AN ABSTRACT OF THE THESIS OF

Sara Hescock for the degree of Master of Arts in Applied Anthropology presented on June 13, 2014.
Title: Geoarchaeological Research within Five River Miles of the Upper Klamath River Canyon: Use of Pedogenic Properties to Calculate Alluvial Terrace Age.

Abstract approved:

________________________________________
Loren G. Davis

Soil is a valuable medium when investigating the past—from understanding rates of development, landform evolution, to the construction of various predictive models. Landforms and sediments provide insight into depositional environments and soil morphology indicates pedogenic change within those landforms. The rate at which pedogenesis occurs has been quantitatively measured by use of eight soil properties (clay films, texture + wet consistence, rubification (hue and chroma), structure, dry consistence, moist consistence, color value, and pH) to better understand landform type, soil development, as well as the archaeology of the Upper Klamath River Canyon.

Soils within the Upper Klamath River Canyon consist of colluvium and Quaternary alluvium, which have been forming over the last 2.59 million years. Archaeological sites in the region are much younger than that and are expected to be found on landforms adjacent to the river channel. Currently the Klamath River chronology is incomplete with little-to-no information covering the Early and Middle Archaic Periods; conversely most archaeological information comes from the most recent period—the Late Archaic.

In order to better understand the history of the canyon, landforms and depositional environments were identified and soil development was quantitatively measured by use of a soil development index and horizon index. A total of 21 soil pits, located on 21 alluvial terraces, within five terrace complexes, in a five-mile segment of the Upper Klamath River Canyon were recorded.
Results indicate that overtime soil properties tend to change in a linear progression and older terraces are higher in elevation from the current river channel. Use of soil development indices have proven useful in demonstrating soil development within a group of terraces as well as by showing pedogenic development within a single soil profile through the quantification of soil morphological characteristics.
Geoarchaeological Research within Five River Miles of the Upper Klamath River Canyon: Use of Pedogenic Properties to Calculate Alluvial Terrace Age

by
Sara Hescock

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Director of the School of Language, Culture, and Society

Dean of the Graduate School

I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

Sara Hescock, Author
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Over the past three years, I’ve become indebted to many people that have not only inspired me, but have also offered assistance in various ways—from on-site fieldwork to advising and mentoring. Without the support and guidance of many, this thesis would not have come to fruition.

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Chapter 1. Introduction

The Klamath Basin of south-central Oregon and northern California contains many prehistoric archaeological sites, representing thousands of years of various aspects of the lifeway of the people of the Klamath Tribes (consisting of the Klamath, Modoc, and Yahooskin band of the Paiute), Shasta Indian Nation, Karuk, Yurok, and the Achomawi, Takelma, Hupa, and possibly others. The information contained in those sites may be composed of a myriad of different artifacts and features. Sites are commonly comprised of lithic debris, including fully formed lithic tools and projectile points; groundstone; plant and animal remains; pottery; clay figurines; charm stones; net weights; fire cracked rock; house pits; rock rings; talus pits; hearths; prayer seats; rock stacks; hunting blinds; weirs; middens; cambium-peeled trees; bow stave trees; rock art; and burials. Some information may not be as obvious, perhaps unseen to the human eye, but may consist of pollen, DNA, minerals, and starches. Other resources pertinent to human history also include traditional gathering areas and key features located on the landscape. This list is nowhere near being complete, but serves to express the variability of archaeological sites.

Many different artifacts and features may be found and a site may consist of any combination of those listed above. Each one of these archaeological resources yields valuable information to past activities and a majority of those listed have been found within the current study area, leading to further information regarding the history of the past people that had inhabited the area.

Archaeological research has been performed in the Upper Klamath Basin for 75 years and in the Upper Klamath River Canyon (UKRC) for 55 years. Excavation of rock shelters, house pits, and midden features were the most extensive; these studies have been synthesized by Joanne Mack and have eventually led to a cultural chronology for the UKRC. However, past studies and e-mail correspondence have expressed the need and interest in
geoarchaeological research within the river canyon (Dabling 2009:9, 45; Mertzman 2013, personal communication). As of now, site forms lead to general documentation of landforms and of the environment; other studies have made note of the landform types, stratigraphy, elevation, and usually height above the current river channel, proximity to the current river channel, aspect, and slope.

The depositional environment of the canyon provides a means to identify landforms, sediments, and soil development that can lead to the identification of potential site locations. Later correlations amongst landform and site type and size, and settlement patterns can be made. The necessary first step is to build a geoarchaeological framework and then conduct archaeological research to fully understand the history of an area.

As mentioned above, in order to better understand the archaeological record as well as the human past, it is important to first understand the setting in which activities had occurred. The setting consists of a variety of environmental aspects that pertain to the dynamic and ever-changing landscape that previous inhabitants had lived upon. Depending on landform type and subsequent geological processes, determines whether or not evidence of past activities are preserved. Through the application of earth science methods and techniques, geoarchaeological research will help to understand how, where, when, and why certain things are present in the archaeological record.

In hopes to better understand the history of the canyon, geoarchaeological research was conducted in a five river mile segment of the UKRC— from River Mile 220 in the north, (just south of the Klamath River Boat Launch), downstream to River Mile 215 in the south, at the northern extent of the Secret Springs Mountain Landslide (SSML) (Figures 1 and 2). This stretch of river offered a unique and attractive setting for early inhabitants and is confirmed by the high amount and variety of archaeological sites that represent occupation and interaction within the canyon since 7,500 B.P. (Beckham 2006:8). The aim of this study is to further understand the landform formation and depositional processes
that have occurred within the canyon, then to understand what landforms have potential to contain an archaeological site.

Over the past three years the author has conducted field research out of the Klamath Falls Resource Area (KFRA), Bureau of Land Management (BLM), on many of the sites, updated site monitoring forms, conducted four archaeological inventories, mapped landforms, documented soil and sediment profiles, and recorded three sites within the canyon corridor (defined as the landforms flanking the river channel and slightly upslope; does not include sites along the rim or in above areas). This has all been done in order to further research the history of the canyon— the archaeology as well as the geology, geomorphology, and pedology.

This study was initiated due to concerns arising from the proposed removal of four dams on the UKRC as part of the Klamath Hydroelectric Settlement Agreement (KHSA). The goal was to understand the geomorphology of the river system— in order to aid in the location of archaeological sites that may be contained in landforms that lie adjacent to the river channel.

Although dam removal is still under contention, this issue has become a topic for countless recent presentations and studies that have shed light on the possibility of erosion and deposition in the river corridor and within now submerged historic channels (Ayres Associates 1999; Eisler and Gubala 2003; FERC 2007; G & G Associates 2003; GEC 2006; Lai and Greimann 2012; PacifiCorp 2004c; BOR 2011; Stillwater Sciences 2008; Stillwater Sciences 2010; USDI 2010; USDI and CDFG 2012; Young 2005).
Figure 1. UKRC and study location map. The black polygon denotes the location of the current study corridor in southern Oregon (BLM 2013a; BLM 2013c).
Figure 2. Klamath Basin and sub-basins of California and Oregon as defined by the Bureau of Land Management (BLM 2013a; BLM 2013c).
Yong Lai and Blair Greimann report that approximately 10 million cubic meters of fine-grained sediments have become impounded within four dam reservoirs, while Stillwater Sciences report a higher number at 11.5 to 15.3 million cubic meters, and Gathard Engineering consulting (GEC) estimates an even higher number at 18.6 cubic meters of sediments, trapped in only three reservoirs (2006:2; 2008:1; 2012). Some sediments are organic, but are mainly high water content (approximately 80 percent by volume) silt and clay. The fine-grained sediments are likely to be eroded when the dams are decommissioned and will travel downstream as a suspended load. A majority of sediments contained within the J.C. Boyle reservoir consists of roughly 576,072 cubic meters of sand (Stillwater Sciences 2008:1; Lai and Greimann 2012:905). Fine-grained sediments are found in the southern portions and peripheries of the reservoirs, where the smaller particles are able to settle out of suspension. These sediments have low cohesion and are highly erodible. Sediment accumulation is thinner in areas where water flowed faster than two-to-four miles per hour and thicker in slow moving water (USDI and CDFG 2012:3.11-9). Pre-reservoir material is coarser grained alluvium (silty gravel and sand), while bedrock is heavily weathered volcaniclastic rock.

In a recent study, Lai and Greimann (2012:916) used different models, running nine different simulations (with three hydrological scenarios and three reservoir bed erodibility conditions), to predict sediment erosion and transport at the Copco 1 Dam. Models indicate that the channel would incise and sediments within the pre-dam channel would erode within 45 days after drawdown, leading to re-occupation of the historic channel.

An area of potential effect (APE) has been established by the Department of the Interior (DOI), which was defined as being 0.5 miles outward from the river bank, 0.5 miles from the highest watermark at reservoirs and facilities, and extending some 250 miles north-south along the river channel (USDI and CDFG 2012:3.13-4). The current study area is located in the northern area of the KHSA APE, slightly south of the J.C. Boyle Dam. Sediments impounded in the J.C.
Boyle Reservoir are likely to become part of the river bedload, when drawdown begins. Sediments may be re-deposited within the study area, covering some of the close river terraces\(^1\).

This APE has aided in defining an area that may be impacted by future river fluctuations. Reservoir drawdown and dam removal could affect sites, especially those that are currently submerged in reservoirs, although the 2012 Environmental Impact Statement (EIS) mentions that effects cannot be fully determined until an alternative is developed (USDI and CDFG 2012:3.13-11). Based on previous reservoir drawdown studies, the transport capacity of the river is probably sufficient to carry the additional load and will likely not have a big effect on sites in the current study area. The sedimentation impacts are anticipated to be short term (USDI and CDFG 2012:3.11-22).

These studies highlight the focus of most work in the canyon and a few of the studies have included geomorphic descriptions and mapping. Unfortunately, out of all the available maps none of the studies have provided geomorphic mapping of River Mile 224 through River Mile 209, but do include maps on the geomorphology surrounding the dams (BOR 2011: Appendix H).

More geological and archaeological research needs to be conducted within the canyon in order to better understand the past, specifically human-landform or archaeological resource-landform interactions, distribution, and location. In order to do this, landforms were recorded and a basic geoarchaeological framework was constructed. Research questions examined during this project include:

- What depositional environments are present in the canyon and where are they located?

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\(^1\) Terraces can be defined as flat landforms that are above, parallel, and adjacent to a river channel, underlain by alluvial deposits and are not frequently inundated (Pazzaglia 2010)
Based on soil profile development index calculations, what alluvial terraces are relatively older or younger? What are the potential ages associated with the landform?

What landforms have potential to contain archaeological sites of certain ages?

Are there any correlations between known archaeological site locations and landform type?

Once the geomorphology of the selected study area is understood, a geoarchaeological framework can be developed. This type of framework can aid in the formation of a predictability model to locate areas that have a higher potential of containing archaeological sites. This is important to apply to the UKRC in regards to the proposed dam removal project, but also because the archaeological record is incomplete\(^2\). This incompleteness may be due to the absence of cultural materials that date to specific periods, but is more likely due to the poor visibility within the river corridor. Thick vegetation and duff cover is found throughout the canyon, and it is probable that residuum and colluvial creep have overlain archaeological materials. Geomorphic mapping, soil recordation, and sediment mapping can aid in predicting the location of key sites that have potential to yield important information about the history of an area. The current geoarchaeological project involved geomorphic mapping and pedologic soil recordation to aid in the creation of a geoarchaeological framework for the UKRC. Prior to initiation of the project, seven essential steps were identified:

1. Research archaeological sites within the study area in order to identify site type and dates of sites located in the UKRC. Sites were then visited and site forms were updated;

\(^2\) There is little-to-no data available for sites dating to the Early Archaic, specifically, the “not-named” phases (pre-7,500 B.P.). There is little archaeological data for the Secret Springs (7,500 – 6,500 B.P.) and Basin (6,500 – 4,500 B.P.) phases (Mack 1991; PacifiCorp 2004a).
(2) To identify, record, and map landforms within the five mile study area;

(3) Alluvial terrace complexes³ were identified for further research. Once the landforms in those complexes were mapped—excavation of soil units (0.5 x 1 x 1.52 m) took place at specific locations on the landforms;

(4) To record the stratigraphy using professional standards;

(5) To analyze and quantify soil morphological characteristics from field descriptions to measure the degree of soil profile development on each terrace;

(6) To identify areas likely to contain archaeological sites of certain ages;

(7) To determine if there are any correlations between landform type and archaeological site presence.

Organization of Study

The thesis is organized as follows: Chapter Two includes a literature review of archaeological theory, geoarchaeology, and introduces the prehistory and history of southern Oregon, through the presentation of the cultural context of the Klamath Basin and UKRC. The UKRC cultural chronology and the general characteristics of the Native American Indian groups that resided in the Upper Klamath Basin are briefly summarized. Chapter Three is comprised of various components that pertain to the current and past environmental setting, including:

³ A Complex is any area along the river that consists of multiple risers (terraces) in successive order that can represent various stages in the river channel over time) (Pazzaglia 2010:3).
climate, paleoclimate, vegetation, hydrology, geology, geomorphology, and pedology of the study area. Chapter Four summarizes methods and techniques used during various stages of the research project, including, the methods and techniques employed. Chapter Five covers data analysis and results. Lastly, Chapter Six closes with a discussion of the study and concludes.
Chapter 2. Literature Review

Theoretical Framework of Past Inhabitants

As people move around the landscape, certain indicators of their presence may be left behind. Quite generally, a person or group of people may be thought of as acting "rationally," to minimize risk by placing themselves strategically throughout the landscape, in regards to resources. Behaviors may be modified to adapt to an environment and characteristics of any particular group can be explained by that adaption. An economic approach can be taken to understand past human behavior, in which the idea of cost and benefits are key to settlement locations and practices. Matthew Johnson (2010:173) refers to these ideas as being part of human behavioral ecology or cultural ecology (HBE and CE) theoretical frameworks. Johnson also mentions that it has been argued as being reductionist—being reduced to a biologic core, leading to an environmental deterministic view of humans and culture.

Resources differ depending on the area, people, and need. Availability of those resources is dynamic—meaning that resources are not continuous through time and space. The distribution is the result of variables, both geomorphic and environmental, including but not limited to climate, geology (e.g., relief, aspect, slope, landform, and elevation), hydrological systems, vegetation, wildlife, and territorial expanses. In reaction to these variables, and probably others, human settlements and hence archaeological sites are likely to occur at strategic points. Therefore, a habitation site may be based on seasonality, or how a group of humans survive throughout the year as resources become available or unavailable (Johnson 2010:174).

Early Klamath Basin inhabitants were known to move around the landscape in response to changes in resource availability and take part in the winter village strategy, which was beneficial in an area with definite seasonal
fluctuations (Aikens et al. 2011:32-40; CLI 2014). Each season reflected differences in the availability of any given resource and people of the Klamath and Shasta had to make up for seasonal shortfalls by gathering food in bulk. For example, the Klamath were known to bulk-harvest camas from seasonal wet meadows during late May through June (Aikens et al. 2011:32-40; Beckham 2000:2-6; Beckham 2006:16-18; CLI 2014; Deur 2008:40-45). The camas was either baked in rock-lined ovens or stored for later consumption. The gathered camas could be used at any time to supplement the diet throughout the rest of the year or consumed during the less productive winter months.

Both the Klamath and Shasta were known to inhabit winter villages where mobility was reduced and people congregated at areas on the landscape that had a certain resource (Aikens et al. 2011:36-39). Storage is then utilized at the village. The winter village was an adaptation strategy to seasonal incongruities or shortfalls in resources. Groups would move to the bottom of river canyons, where there is less snowfall and temperatures are not as cold. Groups living in these areas could tap into their stored foods and also hunt and fish. Villages were the central location from where activities would take form and groups would radiate out in the acquisition of resources. This settlement pattern is consistent with the expectations of a central place foraging strategy where people lived near critical resources and exploited resources within a certain range from their home (Carlisle 2007:17-18; Kelly 2007:135-143). When resources are not in close vicinity, hunter-gatherers will extend their travel time to more distant patches. In all, this strategy relies on the assumption that people would maximize energy in terms of travel and processing time (Carlisle 2007:18; Kelly 2007:133). This also plays into the concept of site catchment analysis, where it is assumed that past peoples would have rationally exploited resources and mapped out to resources around a site (Johnson 2010:173).

Middle-range theory has been used to interpret the past by linking the static present state of an archaeological site to what it would have been in the dynamic past. Middle-range theory acts as a means to observe the present and
make a general statement about the past through the use of ethnoarchaeological analogies and actualistic studies (Johnson 2010:50-54). Through the use of ethnographies conducted in the Klamath Basin (Gatschet 1890; Kroeber 1925; Spier 1930; Stern 1965), earlier archaeologists have been able to identify and interpret archaeological sites by type and possibly by time through the use of known projectile point typologies and artifact and feature types. Early interpretation and identification eventually lead to a cultural chronology.

Lewis Binford designed the forager-collector model, which is especially useful when attempting to ‘bridge-the-gap’ to what past economic, social organization, and settlement patterns were like. This model focuses on a continuum of characteristics that pertain to a forager or collector lifeway. At one end there are the foragers, living in areas of low seasonality and usually uniform availability of resources, high effective temperature (another idea developed by Binford, based on annual temperature and annual range of temperature), high residential mobility, who gather resources on an encounter basis, and exhibit low differentiation of activities based on season (Bettinger 1991:64-67; Binford 1980:5-10; Carlisle 2007:11). On the other end of the spectrum are the collectors, where the Klamath and Shasta would tend to fall more closely. Collectors are affected by changes in the season and must move around the landscape in response to changes in availability of resources. As collectors generally live in areas of lower effective temperatures than foragers, they may ‘map onto resources’ through residential moves and changes in group size and use logistical strategies to make up for seasonal shortfalls (Bettinger 1991:67-70; Binford 1980:10). Binford (1980:10) defines logistical strategies as:

“…labor accommodations to incongruent distributions of critical resources or conditions which otherwise restrict mobility.”

This means that task groups are formed to target specific resources at certain times of the year. Collector activities may lead to three types of sites: the
field camp, a temporary operational center while away from the residential base; the station or area where the special-purpose task groups are located; and the cache or storage of resources and tools that were obtained in bulk and are anticipated to be used in the future (Binford 1980:11-12).

These models and concepts were initially developed in biology and ecology, then adapted to anthropology and archaeology in the 1960s and 1970s, and can form the underlying basis of an archaeological site predictive model. Ultimately, the roots of predictive modeling in archaeology can be traced back to work done in the Great Basin, by Julian Steward (1938), and later in Peru, by Gordon Willey (1953); their studies focused on relationships between settlement patterns and environments. Later studies focused on scientific research methods to investigate the relationships of people and their environment. Thereafter, in the early 1970s, other studies began to explicitly predict site locations (Canning 2005:6).

In more recent years, archaeological concepts and geomorphic variables have been used in conjunction with Geographic Information Systems (GIS) to predict areas that have a higher potential of containing a site. GIS has been used in numerous studies over the past decade to predict the location of archaeological sites by pulling in topographic variables (Canning 2005; Cattani et al. 2004; Deroin et al. 2010; Espa et al. 2007; Ghilardi and Desruelles 2008; Hill et al. 2006; Vaughn and Crawford 2009). GIS is very useful and can aid in the construction of predictive models, which is a great way to expedite survey processes, cover large expanses of land, and organize data.

The history of the landscape should be understood prior to the construction of an archaeological predictive model. Identification and recordation of landforms can ultimately lead to the construction of a geoarchaeological framework. This focuses on the landscape and processes and can pinpoint areas that may preserve a site better than other areas (e.g., alluvial terrace versus landslide). Those areas can be mapped or identified with use of geological and archaeological data that focuses on geomorphology and depositional processes.
GIS can be used in geoarchaeology to build predictive maps, other software (in this case ArcGIS) can be used to organize data and to execute tools for prediction, while other tools can provide three-dimensional visualization and run statistical applications on data (Cattani et al. 2004).

The UKRC Study Area and Geoarchaeology

The previously mentioned archaeological concepts were taken into account when planning the current project; it is important to consider how the past inhabitants were possibly acting. In addition, to archaeological concepts, earth science techniques (e.g., landform identification and mapping, standard soil profile recordation, field morphology indices) were applied to archaeological research in the UKRC. Geologic principles such as the law of superposition (relies on the idea that strata lower down, were deposited first; therefore, anything above is younger), law of original horizontality (layers are deposited in positions that are roughly horizontal), and law of lateral continuity (assumes that strata are continuous until another solid body causes interruption) were utilized when identifying and mapping the landforms in the UKRC (Boggs 1995:3-4; Thomas 2011:27). Those three basic laws aided in identifying terraces, floodplains, drainages and alluvial fans, as well as landslides.

The five-mile study area is located within a river corridor; river valleys have for many years attracted archaeologists and researchers. This is of course due to the fact that they have always been important to humans, which then leave behind records of past activities. Margaret Guccione (2008:378, 379) mentions that archaeological records within river valleys are controlled by three factors: site selection, preservation of those sites, and later recognition by archaeologists.

Since the study area is situated within a river “canyon” alluvial and colluvial actions are most likely the main depositional environments. Fine, medium, and coarse lacustrine sediments, found just north of the study area are
deposited within the canyon. Floods transport and erode materials, while different forms of mass wasting move soil and rock material downhill as gravity acts upon loose sediments. Mass wasting displaces hillsides and covers other areas. Channel mobility can cause site preservation, but preservation is generally reduced in areas near the channel that have high rates of lateral migration. Lateral migration can also expose sites and lead to identification of sites (Guccione 2008:379). These processes change overtime and this variability influences both the temporal and spatial patterns of archaeological sites (Guccione 2008:379).

Past studies in the UKRC have mainly focused on Guccione’s first and third factors—archaeologists have conducted numerous surface pedestrian surveys within the corridor that have led to the identification of archaeological sites. Later, a few sites were tested and excavated, revealing characteristics of the past inhabitants. These finds have aided in understanding the history of the canyon and later studies have been able to make inferences as to where and why sites are located in specific areas. Previous studies focus on the assumption that past canyon occupants chose to live in flat areas (Guccione’s first factor—site selection). The river is wider and slower moving (shoal areas) in the flat expanses, which seems to suggest that there was a preference for those landforms and that they work into the settlement pattern of the UKRC.

This all makes sense, but what about geomorphology and site preservation? Guccione mentions that settlement strategy is difficult to ascertain because the record is incomplete and that the second factor (preservation) and the third factor (identification) control the completeness of that record (2008:394). Guccione sums this up in the “Conclusion:”

“The archeologic record is incomplete and is a measure of original site distribution minus site erosion and incomplete site identification. In river valleys these three factors are controlled in part by evolution of the valley, the alluvial style of the stream, and
human adaptation and manipulation of this evolving environment (2008:299)."

A majority of the sites are located in a flat expansive area, where the river channel is wider, slower moving, has less gradient, and consists of finer-grained sediments. This area would seem ideal to those having occupied the primary and secondary terraces in historic times as well as further back in time.

This area will be referred to as the “Frain” and “Blue Heron” stretches, located within the last two river miles of the study area (River Mile 217 to River Mile 215) (Figure 3). This would have been one long continuous stretch, but a 0.25 mile wide landslide occurred at River Mile 216, breaking the long expansive primary and secondary terraces into two different sections. The north section, from River Mile 217 to River Mile 216 is a bit steeper with more colluvial accumulation at the canyon/terrace interface.

The eastern side of the channel is dominated by primary, secondary, and currently forming floodplain landforms, while the western side of the channel consists of primary, secondary, and newly forming floodplains. These landforms are usually overlain by alluvial fans and colluvium. A majority of the terraces are buried on the western side and are narrow in regards to the terraces seen across the river. This suggests that the channel has been able to laterally migrate eastward.

In this present condition, this area contains certain river morphological characteristics that would aid in site preservation. The channel is currently slow moving; the gradient is low, approximately 0.3 percent; canyon walls are further apart, leading to a wider area for riparian zones and floodplains to form; and a small landslide, is located upstream of the Frain Stretch, which would have supplied sediments to the downriver and may have temporarily dammed the river, leading to the fine-grained terraces just north. It is unknown when the landslide occurred. It is also unknown how long it would have taken the river to work through the mass of colluvial debris.
Certain alluvial features are present that indicate that the depositional environment is influenced a bit more by alluvial factors, rather than colluvial. Primary, secondary, and newly forming river terraces are found in this flat stretch. Cutbanks and excavation reports indicate that sediments are finer-grained in this location; three abandoned river channels were identified; and to a lesser extent—large aprons, likely alluvial fans, but not entirely alluvial driven (colluvium is located on the top of a few fans and in a few areas it appears that colluvial and alluvial environments are interbedded), are seen overlying terraces. The lower energy of this portion of the river allows fine-grained sediments to fall out of suspension and leads to aggradation of deposits in adjacent areas to the river, subsequently “capping” archaeological sites in alluvium.

The wide channel, low gradient, slower moving channel, and fine grained sediments seem to indicate that the Frain and Blue Heron stretches present an alluvial depositional environment that would aid in site preservation. Therefore, it will be argued that the high density of archaeological sites found within this stretch are likely the result Guccione’s first and third factors (human choice or location selection and later identification of the site), but is mainly due to post-depositional processes that have led to site preservation.

The current study in the UKRC will focus a bit more on Guccione’s second factor—preservation of sites—that will rely heavily upon geomorphology, geology, and pedogenesis to identify landforms, parent material, and soil development.
Figure 3. Location of the Frain and Blue Heron alluvial reaches. Polygons categorize identified landforms within the two-mile stretch (BLM 2013b).
After the identification of landforms, relative ages were acquired for specific landforms through the recordation and quantification of soil morphological characteristics. Weathering—chemical, physical, and biological processes, occurs on bedrock eventually leading to the disintegration or decomposition of the rock. During the weathering process, oxides and clay may form in situ; therefore soils are the result of certain constituents of the parent material as well as the new minerals formed during the process (Boggs 1995:17).

Soils are a valuable indicator of supposed stability and can help to determine the surface age of landforms. It is known that a soil can be no older than the deposit that it has formed upon (Schaetzl and Anderson 2005:547). “Surface Exposure Dating,” or SED is an important application in obtaining surface dates for geomorphic units. SED geomorphological and stratigraphic studies can utilize superposition and cross-cutting relationships to construct relative ages for landforms. Other SED methods may be based on soil development.

