TECHNICAL REPORT

Green and Sustainable Remediation Practices, Tools and their Application at DOE Office of Environmental Management Sites

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EXECUTIVE SUMMARY

In 2013, Florida International University (FIU) collaborated with DOE's Office of Environmental Management on a task to identify a DOE EM remediation site contractor willing to work with us on applying the Green and Sustainable Remediation (GSR) tool, SiteWise^{TM}, to a major remediation project at a DOE EM site. This task was entitled, "Sustainable Remediation and Optimization: Cost Savings, Footprint Reductions, and Sustainability Benchmarked at DOE EM Sites." Dialog with several DOE EM site remediation project managers to secure their data support for FIU to apply the SiteWise^{TM} GSR tool at their site were not successful. Conversations with Savannah River National Laboratory (SRNL) personnel working on site remediation identified a remediation system that they would support FIU in applying a level 2 (semi-quantitative) GSR analysis. In 2014, SRNL agreed to supply data and support FIU's GSR analysis of the baseline, optimization studies and development of a system improvement plan for the A/M Area groundwater remediation system. This report summarizes knowledge of GSR, GSR tools and their application acquired by FIU in 2013 that formed the basis for the implementation of SiteWise^{TM} at a DOE EM site. For this reason, the report explores the application of SiteWise^{TM} more than other GSR tools. FIU has created flowcharts depicting the ordering of steps for the implementation of GSR and for the GSR tool, SiteWise^{TM}.

There are a limited number of documents on GSR and its application since the concept and tools have been developed over the past decade and are not widely implemented. For this reason, this report is meant as a primer on Green and Sustainable Remediation. It is hoped that the section with key GSR resources (documents, webpages, and emails for government leaders) might be especially useful for those wishing to learn about and apply GSR tools at their remediation sites.

The Interstate Technology & Regulatory Council (ITRC) GSR training presentation, the U.S. Environmental Protection Agency (EPA) GSR and Green Remediation documents and U.S. DOE EM reports and presentations were the primary sources for this summary technical report.

ACRONYMS

ASTM	American Society for Testing and Materials
BDAT	Best Demonstrated and Available Technologies
CFR	Code of Federal Regulations
BMP	Best Management Practice
CMS	Corrective Measures Studies
CSM	Conceptual Site Model
CVOC	Chlorinated Volatile Organic Compounds
DOE	Department of Energy
EM	Office of Environmental Management
EO	Executive Order
EPA	Environmental Protection Agency
EPEAT	Electronic Product Environmental Assessment Tool
ETTP	East Tennessee Technology Park
FIU	Florida International University
FS	Feasibility Study
GHG	Greenhouse Gas
GSR	Green and Sustainable Remediation
ITRC	Interstate Technology & Regulatory Council
JEEP	Joint Energy Efficiency Plan
LCA	Life-Cycle Assessment
LTM	Long-Term Monitoring
NAVFAC	Naval Facilities Command
NO_x	Nitrogen Oxides
O&M	Operation and Maintenance
PCB	Polychlorinated Biphenyl
PCM	Post-Closure Monitoring
PM	Particulate Matter
PVC	Polyvinyl Chloride
P&T	Pump and Treat
RAC	Remedial Action Construction
RA-O	Remedial Action Operation
RI	Remedial Investigation
SO_x	Sulfur Oxides
SRNL	Savannah River National Laboratory
SRS	Savannah River Site
SRT	Site Remediation Tool by the U.S. Air Force
SSP	DOE Site Sustainability Plan

SSPP	Strategic Sustainability Performance Plan
SURF	Sustainable Remediation Forum
USACE	United States Corps of Engineers
WIPP	Waste Isolation Pilot Plant

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Green and Sustainable Remediation (GSR) and Green Remediation

Definitions for Green and Sustainable Remediation and Green Remediation

There are multiple definitions of "Green Remediation," "Sustainability" and "Green and Sustainable Remediation." For this report, we focus upon GSR and Green Remediation as defined by the Interstate Technology & Regulatory Council (ITRC) and the U.S. EPA below.

GSR: The site-specific employment of products, processes, technologies, and procedures that mitigate contaminant risk to receptors while making decisions that are cognizant of balancing community goals, economic impacts, and net environmental effects**.** (ITRC, May 2011)

Green Remediation: Reducing environmental impacts of common investigation and remediation activities. (ITRC, May 2011)

Green Remediation: The practice of evaluating all environmental effects of remedy implementation and incorporating options to maximize the environmental footprints of cleanup actions. (U.S. EPA, April 2008)

The US EPA identifies **6 core elements** of Green Remediation in its primer (U.S. EPA, April 2008) that are considered when designing and implementing cleanup measures:

- *Material & Waste*: reduce material use; source unrefined materials locally and/or from recycled sources; minimize hazardous and non-hazardous waste generated onsite; and recycle waste generated on site.
- *Land & Ecosystem*: Protection of valuable "ecosystem services" at sites during cleanup [soil erosion control, nutrient uptake and water quality protection, wildlife habitat, etc.].
- *Water:* Seek beneficial use of extracted/treated water; optimize capture zones of pump and treat (P&T) systems; divert clean water around impacted area; infiltrate diverted storm water for aquifer storage; use less-refined water resources when possible; and manage stormwater runoff.
- *Energy:* High-efficiency equipment, low-emission vehicles, carpools, local materials and services, DC motors, cogeneration, on-site renewable energy, etc.
- *Air:* Reduce particulate matter, sulfur oxides, nitrous oxides, and Green House Gases (GHGs).
- *Stewardship:* Reduce emissions of greenhouse gases; install renewable energy systems; use passive sampling; solicit community involvement.

Regulatory Drivers for GSR

Regulatory Drivers are important for implementing Best Demonstrated and Available Technologies (BDATs); fostering the use of Best Management Practices (BMPs); and for achieving a myriad of environmental performance goals such as the cleanup of air, streams, groundwater and more. The following are regulatory drivers to encourage site managers to implement GSR practices and broader Sustainability planning and practices:

- Executive Order 13514; Federal Leadership in Environmental, Energy and Economic Performance. Sets sustainability goals for Federal agencies and focuses on making improvements in their environmental, energy, and economic performance.
- DOE Order 436.1 Departmental Sustainability. Requires sustainability principles be integrated into DOE's Strategic Sustainability Performance Plan (SSPP).
- EPA Strategic Plan 2011-2015: Goal 3: Cleaning up communities and advancing sustainable development. Aimed to prevent and reduce exposure to contaminants and accelerate the pace of cleanup across the country.
- EPA OSWER Policy: Principles for Greener Cleanups
  - Protect human health and the environment
  - Comply with all applicable laws and regulations
  - Consult with communities regarding response action impacts consistent with existing requirements
- Superfund managers fit GSR into Superfund framework, e.g., *EPA shall consider the "potential environmental impacts of the remedial action and the effectiveness and reliability of mitigative measures during implementation." (40 CFR 300.415(e)(iii)(E)(3))*

Benefits of GSR

There are numerous benefits derived from implementing GSR from the concrete saving of monies to the more intangible building of good will and support from community, regulators and other stakeholders. These benefits may vary significantly depending on the specific site characteristics and requirements. The 10 most cited benefits of GSR are: (U.S. DOE 2, September 2013) (U.S. DOE, June 2013)

- Reduces energy consumption;
- Contributes to meeting our greenhouse gas (GHG) goals;
- Reduces toxic air emissions;
- Reduces polluting waste water discharges;
- Lessens impact on ecosystems;
- Decreases land use and carbon footprints;
- Reduces waste generation;
- Reflects BMPs and good environmental stewardship;
- Helps achieve public acceptance; and

- Reduces cost.

