April 28, 2022

SOUTH AUGUSTINE ISLAND NONCOMPETITIVE GEOTHERMAL PROSPECTING PERMIT

Preliminary Written Finding of the Director

Alaska Department of
NATURAL
RESOURCES
DIVISION OF OIL & GAS

Recommended citation:

DNR (Alaska Department of Natural Resources). 2022. South Augustine Island Noncompetitive Geothermal Prosecting Permit Preliminary Written Finding of the Director. April 28, 2022.

Questions or comments about this written finding should be directed to:

Alaska Department of Natural Resources
Division of Oil and Gas
550 W. 7th Ave., Suite 1100
Anchorage, AK 99501-3560
Phone 907-269-8800

For information on alternative formats and questions on this publication, please contact:

DNR, Division of Oil and Gas
550 W. 7th Ave., Suite 1100
Anchorage, AK 99501-3560
Phone 907-269-8800.

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Preliminary Written Finding of the Director

Prepared by:
Alaska Department of Natural Resources
Division of Oil and Gas

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Chapter One: Director's Preliminary Written Finding and Decision

The Alaska Department of Natural Resources (DNR), Division of Oil and Gas (DO&G) administers the geothermal exploration and development program for the State of Alaska. State lands with geothermal potential may be disposed of through prospecting permits or leases to explore and develop geothermal resources. Disposal of land for geothermal exploration and development may only occur after lands are designated as a proposed geothermal disposal area and a best interest finding is issued authorizing the disposal. Only state-owned, unencumbered lands will be available for permit or lease.

A. Procedural Background

Disposal of Augustine Island and surrounding state waters for geothermal exploration was approved on January 14, 2013, with issuance of a written finding that determined that leasing tracts on and around Augustine Island for geothermal exploration was in the state's best interest. A lease sale held on May 8, 2013, offered 65,992 acres in 26 tracts with one bid received. No exploration was attempted, and this lease (ADL 392470) was relinquished on October 8, 2014.

- The process for this South Augustine Island Noncompetitive Geothermal Prospecting Permit (Prospecting Permit) was initiated with a proposal received on April 14, 2021, from GeoAlaska, LLC (GeoAlaska).
- DO&G issued a call for public comments and competing proposals on June 29, 2021, for 65,992 acres in 26 tracts on and around Augustine Island.
- On July 30, 2021, the public comment period and call for competing proposals ended, and no competing proposals or comments were received. Consequently, the current GeoAlaska proposal is being offered as a noncompetitive prospecting permit for a period of 2 years at a rental rate of $3/acre. This disposal is assigned to ADL 394080.

B. Statement of Applicable Law

The state has sufficient authority through general constitutional, statutory, and regulatory authority, the terms of the disposal, and plans of exploration, operation, and development to ensure that permittees/lessees conduct their activities safely and in a manner that protects the integrity of the environment and maintains opportunities for other natural resource uses.

- Geothermal resource exploration and development is authorized under AS 38.05.181 with regulatory guidance outlined at 11 AAC 84.700-950.
- State laws AS 38.05.035(e), AS 38.05.181, and 11 AAC 84.700(b) require that before approving a geothermal prospecting permit, the director must determine whether the disposal is in the best interest of the state.
- This written finding considers the potential that this Prospecting Permit may be converted to leases if the conditions outlined in 11 AAC 84.740 are met. Mitigation measures included in Chapter Nine would be carried forward on any subsequent permit or lease.

C. Analysis Summary

1. Area Description

The Prospecting Permit Area (Permit Area) covers approximately 3,048 acres in parts of 3 tracts on the south side of Augustine Island. Augustine Island is within the Kenai Peninsula Borough (KPB) on the west side of Lower Cook Inlet in Kamishak Bay. Geologic hazards from Augustine Volcano, an active stratovolcano on Augustine Island include lahars, pyroclastic flows, debris avalanches, volcanic blasts, and other volcano-related hazards. Geothermal resources in the form of hot water, hot dry steam, or hot dry rock in the Permit Area are indicated by Augustine Volcano, although no hot springs are known from Augustine Island.

Habitat, fish, and wildlife in the Permit Area are influenced by an island location and periodic eruptions of Augustine Volcano (17.5-year average interval). Nearshore habitats support fish, waterfowl, seabirds, and marine mammals. Intertidal wetlands are used by waterfowl primarily in summer, and rocky cliffs especially near Burr Point on the north side of the island may contain nesting seabirds. Nearshore waters support razor clam beds, Pacific herring spawning, southwest distinct population segment (DPS) northern sea otter designated critical habitat, and harbor seal pupping and molting haulouts.

The primary use of Augustine Island is scientific research and monitoring of Augustine Volcano. Nearshore waters provide habitat for salmon, halibut, and groundfish that support commercial and recreational fisheries managed by Alaska Department of Fish and Game (ADF&G), North Pacific Fisheries Management Council, National Marine Fisheries Service (NMFS), and International Pacific Halibut Commission. Augustine Island and surrounding state waters are within the Anchorage – Mat-Su – Kenai Peninsula nonsubsistence use area. Federal waters east of Augustine Island are used by Seldovia residents for subsistence harvest of halibut, cod, black rockfish, and salmon.

2. Reasonably Foreseeable, Cumulative Effects

At the disposal phase, it is unknown whether geothermal resource exploration, development, power production, or power transmission will be proposed, and if proposed, what the specific location, type, size, extent, and duration would be. This finding discusses the potential cumulative effects, in general terms, that may occur with geothermal exploration, development, power production, and power transmission activities within the Permit Area considering mitigation measures that have been developed for the Prospecting Permit and any subsequent leases. The director has limited the scope of the review for this finding to the applicable statutes and regulations, facts, and issues pertaining to the Permit Area, and the reasonably foreseeable significant cumulative effects of geothermal exploration and power production.

Initial survey and exploration could include geological and geophysical surveys and exploratory drilling to determine the size and temperature of the resource. If a commercially viable geothermal resource is identified, development could include construction of well pads, wells, pipelines, power plant, roads, personnel housing, transportation and maintenance facilities, and a subsea power cable.

a. Air Quality

Geothermal fluids contain dissolved carbon dioxide, hydrogen sulfide, ammonia, and methane gases which are released during depressurization and cooling with hydrogen sulfide oxidizing to sulfur dioxide and ammonia oxidizing to nitrogen oxides. Metal salts of mercury, boron, and arsenic may be released as fine-grained particulates. Air emissions from geothermal power plants are orders of magnitude less than conventional fossil-fuel power plants and US Environmental Protection Agency (EPA) and Alaska Department of Environmental Conservation (ADEC) require industries to limit emissions that may affect air quality. Industry compliance with regulations and measures would ensure that any incremental increases in air pollution from geothermal power production would not result in significant cumulative effects on air quality.

b. Water Quality

Well drilling, power plant construction and operation, and associated discharges, runoff, and water use could affect water availability and quality. Discharge of geothermal wastewater may alter local water quality and temperature. Facilities are required to control and manage stormwater and snow melt runoff to avoid and minimize water pollution and discharges are regulated through ADEC's Alaska Pollutant Discharge Elimination System program. Facilities are required to comply with solid waste, fuel, and hazardous substance handling and storage regulations to avoid and minimize water pollution. Mitigation measures address fuel and hazardous substance storage, transfer, and handling to further ensure protection of surface and subsurface water resources. Industry compliance with regulations and mitigation measures are expected to avoid, minimize, and mitigate potential cumulative effects on water resources.

c. Habitat, Fish, and Wildlife

Potential cumulative habitat, fish, and wildlife impacts from development of geothermal energy include land use, water use, noise, solid and liquid waste generation, pollution, and waste heat generation. Constructing a subsea power cable from Augustine Island would require trenching and burial that would cross Essential Fish Habitat (EFH) for salmon, groundfish, and Pacific scallops, and Endangered Species Act (ESA) designated critical habitat for southwest DPS northern sea otters. Dredging and cable installation could lead to long-term or permanent damage depending on the extent and type of habitat disturbed and mitigation measures used.

Disturbances that flush birds from nest sites may increase predation by bald eagles. Displacement of waterbird adults or broods from preferred habitats during pre-nesting, nesting, and brood rearing can cause disruption of courtship, chick loss, egg breakage, and predation. Sea otters and harbor seals may be disturbed by aircraft and vessel traffic, as well as noise and activity from construction and operation of a power plant. Potential cumulative effects from prolonged or repeated disturbance from traffic and noise could include displacement from preferred feeding or haulout areas, increased stress and energy expenditure, masking of communications, and impaired thermoregulation of neonates. Southwest DPS northern sea otters are protected under both the ESA and the Marine Mammal Protection Act (MMPA) and harbor seals are protected under MMPA. Typical MMPA required mitigation includes minimum flight altitudes and separation distance; exclusion zones for in-water pile construction; and limiting vessel approaches and speeds. Facility siting and aircraft routing to avoid sensitive habitats and haulouts during sensitive periods would minimize potential disturbance of sea otters and harbor seals. Geothermal power plants must comply with local, state, and federal laws and regulations that protect sensitive habitats, and sensitive fish and wildlife.

d. Uses

Induced vibrations from equipment, vibrators, or small explosive charges for seismoelectric surveys, well drilling, and facility construction could interfere with equipment monitored by the Alaska Volcano Observatory (AVO). Removing and reinjecting geothermal fluids leads to subsurface pressure and temperature changes causing volume and stress changes that can induce earthquakes. Most geothermal-related induced seismicity occurs as low-magnitude microearthquakes (M <2.0) that typically go undetected. An artificially induced increase in low-magnitude earthquakes, however, could interfere with AVO's monitoring activities that provide warning of impending eruptions and geophysical and visual information during eruptions. If geothermal production induces seismicity, and if induced seismicity could be hazardous, the permittee will be required, as necessary, to adjust production and injection rates or to suspend operations. In addition, vapor plumes emitted by power plant water cooling towers could interfere with AVO's visual monitoring of Augustine Volcano.

Geothermal development activities most likely to affect commercial and sport fishing include dredging to install a subsea power cable; aircraft and vessel traffic; and any water intake or wastewater discharge from power plant operations that impact fish and invertebrates. Construction of a subsea power cable from Augustine Island could temporarily displace commercial and sport fishers and interfere with harvest activities. Increased aircraft and/or vessel traffic associated with operation of a power plant on Augustine Island is not expected to disrupt fisheries, and regulated water intake and discharge are not expected to result in population-level impacts that would affect management or harvest levels of salmon and groundfish fisheries. Construction of a subsea power cable from Augustine Island to the Kenai Peninsula could temporarily displace some subsistence fishers. Mitigation measures require consultation with potentially affected commercial and sport fisheries users, subsistence communities, and the Kenai Peninsula Borough to discuss the siting, timing, and methods of proposed operations in Lower Cook Inlet and mitigating measures that could be implemented to prevent unreasonable conflicts.

e. Fiscal Effects

Geothermal development on Augustine Island could have long-term and positive economic effects for the State of Alaska. Future revenue sources could include lease rental charges and production royalties outlined in 11 AAC 84.770. Property tax revenues could benefit the KPB. Electricity for Lower Cook Inlet communities is primarily generated by natural gas-fired turbines and diesel generators. Geothermal electricity generation could provide a reliable, renewable source of power for decades and could provide energy security to Lower Cook Inlet that would contribute to the economic wellbeing of Alaskans.

f. Regulation and Mitigation

All geothermal exploration, development, and power production activities conducted under geothermal permits and leases are subject to numerous state, federal, and local laws and regulations. Agencies that have broad authority to regulate and condition activities related to geothermal resources on and around Augustine Island include DNR, ADEC, ADF&G, Alaska Oil and Gas Conservation Commission; EPA; US Army Corp of Engineers, US Fish and Wildlife Service, NMFS, and KPB. Mitigation measures address protection of state lands; air and water quality; habitat for fish and wildlife; commercial, sport, and subsistence fisheries harvest activities; management of fuels, hazardous substances, and wastes; potential spills of geothermal fluids and hazardous substances; and siting of facilities and operations. DNR may impose additional requirements necessary to protect the state's interest during approval of later phase activities.

D. Preliminary Decision and Request for Public Comments

The director considered all applicable statutes and regulations, weighed the facts, and balanced the potential positive and negative effects of geothermal exploration, development, and power production activities in the Permit Area during the development of this preliminary finding. The relevant facts and issues made known within the scope of this review include: the value of research and monitoring of Augustine Volcano; the value of habitat, fish, and wildlife; the value of Lower Cook Inlet commercial and recreational fisheries; potential cumulative effects from a geothermal power plant on Augustine Island; and potential benefits of a geothermal energy source for southcentral Alaska. The director preliminarily finds the potential benefits of issuing this Prospecting Permit outweigh the potential negative effects, such that issuance of the South Augustine Island Noncompetitive Geothermal Prospecting Permit serves the best interests of the State of Alaska.

This preliminary finding is subject to revision based on comments received by DO&G during the period set out for receipt of public comment, as provided in AS 38.05.035(e)(5)(A). Members of the public are encouraged to comment on any part of this preliminary finding. In commenting, please be as specific as possible.

Comments must be in writing and received by May 30, 2022, in order to be considered and must be sent to Best Interest Findings:

By mail: Alaska Department of Natural Resources
Division of Oil and Gas
550 W 7th Ave, Suite 1100
Anchorage AK 99501-3560

By fax: 907-269-8938

By email: dog.bif@alaska.gov

DO&G complies with Title II of the Americans with Disabilities Act of 1990. This publication will be made available in alternate communication formats upon request. Please contact the Best Interest Findings Group at (907) 269-8800 or dog.bif@alaska.gov. Requests for assistance must be received at least 96 hours prior to the comment deadline to ensure necessary accommodations can be provided.

Following review of comments on this preliminary written finding and any additional relevant information, the director will make a final determination whether disposal of geothermal resources in the Permit Area is in the best interest of the state and will issue a final finding and decision. To be eligible to file an appeal of the final finding to the DNR commissioner under AS 38.05.035(i), a person must provide written comments during the comment period of this preliminary finding set out in the previous paragraph. Additional information regarding the public comment process and requests for reconsideration and appeals can be found in Chapter Two. A copy of the final decision can be sent to any person commenting on the preliminary decision and will include an explanation of the appeal process.

DocuSigned by:

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Derek W. Nottingham
Director, Division of Oil and Gas

Chapter Two: Authority and Scope of Review

The Alaska Constitution provides that the state's policy is "to encourage . . . the development of its resources by making them available for maximum use consistent with the public interest" and that the "legislature shall provide for the utilization, development, and conservation of all natural resources belonging to the State . . . for the maximum benefit of its people" (Alaska Constitution, Article VIII, §1 and 2). To comply with this provision, the legislature enacted Title 38 of the Alaska Statutes (AS 38) and directed the Alaska Department of Natural Resources (DNR) to implement the statutes.

A. Authority

The state may develop geothermal resources under the statutory guidance of AS 38.05.181. The procedures for disposal of geothermal resources are set out in regulations 11 AAC 84.700-790. Other agencies also have jurisdiction for activities resulting from resources exploration, development, and production. Disposal of the Augustine Island area for geothermal exploration was first approved on January 14, 2013. A geothermal lease sale was held on May 8, 2013, and 65,992 acres in 26 tracts were offered. One bid was received on Tract 13.

Alaska statutes govern the disposal of state-owned subsurface interests. Under AS 38.05.035(e), the DNR director may not dispose of state land, resources, property, or interests unless the director, with the consent of the commissioner, first determines in a written finding that such action will serve the best interests of the state.

The process for the South Augustine Island Noncompetitive Geothermal Prospecting Permit (Prospecting Permit) was initiated in response to a proposal received on April 14, 2021, from GeoAlaska, LLC (GeoAlaska). GeoAlaska applied for a prospecting permit covering about 3,048 acres on the southern end of Augustine Island. Next, DNR's Division of Oil and Gas (DO&G) issued a call for public comments and competing proposals on June 29, 2021. The area included in the call for competing proposals consisted of 26 tracts comprising approximately 65,992 acres. This expanded acreage was used in the call for competing proposals to disguise GeoAlaska's initial request for 3,048 acres in 3 tracts located on the south side of Augustine Island and to give any competitors an opportunity to apply for coinciding or adjacent lands for geothermal exploration. On July 30, 2021, the public comment period and call for competing proposals ended, and no competing proposals or comments were received. Therefore, this Prospecting Permit is being offered as a non-competitive Prospecting Permit for a period of 2 years at a rental rate of $3/acre. The Prospecting Permit can be renewed for an additional year if the permittee has been unable to show a discovery of geothermal resources in commercial quantities despite showing reasonable diligence as defined in 11 AAC 84.730(b).

B. Scope of Review

As required by AS 38.05.035(e)(1)(A)–(C), the director, in the written finding:

1. shall establish the scope of the administrative review on which the director's determination is based, the scope of the written finding supporting that determination, and the scope of the

administrative review and finding may only address reasonably foreseeable, significant effects of the uses proposed to be authorized by the disposal;

2. may limit the scope of an administrative review and finding for a proposed disposal to a review of (1) applicable statutes and regulations, (2) facts pertaining to the land, resources or property, or interest in them that are material to the determination and known to the director or knowledge of which is made available to the director during the administrative review, and (3) issues that, based on the applicable statutes, regulations, facts, and the nature of the uses sought to be authorized by the disposal, the director finds are material to the determination of whether the proposed disposal will serve the best interests of the state; and
3. may, if the project for which the proposed disposal is sought is a multi-phased development, limit the scope of an administrative review and finding for the proposed disposal to the applicable statutes, and regulations, facts and issues that pertain solely to the disposal phase of a project when the conditions of AS 38.05.035(e)(1)(C)(i)–(iv) are met.

1. Reasonably Foreseeable Effects

The scope of the administrative review and finding may address only reasonably foreseeable, significant effects of the uses proposed to be authorized by the disposal (AS 38.05.035(e)(1)(A)). The director does not speculate about possible future effects (AS 38.05.035(h)).

For an effect to be "reasonably foreseeable", there must be (1) some cause/result connection between the proposed disposal and the effect to be evaluated; (2) a reasonable probability that the effect will occur as a result of the disposal; and (3) the effect will occur within a predictable time after the disposal. Therefore, this finding does not speculate about future effects, but instead reviews only reasonably foreseeable effects of the proposed disposal. A reasonably foreseeable effect must also be "significant." Significant means a known and noticeable impact on or within a reasonable proximity to the area involved in the disposal.

2. Matters Considered and Discussed

Further, the director may limit the scope of an administrative review and finding for a proposed disposal to:

- applicable statutes and regulations;
- the facts pertaining to the land, resources, or property, or interest in them, that the director finds are material to the determination and that are known to the director or knowledge of which is made available to the director during the administrative review; and
- issues that, based on the statutes and regulations, on the facts as described, and on the nature of the uses sought to be authorized by the disposal, the director finds are material to the determination of whether the proposed disposal will best serve the interests of the state (AS 38.05.035(e)(1)(B)).

The scope of review in this finding addresses the reasonably foreseeable, significant effects of the uses to be authorized by the proposed disposal and is limited to the applicable statutes and regulations, the material facts and issues known to the director that pertain to the Prospecting Permit disposal phase, and issues that the director finds are material to the determination of whether the proposed disposal will best serve the interests of the state.

In preparing this written finding, the director considers and discusses facts related to topics set out under AS 38.05.035(g)(1)(B)(i)–(x) applied to geothermal resource exploration and development, and geothermal power production and transmission that are known at the time the finding is being prepared. The director must also consider public comments during the public comment period that are within the scope of review. The scope of this administrative review considers reasonably foreseeable effects on the Permit Area, approximately 3,048 acres in 3 tracts located on the south side of Augustine Island, and the surrounding environment. Figure 1 in Chapter Three depicts the location of the Permit Area.

3. Review by Phase

The director may limit the scope of an administrative review and finding for a proposed disposal to evaluate the potential effects of the proposed disposal when the director has sufficient information and data available upon which to make a reasoned decision.

Under AS 38.05.035(e)(1)(C), if the project for which the proposed disposal is sought is a multi-phased development, the director may limit the scope of an administrative review and finding for the proposed disposal to the applicable statutes and regulations, facts, and issues identified above pertaining solely to the disposal phase of the project under the following conditions:

(i) the only uses to be authorized by the disposal are part of that phase;

(ii) the disposal grants the permittee the exclusive right to prospect for geothermal resources on state land included under the permit, and, before the next phase of the project may proceed, public notice and the opportunity to comment are provided under regulations adopted by the department;

(iii) the department's approval is required before the next phase may proceed; and

(iv) the department describes its reasons for a decision to phase.

Here, the director has met condition (i) because the only uses authorized are part of the disposal phase. The disposal phase is the Prospecting Permit phase of this project. As defined in *Kachemak Bay Conservation Society v. State, Department of Natural Resources*, "disposal" is a catch all term for all alienations of state land and interests in state land.[1] In *Northern Alaska Environmental Center v. State, Department of Natural Resources*, the court further held that a disposal was a conveyance of a property right.[2] For a geothermal development project, the lease or prospecting permit is the only conveyance of property rights DNR approves. The prospecting permit or lease gives the permittee or lessee, subject to the provisions of the permit or lease and applicable law the exclusive right to drill for, extract, remove, and process geothermal resources, as well as the nonexclusive right to conduct within the permitted or leased area geological and geophysical exploration for geothermal resources, the nonexclusive right to install pipelines and build structures on the Prospecting Permit Area or lease to find, produce, save, store, take care of, and market all geothermal resources, and to house and board employees in its operations on

[1] 6 P.3d 270, 278 n.21 (Alaska 2000).

[2] 2 P.3d 629, 635-36 (Alaska 2000).

the Prospecting Permit Area or lease area. While the permittee or lessee has these property rights upon entering into the prospecting permit or lease, the prospecting permit or lease itself does not authorize any geothermal exploration activities on the prospecting permitted or leased tracts without further permits from DNR and other agencies. There are no additional property rights to be conveyed at later phases.

Condition (ii) is met, first, because this Prospecting Permit is for the disposal of available land or an interest in land, for geothermal resources. Second, condition (ii) is met because public notice and opportunity to comment are provided for each phase of a project. Public notice and the opportunity to comment on the disposal phase of a prospecting permit is provided through the preliminary best interest finding under AS 38.05.035(e), AS 38.05.945, and 11 AAC 84.720(c). Subsequent post-disposal phases may not proceed unless public notice and the opportunity to comment are provided under regulations adopted by DNR. DNR provides public notice and opportunity to comment for plans of operation that initiate a new phase under 11 AAC 84 as authorized by AS 38.05.

Condition (iii) is met because DNR's approval is required before the next phase may proceed.

Condition (iv) is met by the findings in Chapter One discussing the speculative nature of current information on what future development projects and methods may be proposed that would require post-disposal authorizations; and what permit conditions and mitigation requirements will be appropriate for authorizations at later phases.

This preliminary best interest finding satisfies the requirements for phased review under AS 38.05.035(e)(1)(C).

C. Appeal

A person affected by this decision may appeal it in accordance with 11 AAC 02. Any appeal must be received within 20 calendar days after the date of "issuance" of this decision, as defined in 11 AAC 02.040(c) and (d) and may be mailed or delivered to the Commissioner, Department of Natural Resources, 550 W. 7th Avenue, Suite 1400, Anchorage, Alaska 99501; faxed to 1-(907) 269-8918, or sent by electronic mail to dnr.appeals@alaska.gov. Under 11 AAC 02.030, appeals and requests for reconsideration filed under 11 AAC 02 must be accompanied by the fee established in 11 AAC 05.160(d)(1)(F), which has been set at $200 under the provisions of 11 AAC 05.160 (a) and (b).

An eligible person must first appeal this decision in accordance with 11 AAC 02 before appealing this decision to the Superior Court. A copy of 11 AAC 02 may be obtained from any regional information office of the Department of Natural Resources.

Chapter Three: Description of the Disposal Area

A. Property Description

Augustine Island is in Kamishak Bay on the west side of Lower Cook Inlet, approximately 68 miles southwest of Homer and approximately 170 miles south-southwest of Anchorage. West of Augustine Island are the Chigmit and Alaska-Aleutian mountain ranges. Augustine Island has been augmented by numerous eruptions of Augustine Volcano from which debris avalanches and lahars have deposited sediment on the flanks of the volcanic cone and in the surrounding waters.

