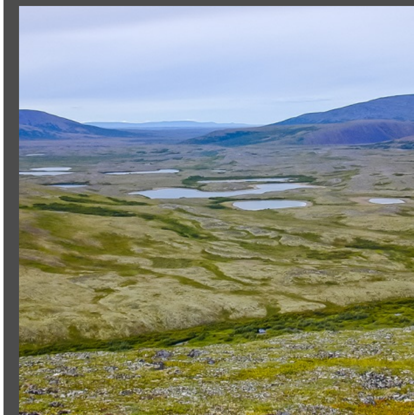
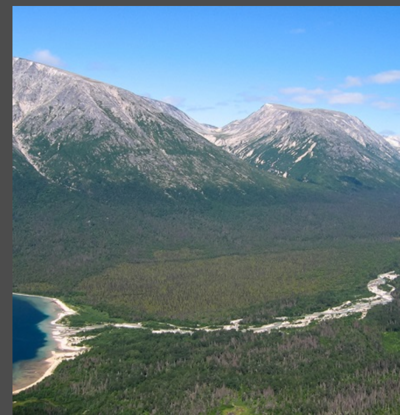




CHAPTER 2. OVERVIEW OF ASSESSMENT

2.1 Structure

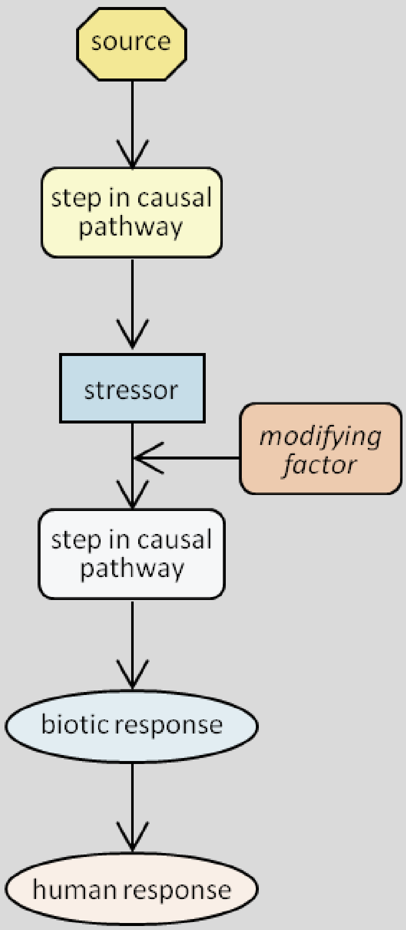
We based this assessment on U.S. Environmental Protection Agency (USEPA) guidelines for ecological risk assessment (ERA) (USEPA 1998). We began by reviewing existing literature to synthesize background information on the Bristol Bay region, particularly the Nushagak and Kvichak River watersheds. This information focused on several topics, including the ecology of Pacific salmon and other fishes; the ecology of relevant wildlife species; mining and mitigation, particularly in terms of porphyry copper mining; potential risks to aquatic systems due to road and pipeline crossings; fishery economics; and Alaska Native culture. These detailed background characterizations are included as appendices to this assessment.

In accordance with the different phases of an ERA, the assessment document itself is organized into two main sections: Problem Formulation (Chapters 2 through 6) and Risk Analysis and Characterization (Chapters 7 through 14). Problem formulation is the first phase of an ERA, during which the purpose and scope of the assessment are defined (USEPA 1998). Risk assessors, decision makers, and stakeholders determine the topical, spatial, and temporal scope needed to effectively address whatever decision process the assessment is meant to inform. Assessment endpoints, or explicit expressions of the environmental entities of interest (USEPA 1998), are identified. Conceptual models illustrating potential linkages among sources, stressors, and endpoints considered in the assessment (Box 2-1), as well as a plan for analyzing and characterizing risks, are developed.

The risk analysis and characterization phases follow problem formulation (USEPA 1998). During the risk analysis phase, available data are used to assess potential exposures to stressors and exposure-response relationships for those exposures and endpoint effects. In the risk characterization phase, information on exposures and effects is integrated, and the uncertainties and limitations associated with the assessment's analyses are identified.

BOX 2-1. CONCEPTUAL MODELS

Throughout this assessment we use conceptual model diagrams to illustrate potential ways in which large-scale mine development may adversely affect the Bristol Bay watershed's biota and Alaska Native cultures. These conceptual model diagrams show hypothesized pathways linking common sources associated with mining to potential stressors, and those stressors to responses of interest. Inclusion of a pathway indicates that the pathway *can* occur, not that it *will definitely* occur. Thus, these diagrams are not meant to illustrate worst-case scenarios in which all pathways occur simultaneously. Rather, they are meant to provide overviews of potential linkages among sources, stressors, and responses, one or more of which may plausibly result from mine development.



The conceptual model diagrams contain the following elements (note that not all elements are found in each diagram).

Sources are entities associated with mining that may directly or indirectly result in one or more stressors.

Steps in causal pathways are processes or states that may link sources to stressors or stressors to responses.

Stressors are physical or chemical entities that may directly induce a response of concern.

Modifying factors are processes, states, or other factors that may influence the delivery, expression, or effect of stressors (e.g., temperature, time or duration of exposure, mitigation).

Biotic responses are potential effects on salmon, other fishes, and wildlife.

Human responses are potential effects on Alaska Native people and culture.

When viewing these diagrams, it helps to keep the following principles in mind.

- Arrows leading from one shape to another indicate a hypothesized cause-effect relationship, whereby the first (or originating) shape could plausibly cause or result in the second shape.
- Arrows leading from a shape to another arrow (or a general section of the diagram) indicate that the originating shape (always categorized as a *modifying factor*) could plausibly influence the cause-effect relationships indicated (e.g., by increasing or decreasing its probability or intensity of occurrence).
- Shapes bracketed under another shape are specific components of the more general shape under which they appear.
- Within a shape, ↑ indicates an increase in the parameter, ↓ indicates a decrease in the parameter, and Δ indicates a change in the parameter.

