NATIONAL
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Environmental Impact Statement for the Arecibo Observatory Arecibo, Puerto Rico

Final

July 27, 2017

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Prepared for

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Cover Sheet

Final Environmental Impact Statement

Arecibo Observatory, Arecibo, Puerto Rico

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Abstract: The National Science Foundation has produced a Final Environmental Impact Statement (FEIS) to analyze the potential environmental impacts associated with potential funding changes for Arecibo Observatory in Arecibo, Puerto Rico. The six Alternatives analyzed in the FEIS are as follows:
1) collaboration with interested parties for continued science-focused operations (the Agency-preferred Alternative); 2) collaboration with interested parties for transition to education-focused operations;
3) mothballing of facilities; 4) partial demolition and site restoration; 5) complete demolition and site restoration; and 6) the No-Action Alternative. The environmental resources and concerns considered in the FEIS are biological resources, cultural resources, geology and soils, groundwater, hazardous materials, solid waste, health and safety, noise, socioeconomics, traffic and transportation, and visual resources.

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Executive Summary

ES.1 Introduction

This Final Environmental Impact Statement (FEIS) has been prepared by the National Science Foundation (NSF) to evaluate the potential environmental effects of proposed operational changes due to funding constraints for Arecibo Observatory in Arecibo, Puerto Rico. The EIS was prepared in compliance with the National Environmental Policy Act of 1969 (NEPA) (42 United States Code §§4321, *et seq*.); Council on Environmental Quality (CEQ) Regulations for Implementing the Procedural Provisions of NEPA (Title 40 *Code of Federal Regulations* [C.F.R.] Parts 1500–1508); and NSF procedures for implementing NEPA and CEQ regulations. The National Aeronautics and Space Administration (NASA) has requested to be a cooperating agency in the NEPA process.

Public and agency scoping on the preliminary Alternatives and issues of concern was initiated with the publication of a Notice of Intent (NOI) to prepare a Draft Environmental Impact Statement (DEIS) in the *Federal Register* on May 23, 2016. Public scoping meetings on this topic were held on June 7, 2016, in San Juan and Arecibo, Puerto Rico. The DEIS was published and distributed to federal, state, local, and private agencies, organizations, and individuals for review and comment; it was also filed with the U.S. Environmental Protection Agency (EPA). A Notice of Availability (NOA) for the DEIS was published in the *Federal Register* on October 28, 2016, and in local newspapers. DEIS public meetings were conducted on November 16, 2017, in Arecibo and on November 17, 2016, in San Juan. NSF considered the public and agency comments in developing the scope of the analysis in the DEIS and in preparing the FEIS.

Arecibo Observatory is located in the western portion of the Island of Puerto Rico, approximately 10 miles (16 kilometers) south of the City of Arecibo at the southern terminus of Puerto Rico Highway 625 (PR-625). A key component of Arecibo Observatory is a 305-meter-diameter, fixed, spherical reflector. Arecibo Observatory infrastructure includes instrumentation for radio and radar astronomy and ionospheric physics, office and laboratory buildings, a visitor and education facility, and lodging facilities for visiting scientists. The Observatory employs 136 individuals, including approximately 16 scientific staff. The remainder of the employees work in support roles, including food service, software, maintenance, and as telescope operators (National Astronomy and Ionosphere Center [NAIC], 2016a; SRI International, 2016). The Angel Ramos Foundation Science and Visitor Center receives over 90,000 visitors per year. Approximately 30 percent of these visitors are schoolchildren.

NSF acknowledges that valuable science and education activities are conducted at Arecibo Observatory, as evidenced by decades of substantial funding of both the facility and research grants. However, the purpose of the current Proposed Action is to reduce NSF funding in light of a constrained budgetary environment. Neither the merits of science and education activities at Arecibo Observatory nor NSF's budgetary decisions are the focus of this review. As explained in the DEIS and during public meetings, NSF relies on the scientific community, via decadal surveys and senior-level reviews, to provide input on priorities, and this community has repeatedly recommended NSF divestment from Arecibo Observatory, as well as from other observatories currently under similar review. These recommendations are summarized in this document only to explain the need for the current proposal. In accordance with NEPA, the DEIS and this FEIS analyze the potential environmental impacts of a range of alternatives to meet the objective of reduced NSF funding for Arecibo Observatory.

ES.2 Purpose and Need

The need for NSF to reduce funding for Arecibo Observatory has been established through reviews and surveys conducted by the scientific community. In 2010, the National Research Council (NRC) conducted its sixth decadal survey in astronomy and astrophysics. In their report, *New Worlds, New Horizons in Astronomy and Astrophysics,* the NRC committee recommended the following:

> "NSF-Astronomy should complete its next senior review before the mid-decade independent review that is recommended in this report, so as to determine which, if any, facilities NSF-AST should cease to support in order to release funds for (1) the construction and ongoing operation of new telescopes and instruments and (2) the science analysis needed to capitalize on the results from existing and future facilities." (NRC, 2010a)

In response to this recommendation, the NSF Directorate for Mathematical and Physical Sciences (MPS) commissioned a subcommittee of the MPS Advisory Committee to assess the portfolio of the Division of Astronomical Sciences (AST) within MPS. This subcommittee, composed solely of external members of the scientific community, was charged with recommending a balanced portfolio to maximize the science recommended by decadal surveys, under constrained budget scenarios. The resulting Portfolio Review Committee (PRC) Report was released in August 2012. It recommended the divestment of a number of telescopes from the federal portfolio to maintain a balance of small-, medium-, and large-scale programs that would best address decadal survey science. With respect to Arecibo Observatory, the PRC Report recommended that "AST should reevaluate its participation in Arecibo and SOAR later in the decade in light of the science opportunities and budget forecasts at that time" (NSF, 2012).

This follows from a recommendation made by the AST Senior Review Committee in 2006: "The National Astronomy and Ionosphere Center [former name for Arecibo Observatory]...should seek partners who will contribute personnel or financial support to the operation of Arecibo...by 2011 or else these facilities should be closed" (NSF, 2006). The Senior Review Committee Report also noted that "If Arecibo is kept operating beyond 2011, it is expected that this will only be a limited-term extension, pending the deliberations of the next decadal survey" (NSF, 2006).

While the AST was the primary funder of Arecibo for over a decade (funding $10.6M annually in 2006, reducing over the years to $4.1M in 2016), the Geospace Section (GS) of the NSF Division of Atmospheric and Geospace Sciences in the Directorate for Geosciences (GEO) was an early co-funder of Arecibo Observatory operations and now provides approximately half of the current NSF funding ($4.1 million annually from GS) for Arecibo. In 2016, a subcommittee of the GEO Advisory Committee concluded its own community-based portfolio review, which recommended a significant and specific funding reduction: "The GS should reduce its M&O [Management and Operations] support for the Arecibo Observatory (AO) to $1.1M by 2020, i.e., to a proportional *pro rata* level approximately commensurate with its fractional NSF GS proposal pressure and usage for frontier research" (NSF, 2016a).

The continued need for the NSF to respond to the PRC Report was reinforced in the annual report of the Congressionally chartered Astronomy and Astrophysics Advisory Committee (AAAC) in March 2016, which recommended that "[s]trong efforts by NSF for facility divestment should continue as fast as is possible" (NSF, 2016b). More recently, in August 2016, the National Academies of Sciences, Engineering, and Medicine (NAS) mid-decadal report, *New Worlds, New Horizons, A Midterm Assessment*, recommended: "The National Science Foundation (NSF) should proceed with divestment from ground-based facilities which have a lower scientific impact, implementing the recommendations of the NSF Portfolio Review, that is essential to sustaining the scientific vitality of the U.S. ground-based astronomy program as new facilities come into operation" (NAS, 2016).

The scientific community evaluations cited previously indicate that the scientific capability of Arecibo Observatory is lower in priority than other scientific capabilities the NSF funds. In a funding-constrained environment, NSF needs to maintain a balanced research portfolio with the largest scientific return for the taxpayer dollar. Therefore, the purpose of this Proposed Action is to substantially reduce NSF's contribution to the funding of Arecibo Observatory.

ES.3 Public Disclosure and Involvement

NSF notified, contacted, and/or consulted with agencies, individuals, and organizations during development of this EIS. Public disclosure and involvement regarding the Proposed Action included pre-assessment notification letters to agencies, social media announcements, website updates, scientific digest and blog postings, newspaper public notices, public scoping meetings (conducted on June 7, 2016, in San Juan and Arecibo) and DEIS public meetings (conducted on November 16, 2017, in Arecibo and on November 17, 2016, in San Juan). Both English and Spanish versions of media notifications and the materials distributed during the meetings were made available to the public. An English/Spanish interpreter was present during all public meetings and interpretation was provided to the public. Detailed information about these activities is provided in Section 5. The public was encouraged to comment during the requisite comment period of the scoping process and after publication of the DEIS. The DEIS was published and distributed to federal, state, local, and private agencies, organizations, and individuals for review and comment, and it was filed with the EPA. An NOA was announced in the *Federal Register* on October 28, 2016. A detailed summary of comments received during the public comment periods is presented in Section 5.

ES.4 Alternatives under Consideration

The following Alternatives are considered in detail in this FEIS; additional alternatives that were not considered in detail are also discussed in this FEIS. The basis for the Alternatives includes the public comments received during the public scoping period and input received from the scientific community.

ES.4.1 Alternative 1: Collaboration with Interested Parties for Continued Science-focused Operations (Agency-preferred Alternative)

Alternative 1 would involve collaborations with new stakeholder(s) who would use and maintain Arecibo Observatory for continued science-focused operations. NSF would reduce its funding of the Observatory and the new stakeholder(s) would be responsible for future upgrades. Under this Alternative, NSF could transfer or retain the property. Alternative 1 would involve the least change to the current facility and would retain the 305-meter-diameter telescope, 12-meter-diameter telescope, and supporting facilities for research.

Onsite housing, recreation facilities, and other buildings determined to be unnecessary would be demolished. Paved roads serving areas that would no longer be used would be removed. The analysis assumes that up to 26 structures could be demolished and no new construction would occur; this represents the maximum amount of disturbance that could result. The specific buildings that would be demolished cannot be known until after a collaborative agreement is in place. Through interaction with the scientific community, NSF identified the structures that may be removed. The analysis in the EIS assumes that all buildings identified for possible demolition would be demolished, as that represents the maximum amount of disturbance expected for each Alternative. However, it must be emphasized that a collaboration may not require the full extent of activities analyzed and could involve none of the activities listed in Table ES-1 or a subset of the activities.

Demolition of buildings and infrastructure would include physical dismantling of structures and the use of heavy equipment to break up and remove concrete portions. Demolition debris would be recycled and reused to the extent possible, and any remaining materials would be properly disposed of in a commercial landfill. Haul trucks would transport the demolition debris from Arecibo Observatory to recycle/reuse centers in nearby municipalities and the remaining debris to a landfill in Poncé.

Table ES-1 provides a detailed list of the 25 buildings and infrastructure that would remain and the 26 buildings and infrastructure that could be removed under Alternative 1.

Equipment, tools, machinery, furniture, and ancillary items with salvage value that are no longer needed for the collaboration to operate would be disposed of in accordance with federal law. Gates and fencing would be evaluated to determine whether upgrades are needed to provide appropriate security and access around portions of the site that would require protection. Existing utilities would be maintained and limited site restoration would occur. Site restoration would include reestablishing native plant species in areas where buildings have been. The demolition period for Alternative 1 is expected to take 12 weeks. Depending on the availability of funds, activities may be spread out over multiple fiscal years.

Landscaped areas would be maintained during operations. All infrastructure related to the 12-meter and 305-meter telescopes would be maintained during operations to prevent the degradation of the instruments and to keep vegetation from overgrowing the facilities. Operations would be expected to continue during demolition activities. Demolition activities that could interfere with the experimental use of the 12-meter and 305-meter telescopes and data collection would be coordinated with Observatory staff to minimize the potential for disrupting scientific work.

Operations after demolition activities would be comparable to current operations.

Alternative 1 is NSF’s Preferred Alternative. This Alternative would meet the Purpose and Need of reducing the funding required from NSF, while allowing continued benefits to the scientific and educational communities. However, Alternative 1 can only be implemented if new stakeholders come forward to participate as collaborating parties, with viable proposed plans to provide additional non-NSF funding in support of their scientific-focused operations.

ES.4.2 Alternative 2: Collaboration with Interested Parties for Transition to Education-focused Operations

Alternative 2 would involve collaborating with outside entities to operate and maintain Arecibo Observatory as an education-focused operation. An official collaboration would be created to keep the science center open for students and visitors. New collaborators could include Commonwealth agencies, educational institutions, industrial or commercial ventures, or private individuals. Under this Alternative, NSF could transfer or retain the property.

The visitor center, learning center, and 12-meter telescope would remain operational. The 305-meter telescope would be made inoperable but retained for visual/historical interest. Retaining the 305-meter telescope dish would require that it be secured and regularly maintained so that structural elements would not degrade or be overgrown by vegetation.

Structures not needed to meet the anticipated operational goals would be safe-abandoned or demolished. The majority of residential housing and recreational facilities would not be retained under Alternative 2.

Table ES-1 provides a detailed list of the 19 buildings and infrastructure that would remain, the 27 buildings and infrastructure that could be removed, which include the 26 items identified under Alternative 1 plus the operations building, and buildings to be safe-abandoned. Specific buildings that would be demolished cannot be known until after a collaborative agreement is in place. NSF identified the 27 structures that may be removed through communication with the scientific community. The analysis assumes that all 27 structures would be demolished and no new construction would occur, which represents the maximum amount of disturbance that would result.

Equipment, tools, machinery, furniture, and ancillary items with salvage value that are no longer needed for the education-based facility to operate would be disposed of in accordance with federal law. Existing utilities would be maintained. There would be limited site restoration to establish native plant species where buildings were previously located. The demolition period for Alternative 2 is expected to take 12 weeks. Depending on the availability of funds, activities may be spread out over multiple fiscal years.

Landscaped areas would be maintained during operations. All infrastructure related to the 12-meter telescope would be maintained during operations to prevent the degradation of the instruments and to keep vegetation from overgrowing the facilities.

Operations associated with education would be expected to continue during removal of unnecessary structures. Demolition activities that could interfere with the experimental use of the 12-meter telescope and data collection would be coordinated with Observatory staff to minimize the potential for disrupting scientific work.

Operations after demolition would be comparable to current operations. It is anticipated that a staff comparable in size to current operations would work onsite under Alternative 2.

ES.4.3 Alternative 3: Mothballing of Facilities

Alternative 3 would involve mothballing (preservation of) essential buildings, telescopes, and other equipment, with periodic maintenance to keep them in working order. This method would allow the facility to suspend operations in a manner that would permit operations to resume efficiently at some time in the future. It is not known what type of operations would be implemented when the mothball phase ends. Operations at the time of resumption could be similar to current operations, other science-based operations, education-based operations, or some other type of operations. Because of this uncertainty, the resumption of operations is not considered part of Alternative 3.

Supporting structures would be evaluated to determine whether they are critical to the operation of the 12-meter and 305-meter telescopes. Structures and facilities that are obsolete and not needed would be removed. Table ES-1 provides a detailed list of the eight facilities that would remain, the 14 facilities that could be removed, and the 29 facilities that could be mothballed under Alternative 3.

A maintenance program would be required to protect the facilities from deterioration, vandalism, and other damage. Regular security patrols would be performed to monitor the site. Common mothballing measures, such as providing proper ventilation, keeping roofs and gutters cleaned of debris, and performing ground maintenance and pest control, would be implemented. Lubrication and other deterioration-preventing measures would be required on the 305-meter-diameter telescope dish, the Gregorian dome, and the support cables for the 305-meter-diameter telescope dish and the Gregorian dome.

Visitor housing and recreational areas would be closed indefinitely under Alternative 3, with water lines drained and electricity turned off. All supplies, books, photographs, furnishings, and other items not needed for periodic maintenance would be removed from the site. Equipment, tools, machinery, furniture, and ancillary items that would not be needed for resumption of operations and that have salvage value would be disposed of in accordance with federal law.

Limited site restoration would be performed to establish native plant species where buildings were previously located. Gates and fencing would be evaluated to determine whether upgrades would be needed to provide appropriate security and access around portions of the site that would require protection. The implementation period for Alternative 3 is expected to take 15 weeks. Depending on the availability of funds, activities may be spread out over multiple fiscal years.

Landscaped areas would be maintained during the mothball period. All infrastructure related to the 12-meter and 305-meter telescopes would be conditioned for safe storage to prevent the degradation of the equipment and to allow operations to be restarted. Regular vegetation maintenance would be implemented to keep vegetation from overgrowing the facilities.

For purposes of the analysis in this FEIS, it is assumed that operations would be suspended for an indefinite time and then resumed at some point in the future. It is anticipated that technical staff responsible for operating the 12-meter and 305-meter-diameter telescopes, scientific support staff, and cafeteria workers would not be retained. However, it is expected that current staffing levels for facilities maintenance would remain the same under Alternative 3 due to the level of maintenance required to keep the infrastructure operable.

ES.4.4 Alternative 4: Partial Demolition and Site Restoration

Alternative 4 involves the demolition of all above-grade structures, except the large concrete structures (that is, towers, tower and catwalk anchors, and rim wall infrastructure). All below-grade foundations would be stabilized and filled in. Table ES-1 identifies the facilities that would be removed and safe-abandoned under Alternative 4.

Equipment, tools, machinery, furniture, and ancillary items with salvage value would be disposed of in accordance with federal law. Demolition of the telescopes and other structures would be conducted during the same timeframe. If another use is identified for the 12-meter telescope, it would be repurposed and relocated rather than demolished. The demolition period for Alternative 4 is expected to take 28 weeks. Depending on the availability of funds, activities may be spread out over multiple fiscal years.

Site restoration would include revegetation of the areas disturbed during demolition with native plant species. Revegetated areas would be maintained for a period of 18 months and vegetation maintenance staff would be retained through this period.

Under Alternative 4, operations at Arecibo Observatory would cease; therefore, it is anticipated that under this Alternative staffing levels would not be maintained.

ES.4.5 Alternative 5: Complete Demolition and Site Restoration

Alternative 5 involves the demolition of all above-grade structures, including the large concrete structures (that is, towers, anchors, and rim wall infrastructure). Below-grade foundations would be removed and the areas backfilled. Explosives may be used to demolish the three towers, six tower anchors, catwalk anchor, and rim wall infrastructure supporting the 305-meter telescope dish. Explosives, if used, would be limited to low-force charges designed to transfer the explosive force only to the structure designated for removal.

Equipment, tools, machinery, furniture, and ancillary items with salvage value would be disposed of in accordance with federal law. Facilities and structures would be demolished. Demolition of the radio telescopes and other structures would be conducted during the same timeframe. If another use is identified for the 12-meter telescope, it would be repurposed and relocated rather than demolished. The demolition period for Alternative 5 is expected to take 38 weeks. Depending on the availability of funds, activities may be spread out over multiple fiscal years.

Site restoration would include revegetation of areas disturbed during demolition with native plant species. Revegetated areas would be maintained for a period of 18 months and vegetation maintenance staff would be retained through this period.

Under Alternative 5, operations at the Observatory would cease; therefore, it is anticipated that staffing levels under this Alternative would not be maintained.

ES.4.6 No-Action Alternative: Continued NSF Investment for Science-focused Operations

Under the No-Action Alternative, NSF would continue funding Arecibo Observatory at current levels. None of the Proposed Action Alternatives would be implemented.

TABLE ES-1
Building Status by Alternative

	Alternative 1: Collaboration with Interested Parties for Continued Science-focused Operations*	**Alternative 2: Collaboration with Interested Parties for Transition to Education-focused Operations***	**Alternative 3: Mothballing of Facilities**	**Alternative 4: Partial Demolition and Site Restoration**	**Alternative 5: Complete Demolition and Site Restoration**
Buildings and Infrastructure to Remain*	1. Reflector Dish and 305-meter Telescope 2. Foundation and Rim Wall Infrastructure 3. Towers 4. Tower and Catwalk Anchors 5. Phase Reference Antenna (12-meter) 6. Operations Center 7. Cable Car House 8. Visiting Scientist Quarters/Cafeteria 9. Entrance Guard House 10. Pump House 11. Maintenance Building 12. Photometry Shack/ Optical Lab 13. Cummings Generator Control Building 14. Cummings Generator Building 15. Main Gate Restroom 16. Grease Pit 17. 750-kilowatt Emergency Generator Building 18. Visitor Center 19. Lidar Laboratory 20. Learning Center 21. Cryogenics Laboratory Trailer 22. Inspiration for Science Office Trailer 23. Engineering Office Building 24. North Visiting Scientists Quarters (VSQ) Building 25. Tank Farm	1. Phase Reference Antenna (12-meter) 2. Visiting Scientist Quarters/Cafeteria 3. Entrance Guard House 4. Pump House 5. Maintenance Building 6. Photometry Shack/ Optical Lab 7. Cummings Generator Control Building 8. Cummings Generator Building 9. Main Gate Restroom 10. Grease Pit 11. 750-kilowatt Emergency Generator Building 12. Visitor Center 13. Lidar Laboratory 14. Learning Center 15. Cryogenics Laboratory Trailer 16. Inspiration for Science Office Trailer 17. Engineering Office Building 18. North VSQ Building 19. Tank Farm	1. Entrance Guard House 2. Cable Car House 3. Pump House 4. Lewis Building 5. Cummings Generator Control Building 6. Cummings Generator Building 7. Main Gate Restroom 8. Engineering Office Building		
Buildings and Infrastructure to be Demolished*	1. Administration Building 2. Swimming Pool/Recreation Area 3. Lewis Building 4. Bowl Shack 5. Warehouse Building 6. Antenna Testing Building 7. Paint and Flammable Material Storage 8. S-Band High Voltage Power Supply Building 9. Antenna Receiving Testing Building 10. Shielded Trailer 11. Atmospheric Science Trailer 12. Scientific Office Trailer 13. HF Transmitter Building 14. Coffee Hut 15. HFF Storage Trailer 16. Electronics Cable Trailer 17. Electronic Trailer 18. Visitor Center Trailer 19. Computer Trailer 20. Ionosonde Trailer 21. Electronic Trailer (Waveguide) 22. Electronic Trailer (Cryogenic) 23. West Hill Bachelor Unit 1	1. Operations Building 2. Administration Building 3. Swimming Pool / Recreation Area 4. Lewis Building 5. Bowl Shack 6. Warehouse Building 7. Antenna Testing Building 8. Paint and Flammable Material Storage 9. S-Band High Voltage Power Supply Building 10. Antenna Receiving Testing Building 11. Shielded Trailer 12. Atmospheric Science Trailer 13. Scientific Office Trailer 14. HF Transmitter Building 15. Coffee Hut 16. HFF Storage Trailer 17. Electronics Cable Trailer 18. Electronic Trailer 19. Visitor Center Trailer 20. Computer Trailer 21. Ionosonde Trailer 22. Electronic Trailer (Waveguide) 23. Electronic Trailer (Cryogenic)	1. Grease Pit 2. Coffee Hut 3. HFF Storage Trailer 4. Electronics Cable Trailer 5. Electronic Trailer 6. Visitor Center Trailer 7. Computer Trailer 8. Ionosonde Trailer 9. Electronic Trailer (Waveguide) 10. Electronic Trailer (Cryogenic) 11. West Hill Bachelor Unit 1 12. West Hill Bachelor Unit 2 13. West Hill Family Unit 1 14. West Hill Family Unit 2	1. Reflector Dish and 305-meter Telescope 2. Phase Reference Antenna (12-meter) 3. Operations Building 4. Administration Building 5. Visiting Scientist Quarters/Cafeteria 6. Entrance Guard House 7. Cable Car House 8. Pump House 9. Swimming Pool/ Recreation Area 10. Lewis Building 11. Maintenance Building 12. Bowl Shack 13. Warehouse Building 14. Antenna Testing Building 15. Paint and Flammable Material Storage 16. Photometry Shack/ Optical Lab 17. S-Band High Voltage Power Supply Building 18. Cummings Generator Control Building 19. Cummings Generator Building 20. Main Gate Restroom 21. Grease Pit 22. 750-kilowatt Emergency Generator Building	1. Reflector Dish and 305-meter Telescope 2. Foundation and Rim Wall Infrastructure 3. Towers 4. Tower and Catwalk Anchors 5. Phase Reference Antenna (12-meter) 6. Operations Building 7. Administration Building 8. Visiting Scientist Quarters/Cafeteria 9. Entrance Guard House 10. Cable Car House 11. Pump House 12. Swimming Pool/Recreation Area 13. Lewis Building 14. Maintenance Building 15. Bowl Shack 16. Warehouse Building 17. Antenna Testing Building 18. Paint and Flammable Material Storage 19. Photometry Shack/Optical Lab 20. S-Band High Voltage Power Supply Building 21. Cummings Generator Control Building 22. Cummings Generator Building 23. Main Gate Restroom

TABLE ES-1
Building Status by Alternative

	Alternative 1: Collaboration with Interested Parties for Continued Science-focused Operations*	**Alternative 2: Collaboration with Interested Parties for Transition to Education-focused Operations***	**Alternative 3: Mothballing of Facilities**	**Alternative 4: Partial Demolition and Site Restoration**	**Alternative 5: Complete Demolition and Site Restoration**
	24. West Hill Bachelor Unit 2 25. West Hill Family Unit 1 26. West Hill Family Unit 2	24. West Hill Bachelor Unit 1 25. West Hill Bachelor Unit 2 26. West Hill Family Unit 1 27. West Hill Family Unit 2		23. Visitor Center 24. Antenna Receiving Testing Building 25. Lidar Laboratory 26. Shielded Trailer 27. Learning Center 28. Atmospheric Science Trailer 29. Cryogenics Laboratory Trailer 30. Scientific Office Trailer 31. HF Transmitter Building 32. Inspiration for Science Office Trailer 33. Coffee Hut 34. Engineering Office Building 35. HFF Storage Trailer 36. Electronics Cable Trailer 37. Electronic Trailer 38. Visitor Center Trailer 39. Computer Trailer 40. Ionosonde Trailer 41. Electronic Trailer (Waveguide) 42. Electronic Trailer (Cryogenic) 43. West Hill Bachelor Unit 1 44. West Hill Bachelor Unit 2 45. West Hill Family Unit 1 46. West Hill Family Unit 2 47. North VSQ Building 48. Tank Farm	24. Grease Pit 25. 750-kilowatt Emergency Generator Building 26. Visitor Center 27. Antenna Receiving Testing Building 28. Lidar Laboratory 29. Shielded Trailer 30. Learning Center 31. Atmospheric Science Trailer 32. Cryogenics Laboratory Trailer 33. Scientific Office Trailer 34. HF Transmitter Building 35. Inspiration for Science Office Trailer 36. Coffee Hut 37. Engineering Office Building 38. HFF Storage Trailer 39. Electronics Cable Trailer 40. Electronic Trailer 41. Visitor Center Trailer 42. Computer Trailer 43. Ionosonde Trailer 44. Electronic Trailer (Waveguide) 45. Electronic Trailer (Cryogenic) 46. West Hill Bachelor Unit 1 47. West Hill Bachelor Unit 2 48. West Hill Family Unit 1 49. West Hill Family Unit 2 50. North VSQ Building 51. Tank Farm
Buildings and Infrastructure to be Safe-abandoned*	None	1. Reflector Dish and 305-meter Telescope 2. Foundation and Rim Wall infrastructure 3. Towers 4. Tower and Catwalk Anchors 5. Cable Car House	None	1. Foundation and Rim Wall Infrastructure 2. Towers 3. Tower and Catwalk Anchors	None
Buildings and Infrastructure to be Mothballed*	None	None	1. Reflector Dish and 305-meter Telescope 2. Foundation and Rim Wall Infrastructure 3. Towers 4. Tower and Catwalk Anchors 5. Phase Reference Antenna (12-meter) 6. North VSQ Building 7. Tank Farm 8. Operations Building 9. Administration Building 10. Visiting Scientist Quarters-/ Cafeteria 11. Swimming Pool/ Recreation Area 12. Maintenance Building 13. Bowl Shack 14. Warehouse Building 15. Antenna Testing Building	None	None

TABLE ES-1
Building Status by Alternative

	Alternative 1: Collaboration with Interested Parties for Continued Science-focused Operations*	Alternative 2: Collaboration with Interested Parties for Transition to Education-focused Operations*	Alternative 3: Mothballing of Facilities	Alternative 4: Partial Demolition and Site Restoration	Alternative 5: Complete Demolition and Site Restoration
			16. Paint and Flammable Material Storage 17. Photometry Shack / Optical Lab 18. S-Band High Voltage Power Supply Building 19. 750-kilowatt Emergency Generator Building 20. Visitor Center 21. Antenna Receiving Testing Building 22. Lidar Laboratory 23. Shielded Trailer 24. Learning Center 25. Atmospheric Science Trailer 26. Cryogenics Laboratory Trailer 27. Scientific Office Trailer 28. HF Transmitter Building 29. Inspiration for Science Office Trailer		

* Depending on the needs of the collaborators under Alternatives 1 and 2, the actual number of buildings and infrastructure demolished could be less than those listed above.

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ES.5 Resources Not Considered in Detail

Initial analysis indicated that certain resource areas would not have the potential for noticeable or measurable impacts under any of the considered Alternatives. These resource areas are identified here and not discussed for the individual Alternatives:

- Air Quality: The Proposed Action could involve the use of diesel generators and short-term emissions associated with demolition. However, Arecibo Observatory is located in an area that is in full attainment for all National Ambient Air Quality Standards (NAAQS) criteria pollutants. Therefore, Clean Air Act (CAA) conformity analysis is not required and given the project activities, there is no potential for the Proposed Action to cause a violation in CAA NAAQS. Any air quality impacts would be negligible on a regional basis.
- Climate Change: Operations at Arecibo Observatory under Alternatives 1 and 2 may require increased use of diesel generators. For example, if usage hours were to double, there could be an increase of approximately 250 additional metric tons of carbon dioxide equivalent (CDE) generated annually. However, usage hours by potential future partners is speculative at this time, and neither this generator usage nor short-term greenhouse gas (GHG) emissions from demolition activities would appreciably affect climate change. Note that there would be a long-term decrease in GHG emissions under Alternatives 4 and 5, as well as under Alternative 3 during the mothballed stage. The location of the facility is such that impacts from climate change are not expected to affect operations.
- Land Use: Because of the relatively small area and remote location, the change in land use among the Alternatives would not be noticeable.
- Surface Waters: There is no potential for direct or indirect impacts to surface water under any Alternative.
- Utilities: No new utility infrastructure would be required and utility usage would either stay the same or be reduced under any Alternative.

ES.6 Mitigation Measures

Under Alternatives 1 through 5, appropriate mitigation measures to include best management practices (BMPs) have been identified that would be implemented to reduce the potential for impacts. Mitigation measures that would be implemented include:

Air Quality

All Alternatives: Contracts for demolition work would require idle reduction and proper equipment maintenance to reduce emissions during demolition.

Biological Resources

- All Alternatives: The expected areas of disturbance that were analyzed to determine potential impacts to protected species would be provided to prospective bidders to provide demolition services. If a bidder indicated that additional areas, including additional or widened roads, would be needed to complete the work, NSF would delay the award until additional consultation with U.S. Fish and Wildlife Service (USFWS), including additional surveys, had been completed.
- All Alternatives: Worksites would be clearly marked and workers would be instructed to stay within the marked areas.
- All Alternatives: Staging areas would be placed in disturbed areas whenever possible.
- All Alternatives: If offsite soil is needed to backfill an excavated area, the minimum amount of soil needed would be brought onto the site.
- All Alternatives: As appropriate, soil to be planted would be augmented with nutrients, organic matter, or bulking agents to provide an appropriate medium for root establishment and subsequent growth of the species selected for planting.
- All Alternatives: A site-specific stormwater pollution prevention plan (SWPPP) would be developed to support the National Pollutant Discharge Elimination System stormwater permit.
- All Alternatives: Erosion control measures such as riprap, check-dams, and compost filter berms would be used to protect exposed soil and minimize erosion, scouring, and sedimentation. Good housekeeping measures would be practiced during demolition and the disturbed areas would be revegetated. Steep slopes that are disturbed would be protected with biodegradable erosion control measures. Pre-demolition runoff patterns will be restored upon completion of demolition activities.
- All Alternatives: Standard operating procedures for the capture and relocation of Puerto Rican boas (Appendix 4.1-A) would be used during demolition and/or site restoration activities and would be implemented as follows:
  - Train key onsite personnel in the identification of boas and the value of boas and boa conservation by qualified personnel.
  - Complete daily pre-work surveys of equipment and work areas, including buildings and karst features, by a qualified personnel trained in boa identification and location.
  - Relocate any boas found on equipment or within the day’s work area to the designated relocation area south of the staging yard on the eastern side of the Observatory; this should be done by an individual authorized by the USFWS and trained in handling Puerto Rican boas.

  - Stop work if a boa is observed in the day's work area until a qualified wildlife biologist trained in handling Puerto Rican boas can relocate the snake to the designated relocation area or the boa voluntarily vacates the work area.

- All Alternatives: A pre-demolition survey for active bird nests would be conducted. Any identified active nests would be protected from disturbance by a 100-foot nesting buffer, which would remain in place until the young have fledged from the nest.
- Alternatives 1 and 2: NSF could retain or transfer property. If Arecibo Observatory is transferred out of federal control in the future, then this would be subject to further consultation under Section 7 of the ESA. NSF, in consultation with USFWS, would consider the appropriate land use controls, such as deed restriction and conservation easement, for the natural areas on the Observatory prior to any transfer to a non-federal entity.
- Alternatives 1, 2, and 3: Re-landscaping would use non-invasive species and would incorporate native vegetation if feasible.
- Alternatives 1, 2, and 3: Landscaped areas would be maintained to avoid the propagation of weed species.
- Alternatives 4 and 5: Areas disturbed from demolition activities would be revegetated using native species to the extent possible. If use of non-native species is necessary to achieve site stabilization, only non-invasive species would be planted.
- Alternatives 4 and 5: Revegetated areas will be monitored for 18 months to ensure establishment of desirable species.
- Alternatives 4 and 5: Demolition of the 305-meter-diameter reflector dish and the demolition or safe-abandonment of the rim wall and foundation infrastructure would not be allowed during the typical period when the Puerto Rican broad-winged hawk would initiate nesting behavior until after the young fledge (typically December through May).
- Alternatives 4 and 5: Prior to start of demolition/safe-abandonment, any known Puerto Rican broad-winged hawk nests in proximity/line of sight to the 305-meter-diameter telescope dish would be assessed to determine whether nesting activity or rearing of non-fledged young was occurring. Demolition of the dish and safe-abandonment of the rim wall structures would not be initiated until after young had fledged and voluntarily left the nest.
- Alternative 5: Prior to use of explosives, the area within 100 feet (30 meters) of the proposed detonation would be checked for the presence of birds. The detonation would be delayed until there are no birds within 100 feet (30 meters) of the detonation site.

- Alternative 5: Explosives used for demolition of towers, anchors, foundations, and rim wall infrastructure would be directional charges to focus the explosion on the object to be removed and would be appropriately sized to meet the demolition need while minimizing shock wave propagation through bedrock.
- Alternative 5: NSF commits to further consultation with the USFWS regarding listed species should Alternative 5 be selected. This consultation will be completed prior to starting intrusive work under Alternative 5. As part of that consultation, it is anticipated that USFWS will issue a biological opinion (BO) and NSF will implement appropriate mitigation specified in the BO.

Cultural Resources

- Alternative 1: Implement stipulations specified in the Section 106 Programmatic Agreement (PA), reached through consultation, to avoid, minimize, and/or mitigate any adverse effects on historic properties. These stipulations would also suffice to address the necessary mitigation for major impacts to cultural resources under NEPA. Specific mitigation measures were developed in consultation with the State Historic Preservation Office (SHPO), the Advisory Council for Historic Preservation (ACHP), and Consulting Parties. The PA would be executed prior to signing the NEPA ROD. If Alternative 1 is ultimately not feasible, NSF will resume Section 106 consultation focusing on Alternatives 2 through 5.
- All Alternatives: An unanticipated discovery plan would be developed prior to implementation under the selected Alternative (if demolition is part of that Alternative) to address any archaeological resources that might be discovered during demolition.
- Alternative 3 (if Alternative 1 is not feasible): Mothballing and protecting historic properties would be completed in accordance with U.S. National Park Service's (NPS's) Preservation Brief 31, "Mothballing Historic Buildings" (Park, 1993), *The Secretary of the Interior's Standards for the Treatment of Historic Properties*, (NPS, 1992), and the *Guidelines for Preserving, Rehabilitating, Restoring and Reconstructing Historic Buildings* (Grimmer, 2017).

Geology and Soils

- All Alternatives: A site-specific SWPPP would be prepared and implemented prior to starting demolition activities.
- All Alternatives: Construction stormwater controls would be implemented and maintained to prevent scour and soil loss from runoff.
- All Alternatives: Disturbed areas would be stabilized and revegetated with native plant species to minimize the potential for erosion after demolition is completed. Revegetation would use native

species to the extent possible, and if use of non-native species is necessary, only non-invasive species would be planted.

- All Alternatives: Before any demolition begins, a geophysical survey would be conducted to inspect designated work areas and note any suspected karst features, including sinkholes, solution cavities, and areas of soil subsidence that could be affected by demolition work. The survey would also evaluate soil stability and the vertical and horizontal projection of sinkholes. These features would be avoided when possible and protected with sandbags, nets, and filter fabric. They would be monitored during the work for changes such as soil subsidence, collapse, water infiltration, and clogging.
- All Alternatives: Earth-disturbing activities would be conducted in a manner that minimizes alteration of the existing grade and the hydrology of existing surficial karst features.
- All Alternatives: Previously unknown karst features that are identified during invasive work activities, including blasting and removal of foundations, anchors, towers, and below-grade structures, would be addressed as follows:
  - Work would stop within a 100-foot radius of the feature and the feature would be assessed to identify its potential for connectivity to impact on other karst features such as groundwater conduits, surface water conduits, and caves. The assessment method could include visual assessment, geophysical survey, or other techniques for subsurface characterization of karst features.
  - The karst feature would be either isolated or temporarily sealed to minimize impacts during demolition work (e.g., blocked with sandbags, protected with baskets, nets, or filter fabric).
- Alternative 5: Any use of explosives would be limited to low-force charges that are designed to transfer the explosive force only to the structure that is designated for removal.

Groundwater

- All Alternatives: A site-specific SWPPP would be prepared and implemented prior to starting demolition activities.
- All Alternatives: Construction stormwater controls would be implemented and maintained to prevent scour and soil loss from runoff.
  - Measures such as compost blankets, mulching, riprap, geotextiles, and slope drains would be used to protect exposed soil and minimize potential for erosion and sedimentation.
  - Measures such as check dams, slope diversions, and temporary diversion dikes would be implemented for runoff to prevent runoff from entering sinkholes.

  - Sediment control measures such as compost filter berms and socks; fiber rolls or berms; sediment basins, rock dams, filters, chambers, or traps; silt fences; and weed-free hay bales would be implemented to prevent or reduce sedimentation.
  - Good housekeeping measures would be practiced during demolition.

- All Alternatives: Disturbed areas would be stabilized and revegetated to minimize the potential for erosion after demolition is completed. Revegetation would use native species to the extent possible, and if use of non-native species is necessary, only non-invasive species would be planted.
- All Alternatives: Before demolition begins, a geophysical survey would be conducted to determine whether proposed work areas contain karst features, including sinkholes, solution cavities, or areas of soil subsidence that could be affected by demolition work. The survey also would evaluate soil stability and the vertical and horizontal projection of sinkholes. These features would be avoided when possible and protected with sandbags, nets, and filter fabric. They would be monitored during the work for changes such as soil subsidence, collapse, water infiltration, and clogging.
- All Alternatives: Earth-disturbing activities would be conducted in a manner that minimizes alteration of the existing grade and hydrology of existing surficial karst features.
- All Alternatives: A spill prevention, control, and countermeasures (SPCC) plan would be developed to address risks to groundwater from potential spills. The SPCC plan would include equipment inspections, equipment refueling, equipment servicing and maintenance, equipment washing, and the use and storage of any hazardous materials, chemicals, fuels, lubricating oils, and other petroleum products.
- All Alternatives: Previously unknown karst features that are identified during demolition activities would be addressed as follows:
  - Work would stop within a 100-foot radius of the feature and the feature would be assessed to identify its potential for connectivity to impact other karst features such as groundwater conduits and surface water recharge conduits. The assessment method could include visual assessment, geophysical survey, or other techniques for subsurface characterization of karst features.
  - The karst feature would be either isolated or temporarily sealed to minimize impacts during demolition work (e.g., blocked with sandbags, protected with baskets, nets, or filter fabric).
- Alternative 5: Any use of explosives would be limited to low-force charges designed to transfer the explosive force only to the structure that is designated for removal.

Hazardous Materials

- All Alternatives: Complete site characterization and removal or remediation of contamination would be completed prior to any demolition activities.
- All Alternatives: Hazardous materials and wastes would be used, stored, disposed of, and transported in compliance with all applicable laws and regulations.
- All Alternatives: Demolition contractors would create and implement a spill response plan.
- All Alternatives: NSF would require all demolition contractors to create and implement a demolition management plan, including hazardous materials discovery protocols. The demolition management plan would include, at a minimum, a list of persons to contact in case of a possible encounter with undocumented contamination; provisions for immediate notification of the observation to demolition management; and notification of the regulatory agency with jurisdiction. If previously unknown contamination is found, demolition activities would halt in the vicinity of the find and the next steps would be decided in consultation with the regulatory agency.
- Alternative 5: Explosive materials would be used in accordance with 29 C.F.R. §1926.900 and the Occupational Safety and Health Administration (OSHA) Puerto Rico State Plan.

Solid Waste

- All Alternatives: Whenever possible, demolition debris (such as soil) would be used onsite.
- All Alternatives: Demolition debris would be diverted from landfills through reuse and recycling to the extent practicable.

Health and Safety

- All Alternatives: The contractor would develop and implement a demolition Health and Safety Plan.
- All Alternatives: Arecibo Observatory personnel would comply with OSHA safety protocols.
- All Alternatives: Fencing and signage would be installed around demolition sites.
- Alternative 3: A maintenance and security program would be implemented for mothballed facilities.
- Alternative 4: A security fence would be maintained to limit access to the large concrete structures after partial demolition.
- Alternative 5: Individuals handling explosives would be properly trained and industry standard safety protocols would be implemented.

Noise

- All Alternatives: Demolition areas would be fenced.
- Alternative 5: Explosive materials would be used only during daylight hours.

- Alternative 5: Explosive materials would be small enough caliber to prevent a blast overpressure or sound pressure wave.

Traffic and Transportation

- All Alternatives: Transport of materials and work vehicles would occur during off-peak hours when practicable.
- All Alternatives: Delivery truck personnel and demolition workers would be notified of all potential height restrictions and overhead obstructions.
- All Alternatives: Vehicles used for material transport would be required to comply with local standards for height, width, and length of vehicles, when practicable. If at any time vehicles of excessive size and weight are required on local roads and bridges, NSF will coordinate with the appropriate transportation authority to obtain the necessary permits.
- All Alternatives: NSF will coordinate with the appropriate transportation authority to determine the appropriate mitigation measures to implement in response to road damage.
- All Alternatives: Further detailed waste haul routes and concerns would be addressed during the detailed design phase of the Proposed Action, including verification that all bridge crossings on the delivery routes have adequate strength and capacity.
- All Alternatives: To minimize the impacts of demolition on local residents, the contractor would coordinate with local public schools to ensure demolition and haul routes do not adversely affect school bus traffic.

ES.7 Impact Summary

The impacts for each of the considered alternatives are presented below. The designated impact level under Alternatives 1 through 5 assumes the BMPs and mitigation measures identified above would be implemented. A definition and explanation of each impact is provided in the corresponding resource section in Section 4.0.

Impacts from any of the Alternatives would not result in disproportionately high and adverse impacts to minority and low-income populations. Therefore, there would be no environmental justice concerns associated with the Proposed Action. A detailed explanation of this finding can be found in Section 4.12.

ES.7.1 Alternative 1: Collaboration with Interested Parties for Continued Science-focused Operations (Agency-preferred Alternative)[1]

Biological Resources: During demolition, impacts to biological resources would include minor, adverse, short-term impacts to vegetation and wildlife, and, negligible, adverse, short-term impacts to migratory birds and the endangered Puerto Rican boa, offsite wetlands, and protected plant species. There would be no impacts to biological resources during operations.

Cultural Resources: Demolition would result in a major, adverse, long-term impact to known historic properties that would be considered an adverse effect to historic properties under Section 106 of the National Historic Preservation Act (NHPA). There would be no impacts to known historic properties during operations and no impacts to archaeology are expected during either demolition or operation activities.

Geology and Soils: Demolition impacts to geology and soils would include negligible adverse, short-term impacts to topography and soils and minor, adverse, long-term impacts to karst features. There would be no impacts during operations.

Groundwater: Demolition would result in minor, adverse, short-term impacts from runoff and negligible, adverse, long-term impacts to underlying groundwater. There would be no impacts during operations.

Hazardous Materials: A minor to moderate, long-term benefit to site contamination would be expected during demolition, depending on the level of contamination that must be addressed. A minor, adverse, short-term impact would result from increased use of hazardous materials during demolition. A minor, long-term benefit would occur from the reduced use of hazardous materials during operations.

Solid Waste: Minor, adverse, short-term impacts to solid waste would occur during demolition due to disposal of the debris from demolished structures that could not be reused or recycled. There would be no impact from solid waste during operations.

Health and Safety: Negligible, adverse, short-term impacts to public safety and protection of children during demolition would be expected. Minor, adverse, short-term impacts to occupational health during demolition may occur. Negligible, adverse, and long-term impacts to public safety could occur during operations, primarily resulting from the reduced capability to observe potentially hazardous objects (PHOs) if and only if the new operator did not maintain and operate the planetary radar subsystem.

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[1] The analysis in the EIS assumes that all buildings identified for possible demolition would be demolished, as that represents the maximum amount of disturbance expected for each Alternative. However, it must be emphasized that a collaboration may not require the full extent of activities analyzed and could involve none of the activities listed in Table ES-1 or a subset of the activities.

Noise: Negligible, adverse, short-term impacts to noise from construction equipment and increased traffic would be expected during demolition. There would be no noise impacts during operations.

Socioeconomics: Demolition activities would result in negligible, adverse, short-term impacts to housing and minor, adverse, short-term impact to education and tourism in the Municipality of Arecibo. There would be negligible, short-term benefits to employment, income, and the economy. There would be no socioeconomic impacts during operations.

Traffic and Transportation: Minor, adverse, short-term impacts to traffic and transportation would be expected during demolition. There would be a minor, adverse, long-term impact from road damage during demolition activities. No traffic impacts would be expected during operations.

Visual Resources: Impacts to visual resources during demolition would be minor, adverse, and short-term. No impacts to visual resources would occur during operations.

No adverse cumulative impacts to resources would occur under Alternative 1.

ES.7.2 Alternative 2: Collaboration with Interested Parties for Transition to Education-focused Operations[2]

Biological Resources: During demolition impacts to biological resources would include minor, adverse, short-term impacts to vegetation and wildlife and negligible, adverse short-term impacts to migratory birds and the endangered Puerto Rican boa, offsite wetlands, and protected plant species. There would be no impacts to biological resources during operations.

Cultural Resources: Demolition and operations activities would result in major, adverse, long-term impact to known historic properties that would be considered an adverse effect to historic properties under Section 106 of the NHPA. There would be no impacts to archaeology expected during either demolition or operations activities.

Geology and Soils: Demolition impacts to geology and soils would include negligible adverse, short-term impacts to topography and soils and minor, adverse, long-term impacts to karst features. There would be no impacts during operations.

Groundwater: Demolition would result in minor, adverse, short-term impacts from runoff and negligible, adverse, long-term impacts to underlying groundwater. There would be no impacts during operations.

Hazardous Materials: A minor to moderate, long-term benefit to site contamination would be expected during demolition, depending on the level of contamination that must be addressed. A minor, adverse,

[2] The analysis in the EIS assumes that all buildings identified for possible demolition would be demolished, as that represents the maximum amount of disturbance expected for each Alternative. However, it must be emphasized that a collaboration may not require the full extent of activities analyzed and could involve none of the activities listed in Table ES-1 or a subset of the activities.

short-term impact would result from increased use of hazardous materials during demolition. A minor, long-term benefit would occur from the reduced use of hazardous materials during operations.

Solid Waste: Minor, adverse, short-term impacts to solid waste would occur during demolition due to disposal of the debris from demolished structures that could not be reused or recycled. There would be no impact from solid waste during operations.

Health and Safety: Negligible, adverse, short-term impacts to public safety and protection of children during demolition would be expected. Minor, adverse, short-term impacts to occupational health during demolition may occur. Negligible, adverse, and long-term impacts to public safety could occur during operations, primarily resulting from the reduced capability to observe PHOs.

Noise: Negligible, adverse, short-term impacts to noise from construction equipment and increased traffic would be expected during demolition. There would be no noise impacts during operations.

Socioeconomics: Demolition activities would result in negligible, adverse, short-term impacts to housing and minor, adverse, short-term impact to education and tourism in the Municipality of Arecibo. There would be negligible, short-term benefits to employment, income, and the economy. Impacts during operations would include negligible, adverse impacts to population, housing, the economy, employment and income. A moderate, adverse, long-term impact would result from fewer regional education activities and science, technology, education, and math (STEM) opportunities. A minor, long-term benefit would result from new STEM programs.

Traffic and Transportation: Minor, adverse, short-term impacts to traffic and transportation would be expected during demolition. There would be a minor, adverse, long-term impact from road damage during demolition activities. No traffic impacts would be expected during operations.

Visual Resources: Impacts to visual resources during demolition would be moderate, adverse, and short-term. Impacts during operations would be minor, adverse and long-term.

No adverse cumulative impacts to resources would occur under Alternative 2.

ES.7.3 Alternative 3: Mothballing of Facilities

Biological Resources: During demolition activities, impacts to biological resources would include minor, adverse, short-term impacts to vegetation and wildlife and negligible, adverse, short-term impacts to migratory birds and the endangered Puerto Rican boa, offsite wetlands, and protected plant species. There would be a minor, long-term benefit to migratory birds during the mothball period.

Cultural Resources: Demolition and operations activities would result in major, adverse, long-term impacts to known historic properties that would be considered an adverse effect to historic properties under Section 106 of the NHPA. There would be no impacts to archaeology expected during either demolition or operations activities.

Geology and Soils: Demolition impacts to geology and soils would include negligible, adverse, short-term impacts to topography and soils and minor, adverse, long-term impacts to karst features. There would be no impacts during the mothball period.

Groundwater: Demolition would result in minor, adverse, short-term impacts from runoff and negligible, adverse, long-term impacts to underlying groundwater. A minor, long-term benefit would be expected during the mothball period.

Hazardous Materials: A minor to moderate, long-term benefit to site contamination would be expected during demolition, depending on the level of contamination that must be addressed. A minor, adverse, short-term impact would result from increased use of hazardous materials during demolition. A minor, long-term benefit would occur from the reduced use of hazardous materials during the mothball period.

Solid Waste: Minor, adverse, short-term impacts to solid waste would occur during demolition due to disposal of the debris from demolished structures that could not be reused or recycled. A minor, long-term benefit due to reduced solid waste would be expected during the mothball period.

Health and Safety: Negligible, adverse, short-term impacts to public safety and protection of children during demolition would be expected. Minor, adverse, short-term impacts to occupational health during demolition may occur. Negligible, adverse, long-term impacts to public safety could occur during the mothball period, primarily resulting from the reduced capability to observe PHOs.

Noise: Negligible, adverse, short-term impacts to noise from construction equipment and increased traffic would be expected during demolition. There would be no noise impacts during the mothball period.

Socioeconomics: Demolition activities would result in negligible, adverse, short-term impacts to housing in the Municipality of Arecibo. There would be negligible, short-term benefits to employment, income, and the economy during demolition. Impacts during the mothball period would include negligible adverse, long-term impacts to population, and housing, and minor, adverse, long-term impacts the economy, employment, and income. A moderate, adverse, long-term impact would result from less regional education activities. A major, adverse impact would be expected from reduced STEM opportunities and tourism in Arecibo, while a minor, adverse, long-term impact would be experienced by other local destinations and tourism within the Commonwealth.

Traffic and Transportation: Minor, adverse, short-term impacts to traffic and transportation would be expected during demolition. There would be a minor, adverse, long-term impact from road damage during demolition activities. A minor, long-term benefit would be expected during the mothball period.

Visual Resources: Impacts to visual resources during demolition would be negligible, adverse, and short-term. Visual impacts during the mothball period would be minor, adverse, and long-term.

No adverse cumulative impacts to resources would occur under Alternative 3.

ES.7.4 Alternative 4: Partial Demolition and Site Restoration

Biological Resources: During demolition there would be moderate, adverse, long-term impacts to vegetation and wildlife; minor, adverse, long-term impacts from weeds; and negligible, adverse, short-term impacts to migratory birds, wetlands, the Puerto Rican broad-winged hawk, the Puerto Rican boa and listed plant species. During operations, there would be minor, long-term benefits to wildlife, listed species, and migratory birds.

Cultural Resources: Demolition would result in a major, adverse, long-term impact to known historic properties that would be considered an adverse effect to historic properties under Section 106 of the NHPA. There would be no impacts to known historic properties after demolition and no impacts to archaeology are expected during or after demolition.

Geology and Soils: Demolition impacts to geology and soils would include minor adverse, short-term impacts to topography and karst features and moderate, adverse, long-term impacts to soils. There would be no impacts after demolition.

Groundwater: Demolition would result in minor, adverse, short-term impacts from runoff and negligible, adverse long-term impacts to underlying groundwater. There would be a minor, long-term benefit to due to a reduced lack of groundwater consumption after demolition.

Hazardous Materials: A minor to moderate, long-term benefit to site contamination would be expected during demolition, depending on the level of contamination that must be addressed. A minor, adverse, short-term impact would result from increased use of hazardous materials during demolition. A moderate, long-term benefit would occur from the reduced use of hazardous materials after demolition.

Solid Waste: Minor, adverse, short-term impacts to solid waste would occur during demolition due to the disposal of debris from demolished structures that could not be reused or recycled. There would be a minor, long-term benefit during operations.

Health and Safety: Negligible, adverse, short-term impacts to the protection of children during demolition would be expected. Minor, adverse, short-term impacts to occupational health and public safety during demolition may occur. Negligible, adverse, and long-term impacts to public safety could occur after demolition, primarily resulting from the reduced capability to observe PHOs.

Noise: Negligible, adverse, short-term impacts to noise from construction equipment and increased traffic would be expected during demolition. There would be no noise impacts after demolition.

Socioeconomics: Demolition activities would result in negligible, adverse, short-term impacts to housing in the Municipality of Arecibo. There would be minor, short-term benefits to employment, income, and the economy during demolition. Impacts after demolition would include negligible, adverse impacts to population, and housing; and minor, adverse and long-term impacts to the economy, employment, and income. Major, adverse impacts would be expected from reduced regional education activities, STEM opportunities, and tourism in Arecibo, while a minor, adverse, long-term impact would be experienced by other local destinations and tourism within the Commonwealth.

Traffic and Transportation: Minor, adverse, short-term impacts to traffic and transportation would be expected during demolition. There would be a moderate, adverse, long-term impact from road damage during demolition activities. A moderate, long-term benefit would be expected from reduced traffic after demolition.

Visual Resources: Impacts to visual resources during demolition would be major, adverse, and short-term. No impacts would occur after demolition.

No adverse cumulative impacts to resources would occur under Alternative 4.

ES.7.5 Alternative 5: Complete Demolition and Site Restoration

Biological Resources: During demolition, there would be moderate, adverse, long-term impacts to vegetation and wildlife; minor, adverse, long-term impacts from weeds; minor, adverse, short-term impacts to listed plant species; moderate, adverse, short-term impacts to migratory birds and wetlands; and major, long-term impacts to the Puerto Rican broad-winged hawk and the Puerto Rican boa. During operations, there would be minor, long-term benefits to wildlife, listed species, and migratory birds Potential cumulative impacts could occur to biological resources under Alternative 5. These impacts involve potential cumulative effects to threatened and endangered species.

Cultural Resources: Demolition would result in a major, adverse, long-term impact to known historic properties that would be considered an adverse effect to historic properties under Section 106 of the NHPA. There would be no impacts to known historic properties after demolition and no impacts to archaeology are expected during or after demolition.

Geology and Soils: Demolition impacts to geology and soils would include moderate adverse, short-term impacts to topography, karst features, and soils. There would be no impacts after demolition.

Groundwater: Demolition would result in minor, adverse, short-term impacts from runoff and moderate, adverse long-term impacts to underlying groundwater. There would be a minor, long term benefit to groundwater after demolition.

Hazardous Materials: A minor to moderate, long-term benefit to site contamination would be expected during demolition, depending on the level of contamination that must be addressed. A moderate, adverse, short-term impact would result from increased use of hazardous materials during demolition. A moderate, long-term benefit would occur from the reduced use of hazardous materials after demolition.

Solid Waste: Minor, adverse, short-term impacts to solid waste would occur during demolition due to disposal of the debris from demolished structures that could not be reused or recycled. There would be a minor, long-term benefit during operations.

Health and Safety: Negligible, adverse, short-term impacts to the protection of children during demolition would be expected. Minor, adverse, short-term impacts to occupational health and public safety during demolition may occur. Negligible, adverse, and long-term impacts to public safety could occur after demolition, primarily resulting from the reduced capability to observe PHOs.

Noise: Negligible, adverse, short-term impacts to noise from construction equipment and increased traffic would be expected during demolition. There would be no noise impacts during operations.

Socioeconomics: Demolition activities would result in negligible, adverse, short-term impacts to housing in the Municipality of Arecibo. There would be minor, short-term benefits to employment, income, and the economy during demolition. Impacts after demolition would include negligible, adverse, long-term impacts to population, and housing, and minor, long-term, adverse impacts to the economy, employment, and income. Major, adverse impacts would be expected from reduced regional education activities, STEM opportunities, and tourism in Arecibo after demolition, while a minor, adverse, long-term impact would be experienced by other local destinations and tourism within the Commonwealth.

Traffic and Transportation: Minor, adverse, short-term impacts to traffic and transportation would be expected during demolition. There would be a moderate, adverse, long-term impact from road damage during demolition activities. A moderate, long-term benefit would be expected from reduced traffic after demolition.

Visual Resources: Impacts to visual resources during demolition would be moderate, adverse, and short-term. No impacts would occur after demolition.

ES.7.6 No-Action Alternative: Continued NSF Investment for Science-focused Operations

Under the No-Action Alternative, current operations of Arecibo Observatory would continue. No demolition would occur and no change from current conditions would result. There would be no impacts to resources under the No-Action Alternative.

SECTION 1.0

Purpose and Need

This Final Environmental Impact Statement (FEIS) has been prepared for the National Science Foundation (NSF) to evaluate the potential environmental effects of proposed operational changes due to funding constraints for Arecibo Observatory in Arecibo, Puerto Rico. This FEIS was prepared in compliance with the National Environmental Policy Act of 1969 (NEPA) (42 United States Code [U.S.C.] §§4321, *et seq*.); Council on Environmental Quality (CEQ) *Regulations for Implementing the Procedural Provisions of NEPA* (Title 40 *Code of Federal Regulations* [C.F.R.] Parts 1500–1508); and NSF procedures for implementing NEPA and CEQ regulations (45 C.F.R. Part 640). The NEPA process ensures that environmental impacts of proposed major federal actions are considered in the decision-making process and that the public has an opportunity to participate.

Public and agency scoping on the preliminary Alternatives and issues of concern was initiated with the publication of a Notice of Intent (NOI) to prepare a DEIS in the *Federal Register* on May 23, 2016. Public scoping meetings were held on June 7, 2016, in San Juan and Arecibo, Puerto Rico. A detailed summary of comments received during scoping is presented in Section 5, *Notification, Public Involvement, and Consulted Parties*. These comments were considered in the Draft Environmental Impact Statement (DEIS), which was published online, distributed to federal, state, local, and private agencies, organizations, and individuals, and filed with the U.S. Environmental Protection Agency (EPA). A Notice of Availability (NOA) for the DEIS was announced in the *Federal Register* on October 28, 2016. Public meetings on the DEIS were held on November 16, 2017, in Arecibo and on November 17, 2016, in San Juan. A summary of comments received during the public review period of the DEIS is presented in Section 5, *Notification, Public Involvement, and Consulted Parties*, and a full listing of all categorized comments and responses can be found in Appendix 5-H. Comments received on the DEIS were considered in preparing this FEIS.

NSF acknowledges that valuable science and education activities are conducted at Arecibo Observatory, as evidenced by decades of substantial funding of both the facility and research grants. However, the purpose of the current Proposed Action is to reduce NSF funding in light of a constrained budgetary environment. Neither the merits of the science and education activities at Arecibo Observatory nor NSF's budgetary decisions are the focus of this review. As explained in the DEIS and during public meetings, NSF relies on the scientific community, via decadal surveys and senior-level reviews, to provide input on priorities, and this community has repeatedly recommended divestment from Arecibo Observatory, as well as from other observatories currently under similar review. These recommendations are summarized in this document only to explain the need for the current proposal. In accordance with NEPA, the DEIS and this FEIS analyze the potential environmental impacts of a range of alternatives to meet the objective of reduced NSF funding for Arecibo Observatory.

NSF will issue a Record of Decision (ROD) following the publication of this FEIS to conclude the NEPA and other environmental review processes. Concurrently with this NEPA process, NSF is carrying out its compliance with Section 106 of the National Historic Preservation Act of 1966 (NHPA) as amended (54 U.S.C. §306108, formerly 16 U.S.C. §470f) and the implementing regulations promulgated by the Advisory Council on Historic Preservation (ACHP) found at 36 C.F.R. Part 800 and Section 7 of the Endangered Species Act of 1973 (ESA) (16 U.S.C. §§1531–1544), and the Department of the Interior and Department of Commerce regulations implementing Section 7 on interagency cooperation, which are found at 50 C.F.R. Part 402.

1.1 Project Background and Location

Arecibo Observatory is located in the western portion of the Island of Puerto Rico, approximately 10 miles (16 kilometers) south of the City of Arecibo at the southern terminus of Puerto Rico Highway 625 (PR-625; Figure 1.1-1). Arecibo Observatory is an NSF-owned scientific research and education facility. In 2011, NSF awarded a 5-year Cooperative Agreement to SRI International, which together with the Universities Space Research Association (USRA) and Universidad Metropolitana (UMET) formed the Arecibo Management Team to operate and maintain Arecibo Observatory for the benefit of scientific research communities. Arecibo Observatory enables research in three scientific disciplines: space and atmospheric sciences, radio astronomy, and solar system radar studies; the last of these is largely funded through a research award to USRA from the National Aeronautics and Space Administration (NASA). An education and public outreach program complements the Arecibo Observatory scientific program.

A key component of the Arecibo Observatory research facility is a 305-meter-diameter, fixed, spherical reflector. The Arecibo Observatory infrastructure includes instrumentation for radio and radar astronomy and ionospheric physics, office and laboratory buildings, a visitor and education facility, and lodging facilities for visiting scientists (Figure 1.1-2).

Arecibo Observatory employs 136 persons, including approximately 16 scientific staff. The remainder of the employees work in support roles, including food service, software, maintenance, and as telescope operators (NAIC, 2016a; SRI International, 2016). The Angel Ramos Foundation Science and Visitor Center receives over 90,000 visitors per year. Approximately 30 percent of these visitors are schoolchildren (NAIC, 2016b).

FIGURE 1.1-1
Location Map

FIGURE 1.1-2
Approximate Study Area

1.2 Purpose and Need

NSF's Division of Astronomical Sciences (AST) is the federal steward for ground-based astronomy in the United States, funding research with awards to individual investigators and small research groups, and via cooperative agreements for the operation of large telescope facilities. These national and international telescope facilities provide world-leading, one-of-a-kind observational capabilities on a competitive basis to thousands of astronomers per year. These facilities also enable scientific advances by making archived data products available to researchers. Along with funding telescope facilities and research awards, AST supports the development of advanced technologies and instrumentation and manages the allocation and assignment of specific frequencies in the radio spectrum for scientific use by the entire NSF community.

The need for NSF to reduce funding for Arecibo Observatory has been established through a number of reviews and surveys conducted by the science community. In 2010, the National Research Council (NRC) conducted its sixth decadal survey in astronomy and astrophysics. In their report, *New Worlds, New Horizons in Astronomy and Astrophysics*, the NRC committee recommended the following:

> "NSF-Astronomy should complete its next senior review before the mid-decade independent review that is recommended in this report, so as to determine which, if any, facilities NSF-AST should cease to support in order to release funds for (1) the construction and ongoing operation of new telescopes and instruments and (2) the science analysis needed to capitalize on the results from existing and future facilities." (NRC, 2010a)

In response to this recommendation, the NSF Directorate for Mathematical and Physical Sciences (MPS) commissioned a subcommittee of the MPS Advisory Committee to assess the portfolio of the AST within MPS. This subcommittee, composed solely of external members of the scientific community, was charged with recommending a balanced portfolio to maximize the science recommended by the National Academies of Sciences, Engineering, and Medicine (NAS) surveys of the field, which are carried out every decade under constrained budget scenarios. The resulting Portfolio Review Committee (PRC) Report was released in August 2012.

The PRC Report recommended the divestment of a number of telescopes from the federal portfolio in order to maintain a balance of small-, medium-, and large-scale programs that would best address decadal survey science. With respect to Arecibo Observatory, the PRC Report made the following recommendation (Recommendation 10.4): "AST should reevaluate its participation in Arecibo and the Southern Astrophysical Research (SOAR) Telescope later in the decade in light of the science opportunities and budget forecasts at that time" (NSF, 2012).

This follows from a recommendation made by the AST Senior Review Committee in 2006 (Recommendation 6): "The National Astronomy and Ionosphere Center [former name for Arecibo Observatory]...should seek partners who will contribute personnel or financial support to the operation of

Arecibo...by 2011 or else these facilities should be closed (NSF, 2006).” The Senior Review Report also noted that “If Arecibo is kept operating beyond 2011, it is expected that this will only be a limited-term extension, pending the deliberations of the next decadal survey” (NSF, 2006).

While the AST was the primary funder of Arecibo for over a decade (funding $10.6M annually in 2006, reducing over the years to $4.1M in 2016), the Geospace Section (GS) of the NSF Division of Atmospheric and Geospace Sciences (AGS) in the Directorate for Geosciences (GEO) was an early co-funder of Arecibo Observatory operations and now provides approximately half of the current NSF funding ($4.1 million annually from GS) for Arecibo Observatory. As a result, AGS has also taken a lead role in making recommendations about the future of Arecibo Observatory. In 2016, the GEO Advisory Committee concluded its own community-based portfolio review, which recommended a significant and specific funding reduction. The report written by AGS and delivered in April 2016 gave the following recommendation (Recommendation 9.11): “The GS should reduce its M&O [Management and Operations] support for the Arecibo Observatory (AO) to $1.1M by 2020, i.e., to a proportional *pro rata* level approximately commensurate with its fractional NSF GS proposal pressure and usage for frontier research” (NSF, 2016a).

This would represent a significant reduction compared with the Fiscal Year 2016 AGS support level of $4.1 million.

The continued importance of the NSF response to the PRC Report was highlighted by the annual report of the Congressionally chartered Astronomy and Astrophysics Advisory Committee (AAAC) in March 2016, which recommended that “[s]trong efforts by NSF for facility divestment should continue as fast as is possible” (NSF, 2016b). More recently, in August 2016, the NAS mid-decadal report, *New Worlds, New Horizons: A Midterm Assessment*, provided their Recommendation 3-1: “The National Science Foundation (NSF) should proceed with divestment from ground-based facilities which have a lower scientific impact, implementing the recommendations of the NSF Portfolio Review that is essential to sustaining the scientific vitality of the U.S. ground-based astronomy program as new facilities come into operation” (NAS, 2016).

At present, Arecibo Observatory serves a variety of scientific user communities in astronomy, aeronomy, and planetary science, and it is funded for all three activities as well as an active education and public outreach program. However, the scientific community evaluations cited previously indicate that the scientific capability of Arecibo Observatory is lower in priority than other scientific capabilities the NSF funds. In a funding-constrained environment, NSF must maintain a balanced research portfolio with the largest science return for the taxpayer dollar. Therefore, the purpose of this Proposed Action is to substantially reduce NSF’s contribution to the funding of Arecibo Observatory.

1.3 Federal Regulatory Setting

This Section identifies the key federal regulations most relevant to this NEPA analysis.

1.3.1 National Environmental Policy Act

In 1969, Congress enacted NEPA to provide for the consideration of environmental issues in federal agency planning and decision making. CEQ issued *Regulations for Implementing the Procedural Provisions of NEPA* (40 C.F.R. Parts 1500–1508) to establish the process for federal agency implementation of NEPA. NEPA requires preparation of an EIS for major federal actions that may significantly affect the quality of the human and natural environments. The EIS must disclose significant direct, indirect, and cumulative environmental impacts of the considered alternatives to inform decision makers and the public.

1.3.2 National Historic Preservation Act

The NHPA, as amended (54 U.S.C. 300101, *et seq.*), recognizes the nation's historic heritage and establishes a national policy for the preservation of historic properties as well as the National Register of Historic Places (NRHP). Section 106 of the NHPA (54 U.S.C. 306108) requires that federal agencies consider the effects of their projects on significant historic properties.

The implementing regulations for the NHPA are found in the Protection of Historic Properties (36 C.F.R. Part 800), which defines historic properties as any prehistoric or historic district, site, building, structure, or object that is included in, or eligible for inclusion in, the NRHP (54 U.S.C. 302101). In the case of this proposed project, use of federal funds establishes the need for Section 106 compliance. The purpose of the Section 106 consultation process is to evaluate the potential for effects on existing historic properties, if any, resulting from the proposed project.

The Section 106 review process encompasses a good faith effort to ascertain the existence and location of historic properties near and within the proposed project site, establishing an Area of Potential Effects (APE) for the proposed project, identifying whether the proposed project may adversely affect historic properties that are listed or are eligible for listing in the NRHP, and, if so, developing ways to avoid, minimize, and/or mitigate those adverse effects. The resolution of any adverse effects is typically memorialized in a Memorandum of Agreement (MOA) or Programmatic Agreement (PA) created through consultation with the State Historic Preservation Officer (SHPO), ACHP (if it chooses to participate), and any consulting government agencies, community associations, and Native American tribes.

1.3.3 Endangered Species Act

The ESA and subsequent amendments thereto provide for the protection and conservation of threatened and endangered species (listed species) of animals and plants, and the ecosystems on which listed species depend. The ESA prohibits federal agencies from funding, authorizing, or carrying out actions likely to jeopardize the existence of listed species through direct taking or through the destruction or adverse modification of critical habitat designated for these species under the ESA. Section 7 of the ESA requires consultation with the U.S. Fish and Wildlife Service (USFWS) when any listed species under its jurisdiction may be affected by a proposed action.

1.4 Agency Notification and Collaboration

NSF and its collaborating agencies began the process of informal consultation with federal and Commonwealth of Puerto Rico agencies in May 2016, along with Commonwealth of Puerto Rico elected officials, community groups, and relevant commercial interests. Details about agency collaboration and consultation throughout this NEPA process can be found in Section 5 of this FEIS. Both formal and informal consultations took place with these parties to ensure full disclosure and information. These included, but were not limited to, discussions and correspondence with the Arecibo Management Team, ACHP, NASA, USFWS, and the Puerto Rico SHPO. On July 25, 2016, NASA requested to be a cooperating agency for this NEPA process. Table 1.4-1 provides a list of the agencies consulted.

TABLE 1.4-1
Agency Consultation

Federal	ACHP EPA NASA USACE USFWS
Commonwealth of Puerto Rico	DRNA Office of the Governor of Puerto Rico Office of the Resident Commissioner of Puerto Rico OGPe EQB PRPB SHPO
Municipality of Arecibo	Mayor of Arecibo
Other Public-Private Stakeholder Organizations	SRI International (NSF Cooperative Agreement Awardee) USRA (NSF Cooperative Agreement Sub-awardee) UMET (NSF Cooperative Agreement Sub-awardee)

DRNA = Departamento de Recursos Naturales y Ambientales (Puerto Rico)
EQB = Environmental Quality Board (Puerto Rico)
OGPe = Oficina de Gerencia de Permisos
PRPB = Puerto Rico Planning Board
USACE = U.S. Army Corps of Engineers

1.5 Public Disclosure and Involvement

NSF notified, contacted, and/or consulted with agencies, individuals, and organizations during development of this FEIS. Public disclosure and involvement regarding the Proposed Action included pre-assessment notification letters to agencies, social media announcements, website updates, scientific digest and blog postings, newspaper public notices, public scoping meetings (conducted on June 7, 2016, in San Juan and Arecibo), and DEIS public meetings (conducted November 16, 2016, in Arecibo and on

November 17, 2016, in San Juan). Both English and Spanish versions of media notifications and the materials distributed during the meetings were made available to the public. An English/Spanish interpreter was present during all public meetings and provided interpretation to the public. Detailed information about these activities is provided in Section 5. The public was encouraged to comment during the requisite comment period of the scoping process and after publication of the DEIS. The DEIS was published and distributed to federal, state, local, and private agencies, organizations, and individuals for review and comment, and it was filed with the EPA. An NOA was announced in the *Federal Register* on October 28, 2016. A summary of comments received during the public comments periods are presented in Section 5, and a full listing of all comments on the DEIS and the responses can be found in Appendix 5-H. NSF gave consideration to public comments when developing the scope of the analysis in the DEIS and preparing the FEIS and ROD.

1.6 Arrangement and Content of the Final Environmental Impact Statement

This FEIS is arranged as follows:

- Executive Summary
- Section 1: Purpose and Need
- Section 2: Description of Proposed Action and Alternatives
- Section 3: Affected Environment
- Section 4: Environmental Consequences
- Section 5: Notification, Public Involvement, and Consulted Parties
- Section 6: List of Preparers
- Section 7: References
- Section 8: Acronyms and Abbreviations
- Section 9: Index

The analysis considers the following resource areas, as these resources would have the potential for environmental impacts under one or more of the considered alternatives. In addition to these resources, potential disproportionate effects to minority and low-income populations were also considered.

- Biological Resources: Potential impacts to vegetation, wildlife, wetlands, threatened and endangered species, and migratory birds
- Cultural Resources: Potential impacts to NRHP-listed and NRHP-eligible structures, within a recognized historic district

- Geologic and Soil Resources: Potential impacts to soil and sensitive geologic features
- Groundwater: Potential impacts to groundwater quality and drainage features
- Hazardous Materials: Potential impacts to existing hazardous material contamination and the generation of hazardous materials
- Solid Waste: Potential impacts from the generation of solid waste
- Human Health and Safety: Potential impacts to public health, occupational health, and the protection of children
- Noise: Potential impacts from construction and traffic noise
- Socioeconomics: Potential impacts from temporary construction jobs and the loss of permanent jobs
- Traffic and Transportation: Potential impacts to traffic and to roads from use by construction vehicles
- Visual: Potential impacts to the existing visual character of the area
- Environmental Justice: Potential impacts, including human health, economic, and social effects, from the Proposed Action on minority and low-income communities

The following resource areas are not considered in detail, because there is no potential for noticeable or measurable impacts to these resources:

- Air Quality: The Proposed Action could involve the use of diesel generators and short-term emissions associated with demolition. However, Arecibo Observatory is located in an area that is in full attainment for all National Ambient Air Quality Standards (NAAQS) criteria pollutants (EPA, 2016a). Therefore, Clean Air Act (CAA) conformity analysis is not required and, given the project activities, there is no potential for the Proposed Action to cause a violation in CAA NAAQS. Any air quality impacts would be negligible on a regional basis. Contracts for demolition work would require idle reduction and proper equipment maintenance to reduce emissions during demolition.
- Climate Change: Operations at Arecibo Observatory under Alternatives 1 and 2 may require increased use of diesel generators. For example, if usage hours were to double, there could be an increase of approximately 250 additional metric tons of carbon dioxide equivalent (CDE) generated annually. However, usage hours by potential future partners is speculative at this time, and neither this generator usage nor short-term greenhouse gas (GHG) emissions from demolition activities would appreciably affect climate change. Note that there would be a long-term decrease in GHG emissions under Alternatives 4 and 5, as well as under Alternative 3 during the mothballed stage. The location of the facility is such that impacts from climate change would not noticeably affect operations.

