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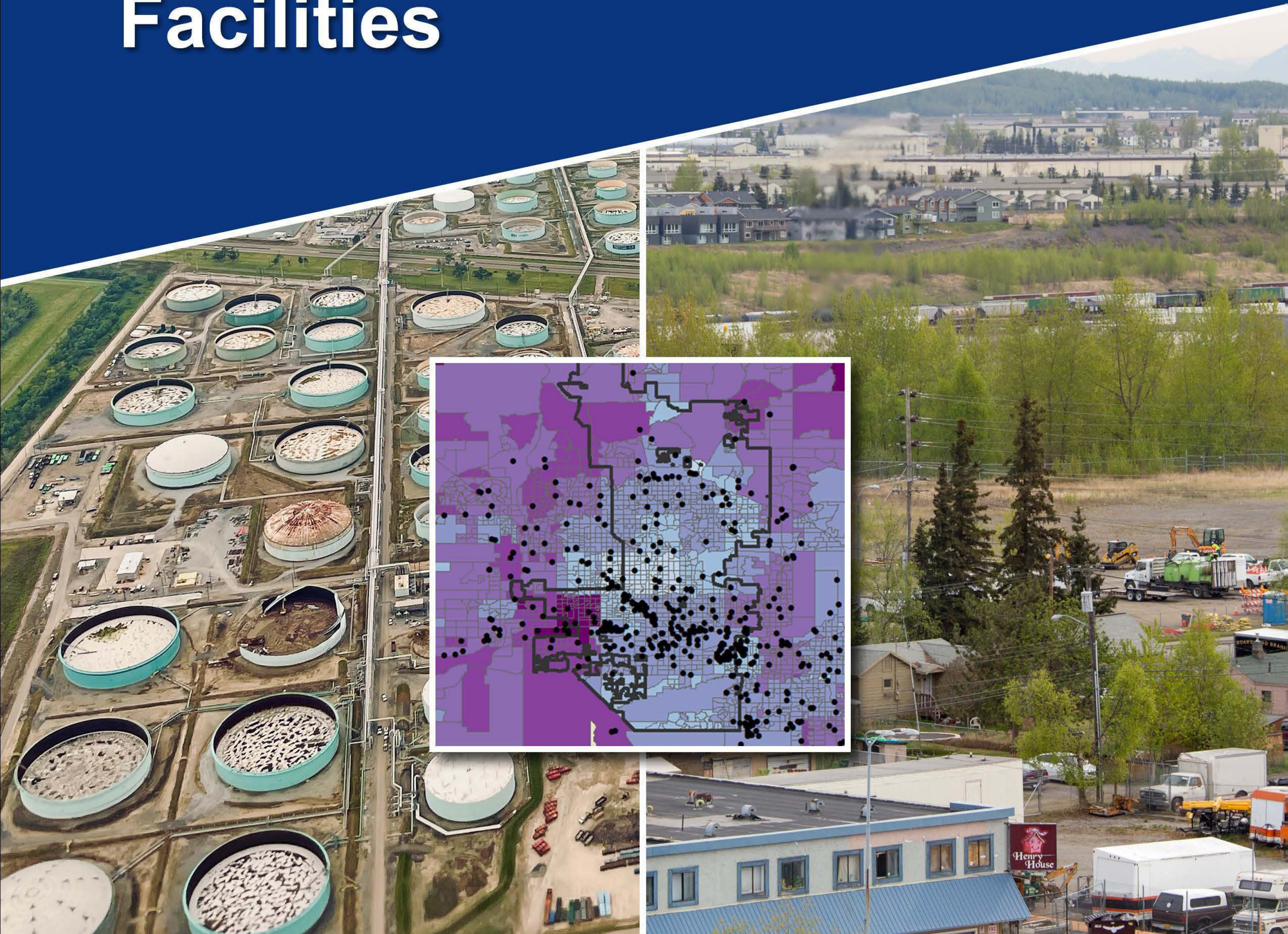
Handbook on Indicators of Community Vulnerability to Extreme Events: Considering Sites and Waste Management Facilities



Office of Research and Development
Center for Public Health and Environmental Assessment

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Handbook on Indicators of Community Vulnerability to Extreme Events:

Considering Sites and Waste Management Facilities

Center for Public Health and Environmental Assessment
Office of Research & Development
U.S. Environmental Protection Agency
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ACRONYMS AND ABBREVIATIONS

3-D	three-dimensional
3DEP	USGS 3-D Elevation Program
ACRES	Assessment, Cleanup and Redevelopment Exchange System
ACS	American Community Survey
ADEQ	Arizona Department of Environmental Quality
API	Application Programming Interface
AST	Aboveground storage tank
AZ	Arizona
AZ DEQ	Arizona Department of Environmental Quality
BG	Block Group
BRAC	Base Realignment and Closure
BRS	Biennial Reporting Service
CESQG	Conditionally Exempt Small Quantity Generators
CIMC	Cleanups in My Community
CIRA	Climate Change Impacts and Risk Analysis
CMIP3	Coupled Model Intercomparison Project Phase 3
CMIP5	Coupled Model Intercomparison Project Phase 5
CONUS	Continental United States
CRAN	Comprehensive R Archive Network
CSV	Comma Separated Value
CT	Connecticut
DEM	Digital Elevation Model
EPA	U.S. Environmental Protection Agency
FEMA	Federal Emergency Management Agency
FRP	Facility Response Plan
FRS	Facility Registry Service
FTP	File Transfer Protocol
GCRP	Global Change Research Program
GHGRP	Greenhouse Gas Reporting Program
GIS	Geographic Information Systems
GRIB2	General Regularly-distributed Information in Binary form; commonly also called as Gridded Binary
HAND	Height Above Nearest Drainage
HUC6	6-digit Hydrologic Unit Code
IPUMS	Integrated Public Use Microdata Series
JSON	JavaScript Object Notation
LMOP	Landfill Methane Outreach Program
LOCA	Localized Constructed Analogs
LQG	Large Quantity Generators
LUST-ARRA	Leaking Underground Storage Tank – American Recovery and Reinvestment Act
MNA	Monitored natural attenuation
NA	Not applicable

NAM	North American Mesoscale Forecast System
NAM-ANL	North American Mesoscale Forecast System Analyses
NCEI	NOAA National Centers for Environmental Information
NCEP	National Centers for Environmental Prediction
NE	Northeast
NetCDF	Network Common Data Form
NFHL	National Flood Hazard Layer
NHD	National Hydrography Dataset
NIH	National Institutes of Health
NOAA	National Oceanic and Atmospheric Administration
NPL	National Priorities List
NW	Northwest
OEM	EPA Office of Emergency Management
ORCR	EPA Office of Resource Conservation and Recovery
ORD	EPA Office of Research and Development
ORNL	Oak Ridge National Laboratory
OSC	On-Scene Coordinator
OSRR EPRB	Office of Site Remediation and Restoration Emergency Planning and Response Branch
PET	Potential evapotranspiration
R1	U.S. EPA Region 1
R9	U.S. EPA Region 9
RCP	Representative Concentration Pathway (Climate Scenario)
RCRA	Resource Conservation and Recovery Act
RV	Recreational vehicle
SAA	Superfund Alternative Approach
SE	Southeast
SEMS	Superfund Enterprise Management System
SHC	Sustainable and Healthy Communities
SNAP	Supplemental Nutrition Assistance Program
SPCC	Spill Prevention, Control, and Countermeasure
SPEI	Standardized Precipitation-Evapotranspiration Index
SPI	Standardized Precipitation Index
SQG	Small Quantity Generators
SW	Southwest
TC	Toxicity characteristic
TCLP	Toxicity Characteristic Leaching Procedure
TSDF	Treatment, Storage, and Disposal Facilities
UGRD	wind vector component, u
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
UST	Underground storage tank
UTC	Coordinated Universal Time
VGRD	wind vector component, v
VOIP	Voice over internet protocol

WHO	World Health Organization

PREFACE

This handbook was prepared by the U.S. Environmental Protection Agency's (EPA's) Sustainable and Healthy Communities (SHC) research program, located within the Office of Research and Development, with support from RTI International. The SHC research program provides scientific information and tools that integrate public health, physical, natural, and social sciences, toxicology, engineering, and ecosystems research to support Agency priorities and empower communities to make scientifically informed decisions. Research is done with and for communities to improve their access to clean air, water, and land for increased health and well-being where people live, learn, work, and play. Across the U.S., there are thousands of sites contaminated by releases of chemicals and toxins. These sites detract from human health and well-being, disrupt ecosystem services, and limit productive use of the land. This handbook provides a conceptual framework and indicators to assess the indirect impacts of extreme events such as extreme heat, floods, drought, and wildfires on communities through potential exposure to contaminant releases from nearby contaminated sites and waste management facilities. The indicator approach assists in identifying and prioritizing communities that may be impacted the most and focusing preparedness, response, recovery, and climate adaptation planning on areas that are the least resilient to extreme events.

AUTHORS, CONTRIBUTORS, AND REVIEWERS

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Executive Summary

When extreme events (extreme heat, floods, droughts, wildfires) happen, sites and waste management facilities have the potential to release contaminants, possibly impacting nearby communities. This handbook describes how to select, develop, map, and analyze indicators as a screening approach to identify community sensitivities and potential vulnerabilities. This approach was developed as a collaborative effort between RTI international, the U.S. Environmental Protection Agency (EPA), and regional, state, and local partners. It has been refined and demonstrated using two case studies (Waterbury, CT and Maricopa County, AZ).

The screening approach described herein involves four key steps:

1) Define the scope and spatial/temporal extent of the analysis in collaboration with partners
2) Identify key vulnerability factors and indicators to represent them
3) Develop and calculate indicators (identified above) for key determinants of impacts of extreme events
4) Use spatial mapping techniques to analyze and communicate results

Throughout the process, close coordination with local partners (e.g., community representatives and members, technical experts, decision-makers) is crucial to ensure that the analysis is customized to suit specific community needs and clearly communicated. (Note: This handbook uses the terms “partners” and “target audience” interchangeably.) In the first two steps, the spatial area and vulnerability factors of interest to the communities are defined and indicators representing these factors are selected. Developing indicators in the third step entails gathering and vetting publicly available geospatial data on indicators that represent historical baseline and projected extreme events, different types of waste facilities and potentially contaminated sites, pathways of contaminant release and transport (via air and water), and characteristics of community populations. Mapping the geospatial data in the fourth step aims to represent and communicate the information in a way that is most useful to the target audience.

This handbook offers a transparent and replicable method of developing vulnerability indicators that teams of planners, decision-makers, and technical advisors (for localities, cities, tribes, states, and regions), scientific researchers, environmental advocates, and community organizations may use to screen and assess where the most vulnerable communities/areas are in order to communicate and focus resources most effectively. More specifically, it provides a way to (1) identify areas that are potentially vulnerable and identify the source(s) of vulnerabilities, (2) track and monitor sites/waste facilities, including those of local interest, and (3) evaluate and communicate how extreme events may impact the sites/waste facilities and the nearby community. Decision-makers can use these results to develop and prioritize targeted strategies (e.g., adaptation, mitigation, resilience, response) to prepare for and prevent potentially deleterious health and environmental impacts from contaminant releases.

1 Introduction

1.1 Context and Purpose

Extreme events, including excessive heat, prolonged droughts, floods, and wildfires, are projected to become more frequent and intense under future climate scenarios. In addition to their direct effects, extreme events also have indirect effects on people through their impacts to infrastructure and the surrounding communities. Indirect consequences of these extreme events may include higher exposures to contaminants accidentally released from sites and facilities that are either actively or have a history of managing or storing hazardous substances, wastes, or potential contamination (henceforth referred to as "sites/waste facilities"). This creates further hazards for surrounding communities. Understanding the risks to communities from potential exposures to water- and airborne contaminants underlies preparedness, emergency response, and mitigation planning.

To better understand and communicate what is known and unknown about such risks, this handbook describes how to select, develop, map, and analyze indicators. Indicators are repeatedly tracked observations or modeled outcomes that describe the state and trends of key variables which can be used to understand changes and to inform decision/policy making, (adapted from Janetos and Kenney 2016). Example applications of the indicators include:

- Identifying communities that are vulnerable and the sources of their vulnerability
- Tracking sites/waste facilities, including those of local interest
- Communicating how extreme events may impact such facilities and the surrounding community.

Box 1. Indicator Approach

Why develop vulnerability indicators?

To support state and local decision-makers in developing and prioritizing targeted mitigation, adaptation, resilience, and response strategies to prepare for and prevent potentially negative health and environmental outcomes from accidental contaminant releases from sites/waste facilities.

Why indicators, why not site-specific modeling?

In-depth modeling activities provide detailed information but are typically:

- Complex, time and resource intensive
- In need of visualization and communication expertise to support decision-making.

Indicators can be helpful as a screening tool for prioritizing areas and resources where more in-depth analysis is needed since they are:

- Easier and quicker to implement
- Simpler to visualize and communicate.

Has the method described in this handbook been applied?

The community vulnerability indicators and maps developed for the Maricopa County case study in collaboration with EPA, Maricopa County, and Arizona Department of Environmental Quality (ADEQ) have been used to communicate, plan, and take action to address community vulnerabilities in the Phoenix Climate Action Plan (www.phoenix.gov/oep/cap).

This handbook provides a transparent and replicable approach that regional, state, and local managers may apply to screen and assess vulnerable communities in order to communicate and focus resources most effectively.

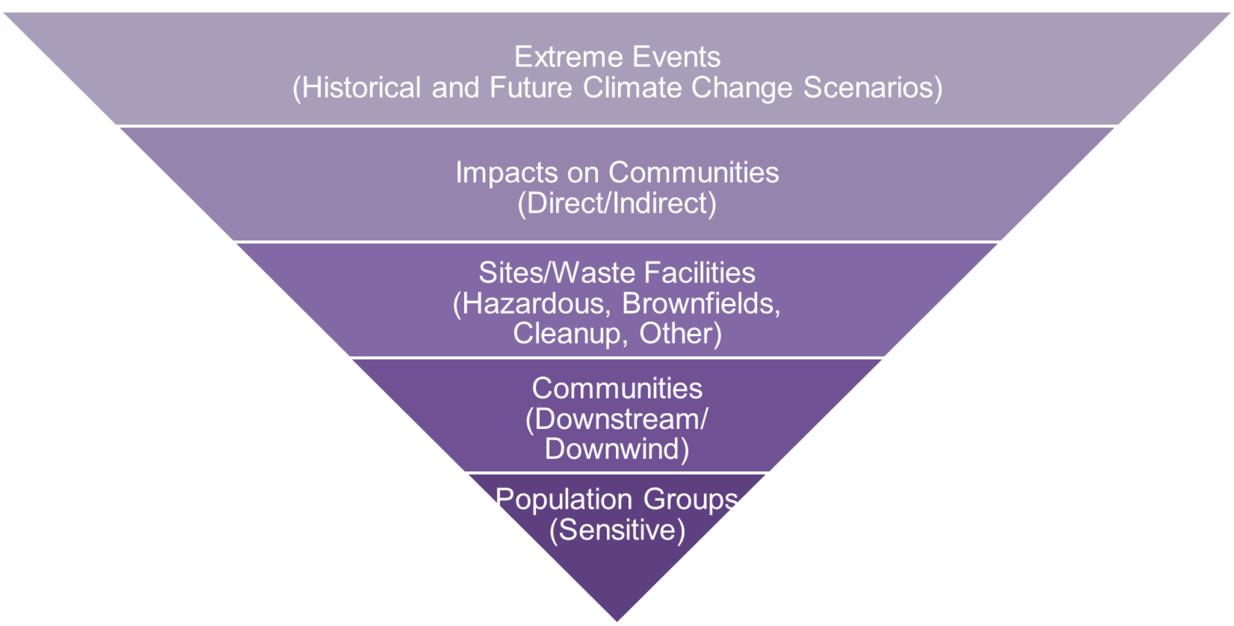
The indicators in this handbook were developed in close collaboration with the U.S. Environmental Protection Agency (EPA) and regional, state, and local partners. They were refined and demonstrated using two case studies (Waterbury, CT and Maricopa County, AZ). Local partners were engaged throughout the process of developing the approach, defining the indicators, selecting, and vetting datasets and mapping the indicators. Quantitative results and maps from the case studies were not included in this document since this is meant to be a handbook for future users.[1]

1.2 Scope

The method presented in this handbook (Figure 1) covers the following measures (indicators):

- Historical and projected spatial information on the magnitude and frequency of extreme heat, floods, droughts, and wildfires
- Characteristics of sites/waste facilities that are typically regulated, managed, or supported by the EPA's Office of Land and Emergency Management or its state and Tribal counterparts
- Wind and hydrological patterns that determine how contaminants may be transported from sites/ waste facilities to communities
- Socioeconomic, demographic, and health characteristics of community populations

Figure 1. Vulnerability Scope: Impacts on Sites/Waste Facilities and Surrounding Communities



[1] For the interested reader, results for Maricopa County are available in a journal article. Box 2 on page 4 provides example applications of the results in Maricopa County/ Phoenix City to illustrate how the indicators in this handbook can be used.

> While there are numerous risks to communities from worsening extreme events, this handbook focuses on indicators of the indirect impacts of extreme heat, floods, droughts, wildfires on communities through potential contaminant releases from sites/waste facilities. Communities that are downstream and downwind of sites/waste facilities are identified. Socioeconomic, demographic and health characteristics of community populations identify individuals who are predisposed to be impacted more.

The indicators method presented in this handbook does not cover:

- Extreme events relevant to coastal areas such as sea level rise and hurricanes.
- Site-specific analysis and in-depth modeling activities that can be extremely resource and time intensive. Instead, this method provides physically based indicators informed by models. These indicators can be applied for screening purposes, so resources for modeling can be focused on the most vulnerable communities.[2] Compared to in-depth modeling, indicators can often effectively convey the impacts of climate change to policymakers and the public in a simpler framework that is easier to implement and understand.
- Direct impacts on human health (e.g., heat stroke, heat exhaustion). Rather, the method focuses on the potential for contaminant releases from sites/waste facilities during the four types of extreme events listed that may indirectly impact downstream or downwind communities.
- Indicators aggregated into an index or score. Keeping the indicators separate allows for each source of vulnerability to be identified and for actions to be targeted toward specific sources.

1.3 Applying the Handbook

This handbook summarizes the steps and key considerations for developing vulnerability indicators to screen, assess, and communicate potential extreme event impacts on sites/waste facilities and surrounding communities.

1.3.1 Who should use this handbook?

This handbook is designed for teams of planners, decision-makers, and technical advisors (for localities, cities, tribes, states, and regions), scientific researchers, environmental advocates, and community organizations. Those new to using indicators and a vulnerability framework for assessing extreme event impacts on communities can use this handbook independently or in consultation with others who have preliminary experience with database management and geographic information systems (GIS) techniques. Extensive expertise in fields such as environmental, health, or social science are not required to use this handbook, since it provides a basic framework and step-by-step process for applying the approach.

[2] While in-depth modeling can provide more detailed and accurate information, communities may not have the resources to undertake such efforts and screening indicators may provide crucial information for protecting the most vulnerable communities.

1.3.2 What should the handbook be used for?

This handbook provides steps for developing indicators to identify local areas and communities that may be vulnerable to accidental releases of hazardous substances during extreme events. By mapping sites/waste facilities, potential extreme events, local environmental conditions, and characteristics of the population in the surrounding community, this information may be used to improve local decisions and planning (e.g., adaptation, mitigation, resilience, response). A few examples of opportunities and decision points where the method may be used include:

1) Citywide and neighborhood land planning and management for improving emergency preparedness
2) Transportation, housing, and community development planning
3) Communication and building understanding of environmental assessment and cleanup needs

Box 2. Application of City of Phoenix and Maricopa County Results: Illustrative Example

The community vulnerability indicators and maps developed for the City of Phoenix and Maricopa County case study were beneficial to Phoenix by:

1) Providing a greater understanding of the type and magnitude of sites/waste facilities in the project area
2) Mapping sites/waste facilities that could be used for emergency preparedness and response
3) Providing maps of future climate scenarios to assess potential impacts of extreme heat drought, wildfire, and flooding events
4) Providing the spatial distribution of population characteristics, particularly those most vulnerable

Initially, Phoenix used the extreme heat mapping scenarios as part of the city's 2021 Climate Action Plan and related presentations to the public to illustrate the effects of temperature increases. As the plan progresses, additional data and indicators for heat and drought will likely be presented and discussed. The social vulnerability indicators may be used to assist in equitable decision-making as it relates to heat and water resilience in the plan. This information will be shared with the city's Office of Homeland Security and Emergency Response to be used, as applicable, in hazard mitigation planning and with city departments focused on equity and environmental justice.

1.3.3 How to use the handbook

This handbook provides an indicator framework and approach for developing vulnerability indicators to screen, assess, and communicate potential extreme event impacts on waste facilities and surrounding communities (Section 2). It then describes how to implement a four-step approach for developing the vulnerability indicators (Section 3). The steps outlined here also can be customized for specific community needs and interests. Such customization is crucial to ensure that the analysis is relevant to the community and can be clearly communicated to the public. The indicator lists provided in this handbook are meant to provide options so that communities can choose what is relevant for them. Further, considering selected indicators in conjunction with each other would allow for a more holistic assessment than considering each indicator in isolation. It is not necessary to use every single indicator presented here. An illustrative example for applying this approach in the context of flooding is provided (Section 4). Later in this handbook, detailed checklists summarize how to develop, analyze, and map each indicator. Users can adapt these checklists as needed for their purposes. Each checklist (accompanied by appendices as needed) is designed to be stand-alone so that users can focus on only those indicators that are relevant or of interest (Section 5).

2 Indicator Framework and Approach

2.1 Framework

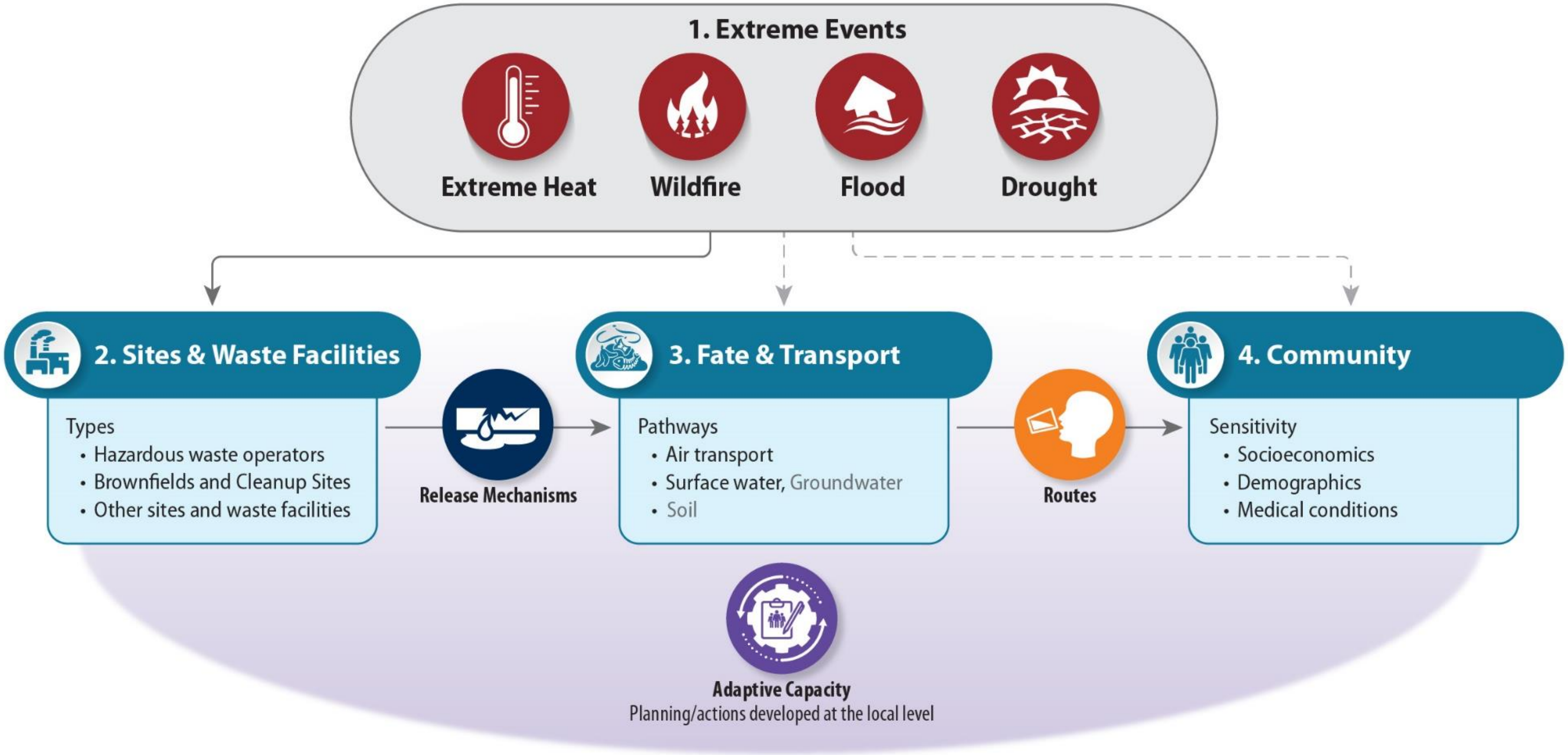
Climate vulnerability refers to the susceptibility to, or level of inability to cope with, the adverse impacts of climate change. This framework and approach specifically address the potential impacts of extreme events (i.e., floods, drought, wildfire, extreme heat) that may be experienced by a community due to a change in climatic conditions. The community impacts assessed include potential **exposure** to contaminants that may be released from sites/waste facilities due to an extreme event and transported by air and water to communities. The degree to which a community may be affected by exposures resulting from an extreme event or changing climate depends on the **sensitivity** characteristics of individuals in the community. Within this handbook, community **adaptive capacity** is the ability to be resilient and adaptable to the risks and impacts of extreme events.

Figure 2 provides a conceptual framework that shows the connections between four sources of vulnerability: extreme events [1], potential contaminant sources [2], exposure pathways [3], and communities [4]. Extreme heat, floods, droughts, and wildfire [1] impact sites/waste facilities in different ways (Table 1). Potential impacted sites/waste facilities include hazardous waste facilities, Brownfields sites, contaminated sites subject to response and cleanup under the Resource Conservation and Recovery Act (RCRA) (Corrective Action sites), federal and state Superfund sites, removal or emergency response sites, and underground storage tank (UST) or aboveground storage tank (AST) sites [2]. Contaminants can be released from such sites/waste facilities exposing people in surrounding communities via numerous pathways [3]. The indicators in this handbook focus on transport through air and surface water.[3]

Contaminant exposures can occur through different routes including inhalation, direct ingestion, incidental ingestion, dermal contact, and indirect ingestion through the food chain. Not all people experience the same severity and nature of impacts—some individuals and population groups are predisposed to be more affected by exposures. In addition, communities have a range of socioeconomic, demographic, and biological susceptibility characteristics [4]. Locational or community conditions (e.g., economy, institutions, governance, natural and built environments, cultural norms, social networks, legacies) interact with individual characteristics resulting in increased vulnerability for some sensitive population groups (Maxwell, 2018). Such sensitive groups experience disproportionately greater impacts because they are more likely to face higher exposures, they experience greater impacts even for the same exposure, or they have more difficulty avoiding and/or recovering from impacts.

[3] Other important exposure pathways may include soil to groundwater; groundwater to surface water; vapor intrusion; for soil, direct and incidental ingestion and dermal contact; and plant uptake. These pathways need to be considered in future research.

Figure 2. Conceptual Framework



Extreme events [1] increase the risk of contaminant release from sites/waste facilities [2], which are then transported via air and surface water [3] potentially exposing nearby communities. Transport via groundwater and soil (shown in gray) will be considered in future research. Impacts may be higher for community populations who are more sensitive [4]. Information on each of these four vulnerability sources can support planning/actions at the local level. Adaptive capacity (in purple) is the ability of the community to address impacts on the four sources. Well-informed planning/ actions can help improve adaptative capacity. Note that direct impacts such as heat stroke and indirect impacts on fate and transport such as change in wind patterns (shown by dashed arrows) are not considered in the handbook.

Table 1. Potential Impacts of Extreme Events on Sites/Waste Facilities

Extreme Heat	
▪ Increased fire hazards ▪ High pressures in closed vessels/tanks ▪ Overheating of equipment	▪ Off-gassing ▪ Changes to remediation effectiveness ▪ Power fluctuations/outages
Wildfires	
▪ Catastrophic damage to facilities, ignitable wastes; high pressure in closed vessels ▪ Overheating of equipment ▪ Incident waste facility closures	▪ Increased hazardous/non-hazardous waste generation ▪ Power fluctuations/outages ▪ Acute air quality incident/emergency: hazardous smoke plume
Drought	
▪ Increased fire hazards, fugitive dust ▪ Reduction in remediation effectiveness ▪ Changes in groundwater plume dynamics and quality due to lower water table	▪ Water use restrictions impacts ▪ Increased scrutiny of groundwater extraction systems ▪ Damage to vegetative covers
Floods	
▪ Erosion may be more likely ▪ Ponding/stormwater management difficult ▪ Water damage (corrosion, water logging) ▪ Power fluctuations/outages ▪ Groundwater plume changes and higher water table ▪ Spreading/migration of contamination ▪ Catastrophic events destroy structures ▪ Releases from overwash, infiltration, and leaching	▪ Incident waste facility closures ▪ Increased hazardous/non-hazardous waste generation ▪ Groundwater pump-and-treat remedies may not be allowed to discharge ▪ Increased potential for flooding of treatment systems ▪ Dislodged debris from treatment/containment systems or contained wastes ▪ Reactive wastes

Note: The table above provides example impacts via soil and groundwater that are not the focus of this handbook but are included in this table for completeness.

2.2 Indicators

The indicators in this handbook represent each of the four vulnerability sources shown in Figure 2 and Table 2. Exposure indicators represent potential exposure due to extreme events (heat, floods, drought, and wildfire), specific sources of contaminant releases (the different types of sites/waste facilities), and contaminant fate and transport (through water and wind). The fourth type of indicator represents population sensitivity characteristics (demographics, socioeconomic conditions, existing health conditions) that indicate which individuals in the community may be impacted more by extreme events. The indicators are provided at the Block Group level (U.S. Census Bureau, 2022), and each Block Group is considered to be a “community”. Other spatial scales can be chosen as relevant.

Table 2. Overview of Vulnerability Sources and Indicator Information

	Sources of Vulnerabilities		What Information Do Vulnerability Indicators Provide?
Exposure	Extreme Events	▪ Extreme heat ▪ Floods ▪ Droughts ▪ Wildfires	Historical and projected information on the magnitude and frequency that indicate which sites/waste facilities and communities face higher risks from specific events and how these risks may change under changing climates
	Sites/Waste Facilities	▪ Hazardous waste operators ▪ Sites and cleanup facilities ▪ Other sites/waste facilities	Potential sources of contaminant releases such as site/waste facilities locations, contaminants/hazardous waste present, and remediation technologies
	Fate and Transport	▪ Surface water ▪ Wind	How far contaminants may be transported due to local hydrological and wind patterns
Sensitivity	Population	▪ Demographics ▪ Socioeconomics ▪ Existing health conditions	Which individuals are least able to prepare for and respond to contaminant exposures due to extreme events

Note: Transport via groundwater and soil will be considered in future research.

2.2.1 Extreme Events

Information on the magnitude and frequency of extreme events can provide useful indicators of potential risks for sites/waste facilities. The heat, wildfire, flood, and drought indicators (Table 3)[4] capture the following:

- Scenarios: Historical trends and future projections represent past and changing environmental conditions. See Box 3 on Climate Change Terms and Concepts (page 11) for additional context.
    - To encompass a wide range of possible futures, multiple climate scenarios can be used. For example, Representative Concentration Pathway (RCP) 4.5 and RCP 8.5 represent moderate and more extreme conditions, respectively. Other climate scenarios/models can be used as needed.
- Time period: Averages over a 20-year period are provided to avoid short-term weather fluctuations or modeling uncertainties and to represent long-term climatic conditions and patterns.
    - In this handbook, historical baseline conditions are represented by averages over 1986–2005, and future conditions by averages over the mid-century (2040–2059). Climate projections in this

[4] Appendix Table A1 provides more detailed descriptions of the indicators.

handbook are calibrated using data for 1986–2005; therefore, these years were selected as the baseline period. The Intergovernmental Panel on Climate Change (IPCC) 5th Assessment Report also used 1986–2005 as the baseline period. A 30-year period can also be used to represent longer-term climatic conditions as needed.[5] Other time periods can be used as needed.

- Metric type: Climate projections vary across time and location and alternate types of metrics that represent extremes (e.g., maximum summer temperature) and differences (e.g., difference between maximum summer temperature in mid-century and historical) are provided.
  - Planners may find different metrics useful depending on their needs. For example, they may want to assess which communities face increased risks over time compared to others. Differences in projected and historical values may be useful either in absolute or in percentage terms.
- Thresholds: To assess what would be considered an "extreme" event in the context of sites/waste facilities, a "threshold" approach is provided. Ideally, site-specific information is needed to capture thresholds beyond which sites/waste facilities are at an increased risk of failure. However, because this handbook aims to provide a simpler, screening indicator- approach, the indicators provided use historical baseline extreme conditions as thresholds. The assumption is that existing sites/waste facilities are typically built to withstand historical baseline average conditions. Anything beyond historical baseline extremes is potentially riskier for sites/waste facilities with (active or legacy) contaminants and technologies that are sensitive to temperature or precipitation.
  - The handbook uses 99th percentile measures for temperature and precipitation to define extremes to represent high-end risks and be most protective. For example, extremely hot days occur when the maximum daily temperature is greater than the 99th percentile of maximum daily temperatures. Different percentiles can be used depending on community needs and local conditions.
  - The handbook provides measures of drought that use a time scale of at least six months. This provides a more likely condition of drought that impacts a site/waste facility (Table 1) due to lack of water availability. At shorter time scales, drought conditions can often be managed through alternate water supplies or demand management (e.g., restricted landscape watering). Measures based on 6 months and 12 months are provided as potential indicator options for community use.
- Physically based measures: For flooding, an indicator based on the terrain (elevation) of the area is provided because precipitation is not the only factor that determines flood risk. Low-lying areas are often more likely to flood.

[5] Traditionally, 30-year timeframes were considered most appropriate for capturing climate conditions and patterns. However, shorter timeframes are now also being considered to reflect more recent changing conditions. For example, NOAA now produces 15-year climate normals in addition to the 30-year normals. Our choice of 20 years was driven by inputs from local partners during the case studies.

Box 3. Climate Change Terms and Concepts

Climate refers to how the atmosphere behaves over long periods of time, while weather refers to short-term changes in the atmosphere. Climate is usually defined as average weather patterns for a particular region and time period. Climate reflects typical expectations, while weather reflects what happens.

- Climate change reflects changes in long term averages of daily weather.
- A baseline period serves as the reference point from which to calculate changes in climate. Due to climate variability, a single year may not be a useful reference point for measuring climate change, since it can be unusually warm, cold, dry, or wet. It is more common to use the average climate over a certain period to define the baseline climate.
- Traditionally, 30-year time frames are considered most appropriate for capturing climate conditions and patterns. However, shorter time frames are used to reflect more recent changing conditions. For example, NOAA now produces 15-year climate normals in addition to the 30-year normals. The IPCC 5th Assessment Report uses a 20-year average for 1986-2005 for their analysis (Collins et al., 2013).

To understand how climate may change in the future, researchers use computer models to simulate Earth's climate system. The simulated results, or climate projections are uncertain due to uncertainty in how human and natural systems may evolve and the responses of the Earth's climate system to the complex interaction of different natural and human systems.

- Scenarios provide climate researchers with a common set of plausible descriptions of how the future may evolve with respect to a range of variables. These variables may include socio-economic change, technological change, energy and land use, and emissions of greenhouse gases and air pollutants.
- The development of scenarios has evolved over time and may continue to do so based on new information and research needs. Currently, representative concentration pathways (RCPs) are the most used scenarios in climate research (e.g., in the IPCC 5th Assessment Report). They provide projections of how concentrations of greenhouse gases in the atmosphere will change in future as a result of human activities. RCPs capture future trends in technology, economies, lifestyle, and policy including climate mitigation and adaptation options.
- Scenarios assist in the evaluation of uncertainty in human contributions to climate change, the response of the Earth system to human activities, the impacts of a range of future climates, and the implications of different approaches to mitigation (measures to reduce net emissions) and adaptation (actions that facilitate response to new climate conditions). Rather than predict the future, scenarios help understand a range of possible futures. The four RCPs (2.6, 4.5, 6.0, and 8.5) range from very high (RCP8.5) to very low (RCP2.6) future concentrations of greenhouse gases.

For more information, please see:

NASA—What's the difference between weather and climate?
https://www.nasa.gov/mission_pages/noaa-n/climate/climate_weather.html

NOAA NCEI—What's the difference between weather and climate?
https://www.ncei.noaa.gov/news/weather-vs-climate

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Table 3. Exposure: Extreme Events

ID*	Indicator Definition**	Parameter Options
Extreme Heat		
1.1.1	Extreme heat: Maximum summer temperature [for selected time period, scenario]	▪ 1986-2005/2040-2059 ▪ RCP 4.5/8.5 ▪ Absolute historical and projected ▪ Difference or percent difference between projected and historical mean
1.1.2	Threshold-based extreme heat: Annual maximum temperature for "extreme heat days" [for selected time period, scenario]	▪ 1986-2005/2040-2059 ▪ RCP 4.5/8.5 ▪ Absolute historical and projected
1.1.3	Threshold-based extreme heat: Change in the annual count of "extreme heat days" between [selected time period, scenario] and historical	▪ 1986-2005/2040-2059 ▪ RCP 4.5/8.5 ▪ Difference between projected and historical count
Wildfire		
1.1.4	Wildfire: Fraction of Block Group area burned for [selected time period, scenario]	▪ 1986-2005/2040-2059 ▪ RCP 4.5/8.5 ▪ Absolute historical and projected ▪ Difference or percent difference between projected and historical mean
Flood		
1.1.5	Percent of Block Group within a [selected degree of flood] floodplain	▪ 100/500-year
1.1.6	Precipitation-based flood: Annual % of precipitation depth falling during "heavy events" for [selected time period, scenario]	▪ 1986-2005/2040-2059 ▪ RCP 4.5/8.5 ▪ Absolute historical and projected
1.1.7	Threshold-based flood: Change in the average annual percent of precipitation depth falling during "heavy events" between [selected time period, scenario] and historical	▪ 1986-2005/2040-2059 ▪ RCP 4.5/8.5 ▪ Difference between projected and historical mean
1.1.8	Physically based flood: Mean height above the nearest drainage	N/A

ID*	Indicator Definition**	Parameter Options
Drought		
1.1.9	Drought: Count of drought (defined by SPEI-6) months for [selected time period, scenario]	▪ 1986-2005/2040-2059 ▪ RCP 4.5/8.5 ▪ Absolute historical and projected
1.1.10	Threshold-based drought: Change in the count of drought (defined by SPEI-6) months between [selected time period, scenario] and historical	▪ 1986-2005/2040-2059 ▪ RCP 4.5/8.5 ▪ Difference between projected and historical count
1.1.11	Drought: Count of drought (defined by SPEI-12) months for [selected time period, scenario]	▪ 1986-2005/2040-2059 ▪ RCP 4.5/8.5 ▪ Absolute historical and projected
1.1.12	Threshold-based drought: Change in the count of drought (defined by SPEI-12) months between [selected time period, scenario] and historical	▪ 1986-2005/2040-2059 ▪ RCP 4.5/8.5 ▪ Difference between projected and historical count

* ID numbering X.Y.Z: X denotes exposure/sensitivity (exposure: 1; sensitivity: 2); Y denotes 3 sources of exposure (extreme events:1, sites/ waste facilities: 2, fate/transport: 3, and 1 source of sensitivity (population characteristics: 1), and Z denotes the indicator (numbered sequentially)

** All indicators are by Block Group

2.2.2 Sites and Waste Facilities

Information on the sites/waste facilities can provide useful indicators of potential risks for contaminant releases. Expertise in the types of sites/waste facilities and their attributes may be valuable in reviewing and selecting which of these indicators to consider. The site/waste facility indicators in Table 4 capture the following:

- Spatial attributes: Location of sites/waste facilities provide the simplest indicators of potential contaminant releases.
    - The handbook provides indicators for counts and density of sites/waste facilities. Counts are simpler to use and communicate, but density accounts for variation in the community/spatial unit size and may provide more information to decision-makers, depending on their needs.
- Broad physical/environmental/regulatory attributes: Types of facilities provide information on the types of contaminants that may be present, the physical structures themselves, and how they are managed or regulated.
    - The handbook provides indicators for 15 types of sites/waste facilities. Communities may be interested in one or more types. The density of each facility type may also be useful.
- Specific hazardous environmental attributes: Types of waste present at each facility handling hazardous wastes provides more information on the different hazards present and what types of extreme events could most impact these sites/waste facilities (Table 5). An EPA listing of hazardous waste codes indicates why the waste was listed as hazardous and crosswalks hazardous waste codes with six hazardous waste characteristics: ignitable, corrosive, reactive, toxicity characteristic, and acute hazardous and toxic (U.S. EPA, 2012a, U.S. EPA, 2022).[6]
    - The handbook provides counts of hazardous waste facilities and quantity of the hazardous waste. Simple counts of hazardous waste facilities may fail to reflect the total amount of waste stored or processed at these sites/waste facilities. The waste tonnage indicator helps address that shortcoming.
    - The handbook provides indicators that map the types of waste present to one or more of the six hazard types. Both counts of facilities with each type of hazard and tons of each type of hazardous waste are included. The count of hazardous waste facilities with a specific type of hazardous waste present can help identify community vulnerabilities to specific waste types. For example, a Block Group with a high number of facilities with ignitable waste may pose a higher risk in extreme heat or wildfires, while a Block Group with reactive wastes may pose a higher risk during flooding. Tonnage of specific types of hazardous waste provides even more detail.

[6] Note that more detailed definitions of hazards (e.g., carcinogenicity, genotoxicity mutagenicity, endocrine disruption, bioaccumulation potential) could be used. However, the EPA listing does not provide crosswalks of such characteristics with waste codes. Also, a detailed breakdown of hazards was not considered for this simple screening approach.

- The handbook provides indicators for the counts and capacity of aboveground and underground storage tanks containing potentially hazardous substances (e.g., petroleum, solvents, hazardous wastes). A high number of tanks does not always translate to a high volume of stored substances. A high number of low-capacity tanks may pose less risk than a small number of high-capacity tanks. Capacity indicators are included to provide information on the volume of substances that can potentially be stored in the tanks.

- Specific environmental/regulatory attributes: Cleanup status and type of contaminants that may potentially be present at Brownfield sites provide more information than simple counts of Brownfields sites. Sites/waste facilities that have been assessed and contaminants found are likely to be riskier unless they have been cleaned up. However, the information in publicly available Brownfield datasets may not be updated regularly and may be inaccurate as a result. Information such as cleanup status should be checked for accuracy with local regulators and other partners prior to use in this application.
    - The handbook provides indicators with information on the potential contaminants that may be present at the site/waste facility. Appendix Table A.2 provides a list of contaminants that may be found in Brownfields data sources. However, caution must be used because datasets with this information are based on voluntary reporting, and assessment and cleanup status available publicly may not be reflective of the most current status at a site/waste facility.
- Specific physical and technological attributes: Sites/waste facilities can have remediation technologies in place that may pose a risk during specific types of extreme events.
    - The handbook provides indicators with information on the counts of Superfund sites with any remediation technology vulnerable to any extreme event. Appendix Table A.3 provides a crosswalk of vulnerability of 27 possible Superfund remediation technologies to drought, fire, flooding, or extreme heat.[7]

[7] Methods provided by U.S. EPA (2012) was adapted and expanded to develop this mapping.

Table 4. Exposure: Sites/Waste Facilities

ID*	Indicator Definition**	Parameter Options
Counts		
1.2.1	Total count of sites/waste facilities	N/A
1.2.2	Count of sites/waste facilities per square km	N/A
1.2.3	Sites/waste facilities count by type	▪ Generators ▪ Treatment, Storage, and Disposal facilities (TSDFs) ▪ Transporters ▪ Transfer facilities ▪ Other operators ▪ Resource Conservation and Recovery Act (RCRA) Corrective Action sites ▪ Brownfields ▪ Federal and State Superfund sites listed on the National Priorities List (NPL) ▪ Sites listed in the Superfund Enterprise Management System (SEMS), but not included on the NPL ▪ Removal/emergency response sites ▪ Nonhazardous landfills ▪ Petroleum storage tanks ▪ Incident waste facilities ▪ Oil spill response/prevention sites ▪ Other locally identified sites/ waste facilities not included above (optional)
Hazardous Waste		
1.2.4	Tons of hazardous waste	N/A
1.2.5	Sites/waste facilities count (by hazard type***)	▪ Ignitable ▪ Corrosive ▪ Reactive ▪ Toxicity characteristic ▪ Acute hazardous ▪ Toxic
1.2.6	Waste tonnage (by hazard type***)	
Brownfields and Superfund		
1.2.7	Brownfield count with contaminant; cleanup unknown (by contaminant)	▪ Contaminant list in Appendix Table A.2
1.2.8	Superfund count with vulnerable remedy technology (by extreme event)	▪ Remediation technology list in Appendix Table A.3

ID*	Indicator Definition**	Parameter Options
Tanks		
1.2.9	Count of specific type of tank (UST/AST)	▪ Underground storage tanks/aboveground storage tanks
1.2.10	Total tank capacity (UST/AST)	N/A

* ID numbering X.Y.Z: X denotes exposure/sensitivity (exposure: 1; sensitivity: 2); Y denotes 3 sources of exposure (extreme events:1, sites/ waste facilities: 2, fate/transport: 3, and 1 source of sensitivity (population characteristics: 1), and Z denotes the indicator (numbered sequentially)

** All indicators are by Block Group

*** The six hazard types (list under Parameter Options) are defined in Table 5.

Table 5. Application of Waste Hazard Basis Codes to Assess Impacts of Extreme Events on Hazardous Waste

Hazard Code*	Hazard Code Description	Application to Extreme Events Impacts
I	Ignitable Waste	Sensitive to high temperatures (heat waves, wildfire). Includes liquids with flash points below 60°C, nonliquids that cause fire through specific conditions, ignitable compressed gases, and oxidizers
C	Corrosive Waste	Aqueous wastes with a pH ≤ 2 or ≥ 12.5; hazards due to flood washout or based on the liquid's ability to corrode steel
R	Reactive Waste	Unstable under normal conditions; reacts with water (floods), may give off toxic gases and may be capable of detonation or explosion under normal conditions or when heated (heat waves, wildfire)
E	Toxicity Characteristic Waste	Harmful when ingested or absorbed. Hazardous through leaching to groundwater (flooding); Determined through Toxicity Characteristic Leaching Procedure (TCLP) (extract leachate and identify when concentrations are greater than regulatory toxicity characteristic [TC] limits)
H	Acute Hazardous Waste	Acutely hazardous waste if it is fatal to humans or animals at low doses, is beyond specified toxicity limits, or is otherwise capable of causing or significantly contributing to an increase in serious irreversible, or incapacitating reversible, illness; may require emergency response if released through water or air
T	Toxic Waste	Waste listed because of toxicity to humans or environment; hazardous exposures through soil, water, or air exposure pathways

* The first four hazard codes apply to wastes that have been listed because they typically exhibit one of the four regulatory characteristics of hazardous waste. The last two hazard codes apply to listed wastes with constituents that pose additional threat to human health and the environment (U.S. EPA, 2012a, U.S. EPA, 2022).

2.2.3 Fate and Transport

Information on how far contaminants travel can provide useful indicators for identifying areas and communities that may potentially face high exposure risks. Once contaminants are released, they move through the environment by naturally occurring processes. As an initial step to identifying areas most vulnerable to impacts, the distance of communities from a site/waste facility can be considered. However, as illustrated in Figure 3, using simple radial distances may not provide accurate measures of how far contaminants can be transported. To more accurately identify communities impacted, this handbook provides indicators based on fate and transport concepts that consider water and air pathways through which contaminants may reach communities. This approach integrates information on site/waste facility count and elevation, hydrology, and meteorology to represent movement processes in the environment.[8] Expertise in hydrologic flow and wind patterns would be valuable for calculating the fate and transport indicators (Table 6), which capture the following:

- Hydrology: Water flowing from a site/waste facility toward a community increases the potential risk of exposure to waterborne contaminants (Figure 4). Increases in risk are not only due to the flowing waters of streams and rivers that may receive contaminants after a release, but also due to erosion and overland flow or runoff generated from flooding events that spread the contamination from a facility.
    - The handbook provides indicators with information on the count of facilities within floodplains, upstream distances (in terms of overland flow) between sites/waste facilities and communities, proximity of facilities to the hydrologic network and counts of facilities within certain upstream "raindrop" distances. Decision-makers have the flexibility of selecting different distance cutoffs for the latter indicator.
- Wind patterns: Wind blowing from a site/waste facility toward a community increases the potential risk of exposure to airborne contaminants (Figure 5). Wind speed and wind direction inform the potential location and estimated time it takes for contaminants to reach communities. However, wind patterns vary significantly across seasons, and both wind speed and wind direction can change within minutes. The method applied here is to use wind rose (e.g., see USDA, 2022) information to identify the predominant wind direction, which refers to the direction from which the wind blows for most of the time during the season, and is calculated based on historical wind patterns. It would be important to also monitor for long-term changes in wind patterns that might impact which communities are vulnerable.
    - The handbook provides indicators with information on upwind distances between sites/waste facilities and communities, proximity of communities to facilities in the direction of wind, the time it may take for contaminants to be transported to communities and counts of facilities within certain upwind distances. Decision-makers have the flexibility of selecting different distance cutoffs for the latter indicator. Each indicator is provided for each of the four seasons.

[8] Future research can consider including characteristics of sites/waste facilities (e.g., contaminants) and population characteristics (e.g., those below the poverty line) in fate and transport indicators.

Figure 3. Potential Wind and Surface Water Transport of Contaminants from Sites/Waste Facilities to Downwind and Downstream Communities

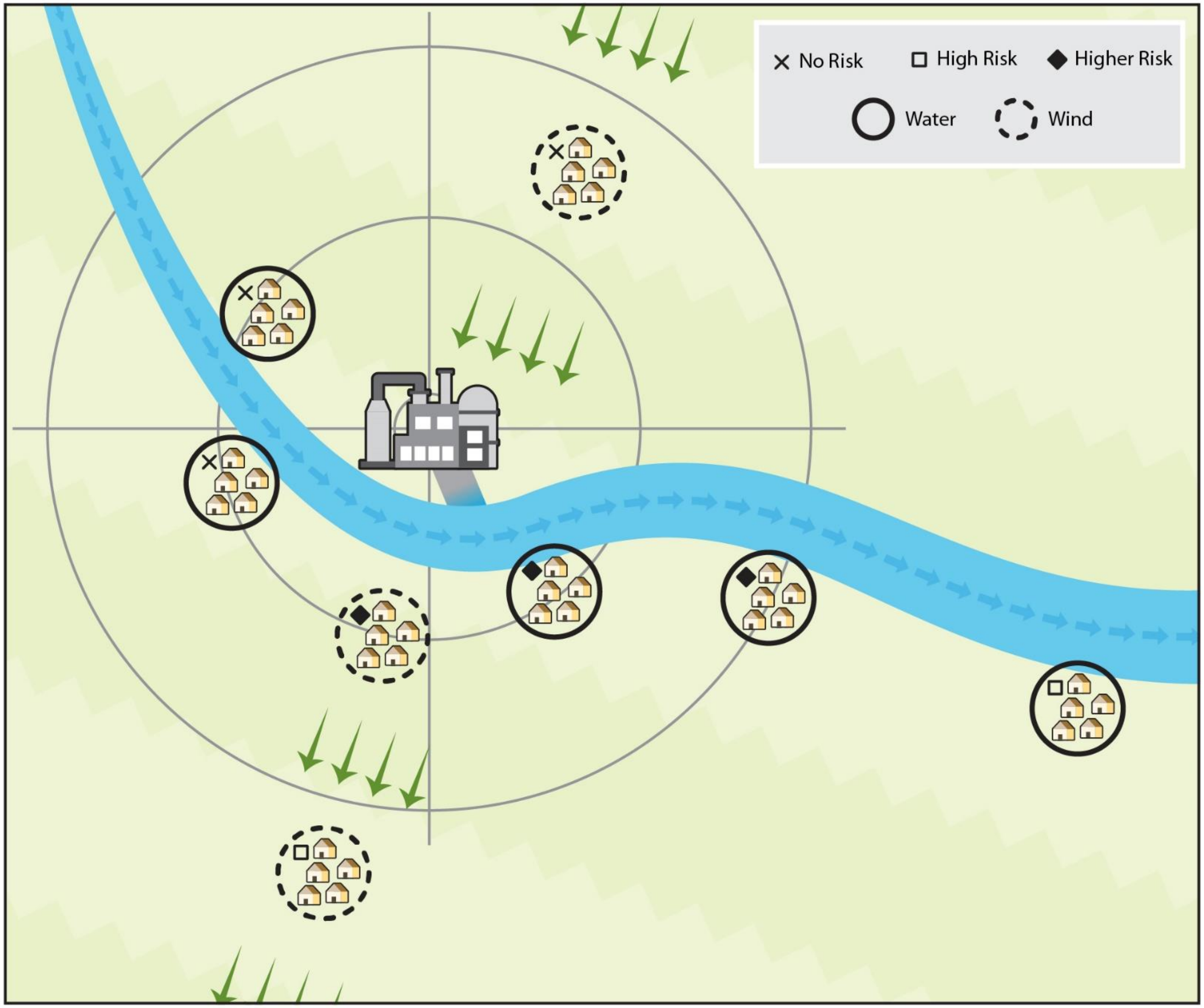


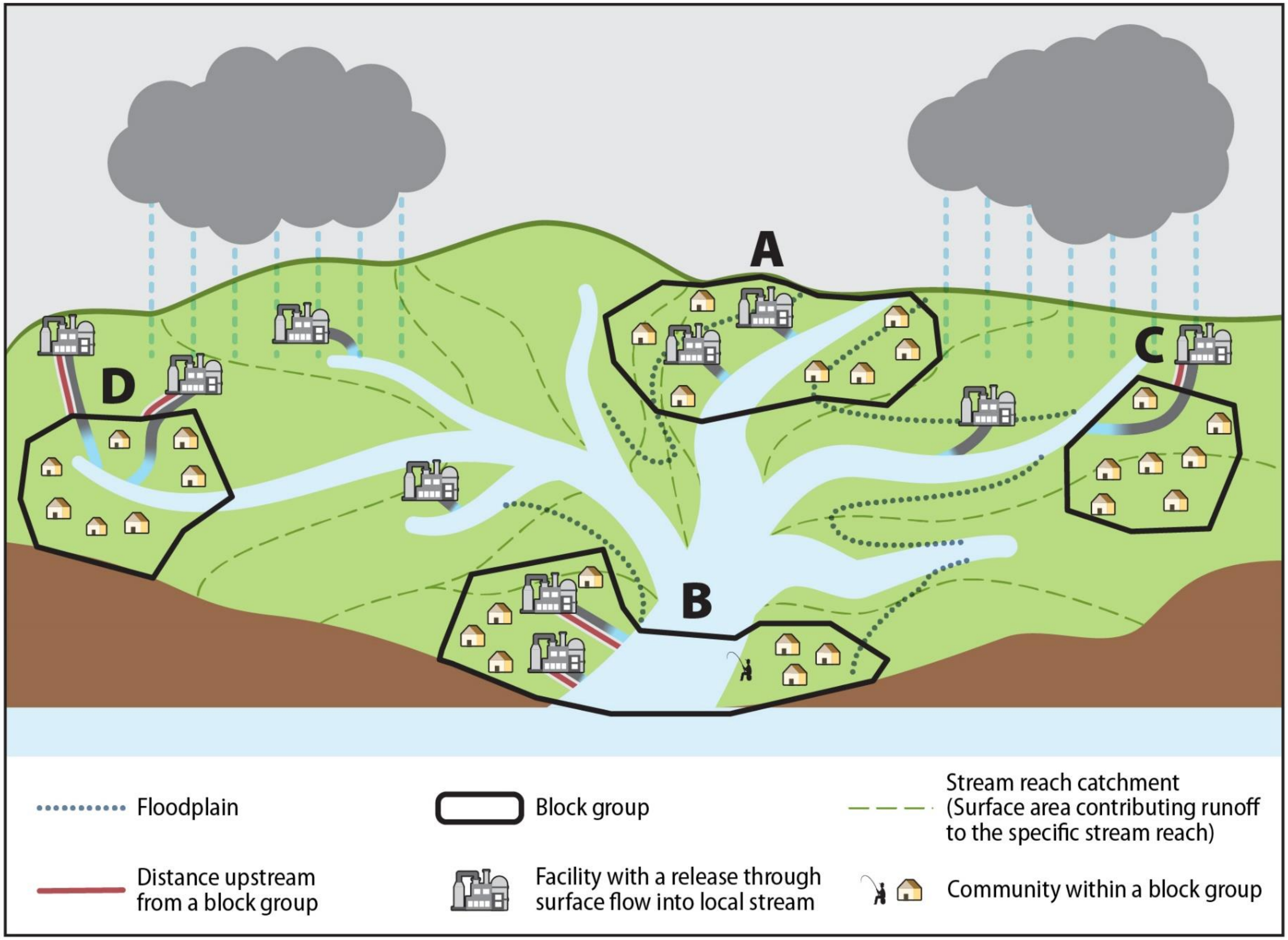
Table 6. Exposure: Transport and Fate

ID*	Indicator Definition**	Parameter Options
Surface Water		
1.3.1	Count of sites/waste facilities in a floodplain [100-year and 500-year]	▪ 100/500-year
1.3.2	Count of sites/waste facilities within a specific hydrologic distance of a flowline	▪ 500 m/1 km/2 km/5 km
1.3.3	Shortest hydrologic distance (m) upstream to a site/waste facility	N/A
1.3.4	Count of upstream sites/waste facilities within a specific hydrologic distance of a community	▪ 500 m/1 km/2 km/5 km
Air		
1.3.5	Shortest distance to a site/waste facility upwind [season]	▪ Spring/summer/fall/winter
1.3.6	Count of sites/waste facilities in predominant wind direction “upwind” within a specific season and distance of a community	▪ Spring/summer/fall/winter ▪ 5 km/15 km/25 km/40 km
1.3.7	Minimum response time, [by season]	▪ Spring/summer/fall/winter
1.3.8	Count of sites/waste facilities that are within specific response time ranges, [by season]	▪ Spring/summer/fall/winter ▪ 2 min/5 min/10 min/15 min/20 min

* ID numbering X.Y.Z: X denotes exposure/sensitivity (exposure: 1; sensitivity: 2); Y denotes 3 sources of exposure (extreme events:1, sites/ waste facilities: 2, fate/transport: 3, and 1 source of sensitivity (population characteristics: 1), and Z denotes the indicator (numbered sequentially)

** All indicators are by Block Group

Figure 4. Conceptual Model of Waterbody and Overland Flow from Sites/Waste Facilities to Surface Waters and Nearby Populated Block Groups



A (Indicator 1.3.1. Count of sites/waste facilities within a floodplain): Block Group A contains both housing and sites/ waste facilities within the floodplain area (green dashed lines surrounding the waterway). In this case, the Block Group contains two sites/waste facilities within the floodplain area.

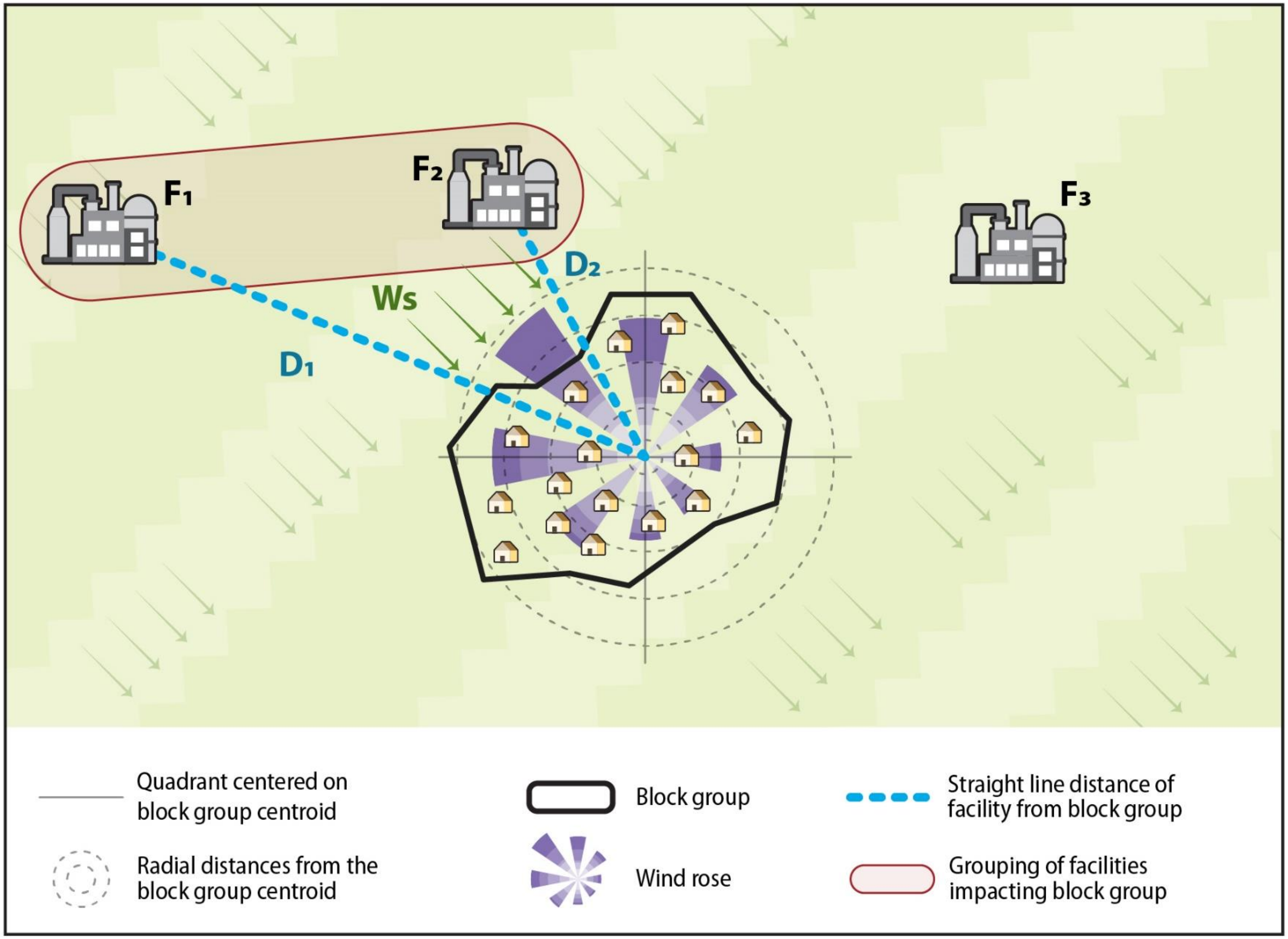
B (Indicator 1.3.2. Count of sites/waste facilities within a certain distance of a flowline): Block Group B contains two sites/waste facilities. The lower site/waste facility in the figure is closer, using the overland distance flow measure (red lines) than the upper site/waste facility. In this case, we may set a threshold for the distance to the flowline (i.e., stream) that counts the lower site/waste facility but does not count the upper site/waste facility as it is farther away and poses less risk of an overland release through heavy rain reaching the stream channel on which the Block Group lies.

