VEGETATION COMMUNITY TYPE MAPS
LOWER COLORADO RIVER

1984

by

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Center for Environmental Studies

for

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Lower Colorado Region
Boulder City, NV. 89005

LOWER COLORADO RIVER RIPARIAN METHODS OF QUANTIFYING VEGETATION COMMUNITIES TO PREPARE TYPE MAPS

Submitted by

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ABSTRACT

Quantification methods and classification of riparian plant communities into community types (based on dominant plant species) and structural types (based on vertical configuration of the vegetation) are presented in this report. Measurements were taken every 500 feet along more than 100 transects (1-mi or 0.5-mi long) located in all major riparian plant communities between Davis Dam south to the Mexican boundary. Total length of all transects was approximately 75 miles. Tree counts and 15 other vegetation measurements were taken on each side of each transect every 500 feet to be used ultimately as descriptors of plant communities.

Six structural vegetation types were recognized in the 6 dominant community types, yielding a total of 23 community and structural types out of a possible 36. Mistletoe (*Phoradendron californicum*) was also quantified since its berries and foliage represent an important food and nesting resource for some vertebrates.

Ultimately these plant community and structural types were delineated from aerial photographs and then ground-truthed to provide vegetation type maps (Anderson and Ohmart 1976, 1984) for the entire study area. These maps show vegetation changes and provide an inventory of the vegetation resource which supports the wildlife found in the riparian habitat along the lower Colorado River.

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TOTAL ACRES OF RIPARIAN VEGETATION FROM DAVIS DAM TO THE SOUTHERLY INTERNATIONAL BOUNDARY WITHIN THE GREATER COLORADO RIVER FLOOD PLAIN

1981

	Structural Type							
Community Type	I	II	III	IV	V	VI	VII	TOTAL
Cottonwood/Willow		155.4	613.2	5003.1	1742.9	1027.3		8541.9
Screwbean Mesquite-Salt Cedar		99.0	1312.4	12924.8	6347.7	3812.9		24496.8
Honey Mesquite			1227.8	10693.3	2155.7	54.5		14131.3
Salt Cedar-Honey Mesquite			204.5	7261.5	1967.9	129.9		9563.8
Salt Cedar	321.6	101.3	425.2	22656.0	11850.6	3863.8		39218.5
Arrowweed						4242.3		4242.3
Marsh	4682.1	1384.9	1253.9	536.9	994.4	635.5	1189.8	10677.5
Atriplex						597.1		597.1
Inkweed						222.6		222.6
					GRAND TOTAL			111691.8

INTRODUCTION

Any classification of vegetation is largely arbitrary; therefore it is of utmost importance to clearly state the purpose of the classification (Kuchler 1967). In 1973 we began studying the riparian vegetation of the lower Colorado River, extending from Davis Dam, California-Nevada-Arizona boundary, to the Mexican border (450 km [273 mi]). Our major objective was to divide the vegetation into broad categories or types, characterized according to their general floristic and physiognomic characteristics. Our next objective was to determine the densities and diversities of wildlife associated with each vegetation type or habitat.

The classification was to be at a level that we could easily use in the field and that individuals associated with management agencies (engineers, hydrologists, biologists, etc.) could quickly learn and use the classification system and rapidly identify habitats in the field by taking only a few, or no, vegetation measurements. They could then quickly and accurately assess a stand of vegetation in terms of habitat classification and wildlife use. In addition to being relatively simple, the classification had to emphasize similarities rather than differences between stands. Although not without merit, emphasizing differences would have been undesirable for our purpose as it would have yielded a classification system defining a large number (hundreds or thousands would be possible) of habitat types. We wanted each vegetation type to be represented by a large enough area so that wildlife use could be accurately quantified in it at all seasons.

Aerial reconnaissance revealed that the riparian vegetation consisted of intermeshed stands of vegetation often encompassing 10 to hundreds of ha. Ground reconnaissance revealed that these stands differed from each other primarily in dominant vegetation and vertical configuration. We then quantified differences and similarities among the various stands. This report emphasizes methods employed in quantifying vegetation data used for classifying vegetation and for showing wildlife-vegetation relationships.

The biologists who have helped collect vegetation data over the past 10 years are too numerous to list by name. We are nonetheless grateful to all of them. We would be remiss not to mention some whose contribution went beyond routine data collection. John Disano and Ronald W. Engel-Wilson, through their creative thinking and sincere personal involvement, did much to bring early field efforts into focus. The organizational skills of George F. Drake were instrumental in getting data collected properly and on time. The enormous efforts of Mark J. Kasprzyk and Camille M. Romano provided us with a massive amount of data from the Cibola National Wildlife Refuge. Much of the field work and final efforts in completing the most recent type maps were undertaken by William C. (Chuck) Hunter to whom we are grateful. Efforts of Janet M. Jackson were instrumental in collecting and analyzing much of the recent data. We thank Roberta Walker and Patsy Ann Fields for assisting with data analysis. Susan M. Cook and Jane R. Durham assisted with editing, and Cindy D. Zisner's skills with the word processor were instrumental in production of the various drafts, including the final one. Cindy D. Zisner also prepared the illustrations, based on original drawings by Brian Woodbridge and Kenneth Clough. We thank Michael Walker, David E. Busch, Phillip E. Sharpe, and William I. Butler, Jr. of the Bureau of Reclamation and Herbert Guenther, currently with the Wellton-Mohawk Irrigation District, for the wide variety of help and ideas through discussion which they provided. The work was supported by U.S. Bureau of Reclamation Contract No. 2-07-30-X0244.

DATA COLLECTION

We established 121 km (75 mi) of transects in riparian vegetation in the lower Colorado River valley. Lines or transects were established by cutting swaths 1 m (3 ft) wide through the middle of stands encompassing at least 10 ha (25 a), with dimensions of at least 750 m (2461 ft) long by 50 m (164 ft) wide. Small patches (<1 ha [<2.5 a]) of vegetation differing in species composition or structure from the basic type in the stand were bisected by the transect at right angles whenever possible. In no case was a transect situated so that vegetation differing from the stand as a whole, paralleled the transect at a distance closer than 15 m (49 ft). Semipermanent markers were placed at the beginning and end of each transect. A stake with distance from beginning of the transect inscribed on it was driven into the ground every 150 m (492 ft). A transect 750 m (2461 ft) long had 5 subplots, each 150 m (492 ft) long on each side, for a total of 10 subplots. Longer transects, of course, had more subplots. Vegetation data were collected for each subplot. Each transect was numbered; transect number and directional orientation were recorded on a map. A typical transect is illustrated in Figure 1.

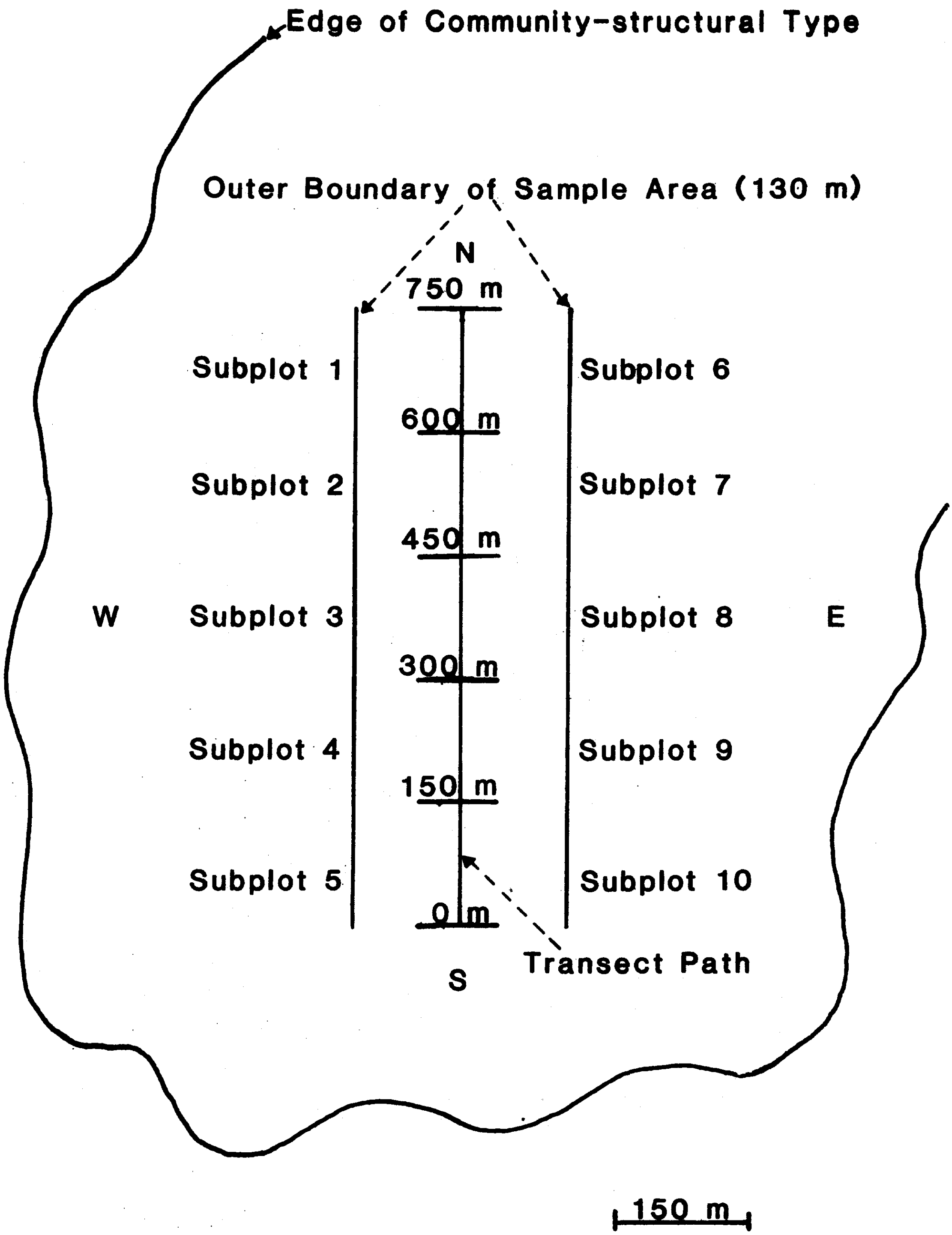


Figure 1. Typical transect through a relatively homogeneous stand of vegetation, showing individual subplots and outer boundaries.

VEGETATION MEASUREMENTS

In each subplot tree counts and foliage density measurements were made. Tree counts were made only once on each transect unless the area was later affected by some major disturbance. Counting was unaffected by amount of foliage present and could be done at any time of year. Individuals of each species of tree or shrub within 15 m (49 ft) of the transect were counted in each 150-m (492-ft) subplot. Each individual tree was categorized by height (> or <3 m [> or <10 ft]), by presence or absence of mistletoe (Phoradendron californicum), and by its condition (alive or dead). The form used for recording this information is shown in Figure 2.

Sometimes shrubs or trees grew in densities so great that it was not possible to count individuals. Often densely packed individuals provided no more ground cover than trees in less dense areas. Thus 20 trees in 1 area could equate in terms of ground cover to 200 trees in another area. To solve this problem we measured the height and north-south crown diameter of hundreds of individuals of each tree species growing at various heights in uncrowded conditions. From these data we developed regression equations for determining the ground cover by an individual tree (shrub) of a given height (Fig. 3 A, B). Thus when we encountered a dense patch of trees or shrubs, we measured the area of the patch and obtained the average height of the trees in it. We then merely divided the area of the patch by the area occupied by the average single tree growing in uncrowded conditions to get the

TREE COUNT

PAGE 1 OF 1

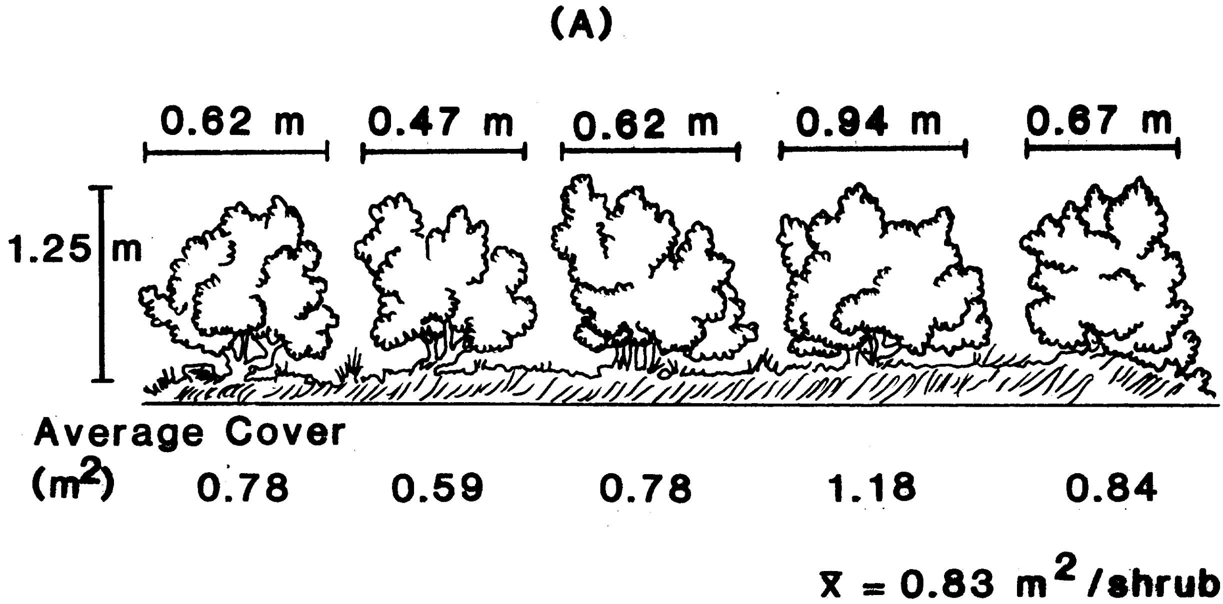
TRANSECT PA25 STARTING DIRECT E DATE W READER DB

DIRECTION S DIRECTION N

SC = Salt Cedar
SAL = Salix

INTERVAL	SPECIES											SPECIES										
	SC <3	SC >3	SAL >3									SC <3	SC >3	SAL >3								
0-150	80	140	3									50	160	2								
150-300	12	95	2									50	200	0								
300-450	110	250	0									75	320	0								
450-600	40	200	4									60	250	3								
600-750	10	150	1									5	100	1								

Figure 2. Tree count data sheet.



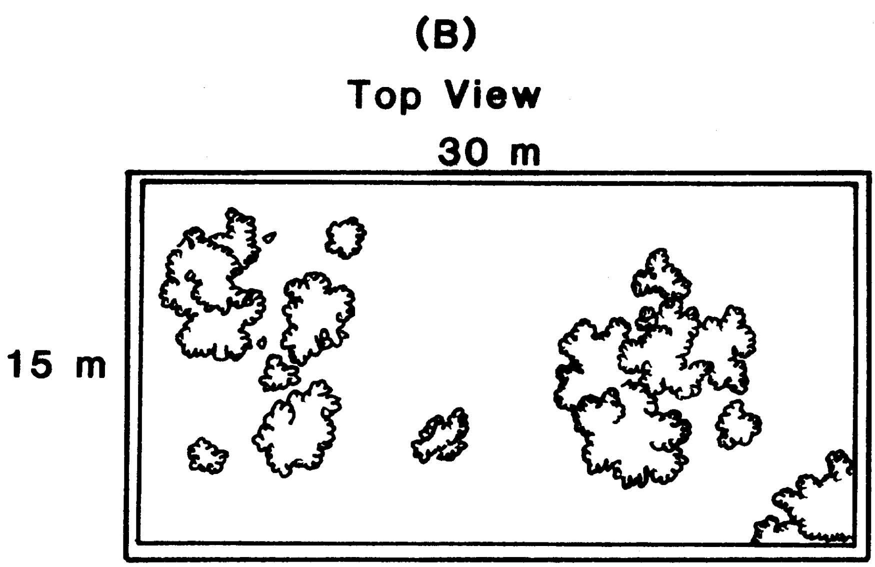


Figure 3. (A) Reference sample of quail bush. (B) Sample area with approximately 30% cover by quail bush or 135 m^2 (1,453 ft^2). Since 1 shrub occupies 0.83 m^2 (9 ft^2), the area has approximately 163 individual shrubs. The area occupied by each patch of quail bush was measured to determine the ground cover by quail bush.

equivalent number of trees or shrubs growing under noncrowded conditions. This method may be applied to all trees and shrubs to obtain a rough estimate of the number of full-sized equivalents of a given plant species in an area.

Foliage density estimates were made in all stands annually between May and July; stands undergoing succession (burned and regenerated areas) were measured again in September or October. Relative foliage density estimates were made using the board technique (MacArthur and MacArthur 1961). Sampling was done at 3 points (15 m [49 ft], 75 m [246 ft], and 135 m [432 ft]) from the beginning of each subplot. Thus on a 750-m (2461-ft) transect, there were 15 points per side for a total of 30 points (Fig. 4).

At each sample point the observer paces 1 step perpendicular to the transect. A second person holds a board (approximately 20 X 40 cm [8 X 16 in]) at a given height behind the nearest green leafy vegetation. The observer stops the second person when green foliage covers one-half of the board. Distance from observer to board is measured with a tape measure or rangefinder (Fig. 5). Foliage density measurements were recorded in feet because of the scaling of equipment used; also all vegetational calculations were based upon the English system of measures. All measurements were rounded to the nearest 1 ft (0.3 m) except in the first 1 ft (0.3 m). In the first 1 ft a distance of 2 in (5 cm) represents very dense vegetation, but 0 means that foliage is absent. Thus any distance >0 but <1 ft (<0.3 m) was called 1 ft

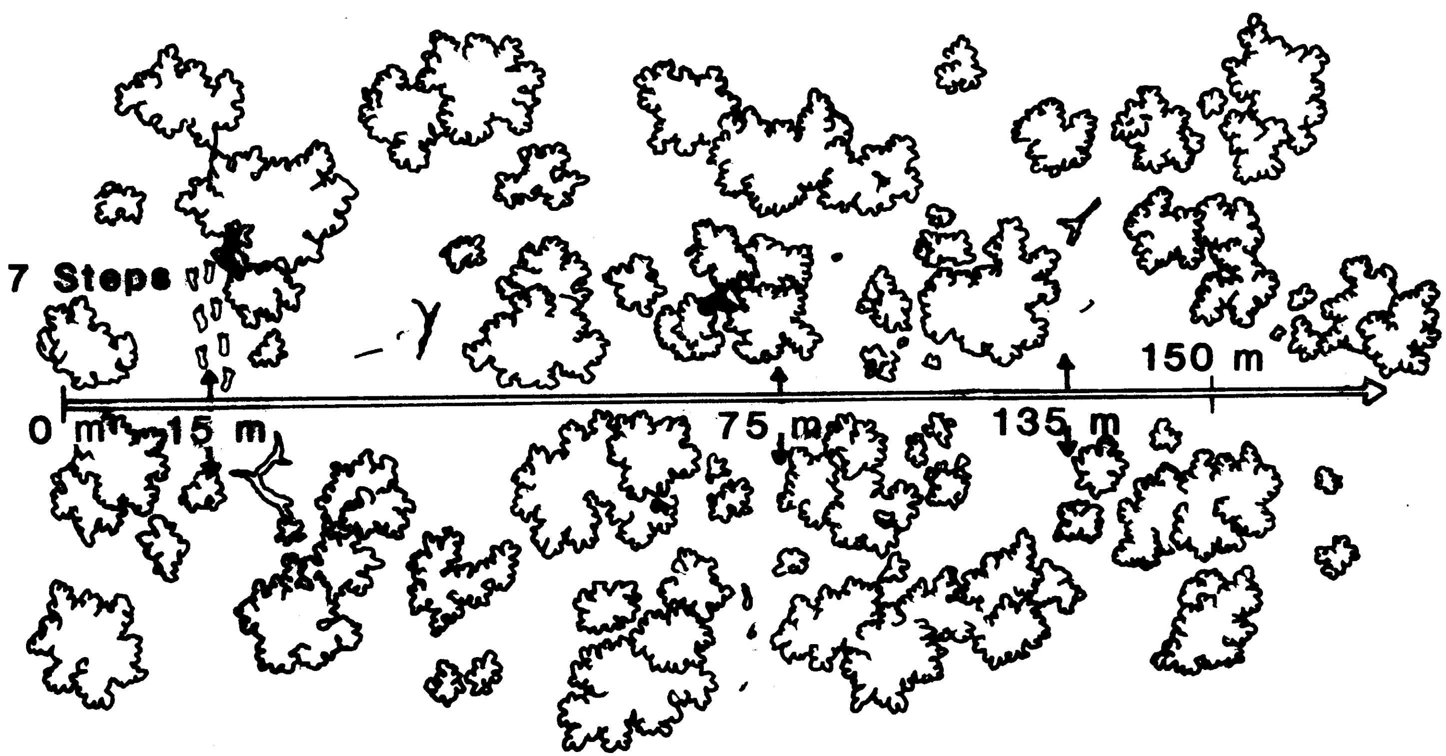


Figure 4. Sampling points for foliage density measurements within each subplot along the length of a transect.

