Appendix H
Upgraded Early Warning Radar Analysis

EXECUTIVE SUMMARY

ES.1.1 INTRODUCTION

In October 1999, the Ballistic Missile Defense Organization published the Notice of Availability of the National Missile Defense (NMD) Draft Environmental Impact Statement (EIS), which identified and addressed potential environmental impacts resulting from deployment of an NMD system. The NMD system would consist of five elements: Battle Management, Command, Control, and Communications, which includes the Battle Management, Command, and Control, communication lines, and the In-flight Interceptor Communications System as subelements; Ground-based Interceptor; X-band Radar; Upgraded Early Warning Radar (UEWR); and a space-based detection system.

Information needed to document the potential environmental effects of the Early Warning Radar (EWR) modifications was not available for inclusion into the NMD Deployment Draft EIS. A Supplement to the NMD Deployment Draft EIS was prepared to incorporate discussion of these effects into the NMD Deployment Final EIS. That analysis is set forth in this appendix. The PAVE PAWS (PAVE is an Air Force program name, while PAWS stands for the Phased Array Warning System) EWR soon to be at Clear Air Force Station* (AFS), Alaska; and the existing PAVE PAWS EWRs at Beale Air Force Base (AFB), California and Cape Cod AFS, Massachusetts are proposed for use by the NMD program. Interior electronic hardware and computer software replacement are planned for these existing radars in conjunction with the NMD program to provide more precise tracking and identification of ballistic missiles launched against the United States. The EWRs with the proposed modifications are referred to as UEWRs.

The U.S. Air Force, which operates and has real property accountability over the PAVE PAWS EWR facilities, has begun the process for a National Environmental Policy Act analysis. This analysis will culminate in a full EIS addressing the modernization, maintenance, and sustainment of EWR current operations at Clear AFS, Alaska, Beale AFB, California, and Cape Cod AFS, Massachusetts. For this reason, if the Proposed Action in this analysis is selected, its implementation is contingent upon the outcome of the Air Force EIS. The Ballistic Missile Defense Organization would reassess its proposed usage of the EWR facilities in light of the results of the Air Force EIS prior to installation of the NMD modifications.

*Note: Effective 4 February 2000, all Air Force Space Command Air Stations located in the United States will be redesignated as Air Force Stations.

ES.1.2 PURPOSE AND NEED FOR THE PROPOSED ACTION

The proposed NMD architecture includes modifications to the existing EWRs to enable them to work with the other NMD elements as part of an integrated system. The modified UEWRs would provide the capability for precise identification and tracking of ballistic missiles launched against the United States' territory, which is critical to the operation and command and control of the NMD system. UEWRs must be located on both the east and west coasts in order to provide the coverage necessary to protect the entire United States.

ES.1.3 PROPOSED ACTION AND NO-ACTION ALTERNATIVE

The Proposed Action is to replace electronic hardware and computer software at existing EWRs at Clear AFS, Beale AFB, and Cape Cod AFS in support of the NMD program. The hardware modifications would consist of replacing existing computers, graphic displays, communication equipment, and the radar receiver/exciter to perform the NMD mission (i.e., identification and precise tracking of a ballistic missile launched against the United States). The EWR software would be rewritten to incorporate the NMD function and allow the acquisition, tracking, and classification of small objects near the horizon. The UEWRs would be able to search for different types of missiles, distinguish hostile objects such as warheads from other objects, and provide this data to other NMD elements using improved communications systems.

The radiated peak and average power, radar antenna patterns, and operating bands of the UEWRs would remain unchanged from current operations. Once upgraded, the current EWR operations would continue with the addition of conducting NMD missions and training exercises. Training for the NMD program is expected to represent less than 1 percent of the total EWR usage (approximately several hours per year). At all other times, the UEWRs would continue to perform their current EWR missions. In either case, radar outputs would be unchanged from current levels. There would also be no changes in the number of personnel required to operate the radar or in the amount of hazardous materials and waste generated by the UEWR when compared to the EWR.

The No-action Alternative of the NMD Deployment EIS is not to deploy the NMD system. Under the No-action Alternative for this analysis, there would be no hardware and software modifications to the existing EWRs as part of the NMD Program. For the EWR sites being considered for NMD, the No-action Alternative would be a continuation of missile early warning and space tracking currently occurring at those locations.

The No-action Alternative has been previously analyzed in National Environmental Policy Act documentation for each EWR.

ES.1.4 SCOPE OF THE STUDY

The scope of this analysis was defined by the range of potential impacts reasonably associated with the proposed UEWR modifications. As previously noted, the EWRs would undergo only interior hardware and software modifications. There would be no change to the exterior of the radar building. There would also be no change to either peak or average power levels emitted by the radar. Staffing levels and daily operations, moreover, would remain essentially unchanged, as the radar would perform NMD missions only for extremely brief periods (approximately 17 minutes per NMD event, with a total NMD usage of just several hours per year). Based on these considerations, this document focuses on the human health and safety resources area—specifically on the radiofrequency (RF) fields associated with the modified EWRs. This document also examines cultural resources since the EWRs have been identified as Cold War era historic properties. The proposed modifications would have no impact on the following resource areas: air quality, airspace, biological resources, environmental justice, geology and soils, hazardous materials and hazardous waste, land use and aesthetics, noise, socioeconomics, transportation, utilities, and water resources. The subsistence resources at Clear AFS, Alaska were considered in the NMD Deployment EIS and would be unaffected by the Proposed Action. Consequently, these areas are not examined.

ES.1.5 SUMMARY OF ENVIRONMENTAL IMPACTS

ES.1.5.1 PROPOSED ACTION

Health and Safety

Human exposure to RF emissions was estimated by calculations of the highest possible RF power density that could be produced at ground level by the radar in publicly accessible areas. These calculations included assumptions about the operation of the radar to determine the maximum exposure potential. The results of these calculations were compared to the most applicable criteria, the American National Standards Institute/Institute of Electrical and Electronic Engineers standard. The standard applicable to the general public is for an “uncontrolled environment,” which refers to the condition for most people who do not knowingly encounter RF fields in their work environment. The exposure limits proposed by this standard are 50 times lower than the estimated RF exposure intensity associated with reversible effects on animals and humans associated with heating. This means that to the best of current knowledge the exposure limit in the standard would need to be 50 times higher to induce those thermal changes upon which the standard is based.

The proposed upgrades would not change the RF levels in the surrounding human environment from existing levels. The proposed upgrades also do not involve changes to the physical facilities that could increase the power or the proportion of time that the radar is operating. The public exposure to RF fields from the UEWRs over a 30-minute averaging period would be similar to that from the existing EWRs and would be well within safe exposure limits. As shown in table ES-1, exposures to the public would remain well below exposure levels recommended by the American National Standards Institute/Institute of Electrical and Electronic Engineers, the State of Massachusetts, or other organizations.

Overall, the results of studies of rodents routinely used to assess effects on human health do not suggest adverse effects from long-term (nearly lifespan) exposures at low levels.

Table ES-1: Far-Field Ground Level Power Densities Calculated for Locations at Maximum Exposure—Reflecting Representative NMD Upgrade, Search, and Track Scenarios

PAVE PAWS Site	Distance from Radar meters (feet)	Maximum Calculated 30-minute Time Average Power Density (mW/cm^2)	Comparison to ANSI/IEEE Standard (0.28 mW/cm^2)
Clear AFS	439 (1,440) [1]	0.00775	36 times lower
	4,850 (15,912) [2]	0.0000684	4,094 times lower
Beale AFB	439 (1,440) [1]	0.007005	40 times lower
	1,859.3 (6,100) [2]	0.000246	1,138 times lower
Cape Cod AFS	439 (1,440) [1]	0.006640	42 times lower
	1,051.6 (3,450) [2]	0.000786	356 times lower

NOTE: The current calculations assume that both radar faces are operating with a 25 percent duty cycle. The duty cycle is divided between surveillance mode (11 percent) and track mode (14 percent).
(1) On-base—beginning of far field exposures
(2) One of nearest locations with likely opportunity for public exposure

In conclusion, the Proposed Action presents no change to the impacts to health and safety determined in previous environmental analyses of the EWRs.

Cultural Resources

No cultural sites have been identified at the PAVE PAWS radar site on Clear AFS.

Preparation of Historic American Building Survey/Historic American Engineering Report (HABS/HAER) documentation or other mitigation measures suggested by the California State Historic Preservation Officer (SHPO) as part of the programmatic agreement with Beale AFB would be implemented.

HABS/HAER documentation has already been provided to the Massachusetts SHPO. This would satisfy Section 106 regulatory requirements for mitigation measures due to the upgrade of the PAVE PAWS radar at Cape Cod AFS.

ES.1.5.2 NO-ACTION ALTERNATIVE

The current emissions of the radars would not change under the No-action Alternative. The power densities estimated in previous environmental analyses would remain the same. Although the standards for human exposure to RF have become more stringent in the last 20 years, the general public's exposure from the PAVE PAWS radars remains far lower than the current state and Federal safety standards. In addition, no reliable scientific data have been found to indicate that exposure to electromagnetic fields produces cumulative damage. The No-action Alternative presents no change to the impacts previously analyzed in National Environmental Policy Act documentation for each EWR.

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1.0 PURPOSE AND NEED

1.1 INTRODUCTION

In October 1999, the Ballistic Missile Defense Organization published the Notice of Availability of the National Missile Defense (NMD) Deployment Draft Environmental Impact Statement (EIS), which identified and addressed potential environmental impacts resulting from deployment of an NMD system. The NMD system would be a fixed, land-based, non-nuclear missile defense system with land- and space-based detection systems capable of responding to a limited strategic ballistic missile threat to the United States.

Among the elements proposed for use by the NMD Program are the PAVE PAWS (PAVE is a U.S. Air Force program name, while PAWS stands for the Phased Array Warning System) early warning radar (EWR) soon to be at Clear Air Force Station* (AFS) in Alaska (early 2001) and the existing PAVE PAWS EWRs at Beale Air Force Base (AFB), California, and Cape Cod AFS, Massachusetts (figure 1-1). Interior electronic hardware and computer software replacement are planned for these existing radars in conjunction with deployment of the NMD system to provide more precise tracking and identification of ballistic missiles launched against the United States. The EWRs with the proposed modifications are referred to as Upgraded Early Warning Radars (UEWRs). Information needed to document the environmental effects of the EWR modifications was not available for inclusion into the NMD Deployment Draft EIS. A Supplement to the NMD Deployment Draft EIS was prepared to incorporate discussion of the environmental effects associated with EWR modifications into the NMD Deployment Final EIS. That analysis is set forth in this appendix.

The U.S. Air Force, which operates and has real property accountability over the PAVE PAWS EWR facilities, has begun the process for an National Environmental Policy Act (NEPA) analysis. This analysis will culminate in a full EIS addressing the modernization, maintenance, and sustainment of EWR operations at Clear AFS, Alaska, Beale AFB, California, and Cape Cod AFS, Massachusetts. For this reason, if the Proposed Action in this analysis is selected, its implementation is contingent upon the outcome of the Air Force EIS. The Ballistic Missile Defense Organization would reassess its proposed usage of the EWR facilities in light of the results of the Air Force EIS prior to installation of the NMD modifications.

*Note: Effective 4 February 2000, all Air Force Space Command Air Stations located in the United States will be redesignated as Air Force Stations.

Ground-Based Interceptor (GBI)

- Clear AFS, Alaska
- Fort Greely, Alaska
- Yukon Training Area (Fort Wainwright)/Eielson AFB, Alaska
- Grand Forks AFB, North Dakota
- Stanley R. Mickelsen Safeguard Complex, North Dakota
  - Missile Site Radar (MSR)

Battle Management, Command and Control (BMC2)

- Clear AFS, Alaska
- Fort Greely, Alaska
- Yukon Training Area (Fort Wainwright)/Eielson AFB, Alaska
- Grand Forks AFB, North Dakota
- Stanley R. Mickelsen Safeguard Complex, North Dakota
  - Missile Site Radar (MSR)

X-Band Radar (XBR)

- Eareckson AS, Alaska
- Stanley R. Mickelsen Safeguard Complex, North Dakota
  - Cavalier AFS
  - Missile Site Radar (MSR)
  - Remote Sprint Launch Site (RSL) 1
  - Remote Sprint Launch Site (RSL) 2
  - Remote Sprint Launch Site (RSL) 4

In-Flight Interceptor Communications System (IFICS)*

- Alaska
- North Dakota

Upgraded Early Warning Radar (UEWR)**

- Clear AFS, Alaska
- Beale AFB, California
- Cape Cod AFS, Massachusetts

EXPLANATION

*Note: Identification of potential IFICS locations is still in progress. Locations depicted are those regions under consideration. Other regions may be identified depending on system requirements.

**Note: Identification of other potential locations outside of the United States is still in progress.

NORTH

Not to Scale

NMD Element Deployment Options

Figure 1-1

deploy001

1.2 NMD PROGRAM OVERVIEW

Within the Department of Defense (DOD), the Ballistic Missile Defense Organization is responsible for managing, directing, and executing the Ballistic Missile Defense Program. The Ballistic Missile Defense Program focuses on three areas: Theater Missile Defenses to meet the existing missile threat to deployed U.S. and allied forces, NMD to negate limited strategic ballistic missile attacks against the United States, and advanced Ballistic Missile Defense technologies to improve the performance of theater and NMD systems. The NMD Joint Program Office of the Ballistic Missile Defense Organization is responsible for developing and deploying the NMD system.

The NMD Program was originally a technology development effort. In 1996, at the direction of the Secretary of Defense, NMD was designated a Major Defense Acquisition Program and transitioned to an acquisition effort. Concurrently, the Ballistic Missile Defense Organization was tasked with developing a deployable system. In the year 2000, there will be a DOD Deployment Readiness Review to review the technical readiness of NMD elements. Thereafter, the U.S. Government will determine whether the threat, developed capability, and other pertinent factors justify deploying an operational NMD system. Should the deployment option not be exercised in the year 2000, improvements in NMD system element technology would continue.

The NMD system would consist of five elements: Battle Management, Command, Control, and Communications (BMC3), which includes the Battle Management, Command and Control (BMC2), the communication lines, and the In-Flight Interceptor Communications System (IFICS) Data Terminal as subelements; Ground-Based Interceptor (GBI); X-Band Radar (XBR); Upgraded Early Warning Radar (UEWR); and a space-based detection system. Depending on the capability available if or when a deployment decision is made, the space-based detection capability would be the existing Defense Support Program early-warning satellites and/or SBIRS satellites currently being developed by the U.S. Air Force. (Ballistic Missile Defense Organization, 1999—Draft EIS for National Missile Defense Deployment)

1.3 EXISTING PAVE PAWS EARLY WARNING RADAR

1.3.1 INTRODUCTION

The PAVE PAWS EWR is a surveillance and tracking radar system operated by the U.S. Air Force. The primary purpose of the radars is to detect, track, and provide early warning of intercontinental ballistic missiles and sea-launched ballistic missiles launched against the continental United

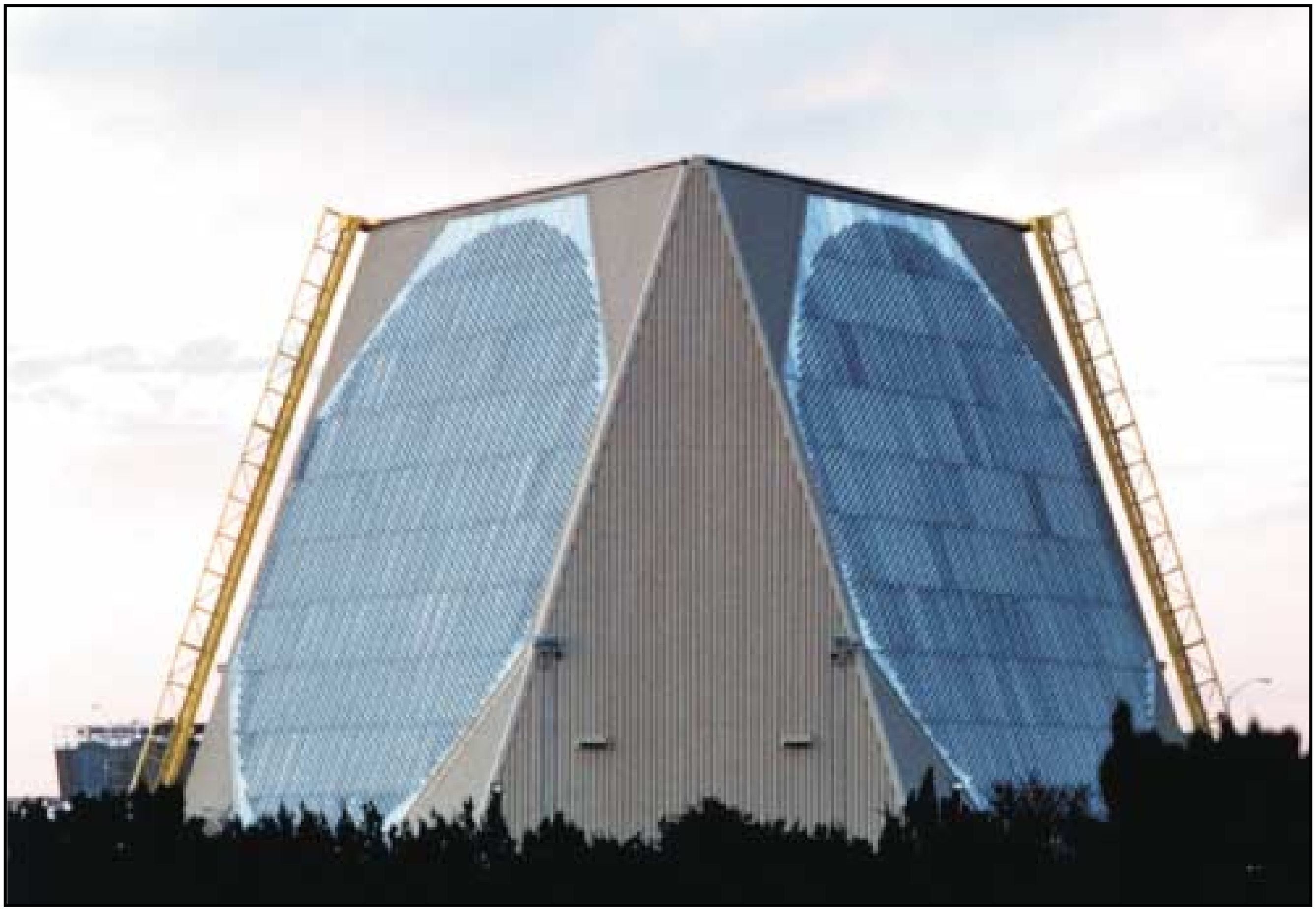
States, but they also assist the U.S. Air Force Spacetrack System by tracking objects in earth orbit. (Department of the Air Force, 1979)

1.3.2 PAVE PAWS RADAR: A SOURCE OF RADIOFREQUENCY FIELDS

The term radar is an acronym for Radio Detection and Ranging. The radar transmits pulsed radiofrequency (RF) signals into space. Signals are reflected by objects back to the radar. These signals are analyzed to determine the distance, speed, and location of the object.

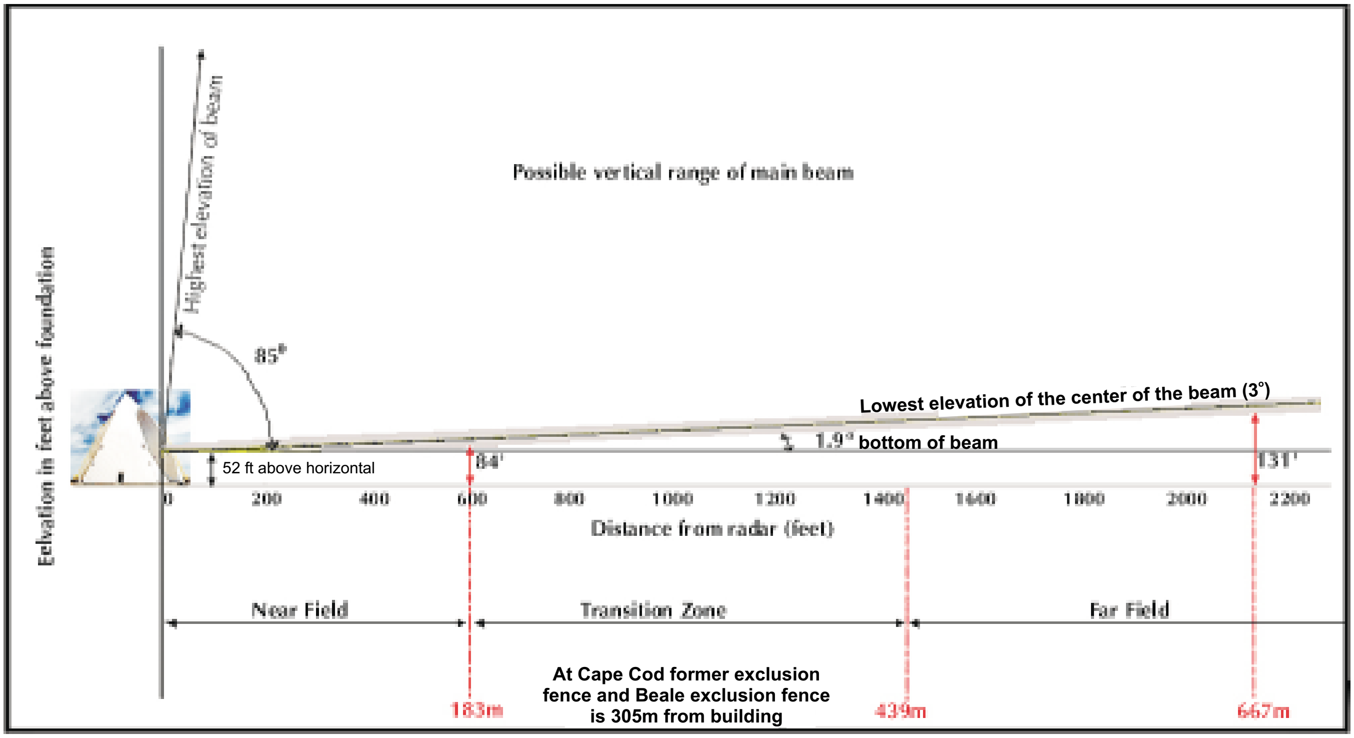
Each of the PAVE PAWS radars is housed in a 32-meter (105-foot) high building with three sides. Two flat arrays of individual radiating elements transmit and receive RF signals generated by the radar. The equipment that generates the RF signals and then analyzes the reflected signals is housed inside the radar building. The two array faces are 31 meters (102 feet) wide and tilted back 20 degrees from vertical (see figure 1-2). The active portion of the array resides in a circle 22.1 meters (72.5 feet) wide in the center of the array. Each radiating element is connected to a solid-state transmit/receive module that provides 325 watts of power and a low-noise receiver to amplify the returning radar signals. Table 1-1 shows the operating parameters for each face of the PAVE PAWS radar.

