Soil Investigation
for
Lees Ferry
Grand Canyon, Arizona

prepared for

U.S. Bureau of Reclamation

Glen Canyon Environmental Studies

September 27, 1995

by

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CONSULTING EARTH SCIENTISTS
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SUBJECT TO REVISION

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Introduction:

Field soil mapping on Quaternary geologic deposits has been completed in the Lees Ferry area. This work is part of the Glen Canyon Environmental Studies project, funded by the U.S. Bureau of Reclamation. This report is a portion of a larger study of geomorphology of the Grand Canyon, lead by Dr. Ivo Lucchitta, Western Regional Geology, U.S. Geological Survey. Lees Ferry along with only a few other downstream sites were chosen because of relatively rare occurrences of preserved or relict alluvium that is present adjacent to the river. Study of relative soil development on various alluvial surfaces aids in understanding the long-term behavior of a river system.

This area is the last of four areas studied. The other areas include Nankoweap, Palisades - Unkar (the largest area) and Granite Park. Each area has its own particular geology, but Quaternary alluvial units found in each are remarkably similar with regard to relative soil development, where clay and secondary carbonate accumulations become greater with increasing elevation and distance from the main stem of the river. Because of knowledge gained in the other areas, less description in this area was undertaken. Enough description was undertake to sort out the geomorphology and correlate mapping areas.

Environmental Setting:

Lees Ferry is situated just above the confluence of the Paria and the Colorado Rivers. Just upstream on the main stem from this confluence is "river mile zero", the "put-in" for boating through Grand Canyon National Park. There are many historical buildings and artifacts associated with this site. Several old abandoned building remain from days when the ferry operated, prior to construction of Navajo Bridge in 1928, approximately 4.3 miles downstream. Engine parts from an old steam ship are strewn about just upstream from the put-in. Currently several large automobile parking facilities are present at the confluence of the drains, along with active administrative and maintenance buildings.

Portions of the Lonely Dell Ranch just above the Paria - Colorado junction are idle now but abandoned hay fields are obvious from the border check irrigation berms still in tact. Irrigation piping and dysfunctional pump apparatus presently resides on the shore of the Paria, about 2 - 3 km north of the existing ranch house. The National Park Service currently is care taking the old ranch site. The ranch site has a prehistoric signature as well. Paleo-Indians occupied the sandy alluvial platform, now well above the present-day occasionally flooded terrace. Anasazi pottery chards are reported in an area that is currently under cultivation as an orchard. This terrace continues to provide a resource for agriculture at Lees Ferry as it has done here and in other parts of the Canyon (and the Southwest) for over the past several

thousand years.

Several park service residential buildings, administrative offices, a large water tower, and numerous camp sites are active on higher terraces. Alluvial terraces in the Lees Ferry locale are in a highly disturbed state, from road excavations, gravel quarrying, and what appears to be exploration, perhaps some form of assay work to prove up gravel deposits (?). Many abandon dirt roads and large pits are distributed across the landscape.

Vegetation along the occasionally flooded zone is mainly tamarisk and arrowweed, with some willow. Mesquite resides on the archeological platform, except on the ranch, where it was likely cleared. Desert flora resides above the archeological platform in the way of Prickly pear, Mormon tea, and Beaver tail. The highest terraces support Black bursh.

Procedures:

The area is accessible by automobile, and a field office and lodging quarters were established at Marble Canyon. Field work was conducted by Ivo Lucchitta and Sid Davis in September of 1994. Escarpments and existing excavations were utilized where possible to expose and describe soils on the terraces above the active flood plain. Standards of the National Cooperative Soil Survey were utilized to describe and interpret soils. Samples of selected pedons were collected and sent to the University of California, Davis for analyses of particle size distribution, total carbonate, iron and aluminum, by Dr. Randy Southard. Mr. Tim Burchett, archeologist with the Glen Canyon National Recreation Area, met and discussed sensitive sites in the area and showed us around the Lonely Dell Ranch.

Field mapping was accomplished with aerial photography and a topographic map of scale 2 cm = 100 M (1:5000).

Findings:

HOLOCENE DEPOSITS

Similarities among the areas are most common to the Holocene soils, the youngest and closest to the river. Elapse time has been short on the young deposits, which restricts the amount of time necessary to accumulate illuviated clay and secondary carbonate. Therefore, the frequently flooded and occasionally flooded zones vary only in terms of relative amounts of coarse fragments - a function of velocity of deposition. Slack water areas on frequently flooded shores often support jurisdictional wetlands usually as a function of finer texture gained from a quiet water depositional regime. Shores subject to faster current typically receive coarse sand, gravel, stones and boulders.

Modern sand beaches, some free of stones (Unit 100) and sandy stony areas (Unit 101) are prevalent in the most active channel, the fluctuating flow zone. These are moderately deep to deep coarse textured soils with little vegetation. Above the fluctuating flow zone soils are similar but less influenced by water and facultative hydrophytic vegetation of tamarisk (Tamarix chinensis) and arrowweed (Tessaria sericea) are encroaching into areas which historically would have gotten scoured out by flooding. These are occupying Units 107, 108 and 109.