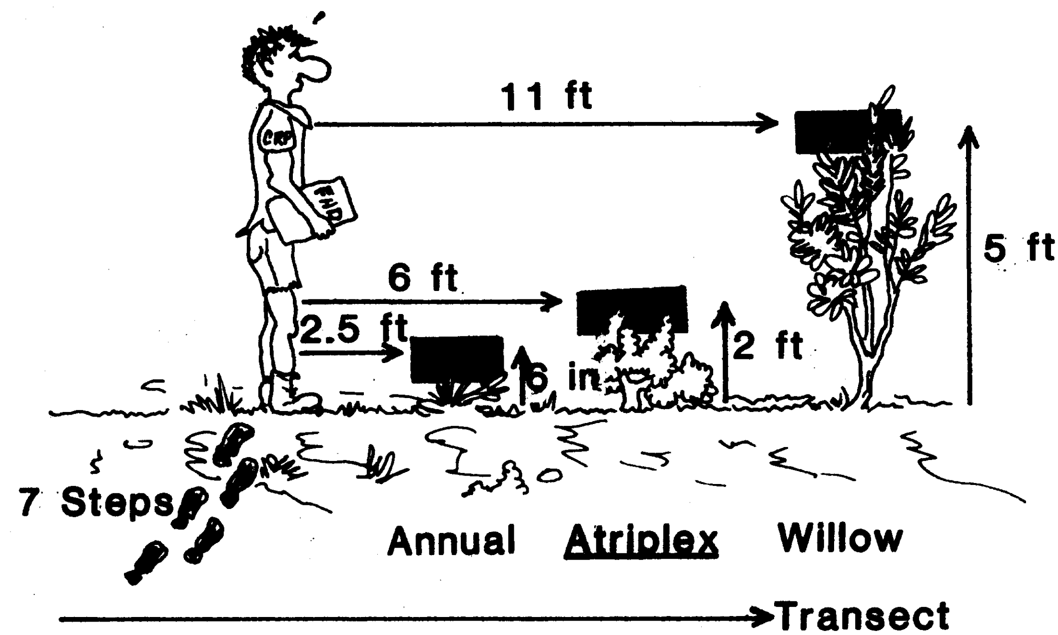


Figure 5. Selection of vegetation for foliage density measurements.

(0.3 m). Often it was difficult to obtain agreement between 2 observers for distances <1 ft (<0.3 m), yet the difference in, for example, the foliage density estimate between 1 in (2.5 cm) and 2 in (5 cm) is large. Rounding to 1 ft (0.3 m) resulted in a conservative estimate of foliage density in very dense places, but yielded results reproducible by other observers. Vertical foliage density determinations were made at 0.5 ft (0.15 m), 2 ft (0.6 m), 5 ft (1.5 m), 10 ft (3 m), 15 ft (4.5 m), 20 ft (6 m), 25 ft (7.5 m), 30 ft (9 m) and every 10 ft (3 m) thereafter until no vegetation was present. Theoretically one should use a ladder to make measurements at higher levels. This was impractical. We used a rangefinder to locate a point, for example, at 8 m (26 ft), then estimated as carefully as possible the distance to a second point where leaves would cover one-half of the board. Plant species contributing to foliage density at each point were recorded.

Distances were measured with a tape measure to the nearest 1 ft (0.3 m) within the first 10 ft (3 m), because the foliage density index is more sensitive to vegetation located nearby. Measurements beyond this were estimated with the aid of a rangefinder. In sparse areas the distance to trees and shrubs with foliage were measured from only 1 sample point within a subplot -- the point to which they were closest. Data were recorded as in the Vegetation Management Final Report (Chapter 2; Anderson and Ohmart in prep.).

Each plant distance measurement was converted to surface area per cubic unit of space (i.e., foliage density) according to the formula:

$$K = \frac{\log_n 2}{D} = \frac{0.693}{D}$$

where K is the foliage density and D is the measured distance. Foliage density per subplot is the sum of the average of the 3 measurements taken at each vertical plane. For example, foliage density at 1.5 m (5 ft) in 1 subplot for which the distances were 9, 15, and 2 ft (2.7, 4.5, and 0.6 m, respectively) would be calculated as follows:

$$\frac{0.693}{9} + \frac{0.693}{15} + \frac{0.693}{2} \div 3 = 0.1556$$

Foliage density at 3 m (10 ft) for distances of 1, 2, and 3 ft (0.3, 0.6, and 0.9 m, respectively) would be:

$$\frac{0.693}{1} + \frac{0.693}{2} + \frac{0.693}{3} \div 3 = 0.4217$$

The density for the 2 vertical planes is 0.1556 + 0.4217 = 0.5773. If no green foliage occurred at a particular point, a zero was used in the calculations. A sample set of foliage density calculations is shown in Table 1.

TREATMENT OF DATA

Vertical Diversity

Vertical or foliage height diversity (FHD) for each transect was calculated according to information theory (Shannon and Weaver 1949):

$$FHD = -\sum_{i}^{n} p_i \log_n p_i$$

Table 1. Sample foliage density estimates used for calculating patchiness and foliage height diversity.

Plot	Foliage density (ft^2/ft^3) 0.5 ft (0.15 m)	2 ft (0.6 m)	5 ft (1.5 m)	10 ft (3.0 m)	15 ft (4.6 m)
1	0.16	0.20	0.29	0.10	0.01
2	0.12	0.15	0.23	0.06	--
3	0.08	0.09	0.27	0.09	0.01
4	0.28	0.15	0.09	0.01	0.00
5	0.19	0.22	0.09	0.02	0.00
6	0.18	0.34	0.29	0.10	0.02
7	0.07	0.31	0.31	0.03	0.01
8	0.08	0.18	0.31	0.02	--
9	0.15	0.16	0.32	0.03	--
10	0.23	0.15	0.13	0.01	--

	Patchiness index 0.5-2 ft (0.15-0.6 m)	5-10 ft (1.5-3.0 m)	15-20 ft (4.6-6.0 m)	≥25 ft (≥7.5 m)	Total
Mean total density	0.35	0.28	0.00	--	
PI(s^2)	0.01	0.01	0.00	--	0.02

	Calculation of foliage height diversity 0.5-2 ft (0.15-0.6 m)	5-10 ft (1.5-3.0 m)	15-20 ft (4.6-6.0 m)	≥25 ft (≥7.5 m)	Total
Mean total density	0.35	0.28	0.00	0	0.63
Proportion (p_i)	0.55	0.44	0.01	0	
$\log_{10}p_i$	-0.26	-0.36	-2.20	0	
$p_i\log_{10}p_i$	-0.14	-0.16	-0.01	0	FHD = 0.31

where p_i is the proportion of total foliage density contributed by the density at height level i (sample calculations are shown in Table 1).

Horizontal Diversity

Horizontal diversity (or patchiness) is a structural feature of a habitat describing the regularity of vegetation as it is distributed in the horizontal plane. A citrus orchard with roughly equal-sized and evenly spaced trees has little horizontal diversity. Patchiness or diversity is greater in a honey mesquite (*Prosopis glandulosa*)-quail bush (*Atriplex lentiformis*) habitat with irregularly spaced trees and shrubs of different heights. Diversity in the horizontal plane can be calculated for any vertical level from which foliage density estimates are made.

Many stands of Colorado River riparian vegetation include a shrubby layer up to about 1 m (3 ft). We chose foliage density estimates from 0.15 m (0.5 ft) and 0.6 m (2 ft) to represent this vertical layer. Foliage density in this layer was the sum of the density at 0.15 m (0.5 ft) and 0.6 m (2 ft). A majority of stands had another layer extending from 0.6-4.5 m (2-15 ft). We chose foliage density estimates at 5 ft (1.5 m) and 10 ft (3 m) to represent this layer. Many stands have a third layer, usually poorly developed, extending above the second layer for an additional 2-3 m (7-10 ft). We chose foliage density estimates at 4.5 m (15 ft) and 6 m (20 ft) to represent this layer. More than 95% of lower Colorado River riparian vegetation had virtually no vegetation above 7.5 m (25 ft). Exceptions included occasional stands of athel tamarisk (Tamarix aphylla), cottonwood (Populus fremontii), or willows (Salix gooddingii), with individual trees reaching 30 m (98 ft). We therefore recognized a fourth layer with foliage $\geq$7.5 m ($\geq$25 ft). The concept of FHD with 4 vertical layers is depicted in Figure 6.

Horizontal diversity was the variance associated with the mean total foliage density for each vertical plane across all subplots. For example, summed foliage densities for 0.15 m (0.5 ft) and 0.6 m (2 ft) in each plot (Table 1) were averaged to obtain mean foliage density for the layer 0.0-0.6 m (0-2 ft), in this case 0.348. Horizontal diversity is the variance or standard deviation squared (= 0.010) associated with mean total foliage density. This procedure was repeated for each vertical layer. Total horizontal diversity is the sum of the variances for all layers. The concept of horizontal diversity or patchiness is depicted in Figure 7.

Note that in calculating horizontal diversity we are assessing the variance between subplots. Therefore, if horizontal diversity is thought of as patchiness, we are defining a patch as a unit 150 m (492 ft) long and as wide as the distance from the transect to the edge of the stand under study, usually 128 m (420 ft). Choice of this patch size was based on evidence that many common birds in the area use patches of about this size (Anderson and Ohmart 1981, Conine 1982, Anderson, Romano, and Ohmart unpubl. ms). Thus it is possible that an area that was rated very patchy on a smaller scale could be rated homogeneous on our scale.

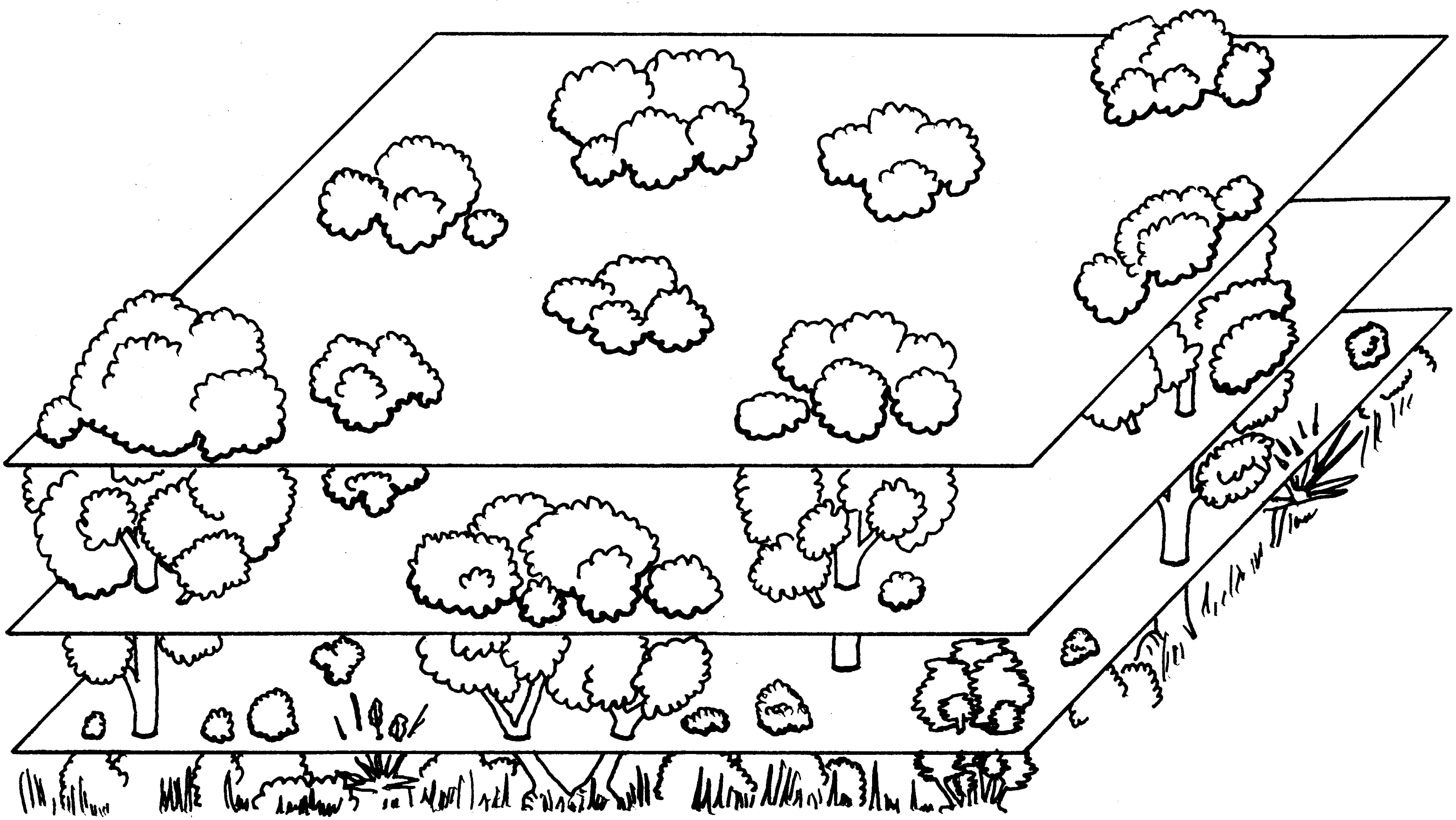


Figure 6. Diagrammatic representation of foliage diversity in the vertical plane. The stand shown depicts an area of at least 10 ha (25 a).

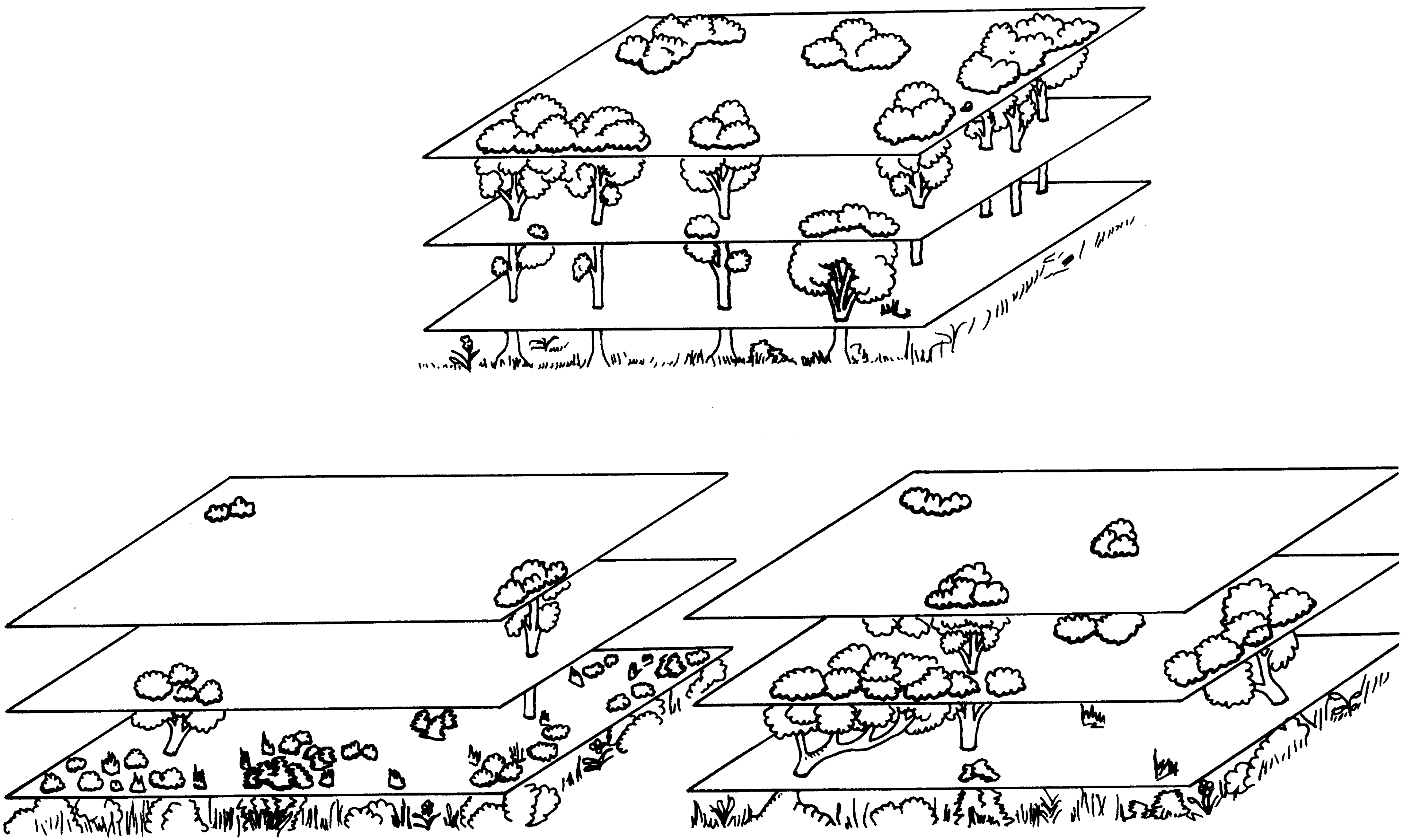


Figure 7. Diagrammatic representation of foliage diversity (patchiness) in the horizontal plane at each of three vertical layers. The blocks represent patches of roughly 2 ha (5 a).

Since 0.00 and 0.69 represent minimum and maximum foliage density values, respectively, maximum horizontal diversity or patchiness for a given layer is 0.238. Since there are 4 layers, maximum horizontal plane diversity is 4(0.238) or 0.9522. Since this is very nearly 1.0, the sum of the diversity for the 4 layers closely represents the percent of maximum diversity possible for an area.

Another method for calculating FHD and patchiness might be to simply record the presence or absence of vegetation at various vertical positions. This could be done with a long pole and/or a rangefinder. More stops would have to be made, but FHD, relative density values, and patchiness estimates could be made on the basis of the proportion of total points at which foliage occurred. This method might be quicker, it would reduce the amount of calculating to be done and it might be equally as accurate.

Frequency of Measurements

It is important to take as many measurements as necessary to obtain a reasonably accurate reflection of the true foliage density and diversity of a stand. In general, the more measurements that are taken the greater the precision, however, for most field workers time and manpower are restraining factors. Additional measurements beyond some number increases labor requirements proportionately more than is justifiable when the increase in precision is very small.

In identifying the effort required to obtain reasonably precise data we made foliage density measurements at 1-5, 9 and 12 points within each subplot on each side of 7 transects which involved 104 subplots. Foliage density calculations were made, using 1 measurement from each subplot, then 2 measurements and so on until 6 separate sets of calculations were made. This was repeated using 9 and 12 measurements per subplot. We assumed that 12 measurements per subplot yielded results as close to reality as possible to obtain with our methods. The foliage density and diversity results obtained for each set of measurements were expressed as percent deviation from the results obtained with 12 measurements per subplot. The mean percent difference and standard deviation decreased as the number of measurement points increased (Fig. 8) until 5 measurements were included per subplot. No increase in precision was made with 9 measurements per subplot. We ultimately chose to make 3 measurements per subplot. Making 5 measurements would decrease the error rate by only 1% but would increase the work by 67%. In our judgment, the additional precision did not warrant the effort to obtain it.

Repeatability

Since our work encompassed a large area (40,000 ha [100,000 a]) it was necessary to have several individuals involved in collecting data. Thus it was imperative to train all personnel carefully and to determine the similarity of data collected from the same stand by different observers. In general we found least agreement in data from stands with tall vegetation ($\geq$10 m [$\geq$33 ft]). Since space precludes an exhaustive presentation of our data we will present data where discrepancies among observer teams were greatest.

