INL/EXT-10-19663

American Recovery and Reinvestment Act (ARRA)

FEMP Technical Assistance

United States Department of Defense
United States Air Force
Mountain Home Air Force Base, Idaho
Nellis Air Force Base, Nevada
Holloman Air Force Base, New Mexico

Geothermal Resource Evaluation Projects

Robert P. Breckenridge
Thomas R. Wood

September 2010

Federal Energy Management Program

AIR COMBAT COMMAND

U.S. AIR FORCE

Idaho National Laboratory

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EXECUTIVE SUMMARY

The purpose of this document is to report on the evaluation of geothermal resource potential on and around three different United States (U. S.) Air Force Bases (AFBs): Nellis AFB and Air Force Range (AFR) in the State of Nevada (see maps 1 and 5), Holloman AFB in the State of New Mexico (see map 2), and Mountain Home AFB in the State of Idaho (see map 3). All three sites are located in semi-arid parts of the western U. S.

The U. S. Air Force, through its Air Combat Command (ACC) located at Langley AFB in the State of Virginia, asked the Federal Energy Management Program (FEMP) for technical assistance to conduct technical and feasibility evaluations for the potential to identify viable geothermal resources on or around three different AFBs. Idaho National Laboratory (INL) is supporting FEMP in providing technical assistance to a number of different Federal Agencies. For this report, the three different AFBs are considered one project because they all deal with potential geothermal resource evaluations. The three AFBs will be evaluated primarily for their opportunity to develop a geothermal resource of high enough quality grade (i.e., temperature, productivity, depth, etc.) to consider the possibility for generation of electricity through a power plant. Secondarily, if the resource for the three AFBs is found to be not sufficient enough for electricity generation, then they will be described in enough detail to allow the base energy managers to evaluate if the resource is suitable for direct heating or cooling.

Site visits and meetings by INL personnel with the staff at each AFB were held in late FY-2009 and FY-2010. This report provides a technical evaluation of the opportunities and challenges for developing geothermal resources on and around the AFBs. An extensive amount of literature and geographic information was evaluated as a part of this assessment. Resource potential maps were developed for each of the AFBs.

For Nellis AFB and AFR, there is a low to medium possibility for the development of an electrical power production-grade geothermal resource (see maps 4 and 5), but prior to conducting any exploratory drilling, it would be necessary to gather additional geochemistry and geologic data for those areas (gathering new data was outside the scope of this effort).

For Holloman AFB, there is only a low chance that an electrical grade geothermal resource is located under the base, or in an area that is close enough to the base to warrant additional exploratory actions (see maps 6 and 7). However, for Holloman AFB, this study did identify that there is a reasonable chance that a medium to high temperature geothermal resource is located at both Ft. Bliss and the White Sands Missile Range, which are located just south and west of Holloman AFB. Since the goal of this evaluation is to identify if there are resources on or around the three AFBs of interest, follow-up discussions are planned regarding a possible Holloman AFB collaboration with Ft. Bliss or White Sands Missile Range personnel to evaluate if a regional resource may be available to help the U. S. Department of Defense (DoD) reduce the electrical generation needs from the grid and improve energy independence.

At Mountain Home AFB, a number of potential low to moderately high (60 to 150°C) geothermal resource sites are located under or near the main base, as well as under the bombing and small arms ranges nearby (see maps 8 and 9). A detailed write-up of the potential resources present at this AFB is discussed in more detail in Appendix A. Based upon gradient heat calculations from data collected from wells on or around the main base, there is sufficient geothermal resource potential to justify drilling an exploratory test well. This drilling is planned to take place in FY-2011. This will be a joint-funded well with part of the funding coming from a DOE grant and part coming from DoD contributions. The well design is identified in this report along with details about other organizations that will be collaborating on the project.

Several challenges and key baseline assumptions have been identified that are considered as part of this assessment. They include:

- The assumption that all of the data and information that were collected and evaluated as a part of this study were of sufficient quality to obtain a reasonably accurate assessment of the resource potential on and around the bases.
- The assumption that only existing data was to be evaluated in this study and recommendations could be made for additional or follow-up work, but that conducting additional field work is beyond the scope of this effort.
- The assumption that best available data could be collected for climate and energy usage for the three AFBs, but that the quality would not be the same.
- The assumption that the resource under Mountain Home AFB will be of high enough temperature to warrant further exploration and development.
- The assumption that annual energy and cost savings at Mountain Home AFB are based on the assumption that the resource located under the base is of high enough quality to replace 50% of the annual consumption of natural gas used by the base. The 50% replacement would be used to replace space heating requirements on the base.

One of the requirements for FEMP was to evaluate the energy usage at each one of the facilities under investigation. The peak monthly usages for the three AFBs are as follows.

Peak monthly energy usage for the three AFBs.

Utility group	Nellis AFB	Holloman AFB	Mountain Home AFB
Electric	11.5 million kWh/month	7.68 million kWh/month	7.1 million kWh/month
Natural gas	5.5 MMBtu/month	39 MMBtu/month	37.9 MMBtu/month
Propane		7582 gal/month	
Solar production	3.25 million kWh/month		

For this assessment, recommendations range from taking little action at Holloman AFB to considering pursuit of a test drill hole at Mountain Home AFB.

For Nellis AFB and AFR, there is a wealth of data that could be evaluated by an interested professor and his/her graduate student(s) to evaluate the chemistry and geochemistry data to identify which, out of the top eight locations that show favorable potential, shows the highest potential for providing a usable geothermal resource.

For Holloman AFB, there is not enough of a potential geothermal resource located under the base to pursue. However, a recent report prepared for the U. S. Navy’s Geothermal Program stated that there is high potential at nearby DoD facilities, such as the Hueco Tanks – McGregor Range on Fort Bliss and possibly the White Sands Missile Range. This potential could warrant collaborative development opportunities. If the goal is to make DoD as an entity as energy-independent as possible, this may be a viable option for that region.

For Mountain Home AFB, there is an opportunity for the base to collaborate with another project that is looking for the potential for geothermal resources that are of high enough quality to support a moderate grade energy production system or to reduce the reliance of the base on natural gas to meet its heating requirements. If the assumptions listed above in this section are reasonable, and a viable resource can be found under the Mountain Home AFB, the base could reduce its natural gas usage by 50% down to 1,088 kilotherms/yr (about 108.8 MMBtu). This would be a reduction in the annual natural gas bill of about $950,000 and would reduce greenhouse gas emissions by about 5.440 Metric tons/yr.

This evaluation project supported about 0.92 FTEs at INL for a combination of environmental, hydrological, geological, and geographic information system scientists.

ACKNOWLEDGEMENTS

The authors would like to recognize the tremendous support from Julie Brizzee and Randy Lee for their development of the geographic information system (GIS) material presented in this report. We would also like to thank the Air Force energy managers Steve Dumont, Joseph Armstrong, Gary Krivokapich, and Charles Transley for their input to the report and critical review. We thank Chris Ischay for his excellent support as the INL project manager. We would also like to thank Gordon Holt for his superior effort in providing technical editing support in the development of this report.

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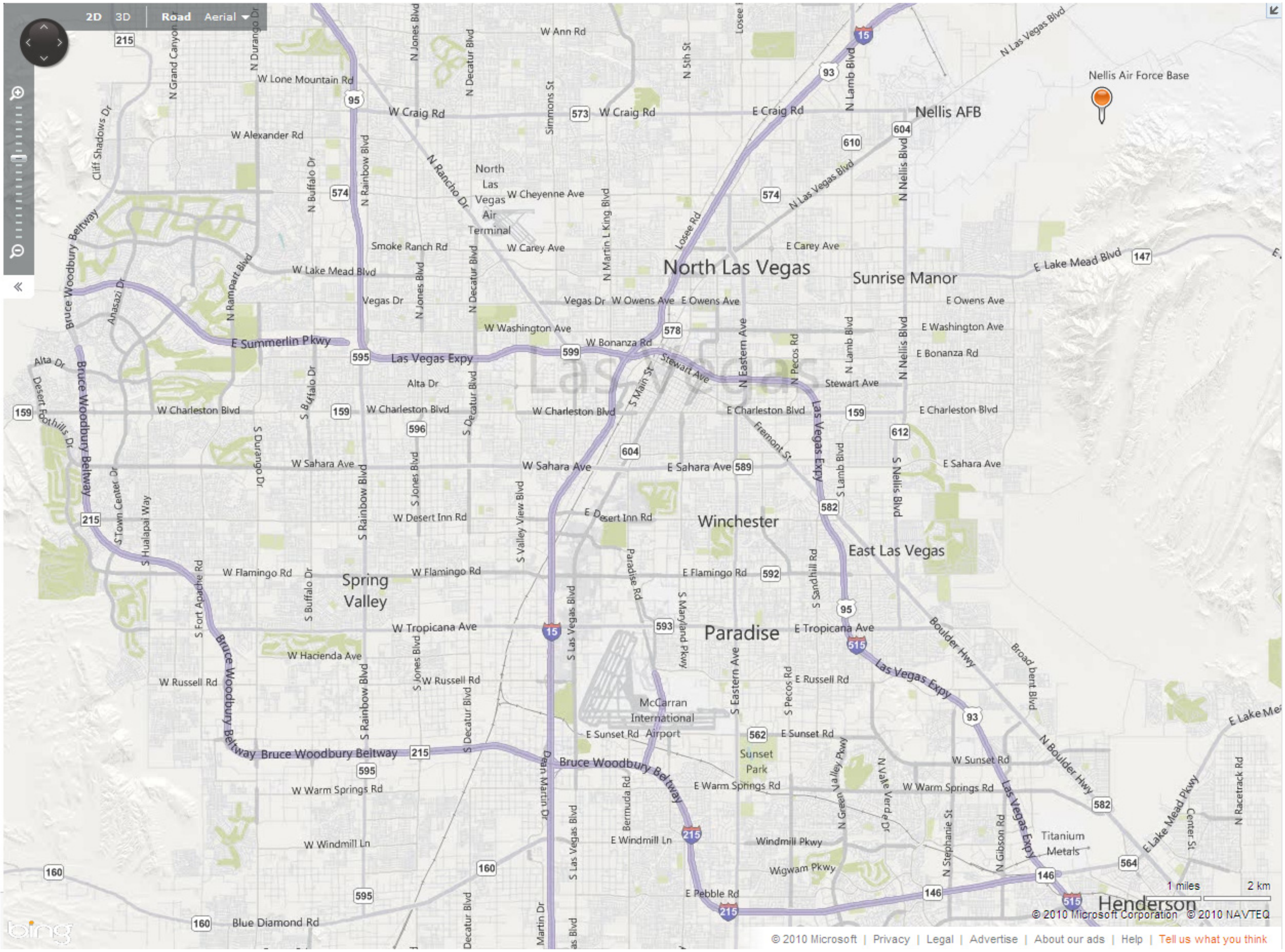
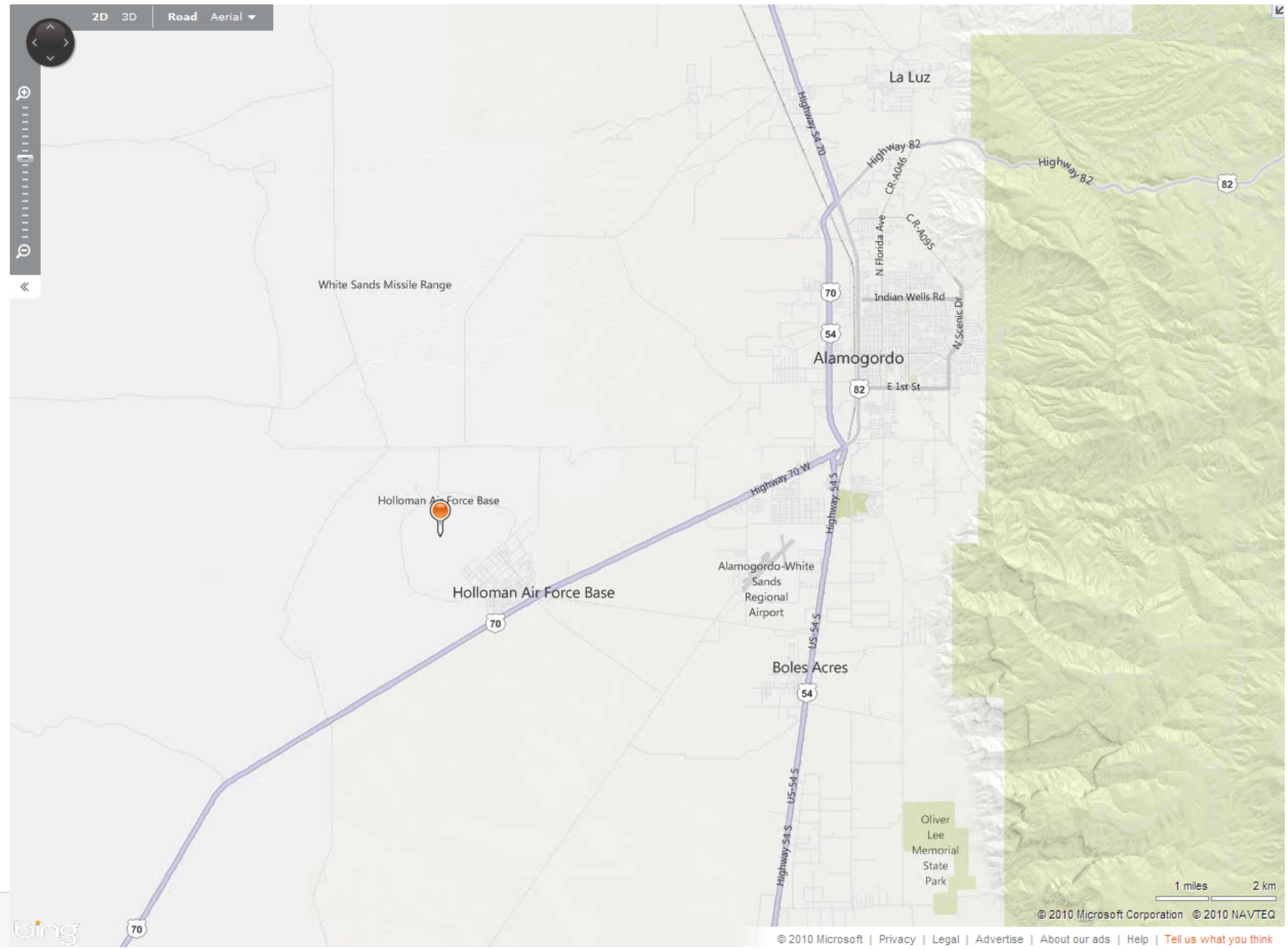
ACRONYMS

44 FG	44th Fighter Group
46 TG	46th Test Group
49 FW	49th Fighter Wing
99 ABW	99th Air Base Wing
ACC	Air Combat Command
AMCOM	Army Aviation and Missile Command
amsl	above mean sea level
ARRA	American Recovery and Reinvestment Act
AFB	U. S. Air Force Base
AFR	U. S. Air Force Range
AWFC	Air Warfare Center
BLM	U. S. Bureau of Land Management
C4I	Command, Control, Computing, Communications and Intelligence Systems
DoD	U. S. Department of Defense
DOE	U. S. Department of Energy
EERE	Energy Efficiency and Renewable Energy
ESPC	Energy Savings Performance Contracts
FEMP	Federal Energy Management Program
FTC	German Air Force Flying Training Center
GIS	Geographic Information System
HAFB	Holloman Air Force Base
ICDP	International Continental Scientific Drilling Program
IDEQ	Idaho Department of Environmental Quality
IDWR	Idaho Department of Water Resources
INL	Idaho National Laboratory
MAJCOM	U. S. Air Force Major Command site
MCF	Thousand Cubic Feet
MHAFB	Mountain Home Air Force Base
MW	Megawatt
kWh	kiloWatt-hour
MMBtu	million BTU
MOU	Memorandum of Understanding
NAFB	Nellis Air Force Base

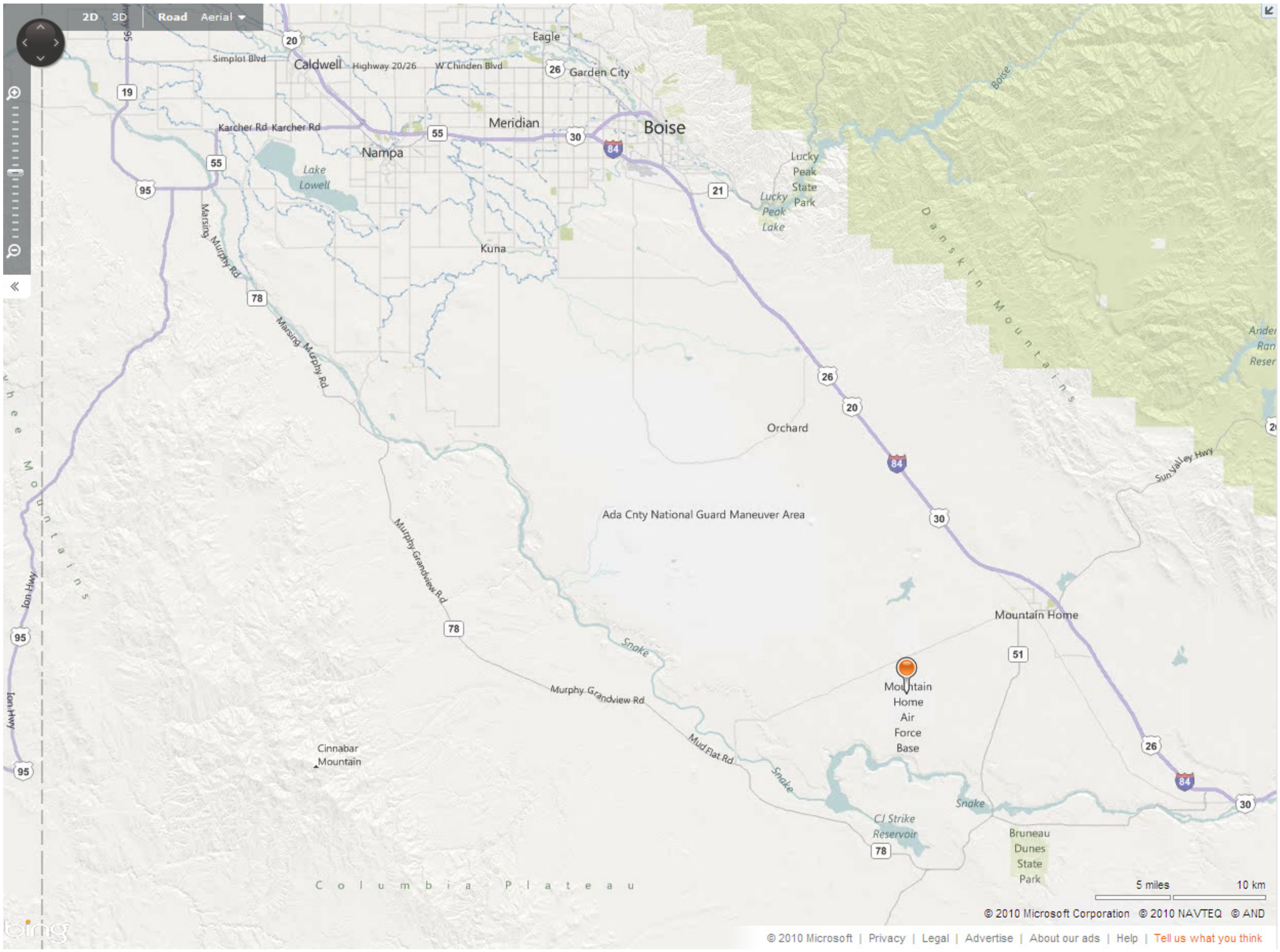
NAFR	Nellis Air Force Range
NOAA	National Oceanic Atmospheric Administration
NTTR	Nevada Testing and Training Range
PPA	Power Purchase Agreements
RDT&E	research, development, test, and evaluation
RPV	Remotely Piloted Vehicles
SAC	Strategic Air Command
SAR	Small Arms Range
SCR	Saylor Creek Range
SDRA	C.J. Strike Dam Recreation Annex
SRP	Snake River Plain
TAC	Tactical Air Command
UESC	Utility Energy Service Contracts
UK	United Kingdom
U. S.	United States
USAF	United States Air Force
USGS	U. S. Geological Service
USU	Utah State University



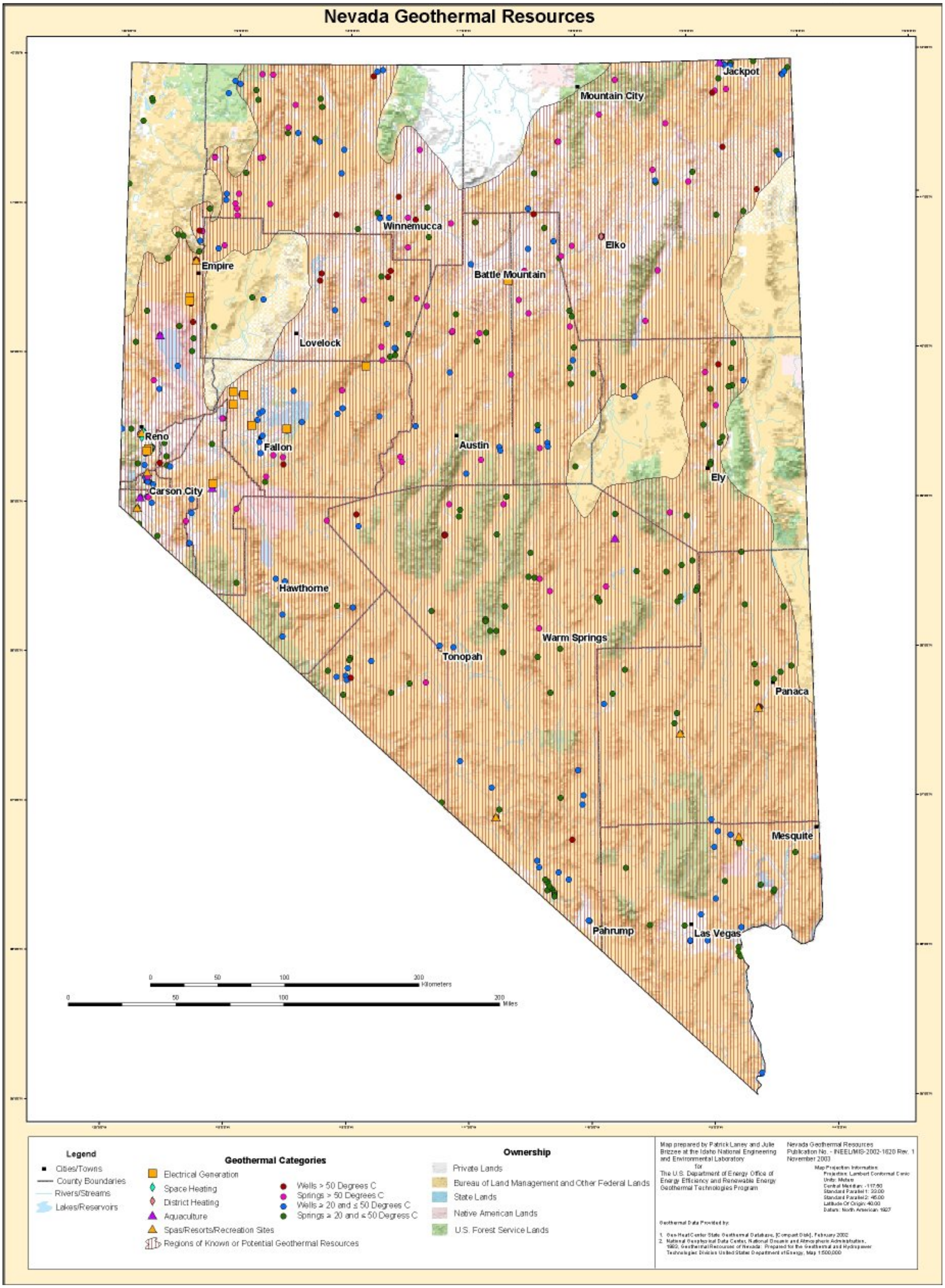
Map 1. Nellis Air Force Base in the State of Nevada.