The South Augustine Island Noncompetitive Geothermal Prospecting Permit Area (Permit Area) consists of the southern portion of Augustine Island. The Permit Area contains about 3,048 acres of onshore portions of 3 tracts, ranging from 320 to 2,240 acres (Figure 1). The state owns the land within the Permit Area, and Augustine Island is entirely located within the Kenai Peninsula Borough (KPB).

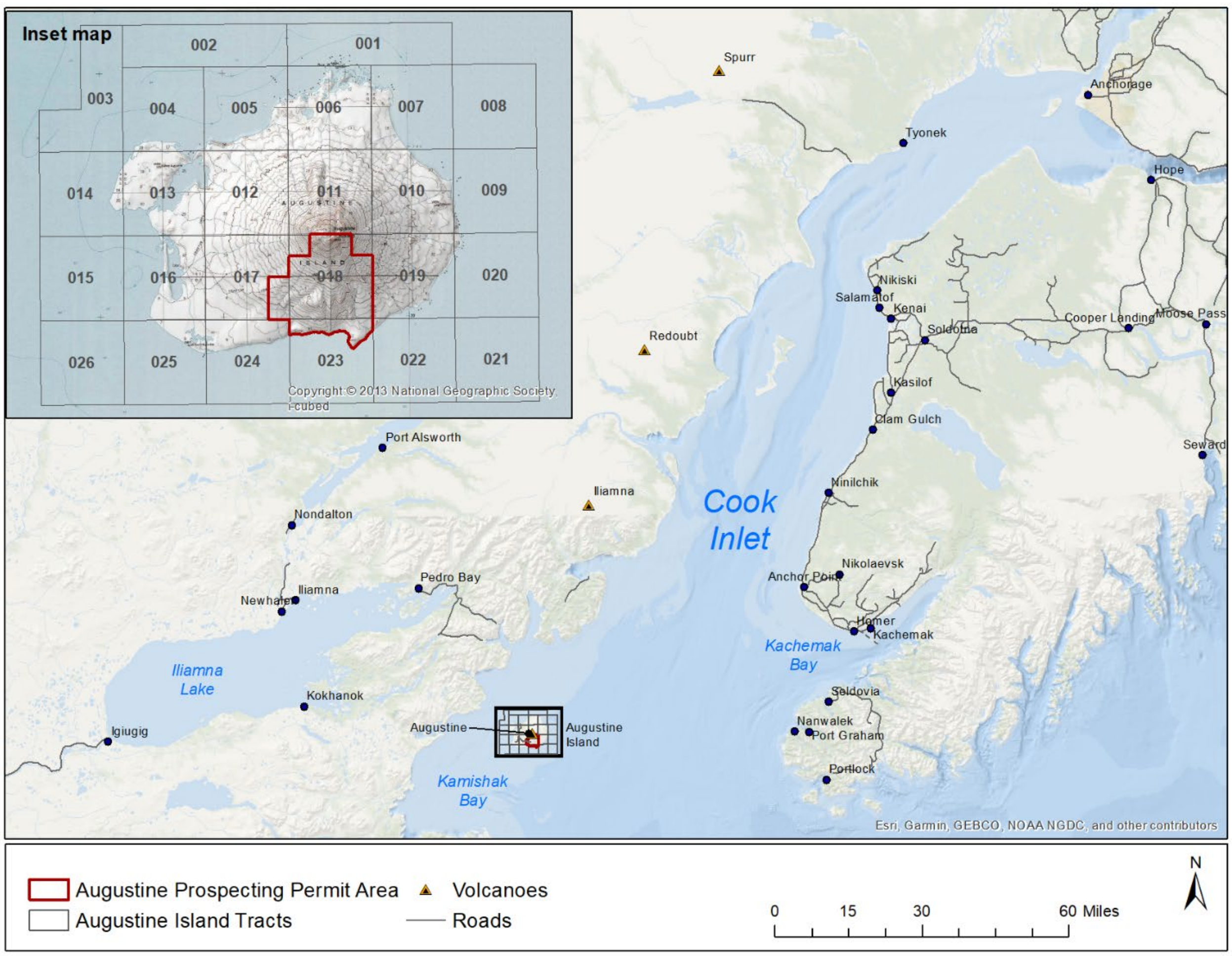

Figure 1. South Augustine Island Noncompetitive Geothermal Prospecting Permit Area

B. Cultural and Historical Background and Resources

At the time of first European contact, Dena'ina Indians occupied the Cook Inlet area. These nomadic bands came to the region about AD 500 to 1000 (CIRI 2021). Evidence from the Yukon Island site in Kachemak Bay shows that Lower Cook Inlet was occupied by Eskimos from about 1500 BC to AD 1000 and then later by Athabaskan Indians (Selkregg 1975). Although historical subsistence hunting and gathering has occurred near Augustine Island, there are no records of settlements on the island aside from a remote, abandoned cabin likely used by miners during a brief stint of pumice mining on the island in the late 1940s. No historic or prehistoric sites are reported on Augustine Island (OHA 2021; Weinberger 2021).

C. Geologic Hazards

Augustine Volcano is an active volcano in the Cook Inlet region and presents several potential geologic hazards to the island and surrounding waters (Waitt and Beget 2009). Augustine Volcano is the most historically active volcano in the Cook Inlet region. Escalating seismic unrest, ground deformation, and gas emissions culminated in an eruption from January 11 to mid-March of 2006, the fifth major eruption in 75 years (Power et al. 2010). Hazardous phenomena recorded at Augustine Island include volcanic ash clouds, ash fallout and volcanic bombs, pyroclastic flows, debris avalanches, tsunamis, earthquakes, directed blasts, lahars and floods, volcanic gases, and lava flow (Waythomas and Waitt 1998). Augustine Volcano has experienced major eruptions since 1883, such as eruptions in 1935, 1963 to 1964, 1976, 1986, and 2006 (Nye 2007). In early 2006, eruptive events resulted in explosive ash, pyroclastic flow eruptions, and lava dome eruptions (Beget and Kowalik 2006). By mid-2006, avalanche events and pyroclastic flows decreased with the exception of a minor spike in such events during April, in which several rock falls and avalanches contributed to the formation of an ash blanket on the southwest flank of Augustine Volcano (Waythomas and Waitt 1998).

1. Volcanic Ash Clouds, Ash Fallout and Volcanic Bombs

Historically, Augustine Volcano has explosively erupted, sometimes ejecting very large fragments of magma thousands of feet into the atmosphere. Ashfall occurs when clouds of ash accumulate and fall to the earth as they drift away from the volcano. Depending on the extent or thickness of the ashfall, infrastructure may collapse under the added weight of ash. Public health is a concern during periods of ashfall as inhaling volcanic ash can cause respiratory issues and may significantly decrease visibility (Waythomas and Waitt 1998).

Larger-sized volcanic debris, called blocks or bombs, typically strike near the vent of the volcano. Microscopic ash or tephra ejected from the volcano form ash clouds which may drift in the wind for several weeks or days and pose potential threats to air travel. The Alaska Volcano Observatory (AVO) reported that ash clouds from the 1976 and 1986 eruptions reached altitudes higher than 40,000 feet (12,000 meters) in height. In 1976, five jet liners experienced severe abrasion on exterior parts of the aircraft, but no crashes resulted from the ash cloud encounters. In March 1986, a DC-10 aircraft encountered an Augustine Volcano ash cloud during descent into Anchorage International Airport, but landed safely, and air traffic was routed around the ash cloud for several days (Waythomas and Waitt 1998).

Significant ashfall and volcanic debris would impact workers and infrastructure on Augustine Island leading to power plant shut down and the need to protect and evacuate workers. Mitigation measures in Chapter Nine include development of a plan to address potential geohazard impacts on operations to mitigate risk to facilities and personnel and coordination with the Alaska Volcano Observatory to ensure that the permittee or operator is always aware of Augustine Volcano's current activity status when personnel are on Augustine Island.

2. Pyroclastic Flows, Landslides, and Debris Avalanches

A pyroclastic flow is a hot fast-moving mixture of volcanic rock, debris, and gas that flows downslope during eruptive events. Pyroclastic flows may result from explosive eruptions or collapse of the lava dome. As the lava dome cools, it may collapse and fall back toward the volcano moving debris downslope several miles beyond the vent (Waythomas and Waitt 1998; USGS 2011). The cone of Augustine Volcano has been built up vertically over the last 2,000 years causing about a dozen major avalanches and creating areas of hummocky topography on Augustine Island and irregular bathymetry in nearshore waters (Waythomas and Waitt 1998; Nye 2007).

Landslides are common on volcanic cones and the surrounding areas because they are typically tall, steep, and weakened by the rise and eruption of molten rock. Magma releases volcanic gases that can partially dissolve in groundwater. The released gasses can result in a hot acidic hydrothermal system that weakens rock formations. The layers of lava and loose fragmented rock debris can lead to fault zones that move frequently. Landslides can cross valley divides and run up slopes several hundred yards high. Geothermal resources are often located under steep terrain, and development may require substantial excavation to prepare facility sites. Extensive excavation can trigger erosion and landslides could occur. Slopes underlain by weak bedrock can be a serious engineering problem (USGS 2021).

A debris avalanche is the rapid downslope movement of rock, volcanic debris, snow, ice, or other pyroclastic materials. Debris avalanches are not always associated with eruptive events, heavy rainfall, the intrusion of magma, or earthquakes can also cause catastrophic avalanches (USGS 2015a). Pyroclastic flows and debris avalanches can move at speeds of 3 to 6 miles per second, creating a serious hazard to life and property on the island (Waythomas and Waitt 1998). An eruption in 1976 caused a pyroclastic flow which damaged AVO infrastructure and equipment on the north shore of the island (Nye 2007). Pyroclastic flows and debris avalanches moving rapidly down the volcano flank can extend beyond tidelands, potentially generating tsunamis (Waythomas and Waitt 1998; Nye 2007). The topography of Augustine Island would cause a pyroclastic flow to spread out laterally from the vent, although it is unlikely that a flow would reach more than 3 miles off the island's shore (Waythomas and Waitt 1998).

Some slopes in the Permit Area are composed of volcanic ash and could be unstable. Design and construction of all drill pads built in the Permit Area must be approved through the plan of operations process by Division of Oil and Gas (DO&G), and sound engineering practices will be required to prevent poor siting of facilities. Mitigation measures are included in Chapter Nine.

3. Tsunamis

A tsunami can be generated by land-based and submarine landslides, volcanic eruptions, calving glaciers, underwater explosions, or meteorite impacts. Volcanic debris flowing rapidly into Cook Inlet during a large eruption of Augustine Volcano can result in generation of a tsunami wave. Several previous eruptions have initiated pyroclastic flows which reached surrounding waters. The 1883 eruption appears to have caused a debris avalanche that initiated a tsunami observed at English Bay, at the location of modern day Nanwalek and Port Graham (Waythomas and Waitt 1998). This tsunami flooded coastal homes and washed away kayaks although no fatalities were reported (Beget and Kowalik 2006). There is potential for a large debris avalanche from Augustine Volcano to flow into lower Cook Inlet and create a radiating tsunami (Waitt 2010). Tsunami magnitude is based on several factors: the volume and velocity of debris, water depth in the runout zone, and the position of tides during the eruption. Low-lying areas along the coastline of lower Cook Inlet would be most susceptible to a tsunami, especially if an eruptive event occurred during high tide (Waythomas and Waitt 1998).

A tsunami generated by any source that reaches Augustine Island could flood or damage infrastructure in low-lying areas, especially any coastal docks or marine floatplane landing areas that could limit subsequent access to the island. Siting for power plants, drill pads, and associated facilities should consider elevation and tsunami hazards. Alaska Department of Natural Resources, Division of Geological and Geophysical Surveys with the University of Alaska’s Geophysical Institute have created tsunami inundation maps for vulnerable coastal communities based on earthquake scenarios and tsunami wave propagation modeling to estimate worst-case flooding (Salisbury and Janssen 2019). Similar modeling could be used to estimate tsunami risk by elevation on Augustine Island to assist with facility siting. Design and construction of all drill pads built in the Permit Area must be approved through the plan of operations process by Division of Oil and Gas (DO&G), and sound engineering practices will be required to prevent poor siting of facilities. Mitigation measures are included in Chapter Nine.

4. Earthquakes and Induced Seismicity

Augustine Island is vulnerable to naturally occurring subduction zone earthquakes, that are caused by one geologic crustal plate moving beneath another. In Southcentral Alaska, the oceanic Pacific Plate is slowly subducting beneath the continental North American Plate. Volcanoes, such as Augustine and those located on the Aleutian Islands, are associated with this type of tectonic plate convergence. Earthquakes can trigger landslides, avalanches, tsunamis, uplift, subsidence, infrastructure failure, and soil liquefaction (DHSEM 2018).

Geothermal fields are typically located in seismically active areas or along active faults. Because geothermal resource extraction redistributes fluid pressure in the reservoir, earthquakes could be triggered. Geothermal fields in tectonically active regions often show increased seismicity, but not always of large magnitude (Buijze et al. 2019). Increased seismicity from geothermal power production could be hazardous to power plant operations and adjoining land uses. The state may install seismographs or other instruments in producing geothermal fields to detect induced seismic activity. If geothermal production induces seismicity, and if induced seismicity could be hazardous, the permittee will be required to adjust production and injection rates or to suspend operations under mitigation measures in Chapter Nine.

5. Directed Blasts and Lava Flow

A directed blast is a large explosion which can occur if a volcano’s internal vent system becomes compromised or uncapped. Directed blasts of Augustine Volcano are rare; there is evidence of only one directed blast occurring in the last 400 years. A directed blast at Augustine Island would happen quickly, leaving little or no time for evacuation, and would destroy anything in the immediate vicinity by impact, burial, and intense heat (Waythomas and Waitt 1998).

Lava flows develop after explosive activity. Narrow streams of molten rock or lava have formed only rarely at Augustine Volcano. Most Augustine lava flows are andesitic in composition and tend to move more slowly. As lava flows develop they may cause debris avalanches (Waythomas and Waitt 1998).

A directed blast or lava flow from Augustine Volcano would likely destroy any infrastructure on the island and could kill any personnel remaining on the island. It is unlikely that design and construction of infrastructure could mitigate for these hazards. Early warning and evaluation prior to any directed blast or lava flow may prevent loss of life. Mitigation measures are included in Chapter Nine.

6. Lahars and Floods

Lahars, also referred to as volcanic mudflows or debris flows, consist of a mixture of water and volcanic debris that moves rapidly downslope. Lahars form through rapid melting of snow and ice by pyroclastic flows, intense rainfall on loose volcanic rock deposits, breakout of a lake dammed by volcanic deposits, and as a consequence of debris avalanches (USGS 2015b). When in contact with hot volcanic materials snow and ice on the flanks of the volcanic cone will melt and move rapidly downslope as lahars and floods. Lahars may carry large boulders, sand, or silt, and travel quickly, or they may subside into smaller events. Both lahars and floods are serious risks on Augustine Island, although it is unlikely either would reach beyond nearshore areas (Waythomas and Waitt 1998).

Lahars and floods could damage or destroy infrastructure and injure or kill personnel within their path. Facility siting and design must consider these hazards and sound engineering practices will be required to prevent poor siting of facilities. Mitigation measures are included in Chapter Nine.

7. Volcanic Gases

Gases are emitted by active volcanoes during periods of unrest or eruptive events. Common gases emitted by Augustine Volcano are water vapor, carbon dioxide, carbon monoxide, sulfur dioxide, and hydrogen sulfide. When dispersed by the wind, gases can displace oxygen, cause acid precipitation, and may cause skin and respiratory irritation. The hazards from volcanic gases at Augustine Island are minor and may only pose a threat to those directly in the vicinity of the cone (Waythomas and Waitt 1998).

8. Geohazards Related to Geothermal Resource Activities and Subsidence

The temperature and geochemistry of geothermal dry steam and liquids can cause potential hazards to humans, wildlife, birds, and fish during exploration and development. Hydrogen sulfide can occur naturally, and toxic exposure can cause injury or death. The high temperatures of geothermal resources can also cause burns upon direct contact (USDOL 2021).

Land subsidence may occur due to the withdrawal of geothermal fluids. If geothermal fluids are not injected back into the reservoir, subsidence may occur because of a drop in reservoir pressure and changes in the pore space in the rock. At the Wairakei geothermal field in New Zealand, 50 feet (15 meters) of subsidence in the land was observed after 50 years of geothermal fluid extraction, and is one of the most prominent examples of man-made subsidence in the world (Keiding et al. 2010).

Whether geothermal development on Augustine Island would cause subsidence is unknown. If hydrothermal resources are discovered on Augustine Island, lessees would be required to conduct a second order survey of the land surface before and during production to determine whether subsidence is occurring. If production results in subsidence, and if subsidence is hazardous to production operations or adjoining land uses, the lessee would be required to adjust production and injection rates or to suspend operations.

D. Mitigation Measures

Geologic hazards exist in the Permit Area that could pose potential risks to geothermal exploration, development, and power production and transmission. Potential hazards include volcanic ash clouds, pyroclastic flows, landslides, debris avalanches, tsunamis, earthquakes, induced seismicity, directed blasts and lava flows, lahars and floods, and volcanic gases. Measures in this written finding, along with laws imposed by the state, federal, and local agencies, in addition to design and construction standards are expected to minimize or mitigate some potential hazards. Geothermal resource exploration, development, and power production on an active volcano have significant geohazard associated risks. Mitigation measures, found in Chapter Nine, include development of a plan to address geohazards and coordination with AVO to ensure awareness of Augustine Volcano's activity status while personnel are on Augustine Island.

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Chapter Four: Habitat, Fish, and Wildlife

This chapter considers and discusses the habitats and fish and wildlife populations of Augustine Island and the South Augustine Island Noncompetitive Geothermal Prospecting Permit Area (Permit Area). The intent is to focus on habitats and fish and wildlife that have important subsistence, recreational, or commercial value and that are material to the determination of whether the disposal will best serve the interests of the state. Uses of fish and wildlife are discussed in Chapter Five, and potential cumulative impacts to fish and wildlife from geothermal exploration and development are discussed in Chapter Eight. Augustine Island and the Permit Area contain habitats that support fish and wildlife.

A. Key Habitats of the Disposal Area

The Permit Area is located within the Alaska Range ecoregion (Nowacki et al. 2001). Key habitats on and around Augustine Island include low and tall shrubs, tidal marshes, beaches and sea cliffs, and nearshore waters (ADF&G 2015).

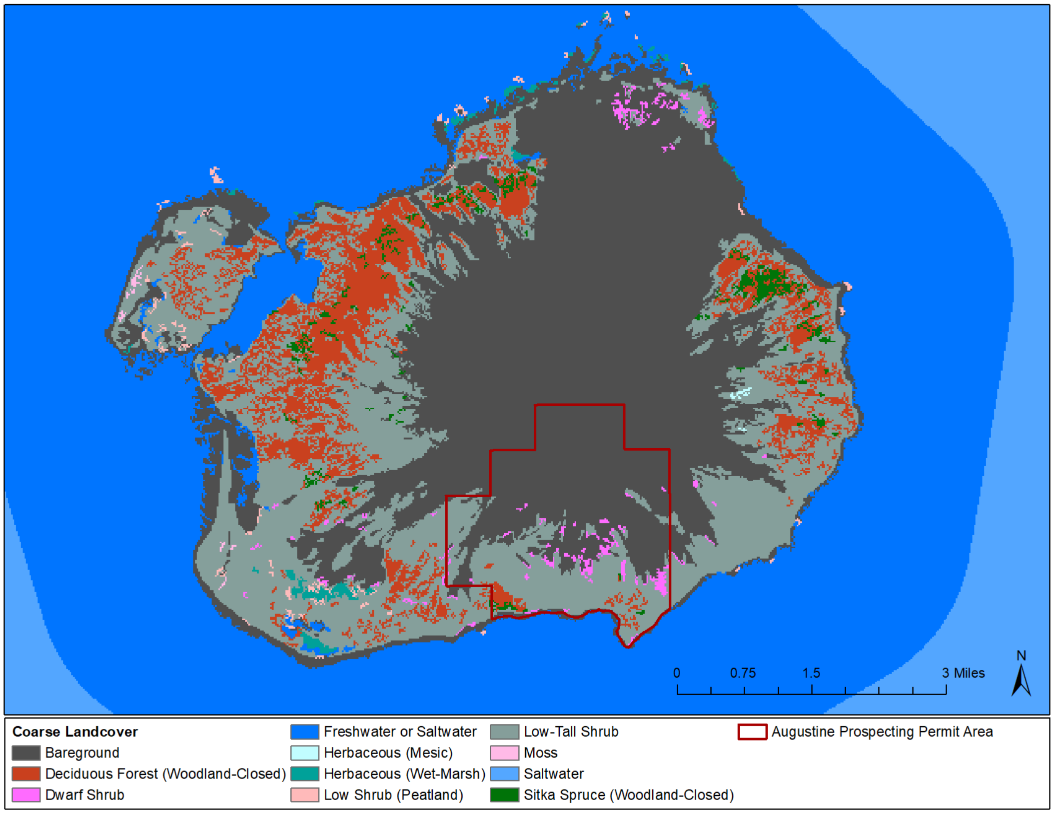
1. Terrestrial Habitats

Landcover on Augustine Island is primarily bare ground, followed by low and tall shrub, and forest patches (Table 1, Figure 2). Low-tall shrub cover of primarily alder *Alder viridis* predominates, followed by deciduous forest patches with black cottonwood *Populus balsamifera* spp. *Triocarpa*, and a few evergreen forest patches with Sitka spruce *Picea sitchensis*. Dwarf shrub patches include alpine bearberry *Arctostaphylos alpine*, crowberry *Empetrum nigrum*, bog blueberry *Vaccinium uliginosum*, and mountain cranberry *Vaccinium vitis-idaea* (Boggs et al. 2019).

Table 1. Landcover in the Prospecting Permit Area and Augustine Island.

	Permit Area		Augustine Island	
Landcover Category	**acres**	**%**	**acres**	**%**
Deciduous Forest	66.5	2%	2,672.5	9%
Evergreen Forest	13.3	<1%	303.1	1%
Total Forested	**79.8**	**3%**	**2,975.6**	**10%**
Low-Tall Shrub	999.0	33%	7,948.6	27%
Low Shrub	0	0%	126.8	<1%
Dwarf Shrub/Lichen	101.9	3%	212.2	1%
Total Shrub	**1,100.9**	**36%**	**8,287.5**	**28%**
Herbaceous Wetland (Aquatic-Wet-Mesic)	0	0%	180.8	1%
Freshwater or Saltwater	3.3	<1%	5,965.5*	20%
Bare Ground	1,870.3	61%	12,245.9	41%
Area Total	**3,054.4**		**29,655.5***	

Source: (Boggs et al. 2019)
* Augustine Island land area totals about 22,035 acres (DNR 2001); analysis includes some saltwater around the island.



Source: (Boggs et al. 2019)

Figure 2. Landcover on Augustine Island.

2. Coastal and Marine Habitats

Coastal habitats and the associated plants and animals are controlled by the composition and character of coastal substrates. Shorelines on the lower west side of Cook Inlet, including Augustine Island, are primarily bedrock controlled (Table 2).

Table 2. Shore types on Augustine Island.

		Augustine Island	
Category	**Description**	**Length (mile)**	**Length (%)**
Shore Type			
Rock and Sediment	Cliff or platform with gravel beach	9.23	18%
Sediment	Gravel or sand beach, flat, or fan	38.10	76%
Estuary Dominant	Organics, wetlands, salt marsh	3.12	6%
Total		**50.45**	

Source: (Harper and Morris 2014; NOAA Fisheries 2015)

Supratidal biotic communities, or biobands, along Augustine Island shorelines include the black lichen *Verrucaria* sp. splash zone and salt marsh (Table 3). Upper to middle intertidal communities include rockweed *Fucus distichus*, blue mussel *Mytilus trossulus*, and barnacle *Balanus glandula* or *Semibalanus balanoides*; lower intertidal communities include soft brown kelps *Saccharina latissimi* and others, Alaria *Alaria marginata*, and red algae *Odonthalia* sp. and others; and subtidal communities include eelgrass *Zostera marina* (Table 3). Eelgrass is found in the lagoon and the northwest corner of the island. Augustine Island intertidal communities were found to be similar to those in Kamishak Bay (Coletti et al. 2017). All biobands, except eelgrass, occur along the Permit Area shoreline.