Jennifer Harden (1982) modified the Bilzi-Ciolkosz Index (B-C) to quantitatively measure the degree of pedogenesis based on eight soil morphological properties: clay films, texture + wet consistence, rubification (hue and chroma), structure, dry consistence, moist consistence, color value (melanization), and pH (1982:1). These soil properties are known to change with time and Hans Jenny’s (1941) factors of soil formation—climate, organisms, relief, parent material, and time (CLORPT) were taken into account (Harden 1982:2). This profile development index (PDI), commonly called the “Harden Index,” assigns points to soil horizons as properties develop or increase. The values are then compared to the parent material to show the degree of difference. If the parent material cannot be identified—a similar parent material must be found nearby4. The horizon points are then divided by the maximum

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4 Newly forming floodplains substituted as the parent material in the current UKRC study, since alluvial soils are defined by the alluvial accumulations on floodplains (Ferring 1992:2).
value, ultimately providing a range between 0 and 1. Values closer to 1 show a higher degree of pedogenesis. These normalized values are then summed, divided by the total properties used, and then multiplied by soil profile depth. This leads to one PDI calculation per soil profile and one weighted PDI per soil profile (Harden 1982:2; Schaetzl and Anderson 2005:575-577).

The Harden Index is a quantitative measurement of soil development in fluvial suites. Harden’s chronosequence\(^5\) study related soil development to time and demonstrates that soil chronosequences are valuable tools for examining soil and landscape evolution (Huggett 1998:155). Soil development is believed to occur somewhat logarithmically and this should be reflected in distinct terrace features, where it is assumed higher terraces are older and lower terraces are younger. PDI calculations should be able to express differences amongst horizons within a profile as well as differences in PDI values and weighted PDI values amongst terrace complexes, since it is known that soil development increases through time.

As established, Harden’s Index should work relatively well on terrace complexes. Soil data can aid in the determination of geomorphic surfaces. One can look at the deposits underlying a soil layer and know that the soil is no older than that sediment deposit, because it had to develop under some sort of stability. As a sediment or layer of sediments becomes stable, CLORPT begins to lead to soil formation. On a general scale, the formation of some characteristics and loss of others is known to occur in relatively large timeframes. Soils are known to develop and change in a predictable way and can be used as a relative dating tool (Schaetzl and Anderson 2005:568).

Overtime sediments are mixed by animal and plant interactions, mineral expansion and contraction, and weather changes. Organic matter is also added. Generally, soil texture become finer grained as a soil ages—going from coarser fragments to clay. Therefore, younger soils should be stratified with a coarser

\(^5\) Suite of soils that are genetically related, that have a similar topography, climate, and vegetation forms (Harden 1982).
texture, while older soils should be "mixed" with a finer texture. However, there are exceptions in vertisol, histosols, and andisol orders. As soils age, the color tends to lighten and become rubified, or change to a more orange-red color. Soils become more basic as the soil is leached, dry consistence becomes harder, wet consistence stickier, structures more defined, properties extend deeper, more horizons should be present, and horizons generally thicken with age. Younger soils would likely contain an A horizon (topsoil with organic matter), but not a B horizon (subsoil, clay accumulated horizon). A mature soil would have both A and B horizons, and an old soil would have thicker horizons with more difference amongst horizons.

The Harden Index has been used on multiple studies to determine relative dates for soil development (McFadden and Weldon 1987; Munster and Harden 2002; Swanson et al. 1993). These studies show the variability in which the index may be used.

Based on soil properties and changes, the Harden Index, or PDI was used to quantify soil morphological characteristics to find relative dates for terrace complexes along the UKRC. These relative dates will provide information as to how long the terrace has been in a somewhat stable condition and will provide insight into what areas have higher potential to contain archaeological sites of relative date ranges.

Local Archaeological Studies

According to more recent reports, the UKRC is not well represented in the documentary record. A void of archaeological synthesis for the UKRC may be due to a variety of reasons that include the remoteness of the canyon, lack of chroniclers, early removal of indigenous people, limited publication of archaeological research (with an exception of work completed by Joanne Mack and Susan Gleason), and possibly because much of the archaeology of the UKRC appears to contain influence from immediate regions (e.g., Northern
California, Northwest Coast, Columbia Plateau, and the Great Basin). This influence may cause the area to ‘blend in’ or be lumped in with a surrounding culture regions (PacifiCorp 2004a:6-16; Theodoratus 1990:6-7). Although ethnographic studies span over 100 years, the lack of complete archaeological synthesis or seems to be somewhat of a reoccurring problem in the UKRC.

The following section summarizes the available cultural data for the UKRC with a focus on archaeological studies. This presentation of data provides a contextual framework for the development of research questions and details the cultural chronology of the UKRC.

The first archaeological excavation to take place in the Klamath Basin was conducted in 1935, by J. Carlisle Crouch and D.H. Canfield (1936) at the Lava Beds National Monument, approximately 35 miles east of the UKRC (Mack 1991b:59). It was not until large-scale dam construction projects began along the Klamath River in the early 20th century that archaeological research was initiated in the river canyon (Boyle 1976; Mack 1983:1; USDI 2011:1). These projects included the Copco Dam 1, completed in 1918; Copco Dam 2, 1925; Big Bend Dam, 1958 (renamed the J.C. Boyle Dam in 1962); Iron Gate Dam, 1962; and the Keno Dam, 1965.

Archaeological investigations were conducted for the Pacific Power and Light, California-Oregon Power Company Division, prior to the construction of the Big Bend Dam and reservoir (roughly 4.5 river miles to the north of the current study area). Sites 35KL13 (FY58-014-001), 35KL14 (FY58-014-002), and 35KL15 (FY58-0143-003) were partially excavated in July and August 1958 and a report was generated in 1959, documenting excavation, analysis, and future recommendations (Newman and Cressman 1959). Newman and Cressman mentioned that two of the sites have potential to yield significantly important archaeological evidence for the area (35KL13 and 35K14), and that 35KL13 should be fully excavated in the future (1959:3). The sites consist of lithic debitage, groundstone (metates and manos), faunal remains, human remains,

Cressman returned to the area in 1960, serving as Chief Investigator on salvage archaeology projects for the next year under the Iron Gate Project (Mack 1991b:3). Between 1961 and 1963 archaeological survey and excavations were completed by Cressman and crew in response to the proposed but never constructed Salt Caves Dam and reservoir (the proposed dam site is located approximately three river miles downriver from the current study area). Seven sites were located during initial survey in 1961; a continuation of the survey occurred in June, which located an additional five sites, totaling to 12 sites. These sites were recorded and assigned “S.C.” numbers (1-12), standing for Salt Cave, and were later assigned Smithsonian Trinomials (35KL16-35KL26). Shortly after, two sites were combined, (SC 1 and SC 2), bringing the number to 11 sites (Mack 1991b:3; PacifiCorp 2004a:6-11).

Nine of the sites were probable habitation sites, consisting of circular and oval depressions—likely house pit features (Cressman and Wells 1961:3). Surface collection occurred at seven sites 35KL16 (SC 1, FY61-014-001), 35KL18 (SC 4, FY61-014-003), 35KL19 (SC 5, FY61-014-004), 35KL20 (SC 6, FY61-014-005/combined with 35KL21, SC 7, FY61-014-006), 35KL22 (SC 8, FY61-014-007), 35KL23 (SC 9, FY61-014-008), and 35KL25 (SC 11, FY61-014-010) (sites will be referred to by the BLM number or by the common name; Table 1).

In addition, a bulldozed gravel test pit was inspected at FY61-014-004 and one house pit was ‘trenched’ at FY61-014-006. Further excavations consisted of a 1 x 1 meter unit, put into the southwest corner of House pit 5 at FY61-014-007 (West Pine Bank Village), revealing a burned post at a 70 centimeter depth, an ash lens, bone fragments, flakes, and charcoal fragments; two test pits (1 x 1 x 0.75 meter) and a third separate 1 x 1 x 0.75 meter test pit (placed into a different cave), were excavated at site FY61-014-009 (Salt Cave), yielding only sterile fill, which is attributed to roof fall (Cressman and Wells 1961:3-6; Mack 1983:4).
House Pit 3 and a 2 x 6 meter area at the western end of a midden were excavated at sites FY61-014-003 (Big Boulder Village) and FY61-014-006 (Klamath Shoal Midden) (Cressman and Wells 1961:10 and 14).

One radiocarbon date was obtained from the western portion of the midden feature at Klamath Shoal Midden, at a depth of 65-to-75 centimeters, which produced a date of 1280 ± 125 B.P. (Cressman and Wells 1961:30).

Table 1. Organizational table of sites located within the UKRC corridor. Site locations extend from River Mile 226 (in the north), to River Mile 209 in the south (540 meters south of the California/Oregon state line). The current study area covers five miles at River Mile 220 to River Mile 215. Sites located within the study area are highlighted in grey.

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The following year, Cressman returned to the canyon, with fellow researcher Michael Olien. No new sites were found, but artifacts were surface collected at three sites, FY61-014-004, FY61-014-010, and FY61-014-011 and a test pit (1 x 1 x 0.75 meter) was put in at Salt Cave, proving once again to be sterile. Cressman and Olien mentioned that all levels of the unit appear to be roof
fall and that a deeper excavation is necessary in order to possibly reach cultural materials. Limited excavations were carried out in a smaller cave (part of the Salt Caves), in which a thick accumulation of bat guano was noted to be present. Two chert cores were recovered during excavation of the smaller cave and a few large chert artifacts were surficially located near the river, downslope and directly in front of the main Salt Cave. In 1990, a Shasta informant identified the cave complex as being ethnographically important to the history of the area; in 2003 three lithics were found on the surface; and in 2013 a gray cryptocrystalline silicate (CCS) core was found downslope to the west of the main cave (on the surface approximately two meters east of river channel) (KFRA 2003; KFRA 2013).

House Pits 11 and 13 were excavated at Big Boulder Village. Cressman attempted to determine the extent of the midden feature at Klamath Shoal Midden by placing a 1 x 2 x 1.5 meter unit in the eastern portion of the midden, one midway (1 x 2 x 1 meter), and a third unit (4 x 6 meter) at the western-most part of the midden, to help determine the extent of the feature (1962:5-9). It was found that the midden extends approximately 60 meters in length (Cressman and Olien 1962:8).

A second radiocarbon date of 6,065 ± 400 B.P. was obtained from a piece of charcoal found below a 200 centimeter depth in the “River Gravel” or Stratum I of the western-most midden unit of the Klamath Shoal Midden (Cressman and Olien 1962:30; Mack 1983:21). Cressman mentions that some of the oldest cultural material found yet, comes from Stratum I, including a large chert scraper, two smaller obsidian scrapers, and an obsidian point fragment (1962:11).

In 1963, archaeological work continued to be conducted by U of O, but now under the guidance of Adrian Anderson and David Cole. Research moved downriver to sites FY61-014-001 and FY61-014-011. Surface collection was done at FY61-014-011, while the identification of 19 depressions were recorded at FY61-014-001, of which House Pit 1 had an extensive excavation (1 x 12 meter) and cross trenches were placed in House Pit 2 (1 x 7 meter E/W and 1 x 8
meter N/S) and House Pit 11 (1 x 8 meter E/W and 1 x 9 meter N/S) (Anderson and Cole 1964:9; Mack 1983:5). A radiocarbon date of 540 ± 210 B.P. was obtained from charred wood fragments found on the floor of House Pit 1 (Anderson and Cole 1964:10). Partial remains of split log planks, one knife, 246 pottery fragments, two flaking tools, one elk antler wedge, one antler spoon, 16 bird bone beads, one pestle fragment, three steatite bowl fragments, one steatite pipe, human remains, and 256 points (70 identifiable) were recovered (Anderson and Cole 1964:17-19). It is believed that some of the artifacts (antler spoon, steatite pipe, two antler flaking tools, and large obsidian flake) found in House Pit 1, near the human remains, may have been grave offerings.

The excavations of these sites were part of an on-going environmental inventory to investigate project impacts in regards to the proposed construction of dams. A ten-year-long re-evaluation, consisting of an interpretation and hypothesis of UKRC cultural materials was initiated by Joanne Mack and was later part of her 1979 dissertation and published in the University of Oregon Anthropological Papers No. 29 in 1983 (Boyle 1976; Gehr 1985:4-83; Mack 1983:5; Mack 1991b:3; Theodoratus 1990:7). Mack found four basic conclusions: the Salt Cave Locality was probably continuously inhabited for the past 7,000 years as demonstrated by radiocarbon dates from Klamath Shoal Midden and Big Boulder Village. Secondly, that sites upriver and downriver show disparities and that this is likely attributed to a division amongst early inhabitants, some being influenced by Great Basin culture and others influenced by cultures west of the Cascades. The canyon corridor served as a passage for cultural influence, as demonstrated in the archaeological record by items thought to have been brought in as a result of trade and/or travel. Lastly, the Salt Cave Locality was likely on the ‘fringe’ of any particular groups’ territory (1983:231). Mack also suggests that more excavations need to be completed in the canyon to fully determine the time span of occupation (1983:232).

In 1980, Pacific Power and Light (PP&L) proposed the construction of a new dam (Salt Cave Dam). The new dam was to be 120 feet high, 380 feet long,
with a 3.7 mile long reservoir (Mosey 1980). In 1984, a new proposal by the City of Klamath Falls for the Salt Cave Dam triggered the need for additional archaeological work in the form of surveys and testing. The methods and findings were summarized in an inventory report, submitted to the Bureau of Land Management (Gehr 1984; Gehr 1985; Miller 1986). From 1984 to 1986, Elliot Gehr of Beak Consultants, led 10-to-20 meter spaced transects along conduit routes, proposed roadways, and on alluvial terraces in all approximately 1,607 acres were inventoried (Gehr 1984; Gehr 1985; Mack 1991b:4; Miller 1986). Gehr also interviewed Shasta informants about sites. Survey resulted in the identification of 43 sites (some were identified in previous inventory by Cressman), of which 34 are prehistoric, three are historic, and six are multi-component (Gehr 1986:4-118). This led to an evaluation of sites. Twenty of which were not likely to be impacted by the proposed project and therefore not tested (Sites 6, 9, 17-19, 26, 28-32, 34, 35 (H), 36 (H), 38 (H), 41, 42 (H), and 43 (H); prehistoric and historic sites were recorded separately, with “H” referencing historic). Seventeen were found to not be impacted by the project, but were tested (Sites 2, 3, 4, 5, 7, 8, 10, 11, 12, 15, 16, 21 (H), 22-24, 25 (H), and 27). Seven sites (2, 4, 5, 7, 10, 11, 16, 23, 24, and 27) were dated to the late prehistoric period by use of radiocarbon dating, cross-dating or time sensitive artifacts or features. However, there was no evidence of sites being occupied during the proto-historic period (Gehr 1985:4-211-4-212). This led to an evaluation of six sites (numbered 1, 13, 14, 20, 33, and 40) that were found with the area of potential effect (APE). Subsurface testing was implemented, utilizing a combination of 0.5 x 1 meter test pits and 40 centimeter shovel pits.

Other finds associated with the field seasons include: 76 projectile points were recovered from the testing and surface collection of 18 sites, which a majority of projectile points were identified as being Gunther stemmed (Gehr mentions that lithic analysis was both technological and typological); 73 points were obsidian and three were chert, although there are no known local obsidian
sources; and Northern Side-notched, Elko, and Gold Hill Leaf points share the same vertical distribution at Klamath Shoal Midden (Miller 1986:4-12, 4-13, 4-45).

In 1986, Peter Jensen, of Jensen Associates continued archaeological research in the canyon by surveying and mapping two sites (FY61-014-001 and FY84-014-002) (Jensen 1987a; 1987b). Further inspections were executed at a depression feature at FY84-014-002 and excavation was performed at FY61-014-001, to determine site eligibility (Jensen 1987a:1.1, 4.3; 1987b). A single depression at site Butler’s Outlook was inspected (through 40 centimeter auger probing and trowel scrapes), which did not yield cultural material. These results led to a decision that the site was not eligible, therefore further inspection was not done. Four backhoe test pits, two backhoe trenches, and 12 test pits were excavated at Border Village. Test Pit 1 (2.5 x 0.8 x 1 meter) was located at the northerly-most extent of cultural deposits and Test Pit 2 (2.5 x 0.8 x 0.8 meter) was placed at the site’s western extent. Two 1 x 1 x 0.5 meter test units (Unit 9 and Unit 10) were located adjacent to Test Pit 2 to help estimate the range and density of midden contents (Jensen 1987a:3.4). Backhoe Test Pit 3 (1 x 3 x 1 meter) was placed in an eroded portion of the site with Test Unit 11 (1 x 1 x 0.4 meter) adjacent. Backhoe Test Pit 4 (2.5 x 1 x 1 meter), was placed in the north of Backhoe Test Pit 3, but closer to the midden feature associated with House Pit 19. In order to test the hypothesis that cultural material was concentrated at and around house pit features, Jensen had one 10 x 0.8 x 1 meter trench dug adjacent to House Pit 14 and a second trench excavated further off; together these trenches spanned a 21 meter area, offering subsurface glimpse of the site (Jensen 1987a:3.3-3.14).

Jensen found that the amount of cultural material recovered from Border Village was lower than materials recovered from late period sites in California, house pit areas represented primary areas for activities, that the site may have been seasonally occupied, and that the midden did not conceal any features. A radiocarbon date of 580 ± 100 years ago was obtained from a charcoal sample in Unit 8 at a 20-30 centimeter depth (midden feature), that compares to other
results obtained from House Pit 14 and dates from the nearby Iron Gate Site, suggesting that occupation approximately occurred between 500 and 325 B.P. (Jensen 1987a:3.15-3.16).

In the 1989, Biosystems Analysis and Mack entered two separate contracts with the BLM to conduct field reconnaissance, analyze finds, and synthesize a report (Theodoratus 1989; Mack 1989). This contract laid the foundation for a later study finished in a 1991—Klamath River Canyon and Prehistory and Ethnology, Mack synthesized and consolidated data that had been collected between 1984 and 1986 in order to assess the canyon for a Wild and Scenic River status. This study created the presently used chronology for the canyon. Mack’s archaeological research and continued focus in the canyon and above in upland areas (30+ years) has led to the excavation and testing of 12 sites since 1991, updating of numerous site forms, in the creation of a culture-history chronology for the UKRC, continued research on SUW, and obsidian hydration testing (Mack 1992, 1993a, 1993b, 1997; PacifiCorp 2004a:6-13).

Mack created an archaeological chronology for the UKRC. The chronology can be divided into three periods—Paleoarchaic, Middle Archaic, and Late Archaic/Late Prehistoric— that contain five identified phases for the UKRC. For the most part these groupings are very general and in some cases have limited representation in the canyon. The archaeological chronology of the UKRC is based on time horizon markers, stratigraphic dating, as well as a few radiocarbon dates. In all, Mack has proposed that the canyon has been occupied for the past 7,000 years and continued until the historic period (1983:1, 231; 1991b:37).

The earliest “not named” phase dates to pre-7,500 and is not well represented in the canyon. PacifiCorp refers to this period as Paleoarchaic (12,000-7,000 B.P.) (2004b:2-24). At this time, it is believed that people were hunter-gatherers, highly mobile (seasonal and annual), practiced a broad-spectrum subsistence economy, populations were low, and people possessed highly ‘flexible’ tool kits (PacifiCorp 2004b:2-24). One Eden projectile point, found at Big Boulder Village, typologically dates to this phase, or to the succeeding
phase. However, Cressman mentions that this artifact is presumably from the American Midwest region and may have been a recent addition to the site via collector's entering and depositing the artifact at the site (1961:26). It is also probable that the point may have been a ceremonial blade.

Many tribes along the Klamath River were known to produce highly prized large points for ceremonial purposes, as documented by Carrol B. Howe in *Frontier Stories of the Klamath Country*, however, the intensity and variation is unknown. Ceremonial blades were found during the Tule Lake Phase (150 B.P. - historic) and within the earlier Gillem Bluff Phase (600 – 150 B.P.), but Howe mentions that the blades were also found at the Nightfire Island site, dating to around 1500 years ago (Howe 1989:56-62; Sampson 1985:33, 34). This type of blade has been found interred with burials west of the Cascades at the Gold Hill Site as well (Sampson 1985:38). Sampson mentions that at the Nightfire Island site, these large blades are expected to appear in the second identified projectile point assemblage, characterized by Elko and Humboldt series. The dates at which the blades appears cannot be predicted, nor or they able to fit into a predictive scheme (Sampson 1985:33, 34, 35, 38).

In addition, the eruptions of the Black Butte and Shastina vents of Mount Shasta (approximately 9,500 B.P.), likely caused disturbances in settlement patterns in this region during the earliest phases. Pyroclastic flows from Black Butte traveled as far as 12 miles, block-and-ash flows spread about six miles south and three miles north, and tephra from the eruption was deposited approximately five miles north and 10 miles south, covering at least a 28 square mile area. While, ash from Shastina spread roughly 11 miles down the west flank (Miller 1980:15).

Based on Mack’s research conducted in the canyon, it was found that the Stratum of Site 35KL21 was dated to 7,646 ± 400 B.P. (1983:17-26, 227; 1991b: 37-38). A small collection of unifacial flaked tools and generalized bone tools were contained in this stratum (Mack 1991:72). The date from the site doesn’t fall completely within the phase, PacifiCorp, placed this site into the “Secret Spring
Phase” (7,500 – 6,500 B.P.) of the Early Archaic Period (7,000 – 4,500 B.P.),
based on component characteristics (2004b:2-20, 2-24). The Secret Spring
Phase is characterized by large lanceolate and stemmed points, knives, gravers,
scrapers, grinding tools, and some ground stone tools (PacifiCorp 2004b:2-24).

Around this time Mount Mazama (6,800 B.P.) erupted also causing
disturbances in lifeways and a second phase has been identified that falls within
the Early Archaic Period, and recognized as the “Basin Phase” (6,500 – 4,500
B.P.). Common features of this phase include ground stone tools, portable
utilitarian items, knives, scrapers, McKee unifaces, and broad-necked projectile
points such as Humboldt Concave Based points and Northern Side-notched
points. It is mentioned that at this point, past people began processing and using
vegetal foods more often as indicated in the archaeological record by the
presence of ground stone tools. The atlatl was used at this time and faunal
remains include turtle and large and small animals.

As paleoenvironmental conditions changed around 4,000 B.P., settlement
patterns shifted towards sedentism during the Middle Archaic (4,500 – 2,500
B.P.) as shown at the Nightfire Island Site, located roughly 16 miles to the
east/southeast of the canyon (PacifiCorp 2004b:2-24; Sampson 1985). The
“River Phase” (6,500 – 4,500 B.P.) occurred in the canyon, and typical artifacts
included the broad-necked point, side-notched points (Elko, Gold Hill Leaf, and
Siskiyou points), chisel-type tools, ground stone, and specialized fishing gear
was also found (Mack 1983; Mack 1991b; PacifiCorp 2004b:2-24). A shift
towards riverine resources was seen in the archaeological record by the amount
of specialized fishing gear, but also seen in the faunal assemblage found at sites.

By 3,500 B.P. conditions were more like today (PacifiCorp 2004b:2-17).
As the climate became drier, marshlands and riverine areas were of importance.
In an area like the Great Basin, people generally became ‘tethered’ to areas with
water. Reliable water sources such as the river provided a reliable source of food
and water (PacifiCorp 2004b:2-17).
The Late Archaic/Late Prehistoric (2,500 – 200 B.P.) was characterized by the widespread appearance of house pits, the oldest house pit in the UKRC dating to 900 B.P. (Mack 1991b:80). Other distinguishing characteristics include: use of storage for bulk resources, more reliance on fisheries, sites are often located near water and marshland areas, extensive trade networks are established (extra-local materials found in the record), and settlement patterns appear to be like the Winter Village land use pattern (PacifiCorp 2004b:2-25). A higher amount of small points (Eastgate, Rosespring, Gunther, and Desert side-notched types) are found in the archaeological record, suggesting that the adoption of the bow and arrow took place during this period.

The “Canyon Phase” runs the full length of the Late Archaic and includes sites with house pit features found in the canyon. Use of specialized muellers or manos (indicative of wocus processing), presence of Olivella shell beads, higher amounts of bone tools, and a shift in burial practices (flexed burials to cremation) take place during this time (Mack 1984; Mack 1991b; PacifiCorp 2004b:2-25). Burial goods are found with cremations.

Mack further divides the Canyon Phase into three subphases: Canyon Subphase 1 (2,200 -850 B.P.), Canyon Subphase 2 (850- 350 B.P.), and Canyon Subphase 3 (350 B.P. - contact) (Mack 1991b:73; PacifiCorp 2004b:2-20). These phases are mainly based on projectile point typologies and presence and absence of SUW. Canyon Subphase 1 includes Gunther stemmed points, Rosegate points, bone tools, and two different types of beads (Saucer Bead and Olivella Ring Bead) found in the lower part of Stratum III of Site 35KL21 and from a midden feature at Site 35KL20 (Mack 1991b:75). This subphase is present in three different house pits and from one stratum layer in four different sites.

Canyon Subphase 2 contains Gunther Barbed and Rosespring series points, mammal bone beads, pottery, and ceramic figurines (SUW) (Mack 1991b:73, 75; PacifiCorp 2004b:2-20). Increased use of the canyon occurs at around 1,000 years ago and as a result more house pit features have been found.
(Aikens et al. 2011: 347; Mack 1991b:75). A total of seven sites date to this subphase (Mack 1991b:39, 75).

In the last subphase—Canyon Subphase 3, there is continued use of Gunther and Rosespring points, the introduction of the Desert side-notch point, figurines, and lack of pottery (Mack 1991b:73, 75; PacifiCorp 2004b:2-20). The lack of pottery is one of the distinguishing characteristics of this subphase. There is an absence of Euro-American trade goods, which indicates that permanent residence in the canyon had ended by the 1800s (Mack 1991b:73, 76).

Table 2. Sites and associated dates found in the UKRC. Sites FY61-014-003, FY61-014-005, and FY61-014-006 are located within the current study area (adapted from Mack 1983:55, 227 and Mack 1991b:37-38).