C (Indicator 1.3.3. Shortest hydrologic distance upstream to a site/waste facility): Block Group C illustrates how a release from a site/waste facility due to heavy rain may reach a Block Group as it flows downslope to a waterway. For this Block Group there is one upstream site/waste facility where the distance reported is shown by the red line, which measures the overland flow distance that a raindrop would flow from the point of release at the facility to the boundary of the Block Group. Additionally, the shortest hydrologic distance upstream to a site/waste facility is illustrated by the other example Block Groups where both A and B would have a value of 0 because they contain sites/ waste facilities, and D would report the distance from the site/waste facility on the right, which is closer in overland flow path.

D (Indicator 1.3.4. Count of upstream facilities within a certain distance of the community): For Block Group D there are two sites/waste facilities that are upstream or upgradient of the Block Group. The distance from the site/waste facility to the community is measured as the overland flow distance to the boundary (red line). In this case, we may set a threshold for that distance that would count the closer site/waste facility on the right, while the site/waste facility on the left is farther away and therefore poses less risk.

Note: The accompanying fate and transport processes within the soil and groundwater that could likely accompany the depicted pathways are not included within this initial screening-level process and are instead referred for future research.

Figure 5. Conceptual Model of Wind Flow from Sites/Waste Facilities to Populated Block Groups and Use of Wind Rose



Schematic showing a community Block Group (black polygon) impacted by sites/waste facilities F1 and F2 that are upwind of the community. The wind rose indicated by the violet spokes shows the direction from which the wind blows. The length of each spoke indicates the percent of time that the wind is blowing from a specific direction. The longer the spoke, the more frequent is the wind from that respective direction. The gradient in the color (shades of violet in this example) refers to the different speeds at which the wind is blowing from that specific direction, resulting in an average wind speed of Ws. In this example, the wind blows predominantly from the northwest at an average wind speed of Ws.

Indicator 1.3.5. Shortest distance to an upwind site/waste facility: D1 and D2 indicate the distance of Sites/waste facilities F1 and F2 respectively from the centroid of the Block Group. In this example, D2 is the shortest distance to the nearest upwind facility F2 in the predominant wind direction.

Indicator 1.3.6. Count of sites/waste facilities in predominant wind direction (“upwind") within a specified distances (5, 15, 25 and 40 km) of community: Sites/waste facilities F1 and F2 (indicated by the red enclosure) impact the community, while F3 does not under northwest wind conditions shown in this example. Thus, a total of 2 sites are upwind; this indicator presents this a cumulative count within specified radial distances from the community. The distances D1 and D2 will determine the counts within each distance. If for example, D1 = 6 km and D2 = 3 km, we would have one site within 5 km and 2 sites within 15 km.

Indicator 1.3.7. Minimum response time: The time for a site/waste facility’s emissions to impact the community is equal to the distance D1 or D2 divided by the wind speed Ws. The shortest distance to a site/waste facility in the predominant (i.e., northwest) direction of the community determines the minimum response time. In this example, the minimum response time for the community to take action is D2/Ws.

Indicator 1.3.8. Count of sites/waste facilities that are within specified response time ranges (2, 5, 10, 15 and 20 min): Similar to indicator 1.3.6, this indicator is a cumulative count of facilities within specified response time ranges. The response times for the two facilities, D1/Ws and D2/Ws, determine the counts within different time ranges.

2.2.4 Sensitivity

Information on household characteristics can provide useful indicators for identifying which population groups may be impacted most. Sensitive households experience disproportionately higher negative impacts because: 1) they are more likely to face higher exposures given current circumstances (e.g., those who work outdoors), 2) they experience greater impacts even for the same exposure (e.g., children/elderly/asthmatics have more respiratory issues), and 3) they may have more difficulty avoiding or recovering from negative impacts (e.g., those with insufficient community networks). A key point to note is that a population group may represent vulnerability due to multiple reasons. For example, elderly may have health concerns, restricted mobility, be less connected to support networks, and have limited resources. Further, communities at greatest risk of exposure and least able to prepare for and respond are often those that have a high proportion of households that are already disadvantaged or face other environmental injustices. The sensitivity indicators (Table 7) capture the following:

- Overall size of community: Population size provides the simplest measure of how many people may be impacted.
    - This handbook provides indicators for total population size and count of households. Total population size includes those living in "group quarters" (U.S. Census Bureau, 2019). Group quarters include such places as college residence halls, residential treatment centers, skilled nursing facilities, group homes, military barracks, correctional facilities, workers' dormitories, and facilities for people experiencing homelessness. Decision-makers may also need information on number of families that need to be sent communications materials before or during an event. The count of households indicator includes only those residences that are occupied.
- Under-resourced households: Households with low income and wealth may not have resources to take preventive measures or recover quickly (e.g., due to low home or medical insurance coverage). They may also live and work in higher exposure areas (e.g., close to sites/waste facilities or in flood-prone areas), which historically have lower property values. Households may also have jobs that are likely to be more locally dependent (e.g., those who work in agriculture/natural resource-based industries or small businesses may be impacted by extreme events). Renters are often underinsured, live in less protected structures, and receive less disaster assistance than homeowners.
    - This handbook provides indicators for household income, self-employed people (who may have less backup and supportive resources), outdoors workers, renters (who may be earning less income (on average), rental units tend to be less maintained and protected, and they often receive less disaster relief (Hamel et al., 2017)), those who live in mobile structures, low education, and minority populations. Decision-makers may also need to identify not just low-income households, but those who have the least resources. The Census Bureau defines the poverty line to measure economic well-being and assess the poverty status of households. These

poverty line data are used to assess the need for assistance and are included in federal allocation formulas for many government programs (U.S. Census Bureau, 2019). The handbook provides indicators for two measures using poverty lines that may be relevant depending on the local contexts.

- Health and safety concerns: Individuals in certain age groups (children, elderly) or those who are disabled may be predisposed to certain health impacts, have mobility issues, and be dependent on caregivers. Those who lack insurance coverage would have difficulties getting medical care.
    - This handbook provides indicators for the children and elderly, those with at least one disabled person, and households with no health insurance.
- Marginalized or isolated: Households with limited family or community networks may face difficulties coping or recovering from impacts. Those who have less access to information or transportation or have cultural or language barriers will also face challenges with warnings, evacuation orders, and recovery efforts. Certain population groups may also face discriminatory or prejudicial practices, which result in isolation.
    - This handbook provides indicators for households without telephone, internet, and vehicle access. Indicators also include elderly individuals living alone, households with female household heads, minority and ethnic groups, and immigrants and recent migrants.

Table 7. Sensitivity: Household Characteristics

ID*	Indicator Definition**	Under-resourced	Health or safety concerns	Marginalized or isolated
2.1.1	Total population***	X	X	X
2.1.2	Count of households/occupied housing units***	X	X	X
2.1.3	Median household Income	X		
2.1.4	Percent of population with ratio of income to poverty level less than 0.5	X		
2.1.5	Percent of population with ratio of income to poverty level between 0.5 and 1	X		
2.1.6	Percent of households with self-employment income	X		X
2.1.7	Percent of civilian employed population 16 years and over who work outdoors		X	
2.1.8	Percent of households that are renters	X		X
2.1.9	Percent of households living in a mobile home/boat/RV/van	X	X	X
2.1.10	Percent of households without telephone service	X		X
2.1.11	Percent of households with no internet access	X		X
2.1.12	Percent of households who do not have a vehicle	X	X	X
2.1.13	Percent of population over 25 with no high school degree	X		X
2.1.14	Percent of population with no health insurance	X	X	X
2.1.15	Percent of households with at least 1 person that has a disability		X	
2.1.16	Percent of population under the age of 18		X	
2.1.17	Percent of population who are 65 or over		X	X
2.1.18	Percent of households with single members who are 65 or over		X	
2.1.19	Percent of population with female household heads			X

ID*	Indicator Definition**	Under-resourced	Health or safety concerns	Marginalized or isolated
2.1.20	Percent of population that is Black or African American alone	X		X
2.1.21	Percent of population that are Native Hawaiian or Other Pacific Islander alone			X
2.1.22	Percent of population that are American Indian or Alaska Native alone			X
2.1.23	Percent of population that are Asian alone			X
2.1.24	Percent of population that belongs to other non-White races			X
2.1.25	Percent of population that are Hispanic or Latino	X		X
2.1.26	Percent of households that have limited English speaking ability			X
2.1.27	Percent of the population who are over 18 and non-U.S. citizens			X
2.1.28	Percent of households that moved within the last 3 years			X

* ID numbering X.Y.Z: X denotes exposure/sensitivity (exposure: 1; sensitivity: 2); Y denotes 3 sources of exposure (extreme events:1, sites/waste facilities: 2, fate/transport: 3, and 1 source of sensitivity (population characteristics: 1), and Z denotes the indicator (numbered sequentially)

** All indicators are by Block Group

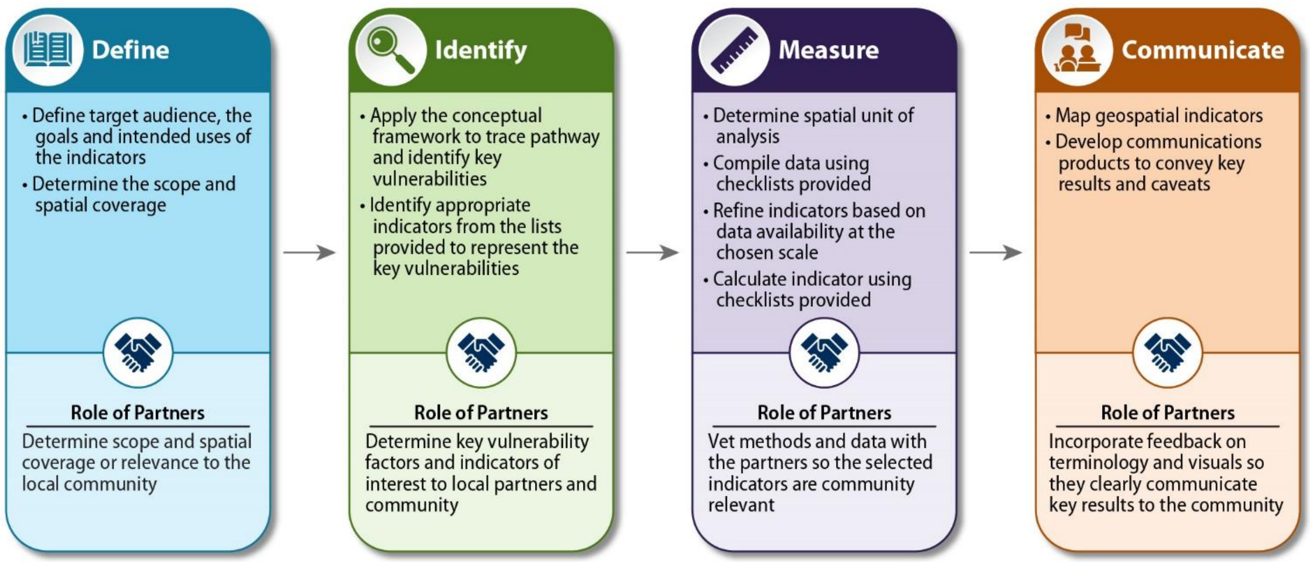
***Total population and households represent overall impacts rather than specific reasons for sensitivity

Note: Alternative options for sensitivity indicators were presented to case study partners. The handbook includes only those that were determined to be most suitable for case study partner's objectives and for which data was publicly available. The table provides an indication of why each group is "sensitive", illustrating that certain groups face multiple types of difficulties.

3 Steps for Implementing Approach

This handbook presents a four-step process to implementing the framework described in Section 2 (Figure 6). Close coordination with partners throughout the process is crucial to ensure that the indicators reflect community needs and local knowledge and can also be communicated in a meaningful way.

Figure 6. Four-step Process for Implementing Indicator Approach



3.1 Step 1: Define the Target Audience, Goals of the Analysis, and Scope

1) Determine the target audience for scoping the analysis and for developing appropriate interim and final products.

2) Define the goals and intended uses to ensure that the indicators are developed, analyzed, and communicated to meet the specific needs and concerns of the community.

3) Define the scope of the analysis to ensure best use of resources.

4) Determine the spatial coverage of the study to ensure that key areas of the community's vulnerability concerns are incorporated.

Box 4. Examples of Considerations: Step 1

- Who will be using the indicators?
- What is the intended use of the indicators? Is the goal to support long-term adaptation? Is it for emergency response?
- Are there specific concerns?
- Are there specific locations that are of interest?

3.2 Step 2: Identify the Vulnerability Factors of Interest and the Indicators to Represent the Factors

1) Apply framework (Figure 2) to identify vulnerability factors of interest.
2) Select the indicators to represent the identified factors from the full list of indicators (Tables 3, 4, 6 and 7). The checklists in Section 5 provides illustrative uses of indicators. These lists are meant to provide options so that decision-makers can choose what is most relevant for their community.
3) Determine the variants and representations that are most useful (e.g., difference versus percent difference in baseline and projected).
4) Determine combinations of indicators that are informative and useful.

Box 5. Examples of Considerations: Step 2

- What have been historical challenges? Are there emerging challenges from recent trends (e.g., more impervious cover from increasing development or urban sprawl)?
- Is the goal to compare changes in risk of extreme events? Is the goal to prioritize communities vulnerable under historical baseline conditions or who may become vulnerable in the future, or both? Do you want to consider the most extreme scenarios to be most protective or do you want to focus on more moderate scenarios?
- Are there specific types of sites/ waste facilities or communities that are of greatest interest?
- Are there combinations of indicators that are most informative?

3.3 Step 3: Measure (Calculate Metrics)

1) Determine spatial unit of analysis. For the purposes of visual display and analysis, this method defines a community as a Block Group, which is a census data collection unit. Decision-makers may choose to use Census Tracts or other spatial units if Block Groups are too difficult to interpret or communicate.[9]
2) Compile data for indicators using publicly available sources identified in the checklists provided in Section 4. Vetting of methods and data by community partners is needed to ensure that the most accurate information is represented to the extent feasible, and that the information is relevant to the community.
   a. Use U.S. EPA databases to compile data for indicators representing sites/waste facilities. Consult with state and local agencies for further detail or timely information that is regularly collected and available. Seek local knowledge to identify or confirm site/waste facility locations at risk.
      i. Use location information shared by your community planners, environmental agencies, and responders to support collaboration.

9 Note that the community serves as the unit of analysis in this method and thus also represents the resolution of the maps.

ii. Remove duplicates after reviewing name and location information since the same facility may come from different data sources.

iii. Decide which sites/waste facilities to include or exclude.

b. Leverage publicly available datasets for data on extreme events, wind and hydrological patterns, and population characteristics.

c. For data on sensitivity characteristics, use Census data as described in the checklists. If a different alternative is desired for the community than what is in the checklists, care must be taken to ensure that the correct population or calculation is being used.

3) Indicators/metrics may need to be refined based on data availability.

4) Calculate metrics for each Block Group or community as described in the checklists. This involves overlaying raw data with Block Group boundary files and calculating metrics (as defined by the indicator) for data found within the Block Group. Equations are also provided in Appendix B for communities who might find them useful.

Box 6. Examples of Considerations: Step 3

- Do I want to look at the most detailed resolution possible or is my area too large for assessing and communicating such fine-scaled results? Are the indicators being used for regional, state, city, or community planning?
- When identifying sites/waste facilities, consider:
  - Current numbers of sites and types of facilities governed by federal, state, or local environmental regulatory authorities can be in flux as new sites are identified, their boundaries change, rules and policies change, science improves detection, and sites or facilities are cleaned up and revitalized for a new reuse.
  - An unrecognized or well-regulated site/waste facility may become unsafe, as a result of extreme events, natural or manmade hazards, and changes in environmental conditions.
  - Prior to “the event” these locations may not be recognized or considered in preparedness planning.

3.4 Step 4: Analyze and Communicate Results

1) Map indicator data. The purpose of mapping indicator data is to present data geographically, allowing the audience to see spatial relationships and trends not obvious when examining tabular data alone.

a. A major part of mapping is symbology.[10] The first decision when choosing a symbology is to determine whether the same symbology is to be applied to different data sets. Doing so allows the map reader to compare the maps more easily, since the same color represents the same category (or bin) on each map. An example of this would be generating multiple maps to compare maximum values across climate scenarios, decades, or locations. The full

[10] Symbology is how maps communicate tabular data without words and is done with a combination of symbols and colors. In this case, we are referring to the colors used to represent values on the maps.

range of values for all scenarios/decades/ locations needs be used to create a single unique symbology to apply to all maps. Therefore, the same color will represent the same value across the maps, making direct comparisons much easier. Browse the data across years and scenarios to identify the number of observations, the maximum, the minimum, and the distribution of values. This will help decide how many bins to use, and how to define them. Data covering the entire study area and all relevant time periods need to be used to create a symbology.

b. Using 5–7 bins/categories is recommended so that the map reader can readily distinguish between color categories and visually match them to the legend. Use equal intervals if the data are equally distributed throughout the range, which create equal steps between categories. For example, 0–10, 11–20, etc. However, all categories may not necessarily contain values on the map since there might not be data values for each bin. The alternative to equal intervals is quantiles, deciles, or any percentile of choice, which attempts to create the same number of observations per bin (e.g., 20% of the Block Groups are in each category/bin when quantiles are chosen. This method should be used when the distribution of the data is concentrated in a few small ranges, since it will create smaller bins and provide additional clarity to the map in these concentrated ranges. Using quantiles also assures that each color in the symbology will appear on the map., but it will make comparisons across different time periods and scenarios more challenging. Allowing the data distribution to drive the map bin generation will produce the optimal results. However, using this method causes each bin to have a different interval and requires careful interpretation and communication.

Box 7. Examples of Considerations: Step 4

- Is the goal to compare communities over time? Or to look at a certain snapshot in time?
- Is the goal to compare absolute values or percentages?
- Has there been proper translation of scientific jargon into accurate but easy-to-interpret language that will be understood within the community? Avoid confusion, lack of clarity, and misunderstandings.
- Do the visuals clearly communicate key results to the community?
- Are there caveats specific to the community?

Indicator data are likely to be continuous (spanning a range of values), rather than categorical (comprised of unique non-sequential values). If data are continuous, use a graduated color ramp progressing from light to dark, depicting less vulnerability to more vulnerability. In some cases, higher values indicate higher vulnerability (e.g., percent of household heads over the age of 65) and in some cases lower values indicate higher vulnerability (e.g., household income). For diverging data (e.g., positive through negative values with an inflection point in the middle), use a diverging color scheme characterized by darker colors at both extremes and lighter in the middle). This may be relevant, for example, when displaying percentage changes across time periods that encompass both positive and negative values. For categorical data, choose colors that are as distinct from each other as possible. A good source of symbology choices can be found on the ColorBrewer website (www.colorbrewer2.org). A variety of options exist that are colorblind safe and appropriate for continuous, categorical, and divergent data.

2) Determine key elements to include in a legend, so that consistency is maintained across maps. For example, each color variation should be matched to its color ramp in the legend.

3) Summarize key results, lessons learned, and caveats considering the target audience. For example, indicators at a high spatial resolution can be provided to a technical audience as tabular data. Summarized, categorized information (i.e., high, medium, or low risk) may be developed from the true values and presented only for specific areas of interest in a color-coded map for non-technical audiences. The user is encouraged to think about ways to understand and clearly present the data to suit their audience once the assessment is completed.

4 Flooding Example

In this section, we provide a hypothetical example illustrating how to implement the four-step process described in Section 3 in the context of flooding. It is not meant to be a comprehensive list of all possible considerations. We demonstrate how the conceptual framework, list of indicators, and detailed checklists may be applied in practice.

4.1 Step 1: Define the Target Audience, Goals of the Analysis, and Scope

Consider a scenario where the mayor of a small city is in the process of revising emergency response plans for different types of hazards. The city has an industrial heritage and multiple rivers running through it. While the city has experienced floods before, they have not been very localized and not very severe. However, other cities in the same region have experienced more severe flooding than usual over the past year. These floods impacted multiple sites/waste facilities resulting in adverse environmental and health consequences for surrounding communities. To prevent similar outcomes in the city, the mayor wants to develop long-term adaptation plans for the city to prepare for worsening extreme events.

Box 8. Examples of Considerations: Step 1

- The mayor and technical advisory committee will be using the indicators.
- The intended use of the indicators is to support long-term adaptation and emergency response.
- The scope of the assessment covers the entire county.
- There are specific concerns about the eastern side of the town where there is a concentration of sites/ waste facilities.

To make the best use of their limited resources, the mayor must identify and prioritize communities to focus on. The mayor is interested in information for the entire county within which the city is located since people commute from outside the city for work. She is especially concerned about the eastern border of the city which has a lot of sites/waste facilities and has also been flooded in the past. The technical advisory committee to the mayor will be conducting an indicators-based vulnerability assessment to help prioritize long-term adaptation and formulate more immediate emergency response plans for the city and county.

4.2 Step 2: Identify the Vulnerability Factors of Interest and the Indicators to Represent the Factors

The technical advisory committee used Figure 2 to identify the vulnerability factors of interest. Among the four extreme events in [1], the committee selected flooding based on earlier conversations with the mayor and their knowledge of the recent issues in the region. After a closer look at the count and type of sites/waste facilities in the area, they selected hazardous waste facilities from [2] as their primary focus. To identify which communities may be impacted by contaminant releases from the hazardous waste sites, they wanted to understand where these contaminants could travel to. Given that they had limited resources, they prioritized on considering different pathways of flowing waters rather than wind direction from [3]. For [4], the committee selected factors that would be important for both long-term adaptation as well as immediate emergency response planning.

After identifying the vulnerability factors, the committee met with the community representatives in the mayor's office to ensure that their concerns were incorporated in the assessment. The mayor agreed with the prioritized list of vulnerability factors. The mayor also added that due to increases in congestion and rising prices in the city center, there were new low-income housing developments (comprising mostly of rental apartments) in the eastern side. There were preliminary ongoing discussions about developing a new assisted care facility near that area and the mayor wanted to know whether the location was appropriate prior to finalizing the decision and engaging a developer.

The mayor was interested in learning more about the ways in which they could measure and track each of these vulnerability factors. The mayor asked questions about each of the factors and the committee used these questions to select appropriate indicators from the indicator checklist. Figure 7 shows example questions and four sets of indicators to represent vulnerability factors described above.

Box 9. Examples of Considerations: Step 2

- Flooding has been an issue historically and regional flood events have been more severe recently. Growth of low-income housing and assisted care living facilities in the eastern part of the city is an emerging trend.
- The goal to understand baseline vulnerabilities and future trends in vulnerabilities under changing climate conditions. More extreme climate scenarios were used to prepare for the worst possible conditions.
- To get a holistic view of the vulnerabilities, indicators on heavy precipitation, low-lying areas, reactive waste tonnage, proximity of sites/waste facilities to flowing waters and downstream communities and households who have difficulty evacuating, getting medical help or other necessities are considered in conjunction with each other.

To answer the question of where the risks of inundation across a given area are during a flood event, a floodplain indicator was chosen. Both 100-year and 500-year floodplains were considered to incorporate smaller, but more frequently inundated areas and larger, but less frequently inundated areas. Given the recent flood events in other areas in the region, the mayor was interested in knowing about the changing patterns of precipitation across the city and county. The indicator showing the percentage of rain that falls as a heavy event (the daily depth is higher than a high percentile of historical daily values) was selected as a surrogate for likely flood-inducing events. To support emergency response planning, historical values of the heavy precipitation indicator were selected. To prepare for changing frequency and intensity of precipitation, the difference between projected and historical time periods was selected. A mid-century time period was considered as a first step to understanding future vulnerabilities. To identify low-lying areas within a community that have the potential for riverine flooding and receiving overland flow during high-depth precipitation events, the Height Above Nearest Drainage (HAND) indicator was selected.

To understand what the sources of contaminant releases and the size of the overall risk may be, indicators showing simple counts by types of sites/waste facilities were considered. To prioritize monitoring activities, the indicator showing the number of hazardous sites with reactive waste was selected. Tonnage of reactive waste was selected to provide additional information on the magnitude of the risk.

Figure 7. Flooding Scenario: Questions the Indicators Aim to Inform (Examples)

*Unstable under normal conditions; reacts with water (floods) or when heated (heat waves, wildfire).

To identify communities most at risk, information on where potential contaminants can flow to was needed. The mayor and the committee decided that to get a complete picture, rivers that may receive contaminants after a release and overland flow or runoff that may spread the contamination from a facility needed to be considered. The count of upstream facilities indicator was selected to identify communities that may face the highest contamination risk. Count of sites/waste facilities close to a flowline (stream/river) was used to understand potential risks to human and ecological health through direct ingestion, incidental ingestion, dermal contact, or secondary exposure. The closest upstream facility indicator was selected to prioritize and plan for emergency containment methods during an event. Distances of 500 meters were selected as a cutoff for determining “close” facilities to be most protective, considering that the stormwater infrastructure within the city would likely intercept overland releases from facilities beyond that distance.

For emergency response planning, the mayor wanted information on who may face mobility issues that prevents them from evacuating. Indicators providing information on households without private vehicles and elderly people living alone was selected to prioritize evacuation measures. Also, people without health insurance who would have difficulty getting care in the event of any flood-related injuries were identified. Information on household income and highest poverty levels were used to identify those who may not be able to afford bottled water and other necessities in the event of contamination.

Box 10. Examples of Considerations: Step 3

- Block Group was chosen because the goal was to look at the finest resolution possible in the dense city center and use less resolution for the outskirts.
- Aggregate tract levels were selected for communications purposes.
- Recently cleaned up Brownfield sites were excluded from the analysis.

4.3 Step 3: Measure (Calculate Metrics)

The mayor wanted to conduct the assessment for the city, which had a dense population center, and the surrounding county, which was more sparsely populated. To get more detailed information in the city center, the mayor requested finer resolution in the more populated areas and coarser resolution outside the city limits. A Block Group was accordingly chosen as the spatial unit of analysis. To allow for easier communication to city residents, the mayor elected to roll up the information to the tract level when presenting results.

Data were compiled by the committee using the checklists in this handbook. The indicator showing counts of sites/waste facilities by type showed a large number of Brownfield sites in the study area. To ensure that the data reflected the most recent information, the mayor was consulted and two sites that had been recently cleaned up (after the data release) were dropped from the dataset. The mayor was also interested in tracking a hazardous waste facility with long-standing community concerns.

The data was overlaid with Block Group boundary files. The metrics were calculated using the methods detailed in the checklists. The equations provided in the Appendix were used to ensure that the correct calculations were done. The Block Group–level information was then rolled up to the tract level for communicating the results to a is a wide audience at town hall meetings. Caveats associated with using the screening indicators were also documented.

4.4 Step 4: Analyze and Communicate Results

The indicators were mapped for the entire city and the county. The data intervals and color scheme were selected to allow for clear communications. A single symbology/color scheme was used for the heavy precipitation indicator to compare across scenarios. For most of the other indicators, the data were divided into intervals using quantiles to ensure that each bin had the same number of observations and all Block Groups on the map were shaded. Custom intervals were chosen for the HAND indicator based on the scientific judgement of the committee. The hazardous waste facility that was of interest to the community was identified and included on the legend of the extreme event maps.

The mayor also wanted to understand where the locations of the sites/waste facilities were relative to where the flood risks were. Also, the mayor wanted to gain an understanding of how close the sites/ waste facilities were to environmental justice communities. The committee, therefore, suggested overlaying site/waste facility locations with the flood and sensitivity indicators. The maps showed that although historical flood risks were more in the eastern part of the city, the northern boundary may experience much more heavy precipitation in the future. Although there were not many hazardous waste facilities with reactive waste in that area, there was a large Superfund site that used remediation technology that was vulnerable to flooding. The indicator showing counts of Superfund sites with remedy technology vulnerable to floods was added to the list of indicators to consider in the next assessment.

The results also highlighted the importance of considering where the contaminants could flow to rather than where sites are located because there were some Block Groups that did not contain any sites/waste facilities but had sites/waste facilities located 500 meters upstream. The planned location for the new assisted care facility was also downstream of hazardous waste facilities.

The tract-level maps were shown at the monthly town hall meeting. It was emphasized that the sites/waste facilities should be viewed as potential sources of contaminant releases and the indicators should not be interpreted as portraying a certain impact. Rather they are meant to be used for screening to prioritize planning and resources. The committee also mentioned that there were ongoing cleanup activities and data releases planned in the county, which may alter results. In this hypothetical example, the mayor, committee, potential developers, and town hall attendees discussed whether the location of the assisted care facility should be reconsidered given the indicator screening results.

Box 11. Examples of Considerations: Step 4

- To compare communities over time, a single symbology was selected for flood indicators and quantiles for other indicators.
- The hazardous waste facility of interest was identified on the heavy precipitation map to place it in context with flood risks.
- The aggregated results were used for communications. Upcoming cleanup and data release information was shared.

5 Checklists for Developing and Applying Indicators

This handbook summarizes the steps and key considerations for developing vulnerability indicators to screen, assess, and communicate potential extreme event impacts on sites/waste facilities and surrounding communities. Again, these indicators are not intended to replace site-specific analysis and in-depth modeling activities (e.g., risk assessments). Rather, potential users can apply indicators for screening and prioritization purposes, so resources for more in-depth analysis can be focused on the most vulnerable communities. Potential users include, but are not limited to, planners, decision-makers, and technical advisors (for localities, cities, tribes, states, and regions), technical advisors to decision-makers, scientific researchers, environmental advocates, and scientific and community organizations.

This section provides detailed descriptions of how to develop, analyze, and map each indicator. These descriptions are not intended to be seen as the only way to develop the indicators. Users can adapt these steps as needed for their purposes and based on their expertise. For example, more advanced users familiar with datasets or methods may not require all the detailed descriptions. Rather the descriptions should be seen as checklists or a “did I consider this” type of document. Each checklist (accompanied by appendices as needed) is designed to be stand-alone so that users can focus on only those indicators that are relevant or of interest. Considering a set of indicators in conjunction with each other would allow for a more holistic assessment than considering each indicator in isolation.

Vulnerability Source 1.1. Exposure: Extreme Events

Indicator 1.1.1. Checklist for Extreme Heat Indicator

Potential impacts of extreme heat on sites and waste facilities include increased fire hazards, high pressures in closed vessels/tanks, overheating of equipment, off-gassing, changes to remediation effectiveness, and power fluctuations/outages.

Extreme Heat Indicator		
Definition of the indicator		
☐	Definition	*Maximum summer temperature for the user-selected time period and climate scenario/model.* *Maximum temperatures for each day during summer (defined as June through August) are assembled and the maximum value of this time series is selected for each year in the selected time period. These maximum values are then averaged over the time period.* *Variants of the indicator that can be considered include (1) absolute historical and projected values for the user-selected time period and (2) difference or percent difference between the projected and historical values.*
☐	Interpretation	*This indicator provides an overall intensity measure based on the highest temperatures expected on average for each community across the summer. Comparing projected values from historic conditions, the indicator shows, for example, how much hotter on average extreme summer temperatures can be expected to get. The indicator also shows variations in extreme heat conditions across and between communities.*
Data source		
☐	Data Source	*The LOCA (Localized Constructed Analogs) downscaled climate data for the historical and future periods for Representative Concentration Pathway (RCP) scenarios provides the necessary temperature inputs.* • *Time periods can be selected to represent historical conditions (e.g., 1986–2005), mid-century (2040–2059), or late century (2080–2099) scenarios. Other time periods/timeframes can be selected depending on user needs.* • *RCP 4.5 and 8.5 are recommended to represent moderate and more extreme conditions but other scenarios can be selected depending on user needs.* • *Outputs from the CanESM2 climate model can be selected to consider more extreme conditions under a given emissions scenario. Other climate models or a combination of climate models can be used based on user needs.*
☐	Temporal Resolution	*Daily time series of maximum temperatures (historical and projected)*

☐	Spatial Resolution	*LOCA data are available for raster cells, which are 1/16th of a degree of latitude and 1/16th of a degree of longitude in size* *Block Group (BG) shapefile*
☐	Data Format	*Shapefile (BG); NetCDF (LOCA)*
Decisions needed for calculation		
☐	Summer Defined as June through August	*Based on long-term climatic conditions, it is assumed that the highest daily temperatures will occur in the months of June–August (defined as the summer season). There is the potential for sporadic heat waves outside of this period, but on average this period is captures the most extreme heat conditions in any study area.*
☐	Use of Daily Maximum Temperatures	*To calculate extreme heat measures, series of average, minimum, or maximum temperatures for each day could be used. Daily maximum, and then the seasonal maximum is used to be represent the worst possible conditions that communities can prepare for.*
☐	Choice of Appropriate Time Period to Represent Long-term Climatic Conditions/ Average Value for Final Indicator	*Averages across a time period covering several years are recommended to avoid short-term weather fluctuations or modeling uncertainties and to capture represent long-term climatic conditions and patterns. Time periods covering 20 years are recommended. An alternate number of years can be used depending on local needs. For example, a 30-year time period represents longer-term climatic conditions and shorter timeframes (e.g.,15 years) reflect more recent changing conditions.*
Calculation steps and assumptions		
☐	Compile Block Group Maximum Temperature Time Series	***Inputs:*** *LOCA data and BG shapefile* ***Calculations:*** • *Extract all grid cells that touch any BGs within the study area.* • *Resample the extracted raster by a factor of 100, to produce smaller grid cells, each with the same value as the original raster. This needs to be done if the BGs are small compared to the grid cells to ensure that even the smallest BGs have at least one grid cell with data fall within it.* • *If there are multiple grid cells overlapping with a BG, use the zonal statistical function to take the average value of the indexed cells to report a temperature value for each BG.* ***Outputs:*** *Daily time series of maximum temperature per BG*
☐	Limit Time Series to Summer Months	***Input:*** *Time series of maximum temperature per BG* ***Calculation:*** *Select values where Day ≥ 152 AND Day ≤ 243 (Note: LOCA data do not include leap years)* ***Output:*** *Time series of maximum temperatures for summer months per BG*

☐	Average Daily Maximum Summer Temperature (Indicator 1)	***Inputs:*** *Time series of maximum temperatures for summer months per BG* ***Calculation:*** *Take the maximum of all values per BG* ***Outputs:*** *Maximum of the daily maximum summer temperature per BG*
☐	Repetition for Time Periods and Summary Value for Time Period	*Repeat all steps for each year in the selected time period (historical and future) and average over the time period.*
☐	Calculate Percent Difference in Summer Maximum Temperature (Variant of Indicator)	***Inputs:*** • *Average daily maximum summer temperature per BG for historic period* • *Average daily maximum summer temperature for future scenario period* ***Calculation:*** *See Appendix Equation EH-1a and EH-1b for more details.* *Find the difference between the average daily maximum summer temperature from the historic period and the future scenario period. Then divide by the average daily maximum summer temperature from the historic period to get the percent change.* ***Output:*** *Percent difference in summer maximum temperature per BG for future scenario.*
☐	Repetition for Future Scenarios	*Repeat the above step for any additional future scenarios.*
Decisions needed for mapping and interpretation		
☐	Mapping Limited to Block Groups Containing Data	*NA - BGs will all have temperature values.*
☐	Choosing a Symbology	*A single unique symbology that spans climate scenarios is recommended. This will result in the same color representing the same value across the maps, making direct comparisons easier. To build this, find the minimum and maximum values across climate scenarios, and then use the full range of values to create a single unique symbology to apply to all maps.*
☐	Binning the Data by Block Groups	*Using 5–7 bins/categories is recommended so that the map reader can readily distinguish between color categories and visually match them to the legend. Use equal intervals, if possible, which create equal steps between categories (e.g., 0–10, 11–20). Not all categories may necessarily contain values on the map.* *An alternative to equal intervals is quantiles, which attempts to create the same number of observations per bin. This causes each bin to have a different interval and requires careful interpretation and communication. Using quantiles ensures that each color in the symbology will appear on the map, and it will add more detail to the map if the data are concentrated in a few small ranges. Deciles or other percentiles can also be used depending on user needs.*

☐	Choosing Colors	*For maps with sequential data, use a symbology that becomes darker as the vulnerability increases.* *For maps with diverging data, such as the variants of the indicator showing percent change, use a diverging color scheme characterized by darker colors at both extremes and lighter in the middle.*
Examples of how the indicator can be useful		
☐	Impacts of Summer Maximum Temperatures on Sites/Waste Facilities	*Given the potential impacts of extreme heat on sites and waste facilities, this indicator (in combination with sites/waste facilities) can be used for identifying which sites/waste facilities and communities may face higher risks of contamination release due to heat. If expressed in differences or percent differences, the indicator can be used to assess how these spatial patterns in risks may change over time.*
Key caveats/limitations		
☐	Spatial Differentiation Based on Climate Data Source	*When interpreting the maps, it is important to remember that the resolution of the LOCA modeled data is fairly coarse compared to BGs. Each raster cell is 1/16th of a degree of latitude and 1/16th of a degree of longitude in size. This equates to approximately 5 km x 7 km at temperate latitudes such as the United States. There is the potential that this indicator may not provide enough variation across BGs consisting of small spatial areas. The other aspect to be aware of is that difference between BGs may be smaller than the errors in the modeled data. Therefore, differences displayed cartographically, may be within the range of model error. This limitation will apply to any indicators developed with the LOCA data as its input source.*
Citations		
☐	Dataset/Tool	*Pierce, D.W. (2016). LOCA (Local Constructed Analogs) statistical downscaling version 40. Scripps Institute of Oceanography, Division of Climate, Atmospheric Sciences, and Physical Oceanography. http://loca.ucsd.edu/*
☐	Additional Resources	*Downscaled CMIP3 and CMIP5 Climate and Hydrology Projections. (2021). http://gdo-dcp.ucllnl.org/downscaled_cmip_projections/*

BG: Block Group, LOCA: Localized Constructed Analogs, RCP: Representative Concentration Pathway

Indicators 1.1.2 & 1.1.3. Checklist for Threshold-Based Extreme Heat Indicator

Potential impacts of extreme heat on sites and waste facilities include increased fire hazards, high pressures in closed vessels/tanks, overheating of equipment, off-gassing, changes to remediation effectiveness, and power fluctuations/outages. Our assumption is that sites and waste facilities are built to withstand the environmental conditions typical of its surroundings. Temperature values beyond historical baseline extremes, are therefore riskier for sites and waste facilities designed for historical average conditions. Historical baseline extremes therefore can be viewed as a "threshold."

Threshold-Based Extreme Heat Indicator		
Definition of the indicator		
☐	Definition	*(1) The change in the annual number of days with maximum daily temperature above the 99th percentile (extreme heat days), where the 99th percentile is calculated for the historical period and the difference is between the historical period and the future scenario period.* *(2) The average of maximum temperatures for extreme heat days (averaged across all the years in the relevant time period).*
☐	Interpretation	*(1) This frequency-based indicator provides a measure of the change, likely an increase, in the number of extreme heat days a community may experience in the future. Presenting the change as an annual average, the community can easily assess how much of their year may experience extreme heat and therefore pose increased risks for the sites/waste facilities.* *(2) This intensity-based indicator provides the average of the maximum temperatures for extreme heat days. So, whether there are few or many extreme heat days in a year, the maximum temperature for those days are included in the overall average for this indicator providing a measure of how hot it may get during these extreme heat episodes for each time period or scenario.*
Data source		
☐	Data Source	*The LOCA (Localized Constructed Analogs) downscaled climate data for the historical and future periods for Representative Concentration Pathway (RCP) scenarios provides the necessary temperature inputs.* • *Time periods can be selected to represent historical conditions (e.g., 1986–2005), mid- century (2040–2059), or late century (2080–2099) scenarios. Other time periods/timeframes can be selected depending on user needs.* • *RCP 4.5 and 8.5 are recommended to represent moderate and more extreme conditions but other scenarios can be selected depending on user needs.* • *Outputs from the CanESM2 climate model can be selected to consider more extreme conditions under a given emissions scenario. Other climate models or a combination of climate models can be used based on user needs.*
☐	Temporal Resolution	*Daily time series of maximum temperatures*

☐	Spatial Resolution	*LOCA data is available for raster cells which are 1/16th of degree of latitude and 1/16th of a degree of longitude in size* *Block Group (BG) shapefile*
☐	Data Format	*Shapefile (BG); NetCDF (LOCA data)*
Decisions needed for calculation		
☐	Use of Daily Maximum Temperatures	*To calculate the percentiles, series of daily average, minimum, or maximum temperatures could be used. Daily maximum is used to be consistent with the other extreme heat indicators.*
☐	Percentile Value from Historic Period	*Determine a percentile value of the daily maximum from the historic period and using that to assess extreme heat days during the future periods. Using a historical threshold provides a means to compare how extreme heat days are changing in number and intensity into the future as compared to the historic conditions to which sites/waste facilities are accustomed.*
☐	Extreme Heat Days Defined as Top 1% of Maximum Temperatures	*We propose using the 99th to capture the most extreme conditions (similar to our logic of using maximum temperature previously). Alternate percentiles such as 85th (as used by U.S. Global Change Research Program [GCRP] for heat waves for assessing health effects), 90th, 95th, 98th, and/or 99th can be used depending on user needs and local conditions.*
☐	Choice of Appropriate Time Period to Represent Long-term Climatic Conditions/ Average Value for Final Indicator	*Averages across a time period covering several years are recommended to avoid short-term weather fluctuations or modeling uncertainties and to capture represent long-term climatic conditions and patterns. Time periods covering 20 years are recommended. An alternate number of years can be used depending on local needs. For example, a 30-year time period represents longer term climatic conditions and shorter timeframes (e.g.,15 years) reflect more recent changing conditions.*
Calculation steps and assumptions		
☐	Compile Block Group Maximum Temperature Time Series	***Inputs:*** *LOCA data and BG shapefile.* ***Calculations:*** • *Extract all grid cells that touch any BGs within the study area.* • *Resample the extracted raster by a factor of 100, to produce smaller grid cells, each with the same value as the original raster. This needs to be done if the BGs are small compared to the grid cells to ensure that even the smallest BGs would have at least one grid cell with data fall within it.* • *If there are multiple grid cells overlapping with a BG, use the zonal statistical function, take the average value of the indexed cells to report a temperature value for each BG.* ***Outputs:*** *Daily time series of maximum temperature per BG.*

☐	Find 99th Percentile Value for Historic Period	***Input:*** *Time series of maximum temperature from historic period per BG.* ***Calculation:*** *Compute the 99th percentile value of maximum temperature across the entire 20-year historic period by BG.* ***Output:*** *99th percentile value per BG.*
☐	Indicate Extreme Heat Days with Maximum Temperature Time Series	***Inputs:*** • *99th percentile value.* • *Time series of maximum temperature per BG.* ***Calculation:*** *See Appendix Equation TBEH-1.* *Using the 99th percentile value, indicate days from the daily time series that are greater than the 99th percentile value for each period by BG with a 1.* ***Outputs:*** *Time series of extreme heat days per BG.*
☐	Calculate Total Number of Extreme Heat Days Each Year	***Inputs:*** *Time series of extreme heat days per BG.* ***Calculation:*** *See Appendix Equation TBEH-2.* *Sum the extreme heat day indicators within each year to find the total number of extreme heat days each year.* ***Output:*** *Total number of extreme heat days per year per BG.*
☐	Calculate Total Number of Extreme Heat Days per Period	***Inputs:*** *Time series of extreme heat days per year per BG.* ***Calculation:*** *See Appendix Equation TBEH-3.* *Sum the yearly total of extreme heat days to find the total number of extreme heat days for the assessment period.* ***Output:*** *Total number of extreme heat days per BG.*
☐	Calculate the Annual Average Maximum Temperature for Extreme Heat Days	***Inputs:*** • *Time series of extreme heat days per year per BG.* • *Total number of extreme heat days each year per BG.* ***Calculation:*** *See Appendix Equation TBEH-4.* *For each year, sum the maximum temperature for days classified as extreme heat days then divide by the number of extreme heat days for the corresponding year.* ***Output:*** *Average maximum temperature for extreme heat days per year per BG.*
☐	Calculate Average Annual Average Maximum Temperature for Extreme Heat Days (Indicator 2)	***Inputs:*** *Average maximum temperature for extreme heat days per year per BG.* ***Calculation:*** *See Appendix Equation TBEH-5.* *Sum the average maximum temperature for extreme heat days per year per BG and divide by 20 (years in time period).* ***Output:*** *Average annual average of maximum temperature for extreme heat days per BG.*
☐	Repetition for Time Periods and Summary Value for Time Period	*Repeat all steps except for the calculation of the 99th percentile value for the future time periods. Use the value from the historic period for the 99th percentile for all time periods.*

☐	Calculate Change in Total Number of Annual Extreme Heat Days (Indicator 1)	***Inputs:*** • *Total number of extreme heat days per BG for historic period.* • *Total number of extreme heat days per BG for future scenario period.* ***Calculation:*** *See Appendix Equation TBEH-6.* *Subtract the number of extreme heat days during the historic period from the number of extreme heat days during the future scenario period. Divide by 20 to get the annual estimates.* ***Output:*** *Change in total number of annual extreme heat days per BG for future scenario.*
☐	Repetition for Future Scenarios	*Repeat the above step for any additional future scenarios.*
Decisions needed for mapping and interpretation		
☐	Mapping Limited to Block Groups Containing Data	*NA - BGs will all have change values.*
☐	Choosing a Symbology	*The recommended symbology for this indicator is a single unique symbology that spans climate scenarios. This will result in the same color representing the same value across the maps, making direct comparisons much easier. To build this, find the minimum and maximum values across climate scenarios, and then use the full range of values to create a single unique symbology to apply to all maps.*
☐	Binning the Data by Block Groups	*Using 5-7 bins/categories is recommended so that the map reader can readily distinguish between color categories and visually match them to the legend. Use equal intervals, if possible, which create equal steps between categories (e.g., 0–10, 11–20). Not all categories may necessarily contain values on the map.* *The alternative to equal intervals is quantiles, which attempts to create the same number of observations per bin. This causes each bin to have a different interval and requires careful interpretation and communication. Using quantiles ensures that each color in the symbology will appear on the map, and it will add more detail to the map if the data is concentrated in a few small ranges. Deciles or other percentiles can also be used depending on user needs.*
☐	Choosing Colors	*For maps with sequential data, use a symbology that becomes darker as the vulnerability increases.* *For maps with diverging data, such as the variants of the indicator showing percent change, use a diverging color scheme characterized by darker colors at both extremes and lighter in the middle.*
Examples of how the indicator can be useful		
☐	Tracking of Days with Possible Emergency Declarations or Health Warnings	*The change in number of annual extreme heat days could provide information on how many times in a year could there be failures for sites/waste facilities.*

☐	Average Maximum Temperature for Extreme Heat Days for Resiliency Planning	*This indicator provides a measure of the highest temperatures that will be experienced occasionally during any year. This indicator (in combination with sites/ waste facilities) can be used for assessing whether facilities, equipment, and operations that are built to historical average conditions may face higher risks under future scenarios.*
Key caveats/limitations		
☐	Calculations Completed within R	*A custom program such as R needs to be created to input the processed LOCA-based climate data indexed by BG unique identifier and complete all calculations. If using the custom R program developed by RTI, a user need only supply the links to the input temperature datasets for the program to complete all calculation steps.*
☐	Spatial Differentiation Based on Climate Data Source	*When interpreting the maps, it is important to remember that the resolution of the LOCA modeled data is fairly coarse compared to BGs. Each raster cell is 1/16th of a degree of latitude and 1/16th of a degree of longitude in size. This equates to approximately 5 km x 7 km at temperate latitudes such as the United States. There is the potential that this indicator may not provide enough variation across BGs consisting of small spatial areas. The other aspect to be aware of is that difference between BGs may be smaller than the errors in the modeled data. Therefore, differences displayed cartographically, may be within the range of model error. This limitation will apply to any indicators developed with the LOCA data as its input source.*
Citations		
☐	Dataset/Tool	*Pierce, D.W. (2016). LOCA (Local Constructed Analogs) statistical downscaling version 40. Scripps Institute of Oceanography, Division of Climate, Atmospheric Sciences, and Physical Oceanography. http://loca.ucsd.edu/*
☐	Additional Resources	*Downscaled CMIP3 and CMIP5 Climate and Hydrology Projections. (2021). http://gdo-dcp.ucllnl.org/downscaled_cmip_projections/*

BG: Block Group, GCRP: U.S. Global Change Research Program; LOCA: Localized Constructed Analogs, RCP: Representative Concentration Pathway

Indicator 1.1.4. Checklist for Wildfire Indicator

The potential impacts of wildfires on sites and waste facilities include catastrophic damage to facilities and ignitable wastes, high pressure in closed vessels, overheating of equipment, incident waste facility closures, increased hazardous/non-hazardous waste generation, power fluctuations/outages, and acute air quality incidents/emergency due to hazardous smoke plumes.

Wildfire Indicator		
Definition of the indicator		
☐	Definition	*The fraction of Block Group (BG) burned for the user-selected time period and climate scenario/model.* *Percent values for each year are assembled in the selected time period. These values are then averaged over the time period.* *Variants of the indicator that can be considered include (1) absolute historical and projected values for the user selected time period and (2) difference or percent difference between the projected and historical values.*
☐	Interpretation	*The percent value would indicate the average area that may burn in a given BG during the specified time period.*
Data source		
☐	Data Source	*The CIRA II data for the historical and future periods for Representative Concentration Pathway (RCP) scenarios provides the necessary wildfire inputs.* • *Time periods can be selected to represent historical conditions (e.g., 1986–2005), mid-century (2040–2059), or late century (2080–2099) scenarios. Other time periods/timeframes can be selected depending on user needs.* • *RCP 4.5 and 8.5 are recommended to represent moderate and more extreme conditions but other scenarios can be selected depending on user needs.* • *Outputs from the CanESM2 climate model can be selected to consider more extreme conditions under a given emissions scenario. Other climate models or a combination of climate models can be used based on user needs.*
☐	Temporal Resolution	*Time series of percent of grid cell burned for each year*
☐	Spatial Resolution	*CIRA data are available for raster cells which are 1/16th of a degree of latitude and 1/16th of a degree of longitude in size* *BG shapefile*
☐	Data Format	*Shapefile (BG); NetCDF (CIRA data available on request from EPA)*

Decisions needed for calculation		
☐	Use of Mean Across Grid Cells	*To calculate wildfire measures, total, average, minimum, or maximum fractions across grid cells within a BG could be used. Average values are recommended to avoid modeling uncertainties at such fine scales. Maximum may also be used to be represent the worst possible conditions that the communities can prepare for.*
☐	Choice of Appropriate Time Period to Represent Long-term Climatic Conditions/ Average Value for Final Indicator	*Averages across a time period covering several years are recommended to avoid short-term weather fluctuations or modeling uncertainties and to capture represent long-term climatic conditions and patterns. Time periods covering 20 years are recommended. An alternate number of years can be used depending on local needs. For example, a 30-year time period represents longer term climatic conditions and shorter timeframes (e.g.,15 years) reflect more recent changing conditions.*
Calculation steps and assumptions		
☐	Compile Block Group Fraction Burned Time Series	***Inputs:*** *CIRA data and BG shapefile* ***Calculations:*** • *Extract all grid cells that touch any BGs within the study area.* • *Resample the extracted raster by a factor of 100, to produce smaller grid cells, each with the same value as the original raster. This needs to be done if the BGs are small compared to the grid cells to ensure that even the smallest BGs would have at least one grid cell with data fall within it.* • *If there are multiple grid cells overlapping with a BG, use the zonal statistical function, take the average value of the indexed cells to report a wildfire value for each BG.* ***Outputs:*** *Annual time series of fraction of BG area burned*
☐	Summary Value for Time Period	***Calculation:*** *See Appendix Equation WF-1.* *Average value over the time period (historical and future).*
☐	Calculate Percent Difference in Fraction of BG Area Burned (Variant of Indicator)	***Inputs:*** • *Average fraction of BG area burned for historic period* • *Average fraction of BG area burned for future scenario period* ***Calculation:*** *See Appendix Equation WF-2.* *Take the difference between the fraction of BG area burned from the historic period to the future scenario period. Then divide by the average fraction of BG area burned from the historic period to get the percent change.* ***Output:*** *Percent difference in fraction of BG area burned for future scenario.*
☐	Repetition for Future Scenarios	*Repeat the above step for any additional future scenarios.*

Decisions needed for mapping and interpretation		
☐	Mapping Limited to Block Groups Containing Data	*NA - BGs will all have percent of grid cell burned values.*
☐	Choosing a Symbology	*A single unique symbology that spans climate scenarios is recommended. This will result in the same color representing the same value across the maps, making direct comparisons easier. To build this, find the minimum and maximum values across climate scenarios, and then use the full range of values to create a single unique symbology to apply to all maps.*
☐	Binning the Data by Block Groups	*Using 5–7 bins/categories is recommended so that the map reader can readily distinguish between color categories and visually match them to the legend. Use equal intervals, if possible, which create equal steps between categories (e.g., 0–10, 11–20). Not all categories may necessarily contain values on the map.* *An alternative to equal intervals is quantiles, which attempts to create the same number of observations per bin. This causes each bin to have a different interval and requires careful interpretation and communication. Using quantiles ensures that each color in the symbology will appear on the map, and it will add more detail to the map if the data are concentrated in a few small ranges. Deciles or other percentiles can also be used depending on user needs.*
☐	Choosing Colors	*For maps with sequential data, use a symbology that becomes darker as the vulnerability increases.* *For maps with diverging data, such as the variants of the indicator showing percent change, use a diverging color scheme characterized by darker colors at both extremes and lighter in the middle.*
Examples of how the indicator can be useful		
☐	Wildfire Indicator	*Given the potential impacts of wildfire on sites and waste facilities, this indicator (in combination with sites/waste facilities) can be used for identifying which sites/waste facilities and communities may face higher risks of contamination release due to wildfires. If expressed in differences or percent differences, the indicator can be used to assess how these spatial patterns in risks may change over time. If expressed in differences, the indicator can be used to assess how these spatial patterns in risks may change over time.*
Key caveats/limitations		
☐	Spatial Differentiation Based on Data Source	*When interpreting the maps, it is important to remember that the resolution of the CIRA modeled data is fairly coarse compared to BGs. Each raster cell is 1/16th of a degree of latitude and 1/16th of a degree of longitude in size. This equates to approximately 5 km x 7 km at temperate latitudes such as the United States. Therefore, for very small BGs, the number of cells that comprise the mean might only be one or two. The other aspect to be aware of is that difference in projected areas between BGs might only be fractions of a percent, which may be smaller than the errors in the modeled data. Therefore, differences displayed cartographically, may be within the range of model error.*

Citations		
	Dataset/Tool (Available upon request from EPA)	*U.S. Environmental Protection Agency (U.S. EPA). 2017. Multi-model framework for quantitative sectoral impacts analysis: A technical report for the Fourth National Climate Assessment. EPA 430-R-17-001.* *https://cfpub.epa.gov/si/si_public_record_Report.cfm?dirEntryId=335095*
	Additional Resources	*Mills, D., Jones, R., Wobus, C., Ekstrom, J., Jantarasami, L., St. Juliana, A., Crimmins, A. (2018). Projecting age-stratified risk of exposure to inland flooding and wildfire smoke in the United States under two climate scenarios. Environmental Health Perspectives, 126(4).* *https://doi.org/10.1289/EHP2594*

BG: Block Group, EPA: U.S. Environmental Protection Agency, RCP: Representative Concentration Pathway

Indicator 1.1.5. Checklist for Floodplain-Based Flood Indicator

Potential impacts of floods on sites and waste facilities include more likely erosion, difficult ponding/stormwater management, water damage (corrosion, water logging), power fluctuations/outages, groundwater plume changes and higher water table, spreading/migration of contamination, catastrophic events destroy structures, releases from overwash, infiltration, and leaching, incident waste facility closures, increased hazardous/non-hazardous waste generation, groundwater pump-and-treat remedies may not be allowed to discharge, increased potential for flooding of treatment systems, and dislodged debris from treatment/containment systems or contained wastes and reactive wastes.

Floodplain-Based Flood Indicator		
Definition of the indicator		
☐	Definition	*Percent of Block Group (BG) area contained within a designated 100-year/500-year floodplain.*
☐	Interpretation	*Floodplains as defined by the National Flood Hazard Layer (NFHL) show the land area along a watercourse likely to be inundated during storm events of corresponding return intervals. By determining the percentage of the BG area containing a floodplain, the relative risk of flood inundation can be determined for the BG and across BGs depending on the recurrence interval/storm probability chosen for the floodplain (i.e., 100- or 500-year).*
Data source		
☐	Data Source	*The NFHL can be accessed at https://msc.fema.gov/portal/advanceSearch. Data for the necessary location is obtained through searching by state and county. A zip file is downloaded from the search result.*
☐	Temporal Resolution	*NA – This indicator is a static measure without a time component. The measure represents the information available at the time of download.*
☐	Spatial Resolution	*NFHL resolution varies depending on location but is generally accurate at a scale <1 meter.* *BG shapefile*
☐	Data Format	*Shapefile (BG and NFHL)*
Decisions needed for calculation		
☐	100-year or 500-year Floodplain Indicator	*The 100-year floodplain defines the area more likely to be inundated by rainfall events with a 1% annual chance of occurrence, while the 500-year floodplain defines the area more likely to be inundated by events with a 0.2% annual chance of occurrence A community can choose which version of the indicator to use. The choice between whether one looks at the 100-year or 500-year floodplain is a choice between defining smaller, but more frequent inundated areas versus large, but less frequently inundated areas.*

Calculation steps and assumptions		
☐	Extract 100- and 500-year Flood Hazard Limits	***Inputs:*** *NFHL* ***Calculations:*** • *Use shapefile S_FLD_HAZ_AR.shp.* • *The field "FLD_ZONE" is used to separate the 100-year and 500-year flood hazard extents.* • *Values of either "A" or "AE" were combined to define the 100-year extent, while a value of "X" was used to define the 500-year extent.*[11] ***Outputs:*** *Shapefile containing polygon extents for the 100-year and 500-year floodplains*
☐	Clip the Block Groups by the Floodplains	***Input:*** • *Shapefile containing polygon extents for the 100-year and 500-year floodplains* • *BG shapefile* ***Calculation:*** • *Within ArcGIS, use the "Clip" tool within the "Extract" toolset, within the "Analysis Tools" toolbox* • *Include area field during clip function* • *Complete twice, once for each floodplain extent* ***Output:*** *Shapefile with BG – floodplain intersection for 100- and 500-year extents*
☐	Calculate the Floodplain-Based Flood Indicator	***Input:*** *Shapefile with BG – floodplain intersection for 100- and 500-year extents* ***Calculation:*** *See Appendix Equation FBF-1.* *Using the area field for the clip and the area field for the original BG, determine the percent area (area-clip/area-original).* ***Output:*** *Percent area within the floodplain per BG per recurrence interval (i.e., 100- and 500-year)*
Decisions needed for mapping and interpretation		
☐	Mapping Limited to Block Groups Containing Data	*NA - BGs will all have count values. Zero is a valid value.*
☐	Choosing a Symbology	*The recommended symbology for this indicator is equal intervals. The percent of BG within the flood plain will range between 0 to 100%. In this case dividing the data into equal intervals will present the data in a way that makes comparisons between categories (or bins) easier. Alternatively, it is also possible to use quantiles. This will create an equal number of observations per category, but it makes comparison between categories less intuitive.*

[11] Definitions of the values contained within this field can be found at https://www.fgdl.org/metadata/metadata_archive/fgdl_html/dfirm_fldhaz_apr08.htm.

☐	Binning the Data by Block Groups	*Using 5–7 bins/categories is recommended so that the map reader can readily distinguish between color categories and visually match them to the legend. Use equal intervals, if possible, which create equal steps between categories (e.g., 0–10, 11–20). Not all categories may necessarily contain values on the map.* *An alternative to equal intervals is quantiles, which attempts to create the same number of observations per bin. This causes each bin to have a different interval and requires careful interpretation and communication. Using quantiles ensures that each color in the symbology will appear on the map, and it will add more detail to the map if the data are concentrated in a few small ranges. Deciles or other percentiles can also be used depending on user needs.*
☐	Choosing Colors	*For maps with sequential data, use a symbology that becomes darker as the vulnerability increases.* *For maps with diverging data, such as the variants of the indicator showing percent change, use a diverging color scheme characterized by darker colors at both extremes and lighter in the middle.*
Examples of how the indicator can be useful		
☐	Community Vulnerability to Flooding	*This indicator provides a spatial representation of vulnerability of a community to flooding. Combining this indicator with information on sites/waste facilities can provide information on direct or indirect risks (e.g., due to compromised infrastructure such as power disruptions).*
Key caveats/limitations		
☐	NFHL Validity	*FEMA maintains the NFHL on a schedule that is set by region. Before beginning any analysis, a user should check for updates to the NFHL polygons. For layers that have not been updated within the last few years, there is a greater probability that the flood extents are out of date due to either land development or changes in precipitation frequencies.*
☐	NFHL Applicability	*Actual inundation during any flooding event will vary depending on preceding hydrologic conditions and the characteristics of the storm event itself. Therefore, these defined floodplains are the best estimates of inundated area based on historic storm events. As extreme precipitation events change into the future, these floodplain boundaries will change and will likely expand to cover larger areas. Further, this indicator does not provide any information on the severity or frequency of flood events. Floodplains data also face other issues such as incomplete coverage and coarse resolution (Wing et al, 2018).*
Citations		
☐	Dataset/Tool	*FEMA. (2021). National Flood Hazard Layer. http://www.fema.gov/national-flood-hazard-layer-nfhl.*
☐	Additional Resources	*Wing, O.E.J., Bates, P.D., Smith, A.M., Sampson, C. C., Johnson, K.A., Fargione, J., & Morefield, P. (2018). Estimates of present and future flood risk in the conterminous United States.* Environmental Research Letters, 13, *034023 https://doi.org/10.1088/1748-9326/aaac65*

BG: Block Group, FEMA: U.S. Federal Emergency Management Agency, NFHL: National Flood Hazard Layer

Indicator 1.1.6. Checklist for Precipitation-Based Flood Indicator

Potential impacts of floods on sites and waste facilities include more likely erosion, difficult ponding/stormwater management, water damage (corrosion, water logging), power fluctuations/outages, groundwater plume changes and higher water table, spreading/migration of contamination, catastrophic events destroy structures, releases from overwash, infiltration, and leaching, incident waste facility closures, increased hazardous/non-hazardous waste generation, groundwater pump-and-treat remedies may not be allowed to discharge, increased potential for flooding of treatment systems, and dislodged debris from treatment/containment systems or contained wastes and reactive wastes.

