UNKAR DELTA ECOLOGY REPORT 1968
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The archeological sites being investigated this summer and last are located on a spot in the canyon bottom known as Unkar Delta. This delta is an accumulation of material presumably deposited by the Colorado River during the Pliestocene. It consists of ill-defined layers of alluvium varying in size from automobile-size boulders to fine sands and silts. The delta is in the form of at least two flat topped, steep sided terraces. Upstream from Unkar the Colorado follows a winding course, and in many of the bends deposits of this same nature are found. It seems conceivable that at one time the whole river bottom was filled up with this material to the level of the tops of the highest terraces that remain. Then the river cut down through and removed most of this deposit, leaving only the isolated deposits of terraced alluvium that one sees today. The Unkar delta, being some 3/4 mile long by 1/2 mile wide, is by far the largest of these. The delta is cut by the Unkar Wash which crosses it on the last leg of its journey from a point near the North Rim to the Colorado River. The name Unkar Delta gives the impression that all this material was deposited there. I think this is a misnomer. The delta is very similar to the other deposits up stream from it, and is composed of material completely different from that which might come down from Unkar Wash. The wash flows for several miles through a red sandstone, which would make up much of the delta had it been formed by the wash. The wash has affected the present day topography of the delta considerably. As it has cut down through the alluvium making up the Unkar Delta it has formed a series of smaller terraces on each side of its present bed. At the north end of the delta the river presses closer to the red sandstone cliffs, which delimit its bed along much of its course, and the alluvium gives way to a tallus slope a weathered sandstone. Along the south and east margins of the delta the steep sided terraces have been broken down by erosion and the land has more of a gradual slope toward the river. Along these margins, also, have developed dunes of wind blown beach sand. A sketch shows an approximation of the north-south cross-section of the delta.

The climate at Unkar Delta is extremely hot and dry, and might be called typical of that of the Lower Sonoran Life Zone. Plants that are well adapted to these conditions, such as Atriplex canesens (four-wing salt bush), Effedra spp. (mormon tea), and Hilaria jamesii (galleta grass) dominate the area. In places where there is sub-surface moisture Prosopus juliflora (mesquite) is also common. But the landscape of the delta includes great differences in slope, exposure, soil, and water table depth; and the extreme climate, acting upon these topographic variations, has produced several different plant community types that must be noted when describing the delta.

The map and the cross section sketch show the outlines of the major geographic features of the delta and various plant communities. One of the purposes for describing the delta in somewhat more detail than had been done previously was to see whether the locations of the sites of human habitation were indicative of a preference for living in one plant community type, or micro environment as they were called last year, rather than another. By locating on the map the sites one was interested in one should be able to answer this question satisfactorily.

The plant life found on the tops of the second and third terraces south is the most typical of the Lower Sonoran Life Zone. These areas are fully exposed to the drying effects of the sun, and receive no additional moisture from runoff. At the surface of the ground one sees little soil exposed, the ground being covered with what is called a desert pavement, a layer of pebbles and cobbles, faceted by the action of wind blown sand. The vegetation is very sparse, consisting for the most part of scattered Effedra, clumps of Opuntia, a few blades of Galleta, an occasional mesquite bush always located near a large rock or in a low spot where it is slightly more moist, and an occasional four-wing saltbush. There are large patches where there is no vegetation what-so-ever. On the south slope of the third terrace the situation becomes even more extreme. Here vegetation and soil are completely absent, except in scattered pockets between rocks. Here a population of barrle cacti dominate the scene.

The north and east slopes of these terraces are much different. Here there is considerably more moisture (relatively speaking) because the land slopes steeply north and receives much less solar energy. The grass population is increased many times over. Bromus rubens, an annual grass forms almost a continuous carpet in some places.

The first terrace, on both sides of the wash, is yet more different.

Because of being lower, these areas receive runoff from the terraces above and down Unkar west. Also, some of the plants here have roots long enough to reach the water table at the Colorado River. The soil here is loose and gravelly and plant roots and water penetrate it readily. In all there is sufficient deep soil moisture to support a population of mesquite, cat claw (Acacia gueggii) and four-wire salt bush. As one nears the river the water table gets closer to the surface of the soil, and mesquite and Acacia reach tree-like proportions, growing up to thitty feet tall and having trunks a foot or more in diameter. The result could almost be called a mesquite woodland, with a fairly dense understory of four-wing salt bush. Although the first terrace areas have more moisture than the second and third terraces south it is mostly deeper in the soil, and the grass population shows little increase.