2.1.1 Data Used in the Assessment

An ERA requires data of sufficient quantity and quality, from a variety of sources. Throughout the problem formulation, risk analysis, and risk characterization phases, relevant data are identified and acquired. These data may result from different kinds of studies, including field studies at the site of interest, field studies at other sites somehow relevant to the site or issue of interest, laboratory tests, and modeling applications.

In this assessment, we prioritized peer-reviewed, publicly accessible sources of information to ensure that the information and data we incorporated were of sufficient quality. In many cases, however, peer-reviewed data—particularly those directly relevant to potential mining in the Bristol Bay region—were not available. Thus, we incorporated credible, non-peer-reviewed data from multiple sources, including state government agencies (e.g., the Alaska Department of Fish and Game [ADF&G], the Alaska Department of Natural Resources [ADNR]), federal government agencies (e.g., the U.S. Geological Survey [USGS], the U.S. Fish and Wildlife Service [USFWS]), and academic organizations (e.g., Scenarios Network for Alaska and Arctic Planning [SNAP] data).

We also incorporated non-peer-reviewed data collected under the auspices of the Pebble Limited Partnership (PLP) (e.g., as presented in Ghaffari et al. 2011, PLP 2011), as these sources contain data directly relevant to the Pebble deposit and the surrounding region. Both Ghaffari et al. (2011) and the PLP's environmental baseline document (PLP 2011) are cited numerous times throughout the assessment. PLP is currently conducting its own peer review of the data presented in its baseline document, but that review had not been completed when this assessment was released.

Other non-governmental organizations have collected data relevant to the assessment. USEPA subjected some of these documents to external peer review and, where defensible, we have incorporated this information into the assessment (e.g., Chambers and Higman 2011, Woody and Higman 2011, Earthworks 2012).

In addition, some minor sources of information (e.g., permits and reports filed by mining companies) were used without peer review. In all cases, sources of information and data included in the assessment are appropriately cited (Chapter 15).

Throughout the assessment, we present numbers from the scientific literature or from PLP (2011) using the number of significant figures in the original source. Numbers derived for this assessment are presented with the appropriate number of significant figures given the precision of the input data and uncertainties due to modeling and extrapolation.

2.1.2 Types of Evidence and Inference

As in other ERAs, the risk analysis and characterization phase of this assessment is based on weighing multiple types of evidence. Available and relevant pieces of evidence from a variety of sources are used to follow different lines of inference and reach the best-supported conclusions.

In this risk analysis, we use general scientific knowledge, mathematical and statistical models, and data from the Bristol Bay region, other sites (e.g., mines in other regions), and laboratory studies to evaluate potential consequences of three mine size scenarios—that is, realistic potential mines of different sizes, the characteristics of which are based largely on a mining company report (Ghaffari et al. 2011)—in terms of sources, exposure to different stressors, and exposure-response relationships. First, we estimate the magnitude of exposures potentially resulting from both routine operation and accidents and failures in the mine scenarios, such as elevated aqueous copper concentrations, kilometers of streams eliminated, and kilometers of streams upstream of road crossings. Then, we consider the effects of these exposures—that is, the exposure-response relationships—on our endpoints of interest (e.g., the relationship between water withdrawal and loss of salmon habitat, concentration-response relationships for copper and fish). We describe and quantify, where possible, exposure-response relationships for the endpoints and estimated exposures. For some issues, multiple lines of evidence are available (e.g., state standards, federal criteria, effects models, field studies, and toxicity tests as lines of evidence for copper toxicity); for other issues, lines of evidence are more limited.

Evidence from existing mines and other analogous facilities is used where relevant. Prior mining activities in comparable watersheds provide examples of what can happen to the environment when metals are mined. Some components of our mine scenarios have analogues in other industries (e.g., oil and gas pipelines). These inferences by analogy reduce the uncertainties that come with modeling and prediction, but introduce other uncertainties related to industry-specific or site-specific differences in environmental conditions and potential changes in practices. Because no analogue is similar in all aspects to potential mines and their components in the Bristol Bay region, we choose analogues to fit the specific issues being assessed and take care to use analogues that are defensible despite their differences from our mine scenarios. For example, the Fraser River watershed could be considered an analogous system to the Bristol Bay watershed because it has similar mines and a similar salmon resource, but we recognize that there are important differences between these systems (e.g., extensive urban development, forestry, and agriculture in the Fraser River watershed). Metal mines in the Rocky Mountain metal belt (e.g., sites near the Coeur d'Alene River, Idaho, and the Clark Fork River, Montana) were developed using mining practices that would not be allowed under current mining laws. However, the fate and effects of tailings in streams and floodplains at these sites, which also supported trout and salmon populations, offer some parallels to the fate and effects of tailings following potential tailings dam failures in the Bristol Bay region, should they occur—even if the underlying causes of failure differ.

The use of data from the historical, operational records of mines, pipelines, and roads is necessary but controversial. It is essential and conventional for risk assessments to use the history of a technology to estimate failure rates. However, developers argue, with some justification, that the record of older technology is not relevant because of technological advances. Despite advances, no technology is perfect, and rates of past failures may be a better guide to future outcomes than the expectation that developers can design a system that will not fail. A classic example is the National Aeronautics and Space Administration (NASA) space shuttle program, which denied the relevance of the failure rate of solid rocket boosters and declared that the shuttle's rate of failure on launch would be one in a million. The Challenger failure showed that the prior failure rate was still relevant, despite updated technology.

For most potential failures, historical failure rates are the only available evidence. New technologies typically have not been in use long enough or widely enough to provide failure rates, and measures to correct past failure modes may unwittingly introduce new ones. Thus, in this assessment we choose failure rates that are most relevant and interpret them cautiously, using them to provide an upper bound estimate of future failure rates.