<table>
<thead>
<tr>
<th>Site</th>
<th>Radiocarbon Date</th>
<th>Time Marker</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>FY61-014-005, Klamath Shoal Village</td>
<td>100 ± 70 B.P.</td>
<td>-</td>
<td>Gehr 1985</td>
</tr>
<tr>
<td>FY61-014-004, Frain South Field</td>
<td>210 ± 80 B.P.</td>
<td>-</td>
<td>Gehr 1985</td>
</tr>
<tr>
<td>FY61-014-011, Men’s Ceremonial Area</td>
<td>330 ± 60 B.P.</td>
<td>-</td>
<td>Gehr 1985</td>
</tr>
<tr>
<td>FY61-014-003, Big Boulder Village</td>
<td>Cal. 564 ± 110 B.P. (House Pit 3, Floor)</td>
<td>Humboldt Concave Base A (Test Pit)</td>
<td>Valastro et al. 1967 Mack 1983</td>
</tr>
<tr>
<td>FY61-014-001, Border Village</td>
<td>Cal. 580 ± 120 B.P., House Pit 1, Floor 3 580 ± 100 B.P., House Pit 1, Floor 3 970 ± 80 B.P.</td>
<td>-</td>
<td>Mack 1983 Jensen 1987</td>
</tr>
<tr>
<td>FY61-014-006, Klamath Shoal Midden</td>
<td>Cal. 1,009 ± 110 B.P., Stratum IIIc, d Cal. 1,296 ± 125 B.P., Stratum IIIb, c Cal. 7,646 ± 400 B.P., Stratum I</td>
<td>Button, Surface (Historical) Olivella bead, Stratum IIIc, d (1,150 – 7,750 B.P.)</td>
<td>Mack 1983 Valastro et al. 1967</td>
</tr>
</tbody>
</table>
The chronology of the canyon relies upon other periods and phases that are adapted from nearby sites, located in different environments, and also borrows dates from point typologies. Mack mentions that this is problematic due to many of these point typologies not being clearly defined and that many of the typologies are not clear temporal time markers (1991b:76). Mack also mentions that additional up-to-date analyses should be conducted on collected and curated materials and that more testing and excavation is needed in order to better understand each phase, and that if there was a larger sample dating to the Secret Spring Phase (7,500 – 6,500 B.P.), it would undoubtedly contain projectile points, knives, scrapers, and perhaps groundstone (1991b:77, 82).

Mack also guided other research in the UKRC over the course of three summers (1992, 1993a, 1993b; 1994a; 1994b; 1995a; 1995b). The first two field seasons focused on inventory, evaluation, and testing; and data recovery work had been done at Aspen Village in 1992 and 1993. (Stepp 1997:7). In a report from 1994, Mack summarizes the third field season and mentions that extensive excavation was performed (1994a:1). This report details excavation work completed at sites FY61-014-007 and FY92-014-002 (not in the canyon corridor, but above on the Klamath Rim). House Pit 5 was vandalized at FY61-014-007 and Mack decided to place a five meter (east-west) by six meter (north-south) grid into the house pit (1994:9). More than one floor was found within the house pit, which Mack notes with interest since past excavation work indicated that many sites located in the northern portion of the UKRC only contained single floors. Conversely excavations of house pits downriver revealed evidence of multiple floors (Mack 1994a:7).

Other work focused on the continuation of research of SUW, finding that SUW assemblages from the Rogue River, Klamath River, and Pit River all date between 350 and 950 B.P. Other works focus on obsidian sourcing, in which a majority of the obsidian found in the canyon has been identified as being from the Medicine Lake Highland locale and one cobble was sourced as far away as Massacre Lake, over 100 miles away (1997; 2002; 2003a; 2003b; 2011; 2013b).
Throughout the mid-to late 1980s and 1990s, ethnobotanist Donn Todt researched geophyte use, ethnobotany, and resource ranking in the Klamath Basin. Todt and Nan Hannon (1998) realized that much archaeological evidence and research focus had been weighted toward faunal resources, despite the fact that in the Klamath River area there are 60 plant species that have been identified as having been important to the diet of the people in the region during the ethnographic period. Out of the 60 species, only a few of the plants are ranked high enough to have probably been important enough to have procurement strategies associated with the plant. Those species include oak (Quercus) and ipos or yampah (Perideridia), while tarweed (Madia), pine (Pinus), and wild rose (Rosaceae) were important to a lesser extent (Todt and Hannon 1998:273).

Following the study of Todt and Hannon (1998), archaeological work conducted in the canyon has been linked to BLM cultural resource evaluations related to Section 106 of the National Historic Preservation Act (NHPA) of 1966, as amended (Public Law 89-665; 16 USC 470-470w-6), the National Environmental Policy Act (NEPA) of 1969 (Public Law 91-190; 42 USC 4321-4347 and applicable regulations (36 CFR Part 60, 63, 800 and 40 CFR Parts 1500-08).

BLM surveys consist of a Class I literature review and other requirements are part of the BLM-Oregon State Historic Preservation Office (SHPO) protocols (1998 Programmatic Agreement). Under Section 8110.21 of the BLM Manual, a survey is defined as “consisting of continuous, intensive survey of an entire target area, aimed at locating and recording all cultural resources that have surface indicators, by walking close-interval parallel transects spaced no more than 30 meters apart until the area has been thoroughly examined (USDI 2003).”

A total of nine surveys conducted by BLM staff (Burnside 1989; Canaday 2003; Durant 2005; Ferguson 1997; Hescock 2007, 2008, 2011, 2012; Ross 1998), and two contracted surveys (Jones 2003; Stepp 1997) were completed between 1989 and 2012. One additional “anonymous” survey was found in BLM
archaeology records, and had recently been digitized into the geodatabase. The survey area is comprised of several discontiguous small polygons and does not have a name, date, or other documentation; it does however, cover 272 acres of the canyon corridor (Anonymous n.d.); however, this is considered unreliable due to missing most of the information that should be associated with the survey.

In all, these surveys covered approximately 8,554 acres within the river corridor, along the Klamath Rim, and/or above on the flats, documenting approximately 49 prehistoric and historic sites. In some instances sites had already previously been recorded and were already assigned Smithsonian Trinomials and Agency Numbers, but for some reason were provided additional site numbers. Sites may possess three Agency Numbers, three Trinomials, and multiple names (e.g., SC 7, Gehr 6, 35KL20, 35KL21, 35KL786, FY61-014-006, FY61-014-005, FY89-014-005, Klamath Shoal Midden/Klamath Shoals Village is currently all contained within one site boundary). This often occurs as a result of multiple people recording a site and/or surface changes with time, which leads to lumping and splitting of a site(s). It should also be noted that many of these sites were not located within the canyon corridor, therefore, were not included in Table 1.

In the past decade, there has been a renewed focus on the canyon, in response to the proposed KHSA. A cultural overview, one large river report, a riverscape study, a second dissertation, a thesis, and a geoarchaeological report (well outside the current study area) have been finished, leading to a synthesis of older cultural works (Beckham 2006; Dabling 2009; Gleason 2001a; Mack 1991b; McCutcheon 2008; King 2004; PacifiCorp 2004b; Theodoratus 1990; Young 2005).

In sum, numerous studies have been conducted in the Klamath Basin and surrounding areas; however, early ethnographic documentation neglected the canyon and the first archaeological excavation occurred 55 years ago (Cressman 1958). Numerous reasons have been brought forth for the lack of documentation and archaeological synthesis—from the canyon being too remote to the early
removal of indigenous people. It wasn’t until large-scale dam construction began in the mid-20th century that archaeological research began. Later works address specific questions and focused on building a cultural chronology, but no geoarchaeological work has been done in the J.C. Boyle locale. It is apparent that evidence and understanding of early occupation in the Upper Klamath Basin, specifically the UKRC, is non-existent. Gehr states that:

“Although, a lot of work has been done in the Klamath Basin, it is obvious that evidence for early occupation is sparse, fragmentary and poorly understood (1985:4-68).”

Since the 1985 study, more work has been conducted in the UKRC, leading to a 1991 synthesis that has identified five phases. The earliest unnamed phase is absent from the archaeological record. Succeeding phases are present at the Klamath Shoal Midden, but not at any other location. Based on this information it is clear that more work needs to be conducted on the geomorphology to aid in understanding the landscape in regards to site locations and patterns. Additional analyses of excavated materials (sourcing, basketry, and pottery), using newer technologies should also take place. And as mentioned by Mack, future excavation should be conducted on key sites that may further our understanding of settlement patterns, subsistence, diet, trade networks, raw materials, and also to further our knowledge in regards to pre-contact basketry and ceramics of the river canyon.
Chapter 3. Environmental Setting

Climate

The Klamath Basin is situated within the Basin and Range and High Cascades physiographic provinces. The weather currently found in the area, specifically the northern and northwestern portion of the basin, is conditioned by the semi-permanent anti-cyclonic cell as well as the location of this cell and the westerly winds created by it (Gehr 1985:4-18). This portion of the basin is situated to the east of the Cascade Mountain Range, falling in the rain shadow, which serves as a buffer from the ocean winds and results in dry climate, low humidity, and extreme temperatures characteristic of southern Oregon (Minor, Beckham, and Toepel 1979: 8). The remaining part of the basin meanders southwesterly through the Siskiyou-Klamath Mountains (PacifiCorp 2004a:6-2).

The modern climate for the basin varies from semi-arid in the northern part, to more of a mesic temperature regime in the southern portion. However, most of the basin is generally categorized by extremes in temperature ranges, both seasonally and diurnally/nocturnally. Precipitation varies across the basin, mainly by elevation (Copco Reservoir, 2,607 feet and Mount McLoughlin, 9,495 feet), with Crater Lake receiving the highest annual precipitation at 167.6 centimeters and Tule Lake the lowest at 27.6 centimeters (Rabe Consulting 2007:3). Within the Klamath Falls area, the winter diurnal temperature is about 40° to 22° F and ranges from 86° to 52°F in the summer months (PacifiCorp 2004a:6-4). Temperatures in the UKRC are not much different than the upper part of the basin, but do seem to be a bit milder, especially during the winter months. Summers are dry and hot, exceeding 80° F (84°-88° in July) and winter temperatures may drop to the low 20° F area, but are generally around 36° to 40° F in January (Mack 1983:11; NPS 1994:33). On average, the annual
precipitation is 357 millimeters (14 inches) and the average snowfall is 104 centimeters for the Klamath Falls area (Franklin and Dryness 1988:38).

Latitude and the Pacific Ocean both exert influence upon the climate, as does topography. The UKRC is lower in elevation than adjacent areas and varies slightly. Precipitation in the canyon averages to about 15-20 inches during the fall, winter, and spring months with an occasional thunderstorm in the summer; snow rarely falls on the canyon floor (Gehr 1985:4-19; NPS 1994:33).

The earliest palynological study in the area took place in 1942 by Henry Hansen, working with an interdisciplinary team along with Cressman on peat profiles from the Lower Klamath Lake. This study focused on fluctuations, lakes and marshes, in regards to changing human populations. Thereafter, few studies have been conducted on the paleoclimates of the basin area. However, Pacific Northwest climatic fluctuations of wet/dry and cold/warm are adapted to the canyon. These patterns are oversimplified and vague to represent such a large amount of time and PacifiCorp research seems to adhere to Ernst Antevs (1955) Holocene pattern, of Anathermal, Altithermal, and Medithermal (2004:2-16).

Overall, it is believed that Early Holocene climates were drier than Pleistocene conditions, but still wetter than today (PacifiCorp 2004b:2-16). This time may lack modern analogues, but it is thought that by 9,500 B.P. a general pattern of vegetation, fauna, and humans were established in the region (PacifiCorp 2004b:2-16).

During the Middle Holocene, paleoenvironmental conditions changed around 4,000 B.P. to having higher rates of precipitation and overall climates were cooler. Grass lands expanded in the region and increased precipitation and lower rates of evaporation must have had an effect on the river flow (PacifiCorp 2004b:2-17). And on more of a micro-scale and within recent times (1564-2004 and 1000-2010 CE) tree-ring data has aided in reconstructed hydroclimates for the basin. It was found that the single-year, three-year, and 50-year droughts were not uncommon and that droughts were most severe in the 11th-13th
centuries and a large drought occurred in the late 16th century (Malevich et al. 2013:13).

**Wildlife**

The UKRC is home to a diversity of terrestrial, avian, and fish species. There are three federally-listed threatened and endangered species present, four candidates, and an additional 11 possible candidates found in the canyon. Nine state-listed threatened, endangered, and sensitive species and two Oregon Natural Heritage Database species also inhabit the area (NPS 1994:13).

A migratory herd of 3,100 (1988-89 population estimate) black-tailed deer (*Odocoileus hemionus*), called the Pokegama herd lives on a flat above and are known to travel through the canyon corridor (NPS 1994:47). Other large game includes the mule deer (*Odocoileus hemionus hemious*) and elk (*Cervus elaphus*).

Larger predators include the mountain lion (*Felis concolor*), bobcat (*Lynx rufu*), coyote (*Canis latrans*), gray fox (*Urocyon cinereoargenteus*), badger (*Taxidea taxus*), river otter (*Lutra canadensis*), and black bear (*Ursus americanus*). The ring-tailed cat (*Bassariscus astutus*) and the wolverine (*Gulo gulo*) are possibly present.

Small mammals are abundant and include: California ground squirrel (*Spermophilus beecheyi*), deer mouse (*Peromyscus maniculatus*), Nuttall’s cottontail (*Sylvilagus audubonii*), striped skunk (*Mephitis mephitis*), beaver (*Castor canadensis*), mink (*Mustela vison*), fisher (*Martes pennanti*), long and short-tailed weasel (*Mustela frenata and erminea*), muskrat (*Ondatra zibethicus*), porcupine (*Erithizon dorsatum*), Hoary bat (*Lasiurus cinereus*), and Townsend’s big-eared bat (*Plecotus townsendii*) (NPS 1994:44-46, 81-82).

Twenty-eight species of Herptiles are found within the study area, including western rattlesnake (*Crotalis viridis*), garter snake (*Thamnophis elegans and sirtalis*), California kingsnake (*Lampropeltis zonata*), rubber boa
(Charina bottae), gopher snake (Pituophis melanoleucus), racer (Coluber constrictor morman), western fence lizard (Scoloporus occidentalis), alligator lizard (Gerrhonotus multicarinatus and coerules), western pond turtle (Clemmys marmorata), western toad (Bufo boreas), and Pacific chorus frog (Hyla regilla) (NPS 1994:81-82).

There are 98 known bird species in the canyon, which are: acorn woodpecker (Melanerpes formicivorus), white-headed woodpecker (Picoides albolarvatus), wild turkey (Meleagris gallopavo), blue grouse (Dendragapus obscurus), wood duck (Aix sponsa), mallard (Anas platyrhynchos), blue heron (Ardea Herodias), double crested cormorant (Phalacrocorax auritus), peregrine falcon (Falco peregrinus), pygmy owl (Glaucidium gnoma), northern spotted owl (Strix occidentalis caurina), bald eagle (Haliaeetus leucocephalus), and golden eagle (Aquila chrysaetos) (NPS 1994:80-81).

The Klamath River is known to have 15 fish species, which include the Lost River sucker (Deltistes luxatus), blue chub (Gila coerulea), and was historically a passage for anadromous fish such as Chinook salmon (Oncorhynchus tshawytscha) and steelhead or rainbow trout (Oncorhynchus mykiss) (NPS 1994:15, 47, 83). Five species of water and terrestrial mollusks are also found in the canyon and include: the Klamath Rim Pebblesnail (Fluminicola sp.), Scale Lanx (Lanx klamathensis), Evening Fieldslug (Deroceras hesperium), Chase Sideband (Monadenia chaceana), and Modoc Rim Sideband (Monadenia fidelis ssp.) (KFRA 2008:10).

Excavation has uncovered numerous terrestrial, avian, and riverine faunal remains in the archaeological record. Mack provides a chart of uncovered faunal remains (1983:236). These charts indicate that a wide variety of fauna were found at Border Village, Big Boulder Village, and Klamath Shoal Midden. Some of the identified remains include: Western pond turtle, antelope, bighorn sheep, elk, mule deer, white tail deer, mountain beaver, ground squirrel, Belding ground squirrel, golden mantle ground squirrel, porcupine, marmot, California vole, bushy tail woodrat, gray squirrel, chickadee, white tooth pocket gopher, Mazama
pocket gopher, California jack rabbit, cottontail, coyote, dog (assumed domesticated), gray fox, red fox, cougar, bobcat, river otter, martin, fisher, mink, spotted skunk, badger, black bear, grizzly, ringtail, and raccoon (1983:236-243). Cressman and Newman found faunal remains in the 1958 excavation: turtle, cervidae, and miscellaneous rodent remains were uncovered (1958:14).

Vegetation

According to the 1994 *Klamath Wild and Scenic River Eligibility Report and Environmental Assessment*:

“The Klamath River Canyon supports a wide diversity of plant communities due to variations in topography, aspect, elevation, soil type, and microclimate provided by the canyon (19).”

The passage above sums up the variability found within the canyon corridor. The environment of the basin consists of various vegetation zones depending on a number of factors, but can generally pertain to location on the landscape. Thus, vegetation zones are a product of a combination of elevation, aspect, precipitation, and soil type.

The Klamath Basin is generally broken into east-west zones; the western zone being located in the Cascade region, while the eastern zone is more arid (Stern 1998:446-447). Five vegetative zones are located in the basin, from east to west, which include: Steppe without *Artemisia tridentata*, Shrub-Steppe with *Artemisia tridentata*, Pinus ponderosa (northern-most part is part of the pumice region), Desert shrub, and at the western-most margin—*Abiesgrandis* and *Pseudotsuga menziesii* Zones (Franklin and Dyrness 1988:44-45).

The majority of the UKRC falls into the Pumice Region/*Pinus ponderosa* and Zone. The *Pinus ponderosa* Zone is comprised of higher elevation areas with short growing seasons. Forests are comprised of pine, oak, and aspen is
present in riparian areas (Franklin and Dyrness 1988:171). Juniper is present in areas that are more xeric-like. Understory components include: wild rose, service berry, Klamath plum, snowberry, and wild strawberry.

The *Pseudotsuga menziesii* (Douglas fir) Zone is more mesic and is located in cooler climates with higher precipitation than ponderosa pine zones. These characteristics are found in the Cascade Mountains. Forests in these areas consist of Douglas fir, pine, and oak communities are found on many south-facing slopes (Franklin and Dyrness 1988:190-193). The *Abies grandis* Zone or grand fir is located on midslopes with pine, western larch, Douglas fir, wild currant, and snowberry, (Franklin and Dyrness 1988:193-197).

It is important to note that although Franklin and Dyrness provide a great overview of vegetative zones throughout Oregon and Washington, the canyon possesses characteristics of various vegetative zones and Mack reports that the canyon also contains many microclimates that are usually found at specific elevations, slopes, and aspects (1983:15).

Portions of the canyon are located at the intersection of many zones, some which are an extension of northern California plant communities intermingled with plant communities that are found in the eastern Cascades and the Sierra-Nevada region (KFRA 2006:1). Four major plant communities have been identified, which are: coniferous forests/woodlands, dense oak woodland, open oak woodlands, and mixed shrub land (KFRA 2006:1; KFRA 2008:2). Generally, and based on observations during field visits— vegetation communities that prefer a drier climate were found above on the flats overlooking the canyon; oak was observed throughout the canyon; pockets of coniferous trees were noted on the slopes of the canyon and in drainages; and seasonal water sources and riparian zones support vegetation more apt to live in wetter environments.

The over story observed in the study area includes: Oregon white oak (*Quercus garryana*), California black oak (*Quercus kelloggii*), ponderosa pine (*Pinus ponderosa*), with a lesser amount of Douglas fir (*Pseudotsuga menziesii*),

A few invasive weeds and non-native species were also observed within the study area and in the surrounding areas, which include: common mullein (*Verbascum thapsus*), teasel (*Dipsacus fullonum*), Scotch thistle (*Onopordum acanthium*), cheatgrass (*Bromus tectorum*), and medusahead rye (*Taeniatherum caput-medusae*).

Little archaeobotanical research has been completed in the California portion of the Klamath River. Macrobotanical remains reveal what plant species were present in the past. Excavated archaeological sites offer a glimpse in time to what was present as well as to what was important to past people—either for consumption, fuel, shelter, or for something else. Mack remarks that macrofloral specimens were not abundant at excavated sites. A total of 42 *Prunus emarginata* seeds were discovered in the fill of House Pit 13 at FY61-014-003; these seeds showed evidence of gnawing and were attributed to rodent interactions. House beams were the only found plant materials that were
attributed to human activities. Cressman cites that the upper fill of the rockshelter at site FY58-014-001, contained broken fruit pits, much like cherry or plum. These are likely bitter cherry, choke cherry, or Klamath plum pits.

In 2001, Gleason assessed 23 charred macrobotanical samples by flotation analysis. The samples were retrieved from three sites, located near the Klamath River, one being within the current study area (FY61-014-003). It was found that these samples represented 35 species, that includes *Chenopodium*, *Apiaceae*, cattail, tule, hazel, and *Rosaceae* (Gleason 2001:781-783, 928-952; Smith 2006:9-11). A pollen analysis study was done in 2006, in which four sites along the Klamath River in the California portion (south of current study area) were tested (Smith 2006). The author found that various grasses and composite pollen were found at each site and was interpreted as evidence of cultural use. The most commonly found archaeobotanical remains include: fir, oak, cedar, pine, sagebrush, snowberry, mock orange, buckbrush, rose, pea, and an assortment of grasses (Smith 2006:12).

Other vegetative information comes from proxy data from charcoal and pollen in sediment cores from lakes located in the eastern area of the Klamath Mountains, California. These cores indicate that vegetation patterns were established about 4,000 years ago and that climatic fluctuations have occurred in the last 4,000 years, mainly around 1,000 years ago (Smith 2006:1).

*Hydrology*

The Klamath Basin starts just north of Crater Lake and the Klamath Marsh and extends south to the South Fork of the Trinity River and west to the Pacific Ocean, covering just over 10 million acres (NRCS 2012; OLA 2012). The basin consists of two parts: Lower and Upper Basins. The Upper Klamath Basin encompasses approximately 5.6 million acres, covering diverse terrain throughout southern Oregon and northern California. The basin extends from the Cascade Mountain Range in the west to Silver and Summer Lakes in the east,
and from the Deschutes River in the north down to the McCloud and Pit Rivers in California (Stern 1998: 446; OR NRCS; USDA 2011).

An extensive network of rivers and tributaries make up the six hydrological sub-basins found in Upper Klamath Basin (draining approximately 5,700 square miles) and seven hydrological sub-basins of the Lower Klamath Basin (NRCS 2012; USDI 2000:1). The Klamath, Williamson, Wood, Lost, and Sprague Rivers are part of the Upper Klamath Basin. The Klamath River is the largest flowing body of water in the Upper Klamath Basin; the upstream end of the river drainage contains about 4,080 square miles of land and is part of the Klamath River-John C. Boyle Reservoir Fifth Field Watershed (USDI 2003:S-17; KFRA 2006:7; Rabe Consulting 2007:3).

In 1994, an 11 mile portion of the Klamath River within the UKRC was designated as a Wild and Scenic River (WSR), becoming the 157th WSR, and the area was determined to be an Area of Critical Environmental Concern (ACEC) by the KFRA, BLM in 1995 (American Rivers n.d.; NPS 1994). The ACEC includes 5,205 acres from canyon rim to canyon rim and starts in the north at the J.C. Boyle Powerhouse and continues south to the California-Oregon state line (KFRA 1995; KFRA 2006:1, 7; NPS 1994). An area must possess certain significant natural and cultural characteristics to become an ACEC. The five mile river segment, under study is located within this portion of the river.

Various unnamed streams, creeks, drainages, and springs are part of the John C. Boyle Reservoir Fifth Field Watershed; most are intermittent and ephemeral. In addition, five named streams flow into the UKRC, between J.C. Boyle Dam and the stateline: the Chert, Frain, Hayden, Rock, and Topsy. Rock Creek and an unnamed stream, near the California-Oregon stateline are the only perennial streams found between River Mile 220 and River Mile 209.

The Klamath Basin is heavily influenced by tectonic and volcanic activity. Earthquakes, volcanic episodes (i.e., Mount Shasta eruption 9,600 B.P.) and many years of down-cutting and slump-flow landslides of Tertiary-aged volcanic rocks have also had an impact on the river system (PacifiCorp 2004:2-10, 2-17;
Currently, the Klamath River starts at Lake Ewauna in the north, and continues flowing approximately 260 miles, southwesterly through California, before ending at the Pacific Ocean (FERC 2007:3-2).

Lake Ewauna is connected to the southern extension of present day Upper Klamath Lake, which is currently the largest freshwater lake in Oregon. The lake is at an elevation of 1,261 meters, covers 61,544 acres, includes an 87 mile perimeter, with about 130 square miles of surface area, is 50 miles long, 10 miles wide, but only averages about an eight-to-nine foot depth (Lynch and Risley 2003:3; OLA 2013; Orr and Orr 2012:78; BOR 2011:3-59). Flows exit from the lake via the Upper Klamath River or through the A-Canal for irrigation (Lynch and Risely 2003:5; USDI 2000). Upper Klamath Lake is connected to Agency Lake in the north, encompassing about 141 square miles of surface area respectively (Dicken 1984:143; OLA 2013).

Upper and Lower Klamath Lakes and nearby Spring, Swan, and Tule Lakes as well as numerous alkaline flats and marshy areas, are the result of the evaporating Pleistocene lake—pluvial Lake Modoc (Dicken 1980; Dicken 1985:3-4; Orr and Orr 2012:94). The old shoreline and extent of Lake Modoc consists of many lowland areas that seem to meander throughout present day Klamath Falls, Langell, Yonna, and Poe Valleys, southward to Tule Lake (the old lake bed is viewable on any map and Google Earth offers a great view of the lowlands that have been converted into farm lands over the past 80 or so years). Massive diatomaceous deposits are located north of present day Klamath Falls and are viewable from Highway 97. These deposits consist of siliceous phytoplanktonic organisms that are extremely abundant in lacustrine environments (Reading 1996:96). Diatom deposits are the result of algal blooms, usually seasonally, but blooms may be stimulated by volcanic activity since diatoms acquire silica to build their exterior.

The lake likely expanded and contracted, coinciding with higher and lower precipitation rates, temperature, and geological changes. At the largest extent, the pluvial lake encompassed some 400 miles of shoreline, 1,000 square miles of
surface water, and was about 75 miles long (Beckham 2006:4; Dicken 1980:179; Dicken 1985:4; Dicken and Dicken 1985: iv; ODGMI 1980:179-184; ODGMI 1984:144; Orr and Orr 2012: 86, 94). The historic shoreline was approximately 4,240 feet above sea level and was probably slightly higher in the north (Dicken and Dicken 1985:1-4).

The beginning of the Pleistocene Epoch brought in higher precipitation rate, cooler temperatures, and ice melt and water accumulation occurred in low-lying areas in Oregon. This led to the formation of many bodies of water, many being ephemeral, while others lasted a bit longer. It is predicted that the state of Oregon was eventually 10 percent water, mostly accumulated in 12 other large lakes that were contemporaneous with Lake Modoc, those other lakes being: Allison, Condon, Elgin, Malheur, Alvord, Catlow, Guano, Warner, Alkali, Fort Rock, Chewaucan, and Goose. Lakes Allison and Condon were both the result of glacial melt and floods; however the Klamath Basin is one of the few areas in Oregon that was not glaciated during the Wisconsin Ice Age (Figures 4 and 5) (Dicken 1984:143; Dicken and Dicken 1985:1-4; Orr and Orr 2012: 86-87; Rabe and Calonje 2009:4-1). Lake Modoc is the only large pluvial Pleistocene-aged lake that was not found in the Great Basin, but in the northwest margin of the Basin and Range physiographic and geologic province (Dicken 1980:179; Dicken 1984:143).