The RF signals transmitted from each array face form one narrow main beam with a width of 2.2 degrees. Most of the energy (approximately 60 percent) is contained in the main beam. Figure 1-3 shows the minimum and maximum vertical angles at which the main beam of the PAVE PAWS radar can be directed. The far-field region begins at 439 meters (1,440 feet). The exclusion fence at Beale AFB and former exclusion fence at Cape Cod AFS are at approximately 305 meters (1,000 feet). The figure also illustrates why restricting the lowest elevation of the main beam to 3 degrees above horizontal prevents anyone on the ground or in buildings or residences from being exposed to RF from the main beam, even considering its 2.2 degree width. When the topography of the sites surrounding the radars is taken into account, the elevation of the main beam is still substantially above ground level. For example, at the Cape Cod AFS, ground elevation is 82 meters (269 feet) and the center of the radar faces are 97.5 meters (320 feet) above sea level. For a variety of locations evaluated in the 1979 Cape Cod AFS EIS, the highest elevation within 11,125 meters (36,500 feet) of the radar was the road portion of the Sagamore Bridge at an 83.8-meter (275-foot) elevation. The bridge was identified as being 2,582 meters (8,470 feet) from the radar (Department of the Air Force, 1979). At this location, the center of the main beam would be 149 meters (489 feet) above the ground, and the bottom of the beam width would be 101 meters (331 feet) above the ground. At the most distant location studied, the Otis Schools, the center of the main beam would be 653 meters (2,142 feet) above the ground, and the bottom of the beam width would be 439 meters (1,440 feet) above the ground.



PAVE PAWS
Early Warning Radar

Figure 1-2



EXPLANATION

Note: The highest (85 degrees) and lowest (3 degrees) elevations above horizontal for which space objects can be tracked by the main radar beam are shown in this figure. The height of the bottom of the main beam (1.9 degrees) above ground level is shown at representative horizontal distances.

Note: At the three PAVE PAWS radar sites the horizontal axis would usually be above the actual ground level. Hence, the elevation of the main beam above ground would be greater than shown in this conceptual drawing.

Note: This drawing does not take into account the topography of the surrounding area.

Note: Lowest elevation of radar beam does not include height of center of radar above sea level.

Note: Height elevations are not to scale.

Maximum and Minimum Vertical Elevation of the Main Radar Beam

Figure 1-3

Table 1-1: PAVE PAWS Operating Parameters

Parameter	Measurement
Peak Power	1,792 active elements at 325 watts = 582.4 kilowatts (kW)
Duty Factor	25% (11% search, 14% track)
Average Power	145.6 kW
Effective Transmit Gain	37.92 decibel (dB)
Active Radar Diameter	22.1 meters
Frequency	420 megahertz (MHz) to 450 MHz
Radar Detection Range	5,556 kilometers (3,000 nautical miles)
Wavelength	0.69 meters at 435 MHz
Sidelobes	-20 dB (first), -30 dB (second), -38 dB (root mean square)
Face Tilt	20 degrees
Number of Faces	2
3 dB Beam Width	2.2 degrees

Smaller amounts of energy are emitted by the radar outside the main beam. These energy patterns are called sidelobes. By convention, sidelobes are given numbered designations with the lower numbers being closer to the main beam than the higher numbered ones. The energy contained in these sidelobes progressively decreases with distance from the main beam and from the radar. The first sidelobe is a concentric circle around the main beam. The second and higher sidelobes are narrow beams arranged around the main beam. Their shapes are similar to the main beam but have significantly lower power densities.

The maximum power density of the first sidelobe is 1/100th (1 percent) of the maximum power density of the main beam. The maximum power density of the second sidelobe is only 1/1000th (0.1 percent) of the maximum power density of the main beam. The power density levels in the sidelobes quickly drop to insignificant levels as they progress away from the main beam. Since the main beam cannot be aimed lower than 3 degrees above a horizontal plane (see figure 1-3), it never intercepts the ground. Therefore, only the sidelobes intercept the ground.

Additionally, the antenna beam is constantly scanning. As the beam scans away from a particular direction, sidelobes intersect the ground progressively further from the main beam. Thus, the higher numbered sidelobes, with significantly lower energy, intersect the ground. The result is that the vast majority of the energy emitted by the radar is directed upward where it is used to detect potential targets in the air.

Very little radar energy is allowed to be wasted near ground level where it cannot detect incoming targets.

The radar beam consists of a series of electromagnetic pulses, the characteristics of which (pulse length, frequency) would vary depending on mission requirements. The beam is directed at elevations between 3 and 85 degrees from horizontal as illustrated in figure 1-3, covering an azimuth of 120 degrees per face, for total coverage of 240 degrees. Software programming and redundant automatic interlocks combine to provide a triple-redundant system, which means that a simultaneous failure of three systems would be required to direct the beam outside the designated elevation and azimuth ranges.

1.3.3 PAVE PAWS OPERATIONAL MISSION ENVIRONMENT

The mission of the three PAVE PAWS radar installations involves two activities. The first activity, surveillance, is to detect and determine attack characteristics of Intercontinental Ballistic Missiles and Sea Launched Ballistic Missiles that might penetrate the PAVE PAWS field of view. Once detected, the launched object is continuously tracked and its trajectory estimated. Any object that separates from a booster is also tracked as it approaches. The second activity, tracking, supports the USSPACECOM Space Surveillance Network, which involves the surveillance and tracking of earth satellites and identification of other space objects.

Surveillance

To detect objects, the radar devotes approximately half of its capabilities to generate what is called a “surveillance fence.” This refers to scanning at elevations between 3 and 10 degrees above horizontal over 240 degrees (the azimuth) of a 360 degree circle with the radar at the center. In the surveillance mode, the position of the beam changes within this surveillance space according to a programmed pattern, moving from one position to another within tens of microseconds. In the surveillance mode, both faces of the radar are simultaneously active. Under normal circumstances, 11 percent of the radar resource is devoted to surveillance activities. The radar is also capable of performing “enhanced search” where the duty cycle is increased to 18 percent with no tracking being performed.

Tracking

To track objects, the radar can allocate the remainder of its capabilities to focus on particular objects or a small cluster of objects. Normally, this would take up about 7 percent of the available radar resource, for a combined surveillance and tracking duty cycle of 18 percent. This means that on average the radar is transmitting pulses only 18 percent of the time. The maximum possible use of the radar resource for combined surveillance and tracking activities is 25 percent and is the operating condition that produces the maximum possible power density.

As noted in the 1979 EIS for the PAVE PAWS radar at Cape Cod AFS, "under very exceptional circumstances of heavy tracking assignment the duty cycle of either face can be increased to 25%; under those conditions the duty cycle of the other face is necessarily reduced to 11%." (Department of the Air Force, 1979)

The proportion of time that the radar is allocated to each activity varies considerably. Each activity demands that different patterns of pulsed signals be transmitted by the radar that are affected by the size, trajectory, and distance of objects. Thus, as part of the existing PAVE PAWS mission there are differences between the number of pulses, their duration, and repetition frequency. While such differences affect the distribution of power density in the space scanned by the main beam, over time they have a much smaller effect on the intensity and distribution of RF energy at ground level from the second sidelobe and higher numbered sidelobes, which are the main source of exposure to RF at ground level.

1.4 PURPOSE AND NEED FOR THE PROPOSED ACTION

The purpose and need for the overall NMD system is described in the Executive Summary for the NMD Deployment Final EIS. The proposed NMD architecture includes modifications to the existing EWRs to work with the other NMD elements as part of an integrated system. The modified EWRs would provide the capability for precise identification and tracking of ballistic missiles launched against the United States' territory, which is critical to the operation and command and control of the NMD system. UEWRs must be located on both the east and west coasts in order to provide the coverage necessary to protect the entire United States.

1.5 SCOPE OF THIS ANALYSIS

This analysis discusses the potential environmental impacts of the proposed hardware and software modifications to the existing EWRs at Clear AFS, Beale AFB, and Cape Cod AFS for the NMD system. The No-action Alternative, which is the continued operation of the EWRs without the NMD modifications, has been previously analyzed in existing NEPA documentation for each EWR.

The scope of this document was defined by the range of potential impacts reasonably associated with the proposed UEWR modifications. As previously noted, the EWRs would undergo only interior hardware and software modifications. There would be no change to the exterior of the radar building. There would be no change to either peak or average power levels emitted by the radar. Staffing levels and daily operations, moreover, would remain essentially unchanged, as the radar would perform NMD missions only for extremely brief periods of time (approximately 17 minutes per NMD event, with a total NMD usage of just several hours per year). Based on these considerations, this document focuses on the human health and safety environmental resources area—specifically on the RF fields associated with the modified EWRs. This document also examines cultural resources since the EWRs have been identified as Cold War era historic properties. The proposed modifications would have no impact on the following resource areas: air quality, airspace, biological resources, environmental justice, geology and soils, hazardous materials and hazardous waste, land use and aesthetics, noise, socioeconomics, transportation, utilities, and water resources. The subsistence resources at Clear AFS, Alaska were considered in the NMD Deployment EIS and would be unaffected by the Proposed Action. As a result, these areas are not examined.

1.5.1 RELATED ENVIRONMENTAL DOCUMENTS

The construction and operation of the EWRs were addressed under previous NEPA documentation. The following documents were prepared for each site under consideration in this analysis to address the operation of the EWRs:

- *Final Environmental Impact Statement, Operation of the PAVE PAWS Radar System at Otis AFB, Massachusetts* (Department of the Air Force, 1979)
- *Final Environmental Impact Statement, Operation of the PAVE PAWS Radar System at Beale AFB, California* (Department of the Air Force, 1980)
- *Environmental Assessment for Radar Upgrade, Clear AS Alaska* (Department of the Air Force, 1997)
- *Supplemental Environmental Assessment for Radar Upgrade, Clear AS Alaska* (Department of the Air Force, 1997)

The U.S. Air Force is in the process of developing an NEPA analysis of proposed actions to sustain current operations of these EWRs.

2.0 ALTERNATIVES INCLUDING THE PROPOSED ACTION

2.1 PROPOSED ACTION

The Proposed Action is to replace electronic hardware and computer software at the existing EWRs in support of the NMD system. The UEWRs would be able to search for different types of missiles and distinguish hostile objects (warheads) from other objects, and provide this data to other NMD elements using improved communications systems. The existing EWRs under consideration for upgrade are located at Clear AFS, Alaska, Beale AFB, California, and Cape Cod AFS, Massachusetts.

The EWRs were sited at their current locations to maximize their ability to perform critical defense missions, including acquisition and tracking of ballistic missiles aimed at the United States. Upgrading the computer hardware and software of the EWRs at these locations will enable them to effectively provide enhanced missile acquisition and tracking functions for the proposed NMD system.

For the UEWRs, the radiated peak and average power and operating bandwidths would remain unchanged from current operations of the EWR. Once upgraded, the current EWR operations would continue with the addition of conducting NMD missions (i.e., identification and precise tracking of a ballistic missile launched against the United States) and training exercises. During NMD operations and training, radiated peak and average power are identical to current EWR operations. In either case, the physical characteristics of the radar (radiated peak and average power, operating bands, etc.) would be the same whether EWR or NMD operations are being conducted. During NMD operations a different radar pattern would be used and different algorithms used to interpret the raw data from the radar returns. There would be no change to the number of personnel operating the radar or in the amount of hazardous materials and waste generated by the UEWR when compared to the EWR. It is anticipated that training for NMD would be less than 1 percent of the total usage. At all other times, the UEWRs would continue to perform their current EWR missions.

The proposed modifications would not increase the output or duty cycle of the radar, and thus would not increase the total energy emitted during operation. The PAVE PAWS radar design included the possibility of a future growth option that would include the activation of additional radar elements and therefore an increase in total RF power. The Proposed Action as part of the NMD mission does not include the “growth option,” nor the activation of additional radar elements. Rather, instead of increasing system performance by increasing power, the electronic hardware and computer software replacements provide enhanced detection and discrimination capabilities. An RF energy survey will be conducted within the next year and prior to the proposed upgrades being installed to assess potential public exposures. This will provide a valuable foundation for future analyses. Following installation of the proposed upgrade, RF energy measurements would be conducted to verify that emissions are not affected by the upgrade and to confirm the predictions based on computer modeling.

The hardware modifications required for NMD would consist of replacing existing computers, graphic displays, communication equipment, and the radar receiver/exciter to perform the NMD mission. The EWR software would be rewritten to incorporate the NMD function and allow the improved acquisition, tracking, and classification of small objects. The UEWRs would contain the following upgraded hardware:

- Data Processors
- Signal Processors
- Displays and Control Processors
- External Communication Processors
- Receiver/Exciters
- Frequency/Time Standards
- Receive Beamformers

UEWRs must be located on both the east and west coasts in order to provide the coverage necessary to protect all parts of the United States.

2.1.1 CLEAR AFS, ALASKA

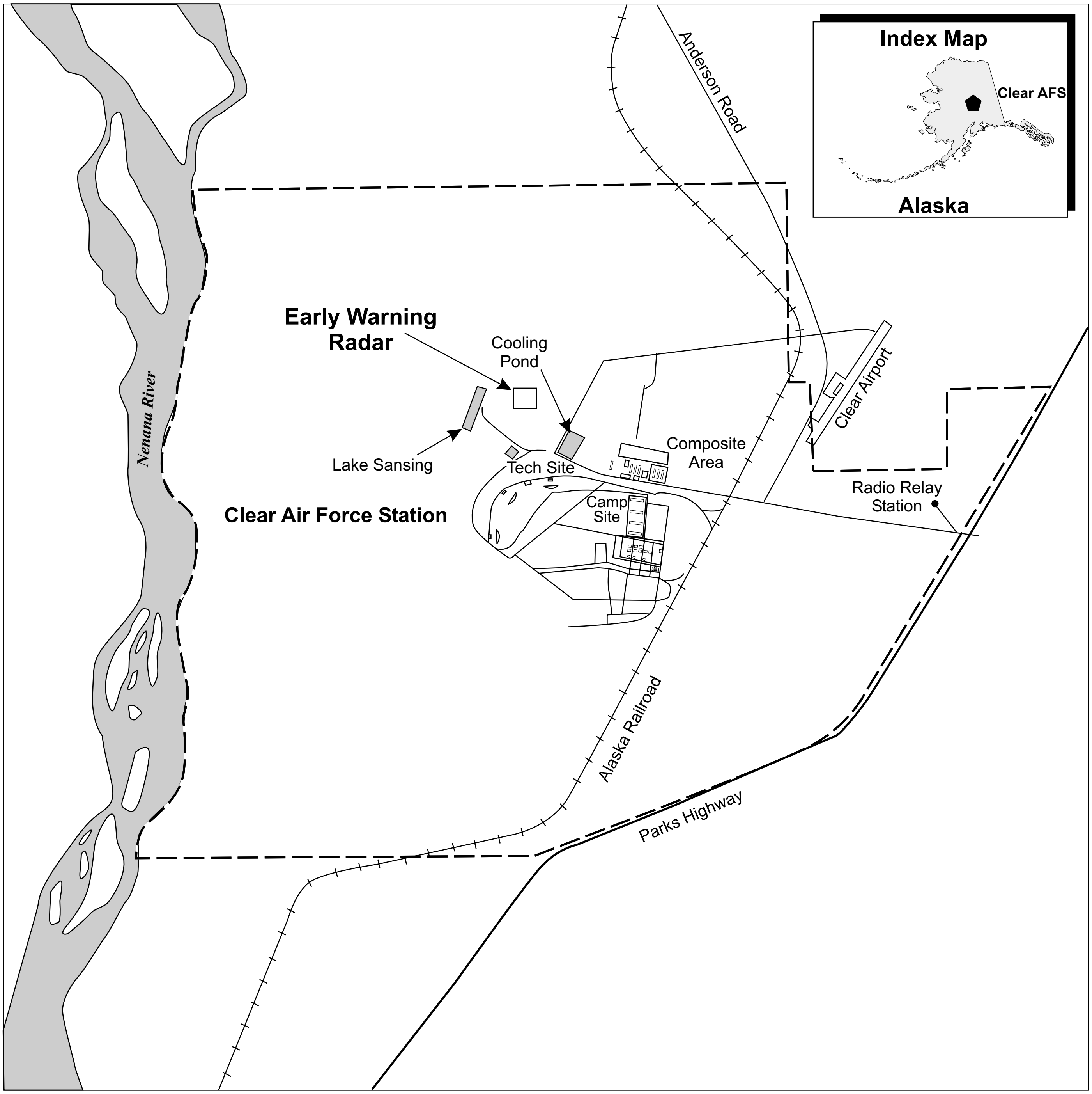
At Clear AFS the existing EWR is to be replaced with a PAVE PAWS radar in early 2001 (figure 2-1). Hardware and software modification to the PAVE PAWS EWR would be required as addressed above. No other changes to the radar or personnel operating or supporting it would be required.

2.1.2 BEALE AFB, CALIFORNIA

At Beale AFB, the existing EWR has been operational since 1980 (figure 2-2). Hardware and software modification would be required to the PAVE PAWS radar as addressed above. No other changes to the radar or personnel operating or supporting it would be required.

2.1.3 CAPE COD AFS, MASSACHUSETTS

At Cape Cod AFS, the existing EWR has been operational since 1979 (figure 2-3). Hardware and software modification to the PAVE PAWS



EXPLANATION

- Roads
- Water Area
- Installation Boundary
- Railroads

NORTH

0 2,500 5,000 Feet

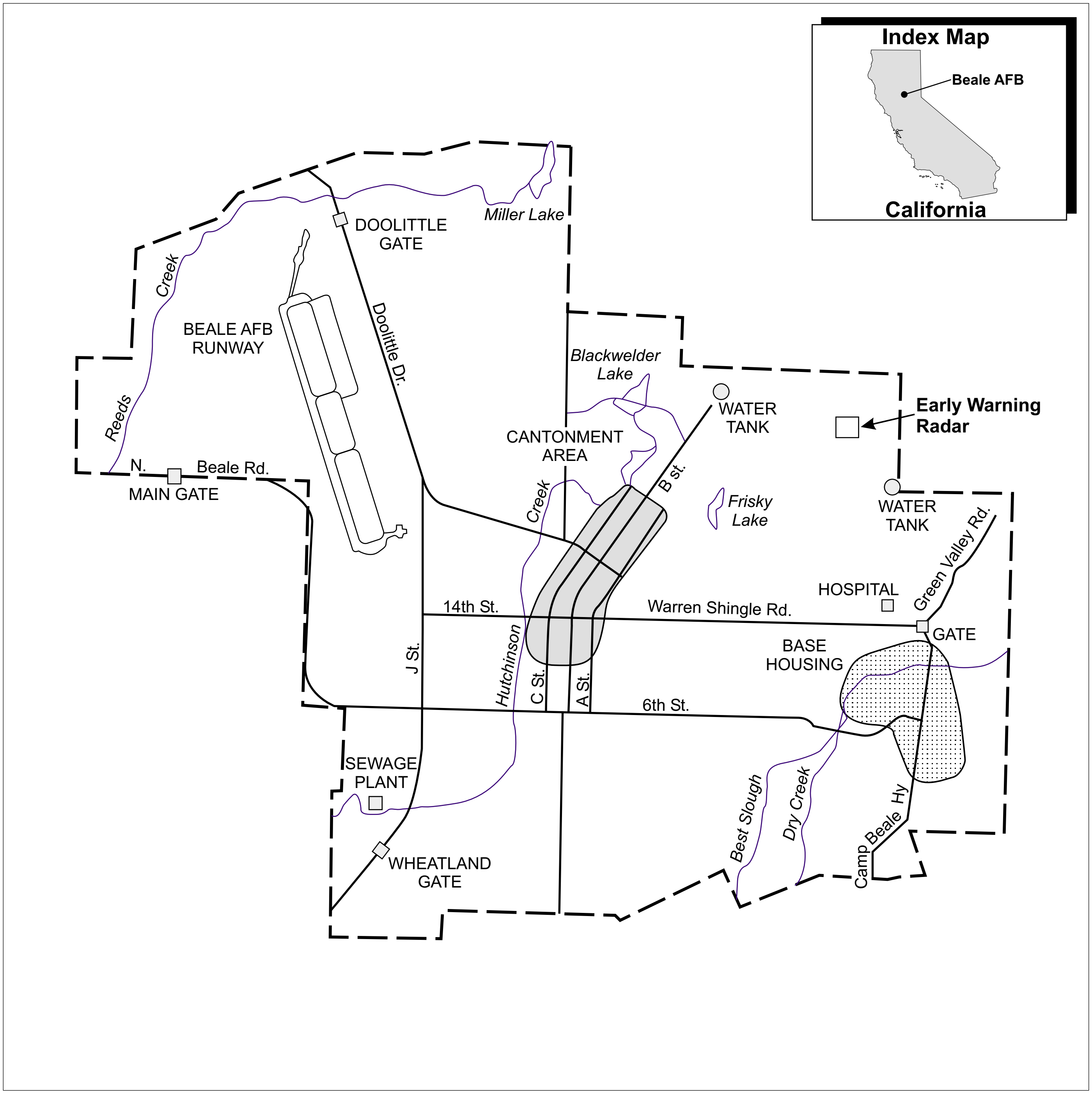
0 762 1,524 Meters

Early Warning Radar Location Map, Clear Air Force Station

Alaska

Figure 2-1

clear001



EXPLANATION

- Roads
- Cantonment Area
- Base Housing
- Installation Boundary

NORTH

0 4800 9600 Feet

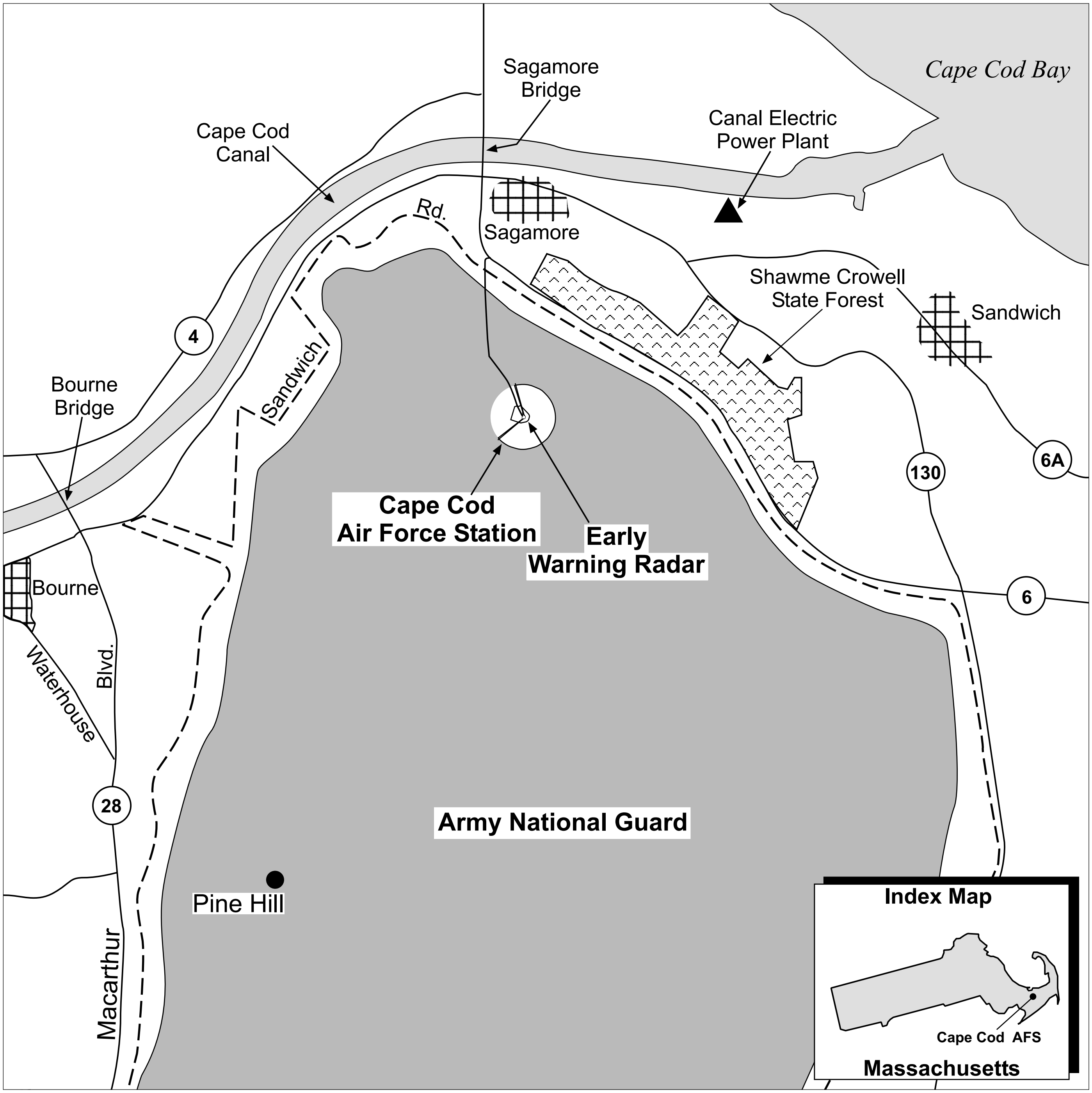
0 1463 2926 Meters

Early Warning Radar Location Map, Beale Air Force Base

California

Figure 2-2

beale002



EXPLANATION

Early Warning Radar Location Map Cape Cod Air Force Station

Massachusetts

Figure 2-3

otis001

radar would be required as addressed above. No other changes to the radar or personnel operating or supporting it would be required.

