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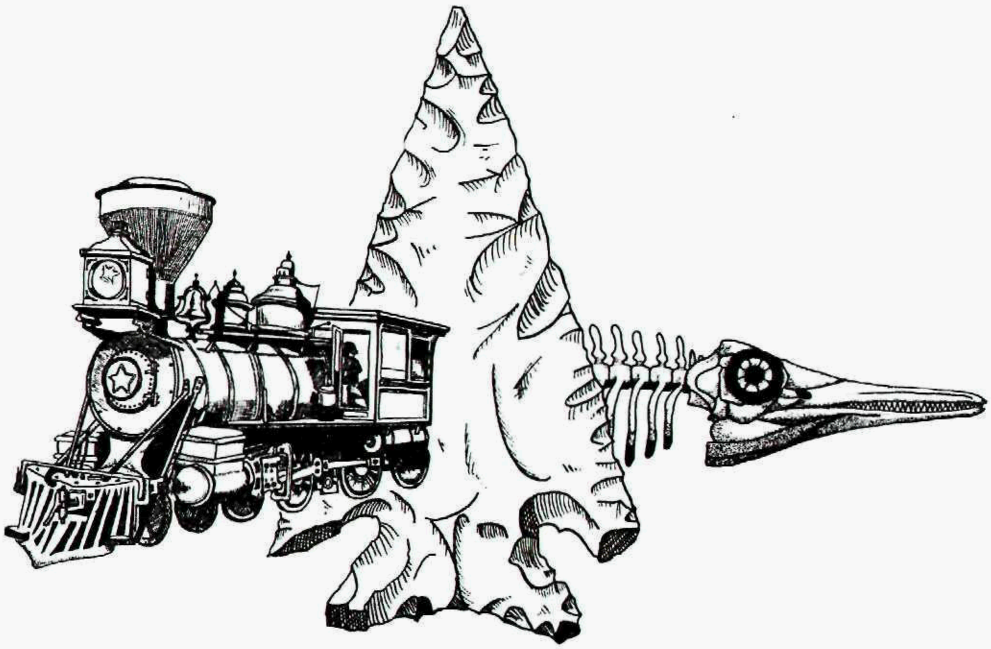

Archaeological Predictive Model, Management Plan, and Treatment Plans for Northern Railroad Valley, Nevada

by

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Management Summary

The Bureau of Land Management (BLM) regulates activity in more than a half million acres of Railroad Valley, Nevada, and there confronts recurrent conflict between cultural resources and competing land use—especially oil and gas exploration and development. An unwieldy and inconsistent cultural resource database compounds the problem. The agency decided that conflict resolution lies in improved cultural resource management and treatment, based on accurate predictions of archaeological site sensitivity and supported by geographic information system (GIS) technology.

The work reported herein models the prehistoric archaeological sensitivity of northern Railroad Valley, plans regional cultural resource management, and treats the Gravel Bar Site and the Trap Springs Archaeological Complex. Accompanying this volume are GIS databases into which are encoded the model and the archive of existing archaeological inventories and site records.

The Regional Cultural Resource Management Plan in Brief

The CRMP subdivides Railroad Valley into five *Management Zones*[1] and prescribes specific inventory, recording, and reporting procedures according to the conditions that set each Management Zone apart. Under the aegis of the plan, the management posture in Railroad Valley will result in the following:

- More cost-effective project planning, allowing BLM to anticipate project effects on cultural resources, and avoid archaeologically sensitive areas during planning phases
- Improved information management procedures, increasing the reliability and accuracy of site number assignment, map plots of site locations and inventory areas, National Register status tracking, and site record searches
- Exclusion of 12,423 acres of low archaeological sensitivity from further inventory
- Lowering present inventory standards in 294,239 acres of moderate archaeological sensitivity
- Strengthening present inventory standards in 220,510 acres of high archaeological sensitivity
- Treatment of the Gravel Bar Site (and subsequent opening to other uses)
- Treatment of the Trap Springs Archaeological Complex (and subsequent opening to other uses)
- Removal of the Stormy-Abel Site Complex from restricted use status or, alternatively, prescribed boundary justification and treatment (and subsequent opening to other uses)
- Simplified site recording and reporting standards emphasizing documentation of the presence or absence of key artifact types and environmental traits

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1 Eight very specialized terms are necessary to this summary and the following report. Each is italicized here and defined in the accompanying glossary.

- A reliable framework for site significance evaluation and treatment planning

- Improved standards for defining *Special Management Units*

The model and the GIS databases are applicable at two levels of intensity. To facilitate records searches, inventories, site evaluations, project planning, treatment planning, and long-term management, the resource manager need look no further than the Management Zones and their prescriptions. On the other hand, long term maintenance, testing, and refinement of the model and databases ask the resource manager to grasp and apply the theoretical and technical foundations of the model.

The Gravel Bar Site Treatment Plan in Brief

The goal of the Gravel Bar Site treatment plan is to mitigate effects of development on the Pre-Archaic component of the site, so that much of it can be opened to competing uses. Simultaneously, the treatment plan entails identification, recording, and evaluation of significant manifestations of the Archaic period, which will then be avoided or treated, as appropriate, on a site-by-site basis. Gravel Bar Site treatment will occur in two phases: Phase I will comprise surface survey, subsurface mechanical testing and hand testing, test data analysis, and reporting to standards on which subsequent Phase II data recovery can depend. Phase II data recovery will comprise mechanical trenching, block excavations, data analysis, and reporting.

Research domains refer to paleoenvironmental reconstruction, cultural chronology with special reference to the Pleistocene-Holocene Transition (ca 12,000-10,000 BP) and the Early Holocene (ca. 10,000-8,000 BP), ancient subsurface remains, subsistence, lithic technology and procurement, and horizontal variation in surface artifact distributions.

The Trap Springs Archaeological Complex Treatment Plan in Brief

Imprecise boundary definitions and a lack of clear justification for special management consideration have bedeviled management of the Trap Spring Archaeological Complex for years. The treatment plan focuses on resolving these issues. It delineates a boundary that encompasses 2174 acres, reducing the size of the complex to a little less than half of one of its former larger manifestations, opening the remainder for competing uses.

Treatment focuses on the complex rather than on component sites, employing quadrat sampling and mitigation in two phases. Despite its emphasis on sampling, full implementation of the treatment plan will open the entire Trap Spring Archaeological Complex to competing uses. Phase I of treatment entails intensive sample inventory, subsurface testing, preliminary analysis and interim reporting. Phase II demands further development of the research design, intensive data recovery and reporting. The plan addresses research domains of paleoenvironment, cultural chronology, assemblage variability and site function, buried deposits, subsistence, lithic technology and procurement, and ceramic origins.

The Modeling Exercise in Brief

The Archaeological Predictive Model for Northern Railroad Valley—its conclusions and predictive power—is the foundation upon which rest the management and treatment plans just summarized. The 527,175 acres of the model universe encompass a large playa basin, portions of the

Duckwater, Currant, Bull Creek, and Hot Springs drainages, and adjacent flanks of the White Pine, Grant, Duckwater, and Pancake Ranges. Modeling human behavior in such complexity depends upon understanding its environmental variability in time and space, which underlies a fine-grained classification of prehistoric resource distributions. Once we come to such understanding, we can predict prehistoric foraging behavior according to optimal foraging theory, which assumes that foragers seek the greatest benefit of resources at the least cost. In summary, this is how we proceeded:

First, we used soil and *range type* descriptions developed by the Natural Resource Conservation Service to define 39 *habitats*, each of which offered a particular constellation of plant and animal resources to prehistoric foragers. Abiotic factors (slope, proximity to water, and availability of toolstone) that influenced the foraging utility of habitats further divide the habitats into a mosaic of 108 *habitat types*. Concurrently, the model must track temporal variability in resource distributions over the last 10,000 years to predict how hunter-gatherer behavior changed over time. We approached this by considering the paleoenvironmental record of the Great Basin, analyzing the geomorphology of the study area, defining thirteen landforms there, and estimating the paleoenvironmental chronology of their formation. At this point, we cross-referenced habitat types by landform to discern how resource structure changed over time. All that done, the prehistoric resource stage was set.

Next, optimal foraging theory and an understanding of archaeological site formation processes allowed us to predict the abundance, function, and complexity of prehistoric sites in each habitat type. We ranked predictions by an eight-point *archaeological complexity scale*, which summarizes the potential of each habitat type for toolstone reduction, residential occupation, and men's and women's foraging activity. A *monothetic site typology* classified the existing database of 1323 prehistoric sites and isolates as lithic reduction sites, residential base camps, men's foraging sites, and women's foraging sites.

Finally, we tested model predictions against the site typology, analyzed the predictive failures, and fine-tuned the model accordingly. The refined model anticipates the density and content of 94% to 97% of known sites. Moreover, sites thought significant by the field archaeologists who observed them are highly correlated with archaeological complexity score, showing that the model accurately tracks the distribution of prehistoric sites that are eligible for inclusion in the National Register of Historic Places. BLM now has in hand a powerful planning tool grounded in accurate predictions of cultural resource distribution and significance.

Constructing the model, testing its predictive utility, and refining its predictive results was a matter of careful progression from one step to another. Our intent, in the following report, is to lead the reader along our path of logic. But the reader may come to believe himself lured into a maze instead. The attached diagram charts the course we are about to take, and offers reassurance later on; the glossary makes sense of the language of predictive model building.

Glossary of Essential Terms

Archaeological Complexity Scale – An eight-point ranking of the predicted prehistoric archaeological sensitivity of the 108 habitat types. Rank 1 habitat types should have the most sites, with the largest and most diverse assemblages, whereas habitat types ranked 8 should yield the fewest sites, with the smallest and most homogeneous assemblages.

Habitat – A particular *potential natural vegetation community* or abiotic circumstance, represented by a range type or set of co-occurring range types, associated with one or more soil map units or water source types. Thirty-nine habitats occur in the study area. Habitats are designated by a letter prefix (A, G, M, S, or W) signifying the primary physiographic or vegetation association (abiotic, greasewood, montane, sagebrush, or wetland), followed by a numeric identifier.

Habitat Type – A habitat cross-stratified by at least one of three abiotic factors which affect the suitability of the habitat for residential or foraging use by hunter-gatherers: proximity to water, toolstone availability, and slope. An array of 108 habitat types occurs in the study area. No special symbol designates individual habitat types within a habitat, but each habitat type is assigned an archaeological complexity score.

Management Zone – Areas encompassing one or more archaeological complexity scores that have been found by the tested, refined model to have similar site density, diversity, significance and prior inventory coverage. Their similarity allows them to be grouped and treated as a unit in the Cultural Resources Management Plan. Five Management Zones have been defined:

MANAGEMENT ZONES 1 and 2 are predicted by the model to have similarly high site density and diversity, but sites eligible for National Register consideration are expected to be more common in Management Zone 1.

MANAGEMENT ZONE 3 is predicted to demonstrate moderate site density and diversity, and rare National Register quality sites.

MANAGEMENT ZONE 4 should demonstrate low site density and diversity, and no National Register quality sites.

MANAGEMENT ZONE 5 represents particular habitat types, which the model predicts to have low archaeological sensitivity, and where extensive previous inventories demonstrate low site density and the absence of sites eligible for National Register consideration.

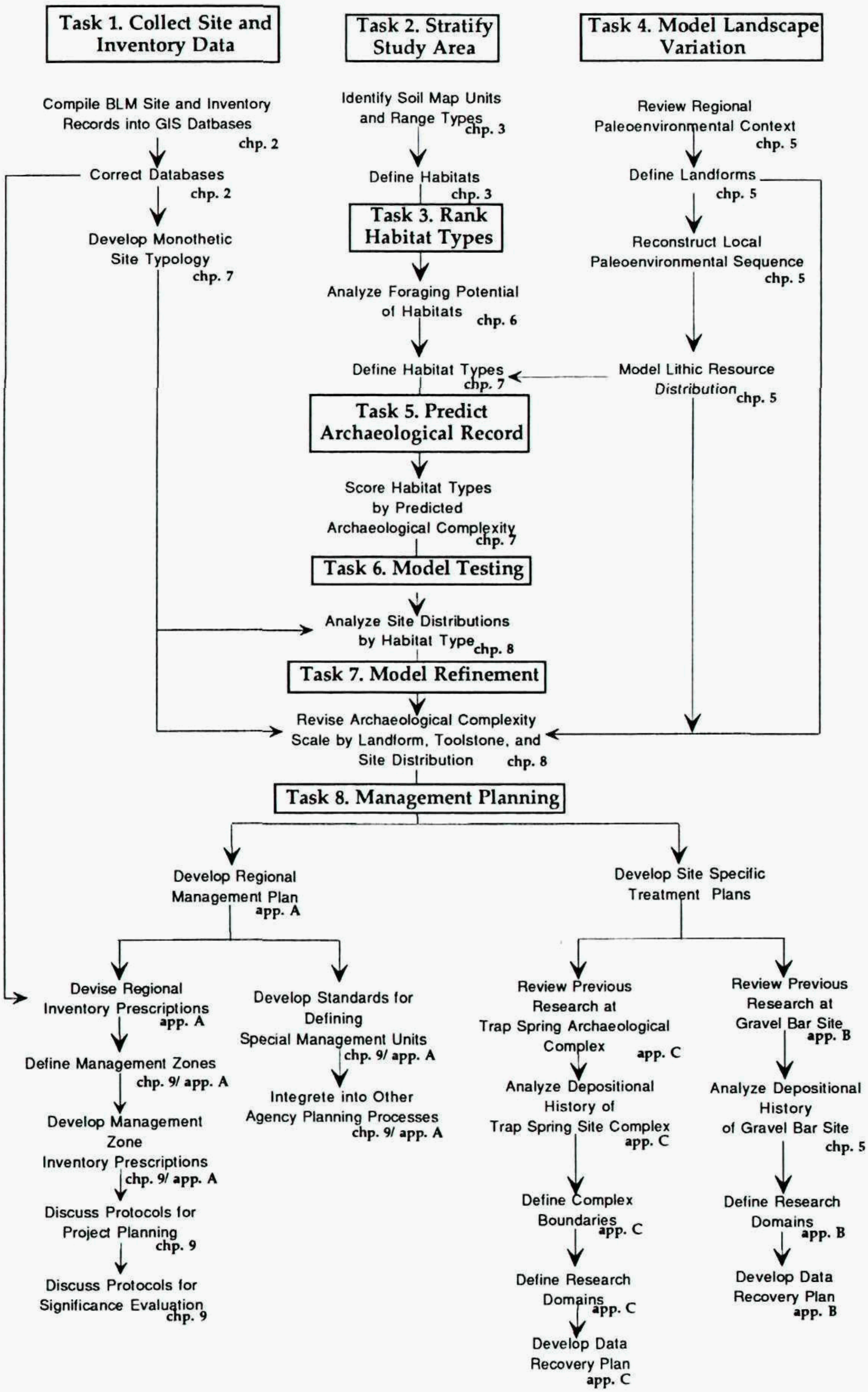
Monothetic Site Typology – A statistical site classification system based on the presence or absence of artifact types (rather than on artifact frequencies). Eighteen statistical groups are apparent in the database of 1323 prehistoric sites and isolates, which are consolidated into five functional site types: lithic reduction sites, men's subsistence sites, residential sites, unclassifiable sites, or women's subsistence sites.

Potential Natural Vegetation Community – The climax vegetation that develops in particular physiological circumstances defined as a range type, if left undisturbed for a sufficient time under current climatic conditions.

Range Type – A set of distinctive geological, topographic, and hydrological circumstances that fosters a particular potential natural vegetation community. Since range types correlate strongly with soil types and landforms, their distribution may be extrapolated from soil map units. Twenty-seven range types occur in various combinations on 53 soil types in the study area.

Special Management Unit – A particular area empirically shown or theoretically predicted to be highly sensitive for significant cultural resources. Special land use restrictions, withdrawals, or ACEC designation may be applied to Special Management Units. Two such units are designated in the study area: the Gravel Bar-Trap Springs Site Complex and the Stormy-Abel Site Complex.

Before formulation of this site sensitivity model, BLM designated two such units in the study area: the Gravel Bar-Trap Springs Site Complex and the Stormy-Abel Site Complex. The model serves to refine boundaries and develop treatment plans for the Gravel Bar-Trap Springs Site Complex, while challenging the management utility of the Stormy-Abel Site Complex.



Flow of Railroad Valley Model Construction, Testing, and Refinement
(keyed to relevant chapters and appendices of *Archaeological Predictive Model, Management Plan, and Treatment Plans for Northern Railroad Valley, Nevada*)

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Chapter 1

Project Objectives

David W. Zeanah and Eric Ingbar

The Bureau of Land Management (BLM) faces an ongoing conflict between its mandate to manage cultural resources and to fulfil its other land management obligations in Railroad Valley. Sections 106 and 110 of the National Historic Preservation Act (NHPA) direct BLM to inventory cultural properties and to avoid or mitigate adverse effects of undertakings on those properties eligible for nomination to the National Register of Historic Places (NRHP). If all properties in Railroad Valley were, in fact, identified and evaluated, this mandate would be relatively simple to fulfill. However, the cost of comprehensive inventory has obliged agency archaeologists to confine inventory to discrete parcels associated with specific undertakings, evaluating and considering effects only on significant properties within any particular project area.

This reactive approach confounds efficient allocation of personnel, time, and funds, while impeding other land uses. For example, more than 450 cultural resource inventories, conducted in response to a variety of undertakings (seismic lines, well pads, access roads, land exchanges, and so on), have recorded 1358 archaeological sites and isolates in Railroad Valley. Keeping track of this tremendous database has created a formidable obstacle to management goals: sites have been misplotted, multiple site numbers have been assigned to the same site and the same number applied to different sites, criteria for distinguishing sites from isolates have been inconsistently applied, inventory areas have been inconsistently recorded, and NRHP eligibility determinations have been poorly documented. Most importantly, hard-won experience gained from past work neither informs nor improves management because BLM lacks a framework for interpreting extant data.

BLM has attempted to alleviate conflicts between cultural resources and land use demands by applying special management protocols for areas empirically judged sensitive or not sensitive with regard to cultural resources. For example, about twenty years ago the Battle Mountain District Manager issued a directive excluding the Railroad Valley playa from further cultural resource inventory. The rationale for exclusion apparently derived from previous inventories of the playa which discovered no sites there. However, this evidence was never documented and no agreement between BLM and the State Historic Preservation Office (SHPO) was ever formalized (M. Baskerville, personal communication to C.D. Zeier 1998).

Conversely, BLM has identified particular National Register eligible properties as special management areas. The Tonopah Resource Management Plan (USDI BLM 1997) identifies two such areas in Railroad Valley, the Trap Spring Site Complex and the Gravel Bar Site. The plan specifies land use restrictions for those areas and recommends development of cultural resource action plans and comprehensive data recovery programs for sites within them. In these cases, however, the rationales for defining these site complexes are undeveloped and boundaries are vague. Consequently, subsequent archaeological inventories could not determine whether newly discovered cultural properties were elements of the complexes. The tendency has been to give site membership the benefit of the doubt and to enlarge the special management areas, aggravating conflicts with other land use demands and hindering coherent management of significant resources.

Approach to a Solution

This report develops a cost-effective solution to the BLM dilemma in Railroad Valley, composed of two parts. The first develops a theoretically informed prehistoric site sensitivity model, anticipating the distribution and significance of prehistoric cultural properties. Use of the model in cultural resource management will allow managers to:

- predict project effects on significant cultural resources before archaeological inventory;
- choose among alternative project locations, avoiding archaeologically dense or complex areas;
- allocate inventory effort according to the probability that specific areas will contain significant properties;
- choose the most appropriate and efficient sampling and inventory techniques;
- anticipate inventory and mitigation costs within any selected project location;
- use the highly specific assumptions of the model to help evaluate site significance; and
- devise cultural resource management plans and site specific treatment plans.

The site sensitivity model developed herein predicts the distribution, function, and significance of prehistoric archaeological sites in northern Railroad Valley by using optimal foraging theory to evaluate the foraging utility of habitat types, and by considering site formation processes, paleo-environmental variability, habitability, and toolstone distribution. From this assessment we assign an archaeological complexity score, monitoring the likelihood of National Register sensitive archaeology to each habitat type in the study area. Similar models have been successfully constructed, tested, and applied in the Carson Desert of western Nevada (Raven and Elston 1989; Raven 1990; Zeanah et al. 1995), and in the Honey Lake Basin of eastern California (Zeanah and Elston 1997). The management utility of such models has been documented (Ingbar et al. 1996).

The second part of the solution for Railroad Valley is to improve the system for managing information about cultural resources and investigations that have searched them out, via automated record keeping, a resource management plan, and two area-specific treatment plans. Electronic datasets can be used to produce site records, summary information about sites and projects, and maps of cultural resources and investigations in a comprehensible format. The information is more quickly accessible than searching paper files.

Electronic datasets do not entirely replace paper records because all the text and imagery of reports, field notes, and other records need not be automated. However, an automated record system serves to index the more detailed paper record. The automated records system created in this work comprises three major elements: a database to contain most attributes of resources and investigations, ArcView GIS datasets of cultural resources and investigations, and images created by scanning site records.

One goal in compiling the existing cultural resources information for Railroad Valley into electronic format is to create an independent dataset suitable for testing and refining the predictions of the site sensitivity model. However, the databases are, in themselves, powerful management tools. BLM use and maintenance of the databases will

- facilitate tracking previously inventoried areas,
- improve the reliability of records searches,
- alleviate problems in site numbering and plotting, and
- improve tracking the National Register status of cultural resource properties.

Together, the model, the electronic databases, and the appended management plan and treatment plans are proactive planning tools that will allow agency archaeologists to protect and manage prehistoric resources more efficiently. Products of the modeling exercise and database compilation are these:

- a cultural resource management plan for northern Railroad Valley;
- site specific treatment plans for the Gravel Bar Site and Trap Spring Site Complex;
- GIS databases for site location and status, inventoried parcels, and site sensitivity;
- GIS databases of habitat types, predicted archaeological sensitivity, and other relevant natural resource and environmental data; and
- a constructed, tested, and refined prehistoric archaeological site sensitivity model.

Report Organization

In Chapter 2, we describe the model area and review its environmental, prehistoric, and ethnographic context. There, we also describe the existing archaeological and environmental data sources used to construct and refine the model. Chapter 3 discusses the rationale, background, and procedures for identifying habitats and defines 39 of them in Railroad Valley. Chapter 4 describes the physiographic location and biotic composition of those habitats, whereas Chapter 5 reviews the paleoenvironmental record of Railroad Valley. Chapter 6 evaluates the foraging potential of habitats, models ethnohistoric hunter-gatherer foraging behavior in Railroad Valley and ranks habitats accordingly, and considers the effects of paleoenvironmental variability on that ranking. Chapter 7 develops expectations about the predicted archaeological complexity of each habitat. In Chapter 8, the existing archaeological database in the Railroad Valley model area is used to test and refine model predictions. Then, in Chapter 9, utility of the model as a management tool is discussed. A cultural resource management plan for northern Railroad Valley follows in Appendix A, with data recovery plans for the Gravel Bar Site and Trap Spring Site Complex given in Appendices B and C, respectively.

Chapter 2

Description of the Railroad Valley Model Area

Robert Elston, David W. Zeanah, and Eric Ingbar

Here we set the stage for predicting prehistoric site distributions in Railroad Valley, defining the study area and describing its environment context, and reviewing its prehistory and ethnography. Finally, we summarize existing archaeological and environmental databases that will serve to construct and test a Railroad Valley Habitat model.

Definition of the Study Area

The study area (Figure 1) encompasses 223,434 ha of northern Railroad Valley, including all its playa, the terminal portions of the Duckwater, Currant, Bull Creek, and Hot Springs drainages, and adjacent flanks of the White Pine Range, Grant Range, Duckwater Hills, and Pancake Range. Boundaries are administratively defined by Township and Range, to incorporate lands administered by Bureau of Land Management (BLM) Battle Mountain and Ely Districts. The study area includes the Railroad Valley Wildlife Management Area, once administered jointly by BLM and Nevada Department of Wildlife (USDI BLM 1990a), now administered solely by the BLM Battle Mountain District, Tonopah Resource Area (USDI BLM 1997). The study area includes private holdings as well.

Environmental Context

Structural and physiographic descriptions focus on the portion of Railroad Valley that is in and adjacent the project area.

Rocks and Structure

The following discussion is taken from Kleinhampl and Ziony (1984, 1985). Pre-Tertiary rocks now comprising mountain ranges in the project area were deposited in marine or near-marine environments in a broad geosyncline adjacent the protocontinent margin (Kleinhampl and Ziony 1985). These rocks are mostly limestone, dolomite, shale, and quartzite, and siliceous clastic rocks (cherty conglomerates); a plutonic body in the southwestern Grant Range is granite-like quartz monzonite.

Tertiary rocks include extrusive volcanics (ash-flow, and air-fall tuffs and lavas), non-marine sedimentary rocks, and intrusive rocks (domes, plugs, dikes). The most abundant igneous rocks are quartz-latitic ash-flow tuffs, followed by other tuffs, and dacitic to andesitic lavas. Wide dispersion of ash-flow tuffs from calderas occurred during the Oligocene and early Miocene. A large area comprising most of what is now Hot Creek Valley and the Pancake Range contained several calderas; the latest of these, dating to the late Tertiary, is marked by Lunar Lake.

Siliceous rocks suitable for stone tool manufacture are widely available in the valley, and chert is a common component in clasts on alluvial fans and gravel bars, and on lacustrine features made of gravel. Jasperoid is common in rocks northeast of Currant, northwest of Lockes, and in the Willow Creek drainage. Cherty silicified rocks are abundant in the vicinity of Storm Spring and in the hills east of Duckwater. While we did not observe any, it is possible that volcanic glass is present in the ash-flow tuffs and other volcanic rocks of the Pancake Range.

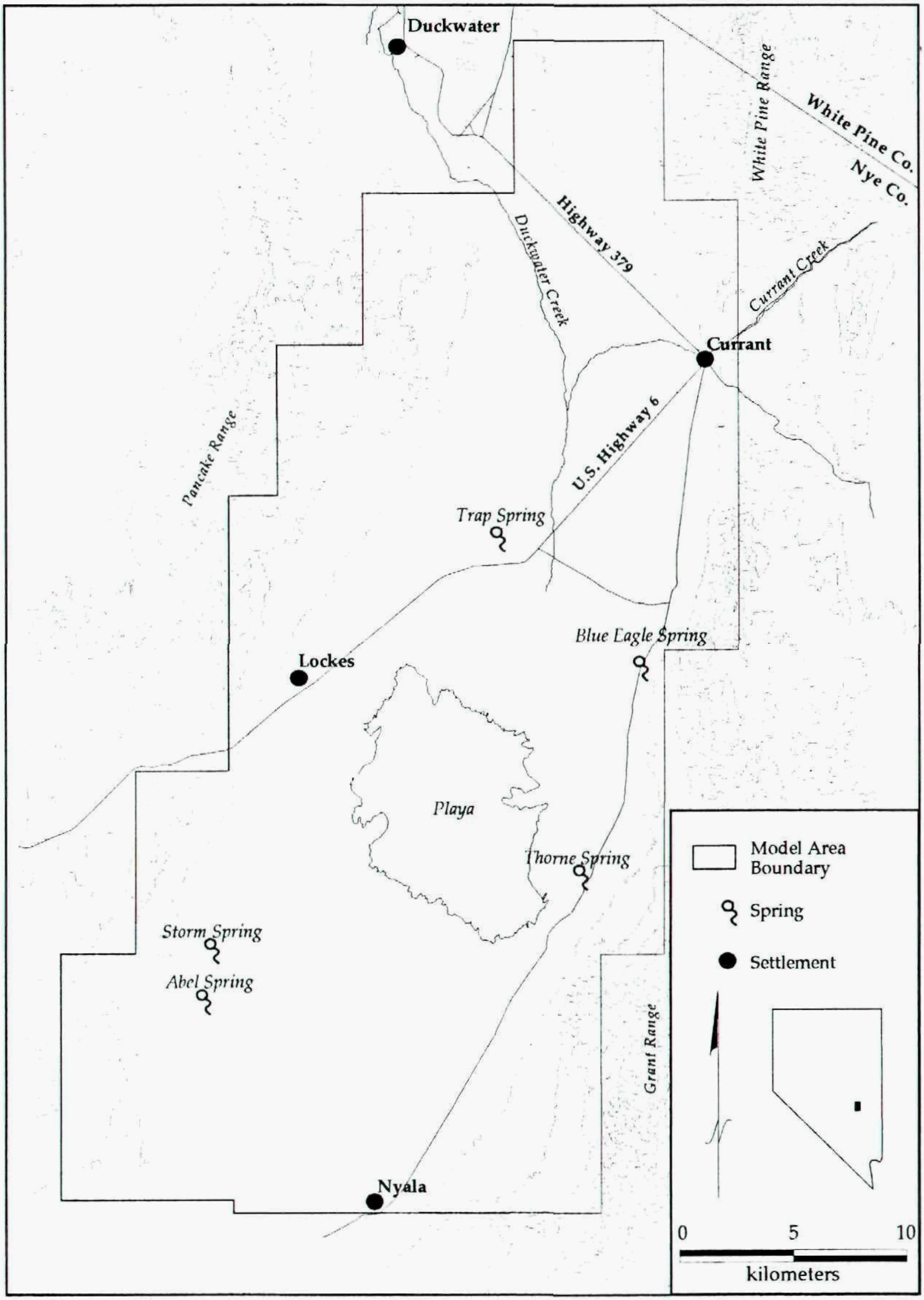

Figure 1. Map of the Railroad Valley Study Area.

The Basin and Range structure of the present landscape resulted from large-scale crustal extension and faulting along lines oriented north-south and northeast-southwest. Faults defining the blocks comprising the White Pine Range and Grant Range are probably between ten and twenty million years old (early to mid-Miocene), although most uplift on these mountains has occurred during the last seven million years (Kleinhampl and Ziony 1985:145). For the most part, faulting that isolated the structural blocks of the Pancake Range postdates the calderas and ash flows of Oligocene and early Miocene, and must be similar in age to the faults bounding the east side of Railroad Valley. However, faulting and volcanic activity on a lesser scale have occurred throughout the Tertiary. In fact, composite cones, cinder cones, and mar, and basalt eruptions from these features are Pliocene and younger (Kleinhampl and Ziony 1985:115). The youngest of four basalt flows originating in the vicinity of Black Rock Summit and flowing eastward into Railroad Valley appears to be no older than 2000 years, possibly only several hundred years old.

Physiography

Railroad Valley is a long, relatively narrow (ca. 110 x 30 mi) bolson bounded on the east by (from north to south) the White Pine, Horse, Grant, and Quinn Canyon Ranges. The western boundary of the valley is formed by (again, north to south) the Duckwater Hills, Pancake Range, and Reveille Range. The valley is closed on the north by western outliers of the White Pine Range, and on the south by the Hot Creek alluvial fan originating in the gap between the Pancake and Reveille Ranges. The broad central portion of the valley is oriented northeast-southwest and contains a large playa, the sink for all streams in the basin. The narrower northern and southern arms are oriented north-south. The southern arm is a separate subbasin with a smaller playa that can contain a lake about 20 m deep before spilling into the middle portion of the valley at about 1500 m asl. The northern arm contains axial streams draining southward into the middle portion of the valley.

Relief between the valley floor and bounding mountains is 2010 m (6594 ft). The 1434 m (4706 ft) elevation on the southwest margin of the large playa in the middle section is the lowest in the valley. Troy Peak in the Grant Range is highest, soaring to 3444 m (11,299 ft); a little farther south, an unnamed ridge above Dry Canyon and Big Creek Canyon reaches 3103 m (10,180 ft). Elevations of the mountains on the west are lower, ranging up to 2816 m (9239 ft) at Portuguese Mountain in the Pancake Range and to 2686 m (8812 ft) in the Reveille Range.

Hot Creek, draining Hot Creek Valley west of the Pancake Range, now flows into Railroad Valley through Twin Springs Slough, in the gap between the Pancake and Reveille Ranges, thence easterly across a broad alluvial fan, then northeastward across a low gradient alluvial plain or fan delta (Peterson 1981) to the southern margin of the large playa. The northern portion of the valley is drained by Bull Creek, tributary to Duckwater Creek which enters Railroad Valley from the west between Duckwater Hills and the northern Pancake Range. Duckwater Creek and Bull Creek also traverse a broad alluvial plain on the valley floor in the northern arm that becomes a fan delta extending from between Current Creek and The Big Wash to the northern margin of the large playa. The northern fan delta is less distinct as a feature than the southern fan delta because it is more thickly mantled with eolian sediments. The alluvial plains and fan deltas are all distinguished by anastomosing (braided) streams forming a complex mosaic of alluvial features and deposits, including active channels, gravel bars, cut-offs, and ox-bows (Brown 1997).

Streams debouching the steep mountain fronts form coalescing alluvial fans which are also mosaics of inactive and active channels, dissected fan remnants, inset fans, and terraces (Peterson 1981). The older fans on the east side of the valley are cut by normal faults parallel the mountain front. Fans on piedmont slopes of the western mountains tend to be highly segmented into landforms of different ages;

older surfaces are more eroded (Peterson 1981). In contrast, the piedmont of the western mountains is much smoother due, in part, to lithological difference: the western mountains are quartzite, shale, and limestones, while the western ranges are mostly ash-flow tuff. Moreover, the western mountains have steeper fronts and greater relief, while the eastern mountain piedmonts are possibly peneplains. For example, the fanhead trench of the Wood Canyon fan in the northern Pancake Range is cut through the alluvium and into soft tuff bedrock near the head of the fan. The surface of the tuff appears smooth, with only a few meters of alluvium perched on the bedrock. Finally, fans on the Pancake Range piedmont may be younger simply because of volcanic activity that continued into the recent Holocene (Kleinhampl and Ziony 1985).

Hydrology and Pluvial Lake Railroad

Railroad Valley is divided into two subbasins. The northern basin includes the northern arm and middle sections described above, occupying 1,375,360 acres. Annual average surface flow (from runoff and spring flow combined) in this basin is estimated at 26,000 acre feet (Walstrom 1973). The smaller southern subbasin occupies only 385,920 acres, with an annual average surface flow of 9,000 acre feet. Hot Creek Valley, which drains into Railroad Valley through Twin Springs Slough, occupies 663,040 acres and has an average annual surface flow of 8,000 acre feet, some of which reaches the northern subbasin of Railroad Valley. However, debouching from Twin Springs Slough in Railroad Valley, Hot Creek can flow in a southerly direction to terminate in the southern subbasin. When this happens, as it apparently has not in historic times, the northern subbasin will be deprived of water contributed by Hot Creek unless its flow is sufficient to fill the southern subbasin to its threshold at ca 1500 m asl. Unfortunately, data regarding annual stream flow in Railroad Valley are sparse and incomplete even for major streams such as Currant Creek.

In the Pleistocene, Railroad Valley was occupied by pluvial lakes (Mifflin and Wheat 1979). Lake Railroad lay in the northern subbasin, extending somewhat into the lower part of the northern valley arm, while Lake Reveille filled the smaller subbasin basin in the southern arm. Much smaller Lake Lunar in Big Sand Springs Valley may have spilled into Lake Railroad through the gap in the Pancake Range known as The Wall.

Except for a small area on its southeastern shore, Pleistocene Lake Railroad lay entirely within the project area. At its highest, Lake Railroad stood between 1484.4 - 1482.9 m (4870 - 4865 ft), while the lowest preserved shoreline is at 1450.5 m (4759 ft) (Mifflin and Wheat 1979; Lillquist 1994b). Between the highest and lowest shorelines are several other features marking lake stands intermediate in elevation. Lacustrine geoforms include platforms and cliffs, beach ridges, bayhead barriers, cuspate spits and lagoons (Lillquist 1994b). The Railroad Valley Bar, a large gravel bar or spit, extends east and west across the valley south of Trap Spring, and is used by Highway 6 as a natural causeway.

Although many factors condition the creation and maintenance of playas (depth of water table, water chemistry, evaporation rates, frequency and duration of flooding; cf. Cooke et al. 1993:206), we assume that the playa in the northern subbasin is partly a result of standing water. At first glance, it seems an easy matter to estimate the size of playa lakes formed under various amounts of runoff reaching the playa. However, there appear to be no historical records regarding the extent of historic lakes in the northern subbasin. Moreover, elevation data presently available to us are insufficient to estimate contours and enclosing areas on the playa at less than one meter resolution. In order to estimate submeter contours and areas, we are compelled to assume that elevations are arranged in a series of steps, each about one meter above the other.

The playa is marked on USGS maps as "Depression" (Lillquist 1994f, g, h). The lowest elevation on the playa as marked on these maps is 1434.33 m asl (4706 ft), found in its northwest corner (Lillquist 1994f), with the basin gradually rising in elevation to the south and east. At its southern margin (Lillquist 1994g), the playa surface is about 1435 m asl (4708 ft), rising to about 1436 m asl (4710 ft) along its eastern margin (Lillquist 1994h). A lake rising above 1436 m would tend to extend southerly into the low gradient Hot Creek and Duckwater Creek fan deltas, which seem likely places for marshes to form. The total area of playa below 1436 m is 46,629 acres; the area between 1434.33 m asl (4706 ft) and 1434.66 m (4707 ft) is 30,482 acres. Thus, if all the potential annual surface flow of Hot Creek and the northern subbasin (34,000 acre feet) reached the playa, it would create a lake about 0.34 m (1.1 ft) deep, occupying about sixty-five percent of the playa below 1436 m. Since, however, annual evaporation in Railroad Valley is about 1,341 mm (4.4 ft) (Houghton et al. 1975:62), such a playa lake cannot be expected to last even a season. In many years, the playa will receive no water except the 102 mm to 204 mm (4-8 in) per annum falling directly upon it. To increase the lake to 1436 m would require, all other things being equal, runoff of several hundred percent above the modern average. Even increased to 1436 m, the lake still would be completely desiccated before the end of a season.

This exercise is sufficient to show that estimating the hydrology of playa lakes in Railroad Valley is difficult. It is further complicated by the fact that significant increases in annual precipitation are likely to be accompanied by decreases in annual evaporation, and that runoff greatly increases when soils are saturated.

Lillquist (1994h) included a strip along the northeastern margin of the valley between 1436 m and 1440 m as playa. This strip is not bounded by contours, and so could not refer to an area of standing water. It probably more nearly resembles the seasonally moist alkali flats (described in Chapter 5) mapped north and south of the Railroad Valley Bar.

Ground water seems plentiful in Railroad Valley. The average depth of the water table is within 3 m of the surface (Walstrom 1973), but the considerable number of artesian wells created by exploratory oil drilling suggest it is much closer to the surface in many places. Moreover, natural springs are numerous; large deposits of travertine at several (Reynolds Spring, Warm Spring, Storm Spring, Butterfield Spring, Bacon Spring) indicate a stable flow over very long intervals. The largest of these springs currently support marshes and ponds, and they probably did so in the past, perhaps to an even greater extent in more mesic intervals. Even though Currant Creek flows only seasonally as it crosses State Highway 6 in its lower reach, the puffy alkali flat adjacent the creek supports isolated willow trees and stands of arrowcane, suggesting a high water table. We can safely assume that in times of increased moisture, these flats and other places like them in the valley would become more marshy.

Biota

The study area occurs at the transition between the Tonopah, Central Great Basin, and Calcareous Mountains floristic sections (Cronquist et al. 1986), although most of its vegetation shows greatest affinity with the Tonopah floristic section (USDA SCS 1981). Greasewood-saltbush communities dominate in areas where the average annual precipitation is less than 20 cm per year. Shadscale is widespread and frequently associated with Bailey greasewood, bud sagebrush, spiny hopsage, ephedra, wolfberry, spiny menodora, dalea, fourwing saltbush, winterfat, galleta, and Indian ricegrass. Black greasewood, Torrey quailbush, and fourwing saltbush are particularly common on alkaline soils of the valley bottom.

Areas with average precipitation between 20 and 30 cm host communities of Wyoming big sagebrush, black sagebrush, ephedra, spiny hopsage, fourwing saltbush, Indian ricegrass, galleta, desert needlegrass, needleandthread, and Sandberg bluegrass. However, basin wildrye, western wheatgrass, alkali sacaton, inland saltgrass, black greasewood, and rubber rabbitbrush dominate communities on sodic soils. At elevations where average annual precipitation exceeds 30 cm, overstory canopies of Utah juniper and singleleaf pinyon are extensive. Dominant understory grass varies according to bedrock; bluebunch wheatgrass is more common on limestone soils, muttongrass prevalent on sandstone and volcanic bedrock. Black sagebrush, antelope bitterbrush, ephedra, serviceberry, curleaf mountain mahogany, and Thurber needlegrass are common throughout. Outside the study area, alpine zones with average precipitation exceeding 40 cm support mountain big sagebrush, snowberry, currant, oceanspray, fescue, brome, and needlegrass.

Wetlands in the study area are localized around seeps, springs, and stream channels. Springs below 1675 m are likely to feed small sloughs and ponds vegetated with cattail, creeping spikerush, and alkali bulrush. Meadows of sedge, rush, Nevada bluegrass, tufted hairgrass, and meadow barley surround springs and seeps at all elevations. Plant communities along perennial stream banks are dominated by basin wild rye, big sagebrush, and rhizomatous wheatgrass.

The study area hosts more than 100 species of migratory and indigenous waterfowl, shorebirds, perching birds, and raptors. Railroad Valley springfish and tui chub are indigenous to various spring-fed ponds in the study area (USDI BLM 1990a). Mammals known to occur here include mule deer, bighorn sheep, pronghorn antelope, badger, coyote, woodrat, Townsend's ground squirrel, black-tailed jackrabbit, cottontail, and a host of small rodents (Zeveloff 1988).

Cultural Context

The following section reviews the prehistory and ethnography of the study area. Because the Railroad Valley habitat model addresses the archaeological record of only prehistoric and ethnohistoric hunter-gatherers, the history of Railroad Valley is ignored except for a discussion of the effects of the arrival of European Americans on Native American lifeways.

Prehistory

Compared to other regions of the Great Basin, the prehistory of Railroad Valley is little investigated and poorly understood. The present synthesis of Railroad Valley prehistory, of necessity, must draw a regional perspective from more intensively investigated areas nearby. Thus, the Railroad Valley study area is discussed in the context of central Great Basin prehistory (Elston 1986).

The prehistoric archaeological record of the central Great Basin shows a gradual transition from a dispersed foraging subsistence strategy by small populations to a more intensive collecting pattern by larger populations. The transition is marked by use of a broader array of resources and greater reliance on resources with high processing costs and low yields. Foraging areas shrank and became more intensively used through time as populations increased. Plant processing technology became more elaborate, while chipped stone tools became less complex. Elston (1986) suggests that these trends may have resulted from the interaction between climatic change, population pressure, and, possibly, migration.

Occupational periods are broadly defined adaptive strategies representing regional trends in Great Basin prehistory, whereas phases are local expressions of these adaptive strategies, represented by different assemblages and settlement patterns in the archaeological record. Chronological sequences of periods and phases are defined by a range of characteristic projectile points and associated radiocarbon dates, together with characteristic artifact types (pottery, for example) and by the timing of such additions to the tool kit as grinding stones. Here, periods are divided into discussions of the Pre-Archaic, the Early to Middle Archaic, and the Late Archaic.

Pre-Archaic (11,500 to 7500 Before Present)

The Pre-Archaic marks adjustment of hunter-gatherers to the transition from Pleistocene to Holocene climatic conditions. Projectile points diagnostic of the period include fluted points (Clovis), and unfluted lanceloate points (Black Rock Concave-base), but a variety of stemmed projectile points (Lake Mohave, Parman, and Silver Lake) collectively referred to as Great Basin Stemmed (Beck and Jones 1997) are a hallmark of the period. Crescents, small flake engraving tools and drills, specialized scrapers, and core choppers and hammerstones are typical, whereas milling stones are rare. Sites are found on gravel bars and other landforms associated with pluvial lakes, marshes, and riparian zones. The location and composition of Pre-Archaic assemblages suggest that subsistence involved procurement of low cost/high return wetland resources with a greater emphasis on large game hunting than in subsequent periods. Sites usually are confined to the surface and lack middens, house features, plant processing equipment, storage facilities, or other indications of intensive occupation. This suggests that population density was low and hunter-gatherer bands were small and mobile.

Radiocarbon dated Pre-Archaic deposits in the central Great Basin occur at the Sunshine locality (Beck and Jones 1997) and at Smith Creek Cave (Bryan 1979) in eastern Nevada. Excavations indicate the possibility of buried Pre-Archaic deposits at the Gravel Bar Site (Elston et al. 1979) in the study area. Pre-Archaic surface finds are widespread in eastern Nevada (Price and Johnson 1988) and are *well documented in riparian settings of the Railroad Valley study area (Zacanella 1988). Price and* Johnston (1988) propose a three phase sequence for the Pre-Archaic period in the central Great Basin, including Railroad Valley: Mt. Moriah Phase (prior to 10,500 BP), Sunshine Phase (10,500 to 8,500 BP) and Newark Phase (8,500 to 7,500 BP).

Early to Middle Archaic (5500 to 1500 Before Present)

The Early and Middle Archaic periods mark inception of broad spectrum foraging strategies adapted to environments similar to those of ethnohistoric circumstances. Artifact assemblages are unlike those of the Pre-Archaic; crescents, stemmed points, and specialized scrapers disappear, groundstone artifacts become common, and a variety of smaller, randomly flaked projectile points associated with atlatl use appear in the archaeological record. Site locations shift to a wider variety of settings, often near springs and perennial streams, as well as in caves and rockshelters. Notable are the appearance of upland hunting camps and pinyon-juniper occupation sites on the flanks of the Monitor and Reese River Valleys (Thomas and Bettinger 1976: Thomas 1988). The proliferation of milling stones is interpreted as marking the inception of the use of high cost/low return seeds in Great Basin subsistence strategies (Simms 1987; Grayson 1993). The dispersion of sites through upland settings, particularly pinyon woodlands, suggests increasing population densities possibly reliant on pinyon seeds (Thomas 1982:165, Simms 1985).

A sequence of three phases, defined by excavations at Gatecliff Shelter (Thomas 1981, 1983b), pertain to the Early and Middle Archaic periods of the central Great Basin. The Clipper Gap Phase (5500 to 4500 BP) is associated with concave-based Triple T projectile points; the Devils Gate Phase (4500 to 3500 BP) is marked by Gatecliff split-stem and contracting stem projectile points; and the Reveille Phase (3500 to 1500 BP) is associated with Elko eared and corner-notched points.

Late Archaic (1500 to 150 Before Present)

The appearance of ceramics and replacement of the atlatl by the bow and arrow are hallmark traits of the Late Archaic. Other elements of the tool assemblage are similar to those of the Middle Archaic. Sites continue to occur in a variety of settings, but often cluster around permanent springs and in riparian settings (McGonagle and Waski 1978), suggesting reduced residential mobility and higher population densities. Late Archaic phase designations, once again, derive from excavation of stratified deposits at Gatecliff Shelter (Thomas 1981, 1983b).

Small, lightweight Rosegate projectile points mark the Underdown Phase (1500 to 750 BP). Occasional, but widespread occurrences of grayware and painted ceramics are also traits of the phase. The presence of ceramics in Underdown Phase assemblages coincides with the appearance of Fremont agriculturists at the Baker and Garrison sites of eastern Nevada (Talbot and Wilde 1989), and suggests contact between foragers and horticulturalists. However, analyses of ceramics recovered from forager sites in eastern Nevada often indicate local manufacture (James 1986; Juell 1987), suggesting that hunter-gatherers incorporated ceramic technology into their foraging repertoire rather than acquiring them by casual trade with farmers (Simms and Bright 1997).

The appearance of Cottonwood Triangular and Desert Side-notched points, and brownware pottery mark the Yankee Blade Phase (750 to 150 BP). Site distributions are similar to the Underdown Phase, but the appearance of high altitude villages, such as the Alta Toquima site on Mount Jefferson, suggests intensified use of marginal environments. Some models of prehistoric subsistence change in the Great Basin suggest that foraging strategies of this time were more intensive and made greater use of high cost-low return resources than in earlier periods (Bettinger and Baumhoff 1982).

Such an intensification may mark the arrival of Numic-speaking people from southern California into the central Great Basin, because the timing of the influx estimated from lexicostatistics (Lamb 1958) corresponds to the inception of the phase. However, others argue from linguistic data that Numic languages developed *in situ* (Goss 1977). Archaeological implications of the issue remain problematic (Madsen and Rhode 1994). For example, replacement of grayware by brownware ceramics suggests the intrusion of a new ceramic tradition. However, comparison of grayware and brownware ceramics around the Great Salt Lake reveals that they are statistically indistinguishable in shaping technique, tempering agent, temper size, and surface color, suggesting that the two wares belong to the same ceramic tradition (Dean 1992). Simms and Bright (1997) suggest that variability between the two wares likely reflects differences in degree of investment in vessel quality, reflecting the mobility of hunter-gatherers and the portability required of ceramic vessels. If so, the dominance of brownwares in the Yankee Blade Phase may reflect an adaptation of ceramic technology to a mobile lifestyle rather than the arrival of a new ceramic tradition.

Ethnography

The appearance of trade beads in Gatecliff Shelter deposits (Thomas 1983b) marks the time when Native American foragers of the central Great Basin came into contact with European American material culture. However, the impact of European Americans on traditional lifeways may not have been significant until the California Gold Rush brought European Americans into close contact with indigenous people. Native Americans in Railroad Valley remained relatively isolated until the late 1860s, when mineral discoveries in the Grant, Quinn Canyon, and Reveille ranges brought numerous prospectors and miners into the region. Thereafter, local Native Americans began to lose access to their best foraging patches, and were employed as wage labor on local ranches and mines. Ultimately, maintaining a hunting and gathering lifeway became impossible in Railroad Valley (McCracken and Howerton 1996:52-53). Ethnographic descriptions of Railroad Valley hunter-gatherers come from

Julian Steward (1938: 101, 117-121; 1941), who recorded the recollections of early twentieth century Native Americans of the nineteenth century lifeways of their parents and grandparents.

Railroad Valley was in the traditional territory of the Western Shoshone. Steward (1938:117) estimates that the indigenous population between Hamilton and Nyala was 250 people. This population resided in camps clustered at Hamilton, Duckwater, Currant Creek, Blue Eagle Spring, Warm Spring, and Nyala. All these camps were near perennial springs and streams.

Such camps were the hub of subsistence strategies throughout the year. Hunter-gatherers usually wintered in their camps and stayed close by from early spring until early autumn. Women harvested and cached seeds for winter use, and men stalked antelope, jackrabbits, and other game within the catchments of these campsites. A notable subsistence activity of the Railroad Valley Shoshone was their cultivation of wild seed plots in well-watered locations close to camp. Men burned brush from plots in fall and sowed goosefoot, mentzelia, and, probably, tanseymustard seed in spring. Wild seed patches and pinyon groves were available to all, but sowed seed plots and food caches were the private property of families.

Occasionally, the Railroad Valley Shoshone journeyed far from home to harvest critical resources that were abundant in distant locations. These occasions encouraged larger social gatherings and festivals. For example, groups from northern Railroad Valley went in spring to Hamilton to participate in antelope drives in the low pass at the north end of the valley. Southern Railroad Valley bands more often journeyed to Hot Creek Valley to participate in antelope drives there. Too, the Railroad Valley Shoshone sometimes traveled to Duckwater to participate in a midsummer festival and to gather grass seeds abundant there at that time.

In autumn, the Railroad Valley Shoshone harvested pinyon nuts, transporting them back to their campsites for storage. Whenever possible, they harvested nuts from the nearest available grove, but when crops were poor, they traveled as far as 50 km from home. Conversely, they overwintered in the mountains during years of exceptional pinyon productivity.

Railroad Valley Shoshone participated in rabbit drives during the autumn. These usually were held in the valley flat between Duckwater and Blue Eagle Springs, probably near Trap Spring. Rabbit drives involved as many as 20 to 30 men and might last as long as six weeks.

In summary, whenever possible, the Railroad Valley Shoshone stayed close to family camp sites that were tethered to perennial water sources. Occasions drawing them from home were pine nut harvests, rabbit and antelope drives, and seed harvests often held in conjunction with social gatherings. Thomas (et al. 1986:278) suggests that this pattern reflects environments with widely dispersed water sources, where some resources are locally abundant and productive, while other critical resources are scattered and unpredictable. These circumstances imposed a dispersed settlement pattern where communal activities were restricted to particular times of the year when resources were briefly abundant in certain locations. Acquisition of key resources often incurred high transport costs and required great logistic mobility and extensive reliance on food storage. In this sense, seed cultivation may have been an attempt to lower transport costs by artificially increasing the abundance of storable resource close to home.

The Archaeological and Environmental Databases

The Bureau of Land Management Tonopah and Ely Field Offices supplied site records, reports, and relevant correspondence for use in constructing and testing the Railroad Valley habitat model. As well, we were given a variety of background information by the Bureau of Land Management Nevada State

Office. The following describes our data sources and how we integrated information into a project database, a set of project GIS files, and ancillary electronic data.

Data Sources

Data provided by BLM comprise three categories: paper records, electronic GIS databases, and electronic relational databases.

Paper Records

The paper records include archaeological site forms, and reports and correspondence pertaining to project reviews and National Register status of sites. The Ely Field Office compiled materials by 10 km X 10 km area, whereas the Tonopah Field Office assembled records by township. All materials received were logged, site forms were separated from reports, and all records were filed by agency site record or report number. No paper records held only by the Nevada State Museum, the Harry Reid Center in Las Vegas, or the State Historic Preservation Office were provided.

The paper records received were less than comprehensive. We cross-referenced the site forms with those listed in relevant inventory and other reports attempting to identify missing site records. We also attempted to check consultation correspondence against reports and records, and found that the consultation correspondence was often missing. Absent such documentation, determining the National Register status of numerous sites or the review status of investigation reports was hampered. Because Nevada maintains a dual numbering system, with federal agencies using an agency number and state repositories assigning a second number, it is possible to have an agency site or report number and not know the filing number within the state repository. This prevented us from finding some records that doubtless are in the state repositories. We searched for copies of the missing materials in the State Historic Preservation Office, the Nevada State Museum, and the Harry Reid Center of UNLV, with fair success. A list of material missing from the project electronic database appears in Appendix F.

Once organized, the site records were scanned into a publicly readable image file format. Now available in electronic format, these records and the free software to read them are described in Appendix G.

Electronic GIS Data

The BLM State Office provided a number of datasets to us in ArcInfo export formats and as electronic text files. Those employed in this study include:

- Natural Resources Conservation Service soil survey map units and associated tables;
- BLM Generalized Cartographic Data Base files of the public land survey system;
- USGS 30m digital elevation models; and
- text listing of known springs and wells.

Ancillary soils data were compiled from the published Natural Resources Conservation Service soils study (USDA Soil Conservation Service 1991, 1993). The electronic datasets and tables were employed in creating spatial analytical units for the 223,434 hectares of the study area. The creation of analytical units is described in Chapter 3.

Scanned USGS 1:100,000 and 1:24,000 quadrangles were created to aid in digitizing, display, and interpretation of data. These were geo-referenced to the project coordinate system for display within the GIS software. Table 1 lists the USGS quadrangles encompassing the study area.

Table 1. USGS Quadrangles and Map Reference Codes for the Railroad Valley Study Area

Series	Map Name	Map Reference Number
1:24,000	Adaven	38115-B5
	Big Creek Ranch	38115-B7
	Black Rock Summit	38115-E8
	Blue Eagle Mountain	38115-E4
	Blue Eagle Springs	38115-E5
	Blue Eagle Springs NE	38115-F5
	Blue Eagle Springs SW	38115-E6
	Bradshaw Spring	38115-G6
	Bullwhacker Springs	38115-D5
	Christian Spring	38115-D6
	Crows Nest	38115-C6
	Currant	38115-F4
	Currant Mountain	38115-H4
	Duckwater NE	38115-H5
	Duckwater SE	38115-G5
	Goat Ranch Well	38115-B8
	Lockes	38115-E7
	Meteorite Crater	38115-F6
	Nyala	38115-B6
	Portuguese Mountain	38115-F7
	Sand Spring	38115-G7
	The Wall	38115-D8
	The Wall NE	38115-D7
	The Wall SE	38115-C7
	The Wall SW	38115-C8
	Troy Canyon	38115-C5
	White Pine Peak	38115-G4
1:100,000	Duckwater	38115-E1-TM-100
	Quinn Canyon	38115-A1-TM-100

All GIS datasets were created or projected into a standard coordinate system (UTM Zone 11, North American Datum 1927) for the project area. Most GIS datasets were created or processed within ArcInfo software, a few directly within ArcView software. Final GIS data products have been conveyed to the Bureau of Land Management along with this report, including metadata describing each data set (Appendix G).

Electronic Relational Databases

The Bureau of Land Management provided electronic data on sites and projects within the Tonopah Field Office administrative area; no such database exists for the Ely Field Office administrative area of Railroad Valley. We used the BLM electronic data to augment and verify our own database created from the paper records.

A project database was created in Microsoft Access (release 8). The database itself is documented in detail in Appendix G. The database contains three sorts of information: site attributes, investigation attributes, and GIS metadata. This database served as the main administrative tool for organizing records, digitizing cultural resources and projects into GIS, and analyzing attributes of the cultural resources.

Attributes of cultural resources (sites and isolated finds) are one kind of information in the database. They include identifying site numbers, general class of resource (historic, prehistoric), descriptive information on the setting and character of the resource (e.g., presence of lithic material sources, chipped stone tools, features), and National Register status of the resource as derived from consultation correspondence and the BLM Tonopah database.

Attributes of investigative projects are another class of information in the project database. They comprise identifying numbers, type of investigation, its bibliographic reference, dates of fieldwork, associated cultural resources, and project review status.

The third sort of information in the database is metadata—information about individual data records—for each digitized cultural resource or investigation area. These tables record the reliability and accuracy of the digitized features. For example, using the metadata, one can tell whether a project boundary was mapped from a small-scale (hence probably inaccurate) map source or a more accurate large-scale map. One record was created for each digitized entity.

Chapter 3

Habitat Strata

David W. Zeanah

This chapter develops a detailed model of environmental variability in the Railroad Valley study area. First, the environment is characterized according to habitats that derive from soils, vegetation, water, and slope. This is done by considering the advantages and limitations of the range type concept in a prehistoric plant community modeling application. Then, soil map units and range types are transformed into a set of Railroad Valley habitats. Habitat characterizations are refined according to presence and absence of perennial water, proximity to perennial water, and slope. Finally, the suitability of habitats for various classes of wildlife important to hunter-gatherer foraging is ranked. This final step provides a typology of habitats in the Railroad Valley study area.

Considering Range Type and Habitat Concepts

To model hunter-gatherer ecology in the study area, we must estimate the spatial distribution of resources as they existed before the middle nineteenth century, when hunter-gatherers still lived in Railroad Valley. Modern vegetation and wildlife inventories are inadequate to the task because ranching, irrigation, fire control, and oil and gas development have so much altered the biota of the study area. Elsewhere in the Great Basin (Raven and Elston 1989; Zeanah et al. 1995; Zeanah and Elston 1997), we have borrowed the range type concept from range management and soil science as a means to model prehistoric biota; one that minimizes distortion induced by historic and modern development.

A range type is a set of distinctive geological, topographic, and hydrological circumstances that fosters a particular potential natural vegetation community (Dyksterhuis 1949, 1958). Such a community is represented by the climax vegetation that develops in particular physiological circumstances defined as the range type, if left undisturbed for a sufficient time under current climatic conditions (Society of Range Management 1983). Range and soil scientists classify potential natural vegetation by analyzing the productivity and composition of vegetation growing on relict range sites, which are sample plots of particular soils that are undisturbed or protected long enough for a climax community to reestablish. These analyses generate estimates of total and species specific annual herbage productivity in kilograms per hectare for each range type (Passey et al. 1982:6).

Range types correlate strongly with soil types because both vary according to the same geological, topographic, climatic, and hydrological conditions (Dyksterhuis 1958, Aandahl and Heerwagen 1964). The USDA Natural Resources Conservation Service uses range types to link soil mapping data to potential natural vegetation communities. Therefore, the spatial distribution of potential natural vegetation can be inferred from soil maps.

Range types serve as a basis for estimating prehistoric plant communities because they describe relict stands that correlate with soil, allowing the distribution of potential natural communities to be extrapolated from soil maps, notwithstanding disruption to current vegetation. However, an important caveat is that modern potential natural vegetation communities are not living fossils of their prehistoric predecessors. Rather, they reflect modern equilibrium as affected by historic alterations (cf. Young et al. 1976). For example, historic livestock grazing has fostered expansion of sagebrush and a variety of forbs and grasses at the expense of the indigenous species that flourished before grazing (Young et al. 1976, Young and Tipton 1990). These introduced and invasive species are now members of the climax vegetation in Railroad Valley.

Too, natural disturbance processes such as flooding, erosion, wildfire, and overgrazing (Young et al. 1976), and activities of prehistoric hunter-gatherers such as intentional burning of rangelands and sowing wild seeds (Steward 1938: 119; 1941: 281) frequently must have disrupted the climax of prehistoric range types, allowing successional communities to flourish. Furthermore, paleoenvironmental data indicate several major changes in the composition of Great Basin plant communities during the Holocene (Hemphill and Wigand 1994; Wigand 1996:70). Modern potential natural vegetation communities are not the same plant communities that existed before these shifts occurred. Therefore, range scientists (Tausch et al. 1993) caution that potential natural vegetation has varied dynamically over time as individual species have adapted to long term climatic change through adaptation, migration, and hybridization.

The foregoing observations compel acknowledgment of the temporal and spatial dynamics of the biotic landscape in Railroad Valley, but, as long as these limitations and criticisms are kept in mind, range types nevertheless serve as useful analytical tools in consideration of prehistoric site distributions. Range types and their associated vegetation communities represent a consistent quantitative description of modern plant community composition and productivity that serves to extrapolate the climax resource landscape that existed in the study area before modern times, so long as generally the same soil, topography, hydrology, and climate structuring the modern resource landscape were operating in the past.

The farther back in time that the range type landscape is projected, the more likely it is that these conditions will vary significantly. Nevertheless, the landscape provides a baseline that estimates prehistoric resource distributions, because plant communities are modeled according to soil type. Since soils and vegetation vary according to the same geological, topographic, hydrological, and climatic conditions, and since the formation of soils reflects the interaction between vegetation and environment over long periods of time (Eckerle 1989), soil types should reflect, grossly but reliably, the vegetation communities that typically grew on them in the past, as long as those soils existed.

Although specific compositions of present range types may differ from their prehistoric predecessors, they should be fundamentally similar in productivity, structure, and function (Tausch et al. 1993:445). Range types that are highly productive in biomass today should have been so in the past, despite differences in particular species composition or stage of succession, so long as modern soil type and hydrology were present. Range types that currently favor particular plant species should have been favorable for those or similar species in the past (although the precise percentage contribution of the species to the community may have been different). The paleoenvironmental record can serve as a guide for estimating how the distribution of critical resources may have varied in the past. For example, the effects on habitat productivity and composition of a constriction of pinyon-juniper woodland, an expansion of marsh wetlands, or sowing of seed plots can be estimated from an understanding of the modern structure of potential natural plant communities.

Thus, range types remain useful heuristic tools for modeling prehistoric resource distributions. A model of Railroad Valley range types is a valid characterization of the climax resource structure that existed before the intrusion of European-Americans. As such, it serves as a model landscape that can be integrated with data on ethnographic Shoshone subsistence and settlement strategies. This, in turn, constitutes a predictive baseline to compare with archaeological site distributions. Moreover, the paleoenvironmental record serves as a guide to how the ethnographic resource landscape may have differed from that of prehistory.

Modeling the Prehistoric Resource Landscape

Having discussed the framework in which we employ range types and habitats to model prehistoric resource distributions, we now construct a habitat landscape for the Railroad Valley study area.

Soil Map Units and Range Types for Railroad Valley

Table 2 lists 53 soil types mapped in the Railroad Valley study area. Table 3 lists 27 range types associated wholly or partially with one or more soils in the Railroad Valley study area. These range types originate from either the central (prefix 28BYO) or southern (prefix 29XYO) Nevada Basin and Range land resource areas (USDA Soil Conservation Service 1991, 1993).

Table 2. Soil Map Units in the Railroad Valley Study Area

Soil Map Unit	Soil Name
3000	Stumble Loamy Sand, 2 to 8 Percent Slopes
3001	Stumble-Koyen Association
3040	Mosida-Rebel-Slaw Association
3041	Mosida Loam, 0 to 4 Percent Slopes
3090	Univega-Koyen Association
3102	Gabbvally-Stewval-Beelem Association
3110	Cath-Zadvar Association
3150	Nuyobe-Blueagle-Playas Complex, 0 to 30 Percent Slopes
3190	Penoyer-Geer Association
3200	Ganaflan Gravelly Loam 2 to 15 Percent Slopes
3221	Stewval, Moist-Rock Outcrop Association
3223	Stewval-Rock Outcrop Association
3224	Stewval-Beelem-Bellehelen Association
3228	Stewval-Gabbvally-Beelem Association
3250	Wardenot Gravelly Sandy Loam, 0 to 4 Percent Slopes
3260	Springwarm-Jotava-Delacit Association
3270	Jotava Silty Clay Loam, 0 to 2 Percent Slopes
3310	Ursine-Veet-Armespan Association
3412	Watoopah-Veet-Zadvar Association
3460	Zadvar-Handpah Association
3463	Zadvar-Veet Association
3467	Zadvar Very Gravelly Sandy Loam, 4 to 30 Percent Slopes
3471	Cirac-Nyserva Complex, 0 to 4 Percent Slopes
3473	Cirac-Slaw-Nyserva Association
3474	Cirac-Nyserva-Kawich Complex, 0 to 30 Percent Slopes
3521	Rustigate-Nuyobe Association
3522	Rustigate-Nuyobe-Kawich Complex, 0 to 15 Percent Slopes
3572	Eaglepass-Kyler-Rock Outcrop Association, 15 to 75 Percent Slopes
3580	Kyler-Rock Outcrop Complex, 15 to 50 Percent Slopes
3581	Kyler, Moist-Rock Outcrop Complex, 15 to 50 Percent Slopes
3610	Tokoper-Garhill-Rock Outcrop Association
3640	Armespan-Zadvar-Veet Association
3642	Armespan Very Gravelly Sandy Loam, 8 to 30 Percent Slopes
3644	Armespan-Cliffdown-Candelaria Association
3651	Candelaria Very Gravelly Sandy Loam, 2 to 8 Percent Slopes
3655	Candelaria-Armespan Association
3660	Titiack-Garhill Association
3670	Logring-Rock Outcrop-Kyler Association
3730	Penelas-Kyler-Rock Outcrop Association
3740	Keefa-Unsel Association
3742	Keefa-Stargo Association
3752	Koyen Sandy Loam, 2 to 8 Percent Slopes
3756	Koyen-Lyx Association
3805	Lyda-Hardhat Association
3830	Downeyville-Rock Outcrop Complex, 15 to 50 Percent Slopes
3831	Downeyville-Stewval Association
3832	Downeyville-Tokoper Association
3850	Garhill-Tokoper-Argalt Association
3860	Hyzen-Kyler-Rock Outcrop Association
3861	Hyzen-Eganroc-Rock Outcrop Association
3880	Hardhat-Candelaria Association
3881	Hardhat-Stargo-Yomba-Association
3900	Playas

Table 3. Range Types in the Railroad Valley Study Area

Range Type Number	Range Type Name
028BY003NV	Loamy Bottom 10-14" P.Z.
028BY028NV	Sodic Terrace 8-10" P.Z.
028BY060NV	Pimo-Juos Wsg:Or4
029XY002NV	Saline Meadow
029XY004NV	Saline Bottom
029XY006NV	Loamy 8-10" P.Z.
029XY008NV	Shallow Calcareous Loam 8-12" P.Z.
029XY010NV	Loamy Slope 8-10" P.Z.
029XY012NV	Sandy 5-8" P.Z.
029XY014NV	Shallow Calcareous Slope 8-12" P.Z.
029XY016NV	Loamy Upland 5-8" P.Z.
029XY017NV	Loamy 5-8" P.Z.
029XY018NV	Sodic Dunes
029XY020NV	Silty 5-8" P.Z.
029XY022NV	Sodic Hill 5-8" P.Z.
029XY024NV	Sodic Terace 5-8" P.Z.
029XY028NV	Shallow Calcareous Slope 12-14" P.Z.
029XY040NV	Limestone Hill
029XY042NV	Coarse Silty 5-8" P.Z.
029XY046NV	Sandy Loam 5-8" P.Z.
029XY049NV	Sandy Loam 8-12" P.Z.
029XY057NV	Loamy Slope 12-14" P.Z.
029XY069NV	Pimo-Juos Wsg:Or4
029XY076NV	Sodic Flat 5-8" P.Z.
029XY081NV	Shallow Calcareous Hill 10-14" P.Z.
029XY087NV	Gravelly Loam 5-8" P.Z.
029XY093NV	Deep Sodic Fan

Table 4 lists the concordance between soil map units and range types comprising at least 15% of the potential natural vegetation community associated with each soil. Note that the summed percentage of range types listed for each soil rarely exceeds 85%. Barren settings, such as small playa basins, rock outcrops, and desert pavement, and contrasting range types occurring in parcels too small to map, take up the remaining proportion of each soil map unit.

One soil, playa (soil map unit 3900), is abiotic and lacks any range type description. The remaining fifty-two soil map units associate with one or more of the 27 range types in 35 different combinations. We designate each range type combination and abiotic playa as separate habitats; thus, "habitat" refers to a particular potential natural plant community (or absence of any community), defined by a specific assortment of range types. The productivity and composition of the potential natural plant communities is calculated by averaging the annual air dry production and species composition of each constituent range type in each habitat (Chapter 4 describes specific habitat productivity and composition).

Table 4. Concordance among Habitats, Soil Map Units, and Range Types in the Railroad Valley Study Area

Soil Map Unit	Primary Range Type	Proportion	Secondary Range Type	Proportion	Tertiary Range Type	Proportion	Habitat
3000	029XY012NV	0.85					G21
3001	029XY012NV	0.65	029XY046NV	0.25			G8
3040	028BY003NV	0.35	028BY028NV	0.3	029XY093NV	0.2	S7
3041	028BY003NV	0.85					S1
3090, 3752	029XY016NV	0.85					G9
3102	029XY057NV	0.5	029XY028NV	0.35			M8
3110, 3460	029XY006NV	0.35-0.5	029XY008NV	0.35-0.5			S8
3150	029XY002NV	0.45	029XY076NV	0.35			G2
3190	029XY020NV	0.55	029XY042NV	0.3			G13
3200, 3610, 3660, 3830, 3832	029XY022NV	0.7-0.85					G14
3221	029XY028NV	0.4	029XY008NV	0.3			M5
3223, 3467, 3642	029XY008NV	0.85					S5
3224	029XY028NV	0.4	029XY081NV	0.35	029XY069NV	0.2	M6
3228	029XY008NV	0.5	029XY010NV	0.35			S9
3250, 3651, 3740	029XY017NV	0.85					G11
3260	029XY004NV	0.65	029XY024NV	0.2			G5
3270	029XY004NV	0.9					G6
3310, 3412, 3463, 3640	029XY008NV	0.15 - 0.7	029XY049NV	0.15 - 0.7			S4
3471	029XY024NV	0.85					G18
3473	029XY024NV	0.55	029XY076NV	0.35			G17
3474	029XY024NV	0.7	029XY018NV	0.2			G16
3521	029XY004NV	0.45	029XY002NV	0.4			G4
3522	029XY004NV	0.4	029XY002NV	0.35	029XY018NV	0.15	G3
3572	029XY040NV	0.35	029XY028NV	0.3			M7
3580, 3730	029XY014NV	0.85					S6
3581	029XY028NV	0.85					M11
3644	029XY008NV	0.4	029XY042NV	0.3	029XY017NV	0.15	S10
3655	029XY017NV	0.5	029XY008NV	0.35			G10
3670	029XY069NV	0.5	029XY014NV	0.15			M9
3742, 3880, 3881	029XY017NV	0.4-0.6	029XY087NV	0.25-.045			G12
3756	029XY046NV	0.85					G22
3805	029XY087NV	0.85					G23
3831, 3850	029XY022NV	0.5-0.7	029XY008NV	0.15-0.35			G15
3860	028BY060NV	0.45	029XY028NV	0.4			M2
3861	028BY060NV	0.85					M3
3900	NA	1					A1

Note that the habitat designator is alphanumeric, bearing a letter prefix (A, G, S, or M) followed by a numeral. The letter prefix designates one of four communities recognized according to physiographic and vegetation associations: abiotic (A), greasewood/saltbush (G), sagebrush (S), and montane (M). The biogeographical literature of the Great Basin (cf. Billings 1945; Cronquist et al. 1986; Young et al. 1976) commonly employs similar designations representing gross classifications of plant communities. Such categories are convenient for designating habitats because, although habitats sometimes cross-cut boundaries among community types, they always qualify unequivocally as one or another community based on elevation and predominant shrub and grass species.

Cross-Stratification of Habitats

In their consideration of Carson Desert habitat types, Raven and Elston (1989:59) considered two abiotic variables pertinent to modeling hunter-gatherer foraging decisions in the archaeological record of Stillwater Marsh: availability of perennial water and potential for irregular (non-annual) inundation. In a broader consideration of the Carson Desert, Zeanah (et al. 1995) added slope as a third abiotic variable affecting prehistoric foraging constraints and options.

Slope and water are also pertinent abiotic features of the prehistoric Railroad Valley foraging landscape. However, Elston noted in Chapter 2 that modern evaporation rates in Railroad Valley far exceed precipitation and stream runoff rates. Therefore, although some habitats in Railroad Valley are prone to irregular inundation (Table 5), floodwaters are unlikely to persist long enough to alter the potential natural vegetation typical of those habitats. Shallow but stable lakes and marshes probably developed in Railroad Valley during mesic periods of the last 10,000 years. However, such lakes probably were restricted to the playa basin in central Railroad Valley (Habitat A1) below the 1436 m contour, and the immediately adjacent habitats; other habitats were relatively unaffected by Holocene lakes (see Chapter 5). This is unlike the circumstance in Stillwater Marsh where a variety of habitats were flooded for periods long enough to alter the potential natural vegetation of those habitats over short periods of time (within the lifespans of hunter-gatherers). For these reasons, irregular inundation is probably not a critical short-term constraint for hunter-gatherers in Railroad Valley. However, irregular inundation does constitute a long-term consideration for modeling paleoenvironmental variability in the Railroad Valley study area (Chapter 5).

Table 5. Habitats Prone to Irregular Inundation in the Railroad Valley Study Area

A1	G3
G12	G4
G14	G5
G16	G6
G17	S1
G2	S7

Cross-Stratification by Water Source

In arid environments, the distribution of perennial water sources constrains feasible camp locations and foraging areas of hunter-gatherers (Birdsell 1953; Lee 1968; Steward 1988:120-121; Taylor 1964). In recognition of its importance, we recorded the presence (and type) or absence of perennial water sources in the study area, recognizing three categories: upland spring, lowland spring, and stream.

We recorded springs by simply reviewing all USGS quadrangles encompassing the study area and digitizing the location of every mapped spring and seep. We divided them into upland and lowland categories at the 2285 m contour, based on elevational differences described by range type descriptions for upland and lowland wet meadow communities (USDA Soil Conservation Service 1993). As a cautionary note, keep in mind that tectonic activity affects springs and seeps. Available data are insufficient to distinguish systematically either springs created by earthquakes in recent times or extinct ancient springs that would have been available to ethnographic and prehistoric populations.

Identification of perennial streams as they would have been available to prehistoric hunter-gatherers is also problematic because short-term fluctuations in water budgets would make some intermittent channels flow perennially or dry perennial channels for brief periods. Two perennial streams occur in modern Railroad Valley: Duckwater and Currant Creeks. We classify the mapped courses of these streams as perennial down to the 1450 m contour. We consider all other stream channels in the Railroad Valley study area to be intermittent.

All three water source types correlate with one or more range types delineated in the southern Nevada Basin and Range range type handbook (USDA Soil Conservation Service 1993), which we designate in Table 6 as three new habitats (prefixed W for wetland). Since these range types associate with climax meadow or riparian communities that extend beyond the mapped boundaries of the water source per se, we designate all area within 50 m of a water source as one of these three wetland habitats according to the water source type. Thus, there are 39 habitats in the Railroad Valley study area.

Table 6. Concordance Among Water Source Types, Habitats, and Range Types in the Railroad Valley Study Area

Habitat	Water Source	Primary Range Type	Proportion	Secondary Range Type	Proportion
W1	Lowland Springs and Seeps	029XY001NV	0.66	029XY044NV	0.33
W2	Upland Springs and Seeps	029XY060NV	1		
W4	Riparian Streams	029XY025NV	1		

A second consideration pertaining to water is the proximity of habitats to perennial water sources. Propinquity of water source affects biomass productivity of habitats (see Chapter 4) and determines the suitability of habitat for game and humans. To measure the relative proximity of habitats to water, we devised a water proximity score. Table 7 presents the total area in hectares of each habitat in the study area, and the relative proportion of that area in each of four ordinal categories of distance from water: < 50 m, 50 m - 3000 m, 3000 m - 10,000 m, and > 10,000 m. We found these intervals pertinent to wildlife habitat and hunter-gatherer site catchment in our previous modeling efforts in the Carson Desert and Honey Lake (Raven and Elston 1989; Zeanah et al. 1995; Zeanah and Elston 1997) and we apply them to Railroad Valley as well.

Table 7. Proximity of Railroad Valley Habitats to Perennial Water

Habitat	Area (ha)	< 50 m	50 m - 3000 m	3000 m - 10000 m	> 10000 m	Water Proximity Score
A1	16238	0	0.395	0.605	0	1.4
G10	3601	0	0.379	0.621	0	1.38
G11	11384	0	0.308	0.691	0.001	1.31
G12	49314	0	0.415	0.536	0.049	1.37
G13	3782	0	0.687	0.313	0	1.69
G14	3408	0	0.36	0.402	0.238	1.12
G15	995	0	0.48	0.52	0	1.48
G16	14573	0	0.332	0.668	0	1.33
G17	11374	0	0.696	0.298	0.007	1.69
G18	9659	0	0.725	0.258	0.017	1.71
G2	10416	0	0.735	0.265	0	1.74
G21	59	0	0	0	1	0
G22	213	0	0	0.972	0.028	0.97
G23	1893	0	0.484	0.516	0	1.48
G3	20447	0	0.832	0.168	0	1.83
G4	6319	0	0.967	0.033	0	1.97
G5	2358	0	0.81	0.19	0	1.81
G6	1717	0	0.896	0.104	0	1.9
G8	3344	0	0.245	0.662	0.093	1.15
G9	4161	0	0.093	0.405	0.502	0.59
M11	1063	0	0.657	0.343	0	1.66

Table 7—*Continued.*

Habitat	Area (ha)	< 50 m	50 m - 3000 m	3000 m - 10000 m	> 10000 m	Water Proximity Score
M2	4041	0	0.327	0.673	0	1.33
M3	55	0	0	1	0	1
M5	3306	0	0.203	0.735	0.062	1.14
M6	3436	0	0.124	0.831	0.044	1.08
M7	1840	0	0	0.911	0.089	0.91
M8	2268	0	0.667	0.333	0	1.67
M9	937	0	0.948	0.052	0	1.95
S1	142	0	1	0	0	2.03
S10	9629	0	0.149	0.851	0	1.15
S4	4447	0	0.7	0.3	0	1.7
S5	1861	0	0.554	0.337	0.109	1.44
S6	1152	0	0.784	0.216	0	1.78
S7	577	0	0.792	0.208	0	1.81
S8	16	0	0	1	0	1
S9	2713	0	0.065	0.935	0	1.06
W1	603	1	1	0	0	3
W2	12	1	1	0	0	3
W3		1	0	0	0	3
No Data	10116	0	0.438	0.559	0.003	1.43

From these data, a score measuring the relative proximity of water to each habitat is calculated by the following equation.

$$WPS = (3^*p_{<50\ m})+(2^*p50\ m\text{-}3000\ m)+(p3000\ m\text{-}10000\ m) \quad \text{(Equation 1)}$$

where:

WPS = water proximity score
$p_{<50\ m}$ = proportion of habitat within 50 m of a perennial water source
$p50\ m\text{-}3000\ m$ = proportion of habitat between 50 m and 3 km of a perennial water source
$p3000\ m\text{-}10000\ m$ = proportion of habitat between 3 km and 10 km of a perennial water source

Note that the water proximity score assigns a value of zero to all area more than 10 km from a water source. Scores range from 0 to 3, with higher scores denoting higher proportional area closer to water. Obviously, the three wetland habitats have the highest scores (WPS = 3), whereas Habitat S1 has the next highest score (WPS= 2.03) and Habitat G21 has the lowest score (WPS= 0).

Cross-Stratification by Slope

Prehistoric hunter-gatherers surely considered slope important in their foraging and settlement decisions in the White Pine, Grant, and Pancake Ranges because the relief in a resource patch significantly affects foraging procurement costs as well as comfort (Zeanah in press). Table 8 groups the proportion of area within each habitat into five ordinal intervals of slope: 0%, 1- 3%, 3%- 6%, 6%- 11%, 11%-18%, and > 18%. As was the case with water proximity intervals, we found similar ordinal classifications of slope useful in our previous characterization of Carson Desert habitats (Zeanah et al. 1995; Zeanah 1996), and apply them here with slight modifications adjusting them to the particular topography of Railroad Valley.

Table 8. Breakdown of Railroad Valley Habitats by Slope Interval

Habitat	Area (ha)	Expected Slope Range	0	1-3%	3-6%	6-11%	11-18%	>18%
A1	16238	0	1	0	0	0	0	0
G10	3601	2%-50%	0	0.1	0.55	0.33	0.01	0.01
G11	11384	2%-15%	0	0.47	0.43	0.09	0.01	0
G12	49314	0%-30%	0.22	0.41	0.23	0.1	0.03	0.01
G13	3782	0%-15%	0.37	0.62	0.01	0	0	0
G14	3408	15%-75%	0.02	0.2	0.23	0.32	0.15	0.08
G15	995	2%-75%	0	0.09	0.23	0.45	0.18	0.05
G16	14573	0%-30%	0.96	0.04	0	0	0	0
G17	11374	0%-8%	0.66	0.34	0	0	0	0
G18	9659	0%-8%	0.66	0.34	0	0	0	0
G2	10416	0%-4%	0.99	0.01	0	0	0	0
G21	59	0%-30%	0	1	0	0	0	0
G22	213	0%-15%	0	0	0.33	0.36	0.28	0.02
G23	1893	0%-30%	0.02	0.32	0.52	0.13	0.01	0
G3	20447	0%-30%	0.96	0.04	0	0	0	0
G4	6319	0%-4%	0.82	0.17	0.01	0	0	0
G5	2358	0%-8%	0.77	0.21	0.02	0	0	0
G6	1717	0%-4%	1	0	0	0	0	0
G8	3344	0%-30%	0.06	0.76	0.15	0.03	0.01	0
G9	4161	0%-50%	0.03	0.47	0.36	0.1	0.02	0.02
M11	1063	8%-75%	0.01	0.04	0.13	0.35	0.29	0.18
M2	4041	8%-75%	0	0	0.03	0.1	0.22	0.65
M3	55	10%-75%	0	0	0	0.15	0.18	0.67
M5	3306	2%-75%	0	0.03	0.06	0.28	0.33	0.3
M6	3436	8%-75%	0	0.05	0.22	0.36	0.25	0.12
M7	1840	8%-75%	0	0	0.01	0.11	0.35	0.53
M8	2268	8%-75%	0	0.05	0.2	0.25	0.27	0.23
M9	937	15%-75%	0	0.01	0.13	0.5	0.14	0.22
S1	142	0%-8%	0	0.85	0.13	0.02	0	0
S10	9629	2%-50%	0.01	0.35	0.47	0.16	0.01	0
S4	4447	0%-50%	0	0.13	0.56	0.27	0.04	0.01
S5	1861	2%-50%	0	0.04	0.24	0.46	0.21	0.05
S6	1152	15%-75%	0	0.02	0.11	0.44	0.25	0.19
S7	577	0%-15%	0.68	0.32	0	0	0	0
S8	16	0%-50%	0	0	0.97	0.03	0	0
S9	2713	2%-75%	0	0.03	0.22	0.37	0.2	0.18
W1	603	0%-4%	0.79	0.17	0.02	0.02	0	0
W2	12	0%-4%	0	0.05	0.03	0.37	0.34	0.21
W3		2%-15%	0.01	0.02	0.08	0.37	0.21	0.3
No Data	10116	No Data	0.43	0.22	0.15	0.1	0.05	0.05

Note that the distribution of these slope intervals by habitat in Railroad Valley corresponds well to the range expected for each habitat in the central and southern Nevada Basin and Range areas (USDA Soil Conservation Service 1991, 1993) as a whole. For example, playa (Habitat A1) falls 100% within the 0% slope intervals, whereas montane habitats bear the highest proportion of area in the 11%-18%, and > 18% intervals.

As was the case with water proximity, it is possible to derive a slope score monitoring the relative slope in each habitat according to the relative proportion of habitat in each slope interval. However, slope requirements vary for different species of wildlife, requiring that slope intervals be weighted differently for particular cases.

Wildlife

Range type descriptions provide quantitative descriptions of plant communities, including species ethnohistorically recorded as having been collected for food by hunter-gatherers. This provides a simple way to model the distribution and productivity of plant food resources in Railroad Valley. However, a predictive model of hunter-gatherer foraging decisions based on optimal foraging theory must also consider animal resources, simply because most game offer higher foraging returns than do most plants (Layton et al. 1991:256; Simms 1987; cf. Chapter 6, this report). Thus, fauna must be included in the Railroad Valley model. Although soil and range data offer no direct mechanism for modeling the spatial distribution or abundance of fauna, they do permit observation of the distributions of many forage plants of those fauna, and variability in water and soil structures wildlife habitat as well as plant habitat (Cooperrider et al. 1986). Therefore, the Railroad Valley habitat landscape can be used to assess the suitability of plant habitat types for animal habitat based on the production of forage and on physiographic requirements of particular game animals. The following section discusses habitat suitability for selected game species.