GSR practices also benefit the surrounding community. Fewer emissions, less waste production, and less natural resources use all help protect public health, and make the community more aesthetically pleasing. In some cases, GSR also translates into shorter cleanup times and reduced disturbance as compared to machinery-intense cleanups (The Horinko Group, February 2014).

When GSR practices include the use of locally sourcing materials, and when cleanup results in the reuse of a site, communities may benefit from economic development, job creation, and increased real state values.

Recommended Steps for GSR Implementation

Footprint reduction is not as straightforward as the other benefits. In order to reduce land use and carbon footprints, it is important that goals and a common ground are found during the remedy selection and design phase. This can be challenging and so below are several steps to follow to facilitate footprint reductions:

- Develop an accurate conceptual site model (CSM);
- Characterize the source areas and contaminant plumes;
- Determine which sustainability metrics should be considered for the site;
- Establish and apply a methodology to quantify or characterize each metric;
- Obtain consensus regarding how metrics are weighed against each other and against traditional criteria in selecting the remedial approach;
- Identify methods to reduce environmental footprint of remedy components; and
- Prioritize, select, and document what footprint reduction methods should be implemented with consideration of the overall net environmental benefit and available funding.

Perceived “Roadblocks” to Institutionalizing Green Remediation

There are many roadblocks to institutionalizing Green Remediation and GSR practices. Some of these roadblocks are real and others result from the perception of site managers regarding what is possible. The US EPA has done extensive surveys on the perceived roadblocks and below is a prioritized list of them in order of their relevancy:

1. Lack of unified approach, common language, education, communication;
2. Existing mindsets and dis-incentives;
3. Authorization and justification to implement;
4. Funding level and schedule constraints;
5. Measurement of the benefit; and
6. Remedy protectiveness and greenwashing.

Progress in overcoming these roadblocks is evident in publications, conferences, emerging Best Management Practices, regulatory guidelines, and numerous other ways.

Five examples of evidence of this change are:

- Growing number of publications, various awards, numerous conferences related to "green remediation," and "sustainability" are now available from journals, conferences and the EPA;
- The new ASTM voluntary green cleanup standard practice;
- Incentives for remediation contractors to counterbalance the many dis-incentives for GSR and BMPs;
- A few federal agencies increased use of SiteWise™ and other GSR tools; and
- Small business trainings and the ITRC GSR training; and
- More websites, documents and other information resources on GSR.

EPA Information Resources on GSR

Listed below are some of the key information resources on GSR from the U.S. EPA:

- EPA's "Methodology for Understanding and Reducing a Project's Environmental Footprint;"
- Primers;
- Guidance documents;
- Case Studies;
- Project profiles;
- Technical bulletins;
- Fact Sheets;
- www.clu-in.org/greenremediation;
- www.brownfieldstsc.org;
- www.triadcentral.org
- www.itrcweb.org/Documents/GSR-1.pdf
- www.sustainableremediation.org/library
- U.S. EPA GSR Contacts is: Carlos Pachon (pachon.carlos@epa.gov) (Interstate Technology & Regulatory Council August 2012)

Implementing GSR

The framework for GSR includes the planning phase and the implementation phase. While implementation is very site specific and relies upon stakeholder involvement, there are established steps to planning GSR and steps for implementing GSR. These are listed below.

Planning GSR steps:

1. Evaluate/update site conceptual model
2. Establish GSR goals
3. Establish strong stakeholder involvement

4. Select metrics, evaluation level, and boundaries
5. Document all GSR activities

GSR implementation occurs during multiple phases of the remediation project. Therefore, it is useful to consider the phases in remediation projects and how GSR may be brought to bear during each of them.

Site remediation steps include:

1. Investigation (GSR applied during planning)
2. Remedy evaluation and selection (best point for implementing GSR)
3. Remedy design (integration of GSR into remedy)
4. Remedy construction (GSR is integral to remedy)
5. Remedy operation, maintenance and monitoring (benefits from GSR accumulate)
6. Remedy optimization (sustainable performance improvements)
7. Close out (support for site reuse, negotiations with regulators may be improved by GSR)
8. Post-closure monitoring, PCM (needed at some sites, allows for GSR framework for PCM)

While progressing through site remediation steps, the GSR steps include:

1. Identify GSR options;
2. Evaluate GSR options;
3. Implement GSR approaches; and
4. Monitor, track and document all GSR activities.

FIU has created a visual flowchart (presented in the next section) that will help improve understanding and implementation of GSR. (See Figures 1a and 1b below).

