***UNITED STATES OF AMERICA, and STATE of NEW MEXICO, ex rel. STATE ENGINEER, Plaintiffs and ZUNI INDIAN TRIBE, NAVAJO NATION, Plaintiffs in Intervention, v. A&R PRODUCTIONS, et al., Defendants***

**CIV. No. 07-00681 BDB/WDS, ZUNI RIVER BASIN ADJUDICATION, Sub-proceedings 1, Zuni Indian Claims**

# Report on
# Water Delivery and Use Efficiencies

Prepared for:

State of New Mexico
Office of the State Engineer
Santa Fe, New Mexico

By:
Franzoy Consulting, Inc.
Carl Eugene Franzoy, P.E.
Registered Professional Engineer
State of New Mexico
Certificate Number 8865

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## WATER DELIVERY AND USE EFFICIENCIES

Irrigation efficiencies are a measure of how well an irrigation system works and is managed. The two efficiencies of concern in this case are the on-farm irrigation efficiency and the conveyance efficiency.

The amount of water required at the point of diversion is determined by three factors: (1) the consumptive irrigation requirement (CIR) of the crop or crops being grown; (2) the on-farm irrigation efficiency; and (3) the efficiency with which water is conveyed from the point of diversion to the field on which the crop is grown.

Each of these factors is affected by the soils and topography in the area and the degree of management exercised by the water users. The crop CIR is addressed in subparagraph 3.8 of United States Vs. A&R Productions, et al, prepared by the New Mexico Office of the State Engineer, Water Use and Conservation Bureau, March 1, 2010.

Following is a discussion of on-farm irrigation efficiency and conveyance efficiency.

### On-farm Irrigation Efficiency

Irrigation efficiency is a measure of the amount of water applied to a crop by irrigation that stays in the crop root zone and is available for beneficial use by the crop. The irrigation efficiency changes with each irrigation until the crop root zone is fully developed. The seasonal irrigation efficiency is determined by dividing the seasonal crop CIR by the amount of water applied to the field.

The uniformity of application of each irrigation event affects the actual irrigation efficiency. Enough water may be applied to a field to meet the crop water needs but if the water is not applied uniformly, some areas of the field will be over-irrigated while others are under-irrigated. As a result crop yields will be less than for a field on which water has been applied uniformly.

Also, irrigation efficiency does not tell whether the crop has been adequately irrigated. If the crop is under-irrigated, there will be little or no runoff or deep percolation loss and the irrigation efficiency will be high. However, potential yield will be lost because the crop experiences drought stress in the areas of the field that were under-irrigated.

The actual on-farm irrigation efficiency is affected by the crop root depth, soils (texture, depth, and uniformity), topography and degree of management.

Crops

The average crop mix and root depth by crop for the Zuni Pueblo Agricultural Areas for the period 1947-1950 based on an analysis by the OSE are shown in the table below.

Table 1. Zuni Crop Mix

| Crop | Mix (%) | Average Root Depth (ft) |
|---|---|---|
| Corn | 23.74 | 2-3 |
| Alfalfa | 24.51 | 4-5 |
| Irrigated Pasture | 1.63 | 4-5 |
| Small Grains | 35.74 | 2-3 |
| Garden Crop | 14.38 | 4-5 |
| Weighted Average | | 3-4 |

The crop mix in the above table does not include fallow acres because the goal of this calculation is to determine the weighted average of the crops grown. Including the fallow acres will result in an erroneous weighted crop root depth average. The weighted average root depth of three to four feet is sufficient to enable the Pueblo farmers to irrigate efficiently.

Soils

Soils data and maps obtained from the Natural Resources Conservation Service ("NRCS") Soil Data Mart for the five (5) agricultural areas are shown in the appendix at the back of this report. The data are shown in Table 2 in the appendix. Maps showing the soil capability units for the five (5) areas are included in the appendix as figures 1 through 5. The data in Table 2 are summarized for all five (5) areas in Table 3 below.

Table 3 shows the Map Unit, Surface Texture, Water Movement, Available Water (in the top sixty inches of the soil profile) and the Irrigated Land Capability Classification. The dominant Map Units in each of the five (5) areas are the first five (5) units shown in the table. The remaining units are listed in the order of their prevalence in the areas.

Map Unit is the NRCS designation for the reported soil classification. Surface Texture is the designation NRCS uses for the dominant surface texture of the soil in the Map Unit. Water Movement is a measure of the ability of the soil to allow water to move in the most restrictive layer. Available Water is the amount of water the soil can retain for use by crops in the top sixty (60) inches of the soil profile. The Irrigated Land Capability Classification is the measure of the ability of the soil to sustain plant growth for agriculture under irrigated conditions as designated by class and sub-class. The class relates to the general capability of the soil and the sub-class designates any deficiencies that may modify the general capability.

Capability class and subclass are assigned to map unit components in the NRCS national soil information system. The capability classes commonly used for agricultural soils are listed below.

- **Class I (1)** soils have slight limitations that restrict their use.
- **Class II (2)** soils have moderate limitations that reduce the choice of plants or require moderate conservation practices.
- **Class III (3)** soils have severe limitations that reduce the choice of plants or require special conservation practices, or both.
- **Class IV (4)** soils have very severe limitations that restrict the choice of plants or require very careful management, or both.
- **Class V (5)** soils have little or no hazard of erosion but have other limitations, impractical to remove, that limit their use mainly to pasture, range, forestland, or wildlife food and cover.
- **Class VI (6)** soils have severe limitations that make them generally unsuited to cultivation and that limit their use mainly to pasture, range, forestland, or wildlife food and cover.

Classes 1 through 4 can be reasonably expected to support irrigated crop production. Classes 5 and 6 are generally associated with non-agricultural uses and are not addressed in this report.

The subclass represents the dominant limitation that defines the capability class. According to the NRCS Land Capability Classification documentation, the subclasses have the following priority: e, w, s, and c when the impacts of limitations to classes are essentially the same. Subclasses are not assigned to soils in capability class I (1) and subclass "e" is not used in class V (5).

- **Subclass e** is made up of soils for which the susceptibility to erosion is the dominant problem or hazard affecting their use. Erosion susceptibility and past erosion damage are the major soil factors that affect soils in this subclass.
- **Subclass w** is made up of soils for which excess water is the dominant hazard or limitation affecting their use. Poor soil drainage, wetness, a high water table, and overflow are the factors that affect soils in this subclass**.**
- **Subclass s** is made up of soils that have soil limitations within the rooting zone, such as shallowness of the rooting zone, stones, low moisture-holding capacity, low fertility that is difficult to correct, and salinity or sodium content.

- **Subclass c** is made up of soils for which the climate (the temperature or lack of moisture) is the major hazard or limitation affecting their use.

Table 3. Summary of NRCS Soils Data for the Zuni Agricultural Areas

| Map Unit | Surface Texture | Water Movement | Available Water (top sixty inches) | Irrigated Land Capability Classification |
|---|---|---|---|---|
| 45 | Clay loam | Moderately low | High | 3s |
| 310 | Sandy loam | Moderately high | High | 3c |
| 60 | Sandy clay loam | Moderately high | High | 3e |
| 51 | Loamy fine sand | High | Low | 4e |
| 54 | Clay, saline | Low | Moderate | 4w |
| 225 | Silt loam | Moderately high | High | 3e |
| 40 | Silt loam | Moderately high | Very High | 4w |
| 42 | Clay loam | Moderately high | Very High | 4w |
| 47 | Clay loam | Moderately low | High | 3s |
| 49 | Clay loam | Moderately low | High | 3c |
| 53 | Clay loam | Moderately low | High | 2s |
| 55 | Clay loam | Moderately low | High | 4w |
| 310 | Sandy loam | Moderately High | High | 3c |
| 325 | Silty clay | Low | High | 3s |
| 352 | Sandy loam | High | Moderate | 3e |
| 357 | Clay | Low | Low | 4w |
| 380 | Clay | Low | Very low to Moderate | None listed |

The soils in all of the Zuni agricultural areas are highly variable and range from loamy fine sands to clay. The variability of the soil water intake rates and water holding capacities in the areas will affect the uniformity of distribution of water across fields and in turn, affect the attainable irrigation efficiencies. All of the Map Units in the Zuni agricultural areas except Map Unit 53 are classified as Class 3 or Class 4 soils, which are marginal for sustained agriculture without careful management. In addition, all Map Units have other inherent deficiencies that affect the ability of the soils to take and hold water for use by crops. These factors, when coupled with the variability, will make it even more difficult to attain high irrigation efficiencies.

Topography

Of the factors considered, topography has the greatest influence on irrigation efficiency. Excessive slope affects the uniformity of distribution of applied water.

