Section 1

OVERVIEW

ABANDONED URANIUM MINES PROJECT ATLAS

PROJECT OVERVIEW

STUDY AREA

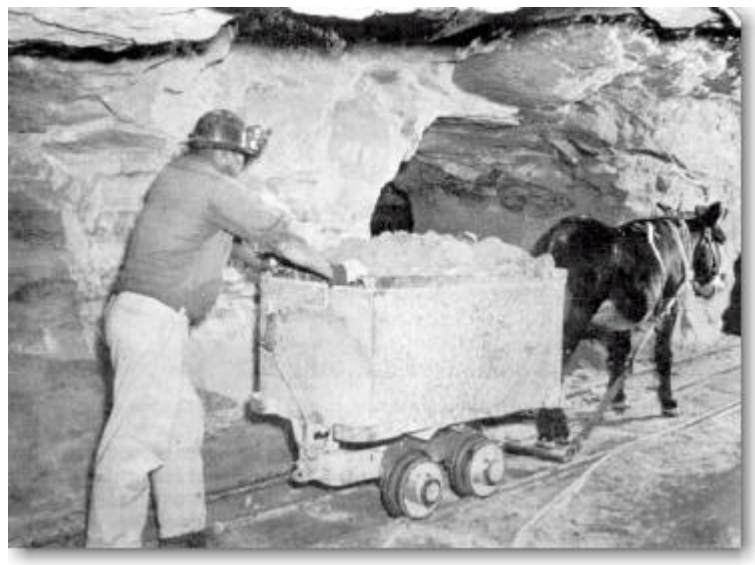
The Navajo Nation is located on the Colorado Plateau and encompasses over 25,000 square miles across Arizona, New Mexico, and Utah. The distinctive physiography of this region has resulted in a major mining area for uranium. The Navajo Nation includes intensely dissected rocky regions and has elevations that range from about 3,000 feet to slightly over 10,000 feet. The region is known for a wide variety of topographies that include broad upland plains, rugged tablelands with dramatic buttes and mesas, and major mountainous regions. The varied topography results in different climate and vegetation regimes. These include warm, arid desert climates with sparse slow growing grasses and browse plants; intermediate steppe climates with grasses, sagebrushes, and pinyon-juniper; and cold, subhumid mountain climates where pine, oaks, and associated grasses and shrubs are found.

The resident population of the Navajo Nation has been estimated (1995) at nearly 170,000. This provides an overall density of less than 7 people per square mile. Navajo Chapters provide an administrative unit similar to counties or parishes. There are currently 110 Chapters throughout the Navajo Nation.

MINING HISTORY

Mining for uranium and vanadium ore was conducted on Navajo Lands from the 1940s through the 1960s. According to Dare (1961) and Chenoweth (1984), mining continued for more than 25 years on land held in trust for the Navajo Nation by the U.S. Department of Interior, Bureau of Indian Affairs (BIA). After mining activities stopped, the mining rights were returned to the Navajo Nation.

Navajo miner hauling ore



Burro haulage in Frank No. 1 Mine (photos by Dare)

The mines were located in geologic terrain that contains deposits of uranium and vanadium ores in sedimentary formations. The ore deposits contain naturally occurring metals and radionuclides: parent isotopes uranium^{238}, thorium^{232}, and uranium^{235}, and daughter isotopes from their decay series (uranium, thorium, and actinium decay series, respectively). The ore deposits vary within regions, but are generally located at shallow depths beneath ground surfaces or exposed on slopes and mesa tops. Ore bodies at or near the surface were excavated, while buried ore bodies and ore bodies exposed on canyon walls were mined by digging down to the ore or into the face of a hillside or canyon wall, creating mine entrances, vertical shafts and/or horizontal tunnels (adits).

Excavation of uranium ore bodies near the surface, such as on mesa tops, generally resulted in shallow pits, often less than 10 feet deep, with unexcavated low-grade ore at the base and low-grade ore debris piles on the surface. Mining of ore bodies exposed in canyon walls or on the sides of mesas removed the exposed ore that emitted high levels of gamma radiation. Below the excavations the large debris piles or talus slopes were left behind. The pits, shafts and other mine structures remained open.

PROJECT BACKGROUND

Concern about the risk of excessive exposure to radiation from mining debris remaining from historical mining activities led to the July 1993 Congressional Committee report titled “Deep Pockets: Taxpayer Liability for Environmental Contamination.” At congressional hearings on November 4, 1993 the Navajo Nation presented testimony concerning abandoned uranium mines and requested assistance in determining if the old mines pose a health risk to residents. The U.S. Environmental Protection Agency (USEPA) presented testimony to describe its federal authority under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) and how the USEPA could assist the tribe. The U.S. Department of Energy (USDOE) and the U.S. Department of Interior (USDOI), the Navajo Nation Environmental Protection Agency (NNEPA) and the Navajo Nation Abandoned Mine Lands Reclamation Department (NNAMLRD) also participated in the hearings.

PROJECT OVERVIEW (continued)

The USEPA Region 9 Abandoned Uranium Mines Project began in 1994 with investigations in the King Tutt Mesa study area located in the Red Valley Chapter of the Navajo Nation. The investigations were conducted with the assistance of the NNEPA Superfund Program, Bechtel Environmental, and the USDOE Remote Sensing Laboratory. The overall objective of the investigation was to determine whether abandoned uranium/vanadium mines and related mine features posed a significant risk to human health, and to identify areas or features requiring action to reduce exposure. Additional objectives of the investigation were to develop a preliminary protocol for evaluation of other uranium mining areas and to outline community involvement steps to assist future investigators in working with other Navajo communities.

In June 1997, the USEPA Region 9 and Bechtel Environmental issued a document titled "Integrated Assessment, Draft for Comment, Navajo Uranium Mines-King Tutt Mesa Study Area, Red Valley Chapter, Navajo Nation, Oak Spring, New Mexico 87420, Site EPA ID Number: NND 986667434". The results of the initial King Tutt Mesa Study led to the development of a three-step process for investigating other areas with abandoned uranium mines:

1. A regional radiation survey conducted by helicopter to find sources of radiation in old mining areas.
2. The testing of water used for human consumption.
3. The surveying of homes constructed with materials from the mines.

Various planning materials were collected and reviewed prior to extending the project. Numerous historical records and reports of mining activity in the Navajo Nation were assembled. The results of studies of similar environmental situations in other mining areas were reviewed. These were combined with the lessons learned from the King Tutt Mesa study to expand the project to other mining areas across the Navajo Nation. Through Interagency Agreements with USDOE and the USACE, senior scientists and field personnel brought expert technologies for surveys and sampling to six mining districts known to be areas of historical mining and exploration for uranium.

The USDOE Aerial Measuring System (AMS) survey capability was used to measure and map radiation sources within known uranium mining areas. The same type of helicopter surveys that were used in 1994 in the Four Corners Area were conducted in 1997, 1998 and 1999 in the other areas. A total of 1,144 square miles were surveyed. In March 1998 the USACE joined the project to investigate water used for human consumption and home construction using mine waste rock in the areas of the old uranium mining activities.

The lead agency was the USEPA Region 9, with Patti Collins as the Project Manager-Senior Scientist and Vicki Rosen as the Community Involvement Coordinator. Working with the USEPA were agencies including NNEPA, NNAMLRD, USDOE, and USACE, as well as academic and scientific institutions.

PROJECT PURPOSE

The purpose of the Abandoned Uranium Mines Project was to identify the radiation sources, characterize the exposure, and recommend methods to reduce radiation exposure from abandoned uranium mines on the Navajo Nation. From the beginning of the field investigations it was recognized that there were several categories of potential risk due to exposure to radiation, metals, and other hazards related to abandoned uranium mines and their setting. The approach to these sources of potential exposure was to focus first on identifying the sources of greatest potential exposure and thus the greatest risk to human health. Given the regional geology, the types of ore bodies, mining, transport of ore, and local land use, it was determined that the greatest potential exposures would be through two primary pathways:

1) Internal exposure by consumption of water containing radioactive and/or stable metals.
2) External exposure to radiation from stone masonry of mine waste rock, or other mining materials used for construction in or around homes.

The potential of abandoned mine structures as physical hazards was also recognized. The primary focus of the data collection activities, however, was to identify the radiation sources and to characterize the types of exposure.

In order for the Abandoned Uranium Mines Project to succeed, it was necessary to involve the affected communities and to engage them as active community partners. An important goal of the project was to develop an outreach strategy that would result in a two-way sharing of information. This involved educational efforts to increase understanding and awareness of the mines and their possible effects as well as engaging participation of Chapter Officials to assist in identifying water sources used for human consumption and homes that should be surveyed. To assist in these outreach activities, an important goal of the project was to provide data and results from the various data collection efforts in a format that was easily accessible to the end user. Providing education and outreach about the radiation and working with individual communities living in proximity to the abandoned mines were key components of the project.

METHODOLOGY

Characterization of Risk

Given the limited resources to sample a large area of mining and mine-related activities, a methodology was designed to utilize the resources across a broad area using aerial surveys and high-quality, one-time samples of water used for human consumption. This approach was used since it provided the greatest amount of information from which to begin actions to determine exposures and to focus more detailed investigations if warranted.

External Exposure

The levels of radiation from numerous sources were measured through aerial and field measurements. In order to evaluate the potential exposure to an external radiation source, three factors were considered: the location of the radiation source, the amount of radiation, and its proximity to people and land use. From this information, the risk of the exposure could be determined.

Internal Exposure

The greatest potential exposure to radiation and related metals was determined to be through consumption of water. Over 200 water sources used for human consumption were identified and tested. The calculation of risk posed by consuming water from each of the sources was performed using standard methods. Appendix A.1 (Summary of the Characterization of Risk Leading to Exposure Reduction) provides an explanation of the standard method used to calculate risk.

Brian Jordan (USACE) collecting a water sample at Lukai Spring (Sample ID BI980713TES004) in the Teesto Chapter

Ludlum 19 used for ground radiation surveys

Community Information and Education

Community Information and Education served two important functions. First, it provided information to the people who were exposed or potentially exposed. The information assisted people in making informed choices about local activities. These included a wide variety of activities such as where to collect water, where to build and where to direct children to play. For example, there were areas where some of the water sources had higher levels of metals such as uranium, yet other local sources were of a better quality. The single most effective and fastest method to reduce possible exposures was for the people who haul water to their homes to know about the condition of their water. This simple step of local education and information was a fast yet effective first step to risk reduction.

Second, education provided the information to help people prevent future exposures. For example, the potential for radiation exposure existed in the construction of new homes and schools located immediately adjacent or on top of old mines or areas of mining activity where radiation sources remain. Different agencies or individuals decide the siting of homes, schools or other structures. Discussions with various agencies, local officials, and others indicated that one of the most effective ways to avoid creating new problems was to share the information about the radiation sources as shown on the area maps with local agencies, schools and community officials. There are generally three ways to inform and educate those in the affected areas: 1) through the grazing official of the local grazing district, 2) through the adults in the family enclaves that form small communities, and 3) through the schools as students take the information home to their families. The simplest form of education, the discussions and explanations that took place during the field operations, proved to be neither complicated nor difficult to do. Emphasis on the timeliness and the quality of the communications was key to the success of education and information.