During the late Pleistocene, some 10,000 years ago, temperatures warmed; the climate began to settle into the current semiarid regime (initially was not as arid as today); Link River became entrenched, and the Klamath River began to severely downcut. Downward and lateral stream erosion accelerated the decline in size of the pluvial lake (Dicken and Dicken 1985:1-4). As the lake shrank, many smaller lakes formed, including Clear, Tule, Klamath, and Agency Lakes.

These lakes also depleted in size due to arid conditions and lately, in the past 80-90 years because of human interference with the water systems; historic marshes have been changed to fields for agriculture, while surrounding areas
have been built up, flattened, and irrigated (Dicken 1980:184-186). Of the roughly five million acres in the Upper Klamath Basin, there is approximately 2.2 million acres of private land, which about 500,000 is now irrigated (OR NRCS). These recent changes have undoubtedly changed hydraulic performance and nutrient and sediment loads.

Figure 4. Oregon Pleistocene lake location (BLM 2013c; BLM 2013d; adapted from Dicken 1984:146 and Orr and Orr 2012:86).
Figure 5. Extent of Lake Modoc shorelines with UKRC (BLM 2013a; BLM 2013c; BLM 2013d; adapted from Dicken 1984:146 and Orr and Orr 2012:86).
The geologic and hydrologic history of the basin has resulted in contemporary conditions that are unique. The Klamath Basin is one of three basins in Oregon that cut across the Cascade and Coastal Ranges to connect to the Pacific Ocean (FERC 2007). The hydrologic morphology of the basin is unique as well. The basin is opposite of the majority of watersheds; the northern part of the watershed drops in elevation less than downstream of the reservoirs. Conversely, in most watersheds, the headwaters tend to be steeper, dropping in elevation in smaller increments of length, eventually becoming wider with less gradient downstream (BOR 2011:2-1) (Figure 6).

![Figure 6. Klamath River slope from the northern area of the watershed downslope to the Pacific Ocean; a unique watershed with less gradient in the northern portion of the watershed (BOR 2011).](image)

The difference in hydrologic morphology is obvious when plotted on a graph. Areas north of the Upper Klamath Lake decline gradually downstream to the open lake area. The lake is contained in a graben, allowing for a large
expanse of slow moving water. The surrounding landforms are flat and irrigated, thereafter, the river runs southwesterly between Lake Ewauna and Keno Dam where river characteristics are low gradient, wide, and slow moving (PacifiCorp 2004:6-1). This is in contrast to River Miles 225 and on, where the river continues through a confined canyon in a series of step-pools with minimal alluvial reaches (PacifiCorp 2004:6-1; USDI and CDFG 2012:3.11-3). Thereafter, the geomorphology tends to be predominantly non-alluvial or at most with restricted alluvial and sediment supply is limited. Eventually, the river exits the High Cascade Province and enters the older Klamath Mountains where the river runs through steep terrain and is high energy, sustaining a coarse grained bedload, that is confined by bedrock (USDI and CDFG 2012:3.11-3). The Klamath Mountains are rugged, faulted, and soils are highly mature form the Ultisol order (Franklin and Dyrness 1988:7, 13). For the most part the river alternates amongst high energy, confined by bedrock areas, with limited sediment supply, high gradient, with interspersed alluvial reaches.

These characteristics are seen in alternation as the river flows through four distinct geologic provinces, in which river characteristics appear to change (USDI and CDFG 2012:3.11-2). Headwaters originate in a heavily volcanic-influenced terrain in the north; then Klamath River meanders through the Modoc Plateau, a fault-blocked landscape, and continues through a relatively flat expanse, where alluvial terrace and flood plains dominate the landscape. Thereafter the river flows into the eastern edge of the Cascade Range, then through the rugged Klamath Mountains and Coastal Range (USDI and CDFG 2012:3.11-2).

It is estimated that 200,000 tons of sediments flow between Keno Dam and Iron Gate Dam on a yearly basis, however, the river is limited in supply for fine-grained sediments. Sediment yield is lower in the upper portions of the basin and river than the downstream portion (FERC 2007:3-1). Low quantities of sediments are supplied from the area north of the Keno Dam, due to the large surface area of the Klamath Lake area, which acts as a sink for fine-grained
sediments (USDI and CDFG 2012:3.11-9). Runoff in the area is low, the porous volcanic geology influences this, but there are also few streams in the Upper Klamath Basin, when compared to the lower portion (FERC 2007:3-1). Gathard Engineering Consulting attributes the odd and disrupted drainage patterns to climatic changes in the region, faulting, volcanism, and the abundance of highly permeable rocks (2006:18). In addition, faulting is causing subsidence of the valley floor, which forms the large lake basins that influence sediment transport (GEC 2006:18).

Floodplain and channel morphology changes continuously along the river. The river is categorized as containing a predominantly non-alluvial geomorphologic characteristic. This is partially due to limited sediment supplies, coarse-grained sediments, steep and high-energy terrain, and much of the channel is constricted by bedrock (FERC 2007:3-6). The river is geologically controlled with minor alluvial reaches found along the river channel. This results in minimal floodplain development and minimal channel migration, as the channel is usually confined by bedrock in steep stretches.

The study area begins at River Mile 220. However, just north of the study area the origin of the river starts in relatively flat terrain that contains floodplains, and accumulations of fine-grained sediment accumulations. Thereafter, the river descends into the “gorge” around River Mile 224. Slope increases at 1.4-to-2.3 percent, colluvium forms “aprons” at the base of the hillslopes, the canyon becomes v-shaped with many boulders and exposed bedrock, and coarse plane-beds and cobbly and gravelly bars are present (FERC 2007:3-12). The section directly north of the study area contains these characteristics as well as pools and boulder cascades. Due to the construction and maintenance of roads, colluvium is often present at the base of the western side of the river.

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6 A plane-bed can be described by long stretches of featureless beds, that generally lack a regular bedform, and there is usually an absence of sufficient lateral flow (Montgomery and Buffington 1997:600).
At River Mile 220, the river is characterized by a broad plane-bed channel with large boulders and scattered within. The channel is still relatively steep, and begins to change to cobble riffles and runs with cobble bar and pool morphology near the “Spring Island” area with a river gradient of about 1.7 percent (FERC 2007:3-12). Within this stretch, sediment accumulations and deposition on point bars and terraces occurs. At this point the channel may be flanked by multiple levels of terraces that contain sediment deposits that are related to thick prehistoric lacustrine deposits, found upstream near the J.C. Boyle Powerhouse (FERC 2007:3-12).

Around River Mile 217, the channel becomes flatter, with a slope of about 0.3 percent. The decrease in gradient allows for deposition (a higher quantity of fine-grained sediments are located in this area); additionally, there are wide lacustrine-derived terraces that expand on both sides of the river channel. A majority of the terraces are primary and secondary, and are often “paired” (i.e., terraces on either side of the river are the same height above the current river channel and consist of similar profiles).

A flat stretch (Blue Heron and Frain) begins at River Mile 217, in the north and extends southward just past River Mile 215, at the southern end of the study area. This area appears to be a bit more influenced by alluvial deposition rather than colluvial.

The basin has undergone many changes in formation and deformation; resulting in a tectonically and volcanically active region. The river also crosses several faults that have been active during the last 10,000 years. Immediately after River Mile 215, the river cuts sharply to the west and continues through a confined five-mile area that is steeper with a two percent gradient, bedrock and boulders are within and surrounding the channel, and if riparian areas are present they are not extensive (FERC 2007:3-12). This area is heavily influenced by the constricted bedrock morphology, and also becomes somewhat sinuous, due to the river not being able to get through tough materials. The topography in this area is completely different than just north or south. It appears that material
from the massive SSML pushed material into the canyon, eventually blocking it. Fine-grained sediments were found high up above the current river channel, which may have been the result of the landslide impounding the river for a long enough time for sediments to drop out of suspension and settle. The topography is dissected and uneven as well.

Similar volcanic interactions have also occurred to the south, near Copco Reservoir. An earthen dam would have caused an impoundment of sediments, and induced upstream backwater and subsequent reduction in channel slope. Eventually, the river would have incised through the volcanic material and Holocene lacustrine deposits (GEC 2006:18).

During field reconnaissance, it was noted that terrace complexes were somewhat rare— most areas adjacent to the river channel were composed of colluvium, talus, bedrock, interspersed with alluvial fans, possibly colluvial flows by solifluction, with majority of alluvial terraces being newly forming (Terrace 0), or primary. There were few distinct areas in the five-mile section that had more than two terraces and a newly forming floodplain.

Physiography, Geology, and Soils

To understand the formation and setting of Lake Modoc and structure of the Klamath River, it is important to look at the geologic history of the area. Lakes in Oregon are the product of glaciers, tectonic activity, volcanic activity, deposition, erosion, thermal springs, as well as organic and human activities (Dicken 1984:144). Lake Modoc was formed by dropped fault blocks, or grabens that filled in during high precipitation events (Dicken 1980:179; Dicken 1984:145).

The Upper Klamath Basin is near the convergence of the three tectonic plates— the Pacific, Juan de Fuca, and the North American Plates— the Cascade Mountain Chain located not too far to the west is the result of interactions between the plates, ultimately causing a subduction zone and

The basin falls into the West Klamath Lake fault zone (WKLFZ), which starts in the north at Crater Lake, continues southward, and is composed of an aggregation of various smaller faults (CLI 2012). The Klamath Graben is located in the middle of the Klamath Lake fault zone. Holocene earthquakes are frequent and average about every ten years, with a 7.0 magnitude occurring approximately every 1,000 years (Orr and Orr 2012:88). These tectonic features form the Basin and Range Physiographic Province and Modoc Plateau, in which the Upper Klamath Basin is situated in the extreme northwest part. The province is characterized by internally draining fault-block mountains, or horsts and grabens (Franklin and Dyrness 1988:34). Tectonic activity in the region is youthful and has undergone east-west crustal extension, where volcanic flows were able to reach the surface (Orr and Orr 2012:78).

Extensive volcanic activity has occurred in the area, as evidenced by the presence of volcanic deposits, in which the Klamath Graben exposes up to 480 meters of volcanic and sedimentary rock (Franklin and Dyrness 1988:33; Priest et al. 2008:1). A majority of the deposits are from the Miocene-to-recent pyroclasts, alluvial sediments, and basalt flows (Alt and Hyndman 1978:265; Franklin and Dyrness 1988:34). Many scattered dry lake beds with silty lacustrine deposits, with soils falling into aridisol, mollisol, and inceptisol soil orders are located in the area. Many of the volcanically-derived soils, like pumice, are immature and are easily re-worked by water (Franklin and Dyrness 1988:36).

The High Cascades make up the eastern edge of the Cascade Mountain Range, spanning from the Oregon-Washington state line in the north to the Oregon-California state line in the south. The High Cascades province is geologically young, volcanic in nature, and characterized by a rolling terrain, interspersed with volcanic peaks and west-flowing streams, found in deep glaciated channels (Franklin and Dyrness 1988:25). The Cascade area has been geologically active for over 35 million years, due to tectonic actions that causes
subduction as the rocky material is heated by high temperatures and pressure; this molten rock is then pushed to the surface, resulting in the Cascade Range. Volcanic deposits from vents date to the Pliocene and Pleistocene and other deposits are only a few hundred years old (Franklin and Dyrness 1988:25). Mount Mazama deposits from 7,000 years ago are the most extensive volcanic deposits found and the majority of the soils are inceptisols (immature), andisols, and spodosols.

The UKRC originates in the Basin and Range then flows into the High Cascades province and is located in upper tertiary volcanics (Beaulieu 2009). The canyon has formed by the river eroding away and down-cutting through geologic deposits. Topography varies from near vertical canyon walls up to 1,000 foot high, to gentle-sloping river terraces (NPS 1994:33). The oldest exposed tuff dates to the Miocene and is overlain with basalts and andesites, which in turn are covered by deposits of Quaternary alluvium, colluvium, lacustrine, talus, and landslide materials (NPS 1994:61; Walker and Naslund 1986:207). The corridor, within the study area, includes Quaternary alluvium along the river and Pliocene mildly alkaline volcanic rocks, Tertiary Western Cascade volcanic rocks, and Pliocene calc-alkaline volcanic rocks above on the slopes (Walker and Naslund 1986:207).

A few extinct volcanoes are located throughout the Upper Klamath River area— Chicken Hills and Grenada Butte. A distinctive feature of the canyon, located on the 7.5’ Mule Hill Quadrangle, is the presence of older volcanic rocks that were erupted and deposited pre-Cascade phase of the Cenozoic volcanism (Mertzman et al. 2008:1). Three phases of volcanic eruption have occurred: the Early Western Cascade Episode (35 – 17 mya), the Late Western Cascade Episode (16.9 – 7.5 mya), and lastly the High Cascade Episode (Mertzman et al. 2008:2). The two older volcanic episodes are covered by the last, except in areas that have been eroded, removing the newer phase. In 1989, three samples of tephra were gathered from a roadcut, upstream (north of the current study area) and upslope at “Big Bend.” These samples were analyzed and found to be from
the same volcanic eruption. The chemical analyses of the tephra samples were identified as Trego Hot Springs Tephra, providing a date of 23,400 B.P. (Foit 1989).

The Salt Caves (just south of the study area) were formed by lava flow and river erosion. In a DOI report, the caves were mentioned to be geologically abnormal, because the feature consists of a cliff face formed by a volcanic rock formation, located next to a river (USDI 2002:1). In 2001, the caves were deemed significant based on the geology, wildlife, cultural importance, and minerals (a salt deposit is located within the largest cave) (USDI 2002).

Secret Springs Mountain is an extinct mafic shield volcano (since the late Miocene) in which many of the andesitic basalt and other sediments in the area are derived from. The mountain is also a kipuka— a relic of a 14 million-year-old rock with younger, 2-8 million-year-old volcanic flows surrounding. It has been hypothesized that the geological layers, just west of Secret Springs Mountain, are not from the mountain vent, but are from a second larger and older volcano that explosively erupted, causing massive pyroclastic deposits (Nilsson 1997:96). Secrets Mountain then formed on the flanks of the older deposits.

Secret Springs Mountain is visible at the southern portion of the canyon and canyon rim. The summit of the mountain has a plug-like mass of igneous rock and is arcuate or half-amphitheater type of form (Mertzman et al. 2008:23). It is hypothesized that a landslide took place, causing the northwestern and western sides of the mountain to slump out, temporarily damming the Klamath River, and later the toe (landslide and river interface) of the slide likely continuously slumped (Figure 7). Eventually, the river worked through the landslide sediment and resulted in a set of class IV+ rapids known as “Hell’s Corner.”

This landslide is located south of the current study area. The SSML, is located at River Mile 214.3 and led to an accumulation of silty lacustrine deposits, approximately 200 feet thick above the blockage, which is now part of
the Frain Stretch (FERC 2007:3-6). This landslide event starts at the Cataract rapid in the north and continues south-southwest (Figures 7-9).

Figure 7. Secret Springs Mountain and associated landslide, dates to the Quaternary, likely to the mid or late Pleistocene. The landslide blocked the UKRC, creating an earthen dam.
Figure 8. Secret Springs Mountain, view south, 2012.

Figure 9. Hell’s Corner rapids at the base of the SSML, view southeast, 2012.
Although there aren’t any dates on the SSML event, it is believed to have occurred within the Quaternary (recent - 2.59 mya) (Nilsson 1997:96). One can use the principles of cross-cutting relationships and superposition to estimate the age of this landslide. The SSML event cuts through the 20 million-year-old Heppsie Formation; Secret Spring volcanic rocks date between 12.5 and 13.5 million years old; 7.4 million-year-old (bottom) to 6 million-year-old (top), plateau-forming basalt flows are exposed; and the landslide also cuts through sporadic flows of an approximately 2 million-year-old, basalt. The landslide event is likely Pleistocene in age and may even be Late Pleistocene or Early Holocene— there hasn’t been any datable material found on top of the landslide material (Mertzman 2013, personal communication).

Based on the size of the river, the water would have likely begun to overflow the landslide blockage and would have eroded the unconsolidated materials within a month, if not weeks. A new permanent channel would be established thereafter (Mertzman 2013, personal communication).

The SSML is associated with exposure of Western Cascade tuff between River Mile 214 and River Mile 210. This basalt movement is caused by slip surfaces in weaker tuff. These slide blocks are large— some nearly 3,000 feet high and may be several hundred feet thick. At times there are repeated landslide events, which have formed the expansive, somewhat flat area just north of the mountain.

A total of eight landslides were identified in a seven mile stretch near the Oregon-California state line, during research for a thesis that was later included in the 1995 Cascade Keck Consortium Project (Christman 1995). The author identified the landslides as the result of slump and earth-debris plug flow activity, triggered by a combination of: 1) the river channel undercutting adjacent landforms; 2) pore water pressure in stratigraphy; and 3) that landslides were mainly initiated by earthquake activity (Christman 1995:4, 13). Christman believes that the large extent of landslides in the UKRC attest to seismic activity,
while the first two factors would have also impacted landforms before and after an earthquake (1995:13). Presently, many of these landslides are noticeable by obvious drops in elevation along the river. These areas have produced some of the higher class rapids that currently attract recreationists to the river.

Subsurface and surface mapping in the J.C. Boyle bypass (north of the SSML) and peaking reaches (at SSML) shows a long history of landslide events having occurred on the canyon walls. Different types of landslides were located, from deep-seated rotational landslides, to shallow secondary, to rockfalls and slumps on talus slopes. As the canyon is steep, gravity-driven erosion occurs. Mass wasting is not limited to catastrophic landslide events, but can also consist of slumps, flow, fall, or creep (Waters 1992:231). These mass movements are located throughout the canyon in steep areas. Steep slopes that are underlain with tuff contain potential for rock falls and landslides, as well as areas that contain deep colluvium and/or talus—these areas can produce slumps (FERC 2007:3-6).

In addition, other important deposits found just south of the UKRC study include: upper deposits of feldspars that have been kaolinized and pyroxene was replaced by calcite, limonite, and chlorite, and that nodules of chalcedony and opal are found in many flows of andesite, which may explain the high amounts of cherts found at sites (Mack 1983:9; Williams 1949).

Soils found within the study area are the result of weathered volcanic material or lacustrine sediments that were transported by fluvial actions. These riverine sediments were deposited sometime during the Quaternary and depending on when the sediments were deposited and became stable, pedogenesis has occurred (Walker and Naslund 1986:207). The five soil forming factors have acted upon each soil in different ways as a result of differing geologies, terrains, and climates, however, in this five mile segment the climate, terrain, and geologies are similar if not the same.

Soils can be differentiated by landscape position—soils found on slopes and those found on flatter areas, such as floodplains and alluvial terraces.
Generally, soils located on slopes are developing on surfaces that are constantly changing from bioturbation (animal activity and tree fall), colluvial creep, and sheet wash in un-vegetated areas. This has resulted in a less stable soil forming environment that consists of soils that are usually shallow, but can be moderately deep and have about a 7-8 inch surface horizon of gravelly loam, with a gravelly, clayey loam underlying (FERC 2007:3-5).

Typically, soils found in flat areas are different than those found on slopes. These soils are deeper and consist of well-drained alluvium and/or colluvium. The upper horizon generally consists of 15 inches of very gravelly loam and a 6-13 inch transitional gravelly clay loam, with a 39 inch heavy clay loam, on top of bedrock (FERC 2007:3-5). The last soil type is found in the newly developing floodplains. These soils consist of unconsolidated materials, usually colluvium, alluvium, and other fluvial deposits of sand, silt, gravel, although one Terrace 0 was found to be sandy clay. These soils are geologically younger than the upper terrace soils (FERC 1990; FERC 2007:3-5; USDI and CDFG 2012:3.11-15).

Two soil series were identified to be within the canyon corridor, but were combined into two soil map unit complexes. The soil survey mentions that the soils intermingle throughout the river corridor, which is narrow, and it is difficult to separate each soil from one another. These complexes alternate throughout the corridor, mainly in part to varying landforms.

The Bogus-Skookum and to a lesser extent the Skookum-Bogus complex were seen continuously throughout the canyon. These soils are well-drained, situated on hillslopes, footslopes, and are found at an elevation of 3,000 to 4,400 feet. Soils from the Bogus-Skookum complex are located within Douglas fir, mixed pine, sedge forests, on 1-12 percent slopes and consist of colluvium and residuum derived from tuff breccia and andesite. Soils from the Skookum-Bogus complex are located on droughty 12-35 percent slopes and consist of colluvium and residuum derived from tuff breccia basalt (Johnson 1993; Web Soil Survey 2013). Bogus-Skookum soils are deeper and are likely found on the alluvial
terraces, while Skookum-Bogus is likely found on the slopes connecting to the terraces.
Chapter 4. Methodology

As described in the Introduction and Literature Review, archaeological research can be utilized to located landforms that have a higher potential to contain archaeological sites. In this case geologic, pedogenic, and geomorphologic concepts were applied to a five mile section of the UKRC, between River Mile 220 to River Mile 215.

Prior to fieldwork, horizontal and vertical geospatial data were collected from the BLM GIS servers or the Oregon-Washington GIS website. Data consists of information on digital elevation model (DEM), light detection and ranging (LiDAR), hydrology, topography (i.e., slope, aspect, and contour). When necessary, geodata were transformed into the correct projection. All geodata was placed into the North American Datum 1983 (NAD 1983), Zone 10 coordinate system and were projected in Transverse Mercator. This type of projection allowed for a squared off flattening of images, which produced clean maps.

ArcMap 10.1 was used to produce maps of topography in order to better understand the landscape. These were overlain with site distribution maps, and correlations amongst site size, location, and landform were immediately observed. As Guccione (2008) had pointed out, sites are the result of human preference, preservation, and/or identification. It seems that certain landforms were preferred, specifically those areas lying in close proximity to water—within the river corridor, adjacent to the river on alluvial terraces, or near drainages. Certain sites, mainly village sites, comprised of multiple house pit features were almost always located within the river corridor, on terraces, in areas with an accumulation of finer-grained sediments than coarse fragments.

For the most part, sites appear to cluster in flat wide channel with large floodplains and terraces. This is likely due to site preservation—the river flows slower here allowing for sediment aggradation. Much of the sediments are finer-grained and the Federal Energy Regulatory Commission (FERC) mentions that
this geomorphology and accumulation of sediments is the result of a landslide
downstream, likely the SSML (2007:3-6).

To help organize geoarchaeological data, a geoarchaeological personal
godatabase was constructed in ArcCatalog 10.1. Geodatabases allow for the
organization and storage of large amounts of data, uniformity in data, coding of
data, as well as a way to retrieve or run queries. Overall, it is a much more
efficient way to store geodata. Different feature classes were built, to be broken
down into alluvial, colluvial, and other. Within each of these feature classes,
various features that are indicative of alluvial or colluvial depositional
environments were constructed. Other necessary features that did not fit into the
alluvial or colluvial feature classes were placed into the other feature class (e.g.,
river mile, soil profile, anthropogenic, etc.).

Both raster (continuous data— has a matrix of cells that represent
something) and vector (discrete point, polyline, and polygon) data were used in
ArcMap. Elevation, topographic, contour, LiDAR, hillshade, NAIP imagery,
hydrology, jurisdiction, facilities, soil layers, and the KFRA-BLM cultural
resources geodatabase were utilized in maps.

A preliminary literature review was conducted on past studies in the
canyon to understand the history. Soil Surveys, archaeological inventory reports,
site forms, excavation reports, oral histories, and ethnographies were reviewed to
understand the history of the basin, and more specifically within the UKRC.

Thereafter, a landform survey was conducted, in which landforms were
mapped over the course of November and December (weather slowed
surveying). Survey resulted in the identification of many landforms spanning
various depositional environments.

After survey and LiDAR mapping, a total of 21 Terrace 0, 22 Terrace 1, 10
Terrace 2, five Terrace 3, three Terrace 4, one Terrace 5, 33 alluvial fans and/or
colluvial flows, 10 historic river channels or overflow channels, two springs, and
two landslides were identified within the five mile study segment. Several
terraces were found to be heavily buried by colluvium as well. These of course
are just a few of the identified landforms, and may not be complete—landforms are broken up and at times may have undergone various processes that make them a bit more inconspicuous.

Five suites of terraces were chosen to continue further research. These complexes were comprised of more than two terraces and a newly forming floodplain was to be present in order to be able to quantify soil development data. Due to an understanding between the Klamath Tribes and KFRA-BLM, soil profile units were not excavated within archaeological sites. The BLM archaeology geodatabase, map book, and site forms were used to find best possible excavation areas away from known archaeological sites.

In one complex—Complex 4, an archaeological site was present along a 400 meter primary river terrace; this area was not excavated due to the presence of the site and units were placed on upper and lower terraces were excavated. As a result, this complex does not have data for a primary terrace.

Twenty-two, 0.5 x 1 x 1.52 meters (5 foot depth) soil profile units were placed at specific places on the landform. When a cutbank was present it was inspected, or was cleaned up, and was recorded. Many tree falls offered an opportunity to look at subsurface strata as well. Unfortunately there were not any large cutbanks found within most of the complexes to aid in faster recordation. Therefore, units were excavated right before the shoulder of alluvial terraces. This area is shallower and allowed for less downward excavation. If the unit was placed directly down onto the tread of the terrace, the unit would be extremely deep and may result in collapsing, especially when soils were saturated. If the unit was placed too far down the slope of the terrace, the recorder may miss stratified alluvial deposits and locate sloughed off materials.

Back dirt was to be screened, but due to the high water saturation, quantity of coarse fragments, amount of clay, and difficulty of excavation—back dirt was not screened. Monitors assisted in excavation and inspected back dirt and the author inspected the unit profile and floor as well routinely checked back dirt.
After units were excavated to a five foot depth, the profile was cleaned, pictures were taken, and the profile was recorded using professional standards outlined in the *Field Book for Describing and Sampling Soils, Version 2; Soil Taxonomy: A Basic System of Soil Classification for Making and Interpreting Soil Surveys, 2nd Edition; Keys to Soil Taxonomy, 11th Edition; North American Stratigraphic Code; A Scale of Grade and Class Terms for Clastic Sediments*; and the *Munsell Color Book* (Schoeneberger et al. 2002; SSS 1999; SSS 2010; NACOSN 2004; Wentworth 1922; USDA 1992).

Locations of profile units were recorded with a Trimble XH GPS unit, the height of the terrace was calculated using a compass, pacing, and basic trigonometry. Later, the elevations of soil units and current river height were double checked with the use of bare-earth imagery (this led to recent adjustments in terrace height).