- Land Use: Because of the relatively small area and remote location, the change in land use among the Alternatives would not be noticeable.
- Surface Waters: There is no potential for direct or indirect impacts to surface water under any Alternative.
- Utilities: No new utility infrastructure would be required and utility usage would either stay the same or be reduced under any Alternative.

SECTION 2.0

Description of Proposed Action and Alternatives

2.1 Introduction

NSF has defined options for the future state of Arecibo Observatory, given the need to significantly decrease or eliminate NSF funding of the Observatory. NSF sought viable concepts of operations from the scientific community via an October 26, 2015 Dear Colleague Letter NSF 16–005 (www.nsf.gov/AST). Preliminary Alternatives were developed based on this input and were included in the NOI published in the *Federal Register* on May 23, 2016.

The scoping process was completed in June 2016. Details of this process can be found in Section 5 of this FEIS. Input received during scoping was used to vet the Alternatives presented in the NOI and to provide focus on the issues to be evaluated. As noted previously, comments on the Alternatives received during the public review period for the DEIS following the publication of the NOA on October 28, 2016, were considered in preparing the FEIS.

2.2 Alternatives Eliminated from Further Consideration

A number of comments received during the scoping phase centered on the potential separate use of the 12-meter-diameter radio telescope by a commercial entity. As the capital cost of this radio telescope and its operations are low compared with the annual cost of operations at the Observatory, a commercial collaboration for the use of the 12-meter-diameter radio telescope would have little impact on the overall cost of operations and would not meet the purpose and need of the Proposed Action. Therefore, this alternative was not carried forward for further consideration.

2.3 Alternatives Considered

This Section describes the Alternatives considered in this FEIS. The basis for these Alternatives includes the public comments received during the public scoping period and the input received from the scientific community.

Under each Alternative described herein, there could be some level of demolition of buildings and structures; buildings are identified that could be demolished for analysis purposes, but these buildings would not necessarily be demolished. Alternatives 1 and 2 are defined by the reduction of NSF funding and the continuance of science-focused (under Alternative 1) or education-focused (under Alternative 2) operations and not the disposition of any one facility or structure. Use or demolition of any particular building or instrument cannot be determined unless or until a viable collaboration option is under consideration. Because reduction of NSF funding may require the safe-abandonment[3], mothballing[4], or demolition of facilities, the Alternatives are described under the most conservative (highest environmental impact) scenario in terms of NSF's analysis of potential changes to facilities, so that the EIS may be inclusive of the full range of potential environmental impacts. The analysis approach is consistent with NEPA requirements and is sufficiently broad to allow NSF to complete the analysis during planning and without regard to the specifics of a future collaboration. Table 2.3-1 provides a detailed list of facilities identified for potential retention, demolition, safe-abandonment, or mothballing under the Alternatives for the purpose of NSF's environmental review. However, it must be emphasized that a collaboration may not require the full extent of demolition, safe-abandonment, or mothballing activities analyzed and could involve none or only a subset of the activities listed in Table 2.3-1. NSF's ROD would contain an explanation of which components of any selected Alternative would be implemented. In any case, the Agency-preferred Alternative does not include, and the EIS does not *mandate*, the destruction/removal of specific buildings and infrastructure, even if specific buildings are identified in the various Alternatives. Because of this, the EIS should not be viewed to preclude a proposed activity or use of infrastructure.

2.3.1 Alternative 1 – Collaboration with Interested Parties for Continued Science-focused Operations (Agency-preferred Alternative)

Alternative 1 would involve collaborations with new stakeholder(s) who would use and maintain Arecibo Observatory for continued science-focused operations. NSF would reduce its funding of the Observatory and the new stakeholder(s) would be responsible for future upgrades. Under this Alternative, NSF could transfer or retain the property. Alternative 1 would involve the least change to the current facility and would retain the 305-meter-diameter telescope, 12-meter-diameter telescope, and supporting facilities for research.

This Alternative includes demolition activities that could remove up to 26 buildings from the site. Specific buildings that would be demolished under this Alternative cannot be known until after a collaborative agreement would be in place. NSF identified the 26 structures that could be removed through communication with the scientific community. Onsite housing, recreation facilities, and other buildings determined to be unnecessary would be expected to be demolished. Paved roads serving areas that would no longer be used would be removed. The analysis assumes that 26 structures would be

[3] Safe-abandonment: To remove a building or facility from service without demolishing it. This includes removing furnishings, disconnecting utilities, and isolating the structure from public access by fencing or other means to reduce fall and tripping hazards and preclude vandalism. The structure is also made secure from environmental damage due to wind, rain, humidity, and temperature extremes. Pest and insect damage must also be taken into account and biodegradable items must be removed to the maximum extent practicable. Under safe-abandonment, there is no intention that structures would be brought back to operational status.

[4] Mothball: Remove a facility or structure from daily use while maintaining the general condition for a defined period. Equipment and structures are kept in working order but are not used.

demolished and no new construction would occur, and that analysis represents the maximum amount of disturbance that would result.

Demolition of buildings and infrastructure would include the physical dismantling of structures and use of heavy equipment to break up and remove concrete portions. Demolition debris would be recycled and reused to the extent possible, and any remaining materials would be properly disposed of in a commercial landfill. Haul trucks would transport the demolition debris from Arecibo Observatory to recycle/reuse centers in nearby municipalities and the remaining debris to a landfill in Poncé.

Table 2.3-1, presented at the end of this Section, provides a detailed list of the 25 buildings and infrastructure that would remain and the 26 buildings and infrastructure that could be removed under this Alternative.

Equipment, tools, machinery, furniture, and ancillary items with salvage value and that are no longer needed for the Observatory to operate would be disposed of in accordance with federal law. Gates and fencing would be evaluated to determine whether upgrades are needed to provide appropriate security and access around portions of the site that would require protection. Existing utilities would be maintained and site restoration would occur. Site restoration would include reestablishing landscaping in areas where buildings were demolished and may involve transporting soil to the site to support landscaping in areas where building foundations or excavated bedrock would prevent vegetation establishment.

The anticipated activities to implement demolition under Alternative 1 include the following:

- Conduct a hazardous materials assessment for asbestos-containing material (ACM), lead-based paint (LBP), and other conditions of concern for structures to be demolished. Remediate as necessary.
- Demolish buildings and structures that are no longer needed. Concrete buildings would be removed using hammerhoes, jackhammers, and other heavy equipment.
- Segregate, load, and transport waste materials to appropriate offsite landfills and recycling centers.
- Establish soil in areas where buildings were removed from bedrock. Landscape areas of bare soil.

The demolition period for Alternative 1 is expected to take 12 weeks. Depending on the availability of funds, activities may be spread out over multiple fiscal years. Any demolition work would be conducted within developed areas of Arecibo Observatory, so there would be no need to construct new access routes to haul debris away and no widening or other improvements to existing roads would occur.

Landscaped areas would be maintained during operations. All infrastructure related to the 12-meter and 305-meter-diameter telescopes would be maintained during operations to prevent the degradation of the instruments and to keep vegetation from overgrowing the facilities.

Operations would be expected to continue during demolition activities. Demolition activities that could interfere with the experimental use of the 12-meter and 305-meter-diameter telescopes and data collection would be coordinated with Observatory staff to minimize the potential for disrupting scientific work.

Operations after demolition activities would be comparable to current operations with regard to the number of employees employed and commuting to the Observatory. Specific scientific research, research programs, and educational activities could change.

Alternative 1 is NSF's Preferred Alternative. This Alternative would meet the Purpose and Need of reducing the funding required from NSF, while allowing continued benefits to the scientific and educational communities. However, implementation of this Alternative can only occur if collaborators come forward to participate as collaborating parties, with viable proposed plans to provide additional non-NSF funding in support of their science-focused operations. Collaborators are being sought and could include Commonwealth agencies, educational institutions, industrial or commercial ventures, or private individuals.

2.3.2 Alternative 2 – Collaboration with Interested Parties for Transition to Education-focused Operations

Alternative 2 would involve collaborating with outside entities to operate and maintain Arecibo Observatory as an education-focused operation. An official collaboration would be created to keep the science center open for students and visitors. New collaborators could include Commonwealth agencies, educational institutions, industrial or commercial ventures, or private individuals. Under this Alternative, NSF could transfer or retain the property.

Under Alternative 2, the visitor center, learning center, and 12-meter-diameter telescope would remain operational. The 305-meter-diameter telescope would be made inoperable but retained for visual/historical interest. Retaining the 305-meter-diameter telescope dish would require that it be secured and regularly maintained so that structural elements would not degrade and it would not be overgrown by vegetation.

Structures not needed to meet the anticipated operations-related goals would be safe-abandoned or demolished. The majority of residential housing and recreational facilities would not be retained. Table 2.3-1 provides a detailed list of the 19 buildings and infrastructure that would remain and the 27 buildings and infrastructure that could be removed, which include the 26 identified under Alternative 1 plus the operations building. Specific buildings that would be demolished cannot be known until after a collaborative agreement, if any, is in place. NSF identified the 27 structures that may be removed through communication with the scientific community. The analysis in this FEIS assumes that all 27 structures would be demolished and no new construction would occur, which represents the maximum amount of disturbance that would result.

Equipment, tools, machinery, furniture, and ancillary items with salvage value that are no longer needed for the education-based facility to operate would be disposed of in accordance with federal law. Existing utilities would be maintained. There would be site restoration to establish landscaping where buildings were previously located.

The anticipated activities to implement demolition activities associated with Alternative 2 include the following:

- Conduct hazardous materials assessment for ACM, LBP, and other conditions of concern for structures to be demolished. Remediate as necessary.
- Demolish or safe-abandon buildings and infrastructure that are no longer needed. Concrete buildings would be removed using hammerhoes, jackhammers, and other heavy equipment.
- Segregate, load, and transport waste materials to appropriate offsite landfills and recycling centers.
- Establish soil in areas where buildings were removed from bedrock. Landscape areas of bare soil.

The demolition period for Alternative 2 would be expected to take 12 weeks. Depending on the availability of funds, activities may be spread out over multiple fiscal years. All demolition work would be conducted within developed areas of Arecibo Observatory, so there would be no need to construct new access routes to haul debris away and no widening or other improvements to existing roads would occur.

Landscaped areas would be maintained during operations. All infrastructure related to the 12-meter and the 305-meter-diameter telescopes would be maintained during operations to prevent the degradation of the instruments and to keep vegetation from overgrowing the facilities.

Operations associated with education would be expected to continue during removal of unnecessary structures. Demolition activities that could interfere with experimental use of the 12-meter-diameter telescope and data collection would be coordinated with Observatory staff to minimize the potential for disrupting scientific work.

Operations after demolition would be comparable to current operations with regard to the number of personnel employed and commuting to the Observatory. The specific job make-up would change, as scientific research would no longer continue. It is anticipated that a staff comparable in size to current operations would work onsite under this Alternative.

2.3.3 Alternative 3 – Mothballing of Facilities

Alternative 3 would involve mothballing (preservation of) essential buildings, telescopes, and other equipment, with periodic maintenance to keep them in working order. This method would allow the facility to suspend operations in a manner that permits operations to resume efficiently at some time in the future. It is not known what type of operations would be implemented when the mothball phase would end. Operations at the time of resumption could be similar to current operations, other science-based operations, education-based operations, or some other type of operations. Because of this uncertainty, the resumption of operations is not considered as part of this Alternative.

Supporting structures would be evaluated to determine whether they are critical to the operation of the 12-meter and 305-meter-diameter telescopes. Structures and facilities that are obsolete and not needed would be removed. Table 2.3-1 provides a detailed list of the eight facilities that would remain, the 14 facilities that could be removed, and the 29 facilities that would be mothballed under this Alternative.

A maintenance program would be required to protect the facilities from deterioration, vandalism, and other damage. Regular security patrols would be performed to monitor the site. Common mothballing measures, such as providing proper ventilation, keeping roofs and gutters cleaned of debris, and performing ground maintenance and pest control, would be implemented. For stabilization, lubrication and other deterioration-preventing measures would be required on the 305-meter-diameter telescope dish, the Gregorian dome, and the support cables for the 305-meter-diameter telescope dish and the Gregorian dome.

Visitor housing and recreational areas would be closed indefinitely, with water lines drained and electricity turned off. All supplies, books, photographs, furnishings, and other items not needed for periodic maintenance would be removed from the site. Equipment, tools, machinery, furniture, and ancillary items that would not be needed for resumption of operations and that have salvage value would be would be disposed of in accordance with federal law.

Site restoration to establish landscaping where buildings were previously located would occur. Gates and fencing would be evaluated to determine whether upgrades would be needed to provide appropriate security and access around portions of the site that would require protection.

The anticipated activities to implement the demolition components of Alternative 3 include the following:

- Prepare buildings and structures to be mothballed and turn off nonessential utilities.
- Conduct hazardous materials assessment for ACM, LBP, and other conditions of concern for structures to be demolished. Remediate as necessary.
- Demolish structures and buildings that are no longer needed. Concrete buildings would be removed using hammerhoes, jackhammers, and other heavy equipment.
- Segregate, load, and transport waste materials to appropriate offsite landfills and recycling centers.
- Establish soil in disturbed areas where buildings were removed from bedrock. Landscape areas of bare soil.
- Complete other limited site restoration activities.
- Establish site security and facilities maintenance.

The implementation period for Alternative 3 would be expected to take 15 weeks. Depending on the availability of funds, activities may be spread out over multiple fiscal years. All demolition work would be conducted within developed areas of Arecibo Observatory, so there would be no need to construct new access routes to haul debris away and no widening or other improvements to existing roads would occur.

Landscaped areas would be maintained during the mothball period. All infrastructure related to the 12-meter and 305-meter-diameter telescopes would be conditioned for safe storage to prevent the degradation of the equipment and allow operations to be restarted. Regular vegetation maintenance would be implemented to keep vegetation from overgrowing the facilities.

For purposes of the analysis in this FEIS, it is assumed that operations would be suspended for an indefinite time and then resumed at some point in the future. It is anticipated that technical staff responsible for operating the 12-meter and 305-meter-diameter telescopes, scientific support staff, and cafeteria workers would not be retained. However, it is expected that current staffing levels for facilities maintenance would remain the same under this Alternative due to the level of maintenance required to keep the infrastructure operable.

2.3.4 Alternative 4 – Partial Demolition and Site Restoration

Alternative 4 involves the demolition of all above-grade structures, except the large concrete structures (that is, towers, tower and catwalk anchors, and rim wall infrastructure). All below-grade foundations would be stabilized and filled in.

Table 2.3-1 provides a list of all of the facilities that would be removed under Alternative 4. The following facilities would be safe-abandoned:

- 305-meter-diameter telescope dish foundation
- Rim wall infrastructure supporting the 305-meter-diameter telescope dish
- Three towers
- Six tower anchors plus the catwalk anchor

Equipment, tools, machinery, furniture, and ancillary items with salvage value would be disposed of in accordance with federal law. Demolition of the telescopes and other structures would be conducted during the same timeframe. If another use is identified for the 12-meter-diameter telescope, it would be repurposed and relocated rather than demolished.

The anticipated activities to implement the demolition activities of Alternative 4 include the following:

- Conduct hazardous materials assessment for ACM, LBP, and other conditions of concern for structures to be demolished. Remediate as necessary.
- Turn off and cap utilities.

- Remove the 305-meter-diameter telescope ground screen and reflector dish.
- Remove the platform, all instrumentation, and support structures suspended above the 305-meter reflector dish.
- Sequentially demolish concrete structures using hammerhoes, jackhammers, and other heavy equipment.
- Demolish structures other than those retained on the site.
- Segregate, load, and transport waste materials to appropriate offsite landfills and recycling centers.
- Conduct site restoration work: re-grade affected areas to desired elevations and contours; use available concrete rubble as necessary; bring in fill as needed to establish grade.
- Install soil and vegetation: place soil where needed to support growth of desired vegetation; seed and transplant native species; install temporary erosion control (biodegradable fiber mats) where needed; maintain (appropriate watering as needed and weed control) until desired vegetation is established.
- Install security fencing around the three towers and the anchors for the southeastern and southwestern towers and conduct measures appropriate to secure the site.

The demolition period for Alternative 4 is expected to take 28 weeks. Depending on the availability of funds, activities may be spread out over multiple fiscal years. All demolition work would be conducted within developed areas of Arecibo Observatory, so there would be no need to construct new access routes to haul debris away and no widening or other improvements to existing roads would occur.

Areas revegetated following demolition activities would be maintained for a period of 18 months, less if target revegetation (80 percent cover by desired species) is achieved sooner. A vegetation maintenance staff would be retained through this period.

Operations at Arecibo Observatory would cease under Alternative 4; therefore, it is anticipated that staffing levels would not be maintained.

2.3.5 Alternative 5 – Complete Demolition and Site Restoration

Alternative 5 involves the demolition of all above-grade structures, including the large concrete structures (that is, towers, anchors, and rim wall infrastructure). Below-grade foundations would be removed and the areas backfilled. Explosives may be used to demolish the three towers, six tower anchors, catwalk anchor, and rim wall infrastructure supporting the 305-meter-diameter telescope dish. Explosives, if used, would be limited to low-force charges designed to transfer the explosive force only to the structure designated for removal.

Equipment, tools, machinery, furniture, and ancillary items with salvage value would be disposed of in accordance with federal law. Facilities and structures would be demolished. Demolition of the radio telescopes and other structures would be conducted during the same timeframe. If another use is identified for the 12-meter telescope, it would be repurposed and relocated rather than demolished.

The anticipated activities to implement Alternative 5 include the following:

- Turn off and cap utilities.
- Conduct hazardous materials assessment for ACM, LBP, and other conditions of concern for structures to be demolished. Remediate as necessary.
- Remove the 305-meter-diameter telescope ground screen and reflector dish.
- Remove the platform, all instrumentation, and support structures suspended above the 305-meter reflector dish.
- Sequentially demolish the smaller concrete structures by using hammerhoes, jackhammers, and other heavy equipment.
- Remove below-grade structures by using hammerhoes, jackhammers, and other heavy equipment.
- Remove 305-meter-diameter telescope dish foundation and rim wall infrastructure, which may entail the use of explosives in addition to hammerhoes, jackhammers, and other heavy equipment.
- Demolish towers, which may entail the use of large cranes and explosives in addition to hammerhoes, jackhammers, and other heavy equipment.
- Demolish tower and catwalk anchors, which may entail the use of large cranes and explosives in addition to hammerhoes, jackhammers, and other heavy equipment.
- Fill and safe-abandon concrete foundations that cannot be removed.
- Segregate, load, and transport waste materials to appropriate offsite landfills and recycling centers.
- Conduct site restoration work: re-grade affected areas to desired elevations and contours; use available concrete rubble as necessary; bring in fill as needed to establish grade.
- Install soil and vegetation: place soil where needed to support the growth of desired vegetation; seed and transplant native species; install temporary erosion control (biodegradable fiber mats) where needed; maintain (appropriate watering as needed and weed control) until desired vegetation is established.
- Conduct measures appropriate to secure the site.

The demolition period for Alternative 5 would be expected to take 38 weeks. Depending on the availability of funds, activities may be spread out over multiple fiscal years. All demolition work would be conducted within developed areas of Arecibo Observatory, so there would be no need to construct new access routes to haul debris away and no widening or other improvements to existing roads would occur.

Areas revegetated following demolition activities would be maintained for a period of 18 months, less if target revegetation is achieved sooner. A vegetation maintenance staff would be retained through this period.

Operations at Arecibo Observatory would cease under Alternative 5; therefore, it is anticipated that staffing levels would not be maintained.

2.4 No-Action Alternative – Continued NSF Investment for Science-focused Operations

Under the No-Action Alternative, NSF would continue funding Arecibo Observatory at current levels. None of the Proposed Action Alternatives would be implemented.

TABLE 2.3-1
Building Status by Alternative

	Alternative 1: Collaboration with Interested Parties for Continued Science-focused Operations	Alternative 2: Collaboration with Interested Parties for Transition to Education-focused Operations	Alternative 3: Mothballing of Facilities	Alternative 4: Partial Demolition and Site Restoration	Alternative 5: Complete Demolition and Site Restoration
Buildings and Infrastructure to Remain	1. Reflector Dish and 305-meter Telescope 2. Foundation and Rim Wall Infrastructure 3. Towers 4. Tower and Catwalk Anchors 5. Phase Reference Antenna (12-meter) 6. Operations Center 7. Cable Car House 8. Visiting Scientist Quarters/Cafeteria 9. Entrance Guard House 10. Pump House 11. Maintenance Building 12. Photometry Shack/Optical Lab 13. Cummings Generator Control Building 14. Cummings Generator Building 15. Main Gate Restroom 16. Grease Pit 17. 750-kilowatt Emergency Generator Building 18. Visitor Center 19. Lidar Laboratory 20. Learning Center 21. Cryogenics Laboratory Trailer 22. Inspiration for Science Office Trailer 23. Engineering Office Building 24. North Visiting Scientists Quarters (VSQ) Building 25. Tank Farm	1. Phase Reference Antenna (12-meter) 2. Visiting Scientist Quarters/Cafeteria 3. Entrance Guard House 4. Pump House 5. Maintenance Building 6. Photometry Shack/Optical Lab 7. Cummings Generator Control Building 8. Cummings Generator Building 9. Main Gate Restroom 10. Grease Pit 11. 750-kilowatt Emergency Generator Building 12. Visitor Center 13. Lidar Laboratory 14. Learning Center 15. Cryogenics Laboratory Trailer 16. Inspiration for Science Office Trailer 17. Engineering Office Building 18. North VSQ Building 19. Tank Farm	1. Entrance Guard House 2. Cable Car House 3. Pump House 4. Lewis Building 5. Cummings Generator Control Building 6. Cummings Generator Building 7. Main Gate Restroom 8. Engineering Office Building		
Buildings and Infrastructure to be Demolished*	1. Administration Building 2. Swimming Pool/Recreation Area 3. Lewis Building 4. Bowl Shack 5. Warehouse Building 6. Antenna Testing Building 7. Paint and Flammable Material Storage 8. S-Band High Voltage Power Supply Building 9. Antenna Receiving Testing Building 10. Shielded Trailer 11. Atmospheric Science Trailer 12. Scientific Office Trailer 13. HF Transmitter Building 14. Coffee Hut 15. HFF Storage Trailer 16. Electronics Cable Trailer 17. Electronic Trailer 18. Visitor Center Trailer 19. Computer Trailer 20. Ionosonde Trailer 21. Electronic Trailer (Waveguide) 22. Electronic Trailer (Cryogenic) 23. West Hill Bachelor Unit 1 24. West Hill Bachelor Unit 2	1. Operations Building 2. Administration Building 3. Swimming Pool / Recreation Area 4. Lewis Building 5. Bowl Shack 6. Warehouse Building 7. Antenna Testing Building 8. Paint and Flammable Material Storage 9. S-Band High Voltage Power Supply Building 10. Antenna Receiving Testing Building 11. Shielded Trailer 12. Atmospheric Science Trailer 13. Scientific Office Trailer 14. HF Transmitter Building 15. Coffee Hut 16. HFF Storage Trailer 17. Electronics Cable Trailer 18. Electronic Trailer 19. Visitor Center Trailer 20. Computer Trailer 21. Ionosonde Trailer 22. Electronic Trailer (Waveguide) 23. Electronic Trailer (Cryogenic) 24. West Hill Bachelor Unit 1	1. Grease Pit 2. Coffee Hut 3. HFF Storage Trailer 4. Electronics Cable Trailer 5. Electronic Trailer 6. Visitor Center Trailer 7. Computer Trailer 8. Ionosonde Trailer 9. Electronic Trailer (Waveguide) 10. Electronic Trailer (Cryogenic) 11. West Hill Bachelor Unit 1 12. West Hill Bachelor Unit 2 13. West Hill Family Unit 1 14. West Hill Family Unit 2	1. Reflector Dish and 305-meter Telescope 2. Phase Reference Antenna (12-meter) 3. Operations Building 4. Administration Building 5. Visiting Scientist Quarters/Cafeteria 6. Entrance Guard House 7. Cable Car House 8. Pump House 9. Swimming Pool/Recreation Area 10. Lewis Building 11. Maintenance Building 12. Bowl Shack 13. Warehouse Building 14. Antenna Testing Building 15. Paint and Flammable Material Storage 16. Photometry Shack/Optical Lab 17. S-Band High Voltage Power Supply Building 18. Cummings Generator Control Building 19. Cummings Generator Building 20. Main Gate Restroom 21. Grease Pit 22. 750-kilowatt Emergency Generator Building 23. Visitor Center	1. Reflector Dish and 305-meter Telescope 2. Foundation and Rim Wall Infrastructure 3. Towers 4. Tower and Catwalk Anchors 5. Phase Reference Antenna (12-meter) 6. Operations Building 7. Administration Building 8. Visiting Scientist Quarters/Cafeteria 9. Entrance Guard House 10. Cable Car House 11. Pump House 12. Swimming Pool/Recreation Area 13. Lewis Building 14. Maintenance Building 15. Bowl Shack 16. Warehouse Building 17. Antenna Testing Building 18. Paint and Flammable Material Storage 19. Photometry Shack/Optical Lab 20. S-Band High Voltage Power Supply Building 21. Cummings Generator Control Building 22. Cummings Generator Building 23. Main Gate Restroom 24. Grease Pit

TABLE 2.3-1
Building Status by Alternative

	Alternative 1: Collaboration with Interested Parties for Continued Science-focused Operations	Alternative 2: Collaboration with Interested Parties for Transition to Education-focused Operations	Alternative 3: Mothballing of Facilities	Alternative 4: Partial Demolition and Site Restoration	Alternative 5: Complete Demolition and Site Restoration
	25. West Hill Family Unit 1 26. West Hill Family Unit 2	25. West Hill Bachelor Unit 2 26. West Hill Family Unit 1 27. West Hill Family Unit 2		24. Antenna Receiving Testing Building 25. Lidar Laboratory 26. Shielded Trailer 27. Learning Center 28. Atmospheric Science Trailer 29. Cryogenics Laboratory Trailer 30. Scientific Office Trailer 31. HF Transmitter Building 32. Inspiration for Science Office Trailer 33. Coffee Hut 34. Engineering Office Building 35. HFF Storage Trailer 36. Electronics Cable Trailer 37. Electronic Trailer 38. Visitor Center Trailer 39. Computer Trailer 40. Ionosonde Trailer 41. Electronic Trailer (Waveguide) 42. Electronic Trailer (Cryogenic) 43. West Hill Bachelor Unit 1 44. West Hill Bachelor Unit 2 45. West Hill Family Unit 1 46. West Hill Family Unit 2 47. North VSQ Building 48. Tank Farm	25. 750-kilowatt Emergency Generator Building 26. Visitor Center 27. Antenna Receiving Testing Building 28. Lidar Laboratory 29. Shielded Trailer 30. Learning Center 31. Atmospheric Science Trailer 32. Cryogenics Laboratory Trailer 33. Scientific Office Trailer 34. HF Transmitter Building 35. Inspiration for Science Office Trailer 36. Coffee Hut 37. Engineering Office Building 38. HFF Storage Trailer 39. Electronics Cable Trailer 40. Electronic Trailer 41. Visitor Center Trailer 42. Computer Trailer 43. Ionosonde Trailer 44. Electronic Trailer (Waveguide) 45. Electronic Trailer (Cryogenic) 46. West Hill Bachelor Unit 1 47. West Hill Bachelor Unit 2 48. West Hill Family Unit 1 49. West Hill Family Unit 2 50. North VSQ Building 51. Tank Farm
Buildings and Infrastructure to be Safe-abandoned	None	1. Reflector Dish and 305-meter Telescope 2. Foundation and Rim Wall Infrastructure 3. Towers 4. Tower and Catwalk Anchors 5. Cable Car House 6. Gregorian Dome and Support Cables	None	1. Foundation and Rim Wall Infrastructure 2. Towers 3. Tower and Catwalk Anchors	None

TABLE 2.3-1
Building Status by Alternative

	Alternative 1: Collaboration with Interested Parties for Continued Science-focused Operations	Alternative 2: Collaboration with Interested Parties for Transition to Education-focused Operations	Alternative 3: Mothballing of Facilities	Alternative 4: Partial Demolition and Site Restoration	Alternative 5: Complete Demolition and Site Restoration
Buildings and Infrastructure to be Mothballed	None	None	1. Reflector Dish and 305-meter Telescope 2. Foundation and Rim Wall Infrastructure 3. Towers 4. Tower and Catwalk Anchors 5. Phase Reference Antenna (12-meter) 6. North Visiting Scientist Quarters Building 7. Tank Farm 8. Operations Building 9. Administration Building 10. Visiting Scientist Quarters / Cafeteria 11. Swimming Pool/Recreation Area 12. Maintenance Building 13. Bowl Shack 14. Warehouse Building 15. Antenna Testing Building 16. Paint and Flammable Material Storage 17. Photometry Shack / Optical Lab 18. S-Band High Voltage Power Supply Building 19. 750-kilowatt Emergency Generator Building 20. Visitor Center 21. Antenna Receiving Testing Building 22. Lidar Laboratory 23. Shielded Trailer 24. Learning Center 25. Atmospheric Science Trailer 26. Cryogenics Laboratory Trailer 27. Scientific Office Trailer 28. HF Transmitter Building 29. Inspiration for Science Office Trailer	None	None

* Depending on the needs of the collaborators under Alternatives 1 and 2, the actual number of buildings and infrastructure demolished could be less than those listed above.

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SECTION 3.0
Affected Environment

This Section provides an overview of the existing physical, biological, economic, and social conditions at Arecibo Observatory. In compliance with NEPA, this description of the affected environment focuses on those resources and conditions potentially impacted by the Proposed Action.

This Section is organized by resource area and describes the existing environment at the site. The Region of Influence (ROI) is also described for each resource. The ROI is defined as the area in which environmental impacts resulting from the Proposed Action could occur.

3.1 Biological Resources

This Section describes the biological resources found at Arecibo Observatory, which include plants and wildlife, wetlands, threatened and endangered species, and migratory birds. The ROI for the biological resources analysis encompasses the areas within and immediately adjacent to the Observatory, although a broader view was taken as necessary; for example, regional populations were considered for impacts to species stability.

3.1.1 General Setting

Arecibo Observatory is located within the northern karst region of Puerto Rico. The area is primarily a subtropical moist forest life zone and is dominated by karst landforms called “mogotes.” Elevations on Arecibo Observatory range from approximately 780 feet below the center of the 305-meter-diameter telescope dish to approximately 1,160 feet at the tops of mogotes. The karst forest region harbors the richest biodiversity in Puerto Rico and includes more than 1,300 species of plants and animals. It provides habitat for most of the native and endemic species of wildlife on the island, including species known only from karst ecosystems. In addition, it serves as important wintering habitat for Neotropical migratory birds (USFWS, 2016a).

The northern karst region is an area of rolling rough surface with numerous mogotes, sinkholes, and caves of various sizes. Mogotes may be over 330 feet (100 meters) high and sinkholes may be hundreds of feet deep and broad. Arecibo Observatory is built over a large sinkhole. Plant and wildlife species composition in the northern karst region are influenced by the altitude, soil, moisture, and seasonal microclimates produced by the mogotes landform. Many of the mogotes exhibit distinctive zonation of physical conditions, morphological variation, and species composition from top to bottom and east to west. The tops are considerably dryer than the middle and lower sections. As a result, the top may be covered by deciduous vegetation, the middle by semi-evergreen vegetation, and the base by evergreen vegetation. Canopy height and diameters of trees also show differences, with tree height and width increasing downslope. This zonation of vegetation present is further influenced by the direction the slopes face. Typically, western sides of mogotes are cooler, moister, and steeper, and the eastern and northern sides are warmer and drier (U.S. Forest Service [USFS], 2009).

Four vegetation types occur in the northern karst region. Mesic forest and dry woodland are the two major vegetation formations; these forest types occur at the base of mogotes and slopes or exposed tops. The other two vegetation types are mixed woodland and cliff fringe; these occur on slopes and at the edges of cliffs (USFWS, 2006).

Mogotes on an area basis are species-diverse. Mogotes typically differ in species composition, but in general the larger/higher the hill, the more species are present. Large hills may have 500 to 800 species of plants and wildlife and small hills could have 200 to 500 species. Large hills can have up to 200 tree species present and small hills may have 50. Many species exhibit an altitude/edaphic preference and cluster out within zones (USFS, 2009).

The Río Abajo Commonwealth Forest is the nearest natural area to the Proposed Action area and is expected to reflect the species found in undisturbed areas at and adjacent to Arecibo Observatory. This 5,782.26-acre protected area is located less than 1.24 miles (2 kilometers) to the east. It contains 1,036 plant species, including 175 species of trees. This includes 878 native plant species (88 endemics) and 158 species that are exotic or naturalized after cultivation. Families with the most common species are Euphorbiaceae, Laureaceae, Leguminosae, Myrtaceae, and Rubiaceae. Within the forest are 24 plant species belonging to 21 families that are considered endangered, threatened, or vulnerable by federal and Commonwealth of Puerto Rico agencies (USFWS, 2006).

Wildlife reported in the forest include 39 resident bird species, 9 species of mammals (including bats), 7 species of amphibians, and 16 species of reptiles. Amphibian species are primarily *Eleutherodactylus* tree frogs and reptile species are mostly *Anolis* lizards. Five federally endangered animal species have been reported in the Río Abajo Forest – four birds and one reptile: Puerto Rican sharp-shinned hawk (*Accipiter straitus venator*), Puerto Rican broad-winged hawk (*Buteo platypterus brunnescens*), peregrine falcon (*Falco peregrinus*), the plain pigeon (*Columba inornata wetmorei*), and the Puerto Rican boa (*Epicrates inornatus*) (USFWS, 2006).

3.1.2 Vegetation

Arecibo Observatory contains mogotes with mesic forest and dry scrub forest habitat types. Plants common to mogotes in karst subtropical moist forests vary by position on the slope. Common cliffside tree species include cupey (*Clusia rosa*), palma de sierra (*Gaussia atternuata*), and tyre palm (*Coccothrinax alta*). Mogote top thickets often include shrub species such as Guadeloupe marlberry (*Ardisia obovata*), wax myrtle (*Myrica [Morella] cerifera*), *Coccoloba costata*, and *Coccoloba pyrifolia*; and tree species such as black olive (*Bucida buceras*), *Tetrazygia eleagnoides*, cupey, *Burnelia cubensis*, plumeria (*Plumeria obtussa*), and ficus (*Ficus* spp.). Top-slope forests commonly include canopy tree species such as ceboruquillo (*Thouinia striata*), aquilon (*Neolaugeria resinosa*), grandleaf seagrape (*Coccoloba pubescens),* Maria (*Calophyllum calaba*), cupey, ficus, and palo amargo (*Rauvolfia nitida*); and understory species such as angelica tree (*Dendropanax arboreus*), carrasco (*Comocladia glabra*), and *Myrsine gulanensis.* Midslope forest species could include canopy trees such as Maria, ceboruquillo (*Thouinia striata*), aquilon (*Neolaugeria resinosa*), *Guarae gidonia*, and *Sapium laurocerasus*; subcanopy trees include *Trichilla pallida*, angelica tree, and *Casearia* spp.; and understory trees include carrasco (USFS, 2009).

At Arecibo Observatory, a mix of shade-tolerant species have colonized the area beneath the 305-meter-diameter radio telescope dish. Typical plants beneath the reflector dish include grasses (family Poaceae), ferns (class Pteridophyta), and vines from the morning glory family (Convolvulaceae) (Reaves and Orsoy, 2016). Woody species are suppressed or removed from beneath the reflector dish to prevent interference with its operation (Gago, 2016, pers. comm.).

3.1.3 Wildlife

Wildlife common to the area include those species described for the Río Abajo Commonwealth Forest (see Section 3.1.1). Fifty-five (55) bird species, including the Puerto Rican Broad-winged hawk, have been identified on Arecibo Observatory (Cornell University, 2016). In addition, bats have been observed in nearby caves.

3.1.4 Wetlands

No wetlands are known to occur on the Arecibo Observatory site (Reaves and Orsoy, 2016; USFWS, 2016b). A drainage channel that connects to the sinkhole beneath the 305-meter-diameter radio telescope dish is the only permanent surface water on the Observatory property. This channel lacks surface connections to other waters, but does connect with groundwater and underground rivers through the karst region.

3.1.5 Threatened and Endangered Species

A USFWS Information for Planning and Conservation (IPaC) Report was generated for the Municipality of Arecibo (USFWS, 2016c). In addition, USFWS was contacted about rare and protected species with the potential to occur on the Arecibo Observatory site (USFWS, 2016d).

No critical habitat has been designated within the Proposed Action area (USFWS, 2016c). Therefore, there is no potential to adversely impact critical habitat and critical habitat is not further discussed in this analysis.

USFWS identified 1 amphibian, 4 bird, 1 mammal, 4 reptile, and 14 plant species that are federally listed and have the potential to occur in the Municipality of Arecibo (Table 3.1-1). Based on the habitat requirements of those species, 3 bird, 1 reptile, and 12 plant species have the potential to occur at the Observatory and are described in greater detail in Table 3.1-1. A survey for listed plant species was conducted in January 2017 in areas where demolition could occur under one or more of the Alternatives and where the habitat conditions indicated the potential to support listed plant species (Vélez Gavilán, 2017). Table 3.1-1 also includes notes on the results of the vegetation survey.

TABLE 3.1-1
Protected Species Known from Municipality of Arecibo

Common Name	Species Name	Status	Habitat	Potential to Occur at Arecibo Observatory
Amphibians				
Puerto Rican Crested Toad	*Peltophryne lemur*	T	Low-elevation (< 660 feet [200 meters]) arid or semi-arid, rocky areas with an abundance of limestone fissures and cavities in well-drained soil (USFWS, 1992a).	No
Birds				
Puerto Rican Broad-winged Hawk	*Buteo platypterus brunnescens*	E	Montane (cloud) forest habitats of three forests: Río Abajo Commonwealth Forest, Carite Commonwealth Forest, and Caribbean National Forest and reported sightings in other locations (USFWS, 1997a).	Yes There were seven incidental sightings of at least three individual birds at the Observatory during the vegetation survey in January 2017.
Puerto Rican Parrot	*Amazona vittata*	E	Mature forest habitats in the El Yunque National Forest and the Río Abajo Commonwealth Forest (USFWS, 2009).	Yes
Puerto Rican Sharp-shinned Hawk	*Accipiter striatus venator*	E	Montane forest habitats of the Maricao Commonwealth Forest, Toro Negro Commonwealth Forest, Guilarte Common Commonwealth Forest, Carite Commonwealth Forest, and Caribbean National Forest (USFWS, 1997a).	Yes
Roseate Tern	*Sterna dougallii*	T	Sparsely vegetated rocky offshore islands (USFWS, 1993a).	No
Mammals				
West Indian Manatee	*Trichechus manatus*	E	Shallow marine habitats (USFWS, 1986a).	No
Reptiles				
Green Sea Turtle	*Chelonia mydas*	T	High-energy oceanic beaches and marine pelagic convergence zones and relatively shallow, protected waters (USFWS, 1991).	No
Hawksbill Sea Turtle	*Eretmochelys imbricata*	E	High-energy and low-energy oceanic beaches and marine pelagic convergence zones, coral reefs, and relatively shallow, protected waters (USFWS, 1993b).	No
Leatherback Sea Turtle	*Dermochelys coriacea*	E	High-energy beaches with deep unobstructed access and marine pelagic habitats (USFWS, 1992b).	No
Puerto Rican Boa	*Epicrates inornatus*	E	Wet monotreme to subtropical dry forests between sea level and 1,300 feet (400 meters) in elevation and in the northern limestone karst belt (USFWS, 1986b).	Yes

TABLE 3.1-1
Protected Species Known from Municipality of Arecibo

Common Name	Species Name	Status	Habitat	Potential to Occur at Arecibo Observatory
Plants				
No common name	*Tectaria estremerana*	E	Limestone hills of Arecibo in the vicinity of Arecibo Observatory radio telescope and in the Río Abajo Commonwealth Forest (USFWS, 1995).	Yes This species was not observed during the vegetation survey in January 2017.
Beautiful Goetzea	*Goetzea elegans*	E	Semi-evergreen forests of the subtropical moist forest zone below 660 feet (200 meters) in elevation near Guajactac Gorge and a ravine east of Quebradillas (USFWS, 1987).	Yes This species was not observed during the vegetation survey in January 2017.
Chupacallos	*Pleodendron macranthum*	E	Subtropical wet forest zone and subtropical lower montane wet forest zone of the Caribbean National Forest, Río Abajo Commonwealth Forest, and near the Carite Commonwealth Forest (USFWS, 1998).	Yes This species was not observed during the vegetation survey in January 2017.
Erubia	*Solanum drymophilum*	E	Evergreen forests in the subtropical wet forest life zone on volcanic soils at elevations of 980 feet (300 meters) to 2,950 feet (900 meters) in Las Tetas de Cayey, Salinas Municipality (USFWS, 1992c). Also will colonize disturbed areas (USFWS, 2016d).	Yes This species was not observed during the vegetation survey in January 2017.
No common name	*Myrcia paganii*	E	Biafara-Arrozal area south of Arecibo and in Quebradillas in limestone region of northwestern Puerto Rico; the preferred habitat is within seasonal evergreen or semi-evergreen forest type within the subtropical moist forest life zone (USFWS, 1997b).	Yes This species was not observed during the vegetation survey in January 2017.
No common name	*Schoepfia arenaria*	T	Low-elevation evergreen and semi-evergreen forest of limestone hills of norther Puerto Rico, known to occur in Isabela, Piñones, Fajardo, and the Río Abajo Commonwealth Forest; also in the Tortuguero Lagoon Natural Reserve (USFWS, 1992d).	Yes This species was not observed during the vegetation survey in January 2017.
No common name	*Cordia bellonis*	E	Serpentine soils at Maricao and Susúa road edges, river margins and on steep slopes; also in the Río Abajo Commonwealth Forest along sunny banks, dirt roads with thick vegetation, or in open saddles between limestone hills (USFWS, 1999). Also will colonize disturbed areas (USFWS, 2016d).	Yes This species was not observed at the Observatory during the vegetation survey in January 2017; however, one individual was observed outside the entrance to the Observatory.
No common name	*Auerodendron pauciflorum*	E	Semi-evergreen forests in the limestone hills of Isabela in northwestern Puerto Rico at elevations less than 330 feet (100 meters) (USFWS, 1997b).	No This species was not observed during the vegetation survey in January 2017.
Palma de Manaca	*Calyptronoma rivalis*	T	Subtropical moist and subtropical wet limestone forest of the northwest part of Puerto Rico at elevations of 330 feet (100 meters) to 490 feet	No, could occur along the rivers east and west of the Observatory.

TABLE 3.1-1
Protected Species Known from Municipality of Arecibo

Common Name	Species Name	Status	Habitat	Potential to Occur at Arecibo Observatory
			(150 meters); also in San Sebastián, along Camuy River and Guajataca River, and the Río Abajo Commonwealth Forest (USFWS, 1992e).	This species was not observed during the vegetation survey in January 2017.
Palo de Nigua	*Cornutia obovata*	E	Semi-evergreen seasonal forests of the limestone hills and lower mountains of northern and central Puerto Rico; also west of the Río Abajo near Arecibo Observatory (USFWS, 1992f).	Yes This species was not observed during the vegetation survey in January 2017.
Palo de Rosa	*Ottoschulzia rhodoxylon*	E	Populations are known to occur in seven areas of western Puerto Rico: Guaynabo, Quebradillas/Isabela, the Sierra Bermeja in Cabo Rojo, Guánica Commonwealth Forest, Susúa Commonwealth Forest, Cambalache Commonwealth Forest, and the Maricao Commonwealth Forest. Habitat requirements include serpentine and limestone derived soils with a narrow moisture tolerance (USFWS, 1994).	Yes This species was not observed during the vegetation survey in January 2017.
No common name	*Daphnopsis hellerana*	T	Limestone hills of northern Puerto Rico to the west of San Juan. Occurs in semi-evergreen and evergreen seasonal forest at elevations of 330 feet (100 meters) to 1,150 feet (350 meters) (USFWS, 1992e).	Yes This species was not observed during the vegetation survey in January 2017.
Uvillo	*Eugenia haematocarpa*	E	Known from the Luquillo Mountains of the Caribbean National Forest adjacent to the Carite Commonwealth Forest in Sierra de Cayey, one location in the municipality of Isabela, and two locations in the Guajataca Commonwealth Forest; preferred habitat is the subtropical lower montane wet forest life zone (USFWS, 1998, 2014; USFWS, 2016d).	Yes This species was not observed during the vegetation survey in January 2017.
No common name	*Thelypteris verecunda*	T	Known from three locations on private land; Quebradillas, Hatillo, and San Sebastián. The preferred habitat is moist, shady rock banks, humus on steep slopes (USFWS, 1995, 2015).	Yes This species was not observed during the vegetation survey in January 2017.

The following is a detailed explanation of the threatened or endangered species that may occur at Arecibo Observatory.

3.1.5.1 Wildlife Species

Puerto Rican Broad-winged Hawk (*Buteo platypterus brunnescens*)

The Puerto Rican broad-winged hawk is known from the nearby Río Abajo Commonwealth Forest. Breeding populations are known to occur in the Maricao, Toro Negro, Guilarte, Carite Commonwealth Forests and the Caribbean National Forest. The preferred habitat is described as subtropical wet forest and subtropical rain forest life zones, including the tabonuco, palo colorado, caimitillo, granadillo, and slope forest types (USFWS, 1997a). The species has recently been recorded at Arecibo Observatory (Cornell

University, 2016), has been observed nesting at the Observatory, and USFWS identified this species as a concern at Arecibo Observatory (USFWS, 2016d). In addition, a nest of this species was observed to the south of the 305-meter-diameter radio telescope dish during a July 2016 site visit; the species was identified by its call in the forest to the east of the reflector dish (Reaves and Orsoy, 2016). There were seven incidental sightings of at least three distinct birds during the January 2017 vegetation survey. The nest south of the reflector dish was determined to be inactive, but nesting behavior was observed near the entrance to the Observatory (Brown, 2017, pers. comm.). It is possible that multiple Puerto Rican broad-winged hawk territories overlap on Arecibo Observatory.

Puerto Rican Parrot (***Amazona vittata***)

The Puerto Rican parrot is a cavity-nesting, frugivorous (fruit-eating) species that is rarely seen far from the forest. The species requires large cavity-forming trees in mature forests. A population is known to occur in the Río Abajo Commonwealth Forest (USFWS, 2009). The species has been recorded on the forested hills surrounding Arecibo Observatory and USFWS identified this as a species of concern at the Observatory (USFWS, 2016d).

Puerto Rican Sharp-shinned Hawk (*Accipiter striatus venator*)

The federally endangered Puerto Rican sharp-shinned hawk is known from three forests, including the Río Abajo Commonwealth Forest, and is restricted to montane forests. Its preferred habitat is described as subtropical wet and subtropical lower montane wet forest life zones, including the caimitillo-granadillo, elfin woodland, sierra palm, and tabonuco forest types. In addition, activity has been observed in the palo colorado forest type in the lower montane life zone (USFWS, 1997a). USFWS indicated that this species could use habitat near Arecibo Observatory and identified it as a species of concern (USFWS, 2016d).

Puerto Rican Boa (*Epicrates inornatus*)

The Puerto Rican boa is known to occur in a wide variety of habitats from subtropical dry forest to wet montane forests. Within the Luquillo National Forest, boas have been found in the virgin forest areas that have experienced a large degree of human disturbance. The most common occurrence is within the northern limestone karst belt that extends from Carolina west to Aguadilla. The most common habitat types where they have been observed are tree branches, rotting stumps, solution cavities, cave entrances, along forest edges, and light gaps (USFWS, 1986b). The species has been recorded on the forested hills surrounding Arecibo Observatory as well as within the property; it is also known to occur in nearby caves. USFWS has identified this as a species of concern at Arecibo Observatory (USFWS, 2016d). This species was observed during a site visit on July 2016 and is reported as regularly seen by Observatory staff sunning on rock faces, fences, and other infrastructure (Reaves and Orsoy, 2016).

3.1.5.2 Plant Species

A vegetation survey was conducted in January 2017 in areas where demolition could occur under one or more of the Alternatives and where the habitat conditions indicated the potential to support listed plant species. The survey included the area beneath the 305-meter-diameter radio telescope dish and around the southeastern tower, the southwestern tower, and the anchors for these two towers. These areas contained potentially suitable habitat for protected plant species. The survey determined that beautiful goetzea, chupacallos, erubia, *Myrcia paganii*, *Schoepfia arenaria*, *Cordia bellonis*, palo de nigua, palo de rosa, uvillo, *Daphnopsis hellerana*, and *Thelypteris verecunda* do not occur in or adjacent to surveyed areas (Vélez Gavilán, 2017).

Tectaria estremerana

Tectaria estremerana is an endemic terrestrial fern that is only known to occur in the limestone hills of northern Puerto Rico. Populations have been observed within semi-evergreen seasonal forest of subtropical moist forest life zone. This species has been located within the property of Arecibo Observatory. It has also been collected in the Río Abajo Commonwealth Forest. USFWS has identified this as a species of concern at Arecibo Observatory (USFWS, 1995, 2016d). Multiple *Tectaria* species were observed during a July 2016 site visit (Reaves and Orsoy, 2016). Based on the habitat quality and abundance of related species, USFWS indicated that *Tectaria estremerana* was likely to occur at the Observatory in addition to the known population (Monsegur, 2016, pers. comm.). This species was not observed in the proposed project work areas with potenitially suitable habitat during the January 2017 vegetation survey (Vélez Gavilán, 2017).

Beautiful Goetzea (*Goetzea elegans*)

The beautiful goetzea is a small evergreen endemic tree known from near Guajactac Gorge and a ravine east of Quebradillas. The preferred habitat is in semi-evergreen forests of the subtropical moist forest zone below approximately 660 feet (200 meters) in elevation (USFWS, 1987). USFWS has indicated that this species could occur on or near the site (USFWS, 2016d). This species was not observed in the proposed project work areas with potenitially suitable habitat during the January 2017 vegetation survey (Vélez Gavilán, 2017).

Chupacallos (*Pleodendron macranthum*)

Chupacallos is an endemic tree species known from the Caribbean National Forest, Río Abajo Commonwealth Forest, and near the Carite Commonwealth Forest. This species occurs in two different habitat life zones, the subtropical wet forest zone and the subtropical lower montane wet forest zone (USFWS, 1998). USFWS has indicated that this species could occur on or near the site (USFWS, 2016d). This species was not observed in the proposed project work areas with potenitially suitable habitat during the January 2017 vegetation survey (Vélez Gavilán, 2017).

Erubia (*Solanum drymophilum*)

Erubia is a small spiny shrub known from Las Tetas de Cayey, Sierra de Cayey central and eastern mountains. This species preferred habitat is within an evergreen forest in the subtropical wet forest life zone on volcanic soils at elevations ranging from 980 feet (300 meters) to 2,950 feet (900 meters) (USFWS, 1992c). USFWS has indicated that this species could occur on or near the site (USFWS, 2016d). This species is known to occur in disturbed habitats (USFWS, 2016d). This species was not observed in the proposed project work areas with potenitially suitable habitat during the January 2017 vegetation survey (Vélez Gavilán, 2017).

Myrcia paganii

Myrcia paganii is a small evergreen tree known to occur in the Biafara-Arrozal area south of Arecibo and in Quebradillas, the limestone region of northwestern Puerto Rico. The preferred habitat is within seasonal evergreen or semi-evergreen forest types within the subtropical moist forest life zone (USFWS, 1997b). USFWS has indicated that this species could occur on or near the site (USFWS, 2016d). This species was not observed in the proposed project work areas with potenitially suitable habitat during the January 2017 vegetation survey (Vélez Gavilán, 2017).

Schoepfia arenaria

Schoepfia arenaria is an evergreen shrub/small tree known from Isabela, Piñones, Fajardo, and the Río Abajo Commonwealth Forest, and has been reported in the Tortuguero Lagoon Natural Reserve. The preferred habitat is within limestone hills at low elevation of evergreen and semi-evergreen forests (USFWS, 1992d). USFWS has indicated that this species could occur on or near the site (USFWS, 2016d). This species was not observed in the proposed project work areas with potenitially suitable habitat during the January 2017 vegetation survey (Vélez Gavilán, 2017).

Cordia bellonis

Cordia bellonis is an endemic shrub species known from the Maricao and Susúa public forests in serpentine soils at road edges, river margins and on steep slopes. It is also found in the Río Abajo Commonwealth Forest along sunny banks, dirt roads with thick vegetation, or in open saddles between limestone hills (USFWS, 1999). USFWS has indicated that this species could occur on or near the site (USFWS, 2016d). This species is known to occur in disturbed habitats (USFWS, 2016d). This species was not observed in the proposed project work areas with potentially suitable habitat during the January 2017 vegetation survey (Vélez Gavilán, 2017).

Palo de Nigua (*Cornutia obovata*)

Palo de Nigua is an evergreen tree known to occur in limestone hillsides in the Río Abajo Commonwealth Forest and along the limestone hillside near Arecibo Observatory. Specimens have been found in the semi-evergreen forest of the subtropical moist forest life zone, most often at elevations between 490 feet (150 meters) and 1,150 feet (350 meters). It prefers limestone hill sites with well-drained, shallow, alkaline soils and interspersed between outcrops of hard limestone (USFWS, 1992f). This species is known from Arecibo Observatory and USFWS has identified this as a species of concern at the Observatory (USFWS, 2016d). This species was not observed in the proposed project work areas with potenitially suitable habitat during the January 2017 vegetation survey (Vélez Gavilán, 2017). Incidental to the January 2017 vegetation survey, a single palo de nigua tree was observed just north of the Observatory entrance (Vélez Gavilán, 2017).

Palo de Rosa (*Ottoschulzia rhodoxylon*)

Palo de Rosa is a small endemic tree of Puerto Rico and Hispaniola. Populations are known to occur in the following seven areas of western Puerto Rico:

- Guaynabo
- Quebradillas/Isabela
- Sierra Bermeja in Cabo Rojo
- Guánica Commonwealth Forest
- Susúa Commonwealth Forest
- Cambalache Commonwealth Forest
- Maricao Commonwealth Forest

Habitat requirements include serpentine and limestone-derived soils with a narrow moisture tolerance (USFWS, 1994). USFWS has indicated that this species could occur on or near the site (USFWS, 2016d). This species was not observed in the proposed project work areas with potenitially suitable habitat during the January 2017 vegetation survey (Vélez Gavilán, 2017).

Daphnopsis hellerana

Daphnopsis hellerana is a small evergreen shrub or tree endemic to the limestone hills of northern Puerto Rico west of San Juan. Populations have been observed in semi-evergreen and evergreen seasonal forest at elevations of 330 feet (100 meters) to 1,150 feet (350 meters) and 2,047 individuals were identified in the proposed right-of-way for PR-10 in the Municipality of Arecibo (USFWS, 1992f, 2013). USFWS has indicated that this species could occur on or near the site (USFWS, 2016d). This species was not observed in the proposed project work areas with potenitially suitable habitat during the January 2017 vegetation survey (Vélez Gavilán, 2017).

Uvillo (*Eugenia haematocarpa*)

Uvillo is an endemic tree species known from the Luquillo Mountains of the Caribbean National Forest on private property adjacent to the Carite Commonwealth Forest in Sierra de Cayey, one location in the municipality of Isabela, and two locations in the Guajataca Commonwealth Forest (USFWS, 1998, 2014, 2016d). The preferred habitat is the subtropical lower montane wet forest life zone (USFWS, 1998). USFWS has indicated that this species could occur on or near the site (USFWS, 2016d). This species was not observed in the proposed project work areas with potenitially suitable habitat during the January 2017 vegetation survey (Vélez Gavilán, 2017).

Thelypteris verecunda

Thelypteris verecunda is an endemic fern known from three locations on private land; Quebradillas, Hatillo, and San Sebastián. The preferred habitat is moist, shady rock banks (USFWS, 1995, 2015). USFWS has indicated that this species could occur on or near the site (USFWS, 2016d). This species was not observed in the proposed project work areas with potenitially suitable habitat during the January 2017 vegetation survey (Vélez Gavilán, 2017).

3.1.6 Migratory Birds

The northern karst region provides habitat for migratory birds. A USFWS IPaC report was generated for the Municipality of Arecibo and identified 25 migratory bird species that could be affected (USFWS, 2016c):

- Antillean mango *Anthracothorax dominicus* (year-round resident)
- Audubon's shearwater *Puffinus lherminieri* (breeding season resident)
- Black swift *Cypseloides niger* (breeding season resident)
- Bridled quail-dove *Geotrygon mystacea* (year-round resident)
- Caribbean coot *Fulica caribaea* (year-round resident)
- Least bittern *Ixobrychus exilis* (year-round resident)
- Least tern *Sterna antillarum* (breeding season resident)
- Limpkin *Aramus guarauna* (year-round resident)
- Loggerhead kingbird *Tyrannus caudifasciatus* (year-round resident)
- Mangrove cuckoo *Coccyzus minor* (year-round resident)
- Masked duck *Nomonyx dominicus* (year-round resident)
- Prairie warbler *Dendroica discolor* (wintering resident)
- Puerto Rican oriole *Icterus dominicensis* (year-round resident)
- Puerto Rican vireo *latimeri* (year-round resident)
- Ruddy duck *Oxyura jamaicensis* (year-round resident)
- Semipalmated sandpiper *Calidris pusilla* (wintering resident)
- Short-eared owl *Asio flammeus* (year-round resident)

- Smooth-billed ani *Crotophaga ani* (year-round resident)
- Solitary sandpiper *Tringa solitaria* (wintering resident)
- Swainson's warbler *Limnothlypis swainsonii* (wintering resident)
- White-cheeked pintail *Anas bahamensis* (year-round resident)
- White-crowned pigeon *Patagioenas leucocephala* (year-round resident)
- Wilson's plover *Charadrius wilsonia* (year-round resident)
- Worm-eating warbler *Helmitheros vermivorum* (wintering resident)
- Yellow-breasted crake *Porzana flaviventer* (year-round resident)

Seven of the listed migratory bird species have been observed at Arecibo Observatory. They include the Antillean mango, black swift, loggerhead kingbird, mangrove cuckoo, Puerto Rican oriole, and smooth-billed ani (Cornell University, 2016).

3.2 Cultural Resources

Cultural resources include historic architectural properties, prehistoric and historic archaeological sites, historic districts, designed landscapes, and traditional cultural properties (TCPs). Three sub-resources (architectural properties, archaeological sites, and TCPs) are defined at the end of this Section.

The primary federal authorities that apply to cultural resources are NEPA and Section 106 of the NHPA at 54 U.S.C. §306108. Cultural resources are specifically included under one of the mandates of NEPA, which is to "preserve important historic, cultural, and natural aspects of our national heritage…" (42 U.S.C. §4331). The implementing regulations for the NHPA are found at the Protection of Historic Properties (36 C.F.R. Part 800), which defines historic properties as any prehistoric or historic district, site, building, structure, or object that is included in, or eligible for inclusion in, the NRHP (36 C.F.R. §800.16). As stated in 36 C.F.R. §800.8(a)(1), the NHPA encourages federal agencies to coordinate compliance with NEPA to maximize the timely and efficient execution of both statutes, and to allow the federal agency, in this case NSF, to use its procedures for public involvement under NEPA to also fulfill the public involvement requirements for Section 106 (36 C.F.R. §800.2[d][3]). Please note that this is not equivalent to using NEPA to comply with Section 106 "in lieu of" the standard Section 106 process as described in 36 C.F.R. §800.8(c).

Area of Potential Effects

The ROI for cultural resources is also referred to as the APE. The APE for the five Alternatives is defined as the property boundary of Arecibo Observatory, which includes 118 acres of land and is located on U.S. Geological Survey (USGS) Topographic Quadrangle maps Bayaney NE (2013) and Utuado NW (2013) (Figure 3.2-1). The boundaries of the Observatory were determined by NSF as the APE to encompass all areas where the Alternatives could occur, as well as all of the Arecibo Observatory NRHP-listed historic district. During a Section 106 Consultation Meeting on November 17, 2017, attended by the Puerto Rico SHPO and Section 106 Consulting Parties, there were no objections raised regarding the APE as described.

NHPA Section 106 Process

The Proposed Action regarding the potential changes to Arecibo Observatory operations is considered a federal undertaking and thus requires compliance with Section 106 of the NHPA. The Proposed Action, as described in Section 2, *Description of Proposed Action and Alternatives*, is limited to five Alternatives considered for the future operations of Arecibo Observatory. Section 106 is a procedural law and the regulations in 36 C.F.R. Part 800 provide the step-by-step approach for satisfying the Section 106 process. The steps include initiating consultation; identifying historic properties; identifying effects, including application of the criteria of adverse effects; and resolving adverse effects on historic properties, if necessary. Historic properties are evaluated and the effects are identified in consultation with the SHPO.

NSF, as the lead federal agency under Section 106 for this Proposed Action, has consulted with the Puerto Rico SHPO, the ACHP, and other Consulting Parties regarding this undertaking. Under Section 106 of the National Historic Preservation Act, Consulting Parties are individuals or entities with an interest in historic preservation who wish to participate in the Section 106 process.

Table 3.2-1 lists the milestones of the Section 106 consultation process for this Proposed Action. Copies of correspondence are provided in Appendix 3.2-A.

TABLE 3.2-1
Section 106 Consultation Process

Date	Action	Details
May 19, 2016	Pre-Scoping Teleconference	NSF attended a teleconference with SHPO, followed by informal email correspondence.
May 20, 2016	Email from SHPO	The Puerto Rico SHPO confirmed that the NRHP-listed historic district includes 118 acres and that five of the Observatory buildings included in the NRHP nomination are non-contributing. The remaining nine buildings and structures are contributing.
May 24, 2016	Public Involvement Initiated	NOI, including the Section 106 notice, was published in the *Federal Register*.
June 6, 2016	Early Coordination Meeting with the SHPO	NSF met with representatives from the Puerto Rico SHPO to discuss the proposed undertaking. This was followed by email correspondence.
June 7, 2016	NEPA Public Scoping Meetings	Public meetings were held in San Juan and Arecibo. NSF provided an opportunity for individuals and organizations to express an interest in participating as Section 106 consulting parties.
June 16, 2016	Email to Potential Consulting Parties	NSF contacted those individuals and organizations that had expressed interest in Section 106 consultation during the NEPA public scoping meetings to provide further details about the Section 106 consultation process and to confirm their

TABLE 3.2-1
Section 106 Consultation Process

Date	Action	Details
		consulting party status for the Proposed Action. Parties were given until June 29 to confirm their interest in consulting party participation.
July 5, 2016	Initiate Section 106 Consultation with the SHPO	NSF initiated formal Section 106 consultation with the Puerto Rico SHPO through written correspondence. NSF invited the SHPO to participate in the cultural resources field investigations that would occur July 19 and 20, 2016, at Arecibo Observatory.
July 11, 2016	Email – Section 106 Initiation Follow-up Regarding Architectural Survey	NSF inquired as to whether the SHPO was interested in attending the cultural resources field investigations at Arecibo Observatory on July 19 and 20, 2016.
July 12, 2016	Email – Request for Architectural Survey Agenda	The SHPO requested the agenda for the cultural resources field investigations.
July 12, 2016	Email – Response to Request for Architectural Survey Agenda	NSF provided the SHPO with the agenda for the cultural resources field investigations.
July 19–20, 2016	Reconnaissance Architectural Survey	Reconnaissance architectural survey completed at Arecibo Observatory to verify existing conditions of known historic properties within the NRHP-listed historic district.
July 19, 2016	Notification to John Fowler at the ACHP	Email from NSF was sent to the ACHP notifying John Fowler of Arecibo Observatory EIS, the NOI, and that coordination with the Puerto Rico SHPO is ongoing.
July 19, 2016	Notification to John Eddins at the ACHP	Email from NSF was sent to the ACHP notifying John Eddins that NEPA process and Section 106 consultation with the Puerto Rico SHPO is ongoing. Asked whether the ACHP would like to be involved in the Section 106 process. Also included: email correspondence with John Fowler (ACHP); Arecibo Observatory fact sheet; correspondence with the Puerto Rico SHPO; handouts provided at the NEPA Public Scoping Meetings.
August 8, 2016	Response from the SHPO	Letter from the Puerto Rico SHPO to NSF acknowledging that proposed Alternatives have been developed that could result in an effect on the Observatory. The SHPO requested that they are kept abreast of any determination regarding the historic property in order to assess and resolve effects.
September 15, 2016	Conference Call with the SHPO	Follow-up was conducted regarding Section 106 initiation letter, followed by email correspondence.
September 15, 2016	Email to SHPO	NSF emailed SHPO several questions that had been discussed during the conference call that occurred earlier that day. NSF requested clarifications regarding scheduling. In addition, NSF asked if SHPO would like to review the Proposed Changes to Arecibo Observatory Operations: Historic Properties Assessment of Effects technical report and provided a list of people who indicated they wished to serve as Consulting Parties in the Section 106 consultation process.
September 16, 2016	Email Response from SHPO	Berenice Sueiro from SHPO confirmed that they could meet with NSF during the week of November 14, 2016 and that they would like to review the Proposed Changes to Arecibo Observatory Operations: Historic Properties Assessment of Effects technical report.
October 6, 2016	Notification to John Eddins	Email from NSF was sent to John Eddins at the ACHP requesting confirmation regarding whether the ACHP will participate in consultation.

TABLE 3.2-1
Section 106 Consultation Process

Date	Action	Details
October 7, 2016	Response from the ACHP	Email from John Eddins at the ACHP to NSF stating he would review the material provided by NSF and provide a response.
October 19, 2016	Email to the SHPO	NSF provided the SHPO with the *Proposed Changes to Arecibo Observatory Operations: Historic Properties Assessment of Effects* technical report for review and comment. A hard copy of the document was also provided by mail. NSF notified the SHPO about the upcoming public and Consulting Party meetings to be held in November 2016. NSF requested to meet with the SHPO the week of November 15, 2016.
October 20, 2016	Email to the Consulting Parties	NSF provided the Consulting Parties with the *Proposed Changes to Arecibo Observatory Operations: Historic Properties Assessment of Effects* technical report for review and comment. NSF invited the Consulting Parties to a meeting held on November 17, 2016, in San Juan.
November 3, 2016	Notification Published in El Norte	Notified the public that NSF has prepared a DEIS and would be hosting two public meetings on the DEIS and one Consulting Party meeting on November 16 and November 17, 2016.
November 4, 2016	Email to the ACHP	NSF emailed John Eddins at the ACHP to follow-up regarding the ACHP's interest in participating in the Section 106 process. The email provided a link to the DEIS.
November 4, 2016	Email Response from John Eddins at the ACHP	John Eddins of the ACHP notified NSF that he would review the DEIS, and if no response was received within 15 days, NSF could move on with the Section 106 process.
November 15, 2016	In-person meeting with SHPO	NSF met in-person with the SHPO in Puerto Rico to discuss the next steps in the consultation process and to prepare for the upcoming consultation meeting.
November 16, 2016	NEPA Public Scoping Meeting	Public meeting was held in Arecibo to discuss the DEIS and receive public comments.
November 17, 2016	NEPA Public Scoping Meeting	Public meeting was held in San Juan to discuss the DEIS and receive public comments.
November 17, 2016	Consulting Party Meeting	Section 106 Consulting Party meeting held in San Juan to provide an overview of the Section 106 process, review the proposed Alternatives and their anticipated effects, and discuss potential mitigation measures.
December 12, 2016	Letter Response from SHPO	SHPO sent a letter to NSF acknowledging receipt of documentation describing all five action Alternatives and noting that all five Alternatives meet the criteria of adverse effect. SHPO recommended that NSF notify the ACHP and continue to consult with Consulting Parties to seek ways to resolve adverse effects.
December 15, 2016	Email to the ACHP	NSF sent an email to the ACHP with clarifications about the proposed project and again asked if they would like to participate in the Section 106 process. No response was received.
December 15, 2016	Email Exchange between NSF and ACHP	The ACHP and NSF exchanged emails concerning the need for ACHP involvement. NSF described public opposition to the proposal and its intention to draft a PA. No further response from the ACHP was received.
April 21, 2017	Email from NSF to SHPO	NSF notified SHPO that they would be receiving the preliminary draft PA for review and comment before NSF sent it out to the Consulting Parties. NSF requested to coordinate a call to discuss the contents of the preliminary draft PA.
April 26, 2017	Email from NSF to SHPO	Follow-up email to confirm that the SHPO received the email from April 21, 2017. NSF requested to discuss the contents of the preliminary draft PA during a brief call on April 27, 2017.

TABLE 3.2-1
Section 106 Consultation Process

Date	Action	Details
April 26, 2017	Email Response from the SHPO to NSF	Notified NSF that there is a new SHPO: Carlos A. Rubio Cancela. Berenice Sueiro informed NSF she is available on April 27 for a teleconference and would try to confirm that Migquel Bonini (Senior Historic Property Specialist) was also available.
April 27, 2017	Teleconference with the SHPO	Call with Berenice Sueiro and Miguel Bonini (SHPO) to discuss the preliminary draft PA. The SHPO asked NSF to reach out to the ACHP and include it in the consultation process. NSF informed the SHPO that it would not be including a provision in the draft PA listing the Observatory as a National Historic Landmark. NSF notified SHPO that it would provide the SHPO and the ACHP with a copy of the preliminary draft PA for informal review and comment.
April 28, 2017	Email to the ACHP (cc the SHPO)	NSF provided the preliminary draft PA to the ACHP and requested comments. The SHPO was copied on the email. Hard copies of the preliminary draft PA were also sent at this time. NSF requested to hold a teleconference with the ACHP to discuss the PA.
April 28, 2017	Letter to ACHP	Hard copies of the Assessment of Effects technical report, consultation record, summary of public and Consulting Parties comments relating to cultural resources, and the preliminary draft PA and a cover letter were sent to the ACHP (in addition to the email mentioned above). Initial thoughts on the preliminary draft PA were requested as soon as possible. Letter included a formal invitation to the ACHP to participate in the Section 106 process.
May 1, 2017	Email Response from John Eddins at the ACHP	The ACHP confirmed receipt of the preliminary draft PA. John Eddins notified NSF that Charlene Vaughn would be handling further coordination for this undertaking.
May 1, 2017	Email Response from NSF to ACHP	NSF requested a teleconference with ACHP.
May 5, 2017	Teleconference with Charlene Vaughn at the ACHP	NSF spoke with Charlene Vaughn. The ACHP notified NSF that it would provide a letter stating the ACHP would formally join the Section 106 consultation process. The ACHP also noted that it would provide informal comments on the preliminary draft PA. The ACHP recommended that NSF have the PA and attachments translated into Spanish and that NSF hold another in-person meeting in Puerto Rico to discuss the PA with the Consulting Parties. In addition, the ACHP recommended several steps to expand outreach for the PA.
May 18, 2017	Email from NSF to ACHP and SHPO	Follow-up email to the April 28 letter regarding the preliminary draft PA to see if the ACHP or SHPO had comments on the document. NSF stated that they would like to send the preliminary draft PA to Consulting Parties before the end of May to allow for sufficient time for review. NSF proposed a meeting in San Juan to discuss remaining issues with the Consulting Parties for either August 14 or 15. NSF also informed the ACHP and SHPO about the possibility of transferring ownership of Arecibo Observatory to a non-federal entity and that it would contact Betsy Merritt of the National Trust for Historic Preservation to see if the Trust would be interested in serving as a Consulting Party.
May 18, 2017	Email Response from SHPO to NSF	SHPO informed NSF that it would send comments soon.
May 23, 2017	Email to ACHP and SHPO	NSF emailed the ACHP and SHPO to inquire about when to expect comments on the preliminary draft PA.
May 24, 2017	Email Response from ACHP	ACHP notified NSF that they are still working on the preliminary draft PA comments and need to speak with SHPO before they respond.
May 24, 217	Email Response from NSF to ACHP	NSF thanked the ACHP for its help and reminded ACHP of the tight deadline.