2.2 NO-ACTION ALTERNATIVE

The No-action Alternative of the NMD Deployment EIS is not to deploy the NMD system. Under the No-action Alternative for this analysis, there would be no hardware and software modifications to the existing EWRs as part of the NMD Program. For the EWR sites being considered for NMD, the No-action Alternative would be a continuation of missile early warning and space tracking currently occurring at those locations.

2.3 ALTERNATIVES CONSIDERED BUT NOT CARRIED FORWARD

The following section briefly describes the methodology used to determine alternative potential locations for NMD UEWR elements. It also provides an overview of how certain sites were eliminated from further consideration.

Beale AFB and Cape Cod AFS are the only two operating PAVE PAWS sites in the United States. A third site at Clear AFS, Alaska is a Ballistic Missile Early Warning System site that is scheduled to become a PAVE PAWS site in early 2001.

There is a decommissioned EWR (a PAVE PAWS radar) site at Robins AFB, Georgia. This site was closed as a cost-saving measure at the end of the Cold War. This location also does not satisfy NMD performance requirements because it cannot provide complete coverage of approaches to the Eastern United States.

There was a PAVE PAWS EWR at Eldorado AFS, Texas. This radar was dismantled and moved to Clear AFS, Alaska and is scheduled to be operational in 2001. If this site were reestablished, it would not fully satisfy NMD performance requirements for coverages of approaches to the Western United States.

A prototype PAVE PAWS radar still operates at Eglin AFB, Florida. Its mission is tracking space debris; it was never an EWR. This location does not satisfy NMD performance requirements because it cannot provide complete coverage of approaches to the Eastern United States. It would also require considerably more hardware and software modifications to be able to locate, identify, and track missiles than the production PAVE PAWS radars require.

This analysis assumes that the Clear AFS, Beale AFB, and Cape Cod AFS EWRs will continue to remain in operation in support of the U.S. Air

Force's ongoing early warning and space-tracking missions, and it does not address the construction of new radar facilities elsewhere in the United States. As previously noted, these three existing EWRs are geographically located in areas of the nation suitable for performance of their proposed NMD mission, and they are readily adaptable to this mission through replacement of interior computer equipment and associated software.

As will be discussed in chapter 4, the modifications do not affect current RF radiation emission levels or pose health or safety risks to the public. Construction of new radar facilities is not cost effective in view of the availability of suitable existing facilities and in view of the very short duration of the NMD mission (approximately 17 minutes per NMD event, with a total NMD usage of just several hours per year) in comparison with overall, year-round, EWR operations. Furthermore, RF radiation emissions from operation of any new facilities would be essentially identical to the current, safe, levels from the existing EWRs, while the direct impacts associated with facilities construction (e.g., site clearing, construction of buildings, power plants, and roads, and associated increases in personnel and traffic density) at any new location would cause more environmental impact than the Proposed Action.

The U.S. Air Force, which operates and has real property accountability over the PAVE PAWS EWR facilities, has begun the process for a NEPA analysis. This analysis will culminate in a full EIS addressing the modernization, maintenance, and sustainment of EWR current operations at Clear AFS, Alaska, Beale AFB, California, and Cape Cod AFS, Massachusetts. For this reason, if the Proposed Action in this analysis is selected, its implementation is contingent upon the outcome of the Air Force EIS. The Ballistic Missile Defense Organization would reassess its proposed usage of the EWR facilities in light of the results of the Air Force EIS prior to installation of the NMD modifications.

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3.0 AFFECTED ENVIRONMENT

3.1 INTRODUCTION

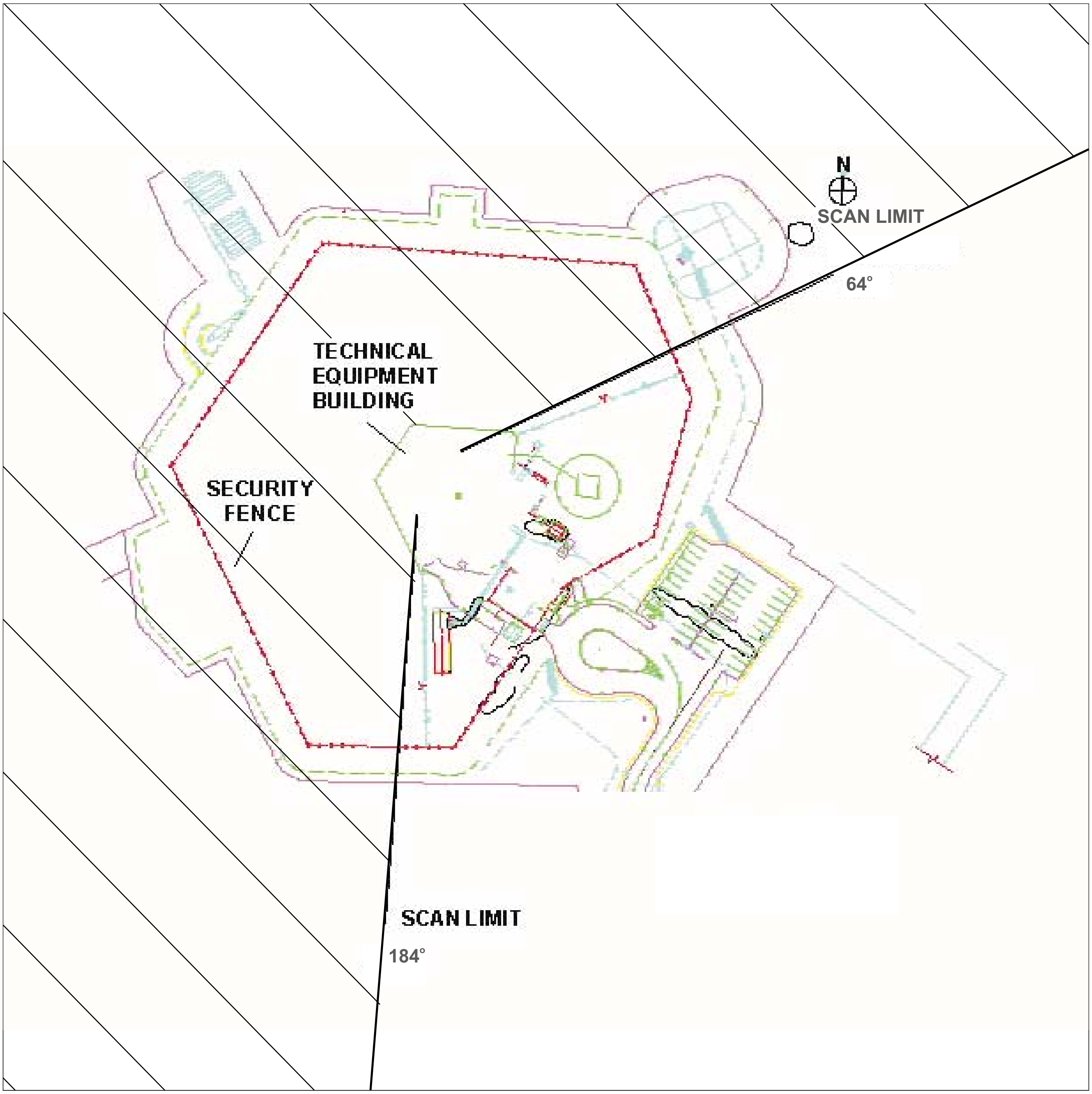
Descriptions of the existing environment in which the three PAVE PAWS radars are located are provided in environmental analyses that were prepared to evaluate potential impacts of the construction and operation of the radars. These reports describe or incorporate by reference the expected impact of the PAVE PAWS missions on the characteristics and intensity of RF fields close to the radar (near field) that includes the facility and the area within the exclusion fence. The characteristics and intensity of RF fields at greater distances (far field) were also described. The effect of the radar in these zones was calculated by modeling and, where available, spot measurements were used to confirm the reasonableness of the calculations. For detailed information on these existing environments, the reports referenced in the following sections should be consulted.

3.2 HEALTH AND SAFETY

3.2.1 CLEAR AFS—HEALTH AND SAFETY

A future PAVE PAWS site will be located at Clear AFS, Clear, Alaska, at coordinates 64.3 degrees north, 149.2 degrees west. The radar face bore sights (relative to true north) are at 351 and 231 degrees for face A (north face) and B (south face), respectively. The radar's scan limits are ±60 degrees of the bore sights. Thus, the overall radar coverage extends from 184 degrees clockwise to 64 degrees relative to true north (64 degrees is relative to 0 degrees true north).

Figure 3-1 shows the PAVE PAWS Clear Radar Upgrade site layout. The security fence is located approximately 61 meters (200 feet) perpendicular to the bottom edges of the two array faces. The radar site is at an elevation of 175 meters (574 feet) above sea level. Within 2 kilometers (1 mile) of the radar site, the ground elevation does not change appreciably as one moves away from the radar. To the north and east, the ground elevation decreases by approximately 8 and 6 meters (26 and 20 feet) over 2 kilometers (1 mile), respectively. To the south and west, the ground elevation increases by approximately 10 and 4 meters (33 and 13 feet) over 2 kilometers (1 mile), respectively.



EXPLANATION

Scan area/direction out to approximately 5,550 kilometers (3,000 nautical miles)

Not to Scale

NORTH

PAVE PAWS Radar and Power Plant Buildings, Clear Air Force Station

Alaska

Figure 3-1

Estimated and Measured Power Densities—Clear AFS

The PAVE PAWS radar at Clear AFS is currently under construction. Therefore, no historic power density measurements are available. Section 4.2.1.1 provides the estimated power densities.

3.2.2 BEALE AFB—HEALTH AND SAFETY

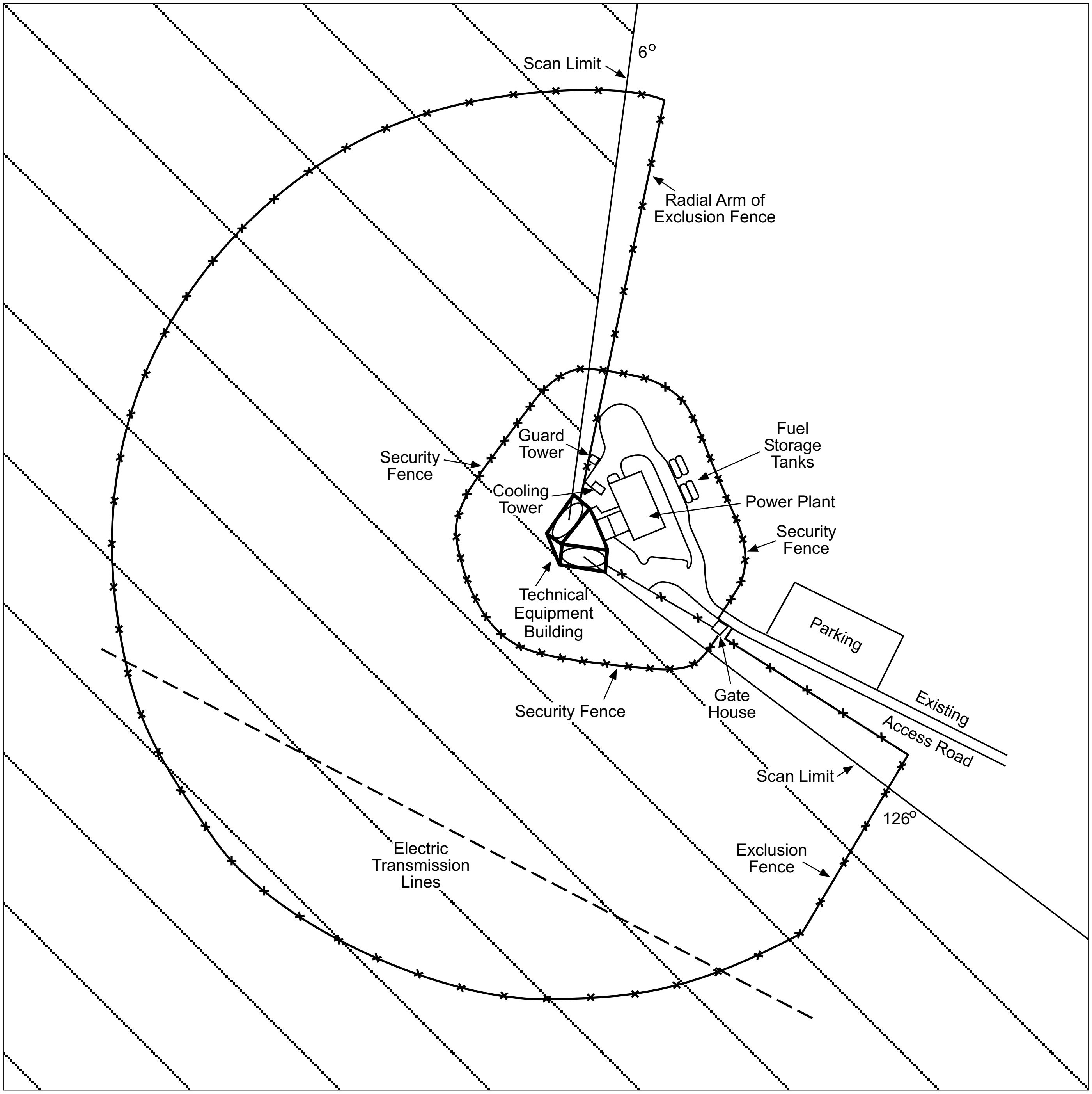
The second PAVE PAWS site is located at Beale AFB, California, at coordinates 39.1 degrees north, 121.3 degrees west. The radar face bore sights (relative to true north) are at 323 and 168 degrees for face A (north face) and B (south face), respectively. The radar's scan limits are ±60 degrees of the bore sights. The overall scan coverage is from 126 degrees clockwise to 6 degrees.

Figure 3-2 shows the PAVE PAWS Beale site layout. The exclusion fence is located approximately 305 meters (1,000 feet) from the array of radar elements. The security fence is located approximately 61 meters (200 feet) perpendicular to the bottom edges of the two array faces.

The Beale AFB PAVE PAWS site is at an elevation of 113 meters (372 feet) above sea level. There are several hills to the north of the radar site. The terrain falls off in elevation to the south and west of the radar site.

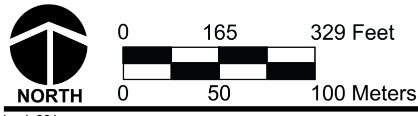
Estimated and Measured Power Densities—Beale AFB

Descriptions of the environmental settings of the three PAVE PAWS radars are provided in the environmental analyses prepared to evaluate potential impacts of the construction and operation of the radars. These reports also describe the expected impact of the PAVE PAWS missions on the characteristics and intensity of RF fields in the areas close to the radar, including the facility as well as the area within the exclusion fence that is located about 305 meters (1,000 feet) from the radar. The area up to 183 meters (600 feet) from the radar is called the near field, and areas up to 439 meters (1,440 feet) are called the transition zone. Employees of the site or surrounding facility might have the need to be within 305 meters (1,000 feet) of the radar. It is only in the far field (beyond 439 meters [1,440 feet]), where the intensity of the RF generated by the radar is much lower, that members of the public could potentially be exposed to RF fields from the PAVE PAWS radar.



EXPLANATION

Scan area/direction out to approximately 5,550 kilometers (3,000 nautical miles)



PAVE PAWS Radar and Power Plant Buildings, Beale Air Force Base

California

Figure 3-2

beale001

The following tables characterize the RF levels near each site based on estimated average power densities in the near-field and far-field zones. These data were reported in previous environmental analyses. Both near-field and far-field estimates were calculated assuming the radar was operating in both track (14 percent duty) and search (11 percent duty) modes for a total duty factor of 25 percent on one array face. The other array face was allocated to an 11 percent search duty cycle. Additionally, comparison estimates were performed in 1979 using an 18 percent duty cycle in a search mode only. The surveillance fence was set at 3 degrees above horizontal. The tables also include near-field and far-field power density measurements reported in these documents.

The calculations and measurements clearly show that the intensity of the RF fields produced by the radar at ground level diminish dramatically with distance from the radar. By 305 meters (1,000 feet), the power density diminishes to less than 4/1000^{ths} of the power density calculated at 30 meters (100 feet).

Tables 3-1 through 3-3 provide calculated and measured power densities in milliwatts per square centimeter (mW/cm^2) for near field and far field, respectively. Figures 3-3 and 3-4 show the site numbers referenced in tables 3-2 and 3-3, respectively.

Table 3-1: 1980 Beale AFB EIS Near-field Calculations

Distance from Radar (meters)	1980 Calculated Average Power Density (mW/cm^2) [1]
30.4	4.0
60.8	0.663
121.6	0.176
182.9	0.0273 [2]
304.8	0.015

[1] Calculations assume that one radar face operates at 25 percent duty cycle (surveillance mode 11 percent, track mode 14 percent) and the alternate face operates at 11 percent duty cycle in the surveillance mode.

[2] This calculation in the 1980 Beale AFB EIS has a math error that has been corrected here. Original stated value was 0.025.

Table 3-2: 1979 Far-field Calculations, Beale AFB

Site Number[1]	Distance from Radar (meters)	Azimuth (degrees)	1980 Calculated Average Power Density (mW/cm^2) [2]
R1	439	NS	0.006200
R2	1,524.0	0	0.001100
R3	2,255.5	180	0.000280
R4	2,438.4	270	0.000590
R5	3,048.0	180	0.000150
R6	6,096.0	180	0.000049
1	2,255.5	157	0.000353
2	3,840.5	157	0.000166
3	2,651.8	248	0.000286
4	6,705.6	280	0.000054
5	3,139.4	286	0.000183
6	6,461.8	298	0.000043
7	6,096.0	239	0.000069
8	2,499.4	108	0.000036
9	19,202.4	258	0.000010
10	21,031.2	273	0.000008
11	1,767.8	298	0.000575
12	2,590.8	5	0.000492
13	1,859.3	333	0.000707
14	3,657.6	344	0.000183

NS = Not specified—use worst-case result

(1) See figure 3-3 for site locations

(2) Calculations assume that one radar face operates at 25 percent duty cycle (surveillance mode 11 percent, track mode 14 percent) and the alternate face operates at 11 percent duty cycle in the surveillance mode.

