APPENDIX V.

GAURA NEOMEXICANA SSP. COLORADENSIS MONITORING STUDIES ON F. E. WARREN AIR FORCE BASE, 1984 THROUGH 1986

Plot Establishment and Monitoring

One control and two affected sites on F. E. Warren Air Force Base (WAFB) were selected for monitoring plot establishment in 1984 (Fig. 1). Field surveys were done on adjacent areas west of WAFB to establish another control site, but only a few small occurrences (less 25 to 50 individuals each) were located. These sites were not chosen because a minimum of 150 individuals of each age class was needed for a statistically sound program. Site 2, along the westernmost portion of Diamond Creek near the Base boundary, was chosen as the control site because it is upstream of the proposed pipeline to be trenched into Diamond Creek within habitat of G. n. ssp. coloradensis. Site 3, below the entry area of the two pipe systems, was selected as one of the affected areas. The other potentially affected area, Site 1, is along Crow Creek below a proposed bridge crossing.

Fifteen plots of ten square feet each were placed within each site (see maps at end of Appendix). For each plot, two permanent stakes were placed at opposite corners so that the plots could be accurately read over the course of the study and beyond. Because a minimum of ten plants of each age group was needed for each plot, plot establishment was selective, rather than random. This was acceptable because plots were compared over time.

Data gathering was designed for two purposes: 1) to monitor impacts on the taxon by construction of MX (Peacekeeper) facilities and 2) to gather ecological and life history data to aid in protecting the taxon and its habitat. To monitor life span and survival rates, five second-year flowering plants and five first-year rosettes in each plot were marked with numbered metal tags secured by eight-inch-long stakes at the base of each plant. A severe storm in early August, 1985, flooded many of the plots. Site 1 was the most heavily affected, Site 2 the least. A metal detector was used to locate tags which had been buried in silt during flooding. Tags 1 through 5, which marked flowering plants in 1984, were removed after recording the status of the plants and placed alongside new basal rosettes. If a plant tagged with numbers 6 through 10 (1984 first-year rosettes) did not survive into 1985, the tag was left. No new plants were tagged with numbers 6 through 10 in 1985.

Plots were monitored in late August-early September, 1984 through 1986. The following data were collected for each plot: number of first-year rosettes, number of second-year flowering plants, total number of plants, status of each tagged plant, number of fruits per plant for five tagged plants (if they survived), a map of tagged individuals, associated taxa, soil type, soil moisture and miscellaneous observations (such as browsing, plant visitors, degree of flood damage in 1985).

Other environmental data were gathered for additional insight concerning habitat requirements, and to aid in determining whether trends observed in the populations were due to natural causes, construction, or the WAFB herbicide spraying program. Climatic data were obtained from the High Plains Research Station, US Department of Agriculture. This station is located approximately 1.5 miles northwest of the study sites. Precipitation data were obtained also from a private station located approximately 0.5 miles west of the study sites. Soil moisture data were gathered from two points within each study plot, one within the 2.5 square feet frame and another from the center of the main plot. There is no stream gauge on either Diamond or Crow Creeks in the