Tailwater runoff will occur on sloped fields when water is applied for a sufficient time to fully replace the soil moisture deficit on the lower end of the field. The effect of topography on farm efficiency begins to increase when the slope in the direction of irrigation exceeds 0.5% (five-tenths foot of fall per 100 feet of distance)

The irrigated lands on the Zuni Pueblo vary from one agricultural area to another. Representative slopes for the historically irrigated areas were determined from US Geological Survey ("USGS") topographic maps, which are included in the appendix at the back of this report (figures 6-10). Cross-sections were taken as shown on the topographic maps and slopes were estimated using the contour features on the maps and are shown in Table 4 in the appendix at the back of this report. The aerial imagery of the agricultural areas shows that the natural slope is broken up by the individual fields. Some grading has likely occurred on the fields so that the natural slopes may be reduced for irrigation and natural undulations have been removed or at least minimized.

The average slopes in the agricultural areas are summarized in Table 5 below.

Table 5 Average Slopes in the Zuni Agricultural Areas

| Agricultural Area | Minimum Slope, feet per 100 feet | Maximum Slope, feet per 100 feet | Average Slope, feet per 100 feet | Effect of Average Slope on Irrigation Efficiency |
|---|---|---|---|---|
| Nutria | 0.000 | 1.701 | 0.733 | Slight |
| Pescado | 0.444 | 2.821 | 1.242 | Considerable |
| Zuni | 0.513 | 1.386 | 0.845 | Moderate |
| Tekapo | 0.234 | 0.247 | 0.442 | Minimal |
| Ojo Caliente | 0.000 | 1.219 | 0.749 | Slight |

The topography in all of the Zuni agricultural areas will affect irrigation efficiencies to some degree, with the least effect occurring in the Tekapo Area and the greatest effect occurring in the Pescado Area.

Farm Layout

The layout of the farm, field size, length of irrigation run and type of irrigation system in use can have an effect on irrigation efficiency. The smaller and more regular shaped the fields are, the more uniformly water can be distributed and the higher the irrigation efficiency.

Appendix A of the report Zuni Indian Reservation Identification of Lands and Estimation of Water Requirements for Past and Present Irrigated Lands Served by Permanent Irrigation Works, prepared by L. Niel Allen, PhD., P.E. dated November 3, 2008 contained data for the tracts of land identified as having a history of irrigation. The tract sizes reported by Allen are for polygons developed for analysis on an area-wide basis and can't be used to determine the size of individual fields because many of the tracts identified in the appendix include more than one field. Observations made during a field visit to the five (5) Zuni agricultural areas in July 2009, confirm that the average field size in all five (5) of the Zuni agricultural areas is small as compared to commercial farms.

The positive effect of the small field size on irrigation efficiency can be somewhat offset by the shape of the field. The evaluation of the field shapes in this report is based on the shapes of the historically irrigated fields as shown in the aerial images in figures 6 through 10 in the appendix at the back of this report. Figures 11 through 15 were prepared by the New Mexico Office of the State Engineer. The shapes of fields in all of the areas are affected to some degree by a canal, ditch, river or wash that passes through the area. The fields adjoining a canal, ditch, river or wash have at least one side of the field that follows the water feature, resulting in some irregularity.

All of the agricultural areas have some fields that are regular in shape. The shapes of these fields will have minimal effect on irrigation efficiencies. The Tekapo Area has the most fields with a regular shape whereas Nutria and Pescado have the least. The resulting irregular shape of affected fields makes it difficult to manage the length of time water is applied to all parts of the field, potentially resulting in a somewhat lower distribution efficiency than could be achieved on similar size fields that have a rectangular or square shape. Overall, the relatively small size of the fields in the Zuni agricultural areas is offset by the irregular shapes resulting in little effect on irrigation efficiency.

Degree of Management

The classes and sub-classes of the soils in all of the Zuni agricultural areas indicate that the soils have less than desirable characteristics as related to the capability of the soils for sustained agriculture. As a result a high degree of management will be required to farm the land over a long period of time. The dominant soils in all of the Zuni agricultural areas are Class 3 or Class 4, except for one Map Unit in the Ojo Caliente Area, which is Class 2. As discussed earlier in this report, the NRCS considers Class 2 soils as having moderate limitations that reduce the choice of plants or require moderate conservation practices, Class 3 soils as having severe limitations that reduce the choice of plants or require special conservation practices, or both, and Class 4 soils as having very severe limitations that restrict the choice of plants or require very careful management, or both. As a result of these limitations, sustained irrigated agriculture in the Zuni agricultural areas will require a high level of management.

The variability in the soil class characteristics will affect the uniformity of distribution of applied water. Irrigation efficiencies will be affected if the level of management is not sufficient to produce healthy, vigorous crops for a sustained period of time.

A range of irrigation efficiencies was developed based on the conditions in each of the Zuni agricultural areas and compared to irrigation efficiencies reported by experts for the two Pueblos[1]. The estimated on-farm irrigation efficiencies, considering all of the factors discussed above are shown in Table 6 below.

Table 6. Zuni Agricultural Areas On-Farm Irrigation Efficiencies

| Agricultural Area | Efficiency, % |
|---|---|
| Nutria | 60 |
| Pescado | 50 |
| Zuni | 55 |
| Tekapo | 60 |
| Ojo Caliente | 60 |

**Conveyance Efficiency**

Conveyance efficiency is a measure of the amount of water that is diverted from the river (or some other source) that is delivered to the farm to meet the needs of crops and includes losses of water to canal or ditch seepage and operational losses. Unlined ditches can have highly variable efficiencies depending on the soils through which the ditches pass. Lined ditches typically have efficiencies in the eighty to ninety percent (80-90%) range.

The canals and ditches observed during a field visit to the five (5) Zuni agricultural areas in July 2009 were all unlined. All of the areas had pipelines for the distribution and delivery of irrigation water but they were underground making it impossible to verify the condition of the lines. Geographic Information System data obtained from the New Mexico Office of the State Engineer contained data on the conveyance systems in the agricultural areas. The conveyance system data from that source are summarized in Table 7 below.

Table 7. Zuni Agricultural Area Conveyance System Lengths

| Agricultural Area | Irrigated Area | Canal Lengths | | Pipeline Lengths | |
|---|---|---|---|---|---|
| | Acres | Feet | Miles | Feet | Miles |
| Nutria | 977 | 48,727 | 9.23 | 2,156 | 0.41 |
| Pescado | 1,318 | 109,590 | 20.76 | 32,224 | 6.10 |
| Zuni | 3,630 | 56,591 | 10.72 | 36,473 | 6.91 |
| Tekapo | 321 | 17,830 | 3.38 | 1,884 | 0.36 |
| Ojo Caliente | 774 | 16,734 | 3.17 | 29,545 | 5.60 |

Seepage losses in the unlined canals and ditches in the agricultural areas will vary based on the characteristics of the soils in which the canal or ditch is constructed. Canals or ditches constructed in soils with low water intake characteristics will have less seepage loss than those constructed in soils with high water intake characteristics. The water

[1] Zuni Indian Reservation Identification of Lands and Estimation of Water Requirements for Past and Present Irrigated Lands Served by Permanent Irrigation Works, prepared by L. Niel Allen, PhD., P.E. dated November 3, 2008.

intake characteristics of the soils in which the canals are constructed in the five (5) Zuni agricultural areas vary from low high. As a result, the seepage losses will vary as will the conveyance efficiencies. Estimated relative seepage losses and conveyance efficiency for the canals in the agricultural areas are shown in Table 8 below. Seepage losses are qualitative in nature in the table because no seepage data were available for the five (5) agricultural areas. The conveyance efficiency is estimated by assuming that the efficiency for a well designed and maintained system that is operated at a high level is seventy percent (70%) and adjusting that efficiency for greater than average seepage losses.

Table 8 Soil Water Intake and Seepage Loss Characteristics

| Agricultural Area | Canal Length, miles | Water Intake Rate | Seepage Loss | Conveyance Efficiency, % |
|---|---|---|---|---|
| Nutria | 9.23 | Moderately Low | Low | 70 |
| Pescado | 20.76 | Moderately High | High | 65 |
| Zuni | 10.72 | Moderately High | High | 65 |
| Tekapo | 3.38 | Moderately High | High | 70 |
| Ojo Caliente | 3.17 | Moderately Low | Low | 70 |

It was not possible to inspect the pipelines in the five (5) agricultural areas. As a result, no assessment of the condition of the pipelines was made. A well designed and maintained pipeline system can achieve conveyance efficiencies as high as eighty-five percent to ninety percent (85%-90%), assuming operational losses are minimal. In the absence of data that show otherwise, a conveyance efficiency of eighty-five percent (85%) will be used in this report.

The overall conveyance efficiency for each area will vary based on the lengths of unlined canals and pipelines through which water is delivered to the farms in the area. Table 9 below shows the conveyance efficiency for each area calculated a length-weighted average of the unlined canal and pipeline efficiencies.