The second terrace on the north side is a fairly extensive flat piece of land that slopes gently toward the east and north. This exposure, plus a little runoff from the adjacent red tallus slopes, makes this area considerably more productive than the upper terraces on the south side. The same species are found on both sides, but are greatly increased both in size and number on the north terrace. Here four-wing salt bush is the dominent species, while on the south side it is found only occasionally. Also the grass population is higher over here.

North of this terrace is a tallus slope of weathered red sandstone from the cliff above. The soil here is 100% sand, containing none of the alluvial material which makes up the rest of the delta. It slopes steeply north east, leveling out as it nears the river. It's a rather barren area, sparcely populated with mesquite, salt bush, Opuntia, and Effedren. In some places, mainly in low spots and drainages there are concentrations of Lycium Pallidum (wolf berry), a species only found in such spots that get extra moisture. On the upper, steeper slopes the grass population increases very noticeably, presumably due to the northern exposure. And here is found a species unique to this area Eriogonum densum (desert buckwheat).

All around the south and east edges of the delta there has accumulated a strip of dune sand. Here, due to the particular porus and structurless nature of the medium in which grows, has developed a unique sanddune community. The porus sand acts as a reservior, soaking up every drop of the winter precipitation, and then supports a plant life completely different from the vegetation found anywhere else on the delta. In the tops of all the large dunes, holding the dunes in place, are large, tangled, half-buried clumps of mesquite bushes. The gentle slopes, hollows and flat areas are dominated by Oryzopsis hymenoides (Indian rice grass), Sphanalcea spp. (mallow), Oenothera pallida (primrose), Sporobolous sp. (dropseed), and many early spring annuals. A large percentage of the plants found in the same area are early spring annuals, completing their whole life cycle, growing, flowering and dying before the dunes dry out in the heat of the summer. Running along side the dune strip, on its north west side, is a strip Shane called semidune. Here the soil is sandy, but shows some structure that is lacking in the dunes. From a vegitational standpoint it is like the dune area except that Rice grass is very noticeably absent.

In a narrow green band around the edge of the delta one finds a riparian community of willows, tammarisk, salt grass, asters, bee-plant and reeds.

The delta was sectioned according to its various plant community types, and sampled each type using the lim-otrip transect, and quadrant methods. Surface pollen samples were also taken from each area of the delta. The following data was obtained:

Red Sandstone tallus slope

Lower slope

area: about 7.5 acres

Prosopis juliflora (Honey Mesquite)

Percent cover 1 1/2%

no trunks/acre 36

Basal area 403 sq. in/acre

Opuntia sp. (Prickly-pear)

Percent cover 3 %

Flowers/acre - 850 acre

Atriplex canescens (Four-wing saltbush)

Percent cover less than 1%

No. plants/ acre - 44 - 54% female

Total area of male plants - 12,400 sq. in.

Lycium pallidum (wolfberry)

Percent cover less than 1%

no. plants/ acre - 45

Total area of plants - 45,500 sq. in.

Griogonum densum ? (desert buckwheat)

Fruiting stalks/acre - 180

Hilaria jumesi (Galleta)

Seed heads/acre - 4650

Sporobolsus sp (dropseed)

Seed heads/ Acre - 625

Red sandstone tallus slope

upper slope

Area: about 6 acres

Acacia greggii (cat claw)

percent cover less than 1%

no. trunks/ acre - 12

basal area - 10.5 sq. in/acre

Opuntia op. (prickly pear)

percent cover 1.5%

no. of flowers/ acre - 720

Atriplex canescens (four-wing saltbush)

percent cover - less than 1%

no. plants/acre 4

total xxxx area/acre - 2300 sq. in/acre

Lycium pallidum - (wolf berry)

percent cover - less than 1%

no. plants/acre - 7

Total area 8500 sq. in/acre

Effedra sp. (Mormon tea)

Percent cover - less than 1%

no. plants/acre - 20

Total area - 7400 sq. in/acre

Hilaria jamesi (Galleta)

Seed heads/acre - 4350

Bromus rubens

Seed heads/acre - 400

Second Terrace, North

Area: about 10 acres

Prosopus juliflora (Honey mesquite)

percent cover 5.5%

Trunks/acre 52

Basal area 800 sq. in/acre

<u>Acacia gregii</u> (cat claw)

percent cover 3.9%

Trunks/acre 38

Basal area 418 sq. in/acre

<u>Opuntia sp</u>. (prickly-pear)

percent cover - 4%

Flowers/acre 2250

<u>Atriplex canescans</u> (four-wing salt bush)

percent cover 3.3%

no. plants/acre 219, 33% male

area of <u>male</u> plants - 45,200 sq. in/acre

<u>Lycium pallidum</u> (wolf berry)

percent cover less than 1%

no. plants acre/35

Total area - 43,200 sq in/Acre

<u>Effedra</u> sp. (Mormon tea)