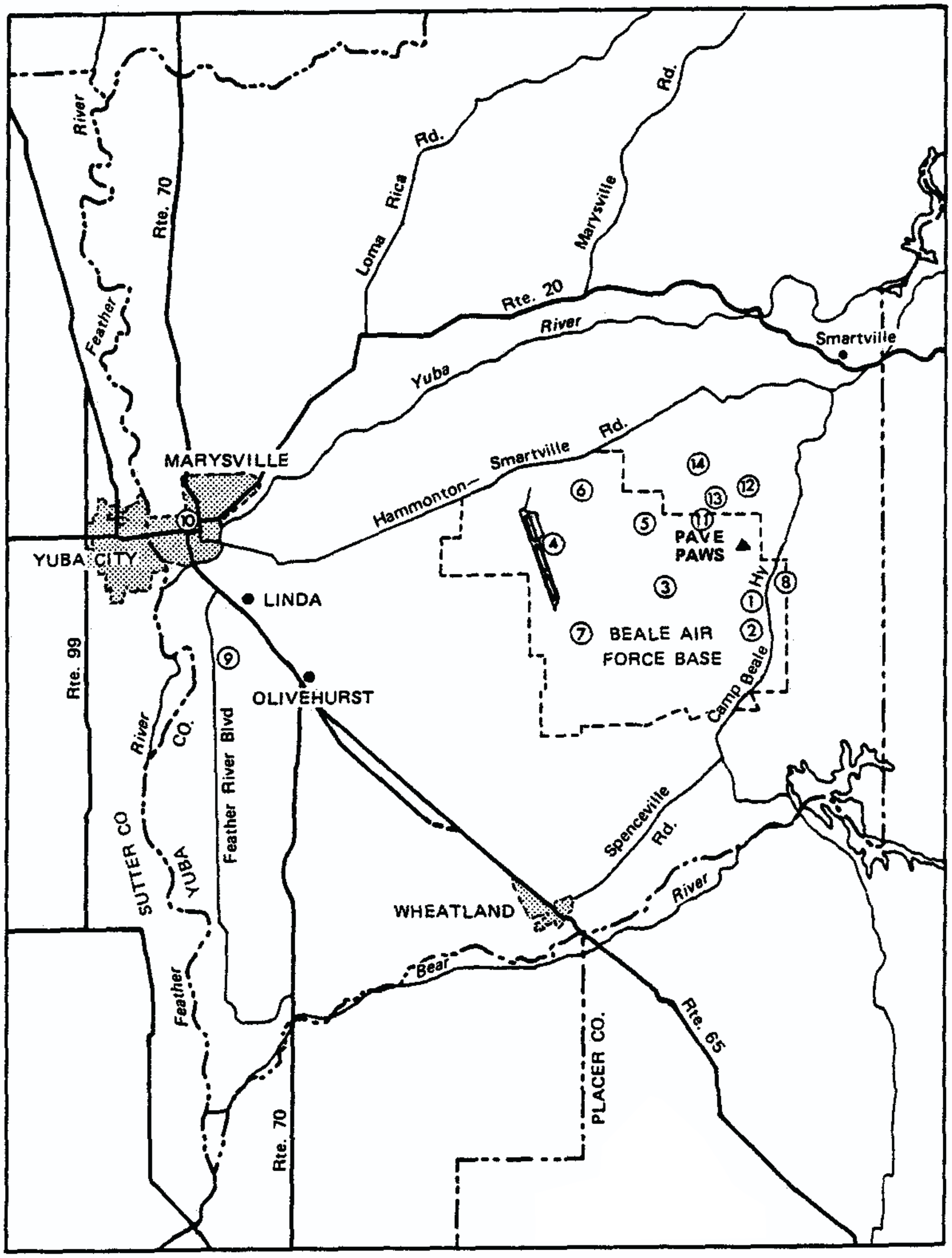
Table 3-3: September 11-12, 1979 Beale AFB PAVE PAWS Far-field Measurements

Site Number (1)	Distance from Radar (meters)	Azimuth (degrees)	1979 Measured Power Density (mW/cm^2) (2)	1980 Calculated Average Power Density (mW/cm^2) (2)
1	2,255.5	157	0.000132	0.000418
2	3,840.5	157	0.000047	0.000203
3	2,651.8	248	0.000041	0.000238
4	6,705.6	280	0.000014	0.000066
10	21,031.2	273	B	0.000013
11	1,767.8	298	0.000800	0.000391
13	1,859.3	333	0.000960	0.000740
14	3,657.6	344	0.000013	0.000224
16	990.6	130	0.002520	0.002610
19	16,306.8	267	B	0.000022
21	15,758.2	211	B	0.000012
22	15,758.2	311	B	0.000012
23	14,478.0	226	B	0.000014
24	1,554.5	22	0.000133	0.000085

B = Below reportable levels (less than 0.000001 mW/cm^2)

(1) The sequencing of the site numbers shown in figure 3-4 is as given in the 1980 Beale AFB EIS.

(2) Both measurements and calculations pertain to an enhanced surveillance mode in which each face operates at 18 percent duty cycle in the surveillance mode with no resources allocated to tracking.



EXPLANATION

(11) Calculation Location

PAVE PAWS Far-field Locations for 1980 Calculations, Beale Air Force Base

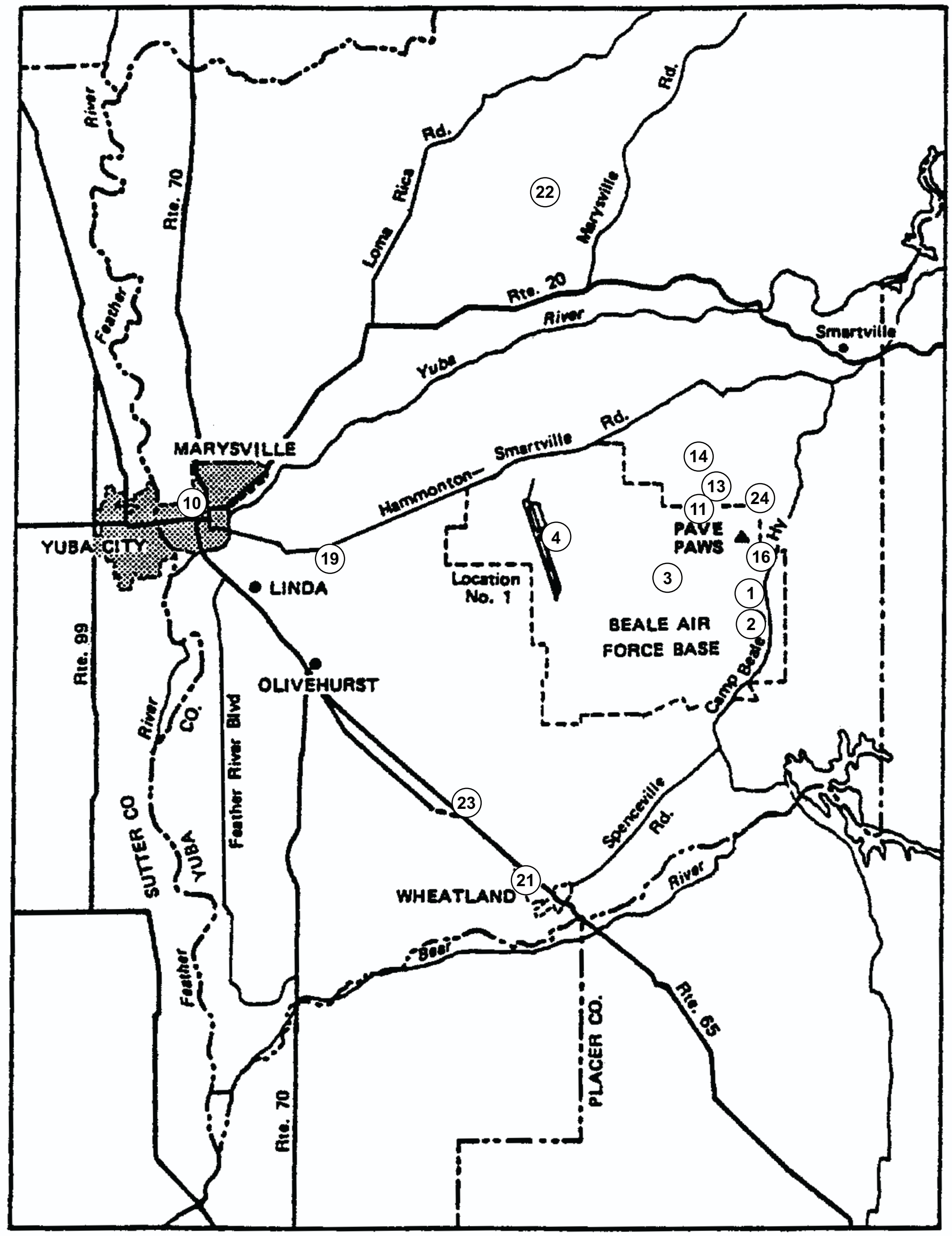
California

0 2.9 5.65 Miles

0 4.55 9.1 Kilometers

NORTH

Figure 3-3



EXPLANATION

11 Field Measurement Site

0 2.9 5.65 Miles

0 4.55 9.1 Kilometers

NORTH

PAVE PAWS Far-field Measurement Locations, Beale Air Force Base

California

Figure 3-4

001

3.2.3 CAPE COD AFS—HEALTH AND SAFETY

A third PAVE PAWS site is located at Cape Cod AFS, Massachusetts, at coordinates 41.8 degrees north, 70.5 degrees west. The radar face bore sights (relative to true north) are at 167.0 and 64.0 degrees for face A (south face) and B (north face), respectively. The overall scan coverage is from 347 degrees clockwise to 227 degrees.

Figure 3-5 shows the PAVE PAWS Cape Cod AFS layout, obtained from the 1979 EIS. The former exclusion fence is located approximately 305 meters (1,000 feet) from the array. The security fence is located approximately 45.7 meters (150 feet) perpendicular to the bottom edges of the two array faces.

The radar site is at an elevation of 82 meters (269 feet) above sea level. As one moves away from the radar, the local terrain falls off in elevation.

Estimated and Measured Power Densities—Cape Cod AFS

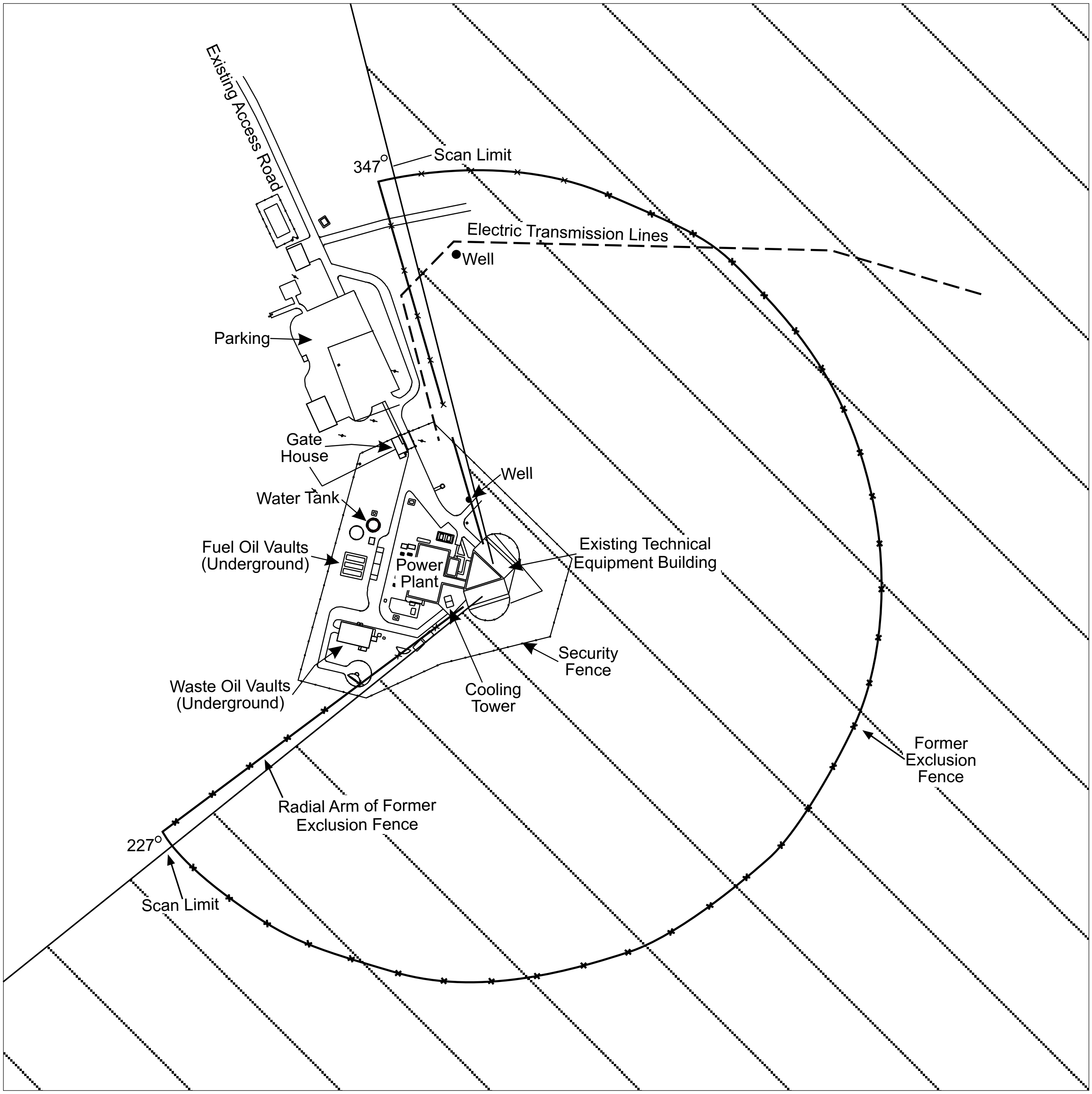
Tables 3-4 and 3-5 provide calculated and measured power densities for near field and far field, respectively. Figures 3-6 and 3-7 show the site numbers referenced in tables 3-5 and 3-6, respectively.

Table 3-4: 1979 Cape Cod EIS Near-field Calculations

Distance from Radar (meters)	1979 Calculated Average Power Density (mW/cm^2) [(1)]
30.4	4.0
60.8	0.663
121.6	0.176
182.9	0.0273 [(2)]
304.8	0.015

(1) Calculations assume that one radar face operates at 25 percent duty cycle (surveillance mode 11 percent, track mode 14 percent) and the alternate face operates at 11 percent duty cycle in the surveillance mode.

(2) This calculation in the 1979 Cape Cod EIS has a math error that has been corrected here. Original stated value was 0.025.



EXPLANATION

Scan area/direction out to approximately 5,550 kilometers (3,000 nautical miles)

PAVE PAWS Radar and Power Plant Buildings, Cape Cod Air Force Station

Massachusetts

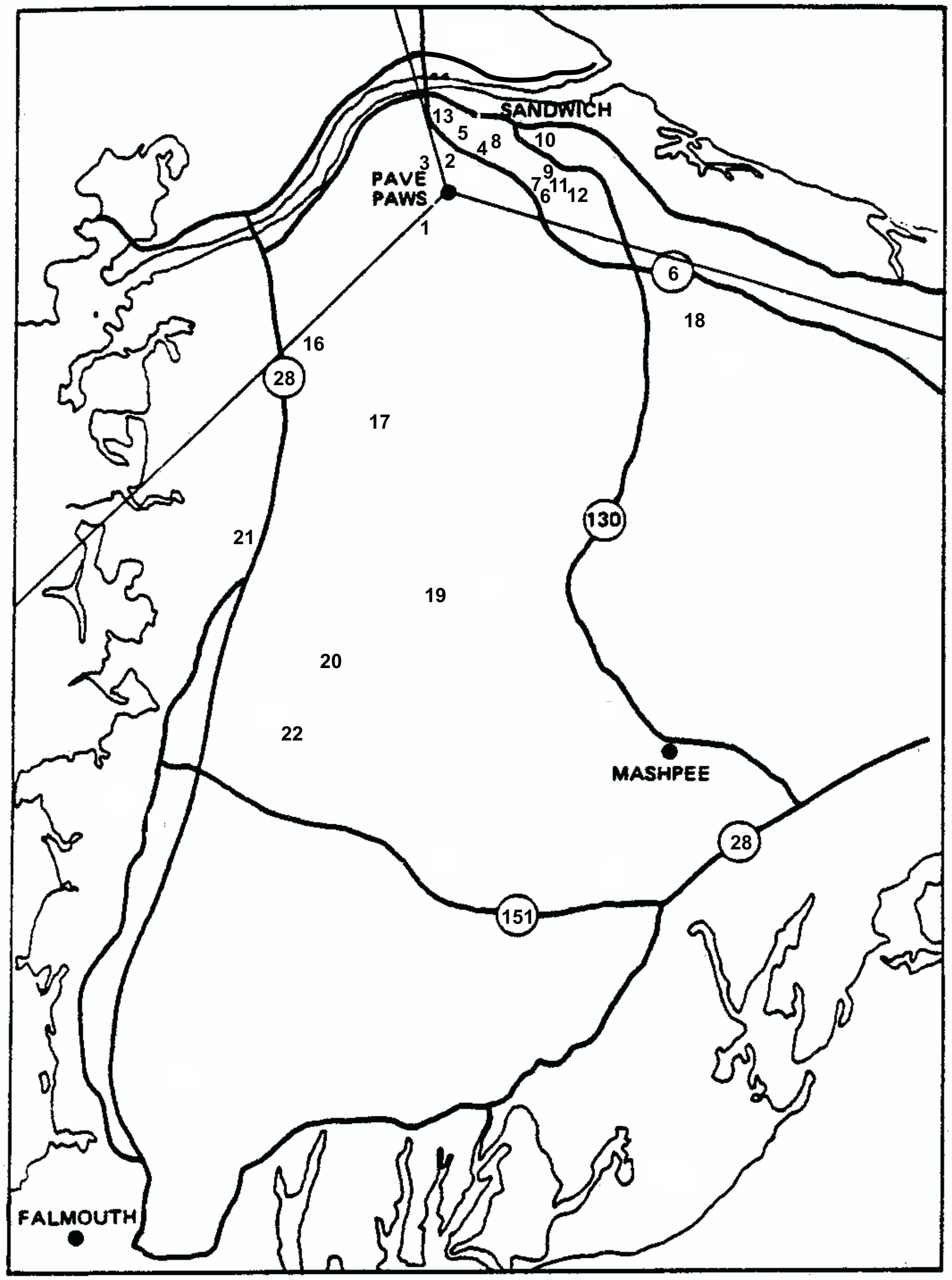
NORTH

0 185 370 Feet

0 64 112 Meters

Figure 3-5

cape001



EXPLANATION

18 Calculation Location

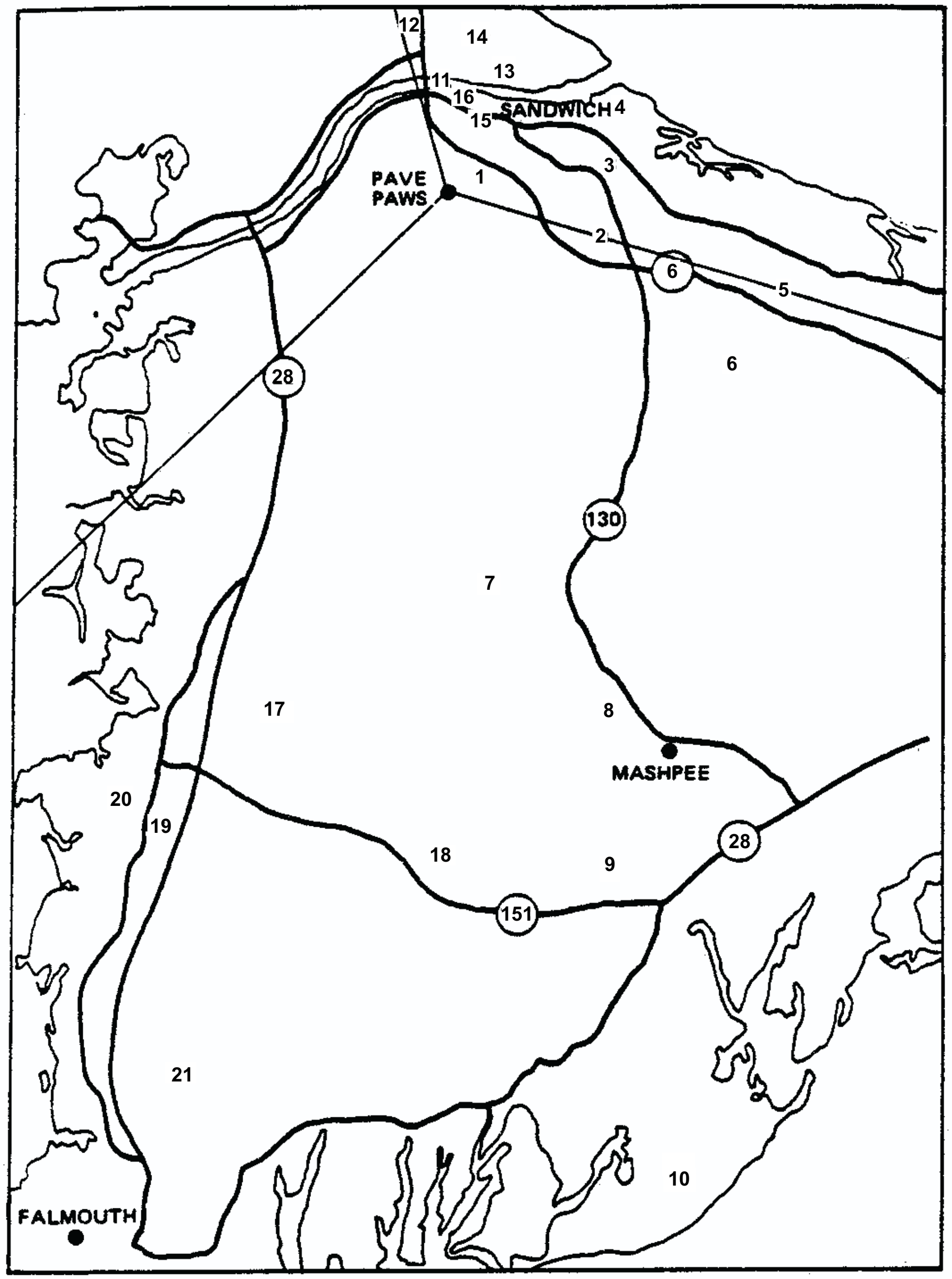
Far-field Locations for 1979 Calculations, Cape Cod Air Force Station

Massachusetts

Figure 3-6

Not to Scale

NORTH



EXPLANATION

18 Field Measurement Site

1978 Far-field Power Density Measurement Locations at the PAVE PAWS Radar, Cape Cod Air Force Station

Massachusetts

NORTH

Not to Scale

Figure 3-7

001

Table 3-5: 1979 Far-field Calculations, Cape Cod AFS

Site Number [1]	Distance from Radar (meters)	Azimuth (degrees) Estimated [2] [3]	1979 Calculated Average Power Density (mW/cm^2) [3]
Beginning of far-field	439	NS	0.0062
1	667.5	212	0.0025
2	819.9	2	0.0017
3	880.9	340	0.0015
4	1,051.6	37	0.0010
5	1,274.1	7	0.0007
6	1,719.1	94	0.00055
7	1,585.0	76	0.00066
8	1,639.8	44	0.00048
9	1,883.7	68.5	0.00032
10	1,945.0	57	0.0003
11	2,004.0	81	0.00042
12	2,551.2	87	0.00024
13	1,762.0	349	0.00036
14	2,851.7	353	0.00037
15	2,883.4	15	0.00014
16	4,718.3	225	0.00011
17	5,405.0	206	0.000084
18	4,858.5	119	0.00015
19	7,772.4	179	0.000041
20	8,991.6	196	0.000031
21	7,955.3	215	0.000039
22	11,125.2	197	0.000020

NS = Not specified-use worst-case result

(1) See figure 3-6 for site locations

(2) Azimuth data was not reported in the 1979 EIS for Cape Cod. Data has been extrapolated from figure 3-6.