Large Mammals

Pronghorn antelope, mule deer, and bighorn sheep are important food sources of ethnographic hunter-gatherers (Fowler 1986; Steward 1938). The habitat distribution of all three species can be inferred from slope, association with water, and forage abundance using a "habitat rating key" (Zeanah et al. 1995).

Typical pronghorn habitat is low, open, gently rolling terrain in sagebrush and greasewood-saltbush plant communities. Antelope generally shun steeper slopes (Kindschy et al. 1982; Yoakum 1980). The preference for open, gentle terrain is attributable to a strategy of using keen eyesight and high running speeds to flee predators in such landscapes (Frison 1978:251). In contrast, mule deer generally prefer steep, rough, or broken terrain offering elevational relief. This kind of topography offers effective escape from predators and easy access to a variety of potential feeding habitats within a small area (Grady 1980; Kerr 1979). Relief is even more vital for sheep habitat, the defining characteristic of which is precipitous, remote topography. Mountain sheep use steep bluffs, cliffs, rock rims, and outcrops as escape terrain. Similarly, bedding and lambing areas are restricted to steeper slopes. Although adult rams occasionally venture as far as 3 km from steep relief, mountain sheep usually remain within 0.8 km of abrupt escape terrain even when rich, well watered foraging patches lie not much farther away (Boyd et al. 1986; Lothson 1989; Van Dyke et al. 1983; Wehausen 1983).

Given the different slope preferences of these three species, a slope suitability score can be calculated for each habitat by individually weighting the slope intervals presented in Table 8 for each of the three large mammals. The antelope slope suitability score is calculated by the following equation.

$$SSS_{antelope} = (4^{*}p_{<3\%})+(3^{*}p_{3\text{-}6\%})+(2^{*}p_{6\text{-}11\%})+(p_{11\text{-}19\%}) \qquad \text{(Equation 2)}$$

where:

$SSS_{antelope}$ = antelope slope suitability score

$p_{<3\%}$ = proportion of habitat of 3% slope or less
$p_{3\text{-}6\%}$= proportion of habitat of 3% to 6% slope
$p_{6\text{-}11\%}$ = proportion of habitat of 6% to 11% slope
$p_{11\text{-}19\%}$ = proportion of habitat of 11% to 19% slope

Note that the score assigns a value of zero to all area greater than 19% slope.

Similarly, the following score measures the slope suitability of habitats for mule deer by weighting the values of slope intervals differently, and assigning a value of zero to all areas of less than 3% slope.

$$SSS_{deer}= (4^*p_{11\text{-}19\%})+(3^*p_{>19\%}) +(2^*p_{6\text{-}11\%})+(p_{3\text{-}6\%}) \quad \text{(Equation 3)}$$

where:

SSS_{deer} = mule deer slope suitability score
$p_{3\text{-}6\%}$= proportion of habitat of 3% to 6% slope
$p_{6\text{-}11\%}$ = proportion of habitat of 6% to 11% slope
$p_{11\text{-}19\%}$ = proportion of habitat of 11% to 19% slope
$p{>}19\%$ = proportion of habitat greater than 19% slope

Also assigning a value of zero to all areas of less than 3% slope, the slope suitability of habitats for bighorn sheep is measured by the following equation.

$$SSS_{sheep}= (4^*p_{>19\%})+(3^*p_{11\text{-}19\%}) +(2^*p_{6\text{-}11\%})+(p_{3\text{-}6\%}) \quad \text{(Equation 4)}$$

where:

SSS_{sheep} = bighorn sheep slope suitability score
$p_{3\text{-}6\%}$= proportion of habitat of 3% to 6% slope
$p_{6\text{-}11\%}$ = proportion of habitat of 6% to 11% slope
$p_{11\text{-}19\%}$ = proportion of habitat of 11% to 19% slope
$p{>}19\%$ = proportion of habitat greater than 19% slope

Table 9 gives the slope suitability score for each large mammal species in each habitat, as calculated from Table 8 and equations 2, 3, and 4.

Handy drinking water is extremely important for antelope habitat (Kindschy et al. 1982; O'Gara and Yoakum 1992; Yoakum 1980). Although antelope occasionally may forage as far as 8 km from water, pronghorn populations stick close to their water sources, as demonstrated by wildlife inventories in Wyoming documenting that 95% of a population of 12,000 pronghorns remained within 6.5 km of water (Yoakum 1980:15). Although proximity of drinking water seems less important to mule deer habitat than to antelope habitat (Grady 1980), mule deer are nevertheless likely to remain within 6.5 km of a water source (Kerr 1979). Particularly important are riparian zones which deer use as fawning areas, migration corridors, and because they provide good forage, cover, and access to water (Lekenby et al. 1982). Proximity of drinking water is also important to mountain sheep habitat; populations generally cluster within 1.6 to 3.2 km of water sources, especially in summer months (Van Dyke et al. 1983). The water proximity score calculated in equation 1 serves to measure habitat suitability for all three large mammals because of their similar water requirements.

Table 9. Slope Suitability Scores by Habitat for Pronghorn Antelope, Mule Deer, and Bighorn Sheep

Habitat	Pronghorn Antelope	Mule Deer	Bighorn Sheep
A1	4	0	0
G10	2.72	1.28	1.28
G11	3.35	0.65	0.65
G12	3.47	0.55	0.53
G13	3.99	0.01	0.01
G14	2.36	1.71	1.64
G15	2.12	2.01	1.88
G16	4	0	0
G17	4	0	0
G18	4	0	0
G2	4	0	0
G21	4	0	0
G22	2	2.26	2
G23	3.19	0.82	0.81
G3	4	0	0
G4	3.99	0.01	0.01
G5	3.97	0.03	0.03
G6	4	0	0
G8	3.76	0.24	0.24
G9	3.3	0.7	0.7
M11	1.57	2.54	2.43
M2	0.51	3.05	3.49
M3	0.48	3.03	3.52
M5	1.19	2.84	2.81
M6	1.84	2.3	2.16
M7	0.6	3.22	3.4
M8	1.58	2.46	2.42
M9	1.58	2.35	2.42
S1	3.83	0.17	0.17
S10	3.17	0.84	0.83
S4	2.76	1.27	1.24
S5	2.01	2.15	1.99
S6	1.51	2.54	2.49
S7	4	0	0
S8	2.97	1.03	1.03
S9	1.74	2.29	2.26
W1	3.94	0.06	0.06
W2	1.37	2.76	2.63
W4	3.94	0.06	0.06

Pronghorn generally are browsers and shrubs are their major food source. Typically, low sagebrush dominates the best summer ranges of antelope, whereas winter ranges maintain saltbush, greasewood, and winterfat; the animals also consume grasses and forbs. Rangelands maintaining a desirable mixture of these plant classes represent best antelope habitat (Kindschy et al. 1982); Yoakum (1980) estimates that mixtures of 30 to 40% grasses, 10 to 30% forbs, and 5 to 30% shrubs are optimum. Mule deer are browsers relying heavily on shrub vegetation in late summer, fall, and winter. Mountain mahogany and antelope bitterbrush are particularly attractive to mule deer. Succulent grasses and forbs make up a greater portion of mule deer diet in spring and early summer. Mountain sheep are primarily grazers, subsisting on grasses augmented by browse and forbs in spring and summer (Van Dyke et al. 1983:8; Wehausen 1983).

Comprehensive lists of forage plants of all three large mammal species are tallied elsewhere (Zeanah et al. 1995: 132, 135, 138-139). Table 10 sums the amount of forage in each habitat and assigns an ordinal forage score based on the following intervals: no forage = 0, 1-250 kg/ha of forage = 1, 251-500 kg/ha of forage = 2, 501-1000 kg/ha of forage = 3, and >1000 kg/ha = 4.

Table 10. Forage Quantity and Forage Scores in Each Habitat for Pronghorn Antelope, Mule Deer, and Bighorn Sheep

Habitat	Antelope Forage (kg/ha)	Antelope Forage Score	Deer Forage (kg/ha)	Deer Forage Score	Sheep Forage (kg/ha)	Sheep Forage Score
A1	0	0	0	0	0	0
G10	216	1	216	1	244	1
G11	214	1	206	1	238	1
G12	147	1	149	1	175	1
G13	188	1	118	1	138	1
G14	153	1	138	1	174	1
G15	139	1	141	1	168	1
G16	194	1	212	1	213	1
G17	132	1	162	1	161	1
G18	214	1	232	1	232	1
G2	417	2	603	3	654	3
G21	210	1	204	1	227	1
G22	231	1	195	1	231	1
G23	128	1	131	1	155	1
G3	565	3	862	3	903	3
G4	618	3	953	3	999	3
G5	194	1	562	3	562	3
G6	170	1	694	3	694	3
G8	232	1	212	1	239	1
G9	438	2	143	1	186	1
M11	233	1	231	1	258	2
M2	302	2	319	2	321	2
M3	264	2	286	2	286	2
M5	269	2	280	2	288	2
M6	295	2	331	2	335	2
M7	148	1	213	1	158	1
M8	366	2	373	2	404	2
M9	146	1	178	1	184	1
S1	685	3	2337	4	2384	4
S10	311	2	272	2	303	2
S4	428	2	383	2	425	2
S5	370	2	230	1	246	1
S6	208	1	211	1	247	1
S7	507	3	1290	4	1309	4
S8	370	2	353	2	403	2
S9	237	1	256	2	279	2
W1	2132	4	1916	4	1916	4
W2	1313	4	1380	4	1717	4
W4	551	3	729	3	688	3

Given the three parameters of suitable habitat for large mammals, the quality of each habitat in the Railroad Valley study area is measurable by multiplying the water proximity score (WPS), slope suitability score (SSS), and forage score. Table 11 gives the resulting scores for each species. The score directly measures the quality of habitat for each species with higher scores denoting higher quality habitat. We assume that the scores indirectly monitor the probability that a particular species of game animal occurs in any specific habitat. The best habitats for antelope include all three wetland habitats (W1, W2, and W4), with lowland wetlands and meadows (Habitat W1) scoring higher by far than any other habitat. Other important antelope habitats are greasewood-saltbush habitats G2, G3, and G4, and sagebrush habitats S1 and S7. Mule deer do best in upland spring meadows (Habitat W2) and riparian zones (Habitat W4). Montane habitats M2, M3, M5, and M8 and Sagebrush Habitat S5 are also highly suitable for mule deer. For bighorn sheep, wetland habitats W2 and W4 score highest, and montane Habitat M9 is by far the best non-wetland habitat.

Table 11. Habitat Suitability for Pronghorn Antelope, Mule Deer, and Bighorn Sheep in the Railroad Valley Study Area

Habitat	Pronghorn Antelope	Mule Deer	Bighorn Sheep
A1	0	0	0
G10	3.75	1.77	1.77
G11	4.38	0.86	0.85
G12	4.74	0.75	0.72
G13	6.73	0.02	0.02
G14	2.65	1.92	1.84
G15	3.15	2.97	2.78
G16	5.33	0	0
G17	6.76	0	0
G18	6.84	0	0
G2	13.89	0	0
G21	0	0	0
G22	1.95	2.19	1.94
G23	4.73	1.22	1.21
G3	22	0	0
G4	23.58	0.05	0.05
G5	7.19	0.15	0.15
G6	7.58	0	0
G8	4.34	0.28	0.28
G9	1.95	0.83	0.41
M11	2.6	4.21	4.03
M2	1.35	8.09	4.63
M3	0.96	6.06	3.52
M5	2.72	6.49	3.2
M6	3.97	4.96	2.34
M7	0.55	2.93	3.1
M8	5.26	8.21	8.07
M9	3.07	4.58	4.72
S1	23.3	1.37	1.38
S10	7.28	1.93	0.96
S4	9.39	4.32	4.21
S5	2.91	6.21	5.74
S6	2.7	4.54	4.43
S7	21.71	0	0
S8	5.95	2.05	2.05
S9	1.85	4.87	2.41
W1	47.3	0.69	0.7
W2	16.49	24.85	31.51
W4	18	11.25	11.25

Medium and Small Mammals

Great Basin hunter-gatherers consumed a variety of medium sized mammals (Steward 1938; Fowler 1986). Here, three categories of medium sized mammals are considered, for which there is sufficient wildlife behavior literature to model their habitats in the Railroad Valley study area: jackrabbits/hares, large ground squirrels, and woodrats/marmots. Also, a set of small mammals including white-tailed antelope squirrel, kangaroo rat, vole, grasshopper mouse, deer mouse, pinyon mouse, least chipmunk, and pocket gopher is considered collectively.

Although the habitats of Nuttall's cottontail, black-tailed jackrabbit, and white-tailed jackrabbit differ, there are considerable similarities. Generally, white-tailed jackrabbit and cottontail share a propensity to occur in sagebrush and montane plant communities at higher elevations than black-tailed jackrabbit (Maser et al. 1984; USDI Fish and Wildlife Service 1978:105). Rabbits and hares are eclectic as regards habitat diversity, but they prefer areas of low growing shrubs and trees for the escape cover they provide. Although rabbits will feed in open grasslands and meadows where they are vulnerable to predation, they usually remain within 300 m of protective brush cover (Chapman and Willner 1986; USDI Fish and Wildlife Service 1978:105). Table 12 lists the average ground cover expected for each habitat and assigns a relative score to each: no cover = 0, 1-30% cover = 1, 31 -45% cover = 2, and > 46% cover = 3.

Table 12. Habitat Suitability for Jackrabbits and Hares in the Railroad Valley Study Area

Habitat	Jackrabbit/Hare Proportion Cover	Cover Score	Jackrabbit/Hare Forage (kg/ha)	Forage Score	Habitat Suitability Score
A1	0	0	0	0	0
G10	0.225	1	270	2	2
G11	0.2	1	217	1	1
G12	0.2	1	329	2	2
G13	0.15	1	217	1	1
G14	0.15	1	203	1	1
G15	0.2	1	198	1	1
G16	0.15	1	345	2	2
G17	0.15	1	304	2	2
G18	0.15	1	351	2	2
G2	0.3	1	924	4	4
G21	0.175	1	284	2	2
G22	0.2	1	321	2	2
G23	0.2	1	262	2	2
G3	0.35	2	1234	4	8
G4	0.475	3	1346	4	12
G5	0.35	2	758	3	6
G6	0.5	3	1021	4	12
G8	0.175	1	313	2	2
G9	0.275	1	268	2	2
M11	0.25	1	272	2	2
M2	0.25	1	303	2	2
M3	0.275	1	250	2	2
M5	0.25	1	294	2	2
M6	0.225	1	313	2	2
M7	0.25	1	157	1	1
M8	0.25	1	400	2	2
M9	0.25	1	164	1	1
S1	0.4	2	685	3	6
S10	0.2	1	368	2	2
S4	0.225	1	419	2	2
S5	0.25	1	441	2	2
S6	0.175	1	263	2	2
S7	0.3	1	626	3	3
S8	0.225	1	436	2	2
S9	0.225	1	293	2	2
W1	0.6	3	2206	4	12
W2	0.725	3	1189	4	12
W4	0.2	1	542	3	3

Unlike many other animals considered herein, proximity of water is not critical to rabbit habitat; rabbits may drink but usually satisfy their water requirements by eating succulent plants. Nevertheless, population densities may parallel closely the distribution of water sources because of the greater densities of succulent plants they support (Chapman and Willner 1986). Since the critical factor is forage, rather than water, we do not include water proximity as a measure of jackrabbit/hare habitat suitability.

Rabbits and hares prefer succulent forbs and grasses, especially in summer when moisture requirements are highest. They are nevertheless quite eclectic diners, feeding on shrub vegetation when succulents are unavailable (USDI Fish and Wildlife Service 1978:105). Known food plants of rabbits and hares are listed elsewhere (Zeanah et al. 1995: 144). Table 12 tallies the quantity of jackrabbit/hare forage species, in kilograms per hectare, for each habitat in the Railroad Valley study area, assigning a forage score based on the same ordinal intervals used for large mammals. The suitability of habitats for jackrabbits and hares is then calculated by simply multiplying the forage score by the cover score. Again, the score directly measures the quality of habitat for jackrabbits and hares, and indirectly monitors the abundance of lagomorphs. The best habitats for jackrabbits and hares are wetland habitats W1 and W2, greasewood-saltbush habitats G3, G4, G5, and G6, and sagebrush Habitat S1.

Large ground squirrels preyed upon by ethnographic Great Basin hunter-gatherers include golden mantled ground squirrel, Belding's ground squirrel, and Townsend's ground squirrel. Ground squirrel thrives in a variety of habitats in greasewood-saltbush, sagebrush, and montane plant communities and are particularly fond of deep, well drained soils that permit burrowing (USDI Fish and Wildlife Service 1978; Maser et al. 1984; Rickart 1987). Zeveloff (1988:122) and Rickart (1987) record that Townsend's ground squirrel populations are particularly large at desert springs, and reproduction frequently occurs near wet meadow, riparian, palustrine, and lacustrine habitats (Maser et al. 1984:84). Thus, the water proximity score of habitats, given in Table 7, pertains to ground squirrel habitat evaluation.

Ground squirrels eat seeds, succulent green vegetation of forbs and grasses, as well as a few insects. Generally, squirrels eat green forbs after emerging from hibernation in January or February and gradually shift reliance to grass seed before estivating in June or July (Yensen and Quinney 1992). In particular, winterfat, Sandberg's bluegrass, and various forbs are favored foods of ground squirrels (Johnson 1977; Rogers and Gano 1980; Yensen and Quinney 1992).

Zeanah et al. (1995:147) list common forage plants of ground squirrel. However, the importance of a preferred set of forage in ground squirrel life history and the eclectic use of a wide variety of grass and forbs warrants consideration of two categories of forage in evaluating ground squirrel habitat: preferred and other forage. Table 13 list the quantity of preferred and general forage in kg/ha for each habitat in the Railroad Valley study area. Ordinal scores are assigned to preferred forage quantities according the following intervals: no forage = 0, 1-45 kg/ha of forage = 1, 46-100 kg/ha of forage = 2, 101-150 kg/ha of forage = 3, and >150 kg/ha = 4. Scores for general grass and forbs are no forage = 0, 1-175 kg/ha of forage = 1, 176-300 kg/ha of forage = 2, 301-1000 kg/ha of forage = 3, and >1000 kg/ha = 4.

A score measuring the suitability of habitats for large ground squirrels is then calculable by multiplying the water proximity score, preferred forage score, and other forage score. These scores (Table 13) reveal that wetland habitats W1, W2, and W4, and sagebrush habitats S1 and S7 are best for ground squirrels.

Table 13. Large Ground Squirrel Habitat Suitability in the Railroad Valley Study Area

Habitat	Preferred Forage (kg/ha)	Preferred Forage Score	Other Forage (kg/ha)	Other Forage Score	Total Score
A1	0	0	0	0	0
G10	26	1	108	1	1.38
G11	25	1	84	1	1.31
G12	15	1	138	1	1.37
G13	83	2	15	1	3.37
G14	22	1	50	1	1.12
G15	34	1	59	1	1.48
G16	7	1	90	1	1.33
G17	1	1	70	1	1.69
G18	0	0	79	1	0
G2	32	1	717	3	5.21
G21	33	1	261	2	0
G22	65	2	102	1	1.94
G23	8	1	117	1	1.48
G3	42	1	1177	4	7.33
G4	42	1	1432	4	7.88
G5	18	1	678	3	5.43
G6	26	1	1105	4	7.58
G8	48	2	192	2	4.61
G9	29	1	197	2	0.89
M11	69	2	149	1	3.31
M2	27	1	162	1	1.33
M3	28	1	115	1	1
M5	35	1	157	1	1.14
M6	52	2	140	1	2.16
M7	18	1	78	1	0.91
M8	81	2	181	2	6.67
M9	66	2	21	1	3.9
S1	118	3	2217	4	24.34
S10	66	2	144	1	2.3
S4	62	2	205	2	6.8
S5	64	2	162	1	3.85
S6	72	2	43	1	3.57
S7	55	2	744	3	10.86
S8	70	2	193	2	4
S9	82	2	90	1	2.13
W1	461	4	2685	4	48
W2	404	4	1840	4	48
W4	49	2	344	3	18

Distributions of desert woodrat, bushy-tailed woodrat, and yellow-bellied marmot overlap: bushy-tailed woodrats occur in sagebrush, pinyon-juniper, and mountain brush vegetation communities; desert woodrats are common in greasewood-shadscale, and sagebrush communities; and marmots are most common in montane communities and wet meadows (Maser et al. 1984; USDI Fish and Wildlife Service 1978). However, all three species live in diverse habitats. Woodrats and marmots both require drinking water to survive, so water proximity is pertinent to evaluating their habitat.

Rock outcrops that provide protection from predators and weather are a critical element of woodrat and marmot habitat strongly affecting population densities (Llewellyn 1981). Ten habitats in the Railroad Valley study area contain rock outcrops (Table 14). Because of the importance of rock outcrops to woodrats and marmots, we restrict our evaluation of woodrat and marmot habitat to these habitats.

Table 14. Woodrat and Marmot Habitat in the Railroad Valley Study Area

Habitat	Forbs (kg/ha)	Forb Score	Woodrat/Marmot Forage (kg/ha)	Forage Score	Habitat Suitability Score
G14	10	1	29	1	1.29
M11	17	1	69	2	3.94
M2	33	2	124	2	6.8
M3	43	2	119	2	5.78
M5	16	1	106	2	3.47
M6	23	2	135	2	6.67
M7	12	1	59	2	2.73
M9	20	2	79	2	4.56
S5	21	1	128	2	6.13
S6	14	1	96	2	2.96

Woodrats and marmots eat a wide variety of forbs (Johnson and Hansen 1979), but also the succulent parts of shrubs and grasses, as well as seeds (Zeveloff 1988:216-217). Zeanah et al. (1995: 148) list food plants of woodrats and marmots. Once again, the reliance of woodrats and marmots on a specific class of forage (forbs), together with the propensity of these species to eat succulent parts of a wider variety of plants, warrants consideration of two classes of forage. Table 14 lists the quantity of forbs and other forage species in each rock outcrop bearing habitat in the Railroad Valley study area. Forage species are scored into three intervals: <50 kg/ha, 51-150 kg/ha, and > 150 kg/ha. Forbs fall into two scoring intervals divided at 20 kg/ha.

The suitability of these habitats for woodrats and marmots is calculated by multiplying the forb, forage, and water proximity scores. The best habitats for woodrats and marmots are montane habitats M2, M3, M6, and M9, and sagebrush Habitat S5.

Ethnographic hunter-gatherers procured a variety of small mammals, including white-tailed antelope squirrel, kangaroo rat, vole, grasshopper mouse, deer mouse, pinyon mouse, least chipmunk, and pocket gopher. These should occur in a variety of habitats throughout the Railroad Valley study area.

Many small mammals such as pinyon mouse, vole, and chipmunk require drinking water, so this means that in arid settings the distributions of these mammals are tethered to water sources to the extent required by their mobility and moisture requirements. Wildlife studies consistently indicate that wetlands maintain higher densities of small mammals than drier habitats (Clary and Medin 1992; Feldhammer 1979).

However, white-tailed antelope squirrel, kangaroo rat, grasshopper mouse, and deer mouse can metabolize moisture from succulent plants and consequently do not require drinking water. The densities of these mammals corresponded significantly to soil depth and soil texture and should coincide with wetland plant communities only (as was the case with rabbits) if the distribution of forage species or other critical habitat variables happen to correlate with proximity to water. Indeed, these mammals should occur in greatest proportion in forage patches too remote from water for competing mammals to rely on. In particular, xeric sand dune habitats rich in grass seeds and forbs can maintain high densities of small mammals (Brown 1973; Brown and Liebermann 1973; see also Billings 1945:11).

The water proximity score calculated in equation 1 is pertinent to evaluating small mammal habitat because of the importance of water to certain small mammal species. Table 15 scores the presence (score =2) or absence (score =1) of sand dunes and sand sheets in each habitat, because of the values to small mammals of deep, well drained, easily dug soils. The table also lists the quantity of grasses and forbs in kg/ha and assigns a forage score according to the following intervals: no forage = 0, < 200 kg/ha = 1, 201-350 kg/ha = 2, 351-1000 kg/ha = 3, and > 1000 kg/ha = 4. Multiplying the foraging suitability score, water proximity score, and presence/absence of sand sheets and dunes calculates the suitability of habitats for small mammals. The best habitats for small mammals include wetland habitats W1, W2, and W4, greasewood-saltbush habitats G2, G3, G4, and G6, and sagebrush Habitat S1.

Table 15. Small Mammal Habitat Suitability in the Railroad Valley Study Area

Habitat	Sand Dunes and Sheets	Grass and Forbs	Forage Score	Habitat Suitability Score
A1	1	0	0	0
G10	1	134	1	1.38
G11	1	108	1	1.31
G12	1	153	1	1.37
G13	1	98	1	1.69
G14	1	72	1	1.12
G15	1	93	1	1.48
G16	2	96	1	2.66
G17	2	71	1	3.38
G18	1	79	1	1.71
G2	2	749	3	10.41
G21	2	295	2	0
G22	1	167	1	0.97
G23	1	125	1	1.48
G3	2	1219	4	14.67
G4	1	1474	4	7.88
G5	1	696	3	5.43
G6	1	1131	4	7.58
G8	2	240	2	4.61
G9	1	226	2	0.89
M11	1	219	2	3.31
M2	2	189	1	2.65
M3	2	143	1	2
M5	1	192	1	1.14
M6	2	192	1	2.16
M7	1	95	1	0.91
M8	1	263	2	3.33
M9	2	88	1	3.9
S1	1	2335	4	8.11
S10	1	211	2	2.3
S4	1	268	2	3.4
S5	1	226	1	1.93
S6	1	114	1	1.78
S7	1	799	3	5.43
S8	1	262	2	2
S9	1	172	1	1.06
W1	1	3146	4	12
W2	1	2244	4	12
W4	2	393	3	18

Birds

We consider two categories of avifauna potential game for hunter-gatherers: waterfowl and upland game birds. We assume that wetlands of the Railroad Valley study area do not support permanent populations of waterfowl and shorebirds, but do host migratory visitors (USDI BLM 1990a:16).

Waterfowl inhabit a variety of feeding and nesting habitats in wetlands. Canada Goose typically nests in emergent vegetation, preferring islands as nesting sites (Eng 1986b:373). They feed on terrestrial and aquatic vegetation in saltgrass meadows and emergent marshes. Canvasback and redhead duck prefer nesting in protected emergent vegetation closely juxtaposed with open water, uplands, and islands (Eng 1986b:375; Thompson and Hallock 1988:63). They feed in emergent and submergent settings (Hamilton and Auble 1993:11-13). Mallards nest in upland settings near wetlands, feeding in saltgrass meadows and emergent vegetation (Eng 1986b:372, 375; Hamilton and Auble 1992:11-13).

Waterfowl rely heavily on aquatic invertebrates to provide protein for molting, egg formation, and hatchling growth (Hamilton and Auble 1992:11-13). Adults subsist on a variety of aquatic vegetation, but sago pondweed is a major food (Eng 1986b; Gullion 1964:7; Thompson and Hallock 1988:63). Waterfowl forage plants are listed elsewhere (Zeanah et al. 1995: 151), however Table 16 tallies the quantity of waterfowl forage in the 12 Railroad Valley habitats where those species occur.

Table 16. Waterfowl Habitat Suitability in the Railroad Valley Study Area

Habitat	Forage Quantity (kg.ha)	Forage Score	Water Proximity Score	Habitat Suitability Score
G16	1	1	1.33	1.33
G17	14	1	1.7	1.7
S7	22	1	1.81	1.81
S1	47	1	2.03	2.03
G2	226	2	1.74	3.47
G5	159	2	1.81	3.62
G3	278	2	1.83	3.67
G6	223	2	1.9	3.79
G4	316	2	1.97	3.94
W4	40	1	3	3
W2	505	2	3	6
W1	1330	3	3	9

Not surprisingly, all three wetland habitats bear waterfowl forage plants, with upland and lowland spring meadows and marshes (Habitats W1 and W2) yielding the highest quantity of forage. The remaining nine habitats bear relatively high water proximity scores of 1.33 or more, highlighting the importance of perennial water to waterfowl. The suitability of Railroad Valley habitats for waterfowl is measured by multiplying water proximity score by forage score. The best habitats for waterfowl are wetland habitat W1 and W2, and greasewood-saltbush habitats G2, G3, G4, G5, and G6.

Upland game birds used as food by ethnographic hunter-gatherers include sage grouse, blue grouse, and mountain quail. However, the present discussion emphasizes sage grouse over other species, because blue grouse and mountain quail typify high altitude, coniferous forests (Maser et al. 1984; USDI Fish and Wildlife Service 1978) and are unlikely ever to have been abundant in the present Railroad Valley study area. Sagebrush is critical to sage grouse habitat because it provides protective cover from weather and predators, and represents the major over winter food source for sage grouse (Call 1979; Call and Masser 1985; Eng 1986a; Roberson 1984). Sage grouse may forage occasionally in greasewood-saltbush vegetation communities in winters when deep snow prevents effective foraging in sagebrush. Similarly, in dry summers sage grouse may migrate to montane pinyon-juniper or mountain brush where water and succulent vegetation are available. However, greasewood-saltbush and montane communities are marginal areas for sage grouse and they reproduce almost exclusively in sagebrush communities (Call and Masser 1985; Masser et al. 1984; Roberson 1984).

Table 17 lists the quantity of sagebrush (defined here as all species belonging to the genus *Artemisia*) in kg/ha in each habitat in the Railroad Valley study area. Each habitat is assigned an ordinal sagebrush score based on the quantity of sagebrush in that habitat. Habitats with no sage score as 0, between 1 and 40 kg/ha score 1, between 41 and 105 kg/ha score 2, between 106 and 200 kg/ha score 3, and with sage exceeding 200 kg/ha score 4.

Table 17. Sage Grouse Habitat Suitability in the Railroad Valley Study Area

Habitat	Sagebrush (kg/ha)	Sagebrush Score	Sage Grouse Forage (kg/ha)	Forage Score	Habitat Suitability Score
A1	0	0	0	0	0
G10	54	2	12	1	3.42
G11	22	1	11	1	1.5
G12	19	1	10	1	1.15
G13	12	1	2	1	1.12
G14	12	1	3	1	1.29
G15	24	1	4	1	1.37
G16	22	1	11	1	0.59
G17	16	1	11	1	1.12
G18	29	1	12	1	1.33
G2	52	2	191	3	10.86
G21	3	1	33	2	2
G22	34	1	25	2	2.97
G23	16	1	5	1	1.12
G3	72	2	273	3	6.39
G4	82	2	309	3	6
G5	6	1	58	2	2.89
G6	0	0	79	2	0
G8	13	1	30	2	1.18
G9	32	1	10	1	1.77
M11	56	2	19	1	3.94
M2	104	2	10	1	3.4
M3	97	2	8	1	2.89
M5	87	2	11	1	3.47
M6	99	2	29	2	6.67
M7	49	2	6	1	2.73
M8	147	3	17	1	5.1
M9	43	2	15	1	2.28
S1	236	4	212	3	24
S10	74	2	10	1	3.31
S4	140	3	18	1	4.74
S5	96	2	11	1	4.24
S6	75	2	21	2	4.44
S7	170	3	97	2	10.7
S8	129	3	20	2	9.01
S9	65	2	20	1	0
W1	0	0	1618	4	0
W2	22	1	718	4	12
W4	162	3	130	3	27

Drinking water is a necessary component of sage grouse habitat: in summer months the birds may venture no farther than 1.5 to 3.5 km from a stream, spring, or seep (Call 1979; Eng 1986b), but in winter may use snow as a water source (Call and Masser 1985). Sage grouse generally prefer flat or gently rolling terrain over steeper slopes. Sage grouse use open meadows closely juxtaposed with patches of dense sagebrush as strutting grounds or leks while mating in the spring, and use meadows as foraging patches to provision hatchlings and fledglings with insects and succulent vegetation (Call 1979; Call and Masser 1985). Therefore, the water proximity score calculated in equation 1 is pertinent to evaluating sage grouse habitat.

Sage grouse subsist on three categories of food: insects vital to the young, succulent grasses and forbs in summer, and sagebrush leaves for overwintering. Elsewhere, we have listed specific forage plants known to be favored by sage grouse (Zeanah et al. 1995: 154). Table 17 tallies all non-sage forage plants by habitat in kg/ha. Once again, these values are simplified into ordinal scores of no forage = 0, 1–20 kg/ha = 1, 21-100 kg/ha = 2, 101- 700 kg/ha = 3, and greater than 700 kg/ha = 4.

Habitat suitability for sage grouse is then determined by multiplying the sagebrush, forage, and water proximity scores. The scores indicate that the best habitats for sage grouse are wetland habitats W2 and W4, sagebrush habitats S1, S7, and 8, greasewood-saltbush Habitat G2, and montane Habitat M6.

Conclusion

In this chapter, we defined 39 habitats that occur in the Railroad Valley study area and evaluated their suitability as wildlife habitat. In chapter 4, we describe the composition, distribution, and productivity of each habitat in detail.

Chapter 4

Habitat Descriptions

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The preceding chapter identified 39 habitats representing sets of range types that commonly co-occur on soil map units in Railroad Valley. Each habitat represents a mosaic of biotic and abiotic characteristics that constrain prehistoric hunter-gatherers seeking to make prudent foraging and settlement decisions. This chapter profiles the biotic composition and physical characteristics of each habitat. Range Site Description Handbooks for the Central and Southern Nevada Basin and Range Land Resource Areas (USDA Soil Conservation Service 1991, 1993), supported by relevant additional sources, provide the basis for descriptions.

For purposes of description, habitats are discussed according to physiographic and vegetation associations: abiotic, wetland, greasewood/saltbush, sagebrush, and montane. Table 18 presents habitats according to community, and summarizes pertinent descriptive detail of each. Figure 2 shows the spatial distribution of these associations in Railroad Valley. The vegetation composition of each habitat, in kilograms per hectare, is presented in Appendix D. Please note that common plant names are used in text throughout this report. A concordance of common and Latin plant names appears in Appendix E.

To further organize habitat description, each habitat within each community is described in order of normal, annual air-dry production of the understory vegetation, most productive habitat first. Note that habitat productivity serves merely as an organizing principle: biomass is not a reliable measure of the foraging value of habitats for hunter-gatherers. Figure 3 illustrates total average annual air-dry production in kilograms per hectare of each habitat for normal years. Average annual productivity ranges from none at all in Habitat A1 to almost 3200 kg/ha in Habitat W1. Wetland habitats are generally most productive for yearly growth, but some habitats in greasewood-saltbush and sagebrush communities are comparably productive. Proximity to perennial water appears an important determinant of habitat productivity. Figure 4 arrays productivity in kilograms per hectare against water proximity score for the 39 habitats. Productivity and proximity to water correlate significantly ($r=.66$, d.f. 38, $p=.0001$), suggesting that water proximity accounts for 43% of all variability in habitat productivity.

Abiotic Associations

Abiotic habitats are ecological settings that normally support no vegetation; consequently, they have no associated range types. Habitat A1 (playa) is the only habitat in the Railroad Valley study area that is abiotic.

Habitat A1: Playa

The largest expanse of Habitat A1 occurs on the large alkaline flat in central Railroad Valley. Soil surveys also map several playa basins in the southwest extreme of the study area, whereas unmapped small playa pans are a component of several other habitats. Playas are flat, arid, shallow basins that lack external drainage. As such, regional streamflow and runoff flood them periodically to form

Table 18. Summary Characteristics of Railroad Valley Habitats

Habitat	Note	Normal Year Productivity (kg/ha)	Slope	Elevation Range (meters asl)	Percent Understory Composition (Grass-Forbs-Shrubs)	Dominant Tree	Dominant Shrub	Dominant Grass or Grass-like Plant
A1	playa	0	0%	< 1436	NA	NA	NA	NA
W1	lowland spring marshes and meadows	3178	<2%	< 2285	85-14-01	willow	willow	sedge
W2	upland spring meadows	2244	<4%	2285-2895	80-20-00	willow	willow	sedge
W4	riparian	785	2%-15%	1450-2285	40-10-50	cottonwood	basin big sagebrush	basin wildrye
G4		1694	<3%	<1675	80-07-13	NA	black greasewood	alkali sacaton
G3	includes playa pans and sand dunes	1543	0%	<1675	70-10-20	NA	black greasewood	alkali sacaton
G6		1414	0%	<1440	75-05-20	NA	black greasewood	alkali sacaton
G2		1170	0%	<1450	55-10-35	NA	black greasewood	alkali sacaton
G5		1055	<3%	<1475	60-05-35	NA	black greasewood	alkali sacaton
G9		502	1%-11%	<1890	40-05-55	NA	spiny hopsage	Indian ricegrass
G21	annual plants may dominate	393		<1828	70-05-25	NA	fourwing saltbush	Indian ricegrass
G18		393	<3%	<1675	15-05-80	NA	shadscale	alkali sacaton
G16	includes playa pans and sand dunes	384	0%	<1585	20-05-75	NA	shadscale	Indian ricegrass
G8	may be capped by eolian sand	353	1%-6%	<1830	65-05-30	NA	fourwing saltbush	Indian ricegrass
G17	coppice dunes and small playa basins	339	<3%	<1645	15-05-80	NA	black greasewood	alkali sacaton
G22		334	4%-18%	<1675	45-05-50	NA	fourwing saltbush	Indian ricegrass
G12	contains small playa pans and desert pavement	325	<11%	<1980	40-05-55	NA	shadscale	Indian ricegrass
G10	contains desert pavement	297	1%-11%	<2130	40-05-55	Utah juniper*	shadscale	Indian ricegrass
G23		278	1%-11%	<1830	40-05-55	NA	black greasewood	Indian ricegrass
G11	contains desert pavement	271	1%-11%	<1980	35-05-60	NA	shadscale	Indian ricegrass
G13		238	<3%	<1830	35-05-60	NA	winterfat	Indian ricegrass
G15		227	1%-18%	<2130	35-05-60	Utah juniper*	shadscale	Indian ricegrass
G14	rock outcrops common	206	1%->19%	<1830	30-05-65	NA	shadscale	galleta
S1	may replace wet meadows	2595	1%-6%	1830-2130	85-05-10	NA	basin big sagebrush	basin wildrye
S7		1453	<3%	1675-2130	50-05-45	NA	basin big sagebrush	basin wildrye
S4		487	1%-11%	1585-2130	50-05-45	NA	black sagebrush	Indian ricegrass
S8		477	4%-6%	1460-2130	50-05-45	Utah juniper*	Wyoming big sagebrush	Indian ricegrass
S5	contains rock outcrops and rare patches of pinyon-juniper woodlands	411	4%-18%	1770-2130	50-05-45	Utah juniper*	black sagebrush	Indian ricegrass
S10	contains desert pavement	390	1%-10%	1520-2130	50-05-45	Utah juniper*	black sagebrush	Indian ricegrass
S9		325	4%->19%	1580-2130	50-05-45	Utah juniper*	black sagebrush	needleandthread
S6	rock outcrops common	286	4%->19%	1585-2130	35-05-65	NA	black sagebrush	Indian ricegrass
M8		424	4%->19%	1825-2745	55-05-40	NA	black sagebrush	beardless wheatgrass
M6	contains pinyon-juniper woodlands and rock outcrops	384	4%->19%	1675-2900	44-06-50	singleleaf pinyon	black sagebrush	beardless wheatgrass
M11	rock outcrops common	337	4%->19%	1980-2740	60-05-35	NA	black sagebrush	beardless wheatgrass
M2	contains pinyon-juniper woodlands and rock outcrops	331	7%->19%	1740-2740	45-10-45	Utah juniper	black sagebrush	wheatgrass
M5	rock outcrops common	314	4%->19%	1585-2745	55-05-40	NA	black sagebrush	beardless wheatgrass
M3	pinyon-juniper woodlands and rock outcrops	286	7%->19%	1585-2500	35-05-60	Utah juniper	black sagebrush	bluebunch wheatgrass
M7	contains rock outcrops and rare patches of pinyon-juniper woodland	233	7%->19%	1585-2745	35-05-60	Utah juniper	littleleaf mtn mahogany	beardless wheatgrass
M9	pinyon-juniper woodlands and rock outcrops	219	4%->19%	1585-2500	30-10-60	singleleaf pinyon	black sagebrush	bluegrass

*invasive of succesional stages

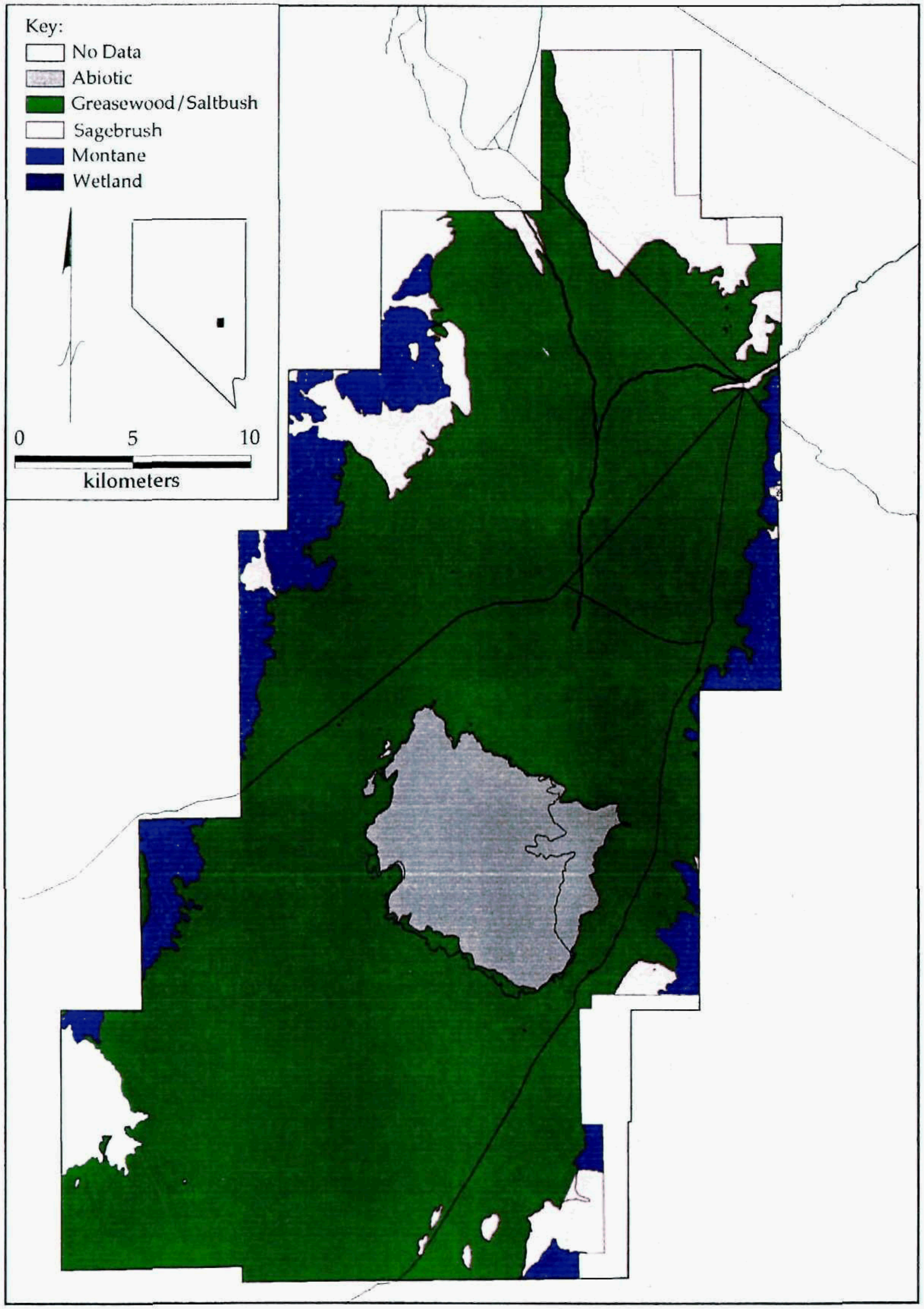

Figure 2. Distribution of habitats by primary plant association in Railroad Valley.

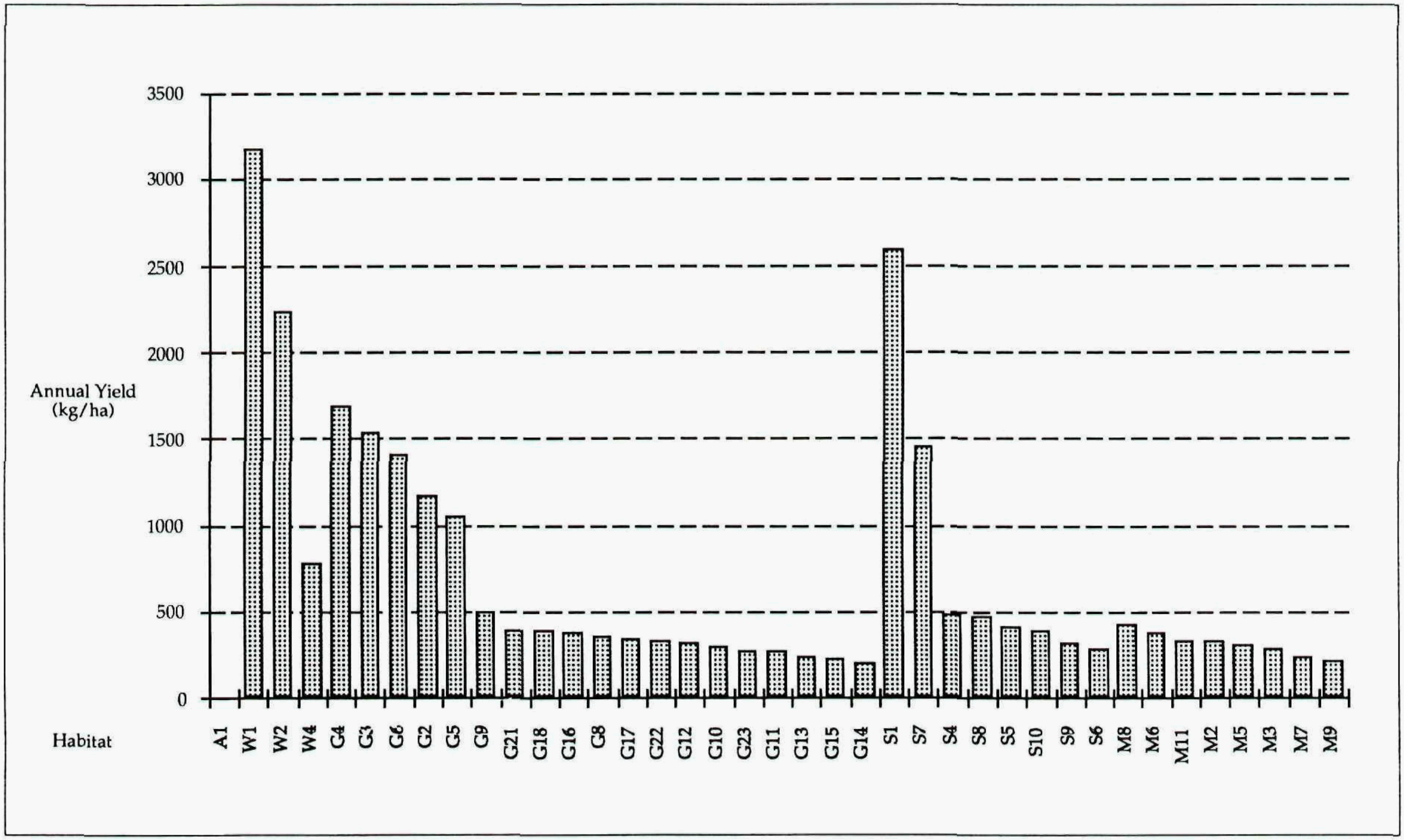

Figure 3. Total average yield of herbaceous growth (kg/ha) in Railroad Valley arranged by primary plant association.

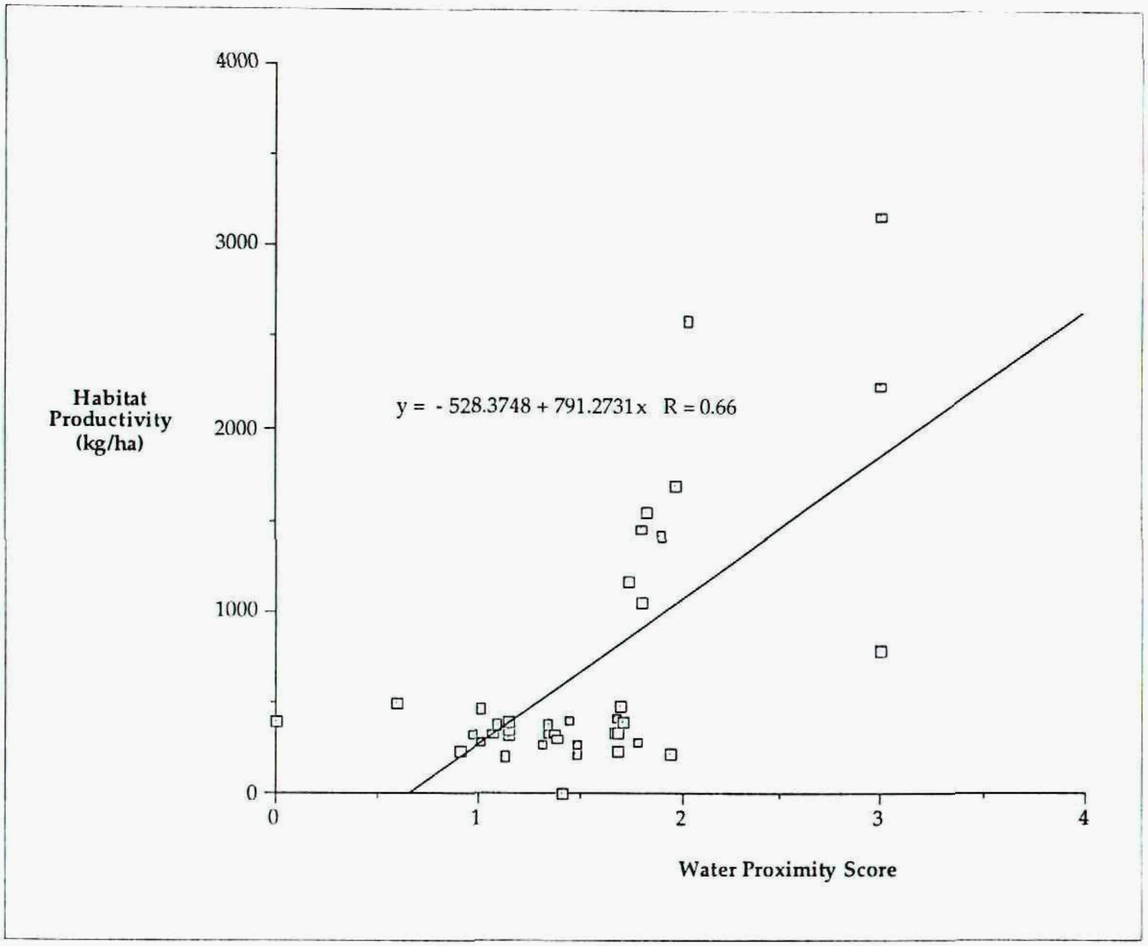

Figure 4. Habitat annual productivity versus proximity to water.

shallow lakes. Rapid evaporation of floodwater accumulates salts in playa sediments. Evaporation rates in Railroad Valley are sufficiently high whereas precipitation and surface runoff are sufficiently low, that such lakes rarely should persevere for longer than a season or so in modern Railroad Valley. However, moister climatic regimes of the Holocene and Late Pleistocene created longer-lasting lakes that surely hosted marshes with stands of cattail, creeping spikerush, and alkali bulrush (Weller 1986). Soil alkalinity, water depth, water turbulence, and seed bank size determine how readily playa lakes develop marsh vegetation. Excessively deep floodwaters retard establishment of marsh plants, but waters too shallow or intermittent fail to dilute soil salinity sufficiently for seed germination (Martin and Uhler 1951:118, 124-16; Weller 1981:56; Kaldec and Smith 1984). Turbulent water inhibits establishment of marsh vegetation (Martin and Uhler 1951:119-122). Finally, the status of dormant seed banks within playa sediments affects marsh development. Seeds from earlier marsh cycles can lie dormant for as long as 15 years, then germinate quickly when floodwaters return (Weller 1981:56). However, playas such as that in Railroad Valley, which have been arid for much longer periods, are depleted of seeds and must await revegetation by wind borne seeds (Kaldec and Smith 1984). This suggests that the infrequently inundated playa in Railroad Valley will develop a marsh wetland community only after prolonged flooding lasting at least several years.

Wetland Associations

Perennial water sources structure wetland habitats. Three wetland habitats occur in the Railroad Valley study area.

Habitat W1: Wet Meadow 8-12 inch Precipitation Zone - Wetland

This habitat occurs adjacent springs and seeps at elevations below 2285 m asl. More than 160 examples of this habitat occur around the numerous springs and seeps surrounding the Railroad Valley playa. Soils are poorly drained and gentle slopes rarely exceed 3%.

Vegetation is 85% grass and grass-like plants, 14% forbs, and 1% shrubs. Productivity is approximately 4400 kg/ha in good years, 3200 kg/ha in normal years, and 1600 kg/ha in poor years. Ground cover may approach 90%. Two separate range types often occur on this habitat: wetlands and wet meadows.

Wetlands occur in stable ponds surrounding springs, and in channels draining the run-off from springs. Such ponds may be 60 cm deep, and may range from a few square meters to almost 8 hectares in extent (Sigler and Sigler 1987:261-263). Emergent and submergent marsh vegetation characterize wetlands, with climax communities dominated by cattail, creeping spikerush, and alkali bulrush. Pioneer forbs and grass-like plants such as Baltic rush are common in successional wetland stages.

Wet meadows occur on soils that are flooded occasionally and remain moist year round. Sedges, rushes, and Nevada bluegrass dominate climax communities of wet meadows. Iris, cinquefoil, yarrow, willow, and rose will expand, and thistle, bluegrass, redtop, foxtail barley, and quackgrass will invade disturbed wet meadows. Prolonged drought will gully wet meadows and lead to replacement of wet meadow plants by drought tolerant vegetation.

The perennial water and vegetation of Habitat W1 are critical for antelope, ground squirrel, jackrabbit, waterfowl, and numerous small mammals, all of which are potential game for hunter-gatherers. Seven thermal springs host populations of Railroad Valley springfish. We assume that the thermal waters of modern springfish habitat precluded ethnohistoric hunter-gatherers from economically harvesting springfish as a food source. However, they may have been an attractive food for prehistoric hunter-gatherers during mesic interludes of the past, if shallow lakes flooded the springs and provided more extensive and easily accessible habitats for the springfish (cf. Grayson 1993: 185-188). Potential plant foods native to Habitat W1 include cattail, bulrush, spikerush, wild rose, bluegrass, meadow barley, iris, sedge, rush, dock, water plantain, and clover.

Habitat W2: Wet Meadow 16+ inch Precipitation Zone

Habitat W2 occurs within inset fans, and around springs and seeps above 2285 m asl. Thirteen examples of Habitat W2 occur in the foothills of the Grant, White Pine, and Pancake Ranges. Soils drain poorly, and the water table often rises to near surface in early spring. Periodic flooding may result from stream overflow or run-off, and ephemeral ponds may form in low-lying areas. Gentle slopes of less than 4% are typical. However, Habitat W2 is susceptible to gully erosion and lowered water tables under drought conditions.

Vegetation is about 80% grasses and grass-like plants, and 20% forbs with a trace of shrubs. Ground cover ranges from 60% to 85%. Annual herbaceous production ranges from 1350 kg/ha in poor years to

3350 kg/ha in favorable years. Sedge, Nevada bluegrass, and tufted hairgrass dominate this habitat, but forbs such as wild iris are common in disturbed areas. Dry meadow vegetation supplants the typical wet meadow vegetation after prolonged drought.

Plants in this habitat that may have lured prehistoric gatherers include bulrush, wild rose, wheatgrass, bluegrass, tufted hairgrass, rush, iris, spikerush, and sedge. Upland meadows associated with springs and seeps are critical to bighorn sheep, mule deer, and sage grouse habitat. They also attract antelope, jackrabbit, cottontail, ground squirrel, waterfowl, and a host of small mammals.

Habitat W4: Streambank 10-14 inch Precipitation Zone

This habitat occurs along banks of perennial streams and occasionally, within ephemeral streambed channels. It follows perennial Duckwater and Currant Creeks through the Railroad Valley study area. Although Soil Conservation Service description limits this community to between 1675 m and 2285 m asl, we traced it along the ephemeral lower reaches of the Duckwater Creek channel down to 1450 m asl. Slopes may be as steep as 15%, but grades between 2% and 8% are typical. Soils are well drained, deep alluvium. Overbank flooding frequently disrupts this habitat, producing a dynamic and variable vegetation community.

Typically, vegetation is about 40% grasses, 10% forbs, and 50% shrubs and trees. Ground cover ranges from 10% to 30%. Favorable year production exceeds 1000 kg/ha, but drops to 450 kg/ha in unfavorable years. The community is dominated by basin wildrye, basin big sagebrush, and rhizomatous wheatgrass. However, annual forbs and grasses, such as cheatgrass, will invade disturbed areas.

Plant resources available for gathering in this habitat include Anderson wolfberry, desert peachbrush, wild rose, basin wild rye, wheatgrass, Indian ricegrass, Nevada bluegrass, needleandthread, bottlebrush squirreltail, and alkali sacaton. Perennial riparian corridors are critical for mule deer habitat and attract antelope, bighorn sheep, rabbit, sage grouse, ground squirrel, and various small mammals.

Greasewood/Saltbush Associations

Habitats belong in this category if they are not directly associated with a perennial water source and their dominant shrub is shadscale, fourwing saltbush, greasewood, winterfat, or spiny hopsage. Indian ricegrass, alkali sacaton, and galleta are the most common grasses.

Habitat G4: Saline Bottoms and Meadows

This habitat occupies alluvial flats, fan skirts, and eolian deposits below 1675 m asl. The only example in the study area covers 6300 hectares at the toe of the Grant Range. Proximity to perennial water is an important characteristic, with over 96% of this parcel within 3 km of water sources such as Bullwhacker, Thorne, Willow, and Christian Springs. Slope rarely exceeds 3% in this habitat. Soils are a mixture of loamy alluvium and residuum derived from lacustrine sediments. Habitat G4 drains poorly, has a seasonally high water table, and floods periodically.

Vegetation is 80% grasses and grass-like plants, 7% forbs, and 13% shrubs, with ground cover ranging from 35% to 60%. Annual productivity ranges from 750 kg/ha to 2500 kg/ha. Alkali sacaton is widespread among patches of inland saltgrass and Baltic rush, and basin wild rye and greasewood.

Rush, saltgrass, greasewood, and rabbitbrush prosper in disturbed examples of this habitat, whereas thistle and annual forbs and grasses invade.

Because of forage, proximity to water, and gentle slope, Habitat G4 offers some of the best habitat in the study area for antelope and jackrabbit. It also hosts ground squirrel, waterfowl, and various small mammals. Harvestable plant foods include shadscale, Torrey quailbush, seepweed, basin wildrye, Nevada bluegrass, alkali saltgrass, inland saltgrass, sedge, thistle, dock, rush, and bottlebrush squirreltail.

Habitat G3: Saline Bottoms and Meadows with Sodic Dunes

This habitat is common on alluvial plains and eolian deposits. Two examples covering more than 20,000 hectares occur in central Railroad Valley: one north of the playa at the terminus of perennial Duckwater Creek, and the other south and west of the playa on the Hot Creek fan delta. Elevations are below 1675 m asl. More than 80% of this habitat occurs within 3 km of a perennial water source. Slopes never exceed 3% in the Railroad Valley study area. The physiographic landscape within this habitat is a mosaic of alluvium, lake sediments, partially stabilized sand dunes, and small playa basins. This habitat is subject to periodic flooding, and sand dunes may become active in arid conditions.

Annual production is about 680 kg/ha in unfavorable years, 1540 kg/ha in normal years, and 2270 kg/ha in favorable years. Vegetation composition is 70% grasses and grass-like plants, 10% forbs, and 20% shrubs. Ground cover ranges from 10% to 60%. Similar to Habitat G4, widespread alkali sacaton with patches of inland saltgrass and Baltic rush, and basin wild rye and greasewood are common. The *vegetation of Habitat G3 differs from G4 by virtue of the black greasewood, Indian ricegrass,* needleandthread, and fourwing saltbush growing on sand dunes. Rush, inland saltgrass, greasewood, rabbitbrush, and horsebrush expand while thistle and annual forbs and grasses invade when this habitat is disturbed.

Dunes and abundant grasses and forbs make this one of the best habitats in the study area for small rodents. It is also particularly good habitat for antelope because of gentle slope, proximity to water, and abundant shrub vegetation. Jackrabbit and ground squirrel should be common here. Shadscale, saltbush, seepweed, basin wildrye, Nevada bluegrass, thistle, inland saltgrass, alkali sacaton, and rush are potential plant foods in this habitat.

Habitat G6: Saline Bottom

Habitat G6 occupies one parcel of a little more than 1600 hectares north of the Railroad Valley playa and east of Trap Spring. It occurs on an alluvial flat below 1440 m asl that Lillquist (1994h) originally mapped as playa. All the area is less than 1% slope. Soils are silty clay loams that drain poorly and often flood for brief periods.

Vegetation is 75% grasses and grass-like plants, 5% forbs, and 20% shrubs, with ground cover of about 50%. Annual productivity ranges from 605 kg/ha to 2020 kg/ha. Basin wildrye, alkali sacaton, and greasewood are prolific among climax vegetation. Rabbitbrush dominates disturbed communities, whereas thistle and annual forbs and grasses invade.

This is among the best habitats in the study area for jackrabbit. It is also suitable for antelope, ground squirrel, and small mammals. Shadscale, saltbush, seepweed, basin wildrye, Nevada bluegrass, inland saltgrass, and alkali sacaton are harvestable plant foods.

Habitat G2: Saline Meadow and Sodic Flat

This habitat occurs on alluvial plains, fan skirts, and eolian deposits fringing the Railroad Valley playa; coppice dunes interspersed among small playa basins are featured. Elevations lie below 1450 m asl, slopes are less than 1% and seventy-three percent of more than 10,000 G2 hectares lie within 3 km of a water source. Soils are poorly drained silt loams derived from mixed lacustrine and eolian sediments. The water table of this habitat may rise seasonally to near surface, and flooding may result from stream overflow.

This habitat may produce as much as 1765 kg/ha in a good year and as little as 545 kg/ha in a poor year. Vegetation composition is 55% grasses, 35% shrubs, and 10% forbs, and ground cover ranges from 10% to 50%. Black greasewood, alkali sacaton, inland saltgrass, and Baltic rush dominate the climax community. Halogeton, cheatgrass, thistle, mustard, and other annual forbs and grasses invade this habitat when disturbed, whereas greasewood, saltgrass, and rush expand in successional stages.

The dunes, vegetation, and proximity to water of this habitat make it one of the best in the study area for small mammals. It also attracts antelope, jackrabbit, and ground squirrel. Plant foods that gatherers would find here include shadscale, saltbush, wolfberry, basin wildrye, Indian ricegrass, alkali sacaton, prince's plume, tansymustard, goosefoot, blazing star, sunflower, and ephedra.

Habitat G5: Saline Bottom and Sodic Terrace 5-8 inch Precipitation Zone

This habitat occupies about 2350 hectares of young alluvial fans and fan skirts southwest of the Railroad Valley playa. Eighty percent of this habitat occurs within 3 km of Warm Spring, Storm Spring, or Coyote Hole Spring. Elevations are below 1475 m and gentle slopes rarely exceed 3%. Soils are poorly drained sandy loam, silty clay loam, and gravely sand derived from alluvium. Rock outcrops occupy 1% of the area of this habitat, which has a seasonally high water table and floods from time to time.

Annual vegetation production is 585 kg/ha in poor years, 1055 kg/ha in normal years, and 1535 kg/ha in good years. Ground cover ranges from 10% to 60%. The vegetation community is 60% grasses, 35% shrubs, and 5% forbs. Shadscale, black greasewood, bud sagebrush, fourwing saltbush, Indian ricegrass, alkali sacaton, bottlebrush squirreltail, and basin wildrye are important components of the climax community. Shadscale and greasewood expand and rabbitbrush dominates in successional communities. Thistle, brome, and other annual forbs and grasses invade disturbed areas.

Gatherers find shadscale, saltbush, seepweed, wolfberry, basin wildrye, Nevada bluegrass, Indian ricegrass, inland saltgrass, bottlebrush squirreltail, ephedra, galleta, glasswort, alkali sacaton, and prince's plume in this habitat. Habitat G5 hosts antelope, jackrabbit, ground squirrel, and small mammals.

Habitat G9: Loamy Upland 5-8 inch Precipitation Zone

This habitat occupies five parcels in the southwest portion of the study area, south of the Pancake Mountains. Together, these parcels take up a little more than 4000 hectares of alluvial fans below 1830 m asl. Slopes may exceed 19%, but 1% to 11% grades are more common. More than 90% of this habitat lies more than 3 km from any perennial water source in the study area. Soils are gravely fine sands and gravely sandy loams derived from alluvium.

Annual vegetation production ranges from 225 kg/ha to 450 kg/ha, and is notably sensitive to summer convection storms that nurture growth of warm season grasses and forbs. Of total production, 55% are shrubs, 40% are grasses, and 5% are forbs. Ground cover ranges from 20% to 35%. The climax community contains spiny hopsage, Nevada ephedra, Indian ricegrass, galleta, and fourwing saltbush. Horsebrush, rabbitbrush, wolfberry, and galleta will increase and annuals such as brome grass will invade successional stages. Severely disturbed examples of this habitat become expanses of horsebrush and rabbitbrush with interspersed patches of annuals or galleta.

This habitat is moderately suitable for antelope and ground squirrel, but its remoteness from water makes it more hospitable for heteromyid rodents and jackrabbit. Shadscale, saltbush, Indian ricegrass, wolfberry, goosefoot, tansymustard, blazing star, sunflower, bottlebrush squirreltail, galleta, globemallow, and prince's plume are potential plant resources. Notably, Habitat G9 offers some of the highest densities of Indian ricegrass (110 to 160 kg/ha) found in the study area.

Habitat G21: Sandy 5-8 inch Precipitation Zone

Habitat G21 occurs on young alluvial fans capped by eolian sand. It occupies only a small parcel of 59 hectares in the southwest extreme of the study area, more than 10 km from any perennial water source. Slope is less than 3%.

The productivity of this habitat ranges from 225 kg/ha to 560 kg/ha, consisting of 70% grasses, 25% shrubs, and 5% forbs. Ground cover ranges between 10% and 25%. Vegetation includes Indian ricegrass, fourwing saltbush, sand dropseed, needleandthread, and winterfat. Nevada dalea, horsebrush, and rabbitbrush expand in disturbed examples, while Russian thistle and brome invade.

Remoteness from water and poor productivity make hunting an exceptionally poor prospect in this habitat, although a lucky hunter might encounter jackrabbit. Potential plant foods are saltbush, ephedra, wolfberry, galleta, Indian ricegrass, needleandthread, evening primrose, dalea, bottlebrush squirreltail, globemallow, and sand dropseed.

Habitat G18: Sodic Terrace 5-8 inch Precipitation Zone

This habitat covers 9700 hectares distributed among five parcels west and north of the Railroad Valley playa. It occupies alluvial flats, fan skirts, lake plain terraces, and stream terraces between 1436 m and 1675 m asl. Slopes never exceed 3%. Some areas of this habitat lie more than 10 km from any water source, but 72% occurs within 3 km of Trap Spring, Storm Spring, Coyote Head Spring, Warm Spring, and Reynolds Spring. Soils are well-drained loamy alluvium.

Herbaceous productivity ranges from 200 kg/ha to 725 kg/ha, but 395 kg/ha is typical. The community is 80% shrubs, 15% grasses, and 5% forbs; ground cover varies from 10% to 20%. Shadscale, black greasewood, bud sagebrush, fourwing saltbush, Indian ricegrass, and bottlebrush squirreltail are common. Disturbed examples of this habitat succumb to brome grass, annual mustard, shadscale, and greasewood.

Antelope, jackrabbit, and small mammals live in this habitat, although they should be rare compared to other habitats. Potential plant foods are shadscale, saltbush, wolfberry, ephedra, tansymustard, blazing star, goosefoot, sunflower, Indian ricegrass, basin wildrye, galleta, and bottlebrush squirreltail. This habitat offers the highest densities of shadscale (120 kg/ha) in the study area.

Habitat G16: Sodic Terrace and Sodic Dunes

This habitat occurs on alluvial plains containing partially stabilized sand dunes, between 1436 m and 1585 m asl. It occupies 14,500 hectares in the study area and is most extensive on the Hot Creek fan delta. Slopes never exceed 3%, and 67% of this habitat lies between 3 and 10 km from perennial water sources. Soils are loams derived from alluvium with dunes of sandy eolian sediment. Small playa pans also occur here.

Productivity ranges from 180 kg/ha to 700 kg/ha, providing between 10% and 20% ground cover. Vegetation composition is 75% shrubs, 20% grasses, and 5% forbs. Shadscale, black greasewood, Indian ricegrass, needleandthread, bottlebrush squirreltail, bud sagebrush, and fourwing saltbush are common. Successional stages have greater proportions of shadscale, greasewood, rabbitbrush, and horsebrush than the climax community, and may be invaded by thistle, cheatgrass, brome, and annual mustard.

Plants of interest to prehistoric gatherers are annual forbs and grasses, shadscale, saltbush, wolfberry, ephedra, basin wildrye, Indian ricegrass, needleandthread, bottlebrush squirreltail, dalea, alkali sacaton, and prince's plume. Lucky hunters might find antelope, rabbit, ground squirrel, and small mammals in this habitat.

Habitat G8: Sandy and Sandy Loam 5-8 inch Precipitation Zone

This habitat comprises about 3240 hectares in five parcels in the southwest portion of the Railroad Valley study area. It occupies young alluvial fans and inset fans below 1830 m asl and less than 3% slope. About 90% of this habitat lies within 10 km of a water source. A layer of eolian sands may cap the alluvial sandy loams of this habitat.

Annual herbaceous productivity ranges from 195 kg/ha to 490 kg/ha. Ground cover is between 10% and 25%. Grasses comprise 65% of the community, whereas the remainder is 30% shrubs and 5% forbs. The community includes Indian ricegrass, fourwing saltbush, dropseed, needleandthread, winterfat, spiny hopsage, bud sagebrush, and galleta. Successional communities include dalea, horsebrush, rabbitbrush, galleta, brome, Russian thistle, halogeton, and other annual forbs and grasses.

The habitat offers annual forbs and grasses, shadscale, saltbush, wolfberry, ephedra, yucca, Indian ricegrass, needleandthread, galleta, dropseed, bottlebrush squirreltail, and dalea to gatherers. Hunters may have found antelope, rabbit, ground squirrel, and small mammals.

Habitat G17: Sodic Terrace and Sodic Flat 5-8 inch Precipitation Zone

Habitat G17 occupies 11,300 hectares in seven parcels north and east of the Railroad Valley playa. It occurs on alluvial flats, fan skirts, lake plains, lake plain terraces, and stream terraces. Coppice dunes among small playa basins are featured. Elevations are between 1436 m and 1645 m asl, and slopes do not exceed 3%. Soils are alluvial silty or sandy loams. Almost all of this habitat lies within 10 km of water sources such as Trap Spring and Duckwater Creek.

Annual herbaceous production ranges from 650 kg/ha to 150 kg/ha. Composition is 80% shrubs, 15% grasses, and 5% forbs. Ground cover is between 10% and 20%. The community contains shadscale, black greasewood, Indian ricegrass, bottlebrush squirreltail, bud sagebrush, fourwing saltbush, and inland saltgrass. Shadscale and greasewood will increase in successional habitats, whereas brome grasses, annual mustard, halogeton, and cheatgrass invade disturbed areas.

Antelope, jackrabbit, ground squirrel, and small mammals occur in this habitat, but their rarity makes hunting prospects poor. Gatherable plant foods include tansymustard, goosefoot, sunflower, blazing star, shadscale, saltbush, wolfberry, seepweed, basin wildrye, Indian ricegrass, galleta, Nevada bluegrass, inland saltgrass, and prince's plume.

Habitat G22: Sandy Loam 5-8 inch Precipitation Zone

This habitat occupies a small parcel of 213 hectares on the west slope of the Pancake Range. Elevations are below 1675 m, and slopes usually range between 4 and 11%. It occurs in inset fans of lower piedmont slopes and on axial stream floodplains and terraces.

The vegetation community is 45% grasses, 5% forbs, and 50% shrubs, covering 15% to 25% of the ground surface. Annual productivity ranges from 165 kg/ha to 430 kg/ha. Fourwing saltbush, winterfat, Indian ricegrass, spiny hopsage, bud sagebrush, galleta, sand dropseed, and spike dropseed are common. Halogeton, thistle, and other annual forbs and grasses invade disturbed examples of this habitat, which are dominated by rabbitbrush and galleta.

This habitat offers poor hunting opportunities, although lucky hunters might encounter antelope, sheep, deer, rabbit, ground squirrel, and small mammals. Gatherers would find tansymustard, blazing star, goosefoot, sunflower, shadscale, wolfberry, ephedra, yucca, galleta, dropseed, needleandthread, bottlebrush squirreltail, globemallow, and Indian ricegrass.

Habitat G12: Loamy and Gravelly Loam 5-8 inch Precipitation Zone

This extensive habitat covers more than 49,000 hectares of alluvial fans and plains on the piedmonts of the White Pine, Grant, and Pancake Ranges and the upper Hot Creek fan. Elevation extends from 1436 m to 1980 m asl, but slopes rarely exceed 6%. Ninety-five percent of this habitat lies within 10 km of a water source. Soils are moderately well drained gravelly loam and alluvium.

Annual herbaceous productivity ranges from 160 kg/ha to 460 kg/ha and is about 55% shrubs, 40% grasses, and 5% forbs. Vegetation ground cover is between 15% and 25%, but small patches of barren playa and desert pavement occur here and there. The climax community includes shadscale, greasewood, bud sagebrush, Indian ricegrass, galleta, winterfat, and bottlebrush squirreltail. Shadscale, greasewood, rabbitbrush, horsebrush, wolfberry, and galleta do well in successional stages, whereas halogeton, Russian thistle, cheatgrass, and annual mustard invade disturbed areas.

This habitat offers only moderate prospects for hunting antelope, rabbit, ground squirrel, and small mammals. Potential plant foods include annual grasses and forbs, shadscale, wolfberry, ephedra, galleta, Indian ricegrass, bluegrass, kochia, alkali sacaton, bottlebrush squirreltail, and prince's plume.

Habitat G10: Loamy 5-8 inch Precipitation Zone
and Shallow Calcareous Loam 8-12 inch Precipitation Zone

This habitat occupies 3300 hectares on alluvial fans and piedmont slopes overlooking Currant Creek and near Ox Spring Wash. All of this area lies within 10 km of a water source. Slopes range between 1% and 18%, but slopes between 4% and 11% are most common. Elevations range from 1436 m to 2130 m asl. Soils are very gravelly alluvium often derived from limestone.

The vegetation community is 55% shrubs, 40% grasses, and 5% forbs. Ground cover ranges from 15% to 30%, but barren patches may occur on occasional rock outcrops and desert pavements. Annual productivity is 135 kg/ha in poor years, 295 kg/ha in normal years, and 470 kg/ha in good years. Shadscale, bud sagebrush, and bottlebrush squirreltail thrive at lower elevations of this habitat, whereas black sagebrush, fourwing saltbush, ephedra, and needleandthread are more common at higher elevations. Indian ricegrass, galleta, and winterfat grow throughout. Shadscale, sagebrush, rabbitbrush, horsebrush, wolfberry, spiny hopsage, and galleta thrive in successional communities that may also contain intrusive halogeton, Russian thistle, cheatgrass, and annual mustard. Notably, Utah juniper may invade upper elevations of this habitat.

This habitat offers moderate hunting opportunities for antelope, deer, rabbit, and ground squirrel. Patches of spiny hopsage are likely to mark rodent burrows. Gatherers would find annual forbs and grasses, shadscale, saltbush, ephedra, juniper, wolfberry, yucca, galleta, needleandthread, Indian ricegrass, bottlebrush squirreltail, globemallow, and prince's plume in this habitat.

Habitat G23: Gravelly Loam 5-8 inch Precipitation Zone

This habitat occupies more than 1900 hectares in Duckwater Valley, in the northwest portion of the study area. The habitat occurs on alluvial fan slopes at elevations between 1436 m and 1830 m asl. Slopes between 1 and 6% are most common, but may exceed 12%. All of this habitat occurs within 10 km of Duckwater Creek.

Annual herbaceous production ranges from 135 kg/ha to 395 kg/ha. The community is 55% shrubs, 40% grasses, and 5% forbs, covering between 15 and 25% of the ground surface. Bailey's greasewood, shadscale, and Indian ricegrass dominate, but galleta and bud sagebrush are common. Greasewood, shadscale, and galleta expand in successional stages, and halogeton, cheatgrass, Russian thistle, and annual mustard invade.

Hunters may encounter deer, sheep, rabbit, ground squirrel and various small mammals in Habitat G23. It offers annual forbs and grasses, shadscale, saltbush, ephedra, wolfberry, galleta, Indian ricegrass, needleandthread, sand dropseed, kochia, globemallow, bottlebrush squirreltail, and prince's plume to gatherers.

Habitat G11: Loamy 5-8 inch Precipitation Zone

Habitat G11 occurs on alluvial fans and piedmont slopes of the Grant and Pancake Ranges in the southern part of the Railroad Valley project area. It covers 11,380 hectares, almost all within 10 km of a water source. Slopes may exceed 11%, but those less than 6% are typical. Soils are gravelly loam alluvium derived from limestone and dolomite. Elevations lie between 1436 m and 1980 m asl.

The habitat is 60% shrubs, 35% grass, and 5% forbs. Ground cover is 15 to 25%, amid occasional patches of desert pavement. Annual productivity can be as low as 100 kg/ha in a poor year, but exceeds 400 kg/ha under more favorable circumstances. Climax communities are dominated by shadscale, bud sagebrush, and Indian ricegrass, with frequent occurrences of galleta, winterfat, and bottlebrush squirreltail. Successional communities are dominated by shadscale, rabbitbrush, horsebrush, wolfberry, and galleta. Halogeton, Russian thistle, cheatgrass, and annual mustard are frequent invaders of disturbed areas.

Potential foods for prehistoric gatherers are annual forbs and grasses, shadscale, saltbush, ephedra, wolfberry, galleta, Indian ricegrass, needleandthread, bottlebrush squirreltail, globemallow, dropseed, and prince's plume. Prey for hunters would include antelope, rabbit, ground squirrel, and small mammals, although prospects for hunting success should be only fair.

Habitat G13: Silty and Coarse Silty 5-8 inch Precipitation Zone

Habitat G13 occurs on alluvial fan piedmonts and inset fans associated with Currant Creek, Big Wash, and Bull Creek. It occupies more than 3780 hectares, all within 10 km of a water source, and all of 3% or less slope. Elevations are between 1436 m and 1830 m asl.

Annual productivity ranges from 95 kg/ha to 395 kg/ha. Community composition is 60% shrubs, 35% grass, and 5% forbs. Ground cover ranges from 10% to 20%. The community is dominated by winterfat and Indian ricegrass, and galleta, bud sagebrush, bottlebrush squirreltail, and fourwing saltbush are common. Galleta rabbitbrush, shadscale, and purple threeawn will thrive in successional habitats. Invasive annuals include Russian thistle, cheatgrass, halogeton, blazing star, tansymustard, and goosefoot. This habitat is notable because annuals may come to dominate disturbed areas; almost pure stands of tansymustard occur on disturbed examples of this habitat in the Duckwater drainage, north of the study area (Blackburn et al. 1968:32-33).

Potential plant foots include tansymustard, blazing star, goosefoot, sunflower, shadscale, saltbush, ephedra, wolfberry, galleta, Indian ricegrass, needleandthread, dalea, bottlebrush squirreltail, globemallow, dropseed, and prince's plume. Lucky hunters might come across antelope, jackrabbit, ground squirrel, and small mammals.

Habitat G15: Sodic Hill 5-8 inch Precipitation Zone and Shallow Calcareous Loam 8-12 inch Precipitation Zone

This habitat occurs in eight discrete parcels in Duckwater Valley and Ike Spring Wash, on summits and slopes of low hills and fan piedmonts between 1436 m and 2130 m asl. Of 885 hectares in the study area, 86% are between 4% and 18% slope, and all are within 10 km of perennial water. Soils are often residuum of basaltic rock and volcanic cinder deposits.

Annual herbaceous productivity ranges from 95 kg/ha to 365 kg/ha, covering between 10% and 30% of the ground surface. Community composition is 60% shrubs, 35% grass, and 5% forbs. Shadscale dominates at lower elevations, whereas sage becomes more common higher up. Indian ricegrass, needleandthread, galleta, winterfat, ephedra, bud sagebrush, and fourwing saltbush are common. Sage, rabbitbrush, shadscale, horsebrush, and greasewood expand in successional communities. Occasional patches of spiny hopsage characteristically betray disturbance resulting from rodent burrowing. Brome, annual mustard, halogeton, and cheatgrass can invade disturbed areas. Utah juniper may expand into upper elevations.

Hunting opportunities are poor in Habitat G15, but hunters feasibly could encounter antelope, sheep, deer, rabbit, and small mammals. Gatherers could harvest annual forbs and grasses, shadscale, saltbush, ephedra, juniper, wolfberry, yucca, Indian ricegrass, bluegrass, needleandthread, dalea, bottlebrush squirreltail, globemallow, and prince's plume.

Habitat G14: Sodic Hill 5-8 inch Precipitation Zone

Habitat G14 occupies 3400 hectares distributed among 29 parcels, mostly in the southwest portion of the study area. The habitat occurs on summits and slopes of low hills, with slopes ranging from 4% to

18%, and elevations between 1436 m and 1830 m asl. Soils are gravely loams composed of residuum of volcanic rocks and lacustrine sediments. Rock outcrops are a common feature of this habitat. Most of this habitat lies within 10 km of perennial water, but 24% occurs more than 10 km from any water source in the study area.

Annual productivity ranges from 95 kg/ha to 380 kg/ha, and is 65% shrubs, 30% grasses, and 5% forbs. Ground cover is between 10 and 20%. Shadscale, galleta, and Indian ricegrass dominate climax vegetation communities that also contain bud sagebrush and winterfat. Shadscale, rabbitbrush, horsebrush, and greasewood increase in successional stages, which may be invaded by brome grass, mustard, and halogeton.

Food items in Habitat G14 include annual grasses and forbs, shadscale, saltbush, ephedra, wolfberry, galleta, Indian ricegrass, needleandthread, dalea, bottlebrush squirreltail, globemallow, and prince's plume. Hunting opportunities are relatively poor, although antelope, sheep, deer, rabbit, and small mammals may occur. Numerous rock outcrops afford relatively good habitat for woodrat.

Sagebrush Associations

Habitats classify to Sagebrush Associations when their dominant shrub is sagebrush and they are not tied to a perennial water source. Dominant grass is usually Indian ricegrass, although wild rye and needleandthread are occasionally dominant. Sagebrush dominated communities tend to occupy alluvial fans and lower mountain slopes above 1525 m elevation, a boundary determined by preference of sagebrush for precipitation of more than 15 cm per year (Billings 1945:18; Cronquist et al. 1986:90).

Habitat S1: Loamy Bottom 10-14 inch Precipitation Zone

Habitat S1 covers 144 hectares distributed among three parcels in the northeast portion of the study area. The habitat occurs in axial stream floodplains and inset fans, all within 3 km of Currant Creek. Slopes are between 1 and 3%, and elevations between 1830 and 2130 m asl. This habitat has a seasonally high water table and may be flooded periodically by stream overflow. It is prone to periods of drought and susceptible to gullying when the water table falls. Falling or rising water table cause significant fluctuations in herbage production. Habitat S1 will replace wet meadow and riparian communities that become entrenched.

Annual production ranges from 1430 kg/ha to 5610 kg/ha and ground cover ranges from 30% to 50%. Community composition is 85% grasses, 10% shrubs, and 5% forbs. Basin wild rye dominates this community, but big sage and rabbitbrush expand in successional stages. Cheatgrass, thistle, and annual mustard invade disturbed areas.

This habitat offers gatherers the richest patches of basin wild rye and wheatgrass in the study area. Other plant foods available for harvest in Habitat S1 are Nevada bluegrass, basin big sagebrush, sedge, rush, and mat muhly. Hunting opportunities are excellent. Habitat S1 is among the best in the study area for antelope, ground squirrel, sage grouse, and small mammals. Hunters might also encounter deer, sheep, and rabbit.

Habitat S7: Loamy Bottom 10-14 inch Precipitation Zone, Sodic Terrace 8-10 inch Precipitation Zone, and Deep Sodic Fan

Habitat S7 occupies 584 hectares distributed among five parcels on fan skirts on the edge of Ox Spring Wash, and inset fans and axial stream floodplains associated with Duckwater Creek. Slopes are 3% or less, and all the parcels occur within 10 km of perennial water. Elevations are between 1675 m and 2130 m asl. The habitat drains poorly, has a seasonally high water table, and floods periodically.

Annual herbaceous productivity ranges from 905 kg/ha to 2570 kg/ha and is 50% grasses and grass-like plants, 45% shrubs, and 5% forbs. Ground cover ranges from 10% to 50%. Basin big sagebrush, basin wildrye, black greasewood, and Torrey quailbush dominate climax communities. Successional communities are vulnerable to invasion by cheatgrass, mustard, halogeton, and Russian thistle, while fostering expansion of big sagebrush, greasewood, and rabbitbrush.