A fairly large area of shallow saturated soils (Unit 104) resides about 500 meters down stream from the put-in, on river right. This area supports juncus, sp. carex, sp. and bermuda grass, with gleyed soils (hydric) and is a jurisdictional wetland. Three pair of Mallard ducks, and a Blue herron were utilizing this emergent marsh at the time of study.

ARCHEOLOCIAL PLATFORM

The most extensive farming terrace resides at the confluence of the Paria and Colorado Rivers (Unit 110). The Lonely Dell Ranch spreads across most of it on Paria River right, and a parking facility covers a good portion of it between the two rivers. Pedon 94002 defines this unit which was taken from an escarpment adjacent to an abandon hay field along the Paria River. It show multiple aggradational events, fining upward from loamy sand to loam, nearly free of gravel, in several discrete packages. These soils are very much the same as what is seen downstream at Nankoweap, Comanche / Espejo, Cardenas, Unkar and Granite Park on the same geomorphic terrace, Level 3. A buried surface at about 25 cm contains charcoal and shows accumulations of segregated lime as filament (Stage I). These are Class II soils (U.S.D.A. Soil Conservation Service), suitable for nearly any cultivated crop, if irrigation water is available (which is). Mr. Burchett reported that the existing orchard of pear, plum and peach was planted some time in the 1930's. The trees are still producing reasonably well.

PLEISTOCENE TERRACES

Similarities are also seen on older, higher elevation alluvium between areas. Just above the archeological platform soil become very gravelly or very stony, exhibit more clay in the subsoil, are redder in color, and contain more secondary carbonate - Stage II. Pedon 94003 and 94004 are examples of Units 114. These are Typic Haplocalcids. Debris flow mantle river gravel in places, and tend to be slightly heavier textured. These are shown Unit 115 and classify as Haplargids. These soils correlate to the Level 4 terraces at Comanche or Unkar, in the 20 to 30 ka range.

Out in an area where there has been considerable disturbance from machinery a Stage III carbonate soil resides (Pedon 94005) at about elevation 1035 (90 meters above the river). These soils classify as Typic Haplocalcids, similar to Unit 114, but

both clay content and total carbonate exceed the lower elevation soils, a sign of longer exposure to the weathering regime. These soils correlate with ones at Ochoa point and the highest terrace levels mapped at Comanche and Espejo, likely in the 85 to 120 ka range.

The oldest terrace at Lees Ferry, resides at Johnson's Point, at 188 M above the river. It is exposed in an escarpment near the edge of the bluff as a pediment cut on the Shinarump formation. This soils has achieved advanced Stage IV carbonate morphology, and is interpreted to be an eroded Stage V. The age is uncertain, paleomagnetic information is pending. Similar soils at Granite Park are approximately 525 ka.

Frequently and Occasionally Flooded Units

100 **Modern Beaches, frequently flooded.** These deep and somewhat poorly drained sandy soils reside immediately adjacent to the active river channel. Because the river flow fluctuates from dam releases, these materials are in constant transition. As a result, little vegetation flourishes other than patchy hydrophytic species. Being near the river and because the entire profile is subject to irregular inundation, temperature (at 50 cm depth) is estimated to be more moderate than just a few feet away, and the regime is considered to be Mesic. These areas are highly desirable for recreation, good for landing boats with smooth access to higher ground. This unit is broadly defined as Sandy, mixed, mesic, Oxyaquic Udifluvents.

101 **Stony or Bouldery Beaches, frequently flooded.** This unit is essentially the same as 100, except it is dominated by cobblestones, stones and boulders, typical of high energy deposition. These soils are deep and irregularly subject to inundation, from storm runoff and dam releases. These areas are less desirable for recreational purposes due to surface roughness. Vegetation is transitional, because of fluctuating river flow, but hydrophytic plant species invade intermittently. These soils are broadly defined as Sandy-skeletal, mixed, mesic, Oxyaquic Udiflufents.

102 **Loamy Alluvium, frequently flooded.** These are deep and somewhat poorly drained soils of medium texture. They typically support hydrophytic vegetation, as water holding capacity is greater than the sandier units (100 and 101). These are commonly associated with backwater eddies, where finer grained material coalesce as a result of quiet water deposition. They are not a common feature, or extensively mapped along the active flood plain. These are defined as Loamy, mixed, mesic, Oxyaquic Udifluvents.

103 **Active Washes, frequently flooded.** These are coarse grained and stony soils, varying in depths from only a few centimeters to over a meter in thickness, associated with the active side canyon creeks and ephemeral drainage channels. The drainage

features typically are void of vegetation and only run water during high intensity storms, or for a relatively short duration at Spring snow melt. At anytime during intense thunder storms these drainages can flash flood, capable of delivering debris flows to their mouth. These are defined as Loamy-skeletal, mixed, hyperthermic, Torriorthents.