Vicki Rosen, USEPA Region 9 Community Involvement Coordinator after a presentation at Monument Valley High School in Oljato, Utah

Glynn Alsup (USACE) teaching a class at Tse' Bit ai Middle School in Shiprock, Arizona

Survey Areas

A general review of historical mining activities in Arizona, New Mexico and Utah, including the works of Chenoweth, Dare and others, identified 6 mining districts that were the focus of this study. Each of these areas contained numerous abandoned uranium/vanadium mines. The areas were:

Four Corners
Monument Valley
Cameron -Tuba City
Bidahochi
Central
Chinle

Four Corners Area

Mines in this area were adits, shafts, pits or trenches in ore-bearing Salt Wash Member of the Morrison Formation. The area was mined using a combination of conventional blasting techniques and manual labor for the removal of overburden and ore. Extracted ore was manually sorted on site with the higher grades being transported off site to processing mills and the lower grades (proto-ore) remaining on site in debris piles.

Monument Valley Area

During the period 1942 through 1946, three "carnotite" (uranium/vanadium ore) leases in Monument Valley produced a total of 156,237 pounds of vanadium oxide. Among the most productive mines were Monument 1, Alma-Seggin, Fern 1, Utah 1, Big Chief 3 & 4, and Radium Hill. In addition, 4,783 pounds of uranium oxide contained in the Utah 1 lease were sold.

Cameron -Tuba City Area

During its lifetime, the Tuba City mill (operated by Rare Metals Corporation of America) processed 800,000 tons of ore, most of which was generated from the Orphan Lode Mine. Orphan Load closed in 1969. Peak production was in 1956 from Cameron area mines. The most significant Cameron area mines were: Jack Daniels, Charles Huskon 4, Paul Huskon 3, Charles Huskon 3, Charles Huskon 1, and Ramco 20. Rare Metals' Ramco pits collectively produced about 47,600 tons of ore between 1956 and 1960. Rare Metals also acquired Charles Huskon Mines 1, 3, 5-8, 10-12, 14, 17 and 26 from Arrowhead in 1955. Charles Huskon mines 4, 9, 18, 19 and 20 were operated by UTCO Uranium Corporation from 1956 to 1959. Late production (1961-1963) is recorded from Charles Huskon 1, 3, 6, 10, 11, 12 and 17; Evans Huskon; 2: Jack Daniels; Julius Chee 3; Yazzie 2, 101 and 312; and Section 9 mines.

Bidahochi Area

The most significant Bidahochi mines were Boot Jack Mine, Fern 1 Mine, Bidahochi Butte prospects, and the Calvin Chee prospect. No mining production information was available for this area.

Central Area

Significant mine leases included the Dan Taylor Mine, Tah Chee Wash leases 8 and 31, Rough Rock Slope 9, Begay and Bahe 1, Todecheenie 1, Charley 1, and Etsitty 1. No mining production information was available for this area.

Chinle Area

No detailed information on mining activities was identified for this area.

Sample Site Selection

The protocol developed under the King Tutt Mesa study was used as a guide in selecting additional sample locations for the other areas. Historical maps and records were researched to identify possible mine locations (see page 1.11). Aerial helicopter radiation surveys were flown to measure radiation over suspected mining areas in order to locate the current sources of radiation. Aerial radiation surveys of 41 selected uranium mining areas on the Navajo Nation were conducted over the period of October 1994 through October 1999. The surveys were flown at the request of the USEPA Region 9 and were performed by the USDOE Remote Sensing Laboratory in Las Vegas, Nevada. The purpose of the aerial surveys was to identify possible sites of mines, spoil piles, transfer stations, and other activities related to uranium mining (see Appendix A.3 - USDOE Aerial Measuring System Summary for more detail).

Planning maps for selecting field sample locations were developed using the radiation contour data in conjunction with readily available spring location data (see page 1.15). The planning maps were reviewed in meetings with representatives of the Navajo Nation Chapters. Involving local Chapter Officials in the sample selection process provided local knowledge needed for identifying water sources used for human consumption. In addition, they were able to identify homes built of mine waste rock. The local Chapter Officials were the most knowledgeable source for information about land and water uses in their communities, and they provided important information about what locations should be sampled.

Aerial Radiation Surveys

The project area encompassed 17.5 million acres of rugged terrain in the states of Arizona, New Mexico and Utah. Much of the area is not accessible by roads. Using aerial survey methods to collect data on the locations of radiation source areas was: 1) to help focus the field investigations in areas of current rather than historic radiation (the Navajo Abandoned Mines Land Reclamation Program had been working for a number of years on the reclamation of old mines); 2) to locate and record the old mining activities that were sources of radiation using a method that would be much faster than scouting and measuring at ground level; and 3) to measure the levels of total radiation as well as the individual isotopes, such as Bismuth^{214} , that could be extracted through data processing as an indicator of mining activity.

The radiation was measured with instruments mounted on a helicopter. The helicopter was initially flown at an altitude of 150 feet recording the radiation along flight lines placed 250 feet apart. At this altitude, the sensor footprint or ground area being measured was determined to be approximately 300 feet in diameter. After analysis of data collected using this protocol, the line spacing was increased to 300 feet to increase operational data collection efficiency, without loss of data quality.

Each radiation measurement from the aerial instruments provided an average radiation level for the ground sample area. This means the data does not pinpoint the radiation levels within the ground sample area (a footprint approximately 300 feet in diameter under the helicopter). Within the sample area, the radiation source could be evenly distributed or made up of a combination of radiation sources, like a higher-level mine waste debris pile sitting on soil that had lower regional radiation levels. Obtaining finer detail measurements of any individual radiation source required additional ground level measurements.

Field Sampling

USACE field sampling operations included water sampling, home construction surveys, radiation surveys, and mine surveys. Using a format similar to sampling used during the 1994 fieldwork, USEPA Region 9, Bechtel Environmental and the USACE developed the 1998 Field Sampling Plan. All field data collected were of sufficient quality, documentation and verification to be available for use for the USEPA Superfund administration processes including, but not limited to, the various removal and remedial actions intended for exposure reduction.

The purpose of the field water-sampling program was to collect water sample data that would allow evaluation of risks to human health by ingestion of radioactive and stable metals in water. The USACE water-sampling program was designed to collect water sample data that was representative of the condition and quality with respect to stable and radioactive metal concentrations in water sources used for human consumption. The sampling program consisted of collecting one water sample at each well, tap, spring, or tank identified as a source for human consumption. If there was a common source for multiple users, such as a community well or tap, only the common source location would be sampled. All samples were collected as a point-of-use sample designed to duplicate the most likely method in which a person would obtain water for human consumption. The data were collected at levels of precision and accuracy to allow comparison of results against standard benchmarks of human risk of consuming the water. At each site, radiation levels were monitored and recorded. Radiation levels were recorded at a standard height of one meter from the ground surface.

The field home surveys were conducted to identify homes that were built with or near mine waste rock and to characterize the radiation exposure. Written records of homes built of mine rock or other waste materials were not identified prior to field operations. Field sampling efforts therefore relied on the local Chapter Officials to identify any homes for radiation measurements. Home surveys were provided as a service to the Chapters, but were undertaken only when requested and the results are not presented in this Atlas.

A detailed description of the sampling methodology and the analytical program used by the USACE is provided in Appendix A.4b - USACE Field Operations Summary. Appendix A.4c - USACE Data Management Summary provides a description of the data management process used for handling and analyzing the samples.

SUMMARY OF ANALYTICAL PROGRAM

STABLE METALS

Aluminum	Antimony	Arsenic	Barium	Beryllium
Cadmium	Calcium	Chromium	Cobalt	Copper
Iron	Lead	Magnesium	Manganese	Mercury
Nickel	Potassium	Selenium	Silver	Sodium
Thallium	Vanadium	Zinc		

RADIOACTIVE METALS

Lead^{210}	Radium^{226}	Radium^{228}	Thorium^{228}	Thorium^{230}
Thorium^{232}	Thorium^{234}	Uranium^{235}	Uranium^{238}	Gross Alpha
Gross Beta				

Calcium, Potassium, Magnesium, Cobalt, and Sodium are secondary analytes (affecting water taste, smell, and color) and are not presented in the Project Atlas data tables.

DEMOBILIZATION

In January 2000, Michael Feeley (Deputy Director of the USEPA Region 9 Superfund Program) initiated demobilization of the field team. The demobilization was based on a request from Derrith Watchman-Moore, Executive Director of the NNEPA, to cease all visits to tribal chapters. The project team began demobilization of all field activities including sampling and communications. The demobilization was completed January 31, 2000. Subsequently all aspects of the project began close-out activities leading to the summarization and distribution of the data collected between 1994 and 2000. These close-out activities included archiving all of the scientific information collected for the project and development of this project Atlas.

WORK COMPLETED

Community Information and Education

From 1994 to 2000, USEPA Region 9 brought the project to approximately 30 chapters on the Navajo Nation. In October 1994 a Blessing Way Ceremony and traditional lunch was held to introduce the project to the first area to be surveyed by helicopter. The helicopter was on hand so people could see it and its crew. As the project progressed, outreach materials in the form of simple flyers and photographs were distributed to the chapter houses and trading posts. Maps were developed from the aerial surveys to show radiation contours, water-sampling results and risk analysis. These maps were provided to, and reviewed with, Chapter Officials. Several presentations on uranium, the mines and the environment were given at schools throughout the Navajo Nation. Presentations with more technical content were given for several science classes to teach the fundamentals of the project and how the water sampling was performed. A coloring book titled "Gamma Goat - The Dangers of Uranium" was created to teach the younger children about uranium mines and radiation.

Aerial Radiation Surveys

Aerial radiological surveys of 41 uranium mining areas (1,144 square miles) within the Navajo Nation were conducted during the period of October 1994 through October 1999. The aerial surveys located hundreds of radiation sources from single mines, clusters of mines and loading areas. The radiation levels measured by the helicopter surveys are shown on two series of maps. The Bismuth^{214} data are indicative of the presence of uranium and, therefore, a good indicator for old mines and mine-related activity. The gross count data are indicative of the total radiation in the area. Identifying current radiation source areas was useful for designing field sampling plans for water and home surveys.

A USDOE Aerial Measuring System helicopter flying over Monument Valley High School.

Field Data Sampling

The USACE identified many radiation sources, sampled water used for human consumption, and conducted home surveys. Between June 1998 and January 2000 the USACE field investigations included 227 water samples, 27 Quality Control Samples (of which 14 were field blanks and 13 were duplicates), 28 home surveys, and 34 radiation surveys. The home surveys are not presented in this Atlas.

Water samples were collected, often under challenging conditions.

After the samples were collected they were processed.

Characterization of Risk Leading to Exposure Reduction

Focusing on the greatest potential exposures supported the overall project goal of exposure reduction. At the close of the investigations conducted from 1994 to 2000 the evaluation of risk and exposure reduction had been viewed in two ways: 1) identifying current exposures by using aerial and field radiation surveys, performing home construction surveys, and conducting extensive water sampling, and 2) preventing future exposures through education. By locating the greatest exposures across all the major mining areas, these data were made available to begin exposure reduction actions, such as removal of radioactive stone masonry in homes and locating alternative local water sources in areas with elevated metals. Although the project was not completed, the data were made available to all interested parties.