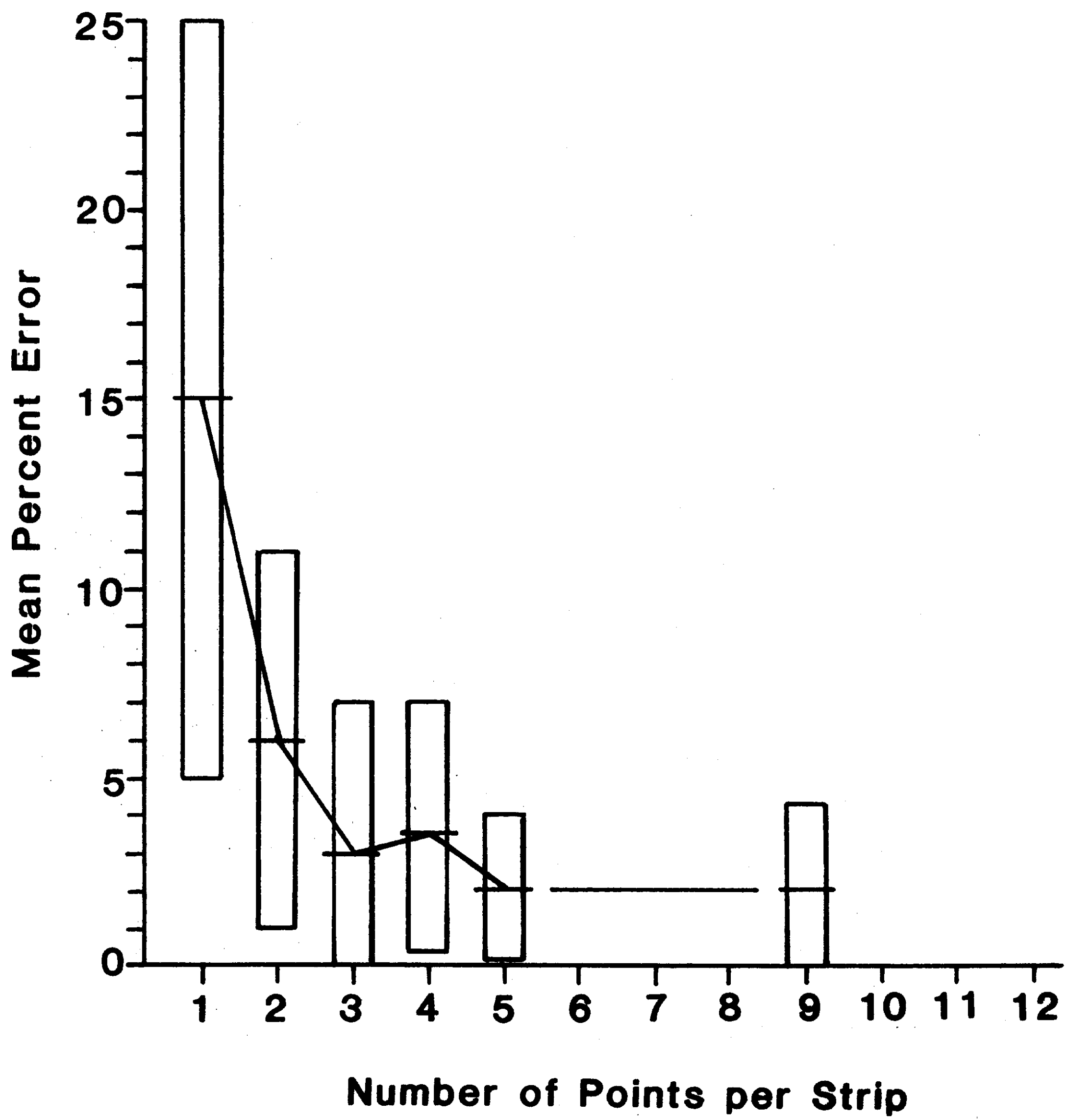


Figure 8. Mean percent error associated with foliage density and diversity measurements when measurements were made at various numbers of points per subplot. The values obtained when 12 measures were done per subplot were assumed to accurately represent the true values. This standard was used for comparing values obtained with smaller numbers of measurements per subplot.

Foliage measurements were taken by 4 teams in a relatively dense stand including about 10 ha (25 a) and with trees to 20 m (64 ft) tall. It was assumed that some observer estimates would be too high and some would be too low, thus the average for the teams would approximate the "correct" estimate for each foliage variable. The deviation from average was then considered to be the error rate for a team. The error divided by the "correct" value yielded the percent of error. This procedure indicated that for all variables the mean error was 8.3%. The greatest difficulty was in assessing vegetation density at the highest levels; the average error at $\geq$8 m ($\geq$26 ft) was 33.1% (Table 2). The mean error was lowest for FHD (2%) and total patchiness (4.3%). Since the error rates for foliage density estimates were higher than we had hoped to find we examined the results in greater detail.

Although foliage density estimates had a mean error rate of 15% the profiles of vertical foliage distribution derived from the estimates were nearly identical in 3 of the 4 cases in the first test and in all 4 cases the vegetation would be classified the same (see next section). In the second test, 2 of the 3 profiles would have led to the same classification (Type V); 1 would have led to a classification as Type IV (Fig. 9). This was of major importance in our study, thus the fact that all 4 teams in the first set obtained results which led to classifying the stand in the same way perhaps minimizes the importance of the observed variation in data obtained by different teams. FHD and patchiness estimates obtained by different teams for a given stand were

Table 2. Average error associated with various vegetation variables collected by 4 different teams from the same stand. The mean measurements by all 4 teams was the standard with which comparisons were made.

	Foliage density at various heights						Patchiness				
Team	0.0-0.6 m (0-2 ft)	0.6-4.5 m (2-15 ft)	4.5-7.5 m (15-25 ft)	>7.5 m (>25 ft)	Total	FHD	0.0-0.6 m (0-2 ft)	0.6-4.5 m (2-15 ft)	4.5-7.5 m (15-25 ft)	>7.5 m (>25 ft)	Total
TEST I											
1	20.5	3.4	20.8	74.2	31.6	1.1	0.9	0.8	0.9	11.6	1.8
2	12.6	13.9	5.9	21.0	1.7	4.1	5.2	3.7	8.7	6.1	6.7
3	16.8	6.1	14.8	27.0	17.3	0.9	2.0	1.4	1.5	6.9	3.7
4	16.2	4.3	11.7	26.3	15.9	2.0	2.3	1.3	1.5	10.7	5.0
TEST II											
1	8.5	3.2	1.0	13.5	2.4	2.8	1.5	0.2	2.4	0.0	2.8
2	4.6	7.3	10.2	42.0	1.3	2.8	1.3	0.9	0.3	2.0	2.8
3	12.7	10.5	11.0	28.0	1.6	0.1	1.6	2.1	1.2	0.6	0.1
Mean	13.3	7.0	10.8	33.1	10.3	2.0	2.1	1.5	2.4	5.4	3.3
SD	4.9	4.0	6.3	20.0	11.7	1.4	1.4	1.1	2.9	4.7	2.1

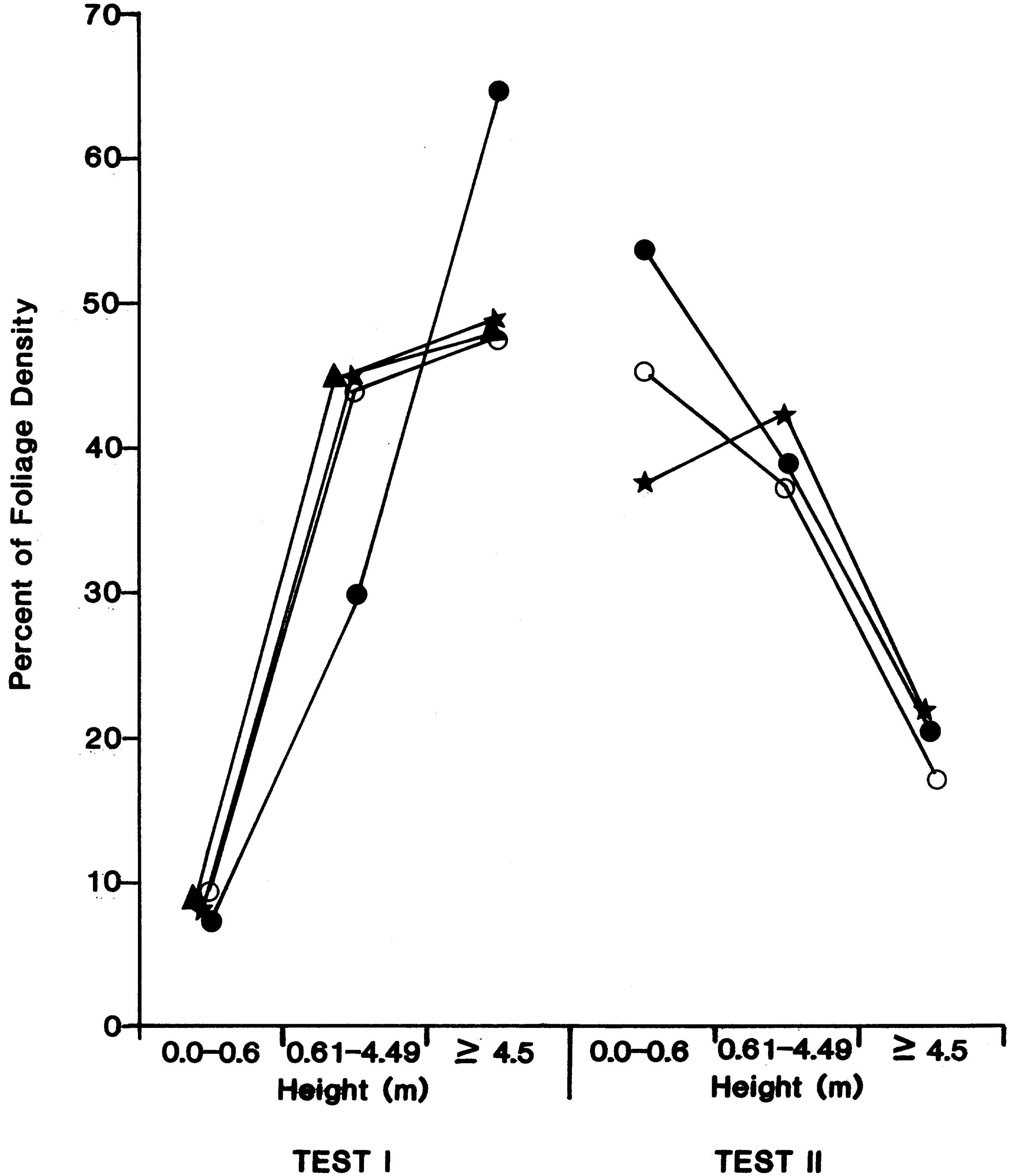


Figure 9. Foliage profiles obtained by different teams for the same area. Such tests are presented for 2 different areas.

always similar. All personnel were thoroughly trained in the techniques before they used them in the field and more experienced personnel always accompanied less experienced personnel. Overall we were satisfied that the methods used accurately and consistently differentiated areas of high, intermediate, and low foliage density and diversity in the vertical and horizontal planes. However, stands differing slightly in foliage density could not be reliably separated.

Need for Preliminary Studies

In any study where discovery of relationships between animals and environmental variables is a goal there is a need for preliminary studies (Green 1979, Platts 1981, Platts et al. 1983). Such studies are essential because they allow the investigators to test to see if their methods satisfactorily produce the desired kinds of information. Preliminary studies also offer an opportunity to become thoroughly familiar with the study area prior to the beginning of the study and provide a training period for field personnel. In addition, preliminary studies allow the investigators to determine if there are any differences between experimental and control areas prior to treatment of the control area. For example, if the objective is to determine the impact of light grazing on an area in terms of changes in wildlife densities and diversities it is critically important to establish plots where all variables except the one being tested are controlled. This means that the vegetation and wildlife use must be analyzed in the control and experimental areas before grazing. Evaluation of impacts can only be determined if the internal variation is known before impact.

The argument is often heard that such preliminary studies are too time-consuming and expensive to carry out. This is fallacy; preliminary studies can save time and money and are the only way of obtaining scientifically valid results (see Green 1979). Without them it is not possible to interpret results obtained after impact because of the lack of knowledge about variation before impact. In other words, as Platts (1981) correctly pointed out, the notion that collection of inventory "garbage" (i.e., data without preliminary studies) leads to reliable analyses is purely mythical. Unfortunately it is a pervasive myth. If preliminary studies cannot be done, the study should not be undertaken, or should be undertaken with the realization that conclusions based on the findings are not well-founded scientifically.

CLASSIFYING THE VEGETATION

Dominant Vegetation

Tree and shrub counts along transects revealed that salt cedar (*Tamarix chinensis*) was virtually the only tree species present in many stands encompassing 10 ha (25 a) or more. There were also such stands of honey mesquite and arrowweed (*Tessaria sericea*). Thus these 3 species were easily recognized as the dominants for 3 vegetation types. Other major vegetation types were more difficult to identify. All other stands included salt cedar in relatively high numbers. In some of these stands the numerical dominance of salt cedar was shared by other species (i.e., other species constituted at least 5% of total trees present). Given that cottonwood and willow were considered to be ecological equivalents (the same species as viewed by wildlife use), numerical dominance was never split among more than 2 species. Based on dominant tree or shrub species present, we recognized 6 vegetation types: (1) honey mesquite; (2) salt cedar; (3) salt cedar mixed with screwbean mesquite (Prosopis pubescens); (4) salt cedar mixed with honey mesquite; (5) salt cedar mixed with cottonwood and/or willow (Table 3); and (6) arrowweed.

Vertical Configuration

In order to quantify the extent of similarity in vertical configuration among transects, we calculated overlap between compared stands in proportional distribution of foliage among 3 layers: 0.0-0.6 m (0-2 ft), 0.6-4.5 m (2-15 ft), and ≥4.5 m (≥15 ft). It was not necessary to consider 4 layers (as in calculations discussed above) because the few areas with very tall vegetation (>6 m [>20 ft]) could be easily separated from stands with only 3 layers of vegetation by considering overlap in just 3 vertical bands. Overlaps were calculated using (Horn 1966):

$$R_o = \frac{\Sigma (x_i + y_i) \log (x_i + y_i) - \Sigma x_i \log x_i - \Sigma y_i \log y_i}{(X + Y) \log(X + Y) - X \log X - Y \log Y}$$

For the compared stands, x_i and y_i represent the proportion of total foliage density occurring at vertical band i. X and Y represent total foliage density. From a matrix of these overlap values, including all possible 2-way comparisons between stands, a dendogram (Fig. 10) was constructed from:

Table 3. Mean percent of trees of various species per 150-X-15-m (492-X-49-ft) subplot in riparian vegetation along the lower Colorado River. Dominant vegetation is underlined. Arrowweed, the sixth vegetation type, is not included in this table because trees were not present in this vegetation type.

		Mean percent of total trees			
Numerically dominant tree species within a stand	Number of subplots	Salt cedar	Honey mesquite	Screwbean mesquite	Cottonwood and/or willow
Honey mesquite	254	0	<u>99</u>	1	0
Salt cedar	216	<u>99</u>	0	1	0
Salt cedar-honey mesquite	38	<u>54</u>	<u>46</u>	0	0
Screwbean mesquite-salt cedar	230	<u>59</u>	2	<u>38</u>	1
Cottonwood and/or willow-salt cedar	194	<u>60</u>	1	4	<u>35</u>
Total/mean	932	51	29	11	9

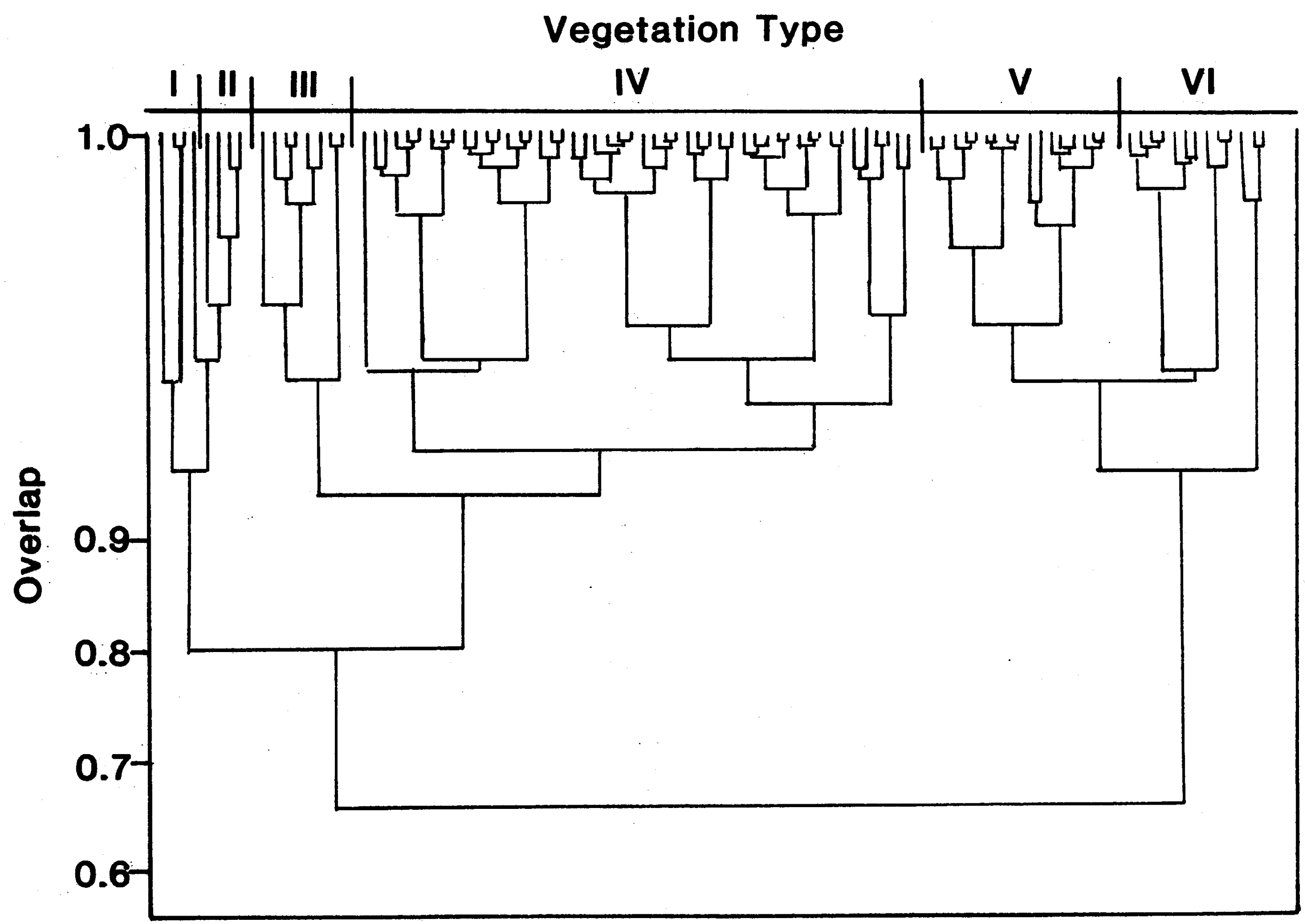


Figure 10. Dendrogram showing similarities in vertical profile between transects, based on overlap in foliage distribution.

$$C, AB = \frac{\alpha C A + \alpha CB}{2}$$

which simply states that overlap in the vertical distribution of foliage of stand C with stands A and B is equal to average overlap of C with A and C with B (Cody 1974). The dendogram was interpreted as revealing existence of 6 categories based on vertical configuration. Each stand within a category (designated I-VI) had a more similar vertical configuration to other stands included in that configuration than to any stand within any other category. Observe that this determination was based on proportional vertical foliage distribution; absolute foliage density had nothing to do with it. That is, the vegetation within any of the 6 categories (or structural types) could theoretically include dense as well as sparse stands.

Profiles

Profiles of the 6 recognized vertical distributions (Fig. 11A, see p. 32) indicate that there was a continuum extending from stands with a majority of foliage in the upper layers (Types I and II) to those with a majority of foliage in the middle layer (Types III and IV) to those with a majority of foliage in the lower layer (Types V and VI). Note that this indicates foliage distribution, not foliage density, in the vertical dimension.

