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United States
Environmental Protection
Agency



Sustainable and Healthy Communities

STRATEGIC RESEARCH ACTION PLAN 2019-2022



Office of Research and Development
Sustainable and Healthy Communities

Sustainable and Healthy Communities

National Research Program

Strategic Research Action Plan

2019 – 2022

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LIST OF ACRONYMS

AALM	All Ages Lead Model
A-E	Air and Energy Research Program
AFFF	Aqueous Film Forming Foam
ANPRM	Advanced Notification of Proposed Rulemaking
AOC	Area of Concern
APA	American Planning Association
APHA	American Public Health Association
ASTHO	Association of State and Territorial Health Officials
ASTSWMO	Association of State and Territorial Solid Waste Management Officials
BLL	Blood Lead Level
BUILD	Brownfields Utilization, Investment and Local Development Act
C&D	Construction and Demolition
CAA	The Clean Air Act
CADDIS	Causal Analysis/Diagnosis Decision Information System
CCR	Coal Combustion Residuals
CDC	Centers for Disease Control and Prevention
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COPCs	Constituents of Potential Concern
CRADA	Cooperative Research and Development Agreements
CRSI	Climate Resilience Screening Index
CS-HWBI	Community-Scale Human Well-being Index
CSS	Chemical Safety for Sustainability Research Program
CyAN	Cyanobacteria Assessment Network
DASEES	Decision Analysis for a Sustainable Environment, Economy, and Society
DoD	United States Department of Defense
DoE	United States Department of Energy
DW	Drinking water
ECOS	Environmental Council of the States
EHHI CoP	Environmental and Human Health Indicators Community of Practice
EPA	United States Environmental Protection Agency
EQI	Environmental Quality Index
ERIS	Environmental Research Institute of the States
ESML	EcoService Models Library
ETSC	Engineering Technical Support Center
F&T	Fate and Transport
FEGS-CS	Final Ecosystem Goods and Services Classification System
FEMA	Federal Emergency Management Agency
FFRRO	Federal Facilities Restoration and Reuse Office
FY	Fiscal Year
GIS	Geographic Information System
GIWiz	Green Infrastructure Wizard
GLLA	Great Lakes Legacy Act
GLNPO	Great Lakes National Program Office

GLRI	Great Lakes Restoration Initiative
GWTSC	Groundwater Technical Support Center
HELP	Hydrologic Evaluation of Landfill Performance
HENUC	Human Exposure Not Under Control
HERA	Health and Environmental Risk Assessment Research Program
HHS	United States Department of Health and Human Services
HIA	Health Impact Assessment
HS	Homeland Security
HSRP	Homeland Security Research Program
HWBI	Human Well-being Index
IEUBK	Integrated Exposure Uptake Biokinetic model
ITRC	Interstate Technology and Regulatory Council
LCA	Life Cycle Assessment
LEAF	Leaching Environmental Assessment Framework
LUST	Leaking Underground Storage Tanks
MIW	Mining-influenced Water
MSW	Municipal Solid Waste
MWiz	Materials Management Wizard
N	Nitrogen
NAAQS	National Ambient Air Quality Standard
NAICS	North American Industry Classification System
NARPM	National or Regional Association of Remedial Project Managers
NARS	National Aquatic Resource Surveys
NGO	Non-Governmental Organization
NIEHS	National Institute of Environmental Health Sciences
NIFA	National Institute of Food and Agriculture
NIMHD	National Institute on Minority Health and Health Disparities
NPL	Superfund National Priority List
NPM	National Program Manager
OA	EPA's Office of the Administrator
OAR	EPA's Office of Air and Radiation
OBLR	Office of Brownfields and Land Revitalization
OCHP	EPA's Office of Children's Health Protection
OCR	EPA's Office of Community Revitalization
OCSPP	EPA's Office of Chemical Safety and Pollution Prevention
OEJ	EPA's Office of Environmental Justice
OEM	Office of Emergency Management
OLEM	EPA's Office Land and Emergency Management
OP	EPA's Office of Policy
ORCR	EPA's Office of Resource Conservation and Recovery
ORD	EPA's Office of Research and Development
OSC	On-Scene Coordinator
OSRTI	EPA's Office of Superfund Remediation and Technology Innovation
OUST	EPA's Office of Underground Storage Tanks
OW	EPA's Office of Water

OWOW	EPA's Office of Wetlands, Oceans, and Watersheds
P3	People, Prosperity, and the Planet
PACT	Partner Alliance and Coordination Team
Pb	Elemental heavy metal – lead
PBT	Persistent, Bioaccumulative, and Toxic chemicals
PCBs	Polychlorinated biphenyls
PFAA	Perfluoroalkyl acids
PFAS	Per- and poly-fluoroalkyl substances
PFOA	Perfluorooctanoic acid
PFOS	Perfluorooctane sulfonate
PFPE	Per- and poly-fluoropolyethers
PVI	Petroleum Vapor Intrusion
R2R2R	Remediation to Restoration to Revitalization
RAO	Remedial Action Objectives
RAU	Ready for Anticipated Use
RCRA	Resource Conservation and Recovery Act
REE	Rare Earth Element
RESES	Regional Sustainability and Environmental Sciences Research Program
RFA	Request for Applications
RIMM	Risk-Informed Materials Management
ROE	EPA's Report on the Environment
RPM	Remedial Project Manager
SARA	Superfund Amendments and Reauthorization Act
SBIR	Small Business Innovation Research
SDWA	The Safe Drinking Water Act
SHC	Sustainable and Healthy Communities Research Program
SHEDS	Stochastic Human Exposure and Dose Simulation model
SMM	Sustainable Materials Management
SRP	Superfund Research Program
SSWR	Safe and Sustainable Water Resources Research Program
STAR	Science to Achieve Results
StRAP	Strategic Research Action Plan
StreamCat	Stream-Catchment dataset
SWDA	Solid Waste Disposal Act
TSCA	The Toxic Substances Control Act
TSP	Superfund Technical Support Project
USACE	United States Army Corps of Engineers
USDA	United States Department of Agriculture
USEEIO	United States Environmentally-Extended Input-Output Model
USGS	United States Geological Survey
UST	Underground Storage Tanks
VELMA	Visualizing Ecosystem Land Management Assessments
VI	Vapor intrusion
VOC	Volatile Organic Compound

EXECUTIVE SUMMARY

The Sustainable and Healthy Communities Research Program (SHC) Strategic Research Action Plan (StRAP) defines a program that emphasizes research and technology to support cleaning up contaminated sites and protecting associated communities, while also restoring ecosystems that provide benefits to those communities. It also emphasizes solutions-driven research to support decisions that will revitalize the Nation's communities and make them more resilient to severe weather and other environmental incidents. The StRAP links engineering solutions and best practices for site remediation and materials management with planning for and recovering from natural disasters to improve health, well-being, and economic vitality. The StRAP reflects the U.S. Environmental Protection Agency's (U.S. EPA) strategic directions from EPA's FY 2018-2022 Strategic Plan and recommendations from the Superfund Task Force of July 2017. In addition, the StRAP draws on the directions given in the FY 2018-2019 Office of Land and Emergency Management (OLEM) National Program Manager (NPM) Guidance and the 2018 EPA Memorandum on Environmental Justice and Community Revitalization Priorities. It also reflects direct input on research priorities obtained through SHC's engagement with EPA program and regional offices and state environmental agencies as provided through the Environmental Council of the States and other stakeholder groups.

SHC's StRAP describes a research portfolio that delivers science-based solutions. The purpose of the StRAP is to inform our Agency Partners (program and regional offices) and our external stakeholders of the program's strategic direction over the next four years. The StRAP serves as planning guide for EPA Office of Research and Development's (ORD) Centers to design specific research products that contribute to the outputs identified in the StRAP.

This portfolio is organized into three topics: (1) Contaminated Sites; (2) Waste and Sustainable Materials Management; and (3) Healthy and Resilient Communities. It supports EPA's mission by working with the states and tribes, in conjunction with EPA's program and regional offices.

This plan emphasizes the following actions:

- Technical support for remediating Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)-designated contaminated sites and returning them to productive use;
- Science to reduce costs and set science-based cleanup levels in areas designated under CERCLA;
- Research to help manage waste in landfills and support sustainable materials management;
- Research to characterize vulnerability and prevent or remediate contamination from leaking underground storage tanks;
- Research to evaluate the causal relationships between human health and ecosystem goods and services, and to document these relationships using SHC's EnviroAtlas;
- Research to assess the impacts of pollution on such vulnerable groups as children, environmental justice communities, and other susceptible populations;
- Research to support community revitalization following contaminated site remediation and restoration and community resilience to natural disasters and extreme events.

INTRODUCTION

EPA's Office of Research and Development (ORD) conducts problem-driven, interdisciplinary research to address specific environmental risks, consistent with the FY 2018-2022 EPA Strategic Plan[1] and the ORD Strategic Plan (Figure 1). ORD is committed to using science and innovation to reduce risks to human health and the environment, based on needs identified by EPA's program and regional offices, as well as state and tribal partners.

ORD's Strategic Research Action Plans (StRAPs) are designed to guide a comprehensive research portfolio that delivers science-based solutions that EPA needs to meet its goals and objectives. These research plans recognize the importance of ORD's role in supporting EPA's mission and in working with the states and tribes. The StRAPs describe innovative and science-based research that integrates environmental and human health research to meet our partners' needs.

The Sustainable & Healthy Communities Research Program (SHC) StRAP for 2019–2022 provides direction for research to achieve the goals and strategies set forth in EPA's Strategic Plan. It highlights how the SHC Research Program integrates efforts with other ORD research programs, EPA program and regional office partners, and external stakeholders to provide a research portfolio aligned around EPA's first strategic goal: to deliver a cleaner, safer, healthier environment for all Americans and future generations by carrying out the Agency's core mission. SHC's contribution to this goal is to conduct research to: (1) accelerate the pace of contaminated site cleanups; (2) return contaminated sites to beneficial use in their communities; (3) protect vulnerable groups, especially children; (4) revitalize the most vulnerable communities; and (5) understand the connections between healthy ecosystems, healthy people, and healthy communities.

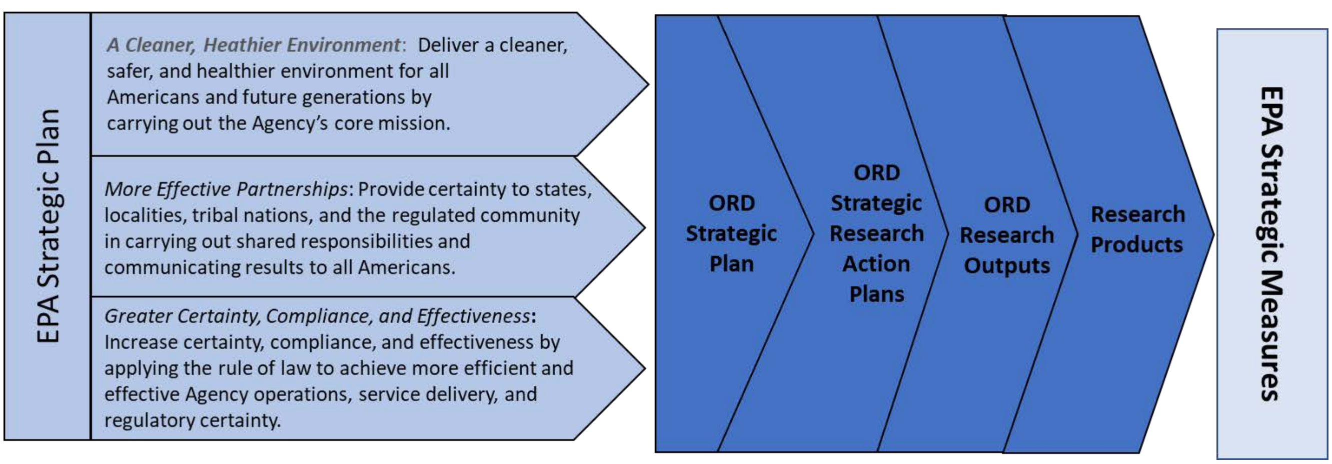

Figure 1. EPA's strategic plan informs ORD's strategic plan, which guides ORD's Strategic Research Action Plans (StRAPs).

[1] FY 2018-2022 EPA Strategic Plan: https://www.epa.gov/planandbudget/strategicplan

Research to Support the EPA Strategic Plan

This StRAP reflects strategic directions drawn directly from the FY 2018-2022 EPA Strategic Plan[2] and recommendations from the Superfund Task Force of July 2017[3]. In addition, this StRAP draws on the direction given in the Final FY 2018-2019 Office of Land and Emergency Management (OLEM) NPM Guidance[4] and in the Memorandum on EPA's Environmental Justice and Community Revitalization Priorities[5]. The FY 2018-2022 EPA Strategic Plan focuses EPA on its role of supporting states and tribes – the primary implementors of environmental programs. EPA's strategic plan establishes agency priority goals (APGs) for accelerating progress on EPA priorities. APGs reflect Agency leadership's top, near-term priorities for implementing performance improvement.

The SHC StRAP is oriented primarily towards EPA's performance goal to: **Accelerate the pace of cleanups and return sites to beneficial use in their communities.** Research conducted by SHC will provide science-based methods and evidence to support achieving this goal. SHC will assist EPA's Office of Land and Emergency Management (OLEM) in reaching their strategic goals related to making Superfund, Brownfield, RCRA corrective action sites, and sites with leaking underground storage tanks ready for anticipated use (RAU). SHC will develop and translate the research that is needed for OLEM to meet these demanding goals. SHC will also develop research to support EPA's Office of Policy (OP), Office of Environmental Justice (OEJ), and Office of Community Revitalization (OCR) in its community revitalization and resiliency goals. SHC will measure its progress over the next four years by increasing the percentage of research products that meet customer needs, specifically those of OLEM, OP and the EPA regional offices. SHC's research to address vulnerable groups and to examine potential links between human health and ecosystem services (under EPA's strategic objective to Prioritize Robust Science) will assist all of EPA's program and regional offices.

The purpose of the StRAP is to inform our Agency Partners (program and regional offices) and our external stakeholders of the program's strategic direction over the next four years. The strategic direction and outputs outlined in the StRAP serve as the focus for engagement with ORD Centers and Offices to identify specific research products to address the identified needs. This refinement of outputs and identification of research products is conducted through targeted research area teams that include ORD, EPA program and regional offices, and state representatives. This engagement is then maintained throughout the research implementation process to optimize the utility of the research products to meet partner needs.

Statutory and Policy Context

SHC's strategic direction for the next four years is grounded in the statutes that provide EPA the authority or guidance to conduct research to support the cleanup and revitalization of contaminated sites and the communities impacted by these sites. The statutes listed below are those that are most relevant to SHC's Agency partners, and hence set the regulatory and policy context for this research program.

[2] https://www.epa.gov/planandbudget/strategicplan
[3] https://www.epa.gov/superfund/superfund-task-force-recommendations
[4] https://www.epa.gov/planandbudget/final-fy-2018-2019-office-land-and-emergency-management-olem-npm-guidance
[5] https://www.epa.gov/environmentaljustice/memorandum-epas-environmental-justice-and-community-revitalization-priorities

CERCLA (https://www.epa.gov/superfund) and **SARA (**https://www.epa.gov/superfund/superfund-amendments-and-reauthorization-act-sara): The Comprehensive Environmental Response, Compensation, and Liability Act also known as Superfund and the Superfund Amendments and Reauthorization Act of 1986. CERCLA specifies that a research program should be established within the EPA to enhance Agency health protective activities related to contaminated sites. SARA authorizes research to fuel the development of innovative treatment technologies.

Brownfields Revitalization Act and the Brownfields Utilization, Investment and Local Development (BUILD) Act (https://www.epa.gov/brownfields/overview-brownfields-program; https://www.epa.gov/brownfields/brownfields-broadcast): The term "Brownfield site" refers to real property, the expansion, redevelopment, or reuse of which may be complicated by the presence or potential presence of a hazardous substance, pollutant, or contaminant.

RCRA (https://www.epa.gov/history/epa-history-resource-conservation-and-recovery-act).
The Resource Conservation and Recovery Act is our nation's primary law governing the disposal of solid and hazardous waste. Congress passed RCRA on October 21, 1976 to address the increasing problems the nation faced from our growing volume of municipal and industrial waste. RCRA, which amended the Solid Waste Disposal Act of 1965, set national goals for:

- Protecting human health and the environment from the potential hazards of waste disposal.
- Conserving energy and natural resources.
- Reducing the amount of waste generated.
- Ensuring that wastes are managed in an environmentally-sound manner.

RCRA authorizes the conduct of research into: (1) any adverse health and welfare effects of the release into the environment of material present in solid waste, and methods to eliminate such effects; (2) the planning, implementation, and operation of resource recovery and resource conservation systems and hazardous waste management systems; (3) the production of usable forms of recovered resources, including fuel, from solid waste; (6) the reduction of the amount of such waste and unsalvageable waste materials; and (7) research pertaining to underground storage tanks and mining waste.

UST (https://www.epa.gov/ust/underground-storage-tanks-usts-laws-and-regulations): Legislation concerning underground storage tanks (UST) is part of the Solid Waste Disposal Act (SWDA), titled the Underground Storage Tank Compliance Act of 2005.

Great Lakes Legacy Act and Great Lakes Restoration Initiative (https://www.epa.gov/great-lakes-legacy-act/about-great-lakes-legacy-act**;** https://www.epa.gov/great-lakes-funding/great-lakes-restoration-initiative-glri):
The Great Lakes Legacy Act (GLLA) was authorized in 2002 and reauthorized in 2008 to revitalize land and communities in the Great Lakes region through remediation of contaminated sediments and other environmental issues and restore the beneficial uses of local ecosystems. The Great Lakes Restoration Initiative (GLRI) Action Plans have sponsored research to facilitate the delisting of beneficial use impairments.

In addition to these statues, cleaning up sediment, soil, and groundwater at contaminated sites (Superfund, hazardous waste) will also improve surface water quality under the **Clean Water Act**. Remediating contaminated groundwater in aquifers that are a source of drinking water is responsive to the **Safe Drinking Water Act**. SHC research on ecosystem services, contaminated sites, and groundwater also informs decisions relevant to the **Clean Air Act**, **Clean Water Act**, **Safe Drinking Water Act**, and **National Environmental Policy Act**.