Percent cover 1.8%

No. plants acre - 271

Total area - 43,200 sq. in/Acre

<u>Hilaria jamesi</u> - (Galleta)

Seed heads/acre 15,790

<u>Aristada</u> sp. (Three-awn grass)

seed heads/acre - 920

<u>Sporobulus</u> sp. (drop seed)

seed heads/acre 610

Bromus rubens

Seed heads/acre 2560

Plantago insularis (Plantain)

Flower heads/Acre - 61,610

First Terrace, North and South

Area: about 23 acres

Prosopus juliflora (Honey mesquite)

percent cover 17%

no. of trunks/acre 200

Basal area - 5000 sq. in/acre

Acacia gregii (cat claw)

percent cover 2.5%

Trunks/acre 98

Basal area - 352 sq in/acre

Opuntia sp. (prickly-pear)

Percent cover - 1.5%

no. of flowers/acre - 225

Atriplex canescans (four-wing salt bush)

percent cover - 5.5%

no. of plants/acre - 573, 33% male

Total area of male plants - 118,400 sq. in

Lycium pallidum (wolf-berry)

percent cover - less than 1%

no. plants/acre 8

Total area acre - 7800 sq. in/acre

First Terrace, North and South

Area: about 23 acres

Prosopus juliflora (Honey mesquite)

percent cover 17%

no. of trunks/acre 200

Basal area - 5000 sq. in/acre

Acacia gregii (cat claw)

percent cover 2.5%

Trunks/acre 98

Basal area - 352 sq in/acre

Opuntia op. (prickly-pear)

Percent cover - 1.5%

no. of flowers/acre - 225

Atriplex canescens (four-wing salt bush)

percent cover - 5.5%

no. of plants/acre - 573, 33% male

Total area of male plants - 118,400 sq. in.

Lycium pallidum (wolf-berry)

percent cover - less than 1%

no. plants/acre 8

Total area/acre - 7800 sq. in/acre

Effedra sp. (Mormon tea)

percent cover - less than 1%

no. of plants/acre - 44

Total area - 16,700 sq in/acre

Hilaria jamasi (Galleta)

seed heads/acre - 6530

Aristada sp. (Three-awn grass)

seed heads/acre - 1340

Sporobolus sp. (dropseed)

seed heads/acre - 550

Bromus rubens

seed heads/acre - 2210

Plantago insularis (Plantain)

Flower heads/acre - 24,100

Second Terrace South

area: about 3 acres

Prosopus juliflora (Honey mesquite)

percent cover 1%

no. of trunks/acre - 33

Basal area: 74.9 sq. in/acre

Opuntia op. (prickly-pear)

percent cover 4%

no. of flowers/acre - 1010

Atriplex canescens (four-wing saltbush)

percent cover - less than 1%

no. of plants/acre - 22, 50% male

Total area of male plants - 6820 sq in/acre

Effedra sp. (Mormon tea)

percent cover - 3.2%

no. of plants/acre - 178

Total area - 66,570 sq. in/acre

Hilaria jamesi (Galleta)

Seed heads/acre - 3350

Bromus rubens

Seed heads/acre - 11,310

Plantago insularis (Plantain)

Flower heads/acre - 142,800

Second Terrace South

Area: about 3 acres

Opuntia sp. (prickly-pear)

percent cover - 5.5%

Flowers/acre - 2280

Atriplex canescens (four-wing saltbush)

Percent cover less than 1%

Plants/acre - 30, 50% male

Total area of male plants - 9300 sq. in/acre

Lycium pallidum (wolfberry)

Percent cover less than 1%

Plants/acre - 26

Total area - 23,200 sq. in/acre

Effedra sp. (Mormon tea)

Percent cover - less than 1%

plants/acre - 37

Total area - 13,830 sq. in.

Hilaria Jamesi (Galleta)

Seed heads/acre - 11,310

Plantago insularis (Plantain)

Flower heads/acre - 142,800

North Slope of Second Terrace South

Area: about 1 acre

Opuntia sp. (prickly-pear)

percent cover - 5.5%

Flowers/acre - 2280

Atriplex canescens (four-wing salt bush)

Percent cover less than 1%

Plants/acre - 30, 50% male

Total area of male plants - 9300 sq. in/acre

Lycium pallidum (wolf berry)

Percent cover less than 1%

Plants/acre - 26

Total area - 23,200 sq. in/acre

Effedra sp. (Mormon tea)

percent cover - less than 1%

plants/acre - 37

total area - 13,830 sq. in.