Soil units were excavate with a shovel, trowel, an auger, a pick, and a scoop. The profile was drawn, measured, and pictures were taken with a Nikon Coolpix digital camera. Various soil properties were recorded in order to find PDI values as well as understand the depositional environments.

Due to the timing of excavation and recordation, samples were collected and put into one gallon freezer bags. These samples were let to dry and some soil characteristics were recorded at a later date. Excavation began in mid-January 2013 and the first units, Complex 5 Terrace 3 1 and Complex 5 Terrace 3 2 were frozen in the upper five centimeters of soil. The units were later inspected in March when they were not frozen and the profile was cleaned and re-recorded. The results were slightly different than the original recordation (mainly in texture and stickiness), but did not differ greatly. However, these differences in texture and stickiness would have resulted in skewed overall texture PDI values.

During early field visits (January and February), the soils were saturated and certain soil properties were not attainable—dry color, dry consistence, and usually pH (soils contained a high quantity of coarse fragments). The bulk
samples that were collected were later recorded and other properties were double checked. This information was placed into Microsoft Excel 2010 for management. Eventually, the spreadsheet grew to contain soil data for 131 horizons, 22 soil profiles, found in five terrace complexes. Only 21 of those soil units were used in later PDI calculations (one of the units on Complex 5, Terrace 3 was excavated to see if the diatomite layer was continuous throughout the landform). Soil units are labeled by complex, terrace, and then number (e.g., Complex 1, Terrace 1, Unit 1 is C1 T1 1).

In order to obtain horizon index (HI) values and PDI values the soil profile depth and eight soil properties (texture + wet consistence, clay films, rubification (hue and chroma), color value (melanization), structure, dry consistence, moist consistence, and pH. These properties generally develop linearly. Overtime soil texture becomes finer grained as particles break down. To quantify the smaller particles, PDI quantification takes into account the “total texture,” by adding wet consistence (includes plasticity and stickiness) and texture. Ideally, a more developed soil would be finer grained. If the parent material is sand and the horizon understudy is sandy loam (20 points are assigned to the horizon value), since the value shifted two places on the texture triangle. Clay particles are smaller sized, stickier, and more plastic than silt or sand (Harden 1982:7). Plasticity and stickiness are assigned 10 points individually and depends on the degree of differences from the parent material. The points are assigned on a scale of non-sticky to very sticky and non-plastic to very plastic. Plasticity and stickiness have four classes each.

The presence of clay films is an indicator of clay translocation or pedogenic clay. A clay film class based on abundance, thickness, and location is 10 assigned points for each as the values move away from parent material values.

Soil color is an observable property and hue, value, and chroma are used in the PDI method. Melanization, or darkening of the A horizon from an accumulation of organic matter is observable and quantifiable. As an A horizon
accumulates organic matter the color value decreases and becomes darker. In PDI quantification melanization is only used for the first meter of the soil profile and a soil profile usually becomes lighter with depth. Rubification or reddening and lightening of a soil occurs if a soil is found in an oxidizing environment (Harden 1982:9). Color hues become brighter and chromas become lighter over time. The color properties of hue, value, and chroma are assigned 10 points each as they diverge from the parent material properties.

Soil structure is evaluated based on grade and aggregate type. Overall, there is a general progression from structureless or massive in new deposits to more developed structure types such as granular, blocky, prismatic, or columnar (Harden 1982:11). Grade would start at weak and progress to strong, while aggregate size would range from very fine to extra coarse. For example, parent material that is massive would have a value of zero, while a weak, fine, granular A horizon would be assigned 30 points (10 points weak, 10 points fine, 10 points granular).

Dry and moist consistence properties become firmer and harder with time. The soil becomes more aggregated with material such as clay, oxides, and organic compounds as it develops. Points for dry and moist consistence range from zero points for loose and is assigned 10 points with each class increase in hardness (dry consistence) and firmness (moist consistence). Soil pH is measurable as leaching occurs overtime and basic cations are displaced. It is assumed that a soil would become more acid with time (Harden 1982:12).
In order to perform HI and PDI calculations a series of eight or nine steps are to be followed (Figure 10). In this study all nine steps were performed and include:

1) Field recording of the soil unit. In order to keep soil descriptions uniform, the same individual recorded each unit. The descriptions were written based on professional standards and are included in Appendix B.

2) The parent material was identified and assessed. In this study the parent material is comprised of the alluvial soils found on the newly forming
floodplain (T0). Alluvial soils are defined by their parent material, meaning these soils form in from alluvial sediments. These soils are surficial and new additions of alluvium, or parent material, may be deposited during floods (Ferring 1992:2).

3) The soil descriptions were deconstructed and eight soil properties were quantified to show the degree of difference between the soil profile unit (alluvial terrace profile) and the parent material (floodplain deposit; T0). Each soil property is assigned points in increments of 10 based on the degree of difference. The eight soil properties are presumed to linearly progress with time and this should be reflected in the degree of differences between terrace units and floodplain units.

4) The properties are then normalized to the “current maximum” or by dividing by the maximum quantities of each property.

5) The normalized values should then be summed.

6) The sum is divided by the total number of soil properties for each horizon, providing the HI value.

7) The horizon thickness is multiplied (should be in centimeters) to weight the horizon properties.

8) The horizon products are then summed for the whole profile, providing the PDI.

9) Divide the PDI value by the depth of the soil profile, thus producing a weighted mean PDI. The values will fall between 0 (low development) and 1 (high development).

The nine steps were followed to quantify eight soil morphological properties of 21 soil profiles in the UKRC. Points were assigned to each soil horizon showing development (no points are allotted to C horizons) and the points were computed in an Excel spreadsheet (Appendix C).
Alluvial terraces form as a river migrates and a floodplain is abandoned by incision (Ferring 1992). Future alluvial deposition or flooding rarely occurs and soil begins to develop as the landform becomes more stable. Over time the river channel continues to migrate and incise. Therefore, older soils should be located higher and further from the current river channel. This assumption should be reflected in pedogenic development and quantifiable by the Harden Index. These older soils should have a greater depth, contain finer textures, be stickier, have a harder consistence, lower pH throughout the profile, have a more developed structure, possess more horizons, and horizons should become thicker and more rubified with age.

The idea that terraces higher and further from the current river channel are older, relies on a few assumptions: mainly that the soils represent successive stages of at least one pedogenic process and the soil contained in each terrace has or will pass through stages seen in other terrace landforms (Schaetzl and Anderson 2005:588). The UKRC falls into the simplest and most common chronosequence, called a “post-incisive” chronosequence. Soils in this type of chronosequence develop at different times as the river channel moves and incises. River incision or down-cutting eventually forms a series of terraces that are located adjacent to the current river channel and sequentially change in elevation and proximity to the channel.

The step-like sequences are seen throughout the five mile study area. Five terrace complexes (chosen based on the presence of supposed chronological terraces) were chosen for further geoarchaeological study (Figure 11). These five complexes were chosen because they contain multiple terraces, consisting of a floodplain and at least two additional terraces. A total of 22 soil profiles were excavated, while 21 were calculated based on the Harden Index. In addition, other areas along the river were inspected and recorded, but have not
been included in the calculations. The inspection and recordation of other areas served to see if landforms were continuous or if terraces were paired.

In the following, a brief landscape description and soil descriptions will be provided for each terrace complex. For more detail on soil profiles, refer to the full profile descriptions and PDI calculations in Appendix B and Appendix C.

Figure 11. Study corridor with terrace complex locations.
Within the fully recorded terraces it was found that terraces sequentially changed along the terrace complex. With distance from the current river channel, terraces also became higher, profile development was usually more mature, and it will be assumed, older as well.

Terrace 0 is approximately half meter above the current river channel, while Terrace 1 varies between 1-2 meters (average 1.8 meters); Terrace 2 was generally 2-7 meters (five meters); Terrace 3 varied 8-17 meters (11 meters); Terrace 4 ranged between 14-18 meters (16 meters); and the only Terrace 5, was 20 meters above the current river channel surface.

The northern a portion of the study unit consisted of a faster moving channel that was restricted by talus slopes, with small rapids. Terrace complexes in this area consisted of heavily vegetated multiple level terraces that were not very wide east-west. Colluvium is present on every terrace in the form of large boulders on the surface as well as under. At around River Mile 218, the river slightly widens and consists of less rapids. Thereafter, at River Mile 217, the river widens and becomes slower moving for the next two miles, prior to entering an area that was heavily influenced by the SSML and a smaller landslide, located just north of River Mile 216.

This smaller landslide is located just north of the Frain area and south of the Blue Heron area (Figure 12). LiDAR imagery indicates that a large concave-shaped feature is present at the slope of the canyon; this would be a likely place for the landslide materials to have originated from. The slide is located at the end of drainage; it is quite possible that solifluction happened, causing the slide to occur. The surface of the landslide is highly uneven, with large hummocks and stones. The interior consists of poorly sorted pumice, gravel, cobbles, and pockets of diatomaceous earth. A few sedimentary rocks were also found in the drainage, indicating that they were displaced from upslope. A diatomaceous deposit (nearly three meters thick), was found at the top of a cut bank (approximately 10 meters deep), at the western edge of the landslide. The
deposit has been eroded by the river and dissected by a historic ditch, constructed by early homesteader, Martin Frain’s wife, in the early 20th century.

Figure 12. Thick diatomaceous deposit north of the Frain alluvial stretch and south of the Blue Heron alluvial stretch. The deposit is located at the western edge of a landslide that has been eroded by the river channel. Looking northeast.

The expansive terraces contain a higher amount of finer-grained sediments that aggraded first downstream of, due to the SSML. Sediments were impounded behind the earthen dam for weeks if not months prior to the river channel working through the mass. In that lower area, fine-grained sediments are found at areas high from the current river channel and in some places are 200 feet thick (FERC 2007:3-6).

Fewer accumulations of boulder fall were found between River Mile 217 and 215, with an exception in the drainages and at the very margins of the terrace/slope area just north of the small landslide. This area also contained more archaeological sites—mainly habitation sites, as evidenced by the
presence of house pit features. Two sites with radiocarbon dates, Big Boulder Village (564 ± 110 cal. B.P) and an uncalibrated Frain South Field (580 ± 60 B.P.) are located in this stretch. Just south of the Frain area site dates are older at the Klamath Shoal Midden (1,009 ± 110 cal. B.P., 1,296 ± 125 cal. B.P., and 7,646 ± 400 cal. B.P.) and younger at the uncalibrated Klamath Shoal Village (100 ± 90 B.P.).

This two mile stretch mainly contains primary and secondary terraces, with what appears to be a small portion of a tertiary terrace at the southwestern edge of the landslide and a large expansive tertiary terrace at Turtle Camp (Complex 5). Some terraces are buried; mainly on the western side of the channel. Based on current height above the river channel and on the few shallow cutbanks that were exposed; that the primary river terraces from River Mile 216 to River Mile 217 are paired. No units were excavated at river left of the Frain or Blue Heron areas due to the amount of archaeological sites; complexes only consisted of newly forming floodplains, primary, and secondary terraces with one small portion of a tertiary terrace that contains a historic site; and a majority of the area is located outside of BLM jurisdiction, on PacifiCorp.

The first complex, Complex 1, is located in the very northern part of the study unit, just south of River Mile 220 on the western side of the river (river right). A USGS gauging station is found at this complex. The complex consists of a floodplain, historic river channel or overflow channel, and both a primary and secondary alluvial terrace (Figures 13 and 14). Many young trees and some underbrush were present within the historic or overflow channel, soils were slightly developing, and organic matter had accumulated, which suggests that the river rarely flows in this channel in contemporary times. However, historic boards and other miscellaneous building debris (likely associated with the nearby gauging station) were present in odd areas of the channel, so the river has flowed into the channel in the last 50 years, likely during a flood event.

A south-flowing deposit of highly unsorted debris (large boulders as well as smaller sized boulders) is located at the northern end of the complex, on
Terrace 2. Many large boulders (approximately ½ - 1 meter diameter) were also found on the surfaces of both terraces, indicating that colluvial activity is presently occurring in that area.

Vegetation is thick throughout both terraces and a thick accumulation of pine needles, oak leaves, and moss obscures the mineral soil. Dominant overstory vegetation includes incense cedar, ponderosa pine, black and white oak, and white fir, while understory consists of mock orange, buckbrush or wild lilac, Oregon grape, wild strawberry, reed canary grass, and trumpet lichen (*Cladonia fimbriata*) and numerous bryophytes cover many of the boulders, cobbles, and woody debris on the ground.

Terrace 1 appears to have been a point bar and the river meanders to the east, contacting a talus deposit, before breaking off into one main channel and a smaller chute at the southeast. The current floodplain expands 5-15 meters east-west and the surface is covered by cobbles, stones, and boulders, with packed fine, medium, and coarse interstitial gravel. The river has eroded the eastern and southeastern edges of Terrace 1, exposing a 10-30 centimeter subsurface view of the terrace.
Figure 13. Overview map of Complex 1 with soil unit locations and landform categorization (BLM).
As expected the soils for Complex 1 were not highly developed. Profile depth is one way to determine soil profile development. The depth of the floodplain was 21 centimeters, while Terrace 1 was 35 centimeters, and Terrace 2 was a bit higher than expected at 91 centimeters, but contained a high amount of large coarse fragments. Subrounded and rounded boulders dominated the lower horizons of the profile and interstitial spaces were packed with gravel; clay coatings were observed on the outer faces of fragments.

Horizon indices and profile development indices (weighted and not weighted) show that soil development became deeper and possessed other soil qualities (e.g., more clay) that led to larger horizon index values. Terrace 2 soils are thicker than those on Terrace 1 and that development for the first two
horizons is low before becoming higher at the Bt horizon and then lowers at the BC horizon. Profile development index values for the two terraces were as expected, with Terrace 2 (17.63 and 0.194) being higher than Terrace 1 (4.16 and 0.119).

The soil profile of Terrace 0 consisted of unconsolidated sandy loam and ended at extremely gravelly loamy coarse sand at 21 centimeters (Figure 15). The surface of the newly forming terrace contained many subrounded boulders with gravel packed into the interstitial areas. Two A horizons (silt loam and sandy clay loam) were found in Terrace 1, spanning from 0 to 35 centimeters before ending at the river alluvium, C horizon (contained many rounded pumice fragments) (Figure 16). Terrace 2 extended deeper—consisting of two A horizons, a Bt and a BC horizon (Figure 17). The A horizons consisted of silt loam and gravelly sandy loam, while the Bt horizon was gravelly sandy clay loam, and the BC consisted of very cobbly sandy loam, and the profile ended at packed rounded boulders, with interstitial areas packed with rounded medium and coarse gravel. In all profiles, rock fragments were subrounded and rounded, poorly sorted, and there was contact amongst coarse fragments. Many boulders were seen on the surface of this terrace as well as subsurface.
Figure 15. Terrace 0, west profile. Tape measure is 60 cm long in picture.
Figure 16. Complex 1, Terrace 1, north profile. Tape measure is 152 cm long in picture.
Figure 17. Complex 1, Terrace 2, north profile. Tape measure is 152 cm long in picture.
Terrace Complex 2 is located at River Mile 219, on the western side of the river, and consists of a floodplain; Terraces 1-4; an “island,” in which a floodplain and primary terrace are present; a drainage, with a buildup of colluvium, and an active channel chute lies between the “island” and terrace complex (Figures 18 and 19). Large boulders (1-3 meters) were found throughout the complex; but most notably on the surface of Terrace 4, Terrace 3, and Terrace 2.

Vegetation is thick throughout Terrace 2, 3, and 4. A spring is present at the northwestern side of Terrace 3. Vegetation consists of incense cedar, ponderosa pine, white fir, Douglas fir, and Engelmann Spruce; with a lesser amount of black and white oak, and juniper. Underbrush is overgrown throughout the unit and mainly consists of mock orange, Oregon grape, California grape, wild lilac, gooseberry, and many groves of immature white fir; while canary grass, stinging nettle, and scouring rush were found along the river. Various bryophytes, trumpet lichen, and woods and wild strawberry were found on the ground. A heavy layer of duff and woody debris is present throughout all terraces, but especially on the Terraces 2 and 3. Organic layers were located in all of the units.

Many cobbles, stones, and boulders are found on and below the surface of the terraces. Large (one meter diameter) boulders were located at the northern portion of Terrace 3 and the surface of Terrace 0 was almost completely covered in subrounded and rounded stones and boulders. Most of the terraces contained coarse gravel, cobbles, stones, and boulders, as well as clay films. A few “rotten” rocks were found in some units as well. Fluvial actions were evident on all rock fragments (i.e., rocks showed rounding). However, it is assumed that most of the boulders were deposited by gravity and this is mainly due to the size of the coarse fragments, proximity to the canyon wall, and steep gradient of the canyon wall.
Figure 18. Overview map of Complex 2 with soil unit locations and landform categorization (BLM 2013b).
A primary terrace is located on what appears to be a small island, and most likely had connected to the primary terrace that is located within the study complex, but has since been eroded down by the river. A newly forming terrace is located at the northern end. A drainage is located at the western end of the study complex and drains downhill, to the south onto Terrace 0 and Terrace 1. A second drainage is located to the southwest of the other drainage and flows into the colluvium on Terraces 0 and 1. The surfaces of Terrace 0 and Terrace 1 are uneven and inclined to the west/northwest.

![Figure 19. Cross section of Complex 2, looking south, with horizon indices graphs.](image)

Horizon indices indicate that soil depth gets deeper as the terraces are higher and further from the river. Horizon values are lower in the upper A horizons, values become higher in the lower B horizon, and then seem to stay
somewhat constant prior to the C horizon. Terrace 0 is very shallow, ending at boulder refusal, the depth of Terrace 1 is slightly more shallow than other primary river terraces in the study area (may have been skewed by the presence of the large boulder found in the profile), while the other three soil profiles found on terraces 2 through 4 are very deep with high amounts of clay.

Terrace 0 extends to an 11 centimeter depth and consists of fine-grained sand, before ending at large subrounded boulders (Figure 20). Many subrounded boulders were seen on the surface as well as subsurface on the newly forming river terrace. Terrace 1 consists of two A horizons (both cobbly sandy loam), that go to a depth of 27 centimeters (Figure 21). A lot of gravel and cobbles are present in the lower portion of the profile. Terrace 2 is a bit more developed with two A horizons (both sandy loam), and AB transition (sandy clay loam), Bt1 (sandy clay loam), a Bt2 (very cobbly sandy clay loam), and ends at packed boulders at 126 centimeter depth (Figure 22). Many subrounded boulders were found the lower portion of the profile. Terrace 3 is even more developed, with two A horizons (both sandy clay loam) and three Bt horizons—Bt1, Bt2, and Bt3 (all very gravelly sandy clay loam). Soil development is deep and extends to 147 centimeters and ends at packed boulders (Figure 23). Terrace 4 is 155 centimeters deep and consists of an A horizon (sandy loam), an AB (sandy loam), four Bt horizons (Bt1 is a sandy clay loam and the other are extremely gravelly sandy clay loam), and a CB gravel with skeletons over clay coats on rock fragments, before ending at clay covered subrounded boulders (Figure 24). There are many coarse fragments in these units, the fragments are poorly sorted, have contact, and in some units seem to be oriented in a north-south direction.

Pedogenesis seems to be bit more developed in this complex when compared to other complexes. PDI values, weighted PDI values, depth, clay amount, the presence of more Bt horizons are seen in each terrace, and horizon values are all significantly higher than any of the other soil profiles found on the other four terrace complexes in the study area.
Figure 20. Complex 2, Terrace 0, west profile. Tape measure is 11 cm in picture.
Figure 21. Complex 2, Terrace 1, west profile. Tape measure is 152 cm in picture.
Figure 22. Complex 2, Terrace 2, west profile. Tape measure is 157 cm in the picture.
Figure 23. Complex 2, Terrace 3, west profile. Tape measure is 141 cm in picture.
Figure 24. Complex 2, Terrace 4, west profile. Tape measure is 165 cm in picture.
Terrace Complex 3 is the only complex under study that was found on river left (east side of river channel) and is situated right after a western bend in the river. The complex is located just south of River Mile 219 and consists of Terraces 1 through 3, a floodplain, and a small alluvial fan (Figures 25 and 26). Medium-sized boulders were present at the surface of all terraces.

Vegetation consists of white fir, ponderosa pine, and white and black oak. Oregon grape was the dominant understory throughout all terraces except on Terrace 3, which was a little more open, with exposed mineral soil.

Colluvium was present at the eastern edges of Terrace 1-3. In addition, the area of Terrace 2 was extremely small in comparison with other terraces. Horizon indices indicate that horizon values increase after the A horizons; this is especially noticeable in Terrace 3. Terrace 2 abruptly stops due to a high amount of coarse fragments, but clay coatings were present in lower Ct horizons.

The floodplain extends to a depth of 36 centimeters and consists of two A horizons (loamy sand and sandy clay loam) (Figure 27). Terrace 1 is deeper than expected and extends to a depth of 82 centimeters and is very dark—the color is black (N 2.5) (Figure 28). Two A horizons were recorded, and were textured to be loam and sandy loam. A1 is slightly unique, in that, it has a low bulk density and feels powdery, perhaps due to a high amount of organic matter. Terrace 2 is shallow in comparison to Terrace 1; it only goes to a 50 centimeter depth (Figure 29). Terrace 2 is comprised of an A horizon (sandy clay loam), a BA (gravelly sandy clay loam) and a Bt (gravelly sandy clay loam). Terrace 3 is 134 centimeters deep and consists of an A horizon (sandy clay loam), an AB (sandy clay), and four Bt horizons (three gravelly sandy clay and one extremely gravelly sandy clay) (Figure 30). In most cases coarse fragments were unsorted and contact was present. A layer of subrounded and rounded coarse gravel was present in Terrace 3, which was poorly sorted.
Figure 25. Overview map of Complex 3 with soil unit locations and landform categorization (BLM 2013b).
Profile and horizon indices exhibit a somewhat linear progression, with the exception that the profile of Terrace 2 is shallow, or that the depth of Terrace 1 was higher than expected. Terrace 3 is a great example of how horizon index values are somewhat low in the top horizons then become higher with horizon depth, and eventually the values lower again in the lower C horizons. This same shape is exhibited in Schaetzl and Anderson (2005).
Figure 27. Complex 3, Terrace 0, east profile. Tape measure is 39 cm in picture.
Figure 28. Complex 3, Terrace 1, east profile. Tape measure is 130 cm in the picture.
Figure 29. Complex 3, Terrace 2, east profile. Profile extends to a 152 cm depth.
Figure 30. Complex 3, Terrace 3, east profile. Tape measure extends to a 152 cm depth in picture.
Terrace Complex 4 is found at River Mile 218.5 and extends across the “Klamath River Campground” (Figures 31 and 32). This area has been highly disturbed by the construction of a vault toilet facility, roads, camping areas, timber thinning, and fuels reduction. These disturbed locations were avoided and are located at the southern end of the complex, while terraces in the northern part were recorded. In addition, an archaeological site spans roughly 400 meters N/S on a primary river terrace. A soil unit was not put into the primary river terrace due the presence of that site. Unfortunately there were no cutbanks or eroded areas to inspect, resulting in Terrace 1 being devoid of profile development information. Landforms include: a floodplain, Terraces 1-5, and a thick accumulation of colluvium is present at the western margins Terrace 5, but is mostly in the southern part of the study area, where alluvial fans and colluvium descended from drainages. A large amount of colluvium has accumulated at the northern edge of Terrace 4, where the terrace and canyon wall meet. Much of the newly deposited colluvium is the result of road construction upslope.

The terraces are somewhat open and recent fuels activities have resulted in an oak savannah on Terrace 4 and 5, interspersed with an occasional ponderosa pine. Vegetation throughout the rest of the area includes: Ponderosa pine, white and black oak, with a lesser amount of incense cedar and white fir. The understory component consists of wild lilac, gooseberry, service berry, Oregon grape, showy milkweed, dwarf lupine, hemp dogbane, and canary reed grass near the river.
Figure 31. Overview map of Complex 4 with soil unit locations and landform categorization (BLM 2013b).
Horizon indices show that for the most part, profiles become deeper as the terrace is further from the current channel, except Terrace 5. Soil development stops abruptly at large stones and boulders.

The floodplain in this complex is unusual; consisting of unconsolidated sandy clay A and two Btg horizons (Figure 33). The profile extends to a depth of 31 centimeters and then is interrupted by a high water table. Gley and redoxomorphic features are present, indicating that the terrace is somewhat poorly drained and that a fluctuating water table is present. No profile description is available for Terrace 1, but the terrace is relatively flat, extends some 400 meters north-south, and has been heavily impacted by recreationists, traffic, and colluvium and alluvial fan formations. Terrace 2 consists of two sandy loam A horizons, a cobbly sandy clay loam AB horizon, and a very gravelly sandy clay
loam Bt horizon that ends at 56 centimeters (Figure 34). Evidence of fire is seen in this profile; burned roots were present down to 31 centimeters and an accumulation of root matter and decomposed wood were found below the A/Bt horizon. Terrace 3 is 82 centimeters deep and consists of a sandy clay A horizon, four Bt horizons (two gravelly sandy clay and two extremely gravelly clay textured horizons), diatomite was found at 82 centimeters, and an obvious thick layer of light grayish brown (10YR 6/2) matter is present at the bottom of the profile (Figure 35). A sample of the light grayish brown material was sent to Washington State University for analysis. Analysis confirms that volcanic glass is present in the sample, but it is a small unidentifiable fraction. The sample mainly consisted of biogenic silica, otherwise known as diatomite (Foit 2013). Terrace 4 is 91 centimeters deep and is comprised of a sandy clay loam A horizon, a sandy clay loam AB horizon, and two Bt horizons (gravelly sandy clay loam and extremely sandy clay loam) (Figure 36). Terrace 5 only extends to a depth of 57 centimeters, consisting of a sandy clay A horizon, a gravelly sandy clay AB horizon, two Bt horizons (both gravelly sandy clay), and overlays a stratum of very cobbly fine sand and large packed boulders (Figure 37). In most horizons, coarse fragments are subrounded and rounded, and are poorly sorted.
Figure 33. Complex 4, Terrace 0, west profile. Tape measure is 43 cm in the picture.
Figure 34. Complex 4, Terrace 2, west profile. Tape measure is 116 cm in picture.
Figure 35. Complex 4, Terrace 3, west profile. Tape measure is 170 cm in picture.
Figure 36. Complex 4, Terrace 4, west profile. Profile extends to 152 cm depth.
Figure 37. Complex 4, Terrace 5, west profile. Tape measure is 152 cm in picture.
Terrace Complex 5 spans from River Mile 217 to River Mile 216 to a dispersed contemporary camping area, referred to as “Turtle Camp” (Figures 38 and 39). This complex consists of a discontinuous floodplain, Terraces 1-3, and two abandoned river channels or overflow channels (Figure 40). Current recreational impacts, colluvium, and bioturbation from large trees and animals were present at the small southern continuation of Terrace 3. No units were put in this portion of the terrace because it was highly disturbed as evidenced by the amount of vehicle ruts, overturned trees, and burrowed ground. The largest and most expansive terrace in this complex and of all the other four complexes is the tertiary terrace of Complex 5. The terrace spans about a half mile and is very conspicuous. Two units were placed into this feature to see if it was continuous. In addition, a road cut and cutbank (both found to the north of the units) were inspected to further conclude that the terrace is mostly continuous; the northern-most area at the roadcut consisted of poorly sorted angular boulders. Findings indicate that soil development throughout the terrace is similar and that a diatomaceous layer is continuously present throughout the terrace at a depth of 60-65 inches (152-165 cm). The diatom layer was roughly 30 centimeters thick in the cutbank and a layer of river alluvium was present underneath.