Map 2. Holloman Air Force Base in the State of New Mexico.



Map 3. Mountain Home Air Force Base in the State of Idaho.



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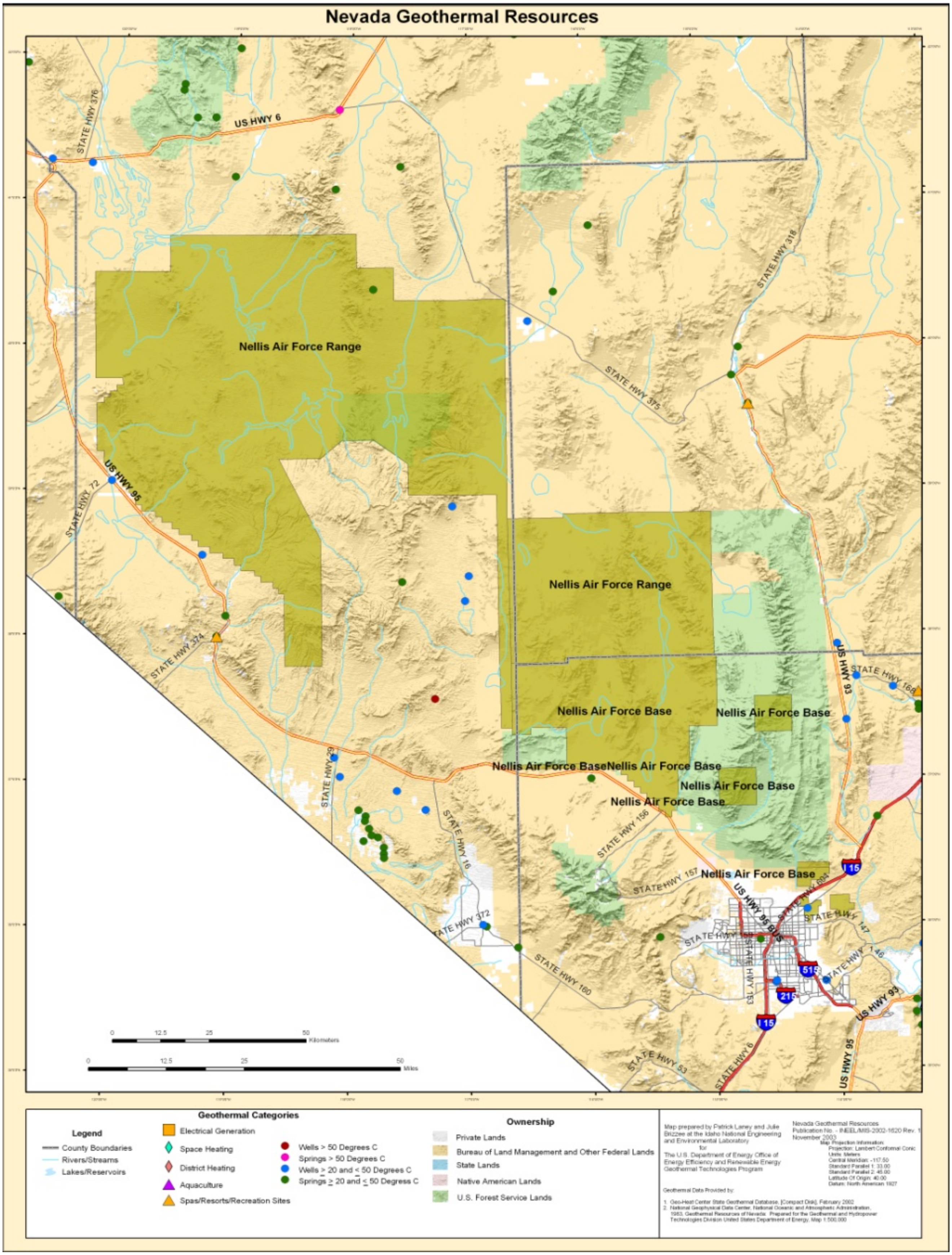

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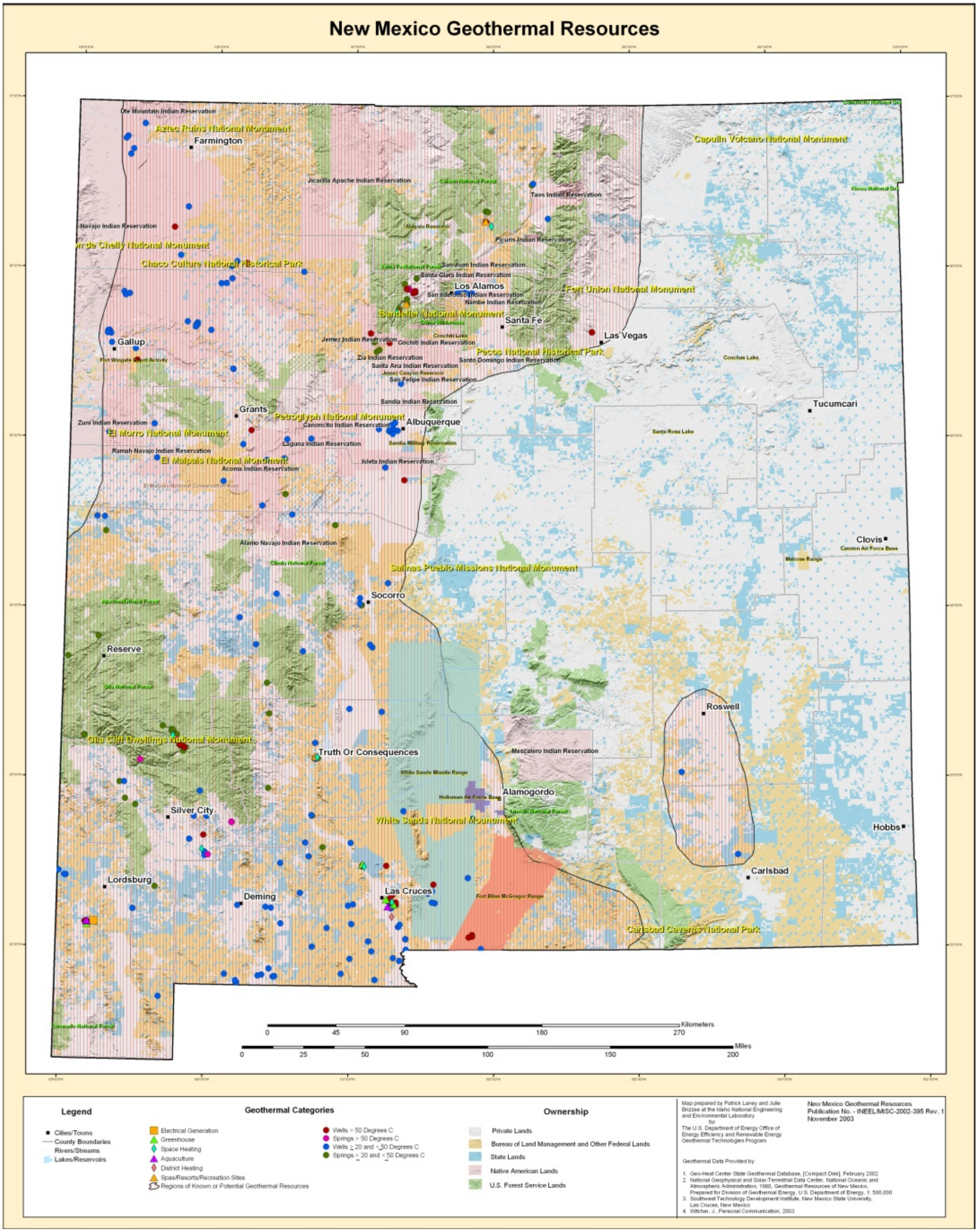

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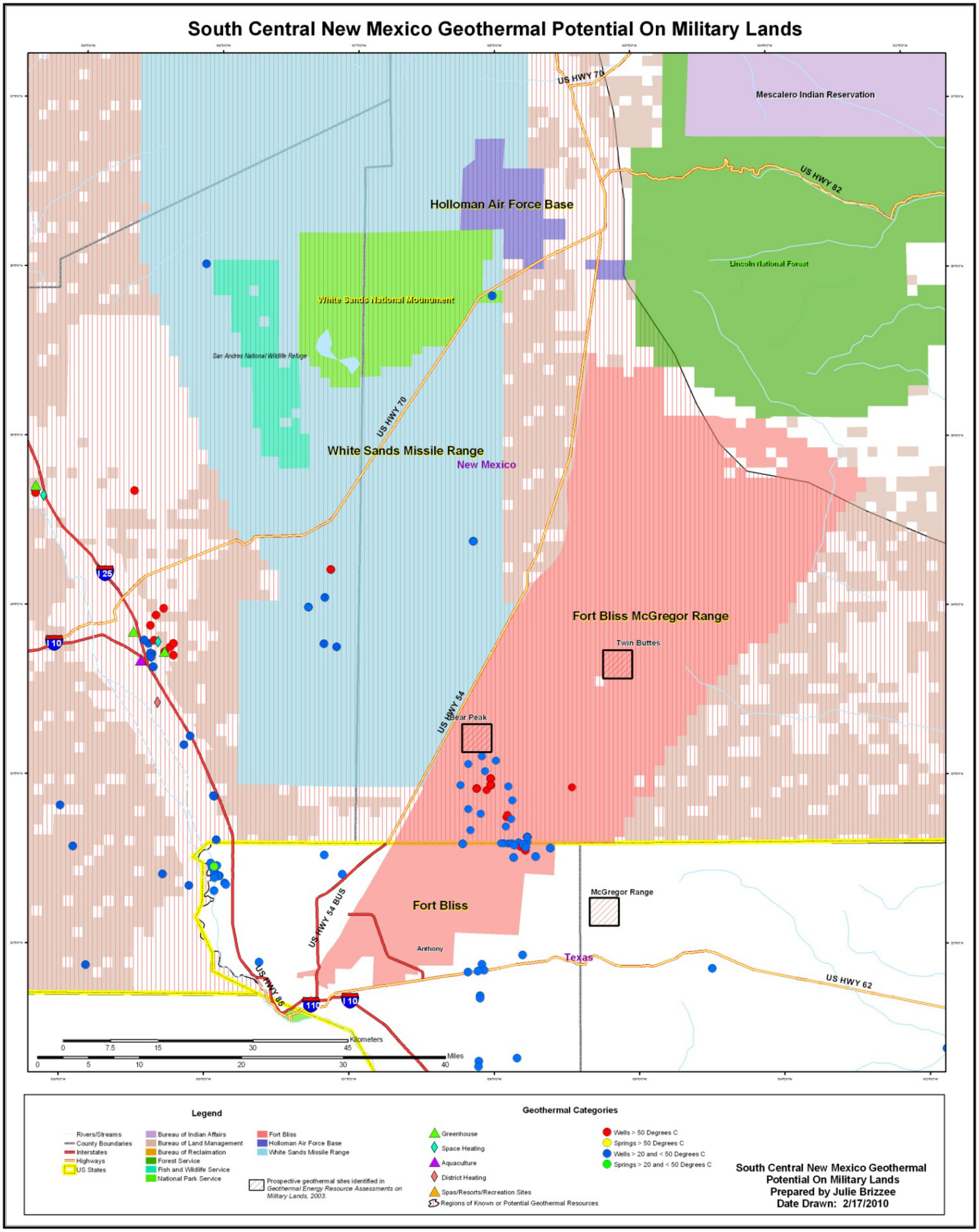

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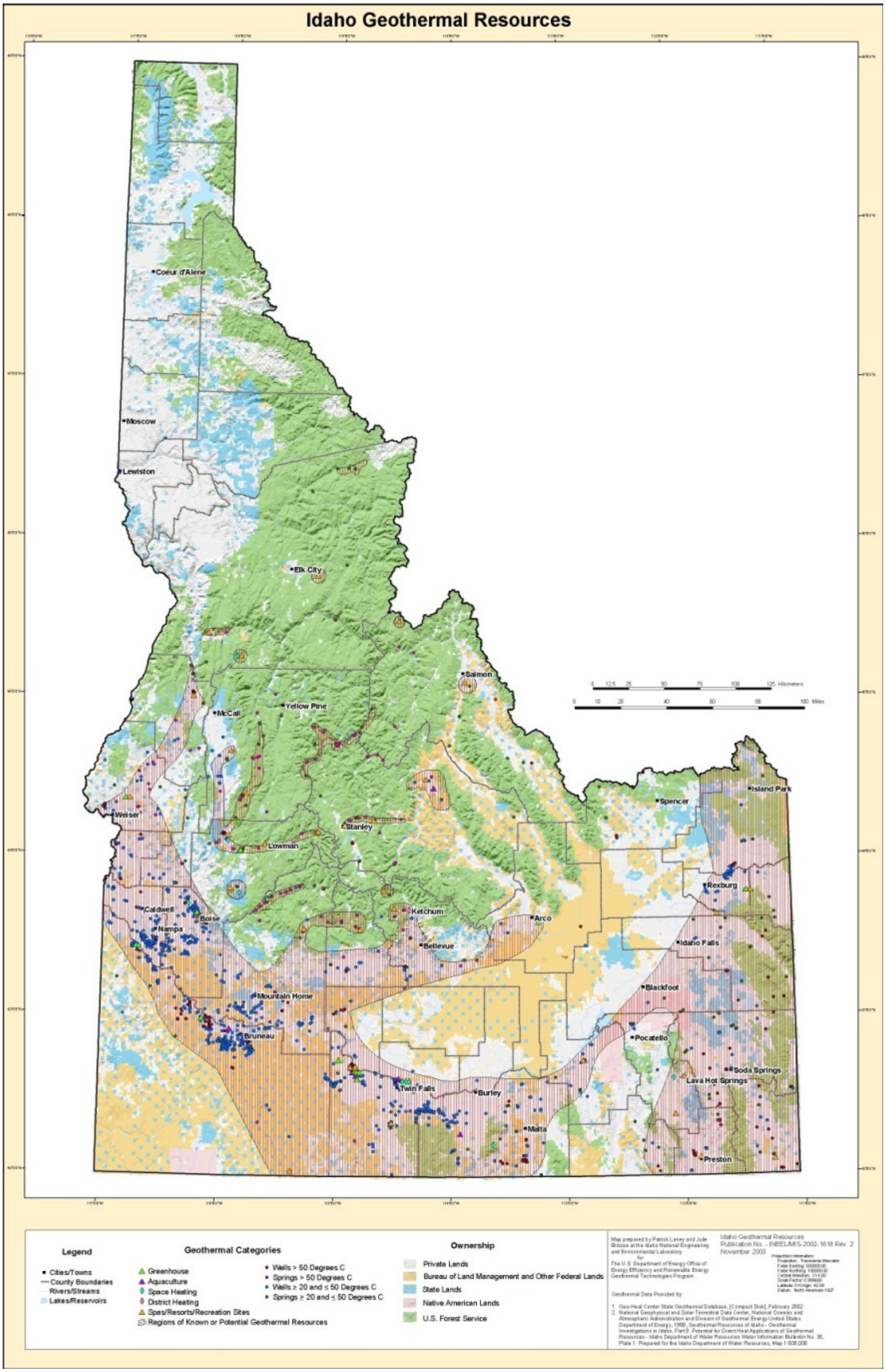
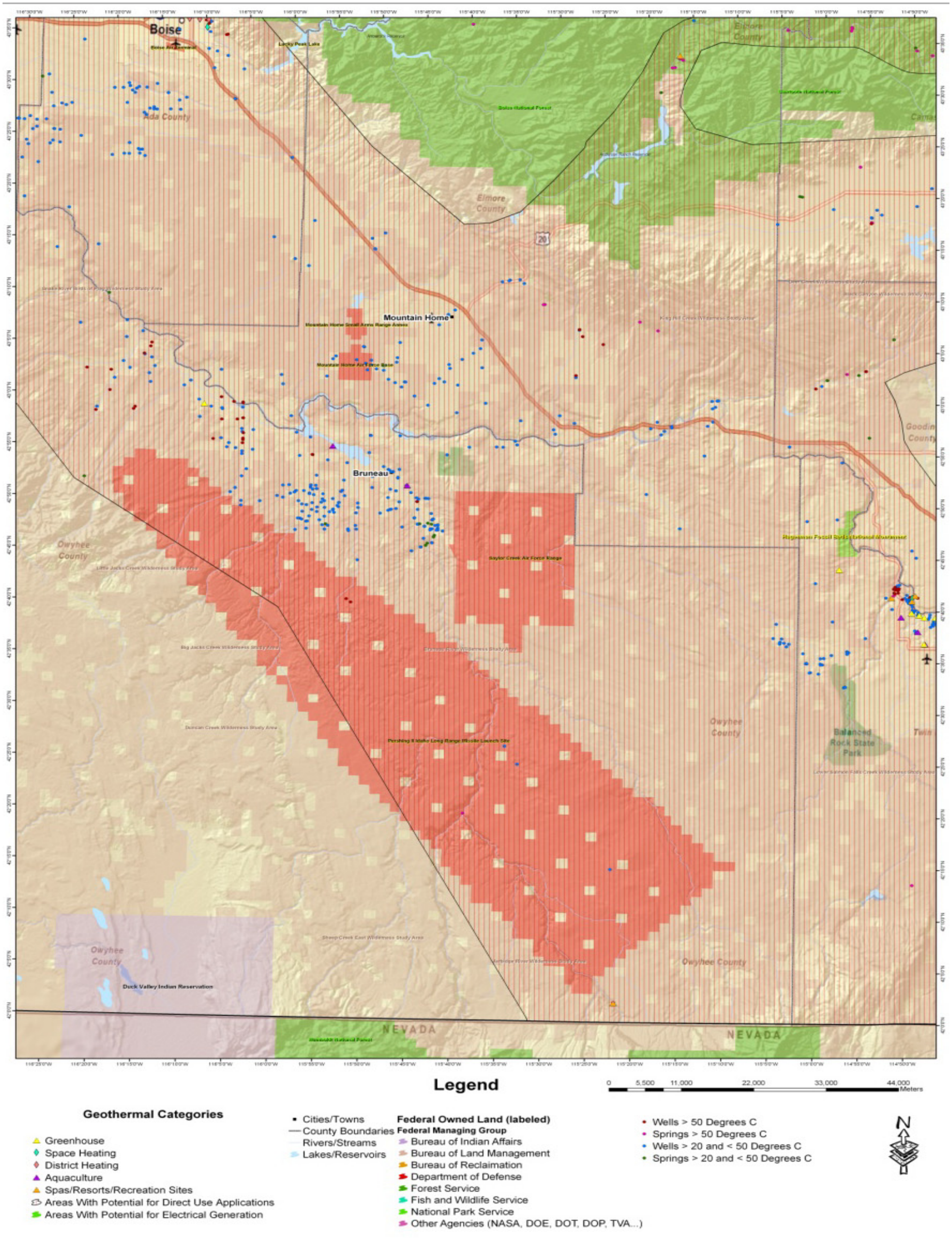


Map 8. Geothermal resource sites in the State of Idaho.



