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Revegetating Desert Cut Slopes With Containerized Native Shrubs

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James A. Racin

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Revegetating highway cut slopes in the California high desert was done to control erosion, restore wildlife habitat, and improve aesthetics. Detailed data analysis of survival, mortality, flowering, and other plant stresses, and recommended site preparation and planting procedures are documented. The objective was to compare relative success among three sources of plant materials: 1- nonlocal seedlings purchased from nurseries in Utah and Washington, 2- nonlocally gathered seed purchased from nurseries in Utah and Washington and seedlings raised locally in California by Caltrans and others. 3- seed collected and seedlings raised locally in California by Caltrans and others. Completed research tasks of species selection, seed collection, seedling propagation, facilities augmentation, and planting seedlings on highway slopes are documented in an Interim Report: "Revegetation of Highway Slopes in the High Desert With Native Plant Seedlings" by Racin and Dayak (1986). Four cut slopes were planted along US 395 in Inyo and Mono Counties, California with containerized native shrubs. Species were big sagebrush (Artemisia tridentata), fourwing saltbush (Atriplex canescens), rubber rabbitbrush (Chrysothamnus nauseosus), gray ephedra (Ephedra nevadensis) and antelope bitterbrush (Purshia tridentata). Extra water was given to half the plants in the fist growing season; survival was comparable to plants not watered. Project survival (65%) was considered good for a desert planting project: 700 live plants of 1080. Presoaking plant holes one week before planting, hardening plants, adding soil amendment, and using cages enhanced survival.

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revegetation, erosion control, aesthetics, habitat restoration, native, woody, desert, shrubs, sagebrush, rabbitbrush, ephedra, saltbush, bitterbrush

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STATE of CALIFORNIA
DEPARTMENT of TRANSPORTATION
DIVISION OF NEW TECHNOLOGY AND RESEARCH
TRANSPORTATION LABORATORY

FINAL REPORT

REVEGETATING DESERT CUT SLOPES WITH CONTAINERIZED NATIVE SHRUBS

Study by ......Research and Enviro-Chemical Services Branch

Supervised by..............................Mas Hatano, P.E.

Principal Investigator...............Thomas P. Hoover, P.E.

Co-Investigators............................James A. Racin
John Edell
Tom Dayak

Project Manager,
Analysis, and Report........................James A. Racin

RAYMOND A. FORSYTH, Chief
Office of Transportation Laboratory

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17. KEY WORDS	18. DISTRIBUTION STATEMENT
revegetation, erosion control, aesthetics, habitat restoration, native, woody, desert, shrubs, sagebrush, rabbitbrush, ephedra, saltbush, bitterbrush	No restrictions, copies available from National Technical Information Service Springfield, VA 22161

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CONVERSION FACTORS

English to Metric System (SI) of Measurement

Quality	English unit	Multiply by	To get metric equivalent
Length	inches (in)or(")	25.40 .02540	millimetres (mm) metres (m)
	feet (ft)or(')	.3048	metres (m)
	miles (mi)	1.609	kilometres (km)
Area	square inches (in^2) square feet (ft^2) acres	6.432×10^{-4} .09290 .4047	square metres (m^2) square metres (m^2) hectares (ha)
Volume	gallons (gal) cubic feet (ft^3) cubic years (yd^3)	3.785 .02832 .7646	litre (l) cubic metres (m^3) cubic metres (m^3)
Volume/Time (Flow)	cubic feet per second (ft^3/s	28.317	litres per second l/s)
	gallons per minute (gal/min)	.06309	litres per second (l/s)
Mass	pounds (lb)	.4536	kilograms (kg)
Velocity	miles per hour (mph) feet per second (fps)	.4470 .3048	metres per second (m/s) metres per second (m/s)
Acceleration	feet per second squared (ft/s^2)	.3048	metres per second squared (m/s^2)
	acceleration due to force of gravity (G) (ft/s^2)	9.807	metres per second squared (m/s^2)
Density	(lb/ft^3)	16.02	kilograms per cubic metre (kg/m^3)
Force	pounds (lbs) (1000 lbs) kips	4.448 4448	newtons (N) newtons (N)
Thermal Energy	British termal unit (BTU)	1055	joules (J)
Mechanical Energy	foot-pounds (ft-lb) foot-kips (ft-k)	1.356 1356	joules (J) joules (J)
Bending Moment or Torque	inch-pounds (in-lbs) foot-pounds (ft-lbs)	.1130 1.356	newton-metres (Nm) newton-metres (Nm)
Pressure	pounds per square inch (psi)	6895	pascals (Pa)
	pounds per square foot (psf)	47.88	pascals (Pa)
Stress Intensity	kips per square inch square root inch ($ksi\sqrt{in}$)	1.0988	mega pascals$\sqrt{metre}$ ($MPa\sqrt{m}$)
	pounds per square inch square root inch ($psi\sqrt{in}$)	1.0988	kilo pascals$\sqrt{metre}$ ($KPa\sqrt{m}$)
Plane Angle	degrees (°)	0.0175	radians (rad)
Temperature	degrees fahrenheit (F)	$\frac{+F - 32}{1.8} = +C$	degrees celsius (°C)

NOTICE

The contents of this report reflect the views of the Office of Transportation Laboratory which is responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the State of California or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

Neither the State of California nor the United States Government endorse products or manufacturers. Trade or manufacturers' names appear herein only because they are considered essential to the object of this document.

ACKNOWLEDGMENTS

Getting this report out demanded patience, about 4-1/2 years worth. Many people from a lot of agencies helped in the initial or "seed collecting, propagation, and planting" phase of this revegetation research. I thank them again. They are listed in the acknowledgments of the Interim report published in 1986. The latter or "data collection, analysis, and reporting" phase of the research was successfully done with help from a team of people. Keeping tabs on 1080 woody shrubs required periodic measuring and recording of plant height and width, counting survivors, documenting stresses, collecting weather data, restaking lath, doing "cage-ectomies", and salvaging cages.

I thank the following people for all their help and cooperation:

Tom Dayak and Jack Edell of CalTrans District 9, Bishop CA.

Dave Babb, Los Angeles Department of Water and Power, Bishop CA

Harold Hunt, Dave Biggs, Mong Nguyen, John Williams, Pete Zaniewski, Tom Hoover, Deane Coats, John Haynes, Phyllis Vought, Marti Garcia-Corralejo, Kennie Callahan, Ed Fong, John Thorne, Irma Gamarra, and Forrest Myhres of the Transportation Laboratory, Sacramento CA.

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1. INTRODUCTION

Project Overview

The initial stage of research to revegetate highway cut slopes in District 9 in the California high desert was completed and reported in an interim report (1, Racin & Dayak). This final report documents the latter stage of the research: updated survival results, observations, and detailed analyses of data for the period from October, 1983 through May, 1988. The project was funded by the Federal Highway Administration. Research was done by the Transportation Laboratory (TransLab) and District 9 of the California Department of Transportation (CalTrans).

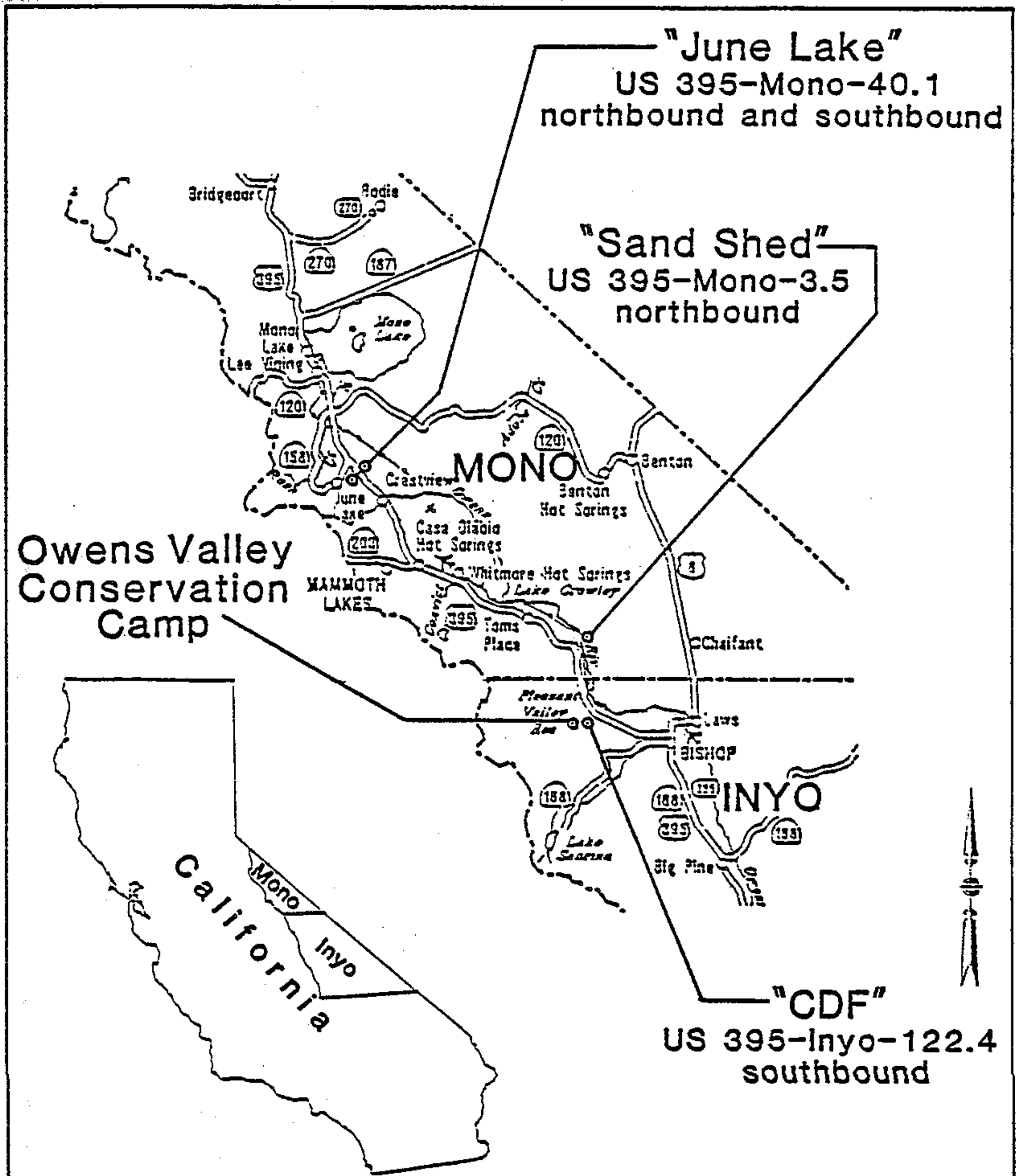
Background

Hydroseeding was unsuccessful for revegetating several high desert highway cut slopes which were constructed in the early 1970's. Seeds of grasses and shrubs were hydroseeded with different combinations of fertilizers and mulches. Containerized native shrubs were planted along US 395 in 1973 and 1974. Survival results ranged from poor to very good (2, Smith, Edell, & Jurak). As a result of the District 9 containerized plantings, this research project began in November 1982.

Objectives

The general objectives of revegetating bare slopes are to reduce erosion, control dust, restore wildlife habitat, and improve aesthetics. Four cut slopes were selected along US Route 395 at three elevations in CalTrans District 9. Figure 1 is a map of the planting sites. A total of 1080 container-grown, native, woody shrubs were planted. There were five species:

big sagebrush	*Artemisia tridentata*	(AT)
fourwing saltbush	*Atriplex canescens*	(AC)
rubber rabbitbrush	*Chrysothamnus nauseosus*	(CN)
gray ephedra	*Ephedra nevadensis*	(EN)
antelope bitterbrush	*Purshia tridentata*	(PT)



Map of Planting Sites

Figure 1

The research objective was to compare the success or failure of revegetating desert cut slopes with seedlings from three sources:

'X' seedlings grown nonlocally in Utah and Washington with seed from high deserts of Utah, Colorado, Nevada, or Washington.

'Y' seedlings grown locally at Owens Valley Conservation Camp (OVCC) by CalTrans and others from nonlocally gathered seed from high deserts of Utah, Colorado, Nevada, or Washington.

'Z' seedlings grown locally at OVCC facilities by CalTrans and others from locally gathered seed from the California high desert.

Seedlings were planted in two groups: one in Fall, 1983 and the other in Spring, 1984. Within each group half the plants were given extra water during the first growing season. Cages were placed around each plant for protection from browsing animals.

Update Since Interim Report

Table 1 summarizes percent changes in survival since the interim report (October, 1985). The "FALL" plants are 6 months older than the "SPRING" plants, so by October 1985 the plants were 2 and 2-1/2 years old, and by May 1988 they were 4 and 4-1/2 years old. Values in Table 1 are based on data in Appendix A, which shows layouts of each planting site and is coded to identify individual plants which: were alive in May 1988, died before October 1985, and died between October 1985 and May 1988.

Plant mortality in the initial stage of the project was most likely due to transplant shock and lack of water (1, Racin & Dayak). There were two consecutive drought years in California, 1987 and 1988. In the latter stage of the project, plant mortality was most likely due to drought stress and failures of individual plants to develop adequate root systems.

The one reported gain in percent survival was due to plants which were thought to be dead. The remains of the apparently dead plants were left in the ground. Their root systems were developed, and they crown-sprouted.

Table 1

* SURVIVAL and NET CHANGE SINCE INTERIM REPORT - ALL SITES

	source X			source Y			source Z	
SPECIES	FALL	SPRING	BOTH	FALL	SPRING	BOTH	FALL	SPRING
AC	90	96	95	25	100	42	N	94
	60	84	78	25	83	38		86
	-30	-12	-17	0	-17	-4		-8
AT	55	96	77	N	90	A	N	94
	46	78	63		72			77
	-9	-18	-14		-18			-17
CN	84	79	81	N	100	100	N	88
	49	56	53		75	75		78
	-35	-23	-28		-25	-25		-10
EN	N	96	A	30	93	74	N	N
		87		15	87	53		
		-9		-15	-6	-21		
PT	73	54	61	N	67	A	N	58
	65	58	49		58			55
	-8	+4	-12		-9			-3

* KEY to tabled values:

90	percent alive in OCTOBER 1985	or	N none planted	or A does not apply
60	percent alive on MAY 17, 1988			
-30	net percent change since OCTOBER 1985			

codes for plant SPECIES:

- AC = fourwing saltbush *Atriplex canescens*
- AT = big sagebrush *Artemisia tridentata*
- CN = rubber rabbitbrush *Chrysothamnus nauseosus*
- EN = gray ephedra *Ephedra nevadensis*
- PT = antelope bitterbrush *Purshia tridentata*

Summary of Results

The project survival count is 700 alive of 1080 plants, about 65 percent. Table 2 shows the range of survival results by site and lists average heights and widths of all live research plants, regardless of source or species. For a desert revegetation project with no replacement planting, these survival rates are considered "very good" (3, Edell). After 4 and 4-1/2 years these native woody shrubs appear to have adapted to the slopes, thus we consider that they have gone beyond the "flower pot stage".

Table 2

SUMMARY of RESULTS by SITE

site	avg. height	avg. width	percent survival
CDF	10	8	73
Sand Shed	8	7	75
June Lake S	14	14	65
June Lake N	13	12	42

2. CONCLUSIONS

1. Revegetating desert cut slopes using containerized native shrubs was successful. By following the detailed procedures in Chapter 6, survival rates of 50 percent or better were achieved. For a desert revegetation effort of this kind, 50 percent survival is considered good. Normal weather conditions in the first 3 years helped. By October 1985, about 2 years after they were planted, most shrubs were developed enough to survive the two consecutive drought years of 1987 and 1988.

In the next three conclusions, "significant" means statistically significant at the 0.05 level. See Chapter 9 for details.

2. There were no significant differences among mean heights of plants from any of the three seedling sources for the species: big sagebrush, rubber rabbitbrush, gray ephedra, or antelope bitterbrush. Plant materials from any of the three seedling sources (X,Y, or Z) grew to similar mean heights.

3. The mean height of source Y fourwing saltbush, locally grown from nonlocal seed, was significantly smaller than source Z fourwing saltbush, locally grown from local seed.

4. There were no significant differences between mean heights of plants which received extra water at 6-week intervals during the first 6 months, as compared with those which did not receive extra water. Two exceptions were:

   A. The fall plants of source X rubber rabbitbrush, nonlocally grown from nonlocal seed, had a significantly smaller mean height when watered, as contrasted to not watering. Thus, extra water did not increase height.

   B. The spring plants of source X antelope bitterbrush, nonlocally grown from nonlocal seed, had a significantly larger mean height when watered, as contrasted to not watering. Thus, extra water increased height.

5. Generally, any of the three seedling sources produced survival counts of 50 percent or better. Survival counts smaller than 40 percent were due to depredation by gophers and planting too late in fall. Plant mortality in the earlier stage of the project was most likely due to transplant shock and lack of water. In the latter stage of the research, plant mortality was most likely due to drought and the inability of individual plants to establish adequate root systems. Metal cages deterred browsing predators.

6. Operating a greenhouse in the winter at the Owens Valley Conservation Camp, California was not feasible.

7. Raising plants locally in a lathhouse was done successfully by starting seedlings in early spring.

A. The total project cost was decreased by upgrading the existing lathhouse at the Owens Valley Conservation Camp, instead of building a whole new facility.

B. Cooperation and assistance was needed from many people in various agencies of the Interagency Committee, especially the California Departments of Correction and Forestry, the Soil Conservation Service, and the US Department of Forestry. Chapter 4 lists member agencies of the Interagency Committee.

8. The cost of a lathhouse operation can be eliminated by purchasing plants. However, there is more risk of plant mortality in transit by shipping via commercial carriers, as contrasted to less risk by raising plants locally. Locally raised plants only need to be transported once, from the lathhouse to the planting site. Also, local seeds of native species are available, as contrasted to commercial nurseries not having native seeds or seedlings which are needed.

9. Walking on the slopes to collect data caused erosion.

3. RECOMMENDATIONS

Recommendations for Revegetation Projects

The district designer can decide which of the three general sources of plant materials to use, if nonlocal plant sources are permitted, based on all the project conclusions. For revegetation projects on which locally grown seedlings will be planted, consider raising more seedlings than you will plant to account for depredation losses. Similarly, for purchased seedlings, consider ordering more to account for transportation losses.

On future revegetation projects on which locally grown seedlings will be planted, to achieve survival rates similar to those on this project, the following general practices are recommended:

1. Begin raising plants in a lathhouse in early spring.
2. Use a loamy soil, not too sandy, in roottrainer containers.
3. Plant large seeds of woody shrubs directly in roottrainers. Similarly, small seeds should be planted directly in roottrainers and thinned, instead of transplanting from flats. See the interim report (1, Racin & Dayak) for more information on raising seedlings.
4. Add slow release fertilizer to containers in the lathhouse.
5. Maintain screening on the lathhouse and monitor for predators. Take appropriate actions early.
6. Harden plants before planting out.
7. Plant when the danger of killing frost is minimal.