Partner and Stakeholder Engagement

SHC has always recognized the need to engage diverse stakeholders throughout the research planning, implementation, and delivery process to assure our products are meeting our partners' needs. To facilitate this engagement, SHC created Partner Alliance and Coordination Teams (PACTs) made up of representatives from SHC staff, scientists in ORD, and the EPA program and regional offices. The PACTs meet regularly to discuss SHC research, focusing on disseminating products, soliciting feedback on research, and collecting input on research directions. In addition, SHC has reached out to state and tribal governments and non-governmental organizations (NGOs) to understand the utility of SHC's research. Included is the Environmental Council of the States (ECOS) and a variety of community-based, non-governmental organizations, such as the American Public Health Association (APHA), the American Planning Association (APA), the Association of State and Territorial Health Officials (ASTHO), the Association of State and Territorial Solid Waste Management Officials (ASTSWMO), the Tribal Waste Response Assistance Program, and the Tribal Superfund Working Group.

Such regular outreach helped formulate this StRAP. As an initial step, SHC requested that program and regional office partners submit a list of priority science needs. SHC then held a series of engagement webinars that were topic-specific (e.g., contaminated sites). The purpose of the webinars was to better understand the problems that partners hope to solve with ORD science. These engagements helped SHC prioritize the research resulting in a StRAP that identifies specific topics and research areas that describe solutions (outputs) that directly address our partners' needs.

ENVIRONMENTAL PROBLEMS AND RESEARCH PROGRAM OBJECTIVES

To support EPA's goal to accelerate the cleanup of contaminated sites and to revitalize communities, SHC's StRAP for FY 2019-22 will conduct research in three topic areas: (1) Contaminated Sites; (2) Waste and Sustainable Materials Management; and (3) Healthy and Resilient Communities. A community by geography is defined as a place. It is made up of the people and their environment attached to a given location: a city, a district, a neighborhood, a country. The simplest definition of community used by SHC is the place where we live. SHC will rely upon the expertise of social scientists and communication experts to engage with communities that can benefit from SHC's research.

Program Vision

Vision: ORD's Sustainable and Healthy Communities research program will integrate and translate public health, environmental engineering, and ecosystem science to provide:

(1) Remediation solutions for contaminated sites;

(2) Operational tools for waste sites and for sustainable materials management; and

(3) Approaches for revitalizing and protecting communities at risk from contamination and natural disasters by linking restoration of the natural and built environments to ecosystem services and human health and well-being.

Contaminated Sites: Accelerating Cleanups

The objective is to: provide cost-efficient, rapid, and effective technical support and innovative methods for site characterization and cleanup, especially for complex site-specific issues; contribute to EPA program guidance and other technical support to manage contaminated groundwater (present at 85% of National Priority List sites), leaking underground storage tanks, and mine waste; and provide science-based approaches so that OLEM, EPA regions, and states can better engage in effective remediation of contaminated sites and restoration of the built and natural environment. The results can inform the public as they participate in the selection of remediation options.

Technical support and research and development under this objective will provide support for OLEM, EPA's Regions, and delegated programs that: 1) clean up contaminated soils, sediments, and groundwater; 2) assess remedy effectiveness and restore beneficial uses of the environment; 3) remediate mining and mineral processing sites; 4) remediate and characterize solvent vapor intrusion; 5) remediate contamination from leaking underground storage tanks; and 6) remediate sites impacted by PFAS and lead (Pb).

Waste and Sustainable Materials Management: Reducing the Burden of Contamination

The objective is an integrated approach to materials management, including the need to evaluate landfill performance and its long-term impact on human health and the environment. Many existing materials considered to be either hazardous or non-hazardous waste, and intended for some form of disposal, could potentially be reused, recycled, or reprocessed into other resources. Sustainable Materials Management (SMM) considers the impacts from the full life cycle of materials thereby identifying ways of reducing toxics and greenhouse gases, and beneficially reusing waste materials. Success in this area will prevent or reduce the disposal of waste products thereby helping to minimize landfill impacts and community costs.

Research and development under this objective will provide data and tools to support OLEM and state and local delegated programs that: 1) manage wastes in municipal and hazardous waste landfills; 2) use input-output economic models to conduct life cycle assessments of waste materials; and 3) reuse wastes in a beneficial manner.

Healthy and Resilient Communities: Revitalizing Communities from Contamination and Natural Disasters and Extreme Weather Events

The objective is to increase community resilience by reducing potential risks, promoting health, and revitalizing communities. Research under this objective will identify links between these desirable outcomes and effective site restoration and the provision of ecosystem services and health-promoting features from built and natural environments. This research includes support for the Agency's goal[6] that all, including vulnerable groups (e.g., children, elderly, minority communities), benefit from remediation, restoration, and revitalization efforts. It also includes understanding the challenges associated with preparing for and recovering from the impacts of natural disasters/extreme weather events, especially when these might result in contaminants migrating from containment sites.

Research and development under this objective will provide data and tools to support Agency and delegated programs to: 1) develop weight-of-evidence approaches to evaluate how remediation and

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[6] https://www.epa.gov/environmentaljustice/memorandum-epas-environmental-justice-and-community-revitalization-priorities

restoration, through the provision of ecosystem services, contribute to community revitalization and well-being; 2) address the risks and impacts to vulnerable communities and groups from contaminated sites; 3) improve the resiliency of communities to natural disasters or extreme events, especially the impacts related to contaminated sites; and 4) measure and report on the outcomes of EPA's environmental protection activities, (e.g., EPA's Report on the Environment).

RESEARCH TOPICS

SHC's strategic direction over the next four years is focused on three research topics, which are subdivided into research areas. Each research area includes a problem statement (or statements) and a proposed solution referred to as an output (see Appendix 1 for summary table). The products that will be developed in response to these outputs are actual deliverables that may take the form of a report, a database, a tool, journal articles, and/or a form that is specified by SHC's partners as addressing their needs. The problem and output statements were developed in collaboration with EPA's program and regional partners. SHC's outputs were also shaped by additional discussions with the Environmental Council of the States (ECOS), the Association of State and Territorial Solid Waste Management Officials (ASTSWMO), and representatives of America's tribes (see Appendix 2 for a summary table).

Topic 1: Contaminated Sites

SHC research provides scientific solutions and technical support to EPA, state, and tribal decision makers to remediate and restore our nation's most challenging and complex contaminated sites. This work will develop permanent remedies and innovative treatment technologies (as specified by SARA) that are needed to accelerate the pace and reduce the cost of cleanups, while also returning contaminated sites to safe and productive use by the community.

The Contaminated Sites research topic contains five research areas: Technical Support, Site Characterization and Remediation, Solvent Vapor Intrusion, Leaking Underground Storage Tanks, and Chemicals of Immediate Concern (lead and PFAS). SHC research to support some aspects of EPA cleanup efforts—such as community engagement, restoration of impacted ecosystems, and community revitalization—is contained in Topic 3 of this StRAP.

Research Area 1: Technical Support

OLEM, ORD, and the EPA regions established the Superfund Technical Support Project (TSP) in 1987 to provide technical assistance to decision makers including regional Remedial Project Managers (RPMs) and On-Scene Coordinators (OSCs). The TSP has four objectives:

1. Provide technical support and assistance to regional staff;
2. Improve communications among the regions and ORD;
3. Ensure coordination and consistency in the application of remedial technologies; and
4. Furnish high-technology workshops and state-of-the-science information to RPMs and OSCs.

ORD has five technical support centers (TSCs)[7] to support OLEM and EPA's 10 Regions, and, indirectly, the states and tribes, in accomplishing these four objectives. Two of these centers, the Engineering

[7] https://www.epa.gov/land-research/technical-support-centers

Technical Support Center (ETSC) and the Groundwater Technical Support Center (GWTSC), provide technical support based on research planned through the SHC program. The TSCs offer short- and long-term resource assistance to Superfund and RCRA decision makers in EPA programs and regions. Much of the technical support is provided by in-house federal scientists and engineers for on-site assessment, conducting laboratory and field experiments, and providing expertise on specific topics.

While the ETSC and GWTSC each have their separate areas of expertise, the TSCs all work collaboratively to fulfill the mission of providing high quality technical support to the Agency. In addition, EPA's regions work with the states and tribes within their areas to request assistance. Providing technical support at contaminated sites is the highest priority need for OLEM and the regions. Below are short descriptions of the TSCs supported through SHC.

Engineering Technical Support Center

The ETSC connects regional staff with ORD technical engineering experts to provide assistance on the latest methods, approaches, and technologies to characterize, remediate, and manage contaminated sites. The ETSC can assist with contaminated site management at any phase – from site identification to remediating contaminated soil, sediment, and mine waste.

Groundwater Technical Support Center

Approximately 50 percent of the drinking water in the United States is obtained from groundwater, with over 15 million U.S. households relying on private wells for drinking water. Most Superfund sites have contaminated groundwater. Of the more than 1,400 Superfund sites with remedies, approximately 80 percent include groundwater remedies that have been documented in more than 2,000 decision documents. This underscores the need to effectively and expeditiously address groundwater contamination at these sites. The GWTSC serves as a critical interface between the research community and field practitioners to ensure that effective groundwater remediation solutions are applied at contaminated sites.

Technical Support at Contaminated Sites

Problem Statement: EPA regions, states, and tribes require technical assistance and support to implement remedial technologies and approaches at CERCLA, RCRA, and Brownfield sites in the United States. OLEM and the EPA regional offices have requested that ORD provide this support to help address complex contamination problems.

Partners: EPA regional offices, who also network with the states and tribes within their area to request assistance.

Technical Support for Contaminated Groundwater

Problem Statement: EPA needs technical support for evaluation and remediation of contaminated groundwater to reach its goals for cleaning up contaminated sites. Priority areas include developing more advanced and robust conceptual models for groundwater contaminated sites and evaluating and treating contaminant source areas and dissolved phase plumes, groundwater contamination in fractured bedrock, and vapor intrusion.

Partners: EPA regional offices, who also network with the states and tribes within their area to request assistance.

Output 1.1: Technical Support for Methods, Tools, Models, and Technologies to Characterize, Remediate, and Manage Contaminated Sites and Contaminated Groundwater. ORD will continue to provide and conduct technical assistance and support for decision makers in EPA's Program and Regional Offices. These decision makers include remedial project managers, corrective action staff, and on-scene coordinators. ORD will deliver expertise on the latest methods, approaches, and technologies to characterize, remediate, and manage risk at contaminated sites. In addition, ORD's Engineering Technical Support Center (ETSC) and Groundwater Technical Support Center (GWTSC) will provide an annual report and quarterly updates, develop issue papers, and co-sponsor workshops, webinars or state-of-the-science informational sessions for partners and stakeholders to ensure knowledge dissemination to a range of clients with responsibility to regulate contaminated sites and groundwater.

Research Area 2: Site Characterization and Remediation

This research area provides state-of-the-science methods, models, tools, and technologies that OLEM uses in programmatic guidance, and that EPA decision makers use in the site cleanup process. Examples of steps in the Superfund process that commonly use ORD research include: 1) the remedial investigation and feasibility study, (which determines the nature and extent of contamination, identifies remedial action objectives, and screens potential treatment and containment technologies); 2) the record of decision, (which explains the cleanup alternatives that will be used at a given National Priorities List site); and 3) the remedial design/remedial action, (which contains preparation and implementation plans and specifications for applying site remedies).

The research described below will provide science-based solutions to the most challenging technical issues identified by OLEM and the EPA regional offices at large-scale, complex sites. These include how to: 1) more efficiently remediate contaminated soils and sediments at Superfund sites; 2) characterize and remediate contaminated groundwater at Superfund sites; and 3) remediate mining and mineral processing sites, which typically have large footprints with large volumes of wastes that have varying geochemical compositions. Accelerating and technically improving Superfund cleanups require taking a multi-disciplinary approach and applying site characterization, risk assessment, and new remediation technologies in large, heterogeneous situations.

Development of Remediation and Assessment Alternatives for Soils and Sediments

Problem Statement: Improved metrics, remediation approaches, and tools are needed to assess and manage contaminant sources, quantify and understand contaminant bioavailability, and define the exposure and biological consequences at both terrestrial and aquatic sites. Existing assessment measures and tools may not be able to fully address all contaminants, conditions, and sources present at contaminated sites. This is especially the case with emerging chemicals of concern such as the per- and poly-fluoroalkyl substances (PFAS). Research Area 5 of this StRAP describes research related to chemicals of concern with the outputs informing the development of remediation methods for soils and sediments, as well as groundwater and leachate from waste sites. The cleanup levels for common contaminants (heavy metals, organics, inorganics) at sediment and soil sites are often low and are close to or below detection limits. Improved techniques are needed to reduce detection limits and improve estimates of bioavailability at sediment sites. Guidance is needed on how to incorporate bioavailability measurements into the process of developing Remedial Action Objectives (RAO). Project and program managers need this work to make informed decisions about which remediation and restoration options are optimal for lowering risks to ecosystems and human health.

Partners: OLEM [primarily the Office of Superfund Remediation and Technology Innovation (OSRTI), but also the Federal Facilities Restoration and Reuse Office (FFRRO), Office of Brownfields and Land Revitalization (OBLR), and Office of Resource Conservation and Recovery (ORCR)], Great Lakes National Program Office (GLNPO), and EPA regional offices.

Output 2.1: Methods, Tools, and Guidance on Remediation Options. SHC will evaluate, develop, validate, and demonstrate remediation alternatives and tools to reduce risk, better assess sources and exposure at contaminated sites, and connect them quantitatively to biological and human health consequences. Potential products include: 1) methods and guidance for assessing contaminant bioavailability using passive sampling; 2) advancements in assessment tools for forecasting residues in fish, shellfish, and wildlife; 3) improvements for addressing temporal and spatial variability associated with contaminant exposure; 4) demonstration projects to validate existing and newly developed assessment measures and tools; and 5) filling of key data gaps for chemicals of concern at contaminated sites, including reducing detection limits for priority contaminants.

Contaminated Groundwater Research – Site Assessment

Problem Statement: At many groundwater sites, remediation is limited by the extent to which complex subsurface conditions (e.g., karst environments, fractured bedrock, heterogeneous sedimentary deposits, complex contaminant mixtures, groundwater/surface water interactions) can be characterized. Moreover, timely site restoration can be impeded by the inability to adequately characterize the distribution of contaminant mass relative to subsurface geologic heterogeneity, as well as the inability to characterize rates of mass transport through, and transfer between, heterogeneous layers.

Partners: OLEM (primarily OSRTI, but also FFRRO, OBLR, and ORCR), and EPA regional offices.

Output 2.2: **Methods and Approaches to Improve Characterization of Heterogeneous Contaminant Sites**. SHC will develop geochemical, geophysical, and modeling tools to support site characterization and the design of timely and cost-efficient groundwater remediation. This can include optimizing existing tools and designing new tools and approaches to define conceptual models at heterogeneous contaminant sites. Research may be based on numerical modeling simulations, laboratory experimentation, or field-based research.

Contaminated Groundwater Research – Site Remediation

Problem Statement: Timely and cost-effective remediation of contaminated groundwater can be hampered by limitations in existing technologies. Research is needed to advance the practice of groundwater remediation including, groundwater treatment delivery and extraction systems, chlorinated solvent plumes, and approaches to meet discharge standards. Improvements of this nature will result in more efficient and effective treatment, which will help achieve faster and less expensive site closures. Combined remedy approaches are needed for treatment of complex Superfund sites.

Partners: OLEM (primarily OSRTI, but also FFRRO, OBLR, and ORCR) and EPA regional offices.

Output 2.3: Remediation Approaches and Technologies for Subsurface Contamination. SHC will conduct laboratory experiments, modeling-based research, and field-based research on priority groundwater remediation topics. Research will focus on remediating source areas, groundwater plumes, and will include data on the effectiveness of available delivery and extraction systems, as well as ways to improve these approaches and technologies. Specific research topics include: activated carbon (as an injected amendment and for optimized *ex-situ* treatment); permeable reactive barriers; and thermal treatment to remediate high priority contaminants such as metals (arsenic, chromium, lead, and heavy metals), chlorinated solvents, and petroleum hydrocarbons. Remedial technologies to address back diffusion will also be included as part of the research.

Innovative Passive Treatment Technologies for Mining-Influenced Waters

Problem Statement: Standard water treatment technologies for mining-influenced water (MIW) include pH adjustment, clarification, and flocculation. These are active technologies, which require constant human intervention, and are generally costly over the long term; they also are difficult to operate in steep and remote locations. Passive and semi-passive (i.e., not requiring constant human intervention) treatment technologies exist (e.g., permeable reactive barriers for groundwater, passive biochemical reactors, limestone drains), but their longevity isn't well known. Modifications to innovative passive technologies or development of new innovative technologies, especially for *in situ* groundwater remediation, are needed, especially those that can decrease treatment costs, treatment waste volumes, and energy usage on Superfund mining sites. Technical support requests relating to *in situ* groundwater remediation and *ex situ* on-site remediation of MIW frequently pertain to longevity, treatment performance, and linking site-specific characteristics with specific technologies to optimize decision making regarding cleanup.

Partners: OLEM (primarily OSRTI, but also FFRRO, OBLR, and ORCR) and EPA regional offices.

Output 2.4: *In Situ* Treatment for Mining-Influenced Waters. SHC will provide information focused on remediation challenges and the current state-of-the-art passive and active treatment technologies for MIW, as well as technical support and outreach on various treatment technologies. SHC will evaluate innovative technologies for treating MIW (especially *in-situ* treatment of groundwater) using field-based studies and share results from these technology pilots with all interested stakeholders.

Mine Waste Source Control

Problem Statement: MIW requires long-term water treatment; therefore, control of the source may be the most viable long-term option for mining sites. Controlling the source will reduce or eliminate the need for perpetual MIW treatment and decrease overall costs, treatment waste volumes, and energy use. Excavation and removal of mining wastes for placement in repositories may be impossible in locations where access is difficult, and, therefore, on-site treatment methods are needed. In addition, effective source control can have beneficial impacts on down-gradient treatment methods, such as passive *in-situ* groundwater technologies, by reducing contaminant flux and extending the lifetime of effective treatment. Adequate characterization through use of various tools (e.g., geophysical, geochemical, remote robotics) may aid in identifying sources where control would provide the greatest improvement to watershed-wide contamination.

Partners: OLEM (primarily OSRTI, but also FFRRO, OBLR, and ORCR) and EPA regional offices.

Output 2.5: Innovative Technologies to Eliminate or Control Mining Wastes as Sources of Water Contamination. SHC will develop and evaluate innovative technologies for source control. SHC will provide an understanding of current technologies for coating or altering the geochemical characteristics of mining waste materials or surfaces (e.g., tailings, waste rock, underground tunnels) to minimize or eliminate generation of MIW, accompanied by technical support to evaluate use of any of these technologies at Superfund sites. Additionally, SHC will explore characterization options that may improve targeting sources to control. SHC will conduct field pilot testing of innovative source control technologies with the EPA regional offices and share findings with all stakeholders.