TABLE 3.2-1
Section 106 Consultation Process

Date	Action	Details
May 25, 2017	Letter from SHPO to NSF	SHPO provided a letter via email (sent May 26, 2017) that acknowledged receipt of the preliminary draft PA. SHPO recommended further consultation with Consulting Parties and the ACHP.
May 26, 2017	Email Response from ACHP with Letter Attachment	ACHP accepted NSF's invitation to participate in the Section 106 consultation process. The letter informed NSF that Charlene Vaughn will handle the ACHP's participation.
May 30, 2017	Letter from ACHP	The ACHP reviewed the DEIS and the transcript from the two onsite public meetings and noted historic preservation concerns related to the five proposed Alternatives. The ACHP recommended further consultation before drafting the PA.
June 1, 2017	Teleconference with the ACHP and SHPO	Meeting to discuss the ACHP's participation in the Section 106 process and the preliminary draft PA.
June 13, 2017	Email from ACHP to NSF	ACHP provided comments on the preliminary draft PA. ACHP stated that the PA does not reflect the last conversation between the SHPO, ACHP, and NSF and fails to reflect the outcome of good faith consultation. Recommended NSF plan a consultation meeting with all Consulting Parties to discuss the PA.
June 14, 2017	Email Response from NSF to ACHP	NSF presented concerns regarding the ACHP's June 13, 2017 email and their comments on the preliminary draft PA. NSF summarized consultation efforts to date and agreed to organize a consultation teleconference with all Consulting Parties and the SHPO. NSF also suggested an in-person meeting with Charlene Vaughn (ACHP) to discuss the status of the Section 106 process and next steps.
June 14, 2017	Email Response from ACHP to NSF	ACHP responded with further explanation regarding ACHP's perspective. Noted that the preliminary draft PA still needs work and is not ready to share with the Consulting Parties; summarized feedback from the Consulting Parties; and encouraged NSF to consult with an agency such as NASA regarding how it has coordinated its NEPA and NHPA reviews.
June 14, 2017	Email Response from NSF to ACHP	NSF notified ACHP that it is in the process of setting up a Consulting Parties teleconference for June 21, 2017. NSF provided meeting notes from the November 17, 2016, consultation meeting. NSF explained that the process for evaluating proposals in response to the solicitation is based on NSF's scientific review process. Referenced the ACHP document entitled *Balancing Historic Preservation Needs with Operation of Highly Technical or Scientific Facilities* (1991) and clarified that NASA is a cooperating agency in NSF's NEPA process.
June 14, 2017	Email Response from ACHP to NSF	ACHP reiterated that the parameters of the Section 106 review need to be clarified for the Consulting Parties.
June 14, 2017	Email to SHPO and ACHP from NSF	NSF invited the SHPO and ACHP to attend a teleconference consultation meeting on June 21, 2017, starting at 3:30 and an in-person consultation meeting in San Juan on July 7, 2017 [later changed to a meeting in Arecibo on July 6, 2017].
June 14, 2017	Email Response from ACHP to NSF and SHPO	ACHP accepted the invitation to participate in a Section 106 consultation teleconference on June 21, 2017 and agreed to call in to the meeting on July 7, 2017 [meeting later changed to July 6, 2017].
June 14, 2017	Email from NSF to Consulting Parties	NSF invited Consulting Parties to a teleconference on June 21, 2017 and an in-person meeting on July 6, 2017. It provided a summary of the consultation that has occurred to date and what would occur moving forward with the Section 106 process. NSF provided some draft measures to use as a starting point for the

TABLE 3.2-1
Section 106 Consultation Process

Date	Action	Details
		discussion of potential avoidance, minimization, and mitigation. Feedback on these draft measures was encouraged and a link to the historic district NRHP nomination was provided for reference. [Two updates were sent as a follow-up to this email because the location of the in-person meeting was changed from San Juan to Arecibo.]
June 16, 2017	Email from NSF to Local Government Officials	NSF invited local government officials to attend and participate in two upcoming Section 106 consultation meetings: a June 21, 2017 teleconference and a July 6, 2017 in-person meeting in Arecibo. It provided a summary of the consultation that has occurred to date and what would occur moving forward with the Section 106 process. NSF provided some draft measures to use as a starting point for the discussion of potential avoidance, minimization, and mitigation. Feedback on these draft measures was encouraged and a link to the historic district NRHP nomination was provided for reference.
June 16, 2017	Email from NSF to Stakeholders	NSF invited stakeholders to participate in a Section 106 consultation public meeting on July 6, 2017, to discuss measures to avoid, minimize, and/or mitigate potential effects to historic properties.
June 21, 2017	Consulting Party Teleconference Meeting	Teleconference with NSF, SHPO, ACHP, and the Consulting Parties to discuss the draft PA and potential avoidance, minimization, and mitigation measures to resolve adverse effects to historic properties. The Consulting Parties expressed particular concern regarding how to emphasize the cultural significance, not just the historic significance, of the Observatory.
June 23, 2017	Email from SHPO to NSF and ACHP	SHPO provided an electronic copy of the Cooperative Agreement between the U.S. Government and Puerto Rico Government for the long-term preservation and maintenance of the Cuartel de Ballaja, Parcels A and B for NSF's and ACHP's reference. SHPO also provided an NPS brochure for the Monuments Program and Recreations Program for review. ACHP confirmed receipt.
June 23, 2017	Email Response from NSF to SHPO	NSF confirmed receipt of the reference materials sent by the SHPO on June 23, 2017, and noted that it would review the document to see what adjustments could be made to the draft PA, which would be sent out momentarily. Since the draft PA was ready for distribution, it would not reflect any components of the cooperative agreement; the next draft would include this information.
June 23, 2017	Email from NSF to Consulting Parties	NSF provided the draft PA for review and comment and notified the Consulting Parties that the 30-day public comment period for the document started on June 23, 2017. The email announced the availability of the document in the Biblioteca Electrónica Pública Municipal Nicolás Nadal Barreto and the Archivo General y Biblioteca Nacional de Puerto Rico. In addition, NSF provided a Frequently Asked Questions (FAQ) document and the NASA Cultural Resource Management document, as well as links to the ACHP's website and their success stories, a link to NSF's request for proposals, and a link to the ACHP's 1991 document entitled *Balancing Historic Preservation Needs with the Operation of Highly Technical or Scientific Facilities*. NSF noted that Spanish versions of the draft PA and FAQ would be posted to the NSF's website on June 26, 2017. NSF included the details for the in-person consultation meeting scheduled for July 6, 2017 in Arecibo.
June 23, 2017	Email from NSF to Stakeholders	NSF provided the draft PA for review and comment to stakeholders and any previous consultation meeting attendees and notified them that the 30-day public comment period for the document started on June 23, 2017. The email announced the availability of the document in the Biblioteca Electrónica Pública Municipal Nicolás Nadal Barreto and the Archivo General y Biblioteca Nacional de Puerto Rico. In addition, NSF provided a FAQ document, and the NASA Cultural Resource Management document, as well as links to the ACHP's website and their success stories, a link to NSF's request for proposals,

TABLE 3.2-1
Section 106 Consultation Process

Date	Action	Details
		and a link to the ACHP's 1991 document entitled *Balancing Historic Preservation Needs with the Operation of Highly Technical or Scientific Facilities*. NSF noted that Spanish versions of the draft PA and FAQ would be posted to the NSF's website on June 26, 2017. NSF included the details for the in-person consultation meeting scheduled for July 6, 2017 in Arecibo.
June 28, 2017	Consulting Party Added	Ramon Lugo of University of Central Florida was added as a Consulting Party.
June 28 and July 6, 2017	Public Notice Published	The Public Notice announcing the availability of the draft PA and the details of the public consultation meeting on July 6, 2017 was published in El Nueva Dia (June 28) and in El Norte (July 6).
July 6, 2017	Meet with U.S. Congresswoman's Office	NSF met with staff of Honorable Jennifer Gonzalez-Colon, U.S. House of Representatives, Puerto Rico-At Large, to discuss the undertaking and to brief them on the NEPA process and the Section 106 process.
July 6, 2017	Consulting Party Meeting/Public Meeting in Arecibo	Consulting Parties meeting held in Arecibo to discuss the draft PA. SHPO and ACHP attended. The public was also invited.
July 7, 2017	Email from NSF to Stakeholders	NSF emailed stakeholders to inform them that the Consulting Parties meeting was held on July 6, 2017 in Arecibo to discuss the draft PA. NSF invited those who could not attend the meeting, as well as those who attended the meeting but had more suggestions, to participate in a Consulting Parties teleconference on July 13, 2017 to continue the discussion. The agenda for the July 6 meeting and the draft PA were attached to the email and a link to the draft PA was also provided.
July 13, 2017	Email from NSF to Stakeholders	NSF emailed stakeholders to remind them about the Consulting Parties teleconference that would be held later that day to continue the discussion of the draft PA contents.
July 13, 2017	Consulting Parties Teleconference	Consulting Parties meeting held via teleconference to discuss draft PA. SHPO and ACHP attended. The public was also invited.

Sub-resource 1 – Architectural Resources

Historic architectural resources consist of physical properties, structures, or built items resulting from human activities that occurred after European settlement.

The federal historic properties database known as the National Register Information System was reviewed to identify existing historic properties within the APE. The search showed that Arecibo Observatory was listed in the NRHP as the NAIC historic district in 2008. The NRHP nomination form notes that the property is considered significant nationally, and the property is generally acknowledged as an internationally important science facility. A total of 14 buildings and structures are included in the 2008 NRHP nomination. Through correspondence with the Puerto Rico SHPO received on May 20, 2016, eight buildings and one structure were identified as contributing to the NRHP-listed district. These buildings are listed in Table 3.2-2. No other buildings or structures on the 118-acre property are listed in or considered eligible for the NRHP. Because Arecibo Observatory is listed in the NRHP, no further inventory or evaluation of historic properties was determined to be necessary, in consultation with the SHPO.

A Secretary of the Interior-qualified architectural historian conducted a reconnaissance architectural survey at Arecibo Observatory on July 19 and 20, 2016. The purpose of the survey was to verify the current conditions of existing known historic properties located at Arecibo Observatory. (Note: In 2008, Arecibo Observatory was listed in the NRHP as a historic district with nine contributing resources.) The survey included a general site assessment and informal interviews with NSF staff and partners to obtain information regarding alterations to those buildings and structures that contribute to the historic district. Field investigations focused on the nine known resources that contribute to the NRHP-listed historic district to verify that no significant alterations had occurred to the buildings and structures since the district was listed in 2008. No information was received from Observatory staff regarding changes in significance to any non-contributing resources.

In 2015, after discovering that Arecibo Observatory was inaccurately listed in the NRHP as owned by Cornell University, NSF contacted the National Park Service and requested that Arecibo Observatory be de-listed and then re-listed with NSF as the owner. That request was granted and Arecibo Observatory was removed and then re-listed in the NRHP on December 22, 2015, reflecting the corrected ownership information. The APE entirely encompasses the boundaries of the NRHP-listed historic district.

In addition to Arecibo Observatory's status as an NRHP-listed historic district, Arecibo Observatory holds significant cultural importance to the people of Puerto Rico. The site is a source of inspiration and pride and is considered to be both culturally and scientifically iconic on the national and international level.

Sub-resource 2 – Archaeological Resources

Prehistoric and historic archaeological resources are items or sites resulting from human activities that predate and postdate written records, respectively.

There are no known archaeological resources at Arecibo Observatory, and no archaeological survey work was conducted there as part of either the NEPA or Section 106 process. However, there may be archaeological resources below-ground that are not currently apparent.

Sub-resource 3 – Traditional Cultural Properties

TCPs are sites, areas, and materials associated with cultural practices or beliefs of a living community that are rooted in that community's history and are important in maintaining the continuing cultural identity of the community.

No TCPs have been identified at Arecibo Observatory; therefore, this sub-resource will not be analyzed further.

3.2.1 Proposed Action Area

3.2.1.1 Architectural Resources

Arecibo Observatory is located in west-central Puerto Rico on federal land, and it occupies 118 acres with infrastructure that includes instrumentation for radio and radar astronomy and ionosphere physics, office and laboratory buildings, a heavily used visitor and education facility, and lodging facilities for visiting scientists.

The construction of the Observatory was funded in the early 1960s by the Department of Defense Advanced Research Projects Agency to perform radar back-scatter studies of the ionosphere. In 1969, the facility was transferred from the Department of Defense to NSF and was made a national research center, with operations led by Cornell University. In 1971, the facility became known as NAIC (Santos, 2007).

The sensitive nature of radio telescopes limits the number of potential locations to establish an observatory. Manmade radio noise from earth can interfere with signals from space, making it difficult to distinguish between various types of data collected. Additionally, severe weather can interfere with the functionality of radio telescopes. Geographic barriers help isolate radio signals from space. Geographic, environmental, and geological requirements had to be considered when deciding on a location for the 305-meter-diameter radio telescope:

> "…it had to be near the equator, since there the radar (capable of studying the ionosphere) could also be used to study nearby planets. Furthermore, a site with moderate temperature changes and low winds was desirable for the stability of the instrument – to minimize the expansion and contraction of the structure and to reduce swaying of the suspended feed. The geological formation of the future site was also a very important factor… [necessitating] an appropriate 'hole in the ground'." (Santos, 2007)

Arecibo was chosen because it was "a natural depression (to minimize excavation for the projected dish), located away from populous areas and air lanes, in order to reduce radio interference" (Santos, 2007).

Construction at Arecibo Observatory started in 1960 and the 305-meter-diameter radio telescope was completed in August of 1963 at a cost of $9 million (Santos, 2007). A feat of engineering, the "capabilities of the instrument derive from its unique design, which includes a large reflector, movable line feeds that correct for spherical aberration, and high-performance transmitters, receivers, and computers for taking data and analyzing them" (Santos, 2007).

The 305-meter-diameter reflector dish has undergone two major upgrades: in 1974, the reflector dish was resurfaced and a high-frequency planetary radar transmitter was installed; and in 1997, major new equipment installations included new ground screen shields that block ground radiation, a Gregorian dome with sub-reflectors and new electronics, and a new radar transmitter (Santos, 2007). These improvements greatly increased the capability of the telescope. The 305-meter-diameter radio telescope and its supporting facilities have been used to make "numerous and significant contributions" to astronomy. "After almost fifty years of operations, the Arecibo [305-meter] Radio Telescope has become a popular icon, it is recognized as an engineering landmark, and scientists from all over the world compete to use the facility" (Santos, 2007). In addition, Arecibo Observatory is notable for sharing high-level results of complicated scientific investigations with the public since the construction of the Angel Ramos Foundation Science and Visitor Center (Building 54, NRHP Building 5) in 1997, which has more than 90,000 visitors each year (Santos, 2007).

In 2008, Arecibo Observatory was listed in the NRHP as the NAIC historic district. At the time of listing, the site was not yet 50 years old and therefore was evaluated under Criteria Consideration G for having achieved an exceptional level of significance within the last 50 years. The associated NRHP nomination form states:

> "The National Astronomy and Ionosphere Center (Arecibo Observatory) has nationwide significance under Criterion A, because of its contribution to the history of the sciences of ionosphere studies and the development of radio and radar astronomy in the United States. The property is also eligible under Criterion C, because it represents a significant work of engineering" (Santos, 2007).

There are eight buildings and one structure that contribute to the NRHP-listed historic district. These contributing resources are listed in Table 3.2-2 and their locations are shown on Figure 3.2-2. The NRHP Registration Form, which was completed in 2007, provides building numbers that do not always correspond to the current facility number designations. For this reason, the current building number is provided in Table 3.2-2 along with the corresponding NRHP Registration Form building number. Two trailers associated with Building 1 are identified in the NRHP Registration Form together as Building 1A; however, these two trailers currently have individual designations as Buildings 66 and 68. In addition, the NRHP Registration Form identifies Buildings 11 and 12, which are currently designated as a single building, as Building 17.

TABLE 3.2-2
Contributing Resources to the NRHP-listed Historic District

Structure/ Building No.	Building Name	Year of Construction
N/A	305-meter-diameter Radio Telescope (including reflector dish, foundation and rim wall, support towers, and anchors)	1960-1963
Building 1 (with trailers, Buildings 66 and 68) (NRHP Buildings 1 and 1A)	Operations Building (with Atmospheric Science Trailer and Visiting Science Trailer)	1963 (addition in 1983) Year of construction for trailers unknown
Building 2 (NRHP Building 2)	Administration Building	1963

TABLE 3.2-2
Contributing Resources to the NRHP-listed Historic District

Structure/ Building No.	Building Name	Year of Construction
Building 54 (NRHP Building 5)	Visitor Center (Angel Ramos Foundation Science and Visitor Center)	1997 (addition 2016)
Building 61 (NRHP Building 6)	Learning Center	2001
Building 27 (NRHP Building 7)	Photometry Shack and Optical Lab	1985/1997
Building 17 (NRHP Buildings 11 and 12)	Warehouse and Business/Purchasing	1967
Building 12 (Building 13)	Maintenance Building	1967

The results of the reconnaissance architectural survey were presented in a technical memorandum entitled *Proposed Changes to Arecibo Observatory Operations: Cultural Resources Reconnaissance Architectural Survey Summary* (CH2M HILL [CH2M], 2016). The results are summarized below.

The 305-meter-diameter radio telescope and its associated facilities are regularly maintained; no significant visible alterations have occurred to the 305-meter-diameter radio telescope, Building 1, Building 2, Building 61, Building 27, Building 17, or Building 12. Building 54, the Angel Ramos Foundation Science and Visitor Center, was renovated in 2016. The renovation included new restrooms, a new entrance, and a new observation deck that extends from the rear (south) elevation of the building. The visitor center is a modern building that was originally constructed in 1997. The building is considered significant within the NRHP-listed historic district for its role in making important scientific investigations available to the public. The recent renovation has not significantly altered the overall integrity of the building; rather, the expansion provided further amenities for visitors, enhancing the utility of the building. The renovation had minor effects on the building's integrity of design, but did not diminish the building's integrity of association, feeling, location, setting, workmanship, or materials. Several other facilities, including the 12-meter radio antenna, were constructed within the district boundaries after 2008, slightly altering the district's integrity of setting. However, the construction of new facilities, most of which are small- to medium-sized utilitarian structures, has not diminished the overall integrity of the historic district; instead, additional construction has allowed the Observatory to adapt to changes in the field of astronomy and remain in operation as a critical research center.

The 305-meter-diameter radio telescope at Arecibo Observatory was designated an Electrical Engineering and Computing Milestone by the Institute of Electrical and Electronic Engineers in 2001. The 305-meter-diameter radio telescope was also designated a Historic Mechanical Engineering Landmark by the American Society of Mechanical Engineers the same year (Santos, 2007).

FIGURE 3.2-1
Cultural Resources Area of Potential Effects

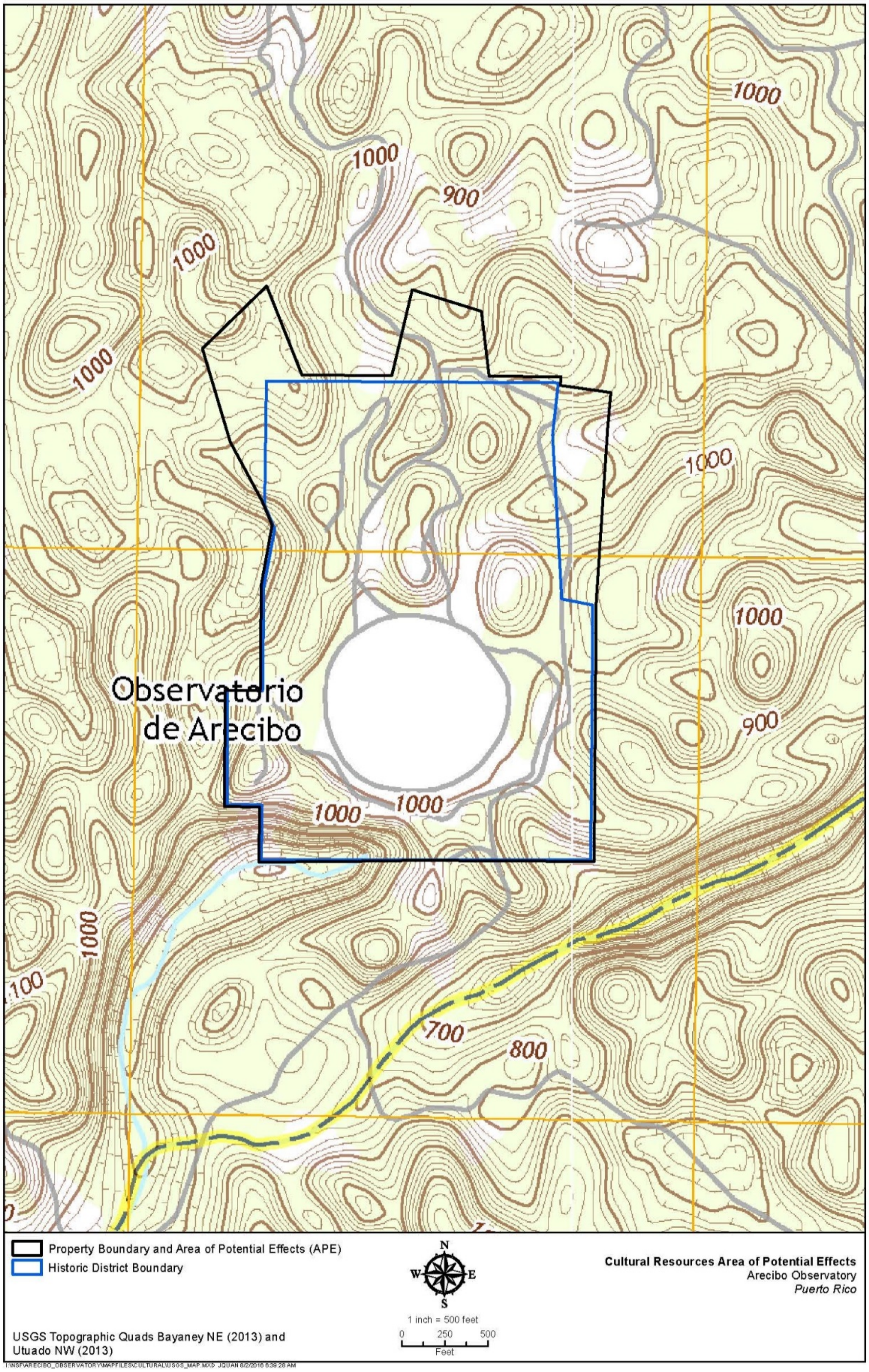
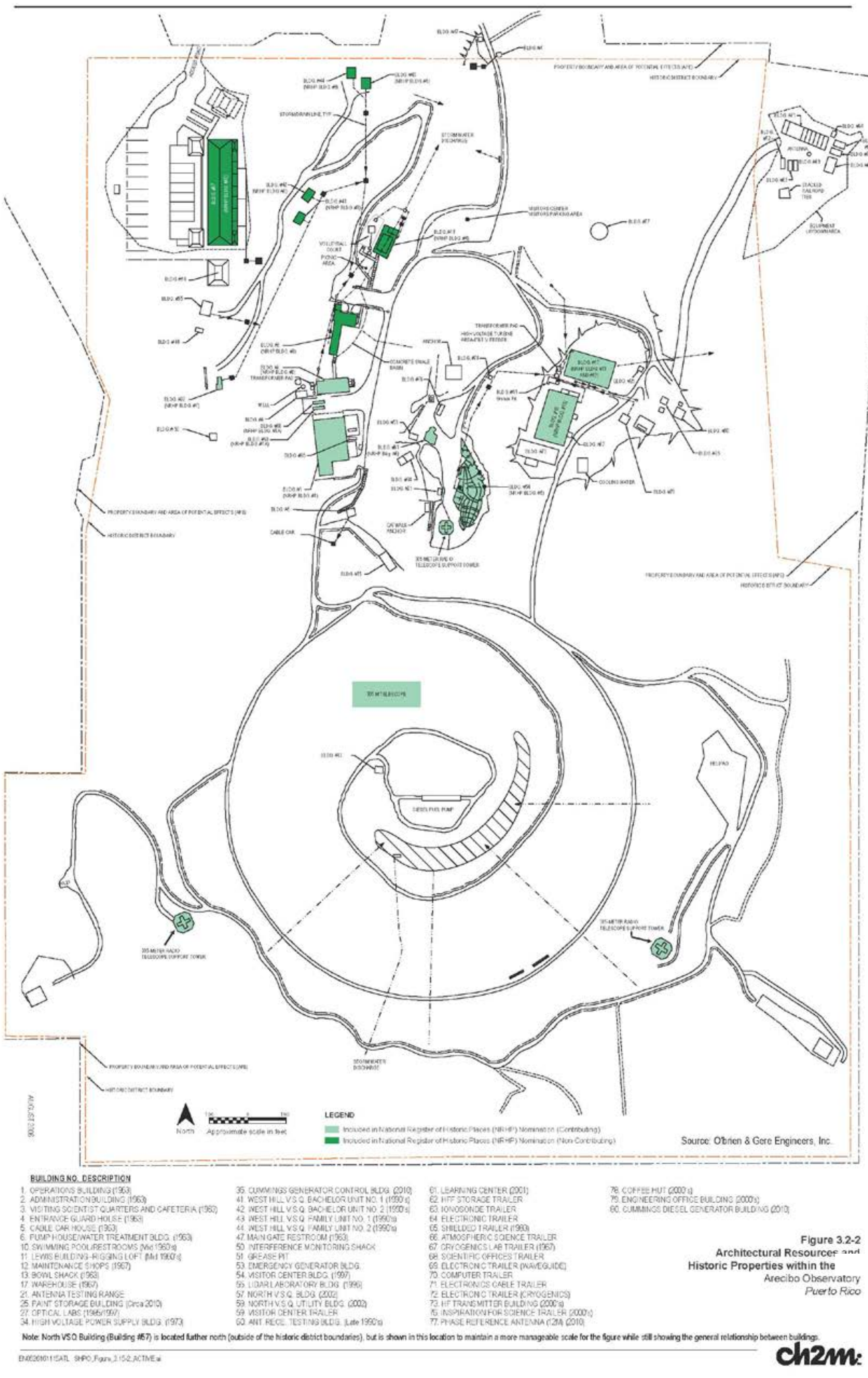


FIGURE 3.2-2
Architectural Resources and Historic Properties within the Area of Potential Effects



3.3 Geology and Soils

This Section describes the geologic and soil conditions at Arecibo Observatory. The ROI for geology and soils is the boundary of the Observatory and the immediately surrounding area.

3.3.1 Proposed Action Area

3.3.1.1 Geology

The Arecibo Observatory site is located within an area of limestone bedrock known as the North Karstic Zone. The karst geology and weathering patterns on and near the site have produced topographic features such as sinkholes and conical hills of cone karst known as mogotes, which are formed by weathering of the underlying limestone. The hills are grouped linearly with intervening sinks. The formation of mogotes is attributed to the solution process along joints in the limestone or to the collapse of caverns along underground rivers. The best developed mogotes in Puerto Rico occur near the site where many of the cones are sharp, pointed, nearly circular, or oval. These mogotes range from 660 to 980 feet (200 to 300 meters) in diameter at the base, and rise 160 to 250 feet (50 to 75 meters) from the bottom of adjacent depressions (Lugo, et al., 2001).

The Arecibo Observatory site reflects the karst geology of the region. It contains karst features, including sinkholes, which are located throughout the property. The 305-meter-diameter radio telescope at the project site is located in an engineered basin containing a sinkhole that connects through karst to the Tanamá River, approximately 2,500 feet (760 meters) to the southwest. There are at least three additional sinkholes on the eastern side of the Observatory property that likely connect with the Tanamá River as well (Reaves and Orsoy, 2016). Sinkholes are typical in karst landscapes and are produced by the solution process, where limestone bedrock dissolves by chemical reaction from contact with water.

Geology in the region is composed of two primary rock sequences. The deeper layer consists of about 15,100 feet (4,600 meters) of deformed Cretaceous and lower Tertiary volcanogenic deposits intruded by dioritic rocks. This layer is divided into five formations. A younger layer divided into three formations rests unconformably on these older rocks and consists of up to 1,800 feet (550 meters) of essentially undeformed middle Tertiary (i.e., Oligocene and Miocene epochs) calcareous and associated deposits. A deep layer of saprolite covers much of the bedrock in the area (Nelson and Tobisch, 1968).

The upper geologic formations within the site and surrounding areas are described below, starting with the uppermost, based on the USGS Geologic Map, Bayaney Quadrangle (Nelson and Tobisch, 1968) and the USGS Karst Map of Puerto Rico (Aleman-Gonzalez, 2010):

- Cibao Formation (Miocene and Oligocene) – Friable pure calcarenite, indurated to an erosion-resistant limestone upon exposure to air with a maximum thickness of 525 feet (160 meters).

- Lares Formation (Oligocene) – Thin-bedded to thick-bedded fairly pure limestone; lower part locally contains grains of quartz and limonite sand, and intertongues to the west with sand and gravel with a maximum thickness of 1,020 feet (310 meters).
- San Sebastián Formation (Oligocene) – Mostly thin-bedded sand and clay with some sandy limestone locally with a maximum thickness of 260 feet (80 meters); also contains sand and gravel (Karst Map, 2010; Bayaney Quad Map)

The Lares Formation gives rise to mogotes in and around the site. These features characteristically consist of round pointed cones, but at places where jointing has affected the cone development jagged sawtooth cones and ridges occur. Mogotes formed only at those places where the limestone is very thickly bedded to massive (Monroe, 1976).

The Cibao Formation underlies all of the site except for the area of the 305-meter-diameter radio telescope dish, which is underlain by the Lares Formation (Nelson and Tobisch, 1968).

3.3.1.2 Soils

Soils on the Arecibo Observatory property and the immediately surrounding areas are mapped as Soller-Rock Outcrop Complex, 5 to 60 percent slopes (Natural Resources Conservation Service, 2016). This complex consists of sloping to very steep, well-drained soils and areas of exposed limestone bedrock. Typically, Soller-Rock Outcrop Complex, 5 to 60 percent slopes occur on ridgetops and side slopes, and the slopes may be up to 500 feet (150 meters) long. Individual areas of the complex are from 50 to 300 acres and consist of 60 percent moderately deep Soller soils, 30 percent exposed bedrock, and 10 percent other soils. Within the complex, Soller soils and exposed bedrock are so intermingled that they cannot be effectively and separately mapped. Other soils that occur within this complex include small areas of Colinas, San German, Espinosa, and Almirante soils. Some areas will have a surface layer of cobbly clay loam and areas of severely eroded soils. Hard fragmental limestone typically occurs depth of 25 inches or less. The Soller soils have moderate permeability and low available water capacity. Runoff is moderate to very rapid. Natural fertility is medium to high. The surface layer and subsoil are neutral to mildly alkaline (circumneutral). The extreme slopes and areas of exposed rock make this complex poorly suited for cultivation, and where it occurs, cultivation must be done by hand. Slope, the areas of exposed rock, and the depth to rock are the main limitations for non-farm development (Soil Conservation Service, 1982).

3.4 Groundwater

This Section addresses the groundwater conditions at and around Arecibo Observatory. The ROI for groundwater is Arecibo Observatory, immediately adjacent aquifer recharge areas, and the Camuy River and Tanamá River drainages.

The primary regulatory driver for groundwater is the Clean Water Act (CWA). Discharges from land-disturbing activities that exceed 1 acre, or from smaller sites that are part of a larger common plan of development, must be authorized under a CWA Construction Stormwater National Pollutant Discharge Elimination System (NPDES) permit.

In addition, EPA promulgated rules to manage stormwater through the Construction and Development Effluent Guidelines and Standards (40 C.F.R. Part 450), which is administered by the EQB in Puerto Rico. A stormwater general permit (permit number PRR120000) has been issued by the EQB that would apply to demolition activities at Arecibo Observatory. The construction stormwater permit requires compliance with effluent limits and other permit requirements, including the development of a stormwater pollution prevention plan (SWPPP).

3.4.1 General Setting

The aquifers of northern Puerto Rico are highly karstified and include sinkholes, mogotes, and other solution features (Jones and Banner, 2003). There are two limestone aquifers in northern Puerto Rico where Arecibo Observatory is located. The uppermost of these two aquifers is not present at Arecibo Observatory. The recharge area for the lower aquifer includes the area of Arecibo Observatory and is discussed further in the following paragraphs.

The aquifer on Arecibo Observatory recharges through infiltration from sinkholes and from perennial and intermittent streams and rivers. The streams and rivers commonly have channels that disappear underground and reappear a few kilometers downstream. Groundwater generally flows towards the north. Recharge to the aquifer varies seasonally based on precipitation and occurs in months with rainfall exceeding 190 millimeters and, thus, is greater during the wet season of June through November (Jones and Banner, 2003).

There are several sinkholes within the boundary of the Observatory. A single large sinkhole receives runoff from within the bowl beneath the 305-meter-diameter radio telescope dish. Three additional sinkholes occur along a trail on the east side of the Observatory property (Reaves and Orsoy, 2016). These sinkholes connect through the karst formations with groundwater and with the Tanamá River to the east and the Camuy River to the west.

Aquifer groundwater discharge takes place primarily along the coast in the form of seepage into the sea (Giusti, 1978). Groundwater residence times in the aquifer are unknown and groundwater flow through the aquifer is highly controlled by fractures (Jones and Banner, 2003). Groundwater is extracted from the aquifer for domestic, industrial, and agricultural purposes. The largest fraction is used for public supply, followed by the industrial and agricultural sectors. Several industrial wells and a few public water supplies withdraw from the aquifer in the vicinity of Arecibo Observatory (Padilla, et al., 2011).

3.4.2 Groundwater Quality

Water quality surveys in Puerto Rico have identified contamination in the aquifer, including chlorinated volatile organic compounds (CVOCs) and phthalates (chemicals used to make plastics). Contamination reflects long-term storage and dispersion of contaminants. Because the aquifer on the Arecibo Observatory site is disconnected from the surface by a confining unit and no significant recent contamination sources have been observed in the recharge area, contamination is presumed to result from historical liquid-waste injections made prior to their ban in the 1970s (Padilla, et al., 2011). In 1969, there were approximately 40 waste-disposal wells operating in Puerto Rico. Wastes injected through this process included sewage, oil, neutralized acid, organic compounds, dyes, pickling liquors, and pineapple cannery wasteland brewery wastes (Zack, et al., 1987).

The sinkhole beneath the 305-meter-diameter radio telescope dish is sampled regularly by EQB. Following heavy precipitation events, water accumulates in the bowl and can reach above the bottom of the reflector dish. When this occurs, the 305-meter-diameter radio telescope is inoperable until water from the bowl is pumped out to the east and allowed to flow by gravity to a receiving stream or infiltrate (Gago, 2016, pers. comm.).

3.5 Hazardous Materials

This Section discusses the hazardous materials contamination that may be present at the site and the handling of hazardous materials and waste during operations. The Resource Conservation and Recovery Act of 1976 (RCRA) defines hazardous wastes as materials that exhibit one of the following four characteristics: ignitability, corrosivity, reactivity, or toxicity.

The ROI for hazardous materials and wastes analyses follows the requirements prescribed by ASTM International (ASTM) Standard Practice E1527-13, *Standard Practice for Environmental Site Assessments: Phase I Environmental Site Assessment Process* (ASTM E1527-13), and includes the area within the Arecibo Observatory property boundary and the approximate minimum search distances for select federal and state standard source environmental databases ranging from the subject property to 1 mile (Appendix 3.5-A provides figures and additional details). No properties within 1 mile of the site appear to have the potential to environmentally affect the Arecibo Observatory site.

3.5.1 Existing Site Contamination

An Environmental Baseline Study (EBS) was prepared for the Arecibo Observatory site by CH2M in 2015 and is presented in Appendix 3.5-A. The hazardous materials section of the EBS was conducted in conformance with ASTM E1527-13. The following discussion of potential contamination present at the site is based on the EBS findings.

No recognized environmental conditions (RECs) or historical recognized environmental conditions were found on the site. However, the following *de minimis* condition was identified on the subject property:

- Staining was found on the warehouse concrete floor and in parking areas.

The following are other conditions on the subject property that are not considered RECs but are conditions that were found at the site:

- ACM was found in some of the buildings.
- LBP was found in some of the buildings and the gate area.
- The polychlorinated biphenyl (PCB) content of the pole-mounted transformers on the property is unknown as the transformers are not labeled non-PCB and documentation was not readily available for review.
- A 55-gallon capacity oil-water separator (OWS) is associated with the tank farm containment area. Stormwater that collects within the containment area is pumped to the OWS and then discharges to the ground surface. Although there was no noticeable evidence of impacts to surrounding soils, because the OWS is 50 years old, a possibility exists that it may have failed at some point and impacted surrounding soils.
- The septic and leachfield system serving the maintenance area has served facilities where hazardous and petroleum products have been stored and used for over 50 years. No visual evidence of contamination was observed during the site reconnaissance.

A more detailed discussion of existing contamination is presented in the EBS (CH2M, 2015; Appendix 3.5-A).

3.5.2 Use of Hazardous Materials

Hazardous materials typically used for building maintenance, landscaping, scientific instruments, fuel for generators, vehicle maintenance, drinking water treatment, and pool maintenance are used onsite. The majority of hazardous materials and petroleum products are stored in areas near the warehouse building. Smaller quantities of products were stored at buildings where they intend to be used (CH2M, 2015).

Fuel oil is stored in ASTs and USTs.

There are five ASTs on the subject property (CH2M, 2015):

- One 1,000-gallon daily tank containing diesel located at the generator building
- One 12,000-gallon tank containing diesel located in the maintenance area tank dike
- One 2,000-gallon tank containing gasoline located in the maintenance area tank dike
- One 2,000-gallon tank containing diesel located north of Building 53
- One 300-gallon tank containing diesel located below the reflector

No USTs are on the subject property. Three gasoline USTs previously existed on the property. A 4,000-gallon tank and a 2,000-gallon tank were installed near the maintenance building in 1983. A 3,000-gallon tank was installed near the former piña colada stand in 1963. This UST was abandoned in place; however, the tank was not properly closed according to the EQB. In 2011, all three USTs were removed and confirmation samples were taken and no contamination was detected above EQB criteria (CH2M, 2015). Additional details on fuel storage are presented in the EBS (Appendix 3.5-A).

Carbon-14 (C-14) is stored onsite and used for experiments. On June 23, 2014, the U.S. Nuclear Regulatory Commission inspected the C-14 and confirmed the C-14 was secured with no leaks (CH2M, 2015).

3.6 Solid Waste

This Section presents a description of the solid waste infrastructure at Arecibo Observatory. Solid wastes at the Observatory comprise a broad range of materials, including garbage, refuse, sludge, demolition and construction waste, nonhazardous industrial waste, municipal wastes, and hazardous waste.

The ROI for solid waste includes the Arecibo Observatory site and the facilities in which the solid waste are landfilled. There are two landfill facilities that receive solid waste from the Arecibo area.

3.6.1 Proposed Action Area

The closest landfill to Arecibo Observatory is the Arecibo Landfill, located 15 miles (24 kilometers) from the site. The Arecibo Landfill only accepts municipal solid waste, such as household and commercial wastes. The Poncé Landfill, which is located 39 miles (63 kilometers) from the site, is the nearest landfill that accepts demolition debris, as well as asbestos waste. Table 3.6-1 contains information describing the landfills.

TABLE 3.6-1
Landfill Facility Summary for the Region of Influence

Facility Name	Address	Wastes Accepted	Distance from Arecibo Observatory (Miles – One Direction)	Estimated Permit Closure Date
Arecibo Landfill	KM 13.5 Zona Industrial Santana 13.5 Zona Industrial Santana, Carr Prairie 682 Arecibo, Puerto Rico 00612	Municipal solid waste	15	2030
Poncé Landfill	Baramaya Final Ave. Rd 500 Sector La Cotorra Poncé, Puerto Rico 00731	Municipal solid waste, asbestos-friable, asbestos-non-friable, construction and demolition debris, and household hazardous waste	39	Permit renewed every 5 years

Sources: ADS, 2016a, 2016b; Clas, 2016a, pers. comm.

3.7 Health and Safety

This Section discusses health and safety within the ROI, which includes a discussion on public safety, occupational health, and the protection of children.

3.7.1 Public Safety

Public safety is defined as the welfare and protection of the general public and includes individuals both on and off the Arecibo Observatory property. For the purpose of evaluating the public safety impacts by the data obtained from the Observatory, the ROI includes the entire human environment.

3.7.2 Occupational Health

Occupational health risks are defined as risks arising from physical, chemical, and other workplace hazards that interfere with establishing and maintaining a safe and healthy working environment. Hazards could include chemical agents; physical agents, such as loud noise or vibration; physical hazards, such as slip, trip, and fall hazards; electricity or dangerous machinery; and natural hazards, such as flooding, botanical hazards, or wildlife hazards. The ROI for occupational health is defined as the Arecibo Observatory boundary.

3.7.3 Protection of Children

Child-centric resource locations, including schools, parks, churches, and daycare centers, were obtained by readily available online spatial data and government agency address lists such as the licensed daycare facilities (Puerto Rico Department of Family, 2016). Occasionally the address only referenced a neighborhood (*barrio*); therefore, the facility was located in the geographic center of the neighborhood. There may be additional child-centric resources such as unlicensed daycare centers that have not been identified. The ROI for protection of children includes 0.5-mile around the facility boundaries and, because traffic changes are a concern, 0.5-mile around the roadway network leading to the Observatory and along the potential demolition waste haul routes.

3.7.4 Proposed Action Area

3.7.4.1 Public Safety

Scientists use Arecibo Observatory to conduct solar system research, including research into smaller solar system bodies such as asteroids. Arecibo Observatory's solar system research includes the study of near-Earth objects (NEOs), along with the subset of NEOs that have the potential to collide with the Earth: potentially hazardous objects (PHOs). Scientists use the Observatory's radar transmitter to improve characterization and tracking of such objects. The task of finding and cataloging these objects is the responsibility of the NASA Planetary Defense Coordination Office (https://www.nasa.gov/planetarydefense/overview). Earth's defense against PHOs is a complex process in which radio telescopes with radar, such as the one at Arecibo Observatory, play a role. Such telescopes have no practical ability to make initial discoveries of PHOs or divert them, but when available, radar observations can help characterize PHO properties and allow for more accurate orbit determinations. A good orbit determination is essential for accurately predicting the probability of a specific PHO impacting the Earth.

Discovery of NEOs is carried out by optical/infrared telescopes. Once a NEO is detected, optical/infrared telescopes are used to make additional observations to define the approximate orbit of the NEO and determine whether it has any probability of intersecting Earth's orbit in the future. Arecibo Observatory can observe approximately 100 to 200 NEOs per year. If the NEO's orbit will pass within 4,650,000 miles of Earth at any time, then the NEO is considered a PHO. After discovery and an initial orbit determination, a PHO can potentially be observed by a radar-equipped radio telescope with the capability of viewing the PHO. The primary purpose of such radar observations is to refine the determination of a PHO's orbit and other characteristics. To successfully make radar observations of a PHO, the PHO must pass through the telescope's observable zone, which is defined as that volume where a PHO is close enough to Earth to be targeted by Arecibo Observatory's radar when it is in the area of the sky (within 20 degrees of zenith) accessible to the 305-meter-diameter raido telescope. The daily rotation of the Earth sweeps this instantaneous observable zone around the sky. Combined with the fact that PHOs move through the sky relatively rapidly when they are near the Earth, roughly 60 to 80 percent of PHOs are likely to pass through Arecibo Observatory's observable zone at some time in their orbit around the Sun (NASA, 2017).

The probability of a sizeable PHO striking Earth at any particular time is very low. According to a 2010 National Academies study, *Defending Planet Earth: Near-Earth Object Surveys and Hazard Mitigation Strategies* (NRC, 2010b), objects of sizes 25, 50, and 140 meters have approximate mean intervals between Earth impacts of 200, 2,000, and 30,000 years, respectively. Objects of 25 meters would likely result in airbursts, while objects of 50 or 140 meters would have local- or regional-scale impacts, respectively (NASA, 2017). According to NASA, in a typical year there are three or fewer newly discovered PHOs that require radar data to conclusively rule out the threat of a future collision with Earth (NASA, 2017). To date, no object of a size that poses significant risk to life or property has been found by NASA to threaten the Earth (NASA, 2017). A function of the Observatory's observations, then, is determining whether any PHO is an actual, imminent hazard.

If a PHO within the Observatory's observable zone did present a near-term threat of striking the Earth, significant capability challenges exist to mitigate such a threat. There is no existing technology that has been tested on an actual asteroid that could prevent a PHO from striking the Earth. Even if there is no ability to mitigate such a threat, precision tracking may still be helpful to inform emergency preparedness if the location of the potential impact can be determined.

Arecibo Observatory is also used as a public shelter during hurricanes and severe storm events; however, it is not officially listed as a shelter by the Puerto Rico Office of Emergency Management.

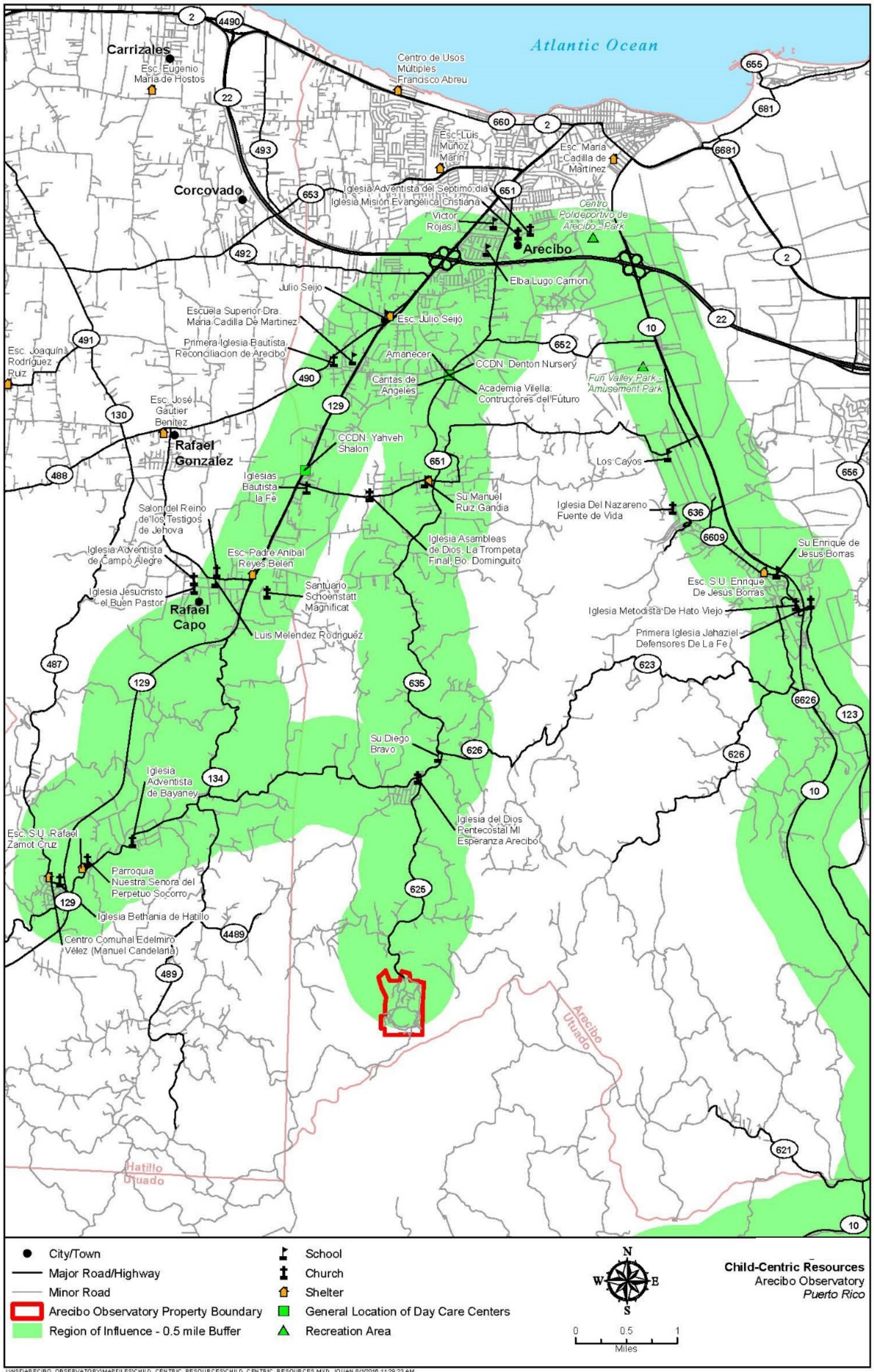
3.7.4.2 Occupational Health

Physical hazards at Arecibo Observatory include hazards associated with a typical office environment and large-scale structures requiring maintenance, including slip, trip, and fall hazards. Natural hazards in the undeveloped portions of the site include poisonous plants, stinging and biting insects, and potentially aggressive animals such as snakes. The site is not located within a floodplain and any flooding risk would be localized in nature.

3.7.4.3 Protection of Children

Arecibo Observatory is located in a rural area surrounded by rugged terrain and is approximately 0.5-mile from the nearest housing area. The Observatory is considered a valuable community resource that serves children, with over 90,000 annual visitors, many of whom are children. There are no child-centric resources within 0.5-mile of the Observatory boundary; however, there are at least 36 within 0.5-mile of the roadway network leading to the Observatory (Figure 3.7-1).

FIGURE 3.7-1
Child-centric Resources



3.8 Noise

Noise is defined as unwanted or undesirable sound. This Section addresses the potential for noise to affect the human environment. Noise impacts to wildlife are discussed in Section 3.1, *Biological Resources*. Noise intensity, or loudness, is determined by how sound pressure fluctuates. Because the range of sound pressure ratios vary greatly over many orders of magnitude, a base-10 logarithmic scale is used to express sound levels in dimensionless units of decibels (dB). Because sound travels in waves, there are also varying frequencies associated with each sound event. The human ear does not respond equally to all frequencies. To obtain accurate measurements and descriptions of noise, as noise is comprised of many frequencies, the noise frequencies are filtered or weighted to most closely approximate the average frequency response of the human ear. This weighting is called the "A" scale on sound-level meters, and is the scale that is used for traffic noise analyses. Decibel units described in this manner are referred to as A-weighted decibels, or dBA. Table 3.8-1 provides a general comparison of dBA levels by noise source.

TABLE 3.8-1
Comparison of dBA Levels by Noise Source

Noise Source at Give Distance	A-weighted Sound Level in Decibels (dBA)	Subjective Impression
Loud Rock Music	110	Very loud
Jet Flyover at 1,000 feet	100	--
Gas lawnmower at 3 feet	90	--
Garbage disposal at 3 feet	80	--
Vacuum cleaner at 10 feet	70	Moderately loud
Heavy traffic at 300 feet	60	--
Quiet urban daytime	50	--
Quiet urban nighttime	40	Quiet
Library	30	--
Recording studio	10	Threshold of hearing

Source: Caltrans, 1998.

3.8.1 Proposed Action Area

Arecibo Observatory is located in a rural area surrounded by rugged terrain and dense vegetation and is approximately 0.62-mile (1 kilometer) to the nearest housing area. The ROI for noise includes the project boundary, local access routes from the construction landfill to the entrance of the Observatory, and adjacent properties. The land uses surrounding the Proposed Action are primarily open space and residential.

Noise-sensitive locations in the ROI include the residential areas along the haul routes, including PR-625, PR-635/651, PR-635/134, PR-129, and PR-10 (see Figures 3.10-1 and 3.10-2 of Section 3.10, *Traffic and*

Transportation). The existing noise environment in the ROI consists primarily of occasional aircraft overflights and traffic noise from automobiles and medium and heavy trucks on the surrounding rural roads. Given the rural environment, the noise level is expected to be in the 40-dB range.

3.9 Socioeconomics

This Section provides a description of the existing socioeconomic conditions for the Commonwealth of Puerto Rico and the Municipality of Arecibo to provide a context for evaluating impacts associated with the Proposed Action with respect to the following indicators: population and housing, employment, economy, income, education, and tourism. These socioeconomic resources are important because local governments, businesses, and individuals could be affected by changes in local employment, educational opportunities, and tourism associated with the Proposed Action. For the purpose of this evaluation, socioeconomic factors are defined as follows:

Population is characterized by the magnitude and distribution of demographic change based on U.S. Census Bureau (USCB) data, population estimates, and population projections. The most recent U.S. Census was completed in 2010; therefore, the 2010–2014 Puerto Rico Community Survey (PRCS) 5-Year Population Estimates are also described. As part of the USCB's American Community Survey (ACS), the PRCS is customized for the Commonwealth. It includes 1-year, 3-year, and 5-year estimates; the 5-year estimates are presented herein as USCB notes they are the most accurate for very small geographic areas (USCB, 2016a). The 2014 PRCS 5-year population estimates are based on monthly samples collected during the 60 months of the 5 most recent calendar years (USCB, 2014a). The estimates are not calculated as a simple average of monthly or annual estimates; instead, the USCB generates the estimates by "pooling" the sample responses of what was observed for every month of the entire time period and applying measures to account for changes in areas such as geography, the value of the dollar, and margins of error, to develop weighting of sample cases (USCB, 2016a).

Housing is described as the quantity and availability of accessible permanent and temporary housing. 2014 PRCS housing data are provided for rental and owner-occupied options in the Municipality of Arecibo.

Economy is defined by a general description of the existing local economy of the Municipality of Arecibo and the Commonwealth of Puerto Rico. The description includes the growth, or lack thereof, of the Gross National Product for the Commonwealth and its change over time.

Employment and Income are described by the size of the labor force (defined as the civilian non-institutionalized population, ages 18 to 64), the unemployment rate, and median household income. These data are provided for the Commonwealth and the Municipality.

Education is characterized by the total public school enrollment figures by grade level for the Municipality and the Commonwealth and by the educational opportunities offered at Arecibo Observatory.

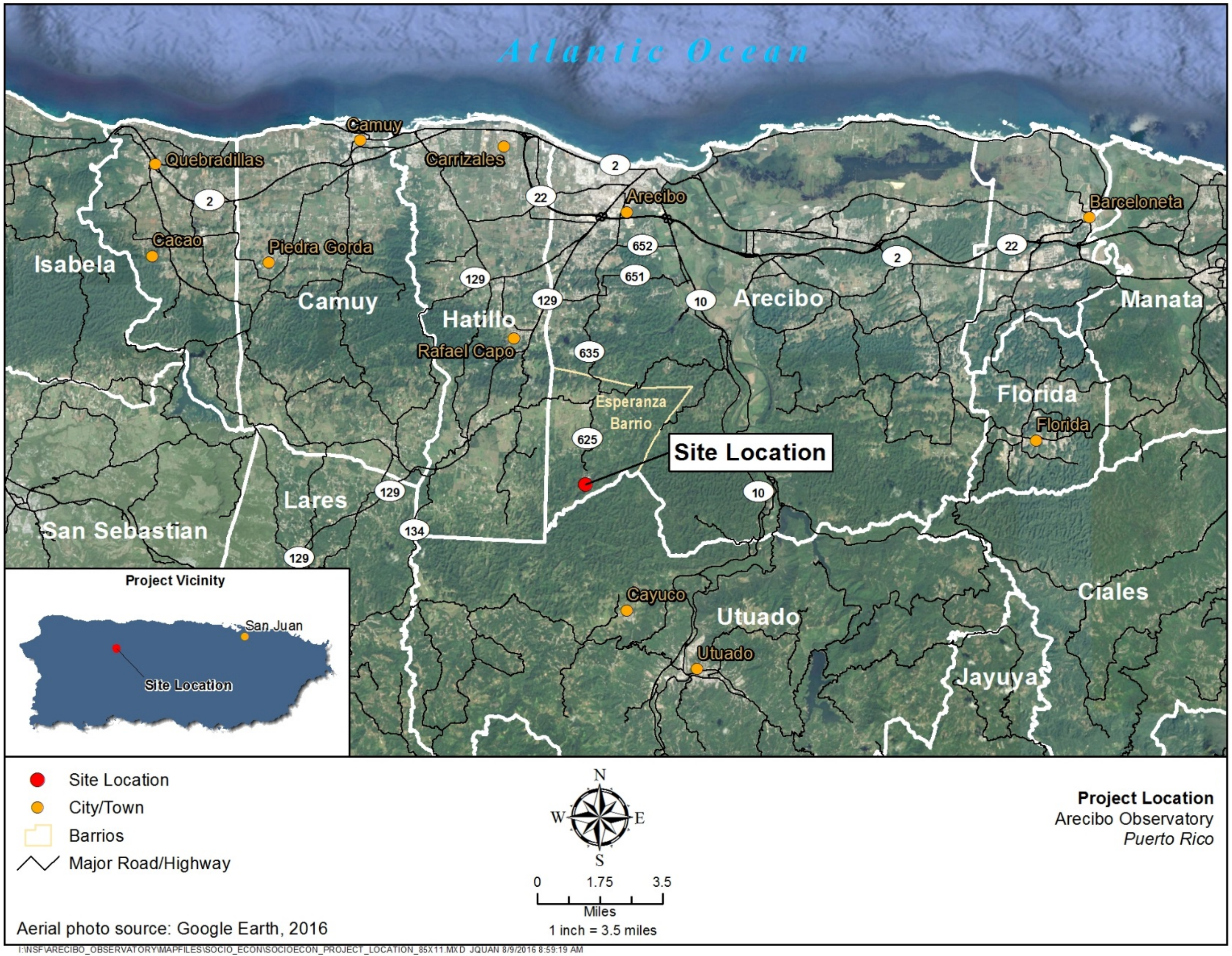
Tourism is characterized by the number of visitors and their expenditures in the Commonwealth for 2015 from the PRPB and from visitor trends at Arecibo Observatory.

The ROI for population, housing, employment, economy, and income is defined as the Municipality of Arecibo. Arecibo Observatory is most easily accessed from roads within the Municipality, providing the Observatory with connectivity to the City of Arecibo; therefore, most of those employed at Arecibo Observatory would tend to be located within this ROI. The ROI for education and tourism is the Commonwealth of Puerto Rico because the education and tourism activities offered draw students and visitors from across the island. Arecibo Observatory is located in the Esperanza Barrio, a small geographical area in the southern tip of the Municipality of Arecibo (see Figure 3.9-1). Information for the Esperanza Barrio is also presented where available. The baseline year for population and housing is 2014, which is the most recent year for which USCB PRCS data are available for most of the socioeconomic indicators. Similarly, economic conditions are presented for 2015, which is the most recent year for which USCB and PRPB data are available.

Arecibo Observatory is located within the Municipality of Arecibo, a governmental delineation that is analogous to a county. The Municipality had an estimated population of 93,969 in 2014 (USCB, 2015a). However, unlike a county, the central government of the Commonwealth is responsible for local police and fire protection, education, public health and welfare programs, and economic development (GDB, 2015). The Municipality of Arecibo is bordered to the west by the Municipality of Hatillo (population 41,830), to the north by the Atlantic Ocean, to the south by the Municipality of Utuardo (population 32,086), and to the east by the Municipality of Bareloneta (population 24,908) and the Municipality of Florida (population 12,565) (see Figure 3.9-1) (USCB, 2015b). The Municipality of Arecibo is part of the four-county Arecibo metropolitan statistical area (MSA[5]) along with the three municipalities to the west: Hatillo, Camuy, and Quebradillas (USCB, 2015c). The Municipality of Arecibo is subdivided into 27 barrios (neighborhoods), nine of which form the City of Arecibo. Arecibo Observatory is located in a remote area of the Esperanza Barrio in the southwestern tip of the Municipality of Arecibo, approximately 11 miles from the City of Arecibo. The Esperanza Barrio is bordered to the southwest by the municipalities of Hatillo and Utuardo and is a sparsely developed area with an estimated population of 1,705 in 2014 (USCB, 2015b). Development within 5 to 10 miles of the Observatory in the adjacent municipalities is also limited and primarily rural.

[5] The USCB defines an MSA as an area that consists of one or more counties with a core urban area of 50,000 or more in population and includes the counties containing the core urban area, as well as any adjacent counties that have a high degree of social and economic integration (as measured by commuting to work) with the urban core (USCB, 2016b).

FIGURE 3.9-1
Project Location



Arecibo Observatory consists of approximately 51 structures on about 120 acres surrounded by land that is primarily undeveloped because of the karst topography and the protection of natural areas (Puerto Rico Department of Natural and Environmental Resources [DNER], 2016). The primary access route is PR-625 and it is an estimated 30-minute drive (18-kilometer distance) to the border of the City of Arecibo and an estimated 1 hour and 20-minute drive (96 kilometers) to San Juan to the east. Other access routes to Arecibo Observatory are limited as a result of the steep and hilly topography.

3.9.1 Population and Housing

This Section describes the 2014 population estimates for the Commonwealth of Puerto Rico, the Municipality of Arecibo, and Esperanza Barrio based on the 2010–2014 PRCS. It also discusses population trends over time and population projections for 2020. Information on racial and ethnic composition of the population is found in Section 4.12, *Environmental Justice*. This Section also provides a description of housing characteristics in the Municipality of Arecibo, including housing types, housing costs, and vacancy rates.

3.9.1.1 Population

According to the 2014 PRCS estimates, the Esperanza Barrio had approximately 1,704 residents in the 10-square-mile barrio, representing 2 percent of the 93,969 residents of the Municipality of Arecibo (see Table 3.9-1; USCB, 2015d). This small population is indicative of the rural and sparsely developed nature of the area immediately outside the Arecibo Observatory boundaries. Table 3.9-1 shows the population, median age, and age distribution of the Esperanza Barrio, the Municipality of Arecibo, and the Commonwealth of Puerto Rico.

TABLE 3.9-1
Population, Median Age, and Age Distribution (estimated 2014)

		Esperanza Barrio	Municipality of Arecibo	Commonwealth of Puerto Rico
Total Estimated Population		**1,704**	**93,969**	**3,638,965**
Distribution				
	Under 5 years	7%	5%	6%
	18 to 64 years	61%	60%	61%
	65 and older	22%	18%	16%
Median Age (years)		**44**	**40**	**38**

Source: USCB, 2015d.

Population Trends

Table 3.9-2 shows recent population trends for the Esperanza Barrio, Municipality of Arecibo, and the Commonwealth of Puerto Rico from the USCB decennial census in 2000 and 2010, as well as PRCS population estimates for 2014 (USCB, 2000, 2010, 2015c). In the 2010 census, the population for the Municipality of Arecibo is reported as 96,440, a decline of 3.7 percent or 3,691 people compared to the population reported for the 2000 census. This population loss is consistent with an island-wide population decline of 2.2 percent between 2000 and 2010. However, the population losses seen in Esperanza Barrio are more pronounced. As shown in Table 3.9-2, the Esperanza Barrios estimated 2014 population of 1,704 is a 10.4 percent decline from 2010, and the 2010 population of 1,882 reflected a decline of 13.2 percent from the 2000 census. Population estimates from the 2014 PRCS indicate that this declining population trend is continuing. Estimates for 2014 indicate a 2.6 percent decrease in population in 2014 for the Municipality of Arecibo.

TABLE 3.9-2
Population Change from 2000, 2010 and Estimated 2014

	2000 Census	2010 Census	2000 to 2010 % Change	PRCS Estimated 2014	2010 to 2014 % Change
Esperanza Barrio	2,130	1,882	-13.2%	1,704	-10.4%
Municipality of Arecibo	100,131	96,440	-3.7%	93,969	-2.6%[a]
Commonwealth of Puerto Rico	3,808,610	3,725,789	-2.2%	3,638,965	-2.3%[c]

Sources: USCB, 2000, 2010, 2015c.

Population Projections

The population for Puerto Rico is expected to continue to decrease from 3,474,182 persons in 2015 to 2,984,291 persons in 2050 (PRPB, 2016a; USCB, 2016c). This is a 0.4 percent annual decrease, for a total of approximately 14 percent decrease in population over the 35-year period (USCB, 2016c). A 2014 analysis by the Research and Statistics Group of the Federal Reserve Bank of New York, which includes the Commonwealth of Puerto Rico, found that Puerto Rico's population decline can be attributed to a slowdown in the natural population increase (births) as well as a significant increase of emigration (Abel and Deitz, 2014). Population projections for the Municipality of Arecibo are not readily available and have not been generated by the USCB.

3.9.1.2 Housing Information

Table 3.9-3 shows 2014 housing information for the Esperanza Barrio, the Municipality of Arecibo, and the Commonwealth of Puerto Rico, including the estimated number of housing units by occupancy type (owner or renter) and vacancy status (USCB, 2015e). Of the 32,732 occupied units in the Municipality of Arecibo, 71 percent are owner-occupied and 29 percent are renter-occupied. This ratio of housing type (owner versus renter) is comparable to the Commonwealth of Puerto Rico in which 69 percent of housing is owner-occupied and 31 percent is renter-occupied. Overall, approximately 20 percent of the existing housing units in the Municipality of Arecibo and the Commonwealth of Puerto Rico are considered vacant.

TABLE 3.9-3
Estimated Number of 2014 Housing Units Ownership and Occupancy

	Esperanza Barrio	Municipality of Arecibo	Puerto Rico
HOUSING OCCUPANCY			
Total housing units	778	41,152	1,553,611
Occupied housing units	602	32,732	1,241,454
Owner-occupied	483	23,286	862,198
Renter-occupied	119	9,446	379,256
Vacant housing units	176	8,420	312,157
Vacancy rate for all housing types	22.6%	20.5%	20.09%
HOUSING COSTS			
Median Value of Owner-occupied Units (dollars)	$ 92,500	$ 101,500	$ 121,700
Median Gross Monthly Rent of Occupied Units (dollars)	$ 337	$ 415	$ 462

Source: USCB, 2015f.

Monthly housing costs (median rent) in the Municipality of Arecibo ($415) and the Commonwealth of Puerto Rico ($462) are similar. However, housing costs (median rent) in the Esperanza Barrio are lower ($337). Housing values for owner-occupied homes have increased in the Municipality of Arecibo since 2010. The median annual value of owner-occupied units in the Municipality of Arecibo has increased 6 percent from $95,700 in 2010 to $101,500 in 2014 (USCB, 2015e, 2015f).

Because of the undeveloped nature of the surrounding area, temporary housing opportunities (rentals) near Arecibo Observatory are very limited. Currently, 20 onsite housing units are available for visiting scientists, distributed among the following buildings:

- Building 3: Visiting Scientist Quarters – 6 hotel-style rooms and a cafeteria
- Building 41: West Hill Visiting Scientist Quarters – Assume single-occupancy, 1 bedroom
- Building 42: West Hill Visiting Scientist Quarters – Assume single-occupancy, 1 bedroom
- Building 43: West Hill Visiting Scientist Family Quarters – Assume 3-bedroom configuration
- Building 44: West Hill Visiting Scientist Family Quarters – Assume 3-bedroom configuration
- Building 57: North Visiting Scientist Quarters – 12 hotel-style rooms and laundry

If lodging is unavailable in these buildings, visitors must arrange for accommodations in the limited number of local guesthouses or hotels, the closest of which is over 40 minutes to the northeast in the City of Arecibo.

3.9.2 Economy, Employment, and Income

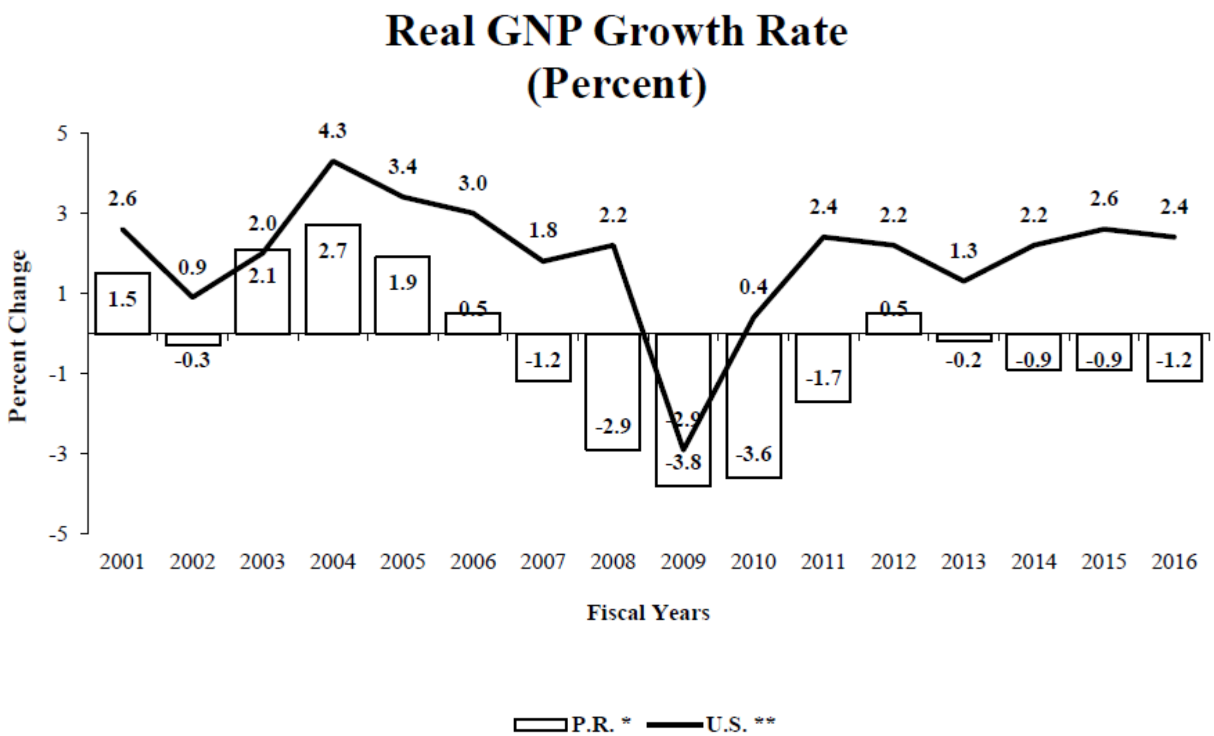
This Section provides information regarding the local economy in the Commonwealth of Puerto Rico and the Municipality of Arecibo, as well as employment and income data for these locations.

3.9.2.1 Economy of Puerto Rico

Puerto Rico's economy was based in agriculture historically but has shifted over the past half century to industrial, manufacturing, and service-oriented sectors (PRPB, 2015). More recently, the PRPB has observed an overall shift from labor-intensive industries to knowledge-intensive industries requiring different skill sets (PRPB, 2015). Manufacturing jobs have transformed from traditional manufacturing to higher wage, high technology industries, such as pharmaceuticals, computer products, biotechnology, professional and scientific instruments, and certain high technology machinery and equipment. The service sector is the largest employer (numerically) in the Commonwealth of Puerto Rico, ranking second to manufacturing in contribution to the gross domestic product (GDB, 2015). The service sector includes finance, insurance, real estate, wholesale and retail trade, transportation, communications, public utilities, and other services.

The economic challenges currently facing the Commonwealth of Puerto Rico have been widely reported with the recent passage of the Puerto Rico Oversight, Management, and Economic Stability Act (PROMESA) by the U.S. Congress; PROMESA was signed into law by the U.S. President on June 30, 2016. PROMESA created a financial control board to manage the restructuring of the Commonwealth of Puerto Rico's debt, oversee its finances, and enforce balanced budgets. It was passed in response to Puerto Rico announcing a year earlier, on June 29, 2015, that it could default on its municipal bond debt if the debt could not be renegotiated (GDB, 2015). One of the main factors contributing to this potential default were the loss of special tax incentives for U.S. mainland companies under the U.S. tax code, which were phased out starting in the mid-1990s, ending completely in 2006 (Kaske and Braun, 2016). This caused a substantial reduction in the number of jobs over time and, with the exception of a modest increase in 2012, the decline of the gross national product (GNP) of the Commonwealth of Puerto Rico since 2007 (see Figure 3.9-2; Working Group for the Fiscal and Economic Recovery of Puerto Rico, 2016). This is in contrast to the U.S. GNP, which has grown every year since 2001, with the exception of 2009 when the U.S economy was in a recession. Other factors contributing to the Commonwealth of Puerto Rico's economic challenges include recent increases to the sales and use tax (SUT) rate from 7 percent to 11.5 percent as of July 1, 2015 (Price Waterhouse Company, 2015). On May 3, 2017, the Commonwealth of Puerto Rico sought judicial relief from its creditors regarding $73 billion in bond debt and $49 billion in pension fund debt. The judicial relief sought is a form of bankruptcy.

FIGURE 3.9-2
Real Gross National Product Growth Rate



Source: GDB, 2015.

The Puerto Rico Department of Economic Development and Commerce (DDEC) recently developed a new Economic Development Plan, referred to as the Economic Roadmap, to "build upon Puerto Rico's historic strengths, creativity, and innovative spirit to achieve a more diversified, knowledge-driven economy that addresses the challenges of globalization and seizes upon emerging opportunities" (DDEC, 2015).

The DDEC plan focuses on the following initiatives (DDEC, 2015):

- Re-energize anchor industries such as manufacturing (life sciences), commerce (small and medium enterprises), and tourism
- Focus on high-impact projects, including the Port of the Americas; Science, Investigation, and Technology Trust; and Roosevelt Roads
- Attract new development through the following programs: Acts 20 and 22 (knowledge services), Jobs Now Act (SMEs), medical tourism, and new agriculture

These initiatives and programs emphasize the need for the Commonwealth of Puerto Rico to continue to diversify its economy by focusing on traditional industries such as agriculture, manufacturing, commerce and tourism, as well as large development projects, and by expanding the science, technology, and knowledge service sectors.

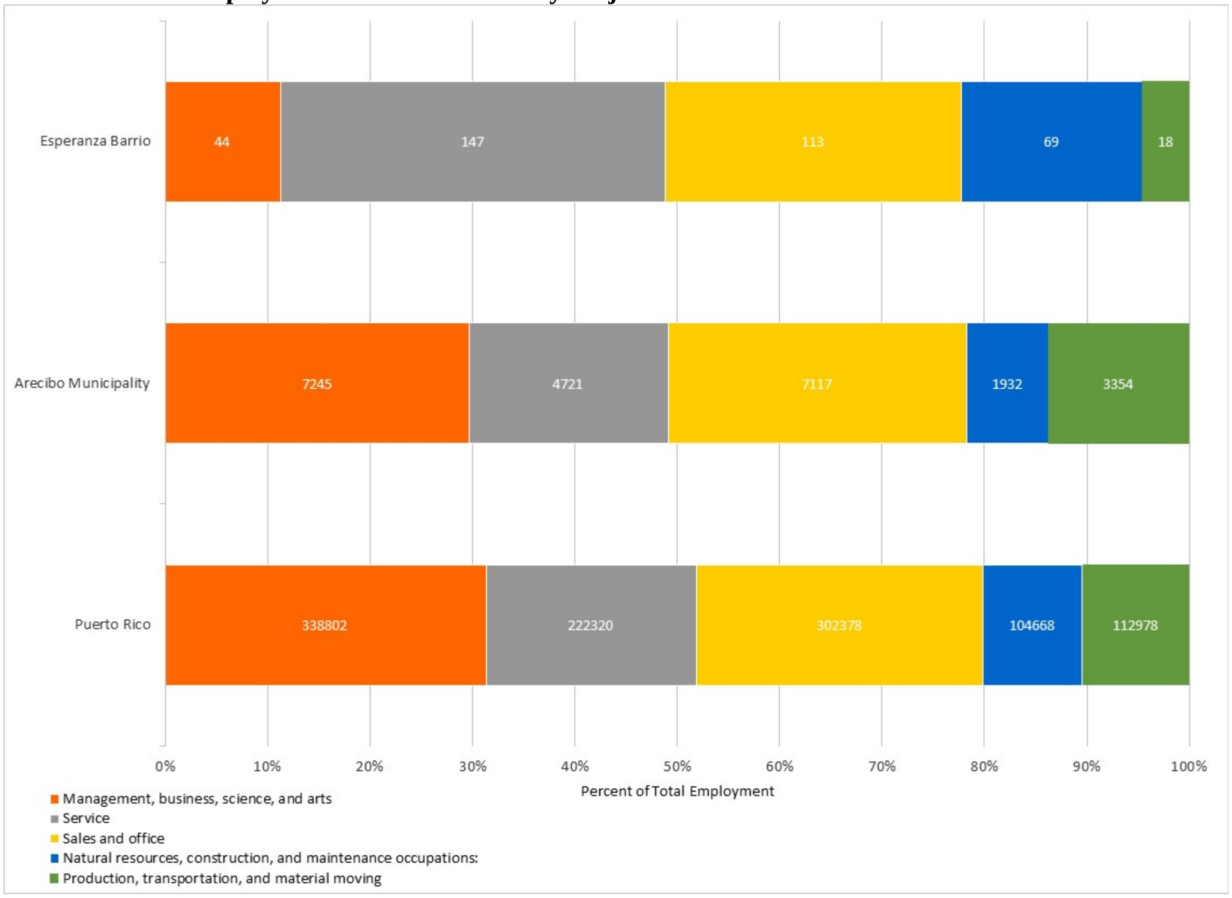
Local Economy of the Municipality of Arecibo

The Commonwealth of Puerto Rico has several regions that are known for biotech industries, including what is referred to as the BioPharma Corridor. This corridor has a high concentration of manufacturing and pharmaceutical industries, including Pfizer, Proctor and Gamble, Bristol-Myers Squibb, Boston Scientific, and Synovis, and extends from San Juan to Dorado, and includes the Municipality of Arecibo, along PR-22, to the Jose de Diego Highway (Puerto Rico Public-Private Partnerships Authority, 2015). An Aerospace Cluster that integrates aerospace manufacturers and related institutions is developing in Puerto Rico and employs 5,000 workers. Arecibo Observatory is not part of the Aerospace Cluster, but the Observatory is considered important in its development by supporting the education and training of engineers and providing data used by these industries. Other economic drivers specific to the Municipality of Arecibo include the University of Puerto Rico at Arecibo (UPRA), St. Jude Medical, and the American Industrial Acquisition Corporation (AIAC), which recently acquired Merck's manufacturing facility in the Municipality of Arecibo, retaining approximately 200 employees at the site. Other recent changes in the local economy of the Municipality of Arecibo include the construction of a new General Electric (GE) manufacturing molded-case circuit breaker facility in the Municipality of Arecibo (GDB, 2015). The Puerto Rico Industrial Development Company (PRIDCO) assisted GE with the construction of this facility.

Employment

In Table 3.9-4, employment in 2009 and 2014 is compared by sector for the Esperanza Barrio, the Municipality of Arecibo, and the Commonwealth of Puerto Rico based on the PRCS to characterize the current workforce composition (USCB, 2009, 2014b). Table 3.9-5 describes the unemployment rate, size of the total labor force, median and per capita income, as well as the highest paying occupations (2014 estimated) for the Municipality of Arecibo and the Commonwealth of Puerto Rico (USCB, 2015g). Overall, the total civilian employment, ages 16 and older, declined by approximately 10 percent between 2009 and 2014 in the Commonwealth of Puerto Rico and the Municipality of Arecibo; however, civilian employment increased by 35 percent in the Esperanza Barrio. The 2014 civilian employed population, ages 16 and older, was estimated to be 1,081,146 in the Commonwealth of Puerto Rico, 24,369 in the Municipality of Arecibo, and 391 in the Esperanza Barrio (USCB, 2014b). According to 2014 estimates, the labor force for the Municipality of Arecibo was employed in the following sectors: management, business, science and the arts (30 percent), service (19 percent), sales and office occupations (19 percent), natural resources (8 percent), and production, transportation and material moving occupations (14 percent). Figure 3.9-3 shows that employment by sector in the Municipality of Arecibo is generally similar to the employment by sector for the Commonwealth of Puerto Rico, but Esperanza Barrio

FIGURE 3.9-3
Estimated 2014 Employment and Distribution by Major Sector



Sources: USCB, 2009, 2014b.

tended to have a greater proportion of service and natural resources, construction, and maintenance occupations in 2014. Natural resources, construction, and maintenance occupations in particular declined substantially (25 percent) from 2009 to 2014, particularly in the Municipality of Arecibo, where farming, fishing, and forestry occupations fell 55 percent and construction and extraction occupations fell 44 percent (USCB, 2009, 2014b). Appendix 3.9-A, Employment and Median Earnings for 2009 and 2014 by Occupation for the Esperanza Barrio, Municipality of Arecibo and Puerto Rico, shows the detailed employment and median earnings for all the subsectors of the large sectors shown in Table 3.9-4.

