Chapter 9

Site Survey

This chapter describes the work of the Site Survey Group and the candidate sites. The Auger Collaboration voted in November 1995 to select Nihuil, Argentina as the Southern Hemisphere site, and in September 1996 selected Millard Co., Utah, USA, as the Northern Hemisphere location.

9.1 Introduction

The Survey Group's task was to identify and characterize candidate sites — both in the Northern and Southern Hemispheres — suitable for construction of the Auger Cosmic Ray Observatories. Towards this end, and in consultation with members of the collaboration, a set of desirable site criteria was established. Contacts were initiated with interested parties in Argentina, Australia, China, Mexico, Russia, South Africa, Spain, and the USA. A summary of the site selection criteria was circulated to these groups, and they were asked to nominate candidate sites based on their knowledge of the respective areas.

Site visits to Argentina, South Africa, and Australia were completed in the first half of 1995 (a second visit to Argentina was made in September 1995). Visits to candidate sites in Spain and in Russia and Kazakstan took place in the second half of 1995. During the first half of 1996 a site in northern Mexico and a number of sites in the western United States were investigated.

The following sections outline the criteria used in site selection, describe site visits and the data being collected as part of the survey effort, and summarize the results of these site visits.

9.2 Site Requirements

Discussions were held with members of the Fluorescence, Surface Detector, and Communications Groups to identify desirable site characteristics. These discussions led to a set of selection criteria: some motivated by physics considerations and others by more practical concerns. In the absence of a detailed detector design these requirements should be viewed as guidelines; a site failing to strictly meet these criteria would not necessarily be excluded from further consideration.

The selection criteria included:

- a latitude between 30° and 45° North or South of the equator;
- an area of about 3000 square kilometers;
- an altitude between 500 and 1500 meters above sea level;
- cloud cover less than $\sim 15\%$ with little ground fog and moderate temperatures;
- good visibility, and no significant nearby sources of light pollution.

Among the practical concerns were:

- that suitable infrastructure (e.g. power supply, freight access, telecommunications, and "goods and services") should exist;
- the site should be relatively level with a mean slope less than 1% and not in excess of 2% to 3% over distances of a few hundred meters (i.e. both locally and globally flat);
- the vegetation, soils, and topography should not significantly impede array installation and maintenance.

Beyond the physical attributes of the sites under consideration the level of interest and support of the local scientific and civilian communities as well as of the governments, Provincial/State and Federal, concerned is of the utmost importance.

9.3 Site Visits and Relevant Data

Visits by the Site Survey Group have generally begun with a review of the materials collected by the host institution(s). These data include:

- "civil" maps indicating the location of roads, highways, railways, and airports; cities and towns; power and telecommunications links;

- topographic maps with elevation contours suitable for verifying access within the array;
- long term weather records including cloud cover, precipitation (both rain and snow), and high, low, and mean temperatures;
- an indication of the level of infrastructure present at or near the site (e.g. technical support services; industrial properties for off-site assembly and storage; facilities for vehicle maintenance; access to housing, fuel and food, etc.);

On-site visits themselves have typically been for a period of two to five days depending on the weather encountered. During this period an effort was made to traverse the sites on existing roads wherever possible. No off-road travel was undertaken and ease of access within any given site remains to be determined. Nearby towns which might provide the goods, services, and housing required by the project have also been visited.

Photometric (UBV) observations of selected stars were made at each site (see Figure 9.1). These data, taken in drift-scan mode throughout a range of zenith angles, yield both the background sky brightness and the apparent magnitude of the star under observation (the absolute magnitude diminished by wavelength dependent atmospheric absorption and scattering). It must be noted, however, that the limited time frame associated with these observations cannot provide a decisive indication of the optical quality of the sites; nor can the relative sensitivity of these measurements from site to site be guaranteed. Nevertheless, these observations do provide the best available measure of the relative atmospheric clarity and background sky brightness levels.

9.4 Argentina

Prior to the Survey Group's initial visit nearly a dozen sites were identified as possible candidates in Argentina. Due to time constraints however, only a few had been examined in significant detail. Of these sites three were selected for further investigation: Laguna Blanca, La Humada, and Monte Coman.

Subsequent to the first site visit, two additional candidates were identified — Nihuil and Somuncura. Work performed by the host institutions in Argentina together with results from a follow-on visit by the Site Survey Group led to the selection of Nihuil as the preferred candidate in Argentina.

