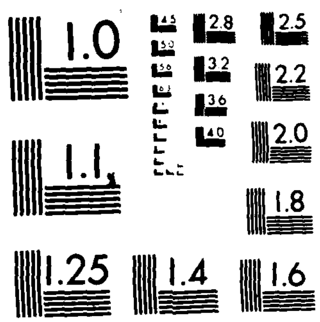
AD-A139 022 SEEDING SUCCESS ON TOPSOILED AND NONTOPSOILED SLOPES AT ADOBE DAM(U) ARIZONA STATE UNIV TEMPE CENTER FOR ENVIRONMENTAL STUDIES C W MOORE ET AL. FEB 83 1/1

UNCLASSIFIED DACW09-80-M-1205 F/G 2/4 NL

END
DATE
FILMED
4-84
DTIC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963 A

Report to the U. S. Army Corps of Engineers

Los Angeles District

Task Nos. 5 and 7

Seeding Success on Topsoiled and Nontopsoiled Slopes at Adobe Dam

Date: Feb 1983

by

Catesby W. Moore

Duncan T. Patten

and

Timothy L. Righetti

Center for Environmental Studies

Arizona State University

Tempe, Arizona

Contract No. DACW 09-80-M-1205

84 01 13 118

ABSTRACT

Four soils from the Army Corps' Adobe Dam project in central Arizona were compared chemically and for seeding responses. Results demonstrated the ability of subsoil fill materials to support seeded species, but in lower densities than topsoiled areas. Seeding date proved crucial in establishment and later seeded topsoils supported significantly lower densities of most seeded species than fill soils seeded earlier. Significant vegetation-soil correlations demonstrated relationships of species densities and both nitrate-nitrogen and total nitrogen. Significant negative correlations of Salsola paulsenii and the seeded species Atriplex canescens are reported. Regression of seeded species and seven soil variables yielded equations explaining sizable variations in seeded species densities. Nitrate-nitrogen was the major factor in these equations, followed by pH, electrical conductivity, percent clay, percent gravel, surface roughness and total cations. Seeding in favorable moisture periods on roughened subsoil seedbeds amended with nitrogen is recommended for similar sites.

ACKNOWLEDGMENTS

This research was supported by the U. S. Army Corps of Engineers whose helpful cooperation made this project possible. William T. Johnson assisted ably in collection of field data. Special thanks are due to the entire staff of the Center for Environmental Studies for support and encouragement. Sara Frischknecht proved invaluable in table design and in typing and editing the manuscript.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

In desert regions, conditions favoring the natural restablishment of vegetation may only occur every four to seven years (Hassell 1977). Barren areas, stripped of vegetation are invaded slowly by plants. Speeding this process requires stable soils properly graded, techniques to improve moisture conditions, and corrections of soil fertility and toxicity problems. Without analyses, undetected soil problems (salinity, alkalinity, and sodicity) can lead to seeding failures. The Department of Transportation wisely utilized soil analyses prior to successfully treating over 5,000 acres of disturbed lands along Arizona's roadways (Mortenson 1979). In 1979, the USDA/SEAM report on soils outlined soil analyses required for reclamation planning and emphasized the need for research to correlate these analyses with plant response.

Fertilizer use is best determined from soil analyses. Nitrogen and phosphorus are commonly deficient in the southwest; however, any additions should be judiciously applied. For desert sites, Cook, Hyde and Sims (1974) recommend nitrogen additions with planting or late in the first growing season. Mortenson (1979) found that excessive fertilizer can induce lush vegetation stands that cannot be supported by the limited moisture available. Thornburg (1982) suggests that fertilizer use may be most appropriate on nontopsoiled areas.

Topsoil, higher in fertility and organic matter, may be replaced over subsoils to improve the seedbed (Cook, Hyde and Sims 1974). Additionally, topsoils can contain a trove of native seed materials which are otherwise unavailable. Benefits, however, are site dependent. Topsoiling costs range from 5-10,000 dollars per hectare (Wright, Berry and Blaser 1978) and available topsoil is often of low quality. Proper use requires careful analyses of subsoil and topsoil materials (Verma and Thames 1978).

Steep slopes rarely support satisfactory vegetation and should be reduced by grading (Thornburg 1982, Mortenson 1979). Furthermore, topsoil will not usually adhere to slopes greater than 25^{o} (Smith 1973). Binding on slopes can be aided by decreasing slope angles and tilling or applying topsoil to roughened areas (Wright, Perry and Blaser 1974). Reducing slope angles and controlling aspect can also favorably affect soil moisture and control solar load (Hassell 1977, Frank and Lee 1966).

In addition to slope reductions, soil surface modifications improve moisture retention and aid in seedling establishment (Cook, Hyde and Sims 1974). Small basins, pits or trenches create depressions for runoff and naturally conserve moisture (Hodder 1977). Woodruff and Blaser (1968) demonstrated that roughened surfaces, whether topsoil or subsoil, increased soil moisture, decreased temperatures, improved germination, and resulted in higher plant densities. A four fold improvement of vegetation cover on roughened subsoils was reported.

> "The detrimental practice of constructing seedbeds with smooth hard surfaces gives a false impression of 'finished grading' and a job well done, but vegetation often fails. Roughened surfaces, with rocks left in place, give an 'ugly' appearance to the novice, but encourage water infiltration and speed up the establishment of vegetation, as well as decrease the rate of water flow" (Wright, Perry, and Blaser 1978. p.559).

In areas where vegetation establishment may be difficult, or soils erosive, mulch is advised (Thornburg 1982). Mulches reduce runoff velocity, increasing water percolation into the soil. Mulches also decrease evaporation and reduce soil temperature (Kay 1978). Cook, Hyde and Sims (1974) propose the use of mulch over depressions created by surface modifications. Mulch alone cannot duplicate the benefits of a soil cover, and Springfield (1972) advocates the application of mulch only after the seeds have been covered with soil. Additionally, heavy mulch application can preclude seedling penetration. As a rule, some soil should be visible after mulch has been applied (Kay 1978).

Straw or hay mulch, favored by the Department of Transportation, requires anchoring and may introduce weedy species (Mortenson 1979). To diminish this problem, Kay (1978) suggests setting a maximum weed content of 0.5% by weight. This problem may be eliminated altogether by using wood fiber which additionally requires no anchoring (Thornburg 1982). Length is the major factor in stability of fibrous mulches and longer fibers yield greater erosion control (Kill and Foote 1971). Rock or gravel often overlooked as mulching materials may be readily available on site and have provided effective moisture conservation on highway slopes west of Phoenix (Hassell 1977). Meyer, Johnson, and Foster (1972) demonstrated that crushed stone can match or exceed the mulching effect of straw. Mulching is expensive and often a rocky undulating seedbed may be the cheapest and most effective treatment for establishing vegetation (Kay 1978).

Plant species selected should be based on planned land use and soil and climate limitations (Thornburg 1982). Adapted species or ecotypes should be selected for their tolerance to adverse conditions. Because of site diversity, the use of a species mix rather than a single species is advised (Plummer, Christenson, and Monsen 1968). Germination and purity of native seed species vary, hence seeding rates should always be expressed as pure live seed (PLS) (Long 1981). Cook, Hyde and Sims (1974) recommend rates of 215-269 PLS/m^2 for grass species in desert areas with surface modifications. When forbs and shrubs are included, they recommend seeding at 32-54 PLS/m^2 and slightly reducing the amount of grass seed. Increased amounts are advised for critical areas such as west and south facing slopes. Arizona Department of Transportation combined seeding rates for mixes range from 215-646 PLS/m^2 depending on the site (Mortenson 1979). Thornburg (1982) counsels that 215 PLS/m^2 is minimal and urges higher rates for use on unfavorable sites. The accepted rule is to double seeding rates for broadcast seeding or for unfavorable sites (Cook, Hyde and Sims 1974, Mortenson 1979).