Habitat S7 attracts antelope, jackrabbit, ground squirrel, sage grouse, and small mammals, offering excellent prospects for hunters. Plant foods available for harvest are shadscale, saltbush, buffaloberry, basin wild rye, wheatgrass, Nevada bluegrass, Indian ricegrass, sagebrush, sedge, rush, mat muhly, and prince's plume.

Habitat S4: Shallow Calcareous Loam and Sandy Loam 8-12 inch Precipitation Zone

Habitat S4 occurs in seven discrete parcels totaling 4450 hectares. These parcels occur on the summits, slopes, and inset fans of fan piedmonts near Ox Spring Wash, Ike Spring Wash, Wood Canyon, and Duckwater Valley. Soils are gravelly and sandy loam alluvium, often derived from limestone and dolomite. Slopes can exceed 18%, but 4 to 11% slope is typical. All of this habitat occurs within 10 km of a water source. Elevations range from 1585 m to 2130 m asl.

Annual productivity can be as low as 215 kg/ha or as high as 825 kg/ha. The community is 50% grasses, 45% shrubs, and 5% forbs. Ground cover ranges from 15 to 30%. Wyoming big sagebrush, black sagebrush, Indian ricegrass, needleandthread, desert needlegrass, bud sagebrush, winterfat, galleta, ephedra, and fourwing saltbush are common. Big sagebrush, rabbitbrush, and galleta expand in successional communities, whereas annual mustard and cheatgrass invade disturbed areas. Small patches of spiny hopsage mark rodent burrows. Utah juniper will expand into the upper elevations of this habitat.

Habitat S4 is suitable for antelope, deer, bighorn sheep, rabbit, ground squirrel, sage grouse, and small mammals, making it a good patch for hunters. Gatherers can harvest annual forbs and grasses, shadscale, saltbush, ephedra, juniper, wolfberry, prickly pear, yucca, galleta, Indian ricegrass, Nevada bluegrass, needleandthread, needlegrass, sagebrush, bottlebrush squirreltail, globemallow, dropseed, and prince's plume.

Habitat S8: Loamy 8-10 inch Precipitation Zone and Shallow Calcareous Loam 8-12 inch Precipitation Zone

Habitat S8 occurs on a single parcel of 18 hectares of fan piedmonts, rock pediments, and low rolling hills in the Pancake Mountains. Slopes are between 4% and 11%, whereas elevations range from 1460 m to 2130 m asl. All the habitat lies within 10 km of water source.

Annual herbaceous productivity ranges from 265 kg/ha to 725 kg/ha, with 475 kg/ha typical of normal years. The vegetation community is 50% grass, 45% shrubs, and 5% forbs. Ground cover ranges from 15 to 30%. Wyoming big sagebrush, black sagebrush, Indian ricegrass, and needleandthread dominate the community. Galleta, winterfat, ephedra, and fourwing saltbush are common at lower elevations. Sagebrush and rabbitbrush increase, and shadscale and galleta may dominate successional stages. Patches of spiny hopsage thrive on rodent burrows. Cheatgrass, mustard, and other annual forbs and grasses invade disturbed areas. Notably, Utah juniper can invade and dominate this habitat if overstory canopies overwhelm understory vegetation.

Habitat S8 offers poor to moderate habitat for sheep, deer, antelope, rabbit, ground squirrel, and small mammals. Plants of economic importance include annual forbs and grasses, shadscale, saltbush, juniper, wolfberry, yucca, galleta, Indian ricegrass, bluegrass, needleandthread, sagebrush, bottlebrush squirreltail, globemallow, and prince's plume.

Habitat S5: Shallow Calcareous Loam 8-12 inch Precipitation Zone

This habitat occurs in 15 discrete parcels scattered about the Pancake and White Pine Ranges. It occurs on piedmont slopes of fans and hills. Slopes are between 4% and 18%, and elevations range from 1770 m to 2130 m asl. Soils are very gravelly sandy loam alluvium, and rock outcrops are common. Altogether, this habitat takes up 1850 hectares, 80% of which lies within 10 km of a perennial water source.

Annual herbaceous productivity ranges from 110 kg/ha to 785 kg/ha, of which 50% are grasses, 45% shrubs, and 5% forbs. Ground cover is between 20% and 30%. Black sagebrush, Indian ricegrass, and needleandthread dominate the climax community, which also contains abundant galleta, winterfat, ephedra, and fourwing saltbush. Black sagebrush, rabbitbrush, shadscale, galleta, cheatgrass, annual mustard, and Utah juniper are typical of successional communities. Isolated patches of pinyon-juniper woodlands (< 4%) may occur within the habitat.

Habitat S5 offers poor to moderate habitat for sheep, deer, antelope, rabbits, ground squirrel, sage grouse, and small mammals. However, the occurrence of rock outcrops and woodlands offers excellent habitat for woodrat. Shadscale, saltbush, annual forbs and grasses, ephedra, juniper, yucca, galleta, Indian ricegrass, bluegrass, needleandthread, bottlebrush squirreltail, globemallow, and prince's plume are available for harvest in this habitat.

Habitat S10: Shallow Calcareous Loam 8-12 inch Precipitation Zone, Coarse Silty and Loamy 5-8 inch Precipitation Zone

This habitat occupies one parcel of 9630 hectares in the northern portion of the study area. It is a mosaic of fan piedmonts, rock pediments, and inset fans at the foot of the White Pine Range. Slopes range between 1 and 11%, and elevations extend from 1520 m to 2130 m asl. All of this habitat is within 10 km of perennial water.

The plant community of Habitat S10 is 50% grasses, 45% shrubs, and 5% forbs. Ground cover varies from 10% to 30% and annual herbaceous productivity ranges from 225 kg/ha to 610 kg/ha. Big sagebrush, Indian ricegrass, needleandthread, galleta, winterfat, ephedra, fourwing saltbush, bud sagebrush, and bottlebrush squirreltail are common. Shadscale, rabbitbrush, horsebrush, wolfberry, galleta, and big sagebrush become more common in successional stages. Halogeton, Russian thistle, cheatgrass, and annual mustard are common invasive plants. Utah juniper invades higher elevations.

Offering only poor to moderate quality habitat for antelope, sheep, deer, rabbit, ground squirrel, sage grouse, and small mammals, Habitat S10 should only occasionally attract hunters. Gatherers would find annual forbs and grasses, shadscale, saltbush, ephedra, juniper, wolfberry, yucca, galleta, Indian ricegrass, needleandthread, bluegrass, sagebrush, bottlebrush squirreltail, globemallow, and prince's plume.

Habitat S9: Shallow Calcareous Loam 8-12 inch Precipitation Zone, and Loamy Slope 8-10 inch Precipitation Zone

Habitat S9 occurs on three parcels totalling 2730 hectares in the Pancake Mountains, in the northwest portion of the study area. It occupies summits and slopes of fan piedmonts, rock pediments, and hills between 1580 m and 2130 m asl. Slopes are usually between 4 and 18%, but 18% of the area exceeds 19% slope. The habitat occurs between 3 km and 10 km of perennial water.

Annual productivity can be 135 kg/ha in poor years, 325 kg/ha in normal years, and 515 kg/ha in favorable years. Ground cover ranges from 15% to 30%. The plant community is 50% grasses, 45% shrubs, and 5% forbs. Black sagebrush, Wyoming big sagebrush, Indian ricegrass, and needleandthread dominate the climax community, but galleta, winterfat, ephedra, and fourwing saltbush are common. Sagebrush and rabbitbrush expand in successional stages, but shadscale and galleta come to dominate. Annual forbs and grasses, and Utah juniper invade.

Habitat S9 is poor habitat for antelope, rabbit, sage grouse, and ground squirrel, but moderately suitable for deer, sheep, and small mammals. Available plant foods are annual forbs and grasses, shadscale, saltbush, ephedra, juniper, yucca, galleta, Indian ricegrass, needleandthread, bluegrass, sagebrush, bottlebrush squirreltail, globemallow, and prince's plume.

Habitat S6: Shallow Calcareous Slope 8-12 inch Precipitation Zone

This habitat occurs in 14 parcels on summits and slopes of mountain foothills and rock pediments in the Grant Range. Altogether these parcels take up 1140 hectares, and all 14 parcels lie within 10 km of a water source. Elevations range from 1585 m to 2130 m asl. Slopes range from 4% to greater than 19%, but 7% to 18% slopes are typical. Rock outcrops are common in this habitat.

Annual herbaceous productivity can be as low as 95 kg/ha in a poor year, but as much as 475 kg/ha in a good year. The vegetation community is 60% shrubs, 35% grasses, and 5% forbs. Ground cover is 15% to 20%. Black sagebrush, needleandthread, Indian ricegrass, galleta, and ephedra are common in the climax stage of this habitat. Sagebrush and rabbitbrush prosper in successional communities, but intermediate stages may be dominated by shadscale and galleta. Annual mustard, cheatgrass, and Utah juniper invade disturbed areas.

Hunting opportunities are good for sheep, deer, and woodrat, but poor to moderate for antelope, rabbit, ground squirrel, sage grouse, and small rodents. Plant resources are annual forbs and grasses, shadscale, saltbush, ephedra, juniper, wheatgrass, galleta, Indian ricegrass, bluegrass, needleandthread, sagebrush, bottlebrush squirreltail, globemallow, and prince's plume.

Montane Associations

Habitats are montane if their distributions are above 2130 m elevation. Montane associations in the Railroad Valley study area often support pinyon-juniper woodlands with understories usually dominated by black sagebrush and beardless wheatgrass. However, littleleaf mountain mahogany, bluebunch wheatgrass, and bluegrass occasionally dominate the understory.

Habitat M8: Loamy Slope and Shallow Calcareous Slope 12-14 inch Precipitation Zone

Two patches of Habitat M8 occur in the Railroad Valley study area, one in the Pancake Mountains and one in the Grant Range. Together these two parcels total 2270 hectares, and both occur within 10 km of a water source. Elevations extend from 1825 m to 2745 m asl, slopes typically are between 7% and 19%. The habitat occurs on slopes and summits of mountains, hills, and rock pediments, frequently on soils derived from volcanic material.

Annual herbaceous production ranges from 295 kg/ha to 670 kg/ha. Ground cover is 15% to 35%. The community is 55% grasses, 40% shrubs, and 5% forbs; it lacks an overstory woodland. Black sagebrush is more likely to dominate northerly exposures whereas Wyoming big sagebrush is more common elsewhere. Beardless wheatgrass, Indian ricegrass, galleta, ephedra, and Stansbury cliffrose are common. Sagebrush, rabbitbrush, galleta, and annual forbs and grasses are likely in successional communities.

Habitat M8 attracts deer and bighorn sheep, but is of poor to moderate value for antelope, rabbit, ground squirrel, sage grouse, and small mammals. Plants available for harvest include annual forbs and grasses, wheatgrass, ephedra, galleta, Indian ricegrass, bluegrass, needlegrass, sagebrush, goldenweed, and bottlebrush squirreltail.

Habitat M6: Shallow Calcareous Slope and Hill 10-14 inch Precipitation Zone, Pinyon Juniper Woodland

Two parcels of Habitat M6, totaling 3440 hectares, occur in the Pancake Mountains, near the headwaters of Ike Spring Wash. The habitat occurs on summits and slopes of hills and mountains with soils of gravely, cobbly, or stony loam derived from volcanic and granitic rocks. Rock outcrops are common. Elevation ranges from 1675 m to 2900 m asl. Slopes can be as gentle as 1% and can exceed 19%, but 61% of the habitat in the study area lies between 7% and 18% slope. Ninety percent of the habitat lies within 3 km of a perennial water source.

The landscape of Habitat M6 is a mosaic of open sagebrush, sparse juniper woodland, and well-developed pinyon-juniper woodland. Understory production ranges from 225 kg/ha to 600 kg/ha in a year, and is 50% shrubs, 44% grasses, and 6% forbs. Ground coverage of both understory and overstory vegetation ranges between 10% and 35%. Black sagebrush, beardless wheatgrass, Stansbury cliffrose, ephedra, Indian ricegrass, muttongrass, and bluegrass are common understory plants. Although distributed in patches of higher density, the habitat as a whole should bear between five and nine trees per hectare. The majority (50% to 70%) of the woodland should be singleleaf pinyon. Woodlands are particularly vulnerable to periodic wildfires that open up the understory for explosive herbaceous growth. Rabbitbrush, black sagebrush, snakeweed, and annual forbs and grasses should thrive in such disturbed, open areas.

Steep slopes, proximity to water, and forage quantity make this good habitat for mule deer, bighorn sheep, and small rodents. Mule deer are particularly fond of ecotones between open sage and woodland. Antelope may also range seasonally in the habitat, despite its excessive slope. Rock outcrops provide good habitat for woodrat and marmot. Other game are small mammals, sage grouse, rabbit, and ground squirrel. Harvestable plant foods in Habitat M6 are annual forbs and grasses, shadscale, saltbush, pinyon, juniper, ephedra, prickly pear, wheatgrass, Indian ricegrass, needlegrass, goldenweed, and bottlebrush squirreltail. Woodlands in Habitat M6 produce between 100 kg/ha and 150 kg/ha of pinyon nuts in favorable years.

Habitat M11: Shallow Calcareous Slope 12-14 inch Precipitation Zone

Habitat M11 occurs in three discrete parcels in the northern Grant Range and northern Pancake Range. Altogether, these parcels total 1060 hectares, 82% of which exceed 7% slope. All three parcels fall within 10 km of perennial water. This habitat occupies the summits and slopes of mountains between 1980 m and 2740 m asl. It favors cool northerly aspects, particularly at lower elevations, and soil formed from volcanic parent materials. Rock outcrops are common (15%).

Annual herbaceous productivity ranges from 100 kg/ha to 560 kg/ha. Vegetation is 60% grasses, 35% shrubs, and 5% forbs; no overstory tree canopy is present. Ground cover ranges from 15% to 35%. Black sagebrush and beardless wheatgrass dominate climax vegetation, whereas rabbitbrush and annual forbs and grasses find successional communities hospitable.

Habitat M11 is of moderate quality for mule deer, bighorn sheep, marmot, woodrat, ground squirrel, and small mammals, and poor for antelope, rabbit, and sage grouse. Annual forbs and grasses, saltbush, ephedra, wheatgrass, galleta, Indian ricegrass, bluegrass, needleandthread, goldenweed, and bottlebrush squirreltail are indigenous edible plants.

Habitat M2: Pinyon Juniper Woodland, Shallow Calcareous Slope 12-14 inch Precipitation Zone

This habitat occurs in ten areas of the Pancake and Grant Ranges, occupying 4040 hectares. It occurs on mountain slopes and summits, on all exposures, often on volcanic soils. Steep slopes are characteristic, with 65% exceeding 19% slope; not surprisingly, rock outcrops are common (10%). Elevations range from 1740 m to 2740 m asl. All the habitat within the study area lies within 10 km of perennial water.

Annual herbaceous productivity of the understory vegetation ranges from 215 kg/ha to 565 kg/ha, with ground cover between 15% and 35%. The composition of the understory is 45% grasses, 45% shrubs, and 10% forbs. Approximately 45% of this habitat is wooded with overstory canopies of 20% to 35%. Altogether, this habitat will bear between three and six trees per acre, with pinyon comprising a little less than half the community. Common understory plants are black sagebrush, wheatgrass, bluegrass, Thurber needlegrass, and Indian ricegrass. Rabbitbrush, black sagebrush, and annual forbs and grasses proliferate in disturbed and successional areas.

Edible plants include annual forbs and grasses, arrowleaf balsamroot, pinyon, juniper, serviceberry, ephedra, wheatgrass, Indian ricegrass, bluegrass, Thurber needlegrass, galleta, tapertip hawksbeard, goldenweed, and bottlebrush squirreltail. In favorable years, woodlands produce between 75 kg/ha and 150 kg/ha of pinyon nuts. Habitat M2 offers excellent circumstances for mule deer, marmot, woodrat, and small mammals, and is moderately favorable for bighorn sheep, rabbit, and sage grouse.

Habitat M5: Shallow Calcareous Slope 12-14 inch Precipitation Zone and Shallow Calcareous Loam 8-12 inch Precipitation Zone

Habitat M5 occupies 3300 hectares in the south Pancake Range and north Grant Range. It occurs on summits and slopes of fan piedmonts, hills, and lower mountains; it is particularly fond of northerly aspects at lower elevations. Its elevation ranges from 1585 m to 2745 m asl, on steep slopes that usually (96%) exceed 7% grades. Examples of this habitat are usually (93%) within 10 km of a perennial water source. Soils in the study area are very gravely fine sandy loams, composed of residuum and colluvium derived from volcanic rock. Rock outcrops take up 15% to 30% of Habitat M5.

Annual herbaceous productivity is 315 kg/ha in a normal year, but can be as low as 180 kg/ha and as high as 550 kg/ha. Lacking an overstory canopy of trees, Habitat M5 is 55% grass, 40% shrubs, and 5% forbs. Ground cover ranges from 15% to 35%. Black sagebrush, Indian ricegrass, beardless wheatgrass, and needleandthread dominate the climax habitat; galleta, winterfat, ephedra, and fourwing saltbush are common at lower elevations. Black sage, rabbitbrush, and annual forbs and grasses prosper in successional communities. Shadscale and galleta may dominate successional stages at lower elevations whereas Utah juniper may invade higher elevations.

This is excellent habitat for mule deer, woodrat, and marmot; fair habitat for sheep and rabbit. Small mammals, sage grouse, and antelope may also occur in Habitat M5, although they should not be common. Harvestable plants include annual forbs and grasses, shadscale, saltbush, juniper, ephedra, yucca, wheatgrass, Indian ricegrass, bluegrass, needleandthread, goldenweed, bottlebrush squirreltail, galleta, and prince's plume.

Habitat M3: Pinyon-Juniper Woodland

Habitat M3 occupies two small parcels of 56 hectares total in the Grant and White Pine Ranges. It occurs on mountain slopes, summits, and crests on all exposures, on slopes that often exceed 19% grade (67%), and elevations between 1585 m and 2500 m asl. Both parcels in the study area occur within 10 km of a perennial water source. Soils are often formed in residuum derived mainly from limestone or dolomite bedrock.

An overstory canopy of 20% to 35% is typical of this habitat. With this coverage of trees, understory herbaceous production ranges from 190 kg/ha to 480 kg/ha. However, natural wildfires open the tree canopy and accelerate understory production to 340 kg/ha to 1100 kg/ha. In contrast, over-mature woodlands with closed canopies produce as little as 85 kg/ha of understory growth. The understory is 50% shrubs, 35% grasses, and 5% forbs. Black sagebrush, bluebunch wheatgrass, bluegrass, Thurber needlegrass, and Indian ricegrass are common in the understory. The overstory bears 13 to 26 trees per hectare, of which about 40% are pinyon and the remainder are Utah Juniper.

Habitat M3 is excellent for mule deer, sheep, wood rat, marmot, and small mammals. Edible plants are arrowleaf balsamroot, pinyon, juniper, serviceberry, ephedra, wheatgrass, Indian ricegrass, bluegrass, tapertip hawksbeard, and bottlebrush squirreltail. Habitat M3 produces between 140 kg/ha and 290 kg/ha of pinyon nuts in favorable years.

Habitat M7: Limestone Hill, Shallow Calcareous Slope 12-14 inch Precipitation Zone

One parcel of Habitat M7 occupies 1840 ha in the Pancake Range, over half the area exceeding 19% grade. More than 90% of the parcel lies within 10 km of a perennial water source. The habitat occurs on slopes and summits of hills and lower mountains between 1585 m and 2745 m asl. Soils are stony or cobbly loams that may be derived from limestone, dolomite, or volcanic rock, and rock outcrops make up 25% of the habitat.

Habitat M7 usually has no tree canopy, but scattered patches of pinyon-juniper woodland take up about 3% of the habitat. The understory is 60% shrubs, 35% grasses, and 5% forbs. Annual herbaceous productivity ranges from 145 to 375 kg/ha, covering between 10% and 35% of the ground. Black sagebrush, littleleaf mountain mahogany, beardless wheatgrass, and needleandthread are common. Rabbitbrush, black sagebrush, and annual forbs and grasses thrive in successional stages.

Habitat M7 is fair quality for mule deer, sheep, woodrat, and marmot. Edible plants are annual forbs and grasses, saltbush, pinyon, juniper, yucca, wheatgrass, Indian ricegrass, bluegrass, needleandthread, goldenweed, and bottlebrush squirreltail.

Habitat M9: Pinyon Juniper Woodland and Shallow Calcareous Slope 8-12 inch Precipitation Zone

Two parcels of Habitat M9, totaling 950 hectares, are located in the Grant Range in the southeast portion of the study area, both within 3 km of perennial water. The habitat occupies summits and slopes of foothills and mountains on all exposures, at elevations between 1585 m and 2500 m asl. Slopes can exceed 19%, but most (77%) of the habitat is between 4% and 18% grade. Soils are cobbly loams of residuum and colluvium derived from limestone and dolomite.

This habitat is a mosaic of pinyon-juniper woodland, open sagebrush, and rock outcrops. An overstory of 20% to 35% cover is typical of mature woodlands, of which about 60% is singleleaf pinyon. Altogether this habitat bears between 6 and 10 trees per hectare. Understory production ranges from 100 kg/ha to 310 kg/ha, although wildfires can increase understory production by removing the tree canopy. The understory is 60% shrubs, 30% grasses, and 10% forbs, and covers 15% to 20% of the ground surface. Black sagebrush, ephedra, muttongrass, bluegrass, needleandthread, Indian ricegrass, and galleta are typical of the climax stage. Sagebrush, rabbitbrush, juniper, and annual mustards are common in successional stages. Shadscale and galleta prosper in successional communities at lower elevations.

Hunters are likely to find mule deer, sheep, woodrat, marmot, small mammals, and sage grouse in Habitat M9. Plant resources for gatherers are annual forbs and grasses, pinyon, juniper, ephedra, shadscale, prickly pear, wheatgrass, Indian ricegrass, galleta, bluegrass, needleandthread, goldenweed, bottlebrush squirreltail, globemallow, and prince's plume. Good crops of pinyon nuts can be from 110 kg/ha to 170 kg/ha.

Chapter 5

Model Variation

Robert G. Elston

Regional Paleoenvironmental Context

Habitat type models of the kind developed in previous chapters are based on the distribution and abundance of plants and animals as they existed about 1850 A.D. However, we are well aware that climate, vegetation, and surface water have not remained static during the 11,000 to 12,000 thousand years that hunting and gathering people lived in Railroad Valley. Very little investigation has been undertaken of paleoenvironments in Railroad Valley, so that we have a very sketchy idea of how and when things changed there. Assuming that Railroad Valley paleoenvironments reflected global and regional changes documented elsewhere, we can extrapolate from what we know to what we do not. Still, this is a little like trying on new clothes in the dark: some obviously fit, some do not, and of many one just cannot decide.

Here, we add a new dimension to the paleoenvironmental context—a relative chronology of depositional and erosional land forms for the entire project area. This allows us to assess the potential of any particular landform for archaeological remains of a given age. For example, we do not expect to find indications of Paleoindian occupation on the youngest alluvial fans.

In the following pages, we first examine the evidence for changes in climate, lake stands, and vegetation. Next, we turn to description of landforms and their classification by relative age. Then we summarize these data into a likely paleoclimatic reconstruction of Railroad Valley. Finally, we apply these insights to archaeological consideration of the Railroad Valley Bar.

Paleoenvironment

The present climate of Railroad Valley is arid (Houghton et al. 1975), with an average annual precipitation of 102 mm to 204 mm (4-8 in). More precipitation falls in the mountains as snow than in the valley, and most falls in spring. The mean annual temperature is about 50° F, with cold winters and hot summers. The prevailing wind is from the southwest.

Comparison of ^{18}O oxygen isotope values from Owens Lake sediment cores, Greenland ice cores, Atlantic marine sediment cores, and cosmogenic ^{36}Cl production in rocks in Sierran glacial moraines indicates that glacial advances in the Sierra Nevada and lake levels in Owens Lake were coupled with iceberg production in the North Atlantic (Benson et al. 1996; Phillips et al. 1996). This in turn suggests lake and glacier response to global scale climatic fluctuation. However, it does not necessarily follow that the rise and fall of all Great Basin Pleistocene lakes were synchronized and, in fact, we see considerable apparent variation in the timing of late Pleistocene lake highstands (Lillquist 1994a). Some of this is due, perhaps, to relatively slight shifts in the position of the polar front and direction of storm tracks. For example, if storms trended northwest to southeast across the Great Basin, Lake Lahontan and Lake Railroad might rise while Owens Lake declined. Different lake stand dating methods can produce different dates; for example, Thompson's (1992) deep water pollen core dates from Ruby Valley suggest a Lake Franklin high stand at 18,500 BP, while Lillquist's (1994a:60) dates on shells from Lake Franklin highstand shore features range between 16,800-15,070 BP. Another problem is that most Great Basin Pleistocene lake basins have not been studied in any detail. This is certainly true of Railroad Valley, for which there are only two radiocarbon dates. The nearest relatively well studied lake basins are Ruby Valley (Thompson 1984; Lillquist 1994a), Lower Pahranagat Lake (Hemphill and Wigand 1994, Wigand 1996), and Bonneville Basin (Currey 1990, 1991; Currey et al. 1984; Rhode and Madsen 1995; Madsen 1997).

Early Late Pleistocene

Winter storms were numerous and severe during the Late Pleistocene (ca. 40,000 to 12,000 BP) (Kutzbach and Wright 1985; Kutzbach 1987; Kutzbach et al. 1993). Several Great Basin mountain ranges were heavily glaciated and most valleys contained large lakes (Grayson 1993:102-103; Thompson et al. 1993:484). However, the mountains bordering Railroad Valley were not glaciated (Kleinhampl and Ziony 1985), even though 3444 m Troy peak is south of the 3300 m glaciation contour drawn across the Great Basin by Porter et al. (1983: Figure 4.2). Based on analysis and radiocarbon dating of *Neotoma* middens in southern Nevada (southwest of Railroad Valley), the climate was cold and dry; effective moisture was much greater than today, but probably due more to reduced temperatures and only a moderate increase in precipitation (Paleobotanical Group 1996). Limber pine prefers cold, dry conditions, while white fir appears to tolerate somewhat warmer, more mesic conditions. Both species were displaced as much as 1000 m lower than present limits, coinciding with the present base of pinyon-juniper woodland. In southern Nevada, episodes of greater precipitation when white fir was favored at lower elevations were 35,000-33,000 BP and 23,000- 21,000 BP, while colder conditions favoring limber pine were at 32,000-29,000 BP and 21,000-16,000 BP (Paleobotanical Group 1996). Lake Bonneville began a transgression about 30,000 BP that peaked at 14,500 BP, when the lake began to drain into the Snake River (Oviat et al. 1992). Thompson's (1984, 1992) pollen cores from Ruby Valley suggest very low lake levels between about 40,000-23,000 BP, but deep water between 20,000-10,000 BP. Lillquist (1994a) indicates this lake reached its maximum at 16,800-15,070 BP. In Thompson's pollen cores, *Artemisia* pollen is dominant, cheno-ams are well represented, and *Pinus* pollen is scarce, suggesting a brushy steppe throughout the Late Pleistocene in Ruby Valley (Thompson 1984:182).

Based on degree of erosion and preservation, Lillquist (1994b:6) suggests the highest lacustrine shoreline in Railroad Valley dates to oxygen isotopic stage 6 (190,000-127,000 B.P.) or oxygen isotopic stage 4 (73,000-61,000 BP) (Bradley 1985:187). However, a radiocarbon assay of gastropod shells from a lagoon behind the highest lacustrine gravel bar in Railroad Valley produced a radiocarbon date of 27,880±310 (Beta 50774) (Donald Currey, personal communication, November 1997; Lillquist 1994a, 1994b), falling within oxygen isotopic stage 2 (29,000-11,000 BP). This radiocarbon date ought to be viewed with caution until confirmed by assay of other materials because shells sometimes produce erroneous radiocarbon dates. The living animals may have absorbed "old" carbon dissolved in the water in which they lived, giving too old a result, or the shells may incorporate new carbon by precipitation of secondary carbonate during recrystallization, giving dates that are too young. The only similar radiocarbon dated highstand in the region (22,060±210 BP - Beta 50777) is from Lake Diamond (Tackman 1993).

Late Pleistocene

Lillquist (1994a:35-48) reviews the latest Pleistocene to Holocene radiocarbon chronology for lakes in the northern Great Basin. Several lakes (Lahontan, Franklin, Diamond, Railroad, and Bonneville) begin to rise near the beginning of oxygen isotopic stage 2, sometime after about 29,000 BP. The putative early oxygen isotopic stage 2 highstands of Lake Diamond and Lake Railroad are anomalous, on present evidence. Most other northern Great Basin lakes reached Late Pleistocene highstands much later; one group (Franklin, Hubbs, and Carpenter) between about 18,000 BP and 17,000 BP, and another group (Lahontan, Jakes, Spring,Waring, and Bonneville) between 14,500 and 12,700 BP. A radiocarbon date on marl from Railroad Valley of 12,890±120 (Beta 29026) suggests a deep lake there in this interval (Donald R. Currey personal communication, November 1997; Lillquist 1994a:Figure 4.2).

The duration of these middle to late oxygen isotopic stage 2 transgressions was short. For example, Lake Franklin in Ruby Valley rose to its highest level between 16,800-15,070 BP. The ensuing decline was reversed by 14,360 BP, but another sharp dip occurred at 12,930 BP, followed by another transgression peaking at 12,720 BP, a regression to 11,560 BP during which the lake possibly desiccated, followed by a final low transgression between 11,500 and 10,400 BP (Thompson 1992; Lillquist 1994a:38, 75-76). Lake Bonneville fell from the Provo highstand at about 13,000 BP (Currey 1990; Oviat et al. 1992). Rhode and Madsen (1995:255) suggest that the last large lake in the Bonneville Basin, known as the Gilbert transgression, occurred between 11,500 BP and 10,500 BP. If true, this would correlate with the Russell shoreline in the Carson Desert, dating to between about 11,500 BP and 10,500 BP (Elston, Katzer and Currey 1988; Currey 1988, 1989). In all three cases, these last transgressions are likely to be responses to the global sharp return to colder conditions known as the Younger Dryas interval between 11,500-10,500 BP (Benson et al. 1992). Rhode and Madsen (1995) estimate that summers in the Bonneville Basin were as much as 6°C colder than present, while winters were no colder or perhaps slightly warmer.

Numerous lake transgressions and regressions within a 3,000-4,000 year period indicate an extreme climatic volatility in the latest Pleistocene that must have affected the extent and distribution of lakes and marshes (Madsen 1997), and likely affected animal species as well. For example, it is during the latest Pleistocene, 13,500-11,500 BP, that the last records of extinct Great Basin mammals occur (Grayson 1993:159). This suggests that these animals were on the wane during the initial warming trend of the Late Pleistocene, but some may have been present at the appearance of human hunters around 11,500 BP. However, all of the large mammals present in the Great Basin throughout the Holocene (bison, elk, deer, antelope, and mountain sheep) were also here in the Late Pleistocene.

Analysis of *Neotoma* middens in the Bonneville Basin and Pahranagat Range give a detailed look at terrestrial vegetation changes in the latest Pleistocene (Rhode and Madsen 1995; Paleobotanical Group 1996). Between 14,000-13,000 BP, the Bonneville Basin was covered by brushy steppe dominated by sagebrush, snowberry, and currant up to 2000 m asl. At 12,280 BP in the Pahranagat Range south of Railroad Valley, white fir was present at 1695 m (5560 ft). Between 13,000 and somewhat after 11,000 BP, with summer temperatures much lower than today, limber pine descended to at least 1500 m asl (4921 ft), occurring with brushy species (sagebrush, snowberry, prostrate juniper) at lower elevations and with Engleman spruce and Rocky Mountain juniper in montane settings. Currant and cinquefoil were replaced by other mesophilic shrubs such as buffalo berry and mountain lover. By several hundred years after 11,000 BP, lowland limber pine woodlands were replaced by sagebrush and shadscale. Unlike the Bonneville Basin or southern Nevada, the low values for *Pinus* in the Ruby Valley throughout the Late Pleistocene (Thompson 1984, 1992) suggest the absence of a low altitude limber pine woodland there. However, we are inclined to assume that paleovegetation in Railroad Valley during the latest Pleistocene included patchy limber pine woodland at intermediate elevations, and *Artemisia* dominated mesophilic shrub steppe on mountain piedmonts and valley bottoms above Lake Railroad, and as woodland understory.

Early Holocene

Early Holocene seasonality was quite different from the present. According to Kutzbach and Webb (1993:5-6), at 9000 BP the orbital geometry of the earth around the sun was such that perihelion (the point at which earth is closest to the sun) occurred in July (it now is in January), and the axial tilt of the earth relative to the sun was greater then (24.5°) than now (23.5°). Solar radiation was high, summer insolation about eight percent greater than today, and summer continental temperatures about 5°C higher than at present, but winters were colder. Warmer summers and colder winters probably prevailed in the Great Basin as well. While precise temperatures are unknown (Thompson et al. 1993:489), Madsen (1997) estimates that annual average temperatures of 2-3°C lower than at present may have been typical of the interval 10,000-8000 BP.

Brushy steppe prevailed in the Great Basin, although its composition changed as mesophilic shrubs were replaced by shadscale and rabbitbrush. Rhode and Madsen (1995) report a 9,300 BP *Neotoma* midden at 1585 m asl in the Bonneville Basin, dominated by *Artemisia* and somewhat less shadscale, where there had been limber pine woodland 3000 years before. At roughly the same time, a slightly lower midden (1475 asl) contained equal quantities of sagebrush, shadscale, and rabbitbrush. This xeric steppe prevailed everywhere, broken only by patches of Utah juniper at higher elevations until about 8500-8000 years ago when Pinyon appeared in the Pahranagat Range south of Railroad Valley (Hemphill and Wigand 1994; Wigand et al. 1994) and about 7000 years ago in the Bonneville Basin (Madsen and Rhode 1990; Rhode and Madsen 1995). However, pinyon-juniper woodland did not assume its present distribution in central Nevada until 6600 BP (Thompson and Hattori 1983; Thompson 1984, 1992). We assume pinyon reached the mountains bounding the east side of Railroad Valley at about 7500 BP.

Shallow lakes and marshes persisted in Ruby Valley until about 7000 BP, and in the Bonneville Basin 10,000-8000 BP (Lillquist 1994a; Madsen 1997). We assume these conditions prevailed in Railroad Valley between 10,000-8000 BP.

Middle Holocene

The warming trend peaked in the Middle Holocene, and vegetation seen on valley floors (greasewood-saltbush) in historic times became established. The warming trend of the Early Holocene continued beyond the fall of Mazama tephra (about 6900 BP), peaking around 6000 BP (Thompson et al. 1993:491). Decreased westerly flow and northward retreat of the polar jetstream continued with the final recession of continental ice and increasing global temperatures (Kutzbach et al. 1993). In the Great Basin, this seems to have reduced winter precipitation and allowed more northward penetration of the summer monsoon (Davis 1982:66). However, the monsoon could not make up for lower winter precipitation because summer rains fall during the season of maximum evaporation; consequently, lakes and marshes declined and may have disappeared altogether for long periods (Benson and Thompson 1987a:256). Packrat (*Neotoma*) nest analysis (Van Devender et al. 1987:347-348) strongly suggests that mid-Holocene warming reduced winter precipitation and brought drought to the Mojave Desert and the Great Basin; at the same time, severe winter freezes due to incursions of Arctic air were much more frequent than today. We assume that after 8000 BP, Railroad Valley was increasingly desiccated. Between 7000-6000 BP, the playa, the Hot Creek and Duckwater Creek fan deltas, and former lake beaches were subject to significant eolian erosion accompanied by dune building downwind.

Late Holocene

Grayson (1993:221) defines the Late Holocene as the period in which "the Great Basin came to look pretty much as it has looked during the last few centuries." By 4500 BP the trend to a cooler, moister climate was well underway. Lake Tahoe began to discharge down the Truckee River again at 4200 BP (Lindström 1990), and Mono Lake was at a very high level at 3700 BP (Stine 1990:366-367). Hemphill and Wigand (1994:56) suggest that climatic amelioration in the Great Basin began about 5400 years ago, and by 4000 BP the modern climatic pattern was established, with strengthened westerlies, a return to winter-dominated precipitation, and a resurgence of lakes and marshes on valley floors (Wigand 1990:84, 1997). Lillquist (1994a:46-47) reports that deeper water returned to Ruby Valley about 4700 BP and cites a personal communication from Ron King of evidence for lakes in the Franklin subbasin at 3200 BP, 1000-800 BP, and 350-150 BP.

Wigand (1994) reviews stable isotope evidence from the several Great Basin records reflecting long term influence of temperature on vegetation. This sequence is supported by fine-grained records from Yucca Mountain and Lower Pahranagat Lake (Hemphill and Wigand 1994; Wigand 1996), indicating more mesic climatic intervals in which marshes redeveloped and spring discharge increased at ca. 3600 BP, 2300-1900 BP, ca. 1000 BP, and ca. 350 BP (Hemphill and Wigand 1994:58).

A pollen record from Lower Pahranagat Lake (Hemphill and Wigand 1994; Wigand 1996:70) indicates a cooler interval between 4,000-2,000 BP. High values for juniper pollen suggest winter-dominant precipitation, cold winter temperatures, a tree line one to two hundred meters lower than present, and a woodland dominated by juniper. Spaulding's (1981, 1985) *Neotoma* midden data from the Sheep Range to the south suggest a similar situation. This cool interval could have included an increase of effective precipitation involving an increase in annual precipitation of at least 10 to 20 mm, and perhaps as much as 70 mm. at elevations around 1500 meters (Wigand 1996:70). At about 2,000 BP, juniper pollen declined and grass pollen increased, followed by increased pinion pollen between 1,600 and 1,200 BP , when Lower Pahranagat Lake was a shallow perennial lake. This suggests milder, dryer winters and a shift to summer dominant precipitation. Since 1,200 BP, the climate is marked by variability with intervals of greater effective precipitation (winter-dominant) marked by increased juniper pollen centered on 800 BP, and in the interval 400-300 BP; severe droughts occurred at 900 and 300 BP. Stronger winter precipitation and cooler temperatures of the "Little Ice Age," 400-300 BP, resulted in an expansion of pinyon (but not juniper) in the southern Great Basin. Wigand and colleagues (et al. 1994:66) note that the increase in temperatures since the end of the Little Ice Age was not accompanied by evidence for massive fires that typified previous drought intervals. They speculate that this may reflect the setting of fewer fires by Native Americans, brought about by population declines after contact with Europeans. We assume a similar climatic and vegetation history for Railroad Valley.

Railroad Valley Geoforms and Geoform Chronology

Lacking radiocarbon dates and detailed weathering profiles for most geomorphic features in Railroad Valley, we are compelled to develop a relative chronology for landforms. Although we can refer to lake records from Ruby Valley, Lower Pahranagat Lake, and the Bonneville Basin to help develop a lacustrine chronology, our task would be simplified if these records were better synchronized. As it is, we must paint our lake model with a broad brush, and rely on our own analyses for the chronology of other land forms. The chronological order of geomorphic features in Railroad Valley, therefore, must serve as a series of hypotheses to be tested in subsequent studies.

Railroad Valley contains lacustrine and alluvial deposits up to thousands of meters thick. The valley margins are bordered by "fanglomerate aprons [that] intertougue valleyward with alluvium and, finally, with beachbounded lacustrine deposits (Kleinhampl and Ziony 1985:115)." Eolian sediments are common, with silt dunes bordering the playa and extensive sand dunes and sand sheets blanketing the Hot Creek fan delta, the playa margin and the lower piedmont on the eastern side of the valley, and the fan delta of Currant Creek.

Based on analysis of 1:24,000 color infrared air photos and brief field review, we divided the landscape of the project area into a number of geomorphic features created by deposition and erosion. These are referred to as "geoforms," including alluvial fans, fan-head trenches, inset fans, lacustrine terraces and ridges, dunes, and so on. We estimated the relative age of these features from degrees of erosion and preservation, presence of faulting, and whether one feature cuts or overlaps another (cf. Davis and Elston 1978; Young 1980; Peterson 1981). Using 1:24,000 orthorphoto quadrangles as a base, geoforms in the entire project area were mapped onto transparent overlays. Our approach to geomorphic mapping differs from Lillquist (1994b) mainly in being much more detailed.

Estimating the relative age of alluvial fans and fan segments was a major task. However, the causes of alluviation and erosion in alluvial fans is a matter of some controversy; Cooke et al. (1993: 183-185) caution against assuming a simple relationship between fan building, fan erosion, and climatic variation, but in the absence of weathering profile data and radiocarbon dates we employ just such a model, framed as a set of hypotheses to be tested in further study. We suppose that alluvial fans are built during mesic intervals when average annual precipitation is more general and more frequent, vegetative cover is more dense, water:sediment ratios are high (more water), and runoff has less tractive force (ability to move heavy items). Erosion is dominant and fan-head trenches (broad, deep arroyos originating at the mountain front or upper piedmont) are cut. In more xeric intervals when annual precipitation is more localized and less frequent, vegetation is more sparse, water:sediment ratios are high and mudflows more frequent, and runoff has greater tractive force. Dorn (1988) argues that in Death Valley, California, fan-head trenching occurred during the glacial to interglacial transition, a time of considerable variation in climate and change in vegetation; it seems reasonable that fan-head trenching in Railroad Valley began then. Fan-head entrenchment may also be associated with faulting, but faults are not consistently associated with fan-head trenches in Railroad Valley.

Map symbols for each geoform are given parenthetically in the following discussions.

Bedrock (B)

These are mostly rock outcrops, cliffs and spurs of the bounding mountains, but on the west side of the valley include cinder cones and lava flows.

Oldest Alluvial Fans (Qoof)

The oldest geoforms in the valley are alluvial fan remnants occurring at the top of the piedmont slope adjacent the mountain front. They are isolated by fan-head trenches and exhibit parallel dendritic drainage patterns. Channels are several meters deep between distinct ridges with flat to slightly rounded tops that range in maximum width between 100 m and 200 m. These oldest fan remnants frequently are cut by faults parallel to the mountain front that mark the lowest extent of these fans. Older, more eroded and partially buried fault scars can be seen on some of these fan remnants above the major fault. Only on the steepest piedmont on the east side of the valley are lacustrine features superimposed on these oldest geoforms, usually only the uppermost wave-cut scarp at 1484 m.

Assuming that the oldest alluvial fans in Railroad Valley were created in a mesic glacial interval prior to oxygen isotopic stage 2, they must be older than 27,000 BP, perhaps interglacial oxygen isotopic stage 6 (188,000-128,000 BP)(Bradley 1985:Table 6.2).

Old Alluvial Fans (Qof)

These are present both as fan remnants with upper boundaries in the middle piedmont slope and as mostly intact fans originating at the top of the piedmont slope. They frequently are inset into Qoof, and are cut by fan-head trenches but rarely by faults. Their surfaces are eroded by dendritic drainages to a few meters deep and 40 m to 120 m apart; surfaces between drainages are flat and do not form distinct ridges. Because the lower reaches of these fans bear lacustrine features at 1484 m and below, they too must predate oxygen isotopic stage 2, dating to perhaps oxygen isotopic stage 4 (72,000-58,000 BP) (Bradley 1985:Table 6.2). In a few cases (for example, the Irwin Canyon fan in the Grant Range), geoforms classified as old alluvial fans may be older (Qoof) alluvial fans rejuvenated below mountain front faulting.

Lacustrine Features (Ql)

The elevation of the highest lacustrine feature in Railroad Valley is about 1484 m asl (4870 ft). In his air photo analysis based on weathering and preservation, Lillquist (1994b) believed this shoreline to date to oxygen isotopic stage 4 or oxygen isotopic stage 6. But because the 1484 m shoreline cuts both sets of older alluvial fans (Qoof and Qof), this highstand must postdate both, making an age of oxygen isotopic stage 2 for this feature more likely. However, although the 27,880±310 BP (Beta-50774) radiocarbon date on *Lymnaea* gastropod shells from a lagoon above the 1484 m shoreline lies within oxygen isotopic stage 2, this single shell date must be regarded as inconclusive. Until tested by additional radiocarbon dates, we hypothesize that the Railroad Valley 1484 m highstand occurred between 17,000-13,000 BP, within the range of highstands of most other well-dated pluvial lakes in the region.

The ages of the lacustrine geoforms below 1484 m are unknown. Lillquist (1994b:6-7) estimated the ages of shorelines between 1478-1475 m (4850-4840 ft) as oxygen isotopic stage 2 (29,000-12,000 BP), but if the 1484 m shoreline dates to 17,000-13,000 B.P, lower shore features must be younger. On the northwest side of the valley, the Railroad Valley Bar is a long gravel spit built out into Lake Railroad by wave currents from the western shore. The southern foot of the spit is at 1450.5 m asl (4759 ft), while its upper surface is about 1452.7 m asl (4766 ft). A radiocarbon date of 12,890±120 (Beta 29026) (Donald Currey, personal communication, November 1997) was obtained from marl south of this feature near a present-day oil refinery on Highway 6. The seeming absence of shallow water deposits overlying the marl argues against the presence of a Late Pleistocene (Younger Dryas) or Holocene lake reaching 1450.5 m. Assuming that overlying sediments were not eroded down to the marl, the most simple scenario is a single transgression to 1484 m about 17,000 BP, followed by a regression with several pauses that created the lower lacustrine features. The complex history of the Railroad Valley Bar (Elston et al. 1979) is considered later in the chapter.

Between 1450.5 m and the playa margin, there are no lacustrine features that can be seen on 1:24,000 air photos. Thus, if shallow lakes were present between 10,500-8000 BP, or 4000-2000 BP, they were either no larger than the current valley playa at 1435.5 m (4710 ft) or they were too shallow (less than 4 m deep; Currey 1991) to form bars and spits. We note that lakes above 1435.5 m would invade the Hot Creek and Currant Creek fan deltas, likely places for marshes to form.

Along the southwest margin of the playa at the termination of the Hot Creek fan delta are (on air photos), light-colored, smooth-surfaced, elongated, smoothly curved geoforms that parallel the southern playa margin. West of these features at the same elevation is a cuspate or chevron-shaped feature with the same color and smoothness. These features seem to share characteristics of both silt dunes and lacustrine features. Perhaps they are both—silt dunes reworked by the occasional shallow lake filling the playa. They lack the dark color of lacustrine bars on the north and east side of the valley, but so do most of the lacustrine features on the west. Presumably, this is because the source material supplied by the western fans is finer-grained and lighter in color.

Lagoon (L)

These form behind or within lacustrine bars by accumulation of sublacustrine or eolian sediment, which may be quite old. They are white on the air photos.

Playa (Qp)

This is the flat, fine-grained, vegetation-free surface exposed in the lowest part of the valley by hydro-eolian processes. Playa sediments are mostly deep lake sediments of Lake Railroad, but the playa surface is very young.

Fan-Head Trenches

These are inset into, and isolate segments of, older fans and fan remnants (Qoof and Qof). Fan-head trenches typically are deepest near the fan apex; the material excavated by trenching is deposited below the piedmont midslope. Although it is likely that fan-head trenching began in the early Holocene (ca-10,500-8000 BP), most of those older sediments are now buried by younger ones. Fan-head trenches sequester runoff from older fan segments and at the present time contain most of the flow issuing onto the piedmont from mountain basins. Fan-head trenches are not mapped as such; rather, the age of the inset fans they contain (Qyf or Qyyf) is given.

Young Alluvial Fans (Qyf)

These usually are intact fans originating at the top of the piedmont slope and are inset into fan-head trenches where such occur. The surfaces of young alluvial fans have relatively shallow, dendritic to braided drainages. Deposits of young fans partially or wholly bury the lower portions of old alluvial fans and lacustrine features on such fans. Young alluvial fans formed by streams with highest runoff extend furthest into the valley. Young alluvial fans probably began to accumulate as the material exhumed during fan-head trenching was deposited down slope. However, these older sediments are likely buried by material deposited in the more mesic interval between 4000-2000 BP.

Youngest Alluvial Fans (Qyyf)

These are created by high volume runoff events that form fan-shaped deposits with shallow braided channels mostly on fan skirts, but also can appear higher on the fan piedmont and within fan-head trenches. These most recent components of fan skirts are light colored or white on air photos. We suggest that most formed in the dryer intervals of the last 1000 years.

Fan Skirts (Qfs)

Deposited in the gentler slope beyond the toes of fans and merging with the basin floor, fan skirts may comprise stacks of sediment of different ages. However, their surfaces are among the youngest in the valley (probably deposited in the last 1000 years), comprised of relatively fine grained sediments forming a belt of smooth, coalescing alluvial fans issuing from gullies in older fans, and from inset fans. Although segments of fan skirts derived from different drainages may differ in lithology and age, their smoothness frequently prevents division of the skirt from perusal of air photos. The exception are the most recent alluvial fans, which tend to be light in color. In Railroad Valley, fan skirts commonly are blanketed by eolian sediment (sand sheets and dunes). Normal runoff may or may not maintain channels across the fan apron through the eolian sediments, but the youngest alluvial fans frequently extend through them to the basin floor.

Alluvium (Qa)

Alluvium is fine grained sediment in active floodplains of axial streams such as Duckwater Creek, Bull Creek, and Hot Creek. This material is usually light colored on air photos, and is no older than a few decades to a century or two.

Gravel Bar (Qb)

These are generally elongated, diamond shaped, vegetated gravel bars in the braided stream systems of Duckwater Creek and Bull Creek. Some are rather small, but others are more than 1 km wide and several km long. Most have no more than 10-50 cm of relief, and are difficult to see on the ground. We suspect that most of these features are young, although the larger, higher specimens might be several thousand years old. Similar features isolated in inset Qyf and Qyyf generally are mapped as fan remnants.

Alluvial Flat (Af)

Alluvial flats are nearly level surfaces beyond the fan skirts where sediments are moved parallel to the valley long axis on the way to the playa. In Railroad Valley, a major alluvial flat lies on the southeast where Big Creek and Willow Creek flow northeastward parallel to the mountain front before merging with the Hot Creek fan delta. Alluvial sediments in alluvial flats may have considerable antiquity, but old deposits usually are blanketed by recent alluvium and eolian sediment, and are not easily available for study. In times of high water, alluvial flats are places where salt marshes are likely to form.

Alluvial Plain (Ap)

These were deltas of pluvial Lake Railroad, and since have been low gradient fans. There are two in northern Railroad Valley, one extending along Duckwater Creek from between Currant Creek and the Big Wash to the northern margin of the large playa, and the other along the lower reach of Hot Creek from west of Nyala to the playa margin where it merges with the Big Creek-Willow Creek alluvial flat. The northern fan delta is more thickly mantled with eolian sediments.

Eolian Sediments (Qe)

These are mostly undifferentiated on our maps because of lack of resolution for smaller dunes. However, the largest dunes and dune fields are sometimes outlined or noted. Silt dunes and silt dunes capped with sand are found adjacent the playa, while individual dunes, dune fields, and sand sheets are common on the margins of the valley below the fan skirts. More or less linear dunes and dune fields are common along the margins of fan toes and lacustrine features. Trap Spring is within one such linear dune field, and another is found along the southern foot of the Railroad Valley Bar at its eastern end. In the latter dune field, reddish older dunes containing artifacts and fire cracked rocks are overridden by more recent tan sands. Dunes and sand sheets sometimes override fans, and form climbing dunes on bedrock.

We suspect that dune building began in Railroad Valley at the end of the Pleistocene as sandy beach sediments were released by lowering lake levels, and large quantities of sand were still supplied to fan deltas. Finer grained sediments were released by middle Holocene desiccation of the valley floor to be deposited as loess on piedmont slopes. Eolian sediments have continued to accumulate through the Holocene as demonstrated by a hearth within Unit III dated to 370±40 BP (Tx-3335) (Elston et al. 1979).

Travertine Deposits (Qt)

These are large, often mound-shaped deposits associated with active springs on the valley margin. Most were inundated by Lake Railroad and have considerable antiquity.

Colluvial Slopes (Qc)

These are steep slopes on the mountain front where colluvial material is actively accumulating. Frequently in mapping these were not distinguished from bedrock.

Paleoenvironmental Reconstruction

The foregoing discussions of regional paleoenvironment and land form chronology applied to Railroad Valley are summarized in Table 19.

Late Pleistocene

In the Late Pleistocene, 17,000-13,000 BP, Lake Railroad transgressed to 1484 m, then fell to about 1455 m. Bar 1 and Bar 2 were created in this interval, but the history of these features is complex and not well worked out. The Grant Range and other mountains on the east side of the valley probably harbored limber pine woodland at about the same position as present pinyon-juniper woodland. An *Artemisia* steppe with a diverse array of mesophilic shrubs occupied the piedmont slopes and valley bottoms between the limber pine and lake shore. At the highstand, the shores of the lake were steep and marshes were likely present only in the Duckwater Creek fan delta. At the 1455 m lowstand and below, marshes were likely in both the Hot Creek and Duckwater fan deltas. Large animals of now extinct species were present.

Between 13,000 and 11,500 BP, the climate grew warmer and Lake Railroad dropped below 1450 m; perhaps the valley floor became dry. Limber pine woodland remained in the eastern mountains, possibly at higher elevations. Some mesophilic shrubs dropped out of the *Artemisia* steppe to be replaced by others, but species diversity probably diminished. The first human visitors to the valley may have arrived in this interval. Many large mammals became extinct.

Table 19. Railroad Valley Paleoenvironments

Interval	Years BP	Climate	Landforms	Vegetation
Oxygen isotopic stage 6	188,000-128,000	Glacial	Oldest fans deposited	unknown
Oxygen isotopic stage 4	72,000-58,000	Glacial	Old fans deposited	unknown
Oxygen isotopic stage 2; Late Pleistocene	17,000-13,000	Cold, dry; greater effective moisture	1484 m highstand; Bar 1 formed as lake transgressed, Bar 2 as lake fell; shore features superimposed on Qof	Limber pine woodland in mountains; Artemisia steppe with mesophilic shrubs on piedmont to lake shore and in valley bottom; large mammals present
	13,000-11,500	Warmer	Lake regression and possible valley desiccation	Limber pine woodland in mountains; Artemisia steppe with mesophilic shrubs on piedmont to lake shore and in valley bottom; large mammals become extinct
Younger Dryas	11,500-10,500	Summers sharply colder	No evidence of transgression; probably shallow lake and marshes	Limber pine woodland in mountains Artemisia steppe with mesophilic shrubs
Oxygen isotopic stage 1; Early Holocene	10,500-8,000	High solar insulation; temperatures higher in summer, colder in winter	Shallow lakes and marshes; fan-head erosion begins	Mountains are treeless; Artemisia and shadscale steppe
Middle Holocene	8,000-5,400	Warm, dry; summer precipitation	Playa desiccated; fanhead trenches cut; surface runoff minimal; low spring flow; eolian erosion and deposition of older dunes	Pinyon-juniper woodland in mountains; Artemisia and shadscale steppe in lowlands
Late Holocene	5400-3,800	Trending cooler and moister	Spring flow; young fans (Oyf) deposited	Pinyon-juniper woodland in mountains; Artemisia and shadscale steppe in lowlands
	3,800-2,300	Cooler, annual precipitation increases; Winter precipitation	Shallow lake and marshes; increased spring flow; young fans (Oyf) deposited	Pinyon-juniper woodland at lower elevations; Artemisia and shadscale steppe in lowlands
	1850-1,000	At first hotter, dryer; then changing to increased summer precipitation	????	Expansion of pinyon-juniper woodland
	900-500	Severe drought; increased fire frequency	Playa desiccated; low spring flow	Retreat of pinyon-juniper woodland
	400-300	Colder, moister Little Ice Age; increased	Shallow lake and marshes	Expansion of pinyon, but not juniper
	300-150	Warming	As presently	As presently

Latest Pleistocene

Unlike the records for Ruby Valley and the Bonneville Basin, the 11,500-10,500 BP Younger Dryas cold snap does not seem to have left a mark on Railroad Valley, as Lake Railroad apparently failed to rise again. Perhaps there was a shallow lake in the valley bottom at 1436 m (covering the area of the present playa) and marshes in the much expanded fan deltas and other wet spots. Vegetation would have remained similar to that of the Late Pleistocene, although limber pine may have descended to lower elevation. The archaeological record on the Railroad Valley Bar and elsewhere suggests that people were in Railroad Valley by this time.

Early Holocene

Warmer summers and colder winters between 10,500-8000 BP made the mountains treeless, and ushered *Artemisia* and Shadscale steppe into the valley. Fan-head trench cutting may have begun. We assume the shallow lake and marshes were maintained for a long time, as they were in other valleys, but gradually declined. Hunting and gathering people were present and leaving stone tools on the Railroad Valley Bar.

Middle Holocene

The interval between 8000-5000 BP was hot and dry, with summer-dominate precipitation. Pinyon-juniper woodland became established in the Grant Range and other mountains on the east side of the valley about 7500 BP. We assume the valley floor was desiccated and spring flow was low. Fan-head trenches were cut. Wind eroded sand and silt from the lake bottom, fan deltas, and former beaches, depositing it downwind in large dune fields.

Late Holocene

A cooling trend characterized the interval between 5800-3800 BP. Spring flow increased and wet spots appeared in the valley, but there was no lake and marshes remained minimal. Between 3800-2300 BP, winter precipitation dominated a much cooler, wetter climate. We assume increased spring flow, marshes in the fan deltas, and a valley lake at 1436 m. Pinyon-juniper woodland encroached on lower elevations. The ensuing 2,000 years or so marked increased climatic volatility, where intervals of severe drought alternated with wetter, sometimes cooler intervals. We assume the playa desiccated in droughts, and perhaps contained lakes or shallow marshes more or less congruent with the present playa at the peak of summer-dominant precipitation between 1,600 and 1,200 BP, as well as during the Little Ice Age of 400-300 BP.

Variability in Lithic Resource Availability

As previously described, siliceous rocks suitable for stone tool manufacture are widely available in the valley, with chert a common component of clasts on alluvial fans and on lacustrine features made of gravel. Processes of lithic silification are commonly associated with heavy mineral emplacement in the formation of metallic ores of gold and silver; consequently, outcrops of silicified rocks are identified and described in the regional geology (Kleinhampl and Ziony 1984, 1985).

We assume that rocks of toolstone quality will be more common and occur in higher quality, larger packages in and adjacent beds and zones of silicified rock than in other places in the landscape.

Furthermore, we assume that alluvial fans and fluvial gravel bars downstream of such outcrops will be relatively richer in clasts of silicified rock than will alluvial landforms not heading in silicified zones. And we assume that silicified clasts will be more common in lacustrine gravel bars where these encroach fans heading in silicified zones. Identifying such areas is important because they are likely to contain more abundant lithic debris. Viewed without understanding that this material was mostly generated by toolstone procurement and processing, we could attribute greater land use intensity to toolstone source areas than is warranted.

Given these assumptions, we identified alluvial fan and lacustrine features most likely to provide a toolstone rich lithic terraine. Field checks of landforms adjacent and downstream of silicified outcrops in the area northeast of Currant and the area around Storm Spring confirmed that these areas are lithically rich.

Depositional History of Railroad Valley Bar

The Railroad Valley Bar has a complex depositional history that does not fit well with the simple scenario of a single Lake Railroad transgression about 17,000 BP, and a final recession after 12,890 BP. While it is impossible to resolve this conflict with present evidence, we suggest some possible alternatives.

The Railroad Valley Bar has three geomorphic components (Elston et al. 1979). The oldest is an offshore gravel bar (Bar 1), indicating Lake Railroad stood somewhat higher than 1453 m (4766 ft) for a considerable period of time. Bar 1 has about one meter of relief and is cut on its western end by a sinuous channel probably created by rip currents as water returned to the lake after breaking over the bar. This breach also allows alluvial drainage during times the lake is lower than the bar. Two smaller breaches suggested to J.O. Davis (Elston et al. 1979:44) that Bar 1 was subsequently eroded, suggesting that the lake fell below it, and that it stood exposed for a substantial amount of time. There are two alternatives to the formation/exposure hypothesis. One is that Bar 1 was not formed as a single feature, so the gaps are not erosional; the other is that Bar 1 was formed, then eroded by sublacustrine currents as the lake rose above it. Bar 1 comprises three stratigraphic units:

> Unit I: well sorted beds 3 to 20 cm thick of fine sand to fine pebbles dipping 20-25 degrees to the north; abrupt, unconformable contact with Unit II.
>
> Unit II: well sorted beds to 20 cm thick of medium sand (slightly cemented) to unconsolidated well rounded pebble gravel; these beds describe surfaces that are convex upward and are best-sorted at the crest. Diffuse contact with Unit III.
>
> Unit III: poorly sorted sandy loam with 20% well rounded gravel up to 1 meter thick on flanks and thinner on the crest. The sandy loam is apparently an eolian mantle with gravels mixed upward into it from Unit II. A thin veneer of pebbles lies on the present surface, but the upper 10-15 cm of Unit III is an Av horizon with few pebbles. A weathering profile is developed on Unit III, extending approximately one meter downward into Unit II. The ashy gray Av horizon has both platy and prismatic structure, while the underlying redder B horizon has prismatic structure.

Subsequently, long shore currents built another gravel bar (Bar 2) parallel and a little south of Bar 1. Davis (Elston et al. 1979) suggested that Bar 2 was built as Lake Railroad rose again to nearly the same level as when Bar 1 was formed. But if Bar 1 was formed (and eroded) as Lake Railroad transgressed, Bar 2 may have appeared as the lake fell. Alternately, the lake could have remained at about the same level during the creation of Bar 1 and Bar 2, but energy delivered through the wind may have varied.

In any case, Bar 2 has about 2.5 meters of relief and is wider and longer than Bar 1, suggesting the water stood at approximately the same level (somewhat higher than 1453 m) for a longer interval than it did when Bar 1 was formed. The sinuous western channel was maintained through Bar 2; two breaches on the east end of Bar 2 may be man-made for drainage control. The eastern end of Bar 2 is slightly curved to the north, indicating slightly deeper water or more energetic wave action at that point.

The stratigraphy of Bar 2 is similar to that of Bar 1, except that Unit 1 was not seen in any of the exposures examined by Davis (Elston et al. 1979). The poorly sorted mantle of Unit III is present but only 0.5 m thick on Bar 2.

The weathering profile on Bar 2 is more strongly developed than on Bar 1 (more cementation, color, and structure), which does not easily fit the hypothesis that Bar 2 is younger than Bar 1. Moreover, a possible thin (1 cm to 5 cm) paleosol was observed within Unit II on Bar 2 at a depth of 85 cm to 95 cm below the surface. It is associated with a bed of finer sediment and characterized by obscured internal bedding, and increased cementation, efflorescence, and iron staining. This suggests a pause during which the lake level dropped to expose Bar 2 and develop the paleosol, followed by a subsequent transgression to deposit the remainder of Unit II, followed by a final regression to expose Bar 2 as it is today, during which Unit III accumulated by eolian processes and the surficial soil profile developed.

The third component of the Railroad Valley Bar is the trough between Bar 1 and Bar 2. The trough contains three stratigraphic units:

> Unit I: well rounded, well sorted gravel; abrupt, unconformable contact with Unit IV.
>
> Unit IV: 1.25 m thick, reverse graded from greenish clay loam at bottom to reddish sandy loam at top; diffuse contact with Unit III.
>
> Unit III: 16-25 cm thick reddish fine sand. The reddish color is pedogenic, extending from the surface through Unit III and into the upper 50 cm of Unit IV.

The reverse grading of Unit IV in the trough is indicative of a gradual change in energy, either a decrease in the level of water over the bar or the gradual filling of the trough itself.

A Railroad Valley Bar Chronology

By comparison with the Toyeh soil and similar shore features in Lake Lahontan of Sehoo age, J. O. Davis (Elston et al. 1979) proposed a chronological sequence for Railroad Valley Bar. The relative order of events he proposed nearly twenty years ago does not fit well with new facts such as the 12,890 BP marl date and lack of later lake sediments. Following is a chronology that fits, more or less, current understanding.

1. Bar 1 formed prior to 17,000 BP (Davis estimated between 35,000 and 22,000 BP), with Lake Railroad standing at about 1454 m (4770 ft).

2. Between 17,000-13,000 BP (Davis estimated 20,000 and 11,000 BP), Lake Railroad rose to 1484 m (Davis estimated 1531 m). Bar 1 was partially buried by littoral sediment (Unit IV), and possibly eroded by sublacustrine currents.

3. By 13,000 BP (Davis estimated 11,000 BP), Lake Railroad dropped to 1455 m (4766 ft). Bar 1 was further eroded and Bar 2 formation began.

4. Sometime after 12 890 BP, Lake Railroad fell below 1450 m, exposing Bar 1 and Bar 2, never to encroach on the Railroad Valley bar again. (However, Davis estimated that the lake rose again to 1453 m between 11,000-7,000 BP, during which time artifacts lying on the surface of Bar 1 and Bar 2 could have acquired coatings of tufa).

5. The gradual desiccation of the valley culminated in the exposure and deflation of the exposed lake bottom between 8000-7000 BP, and deposition of the eolian mantle Unit III on Bar 1, Bar 2 and the intervening trough (Davis estimated 7000 BP).

6. Beginning about 5000 BP, the surficial soil observed on the Railroad Valley Bar began to form.

7. After 4000 BP, a series of shallow lakes may have formed in Railroad Valley. (Davis thought that some of these may have stood as high as the foot of Bar 2 at 1450 m [4760 ft] or higher, briefly covering parts of the Railroad Valley Bar and coating artifacts with carbonate.)

Chapter 6

Implications of Habitat Distributions for Hunter-Gatherer Foraging Behavior in Railroad Valley

David W. Zeanah

Previous chapters describe the distribution and abundance of biotic resources within Railroad Valley habitats. In this chapter, this resource landscape serves to rank habitats based on energetic return rates, and to predict where hunter-gatherers settled and foraged in the study area. Ethnographic descriptions of Shoshone bands in Railroad Valley and nearby areas (Steward 1938, 1941) inform that indigenous people foraged in an arid environment where critical resources were distributed unevenly in space and time, and often were rare and unreliable. Because of this, we expect that the distribution of food and water determined where prehistoric hunter-gatherers chose to live and work.

Behavioral ecology uses optimality models to predict foraging behavior. These assume that, all other things being equal, organisms that forage efficiently enjoy a selective advantage over less efficient competitors. Therefore, evolution favors organisms that make choices which improve their foraging efficiency (Smith and Winterhalder 1992:53). Often, such models simplify the task of evaluating foraging efficiency by presupposing that foragers make decisions motivated to maximize net energetic foraging return rates (kilocalories per hour).

Usually behavioral ecologists use optimal foraging models to test hypotheses about momentary foraging behavior of living organisms so they can compare theoretical expectations directly with observed behavior. In this case, we employ optimal foraging models to hypothesize how generations of hunter-gatherers should have used resource patches over the long term, and test our expectations against the archaeological record. We neither presume that there was only one optimal strategy for foraging in Railroad Valley, nor that the behavior of all Railroad Valley foragers was always optimal. However, the archaeological record proves that hunting and gathering was a successful economic lifeway in Railroad Valley for millennia and that ethnographic foragers benefitted from generations of hard-won, local experience in this lifestyle. Therefore, we expect that some foraging strategies possible in Railroad Valley were more efficient than others, and that those hunter-gatherers who chose better strategies were better-fed and raised more children than less efficient competitors.

Over time, locations offering the best places to live and forage attracted more hunter-gatherer activity than less favorable locations. The archaeological record reflects such locational preferences in the spatial distribution, size, and diversity of archaeological assemblages. Consequently, we can predict the distribution and composition of prehistoric archaeological sites by replicating prehistoric resource distributions in the Railroad Valley study area and modeling how prehistoric people could best forage in that landscape. Such predictions are testable by analysis of archaeological site distributions.

Given this theoretical predilection, we assume that Railroad Valley hunter-gatherers strove for foraging efficiency. Using optimal foraging models as a guide, we expect that prehistoric hunter-gatherers achieved their best returns by living and foraging in habitats providing highest caloric return rates. We can model the foraging options of hunter-gatherers by ranking the energetic productivity and spatial distribution of resources that habitats contain. Development of an optimal foraging analysis of the locational decisions of Railroad Valley hunter-gatherers also requires consideration of three organizational constraints of ethnographic subsistence and settlement strategies which optimal foraging models fail to consider: seasonality, sexual division of labor, and central place foraging. Seasonality structures intra-annual fluctuation in the availability of resources, whereas sexual division of labor and central place foraging are fundamental tactics of hunter-gatherers for scheduling procurement of simultaneously available but spatially dispersed resources (Flannery 1968; Isaac 1978). Introduction of these constraints into the Railroad Valley model improves the realism and accuracy of its predictions.

Thus, this chapter considers a set of subsistence resources that were mapped onto the habitat landscape in Chapters 3 and 4. Caloric costs and benefits serve to rank the relative values of these resources. Next, the ethnographic record serves to divide resources into men's and women's prey, and then into sets of resources that are simultaneously available in the same season. These sets of resources are projected against the habitat landscape to calculate the overall foraging returns available in each habitat and to rank habitats by their seasonal productivity as foraging patches for either sex. Diet breadth and patch choice predictions of the model are then compared with ethnographic observations of Railroad Valley foraging behavior, and implications of predictive failures and successes are considered.

Diet Breadth and Patch Choice Models

Evaluating the foraging potential of Railroad Valley habitats requires consideration of two optimal foraging models: diet breadth and patch choice. The diet breadth model (Schoener 1971) predicts whether a forager should harvest a resource upon encounter, based on the caloric return offered by that resource, compared with the return gained from bypassing that resource and continuing to search for other resources in the environment. The model calculates the return rate of exploiting a particular food based on the time required to pursue and process (handling time) that resource, and the number of calories thereby gained. Return rates are thus expressed as calories per hour and this figure ranks the caloric value of different resources. However, estimates of handling cost only calculate time necessary to extract energy from a resource after it is encountered, ignoring the search time necessary to find that resource. Thus, for any specific environment, the rank of a resource in a diet breadth model is independent of its abundance (i.e., the rate at which a forager successfully encounters the resource), and the post-encounter caloric return rate of any single resource differs from the average return rate for searching and harvesting all dietary items in that environment. Foragers maximize average energetic returns only by harvesting those resources that offer return rates greater than the rate for shunning that resource and exclusively seeking, collecting, and processing all higher ranked resources. Thus, the diet breadth model specifically models trade-offs in energetic return rates between search and handling costs.

The following equations mathematically express this relationship. The average foraging return rate (E/T) obtainable from any set of resources within an environment is calculated as follows (Simms 1984; Stephens and Krebs 1986):

$$E/T = \frac{\left(\sum_{i}^{n} R_i * E_i\right)}{\left[1 + \left(\sum_{i}^{n} R_i * h_i\right)\right]}$$

(equation 1)

where:

E = total calories acquired from foraging for all resources up to and including resource i,
T = total time spent foraging (handling and search time) for all resources up to and including resource i,
E_i = calories available in a unit of resource i (kcal/kg),
h_i = handling time per unit of resource i (hr/kg), and
R_i = encounter rate with resource i per unit of search time (kg/hr).

Thus, according to the diet breadth model, any specific resource (i) should be in the diet only so long as:

$$E / T < E_i / h_i.$$

(equation 2)

The diet breadth model makes three specific predictions: 1) Foragers will take any resource that is in the optimal diet whenever they come across it. 2) Whether any resource is within the optimal diet depends on the comparative abundance of all higher ranked resources, not on the abundance of that particular resource. 3) Optimal diet breadth contracts and expands in response to fluctuations in the abundance of higher ranked resources; if high ranked resources become sufficiently common then low ranked resources may fall from the diet, but diet breadth expands to include new resources if higher ranked resources become sufficiently rare (Schoener 1971).

To conceptualize diet breadth model predictions, imagine that a gatherer forages in an environment where ground squirrel (E_i/h_i = 5,900 kcal/hr), shadscale seed (E_i/h_i = 1,200 kcal/hr), and pickleweed seed (E_i/h_i = 180 kcal/hr) are available. If the gatherer finds ground squirrels sufficiently often that she achieves average foraging returns (E/T) greater than 1,200 kcal/hr for seeking, collecting, and processing only squirrel, she lowers her overall foraging return rate if she harvests seeds of shadscale or pickleweed no matter how often she comes across them. If the overall return rate for harvesting only squirrels falls below 1,200 kcal/hr (perhaps because of over hunting or an environmental change), the gatherer increases her overall foraging return rate by adding shadscale seed to her diet no matter how scarce shadscale may be, but she should also continue to take squirrel whenever she has the opportunity (no matter how rarely). However, as long as her average foraging returns for seeking and harvesting squirrel and shadscale together remain greater than 180 kcal/hr, she maximizes her overall return rate by forsaking pickleweed seed regardless of how common pickleweed may be.

Bettinger (1993:49-50) notes one flaw in the logic of the diet breadth model that bears consideration when applying the model to Great Basin hunter-gatherers. He points out that the diet breadth model calculates optimal behavior according to momentary circumstances. Contingency based predictions can be misleading if other constraints select for foraging efficiency over the longer term. For example, a forager whose selective constraint is to avoid starvation, but who optimizes behavior according to momentary contingencies, may collect the necessary calories less efficiently than a forager who takes resources that seem suboptimal concerning momentary returns. According to Bettinger, this problem may be particularly relevant to foragers who store food.

The diet breadth model assumes that resources are homogeneously distributed through the environment, but principles of the model can be adjusted to predict foraging decisions in environments where resources are unevenly distributed among patches (MacArthur and Pianka 1966). A patch is merely a concentration of food, and the patch choice model assumes that foragers encounter patches randomly and sequentially in the environment. The model predicts which patches foragers should elect to forage in, whenever encountered, in order to maximize their overall caloric return rate. Just as the diet breadth model ranks different resources by rate of caloric return per unit of handling time, the patch choice model also ranks different kinds of patches according to caloric return, but does so by including search time within the patch, along with handling time, as a measure of cost. However, the time necessary to travel between patches is not considered a cost in ranking patches. Thus, just as the ranks of food resources in the diet breadth model are independent of resource abundance (search time), patch type rankings are independent of patch abundance (travel time), and the patch choice model compares trade-offs in energetic return rate between combined search and handling costs with travel costs.

The patch choice model is mathematically expressed as follows (Charnov 1976; Stephens and Krebs 1986:25-27):

$$E / T = \frac{\sum_{i=1}^{n} R_i E_i - C_s}{1 + \sum_{i=1}^{n} R_i h_i}$$

(equation 3)

where:

E = total calories acquired from foraging for all patches up to and including patch i,
T = total time spent foraging (handling, search, and travel time) for all patches up to and including patch i,
R_i = encounter rate with patch type i per unit of time (kg/hr)
E_i = calories available in an example of patch i (kcals/kg),
C_s = energetic cost per unit of time expended in foraging in all patches up to and including patch i, and
h_i = search and handling time per unit of patch i (hr/kg).

Therefore, the equation indicates that a forager should choose a patch only as long as the returns for searching for and handling resources within the patch exceed the overall returns for traveling to and foraging within higher ranked patches, or:

$$E / T < E_i / h_i.$$

(equation 4)

Like the diet breadth model, the patch choice model predicts which patches a forager should choose on encounter. It predicts that foragers prefer the most energetically profitable patches and that a change in resource abundance may alter the breadth of patch selection. However, other patch choice predictions are not so straightforward as those of the diet breadth model because search time is considered a cost in ranking patches; although the rank of patches is independent of the abundance of patches, it is not independent of the abundance of resources within patches. Unlike the diet breadth model, where sufficiently increased abundance of high ranked resources will narrow whereas sufficiently diminished abundance will broaden optimal diet breadth, it is unclear whether the optimal breadth of patches will broaden, narrow, or remain stable when resource abundance changes. This is because changing the abundance of resources may alter both search time within patches (because the abundance of resources within patches may change) and travel time between patches (because the abundance of patches may change). Thus, effects of fluctuating resource abundance on patch breadth are contingent on whether travel, search, or handling time comprise the bulk of costs required for exploiting resources in patches.

Consider patches containing resources that are easily found but expensive to harvest (seeds for example). Increasing the quantity of those resources should increase the number of profitable patches containing those resources and, therefore, lower travel time between patches. However, increasing resource abundance within those patches may not reduce search costs sufficiently to raise the average foraging returns within those patches. In this situation, foragers should select a more narrow range of high ranked patch types because more examples of these patch types are available (i.e., the abundance of high ranked patch types increases). In contrast, increasing the abundance of resources that are hard to find but cheap to handle (for example large game) will increase overall returns within patches as well as number of patches. In these cases, patch breadth may broaden as resources become more abundant, because more patch types are sufficiently high ranked to fall within optimal patch breadth (i.e., the rankings of patches increase). This means that we must consider how paleoenvironmental change would affect the distribution of intrapatch resources with different allotments of search and handling costs before predicting the effects of such change on patch selection in Railroad Valley.

Another ambiguity in the predictions of the patch choice model concerns its assumption that foragers encounter patches sequentially rather than simultaneously. If a forager has the simultaneous option of exploiting more than one patch, then travel time can significantly alter optimal patch choice in ways that contradict the expectation that foragers should always choose the highest ranked patches to maximize foraging returns. As travel time increases (greater distance between patches), it constitutes a greater proportion of the total costs necessary to exploit patches, while the proportional contribution of search and handling costs diminishes. Thus, if a forager is sufficiently close to a low ranked patch, then the additional travel time required to reach a more distant but higher ranked patch may lower its overall return below that of the nearby patch. The forager will achieve greater foraging returns by exploiting the lower ranked, but local, patch.

The complications of simultaneous patch encounters are particularly critical to predicting patch choice of central place foragers, who may choose among a set of simultaneously available patches of varying distances from a stable central point, rather than sequentially encountering patches on a foray (Kaplan and Hill 1992:180; Stephens and Krebs 1986:38-45). For example, imagine a scenario applicable to the arid Great Basin where hunter-gatherers must camp near water, but the best foraging patches are far from water sources. Depending on the particular circumstances of travel costs and relative patch returns, those hunter-gatherers may find it more profitable to forage in lower ranked patches that are close to home than in the distant, but profitable, patches. This means that consideration of patch choice among central place foragers must consider constraints that limit the choice of central place locations.

Neither diet breadth nor patch choice models specifically predict where hunter-gatherers should elect to forage, and both ignore constraints pertinent to those facing central place hunter-gatherers. Yet they can serve as the framework for an optimal foraging approach to modeling the locations of central place foraging and settlement decisions once appropriate constraints are considered. The habitats described in Chapters 3 and 4 are types of patches that differ in the assortment and proportion of resources they contain. To maximize caloric intake, Railroad Valley hunter-gatherers should prefer to forage in habitats (patches) providing highest average return rates. The average return rate obtainable from the optimal diet of each habitat type (E/T) can be calculated by using equation 1 of the diet breadth model and considering the abundance and energetic return rates of resources available within each habitat. Habitats then can be ranked according to the average return obtainable given the net return rate and abundance of resources contained within each habitat type. However, the array of prey available within each habitat varies seasonally, so habitat types are also ranked separately for each season of the year.

Too, ethnographic male and female hunter-gatherers pursue different sets of prey. In this model, sexual division of foraging effort is assumed to be determined by trade-offs between child care and resource variability that are not monitored by these optimal foraging models. Therefore, after considering how extrinsic constraints of variability and mobility determined the array of resources available to each sex, habitat types are ranked separately for men and women.

For the moment, we assume Railroad Valley hunter-gatherers favored habitat types that offered highest returns for both men and women, but sexual division of labor and central place foraging tactics would have allowed them to exploit simultaneously more than one patch. How Railroad Valley foragers may have reconciled conflicts between the foraging interests of men and women will be considered after evaluation of the foraging utility of habitats for male and female foragers.

Ranking Major Resources in Railroad Valley by Caloric Return Rate

Principles of the diet breadth model can predict which resources foragers should harvest in each habitat in order to maximize their overall foraging return rate (E/T) and estimate the foraging return rate obtainable from the optimal diet within each habitat type. To do so, the net return rates (E_i/h_i) of food items in Railroad Valley must be estimated to rank the resources. Table 20 lists food items known from ethnographic records to be in the diet of the Great Basin hunter-gatherers (Fowler 1986), which occur in Railroad Valley habitats. Table 21 lists resources for which experimentally derived caloric return rates are available.

Given the experimental nature of return rates used here, predicting foraging decisions based on deceptive precision in return rates should be avoided. For example, it would be spurious to predict that hunter-gatherers should prefer wildrye seeds over ricegrass seeds because the former return a few more calories per hour than the latter. This minor difference between return rates is too small for predictive purposes, given the limited number of experiments conducted thus far. Here, as in Zeanah et al. (1995:281-282) and Raven and Elston (1989:136), resources are grouped into rank classes defined by ranges of similar return rates (Table 21). This allows comparison of potential return rates available from foraging in different habitats without eliciting predictions based on spurious precision among different resource return rates. Notice that Ranks 1 through 3 have equal intervals of 300 kcal/hr (up to 900 kcal/hr). In contrast, Rank 4 contains resources yielding from 900 to 1,499 kcal/hr, Rank 5 resources provide between 1,500 and 3,499 kcal/hr, Rank 6 contains resources producing between 3,500 and 8,999 kcal/hr, Rank 7 resources provide more than 9,000 kcal/hr, and Rank 8 resources yield 20,000 or more kcal/hr.

Note in Table 21 that caloric return rates (E_i/h_i) are known for only a portion of food items listed in Table 20. This means that caloric return rates must be estimated for the remaining resources. Estimating return rates for resources lacking experimental data is a valid approach for ranking resources so long as the estimates are based on similarities in package size (i.e., seed size, caloric content, etc.) and handling methods (i.e., snares, seed beaters) with resources of experimentally known return rates. Using return rate rank classes simplifies this task because unknown resources need only be assigned to a return rate interval rather than to a specific return rate estimate. Table 22 lists the remaining food items in the Railroad Valley habitat database, assigning each a return rate class and a net return rate (E_i/h_i) representing the mid-point of the return rate interval. Note that the table also cites justification for the assignment based on similarities of resource type, package size, and handling technique with resources that have been experimentally procured.

Table 20. Ethnographically Recorded Food Items Monitored in Railroad Valley Habitat Landscape

Food Item	Resource Category	Food Category
mule deer	large mammal	game
bighorn sheep	large mammal	game
pronghorn antelope	large mammal	game
cottontail/jackrabbit	medium mammal	game
woodrat/marmot	medium mammal	game
large ground squirrel	medium mammal	game
small mammals	small mammal	game
waterfowl	game bird	game
sage grouse	game bird	game
annual forbs	annual forb/grasses	seeds
arrowleaf balsamroot	forb	seeds, roots, leaves
foxtail barley	grass	seeds
basin wild rye	grass	seeds
bentgrass (redtop)	successional perennial	seeds
black greasewood	shrub	seeds
bluegrass	grass	seeds
bulrush	grass	seeds, roots
cattail	grass	pollen, roots, seeds, shoots
clover	forb	seeds, leaves
common arrowhead	forb	roots
dropseed/scratchgrass	grass	seeds
evening primrose	forb	stems, roots
galleta	grass	seeds
glasswort	forb	seeds
globemallow	forb	seeds
goldenweed	forb	seeds
green molly kochia	shrub	seeds
Indian ricegrass	grass	seeds
inland saltgrass	grass	seeds
sago pondweed	grass	seeds
mustard	successional annual	seeds, leaves
needlegrass	grass	seeds
Nevada dalea	shrub	seeds
Nevada ephedra	shrub	seeds
peachbrush/chokecherry	shrub	fruit
pricklypear	shrub	stems, fruits
princesplume	forb	leaves, stems, seeds
wild rose	shrub	fruits
rush	grass	seeds
sagebrush	shrub	seeds
sago pondweed	forb	roots, stalks
saltbush	shrub	seeds
sedge	grass	seeds
seepweed	shrub	seeds
shadscale	shrub	seeds
silver buffaloberry	shrub	fruit
singleleaf pinyon	tree/shrub	seeds
spikerush	grass	bulbs
squirreltail	grass	seeds
tapertip hawksbeard	forb	leaves
thistle	annualforb	stems
tufted hairgrass	grass	seeds
Utah juniper	tree/shrub	seeds
western dock	forb	seeds, stems, leaves
wheatgrass	grass	seeds
wildiris	forb	roots
wolfberry	shrub	fruits
yucca	shrub	fruits

Table 21. Experimental Caloric Return Rates of Food Items in Railroad Valley Habitat Model

Food Item	Return Rate	Resource Class (kcal/hr- Ei/hi)	Class Rank	Source
mule deer	large game	17,971- 50,000	8	Simms 1987; Zeanah 1996
bighorn sheep	large game	17,971- 31,450	8	Simms 1987
pronghorn antelope	large game	15,725-31,450	8	Simms 1987
jackrabbit	medium game	13,475-15,400	7	Simms 1987
cottontail rabbit	medium game	8,000-15,000	7	Winterhalder 1981; Simms 1987
large ground squirrel	medium game	5,390-6,341	6	Simms 1987
cattail	pollen	2,750-9,360	6	Simms 1987
small ground squirrel (small mammal)	small game	2,837-3593	5	Simms 1987
duck (waterfowl)	small game	1,300-3,000	5	Reidhead 1976; Winterhalder 1981; Simms 1987
sage grouse	small game	1,200-1,800	5	Winterhalder 1981
tanseymustad (annual forb/grass)	seed	1,307	4	Simms 1987
singleleaf pinyon	seed	1,003-1,702	4	Simms 1987; Barlow and Metcalfe 1995
shadscale	seed	1,000-1,200	4	Simms 1987
bulrush	seed	302-1,699	3	Simms 1987
goosefoot (annual forb/grass)	seed	725	3	Seeman and Wilson 1984
sunflower (annual forb/grass)	seed	467-504	2	Simms 1987
bluegrass	seed	418-491	2	Simms 1987
basin wild rye	seed	266-492	2	Simms 1987; Bullock 1994
Indian ricegrass	seed	301-392	2	Simms 1987; Jones and Madsen 1991; Larralde and Chandler 1981
cattail	seed	260	1	Rhode 1997 cited in Madsen et al. 1997
dropseed/scratchgrass	seed	162-294	1	Simms 1987
foxtail barley	seed	138-273	1	Simms 1987
sedge	seed	202	1	Simms 1987
bulrush	root	160-257	1	Simms 1987
cattail	root	42-267	1	Simms 1987; Jones and Madsen 1991
princesplume	leaves	150	1	Hooper 1994
inland saltgrass	seed	146-160	1	Simms 1987
bottlebrush squirreltail	seeds	91	1	Simms 1987

Diet and Sexual Divisions of Labor

Sexual division of labor is a fundamental aspect of the organization of hunter-gatherer subsistence strategies (Kaplan and Hill 1992:195; Hames 1992:226) that ethnographic Great Basin groups share (Kelly 1932:79; Steward 1938:44, 1941:253; Stewart 1941:406). Males and females procure different assortments of resources: males typically hunt whereas females emphasize gathering. Sexual division of labor complicates the task of modeling hunter-gatherer foraging strategies because men and women simultaneously procured different prey, sometimes in different places, returning to a common hearth to share food. However, evolutionary ecologists working among modern hunter-gatherers warn that sexual division of labor cannot be overlooked when applying optimal foraging models to humans because men and women have different motives for seeking different sets of prey under different constraints (Hill et al. 1987; Simms 1987:36; Hawkes 1996). Thus, this model evaluates men's and women's foraging strategies separately.