Table 9. Zuni Agricultural Areas Weighted Conveyance Efficiencies

| Agricultural Area | Length, miles | | Conveyance Efficiency, % | | Weighted Conveyance Efficiency, % |
|---|---|---|---|---|---|
| | Canal | Pipeline | Canal | Pipeline | |
| Nutria | 9.23 | 0.41 | 70 | 85 | 71 |
| Pescado | 20.76 | 6.10 | 65 | 85 | 70 |
| Zuni | 10.72 | 6.91 | 65 | 85 | 73 |
| Tekapo | 3.38 | 0.36 | 70 | 85 | 71 |
| Ojo Caliente | 3.17 | 5.60 | 70 | 85 | 80 |

The overall efficiencies for the five (5) Zuni agricultural areas are shown in Table 10 below.

Table 10. Zuni Agricultural Areas Overall Efficiencies

| Agricultural Area | On-farm Efficiency, % | Conveyance Efficiency, % | Overall Efficiency, % |
|---|---|---|---|
| Nutria | 60 | 71 | 43 |
| Pescado | 50 | 70 | 35 |
| Zuni | 55 | 73 | 40 |
| Tekapo | 60 | 71 | 43 |
| Ojo Caliente | 60 | 80 | 48 |

Table 11 below shows a comparison of the overall efficiency as determined using the procedure described in this report with the overall efficiency reported by Dr. Niel Allen.

Table 11. Comparison of Overall Efficiency

| Agricultural Area | Overall Efficiency, % | |
|---|---|---|
| | Franzoy Report | Allen Report |
| Nutria | 43 | 42 |
| Pescado | 35 | 48 |
| Zuni | 40 | 42 |
| Tekapo | 43 | 48 |
| Ojo Caliente | 48 | 54 |

The differences in the overall efficiency in the two reports are due primarily to differences in conveyance efficiencies.

## **<u>Conclusions</u>**

Based on the work described above, it was concluded that the irrigation efficiencies in the five (5) Zuni agricultural areas will be between fifty percent (50%) and sixty percent (60%). Farm delivery requirements should be calculated for each of the five (5) areas separately rather than using an average of the areas.

The range of conveyance efficiencies for Acoma and Laguna Pueblos is seventy percent (70%) to eighty percent (80%). Project diversion requirements should be calculated for each of the five (5) areas separately rather than using an average of the areas.

## **<u>OPINIONS TO BE EXPRESSED</u>**

The following are the opinions to be expressed by C. Eugene Franzoy, P.E. regarding on-farm efficiency and conveyance efficiency.

1. The average seasonal on-farm efficiency in the five Zuni agricultural areas will be between fifty percent (50%) and sixty percent (60%) but each area should be

treated as a discrete area and the on-farm efficiencies shown in Table 10 should be used to determine the farm delivery requirement for each area.

2. The conveyance efficiency of the delivery ditches at Zuni will be between seventy percent (70%) and eighty percent (80%) but each area should be treated as a discrete area and conveyance efficiencies shown in Table 10 should be used to determine the project diversion requirement for each area.

Bibliography

1. Geographic Information Systems Data from New Mexico Office of the State Engineer, December 2009

2. US Department of Agricultural, Natural Resources Conservation ServiceSoilDataMart@nrcs.usda.gov

3. US Geological Survey Topographic Maps

4. Zuni Indian Reservation Identification of Lands and Estimation of Water Requirements for Past and Present Irrigated Lands Served by Permanent Irrigation Works, prepared by L. Niel Allen, PhD., P.E. dated November 3, 2008.

# Appendix
# Tables and Figures

Table 2  Descriptions of Soils in the Zuni Agricultural area

Table 2a. Nutria Area

| Map Unit | Soil Type | Slopes | Map Unit Descriptor |
|---|---|---|---|
| 45 | Clay loam | 0 to 2 percent | Depth to a root restrictive layer is greater than 60 inches. Moderately well drained. Water movement in the most restrictive layer is moderately low. Available water to a depth of 60 inches is high. Shrink-swell potential is high. Irrigated land capability classification is 3s. |
| 325 | Silty clay | 1 to 3 percent | Depth to a root restrictive layer is greater than 60 inches. Well drained. Water movement in the most restrictive layer is low. Available water to a depth of 60 inches is high. Shrink-swell potential is high. Irrigated land capability classification is 3s. |
| 310 | Sandy loam | 1 to 8 percent | Depth to a root restrictive layer is greater than 60 inches. Well drained. Water movement in the most restrictive layer is moderately high. Available water to a depth of 60 inches is high. Shrink-swell potential is moderate. Irrigated land capability classification is 3c. |
| 49 | Clay loam | 0 to 2 percent | Depth to a root restrictive layer is greater than 60 inches. Well drained. Water movement in the most restrictive layer is moderately low. Available water to a depth of 60 inches is high. Shrink-swell potential is moderate. Irrigated land capability classification is 3c. |
| 55 | Clay loam | 0 to 2 percent | Depth to a root restrictive layer is greater than 60 inches. The natural drainage class is well drained. Water movement in the most restrictive layer is moderately low. Available water to a depth of 60 inches is high. Shrink-swell potential is high. Irrigated land capability classification is 4w. |
| 380 | Clay | 2 to 10 percent | Depth to a root restrictive layer is greater than 60 inches. Well drained. Water movement in the most restrictive layer is low. Available water to a depth of 60 inches is very low to moderate. Shrink-swell potential is high. No irrigated land capability classification listed. |

Note: Map Units are listed in the order of their prevalence in the project area.
Source: Natural Resources Conservation Service Soil Data Mart

Table 2b. Pescado Area

| Map Unit | Soil Type | Slopes | Map Unit Descriptor |
|---|---|---|---|
| 310 | Sandy loam | 1 to 8 percent | Depth to a root restrictive layer is greater than 60 inches. Well drained. Water movement in the most restrictive layer is moderately high. Available water to a depth of 60 inches is high. Shrink-swell potential is moderate. Irrigated land capability classification is 3c. |
| 49 | Clay loam | 0 to 2 percent | Depth to a root restrictive layer is greater than 60 inches. Well drained. Water movement in the most restrictive layer is moderately low. Available water to a depth of 60 inches is high. Shrink-swell potential is moderate. Irrigated land capability classification is 3c. |
| 47 | Clay loam | 0 to 2 percent | Depth to a root restrictive layer is greater than 60 inches. Moderately well drained. Water movement in the most restrictive layer is moderately low. Available water to a depth of 60 inches is high. Shrink-swell potential is high. Irrigated land capability classification is 3s. |
| 357 | Clay | 0 to 1 percent | Depth to a root restrictive layer is greater than 60 inches. Well drained. Water movement in the most restrictive layer is low. Available water to a depth of 60 inches is low. Shrink-swell potential is high. Irrigated land capability classification is 4w. |

Note: Map Units are listed in the order of their prevalence in the project area.
Source: Natural Resources Conservation Service Soil Data Mart

Table 2c. Zuni Area

| Map Unit | Soil Type | Slopes | Map Unit Descriptor |
|---|---|---|---|
| 60 | Sandy clay loam | 0 to 2 percent | Depth to a root restrictive layer is greater than 60 inches. Well drained. Water movement in the most restrictive layer is moderately high. Available water to a depth of 60 inches is high. Shrink-swell potential is moderate. Irrigated land capability classification is 3e. |
| 352 | Sandy loam | 1 to 5 percent | Depth to a root restrictive layer is greater than 60 inches. Excessively drained. Water movement in the most restrictive layer is high. Available water to a depth of 60 inches is moderate. Shrink-swell potential is low. Irrigated land capability classification is 3e. |
| 42 | Clay loam | 0 to 2 percent | Depth to a root restrictive layer is greater than 60 inches. Well drained. Water movement in the most restrictive layer is moderately high. Available water to a depth of 60 inches is very high. Shrink-swell potential is moderate. Irrigated land capability classification is 4w. |

Note: Map Units are listed in the order of their prevalence in the project area.
Source: Natural Resources Conservation Service Soil Data Mart

Table 2d. Tekapo Area

| Map Unit | Soil Type | Slopes | Map Unit Descriptor |
| --- | --- | --- | --- |
| 51 | Loamy fine sand | 0 to 2 percent | Depth to a root restrictive layer is greater than 60 inches. Somewhat excessively drained. Water movement in the most restrictive layer is high. Available water to a depth of 60 inches is low. Shrink-swell potential is low. Irrigated land capability classification is 4e. |
| 42 | Clay loam | 0 to 2 percent | Depth to a root restrictive layer is greater than 60 inches. Well drained. Water movement in the most restrictive layer is moderately high. Available water to a depth of 60 inches is very high. Shrink-swell potential is moderate. Irrigated land capability classification is 4w. |
| 40 | Silt loam | 0 to 2 percent | Depth to a root restrictive layer is greater than 60 inches. Well drained. Water movement in the most restrictive layer is moderately high. Available water to a depth of 60 inches is very high. Shrink-swell potential is low. Irrigated land capability classification is 4w. |
| 352 | Sandy loam | 1 to 5 percent | Depth to a root restrictive layer is greater than 60 inches. Excessively drained. Water movement in the most restrictive layer is high. Available water to a depth of 60 inches is moderate. Shrink-swell potential is low. Irrigated land capability classification is 3e. |