There is no question that seeding operations should precede the season with the highest precipitation (Cook et al. 1974, Plummer et al. 1968, Jordon 1982, Thornburg 1982). Jordon (1982:56) argues that the "seedbed is a very poor place to store seeds". He therefore recommends that seeding preceed favorable moisture conditions by no more than three months if conditions are dry. Seed viability decreases the longer the seed remains dormant in the soil, and it is unwise to depend on seed from last season's seeding operation for the success of a revegetation project. Because of the importance of seeding in favorable moisture periods, further studies documenting the importance of site specific seeding dates are necessary.

Both drill and broadcast seeding are used in the southwest. Drill seeding insures better seed cover, results in higher germination and is commonly preferred (USDA/SEAM 1979). A rangeland drill featuring high clearance and rugged construction is widely used (Packer and Aldon 1978). On difficult sites drill use may be precluded and broadcasting is appropriate. Broadcasting methods must be followed by seed covering operations. Discing, harrowing, drag chaining or even hand raking are all used (Thornburg 1982, Mortenson 1979). Although expensive, hydroseeding a mix of seed, fertilizer, and mulch can be very effective on areas with difficult access or roughened seedbeds. To improve results, seed and mulch should be applied independently (Kay 1977).

The following questions arising from a review of literature need further study:

1. Can soil analyses be correlated to seeded species response?
2. Is the use of subsoils rather than expensive topsoil in the establishment of a protective cover appropriate?
3. Can differential establishment of species seeded in favorable and unfavorable moisture periods be documented and utilized?

The reclamation project by the Army Corps of Engineers at Adobe Dam provided an opportunity to conduct these studies. The thrust of this work is to develop inexpensive revegetation alternatives that maximize success through the understanding of natural ecological processes and responses.

SITE DESCRIPTION

Skunk Creek drains a 325km^2 watershed in the Basin and Range province of central Arizona. Because this watershed can generate considerable flood discharges, the Army Corps constructed Adobe Dam in the lower reaches of the Skunk Creek Basin, between the Hedgpeth Hills and Adobe Mountain (US Army Corps of Engineers 1978). The basin consists of quaternary alluvial plains abruptly interrupted by steep basaltic hills uplifted in the Tertiary period (Earl 1983).

Brown (1982) describes this region as Lower Colorado River Valley subdivision of the Sonoran Desert biome. Two major vegetation series occur in this subdivision: the Creosotebush-White Bursage series and the Saltbush series. Of the two, the first is most common. *Larrea divaricata* subsp. *tridentata* (Creosotebush) and *Ambrosia dumosa* (White Bursage) occur in broad plains and decrease in importance on upper bajada slopes. While *Ambrosia* barely extends past valley floors, *Larrea* maintains a position on steep slopes and often into mountainous regions (Brown 1982).

The Saltbush series can be found on gently sloping areas where finer soils promote greater water retention. These soils additionally decrease water penetration, resulting in higher soil salinity. *Atriplex polycarpa* may occur in pure stands in these areas. More commonly, *A. polycarpa* and *A. canescens* are found together in association with *Lycium* and *Prosopis*. When areas predominated by Saltbush are disturbed by heavy livestock grazing, exotic annuals such as *Schismus* (Mediterranean Grass), *Bromus rubens* (Red Brome), and *Sisymbrium irio* (Yellow Rocket) can become established (Brown 1982). Earl (1983) reported grazing by nearly 39,000 head of cattle in the central Skunk Creek Basin from 1900 to 1950.

Succession in the Lower Colorado River Valley subdivision, as described by Karpiscak and Grosz (1979) and Karpiscak (1980), involves mainly exotic species. It was reported that in abandoned agricultural fields, Salsola quickly invades, followed in two to three years by mustard species. These mustards are replaced in time by introduced annual grasses and other non-native species such as Erodium cicutarium (Filaree) and a few natives, most commonly, Spaeralcea (Mallow). Baccharis sarothroides (Desert Broom), Isocoma will usually become established before Larrea or Atriplex reoccupy the area.

Along washes where water is more available, Cercidium floridum (Blue Palo Verde), Olneya tesota (Ironwood), Prosopis glandulosa var torreyana (Honey Mesquite), and Psorothamnus spinosa (Smoketree) are common. Common associates include; Acacia greggi (Catclaw Acacia), Lycium andersonii (Anderson Thornbush) and Baccharis sarothroides (Brown 1982).

Other common Sonoran Desertscrub perennials include Encelia farinosa (Brittlebush), Fouquieria splendens (Ocotillo), Cercidium microphyllum (Foothill Palo Verde), Carnegiea gigantea (Saguaro), Opuntia bigelovii (Teddybear Cholla), Mammilairia tetrancistra (Pincushion Cactus) Echinocereus engelmannii (Englemann Hedgehog) and Ferocactus acanthodes (Barrel cactus) (Brown 1982).

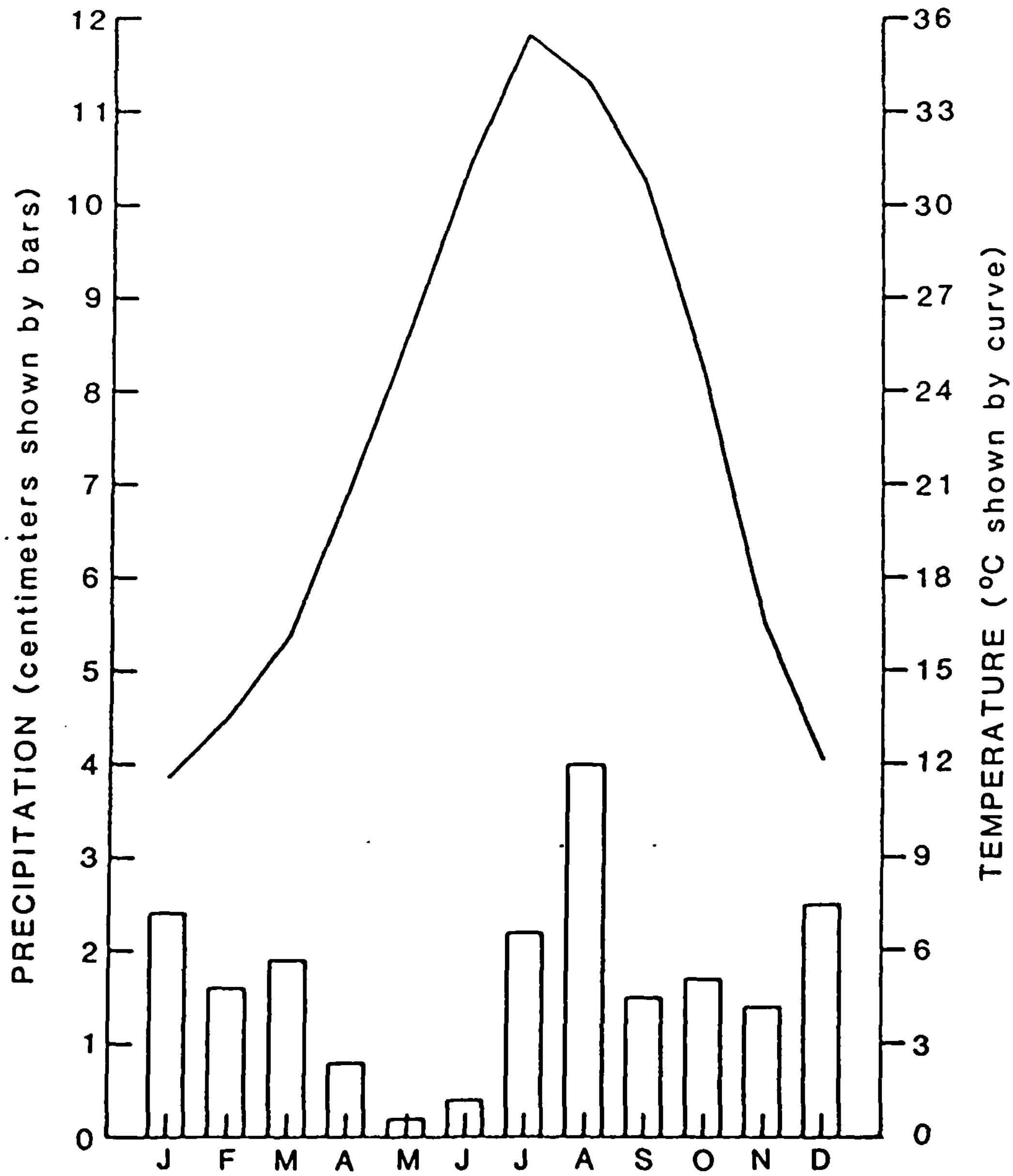
Gasser (1983) noted that Skunk Creek is lined with Cercidium floridum, Prosopis glandulosa var torreyana, Olneya tesota, Acacia *greggi*, *Baccharis sarothroides*, *Celtis pallida* (Desert Hackberry), and *Condalia lycoides* (Greythorn). The alluvial plains are characterized by *Larrea*. He further reports that the basaltic hills commonly support *Carnegiea gigantea*, and *Cercidium microphyllum*.