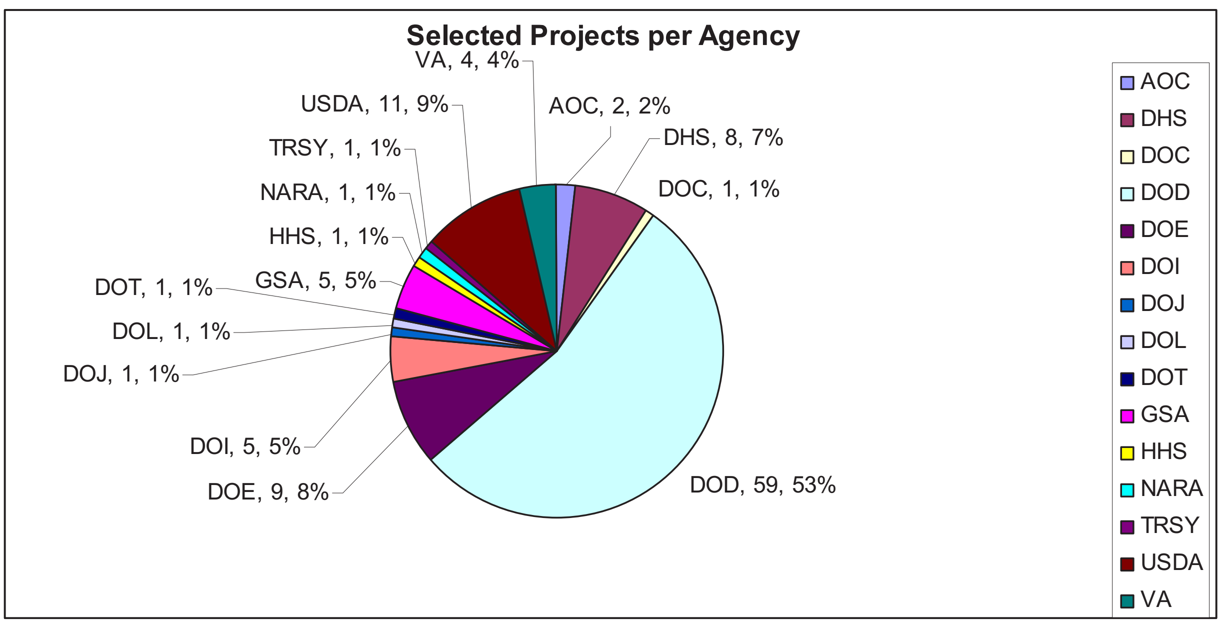
Map 9. Geothermal resource sites at Mountain Home AFB in the State of Idaho.

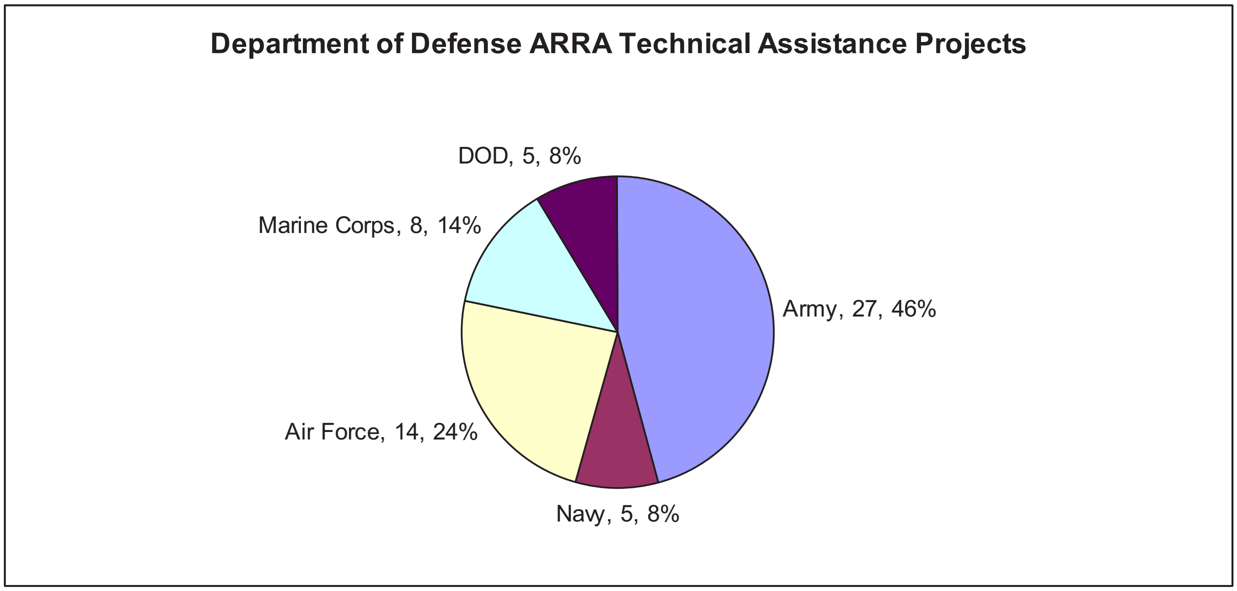
1. AMERICAN RECOVERY AND REINVESTMENT ACT (ARRA)

1.1 Description of ARRA Program

The U. S. Department of Energy (DOE) Federal Energy Management Program (FEMP) received funding through the American Recovery and Reinvestment Act (ARRA) to enhance and accelerate FEMP service functions to the Federal Government for the following projects: Enhanced Technical Assistance, Communications and Training, Energy Savings Performance Contracts (ESPC), Utility Energy Service Contracts (UESC), and Power Purchase Agreements (PPA) project support. Funding from the ARRA enabled increased scope and tempo of FEMP support for other Federal Agencies as they make energy management and investment decisions using their Recovery Act funding.

FEMP issued an initial ARRA request for project submittals at the Interagency Task Force meeting on March 18, 2010, and subsequently announced the Call for FEMP Technical Services to Federal Agencies. In addition, FEMP reviewed applications from viable FY-2008 projects. Of the over 300 applications received, one hundred and ten (110) projects were selected and approved to use ARRA funding, as shown in the following graphs (percentages shown in these graphs represent the percent of total projects).





1.1.1 Technical Assistance Description

FEMP facilitates the Federal Government's implementation of sound, cost-effective energy management and investment practices to enhance the nation's energy security and environmental stewardship. The FEMP Technical Assistance activity helps Federal Energy Managers identify, design, implement, and evaluate new construction and facility improvement projects. These projects involve: energy efficiency; renewable energy; distributed energy and combined heat and power; sustainable design practices; and water-saving technologies. The objective is to help the Federal Agencies meet the goals set by Federal Legislation and Executive Order.

2. GENERAL BACKGROUND

The U. S. Air Force (USAF) is tasked with the primary responsibility for projecting long-range military air power to enhance U. S. defense capability. The USAF is the one branch of the U. S. Department of Defense (DoD) with long-range fighters, tankers, electronic warfare and intelligence aircraft, and airlifters, and is also the only branch with bombers and stealth capabilities, all of which provide the ability to quickly deliver a powerful strike at an enemy over great distances. USAF missions include space surveillance, tactical battlefield surveillance, aerial transport of troops and material, close air support of land forces, all-weather strikes, nuclear deterrence, maritime strikes, and air superiority.

All three of the AFBs that are being evaluated as a part of this geothermal development potential project fall under the control of the Air Combat Command (ACC) headquartered at the Langley AFB in the State of Virginia. ACC is a major command (MAJCOM) of the USAF and is responsible for bases across the U. S. Mr. Steven A. Dumont is the Command Energy Manager at Langley AFB and has a focal point for coordinating USAF interactions on this FEMP project. ACC's mission is to be the primary force provider of combat airpower to America's warfighting commands. To support global implementation of national security strategy, ACC operates fighter, bomber, reconnaissance, battle-management, and electronic-combat aircraft. In addition, ACC provides command, control, computing, communications, and intelligence (C4I) systems, and conducts global information operations.

As a force provider, ACC organizes, trains, equips, and maintains combat-ready forces for rapid deployment and employment while ensuring strategic air defense forces are ready to meet the challenges of peacetime air sovereignty and wartime air defense.

There is a great deal of similarity among the three different air force bases being evaluated for geothermal energy potential. They are all located in semi-arid regions of the western U. S. in areas mostly devoid of trees with access to large tracks of land that make it possible to carry out training missions. The next three subsections will discuss in more detail the specific missions, facilities, and environmental conditions of Nellis, Holloman, and Mountain Home AFBs.

2.1 Nellis AFB and AFR Site Description

Nellis Air Force Base (NAFB) and the adjoining Nellis Air Force Range (NAFR) [in this report also referred to as Nevada Testing and Training Range (NTTR)] consist of portions of Clark, Lincoln, and Nye counties in the State of Nevada, just northwest of the city of Las Vegas. A map of both NTTR and NAFB is shown in Figure 1.

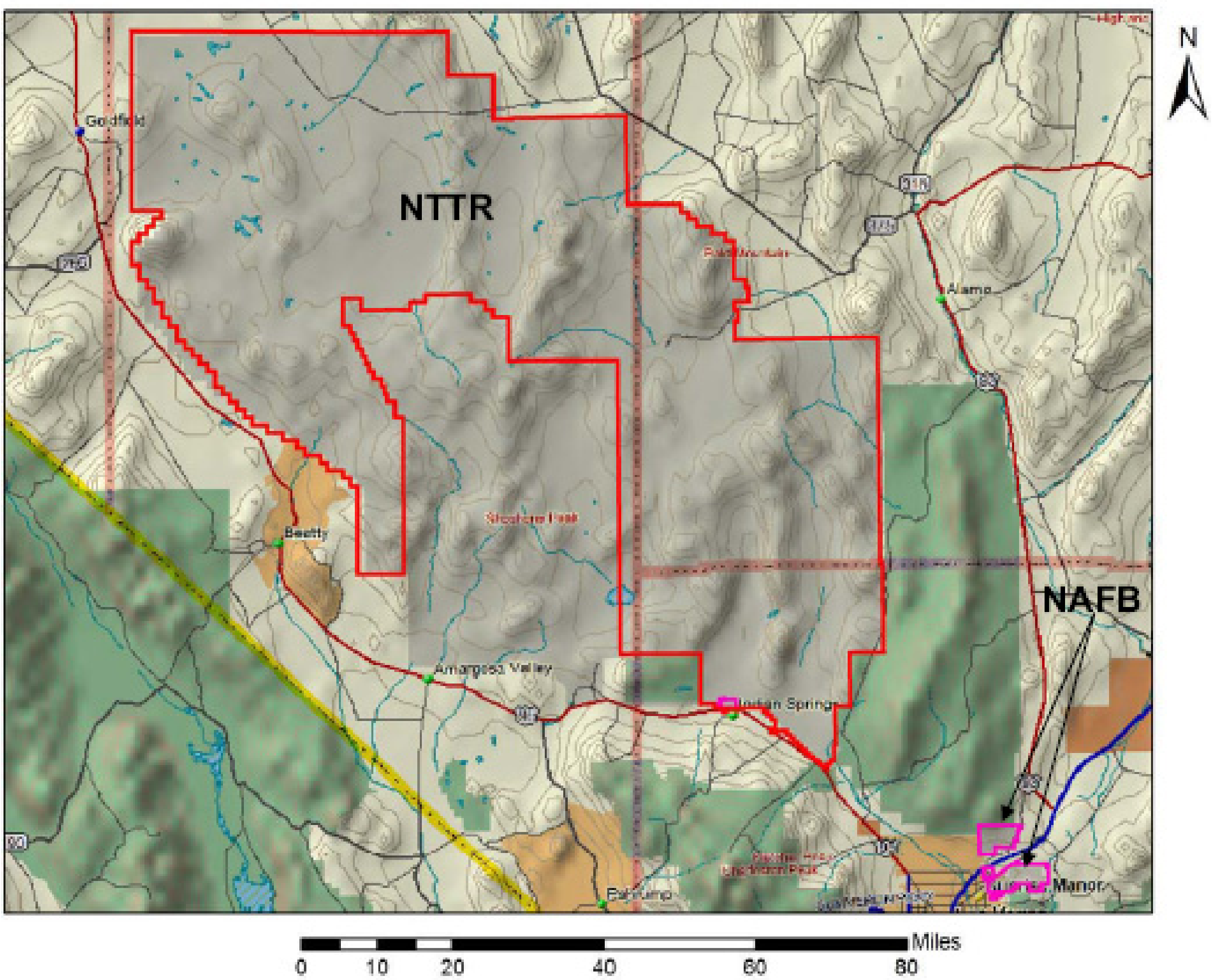


Figure 1. Location of Nevada Testing and Training Range and Nellis AFB in southern Nevada.

2.1.1 Facility Type and Operations

The USAF is tasked with the primary responsibility for projecting long-range military air power to enhance U. S. defense capability. Realistic training and weapons system testing in an environment similar to real combat conditions are the primary means to ensure readiness and to prepare USAF personnel and assets to meet and enforce national policies. Realistic training is critical to maintaining military proficiency and ensuring success on the battlefield. The topography and natural resources found at NAFB and NAFR closely mimic many of the present-day battlefield environments encountered by the USAF in foreign lands. Proper management of the natural resources at NAFR and NAFB guarantees that those areas will continue to provide the USAF with the sustainable environment required to meet mission goals while maintaining and conserving the integrity of the natural environment.

The military and training operations conducted at NAFB in Nevada play a crucial role in the USAF's national defense efforts. The NAFB-based 99th Air Base Wing (99 ABW) assists the ACC in arranging, training, and equipping tactical air forces of the U. S. and allied nations, primarily by providing advanced tactical training to fighter pilots. The Air Warfare Center (AWFC) is an intermediate headquarters for four wings and 24 detachments at NAFB. NAFR, which is located just adjacent to NAFB, is a unique national asset both on a military and environmental basis. NTTR provides the opportunity for weapons system testing combined with the highest level of training available for military personnel, as well as an aerial battlespace that includes a robust threat environment, varied target arrays, operational airspace, topographic complexity, security, and public safety buffers.

NAFR is the only location in the U. S. where both individual and large multi-force training can be conducted in a natural environment that simulates full-scale battlefield scenarios. The advanced level of training and testing that NAFR offers is crucial to the survival of U. S. and allied military personnel and the success of the USAF mission to defend the U. S. and to secure and enhance U. S. interests and policies around the world.

2.1.2 Climate

Temperature variations between night and day tend to be relatively large, with a difference of 39°F in the summer and 33°F in the winter. The warmest month of the year is July with an average maximum temperature of 99.9°F, while the coldest month of the year is December with an average minimum temperature of 27.8°F.

The annual average precipitation at NAFB is 4.05 inches. Rainfall is fairly evenly distributed throughout the year. The wettest month of the year is January with an average rainfall of 0.59 in.

2.1.3 Geology

The geologic formations outcropping on the NAFB and NAFR sites can be divided into the southeastern area, which is mostly Paleozoic sedimentary rocks, and a northwestern area, which is dominated by volcanic rocks of the Cenozoic age (NBMG, 1997).

NAFB lies in the Las Vegas Valley, which is predominantly made up of sedimentary formations and alluvial deposits. The sedimentary formations are found in mountain ranges and consist mainly of limestone mixed with sandstone, shale, dolomite, gypsum, and interbedded quartzite. The alluvial fans found to the east and north of NAFB are composed of many coalescing fans dissected by numerous drainage channels. In the upper reaches, these alluvial fans are comprised of poorly sorted gravelly, cobbly, and stony sand deposits that grade to finer textured material towards the valley floors. Basin floors are depositional areas of late-laid silt and clay and younger alluvial deposits. Most of these alluvial deposits have been transported by water and deposited on the sloping basin floors of the floodplains. The deposition of alluvium is a continuing process.

In NAFR, the mountain ranges in the South Range are dominated by Paleozoic carbonate rocks mixed with smaller amounts of quartzite, sandstone, and shale. Valleys in this area contain thick deposits of alluvium originating from erosion of adjacent mountain ranges. Sedimentary rocks originating from lakes and rivers have been deposited in shallow basins and outcrop in several areas within the NAFR, particularly in the southern Spotted Range, the Pintwater Range, and the Desert Range. Older tertiary valley-fill sediments that were uplifted with the underlying Paleozoic bedrock are exposed on the mountains' flanks (Longwell et al., 1965; NBMG, 1997).

Volcanic rocks dominate the geology of the northern ranges. The Timber Mountain Caldera is one of several centers of volcanic activity in the northern range. Other such centers include the Black Mountain, Cactus Range, and Silent Canyon Calderas, and the Mount Helen Dome. Volcanic tuff originating from the volcanic centers extends throughout the North Range, including the extensive tableland of western Pahute Mesa, the southern Cactus and Kawich Ranges, and Stonewall Mountain (Cornwall, 1972; NBMG, 1997).

Most of the faults at NAFB and NAFR are a result of regional thrust, folds, and wrench faults developed during compressional deformation associated with mountain building, which rearranged the position of sedimentary rocks in southern Nevada. A more detailed discussion of faults in southern Nevada can be found in Armstrong (1968) and Caskey and Schweickerty (1992). The western one-third of NAFR is located within Seismic Zone 3, while the eastern two-thirds of NAFB and NAFR are located in Seismic Zone 2B. Seismic Zone 3 is considered an area with major damage potential, while Seismic Zone 2B is considered an area of moderate damage potential. The Yucca Fault, located in the south-central portion of NAFR, is the only fault that is considered active based on displacement of surface alluvium. Other active faults may also be present on the NAFR site. Several inactive or potentially active faults are also present at NAFR. These faults include the Carpetbag Fault, located west of the Yucca Fault, and the Pahranagat Fault system located in the South Range. Most faults on NAFB and NAFR are considered inactive.

2.1.4 Mineral Resources

The Department of the U. S. Air Force (USAF), per Public Law 106-65, Military Lands Withdrawal Act of 1999, Subtitle A, Section 3011(b)(1), declares that the lands under the Nevada Test and Training Range (NTTR) be closed to public access. They are specifically withdrawn from all forms of appropriation under mining laws, mineral leasing laws, and geothermal laws. USAF has no lands at NTTR compatible with these activities and will continue to enforce current public access policy (USAF, 2007). According to PL 106-65 as amended, the U. S. Secretary of the Interior must determine, at least every five years, whether it is suitable to open any withdrawn lands for mineral resource entry. The intent of this decision is based on three factors: (1) to protect the public from injury due to ordnance hazards; (2) to ensure national security is not compromised; and (3) to ensure that military programs can be conducted without interruption (USAF, 2007).

2.2 Holloman AFB Site Description

Holloman Air Force Base (HAFB) is located seven miles west of the city of Alamogordo in south central New Mexico (see Figure 2). About 85 miles north-northeast of El Paso, TX, HAFB is located within the Tularosa Basin between the Sacramento and San Andreas mountain ranges. The base is easily accessible via State routes 70 and 54.

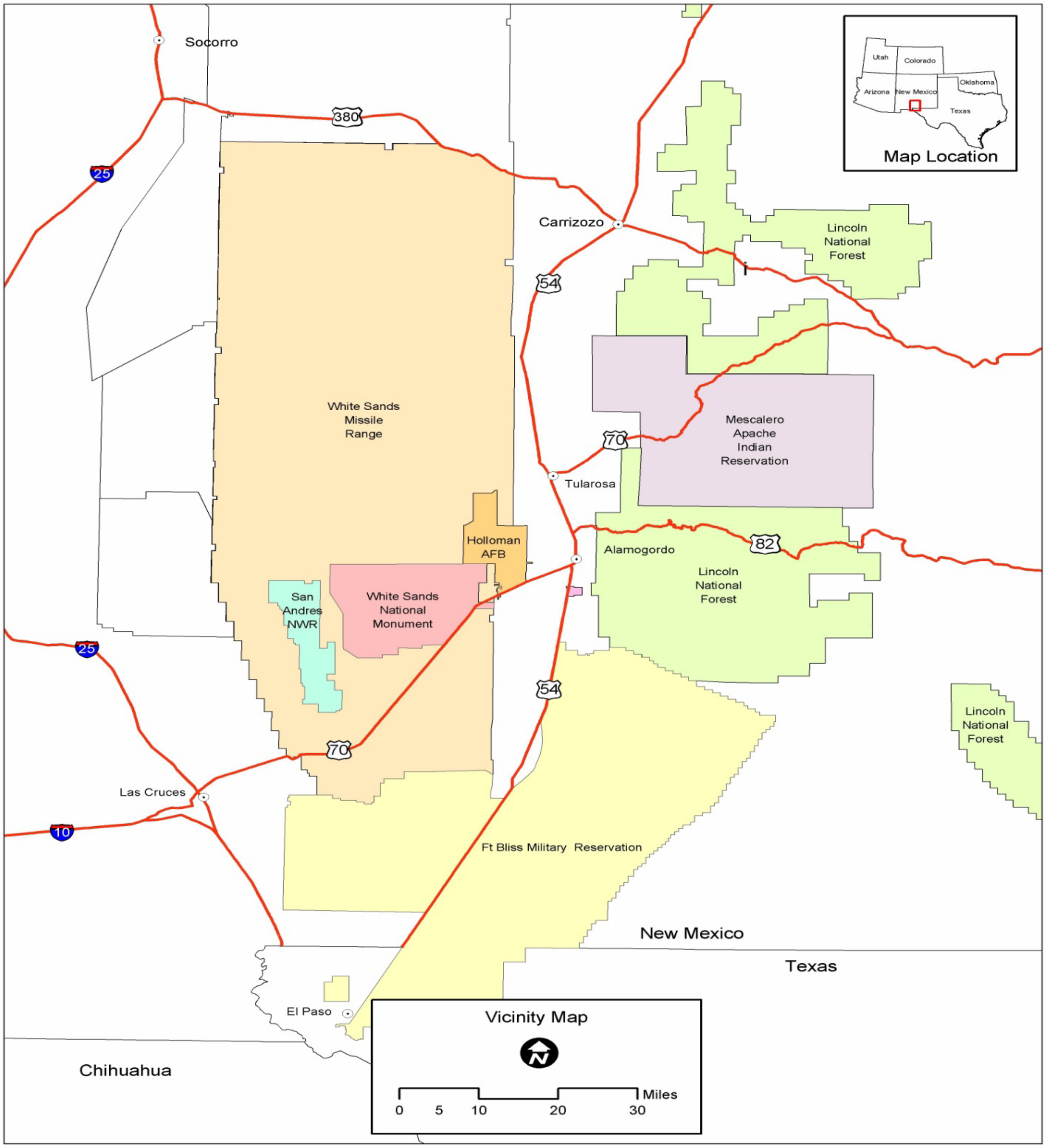


Figure 2. Location of Holloman AFB in south-central New Mexico.

2.2.1 Facility Type and Operations

The mission of the 49th Fighter Wing (49 FW) at HAFB is to train personnel to fly and maintain readiness of the F-22 stealth aircraft and the MQ-1 and MQ-9 Remotely Piloted Vehicles (RPV); support the 44th Fighter Group (44 FG); support the German Air Force Flying Training Center (FTC); support the 46th Test Group's (46 TG) research, development, test, and evaluation (RDT&E) mission; and provide services and facilities for all operations and residents on HAFB.