Table 3. Shoreline biobands on Augustine Island.

Category	Description	Length (miles)		Shoreline* (%)
		Narrow/ Patchy	Med and Wide/ Continuous	
Biobands				
Splash Zone	Dark stripe of black lichen (*Verrucaria* sp.) on rock marking the upper limit of the intertidal zone	0.0	8.6	17%
Salt Marsh	Sedge or grass in estuaries, marshes, and lagoons, associated with freshwater	19.8	3.0	45%
Upper Intertidal	Combination of rockweed (*Fucus distichus*) and blue mussel (*Mytilus trossulus*) biobands	21.9	2.3	48%
Lower Intertidal	Combination of soft brown kelps, Alaria (*Alaria marginata*), and red algae biobands	14.7	20.3	69%
Eelgrass	Eelgrass (*Zostera marina*), generally in areas with fine sediments	5.2	0.0	10%
Total		**61.6**	**34.2**	

Source: (Harper and Morris 2014; NOAA Fisheries 2015)

Notes: Splash zone bioband divided into narrow (<1 meter), medium (1 to 5 meter), and wide (>5 meter) categories; all other biobands divided into patchy (<50% cover) and continuous (>50% cover).

* Proportion (%) of 50.45 mile Augustine Island ShoreZone shoreline identified for biobands.

3. Designated Habitats

Portions of marine waters near Augustine Island (Figure 3) are designated as critical habitat under the Endangered Species Act (ESA) for endangered Cook Inlet beluga whales *Delphinapterus leucas* (76 FR 20180) and threatened southwest distinct population segment of northern sea otters *Enhydra lutris kenyoni* (74 FR 51988). Although not designated as critical habitat, a few ESA listed threatened Alaska breeding Steller's eiders *Polysticta stelleri* (62 FR 31748) may aggregate with non-listed Russian breeding Steller's eiders in lower Cook Inlet in late summer through early spring for molting and over winter (Martin et al. 2015).

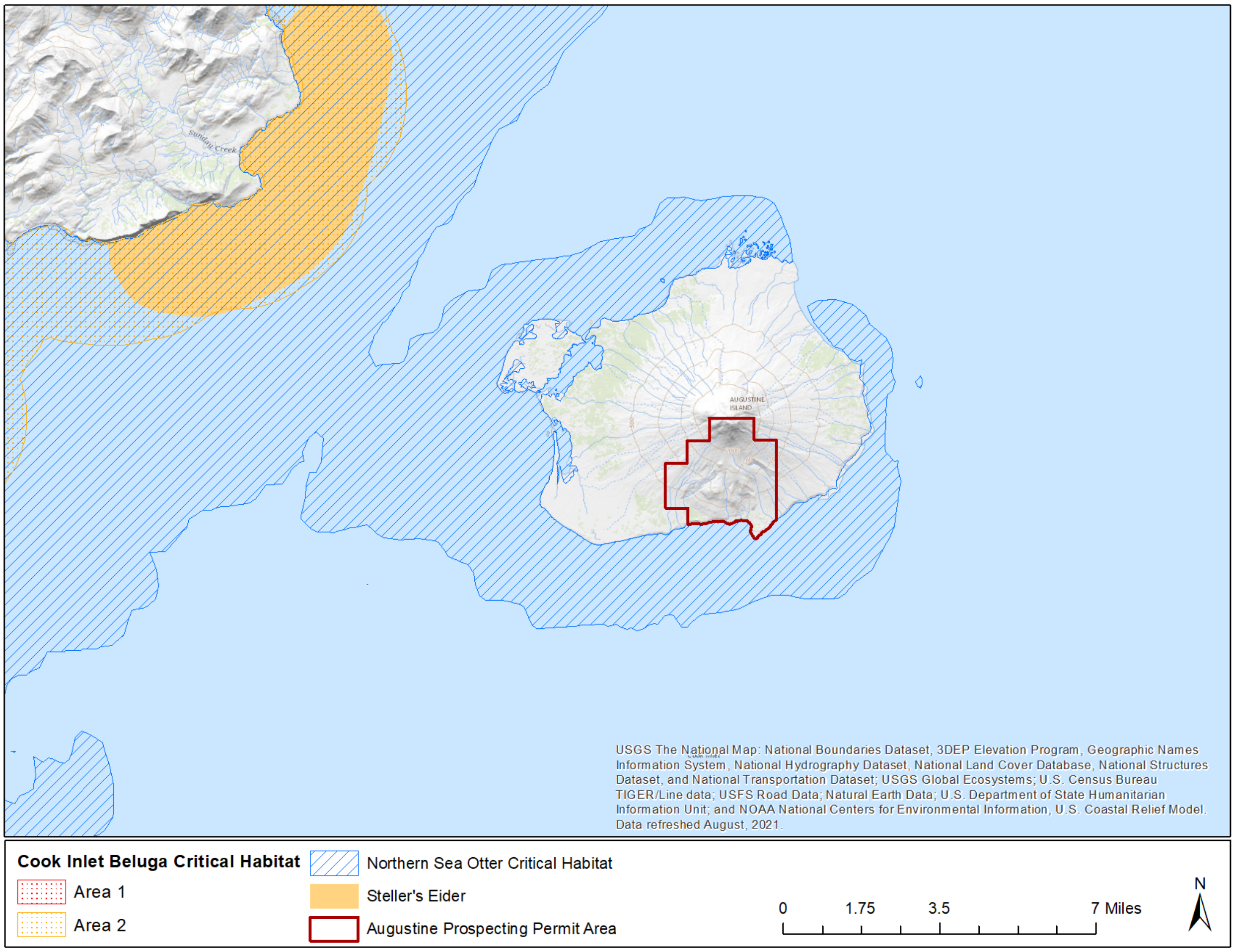


Figure 3. Designated federal Endangered Species Act critical habitats near Augustine Island.

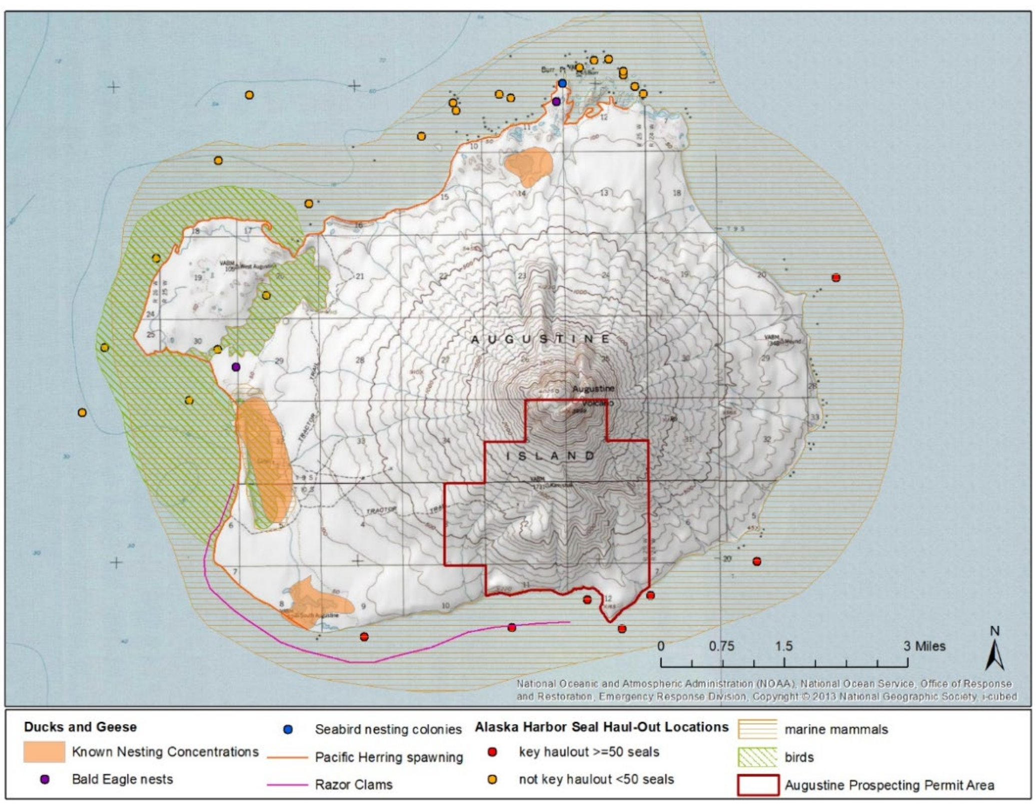
National Marine Fisheries Service (NMFS) defines areas of Essential Fish Habitat (EFH) for federally managed fisheries in Alaska as required by 1996 revisions to the Magnuson-Stevens Act (NOAA Fisheries 2021). EFH is habitat necessary for spawning, breeding, feeding or growth to maturity for fishes managed under federal fishery management plans (FMPs). EFH for two FMPs occur in nearshore waters around Augustine Island: the Salmon FMP (NPFMC et al. 2018) and the Gulf of Alaska Groundfish FMP (NPFMC 2020). Marine EFH for Pacific salmon (*Oncorhynchus* sp.) occurs in the tidal lagoons and nearshore waters surrounding Augustine Island which are used by estuarine juveniles, marine juveniles, and marine immature and maturing adults for feeding and growth to maturity (NMFS 2017; NPFMC et al. 2018). Freshwater EFH for Pacific salmon, regularly updated in ADF&G's Anadromous Waters Catalog (ADF&G 2020b), is used for spawning; with no freshwater EFH reported on Augustine Island. EFH for one or more life stages for most fishes covered under the Gulf of Alaska Groundfish FMP occur in nearshore subtidal and intertidal waters, or shallow inner shelf waters 1 to <164 feet (1 to <50 meters) deep around Augustine Island (NPFMC 2020, Table D-1).

B. Fish and Wildlife Populations

The volcanic characteristic and eruptive history of Augustine Island support primarily pioneering vegetation communities, especially on slopes and near the summit. Surrounding nearshore habitats support fish, waterfowl, seabirds, and marine mammals. Intertidal wetlands are used by waterfowl primarily in summer, and rocky cliffs especially near Burr Point on the north side of the island may contain nesting seabirds. The recent eruption history with pyroclastic flows and debris avalanches may have destroyed seabird and waterfowl nesting areas on the north side of Augustine Island that had been mapped based on information prior to 1985 and 2002 (ADF&G 1985; Power et al. 2010; ORR 2019). Intertidal and nearshore habitats around the island support razor clam *Siliqua patula* beds, Pacific herring *Clupea pallasi* spawning, northern sea otter critical habitat, and harbor seal *Phoca vitulina* haulouts.

1. Fish and Shellfish

Both perennial and intermittent streams appear to radiate out from the peak of Augustine Volcano. No streams on Augustine Island are listed in ADF&G's anadromous waters catalog (Giefer and Blossom 2021), likely because they have not been surveyed. Based on surrounding coastal habitats and similar volcanic island habitats in the Aleutian Islands, salmon may use stream, pond, and tidal lagoon habitats on Augustine Island for spawning and rearing. All five Pacific salmon occur in and are harvested from marine waters of Kamishak Bay and lower Cook Inlet. Pacific herring spawn along northwestern shorelines and razor clam beds occur along the southwestern shorelines (Figure 4).



Source: (ADF&G 1985; ORR 2019; AFSC 2020)

Figure 4. Fish and wildlife use of habitats on and around Augustine Island.

a. Salmon

Pacific salmon (Chinook *Oncorhynchus tshawytscha*, chum *O. keta*, coho *O. kisutch*, pink *O. gorbuscha*, and sockeye *O. nerka*) use similar types of habitat throughout their life cycles. Mature salmon spawn and deposit their eggs in gravels in freshwater rivers and streams, dying shortly after spawning. Eggs incubate in the gravels and hatch in spring, with salmon fry emerging from gravels to rear in either freshwaters or estuaries and nearshore marine waters. Juvenile salmon smolts initially feed on copepods adding larger prey such as squid, juvenile herring, smelt, and other forage fish and invertebrate as they grow larger. Juvenile salmon use nearshore habitats after moving to marine waters, moving offshore as they get older and larger where they use pelagic habitats while at sea. Immature salmon move and forage throughout the North Pacific for up to 6 years before maturing and returning to natal streams to spawn. The Kamishak Bay area around Augustine Island is used by low to moderate densities of juvenile, immature, and maturing adult Pacific salmon (Echave et al. 2012; NMFS 2017).

b. Groundfish

Bottom trawl survey abundance estimates for commercially and recreationally important groundfish in the Kamishak Bay area south and east of Augustine Island from 1998 to 2012 were: Pacific halibut *Hippoglossus stenolepis* 10.2 million pounds, Pacific cod *Gadus macrocephalus* 6.8 million pounds, walleye pollock *Gadus chalcogramma* 6.3 million pounds, sablefish *Anoplopoma fimbria* 0.3 million pounds, and rockfish *Sebastes* species 0.2 million pounds (Byerly and Rheafournier *in prep*). Body condition indices (weight/length), a measure of fish population health, have been below average for Gulf of Alaska groundfish since 2015, with indices trending upward for Pacific cod and adult walleye pollock and downward for rockfish. Before 2011 indices varied from survey to survey and cycled between negative and positive with no clear trends (Ferriss and Zador 2020).

Pacific halibut are large (up to 8 feet long and 500 pounds) wide-ranging, bottom-dwelling flat fish that move into nearshore waters in summer. Pacific halibut spawn in deep continental shelf waters at 600 to 1,600 feet. Ocean currents are an important factor in their life history, carrying larval halibut in a counter-clockwise direction. After rearing in shallower waters for 2 to 3 years (usually less than 12 inches long), juvenile halibut move into deeper waters and migrate in a clockwise direction. Adult halibut make seasonal movements to deeper waters on the slope during the winter for spawning and wintering, returning to shallow coastal waters in the summer for feeding. Halibut live up to 55 years; maturing at about 8 years for males and 12 years for females with a trend of decreasing weight with age since the 1980s (Keith et al. 2014).

Walleye pollock, Pacific cod, and sablefish are important prey for a wide range of fish and marine mammals, and Pacific cod, sablefish, and black rockfish *Sebastes melanops* support commercial fisheries in lower Cook Inlet. Pollock and Pacific cod are relatively short-lived reaching sexual maturity at 4 to 6 years and living up to 19 to 22 years. Spawning usually occurs between January to May. Sablefish are long-lived fish, with half of females reaching maturity at 6.5 years, and living up to 95 years. Sablefish spawn at depth over the margins of the continental slope from January to April (Witherell and Armstrong 2015). Black rockfish are the most abundant rockfish harvested in the Lower Cook Inlet Management Area (Rumble et al. 2019). Rockfish are categorized into three groups based on habitat preferences: pelagic, demersal shelf, and slope assemblages. Black rockfish are pelagic, long-lived, slow growing, viviparous, schooling fish that mature at 6 to 8 years and live to 50 years old (ADF&G 2021a).

c. Pacific Herring and Other Forage Fish

Pacific herring and other forage fish such as Pacific sand lance *Ammodytes hexapterous*, surf smelt *Hypomesus pretiosus*, and capelin *Mallotus villosus*, provide high quality prey for birds, marine mammals, and other fish. Herring become sexually mature at 3 to 4 years and spawn annually after that in spring in shallow, vegetated areas of intertidal and subtidal zones (ADF&G 2021b). Near the Permit Area herring spawn on eelgrass beds around the north and west sides of Augustine Island (ORR 2019). Eggs hatch about 2 weeks after being fertilized and the larvae drift in the current. After reaching the juvenile stage they rear in sheltered bays and inlets. Schools of juveniles move offshore in fall, where they spend the next 2 to 3 years feeding on crustaceans, decapods, and mollusk larvae; adults eat mostly large crustaceans and small fish. Population trends for herring are dynamic and subject to environmental changes (ADF&G 2021b). Schools of forage fish which include herring and other forage fishes are often observed in nearshore habitats on the south side of Augustine Island during fisheries surveys (Hollowell 2022).

d. Razor Clams

Some razor clams reach sexual maturity at 3 years, and all are mature at 7 years. They breed between May and September in response to increasing water temperatures. Larvae are free swimming for 5 to 16 weeks, during which time the shells begin to grow. Young clams settle on sediments where they remain and filter feed on plankton. Razor clams are found at water depths of 4 to 180 feet (ADF&G 2021c), with razor clam beds occurring along the southwestern shorelines of Augustine Island (ORR 2019).

2. Birds

Birds in the Cook Inlet region include waterfowl, shorebirds, seabirds, and landbirds that use habitat in and around the Permit Area. Waterbirds (waterfowl, loons, shorebirds, and seabirds) in the region are generally considered migratory, although coastal habitats in lower Cook Inlet provide winter habitat for some waterbirds that nest further north. Breeding bird surveys inland on the Alaska Peninsula in Katmai National Park and on Kodiak Island identified annual means of 28 to 33 species and 411 to 747 birds per route, respectively during 2000 to 2019 (Pardieck et al. 2020). Landbirds breeding in the Permit Area may be either migratory or resident such as ravens, magpies, jays, and chickadees. Migratory birds arrive or pass through this region beginning with raptors and waterfowl in April continuing with arrival of songbirds through May; and then pass through or depart in July through October. Waterfowl are harvested primarily during the fall migration from September to December.

Breeding birds likely occurring on Augustine Island based on survey data from Katmai National Park and Kodiak Island and the primary habitats available on Augustine Island are described in Table 4. Terrestrial habitats on Augustine Island support nesting waterfowl, shorebirds, seabirds and landbirds. Intertidal, nearshore, and marine habitats in Kamishak Bay support migrant, breeding, molting, and wintering waterfowl; shorebirds; and seabirds (ADF&G 1985; Renner et al. 2017; ORR 2019). The Kamishak Bay coastal/pelagic Important Bird Area south of Augustine Island supports breeding glaucous-winged gulls *Larus glaucescens* (Audubon Alaska 2015). Lower Cook Inlet provides important spring migration stop-over sites for waterfowl and shorebirds (Witten 2003).

Table 4. Breeding birds potentially occurring on Augustine Island.

Common Name Scientific Name	Habitat	Conservation Population Trend	BCR 2 Occurrence Abundance	Birds/Route Kodiak (2000-2019)	Population Size
Waterfowl					
Mallard *Anas platyrhynchos*	wetlands, tidelands	NA = dec 3% AK-Y = dec 20%	Year-round Common	5.19	NA = 9,400,000 AK-Y = 360,000
Green-winged Teal *Anas crecca*	wetlands, tidelands	NA = dec 3% AK-Y = dec 16%	Year-round Common	2.56	NA = 3,200,000 AK-Y = 420,000
Shorebirds					
Black Oystercatcher *Haematopus bachmani*	rocky/gravel shorelines	High Concern Stable	Year-round Common	3.00	NA = 11,000 AK = 61
Seabirds					
Pigeon Guillemot *Cepphus columba*	seacliffs, nearshore	Moderate inc ≥ 3%/year	Year-round Common	2.44	AK = 49,000
Tufted Puffin *Fratercula cirrhata*	seacliffs, nearshore	Not at Risk dec ≥ 3%/year	Spring to Fall Common		AK = 2,300,000
Horned Puffin *Fratercula corniculata*	seacliffs, nearshore	Moderate	Spring to Fall Uncommon		AK = 900,000
Glaucous-winged Gull *Larus glaucesens*	seacliffs, nearshore	Not at Risk Stable	Year-round Common	19.50	AK = 250,000
Landbirds					
Bald Eagle *Haliaeetus leucocephalus*	beaches, seacliffs, nearshore	C Steward inc ≥ 50%	Year-round Uncommon	7.44	NA = 200,000 AK = 35%
Gray-cheeked Thrush *Catharus minimus*	tall and low shrub	C Steward dec 0 to 15%	LDM Common	2.88	NA = 42,000,000 AK = 44%
Hermit Thrush *Catharus guttatus*	tall shrub	Steward inc 0 to 50%	MDM Rare	88.88	NA = 72,000,000 AK = 12%
Common Redpoll *Acanthis flammea*	tall and low shrub	CBSD dec ≥ 50%	Year-round Common	8.63	NA = 76,000,000 AK = 74%
Fox Sparrow *Passerella iliaca*	tall shrub	C & R Steward dec 15 to 50%	MDM Common	171.81	NA = 35,000,000 AK = 45%
Golden-crowned Sparrow *Zonotrichia atricapilla*	tall shrub	C Steward dec 15 to 50%	SDM Common	53.06	NA = 7,500,000 AK = 89%
Song Sparrow *Melospiza melodia*	tall shrub	R Steward dec 15 to 50%	Year-round Common	1.81	NA = 130,000,000 AK = 1%
Orange-crowned Warbler *Leiothlypis celata*	tall shrub	C & R Steward dec 15 to 50%	LDM Common	2.88	NA = 82,000,000 AK = 38%
Yellow Warbler *Setophaga petechia*	tall and low shrub	dec 15 to 50%	LDM Common	76.63	NA = 93,000,000 AK = 16%
Wilson's Warbler *Cardellina pusilla*	tall shrub	CBSD dec ≥ 50%	LDM Common	84.19	NA = 81,000,000 AK = 43%

Source: (Denlinger 2006; ADF&G 2015; ASG 2019; Olson 2020; Pardieck et al. 2020; Handel et al. 2021)
C = Continental; R = Regional; CBSD = Common Bird in Steep Decline; inc = increasing; dec = decreasing; BCR 2 = Bird Conservation Region 2 – Western Alaska; LDM = long-distance migrant; MDM = medium-distance migrant; SDM = short-distance migrant; NA = North America; AK = Alaska; - AK-Y = Alaska-Yukon

a. Waterfowl

Waterfowl – ducks, geese, and swans – go through a flightless molt period, when all flight feathers are shed and regrown. Adult waterfowl typically molt when one (ducks) or both (geese and swans) sexes of a breeding pair are rearing flightless young. Post-breeding male, nonbreeding, and juvenile ducks form large flocks that move and forage together during molting. Waterfowl using habitats on Augustine Island and Kamishak Bay include spring migrant, molting, and wintering seaducks including long-tailed ducks *Clangula hyemalis*, surf scoters *Melanitta perspicillata*, white-winged scoters *Melanitta fusca*, and Steller's eiders (Larned 2005, 2006; Renner et al. 2017); spring migrant geese; and breeding dabbling ducks such as mallards and green-winged teals.

Steller's eiders winter primarily in nearshore waters on both sides of the Alaska Peninsula, and in lesser numbers in the eastern Aleutian Islands, the Kodiak Archipelago, and lower Cook Inlet (Martin et al. 2015). They migrate from wintering grounds to breeding grounds in arctic coastal areas of northern Alaska and Russia in spring. Band recovery, telemetry, and genetic data suggest that Alaska-breeding and Russian-Pacific breeding Steller's eider populations intermix during non-breeding seasons in southwest Alaska (USFWS 2019), such that Alaska-breeding and Russian-breeding populations are indistinguishable. Spring migration staging counts along the Alaska Peninsula average 81,000 eiders with a long-term decline of 2.4 percent per year from 1992 to 2012 (Larned 2012). Fall aerial surveys indicated that the only important molting habitat in Cook Inlet are the shoals and reefs near the Douglas River in Kamishak Bay south of Augustine Island (Larned 2005). Several thousand molting Steller's eiders use lower Cook Inlet in late August, and many remain through the winter during ice-free conditions, departing for breeding grounds in April (Larned 2005, 2006).

b. Shorebirds

Migrating shorebirds appear suddenly in the Cook Inlet area in early May, their numbers increase rapidly, and then they depart abruptly in late May (Gill and Tibbitts 1999). Cook Inlet is important spring migration habitat for western sandpipers *Calidris mauri*, winter habitat for rock sandpipers *Calidris ptilocnemis ptilocnemis*, and year-round habitat for black oystercatchers (ASG 2019; ORR 2019). Tidal mudflats on Augustine Island may provide important foraging habitat for migrating and wintering sandpipers.