Table 22. Estimated Caloric Return Rates of Food Items in Railroad Valley Habitat Model

Food Item	Resource Class	Return Rate (kcal/hr- Ei/hi)	Class Rank	Note	Source
woodrat	medium game	6,250	6	similar size and hunting techniques for gopher	Simms 1987
marmot	medium game	6,250	6	similar size and hunting techniques for gopher	Simms 1987
arrowleaf balsamroot	root	1,200	4	inferred from other highland roots	Couture et al. 1996
blazing star (annual forb/grass)	seed	750	3	similar to goosfoot	DeDecker 1991
Nevada ephedra	seed	750	3	similar seed size and harvest method to shadscale, but higher collection cost	Plummer et al. 1968
peachbrush/chokecherry	fruit	750	3	similarity with known fruits	Reidhead 1976; Zeanah 1996
pricklypear	stem,fruit	750	3	similarity with known fruits	Reidhead 1976; Zeanah 1996
wild rose	fruit	750	3	similarity with known fruits	Reidhead 1976; Zeanah 1996
saltbush	seed	750	3	similar seed size and collection technique, but twice the collection cost of shadscale	Plummer et al. 1968
seepweed	seed	750	3	seed size	Raven and Elston 1989
silver buffaloberry	fruit	750	3	similarity with known fruits	Reidhead 1976; Zeanah 1996
Utah juniper	fruit	750	3	inferred from other fruits	Reidhead 1976; Zeanah 1996
wolfberry	fruit	750	3	similarity with known fruits	Reidhead 1976; Zeanah 1996
yucca	fruit	750	3	similarity with known fruits	Reidhead 1976; Zeanah 1996
galleta	seed	450	2	inferred from seed size	USDA Soil Conservation Service 1990
needlegrass	seed	450	2	comparable seed size to Indian ricegrass	Simms 1987; USDA Soil Conservation Service 1990
wheatgrass	seed	450	2	similar to basin wild rye	Raven and Elston 1989; Plummer et al. 1968
bentgrass (redtop)	seed	150	1	small seed size	USDA Soil Conservation Service 1990
black greasewood	seed	150	1	small seed size	USDA Soil Conservation Service 1990
clover	seed, leaf	150	1	small seed size/ leaf similar to princes' plume	Hooper 1994; USDA Soil Conservation Service 1990
common arrowhead	root	150	1	inferred from cattail root	Simms 1987
evening primrose	stem, root	150	1	inferred from cattail and prince's plume	Simms 1987; Hooper 1994
glasswort	seed	150	1	inferred from pickleweed	Simms 1987; Barlow and Metcalf 1995
globemallow	seed	150	1	small seed size	USDA Soil Conservation Service 1990
goldenweed	seed	150	1	small seed size	USDA Soil Conservation Service 1990
green molly kochia	seed	150	1	small seed size	USDA Soil Conservation Service 1990
mat muly	seed	150	1	inferred from dropseed/scratchgrass	Simms 1987
mustard	leaf	150	1	inferred from princesplume	Hooper 1994
Nevada dalea	seed	150	1	small seed size	USDA Soil Conservation Service 1990
rush	seed	150	1	similar to sedge	Simms 1987
sagebrush	seed	150	1	inferred from harvest method, small seed size and low seed purity	Plummer et al. 1968
sago pondweed	root, stalk	150	1	inferred from cattail roots	Simms 1987
cattail	seed	150	1	small seed size	Raven and Elston 1989
spikerush	bulb	150	1	inferred from cattail roots	Simms 1987
tapertip hawksbeard	leaf	150	1	inferred from prince's plume	Hooper 1994
thistle	stem	150	1	inferred from prince's plume	Hooper 1994
tufted hairgrass	seed	150	1	small seed size	USDA Soil Conservation Service 1990
western dock	seed	150	1	inferred from sedge	Simms 1987
wildiris	root	150	1	inferred from cattail roots	Simms 1987

Table 23 indicates whether men or women foraged for particular food resources. Steward's (1941:312-313) descriptions of Shoshone bands in and near Railroad Valley are specific that women accomplished all seed gathering, whereas men harvested no seeds except pinyon nuts (however, Steward [1938:119] mentions that men burned brush and sowed seed plots). For this reason, Table 23 lists all seeds as women's resources, and lists only pinyon nuts as a men's resource. We infer from the predominance of women's labor in seed procurement that women also harvested all pollen, roots, bulbs, leaves, stems, and fruits, whereas men gathered none.

Table 23. Sexual Division of Labor and Seasonality for Food Items Monitored in Railroad Valley Habitat Landscape

Plant Resource	Food Category	Return Rate Class	Men's Prey	Women's Prey	Spring	Summer	Fall	Winter
bighorn sheep	game	8	X		X	X	X	X
mule deer	game	8	X		X	X	X	X
pronghorn antelope	game	8	X		X	X	X	X
cottontail/jackrabbit	game	7	X	X1	X	X	X3	X
woodrat/marmot	game	7	X		X	X	X	
cattail	pollen	6		X		X		
cattail	root	6		X				X
large ground squirrel	game	6	X		X			
sage grouse	game	5	X	X	X	X		
small mammals	game	5	X		X	X	X	X
waterfowl	game	5	X		X		X	X
arrowleaf balsamroot	root	4		X	X			
shadscale	seed	4		X			X	X
singleleaf pinyon	seed	4	X2	X			X	
tanseymustard (annual forb/grass)	seed	4		X		X		
bulrush	seed	3		X			X	
goosefoot (annual forb/grass)	seed	3		X			X	
cattail	shoot	3		X	X			X
blazing star (annual forb/grass)	seed	3		X		X		
Nevada ephedra	seed	3		X		X		
peachbrush/chokecherry	fruit	3		X		X		
pricklypear	fruit	3		X		X		
saltbush	seed	3		X			X	X
seepweed	seed	3		X			X	
silver buffaloberry	fruit	3		X		X		
Utah juniper	fruit	3		X			X	
wild rose	fruit	3		X		X		
wolfberry	fruit	3		X		X		
yucca	fruit	3		X		X		
basin wild rye	seed	2		X		X	X	
bluegrass	seed	2		X		X		
galleta	seed	2		X		X		
Indian ricegrass	seed	2		X		X		
sunflower (annual forb/grass)	seed	2		X			X	
wheatgrass	seed	2		X		X	X	
bentgrass (redtop)	seed	1		X		X		
black greasewood	seed	1		X			X	X
bottlebrush squirreltail	seed	1		X		X		
bulrush	root	1		X			X	
cattail	root, seed	1		X			X	
clover	seed, leaf	1		X	X			
common arrowhead	root	1		X			X	X
dropseed/scratchgrass	seed	1		X		X	X	
evening primrose	stem, root	1		X	X			X
foxtail barley	seed	1		X		X		
glasswort	seed	1		X	X		X	X
globemallow	seed	1		X			X	X

Table 23—*Continued.*

Plant Resource	Food Category	Return Rate Class	Men's Prey	Women's Prey	Spring	Summer	Fall	Winter
goldenweed	seed	1		X		X		
green molly kochia	seed	1		X		X		
inland saltgrass	seed	1		X		X	X	
mat muly	seed	1		X		X	X	
mustard	leaf	1		X	X			
needlegrass	seed	1		X		X	X	
Nevada dalea	seed	1		X			X	X
princesplume	leaf, stem, seed	1		X	X			
rush	seed	1		X			X	
sagebrush	seed	1		X			X	X
sago pondweed	root, stalk	1		X		X		
sedge	seed	1		X	X			
spikerush	bulb	1		X		X	X	
tapertip hawksbeard	leaf	1		X	X			
thistle	stem	1		X	X			
tufted hairgrass	seed	1		X		X	X	
western dock	seed, stem, leaf	1		X		X	X	
wildiris	root	1		X		X	X	

1- in cooperation with men on drives
2- in cooperation with women
3- drives

Steward's ethnohistoric data allow women no role in hunting large and medium sized game. We question this assessment based on ethnographic description of women's involvement in communal antelope and jackrabbit drives elsewhere in the Great Basin (Fowler 1989: 78; Kelly 1932:79). Communal antelope drives took place north of the present study area (Steward 1938: 120), allowing us to leave hunting antelope as an exclusive men's activity within our area of concern, but communal rabbit drives were a regular event within the study area (Steward 1938:119-120). For this reason we tentatively assign a role for both men and women in driving rabbits. Steward's descriptions also restrict most small game procurement to males (Steward 1941:253, 313, 349), but this contradicts the skill of women in snaring small rodents observed elsewhere in the Great Basin (Fowler 1989:23; Kelly 1932:79). Therefore, Table 23 assigns small mammals to both men and women.

The greatest difference between men's and women's prey lies in resource rank; men do not procure most of the relatively low ranked resources, whereas women do not procure most higher ranked resources. This reflects the different investment in search and handling time required to gather plant resources as opposed to that required to hunt prey. Men's prey are mobile and probably unpredictable, requiring considerable investment of search time. As discussed previously under the patch choice model, this means that an increase in the abundance of men's resources may cause men's patch (habitat) selection to broaden, whereas diminished abundance may cause patch selection to narrow. In contrast, women's resources are relatively stationary and predictable, and entail higher investment in handling time than in search time. Therefore, women's patch selection may narrow as gathered resource abundance increases and expand as gathered abundance declines.

Seasonal Variation in Foraging Opportunities

Technically, diet breadth and patch models can predict forager choice only among resources that are available simultaneously (that a forager encounters sequentially), and thus incur an opportunity cost when a forager forsakes one resource in favor of another. So far, all Railroad Valley resources have been considered collectively without regard to synchronicity, but now patterns in the temporal availability of resources must be controlled to predict diet breadth and patch returns accurately. For example, that bulrush seeds provide higher caloric returns than Indian ricegrass is not informative about the preference of gatherers for either resource, because seeds of the two ripen in different seasons. By procuring one, a gatherer does not forfeit her opportunity to harvest the other; she can take each in season. Whether either or both appear in the diet is not a function of their rank and abundance relative to one another, but of the abundance of concurrently available higher ranked resources (ignoring for the moment the complication that storage can extend the availability of some resources over several consecutive seasons).

Since the set of available resources changes seasonally, optimal diet should vary seasonally as well. Consequently, Table 23 divides resources into seasonal sets according to seasonal availability. "Seasons" are defined according to annual shifts in resource availability in Railroad Valley. Thus, spring begins in late February or early March, as forbs appear and ground squirrels and small mammals come out of hibernation. Summer, beginning in June, offers cattail pollen, grass seed, and berries. Fall begins in late August or early September when pinyon pine nuts, and the seeds of bulrush, shadscale, and saltbush are available. Winter begins with the first significant snow, usually middle November, leaving only a few plant and animal resources available for foraging. Note that all seasons offer pronghorn antelope, mule deer, and bighorn sheep. However, the habitat distribution of these resources changes seasonally. We assume that all three species range in upper elevation habitats during summer and lower elevation habitats during winter.

Estimating Resource Encounter Rates in Railroad Valley Habitats

Preceding discussions have organized food resources according to caloric return rates, seasonal availability, and the gender of the forager who acquires them. Now, data on the density of food items in Railroad Valley serve to estimate the rates at which hunter-gatherers should encounter resources within habitats. Given an estimate of the density of resource items per square kilometer, the following equation calculates an encounter rate in kilograms per hour (Winterhalder et al. 1989:325):

$$R_i = d_i * wt_i * S_v * 2S_r$$

(equation 5)

where:

R_i = number of resource i encountered per unit of time (kg/hr),
d_i = number of resource i per km^2,
wt_i = edible weight (kg) per resource i,
S_v = forager search speed (km/hr), and
S_r = forager search radius (km).

By estimating the density of food items per square kilometer in the habitat landscape, it is possible to calculate an encounter rate for randomly searching for those food items within that habitat. Estimation of resource density differs for plant foods and game, so the two categories are considered separately. For both categories, forager search speed (S_v) is assumed to be 1.5 km/hr.

Plants

The range type descriptions that define habitat types offer precise estimates of the quantity of herbage of plant resources in kilograms per hectare. However, it is unclear how raw herbage rate translates to what the forager actually encounters in the environment (i.e., stands or individual plants). Simms (1987:48-53) and Zeanah (1996:295-299) estimated encounter rates with plants by calculating the percentage ground coverage of those plants. Range type descriptions estimate the percentage plant cover of vegetation communities associated with each range type, and these can be extrapolated to each habitat. Furthermore, percentage cover and total herbage weight are significantly correlated among the habitats ($r=.85$, $p=.0001$), allowing the percentage cover of each plant resource within each habitat type to be gauged from the percentage weight of that species.

Following Simms (1987:49), all plants are assumed to occur in stands of 10 m^2. Therefore, every square kilometer within a habitat contains 10,000 plots that may contain a stand of any particular plant resource indigenous to that habitat. The percentage cover estimated for each plant resource calculates how many stands of that resource occur per square kilometer of any habitat. For example, if a particular plant resource comprises 2% of total herbage weight within a habitat with 40% plant cover, then we presuppose that 80 10 m^2 stands of that resource occur within each square kilometer of that habitat. This value determines the number of items (10 m^2 stands) of each plant resource per square kilometer (d_i) in each habitat (Table 24).

Modeling edible weight in kilograms obtainable in each stand (wt_i) is also problematic because total herbage weight is not equivalent to the quantity of edible seed, root, fruit, or green accessible to a forager. An extensive literature review revealed no consistent way to estimate the quantity of edible tissue that a given quantity of herbage biomass might produce. Too, it is unrealistic to assume that a forager would exhaust all edible resources in a particular stand before finding it more productive to move on to the next stand. A simplifying assumption is to hold constant the time that a forager can harvest any stand, and use experimentally derived harvest rates to calculate the amount of resource procured in that span. In his collection experiments, Simms (1987:50) set the time for collection of a stand at half an hour, the time he found reasonable for harvesting a 10m^2 stand of most plant resources. This time limit also serves here. The harvest rates and estimated edible quantity per 10m^2 stand, per 0.5 collecting hours, for each plant resource are presented in Table 25. Search radius (S_r) is 10 m for all plant resources.

Game

Unlike flora, the habitat database offers no direct measure of faunal abundance within each habitat type. However, in Chapter 3, the biotic and physical characteristics of the habitat type landscape served to rank the probability that habitats contain particular game animals. Using these data, the rates at which hunter-gatherers should encounter different game can be inferred for specific habitats. To do this, we standardize the habitat suitability scores developed in Chapter 3 so that the habitat with highest suitability is ranked 1 and all other habitats ranked proportionally thereof. Table 26 indicates the modified habitat suitability scores for game.

Translating these probabilities into encounter rates in kilograms per hour (R_i) depends on whether the procurement strategy involves stalking, driving, or trapping. For trapping strategies, we follow the simulation of Zeanah (1996:300-303), which assumes that the searching forager comes across procurement locations (i.e., nests, burrows, leks) rather than individual animals. Under this

Table 24. Number of $10m^2$ Stands of Plant Resource per Sq km in Railroad Valley Habitats

	A1	G10	G11	G12	G13	G14	G15	G16	G17	G18	G2	G21	G22	G23	G3	G4	G5	G6	G8	G9	M11	M2	M3	M5	M6	M7	M8	M9	S1	S10	S4	S5	S6	S7	S8	S9	W1	W2	W4
annual forbs & grasses	0	23	20	20	30	22	27	23	21	22	2	0	10	19	2	0	6	0	3	39	10	7	0	17	13	12	4	9	0	20	34	23	27	0	12	27	0	0	0
arrowhead	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	37	0	0
arrowleaf balsamroot	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	33	80	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
bluegrass	0	23	0	9	0	0	47	0	4	0	82	0	0	19	84	118	60	93	0	0	206	177	267	122	166	91	174	542	182	19	24	84	142	110	36	79	870	1305	83
bottlebrush squirreltail	0	80	98	81	60	62	68	42	36	50	2	15	21	68	30	40	80	93	18	26	103	46	80	66	39	24	58	171	0	46	70	23	91	9	43	63	0	0	41
buffaloberry	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0
bulrush	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	335	181	0
cattail	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	465	0	0
clover	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	122	218	0
dock	0	0	0	0	0	0	0	0	0	0	81	0	0	0	55	78	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	122	0	0
dropseed/ scratchgrass	0	11	20	20	15	0	0	128	141	136	809	164	78	0	913	1279	934	1389	166	26	0	0	0	0	0	0	0	0	0	10	11	0	0	11	0	0	0	0	41
ephedra	0	115	54	44	5	62	127	15	11	15	0	15	103	38	1	0	4	0	39	221	103	77	27	122	124	91	74	191	0	66	88	147	91	0	82	169	0	0	41
evening primrose	0	0	0	0	0	0	0	0	0	0	0	30	0	0	0	0	0	0	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
foxtail barley	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	285	0	0
galleta	0	230	208	191	74	179	196	15	11	15	0	74	267	191	1	0	4	0	117	304	206	13	0	66	26	24	182	61	0	157	179	166	206	0	270	161	0	0	0
glasswort	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	77	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
globemallow	0	46	39	40	25	29	35	3	0	0	0	30	21	38	1	0	0	0	31	18	0	0	0	21	0	0	0	6	0	22	27	23	18	13	12	32	0	0	0
goldenweed	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	21	13	0	14	79	24	41	60	0	0	0	0	0	0	0	0	0	0	0
greaswood	0	0	30	324	0	27	24	365	468	299	144	0	0	614	158	151	446	926	0	26	0	0	0	0	0	0	0	0	0	11	0	0	0	212	0	0	19	0	0
basin wildrye	0	0	0	0	0	0	0	40	42	41	136	0	0	0	236	329	745	1157	0	0	0	0	0	0	0	0	0	0	2547	0	0	0	0	1629	0	0	0	0	309
Indian ricegrass	0	541	282	333	287	139	315	138	76	109	2	372	206	238	22	0	20	0	370	656	103	144	187	353	176	122	124	51	0	609	515	509	114	20	508	397	0	0	41
inland saltgrass	0	0	0	0	0	0	0	3	62	0	418	0	0	0	492	689	467	694	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0
juniper	0	12	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	328	619	11	202	10	0	405	0	9	12	23	18	0	24	32	0	0	0
kochia	0	0	0	9	0	0	0	3	8	0	3	0	0	19	1	0	0	0	0	26	0	0	0	0	0	0	0	0	0	0	0	0	0	9	0	0	0	0	0
needlegrass	0	58	53	20	79	102	185	26	0	0	0	74	123	19	11	0	0	0	95	26	206	13	0	129	132	86	273	181	0	57	148	192	206	0	174	430	0	0	41
Nevada dalea	0	0	0	0	51	21	24	3	0	0	0	74	0	0	1	0	0	0	63	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
pinyon	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	218	413	0	162	10	0	607	0	0	0	0	0	0	0	0	0	0	0
prickly pear	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	60	0	0	11	0	0	0	0	0	0	0	0
prince's plume	0	46	39	40	20	29	35	28	30	30	3	0	0	38	1	0	8	0	0	26	0	0	0	21	0	0	0	6	0	14	16	23	18	8	35	12	0	0	0
chokecherry/ desert peach	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	103
rush	0	0	0	0	0	0	0	0	0	0	134	0	0	0	164	230	30	46	0	0	0	0	0	0	0	0	0	0	73	0	0	0	0	40	0	0	907	363	0
sagebrush	0	407	164	116	74	90	215	87	72	109	134	15	206	117	164	230	20	0	66	173	412	784	935	690	578	524	868	494	364	378	646	584	457	350	606	452	0	73	413
sago pondweed	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	56	0	0
sago pondweed	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	73	0	0	0	0	40	0	0	0	0	0
saltbush	0	23	53	29	172	48	46	60	61	54	221	297	308	19	182	249	129	93	333	71	21	13	0	24	10	14	0	0	0	98	43	23	23	226	70	32	0	0	0
sedge	0	0	0	0	0	0	0	0	0	0	81	0	0	0	55	78	0	0	0	0	0	0	0	0	0	0	0	0	73	0	0	0	0	40	0	0	1518	1450	0
seepweed	0	0	0	0	0	0	0	0	8	0	61	0	0	0	108	151	30	46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
shadscale	0	294	495	482	56	296	264	374	305	463	142	0	54	386	169	230	150	46	5	26	0	0	0	11	16	0	0	6	0	71	12	23	18	9	12	12	0	0	0
spikerush	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	465	363	0
tapertip hawksbeard	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	33	80	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
thistle	0	0	0	0	0	0	0	0	0	0	81	0	0	0	55	78	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
tufted hairgrass	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1088	0
wheatgrass	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	412	781	454	624	460	641	513	6	182	0	0	0	18	110	0	0	0	218	248
wild rose	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	73	103
wildiris	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	159	218	0
wolfberry	0	11	20	20	5	58	58	83	76	88	0	74	54	59	1	0	4	0	69	71	0	0	0	0	0	0	0	0	0	10	11	0	0	0	12	0	0	0	103
yucca	0	12	0	0	0	0	7	0	0	0	0	0	21	0	0	0	0	0	5	0	0	0	0	11	0	10	0	0	0	9	12	10	0	0	24	32	0	0	0

Table 25. Plant Encounter Rates (kg/hr)

	A1	G10	G11	G12	G13	G14	G15	G16	G17	G18	G2	G21	G22	G23	G3	G4	G5	G6	G8	G9	M11	M2	M3	M5	M6	M7	M8	M9	S1	S10	S4	S5	S6	S7	S8	S9	W1	W2	W4
annual forbs & grasses (tansymustard)	0.00	0.17	0.15	0.15	0.23	0.16	0.20	0.17	0.15	0.17	0.01	0.00	0.08	0.14	0.01	0.00	0.05	0.00	0.02	0.30	0.08	0.05	0.00	0.13	0.10	0.09	0.03	0.07	0.00	0.15	0.26	0.17	0.21	0.00	0.09	0.20	0.00	0.00	0.00
annual forbs & grasses (blazing star)	0.00	0.17	0.15	0.15	0.23	0.16	0.20	0.17	0.15	0.17	0.01	0.00	0.08	0.14	0.01	0.00	0.05	0.00	0.02	0.30	0.08	0.05	0.00	0.13	0.10	0.09	0.03	0.07	0.00	0.15	0.26	0.17	0.21	0.00	0.09	0.20	0.00	0.00	0.00
annual forbs & grasses (sunflower)	0.00	0.06	0.05	0.05	0.07	0.05	0.06	0.05	0.05	0.05	0.00	0.00	0.02	0.05	0.00	0.00	0.01	0.00	0.01	0.09	0.02	0.02	0.00	0.04	0.03	0.03	0.01	0.02	0.00	0.05	0.08	0.05	0.07	0.00	0.03	0.07	0.00	0.00	0.00
annual forbs & grasses (goosefoot)	0.00	0.32	0.28	0.28	0.43	0.31	0.37	0.32	0.29	0.32	0.02	0.00	0.14	0.27	0.02	0.00	0.08	0.00	0.04	0.56	0.15	0.09	0.00	0.25	0.19	0.17	0.06	0.13	0.00	0.28	0.48	0.32	0.39	0.00	0.17	0.38	0.00	0.00	0.00
wheatgrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.43	8.39	4.88	6.71	4.94	6.89	5.51	0.07	1.95	0.00	0.00	0.00	0.20	1.18	0.00	0.00	0.00	2.34	2.66
sagebrush	0.00	1.40	0.57	0.40	0.26	0.31	0.74	0.30	0.25	0.38	0.46	0.05	0.71	0.41	0.56	0.79	0.07	0.00	0.23	0.60	1.42	2.70	3.23	2.38	1.99	1.81	3.00	1.70	1.26	1.30	2.23	2.01	1.58	1.21	2.09	1.56	0.00	0.25	1.42
shadscale	0.00	8.09	13.60	13.26	1.53	8.13	7.25	10.29	8.38	12.73	3.90	0.00	1.48	10.61	4.65	6.32	4.12	1.27	0.15	0.72	0.00	0.00	0.00	0.29	0.44	0.00	0.00	0.17	0.00	1.96	0.33	0.63	0.50	0.26	0.33	0.32	0.00	0.00	0.00
saltbush	0.00	0.32	0.73	0.40	2.36	0.67	0.63	0.83	0.84	0.75	3.04	4.08	4.24	0.26	2.50	3.42	1.77	1.27	4.58	0.97	0.28	0.18	0.00	0.34	0.14	0.19	0.00	0.00	0.00	1.35	0.60	0.31	0.32	3.10	0.96	0.44	0.00	0.00	0.00
arrlowleaf balsamroot	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.34	0.83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
sedge	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.00	0.00	0.08	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.06	0.00	0.00	2.14	2.04	0.00
thistle	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.32	0.00	0.00	0.00	2.97	4.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
taptertip hawksbeard	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.78	4.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
tufted hairgrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.85	0.00
inland saltgrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.49	0.00	0.00	0.00	0.58	0.81	0.55	0.81	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
basin wild rye	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.43	0.45	0.44	1.46	0.00	0.00	0.00	2.54	3.53	8.00	12.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	27.36	0.00	0.00	0.00	0.00	17.50	0.00	0.00	0.00	0.00	3.32
spikerush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.87	5.35	0.00
ephedra	0.00	3.16	1.50	1.21	0.13	1.71	3.49	0.41	0.30	0.41	0.00	0.41	2.83	1.05	0.03	0.00	0.11	0.00	1.08	6.07	2.83	2.12	0.73	3.35	3.41	2.50	2.05	5.24	0.00	1.82	2.42	4.03	2.51	0.00	2.25	4.65	0.00	0.00	1.13
goldenweed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.01	0.00	0.01	0.06	0.02	0.03	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
galleta	0.00	0.18	0.16	0.15	0.06	0.14	0.15	0.01	0.01	0.01	0.00	0.06	0.21	0.15	0.00	0.00	0.00	0.00	0.09	0.24	0.16	0.01	0.00	0.05	0.02	0.02	0.14	0.05	0.00	0.12	0.14	0.13	0.16	0.00	0.21	0.13	0.00	0.00	0.00
foxtail barley	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.05	0.00	0.00
wildiris	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.35	3.21	0.00
rush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.00	0.00	0.00	0.23	0.32	0.04	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.06	0.00	0.00	1.28	0.51	0.00
juniper	0.00	0.30	0.00	0.00	0.00	0.00	0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.36	15.78	0.27	5.15	0.26	0.00	10.33	0.00	0.24	0.31	0.58	0.47	0.00	0.60	0.82	0.00	0.00	0.00
kochia	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
wolberry	0.00	0.29	0.50	0.51	0.12	1.47	1.48	2.11	1.93	2.25	0.00	1.90	1.37	1.50	0.03	0.00	0.10	0.00	1.75	1.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.26	0.28	0.00	0.00	0.00	0.29	0.00	0.00	0.00	2.63
mat muhly	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0.00
evening primrose	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
prickly pear	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.31	0.00	0.00	1.53	0.00	0.00	0.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Indian ricegrass	0.00	2.03	1.06	1.25	1.08	0.52	1.18	0.52	0.29	0.41	0.01	1.39	0.77	0.89	0.08	0.00	0.08	0.00	1.39	2.46	0.39	0.54	0.70	1.32	0.66	0.46	0.47	0.19	0.00	2.28	1.93	1.91	0.43	0.07	1.91	1.49	0.00	0.00	0.15
pinyon	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.08	3.94	0.00	1.55	0.10	0.00	5.79	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
bluegrass	0.00	0.09	0.00	0.03	0.00	0.00	0.18	0.00	0.02	0.00	0.31	0.00	0.00	0.07	0.32	0.45	0.23	0.35	0.00	0.00	0.79	0.67	1.02	0.46	0.63	0.35	0.66	2.06	0.69	0.07	0.09	0.32	0.54	0.42	0.14	0.30	3.32	4.97	0.31
sago pondweed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.00	0.00
chokecherry/ desert peach	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.63
Nevada dalea	0.00	0.00	0.00	0.00	0.70	0.29	0.32	0.04	0.00	0.00	0.00	1.02	0.00	0.00	0.02	0.00	0.00	0.00	0.87	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
wild rose	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.55	1.85	2.63
dock	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.00	0.00	0.08	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.00
arrowhead	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00
glasswort	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.69	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
greasewood	0.00	0.00	0.41	4.45	0.00	0.37	0.32	5.01	6.43	4.11	1.98	0.00	0.00	8.43	2.17	2.08	6.13	12.72	0.00	0.36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.00	0.00	0.00	2.92	0.00	0.00	0.26	0.00	0.00
bulrush (seeds)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.13	1.15	0.00
burush (roots)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.86	2.09	0.00
buffaloberry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.00	0.00
bottlebrush squirreltail	0.00	0.06	0.08	0.06	0.05	0.05	0.05	0.03	0.03	0.04	0.00	0.01	0.02	0.05	0.02	0.03	0.06	0.07	0.01	0.02	0.08	0.04	0.06	0.05	0.03	0.02	0.05	0.13	0.00	0.04	0.05	0.02	0.07	0.01	0.03	0.05	0.00	0.00	0.03
globemallow	0.00	0.08	0.07	0.07	0.05	0.05	0.06	0.00	0.00	0.00	0.00	0.05	0.04	0.07	0.00	0.00	0.00	0.00	0.06	0.03	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.01	0.00	0.04	0.05	0.04	0.03	0.02	0.02	0.06	0.00	0.00	0.00
dropseed	0.00	0.02	0.04	0.04	0.03	0.00	0.00	0.23	0.26	0.25	1.48	0.30	0.14	0.00	1.67	2.34	1.71	2.54	0.30	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.02	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.08
prince's plume	0.00	2.46	2.09	2.15	1.10	1.55	1.87	1.47	1.62	1.60	0.16	0.00	0.00	2.05	0.06	0.00	0.43	0.00	0.00	1.41	0.00	0.00	0.00	1.13	0.00	0.00	0.00	0.33	0.00	0.74	0.84	1.23	0.98	0.42	1.88	0.63	0.00	0.00	0.00
needlegrass	0.00	0.22	0.20	0.08	0.30	0.38	0.69	0.10	0.00	0.00	0.00	0.28	0.46	0.07	0.04	0.00	0.00	0.00	0.36	0.10	0.77	0.05	0.00	0.49	0.49	0.32	1.02	0.68	0.00	0.21	0.56	0.72	0.77	0.00	0.65	1.61	0.00	0.00	0.15
seepweed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.23	0.00	1.69	0.00	0.00	0.00	2.98	4.16	0.82	1.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
clover	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.54	11.65	0.00
cattail seeds	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.66	0.00	0.00
cattail roots	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.87	0.00	0.00
cattail pollen	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	46.34	0.00	0.00
yucca	0.00	0.30	0.00	0.00	0.00	0.00	0.19	0.00	0.00	0.00	0.00	0.00	0.52	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.00	0.27	0.00	0.26	0.00	0.00	0.00	0.24	0.31	0.26	0.00	0.00	0.60	0.82	0.00	0.00	0.00

assumption, estimates of the density of small animal populations in similar geographic areas approximate the number of items encountered per square kilometer (*di*) in each habitat. The maximum expected densities of waterfowl nests, sage grouse leks, and the burrows of small mammals, large ground squirrels, marmots/woodrats, and rabbits/hares have been estimated elsewhere (Zeanah 1996:300-303), and are represented in Table 27. These densities are assumed to occur in the best habitats for each game category in Railroad Valley (relative habitat suitability score = 1), with densities diminishing proportionally to relative habitat suitability score for all other habitats. For example, if the relative suitability score for rabbits for a particular habitat is .02, the density of rabbit burrows in that habitat is .04 burrows per square kilometer.

Table 26. Relative Habitat Score Monitoring the Probability that Railroad Valley Habitats Host Particular Game Animals

Habitat	Antelope	Deer	Sheep	Rabbit/Hare	Woodrat/ Marmot	Ground Squirrel	Small Mammal	Waterfowl	Sage Grouse
A1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
G10	0.08	0.07	0.06	0.17	0.00	0.03	0.08	0.00	0.04
G11	0.09	0.03	0.03	0.08	0.00	0.03	0.07	0.00	0.02
G12	0.10	0.03	0.02	0.17	0.00	0.03	0.08	0.00	0.02
G13	0.14	0.00	0.00	0.08	0.00	0.07	0.09	0.00	0.04
G14	0.06	0.08	0.06	0.08	0.19	0.02	0.06	0.00	0.02
G15	0.07	0.12	0.09	0.08	0.00	0.03	0.08	0.00	0.03
G16	0.11	0.00	0.00	0.17	0.00	0.03	0.15	0.06	0.02
G17	0.14	0.00	0.00	0.17	0.00	0.04	0.19	0.12	0.04
G18	0.14	0.00	0.00	0.17	0.00	0.00	0.10	0.00	0.04
G2	0.29	0.00	0.00	0.33	0.00	0.11	0.58	0.25	0.25
G21	0.00	0.00	0.00	0.17	0.00	0.00	0.00	0.00	0.00
G22	0.04	0.09	0.06	0.17	0.00	0.04	0.05	0.00	0.00
G23	0.10	0.05	0.04	0.17	0.00	0.03	0.08	0.00	0.03
G3	0.47	0.00	0.00	0.67	0.00	0.15	0.81	0.28	0.28
G4	0.50	0.00	0.00	1.00	0.00	0.16	0.44	0.32	0.32
G5	0.15	0.01	0.00	0.50	0.00	0.11	0.30	0.27	0.09
G6	0.16	0.00	0.00	1.00	0.00	0.16	0.42	0.30	0.00
G8	0.09	0.01	0.01	0.17	0.00	0.10	0.26	0.00	0.03
G9	0.04	0.02	0.01	0.17	0.00	0.01	0.03	0.00	0.01
G9	0.08	0.03	0.01	0.25	0.00	0.02	0.07	0.00	0.01
M11	0.05	0.17	0.13	0.17	0.34	0.14	0.18	0.00	0.07
M2	0.03	0.33	0.15	0.17	0.59	0.03	0.15	0.00	0.04
M3	0.02	0.24	0.11	0.17	1.00	0.02	0.11	0.00	0.00
M5	0.06	0.26	0.10	0.17	0.60	0.02	0.06	0.00	0.02
M6	0.08	0.20	0.07	0.17	0.58	0.05	0.12	0.00	0.03
M7	0.01	0.12	0.10	0.08	0.24	0.02	0.05	0.00	0.00
M8	0.11	0.33	0.26	0.17	0.00	0.14	0.19	0.00	0.11
M9	0.06	0.18	0.15	0.08	0.20	0.08	0.22	0.00	0.11
S1	0.49	0.06	0.04	0.50	0.00	0.51	0.45	0.17	0.69
S10	0.15	0.08	0.03	0.17	0.00	0.10	0.13	0.00	0.02
S4	0.20	0.17	0.13	0.25	0.00	0.14	0.19	0.00	0.23
S5	0.06	0.13	0.09	0.17	0.59	0.06	0.08	0.00	0.06
S6	0.06	0.18	0.14	0.17	0.51	0.07	0.10	0.00	0.09
S7	0.46	0.00	0.00	0.25	0.00	0.23	0.30	0.13	0.27
S8	0.13	0.08	0.07	0.17	0.00	0.08	0.11	0.00	0.00
S9	0.04	0.20	0.08	0.17	0.00	0.04	0.06	0.00	0.01
W1	1.00	0.03	0.02	1.00	0.00	1.00	0.67	1.00	0.00
W2	0.35	1.00	1.00	1.00	0.00	0.75	0.67	0.67	0.44
W4	0.38	0.45	0.36	0.25	0.00	0.50	1.00	0.33	1.00

Table 27. Maximum Encounter Rates Feasible for Trapping Game in Great Basin Habitats (following Zeanah 1996)

Game	Unit of Encounter	Maximum Unit Density (per km^2)	Yield (kg) per Encounter
rabbit/hare	burrow	2	3.2
woodrat/marmot	burrow	3	1.72
ground squirrel	burrow	6	1.16
small mammal	burrow	6	0.52
waterfowl	nesting spot	26	0.25
sage grouse	lek	1	1.28

The edible weight in kilograms (wt_i) obtainable at each trapping point is the amount that a hypothetical trapper who sets a line of 20 snares or deadfall traps at each trapping spot can harvest. After 24 hours, four traps (20%) successfully capture an animal. These estimates are consistent with the size of ethnographic trap lines (Fowler 1989:23; Kelly 1932:88), and the successful trapping rate of modern wildlife biologists in the Great Basin (Brown 1973:777; Clary and Medin 1992:106; Feldhammer 1979:210; Jenkins 1979:24; McAdoo et al. 1983:52; Oldemeyer and Allen-Johnson 1989:393). Maintaining consistency with the 20% trapping rate assumed for other small animals, only two ducks are expected to be trapped for every five nests encountered (assuming two ducks per nest). Search radius (S_r) is 20 m for trapped game. These simple assumptions allow calculation of an encounter rate (R_i) for each habitat in the Railroad Valley study area using equation 5. The encounter rates estimated for each trapped species in each habitat of the Railroad Valley study area are presented in Table 28.

The procedure for estimating encounter rates (R_i) for game procured by stalking or driving techniques differs from those for plants and trapped animals for two reasons. First, the units encountered per kilometer are individual animals rather than plant stands or burrows, requiring estimates of the number of individuals per square kilometer that are difficult to derive. Second, it is unrealistic to assume that pedestrian hunters armed with bow and arrow could successfully detect, pursue, and dispatch every elusive quarry they come across, simply because many mobile animals will escape. Therefore, an encounter rate estimate based simply on animal densities will overestimate the successful encounter rates feasible for stalking or driving game. For these reasons, we follow Simms's (1987:55-72) encounter rate estimates for stalking and driving game animals. Simms's estimates derive from historical, ethnographic, and wildlife conservation literature regarding documented success rates of hunts and drives in the Great Basin. Table 29 lists the encounter rates, which we apply to the Railroad Valley habitat landscape simply by assuming that these rates are feasible in the most sensitive habitat for each game category (relative habitat suitability score = 1). For all other habitats, encounter rates diminish proportionally to relative habitat suitability score. For example, if the relative suitability score for sheep for a particular habitat is .5, the encounter rate for hunting sheep in that habitat is .075 kg/hr.

Table 28. Game Encounter Rates (kg/hr)

Game Resource Procurement Strategy	Antelope stalk	Antelope drive	Deer stalk	Sheep stalk	Rabbit/Hare drive	Rabbit/Hare stalk	Rabbit/Hare snare	Woodrat/Marmot snare	Ground Squirrel stalk	Ground Squirrel snare	Small Mammal snare	Waterfowl stalk	Waterfowl snare	Sage Grouse snare
A1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
G10	0.02	0.00	0.01	0.01	0.00	0.07	0.05	0.00	0.01	0.01	0.01	0.00	0.00	0.00
G11	0.02	0.00	0.01	0.00	0.00	0.05	0.03	0.00	0.01	0.01	0.01	0.00	0.00	0.00
G12	0.02	0.00	0.01	0.00	0.00	0.07	0.05	0.00	0.01	0.01	0.01	0.00	0.00	0.00
G13	0.03	0.00	0.00	0.00	0.00	0.04	0.02	0.00	0.03	0.03	0.02	0.00	0.00	0.00
G14	0.01	0.00	0.02	0.01	0.00	0.04	0.02	0.07	0.01	0.01	0.01	0.00	0.00	0.00
G15	0.01	0.00	0.02	0.01	0.00	0.04	0.02	0.00	0.01	0.01	0.02	0.00	0.00	0.00
G16	0.02	0.00	0.00	0.00	0.00	0.07	0.05	0.00	0.01	0.01	0.03	0.01	0.00	0.00
G17	0.03	0.00	0.00	0.00	0.00	0.07	0.05	0.00	0.02	0.01	0.04	0.03	0.00	0.00
G18	0.03	0.00	0.00	0.00	0.00	0.07	0.05	0.00	0.00	0.00	0.02	0.00	0.00	0.00
G2	0.06	0.92	0.00	0.00	0.95	0.14	0.10	0.00	0.05	0.05	0.11	0.06	0.00	0.02
G21	0.00	0.00	0.00	0.00	0.00	0.07	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00
G22	0.01	0.00	0.02	0.01	0.00	0.07	0.05	0.00	0.02	0.02	0.01	0.00	0.00	0.00
G23	0.02	0.00	0.01	0.01	0.00	0.07	0.05	0.00	0.01	0.01	0.02	0.00	0.00	0.00
G3	0.09	1.45	0.00	0.00	1.90	0.28	0.19	0.00	0.07	0.06	0.15	0.07	0.00	0.02
G4	0.10	1.56	0.00	0.00	2.85	0.42	0.29	0.00	0.07	0.07	0.08	0.08	0.00	0.02
G5	0.03	0.00	0.00	0.00	1.43	0.21	0.14	0.00	0.05	0.05	0.06	0.07	0.00	0.01
G6	0.03	0.00	0.00	0.00	2.85	0.42	0.29	0.00	0.07	0.07	0.08	0.08	0.00	0.00
G8	0.02	0.00	0.00	0.00	0.00	0.07	0.05	0.00	0.04	0.04	0.05	0.00	0.00	0.00
G9	0.01	0.00	0.00	0.00	0.48	0.07	0.05	0.00	0.01	0.01	0.01	0.00	0.00	0.00
G9	0.02	0.00	0.01	0.00	0.71	0.11	0.07	0.00	0.01	0.01	0.01	0.00	0.00	0.00
M11	0.01	0.00	0.03	0.02	0.00	0.07	0.05	0.11	0.06	0.06	0.03	0.00	0.00	0.01
M2	0.01	0.00	0.07	0.02	0.00	0.07	0.05	0.18	0.01	0.01	0.03	0.00	0.00	0.00
M3	0.00	0.00	0.05	0.02	0.00	0.07	0.05	0.31	0.01	0.01	0.02	0.00	0.00	0.00
M5	0.01	0.00	0.05	0.02	0.00	0.07	0.05	0.19	0.01	0.01	0.01	0.00	0.00	0.00
M6	0.02	0.00	0.04	0.01	0.00	0.07	0.05	0.18	0.02	0.02	0.02	0.00	0.00	0.00
M7	0.00	0.00	0.02	0.01	0.00	0.04	0.02	0.07	0.01	0.01	0.01	0.00	0.00	0.00
M8	0.02	0.00	0.07	0.04	0.00	0.07	0.05	0.00	0.06	0.06	0.03	0.00	0.00	0.01
M9	0.01	0.00	0.04	0.02	0.00	0.04	0.02	0.06	0.04	0.03	0.04	0.00	0.00	0.01
S1	0.10	1.54	0.01	0.01	1.43	0.21	0.14	0.00	0.23	0.21	0.08	0.04	0.00	0.05
S10	0.03	0.00	0.02	0.00	0.00	0.07	0.05	0.00	0.04	0.04	0.02	0.00	0.00	0.00
S4	0.04	0.62	0.03	0.02	0.60	0.10	0.06	0.00	0.06	0.06	0.04	0.00	0.00	0.01
S5	0.01	0.00	0.04	0.01	0.00	0.07	0.05	0.22	0.04	0.04	0.02	0.00	0.00	0.01
S6	0.01	0.00	0.04	0.02	0.00	0.07	0.05	0.16	0.03	0.03	0.02	0.00	0.00	0.01
S7	0.09	1.43	0.00	0.00	0.71	0.11	0.07	0.00	0.10	0.09	0.06	0.04	0.00	0.02
S8	0.03	0.00	0.02	0.01	0.00	0.07	0.05	0.00	0.04	0.03	0.02	0.00	0.00	0.00
S9	0.01	0.00	0.04	0.01	0.00	0.07	0.05	0.00	0.02	0.02	0.01	0.00	0.00	0.00
W1	0.20	3.12	0.01	0.00	2.85	0.42	0.29	0.00	0.45	0.42	0.12	0.26	0.39	0.00
W2	0.07	1.09	0.20	0.15	2.85	0.42	0.29	0.00	0.34	0.31	0.12	0.17	0.26	0.08
W4	0.08	1.19	0.09	0.05	0.71	0.11	0.07	0.00	0.23	0.21	0.19	0.09	0.13	0.08

Table 29. Maximum Encounter Rates Feasible for Hunting and Driving Game in Great Basin Habitats (following Simms 1987)

Game	Hunting Technique	Unit of Encounter	Encounter Rate (kg/hr)
rabbit/hare	drive	population	2.85
antelope	encounter	individual	0.2
deer	encounter	individual	0.2
sheep	encounter	individual	0.15
rabbit/hare	encounter	individual	0.42
ground squirrel	encounter	individual	0.45
waterfowl	encounter	individual	0.26

Modeling Seasonal Foraging Opportunities for Men and Women Based on the Railroad Valley Habitat Landscape

Using equations 1 and 2, and estimates of caloric return and encounter rates for each resource, an optimal overall foraging return rate (*E/T*) was calculated for each habitat, by season and gender. Table 30 presents the resulting overall returns rates for women and ranks them in sequence from highest to lowest. Table 31 lists men's projected foraging returns, similarly arranged by habitat.

Table 30. Women's Overall Foraging Returns (kcal/hr) and Ranks by Habitat and Season

Habitat	Spring Return	Spring Rank	Summer Return	Summer Rank	Autumn Return*	Autumn Rank*	Winter Return	Winter Rank
M3	460	1	492	30	1146	7.5	146	35.5
M2	260	2	652	24	1101	14	234	32
W4	187	3	691	12	680 (858)	38 (28)	142	37
G3	152	4	439	36	1112 (1846)	13 (5)	1105	11
W1	150	5.5	5429	1	743 (2561)	25 (2.5)	149	33
W2	150	5.5	487	31	745 (2561)	24 (2.5)	148	34
G2	147	7	426	38	1095	16	1088	13
G4	144	8	436	37	1131 (2561)	12 (2.5)	1129	10
G10	129	9	704	8	1144	9.5	1143	8
G12	127	10.5	659	21	1165	1.5	1165	2
S1	127	10.5	448	32.5	712 (1432)	31 (6)	141	38
G11	126	12.5	667	19	1166	1.5	1166	1
G23	126	12.5	662	20	1157	5	1156	4
G17	125	14.5	642	26	1146	7.5	1145	6
S8	125	14.5	676	17.5	705	34	546	25
G15	124	16	714	4	1138	11	1137	9
G16	122	17	656	22.5	1156	6	1155	5
G18	121	18	656	22.5	1164	3	1163	3
G14	119	19.5	685	14	1144	9.5	1144	7
S7	119	19.5	447	34	729 (933)	27 (25)	472	28
G9	116	21.5	733	2	775	22 (27)	772	18
S5	116	21.5	711	6.5	748	23	734	19
G13	112	23	630	27	954	19	952	15
M5	111	24.5	698	10	721	28	503	27
S4	111	24.5	713	5	691 (892)	36 (26)	546	24
S6	109	26	701	9	740	26	668	20
G5	103	27.5	448	32.5	1097 (1421)	15 (7)	1094	12
S10	103	27.5	678	16	999	18	996	14
G8	94	29	623	28	707	33	603	23
S9	93	30	719	3	716	29	537	26
M9	88	31	711	6.5	1163	4	356	29

Table 30—*Continued.*

Habitat	Spring Return	Spring Rank	Summer Return	Summer Rank	Autumn Return*	Autumn Rank*	Winter Return	Winter Rank
G6	82	32	445	35	926 (2561)	21 (2.5)	913	17
G21	72	33	536	29	683	37	654	21
M11	37	34.5	680	15	715	30	311	30
M8	37	34.5	644	25	708	32	146	35.5
M6	24	36	694	11	1084	17	631	22
G22	11	37	688	13	946	20	945	16
M7	10	38	676	17.5	702	35	244	31
A1	0	39	0	39	0	39	0	39

* return rates and rankings for rabbit drives in parenthesis

Table 31. Men's Overall Foraging Returns (kcal/hr) and Ranks by Habitat and Season

Habitat	Spring Return	Spring Rank	Summer Return	Summer Rank	Autumn Return	Autumn Rank	Winter Return	Winter Rank
W2	1828	1	1299	1	3376	1	1206	1
W1	1796	2	1038	2	3246	2	968	3
W4	1098	3	597	8	1330	9	457	8
G4	1068	4	911	4	3159	3	843	4
S1	1005	5	608	7	1856	6	512	7
G9	995	6	976	3	1520	8	978	2
G6	975	7	819	5	3099	4	764	5
G3	880	8	729	6	2300	5	603	6
G5	603	9	463	10	1770	7	411	9
S7	576	10	369	17	1058	15	301	11
G2	561	11	431	12	1322	10	322	10
S5	509	12	429	13	439	18	200	14
M3	469	13	532	9	1167	12	126	29.5
S6	459	14	372	16	387	20	212	13
S4	436	15	298	20	899	16	275	12
M11	388	16	348	18	330	21	126	29.5
M6	368	17	410	15	1107	14	126	29.5
M2	362	18	447	11	1133	13	126	29.5
M5	347	19	421	14	406	19	126	29.5
S10	297	20	208	22	212	24	189	17
M8	289	21	322	19	288	22	126	29.5
G8	284	22	198	25.5	196	27	153	25
S8	283	23	198	25.5	210	25	190	16
G17	255	24	199	23.5	222	23	162	22.5
S9	249	25	196	27	209	26	199	15
M9	245	26	262	21	1169	11	63	37.5
G16	219	27	183	28	194	28	154	24
G23	208	28	168	30	166	30.5	170	19.5
G14	207	29	168	31	166	30.5	108	35
G10	206	30	163	33	160	33	174	18
G22	204	31	147	34	147	34	170	19.5
G12	200	32	167	32	165	32	163	21
G13	183	33	120	37	117	37	99	36
G18	182	34	182	29	180	29	162	22.5
M7	167	35	199	23.5	535	17	63	37.5
G11	157	36	124	36	123	36	122	34
G15	155	37	98	38	96	38	126	29.5
G21	126	38	126	35	126	35	126	29.5
A1	0	39	0	39	0	39	0	39

How these foraging returns should determine seasonal habitat choice among hunter-gatherers of the study area is considered below. Assuming that external constraints determine the array of prey available to each sex, the principles of patch choice and diet breadth are used to evaluate which habitats male and female Railroad Valley foragers should have preferred and consider situations that may have prompted foraging in less productive habitats. These evaluations are then compared with the ethnographic record to assess the veracity of model inferences.

The Spring Habitat Type Landscape

The two most profitable habitats for women's foraging in spring are montane habitats M3 (460 kcal/hr) and M2 (260 kcal/hr), because various small rodents and arrowleaf balsamroot are available there. Elsewhere, springtime emergence of small mammals make habitats W4, G3, W1, W2, G2 and G4 next most profitable, with returns ranging from 144 kcal/hr to 187 kcal/hr. Most other habitats contain only Rank 1 greens and roots such as sedge, thistle, tapertip hawksbeard, evening primrose and wild iris, offering meager foraging returns of less than 130 kcal/hr. Overall, spring offers the lowest foraging returns to women in Railroad Valley of any season.

Men's spring foraging returns are somewhat better. Habitats W2, W4, W1, G4, S1, G9, G6 and G3 offer returns between 880 kcal/hr and 1830 kcal/hr, because their rich forage and proximity to water attract large game, migrating waterfowl, and small mammals and ground squirrels emerging from hibernation. One ethnographically documented activity for both men and women not reflected in these data are antelope drives, which were held frequently north of the study area near Mount Hamilton (Steward 1938:120). Overall returns to be gained by such drives should have far exceeded any locally available springtime habitat. The ethnohistorically documented willingness of families from the study area to undertake long journeys to participate in such drives (Steward 1938:120) accords well with this assessment of energetic profitability. However, ethnohistorically documented antelope drives elsewhere in the Great Basin (Egan 1917:241) suggest that antelope herds sometimes took as long as a decade to recover. For this reason, we assume that in many years Railroad Valley hunter-gatherers found the costs necessary to travel to distant antelope drives excessive, and so pursued local springtime foraging opportunities within the study area.

In summary, wetland habitats W1, W2, and W4, and greasewood-saltbush habitat G4 offer best returns for both men and women, although feasible returns are comparably low for women. Too, opportunities to participate in non-local antelope drives frequently compelled families to trek outside the study area. Within the study area, the availability of springtime roots made montane habitats M3 and M2 women's best foraging patch, whereas men found their best hunting opportunities in lowland habitats S1, G9, G6 and G3.

The Summer Habitat Type Landscape

Wetlands bearing cattail pollen (Habitat W1) in early summer are by far the most profitable foraging opportunity available in summer (5430 kcal/hr). However, after the brief early summer pollen bonanza, 28 habitats offer competitive return rates ranging from 623 kcal/hr to 733 kcal/hr, reflecting their content of small mammals, annual grass seeds (tanseymustard and blazing star), fruits, and berries. This assessment accords well with Steward's observation that Railroad Valley gatherers often stuck close to home during summer (Steward 1938: 118), since the foraging opportunities available elsewhere would not have been sufficiently more profitable than local alternatives to make the costs of moving worthwhile. However, the simulation of women's summer foraging returns does not accord with the emphasis that ethnohistoric gatherers placed on harvesting seeds (Steward 1938:18), because it predicts that Rank 2 summer seeds (300 kcal/hr - 600 kcal/hr) such as Indian ricegrass, Great Basin wild rye, wheatgrass, and bluegrass should fall out of the optimal diets of gatherers in all but the poorest habitats. The failure to predict collection of most seeds in Railroad Valley is all the more striking because Steward (1938:119) is clear that families sometimes made summertime treks to Duckwater to harvest the rich seed patches there.

Men achieve high foraging returns by hunting in Habitats W1, G9, G4, G6 and G3. These habitats offer returns ranging between 730 kcal/hr and 1030 kcal/hr because they contain abundant antelope, rabbits, and small mammals. Habitats W2 (1299 kcal/hr), S1 (608 kcal/hr), W4 (597 kcal/hr), and M3 (532 kcal/hr) also provide high returns because they contain deer, sheep, rabbits, woodrats, marmots, small mammals, and sage grouse. However, with the exception of Habitat W2, all offer lower returns than lowland wetland and greasewood-saltbush alternatives. This accords well with Steward's statement (1938:118) that Railroad Valley hunters found opportunities to hunt antelope close to home during the summer.

For a brief period in early summer, Habitat W 1 offered the most attractive foraging patches for both men and women. Afterwards, marsh habitats remain productive but a variety of riparian, spring, greasewood-saltbush, and montane habitats compete for the foraging attention of both genders. Seed harvest was an activity of ethnohistoric hunter-gatherers that this model does not predict. This sometimes compelled gatherers to migrate to the best available seed patches.

The Autumn Habitat Type Landscape

Autumn was the most productive time for women's foraging in Railroad Valley. Aiding men in seasonal rabbit drives south of Duckwater was the best option, providing returns between 1420 kcal/hr and 2560 kcal/hr in Habitats G4, G3, G5, G6, S1, W1 and W2. Rabbit drives might last as long as six weeks, but did not require daily attention (Steward 1938:119), so it is likely that women frequently turned their attention to hunting small mammals and harvesting shadscale seeds in seventeen greasewood-saltbush habitats offering between 775 kcal/hr and 1165 kcal/hr. Montane Habitats M9, M3, M2, and M6 offered competitive returns of between 1084 and 1163 kcal/hr because they contain pinyon. This assessment accords well with Steward's account (1938:119) that Railroad Valley hunter-gatherers frequently procured pine nuts from the nearest mountains. However, the high returns offered by the abundance of lowland shadscale seeds is inconsistent with Steward's (1938:119) statement that Railroad Valley hunter-gatherers would travel as far as 30 miles to procure pinyon nuts when local crops were poor. If comparable returns were available from shadscale close at hand, why journey so far from home to procure pinyon? Perhaps women delayed shadscale harvest until late autumn and early winter after the last availability of pinyon.

Also notable is the prediction of the model that Rank 3 (750 kcal/hr), Rank 2 (450 kcal/hr), and Rank 1 (150 kcal/hr) should fall out of the diets of Railroad Valley foragers in most habitats. These resources would include seeds of goosefoot and sunflower, which were cultivated by ethnohistoric Railroad Valley Shoshone (Steward 1938:119).

Rabbit drives would also have been the most profitable fall activities for men, with habitats W1, G3, G4, G6, G5, and S1 offering returns between 1750 kcal/hr and 3250 kcal/hr. These, as well as Habitats G9 (1520 kcal/hr), G2 (1322 kcal/hr), G7 (1078 kcal/hr), and S7 (1058 kcal/hr), also offered good opportunities for hunting antelope. Upland Habitats W2 (3380 kcal/hr), W4 (1330 kcal/hr), M9 (1169 kcal/hr), M3 (1167 kcal/hr), M2 (1133 kcal/hr), and M6 (1107 kcal/hr) were also productive, reflecting the presence of sheep and deer near the upper elevations of their range. These observations are consistent with the range of hunting activities recorded for men in fall (Steward 1941: 271-275) as well as the importance of rabbit drives (Steward 1938:119-120).

In summary, fall was a productive time for men's and women's foraging effort. Both genders would participate in rabbit drives profitably, while women could also harvest shadscale seed and men stalk antelope. Both would also find productive opportunities in montane habitats, with men and women harvesting pinyon and men hunting large game. However, the model does not anticipate the distances ethnohistoric women were prepared to travel to collect pinyon, given the availability of shadscale close to home. Too, the simulation of ethnohistoric foraging returns again fails to predict that women should harvest low ranked seeds.

The Winter Habitat Type Landscape

After the first significant snowfall, women continue to procure relatively high returns (775 kcal/hr to 1165 kcal/hr) in greasewood saltbush habitats, harvesting lingering shadscale seeds. As the availability of shadscale declines, women's diet should expand to include remaining Class 3 (750 kcal/hr) resources such as saltbush, bulrush, and seepweed. However, these resources should quickly disappear as the season progresses. By late winter, women's foraging opportunities are restricted to Rank 1 resources (150 kcal/hr) such as greasewood, sagebrush, and cattail seeds.

Men continue to get relatively high returns for hunting in Habitats W2 (1208 kcal/hr), G9 (978 kcal/hr), W1 (968 kcal/hr), G4 (843 kcal/hr), G6 (764 kcal/hr) and G3 (603 kcal/hr), reflecting the restriction of sheep and deer to lower elevations of their habitat and the continued availability of rabbits. However, overwinter hibernation of woodrats, marmots, ground squirrels, and small mammals limits hunting opportunities elsewhere. Indeed, men's foraging returns fall below 150 kcal/hr in fourteen habitats suggesting a diet breadth as broad as that of women.

The foraging opportunities for men and women should initially occur in greasewood-saltbush and lowland wetland habitats, although men should also find hunting near upland meadows (Habitat W2) productive. However, winter foraging opportunities are strictly limited and quickly disappear for both men and women. By the depth of winter, foraging returns should be low enough in some habitats for men and all habitats for women, that even Rank 1 resources fall into the diet. This suggests that food stores accumulated in earlier seasons were critical during winter months, an inference consistent with Steward's (1938;118-119) observation that Railroad Valley hunter-gatherers occasionally overwintered in mountains if the autumn pinyon harvest were rich enough.

Discussion

The preceding considerations of the habitat landscape have suggested two insights about hunter-gatherer ecology in Railroad Valley, used in subsequent chapters to predict the archaeological record of habitats. First, men and women achieve their highest foraging returns in overlapping, but nonetheless distinctive, sets of habitats. Table 32 lists the Spearman's rank correlation coefficients between habitat rankings for men and women in each season. Men's and women's foraging opportunities are significantly correlated in spring and autumn, although the correlation coefficients account for only 14% and 19% of variability, respectively. Too, rabbit drives account for the fall correlation because men's and women's habitat rankings show no correlation when drives are excluded from consideration. Habitat rankings are also unrelated in summer and winter.

Table 32. Spearman's Rank Correlation Coefficients Between Habitat Ranks for Women and Men by Season

Seasonal Comparison	Spearman's Rho	Z	p
Spring	0.38	2.35	<0.01
Summer	-0.12	-0.76	>0.45
Fall (including rabbit drives)	0.44	2.73	<0.005
Fall (excluding rabbit drives)	-0.07	-0.42	>0.45
Winter	0.01	0.03	>0.45

This means that although the profitability of habitats is occasionally similar for both genders, men and women often procure their best returns from different habitats. Ethnographic Shoshone were central place foragers who exploited dispersed resource patches from residential base camps where they processed, stored, and consumed those resources. Thus, Railroad Valley hunter-gatherers had to decide not only where to forage, but where to position central place base camps and how to exploit spatially and temporally dispersed patches from central places. For the habitat model to adequately predict prehistoric subsistence-settlement patterns in Railroad Valley, it must predict how Railroad Valley hunter-gatherers accommodated scheduling conflicts between the sexes through central place foraging tactics.

Central place foraging models often assume that foragers should locate base camps to minimize travel and transport costs (Horn 1966; cf. Orians and Pearson 1977), and the costs of transporting resources from procurement locations to base camps are expensive for pedestrian hunter-gatherers (Jones and Madsen 1989). Elsewhere (Zeanah 1996:366-372, 519-521), we have shown that under most circumstances of Holocene resource abundance in the Great Basin, central place residential base camps in women's best foraging habitats maximize the caloric intake rate of consumers at camp. Thus, we expect that base camps will tend to occur where women choose to forage in Railroad Valley.

This has implications for the relative mobility of men and women. Women will tend to restrict their subsistence activities to the local catchment of residential bases, undertaking long distance logistic forays only under exceptional circumstances. In contrast, men should be more logistically mobile than women in order to accommodate women's foraging interests while also foraging in their best habitats. However, under many circumstances the high transport and travel costs necessary to exploit distant patches may prompt men to choose lower ranked, but nearby, habitats.

The second insight into Railroad Valley hunter-gatherer ecology concerns the extent to which Railroad Valley foragers harvested seeds. The simulation predicts that most Rank 1, Rank 2, and Rank 3 seeds should fall out of the optimal diet of women, whereas ethnographic Railroad Valley gatherers are known to have taken these resources. Given this discrepancy, we must admit the possibility that the simulation erroneously overestimates the seasonal foraging returns of women. For example, it may be that the model overestimates the abundance or post-encounter profitability of berries in summer and shadscale seed in autumn. If this is the case, women's summer and autumn diet breadth would be broader than the model predicts.

Another possibility is that the discrepancy reflects error induced by the seasonal resolution of the simulation. The model assumes that one scenario of resource abundance is typical for each season, but short term variation in foraging opportunities may have allowed very low ranked resources to enter the diet on a daily or weekly basis. For example, women may have found it profitable to gather summer seeds in the interval between the pollen harvest and the ripening of berries. Similarly, autumn seeds may have entered women's diet in the period between the pinyon and shadscale harvests.

Too, it may be that interannual variability in patch returns account for ethnographic seed use. In this case, the simulation may reflect foraging returns feasible for good years, whereas in poorer years habitat return rates were sufficiently low to allow seeds to enter the diet.

However, we propose that interseasonal variability best accounts for the discrepancy between the simulation and ethnographic data. Figures 5 and 6 illustrate the mean and standard deviation of women's and men's foraging returns of the 39 Railroad Valley habitats. Women's spring returns are low enough for Rank 1 resources to enter women's diet between the last availability of saltbush seeds in early winter and the first availability of arrowleaf balsamroot in spring. Men's returns are low during this period as well. Yet this is the time of year when resources of any sort are rare and travel costs are severe. This suggests that the use of low ranked seeds in other seasons is attributable to the need to accumulate a large food store in anticipation of the winter season. This assessment agrees with Steward (1938:18), who is clear that the objective of summertime seed harvest was accumulation of overwinter caches rather than immediate consumption.

Simms (1987:82-83) first advocated this explanation when his diet breadth analysis failed to predict why Great Basin foragers harvested seeds. Simms (1987:82-83) suggested that storability accounted for seed use; gatherers "banked" low ranked but storable seeds in anticipation of overwinter shortfalls of higher ranked resources.

If Simms is correct, Railroad Valley gatherers foraged at less than the optimal rate in order to cache sufficient quantities of low ranked but storable seeds to last through the following winter. In this scenario, women would have been strongly motivated to embed seed harvesting into their optimal foraging activities and thereby minimize the opportunity costs incurred by forsaking harvest of the optimal resource in favor of the storable resource. However, the ethnographic record reveals that women occasionally made long distance logistic forays to harvest seeds and pinyon nuts, and thereby lost the opportunity to forage in productive habitats close to home while incurring high travel costs to journey to distant patches. This indicates that occasionally it was not possible to simultaneously accumulate the caches needed for overwinter survival and forage in the seasonally optimal habitat.

Appropriate scheduling would have helped minimize lost opportunities. For example, shadscale seeds are easiest to gather in late the fall (Simms 1987:109-110; Plummer et al. 1968: 159), after the pinyon harvest. Therefore, Railroad Valley gatherers may have delayed harvest of shadscale stands in order to collect pinyon, anticipating that the shadscale would still be available later in the season.

Seed cultivation would have been another strategy for minimizing the costs of caching low ranked seeds. Steward (1938: 119) notes that Railroad Valley men burned brush from seed plots in autumn, which they sowed in spring. Sown seeds were annuals such as goosefoot, blazing star, and several unidentified varieties (Steward 1938:119; 1941:333), which we presume included tanseymustard and sunflower. Sown seed plots were the private property of families in Railroad Valley (Steward 1938:119; 1941:314), and probably were prepared in well-watered locations (Steward 1941:232) near winter villages (Steward 1938:104). By seed cultivation, Railroad Valley hunter-gatherers may have intended to increase the abundance of storable seeds close to home in order to minimize the travel and opportunity costs of making long distance forays.

Paleoenvironmental Variability

The Railroad Valley habitat landscape maps the resource mosaic available to ethnohistoric hunter-gatherers, but serves to model prehistoric subsistence, settlement, and mobility decisions, and to predict the distribution of prehistoric archaeological sites. However, Chapter 5 demonstrated that the

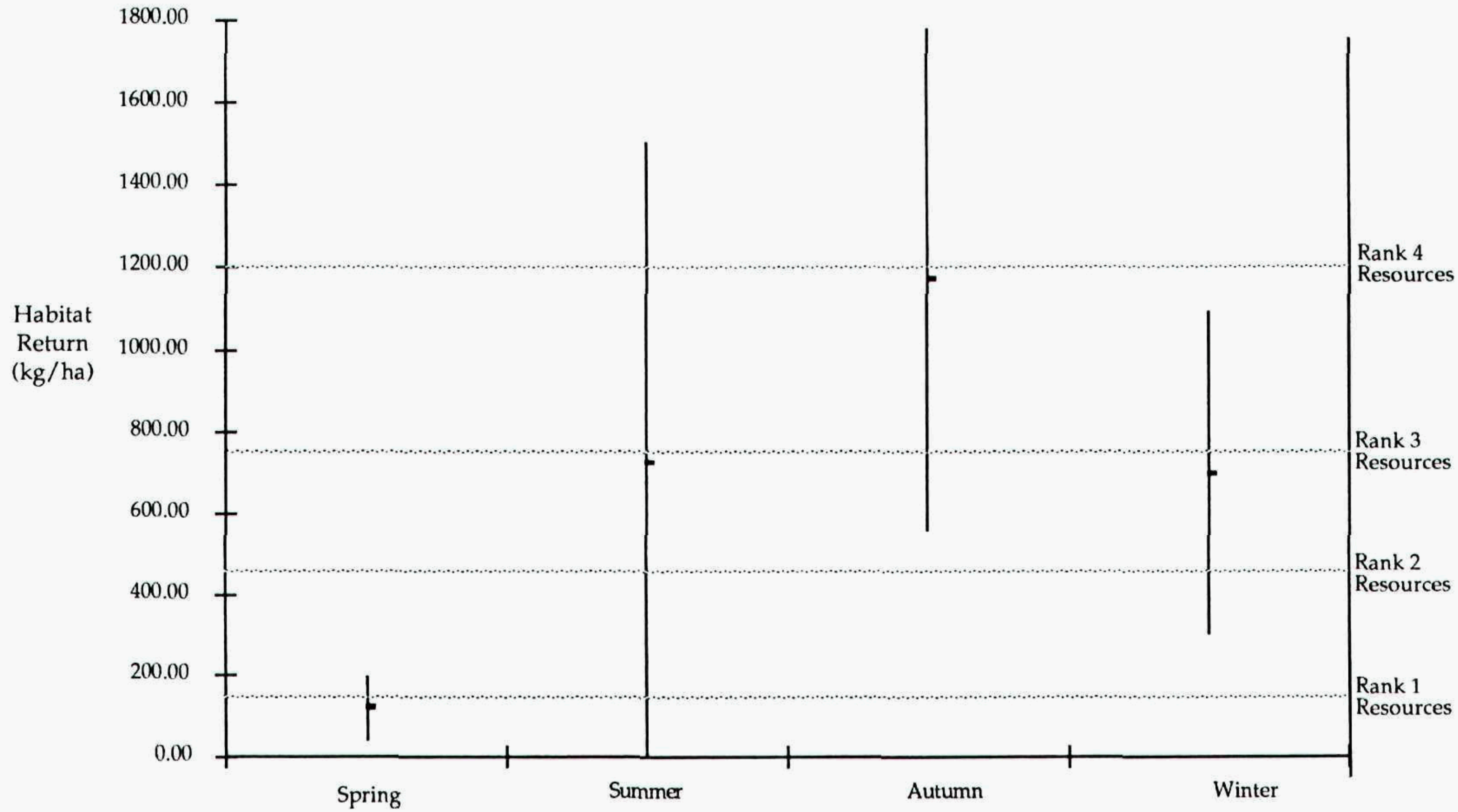

Figure 5. Women's foraging returns (mean and standard deviation) by season for 39 habitats in Railroad Valley, showing thresholds at which different resource classes enter the diet.

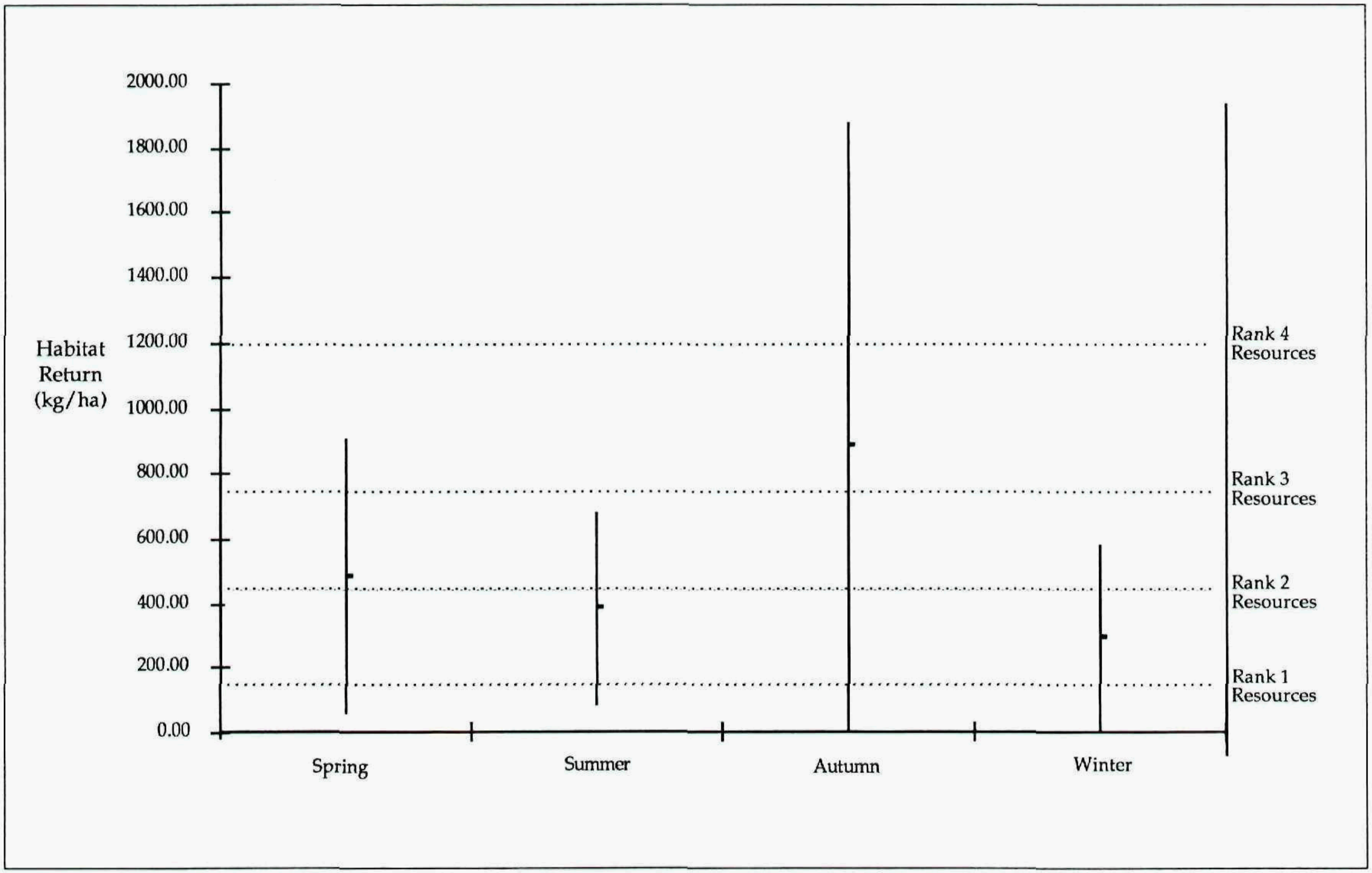

Figure 6. Men's foraging returns (mean and standard deviation) by season for 39 habitats in Railroad Valley, showing thresholds at which different resource classes enter the diet.

environment of Railroad Valley has varied significantly over the last 12,000 years. It stands to reason that the habitat landscape best describes the resource distribution of the more recent past, but is a progressively less satisfactory description of more remote times. It follows, then, that the preceding simulation of ethnohistoric foraging behavior may not accurately reflect the foraging trade-offs faced by ancient hunter-gatherers and, consequently, might lead to erroneous predictions about archaeological site distributions.

However, since modern climate, soil, topography, and hydrology determine the productivity, structure, and function of the habitat landscape, that landscape may serve as a valid baseline for estimating ancient resource distributions and modeling ancient foraging behavior. Thus, the goal of this section is to use the habitat model to assess how paleoenvironmental variability may have altered resource distributions and affected prehistoric foraging behavior in Railroad Valley.

Paleoenvironmental Scenarios for Railroad Valley

Habitat models such as this one offer a unique tool for modeling the effects of paleoenvironmental variability on resource distributions because they derive from range site descriptions (USDA Soil Conservation Service 1991, 1993). Range sites provide estimates of total biotic productivity in kilograms per hectare during normal, favorable, and unfavorable years. The literature on range productivity demonstrates that range productivity correlates strongly with annual precipitation (Blaisdell 1958; Hutchings and Stewart 1953; Sneva and Hyder 1962). Because of this correlation, range site productivity during unfavorable years can serve as an estimate of normal habitat productivity during xeric extremes of the prehistoric past. Similarly, favorable year productivity estimates normal habitat productivity during mesic extremes of the past.

Too, range site descriptions provide information on intrusive and successional plant species, and potential for wildfire, inundation, deflation, and downcutting. These data relate directly to modern plant community responses to winter or summer dominant precipitation regime (Beatley 1974; Ackerman et al. 1980), wetland formation (Kaldec and Smith 1984; Hamilton and Auble 1992), and successional dynamics (Young et al. 1976). Consequently, they provide a guide for estimating changes in plant community composition in the past.

Review of Chapter 5 suggests that extremes of known and inferred paleoclimatic variability in Railroad Valley can be simplified to four scenarios based on whether annual precipitation was greater or lesser than at present, on seasonal precipitation dominance, and on plant community composition:

- mesic, winter dominant precipitation climate of the Early Holocene,
- xeric, summer dominant precipitation climate of the Middle and Late Holocene,
- mesic, winter dominant precipitation climate of the Late Holocene, and
- mesic, summer dominant precipitation climate of the Late Holocene.

Characteristics of each scenario and steps used to model habitat landscapes are described below.

Mesic, Winter Dominant Precipitation Climate of the Early Holocene

We presume this scenario typical of the period between 10,500 and 8000 BP. This scenario is most unlike that of the ethnographic present with many parameters of soil, hydrology, climate, and vegetation utterly unlike those of the last century. Consequently, this model must be regarded as only a rough approximation of feasible habitat productivity and composition.

To model the Early Holocene resource mosaic, we assume that a lake occupied the valley floor playa below the 1435 m contour. Extensive marshes fringed this lake, and would have been most extensive in the Hot Creek and Duckwater Creek deltas. We assume that these wetlands would have been unlike those of modern Habitat W1, in that marsh vegetation surrounding ponds and sloughs (similar to modern range type 29XY044NV wetlands), rather than wet meadows (range type 29XY001NV), would have been dominant. These lake-edge marshes would have hosted a larger variety of fauna such as nesting waterfowl (including bird eggs and fledglings), fish (ancestors of modern Railroad Valley springfish and tui chub), and a variety of small and medium sized mammals (including muskrats). We identify this as a new habitat no longer present in Railroad Valley (W5); we assume that it occurred between 1435 m and 1437 m around the valley lake, and that it consisted of vegetation similar to that of modern wetland range type 29XY044NV.

Marsh ponds and sloughs would also have been more common around the lowland springs surrounding the lake. To reflect the changes, we modify the range type composition of Habitat W1 to include 50% of the pond and slough marshes of range type 29XY044NV (rather than the 33% assumed for modern Habitat W1). We also assume that modern irregularly inundated Habitats G2, G3, G4, G5, and G6 hosted minor occurrences of wet meadows (range type 29XY001NV) during the Early Holocene, and adjust their composition accordingly.

Woodlands were absent from the surrounding uplands, so we remove pinyon-juniper woodland from Habitats M2, M3, M6, and M9, and adjust the production and composition of understory production to that typical of the modern habitats with no woodlands. Finally, we increase the total annual biomass production of all species in all habitats to levels typical of modern favorable years.

Xeric, Summer Dominant Precipitation Climate of the Middle and Late Holocene

This scenario represents paleoenvironmental circumstances of the Middle Holocene (8000 to 5000 BP) and drought periods of the last half of the Late Holocene (2300 to 150 BP). During these times, the valley floor desiccated, spring flow declined, and erosion accelerated. To reflect these circumstances, we modify the composition of wetland habitats to include dry meadows and bottoms, adding range type 29XY003NV (Loamy Bottom 8-12" p.z.) to Habitat W1, range type 29XY054NV (Dry Meadow) to Habitat W2, and range type 28BY003NV (Loamy Bottom 10-14" p.z.) to Habitat W4. To reflect accelerated dune formation, we increase the proportion of range type 29XY018NV (Sodic Dunes) in Habitats G3 and G16, and add it to Habitat G2. Intensified wildfires would have maintained an open canopy in woodland Habitats M2, M3, M6, and M9, so we assume sparse woodlands occurred there and increase understory production and composition accordingly.

In all habitats, we decrease annual biomass productivity of perennial species to that typical of modern habitats during unfavorable years. In contrast, we increase production of annual grass and forb production to that typical of modern favorable years because summer precipitation and intensified wildfires would have been beneficial to these species.

Mesic, Winter Dominant Precipitation Climate of the Early Late Holocene

This scenario represents circumstances of the first half of the Late Holocene between 5000 and 2300 BP. We assume that a lake and lakeside marsh occurred in the valley bottom below 1436 m elevation. Although similar in composition and productivity to wetlands of the early Holocene, we assume that marshes of the early Late Holocene would have supported a less diverse array of fish, waterfowl, and mammals because of local extinction.

We modify wetland Habitat W1 and irregularly inundated habitats G2, G3, G4, and G6 in the same way that we did for the Early Holocene scenario, so that W1 has a greater proportion of range type 29XY044NV (Wetland) and irregularly inundated habitats contain inclusions of 29XY001NV (Wet Meadow 8-12" p.z.). However, unlike the Early Holocene scenario, we assume expansive and dense pinyon-juniper woodlands in adjacent highlands. To reflect this, we modify pinyon-juniper Habitats M2, M3, M6, and M9 to have dense overhead canopies and adjust the production and composition of understory production to that typical of modern dense woodlands. Too, range site descriptions note that modern Habitats G10, G15, M5, M7, S4, S5, S6, S8, S9, and S10 are vulnerable to invasion by Utah juniper in successional stages, so we assume that these habitats would have fostered a sparse canopy of pinyon-juniper woodland during the early Late Holocene. Finally, we increase annual biomass productivity of all species, in all habitats, to that typical of modern favorable years.

Mesic, Summer Dominant Precipitation Climate of the Late Holocene

This scenario captures paleoenvironmental circumstances of mesic intervals of the last half of the Late Holocene: between 1600 and 1200 BP, and 400 and 300 BP, for example. We assume a shallow lake and lakeside marsh below 1436 m, like that of the early Late Holocene. Modifications to wetland Habitat W1 and irregularly inundated habitats G2, G3, G4, G5, and G6 are the same as those made for the Early Holocene and early Late Holocene scenarios.

Summer dominant precipitation, albeit more mesic than at present, would not have benefitted perennial production as much as annual production. Therefore, we increase the annual productivity of annual forbs and grasses to levels typical of modern favorable years while maintaining perennial production to modern normal year standards. Similarly, increased summer precipitation would have benefitted pinyon more than juniper. To reflect this, we keep woodland canopies and understory production in habitats M2, M3, M6, and M9 at modern, moderate levels, but increase the proportional representation of pinyon in those woodlands.

Simulated Foraging Behavior Adjusted to Reflect Paleoenvironmental Scenarios

Using the modified habitat landscapes in the four environmental scenarios, we recalculated overall foraging return rates for men and women, in each season, and ranked habitats accordingly. Table 33 presents Spearman's Rank Correlation Coefficients between the seasonal habitat rankings for men and women, in each paleoenvironmental scenario, with their ethnohistoric equivalent. There are strong and highly significant ($p < .0001$) correlations between ethnohistoric habitat rankings and the habitat rankings of each paleoenvironmental scenario. This means that predictions of the archaeological complexity of habitats based on ethnohistoric rankings should capture paleoenvironmental variability, so long as those predictions are not based on spuriously precise interpretations of the rankings. In other words, predictions of archaeological complexity should follow from rank groups (for example, habitats that consistently are among the top ten ranking habitats in all simulations) rather than precise distinctions between close ranks (for example predicting distinctions in archaeological complexity between rank 1 and rank 2 habitats).

However, the paleoenvironmental simulations do carry implications about temporal variability in foraging behavior. Generally, foraging returns for both men and women improve over ethnohistoric returns in the mesic simulations and worsen in xeric simulations (although foraging returns in particular habitats may be opposite the general trend). This means that diet breadth will narrow in many habitats during mesic episodes and broaden during xeric episodes. The implications for the breadth of patch (habitat) choice differ for men and women because of the different requirements of search costs to procure men's and women's resources. Women should tend to forage in a more narrow array of habitats during mesic periods and broaden their habitat selection during xeric periods. The reverse should be true for men.