GSR Implementation Flowchart

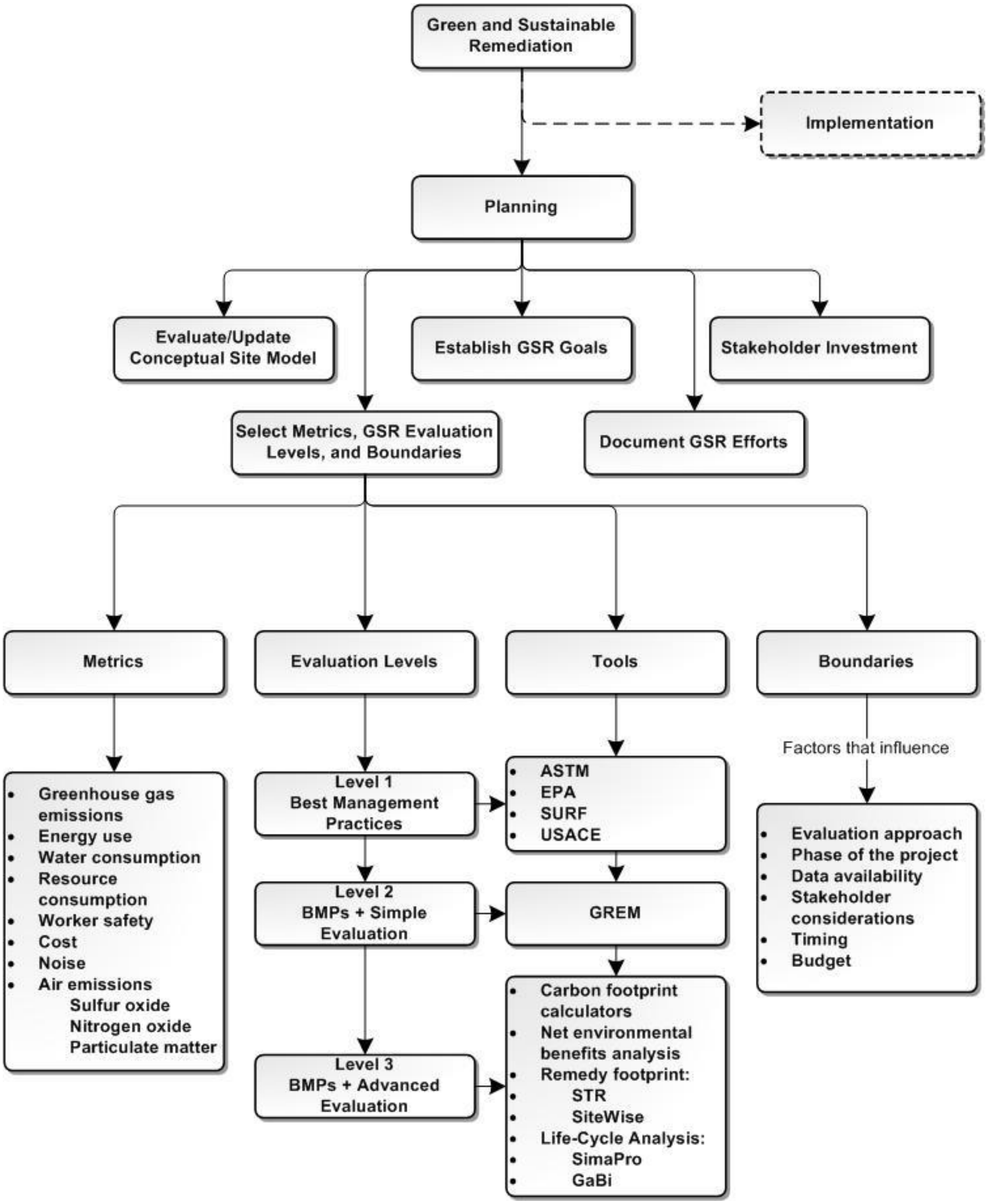

Figure 1a. GSR Planning

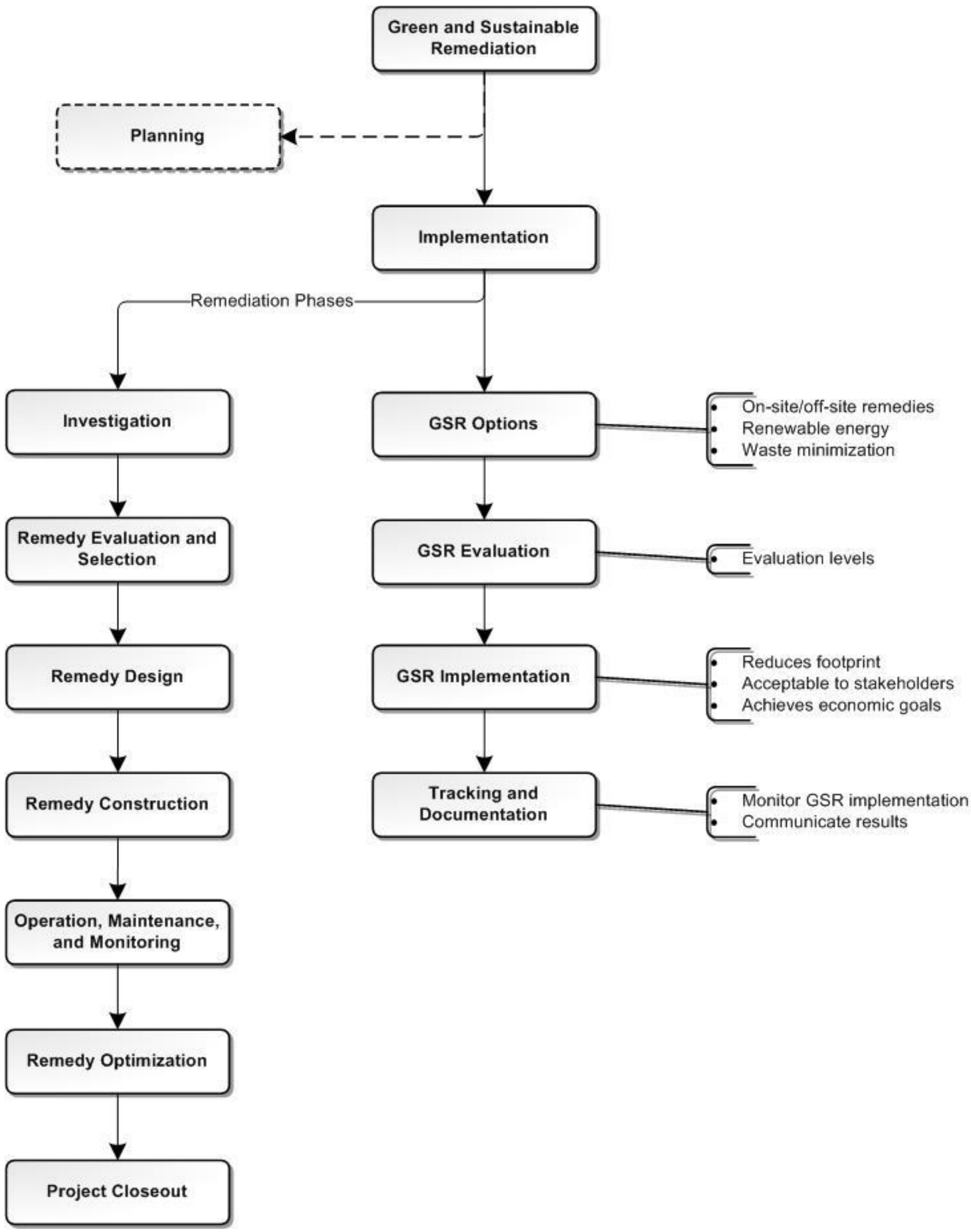

Figure 1b. GSR Implementation

GSR Metrics

The selection of particular metrics varies among all sites implementing GSR. Since regulators and the local community are involved, some low cost intangible GSR metrics can be developed that bring more trust, potential economic development, and good will that can often result in better technical remedies at a lower cost. The most common metrics assessed for possible implementation include:

- Fresh water consumption;
- Biodiversity;
- Renewable energy use;
- GHG emissions;
- Material use;
- Community impacts;
- Land use;
- Waste generation;
- Cultural resources;
- Carbon footprint;
- Capital costs; and
- Employment.

Key Lessons from Case Studies of GSR Implementations

While it in not institutionalized or even common practice, there have been many very successful GSR implementations. From the ITRC GSR training document, key lessons learned from several case studies include:

- Flexibility: the GSR process can be applied to a variety of sites, remediation phases and regulatory programs;
- Communication: communication with stakeholders is critical to successful application of GSR;
- Assumptions: because evaluation methods are new, users must understand the assumptions of the tools being used; and
- Holistic: this holistic approach will minimize a project's life cycle impacts.

GSR Tools and their Selection

There is no certification or industry standard for GSR tools. Important considerations in tool selection include:

- Site specific GSR goals and metrics;
- Scope, budget, schedule and purpose of GSR evaluation;
- Availability of site data;
- Types of remediation technology; and
- Regulatory cleanup program in effect.

GSR Tools include:

- Best Management Practices (BMPs) level 1 (ASTM, EPA, SURF, USACE, EPA fact sheets) *qualitative*
- Best Management Practices (BMPs) level 2 (CA Green Remediation Evaluation Matrix) *semi-quantitative*
- Best Management Practices (BMPs) level 3 [carbon footprint calculators; remedy footprint tools (Air Force Sustainable Remediation Tool; Navy, USACE SiteWise™); Net environmental benefits analysis tools; and Life Cycle Assessment tools] *quantitative*

SiteWise™ Version 3.0

SiteWise™ and SRT™ are two Department of Defense Tools that were developed to quantify effects of an entire remedial action. The Site Remediation Tool (SRT™) by the Air Force will not be covered in this report. Both tools are based on Life Cycle Assessment (LCA) concepts. The advantages of these streamlined tools over full LCA software packages is their relative ease of use, availability (free), and foundation in Microsoft Excel. Several GSR metrics can be calculated and evaluated with SiteWise™ and SRT™. Use of SiteWise™ during the Feasibility Study is a new Navy requirement. Other tools are also available and can be applied in cases where equipment, materials or metrics are not included in SiteWise™ or SRT™.