The Pribilof subspecies of rock sandpiper *Calidris ptilocnemis ptilocnemis* breeds on the tundra on a few islands in the Bering Sea, and winters primarily along Cook Inlet shorelines. This is the northernmost wintering area of any North Pacific shorebird. Pribilof rock sandpipers are able to survive Alaska winters by feeding on large, energy-rich *Macoma* clams found in intertidal mudflats (ADF&G 2015). The population of this subspecies is small, with an estimated 19,800 birds, has an unknown population trend, and is considered of high conservation concern (ASG 2019).

Black oystercatchers typically nest near the high tide line and rear their young along gravel beaches and shorelines. They are completely dependent on intertidal and rocky shoreline habitats, breeding success is generally low, and productivity is limited primarily by predation and flooding caused by storm tides. Oystercatchers' fidelity to breeding territories, conspicuous behavior, and limited reproductive potential make them particularly vulnerable to local extirpation through persistent disturbance by foxes or humans;

and they are considered a high conservation concern because of their small population size, restricted range, and high vulnerability to threats (ASG 2019).

c. Seabirds

Seabirds spend most of their lives at sea foraging and resting, but all nest on land usually in colonies on small islands and isolated rocks on cliff faces, rocky ledges, burrows in soft soil, or on flat ground. Seabirds using Augustine Island for nesting near Burr Point include glaucous-winged gulls, horned puffin, tufted puffin, and pigeon guillemot (ORR 2019). Shallow coastal habitats with high densities of small forage fish, squid, and crustaceans are important for breeding seabirds (Piatt and Roseneau 1997). Common seabirds near Augustine Island include sooty shearwater *Ardenna grisea* (summer and fall), common murre *Uria aalge* (year-round), glaucous-winged gull (year-round), puffins (primarily summer), and guillemots (year-round) (Renner et al. 2017).

Glaucous-winged gulls breed on small, low-relief islands from mid-May through July with nest scrapes located on bare rock, bare ground, or in low vegetation. Nests are lined with stacked grass, weeds, moss, roots, dead twigs, string, bones, turf, and seaweed. Chicks are semiprecocial leaving the nest within days after hatching while depending on parents to deliver food such as fish and intertidal invertebrates. Glaucous-winged gulls are omnivorous, feeding on a wide variety of fish; marine invertebrates including mussels, barnacles, crabs, starfish, and sea urchins; and carrion (Hayward and Verbeek 2020). Red foxes *Vulpes vulpes* arrived on Augustine Island by crossing over ice in winter 1971 and reportedly destroyed glaucous-winged gull nesting colonies on the island (Bailey 1993). Glaucous-winged gull populations in the northern Gulf of Alaska showed no trend from 2009 to 2018, with average productivity in 2018 (Dragoo et al. 2019).

Puffins and guillemots breed from May through September, nesting in burrows or rock crevices and foraging in nearshore waters on fish, squid, and invertebrates (Denlinger 2006). In the northern Gulf of Alaska tufted puffins showed a decreasing population trend of ≥3 percent per year, while pigeon guillemots showed an increasing trend of ≥3 percent per year from 2009 to 2018 (Dragoo et al. 2019). Reproductive performance for Gulf of Alaska seabirds was fair to good in 2020 (Ferriss and Zador 2020).

d. Landbirds

Based on breeding bird surveys on Kodiak Island, general bird-habitat associations, and the prevalent shrub habitats on Augustine Island birds of conservation concern potentially nesting on Augustine Island include both resident and migrant landbirds (Table 4). Most of these landbirds are medium to small songbirds with relatively large populations, with a few such as common redpoll and Wilson’s warbler experiencing steep population declines (ADF&G 2015; Handel et al. 2021).

Bald eagles are widely distributed along waterways and are likely present in the Permit Area. Bald eagles are usually found near water in coastal areas and along lake and river shorelines. The breeding season in Alaska begins with courtship and nest building in February and ends when the young fledge by late August into early September. Fish are the primary diet of bald eagles in summer, but they also prey on waterfowl, small mammals, and carrion. Nests, large structures that can weigh more than 1,000 pounds, are usually constructed in mature old-growth trees or snags, and on cliffs or rock outcrops. In coastal Alaska breeding eagles may remain near their nests year-round. Interior Alaska eagles begin moving to wintering grounds, likely in the Pacific Northwest or Intermountain West, as waters begin to freeze and prey becomes limited in the fall. Eagles may congregate at communal roost sites in winter for feeding and sheltering (USFWS 2020). Based on limited surveys the bald eagle population in Alaska is estimated at 70,500 birds and is considered to be increasing slowly and projected to remain stable (USFWS 2016).

3. Mammals

a. Marine Mammals

Marine mammals observed during surveys in Kamishak Bay including the area around Augustine Island indicate that the most commonly observed and most abundant marine mammals are sea otters, harbor seals, and harbor porpoise *Phocoena phocoena*. Other marine mammals observed in low abundance offshore from Augustine Island include, but are not limited to, Steller sea lion *Eumetopias jubatus*, humpback whale *Megaptera novaeangliae*, and killer whale *Orcinus orca* (Garlich-Miller et al. 2018). Cook Inlet beluga whales may range into lower Cook Inlet generally in late fall and winter (NMFS 2016). Marine mammals most likely to be affected by activities on Augustine Island include sea otters and harbor seals.

Northern sea otters near the Permit Area are assigned to the Southwest Alaska stock. Sea otters breed year-round, but in Alaska most pups are born in late spring. Sea otters forage in shallow coastal waters where they dive to the bottom for 1 to 2 minutes to depths from 5 to 250 feet to forage on shellfish and invertebrates (USFWS 2014). In May 2017 an estimated 10,740 sea otters occurred on the west side of lower Cook Inlet, with the highest densities in Kamishak Bay to the west and north of Augustine Island (Garlich-Miller et al. 2018). The most recent population estimate for the Southwest stock based on surveys from 2000 to 2010 is about 54,770 animals, with an estimated 6,900 animals in Kamishak Bay. The best estimate for the overall trend for this stock is that it has stabilized, with a potentially increasing population in Kamishak Bay (USFWS 2014).

Harbor seals near the Permit Area are assigned to the Cook Inlet/Shelikof Strait stock that ranges from Cook Inlet through Shelikof Strait along the southern side of the Alaska Peninsula westward to Unimak Island (Muto et al. 2020). Harbor seals haul out throughout the year to rest, molt, play and escape aquatic predators. Haulouts in Cook Inlet provide important pupping and lactation habitat during May to mid-July and molting habitat during July to September. Harbor seals use the north and west sides of Augustine Island primarily during pupping in June and the south and east sides primarily during molting in August (Boveng et al. 2011). The most recent population estimate for Cook Inlet/Shelikof Strait harbor seals is 26,907 animals in 2018. The stock may be decreasing at a rate of 111 seals per year from 2010 to 2018 (Muto et al. 2020). Several key haulout sites (sites used by more than 50 harbor seals) are located along the southern border of the Permit Area (Figure 4; AFSC 2020)

b. Terrestrial Mammals

The only terrestrial mammal reported from Augustine Island is red fox *Vulpes vulpes* (Bailey 1993). Red foxes breed during February and March and give birth in earthen dens in April and May with young leaving the den in May or June. Den sites are usually located on the side of a small hill or mound and may have several entrances. Both parents care for the young through fall, when the family unit disperses. Voles are their preferred food, but red foxes also eat muskrats, squirrels, hares, birds, eggs, insects, vegetation, and carrion. Foxes cache excess food (ADF&G 2020a).

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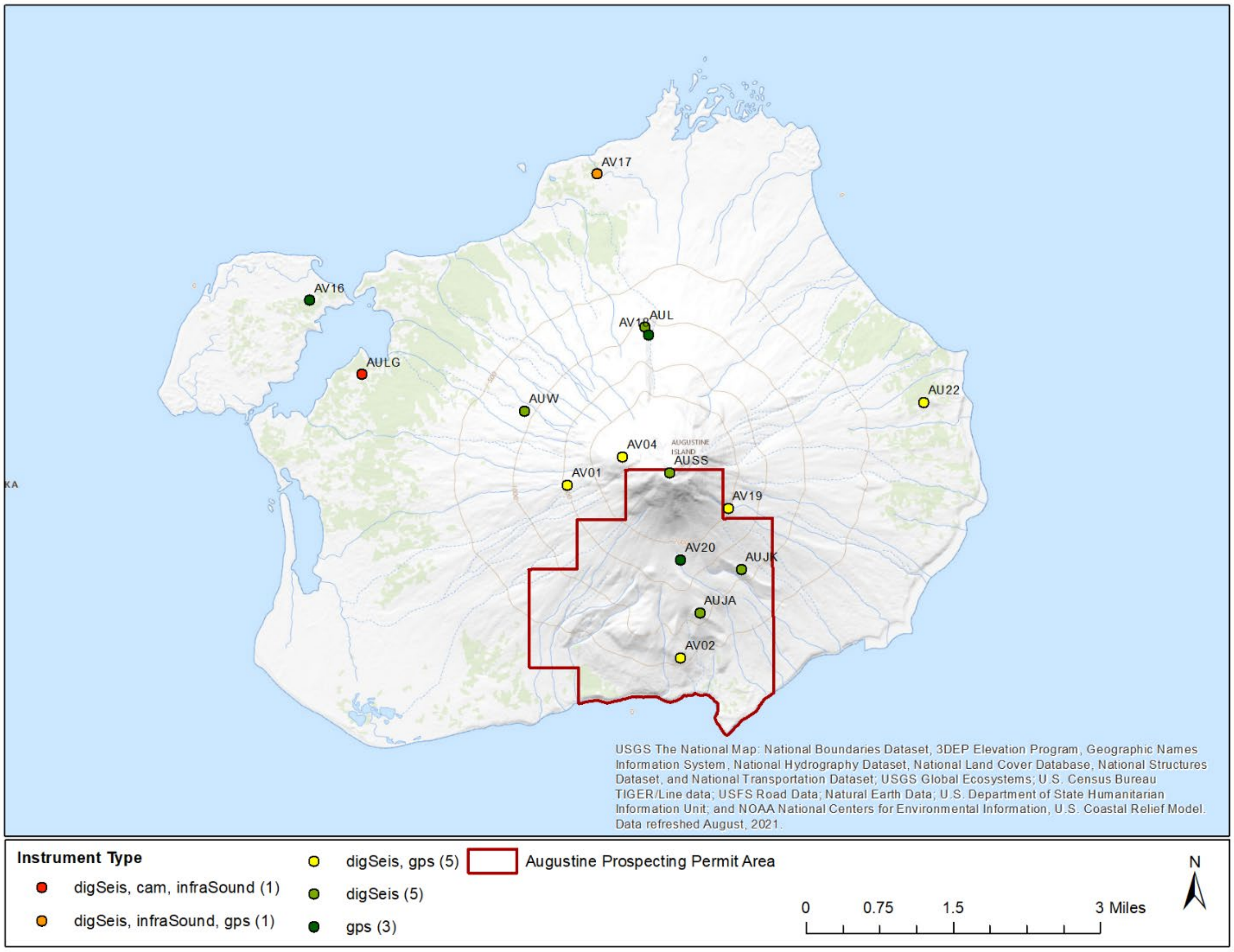
Chapter Five: Current Uses of the South Augustine Island Area

Augustine Island, the South Augustine Island Noncompetitive Geothermal Prospecting Permit Area (Permit Area), and nearshore waters surrounding the island provide habitats for fish and wildlife as discussed in Chapter Four. The primary current use of Augustine Island is scientific research and monitoring of Augustine Volcano. Current and projected use of the Permit Area are considered and discussed below.

A. Research and Education

The Alaska Volcano Observatory (AVO) is an interagency program of Alaska Department of Natural Resources (DNR) Division of Geological and Geophysical Surveys, US Geological Survey (USGS), and University of Alaska – Fairbanks (UAF) Geophysical Institute. AVO monitors Alaska volcanoes, including Augustine Volcano, with the purpose of mitigating hazards by providing timely and accurate information on volcanic activity including unrest and eruptions (AVO 2020). DNR entered into an Interagency Land Management Agreement (ILMA) with UAF's Geophysical Institute on May 26, 1992. The ILMA grants UAF access to all of the island but does not restrict other state or public access (ADL 225681; DNR 2021).

AVO monitors Augustine Island with 4 web cameras (2 in Homer), 12 digital seismometers, 2 infrasound networks, and 9 Global Positioning System (GPS) receivers at 15 sites (Figure 5). The GPS receivers are operated by UNAVCO who has primary responsibility for maintaining the radio telemetry network for these receivers. This monitoring network provides warning of impending eruptions and serves to provide geophysical data and visual information during active eruptions. The total number of active instrument stations may fluctuate depending on battery charge level, technical or telemetry issues, and the level of volcanic activity. More instruments may be deployed during unrest and eruption or may be destroyed during the course of an eruption. Each station consists of the instrument, a power system composed of batteries and solar panels, and a radio-frequency telemetry system with a footprint of a few hundred square feet, with batteries and electronics housed in a small fiberglass enclosure. Seismometers and cables are buried next to the hut extending up to 16.4 feet (5 meters) away. To avoid disruption of data collection, it is important that AVO has uninterrupted access to monitoring locations on Augustine Island and that no instruments are disturbed either physically or electronically through radio interference (Schaefer 2020). Currently there are five instrument locations within the Permit Area (Figure 5).



Source: (Schaefer 2021)

Figure 5. Alaska Volcano Observatory instrument stations on Augustine Island.

B. Fish and Wildlife Uses and Value

The primary use of fish and wildlife populations on and around Augustine Island are commercial and sport fisheries in marine waters around Augustine Island for salmon, halibut, and groundfish. These commercial and sport fisheries target fishes that occur across state, federal, and international waters that are managed for sustainable harvest by Alaska Department of Fish and Game (ADF&G), North Pacific Fisheries Management Council, National Marine Fisheries Service, and International Pacific Halibut Commission (IPHC).

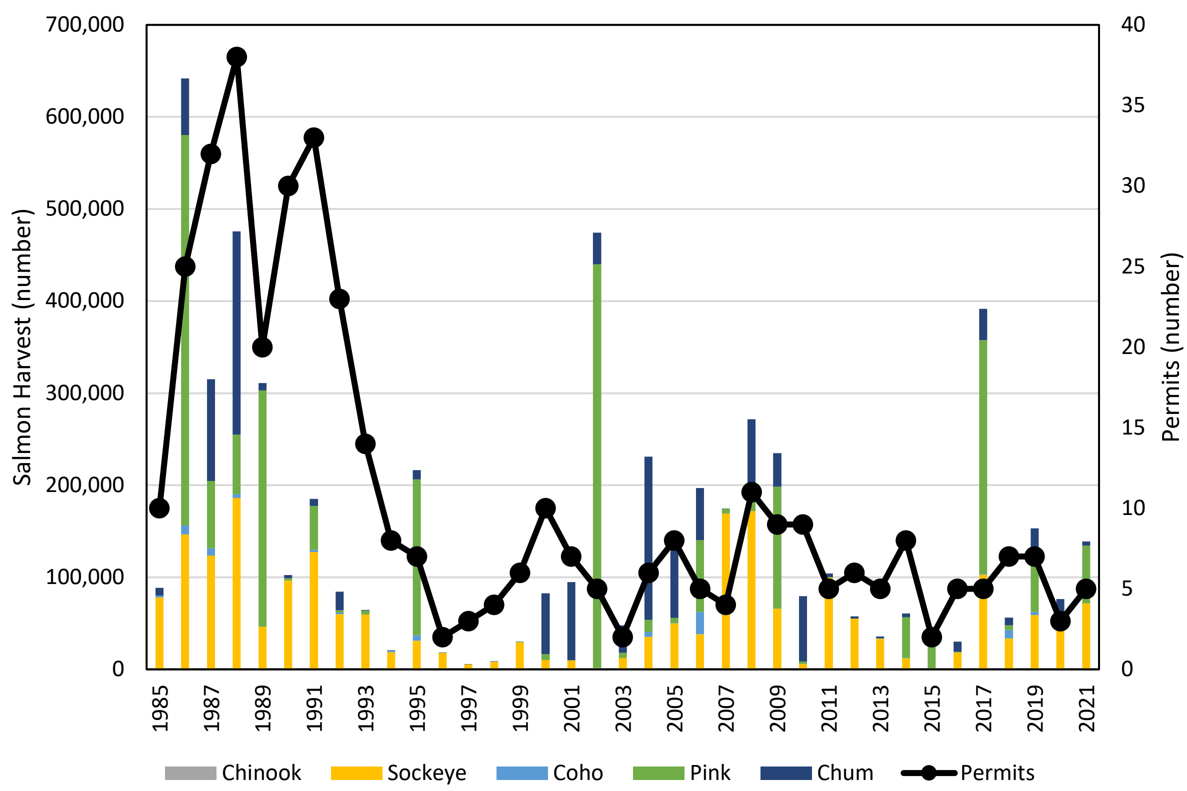
There are no data available that indicate that Augustine Island is used for hunting, trapping, or freshwater fishing. Augustine Island and state waters around Augustine Island are located within the Anchorage – Mat-Su – Kenai Peninsula nonsubsistence use area. Federal waters east of Augustine Island are used primarily by Seldovia residents for subsistence harvest of Pacific halibut, Pacific cod, black rockfish, and salmon (Jones and Kostick 2016; Holen 2019).

1. Commercial Fishing

a. Salmon and Herring

Augustine Island and the Permit Area are within ADF&G's Kamishak Bay District within the Lower Cook Inlet (LCI) Management Area for commercial fisheries for salmon and herring. Purse seines are used to harvest salmon fisheries in the Kamishak Bay District. The Kamishak Bay herring fishery is a commercial purse seine sac roe fishery that began in 1973. This herring fishery has a history of closure due to low stock abundance, no herring harvest has occurred since 1998, and the fishery has been closed since 1999 (Hollowell et al. 2019).

The most recent 10-year average Kamishak Bay District commercial salmon harvest was 47 percent sockeye, 42 percent pink, 10 percent chum, and 1 percent coho by an average of 5 permits per year (Hollowell et al. *in prep*). Pink salmon harvests generally peak in odd-years (Figure 6). Kamishak Bay District salmon harvests represent 6 percent of the most recent 10-year average LCI commercial salmon harvest (Hollowell et al. *in prep*). Estimated exvessel 10-year average annual value for LCI commercial salmon purse seine and set gillnet harvests from 2011 to 2020 was $2.8 million (Hollowell et al. *in prep*).

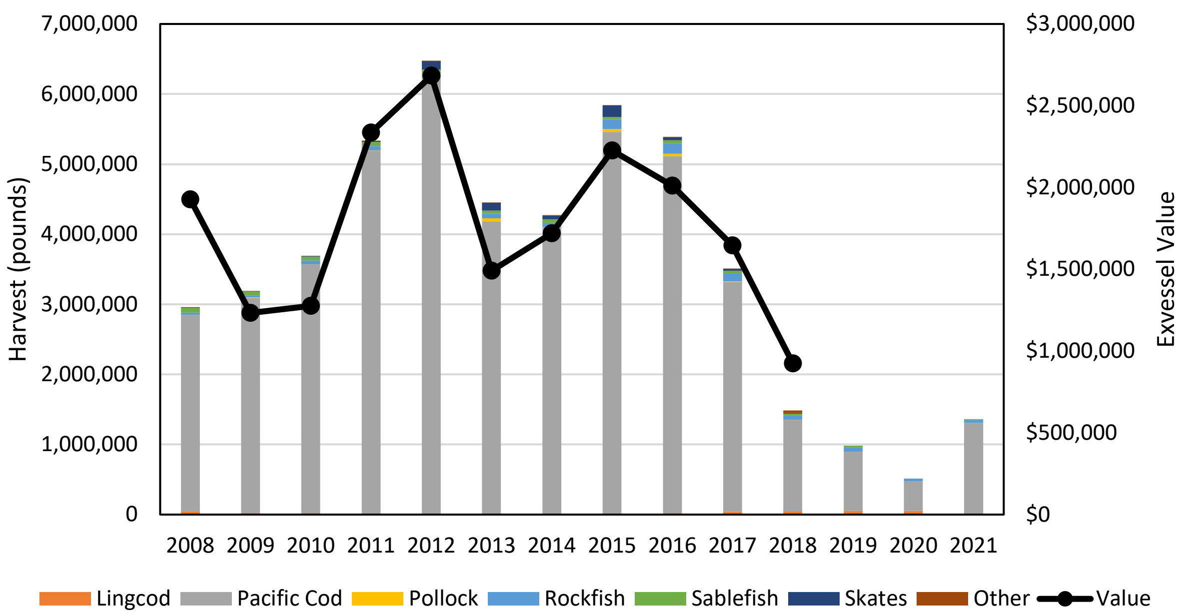


Source: (Hollowell et al. 2019; Hollowell and Ford 2019; Hollowell 2020, 2021)

Figure 6. Commercial salmon harvest from the Kamishak Bay District (249).

b. Groundfish

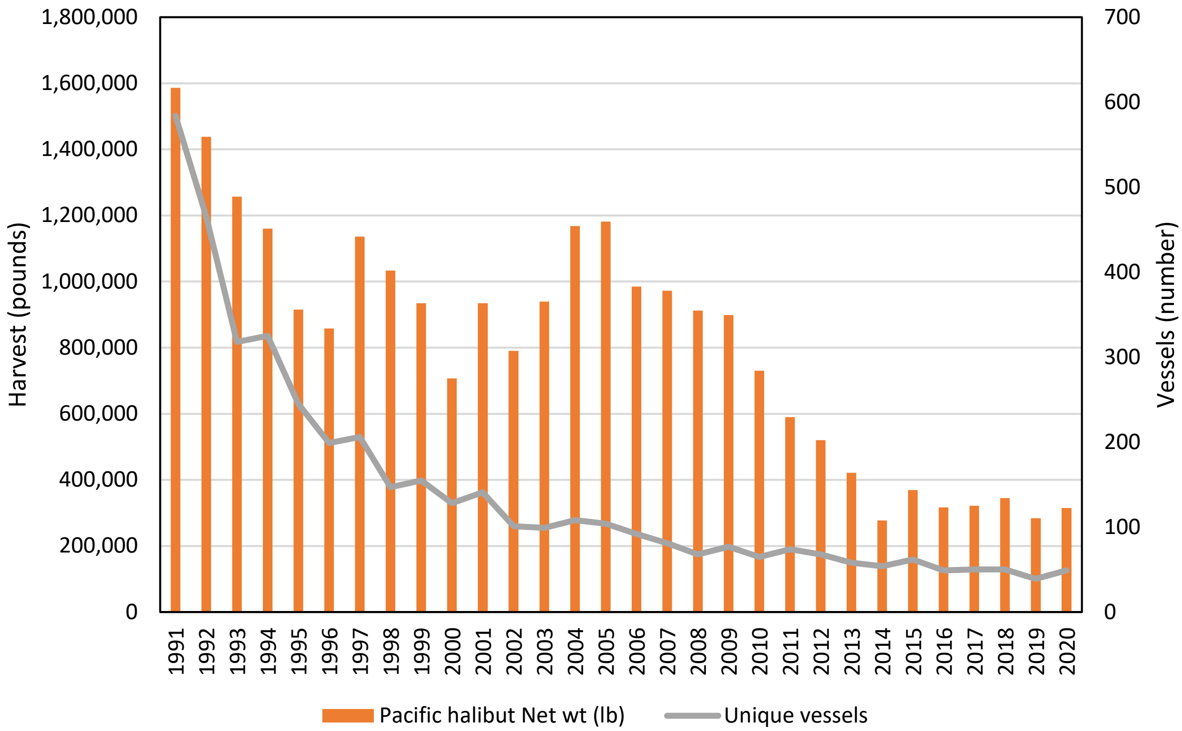
ADF&G has jurisdiction over commercial groundfish fisheries in state waters, except for halibut which is managed by the IPHC. ADF&G's Central Region includes Kamishak Bay and waters surrounding the Permit Area as well as state waters of Cook Inlet and Prince William Sound and also includes federal waters for lingcod *Ophiodon elongatus* and black rockfish. Directed commercial groundfish fisheries in state waters of Cook Inlet include: sablefish, Pacific cod, walleye pollock, lingcod, and pelagic shelf rockfish, primarily black rockfish (Rumble et al. 2019). Some commercial harvest of Pacific cod and halibut occur within statistical area 535905 that surrounds Augustine Island (Russ 2021). Pacific cod dominates the commercial harvest in Area H (Cook Inlet and North Gulf districts) with harvest concentrated in Kachemak Bay and along the southern coastline of the Kenai Peninsula (Rumble et al. 2016, 2019). Cook Inlet groundfish harvest and exvessel value show a declining trend since 2015 (Figure 7).