Soils in the vicinity of Adobe Dam have been mapped by the Soil Conservation Service (1977) and are mostly Antho-Brios sandy loams. These furnished the topsoils used in facing the west dam slopes. The Hedgpeth Hills and Adobe Mountain at either end of the dam are Cherian rock outcrop complexes; shallow gravelly loams over basaltic bedrock. The soils adjacent to Adobe Mountain are Estrella loams and were used for topsoiling the east dam face. The borrow pit, located behind the dam, provided fill materials (Gunsight-Rillito complexes).

Temperature and precipitation data collected from a nearby weather station in Deer Valley reflect the mild winters and hot summers typical of this area (Figure 1). This station reports freezing temperatures on the average of only 25 days annually. Conversely, temperatures in excess of 43°C are common in late June through mid-July before the summer rainy season. Throughout the year, clear skies and dry air facilitate rapid daily surface heating. In areas exposed to nightly cool air drainage, wide diurnal temperature changes can result (Sellers and Hill 1974).

Precipitation in this region averages 18-25 cm annually and is bimodally distributed with December/March July/August maxima (Laboratory of Climatology 1975). Winter precipitation, accounting for 60% of the total, is the result of middle latitude systems forming in the north Pacific and moving eastward. These storms occasionally intensify off

Figure 1. Mean monthly temperature and precipitation for Deer Valley, Arizona.



NOTE: Mean values for period 1950-1970 as reported in Sellers and Hill (1974).

the southern California coast. In summer months, moist tropical air from the Gulf of Mexico rises over mountains and cumulonimbus buildup occurs. As these thunderheads pass over intensely heated ground surfaces, high winds and brief convection thunderstorms result. Weak tropical disturbances moving across Arizona from the Pacific and Gulf of California add to summer precipitation (Sellers and Hill 1974).

Both long duration and high intensity precipitation cause ephemeral flow in Skunk Creek for a mean of seven days annually (Earl 1983). Therefore, the dam retains no permanent reservoir. The dam located at 411.5 m elevation, is earth fill type construction and over 3.4 km in length. The 22° dam face has a south-southeast aspect and is divided at one-third its length by the 35th avenue overpass.

MATERIALS AND METHODS

Slope preparation included removal of large stones and bulldozing fill materials to create a smooth surface. This even surface was completely overlain with 15 cm of crushed rip-rap. The final surface was not homogeneous. Topsoil entirely covers rip-rap east of 35th Avenue; west of 35th Avenue topsoil alternates with rip-rap covered fill. Between the stone rip-rap no fill was visible.

The seed mix of species described below, was applied to the dam face at the rate of 8.7 kg/ha using a Fynn paddle agitation hydroseeder and no mulch. Three _Atriplex_ species were seeded at Adobe Dam. _Atriplex_ is a genus known for drought resistance and tolerance of saline and alkaline soil conditions.

Atriplex canescens (Four-wing Saltbush) is a long lived perennial shrub that is easily established from seed. Once established, it is fairly cold hardy; however young plants are frost sensitive. A deep rooting system provides erosion control and on mine tailings this saltbush has competed successfully with *Salsola* (Hassell 1977). This species was seeded at a rate of 2.2 kg/ha PLS. Recommended rates are 2.2-4.5 kg/ha for broadcast seeding (Jordon 1981, Nord 1977, Thornburg 1982).

Atriplex polycarpa (Desert Saltbush) is not as cold tolerant as Four-wing Saltbush; however, it is more drought tolerant, establishing successfully with as little as 7.5 cm of rainfall annually (Thornburg 1982). It thrives on deep well drained soils at elevations up to 1.5 km. Desert saltbush is easily established on harsh sites and is most often used in conjunction with other *Atriplex* species (Nord 1977, Hassell 1977). *Atriplex polycarpa* was seeded at the rate of 1.0 kg/ha PLS.

Atriplex lentiformis (Quailbush) is tolerant of extreme heat and cold. Quailbush does best with additional water from runoff or where deep roots can penetrate to a shallow water table. Vigorous seedlings and rapid growth characterize this plant which grows at low elevations with a mean annual precipitation of 17.5 cm (Thornburg 1982, Hassell 1977, Duffield and Jones 1981). *Atriplex lentiformis* was seeded at a rate of 2.5 kg/ha PLS.

Baccharis sarothroides (Desert Broom) is an aggressive pioneer on disturbed sites. It has been widely used for revegetation and erosion control on streambanks. Desert broom adapts to a variety of soil types and is moderately salt tolerant. Occasional irrigation may be required for establishment of this species in areas with less than 25 cm of annual rainfall. Seed from *Baccharis* is difficult to collect and clean but has a high germination rate, promoting rapid spreading of this plant once established (Thornburg 1982, Duffield and Jones 1981). *Baccharis sarothroides* was seeded at the rate of 0.7 kg/ha PLS.

Encelia farinosa (Brittlebush) is easily established from seed, however seed germination inhibitors in the seed coat may result in a long dormancy period. Nord (1977) recommends soaking seed in Clorox before seeding. Brittlebush is drought tolerant and does best with 25-30 cm of annual rainfall. It is not very tolerant of saline or alkaline conditions (Nord 1977, Duffield and Jones 1981). *Encelia farinosa* was seeded at the rate of 0.67 kg/ha PLS.

Plantago insularis (Indian Wheat) is an easily established annual. It is most often used for quick color in seeding operations. Erosion control is limited due to the small root system. Drought tolerance and tolerance to salinity varies with ecotype (Kearny and Peebles 1960).

Areas east of 35th Avenue were seeded on February 9, 1982. The topsoil and rip-rap areas west of 35th Avenue were seeded on March 23 of the same year. Only topsoiled areas were drag chained to cover the seed.