104 **Wetlands and Emergent Marshes.** These soils are moderately deep to deep and somewhat poorly drained, supporting obligate and facultative hydrophytic vegetation. They are medium to fine textured, associated with near shore back eddy or return current hydrology environments, or depressional features that receive overbank flooding as a result of fluctuating river flows. Marshes are nearly level with slightly concave topography. They can be characterized as having a thick brown or strong brown clay loam (near clay) topsoil to 30 cm, over a mottled dark brown reduced (redoximorphic depletions) and saturated clay loam subsoil. Typical vegetation includes cattail (Typha, sp.) and bullrush (Eleocharis, sp.) near the center of the unit, and around the perimeter, vegetation of willow (Salix, sp.), sedge (Carex, sp.) and horsetail (Equisetum, sp.) occupy the transition zone to upland terrain. These areas provide high value habitat for vertebrates, such as beaver, and a wide variety of migratory and resident waterfowl. Because they display a dominance of hydrophytic vegetation, hydric soils, and are inundated on a regular interval, they qualify as Jurisdictional Wetlands, as regulated under Section 404 of the Clean Water Act. These soils classify as Fine-loamy, mixed, mesic, Typic Endoaquepts.

105 **Terrace Escarpments, very steep and transitional.** These are shallow very gravelly textured materials comprised of colluvium (scree slopes) from eroding, higher elevation alluvial deposits. They typically support little, if any, vegetation and mantle bedrock. They may carry from high cliffs down into the water, but generally they reside above flood level.

106 **Sand Dunes.** These are shallow to very deep eolian derived soils that mantle gravel bars on occasionally flooded terraces, and low terraces just above the 100 year flood plan. They also represent climbing or falling sand sheets, where prevailing wind velocity slackens. They form downwind of fresh alluvial sand deposits in and along the active river channel. Dunes within the 100 year flood plain exhibit sparse vegetation, but are being invaded by expanding riparian growth. Above the 100 year flood plain, on geomorphic Level 3, dunes are somewhat more stabilized by vegetation, such as Mesquite (Prosopis, sp.) and cheat grass (Bromus tectorum). Available water holding capacity is low, permeability is very rapid, and water erosion is negligible. Although these areas are gaining material, they are susceptible to destabilization by forces of wind, sand blasting and winnowing.

107 **Very Gravelly Alluvium, occasionally flooded.** These soils are moderately deep to deep, composed of extremely coarse grained materials, and occupy a position immediately adjacent to active washes. They are well or somewhat excessively drained. Water holding capacity is low. They are susceptible to intermittent flooding,

scour and redeposition as a result of periodic flash floods, or stream realignment at peak flow. Stones and boulders comprise up to 40 percent of the matrix, gravels approximately 50 percent, with the balance less than 2mm size. Of the fine earth fraction, nearly half is silt and clay (Moenkopi materials ?). Because they are transitional in nature, and very young, these soils have acquired few diagnostic features, and they support little in the way of vegetation, other than a few scattered pioneering annual species. These soils classify as Loamy-skeletal, mixed, hyperthermic, Typic Torriorthents.

108 **Loamy Alluvial Land, occasionally flooded.** These soils are typically deep and and well or moderately well drained, and commonly support facultative hydrophytic species of arrow weed, tamarisk, willow and horse tail. Available water holding capacity is moderate and this is reflective of the vegetation it supports, in that the vegetation canopy is generally thicker than coarser grained soils found at similar geomorphic position. Volunteer maize (milo ?) is flourishing in concave topography on this unit. These soils classify as Fine-loamy, mixed, hyperthermic, Oxyaquic Torrifluvents.

109 **Stony or Bouldery Shores and Bars, occasionally flooded.** These are deep and moderately well drained soils that occupy the majority of the occasionally flooded portion of the mapping area. They are very stony and typically have a fluctuating water table that in places can reach to with 50 cm of the natural ground surface. These soils support mostly hydrophytic vegetation, tamarisk, willow and arrow weed; much of the younger riparian vegetation along the river corridor resides here. Old drift wood lines commonly define the upper boundary of this unit, which is coincidentally at the toe of the mesquite vegetation line. This soil classifies as Sandy-skeletal, mixed, hyperthermic, Oxyaquic Ustifluvents).

Archeological Platform - Soils developed on Holocene materials above the active flood plain.

At the time of paleoindian occupation, the River system was aggrading, as evidenced by buried soils (charcoal layers supported by ^{14}C dates) and habitation sites containing artifacts - tools and pottery chards. Since about 1650 AD the River has downcut approximately 5 meters.

110 **Lands of High Agricultural Potential.** These soils are deep or very deep and well to somewhat excessively drained, with moderately high to high saturated hydraulic conductivity. They are composed mainly of stratified very fine sand, fine sand and loamy fine sand with surface slopes in the 0 to 2 percent range, above the active flood plain. This unit hosts a high number of archeological sites in this reach of the Canyon, and has high agricultural potential (U.S.D.A. Class II), except where excess salts have accumulated.

Areas immediately downstream from major creeks and washes along the main stem tend to be slightly finer textured than soils more distant, within this

unit. Secondary carbonate in the way of soft masses, thin filaments or threads are present in the near surface subsoils (Stage I carbonate development). Loamy textured areas of the 110 unit supports mesquite. The unit is typically well vegetated with a wide variety of annuals and perennials, including filaree (Erodium, sp.), prickly pear (Opuntia, polyacantha), beaver tail (O. basilaris), fourwing salt bush (Atriplex canescens), and cheat grass (Bromus tectorum). Soils of this unit are represented as a complex of Loamy, mixed, hyperthermic, Typic Haplocalcids (or Haplocambids) and Sandy, mixed, hyperthermic, Typic Torriorthents.