Reduce Lead and Other Metal Contamination and Exposure at Former Mining, Smelter, and Mineral Processing Sites

Problem Statement: Mineral processing sites, such as smelters, have many of the same challenges as remote mining sites, including contamination of groundwater, soils, and surface water with acidity and metals. However, many mineral processing sites are in or near residential communities and therefore pose an increased risk of exposure to metals in soil, dust, and fine particulates through ingestion and inhalation during day-to-day indoor and outdoor activities. Like remote mine sites, impacted media footprints from mineral processing can be very large and challenging. Sampling techniques such as incremental soil sampling and field analytical methods offer ways to address these challenges. Source attribution, fingerprinting, and background studies remain a challenge for some smelter sites. Remediation technologies and approaches that minimize treatment volumes and allow treatment or mitigation *in-situ*, (such as through soil amendments, caps, stabilization and solidification, and other techniques) offer significant opportunities for Superfund. This can also include lead contamination at Superfund sites, former smelter sites, mine waste areas, and areas affected by legacy lead paint and leaded gasoline residues. These are often large areas for which current remediation or soil removal and replacement methods are prohibitively expensive or otherwise impractical.

Partners: OLEM (primarily ORSTI, but also FFRRO, OBLR, and ORCR) and EPA regional offices, states, tribes.

Output 2.6: **Technologies, Sampling Methods, and Exposure Models for Reducing Metal Contamination and Exposure at Smelter Sites.** SHC will conduct research and provide technical support regarding current technologies for addressing metal contamination in the cleanup of soil and dust. SHC will also provide support for sampling methods and exposure modeling for ingestion and inhalation of dusts. SHC will conduct field testing of *in-situ* technologies to mitigate exposure of contaminants from soils and groundwater plumes. This can include innovative, cost-effective methods that immobilize, encapsulate, or significantly reduce bioaccessibility of lead and other soil contaminants *in situ* to prevent or mitigate lead exposure risk.

Research Area 3: Solvent Vapor Intrusion

Vapor intrusion (VI) is the migration of vapor-forming chemicals from a subsurface source into an overlying building or structure via any opening or conduit. Industrial chemicals (e.g., volatile organic chlorinated solvents) released into the subsurface may form hazardous vapors that migrate through the vadose zone and eventually enter buildings through openings and conduits such as cracks, seams, foundations, sump pits, utility vaults, floor drains, and sewer lines. These vapors could pose threats to indoor air quality and cause health risks. The most prevalent chlorinated solvents are tetrachloroethene (a.k.a. perchloroethene) and trichloroethene. The most prevalent petroleum hydrocarbons are benzene, toluene, ethylbenzene, and xylenes.

Vapor intrusion can pose health risks to thousands of residents and workers in the United States. Cost-effective, documentable, and reliable ways to control VI are needed to control exposures and to reduce the contamination sources. VI is highly variable both spatially and temporally, creating challenges for sampling and monitoring. VI events are not as continuous as originally thought, but rather occur in distinct events throughout the year. Hence, the timing of when and where to sample is extremely important to capture exposures to the building's residents.

Vapor Intrusion in Large Multi-Compartment Buildings

Problem Statement: There are multiple research needs to improve guidance on vapor intrusion. Nearly all chemical vapor intrusion research has been performed on residential structures, but large non-residential buildings are also affected. Commercial buildings can overlay the original contaminant-release site, which can be fundamentally different from the more typical dilute/dissolved groundwater-sourced vapor intrusion into homes. Research on cost-effective methods for assessing and mitigating large commercial and multi-unit residential buildings is needed. This research will help document the source of and possible control of VI exposures.

Partners: OLEM (primarily OSRTI and ORCR, but also FFRRO and OBLR) and EPA regional offices.

Output 3.1: Characterize Vapor Intrusion in Large Multi-Compartment Buildings. There are multiple research needs to improve guidance on vapor intrusion. This research will help document the source of and possible control of VI exposures. Through research in this output, SHC, in conjunction with EPA program and regional offices, will identify and gain access to a large building that is experiencing VI. SHC will conduct field-based studies to evaluate the factors affecting VI into the building, including weather and building-related parameters, as well as surrogate measures that could provide valuable information on when and whether vapor intrusion will occur. With the selection of a suitable building for research, many of these research needs can be met at that location. Each of the products presented under this output will provide one piece of the puzzle when dealing with large buildings, and a cumulative final report including the entire dataset will be produced. For purposes of comparison, in addition to the selection of a large building, SHC aims to identify a residence (or similar small structure) for monitoring VI in the same general vicinity, over the same contaminant groundwater plume.

Subslab Sampling Methods for VI

Problem Statement: There are no specific methods regarding how to collect subslab soil (e.g., the soil immediately beneath a building) gas samples, in part because there is not an obvious consensus about which sampling method (e.g., grab samples, long-term passive samplers) and duration yield the most representative data for purposes of estimating mass flux via soil gas entry and comparing to indoor air concentrations.

Partners: OLEM (primarily OSRTI and ORCR, but also FFRRO and OBLR) and EPA regional offices.

Output 3.2: Field Testing and Data to Update Guidance on Subslab Sampling of Soil Gas. Through research under this output, SHC will develop a database, based on field testing and monitoring of subslab soil gas collections, to allow us to better describe the temporal and spatial variability beneath a building. Sampling approaches relevant to acute and chronic risk will be addressed when possible. General sampling practices for subslab (immediately below foundation) soil gas (e.g., small volumes, sometimes with grab samples rather than time-integrated samples) may conflict with field evidence at one intensely monitored house, which appears to show that subslab vapor concentrations can vary spatially and temporally underneath residential buildings. Appropriate data from a variety of buildings and subsurface settings might provide evidence for improving current sampling practices. Each of the products presented under this output will provide one piece of the puzzle when dealing with large buildings. A cumulative final report including the entire dataset will be produced.

VI Temporal and Spatial Variability

Problem Statement: There is no unified-coherent theory or consensus about the causes of temporal and spatial variability in vapor concentrations in indoor air arising from soil gas intrusion versus conduit gas intrusion, and their relative importance in various geological and geographic settings. There is no common metric(s) for evaluating and communicating the relative importance among the primary causes of the variability.

Partners: OLEM (primarily OSRTI and ORCR, but also FFRRO and OBLR) and EPA regional offices.

Output 3.3: Data and Models of Temporal and Spatial Variability in Vapor Intrusion. Through research under this output, SHC will measure and model spatial and temporal variability in VI with a focus on common pathways in homes and buildings, including migration of the contaminant from the groundwater or vadose zone source, through the soil, or along utility conduits, and into the building. SHC will also support the collection of concurrent chemical indoor air samples and indicator, tracer, and surrogate measurements in a wider variety of buildings and settings than have been studied to date.

Research Area 4: Leaking Underground Storage Tanks

An underground storage tank system (UST) is a tank and any underground piping connected to the tank that has at least 10 percent of its combined volume underground. Until the mid-1980s, most USTs were made of bare steel, which is likely to corrode over time and allow UST contents to leak into the environment. Faulty installation or inadequate operating and maintenance procedures also can cause USTs to release their contents into the environment. The greatest potential hazard from a leaking UST is that the petroleum or other hazardous substance can seep into the soil and contaminate groundwater, the source of drinking water for nearly half of all Americans. A leaking UST can present other health and environmental risks, including the potential for fire and explosion.

Evaluating Groundwater Vulnerability

Problem Statement: EPA's regions and the states need spatial methods (GIS-based methods) to identify groundwater that is vulnerable to leaking underground storage tanks and to improve site characterization for such conditions. Training state (and regional) regulators is also needed to ensure that these approaches are applied appropriately, and the results are usable for assessing potential human health threats due to contamination from leaking USTs.

Partners: OLEM [primarily the Office of Underground Storage Tanks (OUST), but also FFRRO, OBLR, ORCR, and OSRTI], EPA regional offices, states, and tribes.

Output 4.1: Models, Metrics, and Spatial Tools to Evaluate Groundwater Vulnerability. ORD will develop tools to assist the states, tribes, and the EPA regional offices in identifying vulnerabilities to groundwater from leaking UST sites or from changing conditions affecting functioning UST systems. This will include evolving flood or saltwater intrusion zones. As new methods have identified groundwater wells nationally, these data combined with improved geospatial data on underground storage tank sites, and the United States Department of Agriculture (USDA) and United States Geological Survey (USGS) national soil and groundwater data will be used to develop a groundwater vulnerability model at local, state, and national scales. ORD and OUST will develop training on these tools to assist states, Regions, and tribes in site cleanups and in assessing potential cumulative impacts to groundwater supplies.

Evaluating New Remediation Methodologies and Leak Prevention

Problem Statement: EPA regions and states need technical assistance to keep abreast of latest advancements in technologies to clean up leaking UST sites. In addition, technical guidance documents produced by OLEM and SHC to assist state UST programs in cleaning up releases from leaking USTs need to be updated with information about the latest technological advances. Biofuels and other emerging fuels have been recognized as being potentially incompatible with various UST system components that may result in releases of automotive fuels from USTs into the environment. Support is needed to identify which UST system components are incompatible with various fuels and to develop solutions to reduce the incompatibilities and prevent releases.

Partners: OLEM (primarily OUST, but also FFRRO, OBLR, ORCR, and OSRTI), EPA regional offices, states, and tribes.

Output 4.2: Updates to Technical Guidance Manuals and Evaluations of Risks to UST Systems Due to Compatibility with Fuel Formulations. ORD will assist OUST, EPA regional offices, states, and tribes in assessing developments in prevention and cleanup. ORD will collaborate with OUST to create new technical and policy documents or update technical guidance documents with new information and recent site management advances as needed. ORD will also develop approaches to assist the states in assessing fuel compatibility and fuel corrosion issues with existing UST system components to prevent releases, including during extreme precipitation events.

Research Area 5: Chemicals of Immediate Concern

Chemicals of Immediate Concern: Lead

The United States has made tremendous progress in lowering childhood blood lead levels primarily due to the implementation of multiple laws and regulations aimed at reducing lead exposure. Despite the overall decline of blood lead levels over time, lead exposure remains a significant public health concern for people of all ages because lead hazards persist in the environment. The Federal Government has made mitigating children's lead exposure one of its top priorities. About 3.6 million U.S. families with a child younger than 6 years of age live in residences with one or more conditions that can expose their child to hazardous levels of lead. Sources of lead exposure include drinking water contaminated by old lead service lines, household lead paint, soils contaminated by past hazardous industry sites, and the use of leaded fuels. Other sources of lead can also contribute to a child's lead risk, including food, folk-remedies, cultural products, consumer products, recreational activities such as hunting and stained glass making, and take-home exposure of lead from occupational sources. This research directly supports

Goal 4 of the Federal Action Plan to Reduce Childhood Lead Exposure[8]: Support and conduct critical research to inform efforts to reduce lead exposures and related health risks.

SHC research will inform pending Agency actions on lead including:

- Revision of the Lead and Copper Rule [EPA's Office of Water (OW) under the Safe Drinking Water Act (SDWA)];
- Lead-Free Rule for New Home Fixtures: Use of Lead- Free Pipes, Fittings, Fixtures, Solder and Flux for Drinking Water (OW-SDWA);
- Revision of Technical Guidance on 3Ts (Training, Testing, Telling) for reducing lead in drinking water in schools (OW);
- Steam Electric Effluent Limitations Guidelines (OW);
- Revision of Residential Lead Dust Hazard Standards [EPA's Office of Chemical Safety and Pollution Prevention (OCSPP) under the Toxic Substances Control Act (TSCA)];
- Updated Scientific Considerations for Lead in Soil Cleanups (OLEM-CERCLA/RCRA).

Lead – Identify High Risk Communities and Sources of Exposure

Problem Statement: Identifying U.S. communities with the highest risk of childhood lead exposure is a priority for EPA and is a goal listed in interagency lead collaboration efforts. Identifying these locations (e.g., areas with highest children's exposures and blood lead levels) across the Nation will assist with targeting and prioritization for lead exposure risk reduction, prevention, and mitigation efforts.

Partners: EPA's Office of the Administrator (OA), EPA regional and program offices, states, communities, tribes, federal agencies (CDC, HUD).

Output 5.1: Collaborative Science-Based Approaches and Results to Identify High Lead (Pb) Exposure Locations in the U.S. and Key Drivers at those Locations. This output will produce collaborative science-based approaches and apply results to identify high lead (Pb) exposure locations in the U.S. and key drivers (e.g. housing-related and environmental sources) at those locations. The approaches will be developed and enhanced iteratively, using available housing, sociodemographic, environmental, and states' blood lead level (BLL) data at census tract level in new applications of geospatial and statistical methods and models. New map layers will be developed for Pb sources at different geospatial scales for use in Pb modeling and mapping. Collaborative engagement with EPA regional and program offices, state and federal partners, and others will be critical to this output to produce results informing EPA/stakeholder joint planning discussions. Results will include geospatial data for visualizing high Pb exposure locations, and data analyses to help identify key drivers at those locations and inform effective targeting and exposure reduction efforts. This output responds to EPA's priority for identifying U.S. communities with the highest risk of childhood lead exposure. This is a goal listed in interagency lead collaboration efforts (e.g. Federal Lead Action Plan Goal 4, action 2: "Generate data, maps, and mapping tools to identify high exposure communities or locations…"). Identifying locations with highest potential for children's exposures and blood lead levels will assist with targeting and prioritization for lead exposure risk reduction, prevention, and mitigation efforts.

Lead – Exposure Factors and Exposure Models

Problem Statement: Data are needed to determine key drivers of blood lead levels from multimedia exposures, including the relative contributions to BLL from major sources and exposure pathways, to

[8] https://www.epa.gov/lead/federal-action-plan-reduce-childhood-lead-exposure

inform effective risk reduction strategies at national and local scales. These data are also needed to enhance and apply multimedia exposure modeling for regulatory determinations by reducing uncertainty, especially for the most at-risk groups, and for use in computing cleanup levels at Superfund and other contaminated sites. This includes the need to evaluate regulatory models, such as the Integrated Exposure Uptake Biokinetic (IEUBK) and All Ages Lead Model (AALM), used for estimating potential blood lead levels.

Partners: OLEM, OCSPP, OW, EPA regional offices, states and tribes, and other federal agencies.

Output 5.2: Methods and Data on Key Drivers of Blood Lead Levels in Children. Through research under this output, SHC will provide distributional (location specific) estimates of lead in soil, dust, drinking water, and food and will develop methods to estimate bioaccessibility of lead from soil and dust under different soil chemistry and biological conditions. SHC will explore the best methodologies and approaches to obtain field data for soil and dust ingestion rates as a function of life stage, geographic factors, socioeconomic factors, and factors in the built environment. In conjunction with the Health and Environmental Risk Assessment (HERA) research program's Output 2.1, SHC will develop innovative methods for evaluating exposure factors, and assess impacts of risk management or mitigation actions on lead exposure risk or blood lead levels. The data obtained from research in this output will also feed into HERA Output 4.1 as critical inputs to lead exposure and pharmacokinetic models to predict blood lead levels. The research also ties to the Safe and Sustainable Water Resources (SSWR) research program's Research Area 7 on Drinking Water/Distribution Systems, specifically the output "Resources and tools for characterizing and mitigating lead and copper release in drinking water distribution systems and premise plumbing." This work directly feeds into Goal 4, Action 3 of the Federal Action Plan to Reduce Childhood Lead Exposure (Generate data to address critical gaps for reducing uncertainty in lead modeling and mapping for exposure/risk analyses and for estimating population-wide health benefits of actions to reduce lead exposures).

Chemicals of Immediate Concern: Per- and poly-fluoroalkyl substances (PFAS)

Per- and poly-fluoroalkyl substances (PFAS) are a large group of several thousand industrial chemicals that are used in many consumer products and industrial and manufacturing applications. Sources of environmental releases include: 1) fire training and fire response foam; 2) industrial releases from primary and secondary production and manufacturing; 3) landfills; and 4) wastewater treatment operations. The ubiquitous nature of PFAS-containing products, their resistance to metabolic and environmental degradation, their mobility, and their potential for bioaccumulation and toxicity present serious environmental challenges. Approaches are needed to effectively treat PFAS from the sources identified above.

ORD is participating in cross-EPA and cross-federal agency efforts to address environmental issues arising from this class of emerging contaminants. SHC is focused on: 1) providing technical support; 2) informing site characterization, especially for contaminated sites, landfills, and contaminated groundwater; and 3) characterizing multimedia human and ecological exposure to PFAS. SHC's primary interest is in PFAS found in contaminated sites and sediments, solid waste, landfills and surrounding environmental media (soil, groundwater), leachates, and landfill gas. This research will extend the current understanding of sources, fate and transport, remediation, and exposure beyond perfluorooctane sulfonate (PFOS) and perfluorooctanoic acid (PFOA). It should provide information on other PFAS including, but not limited to: perfluoroalkyl acids (PFAAs); per- and poly-fluorinated carboxylic acids, sulfonic acids, and ethers; per- and poly-fluoropolyethers (PFPE); and PFAS precursors, byproducts, and transformation products. SHC's research in this area is consistent with the EPA's Per- and Poly-Fluoroalkyl Substances Action Plan[9] that notes the potential exposure hazard presented by landfill leachate and the scarcity of exposure data on PFAS.

PFAS – Environmental Characterization

Problem Statement: SHC's partners (including OLEM, OW, EPA regions, states, tribes, and communities) have identified the need to: 1) evaluate analytical methods; 2) characterize sites and sources; and 3) assess treatment/remediation options for PFAS-contaminated environmental media. These needs include support for characterizing AFFF (Aqueous Film Forming Foam) in a public water supply and in recreational waters; PFAS sampling support for soils and sediments; PFAS in leachate from contaminated and solid waste sites; PFAS in groundwater; and atmospheric releases of PFAS from primary production, secondary uses, and incineration.

Partners: OLEM, OW, OCSPP, EPA's Office of Air and Radiation (OAR), EPA regions, states, and tribes.