Regardless of plant sources or regardless of who will do the actual planting (District people, contractors, or California Conservation Corps), to achieve survival results similar to those on this project, you should follow the guidelines for site preparation and planting, logistical considerations, and suggested quantities in Chapter 6. Generally:

1. Presoak plant holes one week before planting out.
2. Add soil amendment, not fertilizer, in plant holes at the

revegetation site.

3. Use water when planting.
4. Plant quickly and carefully, avoiding exposure of roots.
5. Use cages to protect plants after planting.

Future Research, Methods, and Equipment

The wealth of information on the slopes and in the data collected in this research are available for future studies. Monitoring of plant survival and growth after 10 and 15 years is suggested. Appendices A, B, and C should be used as the initial database for the 10-year study.

To minimize the "research impact", it is recommended that future measurement studies (height) use small scale photogrammetry. With proper controls, stereo pairs of photographs may be taken in the field. Several slopes could be photographed in one day, and the measurements could be determined at a later date. Although it may not be possible to eliminate walking on very erosive slopes and assessing aspects of plants that can not be done remotely, consider having only one person walk the slopes.

The ancestry of plants other than those which were planted may be verified by collecting tissue samples and doing electrophoretic analyses. Funds should be allocated for purchasing electrophoretic analytical equipment in a future research project. The equipment would be very useful for plant identification. Currently rare and endangered plant surveys are done when plants blossom. Projects are held in check until these surveys are completed. With electrophoretic equipment, surveys would be done when plant tissue samples were available, thereby "speeding-up" the environmental process.

For a future research project consider choosing only one plant species, thereby giving larger subsets of data for statistical studies. The experimental design can then focus on practices to enhance survival. For example, using one species, plant at least

50 replicates for each of the following four treatments:

1. add a small amount of slow release fertilizer in the planting hole on the slope.
2. add a large amount of slow release fertilizer in planting hole on the slope.
3. only use a small amount of slow release fertilizer in the lathhouse, none in planting hole, and some soil amendment on slope, as we did in this research.
4. as a control group, just plant lathhouse-raised seedlings on the slope with no fertilizer or soil amendment.

By following the suggested site preparation and planting procedures in Chapter 6, there will be a basis for comparing the results of the future project to this research.

If revegetation is a project goal, you can not pull out the plants, dry them, and study "plant mass" as a variate. To assess results of revegetation, it is recommended that you monitor and report: survival, physical measurements (like height, width, and stem thickness), other indicators of success (like flowering and setting of seeds), and various plant stresses (like depredation, competition, and weather).

4. IMPLEMENTATION

Copies of this report will be given to the Federal Highway Administration and member agencies of the Interagency Committee. The Interagency Committee is a multidisciplinary team composed of people from:

City of Bishop
Counties of Inyo and Mono
CalTrans District 9
California Department of Corrections (CDC)
California Department of Forestry (CDF)
California Department of Fish and Game (DFG)
Los Angeles Department of Water and Power (LADWP)
United States Forest Service (USFS)
Death Valley National Monument
White Mountain Research Station, Univ. of CA Riverside
Soil Conservation Service, US Department of Agriculture
Bureau of Land Management (BLM)

TransLab compiled a slide presentation of the research project showing the greenhouse and lathhouse, planting and watering techniques, and research plots. Presentations were given to the Interagency Committee in Bishop on November 2, 1984 and also at the Native Plant Revegetation Symposium in San Diego on November 15, 1984. Copies of the slides and a script are available from TransLab in Sacramento. The color slides (or prints) which are presented in Chapter 5 are also available on request at cost of reproduction.

Due to the successes of propagating and planting native shrubs, TransLab encouraged the Interagency Committee to extend the agreement with CDF and CDC on February 1, 1985 to continue using the lathhouse at the Owens Valley Conservation Camp. Surplus seedlings raised for the research plots and viable seed were planted at sites other than highway slopes in Inyo and Mono

Counties.

The LADWP planted seedlings of gray ephedra and rabbitbrush to revegetate a small roadside south of Tinemaha Reservoir. In 1985 a 61 percent survival rate was reported by LADWP biologists.

The BLM planted seedlings and seed of sagebrush and gray ephedra in a remote area that recently burned. Another project was to restore a meadow that was stressed by sheep from overgrazing. No status reports were available on these projects in 1988.

The USFS revegetated 2 acres at the Convict Lake Campground using labor from the California Conservation Corps (CCC). Both seedlings and seed were planted of sagebrush, bitterbrush, desert peach (Prunus andersonii), and curlleaf mountain mahogany (Cercocarpus ledifolius). District 9 and TransLab were unable to get a 1988 status report of this project. Key people who did the planting are no longer with the Forest Service.

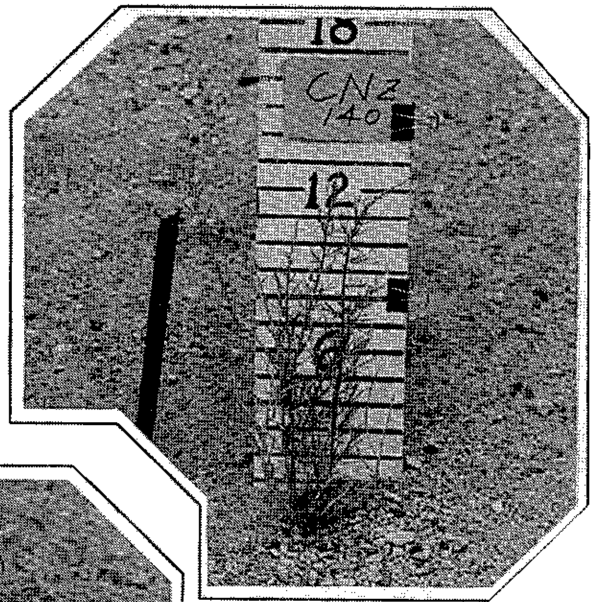
The databases of initial (fall 1983 and spring 1984) and last (May 1988) measurements along with other classes of data are available on a double-sided, double density, (360 kilobytes) 5-1/2 inch floppy disk. Use dBASE III plus to make inquiries and view the data. See Appendix B for information on getting the disk.

Bar graphs of initial and last height for each plant are available on a double-sided, high density (1.2 megabytes) 5-1/2 inch floppy disk. Use LOTUS 1-2-3, release 2.01 to view the graphs in the PGRAPH program. Another similar disk of widths is available. See Appendix C for information on getting the disks.

5. VISUAL ASSESSMENT

Photographs of project highlights make up this chapter.

EPHEDRA-EN



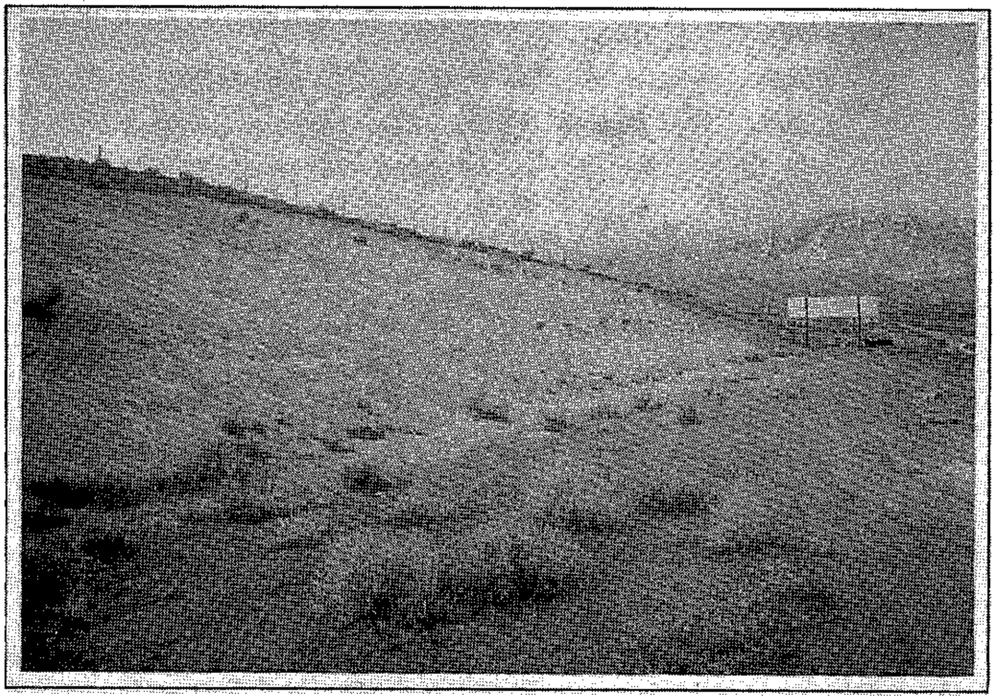
RABBITBRUSH-CN

BITTERBRUSH-PT

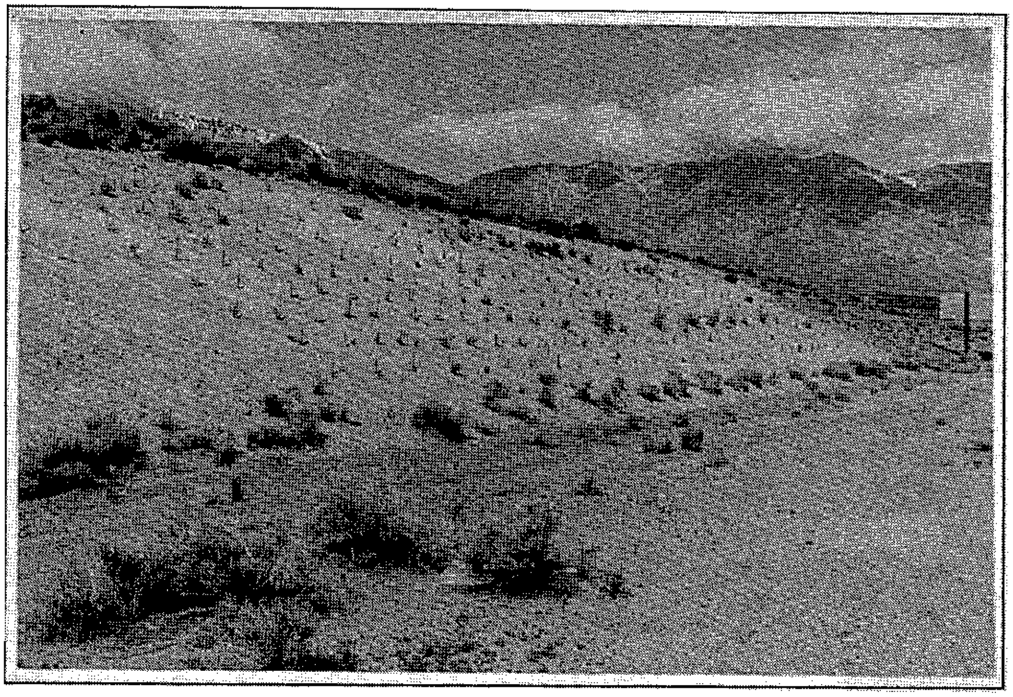
SAGEBRUSH-AT

SALTBUSH-AC

FIGURE 2. EXAMPLES of FIVE SPECIES

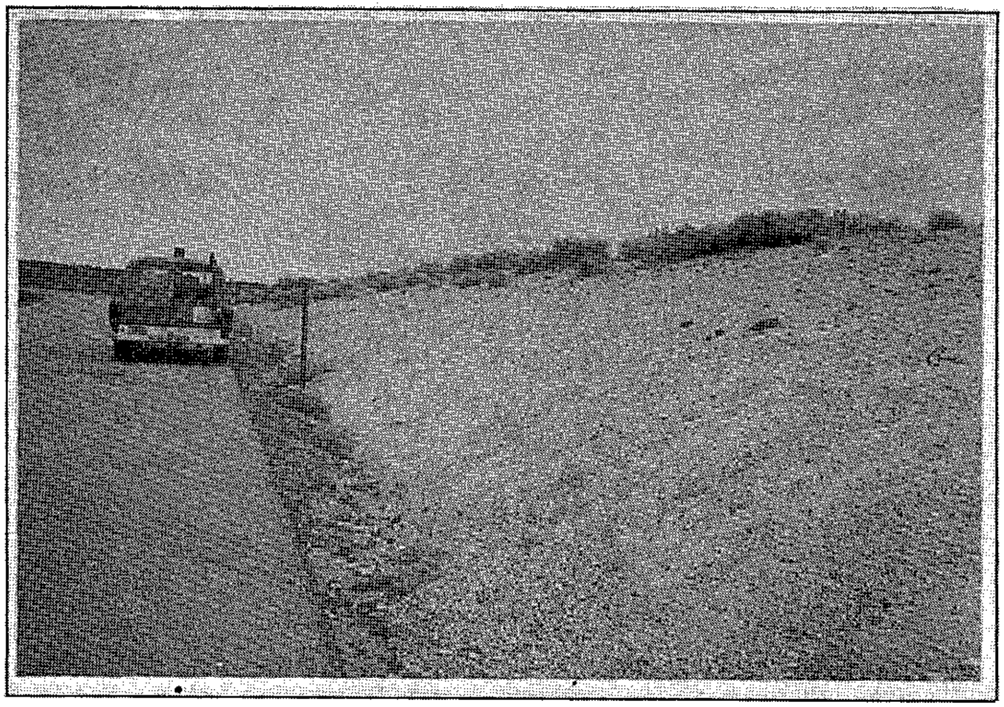


CDF SITE: BEFORE, in 1984

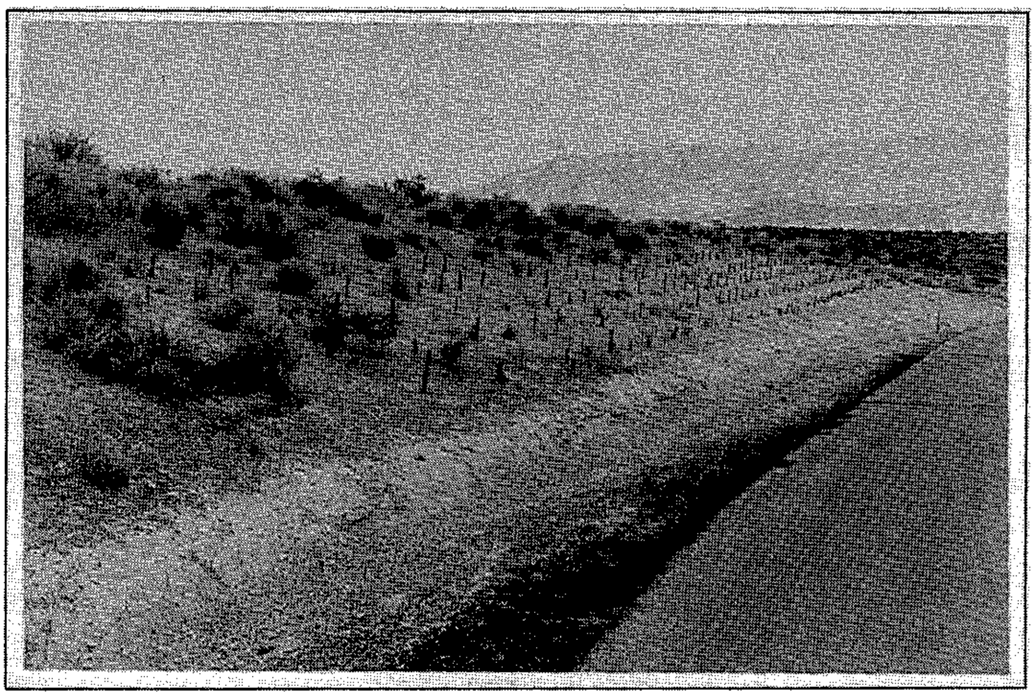


CDF SITE: AFTER, in 1988

FIGURE 3. CDF: RELATIVE INCREASE in COVER and ROUGHNESS

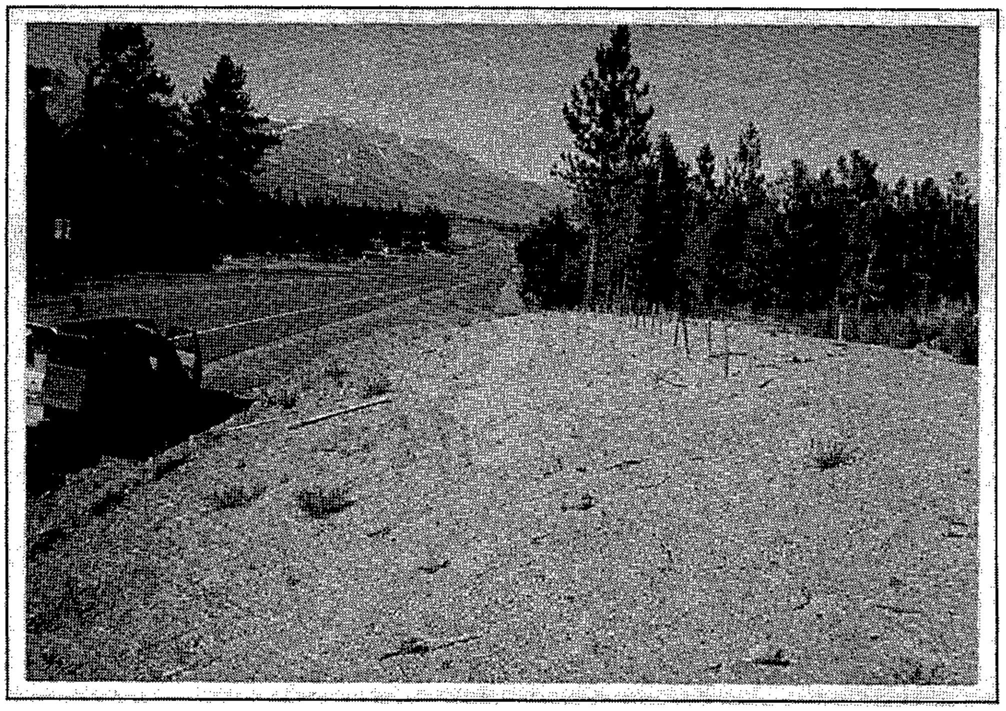


SAND SHED SITE: BEFORE, in 1983



SAND SHED SITE: AFTER, in 1988

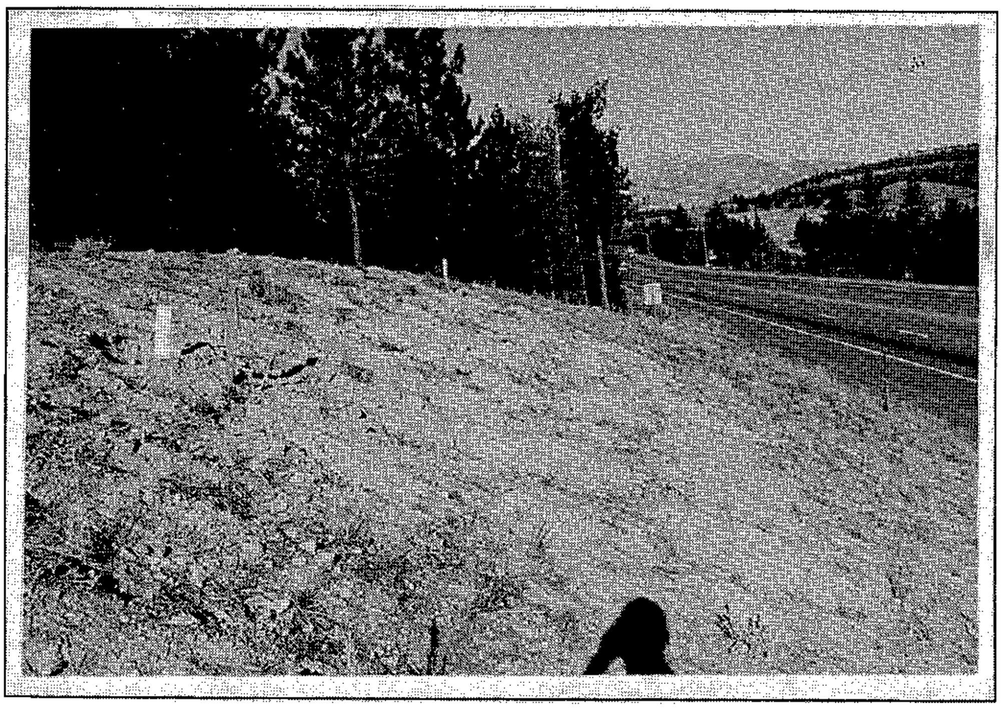
FIGURE 4. SAND SHED: RELATIVE INCREASE in COVER and ROUGHNESS