The description of SiteWise™ below comes from the Naval Facilities Engineering Command's "*SiteWise™ Version 3 User Guide.*"

SiteWise™ is a stand-alone, publically available tool developed jointly by the U.S. Navy, the U.S. Army, the U.S. Army Corps of Engineers (USACE), and Battelle that assesses the remedy footprint of a remedial alternative/technology in terms of a consistent set of metrics, including:

- greenhouse gas (GHG) emissions;
- energy use (total energy use and electricity from renewable and non- renewable sources);
- air emissions of criteria pollutants (total emissions and onsite emissions) including nitrogen oxide (NOx), sulfur oxide (SOx), and particulate matter (PM);
- water consumption;
- resource consumption (landfill space and top soil consumption); and
- worker safety (risk of fatality, injury and lost hours).

The assessment is carried out using a building block approach where every remedial alternative is first broken down into modules that can represent generic components of an alternative or mimic the remedial phases in most remedial actions, including remedial investigations (RIs), feasibility studies (FS), corrective measures studies (CMS), remedial action constructions (RACs), remedial action operations (RA-Os), and long-term monitoring (LTM). Once broken down into various modules, the footprint of each module is individually calculated. The different footprints are then combined to estimate the overall footprint of the remedial alternative.

This building block approach reduces redundancy in the sustainability evaluation and facilitates the identification of specific activities that have the greatest remedy footprint. The inputs that need to be considered include:

- production of material required by the activity;
- transportation of the required materials, equipment and personnel to and from the site;
- all on-site activities to be performed (e.g., equipment operation); and
- management of the waste produced by the activity.

Materials usage is considered only for materials that are completely consumed (referred to hereafter as consumables) and cannot be reused during the application of the alternative. For example, the footprint of polyvinyl chloride (PVC) for well casing or piping is considered because it is a consumable used for well installation or transfer pipe. However, the complete remedy footprint for production of equipment used, or production of the vehicles used for transportation, is not considered. SiteWise™ can be downloaded directly from the Navy Green and Sustainable Remediation (GSR) portal by following the Tools link.

How to Use SiteWise™

SiteWise™ was developed in 2007 in Microsoft® Excel. The tool includes seven different Excel files, which can be downloaded as a zip file. Once downloaded, the SiteWise™ files should be extracted into a folder specifically dedicated to the tool. The folder will contain seven worksheet files, which together make up the SiteWise™ tool. These files are: SiteWise™ Input Sheet, Remedial Investigation, Remedial Action Construction, Remedial Action Operations, Long-term Monitoring, Summary, and Final Summary. The user should never change the file names of the seven files that constitute the SiteWise™ tool.

Once copied into the new project folder, the first sheet that the user should fill out is the input sheet. As soon as an input sheet is opened, all macros should be enabled before the data are entered to allow for all functionalities of the tool to work. Macros should also be enabled in all files of the tool, not just the input sheet. Then click on the Site Info Tab. The site info sheet contains all of the important information about the site where GSR evaluation has to be conducted.

The worksheets representing RI, RAC, RA-O, and LTM are calculation sheets. These are linked to the input sheet such that they receive the data that was entered by the user into the input sheet. In each sheet, the white cells denote a cell for user input and yellow cells denote an input that features a pull-down menu listing options to choose from, and the blue cells denote a user default embedded in the tool, which can be overridden by the user.

SiteWise™ Basis of Calculations

<u>Material Production</u>

Within SiteWise™, consumables are separated into five categories: well materials, treatment chemicals, granular activated carbon (GAC), construction materials, and well decommissioning materials. For all consumables considered in the tool, GHG emissions, energy usage, and criteria air pollutants are considered and calculated based on the weight of the material. Criteria air pollutants emissions for consumables only contribute to total (global) impacts calculated by the tool and not on site impacts.

Transportation

SiteWise™ considers both personnel and material/equipment transportation to calculate the environmental footprint of a remedial action.

The means of personnel transportation considered by SiteWise™ are road, air, and rail. For personnel transportation, the emission factors for air emissions are provided in mass per passenger mile based on the specific fuel used.

For transportation of equipment, SiteWise™ considers transportation by road, air, rail and water. For each mode of transportation, the environmental footprint is calculated based on the mass of material or equipment transported.

Equipment Use

SiteWise™ has the ability to calculate the environmental footprint associated with using pumps (both electrical and fueled), earthwork equipment, blowers, compressors, generators, agricultural equipment, mixers, and stabilization equipment.

Equipment use earthwork is separated into earthwork equipment, well drilling equipment, and trenching. Air emissions are based on mass per gallon of fuel used.

The tool provides the user with several different options to calculate the air emissions impact of pumps used during remediation activities. Impacts can be calculated for general pumps using either electricity or fossil fuels.

The other equipment sheet of SiteWise™ calculates the air emissions impact for agricultural, stabilization, and mixing equipment. For each type of equipment the emission factors are provided in mass per gallon.

Residual Handling

The residual handling section of the input sheet allows the user to calculate the air emissions footprint from transporting residual waste, incinerating waste, and using a thermal oxidizer to oxidize contaminant waste.

FIU has created a visual flowchart that depicts the sequential steps required for implementing SiteWise™ . It has greatly aided our conversations with site remediation managers since it is easier to understand than the many lists of steps and considerations typically found in guides and manuals for GSR tools. The next section contains this flowchart for SiteWise™ .

SiteWise™ Implementation Flowchart

(See Figures 2a – 2e on the next 5 pages for the complete flowchart).