TABLE 3.9-4

Selected Employment and Median Earnings for 2009 and 2014 by Occupation for the Esperanza Barrio, Municipality of Arecibo, and the Commonwealth of Puerto Rico[a]

	Esperanza Barrio					**Municipality of Arecibo**					**Commonwealth of Puerto Rico**				
	2009 Estimated Employment	**2014 Estimate**	**2014 Distribution**	**2009 – 2014 % Change**	**2014 Median earnings (dollars)[a]**	**2009 Estimated Employment**	**2014 Estimate**	**2014 Distribution**	**2009 – 2014 % Change**	**2014 Median earnings (dollars)[a]**	**2009 Estimated Employment**	**2014 Estimate**	**2014 Distribution**	**2009 – 2014 % Change**	**2014 Median earnings (dollars)[a]**
Employed population 16 years and older	290	391		35%	$11,973	27,111	24,369		-10%	$18,024	1,208,908	1,081,146		-11%	$17,754
Management, business, science, and arts occupations	73	44	11%	-40%	$23,636	*7,595*	*7,245*	*30%*	*-5%*	*$26,175*	*352,087*	*338,802*	*31%*	*-4%*	*$29,271*
Service occupations	61	147	38%	141%	$10,393	*5052*	*4,721*	*19%*	*-7%*	*$14,295*	*234365*	*222,320*	*21%*	*-5%*	*$13,347*
Sales and office occupations	58	113	29%	95%	$8,313	*7643*	*7,117*	*29%*	*-7%*	*$16,477*	*334475*	*302,378*	*28%*	*-10%*	*$16,629*
Natural resources, construction, and maintenance occupations	39	69	18%	77%	$15,804	*2,961*	*1,932*	*8%*	*-35%*	*$16,599*	*139724*	*104,668*	*10%*	*-25%*	*$15,385*
Production, transportation, and material moving occupations	59	18	5%	-69%	-	*3860*	*3,354*	*14%*	*-13%*	*$16,602*	*148257*	*112,978*	*10%*	*-24%*	*$16,227*

Sources: USCB, 2009, 2014b.

Note: See Appendix 3.9-A, Employment and Median Earnings for 2009 and 2014 by Occupation for the Esperanza Barrio, Municipality of Arecibo and Puerto Rico, for full detail of this table.

[a] In 2014, inflation-adjusted dollars (calculated using the average Consumer Price Index for a given calendar year) represent the change in “buying power” due to service and good price increases.

The existing labor, employment and income information for the Municipality of Arecibo and the Commonwealth of Puerto Rico is summarized in Table 3.9-5. The unemployment rate (not seasonally adjusted) for the Commonwealth of Puerto Rico was 11.3 percent in May of 2016, while the U.S. national unemployment rate was 4.7 percent (BLS, 2016). The Municipality of Arecibo's unemployment rate was estimated at 16.6 percent and there were approximately 29,239 people ages 16 and older in the labor force in 2014 based on a 5-year average (USCB, 2015g).

TABLE 3.9-5
Total Labor Force, Employment and Income Data (2014 Estimated)

	Esperanza Barrio	Municipality of Arecibo	Commonwealth of Puerto Rico
Total labor force, not seasonally adjusted	468	29,239	1,139,930
Unemployment Rate	16.5%	16.6%	11.3%
Median Income	$11,797	$16,997	$19,686
Per Capita Income	$6,551	$9,638	$11,331
Highest Paying Occupations			
	Protective services, $31,094	Legal, $39,219	Legal, $50,763
	Management, business, science, and arts, $23,636	Architecture and engineering, $38,456	Architecture and engineering, $42,854
	Education, legal, community service, arts, and media, $23,409	Life, physical, and social science, $36,046	Computer and mathematical, $38,447
	Office and administrative support, $16,111	Health diagnosing and treating practitioners and other technical, $32,951	Life, physical, and social science, $36,042
	Natural resources, construction, and maintenance, $15,804	Management, $31,859	Management, $35,652

Source: USCB, 2015g.

Income

As shown in Table 3.9-5, the Commonwealth of Puerto Rico's per capita income was $11,331, while the per capita income in the Municipality of Arecibo's was $9,638 (for the previous 12 months in 2014 dollars) and Esperanza Barrio's was $6,551 (USCB, 2015g). Similarly, the Commonwealth of Puerto Rico's median household income (in 2014 dollars) was $19,686, while the Municipality of Arecibo's was $16,997 (USCB, 2015g). Table 3.9-5 also shows the sectors with the highest paying jobs in the Municipality of Arecibo and the Commonwealth of Puerto Rico, which are in similar sectors, with the exception of computer and mathematical jobs (Commonwealth of Puerto Rico) and health diagnosing and treating practitioners (Municipality of Arecibo). However, within the Esperanza Barrio, protective services, which includes security and law enforcement jobs, was the highest paying at $31,094. On the whole, median income for these top-paying jobs is generally higher in the Commonwealth of Puerto Rico compared to the Municipality of Arecibo.

The estimated poverty status and age distribution of those below the poverty level in the Commonwealth of Puerto Rico and in the Municipality of Arecibo is summarized in Table 3.9-6. Approximately 45 percent of the population in the Commonwealth of Puerto Rico falls within the poverty rate compared to 49 percent in the Municipality of Arecibo and 59 percent in the Esperanza Barrio. Approximately 57 percent of the children (population under age 18 years) falls within the poverty rate in both the Commonwealth of Puerto Rico and Municipality of Arecibo. In the Municipality of Arecibo, 46 percent of the working age population (ages 18 to 64) is at or below the poverty status compared to 42 percent for the Commonwealth of Puerto Rico. Additionally, 47 percent of the elderly population (ages 65 and older) is in the Municipality of Arecibo and lives at or below the poverty level compared to 40 percent in the Commonwealth of Puerto Rico (USCB, 2015h).

TABLE 3.9-6
Poverty Status 5-year Average of the Past 12 Months

Subject	Commonwealth of Puerto Rico			Municipality of Arecibo			Esperanza Barrio		
	Total	Below Poverty Level	Percent Below Poverty Level	Total	Below Poverty Level	Percent Below Poverty Level	Total	Below Poverty Level	Percent Below Poverty Level
	Estimate	Estimate	Estimate	Estimate	Estimate	Estimate	Estimate	Estimate	Estimate
Population for whom poverty status is determined	3,604,637	1,630,965	45%	92,509	44,931	49%	1,704	1,003	59%
AGE									
Under 18 years	829,365	473,611	57%	20,444	11,663	57%	297	217	73%
18 to 64 years	2,199,634	928,792	42%	55,462	25,452	46%	1,039	657	63%
65 years and older	575,638	228,562	40%	16,603	7,816	47%	368	129	35%

Source: USCB, 2015h.

3.9.3 Education

This Section briefly characterizes the current educational resources of the Commonwealth of Puerto Rico and the Municipality of Arecibo, as well as those programs specific to Arecibo Observatory. The government of Puerto Rico and philanthropical organizations have invested in the educational use of Arecibo Observatory. Past investments have included:

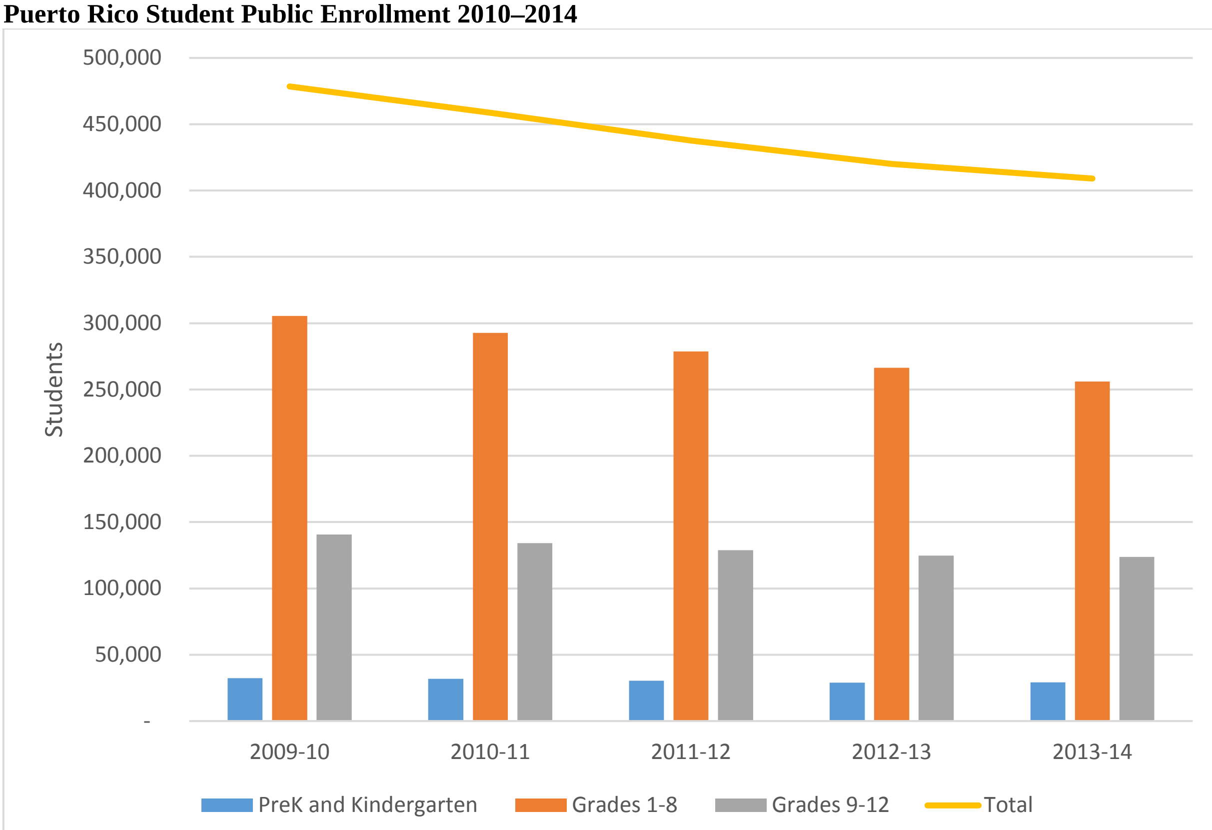
- The Department of Education has invested more than $600,000 in training teachers in the use of the Observatory in their classroom activities.

- The Angel Ramos Foundation and the Ana G. Mendes University System have invested $2.1 million to renovate infrastructure at the Observatory.
- The Puerto Rico Infrastructure Financing Authority has provided $828,635 for infrastructure improvements at the Observatory.

3.9.3.1 School Enrollment in Puerto Rico

The Commonwealth of Puerto Rico is currently the twenty-fifth largest school system in the United States, with 1,458 public schools and a projected 2016–2017 enrollment of 423,858 students (Public School Review, 2016). Additionally, there are approximately 333 private schools in the Commonwealth of Puerto Rico (Puerto Rico Department of Education, 2013). However, the Department of Education has experienced a substantial reduction in student enrollment in recent years as a result of a decline in the birthrate and an increase in emigration that is expected to continue in the foreseeable future (Figure 3.9-4; GDB, 2015).

FIGURE 3.9-4
Puerto Rico Student Public Enrollment 2010–2014



Source: U.S. Department of Education (USDE), 2015.

Table 3.9-7 summarizes public student enrollment trends for the Municipality of Arecibo and the Commonwealth of Puerto Rico between the 2010 and 2014 school years, which showed an annual decline of 3 to 6 percent. Table 3.9-7 also summarizes the grade level distribution for the 2013–2014 school year;

7 percent of the students in the Municipality of Arecibo and Commonwealth of Puerto Rico are in pre-kindergarten or kindergarten, 63 to 65 percent in Grades 1 to 8, and 28 to 30 percent in Grades 9 to 12 (USDE, 2015).

TABLE 3.9-7
Public School Enrollment Trends and Grade Distribution

Municipality of Arecibo	2009–10	2010–11	2011–12	2012–13	2013–14	2013–14 Distribution
Pre-kindergarten and Kindergarten	19	878	805	844	808	7%
Grades 1–8	8,678	8,141	7,659	7,307	7,155	65%
Grades 9–12	3,707	3,518	3,337	‡	3,124	28%
Total	13,304	12,537	11,801	‡	11,087	
Percent Total Change		-6%	-6%	-3%	-3%	
Commonwealth of Puerto Rico	**2009–10**	**2010–11**	**2011–12**	**2012–13**	**2013–14**	**2013–14 Distribution**
Pre-kindergarten and Kindergarten	32,246	31,834	30,347	28,937	29,162	7%
Grades 1–8	305,453	292,681	278,581	266,387	256,029	63%
Grades 9–12	140,785	134,116	128,816	124,638	123,860	30%
Total	478,484	458,631	437,744	419,962	409,051	
Percent Total Change		-4%	-5%	-4%	-3%	

Source: USDE, 2015.

Note: ‡ indicates that the data do not meet NCES data quality standards.

Approximately 241,168 college students were enrolled in 40 public and private institutions of higher education in the Commonwealth of Puerto Rico in 2014, which represents 67 percent of the college age population and is higher than the 65 percent enrollment observed in the U.S. mainland (GDB, 2015). The total number of authorized degrees in the Commonwealth of Puerto Rico in 2013 was 152, with 62 associate degrees, 45 baccalaureate degrees, 36 master degrees, and 9 PhD degrees (Puerto Rico Education Council, 2013). The largest four-year university (based on enrollment) is the Universidad del Turabo, with a total of 19,639 students (College Stats.org, 2016a). The University of Puerto Rico is another large four-year public university offering extensive research programs. At this university, there are 472 academic degree programs across 11 campuses, 32 of which advance to a doctorate degree (College Stats.org, 2016b).

School Enrollment in the Municipality of Arecibo

The Municipality of Arecibo has a total of 40 public schools, with a projected 2016–2017 enrollment of 11,682 students (Public School Review, 2016) and 26 private schools (Schools of Puerto Rico, 2016). Four 4-year colleges and universities are located in the Municipality of Arecibo: the private, non-profit Inter-American University of Puerto Rico (enrollment of 5,595), National University College (enrollment of 1,801), Pontifical Catholic University of Puerto Rico (enrollment of 1,109), and UPRA (enrollment of 3,773) (College Stats.org, 2016a). Enrollment data are based on 2012-2013 reporting years and are compiled from the USDE and the National Center for Educational Statistics (College Stats.org, 2016b).

Arecibo Observatory Related STEM Opportunities

Arecibo Observatory is operated by SRI International under a cooperative agreement with NSF and in collaboration with the Universidad Metropolitana and USRA. According to SRI International, approximately 90,000 individuals visit Arecibo Observatory each year, of which 22 percent (or 19,800) of these visitors are school children (SRI International, 2016). It also offers residential teacher workshops for approximately 30 participants per year on topics ranging from astronomy to geosciences. Every year a summer internship is awarded to a high school teacher who is chosen to participate in a research project and contribute to the outreach and Teacher Workshop activities. Approximately 15 undergraduates participate in the onsite regular and VIP tour guide program performed in collaboration with UPRA and the Interamerican University (Camacho, 2009). Teacher training workshops are offered. A 1-week residential summer camp at Arecibo Observatory is open to 25 middle school participants. The science-oriented lectures and workshops are created in correlation with the PRDE Science Standards of Excellence (Camacho, 2009). The Arecibo Observatory Space Academy is a Saturday/summer program started in 2011; its enrollment has grown from 21 participants in the first year to almost 120 participants during 2016 (SRI International, 2016).

Higher-Education Focused STEM Opportunities Related to Arecibo Observatory

Arecibo Observatory offers two university-level programs: 1) a semester-long internship mostly for engineering and computer science students, sponsored by the Council of Chancellors and Stakeholders, and 2) the Research Experiences for Undergraduates and Research Experience for Teachers (REU-RET) Program, sponsored by NSF.

- Internship Program: This year-long program focuses on specific tasks or problem solving. It is sponsored by the Council of Chancellors and Stakeholders and serves approximately six undergraduate students per year. Participants in this program come from all over the Commonwealth of Puerto Rico.
- The REU-RET Program: This is a 10-week program where students work with staff scientists on projects related to ongoing research or instrumentation development. The program hosted seven REUs and two RETs in 2016. Participants come from anywhere in the U.S. and they must be U.S. citizens or residents (SRI International, 2016). Participating REU students typically receive a $450-per-week stipend, with room and board covered while they reside in the Visiting Scientist Quarters (NAIC, 2016a).

Arecibo Observatory also hosts graduate students working on their master's degrees and doctoral degrees through a Memorandum of Understanding between UMET and the University of Granada, Spain. These are graduate students enrolled in physics, mathematics, or computer science programs.

Additionally, numerous academic and research staff remotely access Arecibo Observatory to conduct research at their home institutions located in the U.S. and internationally (SRI International, 2016). Some of these researchers provided both oral and written comments during the Scoping Period and during the public comment period for the DEIS regarding the impacts of Arecibo Observatory on their research. Section 5 of this FEIS provides a summary of public scoping participants, comments provided in the meeting transcripts, and comments submitted in writing to NSF. Many comments submitted in writing also included references to academic research conducted at Arecibo Observatory. A summary of these academic research papers is provided in Appendix 5-E.

3.9.4 Tourism

Because of its proximity to the continental United States and its mild climate, the Commonwealth of Puerto Rico is a popular travel and tourism destination, with approximately 3.2 million tourist arrivals in 2013. These arrivals resulted in tourism receipts of $3,333.5 (inbound, in U.S. millions), with each tourist spending approximately $1,042 per trip (World Economic Forum [WEF], 2015). The direct contribution of travel and tourism to the GDP was $2,428 million or 2.4 percent of the total GDP in 2014. This economic contribution from tourism is forecasted to rise to $3,179 million in 2025 (World Travel & Tourism Council [WTTC], 2016). Domestic travel spending generated 46 percent of direct travel and tourism GDP in 2014 compared with 54 percent for visitor exports (that is, visitor spending or tourism receipts). Table 3.9-8 shows the number of visitors, their expenditures by the location of their stay in the Commonwealth of Puerto Rico, and their country of origin for 2007, 2011, and 2015. Just over 5 million visitors came to the Commonwealth of Puerto Rico in 2015, of which 70 percent stayed locally on the island and 30 percent were located on cruise ships or were transient military personnel. However, 94 percent of the expenditures associated with these visitors were associated with tourists staying in hotels or other locations locally. The majority of visitors, 87 percent, were from the continental United States and 13 percent were from foreign countries.

TABLE 3.9-8
Number and Expenditures of Visitors in Puerto Rico: Fiscal Years

	2007	**2011**	**2015 (preliminary)**	**2015 % of Total**
NUMBER OF VISITORS, TOTAL (in Thousands)	5,062	4,214	5,051	
Tourists	*3,687*	*3,048*	*3,542*	*70%*
In hotels[a]	1,353	1,409	1,737	49%
In other places[b]	2,334	1,639	1,805	51%

TABLE 3.9-8
Number and Expenditures of Visitors in Puerto Rico: Fiscal Years

	2007	2011	2015 (preliminary)	2015 % of Total
Excursionists[c]	*1,375*	*1,166*	*1,509*	*30%*
VISITORS' EXPENDITURES, TOTAL (in millions of dollars)	3,414	3,143	3,825	
Tourists	*3,242*	*2,973*	*3,597*	*94%*
In hotels[a]	1,502	1,619	2,048	57%
In other places[b]	1,740	1,355	1,550	43%
Excursionists[c]	*172*	*169*	*228*	6%
NUMBER OF TOURISTS BY ORIGIN (in Thousands)				
United States	2,867	2,587	3,064	87%
Foreign countries	800	454	473	13%
Virgin Islands	19	7	5	0%

Source: PRPB, 2016b.
[a] Includes paradores
[b] Includes guest houses
[c] Visitors on cruise ships and transient military personnel

3.9.4.1 Tourism in Arecibo

Tourism in the Municipality of Arecibo consists of visitors to Arecibo Observatory, the Atlantic coast, and the caverns and caves unique to the area's geology, such as La Cueva del Indio and Cueva Ventana (Trip Advisor, 2016). Guide services such as Ruta Nativa, located just north of Arecibo Observatory, provide day trips in the area, including rafting the Tanamá River, hiking, rappelling, caving, and canyoneering (Ruta Nativa, 2016). Additionally, tour bus operators run 9-hour day trips from San Juan that include both Río Camuy Cave Park ($18 entrance fee) and Arecibo Observatory ($13 entrance fee) for approximately $120, not including food and drink or entrance fees (Viator, 2016).

The Angel Ramos Foundation Science and Visitor Center originally opened in 1997 and was recently renovated and re-opened in May 2016 (NAIC, 2016b). The visitor center provides science exhibits, a large auditorium, and a gift shop, while the adjacent Angel Ramos Foundation Conference Center provides a classroom setting for workshops and professional meetings (NAIC, 2016b). An annual average of 90,000 persons visit Arecibo Observatory each year, approximately 19,800 (22 percent) of which are children in school groups or in summer camps (SRI International, 2016).

3.9.4.2 Tourism in Puerto Rico

Tourism in Puerto Rico focuses on a variety of inland natural area-related activities, water sports such as sailing and snorkeling, and beach activities. The Port of San Juan is the busiest ocean terminal in the Caribbean and the second largest cruise port in the Western Hemisphere, with approximately 500 cruise ships on 14 cruise lines, resulting in approximately 1 million passengers annually (Puerto Rico Tourism Company [PRTC], 2016a). The Commonwealth's western coast offers great beaches, surfing, and sightseeing along the Porta del Sol, as well as destinations such as the Cabo Rojo National Wildlife Refuge and Salt Flats. Further inland, the USFS manages El Yunque, the only subtropical rainforest in the United States. Puerto Rico also has numerous cultural sites and destinations to visit such as Old San Juan and the San Juan Historic Site operated by the U.S. National Park Service (NPS). A World Heritage Site, the San Juan Historic Site offers tours of the outer defenses of Castillo San Cristóbal, the largest Spanish fortification in the New World, and a tour of Castillo San Felipe del Morro (NPS, 2016). The PRTC is the primary government agency responsible for developing tourism on the island, including the administration of the Tourism Development Act of 2012, which provides tax incentives for the development of world-class tourism activities (PRTC, 2016b). The potential benefits under this law are substantial and can remain in effect for up to 20 years. Historically, the PRTC has included information about Arecibo Observatory in magazines and newspapers worldwide as part of its outreach efforts.

3.10 Traffic and Transportation

This Section addresses the traffic and transportation network surrounding Arecibo Observatory and includes the potential haul routes to the demolition materials landfill. The ROI for traffic and transportation includes the roadway network leading to Arecibo Observatory and along the potential demolition waste haul routes. The ROI is shown on Figures 3.10-1 and 3.10-2.

3.10.1 Proposed Action Area

Arecibo Observatory is located at the southern terminus of Puerto Rico Highway (PR)-625. The primary access routes from Arecibo Observatory to the municipality of Arecibo are shown on Figure 3.10-1. The main routes from Arecibo Observatory to the municipality of Arecibo are PR-625 to PR-635/651 and PR-625 to PR-635/134 to PR-129. The PR-625 to PR-626/623 to PR-10 route is not often used due to dangerous conditions such as switch backs and steep cliffs. PR-625, PR-635, and PR-134 are two-way asphaltic concrete roadways approximately 30 feet wide. These roads have many narrow sections where the roadway width is less than two lanes. There are tight curves due to its mountainous setting and dense vegetation surrounding the roadways, both of which limit sight-distance for users along the roadways in many areas. Existing road conditions exhibit wear and deterioration in areas likely as a result of a combination of age, climate, and prolonged use by commercial buses, trucks, and farm equipment. Damage is readily apparent on these roads. PR-129 and PR-10 are more frequently-used multi-lane roads with fewer restrictions. There are no posted heavy truck or load restrictions along any of these routes (Nolan-Wheatley, 2016).

Average annual daily traffic (AADT) volumes for the roadway network within the ROI are shown on Figure 3.10-1 (Puerto Rico Open Data Interconnection Portal, 2016). Arecibo Observatory is staffed by approximately 136 people and averages 90,000 visitors yearly.

FIGURE 3.10-1
Transportation Region of Influence

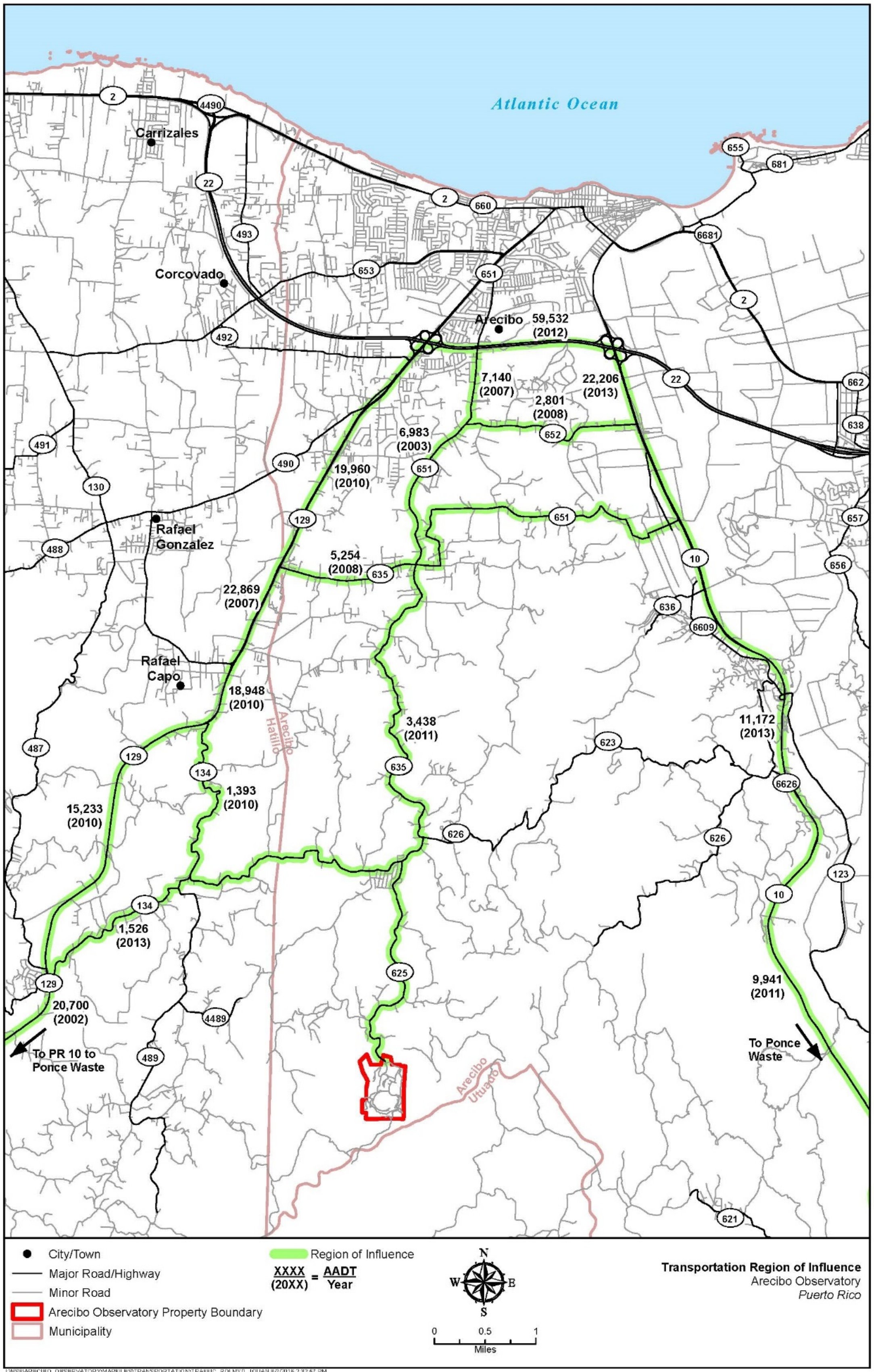
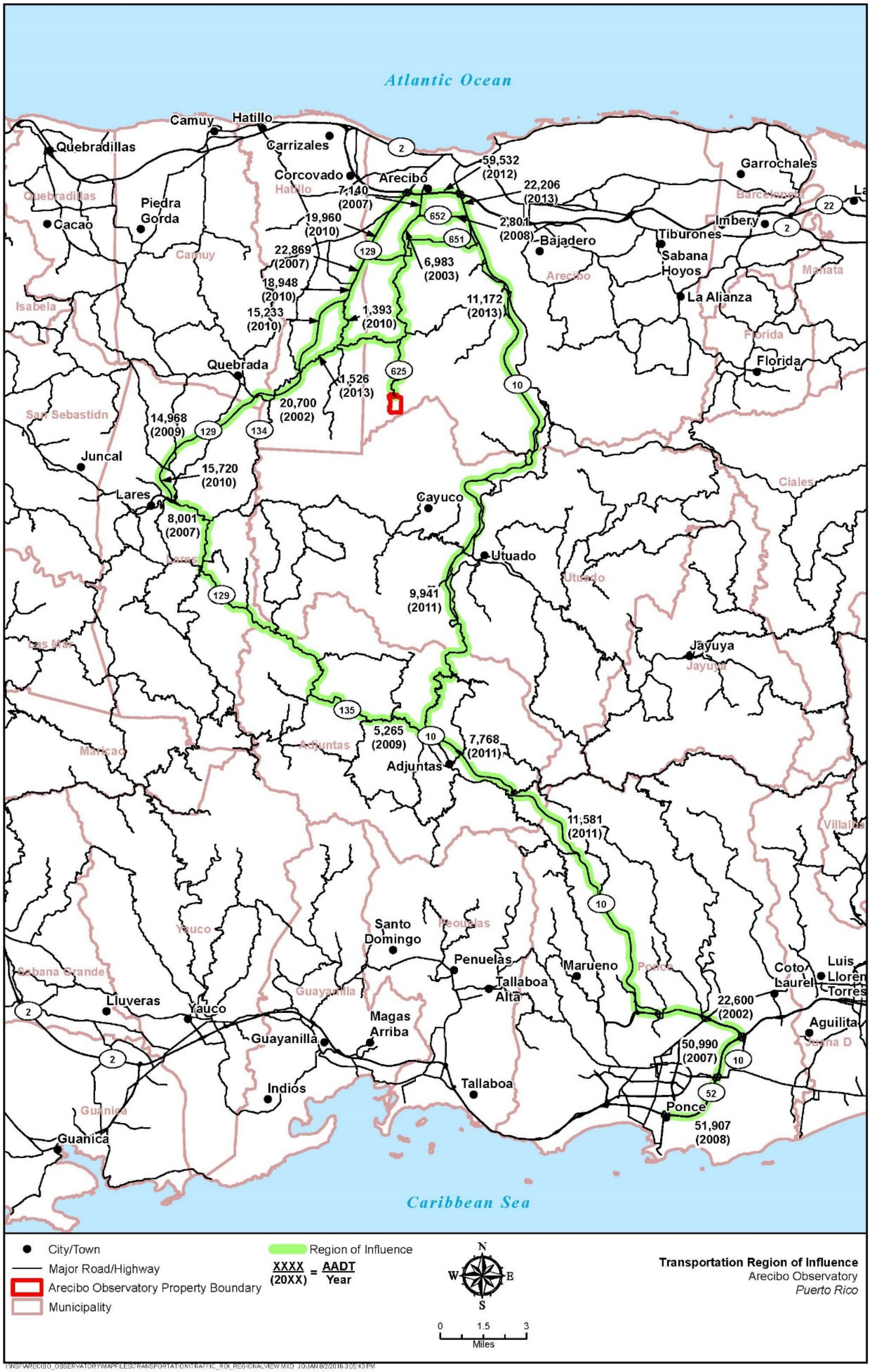


FIGURE 3.10-2
Transportation Region of Influence – Regional View



3.11 Visual Resources

Visual resources include natural and built features that can be seen by the public and contribute to the public's appreciation and enjoyment of these features. Visual resources can include solitary-built and natural landmarks (such as buildings, trees, and bodies of water) or entire landscapes. The CEQ regulations to implement NEPA (40 C.F.R. §1508.8) identify aesthetics (visual resources) as one of the elements of the human environment that must be considered in determining the effects of a proposed project. The ROI for visual resources consists of the area within the Arecibo Observatory property from which the Observatory employees and visiting public would potentially see changes to the site as a result of the Proposed Action.

Impacts to visual resources are defined in terms of the extent to which a proposed project's presence would change the visual character and quality of the environment as seen by the public. Visual character is defined by the relationships between the existing visible natural and built landscape features. These relationships are considered in terms of how objects in the viewed landscape relate to each other in terms of visual dominance, scale, diversity, and continuity. Visual character is non-evaluative, in that it is simply a description of the viewed environment and does not assign value or degree of attractiveness to the viewed environment.

Visual quality is considered to be either high, average, or low. To determine the level of visual quality this assessment asks the following:

- Is this particular view common (average) or dramatic (high)?
- Is it a pleasing composition with a mix of elements that seem to belong together (high) or not pleasing with a mix of elements that either do not belong together, are eyesores, or contrast with the other elements in the surroundings (low)?

Visual resources were identified through study of aerial photos, maps, and previous reports, as well as a site visit. At the site visit on July 19 and 20, 2016, the visual character was observed and documented, and the visual quality of the project area was assessed.

3.11.1 Proposed Action Area

Arecibo Observatory, which contains approximately 118 acres of land, is located in a rural area surrounded by heavy vegetation and rugged, mountainous terrain. The remoteness of the site limits the visual environment to the boundaries of the Observatory property, as it is only visible by those on the property. Most buildings are located on very steep, paved roads. Due to the steep and hilly terrain, the site is blocked from the view of the communities surrounding the property. Only the 12-meter-diamater telescope is visible when approaching the facility by road.

Within the site, the hilly terrain provides for numerous dramatic views, most notably of the surrounding landscape and the 305-meter-diameter radio telescope, with its associated platform and support towers. Numerous views of the 305-meter-diameter radio telescope are accessible throughout the site; however, most visitors view the instrument from the viewing platform that extends from the rear of the visitor center, Building 54. The highest points within the Observatory property, including the platform suspended above the 305-meter-diameter radio telescope, offer views of the surrounding mountainous landscape. Due to the large size of the instrument and the aesthetics of the surrounding landscape, Arecibo Observatory is considered to have high visual quality to the primary viewers, which consist of the Arecibo Observatory employees, visiting scientists, and other visitors. The support buildings within the property are modest and utilitarian facilities that are not considered to have high visual or aesthetic quality.

Therefore, within the ROI there are two sensitive visual resources: the 305-meter-diameter radio telescope, including its associated platform and support towers, and the surrounding mountainous landscape. Due to the presence of these visual resources, Arecibo Observatory is considered to have high visual quality overall. Figures 3.11-1 through 3.11-7 illustrate the existing visual character of Arecibo Observatory.

FIGURE 3.11-1
Landscape, with the 305-meter-diameter radio telescope support towers and the Gregorian dome, view south (2016)

FIGURE 3.11-2
View from the visitor center viewing platform, view southwest (2016)

FIGURE 3.11-3
Gregorian dome, suspended above the 305-meter-diameter radio telescope dish, view northeast (2016)

FIGURE 3.11-4
305-meter-diameter radio telescope dish, view east (2016)

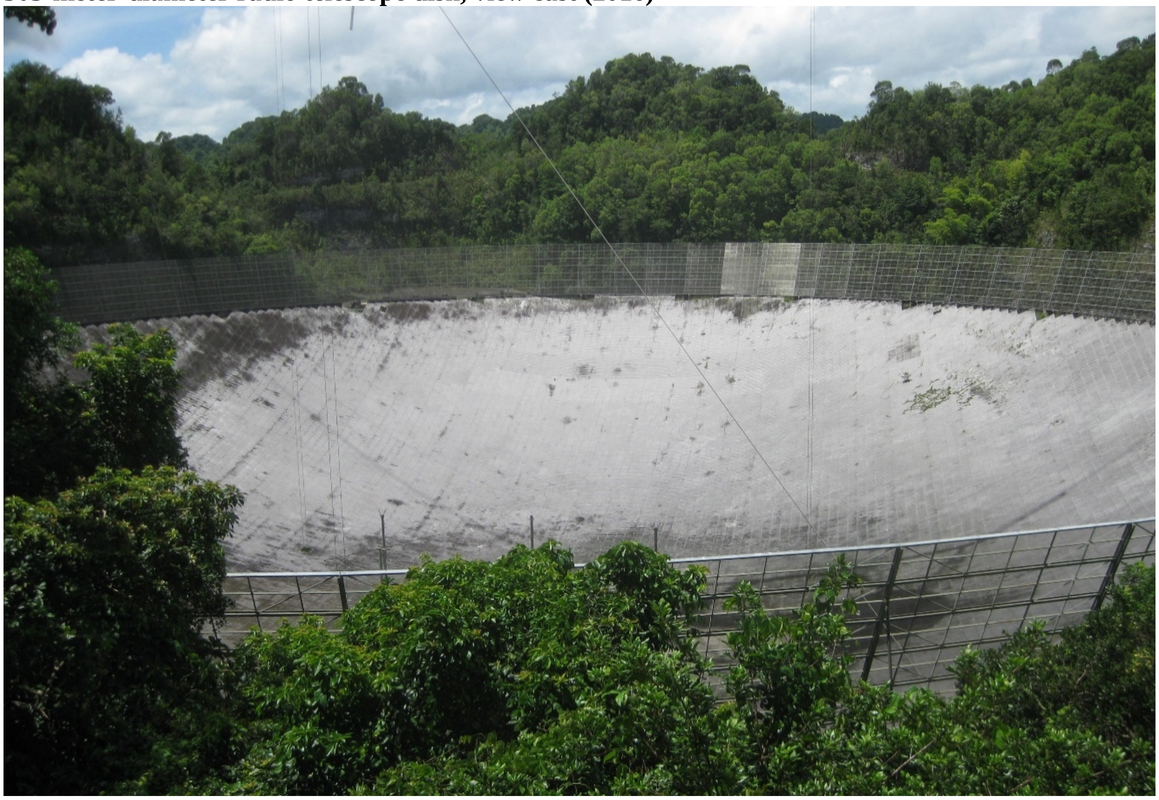


FIGURE 3.11-5
View of the visitor center, from the 305-meter-diameter radio telescope cable car, view north (2016)

FIGURE 3.11-6
View of 305-meter-diameter radio telescope support tower from the platform, view southeast (2016)

FIGURE 3.11-7
12-meter-diameter telescope and the surrounding landscape, view south (2016)

SECTION 4.0

Environmental Consequences

This Section provides an evaluation of the potential environmental impacts of the Proposed Action under the five proposed action Alternatives and the No-Action Alternative, which are the following:

- Alternative 1: Collaboration with Interested Parties for Continued Science-focused Operations
- Alternative 2: Collaboration with Interested Parties for Transition to Education-focused Operations
- Alternative 3: Mothballing of Facilities
- Alternative 4: Partial Demolition and Site Restoration
- Alternative 5: Complete Demolition and Site Restoration
- No-Action Alternative: Continued NSF Investment for Science-focused Operations

The analysis herein identifies likely impacts on the environment based on the ROI for each resource area. The analysis of resource impacts focuses on environmental issues in proportion to their potential impacts. Detailed consideration is given to those resources that have a potential for environmental impacts. Interpretation of impacts in terms of their duration, intensity, and scale is provided where possible. Where best management practices (BMPs) would reduce the duration, intensity, or scale of the impacts, they are identified within the resource evaluations. Impacts identified under the No-Action Alternative are reflective of the baseline conditions of each resource discussed in Section 3.

Section Organization

Sections 4.1 through 4.12 describe the methodology and factors used to evaluate impacts and to determine the significance of impacts consistent with the following:

1. CEQ C.F.R., Title 40, Parts 1500 to 1508, §1508.8, where “Effects” (synonymous with “Impacts” in this analysis) include:
    a) Direct effects, which are caused by the action and occur at the same time and place.
    b) Indirect effects, which are caused by the action and are later in time or farther removed in distance, but are still reasonably known. Indirect effects may include growth-inducing effects and other effects related to induced changes in the pattern of land use, population density or growth rate, and related effects on air and water and other natural systems, including ecosystems.
    c) Cumulative effects, which can result from individually minor, but collectively significant, actions taking place over time.

Impacts include ecological (such as the impacts on natural resources and on the components, structures, and functioning of affected ecosystems), aesthetic, historic, cultural, economic, social, or health. Impacts may also include those resulting from actions that may have both beneficial and adverse impacts, where, even if on balance, the agency believes that the impact would be beneficial.

Section 4.13 presents an evaluation of the cumulative impacts of the Proposed Action. Cumulative impacts result from adding the total impacts of past, present, and reasonably foreseeable future actions to impacts likely caused by the Proposed Action.

Section 4.14 presents an evaluation of the Proposed Action's impacts regarding irreversible or irretrievable commitment of resources, and unavoidable adverse impacts, as required by NEPA.

Section 4.15 presents an evaluation of the Proposed Action's impacts regarding the relationship between local short-term uses of the environment and long-term productivity as required by NEPA.

Terminology

To determine whether an impact is major, CEQ requires the consideration of context and intensity of potential impacts (40 C.F.R. Part 1508 §1508.27; H.R.S. 343§11-200-9, 12). Context normally refers to the setting, whether local or regional, and intensity refers to the severity and duration of the impact. Each resource has its own impact intensity standards that are listed and explained in tables under each resource section. Impacts are described by the following levels of intensity:

1. Negligible
2. Minor
3. Moderate
4. Major

There may be both adverse and beneficial impacts within a single resource category. Where there are both adverse and beneficial impacts, both are described. Impacts are also characterized as short- or long-term in duration.

4.1 Biological Resources

Methodology

This Section identifies potential direct and indirect biological impacts that may result from implementing the Alternatives at Arecibo Observatory, including the No-Action Alternative. The ROI for the biological resources analysis encompasses the areas within and immediately adjacent to Arecibo Observatory, although a broader view was taken as necessary; for example, regional populations were considered for impacts to species stability.

The methods used to determine whether the Alternatives would have impacts on biological resources are as follows:

1. Evaluate existing conditions, including the results of the January 2017 vegetation survey (Vélez Gavilán, 2017), to identify which past actions within the ROI have resulted in either improved or diminished health or diversity of populations of biological resources to evaluate the potential impacts on biological resources for each Alternative.
2. Evaluate each considered Alternative to determine its potential for impacts on biological resources due to loss of habitat, disruption of normal behavior (e.g., from noise or vibration), vehicular traffic, and the introduction of invasive species.
3. Assess the compliance of each Alternative with applicable federal regulations that apply to preservation of biological resources.

Table 4.1-1 defines the thresholds used to determine the intensity of direct and indirect impacts to the biological resources.

TABLE 4.1-1
Impact Thresholds for Biological Resources

Impact Intensity	Description
Negligible	Impact would be below or at the lower levels of detection.
Minor	The Alternative would result in a detectable change to biological resources or habitat; however, the impact would be small, localized, and of little consequence. Any disruption to wildlife would be short-term and species would be expected to return to normal activities after disturbance. No measurable reduction in species population stability would occur. Threatened or endangered species may be in the area but no effects to behavior, mortality, or habitat quality would occur. There would be no take of any threatened or endangered species or migratory birds. There may be some increase in the presence of weed species over a small area, but the increase would be easily controllable.
Moderate	The Alternative would result in a readily apparent change to biological resources or habitat over a relatively wide area. A permanent loss of non-critical vegetative cover or other habitat may occur. However, no measurable reduction in species population stability would occur. Any effects to threatened and endangered species or migratory birds would be temporary and would not result in mortality or impacts to population size. The action may result in a take to a federally listed species. There would be a noticeable increase in the presence of weed species and would require the use of herbicide to control.
Major	The Alternative would result in a substantial change to the character of the biological resource, affecting a large area or a species population, or would result in a violation of the ESA or MBTA. A permanent loss in vegetative cover or other habitat would occur, resulting in a measurable reduction in species population stability. Effects to threatened and endangered species or migratory birds would result in mortality. There would be a large increase in the presence of weed species and would require the use of herbicide to control.

Duration: Short-term – Occurs only during demolition activities.
Long-term – Continues after demolition activities.
MBTA = Migratory Bird Treaty Act

4.1.1 Alternative 1 – Collaboration with Interested Parties for Continued Science-focused Operations (Agency-preferred Alternative)

4.1.1.1 Vegetation

Under Alternative 1, minor, adverse, short-term direct impacts to site vegetation would occur from the creation of staging areas for materials and equipment, and from the removal of unneeded structures, including housing, obsolete buildings, and recreational facilities. To the extent possible, previously disturbed areas would be used for staging areas and as buildings are removed, that cleared area would be used for additional staging if needed and possible. To address the maximum potential disturbance, the analysis assumes that 26 structures would be removed under Alternative 1 (see Table 2.3-1). Landscaped vegetation around these structures and in onsite staging areas would be lost during demolition. In addition, heavy equipment would be used and their placement and operation could further disturb or damage vegetation onsite. Following removal of structures, the building locations and any disturbed staging areas would be re-landscaped to be compatible with the surrounding landscaping. If any soil is brought onsite to facilitate re-landscaping, the amount of soil would be the minimum needed to provide for vegetation growth. As appropriate, soil to be planted would be augmented with nutrients, organic matter, or bulking agents to provide an appropriate medium for root establishment and subsequent growth of the species selected for planting.

To avoid or minimize the potential for incidental impacts to vegetation, the following BMPs would be implemented during demolition work:

- Worksites would be clearly marked to avoid disturbance to areas outside the demolition area.
- Workers would be instructed to stay within marked workspace areas.
- Stormwater controls would be used to prevent scour and erosion outside the work area that could otherwise affect habitat quality.
- Re-landscaping would use non-invasive species and would incorporate native vegetation if feasible.

Operation of the Observatory would likely continue during demolition activities, although possibly at a temporarily decreased level. Any ongoing operations would not be expected to impact vegetation because these operations would not be distinguishable from the baseline conditions of current operations. Once demolition is complete, a normal level of operations and maintenance (O&M) at the Observatory would resume. While specific O&M under a new science-based format is not known, it is expected that O&M would be similar with regard to impacts to vegetation as current operations. No change from baseline conditions would be expected and no adverse impacts to vegetation would be expected from operations.

There would be potential for weed species to become established in areas disturbed during demolition activities. However, demolished areas would be re-landscaped after the demolition period, which would remove any weed species that start to establish in disturbed areas. Landscaped areas would be maintained during operations, which would minimize the potential for the introduction or spread of weed species. Because disturbed areas would be landscaped and because weeds in landscaped areas would be managed during operations, no impacts are expected from establishment of weed species.

While demolition activities are expected to last up to 12 weeks, demolition may be spread out over a longer period based on funding availability. Should the demolition be extended beyond a single 12-week period, soil would be exposed for a longer period of time. However, the BMPs and mitigation measures, as described previously, would be implemented throughout the period of demolition, thereby resulting in no changes to the assessed vegetation impacts.

Transfer of land ownership could occur under Alternative 1. Because there would be no substantial change in operations should a land transfer occur, no additional impacts to vegetation would be expected should NSF transfer the land to another entity.

4.1.1.2 Wildlife

Small areas of landscaped habitat around buildings would be lost and replaced as described above. In addition, impacts would occur to animals that use structures as habitat (e.g., roosting habitat for some bird species). This habitat would be lost following demolition; however, there is extensive similar habitat located near the site, which the species would be expected to use.

Wildlife could experience disruptions in their natural activities, including disruptions in communications, foraging, and avoiding danger during the demolition. Sound levels of 78 to 89 dBA at 50 feet (15 meters) would be expected based on the equipment used during demolition. These levels would not be continuous and would attenuate as sound travels from the work areas, due to the increase in distance, terrain, and generally closed forest vegetation surrounding the Observatory. While wildlife at the Observatory normally experience noise from motor vehicles and maintenance equipment, such as mowers and powered tools, the demolition noise would be of a greater intensity and more localized to the work areas. As a result, wildlife in proximity to active work areas would likely respond to the increased noise levels during demolition. More mobile wildlife (e.g., birds) would be expected to exhibit avoidance behaviors and relocate to avoid noise. Demolition-related noise impacts would cease following completion of demolition. The level of human activity would be increased at active demolition sites compared to baseline conditions. This increased level of activity also may displace some wildlife that would not necessarily respond to increased noise levels. Species displaced by increased human activity are expected to use similar nearby available habitat.

Overall the impacts to wildlife from demolition activities are expected to be minor, adverse, and short-term.

Should the demolition be extended beyond a single 12-week period, there would be no change in the assessed impacts to wildlife. The length of time there would be disturbed soils would be extended, but the

BMPs appropriate BMPs and mitigation measures, as described previously, would be implemented throughout the period of demolition.

Operations would not be expected to impact wildlife because these operations would not be distinguishable from the baseline conditions of current operations. Once demolition is complete, a normal level of O&M at the Observatory would resume. While specific O&M under a new science-based format are not known, it is expected that O&M would be similar with regard to impacts to wildlife as current operations. No change from baseline conditions would be expected and no adverse impacts to wildlife would be expected from normal O&M.

Transfer of land ownership could occur under Alternative 1. Because there would be no substantial change in operations should a land transfer occur, no additional impacts to wildlife would be expected should NSF transfer the land to another entity.

4.1.1.3 Wetlands

Potential changes in runoff patterns and increased erosion and sedimentation during demolition in areas where runoff would flow away from the Observatory bowl could cause impacts to offsite wetlands downslope from the Observatory toward the Tanamá River from erosion of sediment accumulation. However, the following BMPs would be implemented to control stormwater during the demolition period to prevent or reduce potential impacts from scour and offsite movement of sediments:

- Standard construction stormwater BMPs that could include silt fencing, temporary detention or retention basins, and passive filter systems would be implemented as specified in the site-specific SWPPP that would be developed to support the NPDES stormwater permit.
- Disturbed areas would be stabilized by reseeding to establish ground cover to intercept precipitation.
- Steep slopes that are disturbed would be further protected with biodegradable erosion control measures, such as jute mates or coir fiber logs.
- Pre-demolition runoff patterns would be restored when demolition is complete.

Based on the implementation of these BMPs, impacts to wetlands are expected to be negligible, adverse, and short-term.

Should the demolition be extended beyond a single 12-week period, there would be no change in the assessed impacts to wetlands. The length of time there would be ongoing disturbance would be extended, but the appropriate BMPs and mitigation measures, as described previously, would be implemented throughout the period of demolition.

The total impervious area would be reduced with the demolition of 26 structures and landscaping of the areas where buildings are demolished. Consequently, post-demolition runoff volumes would be reduced. While specific O&M under a new science-based format is not known, it is expected that O&M would be similar with regard to impacts to wildlife as current operations. Therefore, no change from baseline conditions would be expected and no adverse impacts to wetlands would be expected from normal operations.

Transfer of land ownership could occur under Alternative 1. Because there would be no substantial change in operations should a land transfer occur, no additional impacts to wetlands would be expected should NSF transfer the land to another entity.

4.1.1.4 Threatened and Endangered Species

NSF prepared a biological assessment (BA) to assess the potential impacts to listed species with the potential to occur on or adjacent to Arecibo Observatory (Appendix 4.1-A). The BA was submitted to USFWS as part of the informal consultation for the Proposed Action. USFWS concurred with the findings of the BA in its letter dated June 23, 2017 (Appendix 4.1-A). The analysis of potential impacts to protected species is based on the analysis in the BA and USFWS concurrence letter.

The Puerto Rican broad-winged hawk and Puerto Rican boa are known to occur on Arecibo Observatory site. There is also the potential for other species to occur, such as the Puerto Rican parrot and Puerto Rican sharp-shinned hawk. The BMPs described for vegetation and wetlands also would benefit protected species. Additional mitigation measures, as specified below, have been developed for specific protected species through consultation with USFWS. These measures would be implemented by NSF.

A Puerto Rican broad-winged hawk nest was observed in a Maria tree on the south rim wall above the 305-meter-diameter telescope dish. This nest was determined to be inactive during the January 2017 vegetation survey (Vélez Gavilán, 2017), but the Puerto Rican broad-winged hawk was observed exhibiting courtship/nesting behavior near the Observatory entrance (Brown, 2017, pers. comm.). Demolition work under Alternative 1 would be north of the 305-meter-diameter radio telescope dish and demolition activities would be screened from the nest by intervening vegetation and topography. The birds have nested above the 305-meter-diameter radio telescope dish in the past with the normal activity of the Observatory. Any activity near the nest site during demolition would be indistinguishable from normal activity. It is unlikely that the Puerto Rican broad-winged hawk would nest in proximity to buildings that would be demolished under Alternative 1. Therefore, no impacts to the Puerto Rican broad-winged hawk would be expected.

Puerto Rican boas could enter buildings slated for demolition, enter heavy equipment left onsite overnight, become entrapped in excavations, or enter an active work area during demolition activities. Demolition could injure or kill a snake, if present. NSF has developed protocols for working in areas where the Puerto Rican boa may occur (Appendix 4.1-A). These protocols were adapted from protocols previously approved by USFWS for the U.S. Navy and the U.S. Army. The NSF protocols address both demolition activities and routine O&M. These protocols would be implemented during all demolition activities under Alternative 1 and include the following:

- Train all onsite personnel in the identification of boas and the value of boas and boa conservation by a qualified wildlife biologist.
- Complete daily pre-work surveys of equipment and work areas, including buildings and karst features, by a qualified wildlife biologist or other agency-authorized person trained in boa location and identification.
- Relocate any boas found on equipment or within the day's work area to the designated relocation area south of the staging yard on the east side of the Observatory by a qualified wildlife biologist or other agency-authorized person trained in handling Puerto Rican boas.
- Stop work if a boa is observed in the work area during the day until a qualified wildlife biologist trained in handling Puerto Rican boas can relocate the snake to the designated relocation area or the boa voluntarily vacates the work area.

With implementation of these Puerto Rican boa protocols, no more than negligible, adverse, and short-term impacts to the species would be expected from demolition-related activities.

Tectaria estremerana is known to occur on the Arecibo Observatory site and a single specimen of the palo de nigua was observed just outside the Observatory entrance. It is likely that palo de nigua occurs in undeveloped areas on the Observatory site. As noted in Section 3.1.2, 11 other protected plant species have the potential to occur in the Proposed Action area. Most of the proposed work areas under Alternative 1 are within paved areas or areas that are landscaped and maintained. These highly altered areas would not support protected plant species. A vegetation survey was conducted in January 2017 in areas that contained potentially suitable habitat for protected plant species. The survey determined that beautiful goetzea, chupacallos, erubia, *Myrcia paganii*, *Schoepfia arenaria*, *Cordia bellonis*, palo de nigua, palo de rosa, uvillo, *Daphnopsis hellerana*, and *Thelypteris verecunda* do not occur at proposed work areas for Alternative 1 (Vélez Gavilán, 2017). Areas where proposed work would occur that were not surveyed consisted of pavement, gravel lots, and maintained landscape vegetation. Protected plant species would not occur in these areas. No new disturbance to natural areas would occur during demolition under Alternative 1. Because protected plants do not occur in the proposed work areas, there would be no disturbance of natural areas, and the BMPs described for vegetation would be implemented; no more than negligible, adverse, short-term impacts to protected plants would be expected from demolition-related activities.

Should the demolition be extended beyond a single 12-week period, there would be no change in the assessed impacts to threatened and endangered species. The disturbance period would be extended, but the BMPs and mitigation measures, including timing restriction on activities described previously, would be implemented throughout the period of demolition. Should the demolition period be extended over multiple years, NSF would coordinate with USFWS to determine whether additional Section 7 consultation under the ESA would be warranted due to additional species being listed under the ESA or current species distributions change.

Under Alternative 1, NSF could retain or transfer property NSF, in consultation with USFWS, would consider the appropriate land use controls, such as deed restriction and conservation easement, for the natural areas on the Observatory if transferred out of federal control. If transferred, the non-federal owners would be required to consult with USFWS under Section 10 of the ESA on actions that may adversely affect the Puerto Rican boa or the Puerto Rican broad-winged hawk. However, there would be no future requirement for consultation on activities that could adversely affect *Tectaria estremerana* absent land use controls. It is expected that NSF's Section 7 consultation would result in measures that would be placed in the land transfer documents to ensure that the future activities of non-federal ownership would not result in more than minor adverse impacts to these three species.

Operations would not be expected to impact threatened and endangered species because these operations would be similar to current operations. Once demolition is complete, a normal level of O&M at the Observatory would resume. While specific O&M under a new science-based format are not known, it is expected that O&M would be similar with regard to impacts to threatened and endangered species as current operations. No change from baseline conditions would be expected and no adverse impacts to threatened and endangered species would be expected from normal operations.

The Puerto Rican boa is regularly encountered by Observatory staff during maintenance activities. While there have been no known instances of injury or death of the Puerto Rican boa on the Observatory in the past, future operations could result in a take of the species. Arecibo Observatory would implement the Puerto Rican boa protocols (Appendix 4.1-A) during O&M for activities in areas where Puerto Rican boas may occur to avoid inadvertent take of the species.

The expected areas of disturbance that were analyzed to determine potential impacts to protected species would be provided to prospective bidders to provide demolition services. If a bidder indicated that additional areas, including additional or widened roads, would be needed to complete the work, NSF would delay the award until additional consultation with USFWS, including additional surveys, had been completed.

4.1.1.5 Migratory Birds

Potential migratory bird nesting habitat is present on the Arecibo Observatory site. Demolition activities could adversely affect the nesting of these species as a result of noise or physical activity in proximity to nest locations. Because of the mild climate, species protected under the MBTA may nest at any time during the year. NSF coordinated with USFWS to establish appropriate procedures for demolition activities to minimize the potential for inadvertent take of migratory birds (Fury, 2016, pers. comm., Appendix 3.2-A). To avoid impacts to nesting birds and nest abandonment, the following measures that are consistent with USFWS recommendations would be implemented:

- Biological inspections would be made to determine whether active nests are in or adjacent to work areas prior to the start of demolition work.
- 100-foot encroachment buffers would be established around identified active nests coupled with work and work would be excluded within the buffer until the young had fledged.

Because impacts would be limited to the immediate area of structures to be demolished, which do not provide substantial amounts of habitat for migratory birds and because the measures identified above would be implemented to prevent mortality or nest abandonment, impacts to migratory birds from demolition are expected to be negligible, adverse, and short-term.

Should the demolition be extended beyond a single 12-week period, there would be no change in the assessed impacts to migratory birds because the BMPs described previously would still be in effect.

Operations would not be expected to impact migratory birds because these operations would not be distinguishable from the baseline conditions of current operations. Once demolition is complete, a normal level of O&M at the Observatory would resume. While specific O&M under a new science-based format are not known, it is expected that O&M would be similar with regard to impacts to migratory birds as current operations. No change from baseline conditions would be expected and no adverse impacts to migratory birds would be expected from normal operations.

Transfer of land ownership could occur under Alternative 1. Because there would be no substantial change in operations should a land transfer occur, no additional impacts to migratory birds would be expected should NSF transfer the land to another entity.

4.1.2 Alternative 2 – Collaboration with Interested Parties for Transition to Education-focused Operations

Under Alternative 2, biological impacts would be similar to those described under Alternative 1. Demolition of selected buildings within the disturbed footprint of the Arecibo Observatory site would occur over a 12-week timeframe and would involve 27 structures, the same 26 structures identified for removal under Alternative 1 and an additional building (see Table 2.3-1). BMPs, as described for Alternative 1, would be implemented to reduce or prevent impacts.

Impacts to site vegetation could be greater due to the additional building that would be removed, but still would be defined as minor, adverse, and short-term. Impacts to wildlife, protected species, and migratory birds would be comparable and in the same areas to those described for Alternative 1, because the level of disturbance would be comparable to what is presented for that Alternative. Because demolition would be the same as described for Alternative 1 plus one additional building, the potential for indirect impacts to offsite wetlands downslope from the Observatory toward the Tanamá River would be limited to stormwater runoff from demolition sites and impacts would also be negligible, adverse, and short-term.

Mitigation measures to avoid, reduce, or minimize impacts to biological resources under Alternative 2 would be the same as those described for Alternative 1.

Similar to Alternative 1, there would be no expected change in the intensity of potential impacts should the demolition be extended beyond a single 12-week period.

Transfer of land ownership could also occur under Alternative 2. Because there would be no substantial change in operations should a land transfer occur, no additional impacts to vegetation, wildlife, wetlands, or migratory birds would be expected should NSF transfer the land to another entity. Alternative 2 has the same potential for adverse impacts to threatened and endangered species as Alternative 1. Additional Section 7 consultation would be required and the impacts to threatened and endangered species would be expected to be comparable to those described for Alternative 1 should land be transferred outside of federal ownership.

4.1.3 Alternative 3 – Mothballing of Facilities

Under Alternative 3, biological impacts would be similar to those described under Alternative 1, but fewer structures would be removed and removal and mothballing would occur over a longer timeframe. BMPs, as described for Alternative 1, would be implemented to reduce or prevent impacts.

Impacts to vegetation from demolition and mothballing activities would occur for a proportionately longer time than the previous alternatives, but intensity would be less in a given period of time. Consequently, these impacts would also be adverse, minor, and short-term. The area impacted would be smaller than for Alternative 1 due to removal of only 14 structures (see Table 2.3-1), and the amount of ground and vegetation disturbance would be correspondingly smaller, though would remain minor, adverse, and short-term. Impacts to wildlife, and protected species would also be minor, adverse, and short-term and similar to those described for Alternative 1. Impacts to migratory birds would be negligible, adverse, and short-term. The amount of demolition would be less than that described for Alternative 1; therefore, the potential for indirect impacts to offsite wetlands downslope from the Observatory toward the Tanamá River would be limited to stormwater runoff from demolition sites as described for Alternative 1, and would remain negligible, adverse, and short-term.

Similar to Alternative 1, there would be no expected change in the intensity of potential impacts if the demolition is extended beyond a single 15-week period.

Once the Observatory is in the mothball phase, ongoing maintenance would be required to keep equipment and infrastructure in suitable condition to restart operations. This maintenance is expected to be similar with regard to impacts to biological resources as maintenance under current operations. No change from baseline conditions would be expected and no adverse impacts to biological resources would be expected from maintenance during the mothball phase.

Mitigation measures to avoid, reduce, or minimize impacts to biological resources under Alternative 3 would be the same as those described for Alternative 1.

4.1.4 Alternative 4 – Partial Demolition and Site Restoration

4.1.4.1 Vegetation

Under Alternative 4, direct impacts would occur to site vegetation from the creation of staging areas for materials and equipment and from the removal of 48 structures onsite (see Table 2.3-1). Safe-abandonment of towers, tower and catwalk anchors, and the foundation and rim wall infrastructure would not be expected to impact vegetation beyond the disturbance associated with staging areas. BMPs, as those described for Alternative 1, would be implemented to reduce or prevent impacts.

Landscaped vegetation around structures and in onsite staging areas would be lost during demolition. In addition, heavy equipment, including cranes, would be used and their placement and operation could further disturb or damage vegetation on site. Following removal of structures, the building locations and staging areas that have suitable soils would be revegetated to stabilize the ground. Revegetation would use native species to the extent possible and the disturbed areas would be allowed to be colonized by native species following abandonment of the site. If non-native species are necessary to achieve site stabilization, only non-invasive species would be used. Revegetation areas would be maintained for up to 18 months to ensure establishment and to minimize the potential for exotic species to become established. Soil would be brought in for vegetation establishment in disturbed areas where the remaining soil following infrastructure removal is insufficient. If necessary, nutrients, organic matter, or bulking agents would be added to the soil to provide an appropriate medium for root establishment and subsequent growth of the species selected for planting (see Section 4.3, *Geology and Soils*, for a discussion of impacts to soils).

While direct physical damage to vegetation would be minimal due to the developed nature of the site, the removal of the 305-meter-diameter telescope dish would result in changes that could substantially alter the vegetation composition of the area beneath the reflector dish. Species that are adapted to the moist, semi-shade conditions beneath the reflector dish would likely die out upon full sun exposure and reduced moisture availability. This would result in the conversion of up to 25 acres of vegetation to species adapted to drier, sunnier conditions. With the loss of vegetation, there could be soil loss that would further alter the vegetation composition of the area to species adapted to root in shallower soil. Through time, vegetation adapted to full sun conditions would establish in this area, which would provide protection from further soil loss and provide habitat and life history needs for wildlife. The soil impacts are discussed in Section 4.3, *Geology and Soils*, and the potential for indirect impacts to groundwater from sedimentation entering the sinkhole is discussed in Section 4.4, *Groundwater*. Overall the impacts to vegetation from Alternative 4 would be moderate, adverse, and long-term.

Demolished areas would be naturally revegetated or re-landscaped after the demolition period and open spaces would be revegetated with native vegetation to minimize the potential for the spread of exotic invasive species. If offsite soil is needed to backfill an excavated area, the minimum amount of soil needed would be brought onto the site. Impacts from weeds would be minor, adverse, and long-term. Vegetation would be maintained for up to 18 months to ensure establishment and minimize the potential for exotic species to become established. Some colonization by non-native weeds would be expected, as the rock walls created by blasting when Arecibo Observatory was constructed show extant colonization by such species. Impacts from weeds would be minor, adverse, and long-term. Native vegetation would be expected to eventually establish on the concrete structures. However, this would be a very slow process and vegetation would likely be more similar to vegetation occurring on rock faces exposed by blasting than that on undisturbed rock faces.

Similar to Alternative 1, there would be no expected change in the intensity of potential impacts if the demolition is extended beyond a single 28-week period.

The only operations that would occur following demolition would be vegetation maintenance and routine maintenance of safety lights required on the towers, including bulb replacement. No impacts to vegetation would result from this activity.

4.1.4.2 Wildlife

Small areas of landscaped habitat around buildings would be lost and replaced. BMPs, as described for Alternative 1, would be implemented to reduce or prevent impacts. The removal of the ground screen and reflector dish would result in the conversion of the vegetative community at that location and may result in a change in wildlife species that use this area.

Permanent direct impacts would occur to animals that use structures as habitat (e.g., roosting or nesting habitat for some bird species). This habitat would be lost following demolition. However, there is ample amount of natural habitat nearby, including karst features that are comparable to the lost building habitat, which would lessen the effects to population stability. Noise, vibration, and increased human activity would cause impacts to wildlife from disruptions to their natural activities and from avoidance behaviors. Impacts would be similar to those described under Alternative 1, but would occur over a longer approximately 28-week timeframe, and greater sound levels would occur at peripheral areas on the observatory due to removal of structures from a larger area. Overall, the impacts to wildlife from demolition would be moderate, adverse, and short-term.

Similar to Alternative 1, there would be no expected change in the intensity of potential impacts if the demolition is extended beyond a single 28-week period.

The only operations that would occur following demolition would be 18 months of vegetation maintenance and routine maintenance of safety lights required on the towers, including bulb replacement. There would be a minor, long-term benefit to wildlife from the reduced human activity and noise in the area.

4.1.4.3 Wetlands

While there are no onsite wetlands, potential changes in runoff patterns and increased erosion and sedimentation during demolition activities in areas where runoff would flow away from the Observatory bowl could cause impacts to offsite wetlands from erosion and sediment accumulation. BMPs, as described for Alternative 1, would be implemented to reduce or prevent impacts and any indirect impacts to offsite wetlands from stormwater or sedimentation would be expected to be negligible, adverse, and short-term.

Similar to Alternative 1, there would be no expected change in the intensity of potential impacts if the demolition is extended beyond a single 28-week period.

The only operations that would occur following demolition would be 18 months of vegetation maintenance and routine maintenance on safety lights required on the towers, including bulb replacement. No impacts to wetlands would result from these activities.

4.1.4.4 Threatened and Endangered Species

Demolition activities may remove habitat for threatened and endangered species or result in the displacement of threatened and endangered animal species. BMPs, as described for Alternative 1, would be implemented to reduce or prevent impacts.

A Puerto Rican broad-winged hawk nest has been observed in a Maria tree on the south rim wall above the 305-meter-diameter telescope dish; however, this nest was determined to be inactive during the January 2017 vegetation survey (Brown, 2017, pers. comm.). The Maria tree with the nest and the other Maria trees in the vicinity would not be impacted by demolition activities. However, demolition of the 305-meter-diameter telescope dish and the metal supports could disrupt nesting in that area by the Puerto Rican broad-winged hawk. Puerto Rican broad-winged hawks were observed exhibiting courtship/nesting behavior near the Observatory entrance (Brown, 2017, pers. comm.) and this species is known to relocate nest sites periodically. The Puerto Rican broad-winged hawk typically initiates nesting behavior in December and its young fledge in May; however, weather conditions could result in the species nesting at other times. Demolition of the 305-meter-diameter reflector dish and the safe-abandonment of the rim wall and foundation infrastructure would not be allowed during the typical period when the Puerto Rican broad-winged hawk would initiate nesting behavior until after the young fledge (typically December through May). In addition, prior to the start of demolition/safe-abandonment, any known Puerto Rican broad-winged hawk nests in proximity/line of sight to the 305-meter-diameter telescope dish would be assessed to determine whether nesting activity or rearing of non-fledged young was occurring. Demolition of the dish and safe-abandonment of the rim wall structures would not be initiated until after young had fledged and voluntarily left the nest. Based on these mitigation measures, nest abandonment would not be expected and only short-term, negligible, adverse impacts to the Puerto Rican broad-winged hawk would be expected.

The Puerto Rican boa protocols identified under Alternative 1 would be implemented throughout the demolition activity period. With implementation of these Puerto Rican boa protocols, negligible, adverse, short-term impacts to the species would be expected during demolition.

No protected plant species were identified in the proposed work areas, including beneath the 305-meter-diameter telescope dish (Vélez Gavilán, 2017). Areas where proposed work would occur that were not surveyed consisted of pavement, gravel lots, and maintained landscape vegetation. Protected plant species would not occur in these areas. Because listed plant species do not occur where demolition work is proposed under Alternative 4, no new disturbance to natural areas would occur under Alternative 4. Because the BMPs described for vegetation under Alternative 1 would be implemented, there would be no direct impacts to protected plant species. There would be the potential for indirect impacts from scour or sedimentation as a result of exposed soil in the proposed work areas. However, with implementation of the BMPs for stormwater control described under Alternative 1, any adverse impacts would be expected to be long-term and negligible.

Similar to Alternative 1, there would be no expected change in the intensity of potential impacts if the demolition is extended beyond a single 28-week period.

The only operations that would occur following demolition would be 18 months of vegetation maintenance and the mandatory routine maintenance of safety lights on the towers, including bulb replacement. No adverse impacts would occur and a minor, long-term beneficial impact on listed plant and wildlife species would be expected from the cessation of human activity on the property.

4.1.4.5 Migratory Birds

Impacts to migratory birds could result from loss of foraging or nesting habitat, nest abandonment, and physical displacement. NSF coordinated with USFWS to establish appropriate procedures for demolition activities to minimize the potential for inadvertent take of migratory birds. To avoid impacts to nesting birds and nest abandonment, the following measures would be implemented:

- Biological inspections would be done to determine whether active nests are in or adjacent to work areas prior to the start of demolition work.
- 100-foot encroachment buffers would be established around identified active nests coupled with work exclusion periods within the buffer until the young had fledged.

Because impacts would be limited to the areas that do not provide substantial amounts of habitat for migratory birds and because the measures identified above would be implemented to prevent mortality or nest abandonment, impacts to migratory birds from demolition are expected to be negligible and short-term.

Similar to Alternative 1, there would be no expected change in the intensity of potential impacts if the demolition is extended beyond a single 28-week period.

Once demolition is complete, a minor, long-term benefit to migratory birds would be expected from the cessation of human activity on the property.

4.1.5 Alternative 5 – Complete Demolition and Site Restoration

4.1.5.1 Vegetation

Under Alternative 5, direct impacts would occur to vegetation from the creation of staging areas for materials and equipment and from the removal of all structures onsite (see Table 2.3-1), which would require additional workspace for the southeastern and southwestern tower anchors. Landscaped vegetation around the structures and onsite staging areas would be lost during demolition. In addition, heavy equipment, including cranes, would be used and their placement and operation could further disturb or damage vegetation on site. Extra workspace for the southeastern and southwestern tower anchors would remove dry-adapted vegetation typical of the tops of mogotes. Up to an additional acre of vegetation would be disturbed at each of these sites. BMPs, as described for Alternative 1, would be implemented to reduce or prevent impacts.

Use of explosives to demolish towers, tower and catwalk anchors, and the foundation and rim wall infrastructure would result in some direct loss of vegetation. Large pieces of concrete from the towers or anchors would break trees and shrubs and could cause minor landslides that would remove vegetation from downslope areas. The steepness of the slopes below the southeastern and southwestern tower anchors, which are outside the slopes confining the 305-meter-diameter radio telescope dish and adjacent to the property boundary, makes it likely that such debris would move offsite and to the river valley below, impacting vegetation all the way to the bottom. These areas would naturally revegetate, but would be susceptible to establishment of exotic invasive weeds following the disturbance.

The removal of the 305-meter-diameter telescope dish would result in changed conditions that would likely and substantially alter the vegetation composition of the area beneath the dish. Species that are adapted to the moist, semi-shade conditions beneath the reflector dish would likely die out upon full sun exposure and reduced moisture availability. This would result in the conversion of up to 25 acres of vegetation to species adapted to drier, sunnier conditions. With the loss of vegetation, there could be soil loss that would further alter the vegetation composition of the area. Through time, vegetation adapted to full sun conditions would establish in this area, which would provide protection from further soil loss and provide habitat and life history needs for wildlife. The soil impacts are discussed in the Section 4.3, *Geology and Soils*, and the potential for indirect impacts to groundwater from sedimentation entering the sinkhole is discussed in Section 4.4, *Groundwater*.

Overall, the impacts to vegetation from Alternative 5 would be moderate, adverse, and long-term. Demolished areas would be naturally revegetated or re-landscaped after the demolition period and open spaces would be revegetated with native vegetation to minimize the potential for the spread of exotic invasive species. Areas that have suitable soils would be revegetated with native species following demolition. Revegetation would use native species to the extent possible and the disturbed areas would be allowed to be colonized by native species following abandonment of the site. If non-native species are necessary to achieve site stabilization, only non-invasive plant species would be used. Revegetation areas would be maintained for up to 18 months to ensure establishment and minimize the potential for exotic species to become established. Soil would be brought in for vegetation establishment in disturbed areas where the remaining soil following infrastructure removal is insufficient. As appropriate, soil to be planted would be augmented with nutrients, organic matter, or bulking agents to provide an appropriate medium for root establishment and subsequent growth of the species selected for planting. If offsite soil is needed to backfill an excavated area, the minimum amount of soil needed would be brought onto the site (see Section 4.3, *Geology and Soils*, for a discussion of impacts to soils). Tower and anchor sites are at or near the tops of mogotes, where soils are thin and conditions are dry. Revegetation of these areas would be difficult and slow compared to areas with greater soils and more moisture. It is likely that soil would need to be added after removal of infrastructure to support plant growth. Biodegradable erosion control matting would be installed to stabilize soils until plant roots are established.

Some colonization by non-native weeds would be expected, as the rock walls created by blasting when Arecibo Observatory was constructed show extant colonization by such species. Vegetation would be maintained for up to 18 months to ensure establishment and minimize the potential for exotic species to become established. Impacts from weeds would be minor, adverse, and long-term.

Similar to Alternative 1, there would be no expected change in the intensity of potential impacts if the demolition is extended beyond a single 38-week period.

No operations, other than the 18-month vegetation maintenance, would occur following demolition. No other impacts to vegetation would occur following demolition.

4.1.5.2 Wildlife

Small areas of landscape habitat around buildings would be lost and replaced. The removal of the ground screen and reflector dish would result in the conversion of the vegetative community at that location and may result in a change in wildlife species that use this area. Permanent direct impacts would occur for animals that use structures as habitat (e.g., roosting or nesting habitat for some bird species). This habitat would be lost following demolition. However, there is ample amount of natural habitat nearby, including karst features that are comparable to the lost building habitat, which would lessen the effects to population stability.