ANALYSIS OF HETEROGENEITY

Because our stands were large (at least 10 ha [25 a]), heterogeneity was inevitably present as a result of several factors. Local edaphic features were a frequent source of heterogeneity. For example, in 1 large stand of honey mesquite there was a narrow finger (20-30 m [66-98 ft] wide), representing an old silted-in oxbow, moister than the surrounding area. Perhaps for this reason salt cedar, seep willow (*Baccharis salicifolia*), and Goodding willow occurred there. Local heterogeneity in soil layering and structure also introduced heterogeneity. The distribution of soil types within a floodplain is typically heterogeneous. A highly localized dense clay soil type could cause a very local concentration of soil electrolytes. Vegetation growing in such soil often attains less stature and biomass (Anderson and Ohmart 1982, Anderson, Ohmart, and Disano unpubl. ms), and therefore vertical differentiation is simpler than that of adjacent vegetation. Such variation was so frequent that it was not feasible or desirable to delineate it within an otherwise relatively homogeneous stand. Although such delineation may be important for understanding some aspects of the distribution of vegetation, it was beyond the scope of our study. Such delineation would have required more time and money than was available to map the vegetation and acquire meaningful wildlife use data. These small parcels typically ranged in size from <1 ha (<2.5 a) to about 5 ha (12.5 a). Areas smaller than about 10 ha (25 a) could not be accurately plotted on maps of the scale (1:9449 cm) we were preparing.

Another source of variation included widely distributed individual trees of formerly more widely distributed species. For example, cottonwood and willow trees, often occurring as widely scattered individuals or as small clumps (20 x 20 m [66 X 66 ft]) of trees, are relicts of a gradually disappearing habitat (Ohmart et al. 1977).

Fire, another source of within-stand heterogeneity, in varying degrees and at various times, has affected nearly every stand of vegetation along the lower Colorado River. When a stand is burned, not all parts of it burn with equal intensity; some corners or clumps remain intact. Parts of a stand may have been burned more than once, so at any given time not all parts of a stand are at precisely the same stage of post-fire recovery. Even when burned evenly, not all parts of a stand redevelop at precisely the same rate. Thus at some level of analysis, considerable heterogeneity could be found within any fundamentally homogeneous stand.

Heterogeneity Between Subplots

The 2-ha (5-a) subplots along transects traversing stands of a given structural type revealed much of the heterogeneity within a habitat. This heterogeneity can reflect differences between subplots in vertical foliage distribution (Fig. 11A), in vertical foliage density (Fig. 11B), or in both of these. A subplot encompassed between 0.2 and 1.9 ha (0.5 and 5 a, respectively), depending on the width of the stand; most subplots were nearer the maximum figure. This is a fact rendering our system of classification entirely unsuitable for stands less than about

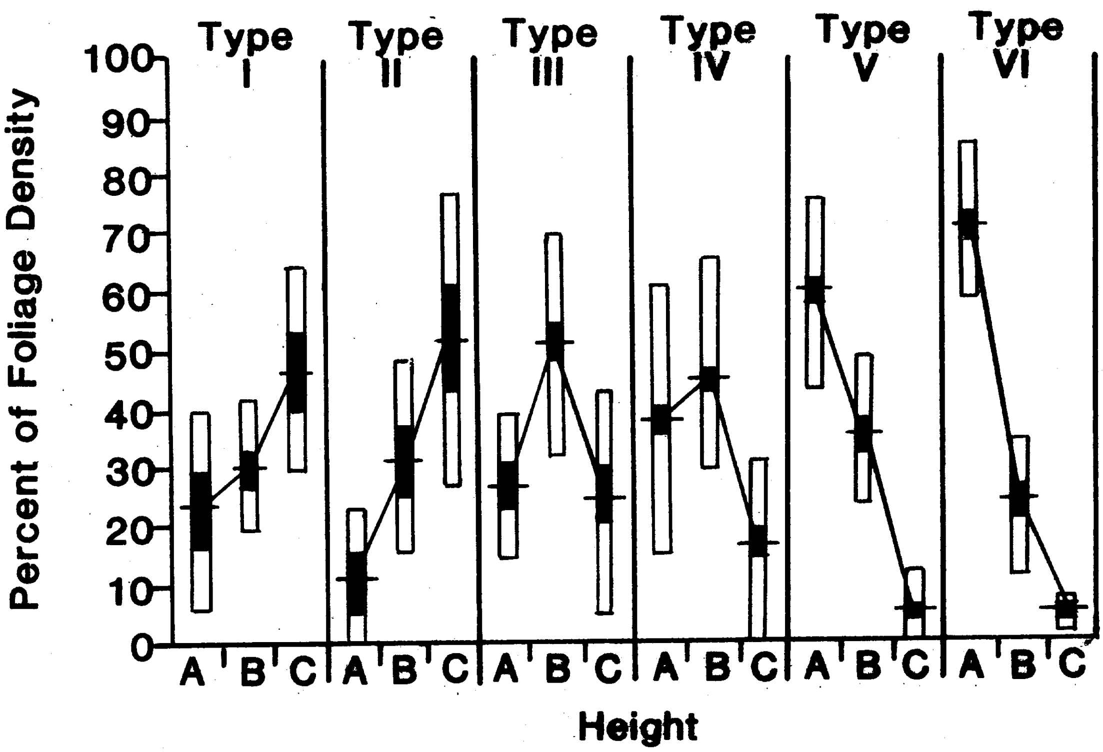


Figure 11 (A). Proportional distribution of the vegetation in 3 vertical layers among subplots within various stands of vegetation which overall were classified as belonging to 1 vertical structural type (I-VI). Horizontal lines represent mean values; large rectangles represent ±1 standard deviation; small rectangles represent ±2 standard errors. A = 0.0-0.6 m (0-2 ft); B = 0.6-4.5 m (2-15 ft); C = ≥4.5 m (≥15 ft).

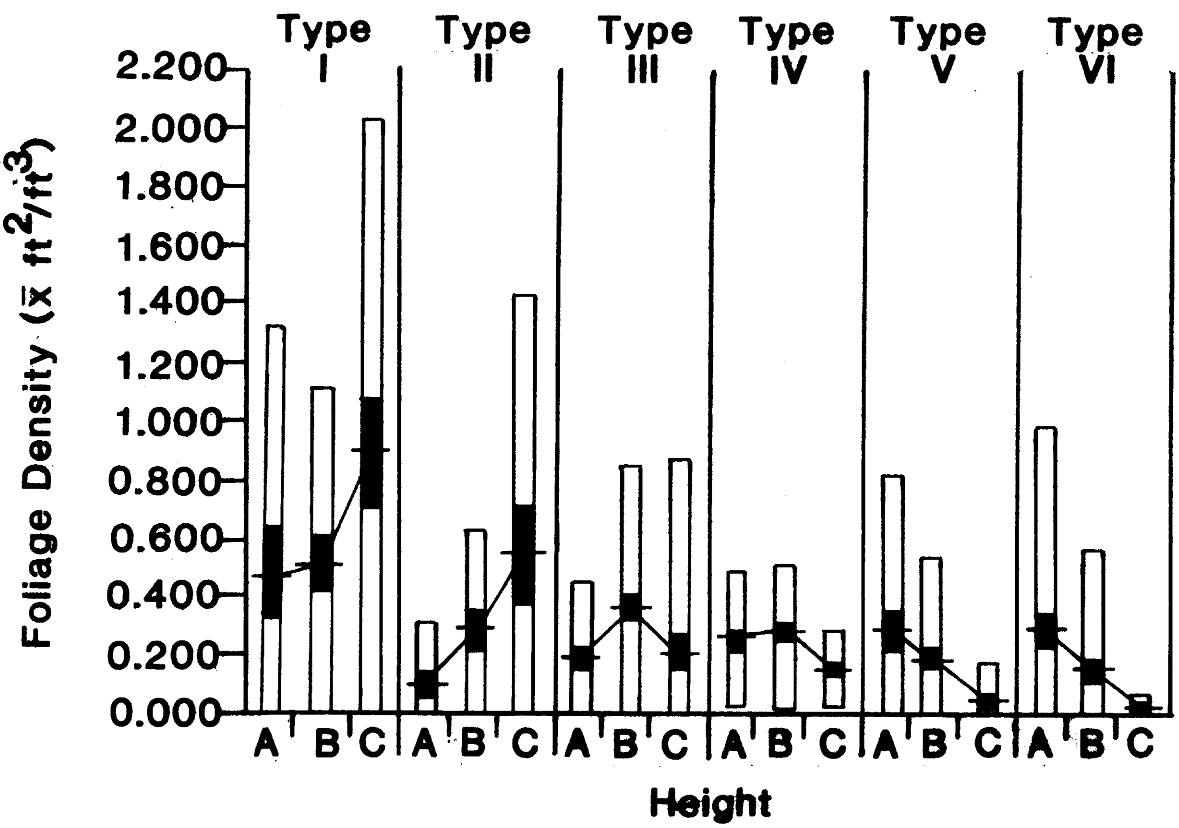


Figure 11 (B). Variation in foliage density between subplots within all structural types at each of 3 vertical levels. Note that the proportional distribution leads to clear differentiation of the vegetation types, but that foliage density does not. Horizontal lines represent mean values; large rectangles represent ± 1 standard deviation; small rectangles represent ± 2 standard errors. A = 0.0-0.6 m (0-2 ft); B = 0.6-4.5 m (2-15 ft); C = $\geq$4.5 m ($\geq$15 ft).

2 ha (5 a), because at 2 ha (5 a) a subplot and stand become the same thing; stands, by definition, are made up of more than 1 subplot. The system becomes more suitable as plot size approaches 10 ha (25 a) thus including about 5 subplots. Within vegetation classified as structural Type IV, vertical configuration in the various subplots more frequently resembled Type IV (Table 4) than any other structural type. However, it is not appropriate to give structural type designations to subplots constituting a certain structural type. Structural types were defined on the basis of transects through plots with similar average vertical foliage distributions. The foliage distributions were determined on the basis of measurements taken in subplots. That it is wrong to classify subplots (or any area <10 ha [<25 a]) can be seen from the following analogy.

Suppose that all books in 6 private libraries were measured and mean heights were found to be 22, 23, 24, 25, 26, and 27 cm (8.7, 9.1, 9.4, 9.8, 10.2, and 10.6 in, respectively) for collections I-VI, respectively. It would be improper to examine books in collection IV and to conclude that those ≤24 cm (≤9.4 in) in height came from collections I, II, or III and that all books ≥26 cm (≥9.8 in) in height came from collections V and VI. Desirable as it might be to know the origin of the books in collection IV, such a determination simply cannot be made from the evidence presented.

We present the data in Table 4 merely to emphasize (1) that there was heterogeneity between subplots and (2) that it is not valid to

Table 4. Each of 6 recognized structural types (see text) was composed of subplots. Variation in vertical configuration among subplots within each structural type is indicated by the data below. See text for discussion of tautology in this type of analysis.

	Subplots	Percent of subplots of structural type					
Structural type	Number	I	II	III	IV	V	VI
I	36	38	31	9	9	13	0
II	30	0	63	20	17	0	0
III	154	6	9	66	11	9	0
IV	366	1	4	23	38	19	15
V	291	0	0	8	4	59	30
VI	279	0	0	0	8	18	75

obtain foliage measurements from a 2-ha (5-a) plot and then to determine its vegetation type. This would be analogous to having a book 26.2 cm (10.3 in) and concluding that it came from collection V. It really could have come from any of the collections. Desirable as it may be to be able to classify a 2-ha (5-a) stand and to assess the wildlife use associated with it, such a determination is not possible with our data. We reiterate that this was compatible with the objectives of this study. A classification at a smaller scale would have led inexorably to a proliferation of the number of vegetation types recognized. This would have been incompatible with the objective of emphasizing elements of similarity between stands rather than differences. More important, we have learned that classification at a smaller scale would have led to a cloudy or erroneous picture of how wildlife used riparian vegetation. Cloudiness begins to appear at a scale of about 20 ha (50 a; Anderson et al. 1983), and an opaqueness emerges from analyses at a scale of about <4 ha (10 a; Rosenberg 1980, Engel-Wilson 1982, Anderson and Ohmart unpubl. ms); i.e., only weak wildlife use patterns are discernible at a scale of ≤20 ha (≤50 a), and wrong or no impressions emerge at a scale of ≤4 ha (≤10 a). Investigators working in other habitats have reported similar findings (Wiens 1981, Wiens and Rotenberry 1981a, 1981b).

Some of our conclusions about wildlife use of riparian vegetation along the lower Colorado River at the vegetation (habitat) type scale have been experimentally tested and confirmed (Meents et al. 1982, Anderson and Ohmart unpubl. ms). Other tests are in progress. It is inevitable that a classification made for one purpose will often fail when used for other than the intended purpose. Our purpose was to define vegetation types based on similarities between plots consisting of many subplots. It is inappropriate to use these criteria for classifying the extent of difference between subplots.

Heterogeneity in Number and Species of Trees

The intra-stand variation in number and species of trees as revealed by subplot analysis was also extensive (Table 5). We showed above how we arrived at a classification based on species or combinations of numerically dominant species which led to the recognition of 6 vegetation types with as many as 6 vertical configurations. Of a theoretical total of 36 vegetation (habitat) types, 23 were actually present.

Intra-habitat variation in number of trees per subplot, in general, fit normal distributions. Vegetation types (habitats) with Type I or II vertical configurations tended to have more trees other than salt cedar per subplot than Type V or VI configurations (Table 5). Coefficients of variation tended to increase inversely with the mean number of trees. This suggests a decrease in foliage density from Type I through Type VI, a point investigated in the next section.

Intra- and Inter-habitat Variation in Foliage Density

Variation in foliage density between subplots within all structural types is considerable at all vertical levels (Fig. 11B). It is

Table 5. Average number of trees (±1 SD) per subplot in each of 23 recognized riparian habitat types along the lower Colorado River. N refers to the number of subplots.

Vegetation type	N	Number of trees per 150-X-15-m (492-X-49-ft) subplots: Salt cedar		Cottonwood		Willow		Screwbean mesquite		Honey mesquite		Percent of subplots with no trees of dominant species
		$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	
Salt cedar												
I	18	95	20	0	0	0	0	0	0	2	20	0
II	8	47	19	0	0	0	0	0	0	0	0	0
III	28	74	25	0	0	0	0	7	13	0	0	0
IV	32	163	105	0	0	0	0	0	0	0	0	0
V	109	133	146	0	0	0	0	1	3	0	0	1
VI	20	31	50	0	0	0	0	0	0	0	0	0
Salt cedar-cottonwood/willow												
I	18	52	13	59	27	87	23	0	0	0	0	0-0
II	10	129	46	38	22	49	34	0	0	0	0	0-0
III	62	130	147	19	44	54	66	13	23	6	7	0-6
IV	52	38	53	0	0	29	17	7	15	0	0	3-8
V	30	44	49	0	0	17	21	0	0	0	0	0-0
VI	22	19	32	1	1	1	26	0	0	0	0	0-50
Salt cedar-screwbean mesquite												
II	10	63	24	2	4	1	1	96	17	0	0	0-0
III	40	49	43	0	0	0	0	18	15	0	0	0-8
IV	78	60	58	0	0	4	25	39	31	0	0	1-6
V	84	45	39	0	0	0	0	44	62	0	0	0-8
VI	18	45	55	0	0	0	0	6	6	0	0	0-22
Salt cedar-honey mesquite												
IV	38	41	53	0	0	0	0	0	0	35	68	2-6
Honey mesquite												
III	24	0	0	0	0	0	0	<1*		93	50	0
IV	122	0	0	0	0	0	0	0	0	31	42	1
V	56	0	0	0	0	0	0	0	0	12	7	2
VI	52	0	0	0	0	0	0	<1*		9	7	2

*Standard deviation not calculated where $\bar{x}$ <1.

important to note that by simply measuring the foliage density at a particular level in a small part (about 2 ha [5 a]) of a stand one cannot, with any certainty, classify the stand as we have defined it. Type I habitats had more foliage at all levels than other structural types. Type II habitats tended to be denser in the upper layer and sparser at the lowest level than all other structural types. Differences among the other structural types in total foliage density were slight and imperceptible in the field.

Inter-habitat Variation in Horizontal Diversity

Horizontal diversity or patchiness at the layer 0.0-0.6 m (0-2 ft) tended to be greatest in habitats of structural types I, V, and VI (Table 6). It is reasonable that Type I would be patchy in this layer because it had a relatively even distribution of foliage among layers (Fig. 11A). Since low-level vegetation usually does not grow densely in heavily shaded areas, this means there must have been patches of tall vegetation with little understory alternating with patches of short, dense vegetation. This would lead to patchiness in the upper as well as in the lower level. Thus Type I vegetation also had large overall patchiness index values. Types V and VI had high patchiness values when dense patches alternated with nearly bare areas. Low patchiness values at 0.0-0.6 m (0-2 ft) could mean that the area was very sparse overall or that dense vegetation was present and evenly distributed throughout the stand. Mean patchiness was about the same in the various vertical layers, although variation was slightly greater in the lower and upper layers (Table 6).

Table 6. Index to relative foliage diversity in the horizontal plane in 23 riparian habitat types found along the lower Colorado River. For each vertical layer horizontal diversity or patchiness is the variance of foliage density at that layer. Total horizontal diversity is the sum of diversity at the vertical layers.

Vegetation type	Number of subplots	Height of vertical foliage layer 0.0-0.6 m (0-2 ft)	0.6-3.0 m (2-10 ft)	≥4.5 m (≥15 ft)	Total
Salt cedar					
I	18	0.12	0.06	0.13	0.31
II	8	0.02	0.01	0.05	0.08
III	28	0.01	0.06	0.03	0.09
IV	32	0.04	0.06	0.02	0.12
V	110	0.03	0.02	0.00	0.05
VI	20	0.37	0.13	0.00	0.50
Cottonwood-willow					
I	18	0.12	0.09	0.26	0.47
II	10	0.00	0.01	0.09	0.09
III	62	0.03	0.05	0.17	0.25
IV	52	0.06	0.08	0.05	0.19
V	30	0.06	0.05	0.02	0.13
VI	22	0.11	0.01	0.00	0.12
Screwbean mesquite					
II	10	0.01	0.05	0.38	0.44
III	40	0.01	0.02	0.05	0.07
IV	78	0.04	0.03	0.04	0.11
V	84	0.14	0.04	0.00	0.18
VI	18	0.03	0.00	0.00	0.04
Salt cedar-honey mesquite					
IV	38	0.04	0.04	0.00	0.08
Arrowweed					
VI	30	0.07	0.02	0.00	0.09
Honey mesquite					
III	24	0.01	0.12	0.04	0.17
IV	122	0.04	0.05	0.12	0.21
V	56	0.03	0.02	0.00	0.05
VI	52	0.01	0.00	0.00	0.01
Mean		0.06	0.04	0.06	0.17
Standard deviation		0.08	0.04	0.10	0.14

It is difficult to describe trends in the patchiness data. The difficulty is compounded if we try to visualize trends in the vegetation across all variables (tree counts, variations in vertical configuration, foliage densities, and patchiness) simultaneously. We therefore applied principal components analysis (PCA) as an aid in recognizing general patterns in this complex vegetation data set.

PRINCIPAL COMPONENTS ANALYSIS OF THE VARIATION AMONG HABITATS

We used PCA to help describe the main differences among the 23 habitat types. For this analysis we used 16 variables (Table 7) obtained from 1975-1979. All data were transformed ($\log_{10}$ of N + 1 for counts and square root for proportions and diversities) in order to meet assumptions about normality. Transformed data were standardized so that the mean of the entire matrix of all vegetation variables did not deviate significantly from zero and the standard deviation was approximately 1; thus all variables contributed equally to the analysis.

PCA reduces a large set of intercorrelated variables of a set of uncorrelated components. The components are essentially a new set of derived components statistically independent of each other. Each variable becomes a significant part of one, or sometimes more, component(s). Highly intercorrelated variables will become a part of (load on) the same component. Although each of the derived components is more complex than any single variable from the original set, they are usually readily interpretable. The derived components can be treated as new variables in subsequent analyses.

Table 7. Loadings of 16 vegetation variables on the VARIMAX rotated axes for each of 4 principal components. Data are from 23 riparian habitats occurring along the lower Colorado River. The explained variance for each variable is at the right and the percent of the total variance for all variables explained by each principal component is given at the bottom. The principal variables (contributing $\geq$0.5 to a principal component) are underlined.