WORK NOT COMPLETED

The following is a description of investigations that were not initiated or not completed prior to demobilization in early 2000.

Data Collection

Work In Progress That Stopped

Chapters With Requests For Assistance and Information - In each area sampled the Chapter Officials were advised that the field team would be returning to complete the field sampling, to assist in locating alternative local water sources in areas where there were elevated metals, and to check for bacteria in good water sources and alternative local water sources. The Chapter Officials had also requested discussions with the project team concerning the maps and results, since understanding the results was vital to assessing alternative sources of water. These activities were not completed before the demobilization.

Tank 8A-299 (Sample ID KY980902OLW001) in Oljato,Utah. The photo on the left shows the tank and the photo on the right shows mine debris located northeast and approximately 1/4 mile from the tank.

Chapters With Helicopter Surveys, But No Ground Surveys - There were some areas where helicopter radiation surveys were completed, but no water or home samples were conducted prior to demobilization. An example was the Sanostee area south of Red Valley and Cove. The helicopter radiation survey was completed. Water and home sampling was discussed with Chapter Officials, but no sampling was conducted prior to demobilization.

Location coordinates were collected using a Global Positioning System (GPS) at all water sample sites as shown in the photo above with Ray Salas (USACE).

Glynn Alsup and Edison Davis collecting water samples at Chandler Spring in the Dilkon Chapter.

Chapters With Water Surveys, But Incomplete Radiation Source Characterization - Conversely, there were some areas where water samples were collected, but there was incomplete radiation source characterization. An example of where this occurred was Sweetwater, located adjacent to Teec Nos Pos at the south end of the T'setah Wash flight area. Water sampling had begun but was not completed. An area of old mines was identified west of the T'setah Wash flight area. No aerial or ground surveys were conducted for radiation from this area to the west.

Uranium Mines Abandoned Post-1977 Surface Mining Control and Reclamation Act (SMCRA) - These mines form a category of abandoned mines that are not reclaimed by the NNAMLRD under authority of the SMCRA. The locations and nature of these sites were not determined by the time of demobilization.

Work Planned But Not Started

Eastern Agency South of Red Valley - In August 1999 the Grazing Officials of the Eastern Agency held a regular meeting, that included a discussion of the investigations in chapters with abandoned uranium mines. They were interested in having the radiation investigations come to their chapters including Two Grey Hills, which is adjacent to Sanostee where the helicopter survey was done, and the chapters along I-40 in the Grants Mineral Belt.

Eastern Agency Along I-40 - No helicopter radiation survey, water sampling or home construction sampling was conducted here. It was planned, but not begun at the time of demobilization.

Uranium Mining Areas Not Surveyed By Helicopter - There were historical records of some mines, many of which are presented on the regional map, in areas that were not surveyed by helicopter. In most of these cases, either the sparse distribution or extreme terrain conditions made the area inefficient or unsuitable for aerial measurement of radiation. These additional mining areas would have been surveyed with radiation equipment used at ground level. This would have been done in coordination with local officials familiar with land use in the vicinity of the mines.

Uranium Mining Exploration Activities - In numerous locations, there was evidence of uranium exploration activities in the form of excavations and test holes of various sizes. The exploration was typically performed to detect the presence of a deposit that might lie near a mined accumulation of ore. The presence of these remnants of exploration presents the possibility of degradation of water quality in the area. The area from Chilchinbito to Rough Rock to Many Farms is an example. Further investigation of water quality over a larger area than the immediate vicinity of the mining sites would be necessary to determine the situation.

Characterization of Risk Leading to Exposure Reduction

Aerial Measurements

The radiation levels measured by the helicopter surveys were shown on two series of maps. However, the radiation source areas were not characterized as to the risk posed by each source since the specific proximity to people and land use had not been determined at the time of the project close out.

Field Measurements

The measurements of radiation made by the field team included a gamma radiation reading at each water sample location, various areas of old mining activity such as pits, mine openings and waste piles, and stone masonry used in home construction. The risk posed by these specific external sources of radiation exposure had not been calculated or presented on maps at the time of the project close out.

The cumulative risks in each area were not fully determined at the time of the project close out.

Community Information and Education

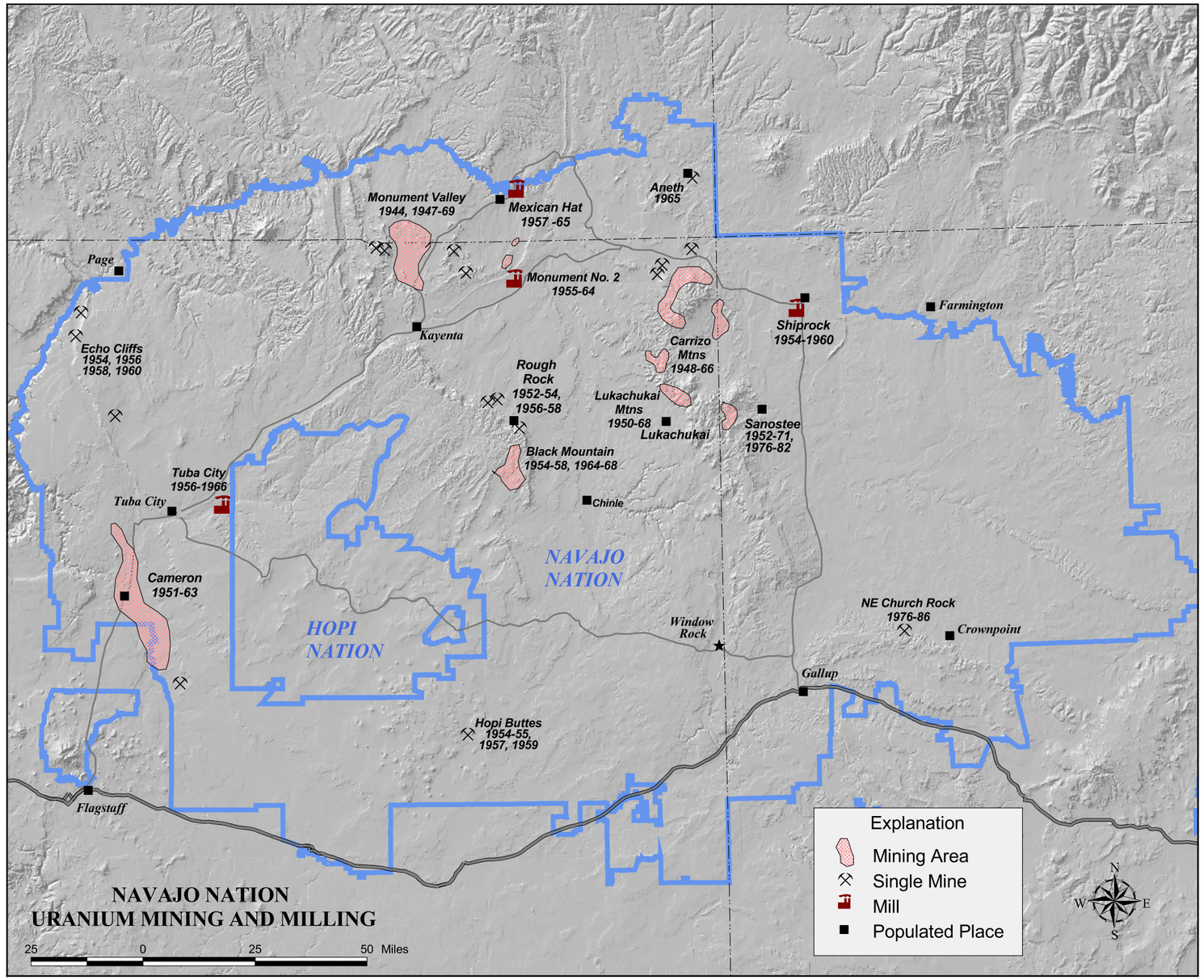
Follow-up visits were planned for each chapter to discuss in detail the results of the sampling, to explain the health risks involved with the water sources, and to assist with possible solutions. Sampling of additional local water sources used for human consumption was planned if the communities requested after the review of data results.

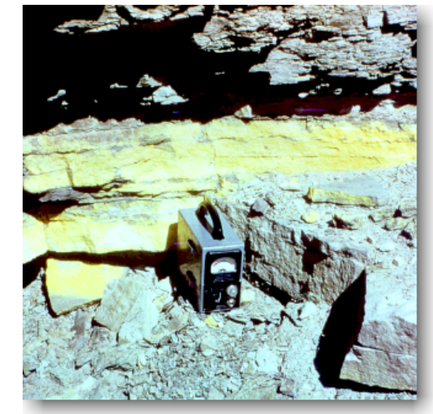
Vicki Rosen explaining the sampling program to teachers at Dine College at the Tsaile Campus

EXPOSURE REDUCTION

The reduction of exposure to the various hazards created by the abandoned uranium mines was to be addressed through field actions to reduce or eliminate the source(s) of the greatest exposure and through education to prevent future exposures. Field actions to reduce or eliminate these source(s) of exposure were underway beginning with a scouting trip to locations in the Four Corners and Monument Valley areas to assess the logistics for Removal Actions (a method of exposure reduction through the USEPA Superfund Program). No field activities to reduce or eliminate the sources of radiation had been completed when the field operations were demobilized in January 2000. Various forms of education to prevent exposure were underway at the time of project close out.