Table 33. Spearman's Rank Correlation Coefficients Between Paleoclimatic Scenarios, by Gender and Season, with Ethnohistoric Equivalents

Climate	Seasonal Precipitation	Period	Gender	Season	Rho	Z
Mesic	Winter Dominant	Late Holocene	Men	Winter	0.871	5.368
Mesic	Winter Dominant	Late Holocene	Women	Winter	0.89	5.488
Mesic	Winter Dominant	Late Holocene	Men	Spring	0.706	4.35
Mesic	Winter Dominant	Late Holocene	Women	Spring	0.724	4.462
Mesic	Winter Dominant	Late Holocene	Men	Summer	0.736	4.534
Mesic	Winter Dominant	Late Holocene	Women	Summer	0.824	5.083
Mesic	Winter Dominant	Late Holocene	Men	Autumn	0.831	5.214
Mesic	Winter Dominant	Late Holocene	Women	Autumn	0.974	6.006
Mesic	Summer Dominant	Late Holocene	Men	Winter	0.896	5.526
Mesic	Summer Dominant	Late Holocene	Women	Winter	0.998	6.152
Mesic	Summer Dominant	Late Holocene	Men	Spring	0.9	5.545
Mesic	Summer Dominant	Late Holocene	Women	Spring	0.85	5.239
Mesic	Summer Dominant	Late Holocene	Men	Summer	0.912	5.621
Mesic	Summer Dominant	Late Holocene	Women	Summer	0.999	6.163
Mesic	Summer Dominant	Late Holocene	Men	Autumn	0.882	5.427
Mesic	Summer Dominant	Late Holocene	Women	Autumn	0.958	5.909
Mesic	Winter Dominant	Early Holocene	Men	Winter	0.766	4.721
Mesic	Winter Dominant	Early Holocene	Women	Winter	0.919	5.667
Mesic	Winter Dominant	Early Holocene	Men	Spring	0.832	5.129
Mesic	Winter Dominant	Early Holocene	Women	Spring	0.72	4.238
Mesic	Winter Dominant	Early Holocene	Men	Summer	0.84	5.181
Mesic	Winter Dominant	Early Holocene	Women	Summer	0.841	5.184
Mesic	Winter Dominant	Early Holocene	Men	Autumn	0.803	4.95
Mesic	Winter Dominant	Early Holocene	Women	Autumn	0.726	4.473
Xeric	Summer Dominant	Mid-Late Holocene	Men	Winter	0.835	5.147
Xeric	Summer Dominant	Mid-Late Holocene	Women	Winter	0.946	5.832
Xeric	Summer Dominant	Mid-Late Holocene	Men	Spring	0.905	5.582
Xeric	Summer Dominant	Mid-Late Holocene	Women	Spring	0.985	6.073
Xeric	Summer Dominant	Mid-Late Holocene	Men	Summer	0.91	5.611
Xeric	Summer Dominant	Mid-Late Holocene	Women	Summer	0.843	5.195
Xeric	Summer Dominant	Mid-Late Holocene	Men	Autumn	0.917	5.652
Xeric	Summer Dominant	Mid-Late Holocene	Women	Autumn	0.935	5.764

Table 34 lists the top ten ranked habitats for each sex, in each season, in each simulation. A similar array of habitats ranks in the top ten in each simulation. The major difference is the addition of lakeside marsh Habitat W5 in the top ten spring and summer habitats during mesic periods. Spring time marsh foraging is particularly important because an opportunity to procure fish, waterfowl eggs and fledglings, and small mammals during the season of greatest food scarcity, was available to Railroad Valley foragers during mesic periods that was unavailable in other circumstances. A second difference is a slight increase in the ranking of pinyon-junper habitats M3 and M9 in women's autumn habitat array during mesic intervals of the Late Holocene, and the disappearance of pinyon-juniper habitats from the top ten women's habitats during xeric extremes of the Middle to Late Holocene. In their stead are a broader array of greasewood-saltbush habitats offering greater returns for annual forbs and grasses.

Table 34. Comparison of Top Ten Ranked Habitats for Both Genders in Each Season and Paleoenvironmental Scenario

	Ethnohistoric	Mid-Late Holocene, Xeric Summer Dominant	Late Holocene, Mesic Summer Dominant	Late Holocene, Mesic Winter Dominant	Early Holocene, Mesic Winter Dominant
Men's Winter Ranking					
1	W2	W2	W2	G6	G6
2	G9	W1	G9	W2	W2
3	W1	G4	W1	G4	W4
4	G4	G6	G4	G3	G4
5	G6	S1	G6	W1	W1
6	G3	W4	G3	G5	G3
7	S1	G3	S1	S1	G5
8	W4	G5	W5	W4	S1
9	G5	S7	W4	G2	W5
10	G2	G2	G5	S7	M3
Women's Winter Ranking					
1	W2	G11	G11	G11	G11
2	G9	G12	G12	G12	G12
3	W1	G18	G18	G18	G18
4	G4	G23	G23	G23	G23
5	G6	G3	G16	G16	G16
6	G3	G17	G17	G17	G17
7	S1	G10	G14	G14	G14
8	W4	G14	G10	G10	G10
9	G5	G16	G15	G15	G15
10	G2	G15	G4	G5	G5
Men's Spring Ranking					
1	W2	W1	W2	G6	G6
2	W1	W2	W1	W2	W2
3	W4	W4	W4	W1	W1
4	G4	M3	G4	M9	S1
5	S1	S1	S1	S1	G4
6	G9	G3	G9	G4	M3
7	G6	M2	G6	G3	G3
8	G3	G4	W5	G5	G5
9	M3	G6	G3	W4	W4
10	G5	S7	M3	S5	W5
Women's Spring Ranking					
1	M3	M3	W5	W5	W5
2	M2	M2	M3	M3	W1
3	W4	W4	M2	M2	M3
4	G3	W1	W4	G3	M2
5	W2	W2	G3	W4	G3
6	W1	G4	W2	G6	W4
7	G2	G2	W1	W2	G6
8	G4	G3	G2	G2	W2
9	G10	G10	G4	W1	G2
10	S1	G12	G10	S1	S1
Men's Summer Ranking					
1	W2	W2	W2	G6	G6
2	W1	M3	W1	W2	W2
3	G9	W1	G9	G4	M3
4	G4	W4	G4	G3	G4
5	G6	M2	G6	G5	W1
6	G3	G4	G3	W1	G3
7	S1	S1	S1	S1	M2
8	W4	M6	W4	S5	G5
9	M3	G6	M3	M5	S1
10	G5	G3	W5	S6	M6
Women's Summer Ranking					
1	W1	W1	W5	W5	W1
2	G9	S6	W1	W1	W5
3	S9	G13	G9	G9	G9
4	G15	S4	S9	S9	S9
5	S4	S9	G15	G15	S4
6	S5	G9	S4	S4	G15
7	M9	G15	S5	S5	S5
8	G10	S5	M9	G10	M9
9	S6	G10	G10	S6	G10
10	M5	G16	S6	M5	S6
Men's Autumn Ranking					
1	W2	M9	W2	G6	G6
2	W1	M3	W1	W2	W2
3	M9	M2	M9	G4	M3
4	M3	M6	M3	W1	W1
5	M2	W2	M2	G3	G4
6	M6	S5	M6	G5	G3
7	G9	W1	W3	M9	M2
8	G4	W4	M5	M3	G5
9	G6	M7	G9	M2	S1
10	G3	G5	G4	S1	W5
Women's Autumn Ranking					
1	G11	G11	M9	G11	G11
2	G12	G12	M3	G12	G12
3	G18	G18	G11	G18	G18
4	M9	G23	G12	M9	G23
5	G23	G3	G18	G3	G16
6	G16	G17	G23	G23	G17
7	M3	G10	G16	G17	G10
8	G17	G14	G17	M3	G14
9	G14	G16	G14	G16	G15
10	G10	G15	G10	G14	G5

Figures 7 and 8 illustrate the mean and standard deviation of women's and men's foraging returns of 40 Railroad Valley habitats during the mesic, winter dominant precipitation regime of the early Late Holocene. Comparison with Figures 5 and 6 indicates that, although early Late Holocene hunter-gatherers faced similar seasonal foraging return variability as ethnohistoric foragers, foraging returns improve in all seasons. In particular, women's autumn returns improve because of the increased productivity of pinyon woodlands and spring returns improve because of the addition of a lakeside marsh foraging habitat. This suggests that the requirement to accumulate overwinter food stores was less demanding and the need to harvest low ranked seeds less severe during mesic periods of the Late Holocene than at the time of ethnohistoric observation.

This trend would have reversed during xeric intervals, when overall foraging returns declined, marshes dried, and pinyon groves thinned out. The need to accumulate large quantities of food to survive winter would have been even greater than that of ethnohistoric hunter-gatherers. Yet, these are the circumstances that would foster greatest productivity of annual forbs and grasses. This suggests that aboriginal cultivation of wild seed plots would have begun and intensified during periods of xeric, summer dominant precipitation of the Late Holocene.

Conclusion

This chapter ranked the foraging utility of habitats using diet breadth and patch choice models; consideration of resource seasonality and sexual division of labor served to increase the realism and accuracy of the evaluation as a simulation of hunter-gatherer foraging behavior. Predictions of the ranking were compared with ethnohistoric descriptions of Railroad Valley hunter-gatherers to yield insight into the role of central place foraging, food storage, and plant cultivation in subsistence-settlement systems. This provides a framework of hunter-gatherer ecology in Railroad Valley that serves to predict the archaeological record of habitats in the next chapter.

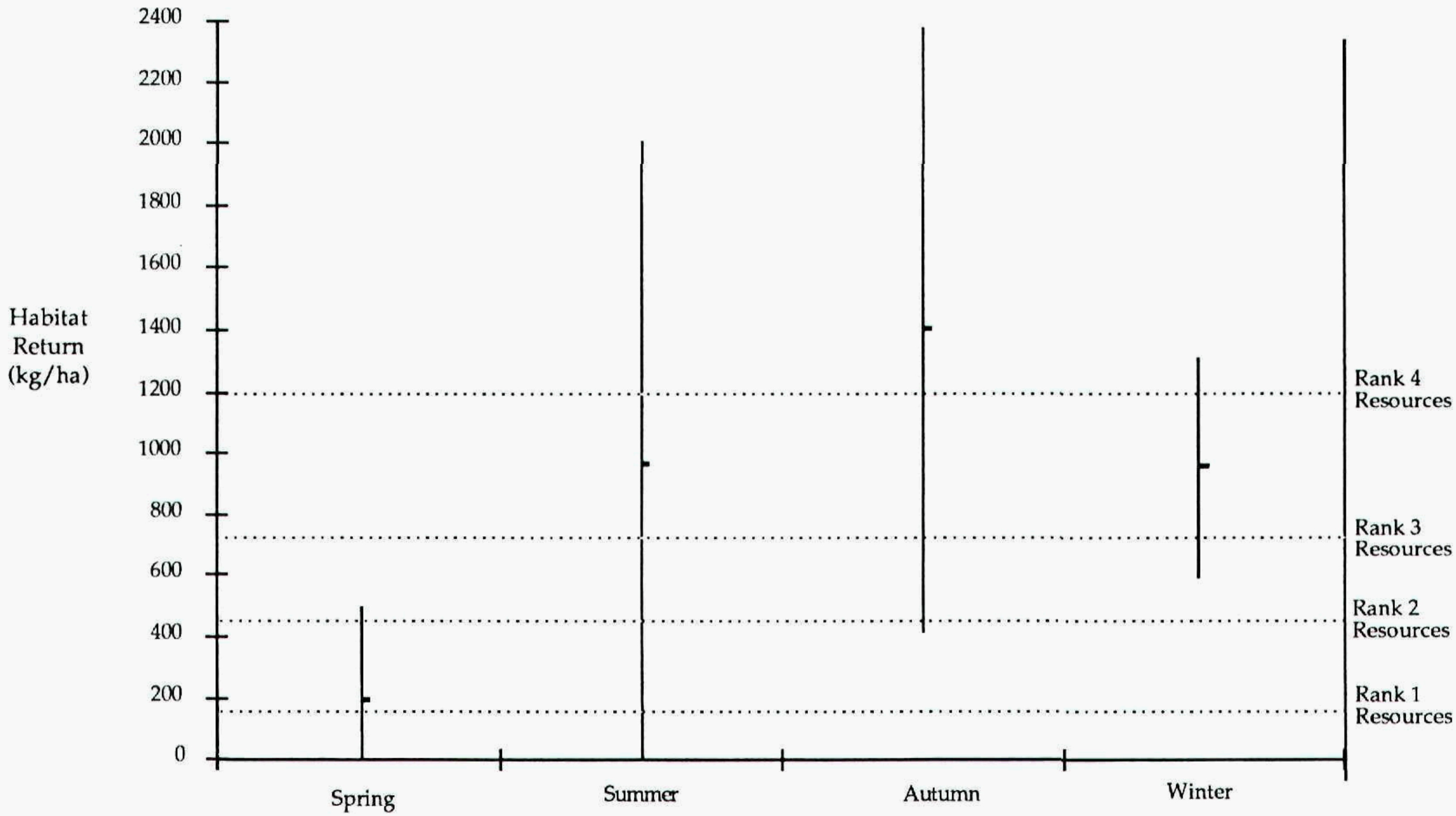

Figure 7. Women's foraging returns (mean and standard deviation) by season for 40 habitats in the early Late Holocene Railroad Valley, showing thresholds at which different resource classes enter the diet.

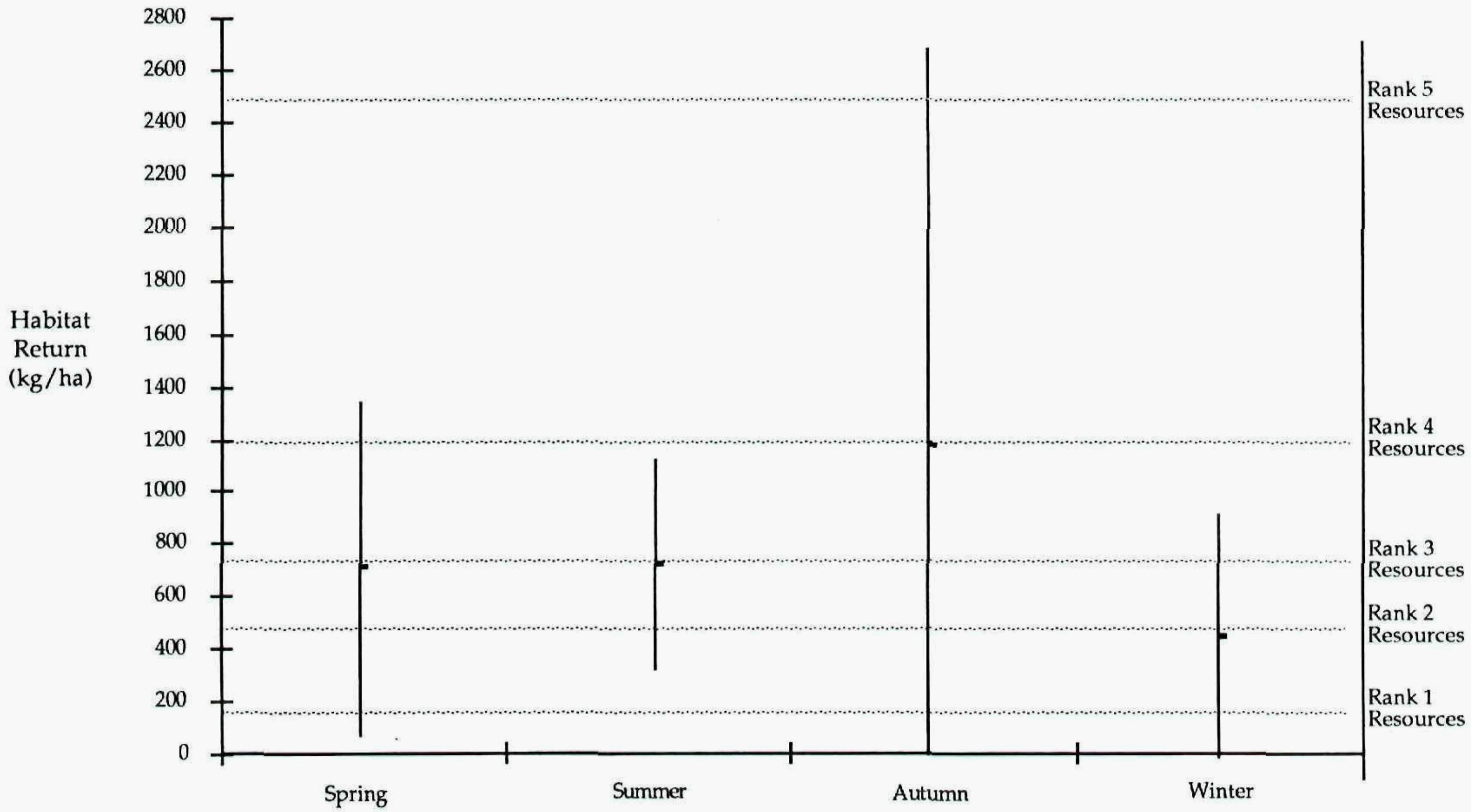

Figure 8. Men's foraging returns (mean and standard deviation) by season for 40 habitats in early Late Holocene Railroad Valley, showing thresholds at which different resource classes enter the diet.

Chapter 7

Archaeological Predictions

David W. Zeanah

We infer how prudent hunter-gatherers should organize their foraging activities in Railroad Valley by estimating the distribution of resources in each habitat, subdividing these resources by season and sex, and modeling their available caloric returns. These expectations now serve to predict how the distribution and composition of the archaeological record will vary according to habitat. Specifically, the relative composition, function, size, and diversity of archaeological assemblages likely to occur in each habitat are forecast based on the productivity of foraging and on the likelihood that hunter-gatherers lived there. From these inferences, habitat types are scaled into predicted archaeological complexity scores. Then, the sample of known sites in Railroad Valley is assessed for bias in recording quality, and a site typology is developed for a selected set of sites in the sample. The typology will allow testing of predictions about the distribution of functional site types in Railroad Valley.

Assumptions About Archaeological Site Formation Processes

If the archaeological record directly reflected foraging activity, then predicting the archaeology of habitats would be simple; archaeological remains should be most dense, diverse, and complex in habitats yielding highest overall foraging returns. However, hunter-gatherer foraging behavior does not translate directly into the archaeological record; deviations between the two reflect effects on site formation processes of central place foraging, mobility strategy, sexual division of labor, food sharing, food storage, tool manufacture, tool curation, and refuse disposal (Binford 1979, 1980). Consequently, four current understandings of how hunter-gatherer subsistence-settlement systems affect archaeological site formation processes temper expectations about the archaeological record of habitats.

First, residential bases that serve as the hub of hunter-gatherer settlement bias the archaeological record, inasmuch as base camps are the central places where foragers prepare, share, store, and consume food; manufacture, repair, and discard tools; and construct, maintain, and cache facilities for human habitation (Thomas 1983a). Therefore, base camps contribute disproportionately to archaeological formation processes. Although other site types exist and habitat types that are residentially unoccupied may contain complex archaeological sites, the archaeological remains of foraging activity represent, for the most part, field processing and hunting loss. Only in situations where resources are abundant or recurrent in the same location over long periods of time should nonhabitation sites produce archaeological manifestations comparable to those of base camps.

Second, constellations of environmental characteristics other than simple foraging productivity strongly influence residential base locations. For example, proximity to potable water is a prerequisite of hunter-gatherer base camps (Steward 1938:120-121; Taylor 1964), so that habitat types adjacent water sources will be more appropriate for habitation than habitat types with similar foraging potential but lacking water sources. Well drained but level terrain is also a requirement for human residence (Peterson 1973), so that those with inundated or steep terrain will be less likely to contain residential bases than equally productive but level and dry habitat types.

Third, removed from residential base camps, men's hunting activities are more archaeologically visible than those of women's gathering (Thomas 1983b:439) because men emphasize a reductive lithic technology, field maintenance of which leaves abundant, archaeologically visible residues (i.e., debitage and discarded tools) on the landscape. In contrast, women generally employ technologies (i.e., ceramics, groundstone, baskets, digging sticks) that do not as often leave archaeologically preserved detritus on the foraging landscape. Too, since men must hunt game and transport kills over large distances from base camps, they frequently construct hunting facilities, field process resources, and prepare overnight field camps. Women, as a rule, forage within a few hours walk of base camp and are less likely to field process food or construct field camps and facilities. Consequently, men's subsistence activities are more likely to leave enduring archaeological signatures on the landscape (i.e., faunal remains, debitage, processing tools, hearths, hunting blinds) than are those of women (i.e., isolated groundstone or ceramic fragments). However, residential base camp assemblages should strongly represent women's subsistence activities and residential locations should reflect primarily women's foraging concerns.

Finally, the ubiquity of lithic material in the archaeological record generally will bias the record toward sites where the procurement of toolstone and initial manufacture of lithic tools occurred (Elston 1988). Since toolstone sources most frequently occur in upland terrain, sites in upland habitats frequently host lithic debris from toolstone processing. Sites nearest toolstone sources possess assemblages rich in lithic material reflecting early stage tool manufacture (hammerstones, cores, early stage bifaces, and associated debitage). Materials representing middle stage manufacture (middle stage bifaces, heat treated bifaces, and associated debitage) are abundant in field camps convenient to toolstone sources. Finished and discarded tools, as well as evidence of late stage manufacture are most prevalent in areas remote from toolstone sources.

Working from these four basic assumptions, the preceding ranking of habitat foraging potential has been used to scale expectations about the archaeological record of habitats. Presumably, habitats providing highest foraging returns for women are most likely to contain frequently reused, archaeologically visible residential base camp locations, a potential that is enhanced by proximity to water or toolstone but diminished by excessive slope or aridity. High foraging returns for men further improve the potential for base camps. Habitats rich in men's resources, but not women's, should be relatively rich in archaeological remains; residential base camps are unlikely, but logistic field camps and hunting locations will be common. Habitats bearing women's foraging resources, but not men's, should have low archaeological visibility. Proximity to toolstone sources will complicate this order of habitat archaeological visibility; those habitats near toolstone will exhibit more extensive archaeological records than habitats of similar foraging or habitation utility but lacking toolstone.

Assessing the Archaeological Sensitivity of Habitats

In the preceding chapter we ranked the foraging potential of each of 39 habitats in each season for each gender. This yields a complicated matrix of rankings that must be simplified to generate straightforward predictions about the archaeological record. The first step toward simplification joined the two gender rankings in each seasonal habitat into a seven-point combined gender score (Table 35), following these habitat scoring criteria:

1 - in the top nine habitats for women and top 20 for men in a particular season
2 - among the top 20 habitats for women and in the top 31 habitats for men
3 - rank 21 to 31 for women in a particular season and among the top 21 for men
4 - rank 21 to 31 for both men and women in a particular season
5 - rank between 31 and 39 for women, but in the top 31 habitats for men
6 - in the top 31 habitats for men while also ranking from 31 to 39 for women in the same season
7 - simultaneously rank from 31 to 39 for both men and women in the same season

Table 35. Gender and Combined Scoring for Each Railroad Valley Habitat in Each Season

Habitat	Season	Men's Rank	Women's Rank	Men's Score	Women's Score	Combined Score
A1	Fa	39	39	4	4	7
A1	Sp	39	39	4	4	7
A1	Su	39	39	4	4	7
A1	Wi	39	39	4	4	7
G10	Fa	33	9.5	4	1	6
G10	Sp	30	9	3	1	2
G10	Su	33	8	4	1	6
G10	Wi	21	8	3	1	2
G11	Fa	36	1	4	1	6
G11	Sp	36	12.5	4	2	6
G11	Su	36	19	4	2	6
G11	Wi	33	1	4	1	6
G12	Fa	32	2	4	1	6
G12	Sp	32	10.5	4	2	6
G12	Su	32	21	4	3	6
G12	Wi	22	2	3	1	2
G13	Fa	37	19	4	2	6
G13	Sp	33	23	4	3	6
G13	Su	37	27	4	3	6
G13	Wi	34	15	4	2	6
G14	Fa	31	9.5	3	1	2
G14	Sp	29	19.5	3	2	2
G14	Su	30.5	14	3	2	2
G14	Wi	36	7	4	1	6
G15	Fa	38	11	4	2	6
G15	Sp	37	16	4	2	6
G15	Su	38	4	4	1	6
G15	Wi	35	9	4	1	6
G16	Fa	28	6	3	1	2
G16	Sp	27	17	3	2	2
G16	Su	28	22.5	3	3	4
G16	Wi	23	5	3	1	2
G17	Fa	23	7.5	3	1	2
G17	Sp	24	14.5	3	2	2
G17	Su	23.5	26	3	3	4
G17	Wi	18.5	6	2	1	1
G18	Fa	29	3	3	1	2
G18	Sp	34	18	4	2	6
G18	Su	29	22.5	3	3	4
G18	Wi	18.5	3	2	1	1
G2	Fa	15	16	2	2	2
G2	Sp	12	7	2	1	1
G2	Su	12	38	2	4	5
G2	Wi	10	13	2	2	2
G21	Fa	35	30	4	3	6
G21	Sp	38	33	4	4	7
G21	Su	35	29	4	3	6
G21	Wi	29	20	3	2	2
G22	Fa	34	20	4	2	6
G22	Sp	31	37	3	4	5
G22	Su	34	13	4	2	6
G22	Wi	25	16	3	2	2
G23	Fa	30	5	3	1	2
G23	Sp	28	12.5	3	2	2
G23	Su	30.5	20	3	2	2
G23	Wi	20	4	2	1	1
G3	Fa	10	13	1	1	1
G3	Sp	8	4	1	1	1

Table 35—*Continued.*

Habitat	Season	Men's Rank	Women's Rank	Men's Score	Women's Score	Combined Score
G3	Su	6	36	1	4	5
G3	Wi	6	11	1	2	2
G4	Fa	8	12	1	1	1
G4	Sp	4	8	1	1	1
G4	Su	4	37	1	4	5
G4	Wi	4	10	1	2	2
G5	Fa	14	15	1	1	1
G5	Sp	10	27	2	3	3
G5	Su	10	32.5	2	3	3
G5	Wi	9	12	1	2	2
G6	Fa	9	21	1	2	2
G6	Sp	7	32	1	4	5
G6	Su	5	35	1	4	5
G6	Wi	5	17	1	2	2
G8	Fa	27	25	3	3	4
G8	Sp	22	29	3	3	4
G8	Su	25.5	28	3	3	4
G8	Wi	24	19	3	2	2
G9	Fa	7	22	1	3	3
G9	Sp	6	21.5	1	3	3
G9	Su	3	2	1	1	1
G9	Wi	2	18	1	2	2
M11	Fa	20	35	2	4	5
M11	Sp	17	35.5	2	4	5
M11	Su	18	15	2	2	2
M11	Wi	29	24	3	3	4
M2	Fa	5	14	1	2	2
M2	Sp	13	2	2	1	1
M2	Su	11	24	2	3	3
M2	Wi	29	26	3	3	4
M3	Fa	4	7.5	1	1	1
M3	Sp	9	1	1	1	1
M3	Su	9	30	1	3	3
M3	Wi	29	33	3	4	5
M5	Fa	17	32	2	4	5
M5	Sp	19	24.5	2	3	3
M5	Su	14	10	2	2	2
M5	Wi	29	22	3	3	4
M6	Fa	6	17	1	2	2
M6	Sp	18	36	2	4	5
M6	Su	15	11	2	2	2
M6	Wi	29	21	3	3	4
M7	Fa	13	34	2	4	5
M7	Sp	35	38	4	4	7
M7	Su	23.5	17.5	3	2	2
M7	Wi	37.5	25	4	3	6
M8	Fa	22	37.5	3	4	5
M8	Sp	21	35.5	3	4	5
M8	Su	19	25	2	3	3
M8	Wi	29	33	3	4	5
M9	Fa	3	4	1	1	1
M9	Sp	26	31	3	3	4
M9	Su	21	6.5	3	1	2
M9	Wi	37.5	33	4	4	7
S1	Fa	12	36	1	3	3
S1	Sp	5	10.5	1	2	2
S1	Su	7	32.5	1	3	3
S1	Wi	7	36	1	4	5

Table 35—*Continued.*

Habitat	Season	Men's Rank	Women's Rank	Men's Score	Women's Score	Combined Score
S10	Fa	24	18	3	2	2
S10	Sp	20	28	2	3	3
S10	Su	22	16	3	2	2
S10	Wi	17	14	2	2	2
S4	Fa	21	27	3	3	4
S4	Sp	16	24.5	2	3	3
S4	Su	20	5	2	1	1
S4	Wi	12	31	2	3	3
S5	Fa	16	23	2	3	3
S5	Sp	14	21.5	2	3	3
S5	Su	13	6.5	2	1	1
S5	Wi	14	29	2	3	3
S6	Fa	18	24	2	3	3
S6	Sp	15	26	2	3	3
S6	Su	16	9	2	2	2
S6	Wi	13	27	2	3	3
S7	Fa	19	26	2	3	3
S7	Sp	11	19.5	2	2	2
S7	Su	17	34	2	4	5
S7	Wi	11	23	2	3	3
S8	Fa	25	28	3	3	4
S8	Sp	23	14.5	3	2	2
S8	Su	25.5	17.5	3	2	2
S8	Wi	16	28	2	3	3
S9	Fa	26	29	3	3	4
S9	Sp	25	30	3	3	4
S9	Su	27	3	3	1	2
S9	Wi	15	30	2	3	3
W1	Fa	2	31	1	2	2
W1	Sp	2	5.5	1	1	1
W1	Su	2	1	1	1	1
W1	Wi	3	37.5	1	4	5
W2	Fa	1	33	1	3	3
W2	Sp	1	5.5	1	1	1
W2	Su	1	31	1	3	3
W2	Wi	1	37.5	1	4	5
W4	Fa	11	37.5	2	4	5
W4	Sp	3	3	1	1	1
W4	Su	8	12	1	2	2
W4	Wi	8	35	1	4	5

The seven combined gender score categories are characterized thus:

1- best for men and women
2- best for women, good for men
3- best for men, good for women
4- good for men and women
5- good for men, bad for women
6- good for women, bad for men
7- bad for men and women

Note that these scores are consistent with expectations about the effects of sexual division of labor and central place foraging on archaeological site formation processes. Habitats scoring 1 through 4 have foraging value simultaneously for men and women, but women's foraging utility takes precedence. Men's and women's subsistence sites should occur in all four categories, but generally diminish from score 1 to score 4, although score 3 habitats may have more men's sites than score 2 habitats. What is more important, score 1 should be most likely and score 4 least likely to contain residential base camps, which are possible in all four categories. In contrast, combined score 5 habitats should lack residential bases and women's subsistence sites, but contain men's subsistence sites. Score 6 habitats may contain women's subsistence sites, but lack residential bases and men's subsistence sites. Score 5 habitats rank higher than score 6 because of the expected higher archaeological visibility of men's activities than women's activities. Finally, score 7 habitats have little or no foraging utility for men or women and, therefore, should have the most scant archaeological records.

The next step toward simplification distills combined gender scores for each habitat in each season into a raw complexity score for each habitat. Table 36 presents the combined gender scores for each habitat in each season. It also counts the number of seasons that each habitat has a combined gender score of 1, 2, and so on through 7. These counts serve to rank habitats into a raw complexity score ranging from 2 through 8. Criteria for assigning raw complexity scores are these:

2 - have combined gender scores of 1 in two seasons, or 1 in one season and 2 in two or three seasons
3 - have combined gender scores of 1 in one season, and 2 in one season or 3 in two or three seasons
4 - do not have a combined gender score of 1 in any season, but have scores of 2 for two or three seasons
5 - have a combined gender score of 2 in only one season
6 - highest score is 3 in one season, whereas all three other seasons score 5
7 - have combined score of 6 in all four seasons
8 - have combined gender scores of 7 in all seasons

The final step refines raw complexity scores into final archaeological complexity scores according to water, slope, and toolstone source. The final complexity score subtracts 1 point from the raw score of all areas of habitats within 1 km of a perennial water source, but adds one point for all areas more than 10 km from any perennial water source. These adjustments track the importance of potable water in determining central place locations and hunter-gatherer foraging activity. All areas of habitat lying on a landform known to contain usable toolstone have one point subtracted from their raw sensitivity score to adjust for effects of a nearby toolstone source on the archaeological record. Finally, all areas of habitat on slopes exceeding 18% have one point added to their raw score to reflect the retarding effect of steep slopes on hunter-gatherer camping and foraging activity.

These steps subdivide the set of 39 Railroad Valley habitats into an array of 108 habitat types, each assigned a final archaeological complexity score ranging from 1 to 8. Table 37 describes characteristics of each habitat type. The prehistoric archaeological record should correlate strongly with the ranking: habitat types scoring 1 should bear the most sites, with the largest and most diverse assemblages, whereas habitat types scoring 8 should yield the fewest sites, with the smallest and most homogeneous assemblages.

Moreover, the ranking predicts site type. Residential base camps may occur in scores 1 through 5 habitats, but should be most likely in score 1 and least likely in score 5. They should not occur at all in scores 6, 7, or 8 habitats. The probability of men's subsistence sites should diminish from scores 1 through 6 and be absent from scores 7 and 8. Women's subsistence sites are most likely in score 1 habitats, progressively less likely through score 7, and altogether absent from score 8. Figure 9 summarizes expectations by archaeological complexity score for residential base camps, men's subsistence sites, and women's subsistence sites, respectively.

Table 36. Final Scoring for Each Railroad Valley Habitat

Habitat	Combined Score Autumn	Combined Score Winter	Combined Score Spring	Combined Score Summer	No. of Score 1 Seasons	No. of Score 2 Seasons	No. of Score 3 Seasons	No. of Score 4 Seasons	No. of Score 5 Seasons	No. of Score 6 Seasons	No. of Score 7 Seasons	Raw Complexity Score
G17	2	1	2	4	1	2	0	1	0	0	0	2
G2	2	2	1	5	1	2	0	0	1	0	0	2
G23	2	1	2	2	1	3	0	0	0	0	0	2
G3	1	2	1	5	2	1	0	0	1	0	0	2
G4	1	2	1	5	2	1	0	0	1	0	0	2
M3	1	5	1	3	2	0	1	0	1	0	0	2
W1	2	5	1	1	2	1	0	0	1	0	0	2
G18	2	1	6	4	1	1	0	1	0	1	0	3
G5	1	2	3	3	1	1	2	0	0	0	0	3
G9	3	2	3	1	1	1	2	0	0	0	0	3
M2	2	4	1	3	1	1	1	1	0	0	0	3
M9	1	7	4	2	1	1	0	1	0	0	1	3
S4	4	3	3	1	1	0	2	1	0	0	0	3
S5	3	3	3	1	1	0	3	0	0	0	0	3
W2	3	5	1	3	1	0	2	0	1	0	0	3
W4	5	5	1	2	1	1	0	0	2	0	0	3
G10	6	2	2	6	0	2	0	0	0	2	0	4
G14	2	6	2	2	0	3	0	0	0	1	0	4
G16	2	2	2	4	0	3	0	1	0	0	0	4
G6	2	2	5	5	0	2	0	0	2	0	0	4
M6	2	4	5	2	0	2	0	1	1	0	0	4
S10	2	2	3	2	0	3	1	0	0	0	0	4
S8	4	3	2	2	0	2	1	1	0	0	0	4
G12	6	2	6	6	0	1	0	0	0	3	0	5
G21	6	2	7	6	0	1	0	0	0	2	1	5
G22	6	2	5	6	0	1	0	0	1	2	0	5
G8	4	2	4	4	0	1	0	3	0	0	0	5
M11	5	4	5	2	0	1	0	1	2	0	0	5
M5	5	4	3	2	0	1	1	1	1	0	0	5
M7	5	6	7	2	0	1	0	0	1	1	1	5
S1	3	5	2	3	0	1	2	0	1	0	0	5
S6	3	3	3	2	0	1	3	0	0	0	0	5
S7	3	3	2	5	0	1	2	0	1	0	0	5
S9	4	3	4	2	0	1	1	2	0	0	0	5
M8	5	5	5	3	0	0	1	0	3	0	0	6
G11	6	6	6	6	0	0	0	0	0	4	0	7
G13	6	6	6	6	0	0	0	0	0	4	0	7
G15	6	6	6	6	0	0	0	0	0	4	0	7
A1	7	7	7	7	0	0	0	0	0	0	4	8

Table 37. Railroad Valley Habitat Types and Defining Cross-Stratification Variables

Final Score	Habitat	Water <3km	Toolstone Source	Water> 10 km	Slope > 18%
7	A1	X			
8	A1				
3	G10	X			
4	G10				
5	G10			X	
5	G11	X	X		
6	G11	X			
7	G11				
8	G11			X	
3	G12	X	X		
4	G12	X			
4	G12		X		
5	G12				
6	G12			X	
5	G13	X	X		
6	G13	X			
7	G13				
3	G14	X			
4	G14				
5	G14			X	
6	G15	X			
7	G15				
8	G15			X	
2	G16	X	X		
3	G16	X			
4	G16				
1	G17	X	X		
1	G17	X			
2	G17				
3	G17			X	
1	G18	X	X		
2	G18	X			
3	G18				
4	G18			X	
1	G2	X			
2	G2				
6	G21			X	
5	G22				
6	G22			X	
1	G23	X			
2	G23				
1	G3	X			
2	G3				
1	G4	X			
2	G4				
1	G5	X	X		
2	G5	X			
3	G5				
3	G6	X			
4	G6				
4	G8	X			
5	G8				
6	G8			X	
2	G9	X			
3	G9				

Table 37—*Continued.*

Final Score	Habitat	Water <3km	Toolstone Source	Water> 10 km	Slope > 18%
4	G9			X	
4	M11	X			
5	M11				
6	M11				X
2	M2	X			
3	M2				
1	M3	X			
2	M3				
4	M5	X			
5	M5				
6	M5				X
7	M5			X	X
3	M6	X			
4	M6				
5	M6				X
6	M6			X	X
4	M7	X			
5	M7				
6	M7				X
7	M7			X	X
5	M8	X			
6	M8	X			X
6	M8				
7	M8				X
2	M9	X			
3	M9				
3	S1	X	X		
4	S1	X			
4	S1	X			
4	S1		X		
5	S1				
3	S10	X			
4	S10				
2	S4	X			
3	S4				
4	S4			X	
2	S5	X			
3	S5				
4	S5			X	
4	S6	X			
5	S6				
6	S6			X	
4	S7	X			
5	S7				
4	S8				
4	S9	X			
5	S9				
6	S9			X	
1	W1	X			
2	W2	X			
3	W2				X
1	W4	X	X		
2	W4	X			

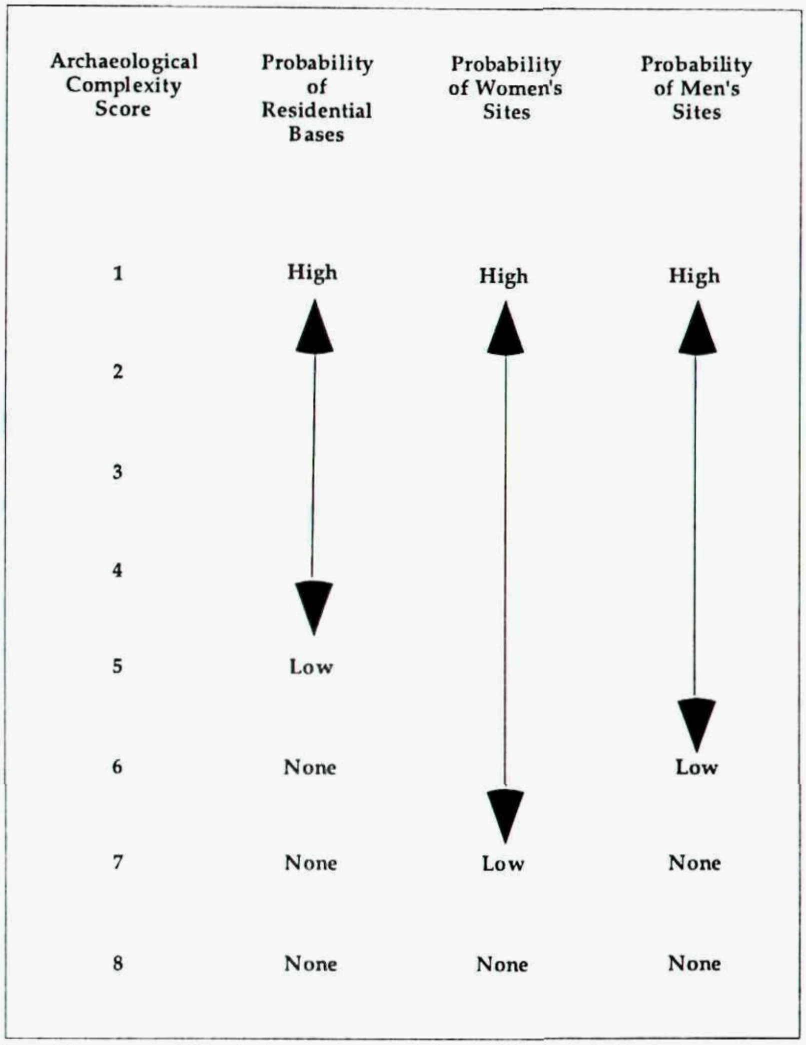

Figure 9. Summary of archaeological expectations by complexity score.

Interpreting the Railroad Valley Site Sample

Expectations about the archaeological record of Railroad Valley follow from an eight-point archaeological complexity scale that addresses male and female foraging and residence behavior, and that predicts the number, size, and diversity of archaeological assemblages and specific site types. Clearly, before the extant body of archaeological survey data can be used to assess the predictive powers of the model, patterning in the composition and diversity of archaeological assemblages in the sample must be analyzed to discern the hunter-gatherer behavior that produced them.

The dilemma is the variable quality of data in the Railroad Valley site sample. For example, of 1323 prehistoric sites and isolates recorded in the Railroad Valley study area, 351 lack any assemblage data whatsoever. Of the remaining 972 properties, only 400 sites categorically count artifacts and features, the remaining 572 are either isolates or indicate only the presence or absence of artifact or feature types. Irregular definition and recording of isolates render them a meaningless category for analytical purposes; excluding them from analysis would only bias the analysis against smaller archaeological sites. Only 750 sites are associated with clearly defined inventory areas, and only 637 sites are map plotted with reliability sufficient to calculate site area.

The variable quality of the Railroad Valley database compels its subdivision into different sets according to their suitability for testing particular predictions. For example, the entire set of 1323 sites and isolates is appropriate for looking at locational patterns, but only the set of 750 associated with inventory areas are suitable for calculating site density, and only the set of 637 reliable map plots are useful for calculating average site size. Functional identifications of site type must be based on the presence or absence of artifacts and features to classify the sample of 972 properties with assemblage data, whereas issues of assemblage size and diversity must refer only to the sample of 400 sites with quantified assemblage descriptions.

Monothetic Classification of Site Types

The model makes specific predictions about the distribution of residential base camps, and men's and women's subsistence sites, as well as anticipating distortion induced by lithic reduction sites. Testing these predictions about the distribution and abundance of functional site categories requires classification of Railroad Valley archaeological sites into appropriate site types. A monothetic technique based on presence or absence, rather than frequency, of artifact categories in assemblages serves to develop a functional site typology for the 972 sites with presence/absence assemblage descriptions (Bettinger et al. 1994; Whallon 1971).

Monothetic typologies divide sample populations into categories based on the presence or absence of a series of individual attributes in a hierarchical sequence (as opposed to polythetic classifications that simultaneously consider all attributes). Each attribute is subjected individually to chi-square analysis against all other variables in a series of two by two celled contingency tables. Chi-square statistics for each table and each variable are summed, and then used to measure the cumulative association of each variable with all other attributes in the sample population. The presence or absence of the variable with the highest cumulative chi-square value serves as the criterion for splitting the population into two smaller groups.

The chi-square analysis is then repeated for all remaining variables, separately within the two subpopulations. Within each subpopulation the presence or absence of the variable with the highest cumulative chi-square statistic divides it further into two smaller categories. Thus, the classification system forms a tree-like sequence in which the original population branches into a series of ever smaller subpopulations (Whallon 1971:4).

The sample population of 972 sites and isolates was subjected to this classification system according to the presence or absence of nine categories: features, points, bifaces, flake tools, cores, groundstone, ceramics, debitage, and other tools. The criteria for listing a particular site as having features included any surface manifestation that archeologists commonly recognize as betraying the presence of buried features, including burned bone, fire-cracked rock, charcoal, and rock or charcoal concentrations. The category "other tools" is an eclectic set of artifact types not observed on enough Railroad Valley sites to consider separately, including choppers, hammerstones, ornaments, drills, and scrapers.

From the outset, we assumed that some artifact categories would associate with the different site types addressed by the model. Features associate with residential camps. Although groundstone tools and ceramics betray women's subsistence activity, they should also reflect residential sites. Bifaces, projectile points, and flake tools are unmistakable signs of men's subsistence activity, but should also occur on residential sites. Finally, cores are a reliable indicator of reduction of locally available toolstones. In contrast, we expected debitage and other tools to be unreliable indicators of site function.

Table 38 tallies the sites bearing each category. The association of each artifact type with all remaining artifact types was measured by conducting a series of two by two contingency tables (for example projectile points vs. bifaces, projectile points vs. utilized flakes, projectile points vs. groundstone tools, etc.) across the population of 972 sites with presence/absence assemblage data.

Table 38. Number of Sites Bearing or Lacking Artifact Categories Used to Develop Monothetic Site Typology

Category	Category Present	Category Absent	Total
Feature Evidence	98	874	972
Projectile Points	197	775	972
Ceramics	51	921	972
Groundstone	88	884	972
Bifaces	190	782	972
Cores	60	912	972
Flake tools	108	864	972
Other Tools	43	929	972
Debitage	859	113	972

The resulting chi-square values were totaled for each artifact category. Artifact types with the highest cumulative chi-square value were then used to splinter the site population into groups based on the presence or absence of that variable, and the exercise repeated for each subgroup. Subgroups were further divided into smaller categories as long as the resulting splinter groups contained a minimum of 20 sites each.

This monothetic typology identifies 9 assemblage groups (Table 39), classified as follows:

Group 1 - sites with evidence of features, but lacking bifaces
Group 2 - sites with evidence of features and bifaces
Group 3 - sites lacking evidence of features, with debitage present, bifaces absent, and groundstone present
Group 4 - sites lacking evidence of features, with debitage present, bifaces, groundstone and points absent
Group 5 - sites lacking evidence of features, with debitage present, bifaces and groundstone absent, and points present
Group 6 - sites lacking evidence of features, but debitage and bifaces present
Group 7 - sites lacking evidence of features and debitage, but flake tools present
Group 8 - sites lacking evidence of features, debitage, and flake tools, but points present
Group 9 - sites lacking evidence of features, debitage, flake tools, and points

Table 39. Identification Key for Monothetic Classification of the Railroad Valley Site Sample

Division 1	Division 2	Division 3	Division 4	Division 5	Assemblage Group
Features Present (n=98)					
	Bifaces Absent (n=64)				Group 1
	Bifaces Present (n=34)				Group 2
Features Absent (n= 874)					
	Debitage Present (n=794)				
		Bifaces Absent (n=654)			
			Groundstone Present (n=11)		Group 3
			Groundstone Absent (n=643)		
				Points Absent (n=581)	Group 4
				Points Present (n=62)	Group 5
		Bifaces Present (n=140)			Group 6
	Debitage Absent (n=80)				
		Flk Tls Present (n=19)			Group 7
		Flk Tls Absent (n=61)			
			Points Present (n=26)		Group 8
			Points Absent (n=35)		Group 9

Referring now only to the set of 400 Railroad Valley sites with artifact counts, the frequencies of artifacts and features in each of the nine monothetic assemblage groups were tallied with (Table 40). The categories of artifacts and features differ slightly from those used in the monothetic site classification. Debitage was excluded from consideration because inconsistent tallies of this artifact prevent quantitative analysis of its frequency. Features, in this case, refer only to the count of identifiable charcoal or fire-cracked rock concentrations, not to the sum of indirect feature evidence (i.e., dispersed, individual specimens of burned bone, fire-cracked rock, or charcoal). The category of "other tools" is divided into fabrication and general utility tools because artifact counts are adequate to allow this division, which site counts were insufficient to permit. Fabrication tools refer to items such as drills, scrapers, abraders, and bone tools used to manufacture other tools. General utility tools are artifacts used for a variety of expedient tasks: hammerstones, choppers, and battered cobbles (cf. Thomas 1983a).

Table 40. Frequency of Artifact Types by Monothetic Site Group for the Sample of 400 Railroad Valley Sites with Quantified Assemblage Descriptions

Site Group	Bifaces	Ceramics	Cores	Fabrication Tools	Features	Flake Tools	General Utility Tools	Groundstone Tools	Projectile Points	Total
Group 1	0	67	3	1	18	6	5	17	12	111
Group 2	200	273	22	0	31	24	21	89	68	697
Group 3	0	0	2	0	0	4	1	17	3	27
Group 4	0	50	25	1	0	50	7	0	0	133
Group 5	0	6	4	0	0	3	0	0	59	72
Group 6	299	71	17	11	0	54	9	14	81	556
Group 7	38	0	3	1	0	40	12	17	43	154
Group 8	11	0	0	0	0	0	0	4	20	35
Group 9	10	5	4	1	0	0	1	7	0	28
Total	558	472	80	15	49	181	56	165	286	1813

This distribution was analyzed in a nine row by nine column contingency table. Obviously, chi-square analysis of artifact frequencies by monothetic site type should reveal significant associations that mirror criteria used to define the site populations. For example, it would not be surprising if projectile points associate significantly with Group 5 sites (those with debitage and points but lacking features, bifaces, and groundstone), whereas features, bifaces, and groundstone are negatively associated. However, the monothetic site typology is based on significant frequencies of sites bearing or lacking a given set of artifact categories, not significant frequencies of artifacts within a given site type. This analysis is intended to detect associations not imposed by the site classification system and, therefore, reveal additional insights into assemblage composition.

Table 41 presents adjusted residual values for the distribution (following Bettinger 1989:312-313); values greater than 1.96 or less than -1.96 are significant at the .05 level. Since the site typology derives from presence or absence data, it is unremarkable that the distribution is significant (chi-square = 1274, p=.0001). However, the analysis reveals significant associations between artifact frequencies and site type that are not merely consequences of the site classification criteria.

For example, Group 1 sites (evincing features but lacking bifaces) contain significant frequencies of ceramics and groundstone tools. Group 2 sites (sites evincing features and bifaces present) also contain significant occurrences of ceramics and groundstone tools, but bifaces, fabrication tools, flake tools, cores, and projectile points occur in significantly lower than expected frequencies. Ceramics are significantly dissociated with Group 3 sites (those lacking features and bifaces but containing debitage and groundstone). Ceramics, cores, and flake tools are significantly common in Group 4 sites (assemblages lacking features, bifaces, groundstone, and points, but with debitage). Group 5 sites (those lacking features, bifaces and groundstone but containing points and debitage) significantly lack ceramics. Group 6 assemblages (sites containing debitage and bifaces but lacking features) significantly lack groundstone and general utility tools, but also contain significant numbers of fabrication tools. Group 7 sites (sites lacking features and debitage but bearing flake tools) significantly lack ceramics, but contain significant proportions of points and general utility tools. Group 8 sites (assemblages lacking features, debitage, and flake tools but containing points) also significantly lack ceramics. Finally, Group 9 sites (lacking features, debitage, flake tools, and points) contain significant numbers of cores and groundstone tools.

Table 41. Adjusted Residuals of Artifact Types by Monothetic Site Groups

Site Group	Bifaces	Ceramics	Cores	Fabrication Tools	Features	Flake Tools	General Utility Tools	Groundstone Tools	Projectile Points
Group 1	-7.36	8.60	-0.91	0.09	9.07	-1.67	0.89	2.36	-1.49
Group 2	-1.79	11.40	-2.09	-3.08	3.65	-7.61	-0.15	4.43	-5.91
Group 3	-3.50	-3.11	0.76	-0.48	-0.87	0.84	0.19	9.81	-0.67
Group 4	-8.13	3.20	8.41	-0.10	-2.00	11.08	1.51	-3.81	-5.22
Group 5	-5.83	-3.52	0.48	-0.79	-1.44	-1.68	-1.55	-2.75	15.78
Group 6	15.74	-9.31	-1.89	3.60	-4.75	-0.26	-2.42	-6.63	-0.98
Group 7	-1.75	-7.82	-1.56	-0.26	-2.16	6.96	3.53	0.88	4.36
Group 8	0.08	-3.56	-1.28	-0.55	-1.00	-1.99	-1.07	0.48	6.79
Group 9	0.57	-1.00	2.56	1.62	-0.89	-1.78	0.15	2.95	-2.31

These associations appear to reflect site function. Groups 1 and 2 sites match expectations of residential base camps because, by definition, they always contain features and are significantly associated with groundstone tools and ceramics. They differ in the kinds of men's artifacts they contain: Group 1 sites always lack bifaces whereas Group 2 sites always contain them. Fabrication tools, flake tools, cores, and projectile points are significantly underrepresented on Group 2 sites, but review of Table 40 indicates that this association is statistical rather than absolute; sites of both groups bear relatively large numbers of these artifacts.

Group 3 sites qualify as women's subsistence locations since they lack features and bifaces, but contain groundstone. However, Group 3 sites significantly lack ceramics. Group 5 sites are easily classified as men's subsistence sites as they always contain points, always lack features and groundstone, and are significantly disassociated with ceramics. Group 8 sites also qualify as men's processing sites because they always contain points, always lack features, and significantly lack ceramics.

However, some groups have defining criteria and significant associations that defy characterization of site function. Group 4 sites always contain debitage, always lack features, groundstone, bifaces, and points, and are significantly associated with ceramics and flake tools. If it is assumed that ceramics associate with women's activity and flake tools with men's activity, then Group

4 sites have traits of both genders, while lacking evidence of residential occupation. Group 6 sites also seem to qualify as men's subsistence sites because they lack features, always contain bifaces, and significantly lack groundstone tools. Similarly, Group 7 sites significantly lack ceramics while containing significant frequencies of points. However, review of Table 40 indicates that Group 6 and 7 sites contain relatively large counts of ceramics and groundstone. Perhaps these are logistic hunting camps in which women accompanied men? Finally, Group 9 sites have significant numbers of cores and groundstone, thus qualifying as both women's subsistence sites and lithic reduction sites.

Review of the site records for these ambiguous sites reveals that conflicting traits more often than not are intrasite rather than intersite phenomena. For example, in Group 9, cores and groundstone rarely co-occur on the same sites. The monothetic typology failed to splinter these groups because the sample of sites grew too small to reliably continue the monothetic chi-square analysis. To correct this, the monothetic site key was revised to further splinter Group 4, 5, 6, 7, 8 and 9 sites. Subdivision criteria were based on our assumption that women's subsistence activities are strongly anchored to base camps. Consequently, the presence of bifaces, points, and flake tools in statistically insignificant quantities was tolerable on women's subsistence sites (because men are likely to hang out close to home), but the presence of ceramics and groundstone was not tolerated on men's subsistence sites (because men should often range far from home where no women are present).

The refined site type key, presented in Table 42, defines 18 site groups, for which artifact tallies are presented in Table 43; Table 44 gives adjusted residuals for chi-square analysis. The significant frequencies of cores and general utility tools on Group 4c sites qualify them as lithic reduction locales. Groups 4a, 5b, 6c, 7b, 8b, and 9c are all men's subsistence sites because of their associations with points, bifaces, or flake tools, and disassociation with ceramics and groundstone tools. Similarly, Groups 3, 4b, 5a, 6a, 6b, 7a, 8a, 9a, and 9b are women's subsistence sites because they associate significantly with groundstone tools or ceramics and frequently disassociate with points, bifaces, and flake tools.

Table 45 sums artifacts among site groups into four site types: lithic reduction, men's subsistence, women's subsistence, and residential camps. Table 46 presents adjusted residuals. This produces a typology which matches our preliminary expectations for the sensitivity of artifact categories to site function. Cores occur significantly on lithic reduction sites, which also contain significant frequencies of general utility tools reflecting use of expedient hammerstones. Ceramics, points, and bifaces are significantly disassociated with lithic reduction sites. Men's subsistence sites contain significant frequencies of points, bifaces, and flake tools, while significantly lacking ceramics, cores, general utility tools, groundstone tools, and features. They also contain significant counts of fabrication tools reflecting logistic field maintenance and processing using drills, scrapers, abraders, and bone tools. Residential sites are significantly associated with features, and with ceramics and groundstone tools reflecting the close association of women's activities with home bases. Women's subsistence sites contain significant frequencies of ceramics and groundstone tools, as well as general utility tools, possibly reflecting the role of choppers and battered cobbles in women's food processing. Both women's subsistence sites and residential sites are statistically disassociated with points, bifaces, flake tools, and fabrication tools. However, review of Table 45 shows that these artifacts often occur on such sites, reflecting the tendency of men to hang out wherever women are.

Table 42. Revised Key Classification of the Railroad Valley Site Sample

Division 1	Division 2	Division 3	Division 4	Division 5	Division 6	Division 7	Assemblage Group
Features Present (n=98)							
	Bifaces Absent (n=64)						Group 1
	Bifaces Present (n=34)						Group 2
Features Absent (n= 874)							
	Debitage Present (n=794)						
		Bifaces Absent (n=654)					
			Ground Stone Present (n=11)				Group 3
			Ground Stone Absent (n=643)				
				Points Absent (n=581)			
					Flake Tools Present (n=46)		Group 4a
					Flake Tools Absent (n=536)		
						Ceramics Present (n=2)	Group 4b
						Ceramics Absent (n=534)	Group 4c
				Points Present (n=62)			
					Ceramics Present (n=1)		Group 5a
					Ceramics Absent (n=61)		Group 5b
		Bifaces Present (n=140)					
			Ground Stone Present (n=10)				Group 6a
			Ground Stone Absent (n=130)				
				Ceramics Present (n=7)			Group 6b
				Ceramics Absent (n=123)			Group 6c
	Debitage Absent (n=80)						
		Flk Tls Present (n=19)					
			Ground Stone Present (n=8)				Group 7a
			Ground Stone Absent (n=11)				Group 7b
		Flk Tls Absent (n=61)					
			Points Present (n=26)				
				Ground Stone Present (n=5)			Group 8a
				Ground Stone Absent (n=21)			Group 8b
			Points Absent (n=35)				
				Ground Stone Present (n=11)			Group 9a
				Ground Stone Absent (n=25)			
					Ceramics Present (n=14)		Group 9b
					Ceramics Absent (n=11)		Group 9c

Table 43. Frequency of Artifact Types by Revised Monothetic Site Group for the Sample of 400 Railroad Valley Sites with Quantified Assemblage Descriptions

Site Group	Ceramics	Projectile Points	Bifaces	Cores	Flake Tools	Fabrication Tools	General Utility Tools	Groundstone Tools	Features	Site Type
Group 1	67	12	0	3	6	1	5	17	18	Residential Base
Group 2	273	68	200	22	24	0	21	89	31	Residential Base
Group 3	0	3	0	2	4	0	1	17	0	Women's Subsistence
Group 4a	0	0	0	2	50	0	1	0	0	Men's Subsistence
Group 4b	50	0	0	2	0	0	0	0	0	Women's Subsistence
Group 4c	0	0	0	21	0	1	6	0	0	Lithic Reduction
Group 5a	6	1	0	4	0	0	0	0	0	Women's Subsistence
Group 5b	0	58	0	0	3	0	0	0	0	Men's Subsistence
Group 6a	1	9	30	5	7	0	4	14	0	Women's Subsistence
Group 6b	70	5	29	5	3	0	0	0	0	Women's Subsistence
Group 6c	0	67	240	7	44	11	5	0	0	Men's Subsistence
Group 7a	0	14	24	2	13	0	10	17	0	Women's Subsistence
Group 7b	0	29	14	1	27	1	2	0	0	Men's Subsistence
Group 8a	0	1	0	0	0	0	0	4	0	Women's Subsistence
Group 8b	0	19	11	0	0	0	0	0	0	Men's Subsistence
Group 9a	0	0	1	0	0	0	1	7	0	Women's Subsistence
Group 9b	8	0	1	1	0	0	22	0	0	Women's Subsistence
Group 9c	0	0	8	3	0	1	0	0	0	Men's Subsistence

Table 44. Adjusted Residuals of Artifact Types by Revised Monothetic Site Groups

Assemblage Group	Ceramics	Projectile Points	Bifaces	Cores	Flake Tools	Fabrication Tools	General Utility Tools	Groundstone Tools	Features	Site Type
Group 1	8.67	-1.43	-7.28	-0.88	-1.63	0.10	0.14	2.42	9.15	Residential Base
Group 2	11.49	-5.69	-1.42	-1.99	-7.45	-3.05	-2.07	4.58	3.74	Residential Base
Group 3	-3.10	-0.64	-3.47	0.78	0.87	-0.47	-0.14	9.89	-0.87	Women's Subsistence
Group 4a	-4.38	-3.18	-4.91	-0.21	20.98	-0.67	-0.86	-2.32	-1.22	Men's Subsistence
Group 4b	11.81	-3.15	-4.86	-0.18	-2.42	-0.66	-1.54	-2.30	-1.21	Women's Subsistence
Group 4c	-3.16	-2.29	-3.53	18.47	-1.76	1.63	4.55	-1.68	-0.88	Lithic Reduction
Group 5a	2.18	-0.59	-2.20	5.22	-1.10	-0.30	-0.70	-1.04	-0.55	Women's Subsistence
Group 5b	-4.72	17.48	-5.28	-1.70	-1.32	-0.72	-1.67	-2.50	-1.32	Men's Subsistence
Group 6a	-4.79	-0.64	2.34	1.17	0.04	-0.77	0.62	3.30	-1.41	Women's Subsistence
Group 6b	9.25	-3.36	-1.08	0.06	-2.64	-0.99	-2.30	-3.44	-1.81	Women's Subsistence
Group 6c	-13.40	1.44	16.90	-2.65	1.41	5.12	-3.14	-6.89	-3.60	Men's Subsistence
Group 7a	-5.44	0.49	-0.07	-0.83	1.97	-0.83	3.75	3.94	-1.51	Women's Subsistence
Group 7b	-5.22	5.75	-2.20	-1.29	7.87	0.52	-0.67	-2.76	-1.45	Men's Subsistence
Group 8a	-1.32	0.27	-1.48	-0.48	-0.74	-0.20	-0.47	5.56	-0.37	Women's Subsistence
Group 8b	-3.27	7.29	0.76	-1.18	-1.83	-0.50	-1.16	-1.74	-0.91	Men's Subsistence
Group 9a	-1.78	-1.29	-1.26	-0.64	-0.99	-0.27	1.02	7.24	-0.50	Women's Subsistence
Group 9b	-0.11	-2.45	-3.39	-0.34	-1.89	-0.52	18.27	-1.79	-0.94	Women's Subsistence
Group 9c	-2.05	-1.49	2.75	3.52	-1.15	2.90	-0.73	-1.09	-0.58	Men's Subsistence

Table 45. Frequency of Artifact Types by Site Type for the Sample of 400 Railroad Valley Sites with Quantified Assemblage Descriptions

Site Type	Lithic Reduction	Men's Subsistence	Residential Sites	Women's Subsistence
Ceramics	0	0	340	135
Projectile Points	0	173	80	33
Bifaces	0	273	200	85
Cores	21	13	25	21
Flake Tools	0	124	30	27
Fabrication Tools	1	13	1	0
General Utility Tools	6	8	26	38
Groundstone Tools	0	0	106	59
Features	0	0	49	0

Table 46. Adjusted Residuals of Artifact Types by Site Types

Site Type	Lithic Reduction	Men's Subsistence	Residential Sites	Women's Subsistence
Ceramics	-3.16	-19.43	16.51	4.37
Projectile Points	-2.29	11.35	-6.41	-4.64
Bifaces	-3.53	10.91	-5.70	-4.70
Cores	18.47	-3.27	-2.38	1.03
Flake Tools	-1.76	11.05	-8.17	-2.35
Fabrication Tools	1.63	4.46	-2.93	-2.05
General Utility Tools	4.55	-4.39	-1.97	5.97
Groundstone Tools	-1.68	-9.65	5.73	4.67
Feature	-0.88	-5.00	8.10	-3.74

The entire set of 1323 known prehistoric sites and isolates in Railroad Valley was classified according to these four site types using the modified site key (Table 42). Table 47 presents the results. Note that 350 sites and isolates in the database remain unclassifiable because of insufficient assemblage data.

Table 47 Site Counts by Site Type in the Railroad Valley Database

Site Type	Site Count
Lithic Reduction	534
Men's Subsistence	273
Residential Sites	98
Women's Subsistence Sites	68
Unclassifiable	350
Total	1323

Chapter 8

Model Testing And Refinement

David W. Zeanah

In Chapter 7, we scored habitat types according to relative scales, anticipating that rank order would correlate with the number, size, function, and diversity of archaeological assemblages. In this chapter, we use survey findings to assess how well the ranking forecasts the archaeological record. Then we fine tune model predictions according to test results.

Survey data collected by numerous archaeological inventories conducted in Railroad Valley over the last two decades serve as the yardstick for testing and refining model predictions. However, the reader is forewarned of limitations in the suitability of extant survey data for model testing purposes, to wit: most inventory data were collected on behalf of undertakings that do not collectively represent a statistically valid sample of Railroad Valley habitats; moreover, variability among inventory methods and site recording standards further biases the database. Notwithstanding, the current sample is suitable for a preliminary evaluation of how well Railroad Valley archaeology corresponds to expectations generated by the habitat model; adequate testing of the model must remain an ongoing process until inventories achieve representative sampling of habitats.

Preliminary Test

A set of 1321 prehistoric sites and isolates (two sites lack habitat data and were excluded from the test) was tallied by archaeological complexity scale (Figure 10). The distribution is consistent with model expectations. Archaeological complexity score 1 habitat types bear the largest number of recorded sites. Site counts diminish with complexity score, with the exception of one reversal in score 4 habitat types.

Table 48 presents site type counts by complexity score, whereas Table 49 lists adjusted residuals of chi-square analysis, combining score 7 and 8 sites to mitigate small sample sizes. The distribution is significant (chi-square = 176, $p<.0001$) and consistent with model predictions. Score 8 habitat types bear only two men's subsistence sites, contradicting model expectations of no sites there. Men's and women's subsistence sites tend to increase in frequency with decreasing complexity score except for one minor reversal for men in score 4 habitat types. Because of the consistency of this trend, neither men's nor women's sites associate significantly with any complexity score. Residential sites are absent from score 6, 7, and 8 habitat types, are significantly under-represented in score 4 and 5 habitat types, and significantly over-represented in score 1 habitat types, all consistent with model predictions. Anomalies in the distribution concern lithic reduction sites that are under-represented in scores 1 and 3 habitat types and over-represented in score 4 and 5 habitat types, and unclassifiable sites that occur more often than expected in score 3 and less often in score 4 and 5 habitat types.

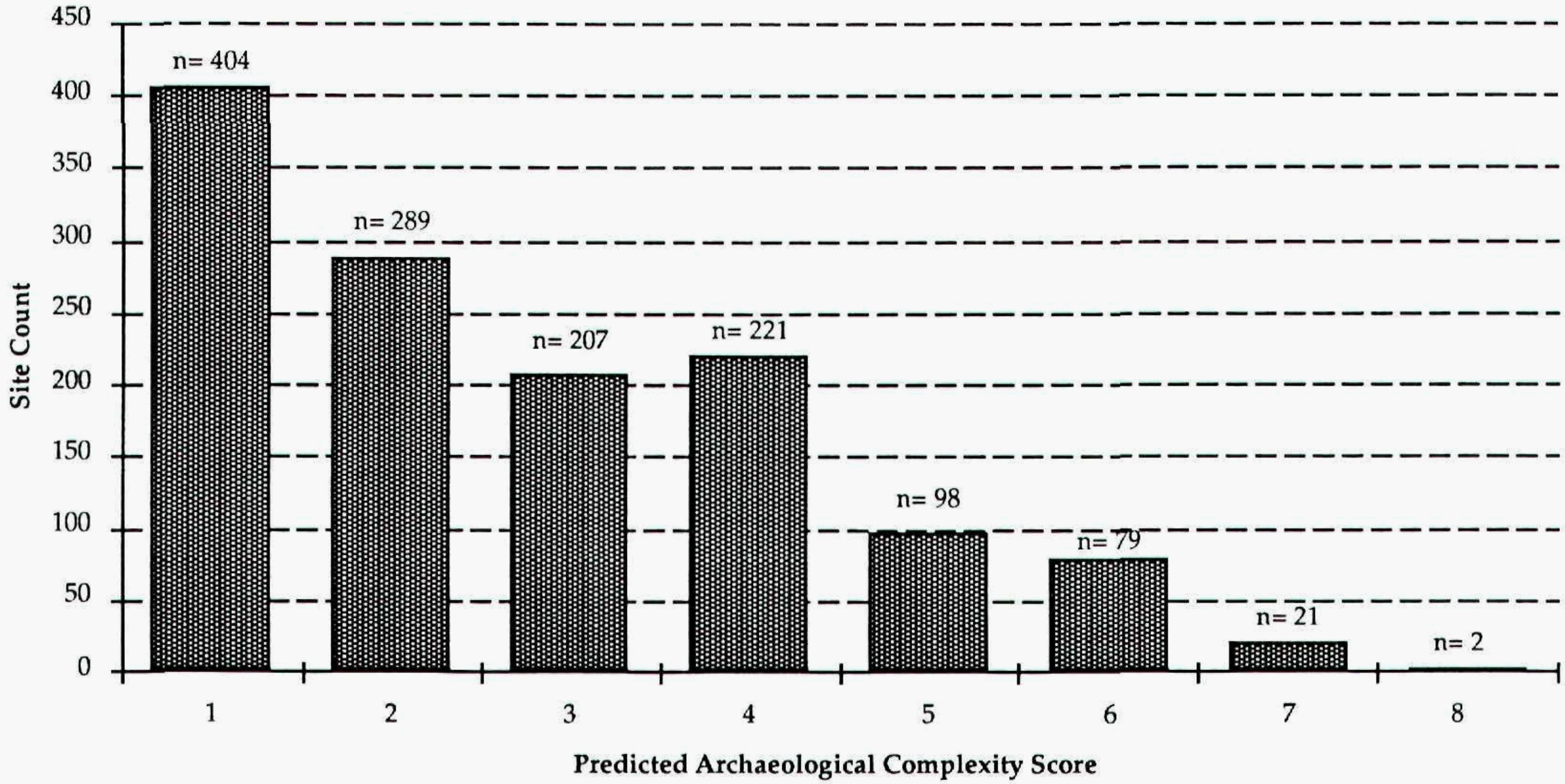

Figure 10. Preliminary Test - site counts by complexity score (Note: Two sites occur in areas with no data regarding habitat).

Table 48. Site Type Frequencies by Archaeological Complexity Score

Archaeological Complexity Score	1	2	3	4	5	6	7		Total
Lithic Reduction Sites	139	119	63	116	51	36	10		534
Men's Subsistence Sites	83	50	46	47	27	16	2	2	273
Residential Sites	54	24	15	4	1	0	0		98
Unclassifiable Sites	108	75	71	47	17	23	9		350
Women's Subsistence Sites	22	21	12	7	2	4	0		68
Total	406	289	207	221	98	79	21	2	1323*

* 2 sites occur in no data areas

Table 49. Adjusted Residuals for Site Type Frequencies
by Archaeological Complexity Score

Archaeological Complexity Score	1	2	3	4	5	6	7 & 8
Lithic Reduction Sites	-3.61	0.35	-3.39	4.33	2.52	0.99	0.31
Men's Subsistence Sites	-0.12	-1.64	0.63	0.26	1.78	-0.09	-0.39
Residential Sites	5.54	0.67	-0.10	-3.51	-2.52	-2.60	-1.37
Unclassifiable Sites	0.09	-0.23	2.88	-1.99	-2.16	0.56	1.39
Women's Subsistence Sites	0.31	1.87	0.47	-1.46	-1.45	-0.03	-1.13

This distribution does not consider the density of sites and isolates within inventoried areas of archaeological complexity groups. To examine density, the set of 750 prehistoric sites and isolates associated with clearly defined inventory areas was used to calculate sites per hectare of inventory area. Figure 11 presents the disappointing results. Although Spearman's rank correlation coefficient reveals that density and complexity score are significantly correlated (r_s=-0.81, $p < 0.05$), two anomalies in the pattern reverse the expected trend. Complexity score 1 habitat types have lower densities (.039 sites and isolates per hectare) than either score 2 (.061 sites and isolates per hectare) or score 3 (.044 sites and isolates per hectare) habitat types. Too, score 6 (.031 sites and isolates per hectare) and 7 (.017 sites and isolates per hectare) habitat types contain higher site densities than score 5 (.012 sites and isolates per hectare) habitat types.

Since the trend of site density by inventory area statistically conforms to expectations, the particular deviations of score 1 and 5 habitat types would be acceptable if the deviations result from expected variability. For example, we recognized from the outset that toolstone availability would distort the archaeological record of habitats. We struggled to predict the distribution of toolstones and adjust model expectations accordingly. However, unanticipated toolstone source areas within the Railroad Valley sample would distort testing results.

Anomalies in the association of lithic reduction sites with archaeological complexity score in Table 49 suggest that the model does not accurately track lithic toolstone source. Table 50 lists Spearman's rank correlation coefficients of the density of sites with features, ceramics, ground stone, projectile points, bifaces, utilized flakes, and cores. If the model accurately assessed the utility of Railroad Valley habitats for habitation, foraging, and toolstone procurement, there should be significant correlations in all categories. There are strong and significant correlations between site densities and archaeological complexity score in every category except sites with cores. This suggests that undetected toolstone sources in the Railroad Valley sample are likely causes of predictive failures of the model.

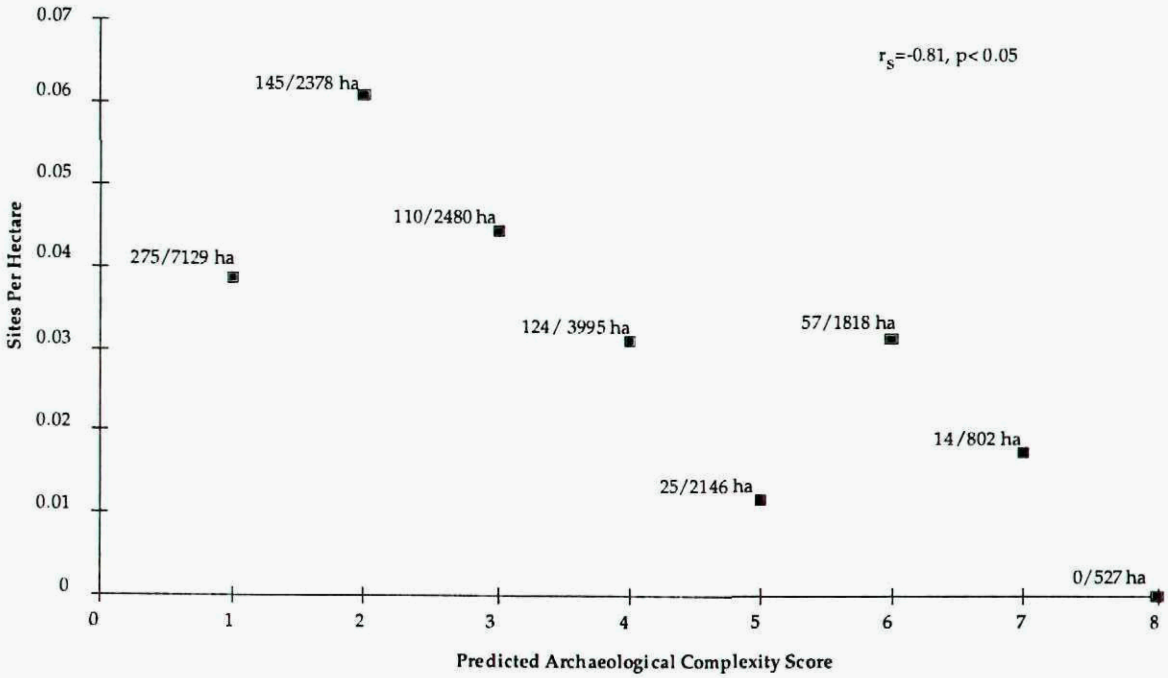

Figure 11. Preliminary Test - sites per hectare of inventory area by complexity score (Note: One site occurs in an area with no data regarding habitats).

Table 50. Preliminary Test - Spearman's Correlation Coefficients for Densities of Sites with Various Artifact Categories by Archaeological Complexity Score

Site Category	rho	p
Sites with Points	-0.95	<.02
Sites with Ceramics	-0.85	<.02
Sites with Features	-0.91	<.02
Sites with Ground Stone Tools	-0.78	<.05
Sites with Bifaces	-0.90	<.02
Sites with Flake Tools	-0.80	<.05
Sites with Cores	-0.30	>.2

If lithic sources are the sole cause of model predictive failures, then consideration of each site type individually should reveal that predictive failures concern only lithic reduction sites. In other words, if the higher site densities of score 2 and 3 and score 6 and 7 habitats than score 1 and 5, respectively, were attributable to lithic reduction sites, we could infer that all anomalies result from undetected toolstone sources alone. The distributions of residential base, women's subsistence, and men's subsistence site densities should conform to model expectations.

However, Table 51 shows that toolstone availability alone cannot account for all predictive failures in the model. The table calculates the density of each site type by inventory hectare. Although lithic reduction sites occur in higher densities in score 2 and 3 habitat types than score 1 habitats types, so do all other site types. Too, score 5 habitat types have lower densities of every site type, including lithic reduction sites, than score 6 habitats.

Table 51. Preliminary Test - Site Type Densities per Hectare of Inventory Area

Archaeological Sensitivity Score	1	2	3	4	5	6	7	8
Lithic Reduction Sites	0.0139	0.0261	0.0145	0.0183	0.0065	0.0154	0.0100	0.0000
Men's Subsistence Sites	0.0088	0.0114	0.0105	0.0053	0.0028	0.0061	0.0000	0.0000
Residential Camps	0.0048	0.0063	0.0040	0.0008	0.0000	0.0000	0.0000	0.0000
Unclassifiable Sites	0.0086	0.0130	0.0105	0.0060	0.0019	0.0077	0.0075	0.0000
Women's Subsistence Sites	0.0025	0.0042	0.0048	0.0008	0.0005	0.0022	0.0000	0.0000

Model Refinement

Preliminary testing revealed strong correlations between site counts and densities and predicted archaeological complexity score. However, deviations between site density and predicted archaeological complexity in score 1 and 5 habitat types are not attributable to expected variability among different site types. Instead, predicted archaeological complexity fails to predict site density of all site types in score 1 and 5 habitat types. For this reason, analysis moved to model refinement, whereby model predictions were empirically refined in light of extant archaeological data. Model refinements fell into three categories: identification of new habitat types containing toolstone sources, reclassification of habitats bearing dunes, and empirical reassessment of the archaeological complexity of selected habitat types.

Identification of New Habitat Types Containing Toolstone Sources

We demonstrated that the distribution of lithic reduction sites alone did not account for model prediction errors. Nevertheless, the lack of association between sites with cores and archaeological complexity score suggests that unanticipated toolstone sources bias the site density of habitat types. To winnow some of this variability from the database, we reviewed site records to identify cases where site recorders saw evidence of nearby toolstone sources that we did not anticipate in model development. Seven such sites were identified (Table 52). The landforms on which each of these sites occur were re-coded as having toolstones, resulting in the subtraction of one point from the final archaeological complexity score of all habitat types situated on those landforms. This changed the predicted archaeological complexity score of habitat types bearing 29 lithic reduction sites, 14 men's subsistence sites, two residential sites, two women's subsistence sites, and 14 unclassifiable sites.

Table 52. Sites with Toolstone Sources Not Anticipated by Model Predictions

Site Number	Site Type	Habitat	Landform
46-5918	Lithic Reduction	G12	Qyf
46-3029	Men's Subsistence	G12	Qb
61-4822	Residential Base	no data	Qe
4-553	Unclassifiable	G18	Qfs
4-554	Unclassifiable	G18	Qfs
4-557	Unclassifiable	G16	Qfs
61-212	Women's Subsistence	G5	Qyf

Reclassification of Habitats Bearing Dunes

The landform analysis of Chapter 5 struggled to identify eolian sand and silt dunes, recognizing that the presence of such dunes would affect the biota and foraging potential of each habitat. However, only larger dunes and dune fields are discernible in air photos, whereas smaller dunes are undifferentiated from fan skirts, fan toes, and lacustrine features where we know, empirically, that they sometimes occur. Range site and soil map unit descriptions expect dunes on only habitats G2, G3, G16 and G17, but regional range and soil characterizations may not completely monitor local dune formation in Railroad Valley.

Consideration of the Railroad Valley archaeological database provides an additional lens on the distribution of dunes; field archaeologists often note on site records when sites occur in dunes. Table 53 lists counts and proportions of sites and isolates recorded in dunes by habitat in the Railroad Valley database.

Table 53. Site and Isolate Counts and Proportion in Dunes by Habitat Type

Habitat	G16	G17	G2	G3	A1	G11	G12	G18	G4	G5	G6
Dunes Expected	Y	Y	Y	Y	N	N	N	N	N	N	N
Raw Complexity Score	4	2	2	2	8	7	5	3	2	3	4
Site and Isolates in Dune	29	7	2	50	1	2	6	35	16	10	12
All Sites and Isolates	83	104	60	127	8	15	308	273	123	19	91
Proportion of Sites in Dunes	0.3494	0.0673	0.0333	0.3937	0.1250	0.1333	0.0195	0.1282	0.1301	0.5263	0.1319

Sites occur in dunes in each of the four habitats where they are expected, although relatively small proportions of dune sites occur in Habitats G2 and G17. Review of the site records in these habitats suggests that this is somewhat attributable to recording bias because relatively few of those particular records provide any information at all about landform. However, Habitat G2 exhibits lower site densities than typical of complexity score 1 (.03 versus .04 sites per hectare) and score 2 (.02 versus .06 sites per hectare), whereas site densities in Habitat G17 are higher than score 1 (.06 versus .04 sites per hectare) but slightly lower than score 2 (.05 versus .06 sites per hectare) habitat types. For this reason, we suspect that the model overestimates the occurrence of dunes in Habitat G2 and add 1 point to its raw complexity score. This changed the expected archaeological complexity of habitat types containing 19 lithic reduction, 15 men's subsistence, three residential, 12 unclassifiable, and three women's subsistence sites. In contrast, we make no adjustment to Habitat G17, assuming that the model accurately reflects the presence of dunes there.

Dune sites also occur in seven additional habitats: A1, G4, G5, G6, G11, G12, and G18. Altogether, dune settings pertain to only nine sites in Habitats A1, G11, and G12, so it is unlikely that the occurrence of dunes in these habitats significantly affects model predictions against the entire set of previously recorded sites and isolates in Railroad Valley. However, Habitats G4, G5, G6, and G18 each contain at least ten cases apiece in dunes accounting for more than 10% of the total number of sites recorded in each habitat. This suggests that either reclassifying soil map units where dunes occur as different habitats or defining habitat types containing dunes, may improve model testing results.

Habitat G4 differs from Habitat G3 solely in presence of dunes, suggesting that cases of Habitat G4 with dune sites should simply be redesignated Habitat G3. However, both Habitats G3 and G4 have the same raw archaeological complexity score, so reclassification of these cases does not change model predictions.

Habitat G18 is similar to Habitats G16 and G17, both of which contain dunes but have different raw archaeological complexity scores. Habitat G17 bears playa-edge coppice dunes whereas Habitat G16 contains semi-active sand dunes and sheets. Review of the forms for Habitat G18 sites in dunes suggests that coppice dunes are unlikely and review of the distribution of Habitat G18 in Railroad Valley indicates that no examples occur adjacent playa (Figure 12). Therefore, cases of Habitat G18 containing dune sites should be reclassified as Habitat G16. Review of Figure 12 suggests that dune sites are widely distributed throughout the soil map units designated G18. Too, eolian dunes and sheets (Qe) frequently occur on G18. Therefore, we reclassified all the area of Habitat G18 as G16, with the exception of one small parcel north of Duckwater Creek lacking either dune sites or eolian landforms. This resulted in the reclassification of habitat types containing 214 sites and isolates, including 81 lithic reduction sites, 34 men's subsistence sites, 22 residential sites, 57 unclassifiable sites, and 20 women's subsistence sites.

Habitats G5 and G6 differ from Habitats G4 and G18 in that there are no similar habitats containing dunes. Therefore, they cannot be simple errors in habitat classification but are new habitat types not recognized in soil and range descriptions. Review of the distributions of dune sites within these habitats (Figures 13 and 14) reveals that dunes only occur within localized parcels, not the entire habitat as was the case with Habitat G18. Specifically, they seem to occur only along the westward margins of the habitats where dunes have accumulated on lacustrine features (Ql) and alluvial fan skirts (Qfs). Based on this distribution, we empirically defined new habitat types within Habitats G5 and G6 as bearing dunes, subtracting one point from their raw archaeological complexity score. So doing resulted in the modification of the predicted archaeological complexity score of habitats bearing 15 lithic reduction sites, ten men's subsistence sites, nine residential bases, eight unclassifiable sites, and two women's subsistence sites.

Empirical Reassessment of the Archaeological Complexity of Selected Habitat Types

In the third set of refinements to the Railroad Valley habitat model, we reviewed site densities in each habitat type to identify habitats that consistently bear too many or too few sites compared to other habitat types with the same complexity score. Then the archaeological complexity scores of such habitats were modified accordingly.

The first such modification concerned habitats bearing pinyon-juniper woodlands: M2, M6, and M9. The habitat model assesses these habitats as having only moderate archaeological complexity, with raw complexity scores of 3, 4, and 3, respectively. However, in Chapter 6 we noted that ethnohistoric accounts of hunter-gatherer foraging behavior in Railroad Valley imply more extensive use of pinyon-juniper woodlands than the model predicts, possibly because of the need to accumulate winter food stores.

Table 54 presents site densities by final complexity score for each of the pinyon-juniper habitat types. Sampling bias is clearly a concern because only from 0.25% to 1.07% of the pinyon-juniper habitat types have been inventoried for archaeological remains. However, in four of the seven habitat types, pinyon-juniper woodlands bear site densities much greater than the density of sites typical for all habitat types with the same complexity score. Given the ethnohistoric data, it seems likely that the habitat model underestimates the archaeological complexity of pinyon-juniper habitat types. For this reason, we subtracted one point from the archaeological complexity scores of all pinyon juniper habitats affecting seven lithic reduction sites, eight men's subsistence sites, eight unclassifiable sites, and two women's subsistence sites.