(3) Calculations assume that one radar face operates at 25 percent duty cycle (surveillance mode 11 percent, track mode 14 percent) and the alternate face operates at 11 percent duty cycle in the surveillance mode.

Table 3-6: October 20-21, 1978 Cape Cod AFS PAVE PAWS Far-field Measurements

Site Number (1)	Distance from Radar (meters)	Azimuth	1978 Measured Power Density (mW/cm^2) (2)	1979 Calculated 30-minute Average Power Density (mW/cm^2) (2)
1	1,078	63	0.000061	0.00079
2	3,380	107	0.000027	0.00015
3	3,637	80	B	0.00013
4	3,798	63	0.00002	0.00012
5	6,791	107	0.000001	0.00005
6	7,210	121.5	B	0.00005
7	8,755	174	B	0.00004
8	12,553	163	B	0.00002
9	15,980	167	B	0.00001
10	24,140	167	B	0.000005
11	2,607	357	0.000051	0.00037
12	3,508	348	0.000016	0.00014
13	2,881	24	0.000001	0.00011
14	4,474	12	0.000002	0.00019
15	1,674	24	0.000003	0.00033
16	2,350	12	B	0.00016
17	12,392	198.5	B	0.000021
18	15,128	181	B	0.000014
19	15,611	205	B	0.000013
20	15,933	208	B	0.000013
21	20,921	197	B	0.000007

B = Below reportable levels (less than 0.000001 mW/cm^2)
(1) Site numbers are shown in figure 3-7
(2) Both measurements and calculations pertain to an enhanced surveillance mode in which each face operates at 18 percent duty cycle in the surveillance mode with no resources allocated to tracking.

3.3 CULTURAL RESOURCES

3.3.1 CLEAR AFS—CULTURAL RESOURCES

No cultural sites have been identified at the PAVE PAWS radar site on Clear AFS. (Department of the Air Force, 1997)

3.3.2 BEALE AFB—CULTURAL RESOURCES

The PAVE PAWS radar at Beale AFB became operational in 1980. Thus, the site is considered part of the Cold War military mission. The U.S. Air Force has initiated consultation with the California SHPO and is currently in the process of having a programmatic agreement signed before providing Historic American Building Survey/Historic American Engineering Report (HABS/HAER) documentation to the SHPO.

3.3.3 CAPE COD AFS—CULTURAL RESOURCES

The PAVE PAWS radar at Cape Cod AFS became operational in 1979. The radar site is considered part of the Cold War military mission. The U.S. Air Force has already provided HABS/HAER documentation to the Massachusetts SHPO.

4.0 ENVIRONMENTAL CONSEQUENCES

4.1 INTRODUCTION

This chapter describes the potential environmental consequences associated with each location that may be affected by the No-action Alternative and the Proposed Action, along with the identification of potential cumulative impacts and mitigation measures. Resources that have a potential for impacts were considered in the analysis to provide the decisionmakers with sufficient evidence and analysis for evaluation of potential effects of the action. For this analysis, the environment is discussed in terms of two resource areas: health and safety and cultural resources. The data presented are commensurate with the importance of the potential impacts.

The following sections discuss the applicable and relevant standards, current scientific research, and power density estimates and analyze the potential impacts of upgrading the existing EWRs.

4.1.1 APPLICABLE AND RELEVANT STANDARDS

The assessment of human health and safety related to environmental exposure hinges on adhering to exposure limits recommended in science-based standards. The relevant primary exposure limits to protect health and safety regarding RF energy are those developed by the Institute of Electrical and Electronic Engineers (IEEE) and adopted by the American National Standards Institute (ANSI) (ANSI/IEEE, 1992). The IEEE standard was developed in 1991 and adopted by ANSI in 1992. The 1999 edition specifically modifies induced and contact current limits, but does not modify the exposure limits applicable to the general public outside of the security fence (IEEE Std C95.1, 1999 edition). In addition, other organizations have published relevant limits. These include state and federal agencies. The Federal Communications Commission (FCC) standard is based on the recommendations of ANSI/IEEE and the U.S. National Council on Radiation Protection (National Council on Radiation Protection, 1997). The Code of Massachusetts Regulations, Title 105, Section 122.000 (105 CMR 122.000) calls for a limit on time averaged exposure to RF that is identical to that of the ANSI/IEEE 1992 standard.

The U.S. Air Force has standards for permissible exposures that also are the same as the ANSI/IEEE 1992 standard for the RF range in which the PAVE PAWS radars operate (Air Force Occupational Safety and Health, 1997). Finally, the Department of Labor, Occupational Safety and Health Administration (OSHA) has a standard for occupational exposures (Code of Federal Regulations [CFR] 1910.97, 1971). This section reviews and compares exposure limits recommended by a variety of recent sources, as well as the major research completed and published subsequent to the 1991 edition, and applicable to the question of potential effects of long-term exposure. In addition, this section summarizes the most recent assessments performed by advisory groups and panels convened by international scientific organizations such as the World Health Organization. Assessments of this type are a component in the development of a standard.

Recommended Limits for Exposures of the General Public

The standards for the recommended human exposure limits for the frequencies used by PAVE PAWS, 420-450 megahertz (MHz), are similar around the world. Table 4-1 lists those standards that are available in English and that include some discussion of the basis of the standard. The first two are from U.S. organizations, ANSI and FCC. The next two national standards are included because they were released in 1999 (New Zealand, Canada). The last two include detailed review and discussion prepared by scientific advisory groups. Each of these standards is based on limiting exposure to prevent an effect that can occur upon acute (short-term) exposures.

The ANSI/IEEE standard explains the scientific rationale for the standard, describes the literature review and consensus process used, and includes appendices naming the studies considered and utilized. The FCC standard was promulgated in 1996 (U.S. National Council on Radiation Protection, 1986). Both the New Zealand and Canadian standards were promulgated in 1999, and a scientific panel convened by the Royal Society of Canada reviewed the basis of the latter. The Royal Society review and the conclusions of the National Radiological Protection Board (NRPB) and International Commission on Non-Ionizing Radiation Protection (ICNIRP) are summarized later in this section. In 1971 OSHA published another standard that is only applicable to the occupational exposures of workers (10 mW/cm^2). In practice, OSHA uses the ANSI/IEEE standard.

Table 4-1 identifies for each of the standards the frequency range that would apply to the PAVE PAWS radars (column 2). Because exposure limits are frequency dependent, the table also shows how the most conservative exposure limits for these radars were calculated (column 3). Except for the NRPB standard, other standards compute the appropriate exposure limit by dividing the lowest frequency produced by the radar by factors published in the standard. Columns 4 and 5 show the calculated exposure limit at 420 MHz and the time period over which the standards prescribe that exposures be averaged, respectively.

Table 4-1: Recent Recommended Limits for General Public Exposure to Radiofrequency Fields (420-450 MHz)

Organization	Applicable Frequency Range (MHz)	Derivation (mW/cm^2)	Exposure Limit at 420 MHz[1] (mW/cm^2)	Averaging Time (minutes)
American National Standards Institute/Institute of Electrical and Electronics Engineers, 1992	300-3,000	f/1,500	0.28	30
Federal Communications Commission, 1996	300-1,500	f/1,500	0.28	30
Massachusetts, 1994	300-3,000	f/1,500	0.28	30
Air Force Occupational Safety and Health, 1997	300-3,000	f/1,500	0.28	30
New Zealand, 1999 [3]	400-2,000	f/2,000	0.21	6
Canada, Safety Code 6 (1999) [3]	300-1,500	f/1,500	0.28	6
National Radiological Protection Board, United Kingdom, 1993, [1998]	400-800	--	2.6[2]	15
International Commission on Non-Ionizing Radiation Protection, 1998	400-2,000	f/2,000	0.21	6

(1) In the relevant frequency range, the lowest limit is for 420 MHz, therefore only this limit is presented in this table.

(2) NRPB refers to these numbers as "Investigation Levels" and are measurement benchmarks for investigating whether compliance with basic restrictions (e.g., 0.4 watts per kilogram) is achieved).

(3) New Zealand Joint Standards Australia/Standards New Zealand Committee TE/7, Human Exposure to Electromagnetic Fields. It has been adopted by New Zealand, but not in Australia, as of October 1999.

(4) Safety Code 6. Revised and reissued in 1999 by Health and Welfare Canada after the review of the Panel convened by the Royal Society of Canada

f = frequency in MHz

The impact of the proposed action was assessed by comparison to the ANSI/IEEE standard. The main criterion of the standard limits exposure to time averaged power density over a 30-minute averaging period (table 4-1). There are also secondary limits for pulsed RF fields that limit the peak power per pulse and peak power over any 100 millisecond (ms) time period. However, the time-averaged power density is the controlling criterion for determining compliance of the PAVE PAWS radars with the ANSI/IEEE standard. The primary reason is because the NMD mission potentially could affect time-averaged power density exposures due to variations in scanning and tracking scenarios but would not change the maximum duration and intensity of single RF pulses.

Other reasons why peak pulse power and other characteristics are not emphasized in this report include: the inability of the radar to produce pulses with sufficient intensity to cause the secondary ANSI/IEEE criteria to be relevant, and the desire to address public concern about the possibility of health effects of long-term exposures to RF energy from PAVE PAWS radars for which the average power density is the most appropriate exposure parameter. Additional details about the RF pulse characteristics and emissions from the PAVE PAWS radars are available in the 1979 and 1980 EISs for Cape Cod AFS and Beale AFB, respectively (Department of the Air Force, 1979; 1980).

ANSI/IEEE Standard Development and Current Status

The applicable standard in the United States is the ANSI/IEEE *Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields* (ANSI/IEEE, 1992). The IEEE initially released the C95.1 standard in 1991. The IEEE recommendations were adopted by ANSI in 1992, and it is therefore referenced as ANSI/IEEE, 1992. The ANSI standards are routinely reviewed every 5 years. This standard was last reaffirmed in 1997. A revision published in 1999 incorporates a supplement that modifies the induced current limits and grasping-contact current limits and provides additional information relevant for hand-held wireless devices. The limits on whole body exposures for the general public have not been changed from the 1991 IEEE standard.

The FCC has also promulgated guidelines. These guidelines are applicable specifically to FCC regulated transmitters, but are important in that they represent the first official consensus of U.S. Federal Government health and safety agencies on RF limits (Federal Communications Commission, 1996). These guidelines were derived from recommendation of other federal agencies, and have been endorsed by the U.S. EPA, Food and Drug Administration, National Institute for Occupational Safety and Health, and OSHA (Cleveland, 1998). In the range of the NMD and PAVE PAWS radar, these limits are exactly the same as in ANSI/IEEE.

ANSI/IEEE Standard Scientific Basis

As with most environmental standards, the ANSI/IEEE standard is based on the weight-of-evidence approach for assessing potential hazardous impacts on health. Scientific and regulatory authorities use the weight-of-evidence approach to study health effects of environmental exposures (U.S. EPA, 1993; 1996; International Agency for Research on Cancer, 1992). In this approach, epidemiology and laboratory studies are evaluated by screening all potentially relevant studies and assessing their scientific quality in terms of study design, exposure considerations, methods and statistical analyses, and quality of data obtained. The most weight is given to the studies of highest quality. Both epidemiology and laboratory studies are essential because they have different strengths and limitations that are complementary. Epidemiology studies provide information about humans in their natural environments, but environmental exposures and other relevant factors that affect health are difficult to isolate and measure. On the other hand, laboratory studies provide information derived from animals, cells and tissues, under conditions in which most exposures and variables can be carefully controlled. It is necessary, therefore, to evaluate complementary data provided by controlled laboratory studies in animals, or in isolated cells and tissues, in order to determine whether the agent or substance could adversely affect human health, and if so, what type of hazard it poses.

The ANSI/IEEE standard includes an appended list, rather extensive, of epidemiology and laboratory studies that were reviewed. Another appendix includes the references selected to form the basis of the standard. The studies considered relevant had to meet several criteria, including peer review and favorable review by members of the committee as to quality and relevance of study design and completeness of documentation. This process is described as engineering and biological validation of the literature.

On the basis of this review and evaluation, the Rationale of the ANSI/IEEE 1992 standard concludes that no reliable scientific data were found to indicate that exposure to electromagnetic fields produces cumulative damage, and that “no reliable scientific data demonstrate that nonthermal (other than shock) or modulation-specific sequella of exposure may be meaningfully related to human health.” The effect to be prevented is behavioral disruption, which is associated with a minimal rise in temperature, leading to the term “thermal effect.”

The standard applicable to the general public is for an “uncontrolled environment, ” which refers to the condition for most people who do not knowingly encounter RF fields in their work environment. These exposure limits are 50 times lower than the estimated RF exposure intensity (power density) that would cause reversible effects on animals and humans associated with heating. This means that to the best of current knowledge, it would require exposures 50 times higher than the standard to induce those thermal changes upon which the standard is based. The ANSI/IEEE standard also includes consideration of occupational exposures and to exposures in other environments where the general public may be exposed. The exposure limits are higher in occupational environments where workers are aware of their exposures than in other places where individuals are not generally aware of, or in control of, potential exposures.

4.1.2 RESEARCH STUDIES OF EFFECTS AFTER LONG-TERM EXPOSURES AT LOW LEVELS

Questions have arisen as to whether chronic effects, such as cancer, could occur after long-term exposures at low levels, that is at levels below those known to produce behavioral effects thought to be related to body heating. Although few studies of long-term, low-level effects were available during the time of the literature review for the ANSI/IEEE 1992 standard, several studies have been published subsequently. The major and most complete long-term studies that used standard experimental procedures and statistical methods are summarized below. Several of these studies used pulsed fields like that produced by PAVE PAWS radars.

Methods for Assessment of Effects of Long-term Exposure

Chronic toxicity studies are those designed to examine the effects of exposures that are repeated and prolonged. Chronic toxicity tests can uncover latent and cumulative effects. Treatment should be for at least 12 months, but in many studies exposure lasts for nearly the entire lifespan of the species, 18-24 months for mice, and 24-30 months for rats.

Long-term RF studies are conducted at exposures below the threshold for effects related to thermal changes. The standard for the general public is an exposure level, or dose, 50-fold below this level. Several long-term studies consist of only one exposure level. In these studies, the exposure level is usually based on the internal dose rate in the standard for controlled environments, 0.4 watts per kilogram (W/kg). This dose rate is the lowest observed level (threshold) for the effect (4 W/kg), divided by a 10-fold safety factor. It is the basis for the standard, at all frequencies. The power density in mW/cm^2 that results in this dose rate depends on the frequency and the species of animal being studied. Therefore, it is not directly useful to present the exposure level used in the animal study. Instead, in the studies reviewed below, the exposure is expressed as the dose rate in W/kg. The exposure limit for the uncontrolled environment used in this EIS is actually 0.08 W/kg. Thus, studies at 0.4 W/kg are exposing the animals to higher intensity than recommended in the relevant standard for the general public.

These studies have examined the animals' survival time (longevity), their overall health, and cancer or other tumors (using microscopic examinations called histopathology). Most have examined other aspects of the animals' overall health, and have evaluated the tissues for evidence of other toxicity or tissue damage as well. Several observations in these studies are relevant for assessing long-term toxicity, at low non-thermal levels of exposure. The U.S. EPA in general considers that well-designed long-term studies in species of laboratory animals such as rats or mice can provide relevant evidence regarding chronic toxicity, or if so designed, cancer (U.S. EPA, 1996). The assessment of cancer also includes genotoxicity studies—laboratory studies in cells and tissues that test for mutagenic effects or effects on the genes and chromosomes.

Long-term Studies of Cancer and Toxicity from RF Exposure

In 1992, Chou et al. published a detailed report of a large, comprehensive, long-term study in rats. The frequency 2,450 MHz was selected so that each rat would have the same ratio of body size to wavelength as a human exposed to 450 MHz, near which PAVE PAWS operates; the pulse modulation was used to simulate radar exposure. The exposed group consisted of 100 rats exposed for over 25 months, for 21.5 hours daily to about 0.5 mW/cm^2. A control group of similar size was administered sham exposure, that is, conditions that mimicked the exposure situation without the RF. The exposure level resulted in a Specific Absorption Rate (SAR) below the SAR specified in the standard, 0.4 W/kg. In addition to comparing longevity and general health among the two groups, the study included tests of neurological effects (open field behavior) and immunologic status. The tissues of each of the 200 animals were examined for cancerous and benign tumors, and tumor incidence rates compared with control animals. The exposed rats did not have increased incidence of any specific type of lesion, or in any specific organ, an important consideration for assessing the ability of any agent to cause cancer (U.S. EPA, 1996).

In the Chou et al study (1992), when all types of cancer were combined regardless of tissue type or anatomical site, the exposed rats had more cancers than controls. However, the biological significance of this is uncertain in view of the observations that: (1) when the incidence of benign and malignant tumors was combined, tumors did not differ between the two groups; and (2) the overall cancer incidence was not greater than found in other groups of control (unexposed, untreated rats) of this type. It is important to consider other long-term studies to assess the significance of the elevated rate of all cancerous tumors combined.

Another study conducted within the range of the PAVE PAWS frequencies examined the exposed mice to see whether RF affected cancer, overall longevity, or the health of other tissues or organs (Toler et al, 1997). Mice of a strain prone to mammary tumors were exposed to pulsed RF radiation at 435 MHz (PAVE PAWS operates between 420 and 450 MHz) for nearly their entire lifespan, 21 months. The exposure was at 1 mW/cm^2, to produce a dose rate in mice of 0.32 W/kg, which is just below the 0.4 W/kg threshold for the controlled environment. These mice are a useful model to assess promotion of breast cancer. There was no difference other than random chance in the numbers of animals who developed mammary tumors, or any type of malignant or benign tumors. Other lesions, non-neoplastic or non-cancer like, developed at the same rate in exposed and unexposed animals.

Two other long-term studies of mice exposed animals at 2,450 MHz for nearly the entire day (20 hours per day) for 18 months, most of the 24-month standard lifespan of the mouse (Frei et al, 1998a,b). One study exposed the animals to 0.3 W/kg, just a bit below the limit in the standard. The other, in the same laboratory, exposed the mice to 1.0 W/kg, which is above the standard, but below the threshold for thermally related effects. The laboratory mice used are a specially bred species sensitive to mammary tumors and are used as a model for promotion of mammary cancer. There was no difference between the body weight and survivorship of the groups at either dose level. The incidence of total tumors (benign and malignant) overall did not differ between the groups. No single tumor of any type or site was increased in the exposed group. Total mammary tumors, time to onset of these tumors, and tumor growth rate of the RF exposed groups was not different from the sham-irradiated (control) group. The RF exposed group at 1 W/kg had longer survival time than the sham exposed group, although the difference was attributed to chance.

Non-neoplastic refers to changes in the cells or tissues that do not include proliferating or cancerous cells. Inflammation or other abnormal morphology are examples of non-neoplastic changes. The incidence of non-neoplastic lesions is a potential indicator of cumulative or chronic effects. The exposed groups showed an increase in two types of these lesions, whereas the sham exposed (control) group had an increase in five types of lesions. No increases were observed between the groups.

Several RF research studies have been conducted at specific frequencies and modulations for wireless communications, for example 900 MHz used for some cell phones and antennas. Studies conducted at frequencies outside of the PAVE PAWS range report the dose (in W/kg), so they may be considered for a broad range of RF exposures.

Australian researchers recently reported a doubling of lymphomas, a type of cancer, in transgenic mice exposed for 18 months to pulse modulated 900 MHz fields at SAR averaged levels of 0.13 to 1.4 W/kg for 1 hour daily (Repacholi et al, 1997). This strain of transgenic mice was bred to be genetically predisposed to develop spontaneous T-cell lymphoblastic lymphoma, for the purpose of studying the role of specific genes in cancer. In this study, the mice exposed to RF did not show a statistically significant increase in T-cell lymphoma prior to 9 months, or over the duration of the study. The reported 2-fold increase results from the combination of all types of lymphoma over the 20-month duration of the study. Because animals of this strain have not been studied for longer than 9 months, and there is as yet no body of data that demonstrates the relevance of this particular animal model to the development of cancer in humans, the implications of this study for humans are unclear.

Scientific questions have arisen regarding the study's design and assessment of exposure and dosimetry. The mice were housed five to a cage, and scientists consider this to be a crowded condition, which has impacts on animal health via stress and sanitation. The estimates of dose did not fully consider the reflected fields that were bound to occur given the exposure facility and housing. The implications of these results, if valid, for humans depend on several unknowns such as how well the transgenic mouse model applies to the human condition, and the actual dose each mouse incurred, and the effects of the housing and environment on the animals' health. Replication studies are underway in Europe and in Australia as part of the International EMF Project. They include significant modifications to the exposure system to improve the characterization of the dose (World Health Organization, 1999).

In a long-term study in rats, the animals were exposed to RF at 836 MHz modulated as for a cellular telephone communications (Adey, 1999). The 2-year study of tumors of the brain and central nervous system included fetal exposure. The exposed animals had longer survival time, and reduced incidence of brain and central nervous system tumors compared to unexposed control animals.

Imaida et al (1998a,b) used a standard animal model designed to test promotion of liver cancer. This medium-term assay used a chemical to initiate cancer. They studied near-field exposure at frequencies in use for cellular telephones—929 MHz and 1,439 MHz. RF exposure did not increase the number of precancerous sites in the liver at either exposure level. The liver is a common site affected by carcinogens in laboratory animals.

With the exception of the study in transgenic mice (Repacholi et al, 1997), long-term studies do not show evidence of changes in normal behavior, adverse effects on clinical measures, changes in body weight or longevity; histopathology examination of body tissues show no evidence of lesions, or decreased survival time (Chou et al, 1992; Frei et al 1998a,b; Toler et al, 1997). The study of transgenic mice is at present uninformative because of questions about several aspects of the study design and the interpretation of results in this relevance of this animal model. Overall, the results of these studies in rodents, routinely used to assess effects on human health, argue against adverse effects from long-term (nearly lifespan) exposures at low levels.

Studies of Genotoxicity and RF Exposure

Studies of mutagenicity, or toxicity to the cell's genetic material, can be conducted by examining the blood cells or tissues of animals that have been exposed to RF. These studies of exposures to living animals are called *in vivo*. If however, the blood or other body tissue is first extracted from the animal and then exposed, outside of the animal's body, this is an *in vitro* study, a study of exposure in glassware. For example, Lai and Singh (1995, 1996) reported breaks in strands of chromosomes, using a specific test, or assay, but this result was not found by others in similar analyses (Malyapa et al, 1997a,b). The exposure levels in these studies were about 2 mW/cm^2 and a whole body SAR of 1.2 mW/kg. In contrast to Lai and Singh's findings, there are other studies in which animals exposed to RF at similar SARs do not report evidence of genotoxic damage (e.g., Vijayalaxmi et al, 1997a,b; 1998).