Source: (Rumble et al. 2019)

Figure 7. Cook Inlet (Area H) groundfish harvest and exvessel value.

Pacific halibut belong to one stock that is harvested both commercially and recreationally in Cook Inlet and throughout state, federal, and international waters of the North Pacific. Both commercial and sport harvest are highly regulated. Pacific halibut harvest has been declining since 2002 due to regulatory actions and declining abundance. Halibut also show a trend in decreasing length with age (older fish are smaller than they once were) since the 1990s (Keith et al. 2014). Commercial harvest of halibut in Cook Inlet (Statistical Area 261) has declined since it peaked in 2004 and 2005 (Figure 8) and represents an average of 4 percent of harvest in Area 3A which covers the central Gulf of Alaska from Kodiak Island to southeast Alaska.



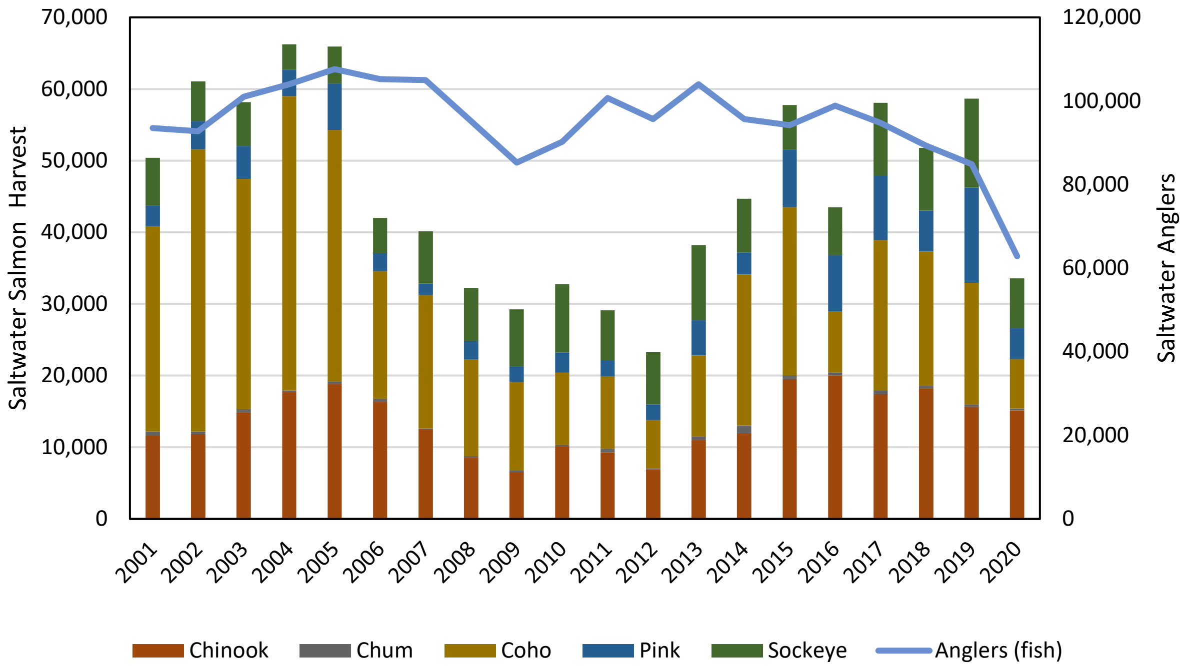
Source: (IPHC 2021a)

Figure 8. Commercial Pacific halibut harvest from Cook Inlet (statistical area 261).

2. Sport Fishing

Saltwater salmon fishing occurs year-round in Kachemak Bay and eastern Cook Inlet which targets mature Chinook salmon during April through August and immature Chinook salmon year-round. Sport fishing for Pacific halibut from Homer Harbor, Anchor Point, or Deep Creek occurs from February 1 to December 31 with most sport fishing between May and early September. Lingcod are harvested from July 1 through December 31, and rockfish may be retained year-round (ADF&G 2021b).

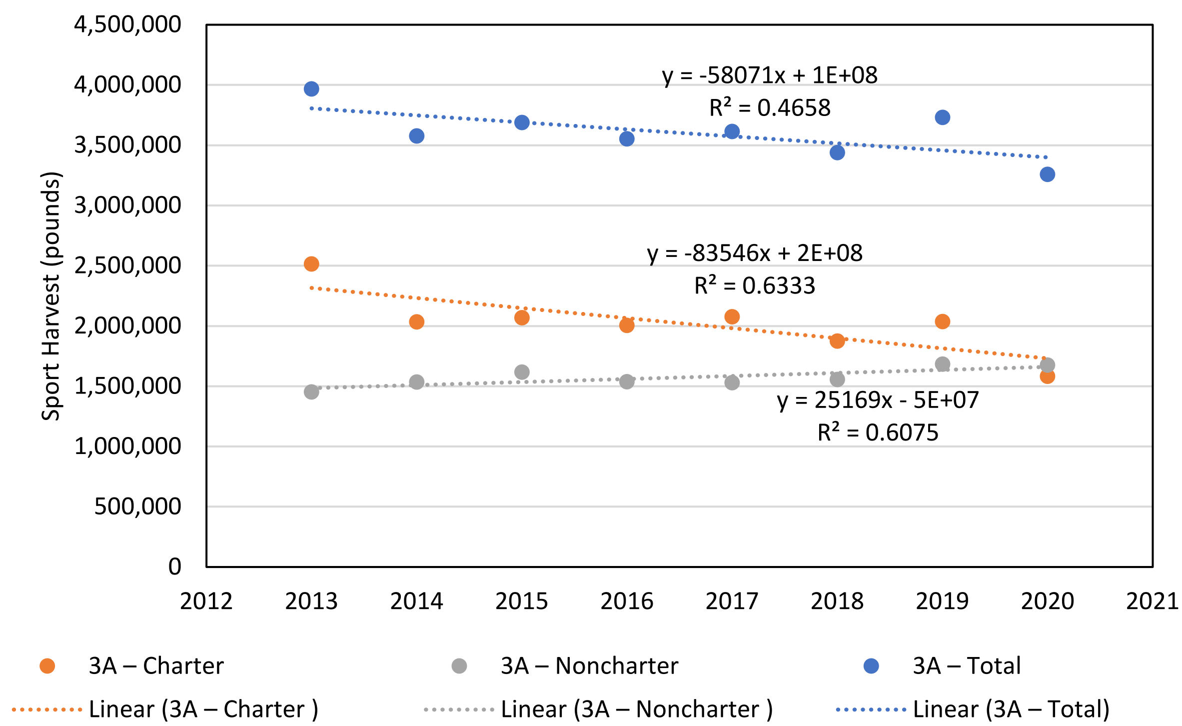
An average of 95,000 anglers fished 183,000 angler-days during 2001 to 2020 in Cook Inlet saltwaters, with a weakly negative trend of about 900 anglers per year and 1,900 angler-days per year (ADF&G 2021a). Saltwater salmon harvest averaged 43 percent coho, 30 percent Chinook, 16 percent sockeye, and 10 percent pink from 2001 to 2020; although the percentages vary year to year (Figure 9).



Source: (ADF&G 2021a)

Figure 9. Recreational salmon harvest from Cook Inlet saltwater.

Halibut dominates saltwater fish harvest in Cook Inlet, averaging 186,600 halibut per year from 2001 to 2020. Halibut comprised 86 percent of groundfish harvest from 2001 to 2020, followed by rockfish at 9 percent, Pacific cod at 3 percent, lingcod at 2 percent, and sablefish at 1 percent (ADF&G 2021a). Sport harvest of halibut in the central Gulf of Alaska region (Area 3A), which includes Cook Inlet, decreased at a rate of about 58,100 pounds per year between 2013 and 2021, with chartered sport halibut harvest declining 83,500 pounds per year while non-chartered sport harvest increased 25,200 pounds per year (Figure 10).



Source: (IPHC 2021b)

Figure 10. Recreational Pacific halibut harvest from the central Gulf of Alaska (Area 3A).

C. Recreation and Tourism

Recreational use of the Permit Area is limited due to its remote location and hazards associated with an active volcano. Augustine Island is uninhabited, although the island is regularly visited by small groups of researchers and occasionally by small groups of recreationists. Access to the island is by small floatplanes, helicopter, or boat. Floatplanes generally land in the lagoon between Augustine and West Augustine islands. According to a mountain climbing website, people occasionally attempt to summit Augustine Volcano. Recommendations are that early summer is the best time to attempt to climb Augustine Volcano because the weather is more favorable and there is more snow cover on the upper slopes that facilitates climbing (Summit Post 2021).

Bear viewing along the western shore of Cook Inlet is a popular recreational activity. The McNeil River State Game Sanctuary, about 30 miles southwest of the Permit Area on Augustine Island, hosts the world's largest congregation of brown bears, *Ursus arctos*, and features a renowned bear viewing program managed by ADF&G, which limits the number of visitors to the sanctuary to 10 individuals per day between June 7 and August 25. Access to the McNeil River Sanctuary and Refuge is by floatplane provided by authorized air taxi operators (ADF&G 2022).

D. Energy and Infrastructure

The Railbelt electrical grid consists of five regulated public utilities that extend from Fairbanks to the Kenai Peninsula. Most Alaskans, 65 percent, live within the Railbelt service region. The Matanuska-Susitna Valley, Anchorage, and Kenai Peninsula depend primarily on natural gas for electricity and heat. Transmission lines with potential for connections from a geothermal power plant on Augustine Island are located on the Kenai Peninsula approximately 63 miles northeast of the Permit Area and operated by Alaska Electric and Energy Cooperative. Pedro Bay on Lake Iliamna is located about 38 miles north northwest of Augustine Island (Figure 11).

Source: (EIA 2021)

Figure 11. Energy infrastructure near Augustine Island.

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Chapter Six: Geothermal Resources in the Prospecting Permit Area

A. Geology

The geology of Augustine Island is primarily related to volcanic activity in the Cook Inlet region. Augustine Volcano is a cone-shaped stratovolcano having at least six eruptions between 1812 and 1998, with the with the most recent eruption in 2006. The summit lava-dome has repeatedly collapsed, depositing pyroclastic debris and ash on the flanks of the volcano and into the surrounding nearshore waters. Ongoing eruptions and debris avalanches have shaped the irregular coastline of Augustine Island (Waythomas and Waitt 1998; Nye 2007).

B. Geothermal Energy Potential

Alaska statutes define geothermal resources as "the natural heat of the earth at temperatures greater than 120°C, measured at the point where the highest temperature resources encountered enter or contact a well shaft or other resource extraction device…" (120°Celsius [°C] = 248°Fahrenheit [°F]; AS 41.06.060(3)). Geothermal resources commonly coincide with areas of tectonic plate boundaries and recent geologic activities. Tectonic activity allows magma or superheated groundwater to reach the earth's surface, creating areas of high temperature resources at recoverable depths (Bronicki 2002). Geothermal resources including hot water, hot dry steam, hot dry rock or any other heated geological material are associated with Aleutian Arc volcanos (Motyka et al. 1994; AEA 2019). These concentrated heat sources can be captured for electric power production or used directly for heating (USDOE 2021).

Although subsurface and geologic data related to geothermal energy production capacity is not available, geothermal resource potential within the South Augustine Island Noncompetitive Geothermal Prospecting Permit Area (Permit Area) is indicated by the presence of Augustine Volcano. Lithology and temperature of the resource determine the size and capacity for a potential geothermal energy project (Soltani et al. 2021). Motyka and others (1994) evaluated geothermal resources of the Aleutian Arc and identified super-heated fumaroles with unknown reservoir temperatures, probably >300°F and a volcanic vent hydrothermal system for Augustine Volcano. An investigation of geothermal fluids at Augustine Volcano in 2008 and 2010 sampled spring-fed creeks and fumaroles. This study found little evidence for geothermal influence on water temperature or water chemistry and fumarole temperatures ranged from 145 to 208°F (Evans et al. 2015).

Alaska's 53 historically active volcanoes and 97 geothermal springs provide tremendous potential for geothermal energy development (DGGS 2022), although attempts to develop Alaska's geothermal resources for community-scale power generation have been largely unsuccessful (AEA 2019). The location of the Permit Area with respect to Southcentral Alaska's power grid may make this area viable as a geothermal energy production site. Construction of geothermal power plants is capital intensive. Like other renewable energy sources, however, geothermal power plants have few additional long-term costs compared to hydrocarbon fuel-based power plants. Geothermal power plants have no fuel costs or associated fuel transportation costs, and operation and maintenance costs are relatively minor. Despite the high capital costs, a typical geothermal plant's lifetime operating costs are much less than that of a diesel-powered facility of equivalent capacity (Yanity and Kolker 2006).

C. Geothermal Development Activities

Development of an Augustine Island geothermal project would begin with an initial survey and exploration phase that could include geological and geophysical surveys and drilling of one or more exploration wells to determine the size and temperature of the resource. If a commercially viable resource is identified and a project designed, development of the project would likely include construction of wells and pipelines, a power plant with turbine and cooling system facilities, roads, personnel housing, transportation and maintenance facilities, and subsea power transmission lines most likely to Anchor Point or Homer (Kagel et al. 2007; Soltani et al. 2021). This section describes typical geothermal exploration and development activities and associated environmental concerns that are evaluated for reasonably foreseeable cumulative effects in Chapter Eight.

1. Geological and Geophysical Surveys

Geological and geophysical surveys are used to collect data on physical and chemical characteristics of the geothermal resource and image subsurface rock formations to identify structures that may contain a permeable geothermal reservoir. Important physical parameters for a geothermal system include reservoir temperature, porosity, and permeability, and chemical composition of the fluid, which are primarily measured indirectly. Indirect methods for imaging geothermal reservoirs include magnetic measurements, gravity measurements, active seismic methods, and passive seismic monitoring (Georgsson 2009). Initial exploration of the Permit Area would potentially use seismoelectric surveys which are based on the generation of electromagnetic fields in soils and rocks induced by seismic waves that allow the measurement of hydraulic conductivity in geothermal reservoirs (EPA 2016).

Seismic surveys measure sound which travels at different velocities through different rock types and is refracted or reflected at discontinuities or between formations. These surveys are divided into two groups, active methods where an external source is used to create sound waves, and passive methods that use natural seismic activity to delineate active faults and permeable zones or to locate the depth to the heat source (Georgsson 2009). Seismoelectric surveys measure the electrokinetic effect or streaming potential that are initiated by sound waves passing through a porous rock that induce relative motion of the rock matrix and fluid. Seismic sources, such as a vibrator or small explosive charges, and electrode pairs are typically used to measure the induced electrokinetic effect. Two electrode pairs are typically located collinear and symmetric to the seismic source, with repeated seismic shots used to improve signal to noise (EPA 2016).

Seismic surveys within the Permit Area would most likely be conducted during summer and have the potential to temporarily disturb wildlife near the surveys. Induced vibrations from vibrators or small explosive charges would likely be identified by equipment monitored by AVO. Access to the island would most likely be by helicopter.

2. Well Drilling

Prior to drilling an exploration well, temperature or thermal gradient holes may be drilled to determine if subsurface temperatures are sufficiently hot to support commercial production, and to potentially define the extent of the geothermal resource. These small boreholes, up to 1,000 feet deep, are used to directly measure subsurface temperatures and also potentially identify the presence of geothermal fluids (Taylor 2007). Drilling geothermal wells uses methods similar to drilling oil and gas wells, although rigs must be equipped to handle extremely high subsurface temperatures. Typically, geothermal wells are drilled 660 to 6,600 feet deep (200 to 2,000 meters), and if directional drilling is used multiple wells can be drilled from the same drill pad (Goldstein et al. 2011). Potential environmental concerns during drilling include well blowouts, drilling mud and geothermal fluid spills and disposal, and fuel spills.

a. Blowouts

Highly pressured steam and fluids are often encountered during geothermal well drilling, with a potential for well blowouts. When the pressure in the wellbore is higher than the drilling mud weight the well will back flow and if this flow is uncontrolled a blowout can result. Blowout preventers are used to shut off the wellbore and prevent fluid from flowing out (Finger and Blankenship 2012). Loss of well control from blowouts could result in drilling mud and geothermal fluid spills. However, operators are required by regulation 11 AAC 87.130 to use blowout prevention equipment, which reduces the likelihood of blowouts.

b. Drilling Fluid and Geothermal Fluid Spills

Drilling fluids, also called drilling muds, are primarily a mixture of water and bentonite (clay) used to lubricated and cool the drill bit, remove rock cuttings from the borehole, and to counterbalance formation pore pressures to keep fluids or gases from entering the wellbore to prevent a blowout. Additives such as barium sulfate are incorporated to adjust mud weight or density (OSHA 2021). Spills of drilling muds and geothermal fluids may affect vegetation, soils, wildlife, and fish. The most commonly spilled fluid during drilling activities is formation water, which is often a brine that can kill vegetation and prevent plants from growing in contaminated soils (Allison and Mandler 2018).

Disposal of drilling muds and rock cuttings may include injection into the well annulus or grinding and injection into a disposal well. For geothermal exploration wells, drilling muds and cuttings are typically stored on-site in holding tanks and then hauled to approved solid waste disposal sites or reinjected for subsurface disposal. Development drilling includes both production wells to extract geothermal fluids or gasses and injection wells to return geothermal fluids to the reservoir (Finger and Blankenship 2012). Class II underground injection wells are used for reinjection of produced water, in this case cooled geothermal fluid, which is usually a brine (EPA 2019). Mitigation measures require subsurface disposal of produced water.

c. Fuel Spills

Geothermal exploration and development require the use and storage of petroleum products and other potential environmental contaminants to fuel equipment and the drilling rig. Potential environmental impacts of spills depend on the size, location, type of fluid, and spread of the spill, including whether it contaminates ground or surface water. Exposure to surface water or groundwater allows a spill to spread further and makes cleanup more difficult. Spilled fuel can prevent plant growth and hinders the movement of water, oxygen, and nutrients through soils. Some fuel components are toxic to plants, animals, and humans; and spilled gasoline or diesel fuel evaporates releasing toxic fumes that degrade air quality and may pose a fire hazard (Allison and Mandler 2018).

3. Facility Construction and Operation

The basic design of geothermal power plants is essentially the same as natural gas and coal-fired power plants. Instead of creating heat from combustion, however, geothermal plants use steam or hot water heated by the earth to turn turbines and generate power. Typical environmental concerns for geothermal power plants include air emissions, cooling water use and handling, ground subsidence, induced seismicity, and noise.

a. Air Emissions

Geothermal power plant emissions include carbon dioxide, nitrogen oxides, sulfur dioxide, and particulate matter (Kagel et al. 2007). Geothermal fluid usually contains dissolved gases including carbon dioxide, hydrogen sulfide, ammonia, and methane which are released during depressurization and cooling when oxidation products including sulfur dioxide and nitrogen oxides are emitted. Metal salts of mercury, boron, arsenic and other metals may be released from cooling towers as fine-grained particulates. Methane is a greenhouse gas and mercury and arsenic are toxic (Soltani et al. 2021). Geothermal plants are generally required to limit emissions of hydrogen sulfide and mercury. Air emissions from geothermal power plants are orders of magnitude less than conventional fossil-fuel power plants (Kagel et al. 2007; Soltani et al. 2021).

b. Water Use

Freshwater is used during drilling and facility construction. Most power plants also use freshwater cooling systems which require a continuous supply of cooling water and create vapor plumes. Spent steam from the turbine (for flash and dry steam type plants) may also be condensed and used for cooling (Kagel et al. 2007). Geothermal fluids are generally reinjected into the reservoir for reuse. Operational freshwater use varies by more than an order of magnitude depending on the type of power plant (dry steam, flash steam, or binary) and local situations (Meldrum et al. 2013). Flash steam, where a mixture of water and steam is produced from geothermal wells with a water cooling system are the most common (Kagel et al. 2007). Flash steam plants use on the order of 5 to 360 gallons per megawatt-hour (Meldrum et al. 2013).

c. Noise

Noise is generated during construction, drilling, and subsequent operation of geothermal facilities. Highest sound levels are produced during unmuffled drilling with air reaching 114 decibels A-weighted (dBA) at 26 feet (8 meters) from the source, compared to drilling with fluids at 80 dBA. Release of high-pressure steam during well testing can produce sound up to up to 120 dBA. Heavy equipment sounds can reach 80 dBA during construction, and if pile driving is required sounds can reach even higher levels (Soltani et al. 2021). During normal geothermal power plant operation sound generally comes from the cooling tower, the transformer, and the turbine-generator building (Kagel et al. 2007). Sound is also produced by fluids moving through pipelines, and by vehicles used for transportation. Water cooling towers generate sound levels of 82 to 83 dBA at 10 feet (3 meters) and turbine buildings generate sound levels of 73 dBA at 26 feet (8 meters; Soltani et al. 2021). Note that sound dissipates with distance from the source.

Noise during all phases can be mitigated through use of mufflers for drilling, sound shields for generators, and turbines, incorporating sound insulating materials in facility construction, and using silencers for cooling towers (Kagel et al. 2007; Soltani et al. 2021).

d. Ground Subsidence

Ground subsidence can result from the extraction of geothermal fluids by reducing pore pressure which can result in collapse of the reservoir rock. This collapse can lead to a slow, downward deformation of the land surface. Where this has occurred from geothermal operations, the deformation has been confined to the wellfield area. Subsidence can also be induced by thermal contraction (cooling) of the reservoir from extraction and natural recharge. Reinjection of geothermal fluids reduces the potential for subsidence by maintaining reservoir pressures. In sedimentary rocks, where porosity and permeability are primarily between rock grains, reinjection can mitigate subsidence (Kagel et al. 2007).

e. Induced Seismicity

Removing and reinjecting geothermal fluids leads to pressure and temperature changes in the subsurface that cause volume and stress changes. These stresses add to the pre-existing tectonic stresses (Buijze et al. 2019). While most geothermal-related induced seismicity is in the form of low-magnitude microearthquakes (M <2.0) that typically go undetected and cause no damage (Kagel et al. 2007), a recent review identified 37 cases of geothermal induced seismicity M >2.0 (Buijze et al. 2019). In this review lithology was found to influence seismicity induced by geothermal operations. Crystalline basement rocks, often the target of Enhanced Geothermal Systems, were very prone to induced seismicity. These rocks are often already critically stressed and can be destabilized by pressure changes from geothermal operations in hydraulically connected sedimentary layers. Geothermal fields in tectonically active areas also showed seismicity, but not always of large magnitude. Geothermal operations targeting shallow (<10,000 feet [3 kilometers]), porous (>15 percent), low temperature (<212 °F [100 °C]) sandstone aquifers were not associated with seismicity M >2. These formations were often far above the basement, hydraulically isolated by clay layers, and may have more stability due to evaporates or clays. Seismicity is site-specific and local geology, faulting, and seismic event potential should be evaluated (Buijze et al. 2019).

Management measures to control induced seismicity include balancing production and injection rates, monitoring reservoir pressure, identifying and studying subsurface faults within the geothermal system, and using warning systems (Soltani et al. 2021). Augustine Island is in an active seismic area with high tectonic pressures. Increased seismicity could be hazardous to production operations and adjoining land uses. The state may install additional seismographs or other instruments in producing geothermal fields to detect induced seismic activity. If geothermal production induces hazardous seismicity, the permittee will be required to adjust production and injection rates or to suspend operations.