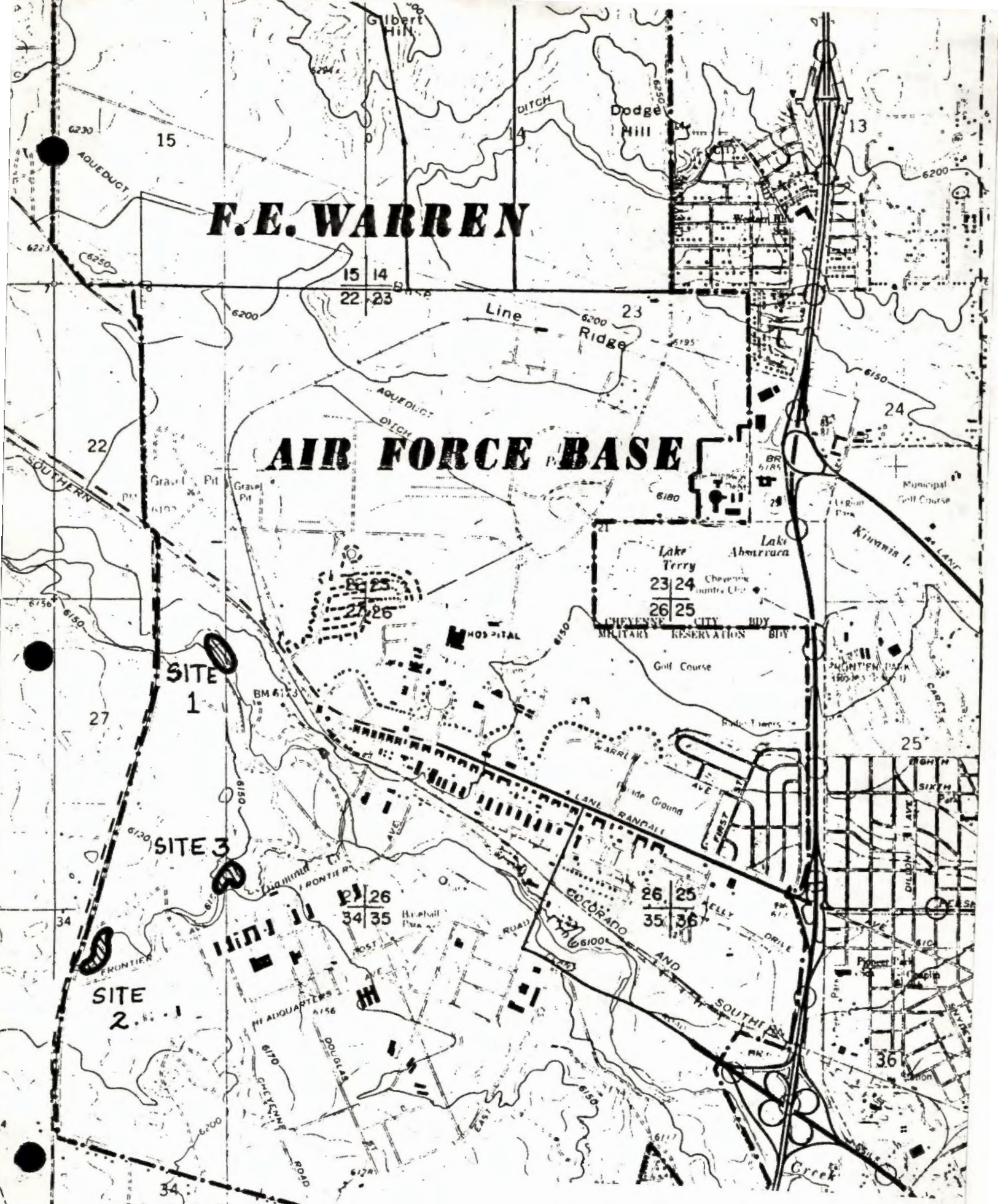


Fig. 1. Study sites, Warren Air Force Base

vicinity of the study sites.

Photographs were taken from the tagged corner of each plot. An overall plot photograph was taken, as well as one within a smaller 2.5 square feet frame. These photographs were compared annually for visible trends and changes. All photographs are currently on file at the Regional Task Force office.

Results

The study sites can be described as broad, shallow drainage bottoms with perennial or intermittent streams which meander through high plains grasslands. The present species composition (Table A) indicates that both creek bottoms have been impacted by human use. Weedy taxa, especially Cirsium arvense, Euphorbia esula, and Glycyrrhiza lepidota, are common. Old headgates and diversion systems are located along both streams, and, in places, the terrain has been impacted by tank training activities during World War II (Cormier 1983, pers. comm.).

The soils of the habitat along Diamond Creek consist primarily of sandy loams in contrast to the sandy gravelly loams along Crow Creek. This difference may be due to more seasonal flooding along Crow Creek. Site 1, along Crow Creek, was the driest site with a mean of 47 percent soil moisture during August, 1984, 1985 and 1986 (Table B). Sites 2 and 3, along Diamond Creek, had means of 53 percent and 60 percent respectively. Site 1 may have a lower soil moisture due to the more porous soil texture. The data collected on soil moisture are suggestive but not statistically valid. Annual precipitation changed little during the course of the study (Table C). The flow of Diamond Creek (Sites 2 and 3), controlled by release from a reservoir, was nearly continuous in 1985 and 1986. These variables had no noticeable effect on the study sites.