9.4.1 Laguna Blanca:

The village of Laguna Blanca (41.5° S, 65° W, 1000 m.a.s.l.) is north of Jacobacci and approximately 200 kilometers east of San Carlos de Bariloche. It was known *a priori* that the site was in fact too small. However, the area is believed to be representative of much of the Province of Rio Negro in terms of the night sky background and atmospheric clarity.

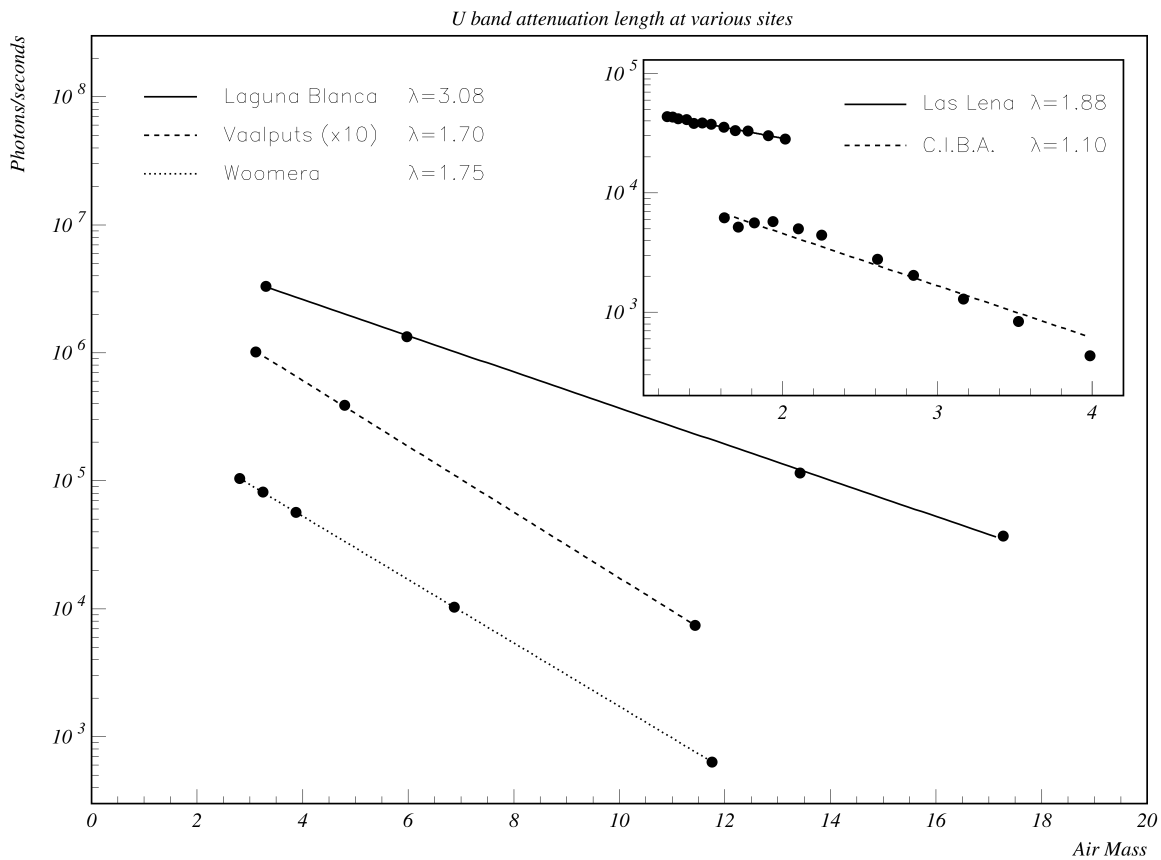

Figure 9.1: Rate vs Air Mass (g/cm^2) for U band (365 nanometers) observations at Laguna Blanca (solid line), Vaalputs (dashed line), Woomera (dotted line) and in the smaller frame Las Lena (solid line) and C.I.B.A. (dashed line). The measured 1/e attenuation distances in units of air mass range from 3.08 (Laguna Blanca) to 1.1 (CIBA). Measurements in the B and V bands are consistent with the above results.

Typically higher and more arid than other Provinces, Rio Negro has the potential for providing a very favorable site (see Somuncura below). On-site observations do indeed confirm that visibility is excellent and the sky extraordinarily dark.