Noise and vibration and increased human activity during demolition would occur over a larger area and for a longer period of time as compared to the other Alternatives, and individual noise events during use of explosives would be much louder than those during conventional demolition activities. It is likely that wildlife species on mogotes below the locations of towers and tower anchors would be the most impacted. Noise and vibrations would be produced for a longer period of time at these locations, which would displace wildlife for a greater length of time. Additionally, use of explosives to demolish the towers and anchors could collapse any small animal burrows or dens and damage any bird nests in the rockface beneath. Populations would be expected to recover and recolonize these areas after demolition is complete. The impacts to common wildlife from noise and vibration during demolition and from general increased human activity would be moderate, adverse, and short-term.

Similar to Alternative 1, there would be no expected change in the intensity of potential impacts if the demolition is extended beyond a single 38-week period.

Once demolition is complete, there would be a minor, long-term benefit to wildlife from reduced noise and human activity.

4.1.5.3 Wetlands

While there are no onsite wetlands, potential changes in runoff patterns and increased erosion and sedimentation during demolition could cause indirect moderate, adverse, short-term impacts to offsite wetlands downslope of the Observatory toward the Tanamá River. Because demolition would occur over a larger area than under other Alternatives and would include demolition work on or adjacent to very steep terrain, the potential for indirect impacts to offsite wetlands would be greater than for other Alternatives. Implementation of BMPs as those described for Alternative 1 would prevent or reduce potential impacts from scour or offsite movement of sediments from most of the demolition sites. The difficult terrain at the southeastern and southwestern towers and tower anchors would result in most normal stormwater BMPs being ineffective at these locations. Site-specific BMPs or other mitigation measures would be developed and implemented, as necessary, by the contractor to minimize the potential for impacts to offsite wetlands.

Similar to Alternative 1, there would be no expected change in the intensity of potential impacts if the demolition is extended beyond a single 38-week period.

The only activity that would occur following demolition is 18 months of vegetation maintenance, which would have no adverse impacts to wetlands.

4.1.5.4 Threatened and Endangered Species

Demolition activities may remove habitat for threatened and endangered species or result in displacement of threatened and endangered animal species. There is potential for injury or mortality to terrestrial species in proximity to the southeastern and southwestern towers and tower anchors. BMPs, as those described for Alternative 1, would be implemented to reduce or prevent impacts.

A Puerto Rican broad-winged hawk nest has been observed in a Maria tree on the south rim wall above the 305-meter-diameter telescope dish. This nest was determined to be inactive during the January 2017 vegetation survey (Brown, 2017, pers. comm.). The Maria tree with the nest and other Maria trees in the vicinity would not be impacted by demolition activities. However, demolition of the 305-meter-diameter telescope dish, including the foundation and rim wall infrastructure, could disrupt nesting in that area by the Puerto Rican broad-winged hawk. Puerto Rican broad-winged hawks were observed exhibiting courtship/nesting behavior near the Observatory entrance (Brown, 2017, pers. comm.), and it is likely that the species relocates nest sites periodically.

Removal of the towers and anchors could alter nesting behavior and success, if the species were nesting near one of these structures at the time of demolition. A hawk nest survey would be conducted prior to demolition of the 305-meter-diameter telescope dish at the beginning of the nesting period. The Puerto Rican broad-winged hawk typically initiates nesting behavior in December and its young fledge in May; however, weather conditions could result in the species nesting at other times.

Removal of the towers and anchors may alter the character of the habitat in the area, which may cause birds to abandon the area. Given the length of time before any demolition would begin, surveys for the Puerto Rican broad-winged hawk would not be completed until closer to the time for the start of demolition activities. The appropriate timing of surveys will be determined through consultation with USFWS.

NSF commits to further consultation with the USFWS should Alternative 5 be selected. This consultation will be completed prior to starting demolition activities, and it is anticipated that as part of the consultation, USFWS will issue a Biological Opinion (BO) and NSF will implement the appropriate mitigation specified in the BO. Potential impacts to the Puerto Rican broad-winged hawk could be major, adverse, and long-term.

The Puerto Rican boa protocols identified under Alternative 1 would be implemented throughout the demolition activity period. However, a survey of all areas in proximity to the southeastern and southwestern towers and tower anchors would likely not be possible due to the very steep terrain and the presence of numerous karst features (fractures and voids). It is likely that some Puerto Rican boas would not be observed and would then be subject to injury or mortality from demolition activities. If fractures or voids collapse, boas could be trapped, resulting in eventual death. As noted previously, NSF commits to further consultation with the USFWS should Alternative 5 be selected. This consultation will be completed prior to starting demolition activities, and it is anticipated that as part of the consultation, USFWS will issue a BO and NSF will implement the appropriate mitigation specified in the BO. With implementation of the Puerto Rican boa protocols, adverse impacts to the species would be minimized, but impacts would be major, adverse, and long-term.

No protected plant species were identified in the proposed work areas for Alternative 5 where natural or disturbed habitats occur (Vélez Gavilán, 2017). Areas where the proposed work would occur that were not surveyed consisted of pavement, gravel lots, and maintained landscape vegetation. Protected plant species would not occur in these areas. Because listed plant species do not occur where the demolition work is proposed, no new disturbance to natural areas would occur under Alternative 5, and the BMPs described for vegetation under Alternative 1 would be implemented, there would be no direct impacts to protected plant species. There would be the potential for indirect impacts from scour or sedimentation as a result of exposed soil in the work areas. With implementation of the BMPs for stormwater control described under Alternative 1, any adverse impacts would be expected to be long-term and negligible.

No listed plant species were identified within or adjacent to the extra workspace that would be required for demolition of the southeastern and southwestern towers and tower anchors (Vélez Gavilán, 2017). No direct impacts to listed plant species would result from the demolition of these structures. There would be the potential for indirect impacts to these species from scour and sedimentation or incidental debris falling onto the walls of the valley below the tower anchor locations. BMPs for stormwater control as described under Alternative 1 would be implemented. Indirect adverse impacts to threatened and endangered plant species as a result of clearing extra workspace under Alternative 5 are expected to be long-term and minor.

Similar to Alternative 1, there would be no expected change in the intensity of potential impacts if the demolition is extended beyond a single 38-week period.

The only operations that would occur following demolition would be 18 months of vegetation maintenance. No adverse impacts would occur and a minor, long-term beneficial impact on listed plant and wildlife species would be expected from the cessation of human activity on the property.

Once demolition is complete, a minor, long-term beneficial impact on protected plants and wildlife species would be expected from the cessation of human activity on the property. The only other activity that would occur following demolition is 18 months of vegetation maintenance, which would have no adverse impacts to threatened and endangered species.

4.1.5.5 Migratory Birds

Potential migratory bird nesting habitat is present on Arecibo Observatory; demolition activities could adversely affect these species. It is likely that migratory bird species on mogotes below the locations of towers and tower anchors would be the most impacted. Noise and vibrations would be produced for a longer period of time at these locations, which could displace birds for a greater length of time. Additionally, use of explosives to demolish the towers and anchors could damage bird nests on the mogotes, either on the rockface or in vegetation below the towers and anchors, or result in nest abandonment. Populations would be expected to recover and recolonize these areas after demolition is complete.

Impacts to migratory birds could result from loss of foraging or nesting habitat, nest abandonment, and physical displacement. To avoid impacts to nesting birds and nest abandonment, the following measures would be implemented:

- Biological inspections would be done to determine whether active nests are in or adjacent to work areas prior to the start of demolition work.
- 100-foot encroachment buffers would be established around identified active nests coupled with work exclusion periods within the buffer until the young had fledged.

If Alternative 5 is selected, NSF would coordinate with USFWS to establish appropriate measures to avoid direct takes of migratory birds and minimize the potential for inadvertent take. Because it is likely that nest identification would not be effective at the southeastern and southwestern tower and tower anchor locations and some birds could be harmed in these areas during demolition, the potential impacts to migratory birds from demolition are expected to be moderate, adverse, and short-term.

Similar to Alternative 1, there would be no expected change in the intensity of potential impacts if the demolition is extended beyond a single 38-week period.

Following demolition, a minor, long-term beneficial impact on migratory birds would be expected from the cessation of human activity on the property. The only activity that would occur following demolition is 18 months of vegetation maintenance, which may have minor, long-term indirect benefits to migratory birds through expediting habitat recovery on disturbed areas.

4.1.6 No-Action Alternative

Under the No-Action Alternative, no demolition activities would occur. Therefore, there would be no impacts to vegetation, wildlife, or protected species.

4.1.7 Mitigation Measures

The following measures would be implemented to reduce impacts to vegetation and wildlife, and to avoid potential effects to species protected by the ESA and MBTA:

- All Alternatives: The expected areas of disturbance that were analyzed to determine potential impacts to protected species would be provided to prospective bidders of demolition services. If a bidder indicated that additional areas, including additional or widened roads, would be needed to complete the work, NSF would delay the award until additional consultation with USFWS, including additional surveys, had been completed.

- All Alternatives: Worksites would be clearly marked, and workers would be instructed to stay within marked areas.
- All Alternatives: Staging areas would be placed in disturbed areas, whenever possible.
- All Alternatives: If offsite soil is needed to backfill an excavated area, the minimum amount of soil needed would be brought onto the site.
- All Alternatives: As appropriate, soil to be planted would be augmented with nutrients, organic matter, or bulking agents to provide an appropriate medium for root establishment and subsequent growth of the species selected for planting.
- All Alternatives: A site-specific SWPPP would be developed to support the NPDES stormwater permit.
- All Alternatives: Erosion control measures such as riprap, check-dams, and compost filter berms would be used to protect exposed soil and minimize erosion, scouring, and sedimentation. Good housekeeping measures would be practiced during demolition and disturbed areas would be revegetated. Steep slopes that are disturbed would be protected with biodegradable erosion control measures. Pre-demolition runoff patterns would be restored upon completion of demolition activities.
- All Alternatives: Standard operating procedures for the capture and relocation of Puerto Rican boas (Appendix 4.1-A) would be used during demolition and/or site restoration activities and would be implemented as follows:
  - Train key onsite personnel in the identification of boas and the value of boas and boa conservation by qualified personnel.
  - Complete daily pre-work surveys of equipment and work areas, including buildings and karst features, by qualified personnel trained in boa identification and location.
  - Relocate any boas found on equipment or within the day's work area to the designated relocation area south of the staging yard on the eastern side of the Observatory; this should be done by an individual authorized by the USFWS and trained in handling Puerto Rican boas.
  - Stop work if a boa is observed in the day's work area until a qualified wildlife biologist trained in handling Puerto Rican boas can relocate the snake to the designated relocation area or the boa voluntarily vacates the work area.
- All Alternatives: A pre-demolition survey for active bird nests would be conducted. Any identified active nests would be protected from disturbance by a 100-foot nesting buffer, which would remain in place until the young have fledged from the nest.

- Alternatives 1-2: NSF could retain or transfer property. If Arecibo Observatory is transferred out of federal control in the future, then this would be subject to further consultation under Section 7 of the ESA. NSF, in consultation with USFWS, would consider the appropriate land use controls, such as deed restriction and conservation easement, for the natural areas on the Observatory prior to any transfer to a non-federal entity.
- Alternatives 1, 2, and 3: Re-landscaping would use non-invasive species and would incorporate native vegetation if feasible.
- Alternatives 1, 2, and 3: Landscaped areas would be maintained to avoid the propagation of weed species.
- Alternatives 4 and 5: Areas disturbed from demolition activities would be revegetated using native species to the extent possible. If use of non-native species is necessary to achieve site stabilization, only non-invasive species would be planted.
- Alternatives 4 and 5: Revegetated areas will be monitored for 18 months to ensure establishment of desirable species.
- Alternatives 4 and 5: Demolition of the 305-meter-diameter reflector dish and the demolition or safe-abandonment of the rim wall and foundation infrastructure would not be allowed during the typical period when the Puerto Rican broad-winged hawk would initiate nesting behavior until after the young fledge (typically December through May).
- Alternatives 4 and 5: Prior to start of demolition/safe-abandonment, any known Puerto Rican broad-winged hawk nests in proximity/line of sight to the 305-meter-diameter telescope dish would be assessed to determine whether nesting activity or rearing of non-fledged young was occurring. Demolition of the dish and safe-abandonment of the rim wall structures would not be initiated until after young had fledged and voluntarily left the nest.
- Alternative 5: Prior to use of explosives, the area within 100 feet (30 meters) of the proposed detonation would be checked for presence of birds. The detonation would be delayed until there are no birds within 100 feet (30 meters) of the detonation site.
- Alternative 5: Explosives used for demolition of towers, anchors, foundations, and rim wall infrastructure would be directional charges to focus the explosion on the object to be removed and would be appropriately sized to meet the demolition need while minimizing shock wave propagation through bedrock.
- Alternative 5: NSF commits to further consultation with the USFWS regarding listed species should Alternative 5 be selected. This consultation will be completed prior to starting intrusive work under

Alternative 5. As part of that consultation, it is anticipated that USFWS will issue a BO and NSF will implement appropriate mitigation specified in the BO.

4.1.8 Summary of Impacts

Table 4.1-2 provides a summary of impacts to biological resources resulting from the Alternatives.

TABLE 4.1-2
Summary of Biological Resources Impacts

	Alternatives					
Impacts	**Alternative 1**	**Alternative 2**	**Alternative 3**	**Alternative 4**	**Alternative 5**	**No-Action**
Impacts to vegetation during demolition	Minor, adverse, short-term impact	Minor, adverse, short-term impact	Minor, adverse, short-term impact	Moderate, adverse, long-term impact	Moderate, adverse, long-term impact	No impact
Impacts to vegetation from operations	No impact	No impact	No impact	No impact	No impact	No impact
Impacts from weeds	No impact	No impact	No impact	Minor, adverse, long-term impact	Minor, adverse, long-term impact	No impact
Impacts to wildlife from demolition	Minor, adverse, short-term impact	Minor, adverse, short-term impact	Minor, adverse, short-term impact	Moderate, adverse, short-term impact	Moderate, adverse, short-term impact	No impact
Impacts to wildlife during operations	No impact	No impact	No impact	Minor, long-term benefit	Minor, long-term benefit	No impact
Impacts to wetlands from demolition	Negligible, adverse, short-term impact	Negligible, adverse, short-term impact	Negligible, adverse, short-term impact	Negligible, adverse, short-term impact	Moderate, adverse, short-term impact	No impact
Impacts to wetlands during operations	No impact	No impact	No impact	No impact	No impact	No impact
Impacts to the Puerto Rican broad-winged hawk during demolition	No impact	No impact	No impact	Negligible, adverse, short-term impact	Major, adverse, long-term impact	No impact
Impact to the Puerto Rican boa during demolition	Negligible, adverse, short-term impact	Negligible, adverse, short-term impact	Negligible, adverse, short-term impact	Negligible adverse, short-term impact	Major, adverse, long-term impact	No impact
Impacts to listed plant species during demolition	Negligible, adverse, short-term impact	Negligible, adverse, short-term impact	Negligible, adverse, short-term impact	Negligible, adverse, long-term impacts	Minor, adverse, short-term impact	No impact
Impacts to all listed species during operations	No impact	No impact	No impact	Minor, long-term benefit	Minor, long-term benefit	No impact

TABLE 4.1-2
Summary of Biological Resources Impacts

	Alternatives					
Impacts	**Alternative 1**	**Alternative 2**	**Alternative 3**	**Alternative 4**	**Alternative 5**	**No-Action**
Impacts to migratory birds during demolition	Negligible, adverse, short-term impact	Negligible, adverse, short-term impact	Negligible, adverse, short-term impact	Negligible, adverse, short-term impact	Moderate, adverse, short-term impact	No impact
Impacts to migratory birds during operations	No impact	No impact	Minor, short-term benefit	Minor, long-term benefit	Minor, long-term benefit	No impact

4.2 Cultural Resources

Methodology

This Section describes the potential impacts to cultural resources within the APE as a result of implementing the Proposed Action or as a result of the No-Action Alternative. The APE for cultural resources corresponds to the boundary of Arecibo Observatory. Because NEPA and NHPA Section 106 are parallel processes that are closely related in their findings of consequences for cultural resources, this Section presents the findings for both regulations. For purposes of clarity, this Section uses the term "impact" when discussing NEPA and the term "effect" when discussing Section 106. No important non-NRHP cultural resources were identified; therefore, impacts are discussed only for properties that contribute to the NRHP-listed historic district. Under Section 106, the Proposed Action is referred to as the undertaking, as defined in Section 2 of this FEIS.

As described in Section 3.2, *Cultural Resources*, Arecibo Observatory is a federally owned property that is listed in the NRHP as the NAIC historic district; therefore, the Proposed Action has the potential to affect NRHP-listed historic properties. In addition, Arecibo Observatory is scientifically iconic on the national and international level and is a significant source of cultural pride for people of Puerto Rico. As a result of the Proposed Action, the five Alternatives could result in adverse effects to historic properties. Use or demolition of any particular building or instrument cannot be determined unless or until a viable collaboration option is under consideration. Because reduction of NSF funding may require the safe-abandonment, mothballing, or demolition of facilities, the FEIS describes these Alternatives under the most conservative (highest environmental impact) scenario in terms of NSF's analysis of potential changes to facilities, so that it may be inclusive of the full range of potential environmental impacts. The resolution of adverse effects for the Preferred Alternative (Alternative 1) would be addressed in a Section 106 PA, which would be executed prior to signing the NEPA ROD. An unanticipated discovery plan would be in place prior to demolition under the selected Alternative to address any archaeological resources that might be discovered during demolition.

After historic properties were identified within the APE, each Alternative was analyzed to determine whether it would have direct or indirect impacts, either during demolition or operations, on those properties. Then the intensity level of the impact was determined under NEPA and a determination was made on whether any effects found would be adverse under Section 106.

To determine the direct impacts under NEPA on historic properties from the Proposed Action, the following information was analyzed:

- Potential partial or complete demolition of historic properties
- Potential alterations to historic properties
- Potential physical changes to the setting and integrity of the NRHP-listed historic district
- General demolition activities
- Potential changes in ownership of historic properties

The extent to which these types of impacts could alter the integrity of historic properties was examined based on the Proposed Action and the types of identified historic properties.

For indirect impacts, broader changes that the Proposed Action may cause (such as changes in land use) were identified and analyzed qualitatively, based primarily on those seen from previous similar projects. This analysis could include activities related to the Proposed Action but not directly part of the Proposed Action's activities. No indirect impacts were identified for the Alternatives or the No-Action Alternative. Therefore, no further discussion of indirect impacts is included for cultural resources.

Section 106 Assessment of Effects

Because this Section addresses both NEPA and Section 106, the following presents an explanation of how Section 106 evaluates consequences of project actions on historic properties. The ACHP's regulations implementing Section 106 of the NHPA create a process by which federally assisted projects are reviewed for their effects on historic properties. After the historic property is identified and evaluated, the Criteria of Adverse Effect (36 C.F.R. §800.5[1]) are applied. These criteria are used to determine whether the undertaking could change the characteristics that qualify the property for inclusion in the NRHP in a manner that would diminish the integrity of the property's location, design, setting, materials, workmanship, feeling, or association. Section 106 of the NHPA allows the following three findings for effects on historic properties:

- No Historic Properties Affected
- No Adverse Effect
- Adverse Effect

An effect is adverse under Section 106 if it diminishes the integrity of the property's historically significant characteristics. Examples of adverse effects include, but are not limited to, the following:

- Demolition of the historic property
- Relocation of the historic property
- Introduction of visual, audible, or atmospheric elements that are out of character with the setting of the historic property
- Transfer of ownership of a federally-owned property to a non-federal entity

The federal agency makes the determination of effects for each historic property. Based on these determinations, an overall finding of effect for the undertaking is reached, in consultation with the SHPO and other consulting parties. In the case of an adverse effect, the agency must notify the ACHP of the finding (see Table 3.2-1 for specific steps and dates of the Section 106 process for this Proposed Action).

The term mothballing is used in this FEIS to refer to the process of removing a facility or structure from daily use while maintaining the general condition for a defined period and removing equipment instruments from use while keeping them in working order. The NPS guidelines for mothballing, presented in Preservation Brief 31, "Mothballing Historic Buildings," applies specifically to historic buildings rather than instruments or equipment (Park, 1993). However, since a similar approach could be used to preserve certain historic instruments and equipment at Arecibo Observatory, the term mothballing is used in this Section for historic instruments and equipment, as well as historic buildings and structures, to indicate that they will be preserved and protected, and maintained in an operational readiness condition. Historic instruments and equipment proposed for mothballing at Arecibo Observatory would be protected and preserved in accordance with *The Secretary of the Interior's Standards for the Treatment of Historic Properties* (NPS, 1992), and the *Guidelines for Preserving, Rehabilitating, Restoring and Reconstructing Historic Buildings* (Grimmer, 2017).

Section 106 Resolution of Effects

As stipulated in 36 C.F.R. §800.1(a), the goal of consultation is to identify historic properties potentially affected by the undertaking, assess effects to them, and seek ways to avoid, minimize, or mitigate any adverse effects on historic properties. When an undertaking is found to have an adverse effect, Section 106 requires notification to the ACHP and consultation with SHPO and other interested parties regarding appropriate avoidance, minimization or mitigation measures. Mitigation measures might include redesigning aspects of a project, or relocating or documenting buildings and/or structures. For a finding of adverse effect, the product of consultation is usually an agreement document per 36 C.F.R. §800.6(c) among the SHPO, federal agency, ACHP if it chooses to participate, and other consulting parties. This agreement contains stipulations specifying measures to be implemented that would avoid, minimize, or mitigate the adverse effects. For this Proposed Action, a PA has been drafted with the participation of the

Puerto Rico SHPO, the ACHP, and the Consulting Parties to avoid, minimize, or mitigate any potential adverse effects from Alternative 1, which NSF identified as the Preferred Alternative. NSF recognizes that Alternative 1 can only occur if collaborators come forward with viable plans to provide additional non-NSF funding in support of their science-focused operations. Because Alternative 1 has been identified as NSF's Preferred Alternative, the PA addresses potential adverse effects only from Alternative 1; if Alternative 1 is ultimately not feasible, NSF will resume Section 106 consultation focusing on Alternatives 2-5. The PA is being finalized in consultation with the SHPO, the ACHP, and the Consulting Parties and will be executed prior to NSF's ROD.

NEPA Impact Thresholds and Section 106 Effects

Table 4.2-1 identifies thresholds of NEPA impacts relevant to historic properties for this Proposed Action, and lists the correlation between NEPA impacts and NHPA Section 106 effects.

TABLE 4.2-1
Impact and Effect Thresholds for NEPA and Section 106

Impact Intensity	Description
Negligible	Impacts to historic properties would not be expected to be detectable and would not alter resource characteristics. *The NHPA Section 106 determination would be no historic properties affected or no adverse effect on historic properties.*
Minor	Impacts to historic properties would result in little, if any, loss of integrity and would be slight but noticeable. Impacts would not appreciably alter resource characteristics. *The NHPA Section 106 determination would be no adverse effect on historic properties.*
Moderate	Impacts to historic properties would result in some loss of integrity and would be noticeable. Impacts could appreciably alter resource characteristics. Measures to mitigate impacts would be sufficient to reduce the intensity of impacts to a level less than major under NEPA. *The NHPA Section 106 determination would likely be no adverse effect, but only after implementing minimization or mitigation measures sufficient to reduce the adverse effects on historic properties.*
Major	Impacts to historic properties would result in disturbance to an important site, substantial loss of integrity, and/or permanent alteration of property conditions, the result of which would significantly affect the human environment. Mitigation would not be sufficient to reduce the intensity of impacts to a level less than major under NEPA. *The NHPA Section 106 determination would be adverse effect to historic properties. Measures to mitigate, avoid, and/or minimize adverse effects under Section 106 would be decided through consultation and stipulated in a PA.*

Duration: Short-term – Occurs only during the demolition period.
Long-term – Continues after the demolition period.

Note: Language shown in *italics* is the corresponding "Section 106 Finding of Effect."

Should the demolition extend beyond the single 12 to 38-week periods identified for the Alternatives, there would be no change in the assessed impacts to cultural resources.

4.2.1 Alternative 1 – Collaboration with Interested Parties for Continued Science-focused Operations (Agency-preferred Alternative)

4.2.1.1 Architectural Resources

Demolition (and Property Transfer)

Alternative 1 could involve the demolition of facilities at Arecibo Observatory that contribute to the NRHP-listed historic district; therefore, Alternative 1 would result in major, adverse, long-term impacts under NEPA and adverse effects under Section 106. Table 4.2-2 lists the contributing resources to the historic district and identifies the potential outcome for each under Alternative 1.

TABLE 4.2-2
Alternative 1 – Description of Proposed Activities

Historic Properties that May be Demolished	• Building 2 (Administration Building) • Building 17 (Warehouse and Business/Purchasing Building) • Buildings 66 and 68 (the Atmospheric Science Trailer and Visiting Scientist Trailer, both associated with Building 1, Operations Building)
Historic Properties that May Remain	• 305-meter-diameter radio telescope and its associated structures (reflector dish, foundation, rim wall, support towers, and anchors) • Building 1 (Operations Building) • Building 12 (Maintenance Building) • Building 27 (Photometry Shack/Optical Lab) • Building 54 (Visitor Center) • Building 61 (Learning Center)

The removal of historic architectural resources results in a major impact. Although mitigation would be implemented, demolition of a historic building cannot be mitigated to less than a major impact because it is a permanent removal of historic fabric. In addition, if ownership of Arecibo Observatory is transferred to a non-federal entity under Alternative 1, this would be considered an adverse effect to historic properties under Section 106 because the NHPA would no longer be applicable, as described below. NSF consulted with the Puerto Rico SHPO, ACHP and other Consulting Parties to determine the appropriate ways in which to avoid, minimize, and/or mitigate these effects. Measures that resulted from these consultations have been documented in the PA and include stipulations such as historic preservation training for any new collaborator(s), as well as how NSF would document properties prior to any potential demolition. Although several contributing buildings could be demolished in the worst case, Alternative 1 would avoid demolition where possible, and would also avoid complete demolition of the historic district. The Observatory would retain most of the contributing historic properties within the historic district, including the site's primary instrument, the 305-meter-diameter radio telescope. As a result, the Observatory would still retain sufficient integrity to convey its significance as an NRHP-listed historic district.

Under Alternative 1, NSF could retain or transfer the property. In the case that the property was transferred to a non-federal entity, the Section 106 consultation process would no longer be applicable to future actions by any new owner. If any future new owner were to make changes that could affect one or more contributing elements to the historic district, that owner would not be required to consult with SHPO under Section 106 of the NHPA to determine ways in which to avoid, minimize, and/or mitigate adverse effects. A change in ownership to a non-federal entity would therefore result in major, adverse, long-term impacts under NEPA and adverse effects under Section 106. NSF has consulted with the Puerto Rico SHPO, ACHP, and other consulting parties to determine the appropriate ways in which to avoid, minimize, and/or mitigate this effect. Measures that resulted from these consultations have been documented in the PA and include provisions that NSF would require of any new owner as a part of any future property transfer.

Operations

Operations of Arecibo Observatory would continue under Alternative 1 through collaboration with interested parties for continued science-focused operations. In the worst case, after demolition, it is possible that only six of the contributing resources to the NRHP-listed historic district would remain extant for operation under Alternative 1. However, the 305-meter-diameter radio telescope, which stands as the focal point of the historic district, and the educational facilities—Building 54 (Visitor Center) and Building 61 (Learning Center)—would be retained under Alternative 1, along with three additional historic buildings. The preservation of the 305-meter-diameter radio telescope and several other support facilities, namely the educational facilities, would allow the small collection of historic properties to retain sufficient integrity to continue to qualify as a historic district. As such, historic properties would remain present and could be impacted by future operations. The PA includes provisions to guide the collaborator in operating Arecibo Observatory in a way that is consistent with historic preservation. There are currently no physical alterations proposed for any properties (including historic ones) during operations under Alternative 1. Any potential changes that could occur during operations are not anticipated to alter the characteristics that qualify the contributing elements or the historic district as a whole for listing in the NRHP. Therefore, operations under Alternative 1 would result in no impact to the NRHP-listed historic district under NEPA and no adverse effect on historic properties under Section 106.

4.2.1.2 Archaeological Resources

Ground disturbance during demolition of Alternative 1 would be limited to activities associated with the demolition of buildings at the Observatory. There are no known archaeological resources within the APE, and therefore no impacts to archaeological resources and no effects to archaeological historic properties under Section 106 are anticipated. However, if previously unidentified archaeological resources were discovered during demolition, ground-disturbing activities would halt in the vicinity of the find and NSF would consult with the SHPO and other consulting parties as appropriate regarding eligibility for listing in the NRHP, project impacts, necessary mitigation, or other treatment measures. An unanticipated discovery plan would be in place prior to demolition to address any archaeological resources that might be discovered during demolition.

4.2.2 Alternative 2 – Collaboration with Interested Parties for Transition to Education-focused Operations

4.2.2.1 Architectural Resources

Demolition (and Property Transfer)

Alternative 2 could involve the demolition of facilities at Arecibo Observatory that contribute to the NRHP-listed historic district and would result in major, adverse, long-term impacts under NEPA and adverse effects under Section 106. Table 4.2-3 lists the contributing resources to the historic district and identifies the potential outcome for each under Alternative 2.

TABLE 4.2-3
Alternative 2 – Description of Proposed Activities

Historic Properties That May be Demolished	• Building 1 (Operations Building) • Building 2 (Administration Building) • Building 17 (Warehouse and Business/Purchasing Building) • Buildings 66 and 68 (the Atmospheric Science Trailer and Visiting Scientist Trailer, both associated with Building 1, Operations Building)
Historic Properties That May Remain	• Building 12 (Maintenance Building) • Building 27 (Photometry Shack/Optical Lab) • Building 54 (Visitor Center) • Building 61 (Learning Center)
Historic Properties to be Safe-abandoned	• 305-meter-diameter radio telescope and its associated structures (reflector dish, foundation, rim wall, support towers, and anchors)

Demolition activities for Alternative 2 would be similar to Alternative 1, in that both could involve the demolition of contributing resources to an NRHP-listed historic district, but would also avoid complete demolition of the historic district. In addition, as with Alternative 1, there is the potential under Alternative 2 that ownership of Arecibo Observatory could be transferred to a non-federal entity. Requirements to resolve adverse effects for Alternative 2 as a result of a potential property transfer out of federal ownership would be the same as those described for Alternative 1.

Alternative 2 would result in additional impacts to the 305-meter-diameter radio telescope than would result from Alternative 1. While Alternative 1 would retain the 305-meter-diameter radio telescope and supporting facilities for research, Alternative 2 would involve the safe-abandonment of the 305-meter-diameter radio telescope, which is the focal point of the NRHP-listed historic district. Preparing the structure for safe-abandonment would involve securing the structure from environmental damage due to wind, rain, humidity, and extreme temperatures. The structure would be isolated from public access through the installation of fencing or other means to reduce fall and tripping hazards and to preclude vandalism. Although physical changes to the 305-meter reflector dish would be negligible, securing the overall structure would involve physical alterations to it, including the removal of the large support cables for the towers and the removal of the Gregorian dome that is suspended above the 305-meter reflector dish, diminishing the structure's integrity of materials and design. These alterations would be noticeable, but would not substantially diminish the primary characteristics of the 305-meter-diameter radio telescope that qualify it for listing in the NRHP. Because impacts from the safe-abandonment of the telescope would be noticeable and would result in some loss of integrity, they would be considered moderate, adverse, and long-term under NEPA. Specific measures to mitigate impacts, agreed upon in consultation with the Puerto Rico SHPO, could ensure that adverse effects to the historic structure and historic district from the safe-abandonment are minimized. If NSF were to consider the selection of Alternative 2, it would resume consultation with the Puerto Rico SHPO, ACHP, and other consulting parties to determine the appropriate mitigation measures to resolve adverse effects. The product of consultation would be an amendment to the PA or a specific MOA for this Alternative.

Operations

Operations of Arecibo Observatory would continue under Alternative 2 through collaboration with interested parties for continued education-focused operations. Operations activities for Alternative 2 would be similar to Alternative 1 and both would retain sufficient integrity to qualify as a historic district. However, under Alternative 2, the 305-meter-diameter radio telescope would experience additional impacts and effects during operation than it would under Alternative 1. The safe-abandonment of the 305-meter-diameter radio telescope under Alternative 2 would involve the removal of the radio telescope from service, isolating the structure from public access, and resulting in a change of use. Since the radio telescope is a scientific instrument, its use is a primary component of its significance. Although the structure would remain extant, a change of use would diminish its integrity of feeling and association. In addition, due to the lack of maintenance and use, the safe-abandonment of the 305-meter-diameter radio telescope under Alternative 2 would result in a gradual depletion of the structure's physical integrity, including its integrity of materials, workmanship, and design. Overall, the loss of the 305-meter-diameter radio telescope as an active instrument would diminish the NRHP-listed historic district's integrity of materials, feeling, setting, design, workmanship, and association. The decline in the structure's integrity could ultimately result in a major, adverse, long-term impact under NEPA and an adverse effect under Section 106.

4.2.2.2 Archaeological Resources

Demolition activities under Alternative 2 would be similar to Alternative 1 in that they involve the demolition of a comparable number of Observatory support buildings. Ground disturbance under Alternative 2, similarly to Alternative 1, would be limited to activities associated with the demolition of buildings at the Observatory. There are no known archaeological resources within the APE, and therefore demolition impacts under NEPA and the effects under Section 106 to archaeological resources for Alternative 2 would be the same as those described for Alternative 1.

4.2.3 Alternative 3 – Mothballing of Facilities

4.2.3.1 Architectural Resources

Demolition (and Property Transfer)

Under Alternative 3, no historic properties would be demolished. Instead, all buildings and structures that contribute to the NRHP-listed historic district would be mothballed.

Avoiding demolition of historic properties means that they would be preserved for potential future use. In this way, Alternative 3 would retain the collection of contributing resources as a unique historic district that captures a significant period in the field of ionosphere studies and radar and radio astronomy, and architecturally embodies the distinctive characteristics of a type, period, and method of construction. Preparing historic properties for mothballing could involve securing buildings, structures, and their associated components, turning off utilities, weatherizing, and providing adequate ventilation. Although the physical treatments required would not substantially change the physical integrity of the property, these steps would remove the buildings and structures from service and would change the character of the property's use for an indefinite period of time, resulting in major, adverse, short-term impacts under NEPA and adverse effects to historic properties under Section 106. Any modifications required during mothballing would be compatible with the historic property's style and materials, and would be executed in accordance with NPS's Preservation Brief 31, "Mothballing Historic Buildings" (Park, 1993), *The Secretary of the Interior's Standards for the Treatment of Historic Properties* (NPS, 1992), and the *Guidelines for Preserving, Rehabilitating, Restoring and Reconstructing Historic Buildings* (Grimmer, 2017). If historic properties were returned to use at a future date, any alterations performed as part of the mothballing process could be reversed without physical harm to the historic fabric. Of the five Alternatives, Alternative 3 would result in the least significant impacts to historic properties. If NSF were to consider the selection of Alternative 3, it would resume consultation with the Puerto Rico SHPO, ACHP, and other consulting parties to determine the appropriate mitigation measures to resolve adverse effects. The product of consultation would be an amendment to the PA or a specific MOA for this Alternative.

Operations

Under Alternative 3, the NRHP-historic district and all its contributing resources would be mothballed, which would include the removal of each facility from daily use, while maintaining the general condition of historic properties for a defined period. Mothballing the 305-meter-diameter radio telescope and the other contributing facilities at Arecibo Observatory would alter the use and setting of the site. Arecibo Observatory is listed in the NRHP under Criterion A for its association with important events relating to the sciences of ionosphere studies, and the development of radio and radar astronomy that has made a significant contribution to history. The site is also listed under Criterion C for embodying the distinctive characteristics of a type, period, or method of construction and as an example of an important achievement in engineering. Historic properties at Arecibo Observatory are mostly utilitarian buildings or scientific instruments and their use is a primary component of their significance. Some buildings onsite have achieved significance through their function supporting the scientific mission of the site. The 305-meter-diameter radio telescope has achieved its significance through its use as a tool for furthering the field of ionosphere studies, and radar and radio astronomy. For these reasons, if the Observatory were mothballed, the historic district and its contributing historic resources would suffer a loss of association and feeling. As a result, operations under Alternative 3 would result in major, adverse, short-term impacts under NEPA and an adverse effect under Section 106.

If NSF were to consider the selection of Alternative 3, it would resume consultation with the Puerto Rico SHPO, ACHP, and consulting parties to address mothballing and preservation methodologies. Specific measures could ensure that the effects are minimized. These measures could include written and photographic documentation of the historic properties at Arecibo Observatory, a detailed conditions assessment of the contributing resources, compliance with certain security and maintenance standards, and regular monitoring of the buildings and structures that contribute to the NRHP-listed historic district. Such measures would ensure the future survival of the historic district and its associated historic properties. To minimize adverse effects from mothballing activities, modifications required to mothball the facilities would be compatible with the historic resource’s style and materials. The mothballing process would be planned and completed in accordance with the NPS Preservation Brief 31, “Mothballing Historic Buildings” by Sharon C. Park. If historic properties are ultimately returned to use at a future date, any alterations performed as part of the mothballing process could be reversed without physical harm to the historic fabric. Instruments and equipment would be protected and preserved in accordance with *The Secretary of the Interior's Standards for the Treatment of Historic Properties*, (NPS 1992), and the *Guidelines for Preserving, Rehabilitating, Restoring and Reconstructing Historic Buildings*, (Grimmer, 2017).

4.2.3.2 Archaeological Resources

Demolition activities for Alternative 3 would be similar in scale to Alternative 1 (but would be limited to the demolition of non-historic buildings and structures). Therefore, the impacts under NEPA and effects under Section 106 to archaeological resources, as well as BMPs, would be the same as those described for Alternative 1.

4.2.4 Alternative 4 – Partial Demolition and Site Restoration

4.2.4.1 Architectural Resources

Demolition (and Property Transfer)

Alternative 4 would involve the demolition of historic properties that contribute to the NRHP-listed historic district, resulting in major, adverse, long-term impacts under NEPA and adverse effects to historic properties under Section 106. Alternative 4 would also involve the safe-abandonment of some elements of the 305-meter-diameter radio telescope, including the foundation and rim wall, support towers, and anchors, as shown in Table 4.2-4.

TABLE 4.2-4
Alternative 4 – Description of Proposed Activities

Historic Properties That May be Demolished	• 305-meter-diameter radio telescope and reflector dish • Building 1 (Operations Building) • Building 2 (Administration Building) • Building 12 (Maintenance Building) • Building 17 (Warehouse and Business/Purchasing Building) • Building 27 (Photometry Shack/Optical Lab) • Building 54 (Visitor Center) • Building 61 (Learning Center) • Buildings 66 and 68 (the Atmospheric Science Trailer and Visiting Scientist Trailer, both associated with Building 1, Operations Building)
Historic Properties That May be Safe-abandoned	• 305-meter-diameter radio telescope's associated structures (foundation, rim wall, support towers, and anchors)

Removal of the radio telescope mechanism and reflector dish would diminish the historic structure's integrity of materials, design, workmanship, feeling, and association. In addition, demolishing all the other resources that contribute to the NRHP-listed historic district would diminish what remained of the 305-meter-diameter radio telescope's integrity of setting. Once only the foundation and rim wall, support towers, and anchors of the 305-meter-diameter radio telescope remain, it is unlikely that they would retain eligibility for the NRHP.

When an undertaking is found to have an adverse effect, Section 106 requires consultation with SHPO and other consulting parties regarding appropriate avoidance, minimization, or mitigation measures. If NSF were to consider the selection of Alternative 4, it would resume consultation with the Puerto Rico SHPO, ACHP, and other consulting parties to determine the appropriate mitigation measures to resolve the adverse effect. The product of consultation would be an amendment to the PA or a specific MOA for this Alternative.

Operations

Operations would completely cease under Alternative 4. No historic properties on the site would retain sufficient integrity to remain eligible for the NRHP; therefore, operations following implementation of

Alternative 4 would result in no impacts to historic properties and no historic properties affected under Section 106.

4.2.4.2 Archaeological Resources

Ground disturbance for Alternative 4 would be associated with demolition activities. Demolition under Alternative 4 would involve more substantial ground disturbance than Alternatives 1, 2, and 3, as nearly all buildings and structures at the Observatory would be demolished. However, there are no known archaeological resources within the APE and no impacts to archaeological resources and no effects to archaeological historic properties under Section 106 are anticipated. BMPs would be implemented as described for Alternative 1, including an unanticipated discovery plan to address any archaeological resources that might be discovered during demolition.

4.2.5 Alternative 5 – Complete Demolition and Site Restoration

4.2.5.1 Architectural Resources

Demolition

Alternative 5 would involve the demolition of the entire NRHP-listed historic district and all contributing resources, resulting in major, adverse, long-term impacts under NEPA and adverse effects to historic properties under Section 106. No historic properties would remain extant. Therefore, of the five Alternatives, Alternative 5 would incur the greatest impacts to historic properties. If NSF were to consider the selection of Alternative 5, it would resume consultation with the Puerto Rico SHPO, ACHP, and other consulting parties to determine the appropriate mitigation measures to resolve the adverse effect. The product of consultation would be an amendment to the PA or a specific MOA for this Alternative.

Operations

Operations would completely cease under Alternative 5; therefore, operations following implementation of Alternative 5 would result in no impacts to historic properties and no historic properties affected under Section 106.

4.2.5.2 Archaeological Resources

Alternative 5 involves the demolition of the 305-meter-diameter radio telescope as well as its foundation and rim wall, support towers, and anchors. As a result, Alternative 5 would involve more ground disturbance than Alternative 4 and would pose a greater risk for encountering previously unidentified archaeological resources. However, there are no known archaeological resources within the APE and therefore no impacts to archaeological resources and no effects to archaeological historic properties under Section 106 are anticipated. The same BMPs that were described for Alternative 1 would be implemented, including an unanticipated discovery plan to address any archaeological resources that might be discovered during demolition.

4.2.6 No-Action Alternative

The No-Action Alternative is the continuation of the current use of Arecibo Observatory. Under the No-Action Alternative, current activities would continue at the site, and no demolition would be expected to occur. Current activities at the Observatory include regular maintenance of buildings and structures, and alterations to resources that contribute to the NRHP-listed historic district in order to adapt to changes in science and technology. Therefore, maintaining the current conditions of the Observatory could involve minor alterations to historic properties to retain their utility. However, a review of proposed alterations would occur prior to any action being taken to determine the impacts on NRHP-listed properties. No proposed alterations are currently pending, and therefore there are no impacts to historic properties under NEPA. The corresponding finding of effect under Section 106 would be no historic properties affected.

4.2.7 Mitigation Measures

The following measures would be implemented to reduce impacts to cultural resources, and to avoid, minimize or mitigate potential adverse effects to NRHP-listed resources:

- Alternative 1 (Preferred Alternative): Implement stipulations specified in the Section 106 PA, reached through consultation, to avoid, minimize, and/or mitigate any adverse effects on historic properties. These stipulations would also suffice to address the necessary mitigation for major impacts to cultural resources under NEPA. Specific mitigation measures were developed in consultation with the SHPO, ACHP, and consulting parties. The PA would be executed prior to signing the NEPA ROD. If Alternative 1 is ultimately not feasible, NSF will resume Section 106 consultation focusing on Alternatives 2-5.

- All Alternatives: An unanticipated discovery plan would be developed prior to implementation under the selected Alternative (if demolition is part of that Alternative) to address any archaeological resources that might be discovered during demolition.

- Alternative 3 (if Alternative 1 is not feasible): Mothballing and protecting historic properties would be completed in accordance with NPS's Preservation Brief 31, "Mothballing Historic Buildings" (Park, 1993), *The Secretary of the Interior's Standards for the Treatment of Historic Properties*, (NPS, 1992), and the *Guidelines for Preserving, Rehabilitating, Restoring and Reconstructing Historic Buildings* (Grimmer, 2017).

4.2.8 Summary of Impacts

Table 4.2-5 provides a summary of impacts to cultural resources resulting from the Alternatives.

TABLE 4.2-5
Summary of Cultural Resources Impacts

	Alternatives					
Impacts	**Alternative 1**	**Alternative 2**	**Alternative 3**	**Alternative 4**	**Alternative 5**	**No-Action**
Impacts to known historic properties (architectural resources) during demolition (and property transfer)	Major, adverse, long-term impact *Adverse effect to historic properties*	Major, adverse, long-term impact *Adverse effect to historic properties*	Major, adverse, short-term impact *Adverse effect to historic properties*	Major, adverse, long-term impact *Adverse effect to historic properties*	Major, adverse, long-term impact *Adverse effect to historic properties*	No impact
Impacts to known historic properties (architectural resources) during operations	No impact *No adverse effect on historic properties*	Major, adverse, long-term impact *Adverse effect to historic properties*	Major, adverse, short-term impact *Adverse effect to historic properties*	No impact *No historic properties affected*	No impact *No historic properties affected*	No impact *No historic properties affected*
Potential impacts to archaeological resources	No impact *No historic properties affected*	No impact *No historic properties affected*	No impact *No historic properties affected*	No impact *No historic properties affected*	No impact *No historic properties affected*	No impact *No historic properties affected*

Note: Language shown in *italics* is the corresponding “Section 106 Finding of Effect.”

4.3 Geology and Soils

Methodology

This Section identifies potential direct and indirect impacts to geology, geologic resources, and soils that may result from implementing the Alternatives for the Arecibo Observatory site, including the No-Action Alternative. The ROI for geology and soils is the Arecibo Observatory site and immediately adjacent areas.

Impacts on geologic resources were evaluated by determining the importance or rarity of each resource that would be adversely affected by the Alternatives. Factors considered in determining whether an alternative would have an impact on geological resources include the extent or degree to which its implementation would meet the thresholds defined in Table 4.3-1. The factors used to determine whether the Alternatives would have impacts on geological resources are as follows:

- Disturbance to a geologic feature of unusual scientific value for study or interpretation
- Triggered or accelerated life or property threatening geologic process (e.g., landslides)
- Substantial alteration of local topography
- Loss of established or potential mineral-bearing resources of economic value or their inaccessibility
- Disturbance to water flow pathways in the underlying karst

The thresholds for the intensity of a direct, indirect, or cumulative impact are defined in Table 4.3-1.

TABLE 4.3-1
Impact Thresholds for Geologic Resources

Impact Intensity	Description
Negligible	The impact would be below or at the lower levels of detection.
Minor	The Alternative would result in a detectable change to geologic or soil resources; however, the impact would be small, localized, and of little consequence. Changes to the geologic conditions would not threaten human life of property or result in a disturbance of water flow pathways in the underlying karst.
Moderate	The Alternative would result in a readily apparent change to geologic or soil resources or over a relatively wide area; however, changes to the geologic conditions would not threaten human life of property. Disturbance of water flow pathways would not substantially change the underlying karst.
Major	The Alternative would result in a substantial change to the character or usability of geologic or soil resources, affecting a large area. Changes to the geologic conditions could threaten human life of property. Disturbance of water flow pathways would substantially change the underlying karst.

Duration: Short-term – Occurs only during the demolition period.
Long-term – Continues after the demolition period.

4.3.1 Alternative 1 – Collaboration with Interested Parties for Continued Science-focused Operations (Agency-preferred Alternative)

Under Alternative 1, negligible, short-term, direct impacts to local topographic conditions would occur from the creation of staging areas for materials and equipment, and from the use of cranes and heavy equipment to remove 26 unneeded structures, including housing, obsolete buildings, and recreational facilities (see Table 2.3-1). Ground and soils around these structures would be compacted and disturbed. Following removal of structures, locations and staging areas would be stabilized and revegetated.

The project site is underlain by karst limestone and karst features such as sinkholes that could be impacted by demolition activities through alteration, collapse, or spills. Impacts to underlying geology could be minor, adverse, and long-term. BMPs that would be implemented to prevent or reduce potential impacts to karst features and water quality would include the following:

- A site-specific SWPPP would be prepared and implemented prior to starting demolition activities.
- Construction stormwater controls that could include check dams, temporary detention basins, and silt fencing would be implemented and maintained to prevent scour and soil loss from runoff.
- Disturbed areas would be stabilized and revegetated to minimize the potential for erosion after demolition is completed. Revegetation would use native species to the extent possible, and if use of non-native species is necessary, only non-invasive species would be planted.

- Before demolition begins, a geophysical survey would be conducted to determine whether proposed work areas contain karst features, including sinkholes, solution cavities, or areas of soil subsidence that could be affected by demolition work. The survey also would evaluate soil stability and the vertical and horizontal projection of sinkholes. These features would be avoided when possible and protected with sandbags, nets, and filter fabric. They would be monitored during the work for changes such as soil subsidence, collapse, water infiltration, and clogging.
- Earth-disturbing activities would be conducted in a manner that minimizes alteration of the existing grade and the hydrology of existing surficial karst features.
- Previously unknown karst features that are identified during demolition activities would be addressed as follows:
  - Work would stop within a 100-foot radius of the feature and the feature would be assessed to identify its potential for connectivity to and impact on other karst features such as groundwater conduits, surface water conduits, and caves. The assessment method could include visual assessment, geophysical survey, or other techniques for subsurface characterization of karst features.
  - The karst feature would be either isolated or temporarily sealed to minimize impacts during demolition work (e.g., blocked with sandbags, protected with baskets, nets, or filter fabric).

Under Alternative 1, impacts to soil resources would be negligible, adverse, and short-term. All areas of demolition work would be within previously disturbed locations where structures have been built. Level, previously graded areas would be used for staging areas. Construction stormwater BMPs as described above would be implemented and maintained to prevent indirect impacts to soils from stormwater runoff. Site stabilization and revegetation would minimize the potential for erosion following demolition.

Should the demolition be extended beyond a single 12-week period, the length of time that soils would be disturbed and that karst features would be at risk would be increased, but the area of disturbance would not be increased. Because the BMPs described above would be implemented and maintained throughout this period, the magnitude of impacts would not be expected to change.

4.3.2 Alternative 2 – Collaboration with Interested Parties for Transition to Education-focused Operations

Under Alternative 2, the impacts to topological conditions, karst features and soils from Alternative 2 would be similar to those described for Alternative 1. Demolition of selected buildings within the disturbed footprint of the Arecibo Observatory site would occur over the same 12-week timeframe and would involve 27 structures, which are the same 26 structures identified for removal under Alternative 1 and one additional building (see Table 2.3-1). BMPs, as described for Alternative 1, would be implemented to reduce or prevent impacts. Impacts to topological conditions would be negligible, adverse, and short-term, impacts to karst features would be minor, adverse, and long-term, and impacts to soils during operations would be negligible, adverse, and short-term. Similar to Alternative 1, there would be no expected change in the intensity of potential impacts if the demolition is extended beyond a single 12-week period.

4.3.3 Alternative 3 – Mothballing of Facilities

Under Alternative 3, the impacts to topological conditions, karst features, and soils would be similar to, but less than, those described for Alternatives 1 and 2. Demolition of selected buildings within the disturbed footprint of the Arecibo Observatory site would occur over a 15-week timeframe and would involve 14 structures (see Table 2.3-1), just over half the structures that would be demolished under Alternatives 1 and 2. BMPs, as described for Alternative 1, would be implemented to reduce or prevent impacts. Impacts to topological conditions would be negligible, adverse and short-term, impacts to karst features would be minor, adverse, and long-term, and impacts to soils during operations would be negligible, adverse, and short-term. Similar to Alternative 1, there would be no expected change in the intensity of potential impacts if the demolition is extended beyond a single 15-week period.

4.3.4 Alternative 4 – Partial Demolition and Site Restoration

Under Alternative 4, direct impacts would occur to site topography from the creation of staging areas for materials and equipment, and from the use of cranes and heavy equipment to remove 48 structures on the site (see Table 2.3-1). Minor, short-term, direct impacts to local topographic conditions would occur from the compaction of ground and soils around these structures. Following removal of structures, the building locations and staging areas would be stabilized and revegetated.

Karst features such as sinkholes and caves could be impacted by demolition activities through alteration, collapse, or spills of liquids or demolition debris into them. However, the BMPs described for Alternative 1 would also be applied under Alternative 4; consequently, impacts to underlying geology would also be minor, adverse, and long-term. Similar to Alternative 1, there would be no expected change in the intensity of potential impacts if the demolition is extended beyond a single 28-week period.

Soils impacts under Alternative 4 would be comparable to but somewhat greater than those described for Alternative 1, because more structures would be demolished than those described for Alternative 1, and there would be potential for soil impacts beneath the 305-meter-diameter telescope dish when it is removed. Removal of the reflector dish would change the light and moisture regime of this area, changing it from a partially shaded, moist environment to a drier area receiving full sun. This could result in a die-off of much of the vegetation beneath the reflector dish and, because the dish would no longer be present to dissipate the energy of precipitation, approximately 18 acres of soil on the steep side slopes would be subject to erosion. Because some of the vegetation on these side slopes would be expected to remain and because stormwater controls would be implemented, impacts to soils in this area would be expected to be moderate, adverse, and long-term.

4.3.5 Alternative 5 – Complete Demolition and Site Restoration

Under Alternative 5, direct impacts would occur to site topography from the creation of staging areas for materials and equipment and from the use of cranes, heavy equipment, and explosives to remove all structures on the site (see Table 2.3-1). Impacts to topography also would occur from the removal of foundations and below-grade structures. Moderate, long-term, adverse direct impacts to local topographic conditions, including mogotes containing towers and anchors, would occur from the removal of foundations, towers, and anchors and from compaction of ground and soils around these structures. Impacts would also occur from regrading activities following the removal of the structures and their foundations. Following demolition, the structure locations and staging areas would be stabilized and revegetated.

Mechanical, explosive, or a combination of both means could be used to remove some of the support towers, anchors, foundations, and below-grade structures. Any use of explosives would be limited to low-force charges that are designed to transfer the explosive force only to the structure that is designated for removal. Nonetheless, direct localized impacts to underlying karst could occur from the alteration or collapse of adjacent or underlying dissolution features following demolition (Langer, 2001). The use of explosives to demolish the southeastern and southwestern towers and tower anchors could result in impacts to small offsite karst features adjacent to the tower and anchor locations from collapse or expansion of fractures or voids. The BMPs described for Alternative 1 would also be applied to Alternative 5. Impacts to underlying geology would be moderate, adverse, and long-term.

Soils impacts under Alternative 5 would be comparable to those described for Alternative 4, including impacts to soils beneath the 305-meter-diameter telescope dish. There would be moderate, adverse, and long-term impacts to soils at and adjacent to the southeastern and southwestern tower and anchor locations. These are remote from other infrastructure on Arecibo Observatory and would require additional staging areas to support the work sites. The degree of disturbance that would result from establishment of staging areas and demolition of these features would result in a substantial change to the character of soils in these locations that cannot be feasibly restored through mitigation.

Similar to Alternative 1, there would be no expected change in the intensity of potential impacts if the demolition is extended beyond a single 38-week period.

4.3.6 No-Action Alternative

Under the No-Action Alternative, no part of Arecibo Observatory would be demolished; therefore, there would be no impacts to geology.

4.3.7 Mitigation Measures

The following measures would be implemented prior to and during demolition activities to reduce impacts to karst features:

- All Alternatives: A site-specific SWPPP would be prepared and implemented prior to starting demolition activities.
- All Alternatives: Construction stormwater controls would be implemented and maintained to prevent scour and soil loss from runoff.
- All Alternatives: Disturbed areas would be stabilized and revegetated to minimize the potential for erosion after demolition is completed. Revegetation would use native species to the extent possible and if use of non-native species is necessary, only non-invasive species would be planted.
- All Alternatives: Before any demolition begins, a geophysical survey would be conducted to inspect designated work areas and note any suspect karst features, including sinkholes, solution cavities, and areas of soil subsidence that could be affected by demolition work. The survey would also evaluate soil stability and the vertical and horizontal projection of sinkholes. These features would be avoided when possible and protected with sandbags, nets, and filter fabric. They would be monitored during the work for changes such as soil subsidence, collapse, water infiltration, and clogging.
- All Alternatives: Earth-disturbing activities would be conducted in a manner that minimizes alteration of the existing grade and the hydrology of existing surficial karst features.
- All Alternatives: Previously unknown karst features that are identified during invasive work activities including blasting and removal of foundations, anchors, towers, and below-grade structures would be addressed as follows:
  - Work would stop within a 100-foot radius of the feature and the feature would be assessed to identify its potential for connectivity to impact on other karst features such as groundwater conduits, surface water conduits, and caves. The assessment method could include visual assessment, geophysical survey, or other techniques for subsurface characterization of karst features.
  - The karst feature would be either isolated or temporarily sealed to minimize impacts during demolition work (e.g., blocked with sandbags, protected with baskets, nets, or filter fabric).
- Alternative 5: Any use of explosives would be limited to low-force charges that are designed to transfer the explosive force only to the structure that is designated for removal.

4.3.8 Summary of Impacts

Table 4.3-2 provides a summary of geology impacts resulting from the Alternatives.

TABLE 4.3-2
Summary of Geology Impacts

Impacts	Alternatives					
	Alternative 1	**Alternative 2**	**Alternative 3**	**Alternative 4**	**Alternative 5**	**No-Action**
Impacts to topological conditions	Negligible, adverse, short-term impact	Negligible, adverse, short-term impact	Negligible, adverse, short-term impact	Minor, adverse, short-term impact	Moderate, adverse, long-term impact	No impact
Impacts to karst features	Minor, adverse, long-term impact	Minor, adverse, long-term impact	Minor, adverse, long-term impact	Minor, adverse, long-term impact	Moderate, adverse, long-term impact	No impact
Impacts to soils	Negligible, adverse, short-term impact	Negligible, adverse, short-term impact	Negligible, adverse, short-term impact	Moderate, adverse, long-term impact	Moderate, adverse, long-term impact	No impact

4.4 Groundwater

Methodology

This Section identifies the potential direct and indirect impacts to groundwater resources that may result from implementing the Alternatives for Arecibo Observatory, including the No-Action Alternative. The ROI for groundwater is Arecibo Observatory, immediately adjacent aquifer recharge areas, and the Camuy and Tanamá rivers.

The methods used to determine whether the Alternatives would have impacts on groundwater are as follows:

- Evaluate each Alternative to determine its potential for impacts on groundwater due to contamination or substantial alteration of recharge areas.
- Assess the compliance of each Alternative with applicable federal regulations that apply to the protection of groundwater.

The thresholds for the intensity of a direct, indirect, or cumulative impact on groundwater are defined in Table 4.4-1.

TABLE 4.4-1
Impact Thresholds for Groundwater

Impact Intensity	Description
Negligible	Changes to groundwater quality and existing recharge area would be below or at the lower levels of detection.
Minor	There would be detectable changes to groundwater quality and/or drainage features; however, the impact would be small, localized, and of little consequence.

TABLE 4.4-1
Impact Thresholds for Groundwater

Impact Intensity	Description
Moderate	There would be readily apparent changes to groundwater quality and/or drainage features or would occur over awide area.
Major	There would be substantial changes to the water quality or usability of groundwater resources, affecting a large area.

Duration: Short-term – Occurs only during the demolition period.
Long-term – Continues after the demolition period.

4.4.1 Alternative 1 – Collaboration with Interested Parties for Continued Science-focused Operations (Agency-preferred Alternative)

Ground disturbance would be associated with the creation of staging areas for materials and equipment, and from the use of heavy equipment to remove the unneeded structures (see Table 2.3-1). Ground and soil around these structures would be compacted and disturbed, which could increase stormwater runoff and erosion. Runoff from the disturbed area could move into the groundwater through the sinkhole beneath the 305-meter-diameter radio telescope dish or another sinkhole on the eastern portion of the Observatory. BMPs to control runoff would be implemented, which would provide protection for groundwater quality. Under Alternative 1, minor, short-term, direct impacts to groundwater quality could occur from demolition runoff entering karst features, such as sinkholes, on or downslope from Arecibo Observatory.

The site is underlain by karst limestone and karst features such as sinkholes, channels, and fractures, and therefore could be impacted by demolition activities through alteration or collapse. However, because demolition would be accomplished with standard heavy equipment (e.g., hammerhoe) and no buildings that would be demolished under Alternative 1 are near sinkholes, collapse or alteration of sinkholes would not be expected. Impacts to underlying geology would be limited to shallow bedrock in or immediately adjacent to demolition sites and would not be expected to alter groundwater recharge pathways or contribute to changes in groundwater quality. Any impacts to karst features that could alter local groundwater recharge would be negligible and long-term.

BMPs that would be implemented to protect groundwater resources include the following:

- A site-specific SWPPP would be prepared and implemented prior to starting demolition activities.
- Construction stormwater controls would be implemented and maintained to prevent scour and soil loss from runoff.
  - Measures such as compost blankets, mulching, riprap, geotextiles, and slope drains would be used to protect exposed soil and minimize potential for erosion and sedimentation.

  - Measures such as check dams, slope diversions, and temporary diversion dikes would be implemented for runoff to prevent runoff from entering sinkholes.
  - Sediment control measures such as compost filter berms and socks; fiber rolls or berms; sediment basins, rock dams, filters, chambers, or traps; silt fences; and weed-free hay bales would be implemented to prevent or reduce sedimentation.
  - Good housekeeping measures would be practiced during demolition.

- Disturbed areas would be stabilized and revegetated to minimize the potential for erosion after demolition is completed. Revegetation would use native species to the extent possible and if use of non-native species is necessary, only non-invasive species would be planted.
- Before demolition begins, a geophysical survey would be conducted to determine whether proposed work areas contain karst features, including sinkholes, solution cavities, or areas of soil subsidence that could be affected by demolition work. The survey also would evaluate soil stability and the vertical and horizontal projection of sinkholes. These features would be avoided when possible and protected with sandbags, nets, and filter fabric. They would be monitored during the work for changes such as soil subsidence, collapse, water infiltration, and clogging.
- Earth-disturbing activities would be conducted in a manner that minimizes alteration of the existing grade and hydrology of existing surficial karst features.
- A SPCC plan would be developed to address risks to groundwater from potential spills. The SPCC plan would include equipment inspections, equipment refueling, equipment servicing and maintenance, equipment washing, and the use and storage of any hazardous materials, chemicals, fuels, lubricating oils, and other petroleum products.
- Previously unknown karst features that are identified during demolition activities would be addressed as follows:
  - Work would stop within a 100-foot radius of the feature and the feature would be assessed to identify its potential for connectivity to impact on other karst features such as groundwater conduits and surface water recharge conduits. The assessment method could include visual assessment, geophysical survey, or other techniques for subsurface characterization of karst features.
  - The karst feature would be either isolated or temporarily sealed to minimize impacts during demolition work (e.g., blocked with sandbags, protected with baskets, nets, or filter fabric).

Should the demolition be extended beyond a single 12-week period, there would be an increased potential for erosion due to the greater length of time with disturbed or exposed soils. However, because the BMPs described above would be implemented and maintained throughout this period, the magnitude of impacts would not be expected to change.

Because the amount of impervious surface would be reduced following demolition, and due to the establishment of landscaping on demolished sites, with the continued implementation of groundwater BMPs there would be no change relative to the baseline conditions and no impacts to groundwater recharge during subsequent operations.

4.4.2 Alternative 2 – Collaboration with Interested Parties for Transition to Education-focused Operations

Under Alternative 2, demolition impacts would be similar to those described under Alternative 1, with one additional building demolished. From the standpoint of groundwater use, there would be no appreciable difference during operations under an education-based format compared to a science-based format or current operations. BMPs identified for Alternative 1 would be implemented to prevent or reduce potential impacts to karst groundwater recharge features and groundwater quality. Consequently, the level of impact to groundwater quality and changes to drainages would also be minor, adverse, and short-term for demolition runoff, and negligible, adverse, and long-term for demolition groundwater impacts. Similar to Alternative 1, there would be no expected change in the intensity of potential impacts if the demolition is extended beyond a single 12-week period.

There would be no impacts from operations.

4.4.3 Alternative 3 – Mothballing of Facilities

Under Alternative 3, demolition activities would be similar to those described under Alternative 1, except that fewer obsolete structures would be removed (only 14 structures). BMPs identified for Alternative 1 would be implemented to prevent or reduce potential impacts to prevent or reduce potential impacts to karst groundwater recharge features and groundwater quality. Consequently, the level of impact to groundwater quality and changes to drainages would also be minor, adverse, and short-term for demolition runoff and negligible, adverse, and long-term for demolition groundwater impacts. Similar to Alternative 1, there would be no expected change in the intensity of potential impacts if the demolition is extended beyond a single 15-week period.

Routine maintenance of mothballed infrastructure would not be expected to impact groundwater resources. These activities would be comparable to maintenance conducted during normal operations of the Observatory and the Observatory would continue to implement groundwater protections identical to those under the No-Action Alternative. Use of well water would be expected to decrease during the mothball period due to less human activity onsite, as compared to Alternatives 1 and 2 and the baseline conditions. Therefore, a minor, beneficial, long-term impact to groundwater recharge would be expected during the mothball phase under Alternative 3.

4.4.4 Alternative 4 – Partial Demolition and Site Restoration

Under Alternative 4, geologic impacts would be similar to those described under Alternative 1, but would be somewhat greater because 48 structures would be demolished rather than 26 (see Table 2.3-1). While a larger area would be subject to demolition activities, any impacts would be limited to the demolition sites and immediately adjacent areas. With implementation of BMPs outlined in Alternative 1, the level of impact to groundwater quality and changes to drainages from demolition would also be minor, adverse, and short-term for demolition runoff.

The BMPs identified for Alternative 1 would be implemented to prevent or reduce potential impacts to karst groundwater recharge features and groundwater quality during demolition. As with Alternative 1, negligible, adverse, short-term direct impacts to groundwater quality could occur from demolition runoff entering karst features, such as sinkholes, on or downslope from Arecibo Observatory. Similar to Alternative 1, there would be no expected change in the intensity of potential impacts if the demolition is extended beyond a single 28-week period.

There would be no operations following demolition and no potential for adverse operational impacts to groundwater quality. Because there would be no consumptive use of groundwater from the well, a minor, long-term, beneficial impact to groundwater recharge would be expected.

4.4.5 Alternative 5 – Complete Demolition and Site Restoration

Under Alternative 5, geologic impacts would be greater than under the other Alternatives because it is expected that explosives would be used to demolish the towers, tower and catwalk anchors, and the foundation and rim wall infrastructure. Conventional demolition techniques would have impacts to groundwater resources comparable to those described for Alternative 1. BMPs identified for Alternative 1 would be implemented to prevent or reduce potential impacts to karst groundwater recharge features and groundwater quality. In addition, any use of explosives would be limited to low-force charges that are designed to transfer the explosive force only to the structure that is designated for removal. Impacts from demolition runoff would be minor, adverse, and short-term. Similar to Alternative 1, there would be no expected change in the intensity of potential impacts if the demolition is extended beyond a single 38-week period.

The potential for use of explosives at the southeast and southwest tower anchor locations, which are on mogotes that contain sinkholes and are near the periphery of the Arecibo Observatory property, increases the potential for offsite impacts to karst features, because these mogotes extend off of the Observatory property. Impacts to offsite portions of these features could alter groundwater flow and recharge. While explosives used at the tower and anchor locations would be limited to low-force charges designed to transfer the explosive force only to the structure designated for removal, the potential for collapse or expansion of existing karst features (dissolution channels or voids) in proximity to the structures to be removed would exist because of the pressure wave that would radiate from the explosion. For the southeast and southwest tower and tower anchor locations, this potential would extend outside the boundaries of Arecibo Observatory. No impacts to regional groundwater recharge and flow would be expected because the surrounding area is connected to the same groundwater system. However, impacts to the local groundwater recharge system from collapse or expansion of karst features following the use of explosives for demolition of towers and anchors are expected to be moderate, adverse, and long-term.

There would be no operations following demolition and no potential for adverse operational impacts to groundwater quality. Because there would be no consumptive use of groundwater from the well, a minor, long-term, beneficial impact to groundwater recharge would be expected.

4.4.6 No-Action Alternative

Under the No-Action Alternative, no part of Arecibo Observatory would be demolished; therefore, there would be no impacts to groundwater. The Observatory staff would continue to implement measures to protect karst and groundwater, including the use of a sediment trap to protect the sinkhole beneath the 305-meter-diameter radio telescope dish and the use of biodegradable lubricants on the radio telescopes, platform, and supporting infrastructure. For these reasons, there would be no impacts to groundwater.

4.4.7 Mitigation Measures

The following measures would be implemented to reduce impacts to groundwater:

- All Alternatives: A site-specific SWPPP would be prepared and implemented prior to starting demolition activities.
- All Alternatives: Construction stormwater controls would be implemented and maintained to prevent scour and soil loss from runoff.
  - Measures such as compost blankets, mulching, riprap, geotextiles, and slope drains would be used to protect exposed soil and minimize potential for erosion and sedimentation.
  - Measures such as check dams, slope diversions, and temporary diversion dikes would be implemented for runoff to prevent runoff from entering sinkholes.
  - Sediment control measures such as compost filter berms and socks; fiber rolls or berms; sediment basins, rock dams, filters, chambers, or traps; silt fences; and weed-free hay bales would be implemented to prevent or reduce sedimentation.
  - Good housekeeping measures would be practiced during demolition.
- All Alternatives: Disturbed areas would be stabilized and revegetated to minimize the potential for erosion after demolition is completed. Revegetation would use native species to the extent possible and if use of non-native species is necessary, only non-invasive species would be planted.

- All Alternatives: Before demolition begins, a geophysical survey would be conducted to determine whether proposed work areas contain karst features, including sinkholes, solution cavities, or areas of soil subsidence that could be affected by demolition work. The survey also would evaluate soil stability and the vertical and horizontal projection of sinkholes. These features would be avoided when possible and protected with sandbags, nets, and filter fabric. They would be monitored during the work for changes such as soil subsidence, collapse, water infiltration, and clogging.
- All Alternatives: Earth-disturbing activities would be conducted in a manner that minimizes alteration of the existing grade and hydrology of existing surficial karst features.
- All Alternatives: A SPCC plan would be developed to address risks to groundwater from potential spills. The SPCC plan would include equipment inspections, equipment refueling, equipment servicing and maintenance, equipment washing, and the use and storage of any hazardous materials, chemicals, fuels, lubricating oils, and other petroleum products.
- All Alternatives: Previously unknown karst features that are identified during demolition activities would be addressed as follows:
  - Work would stop within a 100-foot radius of the feature and the feature would be assessed to identify its potential for connectivity to impact on other karst features such as groundwater conduits and surface water recharge conduits. The assessment method could include visual assessment, geophysical survey, or other techniques for subsurface characterization of karst features.
  - The karst feature would be either isolated or temporarily sealed to minimize impacts during demolition work (e.g., blocked with sandbags, protected with baskets, nets, or filter fabric).
- Alternative 5: Any use of explosives would be limited to low-force charges designed to transfer the explosive force only to the structure that is designated for removal.

4.4.8 Summary of Impacts

Table 4.4-2 provides a summary of groundwater impacts resulting from the Alternatives.

TABLE 4.4-2
Summary of Groundwater Impacts

	Alternatives					
Impacts	**Alternative 1**	**Alternative 2**	**Alternative 3**	**Alternative 4**	**Alternative 5**	**No-Action**
Impacts from demolition runoff	Minor, adverse, short-term impact	Minor, adverse, short-term impact	Minor, adverse, short-term impact	Minor, adverse, short-term impact	Minor, adverse, short-term impact	No impact

Impacts to underlying groundwater geology from demolition	Negligible, adverse, long-term impact	Negligible, adverse, long-term impact	Negligible, adverse, long-term impact	Negligible, adverse, short-term impact	Moderate, adverse, long-term impact	No impact
Impacts from operations	No impact	No impact	Minor, long-term benefit	Minor, long-term benefit	Minor, long-term benefit	No impact

4.5 Hazardous Materials

Methodology

The ROI for hazardous materials is defined as the area within the project boundaries, adjoining properties, and a 1-mile search area. In order to determine potential impacts, experts reviewed and evaluated existing and past actions with respect to the production and management of hazardous wastes to identify the Proposed Action's potential impact on the use and disposal of hazardous materials. They then assessed each Alternative's relative impact based on the thresholds defined in Table 4.5-1. For the purpose of this analysis of hazardous materials, the following three key components were evaluated: existing contamination, demolition-related hazardous materials, and the operational use of hazardous materials.

Table 4.5-1 presents a description of the impact thresholds for hazardous materials.

TABLE 4.5-1
Impact Thresholds for Hazardous Materials

Impact Intensity	Description
Negligible	The Alternative would result in a change (beneficial or adverse) so small that it would not be of measurable or perceptible consequence.
Minor	The Alternative would result in a perceptible change to hazardous materials, but the change (beneficial or adverse) would be small and remain onsite.
Moderate	The Alternative would result in a measurable and consequential change to hazardous materials and could occur onsite or offsite.
Major	The Alternative would result in a substantial change to hazardous materials; the change (beneficial or adverse) would be measurable and result in a severely adverse or major beneficial impact either onsite or offsite.

Duration: Short-term – Occurs only during the implementation of the Proposed Action.
Long-term – Continues after the implementation of the Proposed Action.

4.5.1 Alternative 1 – Collaboration with Interested Parties for Continued Science-focused Operations (Agency-preferred Alternative)

4.5.1.1 Existing Contamination

Alternative 1 could result in the demolition of obsolete buildings. Prior to demolition, an assessment would be required to determine the extent of hazardous materials, such as ACM, LBP, and the unknown conditions explained in Section 3.5.1. Appendix 3.5-A (EBS) provides details on which buildings are known to contain ACM and LBP. All ACM, LBP, and known contamination would be remediated in accordance with the Commonwealth of Puerto Rico and federal regulations, prior to any demolition or land transfer activities.

Prior to demolition, the demolition contractors would prepare and implement a demolition management plan that prescribes activities for workers to follow in the event that unexpected soil or groundwater contamination is encountered based on visual observation and/or smell. The demolition management plan would include, at a minimum, a list of contact persons in case of a possible encounter with undocumented contamination; provisions for immediate notification of the observation to demolition management; and notification of the regulatory agency with jurisdiction. If previously unknown contamination is found, demolition activities would halt in the vicinity of the find and the next steps would be decided in consultation with the regulatory agency.

Given the site history and the currently unknown conditions, contamination at Arecibo Observatory could range from relatively little contamination to areas of significant concern. Consequently, there could be a minor to moderate, long-term benefit at the site for site cleanup, commensurate with the severity of contamination to be remediated.

4.5.1.2 Demolition-related Hazardous Materials

Alternative 1 would require temporary transport, use, storage, and disposal of hazardous materials and wastes during demolition activities. Hazardous materials commonly used at demolition sites, such as diesel fuel, lubricants, paints and solvents, and cement products containing basic or acidic chemicals, may be used. Hazardous wastes generated during demolition would include fuel and lubricant containers, paint and solvent containers, and cement products.

Accidental spills or releases associated with the temporary transport, storage, use, and disposal of hazardous materials and wastes could occur during demolition. However, hazardous materials and wastes would be used, stored, disposed of, and transported in compliance with all applicable laws and regulations. Identification, generation, transportation, storage, treatment, and disposal of all hazardous materials and hazardous wastes would be conducted in compliance with RCRA. All hazardous materials and hazardous wastes would be handled and transported following regulatory requirements.

Accidental spills or releases that result from the routine transport, use, storage, and disposal of hazardous materials and wastes during demolition could create a hazard to public health and the environment. However, with implementation of the abovementioned BMPs and implementation of a spill response plan, this impact would be minor, adverse, and short-term.

The demolition may be extended beyond a single 12-week period. However, appropriate BMPs and mitigation measures, as described previously, would be implemented throughout the period of demolition. There would be no changes to assessment of potential impacts.

4.5.1.3 Operational Use of Hazardous Materials

Chemicals and hazardous materials typically used for building maintenance, operation of scientific equipment, power generation, landscaping, water treatment, vehicle maintenance, and swimming pool maintenance are currently used by Arecibo Observatory. All materials are used, stored, and disposed of in accordance with Commonwealth of Puerto Rico and federal regulations. Arecibo Observatory also stores diesel fuel onsite during operations to supply generators. Diesel storage is maintained in appropriate existing containment.