Population Trends: The data indicate a significant overall decrease in both rosettes and flowering plants from 1984 to 1985, and from 1985 to 1986 (Table D). There was no evidence that population trends were related to the storm damage of early August, 1985. Plot photographs suggest that the trends result, at least in part, from natural succession within the riparian communities at the sites (see discussion of Photographic Documentation below). In addition, Gaura neomexicana ssp. coloradensis, being biennial, would be expected to exhibit year-to-year fluctuations in numbers based on seed production in prior years, habitat availability (bare soil), and germination and establishment success (both in the current year and in years past). For example, in 1984, Site 1 (Crow Creek) contained a high percentage of flowering second-year individuals (46 percent) as compared to Sites 2 (19 percent) and 3 (24 percent). In 1985, the number of flowering individuals dropped dramatically, and the number of basal rosettes somewhat less. In 1986, the number of flowering individuals continued to decline, but the number of basal rosettes increased (by 22 percent). Total number of plants decreased by 55 percent from 1984 to 1985, but then increased by 5 percent from 1985 to 1986. Because of the population fluctuations inherent to the biennial life cycle of Colorado butterfly plant, continued monitoring is required to accurately assess overall population trends. Long-term monitoring is highly recommended as the data gathered thus far suggest that populations of Colorado butterfly plant on WAFB are declining due to community succession.

Survival rate from rosette to flowering plant was estimated at 26 percent for

Table A. Associated species from Gaura neomexicana ssp. coloradensis study sites on Warren Air Force Base.

	Number of plots (out of 15 possible)					
	Site 1		Site 2		Site 3	
Species	1984	1985	1984	1985	1984	1985
Glycyrrhiza lepidota	14	14	12	12	11	12
Poa pratensis	8	12	9	13	15	13
Solidago canadensis	9	10	2	3	10	10
Salix exigua	10	10	0	0	0	0
Carex spp.	2	8	4	9	4	6
Rosa woodsii	6	8	2	6	6	2
Equisetum laevigatum	11	7	10	5	11	9
Cirsium arvense	6	6	10	11	8	9
Rudbeckia hirta	8	6	5	8	6	4
Lycopus americanus	11	6	0	1	1	0
Elymus canadensis	3	5	0	0	5	3
Oenothera villosa	12	5	4	2	1	1
Juncus balticus	1	4	9	8	3	5
Cirsium flodmanii	0	4	0	5	5	4
Agropyron smithii	3	4	5	0	7	3
Artemisia ludoviciana	2	3	4	2	0	0
Ratibida columnifera	2	3	1	1	5	6
Stachys palustris	4	3	0	0	0	0
Helianthus nuttallii	3	2	8	9	7	8
Thermopsis rhombifolia	3	2	2	4	0	0
Deschampsia cespitosa	3	2	1	0	3	3
Mentha arvensis	2	2	1	0	1	0
Salix monticola	3	2	0	0	0	0
Aster falcatus	1	1	5	9	7	9
Euphorbia esula	0	1	7	7	0	0
Achillea millefolium	0	1	7	6	5	6
Asclepias speciosa	3	1	9	4	6	4
Aster adscendens	0	1	1	3	0	0
Iris missouriensis	0	0	5	4	4	0
Linum lewisii	0	0	1	2	0	4
Taraxacum officinale	0	0	0	2	0	3
Scirpus sp.	0	0	0	0	3	4
Solidago mollis	0	0	0	0	1	2
Cynoglossum officinale	0	0	1	0	2	2
Gaura parviflora	6	0	3	0	6	1
Spartina pectinata	2	0	0	0	0	0
Potentilla biennis	7	0	0	0	0	0
Bromus inermis	3	0	0	0	0	0
Grindelia squarrosa	2	0	0	0	0	0
Artemisia dracunculus	2	1	0	0	0	0
Bidens cernua	4	0	0	0	1	0
Muhlenbergia asperifolia	2	0	0	0	0	0
Rumex maritimus	2	0	0	0	0	0
Geum macrophyllum	0	0	2	0	1	0
Andropogon scoparius	0	0	0	0	7	1
Psoralea tenuiflora	0	0	0	0	2	1
Gentianella amarella	0	0	0	0	3	0

Table B. Soil moisture data for Gaura neomexicana ssp. coloradensis study sites on Warren Air Force Base.