Precipitation-Based Flood Indicator		
Definition of the indicator		
☐	Definition	*Average annual percent of precipitation depth falling during "heavy" events where "heavy" events are those with a daily precipitation depth greater than the 99th percentile of daily precipitation for the user selected time period and climate scenario/model. Alternate percentiles can be used to define heavy events.* *Variants of the indicator that can be considered include (1) absolute historical and projected values for the user selected time period and (2) difference or percent difference between the projected and historical values.*
☐	Interpretation	*The average annual proportion of precipitation that falls during the heaviest 1% of precipitation events is a surrogate for likely flood-inducing events. Averaging across the annual values allows for the influence of extreme years on the indicator value (i.e., one year with a smaller number of extremely intense events will lead to a higher indicator value). By using the 1% value from the historic period when calculating the proportions for future periods, the increase or decrease in likely flooding can easily be discerned. The indicator also shows variations in flood risks across and between communities. While the actual flood-causing runoff and streamflow generated from heavy events will depend on a number of factors, including local land cover and antecedent moisture conditions, this indicator is meant to be used for screening purposes that will identify priority areas for more in-depth modeling.*

Data source		
☐	Data Source	*The LOCA (Localized Constructed Analogs) downscaled climate data for the historical and future periods for Representative Concentration Pathway (RCP) scenarios provides the necessary temperature inputs.* • *Time periods can be selected to represent historical conditions (e.g., 1986–2005), mid-century (2040–2059), or late century (2080–2099) scenarios. Other time periods/timeframes can be selected depending on user needs.* • *RCP 4.5 and 8.5 are recommended to represent moderate and more extreme conditions but other scenarios can be selected depending on user needs.* • *Outputs from the CanESM2 climate model can be selected to consider more extreme conditions under a given emissions scenario. Other climate models or a combination of climate models can be used based on user needs.*
☐	Temporal Resolution	*Daily time series of precipitation*
☐	Spatial Resolution	*LOCA data are available for raster cells which are 1/16th of a degree of latitude and 1/16th of a degree of longitude in size.* *Block Group (BG) shapefile*
☐	Data Format	*Shapefile (BG); NetCDF (LOCA)*
Decisions needed for calculation		
☐	Percentile Value from Historic Period	*Determine a percentile value from the historic period and use that to assess heavy events during the future periods. Using a historical threshold provides a means to compare how heavy events are changing into the future as compared to the historic conditions to which sites/waste facilities are accustomed.*
☐	Heavy Events Defined as Top 1% Events	*By using events that fall in the top 1% across the whole period, this analysis captures the most extreme conditions, which therefore keeps annual depth percentages tied to long-term heavy events. For example, USEPA (2016) and USGCRP (2018) define "heavy event indicator" as the top 1% of precipitation events. Alternate percentiles can be used depending on user needs and local conditions.*
☐	Choice of Appropriate Time Period to Represent Long-term Climatic Conditions/ Average Annual Value for Final Indicator	*By averaging the annual percentage of heavy event precipitation across all the years in the relevant time period, the indicator avoids short-term weather fluctuations or modeling uncertainties. It considers the climatic variation of dry and wet years and any patterns in the heavy event precipitation. To capture long-term climatic conditions, time periods covering 20 years are recommended. An alternate number of years can be used depending on local needs. For example, averages over a 30-year time period represent longer term climatic conditions and shorter timeframes (e.g., 15 years) reflect more recent changing conditions.*

	Calculation steps and assumptions	
☐	Compile Block Group Precipitation Time Series	***Inputs:*** *LOCA data and BG shapefile* ***Calculations:*** • *Extract all grid cells that touch any BGs within the study area.* • *Resample the extracted raster by a factor of 100 to produce smaller grid cells, each with the same value as the original raster.* • *This needs to be done if the BGs are small compared to the grid cells to ensure that even the smallest BGs would have at least one grid cell with data fall within it.* • *Using the zonal statistical function, take the average value of the indexed cells to report a precipitation value for each BG.* ***Outputs:*** *Daily time series of precipitation per BG*
☐	Create a Time Series of Wet Days	***Input:*** *Daily time series of precipitation per BG* ***Calculation:*** *For each time period for each BG, select days where precipitation > 0* ***Output:*** *Time series limited to days with precipitation per BG*
☐	Find Percentile Value for Historic Period	***Input:*** *Time series of wet days from historic period per BG* ***Calculation:*** *Compute the selected percentile value of precipitation across the wet days within the entire 20-year historic period by BG. For illustration we use the 99th percentile to define heavy events as the top 1% of precipitation events.* ***Output:*** *Selected percentile value per BG*
☐	Select Heavy Precipitation Days	***Inputs:*** • *Selected percentile value* • *Time series of wet days per BG* ***Calculation:*** *Using the 99th percentile value, select days from the time series of wet days that are greater than the selected percentile value for each period by BG.* ***Outputs:*** *Time series of heavy precipitation days per BG*
☐	Calculate Total Heavy Event Precipitation Each Year	***Inputs:*** *Time series of heavy precipitation days per BG* ***Calculation:*** *See Appendix Equation PBF-1.* *Sum the precipitation depth on heavy precipitation days within each year to find the total precipitation due to heavy events each year.* ***Output:*** *Total heavy precipitation per year per BG*
☐	Calculate Total Precipitation Each Year	***Inputs:*** *Time series of wet days per BG* ***Calculation:*** *See Appendix Equation PBF-2.* *Sum daily precipitation depths within each year.* ***Output:*** *Total precipitation per year per BG*

☐	Calculate Percentage of Precipitation Falling during Heavy Events Each Year	***Inputs:*** • *Total heavy precipitation per year per BG* • *Total precipitation per year per BG* ***Calculation:*** *See Appendix Equation PBF-3.* *For each year divide the total heavy precipitation per year by the total precipitation per year. Complete this calculation for each year and each BG.* ***Output:*** *Percent of precipitation falling as heavy events per year per BG*
☐	Calculate the Precipitation-Based Flood Indicator	***Inputs:*** *Percent of precipitation falling as heavy events per year per BG* ***Calculation:*** *See Appendix Equation PBF-4.* *Sum the percent of precipitation falling as heavy events from each year per BG and divide by 20 (years in time period).* ***Output:*** *Average annual percent of precipitation falling as heavy events per BG*
☐	Repetition for Time Periods/ Scenarios and Summary Value for Time Period	*Repeat all steps except for the calculation of the selected percentile value for the selected time periods (historical and future) and average over the time period. Use the value from the historic period for the selected percentile for all time periods. Repeat the above step for any additional future scenarios.*
Decisions needed for mapping and interpretation		
☐	Mapping Limited to Block Groups Containing Data	*NA - BGs will all have percent values.*
☐	Choosing a Symbology	*A single unique symbology that spans climate scenarios is recommended. This will result in the same color representing the same value across the maps, making direct comparisons easier. To build this, find the minimum and maximum values across climate scenarios, and then use the full range of values to create a single unique symbology to apply to all maps.*
☐	Binning the Data by Block Groups	*Using 5–7 bins/categories is recommended so that the map reader can readily distinguish between color categories and visually match them to the legend. Use equal intervals, if possible, which create equal steps between categories (e.g., 0–10, 11–20). Not all categories may necessarily contain values on the map.* *An alternative to equal intervals is quantiles, which attempts to create the same number of observations per bin. This causes each bin to have a different interval and requires careful interpretation and communication. Using quantiles ensures that each color in the symbology will appear on the map, and it will add more detail to the map if the data are concentrated in a few small ranges. Deciles or other percentiles can also be used depending on user needs.*
☐	Choosing Colors	*For maps with sequential data, use a symbology that becomes darker as the vulnerability increases.* *For maps with diverging data, such as the variants of the indicator showing percent change, use a diverging color scheme characterized by darker colors at both extremes and lighter in the middle.*

Examples of how the indicator can be useful		
☐	Planning for Stormwater Management and Site/Waste Facility Breaches	*This indicator provides a spatial representation of vulnerability of sites/waste facilities to flooding due to extreme precipitation events. These events may represent more frequent storms during wet years or fewer but larger events during dry years. Areas with higher percentages will face greater risks of flooding and risks of site/waste facility breaches. Therefore, the areas with higher indicator values are more vulnerable and should be targeted for adaptation.* *Using this indicator in conjunction with the mean Height Above Nearest Drainage (HAND) per BG (Indicator 1.1.8) provides even more information on flood risk.* *The high percentage areas also face challenges in dealing with the on-the-ground stormwater resulting from these events, whether the event results in flooding or not. Therefore, the areas with higher indicator values should be targeted for stormwater management planning as well.*
Key caveats/limitations		
☐	Calculations Completed within R	*A custom program such as R needs to be created to input the processed LOCA-based climate data indexed by BG unique identifier and complete all calculations. If using the custom R program developed by RTI, a user need only supply the links to the input precipitation datasets for the program to complete all calculation steps.*
☐	Spatial Differentiation Based on Climate Data Source	*When interpreting the maps, it is important to remember that the resolution of the LOCA modeled data is fairly coarse compared to BGs. Each raster cell is 1/16th of a degree of latitude and 1/16th of a degree of longitude in size. This equates to approximately 5 km x 7 km at temperate latitudes such as the United States. There is the potential that this indicator may not provide enough variation across BGs consisting of small spatial areas. The other aspect to be aware of is that difference between BGs may be smaller than the errors in the modeled data. Therefore, differences displayed cartographically, may be within the range of model error. This limitation will apply to any indicators developed with the LOCA data as its input source.*
Citations		
☐	Dataset/Tool	*Pierce, D.W. (2016). LOCA (Local Constructed Analogs) statistical downscaling version 40. Scripps Institute of Oceanography, Division of Climate, Atmospheric Sciences, and Physical Oceanography.* http://loca.ucsd.edu/

☐	Additional Resources	*Downscaled CMIP3 and CMIP5 Climate and Hydrology Projections. (2021).* [*http://gdo-dcp.ucllnl.org/downscaled_cmip_projections/*](http://gdo-dcp.ucllnl.org/downscaled_cmip_projections/) *Groisman, P.Y., Knight, R.W., Karl, T.R., Easterling, D.R., Sun, B., and Lawrimore, J.H. (2004). Contemporary Changes of the Hydrological Cycle over the Contiguous United States: Trends Derived from In Situ Observations. Journal of Hydrometeorology 5, 64-85.* *U.S. Environmental Protection Agency. (2016). Climate change indicators in the United States, 2016. Fourth edition. EPA 430-R-16-004.* [*www.epa.gov/climate-indicators*](http://www.epa.gov/climate-indicators)*.* *U.S. Global Change Research Program. (2018). Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II [Reidmiller, D.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, and B.C. Stewart (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, 1515 pp. doi: 10.7930/NCA4.2018.*

BG: Block Group, LOCA: Localized Constructed Analogs, RCP: Representative Concentration Pathway

Indicator 1.1.7. Checklist for Threshold-Based Flood Indicator

Potential impacts of floods on sites and waste facilities include more likely erosion, difficult ponding/stormwater management, water damage (corrosion, water logging), power fluctuations/outages, groundwater plume changes and higher water table, spreading/migration of contamination, catastrophic events destroy structures, releases from overwash, infiltration, and leaching, incident waste facility closures, increased hazardous/non-hazardous waste generation, groundwater pump-and-treat remedies may not be allowed to discharge, increased potential for flooding of treatment systems, and dislodged debris from treatment/containment systems or contained wastes and reactive wastes.

Threshold-Based Flood Indicator		
Definition of the indicator		
☐	Definition	*The percent change in the depth of precipitation falling during extreme events (i.e., change in total depth over the 20-year period) from the historic period to the user selected future assessment period and climate scenario/model.*
☐	Interpretation	*The percent change in depth due to heavy precipitation from the historic to the future (future total heavy precipitation depth minus historic total heavy precipitation depth as a percent of the historic total heavy precipitation depth) provides a threshold value for the increased risk from heavy precipitation events in the future as compared to the heavy precipitation expected and/or experienced and accounted for by facility operations in the more recent, historic period. A positive value for this indicator means that more of the precipitation that falls over the long-term will be falling as part of heavy precipitation events. It measures the long-term percent change in heavy precipitation depth.*
Data source		
☐	Data Source	*The LOCA (Localized Constructed Analogs) downscaled climate data for the historical and future periods for Representative Concentration Pathway (RCP) scenarios provides the necessary temperature inputs.* • *Time periods can be selected to represent historical conditions (e.g., 1986–2005), mid-century (2040–2059), or late century (2080–2099) scenarios. Other time periods/timeframes can be selected depending on user needs.* • *RCP 4.5 and 8.5 are recommended to represent moderate and more extreme conditions but other scenarios can be selected depending on user needs.* • *Outputs from the CanESM2 climate model can be selected to consider more extreme conditions under a given emissions scenario. Other climate models or a combination of climate models can be used based on user needs.*
☐	Temporal Resolution	*Daily time series of precipitation*
☐	Spatial Resolution	*LOCA data are available for raster cells, which are $1/16^{th}$ of a degree of latitude and $1/16^{th}$ of a degree of longitude in size* *Block Group (BG) shapefile*

☐	Data Format	*Shapefile (BG); NetCDF (LOCA)*
Decisions needed for calculation		
☐	Percentile Value from Historic Period	*Determine a percentile value from the historic period and using that to assess heavy events during the future periods. Using a historical threshold provides a means to compare how heavy events are changing into the future as compared to the historic conditions to which sites/waste facilities are accustomed.*
☐	Heavy Events Defined as Top 1% Events	*By using events that fall in the top 1% across the whole period, this analysis is limited to truly large events, which therefore keeps annual depth percentages tied to long-term heavy events. Alternate percentiles such as can be used depending on user needs and local conditions.*
☐	Choice of Appropriate Time Period to Represent Long-term Climatic Conditions	*Considering a time period covering several years is recommended to avoid short-term weather fluctuations or modeling uncertainties and to capture representative long-term climatic conditions and patterns. Time periods covering 20 years are recommended. An alternate number of years can be used depending on local needs. For example, a 30-year time period represents longer term climatic conditions and shorter timeframes (e.g.,15 years) reflect more recent changing conditions.*
Calculation steps and assumptions		
☐	Compile Block Group Precipitation Time Series	***Inputs:** LOCA data and BG shapefile* ***Calculations:*** • *Extract all grid cells the touch any BGs within the study area.* • *Resample the extracted raster by a factor of 100 to produce smaller grid cells, each with the same value as the original raster. This needs to be done if the BGs are small compared to the grid cells to ensure that even the smallest BGs would have at least one grid cell with data fall within it.* • *If there are multiple grid cells overlapping with a BG, use the zonal statistical function, take the average value of the indexed cells to report a precipitation value for each BG.* ***Outputs:** Daily time series of precipitation per BG*
☐	Create a Time Series of Wet Days	***Input:** Daily time series of precipitation per BG* ***Calculation:** For each time period for each BG, select days where precipitation is greater than 0.* ***Output:** Time series limited to days with precipitation per BG*
☐	Find Percentile Value for Historic Period	***Input:** Time series of wet days from historic period per BG* ***Calculation:** Compute the selected percentile value of precipitation across the wet days within the entire 20-year historic period by BG. For illustration we use the 99th percentile to define heavy events as the top 1% of precipitation events.* ***Output:** Selected percentile value per BG*

☐	Select Heavy Precipitation Days	***Inputs:*** • *Selected percentile value* • *Time series of wet days per BG* ***Calculation:*** *Using the selected percentile value, select days from the time series of wet days that are greater than the selected percentile value for each period by BG.* ***Outputs:*** *Time series of heavy precipitation days per BG*
☐	Calculate Total Heavy Event Precipitation Each Year	***Inputs:*** *Time series of heavy precipitation days per BG* ***Calculation:*** *See Appendix Equation PBF-1.* *Sum precipitation depth on the heavy precipitation days within each year to find the total precipitation depth due to heavy events each year.* ***Output:*** *Total heavy precipitation per year per BG*
☐	Repetition for Time Periods	*Repeat all steps except for the calculation of the 99th percentile value for the future time periods. Use the value from the historic period for the 99th percentile for all time periods.*
☐	Calculate the Threshold-Based Flood Indicator for RCP4.5 Scenario	***Inputs:*** *Total depth of precipitation from heavy events during the historic period and total depth of precipitation from heavy events during the future RCP4.5 scenario, per year per BG.* ***Calculation:*** *See Appendix Equation TBF-1.* *Take the difference between the total depth of precipitation from heavy events from the historic period to the future scenario period. Then divide by the total depth of precipitation during heavy events during the historic period to get the percent change.* ***Output:*** *Percent change in heavy event precipitation from historic conditions for the future scenario per BG*
☐	Repetition for RCP8.5 Scenario	*Repeat the above calculation using the total depth of heavy event precipitation for future RCP8.5 scenario.*
Decisions needed for mapping and interpretation		
☐	Mapping Limited to Block Groups Containing Data	*NA - BGs will all have change values.*
☐	Choosing a Symbology	*A single unique symbology that spans climate scenarios is recommended. This will result in the same color representing the same value across the maps, making direct comparisons easier. To build this, find the minimum and maximum values across climate scenarios, and then use the full range of values to create a single unique symbology to apply to all maps.*

☐	Binning the Data by Block Groups	*Using 5–7 bins/categories is recommended so that the map reader can readily distinguish between color categories and visually match them to the legend. Use equal intervals, if possible, which create equal steps between categories (e.g., 0–10, 11–20). Not all categories may necessarily contain values on the map.* *An alternative to equal intervals is quantiles, which attempts to create the same number of observations per bin. This causes each bin to have a different interval and requires careful interpretation and communication. Using quantiles ensures that each color in the symbology will appear on the map, and it will add more detail to the map if the data are concentrated in a few small ranges. Deciles or other percentiles can also be used depending on user needs.*
☐	Choosing Colors	*For maps with sequential data, use a symbology that becomes darker as the vulnerability increases.* *For maps with diverging data, such as the variants of the indicator showing percent change, use a diverging color scheme characterized by darker colors at both extremes and lighter in the middle.*
Examples of how the indicator can be useful		
☐	Resiliency Planning for Heavy Precipitation Events	*Resiliency planning for sites/waste facilities should consider an increased frequency and/or intensity of heavy events when large values for this indicator are projected. Resiliency could examine efforts to protect from flash floods or to provide stormwater storage, routing, or treatment, for example.* *Using this indicator in conjunction with the mean* Height Above Nearest Drainage (HAND) per BG (Indicator 1.1.8) *provides even more information on flood risk.*
Key caveats/limitations		
☐	Calculations Completed within R	*A custom program such as R needs to be created to input the processed LOCA-based climate data indexed by BG unique identifier and complete all calculations. If using the custom R program developed by RTI, a user need only supply the links to the input precipitation datasets for the program to complete all calculation steps.*
☐	Spatial Differentiation Based on Climate Data Source	*When interpreting the maps, it is important to remember that the resolution of the LOCA modeled data is fairly coarse compared to BGs. Each raster cell is 1/16th of a degree of latitude and 1/16th of a degree of longitude in size. This equates to approximately 5 km x 7 km at temperate latitudes such as the United States. There is the potential that this indicator may not provide enough variation across BGs consisting of small spatial areas. The other aspect to be aware of is that difference between BGs may be smaller than the errors in the modeled data. Therefore, differences displayed cartographically, may be within the range of model error. This limitation will apply to any indicators developed with the LOCA data as its input source.*
Citations		
☐	Dataset/Tool	*Pierce, D.W. (2016). LOCA (Local Constructed Analogs) statistical downscaling version 40. Scripps Institute of Oceanography, Division of Climate, Atmospheric Sciences, and Physical Oceanography. http://loca.ucsd.edu/*

☐	Additional Resources	*Downscaled CMIP3 and CMIP5 Climate and Hydrology Projections. (2021).* *http://gdo-dcp.ucllnl.org/downscaled_cmip_projections/* *Groisman, P.Y., Knight, R.W., Karl, T.R., Easterling, D.R., Sun, B., and Lawrimore, J.H. (2004). Contemporary Changes of the Hydrological Cycle over the Contiguous United States: Trends Derived from In Situ Observations. Journal of Hydrometeorology 5, 64-85.* *U.S. Global Change Research Program. (2018) Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II [Reidmiller, D.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, and B.C. Stewart (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, 1515 pp. doi: 10.7930/NCA4.2018.*

BG: Block Group, HAND: Height Above Nearest Drainage, LOCA: Localized Constructed Analogs, RCP: Representative Concentration Pathway

Indicator 1.1.8. Checklist for Physically Based Flood Indicator

Potential impacts of floods on sites and waste facilities include more likely erosion, difficult ponding/stormwater management, water damage (corrosion, water logging), power fluctuations/outages, groundwater plume changes and higher water table, spreading/migration of contamination, catastrophic events destroy structures, releases from overwash, infiltration, and leaching, incident waste facility closures, increased hazardous/non-hazardous waste generation, groundwater pump-and-treat remedies may not be allowed to discharge, increased potential for flooding of treatment systems, and dislodged debris from treatment/containment systems or contained wastes and reactive wastes.

The Height Above Nearest Drainage (HAND) dataset is a hydrological terrain raster available for the conterminous United States. The national dataset was created using the 10m Digital Elevation Model (DEM) data produced by the U.S. Geological Survey (USGS) 3DEP (the 3-D Elevation Program) and the NHDPlus hydrography dataset produced by USGS and EPA. The value of each raster cell in HAND is an approximation of the relative elevation between the cell and its nearest waterbody. The physically based flood indicator is defined as the mean HAND value per Block Group.

Physically Based Flood Indicator		
Definition of the indicator		
☐	Definition	*The mean Height Above Nearest Drainage (HAND) value per Block Group (BG) approximates the average difference in elevation within the BG from its nearest waterbody.*
☐	Interpretation	*The idea behind using HAND values is that areas with a lower elevation distance between the land and water surface are more likely to experience flooding than higher grounds. Low-lying areas within a study area or community have the potential for both riverine flooding and receiving overland flow during high-depth precipitation events.*
Data source		
☐	Data Source	*The HAND dataset is a hydrological terrain raster available for the conterminous United States from Oak Ridge National Lab (ORNL).*
☐	Spatial Resolution	• *10-meter HAND raster for all 6-digit Hydrologic Unit Code (HUC6) crossed by the study area* • *BG shapefile*
☐	Data Format	*Shapefile (BG); raster in .tif (HAND)*

Decisions needed for calculation		
☐	Mean HAND versus other statistics	*The mean HAND value was chosen as the indicator as opposed to another statistic such as the minimum, maximum, or a percentile. Due to the fine-scale raster gradation of the dataset, it is likely the choice of a single value such as a minimum could identify an outlier cell that is not representative of the BG as a whole. Similarly, choosing a percentile (i.e., 10th percentile) could still define a small outlier area rather than a distributed low-lying area within the BG confusing the flooding risk. By taking an average value the indicator provides a higher likelihood in identifying a range of comparable vulnerabilities due to flooding across the study area. Median values could also be used instead of means.*
Calculation steps and assumptions		
☐	Combine HUC6 HAND Rasters as Needed	***Inputs:*** *10-meter HAND raster for all HUC6 crossed by the study area* ***Calculations:*** • *Use the Mosaic to New Raster command within the Raster Dataset toolset within the Data Management Toolbox within ArcGIS to combine all the extracted rasters into a single raster.* • *These rasters likely extend beyond the limits of the study area.* ***Outputs:*** *A single raster mosaic with the same raster cell size as the inputs*
☐	Create HAND Raster Specific to Study Area	***Input:*** *The single raster mosaic from the previous step and the shapefile of the study area* ***Calculation:*** *Use the Extract By Mask command within the ArcGIS Spatial Analyst Toolbox to extract the portion of the HAND raster mosaic that falls within the study area boundary.* ***Output:*** *Raster coverage that contains 10 m cells with HAND values covering the whole study area*
☐	Calculate the Physically Based Flood Indicator	***Input:*** *HAND raster specific to study area and BG layer* ***Calculation:*** *Use Zonal Stats as Table within the ArcGIS Spatial Analyst toolbox to calculate the mean HAND raster value for each BG.* ***Output:*** *Mean HAND value per BG*
Decisions needed for mapping and interpretation		
☐	Mapping Limited to Block Groups Containing Data	*NA - BGs will all have elevation values.*
☐	Choosing a Symbology	*The recommended symbology for this indicator is one specific to the current area of interest. It is not necessary to create one that can be compared across scenarios, time periods, or locations.*

☐	Binning the Data by Block Groups	*The distribution of HAND values by BG may indicate that either equal intervals or quantiles display the data best. However, the areas of greatest concern are those with the lowest HAND values. Therefore, to highlight these areas use bins that provide differentiation in the lowest values and group the highest values together. This will focus attention on the areas of greatest concern. Use a maximum of 5-7 categories so that the map reader can readily distinguish between color categories and visually match them to the legend.*
☐	Choosing Colors	*Use a color gradation that becomes lighter as the HAND values increase. This will draw the map reader's focus to the areas of greatest concern. Avoid using a divergent color scheme (darker at both extremes and lighter in the middle), which implies an inflection point such as 0 in a dataset containing positive and negative values.*
Examples of how the indicator can be useful		
☐	Localized and Riverine Flood Risk Assessment	*As opposed to delineated floodplains, which are mapped only for certain storm recurrence intervals, the HAND-based flood indicator shows the relative elevation above the nearest waterbody for each BG. Because this indicator takes into account elevation and relief, it provides a more robust and comparable measure of potential flood impacts from large storms. Using this indicator in conjunction with the heavy precipitation indicators (1.1.5/1.1.6) provides even more information on flood risk.*
Key caveats/limitations		
☐	Future Scenarios	*The HAND dataset, being based on land elevation, will not change into the future.*
☐	Spatial Differentiation Based on HAND Data Source	*The HAND data are distributed by HUC6 watersheds with grid cells at 10 m resolution. For study areas where communities span more than one HUC6 watershed, multiple HAND datasets will need to be combined to create a full coverage of the area. Given that the data are included within a national repository, the formatting of data should be consistent, allowing for simple joining methods. The 10 m resolution ensures that each BG can be characterized by multiple cells allowing for the calculation of an average value for the indicator.*
Citations		
☐	Dataset/Tool	*Liu, Y.Y. (2020). Height Above Nearest Drainage (HAND) and Hydraulic Property Table for CONUS - Version 0.2. Oak Ridge Leadership Computing Facility. (2020). DOI: https://doi.org/10.13139/ORNLNCCS/1608331*
☐	Additional Resources	*Liu, Y.Y., Maidment, D.R., Tarboton, D.G., Zheng, X. & Wang, S. (2018). A CyberGIS integration and computation framework for high-resolution continental-scale flood inundation mapping. Journal of the American Water Resources Association, 54(4), 770-784. DOI: 10.1111/1752-1688.12660* *Nobre, A.D., Cuartas, L.A., Momo, M.R., Severo, D.L., Pinheiro, A. & Nobre, C.A., (2016). HAND contour: a new proxy predictor of inundation extent. Hydrological Processes, 30(2), 320-333.*

3DEP: USGS 3-D Elevation Program, BG: Block Group, DEM: Digital Elevation Model, EPA: U.S. Environmental Protection Agency, HAND: Height Above Nearest Drainage, HUC6: 6-digit Hydrologic Unit, ORNL: Oak Ridge National Laboratory, USGS: U.S. Geological Survey

Indicators 1.1.9 & 1.1.11. Checklist for Drought Indicator

Potential impacts of droughts on sites and waste facilities include increased fire hazards and fugitive dust, reduction in remediation effectiveness, changes in groundwater plume dynamics due to lower water table, water use restrictions impacts, increased scrutiny of groundwater extraction systems, and damage to vegetative covers. To summarize, most of the impacts of drought on sites and waste facilities are related to water availability.

Drought Indicator		
Definition of the indicator		
☐	Definition	*The count of months within the 20-year assessment period having a Standardized Precipitation-Evapotranspiration Index (SPEI) within the drought range (as defined by the U.S. Drought Monitor as less than -0.8), where the SPEI may be calculated at either the six-month (SPEI-6) or 12-month (SPEI-12) time scale depending on the community's hydrologic concerns.*
☐	Interpretation	*The SPEI is calculated based on a climatic water balance using monthly precipitation and temperature, making it suitable for assessing differences due to changes in the climate between historic and future periods. The resulting monthly SPEI time series shows the fluctuation over time of drought, dry, normal, wet, and abnormally wet conditions through the SPEI values, which are comparable in space and time due to the standardization process embedded within the SPEI calculation. Positive values indicate wet conditions, while negative values indicate dry conditions; the magnitude of the SPEI represents the severity of a condition. The time scale chosen for SPEI indicates the length of preceding months considered in the calculation.*
Data source		
☐	Data Source	*The LOCA (Localized Constructed Analogs) downscaled climate data for the historical and future periods for Representative Concentration Pathway (RCP) scenarios provides the necessary temperature inputs.* • *Time periods can be selected to represent historical conditions (e.g., 1986–2005), mid-century (2040–2059), or late century (2080–2099) scenarios. Other time periods/timeframes can be selected depending on user needs.* • *RCP 4.5 and 8.5 are recommended to represent moderate and more extreme conditions but other scenarios can be selected depending on user needs.* • *Outputs from the CanESM2 climate model can be selected to consider more extreme conditions under a given emissions scenario. Other climate models or a combination of climate models can be used based on user needs.*
☐	Temporal Resolution	*Time series of precipitation and potential evapotranspiration (PET) by Block Group (BG). PET can be calculated from LOCA data (described below).*

☐	Spatial Resolution	*LOCA is available for raster cells which are 1/16th of a degree of latitude and 1/16th of a degree of longitude in size* *BG shapefile*
☐	Data Format	*Shapefile (BG); NetCDF (LOCA)*
Decisions needed for calculation		
☐	PET Calculation Method	*Data on PET is needed for SPEI and must be calculated. The SPEI formulation is not tied to any one PET method so different methods can be used depending on data availability. The Hargreaves method is recommended and requires minimum and maximum temperature as well as latitude for the location.*
☐	Time Scale for SPEI	*The valid range for calculation is 1 to 48 months for SPEI. Selection of the time scale will depend on the type of drought a user wishes to assess and will therefore be community dependent. We recommend using 6 months (SPEI-6) as a conservative indicator of drought conditions beginning to impact soils and water use and 12 months to represent drought conditions that are more likely to impact water availability. (SPEI-12 follows the similar and well-documented Standardized Precipitation Index at a 12-month time scale [SPI-12] used by the EPA's Climate Change Division)*
☐	Definition of Drought using SPEI	*There are several ranges for defining drought severity using the continuous SPEI values across the months of the 20-year assessment period. The recommendation of this study is to use -0.8 as the upper threshold for drought conditions based on the U.S. Drought Monitor's ranges for drought using the related Standardized Precipitation Index (SPI). All months with SPEI values less than or equal to -0.8 are considered drought conditions.*
☐	Choice of Appropriate Time Period to Represent Long-term Climatic Conditions/Annual Average Value for Final Indicator	*By averaging the count of drought months across all the years in the relevant time period, the indicator avoids short-term weather fluctuations or modeling uncertainties. It considers the climatic variation of cool and hot years and any patterns in the episodes of drought. To capture long-term climatic conditions, time periods covering 20 years are recommended. An alternate number of years can be used depending on local needs. For example, averages over a 30-year time period represent longer-term climatic conditions and shorter timeframes (e.g., 15 years) reflect more recent changing conditions.*

Calculation steps and assumptions		
☐	Compile Block Group Precipitation and Temperature Time Series	***Inputs:*** *LOCA data and BG shapefile* ***Calculations:*** • *Extract all grid cells that touch any BGs within the study area.* • *Resample the extracted raster by a factor of 100, to produce smaller grid cells, each with the same value as the original raster. This needs to be done if the BGs are small compared to the grid cells to ensure that even the smallest BGs would have at least one grid cell with data fall within it.* • *If there are multiple grid cells overlapping with a BG, use the zonal statistical function, take the average value of the indexed cells to report a climate value for each BG.* ***Output:*** *Daily time series for each climate parameter per BG*
☐	Determine Block Group Latitude	***Input:*** *BG shapefile* ***Calculation:*** *Using the centroid of each BG, assign a latitude value using the Calculate Geometry geospatial function.* ***Output:*** *Single latitude value per BG*
☐	Compile Monthly Time Series for Temperature and Precipitation	***Inputs:*** *Daily time series for each climate parameter per BG* ***Calculations:*** • *Minimum temperature: take the minimum of the minimum daily values for each month* • *Maximum temperature: take the maximum of the maximum daily values for each month* • *Precipitation: sum daily values across each month* ***Outputs:*** *Monthly time series of minimum and maximum temperature and precipitation per BG*
☐	Compute PET	*Using the SPEI R Package, compute monthly PET time series based on minimum and maximum temperature and latitude by BG.*
☐	Compute Climatic Water Balance	***Inputs:*** *Monthly precipitation time series and monthly PET time series by BG* ***Calculation:*** *Precipitation – PET* ***Output:*** *Time series of monthly climatic water balance*
☐	Compute SPEI Values	*Using the SPEI R Package, compute the SPEI values for each selected time scale (6 and 12 months) using Climatic Water Balance time series.* • *Two function calls used, one for each time scale. SPEI package computes values for each individual BG.* • *Default selections are accepted within the package for SPEI calculation other than time scale selection.*

☐	Calculate Drought Indicator for each Time Period	***Inputs:*** *Monthly time series of SPEI values by BG* ***Calculation:*** *Count all SPEI values less than or equal to -0.8 (i.e., drought conditions) over the relevant time period for each BG* ***Output:*** *Count of drought months by BG*
☐	Repetition for Time Periods/ Scenarios	*Repeat all steps for the selected time periods (historical and future). Repeat the above step for any additional future scenarios.*
Decisions needed for mapping and interpretation		
☐	Mapping Limited to Block Groups Containing Data	*NA BGs will all have percent values.*
☐	Choosing a Symbology	*A single unique symbology that spans climate scenarios is recommended. This will result in the same color representing the same value across the maps, making direct comparisons easier. To build this, find the minimum and maximum values across climate scenarios, and then use the full range of values to create a single unique symbology to apply to all maps.*
☐	Binning the Data by Block Groups	*Using 5–7 bins/categories is recommended so that the map reader can readily distinguish between color categories and visually match them to the legend. Use equal intervals, if possible, which create equal steps between categories (e.g., 0–10, 11–20). Not all categories may necessarily contain values on the map.* *An alternative to equal intervals is quantiles, which attempts to create the same number of observations per bin. This causes each bin to have a different interval and requires careful interpretation and communication. Using quantiles ensures that each color in the symbology will appear on the map, and it will add more detail to the map if the data are concentrated in a few small ranges. Deciles or other percentiles can also be used depending on user needs.*
☐	Choosing Colors	*For maps with sequential data, use a symbology that becomes darker as the vulnerability increases.* *For maps with diverging data, such as the variants of the indicator showing percent change, use a diverging color scheme characterized by darker colors at both extremes and lighter in the middle.*
Examples of how the indicator can be useful		
☐	SPEI-6 Drought Indicator	*SPEI-6 is an indicator of drought conditions where the impact to soils and water use is likely to become influential. By comparing the indicator values across communities, the relative vulnerability to water resources is visible spatially and can be used to assess the vulnerability of sites/waste facilities dependent on a readily available water supply.*
☐	SPEI-12 Drought Indicator	*SPEI-12 represents drought conditions that are more likely to impact water availability and sustained dry conditions. By comparing the indicator values across communities, the relative vulnerability to water supply or source waters is visible spatially and can be compared to specific water supply locations or water supply watersheds for assessment. This can be used to assess the vulnerability of sites/ waste facilities dependent on a readily available water supply.*

Key caveats/limitations		
☐	Calculations Completed within R using SPEI Package	*A custom R program needs to be created to input the processed LOCA-based climate data indexed by BG unique identifier. The SPEI package available from CRAN (https://cran.r-project.org/web/packages/SPEI/index.html) can be used as a starting point. The Hargreaves PET method was used based on minimum and maximum temperatures. If using the custom R program developed by RTI, a user need only supply the links to the input climate and latitude datasets for the program to complete all calculation steps.*
☐	Spatial Differentiation Based on Climate Data Source	*When interpreting the maps, it is important to remember that the resolution of the LOCA modeled data is fairly coarse compared to BGs. Each raster cell is 1/16th of a degree of latitude and 1/16th of a degree of longitude in size. This equates to approximately 5 km x 7 km at temperate latitudes such as the United States. There is the potential that this indicator may not provide enough variation across BGs consisting of small spatial areas. The other aspect to be aware of is that difference between BGs may be smaller than the errors in the modeled data. Therefore, differences displayed cartographically, may be within the range of model error. This limitation will apply to any indicators developed with the LOCA data as its input source.*
Citations		
	Dataset/Tool	*Pierce, D.W. (2016). LOCA (Local Constructed Analogs) statistical downscaling version 40. Scripps Institute of Oceanography, Division of Climate, Atmospheric Sciences, and Physical Oceanography. http://loca.ucsd.edu/*
	Additional Resources	*Downscaled CMIP3 and CMIP5 Climate and Hydrology Projections. (2021). http://gdo-dcp.ucllnl.org/downscaled_cmip_projections/* *Beguería, S., Vicente-Serrano, S.M., Reig, F. & Latorre, B. (2014). Standardized precipitation evapotranspiration index (SPEI) revisited: parameter fitting, evapotranspiration models, tools, datasets and drought monitoring. Int. J. Climatol., 34, 3001-3023. doi:10.1002/joc.3887* *Vicente-Serrano, S.M., Beguería, S., & López-Moreno, J.I. (2010). A multi-scalar drought index sensitive to global warming: The Standardized Precipitation Evapotranspiration Index – SPEI. Journal of Climate, 23, 1696, DOI: 10.1175/2009JCLI2909.1.* *Naumann, G., Alfieri, L., Wyser, K., Mentaschi, L., Betts, R. A., Carrao, H., et al. (2018). Global changes in drought conditions under different levels of warming. Geophysical Research Letters, 45, 3285–3296. https://doi.org/10.1002/2017GL076521* *Schwalm, C.R., Anderegg, W.R., Michalak, A.M., Fisher, J.B., Biondi, F., Koch, G., Litvak, M., Ogle, K., Shaw, J.D., Wolf, A. & Huntzinger, D.N., 2017. Global patterns of drought recovery. Nature, 548(7666), 202-205.*

BG: Block Group, CRAN: Comprehensive R Archive Network, EPA: U.S. Environmental Protection Agency, LOCA: Localized Constructed Analogs, PET: Potential Evapotranspiration, RCP: Representative Concentration Pathway, SPEI: Standardized Precipitation-Evapotranspiration Index, SPI: Standardized Precipitation Index

Indicators 1.1.10 & 1.1.12. Checklist for Threshold-Based Drought Indicator

Potential impacts of droughts on sites and waste facilities include increased fire hazards and fugitive dust, reduction in remediation effectiveness, changes in groundwater plume dynamics due to lower water table, water use restrictions impacts, increased scrutiny of groundwater extraction systems, and damage to vegetative covers. To summarize, most of the impacts of drought on sites and waste facilities are related to water availability.

Threshold-Based Drought Indicator		
Definition of the indicator		
☐	Definition	*The change in the count of drought months between the historic and future period, where drought is determined by the Standardized Precipitation-Evapotranspiration Index (SPEI) as less than -0.8. SPEI may be calculated at either the 6-month (SPEI-6) or 12-month (SPEI-12) time scale depending on the community's hydrologic concerns.*
☐	Interpretation	*The count of drought months indicates how many months out of the selected period are expected to experience drought conditions. By calculating the change in the count of drought months between the historic and future period, the increase or decrease in length of time of expected drought conditions in the future can be examined.*
Data source		
☐	Data Source	*The LOCA (Localized Constructed Analogs) downscaled climate data for the historical and future periods for Representative Concentration Pathway (RCP) scenarios provides the necessary temperature inputs.* • *Time periods can be selected to represent historical conditions (e.g., 1986–2005), mid-century (2040–2059), or late century (2080–2099) scenarios. Other time periods/timeframes can be selected depending on user needs.* • *RCP 4.5 and 8.5 are recommended to represent moderate and more extreme conditions but other scenarios can be selected depending on user needs.* • *Outputs from the CanESM2 climate model can be selected to consider more extreme conditions under a given emissions scenario. Other climate models or a combination of climate models can be used based on user needs.*
☐	Temporal Resolution	*Time series of precipitation and potential evapotranspiration (PET) by Block Group (BG). PET can be calculated from LOCA data (described below).*
☐	Spatial Resolution	*LOCA is available for raster cells, that are 1/16th of a degree of latitude and 1/16th of a degree of longitude in size* *BG shapefile*
☐	Data Format	*Shapefile (BG); NetCDF (LOCA)*

☐	Additional Inputs	*While the precipitation input required for SPEI is typically readily available, PET often is not and must be calculated. The SPEI formulation is not tied to any one PET method, the methods used depend on data availability. The Hargreaves method is recommended and requires minimum and maximum temperature as well as latitude for the location.*
Decisions needed for calculation		
☐	Time Scale for SPEI	*The valid range for calculation is 1 to 48 months for SPEI. Selection of the time scale will depend on the type of drought a user wishes to assess and will therefore be community dependent. We recommend using 6 months (SPEI-6) as a conservative indicator of drought conditions beginning to impact soils and vegetation and 12 months (SPEI-12 following the similar and well-documented Standardized Precipitation Index at a 12-month time scale [SPI-12] used by the EPA's Climate Change Division) to represent drought conditions that are more likely to impact water availability*
☐	Definition of Drought using SPEI	*There are several ranges for defining drought severity using the continuous SPEI values across the months of the selected assessment period. The recommendation of this study is to use -0.8 as the upper threshold for drought conditions based on the U.S. Drought Monitor's ranges for drought using the related Standardized Precipitation Index (SPI). All months with SPEI values less than or equal to -0.8 are considered drought conditions.*
☐	Choice of Appropriate Time Period to Represent Long-term Climatic Conditions	*Considering a time period covering several years is recommended to avoid short-term weather fluctuations or modeling uncertainties and to capture representative long-term climatic conditions and patterns. Time periods covering 20 years are recommended. An alternate number of years can be used depending on local needs. For example, a 30-year time period represents longer-term climatic conditions and shorter timeframes (e.g., 15 years) reflect more recent changing conditions.*
Calculation steps and assumptions		
☐	Compile Block Group Precipitation and Temperature Time Series	***Inputs:*** *LOCA data and BG shapefile* ***Calculations:*** • *Extract all grid cells the touch any BGs within the study area.* • *Resample the extracted raster by a factor of 100, to produce smaller grid cells, each with the same value as the original raster. This needs to be done if the BGs are small compared to the grid cells to ensure that even the smallest BGs would have at least one grid cell with data fall within it.* • *If there are multiple grid cells overlapping with a BG, use the zonal statistical function, take the average value of the indexed cells to report a climate value for each BG.* ***Output:*** *Daily time series for each climate parameter per BG*
☐	Determine Block Group Latitude	***Input:*** *BG shapefile* ***Calculation:*** *Using the centroid of each BG, assign a latitude value using the Calculate Geometry geospatial function.* ***Output:*** *Single latitude value per BG*

☐	Compile Monthly Time Series for Temperature and Precipitation	***Inputs:*** *Daily time series for each climate parameter per BG* ***Calculations:*** • *Minimum temperature: take the minimum of the minimum daily values for each month* • *Maximum temperature: take the maximum of the maximum daily values for each month* • *Precipitation: sum daily values across each month* ***Outputs:*** *Monthly time series of minimum and maximum temperature and precipitation per BG*
☐	Compute PET	*Using the SPEI R Package, compute monthly PET time series based on minimum and maximum temperature and latitude by BG.*
☐	Compute Climatic Water Balance	***Inputs:*** *Monthly precipitation time series and monthly PET time series by BG* ***Calculation:*** *Precipitation – PET* ***Output:*** *Time series of monthly climatic water balance*
☐	Compute SPEI Values	*Using the SPEI R Package, compute the SPEI values for each selected time scale (6 and 12 months) using the Climatic Water Balance time series.* • *Two function calls used, one for each time scale. SPEI package computes values for each individual BG.* • *Default selections are accepted within the package for SPEI calculation other than time scale selection.*
☐	Calculate Drought Indicator	***Inputs:*** *Monthly time series of SPEI values by BG* ***Calculation:*** *Count all SPEI values less than or equal to -0.8 (i.e., drought conditions) over the assessment period for each BG* ***Output:*** *Count of drought months by BG*
☐	Repetition for Time Periods	*Repeat all steps for each assessment period as needed (i.e., historic, mid-century RCP 4.5, and mid-century RCP 8.5)*
☐	Calculate the Threshold-Based Drought Indicator	***Inputs:*** *Count of drought months by BG for historic period and for future scenario* ***Calculation:*** $Months_{Future} - Months_{Historic}$ ***Output:*** *Change in count of drought months from historic period to future scenario*
Decisions needed for mapping and interpretation		
☐	Mapping Limited to Block Groups Containing Data	*NA - BGs will all have count values. Zero is a valid value.*
☐	Choosing a Symbology	*A single unique symbology that spans climate scenarios is recommended. This will result in the same color representing the same value across the maps, making direct comparisons easier. To build this, find the minimum and maximum values across climate scenarios, and then use the full range of values to create a single unique symbology to apply to all maps.*

☐	Binning the Data by Block Groups	*Using 5–7 bins/categories is recommended so that the map reader can readily distinguish between color categories and visually match them to the legend. Use equal intervals, if possible, which create equal steps between categories (e.g., 0–10, 11–20). Not all categories may necessarily contain values on the map.* *An alternative to equal intervals is quantiles, which attempts to create the same number of observations per bin. This causes each bin to have a different interval and requires careful interpretation and communication. Using quantiles ensures that each color in the symbology will appear on the map, and it will add more detail to the map if the data are concentrated in a few small ranges. Deciles or other percentiles can also be used depending on user needs.*
☐	Choosing Colors	*For maps with sequential data, use a symbology that becomes darker as the vulnerability increases.* *For maps with diverging data, such as the variants of the indicator showing percent change, use a diverging color scheme characterized by darker colors at both extremes and lighter in the middle.*
Examples of how the indicator can be useful		
☐	SPEI-6 Drought Indicator	*SPEI-6 is an indicator of drought conditions where the impact to soils influential. As the number of months with SPEI-6 below -0.8 increases, the impact on water uses for sites and waste facilities increases.*
☐	SPEI-12 Drought Indicator	*SPEI-12 represents drought conditions that are more likely to impact water availability and sustained dry conditions. An increase in months experiencing drought conditions according to SPEI-12 should lead a community to examine the vulnerabilities of their water supplies, particularly surface water supplies, as well as water uses for maintaining sites/waste facilities.*
Key caveats/limitations		
☐	Calculations Completed within R using SPEI Package	*A custom R program was created to input the processed LOCA-based climate data A custom R program needs to be created to input the processed LOCA-based climate data indexed by BG unique identifier. The SPEI package available from CRAN (https://cran.r-project.org/web/packages/SPEI/index.html) can be used as a starting point. The Hargreaves PET method was used based on minimum and maximum temperatures. If using the custom R program developed by RTI, a user need only supply the links to the input climate and latitude datasets for the program to complete all calculation steps.*
☐	Spatial Differentiation Based on Climate Data Source	*When interpreting the maps, it is important to remember that the resolution of the LOCA modeled data is fairly coarse compared to BGs. Each raster cell is 1/16th of a degree of latitude and 1/16th of a degree of longitude in size. This equates to approximately 5 km x 7 km at temperate latitudes such as the United States. There is the potential that this indicator may not provide enough variation across BGs consisting of small spatial areas. The other aspect to be aware of is that difference between BGs may be smaller than the errors in the modeled data. Therefore, differences displayed cartographically, may be within the range of model error. This limitation will apply to any indicators developed with the LOCA data as its input source.*

Citations		
☐	Dataset/Tool	*Pierce, D.W. (2016). LOCA (Local Constructed Analogs) statistical downscaling version 40. Scripps Institute of Oceanography, Division of Climate, Atmospheric Sciences, and Physical Oceanography.* http://loca.ucsd.edu/
☐	Additional Resources	*Downscaled CMIP3 and CMIP5 Climate and Hydrology Projections. (2021).* http://gdo-dcp.ucllnl.org/downscaled_cmip_projections/ *U.S. Environmental Protection Agency. (2015). Climate Change in the United States: Benefits of Global Action. United States Environmental Protection Agency, Office of Atmospheric Programs, EPA 430-R-15-001.*

BG: Block Group, CRAN: Comprehensive R Archive Network, EPA: U.S. Environmental Protection Agency, LOCA: Localized Constructed Analogs, PET: Potential Evapotranspiration, RCP: Representative Concentration Pathway, SPEI: Standardized Precipitation-Evapotranspiration Index, SPI: Standardized Precipitation Index

Vulnerability Source 1.2. Exposure: Sites/Waste Facilities

Indicator 1.2.1. Checklist for Total Count of Sites/Waste Facilities Indicator

<table>
<tr><th colspan="3">Total Count of Sites/Waste Facilities Indicator</th></tr>
<tr><td colspan="3">Definition of the indicator</td></tr>
<tr><td>☐</td><td>Definition</td><td>A count of all sites/waste facilities in a given Block Group (BG).</td></tr>
<tr><td>☐</td><td>Interpretation</td><td>This indicator includes the total number of the following types of sites/waste facilities:

Hazardous waste operators: Resource Conservation and Recovery Act (RCRA) Subtitle C

Hazardous waste generators
Waste treatment, storage, and disposal facilities and units
Waste transporters
Hazardous waste transfer facilities
Other hazardous waste operators

Sites and cleanup facilities:

RCRA Corrective Action
Brownfields
Federal and state Superfund sites
Removal/emergency response sites
Other cleanup sites (not on the National Priorities List [NPL])

Other sites and waste facilities

Fuel terminals and other sites subject to Spill Prevention, Control, and Countermeasure (SPCC) and Facility Response Plan (FRP) regulations to prevent and respond to oil spills
Incident waste facilities
Solid waste landfills (nonhazardous)
Petroleum storage tanks (underground and aboveground)
Any other sites/waste facilities identified by local decision-makers

</td></tr>
<tr><td colspan="3">Data source</td></tr>
<tr><td>☐</td><td>Data Source</td><td>Facility Registry Service (FRS)
Additional data sources should also be consulted to identify sites/waste facilities of interest that are not listed in the FRS data. These data sources are listed in Table A.4.</td></tr>
<tr><td>☐</td><td>Temporal Resolution</td><td>FRS data represents the information available at the time of download</td></tr>
</table>

☐	Spatial Resolution	*BG shapefile, coordinates for each site/waste facility*
☐	Data Format	*Two options available for users to select from:* • *National and state CSV files* • *File geodatabase*
Decisions needed for calculation		
☐	Size of Hazardous Waste Generators	*Excluding Small Quantity Generators (SQGs), Conditionally-Exempt Small Quantity Generators (CESQGs), and facilities with no Generator Status is recommended since these are not likely to pose significant risks. However, users can choose to include these based on their needs.*
☐	Compiling and Vetting of Data	*FRS is recommended as the primary source of coordinate data since it provides consistent spatial information for different types of sites/waste facilities. Any sites/ waste facilities found in additional data sources (Table A.4) but not included in the FRS dataset should be added to the list of sites/waste facilities used to create the indicator. This combined list should be reviewed by local partners to ensure that the facilities most relevant to the community are included.*
☐	Matching Method for Cross-Data Source Comparisons	*Comparing the sites/waste facilities listed in FRS and non-FRS data sources should primarily rely on matching unique facility identification numbers.* • *The most used identification number is the EPA ID. EPA IDs are 12-character unique identifiers.* • *The first two characters of a facility's EPA ID are the state abbreviation for the state in which the facility is located.* *Facilities from datasets that do not include EPA IDs will need to be compared manually using facility names. If there are many facilities without EPA IDs, fuzzy lookup tools can be used in place of manual comparisons.*
Calculation steps and assumptions		
☐	Identify the Block Group Where Each Site/Waste Facility Is Located	***Inputs:*** *BG shapefile, site/waste facility coordinate data.* ***Calculations:*** *Determine the boundaries of each BG. Uses these boundaries to determine the BG where each site/waste facility is located.* ***Output:*** *Site/waste facility dataset with a BG identifier tied to each site/waste facility.*
☐	Count the Sites/ Waste Facilities in Each Block Group	***Inputs:*** *Site/waste facility dataset with a BG identifier tied to each site/waste facility* ***Calculations:*** *Count the total number of sites/waste facilities within each BG. See Appendix Equation SWF-1* ***Output:*** *Total count of sites/waste facilities*
Decisions needed for mapping and interpretation		
☐	Mapping Limited to Block Groups Containing Data	*BGs that do not contain any facilities can be shown a zero or as a separate layer that grays out the polygons.*

☐	Choosing a Symbology	*Maps showing the distribution of counts of sites/waste facilities will generally not be compared across scenarios, time periods, or locations so a single symbology will not be necessary. The symbology will be specific to the data for current study area.*
☐	Binning the Data by Block Groups	*The distribution of counts of sites/waste facilities will likely be skewed towards values closer to zero. For this situation, using quantiles (equal number of observations per bin) is recommended. Using a maximum of 5-7 categories is also recommended so that the map reader can readily distinguish between color categories and visually match them to the legend. However, deciles or other percentiles can also be used depending on user needs.*
☐	Choosing Colors	*Use a color gradation that becomes darker as the count values increase. Avoid using a divergent color scheme (darker at both extremes and lighter in the middle), which implies an inflection point such as 0 in a dataset containing positive and negative values.*
Examples of how the indicator can be useful		
☐	Risks of Contaminant Releases	*A total count of sites/waste facilities in a study area can provide the simplest measures of potential contaminant releases and can be used to identify BGs that may face the highest risks in the event of a release. It can be used to identify priorities for cleanup, maintenance, and adaptation/response strategies.*
☐	Counts vs. Density	*Counts are simpler to use and communicate, but density may provide more information to decision-makers, depending on their needs.*
Key caveats/limitations		
☐	Data Sources are Not Updated with Uniform Frequency	• *Not all data sources listed are updated at the same time and compiling different sources may result in discrepancies.* • *Data sources are also not frequently updated. As a result, the sites/waste facilities included in these data sources may no longer be a concern. More recently identified sites/waste facilities may also be left out.* *Tracking when each dataset was accessed and having local experts review the final list of sites are crucial to ensure the list of sites includes the most concerning sites for the study area and does not include sites that are no longer an issue.*
Citations		
	Dataset/Tool	*U.S. EPA. (2022). Geospatial data download service. https://www.epa.gov/frs/geospatial-data-download-service*
	Additional Resources	*U.S. EPA. (2021). Facility Registry Service (FRS). https://www.epa.gov/frs*

BG: Block Group, CESQC: Conditionally-Exempt Small Quantity Generators, FRP: Facility Response Plan, FRS: Facility Registry Service, NPL: National Priorities List, RCRA: Resource Conservation and Recovery Act, SPCC: Spill Prevention, Control, and Countermeasure, SQG: Small Quantity Generators

Indicator 1.2.2. Checklist for Count of Sites/Waste Facilities per Square Kilometer Indicator

Count of Sites/Waste Facilities per Square Kilometer Indicator		
Definition of the indicator		
☐	Definition	*A count of sites/waste facilities per square kilometer in a given Block Group (BG).*
☐	Interpretation	*This indicator includes the density of the following types of sites/waste facilities:* • *Hazardous waste operators: RCRA (Resource Conservation and Recovery Act) Subtitle C* o *Hazardous Waste Generators* o *Waste Treatment, Storage, and Disposal Facilities & Units* o *Waste Transporters* o *Hazardous Waste Transfer Facilities* o *Other Hazardous Waste Operators* • *Sites and cleanup facilities:* o *RCRA Corrective Action* o *Brownfields* o *Federal and state Superfund sites* o *Removal/emergency response sites* o *Other cleanup sites (not on the National Priorities List (NPL)* • *Other sites and waste facilities* o *Fuel terminals and other sites subject to SPCC and FRP regulations to prevent and respond to oil spills* o *Incident Waste Facilities* o *Solid Waste Landfills (Nonhazardous)* o *Petroleum Storage Tanks* o *Any other sites/waste facilities identified by local decision-makers*
Data source		
☐	Data Source	*Facility Registry Service (FRS)* *Additional data sources should also be consulted to identify sites/waste facilities of interest that are not listed in the FRS data. These data sources are listed in Table A.4.*
☐	Temporal Resolution	*FRS data represents the information available at the time of download*
☐	Spatial Resolution	*BG shapefile, Coordinates for each site/waste facility.*

☐	Data Format	*Two options available for users to select from:* • *National and State Comma Separated Value (CSV) files* • *File Geodatabase*
Decisions needed for calculation		
☐	Size of Hazardous Waste Generators	*Excluding Small Quantity Generators (SQGs), Conditionally Small Quantity Generators (CESQGs), and facilities with no Generator Status is recommended since these are not likely to pose significant risks. However, users can choose to include these based on their needs.*
☐	Compiling and Vetting of Data	*FRS is recommended as the primary source of coordinate data since it provides consistent spatial information for different types of sites/waste facilities. Any sites/ waste facilities found in additional data sources (Table A.4) but not included in the FRS dataset should be added to the list of sites/waste facilities used to create the indicator. This combined list should be reviewed by local partners to ensure that the facilities most relevant to the community are included.*
☐	Matching Method for Cross-Data Source Comparisons	*Comparing the sites/waste facilities listed in FRS and non-FRS data sources should primarily rely on matching unique facility identification numbers.* • *The most used identification number is the EPA ID. EPA IDs are 12-character unique identifiers.* • *The first two characters of a facility's EPA ID are the state abbreviation for the state in which the facility is located.* *Facilities from datasets that do not include EPA IDs will need to be compared manually using facility names. If there are many facilities without EPA IDs, fuzzy lookup tools can be used in place of manual comparisons.*
Calculation steps and assumptions		
☐	Calculate the Count of Sites/ Waste Facilities per square km	***Inputs:*** *BG Shapefile, Total Count of Sites/Waste Facilities Indicator (1.2.1)* ***Calculations:*** *Determine the total square km for each BG. This can be done by using ArcGIS to add a field to hold the square km value, such as "square_km". Open the attribute table and right click on the newly added field and choose "Calculate Geometry". Within this tool choose "Area" as the property, and "Square Kilometers" as the area unit. For the coordinate system, choose an equal area projection such as Albers USGS (USA_Contiguous_Albers_Equal_Area_Conic_USGS_version). The tool calculates the area in square kilometers for each BG.* *Divide the Total Count of Sites/Waste Facilities Indicator for each BG by the total square km for the given BG.* *See Appendix Equation SWF-2.* ***Output:*** *Count of Sites/Waste Facilities per square km*
Decisions needed for mapping and interpretation		
☐	Mapping Limited to Block Groups Containing Data	*BGs that do not contain any facilities can be shown as a separate layer that grays out the polygons.*

☐	Choosing Symbology	*Maps showing the distribution of density of sites/waste facilities will generally not be compared across scenarios, time periods, or locations so a single symbology will not be necessary. The symbology will be specific to the data for current study area*
☐	Binning the Data by Block Group	*For this indicator using quantiles (equal number of observations per bin) is recommended. Using a maximum of 5-7 categories is also recommended so that the map reader can readily distinguish between color categories and visually match them to the legend. However, deciles or other percentiles can also be used depending on user needs.*
☐	Choosing Colors	*Use a color gradation that becomes darker as the density values increase. Avoid using a divergent color scheme (darker at both extremes and lighter in the middle), which implies an inflection point such as 0 in a dataset containing positive and negative values.*
Examples of how the indicator can be useful		
☐	Density of Facilities Within Each Block Group/Risks of Contaminant Releases	*The count of facilities per square kilometer gives a sense of the density of facilities within each BG. Smaller BGs with a certain number of sites/waste facilities may be considered to be riskier than larger BGs with the same number of sites/waste facilities since they are concentrated in a smaller area. BGs with a higher density of facilities may be more vulnerable to extreme events.* *The density of sites/waste facilities in a study area can be used to identify BGs that may face the highest risks in the event of a release. It can be used to identify priorities for cleanup, maintenance, and adaptation/response strategies.*
☐	Counts vs. Density	*Counts are simpler to use and communicate, but density may provide more information to decision-makers, depending on their needs.*
Key caveats/limitations		
☐	Data Sources are Not Updated with Uniform Frequency	• *Not all data sources listed are updated at the same time and compiling different sources may result in discrepancies.* • *Data sources are also not frequently updated. As a result, the sites/waste facilities included in these data sources may no longer be a concern. More recently identified sites/waste facilities may also be left out.* *Tracking when each dataset was accessed and having local experts review the final list of sites are crucial to ensure the list of sites includes the most concerning sites for the study area and does not include sites that are no longer an issue.*
Citations		
	Dataset/Tool	*U.S. EPA. (2022). Geospatial data download service. https://www.epa.gov/frs/geospatial-data-download-service*
	Additional Resources	*U.S. EPA. (2021). Facility Registry Service (FRS). https://www.epa.gov/frs*

BG: Block Group, FRS: Facility Registry Service, RCRAInfo or RCRA: Resource Conservation and Recovery Act Info, API: Application Programming Interface, BRS: Biennial Reporting System, ACRES: Assessment Cleanup and Redevelopment Exchange System, CIMC: Cleanups in My Community, SEMS: Superfund Enterprise Management System, I-Waste: Incident Waste Assessment and Tonnage Estimator, GHGRP: Greenhouse Gas Reporting Program, OSRR EPRB: Office of Site Remediation and Restoration Emergency Planning and Response Branch.