Bromus rubens

seed heads/area 622,000

Plantago insularis

flower heads/acre 5590

Third Terrace -

The top of the third terrace

<u>Prosopus</u> <u>juliflora</u> (Honey mesquite)

percent cover - 1 1/2%

Trunks/acre - 250

Basal area - 240 sq. in/acre

<u>Opuntia</u> sp. (prickly-pear)

percent cover - 2 1/2%

Flowers/acre - 700/acre

<u>Atriplex</u> <u>canescens</u> (four-wing saltbush)

Percent cover - less than 1%

no. of plants/acre - 25 - 53% <u>male</u>

Total area of male plants - 8060 sq. in/acre

<u>Effedra</u> sp. (Mormon tea)

Percent cover - 2%

no. of plants/acre - 250

Total area - 93,500 sq. in.

<u>Hilaria</u> <u>jamesii</u> (Galleta)

Seed heads/acre - 12,000

<u>Plantago</u> <u>insularis</u>

Seed heads/acre - 8700

N.E. Slope of Third terrace area: about 3 acres

<u>Opuntia</u> sp. (prickly-pear)

percent cover - 1.5%

flowers/acre - 360

Effedra sp. (Mormon tea)

percent cover - 2.5%

no. of plants/acre - 220

Total area - 82,300 sq. in./acre

Hilaria jamesi (Galleta)

Seed heads/acre - 30,220

Sporobolus sp. (dropseed)

Seed heads/acre - 6,200

Aristoda sp. (Three-awn grass)

Seed heads/acre - 1000

Plantago insularis (Plantain)

Flower heads/acre - 16,080

_________ _________ ? (an annual mustard)

Flowers/acre - 90,000

Bromus rubens

Seed heads/acre - 345,500

Northwest slope of the third terrace

Area: about 3.5 acres

Opuntia sp. (prickly-pear)

percent cover - 1 1/2%

Flowers/acre - 270

Effedra sp. (Mormon tea)

percent cover - 1 1/2%

no. of plants/acre - 100

Total area - 37,400 sq. in acre

<u>Hilaria jamesi</u> (Galleta)-

Seed Heads/ acre - 19,420

<u>Sporobolus</u> sp. (dropseed)

Seed heads/acre - 700

<u>Bromus rubens</u>

Seed heads/acre - 215,200

Semi Dune area - includes some of the eroded south slope of the second terrace south

Area: about 9 acres

<u>Opuntia</u> op. (Prickly-pear)

percent cover - 2 1/2%

Flowers/acre - 2960

<u>Atriplex canescens</u> (four-wing salt bush)

Percent cover - less than 1%

no. of plants/acre - 77, 33% male

Total area of male plants - 16,100 sq. in

<u>Effedra</u> sp. (Mormon tea)

Percent cover - less than 1%

No. of plants/acre - 32

Total area - 11,950 sq. in.

<u>Oenothera pallida</u> (primrose)

Flowers/acre - 5500

Sphaeralcoa sp. (mallow)

Flowers/acre - 35,000

Hilaria jamesi (Galleta)

Seed heads/acre - 11,160

Sporobolus sp. (dropseed)

Seed heads/acre - 2580

Oryzopsis hymenoides (Indian Rice grass)

Seed heads/ acre - 775

Bromus rubens

Seed heads/acre - 26,050

Plantago insularis (Plantain)

Flower heads/acre - 321,600

Dune area

Area - about 9 acres

Prosopus juliflora (Honey mesquite)

percent cover - 4.3%

Trunks/acre - 37

Basal area - 401 sq. in/acre

Opuntia sp. (prickly-pear)

Percent cover - 3.5%

Flowers/acre - 3700

Atriplex canescens (four-wing saltbush)

Percent cover - 2.7%

Plants/acre - 209, 52% male

Total area of male plants - 66,300 sq. in.