Climatological data documenting precipitation and temperature patterns were collected weekly during the study period

(February-September 1982). Sixes type minimum/maximum thermometers located inside the Army Corps' Adobe Dam compound recorded air temperature at 30 cm. above ground surface. Rain gauges, consisting of number 10 cans with a layer of mineral oil to prevent evaporation, were positioned throughout the study area. Arizona State University Climatological Laboratory provided corresponding data for two proximate weather stations. Solar input for the dam slopes and horizontal areas was assessed using potential irradiation at 34° latitude (Frank and Lee 1966).

A small slope of fill material was constructed in the borrow pit behind the dam to simulate the dam face without topsoil or rip-rap cover. The surface was left rough and was seeded at the same time as the east portion of the dam.

Soils from four study areas at Adobe Dam were compared: east dam topsoils, west dam topsoils, west rip-rap covered fill soils, and soils from the specially constructed slope of fill material. Soil samples were randomly collected along transects in study areas and analyzed for major soil parameters affecting soil fertility. Percent gravel was determined gravimetrically. Standard methods measured texture, electrical conductivity, pH, soil cations (ammonium acetate procedure) and exchangable ammonium-nitrogen (Black 1965). Nitrate-nitrogen was determined by potassium chloride extraction and reduction through a column of cadmium filings (American Public Health Association in 1975). Summing ppm nitrate-nitrogen and ammonium-nitrogen yielded total available nitrogen. Phosphorus was determined by sodium bicarbonate extract (Watanabe and Olsen 1965).

Irregularities in the soil surface were measured as an indication of microhabitat potential. In each slope study area, the distance between the surface and a taunt line was measured at random distance points. The standard deviation of these measurements reflect surface variability, with the larger standard deviations implying rougher microterrain.

Vegetation sampling was conducted at the end of the spring growing and summer rainy seasons. For sampling purposes, the east and west study areas were divided into five 7.6 km^2 sections. The small fill slope was not divided. A modification of Daubenmire's Canopy-coverage technique (Daubenmire 1959) positioned a 2x5 dm plot frame randomly along top, middle, and bottom transect lines for a total of 40 sample frames per section. Within the frame, occurrence and numbers of species were noted. Frequency and density for each species were calculated.

The SAS and BMDP statistical software packages were used in computer analysis of data. The general linear model for analysis of an unbalanced design was used. Statistical differences between mean values for different areas were evaluated with Duncan's multiple range test. Correlations were determined using the Spearman rank coefficient. Equations to determine relationships between soil factors and seeded species were determined using stepwise multiple regression analysis. Transformations were performed when necessary to meet the assumptions for analysis of variance.

RESULTS AND DISCUSSIONS

Temperature data from Adobe Dam and weather stations in Deer Valley and Youngtown show a slight trend for warmer maximum temperatures at the dam (Table 1). Winter precipitation differs moderately for the three areas (Table 2). The highly localized nature of summer convection storms causes summer rainfall variations between stations.

Although values for solar beam irradiation potentially hitting study areas (Figure 2) may differ from actual irradiation, they allow comparison of solar load for this study area to other locations and provide a fairly accurate measure of this site factor (Frank and Lee 1966). Seeding date one corresponded with the lowest irradiation values. These increased gradually throughout the study period, and did not taper off until August.

Microterrain evaluations (roughness) based on the variability of the soil surface did not differ significantly for the areas (Table 3), indicating an overall uniformity of the slope surface. This does not mean that surfaces were uniformly smooth but that roughness variations were similar among areas.

Soil analyses are presented in Table 3. Texture determinations characterized the east topsoils as loams, the west topsoils as a mix of sandy loams and loams, and the rip-rap covered fill and fill slope soils as sandy loams. The two fill soils, with the slope fill being most extreme, are higher in gravel and sand and lower in clay than the two topsoils. The east topsoils are highest in clay and lowest in sand. Therefore, one would expect the east topsoils and the slope fill soils to exhibit texture-related chemical differences.

TABLE 1. Weekly Temperatures in Centigrade. February through September 1982.

Week ending	Adobe Dam		Deer Valley		Youngtown	
	Max	Min	Max	Min	Max	Min
2/9	19	-1	18	-1	19	-1
2/16	27	8	24	7	24	7
2/23	31	8	30	8	29	8
3/2	27	7	26	7	27	8
3/9	29	3	27	4	28	3
3/16	28	9	27	9	28	9
3/23	26	1	24	3	24	2
3/30	28	7	25	4	26	6
4/16	27	4	28	5	28	7
4/13	33	4	32	2	32	6
4/20	33	8	33	8	33	9
4/27	34	8	33	7	34	9
5/4	35	14	36	13	36	16
5/11	35	12	34	11	35	13
5/18	37	11	36	11	37	10
5/25	39	13	34	13	38	14
6/1	38	14	36	14	38	15
6/8	38	15	38	15	37	14
6/15	41	14	37	13	40	16
6/22	42	19	39	18	41	19
6/29	42	18	42	17	43	21
7/6	41	16	42	17	39	18
7/13	43	20	43	21	43	22
7/20	46	23	44	25	44	23
7/27	46	22	42	23	43	23
8/3	42	23	41	26	42	23
8/10	45	24	43	24	44	24
8/17	42	21	42	22	41	22
8/24	43	21	45	22	44	20
8/31	42	21	42	21	41	22
9/7	46	24	43	24	44	24
9/14	37	15	33	16	36	17
9/21	39	16	39	17	39	18
9/27	40	21	42	17	42	21

Values for Centigrade for Youngtown and Deer Valley were obtained from Arizona State University Climatological Laboratory.

TABLE 2. Precipitation in Centimeters. February through September 1982.

Period ending	Adobe Dam	Deer Valley	Youngtown
2/10	11	5	3
2/17	13	12	12
2/24	14	7	4
3/2	-	-	-
3/9	-	2	18
3/17	38	27	34
3/23	6	4	5
3/31	8	14	6
4/6	-	-	-
4/13	4	2	-
4/21	-	-	-
4/27	-	-	-
5/6	5	-	14
5/12	3	T	4
5/19	-	-	-
5/24	-	-	-
6/2	-	-	-
6/8	-	-	-
6/15	-	-	-
6/22	-	-	-
6/29	-	-	-
7/7	3	5	14
7/13	1	-	-
7/19	2	1	2
7/27	11	8	8
8/2	12	3	16
8/10	-	-	-
8/16	20	13	15
8/24	8	70	49
9/3	-	-	1
9/8	7	1	-
9/14	-	4	1
9/20	-	-	1
9/27	-	-	-

Values for Deer Valley and Youngtown were obtained from Arizona State University Climatological laboratory.

Note: Precipitation is reported here on a semiweekly basis and may include more than one rainfall event.

FIGURE 2. Potential daily solar irradiation for a 22° angle SSE slope at 34° latitude Values from Frank and Lee (1966).