Output 5.3: Identification and Characterization of PFAS Sites and Sources. This output will synthesize the state-of-the-science regarding the sampling, analysis, and synthesis methods for identifying and characterizing sources of PFAS related to contaminated soils and sediments, groundwater, landfills, leachate, industrial facilities, and air [jointly with ORD's SSWR, Air and Energy (A-E), and Chemical Safety for Sustainability (CSS) research programs]. Specifically, research under this output will include:

- Developing sampling and analysis methods for identifying and characterizing PFAS sources to groundwater, surface waters, and soils/sediment that include industrial facilities, landfills, industrial wastes, fire training/emergency response activities, etc;
- Characterizing sources of PFAS to the environment at sites (including the determination of background PFAS concentrations in relevant media and biota), focusing on superfund sites, landfills, industrial and municipal waste products, and agricultural practices;
- Providing technical support regarding the identification and characterization of PFAS sites and sources (directly and through the ORD Technical Support Centers), for requests received from regional, state, municipal, and tribal partners.

Research will be communicated via various technical means, including reports and journal papers, training courses at National or Regional Association of Remedial Project Managers (NARPM) meetings, CLU-In seminars, other training/seminar opportunities [e.g. ECOS, Interstate Technology and Regulatory Council (ITRC)], and conferences.

PFAS – Sources, Fate and Transport, Remediation, and Materials Management

Problem Statement: Research is needed on chemical transformation and the mobility of PFAS at contaminated sites and for managing disposal of consumer and industrial solid waste (e.g., within landfills or via incineration), especially if released to soil and groundwater. Information about PFAS sources and fate and transport is spatially and temporally sparse. This lack of information is due, in part, to a lack of validated analytical methods for measuring PFAS in different environmental media; a lack of organized environmental monitoring and sampling activities; as well as the evolving milieu of new

[9] https://www.epa.gov/pfas/epas-pfas-action-plan

parent PFAS and degradation products. Improved characterization and understanding of the nature and behavior of PFAS at contaminated sites and in solid waste, materials management, landfills, groundwater, and the surrounding environments is necessary to better address risks. These data will, 1) help determine which PFAS pose the greatest risks to human health and the environment due to their toxicity and mobility; 2) provide insight into where these risks are most likely to occur, and 3) inform the design of effective remediation or risk management solutions.

Partners: OLEM, OW, OCSPP, OAR, EPA regions, states, and tribes.

Output 5.4: Remediation and Treatment to Manage PFAS in the Environment. This output will synthesize and communicate the state-of-the-science regarding the management, control, treatment, destruction, or removal of PFAS in groundwater, soils, aquifer materials, sediments, waste, wastewater, and landfill leachates. The main goal is to promote innovation in evaluating and managing PFAS in environmental media that will lead to improved decision making, identification of transformation residuals, management practices, and technical methods to minimize the risks to both humans and ecosystems. Systems will be evaluated for performance and cost. End-of-life disposal for consumer and industrial solid waste will be addressed. Research will be communicated with technical transfer activities, such as training courses at NARPM meetings, CLU-In seminars, other training/seminar opportunities (e.g. ECOS, ITRC), conferences, and journals.

Communication and coordination between output leads for Outputs 5.3 and 5.4 will occur to facilitate collaborative research on PFAS fate and transport, which is a common theme between PFAS site characterization and remediation.

The products from this research are generally applicable to a broad set of environmental conditions and could be extended to various potential applications, such as *in-situ*. This includes:

- Research to identify or develop innovative treatment methods for PFAS in groundwater, soil, aquifer material, sediments, landfills, and waste streams to appropriately manage the risks to humans and ecological systems;
- Research to develop novel, rapid, and cost-efficient methods and approaches to evaluate PFAS transport and fate, remediation, and potential transformation;
- Technical support regarding PFAS treatment and remediation technologies, directly and/or through the ORD Technical Support Centers.

In addition, as part of the Science to Achieve Results (STAR) program, ORD issued a 2019 Request for Applications (RFA) on "Practical Methods to Analyze and Treat Emerging Contaminants (PFAS) in Solid Waste, Landfills, Wastewater/Leachates, Soils, and Groundwater to Protect Human Health and the Environment"10. This RFA is focused on: 1) better understanding and characterization of the types and quantities of current and historical PFAS and PFAS-containing waste associated with waste disposal (e.g., landfills), as well as media containing PFAS released from these activities; 2) increased knowledge of the fate, transport, potential for degradation or other changes to PFAS, and their mobility during materials management (e.g., under different landfill conditions) that facilitate or retard such transformation or movement; and 3) new or improved methods that are more effective, efficient (in cost, energy, etc.), and

[10] More details available at: https://www.epa.gov/research-grants/practical-methods-analyze-and-treat-emerging-contaminants-pfas-solid-waste-landfills#Interest/Expected_Outputs

practical in controlling, treating, destroying, or removing PFAS in waste and wastewater, landfill leachates, biosolids, or environmental media.

PFAS - Exposure

Problem Statement: Human exposure likely occurs through multiple environmental media and routes. However, there are currently no predictive models for estimating multimedia PFAS exposure to the general population. Research is needed to identify locations where human exposures to PFAS may pose the highest risk.

Partners: EPA program and regional offices, states, and tribes.

Output 5.5: Methodology for Estimating PFAS Multimedia Human Exposure to Identify Locations of High Potential Exposure. This output will synthesize and provide access to curated information and modeling methods for characterizing PFAS human exposure. The goal will be to understand the important sources, pathways, and determinants of human exposure; variation of human exposure by location, demographics, and consumer practices; and vulnerability of populations to high-level exposure. This research includes:

- Curation of information on extant occurrence data, and product information for PFAS in exposure media and other model inputs from literature and other databases;
- Development of human exposure modeling methodologies to estimate site-specific and background exposures;
- Development of supplemental data to address important gaps for estimating multimedia human exposure;
- Demonstration of scientific workflows to address specific partner needs that combine mechanistic and data-driven approaches to analyze information, estimate exposures, guide research and inform decision makers.

Topic 2: Waste and Sustainable Materials Management

The waste generated and the cycling of materials—the flow of raw materials into and out of our economy—is voluminous, complex, and ever-changing. Some of the largest material flows involve metals and minerals (arsenic, cadmium, lead), non-renewable organic materials (including fossil fuels), and forestry (construction). These flows carry with them inherent human health and environmental implications. RCRA authorizes EPA to help manage this physical flow to avoid harm to human health and the environment. RCRA's goals include protecting human health and the environment from the hazards of waste disposal, conserving energy and natural resources by recycling and recovery, reducing and eliminating waste, and cleaning up waste that may have spilled, leaked, or been improperly disposed. SHC research is strengthening the scientific basis for the Nation's materials management decisions and guidance.

The waste and sustainable materials management research topic contains three research areas: Landfill Management, Life Cycle Inventories and Methodologies, and Waste Recovery and Beneficial Use of Materials.

Research Area 6: Landfill Management

The focus for the future of materials management, promoted by EPA's Office of Resource Conservation and Recovery (ORCR) within the Office of Land and Emergency Management, is an integrated approach to materials management, including source reduction, diversion, and recycling. Landfilling, however, remains a prominent method of waste management. There is still a need to evaluate landfill performance and its long-term impact on human health and the environment. Over the past four years, SHC has partnered with ORCR to work on guidance for ending post-closure care of hazardous and nonhazardous waste sites. SHC provided states much-needed information pertaining to the examination of performance and regulatory compliance monitoring data from a sample of RCRA landfill sites[11]. More research is needed to answer questions regarding the risk associated with these landfill sites after waste is no longer accepted, when the site will be left unattended after a post-closure period. The research will address the need for models and methods to make state and private owners and operators better informed about variables controlling the effectiveness of waste-containment systems.

Landfill Post-Closure Care

Problem Statement: The standard post-closure care period for RCRA Subtitle C and Subtitle D landfills is 30 years, but this can be shortened or extended on a case-by-case basis by the permitting authority. ORCR issued guidance on Subtitle C post-closure care in December 2016[12]. There is no clear or standardized approach under Subtitle D for evaluating the risks associated with a municipal solid waste landfill that is ready for closure, or for evaluating whether the mandated 30-year post-closure care and monitoring should be shortened or extended. In addition, ASTSWMO has requested that EPA provide guidance for post-closure care at Subtitle D sites[13]. Data and approaches are currently unavailable to provide coherent guidance to landfill owner/operators or municipal landfill managers.

Partners: OLEM/ORCR, ASTSWMO.

Output 6.1: Evaluate RCRA Sites Approaching the 30-year Post-Closure Period. SHC will evaluate RCRA Subtitle D sites approaching the end of the 30-year post-closure period and provide a methodology for the determination of impacts of ending post-closure care to minimize environmental risks as sites enter periods of minimum oversight and maintenance. These methods will inform guidance for state, tribal, and local regulatory officials responsible for oversight of RCRA sites.

Landfill Liquids Management

Problem Statement: EPA is considering revisions to the criteria for municipal solid waste landfills (bioreactors) in 40 CFR Part 258 to ease restrictions on the addition of liquids to promote accelerated biodegradation of the waste and increase economic benefits. A better understanding of the variables that influence the effectiveness of containment systems and moisture addition will be key for improving

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[11] Post-Closure Performance of Liner Systems at RCRA Subtitle C Landfills: https://cfpub.epa.gov/si/si_public_record_Report.cfm?Lab=NRMRL&dirEntryId=339571

[12] https://www.epa.gov/hwpermitting/guidelines-evaluating-and-adjusting-post-closure-care-period-hazardous-waste-disposal

[13] http://astswmo.org/files/policies/Materials_Management/ASTSWMO_Subtitle-D_Post-Closure_Position_Paper.pdf

landfill performance with respect to lower waste toxicity and mobility, reduced leachate disposal, gain in landfill space, increased landfill gas generation, and reduced post-closure care.

Partners: OLEM/ORCR, states, landfill managers.

Output 6.2: Evaluate the Impact of Liquids Management. In coordination with OLEM, SHC will gather data to optimize liquids addition parameters and develop recommendations for improved bioreactor processes, such as leachate collection, gas collection, and control wells. Anticipated outcomes include: 1) a better understanding of mechanisms of landfill stability; 2) mitigation approaches for unanticipated reactions; and 3) appropriate approaches for leachate and gas management techniques. To estimate leachate quantities, the Hydrologic Evaluation of Landfill Performance (HELP) model will be modernized and improved to account for liquids introduction. Waste types and compatibility will be examined to develop guidance on technical advances regarding moisture addition.

Landfill Temperature Management

Problem Statement: New challenges facing states and landfill operators include elevated temperatures in landfills that potentially threaten the functionality of containment systems and jeopardize long-term environmental protection. Elevated temperatures also threaten the successful operation and oversight of the waste site, risking increased numbers of landfill malfunctions and environmental releases. A greater technical understanding of the cause of elevated landfill temperatures is needed to develop landfill best practices and to design remedial actions.

Partners: OLEM/ORCR, states.

Output 6.3: **Evaluate the Cause of Elevated Temperatures**. SHC will collaborate with EPA regional offices, states, and industry to gather and analyze data from landfill sites with elevated temperatures to evaluate the nature and causes of these changes. This includes analysis of waste incompatibility, density, pressure, overburden height, degradation dynamics, and management strategies.

Research Area 7: Life Cycle Inventories and Methodologies

Resource conservation under RCRA focuses on reducing material use at the source and recovering and reusing valuable materials from waste streams. EPA describes sustainable materials management (SMM) in its report, Sustainable Materials Management: The Road Ahead[14], as fulfilling human needs and encouraging societal advancement while using less materials, reducing toxics, reducing greenhouse gases, and recovering more of the materials used. Potential SMM policies can include simple efforts to promote material recovery and reuse, more sophisticated actions such as collaborating with local industries to improve their technological performance and material use efficiency, or a combination of policies and actions enacted simultaneously. An important analytical tool for SMM is life cycle assessment (LCA), an evaluation of the environmental impacts of products and services over their entire lifespan, applied to the consumption of goods and services. SHC is developing a life cycle-based SMM Tool for OLEM's Office of Resource Conservation and Recovery (ORCR) using the United States Environmentally-Extended Input-Output (USEEIO) Model[15]. The objective of the tool is to provide a

[14] https://www.epa.gov/smm/sustainable-materials-management-road-ahead
[15]https://cfpub.epa.gov/si/si_public_record_report.cfm?dirEntryId=336332&Lab=NRMRL&simpleSearch=0&showCriteria=2&searchAll=USEEIO&TIMSType=&dateBeginPublishedPresented=07%2F09%2F2016

faster, easier, and less costly way to incorporate streamlined life cycle information into decisions for prioritizing materials and engaging in strategic, system-level dialogue with stakeholders. Further development of the USEEIO model is needed to support key functionalities requested for the SMM Tool, including state-specific models, scenario analysis, and material tracking. These enhancements will provide greater latitude and flexibility for states to work within their own legal mandates to achieve materials management goals.

Readily-Accessible USEEIO Model

Problem Statement: The lack of detailed data describing where and how materials are distributed within commerce is a key challenge hindering the ability of states to adequately address resource conservation in solid waste management plans. State and local governments and other partners and stakeholders would like to have access to results that support identifying state-specific SMM solutions. A strong interest in the state-specific version of USEEIO, demonstrated in the Georgia SMM pilot[16], has emerged in other states and regions. In addition, feedback provided by states during demonstration and dissemination of the SMM Tool has focused on the tool's inability to evaluate potential scenarios for SMM throughout the life cycle of materials. The results of scenario analyses will be key to including resource conservation components in solid waste management plans required under RCRA Subtitle D.

Partners: OLEM/ORCR, EPA regional offices, and states.

Output 7.1: USEEIO Economy-Wide Life Cycle Models. ORD will build upon the current USEEIO model to add model attributes that address gaps and needs expressed by EPA program offices, states, and other users. These attributes will include: expanding the model scope from national to global; differentiating model regions by state and sub-state within the U.S. and by country or global region internationally; differentiating good and service life cycle stages such as material extraction, manufacturing, wholesale/retail, etc; adding physical transaction layers for selected material, energy, or waste flows that enable modeling of material movement and transformation in the economy; creating models at varying levels of good and service aggregation; using different years and sets of economic and environmental data and related indicator sets; defining and modeling subsystems of the economy including food, transportation, and the built environment to enable thematic cross-sector analysis; expanding the scope of the model to include the 'use' phase; providing model results in purchaser prices; creating models with an industry sector orientation to complement the default good and service orientation; hybridizing the model with traditional life cycle inventory data, especially for modeling waste treatment and material recovery; and adding additional waste streams. ORD will expand the current modeling framework to make it increasingly flexible, efficient, robust and usable; build upon the application programming interface (API), making multiple and more complex models available; create embeddable application widgets to easily incorporate real-time model results into web pages and application; make model data and formats compatible with standards being developed for the Federal LCA Commons to enable wider compatibility and enable rapid model description and documentation. The result will be a family of improved USEEIO models with supporting data and tools, targeted for

[16] https://www.epa.gov/sites/production/files/2018-06/documents/state_stories_sept_7_2017.pdf

specific purposes that include relevant data for stakeholder needs and provide desired results. These models will also be more efficient to assemble, compute, quality check, and describe.

Enhance Measurement Methods Used for Waste Tracking

Problem Statement: Each year EPA produces the Advancing Sustainable Materials Management: Facts and Figures Fact Sheet[17] for non-hazardous waste. This fact sheet includes information on the total estimated amount of municipal solid waste (MSW) generated in the United States, a rough composition of the waste based on coarse categories, and the distribution of waste management activities (landfilling, composting, energy recovery, and recycling). These data lack state-specificity and may not consider all materials relevant to a specific state or provide the necessary granularity for states to identify new markets for recovered materials. In recent years, materials such as construction and demolition debris are measured separately, while other materials, such as industrial waste, are not yet tracked. Understanding the flow of MSW can be further complicated by the fact that waste streams can cross both state and international boundaries. For material life cycle tracking to be fully implemented in USEEIO, measurement methods used for waste tracking in EPA need to be enhanced and harmonized to provide more detail about waste generation in the commercial and residential sectors, as well as waste-handling trends at the state level.

Partner: OLEM/ORCR.

Output 7.2: Data and Methods to Advance EPA's SMM - Facts and Figures Report. SHC will collaborate with the Office of Resource Conservation and Recovery (ORCR) to revise existing data or add new data to more accurately capture waste management within the United States. SHC will also evaluate data availability and reliability to determine if waste mismanagement pathways, such as escaped trash or litter, can be included in future Facts and Figures reports. Specifically, ORD will address three focus areas:

(1) SHC will evaluate the current Facts and Figures report and methodology and provide data and analysis to improve transparency and communication of results to stakeholders. As part of this effort, SHC will explore opportunities to replace proprietary data with data from the public domain. Also, SHC will evaluate alternative approaches for calculating recycling rates for the purpose of capturing emerging concerns related to the efficiency and challenges of material recycling facilities.
(2) SHC will develop or improve management pathway models using data describing current waste management activities across the United States.
(3) SHC will develop data and models describing industrial waste generation and management, as this category of waste is of growing importance to ORCR's waste measurement program.

The combination of activities will generate data and methods with detailed documentation that can be shared with partners and stakeholders, including state and local solid waste managers. The outcomes of this work will inform the development of the USEEIO model and SMM Tool as part of Output 7.1. Municipal solid waste management in the United States is complex and varies greatly between states. Sufficiently capturing this variability in the proposed research will require managing the trade-off

[17] For more information see: https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/advancing-sustainable-materials-management

between maximizing the level of detail in the models and data and minimizing the time required to address the immediate interests.

Output 7.3: USEEIO Scenario Modeling Capability, Applications, and Guidance. The USEEIO model provides comprehensive results for potential environmental and economic impacts of regional consumption or production of goods and services analysis for baseline conditions. However, alternative scenarios need to be developed and modeled to evaluate opportunities to reduce negative impacts, create jobs, and add more value. Real-world applications of scenario evaluation are also needed for model demonstration. ORD and OLEM will collaboratively develop scenario modeling capability for USEEIO models. ORD will evaluate stakeholder-defined example scenarios in applications at national and state levels centered around sustainable materials management. ORD will also provide guidance on the use of the USEEIO model for a range of applications at local, state, and national scales, and for more detailed life cycle studies.

Output 7.4: Characterization of Food Waste Reduction Strategies and Identification of Food Waste Prevention Solutions. SHC will collaborate with OLEM/ORCR, EPA's regional offices, states, communities, and the food industry to understand the generation and disposal of food waste from a life cycle or systems perspective. This work will include an understanding of the state-of-the-science in food waste generation and treatment; analysis of treatment technologies; analysis of potential contaminants in compost and digestate; development of decision support tools for use by food waste generators and waste handlers; and identification of promising solutions for food waste prevention. Research will be used to inform public and private sector decision making, develop prevention or mitigation strategies for contaminants, and provide research-supported solutions on how to successfully prevent food waste for federal and state governments, communities, food businesses, and others.