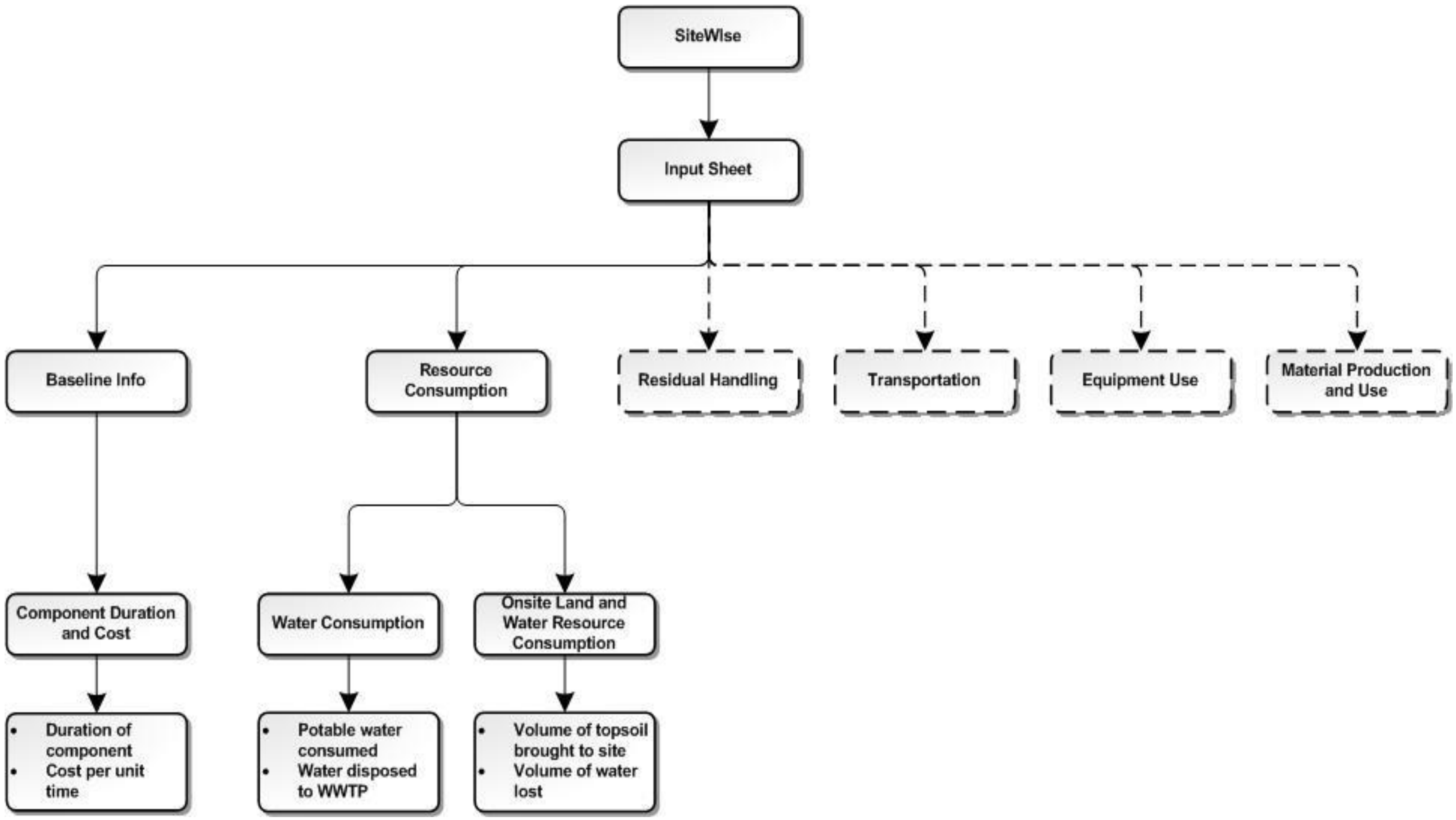

Figure 2a. SiteWise™ Input Sheet – Baseline Info and Resource Consumption

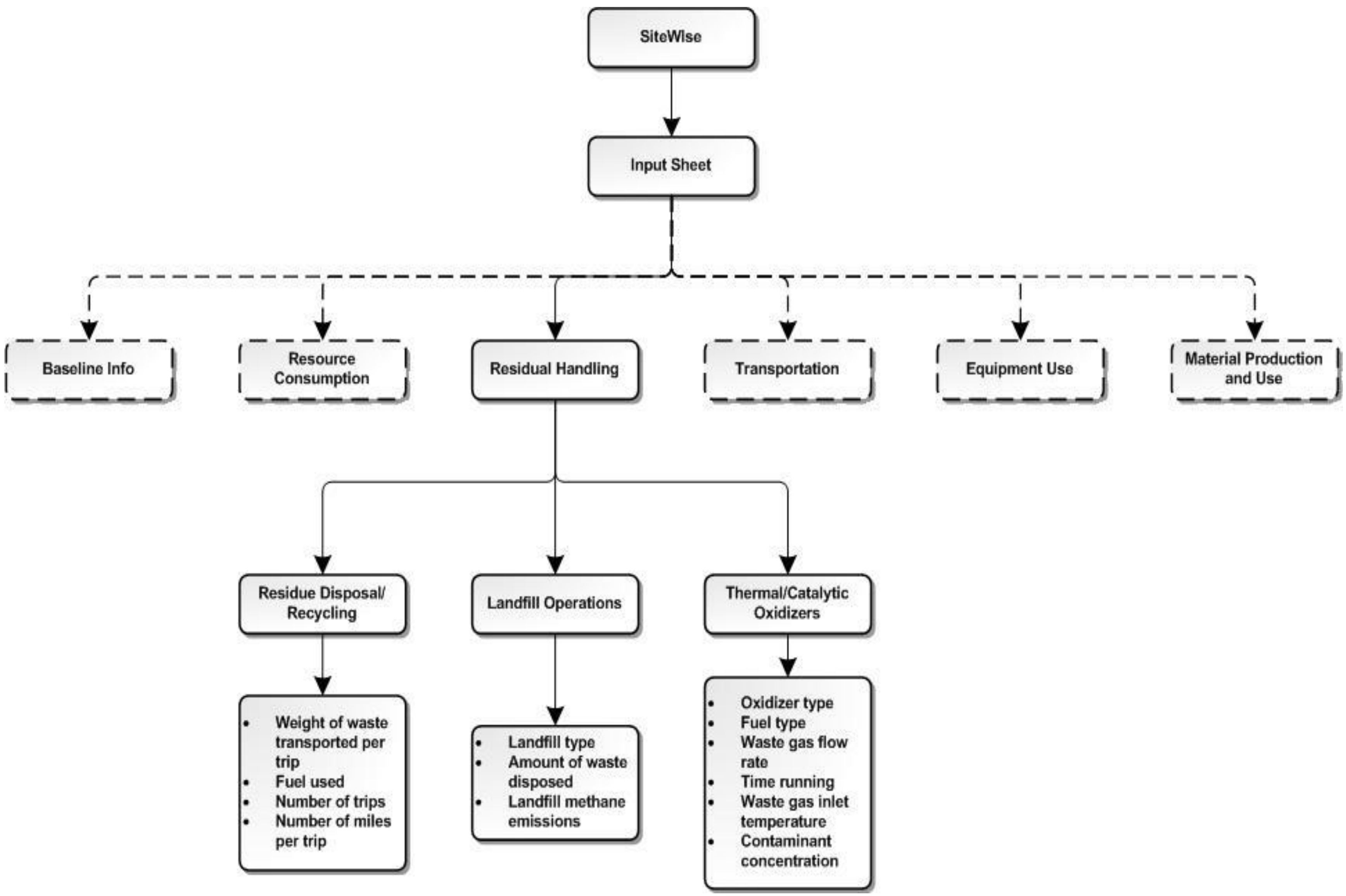

Figure 2b. SiteWise^{TM} Input Sheet – Residual Handling

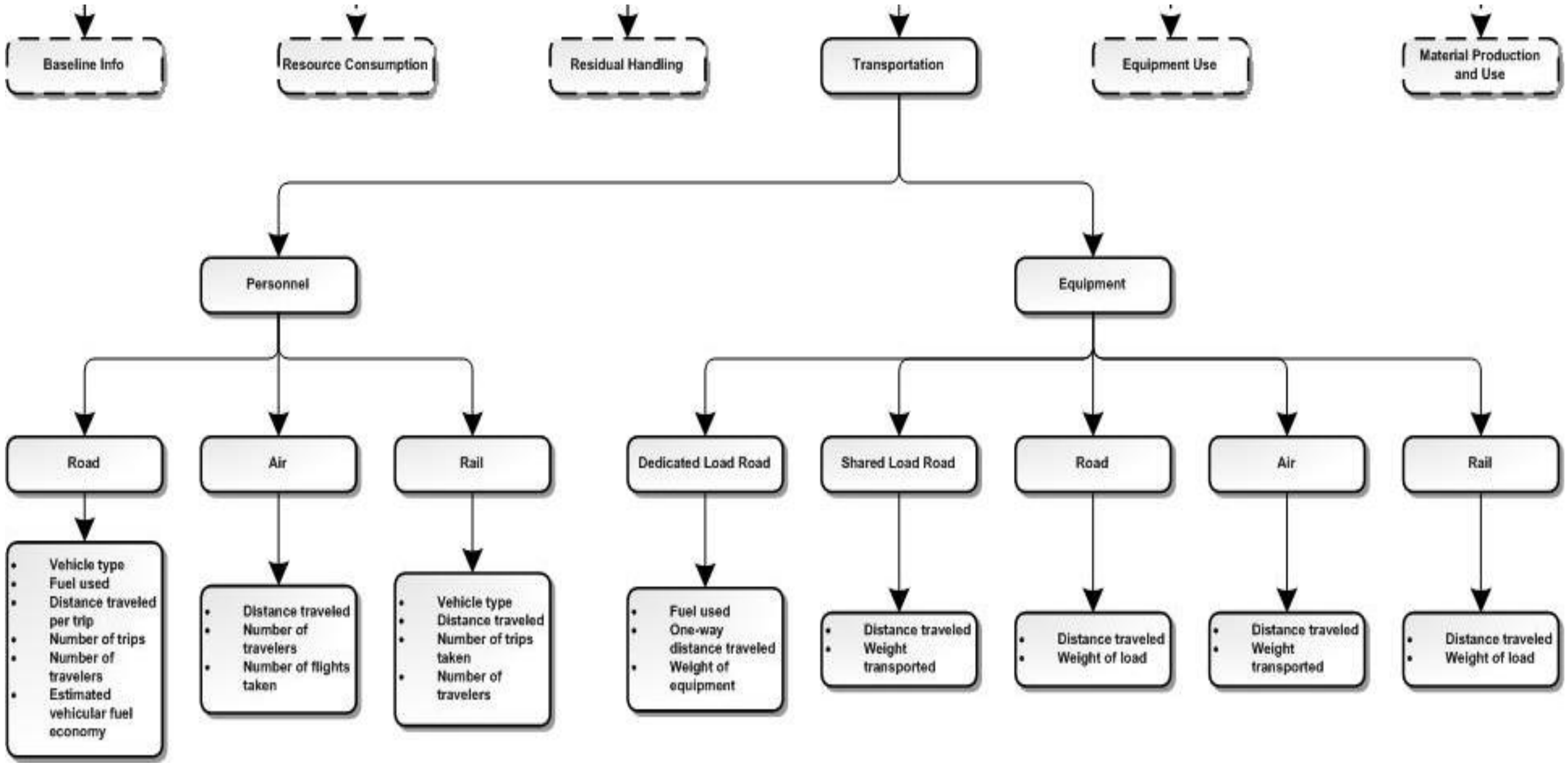

Figure 2c. SiteWise^{TM} Input Sheet – Transportation

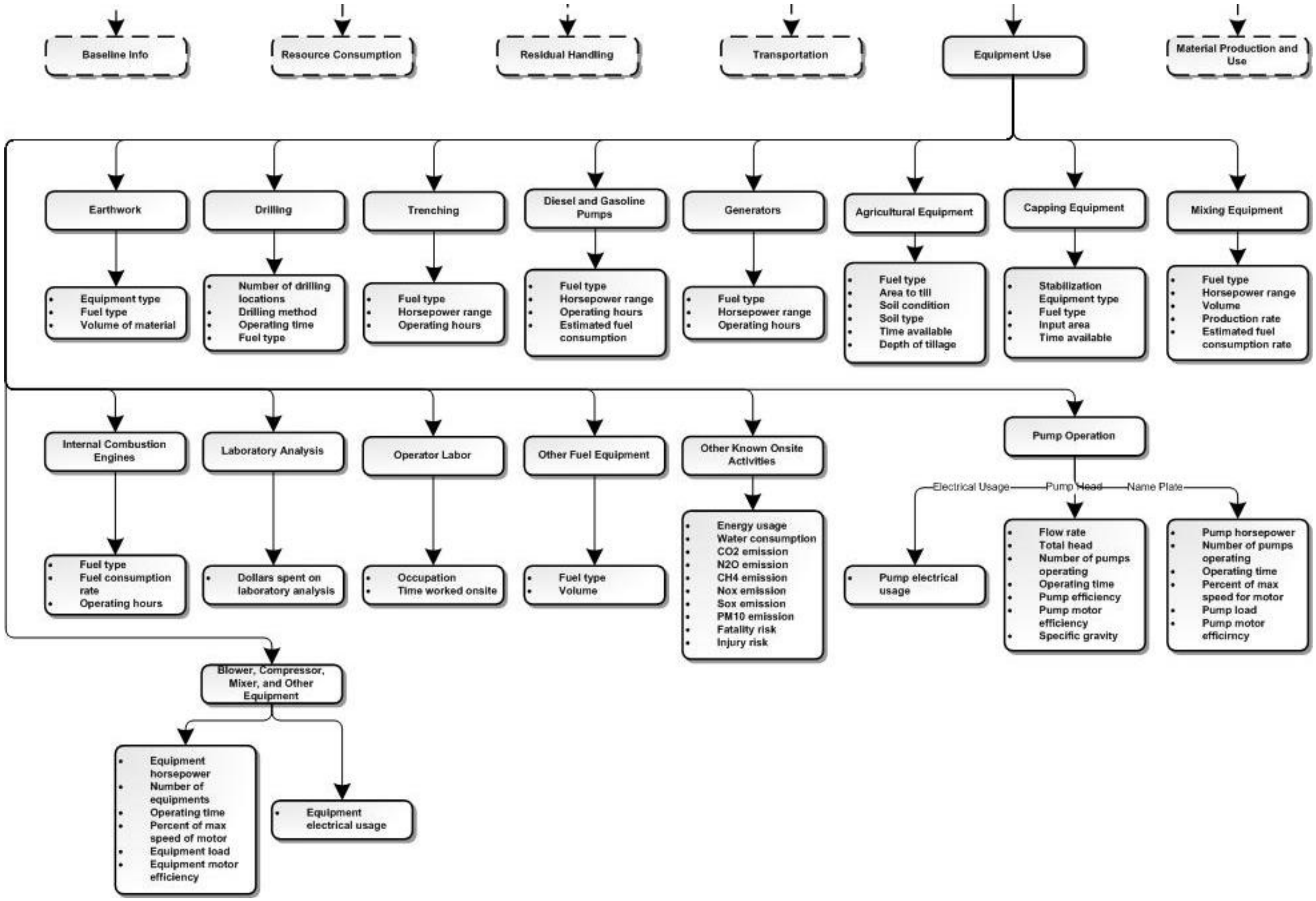

Figure 2d. SiteWise™ Input Sheet – Equipment Use

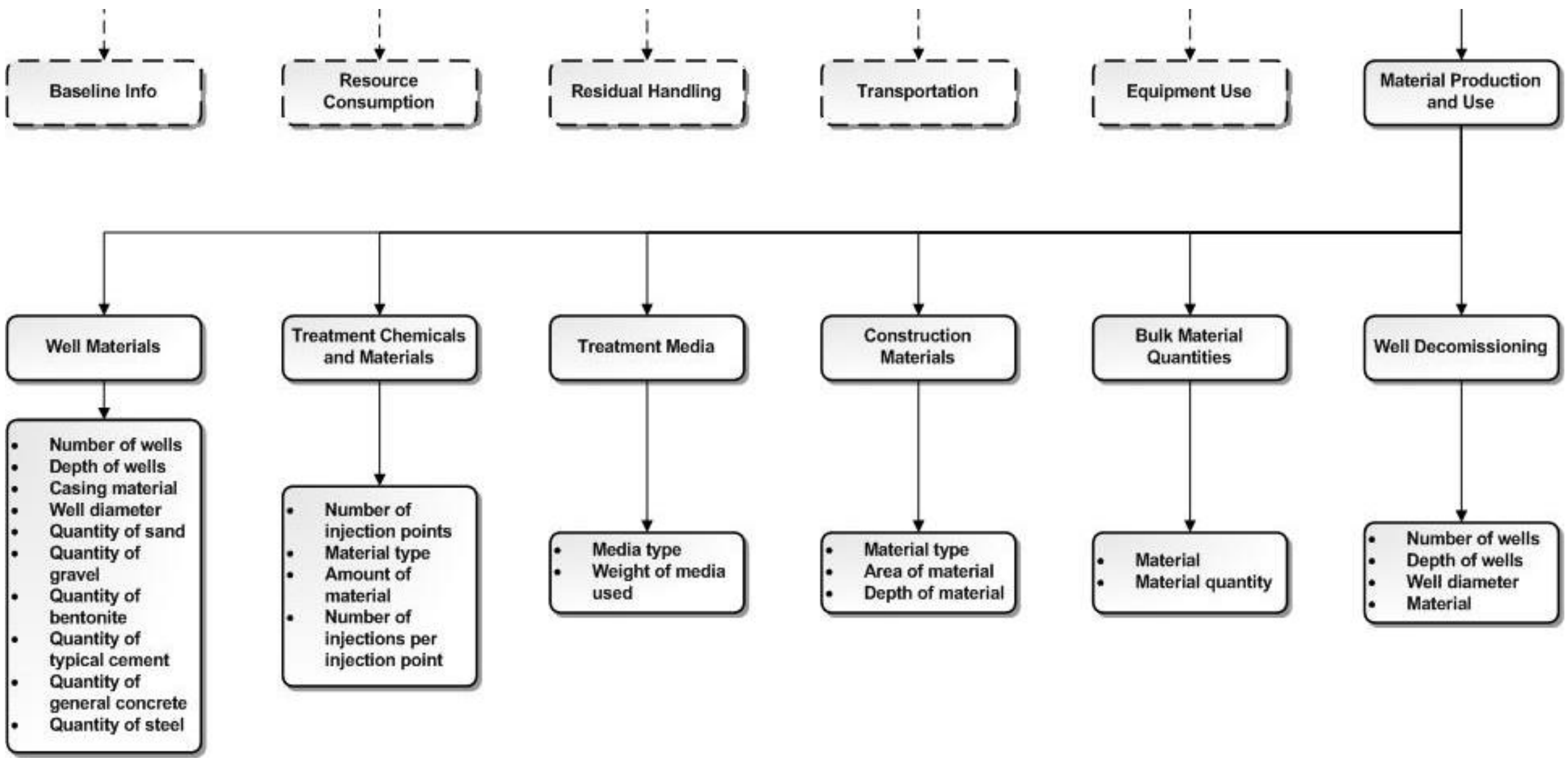

Figure 2e. SiteWise™ Input Sheet – Material Production and Use

SiteWise™ Results

SiteWise™ performs all the calculations based on emission factors collected from credible sources such as the EPA and Argonne National Laboratory GREET model. The remedy footprint is calculated by multiplying the impact factor with the consumption rate of a material, electricity, or fuel during remedy implementation (NAVFAC).

Emission factors for GHG emissions and energy used for consumables such as materials, fuels, and electricity are based on life cycle analysis; the entire life cycle emission for material production is taken into account.

In SiteWise™, the results are given in two forms. The first form are graphical bar-charts for each impact category that can compare between different remediation alternatives, or give a detailed analysis for one remediation alternative that shows the activities with the highest footprint for each metric. The second form is an impact table that shows all the metrics with assigned impact categories such as high, medium or low. These categories are given relative to each other for a specific metric based on the qualified value. SiteWise™ also provides a normalized impacts chart for ease of comparison; this graph compares the alternatives by various metrics. It is important to note that the normalized table compares alternatives, but not metrics, within the same remediation alternative.

SiteWise™ Input Data Characteristics

