
Abandonment of Horizontal wells: • Grout for filling 6"steel wells	• Draft Design Report, October 4, 2013 – Appendix G, Page 3 • For 6" Steel horizontal wells, assume 1400 linear feet total are to be filled with cement grout • 14 lbs of grout per foot to abandon 6"well (EPA, 2012a) • 14 lbs of grout per foot x 1400 feet = 19600 lbs of cement	*Material Use and Trans.* Selected: "Cement" Input: 19,600 lbs *WAFB_DraftDesign-Base_energy.xlsx → Abandoning → Row 69*

EPA (2012a) refers to" Methodology for Understanding and Reducing a Project's Environmental Footprint, February 2012"

Table 3-C: Transport for Materials and Equipment: Draft Design

Item for Footprint Evaluation	Source of Information and/or Comments	SEFA Input - Draft Design
Transportation of drilling equipment for installation of new wells, temperature monitoring points, and well abandoning • Air rotary drill rig	• TT estimates that 5 air rotary rigs will be used on the Site during construction process based on observation during site visit. • TT assumes that transportation for each rig will consist of the rig driving itself to the Site and driving off-site once construction is complete, for one roundtrip. • TT assumes a distance of 100 miles roundtrip to site.	*On-Site Equipment Use, etc.* Input: 1 roundtrips, 100 miles, Diesel 16.7 Gallons of Fuel Used each Input for each drill rig (5 times total) *WAFB_DraftDesign-Base_energy.xlsx → Const. – New Wells → Row 31 & 32* *Plus* *WAFB_DraftDesign-Base_energy.xlsx → Const. – Temp Points → Row 31 & 32* *Plus* *WAFB_DraftDesign-Base_energy.xlsx → Abandoning → Row 31*
Transportation of backhoe for abandonment of steel wells • Backhoe	• TT estimates that 1backhoe will be used on the Site for abandoning steel wells. • TT assumes that backhoe will be transported to site on flatbed truck, consisting of 2 roundtrips to site. • TT assumes a distance of 100 miles roundtrip to site.	*On-Site Equipment Use, etc.* Input: 2 roundtrips, 100 miles, Diesel 33.3 Gallons of Fuel Used *WAFB_DraftDesign-Base_energy.xlsx → Abandoning → Row 32*

Item for Footprint Evaluation	Source of Information and/or Comments	SEFA Input - Draft Design
Transportation of materials used in construction • All materials	• TT professional judgment: The footprint for transportation of all construction materials should be quantified based on truck freight transport, in terms of gallons per ton-mile. • Weight for transportation of sand, cement, steel, stainless steel, and GAC are equal to the amounts calculated in the Material Use section. • Assume 50 miles of transport to site for all materials	*Material Use and Transportation* <u>For all materials</u> Input: 50 miles for transport Selected: Truck freight (gptm) for Mode of Transport, Diesel for Fuel Type Make this selection for all construction materials in Const. – New Wells, Const. – Temp Points, and Abandoning tabs 579.6 Gallons of Fuel Used Total for all Materials *WAFB_DraftDesign-Base_energy.xlsx → Const. – New Wells → Row 67 thru 75* *Plus* *WAFB_DraftDesign-Base_energy.xlsx → Const. – Temp Points → Row 67 & 68* *Plus* *WAFB_DraftDesign-Base_energy.xlsx → Abandoning → Row 67 – 69* *Plus* *WAFB_DraftDesign-Base_energy.xlsx → O&M - Other → Row 68*
Transportation of JP4 off site to fuel recycler	• For base case assume no recovered JP4 is used on site and all recovered JP4 is sent to recycler and will be combusted. • Amount of JP4 for transportation is given in Fuel Use for Operation table. • Assume 50 miles of transport to offsite recycler	*Material Use and Transportation* Input: 50 miles for transport Selected: Truck freight (gptm) for Mode of Transport, Diesel for Fuel Type 9,526.5 Gallons of Fuel Used *WAFB_DraftDesign-Base_energy.xlsx → O&M – JP4 Base → Row 67*

EPA (2012a) refers to" Methodology for Understanding and Reducing a Project's Environmental Footprint, February 2012"