This complex was also interesting because of a hard, iron accumulated, paragavel layer found on the primary terrace. Cressman (1961) and Mack (1983) recorded and described three basic stratigraphic units found at the Klamath Shoal Midden site, which is one mile downstream of Complex 5. Stratum II, also called the “Cemented Gravel Stratum” is described by Mack and seems to possess many of the same characteristics as the profile of Terrace 1: having cemented river gravel and a yellowish or ochre color. The primary river terrace was more developed than the underdeveloped secondary terrace.

The tertiary terrace appears to be a large alluvial fan, pointing westward, upslope. The surface of the fan is highly uneven with large boulders and a thick organic layer. There were not any cutbanks to inspect to observe the river and fans interactions, however, some of the units, placed at the eastern shoulder of
the terrace appear to reflect deposits that would suggest that the river and fan both deposited sediments interchangeably.

The northern-most area of the terrace is overlain with a thick accumulation of colluvium interspersed with large pieces of broken bedrock on top of bedrock; which is not the result of an alluvial fan.

Vegetation mainly consisted of incense cedar, ponderosa pine, white and black oak, wild lilac, and canary reed grass. The forest floor was open, due to recent prescribed underburn activities.

Terrace 0 has a 24 centimeter sandy loam A horizon and ends at the water table (Figure 41). Terrace 1 extends to a 79 centimeter depth and consists of two A horizons (sandy loam and sandy clay loam), a sandy clay loam AB horizon, and an extremely gravelly sandy clay loam Bt horizon (Figure 42). In addition, three hard paragravel layers underlie the soil, and contain iron accumulations. Terrace 2 is less developed than Terrace 1, being only 36 centimeters deep with two sandy loam A horizons (Figure 43). Terrace 3 extends to a depth of 114 centimeters and is comprised of two A horizons (gravelly sandy loam and very gravelly sandy loam), two Bt horizons (very gravelly sandy clay and very gravelly sandy clay loam), an extremely gravelly sandy clay BLdi layer, and two Ldi layers (diatom) underneath, extending from 114 to 152 centimeters (Figure 44).
Figure 38. Overview map of Complex 5 with soil unit locations and landform categorization (BLM 2013b).
Horizon indices graphs show the soil development of Terrace 1, lack of development on Terrace 2, and development and depth on Terrace 3. Terrace 1 was deeper and had a higher accumulation of clay than expected. The depth and horizon index of Terrace 2 was less than expected— the HI graph shows a truncated line that exhibits the shallow 36 cm depth of the profile.
Figure 40. Overview of the historic channel found between Terrace 3 and Terrace 2, looking north.

Although, commonly found in the river canyon, two historic streambeds or possible overflow channels were observed within Complex 5. An obvious north-south running 10 meter wide dip is located just to the west of the Terrace 2. A second expansive flat and 10-30 meter east-west floodplain with shallow fluvial flow indentations was is located to the east of Terrace 2 (not shown in picture).
Figure 41. Complex 5, Terrace 0, west profile. Tape measure is 33 cm in picture.
Figure 42. Complex 5, Terrace 1, southwest profile. Tape measure is 112 cm in picture.
Figure 43. Complex 5, Terrace 2, west profile. Tape measure is 132 cm in picture.
Figure 44. Complex 5, Terrace 3 2, west profile. Profile extends to a 152 cm depth.
PDI calculations were completed for 21 soil profiles (Tables 3 and 4). PDI values suggest that terraces closer to the current river channel are younger, by having a smaller PDI value and usually smaller weighted PDI than sequential higher elevation terraces. Horizon indices for each profile found in each complex indicate that wet and dry consistence, texture, structure, and mostly depth and rubification develop with age, with exceptions found in Terrace 2 of Complex 3, Terrace 5 of Complex 4, and Terrace 2 in Complex 5.

There were instances where the PDI of terraces within a complex did not seem to follow the low number to higher number value; specifically, in Complex 5. There are numerous reasons as to why the PDI values didn’t completely match the assumption that a PDI numbers would be smaller for lower terraces and larger for higher terraces. This may be due to a number of reasons—recorder error or due to different natural processes having had occurred at each individual location. Recordation took place over multiple months and some profiles were recorded in the cold, wetter, and poorly lit winter months; other profiles were recorded during the warmer, dryer and better lit spring months. These minor differences could account for differences in recordation of soil properties. To limit extreme variances in profile recording, only one person recorded the soil profile at all times, however, it is still possible that error may have occurred.

Landforms undergo processes differently and the high amount of coarse fragments may have skewed recordings; specifically dry consistence and mostly plasticity. It seems that many of the subangular blocky fragments, found in Bt horizons, crushed easier than expected. The ped broke due to pressure exerted, but fine gravel always seemed to cause easier breakage. It was also difficult to roll out the Bt horizons— a large enough sample had to be acquired and sieved, which was somewhat difficult and then rolled. Fine-grained gravel always seemed to be stuck in the sample, making it difficult to roll. This may have skewed some of the readings as well.
The PDI value of Terrace 2 of Complex 3 doesn’t seem that far off at 0.221, however the depth of that horizon is only 50 centimeters. The remnant terrace is small (approximately 20 meters north-south by 10-15 meters east-west), only containing a small fraction of what the terrace was historically. A high amount of boulders were found subsurface, making excavation difficult and tedious, but also causing a C horizon to be found higher in the profile than expected. The C horizons of this profile are comprised of a high amount of fine, medium, and coarse gravel as well as numerous cobbles, stones, and boulders. These coarse fragments are covered in clay films, indicating that illuviation is occurring in the upper horizons, depositing the clay downward through the profile. The PDI isn’t low; however, the morphological horizon index is distorted and truncated when graphed.

It could be that the Terrace 5 from Complex 4, may be older than the lower terraces, but according to horizon indices the seemingly constant depth value was lower than proceeding profile depths. The problem with depth may be allotted to different depositional facies. The higher profiles seemed to have been recently influenced heavily by colluvial deposition— the large boulders at the bottom of the units were likely the result of rock fall and accumulations and were later influenced by fluvial processes, causing the rounding of the rocks. Clay accumulations were also lower than expected in Terrace 5, which contained a large quantity of sand in the lower horizons. The sand was packed into interstitial areas of the 2C horizon.

The high clay content in Terrace 0 may be the result of clay aggradation due to the low energy of the river in that area. Clay is likely to settle into the adjacent floodplain. The clay content of Terrace 0 seems to distort the values of the other higher terraces resulting in overall lower PDI values for all terraces in this complex (texture didn’t add any points to the PDI values).

Terrace 2 of Complex 5 is underdeveloped. It is located on the eastern edge of a terrace that gently slopes to a historic river channel or overflow channel. The unit may have been placed in a poor sample area, perhaps the
terrace is evidence of an unconformity in the Terrace 2 record, or it is possible that the landform was not identified correctly. The terrace was originally recorded as a gravel bar due to the evidence of many large rounded coarse gravel and cobbles lining the surface, later it was determined to be a secondary terrace due to the geomorphology of the landform.

All terraces from Complex 2 have higher horizon values and PDI values than all other terraces from other complexes (summarized below in Table 3). This is due to the high amount of clay found within the soil, the shallow and undeveloped Terrace 0, and the depth of Terraces 3 and 4.

Table 3. Profile development index values (weighted and not weighted), organized by complex.

<table>
<thead>
<tr>
<th>COMPLEX</th>
<th>TERRACE</th>
<th>PDI</th>
<th>DEPTH (CM)</th>
<th>WEIGHTED PDI</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>0</td>
<td>21</td>
<td>X</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>4.16</td>
<td>35</td>
<td>0.119</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>17.63</td>
<td>91</td>
<td>0.194</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>0</td>
<td>11</td>
<td>X</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>6.75</td>
<td>27</td>
<td>0.250</td>
</tr>
<tr>
<td>6</td>
<td>2</td>
<td>43.00</td>
<td>126</td>
<td>0.341</td>
</tr>
<tr>
<td>7</td>
<td>3</td>
<td>54.39</td>
<td>147</td>
<td>0.370</td>
</tr>
<tr>
<td>8</td>
<td>4</td>
<td>67.21</td>
<td>155</td>
<td>0.434</td>
</tr>
<tr>
<td>9</td>
<td>3</td>
<td>0</td>
<td>36</td>
<td>X</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>12.89</td>
<td>82</td>
<td>0.157</td>
</tr>
<tr>
<td>11</td>
<td>2</td>
<td>11.05</td>
<td>50</td>
<td>0.221</td>
</tr>
<tr>
<td>12</td>
<td>3</td>
<td>40.17</td>
<td>134</td>
<td>0.300</td>
</tr>
<tr>
<td>13</td>
<td>4</td>
<td>0</td>
<td>32</td>
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<td>0.286</td>
</tr>
<tr>
<td>15</td>
<td>3</td>
<td>25.01</td>
<td>82</td>
<td>0.305</td>
</tr>
<tr>
<td>16</td>
<td>4</td>
<td>28.63</td>
<td>91</td>
<td>0.315</td>
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<td>21.15</td>
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<td>0.371</td>
</tr>
<tr>
<td>18</td>
<td>5</td>
<td>0</td>
<td>24</td>
<td>X</td>
</tr>
<tr>
<td>19</td>
<td>1</td>
<td>18.03</td>
<td>79</td>
<td>0.228</td>
</tr>
<tr>
<td>20</td>
<td>2</td>
<td>5.71</td>
<td>36</td>
<td>0.159</td>
</tr>
<tr>
<td>21</td>
<td>3 1</td>
<td>X</td>
<td>122</td>
<td>X</td>
</tr>
<tr>
<td>22</td>
<td>3 2</td>
<td>34.77</td>
<td>114</td>
<td>0.305</td>
</tr>
</tbody>
</table>
The PDI values for terraces of the same ranking (not separated by complex) are somewhat similar, but the values do vary. Terrace 1 values span between 0.119 and 0.250 (average 0.1885); Terrace 2 values are between 0.159 and 0.341 (average 0.2402); Terrace 3 goes from 0.300 to 0.370 (average...
0.320); Terrace 4 only has two calculations at 0.315 and 0.434 (.3745); and the only Terrace 5 has a weighted PDI of 0.371. The weighted PDI values were plotted on a scatter plot to demonstrate the lateral variations in similarly ranked terraces (Figures 45-49).

Figure 45. Terrace 1 weighted PDI values for Complex 1-3 and 5 (no value for Complex 4 because there was not a unit excavated in the T1). Y axis is the weighted PDI value, while the x axis is the associated terrace.
Figure 46. Terrace 2 weighted PDI values for all five complexes. Y axis is the weighted PDI value, while the x axis is the associated terrace.

Figure 47. Terrace 3 weighted PDI values for Complex 2-5 (no value for Complex 1 because the complex did not contain a T3). Y axis is the weighted PDI value, while the x axis is the associated terrace.
Figure 48. Terrace 4 weighted PDI values for Complex 2 and Complex 4 (no value for Complex 1, 3, or 5 because those complexes did not contain a T4).

Figure 49. Terrace 5 weighted PDI value. One fifth level terrace was identified within the five river mile study corridor.
In a post-incisive soil chronosequence the PDI values should demonstrate differences in pedogenic development. In order to illustrate this, both profile development indices (weighted and not weighted) were graphed in a scatter plots (Figures 50 and 51). Linear regression analysis was then used to model the relationship between PDI values and terrace ranking by fitting a trend line through values. The graphs seem to suggest that there is a linear progression of soil profile development within each complex; with presumed older terraces having higher PDI values. There are a few outliers, but overall there is a positive correlation between PDI values and terrace designation.

The unweighted PDI values do not fit the trend line as well as the weighted PDI values do. Unweighted PDI values contain a R² of 0.3293, whereas the weighted PDI values account for profile depth and has a R² of 0.5965. Weighted PDI values take the depth of a soil profile into account and the results, when graphed appear to suggest that there is a positive correlation between terraces and weighted PDI values.

![Figure 50. Plotted PDI values by terrace (PDI values, y axis; terrace number, x axis).](image-url)
Soil morphological horizon indices have shown useful in evaluating soil profile development as well. For the most part, the morphological horizon indices indicate that soil profiles followed a general linear pattern from Terrace 0 upwards to more developed terraces. Terraces higher in elevation and further from the current river channel consist of more horizons, have greater depths, and higher morphological values.
Chapter 6. Discussion and Conclusion

As it was clear that geoarchaeological research needed to be conducted in the UKRC, to better understand the past, specifically human-landform or archaeological site-landform interactions, distribution, and location. To accomplish this, a series of questions were addressed.

The first question was concerned depositional environments. After careful review of geomorphologic, geologic, pedologic, and archaeological reports and studies, it was clear the Upper Klamath Basin and UKRC have undergone a series of dynamic processes—from tectonic to volcanic, which have resulted in the formation of large lakes that later built up large lacustrine deposits (diatom, clay, silt, sand, and organic matter) that were re-worked along with volcanic material (pumice) to later be deposited within the terraces that have formed over thousands of years in the canyon. Additionally, mass wasting episodes seem to be the main source of sediments and are also one of the main depositional environments found in the canyon—from large rockfalls, to creep, to landslides.

The canyon is controlled by bedrock that constricts the river channel, which causes the channel to have a faster current, steeper gradient, and does not allow fine-grained sediments to fall out of suspension. There are few alluvial reaches within the canyon; these are interspersed between colluvium and bedrock areas.

The depositional environment is the culmination of various factors, but colluvial and alluvial interactions are the main depositional environments found in the UKRC. It appears for the most part that the river has downcut, causing the formation of a steep canyon that erodes into the river. Large boulders and other coarse fragments fall downhill and become entrenched in the river. The river fluctuates and rounds these fragments. Over time the boulders begin to form areas that are slightly higher than the river channel and sediments become deposited there and/or these fragments begin to undergo weathering.
enough time it is likely that riparian species take root and a floodplain begins to form. In times of high water, the channel overflows onto the floodplain and may drop sediments or even scour the surface. The floodplain eventually builds upward and the river downcuts and may even begin to migrate to the other side of the canyon. Tributaries and drainages may also deposit additional sediment. A continuation of colluvium is likely to occur, especially near the canyon wall.

This example provides an over-simplified illustration of what may have occurred at various points in the canyon to demonstrate that system is variable and fluctuates between depositional environments. Both alluvial/fluvial and colluvial deposits were seen on the surface of terraces as well as within. Some soil profiles had angular and subangular cobbles at the top, indicating not much fluvial smoothing had occurred. Those fragments were likely deposited by gravity, after the river channel migrated. Large boulders found at the bottom of profiles would have been too large to move, unless some catastrophic high-energy event occurred that could have displaced them. However, gravity seems more likely. These large boulders were rounded, showing evidence of physical and chemical weathering via the forces of repeated water scouring at the exterior of the boulders. Some profiles had what appeared to be subrounded and rounded alluvial gravel in bands as well.

As for the location, both depositional environments seemed fluctuate back and forth, but never seemed to be completely confined to one location. Recently, colluvial activity occurred on the slopes and at the canyon wall/terrace area and the river was restricted to the channel. However, evidence of both types of deposition was seen alternating in some profiles.

The second question brought forth question of what terraces are older or younger and what are the potential ages associated with the landforms? In regards to ages, unfortunately the HI and PDI form of calculations only provide relative dates; these indices serve as preliminary guides to soil ages by calculating soil characteristics. It is generally assumed that terraces higher and further from the current river channel are older. PDI calculations serve as a
means to quantify soil properties to see if the degree of soil development conforms to this assumption. Overall, the majority of PDI values seem to suggest that terraces further and higher are indeed older. However, I would recommend that in future studies more landforms be included to measure this adequately. The calculations may be a bit off as well, due to a having a limited sample of “older” terraces (Terrace 4 and Terrace 5). The majority of terraces found and recorded are primary and secondary; secondary terraces seemed to be highly variable.

Terraces of that have been assigned the same numbers, or designations are somewhat similar. The PDI and weighted PDI values vary and overlap, but overall increases with presumed older terraces. Terrace 1 values average 0.1885; Terrace 2 averages 0.2402; Terrace 3 averages 0.320; Terrace 4 averages 0.3745; and the only Terrace 5 has a weighted PDI of 0.371.

Also, horizon indices (compiled by soil characteristics and weighted by depth against the parent material) seemed to suggest a somewhat linear progression of soil development from one terrace to the next within a terrace complex. There were a few anomalies and each terrace complex varied a bit from one to the next. Horizon indices in conjunction with profile development indices help to quantify the data observed and collected, as well as to demonstrate soil development on alluvial terraces. Horizon indices showed development within a profile and PDI values provided data to show soil development within a terrace complex.

In addition, to relative dates obtained by PDI calculations, archaeological materials have been radiocarbon dated at three separate sites within the current study area, totaling to five radiocarbon dates. The three sites are situated on terrace landforms 1-3 (Table 5).
Table 5. Known archeological sites within the five mile study area, landforms, radiocarbon dates, and weighted PDI values.

<table>
<thead>
<tr>
<th>Site Name</th>
<th>Radiocarbon Date</th>
<th>Site Type</th>
<th>Associated Landform</th>
</tr>
</thead>
<tbody>
<tr>
<td>FY61-014-002</td>
<td>-</td>
<td>Lithic scatter</td>
<td>T1</td>
</tr>
<tr>
<td>FY61-014-003</td>
<td>564 ± 110 Cal. BP</td>
<td>Village</td>
<td>T1, T2</td>
</tr>
<tr>
<td>FY61-014-005</td>
<td>100 ± 70 BP</td>
<td>Village</td>
<td>T0, T1, T2</td>
</tr>
<tr>
<td>FY61-014-006</td>
<td>Cal. 1,009 ± 110 B.P., Stratum IIIc, d</td>
<td>Midden</td>
<td>T3</td>
</tr>
<tr>
<td></td>
<td>Cal. 1,296 ± 125 B.P., Stratum IIIb, c</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cal. 7,646 ± 400 B.P., Stratum I</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FY61-014-007</td>
<td>-</td>
<td>Village</td>
<td>T2</td>
</tr>
<tr>
<td>FY84-014-001</td>
<td>-</td>
<td>Historic can dump</td>
<td>T1</td>
</tr>
<tr>
<td>FY84-014-005</td>
<td>-</td>
<td>Lithic scatter</td>
<td>T1</td>
</tr>
<tr>
<td>FY84-014-009</td>
<td>-</td>
<td>Village</td>
<td>T1</td>
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<td>-</td>
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<td>T1</td>
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<td>FY84-014-015</td>
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<tr>
<td>FY85-014-011</td>
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<td>T0, T1</td>
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<tr>
<td>FY09-014-047</td>
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<td>Historic irrigation ditch</td>
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<td>Village</td>
<td>T1</td>
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</table>

A majority of the sites are located on Terrace 1 and are village sites. Based on the five radiocarbon dates, sites span from contact to the Secret Springs Phase or not named phase. Based on the five dates it can generally be
said that T0 is currently forming, T1 would date to the Canyon Phase, T2 would date to the Canyon Phase and possibly to the River Phase, and T3 would date to the Secret Springs Phase or not named phase.

Table 6. UKRC cultural chronology, adapted from Mack (1991)

<table>
<thead>
<tr>
<th>Years B.P.</th>
<th>Upper Klamath River</th>
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</thead>
<tbody>
<tr>
<td>Pre-7,500</td>
<td>Not Named Phase: not well represented on the Klamath River.</td>
</tr>
<tr>
<td>7,500</td>
<td>Secret Spring Phase: not well represented, one date from Klamath Shoals Midden (7,646 ± 400 cal. B.P.).</td>
</tr>
<tr>
<td>7,000</td>
<td></td>
</tr>
<tr>
<td>6,500</td>
<td>Basin Phase: substantial evidence of river terraces by generalized hunter-gatherers.</td>
</tr>
<tr>
<td>5,000</td>
<td></td>
</tr>
<tr>
<td>4,500</td>
<td>River Phase: evidence of fishing and use of riverine resources.</td>
</tr>
<tr>
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</tr>
<tr>
<td>3,500</td>
<td></td>
</tr>
<tr>
<td>3,000</td>
<td></td>
</tr>
<tr>
<td>2,500</td>
<td>Canyon Phase: well represented sites are found on a variety of landforms, but with a riverine focus. First house pits found in the canyon at 900 B.P..</td>
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<tr>
<td>2,000</td>
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<tr>
<td>1,500</td>
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<td>1,000</td>
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<td>750</td>
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<tr>
<td>250</td>
<td>Historical Period/Contact: well represented.</td>
</tr>
</tbody>
</table>

The initial alluvial sedimentary deposits date from the Quaternary, or the last 2.59 million years. More recently, sometime within the last 10,000 the UKRC became entrenched and severely incised. This would have caused the river to move a heavy bedload of sediments downstream (Dicken and Dicken 1985:1-4). The eruption of Mt. Mazama (6,850 B.P.) mostly likely had a large impact on the UKRC. The tributaries and drainages would have filled with pumice, adding more sediments to the river system (FERC 2004:6-20).

After the deposition of sediments soils would begin to form. Depending on CLORPT conditions, soil formation can follow a somewhat linear progression.
Most soils start as entisols and begin to take on inceptisol characteristics. Thereafter, the soil progression branches out, and depends a bit more on additional factors. A soil can change to an andisol, spodosol, alfisol, or mollisol if provided certain conditions. In this case, the soils in the canyon have been categorized in the xerolls, broken down that means a mollisol with a xeric climate regime. Based on the progression of soil orders through time, mollisol soil formation spans from approximately 7,000 years to over 100,000 years. Mollisols form in areas that have a decent organic matter input, such as the canyon. Although, this is a large timeframe, soil development on some of the terraces seems to possess these qualities, perhaps dating to at least 7,000 years. The newly forming terraces do not have much soil development, if any. Terrace 1 shows shallow soil formation, falling somewhere in the inceptisol/mollisol area.

The third question pertains to the potential dates of landforms and possible site location. Sites are likely to be found within landscapes that offer a more stable environment. Areas immediately adjacent to fast flowing portions of the channel have a higher chance of erosion. Areas along the channel that are narrow do not provide a good chance of preservation and may not even provide a place for certain sites to even form (e.g., large habitation sites). Referring back to Guccione’s (2008) three factors, those steep and narrow areas are probably not going to be chosen spots, those areas are unlikely to preserve sites, and identification of sites are less likely to occur since many of the steep areas contain thick vegetation as well as thick talus deposits.

Other areas, near the canyon wall may be displaced by colluvial action or more likely—the site would be covered by a thick accumulation of colluvium, leading to less chance of surface identification, but perhaps a better chance of preservation. Best preservation areas include the large expansive flats found at the Blue Heron and Frain stretches. These areas contain many qualities that indicate that site preservation would occur. Other areas likely to contain sites would be other flat expansive terraces, and areas where deposits may settle out slowly—perhaps in locations where slow flowing creeks meet.
Depending on environmental factors, depositional environs, and preservation an earlier site would be found on a Terrace 3 and successive terraces. Sites dating to Mack’s (1983; 1991) not-name phase (pre-7,500 B.P.) would be found on higher terraces (terraces 3, 4, and 5), while later phases would be found buried on newer terraces. It is quite possible that sites belonging to later phases would be found on all terraces. However, these sites would consist of surface finds on older terraces and are known to be mainly situated on the newly developing floodplain as well as Terrace 1 (sites typically date to 580 ± cal. 120 B.P.). The oldest dates for the canyon come from the Klamath Shoal Midden, located on a third terrace. Artifacts were found deeply buried in the feature and a charcoal fragment from a 200 centimeter depth (6.5 feet) in the River Gravel Stratum was dated and is the oldest dated material in the Klamath Basin.

Historic sites and other surface sites are to be found on newly forming floodplains and Terrace 1. Newer sites may also be found on older terraces, but would only consist of surface finds and would not be deeply buried, likely located in the organic matter or perhaps in the A horizon(s).

Based on soil order, soil formation, and PDI values, older sites would be located buried on older landforms and younger sites are to be found on all landforms (Figure 52). However, the newer sites would be shallow, if not surface sites on older landforms. PDI values, known site dates and locations, as well as a familiarity with the past environment and processes would aid in the location of sites. Areas lacking in available archaeological information are from the no-name, pre-7,500 phase and sparse, fragmentary information is found in the subsequent Secret Springs Phase. In order to build up data for these sites; sites dating to these times periods need to be located, studied, and excavated. It is highly likely that these sites would be found deeply buried within Terrace 3 – Terrace 5.

A few correlations were found amongst landforms and site types in the UKRC. The majority of village sites within the canyon were located on flat river
terraces, mostly primary river terraces, with one habitation site located on a newly forming floodplain, and a few house pits at Big Boulder Village were positioned on the secondary river terrace. This pattern was seen outside the current study area as well, where the majority of house pit sites were located on primary terraces, with one exception near the SSML, where a house pit village was found roughly 600 meters above the current river channel, near an intermittent stream, on a somewhat flat area. The oldest date obtained for a house pit in the Klamath Basin is 900 B.P. (Border Village; downstream of project area), suggesting that this type of feature and larger village pattern was a more recent occurrence.

Figure 52. UKRC conceptual predictive schematic— depicting terrace height above current river channel, depth, PDI values, radiocarbon dates, and possible depth and location of archaeological sites dating to Mack’s cultural chronology for the area.
This thesis served to begin geoarchaeological research in the UKRC, by mainly focusing on geomorphology as well pedogenesis. To say that a terrace is older, due to further proximity from the current river channel and being higher than successive terraces is intuitive—it seems obvious. However, to say something does not mean it is true, therefore the Harden Index was used to test this assumption. The PDI values of 21 profiles suggest that this assumption is relevant in this particular stretch of the river canyon. Of course there were a few outliers and one unconformity was observed in a profile. Horizon indices showed that pedogenesis usually increased with terrace depth and with time and that development in the surface horizons usually lingered around the same value, then went higher for the B horizons and generally became smaller around the last B or BC horizons. Horizon index graphs were able to portray this slight curve in values.