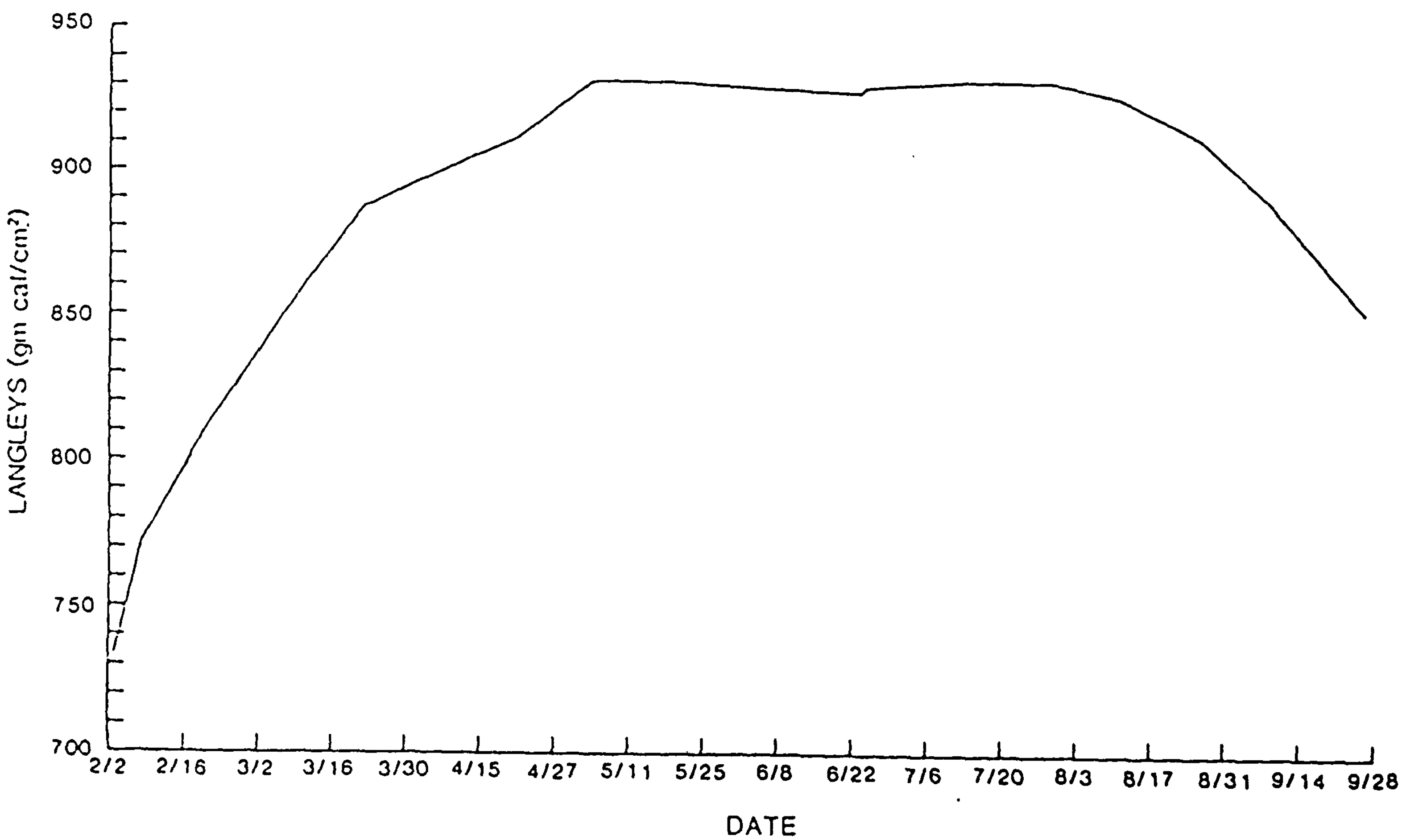


TABLE 3. Mean values from analyses of soils from four locations at Adobe Dam.

	East topsoil	Fill slope	West topsoil	Rip-rap covered fill
Percent sand	49.95 D	70.37 A	55.78 C	65.85 B
Percent clay	18.67 A	10.37 D	14.42 B	13.12 C
Percent gravel	19.77 C	52.37 A	20.07 C	36.69 B
EC*	1.35 A	1.00 A	1.42 A	1.35 A
pH	7.82 C	8.50 A	7.79 C	7.97 B
Nitrate nitrogen (ppm)	15.80 A	7.00 A	14.62 A	8.92 A
Ammonium nitrogen (ppm)	°.23 A	3.70 B	4.94 B	3.52 B
Total nitrogen (ppm)	25.12 A	10.70 B	19.56 AB	12.44 B
Phosphorus ($NaHCO_3$) (ppm)	4.62 AB	3.30 BC	5.94 A	2.42 C
Calcium (ppm)	7150.00 A	6350.00 B	6930.00 A	6155.00 B
Magnesium (ppm)	545.60 A	584.00 A	377.60 B	550.40 A
Sodium (ppm)	278.40 B	586.00 A	203.60 B	236.60 B
Potassium (ppm)	190.80 AB	137.00 C	302.40 A	236.60 B

*Electrical Conductivity in mmhos/cm. Values 4 indicate saline conditions.

NOTE: Values in same rows followed by same letter are not significantly different at the 0.05 level.

Values for electrical conductivity, an indirect measure of salinity, did not indicate saline conditions often associated with desert soils and were not significantly different for test areas. Values for pH differed significantly between slightly alkaline topsoils and moderately alkaline fill materials. Arid soils are typically alkaline, and pose no problem for desert-adapted plant species.

Nitrogen, often the limiting factor in plant growth, is generally low in the tested soils. Topsoils, as expected, were higher in total available nitrogen, with the east area topsoils significantly higher than the two fill soils.

Phosphorous values obtained at Adobe Dam are low in comparison to agricultural soils, but within the range for "virgin" (nonagricultural) soils (Tisdale and Nelson 1975). Quantities present should be sufficient to support native vegetation.

High sodium levels can be problematic. Many species are sensitive to excesses and high amounts deteriorate soil structure, reducing porosity and water infiltration. Sodium values determined at Adobe Dam are insufficient to warrant concern. The other soil cations; magnesium, calcium and potassium are within normal expected ranges for arid, slightly alkaline soils (Chapman 1965).

Fill soils, less fertile than topsoils, were significantly lower in nitrogen and clay, as well as higher in pH, gravel, sand, and sodium. Despite these differences, no major soil problems were detected that preclude vegetation establishment.

Satistical comparison of species densites for the study areas (Table 4) demonstrate the importance of seeding in favorable moisture periods.

TABLE 4. Mean density values (m^2) for seeded and selected nonseeded species.

Species	East topsoil[1]	Fill Slope[1]	West topsoil[2]	Rip-rap covered fill[2]
Seeded				
Atriplex canescens	6.52 A	2.88 B	0.91 C	0.03 D
Atriplex lentiformis	4.75 A	2.31 B	1.17 B	0.10 C
Atriplex polycarpa	8.53 A	8.41 B	2.12 C	0.18 D
Baccharis sarothroides	0.64 A	0.00 B	0.25 AB	0.21 AB
Encelia farinosa	1.67 A	2.19 A	0.39 B	0.08 B
Plantago insularis	5.76 A	10.27 A	0.39 B	0.00 B
Nonseeded				
Erodium cicutarium	0.50 A	0.00 C	0.21 B	0.03 C
Salsola paulsenii	0.70 B	0.35 B	1.34 B	5.22 A
Schismus barbatus	3.99 A	0.00 B	0.84 AB	0.20 B
Sphaeralcea	0.00 B	0.00 B	3.91 A	0.00 B

[1]Seeded 2/2/82

[2]Seeded 3/23/82

NOTE: Values in same row followed by same letter not significantly different at 0.05 level.

Plant densities for Seed date 1 (February 2) are consistently and significantly higher than the other seed time (March 23) with the exception of Baccharis which was low to nonexistant in all areas. Two samples were made and the data generated survivability information. Small significant differences were exhibited. Baccharis densities decreased on the east topsoils. Even at this earlier seed date (February 2) seedling establishment was not adequate to maintain densities during the onslought of summer. Encelia also showed significant declines on the fill slope due in part to high initial establishment. Atriplex polycarpa and A. lentiformis decreased on the west topsoiled areas and rip-rap covered fills respectively.

Topsoils generally supported higher species densities than the fill soils for each seeding date. This is due to higher fertility of the topsoils as well as their stored seed reserves. Encelia and Plantago, however, tended to be nonsignificantly higher on the fill slope. This may be due to low diversity as evidenced by the absence of Baccharis, Erodium, and Schismus. The absence of the nonseeded species as well as the low numbers of Salsola can be explained by the distance between the fill slope and natural seed sources. The absence of Baccharis is more difficult to explain. The high numbers of Encelia found on the fill slope and February seed date may provide answers.