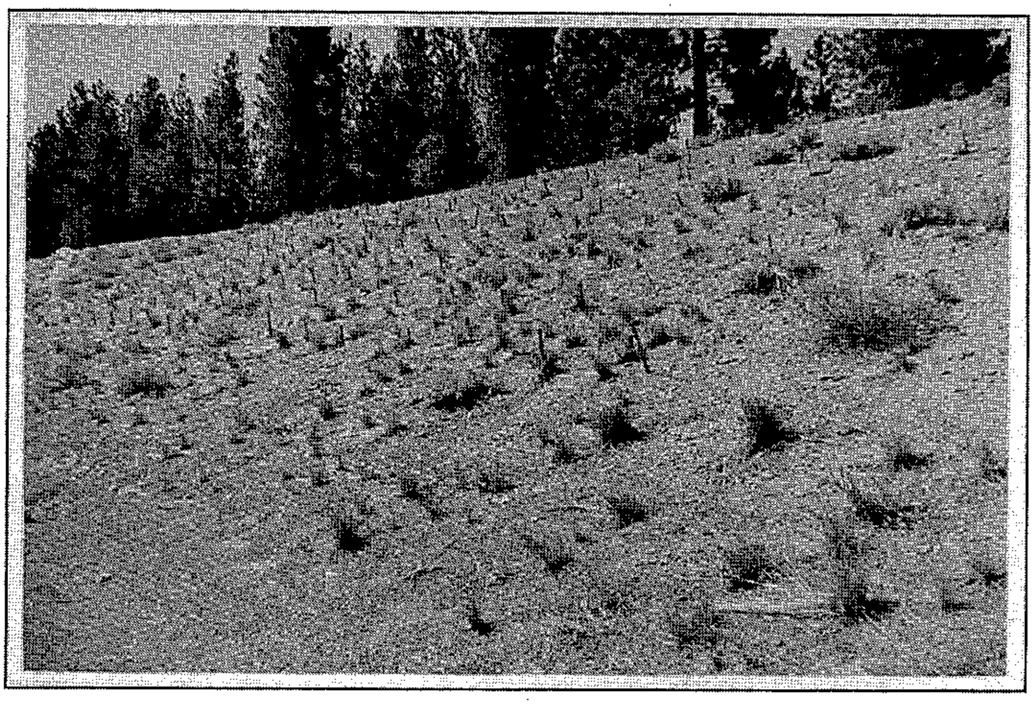
JUNE LAKE S25W SITE: BEFORE, in 1983

JUNE LAKE S25W SITE: AFTER, in 1988

FIGURE 5. JUNE L. S25W: RELATIVE INCREASE in COVER and ROUGHNESS



JUNE LAKE N25E SITE: BEFORE, in 1983



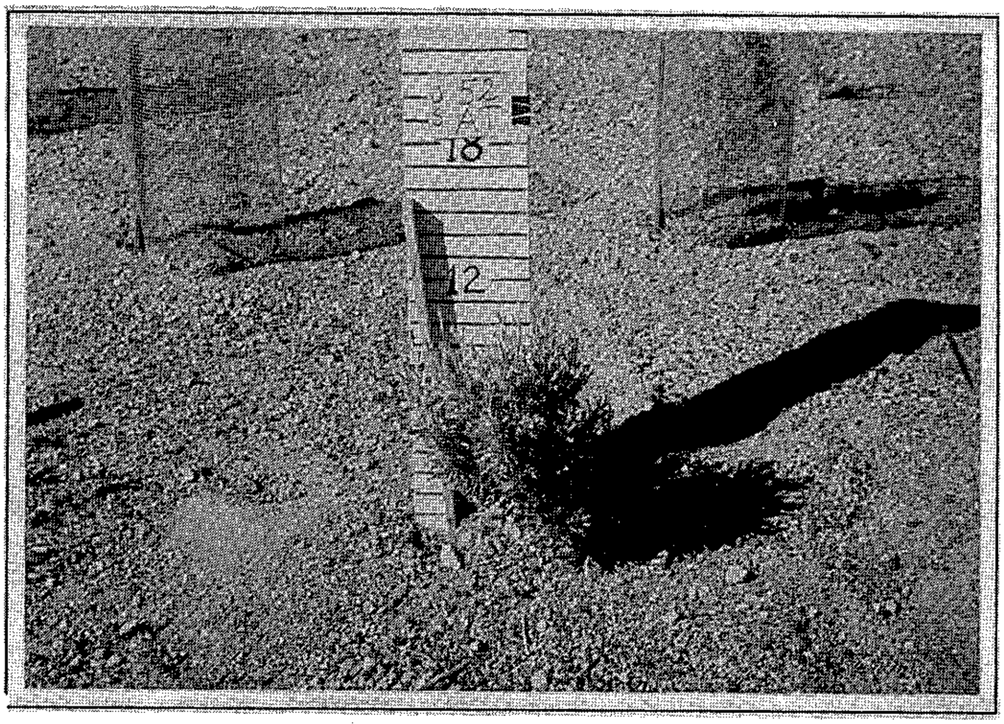
JUNE LAKE N25E SITE: AFTER, in 1988

FIGURE 6. JUNE L. N25E: RELATIVE INCREASE in COVER and ROUGHNESS

PLASTIC CAGE

METAL CAGE

FIGURE 7. TWO KINDS of CAGES



FLOWERING SAGEBRUSH

FLOWERING BITTERBRUSH

FIGURE 8. EXAMPLE of FLOWERING PLANTS

6. RESOURCES, SITE PREPARATION, and PLANTING

General Cost Information, Labor, and Time Estimates

Since many of the time and labor requirements and site conditions will vary from one revegetation project to the next, the estimates in this Chapter should be used as general guidelines, not for contract cost-estimating.

If you are ordering and purchasing seedlings from nonlocal or local nurseries, you may need as much as one year of lead-time, but typically not less than six months, for your order to be fulfilled. Since costs of containerized native shrubs are variable, you should check more than one supplier.

If you are collecting seed and raising seedlings locally, your costs may be decreased by sharing facilities and working with people in other agencies with revegetation needs. An experienced person may spend about three days collecting and storing seed. Collection may start as early as two, but not less than one season before planting. If you are able or plan to work with inmate trustees at a minimum security prison, one person may spend about one day per week for about 8 weeks supervising an experienced nurseryman in a lathhouse operation (1, Racin & Dayak). If you plan on making your own plant cages, estimate two inmate laborers per 5-day week for 1000 cages.

Generally, site preparation and planting are estimated at two experienced people for one week per slope. At least one day should be allocated for mobilizing planting equipment and one day to coordinate the use of an operator and a water truck. Cooperation with other agencies is encouraged. Other task-specific time and labor estimates are in the following discussions. Equipment and materials which were used in this research are discussed, however detailed lists are not provided. Some information is specifically oriented to future researchers.

Site Preparation

Complete the following tasks at least one week before planting.

1. Lay out and mark plant locations well in advance of planting, not the same day you plant.

2. Stagger rows, beginning at the top of slope, so there are no gaps up-and-down the slope. Use a pattern similar to the one shown below. Locate plants (+) on a minimum of 4-foot centers for adequate working space on slopes as steep as 1-1/2:1.

```
top of     row 1      +   +   +   +   +   +   ...   +
slope      row 2        +   +   +   +   +   +   ...   +
           row 3      +   +   +   +   +   +   ...   +
           .
           .
toe of     row n-1    +   +   +   +   +   +   ...   +
slope      row n        +   +   +   +   +   +   ...   +
```

3. Dig holes 12 to 14 inches deep, at least 1.5 times deeper than the depth of containers. Depending on the soil conditions, you can use either a two-man, gasoline powered auger or a manually operated clam-style, posthole digger. Sandy, granitic soils were dug manually and with a power auger. Fine-grained rhyolitic volcanic tuffs were dug with a power auger. The hole diameter should be about 6 inches for a 2-inch by 2-inch roottrainer. Loosen soil at least two inches below the 12-inch depth to accommodate root expansion.

4. Fill each hole with at least 1.5 gallons of water or until water just begins to overflow. Presoaking wets the surrounding soil and helps to prevent "wick-drying" of the soil and root mass. If percolation is slow, leave the site and let the water soak-in overnight.

be planted at each site, if there is more than one site, and if there is more than one species to plant.

3. Water the plants. Use enough water to wet the soil in the container, so the root mass will not fall apart during planting. Do not overwater.

Planting Day

1. Bring only the plants you plan to plant in one day. Minimize or eliminate plant exposure during transit from the hardening area to the planting site, by using an enclosed truck or van. At the site, open the van doors and windows, or simply unload the plants.

2. At the premarked locations, remove the markers. Note the depth of the seedling container. Push a planting dibble into the center of the backfilled hole, as deep as the container. Leave the dibble in the soil.

3. Pour a half-pint of water (1/4 of a 1 pound coffee can) around the dibble. Rotate the dibble to widen the hole, just enough to accommodate the seedling. If the soil is very loose, spin and slightly lift the dibble until the soil is wet enough to hold together, without caving-in. After the water seeps into the soil, remove the dibble.

4. Carefully remove the plant from the container and place it in the hole, either by hand or with a trowel.

5. Gently compact soil around the plant to remove excessive voids, either by hand or with a trowel.

6. Form a small crescent-shaped dam on the downhill side of the plant. To assure deep watering, push a sharp probe into the soil around the plant. Be careful to avoid the roots. Make at least 5 holes around the plant with the probe, then water the plant

Our results indicate that extra watering is not needed for the five species which were tested: if presoaking is done, if rainfall appears to be normal and you are not experiencing a drought, and if water is used at planting time.

5. Place about one pound of soil amendment, at the bottom of each hole (one 50-pound bag of natural humus per 60 holes). The field-measure was approximately 1.5 handfuls of humus per hole. "NITROHUMUS" (Kellogg's, derived from domestic sludge) contained 0.70 % total nitrogen, 1.75 % available phosphoric acid, and "beneficial soil bacteria which release essential minerals". At each site, test results showed very low values of nutrients (1, Racin & Dayak). Slow release fertilizer was added to roottrainers in the lathhouse during seedling propagation. The amounts of soil amendment (provides bacteria) and peat moss (provides some more organic matter, see item 6. below) which were added in the planting hole, were satisfactory for these species. Fertilizer was not used on the slopes or in the planting holes.

6. Backfill the hole with a mixture of native soil from the diggings (no particles larger than one inch) and some finely-textured organic material, like peat moss (1/2-gallon loose measure). The mix ratio was approximately three parts native soil to one part peat moss. Cover the top two to three inches with native soil only, to prevent wick-drying. Lightly (by hand) compact the backfilled hole.

7. Place a 2-foot lath or other suitable marker in the center of the backfilled hole. Let the site stabilize for at least one week, but no longer than two weeks.

The Day Before Planting

1. Instruct the planting crew to review the planting procedures and become familiar with site-specific safety measures.

2. Review the site layout plans, so you know which species will

with a half-pint of water. This practice is recommended on slopes instead of shaping soil to form a concentric watering basin.

Concentric basins are not needed on a slope. They took longer to form than crescent-shaped dams, and they took away from valuable time needed to get the remaining plants in the ground. Basins and dams eroded later and required some minor maintenance.

In fine-grained soils, water ponds and evaporates. A "deep-watering-probe" helps to get water where it is needed most, <u>in the soil</u>. TransLab fabricated such a probe by attaching an 8-inch long, 3/8-inch diameter steel spike in the center of a sawed-off shovel handle.

7. Place a metal cage around each plant to discourage depredation by browsing animals. Secure the cage to the slope with a 6-inch steel jute stake. Drive a 2-foot lath one foot into the slope and next to the cage. Loop a piece of 18- or 20-gage plastic coated wire through the mesh and tie the cage to the lath.

Metal cages were designed by Translab and fabricated by inmates. A cage is a hollow cylinder, 18-inches tall by 8-inches (minimum) diameter. The mesh material is 1/4-inch x 1/4-inch galvanized hardware cloth. The 18-inch dimension was obtained by cutting a 36-inch tall by 100-foot long roll of mesh in half with an electric hacksaw. Ten 100-foot rolls were used to make 1080 cages. Inmates cut 30-inch long sections of the half-height rolls, then overlapped and fastened the mesh 1/2-inch from both cut ends, with four number-2-sized, hog rings to form the cylinder. The ends of the hog-ring pliers were ground down, so they would fit through the mesh without breaking welds while closing the ring. Because inmate labor for fabrication was virtually "free" ($0.50 per day for a laborer) the material and labor cost of one cage was only $1.25. It took about five days and two inmate laborers to make 1080 cages.

Metal cages deterred depredation and significant damage from browsing animals. They were not effective for deterring gophers. Cages also held soil in place which had sloughed from uphill. Cages were salvaged for use on other revegetation projects. Yellow, plastic cages (3-inch diameter by 1-foot tall) were tried on the fall, 1983 plots. They were unsightly and restricted the growth of the shrubs.

8. After planting all the seedlings on a slope and securing the cages, give each plant one more quart of water. Thus, the total amount of water given to each plant should be about 1.5 quarts.

9. To monitor individual plants, mark the lath sequentially from number 1 to the last plant. For studying more than one treatment, a sequential range of integers should be used to define the treatment. Numbering strictly by row or by column without regard to treatments will require additional data storage fields. To monitor more than one site, the first identification number at the next site should be (last+1), etc. Identifying plants in this manner gives the data manager a unique way of tracking plants. It is very useful for data manipulations. Plan on re-marking lath every two years, due to dust and fading. Minimize foot traffic on the slopes. Two (or more) people walking around measuring and recording plant height and width caused erosion. See Future Research, Methods, and Equipment in Chapter 3 for reducing the "research impact."

Plant Establishment

The plants should not need any further care or water. The project manager can decide if replacement planting should be done. Periodically inspect cages and remove or replace damaged ones. Cages may be left around plants for about 3 years, but should be removed before branches get wedged in the mesh.

7. TECHNIQUES AND DATA

Experimental Design

Our project objective was to revegetate cut slopes with containerized native shrubs. In the early 1970's hydroseeding was tried but failed on newly constructed cut slopes. There was no duff. The seed mix was grasses and woody shrubs. After about 12 years, local vegetation was not naturally invading the slopes. The research or experimental objective was to decide which, if any, of three sources of seedlings was "best" for revegetation.

Our experiment consisted of two plantings of 1080 containerized native shrub seedlings. We documented procedures, materials, and conditions for subsequent analyses. Four cut slopes were selected at three elevations: 4200, 6000, and 7800 feet above mean sea level. Three slopes were mostly bare, while one was very sparsely vegetated with grasses and shrubs. One planting was in fall 1983, and one was in spring 1984. We planted five species from the three sources of plant materials which we were comparing. The experimental conditions are a possible scenario of how a revegetation contract might be executed.

The planting technique was identical for all 1080 seedlings. Details are in Chapter 6. Generally, a hole was dug and filled with at least 1.5 gallons of water. Then soil amendment was placed in the bottom of each hole, about 0.5 pound of nitrohumus, which contained 0.70 % (or less) of available nitrogen and various micronutrients. Each presoaked hole was refilled with three parts native soil (dry) to one part peat moss (dry), then left to "stabilize" for at least one week. When the seedlings were planted, they each got 1.5 quarts of water.

A variation in watering was tried. At six week intervals, half of the fall and half of the spring plants, were given one quart of water. There were six supplemental waterings, which began in early spring and ended in late fall of 1984. From then on the plants got their water naturally.

Figures A-2 through A-8 in Appendix A show detailed layouts of plants (watered or not) and their species, source, and identification numbers. For dead plants the identification number is left blank. Figure A-1 is the index sheet for locating layouts (spring and fall) in Figures A-2 through A-8.

Data

The experimental objective was to compare the success of revegetation among three sources of plant materials. To help us decide whether one source was more (or less) successful than the others, we monitored and assessed several kinds of data:

number of survivors

height and width of live plants

stresses (dryness, weeds, depredation, vandalism, etc.)

and maturation (that is flowering and setting of seed).

There are no firmly established numerical guidelines of acceptable survival percentages for any of the native species which we planted. Thus, we used the criterion, "for desert plants 50 percent survival is considered to be very good." (3,Edell). Detailed results are presented in the discussion of Plant Survival Counts in Chapter 8.

Survival was not the only criterion for judging success or failure among the three sources. We also monitored the other classes of data at least twice yearly (spring and fall) from the beginning of the project. We thought these "other than survival" data would help us to make objective decisions regarding the outcome of the research, and also to make logical conclusions and recommendations.

A database was designed. Because no universal software was available, we used several programs. A personal computer (PC) relational database, "dBASE III PLUS" by Ashton-Tate, was used to store, retrieve, count, and report survivors and other classes of data. We plotted and scrutinized bar graphs of plant height and width, which were produced with the "PGRAPH" program of "LOTUS 1-2-3" by Lotus Development Corporation. We did statistical studies using "in-house" software on an EL-5500III pocket computer by Sharp and an "AT" (PC) by International Business Machines.

In the database, tables, file names, and analyses, the plant sources were encoded as "X", "Y", or "Z", where:

X = not grown in Great Basin of California and Nevada,
Y = grown locally in California, seed not from Great Basin
Z = grown locally in California from local seed.