Alternative 1 involves demolition of some buildings, the swimming pool, and recreation facilities. Chemicals and hazardous materials used for operation of the demolished facilities (such as chemicals used for swimming pool maintenance) would no longer be needed for site O&M. These materials would be removed from the site and disposed of in accordance with Commonwealth of Puerto Rico and federal regulations. A limited amount of hazardous waste removal and transport would likely be required.

Overall the use of chemicals and hazardous materials during operations would be reduced under Alternative 1. It is also assumed that the future manager of the site would comply with the legal requirements governing hazardous materials; therefore, future operations are expected to result in a minor, long-term benefit.

4.5.2 Alternative 2 – Collaboration with Interested Parties for Transition to Education-focused Operations

Demolition and operations activities under Alternative 2 would be similar to those described for Alternative 1, except for the addition of one building for demolition. Prior to demolition, an assessment would be required to determine the extent of hazardous materials, such as ACM, LBP, and the unknown conditions explained in Section 3.5.1. Appendix 3.5-A (EBS) provides details on which buildings are known to contain ACM and LBP. All ACM, LBP, and known contamination would be remediated in accordance with the Commonwealth of Puerto Rico and federal regulations, prior to any demolition activities. Consequently, the environmental impacts associated with existing contamination would also be minor to moderate, beneficial, and long-term because the same sites would be affected. Use of hazardous materials during demolition would also be minor, adverse, and short-term because the same hazardous materials would be required during demolition. Similar to Alternative 1, there would be no expected change in the intensity of potential impacts if the demolition is extended beyond a single 12-week period.

Operational use of hazardous materials would be minor, beneficial, and long-term because the same hazardous materials would be used during operations.

4.5.3 Alternative 3 – Mothballing of Facilities

4.5.3.1 Existing Contamination

Under Alternative 3, facilities would be placed in a mothballed state such that they could be made useable in the future for scientific or other purposes. Structures not needed to meet future operational goals could be demolished. Prior to demolition, an assessment would be required to determine whether and to what extent of hazardous materials, such as ACM and LBP, occur in buildings that would be demolished. The contractor may determine that some materials could be left in place (such as floor tile) with wetting during demolition and special handling of debris. All ACM, LBP, and known contaminated areas would be remediated in accordance with the Commonwealth of Puerto Rico and federal regulations, prior to any demolition activities.

Prior to demolition, the contractors would prepare and implement a demolition management plan that prescribes activities for workers to follow in the event that soil or groundwater contamination is encountered based on visual observation and/or smell. If contamination is found, demolition would halt in the vicinity of the find and the next steps would be decided in consultation with the appropriate regulatory agency.

Given the site history and the currently unknown conditions, contamination at Arecibo Observatory could range from relatively little contamination to areas of significant concern. Consequently, there could be a minor to moderate, long-term benefit at the site, commensurate with the severity of contamination to be remediated.

4.5.3.2 Demolition-related Hazardous Materials

The hazardous materials used during demolition would be the same as those described in Alternative 1; consequently, the impacts would also be minor, adverse, and short-term. Similar to Alternative 1, there would be no expected change in the intensity of potential impacts if the demolition is extended beyond a single 15-week period.

4.5.3.3 Operational Use of Hazardous Materials

Chemicals and hazardous materials used for operation of the mothballed and demolished facilities would no longer be needed for site O&M. These materials would be removed from the site and disposed of in accordance with Commonwealth of Puerto Rico and federal regulations. A limited amount of hazardous waste removal and transport would likely be required.

Chemicals and hazardous materials would be used under the maintenance program to protect the facilities from deterioration and other damage. These materials may include diesel fuel and pesticides. All materials would be used, stored, and disposed of in accordance with Commonwealth of Puerto Rico and federal regulations.

Overall the use of chemicals and hazardous materials during operations would be reduced under Alternative 3 and hazardous material handling requirements would continue to be followed during the use or storage of hazardous materials; therefore, future operations are expected to result in a minor, long-term benefit.

4.5.4 Alternative 4 – Partial Demolition and Site Restoration

4.5.4.1 Existing Contamination

Under Alternative 4, all facilities would be fully demolished, except for the concrete towers. Prior to demolition, an assessment would be required to determine the extent of hazardous materials, such as ACM, LBP, and existing contamination. Any ACM, LBP, or known contamination would be remediated prior to initiating demolition. Appendix 3.5-A (EBS) provides details on which buildings contain ACM and LBP.

Alternative 4 would result in all existing contamination being removed and any storage tanks being properly disposed of. Consequently, there could be a minor to moderate, long-term benefit at the site, commensurate with the severity of contamination to be remediated.

4.5.4.2 Demolition-related Hazardous Materials

The hazardous materials used during demolition would be the same as those described in Alternative 1; therefore, the impacts would also be minor, adverse, and short-term. Similar to Alternative 1, there would be no expected change in the intensity of potential impacts if the demolition is extended beyond 28 weeks.

4.5.4.3 Operational Use of Hazardous Materials

Alternative 4 involves the full demolition of all structures, except the concrete towers. All chemicals and hazardous materials typically used for building maintenance, operation of scientific equipment, landscaping, water treatment, vehicle maintenance, and swimming pool maintenance would no longer be utilized. These materials would be removed from the site and disposed of in accordance with Commonwealth of Puerto Rico and federal regulations. A limited amount of hazardous waste removal and transport would likely be required. There would be a moderate, long-term benefit expected from reduction in the use of hazardous materials during operations.

4.5.5 Alternative 5 – Complete Demolition and Site Restoration

4.5.5.1 Existing Contamination

Under Alternative 5, all facilities would be fully demolished. Prior to demolition, an assessment would be required to determine the extent of hazardous materials, such as ACM, LBP, and existing contamination. Any ACM, LBP, or known contamination would be remediated prior to initiating demolition. Appendix 3.5-A (EBS) provides details on which buildings contain ACM and LBP. Despite the increased footprint, the amount of remediated contamination is expected to be the same as that explained for Alternative 4. Consequently, there would also be a minor to moderate, long-term benefit.

4.5.5.2 Demolition-related Hazardous Materials

The hazardous materials used during demolition would be the same as those described in Alternative 1; however, Alternative 5 would also use explosives for demolition. Explosives would be used under federal regulations governing such materials (29 C.F.R. §1926.900 and the Occupational Safety and Health

Administration [OSHA] Puerto Rico State Plan [OSHA, 2016]). The use of explosives increases the hazard level from hazardous materials during demolition; therefore, a moderate, adverse, short-term impact is expected from demolition-related hazardous materials. Similar to Alternative 1, there would be no expected change in the intensity of potential impacts if the demolition is extended beyond 38 weeks.

4.5.5.3 Operational Use of Hazardous Materials

Under Alternative 5, all facilities would be fully demolished. The use of hazardous materials would cease, similar to the situation described for Alternative 4, and would also result in a moderate, long-term benefit.

4.5.6 No-Action Alternative

The No-Action Alternative is the continuation of the current operation of Arecibo Observatory. Under the No-Action Alternative, current activities would continue, and no demolition would occur. Consequently, there would be no new impacts associated with existing contamination, the use of hazardous materials during demolition, or the operational use of hazardous materials.

4.5.7 Mitigation Measures

The following measures would be implemented to reduce impacts from hazardous materials:

- All Alternatives: Complete site characterization and removal or remediation of contamination would be completed prior to any demolition activities.
- All Alternatives: Hazardous materials and wastes would be used, stored, disposed of, and transported during demolition in compliance with all applicable laws and regulations.
- All Alternatives: Demolition contractors would create and implement an SPCC plan.
- All Alternatives: NSF would require all demolition contractors to create and implement a demolition management plan, including hazardous materials discovery protocols. The demolition management plan would include, at a minimum, a list of contact persons in case of a possible encounter with undocumented contamination; provisions for immediate notification of the observation to demolition management; and notification of the regulatory agency with jurisdiction. If previously unknown contamination is found, demolition would halt in the vicinity of the find and the next steps would be decided in consultation with the regulatory agency.
- Alternative 5: Explosive materials would be used in accordance with 29 C.F.R. §1926.900 and the OSHA Puerto Rico State Plan (OSHA, 2016).

4.5.8 Summary of Impacts

Table 4.5-2 provides a summary of impacts resulting from the Alternatives.

TABLE 4.5-2
Summary of Hazardous Materials Impacts

	Alternatives					
Impacts	**Alternative 1**	**Alternative 2**	**Alternative 3**	**Alternative 4**	**Alternative 5**	**No-Action**
Existing hazardous material contamination	Minor to moderate, long-term benefit	Minor to moderate, long-term benefit	Minor to moderate, long-term benefit	Minor to moderate, long-term benefit	Minor to moderate, long-term benefit	No impact
Demolition-related hazardous material use	Minor, adverse, short-term impact	Minor, adverse, short-term impact	Minor, adverse, short-term impact	Minor, adverse, short-term impact	Moderate, adverse, short-term impact	No impact
Operational use of hazardous materials	Minor, long-term benefit	Minor, long-term benefit	Minor, long-term benefit	Moderate, long-term benefit	Moderate, long-term benefit	No impact

4.6 Solid Waste

Methodology

Potential impacts from solid waste were assessed by analyzing the expected solid waste generated during demolition and operations and comparing the waste generated against the capacity of Puerto Rican landfills. The ROI for solid waste includes Arecibo Observatory and the facilities where solid waste would be landfilled. Debris from demolition activities would be recycled and reused to the extent practicable under all Alternatives.

Table 4.6-1 presents the impact thresholds for solid waste.

TABLE 4.6-1
Impact Thresholds for Solid Waste

Impact Intensity	Description
Negligible	The Alternative would result in a change that would be so small that it would not be of any measurable or perceptible consequence.
Minor	The solid waste generated from the Proposed Action would be an increase from current conditions, but would be within the capacity of local landfills.
Major	The solid waste generated from the Proposed Action would be an increase from current conditions, and would result in an exceedance of capacity at local landfills.

Duration: Short-term – Occurs only during the implementation of the Proposed Action.
Long-term – Continues after the implementation of the Proposed Action.

4.6.1 Alternative 1 – Collaboration with Interested Parties for Continued Science-focused Operations (Agency-preferred Alternative)

Demolition

Alternative 1 could result in the demolition of obsolete buildings. Table 4.6-2 presents a summary of the estimated solid waste that would be generated by Alternative 1. These estimates are based on current material found on the site. Appendix 4.6-A includes the calculation spreadsheet for these estimations.

TABLE 4.6-2
Summary of Estimated Solid Waste Generation under Alternative 1

Activity	Demolition Debris (metric ton)	ACM Abatement (metric ton)	LBP Abatement (metric ton)	Universal Waste (metric ton)	Electrical Equipment (metric ton)	Liquid Waste (non-specific) (metric ton)	Septic/ Liquid Waste (metric ton)	Salvage/ Recycle-Non-ferrous (metric ton)	Salvage/ Recycle-Ferrous (metric ton)
Demolition	2,120	140	80	20	40	120	140	20	300

Source: Reese, 2016a, pers. comm.

Based on these estimates, the total quantity of demolition-related waste from Alternative 1 would be approximately 2,760 metric tons before reuse or recycling. This total excludes ACM and LBP wastes. The Poncé Landfill has confirmed this quantity of waste, to include wastewater, is within the landfill capacity (Clas, 2016b, pers. comm.). Because the waste being sent to landfills would be less than current capacity, there would be a minor, adverse, short-term impact on area landfills from demolition-related solid waste.

When possible, demolition materials such as soil from grading would be used onsite**.** A portion of the debris would be diverted from landfills through reuse and recycling. It is estimated that 320 metric tons of material could be recycled. Additional recycling and reuse of demolition debris would be done if feasible.

The demolition may be extended beyond a single 12-week period. However, this would not result in changes to the assessment of potential impacts to solid waste, as the quantity of solid waste would remain the same.

Operations

Operations-related waste generation is typically based on the number of personnel working at a facility. The number of personnel at Arecibo Observatory is not expected to change under Alternative 1; therefore, the amount of waste generated under Alternative 1 is assumed to be the same as under current conditions. It is also assumed the new management at Arecibo Observatory would continue to implement solid waste management and waste reduction, including recycling programs to minimize the amount of waste from facility operations going into the landfills. Based on these assumptions, there would be no impact from operations-related solid waste, when compared with current conditions.

4.6.2 Alternative 2 – Collaboration with Interested Parties for Transition to Education-focused Operations

Demolition

Alternative 2 could also result in demolishing obsolete buildings. Table 4.6-3 presents a summary of estimated solid waste that would be generated by Alternative 2. These estimates are based on current material found on the site. Appendix 4.6-A includes the calculation spreadsheet for the estimations.

TABLE 4.6-3
Summary of Estimated Solid Waste Generation under Alternative 2

Activity	Demolition Debris (metric ton)	ACM Abatement (metric ton)	LBP Abatement (metric ton)	Universal Waste (metric ton)	Electrical Equipment/Goods (metric ton)	Liquid Waste (non-specific) (metric ton)	OWS – Septic/Liquid Waste (metric ton)	Salvage/Recycle-Non-ferrous (metric ton)	Salvage/ Recycle-Ferrous (metric ton)
Demolition	2,560	180	20	20	80	120	0	20	1,700

Source: Reese, 2016a, pers. comm.

Based on these estimates, the total quantity of demolition-related waste from Alternative 2 would be approximately 4,500 metric tons before reuse or recycling. This total excludes ACM and LBP wastes. The Poncé Landfill has confirmed this quantity of waste, to include wastewater, is within the landfill capacity (Clas, 2016b, pers. comm.). Because the waste being sent to landfills would be less than current capacity, there would be a minor, adverse, short-term impact on area landfills from demolition-related solid waste.

When possible, demolition materials such as soil from grading would be used onsite**.** Most of the material that cannot be reused onsite could be reused on other sites or recycled. A portion of the debris would be diverted from landfills through reuse and recycling. It is estimated that 1,720 metric tons of material could be recycled. Additional recycling and reuse of demolition debris would be done if feasible.

Similar to Alternative 1, there would be no expected change in the intensity of potential impacts if the demolition is extended beyond a single 12-week period.

Operations

The number of personnel is not expected to change under Alternative 2; therefore, the amount of waste generated under Alternative 2 is assumed to be the same as under current conditions. It is assumed the new management at Arecibo Observatory would continue to implement solid waste management and waste reduction, including recycling programs to minimize the amount of waste from facility operations going into the landfills. Based on these assumptions, there would be no impact from operations-related solid waste, when compared with current conditions.

4.6.3 Alternative 3 – Mothballing of Facilities

Demolition

Under Alternative 3, facilities would be placed in a mothballed condition such that the facilities would be maintained in a condition where they could be made operational for scientific or other purposes at some point in the future. Structures not needed to meet future operational goals would be demolished. Table 4.6-4 presents a summary of the estimated solid waste that would be generated by Alternative 3.

TABLE 4.6-4
Summary of Estimated Solid Waste Generation under Alternative 3

Activity	Demolition Debris (metric ton)	ACM Abatement (metric ton)	LBP Abatement (metric ton)	Universal Waste (metric ton)	Electrical Equipment/Goods (metric ton)	Liquid Waste (non-specific) (metric ton)	OWS – Septic/Liquid Waste	Salvage/Recycle-Non-ferrous (metric ton)	Salvage/ Recycle-Ferrous (metric ton)
Demolition	620	0	0	20	20	100	200	20	40

Source: Reese, 2016a, pers. comm.

Based on these estimates, the total quantity of demolition-related waste from Alternative 3 would be approximately 1,020 metric tons before reuse or recycling. The Poncé Landfill has confirmed this quantity of waste, to include wastewater is within the landfill capacity (Clas, 2016b, pers. comm.). Because the waste being sent to landfills would be less than current capacity, there would be a minor, adverse, short-term impact on area landfills from demolition-related solid waste.

When possible, demolition materials such as soil from grading would be used onsite**.** Approximately 60 metric tons of debris would be diverted from landfills through reuse and recycling. Additional recycling and reuse of demolition debris would be done if feasible.

Similar to Alternative 1, there would be no expected change in the intensity of potential impacts if the demolition is extended beyond a single 15-week period.

Operations

Operations-related waste generation is typically based on the number of personnel working at a facility. The number of personnel working at Arecibo Observatory would substantially decrease with Alternative 3; therefore, the amount of waste generated under the Proposed Action is assumed to decrease. Consequently, there would be a minor, long-term benefit from operations-related solid waste, when compared with current conditions.

4.6.4 Alternative 4 – Partial Demolition and Site Restoration

Demolition

Under Alternative 4, all above-grade structures, except the large concrete towers, would be demolished, and all below-grade foundations would be stabilized, filled, and abandoned in-place. Table 4.6-5 presents a summary of the estimated solid waste that would be generated by Alternative 4.

TABLE 4.6-5
Summary of Estimated Solid Waste Generation under Alternative 4

Activity	Demolition Debris (metric ton)	ACM Abatement (metric ton)	LBP Abatement (metric ton)	Universal Waste (metric ton)	Electrical Equipment/Goods (metric ton)	Liquid Waste (non-specific) (metric ton)	OWS – Septic/Liquid Waste	Salvage/Recycle-Non-ferrous (metric ton)	Salvage/ Recycle-Ferrous (metric ton)
Demolition	6,820	260	20	40	100	220	280	320	4,380

Source: Reese, 2016a, pers. comm.

Based on estimates, the total quantity of demolition-related waste from Alternative 4 would be approximately 12,160 metric tons before reuse or recycling. This total excludes ACM and LBP wastes. The Poncé Landfill has confirmed this quantity of waste is within the landfill capacity (Clas, 2016b, pers. comm.). Because the waste being sent to landfills would be less than current capacity, there would be a minor, adverse, short-term impact on area landfills from demolition-related solid waste.

When possible, demolition materials such as soil from grading would be used onsite. Approximately 4,700 metric tons of debris would be diverted from landfills through reuse and recycling. Additional recycling and reuse of demolition debris would be done if feasible.

Similar to Alternative 1, there would be no expected change in the intensity of potential impacts if the demolition is extended beyond a single 28-week period.

Operations

Operations-related waste generation would cease under Alternative 4. Consequently, there would be a minor, long-term benefit from operations-related solid waste, when compared with current conditions.

4.6.5 Alternative 5 – Complete Demolition and Site Restoration

Demolition

Under Alternative 5, all facilities would be fully demolished both above-grade and below-grade. Table 4.6-6 presents a summary of the estimated solid waste that would be generated under Alternative 5.

TABLE 4.6-6
Summary of Estimated Solid Waste Generation under Alternative 5

Activity	Demolition Debris (metric ton)	ACM Abatement (metric ton)	LBP Abatement (metric ton)	Universal Waste (metric ton)	Electrical Equipment/Goods (metric ton)	Liquid Waste (non-specific) (metric ton)	OWS – Septic/Liquid Waste (metric ton)	Salvage/Recycle-Non-ferrous (metric ton)	Salvage/Recycle-Ferrous (metric ton)
Demolition	6,940	260	20	40	100	220	280	320	6,800

Source: Reese, 2016a, pers. comm.

Based on the estimates, the total quantity of demolition-related waste from Alternative 5 would be approximately 14,700 metric tons before reuse or recycling. This total excludes ACM and LBP wastes. The Poncé Landfill has confirmed this quantity of waste is within the landfill capacity (Clas, 2016b, pers. comm.). Because the waste being sent to landfills would be less than current capacity, there would be a minor, adverse, short-term impact on area landfills from demolition-related solid waste. When possible, demolition materials such as soil from grading would be used onsite. Approximately 7,120 metric tons of the debris would be diverted from landfills through reuse and recycling. Additional recycling and reuse of demolition debris would be done if feasible.

Similar to Alternative 1, there would be no expected change in the intensity of potential impacts if the demolition is extended beyond a single 38-week period.

Operations

Operations-related waste generation would cease under Alternative 5. Consequently, there would be a minor, long-term benefit from operations-related solid waste, when compared with current conditions.

4.6.6 No-Action Alternative

Under the No-Action Alternative, current activities would continue at Arecibo Observatory, and no demolition would be expected to occur. Because there would be no change from current conditions, no impacts from solid waste would result.

4.6.7 Mitigation Measures

The following measures would be implemented to reduce impacts from solid waste:

- All Alternatives: Whenever possible, demolition debris (such as soil) would be used onsite.
- All Alternatives: Demolition debris would be diverted from landfills through reuse and recycling to the extent practicable.

4.6.8 Summary of Impacts

Table 4.6-7 summarizes individual and overall solid waste impacts for all of the Alternatives.

TABLE 4.6-7
Summary of Solid Waste Impacts

Impact Category	Alternatives					
	Alternative 1	**Alternative 2**	**Alternative 3**	**Alternative 4**	**Alternative 5**	**No-Action**
Solid waste generated from demolition	Minor, adverse, short-term impact	Minor, adverse, short-term impact	Minor, adverse, short-term impact	Minor, adverse, short-term impact	Minor, adverse, short-term impact	No impact
Operations-generated solid waste	No impact	No impact	Minor, long-term benefit	Minor, long-term benefit	Minor, long-term benefit	No impact

4.7 Health and Safety

Methodology

This Section describes the potential short- and long-term impacts to health and safety within the ROI as a result of implementing the Proposed Action. The public expressed a number of health and safety concerns during the scoping period. These comments helped to develop the scope of analysis for this Section and are summarized as follows:

- The use of Arecibo Observatory to study near-earth objects and the Observatory's role in planetary protection
- The use of the Observatory by surrounding communities as shelter during hurricanes
- The potential hazards associated with a mothballed facility

Potential impacts were assessed by analyzing the key components associated with health and safety and comparing the impacts against the impact threshold designations, provided in Table 4.7-1. The key components for health and safety were determined to be public safety, occupational health, and protection of children.

The ROI for the health and safety analysis is defined as follows:

- Public Safety – The human environment

- Occupational Health – Arecibo Observatory boundaries and the potential demolition haul routes
- Protection of Children – The land within 0.5-mile of Arecibo Observatory and 0.5-mile around the roadway network leading to the Observatory and the demolition haul routes

Table 4.7-1 presents the impact thresholds for health and safety.

TABLE 4.7-1
Impact Thresholds for Health and Safety

Impact Intensity	Description
Negligible	Potential impacts to health and safety would be so small they would not be measurable or of perceptible consequence.
Minor	Potential impacts would result in a change to public safety, occupational health, and protection of children, but the change would be small and localized; potential impacts to health and safety would result in localized emergency preparedness consequences.
Moderate	Potential impacts would result in a measurable and consequential change to public safety, occupational health, and protection of children; potential impacts to health and safety would result in regional emergency preparedness consequences.
Major	Potential impacts would result in a substantial change to public safety, occupational health, and protection of children; the change would be measurable and could result in the loss of life; potential impacts to health and safety would result in continental or global emergency preparedness consequences.

Duration: Short-term – Occurs only during the implementation of the Proposed Action.
Long-term – Continues after the implementation of the Proposed Action.

4.7.1 Alternative 1 – Collaboration with Interested Parties for Continued Science-focused Operations (Agency-preferred Alternative)

4.7.1.1 Public Safety

Demolition

Alternative 1 could require demolition to conform to the requirements of future collaborators. The demolition sites would be fenced off and the general public would not have access to the site. Consequently, Alternative 1 demolition would have a negligible, adverse, short-term impact on public safety. It is possible, however, that depending on the needs of future collaborators, no buildings or facilities would be demolished under Alternative 1. If that were the case, there would be no impacts to public safety.

Operations

Under Alternative 1 the Observatory would likely continue to be used as a hurricane shelter, at the discretion of the new operators.

Under this Alternative, Arecibo Observatory's 305-meter-diameter radio telescope would remain in service; however, there could be a change in the scope of operations depending upon the needs of the collaborators. The Observatory could be available to continue to play a role in tracking and characterizing PHOs, as described in Section 3.7.1.1, and it is expected that any future collaborators would continue to support NASA's planetary defense mission and use of the Observatory. Because, the needs of future collaborators under this Alternative are unknown at this time, the impacts of continued, reduced, or eliminated use of Arecibo Observatory for tracking and characterizing PHOs in support of planetary defense must be considered.

If any future collaborators were to continue to support NASA's use of the Observatory, there would be no impacts on public safety; any current benefit to the public from NASA's tracking and characterization of PHOs would be maintained by this Alternative. However, if any future collaborators were to reduce or eliminate the use of the Observatory to support NASA's mission, there could be impacts as described below. Operation of the Observatory, whether continued, reduced, or eliminated, would have no bearing at all on the potential for a PHO to strike Earth. The Observatory can neither discover unknown PHOs nor deflect them from the Earth. The role of the Observatory is to improve the tracking and characterization of PHOs that have already been identified.

Impacts to public safety that could result from the reduction or elimination of the use of the Observatory to characterize PHOs depend on the nature of the information learned about PHOs and how such information may help protect the public through emergency preparedness. In the case a PHO were to be visible within the observable zone of the Observatory (see Section 3.7.1.1 describing this zone's coverage), specific information about the object's orbit and composition could be useful for public safety purposes, if it is obtained early enough for action to be taken. Precision tracking may allow the location of the potential impact site to be determined, and such information could help in preparations for civil defense and disaster preparedness. As noted in Section 3.7.1.1, no existing technology has been tested on an actual asteroid to show it could prevent a PHO from striking the Earth. The main public safety concern regarding Arecibo Observatory's planetary defense operations is whether observatory-generated information is available to help in emergency preparedness. Although the probability of a PHO striking the Earth in a given year is very low (see Section 3.7.1.1), the removal of Arecibo Observatory would result in the loss of characterization of some PHOs. Because it is unknown whether those PHOs would pose a threat that is local, regional, continental, or global in scale, the intensity level of the public safety impacts from removing Arecibo Observatory from NASA's planetary defense mission could lie anywhere on the spectrum from negligible to major, depending on the potential scenario. Based on historical experience in PHO characterization, it is expected that impacts on public safety would be negligible, adverse and short-term.

Public-safety impacts could potentially be mitigated if other instrumentation were able to provide comparable information for PHO characterization. NASA has evaluated what the loss of Arecibo Observatory would mean in terms of planetary defense capabilities and estimates that approximately half of the radar-observing opportunities would be lost. As noted in Section 3.7.1.1, in a typical year there are three or fewer newly discovered PHOs requiring radar data in order to rule out an impact threat. Until now, no object of a size that poses significant risk to life or property has been found by the NASA Planetary Defense Coordination Office to be an actual collision threat to Earth, and in every case, the function of radar has been to retire the risk (rule out the collision threat) from a newly discovered PHO. Generally, without Arecibo Observatory, the probability that NASA could continue to retire the risk from newly discovered PHOs using radar would be cut in half, which would mean that NASA may be unable to ascertain the collision risk of one or two objects per year (NASA, 2017). NASA could potentially recoup half of that loss by obtaining observations using both NASA's Goldstone radar in Goldstone, California, and the Robert C. Byrd Green Bank Telescope (GBT), located in Green Bank, West Virginia. Doubling the power of the NASA Goldstone radar from the current 450 kW to 900 kW could increase by approximately 26 percent the number of objects detectable using Goldstone alone (Naidu, et al., 2016, Astronomical Journal, Vol. 152, number 4). In addition, partial mitigation for the loss of Arecibo Observatory radar data could include adding a powerful radar to the GBT and/or to another Deep Space Network telescope. If necessary, obtaining additional observations with optical telescopes may resolve the collision probability for a particular PHO, although the feasibility and cost of obtaining these additional optical observations would need to be evaluated on a case-by-case basis.

In summary, as the world's largest single-dish radio telescope with radar capabilities, Arecibo Observatory provides useful input to planetary defense, indirectly benefitting public safety through the characterization of potential threats that help in emergency preparedness. As mentioned in Section 3, Arecibo Observatory does not discover NEOs and PHOs; instead, it helps characterizes them. Without Arecibo Observatory, approximately half of the radar data that allows NASA to characterize PHOs could be lost, although the information may be partially recouped through other instrumentation. The probability of PHOs striking Earth is very low. For a potential PHO on a collision course with Earth and not observed because of the loss of Arecibo Observatory data, the impact intensity to public safety from removing Arecibo Observatory from NASA's planetary defense mission could lie anywhere on the spectrum from negligible to major, depending on the potential scenario. Based on historical experience in PHO characterization, it is expected that public-safety impacts would be negligible.

4.7.1.2 Occupational Health

Demolition

Demolition activities can be inherently dangerous. Demolition workers and equipment operators would be required to wear appropriate personal protective equipment and be properly trained for the work being performed. All solid or hazardous wastes generated during demolition would be removed and disposed of at a permitted facility or designated collection point. Section 4.5, *Hazardous Materials*, presents a detailed discussion of hazardous material handling and protection measures. Many sections of the potential demolition haul routes have smaller lanes and there could become safety issues for the truck drivers. Traffic safety measures discussed in Section 4.10, *Traffic and Transportation*, would be employed to lessen the safety risks to drivers and the public.

The demolition contractor would be required to develop and implement a Health and Safety Plan to ensure worker safety during demolition activities. All demolition areas would be clearly marked with appropriate signage. Demolition managers would be required to comply with OSHA, as well as other applicable regulations. For these reasons, Alternative 1 demolition activities would have a minor, adverse, short-term impact on occupational health.

Operations

Alternative 1 would not significantly change the operation of Arecibo Observatory with regard to occupational health, because future tenants and site managers would also be required to follow OSHA principles. Consequently, Alternative 1 would have no new impact on occupational health.

4.7.1.3 Protection of Children

Demolition

Children could be attracted to the demolition sites. However, there are no child-centric community resources within 0.5-mile of Arecibo Observatory and all demolition activities would occur within a fenced-in area with posted signage warning of the danger. Children may be affected by the small increase in truck traffic along the demolition haul routes; however, the BMPs described in Section 4.10, *Traffic and Transportation*, would greatly reduce these potential impacts. With implementation of these BMPs, there would be negligible, adverse, short-term impacts to child safety expected from demolition activities.

Should the demolition period be extended, there would be demolition-related traffic for a longer period of time. However, BMPs, as described in Section 4.10, *Traffic and Transportation*, would be implemented throughout the demolition period and the site would remain access-controlled. There would not be a change in the assessed impacts.

Operations

The continued science-focused operations would have limited impact on the numbers of visiting children provided that future collaborators are interested in continuing the school field trips. Consequently, Alternative 1 operations would have no impacts on the protection of children.

4.7.2 Alternative 2 – Collaboration with Interested Parties for Transition to Education-focused Operations

4.7.2.1 Public Safety

Demolition

Demolition activities for Alternative 2 would be similar to those under Alternative 1, in that both involve the demolition of obsolete facilities to conform to the requirements of future collaborators. Consequently, the level of impact and BMPs for Alternative 2 would also be negligible, adverse, and short-term. Similar to Alternative 1, there would be no expected change in the intensity of potential impacts if the demolition is extended beyond a single 12-week period.

Operations

Arecibo Observatory's 12-meter-diameter telescope would remain in service; however, the 305-meter-diameter telescope would be made inoperable, but retained for visual/historic interest. There would be a reduction in the amount of data obtained by the facility, including information on PHOs. The impacts to public safety would be as described in Section 4.7.1.1.

4.7.2.2 Occupational Health

Demolition

Demolition activities for Alternative 2 would involve the same demolition activities and the use of the same BMPs as Alternative 1. Consequently, the level of impact for Alternative 2 would also be minor, adverse, and short-term.

Operations

Alternative 2 would not significantly change the operation of Arecibo Observatory with regard to occupational health. Alternative 2 would have no new impact on occupational health.

4.7.2.3 Protection of Children

Demolition

Demolition activities and BMPs for Alternative 2 would be similar to those under Alternative 1. Consequently, the level of impact and BMPs for Alternative 2 would also be negligible, adverse, and short-term. Similar to Alternative 1, there would be no expected change in the intensity of potential impacts if the demolition is extended beyond a single 12-week period.

Operations

The transition to education-focused operations would likely result in the continuation of field trips for school-aged children. Under this assumption, Alternative 2 operation would have no impact on the protection of children, when compared with the current conditions.

4.7.3 Alternative 3 – Mothballing of Facilities

4.7.3.1 Public Safety

Demolition

Alternative 3 would involve the demolition of obsolete facilities and the shutting down of buildings. Overall, the demolition activity would be similar in scale to Alternative 1 and would involve the same BMPs. Therefore, the level of impact and BMPs for Alternative 3 would also be negligible, adverse, and short-term. Similar to Alternative 1, there would be no expected change in the intensity of potential impacts if the demolition is extended beyond a single 15-week period.

Operations

Arecibo Observatory's 12-meter and 305-meter-diameter telescopes would no longer be in operation. There would be a significant reduction in the amount of data obtained by the facility, including information on PHOs (see Section 4.7.1.1.).

There would be a maintenance and security program to protect the facility from vandalism, theft, and looting during the mothball period. The facility would no longer be used as a shelter during hurricanes; however, 12 schools with capacity for 2,950 individuals are designated as emergency shelters within the municipality of Arecibo, and all are closer to where the population resides (Puerto Rico Department of Education, 2013). Additionally, the facility is not officially listed as a hurricane shelter. Because of the security and maintenance measures, there would be limited potential for the facility to become a local hazard while it is mothballed.

Overall, Alternative 3 would have a negligible, adverse, long-term impact on public safety.

4.7.3.2 Occupational Health

Demolition

Demolition activities for Alternative 3 would be similar to those under Alternative 1 and would utilize the same BMPs. Consequently, the level of impact for Alternative 3 would also be minor, adverse, and short-term. Similar to Alternative 1, there would be no expected change in the intensity of potential impacts if the demolition is extended beyond a single 15-week period.

Operations

Alternative 3 would greatly reduce onsite activities and the number of employees present. Individuals would be employed to ensure security and maintenance at the mothballed facility; the inherent risk of these activities is expected to be the same as the current conditions, resulting in no new impacts.

4.7.3.3 Protection of Children

Demolition

Demolition activities for Alternative 3 would be similar to Alternative 1, and would require the use of the same BMPs. Consequently, the level of impact and BMPs for Alternative 3 would also be negligible, adverse, and short-term. Similar to Alternative 1, there would be no expected change in the intensity of potential impacts if the demolition is extended beyond a single 15-week period.

Operations

Children would no longer visit the facility with the implementation of Alternative 3; consequently, there would be no impacts to protection of children.

4.7.4 Alternative 4 – Partial Demolition and Site Restoration

4.7.4.1 Public Safety

Demolition

Alternative 4 involves the demolition of the facilities above-grade (except for the large concrete towers), while below-grade facilities would be stabilized, filled, and abandoned in place. The demolition sites would be fenced off and the general public would not have access to the site. Increased demolition-related traffic would result under Alternative 4; however, no more than 12 round-trip trips by truck per day would be expected (Dreher, 2016, pers. comm.), and the BMPs detailed in the *Traffic and Transportation*

Section, would greatly reduce any potential impacts. For these reasons, Alternative 4 would have a minor, adverse, short-term impact on public safety. Similar to Alternative 1, there would be no expected change in the intensity of potential impacts if the demolition is extended beyond a single 28-week period.

Operations

Alternative 4 would also result in the elimination of potential PHO characterizations at the Observatory (see Section 4.7.1.1.) and the elimination of the use of the facility as a hurricane shelter. Consequently, the level of impact for Alternative 4 would be the same as those described for Alternative 3 and result in negligible, adverse, and long-term impacts. The security fence surrounding the facility would remain to separate the public from the concrete structures so that the facility would not become a hazard.

4.7.4.2 Occupational Health

Demolition

The BMPs described in Alternative 1 would also be implemented under Alternative 4. With the adherence to these BMPs, the impacts to occupational health form Alternative 4 would be minor, adverse, and short-term.

Operations

Alternative 4 would eliminate the onsite activities and employees. Consequently, there would be no impacts to occupational health from operations.

4.7.4.3 Protection of Children

Demolition

Children could be attracted to the site during the demolition that would occur in Alternative 4. However, all demolition activities would occur within a fenced in area, with posted signage warning of the danger. There are also no child-centric community resources within 0.5-mile of Arecibo Observatory. The increase in truck traffic along the demolition haul routes would be more than offset by the elimination in visitor traffic along the roadway network to Arecibo Observatory. Also, the BMPs detailed in the, *Traffic and Transportation* Section, would offset the risks from increased truck traffic. There would be negligible, adverse, short-term impacts to child safety expected from the demolition activities. Similar to Alternative 1, there would be no expected change in the intensity of potential impacts if the demolition is extended beyond a single 28-week period.

Operations

Children would no longer visit the facility with the implementation of Alternative 4; consequently, there would be no impacts to protection of children.

4.7.5 Alternative 5 – Complete Demolition and Site Restoration

4.7.5.1 Public Safety

Demolition

While demolition activities would take longer under Alternative 5, with the removal of the towers, the actual work done and BMPs implemented would be similar in nature as Alternative 4. While explosives may be used under Alternative 5, all explosive usage would occur in a controlled setting, away from the general public. Consequently, the level of impact and BMPs for Alternative 5 would be minor, adverse, and short-term. Similar to Alternative 1, there would be no expected change in the intensity of potential impacts if the demolition is extended beyond a single 38-week period.

Operations

Alternative 5 would also result in the elimination of potential PHO characterizations at the Observatory (see Section 4.7.1.1.) and the elimination of the use of the facility as a hurricane shelter. Consequently, the level of impact for Alternative 5 would be the same as those described for Alternative 3 and 4 and result in negligible, adverse, and long-term impacts.

4.7.5.2 Occupational Health

Demolition

BMPs described in Alternative 1 would also be implemented under Alternative 5. However, Alternative 5 would involve substantial demolition of the facility and include the use of explosives. Any individuals involved in explosives use would be properly trained and industry standard protections would be implemented. With the adherence to these BMPs, the impacts to occupational health from Alternative 5 would remain minor, adverse, and short-term.

Operations

Alternative 5 would eliminate the onsite activities and employees. Consequently, there would be no impacts to occupational health from operations.

4.7.5.3 Protection of Children

Demolition

While demolition activities would take longer under Alternative 5, the actual work done would be similar in nature as Alternative 4 and children would not be permitted near the use of explosives. Consequently, the level of impact and BMPs for Alternative 5 would be the same as those described for Alternative 4 and remain negligible, adverse, and short-term. Similar to Alternative 1, there would be no expected change in the intensity of potential impacts if the demolition is extended beyond a single 38-week period.

Operations

Children would no longer visit the facility with the implementation of Alternative 5; consequently, there would be no impacts to protection of children.

4.7.6 No-Action Alternative

Under the No-Action Alternative, no demolition would occur and there would be no change in the operation and visitation to Arecibo Observatory; consequently, there would be no impacts to public safety, occupational health, or protection of children.

4.7.7 Mitigation Measures

The following measures would be implemented to reduce impacts to health and safety:

- All Alternatives: The contractor would develop and implement a demolition Health and Safety Plan.
- All Alternatives: Arecibo Observatory personnel would comply with OSHA safety protocols.
- All Alternatives: Fencing and signage would be installed around demolition sites.
- Alternative 3: A maintenance and security program would be implemented for mothballed facilities.
- Alternative 4: A security fence would be maintained to limit access to the large concrete structures after partial demolition.
- Alternative 5: Individuals handling explosives would be properly trained and industry standard safety protocols would be implemented.

4.7.8 Summary of Impacts

Table 4.7-2 provides a summary of health and safety impacts resulting from the Alternatives.

TABLE 4.7-2
Summary of Health and Safety Impacts

	Alternatives					
Impacts	**Alternative 1**	**Alternative 2**	**Alternative 3**	**Alternative 4**	**Alternative 5**	**No-Action**
Public safety impacts during demolition	Negligible, adverse, short-term impact	Negligible, adverse, short-term impact	Negligible, adverse, short-term impact	Minor, adverse, short-term impact	Minor, adverse, short-term impact	No impact
Public safety impacts during operations	Negligible, adverse, long-term impact	Negligible, adverse, long-term impact	Negligible, adverse, long-term impact	Negligible, adverse, long-term impact	Negligible, adverse, long-term impact	No impact
Occupational health during demolition	Minor, adverse, short-term impact	Minor, adverse, short-term impact	Minor, adverse, short-term impact	Minor, adverse, short-term impact	Minor, adverse, short-term impact	No impact
Occupational health during operations	No impact	No impact	No impact	No impact	No impact	No impact
Protection of children during demolition	Negligible, adverse, short-term impact	Negligible, adverse, short-term impact	Negligible, adverse, short-term impact	Negligible, adverse, short-term impact	Negligible, adverse, short-term impact	No impact

TABLE 4.7-2
Summary of Health and Safety Impacts

	Alternatives					
Impacts	**Alternative 1**	**Alternative 2**	**Alternative 3**	**Alternative 4**	**Alternative 5**	**No-Action**
Protection of children during operations	No impact	No impact	No impact	No impact	No impact	No impact

4.8 Noise

Methodology

Noise impacts were determined based on potential increased noise levels around noise-sensitive land uses. Noise-sensitive land uses are locations where unwanted sound would adversely affect the designated use, and typically include residential areas, hospitals, places of worship, libraries, schools, historic structures/districts, and wildlife preserves and parks.

The ROI for noise includes properties in the vicinity to the Proposed Action boundary, access routes from the landfill to the entrance of Arecibo Observatory, and adjacent properties. Table 4.8-1 presents the impact thresholds for noise under the Proposed Action.

As sound intensity tends to fluctuate with time, a method is required to describe a noise source, such as a highway, in a steady-state condition. The descriptor most commonly used in environmental noise analysis is the equivalent steady-state sound level, or Leq. This value is representative of the same amount of acoustic energy that is contained in a time-varying sound measurement over a specified period. For highway traffic noise analyses, that time period is 1 hour, and the value then reflects the hourly equivalent sound level, or Leq(h).

A 3-dBA change in sound level, which is a doubling of the sound level, generally represents a barely noticeable change in noise level, whereas a 10-dBA change is typically perceived by the human ear as doubling of the level or twice as loud. There are several factors that affect the propagation of sound through the environment. A primary factor is the type of sound generator. For a line source, such as a line of traffic, the intensity will decrease directly according to the distance from the source. That is, for each doubling of the distance from the sources there is a 3-dBA reduction in the sound levels. In the case of spherical spreading from a point source, such as a stationary generator, sound level intensity decreases according to the square of the distance from the source. Thus, for a point source, the sound radiates equally in all directions and is reduced by 6 dBA for each doubling of distance from the source.

TABLE 4.8-1
Impact Thresholds for Noise

Impact Intensity	Description
Negligible	Demolition and operations-related noise would result in a less than a 3-dBA (not perceptible) noise increase.
Minor	Demolition and operations-related noise would result in a 3- to 5-dBA (barely perceivable) noise increase.
Moderate	Demolition and operations-related noise would result in a 5- to 10-dBA (readily perceivable) noise increase.
Major	Demolition and operation-related noise would result in a greater than 10-dBA (twice as loud) noise increase.

Duration: Short-term – Occurs only during the implementation of the Proposed Action.
Long-term – Continues after the implementation of the Proposed Action.

4.8.1 Alternative 1 – Collaboration with Interested Parties for Continued Science-focused Operations (Agency-preferred Alternative)

Demolition

The closest offsite noise-sensitive land uses occur approximately 0.62-mile (1 km) from Arecibo Observatory. Given this distance, demolition noise associated with building demolition would have little effect on offsite noise-sensitive land uses. Individuals working at the facility during demolition activities would be exposed to increased noise conditions. Standard demolition techniques would generate noise from diesel-powered earth-moving equipment such as dump trucks and bulldozers, backup alarms on certain equipment, and compressors. Typical noise levels from these types of equipment are listed in Table 4.8-2. Demolition-related noise at receptor locations would usually depend on the loudest one or two pieces of equipment operating at the moment.

TABLE 4.8-2
Typical Noise Levels Associated with Main Phases of Outdoor Demolition

Demolition Phase	Noise Level at 50 feet (dBA)
Ground Clearing	84
Excavation, Grading	89
Foundations	78
Structural	85
Finishing	89

Source: EPA, 1971.

Table 4.8-2 indicates that the loudest equipment generally emits noise in the range of 80 to 90 dBA at 50 feet (15 meters). Because noise dissipates dependent on the distance to the source, residential areas 0.62-mile (1 kilometer) away would not notice the demolition noise. However, scientists and office workers at Arecibo Observatory would be exposed to demolition noise during operations. Demolition areas using heavy equipment would be fenced off, and it is expected that sensitive noise receptors such as scientists and office workers would be located indoors and substantially farther than 50 feet (15 meters) from demolition-related activities. Based on these factors, it is expected that most workers would be exposed to maximum demolition noise in the 40- to 50-dBA range, which is the same as a quiet urban daytime environment (Table 3.8-1) and roughly equivalent to the current noise environment. Therefore, demolition-related noise would result in a negligible, adverse, short-term impact.

Communities along the haul routes would be exposed to increased demolition-related traffic noise during the demolition period. However, these sporadic spikes in noise would have minimal change on the existing Leq(h) dBA. The added heavy truck traffic from demolition would result in an up to 3-dBA increase in noise levels along the designated haul routes at a distance of 100 feet (30 meters) (Caltrans, 1998). The 3-dBA increase is based on the conservative assumption that the traffic levels would up to double in some rural areas. Based on this conservative assumption, noise impacts from increased traffic volumes would be expected to be negligible, adverse, and short-term.

There would be no increased impacts if the demolition is extended beyond a single 12-week period, as the intensity and duration of exposure would remain the same.

Operations

There would be no changes to the operational noise environment under Alternative 1; consequently, there would be no impacts from noise.

4.8.2 Alternative 2 – Collaboration with Interested Parties for Transition to Education-focused Operations

Demolition

The demolition activities under Alternative 2 would be similar to and utilize the same equipment as Alternative 1; therefore, the expected noise impacts from demolition activities and traffic would also be negligible, adverse, and short-term. Similar to Alternative 1, there would be no expected change in the intensity of potential impacts if the demolition is extended beyond a single 12-week period.

Operations

There would be no changes to the operational noise environment under Alternative 2; consequently, there would be no impacts from noise.

4.8.3 Alternative 3 – Mothballing of Facilities

Demolition

Under Alternative 3, Arecibo Observatory would be mothballed. The demolition activities under Alternative 3 would be similar to and utilize the same equipment as Alternative 1; therefore, the expected noise impacts from demolition activities and traffic would also be negligible, adverse, and short-term. Similar to Alternative 1, there would be no expected change in the intensity of potential impacts if the demolition is extended beyond a single 15-week period.

Operations

Operations would essentially cease under Alternative 3, thereby reducing the current noise environment. There would be no impact from noise under Alternative 3 operations.

4.8.4 Alternative 4 – Partial Demolition and Site Restoration

Demolition

Under Alternative 4, Arecibo Observatory would be partially demolished. While demolition activities under Alternative 4 would take longer than under Alternatives 1, 2, and 3, the same demolition techniques and equipment would be used. Therefore, the noise environment would remain in 40- to 50-dBA range, and possibly quieter depending on individuals' distance from the demolition. There would also be less sensitive noise receptors under Alternative 4. Demolition- and traffic-related noise would result in a negligible, adverse, short-term impact. Similar to Alternative 1, there would be no expected change in the intensity of potential impacts if the demolition is extended beyond a single 28-week period.

Operations

Operations would completely cease under Alternative 4, thereby eliminating the current noise environment. There would be no impact from noise under Alternative 4 operations.

4.8.5 Alternative 5 – Complete Demolition and Site Restoration

Demolition

Arecibo Observatory would be fully demolished under Alternative 5. While demolition activities under Alternative 5 would take longer than under the other Alternatives, the noise environment would be similar to that explained for the previous Alternatives because similar equipment would be used. However, Alternative 5 could require blasting, which may be perceived by offsite sensitive noise receptors.

Noise from blasting explosives can exceed the 100-dBA range; however, the nearest sensitive noise receptors would be located over 0.62-mile (1 kilometer) from the potential blast sites; resulting in a substantially lower noise exposure, expected to be in the 50- to 60-dBA range. This noise range would be roughly equivalent to an urban environment (Table 3.8-1), and expected to be a less than 10-dBA increase from current conditions. Additionally, the dense vegetation surrounding Arecibo Observatory would further mitigate the noise from demolition activities and traffic. Therefore, demolition-related noise impacts under Alternative 5 would be moderate, adverse, and short-term. Explosive usage would be limited to daylight hours. The closest residential or potential sensitive structure would not be expected to be impacted by the air blast overpressure or sound pressure wave, due to the size of the expected blasting munitions.

Similar to Alternative 1, there would be no expected change in the intensity of potential impacts if the demolition is extended beyond a single 38-week period. A longer demolition period would not change the number of magnitude of blasting events.

Operations

Operations would completely cease under Alternative 5, thereby eliminating the current noise environment. There would be no impact from noise under Alternative 5 operations.

4.8.6 No-Action Alternative

The No-Action Alternative is the continuation of the current use of Arecibo Observatory. Under the No-Action Alternative, current activities would continue at the site, and no demolition would be expected to occur. Because there would be no change from current conditions, no impacts from noise would result**.**

4.8.7 Mitigation Measures

The following measures would be implemented to reduce impacts from noise:

- All Alternatives: Demolition areas would be fenced.
- Alternative 5: Explosive materials would be used only during daylight hours.
- Alternative 5: Explosive materials would be small enough caliber to prevent a blast overpressure or sound pressure wave.

4.8.8 Summary of Impacts

Table 4.8-3 provides a summary of noise impacts resulting from the Alternatives.

TABLE 4.8-3
Summary of Noise Impacts

	Alternatives					
Impacts	**Alternative 1**	**Alternative 2**	**Alternative 3**	**Alternative 4**	**Alternative 5**	**No-Action**
Noise from demolition activities	Negligible, adverse, short-term impact	Negligible, adverse, short-term impact	Negligible, adverse, short-term impact	Negligible, adverse, short-term impact	Moderate, adverse, short-term impact	No impact
Noise from demolition traffic	Negligible, adverse, short-term impact	Negligible, adverse, short-term impact	Negligible, adverse, short-term impact	Negligible, adverse, short-term impact	Negligible, adverse, short-term impact	No impact
Noise from operations	No impact	No impact	No impact	No impact	No impact	No impact

4.9 Socioeconomics

Methodology

This Section presents an analysis of the potential impacts to socioeconomic resources from proposed changes to operations at Arecibo Observatory. The public expressed a number of socio-economic concerns during the scoping period which are summarized in Section 5.2.2.2. These comments helped in the development of the scope of analysis for this Section. The potential operations-related impacts to socioeconomic resources include direct and indirect impacts to the population, housing, economy, employment, and income of the Municipality of Arecibo and the educational and tourism resources of the Commonwealth of Puerto Rico. The ROI for population, housing, economy, employment, and income is the Municipality of Arecibo. The ROI for education and tourism is the Commonwealth of Puerto Rico. The impacts analysis is based on activities taking place during the demolition phase and the operations phase. The applicability and duration of each of these phases differs across the Alternatives, and for some of the Alternatives, these activities may occur concurrently with each other (that is, the phases may overlap in time). The primary driver for potential impacts on socioeconomic resources is the increase in employment during demolition activities (all Alternatives) and the reduction in employment if operations cease (Alternatives 3, 4, and 5). A second socioeconomic driver is the expenditures by visitors to Arecibo Observatory, including tourists, students, and researchers. Table 4.9-1 provides a summary of how these factors and the related indicators compare across the Alternatives.

Potential demolition impacts include changes to temporary housing resources associated with the demolition workforce, as well as changes in economic output, employment, and earnings associated with the expenditures on demolition materials and workforce payroll. Expenditures for demolition activities may include the purchase of fuel for demolition equipment and materials, such as temporary site fencing and supplies for erosion and sedimentation control. Although there may be potential impacts such as tax revenues from earnings and sales taxes, these were not assessed because the majority of the demolition workers are assumed to already live and work in the region. Sales tax associated with demolition expenditures is also not included because of the unknown quantities of equipment and materials needed to demolish or partially demolish the site.

The potential effects of each of the Alternatives on education and tourism would begin in the short term, during the demolition period, and, potentially continue after these demolition activities are complete.

Table 4.9-1 summarizes the factors influencing the scale of the impacts for each of the Alternatives. The analysis includes the following assumptions:

Population. Demolition activities for Alternatives 1, 2, 3, and 4 would employ approximately 40 workers (mostly local), as well as up to five non-local workers from a specialty demolition contractor for Alternative 5. It is assumed that the 40 workers under Alternatives 1, 2, 3, and 4 would comprise 25 local workers, 10 equipment operators (five local and five non-local), and five environmental specialists to conduct an asbestos survey and/or abatement and other surveys prior to demolition activities.

For the purposes of analysis, the total operations-related work force under the No-Action Alternative comprises 128 personnel at Arecibo Observatory, eight personnel affiliated with the visitor center and 25 temporary academic guides (SRI International, 2016). In total, it is assumed that a maximum of 136 permanent and part-time jobs could be reduced. It is assumed that the majority of the 136 personnel live within the Municipality of Arecibo. Also, it is assumed that no new permanent jobs would be created as result of the Proposed Action and the Alternatives. Under Alternatives 1 and 2, it is assumed that there would be no net change in operations-related jobs and the visitor center jobs would be retained. For Alternative 3– Mothballing of Facilities, it is assumed that only the 57 grounds and maintenance personnel would remain to conduct periodic maintenance and security functions. Under Alternatives 4 and 5, the number of operations-related jobs that would be lost could be as many as 136. Under Alternative 4– Partial Demolition and Site Restoration, it is assumed that up to six security personnel would be retained to provide security. While there would be no direct gain or loss of population under the various Alternatives, the considered Alternatives could be responsible for the indirect loss of population as the workforce potentially relocates over time in search of comparable employment. It is difficult to predict when and how many workforce personnel would relocate; therefore, the potential loss of population is addressed qualitatively in this Section.

Housing. It is assumed that up to five of the 40 demolition workers under Alternative 5 would be non-local from a specialty demolition contractor and may or may not need temporary housing for up to 1 month (see Table 4.9-1). Additionally, five equipment operators would be non-local and may come for the duration of the demolition period under all Alternatives. It is assumed that these demolition workers would find temporary housing near the Municipality of Arecibo or commute from the cities of Poncé or San Juan.

Information on housing in the Municipality of Arecibo and the Esperanza Barrio and near Arecibo Observatory is characterized to demonstrate current vacancy and occupancy rates and average housing costs.

While some operations personnel would inherently relocate over time because of personal choice and opportunities, it is difficult to predict the specific number of people that would relocate. However, an indirect effect of Alternatives 3, 4, and 5 could be an increase in housing vacancies as the workforce potentially relocates over time in search of comparable employment.

Economy, Employment, and Income. Of the current Observatory staff, 16 are researchers (12.5 percent), 57 are grounds and maintenance staff (45 percent), 24 provide guest services (18.8 percent), 25 are temporary academic guides (19.5 percent), and six are telescope operators (4.6 percent) (SRI International, 2016). In addition, eight personnel work at the visitor center.

For the purposes of this analysis, it is assumed that Arecibo Observatory and visitor center personnel would remain employed under Alternatives 1 and 2. Under Alternative 2, a reduction of fewer than six jobs related to the operation of the 305-meter-diameter telescope is assumed; these jobs are anticipated to be three telescope operators and three maintenance staff. It is assumed that the three remaining telescope operators would be retained to continue operating the remaining radio telescope. For Alternative 3, it is assumed that six security and maintenance personnel would remain.

The direct effects of the Alternatives on the employment and income of the population of the Municipality of Arecibo are quantified, while the effects on the economy are qualitatively described to account for secondary (indirect and induced) economic effects. Examples of indirect effects include “inter-industry” activities such as the purchase of materials and/or supplies from another industry or the benefit of recycling and reusing materials from the demolition activities. Induced effects result from labor income spending, such as a worker eating at a local restaurant or lodging at a local hotel.

For the purposes of this analysis, it is assumed that the demolition jobs would be new jobs in the Municipality of Arecibo. These jobs would be temporary and would exist through the duration of the demolition period as shown below. Demolition work by its nature is a project-to-project industry that does not guarantee full employment on annual basis. Additionally, there are limited construction activities ongoing in Arecibo. Therefore, it is assumed that these demolition jobs would be new, although temporary, jobs.

TABLE 4.9-1
Summary of Factors Influencing Socioeconomic Impact Findings

	Alternative 1 Scientific Collaboration	**Alternative 2 Educational Collaboration**	**Alternative 3 Mothballing of Facilities**	**Alternative 4 Partial Demolition and Site Restoration**	**Alternative 5 Complete Demolition and Site Restoration**	**No-Action Alternative**
Duration of Demolition Activities [a]	12 weeks	12 weeks	15 weeks	28 weeks	38 weeks	N/A
Total Demolition Staff	40	40	40	40	45 b	N/A
Onsite Workers	25	25	25	25	25	0
Equipment Operators	10	10	10	10	10	0
Environmental Specialists (pre-demolition surveys)	5	5	5	5	5	
Haul Truck Drivers	Provided as part of landfill operations	Provided as part of landfill operations	Provided as part of landfill operations	Provided as part of landfill operations	Provided as part of landfill operations	
Origin of Staff						
Local	35	35	35	35	35	
Non-local	5	5	5	5	10 b	
Estimated Demolition Costs (FY 2015)[c]	$3.6M	$3.8M	$2.8Md	$10.6M	$18.7Me	N/A

TABLE 4.9-1
Summary of Factors Influencing Socioeconomic Impact Findings

	Alternative 1 Scientific Collaboration	Alternative 2 Educational Collaboration	Alternative 3 Mothballing of Facilities	Alternative 4 Partial Demolition and Site Restoration	Alternative 5 Complete Demolition and Site Restoration	No-Action Alternative
Onsite Facilities (N = 51)						
Facilities Remaining	25	19	8	0	0	N/A
Facilities Demolished	26	27	14	48	51	N/A
Safe-Abandon i	0	5	0	3	0	N/A
Facilities Mothballed	0	0	29	0	0	N/A
Total Operation Staffing[f]	**<128**	**<128**	**4[g]**	**2[g]**	**2[g]**	128
Researchers	16	16	0	0	0	16
Services	24	24	0	0	0	24
Grounds and Maintenance	57	57	57	6	0	57
Temporary Academic Guides (Educators)	25	25	0	0	0	25
Telescope Operators	6	3	0	0	0	6
Visitor's Center Personnel	8	8	0	0	0	
Annual O&M Cost[h]	$2.1M	$2.0M	$2.1M	< $60,000	< $60,000	$2.1
Visitation[f]						
Onsite Scientific Researchers	16	16	0	0	0	16
Tourists	70,200	70,200	0	0	0	70,200
Education Participants	19, 800	19,800	0	0	0	19,800

TABLE 4.9-1
Summary of Factors Influencing Socioeconomic Impact Findings

	Alternative 1 Scientific Collaboration	Alternative 2 Educational Collaboration	Alternative 3 Mothballing of Facilities	Alternative 4 Partial Demolition and Site Restoration	Alternative 5 Complete Demolition and Site Restoration	No-Action Alternative

Sources: Reese, 2016b, pers. comm.; SRI International, 2016.

[a] Demolition could occur over an extended period of time, depending on availability of funds. Demolition may span multiple fiscal years as money becomes available.

[b] Alternatives 1 through 4 assume that five of the 10 equipment operators would be non-local but from within Puerto Rico, while Alternative 5 could require five specialty demolition contractors from outside Puerto Rico for approximately 1 month.

[c] Class 4 estimates as defined by the Association for the Advancement of Cost Engineering International, and are considered accurate to +50%/-30%.

[d] It is assumed that this is the cost of mothballing the facility, after which the building will remain mothballed for an unknown duration. There would be a continued O&M cost for security and maintenance as described below in Annual O&M costs.

[e] Assumes the use of explosives for demolition of the towers and rim wall; other methods would be substantially greater in cost.

[f] SRI International, 2016

[g.] Alternative 4 assumes six ongoing grounds and maintenance staff to ensure the site is secure and maintained. Alternative 3 assumes 57 ongoing grounds and maintenance staff to ensure mothballed facilities are secure and maintained.

[h] O&M costs reflect maintenance of structures and provision of utilities and do not include any cost of science research and education operations, nor do they include dedicated security staff and facilities for Alternatives 4 and 5. Dedicated security staff and facilities, should they be needed, could cost an additional $315,000 to $675,000 annually for Alternatives 4 and 5.

[i] Safe-abandonment: To remove a building or facility from service without demolishing it. This includes removing furnishings, disconnecting utilities, and isolating the structure from public access by fencing or other means to reduce fall and tripping hazards and preclude vandalism. The structure is also made secure from environmental damage due to wind, rain, humidity, and temperature extremes. Pest and insect damage must also be taken into account and biodegradable items must be removed to the maximum extent practicable. Under safe-abandonment, there is no intention to bring the structures back to operational status.

Education. Arecibo Observatory currently has 16 onsite researchers and accommodates numerous U.S. and international researchers who conduct scientific research remotely using the facilities at Arecibo Observatory. An estimated 19,800 students visit Arecibo Observatory each year for STEM purposes (SRI International, 2016). It is assumed that visiting researchers are housed entirely onsite and that the students travel from across the Commonwealth of Puerto Rico to visit Arecibo Observatory. It is assumed that Alternatives 1 and 2 would continue to support this level of research and education. Alternative 2 would result in the potential loss of a portion of these scientific researchers and students because the reflector dish and 305-meter-diameter telescope would be placed in a “safe-abandonment” condition. Demolition activities under Alternatives 3, 4 and 5 would result in no educational activities or research continuing at Arecibo Observatory.

Tourism. Approximately 90,000 tourists visit Arecibo Observatory annually (estimated 19,800 students and 70,200 adults). It is assumed that the majority of these tourists do not travel to Puerto Rico for the sole purpose of visiting Arecibo Observatory and would not forego their visit if the Observatory is no longer available (SRI International, 2016). As with education, it is assumed that the No-Action Alternative and Alternatives 1 and 2 would continue to generate this level of visitation. Alternatives 3, 4, and 5 would result in no tourism activities at Arecibo Observatory. All of the Alternatives include some demolition activities that may result in temporary and periodic noise and truck traffic that may impact nearby tourist destinations such as the Camuy River Cave Park to the west and Cuevas Ventana to the northeast. The haul routes for the demolition materials coincide with the main route to Camuy River Cave Park. As a result, periodic traffic congestion may occur; however, with an estimated 24 truck trips a day, the increased traffic and noise impacts would be minimal. Traffic mitigation measures would be implemented where possible. Please see Section 4.10, *Traffic and Transportation* and Section 4.8, *Noise* for a more detailed explanation of these impacts. Only Alternative 5 would have the potential to impact Cuevas Ventana. This Alternative would require the demolition of the southeastern tower and its anchors, resulting in disruption of the visual quality. Please see Section 4.11, *Visual Resources*, for a more detailed explanation of visual impacts. No haul routes are near Cuevas Ventana, so there is no potential for truck traffic to impact tourism.

Based on the factors in Table 4.9-1 and the assumptions described previously, the socioeconomic impacts are assessed in the following Sections and described using the thresholds summarized in Table 4.9-2.

TABLE 4.9-2
Impact Thresholds for Socioeconomics

Impact Intensity	Description
Negligible	The Alternative would result in a change to socioeconomic resources (beneficial or adverse) that would be so small, it would be an immeasurable or imperceptible consequence.
Minor	The Alternative would result in a change to socioeconomic resources but the change (beneficial or adverse) would be small and localized.
Moderate	The Alternative would result in a measurable and consequential change to socioeconomic resources.
Major	The Alternative would result in a substantial change to socioeconomic resources; the change (beneficial or adverse) would be measurable and result in a severely adverse or major beneficial impact.

Duration: Short-term: occurs only during the proposed demolition period.
Long-term: continues after the proposed demolition period.

Should the demolition extend beyond the single 12 to 38-week period identified for the Alternatives, there would be no change in the assessed impacts to socioeconomic resources.

4.9.1 Alternative 1 – Collaboration with Interested Parties for Continued Science-focused Operations (Agency-preferred Alternative)

Under Alternative 1, it is estimated that 40 workers would complete the demolition of 26 buildings. Demolition debris would be recycled and reused to the extent possible, and any remaining materials would be properly disposed of in a commercial landfill. Haul trucks from the landfill would transport the demolition debris from the Observatory to recycle/reuse centers in nearby municipalities and the remaining debris to a landfill in Poncé. Under Alternative 1, all operations jobs would remain, including the scientific researchers and the visitor center, cafeteria, and facilities support staff.

4.9.1.1 Demolition

Population and Housing

Under Alternative 1, it is assumed that approximately 40 temporary demolition jobs would be created, and the 40 workers would comprise 25 local workers, 10 equipment operators (five local and five non-local), and five environmental specialists to conduct an asbestos survey and/or abatement and other surveys prior to demolition activities (Reese, 2016b, pers. comm.). It is assumed that the majority of these demolition workers would be local and would not require temporary housing. Approximately five equipment operators may come from the cities of Poncé or San Juan. It is assumed that these workers may commute daily or seek temporary housing in the area. Because the duration of their work is 12 weeks, it is assumed that non-local workers would not relocate or bring their families to the Municipality of Arecibo. Therefore, because no permanent jobs would be created and no workers would relocate, there would be no impact to the population of the Municipality of Arecibo. An estimated 8,420 vacant housing units are available in the Municipality of Arecibo (USCB, 2015f). Therefore, the temporary presence of five non-local equipment operators would likely result in negligible, adverse, short-term impacts to housing in the ROI.

Economy, Employment, and Income

Demolition activities are expected to create 40 temporary demolition jobs over a period of approximately 12 weeks and cost approximately $3.6 million (see Table 4.9-1). These jobs would create income and spending for a 12-week period. Some income from salaries and expenditures would occur, resulting in a short-term positive impact to the local economy of the Municipality of Arecibo. The economy of the Commonwealth of Puerto Rico and the Municipality of Arecibo has been in decline over the last 10 years. Approximately 45 percent of the population in Puerto Rico lives at the poverty rate, compared with 49 percent of the population in the Municipality of Arecibo and 59 percent in the Esperanza Barrio. Additionally, 46 percent of the working age population (ages 18 to 64) in the Municipality of Arecibo is at or below the poverty status, compared with 42 percent for the Commonwealth of Puerto Rico (USCB, 2015h). Therefore, the temporary increase in economic activity from salaries and expenditures would be a direct, negligible, short-term, benefit to the local economy of the Municipality of Arecibo. It is expected there could be some indirect, negligible, short-term benefits to the local economy from increased demolition-related spending in the community, such as expenditures for fuel, temporary site fencing, and erosion and sedimentation control materials, although the amount of such expenditures is unknown at this time and, therefore, a more precise analysis cannot be performed.

The labor force of the Municipality of Arecibo declined from 27,111 to 24,369 (10 percent) from 2009 to 2014 (USCB, 2009, 2014b) (see Table 3.9-4). Similarly, the unemployment rate estimated in 2014 for the Commonwealth of Puerto Rico was 11.3 percent; the unemployment rate for the Municipality of Arecibo was estimated in the same year at 16.6 percent (USCB, 2015g) (see Table 3.9-5). The Commonwealth of

Puerto Rico's median household income (in 2014 dollars) was $19,686, while the median income for the Municipality of Arecibo was $16,997 (see Table 3.9-4; USCB, 2015g).

It is estimated that 40 demolition jobs would be created under this Alternative, which would be a less than 1 percent increase in the labor force of the Municipality of Arecibo (29,239) over a 12-week period (USCB, 2015g). The increase in jobs would be a direct, negligible, short-term benefit to employment within the ROI (USCB, 2015g). The demolition activity would result in additional income in the Municipality of Arecibo. This income would be derived from the salaries of the demolition workers and revenue from the purchase of demolition supplies. This additional income would result in an indirect, negligible, short-term benefit on income in the Municipality of Arecibo.

Education

Under Alternative 1, education programs would continue. During demolition, there may be periodic noise from the demolition activities. All demolition activities would be temporary and periodic; therefore, there would be a direct, minor, adverse, short-term impact on education from demolition activities.

Tourism

Demolition activities may result in the temporary disruption of tourist activities at Arecibo Observatory to accommodate specific activities or the removal of debris. All demolition activity would be temporary and periodic; therefore, there would be a direct, minor, adverse, short-term impact from noise and traffic on tourism from demolition activities at Arecibo Observatory.

4.9.1.2 Operations

Population and Housing

Under Alternative 1, there would be no net change in the number of jobs at the Observatory. These jobs would be financially supported by the scientific collaboration entity that takes over the daily operations of the facility. As a result, there would be no movement of workers into or away from the community. Therefore, there would be no impact to population or housing.

Economy, Employment, and Income

Under Alternative 1, there would be no net change to employment or spending on supplies and materials at Arecibo Observatory. Therefore, there would be no impact to the economy, employment, or income in the Municipality of Arecibo.

Education

Under Alternative 1, there would be no anticipated change in education activities at Arecibo Observatory. Therefore, there would no impact to education.

Tourism

Under Alternative 1, the visitor center would be retained and all tourism would be expected to continue as it does under current operations. Therefore, there would be no impact to tourism.

4.9.2 Alternative 2 – Collaboration with Interested Parties for Transition to Education-focused Operations

Under Alternative 2, 19 facilities would remain and up to 27 facilities could be removed, which include the 26 structures identified under Alternative 1 plus the operations building. As under Alternative 1, 40 temporary demolition jobs would be created. Operations after demolition would be comparable to current operations. Under Alternative 2, it is anticipated that technical staff responsible for the O&M of the 305-meter-diameter telescope would not be retained; instead, other onsite staff would be retained under the new employer(s). Along with the discontinued use of the 305-meter-diameter telescope, there would be a reduction in STEM activities using this radio telescope, but other educational opportunities would be expected to be created.

4.9.2.1 Demolition

Population and Housing

Under Alternative 2, approximately 40 demolition jobs would be created. Impacts from temporary demolition jobs would be similar to those described for Alternative 1. No permanent jobs would be created and no workers would relocate; therefore, there would be no impact to the population of the Municipality of Arecibo. An estimated 8,420 vacant housing units are available in the Municipality of Arecibo (USCB, 2015f); therefore, the temporary presence of five non-local equipment operators would likely result in negligible, adverse, short-term impacts to housing in the ROI.

Economy, Employment, and Income

Under Alternative 2, demolition activities are expected to create 40 demolition jobs over a period of approximately 12 weeks and cost approximately $3.8 million (see Table 4.9-1). These impacts would be similar to Alternative 1 with the exception of a small increase of $0.2 million in demolition costs. Therefore, impacts would be indistinguishable from those described in Alternative 1.

The temporary increase in economic activity from salaries and expenditures would be a direct, negligible, short-term, benefit to the local economy of the Municipality of Arecibo. It is expected there could be some indirect, negligible, short-term benefits to the local economy from increased demolition-related spending in the community, such as expenditures for fuel, temporary site fencing, and erosion and sedimentation control materials, although the amount of such expenditures is unknown at this time and, therefore, a more precise analysis cannot be performed.

It is estimated that 40 demolition jobs would be created under this Alternative, which would be less than a 1 percent increase in the labor force of the Municipality of Arecibo (29,239) over a 12-week period (USCB, 2015g). The increase in jobs would be a direct, negligible, short-term benefit to employment within the ROI (USCB, 2015g). The demolition activity would result in additional income in the Municipality of Arecibo. This income would be derived from salaries of the demolition workers and revenue from the purchase of demolition supplies. This additional income would result in an indirect, negligible, short-term benefit to income in the Municipality of Arecibo.

Education

Impacts from demolition activities to education would be similar to those described for Alternative 1. Under Alternative 2, education programs would continue. During demolition, there may be periodic noise from the demolition activities. All demolition activities would be temporary and periodic; therefore, there would be a direct, minor, adverse, short-term impact to education from demolition activities.

Tourism

Impacts from demolition activities to tourism would be similar to those described for Alternative 1. Under Alternative 2, demolition activities may result in the temporary disruption of tourism activities at Arecibo Observatory to accommodate specific activities or the removal of debris. All demolition activity would be temporary and periodic; therefore, there would be a direct, minor, adverse, short-term impact from noise and traffic to tourism from demolition activities at Arecibo Observatory.

4.9.2.2 Operations

Population and Housing

Under Alternative 2, it is assumed that there would be a small change in the number of jobs at Arecibo Observatory and that the majority of the current positions would be financially supported by the educational collaboration entity that takes over the daily operations of the facility.

It is anticipated that technical staff responsible for the O&M of the 305-meter-diameter telescope would not be retained in that capacity, and that use of this telescope would cease. Currently there are six radio telescope operators (see Table 4.9-1). Under Alternative 2, it is assumed that there would be a reduction of six jobs related to the operation of the 305-meter-diameter telescope. For purposes of analysis, these jobs are described as three radio telescope operators and three maintenance staff. It is assumed that the three remaining telescope operators (of the six total employed at Arecibo Observatory) would be retained to continue operating the remaining radio telescope. This reduction in jobs may result in less than six employees and their families relocating away from the Municipality of Arecibo. However, this small number of individuals would result in a negligible, adverse, long-term impact to population and housing in the Municipality of Arecibo.

Economy, Employment, and Income

Under Alternative 2, research conducted with the 305-meter-diameter telescope would cease. The majority of the research conducted on this telescope is accomplished remotely; therefore, there would be no significant reduction in travel-related spending to the economy of the Municipality of Arecibo (SRI International, 2016).

The reduction of six jobs related to the 305-meter-diameter telescope would result in negligible impacts to the economy. There would be a loss of income from these jobs, which would result in direct and indirect, negligible, adverse, long-term impacts to the economy of the Municipality of Arecibo.

The reduction of six jobs related to the 305-meter-diameter telescope would result in loss of income to the individuals whose jobs were eliminated, as well as a loss of induced income generated from their spending in the community. The reduction of six jobs is considerably less than 1 percent of the labor force in the Municipality of Arecibo (29,239; 0.02 percent of total) (USCB, 2015g). However, given the high unemployment rate in the Municipality of Arecibo (16.6 percent) (USCB, 2015g), the decrease in jobs would likely not be offset by other employment opportunities in the foreseeable future and would not offset in any appreciable way the downward trend in employment and income in the Municipality of Arecibo. Therefore, there would be a direct and indirect, negligible, adverse, long-term impact to employment and income in the Municipality of Arecibo.

Education

Under Alternative 2, the 305-meter-diameter telescope would cease operation. This telescope supports the Research Experiences for Undergraduates and Research Experience for Teachers Program. As a result, there would be a reduction in STEM opportunities. The loss of this telescope operation would result in direct and indirect moderate, adverse, long-term impacts to STEM education.

Because Alternative 2 would be education-focused, it is expected that additional education opportunities would be developed to replace the lost education activities associated with the 305-meter-diameter telescope. It is expected that direct and indirect, minor, long-term benefits to education would result.

Tourism

Under Alternative 2, the visitor center would remain and there would be no impact to tourism.

4.9.3 Alternative 3 – Mothballing of Facilities

Under Alternative 3, eight facilities would remain, 14 facilities would be removed, and 29 facilities would be mothballed. As under Alternative 1, 40 temporary demolition jobs would be created. A maintenance program would be required to protect the remaining facilities from deterioration, vandalism, and other damage until the future uses of these facilities is determined. Staff would be required to continue to maintain the grounds and regular security patrols would be performed to monitor the site. Therefore, it is expected that the current staff of 57 grounds and maintenance personnel would be retained under the Alternative 3. It is anticipated that the technical staff responsible for operating the 12-meter and 305-meter-diameter telescopes, including scientific support staff and cafeteria workers, would not be retained. Under this Alternative, the visitor center would close, resulting in the reduction of eight full-time positions (SRI International, 2016). Under Alternative 3, operations at Arecibo Observatory would be suspended prior to the start of demolition.

4.9.3.1 Demolition

Population and Housing

Under Alternative 3, there would be approximately 40 temporary demolition jobs created for mothballing activities. Impacts would be the same as those for Alternative 1.

Because no permanent jobs would be created and no workers would relocate, there would be no impact to the population of the Municipality of Arecibo. An estimated 8,420 vacant housing units are available in the Municipality of Arecibo (USCB, 2015f). Therefore, the temporary presence of five non-local equipment operators would likely result in direct, negligible, adverse, short-term impacts to housing in the ROI.