Note: Map Units are listed in the order of their prevalence in the project area.
Source: Natural Resources Conservation Service Soil Data Mart

Table 2e. Ojo Caliente Area (above reservoir)

| Map Unit | Soil Type | Slopes | Map Unit Descriptor |
| --- | --- | --- | --- |
| 54 | Clay, saline | 0 to 2 percent | Depth to a root restrictive layer is greater than 60 inches. Moderately well drained. Water movement in the most restrictive layer is low. Available water to a depth of 60 inches is moderate. Shrink-swell potential is high. Irrigated land capability classification is 4w. |
| 60 | Sandy clay loam | 0 to 2 percent | Depth to a root restrictive layer is greater than 60 inches. Well drained. Water movement in the most restrictive layer is moderately high. Available water to a depth of 60 inches is high. Shrink-swell potential is moderate. Irrigated land capability classification is 3e. |

Note: Map Units are listed in the order of their prevalence in the project area.
Source: Natural Resources Conservation Service Soil Data Mart

Table 2f. Ojo Caliente Area (below dam)

| Map Unit | Soil Type | Slopes | Map Unit Descriptor |
| --- | --- | --- | --- |
| 225 | Silt loam | 1 to 5 percent | Depth to a root restrictive layer is greater than 60 inches. Well drained. Water movement in the most restrictive layer is moderately high. Available water to a depth of 60 inches is high. Shrink-swell potential is moderate. Irrigated land capability classification is 3e. |
| 352 | Sandy loam | 1 to 5 percent | Depth to a root restrictive layer is greater than 60 inches. Excessively drained. Water movement in the most restrictive layer is high. Available water to a depth of 60 inches is moderate. Shrink-swell potential is low. Irrigated land capability classification is 3e. |
| 53 | Clay loam | 0 to 2 percent | Depth to a root restrictive layer is greater than 60 inches. Well drained. Water movement in the most restrictive layer is moderately low. Available water to a depth of 60 inches is high. Shrink-swell potential is high. Irrigated land capability classification is 2s. |
| 60 | Sandy clay loam | 0 to 2 percent | Depth to a root restrictive layer is greater than 60 inches. Well drained. Water movement in the most restrictive layer is moderately high. Available water to a depth of 60 inches is high. Shrink-swell potential is moderate. Irrigated land capability classification is 3e. |

Note: Map Units are listed in the order of their prevalence in the project area.
Source: Natural Resources Conservation Service Soil Data Mart

**Table 4**
**Pueblo of Zuni**
**Average Slopes in Proposed Irrigated Areas**

| Cross Section | Length ft | Elevation 1 ft above msl | Elevation 2 ft above msl | Difference ft | Slope ft/100 ft |
|---|---|---|---|---|---|
| Nutria | | | | | |
| N-1 | 869 | 6800 | 6800 | 0 | 0.000 |
| N-2 | 1,646 | 6820 | 6792 | 28 | 1.701 |
| N-3 | 1,408 | 6800 | 6780 | 20 | 1.420 |
| N-4 | 5,534 | 6790 | 6760 | 30 | 0.542 |
| N-5 | 4,910 | 6750 | 6750 | 0 | 0.000 |
| Average Slope | | | | | 0.733 |
| | | | | | |
| Pescado | | | | | |
| P-1 | 1,719 | 6800 | 6780 | 20 | 1.163 |
| P-2 | 3,129 | 6800 | 6760 | 40 | 1.278 |
| P-3 | 1,170 | 6780 | 6747 | 33 | 2.821 |
| P-4 | 4,871 | 6756 | 6720 | 36 | 0.739 |
| P-5 | 9,007 | 6740 | 6700 | 40 | 0.444 |
| P-6 | 2,156 | 6680 | 6660 | 20 | 0.928 |
| Average Slope | | | | | 1.242 |
| | | | | | |
| Zuni | | | | | |
| Z-1 | 5,751 | 6326 | 6280 | 46 | 0.800 |
| Z-2 | 6,833 | 6329 | 6286 | 43 | 0.629 |
| Z-3 | 6,342 | 6334 | 6295 | 39 | 0.615 |
| Z-4 | 4,681 | 6336 | 6312 | 24 | 0.513 |
| Z-5 | 3,422 | 6350 | 6313 | 37 | 1.081 |
| Z-6 | 2,164 | 6335 | 6305 | 30 | 1.386 |
| Average Slope | | | | | 0.845 |
| | | | | | |
| Tekapo | | | | | |
| T-1 | 2,021 | 6195 | 6190 | 5 | 0.247 |
| T-2 | 8,551 | 6190 | 6170 | 20 | 0.234 |
| Average Slope | | | | | 0.442 |
| | | | | | |
| Ojo Caliente | | | | | |
| O-1 | 3,282 | 6300 | 6260 | 40 | 1.219 |
| O-2 | 8,680 | 6240 | 6160 | 80 | 0.922 |
| O-3 | 5,846 | 6220 | 6170 | 50 | 0.855 |
| O-4 | 6,013 | 6240 | 6240 | 0 | 0.000 |
| Average Slope | | | | | 0.749 |