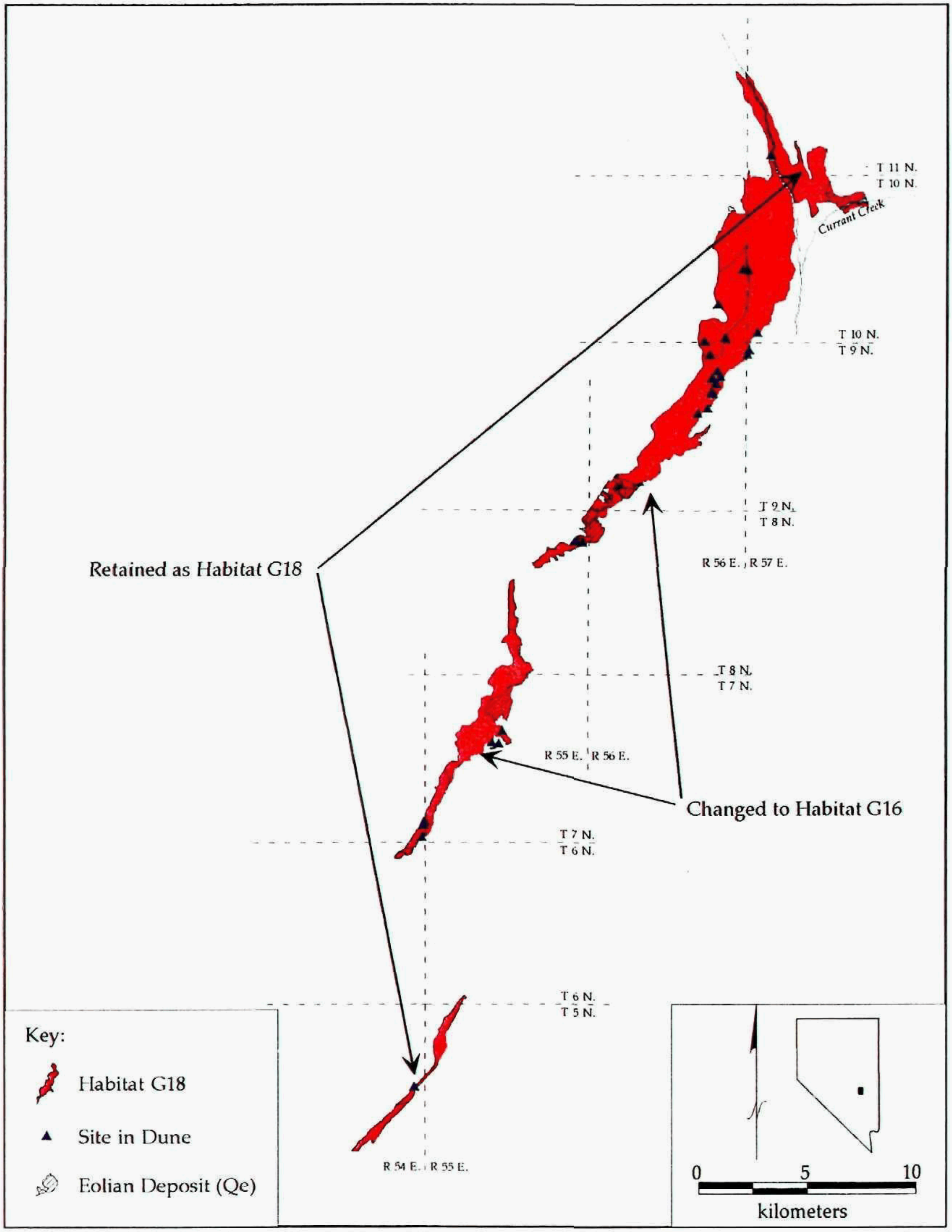

Figure 12. Refinement of Habitat G18 showing sites in dunes and eolian deposits.

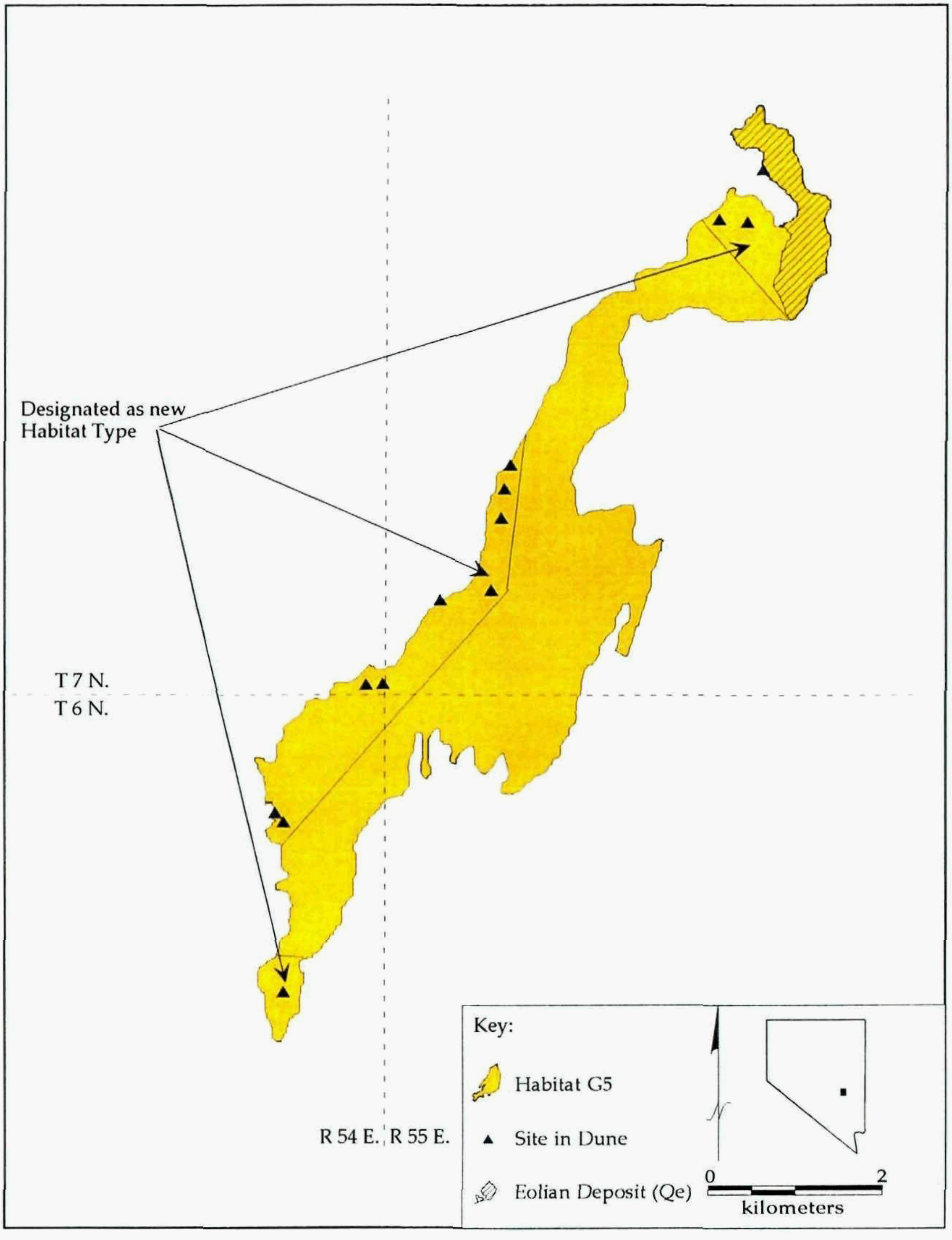

Figure 13. Refinement to Habitat G5 showing distribution of sites in dunes and eolian deposits.

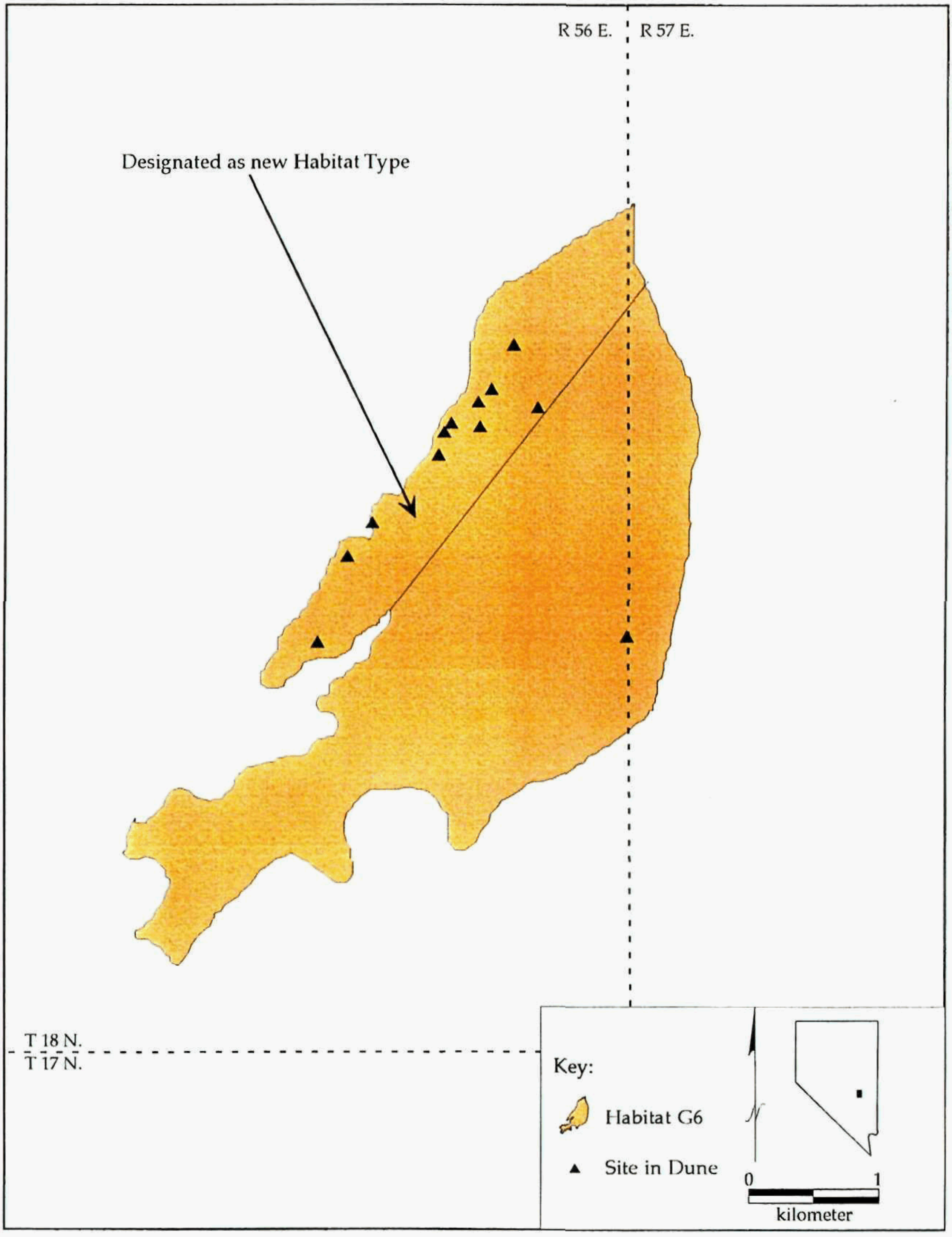

Figure 14. Refinement to Habitat G6 showing distribution of sites in dunes.

Table 54. Site Densities for Pinyon-Juniper Habitats

Habitat	M9	M2	M6	M2	M6	M2	M6
Final Complexity Score	2	2	3	3	4	4	5
Percent Inventory	0.76	0.86	1.07	0.87	1.19	0.25	0.3
Density Sites Per Hectare	0.87	0.28	0.46	0	0.33	0	0
Average Density for Complexity Score	0.06	0.06	0.04	0.04	0.03	0.03	0.01

Habitat G16 (including all G18 sites reclassified as G16 because of dunes) also consistently exhibits much higher site densities than other habitat types in the same archaeological complexity score (Table 55). The model offers no explanation why it underestimates the archaeological complexity of Habitat G16, but we suspect that the error results because sites are more likely preserved in dunes. One point was subtracted from the raw archaeological complexity score of Habitat G16, resulting in recalculation of the final archaeological complexity scores of habitat types bearing 112 lithic reduction sites, 52 men's subsistence sites, 24 residential sites, 85 unclassifiable sites, and 24 women's subsistence sites.

Table 55. Site Densities for G16 Habitat Types
by Archaeological Complexity Score

Final Complexity Score	2	3	4
Percent Inventory	14.56	9.42	4.36
Density Sites per Hectare	0.19	0.23	0.14
Average Density for Complexity Score	0.06	0.04	0.03

Finally, we note that Habitats G18 (areas reclassified as Habitat G16 excluded), G6, S5, and W4 lack sites in score 1 habitat types, but have appropriate site densities in score 2 habitat types (Table 56). Variable sampling may be distorting results, but we note that in each case, the habitat types with complexity score 1 are both on landforms containing toolstone and within 3 km of a perennial water source, subtracting 2 points from their raw complexity score. We suspect that this overestimates their archaeological complexity and we adjust the scoring so that these particular habitat types never score less than 2. This adjustment removes 118 hectares of habitat types bearing no previously recorded sites from archaeological complexity score 1.

Table 56. Inventory Coverage and Site Densities for Habitats G5, G6, G18, and W4

Final Archaeological Complexity Score	1	2	1	2	1	2	1	2
Habitat	G18	G18	G6	G6	S5	S5	W4	W4
Percent Inventoried	0.96	17.21	33.02	35.65	18.66	0.17	95.90	0.25
Site Density	0.00	0.16	0.00	0.27	0.00	0.01	0.00	0.05

Refined Test

After making the specified adjustments to the model, we recalculate the density of sites and isolates by predicted archaeological complexity score and refined model predictions. Tests concern four categories of data: total site and isolate density, functional site density, assemblage size, and site significance.

Total Site and Isolate Density

Figure 15 presents the density of all sites and isolates by predicted archaeological complexity score. Comparison with Figure 11 indicates that although the strength of correlation between predicted archaeological complexity and density improves from .81 to .86, notable reverses in the expected trend remain in the data set. Complexity score 2 habitat types have higher site and isolate densities (.047 sites and isolates per hectare) than score 1 habitats (.044 sites and isolates per hectare); score 6 habitat types (.031 sites and isolates per hectare) have higher densities than either score 5 (.012 sites and isolates per hectare) or score 4 (.027 sites and isolates per hectare) habitat types; and score 7 habitat types have more dense archaeological remains (.017 sites and isolates per hectare) than score 5.

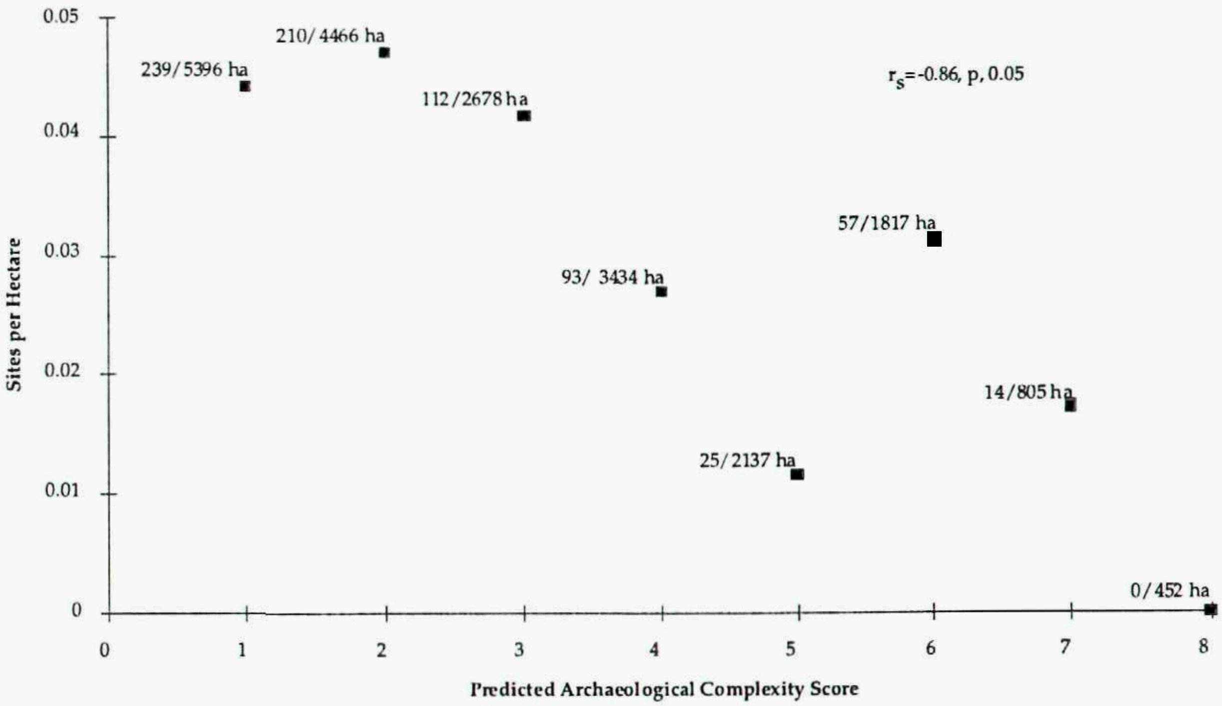

Figure 15. Refined Test - site and isolate density by archaeological sensitivity score.

Functional Site Density

The presence of undetected toolstone sources continues to cause unpredicted variability in site densities. Table 57 lists Spearman's rank correlation coefficients of the revised density of sites with features, ceramics, ground stone, projectile points, bifaces, utilized flakes, and cores. Strong and significant correlations continue to occur between site densities and archaeological complexity score in every category except sites with cores. Although the strength of correlation between sites with cores improves from that in the initial test (.3), it remains insignificant at the .05 level.

Table 57. Refined Test - Spearman's Correlation Coefficients for Densities of Sites with Various Artifact Categories by Archaeological Complexity Score

	rho	p
Sites with Points	-0.95	<.02
Sites with Ceramics	-0.95	<.02
Sites with Features	-0.94	<.02
Sites with Ground Stone Tools	-0.93	<.02
Sites with Bifaces	-0.85	<.02
Sites with Flake Tools	-0.83	<.02
Sites with Cores	-0.44	>.2

Figure 16 presents the distribution of lithic reduction sites by archaeological complexity score, suggesting that lithic reduction sites account for much of the predictive failures. Lithic reduction sites occur in higher densities in score 2 (.018 sites and isolates per hectare), 3 (.018 sites and isolates per hectare), and 4 (.016 sites and isolates per hectare) habitat types than in score 1 habitat types (.016 sites and isolates per hectare), and in score 6 (.015 sites and isolates per hectare) and 7 (.010 sites and isolates per hectare) habitat types than in score 5 habitat types (.007 sites and isolates per hectare). Table 58 illustrates that reallocation of 17 lithic reduction sites from scores 2, 3, and 6 habitat types to scores 1 and 5 habitat types would produce a distribution perfectly consistent with model predictions. Therefore, the model fails to predict 17 (5.3%) of 320 lithic reduction sites.

Table 58. Adjustments Required to Derive a Distribution of Lithic Reduction Consistent with Model Expectations

Archaeological Sensitivity Score	1	2	3	4	5	6	7	8	Total
Inventoried Hectares	5396	4466	2678	3434	2137	1817	805	452	21186
Number of Lithic Reduction Sites	86	81	48	55	14	28	8	0	320
Adjustment	8	-5	-3	0	9	-9	0	0	0
Adjusted Count of Lithic Reduction Sites	94	76	45	55	23	19	8	0	320
Adjusted Lithic Reduction Sites per Hectare	0.0174	0.0170	0.0168	0.0160	0.0108	0.0105	0.0099	0.0000	

The density of sites with unclassifiable function by archaeological complexity score is presented in Figure 17. Unclassifiable sites also account for anomalous total site densities, occurring in higher densities in score 3 (.0101 sites and isolates per hectare) than in score 1 habitat types (.01 sites and isolates per hectare) or score 2 habitat types (.0096 sites and isolates per hectare), and in score 6 (.008 sites and isolates per hectare) and 7 (.007 sites and isolates per hectare) habitat types than in score 4 (.005 sites and isolates per hectare) or score 5 (.002 sites and isolates per hectare) habitat types. Reallocation of 11 unclassifiable sites from scores 3, 6 and 7 habitat types to scores 1, 4, and 5 habitat types would produce a perfect distribution (Table 59). Therefore, the model fails to predict 11 (6.6%) of 166 sites of unclassifiable function.

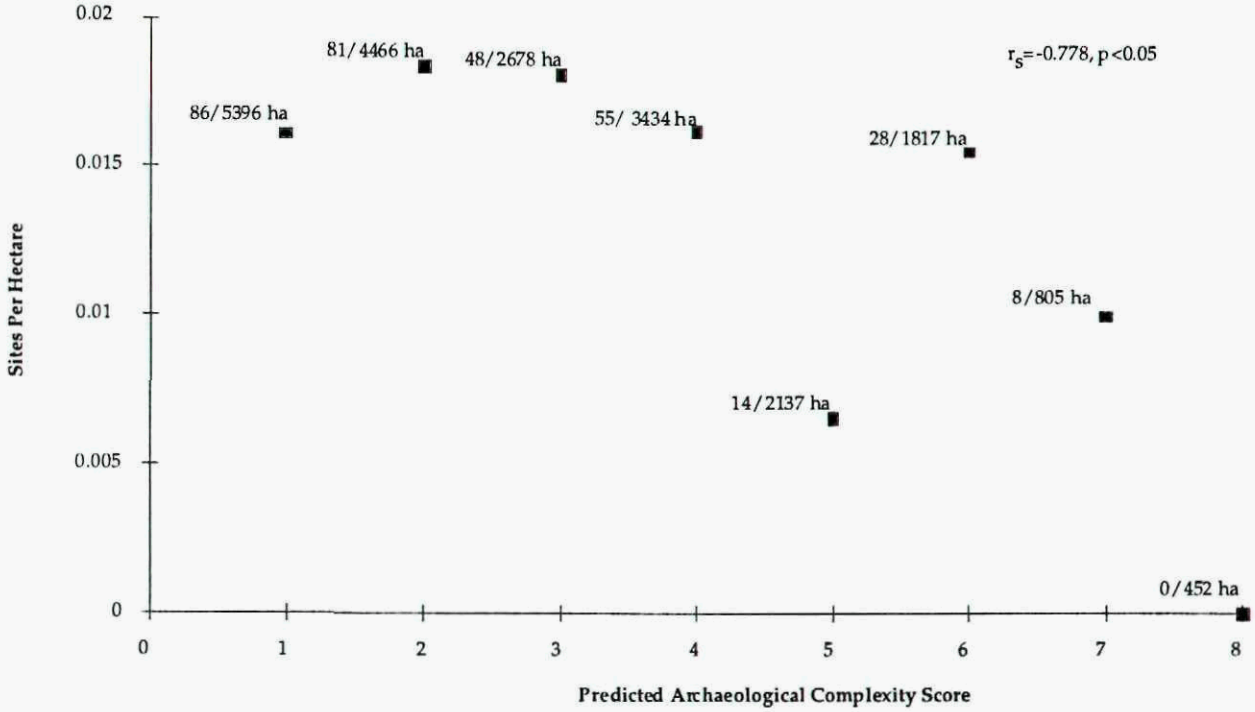

Figure 16. Refined Test - lithic reduction sites per hectare by complexity score.

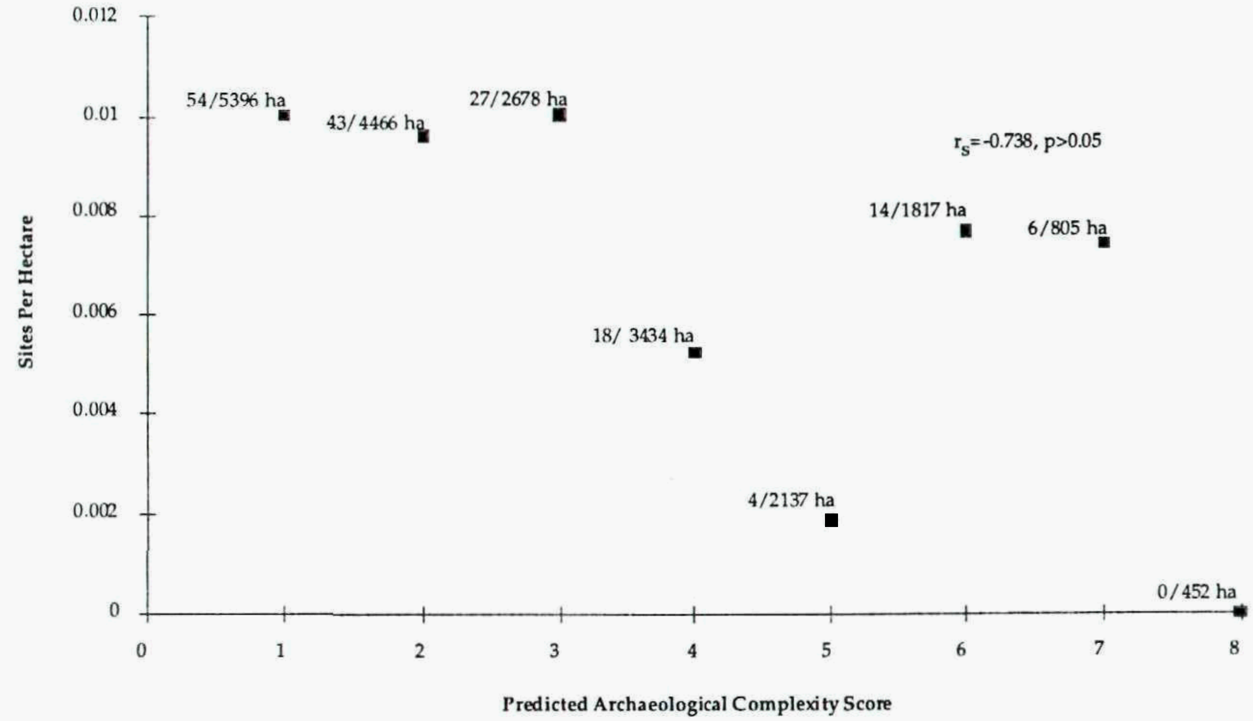

Figure 17. Refined Test - unclassifiable sites per hectare by complexity score.

Table 59. Adjustments Required to Derive a Distribution of Unclassifiable Sites Consistent with Model Expectations

Archaeological Sensitivity Score	1	2	3	4	5	6	7	8	Total
Inventoried Hectares	5396	4466	2678	3434	2137	1817	805	452	21186
Number of Unclassifiable Sites	54	43	27	18	4	14	6	0	166
Adjustment	2	0	-2	2	7	-6	-3	0	0
Adjusted Count of Unclassifiable Sites	56	43	25	20	11	8	3	0	166
Adjusted Unclassifiable Sites per Hectare	0.0104	0.0096	0.0093	0.0058	0.0051	0.0044	0.0037	0.0000	

Figure 18 illustrates the density of men's subsistence sites per hectare by archaeological complexity score. Score 2 habitat types (.011 sites and isolates per hectare) have higher densities of men's subsistence sites than score 1 habitat types (.009 sites and isolates per hectare), and score 6 habitat type (.006 sites and isolates per hectare) have higher densities than score 4 (.004 sites and isolates per hectare) or 5 (.003 sites and isolates per hectare) habitat types. Table 60 shows that reallocation of 11 men's subsistence sites from scores 2, and 6 habitat types to scores 1 and 4, 5, and 7 habitat types would produce a distribution perfectly consistent with model predictions. Therefore, the model fails to predict 11 (7.1%) of 154 cases.

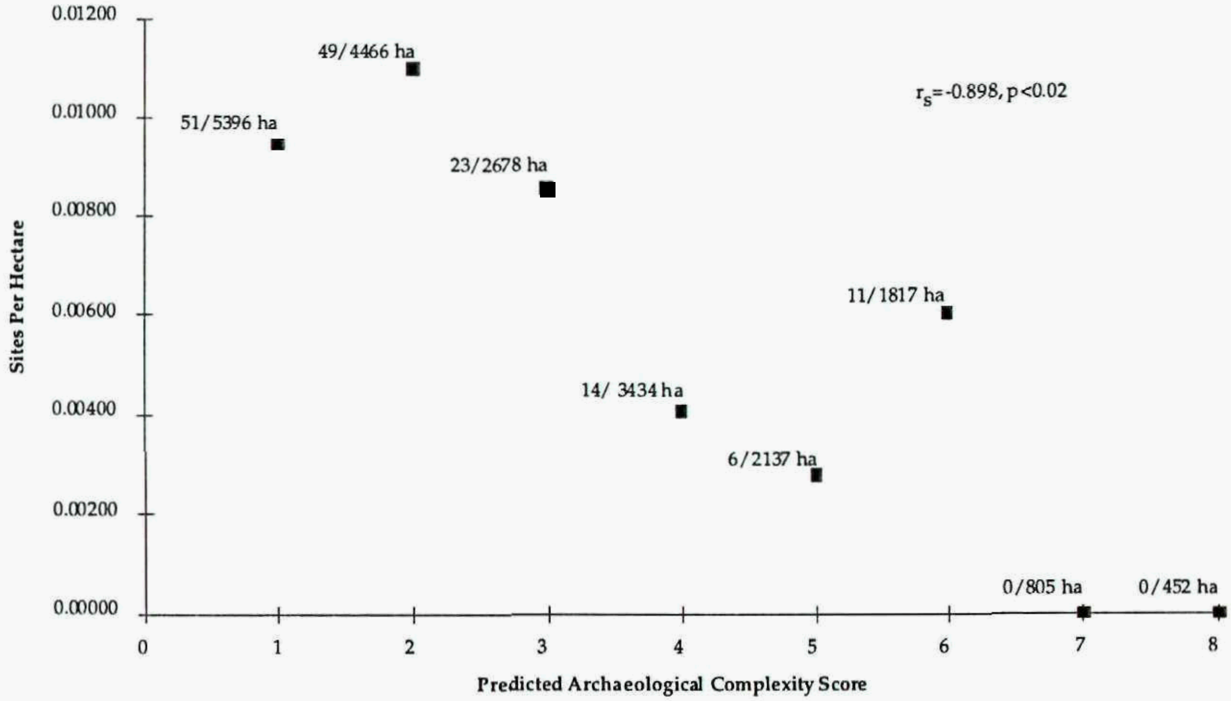

Figure 18. Refined Test - men's subsistence sites per hectare by complexity score.

Table 60. Adjustments Required to Derive a Distribution of Men's Subsistence Sites Consistent with Model Expectations

Archaeological Sensitivity Score	1	2	3	4	5	6	7	8	Total
Inventoried Hectares	5396	4466	2678	3434	2137	1817	805	452	21186
Number of Men's Subsistence Sites	51	49	23	14	6	11	0	0	154
Adjustment	5	-5	0	2	2	-5	1	0	0
Adjusted Count of Men's Subsistence Sites	56	44	23	16	8	6	1	0	154
Adjusted Men's Subsistence Sites per Hectare	0.0104	0.0099	0.0086	0.0047	0.0037	0.0033	0.0012	0.0000	

The distribution of women's subsistence sites is shown in Figure 19. Score 3 (.0037 sites and isolates per hectare) and 2 (.0034 sites and isolates per hectare) habitat types have higher densities of women's subsistence sites than score 1 habitat types (.0028 sites and isolates per hectare). Score 6 habitat types (.0022 sites and isolates per hectare) have higher densities than score 4 (.0009 sites and isolates per hectare) or 5 (.0005 sites and isolates per hectare) habitat types. Shifting 7 sites (14.6%) from scores 2, 3, and 6 habitat types to scores 1, 4, and 5 habitat types produce a distribution that matches model predictions (Table 61).

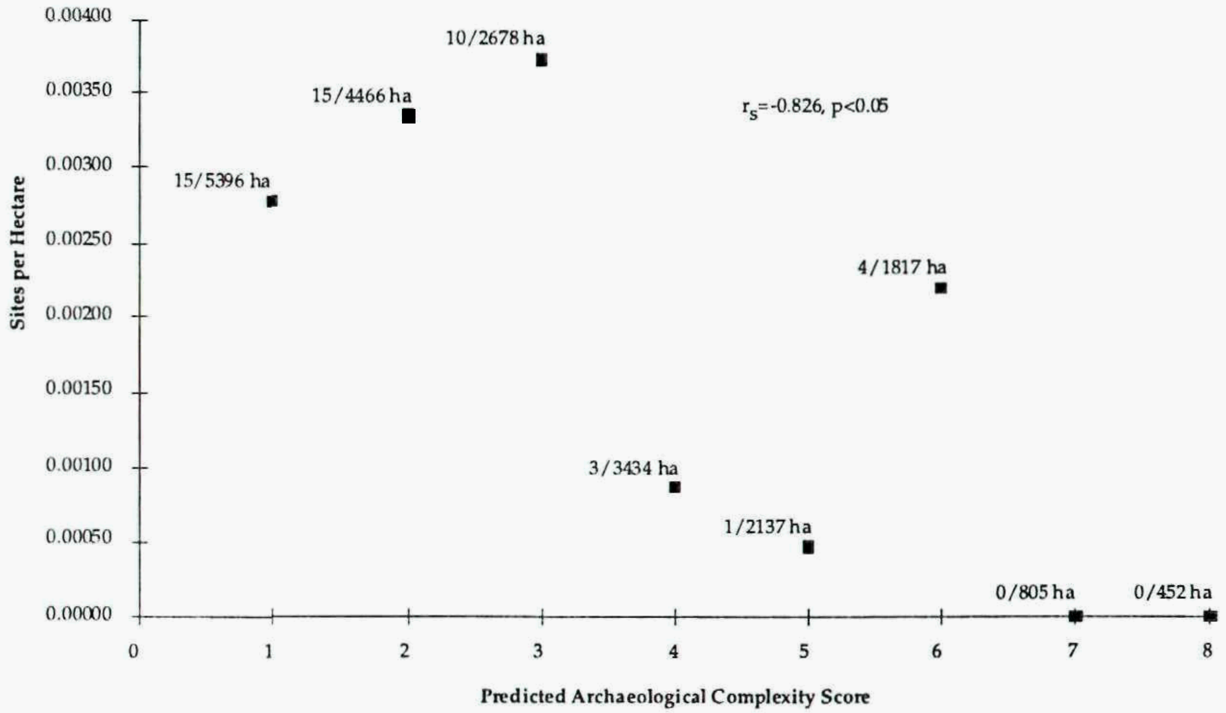

Figure 19. Refined Test- women's subsistence sites per hectare by complexity score.

Table 61. Adjustments Required to Derive a Distribution of Women's Subsistence Sites Consistent with Model Expectations

Archaeological Sensitivity Score	1	2	3	4	5	6	7	8	Total
Inventoried Hectares	5396	4466	2678	3434	2137	1817	805	452	21186
Number of Women's Subsistence Sites	15	15	10	3	1	4	0	0	48
	2	-2	-3	3	2	-2	0	0	0
Adjusted Count of Women's Subsistence Sites	17	13	7	6	3	2	0	0	48
Adjusted Women's Subsistence Sites Per Hectare	0.0032	0.0029	0.0026	0.0017	0.0014	0.0011	0.0000	0.0000	

Figure 20 presents the distribution of residential bases by archaeological complexity score. Residential bases occur in densities consistent with model expectations, declining from a maximum density of .006 sites per hectare in score 1 habitat types to .001 sites per hectare in score 4 habitat types. No residential bases occur in scores 5, 6, 7, or 8 habitat types.

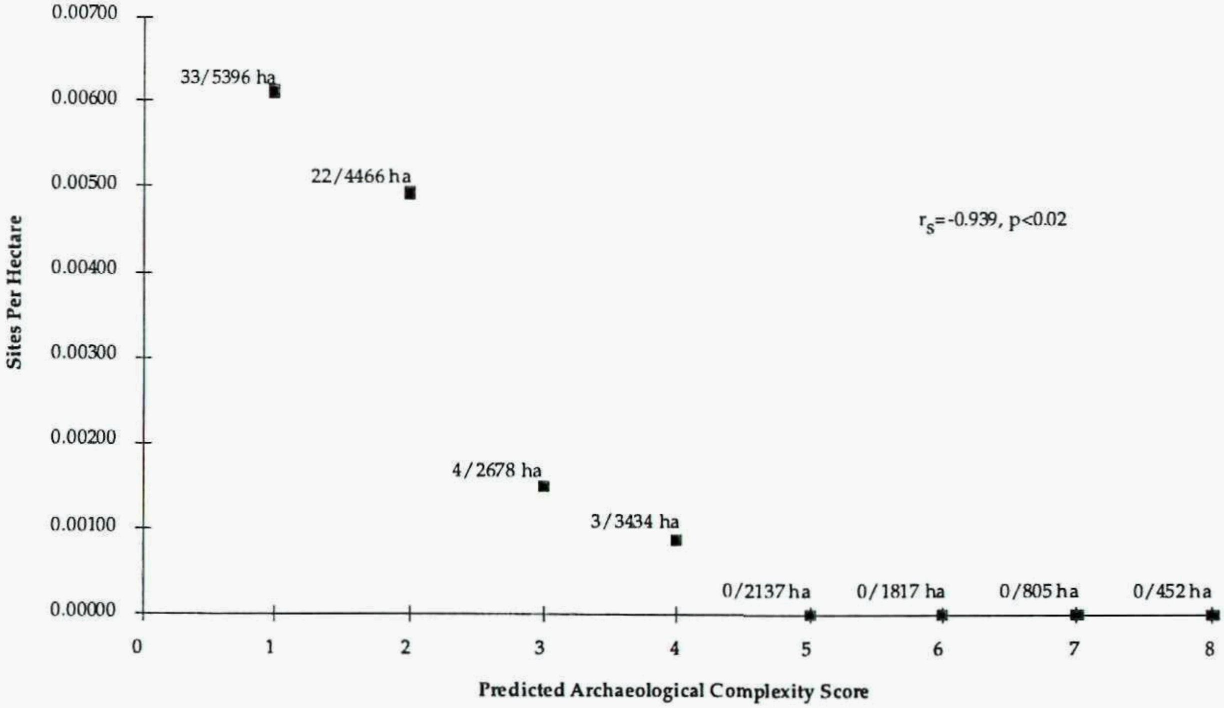

Figure 20. Refined Test - residential sites per hectare by complexity score.

Assemblage Size

Considering only the 400 sites with quantified assemblage data, Figure 21 shows the average count of artifacts and features per site (excluding debitage) and the average number of artifact and feature categories per site by archaeological score. Generally, the distribution fits model predictions, with highest average assemblage size and diversity in score 1 habitat types and smallest, least diverse assemblages in score 7 and 8 habitat types. Both average artifacts and features ($r_s = .802$, $p<.05$), and average artifact and feature categories ($r_s = .826$, $p<.05$) are significantly associated with archaeological complexity score by Spearman's rank correlation coefficient. However, score 4, 5, and 6 habitat types have large, diverse assemblages compared to score 3 habitat types.

Table 62 presents median, mean, and standard deviation values for assemblages in each complexity score. The distributions are highly skewed with a few sites with large assemblages accounting for high means relative to medians. The table indicates that exclusion of 11 large assemblage outliers from complexity scores 4, 5, and 6 produces a distribution consistent with model predictions. Therefore, the model fails to predict assemblage sizes of 11 (2.8%) of 398 sites.

Table 62. Summary Statistics for Assemblage Size by Archaeological Complexity Score

Archaeological Sensitivity Score	1	2	3	4	5	6	7	8	Total
Number of Sites	133	108	69	32	30	20	4	2	398
Total Artifacts and Features	920	547	140	188	77	43	4	2	1921
Median Artifacts and Features Count	2	1	1	1	1	1	1	1	
Mean Artifacts and Features	6.92	5.05	2.03	5.88	2.57	2.15	1	1	
Standard Deviation	15.06	10.44	2	10.83	2.96	2.94	0	0	
Number of Outlying Sites				5	4	2			11
Adjusted Mean	6.92	5.05	2.03	1.63	1.58	1.28	1	1	

* 2 sites excluded because of lack of habitat data

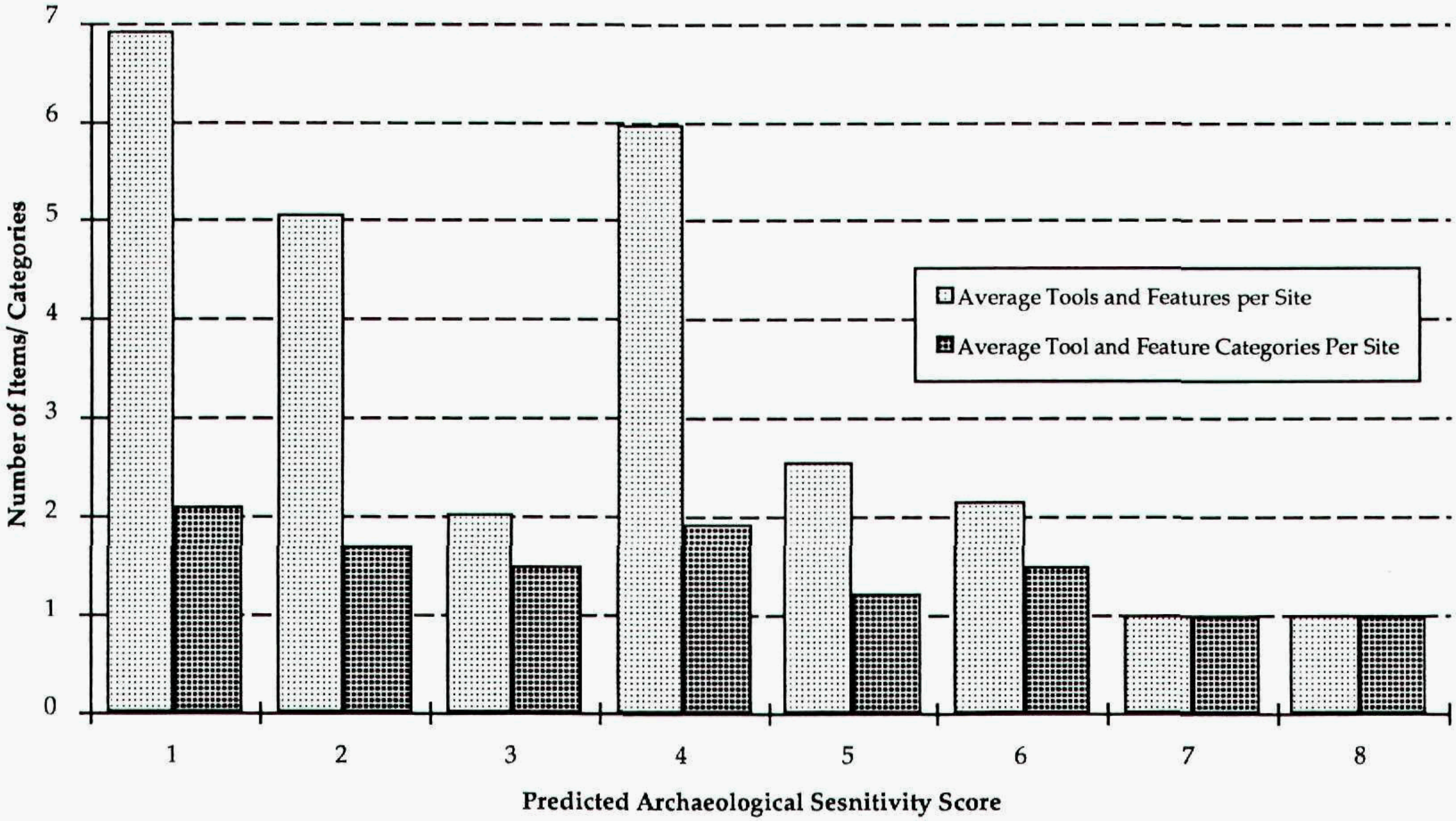

Figure 21. Refined Test - average number of tools/features and tools/feature categories per site by archaeological complexity score.

Site Significance

The habitat model makes no direct predictions about National Register significance. However, preceding tests have shown that residential bases (sites evincing features), and large, diverse assemblages have strong and significant relationships with predicted archaeological complexity score. Since these are criteria by which field archaeologists frequently assess site significance, it is reasonable to expect that significant sites will correlate strongly with complexity score as well.

Figure 22 illustrates the density of sites evaluated as significant by site recorders, per hectare of inventory area. Although there are minor reversals of the expected trend in complexity score 4 and 6 habitat types, there is a significant correlation between the density of significant sites and predicted complexity score. Score 7 and 8 habitat types lack any significant sites whatsoever, whereas score 1, followed by score 2, have the highest densities of significant sites per hectare.

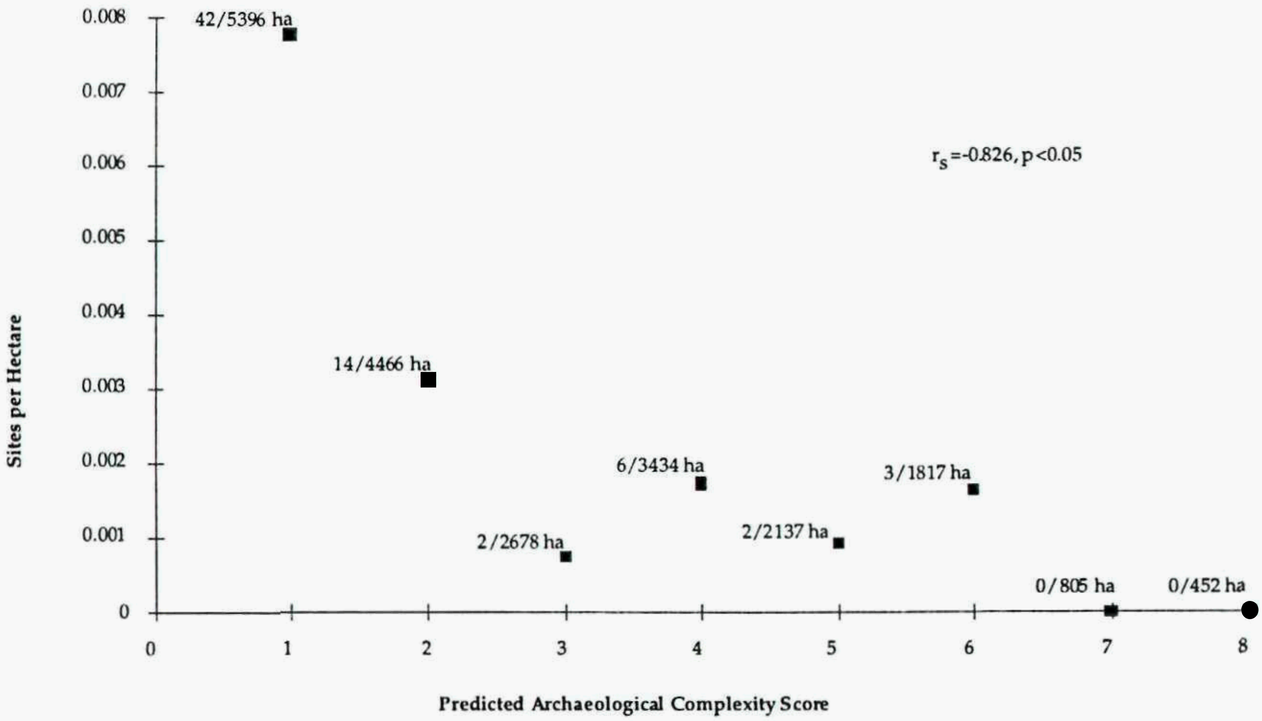

Figure 22. Refined Test- significant sites per hectare by complexity score.

Discussion

Preliminary comparisons of habitat model predictions with extant archaeological data indicated that archaeological complexity score successfully anticipates site counts and site function, but failed to predict site density. Empirical refinement of model predictions improved test results, but unanticipated variability remains.

Much of this variability appears to result from undiscovered toolstone sources as indicated by the low correlation of lithic reduction site density with archaeological complexity score. However, discrepancies between site type density and complexity score also concern unclassifiable sites, men's subsistence sites, and women's subsistence sites. The model perfectly predicts the density of residential bases by complexity score. Altogether, the model fails to account for 46 (6.1%) of 750 sites used to calculate site density by complexity score.

Assemblage sizes are also significantly correlated with archaeological complexity score, although 11 large and diverse assemblages occur in score 4, 5, and 6 habitat types. This represents 2.8% of the 398 sites used to calculate assemblage size by complexity score. Although the habitat model makes no attempt to predict the distribution of sites eligible for nomination to the National Register of Historic Places, sites evaluated as significant by field archaeologists are, nevertheless, strongly correlated with archaeological complexity score. This is a fortuitous result of the correlations of sites evincing features and assemblage size with complexity score.

Chapter 9

Cultural Resource Management Considerations of the Railroad Valley Habitat Model

David W. Zeanah

This chapter suggests how the Bureau of Land Management can use the model as a planning and evaluation tool in Railroad Valley, at the same time that it establishes a framework for the regional management plan and treatment plans appearing in Appendices A, B, and C. The discussion considers levels of inventory intensity, site recording standards, and site evaluation and project planning applications. We also use the model to suggest protocols for definition and management of prehistoric archaeological management areas in Railroad Valley.

The habitat model divides Railroad Valley into areas of predicted archaeological sensitivity according to eight archaeological site complexity scores.* Figure 23 illustrates the distribution of habitat types, classified by refined complexity score, in the Railroad Valley study area. A monothetic site typology classifies Railroad Valley assemblages according to function, based on the presence or absence of artifact categories. Model testing indicates that, with exceptions, density, function, assemblage size, and assemblage diversity of prehistoric sites correlate with prehistoric complexity score. We propose that complexity scores and site types inform project planning, significance evaluation, and prehistoric cultural resource management in Railroad Valley.

Inventory Intensity

Because the model anticipates relative density and significance of prehistoric archaeological sites according to complexity score, the model can serve to specify levels of inventory intensity in habitat types. However, our definition of complexity scores did not consider proportion of inventory coverage. Figure 24 indicates that portions of north central Railroad Valley have been inventoried by various block and linear surveys. Under normal circumstances, these specific inventoried areas, of course, would not need additional inventory, irrespective of predicted score. However, we have found that the quality of site recording and evaluation varies significantly among various projects. In particular, inventories of seismic corridors are often unreliable. For this reason, Appendix A will prescribe that areas previously inventoried by linear surveys be reinventoried should future actions be planned within these corridors.

It is important to consider proportions of inventory coverage of habitat types within complexity scores. Keep in mind that archaeological complexity scores simplify the complexity of 108 habitat types of varying biotic association, landform setting, and foraging potential. Table 63 lists percentage inventory by habitat by complexity score. As can be seen, the percentage inventoried of each complexity score ranges from 4.7% to 15%. In contrast, inventory coverage among habitats is widely variable, ranging from none to 49.3% coverage. It would be a mistake to exclude habitat types of predicted low archaeological complexity scores, but little previous inventory effort, from further archaeological inventory based on better-sampled habitat types within the same complexity score.

* The present chapter continues to examine Railroad Valley in terms of "complexity scores," a term which will come to define "management zones" in Appendix A.

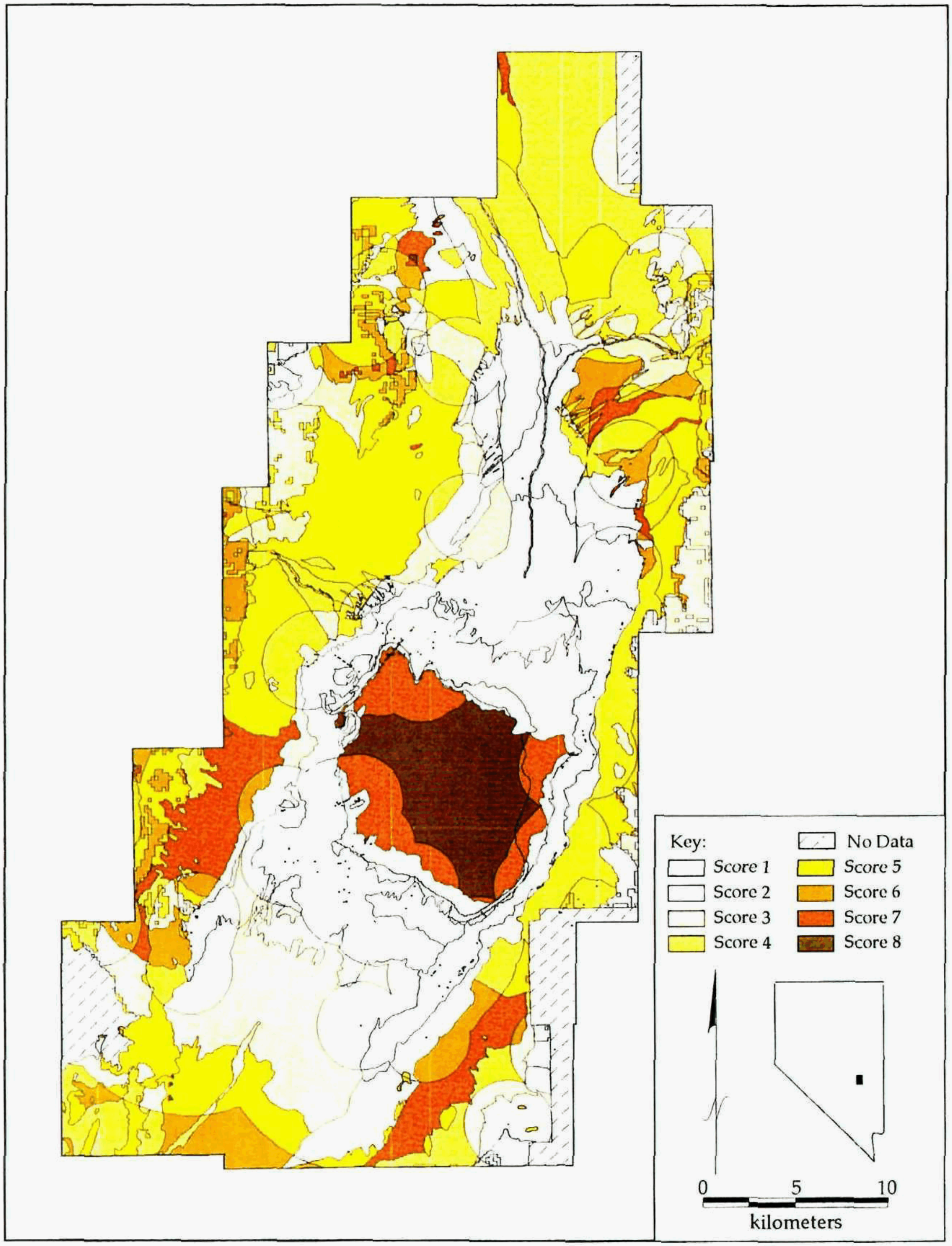

Figure 23. Distribution of refined complexity scores by habitat types in the Railroad Valley study area.

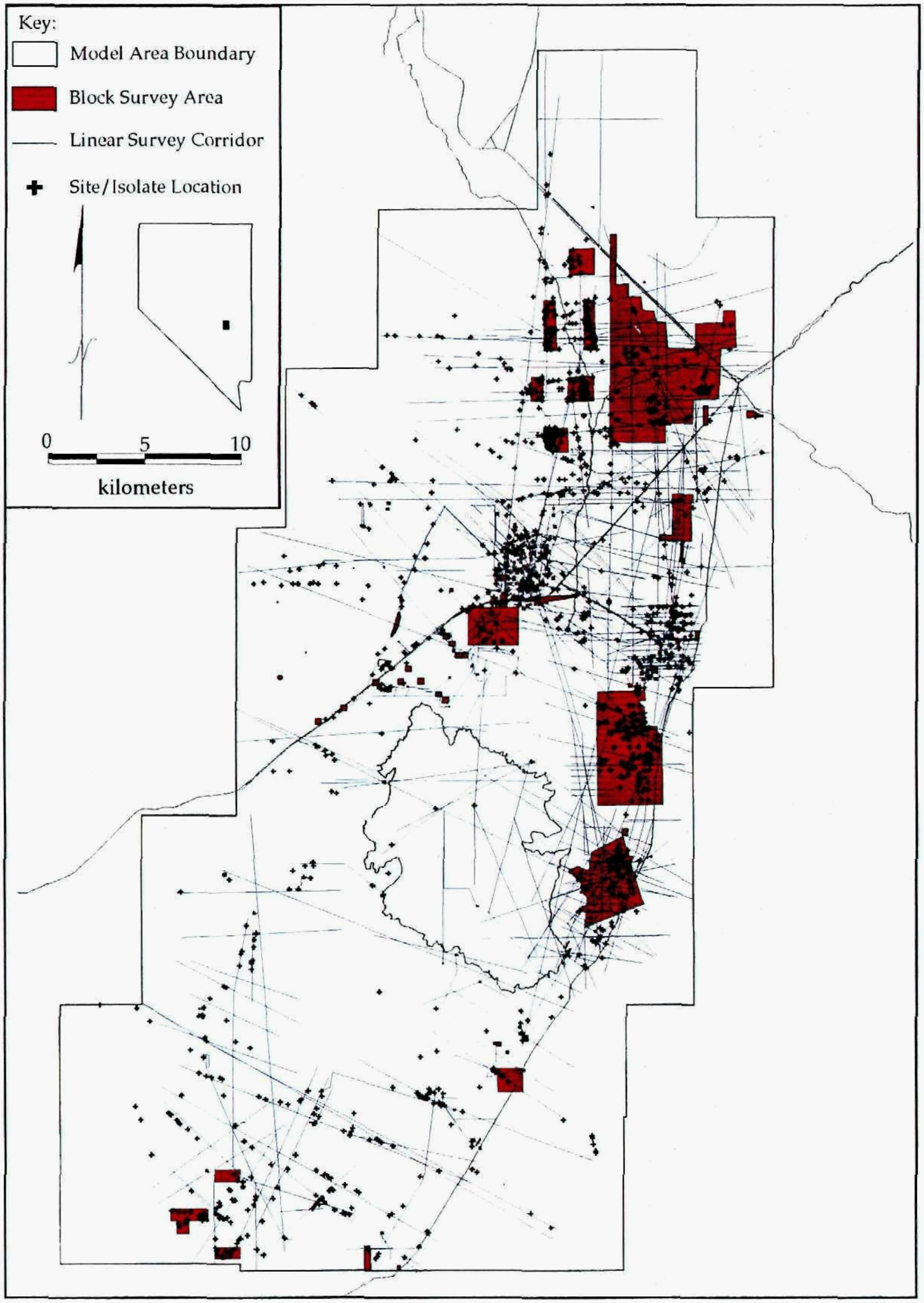

Figure 24. Inventory coverage in the Railroad Valley study area.

Table 63. Percent Inventory Coverage by Habitat and Complexity Score in the Railroad Valley Study Area

	Complexity Score										
Habitat	1	2	3	4	5	6	7	8	Total Ha	Inv Ha	% inv
A1	na	na	na	na	na	na	5.81%	4.68%	16247	835	5.14%
G2	22.55%	12.72%	na	na	na	na	na	na	10408	2084	20.02%
G3	9.52%	7.22%	na	na	na	na	na	na	20456	1870	9.14%
G4	32.41%	5.74%	na	na	na	na	na	na	6322	1999	31.62%
G5	6.12%	2.53%	6.13%	na	na	na	na	na	2356	108	4.59%
G6	na	35.58%	41.78%	17.39%	na	na	na	na	1713	786	45.87%
G8	na	na	na	na	2.70%	0.00%	na	na	3352	75	2.24%
G9	na	0.00%	0.76%	0.64%	na	na	na	na	4161	26	0.63%
G10	na	na	1.46%	0.33%	4.14%	na	na	na	3588	28	0.78%
G11	na	na	na	na	na	5.22%	1.62%	0.00%	11379	313	2.75%
G12	na	na	41.06%	16.82%	6.86%	12.76%	na	na	49282	6509	13.21%
G13	na	na	na	na	73.85%	56.05%	25.51%	na	3782	1865	49.31%
G14	na	2.24%	2.05%	0.29%	0.06%	na	na	na	3394	27	0.80%
G15	na	na	na	na	na	0.59%	1.55%	0.00%	985	11	1.12%
G16	14.56%	9.42%	4.36%	na	na	na	na	na	21015	1506	7.17%
G17	19.30%	6.44%	0.00%	na	na	na	na	na	11381	1750	15.38%
G18	na	22.85%	3.67%	3.46%	na	na	na	na	3223	520	16.14%
G21	na	na	na	na	na	0.00%	na	na	58	0	0.00%
G22	na	na	na	na	0.00%	0.00%	na	na	213	0	0.00%
G23	0.11%	0.83%	na	na	na	na	na	na	1906	9	0.48%
M2	0.89%	0.87%	0.25%	na	na	na	na	na	4041	22	0.56%
M3	1.65%	0.00%	na	na	na	na	na	na	56	0	0.55%
M5	na	na	na	1.41%	0.20%	0.00%	0.00%	na	3303	10	0.30%
M6	na	1.05%	1.09%	0.29%	0.00%	na	na	na	3438	33	0.97%
M7	na	na	na	0.00%	0.34%	0.33%	0.00%	na	1842	6	0.33%
M8	na	na	na	na	0.21%	0.94%	1.64%	na	2273	14	0.60%
M9	0.76%	0.00%	0.00%	na	na	na	na	na	954	6	0.60%
M11	na	na	3.19%	0.61%	1.49%	1.58%	na	na	1057	11	1.03%
S1	na	na	na	1.35%	0.00%	na	na	na	144	22	15.45%
S4	2.71%	1.20%	1.47%	0.00%	na	na	na	na	4449	59	1.33%
S5	na	16.98%	1.60%	3.96%	na	na	na	na	1852	188	10.15%
S6	na	na	0.00%	0.56%	0.29%	0.00%	na	na	1144	5	0.45%
S7	na	na	na	0.89%	1.04%	na	na	na	584	5	0.92%
S8	na	na	na	0.00%	na	na	na	na	18	0	0.00%
S9	na	na	na	na	0.87%	2.06%	na	na	2729	28	1.01%
S10	na	na	4.33%	2.17%	na	na	na	na	9630	233	2.42%
W1	16.64%	na	na	na	na	na	na	na	167	28	16.64%
W2	na	5.00%	0.00%	na	na	na	na	na	10	0	3.67%
W4	na	28.10%	0.00%	na	na	na	na	na	429	121	28.07%
Total Ha	35970	38268	27894	37200	35596	12631	16092	9694			
Inv Ha	5396	4445	2541	3565	2107	1814	793	452			
% inv	15.00	11.62	9.11	9.58	5.92	14.36	4.93	4.67			

On the other hand, some insensitive habitats have sustained extensive survey, suggesting that exclusion from further inventory is warranted. For example, Habitats A1 and G13 both belong to low sensitivity complexity scores 5 through 8, and have been sampled sufficiently to allow empirical confidence that the archaeological complexity of both habitats conforms to model predictions. There is only one archaeological site per 104 hectares in Habitat A1 (complexity scores 7 and 8) and one site per 42 hectares in Habitat G13 (complexity scores 5 to 7). No sites in either habitat are eligible for inclusion on the National Register of Historic Places. We suggest that Habitat A1 (16,247 ha) and Habitat G13 (1865 ha) have been sampled sufficiently to exclude them from further inventory.

Proposed Inventory Intensity for Areas of Archaeological Complexity Scores 7 and 8

Habitats A1 and G13 notwithstanding, Habitats G11, G15, M5, M7, and M8 comprise complexity scores 7 and 8. In Chapter 8, we demonstrated that score 7 and 8 habitat types have low site densities and no National Register eligible sites. However, the percentage of these particular habitat types sampled is low, ranging from zero to only 1.6% (Table 64), and Habitat G11 demonstrates an unexpectedly high site density of one site per 21 hectares. Clearly, sampling of these particular habitat types is insufficient to allow categorical exclusion from inventory, but the success of the model allows some confidence that sites are rare and National Register eligible properties very unlikely. For these reasons, we suggest continued inventory in these particular habitat types, but in an intuitive manner that emphasizes reconnaissance of areas bordering higher ranked habitat types and search for dunes, toolstone sources, and water sources. Specific inventory prescriptions for these habitat types are identified in Appendix A.

Table 64. Area, Percent Inventory and Site Densities for Habitat Types in Complexity Score 7 and 8 Habitat Types

Complexity Score	Habitat Type	Total Hectares	Percent Inventory	Sites per Inventory Hectare
8	G15	19	0	Unknown
8	G11	15	0	Unknown
7	M8	131	1.64	0
7	M7	19	0	Unknown
7	M5	25	0	Unknown
7	G15	508	1.55	0
7	G11	7744	1.62	0.048

Proposed Inventory Intensity for Complexity Scores 3, 4, 5, and 6 Areas

Testing revealed that complexity scores 3, 4, 5, and 6 yield variable site densities unlikely to contain National Register eligible sites. However, exceptional cases of significant sites do occur in these habitat types, often contradicting model predictions, and frequently reflecting undetected toolstone sources, dunes, and water sources. Review of Table 63 indicates that inventory coverage of habitats within complexity scores 3, 4, 5, and 6 ranges from none to 74%. Table 65 lists each habitat with inventory coverage exceeding 5%, giving site density, and indicating presence or absence of sites eligible for the National Register of Historic Places (based on site record assessment). We already have proposed exclusion from inventory of the habitat with highest inventory coverage, Habitat G13, because of low site density and absence of significant sites. With the exception of Habitat G6 in complexity score 4, all other habitats have higher site densities than G13 and, with the exceptions of Habitat G6 in complexity score 4 and Habitat G11 in complexity score 6, all other habitats host significant sites. For these reasons, no other exclusions in complexity scores 3, 4, 5, and 6 habitat types are justifiable, but inventory standards can be adjusted to reflect the rarity of significant sites.

Table 65. Site Densities and Presence or Absence of Significant Sites for Habitat Types with Inventory Coverage Exceeding 5% in Complexity Scores 3, 4, 5, and 6

Habitat Type	Complexity Score	Percent Inventory	Site Density (sites per hectare)	Significant Sites Present
G13	5	73.85	0.0164	N
G13	6	56.05	0.0233	N
G6	3	41.78	0.1235	Y
G12	3	41.06	0.0351	Y
G6	4	17.39	0.0000	N
G12	4	16.82	0.0513	Y
G12	6	12.76	0.1176	Y
G12	5	6.86	0.0435	Y
G11	6	5.26	0.0503	N

Table 66 lists average site size by complexity score for 637 sites with calculable areas in the Railroad Valley database. The table shows that archaeological complexity score is a poor predictor of site size. For example, sites in complexity score 3 habitat types are largest, whereas sites in score 1 habitat types are smaller, on average, than sites in score 2, 3, and 4 habitat types. The standard deviations of site sizes in complexity scores 1 through 5 are much larger than the averages, suggesting that a relative few examples of exceptionally large sites bias averages in every score.

Table 66. Average Site Size and Diameter by Complexity Score*

Complexity Score	No. of Sites	Average Site Area (m^2)	Standard Deviation Area (m^2)	Estimated Site Diameter (m)
1	214	9357	34640	109
2	186	31560	178656	200
3	102	51222	358334	255
4	46	17334	58717	149
5	56	5905	24632	87
6	28	1506	2909	44
7	2	551	na	26
8	1	531	na	26

* 2 sites excluded for lack of habitat data

In contrast, Table 67 indicates that site significance is a good predictor of site size. Eligible sites are significantly larger than non-significant and unevaluated sites, as measured by Mann-Whitney test ($p<.0001$). Although large standard deviations remain biased by exceptionally large outliers, the standard deviation of significant sites is smaller than that of non-significant and unevaluated sites, suggesting less variance among significant examples.

Table 67. Average Site Size and Diameter by Site Record Significance Evaluation

Significance Evaluation	No. of Sites	Average Site Area (m^2)	Standard Deviation Area (m^2)	Estimated Site Diameter (m)
Significant	93	42427	149189	232
Nonsignificant or Unevaluated	544	18977	178980	155

Table 68 indicates site area and estimates site diameters for significant sites in complexity score 3, 4, 5, and 6 habitat types, making the assumption that all sites are circular (length and width were too inconsistently recorded on site forms in the database to consider more realistic elongate shapes). Of 15 significant sites of measurable size, 14 are estimated to be wider than 45 m. Note that the one exception is small enough (19 m) that the current standard survey interval of 30 meters might have missed it. Therefore, a wider survey interval of 45 m in complexity score 3, 4, 5, and 6 habitat types should be adequate to locate all known significant sites in these zones with the same reliability of the current interval of 30 m. We propose widening the Class III inventory interval within complexity score 3, 4, 5, and 6 to 45 meters. Obviously, because many significant sites are elongate rather than circular, a 45 meter transect interval could miss sites which happen to be oriented parallel to the survey transect. To alleviate the possibility that elongate significant sites will fall between wider transects, the Bureau of Land Management will require field archaeologists to orient survey transects perpendicular to linear landforms that may constrain site dimensions.

Table 68. Site Size and Estimated Site Diameters for Significant Sites in Complexity Score 3, 4, 5, and 6 Habitat Types

Site Number	Complexity Score	Site Size (m^2)	Estimated Diameter (m)
61-1602	5	271	19
61-1318	3	1755	47
61-4554	3	1928	50
46-3823	6	2855	60
61-3760	6	4231	73
61-100	4	4359	74
46-3822	5	6177	89
61-3556	3	6503	91
61-7464	4	8238	102
46-6049	4	10158	114
46-4041	3	10511	116
61-3770	6	10775	117
61-7456	4	21498	165
61-7481	4	352947	670
61-899	3	1179611	1226
61-7850	4	no data	no data

Proposed Inventory Intensity for Areas of Complexity Scores 1 and 2

Complexity scores 1 and 2 habitat types have high site densities and are likely to bear sites eligible for the National Register of Historic Places. Although inventory coverage of habitat types within these complexity scores is as high as 36% (Table 63), the likelihood of significant sites within these habitats renders it unjustifiable to exclude any uninventoried areas from additional effort, regardless of current percentage inventory coverage of that habitat type. Similarly, the high standard deviations and relatively small average site sizes within these complexity scores renders widening current 30 m transect intervals unjustifiable. Therefore, we propose no relaxation of current inventory standards within complexity scores 1 and 2 habitat types.

However, one empirical observation of site distributions within habitat types of complexity score 1 and 2 suggests that such modifications may be justifiable after future research, but will require additional attention on the part of contract and agency archaeologists. Specifically, the Bureau of Land Management will require systematic monitoring of all undertakings that disturb the subsurface of complexity score 1 and 2 habitat types.

Figure 23 shows that complexity score 1 and 2 habitat types occupy a broad swath on the valley floor, exclusive of the playa. Sites obviously occur in high densities within these zones, but cluster noticeably along the margins of the valley, usually within three miles of the transition with complexity score 3 and 4 habitat types. In contrast, the interior of complexity score 1 and 2 habitat types on the valley floor are relatively barren of sites.

Comparison with Figure 24 suggests that this may be a sampling problem resulting from the small amount of inventory of the valley bottom, particularly south of the Railroad Valley playa. At the same time, clustering could reflect depositional processes, with sites in the interior of the valley buried beyond the detection of surface inventories. However, a third possibility is that prehistoric hunter-gatherers gained a central place foraging advantage by placing their base camps along the margins of score 1 and 2 habitat types on the valley floor, thereby gaining economical access to higher altitude pinyon-juniper woodlands (also classified as complexity scores 1 and 2 by the model). Ascertaining which explanation is correct requires additional inventory of the valley interior and pinyon-juniper habitats. In particular, the likelihood of features in complexity scores 1 and 2, and the possibility that significant sites are buried in the valley interior, call for monitoring. However, if the latter explanation holds true and significant sites prove rare in the valley interior, it would be justifiable to reclassify all score 1 and 2 habitat types on the valley floor, and more than 3 miles from the valley margin as complexity score 3. Survey intervals within these habitats then could be modified accordingly. Specific guidelines for these protocols are developed in Appendix A.

Using the Railroad Valley Habitat Model for Planningƒ

The Railroad Valley habitat model provides managers with a unique tool for planning projects and undertakings, and for identifying areas meriting special management consideration.

Project Planning

Table 69 lists average site densities, densities of eligible sites, assemblage size and diversity, and recommended inventory intensity of habitat types in complexity scores 1, 2, 3 through 6, and 7 and 8. Consultation of the table in conjunction with the GIS databases during project planning will allow managers to choose the least dense or complex project location alternates and to anticipate inventory and mitigation costs within the selected project location.

Table 69. Site Density, Significant Site Density, Assemblage Size, Assemblage Diversity, and Recommended Inventory Intensity by Complexity Score

Archaeological Complexity Score	1	2	3 through 6	7 and 8
Total Sites/Isolates per 100 Hectares	4.43	4.70	2.85	1.16
Significant Sites per 100 Hectares	0.78	0.31	0.13	0.00
Assemblage Size (Number of tools and features per site/isolate)	0 - 37	0 - 25	0 - 15	0 - 1
Assemblage Diversity (Number of tool and feature categories per site/isolate)	0 - 5	0 - 4	0 - 4	0 - 1
Recommended Survey Strategy/ Transect Interval	Class III/30m	Class III/30m	Class III/45m*	Class II/na*

* Note Habitats A1 and G13 excluded from inventory

For example, imagine that a developer contemplates an undertaking requiring 100 hectares. The preferred location of the undertaking occurs in habitat types of predicted complexity score 1, but an alternative project locations occurs in nearby habitat types of complexity score 3. By referencing Table 69, the manager can anticipate that four prehistoric sites with as many as 37 artifacts and features apiece might lie within the preferred project location, and that at least one of these sites is likely to be eligible for inclusion on the National Register of Historic Places. Transect intervals of 30 m, high site densities and large, diverse assemblages must be factored into inventory and mitigation costs in this project area.

In contrast, the alternative location is likely to have only two or three prehistoric sites with no more than 15 tools apiece. There is a low probability that any prehistoric site will be eligible for National Register consideration, although such sites might occur. An inventory transect interval of 45 m, low site density, and small assemblages can be factored into inventory and mitigation cost estimates.

The manager and proponent presumably will choose the alternate location over the preferred location, if minimizing cultural resource costs or conservation of significant prehistoric properties are overriding concerns. On the other hand, if the preferred location must be selected (or if the undertaking allows consideration of no alternative), the manager and proponent are forewarned as to the level of inventory and mitigation costs that will be incurred.

Special Management Areas

Resource managers have good reason to give special consideration to clusters of National Register eligible properties. So doing allows them to highlight areas that recurrently prove obstructive to other land uses, and to develop practical guidelines for management of cultural resources within that area. The Tonopah Resource Management Plan (USDI BLM 1997) identifies two such management areas in Railroad Valley, the Trap Spring-Gravel Bar Complex (8480 acres) and the Stormy-Abel Site Complex (12,320 acres). The plan specifies land use restrictions in those areas and recommends development of cultural resource action plans and comprehensive data recovery programs for them. Consequently, BLM has charged us to develop data recovery plans for the Gravel Bar site and Trap Spring Site Complex (Appendices B and C).

Reviewing the database, it is clear that attempts to manage the Trap Spring-Gravel Bar Complex as a special management unit have suffered from a lack of defined boundaries for the complex, and from absence of a research context that unifies the complex. The result has been less than efficient management of the resources and aggravated conflicts with development. The Stormy-Abel Site Complex appears headed for the same fate.

Table 70 lists the area, percentage inventory, and site density of each archaeological complexity score within the Stormy-Abel management area defined by the Tonopah Resource Management Plan (RMP). The area includes habitat types ranging from predicted archaeological complexity score 1 to 8. However, sites are recorded only in scores 1, 2, and 3 habitat types. Compare Table 70 with Table 71, which lists similar data for the Trap Spring-Gravel Bar RMP unit. Although site densities in scores 1 through 3 habitat types of Stormy-Abel are comparable to scores 1 through 4 habitat types of the Trap Spring-Gravel Bar RMP unit, note the difference in inventory coverage. The percentage inventory by complexity score in the Stormy-Abel RMP unit ranges from 0 to 6.3%, whereas inventory coverage in the Trap Spring-Gravel Bar RMP unit ranges from 12.7% to 36.5%.

Table 70. Area, Percent Inventory, and Sites per Hectare of Archaeological Complexity Score in the Stormy-Abel RMP Unit

Archaeological Complexity Score	Hectares	Percent Inventory	Sites Per Hectare
1	875	6.36	0.02
2	1215	3.84	0.11
3	764	2.64	0.15
4	635	0.84	0
5	380	3.38	0
6	917	3.51	0
7	194	1.47	0
8	1	0	na

Table 71. Area, Percent Inventory, and Sites per Hectare of Archaeological Complexity Score in the Gravel Bar and Trap Springs RMP Unit

Archaeological Complexity Score	Hectares	Percent Inventoried	Sites Per Hectare
1	900	17.3	0.03
2	1190	22.7	0.12
3	1180	36.5	0.06
4	163	12.7	0.05
5	110	15.7	0.00

The contrast between Stormy-Abel and Trap Spring-Gravel Bar is striking. At Stormy-Abel, 43% of the RMP unit is comprised of habitat types that contain no previously recorded sites and for which the habitat model predicts low site densities and few significant sites. Although the remaining area bears high site densities and is predicted to be archaeologically complex, only 4.3% of those habitats have been surveyed. Absent adequate inventory, the boundaries of the Stormy-Abel RMP unit are without justification and no research perspective unifies its significant sites.

The Stormy-Abel RMP unit would benefit from redefinition of boundaries based on model parameters. Figure 25 shows current RMP unit boundaries, known site locations, predicted complexity scores, and known toolstone source areas. The figure shows that sites occur precisely where the model predicts they should, in complexity scores 1, 2, and 3 habitat types. This suggests that the RMP unit could be restricted to complexity score 1, 2, and 3 zones (2854 ha), a 43% reduction of its current size of 4981 ha. However, the small amount of inventory done in the RMP unit limits any empirical confidence that such boundaries will accurately encompass a site complex. Furthermore, note on Figure 25 that only three sites in the Stormy-Able RMP are currently evaluated eligible for the National Register of Historic Places, and that all three occur in the immediate vicinities of Storm, Abel, and Coyote Hole Spring; all other sites in the RMP unit are ineligible or unevaluated. It is difficult to discern any empirical reason why management of this area as a site complex affords the three discrete significant sites any more protection than is provided by simple National Register eligibility.

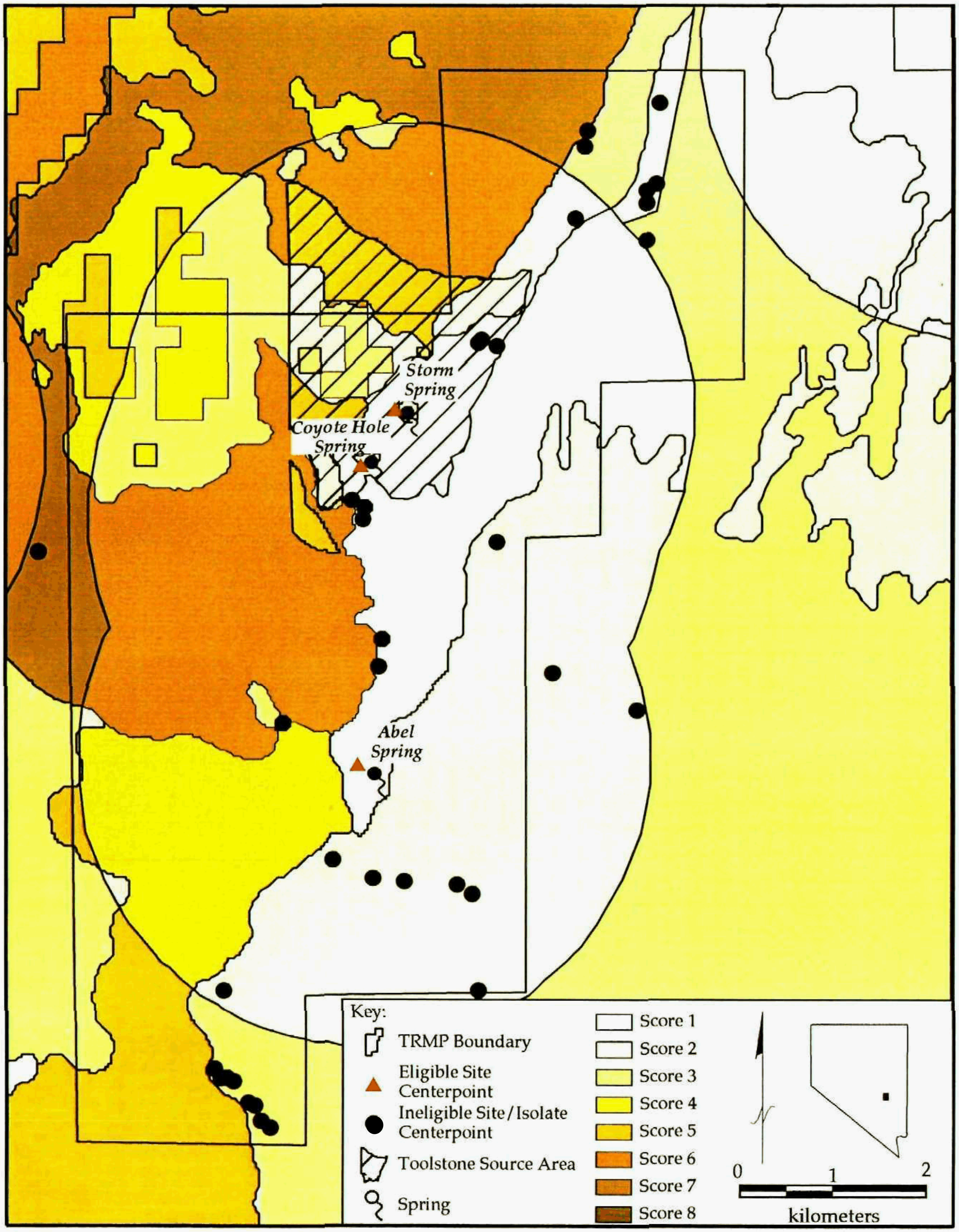

Figure 25. Complexity score and site locations of the Stormy-Abel TRMP Unit.

For these reasons, the Stormy-Abel RMP unit, as it is presently defined, is a poor choice for special management of cultural resources and should be withdrawn from special management status. Assigning such a large area to special management with no empirical and theoretical foundation must surely create a management burden and constraint on other land uses. Alternatively, Bureau of Land Management must justify with additional inventory and site evaluations why the region warrants special management. Specific recommendations for the Stormy-Abel Site Complex are provided in Appendix A.

The foregoing indicates a pressing need for protocols for the definition of special management areas for cultural resources (i.e., archaeological complexes or districts). We propose the following for the Railroad Valley study area:

- Consider only areas which have sustained at least 25% inventory coverage. So doing will ensure that only those areas with a demonstrably high concentration of significant sites will be given special management consideration.

- Define boundaries in consideration of habitats and landforms that are predictably archaeologically complex or which can be empirically shown to contradict model predictions. This will ensure that boundaries will enclose only those uninventoried areas likely to contain additional significant sites, while avoiding needless inclusion of low complexity areas.

- Use the Railroad Valley habitat model to develop a unifying research context and design for the complex .

- Develop management plans based on the research design.

Evaluation of Areas of Critical Environmental Concern (ACEC)

The BLM is currently considering several areas within the Management Area for nomination as ACECs, which will be designated in a forthcoming amendment to the Tonopah Resource Management Plan (Baskerville, personal communication to C.D. Zeier 1998). The Final Tonopah RMP (USDI BLM 1997) does not identify any specific location as being considered for ACEC nomination, but does identify special land use restrictions for specific locations within the Management Area. These restrictions include closure to mineral exploration, no surface occupancy, closure to non-energy leasables, and proposal as new withdrawals. The Draft Tonopah RMP (USDI BLM 1994) does suggest some specific areas as potential ACECs and Table 72 indicates that these are mostly the same areas identified in the Final Tonopah RMP for land-use restrictions. Figure 26 illustrates the locations of these management areas as compiled from the Draft Tonopah RMP (USDI BLM 1994) and the Final Tonopah RMP (USDI BLM 1997). As can be seen in Table 72, there are 22 individual parcels with distinct land-use restrictions. However, as illustrated in Figure 26, these parcels cluster into six discrete areas. In order to illustrate how the model can be used to measure prehistoric cultural values in ACEC evaluation, we assume that these six areas are potential ACECs.

Note that the areas include the Trap Spring - Gravel Bar Site Complex and the Stormy-Abel Site Complex which are explicitly recognized in the Tonopah RMP for the cultural resources they contain, and were evaluated as Special Management Areas in the preceding section. However, cultural resources in the remaining four areas (Blue Eagle, Flowing Well, Lockes, and Warm Spring) are not identified for special consideration in the Tonopah RMP.

Table 72. Area Designation, ACEC Consideration, and Land-Use Prescription by Parcel Number for the Railroad Valley Management Area

Parcel Number	Area Designation	ACEC Consideration (BLM 1994)	Closed to Mineral Material Deposit (BLM 1997)	No Surface Occupancy (BLM 1997)	Closed to Non-Energy Leasables (BLM 1997)	New Withdrawals (BLM 1997)
1	Trap Springs-Gravel Bar	X				
2	Trap Springs-Gravel Bar	X	X		X	
3	Trap Springs-Gravel Bar	X	X		X	
4	Blue Eagle	X	X	X	X	
5	Blue Eagle	X				
6	Blue Eagle	X	X	X	X	
7	Blue Eagle	X	X	X	X	
8	Flowing Well	X				
9	Flowing Well	X	X	X	X	
10	Flowing Well	X	X	X	X	
11	Flowing Well		X	X	X	
12	Lockes	X				
13	Lockes		X	X	X	X
14	Lockes					X
15	Lockes					X
16	Lockes	X				
17	Lockes	X				
18	Lockes	X			X	
19	Lockes	X		X		
20	Lockes	X	X			
21	Warm Spring	X				
22	Stormy-Abel	X				

To be considered an ACEC, a selected area must meet criteria for "Relevance" and "Importance" (43CFR 1610.7-2). "Relevance" refers to the significant cultural, historic, or scenic values of an area, whereas "Importance" specifies that such values be distinctive, have special worth, or merit cause for concern. An area may be nominated as an ACEC on the basis of various resource values other than cultural, but in a cultural context the site sensitivity model provides a basis for evaluating the relevance of a selected area for prehistoric cultural resources.

For each of the six potential ACECs, Table 73 tallies the acreage of each predicted archaeological complexity score. Multiplying the archaeological complexity scores by proportion of acreage and adding the resulting products provides a total archaeological complexity score for each area. This figure measures the predicted archaeological sensitivity of each area and may serve as a scale of relevance of each area for prehistoric archaeological resources. This measure will prove particularly useful for consideration of the relevance of cultural resources in proposed ACECs that have not been adequately sampled for prehistoric cultural resources.