After these analyses and lines of evidence are presented, we characterize risk for each line of evidence by combining exposures and exposure-response relationships to estimate effects and by considering uncertainties. We weigh different lines and types of evidence based on evidence strength and quality. The resulting qualitative or quantitative estimates of risk and uncertainty are based on either the best line of evidence or a combined estimate from multiple lines of evidence and inferences. Bounding analyses, which set upper and lower limits for key parameters, are used to express uncertainties concerning future mine activities and their effects. In particular, multiple mine sizes and durations are included in the mine scenarios (Chapter 6). Bounding is also used to express stochasticity. For example, the occurrence and magnitude of tailings dam failures are random variables that cannot be reasonably defined. Hence, a range of tailings dam failure probabilities and a range of tailings release magnitudes are evaluated (Chapter 9).

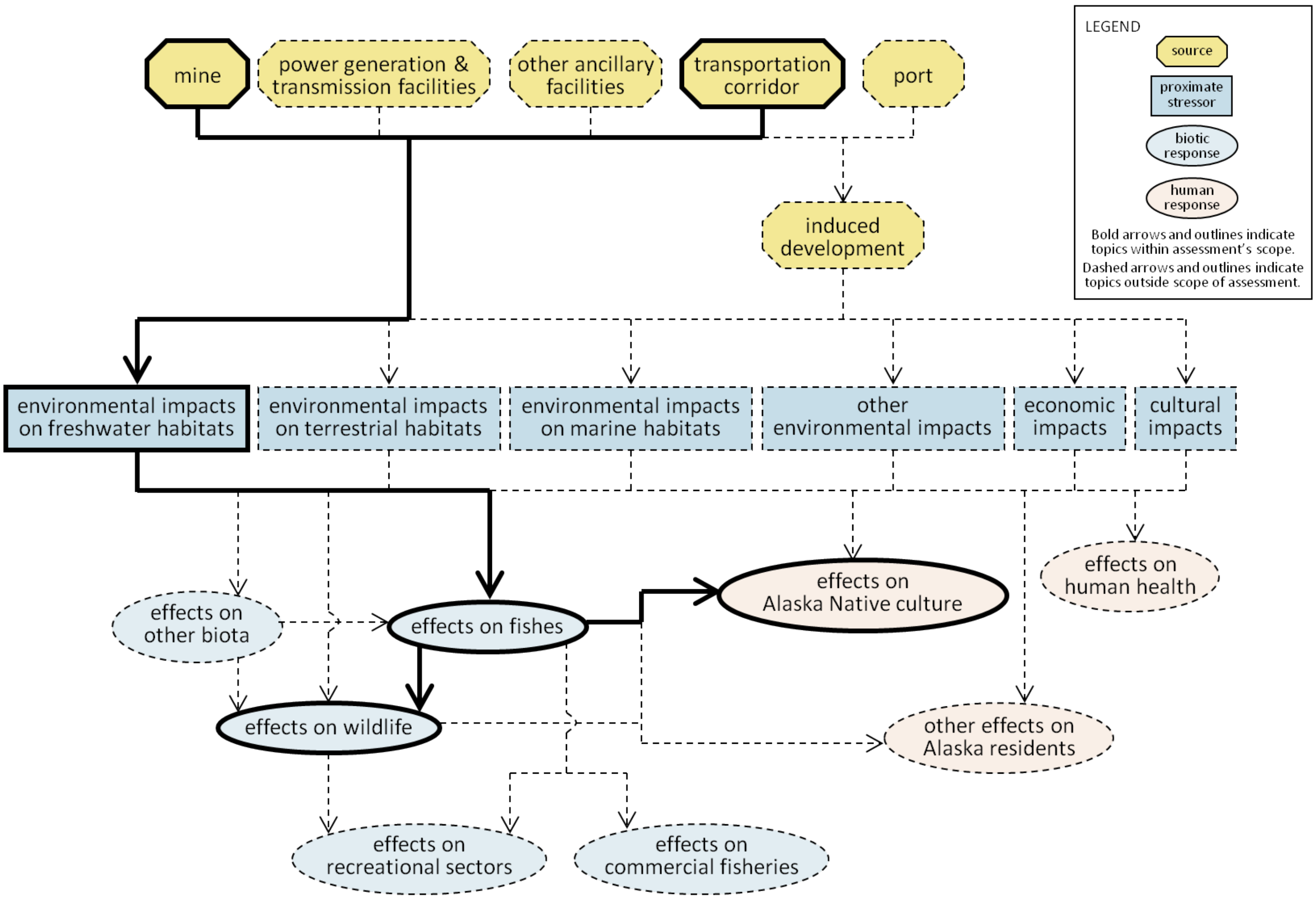
2.2 Scope

2.2.1 Topical Scope

Construction and operation of a large-scale mining operation require the development of extensive infrastructure and involve numerous processes and components, each of which may have repercussions for receiving environments. In this assessment, we do not consider all potential sources of risk associated with the development of large-scale mining in the Bristol Bay watershed, all the stressors that may result from these sources, and all the endpoints that may be affected. Rather, we focus on a more limited set of sources, stressors, and endpoints based on stakeholder concerns and potential decision-maker needs (Chapter 1). These focal components are described in broad terms below. In Chapters 3 through 6, we consider these components in greater detail, and more specifically define the focus of the assessment—in terms of geographic region, type of mining development, and ecological endpoints—for risk analysis and characterization purposes.

In terms of sources, we consider the mine infrastructure and transportation corridor components of a large-scale surface mining operation (Figure 2-1). Exploratory mining activities are ongoing in the region (Box 2-2), but these activities are considered outside the scope of the assessment. Certain sources associated with mining but not directly related to mine operations are not evaluated here, including power generation and transmission facilities and activities, ancillary facilities such as housing for mine workers and wastewater treatment plants to serve an increased human population, and construction and operation of a deep-water port at Cook Inlet (Figure 2-1). A thorough evaluation of induced development—development that is not part of the mine project, but for which the mine project provides the impetus or opportunity, such as residential and commercial growth resulting from increased accessibility—is also outside the scope of this assessment, although its importance is considered qualitatively in Chapter 13.