	Mean Soil Moisture (%)			
Site	1984	1985	1986	Overall (1984-1986)
1	56.1	62.7	21	46.6
2	62.0	81.8	15	52.9
3	72.6	93.3	14	60.0

Table C. Precipitation data for two stations near Gaura neomexicana ssp. coloradensis study sites on Warren Air Force Base.

	Private Stn. (Unshielded, 0.5 mi west of sites)	USDA Stn. (unshielded, 1.5 mi northwest)	USDA Stn. (shielded, 1.5 mi northwest)
1983			
Sep	.60	.35	.39
Oct	.73	.51	.55
Nov	1.35	1.18	2.05
Dec	.32	.28	.47
1984			
Jan	.73	.47	.94
Feb	.59	.63	1.42
Mar	1.13	.83	1.38
Apr	4.11	3.27	4.49
May	.77	.71	.79
Jun	2.85	2.48	2.56
Jul	3.43	3.35	3.39
Aug	2.38	1.57	1.61
TOTAL	19.99 inches	15.63 inches	20.04 inches
Sep	.92	.94	1.06
Oct	1.82	1.77	1.97
Nov	.18	.12	.20
Dec	.37	.24	.39
1985			
Jan	.77	.64	.95
Feb	.21	.16	.23
Mar	.45	.27	.40
Apr	1.29	1.06	1.22
May	1.76	2.06	2.16
Jun	1.63	1.42	1.43
Jul	3.80	3.87	3.90
Aug	3.97*	2.10	2.10
TOTAL	17.17 inches	14.65 inches	16.01 inches
Sep		2.01	2.32
Oct		.98	1.14
Nov		.83	1.46
Dec		.55	1.06
1986			
Jan	not	.16	.31
Feb	available	.31	.47
Mar		.43	.67
Apr		2.01	3.11
May		1.22	1.34
Jun		2.48	2.52
Jul		.47	.51
Aug		1.57	1.57
TOTAL		13.03 inches	16.50 inches

* 3.40 inches in one 3-hour storm

Table D. Age structure and population trends for Gaura neomexicana ssp. coloradensis populations on three sites on Warren Air Force Base (fifteen 10 x 10 ft plots per site).

		Number of plants			Percent change		
Site		1984	1985	1986	1984-1985	1985-1986	1984-1986
1	Rosettes	898	513	628	-42.9	+22.4	-30.1
	Flowering	773	235	154	-69.6	-34.5	-80.1
	(% of total)	(46)	(31)	(20)			
	Total plants	1671	748	782	-55.2	+4.6	-53.2
2	Rosettes	2011	1546	1361	-23.1	-12.0	-32.3
	Flowering	476	493	343	+3.6	-30.4	-27.9
	(% of total)	(19)	(24)	(20)			
	Total plants	2487	2039	1704	-18.0	-16.4	-31.5
3	Rosettes	1308	850	707	-35.0	-16.8	-45.9
	Flowering	411	371	420	-9.7	+3.2	+2.2
	(% of total)	(24)	(30)	(37)			
	Total plants	1719	1221	1127	-29.0	-7.7	-34.4

Survival rates (number of flowering adult plants divided by number of basal rosettes from previous year):

	1984-1985	1985-1986
Site 1:	26%	30%
Site 2:	25%	22%
Site 3:	28%	49%
Overall:	26%	32%

1984 to 1985, and 43 percent from 1985 to 1986. Disposition of tagged plants gave a significantly higher survival rate (52 percent) for 1984 to 1985, but a similar rate (41 percent) for 1985 to 1986. Most likely, plants selected for tagging tended to be more vigorous and well-established, and a higher survival rate would be expected. The figure based on total numbers of plants per plot is probably more reliable, although it does not take into account rosettes persisting for more than one year. Data on survival rates are summarized in Tables D and E.

Age Structure: Table D also summarizes the age structure for Gaura neomexicana ssp. coloradensis plots at the three study sites in 1984 through 1986. There were consistently more individuals in the basal rosette stage, indicating again that not all first year rosettes survive through the winter into the next growing season. Many very young rosettes were apparent in 1985 suggesting that the fruits that were stripped from plants by severe flooding were already producing seedlings. This means that Colorado butterfly plant may be able to exist as a winter annual, as well as a biennial. Data from tagged plants (Table E) suggest that a few plants may remain as rosettes for an extra year, approaching perennials. Almost all flowering plants tagged in 1984 were dead in 1985. The one percent recorded as basal rosettes were probably new plants from seeds of the tagged plant. Another one percent that were observed in flower most likely came from seed of the tagged plant as well, although a second year of flowering cannot be ruled out.