Indicator 1.2.3. Checklist for Sites/Waste Facilities Count by Type Indicator

Sites/Waste Facilities Count by Type Indicator		
Definition of the indicator		
☐	Definition	*Count of [Fill in facility type] by Block Group (BG)*

☐	Interpretation	*This indicator includes the number of each of the following types of sites/waste facilities:*
		• *Hazardous waste operators: RCRA (Resource Conservation and Recovery Act) Subtitle C*
		  ○ *Hazardous Waste Generators*
		  ○ *Waste Treatment, Storage, and Disposal Facilities & Units*
		  ○ *Waste Transporters*
		  ○ *Hazardous Waste Transfer Facilities*
		  ○ *Other Hazardous Waste Operators*
		• *Sites and cleanup facilities:*
		  ○ *RCRA Corrective Action*
		  ○ *Brownfields*
		  ○ *Federal and state Superfund sites*
		  ○ *Removal/emergency response sites*
		  ○ *Other cleanup sites (not on the National Priorities List (NPL)*
		• *Other sites and waste facilities*
		  ○ *Fuel terminals and other sites subject to SPCC and FRP regulations to prevent and respond to oil spills*
		  ○ *Incident Waste Facilities*
		  ○ *Solid Waste Landfills (Nonhazardous)*
		  ○ *Petroleum Storage Tanks*
		  ○ *Any other sites/waste facilities identified by local decision-makers*

Data source		
☐	Data Source	*Facility Registry Service (FRS)* *Additional data sources should also be consulted to identify sites/waste facilities of interest that are not listed in the FRS data. These data sources are listed in Table A.4.*
☐	Temporal Resolution	*FRS data represents the information available at the time of download*
☐	Spatial Resolution	*BG shapefile, Coordinates for each site/waste facility.*

☐	Required Site/ Facility Characteristic Inputs	*Sites/waste facilities can be categorized based on the data source or based on the data fields included in the data source. Table A.4 shows the various types of sites/ waste facilities and how to determine if a site/waste facility falls within a given type.*
☐	Data Format	*Two options available for users to select from:* • *National and state CSV files* • *File geodatabase*
Decisions needed for calculation		
☐	Size of Hazardous Waste Generators	*Excluding Small Quantity Generators (SQGs), Conditionally Small Quantity Generators (CESQGs), and facilities with no Generator Status is recommended since these are not likely to pose significant risks. However, users can choose to include these based on their needs.*
☐	Compiling and Vetting of Data	*FRS is recommended as the primary source of coordinate data since it provides consistent spatial information for different types of sites/waste facilities. Any sites/ waste facilities found in additional data sources (Table A.4) but not included in the FRS dataset should be added to the list of sites/waste facilities used to create the indicator. This combined list should be reviewed by local partners to ensure that the facilities most relevant to the community are included.*
☐	Matching Method for Cross-Data Source Comparisons	*Comparing the sites/waste facilities listed in FRS and non-FRS data sources should primarily rely on matching unique facility identification numbers.* • *The most used identification number is the EPA ID. EPA IDs are 12-character unique identifiers.* • *The first two characters of a facility's EPA ID are the state abbreviation for the state in which the facility is located.* *Facilities from datasets that do not include EPA IDs will need to be compared manually using facility names. If there are many facilities without EPA IDs, fuzzy lookup tools can be used in place of manual comparisons.*
Calculation steps and assumptions		
☐	Calculate the Sites/Waste Facilities Count by Type Indicator	***Inputs:*** *BG Shapefile, coordinates for each site/facility, site/waste facility characteristics* ***Calculations:*** *Identify the facility type for each site/waste facility. Count the total number of sites of a given facility type within a given BG. See Appendix Equation SWF-3.* ***Output:*** *Sites/waste facilities count by type*
Decisions needed for mapping and interpretation		
☐	Mapping Limited to Block Groups Containing Data	*BGs that do not contain any facilities of any type can be shown as a separate layer that grays out the polygons.*

☐	Choosing Symbology	*Maps showing the distribution of counts of sites/waste facilities by type will generally not be compared across scenarios, time periods, or locations so a single symbology will not be necessary. The symbology will be specific to the data for current study area*
☐	Binning the Data by Block Group	*The distribution of counts of sites will likely be skewed towards values closer to zero. For this situation, using quantiles (equal number of observations per bin) is recommended. Using a maximum of 5-7 categories is also recommended so that the map reader can readily distinguish between color categories and visually match them to the legend. However, deciles or other percentiles can also be used depending on user needs.*
☐	Choosing Colors	*Use a color gradation that becomes darker as the count values increase. Avoid using a divergent color scheme (darker at both extremes and lighter in the middle), which implies an inflection point such as 0 in a dataset containing positive and negative values.*
Examples of how the indicator can be useful		
☐	Broad Physical/ Environmental/ Regulatory Attributes	*Types of facilities provide information indicative of the types of contaminants that may be present, physical structures and how they are managed or regulated. It can be used to identify priorities for cleanup, maintenance, and adaptation/response strategies.* *The density of each site/waste facility type may also be useful.*
Key caveats/limitations		
☐	Data Sources are Not Updated with Uniform Frequency	• *Not all data sources listed are updated at the same time and compiling different sources may result in discrepancies.* • *Data sources are also not frequently updated. As a result, the sites/waste facilities included in these data sources may no longer be a concern. More recently identified sites/waste facilities may also be left out.* *Tracking when each dataset was accessed and having local experts review the final list of sites are crucial to ensure the list of sites includes the most concerning sites for the study area and does not include sites that are no longer an issue.*
Citations		
	Dataset/Tool	*U.S. EPA. (2022). Geospatial data download service. https://www.epa.gov/frs/geospatial-data-download-service*
	Additional Resources	*U.S. EPA. (2021). Facility Registry Service (FRS). https://www.epa.gov/frs*

BG: Block Group, FRS: Facility Registry Service, RCRAInfo or RCRA: Resource Conservation and Recovery Act Info, API: Application Programming Interface, BRS: Biennial Reporting System, ACRES: Assessment Cleanup and Redevelopment Exchange System, CIMC: Cleanups in My Community, SEMS: Superfund Enterprise Management System, I-Waste: Incident Waste Assessment and Tonnage Estimator, GHGRP: Greenhouse Gas Reporting Program, OSRR EPRB: Office of Site Remediation and Restoration Emergency Planning and Response Branch.

Indicator 1.2.4. Checklist for Tons of Hazardous Waste Indicator

Tons of Hazardous Waste Indicator		
Definition of the indicator		
☐	Definition	*The total amount of hazardous waste contained at hazardous waste facilities within a Block Group (BG).*
☐	Interpretation	*This waste tonnage indicator reflects the total amount of waste stored or processed at hazardous waste facilities.* *Hazards can be one of six types—ignitable (I), corrosive (C), reactive (R), toxicity characteristic (E), acutely hazardous (H), and toxic (T)—and are identified through an EPA listing (EPA 2012).*
Data source		
☐	Data Source	• *Facility Registry Service (FRS)* • *RCRAInfo (recommend using the RCRAInfo API to access these data)* • *BRS*
☐	Temporal Resolution	• *FRS data, RCRAInfo, and BRS data represent the information available at the time of download* • BRS data are available every two years
☐	Spatial Resolution	*BG shapefile, coordinates for each waste facility that are required to file a BRS report*
☐	Facility Characteristic Inputs	*This indicator only uses waste facilities that are considered hazardous waste generators. This includes hazardous waste generators; hazardous waste treatment, storage, and disposal facilities (TSDFs); transporters; transfer facilities, and other hazardous waste operators. Table A.4 includes details on how to identify these facility types.* *The indicator includes all waste facilities downloaded using the RCRAInfo API that were labeled as "Large Quantity Generators" and were required to file a BRS report. No other waste facilities have waste tonnage data available.*
☐	Required Waste Tonnage Data	*BRS data contain data on the amount of hazardous waste stored at select RCRA waste facilities that are labeled "Large Quantity Generators." (See "BRS Data Availability" below)*

☐	Data Format	• *FRS has two options available for users to select from:*
		  ○ *National and state CSV files*
		  ○ *File geodatabase*
		• *RCRAInfo: The default output is in XML; however, output options of JSON, CSV, or Excel can be requested in the URL during the API query*
		• *BRS data is available in fixed format and can be opened in either Excel or any file editor*

Decisions needed for calculation		
☐	Compiling and Vetting of Data	*FRS is recommended as the primary source of coordinate data. Any waste facilities found in RCRAInfo or BRS (Table A.4) but not included in the FRS dataset should be added to the list of facilities used to create the indicator. This combined list should be reviewed by local partners to ensure that the facilities most relevant to the community are included.*
☐	Matching Method for Cross-Data Source Comparisons	*Waste facilities included in this indicator can be linked using the EPA ID (sometimes referred to as RCRA ID) variable that is common to the FRS, RCRAInfo, and BRS data.*
Calculation steps and assumptions		
☐	Calculate the Tons of Hazardous Waste Indicator	***Inputs:*** *BG shapefile, Coordinates for each waste facility, Waste facility characteristics, Waste tonnage data* ***Calculations:*** • *Identify the facility type for each waste facility.* • *Filter to exclude any facility that is not a Hazardous Waste Generator required to file a BRS report.* • *Sum the tons of waste stored at all Hazardous Waste Generators in a given BG.* • *See Appendix Equation 1.2.4.* ***Output:*** *Tons of Hazardous Waste*
Decisions needed for mapping and interpretation		
☐	Mapping Limited to Block Groups Containing Data	*BGs that do not contain any facilities at all can be shown as a separate layer that grays out the polygons.*
☐	Choosing Symbology	*Maps showing the distribution of tons of waste will generally not be compared across scenarios, time periods, or locations so a single symbology will not be necessary. The symbology will be specific to the data for current study area*
☐	Binning the Data into Block Groups	*For this indicator using quantiles (equal number of observations per bin) is recommended. Using a maximum of 5-7 categories is also recommended so that the map reader can readily distinguish between color categories and visually match them to the legend. However, deciles or other percentiles can also be used depending on user needs.*
☐	Choosing Colors	*Use a color gradation that becomes darker as the indicator values increase. Avoid using a divergent color scheme (darker at both extremes and lighter in the middle), which implies an inflection point such as 0 in a dataset containing positive and negative values.*

Examples of how the indicator can be useful		
☐	Community Vulnerability to High Quantities of Hazardous Waste	*This indicator shows which BGs contain hazardous waste and help identify BGs with large amounts of waste This tonnage indicator provides information on risk of release of contaminants that may be most harmful to communities. It can be used to identify priorities for cleanup, maintenance, and adaptation/response strategies.*
☐	Counts vs. Tonnage	*Simple count of hazardous waste facilities (Indicator 1.2.3) provides information on how many facilities to monitor or prepare for.* *The tonnage (this indicator) reflects the magnitude of the risk, which is determined by the total amount of waste stored or processed at these facilities.*
Key caveats/limitations		
☐	Data Sources Are Not Updated with Uniform Frequency	• *Not all data sources listed are updated at the same time and compiling different sources may result in discrepancies.* • *Data sources are also not frequently updated. As a result, the waste facilities included in these data sources may no longer be a concern. More recently identified waste facilities may also be left out.* *Tracking when each dataset was accessed and having local experts review the final list of waste facilities are crucial to ensure the list includes the most concerning facilities for the study area and does not include those that are no longer an issue.*
☐	BRS Data Availability	*BRS data are generated every two years through mandatory reporting by facilities satisfying the definition of LQGs in any calendar month (See "DETERMINING WHO MUST FILE" in the "Excerpt of RCRA Subtitle C Reporting Forms and Instruction."*
☐	BRS Waste Tonnage Data Do Not Distinguish Between Specific Wastes	*BRS waste tonnage data only provides a total waste tonnage for each facility. The data do not provide disaggregated waste tonnage data showing the amount of each specific type of hazardous waste as defined by the EPA listing. However, certain types of waste may be more vulnerable to specific events.*
Citations		
	Dataset/Tool	• *FRS: U.S. EPA. (2022). Geospatial data download service. https://www.epa.gov/frs/geospatial-data-download-service* • *RCRAInfo (available through API queries on Envirofacts): U.S. EPA. (2022). Envirofacts data service API. https://www.epa.gov/enviro/envirofacts-data-service-api* • *BRS: U.S. EPA. (2022). RCRAInfo public extract. https://rcrapublic.epa.gov/rcra-public-export/*

	Additional Resources	• *FRS: U.S. EPA. (2021). Facility Registry Service (FRS).* *https://www.epa.gov/frs*
		• *RCRAInfo: U.S. EPA. (2021). RCRAInfo overview.* *https://www.epa.gov/enviro/rcrainfo-overview*
		• *BRS*
		  • *Data dictionary and file specifications guide: U.S. EPA. (n.d.). RCRAInfo introduction. https://rcrainfo.epa.gov/rcrainfo-help/application/publicHelp/index.htm*
		  • *BRS general information: U.S. EPA. (2021). Biennial Hazardous Waste Report. https://www.epa.gov/hwgenerators/biennial-hazardous-waste-report*
		  • *BRS reporting form: U.S. EPA. (n.d.). RCRA Subtitle C Reporting Instructions and Forms, EPA Forms 8700-12, 8700-13 A/B, 8700-23. https://www.epa.gov/sites/default/files/2021-05/documents/excerpt_biennial_report_rcra_subtitlec_forms_and_instruction_5_12_2021.pdf*
		• *U.S. EPA. (2012). Hazardous Waste Listings. https://www.epa.gov/sites/default/files/2016-01/documents/hw_listref_sep2012.pdf.*

API: Application Programming Interface, BRS: Biennial Reporting System, BG: Block Group, FRS: Facility Registry Service, RCRA: Resource Conservation and Recovery Act, TSDF: Treatment Storage, and Disposal Facility.

Indicator 1.2.5. Checklist for Sites/Waste Facilities Count (by Hazard Type) Indicator

Sites/Waste Facilities Count (by Hazard Type) Indicator		
Definition of the indicator		
☐	Definition	*A count of hazardous waste facilities with a specific type of hazardous waste present.*
☐	Interpretation	*This indicator provides the number of hazardous waste facilities by each hazard type (Section 3.2, Table 5). Hazard types are identified as ignitable (I), corrosive (C), reactive (R), toxicity characteristic (E), acutely hazardous (H), and toxic (T) through an EPA listing (EPA 2012).*
Data source		
☐	Data Source	• *Facility Registry Service (FRS)* • *RCRAInfo (recommend using the RCRAInfo API to access this data)* • *BRS*
☐	Temporal Resolution	• *FRS data, RCRAInfo and BRS data represent the information available at the time of download* BRS data are available every two years
☐	Spatial Resolution	*Block Group (BG) shapefile, coordinates for each waste facility that are required to file a BRS report*
☐	Facility Characteristic Inputs	*This indicator only uses waste facilities that are considered hazardous waste generators. This includes hazardous waste generators; hazardous waste treatment, storage, and disposal facilities (TSDFs); transporters; transfer facilities, and other hazardous waste operators. Table A.4 includes details on how to identify these facility types.* *The indicator includes all facilities downloaded using the RCRAInfo API that were labeled as "Large Quantity Generators."*
☐	Required Hazard Type Inputs	*The RCRAInfo data downloaded using the RCRAInfo API includes waste codes for the types of waste present at each facility. An EPA listing of hazard codes indicates why the waste was listed as hazardous and crosswalks the classes or types of wastes (see Interpretation).*
☐	Data Format	• *FRS has two options available for users to select from:* 　○ *National and state CSV files* 　○ *File geodatabase* • *RCRAInfo: The default output is in XML; however, output options of JSON, CSV, or Excel can be requested in the URL during the API query*

Decisions needed for calculation		
☐	Compiling and Vetting of Data	*FRS is recommended as the primary source of coordinate data. Any waste facilities found in RCRAInfo (Table A.4) but not included in the FRS dataset should be added to the list of facilities used to create the indicator. This combined list should be reviewed by local partners to ensure that the facilities most relevant to the community are included.*
☐	Matching Method for Cross-Data Source Comparisons	*Waste facilities included in this indicator can be linked using the EPA ID (sometimes referred to as RCRA ID) variable that is common to the FRS, RCRAInfo, and BRS data.*
Calculation steps and assumptions		
☐	Identify the Hazard Types Associated with Each Waste Code	***Inputs:*** *RCRAInfo data, waste codes & hazard codes (EPA, 2012)* ***Calculations:*** *Use the EPA listing to identify each of the six hazard types associated with each waste code for each facility listed in the Facility Characteristic Inputs section above.* ***Output:*** *RCRAInfo data with hazard type identified*
☐	Calculate the Sites/Waste Facilities Count (by Hazard Type) Indicator	***Inputs:*** *BG shapefile, coordinates for each waste facility, RCRAInfo data with hazard type identified* ***Calculations:*** *Count the number of facilities with a given hazard type present within a given BG. See Appendix Equation SWF-5.* ***Output:*** *Sites/waste facilities count (by hazard type)*
Decisions needed for mapping and interpretation		
☐	Mapping Limited to Block Groups Containing Data	*BGs that do not contain any facilities at all should be shown as a separate layer that grays out the polygons.*
☐	Choosing Symbology	*Maps showing the distribution of this indicator will generally not be compared across scenarios, time periods, or locations so a single symbology will not be necessary. The symbology will be specific to the data for current study area*
☐	Binning the Data by Block Group	*The distribution of this indicator will likely be skewed towards values closer to zero. For this situation using quantiles (equal number of observations per bin) is recommended. Using a maximum of 5-7 categories is also recommended so that the map reader can readily distinguish between color categories and visually match them to the legend. However, deciles or other percentiles can also be used depending on user needs.*
☐	Choosing Colors	*Use a color gradation that becomes darker as the indicator values increase. Avoid using a divergent color scheme (darker at both extremes and lighter in the middle), which implies an inflection point such as 0 in a dataset containing positive and negative values.*

Examples of how the indicator can be useful		
☐	Community Vulnerability to Specific Types of Hazardous Waste	*This indicator helps identify community vulnerabilities to specific waste types and events. Certain types of hazardous waste may be more or less concerning under different extreme events. For example, a BG with a high number of facilities with ignitable waste may be at higher risk in extreme heat or wildfires, while a BG with hazardous wastes that exhibit the reactivity characteristic (e.g., forms potentially explosive mixtures with water) may be at higher risk during flooding.* *This indicator can provide more information on how many facilities need to be considered when planning for specific extreme event impacts than simple counts of all facilities or the total number of hazardous waste facilities. (See Section 3.2, Table 5 for more details.)*
☐	Counts vs. Tonnage	*Count of hazardous waste facilities for each hazard type (this indicator) provides information on how many facilities to monitor or prepare for in the context of specific events.* *The tonnage for each hazard type (Indicator 1.2.6) reflects the magnitude of the risk, which is determined by the total amount of waste stored or processed at these facilities in the context of specific events.*
Key caveats/limitations		
☐	Data Sources Are Not Updated with Uniform Frequency	• *Not all data sources listed are updated at the same time and compiling different sources may result in discrepancies.* • *Data sources are also not frequently updated. As a result, the waste facilities included in these data sources may no longer be a concern. More recently identified waste facilities may also be left out.* *Tracking when each dataset was accessed and having local experts review the final list of waste facilities are crucial to ensure the list includes the most concerning facilities for the study area and does not include those that are no longer an issue.*
Citations		
	Dataset/Tool	• *FRS: U.S. EPA. (2022). Geospatial data download service. https://www.epa.gov/frs/geospatial-data-download-service* • *RCRAInfo (available through API queries on Envirofacts): U.S. EPA. (2022). Envirofacts data service API. https://www.epa.gov/enviro/envirofacts-data-service-api* • *U.S. EPA. (2012). Hazardous Waste Listings. https://www.epa.gov/sites/default/files/2016-01/documents/hw_listref_sep2012.pdf*
	Additional Resources	• *FRS: U.S. EPA. (2021). Facility Registry Service (FRS). https://www.epa.gov/frs* • *RCRAInfo: U.S. EPA. (2021). RCRAInfo overview. https://www.epa.gov/enviro/rcrainfo-overview* • *U.S. EPA. (2012). Hazardous Waste Listings. https://www.epa.gov/sites/default/files/2016-01/documents/hw_listref_sep2012.pdf.*

API: Application Programming Interface, BRS: Biennial Reporting System, BG: Block Group, FRS: Facility Registry Service, RCRA: Resource Conservation and Recovery Act, TSDF: Treatment Storage, and Disposal Facility.

Indicator 1.2.6. Checklist for Waste Tonnage (by Hazard Type) Indicator

Waste Tonnage (by Hazard Type) Indicator		
Definition of the indicator		
☐	Definition	*Total tons of a given type (hazard type) of hazardous waste present at a hazardous waste facility. Hazard types include ignitable, corrosive, reactive, toxic, acutely hazardous, and toxicity characteristic.*
☐	Interpretation	*This waste tonnage indicator provides the total amount of waste stored or processed at hazardous waste facilities by each hazard type. Hazard types are identified as ignitable (I), corrosive (C), reactive (R), toxicity characteristic (E), acutely hazardous (H), and toxic (T) through an EPA listing* (EPA, 2012)
Data source		
☐	Data Source	• *Facility Registry Service (FRS)* • *RCRAInfo (Recommend using the RCRAInfo API to access this data)* • *BRS*
☐	Temporal Resolution	• *FRS data, RCRAInfo and BRS data represents the information available at the time of download* *BRS data are available every two years*
☐	Spatial Resolution	*Block Group (BG) shapefile, coordinates for each waste facility that are required to file a BRS report.*
☐	Facility Characteristic Inputs	*This indicator only uses waste facilities that are considered hazardous waste generators. This includes hazardous waste generators; hazardous waste treatment, storage, and disposal facilities (TSDFs); transporters; transfer facilities, and other hazardous waste operators. Table A.4 includes details on how to identify these facility types.* *The indicator includes all facilities downloaded using the RCRAInfo API that were labeled as "Large Quantity Generators" and were required to file a BRS report. No other sites have waste tonnage data available.*
☐	Required Waste Tonnage Data	*BRS data includes data on the amount of hazardous waste stored at select RCRA sites that are labeled "Large Quantity Generators." (See "BRS Data Availability" below.)*
☐	Required Hazard Type Inputs	*The RCRAInfo data downloaded using the RCRAInfo API includes waste codes for the types of waste present at each facility. An EPA listing of hazard codes indicates why the waste was listed as hazardous and crosswalks the classes or types of wastes (see Interpretation).*

☐	Data Format	• *FRS has two options available for users to select from:*
		    o *National and state CSV files*
		    o *File geodatabase*
		• *RCRAInfo: The default output is in XML; however, output options of JSON, CSV, or Excel can be requested in the URL during the API query*
		• *BRS data are available in fixed format and can be opened in either Excel or any file editor*

Decisions needed for calculation		
☐	Compiling and Vetting of Data	*FRS is recommended as the primary source of coordinate data. Any facilities found in RCRAInfo or BRS (Table A.4) but not included in the FRS dataset should be added to the list of facilities used to create the indicator. This combined list should be reviewed by local partners to ensure that the facilities most relevant to the community are included.*
☐	Matching Method for Cross-Data Source Comparisons	*Waste facilities included in this indicator can be linked using the EPA ID (sometimes referred to as RCRA ID) variable that is common to the FRS, RCRAInfo, and BRS data.*
Calculation steps and assumptions		
☐	Identify the Hazard Type Associated with Each Waste Code	***Inputs:*** *RCRAInfo data, waste codes & hazard codes (EPA, 2012)* ***Calculations:*** *Use the EPA listing to identify each of the six hazard types associated with each waste code for each facility listed in the Facility Characteristic Inputs section above.* ***Output:*** *RCRAInfo data with hazard type identified*
☐	Calculate the Waste Tonnage (by Hazard Type) Indicator	***Inputs:*** *BG shapefile, coordinates for each facility, facility characteristics, waste tonnage data, RCRAInfo data with hazard codes* ***Calculations:*** • *Identify the facility type for each waste facility.* • *Filter to exclude any facility that is not a Hazardous Waste Generator required to file a BRS report.* • *Sum the tons of waste stored at all Hazardous Waste Generators for a given hazard type in a given BG.* • *See Appendix Equation SWF-6.* ***Output:*** *Waste tonnage (by hazard type)*
Decisions needed for mapping and interpretation		
☐	Mapping Limited to Block Groups Containing Data	*BGs that do not contain any facilities should be shown as a separate layer with gray polygons.*

☐	Choosing Symbology	*Maps showing the distribution of tons of waste by hazard type will generally not be compared across scenarios, time periods, or locations so a single symbology will not be necessary. The symbology will be specific to the data for current study area*
☐	Binning the Data into Block Groups	*For this indicator using quantiles (equal number of observations per bin) is recommended. Using a maximum of 5-7 categories is also recommended so that the map reader can readily distinguish between color categories and visually match them to the legend. However, deciles or other percentiles can also be used depending on user needs.*
☐	Choosing Colors	*Use a color gradation that becomes darker as the indicator values increase. Avoid using a divergent color scheme (darker at both extremes and lighter in the middle), which implies an inflection point such as 0 in a dataset containing positive and negative values.*
Examples of how the indicator can be useful		
☐	Community Vulnerability to Specific Types of Hazardous Waste	*This indicator shows which BGs contain hazardous waste and help identify BG with large amounts of specific types of hazardous waste. This tonnage indicator provides information on risk of release of contaminants that may be most harmful to communities. Moreover, it reflects the fact that certain types of hazardous waste may be more or less concerning under different extreme events. For example, a BG with a high number of facilities with ignitable waste may be at higher risk in extreme heat or wildfires, while a BG with hazardous wastes that exhibit the reactivity characteristic (e.g., forms potentially explosive mixtures with water) may be at higher risk during flooding.* *This indicator can be used to identify priorities for cleanup, maintenance, and adaptation/response strategies.*
☐	Counts vs. Tonnage	*Simple count of hazardous waste facilities for each hazard type (Indicator 1.2.5) provides information on how many facilities to monitor or prepare for in the context of specific events.* *The tonnage indicator for each hazard type (this indicator) reflects the magnitude of the risk, which is determined by the total amount of waste stored or processed at these facilities in the context of specific events.*
Key caveats/limitations		
☐	Data Sources are Not Updated with Uniform Frequency	• *Not all data sources listed are updated at the same time and compiling different sources may result in discrepancies.* • *Data sources are also not frequently updated. As a result, the waste facilities included in these data sources may no longer be a concern. More recently identified waste facilities may also be left out.* *Tracking when each dataset was accessed and having local experts review the final list of waste facilities are crucial to ensure the list includes the most concerning facilities for the study area and does not include those that are no longer an issue.*

Citations	
Dataset/Tool	• *FRS: U.S. EPA. (2022). Geospatial data download service. https://www.epa.gov/frs/geospatial-data-download-service* • *RCRAInfo (available through API queries on Envirofacts): U.S. EPA. (2022). Envirofacts data service API. https://www.epa.gov/enviro/envirofacts-data-service-api* • *U.S. EPA. (2012). Hazardous Waste Listings. https://www.epa.gov/sites/default/files/2016-01/documents/hw_listref_sep2012.pdf*

Additional Resources	• *FRS: U.S. EPA. (2021). Facility Registry Service (FRS). https://www.epa.gov/frs*
	• *RCRAInfo: U.S. EPA. (2021). RCRAInfo overview. https://www.epa.gov/enviro/rcrainfo-overview*
	• *BRS*
	  ◦ *Data dictionary and file specifications guide: U.S. EPA. (n.d.). RCRAInfo introduction. https://rcrainfo.epa.gov/rcrainfo-help/application/publicHelp/index.htm*
	  ◦ *BRS general information: U.S. EPA. (2021). Biennial Hazardous Waste Report. https://www.epa.gov/hwgenerators/biennial-hazardous-waste-report*
	  ◦ *BRS reporting form: U.S. EPA. (n.d.). RCRA Subtitle C Reporting Instructions and Forms, EPA Forms 8700-12, 8700-13 A/B, 8700-23. https://www.epa.gov/sites/default/files/2021-05/documents/excerpt_biennial_report_rcra_subtitlec_forms_and_instruction_5_12_2021.pdf*
	• *U.S. EPA. (2012). Hazardous Waste Listings. https://www.epa.gov/sites/default/files/2016-01/documents/hw_listref_sep2012.pdf.*

API: Application Programming Interface, BRS: Biennial Reporting System, BG: Block Group, FRS: Facility Registry Service, RCRA: Resource Conservation and Recovery Act, TSDF: Treatment Storage, and Disposal Facility.

Indicator 1.2.7. Checklist for Brownfield Count with Contaminant; Cleanup Unknown (by Contaminant) Indicator

Count of Brownfield Count with Contaminant; Cleanup Unknown (by Contaminant) Indicator		
Definition of the indicator		
☐	Definition	*Count of Brownfield sites with a specific contaminant found and no information on cleanup of that contaminant available.*
☐	Interpretation	*This indicator provides insights on type of contaminants that may potentially be present at Brownfield sites at a particular time. It also indicates if the contaminants found have been cleaned up (if information was available at the time of data download). Brownfields sites where assessment or cleanup was complete, and no further action was indicated are not included in this indicator.*
Data source		
☐	Data Source	• *Facility Registry Service (FRS)* • *ACRES-CIMC: Brownfields data are reported by grant recipients via the ACRES database and updated and stored in Envirofacts monthly and can be accessed through the CIMC web service*
☐	Temporal Resolution	• *FRS data and ACRES-CIMC data represents the information available at the time of download*
☐	Spatial Resolution	*Block Group (BG) shapefile, coordinates for each site.*
☐	Required Brownfield Characteristics Inputs	*ACRES-CIMC includes data on the contaminants found at each site and the contaminants cleaned up at each site. The list of contaminants included in the ACRES-CIMC data is included in Table A.2 in Appendix A.*
☐	Data Format	*Spreadsheet*
Decisions needed for calculation		
☐	Compiling and Vetting of Data	*FRS is recommended as the primary source of coordinate data. Any sites found in ACRES-CIMC (Table A.4) but not included in the FRS dataset should be added to the list of sites used to create the indicator. This combined list should be reviewed by local partners to ensure that the sites most relevant to the community are included.* *Brownfield datasets may not be updated regularly and may be inaccurate as a result. Information such as cleanup status should be checked for accuracy with local regulators and other stakeholders partners prior to use in this application.*

☐	Matching Method for Cross-Data Source Comparisons	*Sites included in this indicator can be linked using the EPA ID variable that is common to the FRS and ACRES-CIMC data.*
Calculation steps and assumptions		

☐	Identifying Sites with No Cleanup Information	***Inputs:*** *The ACRES-CIMC data contain two variables for each potential contaminant (for a list of contaminants see Table A.2 in Appendix A).*
		• *The first variable is called Contaminant Found and indicates whether the specified contaminant was found at the site.*
		• *The second variable is called Contaminant Cleaned Up and refers to whether a cleanup action occurred.*
		Calculations: *To identify sites where a contaminant was found but not cleaned up, match the contaminant found variable to the corresponding contaminant cleaned up variable.*
		• *If Contaminant Found for a given site is marked "Y" and Contaminant Cleaned Up is marked "N" or left blank, count the site as a site with the contaminant found but no information on cleanup status.*
		  ○ *Blank entries reflect missing information.*
		  ○ *"N" reflects information at the time of data update.*
		• *Count of sites described above.*
		• *See Appendix Equation SWF-7.*
		Output: *Count of Brownfield sites where a contaminant was found but not cleaned up in each BG*

Decisions needed for mapping and interpretation		
☐	Mapping Limited to Block Groups Containing Data	*BGs that do not contain any facilities should be shown as a separate layer that grays out the polygons.*
☐	Choosing Symbology	*Maps showing the distribution of counts of sites will generally not be compared across scenarios, time periods, or locations so a single symbology will not be necessary. The symbology will be specific to the data for current study area*
☐	Binning the Data by Block Group	*The distribution of counts of sites will likely be skewed towards values closer to zero. For this situation using quantiles (equal number of observations per bin) is recommended. Using a maximum of 5-7 categories is also recommended so that the map reader can readily distinguish between color categories and visually match them to the legend. However, deciles or other percentiles can also be used depending on user needs.*
☐	Choosing Colors	*Use a color gradation that becomes darker as the indicator values increase. Avoid using a divergent color scheme (darker at both extremes and lighter in the middle), which implies an inflection point such as 0 in a dataset containing positive and negative values.*

Examples of how the indicator can be useful		
☐	Community Vulnerability to Specific Types of Contaminants	*Cleanup status and type of contaminants that may potentially be present at Brownfield sites may provide more information than simple counts of Brownfields sites. Sites that have been assessed and contaminants found are likely to be riskier unless they have been cleaned up. However, the information needs to be vetted with local partners and decision-makers prior to use in this application (See "Compiling and Vetting of Data" above)*
Key caveats/limitations		
☐	Data Sources Are Not Updated with Uniform Frequency	• *Not all data sources listed are updated at the same time and compiling different sources may result in discrepancies.* • *Data sources are also not frequently updated. As a result, the sites included in these data sources may no longer be a concern. More recently identified sites may also be left out.* *Tracking when each dataset was accessed and having local experts review the final list of sites are crucial to ensure the list of sites includes the most relevant sites for the study area and does not include sites that are no longer an issue.* *Caution must be used because datasets (e.g., ACRES-CIMC) with this information are based on voluntary reporting, and assessment and cleanup status available publicly may not be reflective of the most current status at a site.*
☐	Lack of Cleanup Information Is Not Necessarily Concerning	*Sites with a contaminant found but no information on cleanup are not necessarily a source of high risk.* • *It is possible that a cleanup did occur at a given site, but updated information was not entered into ACRES-CIMC at the time of data download.* • *The ACRES-CIMC data on contaminants is only a Yes or No indicator. There is no data on the amount of a contaminant found at a site. A contaminant could be present in very small amounts so that even without cleanup action, the site may not pose high levels of risk.* • *Further, all contaminants do not pose the same risks.*
Citations		
	Dataset/Tool	• *U.S. EPA. (2022). Cleanups In My Community – Create a table. https://ordspub.epa.gov/ords/cimc/f?p=cimc:createtable:0*
	Additional Resources	• *U.S. EPA. (2022). Cleanups In My Community. https://www.epa.gov/cleanups/cleanups-my-community*

ACRES: Assessment Cleanup and Redevelopment Exchange System, BG: Block Group, CIMC: Cleanups in My Community, FRS: Facility Registry Service,

Indicator 1.2.8. Checklist for Superfund Count with Vulnerable Remedy Technology (by Extreme Event) Indicator

Superfund Count with Vulnerable Remedy Technology (by Extreme Event) Indicator		
Definition of the indicator		
☐	Definition	*A count of NPL Superfund sites with a remedy vulnerable to a specific type of extreme event in each Block Group (BG).*
☐	Interpretation	*This indicator provides information on Superfund sites that employ remedy technologies that are vulnerable to each of the four extreme events (extreme heat, wildfire, floods, drought).*
Data source		
☐	Data Source	• *Facility Registry Service (FRS)* • *SEMS data are stored in Envirofacts.*
☐	Temporal Resolution	*FRS and SEMS data represents the information available at the time of download*
☐	Spatial Resolution	*BG shapefile, Coordinates for each site*
☐	Superfund Characteristic Inputs	*SEMS data contain information about* • *NPL status of each site* *Remedies present at each site*
☐	Remedy Vulnerability Inputs	*Table A.3 in Appendix A includes a list of potential remedy technologies found at Superfund sites and their vulnerability to specific extreme events. This vulnerability mapping (developed by RTI) is an adapted version of findings from EPA (2012)*
☐	Data Format	*Superfund sites must be searched individually in SEMS to manually copy their remedy information.*
Decisions needed for calculation		
☐	Compiling and Vetting of Data	*FRS is recommended as the primary source of coordinate data since it provides consistent spatial information for different types of sites/waste facilities. Any sites found in SEMS (Table A.4) but not included in the FRS dataset should be added to the list of sites used to create the indicator. This combined list should be reviewed by local partners to ensure that the facilities most relevant to the community are included.*
☐	Matching Method for Cross-Data Source Comparisons	*Sites included in this indicator can be linked using the EPA ID variable that is common to the FRS and SEMS data.*

Calculation steps and assumptions		
☐	Identifying NPL Superfund Sites	*SEMS data can be filtered along the NPL status variable to exclude sites not on the NPL if desired by local partners/decision-makers.*
☐	Identifying Remedies Vulnerable to Certain Technologies	***Inputs:*** *Table A.3 identifying which events each remedy technology is vulnerable to and remedy technologies being employed at each site from SEMS* ***Calculations:*** • *Table A.3 can be used to look up whether the remedies being used at each Superfund site (available from SEMS) is vulnerable to each of the four events. This will allow you to identify which sites are vulnerable to specific extreme events based on the remedies present at those sites.* • *A count of sites that employ remediation technologies vulnerable to each extreme event can be calculated.* • *Repeat the previous step for all events.* • *See Appendix Equation SWF-8.* ***Output:*** *Count of Superfund sites in each BG with any remedy technology vulnerable to each of the four extreme events (extreme heat, wildfire, floods and drought).*
Decisions needed for mapping and interpretation		
☐	Mapping Limited to Block Groups Containing Data	*BGs that do not contain any facilities should be shown as a separate layer that grays out the polygons.*
☐	Choosing Symbology	*Maps showing the distribution of counts of sites will generally not be compared across scenarios, time periods, or locations so a single symbology will not be necessary. The symbology will be specific to the data for current study area.*
☐	Binning the Data by Block Group	*The distribution of counts of sites will likely be skewed towards values closer to zero. For this situation using quantiles (equal number of observations per bin) is recommended. Using a maximum of 5-7 categories is also recommended so that the map reader can readily distinguish between color categories and visually match them to the legend. However, deciles or other percentiles can also be used depending on user needs.*
☐	Choosing Colors	*Use a color gradation that becomes darker as the indicator values increase. Avoid using a divergent color scheme (darker at both extremes and lighter in the middle), which implies an inflection point such as 0 in a dataset containing positive and negative values.*
Examples of how the indicator can be useful		
☐	Superfund Site Vulnerability to Various Extreme Events	*Sites can have remediation technologies in place that may pose a risk during specific types of extreme events. This indicator can identify specific BGs where a Superfund site could present a risk during a certain extreme event. This could help with disaster planning for climate resiliency, for example, flood risk during hurricanes (U.S. EPA, 2018).*

Key caveats/limitations		
☐	Data Sources are Not Updated with Uniform Frequency	• *Not all data sources listed are updated at the same time and compiling different sources may result in discrepancies.* • *Data sources are also not frequently updated. As a result, the sites included in these data sources may no longer be a concern. More recently identified sites facilities may also be left out.* *Tracking when each dataset was accessed and having local experts review the final list of sites are crucial to ensure the list of sites includes the most relevant sites for the study area and does not include sites that are no longer an issue.*
☐	Sensitivity around Non-NPL Superfund Sites	*Consult with local partners to determine if non-NPL sites are a concern for them and filter the data accordingly.*
Citations		
	Dataset/Tool	*U.S. EPA. (2021). SEMS search.* https://www.epa.gov/enviro/sems-search
	Additional Resources	*U.S. EPA. (2012). Adaptation of Superfund Remediation to Climate Change, Table 1.* *U.S. EPA. (2018). Evaluation of remedy resilience at Superfund NPL and SAA sites, Final Report.* https://www.epa.gov/sites/default/files/2019-02/documents/evaluation-of-remedy-resilience-at-superfund-npl-and-saa-sites.pdf

BG: Block Group, FRS: Facility Registry Service, NPL: National Priorities List, SEMS: Superfund Enterprise Management System

Indicator 1.2.9. Checklist for Count of Specific Type of Tank (UST/AST) Indicator

Count of Specific Type of Tank (UST/AST) Indicator		
Definition of the indicator		
☐	Definition	*A count of specific type of tank (UST or AST) by Block Group (BG)*
☐	Interpretation	*This indicator includes the total number of the following types of sites:* • *Underground Storage Tank (UST)* • *Aboveground Storage Tank (AST)*
Data source		
☐	Data Source	• *Facility Registry Service (FRS)* • *State databases* *Additional data sources should also be consulted to identify sites of interest that are not listed in the FRS data. These data sources are listed in Table A.4.*
☐	Temporal Resolution	*FRS data represent the information available at the time of download*
☐	Spatial Resolution	*BG shapefile, coordinates for each site*
☐	Data Format	*Varies across data sources*
Decisions needed for calculation		
☐	Compiling and Vetting of Data	*FRS is recommended as the primary source of coordinate data since it provides consistent spatial information for different types of sites. Any sites found in additional data sources (Table A.4) but not included in the FRS dataset should be added to the list of sites used to create the indicator. This combined list should be reviewed by local partners to ensure that the facilities most relevant to the community are included.*
☐	Matching Method for Cross-Data Source Comparisons	*State/regional UST and AST databases do not usually include EPA ID so a manual comparison or fuzzy lookup is necessary to identify any duplicate observations between the state/regional databases and FRS data.*
Calculation steps and assumptions		
☐	Exclude Cross Dataset Duplicate Observations	*Once duplicate observations between FRS and state/regional databases have been identified, duplicate observations should be excluded from the mapping data.*

☐	Count Number of ASTs/USTs	***Inputs:*** *FRS and state/regional databases* ***Calculation steps:*** • *USTs: Count the number of open and temporarily closed tanks.* • *ASTs: Count the number of ASTs.* • *See Appendix Equation SWF-9.* ***Outputs:*** *Counts of tanks of each type (ASTs/USTs) by BG*
Decisions needed for mapping and interpretation		
☐	Mapping Limited to Block Groups Containing Data	*BGs that do not contain any facilities should be shown as a separate layer that grays out the polygons.*
☐	Choosing Symbology	*Maps showing the distribution of counts of sites will generally not be compared across scenarios, time periods, or locations so a single symbology will not be necessary. The symbology will be specific to the data for current study area*
☐	Binning the Data by Block Group	*The distribution of counts of sites will likely be skewed towards values closer to zero. For this situation using quantiles (equal number of observations per bin) is recommended. Using a maximum of 5-7 categories is also recommended so that the map reader can readily distinguish between color categories and visually match them to the legend. However, deciles or other percentiles can also be used depending on user needs.*
☐	Choosing Colors	*Use a color gradation that becomes darker as the count values increase. Avoid using a divergent color scheme (darker at both extremes and lighter in the middle), which implies an inflection point such as 0 in a dataset containing positive and negative values.*
Examples of how the indicator can be useful		
☐	Highlighting Block Groups with Large Numbers of Tanks	*This indicator helps identify BGs with the highest number of tanks containing potentially hazardous substances (e.g., petroleum, solvents, hazardous wastes). Such tanks may be susceptible to damage during extreme events, and this may lead to a release of their contents. Certain BGs will likely contain a larger number of USTs/ASTs while others may contain only a handful. BGs with a heavy concentration of tanks may potentially face higher risks. This indicator can be used to identify priorities for cleanup, maintenance, and adaptation/response strategies.*
Key caveats/limitations		
☐	State/Regional Data Quality Varies	*There is no single national database for USTs/ASTs and state/regional database quality can vary significantly.*

☐	Data Sources Are Not Updated with Uniform Frequency	• *Not all data sources listed are updated at the same time and compiling different sources may result in discrepancies.* • *Data sources are also not frequently updated. As a result, the sites included in these data sources may no longer be a concern. More recently identified sites may also be left out.* *Tracking when each dataset was accessed and having local experts review the final list of sites are crucial to ensure the list of sites includes the most relevant sites for the study area and does not include sites that are no longer an issue.*
☐	Limited Information	*This indicator does not include information on the quantity or type of contents in the tanks. For example, a low volume of leaded gasoline stored in a UST poses a greater human health risk than a UST storing a more inert substance in larger capacities. It also does not provide any information on the age and condition of the tank, which can indicate how likely a tank is to be damaged.*
Citations		
	Dataset/Tool	• *State datasets—e.g., Arizona Department of Environmental Quality. (n.d.). Underground storage tank (UST) database search.* *http://legacy.azdeq.gov/databases/ustsearch_drupal.html* • *U.S. Environmental Protection Agency. (2021). UST Finder.* *https://www.epa.gov/ust/ust-finder or https://epa.maps.arcgis.com/apps/webappviewer/index.html?id=b03763d3f2754461adf86f121345d7bc*

AST: Aboveground Storage Tank, BG: Block Group, FRS: Facility Registry Service, LUST-ARRA: Leaking Underground Storage Tank – American Recovery and Reinvestment Act, UST: Underground Storage Tank

Indicator 1.2.10. Checklist for Total Tank Capacity (UST/AST) Indicator

Total Tank Capacity (UST/AST) Indicator		
Definition of the indicator		
☐	Definition	*The total tank capacity of each type of tank (either UST or AST) within a Block Group (BG).*
☐	Interpretation	*This indicator provides information on the volume of substances that can be potentially stored in underground and aboveground storage tanks (USTs and ASTs).*
Data source		
☐	Data Source	• *Facility Registry Service (FRS)* • *State databases* *Additional data sources should also be consulted to identify sites of interest that are not listed in the FRS data. These data sources are listed in Table A.4.*
☐	Temporal Resolution	*FRS data represents the information available at the time of download*
☐	Spatial Resolution	*BG shapefile, coordinates for each site/waste facility*
☐	Data Format	*Varies across data sources*
☐	Required Tank Characteristic Inputs	*Some state/regional databases on tanks include data on the total capacity of each tank. This capacity information will allow you to map the total capacity of tanks within a BG.*
Decisions needed for calculation		
☐	Compiling and Vetting of Data	*FRS is recommended as the primary source of coordinate data since it provides consistent spatial information for different types of sites. Any sites found in additional data sources (Table A.4) but not included in the FRS dataset should be added to the list of sites used to create the indicator. This combined list should be reviewed by local partners to ensure that the facilities most relevant to the community are included.*
☐	Matching Method for Cross-Data Source Comparisons	*State/regional UST and AST databases do not usually include EPA ID so a manual comparison or fuzzy lookup is necessary to identify any duplicate observations between the state/regional databases and FRS data.*
Calculation steps and assumptions		
☐	Match Cross Dataset Duplicate Observations	*Once duplicate observations between FRS and state/regional databases have been identified, duplicate observations should be matched together but not deleted. For this indicator you will need to use FRS coordinates for duplicates alongside the tank capacity data from state/regional databases to map total capacity.*

☐	Calculate the Total Capacity of ASTs/USTs Indicator	***Inputs:*** *FRS and state/regional databases* ***Calculation steps:*** • *USTs: Identify the number of open and temporarily closed tanks and add the capacity across all such tanks.* • *ASTs: Add the capacity of all ASTs.* • *See Appendix Equation SWF-10.* ***Outputs:*** *Total capacity of tanks of each type (ASTs/USTs) by BG*
Decisions needed for mapping and interpretation		
☐	Mapping Limited to Block Groups Containing Data	*BGs that do not contain any facilities should be shown as a separate layer that grays out the polygons.*
☐	Choosing Symbology	*Maps showing the distribution of capacity will generally not be compared across scenarios, time periods, or locations so a single symbology will not be necessary. The symbology will be specific to the data for current study area*
☐	Binning the Data into Block Groups	*For this indicator using quantiles (equal number of observations per bin) is recommended. Using a maximum of 5-7 categories is also recommended so that the map reader can readily distinguish between color categories and visually match them to the legend. However, deciles or other percentiles can also be used depending on user needs.*
☐	Choosing Colors	*Use a color gradation that becomes darker as the indicator values increase. Avoid using a divergent color scheme (darker at both extremes and lighter in the middle), which implies an inflection point such as 0 in a dataset containing positive and negative values.*
Examples of how the indicator can be useful		
☐	Highlighting Block Groups with High Tank Capacity	*A high number of tanks does not always translate to a high amount of stored substances. It is possible that a BG with a high number of low-capacity tanks may be less at risk than a BG with a small number of tanks but high capacity. This indicator helps provide more detailed information on risk by showing capacity instead of raw number of tanks. This indicator can be used to identify priorities for cleanup, maintenance, and adaptation/response strategies.*
Key caveats/limitations		
☐	State/Regional Data Quality Varies	*There is no single national database for USTs/ASTs and state/regional database quality can vary significantly. Noy all state/regional tank data will include data on capacity.*

☐	Data Sources Are Not Updated with Uniform Frequency	• *Not all data sources listed are updated at the same time and compiling different sources may result in discrepancies.* • *Data sources are also not frequently updated. As a result, the sites included in these data sources may no longer be a concern. More recently identified sites may also be left out.* *Tracking when each dataset was accessed and having local experts review the final list of sites are crucial to ensure the list of sites includes the most relevant sites for the study area and does not include sites that are no longer an issue.*
☐	Limited Information	*This indicator does not include information on the actual quantity or type of contents in the tanks. For example, a low volume of leaded gasoline stored in a UST poses a greater human health risk than a UST storing a more inert substance in larger capacities. It also does not provide any information on the age and condition of the tank, which can indicate how likely a tank is to be damaged.*
Citations		
	Dataset/Tool	*State datasets—e.g., Arizona Department of Environmental Quality. (n.d.). Underground storage tank (UST) database search.* *http://legacy.azdeq.gov/databases/ustsearch_drupal.html*

AST: Aboveground Storage Tank, BG: Block Group, FRS: Facility Registry Service, LUST-ARRA: Leaking Underground Storage Tank – American Recovery and Reinvestment Act, UST: Underground Storage Tank

Vulnerability Source 1.3. Exposure: Transport and Fate

Indicator 1.3.1. Checklist for Count of Sites/Waste Facilities in a Floodplain Indicator

Count of Sites/Waste Facilities in a Floodplain Indicator		
Definition of the indicator		
☐	Definition	*Count of site/waste facilities in a floodplain [100-year and 500-year] by Block Group (BG)*
☐	Interpretation	*The identification and count of facilities within the floodplain provides a simple measure of risk to the surrounding, local BGs and the BGs downstream that access the river/stream channel due to the potential transport of hazardous substances released from a site/waste facility during a flooding event. This indicator measures the risk of sites/waste facilities getting flooded and contaminants being released.* *Further, note the delineated land areas inundated during events with a 1% annual chance of flooding (100-year floodplain) or a 0.2% annual chance of flooding (500-year floodplain) are not meant to exactly designate the frequency or the extent of hypothetical flood events. Rather, they should be used to indicate a relative risk of inundation across a given area.*
Data source[12]		
☐	Data Source	*The National Flood Hazard Layer (NFHL). Data for the necessary location is obtained by searching by state and county. A zip file is downloaded from the search result.*
☐	Temporal Resolution	*This indicator is a static measure without a time component. The measure represents the information available at the time of download.*
☐	Spatial Resolution	• *BG shapefile* • *NFHL resolution varies depending on location but is generally accurate at a scale <1 meter*
☐	Data Format	*Shapefile (BG and NFHL)*
Decisions needed for calculation		
☐	100-year or 500-year Floodplain Indicator	*The 100-year floodplain defines the area more likely to be inundated by rainfall events with a 1% annual chance of occurrence, while the 500-year floodplain defines the area more likely to be inundated by events with a 0.2% annual chance of occurrence. Therefore, the 500-year floodplain is more expansive in land area but delineates areas that have lower risk of flooding in terms of frequency. A community must choose which version of the indicator to use.*

[12] For further details on site/waste facility data (data source, decisions for calculations and vetting), see Indicator 1.2.1.

Calculation steps and assumptions		
☐	Extract 100- and 500-year Flood Hazard Limits	***Inputs:*** *National Flood Hazard Layer (NFHL)* ***Calculations:*** • *Use shapefile S_FLD_HAZ_AR.shp.* • *The field "FLD_ZONE" is used to separate the 100-year and 500-year flood hazard extents.* • *Values of either 'A' or 'AE' were combined to define the 100-year extent, while a value of 'X' was used to define the 500-year extent.*[13] ***Outputs:*** *Shapefile containing polygon extents for the 100-year and 500-year floodplains*
☐	Clip the Block Groups by the Floodplains	***Input:*** • *Shapefile containing polygon extents for the 100-year and 500-year floodplains* • *BG shapefile* ***Calculation:*** • *Within ArcGIS, use the "Clip" tool within the "Extract" toolset, within the "Analysis Tools" toolbox* • *Complete twice, once for each floodplain extent* ***Output:*** *Shapefile with BG – floodplain intersection for 100- and 500-year extents*
☐	Identify and Count Facilities within Floodplain Portions of Block Groups (Indicator)	***Input:*** • *Facilities shapefile* • *Shapefile with BG – floodplain intersection* ***Calculation:*** • *Intersect the facilities shapefile with the BG-floodplain intersection shapefile to identify all facilities falling within floodplain areas by BG* • *Using the BG unique identifier, count the facilities identified* • *Complete for each floodplain extent* ***Output:*** *Count of facilities within the floodplain (100- or 500-year) per BG*
Decisions needed for mapping and interpretation		
☐	Mapping Limited to Block Groups Containing Data	*BGs that are partly or wholly within a floodplain and have zero facilities within the floodplain boundary should be appropriately shown with a value of zero. BGs that do not contain any area of the floodplain should be shown separately and not included in the zero-count category as these BGs are not considered at risk from this flooding indicator.*
☐	Choosing Symbology	*Maps showing the distribution of counts of sites within a floodplain will generally not be compared across scenarios, time periods, or locations so a single symbology will not be necessary. The symbology will be specific to the data for study area.*

[13] Definitions of the values contained within this field can be found at https://www.fgdl.org/metadata/metadata_archive/fgdl_html/dfirm_fldhaz_apr08.htm

☐	Binning in the Data by Block Group	*The distribution of counts of sites within a floodplain will likely be skewed towards values closer to zero. For this situation using quantiles (equal number of observations per bin) is recommended. Use a maximum of 5-7 categories so that the map reader can readily distinguish between color categories and visually match them to the legend. Deciles or other percentiles can also be used depending on user needs.*
☐	Choosing Colors	*Use a color gradation that becomes darker as the indicator values increase. Avoid using a divergent color scheme (darker at both extremes and lighter in the middle), which implies an inflection point such as 0 in a dataset containing positive and negative values.*
Examples of how the indicator can be useful		
☐	Community Risk Due to Releases During Floods	*For each BG with a non-zero count for this indicator, there will be a risk of contamination to land within the floodplain (or more specially, within the inundated area) during a flooding event with a release.*
☐	Emergency Preparedness for Specific Contaminants	*By characterizing the different facilities captured within the counts for a BG and combining with other indicators (e.g., Indicators 1.2.6), specific preparedness actions can be taken if there were to be a release of a contaminants from one of these facilities into the floodplain.*
Key caveats/limitations		
☐	NFHL Validity	*FEMA maintains the NFHL on a schedule that is set by region. Before beginning any analyses, a user should check for updates to the NFHL polygons. For layers that have not been updated within the last few years, there is a greater probability that the flood extents are out of date due to either land development or changes in precipitation frequencies.*
☐	NFHL Applicability	*Actual inundation during any flooding event will vary depending on preceding hydrologic conditions and the characteristics of the storm event itself. Therefore, these defined floodplains are the best estimates of inundated area based on historic storm events. As extreme precipitation events change into the future, these floodplain boundaries will change and will likely expand to cover larger areas. Floodplains data also face other issues such as incomplete coverage and coarse resolution (Wing et al., 2018).*
Citations		
	Dataset/Tool	*FEMA. (2021). National Flood Hazard Layer. www.fema.gov/national-flood-hazard-layer-nfhl. Alternate data portal: https://msc.fema.gov/portal/advanceSearch*
	Additional Resources	*Wing, O. E. J., Bates, P. D., Smith, A. M., Sampson, C. C., Johnson, K. A., Fargione, J., & Morefield, P. (2018). Estimates of present and future flood risk in the conterminous United States. Environmental Research Letters, 13, 034023 https://doi.org/10.1088/1748-9326/aaac65*

BG: Block Group, FEMA: Federal Emergency Management Agency, NFHL: National Flood Hazard Layer

Indicator 1.3.2. Checklist for Count of Sites/Waste Facilities Within a Specific Hydrologic Distance of a Flowline Indicator

Count of Sites/Waste Facilities Within a Specific Hydrologic Distance of a Flowline Indicator		
Definition of the indicator		
☐	Definition	*Count of facilities within a certain (500 m, 1 km, 2km, or 5 km) "raindrop" distances to streams/rivers (NHD flowline) or lake/reservoir (shoreline).*
☐	Interpretation	*This indicator first determines the overland flow distance that a raindrop falling at a facility takes to reach the nearest flowline (i.e., stream/river or waterbody), representing the path water on the ground surface at a facility would take as it moves away from a facility.* *Once each facility has an associated distance, the count of facilities within a certain distance (selected by the decision-makers) can be calculated to provide the relative likelihood of contaminants reaching flowing water.* *A limitation for this indicator is that the raindrop analysis does not take into account stormwater infrastructure that may intercept an overland flow release. However, this limitation is countered with the assumption that a storm event of a magnitude high enough to trigger a release from a facility also has a high likelihood of overwhelming a typical stormwater infrastructure. In a full risk assessment, indicator values should be reviewed closely in urban areas with stormwater infrastructure.*
Data source[14]		
☐	Data Source	*The enhanced National Hydrography Dataset (NHDPlus) medium resolution data*
☐	Temporal Resolution	*This indicator is a static measure without a time component. The measure represents the information available at the time of download.*

☐	Spatial Resolution	• *Block Group (BG) shapefile*
		• *NHDPlus; Medium resolution*
		  ○ *Flow Direction Grid raster (30m x 30m resolution)*
		  ○ *Flowlines (1:100,000 scale)*

☐	Processing Tool	• *The "Raindrop Tool" is used to conduct the overland navigation analysis. This online tool includes the NHDPlus Flow Direction Grid raster; therefore, when using this method, a user does not need to provide that spatial input separately.* • *Alternatively, a user may create custom code following the methods provided by RTI (see Bergenroth, 2009) to conduct the raindrop navigation in the absence of the online tool. In that case, the user is required to provide the NHDPlus Flow Direction Grid raster.*

[14] For further details on site/waste facility data (data source, decisions for calculations and vetting), see Indicator 1.2.1.

☐	Data Format	• *Spreadsheet (Site/Waste Facility)* • *Shapefile (BG, NHDPlus)* • *Raster (Flow Direction Grid)*
Decisions needed for calculation		
☐	Distance Limit for Counting	*There is a continuous range of values among the calculated distances from each facility to a flowline. Therefore, depending on the local study area conditions (e.g., relief, density of streams/rivers, presence of stormwater infrastructure), different limits on the distance from a facility to a flowline are applicable to assess a risk of contamination from overland flow. Suggested limits for distance counts include 500 m, 1 km, 2 km, and 5 km. The smallest distance limit, 500 m, may be applicable for densely populated areas, whereas larger distance limits may be applicable in higher relief areas with lower populations.*
Calculation steps and assumptions		
☐	Identify the Applicable Block Group for Each Facility	***Inputs:*** • *Facility shapefile* • *BG shapefile* ***Calculation:*** *Intersect the facility shapefile with the BG shapefile to determine the specific BG in which each facility is located.* ***Outputs:*** *Shapefile containing facility points with unique BG identifier*

☐	Determine Distance to Nearest Flowline for each Facility	***Input:*** *Shapefile containing facility points with unique BG identifier*
		Calculation:
		• *Using the "Raindrop Tool" provided as part of the U.S. EPA's EnviroAtlas, determine the distance from each facility to the nearest flowline.*
		• *Inputs to the tool include the facility shapefile and two parameters*
		  ○ *Maximum raindrop distance (km): suggested value of 10 km as the maximum distance the raindrop process will navigate before exiting its process*
		  ○ *Maximum snap distance (km): suggested value of 0.005 km distance from the end of the navigation line to the flowline to exit the navigation and return a distance value*
		• *Modify the input shapefile to include the distance returned for each facility*
		Output: *Shapefile containing facility points with unique BG identifier and distance to nearest flowline (in km)*

☐	Count Facilities within Specified Distance (Indicator)	***Input:*** *Shapefile containing facility points with unique BG identifier and distance to nearest flowline (in km)* ***Calculation:*** • *Using the unique BG identifier, select all facilities within the specified distance (500 m, 1 km, 2 km, or 5 km) that fall within the BG.* • *Count the selected features and report by BG identifier.* • *For any BG without at least one facility, return a -1 value to use in mapping.* ***Output:*** *Count of facilities within the specified distance (500 m, 1 km, 2 km, or 5 km) per BG*
Decisions needed for mapping and interpretation		
☐	Mapping Limited to Block Groups Containing Counts	*BGs that are not found to have any sites or waste facilities within their boundaries should be shown separately (i.e., in gray) and not included in the distance category as these BGs are not considered at risk from this indicator.*
☐	Choosing Symbology	*Maps showing the distribution of counts of sites will generally not be compared across scenarios, time periods, or locations so a single symbology will not be necessary. The symbology will be specific to the data for study area.*
☐	Binning in the Data by Block Group	*The distribution of counts of sites will likely be skewed towards values closer to zero. For this situation using quantiles (equal number of observations per bin) is recommended. Use a maximum of 5-7 categories so that the map reader can readily distinguish between color categories and visually match them to the legend. Deciles or other percentiles can also be used depending on user needs.*
☐	Choosing Colors	*Use a color gradation that becomes darker as the count values increase. Avoid using a divergent color scheme (darker at both extremes and lighter in the middle), which implies an inflection point such as 0 in a dataset containing positive and negative values.*
Examples of how the indicator can be useful		
☐	Vulnerability due to Contaminate Transport to Waterways	*This indicator measures both the closeness and density of facilities to the hydrologic network. The more facilities there are and the closer they are to flowing waters, the greater the likelihood that an accidental release from a facility or a heavy precipitation event acting on surface contaminants at a facility will produce contamination of the nearby flowing waters. Contaminated water can cause risk to human and ecological health through direct exposure or secondary exposure through drinking water supplies. Therefore, the selection of distance limit can impact the type of vulnerabilities and risks assessed.*
Key caveats/limitations		
☐	Raindrop Navigation	*This navigation does not take into consideration any sewers or stormwater infrastructure. Rather it assumes that any stormwater infrastructure either drains to the same closest waterway or becomes inundated during events that would cause a facility to have substantial enough surface runoff reaching a waterbody.*

☐	Processing of Raindrop Distances	*There are two options for implementing the raindrop navigation, either through the U.S. EPA's EnviroAtlas Interactive Mapping tool or through creation of custom programming against the NHDPlus Flow Direction Grid. Use of the available online tool is subject to the limitations and set-up described within the tool; however, it is a service requiring minimal input or technical expertise. Creating custom programming given the underlying navigation process allows a user greater flexibility for setting limits or including complex hydrologic situations, but it also requires technical expertise around geospatial processing and the NHDPlus dataset.*
☐	Identified Waterbodies	*NHDPlus resolution is 1:100,000, which means it captures the majority of flowing waters in the United States, as well as some ephemeral streams. Therefore, the distances calculated will be from the facility to readily identifiable streams/rivers, which may not account for small drainage channels and ditches that convey stormwater.*
Citations		
	Dataset/Tool	*U.S. EPA. (2021). Get NHDPlus (National Hydrography Dataset Plus) Data. https://www.epa.gov/waterdata/get-nhdplus-national-hydrography-dataset-plus-data* *Bergenroth, B. (2009). Combining vector and raster data for hydro flow analysis: The Raindrop Tool. Oracle Spatial User Conference. Tampa, FL. https://www.oracle.com/technetwork/database/enterprise-edition/osuc2009-raindrop-bergenroth-134405.pdf.* *U.S. EPA. (2022). EnviroAtlas Interactive Map. https://www.epa.gov/enviroatlas/enviroatlas-interactive-map*

BG: Block Group, EPA: U.S. Environmental Protection Agency; NHD: National Hydrography Dataset

Indicator 1.3.3. Checklist for Shortest Hydrologic Distance Upstream to a Site/Waste Facility Indicator

Shortest Hydrologic Distance Upstream to a Site/Waste Facility		
Definition of the indicator		
☐	Definition	*Shortest hydrologic distance (overland) to an upstream facility*
☐	Interpretation	*This indicator represents the shortest navigated upstream hydrologic distance overland from a Block Group (BG) boundary to a facility. Each facility surrounding a BG is examined to find the closest facility in terms of how runoff from a facility would travel to the BG lands. For BGs that contain facilities, the distance is set to zero.* *This indicator examines all facilities upstream of BGs using the "raindrop" distance and finds the closest facility. This means that the indicator reports the shortest hydrologic distance from a facility downstream, overland to a BG. If a BG contains one or more facilities, this distance is set to zero. The distance represents the most likely facility and distance traveled during an overland flow event (i.e., flooding, heavy precipitation, release with wash off), which could contribute contaminants to the BG lands.* *A limitation for this indicator is that the raindrop analysis does not take into account stormwater infrastructure that may intercept an overland flow release. However, this limitation is countered with the assumption that a storm event of a magnitude high enough to trigger a release from a facility also has a high likelihood of overwhelming a typical stormwater infrastructure. In a full risk assessment, indicator values should be reviewed closely in urban areas with stormwater infrastructure.*
Data source[15]		
☐	Data Source	*The enhanced National Hydrography Dataset (NHDPlus) medium resolution data*
☐	Temporal Resolution	*This indicator is a static measure without a time component. The measure represents the information available at the time of download.*

☐	Spatial Resolution	• *BG shapefile*
		• *NHDPlus; Medium resolution*
		  ○ *Flow Direction Grid raster (30m x 30m resolution)*
		  ○ *Flowlines (1:100,000 scale)*

☐	Processing Tool	• *For this indicator, custom code following the methods provided by RTI (see Bergenroth, 2009) to conduct the raindrop navigation was created so that the raindrop navigation could be intersected with BG boundaries rather than an NHDPlus flowline. The code requires the NHDPlus Flow Direction Grid raster.* • *The "Raindrop Tool" provides the basic overland navigation analysis but does not allow for navigation to boundaries other than NHD flowlines. The tool could be explored for the calculation of the indicator but would require additional processing.*

[15] For further details on site/waste facility data (data source, decisions for calculations and vetting), see Indicator 1.2.1.