MINES

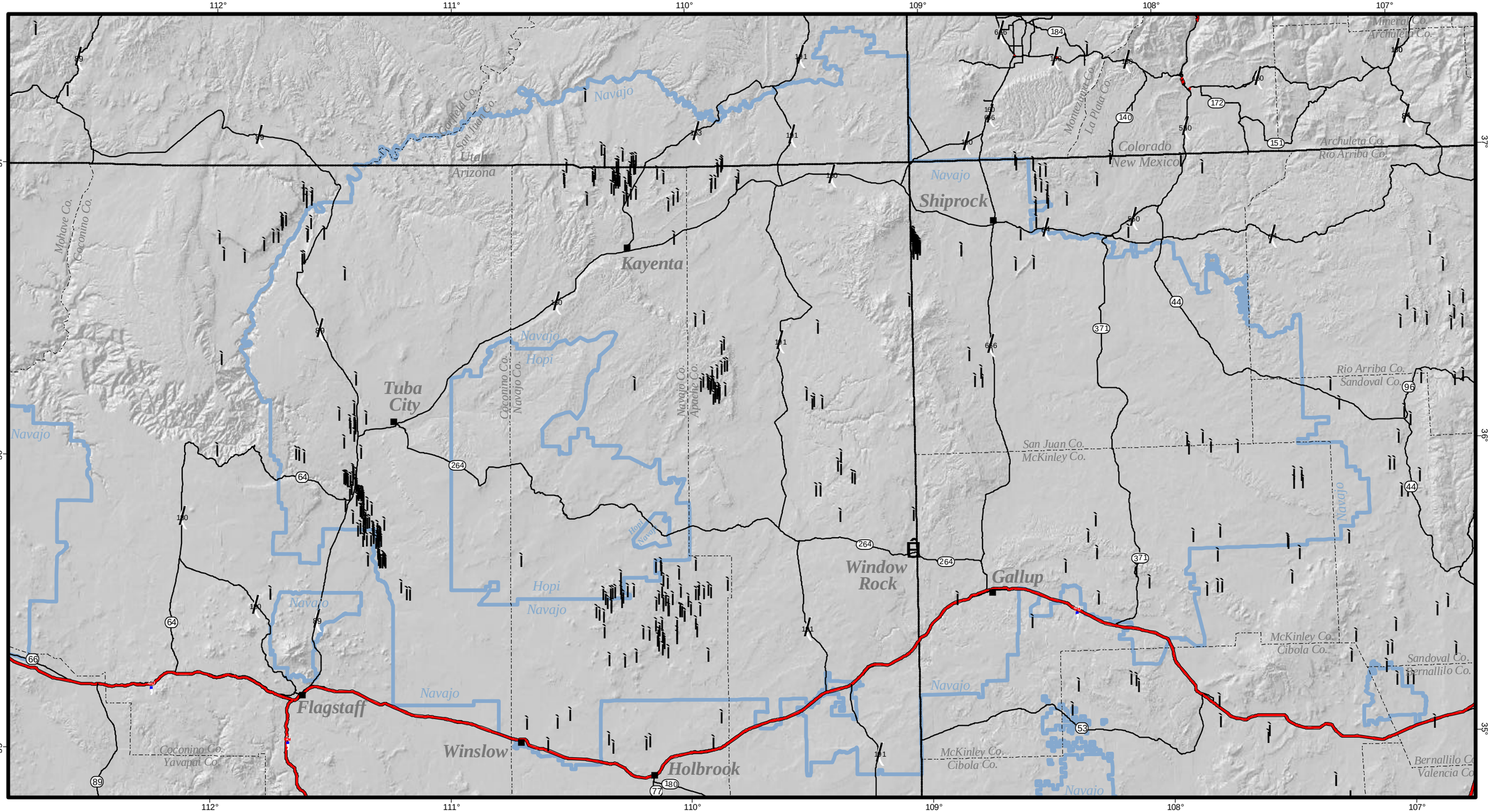




Photos: (Top) A Navajo miner empties fractured uranium bearing sandstone in the Frank No. 1 Mine near Red Valley, Arizona in the late 1950s.
(Middle) 1958 photo of Mesa #2 Mine located in the Lukachukai Mountains showing a mine with large debris piles.
(Bottom) The Moonlight Mine located south of Oljato is an example of an open pit mine.

The facing map shows the locations of historic uranium mines that were used to assist in the flight planning for the helicopter radiation surveys. The uranium mine locations shown on the facing map are approximate and were compiled from various sources by Thane Hendricks, USDOE Remote Sensing Laboratory. The map above shows the general locations and dates of operation of historic mining areas and mills (after a map prepared by W.L. Chenoweth for the USDOJ Radiation Unit). The map shows mining areas, individual mines and mills.

Photos: (Top) A uranium deposit (yellow vein).
(Middle) A reclaimed mine site (Monument #1) north of Kayenta.
(Bottom) Glynn Alsup taking radiation measurements at a mine shaft entrance east of Rattlesnake Mine.



Map Features

Ì Mine

Mine locations are approximate and were compiled from various sources by Thane Hendricks, U.S. Department of Energy, Remote Sensing Laboratory.

4

MINES

20 0 20 Miles

20 0 20 40 Kilometers

1:1,400,000

U.S. Environmental Protection Agency

ABANDONED URANIUM MINES PROJECT

Navajo Nation

AERIAL RADIATION SURVEY AREAS

One of the USDOE Bell B412 helicopters used to fly the aerial radiation surveys over the Navajo Nation. The twin engine helicopters were flown at an altitude of 150 feet above ground level with 300 foot flight line spacings for most of the surveys. This flight configuration resulted in a footprint of 300 feet, or the total radiation from an area with a 300 foot diameter.

A Bell B412 helicopter in-flight. The white detector pods mounted on the sides of the skid rack contained twelve 2x4x16-inch log-type sodium iodide detectors.

To fully characterize the radiation levels, it is necessary to make ground radiation measurements. This is because the aerial surveys do not pinpoint exact levels of radiation within any given area of 300 foot diameter. Field radiation measurements were taken using hand-held radiation meters.

Patti Collins, USEPA Region 9 Project Manager, next to an AMS helicopter at the Flagstaff Airport during the Cameron/Tuba City radiation surveys.

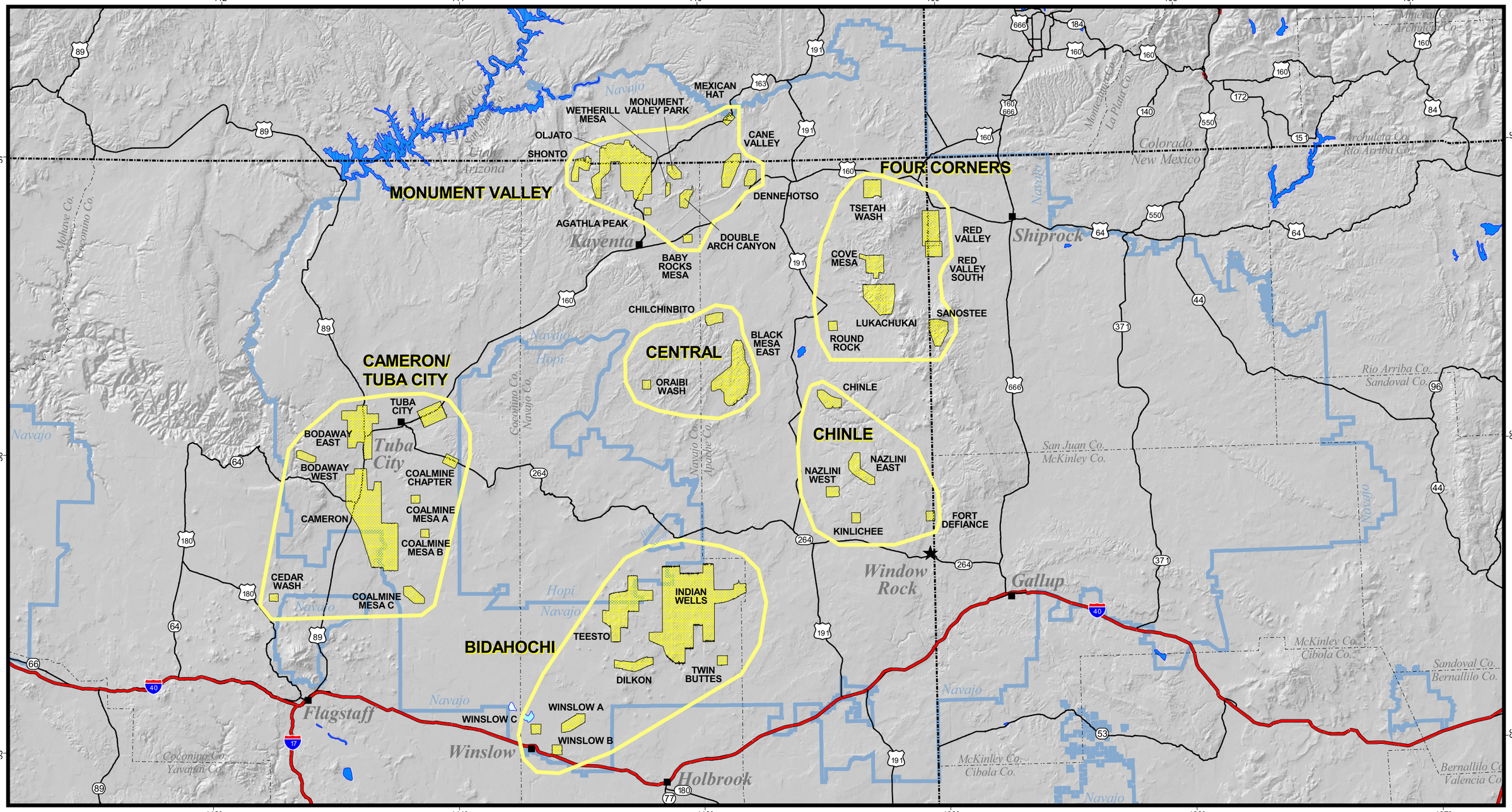
Data processing personnel from the USDOE Remote Sensing Laboratory were in the field to perform post-flight analysis of the data. This photo shows part of the AMS Mobile Laboratory.

A Radiation and Environmental Data Analysis Computer (REDAC) was located at each survey base of operation. Two REDAC configurations were used: 1) a mobile laboratory, based in the AMS mobile laboratory, and 2) a portable system was set up in a motel room. The REDAC systems were used to perform post-flight analysis in the field to ensure that there were no problems with the data.

AMS pilots were available to show the local community the helicopters and to explain what was being surveyed and how the radiation survey equipment worked.

The facing map shows the locations of the aerial radiation survey boundaries flown on the Navajo Nation from 1994 to 1999. The aerial surveys were funded by the USEPA and flown by the USDOE Remote Sensing Laboratory's Aerial Measuring System (AMS) in Las Vegas, Nevada. The AMS records gamma ray, aircraft position, and weather data at one-second intervals on data storage devices for post-flight analysis on a ground-based computer.

Gamma radiation was detected with thallium activated sodium iodide scintillation detectors. Aircraft position was established using a real-time differential Global Positioning System and radar altimeter. After aerial radiation surveys were flown, ground radiation measurements and home surveys were conducted.