Under greenhouse conditions, Gaura neomexicana ssp. coloradensis exists as a perennial. At the University of Wyoming Botany Greenhouse, plants started in 1982 were still alive at the time of this report. They existed as basal rosettes the first year following planting, and have bloomed each subsequent year. Rosettes receiving cold treatment exhibited a significantly lower survival rate than those not treated (W. Higgins, pers. comm.). These studies suggest that both rosette and flowering adult plant survival rates in the wild are limited by cold temperatures.

Heavy flooding from a severe storm in early August, 1985, damaged parts of the study sites, depositing as much as 1/2 inch of silt on some plots. This apparently had no effect on the large and vigorous rosettes. Many very young rosettes were present in places suggesting that the fruits that were stripped from plants by hail and flood waters were already producing seedlings.

Fruit Production: Fruit production in Gaura neomexicana ssp. coloradensis is summarized in Table F. The fruits of the taxon are a nutlet with four ovules; typically one to three ovules per fruit mature into seeds. After the fruits drop off, a short stub is left on the plant; these were counted as fruits during monitoring. Many of the plants were severely browsed, probably by deer for the blossoms, and it is not known to what extent this affected measurement of fruit production. Undoubtedly, browsing removed some stubs as well as flowers, making estimates of fruit production low. The large number of seeds produced and the relatively low number of mature individuals in the plots suggest low germination or seedling survival rates. The data suggest that only one seed in 800 will survive to flower. Because the fruit counts are conservative, the survival rate is probably lower.

In 1985, fruit production decreased due to storm damage. On August 1, a storm classified as a 1 in 500 year event hit the Cheyenne area bringing rain, hail

Table E. Disposition of tagged individuals of Gaura neomexicana ssp. coloradensis on Warren Air Force Base.

	Basal rosettes tagged in 1984, checked in 1985			Flowering adult plants tagged in 1984, checked in 1985			Basal rosettes tagged in 1985, checked in 1986		
Site	Flowering	Rosette	Absent/Dead	Flowering*	Rosette*	Absent/Dead	Flowering	Rosette	Absent/Dead
1	41	7	27	2	172		23	22	30
2	38	15	22	1	1 73		39	15	21
3	37	10	28	-	174		31	20	24

* Likely a new plant from seed of tagged plant.

Survival rates (number of flowering adult plants divided by (75 minus number of second year rosettes)):

	1984-1985	1985-1986
Site 1:	60%	43%
Site 2:	63%	65%
Site 3:	57%	56%

Table F. Fruit production in Gaura neomexicana ssp. coloradensis on Warren Air Force Base (fifteen 10 x 10 ft plots per site).

		1984	1985	1986
Site 1:	total fruits (15 plots)	28,300	4182	805
	mean per plant	380	102	35
Site 2:	total fruits (15 plots)	37,100	7182	8502
	mean per plant	800	189	218
Site 3:	total fruits (15 plots)	20,934	5106	5208
	mean per plant	300	138	168

and high flood waters. Rainfall for the three hour period measured over 6 inches at the National Weather Service office about 3 miles east of the study sites, 3.40 inches at the private station 0.5 mile west of the sites and 1.06 inches at the USDA station 1.5 miles to the northwest. None of the plots were destroyed, but hail and flood damage to plants was obvious. Fruits and flowers present at the time were stripped from the plants; new fruits were just beginning to ripen nearly one month later, at the time of sampling, indicating a loss of about one month of fruit production.

Fruit production within the study plots in 1986 was significantly lower than in 1984 as well, particularly within Site 1. Reasons for this trend are not known. It is possible that the flowering adult plants selected for tagging in 1984 tended to be more vigorous than average, and did not constitute a valid baseline for later comparisons. Long-term monitoring utilizing adequate sampling techniques is needed, as population trend and fruit production data, as well as photographic evidence, suggest declining conditions for the WAFB Gaura neomexicana ssp. coloradensis occurrence.