Codes for species are footnoted on figures or tables. Data fields and values for encoding various phenomena of plant maturation and stresses were:

"FO" data field :

Y = PLANT PRODUCED ITS FLOWERS AND SET SEED
N = DID NOT PRODUCE FLOWERS

"DR" data field :

N = PLANT LOOKED HEALTHY
D = 50 % TO 95 % DRY LEAVES and/or STEMS, LACK OF WATER
V = MORE THAN 95% DRY, VERY STRESSED BUT STILL ALIVE

"WE" data field :

Y = INVADED WEED INSIDE CAGE (WITHIN 4-inch RADIUS OF STEM)
L = INSECT GALL OF SOME SORT ON SEEDLING
N = NO WEEDS WITHIN 4-INCHES OF SEEDLING

"DM" data field :

G = DEAD, PLANT EATEN BY A BURROWING ANIMAL
B = BLACK SCALE
I = INSECTS, BLACK APHIDS
L = LADYBUGS APPEARED TO BE EATING APHIDS
P = PRUNED TO REMOVE CAGES IN JUNE, 1987
A = BROWSED BY LARGE ANIMAL
V = PROBABLE VANDALISM
N = NO APPARENT DAMAGE

Initial values in all 4 data fields were encoded "N". Other values (different phenomena) were counted and compared or contrasted to the number of plants by source, species, site, etc. Besides sources and species of plants, other data fields were needed to keep track of concepts in our experimental design. The ones used most were: alive or dead, spring or fall, slope aspect, and watered or not watered. Plant height and width were also measured and recorded. Data field structure and values for encoding the phenomena can be modified as needed and as "new" phenomena develop in any future studies.

Appendix B documents our database structure and file names of two "raw" databases. One is the initial and the other is the last set of data. In each file there is a record for each plant. The two files are related by the unique identification number assigned to each plant. The databases were created using dBASE III plus, version 1.1 The data are stored on a floppy disk. Appendix B has details for acquiring the disk.

Appendix C documents file names and the naming convention of the bar graph files for use in the "PGRAPH" program of LOTUS 1-2-3. Two floppy disks are available: one disk has the worksheet and 100 bar graphs of initial and last height of each plant, while the other disk has the worksheet and 100 bar graphs of initial and last width. Details are also given for acquiring the disks.

Weather

As detailed above, we presoaked the soil to improve the possibility of survival and growth. After the first year all plants got their water naturally. We did not have on-site continuous records of rainfall. Therefore we studied annual rainfall trends using other nearby data sources to document survival or mortality due to rainfall.

For annual precipitation data, we relied on the California Department of Resources, "Bulletin 120", Water Conditions In

California. The October issues summarize the "water year" in California, which spans the period from October 1 through September 30 of the succeeding calender year. "Annual rainfall" and "percent normal" values were read from isohyetal maps of California (inches and percent of normal) and reported for two locations (4,5,6,7,8,9,10, CA DWR).

Water year conditions and rainfall amounts which span the two years prior to planting through April, 1988 are in Table 3. The first value in the column labelled "5000" was read from isohyets (rainfall contours) near the Inyo-Mono County line, which is roughly between our sites at 4200 and 6000 feet elevation. The second value in the column labelled "7800" is near our sites at 7800 feet elevation. Since these values were interpolated from isohyetal maps, they have a wide error band and are considered only as "likely values" at our research sites.

Table 3

ANNUAL RAINFALL / PERCENT NORMAL

	elevation	5000	7800	5000	7800
	water year	inches of rain		% of normal	
	81-82	13	20	160	200
	82-83	15	20	200	200
*	83-84	10	15	100	150
**	84-85	11	15	120	150
	85-86	14	22	170	200
	86-87	4	9	50	50
	87-88	5	11	57	57

The single * shows when we planted our "fall" seedlings, while the double ** shows when we planted "spring" seedlings.

Before planting we did not intentionally wait for prior "water years" to be above normal. However based on good survival and growth results, it may be good advice to either avoid planting during or immediately after "below normal" water years, or artificially charge the soil with water.

If any future studies are done, long term daily precipitation and temperature data are available from: the Caine Ranch and the Bishop Airport. Data from the airport are reported in Climatological Data by the National Oceanic and Atmospheric Administration. Caine Ranch data are available from the Los Angeles Department of Water and Power, Bishop, CA. The airport data may be useful for our 4200 and 6000 foot sites (CDF and Sand Shed), while Caine Ranch data may be useful for our 7800 foot sites (June Lake).

Only a very few observations of temperature and rainfall at our research sites were collected for general information. A post-mounted rain gage and a "minimum-maximum" thermometer were set up at each of the 3 elevations near our planting sites. On the first day of our field trips, thermometers were reset, then after 24-hours they were read again. Values in Table 4 are 24-hour daily temperature extremes (lo hi). Because of the thermometer exposures (on a post 4-feet above ground, not fully shaded, but facing northerly), values are reasonably close to what the plants experienced. Rainfall values (R) are accumulations since the last field trip, excluding evaporation, and including amounts of rain which fell during the field trip. Gages were not checked frequently enough to report an annual amount or event amounts. Gage readings of "zero" rainfall were frequent and were a useful qualitative check of evaporation. Thermometers and rain gages were occasionally stolen.

Table 4

DAILY TEMPERATURE EXTREMES and RAINFALL

("lo hi" in degrees Fahrenheit) (R hundredth inches)

site	CDF			Sand Shed			June Lake		
elev.	4200			6000			7800		
	lo	hi	R	lo	hi	R	lo	hi	R
JAN 12 1984	19	74	64	22	50	54	-10	60	*
MAR 20 "	24	84	12	28	72	40	2	76	68
AUG 9 "	50	110	0	59	99	0	no data		
SEP 20 "	43	103	0	51	86	0	32	80	24
OCT 30 "	18	94	3	30	68	14	8	86	38
MAY 16 1985	36	94	0	38	82	0	24	82	0
AUG 22 "	46	99	0	54	88	0	38	91	0
OCT 9 "	38	68	0	30	60	2	29	61	61
MAR 21 1986	**		0	26	62	0	-6	78	***
JUN 19 "	47	106	0	52	91	0	32	100	0
JUL 30 "	47	107	4	55	94	2	40	99	0#
JUN 24 1987	66	100	0	63	100	0	40	103	15
OCT 7 "	44	98	0	55	85	0	35	92	0

* 18 inches of snow on ground

** thermometer missing

*** rain gage missing, snow flurries

\# 10 dead "bugs" found in gage !

8. RESULTS

Results are based on studies of information in our database and field observations. Significant observations which were excluded from the database are cited in the discussions below. The discussions are easier to follow by referring to Figure 9, which lists site names, slope aspects, elevations, species, planting dates, and other useful information.

Plant Cages : Plastic vs. Metal

Plastic Cages

To discourage depredation, we tried putting plastic cages around the fall plants. The cage material was cylindrical plastic mesh "tubing" (VEXAR), which was bright yellow, 3-inches in diameter with 1-1/2 inch diamond-shaped openings. The height of the cage was selected by cutting the tube to whatever length you wanted. Our plastic cages were about 12-inches tall. The openings were too large for blocking mice, so a fine mesh (1/8-inch square openings) of yellow, plastic netting was slipped over the large mesh. Because of the 3-inch diameter, cages were very difficult to install without injuring the seedlings.

We visited a nearby research planting at which the same plastic tubing was used. The site was about 6 years old and was part of a joint study by CalTrans and the Soil Conservation Service (11, Clary). A few of the remaining live shrubs were neatly pruned by predators. Some branches were gnawed up to the mesh from the ground up to about 18-inches. Other branches were chewed along the tops of the shrub. Rabbits and deer, which are frequently seen near this site from the road, are the most likely predators. The plastic mesh lasted longer than anticipated. Apparently it did not deteriorate enough (by exposure to ultraviolet radiation) for branches to break the plastic. This product is normally used to protect trees. When the trunk diameter is large enough, the tube should simply break, thereby allowing unrestricted growth.

Orientation is facing slope.
Total seedlings planted was 1080. Refer to KEY below.

fall	spring
10/27/83 60 seedlings	6/13/84 180 seedlings
20 AT, 20 PT, 20 CN	74 AT, 67 PT, 39 CN
(36 by 15) 3 ft. centers	(140 by 16) 4 ft. centers

"June Lake S25W" elevation 7800 US 395 north MONO 40.1

spring	fall
6/13/84 180 seedlings	10/26/83 60 seedlings
73 AT, 67 PT, 40 CN	20 AT, 20 PT, 20 CN
(68 by 36) 4 ft. centers	(36 by 15) 3 ft. centers

"June Lake N25E" elevation 7800 US 395 south MONO 40.1

fall	spring
11/9/83 60 seedlings	5/1/84 220 seedlings
20 AT, 20 EN, 20 CN	75 AT, 38 AC, 53 CN, 54 EN
(36 by 15) 3 ft. centers	(172 by 16) 4 ft. centers

"Sand Shed S60W" elevation 6000 US 395 north MONO 3.5

spring	fall
4/18/84 220 seedlings	11/9,10/83 100 seedlings
61 AT, 60 CN, 60 AC, 39 EN	20 AT, 20 CN, 20 EN, 40 AC
(84 by 36) 4 ft. centers	(27 by 27) 3 ft. centers

"CDF N10E" elevation 4200 US 395 south INYO 122.4

KEY: date planted total planted on date
subtotals and each species planted
slope area spanned (feet by feet) plant spacing in feet

site name, slope aspect feet above msl road COUNTY post mile

codes for SPECIES of plants:

- AC = fourwing saltbush *Atriplex canescens*
- AT = big sagebrush *Artemisia tridentata*
- CN = rubber rabbitbrush *Chrysothamnus nauseosus*
- EN = gray ephedra *Ephedra nevadensis*
- PT = antelope bitterbrush *Purshia tridentata*

SITE DATA and RELATIVE POSITION of FALL and SPRING PLOTS
FIGURE 9

Yellow plastic cages were very noticeable on our research slopes. Because they were difficult to install without injuring seedlings, and because they did not do well at the CalTrans/SCS site, plastic cages were removed from the fall plots. We looked for larger, commercially available cages and found none. Using two plastic meshes meant additional material handling and cost. Therefore, instead of plastic, TransLab designed, built, and installed metal cages around all 1080 research seedlings.

Metal Cages

Metal cages laterally enclosed and partially shaded each seedling. Cages were 8-inch diameter, 18-inch tall cylinders of 1/4-inch galvanized metal mesh. See Chapter 6 for fabrication details.

After planting seedlings, the cages were installed and anchored on the slope. The anchorage consisted of a 6-inch steel jute pin and a wooden lath. The jute pin was slipped through the mesh and pushed into the slope; the cage was wired to a 2-foot wooden lath, which was pounded into the slope about 1-foot. Each lath was numbered for identifying the plant (1, Racin & Dayak). The additional labor and time for installing the cages is estimated as one laborer per day per slope. Maintenance (later removal and salvage of cages) is also estimated as one laborer per day per slope, but occurs over more than one day.

Plant Cages: Evaluations

Cages Dislodged by Wind

During our data collection trips, we noticed plant cages were sometimes "missing". A few cages were installed "loosely", that is, either the jute pin or the lath was not anchored deep enough into the soil. Strong winds dislodged loosely installed cages. Anchorages were inspected and reset; however, some cages still wound up as missing.

On most field trips, by the end of the day we were "dusted" with fine soil. We walked as carefully as possible, trying to avoid scuffing our feet and raising clouds of dust. You received slightly less dust, if you were the upwind observer. However, even if you were alone and standing still, in a strong wind your own body acted as a "chimney" and dust swirled up, around, and landed on you. At each site (over the years) we saw progressive removal of soil at the bases of some cages, sometimes right at the anchorages. We actually saw cages being blown loose and carried across the slope at June Lake S25W during a strong, gusty wind storm. Thus, the sites experienced wind erosion.

Accidentally Crushed Cages

At the June Lake N25E slope, we intentionally removed crushed cages, where people had unknowingly walked or went sleigh-riding on top of the snow-covered research plots. On the S25W slope, along the two lower rows, many cages were removed unintentionally by snowplows. Apparently after one or more storms which produced deep snow, the mass of snow being pushed to the side of the road was large enough to crush cages, eight feet from the plow path. In some instances the cages appeared to have been swept from their anchorages by the plow-induced movement of the snow mass.

"Normal" Maintenance of Cages

By June 1986, spring plants were two years old. Some plants had grown laterally through mesh openings. Cage-bound plants were given "cage-ectomies", that is, cages were briskly yanked from the slope with little or no damage to the plant. By June 1987, it appeared that cages were restricting lateral growth on most plants. So, we removed the remaining 750 cages and salvaged them. Only 23 live plants required pruning before yanking their cage, since branches were tightly wedged in the mesh. Removing cages gave us a qualitative response to judge that root systems on many of the cage-bound plants were well anchored. Roots did not just occupy the limits of the augered holes. Our last mortality count in May 1988 showed that only two of the pruned plants died; however, we have no positive proof that pruning caused mortality.

Browse Damage/Mortality

Perhaps some seedlings were completely consumed shortly after they were planted. However we never saw (nor did anyone ever report) any animals above the ground eating newly planted seedlings at any of the four slopes.

Plant mortality caused by above ground animals appeared to be insignificant. Cages blocked small predators, like mice and voles, from lateral access to seedlings. Apparently, cages also deterred browsing by large predators, like rabbits and deer.

Only 6 of the 1080 plants were noticeably browsed: 5 on the June Lake S25W slope and 1 on the June Lake N25E slope. Deer tracks were seen on both slopes. Despite the browsing, 4 live rabbitbrush on the S25W slope were taller than 17 inches and wider than 13 inches. One browsed bitterbrush on the S25W slope was dead, while the sagebrush on the S25W slope was still alive. Except for the one bitterbrush, there was insufficient evidence to link depredation as a major cause of plant mortality on either of the June Lake slopes. Apparently, local deer and rabbit populations did most of their feeding farther away from these highway slopes.

At the other two cut slopes, no browse damage was seen on live plants or on any of the dried-out, dead plants.

Vandalism

At the Sand Shed site several cages were missing along the entire lowest row (closest to the road) of the fall planting and only a portion of the lowest row of the spring planting. There is a widened shoulder, which is used by motorists as a chain-up area when the road is snowy or icy. Maintenance people reported at least one incident of motorists using some cages to get better tire traction. On another occasion, it appeared that a vehicle drove over a portion of the lower row, because there were crushed cages and broken lath. The cages may have protected some of the heartier plants from being destroyed; our last mortality counts showed several of these plants were alive and healthy.

At the CDF site, along the two lowest rows of the spring plot, more than 20 cages were missing shortly after they were installed. They appeared to have been intentionally removed, since they were very accessible, and a whole uninterrupted line was missing, not just random occurrences. We noted that the CDF site is at the junction of a road which leads to a nearby campground with access to fishing areas. Cage material (1/4-inch hardware cloth) is a popular material for building live bait traps. None of the missing cages were positively linked to plant mortality along the lower rows. In fact several of these plants were still alive in May 1988.

There were no other overt acts of vandalism.

Summary Regarding Metal Cages

Installing and maintaining metal cages was worth the effort and cost. Cages apparently discouraged depredation by browsing animals. They also did not appear to be especially "attractive" as objects for many acts of theft or vandalism. The lack of significant depredation and vandalism contributed to the overall "good" survival of plants on this project. Most plant cages were removed before branches could become tightly wedged in the mesh.

If cages are used on future projects, they should be inspected twice yearly and removed before branches begin growing through the mesh. One inspection should be done in spring after snowmelt to remove crushed cages and to secure any loosely anchored ones. The other inspection should be done in fall to spot the cage-bound plants.

Plant Stresses

Besides browsing, pruning, and vandalism, we recorded other stresses in the "DM" field of our database.

Black Scale

By September 1984 at the Sand Shed site, an outbreak of black scale was seen on rabbitbrush. Scale was uniformly distributed over the area, that is, there were no unaffected zones in the research plot. Also, the scale did not favor plants of either source X, 24 with scale of 45 or source Z, 13 with scale of 28. As documented in (1, Racin & Dayak), no source Y rabbitbrush was planted at the Sand Shed. There is no evidence that any plants died as a result of having the scale. Counts of rabbitbrush with scale by source were 13 live of 13 Z's planted and 15 live of 24 X's planted. Scale did not appear to prevent reproduction. Rabbitbrush of both sources flowered and set seed by the next season (1985).

No black scale was seen on any plants at either of the June Lake sites. There were two source X rabbitbrush with black scale at the CDF site.

Black Aphids and Ladybugs

We saw black aphids and one of their predators, ladybugs, on live research and nearby plants. Generally the aphids appeared to cover plants sparsely by contrast to smothering them. In the "final" database you may see a plant's record marked as dead and having aphids. The plant died after being infested in a prior season. There is no evidence that aphids caused plants to die. These insects are indigenous to the region. We did not introduce them. Aphids favored sagebrush over the other species.

At both June Lake sites, aphids were seen on 37 of 113 live sagebrush. Aphids had no preference for the source (X,Y, or Z) of sagebrush. On the N25E slope aphids were present on 4 X, 8 Y, and 4 Z sagebrushes, while on the S25W slope the counts were 6 X, 7 Y, and 8 Z. Ladybugs were seen eating aphids on 1 Z bitterbrush and 1 Y sagebrush on the N25E slope. On the S25W slope they were on 1 Y sagebrush, 1 Z rabbitbrush, and 2 X rabbitbrush.

At the Sand Shed site only 6 plants were infested with the black aphids: 4 sagebrush (3 X, 1 Z), 1 X saltbush, and 1 Y ephedra. No ladybugs were seen.

At the CDF site we saw only 1 Z rabbitbrush with aphids. No ladybugs were seen.

"Gophers"

The June Lake N25E slope was habitat for burrowing animals, which we never actually saw, but assumed were gophers. Tunnel openings and surface mounding were seen before the slope was planted. The encoded "G" in our database meant that a tunnel opening was inside the boundary of the cage. We counted 30 of these openings, 26 in the spring plot and 4 in the fall plot. There were 19 dead plants in the spring plot: 6 PT X, 2 PT Y, 2 PT Z, 1 AT X, 1 AT Y, 3 AT Z, 2 CN X, and 2 CN Z. The gophers ate the roots on most of those plants, but sometimes the entire plant was missing. The 7 live plants in the fall plot were: 1 CN X, 1 CN Z, 1 AT X, 1 AT Z, 2 PT X, and 1 PT Z. It appears the gophers may have preferred bitterbrush, however there is additional information to dissuade us from accepting this as a definite "finding of fact".

Over the years surface mounds and tunnel openings progressed from the top to the bottom of the slope. Besides the 30 tunnel openings within the plant cages, there were many others on the slope which were not counted or mapped precisely. When we dug the holes to revegetate this slope, we frequently moved the power auger off the planned row lines to miss large stones and boulders. In fact many holes were dug manually (by inmates) because of the rocky character of the soil. We planted where there were no large boulders or cobbles. Thus, plant locations with few rocks were likely places for gophers to dig. Furthermore, shrubs were not the exclusive food of the gophers. It appeared they were also eating root systems of nearby grasses.

Weeds

Weeds were seen growing inside plant cages within the first year, by September 1984. Over the years there appeared to be very few weeds growing on the slopes and outside the cages. Conditions were very favorable for weeds inside cages as contrasted to outside cages on the slope. Within each cage there was moisture, nutrients, partial shade, and a place for the (weed) seed to rest, instead of tumbling downslope under the combined action of gravity and wind.

There were both grassy and woody weeds. Besides an occasional "weed" of the species we planted, only one other species was easily recognized, Salsola kali var. tenuifolia or tumbleweed. It was only present at the CDF site for the first two seasons (1, Racin & Dayak). We did not try to document the species of other weeds. There is insufficient data to conclude that competition with weeds was a singular significant cause of plant mortality or that weeds favored growing next to any particular source or species. Table 5 shows weed counts since planting.