9.4.2 La Humada:

The site near La Humada (36.2° S, 68° W, 750 m.a.s.l.) is 40 kilometers southwest of the small town of Santa Isabel. Santa Isabel, while a major crossroads in the Province of La Pampa, has itself somewhat limited infrastructure (e.g., it is not connected to the national power grid — electrical power is locally generated).

The La Humada site is more than adequate in size, both level and flat, and at an altitude suitable for the use of any of the detector technologies now under consideration. However, the infrastructure in the area is very limited — no power, water, or telecommunications links exist in or near the site. Access is via a single gravel road of good quality. The surface is composed of fine clay soils which are likely to be incompatible with fluorescence or other optical detector. The latter factor, together with the absence of infrastructure, has eliminated La Humada from further consideration.

9.4.3 Monte Coman:

The site (34° S, 67.5° W, 400 m.a.s.l.) is 40 kilometers northeast of the town of Monte Coman and occupies the southern portion of a uniformly flat area of nearly 20,000 square kilometers. Monte Coman is itself 60 kilometers east of San Rafael, one of the principal cities within the Province of Mendoza.

Physical Characteristics

The site is large, level, and with the exception of a few consolidated dunes, extraordinarily flat. The average elevation is 450 meters trending very slightly (0.1%) down towards the east. The surface is composed of compacted sedimentary material mixed with sand. Low vegetation ($\leq$ 2 meters in height) covers much of the area. The Diamante River forms the southern boundary of this extended region while to the east and west the land rises substantially.

Climate

While the area is classified as "arid" the annual precipitation approaches 400 millimeters. Mean monthly rainfall in January (summer) is nearly 70 mm, while in July it falls to 20 mm; the relative humidity is typically 60%. The average nocturnal cloud cover, based on the ISCCP data, is 35% (peaking in July). Temperatures are moderate, averaging 16°C with a mean maximum of 31°C and a mean minimum of 1°C.

Infrastructure

Substantial infrastructure is present in the area. The cities of San Rafael (population 95,000) and San Luis (110,000), and to a lesser degree Monte Coman, provide most of the amenities required by the project. Regular domestic flights connect San Rafael and San Luis to Buenos Aires. Excellent rail and highway access as well as electrical power and water are available at the site's periphery. A good tarred road crosses its southern edge and dirt tracks exist within the site itself.

9.4.4 Nihuil:

Nihuil (35.2° S, 69.2° W, 1400 m.a.s.l.) lies near the center of the Province of Mendoza, 80 kilometers west of San Rafael. Malargüe (population 10,000), which supports the nearby resort of Las Leñas and a small oil processing facility, is near the site's southwestern border. In the western portion of the proposed site some oil extraction is being undertaken.

Physical Characteristics

The site is largely circular in shape encompassing an area of 3100 square kilometers and having a mean slope of less than 0.5%. Incorporating regions in which the slope approaches 1.5% increases this area to more than 3400 square kilometers. The Salado and Atuel rivers enter the site from the west and form an extremely broad and nearly flat alluvial fan composed of well consolidated soil, sand and gravel. At the edge of the fan shallow surface water may be present seasonally. The Salado River joins the Atuel in the western portion of the site and crosses from west to east. In the west it has formed a number of shallow channels extending laterally (that is, north to south) for approximately one kilometer. Across much of the site the river is contained in a single channel whose depth and breadth may exceed 5 and 20 meters respectively — fording will not be feasible and a bridge will be required. Grasses grow throughout the area and though relatively sparse (nowhere exceeding 70% coverage) across the alluvial fan they form an irregular surface — high clearance vehicles may be required.

Climate

Like Monte Coman, Nihuil is classified as “arid”. However, the annual precipitation is considerably lower, at 280 millimeters, and nearly uniform through the year. The estimated nocturnal cloud cover is similar to Monte Coman (35%, peaking in July at nearly 50%). As expected for the higher elevation, temperatures are cooler. The mean annual temperature is only 12°C, mean maximum 20°C, and the mean minimum of -2°C; the mean winter temperature is approximately 4°C with frost occurring 90 or more days per year.

Infrastructure

Nihuil is serviced by good tarred roads from San Rafael and Malargüe. Both cities can provide most of the necessary support facilities. High voltage transmission lines lie along the site's north and western borders. Water is readily available from the Atuel River and from underground aquifers.