Photographic Documentation: Changes observed in comparing 1984 and 1985 photographs of the study sites reflected the storm damage suffered in early August 1985. At Site 1, Crow Creek, the vegetation in 1985 was matted and stripped by flood waters and hail. Trees and shrubs were especially affected. Site 2, the control on Diamond Creek, showed only minor changes; few plots on this site suffered storm damage. At Site 3, also on Diamond Creek, storm damage was intermediate compared to Sites 1 and 2.

Evidence gathered from comparison of 1984 and 1986 photographs suggests that the riparian plant communities where Colorado butterfly plant occurs are undergoing succession, although the evidence is not strong enough at this time to be conclusive. For roughly one-third of the plots, no changes were apparent. The majority of the plots showed changes in composition of the vegetative cover, and often an increase in total cover. In general, forb species (vs. grass) were more common in the 1986 photographs, especially Cirsium arvense (Canada thistle), Euphorbia esula (leafy spurge), Solidago canadensis (a goldenrod) and Helianthus nuttallii (Nuttall's sunflower) at Sites 2 and 3. An increase in cover of Salix exigua (a willow) occurred in several plots at Site 1. Changes observed are presented, by site, in Table G.

Observations of Gaura neomexicana ssp. coloradensis occurrences outside WAFB indicate that the plant requires some bare ground for best development of populations. It does not occur on recently-disturbed sites, but probably is a secondary colonizer. As the surrounding riparian plant community undergoes succession in the absence of disturbance, Colorado butterfly plant appears to be replaced with riparian meadow species. Plot data and photographs suggest that this process may be taking place at the study sites on WAFB. Continued monitoring is required to accurately determine overall population trends.

Table 6. F. E. Warren Air Force Base Study Sites (Gaura neomexicana ssp. coloradensis): photographic trends (1984 through 1986)

Site-Plot #	Observations
1-1	no obvious changes
1-2	more Salix exigua
1-3	
1-4	no obvious changes
1-5	increased forb-to-grass ratio
1-6	no obvious changes
1-7	no obvious changes
1-8	no obvious changes
1-9	decreased cover
1-10	increased cover
1-11	no obvious changes
1-12	increased cover (especially Glycyrrhiza lepidota, Solidago canadensis, Elymus canadensis), decrease in Gaura obvious
1-13	increased cover
1-14	increased cover, increase in Cirsium arvense, Asclepias speciosa, increased forb-to-grass ratio in background
1-15	increased forb-to-grass ratio, increased shrub cover in background
2-1	
2-2	increase in Cirsium arvense, less bare ground
2-3	
2-4	increase in Cirsium arvense
2-5	increase in Cirsium arvense in background
2-6	increase in Cirsium arvense and other tall forbs
2-7	no obvious changes
2-8	increase in Euphorbia esula
2-9	no obvious changes
2-10	increase in Euphorbia esula
2-11	increase in Euphorbia esula
2-12	increase in Helianthus nuttallii
2-13	increased cover, increase in Euphorbia esula, increase in Cirsium arvense in background
2-14	increased cover, increase in Euphorbia esula, increase in Cirsium arvense in background
2-15	no obvious changes
3-1	increased cover
3-2	increased ground cover, slight increase in Solidago canadensis
3-3	no obvious changes (possibly increased cover)
3-4	increase in Cirsium arvense (especially in background), increased forb-to-grass ratio
3-5	increased forb-to-grass ratio
3-6	no obvious changes
3-7	no obvious changes (increase in Helianthus nuttallii, Solidago canadensis in background?)
3-8	no obvious changes
3-9	no obvious changes
3-10	no obvious changes
3-11	no obvious changes
3-12	increased forb-to-grass ratio (especially Cirsium arvense, Glycyrrhiza lepidota)
3-13	no obvious changes
3-14	no obvious changes
3-15	no obvious changes