Table 5

WEEDS INSIDE CAGES

species	total # research seedlings	seedlings with weeds #	seedlings with weeds %	dead seedlings with weeds #	dead seedlings with weeds %
bitterbrush	138	31	22	16	52
sagebrush	364	73	20	44	60
rabbitbrush	272	66	24	29	44
ephedra	133	49	37	19	39
bitterbrush	173	40	23	27	40

Weed counts at each elevation show 34 % (110/320) at CDF, 21 % (59/280) at Sand Shed, and 19 % (90/480) at June Lake. There was no pattern of more or fewer weeds growing with plants which were given supplemental water than those that were not.

Drought Stressed Plants

Since the beginning of monitoring we noticed some plants started getting "dry" or were "very dry". They appeared to be drought stressed, or "shutting down" due to lack of water and high temperature. If a plant appeared to be more than half (but less than 95 %) dry, we encoded a "D" in our database. If a plant appeared to be more than 95 % dry, it was encoded as "V". These assessments were very subjective. We frequently had difficulty determining "D" versus "V" and sometimes "V" versus dead. The records marked in the last database represent drought stressed plants seen since the summer of 1984. These data may be more useful for a future assessment. For now all we can report is: there were 46 of 700 live plants which were 50 to 95 % dry, and 25 of 700 which were more than 95 % dry. Nine of the "D" plants and only 2 of the "V" plants flowered and set seed.

Plant Mortality

Plant mortality was documented since the slopes were planted. We carefully tested very dry looking plants before declaring them dead. The most common test was to bend stems, and if they snapped, it was likely the plant was dead. More rarely we scratched the bark and looked for green wood. For sagebrush a very strong aroma indicated the plant was still alive. Sometimes by doing both of these tests a plant was recorded as dead. However by the next season, there were live sprouts, usually from the crown. See Plant Growth. This dying-back-and-resprouting phenomenon was also seen on indigenous plants nearby each of the sites, for all the species being researched. Consequently, after a plant was declared dead, the remains were left in-place. Very few of the (for sure) dead plants were pulled out to check the roots. Some had poorly developed roots, others had roots anchored beyond the augered hole.

Some of the dead plants were really "dead and missing". Earlier we presented evidence that a few of the missing plants were eaten by gophers. There was no strong evidence of mortality by insects or fungus. It is more likely that "missing" plants within the first two years, did not withstand the shock of being transplanted. They withered, died, and were apparently blown away by strong winds. Mortality in the next three years was probably due to lack of water, extreme temperatures, and very low humidity for plants with poorly developed root systems.

Plant Survival Counts

In May 1988, the fall plants were about 4-1/2 years old and the spring plants were 4 (age on slope). Tables 6 through 15 show counts, number planted, and percentages of plants still alive. Comparisons among the 3 sources (sometimes only two sources) of the same species are considered valid. Interspecies comparisons are not valid, therefore do not sum the columns in the tables, except for verifying totals of seedlings which were planted. Intersite comparisons were not made to arrive at any project conclusions. However, they may be used with caution to suggest further research in a future study, where more replicates of one species could be planted.

The experimental design was the basis for selecting categories in the tables and for the number of tables, one for "ALL SITES" (Table 6) and one for each of the 4 sites (Tables 7 through 10). The primary category in the tables is source: X, Y, and Z. The secondary category is season: fall and spring. Numbers in the "BOTH" column are sums of fall and spring counts for each species by source. They were listed to verify totals of seedlings which were planted. No inferences or conclusions were made with the "BOTH" numbers. Table 11 is patterned after Table 6 (ALL SITES) and shows survivors based on the additional categories of "watered" and "not watered". Similarly Tables 12 through 15 are patterned after Tables 7 through 10, and show survivors in the "watered" and "not watered" categories.

A 25-percent difference was the numerical criterion which was selected and used for detecting a "significant difference in survival." The 25-percent criterion is reasonable for this research. A formalized statistical procedure for detecting differences in survival was not done, because we did not know precise times and exact causes of individual plant mortality. No comparisons were made with small data sets (less than 10 plants). Thus, at site or intersite comparisons in Tables 7 through 10 were less reliable than "ALL SITES" results in Tables 6 and 11. Project conclusions are based on "ALL SITES" and cover the range of experimental conditions.

Although there were different slope aspects, elevations, and rainfall, the spring survivor results in Tables 6 and 11 showed no significant trends that one source did far better or worse than the others. In all survival tables (6 through 15) the seasonal trend that spring plants did better than fall plants stands out. The probable reason for this trend is that the fall planting was late in the season. Plants did not have enough time to acclimate to each slope, and were immediately stressed by cold temperatures. The spring plants were planted in early spring and had a whole summer of growth before having to withstand a winter. A notable exception to this trend of survivors by season and source is seen in Table 8 for the June Lake N25E slope, where the bitterbrush showed higher numbers in fall than in spring. Recall that gophers lived in the spring plot, and they literally "popped-up" more frequently at bitterbrush locations.

Assuming that 50 percent survival is good, and less than 25 percent is unacceptable, based on "ALL SITES" (Tables 6 and 11) the conclusion is, the revegetation effort was good, regardless of plant source.

Table 6

SURVIVORS - ALL SITES May 17, 1988 *

SPECIES	source X FALL	source X SPRING	source X BOTH	source Y FALL	source Y SPRING	source Y BOTH	source Z SPRING
AC	60 12/20	84 48/57	78 60/77	25 5/20	83 5/6	38 10/26	86 30/35
AT	46 37/80	78 73/94	63 110/174	N	72 68/94	A	77 74/96
CN	49 39/80	56 53/94	53 92/174	N	75 3/4	A	78 73/94
EN	N	94 44/47	A	15 6/40	87 40/46	53 46/86	N
PT	65 26/40	38 21/56	49 47/96	N	58 19/33	A	55 24/44

* KEY to tabled values:

75 percent alive

15/20 number alive/total planted

N none planted

A does not apply

codes for plant SPECIES:

AC = fourwing saltbush — Atriplex canescens

AT = big sagebrush — Artemisia tridentata

CN = rubber rabbitbrush — Chrysothamnus nauseosus

EN = gray ephedra — Ephedra nevadensis

PT = antelope bitterbrush — Purshia tridentata

codes for SOURCES:

X = seed collected and grown nonlocally

Y = seed collected nonlocally, grown locally

Z = seed collected and grown locally

Table 7

SURVIVORS - JUNE LAKE S25W - May 17, 1988 *

	source X			source Y	source Z
SPECIES	FALL	SPRING	BOTH	SPRING	SPRING
AT	60 12/20	96 23/24	80 35/44	88 22/25	84 21/25
CN	55 11/20	67 14/21	61 25/41	N	94 17/18
PT	40 8/20	36 10/28	38 18/48	56 9/16	43 10/23

* KEY to tabled values:

75 percent alive

15/20 number alive/total planted

N none planted

codes for plant SPECIES:

- AC = fourwing saltbush *Atriplex canescens*
- AT = big sagebrush *Artemisia tridentata*
- CN = rubber rabbitbrush *Chrysothamnus nauseosus*
- EN = gray ephedra *Ephedra nevadensis*
- PT = antelope bitterbrush *Purshia tridentata*

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Table 8

SURVIVORS - JUNE LAKE N25E - May 17, 1988 *

SPECIES	source X FALL	source X SPRING	source X BOTH	source Y SPRING	source Z SPRING
AT	10	32	22	42	60
	2/20	8/25	10/45	10/24	15/25
CN	5	20	13	N	40
	1/20	4/20	5/40		8/20
PT	90	39	60	59	67
	18/20	11/28	29/48	10/17	14/21

* KEY to tabled values:

75 percent alive

15/20 number alive/total planted

N none planted

codes for plant SPECIES:

AC = fourwing saltbush *Atriplex canescens*

AT = big sagebrush *Artemisia tridentata*

CN = rubber rabbitbrush *Chrysothamnus nauseosus*

EN = gray ephedra *Ephedra nevadensis*

PT = antelope bitterbrush *Purshia tridentata*

codes for SOURCES:

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Z = seed collected and grown locally

Table 9

SURVIVORS - SAND SHED S60W - May 17, 1988 *

	source X			source Y			source Z
SPECIES	FALL	SPRING	BOTH	FALL	SPRING	BOTH	SPRING
AC	N	70 19/27	A	N	83 5/6	A	80 4/5
AT	65 13/20	96 24/25	82 37/45	N	80 20/25	A	72 18/25
CN	65 13/20	56 14/25	60 27/45	N	N	A	89 25/28
EN	N	100 27/27	A	10 2/20	93 25/27	57 27/47	N

* KEY to tabled values:

75	percent alive	N none planted	A does not apply
15/20	number alive/total planted		

codes for plant SPECIES:

- AC = fourwing saltbush — Atriplex canescens
- AT = big sagebrush — Artemisia tridentata
- CN = rubber rabbitbrush — Chrysothamnus nauseosus
- EN = gray ephedra — Ephedra nevadensis
- PT = antelope bitterbrush — Purshia tridentata

codes for SOURCES:
- X = seed collected and grown nonlocally
- Y = seed collected nonlocally, grown locally
- Z = seed collected and grown locally

Table 10

SURVIVORS - CDF N10E - May 17, 1988 *

	source X			source Y			source Z
SPECIES	FALL	SPRING	BOTH	FALL	SPRING	BOTH	SPRING
AC	60	97	82	25	N	A	87
	12/20	29/30	41/50	5/20			26/30
AT	50	90	70	N	80	A	95
	10/20	18/20	28/40		16/20		20/21
CN	70	75	73	N	75	A	78
	14/20	21/28	35/48		3/4		23/28
EN	N	85	A	20	79	49	N
		17/20		4/20	15/19	19/39	

* KEY to tabled values:

75	percent alive	N none	A does
15/20	number alive/total planted	planted	not apply

codes for plant SPECIES:

AC = fourwing saltbush — *Atriplex canescens*
AT = big sagebrush — *Artemisia tridentata*
CN = rubber rabbitbrush — *Chrysothamnus nauseosus*
EN = gray ephedra — *Ephedra nevadensis*
PT = antelope bitterbrush — *Purshia tridentata*

codes for SOURCES:

X = seed collected and grown nonlocally
Y = seed collected nonlocally, grown locally
Z = seed collected and grown locally

Table 11
SURVIVORS- WATER, NOT WATERED - ALL SITES May 17, 1988 *

SPECIES	source X FALL	source X SPRING	source X BOTH	source Y FALL	source Y SPRING	source Y BOTH	source Z SPRING
AC water	70 7/10	74 20/27	73 27/37	40 4/10	67 2/3	46 6/13	89 16/18
AC not watered	50 5/10	93 28/30	83 33/40	10 1/10	100 3/3	38 4/13	82 14/17
AT water	43 17/40	82 40/49	63 57/89	N	75 33/44	A	78 38/49
AT not watered	50 20/40	73 33/45	62 53/85	N	70 35/50	A	77 36/47
CN water	55 22/40	54 26/48	52 46/88	N	100 2/2	A	76 34/45
CN not watered	43 17/40	59 27/46	51 44/86	N	50 1/2	A	80 39/49
EN water	N	96 23/24	A	10 2/20	87 21/24	52 23/44	N
EN not watered	N	91 21/23	A	20 4/20	86 19/22	55 23/44	N
PT water	65 13/20	43 12/28	52 25/48	N	43 6/14	A	60 15/25
PT not watered	65 13/20	32 9/28	46 22/48	N	68 13/19	A	47 9/19

* KEY to tabled values:

75	percent alive	N none planted	A does not apply
15/20	number alive/total planted		

codes for plant SPECIES:
- AC = fourwing saltbush — Atriplex canescens
- AT = big sagebrush — Artemisia tridentata
- CN = rubber rabbitbrush — Chrysothamnus nauseosus
- EN = gray ephedra — Ephedra nevadensis
- PT = antelope bitterbrush — Purshia tridentata

codes for SOURCES:
- X = seed collected and grown nonlocally
- Y = seed collected nonlocally, grown locally
- Z = seed collected and grown locally

Table 12

SURVIVORS - WATER, NOT WATERED - JUNE LAKE S25W May 17, 1988 *

SPECIES	source X FALL	source X SPRING	source X BOTH	source Y SPRING	source Z SPRING
AT water	40 4/10	93 13/14	71 17/24	90 9/10	92 12/13
AT not watered	80 8/10	100 10/10	90 18/20	87 13/15	75 9/12
CN water	60 6/10	82 9/11	71 15/21	N	100 8/8
CN not watered	50 5/10	50 5/10	50 10/20	N	90 9/10
PT water	40 4/10	46 6/13	43 10/23	29 2/7	43 6/14
PT not watered	40 4/10	27 4/15	32 8/25	78 7/9	44 4/9

* KEY to tabled values:

75 percent alive
15/20 number alive/total planted

N none planted

codes for plant SPECIES:

AC = fourwing saltbush *Atriplex canescens*
AT = big sagebrush *Artemisia tridentata*
CN = rubber rabbitbrush *Chrysothamnus nauseosus*
EN = gray ephedra *Ephedra nevadensis*
PT = antelope bitterbrush *Purshia tridentata*

codes for SOURCES:
X = seed collected and grown nonlocally
Y = seed collected nonlocally, grown locally
Z = seed collected and grown locally

Table 13

SURVIVORS - WATER, NOT WATERED - JUNE LAKE N25E - May 17, 1988 *

SPECIES	source X FALL	source X SPRING	source X BOTH	source Y SPRING	source Z SPRING
AT water	10 1/10	42 5/12	27 6/22	50 6/12	54 7/13
AT not watered	10 1/10	23 3/13	17 4/23	33 4/12	67 8/12
CN water	10 1/10	10 1/10	10 2/20	N	40 4/10
CN not watered	0 0/10	30 3/10	15 3/20	N	40 4/10
PT water	90 9/10	40 6/15	60 15/25	57 4/7	82 9/11
PT not watered	90 9/10	38 5/13	61 14/23	60 6/10	50 5/10

* KEY to tabled values:

75 percent alive

15/20 number alive/total planted

N none planted

codes for plant SPECIES:

AC = fourwing saltbush — Atriplex canescens

AT = big sagebrush — Artemisia tridentata

CN = rubber rabbitbrush — Chrysothamnus nauseosus

EN = gray ephedra — Ephedra nevadensis

PT = antelope bitterbrush — Purshia tridentata

codes for SOURCES:

X = seed collected and grown nonlocally

Y = seed collected nonlocally, grown locally

Z = seed collected and grown locally

Table 14

SURVIVORS - WATER, NOT WATERED - SAND SHED S60W - May 17, 1988 *

SPECIES	source X FALL	source X SPRING	source X BOTH	source Y FALL	source Y SPRING	source Y BOTH	source Z SPRING
AC water	N	50 6/12	A	N	67 2/3	A	67 2/3
AC not watered	N	87 13/15	A	N	100 3/3	A	100 2/2
AT water	70 7/10	100 13/13	87 20/23	N	92 11/12	A	77 10/13
AT not watered	60 6/10	92 11/12	77 17/22	N	69 9/13	A	67 8/12
CN water	70 7/10	46 6/13	57 13/23	N	N	A	77 10/13
CN not watered	60 6/10	67 8/12	64 14/22	N	N	A	100 15/15
EN water	N	100 14/14	A	10 1/10	93 13/14	58 14/24	N
EN not watered	N	100 13/13	A	10 1/10	92 12/13	57 13/23	N

* KEY to tabled values:

75 percent alive
15/20 number alive/total planted

N none planted

A does not apply

codes for plant SPECIES:
- AC = fourwing saltbush — *Atriplex canescens*
- AT = big sagebrush — *Artemisia tridentata*
- CN = rubber rabbitbrush — *Chrysothamnus nauseosus*
- EN = gray ephedra — *Ephedra nevadensis*
- PT = antelope bitterbrush — *Purshia tridentata*

codes for SOURCES:
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- Z = seed collected and grown locally

Table 15

SURVIVORS - WATER, NOT WATERED - CDF N10E - May 17, 1988 *

	source X			source Y			source Z
SPECIES	FALL	SPRING	BOTH	FALL	SPRING	BOTH	SPRING
AC water	70 7/10	93 14/15	84 21/25	40 4/10	N	A	93 14/15
AC not watered	50 5/10	100 15/15	80 20/25	10 1/10	N	A	80 12/15
AT water	50 5/10	90 9/10	70 14/20	N	70 7/10	A	90 9/10
AT not watered	50 5/10	90 9/10	70 14/20	N	90 9/10	A	100 11/11
CN water	80 8/10	71 10/14	75 18/24	N	100 2/2	A	86 12/14
CN not watered	60 6/10	79 11/14	71 17/24	N	50 1/2	A	79 11/14
EN water	N	90 9/10	A	10 1/10	80 8/10	45 9/20	N
EN not watered	N	80 8/10	A	30 3/10	78 7/9	53 10/19	N

* KEY to tabled values:

75 percent alive
15/20 number alive/total planted

N none planted

A does not apply

codes for plant SPECIES:
- AC = fourwing saltbush — Atriplex canescens
- AT = big sagebrush — Artemisia tridentata
- CN = rubber rabbitbrush — Chrysothamnus nauseosus
- EN = gray ephedra — Ephedra nevadensis
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codes for SOURCES:
- X = seed collected and grown nonlocally
- Y = seed collected nonlocally, grown locally
- Z = seed collected and grown locally

Flowering: An Indicator of Individual Plant Success

Besides high numbers of survivors, we observed and recorded another indicator of "apparent" success, the setting of flowers and production of seeds. There were also a few recently sprouted plants of the same species as we planted at both June Lake sites and at the CDF site. At the Sand Shed site there did not appear to be any recent sprouts. We did not do any analyses on plants to verify whether the recent sprouts propagated from research seedlings, and we did not do any seed viability tests. Thus we only state "apparent" success and note that "flowering" plants are likely to propagate.

Twenty two percent of the research seedlings (234 of 1080) flowered and produced seed. Thirty one percent, (215 of 700) were still alive in May 1988. So, of the plants which flowered, only 19 died. Percentages and numbers of plants which flowered are in Tables 16 (for "ALL SITES") and 17 through 20 (for each of the 4 slopes). The tables are organized on the basis of species and treatment (watered or not) by source and season planted. They are patterned after Tables 11 through 15.

The numbers in Tables 16 and 6 show that 4 percent (5 of 138) of the saltbush and 1 percent (2 of 173) of the bitterbrush flowered. None of the 133 ephedra flowered. Most research plants of these three species have not matured yet, by contrast to nonresearch plants which flowered nearby each of the sites.

In contrast to ephedra, saltbush, and bitterbrush there were higher percentages of mature sagebrush and rabbitbrush. Flowers and seed were produced by 44 percent (159 of 364) of the sagebrush and 25 percent (68 of 272) of the rabbitbrush. Apparently weather and other conditions were more suitable for the ripening of sagebrush than for rabbitbrush.