9.4.5 Somuncura:

Somuncura (41.5° S, 67.4° W, 1200 m.a.s.l.) is near the southern border of the Province of Rio Negro and is the most southerly of the proposed Southern Hemisphere sites. Even by Argentine standards Somuncura is remote and sparsely inhabited; the settlements which do exist are on its periphery. Los Menucos, 70 kilometers to the north, lies on Route 23 and the rail-line which connects San Carlos de Bariloche to the deep water port at San Antonio Oeste.

Physical Characteristics

The Somuncura Plateau is an extensive basaltic highland totaling nearly 12,000 square kilometers. Elevations extend from 650 to 1350 meters above sea level. The proposed site encompasses 4000 square kilometers at an elevation of 1200 meters and is reported to be extremely level with a few isolated hillocks which are volcanic in origin and typically 100 meters in height.

Climate

Local climatic conditions must be inferred from meteorological stations at some distance from the site. The estimated precipitation is 160 millimeters per year with a cloud cover similar to that observed at Monte Coman and Nihuil. The mean annual temperature is 9°C, mean maximum 15°C, and the mean minimum 3°C. Frost is observed typically 130 days per year.

Infrastructure

The area is virtually devoid of infrastructure with no electrical power, tarred roads, telecommunications or other amenities. Serviceable gravel roads connect the site to Los Menuchos. Tracks provide limited access within the site. Underground rain-fed aquifers provide the only available water. In Los Menucos, wells drilled to a depth of 100 meters supply 90 cubic meters per hour while nearby sources produce perhaps one-third this amount.

9.5 South Africa

Only a single site was selected for investigation in South Africa. It is in many respects the best of the sites visited.

9.5.1 Vaalputs:

The site is in the North Cape Province approximately 300 kilometers north of Cape Town and extends to the northeast from Vaalputs (29.8° S, 18.8° E, 950 m.a.s.l.). Vaalputs is operated by the Atomic Energy Corporation and is home to South Africa's low and intermediate level radioactive waste repository. The facility's primary mission is to receive waste from South Africa's civilian nuclear reactor program, verify the integrity of the casks in which it is transported, and to inter these in clay-lined pits.

The main building at Vaalputs contains three crane equipped high-bay areas for off-loading waste shipments, a small machine shop, a service bay for heavy vehicle maintenance, and administrative offices. The "Camp", located 8 kilometers from the main building, provides comfortable hotel style accommodation for 35 and includes a large communal kitchen, a lounge, and conference facilities.

Physical Characteristics

The proposed site is roughly rectangular in shape extending 45 kilometers to the east and 85 kilometers to the north of Vaalputs. Deviations from the average elevation are everywhere less than 20 meters and slopes are less than 0.5%. The site is bounded in the east by the Koa Valley depression, a relic drainage which seasonally contains a few flooded pans. To the west the land rises slightly becoming quite uneven; this is the uplifted edge of the South African escarpment.

Vegetation over the entire area is limited to grasses and widely scattered low shrubs; the soil is compacted sedimentary material, gravel, and some wind-blown sands.

Climate

Vaalputs maintains an automated meteorological station. Based on these and other records (from Springbok and Pofadder) the annual precipitation is estimated to be less than 40 millimeters per year. The mean annual temperature is 21°C, mean maximum 37°C, and the mean minimum 10°C; temperatures can exceed 40°C in summer. No immediately relevant ground-based cloud cover data is available. However, the atmospheric conditions at Sutherland, an astronomical observatory in the Karoo approximately 150 kilometers south of Vaalputs and sharing much the same weather, rival those of other well known astronomical observatories.

Infrastructure

The infrastructure in South Africa is, in the main, excellent. Even in the sparsely populated North Cape Province tarred roads connect most of the significant communities. To the east of the Koa Valley a heavy rail-line connects iron mines in the northeast of the Province with the coast at Saldanha. The site, which is primarily utilized for grazing, is criss-crossed by a network of well-maintained gravel roads (the personnel at Vaalputs commute daily 120 kilometers to Springbok on these roads). Numerous dirt tracks afford access within the grazing lands themselves.

Two power lines, servicing Vaalputs in the southwest-west and an air navigation beacon to the north-east, extend some 20 kilometers into the site. Both lines could be economically upgraded to 400 KVA. Other than in the seasonally flooded pans, no surface water exists in the area. However, as part of the preparatory work for the waste disposal facility, staff geologists at the Atomic Energy Corporation have thoroughly investigated the area's geohydrology. Substantial quantities of fossil water have been identified at depths of 60 meters at several points within the site. This water is highly mineralized and may require filtering and/or treatment by reverse osmosis.