Figure 2-1. Conceptual model illustrating sources, stressors, and responses potentially associated with large-scale mine development in the Bristol Bay watershed. Pathways explicitly evaluated in this assessment are in bold; dashed pathways may be considered qualitatively in parts of the assessment, but are generally considered outside its scope. See Box 2-1 for a general discussion of how conceptual models are used and structured in the assessment.



BOX 2-2. EXPLORATORY MINING ACTIVITIES

Exploratory activities associated with the Pebble deposit—including geophysical, geochemical, and environmental surveys, geological mapping, and drilling—have been underway for several decades (Ghaffari et al. 2011). For example, 1,158 holes were drilled on the Pebble property through 2010, totaling 948,638 feet (289,145 m) (Ghaffari et al. 2011). These holes are concentrated in the Pebble deposit area, but occur throughout the Pebble claim block. According to the Pebble Limited Partnership's annual reclamation reports (submitted to the State of Alaska by the Pebble Limited Partnership in accordance with their land use permits), the total amount of land disturbed between 2009 and 2012 was approximately 3 acres.

Because these exploratory activities require water, power, personnel support, and the use of chemicals, heavy machinery, helicopters, and other equipment in relatively undeveloped areas, they likely have had some environmental impact on the region. Full evaluation of these effects is beyond the scope of this assessment, and it is likely that any effects of exploratory activities would be small relative to the effects of full mine development.

In terms of stressors, we focus on potential environmental effects on freshwater habitats (Figure 2-1). We focus on freshwater habitats because the Bristol Bay watershed supports exceptional fish populations, and these populations are intimately linked to the watershed's freshwater habitats. Although we recognize that large-scale mining could also have significant direct impacts on terrestrial and marine systems, as well as direct economic and cultural repercussions, we do not evaluate these impacts here (Figure 2-1).

Given the ecological and cultural significance of fishery resources in the Bristol Bay watershed, and the fact that the health and sustainability of the watershed's fish populations are primary concerns shared by all stakeholders interested in the Bristol Bay area (including those who support mining), we focus on effects on key salmonids (Box 2-3) and resulting effects on wildlife and Alaska Native cultures as assessment endpoints (Chapter 5). Direct effects of mining on wildlife and Alaska Native cultures, although potentially significant, are not evaluated in this assessment. For example, construction and operation of a transportation corridor would likely directly affect wildlife populations (Forman and Alexander 1998); however, because the assessment focuses on freshwater habitats, these direct wildlife effects are not considered here. The only effects on wildlife and Alaska Native cultures evaluated in the assessment are those resulting from impacts on fish populations (Chapter 12). We also recognize that many other endpoints may be directly affected by large-scale mining operations, including other biota (e.g., vegetation, small mammals), other recreational and commercial fisheries, and human health (Figure 2-1), but these topics are also outside the scope of the assessment.

It is important to keep in mind that exclusion of a source, stressor, or endpoint from this assessment does not imply that it would be insignificant or unaffected. We recognize that many of the pathways we identify as outside of the assessment's scope could have significant repercussions for the region's biota and people.

BOX 2-3. KEY SALMONIDS IN THE BRISTOL BAY WATERSHED

The Bristol Bay watershed's freshwater habitats support a diverse and robust assemblage of fishes, dominated by the family Salmonidae. This family comprises three subfamilies—Salmoninae (salmon, trout, and char), Thymallinae (grayling), and Coregoninae (whitefish)—all of which are represented in the region. In this assessment, we focus on fishes in the subfamily Salmoninae, particularly the five North American Pacific salmon species (sockeye, Chinook, coho, chum, and pink), rainbow trout, and Dolly Varden (a species of char). Collectively, we refer to these seven species as salmonids throughout this report.

All Salmonidae spawn in freshwater, but they can differ in their life histories. Some populations (e.g., Bristol Bay's Pacific salmon) are anadromous, meaning that individual fish migrate to marine waters to feed and grow before returning to fresh waters to reproduce. Other Bristol Bay populations (e.g., lake trout, Arctic grayling) are non-anadromous (resident), meaning that essentially all individuals remain in fresh waters to feed. Other populations (e.g., rainbow trout, Dolly Varden) can exhibit either anadromous or non-anadromous life histories.

2.2.2 Geographic Scales

Throughout this assessment, we consider data across five geographic scales (Table 2-1, Figure 2-2).

- The **Bristol Bay watershed** (Scale 1, Figure 2-3) includes all the basins and waterways that flow into Bristol Bay.
- The **Nushagak and Kvichak River watersheds** (Scale 2, Figure 2-4) include those drainage areas that contain stream segments flowing either directly or via downstream segments into the mainstem Nushagak River or Kvichak River.
- The **mine scenario watersheds** (Scale 3, Figure 2-5) include the cumulative drainage areas of the South and North Fork Koktuli Rivers to their junction and Upper Talarik Creek to its junction with Iliamna Lake.
- The **mine scenario footprints** (Scale 4, Figure 2-6) include the footprints of the major mine components (i.e., the mine pit, waste rock piles, and tailings storage facilities), the groundwater drawdown zone, and plant and ancillary facilities for each mine size scenario (Chapter 6).
- The **transportation corridor area** (Scale 5, Figure 2-7) includes 32 subwatersheds in the Kvichak River watershed that drain to Iliamna Lake and would be crossed by the transportation corridor (Chapter 6); the transportation corridor does not cross into the Nushagak River watershed.

These geographic scales are defined using the USGS National Hydrography Dataset (USGS 2012) (Box 2-4, Table 2-1). In problem formulation, we use broader geographic scales to describe the physical, chemical, and biological environment in the Bristol Bay region (Table 2-1); we also use broader scales to consider the effects of multiple mines across the landscape. In risk analysis and characterization, we use finer geographic scales to evaluate the potential effects of mining operations.