Table 16

FLOWERED - WATER, NOT WATERED - ALL SITES *

SPECIES	source X FALL	source X SPRING	source X BOTH	source Y FALL	source Y SPRING	source Y BOTH	source Z SPRING
AC water	0	0	0	0	0	0	11 2/18
AC not watered	10 1/10	7 2/30	8 3/40	0	0	0	0
AT water	28 11/40	65 32/49	48 43/89	N	55 24/44	A	31 15/49
AT not watered	30 12/40	62 28/45	47 40/85	N	34 17/50	A	43 20/47
CN water	5 2/40	25 12/48	16 14/88	N	50 1/2	A	44 20/45
CN not watered	3 1/40	28 13/46	16 14/86	N	0	A	39 19/49
PT water	0	4 1/28	2 1/48	N	0	A	0
PT not watered	5 1/20	0	2 1/48	N	0	A	0

* KEY to tabled values:

75 percent flowered
15/20 number flowered/total planted

N none planted

A does not apply

codes for plant SPECIES:

AC = fourwing saltbush <u>Atriplex canescens</u>
AT = big sagebrush <u>Artemisia tridentata</u>
CN = rubber rabbitbrush <u>Chrysothamnus nauseosus</u>
EN = gray ephedra <u>Ephedra nevadensis</u>
PT = antelope bitterbrush <u>Purshia tridentata</u>

codes for SOURCES:
X = seed collected and grown nonlocally
Y = seed collected nonlocally, grown locally
Z = seed collected and grown locally

Table 17
FLOWERED - WATER, NOT WATERED - JUNE LAKE S25W *

SPECIES	source X FALL			source Y SPRING	source Z SPRING
	FALL	SPRING	BOTH		
AT water	30 3/10	71 10/14	54 13/24	70 7/10	62 8/13
AT not watered	20 2/10	60 6/10	40 8/20	47 7/15	42 5/12
CN water	0	18 2/11	10 2/21	N	63 5/8
CN not watered	0	10 1/10	5 1/20	N	20 2/10
PT water	0	8 1/13	4 1/23	0	0
PT not watered	10 1/10	0	4 1/25	0	0

* KEY to tabled values:

75 percent flowered
15/20 number flowered/total planted

N none planted

codes for plant SPECIES:
- AC = fourwing saltbush — _Atriplex canescens_
- AT = big sagebrush — _Artemisia tridentata_
- CN = rubber rabbitbrush — _Chrysothamnus nauseosus_
- EN = gray ephedra — _Ephedra nevadensis_
- PT = antelope bitterbrush — _Purshia tridentata_

codes for SOURCES:
- X = seed collected and grown nonlocally
- Y = seed collected nonlocally, grown locally
- Z = seed collected and grown locally

Table 18
FLOWERED - WATER, NOT WATERED - JUNE LAKE N25E *

SPECIES	source X FALL	source X SPRING	source X BOTH	source Y SPRING	source Z SPRING
AT water	10 1/10	17 2/12	13 3/22	42 5/12	8 1/13
AT not watered	10 1/10	15 2/13	13 3/23	33 4/12	33 4/12
CN water	10 1/10	0	5 1/20	N	20 2/10
CN not watered	0	10 1/10	5 1/20	N	20 2/10

* KEY to tabled values:

75 percent flowered
15/20 number flowered/total planted

N none planted

codes for plant SPECIES:
- AC = fourwing saltbush — Atriplex canescens
- AT = big sagebrush — Artemisia tridentata
- CN = rubber rabbitbrush — Chrysothamnus nauseosus
- EN = gray ephedra — Ephedra nevadensis
- PT = antelope bitterbrush — Purshia tridentata

codes for SOURCES:
- X = seed collected and grown nonlocally
- Y = seed collected nonlocally, grown locally
- Z = seed collected and grown locally

Table 19
FLOWERED - WATER, NOT WATERED - SAND SHED S60W *

SPECIES	source X FALL	source X SPRING	source X BOTH	source Y FALL	source Y SPRING	source Z SPRING
AT water	40 4/10	85 11/13	65 15/23	N	50 6/12	15 2/13
AT not watered	60 6/10	92 11/12	77 17/22	N	23 3/13	58 7/12
CN water	0	46 6/13	26 6/23	N	N	46 6/13
CN not watered	10 1/10	50 6/12	32 7/22	N	N	60 9/15

* KEY to tabled values:

75 percent flowered
15/20 number flowered/total planted
N none planted

codes for plant SPECIES:

AC = fourwing saltbush *Atriplex canescens*
AT = big sagebrush *Artemisia tridentata*
CN = rubber rabbitbrush *Chrysothamnus nauseosus*
EN = gray ephedra *Ephedra nevadensis*
PT = antelope bitterbrush *Purshia tridentata*

codes for SOURCES:
X = seed collected and grown nonlocally
Y = seed collected nonlocally, grown locally
Z = seed collected and grown locally

Table 20
FLOWERED - WATER, NOT WATERED - CDF N10E *

SPECIES	source X FALL	source X SPRING	source X BOTH	source Y FALL	source Y SPRING	source Z SPRING
AC water	0	0	0	0	N	13 2/15
AC not watered	10 1/10	13 2/15	12 3/25	0	N	0
AT water	30 3/10	90 9/10	60 12/20	N	60 6/10	40 4/10
AT not watered	30 3/10	90 9/10	60 12/20	N	30 3/10	36 4/11
CN water	10 1/10	29 4/14	21 5/24	N	50 1/2	50 7/14
CN not watered	0	36 5/14	21 5/24	N	0	43 6/14

* KEY to tabled values:

75 percent flowered
15/20 number flowered/total planted

N none planted

codes for plant SPECIES:
- AC = fourwing saltbush — _Atriplex canescens_
- AT = big sagebrush — _Artemisia tridentata_
- CN = rubber rabbitbrush — _Chrysothamnus nauseosus_
- EN = gray ephedra — _Ephedra nevadensis_
- PT = antelope bitterbrush — _Purshia tridentata_

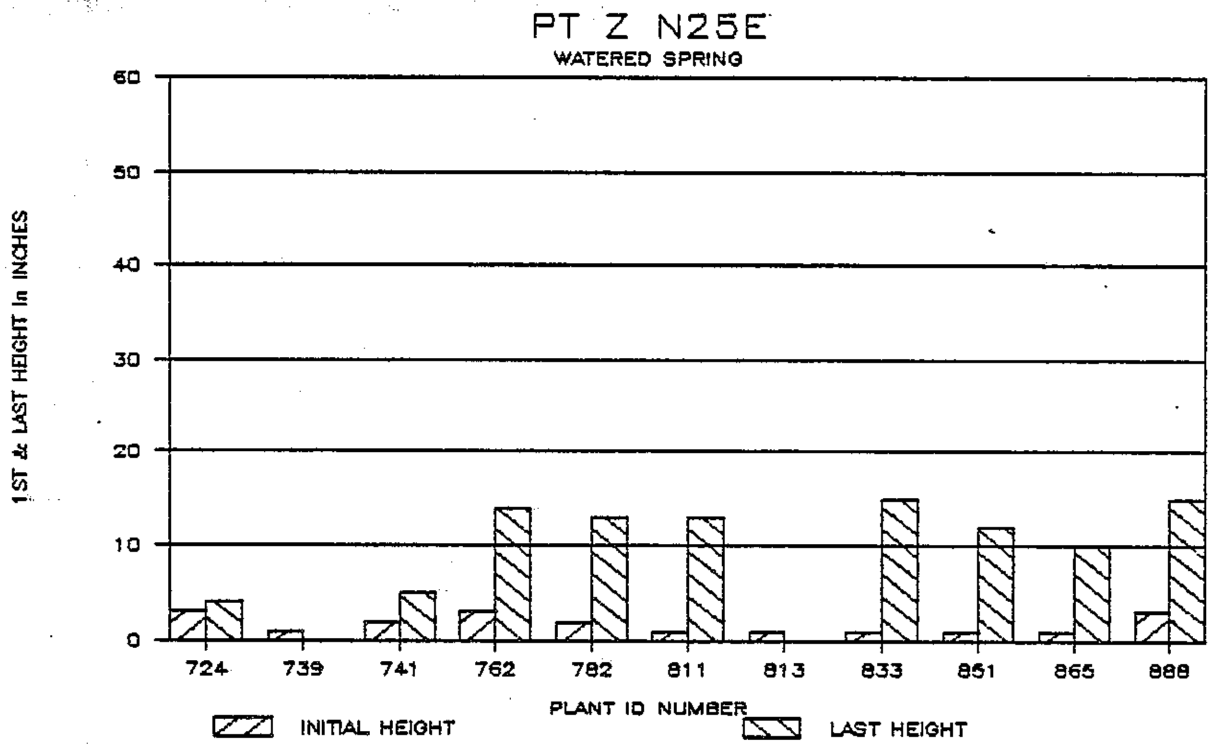
codes for SOURCES:
- X = seed collected and grown nonlocally
- Y = seed collected nonlocally, grown locally
- Z = seed collected and grown locally

Plant Height and Width

We studied plant height and width in addition to survival before making any final conclusions about any of the three sources of plants. Initial (October 1983) and last (October 1987) maximum observed heights and widths for each plant were recorded and assembled in the database. Last heights and widths of dead plants were recorded as zeros. All other measurements were recorded using the precision criterion "to the next higher inch". Using only integers practically eliminated the possibility of "order of magnitude" errors in the field and during key data entry.

We plotted bar graphs of initial and last height for each of the 1080 plants. The graphs were categorized as follows: species, source, slope aspect, fall or spring, and watered or not. Our experimental design produced 100 graphs. Figure 10 (heights) and Figure 11 (widths) are examples of the graphs. There were only two graphs per sheet for readability. Using the same vertical scale on all plots (0 to 60 inches) facilitated visual comparisons. The 100 sheets of height and width graphs are available for perusal at the Transportation Laboratory, or you can see APPENDIX C for information on how to order disks to view and print your own set.

Focusing on live plants, we scrutinized and evaluated the graphs for any outstanding, noticeable patterns or trends among the three sources. There appeared to be no distinct trends of differences in height or width. There did appear to be similar variations of height and width among sources, and similar minimum and maximum heights and widths. Because there were so many graphs to view, statistical tests were done to detect differences of mean height among the sources of plant materials and the effect of giving extra water (or not) to half the plants. See Chapter 9.



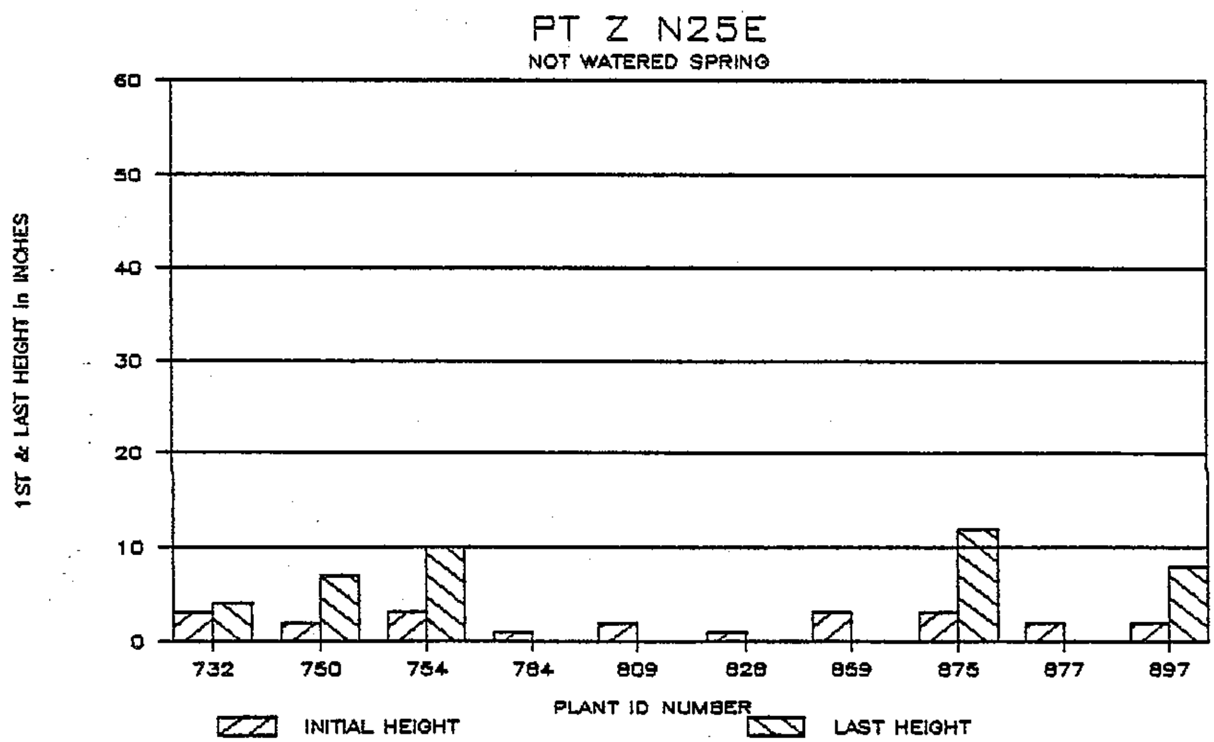
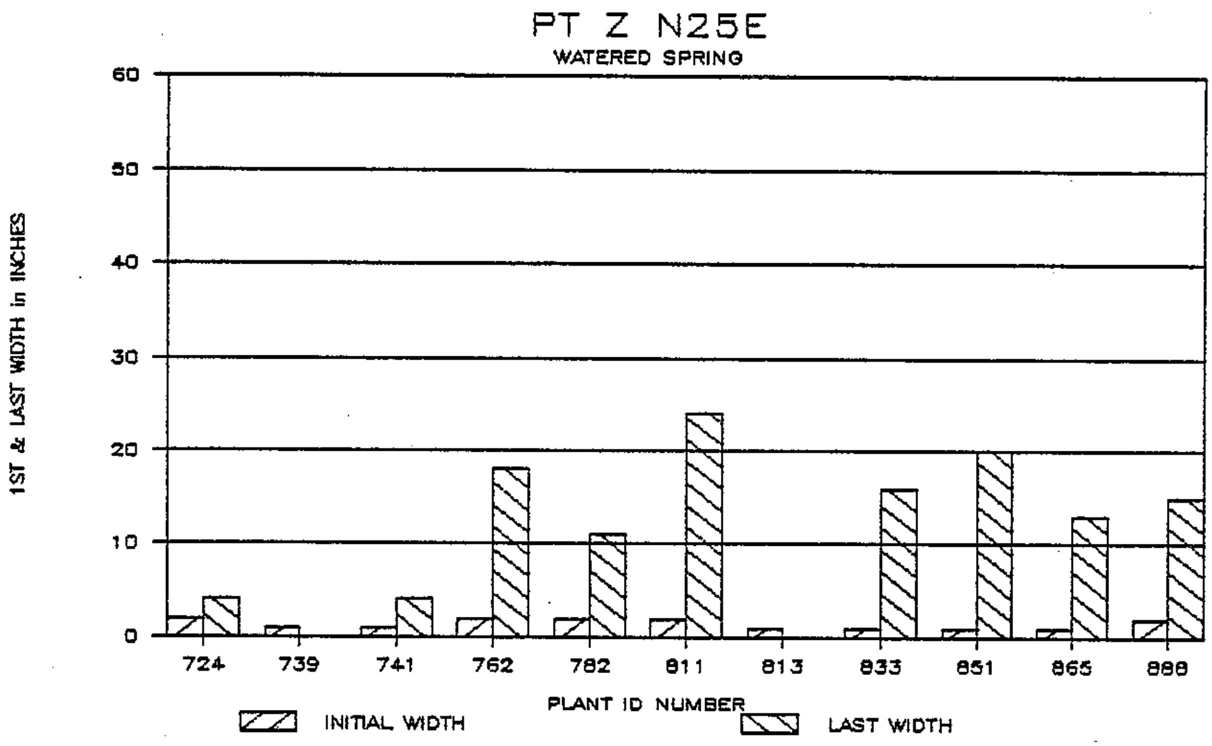


FIGURE 10. SAMPLE BAR GRAPHS of INITIAL and LAST HEIGHTS



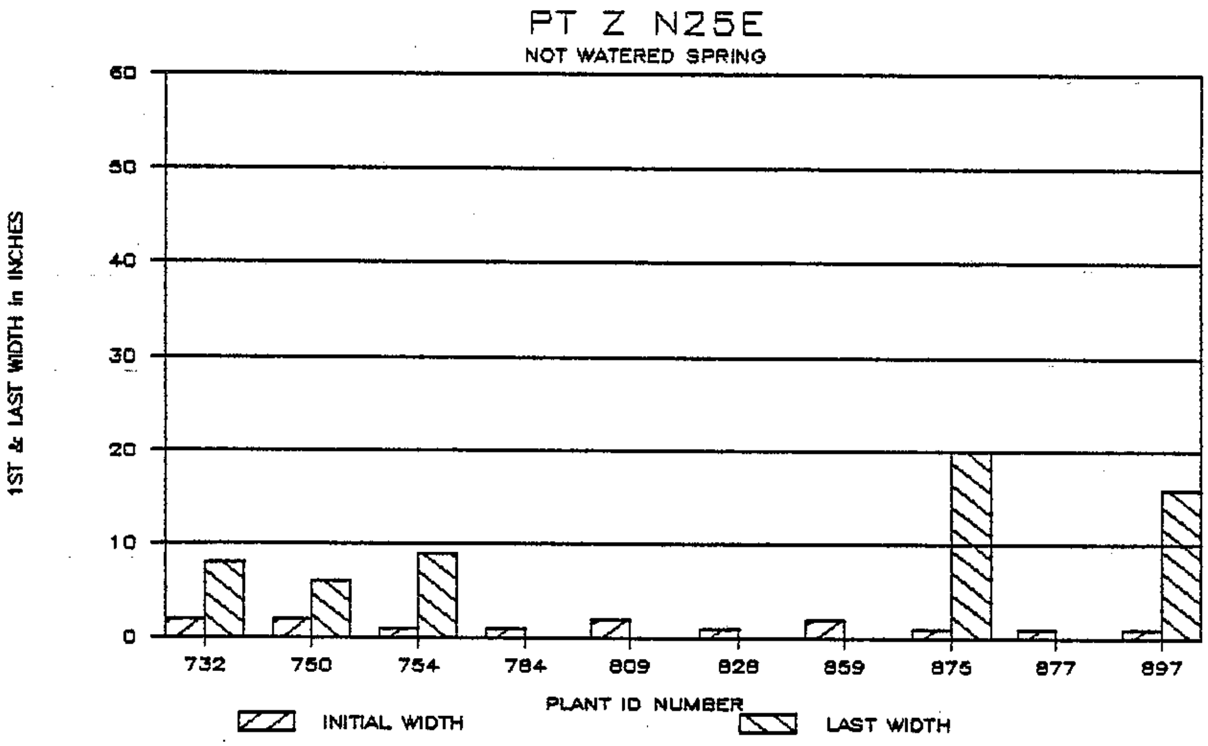


FIGURE 11. SAMPLE BAR GRAPHS of INITIAL and LAST WIDTHS

The "last" height (measured in May, 1988) of most live plants (657 of 700) was less than or equal to 20 inches. The width of most (598 of 700) was less than or equal to 15 inches. Since the cages were removed in 1987, any detailed studies of width should be done in the future, after the plants have had time to grow unrestricted laterally.