Table 3-D: Waste Transport/Disposal: Draft Design

Item for Footprint Evaluation	Source of Information and/or Comments	SEFA Input - Draft Design
Disposal of drill cuttings in landfill • Cuttings from injection and extraction wells	• 61 lbs of drill cuttings for disposal per foot of 6" well (EPA, 2012a) • 5460 feet of drilling for injection wells + 6630 feet of drilling for extraction wells = 12090 feet total • 12090 feet of drilling x 61 lbs of cuttings per foot = 737490 lbs of cutting for disposal / 2000 lbs per ton = 368.745 tons of cuttings for disposal • TT professional judgment: The footprint for transportation of all disposal to landfill should be quantified based on truck freight transport, in terms of gallons per ton-mile. • Transport to landfill assumed to be 50 miles	*Waste Transport and Disposal* Selected: Non-hazardous waste landfill Input: 368.745 tons, 50 miles of transport Selected Truck freight (gptm), Diesel 534.7 Gallons of Fuel Used *WAFB_DraftDesign-Base_energy.xlsx → Const. – New Wells → Row 89*
Disposal of drill cuttings in landfill • Cuttings from temperature monitoring point installation	• 39 lbs of drill cuttings for disposal per foot of 4" well (EPA, 2012a) • 4115 feet of drilling for temperature monitoring point installation • 4115 feet of drilling x 39 lbs of cuttings per foot = 160485 lbs of cutting for disposal / 2000 lbs per ton = 80.243 tons of cuttings for disposal • TT professional judgment: The footprint for transportation of all disposal to landfill should be quantified based on truck freight transport, in terms of gallons per ton-mile. • Transport to landfill assumed to be 50 miles	*Waste Transport and Disposal* Selected: Non-hazardous waste landfill Input: 80.243 tons, 50 miles of transport Selected Truck freight (gptm), Diesel 116.4 Gallons of Fuel Used *WAFB_DraftDesign-Base_energy.xlsx → Const. – Temp Points → Row 89*
Disposal of drill cuttings in landfill • Cuttings from overdrilling of PVC wells to be abandoned (not counting wells/probes being installed at overdrilled locations, those already accounted for)	• 39 lbs of drill cuttings for disposal per foot of 4" well (EPA, 2012a) • 4 PVC wells x 200 feet each = 800 feet of drilling for abandonment • 800 feet of drilling x 39 lbs of cuttings per foot = 31200 lbs of cutting for disposal / 2000 lbs per ton = 15.6 tons of cuttings for disposal • TT professional judgment: The footprint for transportation of all disposal to landfill should be quantified based on truck freight transport, in terms of gallons per ton-mile. • Transport to landfill assumed to be 50 miles	*Waste Transport and Disposal* Selected: Non-hazardous waste landfill Input: 15.6 tons, 50 miles of transport Selected Truck freight (gptm), Diesel 22.6 Gallons of Fuel Used *WAFB_DraftDesign-Base_energy.xlsx → Abandoning → Row 89*

EPA (2012a) refers to" Methodology for Understanding and Reducing a Project's Environmental Footprint, February 2012"

Item for Footprint Evaluation	Source of Information and/or Comments	SEFA Input - Draft Design
Treated water discharge to POTW	• Draft Design Report, October 4, 2013 – Appendix D, Page 30 ○ 110,250,000 gallons total	*Waste Transport and Disposal* Selected: POTW Input: 110,250 Gallons x 1000 *WAFB_DraftDesign-Base_energy.xlsx → O&M – Other → Row 89*

EPA (2012a) refers to" Methodology for Understanding and Reducing a Project's Environmental Footprint, February 2012"

Table 3-E: Transport for Personnel: Draft Design

Item for Footprint Evaluation	Source of Information and/or Comments	SEFA Input - Draft Design
Personnel transportation during construction • Drill rig operators	• TT estimated 2 person crew per air rotary rig, 5 rigs total. • TT estimated 20 miles roundtrip for site labor to travel to site. • 16205 linear feet total for drilling of injection wells, extraction wells, and temp monitoring points. • 800 linear feet total for over drilling of PVC wells for abandonment • 17005 feet / 200 feet per day / 5 rigs operating at a time = 17 days drillers are on site	*Labor, Mobilizations, Mileage, and Fuel* Input: 10 Drillers during construction, 10 crew, 17 days, 8 hours per day, 170 trips, 20 miles roundtrip Selected: Car, Gasoline 142 Gallons of Fuel Used *WAFB_DraftDesign-Base_energy.xlsx → Const. – Personnel Transport → Row 16*
Personnel transportation during construction • Contractors	• TT estimated 6 person crew during drilling and other construction for estimated 120 days • TT estimated 20 miles roundtrip for site labor to travel to site	*Labor, Mobilizations, Mileage, and Fuel* Input: 6 Contractors during construction, 6 crew, 120 days, 8 hours per day, 720 trips, 20 miles roundtrip Selected: Car, Gasoline 600 Gallons of Fuel Used *WAFB_DraftDesign-Base_energy.xlsx → Const. – Personnel Transport → Row 17*
Permanent operator transportation during O&M period	• Draft Design Report, October 4, 2013 – Appendix D, Page 27 ○ 422 days of pre-heating, steam injection, and post-treatment • TT estimated 20 miles roundtrip for site labor to travel to site	*Labor, Mobilizations, Mileage, and Fuel* Input: 2 Permanent Operators, 2 crew, 422 days, 8 hours per day, 844 trips, 20 miles roundtrip Selected: Car, Gasoline 703 Gallons of Fuel Used *WAFB_DraftDesign-Base_energy.xlsx → O&M – Operator Travel → Row 16*