BOX 2-4. THE NATIONAL HYDROGRAPHY DATASET

The National Hydrography Dataset (NHD) is a publicly available database of surface water information for the United States (USGS 2012). Within the NHD, the entire landscape of the United States is organized into a six-tiered system of nested hydrologic units, each with their own identifiable codes (hydrologic unit codes, or HUCs). These tiers are defined as regions (represented by 2-digit codes), subregions (4-digit codes), basins (6-digit codes), subbasins (8-digit codes), watersheds (10-digit codes), and subwatersheds (12-digit codes). In total, the entire United States is divided into roughly 160,000 subwatersheds (12-digit HUCs) within roughly 21 regions (2-digit HUCs). Due to the hierarchical nature of the system, all subwatersheds (12-digit HUCs) within the same watershed start with the same first 10 digits, all watersheds (10-digit HUCs) within the same subbasin start with the same first 8 digits, and so on.

It is important to note that the NHD hydrologic units do not always delineate true hydrologic watersheds (i.e., their boundaries do not always accurately indicate where water drains to a particular point). Nevertheless, these boundaries are useful in both water resource and land management and are used as a foundational geographic layer in this assessment.

Table 2-1. Geographic scales considered in the assessment.

Scale	Description	Hydrologic Unit Codes (HUCs)[a]	Area (% of scale above)	Representative Chapters
1	Bristol Bay watershed	19030202–19030206, 19030301–19030306, 1903010101–1903010113, 1903010201–1903010203, 1903020101–1903020110	116,000 km^2 (NA)	2, 3, 4, 5, 13
2	Nushagak and Kvichak River watersheds	19030301–19030304, 19030205, 19030206[b]	59,900 km^2 (52%)	2, 3, 4, 5, 13
3	Mine scenario watersheds	190303021103, 190303021104, 190303021101–190303021102 1903020607,	925 km^2 (2%)	6, 7, 8, 9, 12
4	Mine scenario footprints			
	Pebble 6.5	NA	103 km^2 (11%)	6, 7, 8, 9, 12
	Pebble 2.0	NA	45.3 km^2 (5%)	6, 7, 8, 9, 12
	Pebble 0.25	NA	18.9 km^2 (2%)	6, 7, 8, 9, 12
5	Transportation corridor area[c]	190302051403–190302051406, 190302060101–190302060104, 190302060201–190302060206, 190302060301–190302060302, 190302060701–190302060702, 190302060704, 190302060901–190302060905, 190302060907, 190302060914[d]	2,340 km^2 (4%[e])	6, 10, 11

Notes:
a From the National Hydrography Dataset (NHD) (USGS 2012). Scale 1 is defined by 8-digit and 10-digit HUCs; Scale 2 by 8-digit and 12-digit HUCs; Scale 3 by 10-digit and 12-digit HUCs; Scale 5 by 12-digit HUCs. See Box 2-4 for further discussion of the NHD.
b Except for 190302062301–190302062311.
c The transportation corridor would include a 113-km road in the Kvichak River watershed; the area presented here represents the area of the 12-digit HUCs incorporating this road.
d The 190302060914 area was clipped to remove the area of Iliamna Lake and any land area draining directly to Iliamna Lake.
e Represents % of Scale 2 encompassed by the transportation corridor area HUCs.
NA = not applicable

Figure 2-2. The five geographic scales considered in this assessment. Only selected towns and villages are shown on this map. See Figures 2-3 through 2-7 for detailed views of each scale.