High densities of A. polycarpa occurred at all locations and reflect a greater drought tolerance than the other Atriplexes. Of the Atriplexes, A. canescens and A. polycarpa exhibit similar distributions in the different areas. Low densities for all seeded species proved the rule for the rip-rap covered areas. Salsola, however, exhibited its highest densities for this area, most likely because of low densities of other species. The primary cause of low densities on rip-rap is probably poor seed/soil contact due to the depth and thickness of the rip-rap cover.

Correlation data for the topsoiled areas are presented in Table 5. The small sample size of the fill slope and the low densities on rip-rap covered fills exclude them from analysis with soil factors. There were substancial differences in correlation relationships between east and west topsoiled areas that are not easily explained by differences in soil factors. The two seeding dates likely effected soil-vegetation relationships. Drought and nonseeded species competition are therefore important in explaining differences in correlations.

In general, vegetation response was positively correlated with nitrate-nitrogen and total available nitrogen for all species with the exception of *A. lentiformis* on the west topsoil area. Responses were inconsistently correlated with ammonium, sometimes showing a negative correlation, as evidenced by *Baccharis* and *Plantago* on the east topsoil. Phosphorus was strongly negative in correlation with the *Atriplex* species on the west topsoil.

The contrary negative relationships of seeded species with nitrogen variables and phosphorus can be understood by examining major nonseeded species correlations with these same soil variables (Table 6). West topsoils, seeded later, allowed more time for nonseeded species establishment without competition from seeded species. Strongly correlated associations of *Salsola*, *Erodium*, and *Sphaeralcea* to nitrogen variables were observed on west topsoils. It is likely then, that the

TABLE 5. Spearman rank correlation coefficients: seeded densities with soil variables.

Species	Soil Variables													
	E.C.	pH	Sand	Gravel	Clay	Phosphorus	Nitrate nitrogen	Ammonium nitrogen	Total nitrogen	Calcium	Magnesium	Sodium	Potassium	Roughness
Atriplex canescens														
East topsoil	-0.06	-0.06	0.08	-0.26	0.14	-0.08	0.56	-0.02	0.54	-0.42	0.11	0.07	-0.27	0.33
West topsoil	0.63	-0.39	-0.18	-0.27	0.28	-0.51	0.57	0.01	0.57	-0.29	-0.09	-0.06	0.38	-0.37
Atriplex lentiformis														
East topsoil	0.39	-0.47	-0.05	0.41	-0.04	-0.06	0.20	0.25	0.27	-0.08	0.13	0.26	-0.28	-0.10
West topsoil	0.17	-0.06	0.21	-0.25	-0.39	-0.59	-0.29	-0.35	-0.29	-0.44	-0.69	0.23	-0.51	-0.19
Atriplex polycarpa														
East topsoil	-0.01	-0.11	0.06	-0.27	0.06	-0.06	0.62	0.01	0.63	-0.46	0.08	0.07	-0.31	0.23
West topsoil	0.67	-0.52	0.15	-0.36	0.05	-0.51	0.32	-0.17	0.30	-0.57	-0.17	-0.26	0.27	-0.34
Baccharis sarothroides														
East topsoil	-0.17	-0.68	0.38	-0.55	-0.38	0.32	0.24	-0.59	0.27	0.04	-0.68	-0.63	0.46	0.05
West topsoil	0.26	0.08	-0.01	0.04	0.01	0.13	0.44	-0.22	0.44	0.05	0.22	0.05	0.30	-0.12
Encelia farinosa														
East topsoil	0.60	-0.07	-0.47	-0.47	0.61	-0.61	0.09	0.25	0.25	-0.44	0.57	0.57	-0.53	0.15
West topsoil	0.40	-0.47	0.02	-0.03	0.09	-0.10	0.69	-0.10	0.69	0.02	0.18	0.02	0.47	0.14
Plantago insularis														
East topsoil	-0.52	0.14	0.32	-0.50	-0.16	0.07	0.24	-0.37	0.18	-0.17	-0.20	-0.31	0.15	0.30
West topsoil	0.00	0.24	-0.22	0.10	0.03	0.22	0.22	0.16	0.22	0.33	0.25	0.09	0.18	0.17

NOTE: East topsoil seeded 2/2/82 West topsoil seeded 3/23/82
Spearman rank coefficients $r = 0.35$ at $p = 0.10$; $r = 0.45$ at $p = 0.05$; $r = 0.60$ at $p = 0.01$

TABLE 6. Spearman rank correlation coefficients: selected nonseeded densities with soil variables.

	Soil Variables													
Species	E.C.	pH	Sand	Gravel	Clay	Phosphorus	Nitrate nitrogen	Ammonium nitrogen	Total nitrogen	Calcium	Magnesium	Sodium	Potassium	Roughness
Erodium cicutarium														
East topsoil	-0.16	0.35	-0.11	0.00	-0.02	0.32	-0.53	-0.06	-0.70	0.54	-0.19	-0.25	0.46	-0.09
West topsoil	0.53	0.05	-0.33	-0.07	0.47	-0.08	0.70	0.26	0.70	0.15	0.31	-0.07	0.59	-0.12
Salsola paulsenii														
East topsoil	-0.09	0.22	-0.18	-0.25	0.13	-0.62	-0.08	-0.13	0.15	-0.46	0.31	0.21	-0.27	-0.11
West topsoil	0.20	0.35	-0.76	-0.29	0.66	-0.04	0.37	0.84	0.37	0.56	0.24	0.09	0.33	-0.10
Schismus barbartus														
East topsoil	-0.26	0.60	-0.34	0.26	0.42	0.38	-0.01	0.54	-0.08	0.10	0.08	0.06	0.05	0.08
West topsoil	-0.31	0.15	-0.12	-0.24	-0.15	0.57	-0.06	0.15	-0.06	0.13	0.57	-0.39	0.33	-0.05
Sphaeralcea sps.														
East topsoil	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
West topsoil	-0.16	0.22	0.02	-0.20	-0.07	0.65	0.28	0.02	0.27	0.27	0.68	-0.22	0.48	0.06

NOTE: East topsoil seeded 2/2/82 West topsoil seeded 3/23/82
Spearman rank coefficients $r = 0.35$ at $p = 0.10$; $r = 0.45$ at $p = 0.05$; $r = 0.60$ at $p - 0.01$

negative correlation for some seeded species with phosphorus and nitrogen are due to competition with nonseeded species.

Although relationships on the two topsoiled areas are different, A. canescens and A. polycarpa densities are similarly correlated to soil variables. This similarity may explain why A. canescens and A. polycarpa are commonly associated in natural plant communities (Brown 1982). A. lentiformis differed from the other Atriplex species. There were significant correlations to potassium and magnesium which were not matched by the other Atriplex species. Density relationships to pH, electrical conductivity, and clay were markedly different. A. lentiformis further differed in that it was the only species that revealed negative correlations with nitrate-nitrogen and total available nitrogen. This may suggest poorer competitive establishment when nitrogen is more limiting. All three Atriplex species showed little relationship to phosphorus on the east topsoil where tests revealed phosphorus to be relatively high (Table 3). Strong negative correlations between Atriplex species and phosphorus however, were evident on the west topsoil. This may imply a more efficient phosphorus association with weedy competitors on the later site. Indeed, Sphaeralcea and Schismus demonstrate a strong positive correlation to phosphorus on west topsoils (Table 6).