While some researchers have reported changes in indicators of genotoxicity in cells, others have not. Brusick et al, (1998) evaluated *in vivo* and *in vitro* tests, including tests of micronuclei formation, chromosomal aberrations, DNA repair, in microbial and in mammalian systems from over 100 studies. Studies were evaluated together according to the nature of the tests and the type of information each could provide. They also assumed that when performing a large number of tests some positive results would occur by chance alone. Statistical analysis indicated that the number of positive results was not more than could be explained by chance alone. The majority of these studies, which covered the full range of frequencies including the 400-450 MHz range, did not show genotoxic effects.

4.1.3 SCIENTIFIC REVIEW PANEL REPORTS

Expert Panel on the Potential Health Risks of RF Fields from Wireless Telecommunications, Royal Society of Canada, 1999

Recently, Health Canada revised guidelines designed to protect workers and the general public from harmful levels of RF radiation. The revision was undertaken because additional scientific information became available since 1991. Public concerns had been expressed regarding the adequacy of Safety Code 6, particularly with regard to wireless telecommunication devices. Health Canada asked the Royal Society of Canada to convene an expert panel to assess the revised Safety Code 6, "Limits of Human Exposure to Radiofrequency Electromagnetic Fields in the Frequency Range from 3 kHz to 300 GHz." Health Canada identified the issues in a set of questions called "Terms of Reference" that were addressed by the eight members of the Panel. After incorporating the recommendations of the reviewers, Health Canada issued a Safety Code 6 in 1999. The panel's report, dated March 1999, recommended some changes in exposure levels for partial body exposures, and called for more research in certain areas. It did not recommend exposure limits based on non-thermal effects, including cancer. The following conclusions are relevant to questions that have been raised regarding RF from PAVE PAWS radars:

> *. . . the panel was particularly sensitive as to whether the biological effects which have been observed in cells and animals following RF exposure have been documented by additional studies to show adverse health effects in the exposed organism. The panel found no evidence of documented health effects in animals or humans exposed to non-thermal levels of radio-frequency fields. The panel therefore does not recommend that Safety Code 6 be altered to included regulation at the non-thermal levels of RF which have been shown to produce these biological effects. (p. 110-111)*
>
> *There is little evidence that exposure to RF fields at non-thermal levels enhances tumorigenesis in animals. There is also little evidence that exposure to RF fields at non-thermal levels promotes the growth of tumours in animals. Although a few studies have shown a significant increase in tumour promotion in the exposed groups, the significance of these findings is unclear pending replication of the results by other investigators. The majority of studies to date have found no significant differences between unexposed and exposed animals, and no clear evidence of an exposure-response relationship. (p. 9)*

Epidemiological studies reported to date have been largely uninformative due to methodological limitations. (p. 111)

The International Commission on Non-Ionizing Radiation Protection, 1998

The ICNIRP works in cooperation with the Environmental Health Directorate of the World Health Organization as did its predecessor, the International Radiation Protection Association (IRPA). The Commission consists of scientists from nine countries who develop the guidelines based on the scientific literature. The guidelines that they published in 1998 include some discussion of the scientific research under the title "Biological Basis for Limiting Exposure." These guidelines have a unique discussion entitled "Special considerations for pulsed and amplitude-modulated waveforms" (p. 506), which notes that:

> *The issue of athermal interactions of high-frequency EMF has centered largely on reports of biological effects of amplitude modulated (AM) fields under in-vitro conditions at SAR values well below those that produce measurable tissue heating.*
>
> *Overall, the literature on athermal effects of AM [modulated] electromagnetic fields is so complex, the validity of reported effects so poorly established, and the relevance of the effects to human health is so uncertain, that it is impossible to use this body of information as a basis for setting limits on human exposure to these fields. (p. 507)*

The National Radiological Protection Board

The NRPB of the United Kingdom gives advice to the British government on protection standards for both ionizing and non-ionizing radiations. Non-ionizing radiation refers to electromagnetic fields, including RF, which do not have the energy to break chemical bonds causing ionization. In 1993, after reviewing the research, the Board stated that RF, including microwave radiation, is not mutagenic, and exposures are unlikely to result in an increase in mutation or chromosome aberrations when body temperatures are maintained within physiological limits.

In 1998, they reiterated that their position is based on a critical appraisal of epidemiological (human health) evidence, biological studies and an examination of the physical interaction of electromagnetic fields with the human body. In their view, non-ionizing radiations (which include RF radiations) cannot cause cancer (NRPB, February, 1998).

Recently, the NRPB prepared a statement to comment on the ICNIRP guidelines and European proposals. The limited data on the potential for causing cancer cannot be used to set standards. Note that while the restrictions on exposure of workers proposed by the NRPB and ICNIRP guidelines are very similar, the guidelines recommended by the ICNIRP for the public are more restrictive (usually 5 times lower) than those recommended by the NRPB. The NRPB declined to set a blanket policy and chose to recommend the lowering of limits for public exposures only when there is established scientific data to justify a more restrictive standard. The NRPB comment on the ICNIRP guidelines is:

> *NRPB does not believe that there is scientific justification for such a blanket approach and that the existing UK limits for workers and for the general public provide adequate protection. The health benefits to be obtained from further reductions in exposure are not clear." (NRPB, July 1998)*

Massachusetts Department of Public Health PAVE PAWS Review

A panel of four scientists was commissioned by the Massachusetts Department of Public Health to assess the public health implications of exposures to RF from the PAVE PAWS radar at Cape Cod. The scientists had recommended in an interim report that additional measurements of RF power densities be made in the community to delineate areas of higher and lower exposures in comparison to background levels in various environments. Such data may also help to determine the need for epidemiological studies. However, epidemiological studies require that detailed estimates of individual exposures be conducted. The scientists further stated that the "available scientific evidence is sufficient to make interim public health recommendations. . ." The conclusion reached was:

> *In our review of the available data on the biological effects of RFR* [radiofrequency radiation]*, we conclude that there is no definitive scientific evidence to claim that the anticipated low RFR levels from PAVE PAWS could cause any harmful effect to the public.* But at the same time, there is suggestive scientific evidence that RFR produces bioeffects at much lower intensities than previously known. The scientific evidence cannot answer the question conclusively whether the PAVE PAWS radar will or will not cause harmful effects to humans in the community. (Section 2)
>
> *It is the opinion of this panel than the evidence for these "low-level" (<10 microwatt/cm^2) effects does not reach a level sufficient to justify claims of any health hazard . . .in the face of scientific uncertainty and some evidence pointing to a possible problem, it is prudent to limit public exposure to PAVE PAWS RFR. . . to levels considered safe by national standards. . .* (Section 4)
>
> (Massachusetts Department of Public Health, 1999)

4.2 PROPOSED ACTION

Under the Proposed Action, the PAVE PAWS EWR soon to be at Clear AFS, Alaska (early 2001) and the existing PAVE PAWS EWRs at Beale AFB, California, and Cape Cod AFS, Massachusetts would be upgraded in support of the decision to deploy the NMD system. The following analysis compares the relevant standards (i.e., 0.28 mW/cm^2) against previously measured power densities for EWR and current estimated average power densities with the NMD addition. This comparison is used to determine how many times lower the NMD density values are than the standard.

4.2.1 HEALTH AND SAFETY

Combined PAVE PAWS EWR and NMD Mission Environment

As discussed in section 2.1, the Proposed Action, as it relates to the generation of RF, affects the type of radar coverage provided by computer software, not the power of radar or the power density of the field produced. The upgrade to the software that controls the radar system will not change the existing PAVE PAWS mission surveillance and tracking activities. The upgrade will only enhance the capability and sensitivity of tracking, identifying, and classifying multiple objects by improved methods of analyzing radar signals to improve the reception of RF signals bounced off distant objects. Therefore, the Proposed Action increases the performance of PAVE PAWS radar without increasing peak or average RF power output.

It should be noted that the 1979 EIS for the Cape Cod AFS considered the effect of increasing the number of antenna elements and transmitter power under a future "growth" option. The proposed NMD enhancements to the reception and analysis capabilities of the existing radar should be viewed as a way of achieving some of the same capability of the “growth” option without any increase in power or generated RF field.

Surveillance. The PAVE PAWS radar will perform the same surveillance activities under both existing and NMD missions.

Tracking. Like the PAVE PAWS missions, the NMD mission includes tracking of objects. In either mission, the focused tracking of objects occurs quite infrequently. The only time that the NMD mission would be active is during periodic tests and in the event a missile is launched against the United States. For NMD the longest total mission is approximately 17 minutes. The total time for NMD missions during a year would be expected to be only a few hours. The rest of the time the radars will be running existing PAVE PAWS missions.

To evaluate whether focused tracking at the site and during a NMD mission would affect average or peak RF power densities in publicly accessible areas surrounding the radar sites, simulated NMD missions were evaluated. The RF fields produced by the radars were calculated for simulated missions under worst-case scenarios, i.e., where the targets tracked are low on the horizon (lowest beam elevation) and closely clustered (relatively fixed azimuth target direction). Such scenarios are expected to produce higher time-averaged power densities in the direction of the targets being tracked because the beam positions are not changing significantly over time. Each face of the radar was assumed to be operating at the maximum 25 percent duty cycle (i.e., the radar is transmitting 25 percent of the time) over a full 30-minute surveillance and tracking mission. Because the scenarios evaluated were the same duration as the 30-minute averaging period called for by the ANSI/IEEE standard for uncontrolled environments (which is longer than an actual NMD mission, which would only have a duration of approximately 17 minutes), the results can be used to directly determine compliance with this standard.

Estimated RF Power Densities

The power required for transmission of RF radar pulses varies with surveillance and tracking requirements. Although it is recommended that an 18 percent duty cycle best reflects the long-term utilization of PAVE PAWS power resources (Department of the Air Force, 1979), the maximum available power (produced by a 25 percent duty cycle) has been assumed for generating “worst case” estimates of potential exposure over a 30-minute period except for some comparisons to calculations made in the EISs for PAVE PAWS at Beale AFB and Cape Cod AFS that assumed different surveillance and tracking resource allocations. The estimates assume that the radar is utilizing both radar faces (face A and face B) in performing surveillance activities requiring 11 percent of power resources (11 percent duty factor) and a tracking scenario requiring the remaining 14 percent of the power resource.

Appendix B contains a brief description of the analysis methodology and lists the current safety standard values.

4.2.1.1 Clear AFS—Health and Safety

The main health and safety concern from operation of the UEWR at Clear AFS in an NMD environment would be associated with RF radiation.

Tables 4-2 and 4-3 present estimated site-specific power densities at the proposed UEWR location. Figure 4-1 shows locations of the site numbers. The estimates were performed to determine if the changes in mission scenarios would change the RF radiated power densities measured and estimated previously. To evaluate potential impacts, maximum power densities estimated for UEWR operation were compared to current safety standards. Appendix B contains a brief description of the analysis methodology and lists the current safety standard values.

Table 4-2: Near-field and Transition Region Power Densities, Clear AFS

Distance from Radar (meters)	Elevation (meters)	Current Calculated 30-minute Time Average Power Density (mW/cm^2) (2)
30.4	175 (1)	0.6256
60.8	175(1)	0.2144
121.6	175 (1)	0.0516
182.9	175(1)	0.0298
304.9	*	0.0119

(1) Use a flat earth model for these points

(2) The ANSI/IEEE standard is 0.28 mW/cm^2 over 30 minutes at 420 MHz.

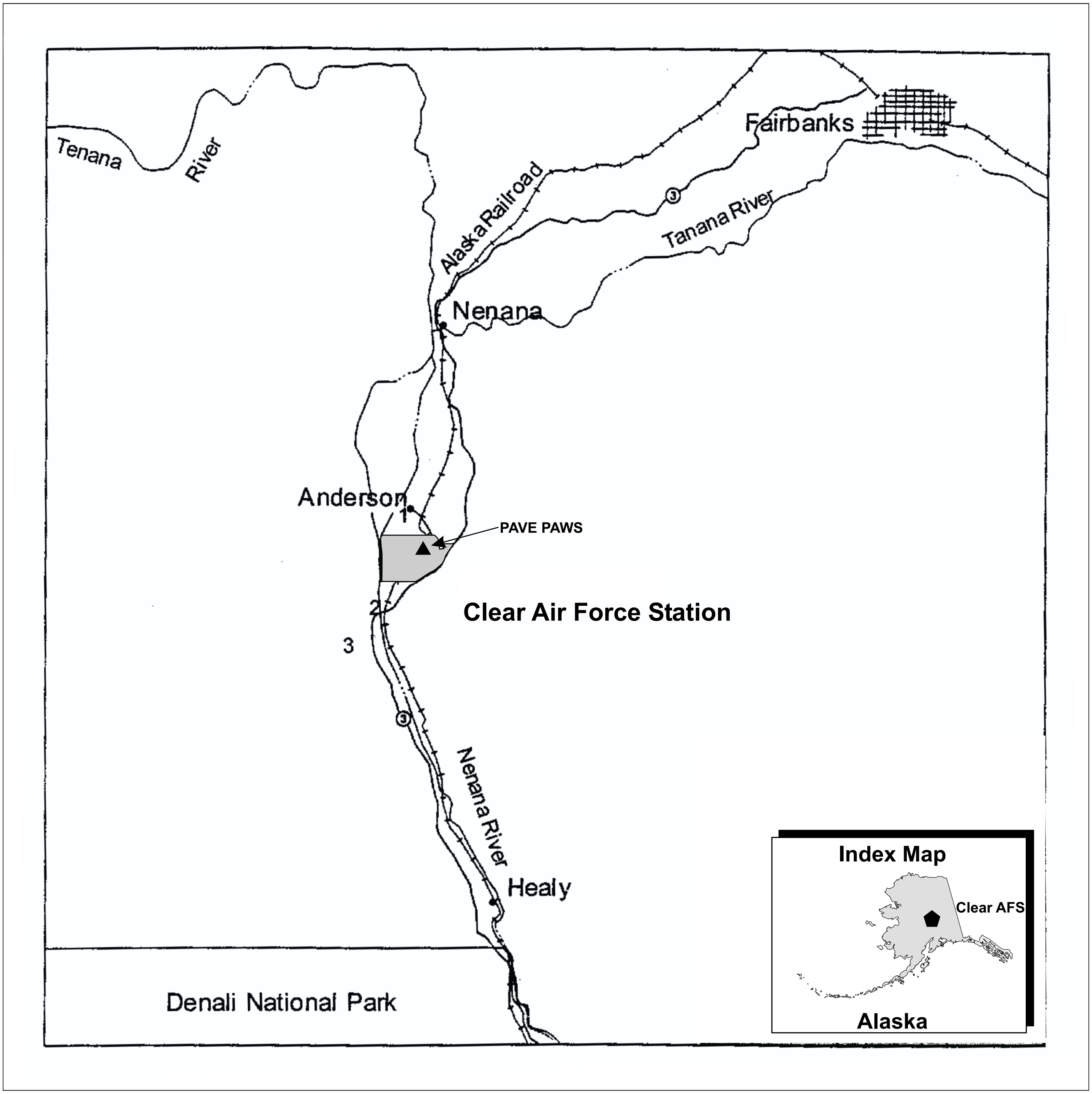
* Used worst case result

Table 4-3: Far-field Ground Level Power Densities, Clear AFS

Site Number (1)	Distance from Radar (meters)	Azimuth (degrees)	Current Calculated 30-minute Time Average Power Density (mW/cm^2) (2)
R1	439	230.9	0.00775
1	4,850	3.8	0.0000684
2	8,391	200	0.00000853
3	15,225	212	0.0000383

(1) See figure 4-1 for site locations

(2) The ANSI/IEEE standard is 0.28 mW/cm^2 over 30 minutes at 420 MHz.



EXPLANATION

- 3 State Highway
- Railroad
- River
- Town
- City
- 1 Field Measurement Site

NORTH

0 6.8 13.6 Miles

0 11 22 Kilometers

Locations for Far-Field Calculations, Clear Air Force Station

Alaska

Figure 4-1

The above estimates clearly show that the RF power density declines rapidly with distance from the radar. To further support this conclusion and to help illustrate why exposures to the public in the far field of the radar are of such low intensity, the maximum power density at 439 meters from the PAVE PAWS at ground level is shown in figure 4-2 as a function of distance from the radar. As shown in table 4-3, at the beginning of the far field, on base at 439 meters (1,140 feet) from the face of the radar, the estimated field is 0.00775 mW/cm^2. Where the public could be closest to the radar, at Anderson, Alaska, at a distance of 4,850 meters (15,912 feet), the estimated field from either face of the radar is 0.0000684 mW/cm^2.

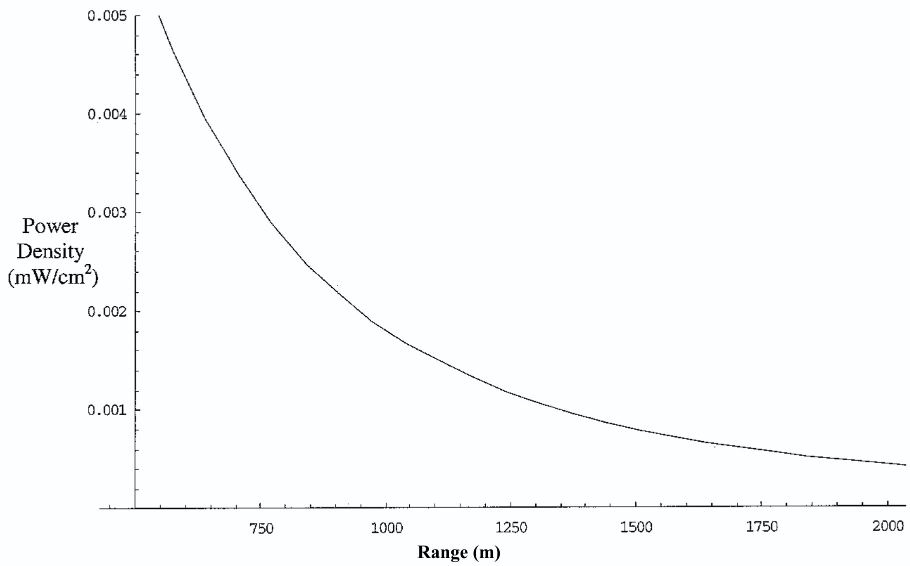
The far-field, ground-level power densities estimated for locations at maximum exposure that reflect representative NMD upgrade, search, and track scenarios would be 36 times lower than the ANSI/IEEE standard of 0.28 mW/cm^2. For Anderson, the estimated density would be 4,094 times lower than the standard. Therefore, the proposed upgrade would be in compliance with the applicable standards.

4.2.1.2 Beale AFB—Health and Safety

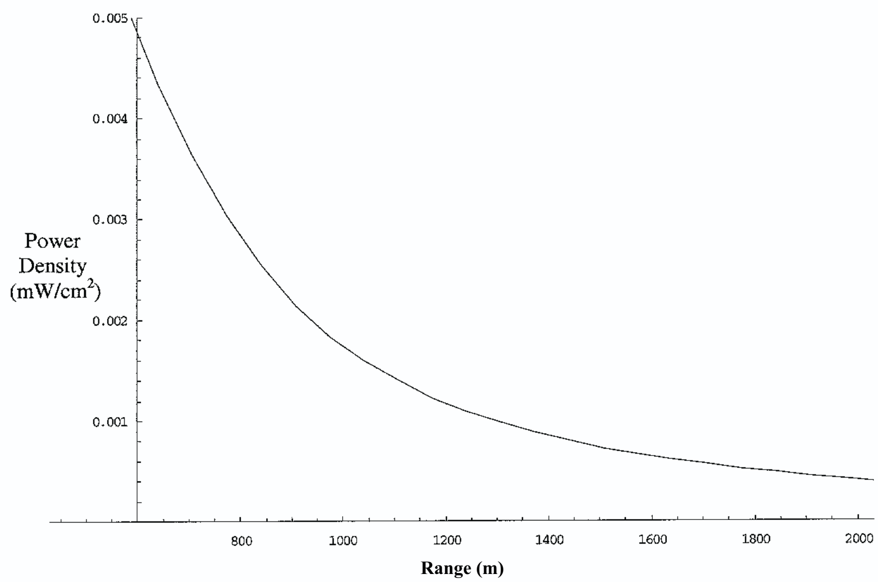
The main health and safety concern from operation of the UEWR at Beale AFB in an NMD environment would be associated with RF radiation.

Tables 4-4 through 4-6 present calculated site-specific power densities at the proposed UEWR location. Figures 3-3 and 3-4 show the locations of site numbers. The calculated values for the UEWR mission were compared to those previously calculated or measured for PAVE PAWS missions. To evaluate potential impacts, comparisons of maximum power densities calculated for UEWR operation were compared to current safety standards. Appendix B contains a brief description of the analysis methodology and lists current safety standard values.

The RF field produced by PAVE PAWS radars was assessed by new comprehensive computations of the power density produced under a variety of conditions, including those considered in the 1980 EIS for PAVE PAWS at Beale AFB. For example, the results show that the calculations made in 1979 predicted higher RF power densities than in 1999 (tables 4-5 and 4-6). The 1999 calculations predict lower exposures to RF that are closer to power densities actually measured at these same locations in 1979 (table 4-6). This suggests that the 1999 calculation model is a more accurate predictor than the 1979 model. In 1979 reasonable but very conservative assumptions were used in parts of the calculation to obtain estimated power densities. This led to higher calculated power densities than the method applied in 1999, which was able to perform much more detailed computations of model parameters due to the development of fast and more easily programmed computers.



Face A



Face B

Ground Level Power Density vs Range at 351 Degrees Azimuth (Face A), 231 Degrees Azimuth (Face B), Clear Air Force Station

Alaska

Figure 4-2

Table 4-4: 1980 EIS Near-field Calculations Compared with Current Calculations, Beale AFB

Distance from Radar (meters)	1980 Calculated Average Power Density (mW/cm^2) [(1)] [(2)]	Current Calculated 30-minute Average Power Density (mW/cm^2) [(3)] [(4)]
30.4	4.0	0.6116
60.8	0.663	0.2295
121.6	0.176	0.0565
182.9	0.0273 [(5)]	0.0287
304.8	0.015	0.0123

[(1)] The 1980 calculated average values represent time-averaged estimates, but the averaging period is not specified; therefore, the values may not be exactly comparable to the current ANSI/IEEE standard, 30-minute time average.

[(2)] Calculations assumed that one radar face operates at 25 percent duty cycle (surveillance mode 11 percent, track mode 14 percent) and the alternate face operates at 11 percent duty cycle in the surveillance mode.

[(3)] The current calculated power densities can be compared directly to the ANSI/IEEE standard of 0.28 mW/cm^2 at 420 MHz.