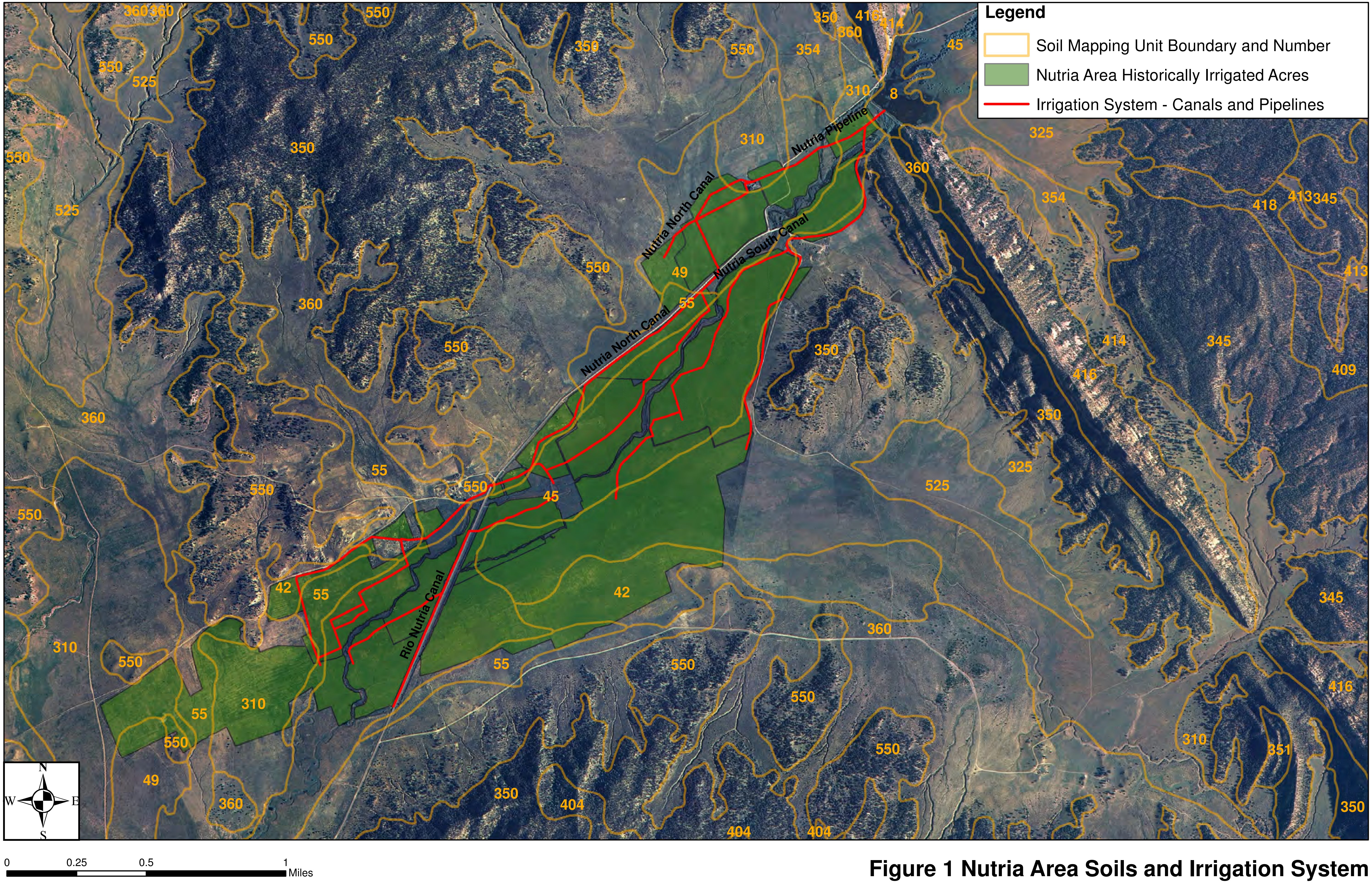



**Figure 1 Nutria Area Soils and Irrigation System**

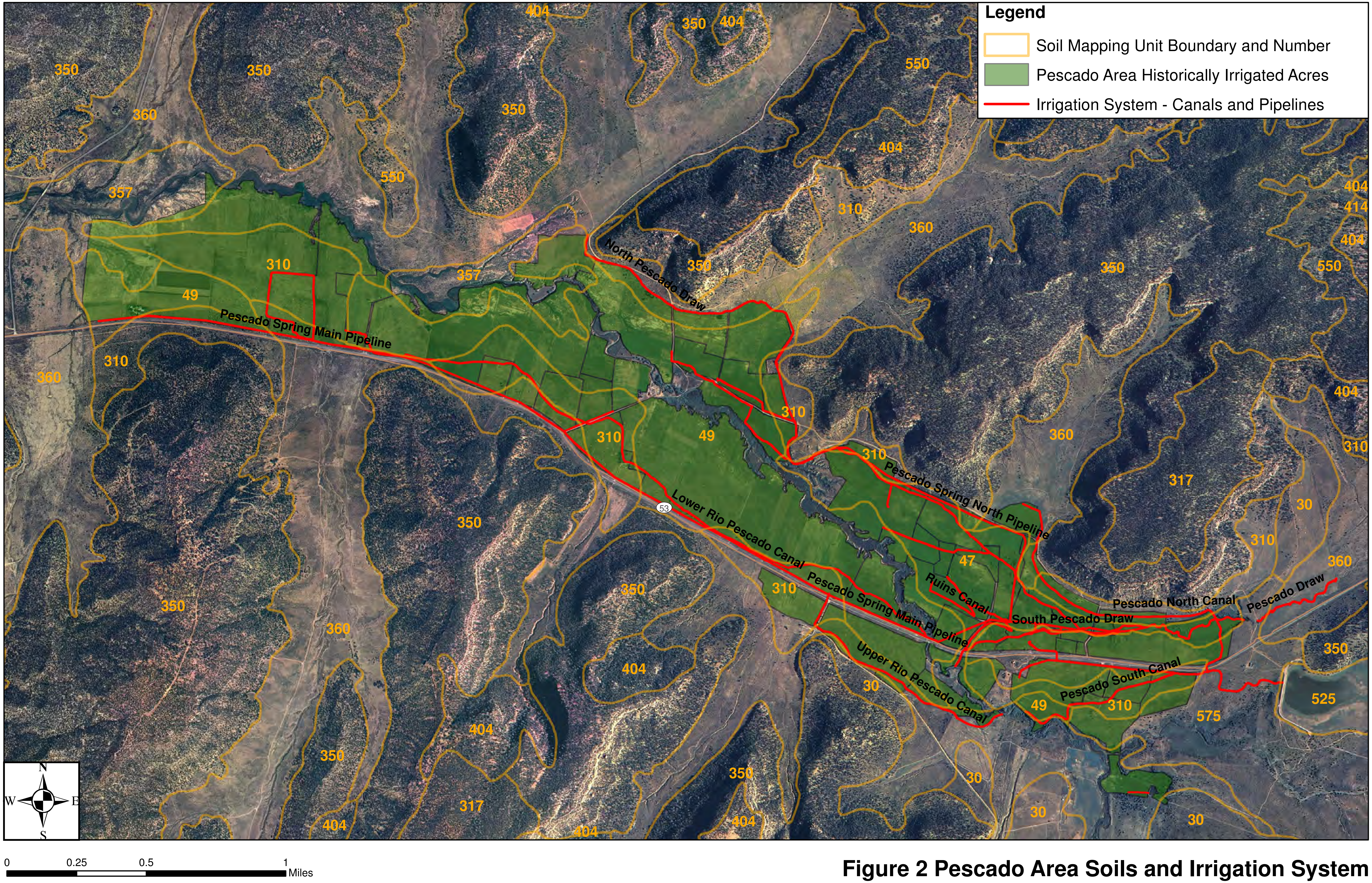



**Figure 2 Pescado Area Soils and Irrigation System**

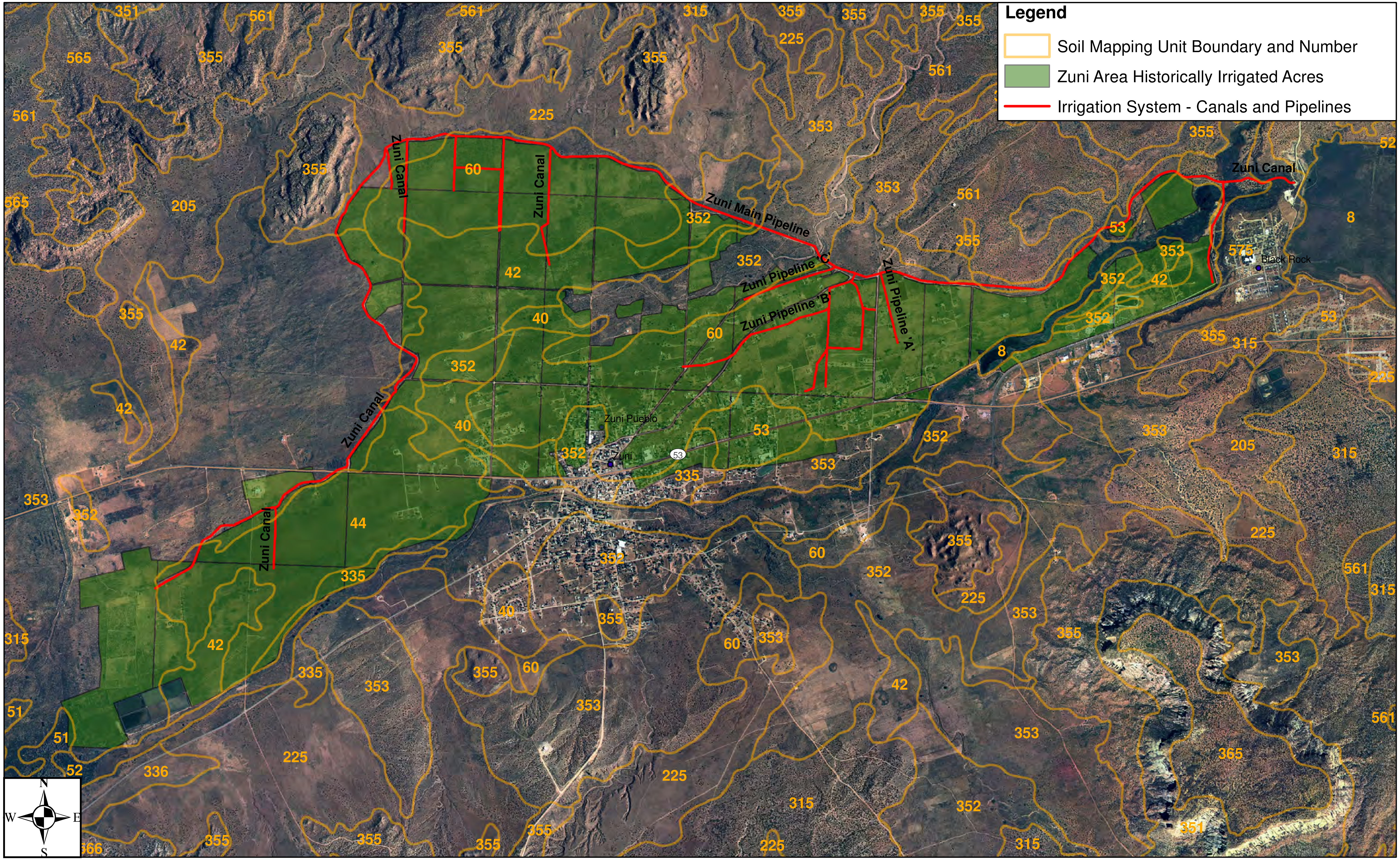