D. Transmission of Geothermal Power

Geothermal resources (hot water or steam) can only be transported short distances using conventional technologies. Usually, the heat from geothermal resources is converted into electricity within a few miles from the resource. Planning for energy projects includes evaluating transmission distances from the project to the local power grid. Geothermal resources can increase the capacity of existing power grids (Fleischmann 2010).

The nearest power plants are small diesel generators serving remote local communities. The Newhalen plant, located about 58 miles northwest of Augustine, has a total of 1.7 megawatts (MW) power generation, 0.8 MW petroleum-fired and 0.9 MW hydroelectric, operated by I-N-N Electric Cooperative, Inc. The Seldovia plant, located about 62 miles east of Augustine, is a 2.2 MW petroleum-fired plant operated by Homer Electric Association, Inc. The largest power plant near Augustine that is connected to the Railbelt grid is the Bradley Lake hydroelectric plant at 126 MW power generation operated by Homer Electric Association, Inc. The nearest potential connection to the Railbelt transmission grid is about 64 miles across Cook Inlet northeast of Augustine near Anchor Point (Figure 11). Transmission of electricity from Augustine Island would require a subsea power cable.

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Chapter Seven: Governmental Powers to Regulate Geothermal Exploration and Development Activities

Geothermal exploration activities are subject to numerous federal, state, and local laws, regulations, policies, and ordinances in addition to the provisions of the Prospecting Permit. The permittee is obligated to comply with all federal, state, and local laws. Regulatory agencies may have different roles in the oversight and regulation of geothermal exploration activities, and some agencies may have overlapping authorities with other agencies. Some common activities requiring prior authorization include construction of pads, roads, support facilities, and drilling wells. Additionally, constructing and operating processing facilities or transmission lines would also require prior authorization.

This chapter is not intended to provide a comprehensive list of every possible regulatory consideration, but a presentation of the broad spectrum of government agencies authorized to prohibit, regulate, and condition geothermal activities that may ultimately occur because of this disposal. Actual processes, terms, conditions, and required authorizations will vary with time-certain, site-specific operations, and the activities discussed in this finding which may not be all inclusive. Some of the anticipated major permits and approvals are listed in Table 5.

Table 5. State, federal, and local applicable laws, permits, approvals and consultations.

Entity	Legal Authority	Agency Responsibility	Requirement
Alaska Department of Natural Resources (DNR), Division of Oil and Gas (DO&G)	Plan of Operations 11 AAC 84.750 Plan of Exploration 11 AAC 84.755 Plan of Development 11 AAC 84.760	DO&G reviews and potentially approves plan of operations, exploration, and development for activities on geothermal prospecting permits and geothermal leases.	Geothermal • Plan of Operations • Plan of Exploration • Plan of Development
DNR, DO&G	Uses Requiring Permits 11 AAC 96.010, 11 AAC 96.210, 11 AAC 96.030(a) 11 AAC 96.060	DO&G issues land use permits for geophysical exploration required for all geophysical and exploration activity.	• Temporary Land Use Permits • Submission of seismic and stratigraphic data
DNR, Division of Mining Land and Water (DMLW)	Land Use and Utility Easements 11 AAC 51.010 Standards and Public Easements 11 AAC 51.015 Application Fees 11 AAC 05.070.	DMLW issues easements for uses such as utility lines on state land. An application is required, and a bond may be required.	• Land Use Permits • Easement Application Form • Easement Right-of-Way (ROW)
DNR, DMLW	Water Use Act AS 46.15 11 AAC 93.035 11 AAC 93.120 and 11 AAC 93.130	DMLW issues a temporary water use authorization for water use during construction and operation, as well as water rights for appropriating significant amounts of water beyond temporary uses.	• Temporary Water Use Permit • Water Rights

Entity	Legal Authority	Agency Responsibility	Requirement
DNR, DMLW	Material Sale Contract 11 AAC 71 Mining Site Reclamation Plan AS 27.19	DMLW issues a material sale contract for state-owned gravel or other materials for construction of pads and roads, and approves mining reclamation plans on state, federal, municipal, and private land and water.	• Material Sales Contract • Approval of Reclamation Plan
DNR, Division of Parks and Outdoor Recreation, Office of History and Archaeology (OHA)	State Historic Preservation Act AS 41.35.010 National Historic Preservation Act (NHPA) 54 USC 300101 Archaeological Resources Protection Act 16 USC 470	Section 106 of the NHPA requires consultation with State Historic Preservation Office (SHPO) [OHA serves as SHPO] when there are adverse effects to cultural resources. OHA issues field archaeology permits for archaeological fieldwork on state lands. SHPO issues a Cultural Resources Concurrence for projects that may affect historic or archaeological sites.	• Section 106 Memorandum of Agreement or Programmatic Agreement • Archaeology collection permit • Field archaeology permit
Alaska Department of Environmental Conservation (ADEC)	Clean Water Act (CWA) 33 USC 1251 Wastewater Disposal 18 AAC 72 Alaska Pollutant Discharge Elimination System (APDES) 18 AAC 83 AS 46.03.100, AS 46.03.120(b) 40 CFR 123	ADEC has authority under the CWA: Provides approval for domestic wastewater collection, treatment, and disposal plans for domestic wastewater. Requires a permit for the disposal of domestic and nondomestic wastewater. Administers EPA's National Pollutant Discharge Elimination System (NPDES) program through APDES. Provides approval for treatment and disposal plans for industrial wastewater.	• APDES permits • Stormwater Pollution Prevention Plans • Treatment systems for drinking water and wastewater • Section 401 Water Quality Certification
ADEC	Clean Air Act (CAA) 42 USC 7401 Air Quality Control 18 AAC 50 18 AAC 15 20 AAC 25.235(c) AS 16.14	ADEC's primary responsibility is to control and mitigate air pollution in Alaska, as well as to issue air quality control permits for construction and operations of stationary sources.	• Title I Construction Permits • Minor permits • Title V Operating Permits
ADEC	Solid Waste Management 18 AAC 60 AS 46.03.100	ADEC regulates solid waste storage, treatment, transportation, and disposal	• Integrated Waste Management Permit/Plans
Alaska Department of Fish and Game (ADF&G)	Anadromous Fish Act AS 16.05.871 Fishway Act AS 16.05.841	ADF&G authorizes activities that could use, divert, obstruct, pollute, or change the natural flow or bed of rivers, lakes, and streams used by anadromous fish. ADF&G authorizes activities within or across a stream used by fish, if activities could be impediments to anadromous fish passage.	• Fish habitat permits • Determination of sufficient fish passage
Alaska Oil and Gas Conservation Commission (AOGCC)	Geothermal Well Drilling 11 AAC 87.070-190 AS 41.06.050 Geothermal Production 11 AAC 87.210-260	AOGCC has permitting approval for each well to be drilled or redrilled. This requirement applies to exploratory, stratigraphic test and development wells, and injection and other service wells related to oil, gas, and geothermal wells.	• Permit to Drill
AOGCC	Annular Disposal 20 AAC 25.080	AOGCC regulates annular disposal of drilling muds and cuttings	• Authorization to dispose of drilling wastes
AOGCC	Bonding Requirements 20 AAC 25.025	AOGCC oversees bonding requirements (bond remains active until wells are plugged and abandoned and well sites are restored).	• Establishment of bond with each operating company to drill, produce, and maintain geothermal wells

Entity	Legal Authority	Agency Responsibility	Requirement
US Environmental Protection Agency (EPA)	Resource Conservation and Recovery Act (RCRA) 42 USC 6901 40 CFR 264	RCRA governs the management of hazardous waste. Any hazardous waste generated at a facility is subject to the hazardous waste regulations administered by EPA.	• Permits for transportation and storage of hazardous waste materials
EPA	CAA 42 USC 7401 Standards for New Stationary Sources 40 CFR 60 Emission Standards for Hazardous Air Pollutants 40 CFR 63	EPA has oversight of ADEC's air quality control program and permits. Standards of Performance establish emission standards for new, modified, and reconstructed stationary sources. National Emission Standards set technology-based standards to regulate hazardous air pollutants.	• Section 309 evaluation • Compliance with certain equipment specifications and emission limits • Requirements for monitoring, recordkeeping, reporting, operation, and maintenance
EPA	CWA 40 CFR 110	EPA has the following authority under the CWA: Section 402: EPA oversees draft APDES permits and can object to permit decisions. Section 404: EPA reviews permit applications for compliance with Section 404(b)(1) guidelines and other authorities.	• Review of APDES Permits • Review Department of the Army (DA)/CWA Section 404 permits
EPA	Underground Injection Control (UIC) Program 40 CFR 144	UIC Program regulates construction and operation of complex Class V geothermal electric power injection wells for the protection of underground sources of drinking water.	• Class V geothermal well UIC permit
US Army Corps of Engineers (USACE)	Rivers and Harbors Act (RHA) 33 USC 403	RHA regulates work and structures in, over, or under waters of the United States (WOUS) as well as work and structures that affect the course, location, condition, or capacity of WOUS.	• DA/RHA Section 10 permit
USACE	CWA 33 USC 1344	CWA regulates the discharge of dredged or fill material into WOUS, including wetlands	• DA/CWA Section 404 permit
US Fish and Wildlife Service (USFWS)	Bald and Golden Eagle Protection Act 16 USC 668 Migratory Bird Treaty Act 16 USC 703–709	USFWS issues permits for the relocation of bald and golden eagle nests that interfere with resource development or recovery operations. USFWS may issue waivers or permits for activities that may injure or kill migratory birds.	• Permits to take, haze, relocate, or destroy eagles or their nests for public safety purposes • USFWS consultation
USFWS and National Oceanic and Atmospheric Administration, National Marine Fisheries Service (NMFS)	Marine Mammal Protection Act (MMPA) 16 USC 1361 Endangered Species Act (ESA) 16 USC 1531	USFWS and NMFS have joint regulatory authority under MMPA and ESA. MMPA prohibits the harassment, hunting, capture, or killing of marine mammals and requires Incidental Take Authorizations (ITAs) for any exemptions. USFWS and NMFS consult on the effects to threatened or endangered species and their designated critical habitat, as well as issue ITAs.	• ITAs (as necessary): Letters of authorization or incidental harassment authorizations • ESA consultations • USFWS/NMFS issuance of concurrence or Biological Opinion
NMFS	Magnuson-Stevens Fishery Conservation and Management Act (MSA) 16 USC 1361	NMFS provides consultation on the effects to essential fish habitat (EFH), as authorized by the MSA. EFH includes habitats necessary to a species for spawning, breeding, feeding, or growth to maturity.	• EFH consultation

Entity	Legal Authority	Agency Responsibility	Requirement
US Department of Justice – Bureau of Alcohol, Tobacco, Firearms, and Explosives (ATF)	Importation, Manufacture, Distribution, and Storage of Explosive Materials 18 USC 1102, Chapter 40 Commerce in Explosives 27 CFR 555	ATF requires that applicants obtain a permit before they purchase, store, and use explosives for blasting activities.	• Permit and license for use of explosives
U.S. Department of Transportation (USDOT), Pipeline and Hazardous Materials Safety Administration (PHMSA)	Hazardous Materials Transportation Act 49 USC 5101–5127	Hazardous materials must be transported according to USDOT regulations. PHMSA has regulatory and civil enforcement authority over the transportation of explosive materials in commerce.	• Hazardous materials transportation requirements and registration • License to transport explosives
Kenai Peninsula Borough (KPB)	Title 21 KPB Code of Ordinances AS 29.40.010 AS 29.35.180	KPB planning commission is responsible for administering planning and zoning ordinances, ensuring compliance with local, state, and federal law regarding land use.	• Zoning/Rezoning

Chapter Eight: Reasonably Foreseeable Cumulative Effects of Geothermal Exploration and Subsequent Activities

The director's decision that disposal of the South Augustine Island Noncompetitive Geothermal Prospecting Permit (Prospecting Permit) best serves the state's interest is contingent upon analysis of the potential effects of the disposal, both adverse and beneficial. Many potential adverse effects are avoidable, and the state imposes laws and regulations for this purpose. Some adverse effects are unavoidable and must be anticipated and balanced against beneficial effects. This section of the director's best interest finding discusses the reasonably foreseeable cumulative environmental, social, and economic effects and mitigation measures that will minimize potential adverse effects from geothermal exploration and development activities described in Chapter Six.

Typical negative effects from development of geothermal energy include: air emissions, water use, discharges, subsidence, induced seismicity, and impacts to vegetation and wildlife. Positive effects from development of geothermal energy for Alaska industries and residents are a reliable, renewable power source with minimal land requirements and emissions that can offset emissions from fossil-fuel power plants (Kagel et al. 2007). Many negative effects can be prevented or reduced through the mitigation measures presented in Chapter Nine or other permit restrictions that may be imposed by regulatory agencies.

Until the Prospecting Permit is issued, a plan of operations is submitted and approved, and discoveries are made, Division of Oil and Gas (DO&G) cannot predict when any geothermal exploration and development activities may occur or the type, exact location, duration, or level of these potential activities. In addition, methods to explore for, develop, produce, and transport energy from geothermal resources will vary depending on the area, permittee, operator, and discovery. The director is not required to speculate about possible future effects subject to future permitting (AS 38.05.035(h)). However, future effects will be analyzed at the time that applications for those future phases are submitted to the state. See Chapter Seven for a description of governmental powers to regulate geothermal exploration and development activities.

The Prospect Permit is not expected to have any effects, other than providing a small initial revenue to the state. Exploration and development activities in the Prospect Permit Area (Permit Area) described in Chapter Six could include seismic surveys; well drilling; construction and use of support facilities such as staging areas, dock or barge landings, road, airstrip, power plant, pipelines, housing, and transmission lines; transportation of machinery and labor to the site.

A. Reasonably Foreseeable Cumulative Effects on Air

Although air emissions from geothermal power plants are orders of magnitude less than conventional fossil-fuel power plants, geothermal fluids contain dissolved carbon dioxide, hydrogen sulfide, ammonia, and methane gases which are released during depressurization and cooling. Metals including mercury, boron, arsenic, and others may be released from cooling towers as fine-grained particulates. Geothermal plants are generally required to limit emissions of air pollutants such as hydrogen sulfide and mercury. (Kagel et al. 2007; Soltani et al. 2021).

1. Potential Cumulative Effects on Air Quality

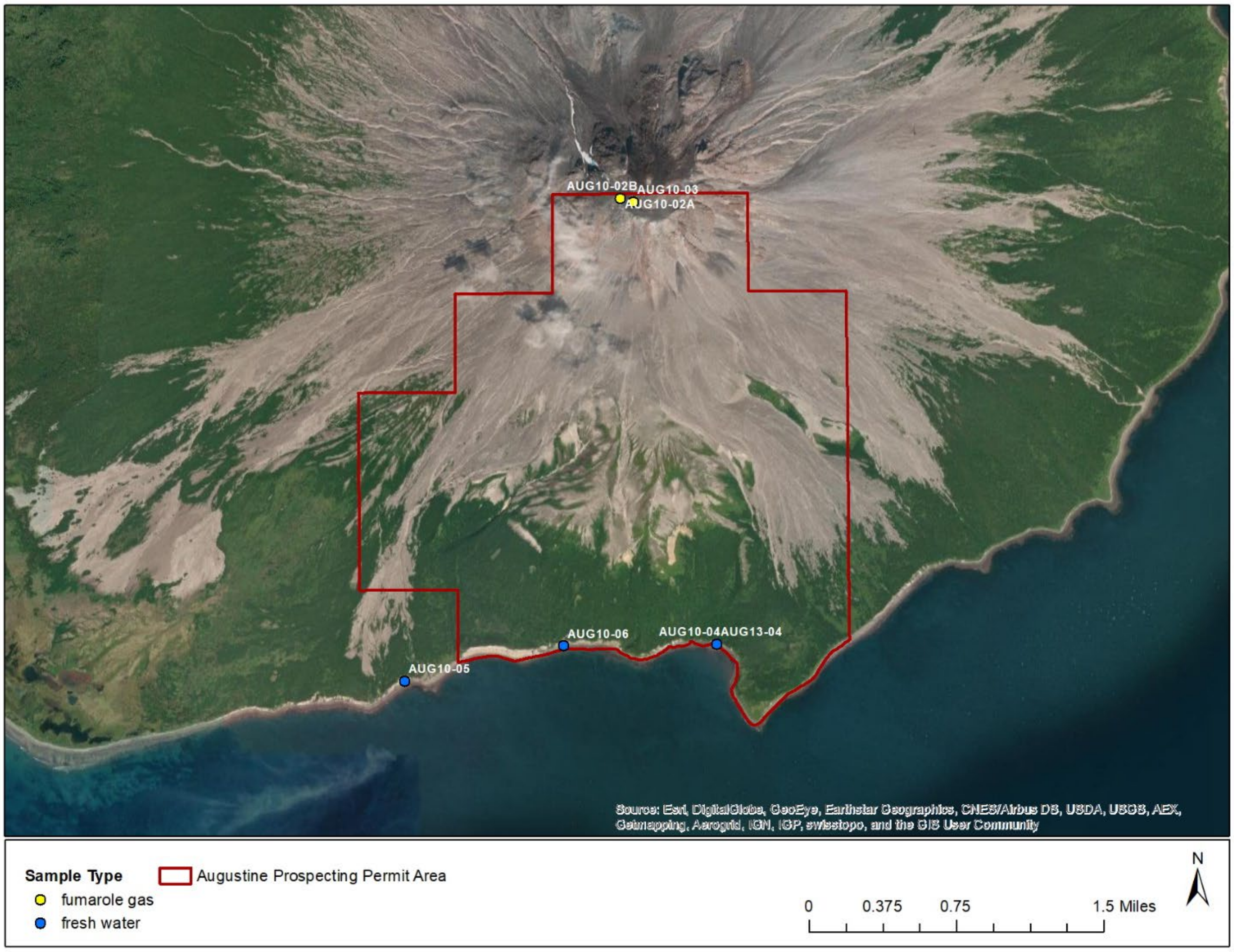
While geothermal power plants generate minimal emissions compared to burning fossil fuels, exploration, development, and use of a geothermal resource to generate power would be responsible for minor amounts of air pollutants. Diesel exhaust from construction and drilling equipment and dust from road and well pad construction would contribute air pollutants to the region. The amount of geothermal gasses present and released during power plant operation depends on the geological, hydrological, and thermodynamic conditions of the geothermal field, the fluid collection and injection system, and the type of power plant (Goldstein et al. 2011). Most flash steam power plants release gasses and steam to the atmosphere after running through the turbine. Typically less than 5 percent of cooling tower non-condensable gases contain regulated pollutants such as hydrogen sulfide and mercury (Kagel 2008).

Geothermal systems may discharge gases mixed with steam from surface features such as fumaroles and vents, and minerals dissolved in water from hot springs. Composition of gasses discharged from fumaroles on Augustine's summit following the 1976 and 1986 eruptions became progressively richer in steam and hydrogen gas (H_2) relative to carbon dioxide (CO_2) and sulfur dioxide (SO_2). Stable isotope values for deuterium (δD [^{2}H]) and oxygen (δ^{18}O) for condensed fumarolic steam indicate that seawater and local precipitation mix with primary magmatic water within the hot core of the volcano. The composition of gasses at two fumaroles on Augustine Volcano are similar to air except for increased carbon dioxide and decreased oxygen (Figure 12, Table 6). Fumarole samples from 2008 and 2010 were low in hydrogen even though low gas to steam ratios indicated the samples were water rich. Samples reflected oxidized conditions as hydrogen sulfide (H_2S) was not detected and carbon monoxide (CO) was barely detectable in only one sample (Evans et al. 2015).

Table 6. Fumarole gas composition (by percent) for two fumaroles near the summit of Augustine Volcano in the Prospecting Permit Area on July 27, 2010.

Description	AUG10-02A	AUG10-02B	AUG10-03
Elevation (feet)	3,940	3,940	4,045
Temperature (°F)	201.4	201.4	198.3
Gasses (%)			
Nitrogen (N_2)	72.8	72.9	77.3
Oxygen (O_2)	15.3	15.3	19.9
Carbon Dioxide (CO_2)	11.0	10.9	1.69
Argon (Ar)	0.848	0.864	0.854
Sulfur Dioxide (SO_2)	0.134	<0.05	0.205
Total	**99.99**	**99.99**	**99.99**

Source: (Evans et al. 2015)



Source: (Evans et al. 2015)

Figure 12. Fumarole gas and freshwater water samples in and near the Prospecting Permit Area.

Hydrogen sulfide is toxic, but rarely occurs in harmful concentrations after venting to the atmosphere and dispersal. Hydrogen sulfide oxidizes to sulfur dioxide and ammonia oxidizes to nitrogen oxides. Sulfur dioxide emitted by geothermal facilities, at 0.35 pounds per megawatt hour (lbs/MWh), represents a fraction of the 6.04 lbs/MWh of sulfur dioxide generated by the average fossil-fuel burning power plant. With the use of abatement equipment, however, emissions of hydrogen sulfide are regularly maintained below established standards (Kagel et al. 2007). Emissions from power plants closest to Augustine Island shown in Figure 11 are listed in Table 7 with representative emissions from geothermal plants.

Table 7. Power plant emissions near Augustine Island and example geothermal plant emissions.

Power Plant Emissions	Power kWh	Fuel bbl, Mcf	CO_2 Ton	SO_2 Ton	NO_x Ton
Newhalen – petroleum	24,000	43	21	0.03	0.40
Nikiski Combined Cycle – natural gas	404,839,000	3,579,503	209,603	1.07	495.94
Seldovia – petroleum	120,000	253	109	0.20	2.36
Soldotna – natural gas	35,259,000	356,020	20,847	0.11	58.39
Example Geothermal Plant Emissions					
Geysers Unit 5-20, CA	4,609,873,000	-	204,763	NR	NR
Puna Geothermal Venture I, HI	9,640,000	-	0	NR	NR
Neal Hot Springs Geothermal Project, OR	192,101,000	-	0	NR	NR

Source: (EIA 2021)

Notes: data are totals for 2020; kWh = kilowatt hours; bbl = barrels; Mcf = million cubic feet; CO_2 = carbon dioxide; SO_2 = Sulfur dioxide; NO_x = Nitrogen oxides; CA = California; HI = Hawaii; OR = Oregon; NR = Not Reported

Gaseous emissions from Augustine Volcano vary in composition and quantity with eruptive phase. Little to no emissions of carbon dioxide or sulfur dioxide, and no hydrogen sulfide were measured during quiet periods in 2002 to 2005, and 2007 to 2008. With trace to 120 tons/day of sulfur dioxide and trace to 180 tons/day of carbon dioxide and no hydrogen sulfide measured in 2008. Augustine Volcano is not considered to be a significant contributor to atmospheric greenhouse gases since eruptions, when most emissions occur, are sporadic at about 17.5-year intervals compared to the many fossil-fuel power plant emissions that occur continuously year after year (McGee et al. 2010). During 2006, the year covering the most recent eruption, Augustine released an estimated 196,000 tons of carbon dioxide and 630,000 tons of sulfur dioxide (McGee et al. 2010), which is a bit less carbon dioxide than emitted by the Nikiski plant for 2020 (see Table 7).

Any incremental increases in pollution will not have a significant cumulative effect on air quality. The US Environmental Protection Agency (EPA) and Alaska Department of Environmental Conservation (ADEC), Division of Air Quality require industries with emissions that may affect air quality to control and reduce their air emissions such that Alaska and national ambient air quality standards are maintained (ADEC 2021a).

The visible plumes rising from water cooled geothermal power plants are water vapor (steam), not smoke, that are caused by the evaporative cooling system. Air cooled systems emit no water vapor. The water vapor likely contains fine particulates carried from the geothermal fluid (Kagel et al. 2007), which may contribute to regional haze. Regional haze is a basic form of air pollution that can impair visibility and scenic quality. Haze results when sunlight is absorbed or scattered by pollution particles in the air, obscuring views. Regional haze is generated by both natural and anthropogenic sources. Natural sources of visibility impairment in Alaska include dimethyl sulfide from oceanic algal blooms, volcanoes both eruptions and off-gassing, glacial dust, wildfires, and sea salt. Alaska is also exposed to large amounts of internationally generated pollution. Typical anthropogenic air pollution sources include power plants, manufacturing, oil and gas exploration and development, mining, agriculture, and mobile sources such as highways, railroads and aircraft (Goodfellow 2020).