Research Area 8: Waste Recovery and Beneficial Use of Materials

Many existing materials considered as waste for disposal could potentially be reused, recycled, or reprocessed to reduce the consumption of natural resources, decrease waste generation, and reduce the volume of materials disposed into hazardous and non-hazardous landfills. For example, virtually all industrial sectors generate secondary materials that have the potential to be reused if they can meet product specifications and do not pose a concern to human health and the environment. Federal, state, tribal, and territorial regulatory bodies make determinations as to whether to allow a given beneficial use under a wide variety of programs. A 2006 ASTSWMO survey[18] found that a major barrier to making these decisions was "insufficient information to determine human or ecological impacts of use rather than disposal." SHC and OLEM have been working to reduce this barrier by providing methodologies to determine the potential for adverse impacts to human health and the environment from a proposed beneficial use versus the use of an analogous product, considering relevant health-based and regulatory benchmarks.

Over the past several years, OLEM has supported beneficial reuse of several non-hazardous waste categories (e.g., coal combustion residuals (CCRs), and silica-based spent foundry sands produced by iron, steel, and aluminum foundries) in an environmentally-appropriate manner. OLEM also has begun

[18] ASTSWMO (Association of State and Territorial Solid Waste Management Officials). 2007; ASTSWMO 2006 Beneficial Use Survey Report. Washington, DC. November.

to further explore concepts such as: 1) utilizing buildings as material banks for a supply of existing materials in new construction or renovation projects; 2) creating more useful inventories; and 3) improving labeling to facilitate sorting of materials (e.g., treated wood). SHC has evaluated, usually on a site-specific basis, the beneficial reuse of materials such as vegetation (biochar), contaminated sediments, poultry waste, waste rock (chat), and slag.

Inventories, Evaluation, and Mass Balances

Problem Statement: Additional research is needed on topics such as: 1) inventories of wastes (e.g., waste generated from construction and demolition activities and industrial processes); 2) tools to evaluate the potential for adverse impacts associated with wastes selected for reuse (e.g., the Risk-Informed Materials Management tool); 3) mass balances associated with reuse activities for construction and demolition (C&D) materials; 4) sorting processes for C&D materials (e.g., through waste labeling); and 5) using buildings as material banks (e.g., repositories of construction materials).

Partner: OLEM/ORCR.

Output 8.1: Inventory and Assessment of Materials for Material Recovery and the Potential to Reduce Waste. SHC will develop tools and methods to advance the use, reuse, and recycling of materials. This will enhance secondary materials markets and reduce barriers for material recovery. These research activities may include: 1) better characterizing and tracking the segments and economic activity of the deconstruction and building materials reuse sector, and identifying data sources and gaps; 2) inventorying and evaluating specific commercial, residential, and industrial wastes of interest; 3) using buildings as material banks (e.g., repositories for useful construction material); and 4) inventorying harmful waste (such as solvents and foundry sands) that are not safe for reuse (e.g., lead based painted wood) and those that can be effectively processed for reuse to increase value and capitalize on these material resources. SHC will develop various methods to inventory waste generated by industrial sectors.

Output 8.2: **Methods to Improve Sorting of Construction and Demolition Materials for Reuse.** SHC will develop methods to assess available product labeling, instrumentation, and technologies to improve the sorting processes for C&D materials. SHC will document or develop best practices to encourage reuse and recovery of building materials from deconstruction and demolition activities.

Treatment Effectiveness of in-situ Stabilization of Contaminants

Problem: In 2017, EPA published the Leaching Environmental Assessment Framework (LEAF), which is a leaching evaluation system that has been validated on inorganic constituents of potential concern (COPCs), such as metals and radionuclides[19]. Continued expansion of this framework is needed to add a broader set of contaminants (especially organic ones) under a greater variety of environmental conditions. This research will support OLEM's development of regulations on the landfilling of hazardous and non-hazardous wastes.

Partner: OLEM/ORCR.

[19] https://www.epa.gov/sites/production/files/2017-11/documents/leaf_how_to_guide.pdf

Output 8.3: Leaching Tests to Develop Source Terms to Evaluate Potential Leaching from Beneficial Use, Land Disposal, and Remediation. SHC will continue to support OLEM's RCRA and CERCLA programs through validation and publication of analytical methods that provide more accurate and precise source terms across a variety of environmental conditions, waste matrices, and constituents of potential concern (COPCs). In May 2019, OLEM published the new LEAF methods for inorganics COPCs and a "How-to" Guide for its implementation[20]. SHC will continue to support OLEM in the deployment and implementation of LEAF for inorganics while transitioning to the development, demonstration, and validation of methods for organic COPCs. The majority of waste and contaminated sites (especially CERCLA sites) have both organics and inorganics. The goal is that through materials compatibility studies, SHC will develop methods to measure both organic and inorganic COPCs, recognizing the different environmental drivers that wastes encounter in the environment. These methods are intended for use by commercial and research labs, and cost is a major factor. Software (i.e., LeachXS-Lite) was developed to automate data collection, analysis, and visualization; currently, it is specific to inorganic COPCs. For conditions not easily simulated in commercial labs, we use geochemical speciation modeling to predict partitioning of COPCs in the environment. For example, SHC evaluated how laboratory and field leachate data compare to determine how well the LEAF predicts environmental release for different material types in 10 different case studies[21].

Beneficial Use of Waste Materials for Site Remediation

Problem Statement: Cost-effective and sustainable solutions, ideally using locally-available materials, are needed for the isolation and containment of chemical spills and for remediation of large-scale soil and groundwater contamination. Several waste materials (such as biochar, coal combustion residue, and slags) have properties that could be used for remediation because of their capacity to adsorb and/or potentially sequester contaminants from the external environment. These materials could be used in land application or in permeable reactive barriers to contain contamination in the soil or remove contamination from groundwater.

Partners: OLEM/ORCR and EPA regional offices.

Output 8.4: **Technologies that Beneficially Reuse Waste Products**. SHC will evaluate, develop, test, and demonstrate technologies that beneficially reuse many types of waste such as industrial-use solvents and infrastructure waste (e.g., chat, foundry sands, coal combustion residue, slag). This research will produce practitioner-oriented tutorials on sustainable engineering technologies that can be used to enhance beneficial use policy and practices. SHC will collaborate with industrial partners through cooperative research and development agreements (CRADAs), where applicable.

Topic 3: Healthy and Resilient Communities

SHC's research on contaminated sites (Topic 1) and waste and sustainable materials management (Topic 2) focuses on protecting human health and the environment in communities impacted by

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[20] https://www.epa.gov/hw-sw846/leaching-environmental-assessment-framework-leaf-methods-and-guidance

[21] Kosson, D., H. van der Sloot, A. Garrabrants, AND P. Seignette. Leaching Test Relationships, Laboratory-to-Field Comparisons and Recommendations for Leaching Evaluation using the Leaching Environmental Assessment Framework (LEAF). US Environmental Protection Agency, Cincinnati, OH, EPA/600/R-14/061, 2014.

contamination. The objectives of Topic 3 are to evaluate and demonstrate the benefits resulting from Topics 1 and 2 and help communities meet their needs for building resilience[22] in socio-ecological systems, including the health and well-being of those most vulnerable. This research will provide the scientific basis for guidance, best practices, and tools to support decisions that optimize health and well-being outcomes, while minimizing unintended consequences.

The research in Topic 3 will identify interrelationships among EPA's work in remediation, restoration, and revitalization and factors affecting those activities such as chronic (e.g., "nuisance" flooding) and acute (e.g., hurricane) environmental stressors, and the realization of benefits to health and well-being, resilience, and economic vitality. Research will be focused on: 1) understanding the causal links between ecosystem goods and services and their effects on human health and well-being; 2) developing weight-of-evidence approaches to evaluate environmental restoration and the contribution of ecosystem services to community revitalization and health promotion; 3) addressing risks and impacts to vulnerable life stages and communities, including characterizing interactions between chemical and non-chemical stressors; 4) providing science to help improve the resilience of communities against contamination and natural disasters; and 5) providing EPA, states, and communities with metrics to evaluate environmental conditions and environmental public health and well-being. Research in this topic will require collaboration with EPA, states, tribes, and affected communities in keeping with EPA's Strategic Plan and Community-based Solutions initiative.

Research Area 9: Community Benefits from Remediation, Restoration, and Revitalization

EPA plays a significant role in helping communities transform impacted sites[23] into assets that improve their community. Research Area 9 develops methods and metrics to characterize and forecast the potential benefits from remediation and restoration that improve ecological and human health and well-being. Remediation and restoration (covered in Topic 1) allow land owners to reuse and redevelop land by turning it into public parks, restored wetlands, new businesses, etc., thereby returning value and benefits for communities.[24]

Research Area 9 builds on the research in Topic 1 by using the Remediation to Restoration to Revitalization (R2R2R) framework developed by GLNPO and ORD to link site-specific environmental improvements to community revitalization after natural disasters and contaminant cleanup and restoration efforts. It examines the impacts of community revitalization goals and priorities (e.g., desired site uses, benefits derived from nature) in the design stages of remediation and restoration efforts and provides methods and tools for community decision making, while realizing the potential impacts of future environmental hazards such as extreme weather events[25]. This research area completes the

[22] Resilience is the capacity of a social-ecological system to cope with a hazardous event or disturbance, responding or reorganizing in ways that maintain its essential function, identity, and structure, while also maintaining the capacity for adaptation, learning, and transformation.

[23] "Impacted sites" include sites that are contaminated or suspected to be contaminated or impacted by natural hazards, such as extreme weather events.

[24] https://www.epa.gov/land-revitalization/basic-information-about-land-revitalization

[25] An "extreme weather event" is the occurrence of a value of a weather variable above (or below) a threshold value near the upper (or lower) ends of the range of observed values of the variable. The distinction between extreme weather events and extreme climate events is related to their specific time scales. An extreme weather event is typically associated with changing weather patterns, that is, within time frames of less than a day to a few weeks.

connections from site-specific remediation and restoration efforts to the surrounding community and nearby communities impacted by contamination or other disasters that render areas unusable. It builds on the experiences and identified needs from the collaborative work with GLNPO, OLEM's Superfund and Brownfields programs, EPA regions, and states.

Evaluation of Restoration Effectiveness

Problem Statement: EPA, states, and the private sector invest heavily in restoration activities relevant to contaminated sites, such as within the Great Lakes Areas of Concern (AOCs). Approaches for assessing the effectiveness of restoration efforts have only recently been developed. Temporal and spatial variability in existing restoration metrics are poorly characterized and difficult to implement for short-term and longer-term assessments of ecological recovery and associated beneficial uses. The resilience of the socio-ecological systems to environmental changes, such as extreme weather events, is also poorly characterized. As a result, managers lack data and methods to project future restoration effectiveness or assess the effectiveness of previous restoration actions.

Partners: OLEM, GLNPO, and EPA regions.

Output 9.1: Methods and Measures for Evaluating Restoration Effectiveness. Existing and innovative methods and metrics will be evaluated to identify relevant spatial and temporal scales for meeting partners' needs. SHC will evaluate both short-term and long-term effectiveness of linked remediation and ecological restoration actions, including potential threats from extreme weather events. SHC will work with GLNPO and other partners to refine existing or develop new approaches that can be used to assess restoration effectiveness and to measure the change in ecological condition and associated beneficial uses. This research will use physical, chemical, genomic, biological, ecological, health promotion, and/or socio-economic lines of evidence to address stakeholder-driven requirements and regulatory mandates at these sites.

Linking Remediation and Restoration to Revitalization

Problem Statement: GLNPO and OLEM's Brownfields program want to know how site remediation and restoration activities contribute to community health and revitalization. In addition to evaluating the effectiveness of remediation and restoration activities, EPA and partner agencies are now assessing how these activities contribute to revitalization of adjacent communities. Project managers need evidence linking the environmental condition of restored sites to measures of human health and well-being. State and federal programs need to understand, and communicate to the public, how investments to clean up contaminated sites will benefit their communities. Approaches are needed to more fully integrate community priorities, redevelopment goals, and human health and well-being impacts into remediation and restoration decisions, such that outcomes are more beneficial for community revitalization efforts. Decision makers need metrics and methods to demonstrate linkages between remediation/restoration and redevelopment/revitalization that span spatial and temporal scales. Cleanup actions, for example, occur at a site-specific scale, over the course of a few years or more. The available metrics are not commonly compatible with the larger spatial extents and longer time periods needed to assess the impacts of long-term ecological restoration or to measure the cumulative benefits of multiple remediation and restoration projects.

Partners: EPA Regional Superfund, RCRA Corrective Action Programs, ecological risk assessors; GLNPO, with application to other geographically-based programs and OW; OLEM/OSRTI, OLEM/OBLR, and Brownfields grantees for evaluating site-reuse options; Federal and state agency staff involved with impact assessments and permitting; OP/OCR and their regional coordinators; States, U.S. Army Corps of Engineers (USACE), ASTHO, APHA, CDC.

Output 9.2: Ecosystem Services Tools and Approaches to Support Remediation to Restoration to Revitalization. SHC will report on applications of ecosystem services tools and approaches in support of community-based Remediation to Restoration to Revitalization (R2R2R) related decision making. This will include: 1) collaborative case study assessments of the utility of existing methods for quantifying and mapping ecosystem services in different decision contexts; 2) evaluation of the potential for application of these methods to support decision making in remediation, restoration, or revitalization contexts; and 3) translation of existing methods and development of new or improved methods, knowledge, and data sets (including publicly-accessible tools for classifying final ecosystem services and associated benefits) to better facilitate the application of ecosystem services and their benefits as decision support in remediation, restoration, or revitalization contexts.

Output 9.3: Contribution of Site Remediation and Restoration to Revitalizing Communities and Improving Well-being. The goal of this output is to identify new metrics and approaches to better promote community revitalization through site remediation and ecological restoration. Collectively, these studies address the contribution of changes in environmental quality and ecological condition to human health and well-being and community revitalization. SHC will develop, validate, and demonstrate innovative metrics to assess longer-term social and economic benefits (e.g., environmental justice, resilience) of remediation and restoration. These studies will evaluate whether and how remediation and restoration efforts revitalize communities, examining metrics across multiple spatial and temporal scales. The research will synthesize published metrics and methods useful for linking remediation and restoration to revitalization and evaluate risks and resilience of contaminated sites from natural hazards. SHC will also address benefits of remediation and restoration as part of this output. Specifically, the research will evaluate causal connections between ecosystem condition (including both chemical and non-chemical stressors) and human health and well-being in the context of communities located near sites undergoing remediation and restoration. The research will also include market and non-market economic valuation to assist communities in measuring the impact of remediation, restoration, and revitalization efforts at contaminated sites. SHC will also assess the impact of sociocultural and biophysical factors that may modify ecosystem-health relationships and the perceived benefit of revitalization. Lastly, this output includes case studies to demonstrate how we integrate community priorities, redevelopment goals, and community benefits into remediation and restoration decisions. Case studies will occur across the United States, including Puerto Rico, Puget Sound, the Great Lakes, and Sun Valley, Colorado; they will address the Great Lakes Legacy Act, Superfund, and Brownfield sites.

Translating ORD Tools for Brownfield Communities

Problem Statement: Brownfield grantees develop area-wide plans and other actions designed to revitalize properties and communities. Those grantees sometimes lack technical expertise or resources to maximize the public benefits from site cleanup, redevelopment, and revitalization efforts. SHC's science-based tools can potentially support improved redevelopment decisions, but need to be more widely available and tested in real-world situations to ensure usability.

Partners: OLEM/OBLR, ECOS.

Output 9.4: Case Studies to Apply and Analyze Use of Tools at Brownfield Sites. SHC will work with OBLR, EPA regions, and communities receiving Brownfield grants to select relevant tools and assess their applicability across different project types, timeframes, and community scales. The objective is to evaluate and improve the applicability and usability of these tools, and identify refinements needed to support their wider use. SHC will develop products that describe the tool functions, experience level needed, data and system requirements, and criteria for tool selection in the context of Brownfield-related activities. The pilot testing will include some of the tools listed in Appendix 4, selected in consultation with OBLR and other relevant partners. This output will also include outreach to users to increase awareness of existing tools.

Research Area 10: Community-Driven Solutions

Research Area 10 addresses community resilience, with a focus on vulnerable groups, and examines potential impacts of hazards with the objective of speeding community recovery and sustaining public benefits. Communities are complex environments where the interrelationships among geography, people, land use, policies, and the built, natural, and social environments help determine a community's health and well-being. Adverse impacts from natural hazards, such as extreme climate events, are magnified when a community's or individual's resilience is low – meaning they lack access to fundamental resources such as healthy food, health care, and robust infrastructure. Vulnerable groups, such as children, the elderly, people with low-income, and minorities, warrant special consideration as these groups often face greater adverse impacts due to disproportionate exposures, susceptible physiologies, or other social or built environment factors.

Many communities responding to, or preparing for, natural hazards struggle with understanding the best way to improve their resilience to chronic and acute stressors. To become resilient, programs and communities need information on the intended and unintended consequences that result from environmental changes. EPA must consider vulnerable groups in its actions, in addition to ensuring that its regulations do not have a differential impact on communities or cause an increase in health disparities. Taking actions that minimize adverse impacts and disparities, while maximizing benefits, requires understanding the linkages between changes in the biophysical environment and the resulting consequences on health, economy, and well-being.

Characterizing Place: Identifying Community Assets and Vulnerabilities

Problem Statement: A community's revitalization, resiliency, and economic success all rely heavily on leveraging existing assets to produce benefits, while protecting those assets and community residents. Therefore, communities need to assess and quantify their natural, social, and economic assets and vulnerabilities, and propose appropriate strategies that will help them realize benefits, avoid hazards, and become more resilient.

Several partners have identified the need for support to characterize determinants of local environmental health risks, assess health disparities and community resilience, and develop and implement resilience and recovery plans. This includes identifying assets and vulnerabilities related to redeveloping impacted sites, as well as recovering from or increasing resilience to natural disasters, (e.g., extreme weather events, which can create chemical contamination, impact infrastructure, and generate disaster debris waste). Some assessments can be made on a nationwide scale; other assessments and actions must be tailored to a specific place.

Partners: OP/OCR, OP/OEJ, OLEM/OBLR, OLEM/OSRTI, EPA regions, OW/Office of Wetlands, Oceans, and Watersheds (OWOW), states, and communities.