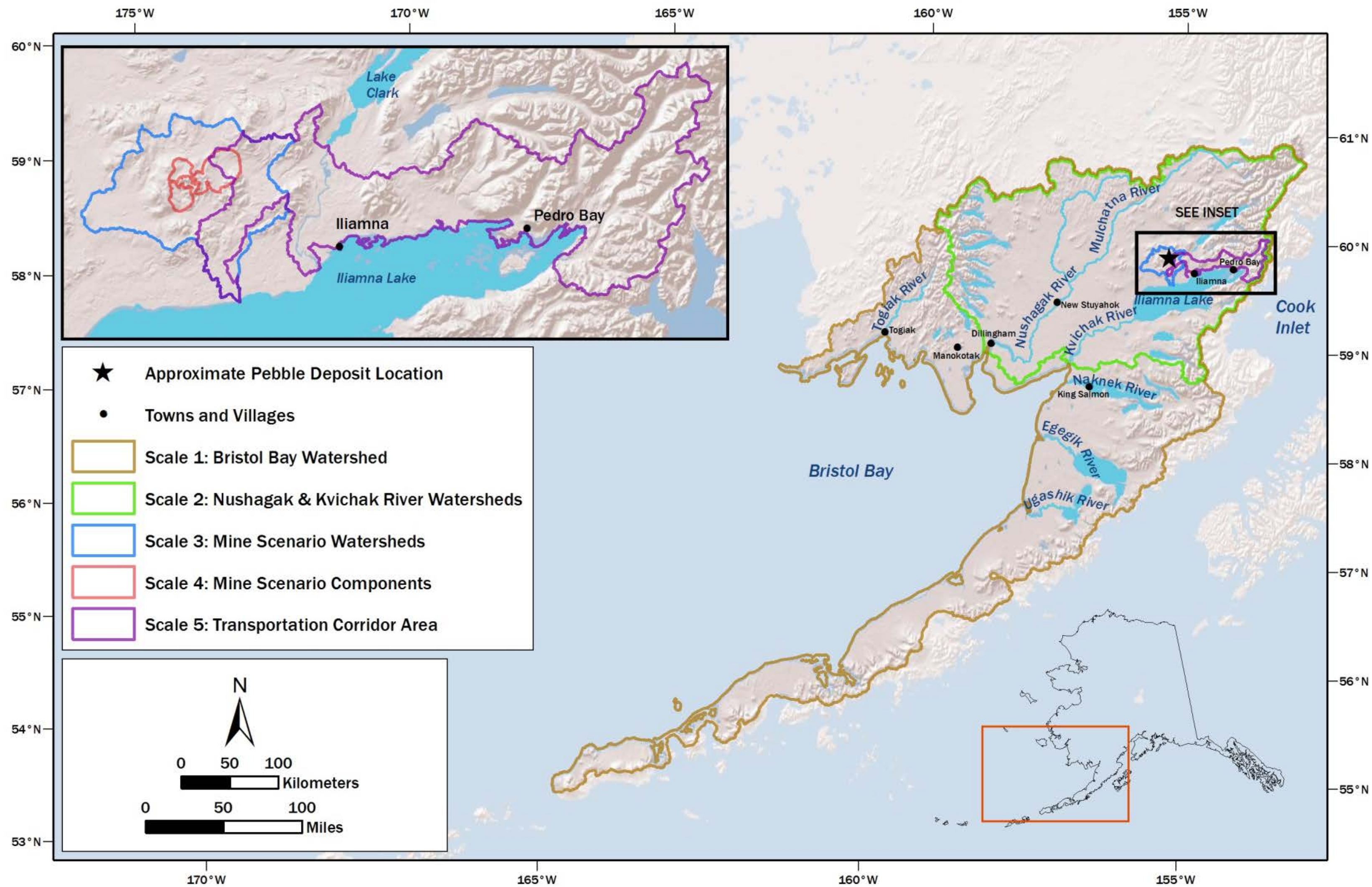


Figure 2-3. The Bristol Bay watershed (Scale 1), comprising the Togiak, Nushagak, Kvichak, Naknek, Egegik, and Ugashik River watersheds and the North Alaska Peninsula. Only selected towns and villages are shown on this map.

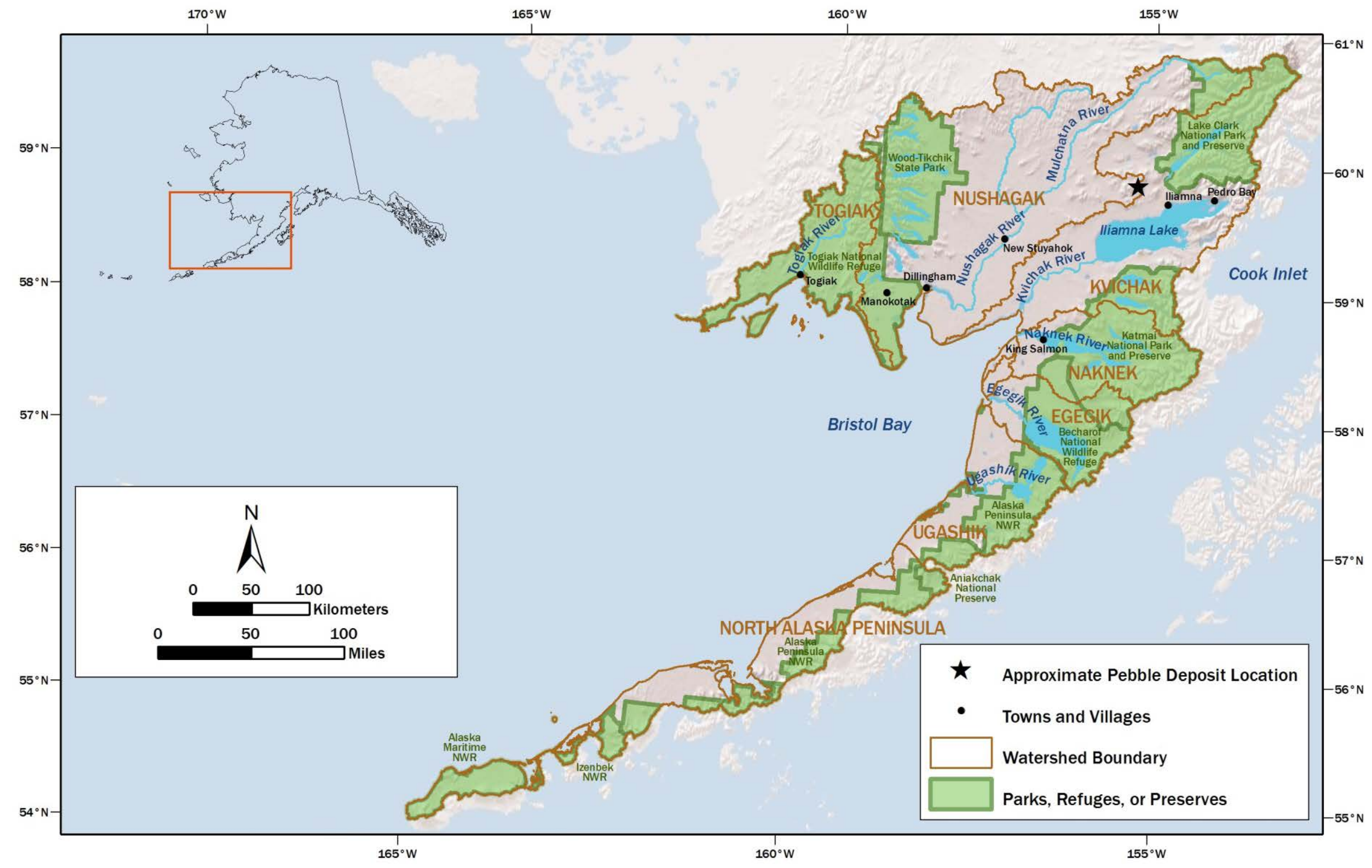


Figure 2-4. The Nushagak and Kvichak River watersheds (Scale 2).