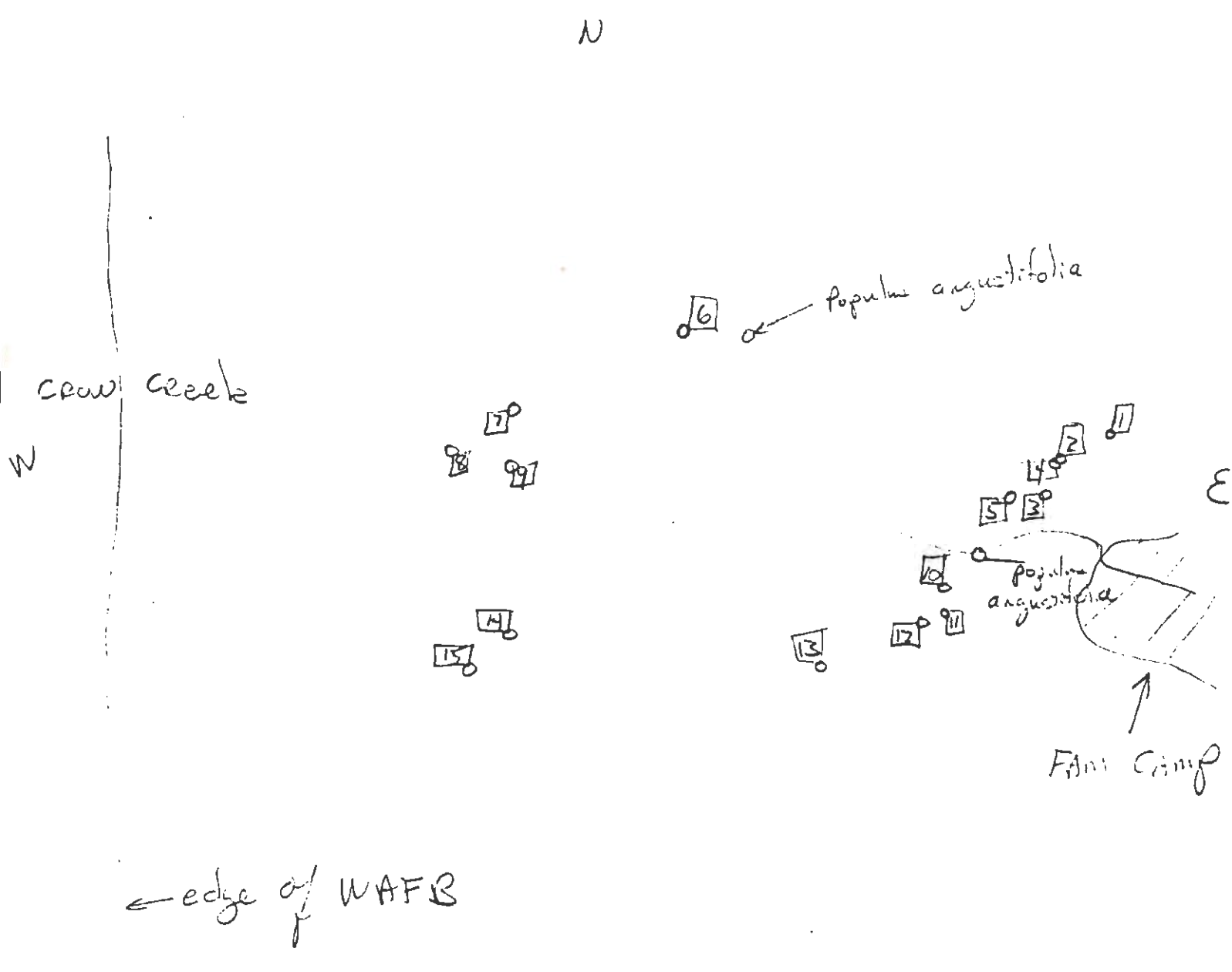
Maps of Warren Air Force Base Study Sites