Effedra sp. (Mormon tea)

percent cover - Less than 1%

Plants/acre - 14

Total area- 5000 sq. in/acre

Sphaeralcea sp. (mallow)

Percent cover - 1.4%

Flowers/acre - 24,800

Sporobulus sp. (dropseed)

Seed heads/acre - 1560

Oryzopsis hymenoides

Seed heads/acre - 32,650

Care was taken to include the amounts of _Bromus rubens_ encountered. This grass is an annual that in this area completes it's life cycle in the early spring and is dead by May. An accurate count of it was considered important because it is an importation from Asia and was not present on the delta when the Anasasi inhabited it. By showing up as graminae pollen in modern pollen samples and not in paleo-sample _Bromus rubens_ pollen might cause one to see a difference between the two samples that really doesn't exist. Equal care was taken to include counts of _Plantago insularis_. This to is an early spring annual. It is probably the only member of its family, Plantaginaceae, in the inner canyon. Thus an analysis for plantaginaceae pollen from certain levels in the sites might indicate a seasonal habitation of the delta if this was the case.

An attempt was made to count or measure these properties of each species present that might be correlated to pollen production. For large bushes and trees like mesquite the trunks were measured and the total basal area in sq. in. per acre was calculated. For grasses, etc. seed heads or flowers per acre were counted. For shrubs like saltbush or effedra the distance across each shrub was measured and the total area in sq. in. per acre was calculated. (Maybe I should have the volume of each plant in cu. in. per acre, I don't know. All I know is that basal area is near impossible to figure on a shrub like effedra with 27 stems ranging from 1/4" - 3" in diameter.)

delete
or
rephrase

The following plants occuring on the delta could be utilized for food by the Anasasi: mesquite, cat claw, prickly-pear, wolf-berry, salt bush, and rice grass. Other plants could probably be used as well, some of the smaller seeded grasses for example. But investigations were limited to these species because they were the only ones that were present in any quantity. The same techniques were used to gather this data that were used in obtaining the potential pollen production data.

Mesquite - The pods a beans of this plant, a legume, were ground into a meal by many peoples and used in what ever way people use meal. It was originally planned to gather all the mesquite beans from certain selected sample areas, and thus calculate the total production for the whole delta. Unfortunately there were hardly any beans produced this year, due to lack of pollenative bees or some other whim of nature. Thus, the only information available for mesquite is the data on number of trunks and basal area per acre, which is shown in the section on pollen production.

Cat claw - This plant is also a legume and also produces pods of beans. Unfortunately the cat claw were just flowering when we left the delta and had produced no pods yet. So the cat claw data is in the same state as the mesquite data. The roots of cat claw have numerous little fleshy swellings in them, like tiny potatoes. I tested them and they taste pretty good. But I have no idea what the yield might be per acre. Anyway, after one harvest all the cat claw would be destroyed.

Prickly-pear - These cacti produce a number of fruits that are edible if one takes care to peel off the skin which is covered with thousands of tiny spines. These fruits are somewhat fleshy, but most of their volume is made up by seeds. These seeds probably contain far more nutritive value than the fleshy portion of the fruit. Prickly-pear seeds were present in the plant material found in the grainery on the south end of the delta. Actually the inner flesh of the whole plant is edible. Acording to my calculation this year there were 450-550 gallons of prickly-pear fruit on the delta.

Wolf-berry - This shrub, in the spring, is covered with juicy little red berries. Various groups of indians are reported to have eaten these berries raw or prepared as a sauce. I estimate that there were 80-120 gallons of these berries on the delta this year. They start to wither up and fall off by June 1, so they must be gathered early.

Four-wing Salt Bush - The seeds of this shrub are reported to have been ground into a meal and used for food by Indians. Also the leaves were apparently eaten as sort of a salad. Unfortunately these seeds were just developing when I was on the delta and were far from their mature size. And so I have no good yeild figure for salt bush seeds. I would guess that one average sized female plant could produce a quart or two a seeds, which adds up to 2000-4000 gallons of seed over the whole area. Perhaps someone who knows more about saltbush could get a more accurate figure from my data in the pollen section. Of a quart of seed, perhaps 1/2-2/3 of the volume would be occupied by the unpalatable seed wings and thick seed coats.

Rice Grass - The seed from this plant has been used by indians like wheat or rice or other small grains. It really isn't too plentiful on the dry Unkar Delta, the bunches of grass being widely spaced because of the keen competition for moisture. According to my estimates there should be 100-120 gallons of harvestable seed on the delta each year.

In summary, the annual wild plant harvest on Unkar Delta should be about: 500 gal of Prickly-Pear fruit, 100 gal of wolf berries, 1000 gal of edible salt bush seed, and 100 gal of rice grass seed. This doesn't include, of course, the unknown amounts of mesquite and cat claw beans. This is just from the delta itself. How much could be gathered from the surrounding countryside is anyone's guess; but it is reasonable to expect that comparable areas along the rim should produce comparable harvests. As a very rough estimate, if we take one gallon of such foods as weighing 5 lbs, and the average intake of one person as 1.5-2.0 lbs/day, we find that the natural plant food harvest from the delta could support perhaps 12-15 people. Of course we all realize that no one could live on a steady diet of prickly-pear and salt bush seeds.