Variables[a]	Principal component I	II	III	IV	Percent variance explained
PI 0.0-0.6 m (0-2 ft)	0.15	-0.05	0.85	0.03	74.8
PI 0.6-4.5 m (2-15 ft)	0.70	0.09	0.34	0.27	68.7
PI $\geq$4.5 m ($\geq$15 ft)	0.92	-0.12	-0.13	-0.12	89.2
PI sum	0.89	0.07	0.22	-0.09	85.4
FD 0.0-0.6 m (0-2 ft)	0.03	0.08	0.90	-0.13	83.4
FD 0.6-4.5 m (2-15 ft)	0.89	-0.08	0.16	0.03	82.5
FD $\geq$4.5 m ($\geq$15 ft)	0.84	-0.22	-0.20	-0.16	82.0
FD sum	0.88	-0.09	0.06	-0.25	84.9
FHD	0.71	-0.25	-0.51	0.02	82.7
Shrubs	-0.26	0.67	-0.01	0.19	55.2
Honey mesquite	0.05	0.90	-0.09	-0.04	82.2
Mistletoe	0.23	0.85	0.08	0.12	70.3
Salt cedar	0.16	-0.75	-0.11	0.32	70.3
Screwbean mesquite	0.12	-0.18	-0.38	0.59	53.9
Cottonwood-willow	0.31	-0.06	-0.09	-0.71	61.2
PSC	-0.16	-0.81	-0.11	0.09	70.2
Percent of total variance explained	35.0	20.9	12.8	7.0	75.7

[a]PI = patchiness index
FD = foliage density
FHD = foliage height diversity
PSC = proportion of total trees which are salt cedar

In order to be certain that derived principal components (PC's) were not statistical artifacts, we performed a PCA on data for each year separately (Karr and Martin 1981). These separate analyses yielded similar results (Meents et al. 1981).

In view of the similarities between years, we performed a PCA on the 4-year combined data set. This yielded 4 PC's (Table 7), which accounted for 76% of the variance in the total data set. Foliage density and horizontal diversity measures above 0.6 m (2 ft) and overall FHD loaded high ($\geq$0.50) on the first component and described a trend going from high to low foliage density and diversity across habitat types. PC II explained 21% of the variance and described a trend going from areas with many honey mesquite trees with mistletoe and shrubs (positive loading) and few salt cedar (negative loading) to areas with none of the former and many of the latter. PC III described a trend going from areas with much foliage density and horizontal diversity at 0.0-0.6 m (2 ft) to areas with low values for these variables and explained 13% of the variance. Finally, PC IV described a trend going from areas with many screwbean mesquite and salt cedar trees to areas with few individuals of these species and with many cottonwood and willow trees.

We can study factor score values (in factor analysis) to evaluate whether or not PC's are a realistic representation of some observable features of the riparian vegetation. Factor scores range from roughly 3.0 to -3.0. From Figure 11B we see that foliage density and vertical diversity were high in Type I vegetation on average and that Types V and VI had low foliage density and vertical diversity. We also know that Type I vegetation had the highest horizontal diversity (Table 5). From this we would predict that Type I vegetation would have above-average (positive) scores on PC I and Types V and VI would have below-average (negative) scores (Table 8).

On PC II we expect stands of salt cedar to have maximum negative scores and stands of honey mesquite to have maximum positive scores. Again, this was demonstrated in factor analysis.

From the information in Figure 11B we would predict that vegetation with Type I, V, and VI configurations would have above-average (positive) scores for PC III (low-level foliage density and diversity), assuming roughly the same horizontal diversity. In fact salt cedar Type VI had a factor score of 3.0, and cottonwood-willow Type I had a score of 2.0. All Type V and VI habitats have above-average (positive) scores except screwbean mesquite Type V and honey mesquite Type VI, both of which were near zero. This suggests that even though a large proportion of their foliage was between ground level and 0.6 m (2 ft), the distribution in the horizontal axis was fairly even; that is, they had low horizontal diversity at this level and/or density was not great. In fact screwbean mesquite Type V ranked seventeenth for foliage density at 0.0-0.6 m (0-2 ft) and honey mesquite Type VI ranked eighteenth for horizontal diversity at 0.0-0.6 m (0-2 ft; Table 6). A low rank and a high rank would tend to cancel each other, resulting in a net score near zero.

Table 8. Factor scores of 23 riparian habitat types on each of 4 principal components. Mean factor scores for each principal component do not deviate significantly (P>0.1) from a mean of 0.0 and standard deviation of 1.0.

Vegetation type	Principal component I	II	III	IV
Salt cedar				
I	0.29	-1.02	-1.13	-0.91
II	0.27	-0.64	-0.64	-0.51
III	-0.50	-0.46	-0.78	0.34
IV	-0.01	-1.23	0.31	0.63
V	-1.02	-0.80	0.13	0.30
VI	-0.32	-0.96	3.00	-0.21
Cottonwood-willow				
I	3.19	0.15	1.97	-0.43
II	0.32	0.29	-2.16	-1.62
III	1.62	0.05	-0.12	-0.63
IV	0.59	-0.36	0.22	0.78
V	0.06	-0.75	0.46	-0.27
VI	-1.06	-0.71	0.58	-1.09
Screwbean mesquite				
II	0.71	-0.53	-1.41	1.41
III	0.03	-0.25	-1.80	0.75
IV	0.31	0.20	-0.60	1.34
V	-0.56	-0.35	-0.09	0.79
VI	-0.90	-0.80	0.13	0.30
Salt cedar-honey mesquite				
IV	-0.17	0.71	0.03	0.56
Arrowweed				
VI	-0.85	-0.05	0.63	-0.72
Honey mesquite				
III	0.87	2.04	0.13	0.75
IV	-0.14	2.19	0.55	0.49
V	-0.71	1.66	0.41	0.02
VI	-1.23	-0.05	0.63	-0.72
Mean	0.03	-0.08	0.01	0.06
Standard deviation	0.98	0.94	1.11	0.98

PC IV indicated that there were habitats with many screwbean mesquite trees and others with many cottonwood or willow trees. That such areas existed is clear from Table 5. We would expect habitats dominated by cottonwood and/or willow trees to have below-average (negative) scores and areas dominated by screwbean mesquite to have above-average (positive) scores. It will be noted (Table 7) that salt cedar loaded 0.32 on this axis, thus salt cedar habitats should also have positive scores. Since all cottonwood-willow habitats included some salt cedar trees, such habitats would not have as high negative scores as they would if salt cedar were absent. Screwbean mesquite habitats had the highest score on PC IV, and cottonwood-willow habitats, in general, had high negative scores. Cottonwood-willow Type IV had a positive score because screwbean mesquite constituted 9% of the total trees and salt cedar an additional 51% (Table 5). Cottonwood and willow trees composed only 39% of the total trees.

In conclusion, PCA summarized a complex data set involving 16 variables and provided a smaller set of PC's which correspond to readily observable features in the field. The analysis revealed that foliage density and diversity measures above 0.0-0.6 m (0-2 ft) levels were highly intercorrelated and that they included vegetation types which were tall, dense, and vertically and horizontally diverse (Type I habitats), but there are those habitats with little foliage density and diversity above the 0.0-0.6 m (0-2 ft) level (Type VI habitats). The analysis revealed some very obvious features of the vegetation (there were stands where salt cedar was the only tree species present and stands with dense and horizontally diverse vegetation), but it also revealed variation hidden if only the dominant vegetation and vertical configuration are known. The distribution of factor scores for each PC did not deviate significantly from normal. Because the distributions of PC factor scores were normal and because they corresponded to readily apparent physiognomic and floral characteristics in the field, they could be used as variables in parametric data testing (including analysis of variance, simple correlation analysis, and multiple linear regression) which could be expected to yield biologically meaningful results.

EXAMPLES OF ANALYSES USING THIS VEGETATION CLASSIFICATION SYSTEM

Correlation analysis using PC's as variables can be used to show relationships between the PC's and physical and chemical features of the 23 habitats (Anderson et al. 1983, Anderson and Ohmart 1982). We routinely use wildlife density and species richness values typical of the different habitats at various seasons to indicate their value to wildlife and to test ecological theories (Anderson and Ohmart 1979, 1981, 1982, 1983, Meents et al. 1981, 1982, 1983, Laurenzi et al. 1982). Many of the results in these studies have been confirmed by using other analytical techniques (nonparametric statistics, discriminant functions analysis) at the transect level rather than the habitat level of analysis (Rice et al. 1980, 1983 a, b) or by experiments involving manipulations of the vegetation (Anderson et al. ms, Meents et al.

1982). A major use of these data has been for designing wildlife enhancement projects (Anderson et al. 1978, Anderson and Ohmart 1978, in press). For example, the rodent-vegetation relationships determined using PCA and relative rodent densities (Fig. 12) can be used in managing areas for rodents. In addition to birds and rodents we have also used the same general approach to discover vegetation relationships with reptiles (Anderson and Ohmart 1982), deer (Haywood et al. 1983), and insects (Anderson and Ohmart in prep.). They can also be used for making habitat assessments in preparing impact statements and assessments (e.g., Benham, Blair, and Affiliates 1981, 1982).

Although vegetation structure is important to wildlife use, it should be emphasized that tree and shrub species composition are extremely important management considerations for wildlife (Rice et al. in press). If this were not true, then salt cedar Type II would equal the wildlife values of cottonwood-willow habitats of the same structure type, and it does not.

SUMMARY AND CONCLUSIONS

Detailed analysis of the vegetation of an area is necessary before accurate assessment of relationships between vegetation characteristics and abiotic features can be made or before value of the vegetation to wildlife can be accurately determined. It should be remembered that when the vegetation over a large area is classified it will be artificial to some extent because almost all environmental variables

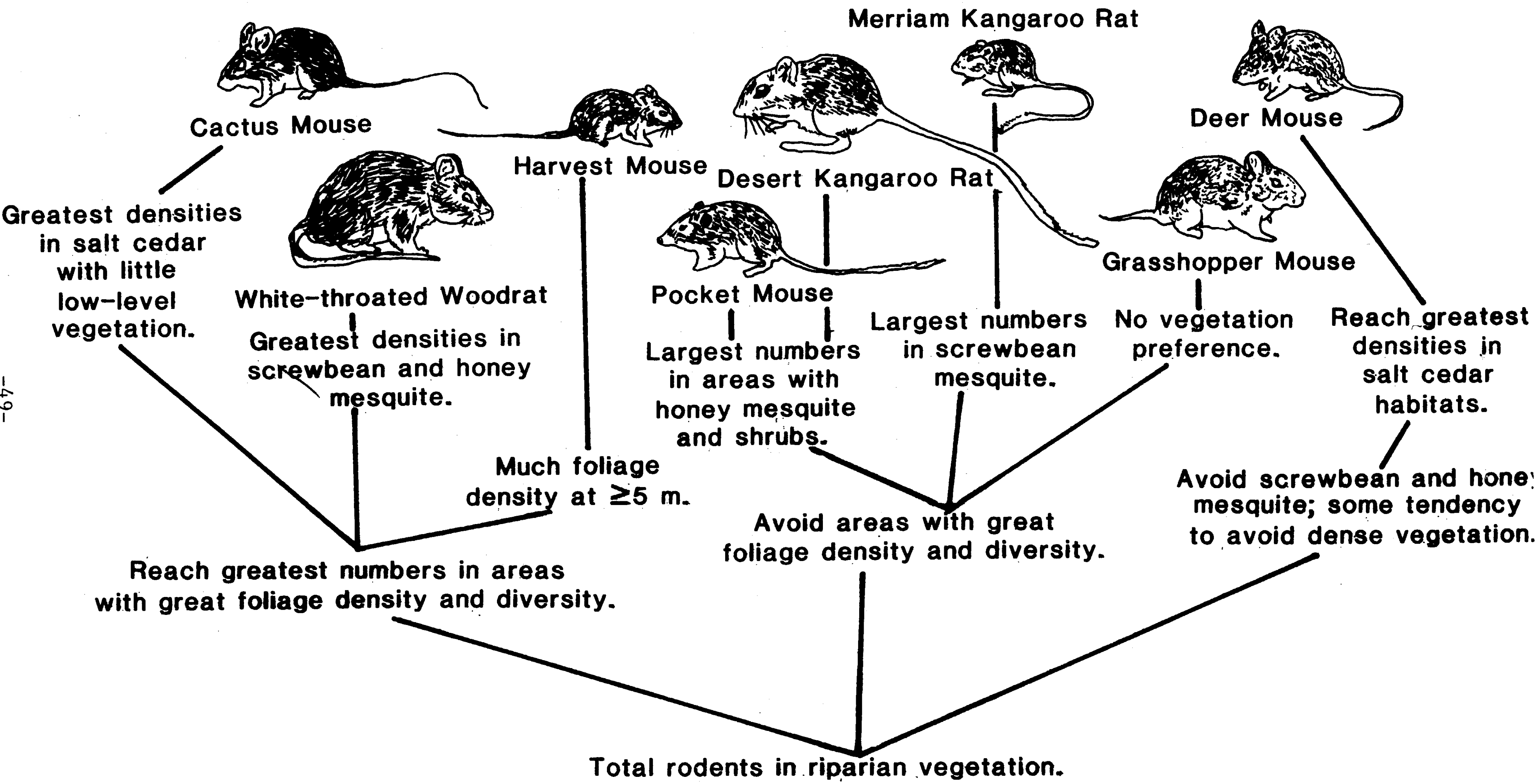


Figure 12. Habitat relationships of some rodent species found in riparian vegetation along the lower Colorado River.

change gradually across space, yet boundaries to habitats are usually precisely, and therefore somewhat arbitrarily, drawn. Vegetational variation will always be ignored at some level with any system of classification. One must decide on a classification system based on (1) the purpose of the classification, (2) the available time, (3) size of the area, (4) manpower requirements, and (5) availability of funds.

The analytical procedures used to develop our classification system on lower Colorado River riparian habitats are complex, but use of the system is simple. A potential user, reasonably satisfied with the statistical treatment, can apply the system by determining (1) that the stand being investigated encompasses at least 10 ha (25 a), (2) the species composition of the stand, and (3) the vertical configuration of the stand. These determinations can be made with maps drawn to scale and by observation from a few vantage points. Visual estimates of vertical foliage distribution can be determined with the aid of Figures 11A and 13. Habitat classification can be determined in part with the aid of Table 9. Both of these determinations can be documented by making a few measurements and counts. With this information the assessor can consult references such as Anderson and Ohmart (1977) to determine mean avian densities (with confidence limits) and relative rodent densities in order to evaluate wildlife use of the area. Theory testing, such as mentioned above, would require a complete set of measurements and counts with which more sophisticated analysis could be conducted.

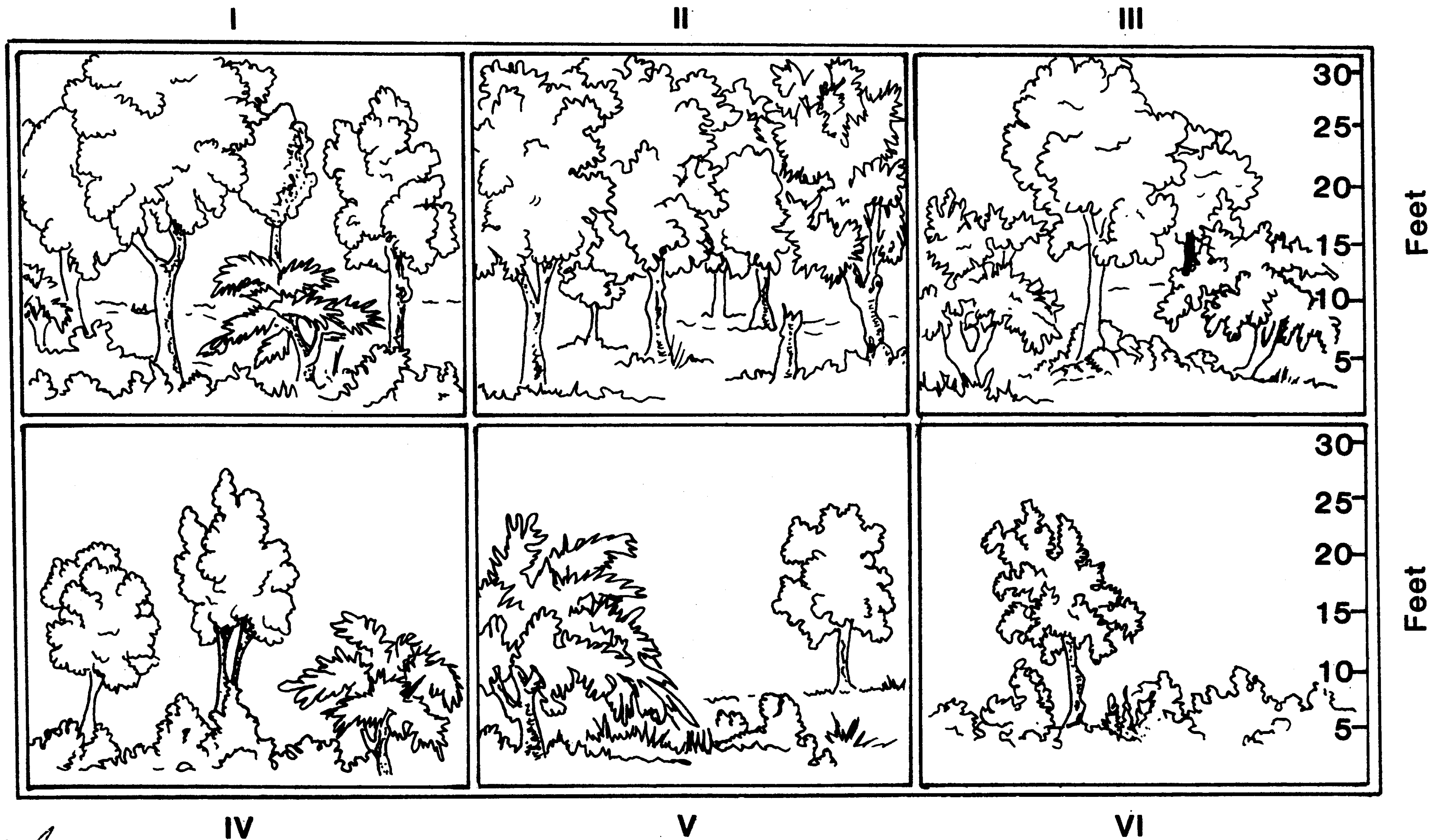


Figure 13. Examples of vertical configurations for the vegetation structural types defined (Fig. 11A) in the lower Coloardo River valley.

Table 9. User's guide to classifying vegetation by dominant tree or shrub species present. This key can be used to classify about 95% of the riparian vegetation found along the lower Colorado River. By applying the same general principles used to construct the key and a little imagination, rare vegetation types can also be classified.