[(4)] The current calculations assume that both radar faces are operating with a 25 percent duty cycle. The duty cycle is divided between surveillance mode (11 percent) and track mode (14 percent).

[(5)] This calculation in the 1980 EIS has a math error that has been corrected here. Original stated value was 0.025.

Table 4-5: 1979 Far-field Calculations Compared to Current Calculations, Beale AFB

Site Number [(1)]	Distance from Radar (meters)	Azimuth (degrees)	1980 Calculated Average Power Density (mW/cm^2) [(2)] [(3)]	Current Calculated 30-minute Average Power Density [(4)] [(5)]
R1	439	NS	0.006200	0.007005
R2	1,524.0	0	0.001100	0.000625
R3	2,255.5	180	0.000280	0.000172
R4	2,438.4	270	0.000590	0.000136
R5	3,048.0	180	0.000150	0.000110
R6	6,096.0	180	0.000049	0.000039
1	2,255.5	157	0.000353	0.000173
2	3,840.5	157	0.000166	0.000107
3	2,651.8	248	0.000286	0.000137
4	6,705.6	280	0.000054	0.000025
5	3,139.4	286	0.000183	0.000106
6	6,461.8	298	0.000043	0.000029

Table 4-5: 1979 Far-field Calculations Compared to Current Calculations, Beale AFB (Continued)

Site Number [(1)]	Distance from Radar (meters)	Azimuth (degrees)	1980 Calculated Average Power Density (mW/cm^2) [(2) (3)]	Current Calculated 30-minute Average Power Density [(4) (5)]
7	6,096.0	239	0.000069	0.000033
8	2,499.4	108	0.000036	0.000022
9	19,202.4	258	0.000010	0.000004
10	21,031.2	273	0.000008	0.000001
11	1,767.8	298	0.000575	0.000367
12	2,590.8	5	0.000492	0.000430
13	1,859.3	333	0.000707	0.000246
14	3,657.6	344	0.000183	0.000056

NS = Not specified—use worst-case result

(1) See figure 3-3 for site locations.

(2) Calculations assumed that one radar face operates at 25 percent duty cycle (surveillance mode 11 percent, track mode 14 percent) and the alternate face operates at 11 percent duty cycle in the surveillance mode.

(3) The 1980 calculated average power densities represent time-averaged estimates, but the averaging period is not specified; therefore, the values may not be exactly comparable to the current ANSI/IEEE standard.

(4) Current calculations assume that both radar faces are operating with a 25 percent duty cycle. The duty cycle is divided between surveillance mode (11 percent) and track mode (14 percent).

(5) The current calculated power densities can be compared directly to the ANSI/IEEE standard of 0.28 mW/cm^2 at 420 MHz.

Table 4-6: September 11-12, 1979 PAVE PAWS Far-field Measurements Compared to 1980 and Current Calculations, Beale AFB

Site Number [(1)]	Distance from Radar (meters)	Azimuth (degrees)	1979 Measured Power Density (mW/cm^2) [(2) (3)]	1980 Calculated Average Power Density (mW/cm^2) [(2) (4)]	Current Estimated 30-minute Average Power Density (mW/cm^2) [(5) (6)]
1	2,255.5	157	0.000132	0.000418	0.000125
2	3,840.5	157	0.000047	0.000203	0.000077
3	2,651.8	248	0.000041	0.000238	0.000098
4	6,705.6	280	0.000014	0.000066	0.000018
10	21,031.2	273	B	0.000013	0.000001
11	1,767.8	298	0.000800	0.000391	0.000250
13	1,859.3	333	0.000960	0.000740	0.000190

Table 4-6: September 11-12, 1979 PAVE PAWS Far-field Measurements Compared to 1980 and Current Calculations, Beale AFB (Continued)

Site Number (1)	Distance from Radar (meters)	Azimuth (degrees)	1979 Measured Power Density (mW/cm^2) (2) (3)	1980 Calculated Average Power Density (mW/cm^2) (2) (4)	Current Estimated 30-minute Average Power Density (mW/cm^2) (5) (6)
14	3,657.6	344	0.000013	0.000224	0.000043
16	990.6	130	0.002520	0.002610	0.002190
19	16,306.8	267	B	0.000022	0.000001
21	15,758.2	211	B	0.000012	0.000004
22	15,758.2	311	B	0.000012	0.000006
23	14,478.0	226	B	0.000014	0.000003
24	1,554.5	22	0.000133	0.000085	0.000053

B = Below reportable levels (less than 0.000001 mW/cm^2)

(1) See figure 3-4 for site locations.

(2) Both measurements and calculations pertain to an enhanced surveillance mode in which each face operates at 18 percent duty cycle in the surveillance mode with no resources allocated to tracking.

(3) The 1979 measured power densities represent the maximum intensity reading measured; therefore, the values may not be exactly comparable to the current 30-minute time average ANSI/IEEE standard.

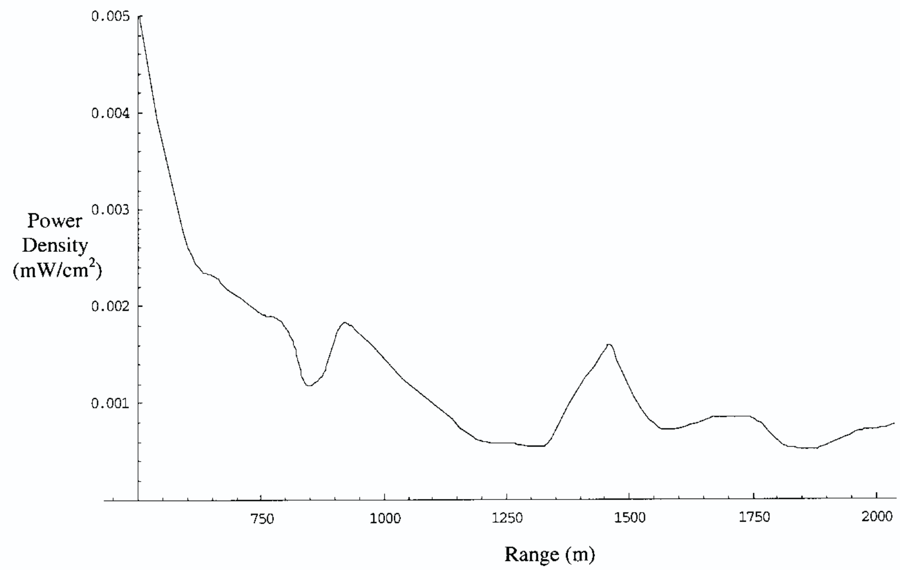
(4) The 1980 calculated average power densities also represent time-averaged estimates, but the averaging period is not specified; therefore, the values may not be exactly comparable to the current ANSI/IEEE standard.

(5) The current calculations assume that both radar faces are operating with a 25 percent duty cycle. The duty cycle is divided between surveillance mode (11 percent) and track mode (14 percent).

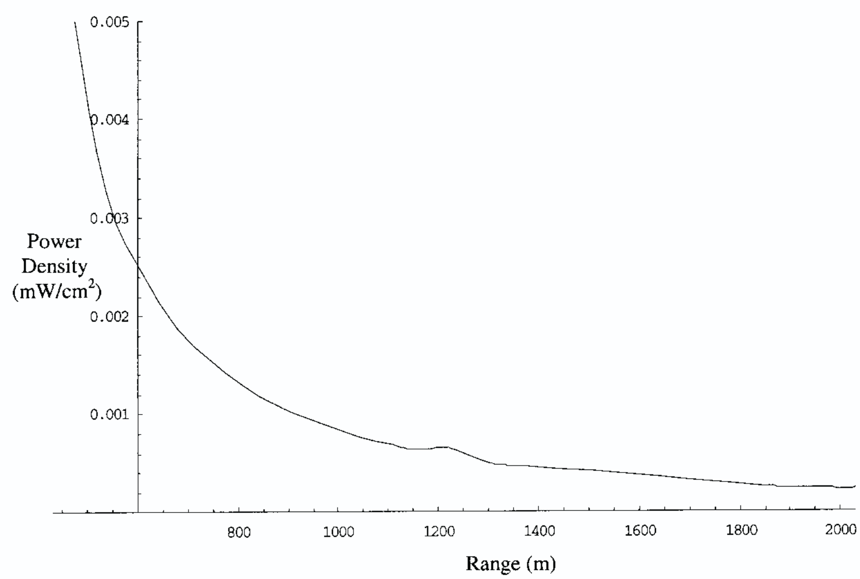
(6) The current calculated power densities can be compared directly to the ANSI/IEEE standard of 0.28 mW/cm^2 at 420 MHz.

The above calculations and measurements clearly show that the RF power density declines rapidly with distance from the radar. To further support this conclusion and to help illustrate why exposures to the public in the far field of the radar are of such low intensity, the maximum power density at 439 meters (1,440 feet) from the PAVE PAWS is shown in figure 4-3 as a function of distance from the radar. Where the public could be closest to the radar (table 3-3, site 13, off-base hilltop northwest of the radar), at a distance of 1,859.3 meters (about 6,100 feet) along this profile, the calculated field from either face of the radar is approximately 0.000707 mW/cm^2.

The far-field, ground-level power densities calculated for locations at maximum exposure that reflect representative NMD upgrade, search, and track scenarios would be 396 times lower than the ANSI/IEEE standard of 0.28 mW/cm^2. Therefore, the proposed upgrade would be in compliance with the applicable standards.



Face A



Face B

Ground Level Power Density vs Range at 323 Degrees Azimuth (Face A), 168 Degrees Azimuth (Face B), Beale Air Force Base

California

Figure 4-3

4.2.1.3 Cape Cod AFS—Health and Safety

The main health and safety concern from operation of the UEWR at Cape Cod AFS in an NMD environment has focused on potential effects of the RF.

Tables 4-7 through 4-9 present calculated site-specific power densities at the proposed UEWR location. Figures 3-6 and 3-7 shows the location of site numbers. The calculated values for the UEWR mission were compared to those previously calculated or measured for PAVE PAWS missions. To evaluate potential impacts, comparisons of maximum power densities calculated for UEWR operation were compared to current safety standards.

Table 4-7: 1979 Near-field Calculations Compared with Current Calculations, Cape Cod AFS

Distance from Radar (meters)	1979 Calculated Average Power Density (mW/cm^2) (1) (2)	Current Calculated 30-minute Average Power Density (mW/cm^2) (3) (4)
30.4	4.0	0.5807
60.8	0.663	0.2149
121.6	0.176	0.0551
182.9	0.0273 (5)	0.0297
304.8	0.015	0.0120

(1) Calculations assumed that one radar face operates at 25 percent duty cycle (surveillance mode 11 percent, track mode 14 percent) and the alternate face operates at 11 percent duty cycle in the surveillance mode.

(2) The 1979 calculated average power densities also represent time-averaged estimates, but the averaging period is not specified; therefore, the values may not be exactly comparable to the current 30-minute time average ANSI/IEEE standard.

(3) Current calculations assume that both radar faces are operating with a 25 percent duty cycle. The duty cycle is divided between surveillance mode (11 percent) and track mode (14 percent).

(4) The current calculated power densities can be compared directly to the ANSI/IEEE standard of 0.28 mW/cm^2 at 420 MHz.

(5) This calculation in the 1979 EIS has a math error that has been corrected here. Original stated value was 0.025.

Table 4-8: 1979 Far-field Calculations Compared to Current Calculations, Cape Cod AFS

Site Number [1]	Distance from Radar (meters)	Azimuth (degrees) Estimated [2]	1979 Calculated Average Power Density (mW/cm^2) [3] [4]	Current Calculated 30-minute Average Power Density [5] [6]
Beginning of far-field	439	NS	0.0062	0.006640
1	667.5	212	0.0025	0.001049
2	819.9	2	0.0017	0.000731
3	880.9	340	0.0015	0.000283
4	1,051.6	37	0.0010	0.000786
5	1,274.1	7	0.0007	0.000525
6	1,719.1	94	0.00055	0.000241
7	1,585.0	76	0.00066	0.000254
8	1,639.8	44	0.00048	0.000344
9	1,883.7	68.5	0.00032	0.000306
10	1,945.0	57	0.0003	0.000226
11	2,004.0	81	0.00042	0.000189
12	2,551.2	87	0.00024	0.000148
13	1,762.0	349	0.00036	0.000139
14	2,851.7	353	0.00037	0.000205
15	2,883.4	15	0.00014	0.000088
16	4,718.3	225	0.00011	0.000039
17	5,405.0	206	0.000084	0.000010
18	4,858.5	119	0.00015	0.000079
19	7,772.4	179	0.000041	0.000024
20	8,991.6	196	0.000031	0.000020
21	7,955.3	215	0.000039	0.000021
22	11,125.2	197	0.000020	0.000008

NS = Not specified—use worst-case result

(1) See figure 3-6 for site locations.

(2) Azimuth data was not reported in the 1979 EIS for Cape Cod. Data has been extrapolated from figure 3-6.

(3) Calculations assumed that one radar face operates at 25 percent duty cycle (surveillance mode 11 percent, track mode 14 percent) and the alternate face operates at 11 percent duty cycle in the surveillance mode.

(4) The 1979 calculated average power densities also represent time-averaged estimates, but the averaging period is not specified; therefore, the values may not be exactly comparable to the current ANSI/IEEE standard.

(5) Current calculations assume that both radar faces are operating with a 25 percent duty cycle. The duty cycle is divided between surveillance mode (11 percent) and track mode (14 percent).

(6) The current calculated power densities can be compared directly to the ANSI/IEEE standard of 0.28 mW/cm^2 at 420 MHz.

Table 4-9: October 20-21, 1978 Far-field Measurements Compared to 1979 and Current Calculations, Cape Cod AFS

Site Number [1]	Distance from Radar (meters)	Azimuth (degrees) Estimated [2]	1978 Measured Power Density (mW/cm^2) [3] [4]	1979 Estimated Average Power Density (mW/cm^2) [3] [5]	Current Estimated 30-minute Average Power Density (mW/cm^2) [6] [7]
1	1,078	63	0.000061	0.00079	0.0007387
2	3,380	107	0.000027	0.00015	0.0001179
3	3,637	80	B	0.00013	0.0000541
4	3,798	63	0.00002	0.00012	0.0000755
5	6,791	107	0.000001	0.00005	0.0000106
6	7,210	121.5	B	0.00005	0.0000152
7	8,755	174	B	0.00004	0.0000115
8	12,553	163	B	0.00002	0.0000080
9	15,980	167	B	0.00001	0.0000079
10	24,140	167	B	0.000005	0.0000035
11	2,607	357	0.000051	0.00037	0.0001072
12	3,508	348	0.000016	0.00014	0.0000465
13	2,881	24	0.000001	0.00011	0.0000944
14	4,474	12	0.000002	0.00019	0.0000363
15	1,674	24	0.000003	0.00033	0.0002629
16	2,350	12	B	0.00016	0.0000808
17	12,392	198.5	B	0.000021	0.0000052
18	15,128	181	B	0.000014	0.0000046
19	15,611	205	B	0.000013	0.0000015
20	15,933	208	B	0.000013	0.0000030
21	20,921	197	B	0.000007	0.0000019

B = Below reportable levels (less than 0.000001 mW/cm^2)

(1) See figure 3-7 for site locations.

(2) Azimuth data was not reported in the 1979 EIS for Cape Cod. Data has been extrapolated from figure 3-7.

(3) Both measurements and calculations pertain to operation in an enhanced surveillance mode in which each face operated 18 percent duty cycle in the surveillance mode with no resources allocated to tracking.

(4) The 1978 measured power densities represent the maximum intensities measured; therefore, the values may not be exactly comparable to the current 30-minute time average ANSI/IEEE standard.

(5) The 1979 calculated average power densities represent time-averaged estimates, but the averaging period is not specified; therefore, the values may not be exactly comparable to the current ANSI/IEEE standard.

(6) The current calculations assume that both radar faces are operating with a 25 percent duty cycle. The duty cycle is divided between surveillance mode (11 percent) and track mode (14 percent).

(7) The current calculated power densities can be compared directly to the ANSI/IEEE standard of 0.28 mW/cm^2 at 420 MHz.

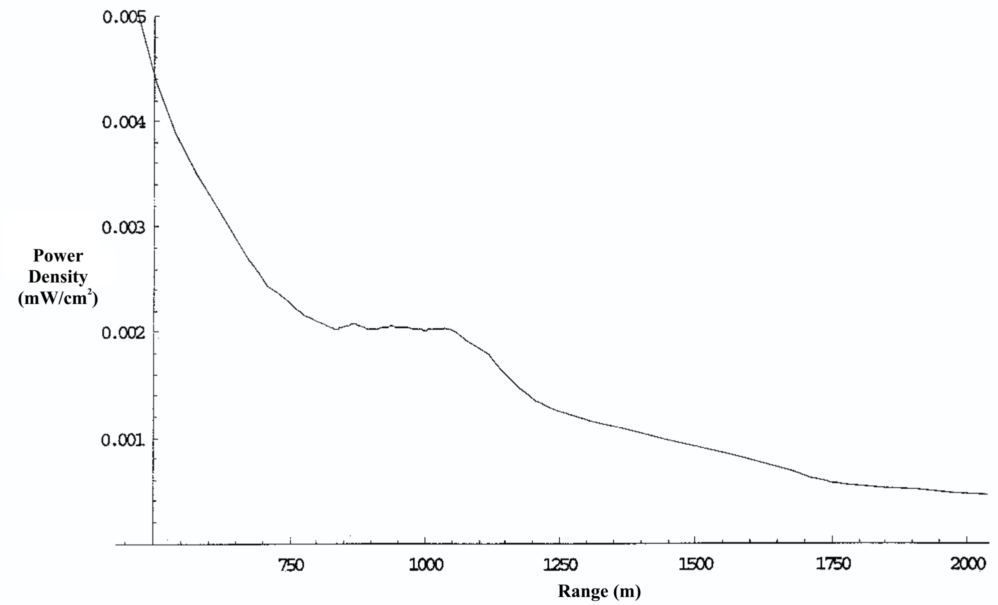
The RF field produced by PAVE PAWS radars was assessed by new comprehensive computations of the power density produced under a variety of conditions, including those considered in the 1979 EIS for PAVE PAWS at Cape Cod AFS. For example, the results show that the calculations made in 1979 predicted higher RF power densities than in 1999 (tables 4-8 and 4-9). The 1999 calculations predict lower exposures to RF that are closer to power densities actually measured at these same locations in 1979 (table 4-8). This suggests that the 1999 calculation model is a more accurate predictor than the 1979 model. In 1979 reasonable but very conservative assumptions were used in parts of the calculation to obtain estimated power densities. This led to higher calculated power densities than the method applied in 1999, which was able to perform much more detailed computations of model parameters due to the development of fast and more easily programmed computers.

The above calculations and measurements clearly show that the RF power density declines rapidly with distance from the radar. To further support this conclusion and to help illustrate why exposures to the public in the far field of the radar are of such low intensity, the power density from the PAVE PAWS is shown in figure 4-4 as a function of distance from the radar. The slight halt in the otherwise smoothly descending power density curve on face A reflects an increased ground elevation at this site between about 800 to 1,200 meters from the radar, which slightly increases predicted values. The power density profile for face A was selected to illustrate the effect of ground elevation. For face B, the profile shown was selected because it included the maximum calculated average power density at 439 meters, the beginning of the far field region. One of the places where the public could be closest to the radar off base on Highway 6, at a distance of 1,051.6 meters (about 3,450 feet), the calculated field from face A of the radar is 0.000786 mW/cm^2.

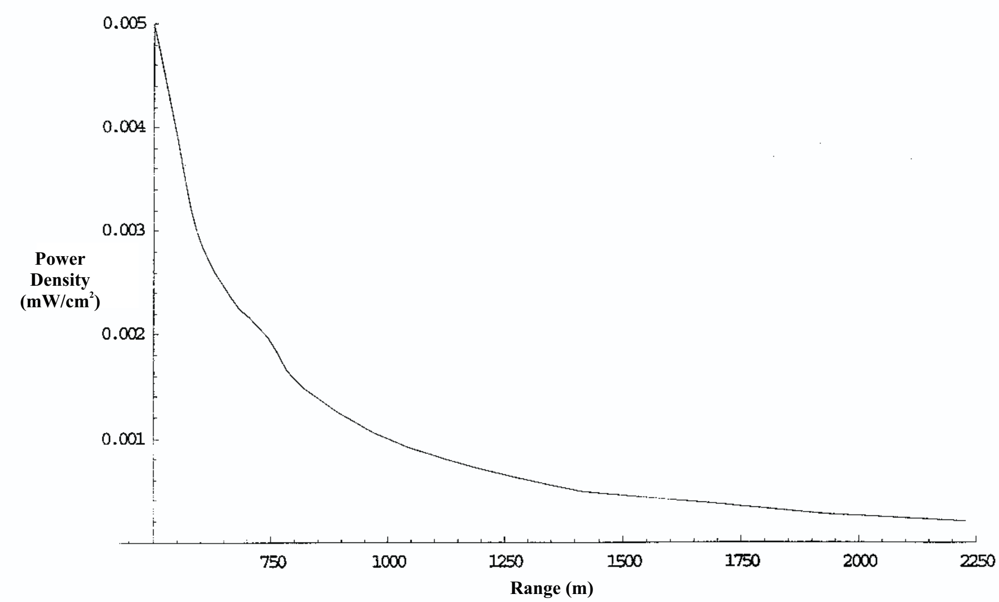
The far-field, ground-level power densities calculated for locations at maximum exposure that reflect representative NMD upgrade, search, and track scenarios would be 356 times lower than the ANSI/IEEE standard of 0.28 mW/cm^2. Therefore, the proposed upgrade would be in compliance with the applicable standards.

4.2.1.4 Summary of Health and Safety Analysis

The purpose of an EIS is to identify what changes will occur in the existing environment, and to assess the health impact of such changes, if any, by comparison to assessment criteria. For this Proposed Action, human exposure was estimated by calculations of the highest possible RF power density that could be produced at ground level by the radar in publicly accessible areas. These calculations included assumptions about the operation of the radar to calculate the maximum exposure potential, the “worst case analysis.” The results of these calculations were compared to the most applicable criteria, in this case the ANSI/IEEE (1992) standard.



Face A



Face B

Ground Level Power Density vs Range at 167 Degrees Azimuth (Face A), 64 Degrees Azimuth (Face B), Cape Cod Air Force Station

Massachusetts

Figure 4-4

The current estimates of RF power density are in good agreement with previous calculations and measurements at the same locations from the radars. Section 4.2.1 describes relevant standards, discusses recent research studies relating to potential effects of long-term exposures, and provides an overview of the conclusions reached by independent scientific and governmental organizations.