Egl
binder - site photos

Map of Crow Creek Site #1

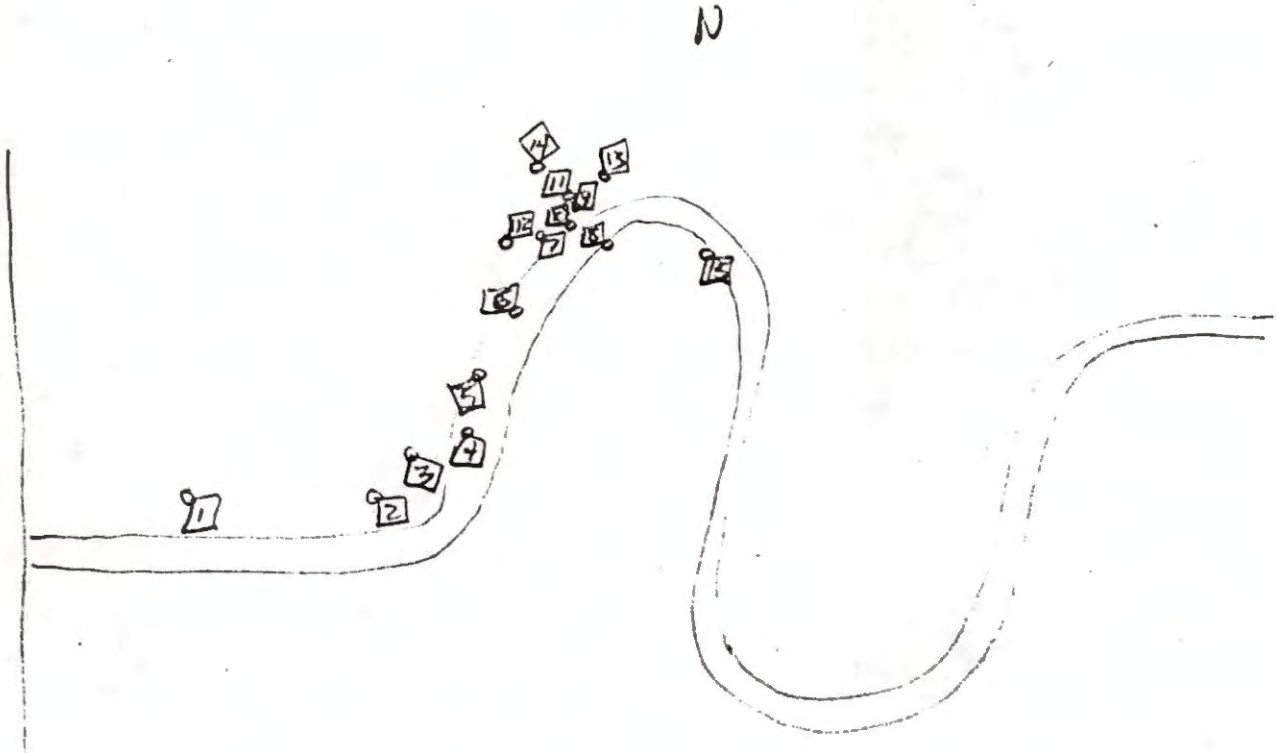
~~Face~~ Plot locations

Location: T14N R67W S27 SW/4



Map of Diamond Creek Control
Site #2 plot locations

Location: T14N R67W S34 aw1/4



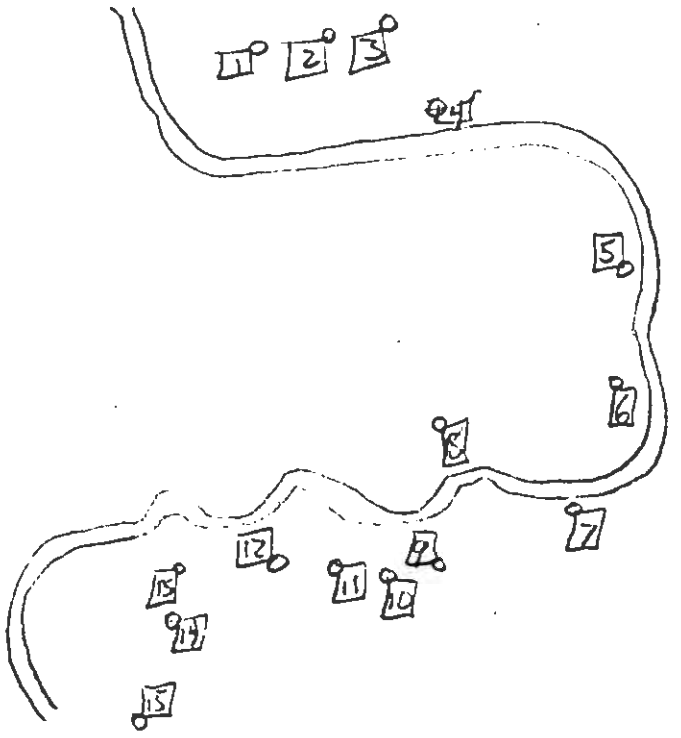
← edge of WAFB

Photograph Camera

Map of Diamond Creek Site #3
Plot locations

Location: T14N R67W S ~~34 NE 1/4~~
27 SW 1/4 SE 1/4

NW



W S

E
N

S

= photograph corner