The problem of estimating the agricultural potential of the delta 700 years ago involves correlating numerous climate variables with an equally large number of soil factors and an uncertain amount of Anasisi technology. It is an intriguing problem, but one which is difficult to answer from little data gathered during a few weeks of observations. So, the figures in the following pages should be taken as a guide not as gosphel.

Terms like "hot and dry" or "Lower Sonoran" describe the climate on the delta in a general way, but something more quantitative was called for. There is no weather station on the delta of course, and so weather data from the area is completely lacking. (? last year?) To get as accurate an idea as possible of the year-round climate at Unkar as possible, I kept some very extensive weather records the few weeks that I was there, which will be correlated to records from other stations in areas of similar climate. I recorded temperature, relative humidity, barometric pressure, wind, rainfall, evaporation, soil moisture, and soil temperature. This data is included as appendix I of this report.

The soil of Unkar Delta, exeepting the red tallus slope, is all derived, basically, from the same alluvial parent material, but it varies widely from place to place on the delta. On the tops of the Second and Third terraces south it is sparce and full of rocks. Down on the first terraces it is deep and loose and gravely, typical of material deposited in conjunction with arroyos such as Unkar Wash. Around the south and east margins of the delta the soil, as has been mentioned before, gives way to dune sand. On the second terrace north the soil is composed of more fine material, and is a little heavier than the first terrace soils. This fine material is underlain by layers of rocks and pebbles, and it almost impossible to find a spot where one can dig very far down without a lot a effort. On the first terraces and the second terrace north as one travels down slope toward the river the fine soil gets deeper, having washed down slope and built up below. By rearranging the abundant rocks there the former inhabitants of the delta converted second terrace north and some parts of the first terraces, into a network of small crude terraces, apparently for agricultural purposes. On the lower portions of these slopes quite a bit of soil has accumulated behind these rock terraces.

I conducted some soil water percolation tests at a few spots around the delta that seemed the most likely to have been Anasasi garden plots. These tests were made by driving a 2 1/2" pipe into the ground a few inches, pouring a given amount of water into it, and measuring the length of time it took to soak in. The results of these tests are found in appendix II. In conjunction with these tests rates of rainfall were measured to determine how much rain water soaked in and how much ran off a given area. Unfortunately we only had one shower that was hard enough to bother measuring. This measurement is included in the weather data. It never rained hard or long enough to cause any runoff what so ever. I never saw any water in Unkar Wash. Soil samples were taken from the spots I tested to be analyzed for nutrient levels, total disolved salts, etc.

As the final step in estimating the agricultural potential of the delta, and to get a little more insight into the problems involved in forming an area like this, it was proposed that I grow an experimental garden. The basic plan called for plots of corn, squash, and beans to be planted on two or three soil types. Sections of the plots were to be kept watered so that some plants got optimum water, some got barely enough to live, and some had to get by on what nature provided in the form of rainfall. I was supplied with some wired-up gypsum blocks that were ___ placed in the soil of the plots which when hooked up to a meter these blocks would give a reading that would allow me to keep track of the amount of moisture in the soil of all the plots at all times. As the plants grew I was to measure them each day. Then at the end I could plot growth against soil moisture and find the amount of water necessary to sustain a certain level of growth, one that would give a good yield. Then I could subtract from the necessary water the amount of water supplied by rainfall, taking into account the ratio of area planted to runoff collection area, multiply by the amount of manpower required to supply a certain volume of irrigation water, and, hopefully arrive at a figure in Indians per acre that the delta could support.

Due to limited time just one garden was planted, a spot was selected on the Second terrace north, where the soil seemed fairly good. A small area of land was cleared and divided it into three small plots, each about six feet by 8 feet. Gypsum moisture blocks were then installed at 6" and 12" below the surface in each plot.

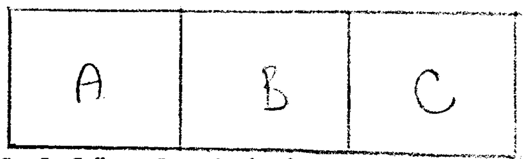
It is estimated that the annual precipitation on the delta is about 6", and with today's rainfall pattern about half of this falls in the winter. When we arrived on the delta in mid May the last bit of soil moisture was disappearing. The soil was still reasonably moist between 12" and 18", but dry above and below that. It is reasonable to assume that this moisture was the last bit left over from winter, and that winter precipitation was sufficient to penetrate to 18" but no further.