☐	Data Format	• *Spreadsheet (Site/Waste Facility)* • *Shapefile (BG, NHDPlus)* • *Raster (Flow Direction Grid)*
Decisions needed for calculation		
☐	N/A	
Calculation steps and assumptions		
☐	Identify the Applicable Block Group for each Facility	***Inputs:*** • *Facility shapefile* • *BG shapefile* ***Calculation:*** *Intersect the facility shapefile with the BG shapefile to determine the specific BG in which each facility is located* ***Outputs:*** *Shapefile containing facility points with unique BG identifier*
☐	Determine Block Groups Containing Facilities	***Input:*** *Shapefile containing facility points with unique BG identifier* ***Calculation:*** *For all BGs containing a facility, set the indicator value to 0* ***Output:*** *BG attribute table with field for indicator where value set to 0 for BGs the contain facilities*
☐	Navigation from Facilities	***Inputs:*** • *Shapefile containing facility points with unique BG identifier* • *BG shapefile* ***Calculation:*** *For all facilities* • *Using the raindrop navigation technique, navigate downstream from each facility to create a flow path per facility* • *Intersect each flow path with the BG boundaries* • *Measure length of raindrop flow path line between facility and intersection of BG boundary* • *Report BG identifier, distance, and facility identifier for each facility* ***Output:*** *Facility attribute table of downstream BGs and distances*
☐	Identify Upstream Facilities per Block Group	***Inputs:*** • *BG attribute table with field for indicator where value set to count of facilities within the BG* • *Facility attribute table of downstream BGs and distances* ***Calculation:*** *Join BG attribute table and Facility attribute table on unique BG identifier* ***Output:*** *BG attribute table containing fields for indicator value, upstream facilities, upstream facility distances*

☐	Find Shortest Upstream Distance to a Facility (Indicator)	***Input:*** *BG attribute table containing fields for indicator value, upstream facilities, upstream facility distances*
		Calculation:
		• *For each BG where indicator value is not 0*
		  ○ *Select all corresponding facilities within the table that correspond to the BG*
		  ○ *Take the minimum facility distance from the selected facilities*
		  ○ *Enter this distance as the value for the indicator field for the BG*
		• *Leave each BG with an indicator value of 0 alone*
		Output: *BG attribute table containing field for indicator value (either 0 or shortest hydrologic distance upstream)*

Decisions needed for mapping and interpretation		
☐	Mapping Limited to Block Groups Containing or Downstream of Sites/Waste Facilities	*BGs that are not found to have any sites or waste facilities within their boundaries or upstream of their boundaries should be shown separately (i.e., in gray) and not included in the distance category as these BGs are not considered at risk from this indicator.*
☐	Choosing Symbology	*Maps showing the distribution of shortest hydrologic distance to an upstream facility will generally not be compared across scenarios, time periods, or locations so a single symbology will not be necessary. The symbology will be specific to the data for study area.*
☐	Binning in the Data by Block Group	*The distribution of shortest hydrologic distances will likely be skewed towards values closer to zero, and it is likely that some BGs will have a value of zero since the closest upstream facility will be in the same BG. For this indicator, create a separate bin for a value of zero, and then for the remainder of the data range using quantiles (equal number of observations per bin) is recommended. Use a maximum of 5-7 categories so that the map reader can readily distinguish between color categories and visually match them to the legend. Deciles or other percentiles can also be used depending on user needs.*
☐	Choosing Colors	*Use a color gradation that becomes lighter as the distance values increase. Avoid using a divergent color scheme (darker at both extremes and lighter in the middle), which implies an inflection point such as 0 in a dataset containing positive and negative values.*
Examples of how the indicator can be useful		
☐	Vulnerability due to Overland Contaminant Releases	*This indicator provides the closest upstream hydrologic distance (in terms of overland flow) from a facility to the BG boundary, where the indicator value is zero if at least one facility exists within the BG. When a BG does not contain a facility knowing the closest upstream facility identifies the facility that could contribute contaminants to the lands of a BG during a release event. Therefore, in addition to any facilities within the BG, a community can plan for the types and levels of action needed to mitigate the impacts of potential contaminant releases during an overland flow event.*

☐	Planning for Emergency Containment Methods During a Release	*Understanding how the overland flow from a facility could travel to reach a downstream receiving area (i.e., a BG), provides information on where potential emergency containment methods could be deployed to mitigate releases from a facility to a community. This indicator provides the shortest flow path (and therefore the contributing facility) that could be prioritized for action in planning.*
Key caveats/limitations		
☐	Processing of Raindrop Distances	*There are two options for implementing the raindrop navigation, either through the U.S. EPA's EnviroAtlas Interactive Mapping Raindrop Tool or through creation of custom programming against the NHDPlus Flow Direction Grid. Use of the available online tool is subject to the limitations and set-up described within the tool; however, it is a service requiring minimal input or technical expertise. Creating custom programming given the underlying navigation process allows a user greater flexibility for setting limits or including complex hydrologic situations, but it also requires technical expertise around geospatial processing and the NHDPlus dataset.*
☐	Geopolitical and Hydrologic Boundary Mismatches	*BGs are political boundaries that do not often correspond to elevation contours like the hydrologic boundaries and flowpaths. Because of this mismatch, when trying to determine hydrologically based attributes for a BG there can be results that appear confounding to the casual viewer. For instance, a facility that looks close to a BG boundary may not actually be hydrologically close. That is the surface runoff from that facility may run in the opposite direction, away from the closer political boundary. Results from this indicator should be viewed giving consideration to the local hydrology and surface relief.*
Citations		
	Dataset/Tool	*U.S. EPA. (2021). Get NHDPlus (National Hydrography Dataset Plus) Data. https://www.epa.gov/waterdata/get-nhdplus-national-hydrography-dataset-plus-data* *Bergenroth, B. (2009). Combining vector and raster data for hydro flow analysis: The Raindrop Tool. Oracle Spatial User Conference. Tampa, FL. https://www.oracle.com/technetwork/database/enterprise-edition/osuc2009-raindrop-bergenroth-134405.pdf.* *U.S. EPA. (2022). EnviroAtlas Interactive Map. https://www.epa.gov/enviroatlas/enviroatlas-interactive-map*

BG: Block Group, EPA: U.S. Environmental Protection Agency; NHDPlus: Enhanced National Hydrography Dataset

Indicator 1.3.4. Checklist for Count of Upstream Sites/Waste Facilities within a Specific Hydrologic Distance of a Community Indicator

Count of Upstream Sites/Waste Facilities Within a Specific Hydrologic Distance of Community Indicator		
Definition of the indicator		
☐	Definition	*Count of facilities within a certain (500 m, 1 km, 3 km, or 5 km) upstream "raindrop" distance to a Block Group (BG) boundary, including any facilities within the BG.*
☐	Interpretation	*This indicator examines all facilities within a specified upstream "raindrop" distance, meaning that it reports the count of facilities that have an overland flow path downstream to a BG within a distance relevant to the community and study area. This count represents the number of facilities that could contribute contaminants during an overland flow event (i.e., flooding, heavy precipitation, release with wash off).* *The greater number of facilities upstream (in terms of overland flow) of a BG, the greater the risk of a quantifiable release reaching the community/BG. This indicator is a proxy for size of contamination.*
Data source[16]		
☐	Data Source	*The enhanced National Hydrography Dataset (NHDPlus) medium resolution data*
☐	Temporal Resolution	*This indicator is a static measure without a time component. The measure represents the information available at the time of download.*
☐	Spatial Resolution	• *BG shapefile* • *NHDPlus; Medium resolution* ○ *Flow Direction Grid raster (30m x 30m resolution)* ○ *Flowlines (1:100,000 scale)*
☐	Processing Tool	• *For this indicator, custom code following the methods provided by RTI (see Bergenroth, 2009) to conduct the raindrop navigation was created so that the raindrop navigation could be intersected with BG boundaries rather than an NHDPlus flowline. The code requires the NHDPlus Flow Direction Grid raster.* • *The "Raindrop Tool" provides the basic overland navigation analysis but does not allow for navigation to boundaries other than NHD flowlines. The tool could be explored for the calculation of the indicator but would require additional processing.*
☐	Data Format	• *Spreadsheet (Site/Waste Facility)* • *Shapefile (BG, NHDPlus)* • *Raster (Flow Direction Grid)*

[16] For further details on site/waste facility data (data source, decisions for calculations and vetting), see Indicator 1.2.1.

Decisions needed for calculation		
☐	Distance Limit for Counting	*There is a continuous range of values among the calculated distances upslope from each BG boundary. Therefore, depending on the local study area conditions (e.g., relief, stormwater infrastructure, soil hydrologic group) different limits on the distance upstream from a BG are applicable to assess a risk of contamination from overland flow. Suggested limits for distance counts include 500 m, 1 km, 3 km, and 5 km. The smallest distance limit, 500 m, may be applicable for densely populated areas, whereas larger distance limits may be applicable in areas with less development.*
Calculation steps and assumptions		
☐	Identify the Applicable Block Group for Each Facility	***Inputs:*** • *Facility shapefile* • *BG shapefile* ***Calculation:*** *Intersect the facility shapefile with the BG shapefile to determine the specific BG in which each facility is located* ***Outputs:*** *Shapefile containing facility points with unique BG identifier*
☐	Determine Number of Facilities within Each Block Group	***Input:*** *Shapefile containing facility points with unique BG identifier* ***Calculation:*** *For all BGs, count the number of facilities within the BG* ***Output:*** *BG attribute table with field for indicator where value set to count of facilities within the BG*
☐	Navigation from Facilities	***Inputs:*** • *Shapefile containing facility points with unique BG identifier* • *BG shapefile* ***Calculation:*** *For all facilities* • *Using the raindrop navigation technique, navigate downstream from each facility to create a flow path per facility* • *Intersect each flow path with the BG boundaries* • *Measure length of raindrop flow path line between facility and intersection of BG boundary* • *Report BG identifier, distance, and facility identifier for each facility* ***Output:*** *Facility attribute table of downstream BGs and distances*
☐	Identify Upstream Facilities per BG	***Inputs:*** • *BG attribute table with field for indicator where value set to count of facilities within the BG* • *Facility attribute table of downstream BGs and distances* ***Calculation:*** *Join BG attribute table and Facility attribute table on unique BG identifier* ***Output:*** *BG attribute table containing fields for indicator value, upstream facilities, upstream facility distances*

☐	Count Facilities within Specified Upstream Distance (Indicator)	***Input:*** *BG attribute table containing fields for indicator value, upstream facilities, upstream facility distances* ***Calculation:*** • *For all BGs, select all corresponding facilities within the table that have a downstream distance less than or equal to the specified upstream distance (500 m, 1 km, 3 km, or 5 km)* • *Count the selected facilities by BG identifier* • *Add this count to the value within the indicator column of the attribute table* ***Output:*** *Count of facilities within the specified upstream distance (500 m, 1 km, 3 km, or 5 km) per BG*
Decisions needed for mapping and interpretation		
☐	Mapping Limited to Block Groups Containing Counts	*All BGs will have valid values, including zero.*
☐	Choosing Symbology	*Maps showing the distribution of counts of sites will generally not be compared across scenarios, time periods, or locations so a single symbology will not be necessary. The symbology will be specific to the data for study area.*
☐	Binning in the Data by Block Group	*The distribution of counts of sites will likely be skewed towards values closer to zero. For this situation using quantiles (equal number of observations per bin) is recommended. Use a maximum of 5-7 categories so that the map reader can readily distinguish between color categories and visually match them to the legend. Deciles or other percentiles can also be used depending on user needs.*
☐	Choosing Colors	*Use a color gradation that becomes darker as the count values increase. Avoid using a divergent color scheme (darker at both extremes and lighter in the middle), which implies an inflection point such as 0 in a dataset containing positive and negative values.*
Examples of how the indicator can be useful		
☐	Vulnerability due to Overland Contaminant Releases	*This indicator provides the number of facilities within a specified upstream distance (in terms of overland flow) of a BG, taking into account only facilities that could contribute releases within a surface runoff event either without or outside of the BG boundary. By understanding the potential number of facilities that could contribute contaminants to the lands of a BG during a release event, a community can plan for the types and levels of action needed to mitigate the impacts.*
☐	Planning for Emergency Containment Methods During a Release	*Understanding how the overland flow from a facility could travel to reach a downstream receiving area (i.e., a BG), provides information on where potential emergency containment methods could be deployed to mitigate releases from a facility to a community. This indicator provides a count of a how many facilities and corresponding flow paths should be considered in planning.*

Key caveats/limitations		
☐	Processing of Raindrop Distances	*There are two options for implementing the raindrop navigation, either through the U.S. EPA's EnviroAtlas Interactive Mapping Raindrop Tool or through creation of custom programming against the NHDPlus Flow Direction Grid. Use of the available online tool is subject to the limitations and set-up described within the tool; however, it is a service requiring minimal input or technical expertise. Creating custom programming given the underlying navigation process allows a user greater flexibility for setting limits or including complex hydrologic situations, but it also requires technical expertise around geospatial processing and the NHDPlus dataset.*
☐	Geopolitical and Hydrologic Boundary Mismatches	*BGs are political boundaries that do not often correspond to elevation contours like the hydrologic boundaries and flowpaths. Because of this mismatch, when trying to determine hydrologically based attributes for a BG there can be results that appear confounding to the casual viewer. For instance, a facility that looks close to a BG boundary may not actually be hydrologically close. That is the surface runoff from that facility may run in the opposite direction, away from the closer political boundary. Results from this indicator should be viewed giving consideration to the local hydrology and surface relief.*
Citations		
	Dataset/Tool	U.S. EPA. (2021). Get NHDPlus (National Hydrography Dataset Plus) Data. https://www.epa.gov/waterdata/get-nhdplus-national-hydrography-dataset-plus-data Bergenroth, B. (2009). Combining vector and raster data for hydro flow analysis: The Raindrop Tool. Oracle Spatial User Conference. Tampa, FL. https://www.oracle.com/technetwork/database/enterprise-edition/osuc2009-raindrop-bergenroth-134405.pdf. U.S. EPA. (2022). EnviroAtlas Interactive Map. https://www.epa.gov/enviroatlas/enviroatlas-interactive-map

BG: Block Group, EPA: U.S. Environmental Protection Agency; NHDPlus: Enhanced National Hydrography Dataset

Indicator 1.3.5. Checklist for Shortest Distance to a Site/Waste Facility Upwind [Season] Indicator

Shortest Distance to a Site/Waste Facility Upwind [Season] Indicator		
Definition of the indicator		
☐	Definition	*The shortest distance between a community and a nearby facility that is in the predominant upwind direction. Predominant wind direction refers to the direction from which the wind blows for most of the time during the season, calculated based on historical wind patterns.*
☐	Interpretation	*The shorter the distance, the greater the risk of the community being impacted by emissions from the facility.* *Since the predominant wind direction may change by season, this indicator is developed for each season. This implies that the list of facilities that pose a risk to the community may be different in each season. We define seasons as follows: winter (December–February), spring (March–May), summer (June–August), and fall (September–November).*
Data source[17]		
☐	Data Source	*The National Oceanic and Atmospheric Administration (NOAA)'s North American Mesoscale Forecast System (NAM) Analyses (NAM-ANL) model data. The NAM model is run by the National Centers for Environmental Prediction (NCEP) for forecasting weather on daily basis.*
☐	Temporal Resolution	*Model simulations were available at four time periods per day corresponding to the start of each forecast simulation: 0000 hours UTC time, 0600 hours UTC, 1200 hours UTC, and 1800 hours UTC. These are normally referred to as 00z, 06z, 12z, and 18z model cycles, respectively.* *Data are available from 2006 to present.*
☐	Spatial Resolution	*12-km grid resolution, continental United States (CONUS)*
☐	Data Format	*GRIB2*

[17] For further details on site/waste facility data (data source, decisions for calculations and vetting), see Indicator 1.2.1.

Decisions needed for calculation		
☐	Model Cycles and Variables	*Incorporating higher time resolution data would enable capturing diurnal variability. However, the choice is also dependent on the computational resources available, and the study timeframe and objectives. At least two model cycles are recommended. Model cycles 00z and 12z are generally considered more reliable due to the extent of assimilation of observational data used for forecast simulations and are recommended for the development of the indicators.* *The wind vector components (UGRD, u wind [m/s] and VGRD, v wind [m/s]) are available at multiple heights (or atmospheric pressure equivalents). We recommend using 10 m height to be consistent with the height at which anemometer measurements are made and to represent wind patterns closer to the surface.* *The "UGRD: 10 m above gnd" and "VGRD: 10 m above gnd" variables representing, respectively, the U and V vector components of wind at 10 m above ground were extracted.*
☐	Wind Direction Sectors	*Choose how fine a resolution you want to resolve the wind direction (e.g., 36 bins of 10° each, or 12 bins of 30° each). The finer the resolution, the more specific and narrow the risk profile will be. For climatological indicators, and given the inherent uncertainty in the forecast simulations, it is recommended to choose a larger wind sector. It would also be easier to interpret.* *We recommend using four sectors of 90° each aligning with the common wind direction terminologies: northeast (NE: 0-90°), southeast (SE: 90°-180°), southwest (SW: 180°-270°) and northwest (NW: 270-360°).*
Calculation steps and assumptions		
☐	Assumptions and Calculations	*The overall approach involves the following steps:* • *Overlay the site/waste facility and Block Group (BG) information on the model data to define a common grid ID* • *Analyze the wind data to understand the frequency of wind speeds and wind directions by season* • *Identify the quadrant (NE, SE, SW, NW) a facility is in relative to the community BG* • *For each grid ID, summarize the calculated wind distribution data for each quadrant to list predominant wind direction and the maximum wind speed in that direction* • *Calculate the time by dividing the straight-line distance from the facility to the centroid of the BG by the wind speed* • *Calculate the relevant metrics* *The shortest distance to a facility is obtained by calculating for each season the minimum value of the distance between the BG and the different facilities.*

☐	Import Model Data into Common Grid System and Extract Model Data	***Inputs:*** • *NAM model data file* • *Shapefile with facilities and BG* ***Calculation:*** • *Superimpose the NAM model grid on facilities and BG using ArcGIS. Develop a mapping linking each facility and centroid of BG and the NAM model grid and create a common mapping grid with a unique grid ID.* • *Calculate the straight-line distance between each combination of facility and census BG.* ***Outputs:*** • *Text file (csv format) with the mapping of facility, BG, unique grid ID and distance between facility and BG* • *Text file (csv format) of extracted UGRD and VGRD values with the matched unique grid ID*
☐	Read Model Data and Calculate Wind Speed and Wind Direction	***Input****: Text file with extracted UGRD and VGRD values* ***Calculations:*** • *Read "u" and "v" component values and calculate scalar wind speed and wind direction.* • *Plot windrose (USDA, 2022) by season. Choose wind speed cutoffs of 2 m/s, 4 m/s, 6 m/s, 10 m/s, and >10 m/s* • *Calculate the cumulative percent of time the wind is blowing from each wind direction sector (e.g., NE, SE) at wind speeds within each cutoff (< 2m/s, < 4m/s, etc.).* • *Calculate percent of time in each speed bin (e.g., 0-2 m/s, 2-4 m/s), and normalize it to calculate relative fractions in each speed bin (e.g., % time in 2-4 m/s bin as a fraction of total cumulative time in that wind direction). This estimate is used to calculate a weighted average wind speed in each wind direction sector for each season.* • *Calculate a weighted wind speed by adding the product of the relative fraction in each speed bin by the top end of the speed bin. For the >10 m/s wind speed bin, use the maximum wind speed. Using the maximum speed in each bin results in a conservative estimate.* ***Output:*** • *Text file (csv format) summarizing the calculated cumulative percent time, the relative fraction within each speed bin, and the weighted wind speed for each wind direction sector.*
☐	Identify Quadrant that the Facility Is Located in Relative to the Block Group	***Input:*** *Text file (csv format) with the mapping of facility, BG, unique grid ID, and distance between facility and BG* ***Calculation:*** *Determine where the facility coordinates (latitude and longitude) fall in relation to the BG centroid coordinates. Accordingly categorize the quadrant that the facility is in relative to the BG as NE, SE, SW, and NW.* ***Output:*** *Quadrant information for each facility and BG combination.*

☐	Calculate Metric	***Inputs:*** • *Text file (csv format) summarizing the calculated cumulative percent time, the relative fraction within each speed bin, and the weighted wind speed for each wind direction sector* • *Quadrant information for each facility and BG combination* ***Calculation:*** • *Link the two datasets using the common grid ID* • *In the wind data file, assign quadrant based on the wind direction* • *For each quadrant (e.g., NE, SE) relative to the BG under consideration, assign the weighted average wind speed and the cumulative percent time that wind blows from that quadrant by season* • *Take the minimum of the distance between all facility and BG combinations in that quadrant for each season. This gives the shortest distance.*
Decisions needed for mapping and interpretation		
☐	Mapping Limited to Block Groups Containing Data	*NA - BGs will all have distance values*
☐	Choosing a Symbology	*The recommended symbology for this indicator is a single unique symbology that spans seasons. This will result in the same color representing the same value across the maps, making direct comparisons much easier. To build this, find the minimum and maximum values across seasons, and then use the full range of values to create a single unique symbology to apply to all maps.*
☐	Binning in the Data by Block Group	*For this indicator, using quantiles (equal number of observations per bin) is recommended. Using a maximum of 5-7 categories is also recommended so that the map reader can readily distinguish between color categories and visually match them to the legend. However, deciles or other percentiles can also be used depending on user needs.*
☐	Choosing Colors	*Use a color gradation that becomes lighter as the distance values increase. Avoid using a divergent color scheme (darker at both extremes and lighter in the middle), which implies an inflection point such as 0 in a dataset containing positive and negative values.*
Examples of how the indicator can be useful		
☐	Adaptation Planning/ Emergency Response	*This indicator provides an estimate of how close the community is to sites/waste facilities with potentially hazardous emissions during extreme events. The indicator provides valuable information on which communities are at risk in the event of an emergency and how to prioritize response. For example, BGs with shorter distances (darkest color) may need to be evacuated or addressed first in the event of an emergency.*

Key caveats/limitations		
☐	Representative-ness	• *Since the indicators are developed for adaptation planning and preparedness for extreme events, the indicators represent a worst-case estimate based on nearest facilities, wind speed and wind direction, without air dispersion modeling. This approach does not account for geographical features (e.g., mountains) that may impact the movement of wind.* • *The values are based on analysis of wind patterns for one year. This analysis will need to be performed over a longer period (e.g., 10 years) to capture long-term climatological patterns.* • *The underlying data are based on weather forecasts and not actual point measurements or modeled retrospective reanalysis meteorological fields. While the forecasts are typically reliable and representative, there may be minor differences between actual meteorology and weather forecasts.* • *For certain locations such as coastal communities, the wind direction may change frequently, and the predominant wind direction may not necessarily be representative every year. This could be mitigated by using multiple years to get a true climatological profile as noted above.*
Citations		
	Dataset/Tool	*NOAA NCEI. (n.d.) North American Mesoscale Forecast System. https://www.ncei.noaa.gov/products/weather-climate-models/north-american-mesoscale. Recent model data available at https://www.ncei.noaa.gov/data/north-american-mesoscale-model/access/. Historical data are available at https://www.ncei.noaa.gov/data/north-american-mesoscale-model/access/historical/analysis/.*
	Additional Resources	*Grange, S. K. (2014). Technical note: Averaging wind speeds and directions. DOI: 10.13140/RG.2.1.3349.2006.* *USDA. (2022). Wind rose resources. https://www.nrcs.usda.gov/wps/portal/wcc/home/climateSupport/windRoseResources/*

BG: Block Group, CONUS: Continental United States, NAM-ANL: North American Mesoscale Forecast System Analyses, NCEP: National Centers for Environmental Prediction, NOAA: National Oceanic and Atmospheric Administration

Indicator 1.3.6. Checklist for Count of Sites/Waste Facilities "Upwind" within a Specific Season and Distance of a Community Indicator

Count of Sites/Waste Facilities "Upwind" within a Specific Season and Distance of a Community Indicator		
Definition of the indicator		
☐	Definition	*The number of facilities that are in the predominant upwind direction with specified distances from the community. Predominant wind direction refers to the direction from which the wind blows for most of the time during the season, calculated based on historical wind patterns.*
☐	Interpretation	*The larger the number of facilities, the greater the risk for a potential aggregated impact if all facilities were to fail at the same time during an extreme event. Since the predominant wind direction may change by season, this indicator is developed for each season. This implies that the list of facilities that pose a risk to the community may be different in each season. We define seasons as follows: winter (December–February), spring (March–May), summer (June–August), and fall (September–November).*
Data source[18]		
☐	Data Source	*The National Oceanic and Atmospheric Administration (NOAA)'s North American Mesoscale Forecast System (NAM) Analyses (NAM-ANL) model data. The NAM model is run by the National Centers for Environmental Prediction (NCEP) for forecasting weather on daily basis.*
☐	Temporal Resolution	*Model simulations were available at four time periods per day corresponding to the start of each forecast simulation: 0000 hours UTC time, 0600 hours UTC, 1200 hours UTC, and 1800 hours UTC. These are normally referred to as 00z, 06z, 12z, and 18z model cycles, respectively.* *Data are available from 2006 to present.*
☐	Spatial Resolution	*12-km grid resolution, continental United States (CONUS)*
☐	Data Format	*GRIB2*

[18] For further details on site/waste facility data (data source, decisions for calculations and vetting), see Indicator 1.2.1.

Decisions needed for calculation		
☐	Model Cycles and Variables	*Incorporating higher time resolution data would enable capturing diurnal variability. However, the choice is also dependent on the computational resources available, and the study timeframe and objectives. At least two model cycles are recommended. Model cycles 00z and 12z are generally considered more reliable due to the extent of assimilation of observational data used for forecast simulations and are recommended for the development of the indicators.* *The wind vector components (UGRD, u wind [m/s] and VGRD, v wind [m/s]) are available at multiple heights (or atmospheric pressure equivalents). We recommend using 10 m height to be consistent with the height at which anemometer measurements are made and to represent wind patterns closer to the surface.* *The "UGRD: 10 m above gnd" and "VGRD: 10 m above gnd" variables representing, respectively, the U and V vector components of wind at 10 m above ground were extracted.*
☐	Wind Direction Sectors	*Choose how fine a resolution you want to resolve the wind direction (e.g., 36 bins of 10° each, or 12 bins of 30° each). The finer the resolution, the more specific and narrow the risk profile will be. For climatological indicators, and given the inherent uncertainty in the forecast simulations, it is recommended to choose a larger wind sector. It would also be easier to interpret.* *We recommend using four sectors of 90° each aligning with the common wind direction terminologies: northeast (NE: 0-90°), southeast (SE: 90°-180°), southwest (SW: 180°-270°) and northwest (NW: 270-360°).*
☐	Distance Limit for Counting	*There is a continuous range of values among the calculated distances upwind from each Block Group (BG). Therefore, depending on the local study area conditions (e.g., size of counties /BG, population distribution, density of facilities, typical wind conditions) different limits on the distance upwind from a BG are applicable to assess a risk of exposure from the facilities. Look at the percentile distribution of distances to come up with suitable distance limits. Suggested limits for distance counts include 1 km, 2 km, 4 km and 5 km for short distance ranges, and 5 km, 15 km, 25 km and 40 km for large distance ranges. The smaller distance limits may be applicable for densely populated areas, whereas larger distance limits may be applicable in areas with less development.*

Calculation steps and assumptions		
☐	Assumptions and Calculations	*The overall approach involves the following steps:* • *Overlay the site/waste facility and BG information on the model data to define a common grid ID* • *Analyze the wind data to understand the frequency of wind speeds and wind directions by season* • *Identify the quadrant (NE, SE, SW, NW) a facility is in relative to the community BG* • *For each grid ID, summarize the calculated wind distribution data for each quadrant to list predominant wind direction and the maximum wind speed in that direction* • *Calculate the time by dividing the straight-line distance from the facility to the centroid of the BG by the wind speed* • *Calculate the relevant metrics* *The number of facilities for each specified distance is obtained by calculating for each season the total count of facilities in the predominant wind direction.*
☐	Import Model Data into Common Grid System and Extract Model Data	***Inputs:*** • *NAM model data file* • *Shapefile with facilities and BG* ***Calculation:*** • *Superimpose the NAM model grid on facilities and BG using ArcGIS. Develop a mapping linking each facility and centroid of BG and the NAM model grid and create a common mapping grid with a unique grid ID.* • *Calculate the straight-line distance between each combination of facility and the centroid of the census BG.* ***Outputs:*** • *Text file (csv format) with the mapping of facility, BG, unique grid ID and distance between facility and BG* • *Text file (csv format) of extracted UGRD and VGRD values with the matched unique grid ID*

☐	Read Model Data and Calculate Wind Speed and Wind Direction	***Input:*** *Text file with extracted UGRD and VGRD values* ***Calculations:*** • *Read "u" and "v" component values and calculate scalar wind speed and wind direction.* • *Plot windrose (USDA, 2022) by season. Choose wind speed cutoffs of 2 m/s, 4 m/s, 6 m/s, 10 m/s and >10 m/s* • *Calculate the cumulative percent of time the wind is blowing from each wind direction sector (e.g., NE, SE) at wind speeds within each cutoff (< 2m/s, < 4m/s, etc.).* • *Calculate percent of time in each speed bin (e.g., 0-2 m/s, 2-4 m/s), and normalize it to calculate relative fractions in each speed bin (e.g., % time in 2-4 m/s bin as a fraction of total cumulative time in that wind direction). This estimate is used to calculate a weighted average wind speed in each wind direction sector for each season.* ***Output:*** • *Text file (csv format) summarizing the calculated cumulative percent time and the relative fraction within each speed bin for each season.*
☐	Identify Quadrant that the Facility Is Located in Relative to the Block Group	***Input:*** *Text file (csv format) with the mapping of facility, BG, unique grid ID and distance between facility and BG* ***Calculation:*** *Determine where the facility coordinates (latitude and longitude) fall in relation to the BG centroid coordinates. Accordingly categorize the quadrant that the facility is in relative to the BG as NE, SE, SW, and NW.* ***Output:*** *Quadrant information for each facility and BG combination.*
☐	Calculate Metric	***Inputs:*** • *Text file (csv format) summarizing the calculated cumulative percent time, and the relative fraction within each speed bin for each season.* • *Quadrant information for each facility and BG combination* ***Calculation*** • *Link the two datasets using the common grid ID.* • *In the wind data file, assign quadrant based on the wind direction.* • *For each quadrant (e.g., NE, SE) relative to the BG under consideration, assign the cumulative percent time that wind blows from that quadrant by season.* • *Count the number of facilities that fall within specified distance limits for each season.*
Decisions needed for mapping and interpretation		
☐	Mapping Limited to Block Groups Containing Data	*NA - BGs will all have count values. Zero is a valid value.*

☐	Choosing a Symbology	*The recommended symbology for this indicator is a single unique symbology that spans seasons for any given distance. This will result in the same color representing the same value across the maps, making direct comparisons much easier. To build this, find the minimum and maximum values across seasons for each distance, and then use the full range of values to create a single unique symbology to apply to all maps.*
☐	Binning in the Data by Block Group	*For this indicator using quantiles (equal number of observations per bin) is recommended. Using a maximum of 5-7 categories is also recommended so that the map reader can readily distinguish between color categories and visually match them to the legend. However, deciles or other percentiles can also be used depending on user needs.*
☐	Choosing Colors	*Use a color gradation that becomes darker as the count values increase. Avoid using a divergent color scheme (darker at both extremes and lighter in the middle), which implies an inflection point such as 0 in a dataset containing positive and negative values.*
Examples of how the indicator can be useful		
☐	Adaptation Planning/ Emergency Response	*This indicator provides an estimate of how many facilities have the potential to impact the community during extreme events. The indicator provides valuable information on which communities are at risk in the event of an emergency and how to prioritize response. By understanding the potential number of facilities whose emissions could impact the BG during a release event, a community can plan for the types and levels of action needed to mitigate the impacts.*
Key caveats/limitations		
☐	Representative-ness	• *Since the indicators are developed for adaptation planning and preparedness for extreme events, the indicators represent a worst-case estimate based on nearest facilities, wind speed and wind direction, without air dispersion modeling. This approach does not account for geographical features (e.g., mountains) that may impact the movement of wind.* • *The values are based on analysis of wind patterns for one year. This analysis will need to be performed over a longer period (e.g., 10 years) to capture long-term climatological patterns.* • *The underlying data are based on weather forecasts and not actual point measurements or modeled retrospective reanalysis meteorological fields. While the forecasts are typically reliable and representative, there may be minor differences between actual meteorology and weather forecasts. The indicator does not categorize by the nature of the facility or by the potential risk of air emissions.* • *For certain locations such as coastal communities, the wind direction may change frequently, and the predominant wind direction may not necessarily be representative every year. This could be mitigated by using multiple years to get a true climatological profile as noted above.*

Citations		
	Dataset/Tool	*NOAA NCEI. (n.d.) North American Mesoscale Forecast System. https://www.ncei.noaa.gov/products/weather-climate-models/north-american-mesoscale. Recent model data available at https://www.ncei.noaa.gov/data/north-american-mesoscale-model/access/. Historical data are available at https://www.ncei.noaa.gov/data/north-american-mesoscale-model/access/historical/analysis/*
	Additional Resources	*Grange, S. K. (2014). Technical note: Averaging wind speeds and directions. DOI: 10.13140/RG.2.1.3349.2006.* *USDA. (2022). Wind rose resources. https://www.nrcs.usda.gov/wps/portal/wcc/home/climateSupport/windRoseResources/*
	Reference	*Technical note: Averaging wind speeds and directions, June 2014. DOI: 10.13140/RG.2.1.3349.2006.*

BG: Block Group, CONUS: Continental United States, NAM-ANL: North American Mesoscale Forecast System Analyses, NCEP: National Centers for Environmental Prediction, NOAA: National Oceanic and Atmospheric Administration

Indicator 1.3.7. Checklist for Minimum Response Time, [by Season] Indicator

Minimum Response Time, [by Season] Indicator		
Definition of the indicator		
☐	Definition	*The minimum time that a community has to respond before being impacted by emissions from nearby facility(ies) during extreme events.*
☐	Interpretation	*The lower the response time, the greater the risk to the community. Communities with very low response time are at higher risk compared to communities that have large response times.* *Since the predominant wind direction may change by season, this indicator is developed for each season. This implies that the list of facilities that pose a risk to the community may be different in each season. We define seasons as follows: winter (December–February), spring (March–May), summer (June–August), and fall (September–November).*
Data source[19]		
☐	Source	*The National Oceanic and Atmospheric Administration (NOAA)'s North American Mesoscale Forecast System (NAM) Analyses (NAM-ANL) model data. The NAM model is run by the National Centers for Environmental Prediction (NCEP) for forecasting weather on daily basis.*
☐	Temporal resolution	*Model simulations were available at four time periods per day corresponding to the start of each forecast simulation: 0000 hours UTC time, 0600 hours UTC, 1200 hours UTC, and 1800 hours UTC. These are normally referred to as 00z, 06z, 12z, and 18z model cycles, respectively.* *Data are available from 2006 to present.*
☐	Spatial resolution	*12-km grid resolution, continental United States (CONUS)*
☐	Data format	*GRIB2*

[19] For further details on site/waste facility data (data source, decisions for calculations and vetting), see Indicator 1.2.1.

Decisions needed for calculation		
☐	Model Cycles and Variables	*Incorporating higher time resolution data would enable capturing diurnal variability. However, the choice is also dependent on the computational resources available, and the study timeframe and objectives. At least two model cycles are recommended. Model cycles 00z and 12z are generally considered more reliable due to the extent of assimilation of observational data used for forecast simulations and are recommended for the development of the indicators.* *The wind vector components (UGRD, u wind [m/s] and VGRD, v wind [m/s]) are available at multiple heights (or atmospheric pressure equivalents). We recommend using 10 m height to be consistent with the height at which anemometer measurements are made and to represent wind patterns closer to the surface.* *The "UGRD: 10 m above gnd" and "VGRD: 10 m above gnd" variables representing, respectively, the U and V vector components of wind at 10 m above ground were extracted.*
Calculation steps and assumptions		
☐	Assumptions and Calculations	*The overall approach involves the following steps:* • *Overlay the site/waste facility and Block Group (BG) information on the model data to define a common grid ID* • *Analyze the wind data to understand the frequency of wind speeds and wind directions by season* • *Identify the quadrant (NE, SE, SW, NW) a facility is in relative to the community BG* • *For each grid ID, summarize the calculated wind distribution data for each quadrant to list predominant wind direction and the maximum wind speed in that direction* • *Calculate the time by dividing the straight-line distance from the facility to the centroid of the BG by the wind speed* • *Calculate the relevant metrics* *The minimum response time is obtained by calculating for each season the minimum value of the travel time for the air based on distance and wind speed.*
☐	Import Model Data into Common Grid System and Extract Model Data	***Inputs:*** • *NAM model data file* • *Shapefile with facilities and BG* ***Calculation:*** • *Superimpose the NAM model grid on facilities and BG using ArcGIS. Develop mapping linking each facility and centroid of the BG and the NAM model grid and create a common mapping grid with a unique grid ID.* • *Calculate the straight-line distance between each combination of facility and census BG.* ***Outputs:*** • *Text file (csv format) with the mapping of facility, BG, unique grid ID and distance between facility and BG* • *Text file (csv format) of extracted UGRD and VGRD values with the matched unique grid ID*

☐	Read Model Data and Calculate Wind Speed and Wind Direction	***Input****: Text file with extracted UGRD and VGRD values* ***Calculations:*** • *Read "u" and "v" component values and calculate scalar wind speed and wind direction.* • *Plot windrose (USDA, 2022) by season. Choose wind speed cutoffs of 2 m/s, 4 m/s, 6 m/s, 10 m/s, and >10 m/s* • *Calculate the cumulative percent of time the wind is blowing from each wind direction sector (e.g., NE, SE) at wind speeds within each cutoff (< 2m/s, < 4m/s, etc.).* • *Calculate percent of time in each speed bin (e.g., 0-2 m/s, 2-4 m/s), and normalize it to calculate relative fractions in each speed bin (e.g., % time in 2-4 m/s bin as a fraction of total cumulative time in that wind direction). This estimate is used to calculate a weighted average wind speed in each wind direction sector for each season.* • *Calculate a weighted wind speed by adding the product of the relative fraction in each speed bin by the top end of the speed bin. For the >10 m/s wind speed bin, use the maximum wind speed. Using the maximum speed in each bin results in a conservative estimate.* ***Output:*** • *Text file (csv format) summarizing the calculated cumulative percent time, the relative fraction within each speed bin, and the weighted wind speed for each wind direction sector.*
☐	Identify Quadrant that the Facility Is Located in Relative to the Block Group	***Input:*** *Text file (csv format) with the mapping of facility, BG, unique grid ID, and distance between facility and BG* ***Calculation:*** *Determine where the facility coordinates (latitude and longitude) fall in relation to the BG centroid coordinates. Accordingly categorize the quadrant that the facility is in relative to the BG as NE, SE, SW, and NW.* ***Output:*** *Quadrant information for each facility and BG combination.*
☐	Calculate Metric	***Inputs:*** • *Text file (csv format) summarizing the calculated cumulative percent time, the relative fraction within each speed bin, and the weighted wind speed for each wind direction sector* • *Quadrant information for each facility and BG combination* ***Calculation:*** • *Link the two datasets using the common grid ID* • *In the wind data file, assign quadrant based on the wind direction* • *For each quadrant (e.g., NE, SE) relative to the BG under consideration, assign the weighted average wind speed and the cumulative percent time that wind blows from that quadrant by season* • *For each BG, calculate the response time for impact from each facility by dividing its distance from the BG by the weighted average wind speed for each season. Take the minimum of all the response times across all facilities for each BG by season.*

Decisions needed for mapping and interpretation		
☐	Mapping Limited to Block Groups Containing Data	*NA - BGs will all have response time values.*
☐	Choosing a Symbology	*The recommended symbology for this indicator is a single unique symbology that spans seasons. This will result in the same color representing the same value across the maps, making direct comparisons much easier. To build this, find the minimum and maximum values across seasons, and then use the full range of values to create a single unique symbology to apply to all maps.*
☐	Binning in the Data by Block Group	*For this indicator using quantiles (equal number of observations per bin) is recommended. Using a maximum of 5-7 categories is also recommended so that the map reader can readily distinguish between color categories and visually match them to the legend. However, deciles or other percentiles can also be used depending on user needs. An alternative would be to use equal intervals.*
☐	Choosing Colors	*Use a color gradation that becomes lighter as the minimum response time values increase. Avoid using a divergent color scheme (darker at both extremes and lighter in the middle), which implies an inflection point such as 0 in a dataset containing positive and negative values.*
Examples of how the indicator can be useful		
☐	Adaptation Planning/ Emergency Response	*This indicator provides an estimate of how much time a community has to respond before being impacted by potentially hazardous emissions from nearby site/waste facilities during extreme events. The indicator provides valuable information on which communities are at risk during an extreme event and how to prioritize response. For example, BGs with shorter response times (darkest color) may need to be evacuated or addressed first in the event of an emergency. If the response time is on the order of a few seconds, it also implies that those communities will need to develop and maintain as part of its disaster response plans, clearly defined actions that can be implemented swiftly during an emergency. In other words, the community will not have time to develop response strategies during an extreme event emergency.* *The indicator can be used to identify priorities for preparedness activities such as cleanup and maintenance of sites/waste facilities that are within short response times. It can also inform longer term adaptation planning. For example, new assisted care facilities should not be built in BGs with shorter response times.* *Depending on how different the response times are across seasons, the strategy may also need to differ by season.*

Key caveats/limitations		
☐	Representative-ness	• *Since the indicators are developed for adaptation planning and preparedness for extreme events, the indicators represent a worst-case estimate based on nearest facilities, wind speed and wind direction, without air dispersion modeling. This approach does not account for geographical features (e.g., mountains) that may impact the movement of wind.* • *The values are based on analysis of wind patterns for one year. This analysis will need to be performed over a longer period (e.g., 10 years) to capture long-term climatological patterns.* • *The underlying data are based on weather forecasts and not actual point measurements or modeled retrospective reanalysis meteorological fields. While the forecasts are typically reliable and representative, there may be minor differences between actual meteorology and weather forecasts.* • *For certain locations such as coastal communities, the wind direction may change frequently, and the predominant wind direction may not necessarily be representative every year. This could be mitigated by using multiple years to get a true climatological profile as noted above.*
Citations		
	Dataset/Tool	*NOAA NCEI. (n.d.) North American Mesoscale Forecast System. https://www.ncei.noaa.gov/products/weather-climate-models/north-american-mesoscale. Recent model data available at https://www.ncei.noaa.gov/data/north-american-mesoscale-model/access/. Historical data are available at https://www.ncei.noaa.gov/data/north-american-mesoscale-model/access/historical/analysis/*
	Additional Resources	*Grange, S. K. (2014). Technical note: Averaging wind speeds and directions. DOI: 10.13140/RG.2.1.3349.2006.* *USDA. (2022). Wind rose resources. https://www.nrcs.usda.gov/wps/portal/wcc/home/climateSupport/windRoseResources/*

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Indicator 1.3.8. Checklist for Count of Sites/Waste Facilities That Are within Specific Response Time Ranges, [by Season] Indicator

Count of Sites/Waste Sites/Waste Facilities That Are within Specific Response Time Ranges, [by Season] Indicator		
Definition of the indicator		
☐	Definition	*The number of facilities that have the potential to impact a community within a specified response time.*
☐	Interpretation	*The larger the number of facilities within a short response time window from the BG, the greater the risk for a potential aggregated impact if all facilities were to fail at the same time during an extreme event.*
Data source[20]		
☐	Data Source	*The National Oceanic and Atmospheric Administration (NOAA)'s North American Mesoscale Forecast System (NAM) Analyses (NAM-ANL) model data. The NAM model is run by the National Centers for Environmental Prediction (NCEP) for forecasting weather on daily basis.*
☐	Temporal Resolution	*Model simulations were available at four time periods per day corresponding to the start of each forecast simulation: 0000 hours UTC time, 0600 hours UTC, 1200 hours UTC, and 1800 hours UTC. These are normally referred to as 00z, 06z, 12z, and 18z model cycles, respectively.* *Data are available from 2006 to present.*
☐	Spatial Resolution	*12-km grid resolution, continental United States (CONUS)*
	Data Format	*GRIB2*
Decisions needed for calculation		
☐	Model Cycles and Variables	*Incorporating higher time resolution data would enable capturing diurnal variability. However, the choice is also dependent on the computational resources available, and the study timeframe and objectives. At least two model cycles are recommended. Model cycles 00z and 12z are generally considered more reliable due to the extent of assimilation of observational data used for forecast simulations and are recommended for the development of the indicators.* *The wind vector components (UGRD, u wind [m/s] and VGRD, v wind [m/s]) are available at multiple heights (or atmospheric pressure equivalents). We recommend using 10 m height to be consistent with the height at which anemometer measurements are made and to represent wind patterns closer to the surface.* *The "UGRD: 10 m above gnd" and "VGRD: 10 m above gnd" variables representing, respectively, the U and V vector components of wind at 10 m above ground were extracted.*

[20] For further details on site/waste facility data (data source, decisions for calculations and vetting), see Indicator 1.2.1.

☐	Time Limits for Counting	*There is a continuous range of values among the calculated response times for each BG. Therefore, depending on the local study area conditions (e.g., size of counties /BG, population distribution, density of facilities, typical wind conditions) different limits on the response time for a BG are applicable to assess a risk of exposure from the facilities. Look at the percentile distribution of response times to come up with suitable response time limits, including some lower end time limits on the order of seconds or a few minutes to capture facilities that pose the greatest risk. Suggested limits for response times include 2 min, 5 min, 10 min, 15 min and 20 min.*
Calculation steps and assumptions		
☐	Assumptions and Calculations	*The overall approach involves the following steps:* • *Overlay the site/waste facility and BG information on the model data to define a common grid ID* • *Analyze the wind data to understand the frequency of wind speeds and wind directions by season* • *Identify the quadrant (NE, SE, SW, NW) a facility is in relative to the community BG* • *For each grid ID, summarize the calculated wind distribution data for each quadrant to list predominant wind direction and the maximum wind speed in that direction* • *Calculate the time by straight-line distance from the facility by the wind speed* • *Calculate the relevant metrics* *The number of facilities is obtained by calculating for each season the total count of facilities within a specified travel time from the community. The travel time for the air from the facility to the community is the response time that the community has to take action.*
☐	Import Model Data into Common Grid System and Extract Model Data	***Inputs:*** • *NAM model data file* • *Shapefile with facilities and BG* ***Calculation:*** • *Superimpose the NAM model grid on facilities and BG using ArcGIS. Develop mapping linking each facility and centroid of the BG and the NAM model grid and create a common mapping grid with a unique grid ID.* • *Calculate the straight-line distance between each combination of facility and census BG.* ***Outputs:*** • *Text file (csv format) with the mapping of facility, BG, unique grid ID and distance between facility and BG* • *Text file (csv format) of extracted UGRD and VGRD values with the matched unique grid ID*

☐	Read Model Data and Calculate Wind Speed and Wind Direction	***Input***: *Text file with extracted UGRD and VGRD values* ***Calculations:*** • *Read "u" and "v" component values and calculate scalar wind speed and wind direction.* • *Plot windrose (USDA, 2022) by season. Choose wind speed cutoffs of 2 m/s, 4 m/s, 6 m/s, 10 m/s, and >10 m/s* • *Calculate the cumulative percent of time the wind is blowing from each wind direction sector (e.g., NE, SE) at wind speeds within each cutoff (< 2m/s, < 4m/s, etc.).* • *Calculate percent of time in each speed bin (e.g., 0-2 m/s, 2-4 m/s), and normalize it to calculate relative fractions in each speed bin (e.g., % time in 2-4 m/s bin as a fraction of total cumulative time in that wind direction). This estimate is used to calculate a weighted average wind speed in each wind direction sector for each season.* • *Calculate a weighted wind speed by adding the product of the relative fraction in each speed bin by the top end of the speed bin. For the >10 m/s wind speed bin, use the maximum wind speed. Using the maximum speed in each bin results in a conservative estimate.* ***Output:*** • *Text file (csv format) summarizing the calculated cumulative percent time, the relative fraction within each speed bin, and the weighted wind speed for each wind direction sector.*
☐	Identify Quadrant that the Facility Is Located in Relative to the Block Group	***Input:*** *Text file (csv format) with the mapping of facility, BG, unique grid ID, and distance between facility and BG* ***Calculation:*** *Determine where the facility coordinates (latitude and longitude) fall in relation to the BG centroid coordinates. Accordingly categorize the quadrant that the facility is in relative to the BG as NE, SE, SW, and NW.* ***Output:*** *Quadrant information for each facility and BG combination.*
☐	Calculate Metric	***Inputs:*** • *Text file (csv format) summarizing the calculated cumulative percent time, the relative fraction within each speed bin, and the weighted wind speed for each wind direction sector* • *Quadrant information for each facility and BG combination* ***Calculation:*** • *Link the two datasets using the common grid ID.* • *In the wind data file, assign quadrant based on the wind direction.* • *For each quadrant (e.g., NE, SE) relative to the BG under consideration, assign the cumulative percent time that wind blows from that quadrant by season.* • *For each BG, calculate the response time for impact from each facility by dividing its distance from BG by the weighted average wind speed for each season.* • *Count the number of facilities that fall within specified response time limits for each season.*

Decisions needed for mapping and interpretation		
☐	Mapping Limited to Block Groups Containing Data	*NA - BGs will all have count values. Zero is a valid value.*
☐	Choosing a Symbology	*The recommended symbology for this indicator is a single unique symbology that spans seasons for any given response time. This will result in the same color representing the same value across the maps, making direct comparisons much easier. To build this, find the minimum and maximum values across seasons for each response time, and then use the full range of values to create a single unique symbology to apply to all maps.*
☐	Binning in the Data by Block Group	*For this indicator using quantiles (equal number of observations per bin) is recommended. Using a maximum of 5-7 categories is also recommended so that the map reader can readily distinguish between color categories and visually match them to the legend. However, deciles or other percentiles can also be used depending on user needs.*
☐	Choosing Colors	*Use a color gradation that becomes darker as the count values increase. Avoid using a divergent color scheme (darker at both extremes and lighter in the middle), which implies an inflection point such as 0 in a dataset containing positive and negative values.*
Examples of how the indicator can be useful		
☐	Adaptation Planning / Emergency Response	*This indicator provides an estimate of how many site/waste facilities have the potential to impact the community within a specified response time. The indicator provides valuable information on which communities are at risk in the event of an emergency and how to prioritize response. The larger the number of facilities, the greater the risk for a potential aggregated impact if all facilities were to fail at the same time during an extreme event. For example, BGs with largest number of facilities (darkest color) may need to be addressed first in the event of an emergency. This is highly critical for situations with shorter response times. By combining response time and number of facilities, this indicator helps with advance planning on clearly defined actions for each community based on the risk.* *Depending on how different the response times and facility counts are across seasons, the strategy may also need to differ by season.* *The indicator can be used to identify priorities for preparedness activities such as cleanup and maintenance of sites/waste facilities that are within small response times. It can also inform longer term planning. For example, new assisted care facilities should not be built in BGs with shorter response times.*

Key caveats/limitations		
☐	Representative-ness	• *Since the indicators are developed for preparedness for extreme events, the indicators represent a worst-case estimate based on nearest facilities, wind speed, and wind direction, without air dispersion modeling. This approach does not account for geographical features (e.g., mountains) that may impact the movement of wind.* • *The values are based on analysis of wind patterns for one year. This analysis will need to be performed over a longer period (e.g., 10 years) to capture long-term climatological patterns.* • *The underlying data are based on weather forecasts and not actual point measurements or modeled retrospective reanalysis meteorological fields. While the forecasts are typically reliable and representative, there may be minor differences between actual meteorology and weather forecasts. The indicator does not categorize by the nature of the facility or by the potential risk of air emissions.* • *For certain locations such as coastal communities, the wind direction may change frequently, and the predominant wind direction may not necessarily be representative every year. This could be mitigated by using multiple years to get a true climatological profile as noted above.*
Citations		
	Dataset/Tool	*NOAA NCEI. (n.d.) North American Mesoscale Forecast System. https://www.ncei.noaa.gov/products/weather-climate-models/north-american-mesoscale. Recent model data available at https://www.ncei.noaa.gov/data/north-american-mesoscale-model/access/. Historical data are available at https://www.ncei.noaa.gov/data/north-american-mesoscale-model/access/historical/analysis/*
	Additional Resources	*Grange, S. K. (2014). Technical note: Averaging wind speeds and directions. DOI: 10.13140/RG.2.1.3349.2006.* *USDA. (2022). Wind rose resources. https://www.nrcs.usda.gov/wps/portal/wcc/home/climateSupport/windRoseResources/*

BG: Block Group, CONUS: Continental United States, NAM-ANL: North American Mesoscale Forecast System Analyses, NCEP: National Centers for Environmental Prediction, NOAA: National Oceanic and Atmospheric Administration

Vulnerability Source 2.1. Sensitivity: Household/Receptor Characteristics

Indicator 2.1.1. Checklist for Total Population Indicator

Total Population Indicator		
Definition of the indicator		
☐	Definition	*The total population in each Block Group (BG)*
☐	Interpretation	*This indicator provides the simplest measure of how many people may be impacted by contaminant exposures due to extreme events.*
Data source		
☐	Data Source	*American Community Survey (ACS) five-year data for historical periods (e.g., 2014-2018). The five-year sample provides increased statistical reliability of the data compared with that of single-year estimates, particularly for small geographic areas and small population subgroups (U.S. Census, 2018). The Census Decadal data or a more recent ACS year can also be considered when available,*
☐	Table Number/ Name	*Table Number B01003. "Total Population"*
☐	Temporal Resolution	*Annual value representing the time period chosen*
☐	Spatial Resolution	*BG*
☐	Data Format	*Excel spreadsheet or shapefile/geodatabase*
Data retrieval		
☐	Webpage	*The data can be accessed through a portal within IPUMS.com: https://data2.nhgis.org/main.*
☐	Account	*An IPUMS account needs to be created with the user email. The data are sent to this email. This could take up to an hour depending on how much data you have requested.*
☐	Spatial Scale	*After logging in, select the Geographic Level of Block Group.*
☐	Temporal Coverage	*Select the Year filter for 5-Year Ranges (e.g., 2014-2018).*
☐	Variable/Topic	*Based on keywords in the indicator definition, select the topic "Total population" under the population tab.*
☐	Tables	*The tables that are available for the filters selected above will be populated below the filters. Search the page for the specific table number (Table Number B01003. "Total Population").*

☐	Selection	*Once the table of interest (Table Number B01003) has been found, select that table and hit "continue" on the top right of the page (a dialogue box will appear).*
☐	Review and Submit	*This will then take you to the "Review and Submit" page where you will want to select the option to filter your data for your selected area. Click Submit.*
Decisions needed for calculations		
☐	Download Source	*The data can be accessed through IPUMS or directly from the Census website. The IPUMS portal provides an easier way to download the needed tables and is recommended.*
☐	Data Table Selection	*Multiple tables may be displayed when the search for keywords is conducted, and users may find alternative tables (in addition to the table number listed here) that can be considered. However, caution must be used if the users want to select a different table to make sure that the table selected captures the information needed.* *Tabular data needs a field to link to the spatial data files. For example, if the data are compiled at the BG level, there needs to be a field indicating the BG value that can thereby be linked to the same value in the BG spatial data.*
☐	Calculations	*Use as is.*
Calculation steps and assumptions		
☐	Calculation on Data	*No calculations are required. Data for Variable AJWME001- "Estimates: Total Population" need to be used "as is".*
Decisions needed for mapping and interpretation		
☐	Mapping Limited to Block Groups Containing Data	*NA – All BGs will have demographic values*
☐	Choosing Symbology	*Maps showing the distribution of this indicator will generally not be compared across scenarios, time periods, or locations so a single symbology will not be necessary. The symbology will be specific to the data for study.*
☐	Binning the Data by Block Group	*The distribution of this indicator by BG will not likely be equal across the data range. For this situation, using quantiles (equal number of observations per bin) is recommended. Using a maximum of 5-7 categories is recommended so that the map reader can readily distinguish between color categories and visually match them to the legend. Deciles or other percentiles can also be used depending on user needs.*
☐	Choosing Colors	*Use a color gradation that becomes darker as the vulnerability or risk increases. Avoid using a divergent color scheme (darker at both extremes and lighter in the middle), which implies an inflection point such as 0 in a dataset containing positive and negative values.*
Examples of how the indicator can be useful		
☐	Emergency Response/	*This indicator can help assess the potential magnitude and distribution of impact of contaminant releases. It could be used to anticipate the number of individuals that*

	Adaptation Planning	*need to be evacuated from each BG in the event of an emergency or the maximum number of people potentially exposed to a release from a site/waste facility.*
Key caveats/limitations		
☐	Aggregate Variable	*This variable is an aggregated measure and does not provide information on characteristics of people.*
☐	Uncertainties for Small BGs	*Margins of error need to be considered for assessing uncertainties in ACS estimates, especially for small BGs.*
Citations		
	Dataset/Tool	*U.S. Census Bureau. (2019). 2014-2018 American Community Survey 5-year Public Use Microdata Samples, Block Groups & Larger Areas [CSV Data file]. https://www.nhgis.org/*
	Additional Resources	*U.S. Census Bureau. (2018). American Community Survey General Handbook 2018, Chapter 3: Understanding and Using ACS Single-Year and Multiyear Estimates. https://www.census.gov/content/dam/Census/library/publications/2018/acs/acs_general_handbook_2018_ch03.pdf*

ACS: American Community Survey, BG: Block Group, IPUMS: Integrated Public Use Microdata Series

Indicator 2.1.2. Checklist for Count of Households/Occupied Housing Units Indicator

Count of Households/Occupied Housing Units Indicator		
Definition of the indicator		
☐	Definition	*The number of households within each Block Group (BG).*
☐	Interpretation	*This indicator provides a measure of the number of occupied residences.*
Data source		
☐	Data Source	*American Community Survey (ACS) five-year data for historical periods (e.g., 2014-2018). The five-year sample provides increased statistical reliability of the data compared with that of single-year estimates, particularly for small geographic areas and small population subgroups (U.S. Census, 2018). The Census Decadal data or a more recent ACS year can also be considered when available,*
☐	Table Number/ Name	*Table Number B25003. "TENURE"*
☐	Temporal Resolution	*Annual value representing the time period chosen*
☐	Spatial Resolution	*BG*
☐	Data Format	*Excel spreadsheet or shapefile/geodatabase*
Data retrieval		
☐	Webpage	*The data can be accessed through a portal within IPUMS.com: https://data2.nhgis.org/main.*
☐	Account	*An IPUMS account needs to be created with the user email. The data are sent to this email. This could take up to an hour depending on how much data you have requested.*
☐	Spatial Scale	*After logging in, select the Geographic Level of Block Group.*
☐	Temporal Coverage	*Select the Year filter for 5-Year Ranges (e.g., 2014-2018).*
☐	Variable/Topic	*Select the topic "Occupancy/Vacancy and Use" under the Housing tab*
☐	Tables	*The tables that are available for the filters selected above will be populated below the filters. The page needs to be searched for the specific table number (Table Number B25003. "TENURE").*
☐	Selection	*Once the table of interest (Table Number B25003) has been found, select that table and hit "continue" on the top right of the page (a dialogue box will appear).*

☐	Review and Submit	*This will then take you to the "Review and Submit" page where you will want to select the option to filter your data for your selected area. Click Submit.*
Decisions needed for calculation		
☐	Download Source	*The data can be accessed through IPUMS or directly from the Census website. The IPUMS portal provides an easier way to download the needed tables and is recommended.*
☐	Data Table Selection	*Multiple tables may be displayed when the search for keywords is conducted, and users may find alternative tables (in addition to the table number listed here) that can be considered. However, caution must be used if the users want to select a different table to make sure that the table selected captures the information needed.* *Tabular data need a field to link to the spatial data files. For example, if the data are compiled at the BG level, there needs to be a field indicating the BG value that can thereby be linked to the same value in the BG spatial data.*
☐	Calculations	*Use as is.*
Calculation steps and assumptions		
☐	Calculation on Data	*No calculations are required. Variable AJ1UE001 – "Estimates: Total Households" needs to be used "as is."*
Decisions needed for mapping and interpretation		
☐	Mapping Limited to Block Groups Containing Data	*NA – All BGs will have demographic values.*
☐	Choosing Symbology	*Maps showing the distribution of this indicator will generally not be compared across scenarios, time periods, or locations so a single symbology will not be necessary. The symbology will be specific to the data for the current area of interest and should become darker as the count increases.*
☐	Binning the Data by Block Group	*The distribution of this indicator by BG will not likely be equal across the data range. For this situation, using quantiles (equal number of observations per bin) is recommended. Use a maximum of 5-7 categories so that the map reader can readily distinguish between color categories and visually match them to the legend. Deciles or other percentiles can also be used depending on user needs.*
☐	Choosing Colors	*Use a color gradation that becomes darker as the count values increase. Avoid using a divergent color scheme (darker at both extremes and lighter in the middle), which implies an inflection point such as 0 in a dataset containing positive and negative values.*
Examples of how the indicator can be useful		
☐	Emergency Response/Adaptation Planning	*The count of households indicator includes only those residences that are occupied. This indicator can be used to assess the magnitude and distribution of risk and thus prioritize outreach, communications, and response in the event of an emergency. For example, the indicator provides information on the number of families that need to be sent communications materials before or during an event.*

Key caveats/limitations		
☐	Aggregate Variable	*This variable is an aggregated measure and does not provide information on characteristics of households.*
☐	Uncertainties for Small BGs	*Margins of error need to be considered for assessing uncertainties in ACS estimates, especially for small BGs.*
Citations		
	Dataset/Tool	*U.S. Census Bureau. (2019). 2014-2018 American Community Survey 5-year Public Use Microdata Samples, Block Groups & Larger Areas [CSV Data file]. https://www.nhgis.org/*
	Additional Resources	*U.S. Census Bureau. (2018). American Community Survey General Handbook 2018, Chapter 3: Understanding and Using ACS Single-Year and Multiyear Estimates. https://www.census.gov/content/dam/Census/library/publications/2018/acs/acs_general_handbook_2018_ch03.pdf*

ACS: American Community Survey, BG: Block Group, IPUMS: Integrated Public Use Microdata Series