---

1. A. Stand in which virtually 100% of the trees present are of 1 species or virtually 100% arrowweed.......................Go to 2
   B. Trees withiin stand of clearly mixed species. The different species may occur as mixed individuals or as small clumps........ ....Go to 3

2. A. Stand in which trees are composed of nearly 100% of some species (may be occasional, widely scattered individuals of 1 or more species). Many large stands have arrowweed in patches encompassing 2 ha (5 a) or more. Honey mesquite stands in addition to, or instead of, arrowweed may have quail bush, four-winged salt bush, wolfberry, or inkweed....Salt Cedar I-IV or Honey Mesquite III-VI
   B. Stand composed of nearly 100% arrowweed, may be an occasional tree or widely scattered clump of some other shrub......Arrowweed

3. A. Stand of vegetation is structural Type I and trees are primarily salt cedar, cottonwood and/or willow with an occasional widely . scattered screwbean or honey mesquite tree or clumps of trees. Arrowweed or some other shrub may occur in relatively widely scattered clumps.................Salt Cedar-Cottonwood/Willow Mix
   B. Vegetation not structural Type I.........................Go to 4

4. A. Stand of vegetation is structural Type II or III..........Go to 5
   B. Stand not structural Type II or III......................Go to 6

5. A. Stand in which trees are salt cedar with large numbers of cottonwood and/or willow present; may be widely scattered individuals or clumps of screwbean or honey mesquite............. ....Salt Cedar-Cottonwood/Willow Mix
   B. Stand in which trees are mainly salt cedar and screwbean mesquite; may be an occasional, widely scattered clump or individual cottonwood and/or willow or honey mesquite............ ....Salt Cedar-Screwbean Mesquite Mix

6. A. Stand of vegetation in structural Type IV.................Go to 7
   B. Stand not structural Type IV.............................Go to 8

7. A. Stand composed mainly of salt cedar but with significant numbers of cottonwood and/or willow present; may be widely scattered individuals or clumps of screwbean or honey mesquite. Shrubs,

Table 9. (cont.)

mainly arrowweed, abundant and occurring in moderate to relatively large patches sometimes encompassing 2 ha (5 a) or more..........................Salt Cedar-Cottonwood/willow Mix

B. Stand much as above but with screwbean mesquite or honey mesquite instead of cottonwood and/or willow.........................Salt Cedar-Screwbean Mesquite Mix or Salt Cedar-Honey Mesquite Mix

8. A. Stand of vegetation is structural Types V or VI...........Go to 9
   B. Stand not V or VI..Go to 3

9. A. Stand composed mainly of salt cedar, but with significant numbers of cottonwood and/or willow occurring as scattered individuals or clumps. Arrowweed is usually abundant (occasionally some other shrub species such as quail bush also present) and occurring in patches encompassing several ha (a)............................. Salt Cedar-Cottonwood/Willow Mix
   B. Stand composed primarily of salt cedar but with significant numbers of individuals or clumps of screwbean or honey mesquite. May be widely scattered individuals or clumps of screwbean or honey mesquite. Arrowweed present as in 9.A................Salt Cedar-Screwbean Mesquite Mix or Salt Cedar-Honey Mesquite Mix

We developed new methods and used other methods already available in creating a meaningful vegetation analysis that was successful for our intended purposes. This does not mean our methods are the best or that they will necessarily succeed in other areas, but we hope that by studying the procedures we used, other investigators will be able to save time in developing a system that will work well in their area.

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UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
COLORADO RIVER FRONT WORK & LEVEE SYSTEM

COLORADO RIVER

DAVIS DAM TO INTERNATIONAL BOUNDARY

VEGETATION COMMUNITIES AND STRUCTURES

LIMITROPHE DIVISION

MAP NO. 423-303-2385

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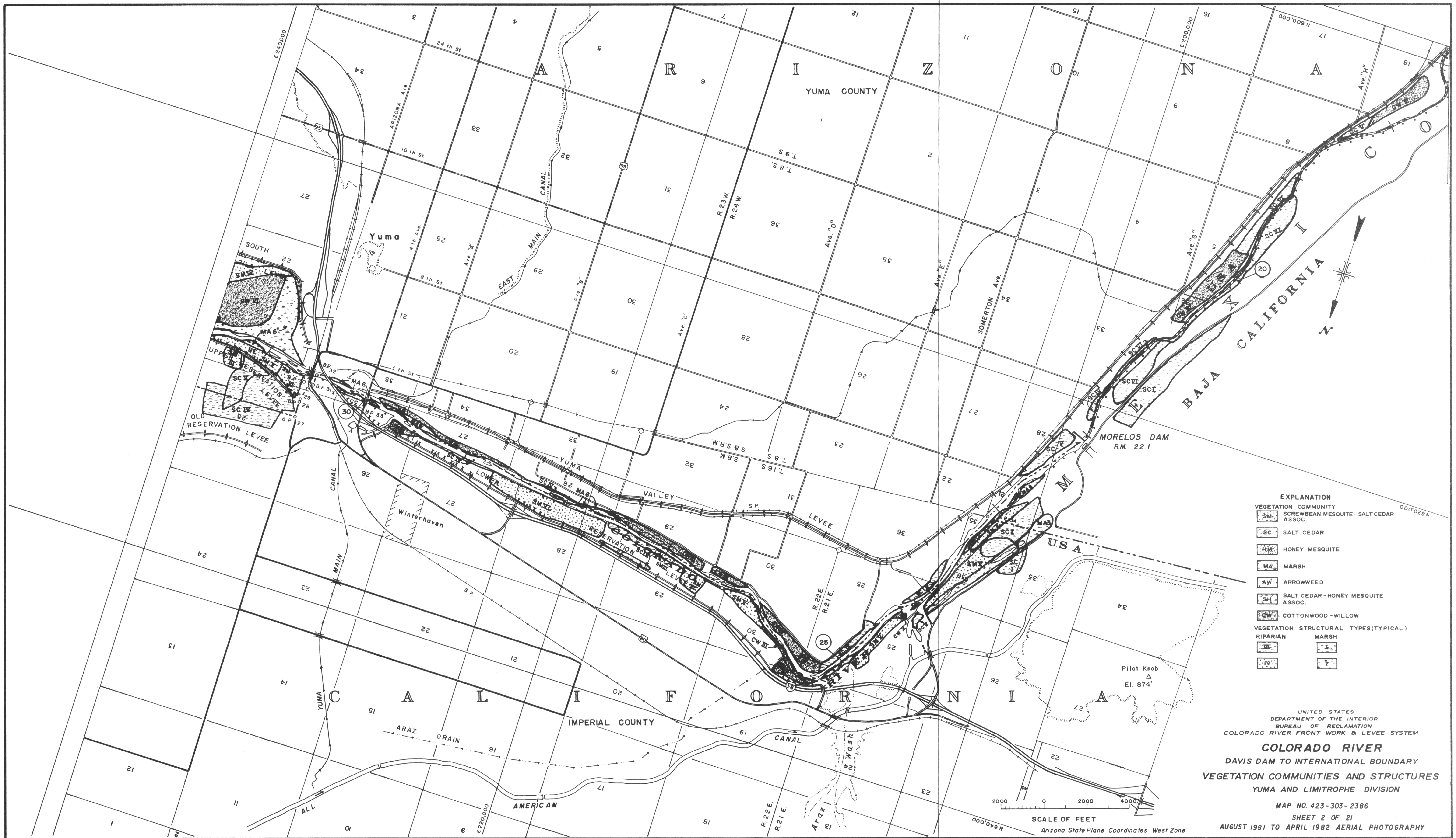
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MEXICO
BAJA CALIFORNIA
CALIFORNIA
IMPERIAL COUNTY
U.S.A.
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Yuma
Winterhaven
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R.M. 22.1
Pilot Knob
El. 874'
SOMERTON Ave.
ARIZONA Ave.
EAST MAIN CANAL
YUMA VALLEY LEVEE
ALL AMERICAN CANAL
YUMA MAIN CANAL
ARAZ DRAIN
Araz Wash
SOUTH LEVEE
OLD RESERVATION LEVEE
UPPER RESERVATION LEVEE
LOWER RESERVATION LEVEE
COLORADO RIVER
T.8S.
T.9S.
T.16S.
R.23W.
R.24W.
R.22E.
R.21E.
G.&S.R.M.
S.B.M.
EXPLANATION
VEGETATION COMMUNITY
SM SCREWBEAN MESQUITE- SALT CEDAR ASSOC.
SC SALT CEDAR
HM HONEY MESQUITE
MA MARSH
AW ARROWWEED
SH SALT CEDAR-HONEY MESQUITE ASSOC.
CW COTTONWOOD-WILLOW
VEGETATION STRUCTURAL TYPES(TYPICAL)
RIPARIAN
MARSH
III
IV
I
V
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
COLORADO RIVER FRONT WORK & LEVEE SYSTEM
COLORADO RIVER
DAVIS DAM TO INTERNATIONAL BOUNDARY
VEGETATION COMMUNITIES AND STRUCTURES
YUMA AND LIMITROPHE DIVISION
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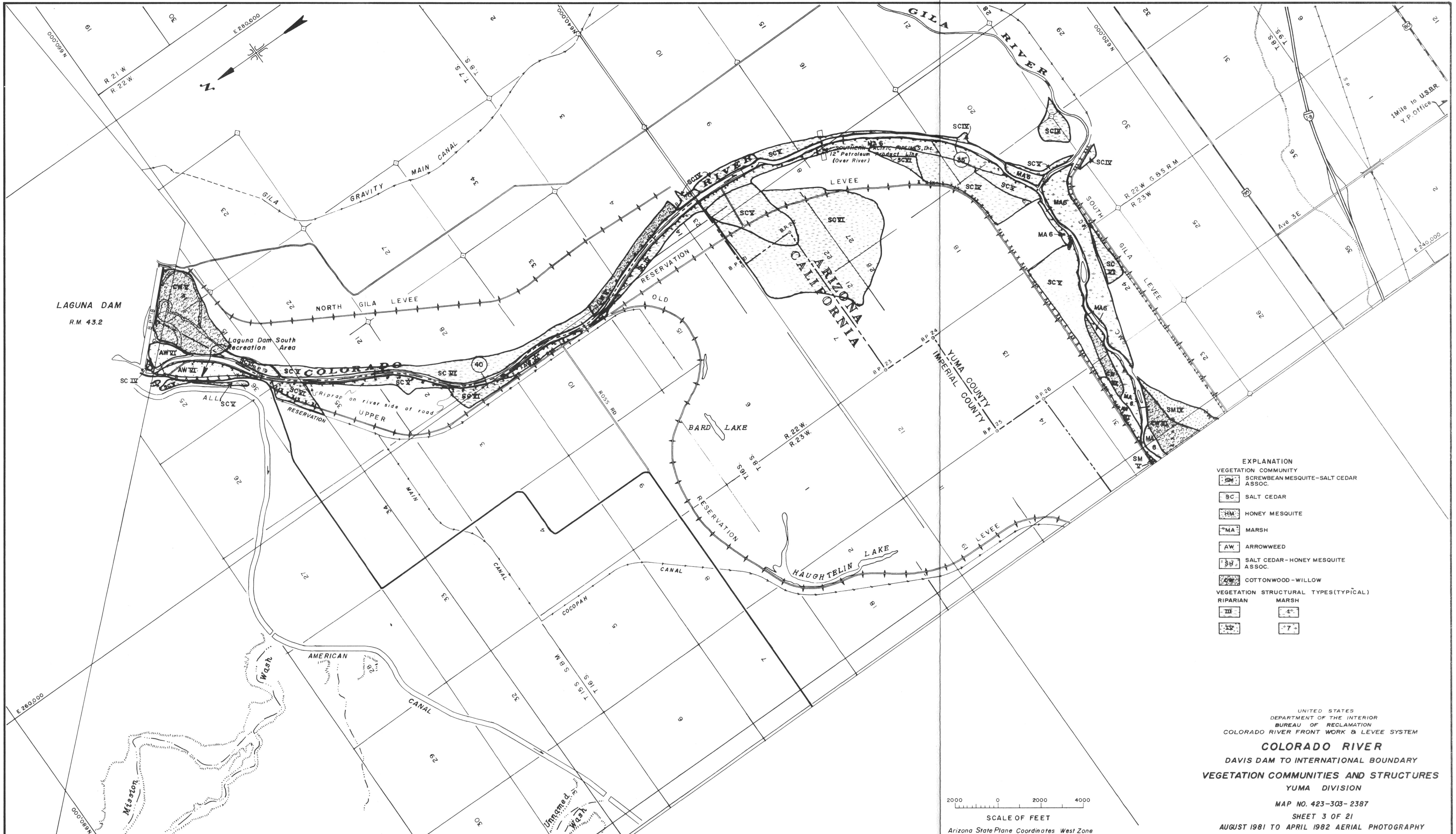

UNITED STATES
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COLORADO RIVER FRONT WORK & LEVEE SYSTEM

COLORADO RIVER

DAVIS DAM TO INTERNATIONAL BOUNDARY

VEGETATION COMMUNITIES AND STRUCTURES

YUMA DIVISION

MAP NO. 423-303-2387

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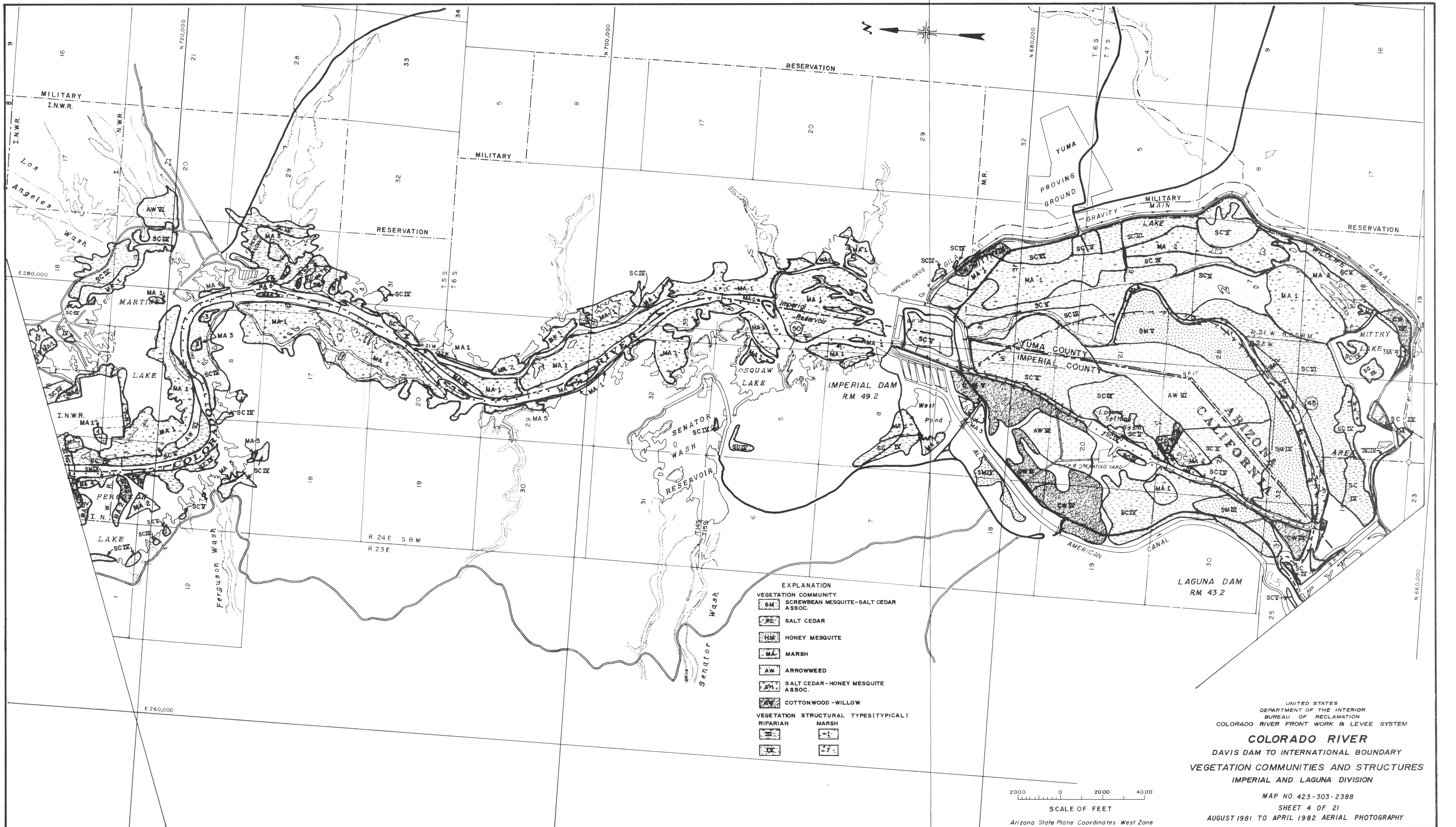
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VEGETATION COMMUNITIES AND STRUCTURES
IMPERIAL AND LAGUNA DIVISION
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EXPLANATION
VEGETATION COMMUNITY
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SC SALT CEDAR
HM HONEY MESQUITE
MA MARSH
AW ARROWWEED
SH SALT CEDAR-HONEY MESQUITE ASSOC.
CW COTTONWOOD-WILLOW
VEGETATION STRUCTURAL TYPES (TYPICAL)
RIPARIAN
MARSH
III
IV
-1-
-7-
IMPERIAL DAM
R.M. 49.2
LAGUNA DAM
RM 43.2
YUMA COUNTY
IMPERIAL COUNTY
ARIZONA
CALIFORNIA
YUMA PROVING GROUND
MILITARY RESERVATION
GRAVITY MAIN
AMERICAN CANAL
WILDLIFE CANAL
MITTRY LAKE
SQUAW LAKE
SENATOR WASH RESERVOIR
Senator Wash
Ferguson Wash
Los Angeles Wash
MARTINEZ LAKE
FERGUSON LAKE
West Pond
IMPERIAL OASIS
GILA
Imperial Reservoir
COLORADO RIVER
I.N.W.R.
R.24E S.B.M.
R.23E
R.21W. G.&S.R.M.
R.22W.
T.5S
T.6S
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T.15S
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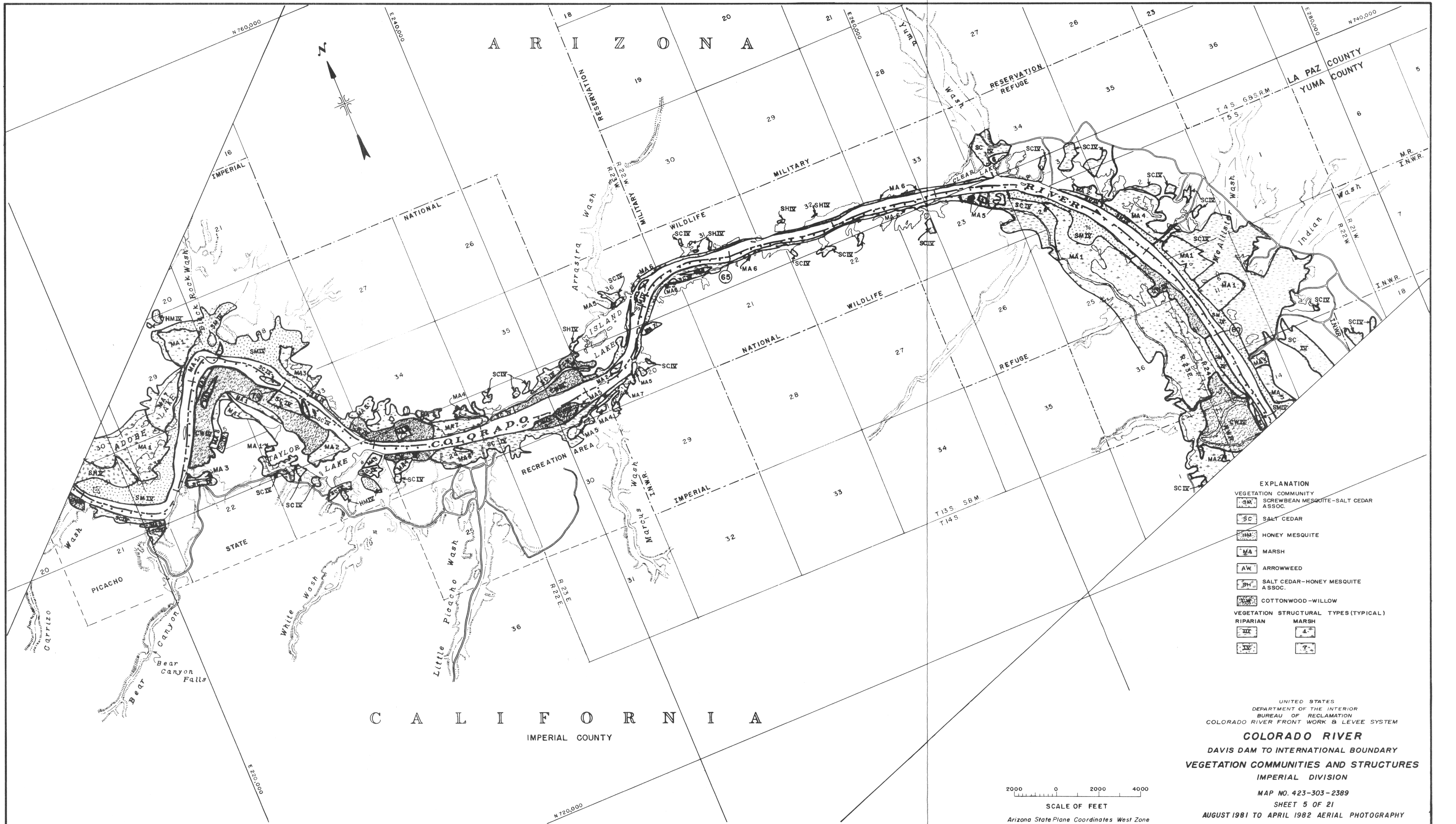
N 660,000
E 280,000
E 260,000