Map Features

Survey Regions

Flight Areas

Lake / Reservoir

N W E S

AERIAL RADIATION SURVEY AREAS

20 0 20 Miles

20 0 20 40 Kilometers

1:1,400,000

U.S. Environmental Protection Agency

ABANDONED URANIUM MINES PROJECT

Navajo Nation

SPRINGS

Cottonwood Springs in the Chinle Chapter

Boiling Over Spring in the Cove Chapter

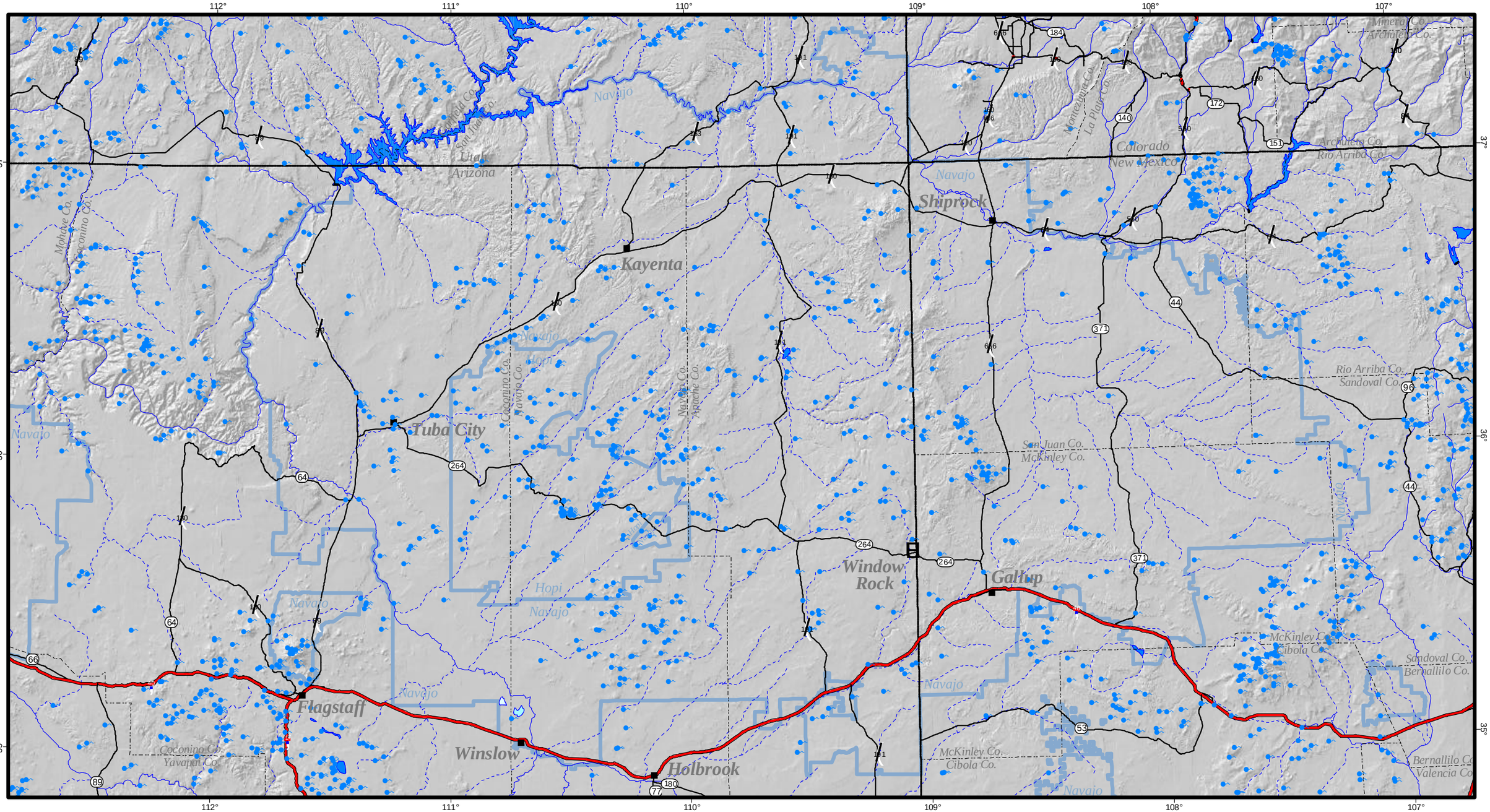
Glynn Alsup taking a water sample at the Gold Spring in the Coalmine Chapter

Tse To Baah Naali Spring in the Coalmine Chapter

Glynn Alsup sampling water at the Alcove Canyon Springs in the Cove Chapter

Aspen Spring in the Shonto Chapter

The facing map shows the locations of springs on and around the project area. Maps of springs were used to help plan the field data collection and water sampling in areas of old uranium mines. Planning maps were developed that showed these spring data combined with the locations of historic mines and results from the helicopter radiation surveys. These maps were used in discussions with local officials to aid the process of selecting sources of water used for human consumption that were sampled.



Map Features

● Springs

▬ Lake / Reservoir

Stream

Stream Intermittent

4

SPRINGS

20 0 20 Miles

20 0 20 40 Kilometers

1:1,400,000

U.S. Environmental Protection Agency

ABANDONED URANIUM MINES PROJECT

Navajo Nation

WATER SAMPLE LOCATIONS

Glynn Alsup taking water samples at Cove Mesa Spring in Cove Chapter

A vehicle loaded for a day of sampling

Water sampling from a hand pump in the Cove Chapter. Location coordinates were also collected at each sample site using a Global Positioning System (GPS) worn in a backpack.

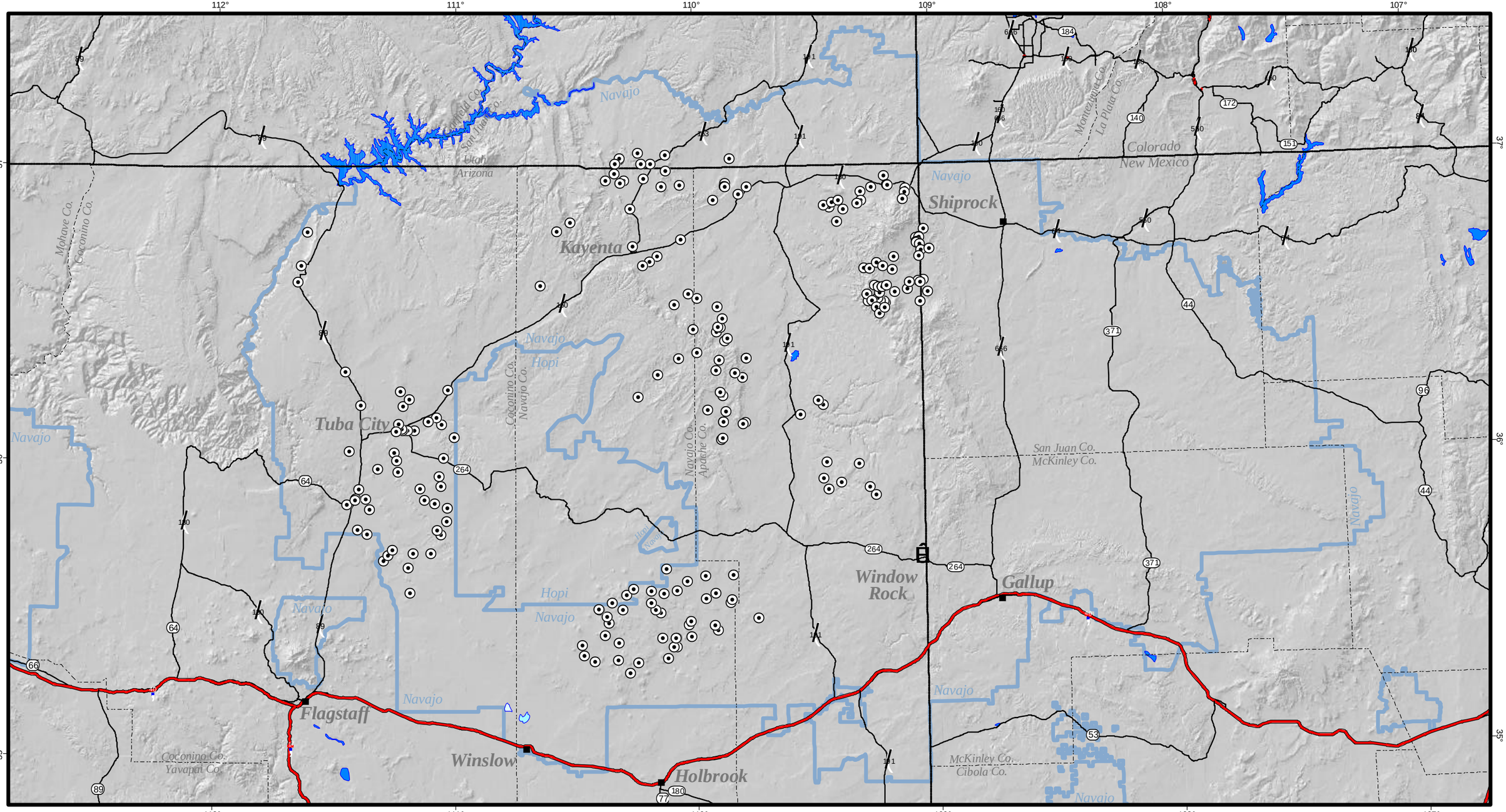
Shadow Mountain Well #20 in Tuba City Chapter

Glynn Alsup conducting a field filtering sample at the Open Pit Mine in the Cameron Chapter

Windmill at Tank 4T-399 in the Black Mesa Chapter

Tank 8K-402 in the Oljato Chapter

The facing map shows the locations of water samples collected for the Navajo Abandoned Uranium Mines Project. To evaluate risks to human health by ingestion of stable and radioactive metals in water, the sampling program was designed to measure analyte concentrations in water sources used for human consumption. The sampling program consisted of collecting one water sample at each well, tap, spring, or tank identified as a source for human consumption. If there was a common source for multiple users, such as a community well or tap, only the common source location was sampled. All samples were collected as a point-of-use sample designed to duplicate the most likely method in which a person would obtain water for human consumption.