2.2.2 Climate

The climate at HAFB is significantly influenced by its location between mountain ranges. Basically "high desert" (about 4000 feet above sea level), average precipitation as recorded at the base weather station is 8.5 inches annually with wet bulb temperature TWB≥73°F. The average annual temperature is 62°F with seasonal mean temperatures of 41°F in January and 82°F in July. Daily temperature fluctuations average about 27°F. Strong southerly wind flow, sometimes reaching 73 miles per hour, with periods of blowing dust and sand characterize the March through May period.

The area averages more than 300 days of sunshine per year. Temperatures range from approximately 81°F during the summer months to 33°F during the winter months. Because of the high summer temperature range, the lack of natural shade and the high percentage of sunny days, solar design and control are being considered on all Holloman AFB design projects.

2.2.3 Geology

The visible natural site character is what might be expected (i.e., harsh, flat desert terrain bounded by dramatic mountains). The most dramatic natural feature is the expanse of white gypsum sand dunes found within the White Sands Missile Range and White Sands National Monument. These dunes cover much of the western edge of the base. This gypsum is highly corrosive to ferrous metals, toxic to many plant species, and tends to dissolve when exposed to water. The immediate proximity to the gypsum concentration creates high gypsum content soil conditions over much of the installation. As a consequence, indigenous desert flora is noticeably less apparent on the base than it is as close as the nearby city of Alamogordo. Much of the higher profile landscaping on the base grows in imported soil. Gypsum content in the soil does, and will continue to, heavily impact the overall approach to base landscaping, storm water management, and the selection of construction materials. The conditions outlined above describe a location with unusually harsh design conditions in terms of both climate and geology.

At approximately 40 miles east-west by 100 miles north-south, the Tularosa Basin is the major feature defining the vicinity of HAFB in south-central New Mexico. Almost entirely between 3,990 and 4,500 feet in elevation, this basin is a far southeast unit of the Basin and Range Physiographic Province that extends throughout much of the mountain west. It is bounded on the east by the layered scarp of the well forested Sacramento Mountains, rising up to 10,000 feet above mean sea level (amsl) within a few miles of HAFB. Forty miles to the west, the scarps of the San Andres Mountains rise to 7,000 feet, with peaks just over 8,000 feet, and strata that are a continuation of the formations found in the Sacramento Mountains. The basin floor is comprised of very deep sediments, over the fault block that dropped between the Sacramento and San Andres fault lines. Much of the earliest (most deeply buried) sediment was deposited by the Rio Grande during a several million-year detour through the basin. The later and modern surface sediments are primarily eroded from the Sacramento and San Andres Mountains, and are heavily calcic and mildly sulfurous.

2.3 Mountain Home AFB Site Description

Mountain Home Air Force Base (MHAFB) is located approximately 50 miles southeast of Boise, ID, and 8 miles southwest of Mountain Home, ID. For the purposes of this document, MHAFB includes the Small Arms Range (SAR), as well as Rattlesnake Radar Station, Middle Marker, and C.J. Strike Dam Recreation Annex (SDRA) (see Figure 3).

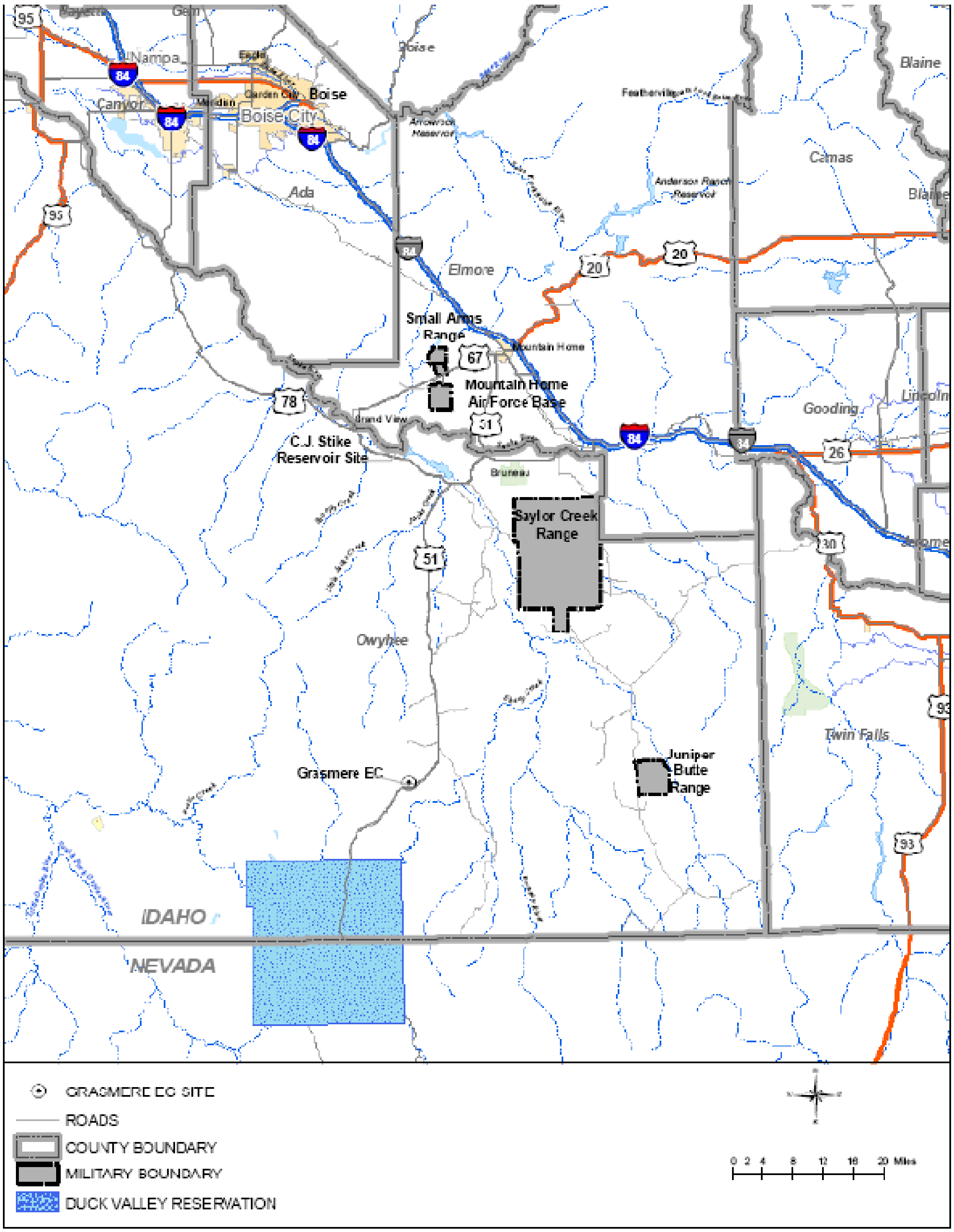


Figure 3. Regional location of Mountain Home AFB, Saylor Creek Range, Juniper Butte Range, and Grasmere Electronic Site in southern Idaho.

The 6,844 acres of MHAFB includes all of Sections 20, 21, 22, 27, 28, 29, 32, 33, and 34; as well as 10 acres of Section 19 in Township 4 South, Range 5 East. Roughly 60 acres of MHAFB extend into Section 19 in Township 5 South, Range 5 East. A barbed-wire fence defines the perimeter of MHAFB.

Buildings, roads, runways, and facilities cover between 20–25% of the land. The most intensively developed areas are located in the central and northeastern portions of the base. Landscaped and disturbed areas account for another 25% of MHAFB. The remainder of the lands range from open, undeveloped fields to partially disturbed areas separating buildings and facilities. The periphery of the base contains the least development.

2.3.1 Facility Type and Operations

The land under MHAFB was undeveloped prior to construction of the base. MHAFB was established in 1943 to provide the U. S. Army Air Corps with bombardment training exercises during World War II. At the end of World War II, the base was deactivated. Between 1943 and 1992, MHAFB changed missions and commands several times, including two deactivations, from 1945–1948 and 1950–1951. MHAFB was reactivated as a Strategic Air Command (SAC) installation in 1949. The Tactical Air Command (TAC) assumed control of the base and Saylor Creek Range (SCR) in 1966. In 1992, Air Combat Command (ACC) assumed control of both MHAFB and SCR. SCR was initially established as a 420,000-acre site for training bombers and pursuit aircraft for World War II.

USAF's mission is to provide decisive combat power worldwide, on demand. MHAFB is home to the 366th Fighter Wing and is an important element of the USAF mission. The primary assigned aircraft to MHAFB include twenty F-15Cs and twenty-nine F-15Es. The 124th Wing of the Idaho Air National Guard has 18-20 A/O A-10s. The 366th Fighter Wing provides integrated combat air power, responds rapidly to contingency taskings, and is known throughout the USAF as the 911 Wing. The logistic components managed by Mountain Home AFB required to produce a well-trained, global force include the base proper, adjacent to the SAR, the Mountain Home AFB Range Complex, and other remote sites.

2.3.2 Climate

The climate in southwestern Idaho is semi-arid. It receives about ten inches of precipitation a year. Most precipitation falls during late fall to early spring. Summers are typically hot and dry with occasional thundershowers. Humidity is low and winds occur on a regular basis during the day. Winds are predominantly from the northwest, averaging 6 miles per hour (mph) or less 39 percent of the time and 7–15 mph 41 percent of the time.

Day and night temperature fluctuations are large, with up to a 35°F difference. During the winter months of December, January, and February, the average temperature is 30–35°F with daily minimum and maximum temperatures ranging from 20–44°F. Extreme lows reach below zero.

When days become warmer and drier, during the months of March through August, average daily temperatures can reach 90°F. However, during August, temperatures may reach as high as 109°F. In the fall, about September to November, average temperatures are 50°F during the day and 28°F at night. The growing season usually begins in May when temperatures rise above 40°F and continues through September. The 30-year normal for growing days is 136, according to the National Oceanic Atmospheric Administration (NOAA) (NOAA, 1996). Table 1 summarizes the weather conditions at MHAFB.

Table 1. Mountain Home, ID, Period of Record Monthly Climate Summary: 8/1/1948 to 12/31/2005.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average Max. Temperature (F)	38.2	45.0	53.8	63.1	72.7	82.9	93.2	91.6	80.9	67.4	49.8	39.4	64.8
Average Min. Temperature (F)	20.6	24.1	28.9	34.5	42.3	49.9	56.5	54.5	45.2	35.3	27.2	21.5	36.7
Average Total Precipitation (in.)	1.35	0.86	1.07	0.84	0.95	0.72	0.27	0.28	0.50	0.63	1.18	1.34	9.98
Average Total Snowfall (in.)	4.4	1.9	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	3.1	10.7
Average Snow Depth (in.)	1	0	0	0	0	0	0	0	0	0	0	1	0

Notes: F = Fahrenheit, in. = inches.
Percent of possible observations for period of record.
Max. Temp.: 95.4% Min. Temp.: 95.5% Precipitation: 96.2% Snowfall: 90.5% Snow Depth: 86%. Check Station Metadata or Metadata graphics for more detail about data completeness. Source: Western Regional Climate Center, http://www.wrcc.dri.edu.

2.3.3 Geology

Much of southern Idaho is characterized by a crescent-shaped, relatively flat, broad swath of the Snake River Plain (SRP) (see Figure 4). While the plain has little relief, geologically, it contains distinctive eastern and western parts that differ in structure and geology. MHAFB, including the SAR, lie within the western SRP. The western SRP is a northwest-trending structural basin bounded on both the southwest and northeast by high-angle faults (Malde, 1991).

The western SRP is thought to be an area of crustal rifting that started about 16 million years ago and grew southeasterly until approximately three million years ago (Malde, 1991). Early volcanism resulted in thick deposits of rhyolites and basalts.

Approximately eight million years ago, a Lake Ontario-sized body of water, often referred to as “Lake Idaho,” formed in the western SRP stretching from roughly the present-day Baker, OR, to Hagerman, ID. This resulted in thick sedimentary deposits of ash, clays, silts, sands, and gravels (Gillerman and Bonnichsen, 1990). It is thought that the lake drained about two million years ago near Hells Canyon, linking the Snake River with the Columbia. Subsequently, basalt flows of the Bruneau Formation and Snake River Group (2–0.5 million years ago), have done much to shape the current landscape. The remains of several shield volcanoes, cones, and vents can be found near MHAFB (USAF ACC, 1996).

The Snake River Canyon, just south of MHAFB, has taken much of its present-day form since the western SRP was inundated under Lake Idaho. Basalt flows from the Bruneau Formation and Snake River Groups have altered the course of the river several times by filling the canyon. The present course of the river lies at the southern margin of the flows from the Snake River Group. The Bonneville Flood, a name given to the catastrophic flood from the outflow of Pleistocene Lake Bonneville about 15,000 years ago, scoured the canyon and deposited the large basalt boulders known as melon gravel. Although there are no outcrops on MHAFB, basalts of the Snake River Group can easily be found in the vicinity.

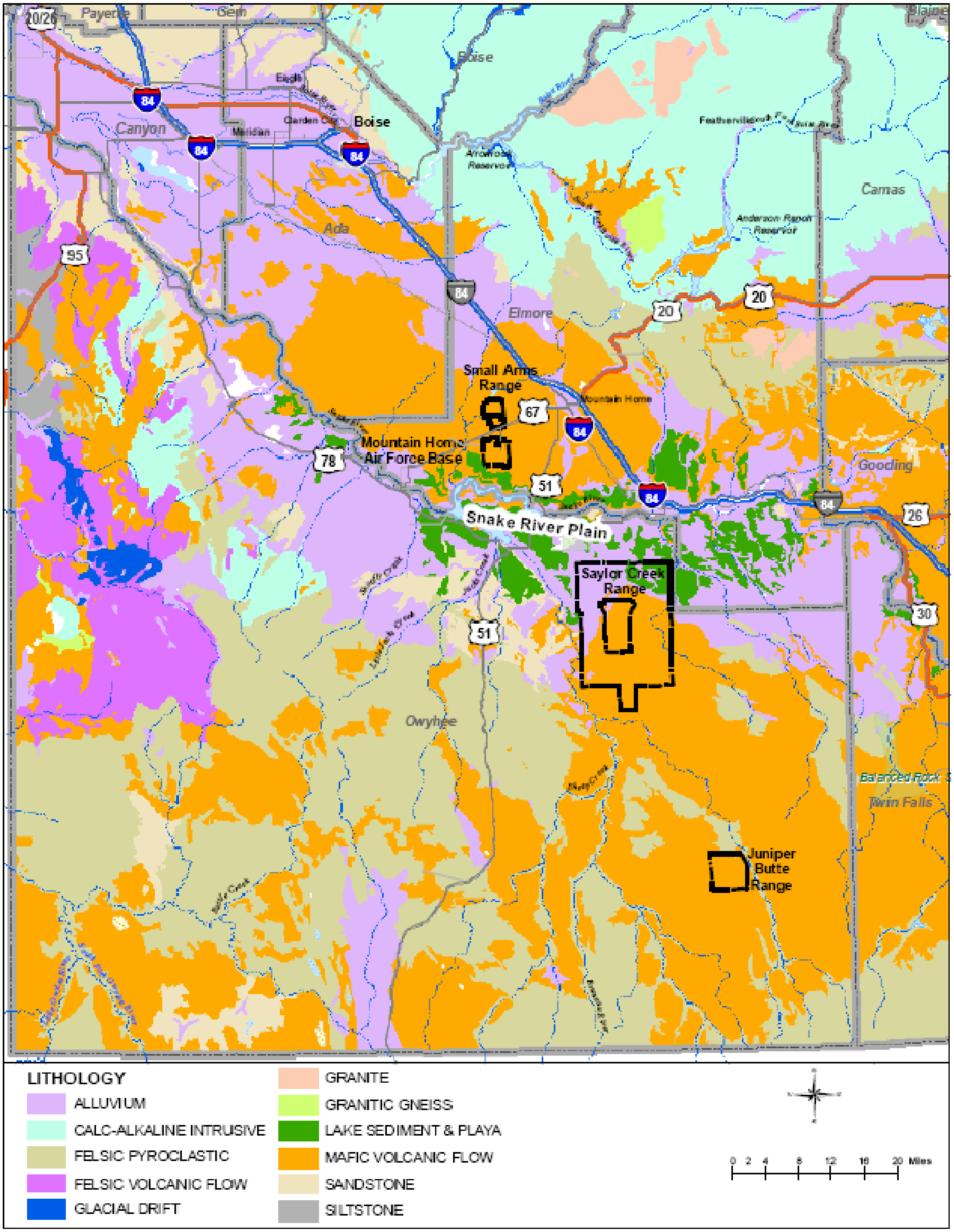


Figure 4. Geologic map of southern Idaho.

There are 11 different soil types found at MHAFB and SAR. The soils are typical of semi-arid regions, characterized by poor drainage and lack of organic matter. The soils vary in thickness, depending on the location of bedrock and hardpans, but may reach 60 inches in depth. These soil types have a moderate potential for wind and water erosion. The original soils underlying MHAFB have been physically altered (i.e., cut, excavated, or covered) to create large, level areas with high load support capabilities designed to accommodate aircraft and support operations (USAF ACC, 1996).

3. ENERGY USE ACCOUNTING

Energy use for the various bases was determined by reviewing past consumption data. The information provides insight into use patterns, summer vs. winter rates and can be useful when conducting assessment about potential geothermal resource use for the bases.

3.1 Current Use of Energy

3.1.1 Nellis AFB and AFR

Nellis AFB and AFR uses a diverse set of energy types to support its varied base operations. The base supplies its energy needs through a combination of natural gas, electricity, solar energy, and transportation fuels. In 2009, the natural gas usage by the base peaked out about 5.30–5.50 kilotherms/month (approx. 530–550 MMBtu/month) and reached a low level of usage of 1.86–3.18 kilotherms/month (approx. 186–318 MMBtu/month) during the summer months of May through August. The electrical usage for the base follows an almost opposite curve as the natural gas. This is because much of the electrical load is used to support cooling operations during the summer. Electrical usage peaked in 2008 at 11.5 million kWh/month in August and reached a low value of 5.3 million kWh/month in April. The solar system at NAFB produces about 50,000 kWh/day in the low month of December and peaks at 105,000 kWh/day during the high months of May through June. During the low month of December, the solar system at NAFB produced about 1.63 million kWh/month. During the high months of April, May, and June, the system can produce up to 3.25 million kWh/month.

3.1.2 Holloman AFB

Holloman AFB has a similar energy usage pattern as that discussed in Section 3.1.1 for Nellis AFB. In 2009, HAFB used between 5.11 million kWh/month of electricity in February to a high of 7.68 million kWh/month in July. The natural gas usage ranges from a low of 4.47kCF/month (approx. 46 MMBtu/month) in July to a high of 39.0 kCF/month (approx. 400 MMBtu/month) in February. The base also uses some propane, ranging from a low of 1,825 gallons during November to a high of 7,582 gallons in January.

The cumulative electricity consumption for the base in 2009 is shown in Figure 5. Good consumption graphs were available for Holloman AFB in FY-2009. Figure 5 shows that the base is currently conserving and actually consumed less electricity than in 2008, but not quite as low as the 2009 target.

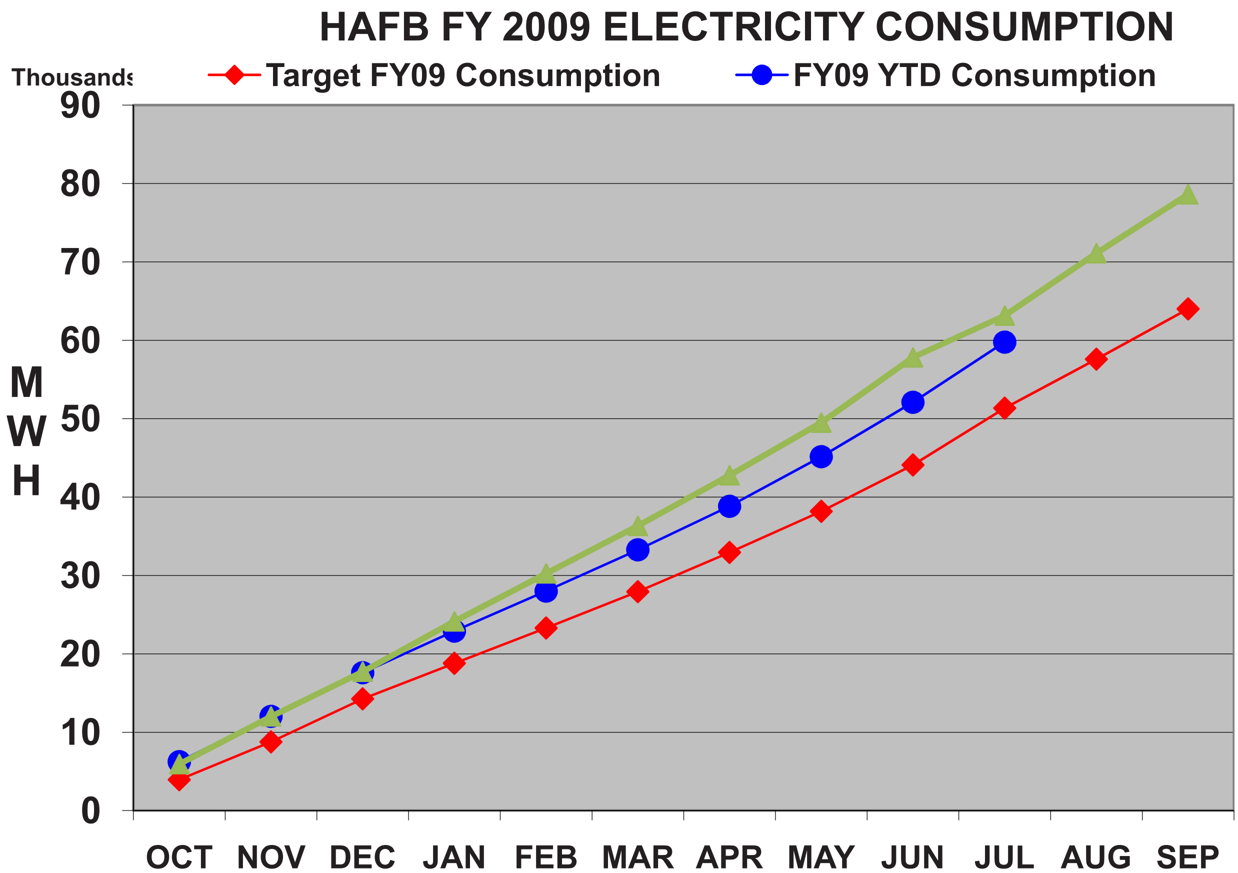


Figure 5. Cumulative electricity usage for Holloman AFB in 2009 (green line shows FY-2008 consumption values).