111 **Very Stony Debris Flow Land.** These soils are typically very deep, very stony and gravelly, with moderate amounts of silt and clay in the fine earth fraction (< 2mm), mainly derived from the Moenkopi or Chinle materials. They form at surface level three, above the active flood plain, adjacent to the active washes, on alluvial fan deposits. They nest with the archeological platform (Units 110, and 113) near the mouths of the drains and side canyons.

Discrete packages of debris flows, marked by highly contrasting textural differences (mostly gravel / stone sizes) across abrupt smooth boundaries are visible in vertical walls of the fans cut by active drains. Secondary carbonate development as fine soft masses (Stage I) is evident in the 50 to 100 cm depth range, similar to what is seen in other units associated with this geomorphic surface.

These units are generally too stony to advance sustainable agriculture. Mesquite grows where eolian materials bury the unit, otherwise vegetation is sparser than other soils in this stratigraphic position, because of low available water holding capacity due to high coarse fragment content. Other plants include Prickly pear, Beaver tail and Mormon tea. These soils classify as Loamy-skeletal, mixed, hyperthermic, Typic Haplocalcids.

113 **Stratified Alluvial Lands of Low Agricultural Potential.** These soils are very deep, excessively drained and consist of stratified sandy alluvium, eolian sand and colluvial gravel. These soils have less water holding capacity than the 110 unit, but if intensively managed can sustain crops of corn, beans, cotton or squash under an irrigation regime (U.S.D.A Class III). These soils have a relatively smooth surface, in the 2 to 5 percent slope range. There are inclusions of Unit 106 within Unit 113, which is defined as a complex of Haplocalcids - Torripsamments - Haplocambids.

Soils on Pleistocene Age and Older Alluvium

Surfaces above, or at higher elevation than the archeological platform display more soil development contain more clay and are rich in secondary carbonate. These surfaces have developed desert pavement and varnish which intensifies with elevation and increasing age.

The depositional processes of these older surfaces is similar to conditions found on the archeological platform, in that fluvial deposits become buried by debris flow deposits, complicated by eolian contributions. Profiles are often laminated and alternate with depth between stratified debris flow / eolian / fluvial facies. As

opposed to the Holocene deposits, which are composed dominantly of sand along the main stem of the Colorado River, Pleistocene surfaces are either very stony or very gravelly and are being subjected to accelerated erosion from both wind and water action while at the same time gaining secondary carbonate from calcareous-rich dust, brought by wind and rainwater. Secondary carbonate content on these Pleistocene surfaces increase from Stage II to a maximum of Stage IV, as defined by the Desert Project (Gile and others, 1981), later modified by Machette (1985). Stage II carbonate development is described where small diameter lime concretions form in the subsoil matrix and begin to line the under sides of gravels. Stage III is defined by essentially continuous dispersion of lime in the subsoil, with large concretions, becoming weakly cemented in advanced development . Stage IV carbonate soil development is defined by setting of a calcrete with a laminar and platy cap, restricting root penetration and downward movement of water. Soils remain open and permeable up until secondary carbonate content overwhelms the subsoil and cements (caliche), and then permeability slows causing surface runoff to increase. This tears the landform down into what is described as "ridge-ravine" topography (Bull, 1991). Some older deposits have eroded to essentially lag gravels showing reformation of secondary carbonate development in the subsoil of Stage II.

Geochronology, or age dating techniques by analysis of ^{10}Be - ^{26}Al (Caffee and Finkel, this study) of surface gravels and boulders of the older surfaces generally places Stage II carbonate development in the range of 20 to 30 ka years before present. Stage III carbonate development ranges from 85 to 130 ka years before present. Ages of surfaces where soils have attained Stage IV carbonate development produce younger age dates, even though stratigraphically they are at a relatively higher (older) position. This is attributed to accelerated erosion, where the surfaces are tearing down, and materials from depth are arriving at the surface, which has the effect of resetting the time of exposure of near surface gravels to cosmogenic bombardment. The soils and geomorphic position document the relative ages - geochronology methodology appears to work well up until the subsoil permeability shuts down and the surfaces begin to disintegrate.

114 Gravelly Alluvium. These soils can be described as deep, very coarse grained, moderately developed with moderately rapid permeability. They typically display desert pavement (without varnish) and are very stony. Surfaces are typically thin (3 to 5 mm) very or extremely stony brown loam, underlain abruptly by reddish brown to dark red very gravelly or stony sandy loam, with 1 to 2 mm secondary carbonate rinds lining the undersides of gravels or as soft masses in the matrix (Stage II carbonate development) to a depth of about 75 cm. Carbonates decrease, and the matrix becomes sandier to approximately 1 meter depth. Surface slopes are in the 8 to 15 percent range, and runoff is medium. There are small inclusions of Unit 115 in this mapping unit, where finer textured debris flows dominate the profile. These soils support Mormon tea, brittle bush, prickly pear and beaver tail. They classify as Loamy-skeletal, mixed, hyperthermic, Typic Haplocalcids.