**Figure 3 Zuni Area Soils and Irrigation System**

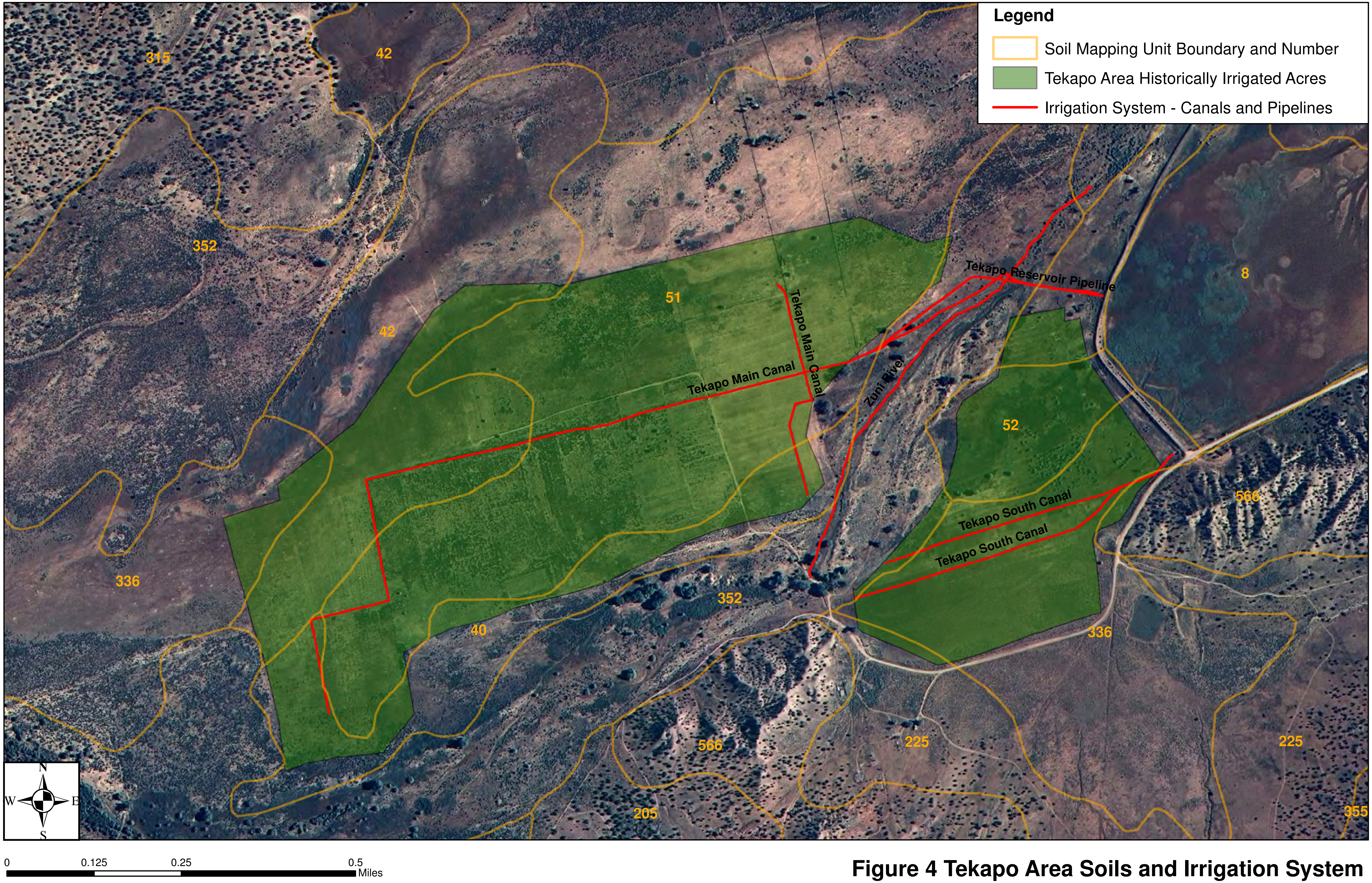



**Figure 4 Tekapo Area Soils and Irrigation System**

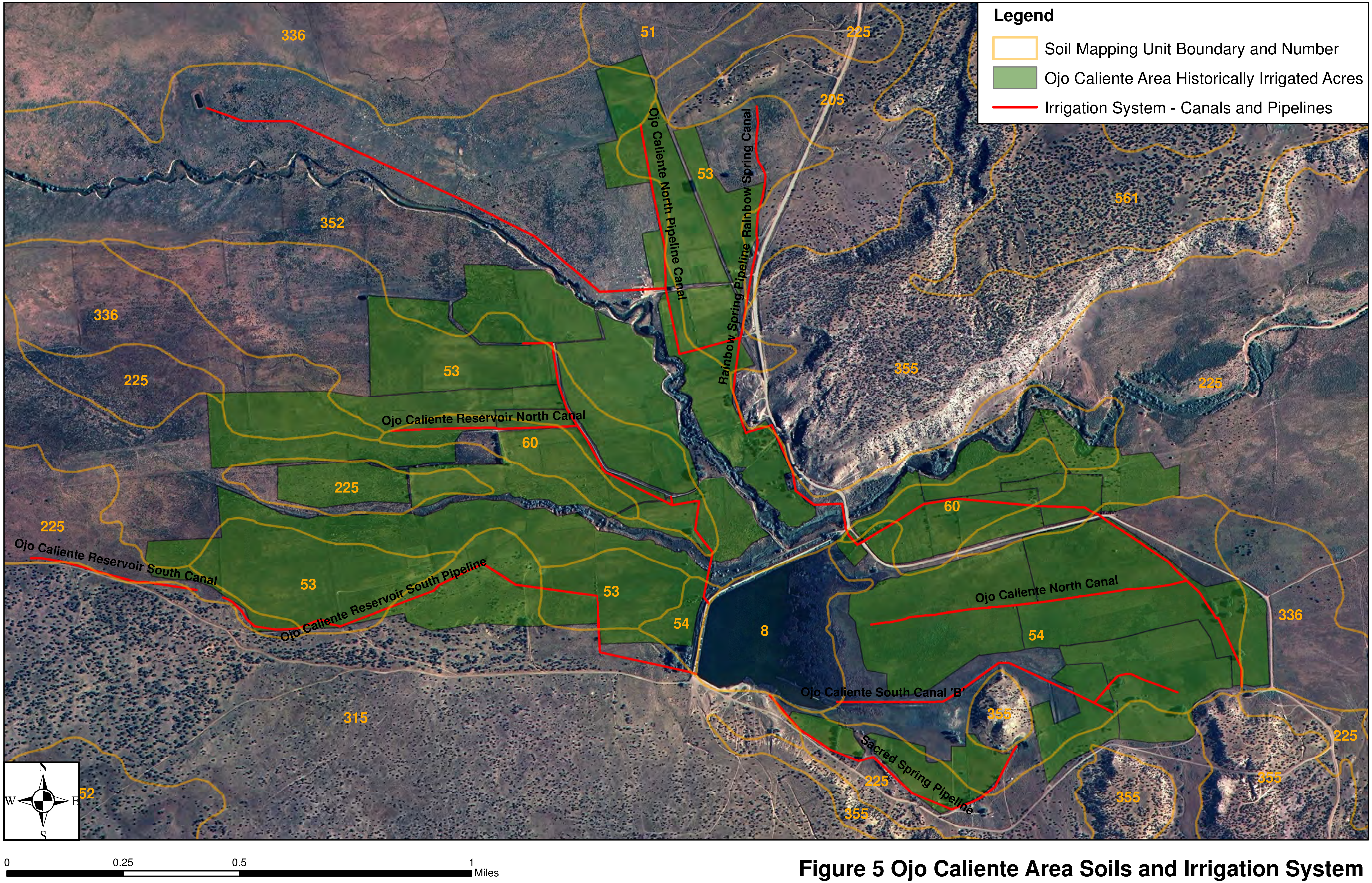
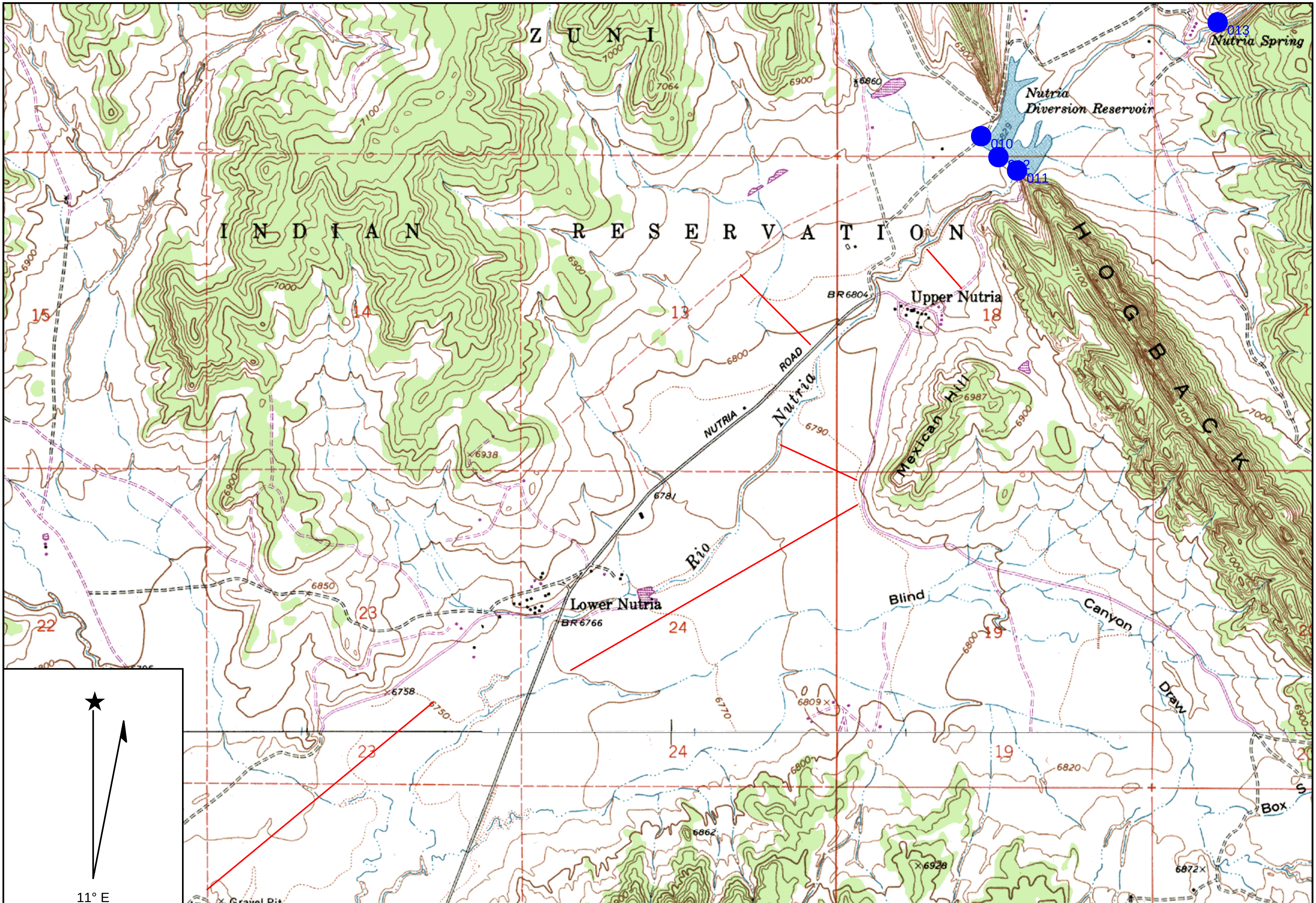