The Tuxedni Wilderness (Chisik Island) is a Class I viewshed north of the Permit Area. An IMPROVE monitoring station located on the coast in Lake Clark National Park and Preserve south of Chisik Island measures air pollutants (both natural and anthropogenic) that effect visibility. Data from the Tuxedni IMPROVE station indicate that the haze index on the haziest days declined at a rate of 0.25 deciview (dV) per year from 2002 to 2014. The clearest days occur primarily from October to January, with the primary contributors to haze being ammonium sulfate – 43 percent, fine sea salt – 19 percent, and coarse mass – 13 percent. The haziest days occur primarily from June to August, with the primary contributors to haze ammonium sulfate 37 – percent, organic carbon 23 – percent, and fine sea salt 22 – percent (CIRA 2021).

Emissions from a geothermal power plant on Augustine Island are not likely to contribute to a reduction in visibility within Tuxedni Wilderness, but water vapor plumes from cooling towers may interfere with visual monitoring of Augustine Volcano (AVO 2020).

2. Mitigation Measures

Geothermal activities may affect air quality. Any geothermal power plant built on Augustine Island as a result of this disposal will be required to use sulfur abatement technologies. Industry compliance with federal and state air quality regulations, particularly the Clean Air Act (42 USC §§ 7401-7671), AS 46.03, AS 46.14, and 18 AAC 50 are expected to prevent potential cumulative negative effects on air quality. Information on air quality permits and regulations can be found in Chapter Seven.

B. Reasonably Foreseeable Cumulative Effects on Water

Freshwater is used during drilling, facility construction, at camps, and most power plants also use freshwater cooling systems which require a continuous supply of cooling water. Produced water (geothermal fluid) is generally reinjected into the reservoir for reuse. Geothermal fluids are a potential source of water and soil contamination due to their high levels of total dissolved solids and for toxic levels of antimony, arsenic, lead, and mercury. Higher concentrations of contaminants are generally present in high-temperature compared to moderate-temperature geothermal fluids (Clark et al. 2011).

Operational freshwater use varies by more than an order of magnitude depending on the type of power plant. Flash steam plants are the most common, using from 5 to 360 gallons per megawatt hour (Kagel 2008; Meldrum et al. 2013). Geothermal plants commonly use geothermal fluids for cooling. Freshwater is used in geothermal plants to manage dissolved solids, reduce scaling, meet makeup water losses, and replenish the reservoir. Geothermal plant efficiencies may decline over time and additional outside fresh, brackish or effluent water sources may be required to replenish the reservoir (Macknick et al. 2012). Spills of fuel, drilling muds, and produced water (geothermal fluids) may degrade water quality. The most commonly spilled fluid during drilling is produced water, which is often a brine. Fuels are toxic to plants, animals, and humans; and spilled gasoline or diesel fuel can degrade water quality (Allison and Mandler 2018).

1. Potential Effects on Water Quantity and Quality

Freshwater resources on Augustine Island include a few ponds and spring-fed perennial streams. Given their elevation and proximity to Cook Inlet, ponds on the island may be brackish rather than freshwater.

Fresh waters sampled on Augustine Island included spring-fed creeks sampled near sea level that were enriched in dissolved solids, but showed little evidence for a thermal component having low temperatures and missing quantities of elements typically associated with thermal springs such as lithium (Li – 0.12 to 0.63 milligrams per liter [mg/L]) and rubidium (Rb – 0.02 to 0.08 mg/L) (Evans et al. 2015). Water samples collected in 2010 and 2013 from two streams in the Permit Area and a nearby spring are summarized in Table 8 and locations are shown on Figure 12.

Table 8. Water quality for two streams in the Prospecting Permit Area and a spring on Augustine Island.

Water Parameters	Spring AUG10-05	Creek 1 AUG10-04	Creek 1 AUG13-04	Creek 3 AUG10-06
Sample Date	July 29, 2010	July 28, 2010	July 31, 2013	July 29, 2010
Water Temperature °F	38.5	45.5	46.9	43.5
Specific Conductivity µS/cm	145	175	187	89.3
pH	6.36	6.81	6.78	7.44
Major Cations				
Calcium (Ca) mg/L	10.0	11.3	11.3	5.62
Magnesium (Mg) mg/L	3.07	3.75	4.1	1.48
Sodium (Na) mg/L	11.8	16.5	17	8.72
Potassium (K) mg/L	1.19	1.14	1.1	0.59
Major Anions				
Bicarbonate (HCO_3) mg/L	28.6	45.4	43.0	26.9
Sulfate (SO_4) mg/L	15	17	18.1	9.8
Chloride (Cl) mg/L	19	20	20	11
Nitrate-Nitrogen (NO_3-N) mg/L	<0.01	<0.01	<0.01	<0.01
Other				
Fluoride (F) mg/L	0.11	0.21	0.26	0.09
Iron (Fe) mg/L	<0.001	0.001	<0.003	0.003
Silicon Dioxide (SiO_2) mg/L	35.7	37.2	35	28.0
Strontium (Sr) mg/L	0.038	0.028	0.027	0.014
Bromine (Br) mg/L	0.037	0.033	0.05	0.022
Phosphate-Phosphorus (PO_4-P) mg/L	<0.01	<0.01	<0.01	<0.01
Lithium (Li) mg/L	<0.01	<0.01	0.01	<0.01
Rubidium (Rb) mg/L	<0.01	<0.01	<0.01	<0.01

Source: (Evans et al. 2015)
°F = degrees Fahrenheit; µS/cm = microsiemens per centimeter; mg/L = milligrams per liter

Intentional or accidental discharge of geothermal fluid into freshwaters may impact local water quality and temperature. Prior to development of injection wells in 2012, district heating water from the Sandıklı Geothermal District Heating Project, which provides heat for about 12,000 homes, was discharged into the Hamamcay Creek drainage in the upper Buyuk Menderes River Basin, Turkey from 1994 and 2012. Discharge resulted in significant increases in water temperature, specific conductivity, and concentrations of sodium and sulfate ions. Trace element concentrations that increased significantly downstream from geothermal fluid discharge in Hamamcay Creek included aluminum, arsenic, boron, iron, chromium, lithium, sulfur, phosphorus, lead, uranium, manganese, and zinc (Davaraz et al. 2017).

Geothermal wastewater is usually hot, and discharge of heated effluents to surface waters can result in thermal pollution. Water temperature directly affects metabolic rates, physiology, productivity, and life-histories of aquatic plants and animals. Permanent temperature regime changes can leave habitats unusable by native plants and animals and may facilitate establishment of invasive plants and animals that are tolerant of high temperatures (Wetang'ula 2004).

2. Mitigation Measures

Geothermal activities may affect water resources in the Permit Area. Adverse effects could result from well drilling and power plant construction and operation with associated discharges, runoff, and freshwater use.

Drilling and operation of geothermal production and injection wells are regulated by the Alaska Oil and Gas Conservation Commission (AOGCC; 11 AAC 87.010 to 11 AAC 87.290; 20 AAC 25.705 to 20 AAC 25.740; AS 41.06.050), which also requires conservation of geothermal resources and oversees annular disposal of drilling fluids (AOGCC 2021). Geothermal injection wells are also regulated as Class V wells under EPA’s Underground Injection Control (UIC) program (40 CFR 144; EPA 2022) under the Safe Drinking Water Act (42 USC §300). Mitigation measure require reinjection of geothermal fluids and surface discharge of drilling muds and cuttings (fluids) is prohibited.

Existing and new facilities are required to control and manage stormwater and snow melt runoff during construction and operation to avoid and minimize potential contamination. Industrial wastewater and stormwater discharges are regulated through ADEC's Alaska Pollutant Discharge Elimination System (APDES) program (ADEC 2021b). ADEC offers a general permit option (AKG250000) for discharge of up to 2.0 million gallons per day of non-contact cooling water, defrost water, heat pump transfer water, and cooling tower blowdown for facilities with intake flow and discharge to fresh or marine surface water (ADEC 2020). Facilities will be required to comply with solid waste, fuel, and hazardous substance handling and storage regulations to avoid and minimize pollution of water resources. Mitigation measures address fuel and hazardous substance storage, transfer, and handling to further ensure protection of surface and subsurface water resources.

Industry compliance with measures in this best interest finding, along with regulations imposed by local, state, and federal agencies are expected to avoid, minimize, and mitigate potential effects on water resources. A complete listing of mitigation measures can be found in Chapter Nine.

C. Reasonably Foreseeable Cumulative Effects on Habitats and Fish and Wildlife Populations

Potential cumulative habitat and fish and wildlife impacts from industrial development to produce geothermal energy include land usage, water usage, noise, solid and liquid waste generation, pollution, waste heat generation, and changes in biodiversity (Shortall et al. 2015; Soltani et al. 2021). Many assessments include areas where geothermal energy has been produced for decades to centuries, with some impacts described for geothermal systems using outdated technology such as surface discharge of geothermal fluids rather than current technology that generally requires reinjection of geothermal fluids back into the reservoir.

Habitat and fish and wildlife in the Permit Area are influenced by an island location and the periodic eruptions of Augustine Volcano (17.5-year average). Habitat in the Permit Area as described in Chapter Four is primarily bare ground, low-tall shrubs, a few perennial streams, and gravel/sand beaches. Fish are not known from freshwaters on Augustine Island, but some pink and coho salmon may use streams, ponds, and coastal lagoon habitat on the island. Nearshore waters around Augustine Island are used by spawning Pacific herring, Pacific salmon, other marine fishes, and razor clams. Wildlife using habitats on and around Augustine Island are primarily birds, sea otters, harbor seals, and red foxes. While discussions of cumulative effects below are focused on habitats and fish and wildlife in the Permit Area, it is possible that some transportation activities could occur outside of the Permit Area, such as barge landings, floatplane landings in the lagoon, or a subsea power cable.

1. Potential Effects on Habitats

Direct habitat loss can result from construction of well pads, pipelines, transmission lines, roads, docks, airstrips, camps, and the power plant. Effects of facility construction on habitats can include direct loss of acreage due to vegetation clearing, surface grading and materials infilling. In general habitat loss from geothermal power plants ranges from 0.3 acres per megawatt without wells and pipelines to 1.8 acres per megawatt including wells and pipelines (Soltani et al. 2021). Total land requirement for a 56-megawatt flash-steam power plant (similar in capacity to the 50-megawatt natural gas-fired Soldotna power plant) would cover an estimated 103 acres.

Siting of production and injection wells would depend on the location of the resource, although given the eruptive history of Augustine Volcano, it would be preferable to site well pads away from recent land slide areas near the summit. It would also be preferable to site the power plant in an area away from recent debris and pyroclastic flows. Vegetation cover may be a good indicator of safety and land stability, with forested habitats taking the longest time to regenerate (Boggs et al. 2019). Within the Permit Area, the largest patches of forested habitat are located next to the shoreline in the southwest corner of the Permit Area (Figure 2). It is likely that the power plant would be sited near the shoreline where topography is flatter and where most vegetation cover occurs. This siting would likely result in disproportionately greater impacts to forested and shrub habitats in the Permit Area.

Based on water quality parameters listed above, perennial streams in the Permit Area likely depend on snow melt and rain for groundwater recharge (Evans et al. 2015). Construction of well pads, buried pipelines, and roads on the side slopes of Augustine, could interrupt shallow groundwater flow. An increase in impervious surfaces such as roads and pads could decrease infiltration of precipitation. Decreased infiltration, geothermal fluid withdrawal (if shallow groundwater interconnections occur), and thermal pollution from wells, pipelines, and the power plant could alter stream flow and habitat suitability (Shortall et al. 2015; Soltani et al. 2021).

Construction of a subsea power cable from Augustine Island to the Kenai Peninsula would require trenching and burial of an approximately 60-mile-long cable which would result in impacts to a small area of benthic habitat. Subsea cables are generally buried in a narrow trench that is dredged by specialized cable laying barges. Routing for a cable to the Kenai Peninsula from Augustine Island would likely cross

Essential Fish Habitat (EFH) for salmon, groundfish, and Pacific scallops in lower Cook Inlet (NPFMC 2014, 2018; NPFMC et al. 2018); and would cross through northern sea otter critical habitat that surrounds the island (74 FR 51988). Dredging and cable installation can result in destruction of organisms and habitats that can lead to long-term or permanent damage depending on the extent and type of habitat disturbed and mitigation measures used (Limpinsel et al. 2017; 74 FR 51988).

While power plant construction and operation has the potential to disturb habitat, geothermal power plants, like any other power plant, must comply with local, state, and federal laws and regulations that protect sensitive habitats, and sensitive fish and wildlife (Kagel et al. 2007).

2. Potential Effects on Fish and Shellfish

Nearshore areas provide nursery and rearing habitats for salmon, groundfish, and forage fish (Limpinsel et al. 2017). Potential impacts on fish and shellfish from geothermal exploration and development on Augustine Island could result from water withdrawal and discharge of cooling water; spills and leaks of fuels, hazardous substances, or geothermal fluids; and habitat loss or alteration from construction of a subsea power cable (Limpinsel et al. 2017; Soltani et al. 2021).

Estuarine and marine water withdrawal for power plant cooling with subsequent discharge of heated and/or chemically treated discharge water can impact fish and aquatic animals through entrainment, impingement, and degraded water quality. Eggs and larval stages of fish may be entrained with cooling water potentially subjecting these life stages to increased heat, antifouling chemicals, physical abrasion, and rapid pressure changes. Long-term water withdrawal may add an additional source of mortality to early life stages which may adversely affect recruitment and year-class strength for fish and shellfish populations. Fish and aquatic organisms too large to be entrained may become trapped against or impinged on screens on water intake structures. Power plant entrainment and impingement studies in coastal areas find that most entrained larvae are resident forage fishes; with less potential for population-level impacts in coastal areas than for power plants located in bays and estuaries. Pink and chum salmon may be particularly susceptible to entrainment because they typically enter estuarine and marine habitats immediately after emergence from spawning gravels (Limpinsel et al. 2017).

Thermal effluents in inshore habitats can directly alter benthic communities and kill aquatic organisms, especially ichthyoplankton. Water temperatures regulate biochemical processes and the behavior (e.g., migration) and physiology (e.g., metabolism) of aquatic organisms (Limpinsel et al. 2017). Changes in water temperature may also favor the establishment of invasive aquatic plants and animals that can displace native fishes and impair habitat quality (Wetang'ula 2004). Power plants may use anti-fouling agents and biocides, such as sodium hypochlorite and sodium bisulfate, to clean intake and discharge structures which are extremely toxic to aquatic life (Limpinsel et al. 2017).

Vessel operations for crew transport and cable installation pose a risk of accidental spills which would affect water quality. Diesel is the most used and spilled fuel. Fish, invertebrates, and plants that come in direct contact with a diesel spill may be killed and fish kills have been reported for small spills in confined, shallow waters. Crabs and bivalves can also be impacted from small diesel spills in shallow, nearshore areas (Michel et al. 2013; Limpinsel et al. 2017).

Installation of subsea power cables can impact fish and shellfish through the destruction of benthic organisms and habitats, increased turbidity, and potential resuspension and release of contaminants. Excavation of organisms and habitats during cable installation can result in long-term or permanent damage depending on the degree and type of disturbance and the mitigation measures used. Increased turbidity resulting from the subsea cable installation can result in decreased primary production and displace fish from the area of the increased turbidity. Erosion around buried cables can lead to uncovering and the formation of an open trench that can interfere with the migration movements of benthic animals. In addition, electric fields generated by submarine cables may be detectable by some fishes resulting in attraction or avoidance of area around the cable (Limpinsel et al. 2017).

3. Potential Effects on Wildlife

Geothermal plants are generally designed to minimize effects on wildlife and vegetation: pipes are insulated to prevent heat loss, power plants are fenced to prevent wildlife access, spill containment systems are put in place, and siting power plants in areas with high concentrations of wildlife or sensitive vegetation is usually avoided (Kagel et al. 2007). Wildlife most likely to be affected by geothermal exploration, development, and operation on Augustine Island with associated vessel and aircraft traffic are nesting, molting, and migrating birds, foraging northern sea otters, and pupping and molting harbor seals. Additional marine mammals including whales, porpoises, and sea lions would be temporarily disturbed by dredging and installation of a subsea power cable which would require monitoring to avoid and minimize injury and disturbance of marine mammals.

The loudest sounds are produced during construction, which is the noisiest phase of geothermal development. Noise from normal power plant operation is generated by the cooling tower, the transformer, and the turbine-generator building (Kagel et al. 2007). Chronic and frequent noise such as operating compressors can interfere with an animal's ability to detect important sounds, while periodic, unpredictable noises can be interpreted as threatening (Francis and Barber 2013). If noise becomes a constant stressor, it can reduce reproductive success and long-term survival (FHWA 2004).

Cumulative habitat and fish and wildlife impacts from geothermal exploration, development, and production could include: land use, water use, noise, traffic disturbance, air and water pollution, and waste heat generation. Habitat and fish and wildlife in the Permit Area are influenced by periodic disturbance from eruptions of Augustine Volcano. Fish are not known from freshwaters on Augustine Island, but nearshore waters provide habitat for razor clams, spawning Pacific herring, and multiple life-stages of salmon and groundfish. Wildlife on and around Augustine Island are primarily birds, sea otters, harbor seals, and red foxes.

a. Birds

Disturbance from vehicles and human activity can affect the success of waterfowl nesting near facilities (Meixell and Flint 2017). The presence of industrial facilities and human activity, and associated noise can alter bird use leading to displacement, reduced productivity, and potentially reduced survival near facilities (Francis and Barber 2013; Thomas et al. 2014; Yoo and Koper 2017). While few studies have been conducted specific to impacts to birds from geothermal energy development, a recent study in Kenya identified both reduced abundance and reduced diversity of savannah bird communities in areas disturbed by geothermal development compared to undisturbed habitats (John 2018).

Seabirds, waterfowl, and songbirds can collide with vessels, coastal buildings, cooling towers, and communication towers especially during poor weather conditions (Veltri and D. Klem 2005; Loss 2016). Exploration, drilling, supporting vessel and aircraft traffic, and production noise could disturb seabirds, shorebirds, and waterfowl away from important habitat areas, potentially displacing them into lower quality habitats that could lead to reduced survival or reproduction potential. Awareness and avoidance of seasonal concentration areas for seabirds, shorebirds, and waterfowl would minimize these potential impacts (Gill and Tibbitts 1999; Larned 2006; Renner et al. 2017; ASG 2019).

Molting waterfowl are particularly vulnerable to disturbance because they cannot fly (Lacroix et al. 2003), and during migration staging waterfowl and shorebirds have limited amounts of time to gain resources at staging areas to fuel migration. Molting areas used by Steller's eiders are primarily located west and south of Augustine Island (Figure 3) and Steller's eiders are not likely to be disturbed by geothermal activities on or transportation to Augustine Island which would likely be initiated from Homer to the east. Staging shorebirds rely on nutrients and energy consumed during spring migration to ensure successful nesting once they reach breeding grounds throughout the state. Disturbance and displacement during these periods can reduce survival and productivity (Gill and Tibbitts 1999; ASG 2019). Tidal mudflats, such as those found around the lagoon between Augustine and West Augustine Islands, likely provide a feeding area for migratory birds (ADF&G 1985; ORR 2019).

Low altitude aircraft overflights and close approaches of cliff-nesting seabird colonies by vessels causes stress and can result in part or all birds flushing from nesting colonies (Rojek et al. 2007), although effects on burrow-nesting seabirds may be lessened. Disturbances that flush birds from nest sites may increase predation by bald eagles that likely also nest on Augustine Island. Flushing and displacement of seabird adults or broods from preferred habitats during pre-nesting, nesting, and brood rearing can cause disruption of courtship, chick loss, egg breakage, and predation (Rojek et al. 2007). Experimental aircraft overflights effects on fall staging geese at Izembek Lagoon determined that geese were more reactive to rotary-winged aircraft (helicopters) than fixed-wing aircraft overflights and that the lateral distance between birds and aircraft was the critical factor in determining disturbance (Ward et al. 1999).

Migratory birds are protected by the Migratory Bird Treaty Act and bald eagles and their nests are protected by the Bald and Golden Eagle Protection Act. Timing ground disturbance and vegetation clearing outside of migratory bird nesting periods minimizes impacts to nesting birds (USFWS 2020b), and disturbing activities are generally prohibited within a 330 foot buffer around bald eagle nests and blasting is prohibited within 1/2 mile of bald eagle nests (USFWS 2021).

b. Sea Otters

Populations of northern sea otters in southwestern Alaska declined substantially between about 1990 and surveys in 2015. Tinker and others (2021) investigated changes in the distribution and abundance of sea otters over this 25-year period with patterns in reproduction, mortality, body size and condition, diet and foraging behavior, food availability, health profiles, and exposure to environmental contaminants. Populations near Katmai and in Prince Willian Sound were considered stable/growing. Survey data implied that increased mortality rather than reduced reproduction or dispersal was the most likely demographic mechanism for the decline. Based on a weight-of-evidence approach, predation by one or several groups of killer whales was the best supported hypothesis for the increased mortality leading to southwest distinct population segment (DPS) sea otter population decline (Tinker et al. 2021).

Geothermal development activities most likely to affect sea otters include dredging to install a subsea power cable, aircraft and vessel traffic, and noise and activity from construction and operation of a power plant. Dredging can change macroinvertebrate prey availability and abundance through sediment suspended in the water column and direct burial. The magnitude of adverse effects from dredging depends on the nature of the dredged sediments, disposal locations, and the benthic community composition.

Vessel and air traffic are common sources of disturbance for sea otters. Boat strikes of sea otters from 1996 to 2019 caused about 4 percent of mortalities based on 1,474 necropsies. Most collision reports are for small, fast-moving vessels, with the probability of sea otter death or serious injury increasing with increasing vessel speed. Sea otters are also vulnerable to fouling of their fur resulting in hypothermia and toxic effects from exposure to fumes or ingestion of spilled fuels. Small spills of fuel and other contaminants associated with vessel traffic seem to be increasing and can be detrimental to small numbers of sea otters in localized areas (USFWS 2020a).

Potential cumulative effects from prolonged or repeated disturbance from traffic and noise include displacement from preferred foraging areas, increased stress levels, increased energy expenditure, masking of communication, and the impairment of thermoregulation of neonates. Sea otters have very high metabolic rates, require a large amount of food, and spend up to 45 percent of their time feeding. Increased disturbance can lead to decreased foraging, resting, and grooming. While energy expended responding to six disturbances within 66 feet (20 meters) per day represents <1 percent of the daily food requirement, chronic exposure to disturbance may have significant longer-term impacts (USFWS 2020a).

Southwest DPS northern sea otters are protected under both the Endangered Species Act (ESA) and the Marine Mammal Protection Act (MMPA). The US Fish and Wildlife Service manages potential harassment of northern sea otters and their habitats through ESA consultation and MMPA incidental harassment authorizations and incidental take regulations. Typical mitigation measures include avoiding aircraft disturbance through maintaining minimum 1,000-foot flight altitudes; minimizing construction disturbance through maintaining a minimum 33-foot (10-meter) radius for in-water construction; and minimizing vessel disturbance through limiting vessel approaches to 1,640 feet (500 meters) from rafting sea otters, and reducing vessel speeds and limiting approaches of sea otters within 328 feet (84 FR 37716).

c. Harbor Seals

Harbor seals haul out on land or glacial ice to give birth and rear pups, rest, escape predators, and molt. Haulout sites are fundamental to harbor seal survival and reproduction. In Cook Inlet harbor seals select haulout sites near available prey and away from Cook Inlet communities (Montgomery et al. 2007). About 1,155 harbor seals hauled out around Augustine Island in August 2017 (AFSC 2019). Generally the largest concentrations (key haulouts ≥ 50 seals; Figure 4) are located on the southeast side of the island during molting in August (Boveng et al. 2011).