115 Very Stony Alluvial Land. These soils have developed from debris flow

materials, rather than from river gravels. They display desert pavement and a thin very stony loam, topsoil, underlain by very stony sandy loam (near sandy clay loam), with 1 to 2 mm secondary carbonate rinds lining the bottoms of gravels and stones at depth between 10 to 50 cm. These soils are moderately permeable with medium runoff and slopes in the 6 to 15 percent range. There minor inclusions of Unit 114 where river gravels dominate the profile. This soil supports Mormon tea, brittle bush, prickly pear and four wing salt bush. Slopes range from nearly level to 7 percent. Soils classify as Loamy-skeletal, mixed, hyperthermic, Typic Haplargids.

116 **Very Gravelly Fan-Terraces.** These soils are deep, well drained and highly eroded, developed from stratified debris flow / eolian / alluvial gravel. They can be characterized as having an exposed subsoil, with desert pavement and varnish, usually with high amounts of secondary carbonate concretion scatter intermixed in the pavement. Textures are coarse throughout (very gravelly sandy loam) with gravel content (including lime concretions) in the range of 50 to 70 percent. Concretions in the upper 40 cm may be many and of large diameter, and the calcic horizons becomes weakly to moderately cemented below, to at least 1.0 meter depth. This soil is of Stage III carbonate development. It is slowly permeable, and runoff is very high. Slopes are in the 8 to 15 percent range. These soils support a very sparse vegetation cover of brittlebush (Encelia farinosa), prickly pear, beaver tail, and perennial grasses. These soils classify as Loamy-skeletal, mixed, hyperthermic, Haplocalcids.

Representative Soil Profiles

94001
9/24/94
Johnson Point - High terrace (off map).
Stop No. 1

Av 0 to 3 cm, reddish brown (5YR 5/4) extremely gravelly loam, dark reddish brown (5YR 3/4) when moist; moderate medium platy structure; common very fine with few fine roots; many very fine and fine tubular pores; Stage II; 80 percent gravel; clear smooth boundary.

Btk 3 to 18 cm, light reddish brown (2.5YR 6/4) very gravelly clay, dark red 2.5YR 3/6) when moist; strong coarse angular blocky structure; slightly hard, very friable, slightly sticky and slightly plastic; few very fine and fine roots; common very fine and fine interstitial pores; common thin clay films occur on ped faces; many large lime concretions; Stage III carbonate; 40 percent gravel; clear smooth boundary.

Bkm1 18 to 97 cm, light reddish brown (2.5YR 6/4) reddish brown (2.5YR 5/4)

when moist; strong coarse platy structure; very hard, very firm; Stage IV calcrete; 40 percent gravel; gradual wavy boundary.

Bkm2 97 to 132 cm, variegated pink (5YR 6/4) and reddish brown (2.5YR 5/4), mottles of light reddish brown (2.5YR 6/4) and dark yellowish brown (10YR 3/6); massive; hard, firm, brittle; Stage III carbonate; 40 percent gravel.

Notes:
Surface is eroded substantially out on the edge. It is calculated that approximately 43 cm of the original surface is missing at the upper edge of the escarpment. The profile description was pieced together by evaluating the eroded subsoil on the escarpment and then moving to the more stabilized center of the deposit, just to the north of the escarpment for the representative upper portion. This appears to be an eroded Stage V calcrete soil.

Classification: Clayey, kaolinitic (?), hyperthermic, Shallow Argic Petrocalcid
Hydrologic Group: D
Permeability: Very slow
Runoff: Very rapid
Vegetation: Black brush

94002
9/26/94 (Lonely Dell Ranch) - archeological platform
Stop No. 1

Ap 0 to 10 cm, light brownish gray (10YR 6/2) loam, dark grayish brown (10YR 4/2) when moist; moderate medium angular blocky structure; hard, friable, slightly sticky and slightly plastic; many fine and medium with common coarse roots; many medium and coarse interstitial pores; clear smooth boundary.

Cp 10 to 23 cm, pale brown (10YR 6/3) loam, brown (10YR 4/3) when moist; strong medium angular blocky structure; hard, friable, slightly sticky and slightly plastic; common fine and medium with few coarse roots; common fine and medium tubular pores, with common medium interstitial pores; clear smooth boundary.

2Ab 23 to 36 cm, light brownish gray (10YR 6/2) silty clay loam, dark grayish brown (10YR 4/2) when moist; moderate medium subangular blocky structure; hard, friable, slightly sticky and slightly plastic; many fine and medium roots; common fine and medium tubular and interstitial pores; common lime occurs in filaments or threads; charcoal flecks; gradual smooth boundary.

2C 36 to 58 cm, light brown (7.5YR 6/4) fine sand, brown (7.5YR 4/4) when moist; single grain; soft, loose, nonsticky and nonplastic; many fine and medium roots; many very fine and fine interstitial pores; abrupt smooth boundary.

3Ab 58 to 66 cm, light brown (7.5YR 6/4) loam, brown (7.5YR 3/4) when moist; moderate fine subangular blocky structure; hard, friable, nonsticky and nonplastic; common fine and medium roots; common very fine and

fine interstitial and tubular pores; abrupt smooth boundary.

3C1 66 to 94 cm, light brown (7.5YR 6/4) sand, brown (7.5YR 4/4) when moist; massive, slightly hard, very friable, nonsticky and nonplastic; common fine and medium roots; many very fine interstitial pores; abrupt smooth boundary.