Plant Growth

A simple growth study was possible by using the two databases, initial and last. Tables 21 through 25 show the average changes in height and width and the average heights and widths for each species by source, season, and watered or not. A positive change means growth, while a negative change means dieback. The tables are patterned similar to Tables 11 through 15. The (by now) familiar key for species and sources was used in these tables but is not shown. The "BOTH" column was omitted. The "number in the sample" is the number of live plants in that category, which was repeated for convenience in assessing whether t-testing should be done.

The following generalizations resulted by looking at "groups" of plants. Whether you look at all sites (Table 21) or each individual site (Tables 22 through 25) the source Z plant groups all showed an average growth. No sources of sagebrush died back. Some groups (fall or spring, watered or not) of source X rabbitbrush, ephedra, saltbush, and bitterbrush showed an average dieback. Of the source Y groups only the fall, watered saltbush at the CDF site showed an average dieback. The bar graphs were scanned to see if the average growth or dieback were due to a single large plant (either initial or last measurement). Usually the average of either growth (+) or dieback (-) was "set" by more than just one plant. There were a few cases of zero average growth for a group.

By July 1986 woody stems were very noticeable. Stem diameters were not recorded routinely for each plant. Some random measurements at all sites showed that stem diameters varied from roughly 1/4 to 1/2 inch about 2-inches from the ground. By 1988 some plants which showed little growth in height or width were developing thicker stems, some as much as 1-inch in diameter. In the total development of above ground growth, a thicker stem diameter and no change in height or width may partially be due to the plants responding to strong winds on these slopes (12, Dayak). Further studies of growth were suspended. These measurements of seedlings to 4-1/2 years, should be archived for a future study of growth, perhaps when the plants are about 10 years old.

Table 21
AVERAGE CHANGES and AVERAGE HEIGHTS and WIDTHS
WATER, NOT WATERED - ALL SITES May 17, 1988 *

SPECIES	source X FALL	source X SPRING	source Y FALL	source Y SPRING	source Z SPRING
AC water	7 1/8 6/7	20 1/11 6/9	4 -1/6 4/5	2 8/10 6/7	16 12/15 9/11
AC not watered	5 2/9 5/6	28 0/9 4/7	1 5/6 5/6	3 0/3 4/5	14 8/11 6/8
AT water	17 3/9 6/7	40 4/10 7/9	N	33 9/11 6/8	38 7/9 7/8
AT not watered	20 5/10 8/9	33 3/9 6/8	N	35 7/9 6/7	36 8/10 6/8
CN water	22 -3/11 6/7	26 6/14 9/11	N	2 8/13 12/14	34 9/16 13/15
CN not watered	17 2/15 9/10	27 5/11 7/9	N	1 0/5 2/5	39 7/14 10/12
EN water	N	23 -4/8 9/10	2 0/2 2/3	21 5/7 9/10	N
EN not watered	N	21 - 3/6 7/9	4 4/5 5/6	19 3/5 6/7	N
PT water	13 7/12 15/16	12 8/12 16/18	N	6 9/10 10/12	15 8/10 11/12
PT not watered	13 7/11 15/16	9 4/7 11/13	N	13 9/10 11/12	9 4/7 11/10

* KEY to tabled values:
13 number alive
7/14 average HEIGHT change / average HEIGHT
6/11 average WIDTH change / average WIDTH

N none planted

Table 22
AVERAGE CHANGES and AVERAGE HEIGHTS and WIDTHS
WATER, NOT WATERED - JUNE LAKE S25W May 17, 1988 *

SPECIES	source X FALL	source X SPRING	source Y FALL	source Y SPRING	source Z SPRING
AT water	4 7/14 10/12	13 5/13 11/14	N	9 14/15 11/13	12 11/13 12/14
AT not watered	8 6/11 12/13	10 2/10 7/10	N	13 10/12 8/10	9 9/11 10/12
CN water	6 -1/13 7/8	9 9/22 16/18	N	N	8 19/29 26/27
CN not watered	5 4/18 12/13	5 7/18 13/15	N	N	9 8/18 14/15
PT water	4 4/10 18/19	6 9/13 18/21	N	2 8/10 14/16	6 6/8 8/9
PT not watered	4 5/10 17/18	4 4/6 6/9	N	7 8/9 13/14	4 3/5 9/11

* KEY to table values:
13 number in sample
7/14 average change in HEIGHT / average HEIGHT
6/11 average change in WIDTH / average WIDTH

N none planted

Table 23

AVERAGE CHANGES and AVERAGE HEIGHTS and WIDTHS
WATER, NOT WATERED - JUNE LAKE N25E - May 17, 1988 *

SPECIES	source X FALL	source X SPRING	source Y FALL	source Y SPRING	source Z SPRING
AT water	1 4/12 10/11	5 5/12 8/10	N	6 12/14 8/9	7 7/9 4/6
AT not watered	1 18/24 11/12	3 7/15 11/14	N	4 14/17 12/14	8 13/15 9/11
CN water	1 7/22 17/18	1 -4/8 4/7	N	N	4 4/12 8/10
CN not watered	0	3 0/10 6/10	N	N	4 16/26 17/18
PT water	9 8/13 14/15	6 7/11 13/15	N	4 9/10 8/10	9 9/11 12/14
PT not watered	9 7/12 14/15	5 4/8 14/16	N	6 9/10 10/11	5 6/8 10/12

* KEY to tabled values:
13 number in sample
7/14 average change in HEIGHT / average HEIGHT
6/11 average change in WIDTH / average WIDTH

N none planted

Table 24
AVERAGE CHANGES and AVERAGE HEIGHTS and WIDTHS
WATER, NOT WATERED - SAND SHED S60W - May 17, 1988 *

SPECIES	source X FALL	source X SPRING	source Y FALL	source Y SPRING	source Z SPRING
AC water	N	6 -2/8 5/7	N	2 8/10 6/7	2 7/12 6/8
AC not watered	N	13 -1/8 3/5	N	3 0/3 4/5	2 2/5 6/7
AT water	7 1/7 5/6	13 2/8 4/6	N	11 5/6 3/4	10 2/4 4/5
AT not watered	6 4/10 5/6	11 2/6 5/6	N	9 3/4 3/4	8 4/6 4/6
CN water	7 -7/7 4/5	6 4/9 4/6	N	N	10 8/13 10/11
CN not watered	6 -2/12 8/9	8 1/7 3/6	N	N	15 2/9 6/8
EN water	N	14 -3/8 9/10	1 0/2 0/1	13 5/8 8/9	N
EN not watered	N	13 - 1/6 7/8	1 7/8 7/8	12 4/6 6/7	N

* KEY to tabled values:
13 number in sample
7/14 average change in HEIGHT / average HEIGHT
6/11 average change in WIDTH / average WIDTH

N none planted

Table 25
AVERAGE CHANGES and AVERAGE HEIGHTS and WIDTHS
WATER, NOT WATERED - CDF N10E - May 17, 1988 *

SPECIES	source X FALL	source X SPRING	source Y FALL	source Y SPRING	source Z SPRING
AC water	7 1/8 6/7	14 3/12 6/9	4 -1/6 4/5	N	14 13/16 9/11
AC not watered	5 2/9 5/6	15 0/9 5/8	1 5/6 5/6	N	12 9/12 6/8
AT water	5 3/8 4/5	9 4/9 4/7	N	7 6/9 3/5	9 6/7 4/6
AT not watered	5 2/7 4/5	9 5/8 4/7	N	9 3/6 2/4	11 5/7 3/5
CN water	8 -3/11 6/7	10 7/11 6/9	N	2 8/13 12/14	12 5/12 9/11
CN not watered	6 5/16 8/9	11 8/11 6/8	N	1 0/5 2/5	11 7/13 10/12
EN water	N	9 -4/8 10/11	1 1/2 4/5	8 4/7 11/12	N
EN not watered	N	8 - 7/6 8/9	3 2/4 4/5	7 1/4 5/6	N

* KEY to tabled values:
13 number in sample
7/14 average change in HEIGHT / average HEIGHT
6/11 average change in WIDTH / average WIDTH

N none planted

9. STATISTICAL STUDIES

We excluded width from statistical studies, because for the first three years, lateral growth was restricted by cages. Maximum height of live plants was selected as the study variate. The 0.05 level of significance was chosen for 1-way analyses of variance (ANOVA's) and also for t-test's. Bar graphs of height indicated similarity in the way height varied. Sometimes there were groups of data which appeared to be taller than other groups, but there was enough variability within groups to make a visual assessment difficult. ANOVA's and t-test's helped us detect differences in mean heights among sources and in giving extra water or not. Height data were extracted from the database with the last set of measurements.

To see if there were differences in mean heights among plant sources X, Y, and Z, we did 1-way (single classification) ANOVA's. The t-test was used when there were only two sources to compare. Before doing any normal statistical tests, histograms were plotted and viewed to confirm that heights were normally distributed. The histograms (not published) plotted roughly as normal distributions with no distinct patterns of uniformity. That is, there was no one source which consistently showed the same height. Also, there were no extremely large sets of height measurements. Thus, there was no need to transform data, like taking square roots or natural logs, to fit a normal distribution.

Site-specific ANOVA's were not done because of the relatively small numbers of observations by species and source at each site. The ANOVA is not reliable for very small data sets. In fall 1983, very small numbers of source Y seedlings, and no source Z seedlings were planted. Therefore, we first tested only the spring groups, for which there were heights of source Z plants. Later we combined the fall and spring data (more X and Y heights) to increase the size of data sets. This refinement did not mask the difference which was found among heights of saltbush sources. Results of ANOVA and t-tests are in Table 26. Since there were no source Z ephedra and no source Y rabbitbrush (1, Racin and Dayak), t-test's were done on ephedra and rabbitbrush.

Table 26

ANOVA and T-TEST RESULTS: MEAN HEIGHTS of PLANT SOURCES

test	species	sources	all sites groups tested	any significant difference
ANOVA	saltbush	X Y Z	spring	yes
ANOVA	saltbush	X Y Z	fall & spring	yes
ANOVA	sagebrush	X Y Z	spring	no
ANOVA	sagebrush	X Y Z	fall & spring	no
t-test	ephedra	X Y	spring	no
t-test	ephedra	X Y	fall & spring	no
t-test	rabbitbrush	X Z	spring	no
t-test	rabbitbrush	X Z	fall & spring	no
ANOVA	bitterbrush	X Y Z	spring	no
ANOVA	bitterbrush	X Y Z	fall & spring	no

For saltbush (fall and spring), a Student-Newman-Keuls test was done to determine which means were "different". This was an "unplanned" test of multiple comparison of means for unequal samples. An "F-max" test was also done to verify that the variances of the samples were heterogeneous, that is, there is equal scatter (13 & 14, Sokal & Rohlf). The mean height of source Y saltbush, 5.9 inches, (nonlocal seed grown locally) was found to be "smaller" than source Z, 13.3 inches, (local seed grown locally) at the 0.05 level of significance.

We also did some t-test's to help us decide whether watering or not during the first growing season made a difference in mean heights, when the plants were evaluated after 4 years for spring and after 4-1/2 years for fall plants. We specifically do not imply that taller is better than shorter or vice versa. The t-test's were done by species, within a source, and within a season. Most groups showed no significant difference. The difference found for source X rabbitbrush suggests that extra water was not needed to produce taller plants. The difference found for source X bitterbrush suggests extra water helped to produce taller plants. All t-test results are reported in Table 27. The pattern of t-test's parallels the structure of results in Table 11.

Table 27

T-TEST RESULTS: MEAN HEIGHTS, WATERED or NOT, ALL SITES

	source X		source Y			source Z
SPECIES	FALL	SPRING	FALL	SPRING	BOTH	SPRING
saltbush	noSD	noSD	NT	NT	noSD	noSD
sagebrush	noSD	noSD	N	noSD	A	noSD
rabbitbrush	10.8 15.1	noSD	N	NT	A	noSD
ephedra	N	noSD	NT	noSD	NT	N
bitterbrush	noSD	11.8 7.3	N	noSD	A	noSD

* KEY to tabled values:
noSD = no significant difference
NT group not tested. N none planted. A does not apply.
difference detected: 10.8 watered mean height (inches)
15.1 not watered mean height (inches)

codes for SOURCES: X = seed collected and grown nonlocally
Y = seed collected nonlocally, grown locally
Z = seed collected and grown locally

REFERENCES

1 Racin, James A. and Dayak, Tom, Revegetation of Highway Slopes in the High Desert With Native Plant Seedlings, Interim Report, 1982-1985, FHWA/CA-TL-86/03, California Department of Transportation, Transportation Laboratory, Sacramento, CA, April, 1986.

2 Smith, P.D., Edell,J.A., and Jurak, F., Rehabilitation of Eastern Sierra Nevada Roadsides, California Agriculture, University of California Press, April, 1978.

3 Edell, Jack, District 09 Project Co-investigator, personal communication, May 18, 1988.

4 California Department of Water Resources, Water Conditions in California, California Cooperative Snow Surveys, Bulletin 120, Fall Report October 1982, DWR, Sacramento, CA.

5 California Department of Water Resources, Water Conditions in California, California Cooperative Snow Surveys, Bulletin 120, Fall Report October 1983, DWR, Sacramento, CA.

6 California Department of Water Resources, Water Conditions in California, California Cooperative Snow Surveys, Bulletin 120, Fall Report October 1984, DWR, Sacramento, CA.

7 California Department of Water Resources, Water Conditions in California, California Cooperative Snow Surveys, Bulletin 120, Fall Report October 1985, DWR, Sacramento, CA.

8 California Department of Water Resources, Water Conditions in California, California Cooperative Snow Surveys, Bulletin 120, Fall Report October 1986, DWR, Sacramento, CA.

REFERENCES

9 California Department of Water Resources, Water Conditions in California, California Cooperative Snow Surveys, Bulletin 120, Fall Report October 1987, DWR, Sacramento, CA.

10 California Department of Water Resources, Water Conditions in California, California Cooperative Snow Surveys, Bulletin 120, Report 3 April, 1988, DWR, Sacramento, CA.

11 Clary, Rai F., Planting Techniques and Materials for Revegetation of California Roadsides, California Department of Transportation, Sacramento, CA, December, 1983.

12 Dayak, Tom, District 09 Project Co-investigator, personal communication, August, 1988.

13 Sokal, Robert R. and Rohlf, F. James, Biometry: The Principles and Practice of Statistics in Biological Research, 1st edition, W.H. Freeman and Company, San Francisco, CA, 1969

14 Sokal, Robert R. and Rohlf, F. James, Statistical Tables, 1st edition, W.H. Freeman and Company, San Francisco, CA, 1969.

APPENDIX A

Planting Layouts at Sites

Orientation below (and of each layout) is facing the slope.

Figure A-2 fall Layout A	Figure A-3 spring Layout C	Figure A-3 spring Layout D

"June Lake" 395 northbound, Mono Co. post mile 40.1 ---> Bishop

Figure A-4 spring Layout E	Figure A-2 fall Layout B

"June Lake" 395 southbound, Mono Co. post mile 40.1 <--- Bishop

Figure A-5 fall Layout F	Figure A-6 spring Layout G	Figure A-6 spring Layout H

"Sand Shed" 395 northbound Mono Co. post mile 3.5 ---> Bishop

Figure A-7 spring Layout I	Figure A-8 fall Layout J

"CDF" 395 southbound, Inyo Co. post mile 122.4 <--- Bishop

codes for SPECIES of plants:

- AC = fourwing saltbush — *Atriplex canescens*
- AT = big sagebrush — *Artemisia tridentata*
- CN = rubber rabbitbrush — *Chrysothamnus nauseosus*
- EN = gray ephedra — *Ephedra nevadensis*
- PT = antelope bitterbrush — *Purshia tridentata*

codes for SOURCES of seedlings:

- x = seedling grown nonlocally (purchased)
- y = seedling grown locally from nonlocally purchased seed
- z = seedling grown locally from locally collected seed

EXAMPLE: species——PTz——source
74——ID-NUMBER (identification number)

INDEX SHEET for LAYOUTS in FIGURES A-2 through A-8
FIGURE A-1

ID-NUMBER under species-source code = plant ALIVE on 5/17/88
Underlined species-source code = plant DIED before 10/7/85
NO underline, NO ID-NUMBER = plant DIED between 10/7/85 & 5/17/88

Layout A - S 25 W June Lake - Planted in FALL, 10/27/83
(Subtract 60 from ID-NUMBER for stake number in field.)

supplemental water						no supplemental water					
PTx 61	<u>CNx</u>	CNx 63	<u>PTx</u>	ATx 65	ATx 66	ATx	PTx	<u>PTx</u>	<u>CNx</u>	ATx 71	CNx 72
<u>PTx</u>	<u>CNx</u>	<u>PTx</u>	<u>CNx</u>	<u>ATx</u>	<u>ATx</u>	<u>CNx</u>	PTx	CNx	ATx	ATx 83	<u>PTx</u>
<u>PTx</u>	PTx 86	CNx 87	CNx 88	<u>ATx</u>	<u>ATx</u>	CNx 91	PTx 92	ATx 93	<u>PTx</u>	ATx 95	<u>CNx</u>
<u>PTx</u>	<u>ATx</u>	<u>CNx</u>	ATx 100	CNx 101	<u>PTx</u>	CNx 103	<u>CNx</u>	PTx 105	ATx 106	PTx 107	ATx 108
<u>ATx</u>	PTx 110	PTx 111	ATx 112	CNx 113	CNx 114	CNx 115	CNx 116	PTx 117	ATx 118	ATx 119	PTx

Layout B - N 25 E June Lake - Planted in FALL, 10/26/83
(ID-NUMBER is same as stake number in field.)

no supplemental water						supplemental water					
PTx 1	PTx 2	<u>ATx</u>	CNx	<u>ATx</u>	CNx	PTx 7	PTx 8	<u>ATx</u>	CNx	CNx	<u>ATx</u>
CNx	PTx 14	<u>ATx</u>	CNx	PTx 17	<u>ATx</u>	PTx 19	CNx	PTx 21	CNx 22	<u>ATx</u>	<u>ATx</u>
ATx 25	CNx	ATx	PTx 28	CNx	PTx 30	<u>ATx</u>	CNx	ATx 33	PTx 34	PTx 35	CNx
PTx 37	CNx	<u>ATx</u>	<u>ATx</u>	<u>PTx</u>	CNx	CNx	PTx 44	<u>ATx</u>	<u>ATx</u>	PTx 47	CNx
PTx 49	CNx	PTx 51	<u>CNx</u>	<u>ATx</u>	<u>ATx</u>	<u>PTx</u>	<u>ATx</u>	CNx	CNx	PTx 59	ATx

LAYOUTS A and B
FIGURE A-2

ID-NUMBER under species-source code = plant ALIVE on 5/17/88
Underlined species-source code = plant DIED before 10/7/85
NO underline, NO ID-NUMBER = plant DIED between 10/7/85 & 5/17/88

Layout C - S 25 W June Lake - Planted in SPRING, 6/13/84
(Subtract 840 from ID-NUMBER for stake number in field.)