ARIZONA
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LA PAZ COUNTY
YUMA COUNTY
COLORADO
RIVER
MILITARY
RESERVATION
NATIONAL
WILDLIFE
REFUGE
IMPERIAL
RECREATION AREA
PICACHO
STATE
ISLAND LAKE
TAYLOR LAKE
ADOBE LAKE
CLEAR LAKE
Arrastra Wash
Marcus Wash
Little Picacho Wash
White Wash
Black Rock Wash
Bear Canyon
Bear Canyon Falls
Carrizo Wash
Yuma Wash
Indian Wash
Wellisit Wash
EXPLANATION
VEGETATION COMMUNITY
SM SCREWBEAN MESQUITE-SALT CEDAR ASSOC.
SC SALT CEDAR
HM HONEY MESQUITE
MA MARSH
AW ARROWWEED
SH SALT CEDAR-HONEY MESQUITE ASSOC.
CW COTTONWOOD-WILLOW
VEGETATION STRUCTURAL TYPES (TYPICAL)
RIPARIAN
III
IV
MARSH
4
7
UNITED STATES
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COLORADO RIVER FRONT WORK & LEVEE SYSTEM
COLORADO RIVER
DAVIS DAM TO INTERNATIONAL BOUNDARY
VEGETATION COMMUNITIES AND STRUCTURES
IMPERIAL DIVISION
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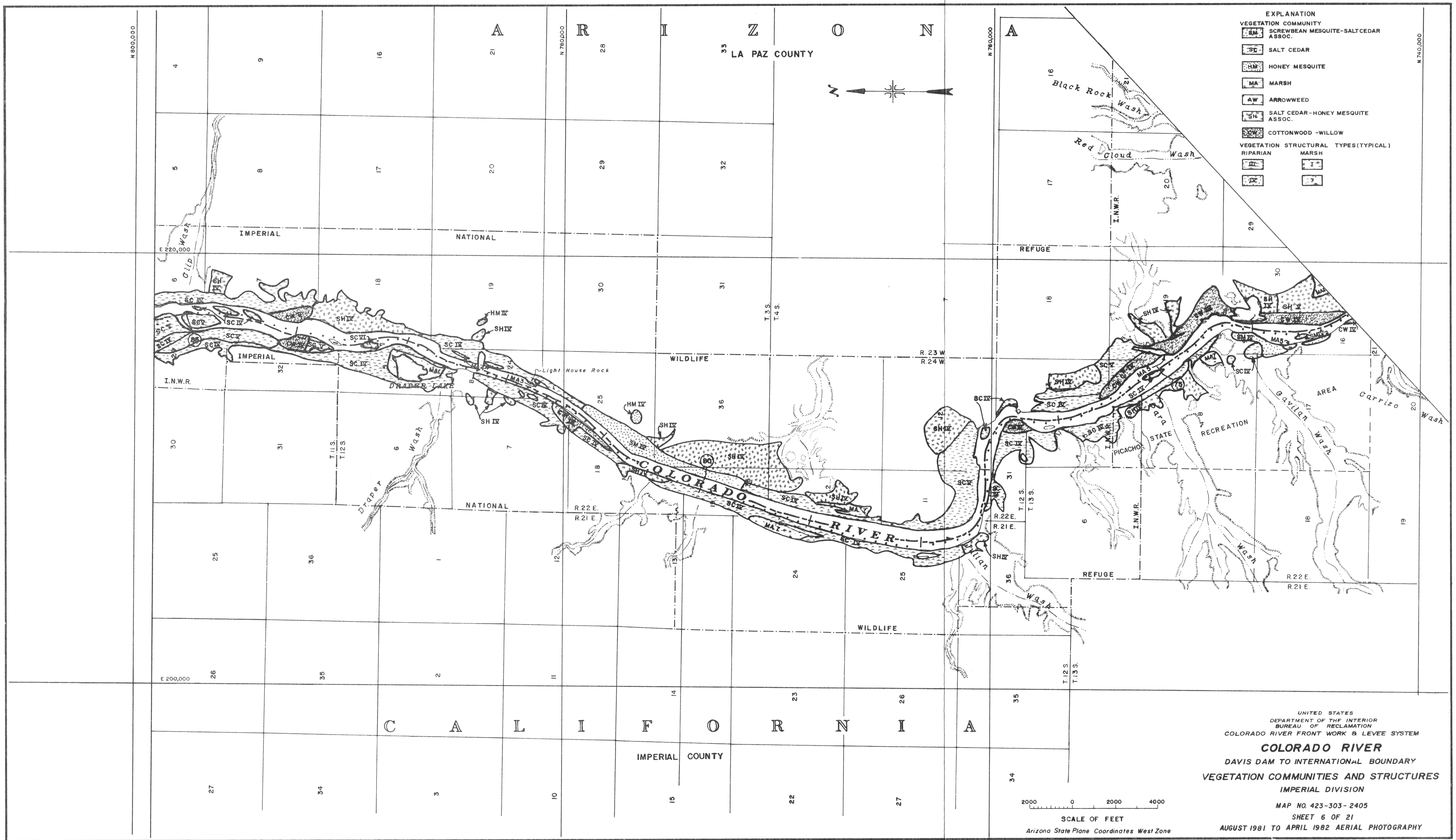

ARIZONA
LA PAZ COUNTY
CALIFORNIA
IMPERIAL COUNTY
EXPLANATION
VEGETATION COMMUNITY
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SC SALT CEDAR
HM HONEY MESQUITE
MA MARSH
AW ARROWWEED
SH SALT CEDAR-HONEY MESQUITE ASSOC.
CW COTTONWOOD-WILLOW
VEGETATION STRUCTURAL TYPES (TYPICAL)
RIPARIAN
MARSH
COLORADO RIVER
Black Rock Wash
Red Cloud Wash
Carrizo Wash
Gavilan Wash
Draper Wash
Draper Lake
Light House Rock
Oilp Wash
IMPERIAL NATIONAL WILDLIFE REFUGE
I.N.W.R.
PICACHO STATE RECREATION AREA
T.3S. T.4S.
T.11S. T.12S.
T.12S. T.13S.
R.23W R.24W
R.22E. R.21E.
N 800,000
N 780,000
N 760,000
N 740,000
E 220,000
E 200,000
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
COLORADO RIVER FRONT WORK & LEVEE SYSTEM
COLORADO RIVER
DAVIS DAM TO INTERNATIONAL BOUNDARY
VEGETATION COMMUNITIES AND STRUCTURES
IMPERIAL DIVISION
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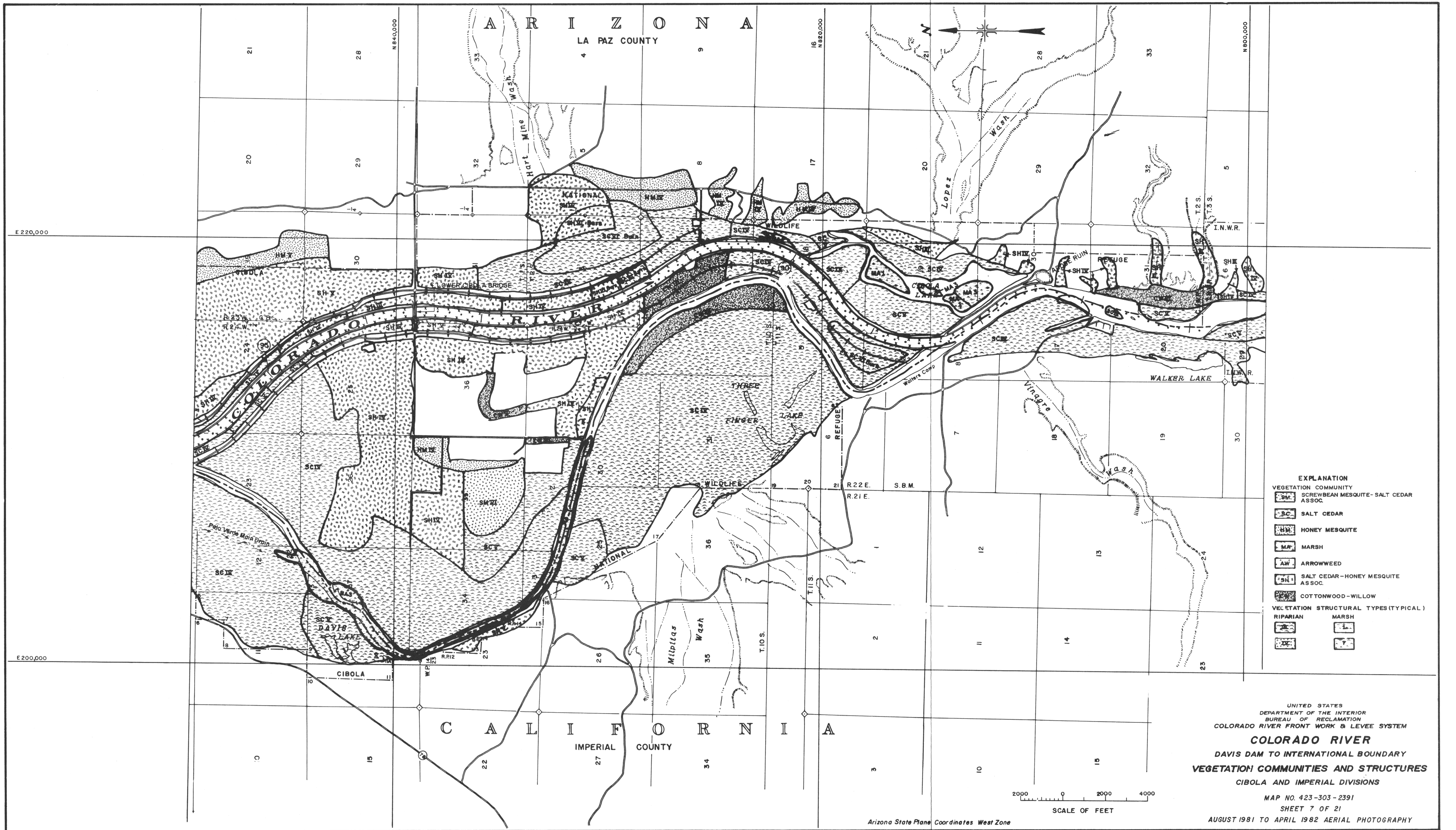
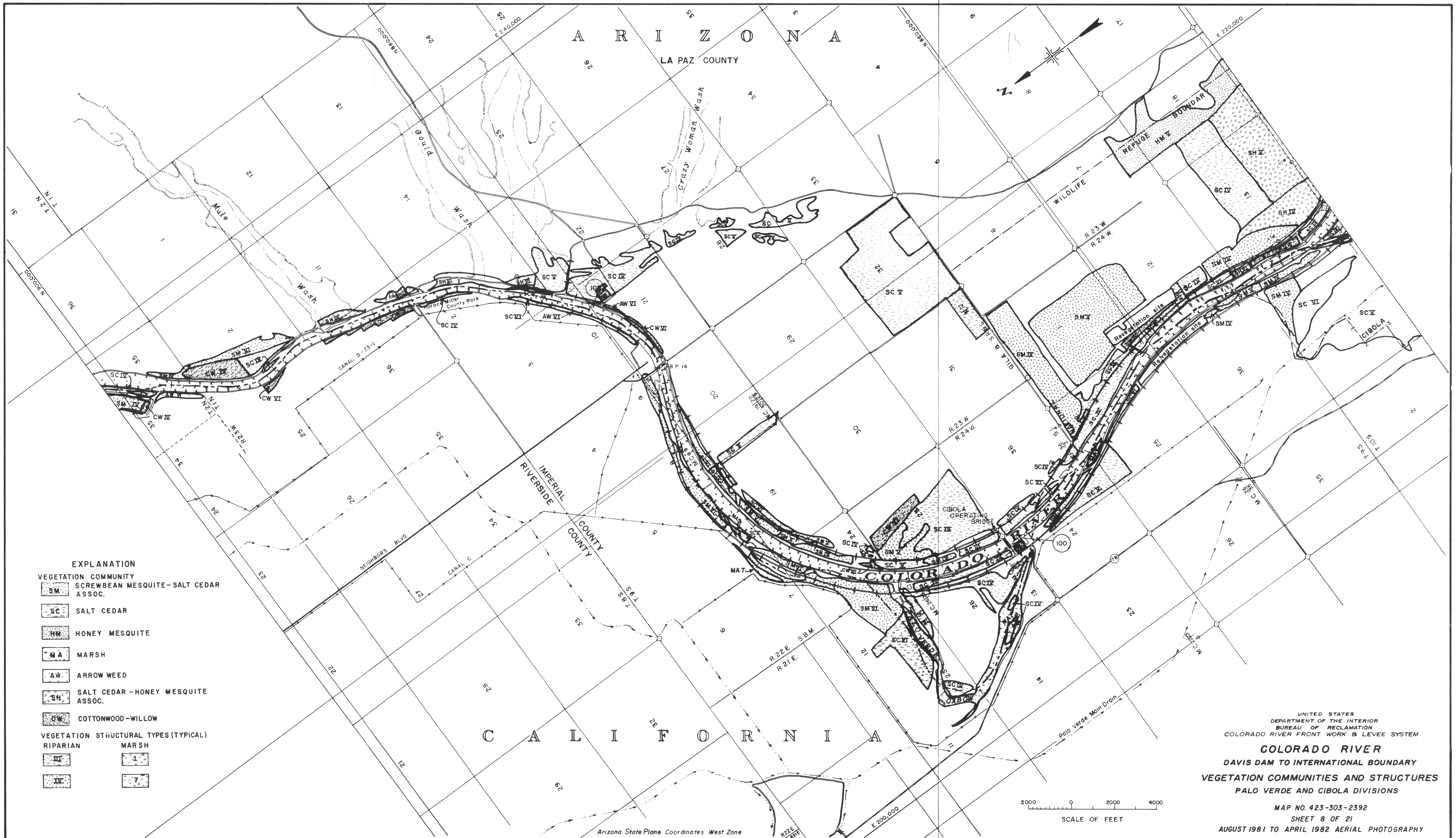
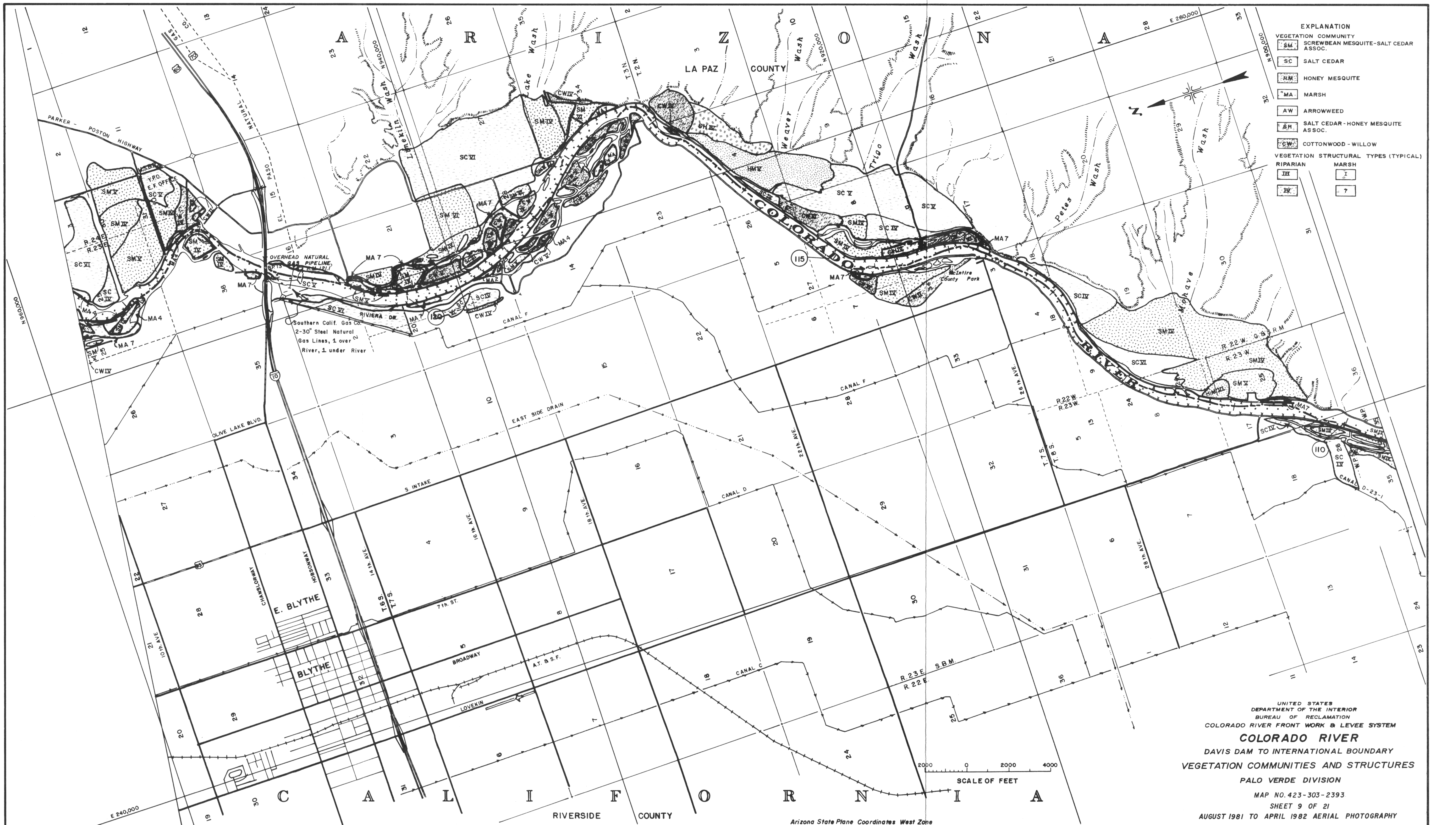


CIBOLA AND IMPERIAL DIVISIONS


ARIZONA
LA PAZ COUNTY
CALIFORNIA
IMPERIAL COUNTY
RIVERSIDE COUNTY
COLORADO RIVER
Gould Wash
Crazy Woman Wash
Mule Wash
WILDLIFE REFUGE BOUNDARY
CIBOLA OPERATING BRIDGE
Revegetation site
Palo Verde Main Drain
NEIGHBORS BLVD
CANAL C
CANAL D-23-1
OXBOW
Arizona State Plane Coordinates West Zone
EXPLANATION
VEGETATION COMMUNITY
SM SCREWBEAN MESQUITE-SALT CEDAR ASSOC.
SC SALT CEDAR
HM HONEY MESQUITE
MA MARSH
AW ARROW WEED
SH SALT CEDAR-HONEY MESQUITE ASSOC.
CW COTTONWOOD-WILLOW
VEGETATION STRUCTURAL TYPES (TYPICAL)
RIPARIAN
III
IV
MARSH
1
7
2000 0 2000 4000
SCALE OF FEET
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
COLORADO RIVER FRONT WORK & LEVEE SYSTEM
COLORADO RIVER
DAVIS DAM TO INTERNATIONAL BOUNDARY
VEGETATION COMMUNITIES AND STRUCTURES
PALO VERDE AND CIBOLA DIVISIONS
MAP NO. 423-303-2392
SHEET 8 OF 21
AUGUST 1981 TO APRIL 1982 AERIAL PHOTOGRAPHY