Economy, Employment, and Income

The cost of demolition and mothballing activities is estimated to be $2.8 million, which is $0.8 million less than the demolition costs for Alternative 1. Therefore, the impacts to the economy of the Municipality of Arecibo would be similar to, but somewhat less than, those described in Alternative 1.

Under Alternative 3, the temporary increase in economic activity from salaries and expenditures would be a direct, negligible, short-term, benefit to the local economy of the Municipality of Arecibo. It is expected there could be some indirect, negligible, short-term benefits to the local economy from increased demolition-related spending in the community, such as expenditures for fuel, temporary site fencing, and erosion and sedimentation control materials, although the amount of such expenditures is unknown at this time and, therefore, a more precise analysis cannot be performed.

The number of demolition jobs would be the same as for Alternative 1. Therefore, the impacts to employment and income would be the same as those described for Alternative 1.

It is estimated that 40 demolition jobs would be created under Alternative 3, which would be less than a 1 percent increase in the labor force of the Municipality of Arecibo (29,239) over a 15-week period (USCB, 2015g). The increase in jobs would be a direct, negligible, short-term benefit to employment within the ROI (USCB, 2015g). The demolition activity would result in additional income in the Municipality of Arecibo. This income would be derived from salary of the demolition workers and revenue from the purchase of demolition supplies. This additional income would result in an indirect, negligible, short-term benefit to income in the Municipality of Arecibo.

Under this Alternative, the visitor center and all operations would cease prior to mothballing activities. The long-term impacts from these losses of jobs are described in the following Section (*Operations*).

For the purposes of this analysis, it is assumed that 57 grounds and maintenance staff would be retained under Alternative 3; however, there will be a loss of over 77 jobs, which would be considerably less than a 1 percent reduction of the total labor force in the Municipality of Arecibo (29,239; 0.26 percent of total)

(USCB, 2015g) and would result in direct and indirect, negligible, adverse, long-term impacts to employment and income.

Education

Because operations at Arecibo Observatory would be suspended prior to demolition, there would be no impact and no potential for demolition activities to affect education at Arecibo Observatory. Impacts to education under Alternative 3 are discussed under the following Section (*Operations*).

Tourism

Because operations at Arecibo Observatory would be suspended prior to demolition there would be no impact and no potential for demolition activities to affect tourism in the Municipality of Arecibo. Impacts to tourism under Alternative 3 are discussed in the following Section (*Operations*).

4.9.3.2 Operations

Population and Housing

Under this Alternative, it is assumed that the 57 current grounds and maintenance positions would be retained to conduct periodic maintenance and security for the mothballed facility. Alternative 3 would result in the loss of employment of approximately 71 (55.4 percent) of the 128 total local operations-related staff across a range of salaries. Of these staff, 16 are researchers (12.5 percent), 24 provide guest services (18.8 percent), 25 are temporary academic guides (19.5 percent), and six are telescope operators (4.6 percent). Under this Alternative, the visitor center would close, resulting in the reduction of eight full-time positions (SRI International, 2016).

It is assumed that 64 percent or 81 of the operations-related workers are non-telescope-related personnel working in grounds maintenance (57) and guest services (24). It is assumed that these personnel would not relocate in the short term and instead attempt to find other employment in the same field (grounds and maintenance and guest services) elsewhere in the Municipality of Arecibo. However, if all current employees were to leave, there would be a decline in the population of the Municipality of Arecibo (93,969) (USCB, 2015d), which would lead to a negligible, adverse, long-term impact on the population within the ROI. Similar to population, the loss of local employment is not likely to immediately affect housing, with the potential exception of those workers renting instead of owning their housing, because these workers have greater flexibility and could relocate closer to their new employment or leave the region altogether. The vacancy rate of all housing units in the Municipality of Arecibo, regardless of being renter- or owner-occupied, was 20.5 percent in 2014. Should operations-related workers choose to relocate, this overall vacancy rate could increase by 0.3 percent if all 136 operations workers left the ROI, resulting in a negligible, adverse, long-term impact to the housing resources in the ROI. Over time, those workers unable to find local employment could be forced to relocate and sell their homes.

Economy, Employment, and Income

For the purposes of this analysis, it is assumed that 57 grounds and maintenance staff would be retained under Alternative 3. However, there will be a loss of over 77 jobs, which would be considerably less than a 1 percent reduction of the total labor force in the Municipality of Arecibo (29,239; 0.26 percent of total) (USCB, 2015g). This impact would result in a direct and indirect, minor, adverse, long-term impact to the economy, employment and income, from the potential loss or reduction in wages, the reduction in indirect revenue from employees spending in the community, and the challenging economic conditions in the Municipality of Arecibo.

Education

Under Alternative 3, all education programs would cease prior to demolition and mothballing activities. Currently Arecibo Observatory accommodates approximately 19,800 students each year from across the Commonwealth of Puerto Rico for STEM purposes, as well as other scientific researchers who access the facility remotely for scientific research (SRI International, 2016). Under Alternative 3, all of the STEM programs described in Section 3.9 would be eliminated. While other STEM programs may be available in the Commonwealth of Puerto Rico and the United States, they would not have the unique features of the program at Arecibo Observatory. Therefore, mothballing the facility would result in a direct, major, adverse, long-term impact to education programs provided by Arecibo Observatory.

Similarly, while difficult to quantify numerically, the loss of the unique Arecibo Observatory STEM programs may cause an indirect, major, adverse, long-term impact by reducing STEM education and career opportunities for the following populations: school children of the Commonwealth of Puerto Rico; undergraduate and graduate researchers in the Caribbean and Latin America, who are under-represented historically in STEM-related fields; and researchers at colleges and universities in the United States and worldwide.

Under Alternative 3, all education programs (such as teacher workshops, summer internships, tour guide programs, summer camps, science lectures, and summer and Saturday programs for students) would be eliminated. Section 3.9 provides specific details on these programs. While other education programs may be available in the Municipality of Arecibo and the Commonwealth of Puerto Rico, they would not have the unique features of the program at Arecibo Observatory. Therefore, Alternative 3 would result in a direct, moderate, adverse, long-term impact to education.

Tourism

Under Alternative 3, the visitor center would be mothballed and tourism at Arecibo Observatory would cease. Mothballing would necessitate the cessation of onsite tourism activities before the start of mothballing activities, which would stop tourism at Arecibo Observatory and result in a loss of approximately 90,000 tourists (estimated 19,800 students and 70,200 adults) annually. This would be a direct, major, adverse, long-term impact to tourism at Arecibo Observatory.

The Camuy River Cave Park to the west could also experience an indirect decline in visitation because the park is often grouped with a visit to Arecibo Observatory by tour buses departing from San Juan cruise ships. There would likely be indirect, minor, adverse, long-term impacts to other local tourist destinations as a result of the potential decline in visitation at Arecibo Observatory. It is unlikely that the majority of the tourists that visit Arecibo Observatory each year travel to Puerto Rico for the sole purpose of visiting the Observatory. Therefore, these tourists would not forego their visit if Arecibo Observatory is no longer available. The potential tourism impacts would likely be greater for the Municipality of Arecibo than for the Commonwealth of Puerto Rico and while resulting in a direct, major, adverse, long-term impact to the tourism resources of the Municipality of Arecibo, a direct, minor, adverse, long-term impact to the tourism resources of the Commonwealth of Puerto Rico would be expected.

4.9.4 Alternative 4 – Partial Demolition and Site Restoration

Under this Alternative, all structures would be removed with the exception of the following facilities, which would be safe-abandoned:

- 305-meter-diameter telescope dish
- Foundation and rim wall infrastructure supporting the 305-meter-diameter telescope dish
- Three towers
- Six tower anchors, including the catwalk anchor

All onsite jobs would be eliminated, except for six personnel who would be retained for intermittent maintenance of fencing and the safety lighting on the towers.

4.9.4.1 Demolition

Population and Housing

Partial demolition of Arecibo Observatory would occur over a 30-week period and is anticipated to use 40 workers. Impacts would be the same as those described for Alternative 1.

Under Alternative 4, no permanent jobs would be created and no workers would relocate; therefore, there would be no impact to the population of the Municipality of Arecibo. An estimated 8,420 vacant housing units are available in the Municipality of Arecibo (USCB, 2015f). Therefore, the temporary presence of five non-local equipment operators would likely result in negligible, adverse, short-term impacts to housing within the ROI.

Economy, Employment, and Income

Partial demolition cost is estimated at $10.6 million (in 2015 dollars) (see Table 4.9-1), of which the majority is equipment rental and disposal of materials from demolition. Approximately 40 temporary demolition jobs (as defined previously) would be needed over a 30-week period. It is assumed that demolition primarily would directly benefit those entities receiving materials for reuse and recycling, as well as local waste disposal companies used for non-hazardous waste transportation and disposal.

Therefore, a direct, minor, short-term, benefit to the economy of Municipality of Arecibo is expected and there could be some indirect, minor, short-term, benefit from increased demolition-related spending in the community for demolition-related expenditures, such as supplies.

Partial demolition would result in approximately 40 temporary jobs for residents of the Municipality of Arecibo for up to 30 weeks. The increase in jobs would be a direct, minor, short-term benefit to employment and income. Spending by the demolition workers and purchases of demolition supplies within the ROI would result in an indirect, minor, short-term, benefit to the income and economy of the Municipality of Arecibo**.**

Education

Because operations at Arecibo Observatory would cease prior to demolition, there would be no impact, and no potential for demolition activities to affect education at Arecibo Observatory. Impacts to education under Alternative 4 are discussed in the following Section (*Operations*).

Tourism

Because operations at Arecibo Observatory would cease prior to demolition, there would be no impact and no potential for demolition activities to affect tourism at Arecibo Observatory. Impacts to tourism under Alternative 4 are discussed in the following Section (*Operations*).

4.9.4.2 Operations

Population and Housing

Partial demolition of Arecibo Observatory would result in the loss of employment for approximately 136 local staff. Six grounds and maintenance personnel would be retained to conduct safety patrols and intermittent maintenance of fencing and the safety lighting on the towers. Impacts to population and housing from this reduction would be the same as those described under Operations for Alternative 3.

Under Alternative 4, if all current employees were to leave, there would be a negligible decline in the population of the Municipality of Arecibo (93,969) (USCB, 2015d) resulting in a negligible, adverse, long-term impact on population in the ROI. Similar to population, the loss of local employment is not likely to immediately affect housing, with the potential exception of those workers renting instead of owning their housing, because these workers have greater flexibility and could relocate closer to their new employment or leave the region altogether. The vacancy rate of all housing units in the Municipality of Arecibo, regardless of being renter or owner occupied, was 20.5 percent in 2014. Should operation workers choose to relocate, this overall vacancy rate could increase by 0.3 percent if all 136 operations workers left the ROI, resulting in a negligible, adverse, long-term impact to the housing resources in the ROI. Over time, those workers unable to find local employment could be forced to relocate and sell their homes.

Economy, Employment, and Income

The loss of 136 jobs, would be considerably less than a one percent reduction of the total labor force in the Municipality of Arecibo (29,239; 0.47 percent of total) (USCB, 2015g). This impact would result in a direct and indirect, minor, adverse, long-term impact to the economy, employment and income from the potential loss or reduction in wages, the reduction in indirect revenue from employees spending in the community, and the challenging economic conditions in the Municipality of Arecibo.

Education

Partial demolition of Arecibo Observatory would result in the loss of education and research opportunities. Impacts to education and research would be the same as those described in the *Operations* Section for Alternative 3 and are summarized below.

Under Alternative 4, all of the STEM programs described in Section 3.9 would be eliminated. While other STEM programs may be available in the Commonwealth of Puerto Rico United States, they would not have the unique features of the program at Arecibo Observatory. Therefore, mothballing the facility would result in a direct, major, adverse, long-term impact to education programs provided by Arecibo Observatory.

Similarly, while difficult to quantify numerically, the loss of the unique Arecibo Observatory STEM programs may cause an indirect, major, adverse, long-term impact by reducing STEM education and career opportunities for the following populations: school children of the Commonwealth of Puerto Rico; undergraduate and graduate researchers in the Caribbean and Latin America, who are under-represented historically in STEM-related fields; and researchers at colleges and universities in the United States and worldwide.

Under Alternative 4, all education programs (such as teacher workshops, summer internships, tour guide programs, summer camps, science lectures, and summer and Saturday programs for students) would be eliminated. Section 3.9 provides specific details on these programs. While other education programs may be available in the Municipality of Arecibo and the Commonwealth of Puerto Rico, they would not have the unique features of the program at Arecibo Observatory. Therefore, Alternative 4 would result in be a direct, major, adverse, long-term impact to education.

Tourism

Partial demolition of Arecibo Observatory would result in the loss of tourism opportunities. Impacts to tourism would be the same as those described under the *Operations* Section for Alternative 3 and are summarized below.

Under Alternative 4, the visitor center and tourism at Arecibo Observatory would cease. Alternative 4 would necessitate the cessation of onsite tourism activities before the start of demolition activities resulting in a loss of approximately 90,000 tourists (estimated 19,800 students and 70,200 adults) that visit the Observatory annually. This would be a direct, major, adverse, long-term impact to tourism at Arecibo Observatory.

The Camuy River Cave Park to the west could also experience an indirect decline in visitation because the park is often grouped with a visit to Arecibo Observatory by tour buses departing from San Juan cruise ships. There would likely be indirect, minor, adverse, long-term impact to other local tourist destinations as a result of the potential decline in visitation at Arecibo Observatory. It is unlikely that the majority of the tourists that visit Arecibo Observatory each year travel to Puerto Rico for the sole purpose of visiting the Observatory. Therefore, these tourists would not forego their visit if Arecibo Observatory is no longer available. The potential tourism impacts would likely be greater for the Municipality of Arecibo than for the Commonwealth of Puerto Rico and while resulting in a direct, major, adverse, long-term impact to the tourism resources of the Municipality of Arecibo, a direct, minor, adverse, long-term impact to the tourism resources of the Commonwealth of Puerto Rico would be expected.

4.9.5 Alternative 5 – Complete Demolition and Site Restoration

Alternative 5 involves the demolition of all facilities at Arecibo Observatory and the elimination of all onsite jobs. This demolition activity would occur over a 38-week period and would require 45 demolition workers. All operations activities including science research, education, tourism, grounds and facilities maintenance, visitor center activities, and support services would be eliminated. Under Alternative 5, there would be major, adverse, long-term impacts to education and tourism. The following Sections provide specific details.

4.9.5.1 Demolition

Population and Housing

Complete demolition of Arecibo Observatory would occur over a 38-week period and is anticipated to use the same number and types of demolition workers as are assumed under Alternative 1. However, this work would require an additional five specialty explosive demolition experts to be brought onsite to oversee the removal of towers, tower and catwalk anchors, and the foundation and rim wall infrastructure supporting the 305-meter-diameter telescope dish (Reese, 2016b, pers. comm.). These demolition experts could stay up to 1 month and are anticipated to find temporary housing (rentals or hotels) in Arecibo, San Juan, or Poncé. As described in Alternative 1, approximately five equipment operators also may come from outside the Municipality of Arecibo to complete these activities. Because of the short duration of this work, it is assumed the 10 non-local workers would not relocate or bring their families to the Municipality of Arecibo. Under Alternative 5, no permanent jobs would be created and no workers would relocate; therefore, there would be no impact to the population of the Municipality of Arecibo. Based on the estimated 8,420 rental units available in the Municipality of Arecibo, there would be a negligible, adverse, short-term impact to housing and population in the ROI.

Economy, Employment, and Income

Complete demolition cost is estimated at $18.7 million (in 2015 dollars) (see Table 4.9-1), of which the majority is equipment rental and the disposal of materials from demolition. It is assumed that full demolition primarily would directly benefit those entities receiving materials for reuse and recycling, as well as local waste disposal companies used for non-hazardous waste transportation and disposal. Therefore, a direct, minor, short-term, benefit to the economy of the Municipality of Arecibo is expected and there could be some indirect, minor, short-term benefit from increased demolition-related spending in the community for demolition-related expenditures, such as supplies. Where the demolition materials would be purchased, as well as the origin of the specialty contractors, is unknown; therefore, the magnitude of this impact was not fully determined.

The employment impacts from full demolition of Arecibo Observatory would be the same as those described in Alternative 4, with the exception of the five additional non-local explosives specialists who would come for approximately 1 month to assist with demolition. Because these specialty contractors would be non-local, no additional impact to employment or the local labor force would result. Spending from these five explosives specialists for meals, lodging, and other travel expenditures while working in the Municipality of Arecibo may result in a short-term increase of income to the community. These potential income impacts would be an indirect, minor, short-term, benefit.

Education

Because operations at Arecibo Observatory would cease prior to demolition, there would be no impact and no potential for demolition activities to affect education at Arecibo Observatory. Impacts to education under Alternative 5 are discussed in the *Operations* Section.

Tourism

Because operations at Arecibo Observatory would cease prior to demolition, there would be no impact and no potential for demolition activities to affect tourism at Arecibo Observatory. Impacts to tourism under Alternative 5 are discussed in the *Operations* Section.

4.9.5.2 Operations

Population and Housing

Complete demolition of Arecibo Observatory would result in the loss of 136 local jobs. Impacts to population and housing would be the same as those described in the *Operations* Section for Alternative 3, and as described below.

If all current employees were to leave, there would be a negligible decline in the population of the Municipality of Arecibo (93,969) (USCB, 2015d) resulting in a negligible, adverse, long-term impact to the population within the ROI. Similar to population, the loss of local employment is not likely to immediately affect housing, with the potential exception of those workers renting instead of owning their housing, because these workers have greater flexibility and could relocate closer to their new employment or leave the region altogether. The vacancy rate of all housing units in the Municipality of Arecibo, regardless of being renter- or owner-occupied, was 20.5 percent in 2014. Should operations-related workers choose to relocate, this overall vacancy rate could increase by 0.3 percent if all 136 operations workers left the ROI, resulting in a negligible, adverse, short-term impact to the housing resources in the ROI. Over time, those workers unable to find local employment could be forced to relocate and sell their homes.

Economy, Employment, and Income

Qualitative analysis of the loss of 136 jobs at Arecibo Observatory (less than 0.5 percent of the Municipality of Arecibo labor force) indicates that direct and indirect, minor, adverse, long-term impacts to the local economy, employment and income of the Municipality of Arecibo would result from the potential loss or reduction in wages, the reduction in indirect revenue from employees spending in the community, and the challenging economic conditions in the Municipality of Arecibo.

Education

Complete demolition would result in the elimination of all education programs at Arecibo Observatory. Impacts to education would be the same as those described in the *Operations* Section for Alternative 3.

Under Alternative 5, all of the STEM programs described in Section 3.9 would be eliminated. While other STEM programs may be available in the Commonwealth of Puerto Rico and the United States, they would not have the unique features of the program at Arecibo Observatory; therefore, demolition of the facilities would result in a direct, major, adverse, long-term impact to education programs provided by Arecibo Observatory.

Similarly, while difficult to quantify numerically, the loss of the unique Arecibo Observatory STEM programs may cause an indirect, major, adverse, long-term impact by reducing STEM education and career opportunities for the following populations: school children of the Commonwealth of Puerto Rico; undergraduate and graduate researchers in the Caribbean and Latin America, who are under-represented historically in STEM-related fields; and researchers at colleges and universities in the United States and worldwide.

Under Alternative 5, all education programs (such as teacher workshops, summer internships, tour guide programs, summer camps, science lectures, and summer and Saturday programs for students) would be eliminated. Section 3.9 provides specific details about these programs. While other education programs may be available in the Municipality of Arecibo and the Commonwealth of Puerto Rico, they would not have the unique features of the program at Arecibo Observatory; therefore, Alternative 5 would result in a direct, major, adverse, long-term impact to education.

Tourism

The potential impacts to tourism from this Alternative start prior to demolition. Impacts to tourism would be the same as those described in the *Operations* Section for Alternative 3.

Under Alternative 5, the visitor center would be removed and tourism at Arecibo Observatory would cease. Alternative 5 would necessitate the cessation of onsite tourism activities before the start of demolition activities resulting in a loss of approximately 90,000 tourists (estimated 19,800 students and 70,200 adults) that visit the Observatory annually. This would be a direct, major, adverse, long-term impact to tourism at Arecibo Observatory.

The Camuy River Cave Park to the west could also experience an indirect decline in visitation because the park is often grouped with a visit to Arecibo Observatory by tour buses departing from San Juan cruise ships. There would likely be indirect, minor, adverse, long-term impact to other local tourist destinations as a result of the potential decline in visitation at Arecibo Observatory. It is unlikely that the majority of the tourists that visit Arecibo Observatory each year travel to Puerto Rico for the sole purpose of visiting the Observatory. Therefore, these tourists would not forego their visit if Arecibo Observatory is no longer available. The potential tourism impacts would likely be greater for the Municipality of Arecibo than for the Commonwealth of Puerto Rico and while resulting in a direct, major, adverse, long-term impact to the tourism resources of the Municipality of Arecibo, a direct, minor, adverse, long-term impact to the tourism resources of the Commonwealth of Puerto Rico would be expected.

4.9.6 No-Action Alternative

Under the No-Action Alternative, no demolition would occur and there would be no change to staffing at or visitation to Arecibo Observatory. There would be no change to socioeconomic conditions within the ROI; therefore, there would be no impacts, adverse or beneficial, resulting from the No-Action Alternative.

4.9.7 Summary of Potential Impacts

Table 4.9-3 provides a summary of the socioeconomic impacts for each of the Alternatives and the No-Action Alternative.

TABLE 4.9-3
Summary of Socioeconomics Impacts

	Alternatives					
Impact	**Alternative 1**	**Alternative 2**	**Alternative 3**	**Alternative 4**	**Alternative 5**	**No-Action**
Demolition Impact Summary						
Population – Municipality of Arecibo	No Impact	No Impact	No Impact	No Impact	No Impact	No Impact

TABLE 4.9-3
Summary of Socioeconomics Impacts

	Alternatives					
Impact	**Alternative 1**	**Alternative 2**	**Alternative 3**	**Alternative 4**	**Alternative 5**	**No-Action**
Housing – Municipality of Arecibo	Negligible, adverse, short-term impact	Negligible, adverse, short-term impact	Negligible, adverse, short-term impact	Negligible, adverse, short-term impact	Negligible, adverse, short-term impact	No Impact
Economy – Municipality of Arecibo	Direct and indirect negligible, short-term benefit	Direct and indirect negligible, short-term benefit	Direct and indirect negligible, short-term benefit	Direct and indirect minor, short-term benefit	Direct and indirect minor, short-term benefit	No Impact
Employment – Municipality of Arecibo	Direct and indirect negligible, short-term benefit	Direct and indirect negligible, short-term benefit	Direct and indirect negligible, short-term benefit	Direct and indirect minor, short-term benefit	Direct and indirect minor, short-term benefit	No Impact
Income – Municipality of Arecibo	Direct and indirect negligible, short-term benefit	Direct and indirect negligible, short-term benefit	Direct and indirect negligible, short-term benefit	Direct and indirect, minor, short-term benefit	Direct and indirect, minor, short-term benefit	No Impact
Education – Commonwealth of Puerto Rico	Direct and indirect minor, adverse, short-term impact	Direct and indirect minor, adverse, short-term impact	No Impact	No Impact	No Impact	No Impact
Tourism – Municipality of Arecibo	Direct, minor, adverse, short-term impact	Direct, minor, adverse, short-term impact	No Impact	No Impact	No Impact	No Impact
Operations Impact Summary						
Population – Municipality of Arecibo	No Impact	Negligible, adverse, long-term impact	Negligible, adverse, long-term impact	Negligible, adverse, long-term impact	Negligible adverse, long-term impact	No Impact
Housing – Municipality of Arecibo	No Impact	Negligible adverse, long-term impact	Negligible adverse, long-term impact	Negligible adverse, long-term impact	Negligible adverse, short-term impact	No Impact
Economy – Municipality of Arecibo	No Impact	Direct and indirect negligible, adverse, long-term impact	Direct and indirect minor, adverse, long-term impact	Direct and indirect minor, adverse, long-term impact	Direct and indirect minor, adverse, long-term impact	No Impact
Employment – Municipality of Arecibo	No Impact	Direct and indirect negligible, adverse, long-term impact	Direct and indirect minor adverse, long-term impact	Direct and indirect minor adverse, long-term impact	Direct and indirect minor adverse, long-term impact	No Impact
Income – Municipality of Arecibo	No Impact	Direct and indirect negligible, adverse long-term impact	Direct and indirect minor, adverse, long-term impact	Direct and indirect minor, adverse, long-term impact	Direct and indirect minor, adverse, long-term impact	No Impact

TABLE 4.9-3
Summary of Socioeconomics Impacts

	Alternatives					
Impact	**Alternative 1**	**Alternative 2**	**Alternative 3**	**Alternative 4**	**Alternative 5**	**No-Action**
Education Commonwealth of Puerto Rico	No Impact	Direct and indirect moderate, adverse, long-term impact to STEM opportunities Direct and indirect minor, beneficial, long-term impact from new STEM programs	Direct and indirect major, adverse, long-term impact to education (STEM programs) Direct moderate, adverse, long-term impact to education (general)	Direct and indirect major, adverse, long-term impact to education	Direct and indirect major, adverse, long-term impact to education	No Impact
Tourism – Municipality of Arecibo and Commonwealth of Puerto Rico	No Impact	No Impact	Direct major, adverse, long-term impact to tourism at Arecibo Observatory and in the Municipality of Arecibo Indirect, minor adverse, long-term impact to other local tourism destinations Direct minor adverse, long-term impact on tourism in the Commonwealth	Direct major, adverse, long-term impact to tourism at Arecibo Observatory and in the Municipality of Arecibo Indirect, minor adverse, long-term impact to other local tourism destinations Direct minor, adverse, long-term impact on tourism in the Commonwealth	Direct major, adverse, long-term impact to tourism at Arecibo Observatory and in the Municipality of Arecibo Indirect, minor adverse, long-term impact to other local tourism destinations Direct minor adverse, long-term impact on tourism in the Commonwealth	No Impact

4.10 Traffic and Transportation

Methodology

This Section describes the potential impacts to the transportation infrastructure and traffic operations for each of the Alternatives within the ROI. The ROI for traffic and transportation includes the roadway network leading to Arecibo Observatory and along the potential demolition waste haul routes as shown on Figures 4.10-1 and 4.10-2. Current traffic levels on the surrounding roadway network are influenced by existing Arecibo Observatory staffing and visitation levels. Predicted changes in traffic patterns resulting from the Alternatives (demolition and operations) were evaluated against the current roadway network and conditions. These predicted changes were then compared against the impact thresholds defined in Table 4.10-1. Figures 4.10-1 and 4.10-2 show the expected haul routes for all five of the Alternatives.

Table 4.10-1 presents the impact thresholds for traffic and transportation.

TABLE 4.10-1
Impact Thresholds for Traffic and Transportation

Impact Intensity	Description
Negligible	The Proposed Action would not result in a change in traffic or transportation resources or the change would be so small that it would not be noticeable.
Minor	The Proposed Action would result in a noticeable change in traffic and road conditions on the roadway network within the ROI; however, the change would not exceed roadway capacity or cause delays on the roadway network. Road damage resulting from NSF activities, while noticeable, would not affect usability.
Moderate	The Proposed Action would result in a measurable and consequential change in traffic within the ROI; while minimal delays may occur, roadway capacity would not be exceeded. Road damage resulting from NSF activities could affect usability but would be reparable.
Major	The Proposed Action would result in a substantial change in traffic on the roadway network within the ROI; noticeable delays would occur and roadway capacity would be exceeded. Road damage resulting from NSF activities would be readily apparent and render a road unusable.

Duration: Short-term – Occurs only during the implementation of the Proposed Action.
Long-term – Continues after the implementation of the Proposed Action.

4.10.1 Alternative 1 – Collaboration with Interested Parties for Continued Science-focused Operations (Agency-preferred Alternative)

Demolition

Approximately 25 workers would be onsite during the anticipated 12-week demolition period to carry out those activities. Additionally, over the 12-week demolition period there would approximately four mobilization-related truck trips and 98 heavy truck trips hauling demolition waste to the landfill. Throughout the 12-week demolition period it is anticipated that no more than 12 truck trips hauling demolition waste would operate on any given 8-hour workday (Dreher, 2016, pers. comm.). It is expected that each of the 12 trucks would perform one trip to and from the site, using the potential haul routes shown on Figures 4.10-1 and 4.10-2. The round-trips would result in a total of 24 truck trips on the roadway per day. Given the current traffic volumes on these routes and the narrow, curving local roadways, this relatively small increase in truck traffic would likely be noticeable, but would not exceed roadway capacity or result in delays; consequently, Alternative 1 would result in a minor, adverse, short-term impact to transportation. Transport of demolition vehicles and materials would occur during off-peak hours when practicable to minimize conflicts between project traffic and normal daily traffic. In addition, to minimize the impacts of demolition on local residents, the contractor would be required to coordinate with local public schools to ensure haul routes do not adversely affect school bus traffic.

Truck drivers working on demolition would be notified of all potential height restrictions and overhead obstructions to ensure no property damage or physical injuries occur. Vehicles used for material transport would be required to comply with local standards for height, width, and length of vehicles when practicable. If at any time vehicles of excessive size and weight are required on local roads and bridges, NSF's selected contractor will coordinate with the appropriate transportation authority to obtain the necessary permits and determine the appropriate mitigations. Further detailed waste haul routes and concerns would be addressed during the detailed design phase of the Proposed Action, including verification that all bridge crossings on the delivery routes have adequate strength and capacity to allow safe hauling of waste. Given the current state of the regional roads leading to Arecibo Observatory and the quantity of construction traffic projected, minor, adverse long-term impacts are expected from road damage associated with demolition activities.

The demolition may be extended beyond a single 12-week period. However, this would not result in changes to the assessment of potential impacts to traffic. The demolition-related traffic, including both worker traffic and debris-hauling traffic, would be spread over a longer period, resulting in less traffic per unit of time. This would result in a reduction of potential impacts, but not enough to warrant changing the assessment of impacts.

Operations

Under Alternative 1, staffing and visitation would remain the same as compared with existing conditions, resulting in no impact to traffic along the access routes to Arecibo Observatory.

4.10.2 Alternative 2 – Collaboration with Interested Parties for Transition to Education-focused Operations

Demolition

The impacts associated with demolition truck traffic for Alternative 2 would be identical to Alternative 1, because the same number of truck trips are expected, and similar BMPs would also be implemented. Consequently, the impacts to traffic and from road damage also would be minor, adverse, short-term impacts. Similar to Alternative 1, there would be no expected change in the intensity of potential impacts if the demolition is extended beyond a single 12-week period.

Operations

Under Alternative 2, staffing and visitation would remain the same compared with existing conditions, resulting in no impact to traffic along the access routes to Arecibo Observatory.

4.10.3 Alternative 3 – Mothballing of Facilities

Demolition

Under Alternative 3, daily visitation and mission-related staffing would cease. During the demolition/mothballing period, traffic accessing Arecibo Observatory would be related to facility demolition. Approximately 25 demolition workers would be onsite during the anticipated 15-week demolition period. Additionally, over the 15-week demolition period there would approximately two mobilization-related truck trips and 51 heavy truck trips hauling demolition waste to the landfill. Throughout the 15-week demolition period it is anticipated that no more than 12 truck trips hauling demolition waste would operate on any given 8-hour workday (Dreher, 2016, pers. comm.). The BMPs described in Alternative 1 would also be implemented for Alternative 3. Overall traffic within the ROI is anticipated to decrease during the demolition period because demolition-related traffic would be less than current staffing-and visitation-related traffic. However, the presence of heavy trucks on the narrow, curving local roadways would still likely be noticeable; consequently, implementation of Alternative 3 would result in a minor, adverse, short-term traffic impact and a minor, adverse, short-term impact from road damage. Similar to Alternative 1, there would be no expected change in the intensity of potential impacts if the demolition is extended beyond a single 15-week period.

Operations

Under Alternative 3, Arecibo Observatory would be mothballed and staffing and visitation would cease with the exception of occasional maintenance and security personnel. This would result in a decrease in traffic along the access routes to Arecibo Observatory. The decrease in operations-related traffic would result in a minor, beneficial, long-term traffic and transportation impact.

4.10.4 Alternative 4 – Partial Demolition and Site Restoration

Demolition

Under Alternative 4, daily visitation- and mission-related staffing would cease. During the demolition period, traffic accessing Arecibo Observatory would be related to facility demolition. Approximately 25 demolition workers would be onsite during the anticipated 28-week demolition period. Additionally, over the 28-week demolition period there would be approximately 12 mobilization-related truck trips and 622 heavy truck trips hauling demolition waste to the landfill. Throughout the 28-week demolition period it is anticipated that no more than 12 truck trips hauling demolition waste would operate on any given 8-hour workday (Dreher, 2016, pers. comm.). Overall traffic within the ROI is anticipated to decrease during the demolition period because demolition-related traffic would be less than current staffing- and visitation-related traffic. However, the presence of heavy trucks on the narrow, curving local roadways would still likely be noticeable; consequently, implementation of Alternative 4 would result in a minor, adverse, short-term traffic impact and a moderate, adverse, long-term impact from road damage. The BMPs described in Alternative 1 would also be implemented for Alternative 4. Similar to Alternative 1, there would be no expected change in the intensity of potential impacts if the demolition is extended beyond a single 28-week period.

Operations

Under Alternative 4, Arecibo Observatory would be partially demolished and staffing and visitation would cease, resulting in a decrease in traffic along the access routes to Arecibo Observatory. The decrease in operations-related traffic would constitute a moderate, beneficial, long-term traffic and transportation impact.

4.10.5 Alternative 5 – Complete Demolition and Site Restoration

Demolition

Under Alternative 5, daily visitation- and mission-related staffing would cease. During the demolition period, traffic accessing Arecibo Observatory would be related to facility demolition. Approximately 25 demolition workers would be onsite during the anticipated 38-week demolition period. Additionally, over the 38-week demolition period there would approximately 18 mobilization-related trucks and 749 heavy truck trips hauling demolition waste to the landfill. Throughout the 38-week demolition period it is anticipated that no more than 12 truck trips hauling demolition waste would operate on any given 8-hour workday (Dreher, 2016, pers. comm.). Overall traffic within the ROI is anticipated to decrease during the demolition period because demolition-related traffic would be less than current staffing- and visitation-related traffic. However, the presence of heavy trucks on the narrow, curving local roadways would still likely be noticeable; consequently, implementation of Alternative 5 would result in a minor, adverse, short-term traffic impact and a moderate, adverse, long-term impact from road damage. The BMPs described in Alternative 1 would also be implemented for Alternative 5. Similar to Alternative 1, there would be no expected change in the intensity of potential impacts if the demolition is extended beyond a single 38-week period.

Operations

Under Alternative 5, Arecibo Observatory would be fully demolished. Similar to Alternative 4, all staffing and visitation would cease, resulting in a decrease in traffic along the access routes to Arecibo Observatory. The decrease in operations-related traffic would constitute a moderate, beneficial, long-term traffic and transportation impact.

4.10.6 No-Action Alternative

Under the No-Action Alternative, no demolition would occur and there would be no change to staffing or visitation to Arecibo Observatory. Therefore, there would be no change to traffic or transportation conditions within the ROI.

4.10.7 Mitigation Measures

The following measures would be implemented to reduce impacts from traffic:

- All Alternatives: Transport of materials and demolition vehicles would occur during off-peak hours when practicable.
- All Alternatives: Delivery truck personnel and demolition workers would be notified of all potential height restrictions and overhead obstructions.
- All Alternatives: Vehicles used for material transport would be required to comply with local standards for height, width, and length of vehicles, when practicable. If at any time vehicles of

excessive size and weight are required on local roads and bridges, NSF will coordinate with the appropriate transportation authority to obtain the necessary permits.

- All Alternatives: NSF will coordinate with the appropriate transportation authority to determine the appropriate mitigations to implement in response to road damage.
- All Alternatives: Further detailed waste haul routes and concerns would be addressed during the detailed design phase of the Proposed Action, including verification that all bridge crossings on the delivery routes have adequate strength and capacity.
- All Alternatives: To minimize the impacts of demolition on local residents, the contractor would coordinate with local public schools to ensure demolition and haul routes do not adversely affect school bus traffic.

4.10.8 Summary of Impacts

Table 4.10-2 provides a summary of traffic and transportation impacts resulting from the Alternatives.

TABLE 4.10-2
Summary of Traffic and Transportation Impacts

	Alternatives					
Impact	**Alternative 1**	**Alternative 2**	**Alternative 3**	**Alternative 4**	**Alternative 5**	**No-Action**
Increased demolition traffic	Minor, adverse, short-term impact	Minor, adverse, short-term impact	Minor, adverse, short-term impact	Minor, adverse, short-term impact	Minor, adverse, short-term impact	No impact
Road damage from demolition traffic	Minor, adverse, long-term impact	Minor, adverse, long-term impact	Minor, adverse, long-term impact	Moderate, adverse, long-term impact	Moderate, adverse, long-term impact	No impact
Operations-related traffic	No impact	No impact	Minor, long-term benefit	Moderate, long-term benefit	Moderate, long-term benefit	No impact

FIGURE 4.10-1
Transportation Haul Routes

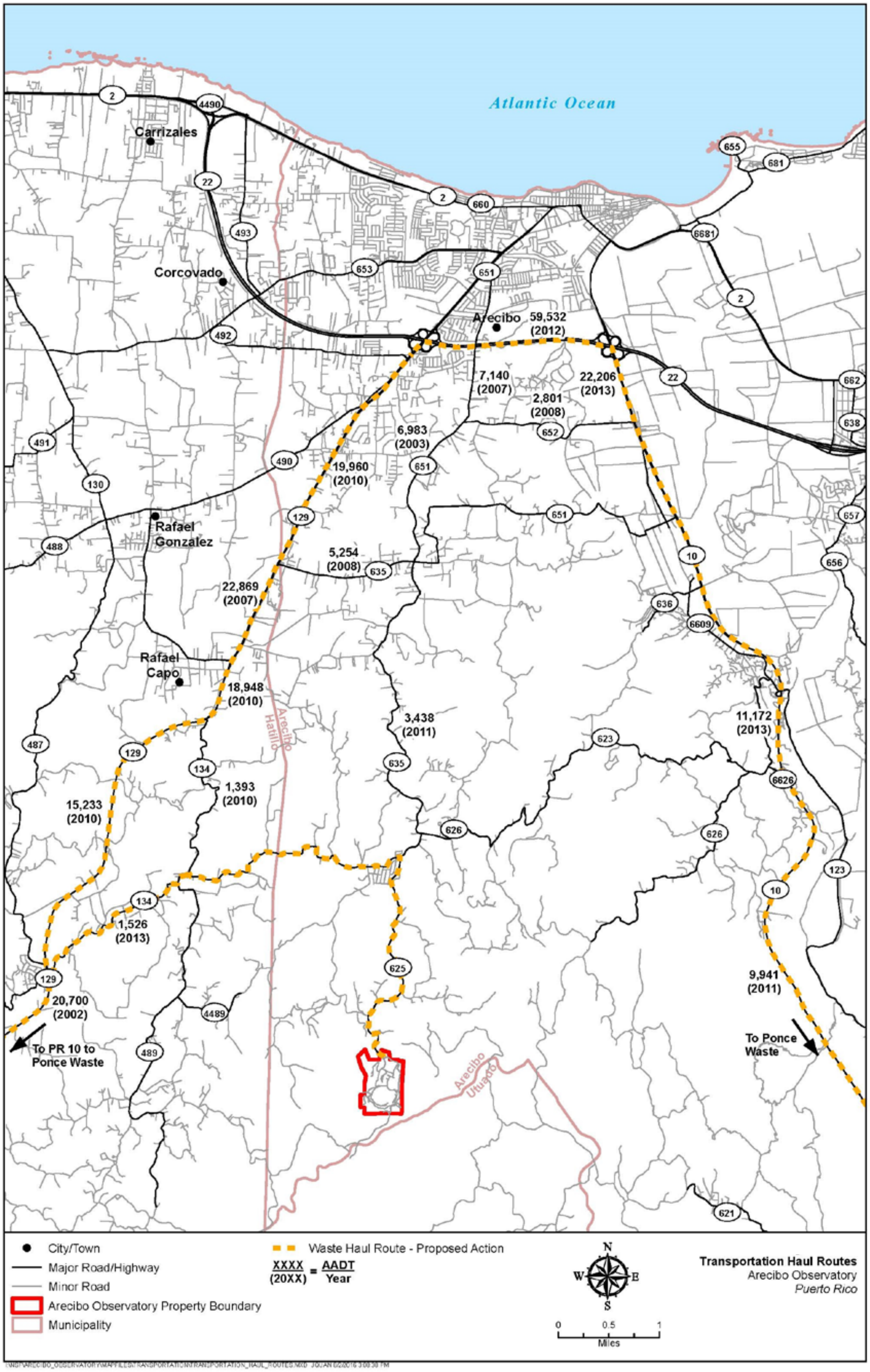
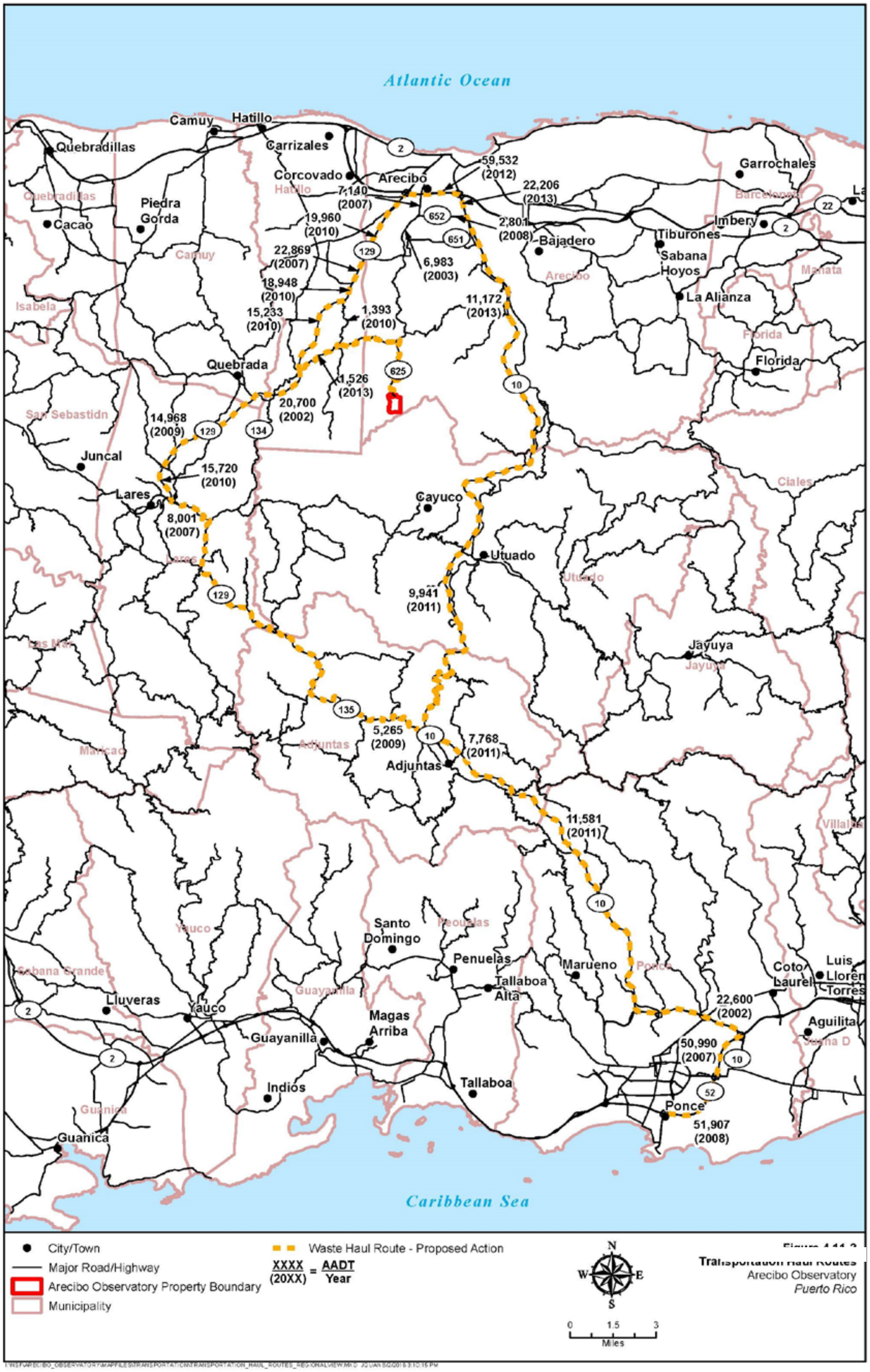


FIGURE 4.10-2

Transportation Haul Routes – Regional View



4.11 Visual Resources

Methodology

This Section describes the potential impacts to visual resources within the ROI as a result of implementing the Proposed Action or as a result of the No-Action Alternative. The visual character and visual quality of the property were used to determine impacts to primary viewers. Answering the following questions helped assess impacts to visual resources:

- Would the Proposed Action result in a perceivable change to the existing visual character of Arecibo Observatory?
- Would perceivable changes provide the same visual quality as the current conditions (i.e., remain high, average, or low)?

Table 4.11-1 identifies the impact thresholds for visual resources.

TABLE 4.11-1
Impact Thresholds for Visual Resources

Impact Intensity	Description
Negligible	Nearly imperceptible impacts to visual resources would be expected.
Minor	There would be only a slight change to the existing visual character of the area; however, the changes would provide the same visual quality as the current conditions (that is, remain high, average, or low).
Moderate	There would be perceivable change to the existing visual character of the area; however, the changes would provide the same visual quality as the current conditions (that is, remain high, average, or low).
Major	There would be a substantial change to the existing visual quality of the area.

Duration: Short-term – Occurs only during the demolition period.
Long-term – Continues after the demolition period.

4.11.1 Alternative 1 – Collaboration with Interested Parties for Continued Science-focused Operations (Agency-preferred Alternative)

Demolition

Demolition activities under Alternative 1 could impact views of the 305-meter-diameter radio telescope and surrounding landscape, which are considered sensitive visual resources. Dust from demolition activities, the presence of heavy equipment, and safety measures implemented during demolition such as fencing and barricades could temporarily diminish the visual quality of the site. Additionally, removal of resources within the Observatory would alter the appearance of the site and could change the visual character overall. However, under Alternative 1, the 305-meter-diameter radio telescope, which is a sensitive visual resource, would remain extant and the visual quality of the site would remain high. Impacts to sensitive visual resources during demolition would be perceivable but minor, adverse, and short-term.

Operations

Operation under Alternative 1 would not result in any change to the sensitive visual resources within Arecibo Observatory and would not alter the visual quality of the overall site. Therefore, operation under Alternative 1 would result in no impact to sensitive visual resources.

4.11.2 Alternative 2 – Collaboration with Interested Parties for Transition to Education-focused Operations

Demolition

Demolition activities for Alternative 2 would be similar to Alternative 1 and could result in similar temporary impacts to visual resources, including dust, heavy equipment, and safety measures. In addition, preparation of the 305-meter-diameter radio telescope for safe-abandonment would involve the removal of the large support cables for the towers and the Gregorian dome that is suspended above the 305-meter-diameter radio telescope dish. This would result in a perceivable change to the existing visual character. However, the 305-meter-diameter radio telescope dish would not be altered as a result of these preparations, and the changes would not alter the site's overall visual quality; the 305-meter-diameter radio telescope dish within the surrounding landscape would retain high visual quality. The impacts to visual resources for Alternative 2 would be moderate, adverse, and long-term.

Operation

Under Alternative 2, the 305-meter-diameter radio telescope would be safe-abandoned. Without regular maintenance, the visual quality of the 305-meter-diameter radio telescope would likely diminish. Over time, this could result in a slight change to the existing visual character of the historic district, although the visual quality of the site would remain high. The 305-meter-diameter radio telescope would remain extant and any visual impacts as a result of safe-abandonment would be considered minor, adverse, and long-term.

4.11.3 Alternative 3 – Mothballing of Facilities

Demolition

Under Alternative 3, most facilities within Arecibo Observatory would be mothballed, while some would be demolished or retained. Demolition activities would result in temporary impacts to visual resources as a result of dust, heavy equipment, and safety measures. However, fewer impacts would result from demolition activities under Alternative 3 than under Alternatives 1 and 2 because fewer facilities would be demolished under Alternative 3. Demolition of facilities would result in a change to the existing visual character of the area, but would not alter the visual quality of the overall Observatory since no sensitive visual resources would be altered. The 305-meter-diameter radio telescope would be mothballed and its setting would be retained. Mothballing the 305-meter-diameter radio telescope would not result in any perceivable visual change to the instrument or its surrounding. Therefore, Alternative 3 would result in negligible, adverse, short-term impacts to visual resources as a result of temporary demolition activities.

Operations

Operation would essentially cease under Alternative 3, thereby eliminating access to the Observatory by its current primary viewers, including Arecibo Observatory employees, visiting scientists, and other visitors. However, visual quality of the overall site would remain high and sensitive visual resources would be preserved for future viewing. Therefore, Alternative 3 would result in no impact to visual resources.

4.11.4 Alternative 4 – Partial Demolition and Site Restoration

Demolition

Alternative 4 involves the demolition of the 305-meter-diameter radio telescope, which is considered a sensitive visual resource located within an area of high visual quality. The demolition of nearly all facilities within the Observatory, including the 305-meter-diameter radio telescope, would result in a significant change to the site’s visual character as few elements of the Observatory would remain extant. Only the foundation and rim, wall towers, and anchors of the 305-meter-diameter radio telescope would remain, as they would be safe-abandoned under Alternative 4. However, without the associated reflector dish and Observatory facilities, these remaining structures would lose their visual context. Visually, the safe-abandoned elements would no longer be part of a larger instrument, but instead would be isolated structures that contrast with the natural surroundings. As a result, the safe-abandoned structures could be viewed as construction debris or intrusions within the landscape. This could change the visual quality of the site from high to low. Therefore, as a result of demolition activities during Alternative 4, the Proposed Action would be a major, adverse, long-term impact to visual resources.

Operations

Operations would completely cease under Alternative 4; therefore, operations following implementation of Alternative 4 would result in no impact to visual resources.

4.11.5 Alternative 5 – Complete Demolition and Site Restoration

Demolition

Demolition activities for Alternative 5 would be similar to Alternative 4, in that both involve the demolition of the 305-meter-diameter radio telescope, which is a sensitive visual resource. In addition, under Alternative 5, all Observatory facilities would be demolished, which would result in a significant change to the site’s visual character. However, under Alternative 5, the site would be restored to a natural state. While the Observatory would not exist and would not be accessible to visitors, the natural setting of the site, without any Observatory-related buildings or structures, would retain high visual quality due to the surrounding landscape. Therefore, Alternative 5 would result in a moderate, adverse, long-term impact to visual resources.

Operations

Operations would completely cease under Alternative 5; therefore, operations following implementation of Alternative 5 would result in no impact to visual resources.

4.11.6 No-Action Alternative

The No-Action Alternative is the continuation of the current use of Arecibo Observatory. Under the No-Action Alternative, current activities would continue at the site, and no demolition would be expected to occur. The visual character and quality of the site would not change. Therefore, the No-Action Alternative would have no impact to visual resources.

4.11.7 Summary of Impacts

Table 4.11-2 provides a summary of impacts resulting from the Alternatives on visual resources.

TABLE 4.11-2
Summary of Visual Resources Impacts

	Alternatives					
Impacts	**Alternative 1**	**Alternative 2**	**Alternative 3**	**Alternative 4**	**Alternative 5**	**No-Action**
Impacts to sensitive visual resources from demolition	Minor, adverse, short-term impact	Moderate, adverse, long-term impact	Negligible, adverse, short-term impact	Major, adverse, long-term impact	Moderate, adverse, long-term impact	N/A
Impacts to sensitive visual resources from operations	No impact	Minor, adverse, long-term impact	No impact	No impact	No impact	No impact

4.12 Environmental Justice

This Section describes the analysis performed to identify potential environmental justice concerns that could result under the five Alternatives. Environmental justice is the fair treatment and meaningful involvement of all people, regardless of race, color, national origin, or income, with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies (EPA, 2015a). The analysis of environmental justice issues is required under Executive Order (E.O.) 12898, *Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations*. E.O. 12898 mandates that opportunities be provided to minority and low-income populations to actively participate in the planning process and evaluates whether the project would result in any disproportionately high and adverse effects on individuals in these populations. E.O. 12898 also directs federal agencies to take appropriate and necessary steps to identify and address disproportionately high and adverse effects of federal projects on the health and environment of minority and/or low-income populations to the greatest extent practicable by law (59 *Federal Register* 7629; February 16, 1994).

As the primary federal agency, responsible for protecting the environment and monitoring environmental issues, EPA sets policy and standards regarding compliance with E.O. 12898. In 2014, EPA issued new guidance and tools for interpreting E.O. 12898, including Plan EJ 2014 and a web-based tool called EJSCREEN, which is used in the following analysis.

4.12.1 Methodology

The ROI for environmental justice is the Municipality of Arecibo. Following E.O. 12898 and considering recent EPA guidance, this analysis will address the following three factors to determine compliance with E.O. 12898:

Fair Treatment and Meaningful Involvement. E.O. 12898 requires agencies to provide full and fair opportunities for minority and low-income populations to engage in the public participation process. EPA guidance provided an additional definition on the terminology used in E.O. 12898 (EPA, 2015a):

- *Fair Treatment* means that no group of people should bear a disproportionate burden of environmental harms and risks, including those resulting from the negative environmental consequences of industrial, governmental, and commercial operations or programs and policies.
- *Meaningful Involvement* means that: (1) potentially affected populations have an appropriate opportunity to participate in decisions about a proposed activity that will affect their environment and/or health; (2) the public's contribution can influence the regulatory Agency's decision; (3) the concerns of all participants involved will be considered in the decision-making process; and (4) the rule writers and decision makers seek out and facilitate the involvement of those potentially affected.

Minority Demographics. Demographic information is available for the Commonwealth of Puerto Rico and the Municipality of Arecibo to provide a context for evaluating impacts associated with the Proposed Action. Minority demographics are defined as follows using USCB data:

- *Black* – a person having origins in any of the black racial groups of Africa
- *Hispanic* – a person of Mexican, Puerto Rican, Cuban, Central or South American, or other Spanish culture or origin, regardless of race
- *Asian American* – a person having origins in any of the original peoples of the Far East, Southeast Asia, the Indian subcontinent, or the Pacific Islands
- *American Indian or Alaskan Native* – a person having origins in any of the original people of North America and who maintains cultural identification through tribal affiliation or community recognition
- *Native Hawaiian and Other Pacific Islander* – people having origins in any of the original peoples of Hawaii, Guam, Samoa, or other Pacific Islands

A minority population is determined to be present if greater than 50 percent of the ROI (Municipality of Arecibo) has a minority population or if the population percentage is meaningfully greater than the minority population percentage in the general population (Commonwealth of Puerto Rico). Because of the Hispanic majority of both the Municipality of Arecibo and the Commonwealth of Puerto Rico, both geographies meet the definition of minority populations. The term “indigenous peoples” includes “state-recognized tribes; indigenous and tribal community-based organizations; individual members of federally recognized tribes, including those living on a different reservation or living outside Indian country; individual members of state-recognized tribes; Native Hawaiians; Native Pacific Islanders; and individual Native Americans” (EPA, 2015a).

Low-Income Demographics. Low-income populations are defined as those individuals whose median household income is twice the poverty threshold. The rationale for using twice the poverty threshold instead of the poverty threshold itself includes considerations such as the effect of income on baseline health; using a calculation that is consistent with previous versions of EPA screening tools; and the conclusion by some analysts that the amount of income actually required for basic living costs without government support is far higher than the current federal poverty thresholds (EPA, 2015b). Puerto Rico has its own “Commonwealth Poverty Level (CPL),” which is set at dollar amounts ($4,800 for individuals and $8,220 for a family of four). However, this figure has been frozen since 1998, with no adjustment for inflation. Because these values are close to 20 years old, this analysis uses the poverty level determinations provided by the PRCS. Approximately 49 percent of the population of the Municipality of Arecibo and 45 percent of the Commonwealth of Puerto Rico is below the poverty level[6] (USCB, 2015h).

The following environmental justice factors are evaluated in this Section, as follows:

- Section 4.12.2 provides a summary of the public disclosure and involvement activities provided as part of this NEPA process. These opportunities were provided to allow for full and fair opportunities for minority and low-income populations (in addition to the general public) to engage in the public participation process.
- Section 4.12.3 describes the minority demographics within the Municipality of Arecibo.
- Section 4.12.4 provides income data to determine the extent of the low-income population within the Municipality of Arecibo.
- Section 4.12.5 provides a summary of the EJSCREEN tool and the results for the area around Arecibo Observatory.

[6] Following the Office of Management and Budget’s Directive 14, the Census Bureau uses a set of money income thresholds that vary by family size and composition to determine who is in poverty.

- Section 4.12.6 reviews the Proposed Action and Alternatives and provides summary tables for each resource section to determine whether there are any disproportionately high and adverse effects on minority and low-income populations.
- Section 4.12.7 provides a conclusion and summary of compliance with E.O. 12898.

4.12.2 Public Disclosure and Involvement

Prior to the public scoping period, NSF notified, contacted, or consulted with multiple agencies, individuals, and organizations. Details of public and agency disclosure and involvement regarding the Proposed Action are included in Appendixes 5-A through 5-H. These disclosure efforts included pre-assessment notification letters, media announcements, social media announcements, website updates, scientific digests and blogs, distribution lists, newspaper public notices, and public scoping meetings (conducted on June 7, 2016, in San Juan and the Municipality of Arecibo). Efforts were made to inform the public of the scoping meetings and multiple opportunities were provided for the public to provide input. Meetings were conducted in both English and Spanish via alternating translation and all meeting materials were presented in both English and Spanish.

4.12.2.1 Public Notices

NSF published a NOI in the *Federal Register* on May 23, 2016. A copy of this NOI is included in Appendix 5-A. Newspaper advertisements were published in the local newspapers to inform the public about the proposed scoping meetings. Newspaper advertisements were published in the *El Nuevo Día* newspaper (Puerto Rico-wide circulation) on May 24, 2016, and a second advertisement was published on May 26, 2016, in the *El Norte* (*Índice*) newspaper (northwest Puerto Rico circulation). Copies of the newspaper display ads are included in Appendix 5-A. All newspaper advertisements were published in English and Spanish. Additionally, the Notice of Availability published in the *Federal Register* will also be available in Spanish and posted on the NSF website.

4.12.2.2 Public Meetings

NSF conducted public scoping meetings on June 7, 2016, and introduced the Proposed Action to those who attended. The purpose of the public scoping process is to determine relevant issues that will influence the scope of the environmental analysis, including identification of viable alternatives, and guide the process for developing the EIS. The public scoping meetings provided an opportunity for the public to comment, in either English or Spanish, on the preliminary Alternatives and to identify potential environmental concerns, both positive and negative.

Two public scoping meetings were held on June 7, 2016:

- Daytime meeting: June 7, 2016, from 9:30 a.m. to 11:30 a.m. at the DoubleTree by Hilton San Juan, 105 Avenida De Diego, San Juan, Puerto Rico

- Evening meeting: June 7, 2016, from 6:00 p.m. to 8:00 p.m. at the Colegio de Ingenieros y Agrimensores de Puerto Rico/Puerto Rico Professional College of Engineers and Land Surveyors (Arecibo Chapter), Ave. Manuel T. Guilla´n Urda´z, Conector 129 Carr. 10, Arecibo, Puerto Rico

The format for each public scoping meeting included an open house for the first hour, which allowed the participants to review the meeting informational boards and materials. All meeting materials were provided in both Spanish and English. Copies of these materials are included in Appendix 5-C of the FEIS. This open house segment was followed by a brief presentation by NSF staff. The presentation covered the following topics: introductions, background information on the Proposed Action, Alternatives, resource areas to be studied, the EIS process, and opportunities for public involvement. Upon completion of the presentation, the public was invited to provide comments orally. Spanish language translation services were provided for both the NSF presentation and the oral comment period.

The presentation and the oral comments were transcribed by the court reporter and are shown in the official meeting transcripts, which are included in Appendix 5-B of this FEIS. In addition to providing spoken comments, the public was invited to write down comments on forms provided during the meeting. Other opportunities to provide comments included mailing comments to NSF or emailing/posting via the project website. During the public scoping meetings, the public was frequently encouraged to provide oral comments or written comments via mail or email. Display material and comment forms with submittal instructions were provided at each meeting (Appendix 5-C). The public also was encouraged to submit any comments during the public comment period (May 23 to June 23, 2016). Comments made during the scoping process are included in Appendix 5-D of this FEIS. No specific environmental justice comments were received during the public scoping period.

Information on these public meetings is provided in Section 5 of this FEIS. Additional opportunities for public involvement were provided during the second round of public meetings on November 16 and 17, 2016, in Arecibo and San Juan, respectively. The intent of these meetings was to receive comments on the DEIS from agencies and the public. NSF accepted comments on the DEIS for 45 days following publication of this NOA. Comments made during the public comment process are included in Appendix 5-H of this FEIS.

4.12.3 Existing Minority Populations

A minority population is determined to be present if greater than 50 percent of the ROI is minority or if the minority population percentage of the ROI is meaningfully greater than the minority population percentage in the general population. USCB (2014b) estimates of the population by race and ethnicity were used to identify the presence of unique minority populations for the Municipality of Arecibo and the Commonwealth of Puerto Rico (see Table 4.12-1). Approximately 99 percent of the population in both areas considers themselves to be Hispanic or Latino, a term for those of Puerto Rican, Cuban, Mexican,

TABLE 4.12-1
Population by Ethnicity and Race

	Commonwealth of Puerto Rico		Municipality of Arecibo	
	2014 Estimate	**Percent of Total**	**2014 Estimate**	**Percent of Total**
Total Population	**3,638,965**		**93,969**	
Population that is Not Hispanic or Latino:	37,047	1%	484	1%
White alone	*25,583*	*69%*	*424*	*88%*
Black or African American alone	*3,037*	*8%*	*6*	*1%*
American Indian and Alaska Native alone	*99*	*0%*	*0*	*0%*
Asian alone	*2,288*	*6%*	*10*	*2%*
Native Hawaiian and Other Pacific Islander alone	*55*	*0%*	*0*	*0%*
Some other race alone	*1,669*	*5%*	*19*	*4%*
Two or more races	*4,316*	*12%*	*25*	*5%*
Population that is Hispanic or Latino:	3,601,918	99%	93,485	99%
White alone	*2,507,998*	*70%*	*80,231*	*86%*
Black or African American alone	*287,962*	*8%*	*3,756*	*4%*
American Indian and Alaska Native alone	*11,003*	*0%*	*205*	*0%*
Asian alone	*9,196*	*0%*	*893*	*1%*
Native Hawaiian and Other Pacific Islander alone	*74*	*0%*	*0*	*0%*
Some other race alone	*393,789*	*11%*	*5,938*	*6%*
Two or more races	*391,896*	*11%*	*2,462*	*3%*

Source: USCB, 2014b.

Central or South American, or other Spanish culture or origin, regardless of race (USCB, 2014b). Of these within the Commonwealth of Puerto Rico, 70 percent are racially white alone, 8 percent are black alone, while 11 percent are either “some other race alone” or “two or more races,” respectively. Because of the Hispanic majority of both the Municipality of Arecibo and the Commonwealth of Puerto Rico, both geographies meet the definition of minority populations under E.O. 12898. However, as noted by EPA’s Region 2 Interim Environmental Justice Policy, because the overwhelming majority (99 percent) of the population in the Commonwealth of Puerto Rico is considered a minority (Hispanic), comparison of its racial composition to that of the Municipality of Arecibo will not necessarily further inform potential environmental justice concerns that could result from the Proposed Action (EPA, 2000).

4.12.4 Low-Income Populations

As noted in Section 4.12.1, low income is defined as the percent of the population in poverty multiplied times 2. The rationale for using twice the poverty threshold instead of the poverty threshold itself includes considerations such as the effect of income on baseline health, and some analysts have concluded that the amount of income actually required for basic living costs without government support is far higher than the current federal poverty thresholds (EPA, 2015b). Table 4.12-2 shows a comparison of poverty statistics for the Municipality of Arecibo and the Commonwealth of Puerto Rico. This information is grouped by the USCB into three categories: working age population (ages 18 to 64), children or dependents (ages newborn to 17 years), and elderly (age 65 years and older) who are typically no longer in the workforce. Approximately 45 percent of the population in the Commonwealth of Puerto Rico is at or below the poverty level, compared to 49 percent in the Municipality of Arecibo. Approximately 57 percent of the children are below the poverty level in both the Commonwealth of Puerto and the Municipality of Arecibo. In the Municipality of Arecibo, 46 percent of the working age population is at or below the poverty status compared to 42 percent for the Commonwealth of Puerto Rico. Additionally, 47 percent of the elderly population in the Municipality of Arecibo falls below the poverty level compared to 40 percent in the Commonwealth of Puerto Rico (USCB, 2015h).

TABLE 4.12-2
Estimated 2014 Poverty Status in the Past 12 Months

Subject	Commonwealth of Puerto Rico			Municipality of Arecibo		
	Total	**Below Poverty Level**	**Percent Below Poverty Level**	**Total**	**Below Poverty Level**	**Percent Below Poverty Level**
	Estimate	**Estimate**	**Estimate**	**Estimate**	**Estimate**	**Estimate**
Population for whom poverty status is determined	3,604,637	1,630,965	45%	92,509	44,931	49%
AGE						
Under 18 years	829,365	473,611	57%	20,444	11,663	57%
18 to 64 years	2,199,634	928,792	42%	55,462	25,452	46%
65 years and older	575,638	228,562	40%	16,603	7,816	47%

Source: USCB, 2015h.

4.12.5 Existing Minority and Low-Income Populations near Arecibo Observatory

In May 2015, EPA issued updated policy guidance and a new EJSCREEN tool to assist in determining the potential impacts to environmental justice communities. EJSCREEN builds on previous tools, providing updated demographic information, environmental indicators, and high-resolution maps to generate standardized reports that bring together environmental and demographic data in the form of environmental justice indexes. EPA describes EJSCREEN as a pre-decisional screening tool that should not be used to identify or label an area as an "Environmental Justice (EJ) Community;" instead, the tool is designed as a starting point to identify candidate sites that might warrant further review or outreach.[7]

For the purpose of this analysis, the EJSCREEN tool was used to generate adjacent population estimates for a 5-mile buffer around Arecibo Observatory using the 2010–2014 PRCS 5-year block group data. The EJSCREEN tool compares the population estimates to those of the Commonwealth of Puerto Rico to assess potential disproportionate impacts. The EPA's EJSCREEN tool was also used to determine whether there were any distinguishing characteristics within a 5-mile geographic buffer of Arecibo Observatory that could further inform the environmental justice analysis. The 5-mile buffer is measured as 5 geographic miles from the center point of Arecibo Observatory (18.344262, -66.752703).

EJSCREEN found approximately 19,577 persons within 5 miles of Arecibo Observatory. This population is primarily concentrated in the Aguadilla–Isabela–San Sebastián Urbanized Area[8] to the southwest and the Arecibo Urbanized Area to the north, which includes the City of Arecibo and the northern portions of the Municipalities of Arecibo, Hatillo, Camuy and Quebradillas. Approximately 8,651 housing units are within 5 miles of Arecibo Observatory, while 41,152 total housing units are in the Municipality of Arecibo. This 5-mile buffer had a per capita income of $8,150 compared to $9,638 for residents of the Municipality of Arecibo, and 82 percent of the population in the 5-mile buffer could be characterized as low income compared to 73 percent of the Commonwealth of Puerto Rico in 2014 (EPA, 2016b).

Table 4.12-3 summarizes the environmental and demographic indicator results for a 5-mile buffer compared to those of the Commonwealth of Puerto Rico. The environmental and demographic indicator results near Arecibo Observatory are much better (lower numbers) than the results for the Commonwealth of Puerto Rico for air, water, lead, and other toxic substances measured by EPA and measured in EJSCREEN (see Appendix 4.12-A for the complete table). All of the environmental indicators within a 5-mile buffer of Arecibo Observatory were much better (lower numbers) than those of the Commonwealth of Puerto Rico, which is an important factor in determining whether the area is currently experiencing the effects of disproportionately high and adverse environmental issues.

[7] "EJSCREEN is not designed to explore the root causes of differences in exposure. The demographic factors included in EJSCREEN are not necessarily causes of a given community's increased exposure or risk. Additional analysis is always needed to explore any underlying reasons for differences in susceptibility, exposure or health" (EPA, 2015c).

[8] Urbanized Areas are contiguous areas of populations greater than 50,000.

TABLE 4.12-3
EJSCREEN Report Results

Environmental Indicators	**5-mile Buffer (Arecibo Observatory)**	**Commonwealth of Puerto Rico**
National Air Toxics Assessment (NATA) Diesel PM ($\mu g/m^3$)	0.234	0.761
NATA Cancer Risk (lifetime risk per million)	27	34
NATA Respiratory Hazard Index	0.69	1.1
Traffic Proximity and Volume (daily traffic count/distance to road)	11	140
Lead Paint Indicator (% Pre-1960 Housing)	0.084	0.15
National Priorities List Proximity (site count/km distance)	0.098	0.15
Risk Management Plan Proximity (facility count/km distance)	0.13	0.51
Treatment Storage and Disposal Facility Proximity (facility count/km distance)	0.039	0.053
Water Discharger Proximity (facility count/km distance)	0.12	0.41
Demographic Indicators	5-mile Buffer (Arecibo Observatory)	Commonwealth of Puerto Rico
Demographic Index	91%	86%
Minority Population	100%	99%
Low-Income Population	82%	73%
Linguistically Isolated Population	82%	70%
Population With Less Than High School Education	39%	28%
Population Under 5 years of age	5%	6%
Population over 64 years of age	17%	16%

Source: EPA, 2015c (see Appendix 4.12-A).

Based on minority and income data from USCB shown in Sections 4.12.3 and 4.12.4 and EPA’s EJSCREEN tool (Section 4.12.5), potential environmental justice populations are prevalent at both the Municipality of Arecibo and the Commonwealth of Puerto Rico. As noted previously, because 99 percent of the island of Puerto Rico is Hispanic, its minority population is not considered a distinguishing environmental justice indicator. However, the high percentage of low-income population (below poverty rate), 82 percent near Arecibo Observatory and 45 percent in the Municipality of Arecibo, does raise the potential for environmental justice concerns.

4.12.6 Identification of Disproportionately High and Adverse Effects on Minority and Low-Income Populations

The following indicators are typically used to determine the effect of a proposed action on minority and low-income populations:

- Environmental conditions, such as the quality of air, water, and other environmental media, as well as the loss of open space
- Human health, such as exposure of environmental justice communities to pathogens and nuisance concerns (odor, noise, and dust)
- Public welfare, such as reduced access to certain amenities like hospitals, safe drinking water, and public transportation
- Economic conditions, such as changes in employment, income, and the cost of housing

These indicators are described in the corresponding resource sections (air, water, noise, socioeconomics) in Chapters 3 and 4 of this FEIS. These Sections were reviewed and potential impacts for the Alternatives are summarized in Table 4.12-4. This table provides the relevant proposed environmental protection measures for each resource under consideration, illustrating whether, following implementation of environmental protection measures, there are residual high or major impacts that require further review to determine whether the Proposed Action may result in disproportionately high and adverse impact on minority and low-income populations. The table shows whether an impact may be caused by the Proposed Action, not whether low-income or minority populations are affected.

The far right column of Table 4.12-4 indicates whether there is a high and adverse impact. It also advises whether a site-specific review is necessary to determine who is affected and whether the Proposed Action may result in disproportionately high and adverse impact on minority and low-income populations. A detailed analysis and full listing of all resource impacts (e.g., air quality, biological, and cultural) are provided in Sections 4.1–4.11.

TABLE 4.12-4
Summary of Potential Adverse Impacts and Environmental Protection Measures for Alternatives 1 through 5

Element of Analysis	Potential Impacts	Relevant Environmental Protection Measures[a]	Potential High Adverse Effects
Air Quality	Slight temporary increase in NAAQS criteria emissions; however, all emissions would be in an area that is in full attainment.	Air quality BMPs would be implemented during construction. Contracts would require idle reduction and proper equipment maintenance to reduce emissions during demolition.	No high adverse effect. Therefore, no further review is necessary.

TABLE 4.12-4
Summary of Potential Adverse Impacts and Environmental Protection Measures for Alternatives 1 through 5

Element of Analysis	Potential Impacts	Relevant Environmental Protection Measures[a]	Potential High Adverse Effects
Cultural Resources	Alternatives would alter buildings and structures that are potentially eligible for the NRHP. Changes to operations-related activities could significantly change the characteristics of NRHP-eligible resources.	Mitigation measures would be coordinated with the SHPO, ACHP and the Consulting Parties and would be implemented.	Potential for a high adverse effect. This resource is analyzed further below.
Hazardous Materials	Presence of existing contamination and use of hazardous materials during construction.	A complete site characterization would be performed. Hazardous materials and wastes would be used, stored, disposed of, and transported during demolition in compliance with all applicable laws and regulations.	No high adverse effect. Therefore, no further review is necessary.
Solid Waste	Short-term increased solid waste production from demolition activities.	Debris would be recycled and reused to the extent practicable. Solid waste would be properly disposed of.	No high adverse effect. Therefore, no further review is necessary.
Health and Safety	Short-term distractive nuisance of demolition site and mothballed facilities.	Demolition and mothballed sites would be fenced and warning signs would be placed explaining the inherent danger at the site.	No high adverse effect. Therefore, no further review is necessary.
Noise	Increased noise from demolition activities.	Demolition noise would be within normal sound levels for the surrounding areas.	No high adverse effect. Therefore, no further review is necessary.
Socioeconomics	Reduction in employment, STEM opportunities, and tourism under the demolition and mothball alternatives.		Potential for a high adverse effect. This resource is analyzed further below.
Transportation	Minimal increase of haul traffic associated with demolition activities.	Haul traffic will limit activities to off-peak hours. The contractor will coordinate with local public schools.	No high adverse effect. Therefore, no further review is necessary.
Visual	Demolition would result in removal of man-made objects and would return the viewshed to a more natural condition.		No high adverse effect. Therefore, no further review is necessary

[a] The environmental protection measures shown in this table represent the measures required to protect residents and individuals to include minority and low-income populations in and around Arecibo Observatory. Additional environmental protection measures are discussed in the resources discussions found in Section 4.

4.12.7 Compliance with Executive Order 12898

The EJSCREEN results for the 5-mile buffer around Arecibo Observatory show that the Observatory is located in an area with 82 percent of the population at or below the poverty rate compared to 73 percent for the Commonwealth of Puerto Rico (EPA, 2015c).

E.O. 12898 calls for federal agencies to provide opportunities for stakeholders to obtain information and provide comments on federal actions. NSF has complied with E.O. 12898 by conducting scoping meetings that included publishing public notices and meeting materials in Spanish, as well as providing for translation between Spanish and English, so all parties could participate.

As emphasized in EPA's recent revision to *Guidance on Considering Environmental Justice during the Development of Regulatory Actions* (May 2015), the role of this environmental justice analysis and screening is to present anticipated impacts across population groups of concern (that is, minority and low-income populations) to NSF, the agency decision maker for the Proposed Action, with the purpose of informing its policy judgement and ultimate determination on whether there is a potential disproportionate impact that may merit additional action (EPA, 2015a).

As shown in Table 4.12-4, there are potential high adverse effects for cultural resources as defined by Section 106 of the NHPA. The potential major impacts/adverse effects for cultural resources result from the demolition and mothballing of historic properties that contribute to the Arecibo Observatory NRHP-listed historic district. These impacts/adverse effects would occur under all Alternatives; however, the impacts will be addressed through consultation with the Puerto Rico SHPO, ACHP, and the Consulting Parties on measures to avoid, minimize, and mitigate adverse effects. The potential major impacts/adverse effects for cultural resources would not be disproportionately high adverse impacts to minority and low-income populations, because the impact to historic properties would be borne equally among demographic groups. Therefore, there is no environmental justice impact regarding cultural resources. See Section 4.3 for additional discussion on cultural resources impacts.