EPA (2012a) refers to" Methodology for Understanding and Reducing a Project's Environmental Footprint, February 2012"

Item for Footprint Evaluation	Source of Information and/or Comments	SEFA Input - Draft Design
Other support personnel transportation during O&M period	• TT estimated 2 additional support staff on site for 100 days during operation. • TT estimated 20 miles roundtrip for site labor to travel to site.	*Labor, Mobilizations, Mileage, and Fuel* Input: 2 support personnel, 2 crew, 100 days, 8 hours per day, 200 trips, 20 miles roundtrip Selected: Car, Gasoline 167 Gallons of Fuel Used *WAFB_DraftDesign-Base_energy.xlsx → O&M – Operator Travel → Row 17*
Personnel transportation for monthly meetings • Air travel for meeting	• TT estimated 4 personnel need to travel by air for meetings. • Assume 18 meetings over period of construction and O&M. • Traveling 2000 miles roundtrip by airplane	*Labor, Mobilizations, Mileage, and Fuel* Input: Travel for meetings - Air, 4 crew, 18 days, 8 hours per day, 72 trips, 2000 miles roundtrip Selected: Airplane, Diesel 3,200 Gallons of Fuel Used *WAFB_DraftDesign-Base_energy.xlsx → O&M – Meeting Travel → Row 16*
Personnel transportation for monthly meetings • Travel by car for meetings	• TT estimated 8 personnel need to travel by car for meetings. • Assume 18 meetings over period of construction and O&M. • Traveling 100 miles roundtrip by car	*Labor, Mobilizations, Mileage, and Fuel* Input: Travel for meetings - Ground, 8 crew, 18 days, 8 hours per day, 144 trips, 100 miles roundtrip Selected: Car, Gasoline 600 Gallons of Fuel Used *WAFB_DraftDesign-Base_energy.xlsx → O&M – Meeting Travel → Row 17*

EPA (2012a) refers to" Methodology for Understanding and Reducing a Project's Environmental Footprint, February 2012"

Table 3-F: Electricity Use: Draft Design

Item for Footprint Evaluation	Source of Information and/or Comments	SEFA Input - Draft Design
Electricity use for ISTT system – O&M	• Draft Design Report, October 4, 2013 – Appendix D, Page 28 ○ "The power usage for the SEE system is estimated to be approximately 11.3 million kilowatt hours (kWh)." ○ Utility usage estimated to be 11,343,000 kWh	*On-Site Electricity Use* Input: 11,343,000 11,343,000 kWh, Energy Used *WAFB_DraftDesign-Base_energy.xlsx → O&M - Elec → Row 59*

EPA (2012a) refers to" Methodology for Understanding and Reducing a Project's Environmental Footprint, February 2012"

Table 3-G: Fuel Use for Operating: Draft Design

Item for Footprint Evaluation	Source of Information and/or Comments	SEFA Input - Draft Design
Natural Gas use for ISTT system – O&M	• Draft Design Report does not specifically indicate natural gas usage. See Table 1 in body of this report. ○ Gas usage estimated to be 400,000 MMBTU total • 400,000 MMBTU = 4.0×10^{11} BTUs • 1 ccf = 100 cubic feet = 103,000 BTUs	*On-Site Natural Gas Use* Input: 400,000,000,000 BTUs, 3,883,495 ccf *WAFB_DraftDesign-Base_energy.xlsx → O&M – Natural Gas → Row 48*
Recovered JP4 combusted off-site – O&M	• Draft Design Report, October 4, 2013 – Appendix D, Page 8 ○ "The system is designed to treat a maximum of approximately 2,000,000 gallons of non-aqueous phase liquid (NAPL)." ○ Recovered fuel = 2,000,000 gallons • For base case assume no recovered JP4 is used on site and all recovered JP4 is sent to recycler and will be combusted. JP4 combustion will be included in this remedy's footprint as if it was combusted on site.	*Material Use* Selected: JP4 Combustion (JP4 Combustion is a user defined input for Activity #1. See Table J for details regarding input) Input: 2,000,000 Gallons *WAFB_DraftDesign-Base_energy.xlsx → O&M – JP4 Base → Row 67*

EPA (2012a) refers to" Methodology for Understanding and Reducing a Project's Environmental Footprint, February 2012"