Much of the economy of the North Cape Province is based on mineral extraction. Springbok provides most of the support required by the surrounding mining communities. Housing, industrial properties, and freight handling facilities are among the numerous services available at Springbok.

9.6 Australia

Australia has a long history of involvement in all aspects of ground based particle astrophysics. In particular, the University of Adelaide until recently operated an air shower array at Buckland Park and continues today to be involved in the design, construction, and operation of several atmospheric Čerenkov detectors at Woomera. Several individuals now at Adelaide have been members of the Fly's Eye collaboration in the past and bring with them a thorough understanding of all aspects of the Auger Project having to do with fluorescence detectors.

9.6.1 Woomera

The site is located in the south-east portion of the Woomera Prohibited Area (WPA; 31.1° S, 136.8° E, 150 m.a.s.l.), north and west of the town of Woomera which is itself 450 kilometers north of Adelaide. The WPA is operated by the Australian Department of Defense whose activities in the area are mainly directed to munitions testing. Most of the land, however, is leased for grazing and access is relatively unrestricted.

Physical Characteristics

The site is bounded in the south by seasonally flooded Lake Hart and in the east by uneven terrain and Lake Torrens. Topographic maps indicate that a significant fraction of the northern portion of the site is covered by consolidated dunes with heights of 2 to 5 meters. Aerial photos confirm the presence of the dune field. Further, they suggest that the dunes run mostly east-west with level areas interleaved between adjacent dunes. Far to the west, though still within the proposed site, trees with heights up to 4 meters are present. Though not dense, over distances of a kilometer or more they do significantly obscure the line-of-sight.

Though for the most part flat, small pans and associated drainages are present within the site. These can rapidly flood making access difficult if not impossible. Soils outside the dune fields or pans are principally "gibber". This surface is characterized by myriad small pebbles or stones on top of a fine soil. While wind-blown dust is not a concern, mobility over the surface following any significant rainfall is reported to be extremely difficult.

Climate

In a climatic sense Woomera is midway between the coastal zone and the continental interior. Temperatures are moderate with a mean annual temperature of 21°C, and mean maximum and minimum temperatures of 32°C and 8°C respectively. Rainfall annually averages 140 millimeters. The University of Adelaide has initiated a sophisticated program of atmospheric monitoring using a technique similar to that used by the Site Survey Group. Observations by the Adelaide group agree with those made concurrently by the Survey Group.

Infrastructure

At present Woomera has 1300 inhabitants. In the past the population has been as high as 5000 and the facilities are commensurate with that number. Electrical power, potable water, housing, and industrial space are all readily available. The Stuart Highway and a railway connect Woomera to Adelaide and ports on the Spencer Gulf. Pimba just to the south of Woomera has a rail spur and unloading facilities.

Woomera's infrastructure extends well into the site itself. Power, water and communications are present at "Range E" 45 kilometers northwest of Woomera, at "Range G", site of Adelaide's Čerenkov telescopes, and at the so-called "Stack Frag" facility. A number of surfaced and gravel roads pass through the site.

9.7 Spain

Initially three sites were under consideration in Spain: Tierra de Campos in Castilla y Leon, Castilla La Mancha northwest of Albacete, and Los Monegros east of Zaragoza. All three are located approximately 250 kilometers from Madrid and are readily accessible via the federal highway system. All three are well serviced by an existing infrastructure network (e.g. roads, electrical power). In the end, however, only Tierra de Campos was selected for further consideration — both La Mancha, a heavily cultivated and somewhat irregular region, and Los Monegros, an area of significant vertical relief, were judged to be unsuitable.

9.7.1 Tierra de Campos

Tierra de Campos (41.8° N, 4.9° W, 780 m.a.s.l.) lies some 40 kilometers north of the city of Valladolid (population 400,000). The proposed site is bounded by Medina de Rioseco and Sahagun to the north and south respectively and by Paredes de Nava and Majorga in the east and west.

The University of Valladolid includes departments of Physics, Meteorology, and Telecommunications (within the Engineering School). The Meteorological Institute operates "CIBA" (Centro de Investigaciones de la Baja Atmosfera) an experimental station near the southern edge of the site. CIBA's facilities include atmospheric monitoring equipment (e.g. acoustic sounding, nephelometers for measurement of atmospheric scattering) and 350 square meters of combined office, laboratory, and living space.