SiteWise™ is a flexible tool that allows the input of non-traditional remedial activities since it does not require knowledge of the contaminant, soil and aquifer characteristics, or nature of the technique. SiteWise™ requires knowledge of materials used and equipment specifics such as lengths of pipes, quantity of construction materials, equipment used based on rated power or flow, and includes some specific processes like excavation, drilling, and agricultural land treatment (Kohn, Nichols, & Looney).

SiteWise™ adapts to novel remediation approaches or uncommon contaminants as long as information regarding the equipment, construction processes, and operational parameter are available. This is very useful for GSR where non-traditional remediation treatments are sought.

Example of GSR Implementation at Brownfield Site using SiteWise™

Brownfield Site (level 3) Case Study SiteWise™ Tool Implementation

New Jersey DEP Brownfield Site - former unlined landfill (1952-1971) with chlorinated benzenes impacting soil and groundwater and excavation as selected remedy.

GSR metrics were energy consumption, air emissions, water consumption, accident risk, and cost savings. Environmental operations used Membrane Interface Probe technology, biofuels and footprint tool comparison. Social aspects included revitalizing a blighted neighborhood and reducing accident risk. Economic considerations included leveraging public and private investment for future development.

SiteWise™ showed that:

- Thermal remediation option **required excessive energy usage and produced excessive GHGs**
- The tool used expedited site characterization (investigation) as a Best Management Practice (BMP) which located contaminated area and boundaries
- Community institutions were strengthened
- Air emissions and energy usage were reduced
- Project helped facilitate neighborhood revitalization and job creation