3C2 94 to 124 cm, pink (7.5YR 7/4) fine sand, brown (7.5YR 5/4) when moist; massive; slightly hard, very friable, nonsticky and nonplastic; common fine and medium roots; many very fine interstitial pores; abrupt smooth boundary.

4Ab 124 to 130 cm, pale brown (10YR 6/3) very fine sandy loam, brown (10YR 4/3) when moist; weak fine subangular blocky structure; slightly hard, very friable, nonsticky and nonplastic; common fine and medium tubular pores; abrupt smooth boundary.

4C1 130 to 150 cm, light brown (7.5YR 6/4) sand, brown (7.5YR 4/4) when moist; massive, slightly hard, very friable, nonsticky and nonplastic; common fine and medium roots; many very fine and fine interstitial pores; abrupt smooth boundary.

4C2 150 to 165 cm, light yellowish brown (10YR 6/4) gravelly sand, dark yellowish brown (10YR 4/4) when moist; massive to single grain; slightly hard, very friable, nonsticky and nonplastic; common fine and medium roots; many very fine and fine interstitial pores; 20% gravel; abrupt smooth boundary.

4C3 165 to 175 cm, brown (7.5YR 5/4) sand, brown (7.5YR 4/4) when moist; massive; slightly hard, very friable, nonsticky and nonplastic; common fine and medium roots; many very fine and fine interstitial pores; abrupt smooth boundary.

5Ab 175 to 180 cm, brown (10YR 5/3) very fine sandy loam, dark brown (10YR 3/3) when moist; massive, slightly hard, friable, nonsticky and nonplastic; common fine and medium roots; common fine and medium tubular pores; charcoal flecks; abrupt smooth boundary.

5C 180 to 221 cm, pale brown (10YR 6/3) sand, dark yellowish brown (10YR 4/4) when moist; massive; slightly hard, very friable, nonsticky and nonplastic; common fine and medium roots; many very fine and fine interstitial pores.

Notes: This area has historically been a hay field. Irrigation comes from the Paria River, upstream. A peach and plum orchard currently occupies the field south of the ranch house, west of this description site (same geomorphic surface). Anasazi pottery chards have reportedly been found in the near vicinity.

Classification: Fin-loamy, mixed, hyperthermic, Typic Haplocambids
Hydrologic Group: B
Permeability: Moderately rapid
Drainage Class: Well drained

Vegetation: Fallow - hay field (?). Mesquite probably cleared.

94003
9/27/94
Stop 1

Av 0 to 3 cm, light reddish brown (5YR 6/4) very gravelly fine sandy loam, reddish brown (5YR 4/4) when moist; moderate fine platy structure; slightly hard, very friable, nonsticky and nonplastic; many very fine and fine tubular pores; 80% sand, 10% cobbles; clear smooth boundary.

AB 3 to 8 cm, light reddish brown (2.5YR 6/4) very gravelly fine sandy loam, reddish brown (2.5YR 4/4) when moist; very gravelly fine sandy loam, moderate fine subangular blocky structure; slightly hard, very friable, nonsticky and nonplastic; few fine roots; common very fine tubular pores; 80% gravel, 10% cobbles; clear wavy boundary.

Bk1 8 to 28 cm, light reddish brown (5YR 6/4) very gravelly loamy sand, strong brown (7.5YR 5/6) when moist; strong fine subangular blocky structure; hard, friable, nonsticky and nonplastic; few very fine roots; few very fine interstitial pores; many fine lime concretions with 2 - 5 mm linings on the undersides of gravels; 30% gravel and 20% cobbles; gradual wavy boundary.

Bkt 28 to 69 cm, pink (5YR 7/4) very gravelly sandy loam, yellowish red (5YR 4/6) when moist; moderate medium subangular blocky structure; hard, firm, nonsticky and slightly plastic; few very fine roots; few very fine interstitial pores; few thin clay films occurs on ped faces; many medium lime concretions with 2 - 5 mm linings on undersides of gravels; 50% stones and 20% gravel; gradual wavy boundary.

Bk2 69 to 101 cm, reddish yellow (7/5YR 7/6) very stony loamy coarse sand, strong brown (7.5YR 5/6) when moist; massive; slightly hard, friable, nonsticky and nonplastic; few very fine interstitial pores; common fine concretions with 1 - 2 mm linings on the undersides of gravel; 40% gravel and 10% cobbles.

Notes: Desert pavement and varnish. Smooth surface, large stones and boulders may be shot. 10% vegetative cover; large stone line at 69 cm; pit to 101 cm. Advanced Stage II carbonate development.

Classification: Loamy skeletal, mixed, hyperthermic Typic Haplocalcids
Drainage Class: Well drained
Runoff: Moderately rapid
Permeability: Moderate
Vegetation: Prickly pear, beaver tail, Mormon tea.

94004
Stop No. 2
9/27/94

Av 0 to 3 cm, light reddish brown (2.5YR 6/4) extremely gravelly loam, dark reddish brown (2.5YR 3/4) when moist; moderate fine platy structure; slightly hard, friable, nonsticky and slightly plastic; few very fine roots; many very fine and fine tubular pores; 90% gravel; clear smooth boundary.