The natural gas usage for Holloman AFB is shown in Figure 6. The base is doing well against their 2009 targets and is only using slightly more gas than was consumed in 2008.

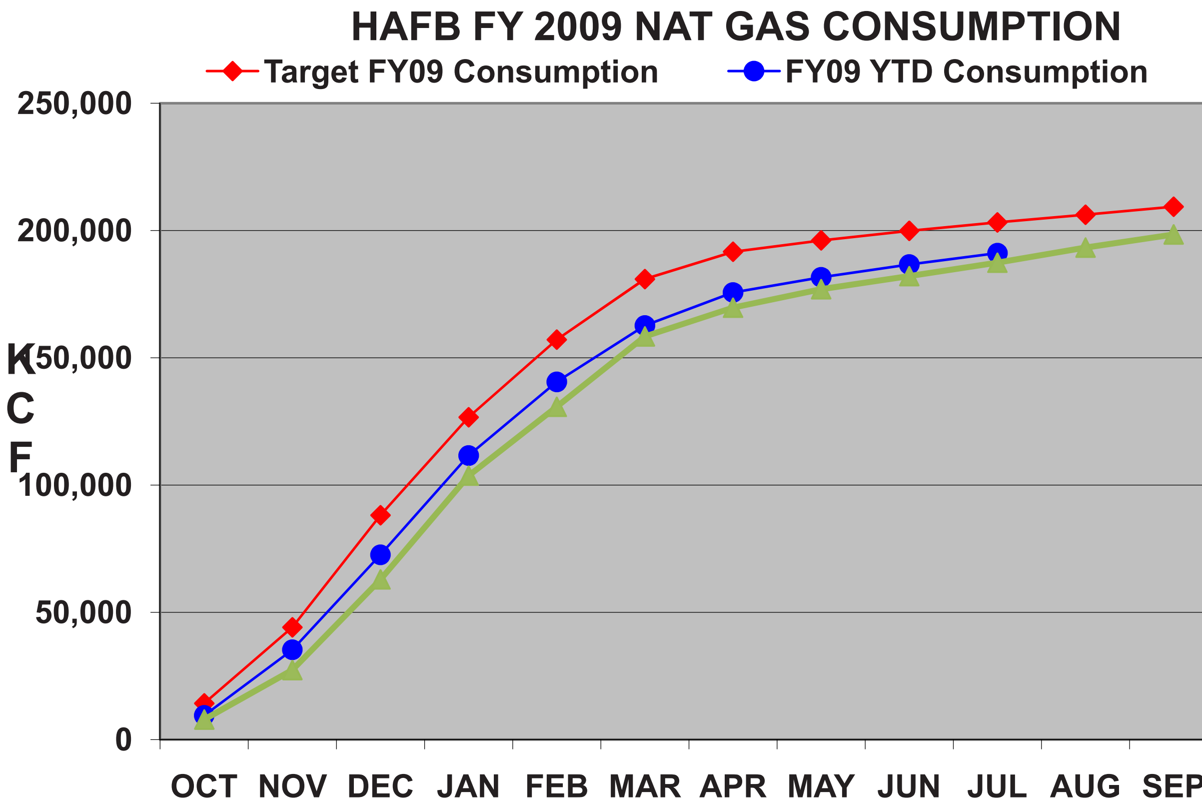


Figure 6. Cumulative natural gas consumption at Holloman AFB in 2009 (green line shows FY-2008 consumption values).

The cumulative energy consumption for all utilities at Holloman AFB is shown in Figure 7, which shows a fairly steady rise over the year. During the winter months, the main source of energy is natural gas used for heating. During the summer months, the load shifts to electricity used for cooling. Any source of geothermal energy for the base would need to focus on meeting both the heating and cooling loads.

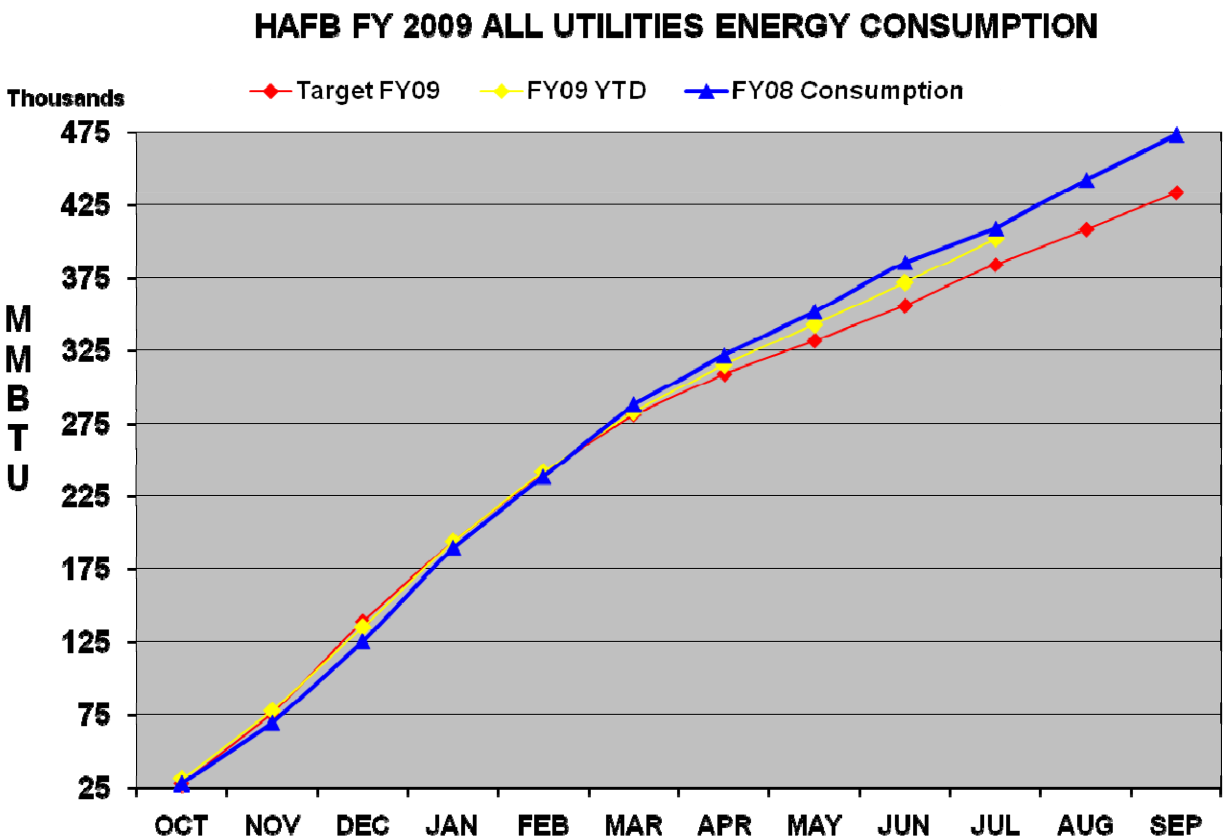


Figure 7. Cumulative energy consumption for all utilities at Holloman AFB in 2009.

3.1.3 Mountain Home AFB

Mountain Home AFB energy usage is slightly different than the pattern relative to electrical usage ranging from a low of 8.8 MW/month in April to a high of 13.2 MW/month in August (based on recent year meter readings). The data available for 2009 shows a modest increase in electrical usage to meet summer cooling requirements. There is also an increase in electrical usage to meet winter heating requirements. Total cumulative electrical usage by the base from August 2009 to 2010 was 136 MW/year at a cost of about $6.5M dollars.

Mountain Home AFB gas usage also follows a similar pattern as for the other two bases. Natural gas usage ranges from low values of 34 kilotherms/month (3.4 MMBtu/month) in August to a high of 379°kilotherms/month (37.9 MMBtu/month) in January. The total gas usage at Mountain Home AFB in 2009 was 2,176 kilotherms/year at a cost of $1.95M dollars.

3.2 Proposed Use of Energy

All three of the bases expect a small to moderate increase in energy usage as projected from 2010–2015 to meet increases in mission objectives. All three are focused on energy conservation to reduce energy usage as much as possible to support reductions identified by Air Force 90-1701, Energy Management, and Executive Orders.

Nellis AFB is focused more on using solar power than any other green technology, and in 2008, their production ranged from 1.63 million kWh/month in December to 3.25 million kWh/month in May.

Holloman AFB is planning 10–15 MW in energy conservation and renewable projects from 2010–2015. They are also focused on installing a 20 MW photovoltaic solar array in the same time frame.

Mountain Home AFB is focused on reducing energy usage by conservation and is interested in renewable solar and geothermal energy sources. Their goal is to reduce usage by 2015 by 30%. MHAFB electrical usage of 9 to 14 MW per year make it attractive to consider some type of geothermal and/or solar hybrid system to reduce dependence on the electrical grid.

3.2.1 Rate Structure for Energy Usages

At NAFB and NAFR, Nevada Energy is the primary local electrical utility. Southwest Gas Corporation is the local natural gas utility. The rate structure for NAFB and NAFR is similar to the rate structure identified for HAFB, which gets its electricity from El Paso Electric and its gas from the Gas Company of New Mexico. The rate structure for electrical energy usage at HAFB in 2008 ranged from a low value of 3.9 cent/kWh to a high of 9.2 cents /kWh in December. In°2009, the rate structure ranged from a low of 6.4 cent/kWh in May to a high of 9.1 cent/kWh in January. Rate structure for MHAFB is estimated to be at 5.5 cent/kWh in 2010, while gas prices will be at about 3.7 cents per MCF (check unit).

4. ENERGY CONSERVATION MEASURES (ECM)/OPTIONS CONSIDERED/GEOTHERMAL RESOURCE POTENTIAL

The current energy usage at each of the three AFBs is a combination of electricity, natural gas, propane, diesel/jet fuel and gas for transportation. The proposed action under this assessment is to locate a site or series of sites that have high enough geothermal potential that any of the bases could use the resource to replace either electrical, gas or propane. The ideal situation of this assessment is to identify a geothermal resource that could be of high enough temperature to allow for production of electricity using a binary cycle power plant (see Figures 8 and 9). A secondary objective is to identify if there is adequate geothermal resource potential that the bases could use to meet the AFB's winter heating and/or summer cooling requirements. For example, space heating would ideally need to have a geothermal temperature exceeding ~175°F. For cooling, the potential to meet this demand would need to come from an absorption refrigeration system with geothermal temperatures at about 200°F.

Figure 9 shows two 15 MW air-cooled binary cycle power plants located near Mammoth Lakes, CA. The air-cooled condensers are located on the perimeter of both plants (the condenser elevation changes for each plant). The length of each set of condenser bays is ~300 ft (or 600 ft length for both plants). The dual plant was designed for a 330°F (166°C) resource. The geothermal heat exchangers for the upper plant are on the right side of the figure between the air-cooled condensers.

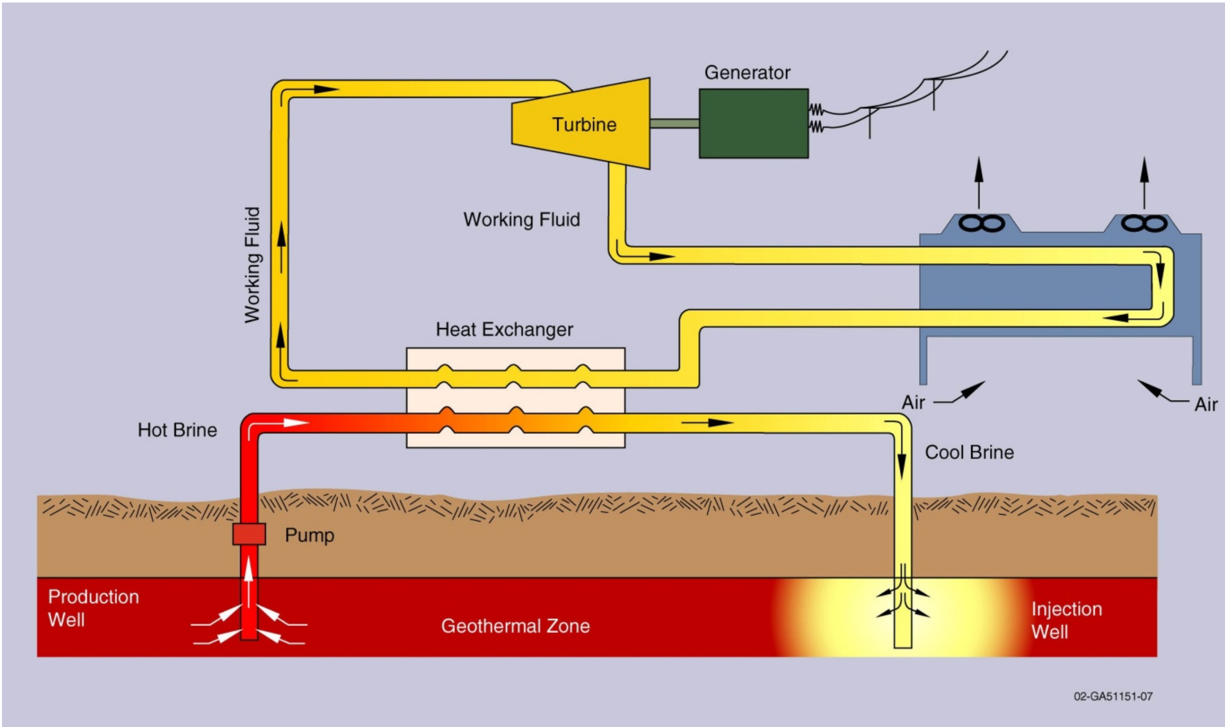


Figure 8. Binary cycle power plant flow diagram.


Figure 9. Two 15 MW air-cooled binary cycle power plants located near Mammoth Lakes, CA.

The geothermal resource temperature that is economically viable for the production of electrical power is dependent upon the cost to develop the well field and the productivity of the reservoir. If the well cost is low and the reservoir is productive, the minimum temperature required decreases. Under favorable conditions, the minimum temperature required can be as low as ~260°F. Power production at these resource temperatures will utilize the binary power cycle technology. In this power cycle, energy extracted from the geothermal fluid in heat exchangers is used to vaporize a secondary working fluid (a refrigerant). The working fluid vapor is then expanded through a turbine to produce electricity. The vapor exiting the turbine is then condensed in air-coolers and the condensate pumped back to the geothermal heat exchangers completing a closed loop for the secondary working fluid. This conversion system is located at the surface, with the hot geothermal fluid flowing from the reservoir to the surface in a production well. The cooled geothermal fluid leaving the plant is reintroduced, via an injection well, back into the reservoir to be reheated and used again.

When the geothermal fluid is not hot enough to produce electricity, other considerations should be evaluated to see if this resource can be utilized. Below we will discuss what some of these alternative approaches could be.

One approach is to utilize the geothermal source for direct heating of buildings during the colder months of the year. By directly using the resource, you do not go through the inefficiencies of power generation to turn around and use it to heat with. Though temperatures above 175°F are considered ideal for space heating (Geothermal Resources Council Special Report No. 7, 1979), lower temperatures might also be used under favorable conditions.

Another option is to incorporate the appropriate refrigeration cycle and utilize the lower temperature heat from the geothermal resource to help drive the process. This idea is being implemented currently with temperatures as low as about 160°F to provide cooling, and could potentially provide a resource of air conditioning, power generation, and/or heating depending on how it is operated. Another concept that could be considered if the geothermal fluid was too low (120–140°F) for a conventional absorption chiller would be to have a hybrid geothermal-solar unit where solar heat exchange could bring the temperature of the geothermal fluid from 140°F to 200°F.

Another approach would set up a system to incorporate ground-source heat pumps. By using heat pumps you can manage a resource and adjust the temperature up and/or down within a defined range. This could potentially upgrade a lower-grade resource into a range that is useable. Geothermal heat pumps reduce electricity use by 30-60% compared with traditional heating and cooling systems, because the electricity that powers them is used only to move heat, not to produce it.

4.1 Nellis AFB and AFR

An extensive amount of literature and Geographic Information System (GIS) coverage was evaluated and/or built for the Nellis complex. The full evaluation of the assessment can be found in Appendix A. Based on the available data from the ITSI report (2003) and Coolbaugh (2005), there are a number of sites at NAFB and NAFR that could be considered “most favorable” or “may be prospective.” They also indicate that thermal indicators from wells in Pahute Mesa and Gold Flat may indicate hot, upwelling fluids in the area.

There is a general lack of thermal springs and other direct manifestations of geothermal energy in Nellis AFR. As a consequence, ITSI (2003) and Coolbaugh (2005) both use indirect methods of determining geothermal potential based on criteria such as geologic/tectonic models, heat flow, seismicity and other information. Although their methods strongly correlate with producing fields, the “sufficiency” and “necessity” of their criterion for deriving potential have not been fully established.

4.1.1 Summary Recommendations and Conclusions

Further work should take into account the potential use of geothermal resources on the base. Exploration and development for electrical generation, if successful, is likely to be feasible anywhere on the base or nearby range since power lines can interconnect generation and users. Direct use grade resources, however, must be co-located with possible uses in order for the resource development to be economic. The higher value of electrical generation also allows greater expenditure for exploration of electrical capable resources.

Initially, Nellis AFB should contract with a qualified geothermal geochemist to review the existing chemical analyses from springs within and close to the Nellis AFR and determine geothermometers where applicable. The review should include not only those analyses reported by ITSI (2003), but also the analyses available from the Great Basin Center for Geothermal Resource web-based data set (http://www.unr.edu/geothermal/GeochemDB.htm).

The project should include a review of the charge balance of all analyses and should also consider the pH if it was determined in the field at the time of sampling. Charge balance is an indicator that the analysis is good and that errors have not been made in reporting major elements (such as Ca, Na, K, and Mg) that are used in the cation geothermometers. High pH, generally above 9, increases the solubility of Si and can lead to erroneous temperatures calculated from silica geothermometers. In areas of the base where groundwater may be affected by high salinity from playa waters, pH may be elevated. Cation geothermometers are also affected by mixing of geothermal fluids with saline groundwater.

In order to define the geothermal resource potential in more detail it requires a detailed evaluation of the site estimated at about two to three man-months of effort. This type of study would ideally be conducted by either a university or consultant firm and target the areas identified above. These areas are highlighted on the resource potential map for Nellis AFB in Figure 10. The numbered areas on this map correspond to the following locations:

1. Sheep Lake and the western Sheep Range
2. a. Kawich Range and Cactus Flat
   b. eastern Kawich Range and western Reveille Valley
3. Stonewall Mountain
4. Groom Range and Groom Lake
5. West side Belted Range and Eastern Kawich Valley
6. Sarcobatus Flat-Scottys Junction
7. Beatty
8. East side Blue Mountain

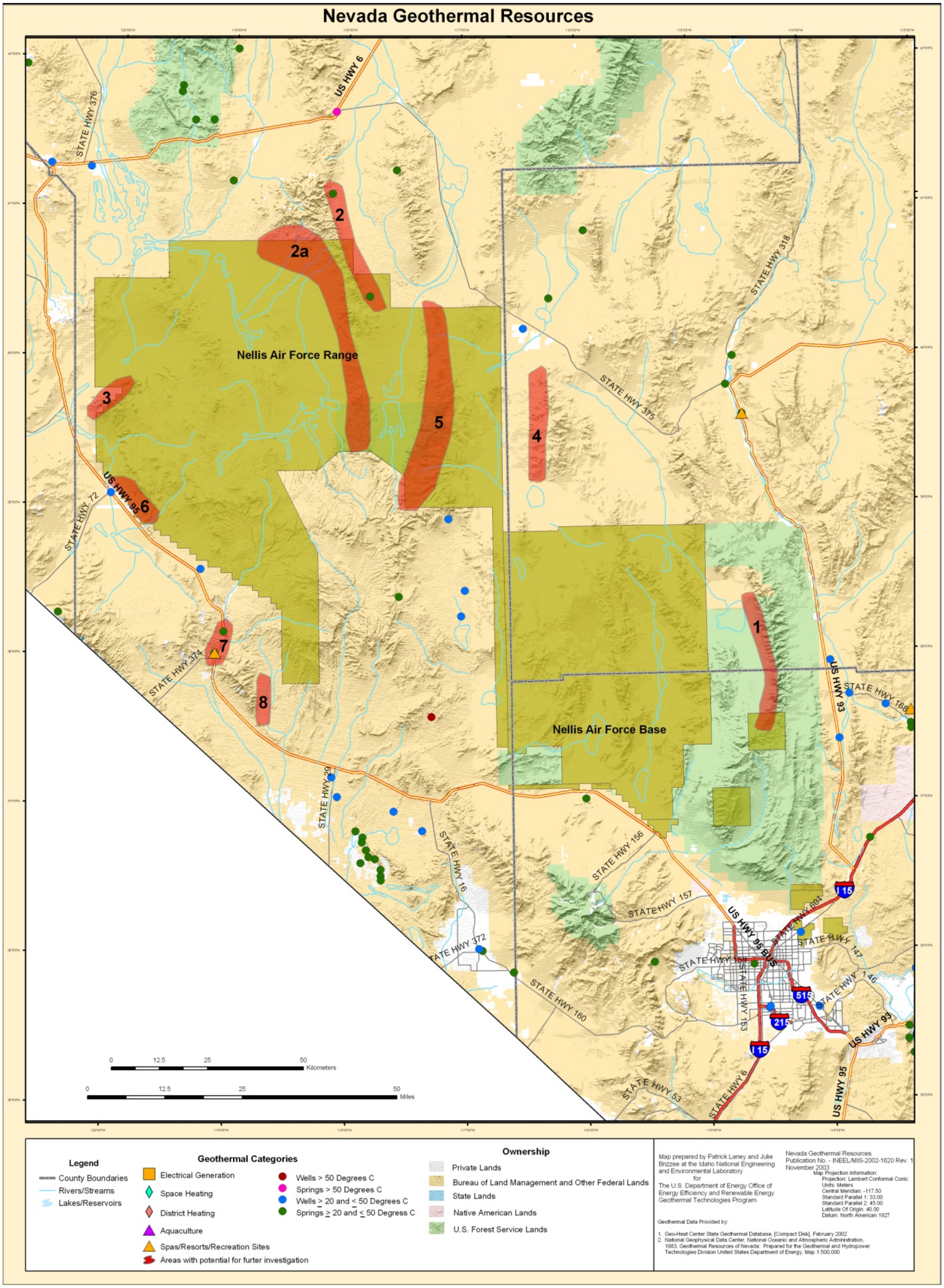


Figure 10. Nellis AFB and AFR high-potential geothermal areas.