Output 10.1: **Data and Approaches for Identifying and Mapping Assets and Vulnerabilities.** SHC will provide methods derived from available data to help partners and stakeholders understand their current socio-ecological and physical conditions (i.e., assets and vulnerabilities that are critical to making decisions regarding redevelopment, revitalization, and resilience planning). Partners will help identify parameters (e.g., those related to the physical environment, ecosystem services, infrastructure) that are of greatest relevance and utility for decisions about the potential for site restoration and redevelopment, and community resilience. This research will identify and use existing federal, state, and local datasets and metrics to quantify, map, and evaluate natural, social, and economic assets and vulnerabilities at the local level. This includes exploring ways to apply and expand existing EPA tools (e.g., EnviroAtlas) and metrics (e.g., Human Well-Being Index) for local-scale decision making. For example, new data layers (e.g., trends over time, community-driven alternative scenarios) can be added to the EnviroAtlas to assist with targeted decision making. Due to the complexity and unique site-specific nature of identifying and mapping assets, this output will also provide data, guidance, and tools to support states and communities in compiling their own maps.

Relationships Between Exposures and Vulnerabilities and Associated Health Outcomes from Multiple and Cumulative Stressors

Problem Statement: EPA's Strategic Plan emphasizes the impact of pollution on vulnerable groups such as children, tribes, overburdened communities, and other susceptible populations and life stages. This is also described in EPA's Memo on Environmental Justice and Community Revitalization[26]. Effectively targeting interventions and resources to serve the most vulnerable communities requires an understanding of how environmental exposures interact with factors such as conditions of the built environment, access to or degradation of valued ecosystem services, and the social determinants that contribute most to disproportionate impacts. Partners need to quantify the cumulative impacts of chemical exposure, life stage vulnerability, and stressors from the built and degraded natural environments on existing background burdens of vulnerable groups.

Partners: OP/OEJ, EPA's Office of Children's Health Protection (OCHP), OLEM/OBLR, EPA regions, states, communities, HERA, and the U.S. Department of Health and Human Services (HHS).

Output 10.2: Characterize Select Interrelationships Between Environmental Stressors to Address Cumulative Impacts on Community Health. SHC will collaborate with EPA partners to develop and use new and existing information, methods, approaches, and tools within a Total Environment[27] framework to address cumulative health impacts for vulnerable groups, such as children. This includes: 1) understanding the myriad chemical and non-chemical stressors found in the total environment (built, natural, social); 2) identifying linkages between built and natural environmental conditions, social

[26] https://www.epa.gov/environmentaljustice/memorandum-epas-environmental-justice-and-community-revitalization-priorities

[27] https://www.ommegaonline.org/article-details/Development-of-a-Conceptual-Framework-Depicting-a-Childs-Total-Built-Natural-Social-Environment-in-Order-to-Optimize-Health-and-Well-Being/1121

determinants of health, and adverse impacts on health and well-being; 3) identifying environmental disparities to enable EPA, states, tribes, and communities to incorporate considerations of disproportionately-impacted groups into risk assessments and epidemiological investigations; and 4) developing and applying these methods and approaches for assessing cumulative health impacts by incorporating a health endpoint, measure or marker.

Integrating Decision Support Tools and Processes to Support Community-Driven Problem Solving

Problem Statement: EPA regions and communities are looking more to holistic, place- and people-based approaches to solve environmental public health problems. However, these approaches often lack scientific evidence or tools to help communities make decisions and avoid unintended consequences. Processes are needed to more easily incorporate scientific evidence into community-driven problem-solving approaches. At the same time, science-based decision support tools can benefit from integrating elements such as capacity building, local and traditional ecological knowledge, partnerships, community building, and education. Integrating different EPA decision support tools and approaches will improve EPA's ability to support community-driven solutions to achieve revitalization goals by: providing an improved understanding of community-specific decision contexts; identifying ways to incorporate additional scientific evidence into community-engaged processes; and providing tools and information that are translated for community needs.

Partners: OP/OEJ, OP/OCR, OCR Regional Coordinators, OLEM/OBLR, OLEM/OSRTI, GLNPO, states, and communities.

Output 10.3: Pathways to Revitalization and Resilience that Build Community Capacity. This output will create actionable information and resources for implementing technical support programs and designing tools for community decision making based on analysis of social factors, organizational factors, and knowledge-transfer techniques that influence success. Opportunities exist to better support communities in their use of decision tools and other scientific resources for resilience and revitalization planning and implementation. In some cases, a disconnect exists between available information and tools, how those tools are designed and deployed, and the capacity of communities to use them. This output will bridge that disconnect. It will create knowledge, insights, and resources about the dimensions of community capacity, capacity growth and changes in response to program and tool use, and the approaches EPA programs and tool designers can implement to maximize their value to communities for decision making. This includes decisions in specific contexts, like planning for post-disaster cleanup activities. The output will also apply knowledge-transfer approaches (e.g., "train-the-trainer" style workshops leveraging existing partnerships, web-based materials) to build community capacity to use various SHC tools to make decisions to revitalize communities and help them become more resilient in the face of environmental stressors and disasters.

Decision Making to Improve Resiliency

Problem Statement: OLEM and EPA's regions support community plans for flood management, general resiliency, and recovery planning or management actions, like site cleanups and restoration. This kind of planning must consider the potential impacts of changing conditions and natural hazards (such as floods, hurricanes, extreme heat, and wildfires). EPA's regions want to incorporate information about expected impacts into effective, cost-efficient plans and actions for resilience, adaptation, and risk reduction in their states and communities. Resilience is the capacity of a social-ecological system to cope with a hazardous event or disturbance, responding in ways that maintain its essential structure and function, while also maintaining the capacity for adaptation and transformation. OLEM requires its programs to consider a project's vulnerability to extreme weather events and capacity to become more resilient. The Office of Community Revitalization and the EPA regions emphasize the need for communities to anticipate changes in extreme weather events, evaluate how these changes will affect a community, and evaluate potential best practices for responding. In summary, this research is needed to help stakeholders prepare for natural hazards, identify beneficial actions, anticipate and respond to events, and evaluate the effectiveness of their actions. The goal is for communities to be more resilient when adverse events occur, and experience greater health and well-being in the long term.

Partners: EPA regions, OLEM/OUST, OLEM/OEM, OP/OCR and their regional community program and disaster contacts, states, and communities.

Output 10.4: Impacts from Environmental and Natural Disasters. SHC will identify critical information and develop approaches to support communities in assessing their vulnerabilities to hazards, especially those related to extreme events (e.g., unintended releases of toxic chemicals from Superfund, hazardous waste disposal, storage and treatment sites, and industrial sites), and evaluating their preparedness. Approaches will include mapping, metrics, and methods developed for Research Area 10 Output 10.1 (Appendix 1), along with other relevant research, to consider the changing conditions to the natural, built, and social environments, (including ecosystem services) that will affect resilience to natural hazards and community health and well-being. It will include recommendations for how to use and apply data and tools to estimate and manage impacts, given changes in land use, ecosystem services, climate conditions, and extreme weather events. Identifying expected impacts will require using forecasts of future changes in weather and climate that lead to chronic conditions and hazardous events. Additional research will examine how anticipated changes to stressors, (e.g., increased flooding, more intense and frequent wildfires, prolonged drought, extreme heat), can lead to cascading shocks to communities through infrastructure failure, heat- and flood-related deaths, property and crop damage, and other outcomes.

Output 10.5: Guidance for Effective Resiliency Actions. The goal of this output is to provide guidance for partners and stakeholders as they develop effective plans to increase communities' resilience. In partnership with the regional sustainability and response coordinators, relevant program offices, and other ORD resiliency programs, SHC will evaluate current approaches, practices, and information quality and flows for effectiveness, and create evidence-based guidance, tools, methods, or other support that communities can use to develop effective and workable resilience and recovery plans. This will include metrics and methods to compare how human-built, social and natural features contribute to resilience, as well as how these features benefit human health and well-being, and how these relationships shift over time.

Research Area 11: Measuring Outcomes

Research Area 11 develops measures that provide a nationwide view of progress in EPA's efforts to protect human health and the environment. EPA's performance-based protection system relies on tracking and anticipating environmental and health issues of concern, managing and planning strategic goals, and making sound environmental decisions and policies. The Report on the Environment (ROE)[28]

[28] ROE: https://www.epa.gov/report-environment

is EPA's resource for high-level, efficient communication of the Nation's environmental and related human health conditions. The ROE brings together indicator datasets to create a comprehensive view of the Nation's status and trends, providing an objective basis for Agency decision making, planning, and tracking. The ROE also responds to the growing need for more in-depth analyses and investigations of site-specific, regional, and national-scale conditions through its analytic and prognostic components.

Partners: The ROE is an EPA-wide resource that is managed by ORD. Thus, all of EPA's programs and regions are partners with ORD in the ROE's development and maintenance. Other partners include other executive branch agencies in the curation of some of the ROE's data.

Nationwide Indicators

Problem Statement: ROE indicator data sources require regular maintenance and updates to fulfill the objective of providing a scientific basis for strategic decision making, along with the option for further exploration and analysis. Relationships and collaborations with data-collection organizations (e.g., EPA, other federal agencies, state agencies, communities) also need to be strengthened to enable more effective communication and visualization of the Nation's environmental and human health status and trends. Enhanced integration with other Agency resources and databases is needed to facilitate the interpretation and communication of cross-cutting indicators, such as lead. Linking the ROE web platform to relevant EPA webpages or local, state, or regional data will serve the needs of a wider partner base.

Partners: EPA program and regional offices.

Output 11.1: The Report on the Environment (ROE). ORD will continue to manage the Report on the Environment, the Agency's authoritative source on the status and trends of nation-wide environmental indicators. Maintenance of the ROE includes updating each indicator as new data become available, revising the website to make it more interactive, and providing overall quality control of the curated data. Since the inception of the ROE, there has been a desire to more effectively align the ROE with partners' needs and expand the utility of ROE indicators for Agency program evaluation, planning, and decision making. Thus, in addition to ROE maintenance, ORD will develop a management plan in consultation with Agency partners and the broader indicators community, to reorient the ROE to serve a wider partner base. The management plan will describe how the ROE program will meet partners' needs, including access to indicators from one platform; improved integration and connection to relevant Agency programs, data sources, databases, and webpages; and cross-cutting indicators (e.g., harmful algal blooms, wildfires, Pb). This management plan will include partnerships with other federal, state, regional, local, international, or non-governmental organizations (e.g., ECOS Results Project) for more effective communication and collaboration, and enhanced decision support. The management plan will also define the goals, scope, and outlook for the ROE program and website, which will set the stage for identifying additional datasets and ROE indicators.

Output 11.2: New Nationwide Indicators. SHC will continue to identify, develop, and pilot new nationwide indicators and indicators of national importance by working collaboratively with Agency decision makers, data providers, indicator practitioners, and end-users through the ROE Steering Committee. Other indicator efforts, such as the Environmental and Human Health Indicators Community of Practice (EHHI CoP), will continue and complement this effort. Work may entail the inclusion of new indicators identified as relevant to EPA priorities and the development of indices that meet the needs of partners by integrating human health, ecologic health, and environmental quality (i.e., as part of a One Health approach). SHC will establish relationships and collaborations with data-collection organizations (e.g., EPA, and/or federal, state, regional, local, international, or non-governmental organizations), as well as other indicator developers (e.g., U.S. Natural Capital Accounts, eEnterprise, Environmental Council of the States, United Nations Environment Programme). This includes capitalizing on already existing and relevant EPA data, research, and tools for expanding current and future indicators [e.g., National Aquatic Resource Surveys (NARS), the Cyanobacteria Assessment Network (CyAN), the Stream-Catchment (StreamCat) dataset, EnviroAtlas, Environmental Quality Index]. Proposed indicators will be vetted for inclusion in the ROE following standard protocols (e.g., utility to Agency clients, plan for indicator maintenance and updating, ROE management plan under Output 11.1).

Interpreting Indicator Trends

Problem Statement: Understanding the cause of an observed environmental or human health indicator trend is important to effectively evaluate performance or actions. The ROE, like many of its underlying data sources and other geospatial tools (e.g., EnviroAtlas), provides numerous opportunities for further investigating and understanding relevant features and underlying causal factors contributing to indicator trends.

Partners: EPA program and regional offices.

Output 11.3: Identify, Investigate, and Analyze Trends Amenable to Interpretation. In response to the indicator analytics priorities of EPA partner offices, SHC will investigate specific ROE indicator trends of importance to EPA policies by interpreting the trend for those indicators that have a causal relationship to Agency regulations and actions. The output will include three components: 1) identifying relevant indicator trends amenable to interpretation; 2) linking to relevant data sources for trend analysis; and 3) investigating and interpreting trends in selected indicator(s) that are directly relevant to EPA policies. These components will be based on an SHC-designed data collection and analysis plan that is informed by the priorities of EPA program offices and collaborators, as well as regional, state, territory, tribal, and/or community data. Most importantly, reported analytic conclusions will be developed in close collaboration with the EPA programs whose policies may be impacted by the analysis. SHC will also analyze existing indicators and indices to provide best practices in refining or developing new ones within the context of EPA program and regional office mandates and priorities.

PROGRAM DESIGN

Program Components

SHC's StRAP describes a program of actionable science to support Agency efforts to accelerate the cleanup of contaminated sites, reduce the burden of waste materials being landfilled, safeguard the health of the most vulnerable, and revitalize communities impacted by contamination and natural disasters. It focuses on meeting the priorities and legislative mandates of EPA and builds upon the EPA strategic plan and the ORD strategic plan. The SHC research program works closely with its Agency partners and external stakeholders, (including other federal agencies, nonprofit organizations, and industrial and academic scientists), to identify and conduct research to address the highest priority issues. SHC strategically integrates intramural and extramural research (STAR grants) to create a robust portfolio. Scientists representing a wide range of disciplines work together to improve our understanding of complex environmental problems.

EPA's updated strategic plan emphasizes cleaning up contaminated sites. It also emphasizes public participation and the revitalization and resilience of America's communities. SHC's Strategic Research Action Plan builds on its strengths in research on contaminated sites, materials, ecosystem services, and human health. It links engineering solutions and best practices for site remediation and managing materials with best practices for restoration of the built and natural environments to help the Agency reach its strategic goals. SHC's StRAP includes research on community-scale ecosystem services that may be impacted by natural disasters or can provide resilience. A conceptual diagram of SHC's strategic plan is shown in Figure 2.

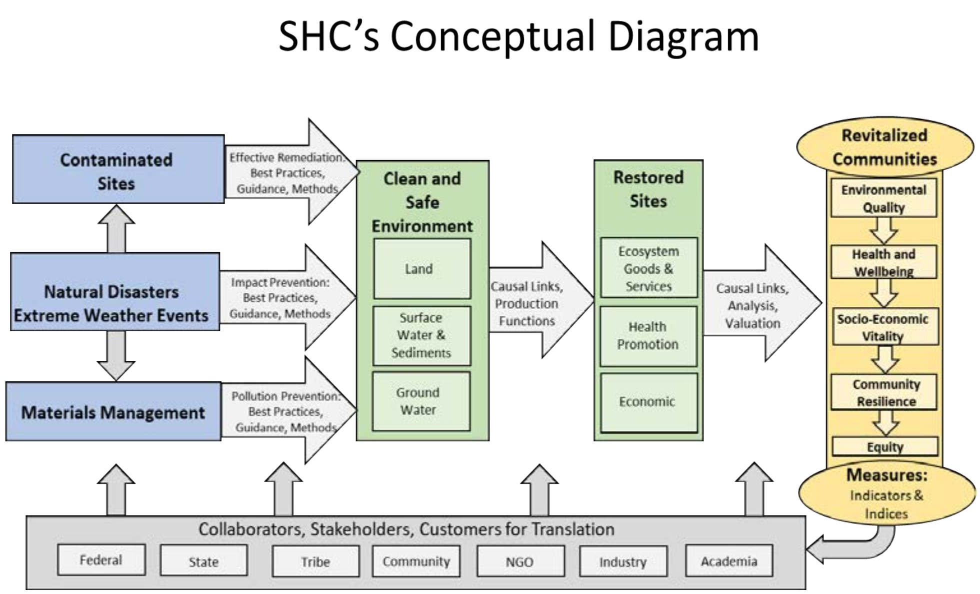

Figure 2. SHC's StRAP links engineering solutions and best practices for cleaning up contaminated sites and managing materials with planning for and recovering from natural disasters/extreme weather events to produce community outcomes such as improved health and well-being and economic vitality. The link between these is the restoration of contaminated lands and waters to restore clean and safe environments. Restored environments promote human health and provide natural benefits that can make communities more resilient and drive community revitalization.

Science to Achieve Results

Historically, ORD's intramural research efforts have been complemented by innovations and scientific advancements conducted by academic institutions. Since 1997, ORD has awarded Science to Achieve Results (STAR) grants and cooperative agreements to leading universities for high-quality research to improve the scientific basis for decisions on national environmental issues. Funding through the STAR program supports the development of a skilled environmental workforce by stimulating academic research in universities and colleges in diverse geographical areas of the Nation. STAR funding through SHC has improved our understanding of the causal relationships between public health, well-being, and ecosystem services, and has helped inform solutions for community-based decision makers.

The following STAR projects are currently active under the SHC FY16-19 StRAP. Many research outputs and publications are expected from the STAR grantees within the FY19-22 StRAP period. The STAR and National Priority research projects are expected to provide advanced scientific results in environmental public health, environmental engineering, and ecosystem research that support efforts in remediation and restoration of contaminated sites, materials management (including the beneficial reuse of waste materials), and causal linkages between ecosystems and public health to inform decision makers. Although the grants listed below were awarded in prior years, the work continues to be relevant to the needs of OLEM, OCHP, and EPA's regions.