AB 3 to 8 cm, reddish brown (2.5YR 5/4) very gravelly loam, dark red (2.5YR 3/6) when moist; moderate fine subangular blocky structure; slightly hard, friable, nonsticky and slightly plastic; few very fine roots; common very fine and fine interstitial pores; 50% gravel; gradual smooth boundary.

Bkt 8 to 36 cm, reddish brown (5YR 5/4) very gravelly sandy clay loam, yellowish red (5YR 4/6) when moist; moderate medium subangular blocky structure; hard, friable, slightly sticky and slightly plastic ; few very fine roots; few thin clay films on ped faces; many medium lime concretions with 2 -4 mm linings on the undersides of gravel; 50% gravel; gradual smooth boundary.

Bk 36 to 56 cm, light reddish brown (5YR 6/3) very gravelly sandy loam, yellowish red (5YR 4/6) when moist; massive, slightly hard, friable, nonsticky and nonplastic; few very fine roots; 50% gravel; gradual smooth boundary.

C 56 to 117 cm, reddish brown (2.5YR 5/4) very gravelly loamy sand, dark red (2.5YR 3/6) when moist; massive to single grain; 50% gravel.

Notes: Stage II carbonate soil.

Classification: Loamy-skeletal, mixed, hyperthermic, Typic Haplocalcids
Drainage Class: Well drained
Permeability: Moderate
Runoff: Moderately rapid
Vegetation: Prickly pear, Mormon tea, Beaver tail

94005
Stop No. 3
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A 0 to 3 cm, reddish brown (2.5YR 5/4) extremely gravelly loam, reddish brown (2.5YR 4/4) when moist; moderate medium platy structure; slightly hard, very friable, nonsticky and slightly plastic; few very fine roots; common very fine and fine tubular pores; clear smooth boundary.

Bw 3 to 10 cm, reddish brown (2.5YR 5/4) gravelly fine sandy loam; weak fine subangular blocky structure; soft, very friable, nonsticky and nonplastic; few very fine roots; common very fine and fine interstitial pores; 20% gravel; gradual smooth boundary.

Bkt1 10 to 20 cm, light reddish brown (2.5YR 6/4) very gravelly loam, dark red (2.5YR 3/6) when moist; moderate medium subangular blocky

structure; slightly hard, friable, nonsticky and slightly plastic; common very fine and fine interstitial pores; few thin clay films occurs on ped faces; lime occurs as many coarse concretions; 50% gravel; gradual wavy boundary.

Bkt2 20 to 36 cm, variegated pink (5YR 7/4) and pinkish gray (5YR 7/2) extremely gravely sandy clay loam, yellowish red (5YR 4/6) when moist; moderate medium subangular blocky structure; hard, friable, slightly sticky and slightly plastic; common very fine and fine interstitial pores; few thin clay films occurs on ped faces; lime occurs as many coarse soft masses and concretions; 70% gravel; clear smooth boundary.

2Bk1 36 to 63 cm, lightly brown (7.5YR 6/4) very gravelly sandy loam, brown (7.5YR 4/4) when moist; massive; slightly hard, very friable, soft, common very fine and fine interstitial pores; lime occurs as common medium soft masses; 50% gravel; gradual smooth boundary.

2Bk2 63 to 101 cm, light reddish brown (5YR 6/4) very gravelly sandy loam, reddish brown (5YR 4/4) when moist; massive; slightly hard, very friable, nonplastic; common very fine and fine interstitial pores; lime as above; 50% gravel.

Notes:
Continuous carbonate dispersion in Bk2; carbonate rinds and concretions 1-2cm thick. Weak Stage III carbonate soil.

Soil Classification: Loamy-skeletal, mixed, thermic (hyperthermic ?) Typic Haplocalcids
Hydrologic Group: C
Hydraulic Conductivity: Moderately slow
Runoff: Moderately high