4.2 Holloman AFB

For Holloman AFB, an extensive amount of literature and GIS layers were evaluated to assess the resource potential. The full evaluation of the assessment can be found in Appendix A. Based on the data available, ITSI (2003, p.122, sect 7.1.4) concluded “no evidence suggests that utility-grade geothermal exists at Holloman AFB and its potential there is rated as **low**.” This interpretation of geothermal resources within and surrounding Holloman AFB appears to be reasonable.

ITSI (2003) conducted field investigations at Bear Peak, approximately 30 miles (48 km) SW of Holloman AFB and within the White Sands Missile Range, and at Twin Buttes, approximately 4 miles (7 km) south of Holloman AFB and adjacent to White Sands Missile Range. Self-potential mapping at Bear Peak and its geologic setting suggested to ITSI (2003) that further work there would be warranted. Such work could include drilling temperature gradient wells and possibly conducting a resistivity survey. ITSI did not recommend any additional work at Twin Buttes.

Based on existing data including the geologic models of forced convection by Morgan et al. (1981) and the ITSI (2003) report, there do not appear to be potential development sites associated with Holloman AFB proper.

Further geothermal work is not recommended at Holloman AFB. However, USAF might want to continue investigation of electrical potential at Bear Peak and wheeling the power to Holloman AFB. Another viable alternative is to continue to have Holloman AFB staff team with base personnel at both White Sands Missile Range and Ft. Bliss to pool resources to evaluate if a resource of high enough quality could be developed to provide enough power to meet requirements from several of the DoD facilities located in the region. Based on the assessment shown in map 7, it looks as though the best potential geothermal resource is located under Ft. Bliss. The principal area of interest on Fort Bliss is at the McGregor Range in an area called the Hueco Tanks. The zone of geothermal interest was discovered when shallow water wells encountered “hot mineralized water” ranging in temperature from 51° to 71°C. Silica geothermometry performed on water from existing wells reveals a NW-SE trending anomaly, with maximum temperatures of about 140°C (Taylor et al., 1980; ITSI, 2003).

ITSI (pages xiii, xiv and xv, 203) rates the potential for both electrical generation and direct use as high in the Holloman-White Sands Fort Bliss region. In fact, Ft. Bliss personnel are collaborating with the city of El Paso, TX, on an exploratory investigation, cost shared with the U. S. Department of Energy, Geothermal Technologies Program,. There is an existing power line from the city of El Paso to Holloman AFB that may make it possible for considering a regional power option very attractive.

Based on the geothermal occurrence models discussed in this report and the results of SP work east of Bear Peak, additional exploration targets for geothermal development should be investigated in the vicinity of WSMR and Fort Bliss along active normal faults that bound the deeper, western half of the Tularosa Basin. Minimally, the Bear Peak SP anomaly as well as several other similar targets not investigated during this project should be evaluated. Suggested additional areas include the Mockingbird Gap region, between Mockingbird and Little Burro Mountains, about 10 miles S of the Trinity site in north central WSMR. Mockingbird Gap may be a releasing bend as evidenced by fault locations and the geometry of the ranges. Additional field reconnaissance work plus possibly a CO2 soil gas survey is recommended. According to Highsmith (R. P. Highsmith, Chemex Labs, Sparks, NV, personal communication 2003), soil gas surveys have proven to be extremely effective for evaluating suspected faults or fractured channelways where upward-flowing fluids are locally concentrated.

Although late Quaternary activity of the San Andres fault and Organ Mountains fault (i.e., the Bear Peak anomaly that sits on the San Andres fault) is well documented, the activity of the Jarilla Fault zone currently is not known. This target area should be investigated, perhaps with geophysical surveys.

4.3 Mountain Home AFB

Mountain Home AFB is located in a part of the Snake River Plain (SRP) where geothermal resources are known to exist.

4.3.1 Potential Development Areas Associated with Mountain Home AFB

The ITSI (2003) report recommended that further work not be conducted at Mountain Home AFB. However, the gravity data suggests that deep fractures may occur beneath the base. This fracturing may host a hydrothermal convective system and is a logical place to conduct additional investigations of the geothermal potential beneath the base.

4.3.2 Summary Recommendations and Conclusions

Although the ITSI (2003) report did not recommend additional work at Mountain Home AFB, that report limited its recommendation to electrical generation grade resources. The current review of their data and earlier studies in this area of the SRP suggest that their conclusion may be correct. However, there does appear to be potential for resources suitable for direct application of heat.

Geothermometry suggests that the source of the water sampled in several water and monitoring wells on the base may be 40–70°C (104–158°F). Additionally, the reported temperature of 94°C (approximately 200°F) of the geothermal well MH-1 reported by Lewis and Stone (1988) is encouraging of temperatures suitable for direct use.

Geothermal resources in the SRP in the vicinity of Mountain Home AFB are likely to be associated with upward movement of fluid along deep fault zones. Hence, as a first phase in reconnaissance we suggest that the existing regional gravity and aeromagnetic studies be reviewed to determine possible fault zones underlying or adjacent to the base. The next phase of investigation should include drilling temperature gradient wells (200–500 feet deep) near the fault zones to investigate whether any temperature anomalies are associated with the fault zones. If anomalies are found, deeper gradient wells should be drilled to intercept the fault zones at depths where temperatures may be suitable for use.

There does appear to be a moderate likelihood that a geothermal resource capable of providing fluid useful for direct use may be found beneath the base. We agree with ITSI (2003) that there is no indication of a resource capable of supporting electrical generation beneath the base. However, there is a chance that temperatures similar to those found in the Bostic 1-A well (195°C at 9700 ft.) may be encountered through deep drilling beneath Mountain Home AFB.

4.4 Recommendations

The recommendation for Nellis AFB and AFR is to seek a consultant or university professor that has an interest in supporting development of geothermal resources on and around the Nellis complex. Ideally, a university professor could receive funding from either DoD or DOE to hire a graduate student to conduct the type of analysis discussed in sections 4.1 and Appendix A.

The recommendation for Holloman AFB is to form collaborations with other DoD bases in the New Mexico area to identify if a regional approach can be established to help them meet their future energy needs using potential geothermal resources.

For Mountain Home AFB, the recommendation is to seek support to drill an exploratory test hole that supports other activities that are currently being pursued. Details of this recommendation are presented in Section 6. A detailed savings report at Mountain Home AFB is shown in Table 2. These values were generated based on the assumption that a test well could find a resource of high enough quality with sufficient flow rate to power an electrical generation system or to run a heat exchange system to meet 50% of the base's current heating requirements supplied by natural gas. The base used about 2,176 kilotherms/yr (approx. 217.6 MMBtu/yr) of natural gas in 2009 at a cost of $1.95 million dollars. A 50% savings of this would be about 1,088 kilotherms/yr (approx. 108.8 MMBtu/yr) at a cost savings of about $950,000/yr. This would equal about 108.8°MMBtu/yr. It is beyond the scope of this assessment to go into design cost savings and O&M savings for a potential geothermal resource to electrical power system. The next step is to assess the potential for the resource and once some good data are available, better energy and cost saving values can be determined.

Table 2. Detailed savings report at Mountain Home AFB.

	Recommendation
Specific energy replacement/ savings /yr	1,088 kilotherms/yr
Specific fuel/energy savings ($/yr)	$950,000/yr
General fuel/energy savings (MMBtu/yr)	108.8 MMBtu/yr
O&M savings ($/yr)	TBD
Productivity improvements ($/yr, materials/yr)	TBD
Labor savings (hours/yr, $/yr)	TBD
Other savings as identified	TBD
Total energy savings (MMBtu/yr)	108.8 MMBtu/yr
Total cost savings ($/yr)	$950,000/yr
Conceptual implementation costs ($)	TBD
Simple payback (years)	TBD

5. POTENTIAL GREEN HOUSE GAS REDUCTIONS

The potential for green house gas (GHG) reductions for a potential Mountain Home AFB project would be significant because a non-carbon based resource would be used to replace natural gas and electricity. If this project is successful and a potential Mountain Home AFB project is capable of setting up a network of well and collection systems, the geothermal energy system could replace some of the natural gas usage and have some benefit in reducing the net national GHG load.

Using the green house gas calculator found at http://www.epa.gov/cleanenergy/energy-resources/calculator, the savings of 1,088 kilotherms/yr (approx. 108.8 MMBtu/yr) of natural gas would reduce carbon dioxide or CO_2 equivalent by about 5,440 Metric tons. This is equal to the annual greenhouse emissions from about 1,040 passenger vehicles.

6. ACTION PLAN FOR IMPLEMENTATION OF ECMS

6.1 Nellis AFB and AFR

The action plan for Nellis AFB is to work with regional geothermal experts to conduct additional testing to determine if a resource of high enough quality exists to warrant potential exploratory test wells in the future. Specific steps that should be taken include a review of all available geochemical data to determine the possible presence of hidden geothermal systems. It would also be a good idea to evaluate the existing geochemistry data and use it to run models to evaluate the potential of the resource and interactions between chemistry constituents to determine probable resource temperature. The time frame to conduct these types of geochemistry assessment would most likely be on the order of one to two months of effort. A rough estimate of the costs for these types of assessments would be between \$5k and \$10k. If geothermometers suggest systems with temperatures suitable for electrical generation, further exploration would be warranted. The next step should include a review of aerial or satellite imagery, which coupled with field visits, could determine if alteration zones or silica or carbonate deposits suggest geothermal activity. The same imagery should also be used to determine if there is recent faulting that could indicate potential pathways for the circulation of geothermal fluids. If the preceding studies are positive, then the next logical step would be the determination of shallow subsurface temperatures through the drilling of temperature gradient holes. Shallow holes, approximately two to five meters deep, can indicate upwelling of thermal water and can be rapidly drilled and sampled. However, their use is limited in areas where groundwater movement affects the temperature profile. Shallow thermal anomalies most likely represent outflow plumes, but do provide an indication that a deeper geothermal system may be present.

6.2 Holloman AFB

The overall action plans for the geothermal projects at Holloman AFB range from taking limited action to actual drilling of an exploratory well. This action is focused on having the energy manager at the base and USAF collaborate with both Ft. Bliss and the White Sands Missile Range to identify if there is an opportunity for HAFB to meet some of their energy needs through a collaborative venture with other DoD partners. The geothermal resource under HAFB is judged to not be of sufficient quality to support additional exploration at the current time.

6.3 Mountain Home AFB

The plan for Mountain Home AFB is to have the USAF and base staff team up with collaborators from the International Continental Scientific Drilling Program (ICDP) on drilling an exploratory well on the main base site. There is a very unique opportunity to develop this teaming partnership. FEMP has allowed for technical expertise to be focused on challenges and opportunities on and around Mountain Home AFB. It has also provided the opportunity to coordinate with collaborators to verify where the well will be located and to help develop the drilling specifications for the well. The information provided in the remainder of this section will provide background and detailed information on the further actions that will be taken to support the drill of the exploratory well at Mountain Home AFB.

6.3.1 Background

There has been scientific interest in collecting additional information on geothermal resources associated with the SRP for many years. More recently there has been a collaborative effort to seek support in increasing exploration across the SRP and at MHAFB through the efforts of the ICDP (http://www.icdp-online.org), Utah State University (USU), the U. S. Bureau of Land Management (BLM), DOE, and DoD, among others. ICDP has long held an interest in addressing pressing basic science questions related to geology, hydrogeology, geochemistry, and geophysics of the earth's crust. In particular, ICDP is interested in the SRP because it represents a world-class example of active mantle plume volcanism in an intra-continental setting. To characterize and understand this unique geologic province, ICDP developed a plan, called "Project Hotspot," to core a series of three drill holes along the axis of the eastern and western SRP to study the geochemical and stratigraphic variations in plume-related volcanism in space and time. The initial Technical Workshop for Project Hotspot was convened on May 18-21, 2006 in Twin Falls, ID. A second Technical Workshop was conducted on 21 Sept. 2009 in Twin Falls, ID. At the 2009 meeting, there were 18 participants from four countries (U. S., Germany, Canada, and the United Kingdom [UK]), including site representatives from USAF (MHAFB), BLM, and the University of Idaho-Extension Farm. Dennis Nielson, president of Drilling, Observation and Sampling of the Earths Continental Crust Exploration Services, LLC (DOSECC) was also present.

The scientific goals and objectives of Project Hotspot are described in some detail in white papers and in the full proposal to ICDP (http://www.usu.edu/geo/shervais/Shervais-USU-Geology/Project_Hotspot.html). The over-arching goal is to understand the Snake River-Yellowstone hotspot system, and to determine whether it represents deep-seated processes involving the lower mantle, or shallow processes confined to the lithosphere and underlying asthenosphere. Major research questions include: (1) How do mantle plumes interact with continental lithosphere/crust, and (2) What does this interaction tell us about fundamental processes of continental dynamics & geochemical evolution of earth? Project Hotspot will address these questions using basalts as a probe of mantle geochemistry, and results from oceanic hotspots as a baseline for non-continental plume volcanics.

At the 2006 and 2009 workshops, it became apparent that by working together, MHAFB and Project Hotspot could achieve their respective program goals at a greatly reduced cost. MHAFB is situated in an active geothermal region and needs to evaluate the geothermal potential of the deep subsurface beneath the base. Deep coring has been performed in the past with limited success and due to cost constraints at the time of the previous drilling, some needed deep data were not collected, specifically geophysical logs and hydraulic tests. In the previous MHAFB geothermal drilling project, core was not taken for the entire thick sequence of lake bed sediments (~532 to 1900 ft) because the shallow geology is not important for evaluating geothermal resources. However, core was taken below 1,000 ft to 4,403 ft (below 1,900 ft the rock was principally basalt (Lewis and Stone, 1988). Project Hotspot needs a complete section of core through the lake bed sequence to answer major science issues, for instance, the biotic recovery of ecosystems following large explosive volcanic eruptions on the SRP. Project Hotspot also needs core data, geophysical logs, and hydraulic tests of the deep basalts. Thus, by Project Hotspot paying for the upper 2,000 ft of drilling and the USAF paying for drilling below 2,000 ft, both entities will be able obtain the required data at about a 50% reduction in cost compared to working alone.

In May 2010, a workshop was held to bring together a set of experts to discuss and develop a process for conducting collaborative drilling of a Project Hotspot Well at MHAFB. In attendance at this workshop were representatives from MHAFB, Langley AFB, USU, the U. S. Geological Service (USGS), INL, Idaho Power, and URS Corporation. It was collectively determined by all in attendance that the Project Hotspot Drilling Project provided an incredible opportunity for achieving considerable cost savings for investigating the deep geothermal resources beneath the base. Base and headquarters staff decided to pursue this opportunity and would seek DoD funds to deepen the Project Hotspot Hole to at least 4,000 ft or more. Assignments were made to various team members at the end of the May 2010 meeting in order to get the project on line and operational for a drilling start date of about February 2011. The remainder of this section describes design aspects for the project related to drilling and subsurface testing.

6.3.2 Project Hotspot Drilling Plan

The overall drilling plan for Project Hotspot is described briefly here to provide context for the drilling to be done at MHAFB, because it will precede the drilling performed and funded by USAF. The Project Hotspot drilling plan calls for two deep holes in the central SRP and one shallow hole in the western SRP (MHAFB). The two deep holes in the central SRP comprise an offset pair, with one hole sited to recover the upper part of the section and the second hole sited to recover the lower portion of the section. This will allow for recovery of a complete section through the volcanics—something that has never been accomplished in any of the existing holes—at minimal cost per meter. It will also allow each hole to be sited for optimal recovery. The maximum thickness of basalt is found along the axis of the plain, but sites here are likely to coincide with sections of thick intracaldera fill that need to be avoided in the rhyolite hole. The shallow western hole will be sited to recover the upper portion of the Mountain Home section not cored by the Mountain Home AFB hole. These holes are described in more detail below.

Drilling will be carried out by DOSECC using their equipment. DOSECC recently purchased a new Atlas-Copco CP4002 truck-mounted drill rig with a lift capability of 18,000 kg and depth capacities of up to 3,500 ft with PQ drill string, 5,250 ft with HQ drill string, and 8,000 ft with NQ drill string. Figure 11 shows a picture of this drilling rig. This will allow Project Hotspot to reach the projected depth targets (1.5 to 1.8 km) with the capacity to penetrate deeper if needed and funds are available. This rig was purchased specifically to address continental scientific drilling projects with moderately deep target depths, including Project Hotspot.

Figure 11. DOSECC Atlas-Copco CP4002 truck-mounted drill rig.

DOSECC will be responsible for all drilling related activities, including site preparation and cleanup, mobilization, and demobilization. Logging will occur at intervals agreed upon by the Project Hotspot science team and DOSECC in advance. Responsibility for core handling will be transferred to the science team at the rig, after the core is removed from the core barrel. The holes will all have a surface seal (40 ft) that will be cased to comply with Idaho Department of Water Resources (IDWR) regulations on well construction. The subsequent core will be PQ to 800 m, and HQ down to around 1,600 m; the PQ and HQ rod will be left in the hole as casing and the lower part of the hole will be cored in NQ size to depth, through the PQ and HQ rod. Final depths for the deep holes will be 1.5-1.8 km; final depth for the shallow hole will be 2,300 ft.

(1) Hotspot Hole #1 Kimama (basalt).

This hole will be located just north of Kimama junction, along the axial volcanic high of the central SRP, within or adjacent to the BLM Kimama Fire Station. Potential field, resistivity, and well data have been used to infer a basalt thickness of 1.2 km to 1.4 km in this area (Lindholm, 1996), which lies ~25 km west of the Great Rift. The topographic axial volcanic high is apparently mirrored by a keel of basalt that runs from the central plain to the eastern plain, and thins both towards the margins and towards the ends. The hole will spud into late Pleistocene basalts around 200 ka in age and should end in rhyolite around 1.4 km depth. Drilling will continue ~650–975 ft into the underlying rhyolite to allow correlation with Hotspot Hole 2. Anticipated total depth for this hole is 1.5 km. This hole will be drilled in cooperation with BLM and the National Park Service at Craters of the Moon, and developed into a long-term observatory and outreach site.

(2) Hotspot Hole #2 Twin Falls [Kimberly] (rhyolite).

This hole will be located at the University of Idaho Extension Farm in Kimberly, five miles east of Twin Falls, along the southern margin of the central SRP. Potential field and resistivity data have been used to infer a basalt thickness of 100–500 ft in this area (Lindholm, 1996), which is confirmed by exposures in the Snake River Canyon at Twin Falls and drillers logs for existing geothermal and water wells located in and around Twin Falls. This hole will spud into the Basalt of Hansen Butte, which has an Ar-Ar age of 2.0 Ma (Tauxe et al., 2004). The location of this hole is based on the goal of penetrating a complete section of proximal rhyolite outflow sheets from the underlying eruptive complex and sampling the underlying basement – which may include pre-rhyolite basalt, based on the current model for hotspot volcanic progression. Deep holes near the volcanic axis of the SRP must first penetrate thick sections of basalt before hitting rhyolite. More importantly, locations near the central axis of the plain are likely to penetrate the central regions of the rhyolite eruptive complexes, sampling thick sections of intra-caldera fill (breccias, lavas, ignimbrites) that may be underlain by intrusive rhyolite as in the drill hole INEL-1, which bottoms in rhyolite at 3 km depth (Morgan et al., 1984). Hotspot Hole #2 will be situated to penetrate a thin cover of basalt and sediment, underlain by proximal rhyolite outflow sheets of finite thickness. These may be underlain by pre-rhyolite basalts, which will be crucial to understanding the Hotspot magmatic system, and have never been sampled before (these basalts do not occur outside the margins of the plain). Anticipated total depth for this hole is 1.8 km.

(3) Hotspot Hole #3 Upper MH (basalt, sediment).

The primary science goals of the Mountain Home drill core are to sample the upper section of basalts not cored by the existing MHAFB MH-1 drill core, and to sample the Pliocene-Pleistocene transition in lake bed sediments which underlie the upper basalts (also not sampled by the MH-1 core). Target depths are well known by lithological and geophysical logs from the MH-1 geothermal exploration well (Lewis and Stone, 1989), USGS monitoring wells (USGS, 1999), and from more recent monitoring wells. The local stratigraphy was reviewed by David Schwarz (URS Corporation), who has overseen much of the recent work at MHAFB, which involved a series of wells up to 450 ft. deep. As a result, there is an excellent understanding of the local stratigraphy. This hole will sample the upper part of the section penetrated by the Mountain Home AFB drill hole, which was rotary drilled to ~330 m, and recover a complete section of the upper plateau-forming basalts and the underlying lacustrine sediments. The upper basalts formed after a prolonged volcanic hiatus of 3-5 million years; comparing these with the older sub-lacustrine basalts will be central to understanding long-term hotspot volcanism. The lacustrine sediments provide a record of climate change during the late Pliocene to Pleistocene, and contain fossil fauna that may record the impact of major cataclysmic volcanic eruptions on faunal diversity and evolution.