The following paragraphs summarize selected topics related to potential RF effects on human health and safety and their respective conclusions reached in this analysis.

RF Levels in the Surrounding Human Environment

The upgrade will not change the RF levels in the surrounding human environment from existing levels. The upgrade does not involve changes to the physical facilities that could increase the power or the proportion of time that the radar is operating in each duty cycle.

Both PAVE PAWS and NMD missions involve surveillance and tracking activities. The anticipated time spent on tracking for NMD missions during a year would not be greatly different from similar tracking activities performed periodically under the PAVE PAWS missions. Over a 30-minute averaging period, as called for in the ANSI/IEEE 1992 standard, the public exposures associated with varying proportions of these activities will be similar.

An evaluation of specific search and tracking scenarios performed under a simulated NMD mission indicated that the proposed change would not cause any of the radar sites to produce exposures to the general public that are greater than those estimated in the 1979 and 1980 PAVE PAWS EISs.

Compliance of RF Levels in the Public Environment with Relevant and Applicable Standards

These levels will be well below the recommended exposure limits. Based on the 1999 calculations, exposures to the general public will not exceed exposure limits recommended by ANSI/IEEE, the State of Massachusetts, or other organizations. In Massachusetts, the RF Exposure Limits in 105 CMR-485 are applicable; the exposure limits for the general public for this facility are the same as the ANSI/IEEE standard for time-averaged power density, 0.28 mW/cm^2. The ANSI/IEEE standard MPE limits for any single RF pulse and for the maximum power density in any 100 ms period, 6,300 mW/cm^2 and 100.8 mW/cm^2, are calculated in appendix B.

Table 4-10 shows that the Proposed Action is well below the applicable standard even when comparing the maximum estimated time-averaged power density level in public areas.

Table 4-10: Far-Field Ground Level Power Densities Calculated for Specified Locations and Compared to the ANSI/IEEE Standard

PAVE PAWS Site	Distance from Radar meters (feet)	Maximum Calculated 30-minute Time Average Power Density (mW/cm^2) [3]	Comparison to ANSI/IEEE Standard (0.28 mW/cm^2)	Maximum Peak Power Density per Pulse (mW/cm^2) [4]	Comparison to ANSI/IEEE Standard (6,300 mW/cm^2)	Maximum Peak Power Density per 100 ms (mW/cm^2) [4]	Comparison to ANSI/IEEE Standard (100.8 mW/cm^2)
Clear AFS	439 (1,440) [1]	0.00775 (table 4-3)	36 times lower	0.1664	37,861 times lower	0.0533	1,891 times lower
	4,850 (15,912) [2]	0.0000684 (table 4-3)	4,094 times lower	0.0069	913,043 times lower	0.0022	45,818 times lower
Beale AFB	439 (1,440) [1]	0.007005 (table 4-5)	40 times lower	0.1574	40,025 times lower	0.0504	2,000 times lower
	1,859.3 (6,100) [2]	0.000246 (table 4-5)	1,138 times lower	0.0638	98,746 times lower	0.0204	4,941 times lower
Cape Cod AFS	439 (1,440) [1]	0.006640 (table 4-8)	42 times lower	0.1606	39,228 times lower	0.0514	1,961 times lower
	1,051.6 (3,450) [2]	0.000786 (table 4-8)	356 times lower	0.0226	278,761 times lower	0.0072	14,000 times lower

(1) On-base—beginning of far field exposures

(2) One of nearest locations with likely opportunity for public exposure

(3) The current calculations assume that both radar faces are operating with a 25 percent duty cycle. The duty cycle is divided between surveillance mode (11 percent) and track mode (14 percent). Maximum exposure reflects representative NMD upgrade, search, and track scenarios.

(4) The current calculations assume that the radar is operating with a maximum pulse width of 16 ms.

Average RF power density values in the surrounding environment of the EWRs will be at least 36 times lower than the limit of the standard on time-averaged power density. However, these data apply to the worst-case scenario, i.e., for the highest of the higher sidelobe emissions, and close to the radar's exclusion fence. RF energy from any source decreases with distance from the source. For most public areas around these EWRs, the levels are lower by a factor of 100 or more. For this reason, RF energy at ground level beyond Clear AFS, for example, is estimated to be 4,094 times lower than the standard. Limits specifically recommended by ANSI/IEEE for peak intensity of RF pulses would not be exceeded either. The peak intensity of RF pulses is not affected by the NMD mission. Furthermore, neither the existing or proposed operating conditions would cause the exposures to the public to even remotely approach the ANSI/IEEE secondary criteria for limiting peak power intensities. Thus, the inclusion of the NMD mission in the activities of the PAVE PAWS radar would not be expected to produce any significant change in either the time-averaged or peak RF levels in the surrounding environment.

Consideration of the Research Reporting Effects Below the Threshold for Body Heating

The ANSI/IEEE standard considered all of the research that was available for review, usually published in the literature, regarding any and all reported effects. On the basis of this review and evaluation, the Rationale section of the ANSI/IEEE 1992 standard concluded that no reliable scientific data were found to indicate that exposure to electromagnetic fields produces cumulative damage, and that "no reliable scientific data demonstrate that non-thermal (other than shock) or modulation-specific sequella of exposure may be meaningfully related to human health."

Relevant Research to Assess Potential Health Impacts from Long-term Exposures to RF

Although few studies of long-term, low-level effects were available during the time of the literature review for the ANSI/IEEE 1992 standard, several studies have been published subsequently. With the exception of a study of transgenic mice (Repacholi et al, 1997), long-term studies do not show evidence of changes in normal behavior, adverse effects on clinical measures, or changes in body weight or longevity. Histopathology examination of body tissues shows no evidence of cancerous or non-cancerous lesions, or decreased survival time attributable to the RF exposure (Chou et al, 1992; Frei et al 1998a,b; Toler et al, 1998). Overall, the results of studies of rodents routinely used to assess effects on human health do not suggest adverse effects from long-term (nearly lifespan) exposures at low levels.

In conclusion, the upgrade will not change the RF levels in the existing environment. Potential exposure in areas accessible to the general public will be many times below the exposure limits recommended by relevant standards. Additional and relevant information is available from research completed after the literature review that supported the standard; in particular, long-term studies in animal models do not provide evidence of long-term effects from low-level exposures. The calculations in table 4-10 indicate the RF emissions resulting from the proposed modifications would be well below the current safety standards at all three UEWR locations. The Proposed Action presents no change to the impacts analyzed in the previous environmental analyses.

4.2.1.5 Cumulative Impacts

No other projects, in the frequency range between 420 and 450 MHz, have been identified that could contribute to cumulative health and safety impacts at the locations proposed for use by the NMD program. The Air Force has proposed a modernization, maintenance, and sustainment project that would only sustain (not change) current operations. Therefore, there would not be any cumulative impact above what has been previously analyzed.

4.2.1.6 Mitigation Measures

No mitigation measures would be required.

4.2.2 CULTURAL RESOURCES

4.2.2.1 Clear AFS—Cultural Resources

No impacts to cultural resources at Clear AFS are expected since no cultural sites have been identified.

4.2.2.2 Beale AFB—Cultural Resources

Preparation of HABS/HAER documentation or other mitigations suggested by the California SHPO as part of the programmatic agreement with Beale AFB would be implemented.

4.2.2.3 Cape Cod AFS—Cultural Resources

As mentioned in section 3.3.3.1, HABS/HAER documentation has already been provided to the Massachusetts SHPO, and this would satisfy the regulatory requirements for potential mitigations due to upgrade of the PAVE PAWS radar.

4.2.2.4 Summary of Cultural Resources Analysis

Current and proposed HABS/HAER documentation for upgrades of the EWRs at the proposed locations would satisfy the regulatory requirements of each state.

4.2.2.5 Cumulative Impacts

No other projects that could contribute to cumulative cultural resources impacts have been identified at the locations proposed for use by the NMD program.

4.2.2.6 Mitigation Measures

No other mitigation measures would be required.

4.3 NO-ACTION ALTERNATIVE

The current emissions of the radars as described in chapter 3.0 will not change. The power densities estimated previous environmental analyses as shown in tables 3-1 through 3-4 will remain the same. Even though the standards for human exposure to RF have become more stringent in the last 20 years (Hammett, 1997), the general public's exposure from the PAVE PAWS radars remains far lower than the current state and Federal safety standards. In addition, as stated in section 4.1.1, no reliable scientific data have been found to indicate that exposure to electromagnetic fields produces cumulative damage. The No-action Alternative presents no change to the impacts analyzed in previous NEPA documentation for each EWR.

4.4 UNAVOIDABLE ADVERSE ENVIRONMENTAL EFFECTS

No unavoidable adverse environmental effects are expected.

4.5 RELATIONSHIP BETWEEN LOCAL SHORT-TERM USE OF THE ENVIRONMENT AND THE MAINTENANCE AND ENHANCEMENT OF LONG-TERM PRODUCTIVITY

All UEWR modification activities would occur on existing military facilities that are dedicated to supporting the DOD. No impacts to the long-term productivity of the environment would be anticipated.

4.6 IRREVERSIBLE AND IRRETRIEVABLE COMMITMENT OF RESOURCES FROM IMPLEMENTATION OF THE PROPOSED ACTION

Under the No-action Alternative and the Proposed Action, there would be the use of irretrievable resources (e.g., fuel, labor). Proposed activities would not result in the change of any existing land uses and would not irreversibly curtail the range of potential uses of the environment.

4.7 COMPATIBILITY OF THE PROPOSED ACTION AND NO-ACTION ALTERNATIVE WITH THE OBJECTIVES OF FEDERAL, REGIONAL, STATE, AND LOCAL LAND USE PLANS, POLICIES AND CONTROLS

After review of the documentation, neither the No-action Alternative nor the Proposed Action conflicts with any land use plans, policies, or controls.

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5.0 CONSULTATION AND COORDINATION

The Federal, state, local, and private agencies/organizations that were contacted during the preparation of the NMD Deployment Draft EIS and this supplement are listed below.

FEDERAL AGENCIES

Advisory Council on Historic Preservation

Ballistic Missile Defense Organization

U.S. Army Corps of Engineers

U.S. Coast Guard

U.S. Department of the Air Force

U.S. Department of the Army

U.S. Department of the Navy

U.S. Environmental Protection Agency

U.S. Representative Wally Herger, California

U.S. Representative Bill Delahunt, Massachusetts

U.S. Senator Frank H. Murkowski, Alaska

U.S. Senator Ted Stevens, Alaska

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U.S. Senator Barbara Boxer, California

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Denali Borough

North Star Borough

California

City of Auburn

City of Marysville

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Bourne Board of Health

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Sandwich Board of Health

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Wareham Board of Health

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Director of Community Services

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APPENDIX A1—GLOSSARY OF TERMS

Amplitude—the maximum value of a radiofrequency field

Assay—term referring to a laboratory test that has been evaluated for its capability to predict specific diseases or injury to specific organs

Athermal—any effect of electromagnetic energy absorption not associated wit ha measurable rise in temperature. Synonymous with non-thermal

Controlled Environment—areas that may be occupied by personnel who accept potential exposure to radiation as a contingency of employment or duties, by individuals who knowingly enter areas where such levels of radiation are to be expected, and by personnel passing through such areas

Decibel— Decibel (dB)—a unit of measurement on a logarithmic scale which describes the magnitude of a particular quantity of sound pressure or power with respect to a standard reference value; the accepted standard unit for the measurement of sound

Dosimetry—the way in which external exposures relate to internal body exposures or “doses”

Duty Factor—the ratio of pulse duration to the pulse period of a periodic pulse train; a duty factor of 1.0 corresponds to continuous operations

Epidemiology—the scientific method of drawing inferences about the causes of disease by studying the exposures and other characteristics of human populations

Gain (of an antenna)—a ratio, expressed in decibels, of the action of an antenna increasing the strength of a signal

Genotoxicity—referring to damage to the genetic material of cells, i.e., chromosomes and/or the DNA molecules that make up chromosomes

Histopathology—a branch of pathology concerned with analyzing an interpreting the tissue changes characteristic of disease by microscopic or biochemical methods

Immunologic—pertaining to cells and proteins that protect the body against potentially harmful organisms, e.g., bacteria, viruses or substances and foreign organisms and the control of cancer

In vivo—study of biological processes occurring in an intact, living organism

In vitro—study of biological processes in cells or components of cells isolated from an intact organism

Ionizing radiation—radiation with sufficient energy to produce ions in matter and break chemical bonds, as contrasted to non-ionizing radiation, like radiofrequency fields, that lack the energy to break chemical bonds

Lymphoma—a solid tumor of lymphocytes, e.g., in the lymph nodes, thymus or spleen

Micronuclei—chromosomes or fragments of chromosomes that separate from the nuclei of daughter cells during cell division. An increase in the frequency of micronuclei is widely used as an indicator of genetic damage to cells

Morphology—the form and structure of cells and tissues

Mutagenic—having the ability to cause changes in the structure of the genetic material of cells, i.e., the DNA of a cell's chromosomes

Neoplastic—characteristics and behavior of cells reflecting a progressive, abnormal multiplication of cells as is observed in tumors

Non-ionizing radiation—radiation, such as radiofrequency fields, that does not have sufficient energy to produce ions in matter or break chemical bonds

Non-thermal—see athermal; refers to exposures that do not produce heating of tissue

Radiological—pertaining to sciences dealing with radioactive substances and radiant energy as well as with the diagnosis and treatment of disease by means of both ionizing (e.g., x-rays) and nonionizing (e.g., ultrasound, radiofrequency) energy

Sequella—effects that occur after, or as a result of, an exposure

Sidelobe—the radiofrequency field present outside the main beam of a radar. By convention, sidelobes are numbered; higher numbered sidelobes contain progressively smaller fractions of the energy of the main radar beam

Specific Absorption Rate—the time rate at which radio frequency energy is absorbed per unit mass of material, usually measured in watts per kilogram (W/kg)

Spontaneous T-cell lymphoblastic lymphoma—a tumor caused by the abnormal proliferation of T-type lymphocytes

Subsistence—refers to human populations whose major food sources are derived from the natural environment by hunting, fishing, or by gathering of wild plants

Transgenic—refers to cells or animals in which a specific gene(s) has been introduced. One use for transgenic cells and animals is in learning the roles of a specific gene and how it may be involved in the development of tumors

Tumorigenesis—the biological processes that cause tumors

Uncontrolled Environment—areas where personnel would not expect to encounter higher levels of radiation such as living quarters, workplaces, and public access areas

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APPENDIX A2–ACRONYMS/ABBREVIATIONS

AFB	Air Force Base
AFOSH	Air Force Office of Safety and Health
AFS	Air Force Station
ANSI	American National Standards Institute
BMC2	Battle Management, Command and Control
BMC3	Battle Management, Command, Control, and Communications
CFR	Code of Federal Regulations
dB	decibel(s)
DOD	Department of Defense
EIS	Environmental Impact Statement
EMF	Electromagnetic Field
EWR	Early Warning Radar
FCC	Federal Communications Commission
GBI	Ground-Based Interceptor
HABS/HAER	Historic American Building Survey/Historic American Engineering Report
ICNIRP	International Commission on Non-Ionizing Radiation Protection
IEEE	Institute of Electrical and Electronics Engineers
IFICS	In-Flight Interceptor Communications System
IRPA	International Radiation Protection Association
kW	kilowatt(s)
MHz	megahertz
MPE	Maximum Permissible Exposure
ms	Millisecond

mW/cm^2	milliwatts per square centimeter
mW/kg	milliwatts per kilogram
NEPA	National Environmental Protection Act
NMD	National Missile Defense
NRPB	National Radiological Protection Board
OSHA	Occupational Safety and Health Administration
PAWS	Phased Array Warning System
RF	radiofrequency
RFR	radiofrequency radiation
SAR	Specific Absorption Rate
SBIRS	Space-Based Infrared System
SHPO	State Historic Preservation Officer
U.S. EPA	United States Environmental Protection Agency
UEWR	Upgraded Early Warning Radar
W/cm^2	watts per square centimeter
W/kg	watts per kilogram
XBR	X-Band Radar

APPENDIX B
CALCULATIONS OF RF FIELDS FROM PAVE PAWS/UEWR RADARS

B1.1 ANALYSIS METHODOLOGY

This section describes the methodology taken to determine if the proposed changes in mission scenarios will change the PAVE PAWS RF radiated power densities. It also compares these new estimates with current guidelines for exposure to RF by personnel.

For the PAVE PAWS system, the boundaries between the field regions are determined by assuming the antenna is a circular aperture and using the diameter of active elements for the antenna dimension. Taking the wavelength at the center of the operating bandwidth, one obtains the field region boundaries in table B-1.

Table B-1: Field Region Boundaries for PAVE PAWS

λ	@ 435 MHz = 0.69 meters
Near-Field Extent	0-183 meters (600 feet)
Transition Zone	183-439 meters (600-1,440 feet)
Far-Field Begins	439 meters (1,440 feet)

Power Density Calculations

Power density calculations were performed using conservative assumptions and 'worst case' mission scenarios. A composite sum of radiated fields was constructed from a search fence and track beams. The track beam positions were generated from analysis of mission simulations. In general, the worst case coverage was selected from cases exhibiting beam clustering at low elevation angles, and with small azimuthal spread.

Coverage Analysis

For the various mission scenarios, the beam scans in both azimuth and elevation over the course of the mission were analyzed while simultaneously performing a search fence. As observed on the ground, scenarios exhibiting beam positions with the lowest elevation angles and the narrowest azimuth distribution will produce the highest power density result.

B1.2 MAXIMUM PERMISSIBLE EXPOSURE LIMITS

The Maximum Permissible Exposure (MPE) limits were based on the ANSI/IEEE 1992 standard. The goal of the standard is to define:

> *The RMS and peak electric and magnetic field strengths, their squares, or the plane-wave equivalent power densities associated with these fields and the induced and contact currents to which a person may be exposed without harmful effect and with an acceptable safety factor (ANSI/IEEE 1992).*

MPEs are developed for two environments:

1. *Controlled Environments – Location(s) where there is exposure that may be incurred by persons who are aware of the potential for exposure as a concomitant of employment, by other cognizant persons ...* (ANSI/IEEE 1992).

2. *Uncontrolled Environments – Location(s) where there is the exposure of individuals who have no knowledge or control of their exposure.* (ANSI/IEEE 1992)

For the general public, the MPEs for uncontrolled environments are used in this report.

ANSI/IEEE 1992 MPE Limits

For the purposes of this report, the MPEs suggested in the IEEE document for uncontrolled environments are used as impact criteria.

Calculation of MPE Limits for PAVE PAWS and UEWR Radars

The MPEs for PAVE PAWS and UEWR are found in Section 4.1.2 of the reference ANSI/IEEE 1992 standard, "MPE in uncontrolled environments." This section describes the limits for RF exposure permitted in an uncontrolled environment, i.e. for the general population.

Table 2 of (ANSI/IEEE 1992) gives the MPE for uncontrolled environments as:

MPE = f/1,500 mW/cm^2, where "f" is the frequency in MHz.

Taking the lowest UEWR operating frequency of 420 MHz (which will result in the lowest MPE), this becomes:

$$MPE = 420/1{,}500 \ (mW/cm^2), \text{ or } 0.28 \ mW/cm^2$$

The limit calculated above is for steady state (continuous) irradiation. Additional rules must be met for pulsed RF. Subparagraph "g" of this section discusses the exposure to pulsed radio frequency fields: Excerpt from the reference ANSI/IEEE 1992 standard, Section 4.1.2 (g):):

> *"For exposure to pulsed radio frequency fields of pulse durations less than 100 ms, and frequencies in the range of 0.1 to 300 000 MHz, the MPE, in terms of peak power density for a single pulse, is given by the MPE (Table 2, E-field equivalent power density), multiplied by the averaging time in seconds, and divided by 5 times the pulse width in seconds. That is*
>
> *peak MPE = MPE x Avg Time (seconds) / [5 x Pulsewidth (seconds)]"*

In this equation, the Avg Time (seconds) would be 1,800, derived from the 30 minutes Averaging Time taken from Table 2 (30 min x 60 sec/min = 1,800 sec). The maximum pulsewidth (seconds) is 0.016 seconds (16 msec), and the MPE is 0.28 mW/cm^2 as calculated above.

Substituting these values into the above equation:

$$\text{peak MPE} = 0.28 \ (mW/cm^2) \times 1{,}800 \text{ (seconds)} / [5 \times 0.016 \text{ (seconds)}],$$
$$= \text{ or } 6300 \ (mW/cm^2)$$

To prevent RF exposures for which the intensity of peak pulses is very high but the average power density still meets the standard for time averaged power density, the ANSI/IEEE 1992 standard, Section 4.1.2 (g) further specifies:

> *"A maximum of five such pulses, with a pulse-repetition period of at least 100 ms, is permitted during any period equal to the averaging time [see item (c)]. If there are more than five pulses during any period equal to the averaging time, or if the pulse durations are greater than 100 ms, normal averaging-time calculations apply, except that during any 100 ms period, the energy density is limited per the above formula, viz*
>
> *Σ peak MPE x Pulsewidth (seconds) = MPE x Avg Time (seconds) / 5"*

For this equation, UEWR has more than five pulses during any period equal to the averaging time (1,800 seconds); therefore, normal averaging-time calculations apply. This means that time-averaged RF energy is to be compared to the 0.28 mW/cm^2 standard.

To compute the maximum peak power density for any 100 ms period, UEWR values are substituted into the above equation:

$$\Sigma 6300\ \text{W/cm}^2 \times 0.016\ \text{(seconds)} = 0.28\ (\text{mW/cm}^2) \times 1{,}800\ \text{(seconds)} / 5,\ (\text{or } 100.8\ \text{mW/cm}^2)$$

Therefore, the greatest average peak power density value calculated for the PAVE PAWS or UEWR missions should be less than 100.8 mW/cm^2 energy density limit for a 100 msec period.

Comparison of Current vs. Original MPEs

The following table presents a comparison of standards and regulations relating to the exposure of personnel to RF, both in 1979 and 1999. Please note that none of these standards or regulations is apparently legally applicable to the PAVE PAWS system, but are used as guidance in formulating the Maximum Permissible Exposure (MPE) for this report. The most restrictive (lowest MPE) was used as the limit for this report.

Table B-2: Comparison of MPEs for Uncontrolled Personnel Exposure

	1979	1999
ANSI/IEEE	C95.1-1974 : 10 mW/cm^2	C95.1-1999: (0.28 mW/cm^2, 30-min avg.)
MA State Limit	Non-existent until 1984	105 CMR 122.000, 4/1/94 (0.28 mW/cm^2, 30 min avg.)
United States Dept. of Labor, Occupational Safety and Health Administration	10 mW/cm^2	CFR 1910.97, 3/7/96 10 mW/cm^2