Lees Ferry

Soil Morphology Lab, LAWR, UC Davis

6/20/95

SAMPLE	HORIZON	DEPTH (in.)	SAND %	SILT %	CLAY %	VCS %	CS %	MS %	FS %	VFS %	GRAVEL % (unwashed)	CaCO3 %
9/24/94 - 1	Av	0-1"	49.23	31.74	19.03	1.50	5.97	6.80	20.49	14.47	48.15	6.90
		1-7"	29.41	26.70	43.89	1.24	2.16	3.94	14.41	7.66	49.40	7.36
	Bkm	7-38"	+	+	+	+	+	+	+	+	100.00	+
		38-52"	86.55	2.29	11.16	2.38	11.19	22.69	34.18	16.10	74.23	26.25
9/24/94 - 1	Johnson Pt Db	+	+	+	+	+	+	+	+	+	100.00	+
9/26/94 - 1		0-4"	34.61	25.37	40.01	0.05	0.64	3.49	17.73	12.70	0.00	13.83
		4-9"	22.45	27.48	50.07	0.00	0.65	1.51	11.60	8.69	0.00	14.32
		9-14"	17.90	24.74	57.35	0.00	0.72	1.60	8.82	6.76	0.00	13.33
		14-23"	86.33	7.33	6.34	0.00	0.41	3.10	57.54	25.29	0.84	4.36
		23-26"	42.06	32.17	25.77	0.00	0.15	1.59	18.36	21.96	25.26	10.39
		26-37"	87.31	8.42	4.28	0.30	1.00	6.13	52.06	27.81	0.00	4.74
		37-49"	89.29	6.99	3.73	1.38	5.32	19.08	44.12	19.38	0.00	4.58
		49-51"	44.05	31.34	24.61	0.00	0.15	1.87	18.08	23.94	0.00	11.74
		51-59"	77.12	16.60	6.27	0.00	0.25	0.45	37.23	39.19	0.00	8.30
		59-65"	89.40	7.64	2.95	5.66	14.56	24.55	32.33	12.30	10.74	5.66
		65-69"	87.17	8.31	4.53	0.05	1.56	21.46	50.05	14.05	0.00	5.73
		69-71"	60.31	31.35	8.34	0.10	0.60	2.41	22.97	34.23	0.00	12.15
		71-87"	91.86	6.77	1.37	0.49	15.69	36.26	30.59	8.84	63.80*	3.02
9/27/94 - 1	Av	0-1"	49.39	36.86	13.76	3.58	2.20	2.10	16.12	25.38	61.33	10.92
	AB	1-3"	51.77	27.53	20.71	2.33	2.18	3.19	19.94	24.14	39.01	10.13
	Bk1	3-11"	70.61	18.34	11.05	7.63	7.23	11.65	31.09	13.01	47.28	22.71
	Bkt	11-27"	72.22	23.76	4.02	2.51	4.32	4.27	18.14	42.97	19.97	19.07
	Bk2	27-40"	88.40	6.05	5.56	29.09	34.26	8.72	11.30	5.02	73.36	7.25
9/27/94 - 2		0-1"	43.37	38.37	18.27	2.10	2.10	3.27	14.52	21.38	60.96	7.38
		1-3"	55.94	27.97	16.08	2.44	3.81	7.41	21.68	20.61	39.27	8.77
		3-14"	80.87	6.58	12.55	10.44	13.12	17.46	25.88	13.97	97.87	8.21
	Bk	14-22"	85.39	9.59	5.02	9.90	13.20	24.90	27.55	9.85	59.65	6.35
	C	22-40"	81.42	11.97	6.61	12.97	10.63	10.63	31.48	15.71	81.28	9.66
9/27/94 - 3	A	0-1"	57.41	29.23	13.36	2.08	2.08	5.08	24.77	23.40	48.84	11.49
	Bw	1-4"	52.47	24.40	23.14	1.48	2.41	6.04	24.37	18.17	31.71	12.25
	Bkt1	4-8"	52.42	20.74	26.83	3.89	4.92	15.22	19.52	8.87	74.34	14.48
	Bkt2	8-14"	68.53	18.53	12.94	2.04	7.82	24.63	28.77	5.26	37.56	16.64
	2Bk1	14-25"	70.19	17.88	11.93	3.38	9.23	27.50	24.32	5.75	74.28	21.31
	2Bk2	25-40"	85.29	9.54	5.17	4.48	18.47	37.66	19.69	4.99	75.47	13.04

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SAMPLE	HORIZON	DEPTH (in)	ORIGINALLY REPORTED % GRAVEL(unwashed)	% GRAVEL of WHOLE SOIL AFTER HCl	% CO3 of WHOLE SOIL FROM GRAVEL FRACTION	% FINE EARTH of WHOLE SOIL FROM GRAVEL FRACTION	% CO3 of GRAVEL FRACTION
9/24/94 - 1	Av	0-1"	48.15	38.98	7.81	1.36	16.21
		1-7"	49.4	9.53	34.14	5.73	69.11
	Bkm	7-38"	100	9.18	73.50	17.31	73.50
		38-52"	74.23	5.18	31.25	37.79	42.10
9/24/94 - 1	Johnson Pt Db		100	23.56	60.27	16.17	60.27
9/26/94 - 1		14-23"	0.84	0.00	0.12	0.72	14.19
		23-26"	25.26	0.00	5.22	20.04	20.67
		59-65"	10.74	2.87	6.62	1.25	61.61
		71-87"	63.8	0.00	57.51	6.29	90.14
9/27/94 - 1	Av	0-1"	61.33	54.14	2.90	4.29	4.73
	AB	1-3"	39.01	29.24	4.96	4.81	12.70
	Bk1	3-11"	47.28	19.65	18.13	9.51	38.34
	Bkt	11-27"	19.97	1.96	8.24	9.77	41.26
	Bk2	27-40"	73.36	60.88	7.83	4.64	10.68
9/27/94 - 2		0-1"	60.96	57.65	1.68	1.63	2.76
		1-3"	39.27	30.18	5.71	3.38	14.54
		3-14"	97.87	52.21	34.58	11.09	35.33
	Bk	14-22"	59.65	19.10	28.86	11.69	48.39
	C	22-40"	81.28	39.39	35.44	6.44	43.61
9/27/94 - 3	A	0-1"	48.84	32.54	10.42	5.88	21.33
	Bw	1-4"	31.71	18.35	10.08	3.28	31.78
	Bkt1	4-8"	74.34	50.63	17.81	5.90	23.96
	Bkt2	8-14"	37.56	21.08	12.10	4.38	32.23
	2Bk1	14-25"	74.28	54.64	14.54	5.11	19.57
	2Bk2	25-40"	75.47	69.60	4.00	1.88	5.30