Physical Characteristics

The proposed site occupies a portion of the Castilla y Leon region which covers some 6000 square kilometers in total. The terrain is broadly flat with a mean slope from north to south downwards of 0.65°C. Shallow valleys in the southwest and northeast associated with the Valderaduey and Sequillo rivers cross the area; rolling hills are present in some areas, particularly in the north.

Approximately 80% of the land is either fallow or used in the production of cereal crops. The population density, low by European standards, is between 5 and 10 individuals per square kilometer. Within the site there are 4 or 5 villages of ten to fifteen thousand and an additional half dozen with populations between one and five thousand. (In contrast, the population density within the three southern hemisphere sites is significantly less than 0.1 per square kilometer.)

Climate

The climate in Tierra de Campos is classified as "semi-arid" with a mean annual precipitation of 450 millimeters. Monthly rainfall peaks in the winter at 55 millimeters, falling to typically 10 millimeters during the summer months. Cloud cover, based on estimates of the annual available sunshine, is 35%. The mean annual temperature is 12°C. Mean maximum (summer) and minimum (winter) temperatures are 28°C and 0.5°C respectively.

Infrastructure

As is expected, in association with the relatively high population density, the infrastructure is particularly well developed. The site is served by two highways and a network of national and regional roads (all tarred). In addition, a large number of well established (though untarred) roads provide ready access throughout the cultivated lands. A rail-line connects the area to Valladolid in the south (and hence on to Madrid) and to Leon in the north. Electrical power is available throughout the site from a number of high voltage transmission lines and from a network of low voltage distribution lines which serve the inhabitants of the immediate area. Water is readily available from domestic (municipal) supplies and from underground aquifers.

The industrial sector in Castilla y Leon is extensive and includes both heavy and high-technology manufacturing.

9.8 Mexico

In consultation with a group of geologists with extensive experience in the area a number of candidate sites were identified in northern Mexico. However, most were south of latitude 30°C and would provide only limited northern sky coverage. The preferred candidate, El Barreal, lies just south of the international border between Mexico and the United States.

9.8.1 El Barreal

The proposed site is approximately 100 kilometers west-south-west of the cities of Ciudad Juarez and El Paso (population > 1,000,000) and within the "tax free" border zone (31.3° N, 107.2° W, 1200 m.a.s.l.). Land use is principally grazing (30 – 40 ranches) though a few thousand hectares are under irrigated cultivation.

In addition to the scattered ranches two small villages, Las Palomas and Rodrigo Quevedo, lie within or immediately adjacent to the site; the population on-site is estimated to be less than 3000.

Physical Characteristics

The total land area at El Barreal is in excess of 6000 square kilometers; thus, several siting options are available. A regular hexagon containing no significant line-of-sight obstructions could be accommodated in the eastern portion of the area. However, the surface there is primarily consolidated dunes 1 to 3 meters in height — access would to a degree be impaired. In the north, northwest, and western sections the soils are basaltic and/or calcareous (i.e. of a much firmer nature). While generally flat this area does contain some high ground. The higher locations are typically 200 – 300 meters above the surrounding terrain, limited in extent, and are generally accessible (excepting some steep terrain in a portion of the southwest).

Vegetation throughout the area is limited to low scrub, grasses, and some cacti.

Climate

The area is best described as "semi-desert". The mean annual temperature is 25°C. The mean maximum (summer) temperature is 35°C, with a mean minimum in winter of -1°C. Annual precipitation averages 220 millimeters with more than 60% of the total falling in the months of July, August, and September. Between 180 and 220 days per year are cloudless; only 80 days are classified as cloudy (more than 50% cloud cover).

Infrastructure

Infrastructure at El Barreal is somewhat limited. A good tarred road crosses east to west across the northern portion of the site (connecting Juarez to Ascension southwest of the site). A second tarred road runs north to the border crossing at Rodrigo Quevedo near the western edge of the site. All other access throughout the site is via gravel roads of only moderate quality.

Electrical power is available only in the western portion of the site west and north of Las Palomas. An optical fiber connects Juarez and Ascension and a (presently) disused rail-line crosses the center of the site. Supplies and accommodation are available in Ascension and Rodrigo Quevedo.

9.9 United States of America

More than a dozen sites in the southwestern United States were considered as potential candidates for the Northern Auger Observatory (one in Nevada; three each in Arizona, Colorado, and Utah; five in New Mexico). After visits to each of the sites and following a careful review of the available data (e.g climatological, topographic), and in consultation with representatives from each State, four sites were selected for more detailed investigation.