Map Features

- Water Sample Location
- Lake / Reservoir

4

WATER SAMPLE LOCATIONS

20 0 20 Miles

20 0 20 40 Kilometers

1:1,400,000

U.S. Environmental Protection Agency

ABANDONED URANIUM MINES PROJECT

Navajo Nation

LAND OWNERSHIP

Black Mesa Chapter House

Bodaway Gap Chapter House

Cameron Chapter House

Chilchinbito Chapter House

Chinle Chapter House

Cottonwood Chapter House

Dilkon Chapter House

Indian Wells Chapter House

Lower Greasewood Chapter House

Nazlini Chapter House

Red Valley Chapter House

Teec Nos Pos Chapter House

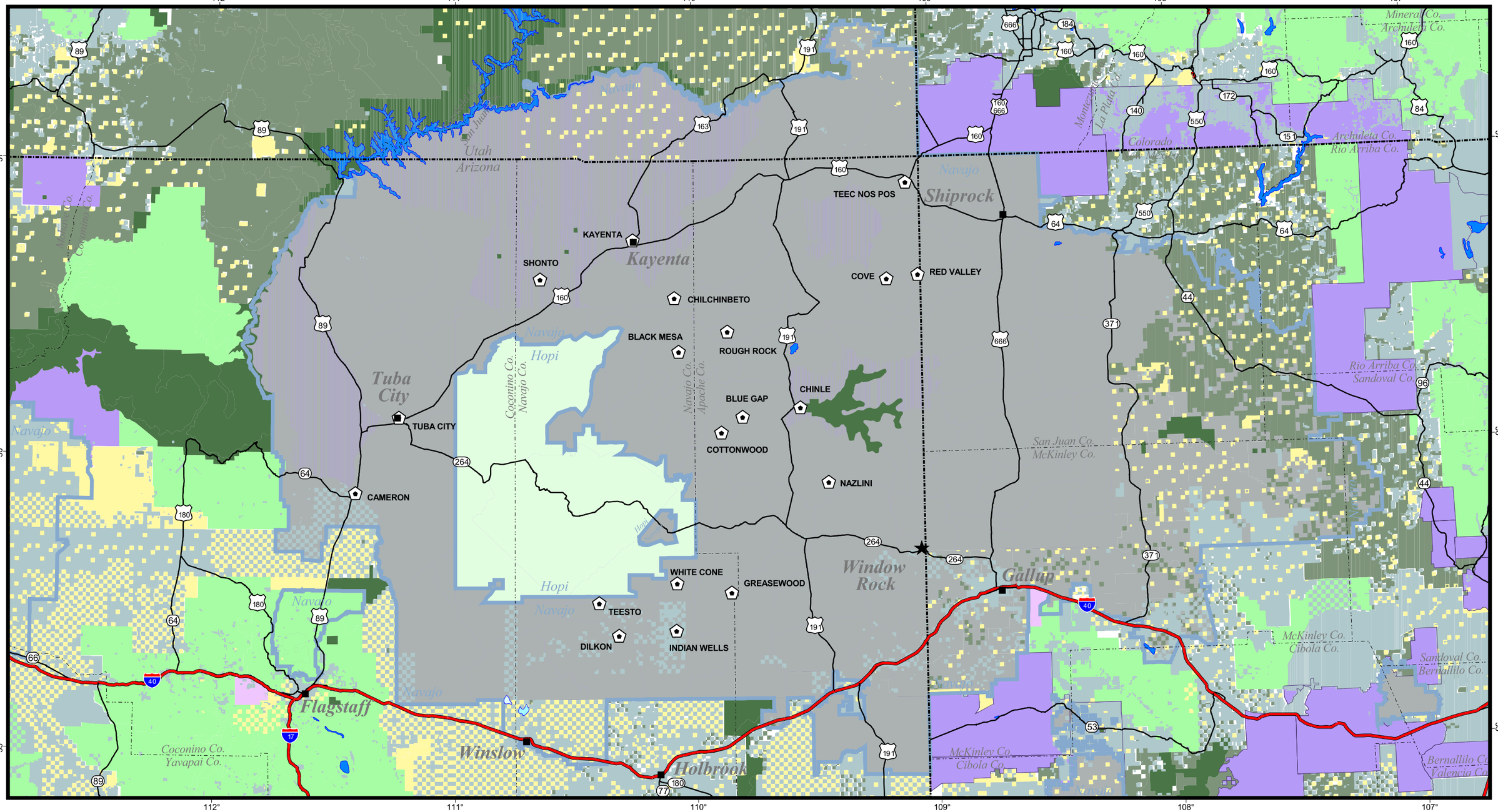
Teesto Chapter House

Tuba City Chapter House

White Cone Chapter House

The map on the facing page shows the land ownership boundaries for lands within and near the Navajo Nation. The Navajo and Hopi Nation boundaries were provided by the Navajo Nation. Federal Land Features of the United States were provided by the National Atlas of the United States developed and maintained by the U.S. Geological Survey (1999). State and private land boundaries were provided by the Bureau of Land Management (1999). The Federal, State and private lands are approximately located, are updated infrequently, and have not been verified for accuracy.

The Navajo Nation is divided into political entities called Chapters. They function similar to counties or parishes and are a forum for solving community issues and problems. There are presently 110 Chapters; 19 of the 30 chapters visited are indicated on the facing map. Chapter leaders and delegates to the Tribal Council are elected. Delegates are based on population. The photos above show some of the Chapter Houses where water samples were collected.



Jurisdictional Lands

- Navajo Nation
- Hopi Nation
- Other Native American
- Private
- State
- Bureau of Land Management
- Department of Defense
- Forest Service
- National Park Service
- Other
- Chapter Houses

N W E S

LAND OWNERSHIP

20 0 20 Miles

20 0 20 40 Kilometers

1:1,400,000

U.S. Environmental Protection Agency

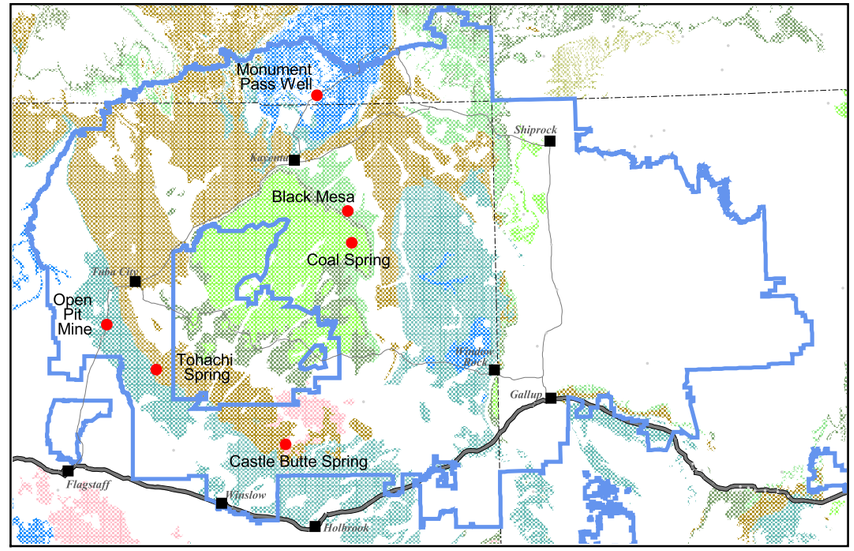
ABANDONED URANIUM MINES PROJECT

Navajo Nation

GEOLOGY

Monument Pass Well in the Monument Valley Area.

Open Pit Mine in the Cameron/Tuba City area.



This map depicts the general location of surface geology shown in these photos.

Patti Collins on Black Mesa above the Rough Rock Chapter looking northeast into the Chinle Valley.

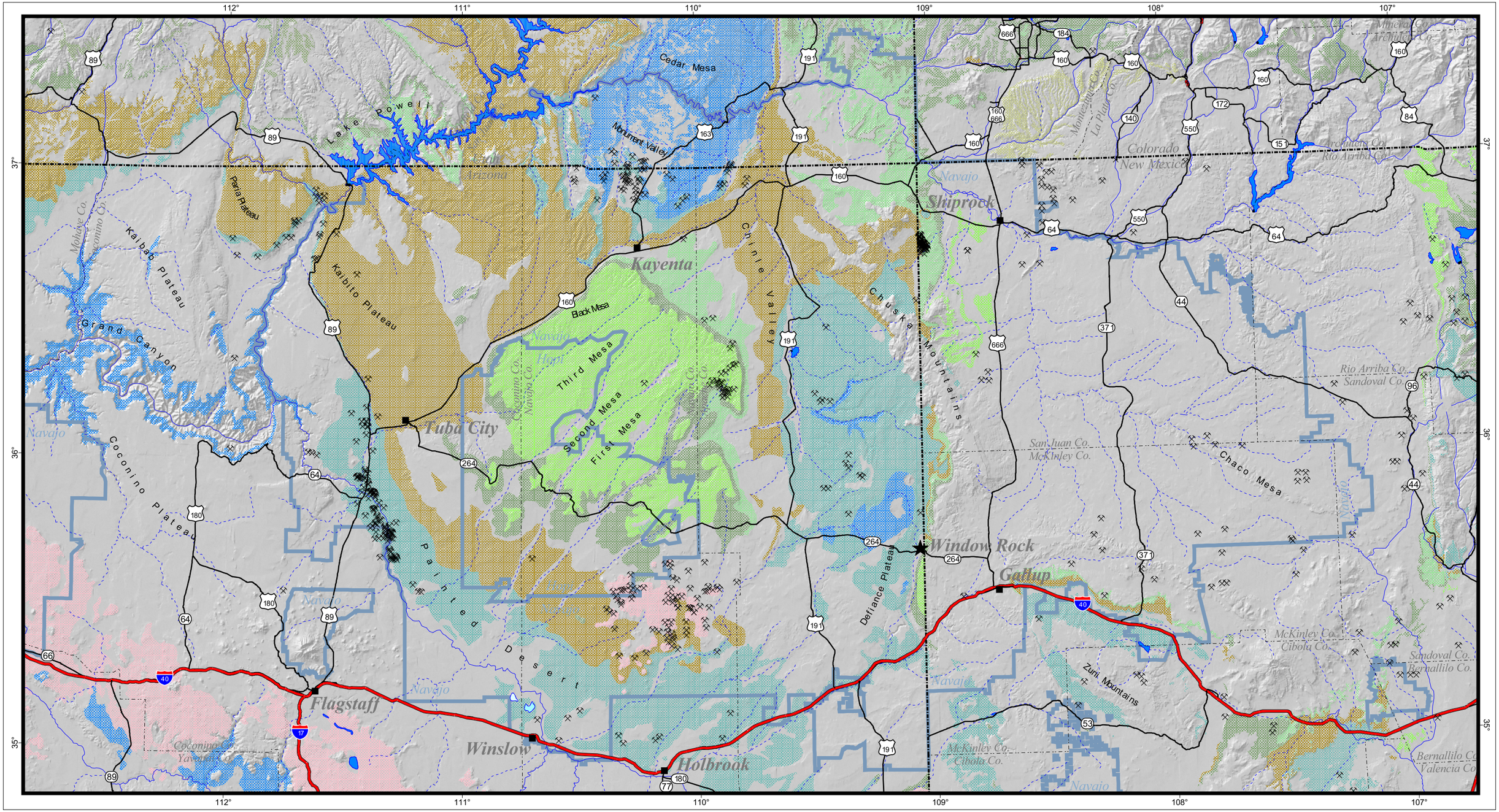
Tohachi Spring in the Cameron/Tuba City area.

Castle Butte Spring in the Bidahochi Area.

Coal Spring in the Central Area

The facing map shows the generalized geology of the project area. Geological units shown are primarily those that host sandstone-uranium deposits. These mostly clastic sedimentary units, within the Colorado Plateau, range in age from Pennsylvanian-Permian to Early Cretaceous. Also included are Late Miocene to Pliocene basaltic host rocks of northeastern Arizona. Not shown are vein, replacement, or other minor hosts of uranium.

This map is based on generalized geological maps for each of the Four Corners states. Generalization results in smaller outcrops being grouped with large outcrop expanses of other units. This map shows geological units only where they have been mapped as outcrops at the surface.



Geological Units (Age and Unit Description)

Tby	Pliocene to Late Miocene Basaltic Rocks
Kmv	Cretaceous Mesa Verde Group
Kd	Cretaceous Dakota Sandstone
Jm	Jurassic Morrison Formation
Jgc	Jurassic Glen Canyon Group
TRc	Triassic Chinle Formation
PP	Permian to Pennsylvanian Sedimentary Rocks
⚒	Mine

N W E S

GEOLOGY

20 0 20 Miles

20 0 20 40 Kilometers

1:1,400,000

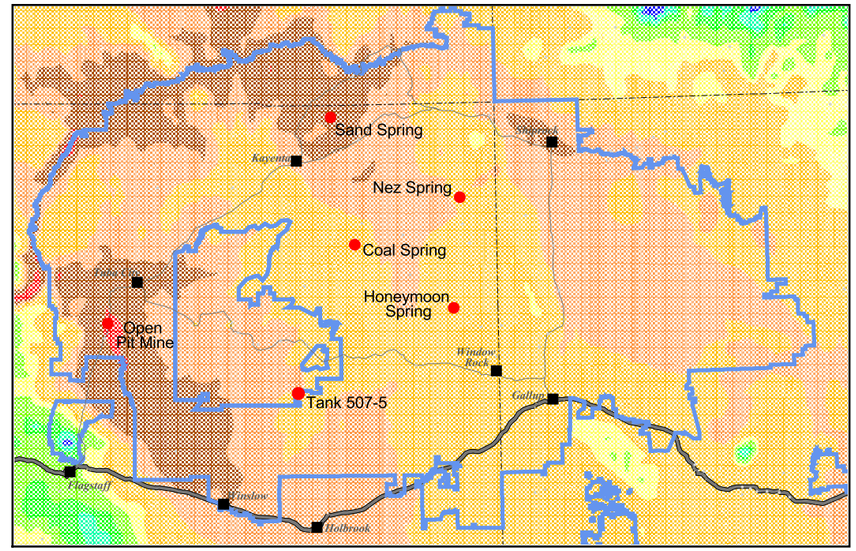
U.S. Environmental Protection Agency

ABANDONED URANIUM MINES PROJECT

Navajo Nation

ANNUAL PRECIPITATION

Sand Spring in the Oljato Chapter within the Monument Valley area. Elevation is approximately 5,010 feet.