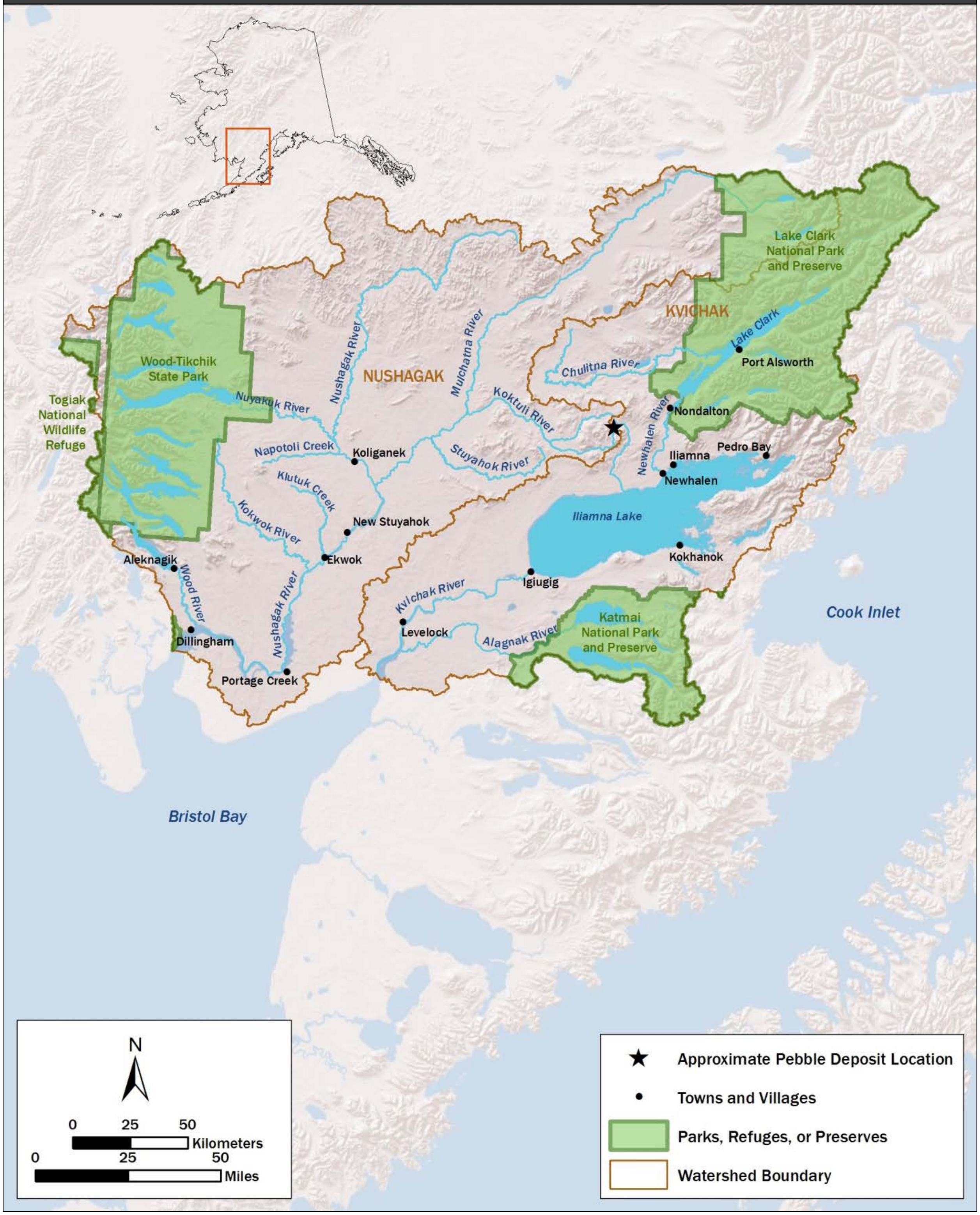


Figure 2-5. The mine scenario watersheds—South Fork Koktuli River, North Fork Koktuli River, and Upper Talarik Creek—within the Nushagak and Kvichak River watersheds (Scale 3).