9.9.1 Engle, NM:

The center of the site lies approximately 30 kilometers east of Truth or Consequences (33.1° N, 106.9° W, 1500 m.a.s.l.). The site is bounded in the east by White Sands Missile Range and the San Andreas Mountains, in the southwest by the Caballo Mountains, and in the northwest by the Fra Cristobal Mountains. Las Cruces (New Mexico State University) is roughly 80 kilometers south of the site; Albuquerque lies 150 kilometers to the north.

Physical Characteristics

The site deviates significantly from the "ideal" hexagonal configuration; its north-south extent is roughly three times that of its east-west dimension. (Dividing the site into fifths north to south, its east-west dimensions are 40, 27, 32, 40, and 42 kilometers respectively).

The mean elevation of the site is 1500 meters. However, very little of the land is level. Rather, it trends downward from the east and west towards a mid-valley line running north-south at an elevation of 1400 – 1450 meters. While numerous east-to-west and west-to-east drainages exist they are not generally deep. Elevated locations (up to 1750 meters) overlooking the site are accessible on the flanks of the Caballo, Fra Christobal, and San Andreas Mountains.

Approximately 70% of the land is State or Federal. The balance is held by a small number of individuals and lies principally in the north and northwest. Land cover is primarily grass and scrub. No significant areas of sand dunes or mud flats exist; some volcanic outflows are present in the far northern portion of the site.

Climate

The mean annual rainfall (at Truth or Consequences) is 240 millimeters. Precipitation is less than 0.5 millimeters per day excepting the period July through September when it increases roughly four-fold. During this period the likelihood of rainfall on any given day is 15% to 30%. Mean maximum and minimum temperatures in January (the coldest month) are 12°C and -3°C. The record maximum (minimum) temperature is 41°C (-21°C).

Infrastructure

An excellent tarred road connects Truth or Consequences to Engle. North and south from Engle are gravel roads of good quality (in the south connecting to the Interstate Highway near Hatch, New Mexico). Both a rail-line and a high voltage transmission line run north to south. A rail siding exists at Engle.

9.9.2 Grand Canyon, AZ:

The site is located on the Coconino Plateau just to the south of the Grand Canyon (35.8° N, 112.4° W, 1700 m.a.s.l.). Flagstaff lies 90 kilometers to the southeast beyond the San Francisco Mountains.

Physical Characteristics

The site is roughly elliptical in shape (30 by 75 kilometers) and extends from east of Valle, AZ to the Hualapai Reservation in the west and is bounded in the north by the Havasupai

Reservation and the Kaibab National Forest. The elevation increases to 1800 meters in all directions except north. A number of particularly high points lie along the southwest (long) edge of the site (e.g. Long Point which stands 200 meters above the site). Cataract Canyon, though narrow, bisects the site from southeast to northwest and forms a formidable barrier across the northern one-third of the site.

Approximately 45% of the land is held by the State of Arizona, 28% is owned and managed by the Navajo Tribe, and 27% by the Babbitt Ranches. Both the Babbitt Ranches and the Director of the Navajo Division of Natural Resources have expressed strong support for the project. The land cover is primarily grass with very little scrub; above 1800 meters elevation pinyon-pine is dominant.

Climate

The nearest National Weather Station is in Flagstaff 90 kilometers to the southwest and 400 meters higher — climate data there may not be representative of the site. Nevertheless, annual rainfall at Flagstaff is 580 millimeters (plus 2760 millimeters of snow). The mean rainfall is 2 millimeters per day decreasing significantly April through July; the "Percent of Possible Sun" is typically 75%, peaking in mid-June at 95%. The record maximum and minimum temperatures in Flagstaff are 36°C and -30°C respectively. The mean high (low) in January is 6°C (-9.3°C).

Infrastructure

Flagstaff and Williams (population 2500; 60 kilometer to the south) provide most of the required goods and services. State Highway 180 connects Grand Canyon Village to Flagstaff via Valle. Highway 64 connects Valle directly to Interstate 40 at Williams. No other tarred roads exist within the site. However, a number of good quality gravel roads enter the site from the south, southwest, and west; a paved road which serves the Hualapai reservation lies along the western boundary of the site. An electrical transmission line crosses the site east to west near Valle. A rail-line connects Williams to the South Rim of the Grand Canyon and a siding exists at Valle.