Indicator 2.1.3. Checklist for Median Household Income Indicator

Median Household Income Indicator		
Definition of the indicator		
☐	Definition	*The median household income for each Block Group (BG).*
☐	Interpretation	*This indicator provides information on the extent and distribution of under-resourced households in the BG who may not have resources to take preventive measures or recover quickly (e.g., due to low home or medical insurance coverage).*
Data source		
☐	Data Source	*American Community Survey (ACS) five-year data for historical periods (e.g., 2014-2018). The five-year sample provides increased statistical reliability of the data compared with that of single-year estimates, particularly for small geographic areas and small population subgroups (U.S. Census, 2018). The Census Decadal data or a more recent ACS year can also be considered when available,*
☐	Table Number/ Name	*Table Number B19013. "Median Household Income In The Past 12 Months (In 2018 Inflation-Adjusted Dollars)"*
☐	Temporal Resolution	*Annual value representing the time period chosen*
☐	Spatial Resolution	*BG*
☐	Data Format	*Excel spreadsheet or shapefile/geodatabase*
Data retrieval		
☐	Webpage	*The data can be accessed through a portal within IPUMS.com: https://data2.nhgis.org/main*
☐	Account	*An IPUMS account needs to be created with the user email. The data are sent to this email. This could take up to an hour depending on how much data you have requested.*
☐	Spatial Scale	*After logging in, select the Geographic Level of Block Group*
☐	Temporal Coverage	*Select the Year filter for 5-Year Ranges (e.g., 2014-2018)*
☐	Variable/Topic	*Select the topic "Household and Family Income" under the Population tab*

☐	Tables	*The tables that are available for the filters selected above will be populated below the filters. Search the page for the specific table number (Table Number B19013- "Median Household Income In The Past 12 Months (In 2018 Inflation-Adjusted Dollars)").* *Tabular data need a field to link to the spatial data files. For example, if the data are compiled at the BG level, there needs to be a field indicating the BG value that can thereby be linked to the same value in the BG spatial data.*
☐	Selection	*Once the table of interest (Table Number B19013) has been found, select that table and hit "continue" on the top right of the page (a dialogue box will appear).*
☐	Review and Submit	*This will then take you to the "Review and Submit" page where you will want to select the option to filter your data for your selected area. Click Submit.*
Decisions needed for calculation		
☐	Download Source	*The data can be accessed through IPUMS or directly from the Census website. The IPUMS portal provides an easier way to download the needed tables and is recommended.*
☐	Data Table Selection	*Multiple tables may be displayed when the search for keywords is conducted, and users may find alternative tables (in addition to the table number listed here) that can be considered. However, caution must be used if the users want to select a different table to make sure that the table selected captures the information needed.*
☐	Calculations	*Use as is.*
Calculation steps and assumptions		
☐	Calculation on Data	*No calculations required. Variable AJZAE001 – "Estimates: Median Income" needs to be used "as is."*
Decisions needed for mapping and interpretation		
☐	Mapping Limited to Block Groups Containing Data	*NA – All BGs will have demographic values.*
☐	Choosing Symbology	*Maps showing the distribution of this indicator will generally not be compared across scenarios, time periods, or locations so a single symbology will not be necessary. The symbology will be specific to the data for study.*
☐	Binning the Data by Block Group	*The distribution of this indicator by BG will not likely be equal across the data range. For this situation using quantiles (equal number of observations per bin) is recommended. Use a maximum of 5-7 categories so that the map reader can readily distinguish between color categories and visually match them to the legend. Deciles or other percentiles can also be used depending on user needs.*
☐	Choosing Colors	*Use a color gradation that becomes darker as the vulnerability or risk increases. Avoid using a divergent color scheme (darker at both extremes and lighter in the middle), which implies an inflection point such as 0 in a dataset containing positive and negative values.*

Examples of how the indicator can be useful		
☐	Emergency Response/ Adaptation Planning	*Lower income residents may not have resources to take preventive measures or respond and recover when an incident occurs, and they may live and work in higher exposure areas. This indicator is useful for assessing the income and poverty status of BG residents, which in turn describes their level of exposure, access to resources, and ability to respond to an emergency. This indicator will help assess the need for assistance.*
Key caveats/limitations		
☐	Variable Represents a Central Income Value	*This variable is an overall measure of central tendency of the income distribution in the BG and does not provide information on households at the lower end of the distribution or the poverty status of BGs.*
☐	Uncertainties for Small BGs	*Margins of error need to be considered for assessing uncertainties in ACS estimates, especially for small BGs.*
Citations		
	Dataset/Tool	*U.S. Census Bureau. (2019). 2014-2018 American Community Survey 5-year Public Use Microdata Samples, Block Groups & Larger Areas [CSV Data file]. https://www.nhgis.org/*
	Additional Resources	*U.S. Census Bureau. (2018). American Community Survey General Handbook 2018, Chapter 3: Understanding and Using ACS Single-Year and Multiyear Estimates. https://www.census.gov/content/dam/Census/library/publications/2018/acs/acs_general_handbook_2018_ch03.pdf*

ACS: American Community Survey, BG: Block Group, IPUMS: Integrated Public Use Microdata Series

Indicator 2.1.4. Checklist for Percent of Population with Ratio of Income to Poverty Level Less Than 0.5 Indicator

Percent of Population with Ratio of Income to Poverty Level Less Than 0.5		
Definition of the indicator		
☐	Definition	*The percent of population whose ratio of household income to poverty level falls below 0.5.*
☐	Interpretation	*This indicator represents people with the least resources.*
Data source		
☐	Data Source	*American Community Survey (ACS) five-year data for historical periods (e.g., 2014-2018). The five-year sample provides increased statistical reliability of the data compared with that of single-year estimates, particularly for small geographic areas and small population subgroups (U.S. Census, 2018). The Census Decadal data or a more recent ACS year can also be considered when available,*
☐	Table Number/ Name	*Table Number C17002. "Ratio of Income to Poverty Level in the Past 12 Months"*
☐	Temporal Resolution	*Annual value representing the time period chosen*
☐	Spatial Resolution	*Block Group (BG)*
☐	Data Format	*Excel spreadsheet or shapefile/geodatabase*
Data Retrieval		
☐	Webpage	*The data can be accessed through a portal within IPUMS.com: https://data2.nhgis.org/main.*
☐	Account	*An IPUMS account needs to be created with the user email. The data are sent to this email. This could take up to an hour depending on how much data you have requested.*
☐	Spatial Scale	*After logging in, select the Geographic Level of Block Group.*
☐	Temporal Coverage	*Select the Year filter for 5-Year Ranges (e.g., 2014-2018).*
☐	Variable/Topic	*Select the topic "Poverty (Income Relative to Poverty Level)" under the Population tab.*
☐	Tables	*The tables that are available for the filters selected above will be populated below the filters. Search the page for the specific table number (Table Number C17002. "Ratio of Income to Poverty Level in the Past 12 Months").*

☐	Selection	*Once the table of interest (Table Number C17002) has been found, select that table and hit "continue" on the top right of the page (a dialogue box will appear).*
☐	Review and Submit	*This will then take you to the "Review and Submit" page where you will want to select the option to filter your data for your selected area. Click Submit.*
Decisions needed for calculation		
☐	Download Source	*The data can be accessed through IPUMS or directly from the Census website. The IPUMS portal provides an easier way to download the needed tables and is recommended.*
☐	Data Table Selection	*Multiple tables may be displayed when the search for keywords is conducted, and users may find alternative tables (in addition to the table number listed here) that can be considered. However, caution must be used if the users want to select a different table to make sure that the table selected captures the information needed.* *Tabular data needs a field to link to the spatial data files. For example, if the data are compiled at the BG level, there needs to be a field indicating the BG value that can thereby be linked to the same value in the BG spatial data.*
☐	Calculations	*Use to calculate percent of population whose ratio is less than 0.5*
Calculation steps and assumptions		
☐	Calculation on Data	*See Appendix Equation S-4. Divide the estimated population whose ratio is under 0.5 (AJY4E002 "Estimates: Under .50") by the total population (AJY4E001 "Estimates: Total").*
Decisions needed for mapping and interpretation		
☐	Mapping Limited to Block Groups Containing Data	*NA – All BGs will have demographic values.*
☐	Choosing Symbology	*Maps showing the distribution of this indicator will generally not be compared across scenarios, time periods, or locations so a single symbology will not be necessary. The symbology will be specific to the data for current area of interest.*
☐	Binning the Data by Block Group	*Percent values will be continuous from minimum to maximum values. Data can either be divided into equal intervals (recommended for percent values ranging from 0-100) or quantiles (recommended for percent values not ranging from 0-100 or raw count values). Using quantiles is also recommended when the data are not evenly distributed across the entire range to discern variations within concentrated ranges. Use a maximum of 5-7 categories so that the map reader can readily distinguish between color categories and visually match them to the legend. Deciles or other percentiles can also be used depending on user needs.*
☐	Choosing Colors	*Use a color gradation that becomes darker as the vulnerability increases. Avoid using a divergent color scheme (darker at both extremes and lighter in the middle), which implies an inflection point such as 0 in a dataset containing positive and negative values.*

Examples of how the indicator can be useful		
☐	Emergency Response/ Adaptation Planning	*This indicator provides a measure of extreme poverty status, which can help identify the lowest-income population with the fewest access to resources. This indicator helps assess the need for assistance and can inform prioritization during an emergency response.*
Key caveats/limitations		
☐	Poverty Definition	*The poverty level is determined by the Census definitions. The Census Bureau uses the poverty line to measure economic well-being and to assess the need for assistance. These data are included in federal allocation formulas for many government programs (U.S. Census Bureau, 2019). Other cutoffs for identifying those in need of assistance (e.g., those in the bottom decile of income levels) may be considered depending on community needs.*
☐	Uncertainties for Small BGs	*Margins of error need to be considered for assessing uncertainties in ACS estimates, especially for small BGs.*
Citations		
	Dataset/Tool	*U.S. Census Bureau. (2019). 2014-2018 American Community Survey 5-year Public Use Microdata Samples, Block Groups & Larger Areas [CSV Data file].* *https://www.nhgis.org/*
	Additional Resources	*U.S. Census Bureau. (2018). American Community Survey General Handbook 2018, Chapter 3: Understanding and Using ACS Single-Year and Multiyear Estimates.* *https://www.census.gov/content/dam/Census/library/publications/2018/acs/acs_general_handbook_2018_ch03.pdf* *U.S. Census Bureau. (2022). Poverty Thresholds.* *https://www.census.gov/data/tables/time-series/demo/income-poverty/historical-poverty-thresholds.html*

ACS: American Community Survey, BG: Block Group, IPUMS: Integrated Public Use Microdata Series

Indicator 2.1.5. Checklist for Percent of Population with Ratio of Income to Poverty Level Between 0.5 and 1 Indicator

Percent of Population with Ratio of Income to Poverty Level between 0.5 and 1 Indicator		
Definition of the indicator		
☐	Definition	*The percent of population whose ratio of household income to poverty level falls between 0.5 and 1.*
☐	Interpretation	*This indicator represents people with very low resources, second only those whose ratio of household income to poverty level is below 0.5.*
Data source		
☐	Data Source	*American Community Survey (ACS) five-year data for historical periods (e.g., 2014-2018). The five-year sample provides increased statistical reliability of the data compared with that of single-year estimates, particularly for small geographic areas and small population subgroups (U.S. Census, 2018). The Census Decadal data or a more recent ACS year can also be considered when available,*
☐	Table Number/ Name	*Table Number C17002. "Ratio of Income to Poverty Level in the Past 12 Months"*
☐	Temporal Resolution	*Annual value representing the time period chosen*
☐	Spatial Resolution	*Block Group (BG)*
☐	Data Format	*Excel spreadsheet or shapefile/geodatabase*
Data Retrieval		
☐	Webpage	*The data can be accessed through a portal within IPUMS.com: https://data2.nhgis.org/main.*
☐	Account	*An IPUMS account needs to be created with the user email. The data are sent to this email. This could take up to an hour depending on how much data you have requested.*
☐	Spatial Scale	*After logging in, select the Geographic Level of Block Group.*
☐	Temporal Coverage	*Select the Year filter for 5-Year Ranges (e.g., 2014-2018).*
☐	Variable/Topic	*Then select the topic "Poverty (Income Relative to Poverty Level) topic under the Population tab.*
☐	Tables	*The tables that are available for the filters selected above will be populated below the filters. You can either look through the tables to find the one of interest or you can search the page for the specific table number.*

☐	Selection	*Once the table of interest (Table Number C17002) has been found, select that table and hit "continue" on the top right of the page (a dialogue box will appear).*
☐	Review and Submit	*This will then take you to the "Review and Submit" page where you will want to select the option to filter your data for your selected area.*
Decisions needed for calculation		
☐	Download Source	*The data can be accessed through IPUMS or directly from the Census website. The IPUMS portal provides an easier way to download the needed tables and is recommended.*
☐	Data Table Selection	*Multiple tables may be displayed when the search for keywords is conducted, and the users may find alternative tables (in addition to the table number listed here) that can be considered. However, caution must be used if the users want to select a different table to make sure that the table selected captures the information needed.* *Tabular data need a field to link to the spatial data files. For example, if the data are compiled at the BG level, there needs to be a field indicating the BG value that can thereby be linked to the same value in the BG spatial data.*
☐	Calculations	*Use to calculate percent between 0.5 and 1.*
Calculation steps and assumptions		
☐	Calculation on Data	*See Appendix S-5. Divide the population between 0.5 and 1 (AJY4E003 "Estimates: .50 to .99") by the total population (AJY4E001 "Estimates: Total").*
Decisions needed for mapping and interpretation		
☐	Mapping Limited to Block Groups Containing Data	*NA – All BGs will have demographic values*
☐	Choosing Symbology	*Maps showing the distribution of percent will generally not be compared across scenarios, time periods, or locations so a single symbology will not be necessary. The symbology will be specific to the data for current area of interest.*
☐	Binning the Data by Block Group	*Percent values will be continuous from minimum to maximum values. Data can either be divided into equal intervals (recommended for percent values ranging from 0-100) or quantiles (recommended for percent values not ranging from 0-100 or raw count values). Using quantiles is also recommended when the data are not evenly distributed across the entire range to discern variations within concentrated ranges. Use a maximum of 5-7 categories so that the map reader can readily distinguish between color categories and visually match them to the legend. Deciles or other percentiles can also be used depending on user needs.*
☐	Choosing Colors	*Use a color gradation that becomes darker as the vulnerability increases. Avoid using a divergent color scheme (darker at both extremes and lighter in the middle), which implies an inflection point such as 0 in a dataset containing positive and negative values.*

Examples of how the indicator can be useful		
☐	Emergency Response/ Adaptation Planning	*This indicator provides a measure of populations that are below the poverty line but are not among the lowest income in the BG. This can help identify the second lowest-income population with limited access to resources. This indicator helps assess the need for assistance and can inform prioritization during an emergency response.*
Key caveats/limitations		
☐	Poverty Definition	*The poverty level is determined by the Census definitions. The Census Bureau uses the poverty line measure to measure economic well-being and to assess the need for assistance. These data are included in federal allocation formulas for many government programs (U.S. Census Bureau, 2019). Other cutoffs for identifying those in need of assistance (e.g., those in the second to lowest decile of income levels) may be considered depending on community needs.*
☐	Uncertainties for Small BGs	*Margins of error need to be considered for assessing uncertainties in ACS estimates, especially for small BGs.*
Citations		
	Dataset/Tool	*U.S. Census Bureau. (2019). 2014-2018 American Community Survey 5-year Public Use Microdata Samples, Block Groups & Larger Areas [CSV Data file]. https://www.nhgis.org/*
	Additional Resources	*U.S. Census Bureau. (2018). American Community Survey General Handbook 2018, Chapter 3: Understanding and Using ACS Single-Year and Multiyear Estimates. https://www.census.gov/content/dam/Census/library/publications/2018/acs/acs_general_handbook_2018_ch03.pdf* *U.S. Census Bureau. (2022). Poverty Thresholds. https://www.census.gov/data/tables/time-series/demo/income-poverty/historical-poverty-thresholds.html*

ACS: American Community Survey, BG: Block Group, IPUMS: Integrated Public Use Microdata Series

Indicator 2.1.6. Checklist for Percent of Households with Self-Employment Income Indicator

Percent of Households with Self-Employment Income Indicator		
Definition of the indicator		
☐	Definition	*The percentage of households whose income (in part or as a whole) is categorized as “self-employment income.”*
☐	Interpretation	*This indicator represents households who may have less stable income sources and less resources for recovery.*
Data source		
☐	Data Source	*American Community Survey (ACS) five-year data for historical periods (e.g., 2014-2018). The five-year sample provides increased statistical reliability of the data compared with that of single-year estimates, particularly for small geographic areas and small population subgroups (U.S. Census, 2018). The Census Decadal data or a more recent ACS year can also be considered when available,*
☐	Table Number/ Name	*Table Number B19053. “Self-Employment Income in the Past 12 Months for Households”*
☐	Temporal Resolution	*Annual value representing the time period chosen*
☐	Spatial Resolution	*Block Group (BG)*
☐	Data Format	*Excel spreadsheet or shapefile/geodatabase*
Data Retrieval		
☐	Webpage	*The data can be accessed through a portal within IPUMS.com: https://data2.nhgis.org/main.*
☐	Account	*An IPUMS account needs to be created with the user email. The data are sent to this email. This could take up to an hour depending on how much data you have requested.*
☐	Spatial Scale	*From there select the Geographic Level of Block Group.*
☐	Temporal Coverage	*Next select the Year filter for 5-Year Ranges (2014-2018).*
☐	Variable/Topic	*Then select the topic “Household and Family Income” in the Population tab.*
☐	Tables	*The tables that are available for the filters selected above will be populated below the filters. Search the page for the specific table number (Table Number B19053. “Self-Employment Income in the Past 12 Months for Households”).*
☐	Selection	*Once the table of interest (Table Number B19053) has been found, select that table and hit “continue” on the top right of the page (a dialogue box will appear).*

☐	Review and Submit	*This will then take you to the "Review and Submit" page where you will want to select the option to filter your data for your selected area. Click Submit.*
Decisions needed for calculation		
☐	Download Source	*The data can be accessed through IPUMS or directly from the Census website. The IPUMS portal provides an easier way to download the needed tables and is recommended.*
☐	Data Table Selection	*Multiple tables may be displayed when the search for keywords is conducted, and the users may find alternative tables (in addition to the table number listed here) that can be considered. However, caution must be used if the users want to select a different table to make sure that the table selected captures the information needed.* *Tabular data need a field to link to the spatial data files. For example, if the data are compiled at the BG level, there needs to be a field indicating the BG value that can thereby be linked to the same value in the BG spatial data.*
☐	Calculations	*Use to calculate households with self-employed income divided by total households.*
Calculation steps and assumptions		
☐	Calculation on Data	*See Appendix Equation S-6. The total number of households with self-employment income (AJZQE002 "Estimates: With self-employment income") was divided by the total number of households (AJZQE001 "Estimates: Total").*
Decisions needed for mapping and interpretation		
☐	Mapping Limited to Block Groups Containing Data	*NA – All BGs will have demographic values*
☐	Choosing Symbology	*Maps showing the distribution of percent will generally not be compared across scenarios, time periods, or locations so a single symbology will not be necessary. The symbology will be specific to the data for current area of interest.*
☐	Binning the Data by Block Group	*Percent values will be continuous from minimum to maximum values. Data can either be divided into equal intervals (recommended for percent values ranging from 0-100) or quantiles (recommended for percent values not ranging from 0-100 or raw count values). Using quantiles is also recommended when the data are not evenly distributed across the entire range to discern variations within concentrated ranges. Use a maximum of 5-7 categories so that the map reader can readily distinguish between color categories and visually match them to the legend. Deciles or other percentiles can also be used depending on user needs.*
☐	Choosing Colors	*Use a color gradation that becomes darker as the vulnerability increases. Avoid using a divergent color scheme (darker at both extremes and lighter in the middle), which implies an inflection point such as 0 in a dataset containing positive and negative values.*

Examples of how the indicator can be useful		
☐	Emergency Response/ Adaptation Planning	*Self-employed households may face more disruptions and may not have resources to take preventive measures or recover quickly. They may also have low insurance coverage and thus may face health issues. They may also have lower ability to respond and recover from shocks, as they are not incorporated into the main workforce and are thus less socially connected than other workers. This indicator will help assess the need for assistance.*
Key caveats/limitations		
☐	Size of Income	*This indicator does not provide the magnitude of self-employment. Self-employed individuals may earn large incomes and may not always be in need of assistance. Depending on community needs, further screening is recommended to determine priorities for response and planning.*
☐	Uncertainties for Small BGs	*Margins of error need to be considered for assessing uncertainties in ACS estimates, especially for small BGs.*
Citations		
	Dataset/Tool	*U.S. Census Bureau. (2019). 2014-2018 American Community Survey 5-year Public Use Microdata Samples, Block Groups & Larger Areas [CSV Data file]. https://www.nhgis.org/*
	Additional Resources	*U.S. Census Bureau. (2018). American Community Survey General Handbook 2018, Chapter 3: Understanding and Using ACS Single-Year and Multiyear Estimates. https://www.census.gov/content/dam/Census/library/publications/2018/acs/acs_general_handbook_2018_ch03.pdf*

ACS: American Community Survey, BG: Block Group, IPUMS: Integrated Public Use Microdata Series

Indicator 2.1.7. Checklist for Percent of Civilian Employed Population 16 Years and over Who Work Outdoors Indicator

Percent of Civilian Employed Population 16 Years and over Who Work Outdoors Indicator		
Definition of the indicator		
☐	Definition	*The total percentage of population of each Block Group (BG) that is over the age of 16 and who work outdoors*
☐	Interpretation	*This indicator provides information on people who work in occupations that may require them to work outdoors and may face high exposure risks if contaminant releases occur during an extreme event.*
Data source		
☐	Data Source	*American Community Survey (ACS) five-year data for historical periods (e.g., 2014-2018). The five-year sample provides increased statistical reliability of the data compared with that of single-year estimates, particularly for small geographic areas and small population subgroups (U.S. Census, 2018). The Census Decadal data or a more recent ACS* year *can also be considered when available,*
☐	Table Number/ Name	*Table Number C24010. "Sex by Occupation for the Civilian Employed Population 16 Years and Over"*
☐	Temporal Resolution	*Annual value representing the time period chosen*
☐	Spatial Resolution	*BG*
☐	Data Format	*Excel spreadsheet or shapefile/geodatabase*
Data Retrieval		
☐	Webpage	*The data can be accessed through a portal within IPUMS.com: https://data2.nhgis.org/main.*
☐	Account	*An IPUMS account needs to be created with the user email. The data are sent to this email. This could take up to an hour depending on how much data you have requested.*
☐	Spatial Scale	*After logging in, select the Geographic Level of Block Group.*
☐	Temporal Coverage	*Select the Year filter for 5-Year Ranges (e.g., 2014-2018).*
☐	Variable/Topic	*Then select the topic "Sex" under the population tab.*

☐	Tables	*The tables that are available for the filters selected above will be populated below the filters. Search the page for the specific table number (Table Number C24010. "Sex by Occupation for the Civilian Employed Population 16 Years and Over").*
☐	Selection	*Once the table of interest (Table Number C24010) has been found, select that table and hit "continue" on the top right of the page (a dialogue box will appear)*
☐	Review and Submit	*This will then take you to the "Review and Submit" page where you will want to select the option to filter your data for your selected area.*
Decisions needed for calculation		
☐	Download Source	*The data can be accessed through IPUMS or directly from the Census website. The IPUMS portal provides an easier way to download the needed tables and is recommended.*
☐	Data Table Selection	*Multiple tables may be displayed when the search for keywords is conducted, and the users may find alternative tables (in addition to the table number listed here) that can be considered. However, caution must be used if the users want to select a different table to make sure that the table selected captures the information needed.* *Tabular data need a field to link to the spatial data files. For example, if the data are compiled at the BG level, there needs to be a field indicating the BG value that can thereby be linked to the same value in the BG spatial data.*
☐	Calculations	*Use to calculate sum of male and female in outdoor occupations.*
Calculation steps and assumptions		
☐	Calculation on Data	*See Appendix Equation S-7. The sum of the following four variables were used as the total outdoor occupations: 1. AJ1FE030 "Estimates: Male: Natural resources, construction, and maintenance occupations"; 2. AJ1FE066 "Estimates: Female: Natural resources, construction, and maintenance occupations"; 3. AJ1FE070 "Estimates: Female: Production, transportation, and material moving occupations"; and 4. AJ1FE034 "Estimates: Male: Production, transportation, and material moving occupations". This sum was then divided by the total population above 16 (AJ1FE001 "Estimates: Total").*
Decisions needed for mapping and interpretation		
☐	Mapping Limited to Block Groups Containing Data	*NA – All BGs will have demographic values*
☐	Choosing Symbology	*Maps showing the distribution of percent will generally not be compared across scenarios, time periods, or locations so a single symbology will not be necessary. The symbology will be specific to the data for current area of interest.*

☐	Binning the Data by Block Group	*Percent values will be continuous from minimum to maximum values. Data can either be divided into equal intervals (recommended for percent values ranging from 0-100) or quantiles (recommended for percent values not ranging from 0-100 or raw count values). Using quantiles is also recommended when the data are not evenly distributed across the entire range to discern variations within concentrated ranges. Use a maximum of 5-7 categories so that the map reader can readily distinguish between color categories and visually match them to the legend. Deciles or other percentiles can also be used depending on user needs.*
☐	Choosing Colors	*Use a color gradation that becomes darker as the vulnerability increases. Avoid using a divergent color scheme (darker at both extremes and lighter in the middle), which implies an inflection point such as 0 in a dataset containing positive and negative values.*
Examples of how the indicator can be useful		
☐	Emergency Response/ Adaptation Planning	*This indicator shows the number of workers that are most likely to be exposed to hazardous waste and contaminants during a release event, which helps inform response planning by providing information on where workers who may face high risks of exposure may live.*
Key caveats/limitations		
☐	Location of Outdoor Workers Residence	*This indicator provides information on where people who work in occupations that may require them to work outdoors live. This does not always mean that all workers in this category will always be outdoors. Further, it does not provide information on the work location. Depending on community needs, further assessments may be needed to determine outdoor exposures.*
☐	Uncertainties for Small BGs	*Margins of error need to be considered for assessing uncertainties in ACS estimates, especially for small BGs.*
Citations		
	Dataset/Tool	*U.S. Census Bureau. (2019). 2014-2018 American Community Survey 5-year Public Use Microdata Samples, Block Groups & Larger Areas [CSV Data file]. https://www.nhgis.org/*
	Additional Resources	*U.S. Census Bureau. (2018). American Community Survey General Handbook 2018, Chapter 3: Understanding and Using ACS Single-Year and Multiyear Estimates. https://www.census.gov/content/dam/Census/library/publications/2018/acs/acs_general_handbook_2018_ch03.pdf*

Indicator 2.1.8. Checklist for Percent of Households That Are Renters Indicator

Percent of Households That Are Renters Indicator		
Definition of the indicator		
☐	Definition	*The total percentage of households who are "renters".*
☐	Interpretation	*This indicator provides information on the percentage of housing units that are occupied by renters rather than owners.*
Data source		
☐	Data Source	*American Community Survey (ACS) five-year data for historical periods (e.g., 2014-2018). The five-year sample provides increased statistical reliability of the data compared with that of single-year estimates, particularly for small geographic areas and small population subgroups (U.S. Census, 2018). The Census Decadal data or a more recent ACS year can also be considered when available,*
☐	Table Number/ Name	*Table Number B25003. "TENURE"*
☐	Temporal Resolution	*Annual value representing the time period chosen*
☐	Spatial Resolution	*Block Group (BG)*
☐	Data Format	*Excel spreadsheet or shapefile/geodatabase*
Data Retrieval		
☐	Webpage	*The data can be accessed through a portal within IPUMS.com: https://data2.nhgis.org/main.*
☐	Account	*An IPUMS account needs to be created with the user email. The data are sent to this email. This could take up to an hour depending on how much data you have requested.*
☐	Spatial Scale	*After logging in, select the Geographic Level of Block Group.*
☐	Temporal Coverage	*Select the Year filter for 5-Year Ranges (e.g., 2014-2018).*
☐	Variable/Topic	*Then select the topic "Occupancy/Vacancy and Use" under the Housing tab.*
☐	Tables	*The tables that are available for the filters selected above will be populated below the filters. Search the page for the specific table number (*Table Number B25003. "TENURE"*).*
☐	Selection	*Once the table of interest (*Table Number B25003*) has been found, select that table and hit "continue" on the top right of the page (a dialogue box will appear).*

☐	Review and Submit	*This will then take you to the "Review and Submit" page where you will want to select the option to filter your data for your selected area.*
Decisions needed for calculation		
☐	Download Source	*The data can be accessed through IPUMS or directly from the Census website. The IPUMS portal provides an easier way to download the needed tables and is recommended.*
☐	Data Table Selection	*Multiple tables may be displayed when the search for keywords is conducted, and users may find alternative tables (in addition to the table number listed here) that can be considered. However, caution must be used if the users want to select a different table to make sure that the table selected captures the information needed.* *Tabular data needs a field to link to the spatial data files. For example, if the data are compiled at the BG level, there needs to be a field indicating the BG value that can thereby be linked to the same value in the BG spatial data.*
☐	Calculations	*Use to calculate percent of renters of total households.*
Calculation steps and assumptions		
☐	Calculation on Data	*See Appendix Equation S-8. The total number of renter occupied housing units (AJ17E003 "Estimates: Renter occupied") was divided by the total number of housing units (AJ17E001 "Estimates: Total").*
Decisions needed for mapping and interpretation		
☐	Mapping Limited to Block Groups Containing Data	*NA – All BGs will have demographic values*
☐	Choosing Symbology	*Maps showing the distribution of percent will generally not be compared across scenarios, time periods, or locations so a single symbology will not be necessary. The symbology will be specific to the data for current area of interest.*
☐	Binning the Data by Block Group	*Percent values will be continuous from minimum to maximum values. Data can either be divided into equal intervals (recommended for percent values ranging from 0-100) or quantiles (recommended for percent values not ranging from 0-100 or raw count values). Using quantiles is also recommended when the data are not evenly distributed across the entire range to discern variations within concentrated ranges. Use a maximum of 5-7 categories so that the map reader can readily distinguish between color categories and visually match them to the legend. Deciles or other percentiles can also be used depending on user needs.*
☐	Choosing Colors	*Use a color gradation that becomes darker as the vulnerability increases. Avoid using a divergent color scheme (darker at both extremes and lighter in the middle), which implies an inflection point such as 0 in a dataset containing positive and negative values.*
Examples of how the indicator can be useful		
☐	Emergency Response/	*Renters have fewer assets, less housing security, and less insurance than homeowners. Rental housing units also often less maintained and protected.*

	Adaptation Planning	*Renters may have less resources overall to take preventive measures, respond and recover when an incident occurs. This indicator will help assess the need for assistance.*
Key caveats/limitations		
☐	Universe of Renters	*Not all renters are necessarily under-resourced.*
☐	Uncertainties for Small BGs	*Margins of error need to be considered for assessing uncertainties in ACS estimates, especially for small BGs.*
Citations		
	Dataset/Tool	*U.S. Census Bureau. (2019). 2014-2018 American Community Survey 5-year Public Use Microdata Samples, Block Groups & Larger Areas [CSV Data file]. https://www.nhgis.org/*
	Additional Resources	*U.S. Census Bureau. (2018). American Community Survey General Handbook 2018, Chapter 3: Understanding and Using ACS Single-Year and Multiyear Estimates. https://www.census.gov/content/dam/Census/library/publications/2018/acs/acs_general_handbook_2018_ch03.pdf*

ACS: American Community Survey, BG: Block Group, IPUMS: Integrated Public Use Microdata Series

Indicator 2.1.9. Checklist for Percent of Households Living in a Mobile Home/Boat/RV/Van Indicator

Percent of Households Living in a Mobile Home/Boat/RV/Van Indicator		
Definition of the indicator		
☐	Definition	*Percent of households living in a mobile home/boat/RV/van*
☐	Interpretation	*This indicator provides information on the percentage of housing units that are mobile homes, boats, RVs, or vans.*
Data source		
☐	Data Source	*American Community Survey (ACS) five-year data for historical periods (e.g., 2014-2018). The five-year sample provides increased statistical reliability of the data compared with that of single-year estimates, particularly for small geographic areas and small population subgroups (U.S. Census, 2018). The Census Decadal data or a more recent ACS year can also be considered when available,*
☐	Table Number/ Name	*Table Number B25024. "UNITS IN STRUCTURE"*
☐	Temporal Resolution	*Annual value representing the time period chosen*
☐	Spatial Resolution	*Block Group (BG)*
☐	Data Format	*Excel spreadsheet or shapefile/geodatabase*
Data Retrieval		
☐	Webpage	*The data can be accessed through a portal within IPUMS.com: https://data2.nhgis.org/main.*
☐	Account	*An IPUMS account needs to be created with the user email. The data are sent to this email. This could take up to an hour depending on how much data you have requested.*
☐	Spatial Scale	*After logging in, select the Geographic Level of Block Group.*
☐	Temporal Coverage	*Next select the Year filter for 5-Year Ranges (2014-2018).*
☐	Variable/Topic	*Select the topic "Occupancy/Vacancy and Use" under the Housing tab.*
☐	Tables	*The tables that are available for the filters selected above will be populated below the filters. You can either look through the tables to find the one of interest or you can search the page for the specific table number.*
☐	Selection	*Once the table of interest (Table Number B25024) has been found, select that table and hit "continue" on the top right of the page (a dialogue box will appear).*

☐	Review and Submit	*This will then take you to the "Review and Submit" page where you will want to select the option to filter your data for your selected area. Click Submit.*
Decisions needed for calculation		
☐	Download Source	*The data can be accessed through IPUMS or directly from the Census website. The IPUMS portal provides an easier way to download the needed tables and is recommended.*
☐	Data Table Selection	*Multiple tables may be displayed when the search for keywords is conducted, and users may find alternative tables (in addition to the table number listed here) that can be considered. However, caution must be used if the users want to select a different table to make sure that the table selected captures the information needed.* *Tabular data need a field to link to the spatial data files. For example, if the data are compiled at the BG level, there needs to be a field indicating the BG value that can thereby be linked to the same value in the BG spatial data.*
☐	Calculations	*Use to add Mobile + Boat/RV/Van and then divide by housing units.*
Calculation steps and assumptions		
☐	Calculation on Data	*See Appendix Equation S-9. Take the sum of AJ2JE010 "Estimates: Mobile home" and AJ2JE011 "Estimates: Boat, RV, van, etc." divided by the total AJ2JE001 "Estimates: Total".*
Decisions needed for mapping and interpretation		
☐	Mapping Limited to Block Groups Containing Data	*NA – All BGs will have demographic values*
☐	Choosing Symbology	*Maps showing the distribution of percent will generally not be compared across scenarios, time periods, or locations so a single symbology will not be necessary. The symbology will be specific to the data for current area of interest.*
☐	Binning the Data by Block Group	*Percent values will be continuous from minimum to maximum values. Data can either be divided into equal intervals (recommended for percent values ranging from 0-100) or quantiles (recommended for percent values not ranging from 0-100 or raw count values). Using quantiles is also recommended when the data are not evenly distributed across the entire range to discern variations within concentrated ranges. Use a maximum of 5-7 categories so that the map reader can readily distinguish between color categories and visually match them to the legend. Deciles or other percentiles can also be used depending on user needs.*
☐	Choosing Colors	*Use a color gradation that becomes darker as the vulnerability increases. Avoid using a divergent color scheme (darker at both extremes and lighter in the middle), which implies an inflection point such as 0 in a dataset containing positive and negative values.*

Examples of how the indicator can be useful		
☐	Emergency Response/ Adaptation Planning	*This indicator provides a measure of housing security and risk of exposure by showing the number of households living in temporary, outdoor, or mobile structures. Households with mobile homes serving as their place of residence may have fewer assets and resources, at higher risk of exposure to a release event, and less able to respond and recover post-incident.*
Key caveats/limitations		
☐	Include owned and rented units	*Mobile homes may be owned or rented. Households renting such units may have fewer access to resources than those that own such units. Further, the condition of the unit is not reflected in this indicator. Further information, such as age of the structure and ownership status, would provide additional information.*
☐	Uncertainties for Small BGs	*Margins of error need to be considered for assessing uncertainties in ACS estimates, especially for small BGs.*
Citations		
	Dataset/Tool	*U.S. Census Bureau. (2019). 2014-2018 American Community Survey 5-year Public Use Microdata Samples, Block Groups & Larger Areas [CSV Data file]. https://www.nhgis.org/*
	Additional Resources	*U.S. Census Bureau. (2018). American Community Survey General Handbook 2018, Chapter 3: Understanding and Using ACS Single-Year and Multiyear Estimates. https://www.census.gov/content/dam/Census/library/publications/2018/acs/acs_general_handbook_2018_ch03.pdf*

ACS: American Community Survey, BG: Block Group, IPUMS: Integrated Public Use Microdata Series

Indicator 2.1.10. Checklist for Percent of Households without Telephone Service Indicator

Percent of Households without Telephone Service Indicator		
Definition of the indicator		
☐	Definition	*Percent of households without telephone service*
☐	Interpretation	*This indicator provides information on whether telephone service was available (and working) in the housing unit that allows the respondent to make and receive calls.*
Data source		
☐	Data Source	*American Community Survey (ACS) five-year data for historical periods (e.g., 2014-2018). The five-year sample provides increased statistical reliability of the data compared with that of single-year estimates, particularly for small geographic areas and small population subgroups (U.S. Census, 2018). The Census Decadal data or a more recent ACS year can also be considered when available,*
☐	Table Number/ Name	*Table Number B25043. "Tenure by Telephone Service Available by Age of Householder"*
☐	Temporal Resolution	*Annual value representing the time period chosen*
☐	Spatial Resolution	*Block Group (BG)*
☐	Data Format	*Excel spreadsheet or shapefile/geodatabase*
Data Retrieval		
☐	Webpage	*The data can be accessed through a portal within IPUMS.com: https://data2.nhgis.org/main.*
☐	Account	*An IPUMS account needs to be created with the user email. The data are sent to this email. This could take up to an hour depending on how much data you have requested.*
☐	Spatial Scale	*After logging in, select the Geographic Level of Block Group.*
☐	Temporal Coverage	*Select the Year filter for 5-Year Ranges (e.g., 2014-2018).*
☐	Topic	*Then select the topic "Occupancy/Vacancy and Use" under the Housing tab.*
☐	Tables	*The tables that are available for the filters selected above will be populated below the filters. Search the page for the specific table number (Table Number B25043. "Tenure by Telephone Service Available by Age of Householder").*
☐	Selection	*Once the table of interest (Table Number B25043) has been found, select that table and hit "continue" on the top right of the page (a dialogue box will appear)*

☐	Review and Submit	*This will then take you to the "Review and Submit" page where you will want to select the option to filter your data for your selected area.*
Decisions needed for calculation		
☐	Download Source	*The data can be accessed through IPUMS or directly from the Census website. The IPUMS portal provides an easier way to download the needed tables and is recommended.*
☐	Data Table Selection	*Multiple tables may be displayed when the search for keywords is conducted, and users may find alternative tables (in addition to the table number listed here) that can be considered. However, caution must be used if the users want to select a different table to make sure that the table selected captures the information needed.* *Tabular data need a field to link to the spatial data files. For example, if the data are compiled at the BG level, there needs to be a field indicating the BG value that can thereby be linked to the same value in the BG spatial data.*
☐	Calculations	*Use to calculate the sum of renters and owners with no telephone service available divided by the total number of households.*
Calculation steps and assumptions		
☐	Calculation on Data	*See Appendix Equation S-10. Take the sum of (AJ2VE007 "Estimates: Owner occupied: No telephone service available", and AJ2VE016 "Estimates: Renter occupied: No telephone service available") divided by AJ2VE001 "Estimates: Total".*
Decisions needed for mapping and interpretation		
☐	Mapping Limited to Block Groups Containing Data	*NA – All BGs will have demographic values*
☐	Choosing Symbology	*Maps showing the distribution of percent will generally not be compared across scenarios, time periods, or locations so a single symbology will not be necessary. The symbology will be specific to the data for current area of interest.*
☐	Binning the Data by Block Group	*Percent values will be continuous from minimum to maximum values. Data can either be divided into equal intervals (recommended for percent values ranging from 0-100) or quantiles (recommended for percent values not ranging from 0-100 or raw count values). Using quantiles is also recommended when the data are not evenly distributed across the entire range to discern variations within concentrated ranges. Use a maximum of 5-7 categories so that the map reader can readily distinguish between color categories and visually match them to the legend. Deciles or other percentiles can also be used depending on user needs.*
☐	Choosing Colors	*Use a color gradation that becomes darker as the vulnerability increases. Avoid using a divergent color scheme (darker at both extremes and lighter in the middle), which implies an inflection point such as 0 in a dataset containing positive and negative values.*

Examples of how the indicator can be useful		
☐	Emergency Response/ Adaptation Planning	*This indicator shows the percent of households that have limited communications access, which prevents them from receiving timely warnings and ensuring efficient evacuation. This leaves them socially isolated prior to, during, and after an incident.*
Key caveats/limitations		
☐	Traditional telephone service	*This indicator does not include information on the households who may have internet access and VOIP-based communications means. However, households who rely only on internet-based communications means are limited. Also, ACS added instructions on including cell phones in 2008. This indicator also does not provide information on whether multiple phone services (and therefore backups) are present.*
☐	Uncertainties for Small BGs	*Margins of error need to be considered for assessing uncertainties in ACS estimates, especially for small BGs.*
Citations		
	Dataset/Tool	*U.S. Census Bureau. (2019). 2014-2018 American Community Survey 5-year Public Use Microdata Samples, Block Groups & Larger Areas [CSV Data file]. https://www.nhgis.org/*
	Additional Resources	*U.S. Census Bureau. (2018). American Community Survey General Handbook 2018, Chapter 3: Understanding and Using ACS Single-Year and Multiyear Estimates. https://www.census.gov/content/dam/Census/library/publications/2018/acs/acs_general_handbook_2018_ch03.pdf*

ACS: American Community Survey, BG: Block Group, IPUMS: Integrated Public Use Microdata Series

Indicator 2.1.11. Checklist for Percent of Households with No Internet Access Indicator

Percent of Households with No Internet Access Indicator		
Definition of the indicator		
☐	Definition	*Percent of households with no internet access*
☐	Interpretation	*This indicator provides information on whether or not someone in the household uses or can connect to the internet.*
Data source		
☐	Data Source	*American Community Survey (ACS) five-year data for historical periods (e.g., 2014-2018). The five-year sample provides increased statistical reliability of the data compared with that of single-year estimates, particularly for small geographic areas and small population subgroups (U.S. Census, 2018). The Census Decadal data or a more recent ACS year can also be considered when available,*
☐	Table Number/ Name	*Table Number B28002- "PRESENCE AND TYPES OF INTERNET SUBSCRIPTIONS IN HOUSEHOLD"*
☐	Temporal Resolution	*Annual value representing the time period chosen*
☐	Spatial Resolution	*Block Group (BG)*
☐	Data Format	*Excel spreadsheet or shapefile/geodatabase*
Data Retrieval		
☐	Webpage	*The data can be accessed through a portal within IPUMS.com: https://data2.nhgis.org/main*
☐	Account	*An IPUMS account needs to be created with the user email. The data are sent to this email. This could take up to an hour depending on how much data you have requested.*
☐	Spatial Scale	*After logging in, select the Geographic Level of Block Group*
☐	Temporal Scale	*Select the Year filter for 5-Year Ranges (2014-2018)*
☐	Variable/Topic	*Then select the topic "Occupancy/Vacancy and Use" under the Housing tab*
☐	Tables	*The tables that are available for the filters selected above will be populated below the filters. Search the page for the specific table number (Table Number B28002- "PRESENCE AND TYPES OF INTERNET SUBSCRIPTIONS IN HOUSEHOLD").*
☐	Selection	*Once the table of interest (Table Number B28002) has been found, select that table and hit "continue" on the top right of the page (a dialogue box will appear)*

☐	Review and Submit	*This will then take you to the "Review and Submit" page where you will want to select the option to filter your data your selected area. Click Submit.*
Decisions needed for calculation		
☐	Download Source	*The data can be accessed through IPUMS or directly from the Census website. The IPUMS portal provides an easier way to download the needed tables and is recommended.*
☐	Data Table Selection	*Multiple tables may be displayed when the search for keywords is conducted, and users may find alternative tables (in addition to the table number listed here) that can be considered. However, caution must be used if the users want to select a different table to make sure that the table selected captures the information needed.* *Tabular data need a field to link to the spatial data files. For example, if the data are compiled at the BG level, there needs to be a field indicating the BG value that can thereby be linked to the same value in the BG spatial data.*
☐	Calculations	*Use to calculate the number of households without internet access over the total number of households.*
Calculation steps and assumptions		
☐	Calculation on Data	*See Appendix Equation S-11. Take AJ37E013 "Estimates: No Internet access" divided by AJ37E001 "Estimates: Total".*
Decisions needed for mapping and interpretation		
☐	Mapping Limited to Block Groups Containing Data	*NA – All BGs will have demographic values*
☐	Choosing Symbology	*Maps showing the distribution of percent will generally not be compared across scenarios, time periods, or locations so a single symbology will not be necessary. The symbology will be specific to the data for current area of interest.*
☐	Binning the Data by Block Group	*Percent values will be continuous from minimum to maximum values. Data can either be divided into equal intervals (recommended for percent values ranging from 0-100) or quantiles (recommended for percent values not ranging from 0-100 or raw count values). Using quantiles is also recommended when the data are not evenly distributed across the entire range to discern variations within concentrated ranges. Use a maximum of 5-7 categories so that the map reader can readily distinguish between color categories and visually match them to the legend. Deciles or other percentiles can also be used depending on user needs.*
☐	Choosing Colors	*Use a color gradation that becomes darker as the vulnerability increases. Avoid using a divergent color scheme (darker at both extremes and lighter in the middle), which implies an inflection point such as 0 in a dataset containing positive and negative values.*

Examples of how the indicator can be useful		
☐	Emergency Response/ Adaptation Planning	*This indicator shows the percent of households that are disconnected from information and communications lines, which prevents them from receiving timely warnings and up-to-date information and ensuring efficient evacuation. This leaves them socially isolated during and after an incident.*
Key caveats/limitations		
☐	Type of Internet Service	*This indicator does not provide any information about the type of internet service or the reliability of the service. This indicator also does not provide information on whether multiple services (and therefore backups) are present. These questions are not asked for the group quarters population, so do not include data about people living in housing such as dorms, prisons, nursing homes, etc.*
☐	Uncertainties for Small BGs	*Margins of error need to be considered for assessing uncertainties in ACS estimates, especially for small BGs.*
Citations		
	Dataset/Tool	*U.S. Census Bureau. (2019). 2014-2018 American Community Survey 5-year Public Use Microdata Samples, Block Groups & Larger Areas [CSV Data file]. https://www.nhgis.org/*
	Additional Resources	*U.S. Census Bureau. (2018). American Community Survey General Handbook 2018, Chapter 3: Understanding and Using ACS Single-Year and Multiyear Estimates. https://www.census.gov/content/dam/Census/library/publications/2018/acs/acs_general_handbook_2018_ch03.pdf*

ACS: American Community Survey, BG: Block Group, IPUMS: Integrated Public Use Microdata Series

Indicator 2.1.12. Checklist for Percent of Households Who Do Not Have a Vehicle Indicator

Percent of Households Who Do Not Have a Vehicle Indicator		
Definition of the indicator		
☐	Definition	*Percent of households who do not have a vehicle*
☐	Interpretation	*This indicator provides information on vehicles available for the use of household members. Motorcycles/other recreational vehicles, dismantled/ immobile vehicles and vehicles used only for business purposes are excluded.*
Data source		
☐	Data Source	*American Community Survey (ACS) five-year data for historical periods (e.g., 2014-2018). The five-year sample provides increased statistical reliability of the data compared with that of single-year estimates, particularly for small geographic areas and small population subgroups (U.S. Census, 2018). The Census Decadal data or a more recent ACS year can also be considered when available,*
☐	Table Number/ Name	*Table Number B25044. "Tenure by Vehicles Available"*
☐	Temporal Resolution	*Annual value representing the time period chosen*
☐	Spatial Resolution	*Block Group (BG)*
☐	Data Format	*Excel spreadsheet or shapefile/geodatabase*
Data Retrieval		
☐	Webpage	*The data can be accessed through a portal within IPUMS.com: https://data2.nhgis.org/main*
☐	Account	*An IPUMS account needs to be created with the user email. The data are sent to this email. This could take up to an hour depending on how much data you have requested.*
☐	Spatial Scale	*After logging in, select the Geographic Level of Block Group*
☐	Temporal Coverage	*Select the Year filter for 5-Year Ranges (e.g., 2014-2018)*
☐	Variable/Topic	*Then select the topic "Occupancy/Vacancy and Use" under the Housing tab*
☐	Tables	*The tables that are available for the filters selected above will be populated below the filters. Search the page for the specific table number (Table Number B25044. "Tenure by Vehicles Available").*
☐	Selection	*Once the table of interest (Table Number B25044) has been found, select that table and hit "continue" on the top right of the page (a dialogue box will appear)*

☐	Review and Submit	*This will then take you to the "Review and Submit" page where you will want to select the option to filter your data for your selected area. Click Submit.*
Decisions needed for calculation		
☐	Download Source	*The data can be accessed through IPUMS or directly from the Census website. The IPUMS portal provides an easier way to download the needed tables and is recommended.*
☐	Data Table Selection	*Multiple tables may be displayed when the search for keywords is conducted, and users may find alternative tables (in addition to the table number listed here) that can be considered. However, caution must be used if the users want to select a different table to make sure that the table selected captures the information needed.* *Tabular data need a field to link to the spatial data files. For example, if the data are compiled at the BG level, there needs to be a field indicating the BG value that can thereby be linked to the same value in the BG spatial data.*
☐	Calculations	*Use to calculate the sum of renters and owners with no vehicle over the total number of households.*
Calculation steps and assumptions		
☐	Calculation on Data	*See Appendix Equation S-12. Take the sum of (AJ2WE003 "Estimates: Owner occupied: No vehicle available", and AJ2WE010 "Estimates: Renter occupied: No vehicle available") divided by AJ2WE001 "Estimates: Total".*
Decisions needed for mapping and interpretation		
☐	Mapping Limited to Block Groups Containing Data	*NA – All BGs will have demographic values*
☐	Choosing Symbology	*Maps showing the distribution of percent will generally not be compared across scenarios, time periods, or locations so a single symbology will not be necessary. The symbology will be specific to the data for current area of interest.*
☐	Binning the Data by Block Group	*Percent values will be continuous from minimum to maximum values. Data can either be divided into equal intervals (recommended for percent values ranging from 0-100) or quantiles (recommended for percent values not ranging from 0-100 or raw count values). Using quantiles is also recommended when the data are not evenly distributed across the entire range to discern variations within concentrated ranges. Use a maximum of 5-7 categories so that the map reader can readily distinguish between color categories and visually match them to the legend. Deciles or other percentiles can also be used depending on user needs.*
☐	Choosing Colors	*Use a color gradation that becomes darker as the vulnerability increases. Avoid using a divergent color scheme (darker at both extremes and lighter in the middle), which implies an inflection point such as 0 in a dataset containing positive and negative values.*

Examples of how the indicator can be useful		
☐	Emergency Response/ Adaptation Planning	*Households without vehicles will be more isolated and less able to evacuate during an extreme event. This indicator can help assess if household have sufficient access to transportation in order to safely evacuate in the event of an emergency and can inform design of evacuation and recovery plans. Households without vehicles will also face challenges accessing medical and other basic necessities during and after an event. They may also face isolation issues and thus experience higher impacts than average.*
Key caveats/limitations		
☐	Vehicle Capacity	*This indicator does not provide information on the number of vehicles. If the household size is large compared to the seating capacity, evacuation may still be difficult.*
☐	Uncertainties for Small BGs	*Margins of error need to be considered for assessing uncertainties in ACS estimates, especially for small BGs.*
Citations		
	Dataset/Tool	*U.S. Census Bureau. (2019). 2014-2018 American Community Survey 5-year Public Use Microdata Samples, Block Groups & Larger Areas [CSV Data file]. https://www.nhgis.org/*
	Additional Resources	*U.S. Census Bureau. (2018). American Community Survey General Handbook 2018, Chapter 3: Understanding and Using ACS Single-Year and Multiyear Estimates. https://www.census.gov/content/dam/Census/library/publications/2018/acs/acs_general_handbook_2018_ch03.pdf*

ACS: American Community Survey, BG: Block Group, IPUMS: Integrated Public Use Microdata Series

Indicator 2.1.13. Checklist for Percent of Population with No High School Degree Indicator

	Percent of Population over 25 with No High School Degree Indicator	
Definition of the indicator		
☐	Definition	*Percent of population over 25 with no high school degree*
☐	Interpretation	*This indicator provides information on the population who do not have minimal educational attainment levels.*
Data source		
☐	Data Source	*American Community Survey (ACS) five-year data for historical periods (e.g., 2014-2018). The five-year sample provides increased statistical reliability of the data compared with that of single-year estimates, particularly for small geographic areas and small population subgroups (U.S. Census, 2018). The Census Decadal data or a more recent ACS year can also be considered when available,*
☐	Table Number/ Name	*Table Number B15003- "EDUCATIONAL ATTAINMENT FOR THE POPULATION 25 YEARS AND OVER"*
☐	Temporal Resolution	*Annual value representing the time period chosen*
☐	Spatial Resolution	*Block Group (BG)*
☐	Data Format	*Excel spreadsheet or shapefile/geodatabase*
Data Retrieval		
☐	Webpage	*The data can be accessed through a portal within IPUMS.com: https://data2.nhgis.org/main*
☐	Account	*An IPUMS account needs to be created with the user email. The data are sent to this email. This could take up to an hour depending on how much data you have requested.*
☐	Spatial Scale	*After logging in, select the Geographic Level of Block Group.*
☐	Temporal Coverage	*Select the Year filter for 5-Year Ranges (2014-2018).*
☐	Variable/Topic	*Then select the topic "Educational Attainment" under the Population tab.*
☐	Tables	*The tables that are available for the filters selected above will be populated below the filters. Search the page for the specific table number (Table Number B15003. "EDUCATIONAL ATTAINMENT FOR THE POPULATION 25 YEARS AND OVER").*
☐	Selection	*Once the table of interest (Table Number B15003) has been found, select that table and hit "continue" on the top right of the page (a dialogue box will appear)*

☐	Review and Submit	*This will then take you to the "Review and Submit" page where you will want to select the option to filter your data for your selected area. Click Submit.*
Decisions needed for calculation		
☐	Download Source	*The data can be accessed through IPUMS or directly from the Census website. The IPUMS portal provides an easier way to download the needed tables and is recommended.*
☐	Data Table Selection	*Multiple tables may be displayed when the search for keywords is conducted, and users may find alternative tables (in addition to the table number listed here) that can be considered. However, caution must be used if the users want to select a different table to make sure that the table selected captures the information needed.* *Tabular data need a field to link to the spatial data files. For example, if the data are compiled at the BG level, there needs to be a field indicating the BG value that can thereby be linked to the same value in the BG spatial data.*
☐	Calculations	*Use to calculate sum of (no schooling completed Nursery school Kindergarten 1st grade to 12th grade, no diploma) and divide by total; Convert to percent.*
Calculation steps and assumptions		
☐	Calculation on Data	*See Appendix Equation S-13. Take the sum of all education groups divided by the total:* *((AJYPE002, "Estimates: No Schooling Completed" +AJYPE003, "Estimates: Nursery School," +AJYPE004, "Estimates: Kindergarten," +AJYPE005, "Estimates: 1st Grade," +AJYPE006, "Estimates: 2nd Grade," +AJYPE007, "Estimates: 3rd Grade," +AJYPE008, "Estimates: 4th Grade,"* *+AJYPE009, "Estimates: 5th Grade," +AJYPE010, "Estimates: 6th Grade," +AJYPE011, "Estimates: 7th Grade," +AJYPE012, "Estimates: 8th Grade," +AJYPE013, "Estimates: 9th Grade," +AJYPE014, "Estimates: 10th Grade," +AJYPE015, "Estimates: 11th Grade,"* *+AJYPE016, "Estimates: 12th Grade, No Diploma,")/AJYPE001, "Estimates: Total) *100*
Decisions needed for mapping and interpretation		
☐	Mapping Limited to Block Groups Containing Data	*NA – All BGs will have demographic values*
☐	Choosing Symbology	*Maps showing the distribution of percent will generally not be compared across scenarios, time periods, or locations so a single symbology will not be necessary. The symbology will be specific to the data for current area of interest.*

☐	Binning the Data by Block Group	*Percent values will be continuous from minimum to maximum values. Data can either be divided into equal intervals (recommended for percent values ranging from 0-100) or quantiles (recommended for percent values not ranging from 0-100 or raw count values). Using quantiles is also recommended when the data are not evenly distributed across the entire range to discern variations within concentrated ranges. Use a maximum of 5-7 categories so that the map reader can readily distinguish between color categories and visually match them to the legend. Deciles or other percentiles can also be used depending on user needs.*
☐	Choosing Colors	*Use a color gradation that becomes darker as the vulnerability increases. Avoid using a divergent color scheme (darker at both extremes and lighter in the middle), which implies an inflection point such as 0 in a dataset containing positive and negative values.*
Examples of how the indicator can be useful		
☐	Emergency Response/ Adaptation Planning	*This indicator provides a measure of educational attainment within the community, which in turn describes potential earnings opportunities and access to information. Less educated residents may have difficulties understanding communication and event preparedness materials, leaving them more isolated and vulnerable during and after an event.*
Key caveats/limitations		
☐	Limited Information Overall Education Levels	*Populations who do have a high school degree may not necessarily have higher educational qualifications and may still have limited earnings potential and awareness.*
☐	Uncertainties for Small BGs	*Margins of error need to be considered for assessing uncertainties in ACS estimates, especially for small BGs.*
Citations		
	Dataset/Tool	*U.S. Census Bureau. (2019). 2014-2018 American Community Survey 5-year Public Use Microdata Samples, Block Groups & Larger Areas [CSV Data file]. https://www.nhgis.org/*
	Additional Resources	*U.S. Census Bureau. (2018). American Community Survey General Handbook 2018, Chapter 3: Understanding and Using ACS Single-Year and Multiyear Estimates. https://www.census.gov/content/dam/Census/library/publications/2018/acs/acs_general_handbook_2018_ch03.pdf*

ACS: American Community Survey, BG: Block Group, IPUMS: Integrated Public Use Microdata Series

Indicator 2.1.14. Checklist for Percent of Population with No Health Insurance Indicator

Percent of Population with No Health Insurance Indicator		
Definition of the indicator		
☐	Definition	*Percent of population with no health insurance*
☐	Interpretation	*This indicator uses the Census definition of coverage which include plans and programs that provide comprehensive health coverage.*
Data source		
☐	Data Source	*American Community Survey (ACS) five-year data for historical periods (e.g., 2014-2018). The five-year sample provides increased statistical reliability of the data compared with that of single-year estimates, particularly for small geographic areas and small population subgroups (U.S. Census, 2018). The Census Decadal data or a more recent ACS year can also be considered when available,*
☐	Table Number/ Name	*Table Number B27010. "Types of Health Insurance Coverage by Age"*
☐	Temporal Resolution	*Annual value representing the time period chosen*
☐	Spatial Resolution	*Block Group (BG)*
☐	Data Format	*Excel spreadsheet or shapefile/geodatabase*
Data Retrieval		
☐	Webpage	*The data can be accessed through a portal within IPUMS.com: https://data2.nhgis.org/main.*
☐	Account	*An IPUMS account needs to be created with the user email. The data are sent to this email. This could take up to an hour depending on how much data you have requested.*
☐	Spatial Scale	*From there select the Geographic Level of Block Group*
☐	Temporal Coverage	*Next select the Year filter for 5-Year Ranges (2014-2018)*
☐	Variable/Topic	*Then select the topic Health Insurance under the population tab.*
☐	Tables	*The tables that are available for the filters selected above will be populated below the filters. Search the page for the specific table number (*Table Number B27010. "Types of Health Insurance Coverage by Age"*).*
☐	Selection	*Once the table of interest (*Table Number B27010*) has been found, select that table and hit "continue" on the top right of the page (a dialogue box will appear)*

☐	Review and Submit	*This will then take you to the "Review and Submit" page where you will want to select the option to filter your data your selected area. Click Submit.*
Decisions needed for calculation		
☐	Download Source	*The data can be accessed through IPUMS or directly from the Census website. The IPUMS portal provides an easier way to download the needed tables and is recommended.*
☐	Data Table Selection	*Multiple tables may be displayed when the search for keywords is conducted, and users may find alternative tables (in addition to the table number listed here) that can be considered. However, caution must be used if the users want to select a different table to make sure that the table selected captures the information needed.* *Tabular data need a field to link to the spatial data files. For example, if the data are compiled at the BG level, there needs to be a field indicating the BG value that can thereby be linked to the same value in the BG spatial data.*
☐	Calculations	*Use to calculate the sum of "No health insurance coverage" across all age groups and divide by Total.*
Calculation steps and assumptions		
☐	Calculation on Data	*See Appendix Equation S-14. Take the sum of (AJ35E017 "Estimates: Under 19 years: No health insurance coverage", AJ35E033 "Estimates: 19 to 34 years: No health insurance coverage", AJ35E050 "Estimates: 35 to 64 years: No health insurance coverage", and AJ35E066 "Estimates: 65 years and over: No health insurance coverage") divided by AJ35E001 "Estimates: Total".*
Decisions needed for mapping and interpretation		
☐	Mapping Limited to Block Groups Containing Data	*NA – All BGs will have demographic values*
☐	Choosing Symbology	*Maps showing the distribution of percent will generally not be compared across scenarios, time periods, or locations so a single symbology will not be necessary. The symbology will be specific to the data for current area of interest.*
☐	Binning the Data by Block Group	*Percent values will be continuous from minimum to maximum values. Data can either be divided into equal intervals (recommended for percent values ranging from 0-100) or quantiles (recommended for percent values not ranging from 0-100 or raw count values). Using quantiles is also recommended when the data are not evenly distributed across the entire range to discern variations within concentrated ranges. Use a maximum of 5-7 categories so that the map reader can readily distinguish between color categories and visually match them to the legend. Deciles or other percentiles can also be used depending on user needs.*
☐	Choosing Colors	*Use a color gradation that becomes darker as the vulnerability increases. Avoid using a divergent color scheme (darker at both extremes and lighter in the middle), which implies an inflection point such as 0 in a dataset containing positive and negative values.*

Examples of how the indicator can be useful		
☐	Emergency Response/ Adaptation Planning	*Households that lack health insurance will have difficulties accessing healthcare in the event of an emergency. This indicator is useful for assessing the health vulnerability of populations and their ability to recover after an incident. This can help inform public health planning.*
Key caveats/limitations		
☐	Census Definition of Health Insurance Coverage	*The definition is specific to the one used by the Census and does not include insurance for specific conditions, dental, vision, life and disability insurance. This indicator also does not capture those who have limited insurance, less access to medical facilities and good quality of medical care.*
☐	Uncertainties for Small BGs	*Margins of error need to be considered for assessing uncertainties in ACS estimates, especially for small BGs.*
Citations		
	Dataset/Tool	*U.S. Census Bureau. (2019). 2014-2018 American Community Survey 5-year Public Use Microdata Samples, Block Groups & Larger Areas [CSV Data file]. https://www.nhgis.org/*
	Additional Resources	*U.S. Census Bureau. (2018). American Community Survey General Handbook 2018, Chapter 3: Understanding and Using ACS Single-Year and Multiyear Estimates. https://www.census.gov/content/dam/Census/library/publications/2018/acs/acs_general_handbook_2018_ch03.pdf*