The proposed depth for coring in this hole is 2,300 ft below land surface (bls). This depth would penetrate the lake sediments and overlying basalts, and tag lower basalts at around 1,900 ft (Lewis and Stone, 1989). The USAF will extend the hole depth using a rotary rig below 2,300 ft to test the economic potential of the known geothermal resource that exists under the base. The anticipated total depth for this hole is 5,000

6.3.3 Well Location

Hotspot Hole #3 (HH-3), or the Mountain Home Geothermal Well, will be located near the undeveloped northwest corner of MHAFB (see Figure 12). There is geophysical evidence suggesting this area may be located near a gravity anomaly, perhaps caused by Basin and Range faulting, which may be favorable for geothermal exploration. The location was selected for several reasons including favorable indications of deep faulting, the proximity to base utilities, and the close proximity of the well to the northwest entrance of MHAFB, which allows for ready access to and from the site by the drillers and the scientific team. The drill pad has been constructed by base personal and consists of approximately a one-foot thick layer of pit run gravel covering an area of 100 x 100 ft and an all-weather access road from Perimeter Road to the drill pad. Power will be supplied by on site generators provided by DOSECC and the science team.

The drill site is less than 1.5 miles from the original MH-1 (4,403 ft) geothermal exploration well, which was drilled along the eastern margin of the Base. The overall stratigraphy at this site is expected to be more or less identical to that found in the MH-1 well. The proposed site is within 2,500 feet of an existing 450-ft deep monitoring well (MW-3-2), and near two other monitoring wells, so the upper stratigraphy is known. However, no core is available from the monitoring wells. Logistically, the proposed site is located adjacent to the contractor’s gate, making access relatively easy and avoiding the need to drive through the residential and access-restricted industrial areas of the base. The MHAFB location is located 8 miles southwest of the town of Mountain Home, ID (population 13,000), which has most needed services, and approximately 50 miles southeast of Boise, ID, which hosts a major regional airport.

Figure 12. Location map of Well HH-3 and distances to existing monitoring wells.

Because drilling at this site will be carried out in conjunction with the USAF ACC as part of their geothermal exploration project, the USAF will acquire all the necessary permits and complete any needed surface restoration for this site. They will assume ownership of the drill hole on completion and may keep this well open (and enlarge it) to potentially use as geothermal reinjection well. USAF is interested in obtaining geophysical logs for the proposed well, especially detailed thermal logs. A further goal is to carry out aquifer tests at deeper intervals, which will require a relatively large diameter drill hole.

6.3.4 Well Design

Design of the drill holes and coring strategy was driven by State of Idaho regulations, the science goals, and the capabilities of the CS4002 drill rig. The IDWR and Idaho Department of Environmental Quality (IDEQ) are the lead agencies in charge of administering and enforcing the various rules and regulations governing water use and water quality in the State of Idaho. IDWR is responsible for issuing water rights, well construction permits, and underground fluid injection wells. IDEQ is responsible for administering surface disposal of wastewater, including geothermal fluids.

IDWR is the lead agency responsible for regulating all water, monitoring, low temperature geothermal, and injection wells, and other artificial openings and excavations in the ground greater than 18 feet below land surface. A surface casing and its annular seal must extend to not less than 38 feet below land surface for the proposed wells. The minimum annular space required between the borehole and the surface casing must provide for a uniform seal thickness not less than two inches larger than the outside diameter of the casing to be sealed. These administrative rules and regulations governing well construction described in IDAPA 37 Title 3 Chapter 9 will be followed in our well designs and permit applications.

During the two previously described workshops participants familiar with drilling activities elsewhere on the SRP strongly recommend drilling the upper portion of each hole as deep as possible with PQ drill rod to allow two size reductions at depth (to HQ and NQ) in case of problems during drilling. This is especially important in the basalt sections, where rubble intervals may be encountered. They further recommend that after switching from PQ to HQ drill rod, to continue with HQ to the maximum depth achievable before switching to NQ, for the same reasons. In all cases, the switch to the next smaller drill rod may occur above the stated design depth in response to stuck drill rods, to improve drilling rate, or to meet cost-depth targets. In all cases, the decision to switch from larger to smaller drill rod above the stated design depth will be made by the Chief Scientist, in consultation with the Chief Driller, the principal investigators, and the MHAFB representative.

The Mountain Home AFB drill hole will have slightly different construction than the other two hotspot wells, in part to accommodate the collection of larger diameter core from the lake sediments, and in part to allow the deepening of the drill hole to 5,000 ft, with a large enough diameter hole to accommodate a submersible pump for pump testing the geothermal resource. As a result, the Mountain Home drill hole will be designed with a larger surface casing (10 in.) and be drilled from 0-2,300 ft bls with PQ drill rod. This rod accommodates the plastic liner used for the lake core samples, which will be sealed and sent to LaCore for further study.

The section below 2,300 ft bls will be rotary drilled. Drilling to 5,000 ft bls into a potential geothermal aquifer will require posting of a surety bond with IDWR; the cost of the bond will be borne by the USAF. IDWR may require the installation of gate valves or annular blow out prevention equipment to prevent the uncontrolled blow out of drilling mud and geothermal fluid.

If such equipment is required by IDWR, then the additional cost would also be borne by the USAF.

Well construction and testing will follow these basic steps:

1. Drill from land surface to 40 ft with PHD drill rod collecting PQ core.
2. Ream to a 13-inch hole to 40 ft.
3. Set 10-inch schedule 40 surface casing to 40 ft.
4. Pressure grout 10-inch surface casing to land surface creating a 2 ¼ -inch annular seal.
5. Drill from 40 ft to 1,000 ft with PHD drill rod collecting PQ core (3.34" core and 4.8" hole).
6. Geophysical logging by INL USGS.
7. Ream to a nominal 10-inch hole (9 ¾-in) from 40 to 1,000 ft.
8. To the extent practical and based on geologic conditions set a packer at 600 ft and conduct a pumping test of zone 600 to 1,000 ft (for water yield).
9. Set 8-inch schedule 40 casing from +2 ft land surface to 1,000 ft.
10. Pressure grout 8-inch surface casing to land surface creating a 0.69-inch annular seal.
11. Install suitable blow out preventer (BOP) stack for well control as required.
12. Drill from 1,000 ft to 2,300 ft with PHD drill rod collecting PQ core.
13. Geophysical logging by INL USGS.
14. Demob Atlas COPCO 4002 rig from site.
15. Mob rotary rig with downhole hammer capabilities.
16. Ream to nominal 8-inch hole (7 ¾") 1000 to 2300 ft.
17. Drill nominal 8-inch hole, 2300 to 5000 ft.
18. Perform geophysical logging.
19. If needed, install 6-inch casing (0 to 4,000 ft) and drill ahead with nominal 6-inch open hole (5 ¾").
20. As appropriate, based on thermal profile and geophysical well logs, perform packer tests and collect water samples of lower borehole.
21. Lock and secure well.
22. Perform temperature logging (wait for temperature equilibrium ~3 months after drilling).

A schematic well diagram is provided in Figure 13.

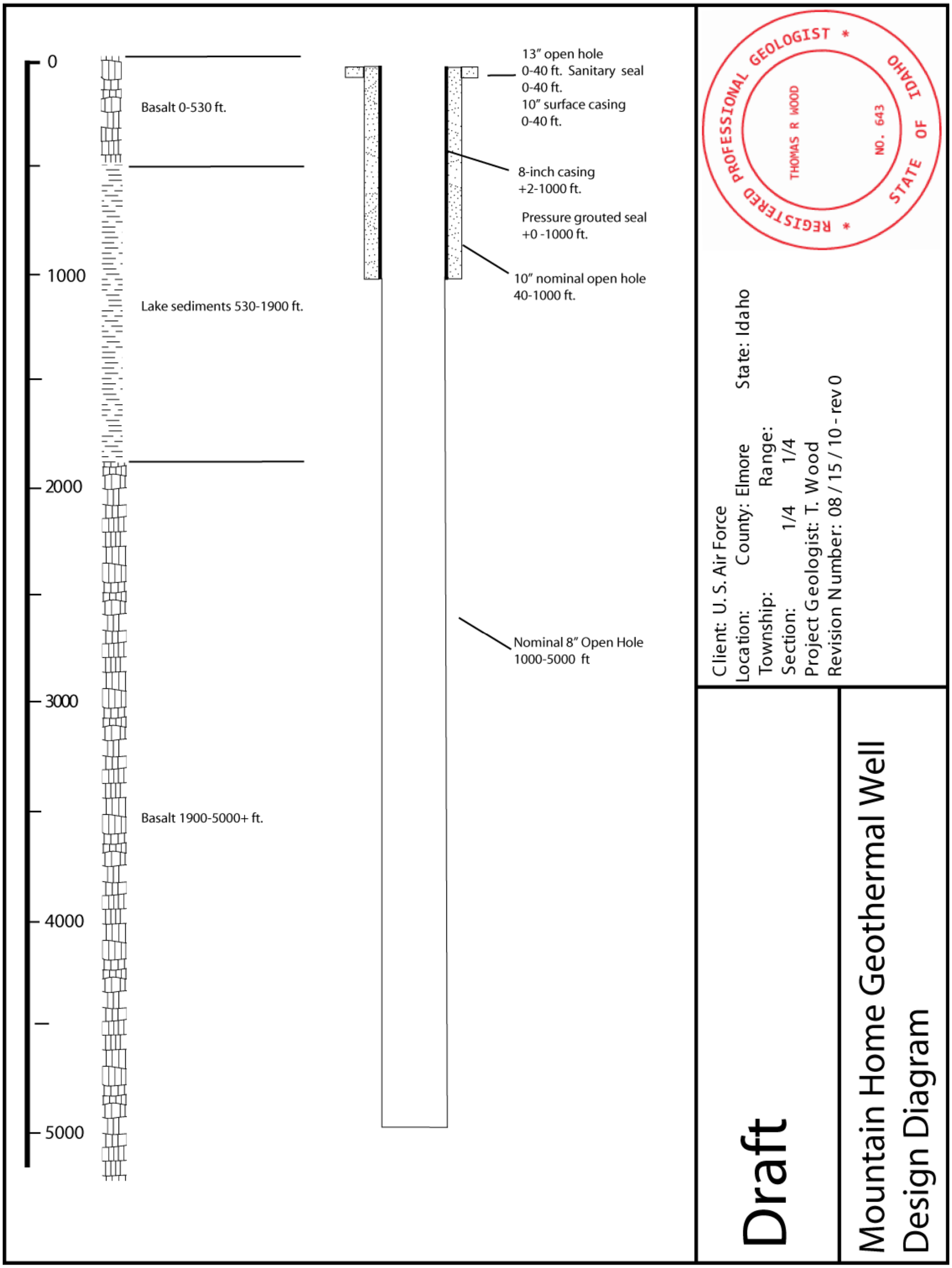


Figure 13. Well HH-3 design schematic.

6.3.5 Environmental and Other Concerns

During all drilling and testing operations phases, precautions will be made to avoid environmental contamination, with the principal concern being the drilling mud and its additives. The drill mud will be bentonite mixed with food-grade biodegradable thickeners. DOSECC has the capability to install its mud system completely above ground if needed. However, the USAF may allow a lined sump pit to be used.

7. FUNDING ASSISTANCE AVAILABLE

There are a number of different funding mechanisms that could be used to make the USAF geothermal projects successful.

7.1 Nellis AFB and AFR

At Nellis AFB, funding will need to be secured in order to conduct the appropriate studies to improve the data set that can be used to determine if exploratory drilling is warranted. The base has several possible options that could be pursued to identify a viable funding option. First, the base might team with some of the regional universities. Then, they need to investigate if there is a professor that has a research interest in geothermal resources in the State of Nevada. If so, graduate students could help develop grant proposals that could be submitted to DOE for collecting data to evaluate the resource in more detail.

Secondarily, the base could work with ACC to identify resources that could be used to support further studies for the top two or three locations on the base. Based on current knowledge, the top three areas of potential appear to be the eastern side of the Kawich Range and adjacent western Reveille Valley; the west side of the Belted Range and adjacent eastern Kawich Valley; and the east side of Blue Mountain. Geothermometry evaluation could change these rankings.

Finally, the base could use the newly signed Memorandum of Understanding (MOU) between DOE and DoD, which is focused on collaboration between the two agencies on joint energy issues. If the base senior management pursues this option, there may be some funding that could be made available on a project that benefits both agencies.

Probably the best option for Nellis AFB is to seek an option that is a combination of the three options above. There is an important need to obtain more scientific data to verify the quality of the geothermal resource, a good role for a university collaborator. There is also an important need for the base to develop a management strategy that allows the base to cut back on the reliance of regional energy providers and become more energy independent, which constitutes a key role for the DoD/DOE MOU.

7.2 Holloman AFB

Holloman AFB will not need substantial additional funding to allow the base energy manager to increase the level of collaboration with Ft. Bliss and the White Sands Missile Range. The base energy manager already meets with his DoD collaborators and one action that would be helpful would be to develop a more formal agreement with these organizations to ensure that senior level managers at the Base and Forts talk about how to best collaborate into the future to need their collective energy needs.

7.3 Mountain Home AFB

There is a good history of agencies and universities working together with Mountain Home AFB to develop collaborative efforts that can help meet multiple goals. The University of Utah has been working with the base energy manager and has developed a proposal that has been funded to drill a 2,000-ft. hole on the base. The funding for the proposal is coming through a grant from DOE through their Golden Field Office. One of the important tasks that was conducted as a result of the FEMP funding was to hold a workshop at MHAFB. The workshop was intentionally kept small with two objectives: (1) to evaluate existing data and determine if drilling another exploratory hole under the base was warranted; and (2) to discuss funding options for drilling the hole to the 2,000-ft. depth and identify if there were options to secure funding to drill the hole to at least 4,000 ft. The USAF ACC came up with additional funding that should allow the exploratory well to be drilled to 4,000 ft or even deeper. This will be a research well and as such, the design and sampling protocols discussed in Section 6 will be followed to ensure that adequate high quality data are collected to assess the quality of the geothermal resource.

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APPENDIX A

Assumptions, Methodology, References, and Parameters Used for Geothermal Resource Assessment by AFB

by Joel Renner (retired)

This appendix provides a compilation and evaluation of readily available reports for three Air Force bases being evaluated by this project: Nellis Air Force Base and Nevada Test and Training Range (NAFB/NTTR), Holloman Air Force Base (HAFB), and Mountain Home Air Force Base (MHAFB). This review was not comprehensive and the effort precluded independent analysis of the available geochemical data, particularly that for NAFB/NTTR.

Geothermal resources are evaluated by drilling both temperature gradient wells and production wells. Production wells are similar to those used by the oil industry but are generally larger in diameter because of the requirement for higher flow rates. Prior to drilling wells exploration is required to limit the risk of well drilling. Geologic mapping, analysis of the chemistry of fluid from hot springs and wells, and various geophysical techniques are used for exploration. Renner et al. (2007) provides a review of commonly used exploration methods as well as a discussion of the occurrence of geothermal energy, geothermal reservoir engineering, and the conversion of geothermal energy to electricity.

The use of the chemistry of thermal springs and fluids from wells to determine the temperature of fluids in the subsurface is worth some discussion here since it is an important early step in evaluating geothermal potential. Fluids in the subsurface equilibrate over time with the rocks in which they occur. The equilibration concentrations of chemicals in the subsurface fluids are usually dependent on temperature so that the chemical species present in a sample may be used to estimate the equilibration temperature. If the fluid moving to the surface does not re-equilibrate before sampling, the analysis of the water from thermal springs and wells can be used to determine subsurface temperatures. The process of determining these temperatures is referred to as geothermometry. The chemical species temperature relationships are called geothermometers. The most commonly used geothermometers are based on silica (SiO_2) concentrations and the concentrations of Na, K, Ca, and Mg. Complexity is added to the interpretation since there are two commonly occurring forms of silica in the subsurface—quartz and chalcedony—with different solubility at a given temperature. Use of the Na, K, Ca, Mg geothermometer also requires interpretation by a qualified geothermal geochemist. Williams et al. (2008) provides a discussion of the chemical methods of determining subsurface temperatures and precautions that must be considered in their application.

Geothermal resources are utilized to produce electricity and for various direct uses, such as space heating and aquaculture. Exploration and development for electrical generation, if successful, is likely to be feasible anywhere on a base since power lines can interconnect generation and users. Direct use grade resources, however, must be co-located with possible uses in order for the resource development to be economic. The higher value of electrical generation also allows greater expenditure for exploration of electrical capable resources. Electrical generation usually requires a resource temperature greater than 150°C. Direct use applications generally utilize temperatures between 40 and 150°C (http://geoheat.oit.edu/).

Temperatures less than 150°C can be utilized to produce electricity if special circumstances are present:

1. If wells already drilled have temperatures less than 150°C, electrical generation can proceed if the value of the electricity exceeds the cost of building and operating the electrical generation system. *Note:* In this case, some or all of the cost of exploration and well drilling may not be recovered.
2. If wells are shallow and the flow rate of fluids is high, the cost of drilling and developing the system may be sufficiently low to produce electricity from lower temperature fluids.
3. External factors (such as high electrical costs, security, etc.) may allow generation of electricity from resources normally uneconomic.

Electricity is generated from geothermal resources by either flashing the fluid produced by a well to a mixture of steam and liquid and separating the steam, which is then fed to a turbine-generator set, or by passing the geothermal fluid through a heat exchanger, which boils a secondary (or binary) fluid that passes through the generator. The former is referred to as "flashed-steam production" and the latter "binary production." Flashed-steam resources are usually greater than 180°C.

Nellis Air Force Base and Nevada Test and Training Range

Summary of Existing Data Sets Used in Assessment

Numerous reports are available on the geothermal resources of the State of Nevada. Hot springs have been tabulated in reports such as Waring (1965), Garside and Schilling (1979), Berry (19800, and Garside (1994a). The Great Basin Center for Geothermal Energy at the University of Nevada–Reno maintains a web site, http://www.unr.edu/geothermal/index.htm, that includes geothermal favorability maps of the State of Nevada and a Great Basin Groundwater Geochemical Database (http://www.unr.edu/geothermal/GeochemDB.htm) that can be used to determine chemically estimated subsurface temperatures for springs and wells in Nevada.

Assessments of Nevada's geothermal resources are also available (White and Williams,1975), Muffler 1979; Reed 1983; and Garside 1994b). Garside (1994b) contains an extensive bibliography of Nevada geothermal reports. The Great Basin Center for Geothermal Energy through the Nevada Bureau of Mines and Geology published a map of the potential for geothermal energy in the Great Basin (Coolbaugh et al., 2005) that provides the most recent outline of areas with geothermal potential in the State of Nevada, Nellis Air Force Base (NAFB), and the Nevada Test and Training Range (NTTR).

Little has been published about the geothermal potential on the NTTR. The most recent and comprehensive review was prepared in 2003 for the Naval Air Weapon Station (NAWS) China Lake by Innovative Technical Solutions, Inc. (ITSI, 2003). This report suggests at least three sites within the NTTR bombing and gunnery ranges, and one just outside the NTTR boundary, that exhibit unique structural and geothermal features similar to many of the identified geothermal fields in the western United States: (1) Stonewall Mountain, (2) the Kawich and Reveille Valleys, and (3) Groom Range and Groom Lake.

1. ***Stonewall Mountain*** is located at the western edge of NTTR and is bound to the north by what appears to be recently active strike-slip faulting which may provide a conduit or pathway for vertical water movement. It is adjacent to the Walker Lane seismic zone and 1-2 miles east of a cluster of thermal wells, one with a temperature gradient exceeding

100°C/km. The Walker Lane is a zone of seismic activity that is believed by some to hold promise for geothermal development.

2. ***The Kawich and Reveille Valleys*** are bound by northerly trending Quaternary faults along trend with the Hot Creek Canyon (Hot Creek Valley) geothermal occurrence and numerous hot (>37°C) and warm (>37°C) wells to the north.
3. ***Groom Range and Groom Lake*** are both located near the center of NTTR and are characterized by steep, linear range fronts and active playas. The structural geology in this area may be conducive for creating geological structures suitable for hosting geothermal systems.

The Geothermal Potential Map of the Basin and Range (Coolbaugh et al., 2005), which was not available to the authors of ITSI (2003) , shows "most favorable" to "very favorable" status for Stonewall Mountain, locations along the western margin of Reveille Valley within NTTR, portions of the southern Kawich Valley including Cliff Spring and the eastern slopes of the Belted Range somewhat northwest of Groom Lake. The Coolbaugh et al. (2005) map also suggests potential associated with the area surrounding Cactus Flat. Sammel (1979) suggests that the Sarcobatus Flats-Beatty area, Yucca Flat and Amargosa Desert are areas favorable for discovery and development of low-temperature resources. Warm wells and springs are present in the Alamo, Crystal Spring and Hiko areas and Garside and Hess (1994) report that warm water was used to heat a spa at Ash Springs.

Evaluation of Existing Data Sets and Related Literature

The interpretation of geothermal potential in ITSI (2003) is well thought out and serves as a good base for further evaluation of the potential of the Nellis Training Range and should be carefully reviewed before additional work is undertaken at Nellis. Their conclusions are generally supported by the regional geothermal potential assessment work of Coolbaugh et al. (2005). The ITSI assessment states that at least three sites within the Nellis Air Force Range and one just outside the NAFR boundary, exhibit unique structural and geothermal features that characterize many of the identified geothermal fields in the western United States. These sites include Stonewall Mountain, Kawich and Reveille Valleys, and the Groom Range-Groom Lake areas within the Nellis Range and Sheep Lake and Sheep Range just to the east of the Range. Additional areas of interest from Coolbaugh et al. (2005) include the western edge of the Cactus Range and Cliff Spring. However, as pointed out by Coolbaugh et al. (2005), their map is regional in nature and it is not yet know whether the predictive methods are applicable to all areas of the Basin and Range. In particular, in areas of regional aquifers, such as the Nellis/Las Vegas area, lack of geothermal exploration does not allow verification of the Coolbaugh et al. interpretation. Sammel (1978) notes that Sarcobatus Flats, Amargosa Desert, Yucca Flat and the Las Vegas Valley all contain areas with potential for low-temperature geothermal development.