Sixty gallons of water were put on each plot to simulate about 2" of rainfall. I believe that the soil at this point was in about the same condition, moisture-wise, as the soil would have been when the Anasasi planted their corn, if the rainfall patterns then and now were similar. One hill of Zuni dryland corn, one hill of Aztec Beans, and one hill of Crooked-neck squash were planted in each plot.

I don't believe the gypsum moisture blocks ever worked properly. I think that due to the way they had to be installed they always lay in their own little pockets of mud and recorded more moisture than was in the rest of the soil. Also, once the soil dried they seemed to lose contact with the soil and wouldn't record any increases in moisture after that.

In order to get a better idea of what was happening in the soil, an evaporation plot was set up. I cleared it and wet it down in the same manner as the garden plots. Then every few days samples of soil were taken from it and their moisture content determined by weighing, drying, and weighing again. Due to many unfavorable condition such as not having a good drying oven, and never being able to find a place where the wind wouldn't blow on the balance and throw off the weighings, some of the results don't fit into the pattern that one would expect them to. However I was able to come up with what I believe is a fairly good approximation of the drying curve of this soil at 10"-14" depth. The accompaning graph shows this curve. It shows that, starting initially with 3" of water, either from rainfall or irrigation, the soil should be too dry to support the growth of crops after about 30 days. This of course neglects any water loss by plant transpiration. It also neglects any tapping of deeper soil moisture by the plants. The portion of the soil below 10"-14" would not dry out quickly and would still supplying be the moisture to the plants after the upper soil was dry. But since the soil was essentially dry below 18"-25", I don't believe there was enough deep soil moisture to throw this figure off too much.

The plants in the garden plots received no more water after this initial dose. The beans and squash did very poorly, but most of the corn grew very well. The corn was thinned to four plants/hill. Each day I measured their growth and observed them for signs of water stress. The plots were laid out side by side and were labeled "A," "B," and "C."



After 23 days I added 1" of additional water to plots A and C, and let plot B continue on as it was. In a few more days, the corn in plot B started to show signs of sever water stress. It began to wilt and curl badly during the hear of the day, even as early as 8:30 or 9:00 A.M. Corn A and C did not show these symptoms. It's unfortunate that out of ignorance I added additional water to plots A and C, because Corn B never quite reached the permanent wilting stage because of a slow lateral movement of soil water in from A and C. But I think that these results tend to indicate that the drying curve is reasonably accurate. I continued to take readings from the gypsum blocks in each plot. The readings are in atmospheres of moisture tension and can be converted to % moisture only by tests on samples I provided from the spots where I installed the blocks. The data from these blocks indicated that the soil lost moisture less rapidly than my drying curve shows. This data is found in appendix III. Without the results of the tests I'd be hard put to say how much this data differs from my evaporation plot drying curve.

Anasasi corn, then, could have probably grown for the first 30 days or so with no additional water needed. Then, according to my observations, if their corn took 120 days to mature, it would require at least three more doses of 3" of water each, or about 9" of water, to complete it's growth. I would not expect the yield of this corn to be over 20 to 25 bushes/acre, or about 1100-1400 pounds/acre. In producing this much corn, one acre of plants would have transpired somewhere around 50,000 gallons of water. This water is in addition to the water lost from the ground by evaporation. This would bring the total to 11" or 300,000 gal/acre that must be gotten on to the fields, either by rain or irrigation.

In the course of the growing season another 2" of rainfall could probably be expected. I didn't see anything in the arrangement of the Anasasi built terrace system to indicate that very much runoff water was collected. I believe that most of the land area within the Terrace system was actually used to grow crops. I think that the terraces were built more to prevent erosion and runoff than to collect additional runoff. Therefore I think that at least 9", or about 245,000 gallons/acre had to be carried up from the river.

Judging from the water I carried to my small garden I estimate that a person in reasonably good physical condition could carry 60 gal/hour from the river to the fields. At this rate the per acre water requirement represents 4080 man-hours per acre during the last 90 days of the growing season. Four people working 11 1/2 hours a day for each of these 90 days could supply this water, as could five people working 9.0 hours a day. That four or five people could live all year on 1100-1400 pounds of corn plus whatever they could hunt and gather doesn't seem too farfetched. But that they could have water 10 hours/day all summer is a little harder to believe. Surely they would have had to develop a more efficient way of getting water onto the fields.