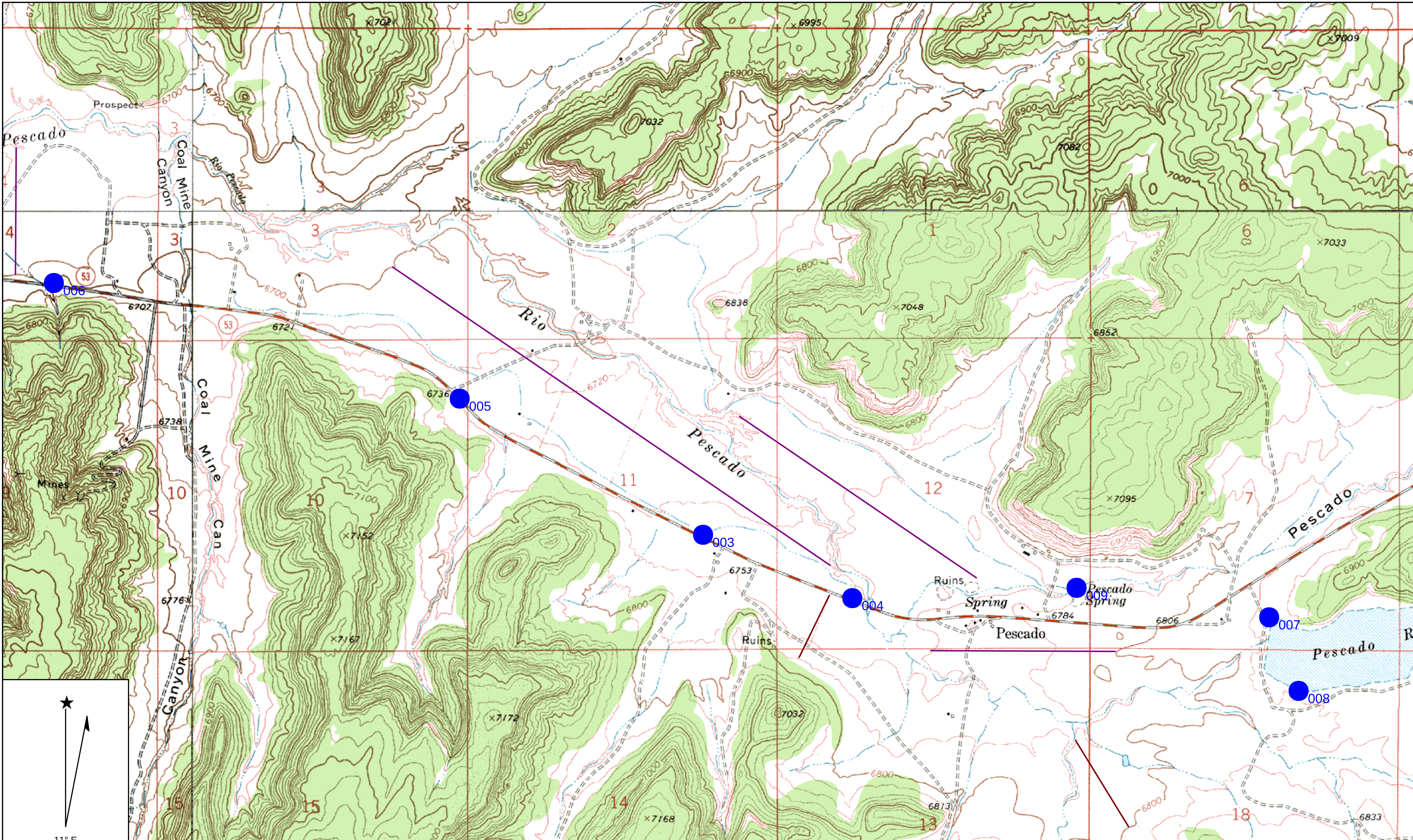

**Figure 5 Ojo Caliente Area Soils and Irrigation System**




Name: UPPER NUTRIA
Date: 1/5/2010
Scale: 1 inch equals 2000 feet

Location: 035° 15' 45.8" N 108° 35' 02.7" W

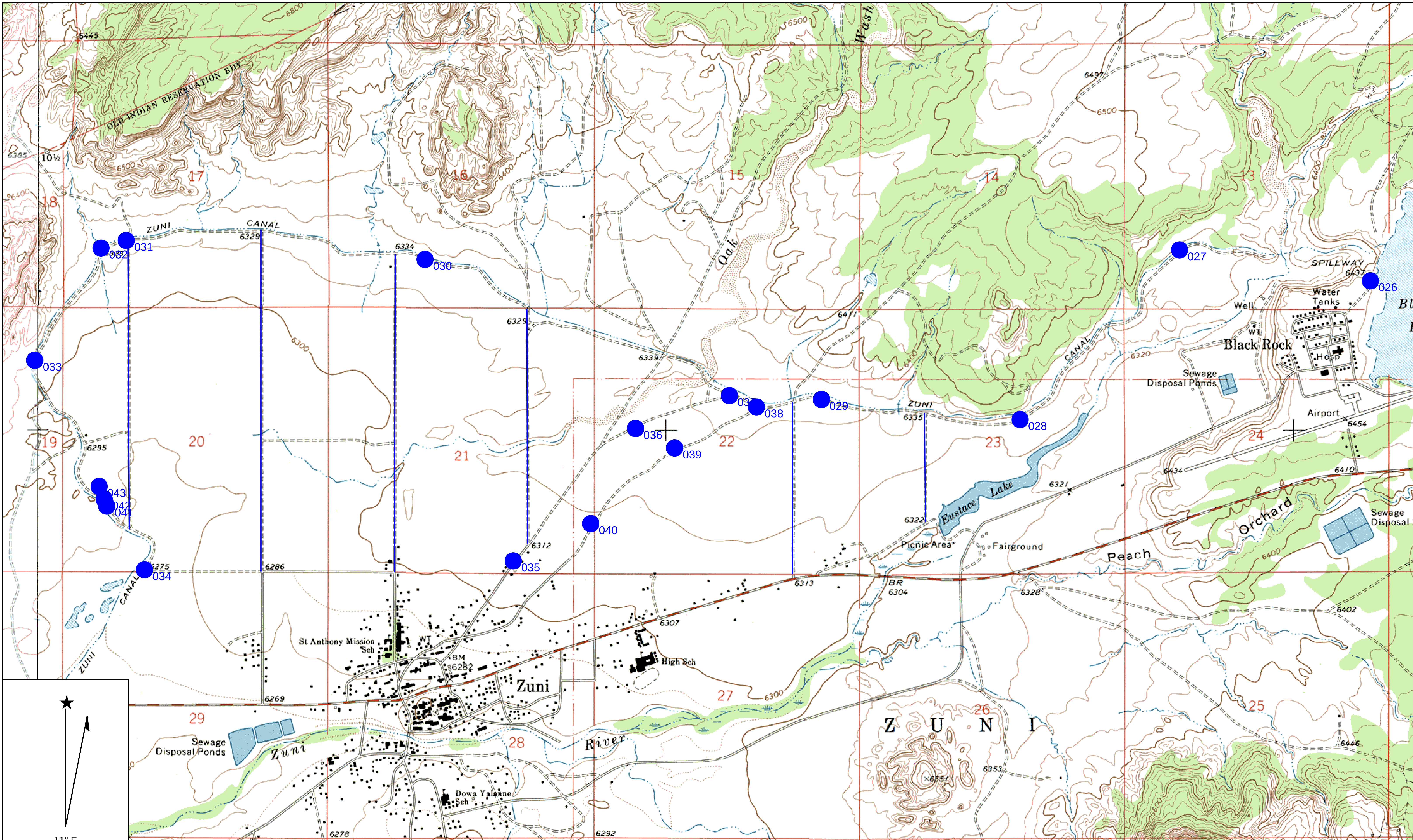
Figure 6 Nutria Area




Name: PESCADO
Date: 1/5/2010
Scale: 1 inch equals 1428 feet

Location: 035° 06' 54.0" N 108° 35' 43.4" W

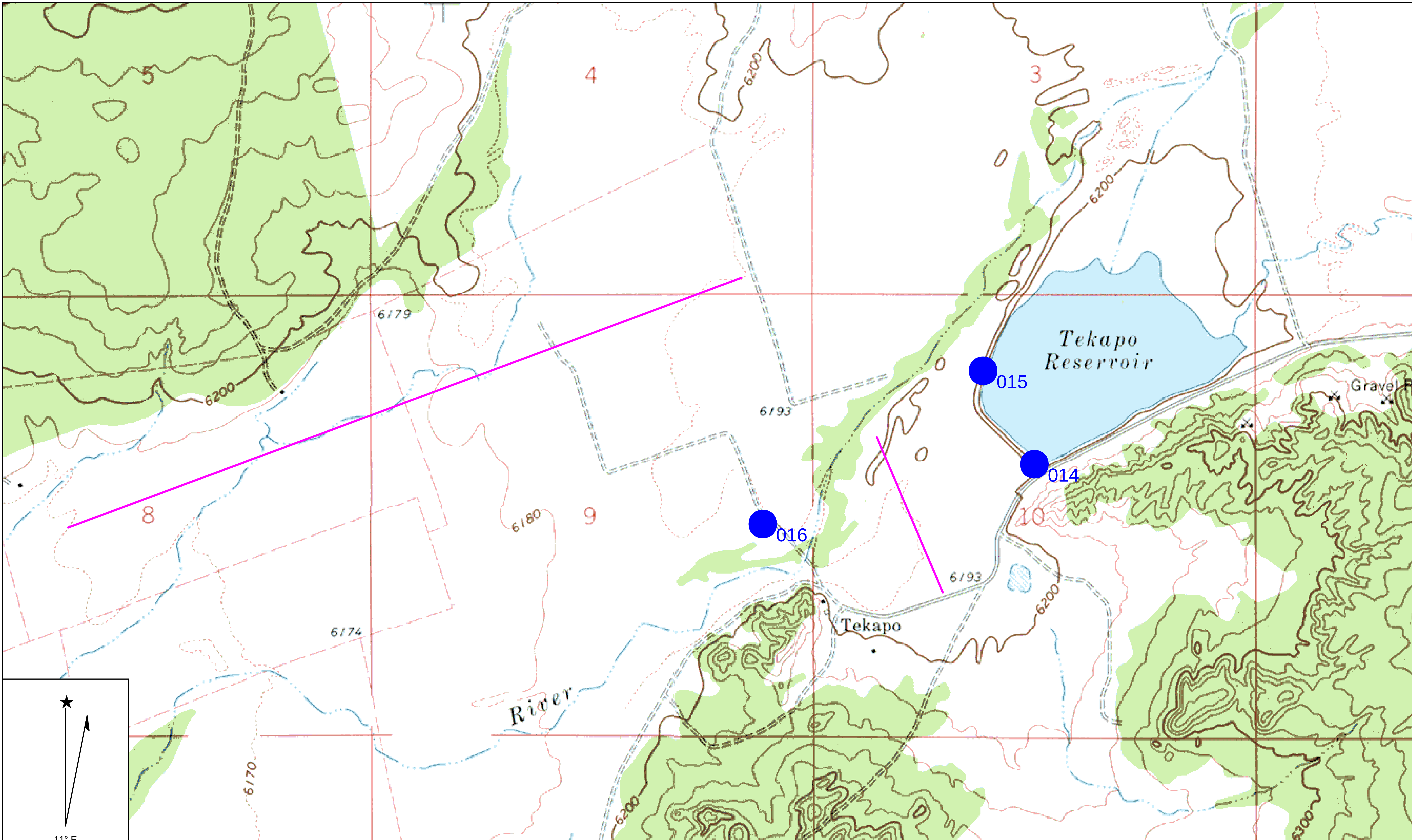
Figure 7 Pescado Area