Harbor seals concentrate around Augustine Island during breeding and molting during May through September. While the northwest side of Augustine Island is used throughout the year, the southeast side is used in high concentrations during the molt in August. Haulout locations are chosen in response to environmental conditions. Prevailing winds in Cook Inlet are typically from the southeast, so the northwest side of the island is generally the lee side which is used across all seasons. Pup numbers and ratios show a preference for haulout sites protected from prevailing winds on the northwest side of the island. Reduced winds in the late summer make the relatively large southern beaches more suitable for prolonged haul-out bouts for molting seals, and in August the number of seals using the southeast side of the island increases (Boveng et al. 2011).

Disturbance of harbor seals hauled out on land can cause seals to temporarily, long-term, or permanently abandon haulout sites, or change haul out timing. Studies have found increased tolerance of harbor seals to repeated small boat disturbances, with increased responses when pups are present (Jansen et al. 2015). When threatening disturbances are frequent, seals may alter haul out times, or abandon haulouts, although seals have also been shown to habituate to frequent disturbance. Pregnant and postpartum females are more sensitive to disturbance, and successful weaning and pup production can be reduced by chronic disturbance (Jansen et al. 2015; Mathews et al. 2016).

Seals hauled out on glacial icebergs were found to enter the water at higher rates when vessels were present (>2 times) or within 330 feet – 100 meters (3.7 times), and when a pup was present (1.3 times). Harbor seal fitness could be reduced by vessel disturbances during breeding and pupping (Mathews et al. 2016). In Kenai Fjords National Park, disturbance (flushing from haulouts) was associated with 5.1 percent of vessel sightings, 28 percent of vessel interactions (vessel observed within about 980 feet [300 meters] of seals), 11.5 percent of kayak sightings, and 61 percent of kayak interactions. Voluntary changes in operations were found to reduce vessel and kayak disturbance of seals by 60 to 80 percent. (Hoover-Miller et al. 2013).

Installation of a subsea power cable would likely disturb some shoreline, nearshore, and benthic habitats used by harbor seals and could temporarily displace seals from these habitats. Aircraft and vessel traffic to and from the Permit Area could disturb some harbor seals. Permanent shoreside facilities located less than 1,640 feet (500 meters) from haulout locations used by more than 50 animals would likely result in long-term displacement of harbor seals from these traditionally used haulouts. Careful facility siting and aircraft overflights and vessel approaches that avoid key haulout locations and hauled out seals would minimize potential disturbance of harbor seals.

Harbor seals are protected under MMPA and geothermal activities that disturb harbor seals may require consultation with marine mammal specialists as described in mitigation measures in Chapter Nine. The National Marine Fisheries Service manages potential harassment of harbor seals through MMPA incidental harassment authorizations and incidental take regulations. Typical mitigation measures could include avoiding aircraft disturbance through maintaining a minimum 1,640-foot (500-meter) flight separation distance; minimizing construction disturbance through maintaining a minimum 328-foot (100-meter) exclusion zone for in-water pile driving during construction; and vessel strike and disturbance avoidance procedures (84 FR 37442).

4. Mitigation Measures

Geothermal power plant construction and operation with associated transportation related facilities have the greatest potential for cumulative effects on habitats and fish and wildlife populations in the area. A facility could include a network of well pads and pipelines, a power plant, airstrip, roads, and potentially a dock or barge landing area that could cover habitat and displace animals. Mitigation measures in this best interest finding, along with regulations imposed by federal, state, and local agencies are expected to avoid, minimize, and mitigate potential effects to habitats and fish and wildlife populations.

Mitigation measures included in this best interest finding address avoidance of habitat loss; protection of wetland, riparian, and aquatic habitats; disturbance avoidance; and free passage and movement of fish and wildlife. Other measures and regulatory protections address seismic surveys, siting of facilities, pipelines, drilling waste, and fuel spill prevention and control. New facilities are required to be located away from lakes, rivers, and streams. Any water intake structures in fish bearing waters will be designed, operated, and maintained to prevent fish entrapment, entrainment, or injury. All water withdrawal equipment must be equipped and must use fish screening devices approved by Alaska Department of Fish and Game (ADF&G) and withdrawal volumes may be regulated. Surface discharge of drilling muds and cuttings is prohibited. Disposal of wastewater into water bodies is prohibited unless authorized by an APDES permit. Mitigation measures require subsurface disposal of produced water (geothermal fluids, brine) through reinjection. Best management practices and mitigation including perpendicular crossing of waterways by roads and pipelines, appropriately sized culverts and bridges, and siting permanent infrastructure at least 1/2 mile from fish-bearing waters minimize the potential for cumulative effects of geothermal activities in the Permit Area. To minimize disturbance to wildlife, mitigation measures require operators to minimize sight and sound impacts for new facilities on important wildlife habitat.

Mitigation measures included in this finding, along with regulations imposed by other federal, state, and local agencies, can minimize many negative effects of geothermal exploration, development, and power production activities. Mitigation measures and regulations, however, cannot protect activities and facilities from eruptions of an active volcano. A complete listing of mitigation measures can be found in Chapter Nine. Chapter Seven lists requirements for solid waste and wastewater disposal in the Permit Area.

D. Reasonably Foreseeable Cumulative Effects on Fish and Wildlife Uses

As described in Chapter Five fish and wildlife resources in the Permit Area support commercial and sport fisheries, which may experience cumulative effects from geothermal exploration and development as described above. Potential geothermal exploration and development activities that could have cumulative effects on fish and wildlife uses within the Permit Area include discharges from well drilling and geothermal power plant construction and operation, and ongoing disturbances from power plant operation such as vessel and aircraft traffic. In addition, spills could potentially occur during geothermal exploration and development, and power plant operation. No cumulative effects from geothermal activities in the Permit Area on Augustine Island are expected for wildlife or wildlife viewing at the McNeal River State Game Sanctuary.

1. Potential Effects on Commercial and Sport Fishing

Geothermal development activities most likely to affect commercial and sport fishing include dredging to install a subsea power cable; aircraft and vessel traffic; and any water intake or wastewater discharge impacts to fish and invertebrates from operation of a power plant. Construction of a subsea power cable from Augustine Island to the Homer area could temporarily displace commercial and sport fishers. A small area of scallop habitat and some scallops east of Augustine Island would also likely be affected by dredging and construction of a subsea power cable and could interfere with harvest of this resource. Increased aircraft and/or vessel traffic associated with operation of a power plant on Augustine Island is not expected to disrupt commercial or sport fishers in the lower Cook Inlet region. Potential water intake and discharge would be regulated and are not expected to result in population-level fish or invertebrate impacts that would affect management or harvest levels of salmon and groundfish fisheries.

2. Potential Effects on Subsistence

Although Augustine Island and state waters around Augustine Island are located within the Anchorage – Mat-Su – Kenai Peninsula nonsubsistence use area, federal waters east of Augustine Island are used for subsistence harvest of Pacific halibut, Pacific cod, black rockfish, and salmon (Jones and Kostick 2016; Holen 2019). Construction of a subsea power cable from Augustine Island to the Homer area would cross through these federal waters and could temporarily displace subsistence fishers.

3. Mitigation Measures

Potential water intake or wastewater discharge impacts on fisheries resources around Augustine Island would be minimized by ADF&G regulations that require water intake structures to be screened to minimize entrainment and withdrawal rates controlled to minimize impingement of fish and invertebrates. Wastewater discharges are regulated by ADEC and would require an APDES discharge permit which would minimize potential impacts to water quality, temperature, and fisheries resources in the area.

Mitigation measures in this best interest finding require consultation with potentially affected subsistence communities, commercial and sport fisheries, and the Kenai Peninsula Borough to discuss the siting, timing, and methods of proposed operations in subsistence areas and mitigating measures that could be implemented to prevent unreasonable conflicts. After installation, the subsea power cable is not expected to impact subsistence, commercial or sport fisheries.

E. Reasonably Foreseeable Cumulative Effects on Historic and Cultural Resources

1. Potential Effects on Historic and Cultural Resources

If development occurs, impacts and disturbance to historic and cultural resources could be associated with installation and operation of drill pads, roads, airstrips, docks, pipelines, camp, power plant, and any other ground disturbing activities. Damage to undiscovered archaeological sites can include direct breakage of cultural objects; damage to vegetation and the thermal regime, leading to erosion and deterioration of organic sites; shifting or mixing of components in sites resulting in loss of association between objects; and damage or destruction of archeological or historic sites. The Permit Area contains no documented historic or prehistoric sites and has a low potential for containing other cultural resources (OHA 2021; Weinberger 2021). However, if a site, structure, or object of prehistoric, historic, or archaeological significance is discovered during permit/lease operations, the permittee must report the discovery to the director as soon as possible and take steps to protect it.

2. Mitigation Measures

Historic and cultural resources are irreplaceable, and caution is necessary to protect these resources. Appropriation, excavation, removal, damage to, or destruction of any state-owned cultural site is prohibited under AS 41.35.200. All field-based workers are required to adhere to historic properties protection policies that reinforce these statutory requirements, and to immediately report any historic property that they see or encounter. Mitigation measures in Chapter Nine address surveys to identify and measures to protect historic and archeological sites.

F. Reasonably Foreseeable Fiscal and Other Effects on the State and Communities

1. Potential Effects on the State and Communities

The state may permit or lease state-owned land for development of geothermal resources. Disposal and leasing activities alone are not expected to have any effects, other than to provide initial revenue to the state. The related revenue sources include rental and royalty payments. There are currently no active geothermal resource production activities on state land.

Geothermal development on Augustine Island has potential to have long-term and positive economic effects for the State of Alaska. Future revenue sources to the state that could be derived from the project would be lease rental charges and production royalties outlined in 11 AAC 84.770. Property tax revenues would also accrue to the Kenai Peninsula Borough. Additional economic benefits would result from project spending with potential opportunities for Alaskan firms likely for material, labor, transportation, construction, and other contract services.

Development of an Augustine Island geothermal project would be in two phases. The initial survey and exploration phase may include geophysical surveys and drilling of one or more exploration wells to determine the size and temperature of the resource. The lithology and temperature of the resource will inform the size and capacity of the project. The second phase would involve the development of the project infrastructure comprised of wells, pipelines, water handling and turbine facilities, roads, subsea power transmission cables, control systems, and personnel housing, transportation, and maintenance facilities. The initial phase which could last 2 to 3 years would have smaller amounts of spending for survey crews and exploration drilling. Most of the spending and employment for labor, materials, services, and transportation would likely peak during the second phase of development and construction, an additional 3 to 5 years. Spending and employment would drop considerably during the operational phase of the project due to the efficiencies of geothermal electricity production and reduced manpower needs (Soltani et al. 2021).

A geothermal development project on Augustine Island faces significant development risk. This would be a greenfield development with no existing infrastructure in place making it a challenging project. Geothermal wells also typically cost more than oil and gas wells which translates into higher up-front costs and a longer payback period, 5.7 years compared to other renewable energy sources (Soltani et al. 2021). A successful geothermal project would help to diversify the state's energy supply and economic base. This project has the potential to be the state's first volcanic geothermal development. The project would demonstrate the viability of a new energy source in Alaska. The project also has the potential to help establish a geothermal industry in Alaska across regions that have already been identified as having geothermal energy potential.

Finally, an additional benefit to the state would result from adding a new source of electricity generation and capacity to the Cook Inlet region. Currently, electricity is primarily generated for the region by use of natural gas-fired turbines. Geothermal electricity generation has the potential to be a reliable source of power for decades and could provide energy security to the Cook Inlet region contributing to the economic wellbeing of Alaskans. Geothermal electricity provides a consistent price to consumers as its cost does not rise and fall with oil and gas prices. Geothermal electricity generation can also be combined with other renewable sources of energy like wind or solar providing additional energy, higher reliability, and reduced costs (Soltani et al. 2021).

The Alaska Energy Authority (AEA) rated the state as commercially ready to implement geothermal technology. Siting, permitting, and customer markets must overcome the risk of bearing the high exploration and capital investments in the initial development phases. Power plants must be designed to maximize reservoir potential and sustainability. Adequate financing is required for plant and transmission line construction. It may take 2 to 3 years to construct a small power plant (2 to 3 megawatts), and 10 years to construct a plant exceeding 10 megawatts capacity. Operational costs may be low after power generation begins for properly managed reservoirs and facilities. Operating and maintenance costs for a geothermal power plant can range from $15 to $30 per megawatt, or $.015 to $.03 per kilowatt (AEA 2009). AEA does not currently fund geothermal power projects in the state, but plans to bring the geothermal program online when funding is available (AEA 2021). These estimates are speculative and based on AEA information on standard expectations. Current interest in geothermal power is with exploration companies without agreements or input from Railbelt utilities.

2. Mitigation Measures

Mitigation measures encourage the permittee to employ local Alaska residents and contractors, to the extent they are available and qualified. Operators must submit, as part of the plan of operations, a plan detailing the means by which they will comply with mitigation measures. This plan must describe the operator’s plans for partnering with local communities to recruit, hire, and train local and Alaska residents and contractors to the extent allowed under the Alaska Constitution.

G. References

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Chapter Nine: Mitigation Measures

Operations will be conditioned by mitigation measures that are attached to all geothermal prospecting permits or leases (permits) issued and are binding on the permittee or lessee (permittee). These measures were developed to mitigate potential effects of permit-related activities, considering all information made known to the director. Additional measures may be imposed when the permittee submits a proposed plan of operations, exploration, or development (11 AAC 84.750, 11 AAC 84.755, or 11 AAC 84.760). The director may consult with local organizations, government, and other agencies in implementing the mitigation measures below. The permittee is subject to applicable local, state, and federal laws and regulations, as amended. Permittees are notified, however, that mitigation measures may not protect activities and facilities from the effects of Augustine Volcano.

The director may grant exceptions to these mitigation measures upon a showing by the permittee that compliance with the mitigation measure is not practicable and that the permittee will undertake an equal or better alternative to satisfy the intent of the mitigation measure. Requests and justifications for exceptions must be included in the plan of operations application as specified by the application instructions, and decisions of whether to grant exceptions will be made during the plan of operations review.

A. Mitigation Measures

1. Facilities and Operations

a. Geothermal facilities, including pipelines, will be designed using industry-accepted engineering codes and standards. Technical submittals to the Division of Oil and Gas (DO&G) that reflect the "practice of engineering," as defined by AS 08.48.341, must be sealed by a professional engineer registered in the State of Alaska.

b. A plan of operations will be submitted and approved before conducting exploration, development, or production activities in accordance with 11 AAC 84.

c. The permittee or operator will provide a plan to address potential geohazard impacts on operations to mitigate risk to facilities and personnel.

d. The permittee or operator will coordinate with the Alaska Volcano Observatory and the Division of Geological and Geophysical Surveys to avoid disturbance to monitoring equipment on Augustine Island and to ensure that the permittee or operator is aware of Augustine Volcano's current activity status at all times when personnel are on-site.

e. Facilities will be designed and operated to minimize sight and sound impacts in areas of high residential, recreational, and subsistence use and important wildlife habitat.

f. The siting of facilities, other than docks or barge landings and road, utility, and pipeline crossings, is prohibited within 1/2 mile of the coast as measured from the mean high-water mark and 500 feet of all fish bearing waterbodies.

g. Impacts to important wetlands will be minimized to the satisfaction of the director, in consultation with the Alaska Department of Fish and Game (ADF&G) and Alaska Department of

Environmental Conservation (ADEC). The director will consider whether facilities are sited in the least sensitive areas.

h. Exploration roads, pads, and airstrips will be temporary. Use of gravel roads, pads, and airstrips may be permitted on a case-by-case basis by the director, in consultation with Division of Mining, Land, and Water (DMLW) and ADF&G.

i. Road and pipeline crossings will be aligned perpendicular or near perpendicular to watercourses.

j. Pipelines and gravel pads will facilitate the containment and cleanup of spilled fluids, use existing transportation corridors wherever possible, and be buried where soil and geophysical conditions permit.

k. Wherever possible, transmission lines will use existing transportation corridors and must be designed and constructed to minimize impacts to fish and wildlife movement.

l. Upon abandonment of material sites, drilling sites, roads, buildings or other facilities, such facilities must be removed, and the site rehabilitated to the satisfaction of the state, unless the state, in consultation with any non-state surface owner, as applicable, determines that such removal and rehabilitation is not in the state's interest.

m. Material sites required for exploration and development activities will be restricted to the minimum necessary to develop the geothermal field efficiently and with minimal environmental damage.

n. Permittees will conduct a second order survey of the land surface before and during hydrothermal resources production to determine any elevation changes. If production results in subsidence, and if subsidence is determined to be hazardous to geothermal production operations or adjoining land uses, the permittees will adjust production and injection rates or suspend operations.

o. The state may install seismographs or other instruments in producing geothermal fields to detect induced seismic activity. If geothermal production induces increased seismicity and if induced seismicity is determined to be hazardous to geothermal production operations or adjoining land uses, permittees will adjust production and injection rates or suspend operations.

2. Fish and Wildlife Habitat

a. Detonation of explosives is prohibited in open water areas of fish bearing waterbodies. Blasting criteria have been established by ADF&G and are available upon request. The location of known fish-bearing waters within the permit area can be obtained from ADF&G.

b. Removal of water from fish-bearing rivers, streams, and natural lakes shall be subject to prior written approval by DMLW and ADF&G.

c. Any water intake structures in fish-bearing waterbodies will be designed, operated, and maintained to minimize fish entrapment, entrainment, or injury. All water withdrawal equipment must use fish screening devices approved by ADF&G.

d. The director, in consultation with ADF&G, will restrict or modify permit- or lease-related activities if scientific evidence documents the presence of Steller's eiders from the Alaska breeding population in the area and it is determined that geothermal exploration and development will impact them or their overwintering habitat in the nearshore waters of Cook Inlet.

e. To minimize disturbance to marine mammals, consultation with federal or other marine mammal specialists should be conducted.

3. Commercial, Sport, and Subsistence Harvest Activities

a. Permit and lease-related use may be restricted, if necessary, to prevent unreasonable conflicts between geothermal exploration and development activities and commercial, sport, and local subsistence harvest activities. The permittee will consult with the Kenai Peninsula Borough (KPB), ADF&G, nearby communities, and native organizations for assistance in identifying and contacting local commercial, sport, and subsistence user groups.

b. Before submitting a plan of operations for either onshore or offshore activities which have the potential to disrupt commercial, sport, and local subsistence harvest activities, the permittee shall consult with KPB and potentially affected subsistence users (parties) to discuss the siting, timing, and methods of proposed operations and safeguards or mitigating measures that could be implemented by the operator to prevent unreasonable conflicts. The parties shall also discuss the reasonably foreseeable effect on harvest activities of any other operations in the area that they know will occur during the permittee’s proposed operations. Through this consultation, the permittee shall make reasonable efforts to assure that exploration, development, and production activities are compatible with harvest activities and will not result in unreasonable interference with harvests.

4. Fuel, Hazardous Substances, and Waste

a. Secondary containment will be provided for the storage of fuel or hazardous substances and sized as appropriate to container type and according to governing regulatory requirements in 18 AAC 75 and 40 CFR 112. Containers with an aggregate storage capacity of greater than 55 gallons that contain fuel or hazardous substances shall not be stored within 100 feet of a waterbody or within 1,500 feet of a current surface drinking water source.

b. During equipment storage or maintenance, the permittee will ensure that the site is protected from leaking or dripping fuel and hazardous substances by the placement of drip pans or other surface liners designed to catch and hold fluids under the equipment, or by creating an area for storage or maintenance using an impermeable liner or other suitable containment mechanism.

c. During fuel or hazardous substance transfer, the permittee will ensure that secondary containment or a surface liner is placed under all container or vehicle fuel tank inlet and outlet points, hose connections, and hose ends. Appropriate spill response equipment, sufficient to respond to a spill of up to 5 gallons, must be on hand during any transfer or handling of fuel or hazardous substances.

d. The permittee will ensure that vehicle refueling will not occur within the annual floodplain, except as addressed and approved in the plan of operations. This measure does not apply to waterborne vessels.

e. The permittee will ensure that all independent fuel and hazardous substance containers are permanently marked with the contents and the permittee's or contractor's name.

f. The permittee will ensure that waste from operations is reduced, reused, or recycled to the maximum extent feasible and prudent. Garbage and domestic combustibles must be incinerated whenever possible or disposed of at an approved site in accordance with 18 AAC 60.

g. New solid waste disposal sites, other than for drilling waste, will not be approved or located on state property for exploration. Disposal sites may be provided for drilling waste if the facility complies with 18 AAC 60.

h. The preferred method for disposal of drilling mud and cuttings from geothermal drilling is by underground injection. The permittee will ensure that drilling mud and cuttings will not be discharged into lakes, streams, rivers, or wetlands. On-pad temporary cuttings storage may be allowed as necessary to facilitate annular injection and backhaul operations.

i. All produced water will be disposed to the subsurface to eliminate the potential for contamination of surface water or a drinking water aquifer.

5. Access

a. Public access to, or use of, the permit area may not be restricted, except within the immediate vicinity of drill sites, buildings, and other related structures. Areas of restricted access must be identified in the plan of operations. Facilities and operations will not block access to or along navigable or public waters as defined in AS 38.05.965.

6. Prehistoric, Historic, and Archaeological Sites

a. Before the construction or placement of any structure, road, or facility resulting from exploration, development, or production activities, the permittee must conduct an inventory of prehistoric, historic, and archaeological sites within the area, including a detailed analysis of the effects that might result from that construction or placement.

b. The inventory of prehistoric, historic, and archeological sites must be submitted to the director and to the Office of History and Archaeology (OHA), who will coordinate with the KPB for review and comment. If a prehistoric, historic, or archaeological site or area could be adversely affected by a permit/lease activity, the director, after consultation with OHA and KPB, will direct the permittee as to the course of action to take to avoid or minimize adverse effects.

c. If a site, structure, or object of prehistoric, historic, or archaeological significance is discovered during permit/lease operations, the permittee will report the discovery to the director as soon as possible. The permittee will make all reasonable efforts to preserve and protect the discovered site, structure, or object from damage until the director, after consultation with OHA and KPB, has directed the permittee on the course of action to take for its preservation.

7. Hiring Practices

a. The permittee is encouraged to employ local and Alaska residents and contractors, to the extent they are available and qualified, for work performed in the permit area. Permittees will submit, as part of the plan of operations, a hiring plan that will include a description of the operator's plans for partnering with local communities to recruit, hire, and train local and Alaska residents and contractors to the extent allowable under State and federal law. As a part of this plan, the permittee is encouraged to coordinate with employment and training services offered by the State of Alaska and local communities to train and recruit employees from local communities.

b. A plan of operations application must describe the permittee's past and prospective efforts to communicate with local communities and interested local community groups.

c. A plan of operations application must include a training program

   i. for all personnel including contractors and subcontractors;

   ii. designed to inform each person working on the project of environmental, social, and cultural concerns that relate to that person's job;

   iii. using methods to ensure personnel understand and use techniques necessary to preserve geological, archaeological, and biological resources; and

   iv. designed to help personnel increase their sensitivity and understanding of community values, customs, and lifestyles in areas where they will be operating.

B. Definitions

Facilities – Any structure, equipment, or improvement to the surface, whether temporary or permanent, including, but not limited to, roads, pads, docks, material sites, waste disposal sites, water supplies, power generating facilities, pipelines, power lines, generators, utilities, airstrips, wells, compressors, drill rigs, camps, and buildings.

Hazardous substance – As defined under 42 USC 9601 – 9675 (Comprehensive Environmental Response, Compensation, and Liability Act of 1980).

Important wetlands – Those wetlands that are of high value to fish, waterfowl, and shorebirds because of their unique characteristics or scarcity in the region or that have been determined to function at a high level using the hydrogeomorphic approach.

Minimize – To reduce adverse impacts to the smallest amount, extent, duration, size, or degree reasonable in light of the environmental, social, or economic costs of further reduction.

Plan of operation – A geothermal lease or prospecting permit plan of operations under 11 AAC 84.750.

Practicable – Feasible in light of overall project purposes after considering cost, existing technology, and logistics of compliance with the mitigation measure.

Reasonable access – Access using means generally available to subsistence users.

Secondary containment – An impermeable diked area, portable impermeable containment structure, or integral containment space capable of containing the volume of the largest independent container. The containment will, in the case of external containment, have enough additional capacity to allow for local precipitation.

Temporary – No more than 12 months.