Four Examples of GSR Implementation at 3 DOE EM Sites

Example 1: Project: PCB Containment

- **Conventional Strategy:** Remove and dispose of contaminated sediments.
- **Green Strategy:** Create barriers and ecosystem to minimize PCB uptake by aquatic biota (Vegetation Planting at Oak Ridge ETTP Pond).
- **Solution:** (1) Cover sediments with clean soil, (2) Replace fish with those that do not bioaccumulate PCBs, (3) Plant to stabilize new soil promote new fish habitat.
- **Results:** ***Avoided removal of 108,000 cubic yards, saving $8.3M in cleanup and disposal costs.***

Example 2: Project: Re-Purposing Water from Environmental Restoration Activities at Hanford Remediation Site

- **Remediation Activity:** In-place closure remedy for the 221-U Facility (U Canyon, Hanford).
- **GSR Application:** Waste water generated from the cleaning of transport trucks was discharged into a pond, the solids settled out, the clean water flowed into another pond and the water was reused to clean more trucks.
- **Result:** Over ***250,000 gallons of water*** were recycled.

Example 3: Project: Solar Power Lighting Deployed at a Hanford Remediation Site

- **Remediation Activity:** Remotely-located the 618-11 Burial Ground.
- **GSR Application:** In lieu of the original design calling for the use of conventional overhead power lines, pad mounted solar lighting was installed.
- **Result:**
  - Minimized ***ground disturbance*** and preserved portions of the ecologically sensitive desert by eliminating the need to install 1.5 km of power line and 15-20 poles.
  - Eliminated the ***fuel use*** and ***air emissions*** associated with installing the poles.
  - Saved ***$850,000*** in design and construction costs.
  - Saved approximately ***thirty days*** in the overall construction schedule.

- ***Reduced energy usage*** across the life cycle of the project.