Baccharis and Encelia both show positive correlations with nitrate-nitrogen and total nitrogen, but are notably different in their relationship to other soil factors. However, Baccharis has a significant negative association with ammonium which can be interpreted as a competition response. Encelia and Baccharis show contradicting significant correlations with variables sodium, clay, magnesium and potassium. This trend is followed and illustrated by a significant negative correlation between Encelia and phosphorus and a positive correlation between Baccharis and phosphorus.

Plantago follows the major trends of positive correlation to nitrate and total nitrogen as well as the contrary negative correlation to ammonium observed at this site. The differing correlations observed for the two areas do not correspond to major soil differences (Table 3) and show that nonsoil factors like competition and differing seeding date must be considered.

Table 7 shows the correlation coefficients between seeded and four nonseeded species. The overall implication is that negative correlations observed are due to a competitive response between seeded and nonseeded species. Additionally, it can be surmised, that when seeded densities are low (as with the later seeded areas) weedy species like Salsola take over. The significant negative correlation between Salsola and Atriplex canescens supports evidence (Hassell 1977) that A. canescens successfully competes with Salsola.

Combinations of soil factors regressed with plant densities explain substantial variability in plant densities (Table 8). Nitrate-nitrogen proved to be the foremost factor in the equations. Other important variables included pH, followed by EC, clay, and gravel. Total cations and roughness, although not prominant in all equations, did account for sizable variations in selected species (A. lentiformis in particular). Equations generated for the east topsoil areas accounted for more of the species variation than did equations for the west topsoil areas. Strong

TABLE 7. Spearman correlation coefficients: Seeded densities with selected nonseeded densities.

Species	*Salsola paulsenii*	*Schismus barbatus*	*Sphaeralcea* sps.	*Erodium cicutarum*
Atriplex canescens	-0.31	0.20	-0.17	0.48
Atriplex lentiformis	-0.30	0.08	-0.13	0.35
Atriplex polycarpa	-0.34	0.14	-0.12	0.35
Baccharis sarothroides	-0.12	-0.05	0.20	0.23
Encelia farinosa	-0.33	0.16	-0.06	0.27
Plantago insularis	-0.20	0.25	-0.04	0.43

NOTE: Spearman rank coefficients $r = 0.18$ at $p = 0.10$
$r = 0.23$ at $p = 0.05$
$r = 0.33$ at $p = 0.01$

TABLE 8. Stepwise multiple regression equations: seeded species densities with soil variables*

Species	Intercept	First step	Second step	Third step	Fourth step	Fifth step	Sixth Step	Final r^2
Atriplex canescens								
East topsoil	- 42.73	+ 0.48 N	+ 0.41 C	- 0.38 G	+5.26 H			0.53
r^2		0.34	0.50	0.50	0.53			
West topsoil	18.27	+ 0.63 E	- 2.39 H					0.55
r^2		0.52	0.55					
Atriplex lentiformis								
East topsoil	250.76	-33.32 H	+ 0.10 G	- 0.77 R				0.75
r^2		0.34	0.69	0.75				
West topsoil	89.36	- 0.01 T	- 0.80 G	+ 1.10 R	+0.38 N	-1.56 E		0.62
r^2		0.36	0.43	0.55	0.58	0.62		
Atriplex polycarpa								
East topsoil	-313.18	+ 1.63 N	+39.33 H	+ 5.24 E	-0.52 G	-1.16 R		0.68
r^2		0.44	0.53	0.56	0.62	0.68		
West topsoil	97.86	+ 2.44 E	-12.22 H	- 0.19 N	-0.26 C	+0.23 R		0.72
r^2		0.55	0.61	0.66	0.70	0.72		

*C = Clay E = Electrical conductivity G = Gravel H = pH N = Nitrate R = Roughness T = Total cations

TABLE 8. (Completed)

	Intercept	First step	Second step	Third step	Fourth step	Fifth step	Sixth step	Final r^2
<u>Baccharis sarothroides</u>								
East topsoil	275.66	- 0.08 N	-29.91 H	- 2.96 E	+0.76 C	-0.01 T		0.76
r^2		0.40	0.52	0.58	0.74	0.76		
West topsoil	- 30.01	+ 0.05 N	+ 3.89 H	- 0.06 C				0.42
r^2		0.15	0.36	0.42				
<u>Encelia farinosa</u>								
East topsoil	243.75	+ 0.89 C	- 0.02 T	-13.04 H	-0.48 N	+0.21 G	+1.22 E	0.93
r^2		0.26	0.50	0.63	0.84	0.91	0.93	
West topsoil	19.53	+ 0.08 N	- 0.10 C	- 2.43 H				0.66
r^2		0.55	0.62	0.66				
<u>Plantago insularis</u>								
East topsoil	-129.48	+ 0.57 N	- 1.13 G	+18.06 H	+3.01	-4.91 E		0.72
r^2		0.25	0.39	0.55	0.67	0.72		
West topsoil	7.06	+ 0.17 N	- 0.21 G	- 0.30 C				0.26
r^2		0.15	0.20	0.26				

*C = Clay E = Electrical conductivity G = Gravel H = pH N = Nitrate R = Roughness T = Total cations similarities are however, evident between equations. Notable is the high r^2 value obtained by regressing A lentiformis with just three variables (Table 8). Less variability was explained for the other Atriplexes. Encelia and Baccharis appear more selective and thus their variation is easier to explain. Only seven soil factors provide sizable explanations for variations, demonstrating that soil factors are related to species response.

The seeding operation at Adobe Dam provided rich opportunities to examine revegetation techniques. Topsoiling was not necessary for this particular site and seeding earlier in the rainy season would have raised densities for seeded species. If erosion control and plant establishment both are desired, then rip-rap areas to be seeded should have less rip-rap cover. Fill materials should be visable between the stone (Kay 1978), providing greater potential for seed/soil contact. Relations between soil variables and plant species yielded management decision information. The most important variable, nitrate-nitrogen is easily manipulated. Both regressions and correlations indicate that application of nitrogen fertilizer, as recommended by Cook, Hyde and Sims (1974), would result in greater densities of species.

Roughness, although not as major an accounting factor, is important in creating habitats. The contradicting negative and positive correlations reveal that roughness is a complex soil factor. Trade-offs need to be made between the favorable creation of microhabitat potential and the sacrifice of seed soil contact. Blaser and Woodruff (1968) conducted their study on the microhabitats created by roughened seedbeds in a humid region. The positive correlation with roughness on east topsoils and the negative correlation on west topsoils may result from higher moisture stress during the second seeding. Decreased seed/soil contact severely restricts water imbibition by seeds and in unfavorable moisture periods this factor limits germination. It is believed, however, that the benefits of a roughened seedbed justify its use when seeding dates correspond with favorable moisture periods.

LITERATURE CITED

American Public Health Association. 1975. Standard methods for the analysis of water and waste water. Fourteenth edition. American Public Health Association, New York, New York, USA.

Black, C. A., editor. 1965. Methods of soil analysis. American Society of Agronomy, Madison, Wisconsin, USA.

Blaser, R. E., and J. M. Woodruff. 1968. The need for specifying two-or three-step seeding and fertilization practices for establishing sod on highways. Report number 246, National Academy of Sciences, Highway Resource Recovery, Washington, District of Columbia, USA.

Brown, D. E., editor. 1982. Desert plants: Biotic communities of the American Southwest - United States and Mexico. University of Arizona, Tucson, Arizona, USA.

Chapman, H. D., editor. 1975. Diagnostic criteria for plants and soils. Quality Printing Company, Incorporated, Abilene, Texas, USA.

Cook, C. W., R. M. Hyde, and P. L. Sims. 1974. Guidelines for revegetation and stabilization of surface mined areas. Science Series Number 16, Range Science Department, Colorado State University, Fort Collins, Colorado, USA.