9.9.3 Lamar, CO:

The center of the proposed site lies near Highway 287 midway between Lamar and Springfield (37.7° N, 102.5° W, 1300 m.a.s.l.) The precise location is flexible due to the site's size and overall uniformity. A hexagonal or "superman" configuration would be readily accommodated.

Physical Characteristics

The land slopes slightly from 1370 meters in the southwest portion of the site downwards to the north and east to an elevation of 1220 meters. Shallow drainages cross the area. Twin Buttes, at 50 meters above the surrounding terrain, is the only high point within the site. No other particularly significant topographic features exist.

Virtually all the land is privately held; the estimated number of land holders is 150. Local municipal and county officials believe that access is unlikely to be a significant concern. Land use is primarily grazing though up to 20% is under irrigated cultivation.

Climate

The mean annual rain and snow fall are 282 and 673 millimeters respectively. Precipitation is low October through April, typically 0.5 millimeters per day, increasing roughly three fold May to September. The mean maximum and minimum temperatures in January are 6°C and -10°C respectively.

Infrastructure

Lamar (population 8343) and Springfield (population 1475) lie 40 kilometers to the north and south respectively. Both are primarily farming communities. Pueblo, the nearest large community, is some 200 kilometers west of Lamar via the town of Las Animas.

The site is bisected by Highway 287 and bounded in the south at Springfield by Highway 160. A very extensive network of roads (on a standard one mile grid) covers much of the area; most are gravel of good quality. A large number of electrical distribution lines cross the area and a rail-line runs through Springfield northwest to Las Animas.

9.9.4 Millard, UT:

The site lies in Millard County just to the south of Delta and west of Filmore (150 kilometers southwest of Salt Lake City); its center is 6 – 8 kilometers southwest of Pavant Butte a prominent landmark (39.1° N, 112.6° W, 1400 m.a.s.l.) Inclusion of some high ground (the Cricket Mountains) in the west permits a hexagonal array configuration. The site is bounded to the east and southeast by Interstate 15 and in the south by rising ground near the Twin Peaks.

Physical Characteristics

The northern half of the site is at an elevation of 1400 meters, sloping slightly upwards toward the south to 1450 meters. A number of peaks and ridges exist within the proposed bounds of the site including: the northern portion of the Cricket Mountains, Pavant Butte, Beaver Ridge (Telegraph Point), and Black Rock.

The Cricket Mountains are probably the most significant impediment within the Millard site. However, while they extend into the site approximately 15 kilometers, their lateral dimension are typically only 2 kilometers. Peak elevations are near 1800 meters and microwave relay stations are present at two locations. Pavant Butte is a prominent volcanic cinder cone roughly 2.5 – 3 kilometers in diameter and with an elevation of 1750 meters.

Volcanic outflows cover an area of 50 – 60 square kilometers; access is limited due to the extremely rough surface. Seasonally inundated mud flats exist covering an area of 150 square kilometers.

Approximately 80% of the land is Federal or State, the balance is in private hands (some 200-300 landholders) and lies near Interstate 15 in the eastern portion of the proposed site. Public lands are used for grazing while the private lands are under irrigated cultivation. Land cover throughout most of the public lands area is grasses with very little scrub.

Climate

Long term climatic records are not available for Delta. The nearest reporting station is in Milford 80 kilometers to the south and 100 meters higher in elevation. At Milford, the mean annual rain (snow) fall is 249 (1221) millimeters. The "Percent of Possible Sun" ranges from 60% during the fall and winter to 75% during spring and summer. (There is little seasonal variation in precipitation.) Mean maximum and minimum temperatures in January are 3.4°C and -10.9°C respectively.

Infrastructure

Delta (population 2998) is some 15 kilometers north of the northern boundary of the site; The northeast, and east and southeast sides of the area are bounded by Highway 50 and Interstate 15 respectively. Numerous gravel roads cross the site and the high ground of the Cricket Mountains, Pavant Butte, and Black Rock are all accessible via gravel road. A power line crosses Beaver Ridge in the south and a high voltage transmission line passes east-west just north of Pavant Butte. A rail-line with numerous sidings parallels Hwy 257 as does a fiber optic telecommunications link.

The Intermountain Power Plant (IPP), a multi-gigawatt coal burning facility, lies approximately 20 kilometers northeast of Delta. Assets at the IPP which may be available to the Auger Project include high-bay fabrication areas, office space, computing access, and industrial scale ultra-pure water production facilities.