Example 4: Degradation of a Chlorinated Solvent Groundwater Plume with Edible Oil Injection at Savannah River Site (SRS)

Non-radioactive waste was disposed in unlined basins which resulted in the contamination of the vadose zone and shallow groundwater with CVOCs. To treat the contaminants, a pump- and-treat system with air stripping was used for 10 years to immobilize the contaminant plume, while soil vapor extraction was used for a year to treat the source in the soil. The pump-and-treat system was followed by treatment with edible oil pumped into the aquifer as a final treatment to stimulate microbial activity to further degrade the CVOCs in the groundwater.

- **GSR Application Level 3: SRS evaluated the plume using the *enhanced attenuation* paradigm**—an engineering and regulatory strategy developed by DOE and ITRC.
- The groundwater remediation strategy was designed to contain the contaminated groundwater while a final action was identified.
- **Result:**
  - Design using a combination of technologies, including vegetable oil injection, was implemented.
  - Contamination plume was recently degraded.
  - ***Power requirements*** of a pump-and-treat system were avoided.
  - Remediation and closure time was reduced from ***30 years to 10 years.***
  - Savings of ***$1,000,000 annually*** in O&M costs were realized.

SIteWise™ Input Data and Output Values for Oil Injection Treatment		
Quantity of media treated:	3.50E+08	gal groundwater
Quantity of contaminant treated:	66.1	kg CVOCs
Time frame analyzed:	5	years
Primary equipment:	1	high head pump variable rate
Energy consumption:	2.53E+05	Mega-joules
GHG emissions:	11	metric ton
NOx:	3.94E-03	metric ton
SOx:	1.43E-02	metric ton
PM10:	1.81E-03	metric ton
Injury risk:	5.57E-04	

Green Remediation at DOE was made much easier when DOE EM management issued a memorandum on Green and Sustainable Remediation (GSR) contract language on December 30, 2013. The memorandum is intended to ensure that GSR clauses are integrated into EM remediation contracts. EM sites can benefit from more comprehensively identifying opportunities for increased level of GSR work, resulting in decreasing levels of cost, resource consumption, and GHG emissions.

DOE EM Site-wide Best Practices for Sustainability from the EM SSPs

Since many environmental remediation projects are located at sites active in other missions, there is a synergy between site-wide recycling and other environmental sustainability practices and programs and those for the on-site remediation project. Personnel at DOE EM sites working on GSR work closely with colleagues working on site-wide initiatives and programs. For this reason, listed below are the top Best Practices for Sustainability as referenced from DOE Site Sustainability Plans (SSPs) for 2012:

- SRS and Portsmouth successfully reduced their Scope 1 and 2 GHG emissions by 75% and 33%, respectively. This was largely due to SRS's new biomass cogeneration facility, which was in full operation in FY 2013, and Portsmouth's new gas fired boiler.
- SRS has implemented many improvements, including a new site-wide domestic water system, which enabled the shutdown of multiple electrical pumping stations. SRS also implemented a new central sanitary wastewater treatment facility, resulting in the closure of multiple sanitary plants across the site. Other projects at SRS include retrofitting over 30,000 lighting fixtures and installing more efficient chillers.
- WIPP is pursuing a Joint Energy Efficiency Plan (JEEP) with Xcel Energy. The JEEP will allow WIPP to obtain rebates on facility enhancements that produce energy savings.
- Paducah has an outstanding recycle program, which also includes recycling of hazardous waste. Paducah recycles vehicles through reuse organizations, which also collect tires, oil, and other vehicle components for recycling.
- Moab procures equipment and supplies excessed at other Federal agencies in place of purchasing new items. Due to these efforts, Moab saved about $150,000 in costs in FY 2013, and these re-used materials avoided the waste stream. Moab also achieved a "Gold" award from the DOE Green Buy Program, and was the only EM site to obtain Green Buy recognition for excellence in sustainable acquisition in 2013.
- EM has the highest overall performance amongst DOE program offices in lifecycle electronics stewardship metrics – EPEAT purchasing, power management, and end-of-life management.

The U.S. DOE 2013 Strategic Sustainability Performance Plan delineates 9 major DOE goals:

1. Green House Gas Emission reduction
2. Sustainable Buildings
3. Fleet Management
4. Water Use: efficiency and management
5. Pollution Prevention and Waste Reduction
6. Sustainable Acquisition
7. Electronic Stewardship and Data Centers
8. Renewable Energy
9. Climate Change Resilience

These goals will help foster growth in sustainability, GSR, and other environmentally green programs and initiatives at DOE sites.

Summary

This report reviews Green Remediation and Green and Sustainable Remediation including: definitions, regulatory drivers, benefits, perceived roadblocks to implementation, information resources, planning process, implementation process, tools and how to select them, and examples of implementation at DOE EM and one Brownfield site.

DOE sites are moving forward in developing Sustainability programs, projects and initiatives in order to help meet DOE site goals as well as DOE's overall goals as set out in individual Site Sustainability Plans (SSPs) and the overall U.S. DOE 2013 Strategic Sustainability Performance Plan. Scientists, engineers, managers and others involved in GSR programs at DOE EM sites work with colleagues involved in these Sustainability efforts and often report their successes through this reporting program.

There are many benefits of implementing GSR practices. Many practices can reduce overall costs, all foster better engagement and more likely acceptance of improved remediation strategies and GSR practices by regulators, the public, and other stakeholders. This improved relationship, common understanding, and acceptance by stakeholders can result in future approvals of better technologies and practices. These benefits are in addition to the more obvious ones of improving air and water quality, minimizing impact to soils, smaller carbon footprints, and reduced waste generation.

The 3 primary roadblocks to institutionalizing GSR at remediation sites are:

1. Lack of unified approach, common language, education, communication
2. Existing mindsets and dis-incentives
3. Authorization and justification to implement

The U.S. EPA, ITRC and U.S. DOE have developed implementation and educational resources that are available to remediation managers that will support implementation of GSR. The U.S. DOE has implemented various incentives into contracts for remediation contractors that will incentivize and remove dis-incentives to GSR and Green Remediation practices. Finally, the environmental remediation field now has trainings, conference topical areas, and several case studies of GSR tool implementation that will support managers in justifying and getting authorization for implementing GSR at their sites.

Conclusions

Implementation of GSR at DOE EM sites is easier to justify and more likely to be authorized since case studies at DOE EM sites and several other sites demonstrate cost savings and improved remediation results while better protecting the environment. The U.S. DOE Strategic Sustainability Performance Plan goals bring top management support for Sustainability programs and projects which vastly increase the likelihood of future authorization of GSR practices and programs. The U.S. DOE is now categorizing GSR and Green Remediation at its sites under the label, "Sustainable Remediation."

The roadblocks to more widespread implementation of GSR at sites are going away as information resources have become available, real measurable benefits have been documented at many sites, and implementing GSR is slowly becoming a Best Management Practice (BMP) that federal site remediation managers are expecting to see.

The GSR process can be applied to a variety of sites, remediation phases and regulatory programs. It is FLEXIBLE in its implementation. COMMUNICATION with stakeholders is critical to its successful. Because evaluation methods are new, users must understand the assumptions of the tools being used and communicate these with their site stakeholders.

Finally, the acceptance and authorization for implementing GSR at a site is improved if the first projects selected are limited in scope (e.g., single project or part of a project), likely to have a major positive impact on the site (e.g., large cost savings or major risk mitigated) and starts with GSR analysis that is level 1 (qualitative) or level 2 (semi-quantitative).

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