no supplemental water

<u>CNx</u>	<u>PTz</u>	<u>PTy</u>	ATy 904	PTx	<u>CNz</u>	<u>CNx</u>	<u>PTx</u>	CNz 909	ATy 910	ATy 911	ATx 912	<u>PTz</u>	ATy 914	ATz 915	ATx 916	ATz 917	PTx 918
PTy	PTz 938	CNx	ATz 940	ATy 941	PTx	<u>PTx</u>	ATz 944	ATx 945	CNz 946	<u>ATy</u>	PTx	PTz 949	PTy 950	ATy 951	ATx 952	CNx 953	CNz 954
<u>PTz</u>	ATx 974	PTx 975	ATz 976	PTx	CNz 978	ATy 979	CNz 980	ATy 981	CNx 982	PTx 983	ATx 984	PTx	CNx 986	ATy 987	ATz 988	PTy 989	PTy 990
ATy 1009	ATx 1010	<u>CNx</u>	PTy 1012	PTz 1013	<u>PTx</u>	ATz 1015	PTy 1016	CNx 1017	ATx 1018	CNz 1019	<u>PTx</u>	CNz 1021	ATz 1022	<u>ATz</u>	ATy 1024	<u>PTx</u>	<u>PTz</u>
<u>ATz</u>	<u>PTz</u>	<u>ATy</u>	<u>ATz</u>	PTx 1049	PTy 1050	CNx 1051	ATy 1052	ATx 1053	ATy 1054	CNz 1055	ATx 1056	CNz 1057	ATz 1058	<u>CNx</u>	PTy 1060	<u>PTx</u>	PTz 1062

Layout D - S 25 W June Lake - Planted in SPRING, 6/13/84
(Subtract 840 from ID-NUMBER for stake number in field.)

supplemental water

PTz 919	<u>CNx</u>	PTz 921	<u>PTy</u>	ATx 923	ATy 924	ATy 925	CNz 926	CNz 927	ATz 928	PTx 929	<u>ATx</u>	ATx 931	<u>CNx</u>	ATz 933	PTz 934	<u>PTx</u>	PTz
ATy 955	ATz 956	ATx 957	CNz 958	ATz 959	ATx 960	<u>ATy</u>	<u>PTz</u>	PTx 963	ATz 964	CNz 965	PTy 966	CNx 967	<u>PTz</u>	CNx 969	<u>PTx</u>	PTz 971	<u>PTy</u>
ATx 991	CNz 992	ATx 993	CNx 994	<u>PTy</u>	ATy 996	ATz 997	ATy 998	PTx 999	PTx 1000	ATx 1001	CNx 1002	ATz 1003	<u>PTz</u>	<u>PTx</u>	PTz 1006	PTx	CNx 1008
PTy 1027	ATx 1028	<u>PTz</u>	ATx 1030	ATx 1031	ATy 1032	CNz 1033	<u>PTy</u>	PTx 1035	PTz	ATz 1037	CNz 1038	CNx 1039	<u>PTx</u>	CNx 1041	ATz 1042	ATz	ATy 1044
<u>PTx</u>	PTx 1064	ATz 1065	CNz 1066	ATx 1067	<u>PTx</u>	<u>PTz</u>	ATx 1070	CNx 1071	<u>PTy</u>	ATz 1073	ATy 1074	<u>PTz</u>	ATx 1076	ATz 1077	ATy 1078	PTz 1079	CNx 1080

LAYOUTS C and D
FIGURE A-3

ID-NUMBER under species-source code = plant ALIVE on 5/17/88
Underlined species-source code = plant DIED before 10/7/85
NO underline, NO ID-NUMBER = plant DIED between 10/7/85 & 5/17/88

Layout E - N 25 E June Lake - Planted in SPRING, 6/12/84
(Subtract 660 from ID-NUMBER for stake number in field.)

supplemental water									no supplemental water								
PTx	CNz	ATx	PTz	ATz	PTx	ATy	PTy	CNx	PTx	ATz	PTz	PTy	CNx	ATy	CNz	ATx	ATz
721			724	725			728	729			732	733	734				738
PTz	ATx	PTz	CNx	PTx	ATx	CNz	ATy	ATz	PTx	PTy	PTz	CNx	ATx	CNz	PTz	ATy	ATz
	740	741		743		745	746	747		749	750	751			754		756
CNz	ATz	PTy	CNx	ATy	PTz	ATx	ATz	PTx	PTy	PTx	ATz	CNz	ATx	ATy	PTx	CNx	ATy
	758			761	762			765		767	768	769		771			
ATz	PTy	ATy	CNz	PTx	CNx	ATx	PTz	ATz	PTz	ATx	ATy	ATz	PTy	ATz	PTx	CNz	CNx
775	776	777				781	782			785	786		788				
PTx	ATy	CNx	CNz	PTx	ATy	ATx	ATz	PTy	PTy	PTx	ATy	ATx	ATy	CNx	CNz	PTz	ATz
	794					799					804			807			810
PTz	ATx	PTz	CNz	ATz	ATy	ATx	CNx	PTx	CNz	PTx	ATy	PTx	ATz	PTy	CNx	ATx	PTz
811	812			815					820				824				
CNz	ATz	CNx	ATy	PTz	ATx	PTx	ATy	PTx	CNx	ATz	ATx	PTy	PTx	CNz	PTx	ATx	ATy
				833			836			839		841	842		844		
ATz	ATz	PTx	CNz	PTz	CNx	PTx	ATy	PTy	ATx	ATy	ATz	PTz	ATx	CNz	PTy	CNx	ATx
847			850	851		853	854	855			858		860				864
PTz	ATx	PTx	ATx	CNz	PTy	ATz	ATy	CNx	PTy	PTz	CNx	PTz	ATy	CNz	ATz	PTx	PTx
865		867		869					874	875			878	879	880	881	882
ATx	ATz	PTx	PTx	CNz	PTz	ATy	CNx	PTy	PTx	ATy	ATz	CNx	ATx	PTz	CNz	ATx	PTy
883	884		886	887	888			891						897	898		900

LAYOUT E
FIGURE A-4

ID-NUMBER under species-source code = plant ALIVE on 5/17/88
Underlined species-source code = plant DIED before 10/7/85
NO underline, NO ID-NUMBER = plant DIED between 10/7/85 & 5/17/88

Layout F - S 60 W Sand Shed - Planted in FALL, 11/9/83
(Subtract 120 from ID-NUMBER for stake number in field.)

supplemental water						no supplemental water					
ATx	ENy	CNx	ENy	CNx	ATx	ATx	ENy	CNx	CNx	ENy	ATx
121					126						132
ENy	ATx	ENy	ATx	CNx	CNx	ATx	ENy	CNx	ENy	ATx	CNx
	134			137		139					144
ATx	ENy	CNx	ATx	CNx	ENy	CNx	ATx	CNx	ENy	ENy	ATx
145		147	148	149			152	153			
CNx	ATx	ENy	ATx	CNx	ENy	ENy	CNx	CNx	ATx	ENy	ATx
157			160	161			164	165	166		
ENy	ENy	ATx	ATx	CNx	CNx	CNx	ENy	ATx	ENy	CNx	ATx
	170	171		173	174	175		177	178	179	180

LAYOUT F
FIGURE A-5

ID-NUMBER under species-source code = plant ALIVE on 5/17/88
Underlined species-source code = plant DIED before 10/7/85
NO underline, NO ID-NUMBER = plant DIED between 10/7/85 & 5/17/88

Layout G - S 60 W Sand Shed - Planted in SPRING, 5/1/84
(Subtract 440 from ID-NUMBER for stake number in field.)

no supplemental water

ATz	CNx	ENx	ENy	ENy	CNx	CNz	ATy	CNx	ACx	ATx	ENy	ATz	CNz	ACx	ENx	ENy	CNx	ENx	ATx	ATy	CNz
501	502	503	504	505		507	508		510	511	512	513	514	515	516	517		519	520	521	522
ATy	ENy	ACx	ENx	ACy	ATz	ATy	ACx	CNx	ATx	CNz	CNz	ENx	ATy	ATx	ATy	ENx	ATz	ACx	CNx	ACx	ENy
545	546		548	549		551	552	553	554	555	556	557	558	559	560	561	562	563	564	565	566
CNx	ATx	ATy	ENy	CNz	ACz	ACx	CNz	ATz	CNz	ENx	ENy	ACy	CNx	ATx	CNz	CNz	ENx	ACx	ATz	ACz	ATy
589	590	591	592	593	594		596	597	598	599		601		603	604	605	606	607		609	
ATz	ATx	ENy	ATx	ATy	ENx	CNx	CNz	ATy	ENx	ACx	ACx	ACx	CNz	ATy	CNz	ATz	ACx	ATx	ENx	CNx	ENy
633	634	635			638	639	640	641	642	643	644	645	646	647	648	649	650	651	652	653	654
ENx	ATz	ACx	CNx	ACx	ACy	ENy	ATz	ATx	ATy	CNz	ENy	ACx	ENy	ATz	CNz	ATx	ATy	CNx	ATx	ENx	ATz
677	678	679	680	681	682	683		685		687	688	689	690		692	693		695	696	697	698

Layout H - S 60 W Sand Shed - Planted in SPRING, 5/1/84
(Subtract 440 from ID-NUMBER for stake number in field.)

supplemental water

ATz	ENy	CNx	ENx	ATz	ATy	ACx	ATx	ENx	CNz	ATx	CNx	ATx	ATz	CNx	CNz	ENx	ENy	ACx	ATy	ACx	ATx
523	524		526	527	528	529	530	531		533		535	536	537	538	539	540		542		544
ATz	CNz	ATx	ATy	ACx	ENx	ENy	ATz	CNx	ATy	ATz	ATz	ATx	ENy	ENx	ACy	ENy	ATy	CNx	ACz	CNz	ACx
567		569	570	571	572	573		575	576	577	578	579	580	581			584			587	
CNx	ATx	ATz	CNz	ENy	ATy	ENx	ATy	CNz	ENy	ACx	CNx	ACx	ENx	ATx	ACx	ENx	ENy	ATz	CNz	CNx	ATy
611	612		614	615		617	618	619	620			623	624	625		627	628	629		631	632
ACx	ENy	ATz	CNx	ENx	ATy	CNz	ENx	ACz	ATx	CNz	ATy	ATx	ACy	CNx	CNz	ACx	ENy	ATx	ATz	ENy	ENx
655	656	657	658	659	660	661	662	663	664	665	666	667	668		670		672	673	674	675	676
ENy	ATx	ATz	CNx	ENx	ENx	CNx	ACy	CNz	ACx	ATy	ATz	ATy	ENy	ACx	ACz	CNx	CNz	ENy	ATx	CNz	ENx
699	700		702	703	704		706	707	708	709	710	711	712	713	714		716	717	718	719	720

LAYOUTS G and H

FIGURE A-6

ID-NUMBER under species-source code = plant ALIVE on 5/17/88
Underlined species-source code = plant DIED before 10/7/85
NO underline, NO ID-NUMBER = plant DIED between 10/7/85 & 5/17/88

Layout I - N 10 E CDF - Planted in SPRING, 4/18/84
(Subtract 180 from ID-NUMBER for stake number in field.)

supplemental water											no supplemental water										
ENy 281	ACx 282	CNz	CNz 284	ATx	ENx 286	CNx 287	ATy	ACz 289	ACz 290	ATz 291	CNz 292	ATz 293	ENx 294	ACz 295	CNx	ATx 297	CNx 298	ATy 299	ATz 300	ACx 301	ACz
ATx 303	CNy 304	ATy 305	ENx 306	ACz 307	CNx 308	ATz 309	ACz 310	ACx 311	CNz 312	ENy	ENy 314	ATy	ATz 316	ENx 317	CNz 318	CNz 319	ATx 320	ACx 321	ACz	ACx 323	CNx
ATy	CNz 326	CNx	ENx	ATz 329	ACx 330	CNz 331	ACz 332	ENy	ATx 334	ACx 335	ATy 336	CNz 337	ACx 338	ENy	ACz 340	ATx 341	ENx	ACx 343	ATz 344	CNx 345	CNz 346
ATx 347	ATz 348	CNz 349	CNx 350	ACz 351	ATy 352	ENx 353	ACz 354	ENy 355	CNx	ACx 357	ATx 358	ACz 359	CNx 360	ACz 361	CNy	ENy	CNz 364	ATz 365	ATy 366	ACx 367	ENx 368
ACx 369	CNz	ATz 371	ENy 372	ACx 373	ACz	CNx 375	CNx	ATy	ATx 378	ENx 379	ENx 380	ACx 381	ATy 382	ATx 383	ENy 384	ACx 385	CNx 386	ATz 387	CNx 388	CNz	ACz
ATx 391	ACz 392	ENx 393	CNy 394	ATz 395	ATy 396	CNx 397	ACx 398	CNz 399	ENy 400	ACz 401	CNz 402	ATy 403	ENy 404	ATx	CNz 406	ENx 407	ACx 408	CNx 409	ATz 410	ACz 411	ACz 412
ACz 413	ENx 414	ACz 415	CNx 416	CNz 417	ATx 418	CNx 419	ENy 420	ACx 421	ATz 422	ATy 423	ACz 424	ATx 425	ATz 426	ATy 427	ENy 428	ENx 429	CNx	ACx 431	ACz 432	CNz 433	CNz
CNx 435	ATy 436	ACx 437	CNz 438	ATz 439	ACz 440	ENx 441	ATx 442	ENy 443	ACx 444	CNz 445	CNx 446	ACz 447	ACx 448	ATy 449	ENx	ACx 451	ENy 452	ATx 453	CNz 454	ATz 455	CNx 456
ATy 457	ATz	CNx 459	CNz 460	ACz 461	ACx 462	CNx 463	ENx 464	ENy 465	ACx	ATx 467	ACx 468	ACz 469	ATy 470	CNx 471	CNy 472	ATz 473	ENy 474	CNz	ATx 476	ENx 477	ACz 478
ENy 479	CNz 480	ACx 481	ATy 482	ATx 483	CNx	ENx 485	CNz 486	ACx 487	ATz 488	ACz 489	ENy 490	CNx 491	ACx 492	ATz 493	CNx 494	ATx 495	ATy 496	ACx 497	ACz 498	ENx 499	CNz 500

LAYOUT I

FIGURE A-7

ID-NUMBER under species-source code = plant ALIVE on 5/17/88
Underlined species-source code = plant DIED before 10/7/85
NO underline, NO ID-NUMBER = plant DIED between 10/7/85 & 5/17/88

Layout J - N 10 E CDF - Planted in FALL, 11/9-10/83
(Subtract 180 from ID-NUMBER for stake number in field.)

no supplemental water					supplemental water				
ENy	ATx	CNx	ACx	ACy	CNx	ENy	ACx	ATx	ACy
	182								190
ENy	ACx	CNx	ATx	ACx	CNx	ATx	ENy	ACy	ACx
	192			195		197	198	199	200
CNx	ACx	ENy	ATx	ACy	CNx	ENy	ACx	ATx	ACy
	202				206		208	209	
ENy	ACy	ACx	CNx	ATx	ENy	ACx	CNx	ATx	ACy
211		213	214	215		217	218	219	
CNx	ENy	ACy	ATx	ACy	ACx	ACy	CNx	ATx	ENy
221					226		228		
ATx	ACx	CNx	ACy	ENy	ACy	ACx	ATx	CNx	ENy
231	232	233		235	236	237	238	239	
ATx	ENy	ACx	CNx	ACy	ACx	ACy	CNx	ATx	ENy
			244				248		
CNx	ACy	ACx	ATx	ENy	CNx	ACy	ACx	ENy	ATx
			254		256				260
ACx	ENy	CNx	ATx	ACy	CNx	ENy	ATx	ACy	ACx
		263			266				270
ACx	ACy	ATx	ENy	CNx	ENy	ACx	ACy	CNx	ATx
	272	273	274	275		277	278	279	

LAYOUT J
FIGURE A-8

APPENDIX B

Information on Database Disk

To obtain the project database disk, send a check for twenty US dollars payable to "California Department of Transportation" to:

Transportation Laboratory
Erosion Control & Geosynthetics Unit
5900 Folsom Blvd.
Sacramento, CA 95819

The disk (5-1/4 inch, double-sided, double density, soft-sectored, 360 kilobytes) will be marked "DATABASES". Use dBASE III plus, version 1.1 for reading, inquiring, and printing reports. There are two databases: "START1.DBF" and "FINAL1.DBF". Each has 1080 records. All numeric fields are integers. Database structures and an example record from FINAL1.DBF are shown below. Values or ranges are listed for all fields, except fields 13 through 16, which are documented in Chapter 7.

FIELD	NAME	DATA TYPE	WIDTH	DESCRIPTION
1	IDNUM	numeric	4	id number, 1 - 1080
2	PNUM	numeric	3	plot id number, 1 - 320
3	AD	character	1	alive or dead, Y or N
4	GSP	character	2	species, AC AT CN EN or PT
5	SR	character	1	source, X Y or Z
6	HIT	numeric	2	maximum height, 0 if AD=N
7	WID	numeric	2	maximum width, 0 if AD=N
8	H2	character	1	extra water, Y or N
9	FA	character	1	fall = Y, spring = N
10	ROW	numeric	2	row number, 1 - 10
11	ELEVA	numeric	4	site elevation <=7800
12	ASPEC	character	4	slope aspect, bearing
13	FO	character	1	flowered
14	DR	character	1	dry
15	WE	character	1	weed
16	DM	character	1	damage
17	PH	character	1	photographs Y = yes N = no

Record	IDNUM	PNUM	AD	GSP	SR	HIT	WID	H2	FA	ROW	ELEVA	ASPEC	FO	DR	WE	DM	PH
956	956	116	Y	AT	Z	16	14	Y	N	2	7800	S25W	Y	N	N	I	N

APPENDIX C

Information on Bar Graph Disks

To obtain the bar graph disks of height and width, send a check for twenty five US dollars payable to "California Department of Transportation" to:

Transportation Laboratory
Erosion Control & Geosynthetics Unit
5900 Folsom Blvd.
Sacramento, CA 95819

The disks (5-1/4 inch double-sided, high density, soft sectored, 1.2 megabytes) will be marked C-HEIGHT for height and C-WIDTH for width bar graphs. Use PGRAPH of LOTUS 1-2-3, release 2.01 to view or print graphs. There are 100 graph images and one worksheet on each disk. Graph file names are the same on both disks. A decoded file name, "PTZS25NN", is:

PT	Z	S25	N	N
species	source	site	extra water	season planted

codes for plant SPECIES:

AC = fourwing saltbush	*Atriplex canescens*
AT = big sagebrush	*Artemisia tridentata*
CN = rubber rabbitbrush	*Chrysothamnus nauseosus*
EN = gray ephedra	*Ephedra nevadensis*
PT = antelope bitterbrush	*Purshia tridentata*

codes for SOURCE:
- X = seed collected and grown nonlocally
- Y = seed collected nonlocally, grown locally
- Z = seed collected and grown locally

codes for SITE:

S25 = "June Lake"	S25W slope aspect
N25 = "June Lake"	N25E slope aspect
S60 = "Sand Shed"	S60W slope aspect
N10 = "CDF"	N10E slope aspect

EXTRA WATER codes: Y = given extra water N = no extra water

SEASON PLANTED codes: Y = fall N = spring