Table 3-H: Water Use: Draft Design

Item for Footprint Evaluation	Source of Information and/or Comments	SEFA Input - Draft Design
Public Water use for cooling tower and creation of steam	• Draft Design Report, October 4, 2013 – Appendix D, Page 30 ○ Fresh water usage estimated to be 62,662,000 gallons total	*Material Use* Selected: Public Water Input: 62,662 gallons x 1000 *WAFB_DraftDesign-Base_energy.xlsx → O&M – Other → Row 67*

EPA (2012a) refers to" Methodology for Understanding and Reducing a Project's Environmental Footprint, February 2012"

Table 3-I: eGRID Subregion AZNM—WECC Southwest, 2009 Characteristics

Electricity Source	Fuel Mix %
Nonrenewable Resource	
Coal	38.5979
Oil	0.0598
Gas	35.6808
Other Fossil	0.0013
Nuclear	16.4726
Other Unknown / Purchased Fuel	0.0000
Nonrenewable Total	90.8124
Renewable Resource	
Wind	0.5008
Solar	0.1012
Geothermal	2.1789
Biomass	0.3166
Hydro	6.0901
Renewable Total	9.1876

Source: EPA eGRID 2012 files,
http://www.epa.gov/cleanenergy/energy-resources/egrid/index.html

Table 3-J: User defined input for combustion of JP4 - Draft Design

Footprint for combustion of JP4 (per gallon)*		
Tons per Gal	0.003285**	tons
Energy	0.1315	MMBTU/unit
CO2e	21.05	lbs/unit
NOx	0.14	lbs/unit
SOx	0.00495	lbs/unit
PM	0.00197	lbs/unit
Air Toxics	0.0000221	lbs/unit

* *Based on the assumption that the footprint for combustion of JP4 is equivalent to 50% of the foot print for combustion of gasoline plus 50% of the footprint for combustion of diesel.*

** *Weight per unit for JP4 is based on values provided in Draft Design Report that indicate recovered JP4 will be 2,000,000 gallons and 13,140,000 pounds. This is a different conversion rate between gallons and pounds than in the Conceptual Design Report*

Attachment 4:

Tables Detailing SEFA Input Based on Draft Design Report – "Alt 1" (Recovered JP-4 Used Within the Remedy)

"Alt 1" specifies a different use of the recovered JP-4 fuel. In the "Base Case," the recovered JP-4 is shipped off-site and subsequently combusted as fuel. In "Alt 1,"the recovered JP-4 is used on site and offsets some of the natural gas required (and the transportation of JP-4 offsite is eliminated). The only differences in SEFA input relative to the "Base Case" using information from the Conceptual Design Report are the following:

Table 4-C: Transport for Materials and Equipment: Draft Design

Item for Footprint Evaluation	Source of Information and/or Comments	SEFA Input - Draft Design
Transportation of JP4 off site to fuel recycler	• JP4 Transport off site is eliminated	NO INPUT

Table 4-G: Fuel Use for Operating: Draft Design

Item for Footprint Evaluation	Source of Information and/or Comments	SEFA Input - Draft Design
Natural Gas use for ISTT system – O&M	• Draft Design Report, October 4, 2013 – Appendix D, Page 8 • Draft Design Report does not specifically indicate natural gas usage. See Table 1 of this report. ○ Recovered JP4 = 2,000,000 gallons ○ Original Natural Gas use = 400,000 MMBTUs • Assume that 13,140,000 lbs of JP-4 is recovered and is used to offset 243,000 MMBTUs of Natural Gas • Natural Gas consumption for Alternative 1 = 400,000 MMBTUs – 243,000 MMBTUs = 157,000 MMBTUs of Natural Gas • 157,000 MMBTUs = 1524272 ccf	*On-Site Natural Gas Use* Input: 157,000,000,000 BTUs, 1,524,272 ccf *WAFB_DraftDesign-Alt1_energy.xlsx → O&M – Natural Gas → Row 48*

Item for Footprint Evaluation	Source of Information and/or Comments	SEFA Input - Draft Design
Recovered JP4 use for Steam or Oxidizer – O&M	• Draft Design Report, October 4, 2013 – Appendix D, Page 8 ○ Recovered fuel = 2,000,000 gallons • For alternative case assume all recovered JP4 is used on site and no transportation for JP4 is required	*On-Site: Other forms of on-site conventional energy use* Define: JP4 Combustion as Other form of on-site conventional energy use #1 (Row 39 of User Defined Factors tab) (See Table J for details regarding input) Input: 1,383,000 gallons *WAFB_DraftDesign-Alt1_energy.xlsx → O&M – JP4 Alt1 → Row 101*