1. RFA Title: *Science for Sustainable and Healthy Tribes*, 2013 STAR RFA, 6 grants through 9/2019.
    - **Outputs**: 2018 Research Factsheet and 2020 Research Summary Report
2. RFA Title: *Healthy Schools: Environmental Factors, Children's Health and Performance, and Sustainable Building Practices*, 2013 STAR RFA, 7 grants through 12/2019.
    - **Outputs**: Research Synthesis Report and Wiki Tool and Workshop for Healthy Schools for School Practitioners and Communities
3. RFA Title*: Children's Environmental Health and Disease Prevention Research Centers*, 2014 Joint RFA with the National Institute of Environmental Health Sciences (NIEHS), 5 Center grants through 8/31/2020; and 2012 Joint RFA with NIEHS, 8 center grants through 6/31/2020.
    - **Outputs:** 2017 Impacts Report and 2021 Impacts Report
4. RFA Title: *Health Effects of Non-Traditional Agricultural Water* Usage, 2016 Joint RFA with USDA/ National Institute of Food and Agriculture (NIFA), 1 grant through 9/30/2020.
    - **Output**: 2020 Workshop jointly with USDA/NIFA
5. RFA Title: *Integrating Human Health and Well-Being with Ecosystem Services*, 2016 STAR RFA, 4 grants through 7/31/2020.
    - **Outputs:** 2019 Interim Researcher-Practitioner Workshop/Report, 2021 Impact Report
6. RFA Title: *Oil and Gas Development in the Appalachian Basin*, 2017 National Priority Research Project, 1 grant through 8/31/2020.
    - **Outputs:** 2020 Interim Researcher-Practitioner Workshop/Report, 2021 Exposure via Water Pathways Workshop
7. RFA Title: *Using a Total Environment Framework (Built, Natural, Social Environments) to Assess Life-long Health Effects of Chemical Exposures*, 2017 STAR RFA, 3 grants through 12/31/2021.
    - **Outputs:** 2020 Interim Workshop/Report, 2022 Impacts Report
8. RFA Title: *Centers of Excellence on Environmental Health Disparities Research*, 2014 Joint RFA with the National Institute on Minority Health and Health Disparities (NIMHD)/NIEHS, 5 center grants through 6/30/2021.
    - **Outputs:** 2018 Research Summary Report and 2021 Impacts Report
9. New RFA for FY19 – RFA Title: *Practical Methods to Analyze and Treat Emerging Contaminants (PFAS) in Solid Waste, Landfills, Wastewater/Leachates, Soils, and Groundwater to Protect Human Health and the Environment*.

The STAR program also funds the People, Prosperity, and the Planet (P3) program. The P3 program promotes and facilitates undergraduate research projects in anticipation of nurturing future scientists and researchers in environmental, ecological, and public health areas. Currently, the following P3 projects are active:

- P3 Phase I, 2017 RFA, 31 grants through 2019.
- P3 Phase II, 2015-17 RFA's, 21 grants through 2019.

Solutions-Driven Research

ORD is adopting a 3-pronged strategy for solutions-driven research:

1) Apply principles of solutions-driven research broadly across ORD's six national research programs
2) Conduct pilot translational science projects that apply and evaluate methods of solutions-driven research that address well-defined and unmet needs of partners and stakeholders
3) Conduct case studies of previous and current research activities that embody the principles of solutions-driven research, which will help inform a list of best practices

Risk communication is a central factor in solutions-driven research, allowing people to understand their risks and adopt protective behaviors, as well as informing risk management decisions. ORD will emphasize advances in the science of risk communication and will apply best practices for communicating risk to different audiences across the six national research programs.

The SHC emphasis on translating science is exemplified by the outputs listed in this StRAP—they provide solutions to problems that are identified by our partners. An output synthesizes a body of work (e.g., journal articles, reports, tools, databases, etc.) so that it can be readily used by our partners to solve their problems. SHC worked with its partners during calendar year 2018, to define the problems to be solved through a series of face-to-face meetings and engagement webinars that informed the writing of this StRAP. SHC will continue to work with Agency partners to identify research products to address these problems, explicitly bringing in the perspective of the users of the science. Three central examples of SHC translational research are the development of tools, the Regional Sustainability and Environmental Sciences Research Program (RESES) program, and the NIEHS Superfund Research Program as described below.

Tools

Tools are an effective method for compiling, operationalizing, and conveying complicated information to support our partners and are a form of research translation. SHC has developed or refined several tools in the past four years and will continue developing user-friendly tools that help inform science-based decisions. Two examples are the EnviroAtlas and the Materials Management Wizard (MWiz). Appendix 4 describes currently available SHC-supported tools that serve as examples of translating research for decision makers.

RESES

The Regional Sustainability and Environmental Sciences Research Program (RESES), sponsored by SHC, is an ORD/Regional partnership program to build user-engaged research and development that assists states, tribes, and communities in addressing priority environmental issues through a collaborative approach to problem solving. RESES addresses real-world problems faced by communities. SHC is particularly interested in projects that use SHC tools that can be generalizable or transferable to multiple communities or regions.

NIEHS Superfund Research Program
SHC recognizes that related research is conducted by other federal agencies. One example is the NIEHS Superfund Research Program[29]. NIEHS has a large and long-standing Superfund Research Program (SRP) that funds over a dozen university research centers as well as individual research project grants and Small Business Innovative Research grants. SRP-funded Centers include research translation and community outreach cores. SHC will work jointly with NIEHS, OLEM, and the EPA regions to learn from their experience and help further translate results from the NIEHS Superfund Research Program for application to EPA issues.

Integration Among Research Programs

EPA's six national research programs work together to identify and address science challenges. Coordination efforts can range from formal integration across the programs, to collaboration among EPA scientists working on related issues. There are many opportunities for integration and the ORD research programs will continue working together to identify additional opportunities. SHC is coordinating with other research programs in several areas (Appendix 3). Examples of interconnectivity include:

PFAS: ORD's PFAS research program is part of the Agency's PFAS Action Plan. ORD is focused on developing and applying scientific information and tools to enable states, tribes, and their EPA regional and program office partners to make informed decisions for protecting public health and the environment from harm associated with PFAS. The research program is designed to support the cross-EPA and cross-federal agency efforts to address PFAS issues. SHC's research outputs on PFAS are included in Research Area 5. ORD's other research programs are also sponsoring research on PFAS including: standardized analytical methods and water treatment (SSWR); standards development, toxicological libraries and databases, and high throughput toxicological evaluation (CSS); PFAS air emissions (A-E); PFAS risk characterizations (HERA).

Lead: EPA is a primary participant in the Federal Action Plan to Reduce Childhood Lead Exposure and Associated Health Impacts (Action Plan)[30]. Agency scientific efforts are aligned with the Office of the Administrator priorities and support Action Plan Goal 4, to support and conduct critical research to inform efforts to reduce lead exposures and related health risks, including the following: 1) identifying the most highly exposed communities for effective Pb actions; 2) addressing critical data gaps to reduce exposure/risk uncertainties; 3) providing technical assistance for reducing Pb in drinking water and contaminated sites; and 4) advancing Pb models to support EPA decision making and characterize multimedia Pb exposures.

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[29] https://www.niehs.nih.gov/research/supported/centers/srp/index.cfm
[30] https://www.epa.gov/lead/federal-action-plan-reduce-childhood-lead-exposure

SHC's proposed scope of work on lead is described in Research Area 5. SHC and SSWR will provide innovative mitigation methods and technical support for reducing Pb in drinking water and at contaminated sites. SHC and HERA will work with EPA program and regional offices to advance lead exposure and biokinetic models for consideration in EPA Pb decisions and site assessments; this will include further evaluation and applications of IEUBK (Integrated Exposure Uptake Biokinetic) and AALM (All Ages Lead Model) models, and these models coupled with the SHEDS-Multimedia (Stochastic Human Exposure and Dose Simulation Model for Multimedia chemicals) framework.

Resilience: Resilience is the capacity of a social-ecological system to cope with a hazardous event or disturbance, responding in ways that maintain its essential structure and function, while also maintaining the capacity for adaptation and transformation. EPA works closely with other federal agencies, states, tribes, and communities to support recovery (per Presidential Preparedness Directive-8[31] and the National Disaster Recovery Framework[32]), as well as preparedness and planning. The cross-ORD resilience effort is focused on integrating ORD's work that supports EPA's efforts to assist communities in preparing for and recovering from natural disasters. Related research in other ORD research programs will assess the development of future scenario assessment products for disasters and address resilience and preparedness with respect to immediate emergency response, long-term planning for resilient communities, contaminated site remedies, and watersheds and water infrastructure. SHC's research outputs on resilience are included in Topic 3.

Anticipated Research Accomplishments and Projected Impacts

SHC will conduct research that supports the Agency's mission. Examples of some accomplishments anticipated over the next four years are listed below:

Cleanup contaminated soils and sediments, remediate groundwater, and control the source of mine-influenced waters. Anticipated accomplishments include the production of relevant and scientifically-defensible studies on cleanup technologies and human health exposure estimates in soils, sediments, and groundwater. The research will focus on priority metals commonly found at Superfund sites such as lead, arsenic, mercury, and cadmium. SHC will provide information focused on remediation challenges and the current state-of-the-art passive and active treatment technologies for mine-influenced waters. SHC will also provide technical support and outreach on the various treatment technologies. The overall impact of this work will be research that: 1) strengthens EPA's ability to protect human health at contaminated sites; 2) develops human health exposure information that can be directly used by state and EPA regulators; and 3) develops technologies, sampling methods, and exposure models for reducing metal contamination and exposure at smelter sites. This research will benefit OLEM, GLNPO, state and tribal entities, academia, the business community, non-governmental organizations, and the public by providing a collection of publicly-available, translated products.

Characterize the contamination from leaking underground storage tanks. SHC will develop tools to identify vulnerabilities to groundwater from leaking underground storage tank sites. New methods will identify groundwater wells nationally, which will then be used to develop a groundwater vulnerability model at local, state, and national scales. These tools will assist states and regions in triaging site cleanups and assessing potential cumulative impacts to groundwater supplies.

Expedite the remediation of sites impacted by PFAS and lead. SHC will improve the predictions of national- and local-scale geographic distributions of children's blood-lead levels to address data gaps

[31] https://www.dhs.gov/presidential-policy-directive-8-national-preparedness
[32] https://www.fema.gov/national-disaster-recovery-framework

(where states' BLL data are not available) using evaluated statistical or other modeling approaches and available data. This will help target effective lead exposure risk reduction, prevention, and mitigation efforts. SHC will conduct research to develop innovative methods to treat or manage PFAS in solid waste landfills, surrounding environmental media (soil, sediment, groundwater), leachates, and landfill gas to minimize their risks to humans and ecological systems.

Manage wastes in municipal and hazardous waste landfills. SHC will collaborate with regions, states, and industry to gather and analyze data from landfill sites with elevated temperatures to evaluate the nature and cause of these elevated temperatures. Included are waste incompatibility, density, pressure, overburden height, degradation dynamics, and management strategies for landfill operation. The results will allow states to more effectively manage existing landfills with elevated temperatures and prevent future occurrences.

Conduct life cycle assessments of waste materials. SHC will systematize the development of state-specific versions of a Life Cycle Assessment tool [U.S. Environmentally-Extended Input-Output Model (USEEIO)]. This will be conducted in an open and transparent framework that will allow state governments and their diverse stakeholder groups to use or further tailor the model for materials-management planning. Use of this tool can lead to reduced environmental impacts and introduce new material markets to the economy.

Reuse wastes in a beneficial manner. SHC will evaluate, develop, test, and demonstrate technologies that beneficially reuse many types of waste materials for applications such as infrastructure (chat, foundry sands, coal combustion residuals, slag, etc.) or environmental restoration projects (e.g., soil and groundwater remediation using active or passive systems). Reusing these large quantities of wastes reduces the load to landfills, lessens the impact on environmental media, and creates new marketplaces and economic opportunity.

Characterize the benefits from remediation, restoration, and revitalization. SHC will develop a set of partner-specific use cases illustrating the application of research to quantify, map, and forecast ecosystem services and their human health and well-being benefits at contaminated sites and in communities impacted by natural disasters. The results will help communities transform impacted sites into assets. This allows land owners to reuse and redevelop land through creation of public parks, restored wetlands, and new businesses, thereby stimulate local economies.

Address vulnerable communities and groups from contaminated sites. SHC will develop a framework, within a Total Environment concept, to characterize the interrelationships between chemical and non-chemical stressors from the built, natural, and social environments and their impacts on human health and well-being. The work will identify community-level information on pollutant-source locations, pollutant exposure, and social determinants of health, as well as characterize community demographics, health risks, and other forms of population vulnerability for those living in or near contaminated sites. This information will elucidate environmental disparities, incorporate considerations of disproportionately-impacted communities into risk assessments used in decision making for revitalization, and identify linkages between redevelopment of contaminated sites and social determinants of health.

Improve the resiliency of communities impacted by contamination and natural disasters. Research in resiliency will provide a better understanding of how issues of extreme weather and actions taken to increase community resilience cascade through the physical, environmental, and social systems in which decisions are made. This work will integrate SHC's work on ecosystem services and vulnerable communities with information on extreme events, with the objective of informing site-specific cleanup and natural disaster plans. Improved planning will better enable decision makers to address disparities, thereby maximizing benefits, minimizing impacts, and sustaining the gains from public investments.

Measure the outcomes of environmental protection. For the Report on the Environment (ROE) there will be the addition of a scientifically-defensible interpretation of the status and trends and future projections of indicators of national importance. The overall impact of this work will be that ROE indicators and associated interpretive and predictive analyses will 1) strengthen EPA's ability to track and anticipate environmental and health issues of concern, manage and plan strategic goals, and make sound environmental decisions and policies, and 2) benefit state and tribal entities, academia, the business community, non-governmental organizations, and the public by providing an extensive indicators-knowledge base.

CONCLUSION

Consistent with EPA's strategic plan, SHC will continue to work with our EPA program partners and regional offices, as well as with state and tribal partners, to identify the most important environmental problems they face and provide the high-quality science outputs they need to accomplish their top human health and environmental protection priorities for contaminated sites and revitalizing communities. SHC will work with partners to evaluate the usefulness and effectiveness of our research in helping them solve environmental and public health problems.

SHC's three research topics will be integrated based on the following propositions:

1. Environmental quality, human health, and the economic viability of communities are inextricably linked.
2. Environmental quality includes the benefits of nature (ecosystem goods and services) such as providing clean drinking water, decomposing waste, and natural pollination of crops and other plants.
3. Ecosystem goods and services have both a direct and indirect effect on human health and well-being.
4. Communities with contaminated sites (Superfund, hazardous waste, Brownfields) cannot be fully revitalized until the contamination is remediated.
5. Effectively managing materials, using a life cycle approach, can reduce the flow of waste generated and sent to landfills.
6. Natural disasters (e.g., extreme weather events, wildfires) can have significant impacts on communities due to the potential loss of ecosystem goods and services and the remobilization of contaminants.
7. Vulnerable groups (e.g., children, elders) and underserved communities (e.g., environmental justice communities) are disproportionally impacted by living in communities with contaminated sites and are disproportionally vulnerable to natural disasters or extreme weather events.
8. Communities that consider the benefits of ecosystem goods and services as they remediate contaminated sites will be more resilient to natural disasters and extreme weather events.
9. Meaningful public participation informed by a strong evidence base, including sound science, is essential for communities to make effective decisions.

APPENDICES

Appendix 1: Summary Table of Proposed Outputs for the Sustainable and Healthy Communities Research Program (FY2019 -2022)

The following table lists summary versions of the proposed Problem and Output statements in this StRAP, organized by Topic and Research Area. The problem statements (the need) were derived from a series of engagements with EPA's Program Offices, particularly the Office of Land and Emergency Management (OLEM), the EPA regional offices, as well as input from the Environmental Council of the States (ECOS). It should be noted that the Outputs may change as new scientific findings emerge. Outputs are also contingent on budget appropriations.

Research Area	Problem Statement (The Need)	Solution (Output) Title
	Topic 1: Contaminated Sites	
1. Technical Support	*Technical Support at Contaminated Sites:* Solutions are needed for complex contamination scenarios which require implementing remedial technologies or approaches at CERCLA, RCRA, and Brownfield contaminated sites in the United States.	1.1 Technical Support for Methods, Tools, Models, and Technologies to Characterize, Remediate, and Manage Contaminated Sites and Contaminated Groundwater (FY22)
	Technical Support for Contaminated Groundwater: The Agency needs technical support for evaluation and remediation of contaminated groundwater to reach its goals for cleaning up contaminated sites.	
2. Site Characterization and Remediation	*Development of Remediation and Assessment Alternatives for Soils and Sediments:* Improved techniques are needed to characterize and treat contaminant sources, reduce detection limits, and improve estimates of bioavailability at contaminated soil and sediment sites.	2.1 Methods, Tools, and Guidance on Remediation Options (FY22)
	Contaminated Groundwater Research – Site Assessment: At many groundwater sites, remediation is limited by the extent to which complex subsurface conditions can be characterized.	2.2 Methods and Approaches to Improve Characterization of Heterogeneous Contaminant Sites (FY22)
	Contaminated Groundwater Research – Site Remediation: Research to advance the practice of groundwater remediation, as well as support to help translate the research, is needed to improve both existing technologies and approaches, and to develop new technologies.	2.3 Remediation Approaches and Technologies for Subsurface Contamination (FY22)
	Innovative Passive Treatment Technologies for Mining-Influenced Waters: Modifications to innovative passive technologies or development of new innovative technologies, especially for *in situ* groundwater remediation, are desired, especially those that can decrease treatment costs, treatment waste volumes, and energy usage on Superfund mining sites.	2.4 *In Situ* Treatment for Mining-Influenced Waters (FY22)

	Mine Waste Water Source Control: Adequate source characterization is needed where control would provide the greatest improvement to watershed-scale contamination.	2.5 Innovative Technologies to Eliminate or Control Mining Wastes as Sources of Water Contamination (FY22)
	Reduce Lead and other Metal Contamination and Exposure at Former Mining, Smelter, and Community Sites: Mineral processing sites in or near residential communities pose an increased risk of exposure to metals in soil, dust, and fine particulates, through ingestion/inhalation during day-to-day indoor and outdoor activities or through recreational activities.	2.6 Technologies, Sampling Methods, and Exposure Models for Reducing Metal Contamination and Exposure at Smelter Sites (FY22)
3. Solvent Vapor Intrusion	*Vapor Intrusion in Large Non-residential Buildings:* Research on cost-effective methods for assessing and mitigating large buildings is needed as nearly all chemical vapor intrusion research has been performed on residential structures.	3.1 Characterize Vapor Intrusion in Large Multi-Compartment Buildings (FY22)
	Subslab Sampling Methods: Data are needed on sampling methods and sampling duration to yield the most representative data for estimating mass flux via soil gas entry for comparison to indoor air concentrations.	3.2 Field Testing and Data to Update Guidance on Subslab Sampling of Soil Gas (FY21)
	Temporal and Spatial Variability: There is no unified/coherent theory or consensus about the causes of temporal and spatial variability in vapor concentrations in indoor air arising from soil gas intrusion versus conduit gas intrusion, and their relative importance in various geological and geographic settings.	3.3 Data and Models of Temporal and Spatial Variability in Vapor Intrusion (FY22)
4. Leaking Underground Storage Tanks	*Groundwater Vulnerability:* EPA's Regions, and the states, need models and spatial tools to identify sites that are vulnerable to groundwater contamination from leaking USTs.	4.1 Models, Metrics, and Spatial Tools to Evaluate Groundwater Vulnerability (FY22)
	Evaluating New Remediation Methodologies and Leak Prevention: EPA regional offices and state staff need technical assistance to keep abreast of latest advancements in technologies to prevent and clean up leaking UST sites.	4.2 Updates to Technical Guidance Manuals and Evaluations of Risks to UST Systems Due to Compatibility with Fuel Formulations (FY22)
5. Chemicals of Immediate Concern	**Lead:**	
	Identify high risk communities and sources of exposure: EPA's Administrator and interagency collaborative efforts have made identifying US communities with the highest risk of childhood lead exposure a top priority to help target effective lead exposure risk reduction, prevention, and mitigation efforts.	5.1 Collaborative Science-Based Approaches and Results to Identify High Lead (Pb) Exposure Locations in the U.S. and Key Drivers at those Locations (FY21)