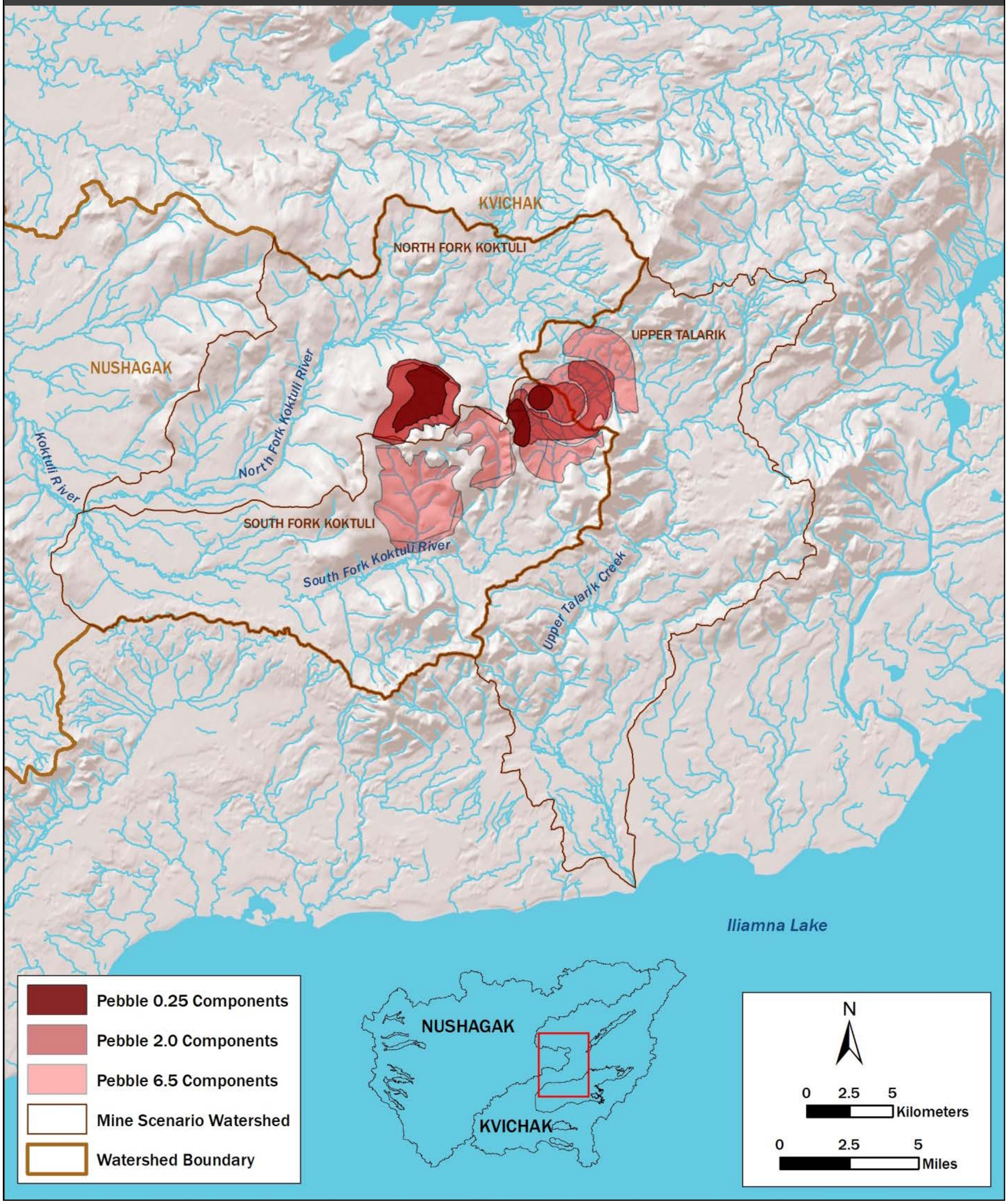


Figure 2-6. Footprints of the major mine components for the three scenarios evaluated in the assessment (Scale 4). Pebble 0.25 represents 0.25 billion ton of ore; Pebble 2.0 represents 2.0 billion tons of ore; Pebble 6.5 represents 6.5 billion tons of ore. Each mine footprint includes the footprints of the major mine components shown here, as well as the groundwater drawdown zone and the area covered by plant and ancillary facilities. See Figures 6-1, 6-2, and 6-3 for more detailed maps of the major mine components for each scenario. Light blue areas indicate streams and rivers from the National Hydrography Dataset (USGS 2012) and lakes and ponds from the National Wetlands Inventory (USFWS 2012); dark blue areas indicate wetlands from the National Wetlands Inventory (USFWS 2012).

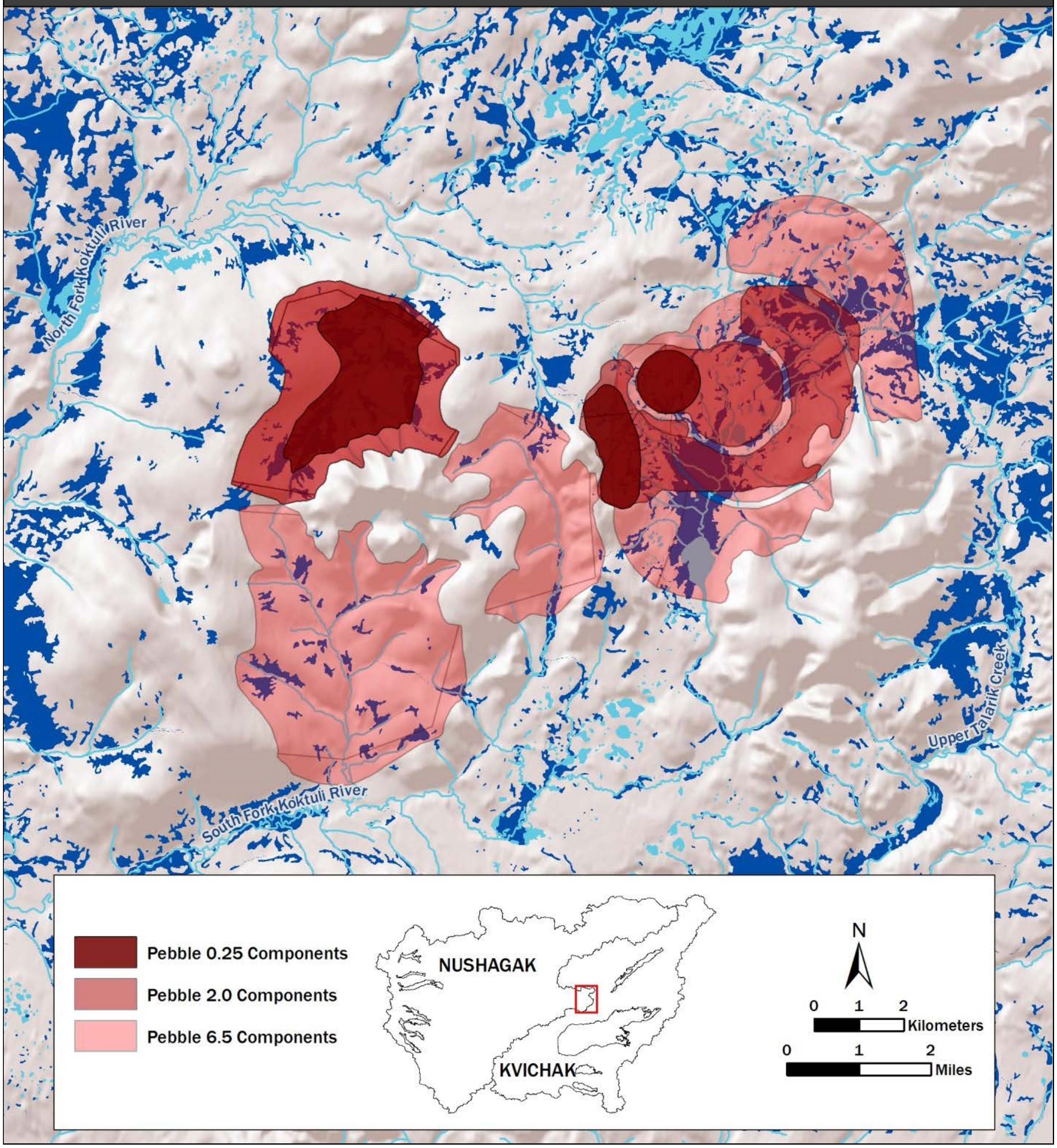


Figure 2-7. The transportation corridor area (Scale 5), comprising 32 subwatersheds in the Kvichak River watershed that drain to Iliamna Lake. Subwatersheds are defined by 12-digit hydrologic unit codes according to the National Hydrography Dataset (USGS 2012) (Box 2-4).