The analysis of socioeconomic resources finds that mothballing (Alternative 3) or demolishing Arecibo Observatory (Alternatives 4 and 5) would result in minor, long-term, adverse impacts from the loss of operations-related jobs. Potential impacts to STEM and tourism under these Alternatives would be major, adverse, long-term, which would equate to a high adverse effect. However, other STEM, education, and tourism opportunities are available in the Municipality of Arecibo and the Commonwealth of Puerto Rico. These potential major impacts would not be disproportionately borne by minority and low-income populations. Therefore, there is no environmental justice impact regarding socioeconomic resources. Section 4.9 provides additional discussion on socioeconomic impacts.

While these socioeconomic and cultural losses would occur in an area that is already economically depressed and may affect low-income populations, the impacts are not disproportionate, because they would not be borne solely by minority and low-income populations. Therefore, impacts from any of the Alternatives would not result in <u>disproportionately high and adverse</u> to minority and low-income populations.

4.13 Cumulative Impacts

This cumulative impacts analysis follows the requirements of NEPA and CEQ guidance (CEQ, 1997). The CEQ provides the implementing regulations for NEPA, which define a cumulative impact as follows:

> "… the impact on the environment, which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions, regardless of what agency (federal or non-federal) or person undertakes the actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time." (40 C.F.R. §1508.7)

The concern is the contribution of an action to the overall impacts in the analysis area. A project may have minor impacts in isolation but could have significant impacts when considered collectively with other projects on a regional scale.

Cumulative impacts occur when the incremental effects of the Proposed Action result in an increased impact when added to the environmental effects of past, ongoing, and reasonably foreseeable activities that are related to the Proposed Action in space and time, or that are of a similar character that could affect the same environmental resources within the ROI, as defined for each resource. Reasonably foreseeable activities include activities identified by regional or Commonwealth of Puerto Rico planning boards, or activities that have an application pending and that would occur in the same time frame as the Proposed Action or close enough in time that the impacts could be additive. Past activities are considered only when their impacts are evident during implementation of the Proposed Action. Cumulative impacts of an Alternative are based on all of the impacts analyzed in the preceding resource sections, and it is assumed that any BMPs, design measures, or mitigation measures to reduce impacts, as described in each resource section, would be implemented.

The cumulative impacts analysis for each resource involved the following methodology:

- Identify the appropriate level of analysis for each resource.
- Define the ROI and time frame for the cumulative impacts analysis for each resource.
- Identify past, present, and other reasonably foreseeable actions in the relevant geographic regions that affect each resource.
- Determine current resource conditions and trends, as applicable.
- Identify the potential impacts of each Alternative that could contribute to the cumulative impacts for each resource.
- Analyze potential cumulative impacts.

The level of cumulative analysis for each resource in this FEIS varies, depending on the sensitivity of the resource to potential cumulative impacts.

4.13.1 Cumulative Activities

This Section identifies any past, present, or reasonably foreseeable activities that could interact with the Proposed Action to contribute to cumulative impacts. NSF's potential funding changes for another observatory that conducts radio astronomy, the Green Bank Observatory in Green Bank, West Virginia, were not considered a cumulative activity, as no decision on the future of Green Bank Observatory has been made; therefore, any potential future use or disposition of the Observatory is speculative at this time.

A review of planning and permit programs, as detailed below, have identified no pending, planned, or recently completed projects in the region of Arecibo Observatory:

- The PRPB has no pending or planned projects on record for the area of Arecibo Observatory or along the proposed haul routes for the demolition debris.
- The Municipality of Arecibo has no pending or planned projects on record for the area of Arecibo Observatory or along the proposed haul routes for the demolition debris.
- The USACE Civil Works Division has no pending or planned projects for the area of Arecibo Observatory or along the proposed haul routes for the demolition debris.
- The USACE Regulatory Division has no pending or recently completed CWA permits for the area of Arecibo Observatory or along the proposed haul routes for the demolition debris.
- The Federal Highway Administration Puerto Rico and Virgin Islands Division website (http://www.fhwa.dot.gov/prdiv/projects.cfm) indicates that there are two planned projects in the Poncé region (Federal Numbers of 0009[007] and 009[006]) and no other planned projects in the vicinity of Arecibo Observatory or the proposed haul routes. However, as neither project connects with PR-10, it would not interact with debris-haul traffic from Arecibo Observatory.

USFWS has reintroduced the Puerto Rican parrot into the Río Abajo Commonwealth Forest. The Alternatives could interact with this project because of the proximity of the forest to Arecibo Observatory.

Routine activities such as agriculture and residential development could occur outside Arecibo Observatory and within the ROI for a number of resources.

There would be no expected change in the intensity of potential impacts if the demolition is extended beyond the single 12 to 38-week periods identified for the Alternatives.

4.13.2 Cumulative Impacts

Based on the identified cumulative activities, the following resource areas would have no potential for noticeable adverse cumulative impacts under any of the Alternatives:

- Air Quality – The ROI is in full attainment for all NAAQS. Therefore, the likelihood of the Proposed Action to combine with identified cumulative activities (i.e., reintroduction of the Puerto Rican parrot and routine activities) to create a noticeable impact is remote.
- Climate Change – The Proposed Action would not appreciably alter GHG emissions and would not meaningfully contribute to cumulative impacts for climate change.
- Land Use – No noticeable changes to land uses would occur under the Proposed Action or the identified cumulative activities; consequently, no cumulative impacts would occur.
- Surface Waters – No impacts to surface waters would occur under the Proposed Action or the cumulative activities.
- Utilities – The Alternatives would either have no impact on utilities or there would be a minor decrease in utility demand. There would be no cumulative impacts to utilities.
- Cultural Resources – Impacts to cultural resources at Arecibo Observatory would not interact with the identified cumulative activities (i.e., routine activities and reintroduction of the Puerto Rican parrot).
- Geology and Soil –Impacts to geology and soil would not incrementally add to other cumulative activities, due to the distance between locations.
- Groundwater – Disturbance during demolition activities would be temporary and would not occur in the same vicinity of identified cumulative activities. There would be no cumulative impacts to groundwater.
- Hazardous Materials – The removal of existing hazardous material contamination would occur concurrently with the removal of structures, which would be a long-term benefit and would incrementally contribute to the beneficial cumulative impacts from hazardous materials. Use of hazardous materials during demolition would be temporary and would not interact with other activities to contribute to cumulative impacts. There would be no cumulative impacts to hazardous materials.
- Human Health and Safety – The identified cumulative activities would not combine with the Alternatives to result in increased impacts to health and safety.
- Noise – None of the cumulative activities would be expected to result in an increase in noise; therefore, there would be no cumulative impacts.
- Socioeconomics – None of the cumulative activities would result in impacts to socioeconomics; therefore, there would be no cumulative impacts.
- Solid Waste – The Poncé Landfill has confirmed that the landfill capacity could accommodate more than the projected amount of waste without adversely impacting operations (Clas, 2016b, pers.

comm.). It is expected that the landfills will also be able to accommodate the waste from the cumulative activities, due to the limited amount of waste expected from these activities. Therefore, no cumulative impacts to solid waste disposal would result.

- Traffic and Transportation – Demolition activities would result in a minor increase in traffic on local roads and along the haul routes to Poncé. This temporary increase in traffic during demolition would not interact with any other activities to create cumulative impacts to traffic and transportation, due to the very small increase in traffic expected from cumulative activities.
- Visual Resources – None of the cumulative activities would result in impacts to visual resources; therefore, there would be no cumulative impacts.

4.13.3 Cumulative Impacts to Biological Resources

Biological resources are the only resource area with the potential for cumulative impacts, based on the identified cumulative activities. There would be no potential cumulative impacts to common vegetation and wildlife or species protected by the MBTA under any of the Alternatives. No cumulative impacts to protected species, including the Puerto Rican parrot and the Puerto Rican boa, would be expected under Alternatives 1, 2, 3, or 4 because of the lack of direct impacts and very low magnitude of impacts to habitat under these Alternatives. However, there is potential for cumulative impacts to the Puerto Rican parrot and the Puerto Rican boa under Alternative 5. The impacts would primarily result from incremental population effects as a result of incidental mortality and incremental habitat loss under Alternative 5.

The USFWS has recently reintroduced the Puerto Rican parrot on forest lands adjacent to Arecibo Observatory. Demolition activities at the southeastern and southwestern tower and tower anchor locations could result in habitat modification or mortality to the Puerto Rican parrot, which could interact with this reintroduction and result in cumulative impacts. Because the implementation of Alternative 5 could result in changes to habitat used by the Puerto Rican parrot on land adjacent to Arecibo Observatory, there would be potential for incremental adverse cumulative impacts to the Puerto Rican parrot reintroduction effort.

Mortality of the endangered Puerto Rican boa is also likely under Alternative 5. Adult mortality from the Proposed Action could contribute to long-term cumulative impacts to this species through reduced reproduction, while juvenile mortality would reduce recruitment and also result in reduced population levels.

Territory abandonment by the Puerto Rican broad-winged hawk is possible under Alternative 5. Territory abandonment could contribute to long-term cumulative impacts to this species through reduced reproduction and in reduced population levels, as one or more cohorts may be lost to failed reproduction.

After demolition is complete, the restoration of the property to near-natural conditions, coupled with the cessation of regular human activities at the Arecibo Observatory site and the Puerto Rican parrot reintroduction effort, would result in an overall benefit to biological resources.

4.14 Irreversible and Irretrievable Commitment of Resources

Irreversible or irretrievable resource commitments are related to the use of nonrenewable resources and the effects that use of those resources would have on future generations. These effects primarily result from the use or conversion of a specific resource (e.g., energy from hydrocarbons) that cannot be replaced within a reasonable timeframe. Irreversible or irretrievable resource commitments involve the loss in value of an affected resource that cannot be restored after implementing a Proposed Action (e.g., extinction of a species).

The effects would be similar for all five Alternatives except where indicated below. Demolition, paving, and vegetation clearing would consume electricity, hydrocarbon fuels, and water and would require landfill disposal. Demolition and paving materials would be recycled and reused to the extent practicable; however, some irreversible or irretrievable resource loss would result. Demolition debris would lead to the irreversible or irretrievable resource loss in the reduction of landfill capacity. However, the capacity of landfills to accept demolition waste is adequate for all five Alternatives. The hydrocarbon-based energy required to conduct these activities or to procure the finished materials would be permanently lost.

Demolition, paving, and vegetation clearing would result in some loss of vegetated areas. Many of the areas have been previously disturbed but demolition may affect vegetation or habitat in areas that support biological resources. The loss of vegetation and wildlife habitat from proposed activities could be mostly reversed through landscaping or subsequent restoration. Clearing of vegetation would not result in an irreversible or irretrievable commitment of resources.

Loss of cultural resources would represent an irretrievable action, but any such losses that may result from implementation of the Proposed Action would be appropriately mitigated through consultation with the SHPO, interested tribes, and other consulting parties.

4.15 Short-term Uses of the Environment and Maintenance and Enhancement of Long-term Productivity

Short-term uses of the environment associated with the Proposed Action would result in impacts to certain resources that could affect the maintenance and enhancement of long-term productivity. Increased soil erosion could result from soil disturbance during demolition activities. Offsite streams could experience increased scour and sedimentation from stormwater runoff. Air quality could be affected by increased dust and vehicle emissions from demolition activities. Demolition could also generate increased noise. However, the following BMPs would be implemented to lessen these effects:

- Implementation of standard practices to reduce soil erosion, control noise, and improve safety
- Adherence to management plans and programs
- Compliance with federal, state, and local regulations

SECTION 5.0

Notification, Public Involvement, and Consulted Parties

5.1 Agency Notification and Collaboration

NSF began the process of informal consultation with federal and Commonwealth of Puerto Rico agencies in May 2016, along with Commonwealth of Puerto Rico elected officials and relevant commercial interests. A list of the agencies consulted is provided in Table 5.1-1. Involvement activities to date include scoping activities, ad-hoc agency meetings, DEIS public meetings, and Section 106 of the NHPA Consulting Parties meetings. NSF sent scoping invitation letters to over 100 agencies, organizations, Puerto Rico government representatives, as well as other potentially interested parties. Additionally, a number of formal and informal consultations took place with these parties to ensure they understood the objectives of the Proposed Action and had all of the appropriate information. These consultations included, but were not limited to, discussions and correspondence with the Arecibo Management Team, the Puerto Rico SHPO, and USFWS. On July 25, 2016, NASA requested to be a cooperating agency for this NEPA process. Agency representatives provided a number of comments that helped NSF focus on the environmental issues to be considered in this EIS.

Consultation with the SHPO, the ACHP, and the Consulting Parties under Section 106 of NHPA and with USFWS under Section 7 of ESA are described in detail in Sections 5.3 and 5.4.

TABLE 5.1-1
Agency Coordination

Federal	ACHP EPA NASA USACE USFWS Office of U.S. House of Representatives Puerto Rico – At Large
Commonwealth of Puerto Rico	DRNA Office of Governor of Puerto Rico Office of Resident Commissioner of Puerto Rico OGPe EQB PRPB SHPO
Municipality of Arecibo	Mayor of Arecibo
Other Public-Private Stakeholder Organizations	SRI International (NSF Cooperative Agreement Awardee) USRA (NSF Cooperative Agreement Sub-awardee) UMET (NSF Cooperative Agreement Sub-awardee)

5.2 Public Disclosure and Involvement

NSF has notified, contacted, or consulted with agencies, individuals, and organizations throughout this NEPA process. Details of public and agency disclosure and involvement regarding the Alternatives are described in this Section. Public notification efforts included pre-assessment notification letters, media announcements, social media announcements, website updates, scientific digests/blogs, documentation distribution lists, newspaper public notices, and public scoping meetings conducted on June 7, 2016, in San Juan and Arecibo. These meetings were followed by the DEIS public meetings conducted on November 16, 2017, in Arecibo and on November 17, 2016, in San Juan. Copies of this information are also provided in Appendix 5-A.

5.2.1 Public Notices

NSF published an NOI in the *Federal Register* on May 23, 2016. The NOA was published in the *Federal Register* on October 28, 2016, notifying interested parties of the availability of the DEIS for public review over a 45-day public comment period. Copies of the NOI and NOA are contained in Appendix 5-A. Newspaper announcements were published in both English and Spanish in the local newspapers to inform the public of the proposed meetings. Scoping newspaper announcements were published in the *El Nuevo Día* newspaper (Puerto Rico-wide circulation) on May 24, 2016, and a second announcement was published on May 26, 2016, in the *El Norte* (*Índice*) newspaper (northwest Puerto Rico circulation). Public DEIS meeting announcements were placed in the same newspapers on November 1, 2016, and November 3, 2016. Copies of the newspaper announcements are provided in Appendix 5-A.

5.2.2 Public Scoping Meetings

NSF conducted scoping meetings on June 7, 2016, and described the Proposed Action and NSF's environmental compliance process, including the preliminary Alternatives to the meeting attendees. The purpose of the public scoping process was to determine relevant issues that would influence the scope of the environmental analysis, including identification of viable alternatives, and to guide the process for developing the EIS. The public scoping meetings provided an opportunity for the public to comment on the preliminary Alternatives, and to identify potential environmental concerns, both positive and negative.

5.2.2.1 Scoping Meetings Held

The following two public scoping meetings were held on June 7, 2016:

- Daytime meeting: June 7, 2016, from 9:30 a.m. to 11:30 a.m., DoubleTree by Hilton San Juan, 105 Avenida De Diego, San Juan, Puerto Rico
- Evening meeting: June 7, 2016, from 6:00 p.m. to 8:00 p.m., Colegio de Ingenieros y Agrimensores de Puerto Rico/Puerto Rico Professional College of Engineers and Land Surveyors (Arecibo Chapter), Ave. Manuel T. Guillán Urdáz, Conector 129 Carr. 10, Arecibo, Puerto Rico

The attending public was invited to sign in, view, and receive information regarding the preliminary Alternatives and listen to presentations given by members of the NSF team. The public was given the opportunity to ask questions, comment about issues and concerns, and provide oral and written comments. Additionally, meeting participants were invited to indicate whether they wished to be included as a Consulting Party for the undertaking under Section 106 of the NHPA. The format for each meeting was identical. A representative of CH2M, NSF's environmental consultant, made opening statements announcing the purpose of the meeting, introducing key members of the NSF EIS team, describing the process to sign up to provide public comment and explaining that the meeting would be translated. Alternating Spanish and English translation was provided by Lcda Mayra Cardona, a U.S. courts-certified interpreter and National Association of Judiciary Interpreters and Translators-certified interpreter and translator. During each meeting, the public was encouraged to provide oral or written comments via regular mail or email. Display material and comment forms with submittal instructions were provided at each meeting. A stenographer from Verbatim Reporting recorded each meeting. Copies of the meeting transcripts are provided in Appendix 5-B.

Table 5.2-1 lists the number of participants who registered at each meeting and the number of speakers who signed up to provide oral comments. The number of registered participants is based on the number of individuals who signed in on the attendance sheet upon arriving at the meeting. During the course of the meeting, some attendees who had indicated on the sign-up form that they wished to speak, ultimately chose not to speak, and conversely, some who did not register to speak chose to speak. The meeting transcripts, including a list of attendees who spoke, are provided in Appendix 5-B.

TABLE 5.2-1
Summary of Scoping Meeting Participants

Meeting Location	**Registered Participants**	**Number of Speakers[a]**
San Juan	29	9 registered speakers / 13 actual speakers[b]
Arecibo	44	13 registered speakers / 13 actual speakers[b]
Section 106 Meeting Participants		
Meeting Location	Registered Participants	Number of Speakers[a]
San Juan	29	9 registered speakers / 13 actual speakers[b]

[a] The number of actual speakers is different from those who requested to speak on the sign-in sheet. Please see the meeting transcript for names of individuals who provided oral comments.

[b] Due to the length of some comments, some of those who spoke at the meeting were asked to provide the remainder of their comments at the end of the meeting in order to allow all speakers a chance to provide comments. Individuals who spoke twice are only counted once in these numbers. Due to time availability toward the end of the meeting, all speakers were allowed to complete their comments.

Each public scoping meeting included an open house for the first 30 minutes that allowed participants to review the meeting informational boards and materials and to informally discuss the process with members of the NSF team. Copies of these materials are included in Appendix 5-C. This open house segment was followed by a brief presentation by NSF staff. The presentation covered the following topics:

- Introductions
- Background information on the preliminary Alternatives
- Resource areas to be studied
- The EIS process, the Section 106 process, and opportunities for public involvement

Upon completion of the presentation, the public was invited to orally provide comments. Spanish language translation services were provided for both the NSF presentation and the oral comment period. The presentation and the oral comments were transcribed by the court reporter and are shown in the official meeting transcripts, provided in Appendix 5-B. In addition to providing spoken comments, the public was invited to provide written comments on comment forms provided during the meeting. Other opportunities to provide comments included mailing comments to NSF at the following address: Ms. Elizabeth Pentecost, RE: Arecibo Observatory, National Science Foundation, Suite 1045, 4201 Wilson Blvd., Arlington, VA 22230, and submitting them via email to the following email address: envcomp-AST@nsf.gov, with subject line ‘‘Arecibo Observatory.’’ Additionally, comments could also be received through the NSF project website available at www.nsf.gov/AST.

5.2.2.2 Public Comment Results

The public was encouraged to comment during the public comment period (May 23, 2016 through June 23, 2016).

All public and agency comments were reviewed and evaluated by NSF. Many comments were similar in nature and conveyed similar themes; therefore, the comments were organized into the categories listed in Table 5.2-2. The following discussion summarizes the public comments received during the scoping comment period. Table 5.2-2 quantifies the comment themes by category. A matrix of all the comments received, including their assigned category, is provided in Appendix 5-D.

TABLE 5.2-2
Scoping Comments Summarized by Category

Category	Description	Number of Comments[a]
Support Closure	Comments in support of closing Arecibo Observatory	1
Against Closure	Comments against closing Arecibo Observatory	212
Alternative Considerations	Suggestions for additional uses of the facility and sources of funding	15
Resource Considerations	Suggestions on what resources to include in the EIS	7
Decision Process	General questions about the decision-making process	3
General	General questions about the EIS	2

[a] The number of total comments as of June 23, 2016 was 240. One letter was received on June 27, but was identical to the attachment of one of the prior comments submitted via email during the official comment period. This number of total comments was adjusted after July 3, which is approximately 10 days after the close of the public comment period. This date was chosen to allow for possible delay in delivery of U.S. mail from Puerto Rico.

Comments Received Electronically During the Scoping Period

The following is a discussion of the substantive categories from the scoping comments.

Support for Closure

There was one public comment that showed strong support for closure of Arecibo Observatory. The rationale for the support was based on economic factors.

Against Closure

Individuals concerned with closure presented the following issues:

- **Cultural–**Comments cited the importance of Arecibo Observatory to local culture and Puerto Rican history. The comments indicated that Arecibo Observatory is important to Puerto Rican identity and that there would be a loss of pride in the community if Arecibo Observatory were to be closed.
- **Economics–**Comments cited the impact of closure on the local economy due to job loss and tourism effects.
- **Education–**Comments cited the importance of Arecibo Observatory as an educational destination and its influence on local schoolchildren.
- **Research–**Comments cited concern about the negative effect that closure of Arecibo Observatory would have on the scientific community. The public submitted references for research papers that were written using data obtained by Arecibo Observatory. A list of these papers is provided in Appendix 5-E.
- **Health and Safety**–Comments cited claims that Arecibo Observatory is important to national security as it tracks asteroids that may impact the earth.

Alternative Considerations

The public had the following suggestions designed to keep Arecibo Observatory open:

- **Funding**–The public had many types of funding suggestions, including telethons, crowdfunding, and grants.
- **Marketing**–It was suggested that better marketing would boost tourism to the facility.
- **Partnerships**–Partnerships with other governmental agencies, educational institutions, foundations, and corporations were suggested.

Resource Considerations

The public had comments on evaluation criteria to be used for the EIS, including the following:

- **Endangered Species**–Evaluate the effects of the Alternatives on endangered species, specifically the Puerto Rican parrot and Puerto Rican broad-winged hawk.
- **Environmental Justice**–Consider whether there is a disproportionate impact on minority populations.
- **Renovation**–Consider the facility renovations needed to meet collaboration requirements.
- **Restoration**–Consider the environmental impact of restoring Arecibo Observatory back to operation. This comment requested that analysis be provided regarding the costs and environmental impact of restoring or returning the equipment after the facility has been mothballed.
- **Health and Safety**–Consider the impacts due to loss of asteroid detection ability, hazardous condition of the "mothballed" facility, and hazardous materials encountered during demolition of the facility.

Decision Process

The public had general questions and comments about the decision-making process, such as NSF hosting a conference and inviting the responders to the Dear Colleague Letter, along with other stakeholders with the goal of finding a way forward with NSF as a minor player.

General

The public had general questions about the EIS, such as where information on the EIS process is archived and how many comments have been received.

Oral Comments Received at the Scoping Meetings

Public comments received orally during the scoping meetings are provided in the public meeting transcripts (Appendix 5-B). The comments were assigned to the aforementioned categories, as appropriate, with the following exceptions:

- **NSF Portfolio Review Studies**–Previous portfolio review studies. One meeting participant questioned the facts in the NSF studies that were used to substantiate the recommendation to potentially close Arecibo Observatory.
- **Current Management of Arecibo Observatory Should Be Considered**–Alternative 2 as presented in opening remarks should be considered as the existing condition. Arecibo Observatory is currently operating as an education-focused collaboration.
- **Quiet Zone Issue: Puerto Rico Law No. 88 Restricting Development near Arecibo**–Consider that if Arecibo Observatory is removed there would be changes to the environment and the possibility for further development.

- **Request for Science Studies**–A full geological, biological, and water runoff study should be conducted before any other options are considered.

Written Comments Received at the Scoping Meeting

One hard copy comment was submitted at the evening public meeting in Arecibo. This comment requested the study of a public-private collaboration.

5.2.3 Public DEIS Meetings

A second round of public meetings was held on November 16, 2016, and November 17, 2016, following the publication of the DEIS. The intent of these meetings was to receive comments on the DEIS from agencies and the public.

5.2.3.1 Public DEIS Meetings Held

The following two public meetings were held on November 16, 2016 and November 17, 2016:

- Evening meeting: November 16, 2016, from 6:00 p.m. to 9:30 p.m., Colegio de Ingenieros y Agrimensores de Puerto Rico/Puerto Rico Professional College of Engineers and Land Surveyors (Arecibo Chapter), Ave. Manuel T. Guillán Urdáz, Conector 129 Carr. 10, Arecibo, Puerto Rico
- Daytime meeting: November 17, 2016, from 10:00 a.m. to 12:30 p.m., DoubleTree by Hilton San Juan, 105 Avenida De Diego, San Juan, Puerto Rico

The following public NHPA Section 106 consultation meeting was held on November 17, 2016:

- Daytime meeting: November 17, 2016, from 1:00 p.m. to 3:00 p.m., DoubleTree by Hilton San Juan, 105 Avenida De Diego, San Juan, Puerto Rico

The public was invited to sign in, view, and receive information regarding the Alternatives and listen to presentations given by members of the NSF team. The meeting participants were given the opportunity to ask questions, comment about issues and concerns, and provide oral and written comments. The format for each meeting was identical. NSF made opening statements announcing the purpose of the meeting, introducing key members of the NSF EIS team, describing the process to sign up to provide public comment, and explaining that the meeting would be translated. Alternating Spanish and English translation was provided by a U.S. courts-certified interpreter and National Association of Judiciary Interpreters and Translators-certified interpreter and translator. During each meeting, the meeting participants were encouraged to provide oral or written comments via regular mail or email. Display material and comment forms with submittal instructions were provided at each meeting. A stenographer recorded each meeting. Copies of the meeting transcripts are provided in Appendix 5-F.

Table 5.2-3 lists the number of participants who registered at each meeting and the number of speakers who signed up to provide oral comments. The number of registered participants is based on the number of individuals who signed the attendance sheet upon arriving at the meeting. During the course of the meeting, some attendees who had indicated on the sign-up form that they wished to speak chose not to speak, and conversely, some who did not register to speak chose to speak. The meeting transcripts, including a list of attendees who spoke, are provided in Appendix 5-F.

TABLE 5.2-3
Summary of Public DEIS Meeting Participants

Meeting Location	Registered Participants	Number of Speakers
Summary of November 16, 2016 Public Meeting Participants		
Arecibo	53	23 registered speakers / 20 actual speakers[b]
Summary of November 17, 2016 Public Meeting Participants		
San Juan	32	15 registered speakers / 20 actual speakers[b]
Summary of the Public Consultation Section 106 Meeting Participants		
San Juan	29	9 registered speakers / 13 actual speakers[b]

[a] The number of actual speakers is different from those who requested to speak on the sign-in sheet. Please see the meeting transcript for names of individuals who provided oral comments.

[b] Due to the length of some comments, some of those who spoke at the meeting were asked to provide the remainder of their comments at the end of the meeting in order to allow all speakers a chance to provide comments. Individuals who spoke twice are only counted once in these numbers. Due to time availability toward the end of the meeting, all speakers were allowed to complete their comments.

In addition to providing spoken comments, meeting participants were invited to provide written comments on comment forms provided during the meeting. Other opportunities to provide comments included mailing comments to NSF at the following address: Ms. Elizabeth Pentecost, RE: Arecibo Observatory, National Science Foundation, Suite 1045, 4201 Wilson Blvd., Arlington, VA 22230, and submitting them via email to the following email address*:* envcomp-AST@nsf.gov, with subject line ‘‘Arecibo Observatory.’’ Additionally, comments could also be received through the NSF project website at www.nsf.gov/AST.

5.2.3.2 Public Comment Results

The public was encouraged to comment during the public comment period (October 28 through December 12, 2016). All public and agency comments were reviewed and evaluated by NSF. Many comments were similar in nature and conveyed similar themes; therefore, the comments were organized into categories, as shown in Table 5.2-4. The categorized comments were placed into separate matrixes to accommodate responses by category. A full listing of all the categorized comments and responses is located in Appendix 5-H. Where necessary, this FEIS has been updated in response to these comments. A compilation of all hard copy and email copies received is located in Appendix 5-I.

TABLE 5.2-4
Public Comments (Oral and Written) Summarized by Category

Category	Description	Number of Comments[a,b]
Against Closure/Reasons Why	Comments against closing Arecibo Observatory	254

TABLE 5.2-4
Public Comments (Oral and Written) Summarized by Category

Category	Description	Number of Comments[a,b]
Against Closure/Alternative Considered	Suggestions for additional uses of the facility and sources of funding	43
Resource Considerations for Document Analysis	Suggestions on what resources to include in the EIS	109
Procedural	Comments referring to the NEPA process and procedures	12
Background	General personal information or background information from the DEIS	12

[a] The number of comments as of January 27, 2017, was approximately 430. Several commenters provided the same comment as a verbal comment at the public meeting and as a written comment. Duplicate comments from the same commenter were considered a single comment and addressed with the submitted written comments.

[b] This tally includes 72 handwritten comments and pictures from students identified collectively as number 66 in the comment matrix and provided in Appendix 5-I.

Summary of Non-Substantive Comments

Comments that do not address the EIS scope, analysis, or process are considered non-substantive. Non-substantive comments comprise 12 comments categorized as “Background” and 254 comments categorized as “Against Closure/Reasons Why.” The “Against Closure/Reasons Why” category captures a variety of re-occurring themes in the comments that raise specific concerns about closure. Some of the comments were the commenters’ opinions regarding the importance of the role of Arecibo Observatory as a scientific icon/national treasure and/or the importance of Arecibo Observatory in supporting education and STEM programs. Many of these comments were solely the commenters’ opinions and did not require changes to the EIS[9]. Other non-substantive comments in this category included comments around the themes of research, NSF mission, funding decision process, and costs. These themes are further defined below along with an explanation for why they were not specifically addressed in the EIS.

Research – Comments cited in this group include concerns about the negative effect that closure of Arecibo Observatory would have on the astronomy community. The comments indicated that discoveries made capable by the radio telescopes at Arecibo Observatory are vital to the field of radio astronomy. Other commenters stated that it was important to keep this capability in the United States. Other themes include the potential loss of current and future science; funding; future uses; positive impact on research careers; negative impact to Puerto Rico and students and researchers; history of Arecibo Observatory; importance of emerging science; unique scientific capabilities for Puerto Rico; and historical contribution

[9] Some comments touched upon education and STEM programs and identified potential issues with the NEPA process or the content of the FEIS and analysis; these comments are considered substantive. NSF has provided specific responses and the FEIS has been revised, accordingly. These comments are described in Section 5.2.3.2.2 as substantive comments by resource.

of discoveries made at Arecibo Observatory. Comments in this theme did not identify any issues to address in the NEPA document.

NSF Mission, Decision Process, and Costs – A range of comments were submitted that focused on the funding decision process, the interpretation of the Portfolio Review process and other reports, how NSF manages the budget, and how NSF funds and prioritizes projects and values scientific missions. Other comments requested clarification of cost estimates for the various Alternatives being proposed. Comments in this theme did not identify any issues to address in the NEPA document.

Response Regarding Non-Substantive Comments – NSF agrees that valuable science and education activities are being conducted at Arecibo Observatory, as evidenced by decades of significant funding of both the facility and research grants. However, the purpose of the current proposal is to reduce NSF funding in light of a constrained budgetary environment. Neither the merits of science and education activities at Arecibo Observatory nor NSF's budgetary decisions are the focus of this review. As explained in the DEIS and during public meetings, NSF relies on the scientific community via decadal surveys and senior-level reviews to provide input on priorities, and this community has repeatedly recommended divestment from Arecibo Observatory, as well as from other observatories currently under similar review. These recommendations are summarized in this document only to explain the need for the current proposal. In accordance with NEPA, the DEIS and this FEIS analyze the potential environmental impacts of a range of alternatives to meet the objective of reduced funding by NSF for Arecibo Observatory. Comments on environmental impacts are addressed throughout this document where appropriate and as noted in Section 5.2.3.2.2.

With regard to federal decision-making as it relates to NEPA review, environmental impacts must be analyzed and considered by the funding agency, with opportunity for public comment. An agency's ultimate decision, which is formalized during this process via a ROD, may be based on a variety of factors, including environment, budget, and mission-related. Although an Agency-preferred Alternative (collaboration with interested partners for continued science-focused operations) has been identified and analyzed in both the DEIS and this FEIS, implementation of this Alternative may occur only if a viable collaboration is identified.

Substantive Comments

The remaining comments were categorized as substantive and were grouped into the following categories:

- Against Closure/Alternatives Considered (Alternatives)
- Resource Considerations for Document Analysis
- Procedural

These comments are grouped by the resource themes found in the FEIS, except for Alternatives and Procedural, which were added to cover other NEPA-related topics. These substantive comments are shown in Appendix H under the individual comment response matrices, which are titled "Response Matrices for Substantive Comments Grouped by Topic." Where applicable, these matrices indicate where each comment is addressed in the FEIS.

5.3 Section 106 of NHPA Consultation Process

This Section describes the Section 106 consultation process and identifies the Section 106 Consulting Parties. As stated in 36 C.F.R. §800.1:

> "Section 106 of the National Historic Preservation Act requires Federal agencies to take into account the effects of their undertakings on historic properties and afford the Council [Advisory Council on Historic Preservation (ACHP]) a reasonable opportunity to comment on such undertakings. The procedures in this part define how Federal agencies meet these statutory responsibilities. The section 106 process seeks to accommodate historic preservation concerns with the needs of Federal undertakings through consultation among the agency official and other parties with an interest in the effects of the undertaking on historic properties, commencing at the early stages of project planning. The goal of consultation is to identify historic properties potentially affected by the undertaking, assess its effects and seek ways to avoid, minimize or mitigate any adverse effects on historic properties."

In compliance with Section 106, NSF invited the SHPO, the ACHP, Consulting Parties, and the public to participate in the consultation process.

5.3.1 Section 106 Consultation Chronology

Table 5.3-1 presents the chronology of the Section 106 consultation.

TABLE 5.3-1
Section 106 Consultation Process

Date	Action	Details
May 19, 2016	Pre-Scoping Teleconference	NSF attended a teleconference with SHPO, followed by informal email correspondence.
May 20, 2016	Email from SHPO	The Puerto Rico SHPO confirmed that the NRHP-listed historic district includes 118 acres and that five of the Observatory buildings included in the NRHP nomination are non-contributing. The remaining nine buildings and structures are contributing.
May 24, 2016	Public Involvement Initiated	NOI, including the Section 106 notice, was published in the *Federal Register*.
June 6, 2016	Early Coordination Meeting with the SHPO	NSF met with representatives from the Puerto Rico SHPO to discuss the proposed undertaking. This was followed by email correspondence.
June 7, 2016	NEPA Public Scoping Meetings	Public meetings were held in San Juan and Arecibo. NSF provided an opportunity for individuals and organizations to express an interest in participating as Section 106 consulting parties.
June 16, 2016	Email to Potential Consulting Parties	NSF contacted those individuals and organizations that had expressed interest in Section 106 consultation during the NEPA public scoping meetings to provide

TABLE 5.3-1
Section 106 Consultation Process

Date	Action	Details
		further details about the Section 106 consultation process and to confirm their consulting party status for the Proposed Action. Parties were given until June 29 to confirm their interest in consulting party participation.
July 5, 2016	Initiate Section 106 Consultation with the SHPO	NSF initiated formal Section 106 consultation with the Puerto Rico SHPO through written correspondence. NSF invited the SHPO to participate in the cultural resources field investigations that would occur July 19 and 20, 2016, at Arecibo Observatory.
July 11, 2016	Email – Section 106 Initiation Follow-up Regarding Architectural Survey	NSF inquired as to whether the SHPO was interested in attending the cultural resources field investigations at Arecibo Observatory on July 19 and 20, 2016.
July 12, 2016	Email – Request for Architectural Survey Agenda	The SHPO requested the agenda for the cultural resources field investigations.
July 12, 2016	Email – Response to Request for Architectural Survey Agenda	NSF provided the SHPO with the agenda for the cultural resources field investigations.
July 19–20, 2016	Reconnaissance Architectural Survey	Reconnaissance architectural survey completed at Arecibo Observatory to verify existing conditions of known historic properties within the NRHP-listed historic district.
July 19, 2016	Notification to John Fowler at the ACHP	Email from NSF was sent to the ACHP notifying John Fowler of the Arecibo Observatory EIS, the NOI, and ongoing coordination with the Puerto Rico SHPO is ongoing.
July 19, 2016	Notification to John Eddins at the ACHP	Email from NSF was sent to the ACHP notifying John Eddins that NEPA process and Section 106 consultation with the Puerto Rico SHPO is ongoing. Asked whether the ACHP would like to be involved in the Section 106 process. Also included: email correspondence with John Fowler (ACHP); Arecibo Observatory fact sheet; correspondence with the Puerto Rico SHPO; handouts provided at the NEPA Public Scoping Meetings.
August 8, 2016	Response from the SHPO	Letter from the Puerto Rico SHPO to NSF acknowledging that the Alternatives have been developed that could result in an effect on the Observatory. The SHPO requested that they are kept abreast of any determination regarding the historic property in order to assess and resolve effects.
September 15, 2016	Conference Call with the SHPO	Follow-up was conducted regarding Section 106 initiation letter, followed by email correspondence.
September 15, 2016	Email to SHPO	NSF emailed SHPO several questions that had been discussed during the conference call that occurred earlier that day. NSF requested clarifications regarding scheduling. In addition, NSF asked if SHPO would like to review the Proposed Changes to Arecibo Observatory Operations: Historic Properties Assessment of Effects technical report and provided a list of people who indicated they wished to serve as Consulting Parties in the Section 106 consultation process.
September 16, 2016	Email Response from SHPO	Berenice Sueiro from SHPO confirmed that they could meet with NSF during the week of November 14, 2016, and that they would like to review the *Proposed Changes to Arecibo Observatory Operations: Historic Properties Assessment of Effects* technical report.
October 6, 2016	Notification to John Eddins	Email from NSF was sent to John Eddins at the ACHP requesting confirmation regarding whether the ACHP will participate in consultation.
October 7, 2016	Response from the ACHP	Email from John Eddins at the ACHP to NSF stating he would review the material provided by NSF and provide a response.

TABLE 5.3-1
Section 106 Consultation Process

Date	Action	Details
October 19, 2016	Email to the SHPO	NSF provided the SHPO with the *Proposed Changes to Arecibo Observatory Operations: Historic Properties Assessment of Effects* technical report for review and comment. A hard copy of the document was also provided by mail. NSF notified the SHPO about the upcoming public and Consulting Party meetings to be held in November 2016. NSF requested to meet with the SHPO the week of November 15, 2016.
October 20, 2016	Email to the Consulting Parties	NSF provided the Consulting Parties with the *Proposed Changes to Arecibo Observatory Operations: Historic Properties Assessment of Effects* technical report for review and comment. NSF invited the Consulting Parties to a meeting held on November 17, 2016, in San Juan.
November 3, 2016	Notification Published in *El Norte*	Notified the public that NSF has prepared a DEIS and would be hosting two public meetings on the DEIS and one Consulting Party meeting on November 16 and November 17, 2016.
November 4, 2016	Email to the ACHP	NSF emailed John Eddins at the ACHP to follow-up regarding the ACHP's interest in participating in the Section 106 process. The email provided a link to the DEIS.
November 4, 2016	Email Response from John Eddins at the ACHP	John Eddins of the ACHP notified NSF that he would review the DEIS, and if no response was received within 15 days, NSF could move on with the Section 106 process.
November 15, 2016	In-person meeting with SHPO	NSF met in-person with the SHPO in Puerto Rico to discuss the next steps in the consultation process and to prepare for the upcoming consultation meeting.
November 16, 2016	NEPA Public Scoping Meeting	Public meeting was held in Arecibo to discuss the DEIS and receive public comments.
November 17, 2016	NEPA Public Scoping Meeting	Public meeting was held in San Juan to discuss the DEIS and receive public comments.
November 17, 2016	Consulting Party Meeting	Section 106 Consulting Party meeting held in San Juan to provide an overview of the Section 106 process, review the Alternatives and their anticipated effects, and discuss potential mitigation measures.
December 12, 2016	Letter Response from SHPO	SHPO sent a letter to NSF acknowledging receipt of documentation describing all five action Alternatives and noting that all five Alternatives meet the criteria of adverse effect. SHPO recommended that NSF notify the ACHP and continue to consult with the Consulting Parties to seek ways to resolve adverse effects.
December 15, 2016	Email to the ACHP	NSF sent an email to the ACHP with clarifications about the proposed project and again asked if they would like to participate in the Section 106 process. No response was received.
December 15, 2016	Email Exchange between NSF and ACHP	The ACHP and NSF exchanged emails concerning the need for ACHP involvement. NSF described public opposition to the proposal and its intention to draft a PA. No further response from the ACHP was received.
April 21, 2017	Email from NSF to SHPO	NSF notified SHPO that they would be receiving the preliminary draft PA for review and comment before NSF sent it out to the Consulting Parties. NSF requested to coordinate a call to discuss the contents of the preliminary draft PA.
April 26, 2017	Email from NSF to SHPO	Follow-up email to confirm that the SHPO received the email from April 21, 2017. NSF requested to discuss the contents of the preliminary draft PA during a brief call on April 27, 2017.
April 26, 2017	Email Response from the SHPO to NSF	Notified NSF that there is a new SHPO: Carlos A. Rubio Cancela. Berenice Sueiro informed NSF she is available on April 27 for a teleconference and would try to confirm that Migquel Bonini (Senior Historic Property Specialist) was also available.

TABLE 5.3-1
Section 106 Consultation Process

Date	Action	Details
April 27, 2017	Teleconference with the SHPO	Call with Berenice Sueiro and Miguel Bonini (SHPO) to discuss the preliminary draft PA. The SHPO asked NSF to reach out to the ACHP and include it in the consultation process. NSF informed the SHPO that, after careful consideration, it was not planning to include a stipulation in the draft PA for listing the Observatory as a National Historic Landmark. NSF notified SHPO that it would provide the SHPO and the ACHP with a copy of the preliminary draft PA for informal review and comment.
April 28, 2017	Email to the ACHP (cc the SHPO)	NSF provided the preliminary draft PA to the ACHP and requested comments. The SHPO was copied on the email. Hard copies of the preliminary draft PA were also sent at this time. NSF requested to hold a teleconference with the ACHP to discuss the PA.
April 28, 2017	Letter to ACHP	Hard copies of the Assessment of Effects technical report, consultation record, summary of public and Consulting Parties comments relating to cultural resources, and the preliminary draft PA and a cover letter were sent to the ACHP (in addition to the email mentioned previously). Initial thoughts on the preliminary draft PA were requested as soon as possible. Letter included a formal invitation to the ACHP to participate in the Section 106 process.
May 1, 2017	Email Response from John Eddins at the ACHP	The ACHP confirmed receipt of the preliminary draft PA. John Eddins notified NSF that Charlene Vaughn would be handling further coordination for this undertaking.
May 1, 2017	Email Response from NSF to ACHP	NSF requested a teleconference with ACHP.
May 5, 2017	Teleconference with Charlene Vaughn at the ACHP	NSF spoke with Charlene Vaughn. The ACHP notified NSF that it would provide a letter stating the ACHP would formally join the Section 106 consultation process. The ACHP also noted that it would provide informal comments on the preliminary draft PA. The ACHP recommended that NSF have the PA and attachments translated into Spanish and that NSF hold another in-person meeting in Puerto Rico to discuss the PA with the Consulting Parties. In addition, the ACHP recommended several steps to expand outreach for the PA.
May 18, 2017	Email from NSF to ACHP and SHPO	Follow-up email to the April 28 letter regarding the preliminary draft PA to see if the ACHP or SHPO had comments on the document. NSF stated that they would like to send the preliminary draft PA to Consulting Parties before the end of May to allow for sufficient time for review. NSF proposed a meeting in San Juan to discuss remaining issues with the Consulting Parties for either August 14 or 15. NSF also informed the ACHP and SHPO about the possibility of transferring ownership of Arecibo Observatory to a non-federal entity and that it would contact Betsy Merritt of the National Trust for Historic Preservation to see if the Trust would be interested in serving as a Consulting Party.
May 18, 2017	Email Response from SHPO to NSF	SHPO informed NSF that it would send comments soon.
May 23, 2017	Email to ACHP and SHPO	NSF emailed the ACHP and SHPO to inquire about when to expect comments on the preliminary draft PA.
May 24, 2017	Email Response from ACHP	ACHP notified NSF that they are still working on the preliminary draft PA comments and need to speak with SHPO before they respond.
May 24, 217	Email Response from NSF to ACHP	NSF thanked the ACHP for its help and reminded ACHP of the tight deadline.
May 25, 2017	Letter from SHPO to NSF	SHPO provided a letter via email (sent May 26, 2017) that acknowledged receipt of the preliminary draft PA. SHPO recommended further consultation with the Consulting Parties and the ACHP.

TABLE 5.3-1
Section 106 Consultation Process

Date	Action	Details
May 26, 2017	Email Response from ACHP with Letter Attachment	ACHP accepted NSF's invitation to participate in the Section 106 consultation process. The letter informed NSF that Charlene Vaughn will handle the ACHP's participation.
May 30, 2017	Letter from ACHP	The ACHP reviewed the DEIS and the transcript from the two onsite public meetings and noted historic preservation concerns related to the five Alternatives. The ACHP recommended further consultation before drafting the PA.
June 1, 2017	Teleconference with the ACHP and SHPO	Meeting to discuss the ACHP's participation in the Section 106 process and the preliminary draft PA.
June 13, 2017	Email from ACHP to NSF	ACHP provided comments on the preliminary draft PA. ACHP stated that the PA does not reflect the last conversation between the SHPO, ACHP, and NSF and fails to reflect the outcome of good faith consultation. Recommended NSF plan a consultation meeting with all Consulting Parties to discuss the PA.
June 14, 2017	Email Response from NSF to ACHP	NSF presented concerns regarding the ACHP's June 13, 2017 email and their comments on the preliminary draft PA. NSF summarized consultation efforts to date and agreed to organize a consultation teleconference with all Consulting Parties and the SHPO. NSF also suggested an in-person meeting with Charlene Vaughn (ACHP) to discuss the status of the Section 106 process and next steps.
June 14, 2017	Email Response from ACHP to NSF	ACHP responded with further explanation regarding ACHP's perspective. Noted that the preliminary draft PA still needs work and is not ready to share with the Consulting Parties; summarized feedback from the Consulting Parties; and encouraged NSF to consult with an agency such as NASA regarding how it has coordinated its NEPA and NHPA reviews.
June 14, 2017	Email Response from NSF to ACHP	NSF notified ACHP that it is in the process of setting up a Consulting Parties teleconference for June 21, 2017. NSF provided meeting notes from the November 17, 2016, consultation meeting. NSF explained that the process for evaluating proposals in response to the solicitation is based on NSF's scientific review process. Referenced the ACHP document entitled *Balancing Historic Preservation Needs with Operation of Highly Technical or Scientific Facilities* (1991) and clarified that NASA is a cooperating agency in NSF's NEPA process.
June 14, 2017	Email Response from ACHP to NSF	ACHP reiterated that the parameters of the Section 106 review need to be clarified for the Consulting Parties.
June 14, 2017	Email to SHPO and ACHP from NSF	NSF invited the SHPO and ACHP to attend a teleconference consultation meeting on June 21, 2017, starting at 3:30 and an in-person consultation meeting in San Juan on July 7, 2017 [later corrected to a meeting in Arecibo on July 6, 2017].
June 14, 2017	Email Response from ACHP to NSF and SHPO	ACHP accepted the invitation to participate in a Section 106 consultation teleconference on June 21, 2017 and agreed to call in to the meeting on July 7, 2017 [meeting later changed to July 6, 2017].
June 14, 2017	Email from NSF to Consulting Parties	NSF invited Consulting Parties to a teleconference on June 21, 2017 and an in-person meeting on July 6, 2017. It provided a summary of the consultation that has occurred to date and what would occur moving forward with the Section 106 process. NSF provided some draft measures to use as a starting point for the discussion of potential avoidance, minimization, and mitigation. Feedback on these draft measures was encouraged and a link to the historic district NRHP nomination was provided for reference. [Two updates were sent as a follow-up to this email because the location of the in-person meeting was changed from San Juan to Arecibo.]

TABLE 5.3-1
Section 106 Consultation Process

Date	Action	Details
June 16, 2017	Email from NSF to Local Government Officials	NSF invited local government officials to attend and participate in two upcoming Section 106 consultation meetings: a June 21, 2017 teleconference and a July 6, 2017 in-person meeting in Arecibo. It provided a summary of the consultation that has occurred to date and what would occur moving forward with the Section 106 process. NSF provided some draft measures to use as a starting point for the discussion of potential avoidance, minimization, and mitigation. Feedback on these draft measures was encouraged and a link to the historic district NRHP nomination was provided for reference.
June 16, 2017	Email from NSF to Stakeholders	NSF invited stakeholders to participate in a Section 106 consultation public meeting on July 6, 2017, to discuss measures to avoid, minimize, and/or mitigate potential effects to historic properties.
June 21, 2017	Consulting Party Teleconference Meeting	Teleconference with NSF, SHPO, ACHP, and the Consulting Parties to discuss the draft PA and potential avoidance, minimization, and mitigation measures to resolve adverse effects to historic properties. The Consulting Parties expressed particular concern regarding how to emphasize the cultural significance, not just the historic significance, of the Observatory.
June 23, 2017	Email from SHPO to NSF and ACHP	SHPO provided an electronic copy of the Cooperative Agreement between the U.S. Government and Puerto Rico Government for the long-term preservation and maintenance of the Cuartel de Ballaja, Parcels A and B for NSF's and ACHP's reference. SHPO also provided an NPS brochure for the Monuments Program and Recreations Program for review. ACHP confirmed receipt.
June 23, 2017	Email Response from NSF to SHPO	NSF confirmed receipt of the reference materials sent by the SHPO on June 23, 2017, and noted that it would review the document to see what adjustments could be made to the draft PA, which would be sent out momentarily. Since the draft PA was ready for distribution, it would not reflect any components of the cooperative agreement; the next draft would include this information.
June 23, 2017	Email from NSF to Consulting Parties	NSF provided the draft PA for review and comment and notified the Consulting Parties that the 30-day public comment period for the document started on June 23, 2017. The email announced the availability of the document in the Biblioteca Electrónica Pública Municipal Nicolás Nadal Barreto and the Archivo General y Biblioteca Nacional de Puerto Rico. In addition, NSF provided a Frequently Asked Questions (FAQ) document and the NASA Cultural Resource Management document, as well as links to the ACHP's website and their success stories, a link to NSF's request for proposals, and a link to the ACHP's 1991 document entitled *Balancing Historic Preservation Needs with the Operation of Highly Technical or Scientific Facilities*. NSF noted that Spanish versions of the draft PA and FAQ would be posted to the NSF's website on June 26, 2017. NSF included the details for the in-person consultation meeting scheduled for July 6, 2017, in Arecibo.
June 23, 2017	Email from NSF to Stakeholders	NSF provided the draft PA for review and comment to stakeholders and any previous consultation meeting attendees and notified them that the 30-day public comment period for the document started on June 23, 2017. The email announced the availability of the document in the Biblioteca Electrónica Pública Municipal Nicolás Nadal Barreto and the Archivo General y Biblioteca Nacional de Puerto Rico. In addition, NSF provided a FAQ document, and the NASA Cultural Resource Management document, as well as links to the ACHP's website and their success stories, a link to NSF's request for proposals, and a link to the ACHP's 1991 document entitled *Balancing Historic Preservation Needs with the Operation of Highly Technical or Scientific Facilities*. NSF noted that Spanish versions of the draft PA and FAQ would be posted to the NSF's website on June 26, 2017. NSF included the details for the in-person consultation meeting scheduled for July 6, 2017, in Arecibo.

TABLE 5.3-1
Section 106 Consultation Process

Date	Action	Details
June 28, 2017	Consulting Party Added	Ramon Lugo of University of Central Florida was added as a Consulting Party
June 28 and July 6, 2017	Public Notice Published	The Public Notice announcing the availability of the draft PA and the details of the public consultation meeting on July 6, 2017, was published in *El Nueva Dia* (June 28) and in *El Norte* (July 6).
July 6, 2017	Meet with U.S. Congresswoman's Office	NSF met with staff of Honorable Jennifer Gonzalez-Colon, U.S. House of Representatives, Puerto Rico-At Large, to discuss the undertaking and to brief them on the NEPA process and the Section 106 process.
July 6, 2017	Consulting Party Meeting/Public Meeting in Arecibo	Consulting Parties meeting held in Arecibo to discuss the draft PA. SHPO and ACHP attended. The public was also invited.
July 7, 2017	Email from NSF to Stakeholders	NSF emailed stakeholders to inform them that the Consulting Parties meeting was held on July 6, 2017, in Arecibo to discuss the draft PA. NSF invited those who could not attend the meeting, as well as those who attended the meeting but had more suggestions, to participate in a Consulting Parties teleconference on July 13, 2017, to continue the discussion. The agenda for the July 6 meeting and the draft PA were attached to the email and a link to the draft PA was also provided.
July 13, 2017	Email from NSF to Stakeholders	NSF emailed stakeholders to remind them about the Consulting Parties teleconference that would be held later that day to continue the discussion of the draft PA contents.
July 13, 2017	Consulting Parties Teleconference	Consulting Parties meeting held via teleconference to discuss draft PA. SHPO and ACHP attended. The public was also invited.

5.3.1.1 Advisory Council on Historic Preservation

The ACHP was notified on July 19, 2016, of NSF's intent to prepare an EIS for Arecibo Observatory and was asked whether the ACHP wished to participate in the consultation. NSF sent a follow-up email to John Eddins at the ACHP on October 6, 2016, to confirm that the ACHP would participate in the consultation. On October 7, 2016, Mr. Eddins responded to NSF, stating he would review the material provided. On November 4, 2016, NSF sent an email to the ACHP to provide the link to the DEIS. Mr. Eddins responded on the same day, letting NSF know that he would review the DEIS, and if no response was received within 15 days, NSF could continue with the Section 106 process. NSF emailed the ACHP on December 15, 2016, to provide clarification about the Proposed Action and ask if the ACHP would like to participate in the Section 106 process.

During a teleconference on April 27, 2017, the Puerto Rico SHPO asked NSF to reach out to the ACHP and encourage its participation in the consultation process. On April 28, 2017, NSF provided the ACHP with the preliminary draft PA for informal review and comment. Mr. Eddins responded by email the same day, confirming receipt of the preliminary draft PA and notifying NSF that Charlene Vaughn of the ACHP would be handling further coordination for the proposed undertaking. A teleconference was held between NSF and the ACHP on May 5, 2017. The ACHP said it would provide a letter formally joining the Section 106 consultation process and it would provide informal comments on the preliminary draft PA. The ACHP sent a formal letter on May 26, 2017, confirming its intent to join the consultation process. A follow-up teleconference was conducted with ACHP and SHPO on June 1, 2017 to discuss the ACHP's participation in the Section 106 process and the content of the preliminary draft PA. The ACHP provided comments on the preliminary draft PA on June 13, 2017. The draft PA was submitted to the ACHP on June 23, 2017, for formal review and comment. The ACHP participated in the Consulting Parties meetings on July 6, 2017 (in-person) and July 13, 2017 (via teleconference) to discuss revisions to the draft PA. At the end of the 30-day review period, the ACHP's comments were reviewed and a conference call was scheduled with NSF, the SHPO, the ACHP, and the Consulting Parties in August 2017 to discuss the comments and provide clarification. Based on the comments and the discussions during the August conference call, NSF will revise the second draft PA and submit a final version of the PA to the ACHP for signature. All drafts of the PA are provided in both English and Spanish.

5.3.1.2 Puerto Rico State Historic Preservation Office

The SHPO is the responsible Commonwealth of Puerto Rico entity with which NSF is required, pursuant to the NHPA, to engage in Section 106 consultation regarding the Proposed Action, defined as the undertaking for Section 106. The SHPO was initially contacted via email on May 18, 2016, followed by a telephone conversation the next day (May 19, 2016) to discuss the proposed undertaking and introduce the preliminary Alternatives. A copy of the NOI was provided to the Puerto Rico SHPO via email during the week of May 23, 2016. NSF met with the SHPO to discuss the proposed undertaking and preliminary Alternatives on June 6, 2016. A letter to formally initiate Section 106 was sent to the SHPO on July 5, 2016, which included the Delivery Control Form and all attachments required by SHPO. The letter also included an invitation for representatives of the Puerto Rico SHPO to attend a site visit at Arecibo Observatory, scheduled for July 19 and 20, 2016. On August 8, 2016, NSF received a letter from the Puerto Rico SHPO acknowledging that Alternatives have been developed that could result in an effect on the Observatory. The SHPO requested that it be kept abreast of any determination regarding the historic property in order to assess and resolve any effects. NSF had a teleconference with SHPO on September 15, 2016, to confirm the Consulting Parties who wished to participate in the Section 106 consultation, discuss the potential dates for the SHPO and Consulting Parties meetings in November 2016, and determine the SHPO's availability to review upcoming deliverables.

On October 19, 2016, NSF provided the SHPO with the *Proposed Changes to Arecibo Observatory Operations: Historic Properties Assessment of Effects* technical report for review and comment. No comments were received. An in-person meeting between NSF and the SHPO was held in Puerto Rico on November 15, 2016, to discuss the next steps in the consultation process and the preparation of the upcoming public and Consulting Parties meetings. The Puerto Rico SHPO sent a letter to NSF on

December 12, 2016, acknowledging receipt of documentation describing all five action Alternatives and noting that all five Alternatives meet the criteria of adverse effect under Section 106.

On April 27, 2017, NSF and the SHPO met via teleconference to discuss the preliminary draft PA. The SHPO requested that NSF reach out to the ACHP to request that it participate in the Section 106 consultation process. NSF sent the preliminary draft PA to the SHPO on April 28, 2017, and requested informal comments. On May 26, 2017, SHPO emailed a letter to NSF, dated May 25, 2017, that acknowledged receipt of the preliminary draft PA and recommended further consultation with the Consulting Parties and the ACHP. NSF participated in a teleconference with the SHPO and the ACHP on June 1, 2017, to discuss the ACHP's participation in the Section 106 process and the preliminary draft PA. The draft PA was submitted to the Puerto Rico SHPO on June 23, 2017, for formal review and comment. The SHPO participated in the Consulting Parties meetings on July 6, 2017 (in-person) and July 13, 2017 (via teleconference) to discuss revisions to the draft PA. At the end of the 30-day review period, the SHPO's comments were reviewed and a conference call was scheduled with NSF, the SHPO, the ACHP, and the Consulting Parties in August 2017 to discuss comments and provide clarification. Based on the comments and upcoming discussions during the August conference call, NSF will revise the second draft PA and submit a final version of the PA to the SHPO for signature. All drafts of the PA are provided in both English and Spanish.

5.3.1.3 Identification of Consulting Parties

During the initial pre-scoping teleconference with the SHPO, NSF requested a list of potential Consulting Parties who may be interested in Arecibo Observatory. Currently, the SHPO does not maintain a formal list of individuals or organizations interested in Arecibo Observatory; therefore, it was determined that attendees at the public scoping meetings would be offered the opportunity to participate in this process through announcements at the scoping meeting. The Section 106 process was explained as part of the oral remarks provided by NSF. Additionally, scoping meeting participants were asked to sign in for each meeting. The sign-in sheet included a box to check if meeting participants wished to be considered Consulting Parties as part of the Section 106 process. Approximately nine individuals in the daytime meeting and eight individuals in the evening meeting requested to participate. NSF sent a confirmation email on June 16, 2016 to all attendees that indicated interest in being a Consulting Party, and six individuals confirmed their request to be Consulting Parties. On October 20, 2016, NSF provided the Consulting Parties with the *Proposed Changes to Arecibo Observatory Operations: Historic Properties Assessment of Effects* technical report for review and comment. The cover letter to the report invited the Consulting Parties to a meeting on November 17, 2016, in San Juan. The Consulting Parties meeting included an overview of the Section 106 process, a review of the Alternatives and their anticipated effects, and a discussion of potential mitigation measures. Two public meetings were held in Puerto Rico on November 16 and November 17, 2017, prior to the Consulting Parties meeting. During these meetings, participants were asked if they would like to participate as Consulting Parties. Four additional individuals confirmed that they would like to be a Consulting Party. One additional Consulting Party was subsequently identified, for a total of 11 Consulting Parties. Table 5.3-2 identifies all Consulting Parties.

TABLE 5.3-2
Section 106 Consulting Parties

Name	Organization
Tony Van Eyken	Arecibo Observatory
Brett Isham	Interamerican University-Bayamón
Xavier Siemens	North American Nanohertz Observatory for Gravitational Waves
Nicholas White	USRA
Qihou Zhou	Miami University
Luisa Fda Zambrano-Marin	Arecibo Observatory Space Academy
Daniel R. Altschuler	University of Puerto Rico
Miguel Babilonia	Fundación de Investigaciones Espeleológicas del Karso Puertorriqueño
Carmen Pantoja	University of Puerto Rico
Joan Schmelz	USRA
Ramon Lugo	University of Central Florida

NSF held a conference call with the SHPO, the ACHP, and the Consulting Parties on June 21, 2017, to discuss measures to avoid, minimize, or mitigate adverse effects and to explain the contents of the draft PA. A draft of the PA was provided to the Consulting Parties on June 23, 2017, for review and comment. NSF conducted a follow-up meeting with the SHPO, the ACHP, and the Consulting Parties on July 6, 2017, to discuss and refine the draft PA. The meeting was held at the Colegio de Ingenieros y Agrimensores de Puerto Rico/Puerto Rico Professional College of Engineers and Land Surveyors (Arecibo Chapter) in Municipality of Arecibo. An additional conference call with the Consulting Parties was conducted via teleconference on July 13, 2017. At the end of the 30-day review period, comments from the Consulting Parties were reviewed and a conference call was scheduled with NSF, the SHPO, the ACHP, and the Consulting Parties in August 2017 to discuss the comments and provide clarification. Based on the comments and the upcoming discussions during the August conference call, NSF will revise the second draft PA and submit a final version of the PA to the Consulting Parties for signature as Concurring Parties. All drafts of the PA are provided in both English and Spanish.

5.3.1.4 Public Invitation to Participate

Public notice and involvement regarding the undertaking included social media announcements, website updates, scientific digests and blogs, newspaper public notices, and public scoping meetings. The public was invited to participate in the Section 106 process through the NOI published on May 23, 2016, and also at the public scoping meetings. A notice was published on November 3, 2016, in *El Norte* to announce the beginning of the public comment period to solicit comments on the DEIS and continuation of public involvement under Section 106. The DEIS was posted on NSF's Division of Astronomical Sciences website, and NSF announced the availability of the DEIS using social media. The *El Norte* notice also informed the public of two public meetings on the DEIS, which were held on November 16 and November 17, 2016, in Arecibo and San Juan, respectively. The public was also invited to the Consulting Parties meeting that was held on November 17, 2016, after the San Juan public meeting.

NSF sent the draft PA to interested members of the public on June 23, 2017, for public review and comment and to notify them of the start of the 30-day public comment period for the document. The public was invited to participate in the Consulting Parties meeting held in the Municipality of Arecibo on July 6, 2017, and the teleconference held on July 13, 2017. A Public Notice announcing the availability of the draft PA and the details of the consultation meeting on July 6, 2017, was published in *El Nueva Dia* (June 28) and in *El Norte* (July 6). Invitations to the July 6 and July 13 meetings were also sent via email to interested members of the public. The draft PA was posted on NSF's Division of Astronomical Sciences website for review and comment, and the June 28 and July 6 Public Notices advertised the availability of the draft PA on NSF's website. Copies of the Draft PA were also made available at the Biblioteca Electrónica Pública Municipal Nicolás Nadal Barreto and the Archivo General y Biblioteca Nacional de Puerto Rico.

Both English and Spanish versions of media notifications and the materials distributed during the meetings were made available to the public. An English/Spanish interpreter was present during all in-person public meetings.

5.4 Endangered Species Act Consultation

In May 2016, NSF began its informal consultation with USFWS with a telephone call identifying the general project and discussing preliminary options for alternatives. On June 17, 2016, NSF submitted a data request to USFWS regarding the project area (all natural resource agency correspondence is included in Appendix 5-F). On June 24, 2016, USFWS responded to the data request and also requested a site visit, which was conducted on July 20, 2016. The site visit included a walk-through of the undeveloped areas on the Observatory and a discussion of potential impacts to listed species from the potential demolition of the large concrete infrastructure (towers and towers anchors). The endangered Puerto Rican boa and the endangered fern *Tectaria estremerana* were known to occur on Arecibo Observatory and, during the site visit, USFWS confirmed the use of Arecibo Observatory grounds by the endangered Puerto Rican broad-winged hawk.

During the discussions at the site visit, USFWS recommended that NSF adopt procedures for working in areas of Arecibo Observatory where the Puerto Rican boa may occur that would be consistent with those developed and implemented by the U.S. Army at Fort Buchanan. USFWS provided the Fort Buchanan boa procedures and NSF's contractor worked with NSF to develop protocols to ensure that neither routine operations nor demolition activities would result in an inadvertent take of a boa.

Additional teleconferences were held on September 27, 2016, and October 18, 2016, to discuss surveys for listed plant species, Endangered Species Act Section 7 compliance, potential mitigation activities that could be implemented to reduce the potential for a take of a listed species, and to set the date of the meeting at the USFWS office in Boquerón for November 16, 2016. On October 20, 2016, USFWS requested information on property ownership, size of the property, ultimate disposition of the property if the Observatory were closed, and the responsible party for ensuring any mitigation would be implemented. USFWS also requested that the DNER be invited to November 16, 2016 meeting. NSF responded with the requested information and agreed to DNER's being invited to the November 16 meeting.

On November 18, 2016, a meeting was held with USFWS, DNER, and NSF at the USFWS office in Boquerón. Attendees discussed vegetation surveys planned for December 2016, potential direct, indirect, and cumulative impacts of the Alternatives on listed species, and potential avoidance and other mitigation measures. It also was decided that informal consultation could adequately address Alternatives 1, 2, and 3, regardless of which of these Alternatives were selected. Formal consultation was likely to be needed if Alternative 4 were selected, and formal consultation would be required if Alternative 5 were selected.

On November 22, 2016, NSF informed USFWS and DNER that the vegetation surveys would be delayed until January 2017 because of a conflict with operation of the 305-meter-diameter radio telescope. On December 14, 2016, NSF confirmed the dates of January 9 through 11, 2017, for the vegetation survey with USFWS and DNER. On December 16, 2017, USFWS confirmed it would attend the surveys on January 10, 2017. On December 21, 2016, NSF informed USFWS of potential issues with using a global positioning system receiver to record locations beneath the 305-meter-diameter dish and offered an alternate mapping method should signal interference be encountered. USFWS agreed with the proposed approach.

On January 13, 2017, USFWS emailed NSF with an update on the vegetation survey and requested information on the areas around buildings that could be demolished. NSF confirmed receipt of this email on January 18, 2017. On February 17, 2017, NSF provided USFWS with the preliminary results of the vegetation surveys, confirming there were no listed plants in areas with suitable habitat where demolition could occur. NSF noted the vegetation survey report would be sent to USFWS. On February 23, 2017, NSF requested a teleconference with USFWS to discuss moving forward based on the findings of the vegetation survey and March 3, 2017, was set as the date for the teleconference.

On March 3, 2017, NSF, USFWS, and DNER held a teleconference to discuss ESA consultation and the NEPA analysis for the proposed NSF action. No impacts to listed plant species were anticipated based on the expected areas of disturbance, the lack of plant species in areas with potentially suitable habitat, and the lack of suitability for listed plant species in developed and maintained areas. The expected areas of disturbance would be provided to prospective bidders. If a bidder indicated that additional areas, including additional or widened roads, would be needed to complete the work, NSF agreed it would delay the award until additional consultation with USFWS, including additional surveys, had been completed. This commitment will be specified in the ROD for the EIS. NSF clarified that some vegetation would be removed under all Alternatives. NSF indicated that the solicitation of proposals included the possibility of land transfer. However, whether a prospective bidder would want the land was unknown. If a land transfer were included in a proposal, the proposed transfer would be assessed in the future through a separate consultation that would address the appropriate conservation measures.

There was a discussion of potential impacts to the Puerto Rican broad-winged hawk, including the potential for overlapping territories on the Observatory. USFWS provided a copy of the BO issued for construction of Puerto Rico Highway 10, which included conservation measures for the hawk. NSF committed to performing work outside the breeding period for the Puerto Rican broad-winged hawk. DNER requested that the Puerto Rican Boa Protocol be updated to include DNER points of contact and NSF agreed. DNER reiterated that prior to using explosives, the area within 100 feet (30 meters) of the detonation site would be inspected for presence of boas or birds and the detonation delayed until no animals were present

On March 13, 2017, NSF conveyed to USFWS that a BA would be submitted to USFWS to request informal consultation for all Alternatives. If Alternative 5 is selected, NSF will commit to conduct hawk surveys and additional formal consultation with USFWS, with implementation of appropriate mitigation, prior to any demolition activities.

On May 4, 2017, NSF submitted its BA and request for consultation to USFWS. NSF also conveyed this information via email. USFWS responded, acknowledging receipt of the email and stated that the BA would be assigned for review upon receipt of the hard copy request.

On May 22, 2017, NSF informed USFWS that, based on feedback from an ongoing solicitation for collaborators, NSF may entertain land transfer as an option under Alternatives 1 and 2, but that any potential transfer would remain uncertain. As such, NSF would commit to additional consultation with the USFWS prior to any transfer, consistent with language in the BA and did not expect that the BA would need to be modified. USFWS responded, identifying the assigned reviewers of the BA and indicating they would review the document to determine whether any modifications would be required.

USFWS concurred with the findings of the BA, including proposed mitigation measures, in a letter dated June 23, 2017.

SECTION 6.0

List of Preparers

TABLE 6-1.1
List of Preparers

Name	Role	Education	Years of Experience
Kira Zender	Project Manager and Socioeconomics Lead	M.S. Urban and Regional Planning B.A. Urban Studies	22
Stephen Petron	Senior Technical Advisor	Ph.D. Zoology M.S. Natural and Environmental Resources B.S. Wildlife Management	40
Paul Thies	Technical Advisor	Ph.D. Civil and Environmental Engineering M.S. Water Resources B.S. Forestry	37
Michelle Rau	NEPA Lead	M.S. Business Administration B.S. Ecology and Evolutionary Biology	19
Richard Reaves	Lead Technical Reviewer	Ph.D. Wetland and Wildlife Ecology B.S. Wildlife Ecology and Resource Management	23
Lori Price	Cultural Resources Lead and Cultural Surveys/Section 106	M.F.A. Historic Preservation and Architectural History B.A. English and Political Science	21
MaryNell Nolan-Wheatley	Cultural Resources Specialist and Cultural Surveys/Section 106	M.P.S. Preservation Studies B.A. Anthropology	5
Robert Price	Air Quality, Biology, Geology, and Groundwater Lead	M.S. Environmental Science and Master of Public Affairs B.A. Zoology and History	20
Kristine MacKinnon	Hazardous Materials and Solid Waste Lead	M.S. Urban and Regional Planning B.E. Biological Systems Engineering	14
Christina McDonough	Health and Safety Lead	M.E. Environmental Engineering B.S.C.E. Civil Engineering	23
Laura Dreher	Transportation Lead	B.S. Civil Engineering	15
Heather Dyke	Socioeconomics Specialist and Environmental Justice Lead	M.C.P. Environmental Planning B.A. Business Administration	22
Madeline Almodovar	Public Involvement Lead	M.S. Business Administration B.S., Industrial Biotechnology	14
Daniel G. Concepción James	Community Involvement/ Water Engineer	Graduate Studies Civil/Environmental Engineering B.Sc. Mechanical Engineering	7

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SECTION 8.0
Acronyms and Abbreviations

AAAC	Astronomy and Astrophysics Advisory Committee
AADT	average annual daily traffic
ACHP	Advisory Council on Historic Preservation
ACM	asbestos-containing material
ACS	American Community Survey
ADS	Autoridad de Desperdicios Sólidos
AIAC	American Industrial Acquisition Corporation
AGS	Division of Atmospheric and Geospace Sciences (NSF)
APE	Area of Potential Effects
AST	Division of Astronomical Sciences (NSF)
ASTM	ASTM International
BA	biological assessment
BMP	best management practice
BO	Biological Opinion
C.F.R.	*Code of Federal Regulations*
C-14	Carbon-14
CAA	Clean Air Act
CDE	carbon dioxide equivalent
CEQ	Council on Environmental Quality
CH2M	CH2M HILL, Inc.
CPL	Commonwealth Poverty Level
CVOC	chlorinated volatile organic compound
CWA	Clean Water Act
dB	decibels
dBA	A-weighted noise sound level

DDEC	Department of Economic Development and Commerce (Puerto Rico)
DEIS	Draft Environmental Impact Statement
DNER	Department of Natural and Environmental Resources
DRNA	Departamento de Recursos Naturales y Ambientales (Puerto Rico)
E.O.	Executive Order
EBS	Environmental Baseline Study
EIS	Environmental Impact Statement
EPA	U.S. Environmental Protection Agency
EQB	Environmental Quality Board (Puerto Rico)
ESA	Endangered Species Act of 1973
FEIS	Final Environmental Impact Statement
GDB	Government Development Bank of Puerto Rico
GE	General Electric
GEO	Directorate for Geosciences (NSF)
GHG	greenhouse gas
GNP	gross national product
GS	Geospace Section of the Division of Atmospheric and Geospace Sciences (NSF)
IPaC	Information for Planning and Conservation
LBP	lead-based paint
Leq	equivalent sound level
Leq(h)	hourly equivalent sound level
MBTA	Migratory Bird Treaty Act
MOA	Memorandum of Agreement
MPS	Directorate for Mathematical and Physical Sciences (NSF)
MSA	metropolitan statistical area
NAAQS	National Ambient Air Quality Standards
NAIC	National Astronomy and Ionosphere Center

NAS	National Academies of Sciences, Engineering, and Medicine
NASA	National Aeronautics and Space Administration
NEO	near-Earth object
NEPA	National Environmental Policy Act of 1969
NHPA	National Historic Preservation Act of 1966
NOA	Notice of Availability
NOI	Notice of Intent
NPDES	National Pollutant Discharge Elimination System
NPS	U.S. National Park Service
NRC	National Research Council
NRHP	National Register of Historic Places
NSF	National Science Foundation
O&M	operations and maintenance
OGPe	Oficina de Gerencia de Permisos
OSHA	Occupational Safety and Health Administration
OWS	oil-water separator
PA	Programmatic Agreement
PCB	polychlorinated biphenyl
PHO	potentially hazardous object
PR	Puerto Rico Highway
PRC	Portfolio Review Committee
PRCS	Puerto Rico Community Survey
PRIDCO	Puerto Rico Industrial Development Company
PROMESA	Puerto Rico Oversight, Management, and Economic Stability Act
PRPB	Puerto Rico Planning Board
PRTC	Puerto Rico Tourism Company
RCRA	Resource Conservation and Recovery Act of 1976

REC	recognized environmental condition
REU-RET	Research Experiences for Undergraduates and Research Experience for Teachers
ROD	Record of Decision
ROI	Region of Influence
SOAR	Southern Astrophysical Research Telescope
SHPO	State Historic Preservation Office
SPCC	spill prevention, control, and countermeasures
STEM	science, technology, education, and math
SUT	sales and use tax
SWPPP	stormwater pollution prevention plan
TCP	traditional cultural property
U.S.C.	United States Code
USCB	U.S. Census Bureau
UMET	Universidad Metropolitana
UPRA	University of Puerto Rico at Arecibo
USACE	U.S. Army Corps of Engineers
USDE	U.S. Department of Education
USFS	U.S. Forest Service
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
USRA	Universities Space Research Association
VSQ	Visiting Scientists Quarters
WEF	World Economic Forum
WTTC	World Travel & Tourism Council

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