	Exposure Factors and Exposure Models. EPA needs data and improved models on the key contributors to high blood lead levels in children for regulatory decisions that will reduce lead exposure from all environmental media.	5.2 Methods and Data on Key Drivers of Blood Lead Levels in Children (FY23)
	PFAS:	
	Environmental Characterization: Research is needed to (1) evaluate analytical methods, (2) characterize sites/sources, and (3) assess treatment/remediation options for PFAS-contaminated environmental media.	5.3 Identification and characterization of PFAS sites and sources (FY22)
	Sources, Fate and Transport, Remediation, and Materials Management: The Agency and states need information about PFAS sources, fate, and transport, and human and ecological exposure, to design effective remediation or risk management solutions for contaminated and/or solid waste containment sites.	5.4 Remediation and treatment to manage PFAS in the environment (FY22)
	Exposure: The Agency needs predictive models for estimating multi-media PFAS exposure to the general population for assessment of specific source impacts and for identification of potential human exposure hotspots.	5.5 Methodology for Estimating PFAS Multi-media Human Exposure to Identify Locations of High Potential Exposure (FY22)
Topic 2: Waste and Sustainable Materials Management		
6. Landfill Management	*Landfill Post-closure Care:* Data are needed to establish standardized approaches for evaluating the risk associated with closure of municipal solid waste landfills and for evaluating 30-year post-closure care options.	6.1 Evaluate RCRA Sites Approaching the 30-Year Post-Closure Period (FY22)
	Landfill Liquids Management: Better understanding of the variables that influence the effectiveness of containment systems. Moisture addition may be key in improving landfill performance with respect to lower waste toxicity and mobility, reduced leachate disposal, gain in landfill space, increased landfill gas generation, and reduced post-closure care.	6.2 Evaluate the Impact of Liquids Management (FY22)
	Landfill Temperature Management: Research is needed on the causes and mitigation of elevated temperatures in landfills. Elevated temperatures can threaten the functionality of containment systems and the successful operation and oversight of the waste site. Greater technical understanding is needed to identify best practices and design remedial actions for landfill operators or municipal landfill managers.	6.3 Evaluate the Cause of Elevated Temperatures (FY23)

7. Life Cycle Inventories and Methodologies	*Readily-Accessible USEEIO Model:* Detailed data are needed that describe where and how materials are distributed within commerce. A module must be added to the existing United States Environmentally-Extended Input- Output (USEEIO) Model to enable users to do scenario-analysis for SMM throughout the life cycle of materials.	7.1 USEEIO Economy-Wide Life Cycle Models (FY22)
	Enhance Measurement Methods Used for Waste Tracking: The USEEIO tool needs enhanced measurement methods for use in waste tracking, to fully implement material life cycle tracking, and for input to the Facts and Figures Report.	7.2 Data and Methods to Advance EPA's SMM - Facts and Figures Report (FY23) 7.3 USEEIO Scenario Modeling Capability, Applications, and Guidance (FY22) 7.4 Characterization of Food Waste Reduction Strategies and Identification of Food Waste Prevention Solutions (FY22)
8. Waste Recovery and Beneficial Use of Materials	*Inventories, Evaluation, and Mass Balances:* Inventories of wastes and evaluations of potential adverse impacts, projected costs, and strategies are needed to improve reuse of different materials, especially construction and demolition (C&D) materials.	8.1 Inventory and Assessment of Materials for Material Recovery and the Potential to Reduce Waste (FY22) 8.2 Methods to Improve Sorting of Construction and Demolition Materials for Reuse (FY22)
	Treatment Effectiveness of in-situ Stabilization of Contaminants: Data and methods are needed to expand the Leaching Environmental Assessment Framework (LEAF) to include organic contaminants under a variety of environmental conditions.	8.3 Leaching Tests to Develop Source Terms to Evaluate Potential Leaching from Beneficial Use, Land Disposal, and Remediation (FY22)
	Beneficial Use of Waste Materials for Site Remediation: Cost effective, sustainable solutions are needed for the isolation and containment of chemical spills and for remediation of large-scale soil and groundwater contamination.	8.4 Technologies that Beneficially Reuse Waste Products (FY22)
Topic 3: Healthy and Resilient Communities		
9. Community Benefits from Remediation, Restoration, and Revitalization	*Evaluation of Restoration Effectiveness:* Temporal and spatial variability in existing restoration metrics are poorly characterized and difficult to implement for both short-term and longer-term assessments of ecological recovery and associated beneficial uses. Mapping is needed, especially for tracking ecosystem services.	9.1 Methods and Measures for Evaluating Restoration Effectiveness (FY22)

	Linking Remediation and Restoration to Revitalization: Metrics and methods to demonstrate linkages between remediation, restoration, and redevelopment and revitalization are needed that span spatial and temporal scales.	9.2 Ecosystem Services Tools and Approaches to Support Remediation to Restoration to Revitalization (FY22) 9.3 Contribution of Site Remediation and Restoration to Revitalizing Communities and Improving Well-being (FY22)
	Translating ORD Tools for Brownfield Communities: Science-based tools are needed for use by Brownfield grantees to improve the quality of re-development decisions to maximize public benefits from site cleanup, redevelopment, and revitalization efforts.	9.4 Case Studies to Apply and Analyze Use of Tools at Brownfield Sites (FY22)
10. Community-Driven Solutions	*Characterizing Place: Identifying Community Assets and Vulnerabilities:* To develop and implement resilience or recovery plans, it is necessary to characterize determinants of local health risks and assess health disparities and factors affecting community resilience. This includes identifying and mapping assets and vulnerabilities related to redeveloping impacted sites and recovering from, or planning for, resilience to natural hazards, such as extreme weather events.	10.1 Data and Approaches for Identifying and Mapping Assets and Vulnerabilities (FY22)
	Relationships Between Exposures and Vulnerabilities and Associated Health Outcomes from Multiple and Cumulative Stressors: To solve long-term environmental health issues at the community scale, it is necessary to be able to quantify the cumulative impacts of chemical exposure, life stage vulnerability, and stressors from the built and degraded natural environments on existing background burdens of poor general health, high rates of disease, and poor mental health.	10.2 Characterize Select Interrelationships Between Environmental Stressors to Address Cumulative Impacts on Community Health (FY22)
	Integrating Decision Support Tools and Processes to Support Community-Driven Problem Solving: Processes are needed to more easily incorporate scientific evidence into community-driven problem-solving approaches. Integrating different EPA decision support tools and approaches will improve EPA's ability to support community driven solutions to achieve revitalization goals.	10.3 Pathways to Revitalization and Resilience that Build Community Capacity (FY22)
	Decision Making to Improve Resiliency: The Agency needs to be able to identify expected impacts from natural or manmade perturbations, to integrate that information into effective, cost-efficient plans and actions for resilience, adaptation, and risk	10.4 Impacts from Environmental and Natural Disasters (FY22) 10.5 Guidance for Effective Resiliency Actions (FY22)

	reduction, and to capture multiple benefits for communities and residents, while avoiding unintended consequences.	
11. Measuring Outcomes	*Nationwide Indicators:* Decision and policy makers in the EPA require updated and easily accessed indicator data from EPA's Report on the Environment (ROE). Enhanced integration with other Agency resources and databases is needed to facilitate the interpretation and communication of cross-cutting indicators (e.g., lead).	11.1 The Report on the Environment (ROE) (FY22) 11.2 New Nationwide Indicators (FY22)
	Interpreting Indicator Trends: The Agency needs effective evaluation of changes in environmental conditions and the impact of environmental actions. This requires an improved understanding of the underlying causal factors for observed environmental or human health indicator trends.	11.3 Identify, Investigate, and Analyze Trends Amenable to Interpretation (FY22)

Appendix 2: State Needs Reflected in ORD Research Planning

The table below lists the state needs identified in the 2016 Environmental Council of the States (ECOS) survey and in discussions with ORD in spring of 2018. The state needs are aligned to the relevant ORD Research Areas planned in the six ORD StRAPs, with those needs specific to SHC identified below.

Source	***State Need***	***Research Area***
	Water	
2016 Survey	More work on wastewater treatment plants and landfills (MI)	Materials Management – Landfills
	Issues with Altered Hydrology	Groundwater
	Groundwater remediation: would be beneficial to see data from past *in situ* efforts and designs related to hydro technologies (AZ)	
	Capitalize on teamwork/agency cooperation to promote Arizona Department of Environmental Quality's mapping tool to locate drinking water sources near gas stations (currently selecting samples of tanks they will remove) (AZ).	Groundwater & Leaking Underground Storage Tanks
	Emerging Contaminants	
2016 Survey	Manage new chemicals of emerging concern and existing chemicals	Chemicals of Immediate Concern, PFAS and Pb
	Waste/Remediation	
2016 Survey	Remediation and changing standards: soil, groundwater, surface water, sediment	Soils and Sediments; Groundwater
	Vapor Intrusion	Solvent Vapor Intrusion
	Chlorinated solvent groundwater plumes	Groundwater
	Remediation of legacy contaminants ranging from PBTs to nutrients	Benefits from Remediation, Restoration, and Revitalization
	Emerging contaminants (e.g. PFAS)	Chemicals of Immediate Concern, PFAS
	Beneficial uses of solid waste	Waste Recovery and Beneficial Use
	Solid waste landfills post-closure stability	Materials Management – Landfills
	Need realistic goals for bedrock contamination remediation (AZ)	Mining and Mineral Processing Site Remediation
	Want data on past *in situ* remediation of groundwater work including what has/has not worked in different hydrogeologies. There	Groundwater

	is an ITRC team on this, but it doesn't address the hydrogeological differences (AZ)	
	Materials Management/Waste Minimization (TN) • Economics and effectiveness of food waste minimization programs • Effectiveness/benefits of urban farm development • Life cycle cost analysis for plastic and glass recycling and composting	Life Cycle Inventories and Methodologies
Cross-Media		
2016 Survey	PFAS • Need remediation techniques to accompany EPA's work on analysis/detection (OK) • Actual health or environmental impacts of PFAS (currently only speculation exists) (TN)	Chemicals of Immediate Concern;

Appendix 3: Cross-cutting Research Issues

The following table lists research issues and activities coordinated across the ORD national research programs.

Research Issue	A-E	CSS	HERA	HSRP	SHC	SSWR
Ecosystem services	• Secondary NAAQS • Near road & urban air quality • Wildfires • Extreme heat	• Ecotoxicity	• Eco risk assessment	• Regulating services (mitigation of flooding, other extreme events)	• Site recovery • Health promotion • Community revitalization • Ecosystem services	• Secondary NAAQS
Lead			• Regulatory models • Risk Assessment	• Sensors and water infrastructure modeling, including contaminant fate and transport	• Locations • Exposure data & evaluated models • Innovative solutions	• Water treatment systems • Drinking water quality sampling • Risk Assessment • Sensors & Water Infrastructure
Nutrients	• Atmospheric deposition of airborne nitrogen and phosphorus to ecosystems	• Toxicity testing				• Sensors and Water Infrastructure(w/SHC) • N & Co-pollutants • Toxicity Testing (w/CSS)
PFAS	• Air and emissions sampling and control potential	• Analytical standards • Adverse outcome pathways • Rapid toxicity testing	• Risk characterization	• Treatment of contaminated water from emergency response activities, including use of PFAS containing firefighting foam	• Tech Support • F&T at contaminated sites and landfills • Estimating human exposure	• Analytical methods • Remediation • Waste-water treatment • Toxicity Testing
Resilience	• Sector-based approaches to resilience • Assessment of trends and development of scenario to support adaptation and resilience for extreme events			• Emergency preparedness and response for all hazards	• Indicators of long-term resilience • Preparation and response to natural disasters	• Coastal Resilience • Stormwater
Wildland fires	• Models and measurement methodologies • Vulnerable ecosystems and human populations • Approaches to mitigate risks			• Fate and transport of contaminants during wildland fires, e.g., fire in asbestos contaminated area	• Models and measurement methodologies	

Appendix 4: Table of Currently Available SHC-funded Tools for Translation

This list of tools is representative of tools that help translate research for decision makers in the program and regional offices, the states, and tribal communities.

Tool Name: Description
Causal Analysis/Diagnosis Decision Information System (CADDIS)[33]: An online application designed to help users conduct causal assessments of biological impairments, primarily in stream ecosystems, so they may develop appropriate management actions.
Eco-Health Relationship Browser[34]: An easy, interactive tool providing the scientific evidence for linkages between ecosystem services and their benefits for people's health and well-being. The tool points users to the supporting scientific literature and is a part of, and accessed through, the EnviroAtlas.
EPA H2O: A desktop GIS-based decision support tool for exploring the spatial arrangement and value of ecosystem goods and services at regional to local scales, and along stream and road networks. Users can use the tool to make alternative future land use scenarios and generate reports estimating resulting changes in nature's benefits for humans.
EnviroAtlas[35]: A web-based decision support tool giving users the ability to view, analyze, and download information related to ecosystem services (nature's benefits) for the contiguous United States and at finer spatial resolution for 18 featured metropolitan areas to date, with more added yearly. Contains an interactive, geospatial mapping application with hundreds of data layers that can be used at a wide variety of scales, from national to community level, and helps communities understand how various decisions can affect an array of ecological and human health outcomes. Purpose is to allow a range of user groups to explore information and maps on ecosystem services supply, demand, and drivers of change to inform planning and decisions on multiple scales. Also includes the Eco-Health Relationship Browser.
Environmental Quality Index (EQI)[36]: A composite measure at county-scale to better estimate and convey overall environmental quality and the relationship between environmental conditions and human health, using indicators from the chemical, natural, built, and social environment in five environmental domains: air, water, land, built, and sociodemographic. It is expected to be used for modeling and research, however, other users can include local, county, state, and federal governments, non-governmental organizations (NGOs), and academic institutions.
EcoService Models Library (ESML)[37]: An online database for ecological models that are usable for estimating the production and value of ecosystem goods and services; it provides detailed descriptions of models – covering purpose, approach, and environmental use of each model and the model's variables.
Final Ecosystem Goods and Services Classification System (FEGS-CS)[38]: FEGS-CS defines and classifies ecosystem services, providing a foundation for measuring, quantifying, mapping, modeling, and valuing ecosystem services for specific beneficiaries. This is a common "language" to facilitate discussion and the development of measures to link ecosystem goods and services to human well-being, so that information can be applied for assessment and decision-making purposes.

[33] https://www.epa.gov/caddis
[34] https://www.epa.gov/enviroatlas/enviroatlas-eco-health-relationship-browser
[35] https://www.epa.gov/enviroatlas
[36] https://www.epa.gov/healthresearch/epas-environmental-quality-index-supports-public-health
[37] https://www.epa.gov/eco-research/ecoservice-models-library
[38] https://www.epa.gov/eco-research/final-ecosystem-goods-and-services-classification-system-fegs-cs

Green Infrastructure Wizard (GIWiz)[39]: A user-friendly web-based database and search tool for finding appropriate and relevant EPA information and tools for making decisions about stormwater management and other uses of green infrastructure.
Advanced Streamline-Based Ground Water Transport Model (GW Transport): A model to inform users about the impacts of subsurface contamination on community water supplies by enabling rapid assessment of subsurface contaminant transport from multiple sources under climate change scenarios.
Hydrologic Evaluation of Landfill Performance (HELP) Model[40]: A technical model that estimates water buildup for landfills and other land disposal systems, using information on rainfall, runoff, infiltration, and other water pathways.
Human Well-being Index (HWBI)[41]: A summary measure that characterizes well-being for all counties of the United States using 84 metrics for existing cultural, economic, health, and other data. The **Community-Scale Human Well-being Index Tool (CS-HWBI)[42]** offers a way for communities to "customize" HWBI values using temporally- and geographically-specific information to produce HWBI indicators that better reflect local conditions, culture, and interests.
Materials Management Wizard (MWiz)[43]: A user-friendly web-based database and search tool for finding appropriate and relevant EPA decision support tools and resources for sustainable materials management.
PVIScreen (PVIScreen)[44]: The Petroleum Vapor Intrusion Screening Tool was developed to assess the potential for petroleum vapor intrusion into nearby building from leaking UST sites. Modeling results may help regulators determine when sites can be screened out from further investigation.
Report on the Environment (ROE)[45]: A comprehensive and interactive online source of 85 scientific indicators that describe the current status and historical trends in U.S. air, water, land, human health, exposure, and ecological systems at the national and, in some cases, regional levels.
United States Environmentally Extended Input-Output Model (USEEIO)[46]: A National-scope environmental life cycle model of goods and services, which melds data on economic transactions between 389 industry sectors with environmental data for these sectors covering land, water, energy, and mineral usage and emissions of greenhouse gases, criteria air pollutants, nutrients, and toxics to build a life cycle model of 385 US goods and services.
Visualizing Ecosystem Land Management Assessments (VELMA)[47]: An eco-hydrological modeling framework for assessing potential trade-offs among ecosystem services in response to alternative land use, climate, and other changes within a watershed; includes green infrastructure and climate-related considerations.

39 https://www.epa.gov/sustainability/giwiz
40 https://www.epa.gov/land-research/hydrologic-evaluation-landfill-performance-help-model
41 https://cfpub.epa.gov/si/si_public_record_report.cfm?Lab=NHEERL&dirEntryId=245973
42 https://webx.ord.epa.gov/shc/community-scale-human-well-being-index-cs-hwbi
43 https://www.epa.gov/sustainability/mwiz
44 https://www.epa.gov/ust/petroleum-vapor-intrusion
45 https://www.epa.gov/report-environment
46 https://cfpub.epa.gov/si/si_public_record_report.cfm?Lab=NRMRL&dirEntryId=336332
47 https://www.epa.gov/water-research/visualizing-ecosystem-land-management-assessments-velma-model-20