ACS: American Community Survey, BG: Block Group, IPUMS: Integrated Public Use Microdata Series

Indicator 2.1.15. Checklist for Percent of Households with at Least 1 Person That Has a Disability Indicator

Percent of Households with at Least 1 Person That Has a Disability Indicator		
Definition of the indicator		
☐	Definition	*Percent of households with at least 1 person that has a disability*
☐	Interpretation	*This indicator provides information on people who experience any of the six difficulties (hearing, vision, cognitive, ambulatory, self-care, independent living).*
Data source		
☐	Data Source	*American Community Survey (ACS) five-year data for historical periods (e.g., 2014-2018). The five-year sample provides increased statistical reliability of the data compared with that of single-year estimates, particularly for small geographic areas and small population subgroups (U.S. Census, 2018). The Census Decadal data or a more recent ACS year can also be considered when available,*
☐	Table Number/ Name	*Table Number B22010. "Receipt of Food Stamps/SNAP in the Past 12 Months by Disability Status for Households"*
☐	Temporal Resolution	*Annual value representing the time period chosen*
☐	Spatial Resolution	*Block Group (BG)*
☐	Data Format	*Excel spreadsheet or shapefile/geodatabase*
Data Retrieval		
☐	Webpage	*The data can be accessed through a portal within IPUMS.com: https://data2.nhgis.org/main.*
☐	Account	*An IPUMS account needs to be created with the user email. The data are sent to this email. This could take up to an hour depending on how much data you have requested.*
☐	Spatial Scale	*After logging in, select the Geographic Level of Block Group.*
☐	Temporal Coverage	*Select the Year filter for 5-Year Ranges (e.g., 2014-2018).*
☐	Variable/Topic	*Based on keywords in the indicator definition, select the topic "disability" under the population tab.*
☐	Tables	*The tables that are available for the filters selected above will be populated below the filters. Search the page for the specific table number (Table Number B22010. "Receipt of Food Stamps/SNAP in the Past 12 Months by Disability Status for Households")*

☐	Selection	*Once the table of interest (Table Number B22010) has been found, select that table and hit "continue" on the top right of the page (a dialogue box will appear).*
☐	Review and Submit	*This will then take you to the "Review and Submit" page where you will want to select the option to filter your data for your selected area. Click Submit.*
Decisions needed for calculation		
☐	Download Source	*The data can be accessed through IPUMS or directly from the Census website. The IPUMS portal provides an easier way to download the needed tables and is recommended.*
☐	Data Table Selection	*Multiple tables may be displayed when the search for keywords is conducted, and users may find alternative tables (in addition to the table number listed here) that can be considered. However, caution must be used if the users want to select a different table to make sure that the table selected captures the information needed.* *Tabular data need a field to link to the spatial data files. For example, if the data are compiled at the BG level, there needs to be a field indicating the BG value that can thereby be linked to the same value in the BG spatial data.*
☐	Calculations	*Use to calculate the sum of "Households with 1 or more persons with a disability" across the 2 groups {received or did not receive food stamps} and divide by total.*
Calculation steps and assumptions		
☐	Calculation on Data	*See Appendix Equation S-15. Take the sum of (AJ05E003 "Estimates: Household received Food Stamps/SNAP in the past 12 months: Households with 1 or more persons with a disability", and AJ05E006 "Estimates: Household did not receive Food Stamps/SNAP in the past 12 months: Households with 1 or more persons with a disability") divided by AJ05E001 "Estimates: Total".*
Decisions needed for mapping and interpretation		
☐	Mapping Limited to Block Groups Containing Data	*NA – All BGs will have demographic values*
☐	Choosing Symbology	*Maps showing the distribution of percent will generally not be compared across scenarios, time periods, or locations so a single symbology will not be necessary. The symbology will be specific to the data for current area of interest.*
☐	Binning the Data by Block Group	*Percent values will be continuous from minimum to maximum values. Data can either be divided into equal intervals (recommended for percent values ranging from 0-100) or quantiles (recommended for percent values not ranging from 0-100 or raw count values). Using quantiles is also recommended when the data are not evenly distributed across the entire range to discern variations within concentrated ranges. Use a maximum of 5-7 categories so that the map reader can readily distinguish between color categories and visually match them to the legend. Deciles or other percentiles can also be used depending on user needs.*

☐	Choosing Colors	*Use a color gradation that becomes darker as the vulnerability increases. Avoid using a divergent color scheme (darker at both extremes and lighter in the middle), which implies an inflection point such as 0 in a dataset containing positive and negative values.*
Examples of how the indicator can be useful		
☐	Emergency Response/ Adaptation Planning	*People with disabilities are highly vulnerable to emergencies due to their dependence on caregivers, reliance on medical equipment, and limited mobility, which prevents them from adequately preparing for evacuation, shelter, and medical needs. This indicator will help assess the overall health vulnerability of the population, which will inform public health planning, emergency planning and response.*
Key caveats/limitations		
☐	Census Definition of Disability	*The definition is specific to the one used by the Census and may not be comparable with other definitions. Further, this variable does not provide information on the severity of the disability.*
☐	Uncertainties for Small BGs	*Margins of error need to be considered for assessing uncertainties in ACS estimates, especially for small BGs.*
Citations		
	Dataset/Tool	*U.S. Census Bureau. (2019). 2014-2018 American Community Survey 5-year Public Use Microdata Samples, Block Groups & Larger Areas [CSV Data file]. https://www.nhgis.org/*
	Additional Resources	*U.S. Census Bureau. (2018). American Community Survey General Handbook 2018, Chapter 3: Understanding and Using ACS Single-Year and Multiyear Estimates. https://www.census.gov/content/dam/Census/library/publications/2018/acs/acs_general_handbook_2018_ch03.pdf*

ACS: American Community Survey, BG: Block Group, IPUMS: Integrated Public Use Microdata Series

Indicator 2.1.16. Checklist for Percent of Population under the Age of 18 Indicator

Percent of Population under the Age of 18 Indicator		
Definition of the indicator		
☐	Definition	*Percent of population under the age of 18*
☐	Interpretation	*This indicator provides information on minor populations who may be predisposed to more severe health impacts and are dependent on caregivers.*
Data source		
☐	Data Source	*American Community Survey (ACS) five-year data for historical periods (e.g., 2014-2018). The five-year sample provides increased statistical reliability of the data compared with that of single-year estimates, particularly for small geographic areas and small population subgroups (U.S. Census, 2018). The Census Decadal data or a more recent ACS* year *can also be considered when available,*
☐	Table Number/ Name	*Table Number B01001. "SEX BY AGE"*
☐	Temporal Resolution	*Annual value representing the time period chosen*
☐	Spatial Resolution	*Block Group (BG)*
☐	Data Format	*Excel spreadsheet or shapefile/geodatabase*
Data Retrieval		
☐	Webpage	*The data can be accessed through a portal within IPUMS.com: https://data2.nhgis.org/main*
☐	Account	*An IPUMS account needs to be created with the user email. The data are sent to this email. This could take up to an hour depending on how much data you have requested.*
☐	Spatial Scale	*After logging in, select the Geographic Level of Block Group.*
☐	Temporal Coverage	*Select the Year filter for 5-Year Ranges (2014-2018).*
☐	Topic	*Based on keywords in the indicator definition, select the topic "Age" under the population tab.*
☐	Tables	*The tables that are available for the filters selected above will be populated below the filters. Search the page for the specific table number (Table Number B01001. "SEX BY AGE").*
☐	Selection	*Once the table of interest (Table Number B01001) has been found, select that table and hit "continue" on the top right of the page (a dialogue box will appear).*

☐	Review and Submit	*This will then take you to the "Review and Submit" page where you will want to select the option to filter your data for your selected area. Click Submit.*
Decisions needed for calculation		
☐	Download Source	*The data can be accessed through IPUMS or directly from the Census website. The IPUMS portal provides an easier way to download the needed tables and is recommended.*
☐	Data Table Selection	*Multiple tables may be displayed when the search for keywords is conducted, and users may find alternative tables (in addition to the table number listed here) that can be considered. However, caution must be used if the users want to select a different table to make sure that the table selected captures the information needed.* *Tabular data need a field to link to the spatial data files. For example, if the data are compiled at the BG level, there needs to be a field indicating the BG value that can thereby be linked to the same value in the BG spatial data.*
☐	Calculations	*Use to calculate the sum of {5-9 years, 10-14, and 15-17 years old} divided by the total population.*
Calculation steps and assumptions		
☐	Calculation on Data	*See Appendix Equation S-16. Take the sum of all age groups under 18 divided by the total:* *(((AJWBE003, "Estimates: Male: Under 5 years," +AJWBE004, "Estimates: Male: 5 to 9 years," +AJWBE005, "Estimates: Male: 10 to 14 years," +AJWBE006, "Estimates: Male: 15 to 17 years," +AJWBE027, "Estimates: Female: Under 5 years," +AJWBE028, "Estimates: Female: 5 to 9 years," +AJWBE029, "Estimates: Female: 10 to 14 years,"* *+AJWBE030, "Estimates: Female: 15 to 17 years")/AJWBE001, "Estimates: Total") *100)*
Decisions needed for mapping and interpretation		
☐	Mapping Limited to Block Groups Containing Data	*NA – All BGs will have demographic values*
☐	Choosing Symbology	*Maps showing the distribution of percent will generally not be compared across scenarios, time periods, or locations so a single symbology will not be necessary. The symbology will be specific to the data for current area of interest.*
☐	Binning the Data by Block Group	*Percent values will be continuous from minimum to maximum values. Data can either be divided into equal intervals (recommended for percent values ranging from 0-100) or quantiles (recommended for percent values not ranging from 0-100 or raw count values). Using quantiles is also recommended when the data are not evenly distributed across the entire range to discern variations within concentrated ranges. Use a maximum of 5-7 categories so that the map reader can readily distinguish between color categories and visually match them to the legend. Deciles or other percentiles can also be used depending on user needs.*

☐	Choosing Colors	*Use a color gradation that becomes darker as the vulnerability increases. Avoid using a divergent color scheme (darker at both extremes and lighter in the middle), which implies an inflection point such as 0 in a dataset containing positive and negative values.*
Examples of how the indicator can be useful		
☐	Emergency Response/ Adaptation Planning	*Children are more vulnerable to contaminant releases, as they are more susceptible to health impacts. They are also more dependent on caregivers. This indicator informs priorities for emergency response, adaptation, and public health planning by identifying areas that have a high proportion of children.*
Key caveats/limitations		
☐	Percent of Population	*This variable does not distinguish between infants who may be among the most vulnerable and older children. It also does not provide information on how many children are present within a household or the health status of children.*
☐	Uncertainties for Small BGs	*Margins of error need to be considered for assessing uncertainties in ACS estimates, especially for small BGs.*
Citations		
	Dataset/Tool	*U.S. Census Bureau. (2019). 2014-2018 American Community Survey 5-year Public Use Microdata Samples, Block Groups & Larger Areas [CSV Data file]. https://www.nhgis.org/*
	Additional Resources	*U.S. Census Bureau. (2018). American Community Survey General Handbook 2018, Chapter 3: Understanding and Using ACS Single-Year and Multiyear Estimates. https://www.census.gov/content/dam/Census/library/publications/2018/acs/acs_general_handbook_2018_ch03.pdf*

ACS: American Community Survey, BG: Block Group, IPUMS: Integrated Public Use Microdata Series

Indicator 2.1.17. Checklist for Percent of Population Who Are 65 or Over Indicator

Percent of Population Who Are 65 or Over Indicator		
Definition of the indicator		
☐	Definition	*Percent of population who are 65 or over*
☐	Interpretation	*This indicator provides information on older populations who may be predisposed to more severe health impacts, have mobility issues, and are dependent on caregivers.*
Data source		
☐	Data Source	*American Community Survey (ACS) five-year data for historical periods (e.g., 2014-2018). The five-year sample provides increased statistical reliability of the data compared with that of single-year estimates, particularly for small geographic areas and small population subgroups (U.S. Census, 2018). The Census Decadal data or a more recent ACS year can also be considered when available,*
☐	Table Number/ Name	*Table Number B01001. "SEX BY AGE"*
☐	Temporal Resolution	*Annual value representing the time period chosen*
☐	Spatial Resolution	*Block Group (BG)*
☐	Data Format	*Excel spreadsheet or shapefile/geodatabase*
Data retrieval		
☐	Webpage	*The data can be accessed through a portal within IPUMS.com): https://data2.nhgis.org/main.*
☐	Account	*An IPUMS account needs to be created with the user email. The data are sent to this email. This could take up to an hour depending on how much data you have requested.*
☐	Spatial Scale	*After logging in, select the Geographic Level of Block Group.*
☐	Temporal Coverage	*Select the Year filter for 5-Year Ranges (2014-2018).*
☐	Variable/Topic	*Based on the keywords in the indicator definition, select the topic "Age" under the population tab.*
☐	Tables	*The tables that are available for the filters selected above will be populated below the filters. Search the page for the specific table number (Table Number B01001. "SEX BY AGE").*
☐	Selection	*Once the table of interest (Table Number B01001) has been found, select that table and hit "continue" on the top right of the page (a dialogue box will appear).*

☐	Review and Submit	*This will then take you to the "Review and Submit" page where you will want to select the option to filter your data for your selected area. Click Submit.*
Decisions needed for calculation		
☐	Download Source	*The data can be accessed through IPUMS or directly from the Census website. The IPUMS portal provides an easier way to download the needed tables and is recommended.*
☐	Data Table Selection	*Multiple tables may be displayed when the search for keywords is conducted, and users may find alternative tables (in addition to the table number listed here) that can be considered. However, caution must be used if the users want to select a different table to make sure that the table selected captures the information needed.* *Tabular data needs a field to link to the spatial data files. For example, if the data are compiled at the BG level, there needs to be a field indicating the BG value that can thereby be linked to the same value in the BG spatial data.*
☐	Calculations	*Use to calculate the sum of {males and females ages 65-66,67-69,70-74,75-79,80-84, and 85+} divided by the total population.*
Calculation steps and assumptions		
☐	Calculation on Data	*See Appendix Equation S-17. Take the sum of all age groups above 65 divided by the total population:* *((AJWBE020, "Estimates: Male: 65 and 66 years," +AJWBE021, "Estimates: Male: 67 to 69 years," +AJWBE022, "Male: 70 to 74 years," +AJWBE023, "Estimates: Male: 75 to 79 years," +AJWBE024, "Estimates: Male: 80 to 84 years," +AJWBE025, "Estimates: Male: 85 years and over," +AJWBE044, "Estimates: Female: 65 and 66 years,"* *+AJWBE045, "Estimates: Female: 67 to 69 years," +AJWBE046, "Estimates: Female: 70 to 74 years," +AJWBE047, "Estimates: Female: 75 to 79 years," +AJWBE048, "Estimates: Female: 80 to 84 years," +AJWBE049, "Estimates: Female: 85 years and over)/AJWBE001, "Estimates: Total) *100*
Decisions needed for mapping and interpretation		
☐	Mapping Limited to Block Groups Containing Data	*NA – All BGs will have demographic values*
☐	Choosing Symbology	*Maps showing the distribution of percent will generally not be compared across scenarios, time periods, or locations so a single symbology will not be necessary. The symbology will be specific to the data for current area of interest.*
☐	Binning the Data by Block Group	*Percent values will be continuous from minimum to maximum values. Data can either be divided into equal intervals (recommended for percent values ranging from 0-100) or quantiles (recommended for percent values not ranging from 0-100 or raw count values). Using quantiles is also recommended when the data are not evenly distributed across the entire range to discern variations within concentrated ranges. Use a maximum of 5-7 categories so that the map reader can readily distinguish between color categories and visually match them to the legend. Deciles or other percentiles can also be used depending on user needs.*

☐	Choosing Colors	*Use a color gradation that becomes darker as the vulnerability increases. Avoid using a divergent color scheme (darker at both extremes and lighter in the middle), which implies an inflection point such as 0 in a dataset containing positive and negative values.*
Examples of how the indicator can be useful		
☐	Emergency Response/ Adaptation Planning	*Elderly populations are at higher risk of negative health impacts from exposure to release events. They may also have mobility issues and be dependent on caregivers. This indicator informs priorities for emergency response, adaptation, and public health planning by identifying areas that have a high proportion of elderly individuals at risk.*
Key caveats/limitations		
☐	Population over 65	*This variable uses 65 as a threshold for identifying the most vulnerable. However, it does not distinguish between people over 65 and people over 90, for example. It also does not provide information on whether there are caregivers within the household or their health status.*
☐	Uncertainties for Small BGs	*Margins of error need to be considered for assessing uncertainties in ACS estimates, especially for small BGs.*
Citations		
	Dataset/Tool	*U.S. Census Bureau. (2019). 2014-2018 American Community Survey 5-year Public Use Microdata Samples, Block Groups & Larger Areas [CSV Data file]. https://www.nhgis.org/*
	Additional Resources	*U.S. Census Bureau. (2018). American Community Survey General Handbook 2018, Chapter 3: Understanding and Using ACS Single-Year and Multiyear Estimates. https://www.census.gov/content/dam/Census/library/publications/2018/acs/acs_general_handbook_2018_ch03.pdf*

ACS: American Community Survey, BG: Block Group, IPUMS: Integrated Public Use Microdata Series

Indicator 2.1.18. Checklist for Percent of Households with Single Members Who Are 65 or Over Indicator

Percent of Households with Single Members Who Are 65 or Over Indicator		
Definition of the indicator		
☐	Definition	*Percent of households with single members who are 65 or over*
☐	Interpretation	*This indicator provides information on older populations who may be more vulnerable than the average population but do not have other household members living with them.*
Data source		
☐	Data Source	*American Community Survey (ACS) five-year data for historical periods (e.g., 2014-2018). The five-year sample provides increased statistical reliability of the data compared with that of single-year estimates, particularly for small geographic areas and small population subgroups (U.S. Census, 2018). The Census Decadal data or a more recent ACS year can also be considered when available,*
☐	Table Number/ Name	*Table Number B11007. "Households by Presence of People 65 Years and Over, Household Size and Household Type"*
☐	Temporal Resolution	*Annual value representing the time period chosen*
☐	Spatial Resolution	*Block Group (BG)*
☐	Data Format	*Excel spreadsheet or shapefile/geodatabase*
Data Retrieval		
☐	Webpage	*The data can be accessed through a portal within IPUMS.com: https://data2.nhgis.org/main.*
☐	Account	*An IPUMS account needs to be created with the user email. The data are sent to this email. This could take up to an hour depending on how much data you have requested.*
☐	Spatial Scale	*After logging in, select the Geographic Level of Block Group.*
☐	Temporal Coverage	*Select the Year filter for 5-Year Ranges (2014-2018).*
☐	Variable/Topic	*Based on keywords in the indicator definition, select the topic "Age" under the population tab.*

☐	Tables	*The tables that are available for the filters selected above will be populated below the filters Search the page for the specific table number (Table Number B11007. "Households by Presence of People 65 Years and Over, Household Size and Household Type").*
☐	Selection	*Once the table of interest (Table Number B11007) has been found, select that table and hit "continue" on the top right of the page (a dialogue box will appear).*
☐	Review and Submit	*This will then take you to the "Review and Submit" page where you will want to select the option to filter your data for your selected area. Click Submit.*
Decisions needed for calculation		
☐	Download Source	*The data can be accessed through IPUMS or directly from the Census website. The IPUMS portal provides an easier way to download the needed tables and is recommended.*
☐	Data Table Selection	*Multiple tables may be displayed when the search for keywords is conducted, and users may find alternative tables (in addition to the table number listed here) that can be considered. However, caution must be used if the users want to select a different table to make sure that the table selected captures the information needed.* *Tabular data need a field to link to the spatial data files. For example, if the data are compiled at the BG level, there needs to be a field indicating the BG value that can thereby be linked to the same value in the BG spatial data.*
☐	Calculations	*Use to calculate Households with one or more people 65 years and over: 1-person household divided by the total population.*
Calculation steps and assumptions		
☐	Calculation on Data	*See Appendix Equation S-18. Take (AJX8E003, "Estimates: Households with one or more people 65 years and over," divided by AJX8E001, "Estimates: Total") *100*
Decisions needed for mapping and interpretation		
☐	Mapping Limited to Block Groups Containing Data	*NA – All BGs will have demographic values*
☐	Choosing Symbology	*Maps showing the distribution of percent will generally not be compared across scenarios, time periods, or locations so a single symbology will not be necessary. The symbology will be specific to the data for current area of interest.*
☐	Binning the Data by Block Group	*Percent values will be continuous from minimum to maximum values. Data can either be divided into equal intervals (recommended for percent values ranging from 0-100) or quantiles (recommended for percent values not ranging from 0-100 or raw count values). Using quantiles is also recommended when the data are not evenly distributed across the entire range to discern variations within concentrated ranges. Use a maximum of 5-7 categories so that the map reader can readily distinguish between color categories and visually match them to the legend. Deciles or other percentiles can also be used depending on user needs.*

☐	Choosing Colors	*Use a color gradation that becomes darker as the vulnerability increases. Avoid using a divergent color scheme (darker at both extremes and lighter in the middle), which implies an inflection point such as 0 in a dataset containing positive and negative values.*
Examples of how the indicator can be useful		
☐	Emergency Response/ Adaptation Planning	*Elderly populations are at higher risk of negative health impacts from exposure to release events. They may also have mobility issues and be dependent on caregivers. Elderly people living alone do not have caregivers or support at home and are more likely to be socially isolated and have more mobility issues than those who have other household members., in addition to being more susceptible to health consequences of exposure. This indicator informs priorities for emergency response, adaptation, and public health planning by identifying areas that have a high proportion of elderly individuals at risk and without immediate support.*
Key caveats/limitations		
☐	Population over 65	*This variable uses 65 as a threshold for identifying the most vulnerable. However, it does not distinguish between people over 65 and people over 90, for example. It also does not provide information on the health status.*
☐	Uncertainties for Small BGs	*Margins of error need to be considered for assessing uncertainties in ACS estimates, especially for small BGs.*
Citations		
	Dataset/Tool	*U.S. Census Bureau. (2019). 2014-2018 American Community Survey 5-year Public Use Microdata Samples, Block Groups & Larger Areas [CSV Data file]. https://www.nhgis.org/*
	Additional Resources	*U.S. Census Bureau. (2018). American Community Survey General Handbook 2018, Chapter 3: Understanding and Using ACS Single-Year and Multiyear Estimates. https://www.census.gov/content/dam/Census/library/publications/2018/acs/acs_general_handbook_2018_ch03.pdf*

ACS: American Community Survey, BG: Block Group, IPUMS: Integrated Public Use Microdata Series

Indicator 2.1.19. Checklist for Percent of Population with Female Household Heads Indicator

Percent of Population with Female Household Heads Indicator		
Definition of the indicator		
☐	Definition	*Percent of population with female household heads*
☐	Interpretation	*This indicator provides information on the composition of the household and indicates that the head of the household is female.*
Data source		
☐	Data Source	*American Community Survey (ACS) five-year data for historical periods (e.g., 2014-2018). The five-year sample provides increased statistical reliability of the data compared with that of single-year estimates, particularly for small geographic areas and small population subgroups (U.S. Census, 2018). The Census Decadal data or a more recent ACS year can also be considered when available,*
☐	Table Number/ Name	*Table Number B09019. "Household Type (Including Living Alone) By Relationship"*
☐	Temporal Resolution	*Annual value representing the time period chosen*
☐	Spatial Resolution	*Block Group (BG)*
☐	Data Format	*Excel spreadsheet or shapefile/geodatabase*
Data Retrieval		
☐	Webpage	*The data can be accessed through a portal within IPUMS.com: https://data2.nhgis.org/main.*
☐	Account	*An IPUMS account needs to be created with the user email. The data are sent to this email. This could take up to an hour depending on how much data you have requested.*
☐	Spatial Scale	*After logging in, select the Geographic Level of Block Group.*
☐	Temporal Coverage	*Select the Year filter for 5-Year Ranges (2014-2018).*
☐	Variable/Topic	*Based on keywords in the indicator definition, select the topic "Households (Termed "Families" before 1940)" under the population tab.*
☐	Tables	*The tables that are available for the filters selected above will be populated below the filters. Search the page for the specific table number (Table Number B09019. "Household Type (Including Living Alone) By Relationship").*
☐	Selection	*Once the table of interest (Table Number B09019) has been found, select that table and hit "continue" on the top right of the page (a dialogue box will appear).*

☐	Review and Submit	*This will then take you to the "Review and Submit" page where you will want to select the option to filter your data for your selected area. Click Submit.*
Decisions needed for calculation		
☐	Download Source	*The data can be accessed through IPUMS or directly from the Census website. The IPUMS portal provides an easier way to download the needed tables and is recommended.*
☐	Data Table Selection	*Multiple tables may be displayed when the search for keywords is conducted, and users may find alternative tables (in addition to the table number listed here) that can be considered. However, caution must be used if the users want to select a different table to make sure that the table selected captures the information needed.* *Tabular data need a field to link to the spatial data files. For example, if the data are compiled at the BG level, there needs to be a field indicating the BG value that can thereby be linked to the same value in the BG spatial data.*
☐	Calculations	*Use to calculate the sum of infamily and in nonfamily female householders divided by the number of households.*
Calculation steps and assumptions		
☐	Calculation on Data	*See Appendix Equation S-19. Take ((AJXHE006, "Estimates: In households: In family households: Householder: Female," + AJXHE029, "Estimates: In households: In nonfamily households: Householder: Female") divided by AJXHE001, "Estimates: Total") *100.*
Decisions needed for mapping and interpretation		
☐	Mapping Limited to Block Groups Containing Data	*NA – All BGs will have demographic values*
☐	Choosing Symbology	*Maps showing the distribution of percent will generally not be compared across scenarios, time periods, or locations so a single symbology will not be necessary. The symbology will be specific to the data for current area of interest.*
☐	Binning the Data by Block Group	*Percent values will be continuous from minimum to maximum values. Data can either be divided into equal intervals (recommended for percent values ranging from 0-100) or quantiles (recommended for percent values not ranging from 0-100 or raw count values). Using quantiles is also recommended when the data are not evenly distributed across the entire range to discern variations within concentrated ranges. Use a maximum of 5-7 categories so that the map reader can readily distinguish between color categories and visually match them to the legend. Deciles or other percentiles can also be used depending on user needs.*
☐	Choosing Colors	*Use a color gradation that becomes darker as the vulnerability increases. Avoid using a divergent color scheme (darker at both extremes and lighter in the middle), which implies an inflection point such as 0 in a dataset containing positive and negative values.*

Examples of how the indicator can be useful		
☐	Emergency Response/ Adaptation Planning	*Female-headed households may be more socially isolated and have less access to resources, support systems, and family and community networks. This indicator describes the amount of social connectivity and helps identify those who may be impacted disproportionately more than average.*
Key caveats/limitations		
☐	Census Definition of Household Head	*Census designates one person in each household as the householder. Typically, this is the person who is listed on line one of the survey questionnaire or one of the people in whose name the home is owned, being bought, or rented and If there is no such person in the household, any adult household member 15 years old and over could be designated as the householder. If a household head is identified as a female, it does not necessarily mean that this is a single parent or that there is no partner living in the household.*
☐	Uncertainties for Small BGs	*Margins of error need to be considered for assessing uncertainties in ACS estimates, especially for small BGs.*
Citations		
	Dataset/Tool	*U.S. Census Bureau. (2019). 2014-2018 American Community Survey 5-year Public Use Microdata Samples, Block Groups & Larger Areas [CSV Data file]. https://www.nhgis.org/*
	Additional Resources	*U.S. Census Bureau. (2018). American Community Survey General Handbook 2018, Chapter 3: Understanding and Using ACS Single-Year and Multiyear Estimates. https://www.census.gov/content/dam/Census/library/publications/2018/acs/acs_general_handbook_2018_ch03.pdf*

ACS: American Community Survey, BG: Block Group, IPUMS: Integrated Public Use Microdata Series

Indicator 2.1.20. Checklist for Percent of Population That Is Black or African American Alone Indicator

Percent of Population That Is Black or African American Alone Indicator		
Definition of the indicator		
☐	Definition	*Percent of population that is Black or African American alone*
☐	Interpretation	*This indicator provides information on the racial demographics of the population.*
Data source		
☐	Data Source	*American Community Survey (ACS) five-year data for historical periods (e.g., 2014-2018). The five-year sample provides increased statistical reliability of the data compared with that of single-year estimates, particularly for small geographic areas and small population subgroups (U.S. Census, 2018). The Census Decadal data or a more recent ACS year can also be considered when available,*
☐	Table Number/ Name	*Table Number B02001. "RACE"*
☐	Temporal Resolution	*Annual value representing the time period chosen*
☐	Spatial Resolution	*Block Group (BG)*
☐	Data Format	*Excel spreadsheet or shapefile/geodatabase*
Data Retrieval		
☐	Webpage	*The data can be accessed through a portal within IPUMS.com: https://data2.nhgis.org/main*
☐	Account	*An IPUMS account needs to be created with the user email. The data are sent to this email. This could take up to an hour depending on how much data you have requested.*
☐	Spatial Scale	*After logging in, select the Geographic Level of Block Group.*
☐	Temporal Coverage	*Select the Year filter for 5-Year Ranges (2014-2018).*
☐	Variable/Topic	*Based on keywords in the indicator definition, select the topic "Race" under the population tab.*
☐	Tables	*The tables that are available for the filters selected above will be populated below the filters. Search the page for the specific table number (Table Number B02001. "RACE").*
☐	Selection	*Once the table of interest (Table Number B02001) has been found, select that table and hit "continue" on the top right of the page (a dialogue box will appear).*

☐	Review and Submit	*This will then take you to the "Review and Submit" page where you will want to select the option to filter your data for your selected area. Click Submit.*
Decisions needed for calculation		
☐	Download Source	*The data can be accessed through IPUMS or directly from the Census website. The IPUMS portal provides an easier way to download the needed tables and is recommended.*
☐	Data Table Selection	*Multiple tables may be displayed when the search for keywords is conducted, and users may find alternative tables (in addition to the table number listed here) that can be considered. However, caution must be used if the users want to select a different table to make sure that the table selected captures the information needed.* *Tabular data need a field to link to the spatial data files. For example, if the data are compiled at the BG level, there needs to be a field indicating the BG value that can thereby be linked to the same value in the BG spatial data.*
☐	Calculations	*Use to calculate the number of Black or African American Alone over the total population.*
Calculation steps and assumptions		
☐	Calculation on Data	*See Appendix Equation S-20. Take AJWNE003 "Estimates: Black or African American alone" divided by AJWNE001 "Estimates: Total"*
Decisions needed for mapping and interpretation		
☐	Mapping Limited to Block Groups Containing Data	*NA – All BGs will have demographic values*
☐	Choosing Symbology	*Maps showing the distribution of percent will generally not be compared across scenarios, time periods, or locations so a single symbology will not be necessary. The symbology will be specific to the data for current area of interest.*
☐	Binning the Data by Block Group	*Percent values will be continuous from minimum to maximum values. Data can either be divided into equal intervals (recommended for percent values ranging from 0-100) or quantiles (recommended for percent values not ranging from 0-100 or raw count values). Using quantiles is also recommended when the data are not evenly distributed across the entire range to discern variations within concentrated ranges. Use a maximum of 5-7 categories so that the map reader can readily distinguish between color categories and visually match them to the legend. Deciles or other percentiles can also be used depending on user needs.*
☐	Choosing Colors	*Use a color gradation that becomes darker as the vulnerability increases. Avoid using a divergent color scheme (darker at both extremes and lighter in the middle), which implies an inflection point such as 0 in a dataset containing positive and negative values.*

Examples of how the indicator can be useful		
☐	Emergency Response/ Adaptation Planning	*This indicator provides demographic information for the population. Black populations are often marginalized, so they may have less integration with social networks, support, and communications in the event of an emergency. They may also be less educated and/or under-resourced and historically received less financial support/insurance coverage. They also often live close to contaminated sites/waste facilities. Identifying such minority population groups may help determine priorities and strategies for emergency response, adaptation, and public health planning.*
Key caveats/limitations		
☐	One Racial Group	*This indicator represents one racial group and other minority groups need to be considered as well.*
☐	Uncertainties for Small BGs	*Margins of error need to be considered for assessing uncertainties in ACS estimates, especially for small BGs.*
Citations		
	Dataset/Tool	*U.S. Census Bureau. (2019). 2014-2018 American Community Survey 5-year Public Use Microdata Samples, Block Groups & Larger Areas [CSV Data file]. https://www.nhgis.org/*
	Additional Resources	*U.S. Census Bureau. (2018). American Community Survey General Handbook 2018, Chapter 3: Understanding and Using ACS Single-Year and Multiyear Estimates. https://www.census.gov/content/dam/Census/library/publications/2018/acs/acs_general_handbook_2018_ch03.pdf*

ACS: American Community Survey, BG: Block Group, IPUMS: Integrated Public Use Microdata Series

Indicator 2.1.21. Checklist for Percent of Population That Are Native Hawaiian or Other Pacific Islander Alone Indicator

Percent of Population That Are Native Hawaiian or Other Pacific Islander Alone Indicator		
Definition of the indicator		
☐	Definition	*Percent of population that are Native Hawaiian or Other Pacific Islander alone*
☐	Interpretation	*This indicator provides information on the racial demographics of the population.*
Data source		
☐	Data Source	*American Community Survey (ACS) five-year data for historical periods (e.g., 2014-2018). The five-year sample provides increased statistical reliability of the data compared with that of single-year estimates, particularly for small geographic areas and small population subgroups (U.S. Census, 2018). The Census Decadal data or a more recent ACS year can also be considered when available,*
☐	Table Number/ Name	*Table Number B02001. "RACE"*
☐	Temporal Resolution	*Annual value representing the time period chosen*
☐	Spatial Resolution	*Block Group (BG)*
☐	Data Format	*Excel spreadsheet or shapefile/geodatabase*
Data Retrieval		
☐	Webpage	*The data can be accessed through a portal within IPUMS.com: https://data2.nhgis.org/main*
☐	Account	*An IPUMS account needs to be created with the user email. The data are sent to this email. This could take up to an hour depending on how much data you have requested.*
☐	Spatial Scale	*After logging in, select the Geographic Level of Block Group.*
☐	Temporal Coverage	*Select the Year filter for 5-Year Ranges (2014-2018).*
☐	Variable/Topic	*Based on keywords in the indicator definition, select the topic "Race" under the population tab.*
☐	Tables	*The tables that are available for the filters selected above will be populated below the filters. Search the page for the specific table number (Table Number B02001. "RACE").*

☐	Selection	*Once the table of interest (Table Number B02001) has been found, select that table and hit "continue" on the top right of the page (a dialogue box will appear)*
☐	Review and Submit	*This will then take you to the "Review and Submit" page where you will want to select the option to filter your data for your selected area. Click Submit.*
Decisions needed for calculation		
☐	Download Source	*The data can be accessed through IPUMS or directly from the Census website. The IPUMS portal provides an easier way to download the needed tables and is recommended.*
☐	Data Table Selection	*Multiple tables may be displayed when the search for keywords is conducted, and users may find alternative tables (in addition to the table number listed here) that can be considered. However, caution must be used if the users want to select a different table to make sure that the table selected captures the information needed.* *Tabular data need a field to link to the spatial data files. For example, if the data are compiled at the BG level, there needs to be a field indicating the BG value that can thereby be linked to the same value in the BG spatial data.*
☐	Calculations	*Use to calculate the number of Native Hawaiian or Other Pacific Islander Alone over the total population.*
Calculation steps and assumptions		
☐	Calculation on Data	*See Appendix Equation S-21. Take AJWNE006 "Estimates: Native Hawaiian and Other Pacific Islander alone" divided by AJWNE001 "Estimates: Total"*
Decisions needed for mapping and interpretation		
☐	Mapping Limited to Block Groups Containing Data	*NA – All Block Groups will have demographic values*
☐	Choosing Symbology	*Maps showing the distribution of percent will generally not be compared across scenarios, time periods, or locations so a single symbology will not be necessary. The symbology will be specific to the data for current area of interest.*
☐	Binning the Data by Block Group	*Percent values will be continuous from minimum to maximum values. Data can either be divided into equal intervals (recommended for percent values ranging from 0-100) or quantiles (recommended for percent values not ranging from 0-100 or raw count values). Using quantiles is also recommended when the data are not evenly distributed across the entire range to discern variations within concentrated ranges. Use a maximum of 5-7 categories so that the map reader can readily distinguish between color categories and visually match them to the legend. Deciles or other percentiles can also be used depending on user needs.*
☐	Choosing Colors	*Use a color gradation that becomes darker as the vulnerability increases. Avoid using a divergent color scheme (darker at both extremes and lighter in the middle), which implies an inflection point such as 0 in a dataset containing positive and negative values.*

Examples of how the indicator can be useful		
☐	Emergency Response/ Adaptation Planning	*This indicator provides demographic information for the population. Native/ indigenous populations are among minority groups, so they may have less integration with social networks, support, and communications in the event of an emergency. Identifying such minority population groups may help determine priorities and strategies for emergency response, adaptation and public health planning.*
Key caveats/limitations		
☐	One Racial Group	*This indicator represents one racial group and other minority groups need to be considered as well.*
☐	Uncertainties for Small BGs	*Margins of error need to be considered for assessing uncertainties in ACS estimates, especially for small BGs.*
Citations		
	Dataset/Tool	*U.S. Census Bureau. (2019). 2014-2018 American Community Survey 5-year Public Use Microdata Samples, Block Groups & Larger Areas [CSV Data file]. https://www.nhgis.org/*
	Additional Resources	*U.S. Census Bureau. (2018). American Community Survey General Handbook 2018, Chapter 3: Understanding and Using ACS Single-Year and Multiyear Estimates. https://www.census.gov/content/dam/Census/library/publications/2018/acs/acs_general_handbook_2018_ch03.pdf*

ACS: American Community Survey, BG: Block Group, IPUMS: Integrated Public Use Microdata Series

Indicator 2.1.22. Checklist for Percent of Population That Are American Indian or Alaska Native Alone Indicator

Percent of Population That Are American Indian or Alaska Native Alone Indicator		
Definition of the indicator		
☐	Definition	*Percent of population that are American Indian or Alaska Native alone*
☐	Interpretation	*This indicator provides information on the racial demographics of the population.*
Data source		
☐	Data Source	*American Community Survey (ACS) five-year data for historical periods (e.g., 2014-2018). The five-year sample provides increased statistical reliability of the data compared with that of single-year estimates, particularly for small geographic areas and small population subgroups (U.S. Census, 2018). The Census Decadal data or a more recent ACS year can also be considered when available,*
☐	Table Number/ Name	*Table Number B02001. "RACE"*
☐	Temporal Resolution	*Annual value representing the time period chosen*
☐	Spatial Resolution	*Block Group (BG)*
☐	Data Format	*Excel spreadsheet or shapefile/geodatabase*
Data Retrieval		
☐	Webpage	*The data can be accessed through a portal within IPUMS.com: https://data2.nhgis.org/main*
☐	Account	*An IPUMS account needs to be created with the user email. The data are sent to this email. This could take up to an hour depending on how much data you have requested.*
☐	Spatial Scale	*After logging in, select the Geographic Level of Block Group.*
☐	Temporal Coverage	*Select the Year filter for 5-Year Ranges (2014-2018).*
☐	Variable/Topic	*Based on keywords in the indicator definition, select the topic "Race" under the population tab.*
☐	Tables	*The tables that are available for the filters selected above will be populated below the filters. Search the page for the specific table number (Table Number B02001. "RACE").*

☐	Selection	*Once the table of interest (Table Number B02001) has been found, select that table and hit "continue" on the top right of the page (a dialogue box will appear).*
☐	Review and Submit	*This will then take you to the "Review and Submit" page where you will want to select the option to filter your data for your selected area. Click Submit.*
Decisions needed for calculation		
☐	Download Source	*The data can be accessed through IPUMS or directly from the Census website. The IPUMS portal provides an easier way to download the needed tables and is recommended.*
☐	Data Table Selection	*Multiple tables may be displayed when the search for keywords is conducted, and users may find alternative tables (in addition to the table number listed here) that can be considered. However, caution must be used if the users want to select a different table to make sure that the table selected captures the information needed.* *Tabular data need a field to link to the spatial data files. For example, if the data are compiled at the BG level, there needs to be a field indicating the BG value that can thereby be linked to the same value in the BG spatial data.*
☐	Calculations	*Use to calculate the number of American Indian or Alaska Native Alone over the total population.*
Calculation steps and assumptions		
☐	Calculation on Data	*See Appendix Equation S-22. Take AJWNE004 "Estimates: American Indian and Alaska Native alone" divided by AJWNE001 "Estimates: Total"*
Decisions needed for mapping and interpretation		
☐	Mapping Limited to Block Groups Containing Data	*NA – All BGs will have demographic values*
☐	Choosing Symbology	*Maps showing the distribution of percent will generally not be compared across scenarios, time periods, or locations so a single symbology will not be necessary. The symbology will be specific to the data for current area of interest.*
☐	Binning the Data by Block Group	*Percent values will be continuous from minimum to maximum values. Data can either be divided into equal intervals (recommended for percent values ranging from 0-100) or quantiles (recommended for percent values not ranging from 0-100 or raw count values). Using quantiles is also recommended when the data are not evenly distributed across the entire range to discern variations within concentrated ranges. Use a maximum of 5-7 categories so that the map reader can readily distinguish between color categories and visually match them to the legend. Deciles or other percentiles can also be used depending on user needs.*
☐	Choosing Colors	*Use a color gradation that becomes darker as the vulnerability increases. Avoid using a divergent color scheme (darker at both extremes and lighter in the middle), which implies an inflection point such as 0 in a dataset containing positive and negative values.*

Examples of how the indicator can be useful		
☐	Emergency Response/ Adaptation Planning	*This indicator provides demographic information for the population. American Indian or Alaska Native populations are among minority groups, so they may have less integration with social networks, support, and communications in the event of an emergency. Identifying such minority population groups may help determine priorities and strategies for emergency response, adaptation and public health planning.*
Key caveats/limitations		
☐	One Racial Group	*This indicator represents one racial group and other minority groups need to be considered as well.*
☐	Uncertainties for Small BGs	*Margins of error need to be considered for assessing uncertainties in ACS estimates, especially for small BGs.*
Citations		
	Dataset/Tool	*U.S. Census Bureau. (2019). 2014-2018 American Community Survey 5-year Public Use Microdata Samples, Block Groups & Larger Areas [CSV Data file]. https://www.nhgis.org/*
	Additional Resources	*U.S. Census Bureau. (2018). American Community Survey General Handbook 2018, Chapter 3: Understanding and Using ACS Single-Year and Multiyear Estimates. https://www.census.gov/content/dam/Census/library/publications/2018/acs/acs_general_handbook_2018_ch03.pdf*

ACS: American Community Survey, BG: Block Group, IPUMS: Integrated Public Use Microdata Series

Indicator 2.1.23. Checklist for Percent of Population That Are Asian Alone Indicator

Percent of Population That Are Asian Alone Indicator		
Definition of the indicator		
☐	Definition	*Percent of population that are Asian alone*
☐	Interpretation	*This indicator provides information on the racial demographics of the population.*
Data source		
☐	Data Source	*American Community Survey (ACS) five-year data for historical periods (e.g., 2014-2018). The five-year sample provides increased statistical reliability of the data compared with that of single-year estimates, particularly for small geographic areas and small population subgroups (U.S. Census, 2018). The Census Decadal data or a more recent ACS year can also be considered when available,*
☐	Table Number/ Name	*Table Number B02001. "RACE"*
☐	Temporal Resolution	*Annual value representing the time period chosen*
☐	Spatial Resolution	*Block Group (BG)*
☐	Data Format	*Excel spreadsheet or shapefile/geodatabase*
Data Retrieval		
☐	Webpage	*The data can be accessed through a portal within IPUMS.com: https://data2.nhgis.org/main.*
☐	Account	*An IPUMS account needs to be created with the user email. The data are sent to this email. This could take up to an hour depending on how much data you have requested.*
☐	Spatial Scale	*After logging in, select the Geographic Level of Block Group*
☐	Temporal Coverage	*Select the Year filter for 5-Year Ranges (2014-2018)*
☐	Variable/Topic	*Based on keywords in the indicator definition, select the topic "Race" under the population tab*
☐	Tables	*The tables that are available for the filters selected above will be populated below the filters. Search the page for the specific table number (Table Number B02001. "RACE").*
☐	Selection	*Once the table of interest (Table Number B02001) has been found, select that table and hit "continue" on the top right of the page (a dialogue box will appear)*

☐	Review and Submit	*This will then take you to the "Review and Submit" page where you will want to select the option to filter your data for your selected area. Click Submit.*
Decisions needed for calculation		
☐	Download Source	*The data can be accessed through IPUMS or directly from the Census website. The IPUMS portal provides an easier way to download the needed tables and is recommended.*
☐	Data Table Selection	*Multiple tables may be displayed when the search for keywords is conducted, and users may find alternative tables (in addition to the table number listed here) that can be considered. However, caution must be used if the users want to select a different table to make sure that the table selected captures the information needed.* *Tabular data need a field to link to the spatial data files. For example, if the data are compiled at the BG level, there needs to be a field indicating the BG value that can thereby be linked to the same value in the BG spatial data.*
☐	Calculations	*Use to calculate the number of Asian Alone over the total population.*
Calculation steps and assumptions		
☐	Calculation on Data	*See Appendix Equation S-23. Take AJWNE005 "Estimates: Asian alone" divided by AJWNE001 "Estimates: Total"*
Decisions needed for mapping and interpretation		
☐	Mapping Limited to Block Groups Containing Data	*NA – All BGs will have demographic values*
☐	Choosing Symbology	*Maps showing the distribution of percent will generally not be compared across scenarios, time periods, or locations so a single symbology will not be necessary. The symbology will be specific to the data for current area of interest.*
☐	Binning the Data by Block Group	*Percent values will be continuous from minimum to maximum values. Data can either be divided into equal intervals (recommended for percent values ranging from 0-100) or quantiles (recommended for percent values not ranging from 0-100 or raw count values). Using quantiles is also recommended when the data are not evenly distributed across the entire range to discern variations within concentrated ranges. Use a maximum of 5-7 categories so that the map reader can readily distinguish between color categories and visually match them to the legend. Deciles or other percentiles can also be used depending on user needs.*
☐	Choosing Colors	*Use a color gradation that becomes darker as the vulnerability increases. Avoid using a divergent color scheme (darker at both extremes and lighter in the middle), which implies an inflection point such as 0 in a dataset containing positive and negative values.*

Examples of how the indicator can be useful		
☐	Emergency Response/ Adaptation Planning	*This indicator provides demographic information for the population. Asian populations are among minority groups, so they may have less integration with social networks, support, and communications in the event of an emergency. Identifying such minority population groups may help determine priorities and strategies for emergency response, adaptation and public health planning.*
Key caveats/limitations		
☐	One Racial Group	*This indicator represents one racial group and other minority groups need to be considered as well.*
☐	Uncertainties for Small BGs	*Margins of error need to be considered for assessing uncertainties in ACS estimates, especially for small BGs.*
Citations		
	Dataset/Tool	*U.S. Census Bureau. (2019). 2014-2018 American Community Survey 5-year Public Use Microdata Samples, Block Groups & Larger Areas [CSV Data file]. https://www.nhgis.org/*
	Additional Resources	*U.S. Census Bureau. (2018). American Community Survey General Handbook 2018, Chapter 3: Understanding and Using ACS Single-Year and Multiyear Estimates. https://www.census.gov/content/dam/Census/library/publications/2018/acs/acs_general_handbook_2018_ch03.pdf*

ACS: American Community Survey, BG: Block Group, IPUMS: Integrated Public Use Microdata Series

Indicator 2.1.24. Checklist for Percent of Population That Belongs to Other Non-White Races Indicator

Percent of Population That Belongs to Other Non-White Races Indicator		
Definition of the indicator		
☐	Definition	*Percent of population that belongs to other non-White races*
☐	Interpretation	*This indicator provides information on the racial demographics of the population.*
Data source		
☐	Data Source	*American Community Survey (ACS) five-year data for historical periods (e.g., 2014-2018). The five-year sample provides increased statistical reliability of the data compared with that of single-year estimates, particularly for small geographic areas and small population subgroups (U.S. Census, 2018). The Census Decadal data or a more recent ACS year can also be considered when available,*
☐	Table Number/ Name	*Table Number B02001. "RACE"*
☐	Temporal Resolution	*Annual value representing the time period chosen*
☐	Spatial Resolution	*Block Group (BG)*
☐	Data Format	*Excel spreadsheet or shapefile/geodatabase*
Data Retrieval		
☐	Webpage	*The data can be accessed through a portal within IPUMS.com): https://data2.nhgis.org/main.*
☐	Account	*An IPUMS account needs to be created with the user email. The data are sent to this email. This could take up to an hour depending on how much data you have requested.*
☐	Spatial Scale	*After logging in, select the Geographic Level of Block Group.*
☐	Temporal Coverage	*Select the Year filter for 5-Year Ranges (2014-2018).*
☐	Variable/Topic	*Based on keywords in the indicator definition, select the topic "Race" under the population tab.*
☐	Tables	*The tables that are available for the filters selected above will be populated below the filters. Search the page for the specific table number (Table Number B02001. "RACE").*
☐	Selection	*Once the table of interest (Table Number B02001) has been found, select that table and hit "continue" on the top right of the page (a dialogue box will appear).*

☐	Review and Submit	*This will then take you to the "Review and Submit" page where you will want to select the option to filter your data for your selected area. Click Submit.*
Decisions needed for calculation		
☐	Download Source	*The data can be accessed through IPUMS or directly from the Census website. The IPUMS portal provides an easier way to download the needed tables and is recommended.*
☐	Data Table Selection	*Multiple tables may be displayed when the search for keywords is conducted, and users may find alternative tables (in addition to the table number listed here) that can be considered. However, caution must be used if the users want to select a different table to make sure that the table selected captures the information needed.* *Tabular data need a field to link to the spatial data files. For example, if the data are compiled at the BG level, there needs to be a field indicating the BG value that can thereby be linked to the same value in the BG spatial data.*
☐	Calculations	*Use to calculate the sum of {some other race alone and two or more races} over the total population.*
Calculation steps and assumptions		
☐	Calculation on Data	*See Appendix Equation S-24. Take the sum of (AJWNE007 "Estimates: Some other race alone", AJWNE009 "Estimates: Two or more races: Two races including Some other race", and AJWNE010 "Estimates: Two or more races: Two races excluding Some other race, and three or more races") divided by AJWNE001 "Estimates: Total".*
Decisions needed for mapping and interpretation		
☐	Mapping Limited to Block Groups Containing Data	*NA – All BGs will have demographic values*
☐	Choosing Symbology	*Maps showing the distribution of percent will generally not be compared across scenarios, time periods, or locations so a single symbology will not be necessary. The symbology will be specific to the data for current area of interest.*
☐	Binning the Data by Block Group	*Percent values will be continuous from minimum to maximum values. Data can either be divided into equal intervals (recommended for percent values ranging from 0-100) or quantiles (recommended for percent values not ranging from 0-100 or raw count values). Using quantiles is also recommended when the data are not evenly distributed across the entire range to discern variations within concentrated ranges. Use a maximum of 5-7 categories so that the map reader can readily distinguish between color categories and visually match them to the legend. Deciles or other percentiles can also be used depending on user needs.*
☐	Choosing Colors	*Use a color gradation that becomes darker as the vulnerability increases. Avoid using a divergent color scheme (darker at both extremes and lighter in the middle), which implies an inflection point such as 0 in a dataset containing positive and negative values.*

Examples of how the indicator can be useful		
☐	Emergency Response/ Adaptation Planning	*This indicator provides demographic information for the population. Other Non-White Races populations are among minority groups, so they may have less integration with social networks, support, and communications in the event of an emergency. Identifying such minority population groups may help determine priorities and strategies for emergency response, adaptation, and public health planning.*
Key caveats/limitations		
☐	One Racial Group	*This indicator represents one racial group and other minority groups need to be considered as well.*
☐	Uncertainties for Small BGs	*Margins of error need to be considered for assessing uncertainties in ACS estimates, especially for small BGs.*
Citations		
	Dataset/Tool	*U.S. Census Bureau. (2019). 2014-2018 American Community Survey 5-year Public Use Microdata Samples, Block Groups & Larger Areas [CSV Data file]. https://www.nhgis.org/*
	Additional Resources	*U.S. Census Bureau. (2018). American Community Survey General Handbook 2018, Chapter 3: Understanding and Using ACS Single-Year and Multiyear Estimates. https://www.census.gov/content/dam/Census/library/publications/2018/acs/acs_general_handbook_2018_ch03.pdf*

ACS: American Community Survey, BG: Block Group, IPUMS: Integrated Public Use Microdata Series

Indicator 2.1.25. Checklist for Percent of Population That Are Hispanic or Latino Indicator

Percent of Population That Are Hispanic or Latino Indicator		
Definition of the indicator		
☐	Definition	*Percent of population that are Hispanic or Latino*
☐	Interpretation	*This indicator provides information on the ethnicity of the population.*
Data source		
☐	Data Source	*American Community Survey (ACS) five-year data for historical periods (e.g., 2014-2018). The five-year sample provides increased statistical reliability of the data compared with that of single-year estimates, particularly for small geographic areas and small population subgroups (U.S. Census, 2018). The Census Decadal data or a more recent ACS year can also be considered when available,*
☐	Table Number/ Name	*Table Number B03003. "Hispanic or Latino Origin"*
☐	Temporal Resolution	*Annual value representing the time period chosen*
☐	Spatial Resolution	*Block Group (BG)*
☐	Data Format	*Excel spreadsheet or shapefile/geodatabase*
Data Retrieval		
☐	Webpage	*The data can be accessed through a portal within IPUMS.com: https://data2.nhgis.org/main*
☐	Account	*An IPUMS account needs to be created with the user email. The data are sent to this email. This could take up to an hour depending on how much data you have requested.*
☐	Spatial Scale	*After logging in, select the Geographic Level of Block Group.*
☐	Temporal Coverage	*Select the Year filter for 5-Year Ranges (2014-2018).*
☐	Variable/Topic	*Based on keywords in the indicator definition, select the topic "Race" under the population tab.*
☐	Tables	*The tables that are available for the filters selected above will be populated below the filters. Search the page for the specific table number (Table Number B03003. "Hispanic or Latino Origin").*
☐	Selection	*Once the table of interest (Table Number B03003) has been found, select that table and hit "continue" on the top right of the page (a dialogue box will appear).*

☐	Review and Submit	*This will then take you to the "Review and Submit" page where you will want to select the option to filter your data for your selected area. Click Submit.*
Decisions needed for calculation		
☐	Download Source	*The data can be accessed through IPUMS or directly from the Census website. The IPUMS portal provides an easier way to download the needed tables and is recommended.*
☐	Data Table Selection	*Multiple tables may be displayed when the search for keywords is conducted, and users may find alternative tables (in addition to the table number listed here) that can be considered. However, caution must be used if the users want to select a different table to make sure that the table selected captures the information needed.* *Tabular data need a field to link to the spatial data files. For example, if the data are compiled at the BG level, there needs to be a field indicating the BG value that can thereby be linked to the same value in the BG spatial data.*
☐	Calculations	*Use to calculate the number of Hispanics or Latino over the total population.*
Calculation steps and assumptions		
☐	Calculation on Data	*See Appendix Equation S-25. Take AJWWE003, "Estimates: Hispanic or Latino" divided by AJWWE001 "Estimates: Total"*
Decisions needed for mapping and interpretation		
☐	Mapping Limited to Block Groups Containing Data	*NA – All BGs will have demographic values*
☐	Choosing Symbology	*Maps showing the distribution of percent will generally not be compared across scenarios, time periods, or locations so a single symbology will not be necessary. The symbology will be specific to the data for current area of interest.*
☐	Binning the Data by Block Group	*Percent values will be continuous from minimum to maximum values. Data can either be divided into equal intervals (recommended for percent values ranging from 0-100) or quantiles (recommended for percent values not ranging from 0-100 or raw count values). Using quantiles is also recommended when the data are not evenly distributed across the entire range to discern variations within concentrated ranges. Use a maximum of 5-7 categories so that the map reader can readily distinguish between color categories and visually match them to the legend. Deciles or other percentiles can also be used depending on user needs.*
☐	Choosing Colors	*Use a color gradation that becomes darker as the vulnerability increases. Avoid using a divergent color scheme (darker at both extremes and lighter in the middle), which implies an inflection point such as 0 in a dataset containing positive and negative values.*

Examples of how the indicator can be useful		
☐	Emergency Response/ Adaptation Planning	*This indicator provides ethnicity information for the population. Hispanic and Latino populations are among minority groups, so they may have less integration with social networks, support, and communications in the event of an emergency. In some cases, they may be undocumented, or have limited English speaking ability. Identifying such minority population groups may help determine priorities and strategies for emergency response, adaptation, and public health planning.*
Key caveats/limitations		
☐	Other Characteristics Need to Be Considered	*Being Hispanic does not necessarily mean that they are undocumented or have limited English speaking ability. Other indicators that directly measure these characteristics need to be considered as well.*
☐	Uncertainties for Small BGs	*Margins of error need to be considered for assessing uncertainties in ACS estimates, especially for small BGs.*
Citations		
	Dataset/Tool	*U.S. Census Bureau. (2019). 2014-2018 American Community Survey 5-year Public Use Microdata Samples, Block Groups & Larger Areas [CSV Data file]. https://www.nhgis.org/*
	Additional Resources	*U.S. Census Bureau. (2018). American Community Survey General Handbook 2018, Chapter 3: Understanding and Using ACS Single-Year and Multiyear Estimates. https://www.census.gov/content/dam/Census/library/publications/2018/acs/acs_general_handbook_2018_ch03.pdf*

ACS: American Community Survey, BG: Block Group, IPUMS: Integrated Public Use Microdata Series

Indicator 2.1.26. Checklist for Percent of Households That Have Limited English Speaking Ability Indicator

Percent of Households That Have Limited English Speaking Ability Indicator		
Definition of the indicator		
☐	Definition	*Percent of households that have limited English speaking ability*
☐	Interpretation	*This indicator identifies households that may need English-language assistance. This provides information on households in which no member 14 years old and over (1) speaks only English at home or (2) speaks a language other than English at home and speaks English "Very well."*
Data source		
☐	Data Source	*American Community Survey (ACS) five-year data for historical periods (e.g., 2014-2018). The five-year sample provides increased statistical reliability of the data compared with that of single-year estimates, particularly for small geographic areas and small population subgroups (U.S. Census, 2018). The Census Decadal data or a more recent ACS year can also be considered when available,*
☐	Table Number/ Name	*Table Number C16002. "Household Language by Household Limited English Speaking Status"*
☐	Temporal Resolution	*Annual value representing the time period chosen*
☐	Spatial Resolution	*Block Group (BG)*
☐	Data Format	*Excel spreadsheet or shapefile/geodatabase*
Data Retrieval		
☐	Webpage	*The data can be accessed through a portal within IPUMS.com: https://data2.nhgis.org/main*
☐	Account	*An IPUMS account needs to be created with the user email. The data are sent to this email. This could take up to an hour depending on how much data you have requested.*
☐	Spatial Scale	*After logging in, select the Geographic Level of Block Group.*
☐	Temporal Coverage	*Select the Year filter for 5-Year Ranges (2014-2018).*
☐	Variable/Topic	*Based on keywords in the indicator definition, select the topic "Language" from the Population tab.*

☐	Tables	*The tables that are available for the filters selected above will be populated below the filters. Search the page for the specific table number (Table Number C16002. "Household Language by Household Limited English Speaking Status").*
☐	Selection	*Once the table of interest (Table Number C16002) has been found, select that table and hit "continue" on the top right of the page (a dialogue box will appear).*
☐	Review and Submit	*This will then take you to the "Review and Submit" page where you will want to select the option to filter your data for your selected area. Click Submit.*
Decisions needed for calculation		
☐	Download Source	*The data can be accessed through IPUMS or directly from the Census website. The IPUMS portal provides an easier way to download the needed tables and is recommended.*
☐	Data Table Selection	*Multiple tables may be displayed when the search for keywords is conducted, and users may find alternative tables (in addition to the table number listed here) that can be considered. However, caution must be used if the users want to select a different table to make sure that the table selected captures the information needed.* *Tabular data need a field to link to the spatial data files. For example, if the data are compiled at the BG level, there needs to be a field indicating the BG value that can thereby be linked to the same value in the BG spatial data.*
☐	Calculations	*Use to calculate the sum of the "Limited English speaking household" columns across the different languages and divide by Total number of households.*
Calculation steps and assumptions		
☐	Calculation on Data	*See Appendix Equation S-26. Take the sum of (AJY2E004 "Estimates: Spanish: Limited English speaking household", AJY2E007 "Estimates: Other Indo-European languages: Limited English speaking household", AJY2E010 "Estimates: Asian and Pacific Island languages: Limited English speaking household", and AJY2E013 "Estimates: Other languages: Limited English speaking household") divided by AJY2E001 "Estimates: Total".*
Decisions needed for mapping and interpretation		
☐	Mapping Limited to Block Groups Containing Data	*NA – All BGs will have demographic values*
☐	Choosing Symbology	*Maps showing the distribution of percent will generally not be compared across scenarios, time periods, or locations so a single symbology will not be necessary. The symbology will be specific to the data for current area of interest.*

☐	Binning the Data by Block Group	*Percent values will be continuous from minimum to maximum values. Data can either be divided into equal intervals (recommended for percent values ranging from 0-100) or quantiles (recommended for percent values not ranging from 0-100 or raw count values). Using quantiles is also recommended when the data are not evenly distributed across the entire range to discern variations within concentrated ranges. Use a maximum of 5-7 categories so that the map reader can readily distinguish between color categories and visually match them to the legend. Deciles or other percentiles can also be used depending on user needs.*
☐	Choosing Colors	*Use a color gradation that becomes darker as the vulnerability increases. Avoid using a divergent color scheme (darker at both extremes and lighter in the middle), which implies an inflection point such as 0 in a dataset containing positive and negative values.*
Examples of how the indicator can be useful		
☐	Emergency Response/ Adaptation Planning	*Households with limited English will be linguistically isolated due to limited ability to receive communications, public information, and communicate with responders, thus making them more vulnerable in emergencies. This indicator is useful to assess the capacity of the population to access and understand communications materials and information in an emergency.*
Key caveats/limitations		
☐	Measure Based on Perceptions	*This indicator reflects the perceptions of the person filling in the questionnaire rather than own perceptions of each household member.*
☐	Uncertainties for Small BGs	*Margins of error need to be considered for assessing uncertainties in ACS estimates, especially for small BGs.*
Citations		
	Dataset/Tool	*U.S. Census Bureau. (2019). 2014-2018 American Community Survey 5-year Public Use Microdata Samples, Block Groups & Larger Areas [CSV Data file]. https://www.nhgis.org/*
	Additional Resources	*U.S. Census Bureau. (2018). American Community Survey General Handbook 2018, Chapter 3: Understanding and Using ACS Single-Year and Multiyear Estimates. https://www.census.gov/content/dam/Census/library/publications/2018/acs/acs_general_handbook_2018_ch03.pdf*