Red dots on this map depict the location of the water sample sites shown in the photos.

Nez Spring in the Cove Chapter within the Four Corners area. Elevation is approximately 8,260 feet.

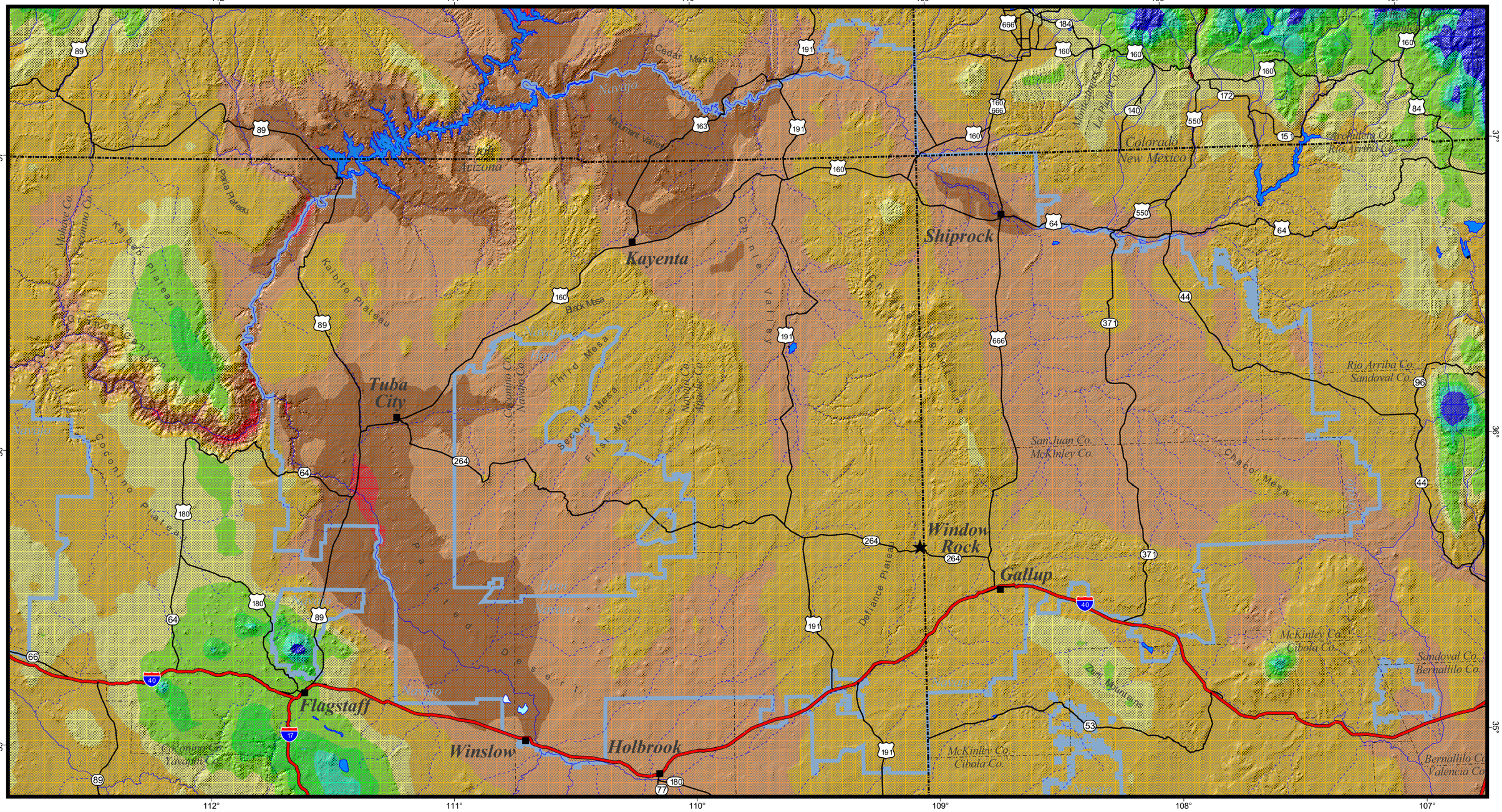
Coal Spring in the Black Mesa Chapter within the Central area. Elevation is approximately 6,910 feet.

Open Pit Mine waste piles in the Cameron Chapter within the Cameron/Tuba City area. Elevation is approximately 4,100 feet.

Tank 507-5 in the White Cone Chapter within the Bidahochi area. Elevation is approximately 6,000 feet.

Honeymoon Spring in the Nazlini Chapter within the Chinle area. Elevation is approximatlely 7,210 feet.

The facing map shows the generalized annual precipitation (in inches) for the Navajo Nation. The annual precipitation data is from the Western U.S. Annual Precipitation (1961-90), developed by the Natural Resources Conservation Service (NRCS) Water and Climate Center. The region's climate spans a warm, arid desert, intermediate steppe, and cold, subhumid climate of the mountains. Desert vegetation includes grasses and browse plants which are sparse, slow growing, are easily injured by overgrazing, and requires long periods of recovery after depletion. Steppe vegetation includes grasses, sagebrushes, and pinyon-juniper. Subhumid vegetation includes yellow pine timber, oak, and grasses and shrubs.



Annual Precipitation (Inches)

3 - 5	10 - 15	25 - 30
5 - 7	15 - 20	30 - 35
7 - 10	20 - 25	35 - 40

N W E S

ANNUAL PRECIPITATION

20 0 20 Miles

20 0 20 40 Kilometers

1:1,400,000

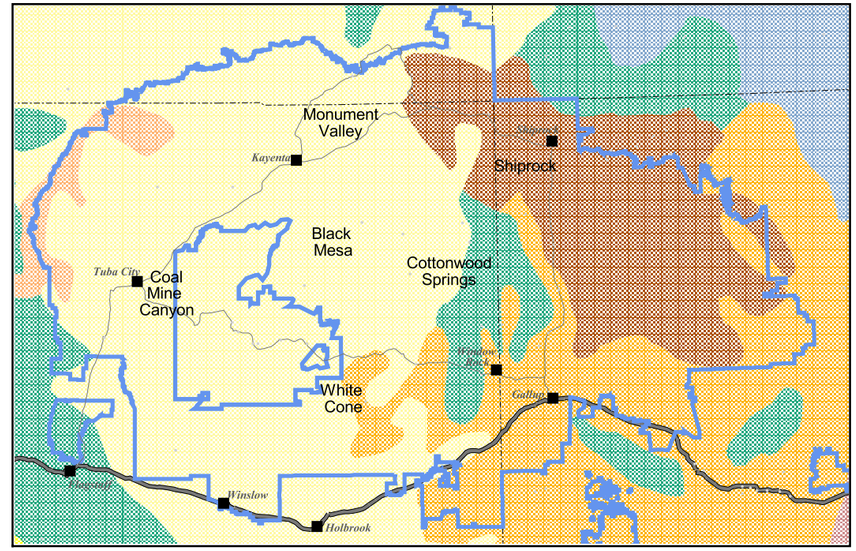
U.S. Environmental Protection Agency

ABANDONED URANIUM MINES PROJECT

Navajo Nation

PHYSIOGRAPHY

Monument Valley



This map depicts the general location of physiographic features shown in these photos.

Shiprock Peak is the remains of a solidified lava core of a dormant 40 million year old volcanic pinnacle. It rises 1,800 feet above the plain, with an elevation of 7,178 feet above sea level. It lies about 13 miles southest of the town of Shiprock New Mexico.

View from Black Mesa. Black Mesa, also known as Black Mountain, is an extended high mesa, located in central western Navajo country. Black Mesa has a pine covered rim at an elevation of about 8,000 feet.

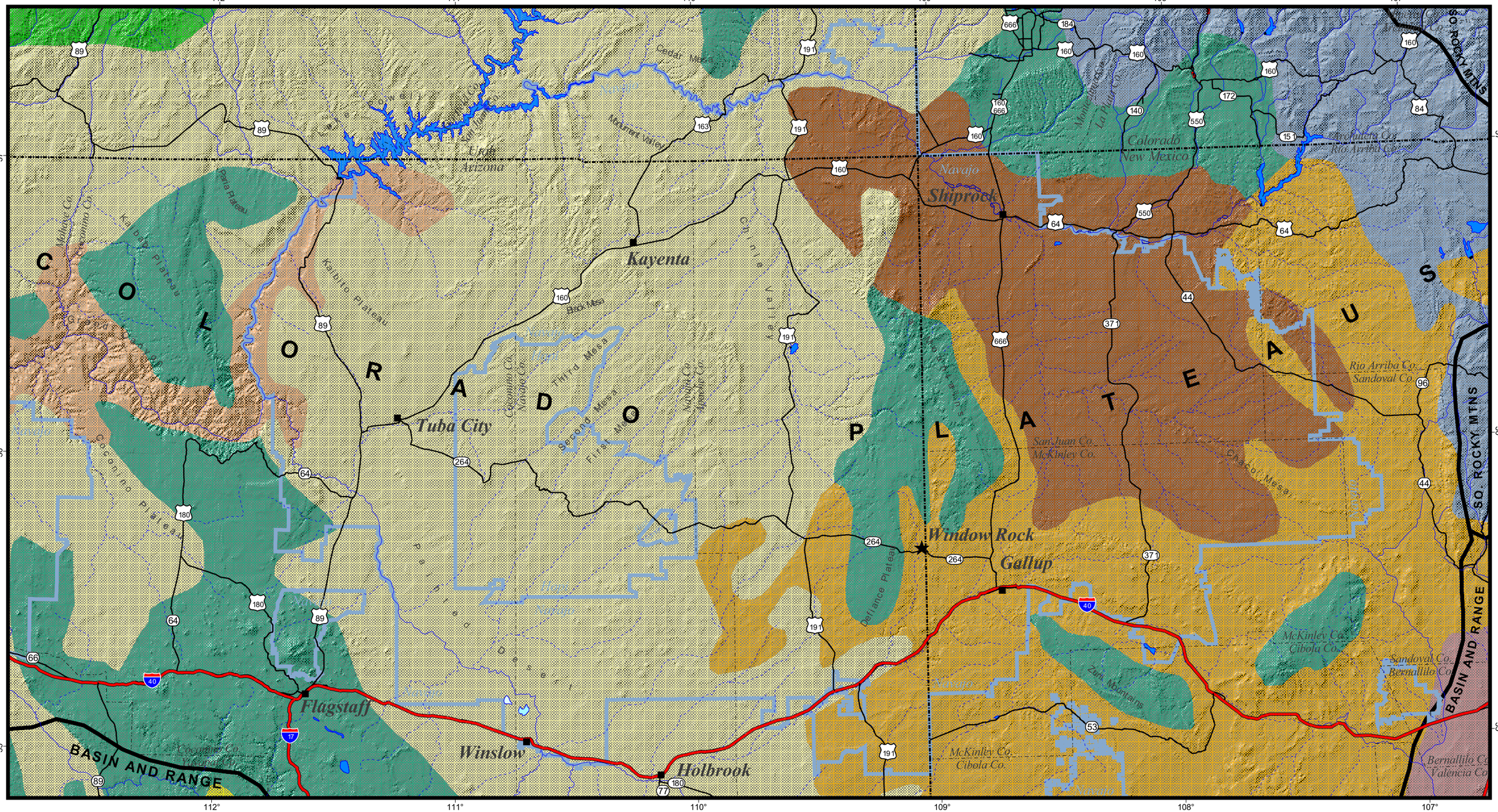
The Navajo name for Coal Mine Canyon means saw-toothed or jagged, and refers to the erosion occurring at the high parts of Coal Mine Canyon. This scenic formation cuts into the Mesa Verde and Mancos shales.