More geoarchaeological research should be done in the canyon to construct a more relevant framework (additional mapping of the geology and soils; in-depth studies of site locations, depths, and dates; and more dates need to be obtained). While my research has provided a foundation for geoarchaeological work in the UKRC, it is clear that additional excavation and testing should occur to fill in the blanks in the cultural chronology and fill in the areas lacking data.
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APPENDICES
Appendix A. Landform Map
Appendix B. Profile Descriptions
Soil Profile Description

Complex 1, Terrace 0

**A** — 0 to 21 centimeters, dark gray (2.5Y 4/1) sandy loam, gray (2.5Y 6/1) dry; weak fine granular structure; soft, very friable, slightly sticky, slightly plastic; many medium, common coarse, and many very coarse roots throughout; common fine interstitial pores; five percent subrounded prismoidal, subprismoidal, and spherical gravel; neutral (6.7 pH); clear wavy boundary (2-4 centimeters).

**C** — 21 to 51 centimeters, dark grayish brown (2.5Y 4/2) extremely gravelly loamy coarse sand, light yellowish brown (2.5Y 6/3) dry; single grained structure; loose, loose, non-sticky, non-plastic; few fine interstitial pores; 70 percent subangular, subrounded, rounded, and well rounded prismoidal, subprismoidal, spherical, subdiscoidal, and discoidal gravel; neutral (7.0 pH); refusal.
Soil Profile Description

Complex 1, Terrace 1

A1 — 0 to 10 centimeters, black (10YR 2/1) silt loam, dark gray (10YR 3/1) dry; weak very fine granular structure; soft, very friable, slightly sticky, slightly plastic; common very fine, many fine, many medium, common coarse, and many very coarse roots throughout; many fine interstitial and few fine tubular pores; five percent subrounded spherical gravel; neutral (6.6 pH); gradual smooth boundary.

A2 — 10 to 35 centimeters, very dark grayish brown (10YR 2/2) sandy clay loam, dark gray (10YR 4/1) dry; weak very fine granular structure; soft, very friable, slightly sticky, slightly plastic; common very fine, common fine, common medium, many coarse, and many very coarse roots throughout; many fine interstitial and few very fine and fine tubular pores; five percent subrounded, rounded, and well rounded prismoidal and subprismoidal gravel (contact and long axis of most coarse fragments is north-south); neutral (6.8 pH); clear smooth boundary

C — 35 to 152 centimeters, gravel; single grained; loose, loose, non-sticky, non-plastic; few medium, common coarse, and few very coarse roots throughout and matted around rock fragments; 60 percent subrounded, rounded, and well rounded subprismoidal and spherical gravel; 15 percent cobbles, 10 percent stones, and five percent boulders (long axis of most coarse fragments is northeast-southwest); refusal.
Soil Profile Description

Complex 1, Terrace 2

Oi – 3 to 0 centimeters, oak leaves and twigs.

A1 – 0 to 12 centimeters, dark brown (10YR 3/2) silt loam, dark grayish brown (10YR 4/2) dry; strong fine granular structure; soft, friable, slightly sticky, slightly plastic; many very fine, many fine, many medium, many coarse, common very coarse roots throughout; many fine interstitial, few fine tubular, and few fine dendritic pores; five percent subrounded subdiscoidal cobbles, five percent stones, and five percent boulders; neutral (6.7 pH); gradual smooth boundary.

A2 – 12 to 30 centimeters, very dark grayish brown (10YR 3/2) gravelly sandy loam, brown (10YR 5/3) dry; moderate fine granular structure; slightly hard, friable, slightly sticky, slightly plastic; common very fine, many fine, common medium, many coarse, and many very coarse roots throughout; many fine interstitial pores; 20 percent subrounded, rounded, and well rounded gravel; neutral (6.7 pH); clear smooth boundary.

Bt – 30 to 60 centimeters, dark yellowish brown (10YR 4/4) gravelly sandy clay loam, brown (10YR 5/3) dry; weak medium subangular blocky structure; slightly hard, friable, slightly sticky, slightly plastic; common very fine, many fine, common medium, many coarse, and many very coarse roots throughout; many fine interstitial pores; 60 percent continuous distinct clay films on rock faces; 15 percent subrounded, rounded, and well rounded gravel and five percent cobbles; neutral (6.8 pH); clear smooth boundary.

BC – 60 to 91 centimeters, yellowish brown (10YR 5/4) very cobbly sandy loam, light yellowish brown (10YR 6/4) dry; weak fine subangular blocky structure; slightly hard, friable, slightly sticky, slightly plastic; few very fine roots and few medium roots throughout; many fine interstitial pores; 40 percent continuous distinct clay films on rock fragments; 20 percent subrounded, rounded, well rounded, prismoidal, subprismoidal, spherical, subdiscoidal, and discoidal gravel; 40 percent cobbles and 10 percent stones; neutral (6.8 pH); clear smooth boundary.

C1 – 91 to 129 centimeters, brown (10YR 4/3) very cobbly fine sand, very pale brown (10YR 7/4) dry; single grain structure; loose, loose, non-sticky, non-plastic; common medium and common coarse roots throughout; many fine and medium interstitial pores; 25 percent subrounded, rounded, well rounded, subprismoidal, spherical, and subdiscoidal gravel; 40 percent cobbles and 10 percent stones; neutral (7.0 pH); clear wavy boundary (8-13 centimeters).
**C2** – 129 to 152 centimeters, very dark grayish brown (10YR 3/2) very cobbly fine sand, dark yellowish brown (10YR 4/6) dry; single grain structure; loose, loose, non-sticky, non-plastic; many fine and medium interstitial pores; 40 percent subrounded, rounded, well rounded, subprismoidal, spherical, and subdiscoidal gravel; 10 percent cobbles, 10 percent stones, and 10 percent boulders; neutral (7.3 pH); refusal.
Soil Profile Description

Complex 2, Terrace 0

Oi – 10 to 0 centimeters, grass.

A – 0 to 11 centimeters, light olive brown (2.5Y 5/4) fine grained sand, light brownish gray (2.5Y 6/2) dry; single-grained structure; loose, loose, non-sticky, non-plastic; many very fine, many fine, many medium, many coarse, and many very coarse roots throughout; many fine and very fine interstitial pores; slightly acid (6.5); clear smooth boundary.

C – 11+ centimeters, subrounded boulders, refusal.
Soil Profile Description

Complex 2, Terrace 1

Oi – 2 to 0 centimeters, oak leaves, needles, and twigs.

A1 – 0 to 13 centimeters, very dark brown (10YR 2/2) cobbly sandy loam, brown (10YR 5/3) dry; weak fine granular structure; soft, very friable, slightly sticky, slightly plastic; few very fine, few fine, many medium, many coarse, many very coarse roots throughout; many fine interstitial, common fine and medium tubular, and few fine dendritic pores; 10 percent subrounded, rounded, and prismoidal gravel and 10 percent cobbles; slightly acid (6.4 pH); gradual smooth boundary.

A2 – 13 to 27 centimeters, very dark grayish brown (10YR 3/2) cobbly sandy loam, dark grayish brown (10YR 4/2) dry; weak fine granular structure; soft, very friable, slightly sticky, slightly plastic; few very fine, few fine, common medium, many coarse, and many very coarse roots throughout; many very fine and fine interstitial and common fine tubular pores; 10 percent subangular, subrounded, rounded, well rounded, prismoidal, subprismoidal, spherical, subdiscoidal, and discoidal gravel; 10 percent cobbles; slightly acid (6.4 pH); clear wavy boundary (five centimeters).

C – 27 to 152 centimeters, gravel; single grained structure; loose, loose, non-sticky, non-plastic; few medium and few coarse roots throughout; many fine and medium interstitial pores; 70 percent subangular, subrounded, rounded, well rounded, prismoidal, subprismoidal, subdiscoidal, and discoidal gravel and 20 cobbles.
Soil Profile Description

Complex 2, Terrace 2

Oi – 8 to 7 centimeters, oak leaves, needles, and twigs.

Oe – 7 to 0 centimeters, moderately decomposed leaves and needles; many coarse and some very coarse tubular pores; five to 10 percent subangular coarse gravel.

A1 – 0 to 7 centimeters, dark brown (10YR 3/2) sandy loam, grayish brown (10YR 5/2) dry; moderate medium granular structure; soft, very friable, slightly sticky, slightly plastic; common very fine, common fine, common medium, common coarse, and many very coarse roots throughout; common fine interstitial and common fine tubular pores; 10 percent rounded prismatic gravel and five percent cobbles; neutral (6.7 pH); clear smooth boundary.

A2 – 7 to 18 centimeters, dark brown (10YR 3/2) sandy loam, pale brown (10YR 5/3) dry; moderate medium granular structure; soft, very friable, slightly sticky, slightly plastic; few very fine, few fine, common medium, many coarse, and common very coarse roots throughout; many very fine interstitial and common fine tubular pores; 10 percent subangular, subrounded, subrounded and rounded, prismoidal gravel and five percent cobbles; neutral (6.8 pH); clear smooth boundary.

AB – 18 to 39 centimeters, dark brown (10YR 3/2) sandy clay loam, pale brown (10YR 6/3) dry; moderate medium subangular blocky structure; slightly hard, friable, slightly sticky, slightly plastic; many medium, many coarse, and common very coarse roots throughout; many fine interstitial and few fine dendritic pores; five percent discontinuous distinct clay films on vertical faces of peds and on surfaces along pores; 10 percent subrounded, rounded, and well rounded gravel and five percent cobbles (contact amongst coarse fragments); neutral (6.7 pH); clear wavy boundary (five centimeters).

Bt1 – 39 to 61 centimeters, brown (10YR 4/3) sandy clay loam, very pale brown (10YR 7/3) dry; moderate medium subangular blocky structure; moderately hard, friable, slightly sticky, slightly plastic; few very coarse roots (roots are rotten); common interstitial and common dendritic pores; 10 percent discontinuous distinct clay films on vertical faces of peds; 10 rounded prismoidal, subprismoidal, spherical, subdiscoidal, and discoidal gravel and five percent cobbles; neutral (6.8 pH); clear smooth boundary.

Bt2 – 61 to 126 centimeters, dark yellowish brown (10YR 4/4) very cobbly sandy clay loam, very pale brown (10YR 7/3) dry; strong medium subangular blocky
structure; moderately hard, friable, slightly sticky, slightly plastic; common coarse and common very coarse roots throughout (most roots are rotten); many fine interstitial pores and many very fine and fine dendritic pores; 20 percent discontinuous distinct clay films on vertical faces of peds; 50 percent rounded, prismoidal, subprismoidal, spherical, subdiscoidal, and discoidal cobbles and 20 percent stones (contact amongst rocks); neutral (6.8 pH); gradual wavy boundary (10-15 centimeters).

**C** – 126 to 152 centimeters, packed boulders, refusal.
Soil Profile Description

Complex 2, Terrace 3

Oi – 6 to 2 centimeters, oak leaves and needles.

Oe – 2 to 0 centimeters, moderately decomposed leaves and needles; five to 10 percent angular, subangular, spherical and subprismoidal cobbles.

A1 – 0 to 13 centimeters, dark brown (7.5YR 3/2) sandy clay loam, dark grayish brown (7.5YR 5/2) dry; moderate fine granular structure; slightly hard, friable, slightly sticky, slightly plastic; common very fine, many fine, many medium, many coarse, and many very coarse roots throughout and matted around rock fragments; many fine interstitial and common tubular pores; 10 percent angular, subangular, subrounded subdiscoidal gravel and five percent cobbles; neutral (6.6 pH); gradual smooth boundary.

A2 – 13 to 25 centimeters, dark gray (7.5YR 3/2) sandy clay loam, grayish brown (7.5YR 5/2) dry; moderate medium granular structure; slightly hard, friable, slightly sticky, slightly plastic; many very fine, many fine, common medium, many coarse, and many very coarse roots throughout; common very fine interstitial and common fine tubular pores; 15 percent well rounded discoidal gravel and five percent cobbles; neutral (6.8 pH); clear smooth boundary.

Bt1 – 25 to 39 centimeters, dark brown (7.5YR 3/3) very gravelly sandy clay loam, brown (7.5YR 5/3) dry; moderate medium subangular blocky structure; moderately hard, friable, slightly sticky, slightly plastic; few medium, few coarse, and many very coarse roots throughout and matted around rock fragments (many roots are brittle and have grown horizontal); common very fine interstitial pores; 25 percent continuous distinct clay films on rock fragments; 45 percent well rounded spherical gravel and 15 percent cobbles (contact amongst coarse fragments); neutral (6.9 pH); clear wavy boundary (five centimeters).

Bt2 – 39 to 69 centimeters, brown (7.5YR 4/4) very gravelly sandy clay loam, light brown (7.5YR 6/4) dry; moderate medium subangular blocky structure; moderately hard, friable, slightly sticky, slightly plastic; common very fine interstitial pores; 25 percent continuous distinct clay films on rock fragments; few, fine, prominent, light olive brown (2.5Y 5/6), iron masses, moist, spherical, in the matrix, non-cemented, sharp; 50 percent rounded and well rounded discoidal gravel, 10 percent cobbles, and 10 percent stones (contact amongst coarse fragments); neutral (7.0 pH); clear smooth boundary.

Bt3 – 69 to 147 centimeters, brown (7.5YR 4/4) very gravelly sandy clay loam, light brown (7.5YR 6/4) dry; moderate medium subangular blocky structure;
moderately hard, friable, slightly sticky, slightly plastic; many fine interstitial pores; 25 continuous distinct clay films on rock fragments; 25 percent continuous distinct sand coats on rock fragments; 50 percent rounded and well rounded discoidal gravel; 10 percent cobbles, 10 percent stones, and two percent boulders (contact amongst coarse fragments); neutral (7.0 pH); refusal.

**C** – 147+ centimeters, packed subrounded boulders.
Soil Profile Description

Complex 2, Terrace 4

Oi – 1 to 0 centimeters, oak leaves and twigs.

A – 0 to 12 centimeters, dark reddish brown (5YR 3/2) sandy loam, brown (7.5YR 4/3) dry; moderate medium subangular blocky structure; soft, friable, slightly sticky, slightly plastic; common very fine, common fine, many medium, many coarse, and many very coarse roots throughout; many fine interstitial and few tubular pores; five percent subrounded and rounded spherical gravel; neutral (6.9 pH); clear smooth boundary.

AB – 12 to 24 centimeters, dark reddish brown (5YR 3/3) sandy loam, brown (7.5YR 5/3) dry; moderate medium subangular blocky structure; slightly hard, friable, slightly sticky, slightly plastic; common very fine, common fine, many medium, many coarse, and many very coarse roots throughout; common very fine interstitial and common fine tubular pores; five percent patchy distinct clay films on rock fragments; five percent subrounded, rounded, well rounded spherical and subdiscoidal gravel; neutral (6.9 pH); clear smooth boundary.

Bt1 – 24 to 41 centimeters, reddish brown (5YR 3/3) sandy clay loam, brown (7.5YR 5/4) dry; moderate coarse subangular blocky structure; slightly hard, friable, slightly sticky, slightly plastic; many medium, many coarse, and many very coarse roots throughout; common very fine interstitial and fine dendritic pores; 10 percent discontinuous distinct clay films on rock fragments; 10 percent subrounded and rounded subprismoidal and spherical gravel and 10 percent cobbles (contact and long axis of most fragments are north-south); neutral (6.9 pH); clear wavy boundary (four centimeters).

Bt2 – 41 to 60 centimeters, reddish brown (5YR 4/4) extremely gravelly sandy clay loam, light brown (7.5YR 5/4) dry; moderate fine angular blocky structure; slightly hard, friable, moderately sticky, slightly plastic; few fine, many medium, common very coarse roots throughout; many very fine interstitial and few fine dendritic pores; 15 percent discontinuous distinct clay films on rock fragments; common, 1-2 percent patchy faint ferriargillans on rock fragments, dark reddish brown (5YR 3/4), moist, sharp; 60 percent subrounded and rounded subprismoidal and spherical gravel; neutral (7.0 pH); diffuse wavy boundary (15 centimeters).

Bt3 – 60 to 100 centimeters, reddish brown (5YR 4/4) extremely gravelly sandy clay loam, reddish brown (5YR 5/5) dry; moderate fine angular blocky structure; moderately hard, friable, moderately sticky, slightly plastic; common coarse and common very coarse roots throughout; many very fine interstitial pores and few
fine and medium dendritic pores; 15 percent discontinuous distinct clay films on rock fragments and on surfaces along pores; five percent patchy faint ferriargillans on rock fragments, dark red (2.5R 4/8), moist, sharp; 60 percent subrounded, rounded, and well rounded subprismoidal and spherical gravel and 15 percent cobbles; neutral (7.0 pH); gradual wavy boundary (nine centimeters).

**Bt4** – 100 to 137 centimeters, dark reddish brown (5YR 3/4) extremely gravelly sandy clay loam, yellowish red (5YR 4/6) dry; moderate fine angular structure; moderately hard, friable, moderately sticky, slightly plastic; common medium roots; many fine interstitial and few fine dendritic pores; 15 percent discontinuous distinct clay films on rock fragments; 1-2 percent discontinuous patchy faint ferriargillans on rock fragments, dark red (2.5R 3/6), moist, sharp and 1-2 percent patchy faint ferriargillans on pore faces, dark red (2.5R 3/6), moist, sharp; 60 percent rounded and well rounded subprismoidal, spherical, and subdiscoidal gravel and 15 percent cobbles; neutral (7.0 pH); clear distinct boundary.

**CB** – 137 to 155 centimeters, reddish brown (5YR 4/3) gravel, yellowish red (5YR 4/6) and light brown (7.5YR 6/4) dry; single grained structure; loose, loose, slightly sticky, non-plastic; many fine interstitial and few fine and medium dendritic pores; five percent discontinuous distinct clay films on rock fragments; 25 percent discontinuous distinct skeletons over clay coats on rock fragments; 70 percent subrounded, rounded, and well rounded subprismoidal, spherical and subdiscoidal gravel; 10 percent cobbles and 10 percent stones (contact, long axis of coarse fragments is north-south); refuse.

**Ct** – 155+ centimeters, subrounded boulders, refusal.
Soil Profile Description

Complex 3, Terrace 0

A1 – 0 to 10 centimeters, olive brown (2.5Y 4/4) loamy sand, grayish brown (2.5Y 5/2) dry; moderate very fine granular structure; soft, very friable, non-sticky, non-plastic; common very fine and common fine roots throughout; many fine interstitial pores; two percent subangular and subrounded subprismoidal and spherical gravel and three percent cobbles; slightly acid (6.5 pH); clear smooth boundary.

A2 – 10 to 36 centimeters, black (N 2.5) sandy clay loam, dark gray (2.5Y 4/1) dry; moderate fine granular structure; slightly hard, friable, moderately sticky, moderately plastic; many very coarse roots throughout; many fine interstitial pores; 15 percent subangular and subrounded subprismoidal and spherical gravel and five percent cobbles; neutral (6.7 pH); clear smooth boundary.

C – 36 to 51 centimeters, brown (10YR 3/2) extremely gravelly sandy clay loam, light brown (10YR 6/6) dry; loose, loose, non-sticky, non-plastic; 80 percent subangular, subrounded, and rounded spherical and subdisoidal gravel; five percent cobbles and 10 percent stones; refusal.
Soil Profile Description

Complex 3, Terrace 1

Oi – 14 to 10 centimeters, oak leaves, needles, and Oregon grape leaves.

Oe – 10 to 0 centimeters, moderately decomposed leaves and needles.

A1 – 0 to 14 centimeters, black (N 2.5) loam, black (2.5Y 2.5/1) dry; weak very fine granular structure; soft, very friable, slightly sticky, slightly plastic; many very fine, many fine, common medium, few coarse, and few very coarse roots throughout and matted around rock fragments; few fine interstitial and common fine and medium dendritic pores; 10 percent subangular and subrounded subprismoidal and spherical gravel and five percent cobbles; slightly acid (6.5 pH); gradual smooth boundary.

A2 – 14 to 82 centimeters, black (2.5Y 2.5/1) sandy loam, very dark gray (2.5Y 3/1) dry; moderate fine granular structure; soft, very friable, slightly sticky, slightly plastic; many fine, many medium, many coarse, common very coarse roots throughout; many fine interstitial and common dendritic pores; 15 percent rounded spherical and subdisoidal gravel and five percent cobbles; neutral (6.6 pH); clear wavy (2-5 centimeters).

C – 82 to 152 centimeters, very dark grayish brown (10YR 3/2) extremely gravelly sandy clay loam, brownish yellow (10YR 6/6) dry; single-grained structure; loose, loose, non-sticky, non-plastic; few medium roots throughout; many fine pores; 55 percent subrounded, rounded, and well rounded subprismoidal and spherical gravel; 15 percent cobbles, 15 percent stones, and five percent boulders (contact, coarse fragments are horizontal to surface); refusal.
Soil Profile Description

Complex 3, Terrace 2

Oi – 6 to 4 centimeters, oak leaves, needles, grasses, strawberry leaves, moss, and twigs.

Oe – 4 to 0 centimeters, moderately decomposed leaves and needles.

A – 0 to 12 centimeters, black (10YR 2/1) sandy clay loam, very dark grayish brown (10YR 3/2) dry; moderate fine granular structure; soft, very friable, slightly sticky, slightly plastic; many very fine, many fine, common medium, few coarse, and few very coarse throughout; many very fine interstitial and few fine tubular pores; 10 percent subrounded and rounded prismatic, subprismatic, spherical, subdiscoidal, and discoidal gravel; slightly acid (6.4 pH); gradual smooth boundary.

BA – 12 to 21 centimeters, dark brown (10YR 3/3) gravelly sandy clay loam, brown (10 YR 4/3) dry; weak fine subangular blocky structure; slightly hard, friable, moderately sticky, slightly plastic; many very fine, many fine, and common medium roots throughout; many very fine interstitial pores; five percent patchy faint clay films on rock fragments; 20 percent rounded prismatic, subprismatic, and spherical gravel and five percent cobbles; neutral (6.9 pH); clear smooth boundary.

Bt – 21 to 50 centimeters, dark brown (10YR 3/3) gravelly sandy clay loam, pale brown (10YR 6/3) dry; moderate fine subangular blocky structure; slightly hard, friable, slightly sticky, slightly plastic; many very fine, many fine, common medium, and few very coarse throughout; many very fine interstitial pores; 40 percent continuous distinct clay films on rock fragments; 20 percent rounded prismatic, subprismatic, and spherical gravel and five percent cobbles; neutral (6.9 pH); clear smooth boundary.

Ct1 – 50 to 100 centimeters, brown (10YR 4/3) extremely gravelly sandy clay loam, light yellowish brown (10YR 6/4) dry; single-grained structure; common fine and common medium roots throughout; many very fine interstitial pores; 50 percent continuous distinct clay films on rock fragments; 55 percent subrounded and rounded spherical and subdiscoidal gravel; 10 cobbles and 10 percent stones (contact amongst coarse fragments); gradual smooth boundary.

Ct2 – 100 to 152 centimeters, dark yellowish brown (10YR 3/6) extremely gravelly sandy clay loam, dark yellowish brown (10YR 4/6) dry; single-grained structure; common coarse and common very coarse roots throughout; many very fine interstitial pores; 50 percent continuous distinct clay film on rock fragments;
55 percent subrounded and rounded spherical and subdisoidal gravel; 10 percent cobbles and 10 percent stones; refusal.
Soil Profile Description

Complex 3, Terrace 3

Oi – 2 to 0 centimeters, oak leaves and woody debris.

A – 0 to 12 centimeters, dark brown (7.5YR 3/2) sandy clay loam, brown (7.5YR 5/3) dry; strong fine granular structure; soft, friable, moderately sticky, slightly plastic; many very fine, many fine, many medium, common coarse, and common very coarse roots throughout; many very fine and fine tubular pores; two percent subrounded and rounded subprismoidal and spherical gravel; neutral (6.6 pH); clear smooth boundary.

AB – 12 to 25 centimeters, dark brown (7.5YR 3/3) sandy clay, brown (7.5YR 4/3) dry; weak fine subangular blocky structure; soft, friable, moderately sticky, moderately plastic; many very fine, many fine, many medium, and few coarse roots throughout; many fine dendritic pores; five percent subrounded and rounded subprismoidal gravel; neutral (6.6 PH); gradual smooth boundary.

Bt1 – 25 to 46 centimeters, dark brown (7.5YR 3/4) gravelly sandy clay, brown (7.5YR 5/4) dry; moderate medium subangular blocky structure; slightly hard, friable, moderately sticky, slightly plastic; few very fine, common fine, many coarse, and common very coarse roots throughout; 40 percent discontinuous distinct clay films on rock fragments and five percent patchy distinct clay films on surfaces along pores; 30 percent subrounded and rounded subprismoidal gravel and 10 percent cobbles; neutral (6.8 pH); clear smooth boundary.

Bt2 – 46 to 65 centimeters, brown (7.5YR 4/4) gravelly sandy clay, brown (7.5YR 5/4) dry; moderate medium subangular blocky; slightly hard, friable, moderately sticky, slightly plastic; few very fine, many fine, many medium, many coarse, and few very coarse roots throughout; many very fine interstitial and few dendritic pores; 30 percent discontinuous distinct clay films on rock fragments and five percent patchy distinct clay films on surfaces along pores; 25 percent subrounded and rounded subprismoidal gravel and five percent cobbles (contact and poorly sorted); slightly acid (6.4 pH); gradual smooth boundary.

Bt3 – 65 to 83 centimeters, dark brown (7.5YR 3/2) gravelly sandy clay, reddish yellow (7.5YR 7/6) dry; weak fine subangular blocky structure; slightly hard, friable, slightly sticky, slightly plastic; few medium, few coarse, and few very coarse roots throughout (many rotten roots); many very fine interstitial pores; 30 percent discontinuous distinct clay films on rock fragments and 10 percent discontinuous distinct clay bridging; 50 percent subrounded and rounded subprismoidal, spherical, subdiscoidal, and discoidal gravel (contact and long
axis of many coarse fragments is north-south); neutral (6.8 pH); abrupt smooth boundary.

**Bt4** – 83 to 134 centimeters, dark brown (7.5YR 3/4) extremely gravelly sandy clay, reddish yellow (7.5YR 6/6) dry; weak fine subangular blocky structure; slightly hard, friable, slightly sticky, slightly plastic; few medium, few coarse, and few very coarse roots throughout; common very fine interstitial and few coarse tubular pores (krotovina, three centimeters); 10 percent faint patchy clay films on rock fragments; 10 percent clean sandy films over clay coats on rock fragments; 30 percent subrounded prismoidal, subprismoidal and discoidal gravel and 10 percent cobbles; neutral (7.0); clear smooth boundary.