ACS: American Community Survey, BG: Block Group, IPUMS: Integrated Public Use Microdata Series

Indicator 2.1.27. Checklist for Percent of the Population Who Are over 18 and Non-U.S. Citizens Indicator

Percent of the Population Who Are over 18 and Non-U.S. Citizens Indicator		
Definition of the indicator		
☐	Definition	*Percent of the population who are over 18 and non-U.S. citizens*
☐	Interpretation	*This indicator provides information on respondents who indicated that they were not U.S. citizens at the time of the survey.*
Data source		
☐	Data Source	*American Community Survey (ACS) five-year data for historical periods (e.g., 2014-2018). The five-year sample provides increased statistical reliability of the data compared with that of single-year estimates, particularly for small geographic areas and small population subgroups (U.S. Census, 2018). The Census Decadal data or a more recent ACS year can also be considered when available,*
☐	Table Number/ Name	*Table Number B29002. "Citizen, Voting-Age Population by Educational Attainment and Table Number B01001. "SEX BY AGE"*
☐	Temporal Resolution	*Annual value representing the time period chosen*
☐	Spatial Resolution	*Block Group (BG)*
☐	Data Format	*Excel spreadsheet or shapefile/geodatabase*
Data Retrieval		
☐	Webpage	*The data can be accessed through a portal within IPUMS.com: https://data2.nhgis.org/main.*
☐	Account	*An IPUMS account needs to be created with the user email. The data are sent to this email. This could take up to an hour depending on how much data you have requested.*
☐	Spatial Scale	*After logging in, select the Geographic Level of Block Group.*
☐	Temporal Coverage	*Select the Year filter for 5-Year Ranges (2014-2018).*
☐	Variable/Topic	*Based on keywords in the indicator definition, select the topic "Language" under the population tab.*
☐	Tables	*The tables that are available for the filters selected above will be populated below the filters. Search the page for the specific table numbers (Table Number B29002– "Citizen, Voting-Age Population by Educational Attainment and Table Number B01001- "SEX BY AGE").*

☐	Selection	*Once the table of interest (Table Number B29002 and Table Number B01001) has been found, select that table and hit "continue" on the top right of the page (a dialogue box will appear).*
☐	Review and Submit	*This will then take you to the "Review and Submit" page where you will want to select the option to filter your data for your selected area. Click Submit.*
Decisions needed for calculation		
☐	Download Source	*The data can be accessed through IPUMS or directly from the Census website. The IPUMS portal provides an easier way to download the needed tables and is recommended.*
☐	Data Table Selection	*Multiple tables may be displayed when the search for keywords is conducted, and users may find alternative tables (in addition to the table number listed here) that can be considered. However, caution must be used if the users want to select a different table to make sure that the table selected captures the information needed.* *Tabular data need a field to link to the spatial data files. For example, if the data are compiled at the BG level, there needs to be a field indicating the BG value that can thereby be linked to the same value in the BG spatial data.*
☐	Calculations	*Use to calculate the {total population over 18 minus the total Citizen population divided} by the total population over 18.*
Calculation steps and assumptions		
☐	Calculation on Data	*See Appendix Equation S-27. First calculate the total population over 18 using table B01001:* *Take the total population AJWBE001 "Estimates: Total" minus the sum of male and female age groups below 18 (AJWBE003, "Estimates: Male: Under 5 years," +AJWBE004, "Estimates: Male: 5 to 9 years," +AJWBE005, "Estimates: Male: 10 to 14 years," +AJWBE006, "Estimates: Male: 15 to 17 years," +AJWBE027, "Estimates: Female: Under 5 years,"* *+AJWBE028, "Estimates: Female: 5 to 9 years," +AJWBE029, "Estimates: Female: 10 to 14 years," +AJWBE030, "Estimates: Female: 15 to 17 years)* *Next, pull the total variable for B29002 (AJ4QE001 "Estimates: Total") and calculate the percent of population who are over 18 and non-U.S. citizens with the following equation:* *((Over 18 Population - AJ4QE001 "Estimates: Total")-Over 18 Population)*
Decisions needed for mapping and interpretation		
☐	Mapping Limited to Block Groups Containing Data	*NA – All BGs will have demographic values*
☐	Choosing Symbology	*Maps showing the distribution of percent will generally not be compared across scenarios, time periods, or locations so a single symbology will not be necessary. The symbology will be specific to the data for current area of interest.*

☐	Binning the Data by Block Group	*Percent values will be continuous from minimum to maximum values. Data can either be divided into equal intervals (recommended for percent values ranging from 0-100) or quantiles (recommended for percent values not ranging from 0-100 or raw count values). Using quantiles is also recommended when the data are not evenly distributed across the entire range to discern variations within concentrated ranges. Use a maximum of 5-7 categories so that the map reader can readily distinguish between color categories and visually match them to the legend. Deciles or other percentiles can also be used depending on user needs.*
☐	Choosing Colors	*Use a color gradation that becomes darker as the vulnerability increases. Avoid using a divergent color scheme (darker at both extremes and lighter in the middle), which implies an inflection point such as 0 in a dataset containing positive and negative values.*
Examples of how the indicator can be useful		
☐	Emergency Response/ Adaptation Planning	*This indicator shows the proportion of immigrants in a community, who typically have less integration with social networks, support, and communications in the event of an emergency. They may also face cultural and language barriers. Identifying such minority population groups may help determine priorities and strategies for emergency response, adaptation and public health planning.*
Key caveats/limitations		
☐	Representative of Survey Year	*Citizenship status may change over years if an individual is going through naturalization.*
☐	Immigration Status	*This indicator does not reflect immigration status.*
☐	Uncertainties for Small BGs	*Margins of error need to be considered for assessing uncertainties in ACS estimates, especially for small BGs.*
Citations		
	Dataset/Tool	*U.S. Census Bureau. (2019). 2014-2018 American Community Survey 5-year Public Use Microdata Samples, Block Groups & Larger Areas [CSV Data file]. https://www.nhgis.org/*
	Additional Resources	*U.S. Census Bureau. (2018). American Community Survey General Handbook 2018, Chapter 3: Understanding and Using ACS Single-Year and Multiyear Estimates. https://www.census.gov/content/dam/Census/library/publications/2018/acs/acs_general_handbook_2018_ch03.pdf*

ACS: American Community Survey, BG: Block Group, IPUMS: Integrated Public Use Microdata Series

Indicator 2.1.28. Checklist for Percent of Households That Moved within the Last 3 Years Indicator

Percent of Households That Moved within the Last 3 Years Indicator		
Definition of the indicator		
☐	Definition	*Percent of households that moved within the last 3 years*
☐	Interpretation	*This indicator provides information on those who moved into their current residence within the last 3 years.*
Data source		
☐	Data Source	*American Community Survey (ACS) five-year data for historical periods (e.g., 2014-2018). The five-year sample provides increased statistical reliability of the data compared with that of single-year estimates, particularly for small geographic areas and small population subgroups (U.S. Census, 2018). The Census Decadal data or a more recent ACS year can also be considered when available,*
☐	Table Number/ Name	*Table Number B25038. "Tenure by Year Householder Moved into Unit"*
☐	Temporal Resolution	*Annual value representing the time period chosen*
☐	Spatial Resolution	*Block Group (BG)*
☐	Data Format	*Excel spreadsheet or shapefile/geodatabase*
Data Retrieval		
☐	Webpage	*The data can be accessed through a portal within IPUMS.com: https://data2.nhgis.org/main*
☐	Account	*An IPUMS account needs to be created with the user email. The data are sent to this email. This could take up to an hour depending on how much data you have requested.*
☐	Spatial Scale	*After logging in, select the Geographic Level of Block Group.*
☐	Temporal Coverage	*Select the Year filter for 5-Year Ranges (2014-2018).*
☐	Variable/Topic	*Based on keywords in the indicator definition, select the topic "Occupancy/Vacancy and Use" under the Housing tab.*
☐	Tables	*The tables that are available for the filters selected above will be populated below the filters. Search the page for the specific table number (Table Number B25038. "Tenure by Year Householder Moved into Unit").*

☐	Selection	*Once the table of interest (Table Number B25038) has been found, select that table and hit "continue" on the top right of the page (a dialogue box will appear).*
☐	Review and Submit	*This will then take you to the "Review and Submit" page where you will want to select the option to filter your data for your selected area. Click Submit.*
Decisions needed for calculation		
☐	Download Source	*The data can be accessed through IPUMS or directly from the Census website. The IPUMS portal provides an easier way to download the needed tables and is recommended.*
☐	Data Table Selection	*Multiple tables may be displayed when the search for keywords is conducted, and users may find alternative tables (in addition to the table number listed here) that can be considered. However, caution must be used if the users want to select a different table to make sure that the table selected captures the information needed.* *Tabular data need a field to link to the spatial data files. For example, if the data are compiled at the BG level, there needs to be a field indicating the BG value that can thereby be linked to the same value in the BG spatial data.*
☐	Calculations	*Use to calculate the sum of 2017 or later and 2015-2016 across owners and renters and divide by Total Number of Households (check that "total" is all households).*
Calculation steps and assumptions		
☐	Calculation on Data	*See Appendix Equation S-28. Take the sum of (AJ2QE003 "Estimates: Owner occupied: Moved in 2017 or later", AJ2QE004 "Estimates: Owner occupied: Moved in 2015 to 2016", AJ2QE010 "Estimates: Renter occupied: Moved in 2017 or later", AJ2QE011 "Estimates: Renter occupied: Moved in 2015 to 2016") divided by AJ2QE001 "Estimates: Total"*
Decisions needed for mapping and interpretation		
☐	Mapping Limited to Block Groups Containing Data	*NA – All BGs will have demographic values*
☐	Choosing Symbology	*Maps showing the distribution of percent will generally not be compared across scenarios, time periods, or locations so a single symbology will not be necessary. The symbology will be specific to the data for current area of interest.*
☐	Binning the Data by Block Group	*Percent values will be continuous from minimum to maximum values. Data can either be divided into equal intervals (recommended for percent values ranging from 0-100) or quantiles (recommended for percent values not ranging from 0-100 or raw count values). Using quantiles is also recommended when the data are not evenly distributed across the entire range to discern variations within concentrated ranges. Use a maximum of 5-7 categories so that the map reader can readily distinguish between color categories and visually match them to the legend. Deciles or other percentiles can also be used depending on user needs.*

☐	Choosing Colors	*Use a color gradation that becomes darker as the vulnerability increases. Avoid using a divergent color scheme (darker at both extremes and lighter in the middle), which implies an inflection point such as 0 in a dataset containing positive and negative values.*
Examples of how the indicator can be useful		
☐	Emergency Response/ Adaptation Planning	*This indicator shows the proportion of recent migrants in a community, who typically have less integration with social networks, support, and communications in the event of an emergency. They may also face cultural and language barriers. Identifying such population groups may help determine priorities and strategies for emergency response, adaptation and public health planning.*
Key caveats/limitations		
☐	No Information on Where They Moved From	*This indicator does not include information on where people moved from. If they lived in neighborhoods close by, they may not necessarily be socially isolated. On the other hand, if they moved from a different region of the country or from abroad, they may be more isolated.*
☐	Uncertainties for Small BGs	*Margins of error need to be considered for assessing uncertainties in ACS estimates, especially for small BGs.*
Citations		
	Dataset/Tool	*U.S. Census Bureau. (2019). 2014-2018 American Community Survey 5-year Public Use Microdata Samples, Block Groups & Larger Areas [CSV Data file]. https://www.nhgis.org/*
	Additional Resources	*U.S. Census Bureau. (2018). American Community Survey General Handbook 2018, Chapter 3: Understanding and Using ACS Single-Year and Multiyear Estimates. https://www.census.gov/content/dam/Census/library/publications/2018/acs/acs_general_handbook_2018_ch03.pdf*

ACS: American Community Survey, BG: Block Group, IPUMS: Integrated Public Use Microdata Series

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Appendix A. Indicator Descriptions, Potential Contaminants and Brownfield Sites and Vulnerability of Superfund Remediation Technology

Table A.1. Description of Options for Indicators.

ID*	Indicator Definition**	Description of Options for Indicators
Extreme Event: Heat		
1.1.1	Extreme Heat: Maximum Summer Temperature for [for selected time period, scenario]	▪ Maximum Summer Temperature, mean over years in historical period ▪ Maximum Summer Temperature, mean over years in time period 2040-2059 (scenario RCP 4.5) ▪ Maximum Summer Temperature, mean over years in time period 2040-2059 (scenario RCP 8.5) ▪ Difference between mean Maximum Summer Temperature in time period 2040-2059 (scenario RCP 4.5) and historical mean ▪ Difference between mean Maximum Summer Temperature in time period 2040-2059 (scenario RCP 8.5) and historical mean ▪ Percent difference between mean Maximum Summer Temperature in time period 2040-2059 (scenario RCP 4.5) and historical mean ▪ Percent difference between mean Maximum Summer Temperature in time period 2040-2059 (scenario RCP 8.5) and historical mean
1.1.2	Threshold-based Extreme Heat: Annual maximum temperature for “extreme heat days” for [for selected time period, scenario]	▪ Annual maximum temperature for "extreme heat days" (defined as Maximum daily temperature > 99th percentile of maximum daily temperatures over 1986-2005), mean over years in historical period ▪ Annual maximum temperature for "extreme heat days" (defined as Maximum daily temperature > 99th percentile of maximum daily temperatures over 1986-2005), mean over years in time period 2040-2059 (scenario RCP 4.5) ▪ Annual maximum temperature for "extreme heat days" (defined as Maximum daily temperature > 99th percentile of maximum daily temperatures over 1986-2005), mean over years in time period 2040-2059 (scenario RCP 8.5)
1.1.3	Threshold-based Extreme Heat: Change in the annual count of "extreme heat days" between [selected time period, scenario] and historical	▪ Difference between count of "extreme heat days" in time period 2040-2059 (scenario RCP 4.5) and historical mean, mean over years in time period 2040-2059 ▪ Difference between count of "extreme heat days" in time period 2040-2059 (scenario RCP 8.5) and historical mean, mean over years in time period 2040-2059

ID*	Indicator Definition**	Description of Options for Indicators
Extreme Event: Wildfire		
1.1.4	Wildfire: Fraction of Block Group Area Burned for [selected time period, scenario]	▪ Fraction of Block Group Burned, mean over years in historical period ▪ Fraction of Block Group Burned, mean over years in time period 2040-2059 (scenario RCP 4.5) ▪ Fraction of Block Group Burned, mean over years in time period 2040-2059 (scenario RCP 8.5) ▪ Difference between mean Fraction of Block Group Burned in time period 2040-2059 (scenario RCP 4.5) and historical mean ▪ Difference between mean Fraction of Block Group Burned in time period 2040-2059 (scenario RCP 8.5) and historical mean ▪ Percent difference between mean Fraction of Block Group Burned in time period 2040-2059 (scenario RCP 4.5) and historical mean ▪ Percent difference between mean Fraction of Block Group Burned in time period 2040-2059 (scenario RCP 8.5) and historical mean
Extreme Event: Flood		
1.1.5	Flood: Percent of Block Group within a [selected degree of flood] floodplain	▪ Percent of Block Group Within 100-year Floodplain ▪ Percent of Block Group Within 500-year Floodplain
1.1.6	Precipitation-based Flood: Annual % of precipitation depth falling during “heavy events” for [selected time period, scenario]	▪ Annual percent of precipitation depth falling during “heavy events" (defined as Daily depth > 99th percentile for 1986-2005), mean over years in historical period ▪ Annual percent of precipitation depth falling during “heavy events" (defined as Daily depth > 99th percentile for 1986-2005), mean over years in time period 2040-2059 ▪ Annual percent of precipitation depth falling during “heavy events" (defined as Daily depth > 99th percentile for 1986-2005), mean over years in time period 2040-2059
1.1.7	Threshold-based Flood: Change in the average annual percent of precipitation depth falling during "heavy events" between [selected time period, scenario] and historical	▪ Change in the average annual percent of precipitation depth falling during “heavy events" (defined as Daily depth > 99th percentile for 1986-2005) between time period 2040-2059 (scenario RCP 4.5) and historical mean ▪ Change in the average annual percent of precipitation depth falling during “heavy events" (defined as Daily depth > 99th percentile for 1986-2005) between time period 2040-2059 (scenario RCP 8.5) and historical mean
1.1.8	Physically based Flood: Mean Height Above the Nearest Drainage	▪ Mean Height Above the Nearest Drainage

ID*	Indicator Definition**	Description of Options for Indicators
Extreme Event: Drought		
1.1.9	Drought: Count of drought (defined by SPEI-6) months for [selected time period, scenario]	▪ Count of drought months (as defined by SPEI-6 ≤ -0.8), total over years in time period 1986-2005 ▪ Count of drought months (as defined by SPEI-6 ≤ -0.8), total over years in time period 1986-2006 ▪ Count of drought months (as defined by SPEI-6 ≤ -0.8), total over years in time period 1986-2007
1.1.10	Threshold-based Drought: Change in the count of drought (defined by SPEI-6) months between [selected time period, scenario] and historical	▪ Change in the total count of drought months (as defined by SPEI-6 ≤ -0.8), between time period 2040-2059 (scenario RCP 4.5) and historical mean ▪ Change in the total count of drought months (as defined by SPEI-6 ≤ -0.8), between time period 2040-2059 (scenario RCP 8.5) and historical mean
1.1.11	Drought: Count of drought (defined by SPEI-12) months for [selected time period, scenario]	▪ Count of drought months (as defined by SPEI-12 ≤ -0.8), total over years in time period 1986-2005 ▪ Count of drought months (as defined by SPEI-12 ≤ -0.8), total over years in time period 1986-2006 ▪ Count of drought months (as defined by SPEI-12 ≤ -0.8), total over years in time period 1986-2007
1.1.12	Threshold-based Drought: Change in the count of drought (defined by SPEI-12) months between [selected time period, scenario] and historical	▪ Change in the total count of drought months (as defined by SPEI-12 ≤ -0.8), between time period 2040-2059 (scenario RCP 4.5) and historical mean ▪ Change in the total count of drought months (as defined by SPEI-12 ≤ -0.8), between time period 2040-2059 (scenario RCP 8.5) and historical mean
Facilities: Counts		
1.2.1	Total count of sites/waste facilities	▪ Total number of sites/waste facilities
1.2.2	Count of sites/waste facilities per square km	▪ Density of sites/waste facilities
1.2.3	Sites/waste facilities count by type	▪ Total number of each of the 15 types of sites/waste facilities (e.g., Superfund)
Facilities: Hazardous Waste		
1.2.4	Tons of hazardous waste	▪ Quantity of managed waste stream in LQGs that are included in the BRS; Includes Environmental attributes (E)
1.2.5	Sites/waste facilities count (by hazard type)	▪ Number of sites/waste facilities producing each of the 6 types of hazardous wastes; Includes Environmental attributes (E)

ID*	Indicator Definition**	Description of Options for Indicators
1.2.6	Waste tonnage (by hazard type)	▪ Quantity of each of the 6 types of managed hazardous waste streams; Includes Environmental attributes (E)
Facilities: Brownfields and Superfund		
1.2.7	Brownfield count with contaminant; cleanup unknown (by contaminant)	▪ 20 contaminants; Includes Environmental attributes and Regulatory attributes
1.2.8	Superfund count with vulnerable remedy technology (by extreme event)	▪ Number of Superfund Sites with a remedy present that is vulnerable to a specific extreme event.
Facilities: Tanks		
1.2.9	Count of specific type of tank (UST/AST)	▪ open/temp closed for USTs (ASTs and USTs separately) ▪ open/temp closed for USTs (ASTs and USTs separately)
1.2.10	Total tank capacity (UST/AST)	▪ Includes physical attributes
Transport and Fate: Surface Water		
1.3.1	Count of sites/waste facilities in a floodplain [100-year and 500-year]	▪ Count of sites/waste facilities Within 100-year Floodplain ▪ Count of sites/waste facilities Within 500-year Floodplain
1.3.2	Count of sites/waste facilities within a specific hydrologic distance of a flowline	▪ Count of sites/waste facilities Within 500m of an NHD Flowline ▪ Count of sites/waste facilities Within 1 km of an NHD Flowline ▪ Count of sites/waste facilities Within 2 km of an NHD Flowline ▪ Count of sites/waste facilities Within 5 km of an NHD Flowline
1.3.3	Shortest Hydrologic Distance (m) Upstream to a Site/ Waste Facility	▪ Shortest Hydrologic Distance (m) Upstream to a Site/ Waste Facility
1.3.4	Count of Upstream Facilities within a specific hydrologic distance of a community	▪ Count of sites/waste facilities Within 500 m of a Community ▪ Count of sites/waste facilities Within 1 km of a Community ▪ Count of sites/waste facilities Within 3km of a Community ▪ Count of sites/waste facilities Within 5 km of a Community
Transport and Fate: Air		
1.3.5	Shortest Distance to a site/waste facility upwind [season]	▪ Spring Season: Shortest distance to a facility ▪ Summer Season: Shortest distance to a facility ▪ Fall Season: Shortest distance to a facility ▪ Winter Season: Shortest distance to a facility

ID*	Indicator Definition**	Description of Options for Indicators
1.3.6	Count of sites/waste facilities "upwind" within a specific season and distance of a community	▪ Spring Season: Count of sites/waste facilities Within 40 km ▪ Summer Season: Count of sites/waste facilities Within 40 km ▪ Fall Season: Count of sites/waste facilities Within 40 km ▪ Winter Season: Count of sites/waste facilities Within 40 km ▪ Spring Season: Count of sites/waste facilities Within 25 km ▪ Summer Season: Count of sites/waste facilities Within 25 km ▪ Fall Season: Count of sites/waste facilities Within 25 km ▪ Winter Season: Count of sites/waste facilities Within 25 km ▪ Spring Season: Count of sites/waste facilities Within 15 km ▪ Summer Season: Count of sites/waste facilities Within 15 km ▪ Fall Season: Count of sites/waste facilities Within 15 km ▪ Winter Season: Count of sites/waste facilities Within 15 km ▪ Spring Season: Count of sites/waste facilities Within 5 km ▪ Summer Season: Count of sites/waste facilities Within 5 km ▪ Fall Season: Count of sites/waste facilities Within 5 km ▪ Winter Season: Count of sites/waste facilities Within 5 km
1.3.7	Minimum response time, [by season]	▪ Spring Season: Minimum Response Time ▪ Summer Season: Minimum Response Time ▪ Fall Season: Minimum Response Time ▪ Winter Season: Minimum Response Time
1.3.8	Count of sites/waste facilities that are within specific response time ranges, [by season]	▪ Spring Season: Count of sites/waste facilities Within 20 Minute Response Time ▪ Summer Season: Count of sites/waste facilities Within 20 Minute Response Time ▪ Fall Season: Count of sites/waste facilities Within 20 Minute Response Time ▪ Winter Season: Count of sites/waste facilities Within 20 Minute Response Time ▪ Spring Season: Count of sites/waste facilities Within 15 Minute Response Time ▪ Summer Season: Count of sites/waste facilities Within 15 Minute Response Time ▪ Fall Season: Count of sites/waste facilities Within 15 Minute Response Time ▪ Winter Season: Count of sites/waste facilities Within 15 Minute Response Time ▪ Spring Season: Count of sites/waste facilities Within 10 Minute Response Time ▪ Summer Season: Count of sites/waste facilities Within 10 Minute Response Time ▪ Fall Season: Count of sites/waste facilities Within 10 Minute Response Time ▪ Winter Season: Count of sites/waste facilities Within 10 Minute Response Time ▪ Spring Season: Count of sites/waste facilities Within 5 Minute Response Time ▪ Summer Season: Count of sites/waste facilities Within 5 Minute Response Time ▪ Fall Season: Count of sites/waste facilities Within 5 Minute Response Time ▪ Winter Season: Count of sites/waste facilities Within 5 Minute Response Time ▪ Spring Season: Count of sites/waste facilities Within 2 Minute Response Time ▪ Summer Season: Count of sites/waste facilities Within 2 Minute Response Time ▪ Fall Season: Count of sites/waste facilities Within 2 Minute Response Time ▪ Winter Season: Count of sites/waste facilities Within 2 Minute Response Time

ID*	Indicator Definition**	Description of Options for Indicators
Household/Receptor Characteristics		
2.1.1	Total population	
2.1.2	Count of households/occupied housing units	
2.1.3	Median household Income	
2.1.4	Percent of population with ratio of income to poverty level less than 0.5	
2.1.5	Percent of population with ratio of income to poverty level between 0.5 and 1	
2.1.6	Percent of households with self-employment income	
2.1.7	Percent of civilian employed population 16 years and over who work outdoors	
2.1.8	Percent of households that are renters	
2.1.9	Percent of households living in a mobile home/boat/RV/van	
2.1.10	Percent of households without telephone service	
2.1.11	Percent of households with no Internet access	
2.1.12	Percent of households who do not have a vehicle	
2.1.13	Percent of population over 25 with no high school degree	
2.1.14	Percent of population with no health insurance	
2.1.15	Percent of households with at least 1 person that has a disability	
2.1.16	Percent of population under age of 18	
2.1.17	Percent of population who are 65 or over	
2.1.18	Percent of households with single members who are 65 or over	
2.1.19	Percent of population with female household heads	
2.1.20	Percent of population that is Black or African American alone	
2.1.21	Percent of population that are Native Hawaiian or Other Pacific Islander alone	

ID*	Indicator Definition**	Description of Options for Indicators
2.1.22	Percent of population that are American Indian or Alaska Native alone	
2.1.23	Percent of population that are Asian alone	
2.1.24	Percent of population that belongs to other non-White races	
2.1.25	Percent of population that are Hispanic or Latino	
2.1.26	Percent of households that have limited English speaking ability	
2.1.27	Percent of the population who are over 18 and non-U.S. citizens	
2.1.28	Percent of households that moved within the last 3 years	

* ID numbering X.Y.Z: X denotes exposure/sensitivity (exposure: 1; sensitivity: 2); Y denotes 3 sources of exposure (extreme events:1, sites/ waste facilities: 2, fate/transport: 3, and 1 source of sensitivity (population characteristics: 1), and Z denotes the indicator (numbered sequentially)

** All indicators are by Block Group

Table A.2. List of Possible Contaminants Found in Brownfield Sites (from ACRES-CIMC)

Contaminant	
Controlled substances	Cadmium
Petroleum	Chromium
Asbestos	Copper
Lead	Mercury
PAHs	Nickel
PCBs	Pesticides
VOCs	SVOCs
Selenium	Other Metals
Iron	Other
Arsenic	Unknown

Table A.3. Vulnerability of Superfund Remediation Technologies to Flooding, Drought, Fire and Extreme Heat

This table, which builds upon U.S. EPA (2012), lists commonly applied contaminated site cleanup remediation technologies that may be present at a cleanup site and indicates whether they are vulnerable to damage by the extreme events addressed in this document (flooding, drought, fire, and extreme heat). This handbook applies this table to develop indicators that identify which of these remediation technologies are present at Superfund sites and what events these sites may be vulnerable to. Reasons for this simple yes/no ranking are included, including basic assumptions about the site's operational status and condition. Site conditions should be checked to ensure that these assumptions are appropriate. For example, if the technologies in place do not allow contact with contaminants during wildfires, the site may not be vulnerable to fire.

Remedy	Media	Drought	Flooding	Fire	Extreme Heat	Assumptions
In-situ solidification/ stabilization	soil/source	Y	Y	N	N	assumes injection is not ongoing
In-situ thermal treatment	soil/source	N	Y	N	N	assumes above-ground components removed before event
In-situ bioremediation	soil/source	Y	Y	N	N	assumes injection is not ongoing, and contaminants are well below ground surface
Onsite containment (cap)	soil/source	Y	Y	Y	Y	assumes flood damages earthworks, drought damages vegetative cover; contact with contaminants may occur through cap for fire and extreme heat
Soil vapor extraction	soil/source	Y	Y	Y	Y	onsite external equipment can be damaged by fire or heat
Vapor intrusion mitigation	soil/source	N	Y	Y	Y	flood can raise water table, cutting off mitigation flow; volatized contaminants may be in contact with fire or extreme heat
Multiphase extraction	soil/source	Y	Y	Y	Y	onsite external equipment can be damaged by fire or heat
Excavation and physical separation	soil/source	N	N	N	N	assumes onsite operations are complete or paused
Excavation and recycling	soil/source	N	N	N	N	assumes onsite operations are complete or paused
Excavation and offsite disposal	soil/source	N	N	N	N	assumes onsite operations are complete or paused
Excavation and offsite treatment	soil/source	N	N	N	N	assumes onsite operations are complete or paused

Remedy	Media	Drought	Flooding	Fire	Extreme Heat	Assumptions
Excavation and onsite bioremediation	soil/source	N	Y	Y	Y	aboveground equipment can be damaged by flood, fire; process disturbed by fire, heat
Surface water treatment	surface water	Y	Y	Y	Y	onsite external equipment can be damaged by fire or heat
Sediment containment	sediment	Y	Y	N	N	drought can expose containment structures; floods can wash them away
Sediment excavation and treatment	sediment	N	Y	N	N	floods can interrupt excavation operations, or spread unexcavated sediments
Sediment in-situ treatment	sediment	Y	Y	N	N	drought can expose treatment areas; floods can wash away treatment materials
In-situ bioremediation	groundwater	Y	Y	N	N	injection is not ongoing, and contaminants are well below ground surface
In-situ chemical treatment	groundwater	Y	Y	N	N	injection is not ongoing, and contaminants are well below ground surface
Permeable reactive barrier	groundwater	Y	Y	N	N	extreme event occurs post-installation
Pump and treat	groundwater	Y	Y	Y	Y	onsite external equipment can be damaged by fire or heat
Air sparging	groundwater	Y	Y	Y	Y	onsite external equipment can be damaged by fire or heat
Vertical Engineered Barrier	groundwater	Y	Y	N	N	extreme event occurs post-installation
Onsite containment (NOS)	groundwater	Y	Y	N	N	extreme event occurs post-installation
Onsite containment (hydraulic)	groundwater	Y	Y	N	N	extreme event occurs post-installation
Monitored natural attenuation (MNA)	groundwater	Y	Y	N	N	no subsurface remediation components
Vapor intrusion mitigation	groundwater	N	Y	N	N	flood can raise water table, cutting off mitigation flow, extreme event occurs post-installation

Adapted from U.S. EPA, Adaptation of Superfund Remediation to Climate Change, February 2012, Table 1.

Table A.4. Data Sources for Each Type of Site/Waste Facility

Source Category/Facility Type	Programs Collecting Data	Publicly Available Databases	Data Queries
Hazardous Waste Operators			
RCRA (Resource Conservation and Recovery Act) Subtitle C Hazardous Waste Generators: large, small, conditionally exempt small quantities generated	EPA RCRA (Office of Resource Conservation and Recovery [ORCR])	RCRAInfo Envirofacts RCRAInfo FTP RCRAInfo API Biennial Reporting Service (BRS) Facility Registry Service (FRS)	Sites/Waste Facilities downloaded using the RCRAInfo API that were labeled as "Large Quantity Generators"
RCRA Subtitle C Hazardous Waste Treatment, Storage, and Disposal Facilities (TSDFs): landfills, surface impoundments, land application units, waste piles, tanks, etc.	EPA RCRA (ORCR)	RCRAInfo Envirofacts RCRAInfo FTP RCRAInfo API Biennial Reporting Service (BRS) Facility Registry Service (FRS)	Sites/Waste Facilities downloaded using the RCRAInfo API that were labeled as "TSDF" or "TSD"
RCRA Subtitle C Hazardous Waste Transporters	EPA RCRA (ORCR)	RCRAInfo Envirofacts RCRAInfo FTP RCRAInfo API Biennial Reporting Service (BRS) Facility Registry Service (FRS)	Sites/Waste Facilities downloaded using the RCRAInfo API that were labeled as "Transporter"
RCRA Subtitle C Hazardous Waste Transfer Facilities	EPA RCRA (ORCR)	RCRAInfo Envirofacts RCRAInfo FTP RCRAInfo API Biennial Reporting Service (BRS) Facility Registry Service (FRS)	Sites/Waste Facilities downloaded using the RCRAInfo API that were labeled as "Transfer Facility"
RCRA Subtitle C Other Hazardous Waste Operators	EPA RCRA (ORCR)	RCRAInfo Envirofacts RCRAInfo FTP RCRAInfo API Biennial Reporting Service (BRS) Facility Registry Service (FRS)	Sites/Waste Facilities downloaded using the RCRAInfo API that were labeled as "Transfer Facility"

Source Category/Facility Type	Programs Collecting Data	Publicly Available Databases	Data Queries
Waste Cleanup Sites			
RCRA Subtitle C Corrective Action Sites	EPA RCRA (ORCR)	RCRAInfo Envirofacts	Sites downloaded using the RCRAInfo API that were labeled as "Subject to Corrective Action" or "Corrective Action Workload"
		RCRAInfo FTP	
		RCRAInfo API	
		Biennial Reporting Service (BRS)	
		FRS	
Brownfields Sites	EPA Brownfields	Cleanups in My Community (CIMC)	Sites downloaded from ACRES-CIMC
		Assessment, Cleanup and Redevelopment Exchange System (ACRES)	
		FRS	
Superfund Sites	EPA Superfund/BRAC and NIH	Superfund Enterprise Management System (SEMS) Envirofacts	Sites downloaded from SEMS and labeled as being on the National Priorities List (NPL)
		FRS	
		Toxmap (National Priorities List Sites)	
Non-NPL Sites	EPA Superfund/BRAC, State Superfund	SEMS Envirofacts, State Databases (e.g., AZ)	Sites downloaded from SEMS and labeled as being not on the National Priorities List (NPL)
		FRS	
Removal/Emergency Response Sites	EPA Emergency Response/Removals (Office of Emergency Management, OEM)	FRS	Sites included in OSRR EPRB data provided by EPA Region
		SEMS Envirofacts	
Other Facilities/Sites			
Fuel terminals and other sites subject to SPCC and FRP regulations to prevent and respond to oil spills	EPA Emergency Response/Removals (OEM)	EPA OSC website	Sites included in FRS data and labeled as "OIL" or included in OSRR EPRB data and labeled as "Oil Spill…"
	OIL	FRS	
Incident Waste Facilities	EPA ORD and OEM	I-Waste	Sites/Waste Facilities included in I-Waste data provided by EPA Region
Solid Waste Landfills (Nonhazardous)	State (e.g., ADEQ)	AZURITE (AZ Only)	Sites/Waste Facilities included in GHGRP data, included in FRS data and labeled as "LMOP," or included in state and local landfill datasets.
	Landfill Methane Outreach Program (LMOP)	FRS LMOP	
	EPA Greenhouse Gas Reporting Program (GHGRP)	EPA GHGRP Database	

Source Category/Facility Type	Programs Collecting Data	Publicly Available Databases	Data Queries
Petroleum Storage Tanks (USTs & ASTs)	State Databases (e.g., ADEQ)	AZ UST Database (AZ Only)	USTs include sites/waste facilities included in state and local UST datasets and labeled as "open" or "temporarily closed." USTs also include sites/waste facilities included in FRS data and labeled as "LUST-ARRA." ASTs included sites/waste facilities in state and local AST datasets provide by EPA Region.
	Leaking Underground Storage Tank - American Recovery and Reinvestment Act (LUST-ARRA)	FRS LUST-ARRA	
Other Sites/Waste Facilities	identified by local decision-makers as needed	Other Sites/Waste Facilities	Any site/waste facility that the community identifies as a site of interest and does not fit into any of the categories listed above.

FRS: Facility Registry Service, RCRAInfo or RCRA: Resource Conservation and Recovery Act Info, API: Application Programming Interface, BRS: Biennial Reporting System, ACRES: Assessment Cleanup and Redevelopment Exchange System, CIMC: Cleanups in My Community, SEMS: Superfund Enterprise Management System, I-Waste: Incident Waste Assessment and Tonnage Estimator, GHGRP: Greenhouse Gas Reporting Program, OSRR EPRB: Office of Site Remediation and Restoration Emergency Planning and Response Branch.

Appendix B. Equations

B.1. Vulnerability Source 1.1. Exposure: Extreme Events

Indicator 1.1.1. Equations for Extreme Heat Indicator

	$$\mathrm{MaxSumT}_{hist/scen} = \left(\frac{1}{N}\right) \sum_{y=1}^{N} \left(\mathrm{Max}\left\{\mathrm{MaxDailyTemp}_{iy}\right\}_{summer}\right)$$	EH-1a
Where:	$\mathrm{MaxSumT}_{hist/scen}$ = Average maximum summer temperature for the historic/future time period	
	$\mathrm{MaxDailyTemp}_{iy}$ = Maximum daily temperature for day i in year y	
	Summer = All days in the months of June–August (defined as the summer season)	
	N = Number of years in the historical/future time period	

	$$\mathrm{PercentMaxSumT}_{scen} = \frac{\mathrm{MaxSumT}_{scen} - \mathrm{MaxSumT}_{hist}}{\mathrm{MaxSumT}_{hist}}$$	EH-1b
Where:	$\mathrm{MaxSumT}_{scen}$ = Average maximum summer temperature for the future scenario	
	$\mathrm{MaxSumT}_{hist}$ = Average maximum summer temperature for the historic time period	
	$\mathrm{PercentMaxSumT}_{scen}$ = The percent change in maximum summer temperature from historic conditions to the future scenario	

Indicators 1.1.2 & 1.1.3. Equations for Threshold-Based Extreme Heat Indicator

	EHD_{iy} =1 if $\mathrm{MaxTemp}_{iy} > \mathrm{MaxTemp}_{99}$ =0 otherwise	TBEH-1
Where:	EHD_{iy} = Extreme heat day Boolean indicator for day i in year y. Computed for all days in all years of the assessment period.	
	$\mathrm{MaxTemp}_{iy}$ = Maximum daily temperature for day i in year y	
	$\mathrm{MaxTemp}_{99}$ = 99th percentile for daily maximum temperatures for extreme heat days over the historic period	

	$$TotEHD_y = \sum_{i=1}^{W_y} EHD_{iy}$$	TBEH-2
Where:	TotEHD_y =Total number of extreme heat days for year y	
	EHD_{iy} = Extreme heat day daily time series of Boolean indicators	
	W_y = Total number of days in year y	

	$$TotEHD = \sum_{y=1}^{N} \mathrm{TotEHD}_y$$	TBEH-3
Where:	TotEHD = Total number of extreme heat days for assessment period	
	$TotEHD_y$ = Total number of extreme heat days for year y	
	N = Number of years in the assessment period that contain extreme heat days	

	$$\mathrm{AvgMaxTemp}_y = \frac{\sum_{i=1}^{W_y}(\mathrm{MaxTemp}_{iy} * \mathrm{EHD}_{iy})}{TotEHD_y}$$	TBEH-4
Where:	$AvgMaxTemp_y$ = Average maximum daily temperature for extreme heat days in year y	
	$MaxTemp_{iy}$ = Maximum daily temperature for day i in year y	
	EHD_{iy} = Extreme heat day Boolean indicator for day i in year y	
	$TotEHD_y$ = Total number of extreme heat days for year y	
	W_y = Total number of days in year y	

	$$\mathrm{AvgMaxTemp} = \left(\frac{\sum_{y=1}^{N} \mathrm{AvgMaxTemp}_y}{N}\right)/20$$	TBEH-5
Where:	AvgMaxTemp = Average annual average maximum daily temperature for extreme heat days	
	$AvgMaxTemp_y$ = Average maximum daily temperature for extreme heat days in year y	
	N = Number of years that contain extreme heat days	

	$$\mathrm{DiffEHD}_{scenario} = \frac{\mathrm{TotEHD}_{scenario} - \mathrm{TotEHD}_{historic}}{20}$$	TBEH-6
Where:	$DiffEHD_{scenario}$ = Change in annual total number of extreme heat days from the historic period to the future scenario period	
	$TotEHD_{scenario}$ = Total number of extreme heat days for future scenario period	
	$TotEHD_{historic}$ = Total number of extreme heat days for the historic period	

Indicators 1.1.4. Equations for Wildfire Indicator

	$$\mathrm{AvgMaxBurned}_{hist/scen} = \frac{\sum_{\mathrm{i}=1}^{\mathrm{N}} \mathrm{MaxBurned}_{\mathrm{i}}}{N}$$	WF-1
Where:	$\mathrm{AvgMaxBurned}_{hist/scen}$ = Fraction of Block Group burned for historical/ future period.	
	$\mathrm{MaxBurned}_{\mathrm{i}}$ = Maximum fraction of the grid cell burned value for historical/ future period.	
	N = Number of wildfires in a given time period.	

	$$\text{DiffBurned}_{scen} = \frac{\text{AvgMaxBurned}_{scen} - \text{AvgMaxBurned}_{historic}}{\text{AvgMaxBurned}_{historic}} * 100$$	WF-2
Where:	DiffBurned_{scen} = Percent change in the Fraction of Block Group burned from the historic period to the future scenario	
	$\text{AvgMaxBurned}_{hist}$ = Fraction of Block Group burned for historical period.	
	$\text{AvgMaxBurned}_{scen}$ = Fraction of Block Group burned for future period.	

Indicator 1.1.5. Equation for Floodplain-Based Flood Indicator

	$\text{PercentBGFP} = \text{BGArea}_{FP} / \text{BGArea}_{Total} * 100$	FBF-1
Where:	PercentBGFP = Percent of the Block Group area within the floodplain	
	BGArea_{FP} = Block Group area within the floodplain (determined through geospatial analysis)	
	BGArea_{Total} = Total Block Group area	

Indicator 1.1.6. Equations for Precipitation-Based Flood Indicator

	$$R99_y = \sum_{i=1}^{W_y} P_{iy} \text{ where } P_{iy} > P_{99}$$	PBF-1
Where:	P_{iy} = Daily precipitation depth for day i in year y	
	P_{99} = 99^{th} percentile for daily precipitation depth over the historic period	
	$R99_y$ = Total precipitation depth due to heavy events in year y	
	W_y = Total number of days in year y with precipitation	
Note:	*For illustration we use the 99^{th} percentile to define heavy events as the top 1% of precipitation events. Alternate percentiles can be used depending on user needs and local conditions.*	

	$$P_y = \sum_{i=1}^{W_y} P_{iy}$$	PBF-2
Where:	P_y = Total precipitation depth in year y	
	P_{iy} = Daily precipitation depth for day i in year y	
	W_y = Total number of days in year y with precipitation	

	$$PR99_y = \frac{R99_y}{P_y}$$	PBF-3
Where:	$PR99_y$ = Percentage of precipitation depth falling as heavy events in year y	
	$R99_y$ = Total precipitation depth due to heavy events in year y	
	P_y = Total precipitation depth in year y	
Note:	*For illustration we use the 99th percentile to define heavy events as the top 1% of precipitation events. Alternate percentiles can be used depending on user needs and local conditions.*	

	$$\mathrm{PR99} = \frac{\sum_{y=1}^{Y} PR99_y}{Y}$$	PBF-4
Where:	PR99 = Annual average percent of precipitation falling as heavy events across all years	
	$PR99_y$ = Percentage of precipitation depth falling as heavy events in year y	
	Y = 20 (years)	
Note:	*For illustration we use the 99th percentile to define heavy events as the top 1% of precipitation events. Alternate percentiles can be used depending on user needs and local conditions.*	

Indicator 1.1.7. Equation for Threshold-Based Flood Indicator

	$$\Delta \mathrm{R99}_{scen} = \frac{\sum_{y=1}^{Y} R99_{y,scen} - \sum_{y=1}^{Y} R99_{y,Hist}}{\sum_{y=1}^{Y} R99_{y,Hist}}$$	TBF-1
Where:	$R99_{y,scen}$ = Total precipitation depth due to heavy events in year y of the future scenario period	
	$R99_{y,Hist}$ = Total precipitation depth due to heavy events in year y of the historic time period	
	Y = 20 (years)	
	$\Delta R99_{scen}$ = The percent change in heavy event precipitation depth from historic conditions to the future scenario	
Note:	*For illustration we use the 99th percentile to define heavy events as the top 1% of precipitation events. Alternate percentiles can be used depending on user needs and local conditions.*	

Indicator 1.1.8. Equation for Physically Based Flood Indicator

	$$HAND_{mean} = \frac{\sum_{n=1}^{N} HAND}{N}$$	PhBF-1
Where:	$HAND_{mean}$= Mean HAND value	
	HAND = Height above nearest drainage value for each raster cell falling within a BG (determined through geospatial analysis)	
	N = total number of raster cells falling within a BG	

Indicators 1.1.9 & 1.1.11. Equation for Drought Indicator

	$D_i = P_i - PET_i$	DRT-1
Where:	D_i = Values aggregated at selected time scale then transformed to a normal distribution, with final SPEI values presented as standard deviations	
	i = month	
	P_i = Precipitation for month i	
	PET_i = Potential evapotranspiration for month i	

Indicators 1.1.10 & 1.1.12. Equation for Threshold-Based Drought Indicator

	$\Delta Drought = Drought_{Future} - Drought_{Historic}$	TBD-1
Where:	ΔDrought = Change in the count of drought months between the historic and future period	
	$Drought_{Future}$ = Count of all months with SPEI values less than or equal to -0.8 (i.e., drought conditions) over the 20-year period future period	
	$Drought_{Historic}$ = Count of all months with SPEI values less than or equal to -0.8 (i.e., drought conditions) over the 20-year period historic period	

B.2. Vulnerability Source 1.2. Exposure: Sites/Waste Facilities

Indicator 1.2.1. Equation for Total Count of Sites/Waste Facilities Indicator

	$T_b = \sum_{i=1}^{F_b} f$	SWF-1
Where:	T_b = Total count of facilities in Block Group b	
	F_b = The maximum number of facilities within Block Group b	
	f = an individual facility	

Indicator 1.2.2. Equation for Count of Sites/Waste Facilities per Square Kilometer Indicator

	$TK_b = \frac{T_b}{SqK_b}$	SWF-2
Where:	TK_b = Total count of facilities per square kilometer in Block Group b	
	T_b = Total count of facilities in Block Group b	
	SqK_b = Total square kilometers in Block Group b	

Indicator 1.2.3. Equation for Sites/Waste Facilities Count by Type Indicator

	$$T_{bx} = \sum_{i=1}^{F_{bx}} f_x$$	SWF-3
Where:	T_{bx} = Total count of facilities of type x in Block Group b	
	F_{bx} = The maximum number of facilities of type x within Block Group b	
	f_x = Facility of type x	

Indicator 1.2.4. Equation for Tons of Hazardous Waste Indicator

	$$Tn_b = \sum_{i=1}^{HF_b} W_i$$	SWF-4
Where:	Tn_b = The total tons of hazardous waste present in Block Group b	
	HF_b = The total number of facilities with hazardous waste within Block Group b	
	W_i = The amount of waste present at hazardous waste facility i.	

Indicator 1.2.5. Equation for Sites/Waste Facilities Count (by Hazard Type) Indicator

	$$T_{bh} = \sum_{i=1}^{F_{bh}} f_h$$	SWF-5
Where:	T_{bh} = Total count of facilities storing hazardous waste of hazard type h in Block Group b	
	F_{bh} = The maximum number of facilities storing hazardous waste of hazard type h within Block Group b	
	f_h = Facility storing hazardous waste of hazard type h	

Indicator 1.2.6. Equation for Waste Tonnage (by Hazard Type) Indicator

	$$Tn_{bh} = \sum_{i=1}^{F_{bh}} W_{ih}$$	SWF-6
Where:	Tn_{bh} = The total tons of hazardous waste of hazard type h present in Block Group b	
	F_{bh} = The total number of facilities storing hazardous waste of hazard type h within Block Group b	
	W_{ih} = The amount of waste of hazard type h present at facility i.	

Indicator 1.2.7. Equation for Brownfield Count with Contaminant; Cleanup Unknown (by Contaminant) Indicator

	$$BN_{bx} = \sum_{i=1}^{B_{bx}} bf_{ix}$$	SWF-7
Where:	BN_{bx} = Total count of brownfields sites with contaminant type x found and no information on cleanup in Block Group b	
	B_{bx} = The maximum number of brownfields sites with contaminant type x in Block Group b	
	bf_{ix} = Brownfield site with contaminant x found and no information on cleanup in Block Group b	

Indicator 1.2.8. Equation for Superfund Count with Vulnerable Remedy Technology (by Extreme Event)

	$$S_{bx} = \sum_{i=1}^{S_b} s_{ix}$$	SWF-8
Where:	S_{bx} = Total count of superfund sites with remedy vulnerable to extreme event type x in Block Group b	
	S_b = The maximum number of Superfund sites in Block Group b	
	s_{ix} = Superfund site with remedy vulnerable to extreme event type x in Block Group b	

Indicator 1.2.9. Equation for Count of Specific Type of Tank (UST/AST)

	$$TNK_{bx} = \sum_{b=1}^{TNK_b} tnk_{bx}$$	SWF-9
Where:	TNK_{bx} = Total count of tanks of type x in Block Group b	
	TNK_b = The maximum number of tanks in Block Group b	
	Tnk_{bx} = Tank of type x in Block Group b	

Indicator 1.2.10. Equation for Total Tank Capacity (UST/AST)

	$$TNKC_{bx} = \sum_{b=1}^{TNK_b} tnkc_{bx}$$	SWF-10
Where:	$TNKC_{bx}$ = Sum of capacity of tanks of type x in Block Group b	
	TNK_b = The maximum number of tanks in Block Group b	
	$Tnkc_{bx}$ = Capacity of an individual tank of type x in Block Group b	

B.3. Vulnerability Source 1.3. Exposure: Transport and Fate

No equations were provided since programming rather than equations were used.

B.4. Vulnerability Source 2.1. Sensitivity: Household/Receptor Characteristics

Indicator 2.1.1. Equation for Total Population

	TP	Eq S-1
Where:	TP = The total population (AJWME001)	

Indicator 2.1.2. Equation for Count of Households/Occupied Housing Units

	OH_C	Eq S-2
Where:	OH_C= The total number of occupied housing units within the county (AJ1UE001)	

Indicator 2.1.3. Equation for Median Household Income

	MI_C	Eq #S-3
Where:	MI_C= The median income of the county (AJZAE001)	

Indicator 2.1.4. Equation for Percent of Population with Ratio of Income to Poverty Level Less Than 0.5

	$P_C = \frac{PR_C}{T_c} x\ 100$	Eq #S-4
Where:	P_C= The percent of population with ratio of household income to poverty level less than 0.5	
	PR_c = The estimated number of individuals under 0.5 (AJY4E002)	
	T_C = The total population (AJY4E001) for whom poverty level was assessed	

Indicator 2.1.5. Equation for Percent of Population with Ratio of Income to Poverty Level Between 0.5 and 1

	$P2_C = \frac{PR2_C}{T_c} x\ 100$	Eq #S-5
Where:	P_C= The percent of population with ratio of household income to poverty level between 0.5 and 1	
	$PR2_c$ = The estimated number of individuals between 0.5 and 1 (AJY4E003)	
	T_C = The total population (AJY4E001) for whom poverty level was assessed	

Indicator 2.1.6. Equation for Percent of Households with Self-Employment Income

	$$SEI_C = \frac{SE_C}{H} x\ 100$$	Eq #S-6
Where:	SEI_C= The percent of households with self-employment income	
	PE_c = The estimated number of households with self-employment income (AJZQE002)	
	H = The total number of households (AJZQE001)	

Indicator 2.1.7. Equation for Percent of Civilian Employed Population 16 Years and over Who Work Outdoors

	$$OW_C = \frac{(MN + FN + MP + FP)}{T16_c} x\ 100$$	Eq #S-7
Where:	OW_C= Percent of civilian employed population 16 years and over who work outdoors	
	MN = Estimates: Male: Natural resources, construction, and maintenance occupations (AJ1FE030)	
	FN= Estimates: Female: Natural resources, construction, and maintenance occupations (AJ1FE066)	
	MP = Estimates: Female: Production, transportation, and material moving occupations (AJ1FE070)	
	FP = Estimates: Male: Production, transportation, and material moving occupations (AJ1FE034)	
	$T16_C$ = The total population above the age of 16 (AJ1FE001)	

Indicator 2.1.8. Equation for Percent of Households That Are Renters

	$$RE_C = \frac{R_C}{H_c} x\ 100$$	Eq #S-8
Where:	RE_C= Percent of households that are renters	
	R_c = The total number of renter occupied housing units (AJ17E003)	
	H_C = the total number of housing units (AJ17E001)	

Indicator 2.1.9. Equation for Percent of Households Living in a Mobile Home/Boat/RV/Van

	$$MH_C = \frac{M_C + B_C}{H_c} x\ 100$$	Eq #S-9
Where:	MH_C= Percent of households living in Mobile Homes, Boats, RVs, or Vans	
	M_C= total number of mobile home units (AJ2JE010)	
	B_C= total number of households boat, RV, van, etc units (AJ2JE011)	
	H_C = the total number of housing units (AJ17E001)	

Indicator 2.1.10. Equation for Percent of Households without Telephone Service

	$$T = \frac{O + R}{H_c} x\ 100$$	Eq #S-10
Where:	T = Percent of households without telephone service	
	O = The total number of owner occupied: No telephone service available (AJ2VE007)	
	R = the total number of renter occupied: No telephone service available (AJ2VE001)	
	H_C = the total number of housing units (AJ2WE001)	

Indicator 2.1.11. Equation for Percent of Households with No Internet Access

	$$I = \frac{N}{H_c} x\ 100$$	Eq #S-11
Where:	I = Percent of households without internet access	
	N = The total number of estimates: No internet access (AJ37E013)	
	H_C = The total number of households (AJ37E001)	

Indicator 2.1.12. Equation for Percent of Households Who Do Not Have a Vehicle

	$$V = \frac{O + R}{H_c} x\ 100$$	Eq #S-12
Where:	V = Percent of households with no vehicle available	
	O = The total number of owner occupied: No vehicle available (AJ2WE003)	
	R = the total number of renter occupied: No vehicle available (AJ2WE003)	
	H_C = the total number of housing units (AJ2WE001)	

Indicator 2.1.13. Equation for Percent of Population with No High School Degree

	$$E = \frac{\sum_{i=2}^{16} E_i}{H_c} x\ 100$$	Eq #S-13
Where:	E= Percent of population without a high school degree	
	$E2$= percent of population with no schooling completed (AJYPE002)	
	$E3$= percent of population with highest level of school completed: nursery school (AJYPE003)	
	$E4$= percent of population with highest level of school completed: kindergarten (AJYPE004)	
	$E5$= percent of population with highest level of school completed: 1st grade (AJYPE005)	
	$E6$= percent of population with highest level of school completed: 2nd grade (AJYPE006)	
	$E7$= percent of population with highest level of school completed: 3rd grade (AJYPE007)	
	$E8$= percent of population with highest level of school completed: 4th grade (AJYPE008)	
	$E9$= percent of population with highest level of school completed: 5th grade (AJYPE009)	
	$E10$= percent of population with highest level of school completed: 6th grade (AJYPE010)	
	$E11$= percent of population with highest level of school completed: 7th grade (AJYPE011)	
	$E12$= percent of population with highest level of school completed: 8th grade (AJYPE012)	
	$E13$= percent of population with highest level of school completed: 9th grade (AJYPE013)	
	$E14$= percent of population with highest level of school completed: 10th grade (AJYPE014)	
	$E15$= percent of population with highest level of school completed: 11th grade (AJYPE015)	
	$E16$= percent of population with highest level of school completed: 12th grade, no diploma (AJYPE016)	
	H_C = the total population (AJYPE001)	

Indicator 2.1.14. Equation for Percent of Population with No Health Insurance

	$$H = \frac{H1 + H2 + H3 + H4}{H_c} x\ 100$$	Eq #S-14
Where:	H= Percent of population with no health insurance Indicator	
	$H1$= Percent of population under 19 years: No health insurance coverage (AJ35E017)	
	$H2$= Percent of population 19 to 34 years: No health insurance coverage (AJ35E033)	
	$H3$= Percent of population 35 to 64 years: No health insurance coverage (AJ35E050)	
	$H4$= Percent of population 65 years and over: No health insurance coverage (AJ35E066)	
	H_C = the total population	

Indicator 2.1.15. Equation for Percent of Households with at Least 1 Person That Has a Disability

	$$D = \frac{\mathrm{D1} + \mathrm{D2}}{H_c} x\ 100$$	Eq #S-15
Where:	D= Percent of households with at least 1 person that has a disability Indicator	
	$D1$ = Household received Food Stamps/SNAP in the past 12 months: Households with 1 or more persons with a disability (AJ05E003)	
	$D2$ = Household did not receive Food Stamps/SNAP in the past 12 months: Households with 1 or more persons with a disability (AJ05E006)	
	H_C = the total number of households	

Indicator 2.1.16. Equation for Percent of Population under Age of 18

	$$TP18 = \frac{\mathrm{P18}}{T_c} x\ 100$$	Eq #S-16
Where:	$TP18$= Percent of population under 18	
	$P18$ = Population under 18- The sum of the following variables: AJWBE003 "Estimates: Male: Under 5 years" AJWBE004 "Estimates: Male: 5 to 9 years" AJWBE005 "Estimates: Male: 10 to 14 years" AJWBE006 "Estimates: Male: 15 to 17 years" AJWBE027 "Estimates: Female: Under 5 years" AJWBE028 "Estimates: Female: 5 to 9 years" AJWBE029 "Estimates: Female: 10 to 14 years" AJWBE030 "Estimates: Female: 15 to 17 years"	
	T_C = Total population	

Indicator 2.1.17. Equation for Percent of Population Who Are 65 or Over

	$$TP65 = \frac{\text{P65}}{T_c} x\ 100$$	Eq #S-17
Where:	$TP65$= Percent of population above 65	
	$P65$ = Population above 65 – The sum of the following variables: AJWBE020 "Estimates: Male: 65 and 66 years" AJWBE021 "Estimates: Male: 67 to 69 years" AJWBE022 "Estimates: Male: 70 to 74 years" AJWBE023 "Estimates: Male: 75 to 79 years" AJWBE024 "Estimates: Male: 80 to 84 years" AJWBE025 "Estimates: Male: 85 years and over" AJWBE044 "Estimates: Female: 65 and 66 years" AJWBE045 "Estimates: Female: 67 to 69 years" AJWBE046 "Estimates: Female: 70 to 74 years" AJWBE047 "Estimates: Female: 75 to 79 years" AJWBE048 "Estimates: Female: 80 to 84 years" AJWBE049 "Estimates: Female: 85 years and over"	
	T_C = Total population	

Indicator 2.1.18. Equation for Percent of Households with Single Members Who Are 65 or Over

	$$TS65 = \frac{\text{PS65}}{T_c} x\ 100$$	Eq #S-18
Where:	$TS65$= Percent of households with single members who are 65 or over	
	$P65$ = Households with one or more people 65 years and over: 1-person household (AJX8E003)	
	T_C = Total population (AJX8E001)	

Indicator 2.1.19. Equation for Percent of Population with Female Household Heads

	$$TF = \frac{\text{Fh1} + \text{Fh1}}{T_c} x\ 100$$	Eq #S-19
Where:	TF= % of population with female household heads	
	$Fh1$= In family households: Householder: Female (AJXHE006)	
	$Fh2$= In households: In nonfamily households: Householder: Female (AJXHE029)	
	T_C = Total population (AJXHE001)	

Indicator 2.1.20. Equation for Percent of Population That Is Black or African American Alone

	$$TB = \frac{\text{AA}}{T_c} x\ 100$$	Eq #S-20
Where:	TB= Percent of population that is Black or African American alone	
	AA= Black or African American alone (AJWNE003)	
	T_C = Total population (AJWNE001)	

Indicator 2.1.21. Equation for Percent of Population That Are Native Hawaiian or Other Pacific Islander Alone

	$$NH\ = \frac{\text{PI}}{T_c} x\ 100$$	Eq #S-21
Where:	NH= % of population that are Native Hawaiian or Other Pacific Islander	
	PI= Native Hawaiian and Other Pacific Islander alone (AJWNE006)	
	T_C = Total population (AJWNE001)	

Indicator 2.1.22. Equation for Percent of Population That Are American Indian or Alaska Native Alone

	$$AI\ = \frac{\text{A}}{T_c} x\ 100$$	Eq #S-22
Where:	AI = % population that are American Indian or Alaska Native	
	A= American Indian and Alaska Native alone (AJWNE004)	
	T_C = Total population (AJWNE001)	

Indicator 2.1.23. Equation for Percent of Population That Are Asian Alone

	$$AI\ = \frac{\text{A}}{T_c} x\ 100$$	Eq #S-23
Where:	AI = % of population that are Asian	
	A= Asian alone (AJWNE005)	
	T_C = Total population (AJWNE001)	

Indicator 2.1.24. Equation for Percent of Population That Belongs to Other Non-White Races

	$$OR = \frac{\mathrm{SO} + \mathrm{SO2} + \mathrm{R}}{T_c} x\ 100$$	Eq #S-24
Where:	AI = Percent of population that belongs to other non-white races	
	SO = Some other race alone (AJWNE007)	
	$SO2$ = Two or more races: Two races including Some other race (AJWNE009)	
	R= Two or more races: Two races excluding Some other race, and three or more races (AJWNE010)	
	T_C = Total population (AJWNE001)	

Indicator 2.1.25. Equation for Percent of Population That Are Hispanic or Latino

	$$TH = \frac{\mathrm{H}}{T_c} x\ 100$$	Eq #S-25
Where:	TH = % of population that are that are Hispanic or Latino	
	H = Hispanic or Latino (AJWWE003)	
	T_C = Total population (AJWNE001)	

Indicator 2.1.26. Equation for Percent of Households That Have Limited English Speaking Ability

	$$TH = \frac{S1 + S2 + S3 + S4}{T_c} x\ 100$$	Eq #S-26
Where:	TH = % of population that have limited English speaking capability	
	$S1$ = Spanish: Limited English speaking household (AJY2E004)	
	$S2$ = Other Indo-European languages: Limited English speaking household (AJY2E007)	
	$S3$ = Asian and Pacific Island languages: Limited English speaking household (AJY2E010)	
	$S4$ = Other languages: Limited English speaking household (AJY2E013)	
	T_C = Total population (AJY2E001)	

Indicator 2.1.27. Equation for Percent of the Population Who Are over 18 and Non-U.S. Citizens

	$$US = \frac{O18 - TC}{O18} x\ 100$$	Eq #S-27
Where:	US = % of population who are over 18 and non-U.S. citizens	
	$O18$ = *Population over 18 (AJWBE003+AJWBE004+AJWBE005+AJWBE006+AJWBE027 +AJWBE028+AJWBE029+AJWBE030)*	
	TC = Over 18 population who are US citizens (AJ4QE001)	

Indicator 2.1.28. Equation for Percent of Households That Moved within the Last 3 Years

	$$M = \frac{M1 + M2 + M3 + M4}{H} x\ 100$$	Eq #S-28
Where:	M = Percent of households that moved within the last 3 years	
	$M1$ = *Owner occupied: Moved in 2017 or later (AJ2QE003)*	
	$M2$ = *Owner occupied: Moved in 2015 to 2016 (AJ2QE004)*	
	$M3$ = *Renter occupied: Moved in 2017 or later (AJ2QE010)*	
	$M4$ = *Renter occupied: Moved in 2015 to 2016 (AJ2QE011)*	
	H = Total number of households (AJ2QE001)	

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