Note in Table 73 that the Blue Eagle, Flowing Well, Lockes, and Warm Springs areas all have higher total archaeological complexity scores than the Trap Springs-Gravel Bar Site Complex and the Stormy-Abel Site Complex. This suggests that they have greater potential relevance, or value, for prehistoric cultural resources than the two areas identified by the Tonopah RMP for cultural resource management related recommendations. This suggests that the relevance of prehistoric cultural resources of these four areas merits as much consideration in ACEC evaluation as they do in the two archaeological site complexes.

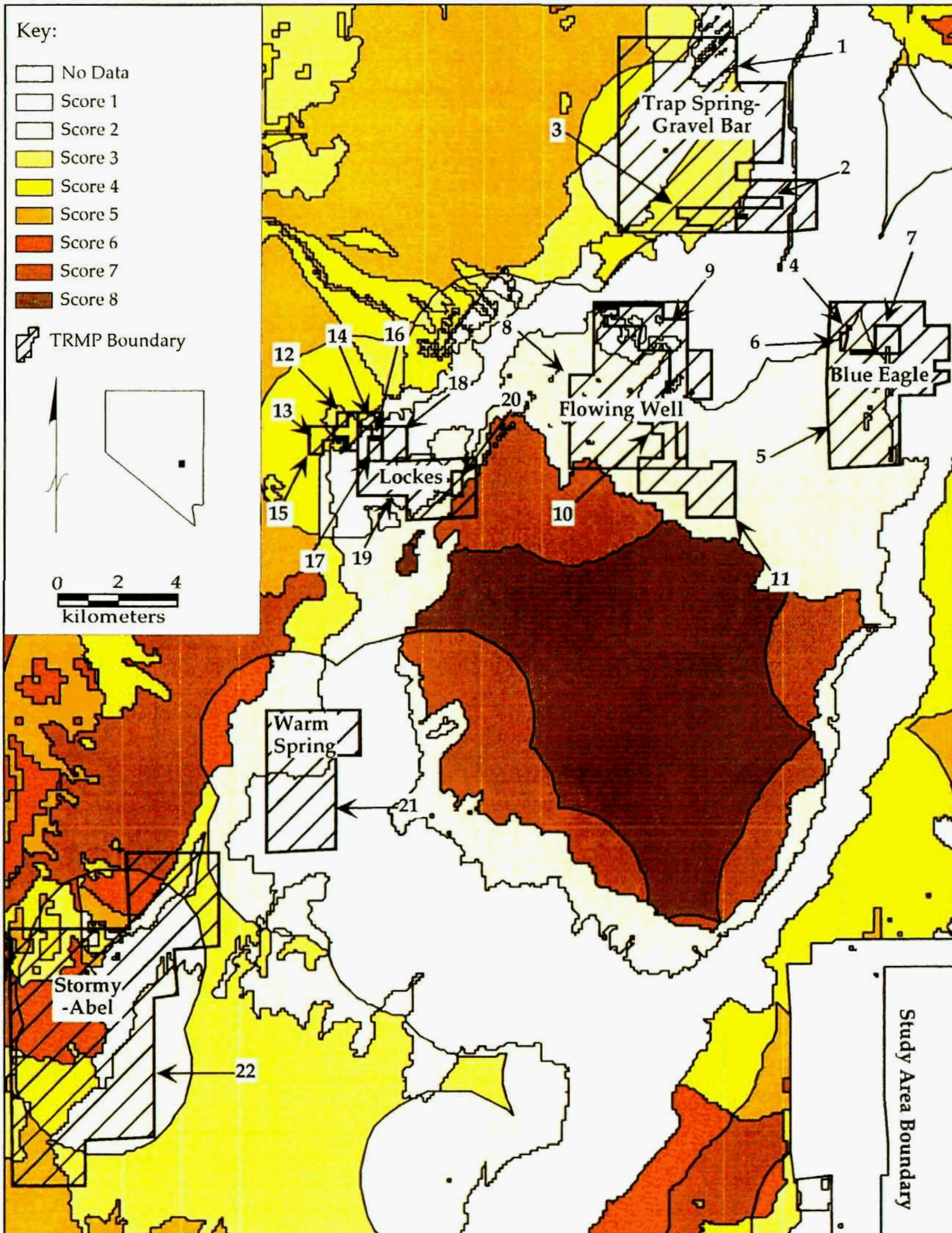

Figure 26. Proposed ACECS and Land-Use Restriction Areas in Railroad Valley (after BLM 1994 and BLM 1997 - Numbers keyed to Table 9.10).

Table 73. Total Archaeological Complexity Score by Area Designation, ACEC Consideration, and Land-Use Prescription by Parcel Number for the Railroad Valley Management Area

Area Designation	Archaeological Complexity Score	Hectares	Proportion of Area	Proportional Score
Trap Spring-Gravel Bar				
	1	900	0.25	0.25
	2	1190	0.34	0.67
	3	1180	0.33	1.00
	4	163	0.05	0.18
	5	110	0.03	0.16
	Total	3543	1.00	2.26
Stormy-Abel				
	1	875	0.18	0.18
	2	1215	0.24	0.49
	3	764	0.15	0.46
	4	635	0.13	0.51
	5	380	0.08	0.38
	6	917	0.18	1.10
	7	194	0.04	0.27
	8	1	0	0
	Total	4981	1.00	3.39
Warm Spring				
	1	829	0.64	0.64
	2	471	0.36	0.72
	Total	1300	1.00	1.36
Flowing Well				
	unknown 109	0		
	1	755	0.30	0.30
	2	1738	0.69	1.38
	7	28	0.01	0.08
	Total	2521	1.00	1.76
Blue Eagle				
	1	867	0.49	0.49
	2	919	0.51	1.03
	Total	1786	1.00	1.51
Lockes				
	unknown 28			
	1	463	0.45	0.45
	2	327	0.32	0.64
	3	84	0.08	0.25
	4	62	0.06	0.24
	7	91	0.09	0.62
	Total	1027	1.00	2.19

The importance of prehistoric cultural resources in a proposed ACEC must be considered on the basis of the National Register eligibility evaluations of individual sites, which document the presence of prehistoric resources that are of special worth and elicit cause for special concern. Therefore, consideration of importance may override consideration of relevance, as measured by archaeological complexity score, in ACEC evaluation. For example, the Trap-Spring Gravel Bar Site Complex may merit ACEC designation more than cultural resources in the Blue Eagle, Flowing Well, Lockes, and Warm Springs areas, despite its lower predicted archaeological complexity score, because the Gravel Bar Site (26Ny1908) is a uniquely important resource. However, as discussed in the previous section, no special significance, worth, or concern is apparent in the existing record of the Stormy-Abel Site Complex. This suggests that BLM should give equal consideration of the importance of cultural resources in the Blue Eagle, Flowing Well, Lockes, and Warm Springs areas, if it chooses to nominate the Stormy-Abel Site Complex as an ACEC because of the value of cultural resources it contains.

Using the Railroad Valley Habitat Model to Assist Evaluation of Site Significance

The Railroad Valley habitat model can aid National Register eligibility evaluation because it provides a unique perspective on the regional environmental context of each site. The habitat model facilitates development of context for site evaluation, and linkage to significant regional research domains. By referring to previous chapters describing the composition, foraging utility, toolstone potential, and paleoenvironmental variability of habitats and landforms, archaeologists can develop expectations about site chronology, subsistence, settlement pattern, seasonality, and lithic technology based on the habitat and landform in which a significant site occurs.

The habitat model and monothetic site typology constitute a convenient gauge of whether particular site types in particular habitats are recurrently evaluated as significant to the exclusion of exceptional examples of other site types in other habitats. For example, the clustering of eligible sites in complexity score 1 and 2 habitat types suggests eligibility evaluations are inadvertently biased against sites in habitat types of lower predicted archaeological complexity. This bias contributes to the significance of rare, but potentially eligible, sites in habitat types of other complexity scores.

Tables 74 and 75 suggest that eligibility evaluation is biased by site type as well. Residential sites and women's subsistence sites are disproportionately likely to be evaluated as significant, whereas men's subsistence sites are prone to be evaluated as non-significant, and lithic reduction sites are seen as non-significant or are unevaluated. To a great extent, this bias is unavoidable because residential sites and women's subsistence sites are more likely to contain evidence of buried deposits and large, diverse assemblages than are men's subsistence sites and lithic reduction sites. However, foreknowledge of this bias in site evaluation allows the manager to give extra consideration to borderline cases of site types that rarely sustain an evaluation of significant.

Table 74. Counts by Site Type of Significant, Nonsignificant, and Unevaluated Sites

Site Type	Significant	Nonsignificant	Unevaluated	Total
Lithic Reduction	7	57	470	534
Men's Subsistence	24	36	212	272
Residential	52	6	40	98
Unclassifiable	1	7	342	350
Women's Subsistence	12	10	47	69
Total	96	116	1111	1323

Table 75. Adjusted Residuals of Site Counts by Site Type of Significant, Nonsignificant, and Unevaluated Sites

Site Type	Significant	Nonsignificant	Unevaluated
Lithic Reduction	7.04	2.08	2.08
Men's Subsistence	1.13	2.96	2.22
Residential	18.22	0.97	15.82
Unclassifiable	5.94	5.31	8.87
Women's Subsistence	3.34	1.73	4.36

Interestingly, this highlights the model's utility in evaluating the significance of sites that are inconsistent with model predictions. Recall that the probability of significant sites in complexity scores 3, 4, 5, and 6 is low but possible. The appearance of such occasional, anomalous sites offers opportunities to investigate unknown circumstances of prehistoric hunter-gatherer ecology and paleoenvironmental variability that are not anticipated by the regional context of the model. If exceptional sites meet integrity standards necessary for National Register consideration, then their inconsistency with model predictions can support arguments for their ability to provide significant information about prehistory. We cannot stress this aspect of model application too strongly, because predictive failures of the model draw the attention of managers to properties most likely to provide new information about prehistoric ecology and economy in Railroad Valley and, thus, contribute important scientific knowledge about prehistory (i.e., are eligible for inclusion on the National Register of Historic Places under criterion d).

Standards for Fieldwork, Site Recording, and Reporting

Clearly, using the model to evaluate site significance requires familiarity with the model by field archaeologists inventorying Railroad Valley. They must be aware of the environmental characteristics and expected archaeological sensitivity assigned to their area of study so that they can recognize unanticipated findings in the field and determine if such are truly anomalous or merely a consequence of mistaken sensitivity classification (for example, did the model overlook unmapped water sources, dunes, or toolstone sources). Field archaeologists and managers must be alert for archaeological evidence that particular sites in complexity score 3 through 6 are exceptional and merit special attention in site evaluation. Such signs include large, diverse assemblages (particularly those with more than 15 tools and features, and four tool/feature categories); features, ceramics, and ground stone; or evidence of reduction of local toolstones. This assessment is necessary to proper application of the model in evaluating site significance, and is best done on the ground. All inventory reports ought to review expected archaeological sensitivity for every study area, and compare it with field observations.

The monothetic site typology offers an additional application of the model to site recording. We have observed, particularly in complexity score 1 and 2 habitat types, that inventories for small undertakings (i.e., seismic lines, well pads, and access roads) frequently encounter large, significant sites that extend far beyond an area of potential effect (APE). The cost of fully recording these properties according to current standards (USDI BLM 1990) inflates cultural resources costs of small undertakings. Yet accurate delineation of site boundaries and description of assemblage composition is vital for site evaluation and management.

It seems a tendency of field archaeologists to draw site boundaries as tightly to their particular inventory area as possible. This inflates the potential for management errors such as assigning multiple site numbers to the same site, inadvertent re-recordings of the same site, errors in significance assessment, failure to avoid large and significant sites, and so on. We have noted, for example, cases where linear surveys have recorded strings of isolates and small sites within the boundaries of large sites recorded during larger block surveys.

To test the Railroad Valley habitat model, we developed a monothetic site typology that characterizes assemblage function based on the presence or absence of particular artifact or feature categories. This typology has management utility in reducing the cost of small inventories where large sites extend beyond the APE. Within APEs, sites should continue to be recorded to the same standards that are required now (i.e., detailed scale mapping, drawings and photographs of individual artifacts, and counts of individual artifact and debitage types, etc.). However, outside APEs, we suggest that noting presence or absence of artifact categories used in the monothetic typology and accurately plotting of site boundaries should be sufficient to

- provide data for characterizing site assemblages, evaluating site significance, and accurately plotting site locations;

- ensure that all sites are classifiable in terms of the model;

- reduce management errors such as multiple recordings of the same site; and

- minimize inventory costs of small undertakings.

Therefore, implementing different inventory standards for area within and outside the APE will ensure accurate delineation of site boundaries and description of assemblage composition, while reducing the costs of inventorying small undertakings.

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Appendix A

A Cultural Resources Management Plan for Northern Railroad Valley, Nye County, Nevada

C. D. Zeier

Introduction

The northern portion of Railroad Valley, Nye County, Nevada, contains oil and natural gas reserves. Cultural resources also are known to be abundant in the region. The Bureau of Land Management (BLM) is responsible for managing both resources on public lands in the area.

To better meet its dual management obligations, BLM commissioned development of an archaeological sensitivity model for the northern portion of Railroad Valley. Prepared by Intermountain Research and Gnomon, Inc., the model predicts the distribution and significance of prehistoric period cultural resources. The model is based on an analysis of habitat types, site formation processes, paleoenvironmental variability, habitability, and toolstone distribution, all seen within the context of optimal foraging theory.

Development, testing, and empirical refinement of the model provides the BLM with a context that satisfactorily anticipates the density and contents of 94% to 97% of previously recorded sites with sufficient information to test model predictions. More importantly from a management context, sites evaluated as significant by field archaeologists are highly correlated with archaeological complexity score, suggesting that the model accurately tracks the distribution of prehistoric sites that are eligible for inclusion in the National Register of Historic Places. Finally, the electronic datasets, which accompany the model, provide an updated system for managing cultural resource information.

Developed with management goals in mind, the model and datasets offer the BLM a unique ability to

- predict effects of an undertaking on significant prehistoric resources in advance of a resource inventory;
- modify inventory procedures based on the likelihood of locating significant prehistoric resources;
- evaluate resource significance based on region-specific, model-derived research goals;
- amend resource recording and reporting procedures based on model predictions, testing, and refinement; and,
- devise prehistoric resource treatment procedures that are relevant to resources likely to be encountered, and to the type and magnitude of impacts likely to occur.

Review of the model and implications derived from its construction allows the definition of such management directions. The following plan addresses such directions.

Spatial Considerations

Management considerations identified in this plan will be implemented throughout the area that was subject to modeling (see Figure 1). Hereinafter, this is referred to as the Management Area.

Identification of Management Zones

The Railroad Valley model identified eight complexity scores comprised of specific habitats defined on the basis of biotic association, landform setting, and foraging utility. Every place within the

Management Area for which data were available has been assigned a complexity score. For purposes of this plan, the complexity score areas have been consolidated into five Management Zones, as follow:

- Complexity score areas 1 and 2 are hereinafter designated Management Zones 1 and 2, respectively.

- Complexity score areas 3 through 6 are combined to form Management Zone 3.

- Complexity score areas 7 and 8 are combined to form Management Zone 4.

- Habitat types A1 and G13, regardless of which complexity score area they are located in (scores 5 through 8), are combined to form Management Zone 5.

Figure A.1 depicts the distribution of Management Zones within the Management Area.

Identification of Special Management Units

The BLM may, at its discretion, designate cultural resource sensitive areas as Special Management Units. In general, physically large cultural resource properties, such as the Gravel Bar, or clusters of interrelated cultural resources, such as the Trap Spring Site Complex, are most often the subjects of special management consideration. In either circumstance, the cultural resource property(s) usually is far more extensive than any one potentially impacting activity that may occur within it; from a management perspective, repeated, spatially confined impacts within the properties are more likely. Special management consideration can ensure that any cultural resource treatment conducted in response to impacting proposals is undertaken in accordance with a plan relevant at the larger cultural resource level.

Care must be taken when defining a Special Management Unit. Such a designation will not be considered unless at least 25 percent of the prospective unit has been inventoried for cultural resources. Defining the boundary of a Special Management Unit may be accomplished on the basis of intensive inventory, on habitat type boundaries, on expectations justified by the model, or on some combination of these. However derived, the boundary must be explicitly defined and described. In all events, the need for special management consideration is conditioned by the significance of cultural resource properties: that is, they must be eligible for nomination to the National Register of Historic Places.

When designating a Special Management Unit, BLM will prepare a treatment plan that includes: a geographic definition of the Special Management Unit, any relevant spatial considerations (resource or Unit stratification), a summary of past activities in the area and current understandings regarding the resources present, a work plan that addresses inventory and data recovery considerations, any procedural considerations specific to the Unit, and any analytic or reporting considerations specific to the Unit. Consultation with the Nevada State Historic Preservation Office must precede implementation of the treatment plan.

Heretofore, BLM management has identified two areas as Special Management Units - the Trap Spring - Gravel Bar Site Complex (8480 acres) and the Stormy-Abel Site Complex (12,320 acres). However, designation of these areas does not satisfy the criteria defined above. The model offers a context in which these areas, and others, can be reviewed.

Boundaries for a Trap Spring Archaeological Complex, as defined in Appendix C, and boundaries for the Gravel Bar site as indicated in Figure B.1 will replace those boundaries suggested in the Tonopah

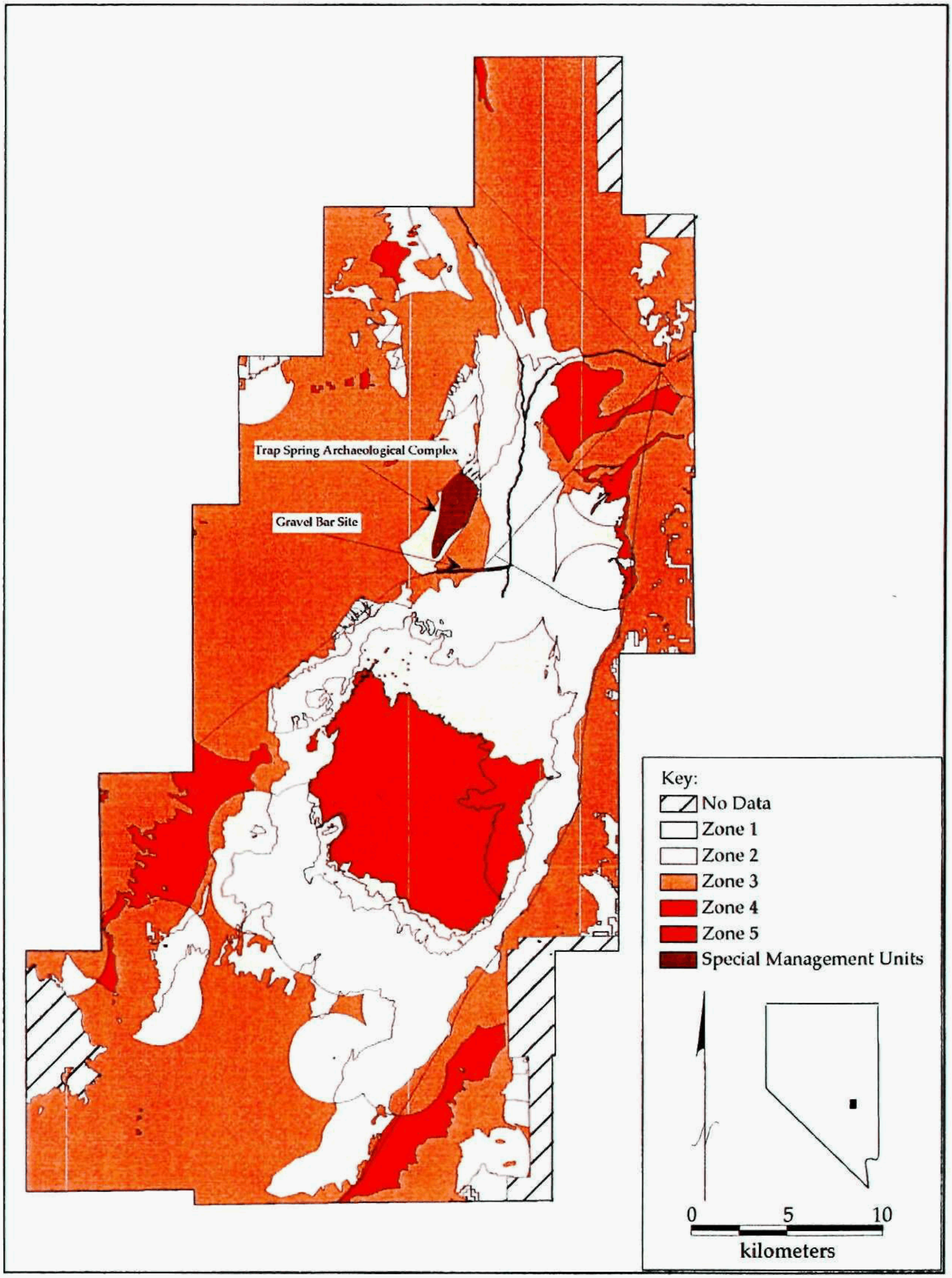


Figure A.1. Distribution of Management Zones in Railroad Valley Management Area.

Resource Area Management Plan (USDI BLM 1997) for the Trap Spring - Gravel Bar Site Complex. Treatment plans for Trap Spring and the Gravel Bar have been developed (Appendices B and C, herein). Implementation of these treatment plans will fully mitigate and alleviate the need for further management consideration of these properties.

Analysis of the Stormy-Abel Site Complex in Chapter 9 reveals that it, as currently defined, does not warrant special management consideration. However, this assessment is based on current site records projected against the theoretical context of the model, and may not take into account personal knowledge that BLM personnel may have concerning the area. Therefore, BLM will implement one of the following two courses of action.

- Remove the Stormy-Abel Site Complex from special management consideration and lift special land use restrictions prescribed in the Tonopah Resource Management Plan (USDI BLM 1997). Henceforth, cultural properties within the Stormy-Abel Site Complex will be evaluated and managed individually according to their eligibility for the National Register of Historic Places as defined in Section 106 of the National Historic Preservation Act (NHPA).

- Perform a Class II sample inventory (25%) of the Stormy-Abel Site Complex to document a high density of significant sites in the region which warrant special management prescriptions (i.e., a site complex that is more extensive than any potential undertaking in the area, requiring long-term management of numerous, small-scale, adverse effects). Then, define boundaries and develop a special treatment plan in light of the Railroad Valley site sensitivity model (see Appendices B and C for similar considerations of the Trap Spring - Gravel Bar Site Complex). The boundaries must identify habitats and landforms that are predictably archaeologically complex or empirically demonstrated to contradict model predictions, whereas the treatment plan must draw a unifying research context and design for the complex from the predictive model. Then, implement the treatment plan to remove the Stormy-Abel Site Complex from special management consideration.

Finally, Chapter 9 identified four areas in the Railroad Valley Management Area for which land-use restrictions are prescribed in the Tonopah RMP (USDI BLM 1997) and which the BLM has previously considered for ACEC nomination (USDI BLM 1994). These are the Lockes, Blue Eagle, Warm Spring, and Flowing Well areas as delineated in Figure 26. The site sensitivity model predicts that these areas should be archaeologically more complex than the Trap Spring - Gravel Bar and the Stormy-Abel Special Management Units, but the Tonopah RMP does not consider cultural resources within these parcels. As a long-term objective, BLM will evaluate these four areas as Special Management Units for cultural resources. This evaluation process will be reviewed every three years and will entail

- inventory of at least 25% of each of the areas;

- evaluation of the significance and importance (as defined in 43CFR 1610.7-1) of cultural resources known to exist in the areas;

- definition of boundaries empirically shown or theoretically expected to enclose high densities of significant sites;

- as necessary, revise land-use restrictions to protect cultural resources in the areas from long-term, small-scale adverse effects; and

- develop treatment plans for each area determined to be a Special Management Unit.

Management Considerations

Management considerations pertain to general and Management Zone-specific inventory procedures, and to resource recording and reporting.

General Inventory Prescriptions

The Management Area is some 223,434 hectares in area of which 213,345 hectares have been assigned to five Management Zones. Portions of the Management Area have been subjected to cultural resource inventories previously. Some 21,113 hectares, or about 9.9 percent of the area assigned to the five Management Zones, have been inventoried. However, that coverage is not consistent among Management Zones or habitats. The level of inventory in Management Zones varies from 1.6 to 15.0 percent, while the level of inventory by habitat type varies between 0.0 and 49.3 percent.

When considering a proposed action in the Management Area, BLM will need to determine whether or not an inventory is necessary. BLM will use the project authorization process as a means of providing specific information to consulting archaeologists as to the type and level of inventory required, taking the following matters into consideration:

- Block areas examined previously to BLM's Class III inventory standards (USDI BLM 1990b) need not be reexamined.

- Some portions of the Management Area exhibit a myriad of intersecting and parallel linear inventory corridors. None has been surveyed to BLM Class III inventory standards. Therefore, none of these areas can be redefined as block inventory areas.

- Numerous linear corridors have been examined in the Management Area. Except where some form of linear development has occurred (pipeline or road construction, for example), it is unlikely that these corridors can be accurately relocated. Consequently, it will be necessary to re-inventory previously examined linear corridors unless existing development clearly marks the corridor location. The type and level of inventory will be consistent with prescriptions contained in this plan.

- BLM standards for archival research prior to the onset of field activities must be met. The model in general, and study area-specific implications of the model will be reviewed during that research effort. Given the regional context appearing in the model, such review will be particularly relevant to consideration of National Register eligibility and data recovery planning.

- When planning inventories, emphasize the examination of block areas no less than one hectare in size. The corners of all inventory blocks will be documented in UTM meters (NAD 27) using a global positioning system (GPS) unit corrected to a nominal accuracy of ±10 m.

- In some circumstances, BLM may determine that examination of a linear corridor is appropriate. Each corridor will encompass a minimum of two parallel transects (thus linear inventories will examine a corridor at least 60 m wide). At a minimum, the centerline of the inventory corridor will be documented at the beginning point, at any points of inflection, and at the end point of the corridor. All such locations will be documented in UTM meters (NAD 27) using a global positioning system unit corrected to a nominal accuracy of ±10 m.

Management Zone-Specific Inventory Prescriptions

Previous inventories indicate that relative cultural resource density, size, and significance varies by Management Zone. Consequently, it is possible to adjust inventory procedures, allowing for a reasonable fit between prescribed field methods and expectations regarding the likely presence and importance of cultural resources.

Implementation of zone specific inventory prescriptions described below will substantially reduce the level of inventory required in lower sensitivity areas. By designation of Management Zone 5, 5,029 hectares will be excluded from further inventory. The 8,462-hectare Management Zone 4 will require review at only the reconnaissance level of inventory. The inventory transect interval will be increased from 30 to 45 m in the 110,615 hectares of Management Zone 3. Viewed cumulatively, changes in inventory standards will occur over 124,106 hectares, or 56 percent of the Management area.

Management Zones 1 and 2

Management Zone 1 comprises 16.9 percent and Management Zone 2 includes 17.9 percent of the Management Area. Both zones occur mostly on fan piedmonts and fan skirts. Approximately 15 percent of Management Zone 1 and about 12 percent of Management Zone 2 has been inventoried, mostly by block inventories. Site type diversity is high in both Management Zones. Site density is similarly high in both management zones: approximately one site for every 14 hectares inventoried in Management Zone 1 and one site for every 12 hectares inventoried in Management Zone 2. However, the density of National Register eligible properties differs dramatically between the two zones: one eligible site for every 128 hectares inventoried in Management Zone 1, whereas only one significant site for every 319 acres in Management Zone 2. Inventory prescriptions are identical for the two zones because of the high density and diversity of sites in both classifications. However, BLM will recognize Management Zones 1 and 2 as distinct entities because of the different densities of National Register eligible properties. So doing will allow BLM the flexibility in project planning to prefer project areas in Management Zone 2 over Zone 1 (whenever possible), and to anticipate different mitigation costs within the two zones.

Inventory Type Required - Class III.

TRANSECT INTERVAL REQUIRED - When in a Special Management Unit, the transect interval will be consistent with the approved data recovery plan. When outside the context of a Special Management Unit, the transect interval will be 30 m.

SPECIAL CONSIDERATIONS

1. Special consideration will be given to the identification and notation of previously undetected dunes, toolstone sources, and water sources. Site densities are likely to be exceptionally high in these areas.

2. Site distribution within these Zones appears uneven. Site densities appear higher in patches along the valley margin, whereas densities appear lower in patches closer to the playa, and southwest and northeast of the playa. BLM will review inventory data from Management Zones 1 and 2 at three-year intervals to determine whether low density areas in the valley interior may be redesignated as Management Zone 3.

3. Special inventory attention will be given to places where subsurface deposits may be exposed, such as road cuts, stream cuts, etc. There is particular concern that depositional processes may be limiting site visibility.

4. BLM will require professional archaeological monitoring of all blading and trenching activities conducted in this Zone. The purpose of monitoring will be to ascertain whether or not subsurface cultural deposits are present, both within and outside defined resource boundaries.

5. Because of the high potential for subsurface deposits in these Management Zones, BLM will require a testing component as part of the site evaluation effort.

Management Zone 3

This Zone, which includes complexity score areas 3 through 6 as defined by the model, comprises 51.8 percent of the Management Area. Approximately eight percent of this zone has been inventoried, mostly by block inventory. The site density is approximately one site for every 17 hectares inventoried. A moderate diversity of site types is present. Thirteen National Register eligible properties have been identified to date (one for every 649 hectares inventoried).

Inventory Type Required - Class II.

TRANSECT INTERVAL REQUIRED - When in a Special Management Unit, the transect interval will be consistent with the approved data recovery plan. When outside the context of a Special Management Unit, the average size of significant sites is such that the transect interval can be set at 45 m. In areas where landform may promote the formation of linear sites, transects will be oriented perpendicular to the locally dominant contour so as to ensure that any significant sites less than 45 m in width are captured.

SPECIAL CONSIDERATIONS - Agency and field archaeologists will be aware of the potential for anomalous areas of high site density within this Management Zone. Such areas include places where Zone 3 abuts Zone 1 or 2. Too, field archaeologists may discover previously undetected dunes, toolstone sources, or water sources within this zone that will probably accompany high site densities. No *a priori* modifications to transect interval or inventory type are recommended for these cases, but additional inventory effort may be warranted once an anomalous site cluster is discovered, particularly if that cluster appears to merit special management consideration. BLM will evaluate the need for additional inventory of site clusters on a case by case basis.

Management Zone 4

This zone, which includes complexity score areas 7 and 8 as defined by the model, comprises 4.0 percent of the Management Area. Approximately two percent of this zone has been inventoried, mostly by linear corridor inventory. Site density is approximately one site for every 23 hectares inventoried. Site type diversity is limited; no National Register eligible properties have been identified.

Inventory Type Required - Class II.

TRANSECT INTERVAL REQUIRED- Not applicable. The BLM may require the conduct of intuitive, reconnaissance style inventory. If so, initial examination may be conducted on foot or by vehicle.

Areas identified as requiring systematic inventory will be examined in accordance with current BLM standards for a Class II inventory with a 45 m transect interval. At a minimum, any such intensive inventory will address an area of one square hectare.

SPECIAL CONSIDERATIONS

1. Because this management plan allows flexibility in inventory effort for this management zone, it is vital that agency and field archaeologists be aware of circumstances where anomalous high site densities and significant sites may occur. During the project permitting phase, agency archaeologists will consider places where Zone 4 abuts Zones 1, 2, or 3, as locations requiring systematic, 45 m transect interval survey. Even during intuitive reconnaissance inventory, field archaeologists will pay particular attention to locating previously undetected rockshelters, dunes, toolstone sources, or water sources where unanticipated high site densities are likely to occur. If such areas are located, BLM will evaluate the need for additional Class III inventory effort on a project by project basis.

2. The inventory report will contain a comprehensive description of the inventory methods employed. Intensively examined areas will be identified and located in accordance with other provisions of this plan.

3. This Management Zone includes seven habitat types of varying size (Table 9.2). Four habitat types have had no previous inventory, but cover areas no greater than 25 hectares in extent (Habitat G15, Complexity Score 8: Habitat G11 Complexity Score 8: Habitat M7 Complexity Score 7: and Habitat M5, Complexity Score 7). Because of their small size, BLM personnel will undertake Class II, reconnaissance inventory of these parcels in order to confirm the predicted absence of significant sites and exclude them from further cultural resource management consideration.

Management Zone 5

This Zone consists of habitat types A1 and G13, regardless of where in the Management Area they occur. This zone comprises 9.4 percent of the Management Area, restricted to portions of the Management Area reflecting low complexity scores. Approximately fourteen percent of this zone has been inventoried, mostly by linear corridor inventories. Site density is approximately one site for every 52 hectares inventoried. Site type diversity is limited; no National Register eligible properties have been identified.

Inventory Type Required - No additional inventory will be required in this Zone.

TRANSECT INTERVAL REQUIRED - Not applicable.

SPECIAL CONSIDERATIONS - None.

Recording and Reporting Considerations

Model development required a detailed examination of site records. This led to the identification of several areas of potential improvement. The following actions will reduce, if not alleviate, the noted deficiencies.

In many places, the valley floor lacks the distinctive topographic features that allow for accurate location of a cultural resource property on USGS maps. To ensure such accuracy, resource locations will be documented in UTM meters (NAD 27) using a global positioning system receiver; resulting data will be corrected to a nominal accuracy of ±10 m. Reports and site forms will state how the UTM coordinates were derived.

Examination of past data shows that the same cultural resource has been recorded several times, or that various portions of a larger resource have been recorded as separate entities. Every effort will be made to avoid assigning one resource, or parts thereof, more than one agency or trinomial registration number. BLM will minimize misnumbering by the following actions:

- BLM will not issue an authorization to begin fieldwork until a complete archive search has been conducted. Reliance on previous, often dated, archive searches will not be permitted, and all archive searches must include a review of data integrated into the Railroad Valley model, and of all data generated since its formulation. A required objective of the archive search is identification of specific model expectations (expected constellation of biotic and abiotic resources available by habitat type, predicted archaeological complexity score, and anticipated site types) for the study area. These expectations will be compiled by referencing the GIS databases developed in this report and maintained by BLM.

- BLM will check the GIS data or map plots before assigning a number to a recorded resource. If previously recorded, the original form will be updated, as necessary. If not previously recorded, the resource will be assigned an agency designation.

Information about isolates will be integrated into the model. Reports will contain a table listing all isolates discovered by an inventory, a description of the isolate, and its UTM location. A map showing the location of all isolates will be included in the report. Isolates will be assigned an agency number consisting of the agency report number followed by the letter "I" and a serially assigned number (for example 6-1210-I1, 6-1210-I2, and so on). This will facilitate their integration into the model database, but does not obligate the State to integrate isolates into its database.

Numerous inventories have addressed comparatively small surface areas. However, the inventories of linear and small areas often encounter large resources that extend well beyond the study area boundaries. The field archaeologist is often reluctant to record more than is present in the immediate study area. This results in incomplete recording of the resource and a consequent management headache. To minimize the potential for this to occur, BLM will take the following actions:

- That portion of a resource within the defined study area will be documented in accordance with standing BLM policies. At regular intervals, the resource boundary will be documented in UTM meters (NAD 27) using a global positioning system receiver; resulting data will be corrected to a nominal accuracy of ±10 m. Reports and site forms will record how the UTM coordinates were derived.

- That portion of a resource outside the defined study area will be documented as follows:

  - The content of the resource will be documented by recording the presence or absence of key artifact and feature types.

  - Attention will be paid to the documentation of artifacts, features, or resource characteristics that, if left unrecorded, would materially skew evaluation of National Register eligibility.

- At regular intervals, the resource boundary will be documented in UTM meters (NAD 27) using a global positioning system receiver; resulting data will be corrected to a nominal accuracy of ±10 m. Reports and site forms will record how the UTM coordinates were derived.

These actions will ensure accurate, but cost effective, delineation of site boundaries and characterization of surface assemblages, as well as comprehensive site recording within areas of potential effect.

Each inventory report will, as part of its conclusions, compare model-based expectations with what was actually observed in the field. Particular attention will be given to unanticipated geographic findings that suggest a need for the correction of a sensitivity classification, of unanticipated cultural resource types, or of larger or more complex sites than anticipated. Such comparison is crucial to an understanding of research contexts, the evaluation of National Register eligibility, and ongoing evaluation of the model.

In accordance with BLM permit conditions (USDI BLM 1990b), an initial report will be submitted to BLM by the consulting archaeologist within one calendar week of completing field activities. In addition to items listed in the BLM standards, the initial report will contain a list of identified resources and a map showing their locations.

The draft and final report submitted to BLM by the consulting archaeologist will be accompanied by a form that provides summary inventory information, designed to facilitate entry of the project into the Railroad Valley data base. Similarly, each IMACS form will be accompanied by a form intended to facilitate entry of the resource into the Railroad Valley database. Isolates will also be recorded on the form, albeit without accompanying IMACS documentation. Sample forms are appended to this management plan.

Management Plan Implementation

Implementation of this management plan will constitute an undertaking as that term is defined within the context of the National Historic Preservation Act. Thus, BLM will need to consult with the State Historic Preservation Office prior to implementing the plan's provisions. This can be accomplished through the preparation and execution of a Memorandum of Agreement between BLM and the Nevada State Historic Preservation Office. The agreement will:

- acknowledge the Railroad Valley model as the regional context for prehistoric resources in the Management Area;

- permit the variations in inventory, recording, and reporting standards identified in the management plan; and,

- set the stage for the definition of Special Management Units.

As noted in the introduction, this management plan addresses only prehistoric period cultural resources, and lacks a historic component. Based on past inventory results, historic period resources are rare in Railroad Valley; only 58 historic components are recorded in the Railroad Valley database of 1358 sites. Most are clustered around springs and seeps and represent transportation and ranching themes. If past observations are representative, areas most likely to contain historic period resources are located in Management Zones 1 and 2, and will be inventoried at the Class III level. Consequently, implementation of the adjusted inventory standards will not result in failure to encounter historic resources. However, BLM must consult with SHPO regarding this matter and incorporate a consideration of historic resources into the Memorandum of Agreement.

Future Considerations

To serve as a long-term basis for cultural resource management in Railroad Valley, BLM must undertake ongoing long-term review and maintenance of the Railroad Valley Model and Management Plan.

Three-Year Review Period

The predictive powers of the Railroad Valley Model were considerably improved by testing and empirical refinement in light of the extant site database. It stands to reason that future inventory work in Railroad Valley will further hone the model's predictive edge, and yield new insights meriting consideration in this Management Plan. For this reason, BLM will review the model and management plan at three-year intervals (first review to be held in AD 2002). During each review, BLM will

- examine the results of all work conducted in the Management Area since the last review,
- further test model predictions against inventory data acquired since the last review,
- consider the appropriateness of reclassifying specific habitats, landforms, or empirically defined areas into different Management Zones (particular attention will be given to areas of Management Zones 1 and 2 empirically found to have low site density and high site density clusters of Management Zones 3 and 4),
- revise or refine the site typology developed in Chapter 7,
- consider modification of any inventory standards prescribed in this management plan,
- monitor implementation of land use prescriptions and treatment plans for special management areas, and
- identify any site complexes warranting designation as Special Management Units.

Long Range Modeling and Management Goals

As noted above, the Management Area comprises some 223,434 hectares of which 213,345 hectares have been assigned to five Management Zones. A lack of information precluded characterization of the remaining 10,089 hectares into habitat, complexity score, or Management Zone. Whenever possible, BLM will obtain the needed information so that these "blank areas" can be filled in and integrated into the model.

As resources allow, BLM will expand the Management Area so that it is defined on the basis of watershed. Initially, this will be accomplished by extending the Management Area boundaries to ridgelines on the east and west. Following that, expansion efforts will extend to the north and, finally, to the south.

Numerous minor corrections were made to the existing resource and project databases. While available in the electronic version of the database, these corrections are not reflected in paper copies of site forms or reports held by either BLM or the Nevada State Museum. BLM will make electronic copies of the corrected data available to its Battle Mountain District Office, the Tonopah Field Office, and the Nevada State Museum.

If needed to formalize a Memorandum of Agreement with SHPO, BLM will integrate a consideration of historic period resources into the model and management plan.

Sample Form 1

RAILROAD VALLEY MANAGEMENT AREA
CULTURAL RESOURCE INVENTORY PROJECT
COVER SHEET

Date __________ BLM Project Number ____________

Management Zone Represented in Survey Area:

Zone #	Area Inventoried	No. Sites Recorded
Zone 1	__________ Hectares	__________
Zone 2	__________ Hectares	__________
Zone 3	__________ Hectares	__________
Zone 4	__________ Hectares	__________
Zone 5	__________ Hectares	__________
Other	__________ Hectares	__________
TOTAL	__________ Hectares	__________

Physiographic Characteristics Noted

Mark As Appropriate	Characteristic	Management Zones	Associated Sites/Isolates (include site numbers.)
__________	Sand Dunes	__________	__________
__________	Coppice Dunes	__________	__________
__________	Spring/Seep (active)	__________	__________
__________	Spring Mound	__________	__________
__________	Travertine Deposit	__________	__________
__________	Playa Basin	__________	__________
__________	Stream Channel	__________	__________
__________	Ephemeral Drainage	__________	__________
__________	Tool Stone Source	__________	__________

Temporally Diagnostic Artifacts:

Mark As Appropriate	Artifact Type	Management Zones
__________	Projectile Points	__________
__________	Ceramics	__________
__________	Other	__________

Sample Form 2

RAILROAD VALLEY MANAGEMENT AREA
CULTURAL RESOURCE SITE / ISOLATE FORM
COVER SHEET

Date ________

Management Zone ________ BLM Site Number ________

Site Area ________ Square Meters

Preliminary National Register Recommendation ________

Artifact Categories Present (check as appropriate)

____ Evidence of Feature/Buried Deposits
____ Scattered Fire-Cracked Rock
____ Dispersed Charcoal
____ Burned Animal Bone
____ Human Bone
____ Charcoal/Rock/Bone Clusters
____ Other

____ Projectile Points
____ Fabrication Tools
____ Bifaces
____ Drills
____ Scrapers
____ Abraders
____ Bone Tools
____ Other

____ General Utility Tools
____ Flake Tools
____ Choppers
____ Hammerstones
____ Battered Cobbles
____ Other

____ Ground Stone Tools
____ Milling Stones
____ Manos
____ Other

____ Ceramics

____ Cores

____ Debitage
____ Obsidian
____ Local Sources
____ Exotic Material

Site Type (based on artifacts and features present): ________

Appendix B

Archaeological Treatment Plan for Gravel Bar Site 26Ny1908

Robert G. Elston

Research Context

Oil exploration in Railroad Valley during the mid to late 1970s generated numerous archaeological surveys along seismic lines, drill pads, and connecting roads on the Gravel Bar Site 26Ny1908 (referred to hereafter as GBS) and in its vicinity (Figure B.1). Archaeological evidence accumulated as a result of this work suggested that an archaeological record of considerable interest was present on the GBS. Although all periods of prehistory were represented, artifacts thought to date to the Pleistocene/Holocene transition (ca. 11,000-8,000 BP) were commonly observed there, some in disturbed contexts (particularly gravel pits at Flowing Well on the east end of the bar), indicating the possibility they had been exhumed from buried deposits. The prospect of a buried archaeological site of this age assumed considerable importance because this interval apparently marks the inception of human occupation of the Great Basin, and because most of these earliest sites were (and remain) surface phenomena without associated subsistence indicators (faunal and floral remains) or carbon suitable for radiocarbon dating.

In order to better define the archaeological remains of the GBS, the Bureau of Land Management contracted with the Nevada Archaeological Survey (NAS) to test five known archaeological localities there. In addition to testing the known localities, NAS proposed to document the geologic context of the Bar (Nevada Archaeological Survey 1978). NAS (Elston et al. 1979:1) was particularly interested in the extent (distribution, density) of surficial archaeological remains on the Bar, and whether buried (and better preserved) remains existed there. Furthermore, NAS welcomed the opportunity to describe and analyze the oldest lithic technology which seemed to date to the Pleistocene-Holocene transition. However, the project did not include survey to present BLM Class III standards of the entire site; indeed, to date, such a survey has never been done. The report produced by NAS (Elston et al. 1979) remains in draft form with errors and contradictions, several of which are identified in the following discussion.

Figure B.1 is based on the site map prepared by NAS (Clerico and Davis 1979). Although present on the original map, Figure B.1 does not show the 1979 metric grid or most excavation unit locations. Of sites recorded prior to 1979, the largest are indicated on Figure B.1 by hatching, but the smallest sites are not shown, nor are any pre-1979 site numbers. Note that the Tin Shed locality did not appear on the GBS map made in 1979 (Clerico and Davis 1979); it's position in Figure B.1 is estimated from incomplete field notes available to us.

NAS excavated sixteen 1 x 1 m and two 2 x 2 m test pits at various points on the GBS, as well as ten backhoe trenches shown in Figure B.1 (many named for glacial intervals in light of the December field work conditions). These trenches were, in order from west to east: Würm, Mindel (the precise location of the Mindel trench was not recorded in field notes and, therefore, is not indicated on Figure B.1), Riis, Minnesotan, Niobrara, Wisconsin, Kansan, Gunz, Olduvai, and Lake Louise. Artifacts were collected from the surface in a 10 x 10 m area around each test unit, and surface collections were made in an area seven meters wide, the length of each backhoe trench.

Excavation or surface collection assemblages large enough for useful comparison were obtained from the vicinity of the backhoe trenches (Würm, Mindel, Riis, and Minnesotan) and the Tin Shed locality, and in two areas tested by 1x1 excavation units (Tin Shed and Flowing Well). In several tables, these assemblages are compared to the "Surface Sweep assemblage" created by collecting isolated artifacts, and to small scatters from numerous locations on the site.

In addition, stratigraphy was examined where revealed in several existing gravel pits. As previously described, the highest surface of GBS lies at about 1452.7 m asl (4766 ft), and it has three

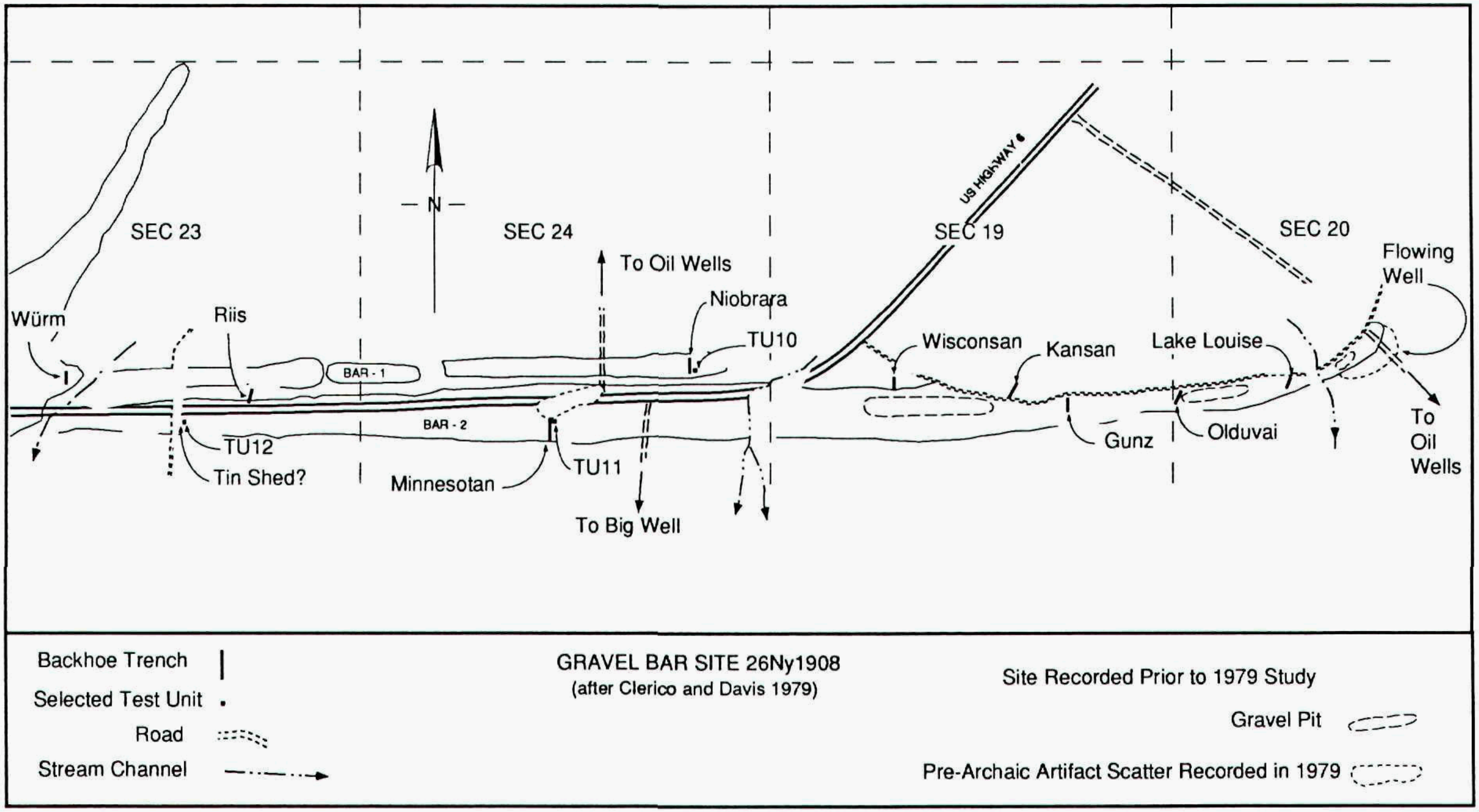


Figure B.1 Gravel Bar Site 26Ny1908, Railroad Valley, Nevada geomorphic components: Bar 1 and Bar 2 (offshore gravel bars with 1 to 2.5 m of relief) and the trough between them. Overall, the stratigraphic sequence is as follows:

- Unit I (not seen on Bar 2): 10-30 cm thick, well sorted beds of fine sand to fine pebbles;
- Unit II: 20 cm thick, well sorted beds of medium sand (slightly cemented) to unconsolidated well rounded pebble gravel;
- Unit III: to 1 m thick, poorly sorted sandy loam with 20% well rounded gravel; weathering profile extends to one meter downward into Unit II;
- Unit IV: (present only between units II and III in trough) 1.25 m thick, reverse graded from greenish clay loam at bottom to reddish sandy loam at top.

Archaeological sites on the GBS include those recorded prior to 1979, ranging in complexity from isolated artifacts to lithic scatters of various sizes and densities, as well as archaeological localities discovered by the NAS project. The site number 26Ny1908 refers to all of the isolated artifacts and lithic scatters that appear to date to the Pre-Archaic of the Pleistocene-Holocene transition. Since these are found the length and breadth of the GBS, 26Ny1908 is considered to include the entire spit and immediately adjacent salt flats. Later (Archaic) sites and isolated artifacts apparently retain their original site numbers.

This emphasis on Pre-Archaic materials greatly complicates management of cultural properties on GBS. For example, several sites and localities are multicomponent; that is, some localities (cf. Minnesotan) with Archaic artifacts also contain earlier materials. It is unclear in such cases whether the Archaic components are also part of 26Ny1908. Moreover, while the draft report (Elston et al. 1979) argues strongly (in retrospect, too strongly for the evidence in hand) for the presence of buried archaeological remains in 26Ny1908 dating to the Pleistocene-Holocene transition, it is contradictory about which data support this conclusion (see discussion below) and where these deposits lie, exactly. The management response to this ambiguity has been to withdraw the entire GBS from development.

Goal of Treatment Plan

Since the late 1970s, scientists and land managers have focused on the portion of the GBS archaeological record dating to the Pleistocene-Holocene transition, while ignoring components dating to the Archaic period. As a result, sufficient information exists to develop a treatment plan for Pre-Archaic components along the gravel bar, but scattered Archaic components lack enough prior description to even estimate their distribution, much less develop a common research design. The overall goal of the following treatment plan is to mitigate impacts from development on the Pre-Archaic portion of the record through data recovery, analysis, and publication of findings. In so doing, we expect that much of site 26Ny1908 will be opened to potential development. The Treatment Plan ensures that significant Archaic sites and localities that remain on the GBS will be properly recorded, their boundaries will be sharply defined, and that each will be assigned an individual site number, if needed. In this way, developers can either avoid Archaic sites or mitigate impacts of development through standard means of testing, evaluation, data recovery, and publication.

Research Domains

Archaeological remains dating to the Pleistocene-Holocene Transition (ca. 12,000-10,000 BP) and early Holocene (10,000-8,000 BP) frequently are found in valleys of the Great Basin (Elston 1982, 1986a, 1986b, 1994; Elston et al. 1995; Grayson 1993; Beck and Jones 1988, 1990, 1997; Price and Johnston 1988; Zancanella 1988). Western Stemmed sites, such as the localities in the GBS, contain large stemmed, edge-ground projectile points. Other tools include bifaces, a variety of scrapers, choppers, gravers, and crescentic objects. Although andesitic basalt is the preferred raw material for points, chert and obsidian are also employed. Scrapers tend to be made of chert and basalt, while the majority of crescents are chert. Ground stone artifacts are rare or absent in these ancient sites, suggesting that plant foods were not extensively exploited. Neither constructed shelters nor storage facilities dating to this time period have been found in the Great Basin.

Although they occur in a variety of settings, sites of this period in the interior Great Basin most frequently occur on valley margins adjacent now extinct shallow lakes or marshes, or along rivers; upland settings tend to preserve only very small lithic scatters or isolated points. In valleys that have contained Pleistocene lakes, sites usually are associated with riverine terraces, lacustrine gravel bars representing the terminal Pleistocene lake stand, or other elevated landforms in roughly the same position. In Railroad Valley, as in Grass Valley (Elston 1986b), early archaeological materials are concentrated on spits extending eastward from the western valley margin, and on gravel bars and terraces of the major axial stream. In both cases, the spits, bars, and terraces appear to offer access to surrounding wetlands (marshes, shallow lakes) and axial streams passing nearby. People occupying these low-lying gravel bars and spits were also positioned to access resources of the shrubby piedmont below the mountain front, which at the Pleistocene-Holocene transition likely contained a more diverse array of plants providing better forage for large and small herbivores than do modern plant communities in the same position (Elston et al. 1995:300-302).

Throughout the Great Basin, significant research questions remain unanswered regarding cultural chronology, subsistence, land use, and technological organization during the Pleistocene-Holocene transition. The archaeological record of the GBS has the potential to contribute information to each of the domains summarized below. Relevant research questions are identified.

Paleoenvironment

Reconstructing ancient environments is necessary to an understanding of the nature and distribution of prehistoric resources such as surface water, plants, and animals. Previous investigation (Elston et al. 1979) suggests the GBS *per se* is not a likely environment for the preservation of pollen or plant macrofossils, although these materials may be preserved nearby in spring mounds and bogs. Determining the ages of the bar and its various stratigraphic and geomorphic components is necessary to unravel its depositional history and the sequence of lake transgression and regression in Railroad Valley during the Pleistocene-Holocene transition. Consequently, every effort must be made to date various stratigraphic and geomorphic components of the GBS. For example, small pieces of tufa are present on the surface of the gravel bar; ^{14}C assay of these may provide a limiting date for the last highstand of Lake Railroad. We recommend that samples be collected and assayed.

Although none were observed in previous tests (Elston et al. 1979), materials datable by ^{14}C assay (ostracods, gastropods, bivalves) may be present in the bar. These could provide the means to date the various stratigraphic components of the bar and trough. In addition, some species of shelled animals are sensitive indicators of water quality and temperature. We recommend searching for deposits containing shell via backhoe trenches.

Deposits adjacent the bar may provide important paleoenvironmental evidence if they are also overlain by or overlie bar deposits. For example, marl exposed a short distance south of the bar and dated to 12,890±120 (Beta 29026) (Donald Currey, personal communication, November 1997) was deposited in deep water. However, even though there is an eolian cap on the bar itself, there seemed to be neither shallow water nor eolian deposits overlying the marl. This suggests the possibility that the present surface of the marl is erosional. If true, any shallow lake and/or eolian deposits that once overlay the marl have been removed, along with an unknown amount of the marl itself. Perhaps a more complete stratigraphic record exists where topography, greater soil moisture, or alluvial deposition have protected sediments from eolian erosion. Such places may lie in the alluvial channel breaching the bar at its west end and under its fan on the south side of the bar, in alluvial deposits of Duckwater Creek beyond the east end of the bar, and on the north side of the bar, protected from the prevailing southwest winds (Figure B.1). Another likely place is about 2 km west of the GBS, where a large, linear dune field lies on, and south of, shore features at the same elevation (1452.7 m asl or 4766 ft). In this field, reddish older dunes containing artifacts and fire cracked rocks are overridden by more recent tan sands. The red sands may be equivalent in age to Stratum III on the GBS. We suggest sampling likely localities with a backhoe and recording the stratigraphy revealed.

When the aeolian mantle began to accumulate on the bar is an important paleoenvironmental datum since it signals a change in the supply of fine sand and silt that is most likely related to the final recession of the lake and deflation of beach and lake bed sediments. In the absence of sufficient organic samples for radiocarbon dating, we recommend collecting soil samples from Stratum III for dating by thermoluminescence (Bradley 1985).

Cultural Chronology

Various cultural chronologies have been proposed for the Pleistocene-Holocene transition of the Great Basin. Elston (1986a) characterizes the adaptive strategies of all archaeological cultures prior to 8,000 BP as Pre-Archaic, while assuming that Clovis points are probably earlier than Great Basin Stemmed points. Willig and Aikens (1988) agree there are two succeeding archaeological complexes: Western Clovis between 11,500 and 10,000 BP and the ensuing Western Stemmed Complex between 10,000 and 8,000 to 7,500 BP James (1981) and Zancanella (1987) also employ a two part chronology, including all the time between 15,000 BP and 11,000 BP in the Paleoindian Period, followed by the Proto-Archaic Period between 11,000 BP and 8,000 BP. In this scheme, fluted points are characteristic of the Paleoindian Period, but possibly carry over into the early portion of the subsequent Proto-Archaic. Table B.1 summarizes the tripartite chronology of Price and Johnston (1988), also accepted by Zancanella (1988). This scheme, however, seems more complex than justified by current data. For example, we see little to support the co-occurrence of Western Clovis and large stemmed points as proposed for the Mt. Moriah Phase, or any evidence of chronological separation of large and small stemmed points (Willig and Aikens 1988). Moreover, Western Clovis points are poorly dated in the Great Basin (Willig and Aikens 1988), and no great antiquity has been established for large fluted and unfluted, concave base points found there (Pendleton 1979; Bryan 1988:59). For the purposes of this report, we adopt the simpler chronology of Willig and Aikens (1988).

Table B.1. Proposed Cultural Chronology for the Pleistocene-Holocene Transition in Eastern Nevada (after Price and Johnston [1988])

	Interval (years BP)	Diagnostic Artifacts
Mt. Moriah	> 10,500	large, edge-ground points including Clovis fluted points; unfluted concave base points; large stemmed points with square and rounded bases; single shouldered points
Sunshine	10,500-8,500	smaller, unground, stemmed points; crescents
Newark	8,500-7,500	unground, stemmed, indented base points (Pinto, Elko)

Table B.2 lists artifacts thought to be diagnostic of the Pre-Archaic Pleistocene-Holocene transition by GBS locality. Typical of the Pre-Archaic are GB points (stemmed and large concave base points), GB bifaces (various reduction stages in the manufacture of Great Basin Stemmed and fluted/concave-base points), crescents, and steep-edged scrapers. These artifacts are widespread on the GBS, although early points are not particularly abundant (probably due to amateur collecting). Other bifaces are knives and projectile point blanks used later in various periods of the Archaic, and Archaic points include Pinto, Elko Series, Rosegate, and Desert Series. A Chi-squared analysis of these data suggests the differences between assemblages are significant (X^2 =109.05; p=.0001).

Pre-Archaic artifacts are present in the Würm, Flowing Well, Tin Shed, and Surface Sweep assemblages (Table B.2), but are most abundant at Würm and Flowing Well. The other localities are multicomponent, with relatively small numbers of GB bifaces, GB points, steep scrapers, and larger numbers of Archaic points and bifaces. For example, Middle Archaic points were present in the Würm, Minnesotan, and Surface Sweep assemblages, and Late Archaic points in Minnesotan, Tin Shed and Surface Sweep assemblages (Elston et al. 1979: Table 3). Thus, only the Flowing Well assemblage appears to be a single component dating to the Pleistocene/Holocene transition, although the Würm assemblage contains only one later diagnostic artifact, a Pinto point.

Table B.2. Time-Diagnostic Lithic Artifacts from Gravel Bar Site

Technology	Locality							
	Würm	Mindel	Tin Shed	Minnesotan	Flowing Well	Surface Sweep	Other	Total
*GB Biface	11	2	4	14	34	2	4	71
†GB Pt./Crescent	2	0	1	0	5	2	7	17
Steep Scraper	10	0	1	1	9	4	0	25
Other Biface	4	1	11	14	6	12	3	51
Archaic Point	0	2	2	13	0	4	1	22

*Manufacturing stages of stemmed and concave base points.
†Stemmed points and large concave base points;.

Locating material datable by radiocarbon assay (charcoal, bone, shell, peat) in association with diagnostic artifacts is important. Previous testing revealed three hearths (lens-shaped, charcoal-stained features lined with stones) on the GBS (Elston et al 1979:37), in excavation units 10 (Niobrara locality), 11 (Minnesotan locality), and 12 (Tin Shed locality)(Figure B.1). The excellent preservation of these features suggest they are rather late; in fact, Feature 2 in unit 12 produced a radiocarbon date of 370±40 (Tx-3335). All three features were within Stratum III, the eolian cap draped over the lacustrine gravel of the bar. Depths below surface of these features are not reported, but since Stratum III is up to 1 m thick, it is possible that hearths dating to the Pleistocene-Holocene transition are present as well. We recommend searching for additional hearths with backhoe trenches.

Obsidian hydration could provide a relative chronology of artifacts, but obsidian is quite rare on the GBS. Nevertheless, as many hydration samples as possible should be obtained from the GBS and elsewhere in Railroad Valley. Eventually, there will be a sample sufficient for a hydration chronology.

If it can be demonstrated that Stratum III contains buried artifacts *in situ* (see discussion below), then thermoluminescence dates of Stratum III soil could date the artifacts as well.

Ancient Subsurface Remains

Whether or not there are substantial numbers of early artifacts in buried deposits at GBS is an important research issue. The surface assemblages have been disturbed by collecting and construction of highways and petroleum production facilities. If sufficient numbers of artifacts are present in buried sediments, and can be located and recovered, it will be possible to obtain a sample less biased than the surface assemblages so far collected.

Elston et al. (1979) gave two reasons for thinking buried artifacts were present in the GBS. First, wind damage (frosting, rounding) was severe on artifacts collected from the surface and minimal on artifacts recovered from below the surface. This suggested that artifacts deposited originally were on the upper surface of gravel Stratum II and thence worked upward to the surface by various turbating agents. It was also thought that excavation units in the Würm, Mindel, Minnesotan, and Flowing Well localities produced artifacts below the upper ten centimeters of the soil column (Elston et al 1979:35). However, reexamination of the provenience tabulations (Elston et al. 1979: Appendix B) indicates that no artifacts were recovered below level one in the Würm locality, while Mindel produced only one or two items per level below level one. Table B.3 indicates that only the Minnesotan and, possibly, Flowing Well localities may have buried archaeological remains.

Table B.3. Numbers of Artifacts by Level in Selected Excavation Units

	Numbers of Artifacts by Level			
Locality and Unit	Level 1	Level 2	Level 3	Level 4
Minnesotan, Unit 11	6	2	11	2
Minnesotan, Unit 13	19	22	13	2
Flowing Well, Unit 17	12	1	1	unexcavated
Flowing Well, Unit 18	4	3	5	unexcavated

Note, however, that subsurface artifacts are not abundant in either locality, and most are merely debitage (although Unit 17 at Flowing Well did produce a biface from Level 3). Moreover, the Minnesotan locality appears to be multicomponent; we do not know if the buried artifacts there date to the Pleistocene-Holocene transition or to later phases of the Archaic.

The slow accumulation of eolian Unit III through the middle Holocene and the subsequent millennia of bioturbation in the Late Holocene bodes ill for finding a significant number of Paleoindian artifacts in situ on the surface of Unit II. The best hope of finding deeply buried, relatively undisturbed artifacts are in places where Stratum III is thickest, such as the south slope of Bar 2 (for example, the Minnesotan locality) and the north slope of Bar 1 (the Würm and Niobrara localities). The Flowing Well locality, severely impacted by gravel mining, may not produce as much as hoped for. Another good prospect for finding ancient artifacts in situ may be under the reddish dune sands west of the GBS. Perhaps these sands accumulated fast enough and deep enough that bioturbation has had less effect there. If so, archaeological and geomorphic data from this area may be important for interpreting the archaeological record of the GBS.

Subsistence

Dietary evidence is scant for archeological sites of the Pleistocene-Holocene transition (Dansie 1987; Layton 1979), but a broad diet is indicated, including birds, fish, shellfish, rabbits, and large game including bison. On the other hand, early flaked stone tools seem well suited for taking and processing large game, and early sites lack evidence of intensive plant processing and storage, or residential structures. Perhaps people in this period operated mostly in a foraging mode (Binford 1980), seldom stopping anywhere for very long.

The 1979 tests of the GBS (Elston et al 1979) produced no bone, so the chances of finding direct evidence of ancient animal diet there seems remote. Nevertheless, if early hearths are found, they will be processed by flotation to recover any charred seeds and bone fragments that may be present.

Lithic Technology and Procurement

Previous investigation (Elston et al. 1979) of GBS suggests that much of the archaeological record there reflects the production and repair of projectile points and other lithic tools. The GBS offers the opportunity to analyze large collections of artifacts from the Pleistocene-Holocene transition and to compare these with later Archaic materials. The procurement of toolstone is of particular interest. We assume that most of the andesitic basalt used for early tools was procured locally, and all of the obsidian is exotic, but neither local nor distant sources have been identified.

Horizontal Variation in Distribution of Surface Artifacts on GBS

The failure to discriminate between archaeological components on the GBS has contributed a great deal to management difficulties. A statistical analysis (X^2 = Chi-squared) shows significant differences between assemblages listed in Table B.2. Table B.4 gives the adjusted standardized residuals of the X^2 table (Bettinger 1989), allowing us to see which variables in each assemblage are significant. A positive value equal to or greater than 1.96 suggests a greater than expected frequency, while a negative value equal to or greater than -1.96 suggests a lower than expected frequency. For example, in the Würm assemblage, steep scrapers are more abundant than expected and Archaic points are less abundant. The Flowing Well assemblage has more GB bifaces and fewer other bifaces and Archaic points than expected. In fact, the values for adjusted standardized residuals on frequencies of steep scrapers and Archaic points in the Würm and Minnesotan localities, and between Archaic points and GB bifaces in the Minnesotan and Flowing Well localities suggests the inverse relationship between these artifact classes predicted by their putative age (Archaic and Pleistocene-Holocene transition). Table B.4 also suggests functional differences between the assemblages of the same age; for example, the numerous steep scrapers in the Würm assemblage may indicate a focus on hide processing, while the abundant bifaces at Flowing Well suggest a focus on projectile point manufacture. Finally, the high positive value of GB points in other assemblages suggests either functional differences between these small scatters and the larger localities, or a possible bias in collection.

Additional surface collections will be obtained through a stratified and randomized sampling protocol designed to minimize sample bias. Ambiguity regarding the spatial relationships between sites and localities can be eliminated by recording sites and localities to contemporary standards and firmly establishing their boundaries.

Table B.4. Adjusted Standardized Residuals for Time-Diagnostic Lithic Artifacts from Gravel Bar Site (based on Table B.2 in this report)

	Locality						
Technology	Würm	Mindel	Tin Shed	Minnesotan	Flowing Well	Surface Sweep	Other
GB Biface	0.31	0.09	-1.68	-0.81	**5.12**	**-3.37**	-0.98
GB Point/Crescent	-0.34	-0.72	-0.62	**-2.37**	0.04	-0.15	**5.28**
Steep Scraper	**3.94**	-0.89	-1.11	**-2.44**	0.85	0.50	-1.60
Other Biface	-1.64	-0.38	**3.21**	1.03	**-3.46**	**2.73**	-0.68
Archaic Point	**-2.08**	**1.98**	-0.19	**4.44**	**-3.28**	0.79	-0.65

Significant values are indicated in boldface.

Treatment Plan

Management of the Gravel Bar Site (26Ny1908) suffers from insufficient information.

- There are too few data from which to accurately estimate surface artifact distribution and density.
- The functional variability of archaeological localities over the GBS is poorly understood.
- The site is poorly dated, and little is known about the distribution of ancient artifacts within the eolian cap, Stratum III.
- We do not know how much of a subsurface archaeological record is left at the Minnesotan locality, Flowing Well, or elsewhere.
- There is little information from which to reconstruct the paleoenvironmental context of the site.
- Extant artifact collections (cf. Elston et al. 1979) are only minimally described; little is known of lithic technology and procurement.

To acquire the information needed to properly interpret and manage the GBS, the following tasks will be accomplished in two phases.

Phase I is designed to provide the basic contextual data needed for future management of the GBS, and to test for the presence of significant buried archaeological remains (artifacts or features) there. Buried archaeological remains will be considered significant if they remain approximately where originally deposited and are sufficiently abundant that good samples can be recovered through excavation. Of particular significance will be *in situ* artifacts and features dating to the Pleistocene-Holocene transition on the surface of Stratum II or minimally displaced upward into Stratum III.

If significant buried archaeological are present, impacts of future development will be mitigated by Phase II data recovery. If Phase I fails to show the presence of significant buried archaeological remains, Phase II will be unnecessary.

Phase I Survey and Testing

1. Perform a close order survey of the entire GBS and adjacent alkali flats; survey sample units in the dune field west of GBS, recording artifact distribution and density; in both areas, complete fresh IMACS forms for all sites; especially attend to previously recorded archaeological sites and localities and note changes from original conditions; collect surface tufa samples for radiocarbon dating.

2. Collect detailed mapping data regarding GBS localities, surface collection units, backhoe trenches, and test excavations with Global Positioning System (GPS) and total station survey.

3. Stratify GBS by temporal/function units and collect samples of surface artifacts.

4. Excavate eight backhoe trenches in places likely to contain paleoenvironmental information (one in the alluvial channel breaching the bar at its west end, one under the fan of the channel south of the bar, one in alluvial deposits of Duckwater Creek east of the bar, two on the north side of the bar, and three within the dune field west of GBS); make detailed stratigraphic descriptions and profiles at significant locations in each trench.

5. If possible to relocate, reopen the 1979 Minnesotan backhoe trench to relocate the hearth features exposed there; excavate an additional trench in the Minnesotan locality to locate additional hearths.

6. In blocks, excavate ten 1 x 1 m units at Flowing Well locality and five 1x1 m units at Minnesotan locality to demonstrate the distribution of artifacts in Stratum III (previous artifact recovery rates suggest that this will generate about 200 artifacts from each locality).

7. Excavate ten 1x1 m test units in the dune field west of GBS to seek buried features and artifacts at the Unit II/Unit III contact (these can be adjacent the three backhoe trenches); make detailed stratigraphic descriptions and profiles at significant locations in each excavation block.

8. Collect tufa, shell, charcoal, bone, or organic matter from backhoe trenches and excavation units for flotation and radiocarbon assay. Determine if any such samples were collected and curated from the original excavation. If so, submit those for flotation and radiocarbon assay as well.

9. If samples for radiocarbon assay are insufficient to address the age of Stratum III, collect sediments samples and emplace dosimeter for dating by thermoluminescence.

10. Collect and submit samples of local andesitic basalt and obsidian for chemical analysis by X-ray florescence.

11. Submit obsidian samples for hydration readings.

Phase I Test Data Analysis

1. Assemble all previous archaeological records and collections from GBS; create master catalog.

2. Enter test records and recovered artifacts into master catalog.

3. Prepare detailed map of GBS, showing location of archaeological localities, surface collection units, backhoe trenches and test excavations, as well as surface artifact densities.

4. Submit samples (soil, tufa, shell, charcoal, bone, or organic matter) collected from the surface and recovered from backhoe trenches and excavation units for radiocarbon assay and thermoluminescence dating. Establish whether samples from the hearth features observed in 1979 at the Minnesotan locality were collected and preserved; if so, submit for radiocarbon assay.

5. Prepare stratigraphic descriptions and profiles of backhoe trenches and excavation units.

6. Identify faunal materials; analyze faunal assemblages.

7. Process hearth samples (if any) by flotation.

8. Identify plant macrofossils from float samples; analyze macrofossil assemblages.

9. Collect metric and technological data from test artifacts, as well as from artifacts in previous collections as needed (eg. point typology, biface stage analysis, debitage analysis, tool function analysis).

10. Submit obsidian and basalt samples (artifacts and local source specimens) for chemical analysis by X-ray florescence.

11. Submit obsidian samples for hydration readings.

12. Create comprehensive descriptions of all extant artifacts from GBS.

13. Perform statistical analysis of horizontal assemblage variability between and within collected and tested archaeological localities and sites; address discrimination of Archaic and Pre-Archaic sites.

14. Perform analysis of artifact distribution by stratum for excavated samples.

15. Prepare, produce and distribute a comprehensive, illustrated test report with interpretations and recommendations.

Phase II Data Recovery

1. Excavate additional backhoe trenches as needed; make detailed stratigraphic descriptions and profiles at significant locations in each trench.

2. Map Phase II excavations.

3. Make block excavations sufficient to recover samples of buried artifacts and features where these exist (these can be adjacent backhoe trenches); make detailed stratigraphic descriptions and profiles at significant locations in each excavation block.

4. Collect tufa, shell, charcoal, bone, or organic matter from backhoe trenches and excavation units for flotation and radiocarbon assay.

Phase II Data Analysis

1. Add Phase II archaeological records and collections to master catalog developed in Phase I.

2. Add Phase II map data to master map developed in Phase I.

3. Submit Phase II samples (soil, tufa, shell, charcoal, bone, or organic matter) for radiocarbon assay and thermoluminescence dating.

4. Prepare stratigraphic descriptions and profiles of Phase II backhoe trenches and excavation units.

5. Identify faunal materials; analyze faunal assemblages.

6. Process hearth samples (if any) by flotation.

7. Identify plant macrofossils from float samples; analyze macrofossil assemblages.

8. Collect metric and technological data from Phase II artifacts.

10. Submit obsidian and basalt samples (artifacts and local source specimens) for chemical analysis by X-ray florescence.

11. Submit obsidian samples for hydration readings.

12. Create comprehensive descriptions of Phase II artifacts.

13. Perform statistical analysis of assemblage variability between and within collected and tested archaeological localities.

14. Perform analysis of artifact distribution by stratum for excavated samples.

15. Prepare, produce, and distribute a comprehensive, illustrated report with interpretations and recommendations.

Once implemented, this treatment plan will fully mitigate Pre-Archaic components of the GBS (26Ny1908). This will alleviate the need for special land use prescriptions and open most of the gravel bar for development. All Archaic components identified during Phase I survey and testing will be redesignated with new site numbers and evaluated individually for their eligibility to the National Register of Historic Places.

Appendix C

Archaeological Treatment Plan for Trap Spring Archaeological Complex BLM CrNV-06-220

Robert G. Elston

Research Context

For more than a decade, management of the Trap Spring Archaeological Complex has been bedeviled by imprecise boundary definitions and by no clear idea why designation as a *complex* is warranted. It appears (although we find no paper record) that the idea arose because managers recognized that the large number of significant sites near the spring posed a recurrent obstacle to oil and gas development. Thus, designating a "Trap Spring Archaeological Complex" put a name to a constant headache and, perhaps, served to dissuade developers from shifting their attention there.

Prehistoric materials surrounding Trap Spring and extending into dunes just to the west were recorded as one archaeological site in 1979, assigned the Smithsonian number 26Ny624 (BLM CrNV-06-220). Subsequent surveys recorded similar sites in dunes and sand sheets nearby. Apparently, agency and consulting archaeologists began to consider all these sites in some way related to one another (probably because of similarity in location and content) and thought that the relatedness engendered a special significance beyond that of any individual site within the group. Early in 1988, archaeologists began to record archaeological sites in a large area centered on Trap Spring as localities of CrNV-06-220, while referring to a Trap Spring Archaeological Complex (TSAC).

The problem was that no one defined the boundaries of the complex or delineated research issues that would bind various sites around the spring to a common research theme. One attempt to define site boundaries for the TSAC consists of a map and a set of UTM points on an IMACS form (Mariah Associates 1989). The map shows a large (ca. 120 to 160 ha) area extending more than a mile northeast of Trap Spring as "the area of site recorded by the Jebco Seismic lines A, B, and C" (Figure C.1). A larger polygon, labeled "Site Complex Area," surrounds the site. As mapped, the complex is 3.5 miles long (north - south) by 2.25 miles wide (east - west), encompassing 1978 ha. However, hand-written notes on the margins of the map (presumably those of an agency archaeologist) indicate that boundaries of the complex were yet undetermined.

Absent clear boundaries and explicit research design, it was impossible for field archaeologists to determine whether subsequent inventories intruded into the Trap Spring Archaeological Complex. From a specific set of archaeological remains in sand dunes adjacent Trap Spring, TSAC came to refer to all archaeological localities in sand dunes in the general vicinity of Trap Spring. Archaeologists tended to record all sites in this area as members of TSAC even when they differed in content, temporal indicators, and specific situation. Given the looseness of the definition, some recorders have noted "Trap Spring like" sites on the east side of Railroad Valley (Pat Hicks personal communication to Eric Ingbar 12/23/97). It is no surprise that the Trap Spring Archaeological Complex designation has grown beyond management utility and became a needless hindrance to oil and gas developers.

Definition of TSAC Boundaries

Obviously, before we can develop a treatment plan for TSAC we must define usable boundaries. Our goal here is to delineate such boundaries, using the Railroad Valley habitat model and the extant archaeological database as analytical tools. Our starting point is the boundary derived from cadastral descriptions given in the Tonopah Resource Management Plan (USDI BLM 1997) defining an area of no surface occupancy (NSO) and closed to mineral material disposal (Figure C.1). The NSO area of 3554 ha encompassing both TSAC and the Gravel Bar Site is the only clearly defined management area pertaining to the TSAC we have been able to identify.

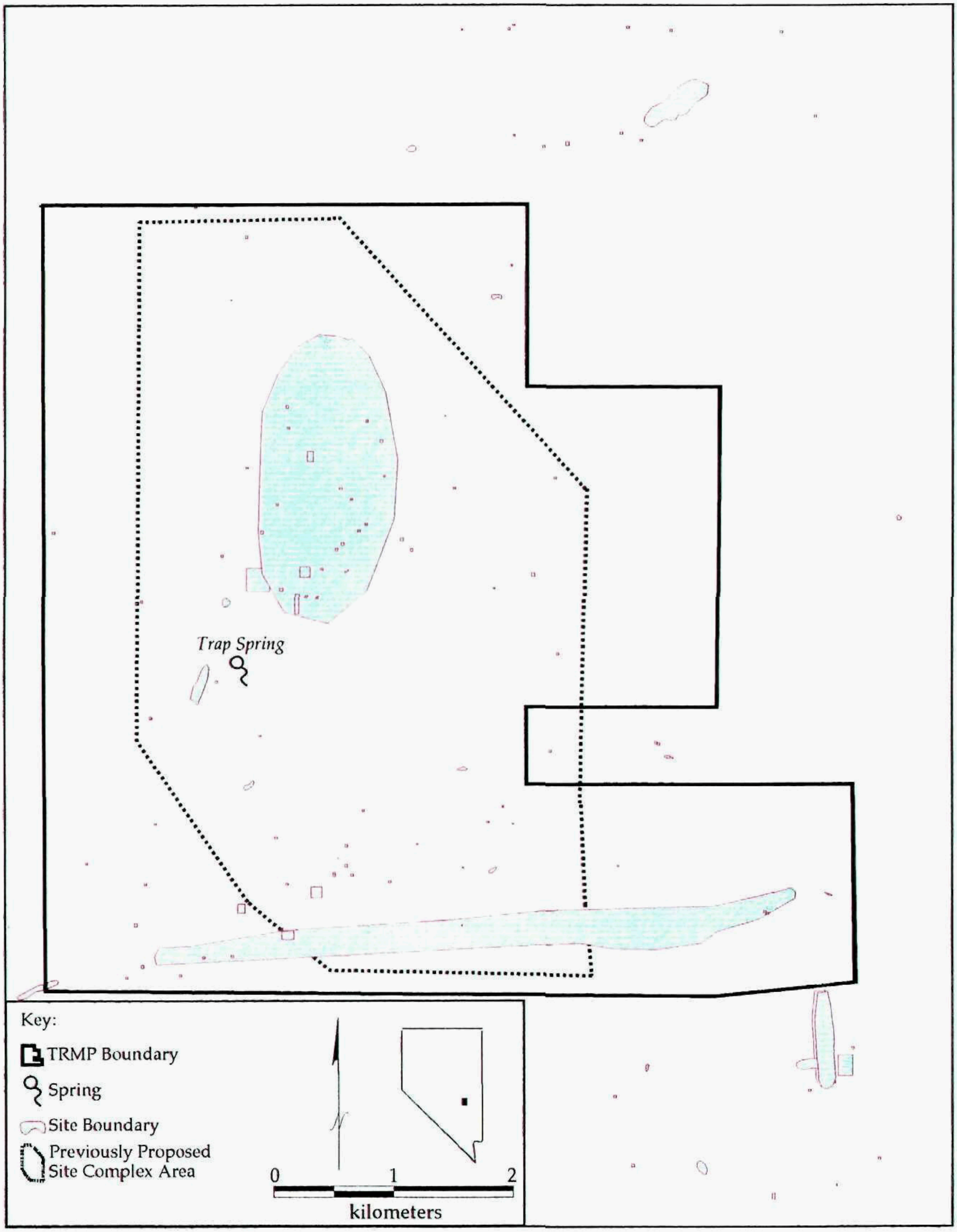


Figure C.1 Boundaries proposed for the Trap Spring Archaeological Complex and the Trap Spring/Gravel Bar TRMP Unit (after Mariah Associates 1989 and BLM 1997)

Table C.1 lists the area, percentage inventory, and site density of each area ranked by archaeological complexity score within the management area defined by the Tonopah Resource Management Plan (TRMP). Clearly, the model fails to predict archaeological complexity within the area; although site density correlates with complexity score in four cases (2, 3, 4, and 5), score 1 areas have lower site density than do score 2, 3, and 4 areas. Table C.2 and Figure C.2 suggest why this is so. With exception of one hectare of complexity score 1 (Habitat W1 around Trap Spring), all complexity score 1 habitat occurs on the far eastern and northern extremes of the TRMP area. These are areas of Habitats G3 and G17 associated with Duckwater Creek more than 2 miles from Trap Spring; perhaps archaeological remains in this area are more subject than elsewhere to burial by overbank flood deposits. Whatever the reason, these particular parcels have low site density and clearly are unrelated to Trap Spring.

Table C.1. Area, Percent Inventory, and Sites per Hectare in Areas Characterized by Archaeological Complexity Score in the Gravel Bar and Trap Springs TRMP Unit

Archaeological Complexity Score	Number of Hectares	Percent Inventoried	Sites per Hectare
1	900	17.3	0.03
2	1190	22.7	0.12
3	1180	36.5	0.06
4	163	12.7	0.05
5	110	15.7	0

Table C.2. Area, Percent Inventory, and Sites per Hectare of Habitat in the Gravel Bar and Trap Springs TRMP Unit

Habitat	Number of Hectares	Percent Inventoried	Sites Per Hectare
G17	273	13.9	0.03
G16	1110	15.4	0.09
G17	124	15.3	0
G3	608	20.4	0.02
G6	1409	38.1	0.08
W1	1	100	0
W4	18	21.5	0

The only defining criterion for the Trap Spring Archaeological Complex we have gleaned from site records is *sites in dune settings near Trap Spring*. Table C.3 provides empirical evidence that dune settings correlate with the criteria by which field archaeologists have judged sites eligible for the National Register of Historic Places. The table tallies site counts noted by site records in dune, non-dune, and unknown settings, versus site evaluations as eligible, ineligible, or not evaluated. Sample sizes within cells are too small for a reliable Chi-square analysis, but the table shows a correlation between dune settings and eligibility evaluation: 73% of all eligible sites occur in dunes (n=8).