The ITSI (2003) sites and those of Coolbaugh et al. (2005) are worthy of additional investigation for their geothermal potential. A possible approach is included in the Recommendations and Conclusions section of this Appendix.

Several authors (ITSI, 2003; Tingley, 1998) have cautioned that evaluation of geothermal potential within the NTTR is uncertain since there is a paucity of data on warm springs and other geothermal indicia within the area because of site restrictions. However, the lack of springs may actually be real. The authoritative compilation of hot springs by Waring (1965) is an extensive compilation prepared from data collected before restrictions on access were in place. Waring (1965) includes very few springs within the boundaries of the NTTR.

The Great Basin Center for Geothermal Energy at the University of Nevada, Reno has compiled a comprehensive catalogue of the chemistry of water from hot springs and wells in Nevada. The data can be used to chemically estimate subsurface temperatures for springs and wells in Nevada. More than 1,500 analyses are included within the latitude and longitudes surrounding the Nellis AFB Range. It was beyond the resources of this study to evaluate these analyses for estimating subsurface temperatures through geothermometry.

Previous studies (ITSI, 2003; Tingley et al., 1998) that used geochemistry to estimate temperatures within the NTTR reported that geothermometers indicate temperatures within the range for direct use but do not indicate high temperatures useful for electrical generation. Tingley et al. (1998) report that geothermometers within NTTR indicate subsurface temperatures mainly less than 100°C and that “only about 4% of the values are between 110°C and 150°C.” Their study included 113 records deemed suitable for estimation of geochemically determined temperatures. ITSI (2003) reports that the majority of thermal springs have geochemical temperatures between 25 and 90°C. However, several wells near Pahute Mesa show calculated temperatures over 150°C ITSI (2003).

The geothermometry from ITSI (2003) is included as Table 3. It should be noted that none of the geochemically determined temperatures are high enough for electrical generation. Several, however indicate the likelihood of subsurface temperatures high enough for direct use if the resource is within economically drillable depth.

Potential Development Areas around NTTR

ITSI (2003) recommends four areas that “may be prospective” for geothermal potential at Nellis AFR (see Section 8.3 pages 130-131):

1. Sheep Lake and the western Sheep Range
2. Kawich Range, Kawich Valley and Cactus Flat
3. Stonewall Mountain
4. Groom Range and Groom Lake

Young faulting was also noted by ITSI (2003) on the west side of the Belted Range, although “young” was not quantified. This faulting may provide conduits for deep circulation of fluids and the possibility of thermal water at drillable depths.

Sarcobatus Flat-Scottys Junction and the Beatty areas just to the southwest of the NTTR also have indications of thermal systems (Shevenell and Garside, 2003). These sites as well as the eastern side of the Blue Mountains are indicated by Coolbaugh et al. (2005) as areas of most favorable potential.

There is a general lack of thermal springs and other direct manifestations of geothermal energy in NTTR. As a consequence, ITSI (2003) and Coolbaugh et al. (2005) both use indirect methods of determining geothermal potential based on criteria such as geologic/tectonic models, heat flow, seismicity and other information. Although their methods strongly correlate with producing fields, there is uncertainty surrounding this method and their criteria for deriving potential have not been fully established.

Summary Recommendations and Conclusions

Further work should take into account the potential use of geothermal resources on the base. Exploration and development for electrical generation, if successful, is likely to be feasible anywhere on the base and range since power lines can interconnect generation and users. Direct use grade resources, however, must be co-located with possible uses in order for the resource development to be economic. The higher value of electrical generation also allows greater expenditure for exploration of electrical capable resources:

1. ***Geothermometry:*** Initially Nellis should contract with a qualified geothermal geochemist to review the existing chemical analyses from springs and wells within and close to NTTR and estimate subsurface temperatures using geothermometers where applicable. The review should include not only those analyses reported by ITSI (2003), but also the analyses available from the Great Basin Center for Geothermal Resource web based data set (http://www.unr.edu/geothermal/GeochemDB.htm).

   The recommend geochemical review should include a review of the charge balance of all analyses and should also consider the pH if pH was determined in the field at the time of sampling. Charge balance is an indicator that the analysis is good and that errors have not been made in reporting major elements such as Na, K, Ca and Mg that are used in the cation geothermometers. High pH, generally above 9, increases the solubility of Si and can lead to erroneous temperatures calculated from silica geothermometers. In areas of the base where groundwater may be affected by high salinity form playa waters, pH may be elevated.

   Since the geochemical database is large and the Nellis AFB is also large initial efforts can be focused in the areas recommended by ITSI (2003) and areas where the Great Basin analyses indicate possible high temperatures.

   Any previously unsampled thermal springs should be sampled and subsurface temperatures estimated using appropriate geothermometers.

2. ***Detailed geology:*** Detailed geologic mapping focused on locating any possible indications of recent surface geothermal activity such as alteration zones should be conducted.

3. ***Temperature gradient determination:*** Temperature gradient holes are often drilled in areas of high potential. However, as discussed by ITSI (2003) and Tingley (1998), the presence of deep carbonate aquifers may mask high temperatures at depth and probably will require drilling of deep temperature gradient wells to determine subsurface temperatures not controlled by through flow of cool water in the aquifers.

4. ***Geophysics:*** If the results from the above surveys are positive geophysical techniques should be utilized to delineate drilling targets for exploration wells.

The USAF may want to consider performing the geochemical review and geologic mapping of selected areas of highest potential and then lease the geothermal resources to private developers as the Navy did at the Coso geothermal field. Table 3 provides a list of the geothermometry results for NAFB.

Table 3. Geothermometry Results for Nellis AFB from ITSI (2003).

Well/Spring ID	Location	Depth (feet)	Temperature of Sample (oC)	SiO_2-chalcedony (°C)	Na-K-Ca (Mg-corrected) (°C)
Northwest Area					
02S51E21	Spring on N portion of NAFR		25	58.8	28.9
02S49E22	On AFR	854	26.7	104.9	86.9
05S52E33	Spring on N portion of NAFR			98	66.3
01S47E15	On AFR		17.5	88.2	85.7
01N47E30	2 mi NW		17.5	91.3	80.2
01N49E23	2 mi N			67.9	20.9
02N47E14	10 mi N		29	40.5	57.6
02S50E10	Spring on N portion of NAFR			53.7	31.8
06S52E09	Spring on N portion of NAFR			75	79.7
03N42E35	14 mi NW	706	41.1	85.5	44.5
01S50E23	On N portion of NAFR		15	72	65.9
Main Base Area					
20S62E21	0.5 mi SE	95	21.5	92.9	56.9
20S62E16	SE of NAFR	694	24	95.8	76.1
20S62E15	0.3 mi SE NAFR portion	1000	25	49.6	71.8
20S61E01	2.5 mi W		25	105.5	31.7
18S63E33	2 mi SE		31	37.1	71.3
19S62E36	SE portion of NAFR	880	28	73.1	80.3
20S62E01	SE portion of NAFR		25	95.1	62.8

Well/Spring ID	Location	Depth (feet)	Temperature of Sample (oC)	SiO_2-chalcedony (°C)	Na-K-Ca (Mg-corrected) (°C)
Southwest Area					
13S49E14	1 mi S of Yucca Mtn		40.5	75.9	54
13S49E20	3 mi S of Yucca Mtn		38.7	67.9	65.3
12S49E13	On Yucca Mtn.	6000	34.2	73	90.6
12S53E01	5 mi W of NAFR		37	45.2	46
12S48E04	4 mi W of NAFR	1600	31.5	70	70.2
East Area					
16S54E01	On base		27.2	20.7	1.6
13S55E	On base		37.8	38.8	39
16S56E	1 mi S		26	25.3	62.4
16S58E23	1 mi SE	720	29	35.3	36.7
16S58E14	1 mi SE	930	22.5	42.1	53.8
14S60E22	4 mi E		10	65.7	
11S60E36	6 mi E		19	71	
15S61E12	13 mi SE		12	25.3	-16.8
16S56E16	2 mi SE		25	15.6	

Holloman AFB

Summary of Existing Data Sets Used in Assessment

Numerous studies have been conducted on the geothermal resources of south-central New Mexico. However, none of them other than the review prepared in 2003 for the Naval Air Weapon Station (NAWS) China Lake by Innovative Technical Solutions, Inc. (ITSI, 2003, provide significant information concerning geothermal resources at Holloman AFB. The nearest reported thermal occurrence is an oil well drilled some time before 1929. Summers (1976, p. 73) reports that the well had a flowing temperature of 33.7°C (92.7°F) on December 17, 1965 and was 33.3°C (92°F) in 1976. The well is referred to as the Garton well and is in SE1/4, SE1/4, NW1/4 Section 5, Township 18 S., Range 5 E, at about Latitude 32.8°N, Longitude 106.106.1°W.

Morgan et al. (1981) developed a model for geothermal occurrences in the Rio Grande Rift area of New Mexico. The model suggests that deep flow of water within and between basins can initiate convection causing warm water from great depths to convect upward to the surface and provide the source for warm water utilized near Las Cruces and other geothermal systems in southwestern New Mexico.

ITSI (2003) utilized a U. S. geological survey map (see Figure 1) of Quaternary Faults in the Tularosa Basin (Machette et al., 1998) as a key in their structural interpretation of potential sites for possible geothermal resources in the basin.

Table 4 (ITSI 2003, Table 5.3) provides a list of temperature gradients to the south and east of Holloman AFB. The gradients range from 30 to 42°C/km. If the near surface groundwater temperature is assumed to be 15°C, and the gradients can be extended to 3 km, the temperature at 3 km could be as high as about 140°C. This is optimistic, however, since temperature gradients often decrease with depth.

Table 4. Temperature Gradients at Holloman AFB from ISTI (2003).

Longitude	Latitude	Hole Name	Publication Reference	Uncorrected Gradient (°C/km)	Corrected Gradient (°C/km)	Uncorrected Heat Flow (mW/m^2)	Corrected Heat Flow (mW/m^2)
-106.4000	32.2833	WHTSAND2	REIT754	41	41	95	95
-106.1167	32.4000	OROGRAND	DECK752	43	42	123	129
-106.1167	32.4167	ORGRANDS	REIT783	35	35	92	92
-106.4500	32.4333	WHTSND3	REIT754	38	38	87	87
-106.0955	32.4417	UCSD-6	WARR694	40	40	94	94
-106.6000	32.4500	ORGAN	DECK752	29	29	116	115
-106.6000	32.4500	ORGANN1	REIT783	37	37	136	136
-106.6000	32.4500	ORGANN2	REIT783	36	36	104	104
-106.1000	32.5000	OROGRN	REIT754				73
-106.4167	32.5333	WHTSND4	REIT754				91
-106.0500	32.5667	NO1TUR	REIT864	42	42	90	90
-106.1167	32.7500	FEDG1	REIT864	43	43	135	135
-106.13333	32.83333	Holloman AFB					
-105.9667	33.2833	NO2LEW	REIT864	40	40	111	111
-105.9333	33.2833	NO1LEW	REIT864	32	32	101	101
-105.7833	33.4667	SBLANCA	REIT754	30	30	70	70

Witcher (1995) discusses a database of geothermal information from New Mexico assembled with funding from DOE. The data is available through the Geo-Heat Center at the Oregon Institute of Technology (http://geoheat.oit.edu/database.htm).

Geothermal potential maps of New Mexico (Brizzee and Laney, 2003; NOAA, 1980) include Holloman within the "regions of known or potential geothermal resources." However that designation does not designate the likelihood that resources will be discovered.

Evaluation of Existing Data Sets and Related Literature

Morgan, et al. (1981) observed:

> *"There can be little doubt that many, if not all of the geothermal anomalies along the Rio Grande rift, excluding the Jemez Mountains, are primarily the result of forced convection by inter- and intra-basin groundwater flow. In some anomalies forced convection creates high enough gradients for free convection to occur also, creating mixed convection systems. The temperatures within these systems are limited by the maximum depth of water circulation, and the regional*

> *geothermal gradient. These conditions are unlikely to produce high enough temperatures at shallow enough depths for electricity generation under current **(1981)** economic conditions. The geothermal systems have great potential for direct heat applications, however."*

Since the reporting of Morgan et al. (1981), binary technology has been developed that allows economic production of electricity from resources with temperatures in the range of 150°C, and in special cases it is economic to produce electricity from resources near 100°C.

Minimal data is available from the referenced data sets on which to base definite conclusions on the geothermal potential at Holloman AFB. None of the data available comes from on the base. Temperature gradient and heat flow data assembled by ITSI (2003) are all to the east or south of the base. These data do not indicate a shallow resource. The highest gradients indicate possible temperatures near 140°C at 3 km. Such temperatures are likely to be uneconomic without dramatic decreases in the cost of drilling or improvements in conversion of geothermal energy into electricity. Temperature gradients also tend to become lower at depth due to compaction of sediments at depth and the replacement of sediments with igneous rocks at depth, both factors increasing the conductivity of the rocks and decreasing the temperature gradient.

The only data in the Geo-Heat Center (1995) database near Holloman AFB comes from the Garton well. Silica solubility suggests a subsurface temperature of about 50°C for this well. ITSI (2003, p.99) utilized a USGS water quality database but the database did not include any wells with adequate data for geochemical interpretation at Holloman AFB.

Based on the data available, ITSI (2003, p.122, sect 7.1.4) concluded "no evidence suggests that utility-grade geothermal exists at Holloman AFB and its potential there is rated as **low**." The authors of this report agree with the ITSI finding.

ITSI (2003) conducted field investigations at Bear Peak, approximately 30 miles (48 km) SW of Holloman and within the White Sands Missile Range, and at Twin Buttes, approximately 4 miles (7 km) S of Holloman AFB and adjacent to White Sands Missile Range. Self potential mapping at Bear Peak and its geologic setting suggested to ITSI (2003) that further work would be warranted. Such work could include drilling temperature gradient wells and possibly conducting a resistivity survey. ITSI did not recommend any additional work at Twin Buttes.

Potential Development Areas around Holloman AFB

Based on existing data including the geologic models of forced convection by Morgan et al. (1981) and the ITSI (2003) report, there do not appear to be potential development sites associated with Holloman AFB.

Jim Witcher (personal communication, 2010), an expert on geothermal resources in New Mexico, suggests that the most likely source of geothermal energy within the Holloman AFB-White Sands Missile Range may be deep in the Tularosa Basin. He believes that such resources would be contained in lower Paleozoic limestones and dolomites at depths of 8,000 to 10,000 feet with temperature controlled by a conductive gradient.

Summary Recommendations and Conclusions

If Holloman AFB is interested in investigating the potential for geothermal energy beneath the Holloman AFB-White Sands Missile Range, it will most likely require deep drilling if the model proposed by Witcher (personal communication, 2010) is true. Most likely locations for further work would be on the east and west margins of the Tularosa Basin where there is a possibility of convective fluid flow along the basin's bounding faults. The USAF might want to continue investigation of electrical potential at Bear Peak and wheeling the power to Holloman AFB. Holloman AFB may also want to investigate the possibility of joint exploration at the Army's Fort Bliss.

Mountain Home AFB

Summary of Existing Data Sets Used in Assessment

Several studies have investigated the geothermal resources of the SRP in the vicinity of Mountain Home AFB. The most recent study (ITSI, 2003) reviewed the potential of MHAFB and the nearby Saylor Creek bombing range as part of a nationwide assessment of the geothermal potential on military lands. Lewis and Stone (1988) describe a 1,342 m deep well (MH-1) drilled on the base testing its geothermal potential. The temperature measured in the well at 1207 m, the depth limit of the temperature tool, was 93°C. Regional studies include Blackwell (1989), Young and Mitchell (1973), and Young and Lewis (1982).

The Bostic 1-A well, on the northern margin of the SRP near Mountain Home, Idaho (T4S, R8E, Sec. 25) was drilled as an oil and gas wildcat to 2950 m 1973. In 1974 Gulf Mineral Resources Co. took over the well as a geothermal prospect and ran additional lithologic and geophysical logs. In early 1978 the well was acquired by Union Oil Co., who plugged and abandoned it in October 1978 (Arney et al., 1984). The bottom hole (2950 m) temperature was reported as 195°C (Arney et al., 1984).

Los Alamos National Laboratory (Arney et al., 1982) evaluated the potential for Hot Dry Rock (HDR) development in an irregularly shaped area of about 17 miles in an East-West direction and 11 miles in a north to south direction. The southwestern corner of the area is about 15 miles east of Mountain Home Air force base and 6 miles east of Mountain Home.

Arney et al. (1982) suggest that thermal waters apparently circulate along northwest-trending faults or buried faults as indicated by the lineation of their points of occurrence. The HDR study area is sufficiently far from the AFB that geothermal indicia are not expected to be directly comparable to conditions at the AFB. However, control of convective systems is likely to be true for any thermal circulation beneath Mountain Home AFB as well.

Thermal springs that were analyzed in and immediately surrounding the study areas (Arney et°al., 1982) indicated thermal waters equilibrated at between 40 and 85°C.

Evaluation of Existing Data Sets and Related Literature

The following discussion of the geochemistry of wells on the base is taken from ITSI (2003):

> *"The Mountain Home AFB main site contains over 30 operational monitoring and water wells. These wells extend from 30 feet to over 500 feet below ground surface (bgs) and are routinely monitored for temperature, conductivity and a selected suite of metals and organic compounds."*
>
> *"Geothermometry calculations applied to the shallower wells indicate a fairly small temperature range for these wells (generally 40° to 70°C). As these temperatures are greater than ambient groundwater temperature (near 10°C), there is evidence for some upflow of warm fluids; however, large upflow systems do not appear to be present at or near the base."*

Other than the above geochemical data, ITSI (2003)states that the Mountain Home AFB main site has no outstanding geothermal characteristics. However, ITSI did do additional investigation in the northeastern portion of the base. This area of the installation was selected by ITSI as a target for field investigations for the following reasons:

- A sharp groundwater gradient trending northwesterly exists just outside the northeastern corner of the base; it was assumed that this gradient may be controlled by basement topography which may in turn be due to a northwest-trending structure (typical of regional structural trends and thus a potential deep fluid upflow zone)
- A slightly elevated temperature was determined from a well several miles east of the northeastern corner of the base
- The only portion of the main site suitable for any sampling or geophysical analysis was this northeastern region in addition to BLM land on the eastern side of the fence.

ITSI also performed an SP survey and collected soil samples. Neither study provided evidence supporting a geothermal resource capable of generating electricity beneath the base.

Geothermometry by Arney et al. (1982) also suggest that water from warm springs and wells east of Mountain Home in the HDR study area equilibrated with rocks in the subsurface at temperatures generally between 40 and 85°C utilizing the NA-K-Ca geothermometer. They did not believe that the various SiO2 geothermometers could be used in the HDR area. Hence the temperatures reported by ITSI may also be suspect. The Arney et al. (1982) temperatures suggest that the source of water in the study HDR study area was shallower than the depth of the Bostic 1-A well which has a reported temperature of 195°C at 2,950 m.

The strongest pieces of evidence for elevated temperatures beneath MHAFB are the measured temperature in the AFB deep geothermal well (MH-1) and the temperature reported in the Bostic 1-A well. The Bostic well, however, is about 20 miles to the east of the deep well on the base.

Blackwell (1989) reports quite similar temperature gradients of MHAFB MH-1 and Bostic 1-A wells, 67.2°C/km and 65.9°C/km, respectively. The temperature with depth plots of Blackwell show a nearly linear temperature gradient, particularly below about 500 m. Such gradients are suggestive of conductive heat transfer rather than convection. If the lithology beneath the AFB is similar to that of the Bostic 1-A well, the temperatures beneath the AFB may be similar to those of the Bostic well. Convection beneath the base along possible faults would increase shallow temperatures and might provide sufficient fluid flow for geothermal production. A planned seismic study by Shervais (personal communication, 2010) will shed additional information on the presence or absence of faults beneath the AFB.

Potential Development Areas associated with Mountain Home AFB

The ITSI (2003) report recommended that further work not be conducted at Mountain Home AFB. However, the gravity data suggests that deep fractures may occur beneath the base. This fracturing may host a hydrothermal convective system and is a logical place to conduct additional investigations of the geothermal potential beneath the base.

Summary Recommendations and Conclusions

Although the ITSI (2003) report did not recommend additional work at Mountain Home AFB, that report limited its recommendation to electrical generation grade resources. The current review of their data and earlier studies in this area of the SRP suggest that their conclusion may be correct. However, there does appear to be potential for resources suitable for direct application of heat. If fracture zones are present beneath the base, there is the possibility for convective circulation of sufficiently hot water for electrical generation closer to the surface than the temperatures measured in the Bostic 1-A well.

Geothermometry suggests that the fluid from MH-1 may be about 30°C higher than the flowing temperature reported by Lewis and Stone (1988) or about 74°C to 80°C, encouraging of temperatures suitable for direct use.

Geothermal resources in the SRP in the vicinity of Mountain Home AFB are likely to be associated with upward movement of fluid along deep fault zones. Hence, as a first phase in reconnaissance we suggest that the existing regional gravity and aeromagnetic studies be reviewed to determine possible fault zones underlying or adjacent to the base. The next phase of investigation should include drilling temperature gradient wells (200–500 feet deep) near the fault zones to investigate whether any temperature anomalies are associated with the fault zones. If anomalies are found deeper gradient wells should be drilled to intercept the fault zones at depths where temperatures may be suitable for use.

There does appear to be a moderate likelihood that a geothermal resource capable of providing fluid useful for direct use may be found beneath the base. We agree with ITSI (2003) that there is no indication of a resource capable of supporting electrical generation beneath the base. However, there is a chance that temperatures similar to those found in the Bostic 1-A well (195°C at 9,700 ft.) may be encountered through deep drilling beneath Mountain Home AFB.

APPENDIX B

References

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