All the fields would have not to be put into corn of course. Beans and squash were probably raised as well. But my experience with trying to grow these crops this summer indicates that they would require much more water than corn. They did poorly on the same amount of water that allowed the corn to do quite well. Thus the more beans and squash you try to raise the more work is required for irrigation.

The types of native vegetation indicate that no area of the delta receives enough water, either as rain or runoff to support corn without irrigation, But, because of the large size of the pore spaces between the soil particles and the resultant decrease in the capillary size of water, sand holds water against the forces of evaporation better than the finer soils. The question was asked, then, could these people have planted crops on the sand dunes and thus reduced their irrigation work? I don't believe they could have. As a secondary experiment I planted corn, beans and squash in a sand dune. Even with abundant water they did poorly, due to what I interpreted as nitrogen and possibly potassium defficiencies. Beans of course don't generally suffer from nitrogen defficiencies, and the ones I planted seemed to do pretty good in the sand for as long as I grew them. As they got bigger I couldn't have been surprized to see them develop some other defficiency symptoms, like potassium. The plants grown in the soil of the second terrace north showed no symptoms of nutrient defficiencies that I recognized.

The mention of fertility brings to mind another question. How long could the land be cropped, without the addition of fertilizer, before the nutrients in the soil would be exhausted? I can't answer this question with certainty, but in Iowa, at Iowa State University I believe, experiments have shown that sufficient nutrients are returned to the soil each year from the weathering of rock material in the soil, from decaying vegitation, including the remains of each year's corn crop, in rainfall (some 10 pounds of Nitrogen/acre are added to the soil each year by rainfall alone, this element being fixed by lightening and disolved in the raindrops I believe), in dust blowing in from other places etc., so that if the soil is reasonably fertile to begin with a small harvest can be taken each year almost indefinately without exhausting the land. Workers have harvested 25 bushels of corn/acre from an experimental plot in Iowa every year since 1910, and no fertilizer has ever been added. One thing to be considered here is that after so many years the salts that were disolved in the irrigation water would build up in the soil and render it useless for farming. I have no absolutely idea how long this might take.

An accurate figure would require soil fertility lists, but I would estimate that there are 20-25 acres of land on the delta that are comparable in nutrient level to my garden plot. It is for an expert in nutrition to decide just how many people could live on 20-25 acres of corn, beans, squash etc., but if this number is much less than five people per acre, then either they had a much more efficient method of hauling water than I did, or it rained a lot.

The possibility of growing two crops of corn per year has been raised, but my own opinion is that it wouldn't work. There are two reasons for this. Having no definate information on the length of the growing season at Unkar I can only guess, but I would think that cold air drainage at night from the cooler north and south rims would cause untimely frosts and result in Unkar having a shorter growing season than other areas of equal summer temperature, like for instance, Phoenix Ariz. I don't think the growing season is long enough for two crops. Also, while one crop might be taken from the land each year with no loss in productivity. I would suspect that two

crops a year would soon exhaust the nutrient supply of the soil, and cause production to cease altogether.

Besides the big questions of climate and soil a couple of other variable factors should probably be considered when discussing the agricultural potential of Unkar Delta. These are the problems of weeds and insects. As for weeds, I don't think they would present too much of a difficulty. A farmer there would want to keep the top few inches of his soil stirred up to break up the paths of capilary water movement toward the surface and retard evaporation as much as possible. This cultivation I'm sure would be enough to take care of any weeds. Insects might be a different story. During the few weeks that I tended my garden I saw little insect damage. But I noticed that whenever I wet down any plot of soil dozens of little blue butterflies appeared out of nowhere, presumably to lay their eggs in this wet ground. If the larvae which hatched were detrimental to corn plants, and if a good population of them got built up because of corn being grown in the same fields year after year and the being kept moist by irrigation, the Anasasi farmers might have had a serious problem. I wouldn't know when to start to assess a possible potential insect pest in terms of reduction of potential yield. I did have one pest problem in my garden, a packrat or something ate all my bean plants. I'm sure, however, that if the delta had been inhabited by hungry indians, the pack rats would have quickly disappeared, serving to fill a few stomachs.

Another objective was to identify all the plants found on the delta, and to suppliment and possibly correct the list of species that was made the year before. I have but a few additions:

Plantago insularus (Plantain)

Bromus rubens

Oenothera pallida (primrose)

Hilaria jamesi (Galleta)

Eriogonam densum (desert buckwheat)

Channel Catfish were noted in the river this year, but did not appear in last year's report.