Name: ZUNI
Date: 1/5/2010
Scale: 1 inch equals 1666 feet

Location: 035° 05' 01.0" N 108° 49' 48.4" W

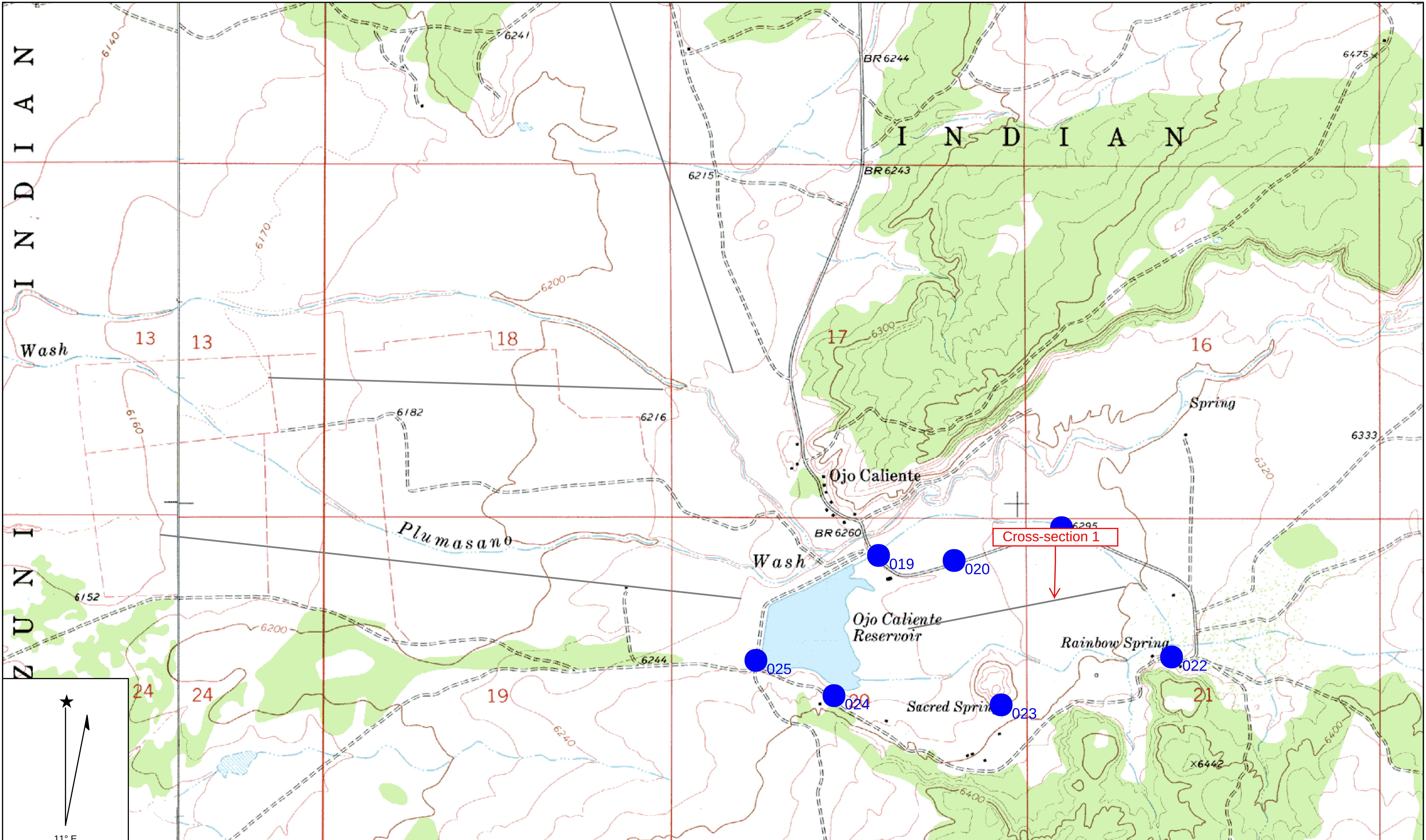
Figure 8 Zuni Area




Name: TEKAPO
Date: 1/5/2010
Scale: 1 inch equals 1000 feet

Location: 035° 01' 40.2" N 108° 56' 51.2" W

Figure 9 Tekapo Area




Name: OJO CALIENTE RESERVOIR
Date: 1/5/2010
Scale: 1 inch equals 1250 feet

Location: 034° 55' 11.6" N 108° 58' 24.4" W

Figure 10 Ojo Caliente Area