Daubenmire, R. 1959. A canopy-coverage method of vegetational analysis. Northwest Science 33 (1):43-66.

Duffield, M. R. and W. D. Jones. 1981. Plants for dry climates. High Performance Books, Tucson, Arizona, USA.

Earl, R. A. 1983. Paleohydrology and paleoclimatology of the Skunk Creek Basin during Holocene time. Doctoral Dissertation, Arizona State University, Tempe, Arizona, USA.

Frank, E.C. and R. Lee. 1966. Potential solar beam irradiation on slopes. United States Forest Service Research Paper RM-18, Rocky Mountain Forest and Range Experimental Station, Fort Collins, Colorado, USA.

Gasser, R. E. 1983. Modern vegetation in the Adobe Dam project area. Pages 24-26 in R. A. Earl. Paleohydrology and paleoclimatology of the Skunk Crek Basin during the Holocene time. Doctoral Dissertation, Arizona State University, Tempe, Arizona, USA.

Hassell, W. G. 1977. Plant species for critical areas. Pages 340-346 in J. L. Thames, editor. Reclamation and use of disturbed lands in the Southwest. University of Arizona Press, Tucson, Arizona, USA.

Hodder, R. L. 1977. Dry land techniques in the semiarid west. Pages 217-223 in J. L. Thames, editor. Reclamation and use of disturbed lands in the Southwest. University of Arizona Press, Tucson, Arizona, USA.

Jordon, G. L. 1981. Range seeding and brush management on Arizona rangelands. Cooperative Extension Service, Agricultural Experiment Station, College of Agriculture, University of Arizona, Tucson, Arizona, USA.

Karpiscak, M. M. and O. M. Grosz. 1979. Secondary succession of abandoned fields in southern Arizona. Arizona-Nevada Academy of Science 14 (Suppliment):23.

Karpiscak, M. M. 1980. Secondary succession of abandoned fields in southern Arizona. Doctoral dissertation. University of Arizona, Tucson, Arizona, USA.

Kay, B. L. 1978. Mulch and chemical stabilizers for land reclamation in dry regions. Pages 467-482 in F. W. Schaller and P. Sutton, editors. Reclamation of drastically disturbed lands. American Society of Agronomy, Crop Science Society of America, Soil Science Society of America, Madison, Wisconsin, USA.

Kearney, T. H. and R. H. Peebles. 1960. Arizona flora. Second edition. University of California Press, Berkeley, California, USA.

Kill, K. D. and L. E. Foote. 1971. Comparisons of long and short-fibered mulches. Transcripts of American Society Agricultural Engineers 14:942-944.

Laboratory of Climatology. 1975. Arizona precipitation. Cooperative Publication Number 5, Arizona Resources Information System, Tempe, Arizona, USA.

Long, S. G. 1981. Characteristics of plants used in western reclamation. Second edition. Environmental Research and Technology, Incorporated, Fort Collins, Colorado, USA.

Meyer, L. D., C. B. Johnson, and G. R. Foster. 1972. Stone and woodchip mulches for erosion control on construction sites. Journal of soil and Water Conservation 27:264-269.

Mortenson, M. A. 1979. Establishing vegetation on highway Slopes in Arizona. Desert Plants 1 (2):58-60.

Nord, E. C. 1977. Shrubs for revegetation. Pages 284-301 in J. L. Thames, editor. Reclamation and use of disturbed lands in the Southwest. University of Arizona Press, Tucson, Arizona, USA.

Packer, P. E. and E. F. Aldon. 1978. Revegetation techniques for dry regions. Pages 425-450 in F. W. Schaller and P. Sutton, editors. Reclamation of drastically disturbed lands. American Society of Agronomy, Crop Science Society of America, Soil Science Society of America, Madison, Wisconsin, USA.

Plummer, A. P., D. R. Christenson and S. B. Monsen. 1968. Restoring big-game range in Utah. Publication Number 68.6, Utah Division of Fish and Game, Salt Lake City, Utah, USA.

Sellers, W. D. and R. H. Hill, editors. 1974. Arizona climate 1931-1972. Second edition. University of Arizona Press, Tucson, Arizona, USA.

Smith, N. 1973. On preserving topsoil. Pages 217-219 in Conservation tillage. National Conference, Soil Conservation Society of America, Ahkeny, Iowa, USA.

Soil Conservation Service, University of Arizona Agricultural Experiment Station. 1977. Soil Survey of Maricopa County, Arizona Central Part. National Cooperative Soil Survey, Tucson, Arizona, USA.

Springfield, H. W. 1971. Selection and limitations of mulching materials for stabilizing critical areas. Pages 128-161 in Proceedings Critical Area Stabilization Workshop. United States Department of Agriculture Agriculture Research Service, Los Cruces, New Mexico, USA.

Thornburg, A. A. 1982. Plant materials for Use on Surface-mined lands in Arid and semiarid Regions. United States Department of Agriculture, United States Government Printing Office, Washington, District of Columbia, USA.

Tisdale, S. L. and W. L. Nelson. 1975. Soil fertility and fertilizers. Third edition. Macmillan Publishing Company Incorporated, New York, New York, USA.

United States Army Corps of Engineers. 1978. New River and Phoenix city streams, Arizona. Design Memorandum Number 3, Adobe Dam. United States Army Corps of Engineers, Los Angeles, California, USA.

United States Department of Agriculture, Surface Environment and Mining Program. 1979. User guide to soils, mining, and reclamation in the west. General Technical Report INT-68, Intermountain Forest and Range Experiment Station. Ogden, Utah, USA.

Verma, T. R. and J. L. Thames. 1978. Grading and shaping for erosion control and vegetation establishment in dry regions. Pages 399-409 _in_ F. W. Schaller and P. Sutton, editors. Reclamation of drastically disturbed lands. American Society of Agronomy Crop Science Society of America, Soil Science Society of America, Madison, Wisconsin, USA.

Watanabe, F. S. and S. R. Olsen. 1965. Test of an ascorbic acid method for determining Phosphorus in water and Sodium Bicarbonate extracts from soil. Soil Science Society of America Proceedings 26:677-678.

Woodruff, J. M., and R. E. Blaser. 1970. Establishing and maintaining turf on steep slopes along Virginia highways. Annual Report for the Virginia Department of Highways and United States Bureau of Public roads, Agronomy Department, Virginia Polytechnic and State University, Blacksburg, Virginia, USA.

Wright, D. C., H. D. Perry and R. E. Blaser. 1978. Persistant low maintenance vegetation for erosion control and aesthetics in highway corridors. Pages 553-583 in F. W. Schaller and P. Sutton, editors. Reclamation of drastically disturbed lands. American Society of Agronomy, Crop Science Society of America, Soil Science Society of America, Madison, Wisconsin, USA.

BIOGRAPHICAL SKETCH

Catesby Willis Moore was born in Fredericksburg, Virginia on May 15, 1958. She began her elementary education in New York and completed it in California. She was a member of the National Honor Society and the California Scholarship Federation throughout her secondary education at Palos Verdes High School in California. In 1977, she attended the University of California at San Diego for one year. In 1978, she entered Arizona State University, graduating cum laude with a Bachelor of Science in Biology in 1980. In August, 1980, she entered the Graduate College at Arizona State University in the field of plant ecology. From Aguust 1980 to May 1982 she served as a Graduate Teaching Assistant in the Department of Botany and Microbiology, receiving the homor of Teaching Assistant of the Year for the Department, 1981-1982. Since 1982, she has devoted her time to studying for the completion of her Master's degree, and performing consultation work for the Army Corps of Engineers and the city of Fountain Hills.

FIL