**C** – 134 to 152 centimeters, unconsolidated river alluvium, alternating brown (7.5YR 4/3 and 7.5YR 4/4) gravel, alternating reddish yellow (7.5YR 6/6 and 7.5YR 7/6) dry; single-grained structure; many very fine interstitial pores; 70 percent subrounded, rounded, and well rounded prismoidal, subprismoidal, spherical, subdiscoidal, and discoidal gravel; five percent cobbles, five percent stones, and 10 percent boulders (contact); neutral (7.0 pH); refusal.
Soil Profile Description

Complex 4, Terrace 0

Oi – 14 to 4 centimeters, oak leaves and sedges.

Oe – 4 to 0 centimeters, moderately decomposed plant matter.

A – 0 to 8 centimeters, black (2.5Y 2.5/1) sandy clay, light gray (2.5Y 7/1) dry; single-grained structure; loose, loose, moderately sticky, very plastic; few very fine and common fine roots throughout; many very fine interstitial pores; five percent subrounded prismatic and subprismatic gravel and five percent cobbles; slightly acid (6.4 pH); clear smooth boundary.

Btg1 – 8 to 22 centimeters, light olive brown (2.5Y 5/3) sandy clay, light gray (2.5Y 7/2) dry; single-grained structure; loose, loose, moderately sticky, very plastic; common very fine and common fine roots throughout; 40 percent continuous prominent clay films on rock fragments and 10 percent patchy faint clay films on all faces of peds; few, medium, prominent, light yellowish brown (2.5Y 6/3), clay depletions, moist, irregular, throughout matrix, very friable, clear; few, medium, prominent, dark reddish brown (5YR 3/4) iron masses, moist, irregular, in matrix around depletions, very friable, sharp; 10 percent subrounded subprismatic and spherical gravel; neutral (6.7 pH); clear smooth boundary.

Btg2 – 22 to 31 centimeters, light olive brown (2.5Y 5/3) sandy clay, light brownish gray (2.5Y 6/2) dry; single-grained structure; loose, loose, moderately sticky, very plastic; 60 percent continuous prominent clay films on rock fragments and 10 percent patchy faint clay films on all faces of peds; few, medium, prominent, light yellowish brown (2.5Y 6/3), clay depletions, moist, irregular, throughout matrix, very friable, clear; common, medium, prominent, dark reddish brown (5YR 3/4) iron masses, moist, irregular, in matrix around depletions, very friable, sharp; two percent subrounded subprismatic gravel; neutral (6.9 pH); clear smooth boundary.

W – 32+ centimeters, water table, refusal.
Soil Profile Description

Complex 4, Terrace 2

Oi – 2 to 0 centimeters, oak leaves, moss, and twigs.

A1 – 0 to 8 centimeters, very dark brown (10YR 2/2) sandy loam, grayish brown (10YR 5/2) dry; strong medium granular structure; soft, friable, slightly sticky, slightly plastic; many very fine, many fine, common medium, many coarse, and many very coarse roots throughout; many very fine and fine interstitial, many fine and medium tubular, and many fine dendritic pores; two percent angular, subangular, subrounded, rounded, and well rounded spherical, subdiscoidal, and discoidal gravel and five percent cobbles; neutral (6.8 pH); gradual smooth boundary.

A2 – 8 to 20 centimeters, very dark grayish brown (10YR3/2) sandy loam, brown (10YR 5/3) dry; moderate fine subangular blocky structure; soft, friable, slightly sticky, slightly plastic; many very fine, many fine, common medium, many coarse, and many very coarse roots throughout and matted around rocks; common very fine and fine interstitial, many very fine and fine dendritic, and common medium and coarse tubular pores; 1-2 percent angular, subangular, subrounded, rounded, and well rounded spherical, subdiscoidal, and discoidal gravel and 10 percent cobbles; neutral (6.8 pH); gradual wavy boundary (10 centimeters).

AB – 20 to 31 centimeters, very dark brown (7.5YR 2.5/2) cobbly sandy clay loam, brown (7.5YR 5/2) dry; moderate medium subangular blocky structure; slightly hard, friable, slightly sticky, slightly plastic; many very fine, many fine, common medium, and common coarse roots throughout (organic matter, possible burned root area on the southern side of profile, 15-16 centimeters); many very fine and fine interstitial and common very fine and fine tubular pores; 1-2 percent rounded, well rounded prismoidal, subprismoidal, spherical, subdiscoidal, and discoidal gravel and 15 percent cobbles; neutral (6.8 pH); abrupt smooth boundary.

Bt – 31 to 56 centimeters, dark brown (7.5YR 3/3) very gravelly sandy clay loam, brown (7.5YR 5/3) dry; moderate medium subangular blocky; slightly hard, friable, slightly sticky, slightly plastic; common very fine, many fine, many medium, common coarse, and few very coarse roots throughout and matted around rocks; many very fine interstitial pores; 30 discontinuous distinct clay films on rock fragments; 35 percent rounded, well rounded prismoidal, subprismoidal, spherical, subdiscoidal, and discoidal gravel and 15 percent cobbles; slightly acid (6.5 pH); abrupt wavy boundary (one centimeter).
C – 56 to 152 centimeters, dark yellowish brown (10YR 3/4) extremely gravelly medium grained sand, light yellowish brown (2.5Y 6/3) dry; single-grained structure; few fine, common medium, common coarse, and very coarse roots throughout; many very fine interstitial and common coarse and very coarse dendritic pores; 60-70 percent rounded, well rounded prismoidal, subprismoidal, spherical, subdiscoidal, and discoidal gravel; 15 percent cobbles and five percent stones; refusal.
Soil Profile Description

Complex 4, Terrace 3

Oi – 2 to 0 centimeters, oak leaves.

A – 0 to 15 centimeters, very dark gray (7.5YR 3/1) sandy clay, brown (7.5YR 4/2) dry; moderate medium granular structure; soft, friable, moderately sticky, moderately plastic; common very fine, few fine, few medium, common coarse, and few very coarse roots throughout; many very fine interstitial and common fine tubular pores; five percent subrounded and rounded spherical and subdiscoidal gravel and five percent cobbles; neutral (6.8 pH); clear smooth boundary.

Bt1 – 15 to 26 centimeters, brown (7.5YR 4/2) gravelly sandy clay, brown (7.5YR 5/2) dry; moderate medium subangular blocky structure; slightly hard, friable, moderately sticky, moderately plastic; common very fine, common fine, many medium, many coarse, and common very coarse roots throughout; many very fine interstitial and few very fine and fine tubular pores; 10 percent discontinuous faint clay films on rock fragments; 20 percent subrounded, rounded, and well rounded subprismoidal gravel and five percent cobbles; neutral (6.9 pH); gradual smooth boundary.

Bt2 – 26 to 39 centimeters, dark reddish brown (5YR 3/2) gravelly sandy clay, brown (7.5YR 5/3) dry; moderate medium subangular blocky structure; moderately hard, friable, moderately sticky, slightly plastic; few very fine, common fine, many medium, many coarse, and common very coarse roots throughout; 20 percent discontinuous distinct clay films on rock fragments; 35 percent subrounded and rounded subprismoidal gravel; neutral (6.9 pH); clear smooth boundary.

Bt3 – 39 to 51 centimeters, dark reddish gray (5YR 4/2) extremely gravelly sandy clay, brown (7.5YR 5/4) dry; moderate medium subangular blocky; moderately hard, friable, moderately sticky, slightly plastic; few medium, many coarse, and many very coarse roots throughout; many very fine interstitial and few fine dendritic pores; 20 percent discontinuous faint clay films on rock fragments; 55 percent subrounded and rounded subprismoidal gravel and 15 percent cobbles; neutral (7.0 pH); gradual smooth boundary.

Bt4 – 51 to 82 centimeters, dark reddish gray (5YR 4/2) extremely gravelly sandy clay, light brown (7.5YR 6/3) dry; moderate medium subangular blocky structure; slightly hard, friable, moderately sticky, slightly plastic; common fine, common medium, many coarse, and common very coarse roots throughout; many very fine interstitial and common fine and medium dendritic pores; 25 percent
discontinuous distinct clay films on rock fragments; 5 percent continuous faint skeletons on rock fragments and 1-2 percent patchy faint skeletons on all faces of peds; smeary; 55 percent subrounded, rounded, and well rounded spherical, subdiscoidal, and discoidal gravel and 20 percent cobbles; neutral (7.0 pH); clear smooth boundary.

**CLdi** – 82 to 119 centimeters, dark reddish brown (5YR 3/3) gravel, light brown (7.5YR 6/4) dry; single-grained structure; loose, loose, moderately sticky, non-plastic; few very fine, few fine, few medium, many coarse, and few very coarse roots throughout; common very fine interstitial and common fine and medium dendritic pores; five percent continuous faint skeletons on rock fragments and 1-2 percent patchy faint skeletons on all faces of peds; few, patchy, faint, very pale brown (10YR 8/2), moist, diatomaceous on rock fragments, clear; moderately smeary; 60 percent subrounded, rounded, and well rounded discoidal gravel and 25 percent cobbles; very smooth boundary.

**Ldi1** – 119 to 157 centimeters, brown (7.5YR 5/2) very gravelly diatomite, very pale brown (10YR 7/3) dry; massive when wet, breaks into medium angular blocky structure when dry; moderately sticky, very plastic; smeary; few medium, common coarse, and few very coarse roots throughout; many very fine interstitial and common medium dendritic pores; 50 percent continuous distinct skeletons on rock fragments; common, discontinuous, distinct, very pale brown (10YR 8/2), moist, diatomaceous on rock fragments, clear; moderately smeary; 60 percent subrounded, rounded, and well rounded, spherical, discoidal, and subdiscoidal gravel and 10 percent cobbles; very smooth boundary.

**Ldi2** – 157 + centimeters, light grayish brown (10YR 6/2) diatomaceous, very pale brown (10YR 8/2) dry; massive when wet, breaks into a moderate angular blocky structure when dry; moderately hard, friable, moderately sticky, very plastic; common medium and few very coarse roots throughout; few medium and coarse dendritic pores; few, discontinuous, prominent, very coarse, black (2.5Y 2.5/1), moist, dendritic, root sheaths, throughout the matrix, sharp; strongly smeary; slightly acid (6.1 pH); refusal.
Soil Profile Description

Complex 4, Terrace 4

Oi – 1 to 0 centimeters, oak leaves and various grasses.

A – 0 to 10 centimeters, black (5YR 2.5/1) sandy clay loam, dark reddish gray (5YR 4/2) dry; moderate medium granular structure; soft, friable, moderately sticky, moderately plastic; many very fine, many fine, common medium, and common coarse roots throughout; many very fine interstitial and many fine tubular pores; five percent subangular, subrounded, and rounded spherical and subdiscoidal gravel; neutral (6.8 pH); gradual smooth boundary.

AB – 10 to 21 centimeters, dark reddish brown (5YR 3/2) sandy clay loam, reddish brown (5YR 4/3) dry; moderate medium granular structure; slightly hard, friable, moderately sticky, moderately plastic; common very fine, common fine, many medium, many coarse, and common very coarse roots throughout; many very fine interstitial and few very fine and fine tubular pores; 10 percent discontinuous faint clay films on rock fragments; 12 percent subrounded, rounded, and well rounded subprismatic and spherical gravel; neutral (6.8 PH); clear smooth boundary.

Bt1 – 21 to 39 centimeters, dark reddish gray (5YR 4/2) gravelly sandy clay loam, reddish brown (5YR 5/3) dry; moderate medium subangular structure; slightly hard, friable, moderately sticky, slightly plastic; common very fine, common fine, common medium, and few coarse roots throughout; 20 percent discontinuous distinct clay films on rock fragments; 30 percent subrounded and rounded subprismatic, spherical, and subdiscoidal gravel and five percent cobbles; neutral (6.9 pH); clear smooth boundary.

Bt2 – 39 to 91 centimeters, dark reddish brown (5YR 3/2) extremely gravelly sandy clay loam, reddish brown (5YR 5/4) dry; weak medium subangular blocky structure; slightly hard, friable, moderately sticky, slightly plastic; common very fine, common fine, and common medium roots throughout; common very fine interstitial pores; 15 percent patchy faint clay films on rock fragments; 60 percent subangular, subrounded, and rounded spherical and subdiscoidal gravel (contact, fine grained sand packed into interstitial areas); neutral (6.9 pH); clear smooth boundary.

C – 91 to 152 centimeters, dark reddish gray (5YR 3/2) gravel, reddish brown (5YR 5/4) dry; single grained structure; many fine and medium interstitial pores; 70 percent subrounded, rounded, well rounded spherical and subdiscoidal gravel and 10 percent cobbles, and 10 percent stones (contact, fine grained sand packed into interstitial areas); refusal.
Soil Profile Description

Complex 4, Terrace 5

Oi – 2 to 0 centimeters, oak leaves and various grasses.

A – 0 to 13 centimeters, black (5YR 2.5/1) sandy clay, dark reddish brown (5YR 4/2) dry; strong moderate subangular blocky structure; soft, friable, slightly sticky, very plastic; common very fine, common fine, many medium, many coarse, and common very coarse roots throughout; many very fine interstitial pores, few fine dendritic, and few very and fine tubular pores; two percent rounded spherical and subdiscoidal gravel; neutral (6.4 pH); clear smooth boundary.

AB – 13 to 27 centimeters, dark reddish brown (5YR 3/2) gravelly sandy clay, reddish brown (5YR 4/3) dry; strong moderate subangular blocky structure; slightly hard, friable, moderately sticky, very plastic; few very fine, common fine, common medium, many coarse, and common very coarse roots throughout; many very fine interstitial pores; 20 percent discontinuous distinct clay films on rock fragments; two percent subrounded and rounded spherical and subdiscoidal gravel; slightly acid (6.3 pH); clear smooth boundary.

Bt1 – 27 to 40 centimeters, dark reddish brown (5YR 3/2) gravelly sandy clay, reddish brown (5YR 4/4) dry; moderate medium subangular blocky structure; slightly hard, friable, moderately sticky, moderately plastic; few fine and few medium roots throughout; many very fine interstitial pores; 50 percent discontinuous distinct clay films on rock fragments; 35 percent subrounded and well rounded spherical and subdiscoidal gravel contact, long axis north-south); neutral (6.7 pH); abrupt smooth boundary.

Bt2 – 40 to 57 centimeters, dark reddish brown (5YR 3/3) very gravelly sandy clay, reddish brown (5YR 4/4) dry; moderate medium subangular blocky structure; slightly hard, friable, slightly sticky, slightly plastic; few fine and few medium roots throughout; many very fine interstitial pores; 50 percent discontinuous distinct clay films on rock fragments; 40 percent subrounded, rounded, and well rounded subprismoidal, spherical, and subdiscoidal gravel and 10 percent cobbles (contact, long axis north-south); neutral (6.8 pH); clear smooth boundary.

C – 57 to 106 centimeters, dark reddish brown (5YR 3/4) very cobbly fine sand, reddish brown (5YR 5/4) dry; single-grained structure; common medium, common coarse, and common very coarse roots throughout; many very fine interstitial pores; 35 percent subrounded, rounded, and well rounded subprismoidal, spherical, subdiscoidal, and discoidal gravel and 35 percent cobbles (contact); clear smooth boundary.
2C – 106 to 152 centimeters, few coarse and common very coarse roots throughout and matted around rock fragments; many coarse and very coarse interstitial and few medium and coarse dendritic pores; few, discontinuous, prominent, very coarse, black (2.5Y 2.5/1), moist, dendritic, root sheaths, throughout the matrix, clear; 30 percent subrounded, rounded, and well rounded spherical, subdiscoidal, and discoidal cobbles and 60 percent stones; refusal.
Soil Profile Description

Complex 5, Terrace 0

Oi – 5 to 0 centimeters, cat-tail and tule fragments, sedges, and various grasses.

A – 0 to 24 centimeters, very dark gray (2.5Y 3/1) sandy loam, gray (2.5Y 5/1) dry; single-grained structure; loose, loose, slightly sticky, non-plastic; common very fine, common fine, common medium, common coarse, and few very coarse roots throughout; many very fine interstitial pores; slight acid (6.4 pH); abrupt smooth boundary.

W – 24+ water table.
Soil Profile Description

Complex 5, Terrace 1

Oi – 2 to 0 centimeters, grass, oak leaves, and twigs.

A1 – 0 to 9 centimeters, black (10YR 2/1) sandy loam, dark gray (2.5Y 4/1) dry; weak fine granular structure; soft, very friable, slightly sticky, slightly plastic; many very fine, many fine, common medium, common coarse and common very coarse roots throughout; many very fine and fine interstitial and many fine tubular pores; 10 percent subangular, subrounded, rounded, and well rounded subprismatical, spherical, and subdiscoidal gravel; neutral (6.6 pH); clear smooth boundary.

A2 – 9 to 23 centimeters, black (10YR 2/1) sandy clay loam, brown (10YR 4/3) dry; moderate fine granular structure; soft, very friable, slightly sticky, slightly plastic; many very fine, many fine, common medium, common coarse, and common very coarse roots throughout; many very fine interstitial pores; 12 percent rounded and well rounded subprismatical, spherical, subdiscoidal, and discoidal gravel; neutral (6.9 pH); clear smooth boundary.

AB – 23 to 49 centimeters, black (10YR 2/1) sandy clay loam, gray (10YR 5/1) dry; moderate fine granular structure; soft, friable, slightly sticky, slightly plastic; few very fine, common fine, common medium, and common very coarse roots throughout; many very fine interstitial pores; 15 percent rounded and well rounded prismatical, subprismatical, spherical, subdiscoidal, and discoidal gravel; neutral (6.9 pH); clear irregular boundary (four centimeters).

Bt – 49 to 79 centimeters, brown (10YR 4/3) extremely gravelly sandy clay loam, grayish brown (10YR 5/2) dry; moderate medium subangular blocky structure; slightly hard, friable, moderately sticky, slightly plastic; common medium, common coarse, and few very coarse roots throughout; many very fine interstitial pores; 15 percent discontinuous distinct clay films on rock fragments; 60 percent rounded and well rounded subprismatical, spherical, subdiscoidal, and discoidal gravel; neutral (7.0 pH); clear smooth boundary.

C1 – 79 to 80 centimeters, dark yellowish brown (10YR 4/4) paragravel, grayish brown (10YR 5/2) dry; single-grained structure; very hard, very firm, non-sticky, non-plastic; common, fine, prominent, reddish brown (5YR 4/4) ironstone nodules, moist, spherical, in the matrix, strongly cemented, sharp; few, fine, prominent, black (N 2.5) manganese nodules, moist, in the matrix, moderately cemented, sharp; few, fine, distinct, light olive brown (2.5Y 4/4), clay depletions, moist, irregular, in the matrix, weakly cemented, sharp; 80 percent rounded and
well rounded prismoidal, subprismoidal and spherical fine grained and 10 percent medium gravel; very smooth boundary.

**C2** – 80 to 95 centimeters, brown (10YR 4/3) paragravel, yellowish brown (10YR 5/4) dry; single-grained structure; common, medium, prominent, reddish brown (5YR 4/4) ironstone nodules, moist, spherical, in the matrix, strongly cemented, sharp; few, fine, prominent, black (N 2.5) manganese nodules, moist, in the matrix, moderately cemented, sharp; few, fine, distinct, light olive brown (2.5Y 4/4), clay depletions, moist, irregular, in the matrix, weakly cemented, sharp; 80 percent rounded and well rounded prismoidal, subprismoidal and spherical gravel; very smooth boundary.

**C3** – 95 to 96 centimeters, dark yellowish brown (10YR 5/2) paragravel, grayish brown (10YR 5/2) dry; single-grained structure; very hard, very firm, non-sticky, non-plastic; common, fine, prominent, reddish brown (5YR 4/4) ironstone nodules, moist, spherical, in the matrix, strongly cemented, sharp; few, fine, prominent, black (N 2.5) manganese nodules, moist, in the matrix, moderately cemented, sharp; few, fine, distinct, light olive brown (2.5Y 4/4), clay depletions, moist, irregular, in the matrix, weakly cemented, sharp; 80 percent rounded and well rounded prismoidal, subprismoidal and spherical fine grained and 10 percent medium gravel; refusal.
Soil Profile Description

Complex 5, Terrace 2

A1 – 0 to 15 centimeters, black (10YR 2/1) sandy loam, dark gray (2.5Y 4/1) dry; weak fine granular structure; soft, very friable, slightly sticky, slightly plastic; many very fine, many fine, many medium, common coarse and common very coarse roots throughout; many very fine interstitial and common fine tubular pores; 15 percent angular, subangular, subrounded, and rounded subprismoidal, spherical, and subdiscoidal gravel and five percent cobbles; neutral (6.8 pH); gradual smooth boundary.

A2 – 15 to 36 centimeters, very dark brown (10YR 2/2) sandy loam, grayish brown (10YR 5/2) dry; weak fine subangular blocky structure; soft, very friable, slightly sticky, slightly plastic; few very fine, common fine, many medium, many coarse, and few very coarse roots throughout (heavily aggregated around roots); many very fine and fine interstitial pores; 20 percent angular, subangular, and subrounded subprismoidal, spherical, subdiscoidal, and discoidal gravel and five percent cobbles; neutral (6.8 pH); clear smooth boundary.

C – 36 to 125 centimeters, color alternates between dark yellowish brown and brown (10YR 4/3 and 10YR 4/4) gravel, grayish brown (10YR 5/2) dry; single-grained structure; few coarse and few very coarse roots throughout; many very fine interstitial pores; few, silt coats on rock fragment; 60 percent subrounded, rounded, and well rounded subprismoidal, spherical, subdiscoidal, and discoidal gravel, 10 percent cobbles, and 10 percent stones (contact, long axis of most coarse fragments is east-west); refusal.
Soil Profile Description

Complex 5, Terrace 3 2

Oi – 2 to 0 centimeters, needles and moss.

Charcoal – 0 to 1 centimeter, black (N 2.5) charcoal, black (N 2.5) dry; very abrupt smooth boundary.

A1 – 0 to 10 centimeters, dark reddish brown (5YR 3/2) gravelly sandy loam, pinkish gray (7.5YR 7/2) dry; moderate fine granular structure; slightly hard, friable, slightly sticky, slightly plastic; many very fine, many fine, common medium, common coarse, and few very coarse roots throughout; many very fine and fine interstitial pores; 30 percent subrounded, and rounded spherical, subdiscoidal, and discoidal gravel; neutral (6.8 pH); clear smooth boundary.

A2 – 10 to 24 centimeters, dark reddish brown (5YR 2.5/2) very gravelly sandy loam, brown (7.5YR 5/2) dry; weak fine granular structure; slightly hard, friable, slightly sticky, slightly plastic; many very fine, many fine, common medium, common coarse, and few very coarse roots throughout; many very fine interstitial pores; 50 percent subrounded, rounded, and well rounded subprismoidal, spherical, subdiscoidal, and discoidal gravel and 10 percent cobbles; neutral (6.8 pH); clear smooth boundary.

Bt1 – 24 to 57 dark reddish brown (5YR 3/2) very gravelly sandy clay, pinkish gray (7.5YR 6/2) dry; weak fine subangular blocky structure; moderately hard, friable, moderately sticky, moderately plastic; common medium, common coarse and common very coarse roots throughout; many very fine interstitial pores; 40 percent continuous distinct clay films on rock fragments; 50 percent subrounded, rounded, and well rounded prismatic, subprismatic, spherical, subdiscoidal, and discoidal gravel and 10 percent cobbles; neutral (6.8 pH); gradual smooth boundary.

Bt2 – 57 to 94 centimeters, dark reddish gray (5YR 4/2) very gravelly sandy clay loam, pinkish gray (7.5YR 7/2) dry; weak fine angular blocky structure; moderately hard, friable, moderately sticky, moderately plastic; common medium and common coarse roots throughout; many very fine interstitial and few fine dendritic pores; 40 percent continuous distinct clay films on rock fragments; 50 percent rounded and well rounded prismatic, subprismatic, spherical, subdiscoidal, and discoidal gravel and 10 percent cobbles; neutral (6.7 pH); gradual smooth boundary.
**BLdi** – 94 to 114 centimeters, dark reddish gray (7.5YR 4/2) extremely gravelly sandy clay with diatomite, pinkish white (7.5YR 8/2) dry; single grained; slightly hard, friable, moderately sticky, moderately plastic; common coarse and common very coarse roots throughout; common interstitial and few dendritic pores; 20 percent continuous prominent clay films on rock fragments; few, continuous, distinct, very pale brown and white (10YR 7/3 and 10YR 8/1), moist, diatomaceous on rock fragments, clear; few, faint, skeletons on rock fragments; 65 percent rounded and well rounded prismoidal, subprismoidal, spherical, subdiscoidal, and discoidal gravel; 10 percent cobbles and 10 percent stones; slightly acid (6.4 pH); clear smooth boundary.

**LDi1** – 114 to 130 centimeters, brown (10YR 5/3) gravelly diatomite, very pale brown (10YR 7/3) dry; weak fine angular blocky structure; slightly hard, friable, very sticky, very plastic; 10 percent patchy faint clay films on rock fragments; 15 percent continuous distinct skeletons on rock fragments; common, discontinuous, distinct, very pale brown and white (10YR 7/3 and 10YR 8/1), moist, diatomaceous on rock fragments, clear; moderately smeary; 15 percent sand on rock fragments; 35 percent rounded and well rounded prismoidal, subprismoidal, spherical, subdiscoidal, and discoidal gravel; slightly acid (6.4 pH); very abrupt smooth boundary.

**LDi2** – 130 + centimeters, light brownish gray (10YR 6/2) diatomite, white (10YR 8/1) dry; massive; moderately hard, very friable, very sticky, very plastic; strongly smeary; 10 percent rounded and well rounded spherical cobbles and 10 percent stones; slightly acid (6.3 pH); refusal.
Appendix C. Profile Calculations
### Complex 1, Terrace 1

| Horizon | Horizon Thickness | pH | Norm pH | Rubification | Horizon | Texture | Texture Calc | Dry Consistence | Dry Calc | Moist Consistence | Moist Calc | clay films | Sum | HDI | Horizon Products | PKI | total depth | Profile thickness
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### Complex 2, Terrace 1

| Horizon | Horizon Thickness | pH | Norm pH | Rubification | Horizon | Texture | Texture Calc | Dry Consistence | Dry Calc | Moist Consistence | Moist Calc | clay films | Sum | HDI | Horizon Products | PKI | total depth | Profile thickness
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### Complex 2, Terrace 1

| Horizon | Horizon Thickness | pH | Norm pH | Rubification | Horizon | Texture | Texture Calc | Dry Consistence | Dry Calc | Moist Consistence | Moist Calc | clay films | Sum | HDI | Horizon Products | PKI | total depth | Profile thickness
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Complex 5, Terrace 1

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Complex 5, Terrace 3 2