Landscape of the White Cone, Bidahochi area.

Cottonwood Spring in the Chinle Chapter within the Chinle area.

The facing map shows the generalized physiography of the Navajo Nation and surrounding region. The Navajo Nation is mostly within the stable Colorado Plateaus physiographic province. Physiographic provinces represent distinctive areas having common topography, rock types and structures, and geologic and geomorphic history. The Colorado Plateaus province is the locus of one of the United States' largest uranium mining area.

The area can also be described by major land resource areas. Land resource regions are geographic areas that are characterized by a particular pattern of soils, climate, water resources and land uses. The Navajo Nation is located primarily within the Colorado and Green River Plateaus and Mesas region to the west, and the San Juan River Valley Mesas and Platueaus region to the east. The southeastern portion includes the Arizona and New Mexico Mountains, Plateaus and Mesas regions.



Major Land Resource Areas

▨ Arizona and New Mexico Mountains
▨ Central Arizona Basin and Range
▨ Colorado and Green River Plateaus
▨ New Mexico and Arizona Plateaus and Mesas
▨ San Juan River Valley Mesas and Plateaus
▨ Sonoran Basin and Range
▨ Southern Desertic Basins, Plains, and Mountains
▨ Southern Rocky Mountains
▨ Wasatch and Uinta Mountains
Physiographic Province Boundary

N
W E
S

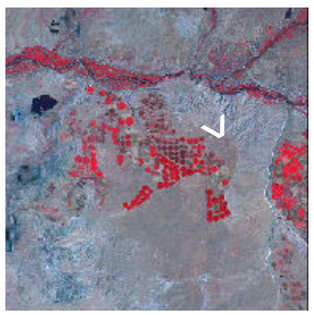
PHYSIOGRAPHY

20 0 20 Miles
20 0 20 40 Kilometers
1:1,400,000

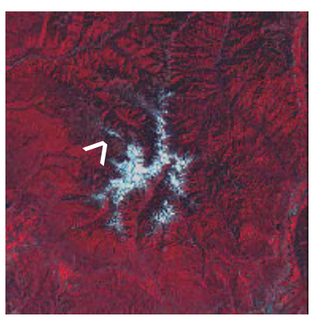
U.S. Environmental Protection Agency
ABANDONED URANIUM MINES PROJECT
Navajo Nation

LANDSAT SATELLITE IMAGE

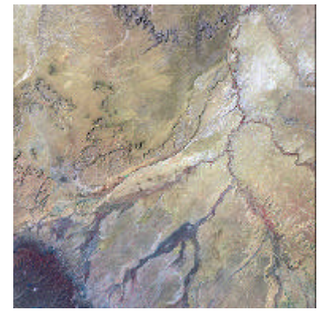
Natural Vegetation - broad medium to dark reddish areas, mostly in mountains or on higher plateaus



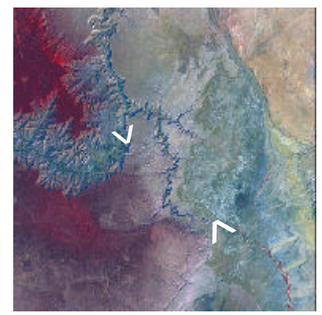
Irrigated Crops - Typically dark to bright red circles, squares, and rectangles



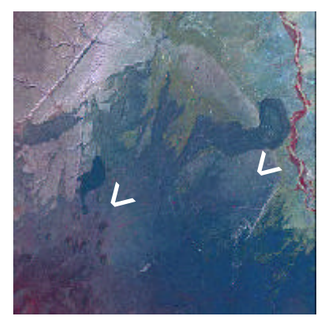
Snow - White to light-blue in shadow, and surrounded by the red of the vegetation in the high mountains



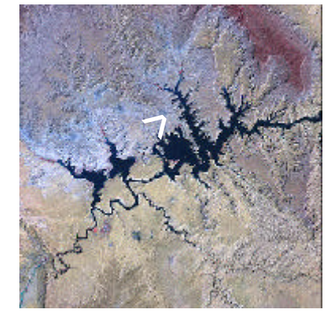
Barren Rocks, Reddish - Broad light to medium yellowish areas



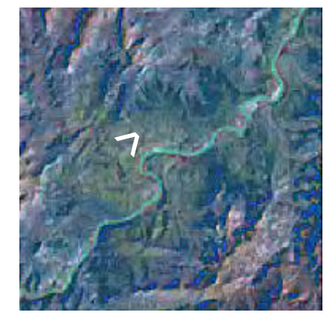
Barren Rocks, Non-reddish - mostly broad medium to dark bluish-green areas



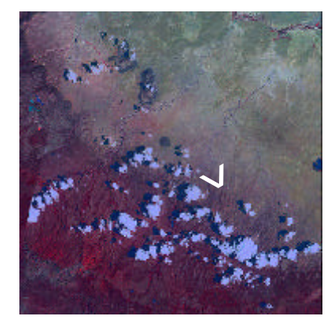
Basaltic Volcanic Rocks - Small to somewhat broad dark bluish-black, areas having the appearance of having flowed



Deep Open Waters - Generally linear solid black features

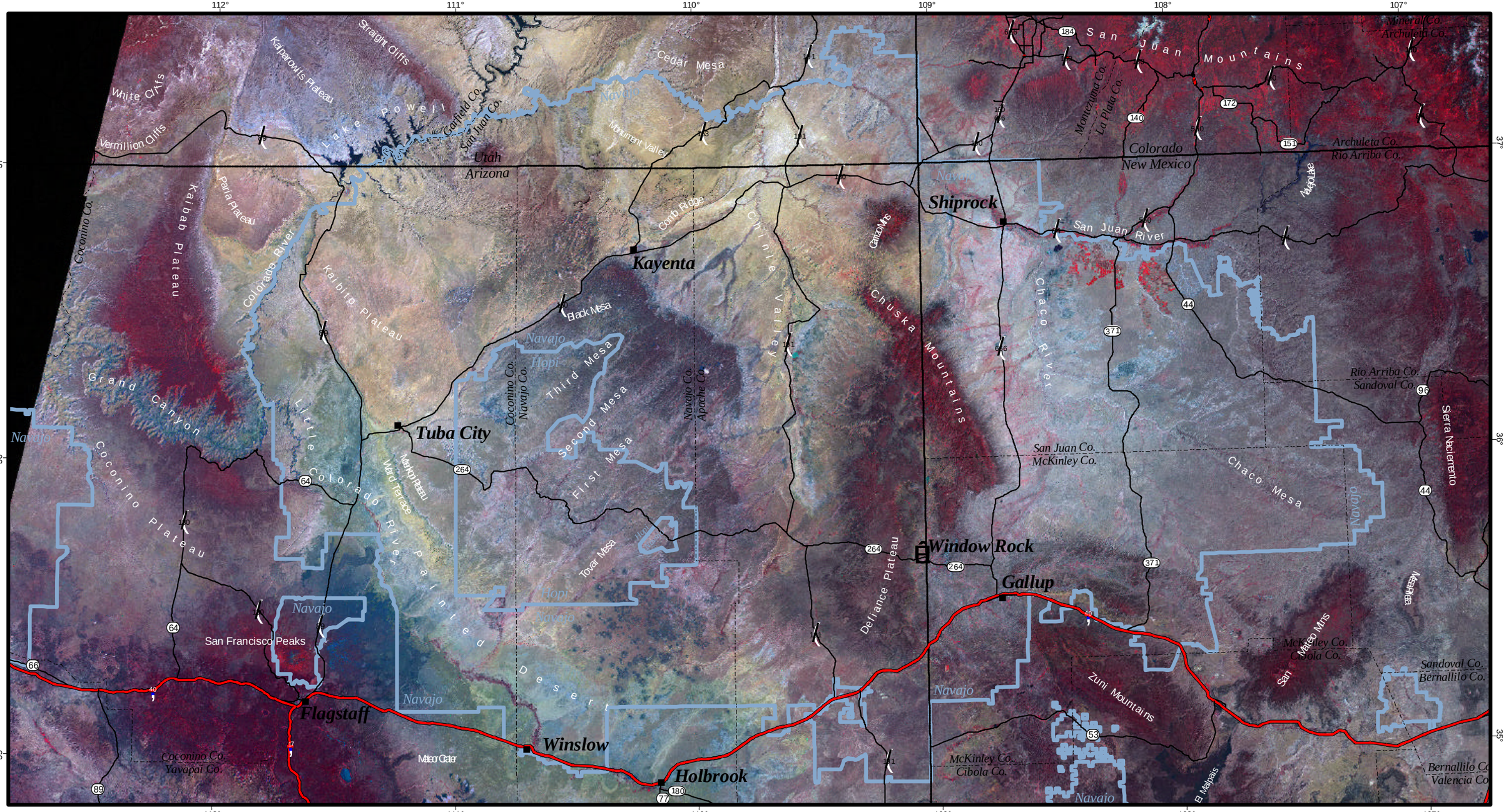


Shallow, Turbid Waters - Riparian features are typically sinuous thin features that are medium greenish to bluish-green



Clouds - Whitish cotton ball-like features with dark shadows to the upper left

This Landsat image mosaic was produced to provide an overview of the Navajo Nation similar to that of an aerial photograph. Landsat imagery differs from color photography in that it senses a different part of the electromagnetic spectrum than what the human eye normally sees. This Landsat image includes "light" from the reflective near-infrared, red, and green parts of the spectrum. These are displayed in red, green, and blue, respectively. This results in ground features that appear differently than what would be expected in a color aerial photograph. For example, vegetation appears as various shades of red rather than green. The picture key above identifies several of the features found in the Landsat image mosaic.



See facing page for legend

4

LANDSAT SATELLITE IMAGE

20 0 20 Miles
20 0 20 40 Kilometers
1:1,400,000

U.S. Environmental Protection Agency
ABANDONED URANIUM MINES PROJECT

Navajo Nation

Navajo Superfund Program
and
U.S. Environmental Protection Agency Region IX

Traditional Blessing Way Opening Ceremony

(Hózhóǫjí)

To be held on Wednesday, October 19, 1994
Beclabito Chapter House

9:00 am	Greetings - Master of Ceremonies Delegate: Lee B. Roy
9:30 am	Ceremony - Medicine Man: Willie Weaver
11:00 am	U.S. Environmental Protection Agency and EG&G presentation of the project.
Noon	Lunch Mutton Stew Grilled Ribs Fry Bread Watermelon Coffee & Punch
Afternoon	Navajo Superfund Program, U.S. Environmental Protection Agency and EG&G will be available to answer any questions.

Thank you for your support.