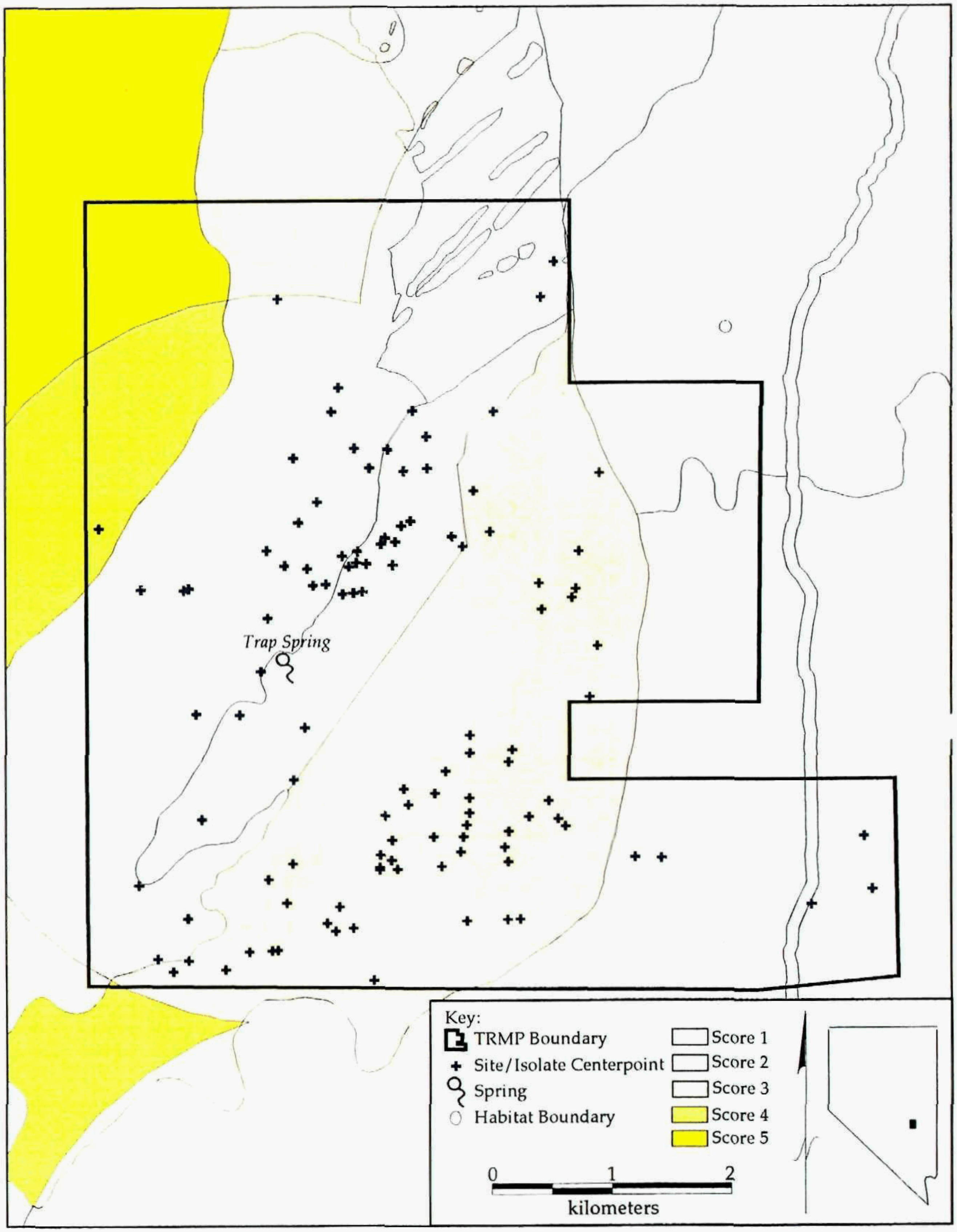


Figure C.2 Habitats, complexity score, and site locations of the Trap Spring/Gravel Bar TRMP Unit.

Table C.3. Eligibility Evaluations for Sites and Loci in Dune Settings Recorded within the Trap Springs/Gravel Bar TRMP Unit

	In Dune	Not In Dune	Unknown	Total	Proportion In Dune
Eligible	8	2	1	11	0.73
Ineligible	1	1	2	4	0.25
Not evaluated	16	17	76	109	0.15
Total	25	20	79	124	
Proportion Eligible	0.32	0.1	0.01	0.09	

In the seven habitats occurring within the Trap Spring and Gravel Bar TRMP Unit, coppice dunes should occur in Habitats G3 and G17, whereas semi-stabilized dunes and sand sheets should occur in Habitats G6 and G16. Table C.4 lists sites recorded within dunes by habitat in the area. No sites whatsoever occur in Habitat G17, but in G3, one of five occur in dunes. Sites in dunes account for 41% in Habitat G16 and 13% in Habitat G6. Table C.5 presents the distribution of eligible sites by habitat. Eligible sites occur only in Habitats G6 and G16. The absence of sites from Habitat G17, and the presence of eligible sites only in Habitats G6 and G16 suggests that the regional habitat model does not capture the local dynamics of dune formation within the vicinity of Trap Spring.

Table C.4. Sites in Dune Settings by Habitat in the Trap Springs/Gravel Bar TRMP Unit

Habitat	In Dune	Not in Dune	Unknown	Total	Proportion in Dune
G12	0	0	1	1	0
G16	12	3	14	29	0.41
G3	1	4	0	5	0.2
G6	12	13	64	89	0.13

Table C.5. Significance Evaluations by Habitat in the Trap Springs/Gravel Bar TRMP Unit

Habitat	Eligible	Not Eligible	Not Evaluated	Total	Proportion Eligible
G12	0	0	1	1	0
G16	4	2	23	29	0.14
G3	0	0	5	5	0
G6	7	2	72	88	0.08

Trap spring is located at the toe of the Ike Spring Wash fan where, after flowing through the coarse sediments of the fan, water is forced to the surface as it encounters the finer grained lake and alluvial sediments. A broad band of gravely lacustrine features including offshore bars oriented northeast/southwest covers the lower reach of the fan. East of the shore features lie salty, fine-grained sediments of an alkali flat, part of the alluvial plain of Duckwater Creek north of Gravel Bar Site. Duckwater Creek may have, from time to time, flowed west of its present course to breach the GBS through the channel at its west end. A discontinuous dune field several hundred meters wide lies on the juncture of lacustrine features and alluvial plain, in part, surrounding Trap Spring, but extending quite far to the northeast and southwest along the trend of fan toes and lacustrine gravel bars. The sand probably accumulates here because the change in slope and vegetation at the interface of fan toe and alkali flat catches wind borne sediments. However, southwesterly winds also form isolated small dunes and sand sheets on the alluvial plain east of Trap Spring. Sand and finer eolian sediments deposited on upslope alluvial fans are cycled back down to the alluvial plain by runoff where they contribute to the fan skirts and youngest alluvial fans; these are frequently inset in channels through the lacustrine gravel bars.

The distributions of sites recorded in dunes by landform (Table C.6) bear out this scenario. Although the alluvial plain (Qap) bears half the sites recorded in the Trap Spring and Gravel Bar TRMP Unit, only 8% of those occur in dune settings. In contrast, 34% of sites on fan skirts (Qfs), lacustrine gravel bars (Ql), and alluvial fans (Qof, Qyf, and Qyyf) occur in dunes.

Table C.6. Sites in Dune Settings by Landform in the Trap Springs/Gravel Bar TRMP Unit

Landform*	In Dune	Not In Dune	Unknown	Total	Proportion In Dune
Qap	5	13	48	66	0.08
Qfs	2	1	1	4	0.5
Ql	4	2	8	14	0.29
Qof	2	1	6	9	0.22
Qyf	9	2	10	21	0.43
Qyyf	3	1	6	10	0.3
Total	25	20	79	124	

*Qap = alluvial plain; Qfs = fan skirt; Ql= lacustrine bar; Qof = old fan; Qyf=young fan; Qyyf=youngest fan

Table C.7 shows the distribution of eligible sites by landform. Alluvial plains have a lower than expected proportion of eligible sites, consistent with the low proportion of sites in dunes. In fact, a map plot of eligible sites in the TSAC shows them aligned in a relatively narrow zone between 1460 m and 1480 m asl, largely coinciding with the dune field aligned northeast-southwest along the juncture of lacustrine features and alluvial plan. However, old alluvial fans and very young alluvial fans lack eligible sites, despite the high proportions of dune sites on these settings. This suggests that dunes and redeposited sand sheets on these landforms are too old or young to have been the loci of prehistoric activity (i.e., cultural materials in these sands are redeposited), or that more recent sand dunes and sheets have buried eligible cultural deposits.

Table C.7. Eligibility Evaluations by Landform in the Trap Springs/Gravel Bar TRMP Unit

Landform*	Eligible	Noneligible	Not evaluated	Total	Proportion Eligible Sites
Qap	3	2	61	66	0.05
Qfs	1	2	1	4	0.25
Ql	3	0	11	14	0.21
Qof	0	0	9	9	0
Qyf	4	9	17	30	0.13
Qyyf	0	0	10	10	0

Qap = alluvial plain; Qfs = fan skirt; Ql= lacustrine bar; Qof = old fan; Qyf=young fan; Qyyf=youngest fan

Our field examination of Trap Spring confirmed that artifacts, fire-cracked rock aggregations, and hearths are common in dune blowouts adjacent the spring, but uncommon on the gravely surfaces not covered by dunes. The surface sand is tan while the sand below surface is reddish in color due to weathering, indicating the possibility of some antiquity for the dune field. However, the presence of several active blowouts and others in the process of being recovered with sediment, suggests frequent reworking of the sands. Nevertheless, there are undoubtedly intact cultural features adjacent the spring.

These findings suggest boundaries for the Trap Spring Archaeological Complex. The complex concerns sites in a dune field that has formed near Trap Spring, in Habitats G16 and G6, on fan skirts, alluvial fans, and gravel bars. Testing must determine whether dunes and sand sheets on old and very young fans contain eligible sites, but surface data confirm that gravel bars, fan skirts, and young fans often contain eligible loci. Figure C.3 shows the boundaries of habitats (in color), landforms (outlined and labeled), inventory areas (color outlined), and center-points of previously recorded sites. Different center point symbols differentiate between those sites occurring in dunes and those not. Figure C.2 clearly indicates the linear northeast - southwest trend of sites in dunes along fan toes and gravel bars at the contact between Habitats G6 and G16, extending through Trap Spring. This area has been inventoried extensively and many sites have been recorded there.

Sites are also numerous on the alluvial plain in Habitat G6 and G3. However, these cluster on the eastern and southern margins of the TRMP unit, near Duckwater Creek. Only one occurs in a dune, none is eligible, and all probably are unrelated to Trap Spring. The extensively inventoried westward reach of the alluvial plain towards Trap Spring is barren of sites. The contrast between the duny, site-rich zone running through Trap Spring and the large empty area to the southeast is further support for the importance of sites in dunes as the defining criterion for delimiting the Trap Spring Archaeological Complex in the TRMP Unit.

We delineate such a boundary in Figure C.4, enclosing 880 ha, 44.5% of one previous delineation of the Trap Spring complex of 1998 ha. It encompasses all dune sites recorded in the TRMP area, with the exception of one in the far southeast. It also includes Trap Spring and the majority of eligible sites recorded in the TRMP.

Note that while the boundary encompasses the primary cluster of significant sites known to occur within 2 km of Trap Spring, it also extends an additional 3 km northward to include four peripheral sites. The intervening area appears in Figure C.4 to lack sites, but comparison with Figure C.3 reveals that this region has been subjected to comparatively little previous inventory. Furthermore, the intervening area of low significant site density includes lacustrine bars, fan skirts, and young alluvial fans in Habitat G16; circumstances that the preceding analysis suggests are very likely to bear eligible sites in dunes. Therefore, we have defined the boundaries to include these low density, but under sampled areas under the suspicion that they will prove to bear significant sites associated with the Trap Springs Archaeological Complex.

We propose these reduced boundaries as more suitable for management of significant resources than previously defined boundaries in the TRMP. We also propose this area as the subject of a Trap Spring Archaeological Complex data recovery plan. It encompasses a constellation of at least three features that were a major attraction to ancient people in TSAC: dunes, proximity to a perennial spring, and an ecotone between piedmont fans and the alluvial plain. This is an ancient and long term association, apparently extending from the earliest through the latest archaeological periods.

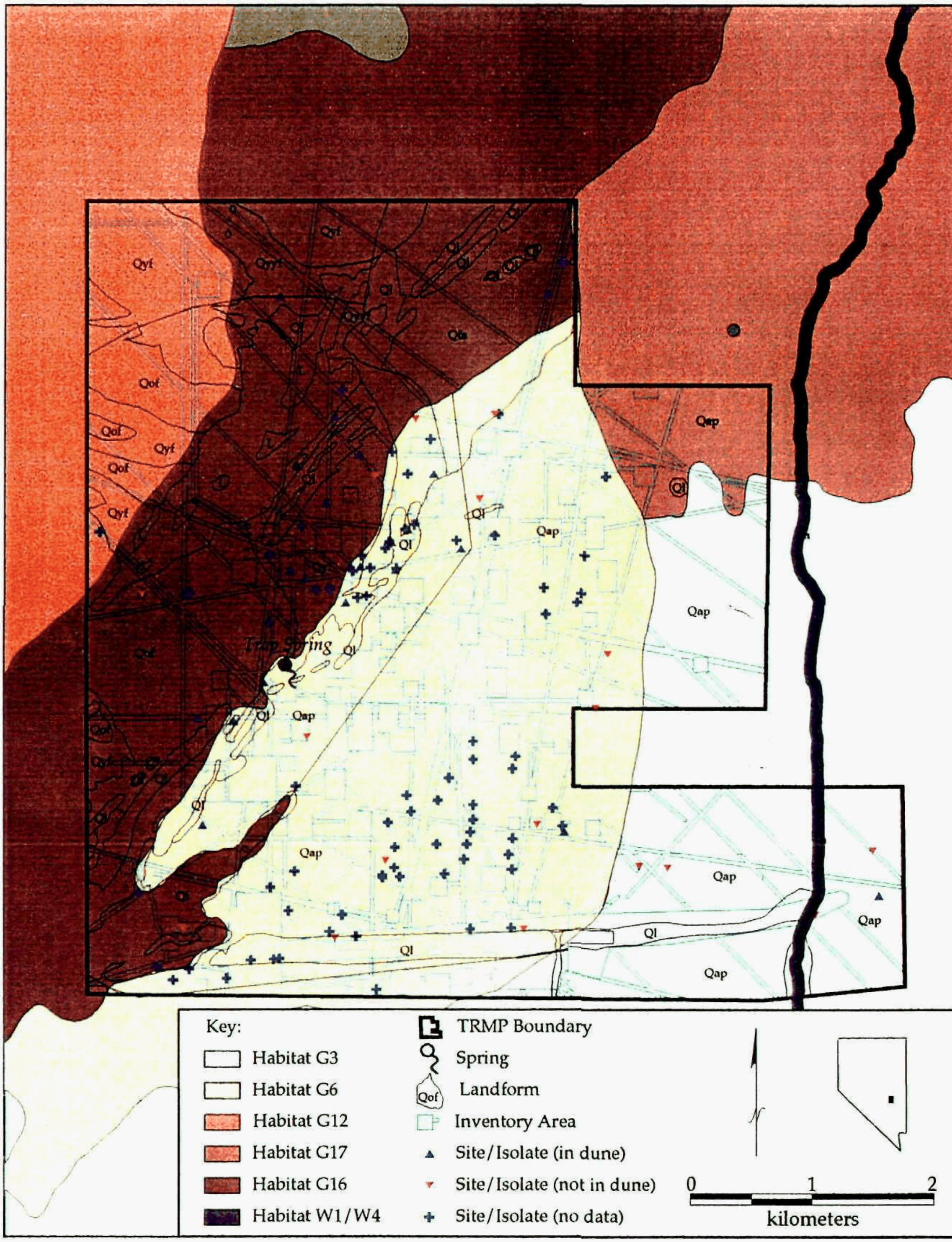


Figure C.3. Habitats, landforms, inventory areas, and site centerpoints of the Trap Spring/Gravel Bar TRMP Unit.

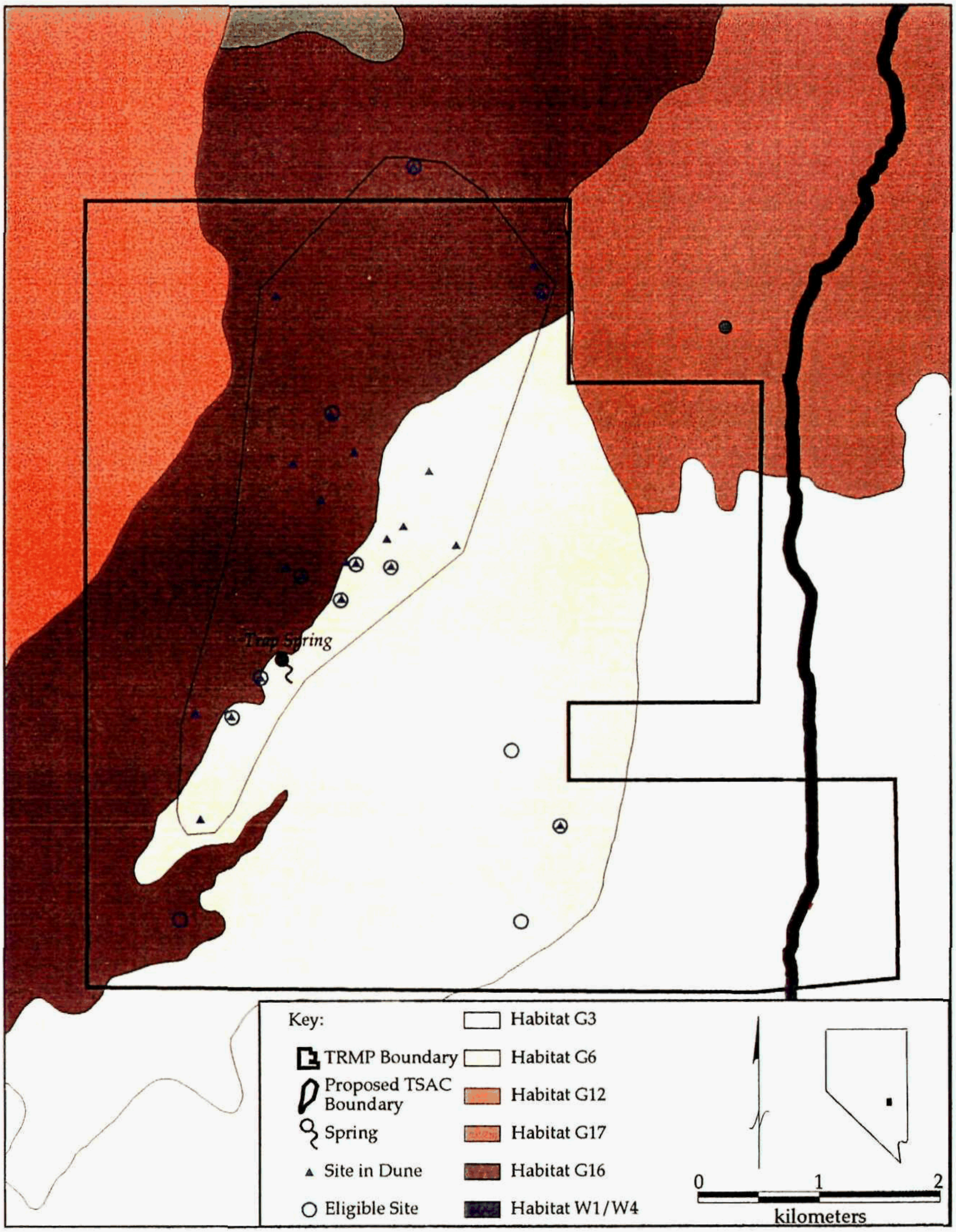


Figure C.4 Sites in dunes, eligible sites, and proposed boundaries for Trap Spring Archaeological Complex.

Goal of the Treatment Plan

The goal of this treatment plan is threefold:

- Sample a sufficient fraction of the archaeological content of the TSAC to characterize its variability along several axes.
- Evaluate individual sites for eligibility to the National Register of Historic Places.
- Mitigate impacts to archaeological materials threatened by development through data recovery, analysis, and publication of findings.

Research Domains

Sites in TSAC apparently span the complete range of archaeological time from the Pleistocene-Holocene transition to the latest Archaic. Consequently, many of the specific research questions we posed for investigation of the old archaeological materials on Gravel Bar Site are relevant here. At the other end of the temporal spectrum is the ethnographic period of the mid-nineteenth century. Julian Steward notes that "Duckwater people drove rabbits about 15 miles south of Duckwater in the valley flat...(1938:119)." This description and his map (Steward 1938:Figure 8) roughly coincide with the TSAC where, as noted in Chapter 4, Habitat G6 on the alluvial plain east of Trap Spring is one of the best habitats for jackrabbit.

Rabbit drives were directed by a rabbit boss from Duckwater and involved many people over a considerable period of time: "Twenty or thirty men had nets; the remaining men drove the rabbits to them. Hunts might last six weeks, though they did not drive every day. Villages participating with Duckwater were Curran [sic] Creek, Warm Springs, Hamilton and other villages in the northern part of the valley near Duckwater... (Steward 1938:119-120)".

If we assume that people desired a camp convenient to the rabbit drive, then perhaps the best choice would have been in Habitat G16 adjacent Trap Spring where water was available. With such a large number of people gathered for the rabbit drive, however, it is unlikely that everyone could have camped at the spring. Thus, the cluster of recorded sites within a kilometer or two of the spring is what we might expect. Of course, Habitat G16 is also fairly rich in other resources, including annual forbs, grasses, and shadscale; ground squirrel and other small animals are expected to be abundant in dunes and sand sheets, and antelope would have been attracted to the small patch of W1 habitat around Trap Spring itself. In fact, when antelope were the target prey, it would have made sense for people to camp some distance from the spring to avoid alarming the animals.

Most of the resources offered by Habitat G16, including rabbits, would have been attractive to people throughout much of prehistory—certainly from the early Middle Archaic. However, whether this was the case for Pre-Archaic people of the Pleistocene-Holocene transition is unknown. We suggested with regard to the Gravel Bar Site that many Pre-Archaic sites seem located convenient to both marsh resources and large game, while Pre-Archaic flaked stone tools seem appropriate for hunting and processing large game. Are the Pre-Archaic sites in the TSAC, therefore, more oriented to large game hunting than the early localities on the Gravel Bar Site?

The archaeological record of TSAC has the potential to contribute information toward significant research questions regarding cultural chronology, subsistence, land use, and technological organization throughout prehistory. Each of these domains is summarized below, and relevant research questions are identified.

Paleoenvironment

Reconstructing ancient environments is key to understanding prehistoric resources. While most of TSAC seems a poor environment for the preservation of pollen or plant macrofossils, it is possible that these are present in old deposits of Trap Spring. The Trap Spring site record (BLM CRNV-06-220, McGonagle 1979) shows an old spring mound south of the extant spring, and other spring deposits could be buried under dune sand and/or alluvial deposits. It is even remotely possible that, if present, such deposits may intercalate with lacustrine sediments of the Pleistocene-Holocene transition. Consequently, an effort will be made to locate these deposits by coring and/or by mechanical excavation. Samples will be taken for radiocarbon assay and analysis of any pollen or plant macrofossils present.

It is also likely that the linear dune field in TSAC is related to the dunes on and west of GBS. Correlations between the two will be sought in stratigraphic studies of test excavations and backhoe trenches.

Cultural Chronology

It may be that archaeological research in TSAC can inform about issues regarding cultural chronologies proposed for the Pleistocene-Holocene transition. Most sites there seem later in age, however, and more likely related to the Archaic (Elston 1986a). The basic chronological structure for the various periods of the Archaic in the Great Basin are fairly well worked out (Thomas 1981; Elston 1986a; Holmer 1986). Chronological questions have tended to focus on the temporal boundaries of changes in projectile point style (Flenniken and Wilke 1989; Bettinger et al. 1991). When, for example, were projectile points classified by archaeologists as Elko Corner-notched in use - during a relatively restricted interval between 4300 and 1300 BP or through a much longer interval? If the former, these artifacts are valuable time markers that can be used to roughly date sites; if the latter, they are poor time markers. Resolution of this and similar questions regarding projectile point chronology requires relatively undisturbed cultural deposits, associations with radiocarbon dated materials, and obsidian specimens. All of these data classes are likely to occur in TSAC.

On the other hand, an important chronological question which may well be addressed in the TSAC regards when ceramics first appeared. This question relates to the Numic Spread hypothesis (Bettinger and Baumhoff 1982) and to westward expansion of Fremont hunter-gatherer-farming people from Utah (Talbot and Wilde 1989).

Judging from the frequency of fire-cracked rock in sites of TSAC, hearths with datable charcoal are likely to be common. We recommend searching for hearths with test excavations and backhoe trenches, and collecting and dating charcoal samples for radiocarbon assay. Obsidian hydration could provide a relative chronology of artifacts if obsidian is more common in TSAC than at GBS. As many hydration samples as possible will be obtained from TSAC. If necessary, pottery can be directly dated by thermoluminescence (Bradley 1985). The expense of this technique, however, suggests resort to it only if no pottery can be found in association with materials that can be dated by ^{14}C assay.

Assemblage Variability and Site Function

The lack of reliable quantitative data regarding the density, content, and variability among surface lithic assemblages in TSAC makes it difficult to discriminate between archaeological components or to evaluate them. Consequently, we are unable to statistically compare site assemblages within the complex as we did with our (Chi-squared) analysis of collected assemblages from GBS. This limits our confidence in discerning differences in temporal occupation and function, although we have done so using the regional monothetic site typology and extant site records. Table C.8 compares the frequencies and percentages of functional site types, as defined in the regional typology, in TSAC with all recorded sites in Railroad Valley. The difference between the two samples is significant ($X^2 = 19.97$, $p = .0005$). Analysis of standardized residuals of the X^2 matrix (Bettinger 1989) shows that the greatest difference lies in frequencies of residential sites which are greater than expected in TSAC and less than expected in Railroad Valley as a whole. The abundance of residential sites in TSAC fits well with the ethnographic model, since field camps associated with logistic rabbit drives are likely to be classified as residential sites.

Table C.8. Frequency and Percent of Functional Site Types in Trap Springs Archaeological Complex and All Railroad Valley

Site Type	TSAC n	TSAC %	Railroad Valley n	Railroad Valley %
Lithic Reduction	16	30.77	534	40.33
Men's Subsistence	11	21.15	273	20.62
Women's Subsistence	2	3.85	69	5.21
Residential	12	23.08	98	7.4
Unclassifiable	11	21.15	350	26.44
Total	52		1324	

More detailed site recording and systematic surface collection will be made at all sites in TSAC so far evaluated as eligible for the National Register of Historic Places, as well as sites discovered in the recommended quadrat sample described later.

Buried Deposits

We believe that many of the sites in dunes are likely to contain buried cultural deposits because of their depostional context, the frequent occurrence of fire-cracked rock features reported on TSAC sites, and the high frequency of residential sites documented in Table C.8. If the ethnographic record is correct, some sites or components of sites, were created during short-term residential occupations, and these probably will provide the best chance of recovering features such as hearths and possibly brush structures. Such deposits may be rather limited in area and thickness, which will facilitate their exposure and collection. Assemblages of artifacts and features recovered from such excavation will provide data regarding assemblage variability, site structure, and chronology.

Subsistence

If faunal and floral remains are preserved in hearth fill and other cultural deposits, their excavation will support model predictions for resources in Habitats G6, G16 and W1. The model suggests that bones of rabbit, ground squirrel, and antelope will be relatively abundant. The sites of rabbit drives themselves, held east of Trap Spring out in the alluvial plain (Steward 1938:119), may be effectively invisible since use of nets and rabbit sticks would have generated few lithic artifacts. On the other hand, processing rabbits entailed evisceration, skinning, and drying. Assemblages at processing sites will contain lots of rabbit bone, along with processing tools such as flake tools and bifaces. Features may include cooking and drying hearths, and perhaps evidence of drying racks. Antelope bone should be common in sites closest to Trap Spring where antelope would have been attracted to water and most vulnerable to hunters. We anticipate that sites at which people focused on seed collection will contain abundant ground stone tools, along with hearths containing parched seeds from annual grasses and shadscale. If pottery is found, it can contribute direct information concerning subsistence through analysis of cooking residues.

Lithic Technology and Procurement

We assume that Steward (1938) was correct in his characterization of rabbit drives in northern Railroad Valley. Trips to the rabbit drive from the village site were logistic (Binford 1980), in that a special trip was made from home base to procure a particular resource from special camps set up for the purpose. Thus, we expect that people geared up (prepared the tools and supplies needed to support the trip) while at home. If so, they would have tended to bring fully functional tools with them, and we expect to see relatively little procurement of local toolstone, or manufacture of tools made from it, but substantial evidence of tool repair and resharpening. Moreover, if many different groups of people from northern Railroad Valley cooperated in rabbit drives, and each group tooled up at home in preparation, toolstone source variability will probably be high in lithic assemblages at rabbit processing and rabbit drive base camp sites.

Origins of Ceramics

Ceramics in Railroad Valley may have gotten there in one of two ways: either they were manufactured locally, or they were imported. For example, it is likely in Railroad Valley that painted black and white pottery, as well as some gray ware, was imported from Fremont areas to the east. Local manufacture of painted ware, however, would suggest closer ties between Railroad Valley and Fremont people than currently accepted; it might even suggest the presence of Fremont People in Railroad Valley. Petrographic analysis through thin section can reveal whether ceramics were made from local or exotic materials, and when pottery is non-local, analysis often can identify its source (Dean 1992). We strongly suggest that ceramics recovered in TSAC be subjected to petrographic analysis.

Too, the circumstances under which central Great Basin hunter-gatherers incorporated ceramics into their foraging technology remains poorly understood. Were ceramics merely added into previous subsistence-settlement strategies, does their appearance mark the arrival of immigrant foragers into the area, or do they signal a subsistence-settlement intensification among indigenous foragers associated with seed use, wild seed cultivation, food storage, or residential stability? Investigations of ceramics in the context of chronological data, assemblage composition, and subsistence will be informative about these issues.

Treatment Plan

Management of archaeological sites in TSAC suffers from insufficient information.

- Sites have been recorded to different standards over time and site records are of variable quality
- There are too few data from which to estimate accurately surface artifact distribution and density; site boundaries often are poorly defined.
- Artifact collections from sites in TSAC are limited to grab samples of tools and projectile points. Artifacts are minimally described; little is known of lithic technology and procurement.

- Absent systematic artifact collections, analysis of variability and assignment of functional site type are problematic in TSAC.
- Sites in TSAC are poorly dated.
- Virtually nothing is known about the presence or absence of a subsurface archaeological record in TSAC sites.
- There is little information from which to reconstruct the paleoenvironmental context of sites in TSAC.

The following treatment plan will collect information with which to assess archaeological variability, evaluate archaeological significance of selected archaeological sites, and mitigate impacts to archaeological properties by potential development.

Treatment Plan: Quadrat Sampling and Mitigation

This plan entails sampling TSAC and performing data recovery on a fraction of the archaeological record at a level determined during implementation of the treatment plan. Among other advantages, this approach will allow further testing and refinement of quantitative predictions about the likely archaeological content of TSAC and each of its various environmental strata (habitats, geomorphic units) made by the model developed in this report. However, this proposal is quite different from standard approaches where the archaeological units are sites, but is similar to sampling designs employed in the Carson Desert (Raven and Elston 1989; Zeanah 1996), and especially in the Reese River and Monitor Valleys (Thomas 1971, 1975, 1988).

When the population is a group of sites, one first selects either the entire population of sites or some fraction for study, and then samples again (by surface collection, excavation, and so on) within each site chosen. A problem with using sites as study units is that the population of sites must be defined prior to drawing the sample. To employ a sampling approach to sites in TSAC, for example, all sites (or a large fraction) must be known prior to drawing the sample. Another problem is how sites in the population have been defined. If isolated finds and small lithic scatters have received less attention in the past, these classes of site will be underrepresented in the sample.

To avoid the problem of imperfect knowledge of site population, this treatment plan views the redefined TSAC as the entity to be studied: an area in which the archaeology is likely to be related to particular themes such as rabbit drives, antelope hunting, seed gathering, and Pre-Archaic large game hunting is to be studied, and 1 ha quadrats are the sample units. This requires a grid of 1 ha sample units imposed on the TSAC, from which a random sample of units can be drawn. Random sampling has the advantage of allowing the sample size to be estimated prior to field work. The sample fraction in TSAC (as explained below) will be about 22%.

Two phases of investigation are anticipated, but these are not the usual "evaluation" and "data recovery" of the standard Section 106 process, because data collected during the sampling phase are data recovered to make a major contribution to mitigation. Research questions will be informed by the archaeological content of quadrats and the distribution of artifacts among quadrats in different environmental situations. Each quadrat drawn in the stratified random sample will be intensively surveyed at close transect intervals (10 m) and the archaeological contents recorded in detail. Subsurface testing may be required to fully evaluate the archaeological record in particular quadrats. The content of each quadrat will indicate whether more fine grained data collected by surface collection or excavation is warranted in that quadrat. Site boundaries will be mapped within each sampled quadrat, but nothing will be recorded outside sample units (i.e., site boundaries will not be "chased"). Upon completion of the sample inventory, the field data will be analyzed and an interim report prepared which presents inventory findings and recommendations for further data recovery through systematic surface collection and/or excavation, if warranted.

The two phases entail several groups of tasks: 1) drawing and inventorying a sample of TSAC in 1 ha quadrats at 5m transect intervals; producing a report evaluating the archaeological content of sample quadrats with regard to thematic research questions and containing a research design for further data recovery if warranted; 2) conducting any further data recovery; completing analysis of collected data; creating a final report.

Because the treatment plan is essentially a shortcut to data recovery and mitigation of archaeological values in TSAC bypassing the usual Section 106 consultation, its implementation probably will require a Memorandum of Agreement. However, because mitigation of archaeological values will be complete when the final report is accepted, there is no need for a TSAC National Register District at any point in the process.

The Treatment Plan has the advantage of completing mitigation in TSAC in a short amount of time with little management overhead, and it is likely to be very productive from a scientific standpoint. It is an innovative, streamlined approach to cultural resource management. Its disadvantage lies in the cost of mitigation which would be upfront rather than spread out over a long time.

Sampling Tasks

The sample will not be drawn from the population of archaeological *sites* in TSAC. Rather, a sample of quadrats in TSAC will be selected for study. With reasonable confidence we wish to draw a *sample* of quadrats in which the proportions of archaeological entities (tools, items of debitage, features, manuports, and so on) are representative of the *population* of the proportions of archaeological entities in TSAC (cf. Thomas 1975:62). Accomplishing this requires a strategy of random sampling, wherein we

- choose a sample unit;
- impose a grid of sample units on a map of the study area;
- choose a level of confidence;
- choose a sample size (number of units to be sampled);
- select the units to be sampled; identify the units on the gridded map.

Drawing a sample of quadrats is a strategy of cluster sampling, wherein "the samples consist not of elements [sites] but of units of...space (Judge et al. 1975:86)." We want to be confident that our sample of quadrats with their content of archaeological entities is a representative sample. Because we have no idea of the population parameters of archaeological entities in TSAC, we must either guess (cf. Drennan 1996:143) or employ a proxy. Fortunately, we can use the extant sample of recorded sites in TSAC as a proxy. Perhaps this seems paradoxical, since we have decided to sample among quadrats rather than sites in order to discover the distribution of archaeological entities (tools, items of debitage, features, manuports, and so on) in TSAC. Sites are aggregations of archaeological entities, and we assume that the sample of sites recorded by previous Class III inventories within TSAC at least roughly reflects the population of sites in TSAC (minus isolated finds and small lithic scatters, large numbers of which may go unrecorded in Class III inventory). Therefore, we assume that the population of archaeological entities in the recorded sites at least roughly reflects the population of entities in TSAC. We impose a grid of 1 ha quadrats over TSAC, count the numbers of quadrats covered (even partially) by Class III inventory, and count the numbers of "hits" or quadrats containing recorded sites (of course, the number of hits is not equal to the number of sites because some sites are larger than 1 ha, and some quadrats contain more than one site). The ratio of hits among Class III inventoried quadrats (expressed as a percentage) is then used to estimate population parameters within specified confidence levels.

Our experience in regional sampling suggests that square units (quadrats) are the most economical to map, locate on the ground, and survey. The size of the quadrat usually conditions sample size (number of quadrats) which, in turn, influences the magnitude of variation around the mean in the sample, a number we prefer to minimize. Large quadrats are more economical to locate and survey, but their use reduces sample size, which increases variation. For example, the error around the mean in a sample of 20 quadrats of $5m^2$, will be greater than that for a sample of 100 quadrats of $1m^2$, even though the area covered by both samples is the same. Too, we want sample units to approach the size of well pads and other elements of petroleum development and production. Consequently, for sampling within TSAC, we recommend 100 m by 100 m square quadrats, 1 ha in area.

The border around the revised TSAC encompasses 880 ha. However, imposing a 100 m grid over the area creates a sample universe of 969 quadrats, each 1 ha. in area. The sample universe is larger because, to avoid border effects, the sample universe is comprised of all quadrats within the TSAC border, as well as all quadrats touched by the border, many of which extend outside it.

What is the probability that the proportion of quadrats containing sites in our sample is close to the proportion of quadrats containing sites in the population of 969 quadrats comprising TSAC? A 95% confidence interval is common in archaeological sampling and statistical analysis, and we would feel comfortable recommending it. At a 95% confidence interval, we will have only a 5% chance of being wrong when we estimate that the proportion of quadrats with sites in TSAC is equal to the proportion in the sample, ± the standard error.

To calculate the standard error, we must first calculate the standard deviation of the sample proportion (Drennan 1996:140):

$$s = \sqrt{pq} \qquad \text{(equation 1)}$$

where:

s = the standard deviation of the sample proportion;
p = the proportion expressed as decimal fraction
$q = 1 - p$

We can estimate s (sample proportion) from extant data. First, to obtain sample proportions, we imposed a grid of 100 x 100 m (1 ha) quadrats over TSAC and counted all the quadrats containing a recorded archaeological site or portion of a site. In Table C.9, the sample of recorded sites from TSAC is divided or stratified by occurrence in habitat and geomorphic unit. The proportions (expressed as a percentage) of quadrats in each category containing sites is given in the seventh column of the table. These numbers provided the values for p in equation (1).

The standard error of the proportion given in column 8 of Table C.9 is calculated by equation (2), substituting s for σ (the population standard deviation) (Drennan 1996:140):

$$SE = \frac{\sigma}{\sqrt{n}}\, t \sqrt{1 - \frac{n}{N}} \qquad \text{(equation 2)}$$

where:

σ = population standard deviation
n = sample size
t - Student's t for n-1, 95% confidence interval
N = population size

The second radical in equation (3) is the finite population corrector (FPC) which can be applied because we know the population size of TSAC is 969 quadrats. Use of the FPC reduces the standard error.

For example, with a corrected standard error of ±2.69, we can be 95% confident that the proportion (expressed as a percentage) of quadrats in TSAC containing sites in Habitat G16 and located on young fans lies between 23.37% and 34.04%. Table C.9 reflects the effects of both sample size (number of units) and sample fraction (percent inventoried). Notice that the standard error is generally lower for samples in which the number of inventoried quadrats is highest (for example, G16/Ql; G16/Qyf; G6/Qap and total), while sample size effects the standard error less.

Table C.9. Standard Errors (95%) of Sample Proportions (Expressed as Percent) for Strata Comprised of Habitat and Geomorphic Unit in Trap Springs Archaeological Complex

Habitat	Geomorphic Unit*	Total Quadrats	Inventoried Quadrats	% Inventoried	Total with Sites	% with Sites	95% Standard Error
G16	L	16	8	62.5	0	0	
G16	Qap	1	1	100	1	100	
G16	Qfs	156	50	32.05	4	8	±3.84
G16	Ql	187	95	51.34	8	8.42	±2.85
G16	Qof	94	79	84.04	18	22.78	±4.72
G16	Qyf	175	108	65.71	31	28.7	±4.35
G16	Qyyf	52	25	51.92	1	4	±3.92
G6	Qap	141	114	82.98	9	7.89	±2.53
G6	Qfs	41	30	70.73	12	40	±9.46
G6	Ql	29	27	93.1	12	44.44	±5.13
G6	Qof	20	16	80	1	6.25	±5.77
G6	Qyf	19	14	78.95	9	64.29	±14.19
G6	Qyyf	37	34	97.3	17	50	±4.93
W1	Qyf	1	1	100	1	100	

*L = lagoon; Qap = alluvial plain; Qfs = fan skirt; Ql= lacustrine bar; Qof = old fan; Qyf=young fan ; Qyyf=youngest fan

Table C.9 suggests we should reduce the number of strata to decrease the sample size effect. Table C.10 shows the relatively small standard errors calculated for two strata comprising the two major habitats in TSAC, G16 and G6, as well as for TSAC as a whole. This approach also focuses attention on habitat type, which serves as the predictive basis of our land use model. Table C.10 indicates that we can be 95% confident that the proportion (expressed as a percentage) of quadrats in TSAC containing sites in Habitat G16 lies between 15.87% and 18.55%, while that of Habitat G6 lies between 46.13% and 53.05%. Table C.10 also provides the standard error for the proportion of quadrats in TSAC as a whole, between 19.59% and 21.61%.

Table C.10. Standard Errors (95%) of Sample Proportions (Expressed as Percent) for Strata Comprised of Habitats G16 and G6 in Trap Springs Archaeological Complex

Habitat	Total Quadrats	Inventoried Quadrats	% Inventoried	Total with Sites	% with Sites	95% Standard Error
G16	681	366	53.74	63	17.21	±1.34
G6	287	121	42.16	60	49.59	±3.46
All	969	602	36.04	52	20.6	±1.01

To decide how large our random sample of quadrats must be in order to estimate proportions of quadrats with sites in particular habitats or containing particular types of sites, we employ equation (3) in which s (the standard deviation of the sample proportion) is again substituted for σ (the population standard deviation) (Drennan 1996:143):

$$n = \left(\frac{\sigma t}{ER} \right)^2 \qquad \text{(equation 3)}$$

where:

n = sample size
σ = population standard deviation
t - Student's t for n-1, 95% confidence interval
ER = error range (5% at the 95% confidence level)

We want to be reasonably sure we can estimate from our sample the proportions of quadrats with sites in TSAC by habitat, landform, site type contained, or other variable. To this end, we choose an error range of 5%, insuring a spread no wider than ± 5% at the 95% confidence level. Note that when we assure ourselves of the ability to make estimates within particular limits of proportions of quadrats with various characteristics, we are also assuring ourselves that the sample we draw will be representative of the variation present in the total population of quadrats in TSAC.

Table C.11. Sample Sizes Required to Estimate Proportions of Quadrats with Sites in Habitats G16 and G6, 5% Error Range at 95% Confidence Level

Sampling Stratum	Sample Size (n)	Sample Fraction (%)
Habitat G16	218.97	32.15
Habitat G6	384.13	56.41
All Quadrats	251.32	32.15

Note the difference in sample size and sample fraction between the two sample strata in Table C.11. This is again due mostly to the sample size effect (G16 three times larger than G6). To sample both Habitats G6 and G16 to produce a 5% error range at the 95% confidence interval will require a total sample of 384 quadrats, a sample size of 62%.

But consider that the 5% error sample size for all quadrats (an unstratified sample) is only 251 quadrats (sample fraction = 25.94%). Could we be content with a slightly higher error range for estimating the proportion of quadrats with sites in habitats G16 and G6? At an error rate of 10%, the estimated ranges for numbers of quadrats with sites in each stratum are given in Table C.12. Substituting a sample size (n) of 125 in equation (3) and solving for ER, yields error ranges of 6.62% for Habitat G16 and 8.77% for Habitat G6, both somewhat lower than estimated in Table C.11. Thus, the somewhat higher error rates seem reasonable to us, and we can recommend a sample of 125 quadrats in each of strata G16 and G6.

Table C.12. Estimated Range of Quadrats with Sites in Sampling Strata G16 and G6 at 0.10% Error Range at 95% Confidence Level

Sampling Stratum	Number of Quadrats in Stratum	Estimated Number of Quadrats with Sites	Range of Estimated Quadrats with Sites	
			Low	High
G16	681	117	102	132
G6	287	139	123	155
Total	968	256	225	287

Aggregations of archaeological entities commonly referred to as residential sites are key to both scientific inquiry and management in TSAC because they are more likely to be complex and data-rich than other types of aggregations, and information from them can contribute to a large number of research questions. As we have discussed, the proportion of residential sites is higher in TSAC than in Railroad Valley as a whole; perhaps this is due to ethnographic and prehistoric use of TSAC for rabbit drives. Since residential sites comprise 23.08% of recorded sites in TSAC (Table C.8), at the 10% error rate, we can expect between 23.5 and 30.5 quadrats with residential sites in stratum G16, and between 28.4 and 35.8 quadrats with residential sites in stratum G6.

Two random samples of 125 quadrats were chosen from Habitat G6 and Habitat G16 (Table C.13). The combined sample 250 quadrats will be subjected to intensive inventory and data recovery. Some argue that sampling is all very well for obtaining the range of common archaeological entities, but a poor strategy for discovery of the unique, data-rich aggregation such as at Danger Cave or the Great Pyramid of Giza, either of which might fall outside the sample drawn randomly. We agree! Our experience suggests that the most data-rich archaeological aggregations are likely to be at and adjacent Trap Spring. Consequently, we purposely select a an additional nine 1 ha quadrats centered on Trap Spring for inventory and treatment. Too, we select an additional two quadrats known from prior inventory to contain Pre-Archaic materials. This creates a final sample of 261 quadrats, illustrated in Figure C.5.

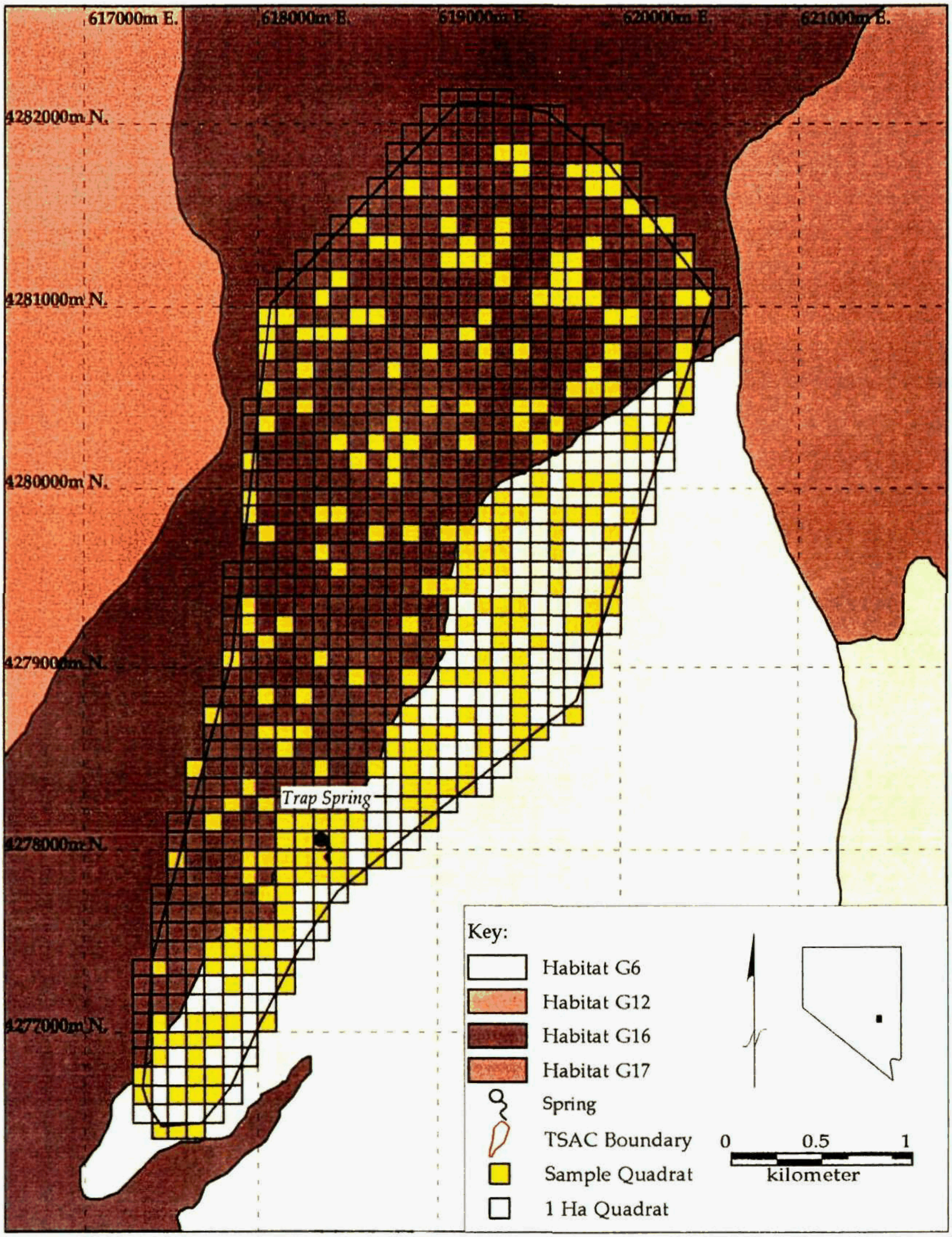


Figure C.5 Sample units selected for data recovery at the Trap Springs Archaeological Complex.

Treatment Tasks

Treatment is designed to be the completed in the shortest possible time, by a single research organization.

SAMPLE INVENTORY OF TSAC, DATA COLLECTION PHASE

1. For each sample quadrat, conduct intensive survey at 10 m transect intervals, flagging artifacts and features; establish site boundaries within quadrat.
3. Map quadrat; record surface artifact distribution and density.
4. If necessary, undertake test excavations to check for presence of buried features and cultural deposits, and for paleoenvironmental potential.
5. Prepare any stratigraphic descriptions and profiles from tests.
6. Collect any faunal or floral materials from test units.

CONDUCT PRELIMINARY ANALYSIS AND PREPARE INTERIM REPORT

1. Create master catalog for TSAC.
2. Create master map; add surface artifact data and locations of test units.
3. Submit samples for radiocarbon assay.
4. Prepare stratigraphic descriptions and profiles of backhoe trenches and excavation units.
5. Identify faunal materials recovered from test units; analyze faunal assemblages.
6. Process any hearth samples by flotation.
7. Identify plant macrofossils from float samples; analyze macrofossil assemblages.
8. Create comprehensive descriptions of artifacts recovered in tests.
9. Perform analysis of artifact distribution by stratum for excavated samples.
10. Evaluate contents of sample quadrats for further data recovery via surface collection and/or more extensive excavation.
11. Prepare, produce, and distribute a comprehensive, illustrated inventory report with preliminary interpretations and research design for further data recovery, if necessary.

INTENSIVE DATA RECOVERY IN TSAC

We expect that survey, testing, and evaluation will comprise sufficient mitigation in many quadrats of the TSAC sample. However, some sample quadrats will contain aggregations of archaeological entities requiring more extensive investigation. It is not possible to specify in advance all of the tasks involved in intensive data recovery. Different questions and problems will call for different approaches. For example, very extensive and/or dense lithic scatters might require large scale surface collection or development of strategies for sampling. The study of groups of buried features may require block excavations, excavation of large surfaces, or both. A few quadrats (such as those adjacent Trap Spring) may contain significant paleoenvironmental information best recovered by backhoe trenching or coring. Data recovery beyond the inventory phase will generate additional tasks of analysis and report preparation, including cleaning, cataloging, describing, analyzing, interpreting, illustrating, writing, managing documents and specimens, and final report production.

Once intensive data recovery is implemented, the entire TSAC (including all non-sampled quadrats) will be fully mitigated and open for development.

Table C.13. Sample Units Selected for Data Recovery at the Trap Springs Archaeological Complex

UTM Easting of SW Corner	UTM Northing of SW Corner	Habitat	Landform	Sites Previously Recorded	Previous Inventory	Note
617300	4276600	G6	Qof	N	N	
617300	4276700	G6	Qof	N	Y	
617400	4276400	G6	Qap	N	N	
617400	4276800	G6	Qof	N	Y	
617400	4276900	G16	Qof	N	Y	
617400	4277000	G16	Qof	N	Y	
617400	4277300	G16	Qof	N	Y	
617500	4276400	G6	Qap	N	Y	
617500	4276600	G6	Qap	Y	Y	
617500	4276900	G6	Qof	N	Y	
617500	4277900	G16	Qof	N	N	
617600	4276400	G6	Qap	N	Y	
617600	4276600	G6	Qap	N	Y	
617600	4276700	G6	Qap	N	N	
617600	4276800	G6	Qap	N	Y	
617600	4276900	G6	Qap	N	Y	
617600	4277000	G6	Qof	N	Y	
617600	4278400	G16	Qof	N	Y	
617700	4276600	G6	Qap	N	N	
617700	4276700	G6	Qap	N	Y	
617700	4276900	G6	Qap	N	Y	
617700	4277000	G6	Qof	N	Y	
617700	4277300	G6	Qof	N	Y	
617700	4277400	G6	Ql	Y	Y	
617700	4278100	G16	Qof	N	Y	
617700	4278700	G16	Qof	N	Y	
617800	4277000	G6	Qof	N	Y	
617800	4277200	G6	Ql	N	Y	
617800	4277400	G6	Qof	Y	Y	contains Pre-Archaic material
617800	4277500	G6	Qof	N	Y	
617800	4278200	G16	Qof	N	N	
617800	4279000	G16	Qof	N	Y	
617900	4277300	G6	Ql	N	Y	
617900	4277400	G6	Qof	N	Y	
617900	4277500	G6	Ql	Y	Y	
617900	4277800	G16	Qof	Y	Y	
617900	4277900	G16	Qof	Y	Y	
617900	4278300	G16	Qof	N	N	
617900	4279200	G16	Ql	N	N	
617900	4279300	G16	Ql	N	N	
617900	4279800	G16	Ql	N	N	
617900	4279900	G16	Ql	N	N	
617900	4280100	G16	Ql	N	N	
618000	4277000	G6	Qap	N	Y	
618000	4277400	G6	Ql	N	Y	
618000	4277500	G6	Ql	N	Y	
618000	4277700	G16	Qap	Y	Y	
618000	4277900	G16	Qof	Y	Y	
618000	4278200	G16	Qof	Y	Y	
618000	4278600	G16	Qof	N	Y	
618000	4278800	G16	Qyf	Y	Y	
618000	4279100	G16	Qyf	N	Y	

Table C.13—*Continued.*

UTM Easting of SW Corner	UTM Northing of SW Corner	Habitat	Geogorm	Sites Previously Recorded	Previous Inventory	Note
618000	4279700	G16	L	N	N	
618000	4280300	G16	Ql	N	N	
618000	4280500	G16	Ql	N	Y	
618000	4280700	G16	Ql	N	Y	
618000	4280800	G16	Qyyf	N	Y	
618000	4280900	G16	Qyyf	N	N	
618100	4277200	G6	Qap	N	Y	
618100	4277300	G6	Qap	N	Y	
618100	4277500	G6	Ql	N	Y	
618100	4277600	G6	Qap	N	Y	
618100	4277700	G6	Ql	Y	Y	
618100	4277800	G6	Qap	N	Y	adjacent Trap Spring
618100	4277900	G16	Qof	N	Y	adjacent Trap Spring
618100	4278000	G16	Qof	N	Y	adjacent Trap Spring
618100	4278100	G16	Qof	N	Y	
618100	4278500	G16	Qof	N	Y	
618100	4278600	G16	Qyf	N	Y	
618100	4279200	G16	Qyf	N	Y	
618100	4280900	G16	Qyyf	Y	N	
618200	4277800	G6	Qap	N	Y	adjacent Trap Spring
618200	4277900	W1	Qyf	N	Y	Trap Spring
618200	4278000	G16	Qof	N	Y	adjacent Trap Spring
618200	4278100	G16	Qof	N	Y	
618200	4278600	G16	Qyf	Y	Y	
618200	4278800	G16	Qyf	N	Y	
618200	4280400	G16	Ql	N	N	
618200	4280600	G16	Ql	N	Y	
618200	4280800	G16	Ql	N	N	
618300	4277600	G6	Qap	N	Y	
618300	4277800	G6	Qap	N	Y	adjacent Trap Spring
618300	4277900	G6	Qyf	N	Y	adjacent Trap Spring
618300	4278000	G16	Qyf	N	Y	adjacent Trap Spring
618300	4278100	G16	Qyf	N	Y	
618300	4278400	G16	Qyf	N	Y	
618300	4279000	G16	Qyf	Y	N	
618300	4279600	G16	Qyf	N	N	
618300	4279800	G16	Ql	N	N	
618300	4280800	G16	Qyyf	N	Y	
618300	4281000	G16	Qyyf	N	Y	
618400	4277800	G6	Qap	N	N	
618400	4277900	G6	Qap	N	N	
618400	4278000	G6	Qyf	N	Y	
618400	4278100	G6	Qyf	N	Y	
618400	4279500	G16	Qyf	N	N	
618400	4279800	G16	Ql	N	N	
618400	4280200	G16	Ql	N	N	
618400	4280800	G16	Qyyf	N	N	
618400	4281100	G16	Qyyf	N	Y	
618500	4277800	G6	Qap	N	Y	
618500	4278100	G6	Qap	N	N	
618500	4278900	G16	Qyf	N	Y	
618500	4280100	G16	Ql	N	Y	

Table C.13—*Continued.*

UTM Easting of SW Corner	UTM Northing of SW Corner	Habitat	Geogorm	Sites Previously Recorded	Previous Inventory	Note
618500	4280900	G16	Qyyf	N	Y	
618500	4281400	G16	Qyf	N	N	
618600	4277900	G6	Qap	N	Y	
618600	4278000	G6	Qap	N	Y	
618600	4278400	G16	Qyf	N	Y	
618600	4279700	G16	Qyf	N	Y	
618600	4280200	G16	Ql	Y	Y	
618600	4280900	G16	L	N	Y	
618600	4281300	G16	Qyf	N	N	
618700	4278500	G6	Qyf	Y	Y	
618700	4278600	G6	Qyf	Y	Y	
618700	4280000	G16	Qyf	N	Y	
618700	4280100	G16	Ql	Y	Y	
618700	4280300	G16	Ql	N	Y	
618700	4280600	G16	Ql	N	Y	
618700	4281300	G16	Qyf	N	N	
618800	4278200	G6	Ql	N	N	
618800	4278300	G6	Qyf	N	N	
618800	4278400	G6	Qyf	Y	Y	
618800	4278500	G6	Qyyf	Y	Y	
618800	4278700	G6	Qyf	Y	Y	
618800	4278900	G16	Qyf	N	Y	
618800	4279200	G16	Qyf	N	Y	
618800	4279700	G16	Ql	Y	Y	
618800	4280200	G16	Qyf	N	N	
618800	4281600	G16	Qyf	N	N	
618900	4278100	G6	Qap	N	Y	
618900	4278200	G6	Qap	N	N	
618900	4278300	G6	Qap	N	Y	
618900	4278500	G6	Qyyf	Y	Y	
618900	4278600	G6	Ql	N	Y	
618900	4279400	G16	Qyf	Y	Y	contains Pre-Archaic material
618900	4280400	G16	Ql	N	Y	
618900	4280700	G16	Qyyf	N	Y	
619000	4278300	G6	Qap	N	Y	
619000	4278600	G6	Ql	N	N	
619000	4278900	G6	Qyyf	Y	Y	
619000	4279100	G6	Qyf	N	Y	
619000	4279400	G6	Qyf	Y	Y	
619000	4279700	G16	Qyf	Y	Y	
619000	4281200	G16	Ql	N	N	
619000	4281400	G16	Qyf	N	Y	
619000	4281600	G16	Qyf	N	N	
619100	4278300	G6	Qap	N	Y	
619100	4278400	G6	Qap	N	Y	
619100	4278700	G6	Ql	Y	Y	
619100	4278900	G6	Ql	Y	Y	
619100	4279200	G6	Qyyf	N	Y	
619100	4279400	G6	Qyyf	Y	Y	
619100	4279500	G6	Qyf	N	N	
619100	4279600	G6	Qyf	Y	Y	
619100	4279700	G6	Qyyf	Y	Y	

Table C.13—*Continued.*

UTM Easting of SW Corner	UTM Northing of SW Corner	Habitat	Geogorm	Sites Previously Recorded	Previous Inventory	Note
619100	4280200	G16	Qyyf	N	Y	
619100	4280400	G16	Qfs	N	Y	
619100	4280800	G16	Ql	N	N	
619100	4281200	G16	Qfs	N	Y	
619100	4281300	G16	Qfs	N	Y	
619200	4278500	G6	Qap	N	Y	
619200	4278600	G6	Qap	N	Y	
619200	4278900	G6	Ql	Y	Y	
619200	4279000	G6	Qyyf	Y	Y	
619200	4279300	G6	Qyyf	Y	Y	
619200	4279500	G6	Qyyf	Y	Y	
619200	4279600	G6	Qyyf	N	Y	
619200	4279800	G6	Qyyf	N	Y	
619200	4280700	G16	Ql	N	N	
619200	4280900	G16	Qfs	N	N	
619200	4281200	G16	Qfs	N	Y	
619300	4278900	G6	Ql	Y	Y	
619300	4279100	G6	Qap	Y	Y	
619300	4279200	G6	Ql	N	Y	
619300	4279300	G6	Qyyf	N	N	
619300	4279500	G6	Qyyf	N	Y	
619300	4279600	G6	Qyyf	N	Y	
619300	4279700	G6	Qyyf	N	Y	
619300	4279800	G6	Qyyf	N	Y	
619300	4279900	G6	Qyyf	Y	Y	
619300	4281100	G16	Qfs	N	Y	
619300	4281300	G16	Qfs	N	N	
619300	4281400	G16	Qfs	N	N	
619300	4281800	G16	Qyf	N	N	
619400	4278500	G6	Qap	N	N	
619400	4278600	G6	Qap	N	N	
619400	4278700	G6	Qap	N	Y	
619400	4278800	G6	Qap	N	Y	
619400	4278900	G6	Qap	N	Y	
619400	4279000	G6	Qap	N	Y	
619400	4279200	G6	Qap	N	Y	
619400	4279300	G6	Qap	N	Y	
619400	4279800	G6	Qyyf	Y	Y	
619400	4280300	G16	Qfs	N	Y	
619400	4280400	G16	Qfs	N	Y	
619400	4280700	G16	Qfs	N	N	
619400	4281700	G16	Qfs	N	N	
619400	4281800	G16	Qfs	N	N	
619500	4278600	G6	Qap	N	N	
619500	4279100	G6	Qap	N	Y	
619500	4279900	G6	Qfs	N	Y	
619500	4280000	G6	Qfs	N	Y	
619500	4280200	G16	Qfs	N	Y	
619500	4280400	G16	Qfs	N	N	
619500	4281000	G16	Qfs	N	Y	
619600	4279400	G6	Qap	N	N	
619600	4279600	G6	Qfs	N	Y	
619600	4279700	G6	Qfs	N	Y	

Table C.13—*Continued.*

UTM Easting of SW Corner	UTM Northing of SW Corner	Habitat	Geogorm	Sites Previously Recorded	Previous Inventory	Note
619600	4279800	G6	Qfs	N	Y	
619600	4280300	G16	Qfs	N	N	
619600	4281000	G16	Qfs	N	N	
619600	4281100	G16	Ql	N	N	
619600	4281200	G16	Ql	N	N	
619700	4278700	G6	Qap	N	Y	
619700	4279200	G6	Qap	N	Y	
619700	4279800	G6	Qfs	N	Y	
619700	4280000	G6	Qfs	N	N	
619700	4280500	G16	Qfs	N	N	
619700	4281000	G16	Qfs	N	N	
619700	4281100	G16	Qfs	N	N	
619700	4281200	G16	Ql	N	N	
619700	4281700	G16	Qfs	N	N	
619800	4278900	G6	Qap	N	Y	
619800	4279200	G6	Qap	Y	Y	
619800	4279300	G6	Qap	Y	Y	
619800	4279800	G6	Qap	N	Y	
619800	4280000	G6	Qfs	N	Y	
619800	4280500	G16	Qfs	N	N	
619800	4280600	G16	Qfs	N	N	
619800	4281000	G16	Qfs	N	N	
619800	4281300	G16	Ql	N	N	
619800	4281600	G16	Ql	N	N	
619800	4281700	G16	Qfs	N	N	
619900	4279300	G6	Qap	N	Y	
619900	4279400	G6	Qap	N	Y	
619900	4279500	G6	Qap	N	Y	
619900	4279700	G6	Qap	N	Y	
619900	4279900	G6	Qap	Y	Y	
619900	4280000	G6	Qfs	Y	Y	
619900	4280500	G16	Qfs	N	N	
619900	4280700	G16	Qfs	N	Y	
619900	4280900	G16	Qfs	N	N	
619900	4281600	G16	Qfs	N	N	
619900	4281700	G16	Qfs	N	N	
620000	4279800	G6	Qap	N	Y	
620000	4280200	G6	Qfs	N	N	
620000	4280300	G6	Qfs	N	N	
620000	4280900	G16	Qfs	N	N	
620000	4281500	G16	Ql	N	N	
620100	4280200	G6	Qfs	N	Y	
620100	4281400	G16	Qfs	N	N	
620200	4280300	G6	Qfs	N	Y	
620200	4281400	G16	Qfs	N	N	
620300	4280400	G6	Qfs	N	Y	
620300	4280500	G6	Qfs	N	Y	
620300	4280600	G6	Qfs	N	Y	
620300	4280700	G16	Qfs	N	Y	
620300	4281000	G16	Qfs	Y	Y	
620300	4281200	G16	Qfs	N	N	
620400	4281000	G16	Qfs	Y	Y	

Appendix D

Vegetation Composition of Railroad Valley Habitats

David W. Zeanah

Table D.1. Concordance of USDA Symbols, Latin Name, Common Name, and Category for Plants in the Habitat Database

USDA Symbol	Latin Name	Common Name	Category
AAFF/AAGG			annual forbs and grasses
ACHIL	*Achilea*	yarrow	forb
AGROP	*Agropyron* spp	wheatgrass	grass
ALPL	*Alisma plantago- aquatica*	common waterplantain	forb
ARIST	*Aristida*	threeawn	grass
ARPU9	*Aristida purpurea*	purple threeawn	grass
ARTEM	*Artemisia* spp.	sagebrush	shrub
ASTER	*Aster*	aster	forb
ASTRA	*Astragalus*	milkvetch	forb
ATCO	*Atriplex confertifolia*	shadscale	shrub
ATRIP	*Atriplex*	saltbush	shrub
BASA3	*Balsamorhiz sagittata*	arrowleaf balsamroot	forb
BLKI	*Blepharidachne kingii*	King Desertgrass	grass
BOGR2	*Bouteloua gracilis*	blue grama	grass
CAREX	*Carex*	sedge	grass
CERCO	*Cercocarpus* spp.	mountain mahogany	shrub
CHRYS9	*Chrysothamnus* spp.	rabbitbrush	shrub
CIRSI	*Cirsium*	thistle	forb
COMES	*Cowania mexicana stanburiana*	Stansbury cliffrose	shrub
CRAC2	*Crepis acuminata*	tapertip hawksbeard	forb
DECE	*Deschampsia cespitosa*	tufted hairgrass	grass
DISPS2	*Distichlis spicata stricta*	inland saltgrass	grass
ELCI2	*Elymus cinereus*	basin wild rye	grass
ELEOC	*Eleocharis* spp.	spikerush	grass
EPHED	*Ephedra*	ephedra	shrub
EQUIS	*Equisetum*	horsetail	forb
ERIOG	*Eriogonum*	buckwheat	annual forb
ERPU8	*Erionueron pulchellum*	fluffgrass	grass
EULA5	*Eurotia lanata*	winterfat	shrub
FONE2	*Forsellesia nevadensis*	Nevada greasebush	shrub
GRSP	*Grayia spinosa*	spiny hopsage	shrub
GUTIE	*Gutierrezia*	snakeweed	shrub
HAPLO2	*Haplopappus* spp.	goldenweed	forb
HIJA	*Hilaria jamesii*	galleta	grass
HORD	*Hordeum* spp.	meadow barley	grass
IRMI	*Iris missouriensis*	wildiris	forb
IVAX	*Iva axillaris*	povertyweed	forb
JUNCU	*Juncus* spp.	rush	grass
JUOS	*Juniperus osteosperma*	Utah juniper	tree
KOCHI	*Kochia* spp.	kochia	shrub
KOPI	*Koeleria pyramidata*	prarie junegrass	grass
LATHY	*Lathyrus*	peavine	forb
LUPIN	*Lupinus*	lupine	forb
LYCIU	*Lycium*	wolfberry	shrub
MENTZ	*Mentzelia*	Mentzelia	forb
MESP2	*Menodora spinescens*	spiny menodora	shrub
MURI	*Muhlenbergia richardsonis*	mat muly	grass
NAFL	*Najas flexilis*	nodding waternymph	forb
NITRO	*Nitrophila*	miterwort	forb
OENOT	*Oenothera*	evening primrose	forb
OPUNT	*Opuntia*	pricklypear	shrub
ORHY	*Oryzopsis hymenoides*	Indian ricegrass	grass

Table D.1—*Continued.*

USDA Symbol	Latin Name	Common Name	Category
PENST	*Penstemon*	penstemon	forb
PHAL2	*Phleum alpinum*	alpine timothy	grass
PHAU7	*Phragmites australis*	common reed	grass
PHLOX	*Phlox*	phlox	forb
PIMO	*Pinus monophylla*	singleleaf pinyon	tree
POA	*Poa* spp.	bluegrass	grass
POPUL	*Populus*	cottonwood	tree/shrub
POTAM	*Potamogeton*	sago pondweed	forb
POTEN	*Potentilla*	cinquefoil	forb
PRUN	*Prunus* spp.	peachbrush/ chokecherry	shrub
PSPO	*Psorothamnus polydenis*	Nevada dalea	shrub
PUCCI	*Puccinellia*	alkaligrass	grass
PURSH	*Purshia* spp.	bitterbrush	shrub
ROSA+	*Rosa*	rose	shrub
RUDBE	*Rudbeckia*	coneflower	forb
RUOC3	*Rumex occidentalis*	western dock	forb
SALA2	*Sagitattaria latifolia*	common arrowhead	forb
SALIC	*Salicornia*	glasswort	forb
SALIX	*Salix* spp.	willow	shrub
SARCO	*Sarcobatus* spp.	greasewood	shrub
SCIRP	*Scirpus* spp.	bulrush	grass
SHAR	*Sheperdia argenta*	silver buffaloberry	shrub
SIHY	*Sitanion hystrix*	bottlebrush squirreltail	grass
SPGR	*Spartina gracilis*	alkali cordgrass	grass
SPHAE	*Sphaeralcea*	globemallow	forb
SPORO	*Sporobolus*	dropseed/scratchgrass	grass
STANL	*Stanleya*	princesplume	forb
STIPA	*Stipa* spp.	needlegrass	grass
SUAED	*Suaeda*	seepweed	shrub
SYMPH	*Symphoricarpos* spp.	snowberry	shrub
TETRA3	*Tetradymia*	horsebrush	shrub
THELY	*Thelypodium*	thelypody	forb
TRIFO	*Trifolium*	clover	forb
TRIGL	*Triglochin*	arrowgrass	grass
TYPHA	*Typha*	cattail	grass
VUOC	*Vulpia octoflora*	sixweeks fescue	annual grass
YUCCA	*Yucca*	yucca	shrub

Appendix E

Common/Latin Name Concordance

David W. Zeanah

Table E.1. Common/Latin Name Concordance of Plant Species Mentioned in Text

Category	Common Name	Latin Name
Grasses		
	alkali sacaton	*Sporobolus airoides*
	alkaligrass	*Puccinellia* sp.
	alpine timothy	*Phleum alpinum*
	arrowgrass	*Triglochin* sp.
	bentgrass, redtop	*Agrostis* sp.
	bluebunch wheatgrass	*Agropyron spicatum*
	bluegrass	*Poa* sp.
	bottlebrush squirreltail	*Sitanion hystrix*
	desert needlegrass	*Stipa speciosa*
	foxtail barley	*Hordeum jubatum*
	Great Basin wildrye	*Elymus cinereus*
	Indian ricegrass	*Oryzopsis hymenoides*
	inland saltgrass	*Distichlis stricta*
	mat muhly	*Muhlenbergia richardsonis*
	meadow barley	*Hordeum brachyantherum*
	muttongrass	*Poa Fendleriana*
	needleandthread	*Stipa comata*
	needlegrass	*Stipa* sp.
	Nevada bluegrass	*Poa nevadensis*
	sacaton	*Sporobolus* sp.
	saltgrass	*Distichlis* sp.
	sand dropseed	*Sporobolus cryptandrus*
	Sandberg's bluegrass	*Poa secunda*
	scratchgrass	*Sporobolus asperifolius, Muhlenbergia asperifolia*
	six-weeks fescue	*Festuca octoflora*
	squirreltail	*Sitanion* sp.
	Thurber needlegrass	*Stipa Thurberiana*
	tufted hairgrass	*Deschampsia caespitosa*
	western wheatgrass	*Agropyron Smithii*
	wheatgrass	*Agropyron* sp.
	wildrye	*Elymus* sp. or *Leymus* sp.
Upland Annual and Perennial Forbs		
	arrowleaf balsamroot	*Balsamorhiza sagittata*
	balsamroot	*Balsamorhiza* spp.
	Baltic rush	*Juncus balticus*
	blazing star	*Mentzelia albicaulis*
	brome	*Bromus* sp.
	cinquefoil	*Potentilla* sp.
	clover	*Trifolium* sp.
	dalea	*Dalea* sp.
	dock	*Rumex* sp.
	evening primrose	*Oenothera* sp.
	galleta	*Hilaria jamesii*
	glasswort	*Salicornia* sp.
	globemallow	*Sphaeralcea* sp.
	goldenweed	*Applopappus* sp.
	goosefoot	*Chenopodium* sp.
	hopsage	*Grayia spinosa*
	horsebrush	*Tetradymia* sp.
	lupine	*Lupinus* sp.

Table E.1—*Continued.*

Category	Common Name	Latin Name
Upland Annual and Perennial Forbs, continued		
	milkvetch	*Astragalus* sp.
	oceanspray	*Holodiscus* sp.
	penstemon	*Penstemon* sp.
	phlox	*Phlox* sp.
	povertyweed	*Iva axillaris*
	prickly pear	*Opuntia erinacea*
	prince's plume	*Stanleya elata*
	snowberry	*Symphoricarpos*
	sunflower	*Helianthus* sp.
	tansymustard	*Descurainia pinnata*
	wildiris	*Iris missouriensis*
	yarrow	*Achillea* sp.
Shrubs		
	Anderson peachbrush	*Prunus Andersonii*
	antelope bitterbrush	*Purshia tridentata*
	Bailey's greasewood	*Sarcobatus vermiculatus Baileyi*
	Basin big sagebrush	*Artemisia tridentata tridentata*
	big/tall sagebrush	*Artemisia tridentata*
	black greasewood	*Sarcobatus vermiculatus*
	black sagebrush	*Artemisia arbuscula nova*
	bud sagebrush	*Artemisia spinescens*
	choke cherry	*Prunus virginiana*
	currant	*Ribes* sp.
	desert peach	*Prunus Andersonii*
	four-wing saltbush	*Atriplex canescens*
	green molly kochia	*Kochia americana*
	hawksbeard	*Crepis* sp.
	iodine bush	*Allenrolfea occidentalis*
	kochia	*Kochia* sp.
	mountain big sagebrush	*Artemisia vesayana*
	mountain mahogany	*Cerocarpus ledifolius*
	Nevada ephedra	*Ephedra nevadensis*
	rabbitbrush	*Chrysothamnus* sp.
	rubber rabbitbrush	*Chrysothamnus nauseosus*
	sagebrush	*Artemisia* sp.
	saltbrush	*Atriplex argentea*
	serviceberry	*Amelanchier* sp.
	shadscale	*Atriplex confertifolia*
	silver buffaloberry	*Sherpherdia argentea*
	spiny menodora	*Menodora spinescens*
	Torrey quailbush	*Atriplex Torreyi*
	seepweed	*Suaeda depressa*
	wild rose	*Rosa* sp.
	willow	*Salix* sp.
	winterfat	*Eurotia lanata*
	wolfberry	*Lycium* sp.
	Wood's rose	*Rosa woodsii*
	Wyoming big sagebrush	*Artemisia tridentata wyomingensis*
	yucca	*Yucca* sp.

Table E.1—*Continued.*

Category	Common Name	Latin Name
Wetland Plants		
	alkali bulrush	*Scirpus robustus*
	arrowhead	*Sagittaria latifolia*
	bulrush	*Scirpus* spp.
	common catttail	*Typha latifolia*
	dock	*Rumex occidentalis*
	rush	*Juncus* sp.
	sedge	*Carex* sp.
	sego pondweed	*Potamogeton pectinatus*
	spikerush	*Eleocharis palustris*
	water plantain	*Alisma geyeri*
Trees		
	Engelmann spruce	*Picea engelmannii*
	Fremont cottonwood	*Populus fremontii*
	limber pine	*Pinus flexilis*
	pinyon	*Pinus monophylla*
	Rocky Mountain juniper	*Juniperus scopulorum*
	white fir	*Abies concolor*
	Utah juniper	*Juniperus osteosperma*

Table E.2. Common/Latin Name Concordance of Animal Species Mentioned in Text

Category	Common Name	Latin Name
Large Animals		
	bighorn sheep	*Ovis canadensis*
	bison	*Bison bison*
	elk	*Cervus elaphus*
	mule deer	*Odocoileus hemionus*
	pronghorn antelope	*Antelocapra americana*
Small/Medium-sized Animals		
	badger	*Taxidae taxus*
	Belding's groundsquirrel	*Spermophilus beldingi*
	black-tailed jackrabbit	*Lepus californicus*
	bushy-tailed woodrat	*Neotoma cinerea*
	deer mouse	*Peromyscus maniculatus*
	desert woodrat	*Neotoma lepida*
	grasshopper mouse	*Onychomys* spp.
	kangaroo rat	*Dipodomys* sp.
	least chipmunk	*Tamius minimus*
	muskrat	*Ondatra zibethicus*
	Nuttall's cottontail	*Sylvilagus nuttallii*
	pinyon mouse	*Peromyscus truei*
	pocket gopher	*Thomomys* spp.
	Townsend's groundsquirrel	*Spermophilus townsendii*
	vole	*Microtus* sp.
	white-tailed antelope squirrel	*Ammospermophilus leucurus*
	white-tailed jackrabbit	*Lepus townsendii*
	yellow-bellied marmot	*Marmota flaviventris*
Waterfowl and Shorebirds		
	Canada goose	*Branta canadensis*
	canvasback duck	*Aythya valisineria*
	mallard duck	*Anas platyrhynchos*
	redhead duck	*Aythya americana*
Upland Game Birds		
	blue grouse	*Dendragapus obscurus*
	mountain quail	*Oreortyx pictus*
	sage grouse	*Centrocercus urophasianus*
Fish		
	Railroad Valley springfish	*Crenichthys nevadae Hubbs*
	tui chub	*Gila bicolor obesus*
Invertebrates		
	snail	*Gastropoda* spp.

Appendix F

Site and Report Numbers Missing from the Railroad Valley Database

Gnomon, Inc.

Missing Report Numbers (some may be outside the project area):

6-1237 (Zerga 1989a)-61-5312 (Extensive field camp, extensive field camp?)
6-1064 (Billat and Billat 1988)-61-5256, 61-5257
6-1237
6-1121
6-1122
6-290 or 190 Poor copy can't tell which
6-145
6-1275
6-1275-1
6-1246 (we have 4-978)
6-1439 (7 isolates no site numbers just a 106 review)
6-1044 (significant properties)
6-1086 (negative)
6-824

Missing Report Numbers (probably outside the project area):
4-206
4-205
4-202
4-212
4-211
4-215
4-216
4-970
4-957
4-960

Site forms too incomplete to digitized:
64-9202
61-5387
61-756
61-758

Missing site forms pulled from the BLM database:
61-609 (6-58)
61-754 (6-58)
61-858 (6-58)
61-859 (6-58)
61-1305 (6-445)
61-1306 (6-445)
61-1307 (6-445)
61-1308 (6-445)
61-1309 (6-445)
61-2231 (6-445)
61-228 (6-445)
61-977 (6-445)
61-754
61-598
4-389 (6-102)

6/61-1351 (6-196)(Acker 1979 Two Seismic Line Extensions)
61-3794
61-3794
61-2875
61-2879
61-616
61-222
61-223
61-224
61-3054
61-3435
61-611
61-770

Site forms missing from all resources:
26Ny934-(6-124/323) sec. 32 t. 6n, r.56e in 124
26Ny228-(6-124/323) sec. 3/10, t.5n, r.56e in 323/124
26Ny3213 (6-1059)
26Ny603 (6-1059)
26Ny3151-(6-1059)
26Ny4292
26Ny4293
26Ny4377 (6-286)
26Ny4378-(6-286)
61-2254
61-776
61-1765
61-1766
61-1770
61-1943
61-1944
61-2647
61-3049
61-4824
61-5015
61-5016
61-5017
61-5018
61-5019
61-4998
61-4999
61-1601
61-3889 (This site is in 6-1211 but the map is to poor to digitize from)
26Ny1600 (6-1467 and 1215) (Rafferty 1988)
4-625 (A Cultural Resource Inventory of Land Applied for Under the Desert Land Act and Carey Act Application in Northern Railroad Valley, Nye And White Pine Counties, Nevada) All site forms were missing and had to be imaged scanned in, site information was taken from the report information.

Appendix G

Railroad Valley Cultural Resource and Habitat GIS Databases

(submitted separately)

Gnomon, Inc.

Appendix H

Railroad Valley, Nye, and White Pine Counties, Nevada: Management Zones

(in pocket)

Gnomon, Inc.

Railroad Valley, Nye and White Pine Counties, Nevada

Management Zones

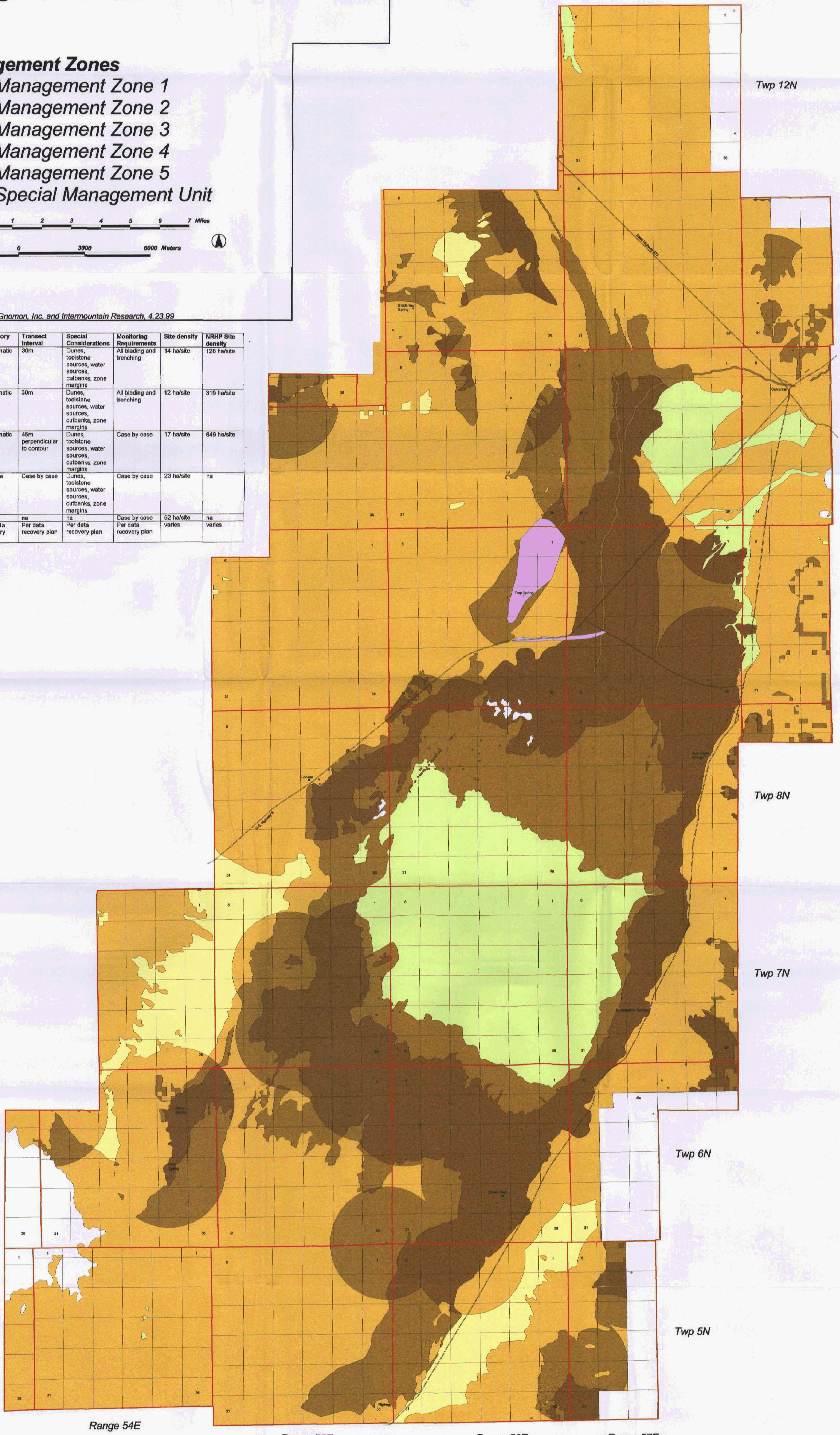
KEY

Management Zones

- *Management Zone 1*
- *Management Zone 2*
- *Management Zone 3*
- *Management Zone 4*
- *Management Zone 5*
- *Special Management Unit*

1 0 1 2 3 4 5 6 7 Miles

3000 0 3000 6000 Meters



Map prepared by Gnomon, Inc. and Intermountain Research, 4.23.99

Management Unit	Inventory Type	Transect Interval	Special Considerations	Monitoring Requirements	Site density	NRHP Site density
Zone 1	Systematic	30m	Dunes, toolstone sources, water sources, cutbanks, zone margins	All blading and trenching	14 ha/site	128 ha/site
Zone 2	Systematic	30m	Dunes, toolstone sources, water sources, cutbanks, zone margins	All blading and trenching	12 ha/site	319 ha/site
Zone 3	Systematic	45m perpendicular to contour	Dunes, toolstone sources, water sources, cutbanks, zone margins	Case by case	17 ha/site	649 ha/site
Zone 4	Intuitive	Case by case	Dunes, toolstone sources, water sources, cutbanks, zone margins	Case by case	23 ha/site	na
Zone 5	None	na	na	Case by case	52 ha/site	na
Special Management Units	Per data recovery plan	Per data recovery plan	Per data recovery plan	Per data recovery plan	varies	varies