EXPLANATION
VEGETATION COMMUNITY
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SC SALT CEDAR
HM HONEY MESQUITE
MA MARSH
AW ARROWWEED
SH SALT CEDAR-HONEY MESQUITE ASSOC.
CW COTTONWOOD-WILLOW
VEGETATION STRUCTURAL TYPES (TYPICAL)
RIPARIAN
MARSH
III
IV
I
7
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
COLORADO RIVER FRONT WORK & LEVEE SYSTEM
COLORADO RIVER
DAVIS DAM TO INTERNATIONAL BOUNDARY
VEGETATION COMMUNITIES AND STRUCTURES
PALO VERDE DIVISION
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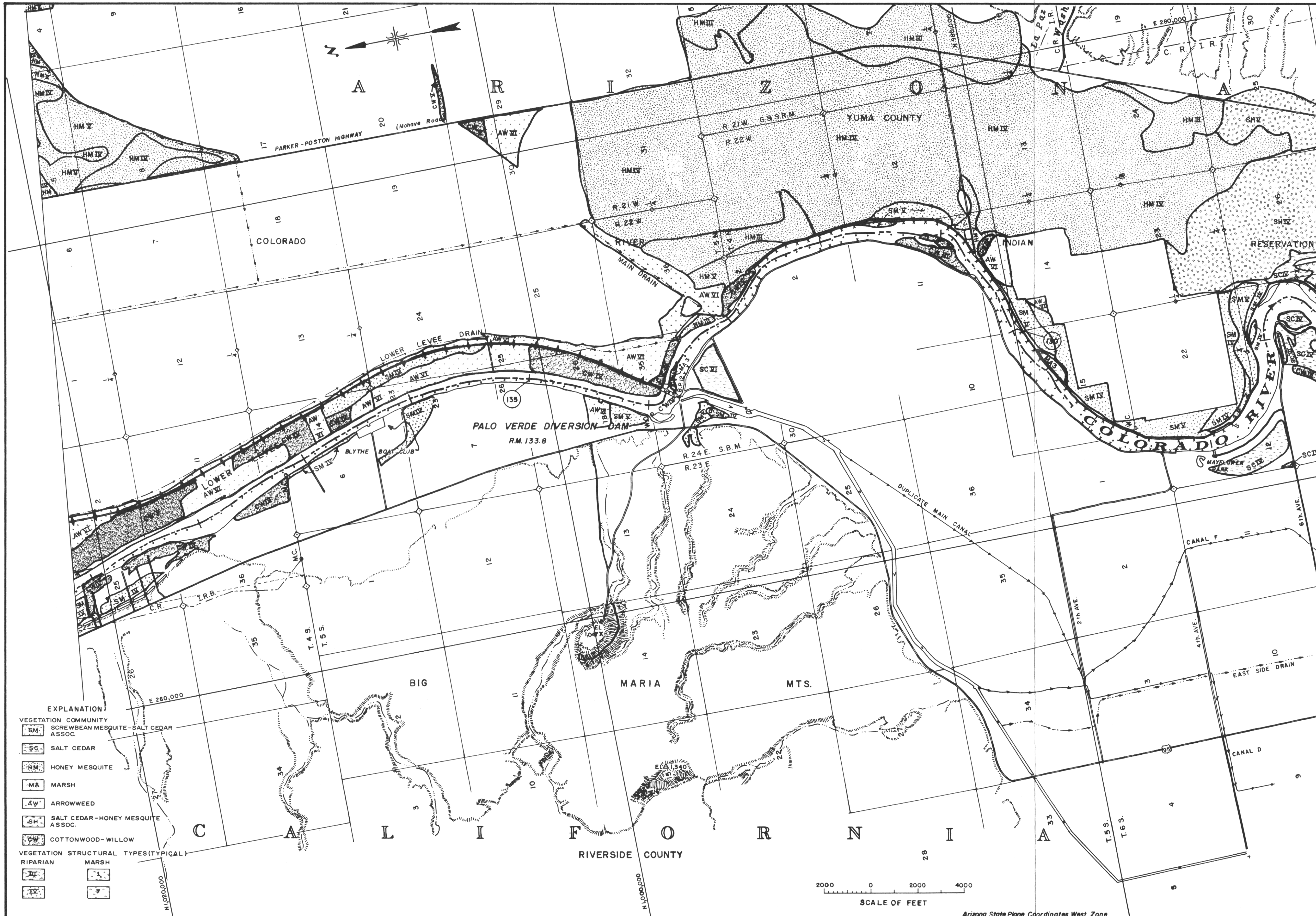
Arizona State Plane Coordinates West Zone
A R I Z O N A
C A L I F O R N I A
LA PAZ COUNTY
RIVERSIDE COUNTY
COLORADO
RIVER
E. BLYTHE
BLYTHE
PARKER - POSTON HIGHWAY
OVERHEAD NATURAL GAS PIPELINE
Southern Calif. Gas Co.
2-30" Steel Natural Gas Lines, 1 over River, 1 under River
RIVIERA DR.
McIntire County Park
Lovekin Wash
Lake Wash
Weaver Wash
Trigo Wash
Petes Wash
Mohave Wash
Y.P.O.
E.F. OFFICE
OLIVE LAKE BLVD.
EAST SIDE DRAIN
S. INTAKE
CANAL F
CANAL D
CANAL C
CANAL D-23-1
7th ST.
BROADWAY
A.T. & S.F.
LOVEKIN
CHANSLORWAY
HOBSONWAY
10th AVE
14th AVE
16th AVE
18th AVE
22nd AVE
26th AVE
28th AVE
T.3N.
T.2N.
T.6S.
T.7S.
T.8S.
R.24E.
R.23E.
R.22E.
R.22W.
R.23W.
S.B.M.
G.&S.R.M.
N 960,000
N 940,000
N 920,000
N 900,000
E 240,000
E 260,000
110
115
120
NATURAL GAS
EL PASO



UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
COLORADO RIVER FRONT WORK & LEVEE SYSTEM

COLORADO RIVER

DAVIS DAM TO INTERNATIONAL BOUNDARY

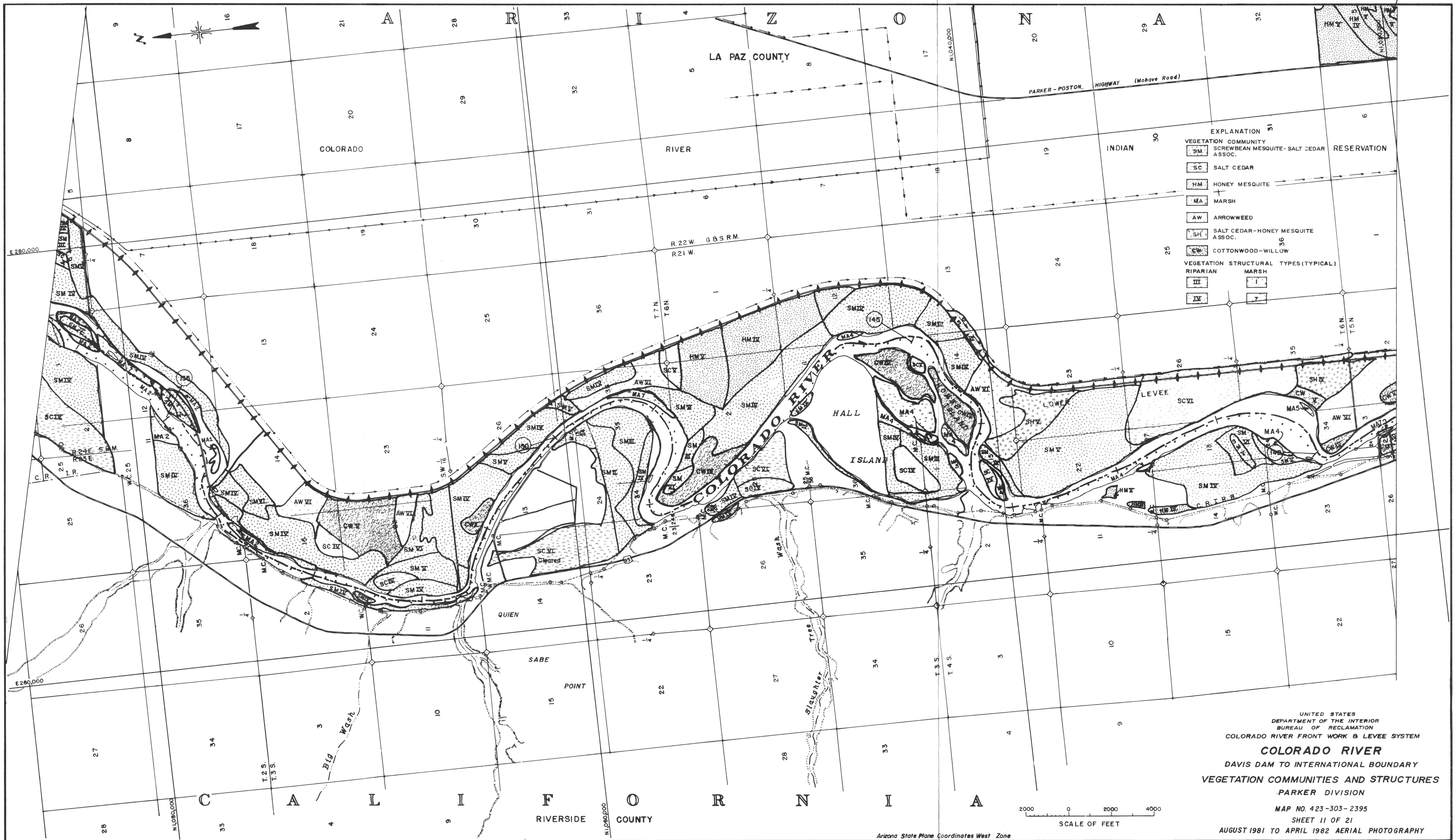
VEGETATION COMMUNITIES AND STRUCTURES

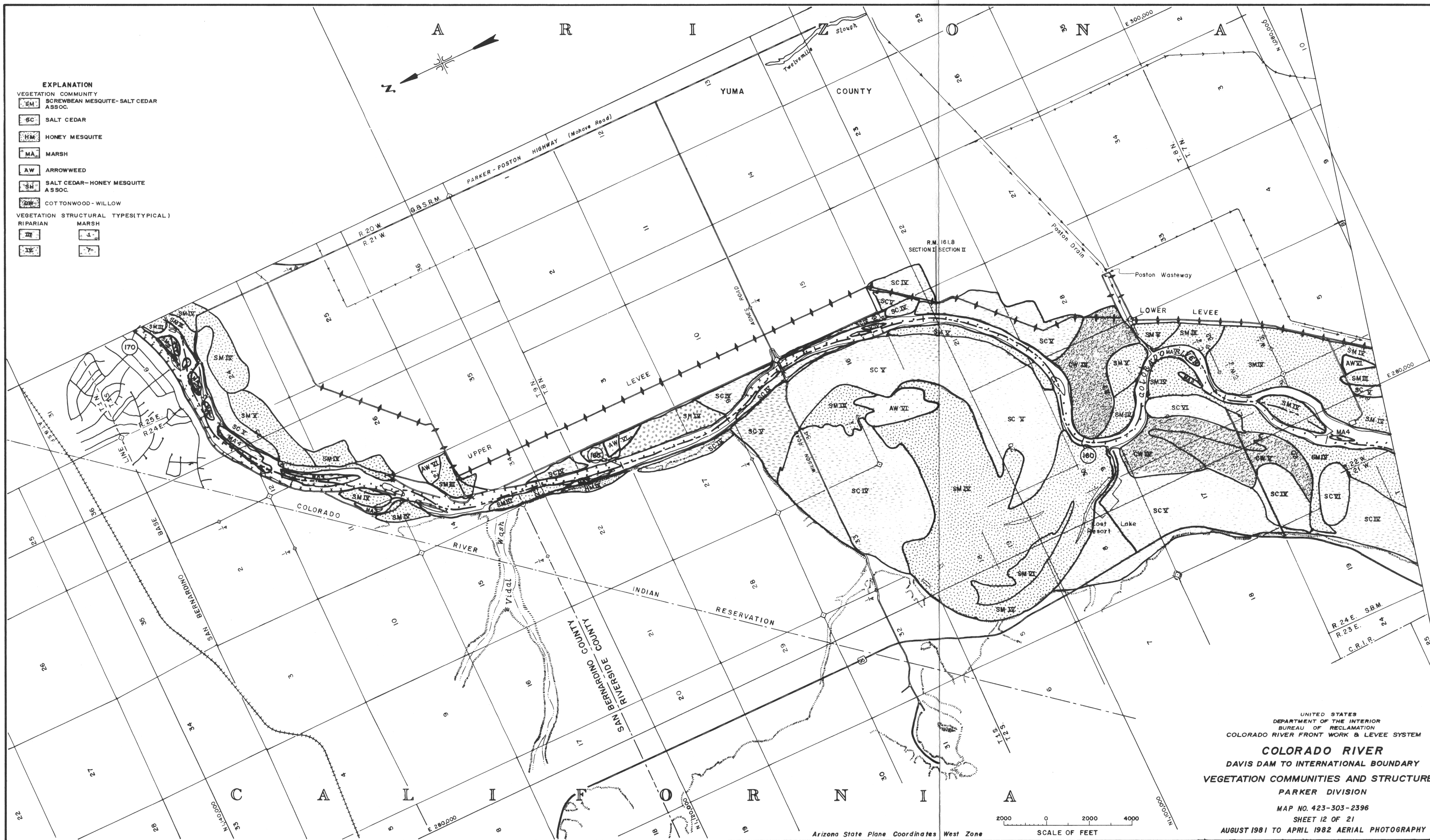
PARKER AND PALO VERDE DIVISIONS

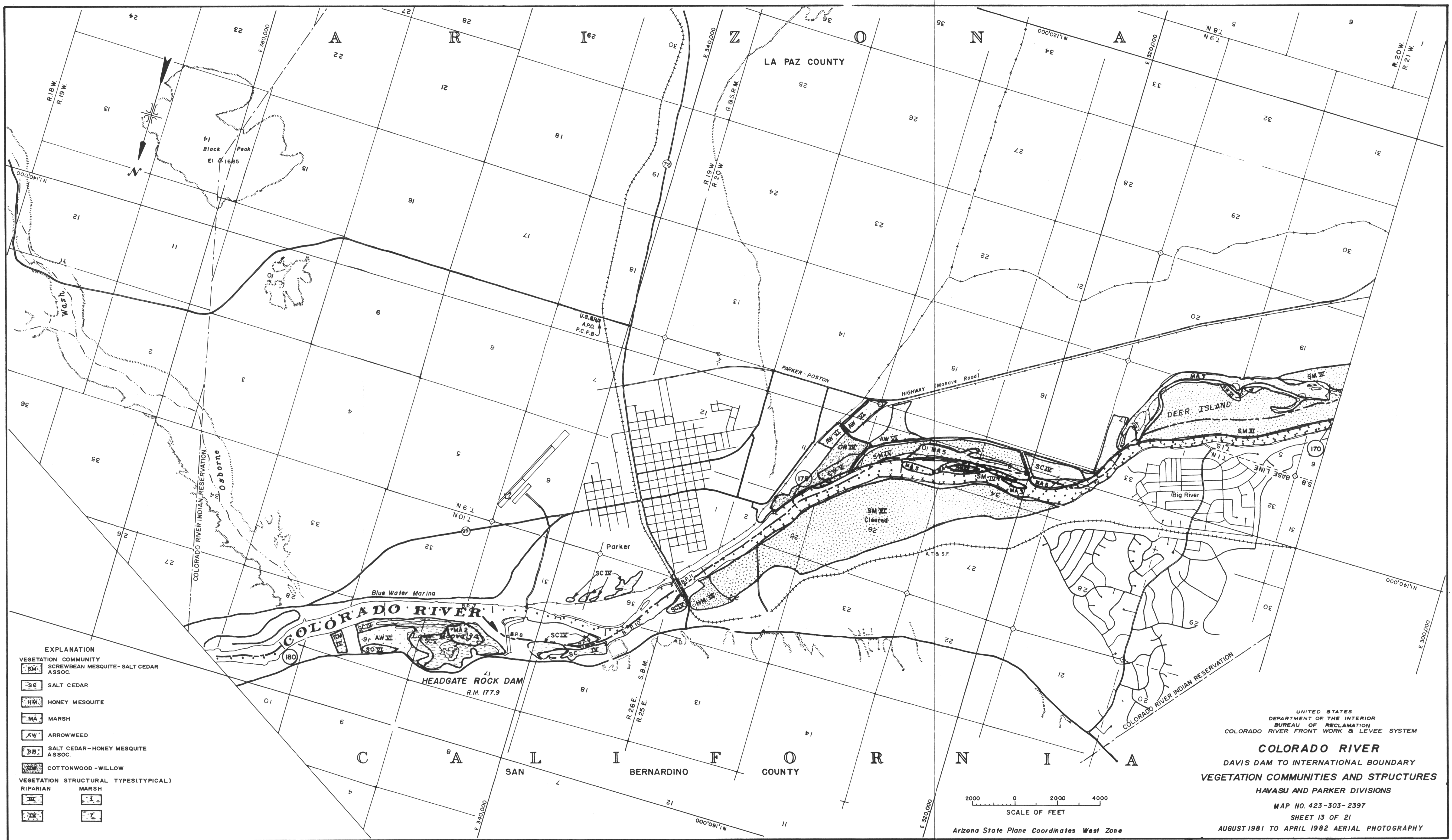
MAP NO. 423-303-2394

SHEET 10 OF 21

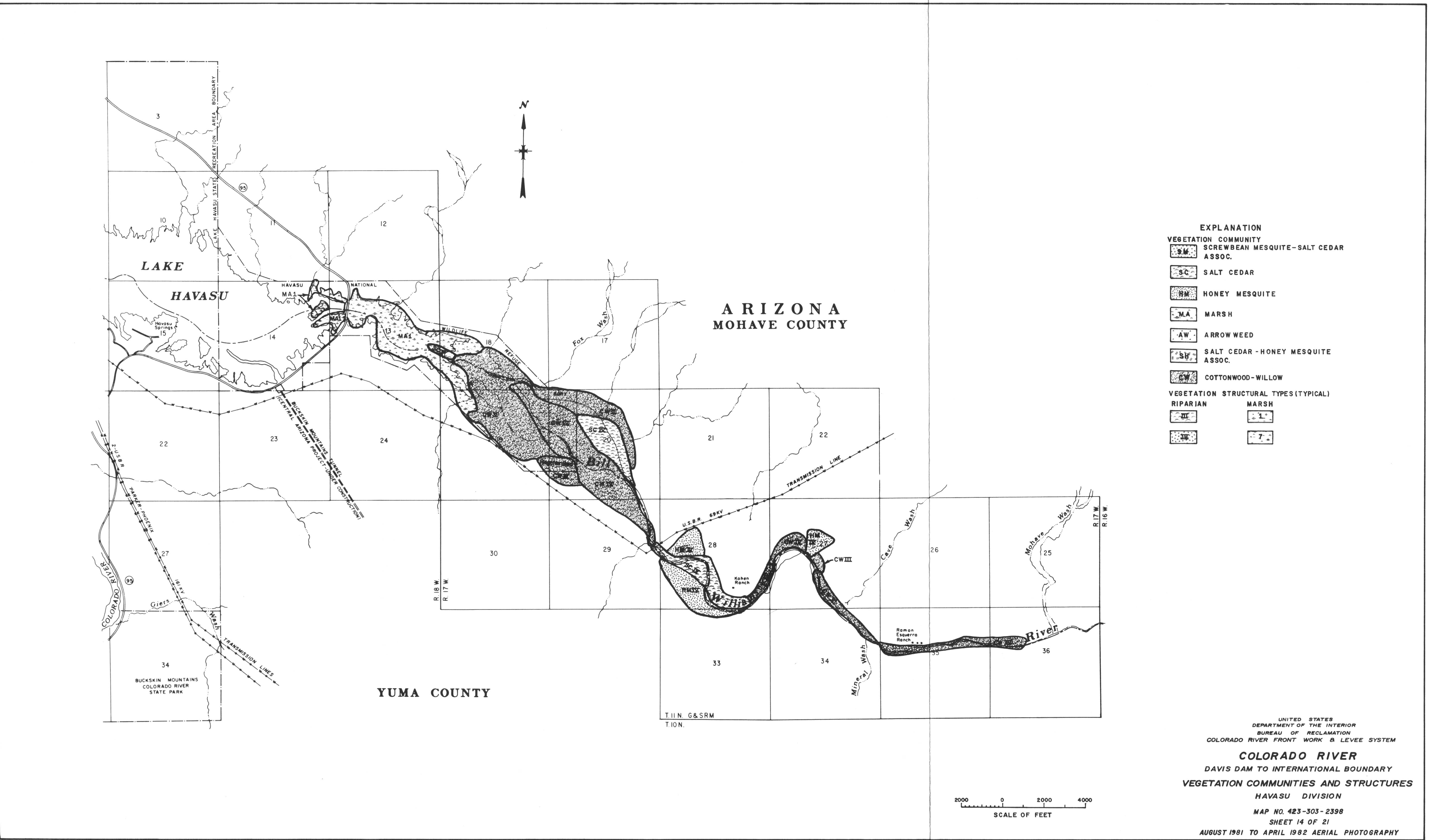
AUGUST 1981 TO APRIL 1982 AERIAL PHOTOGRAPHY

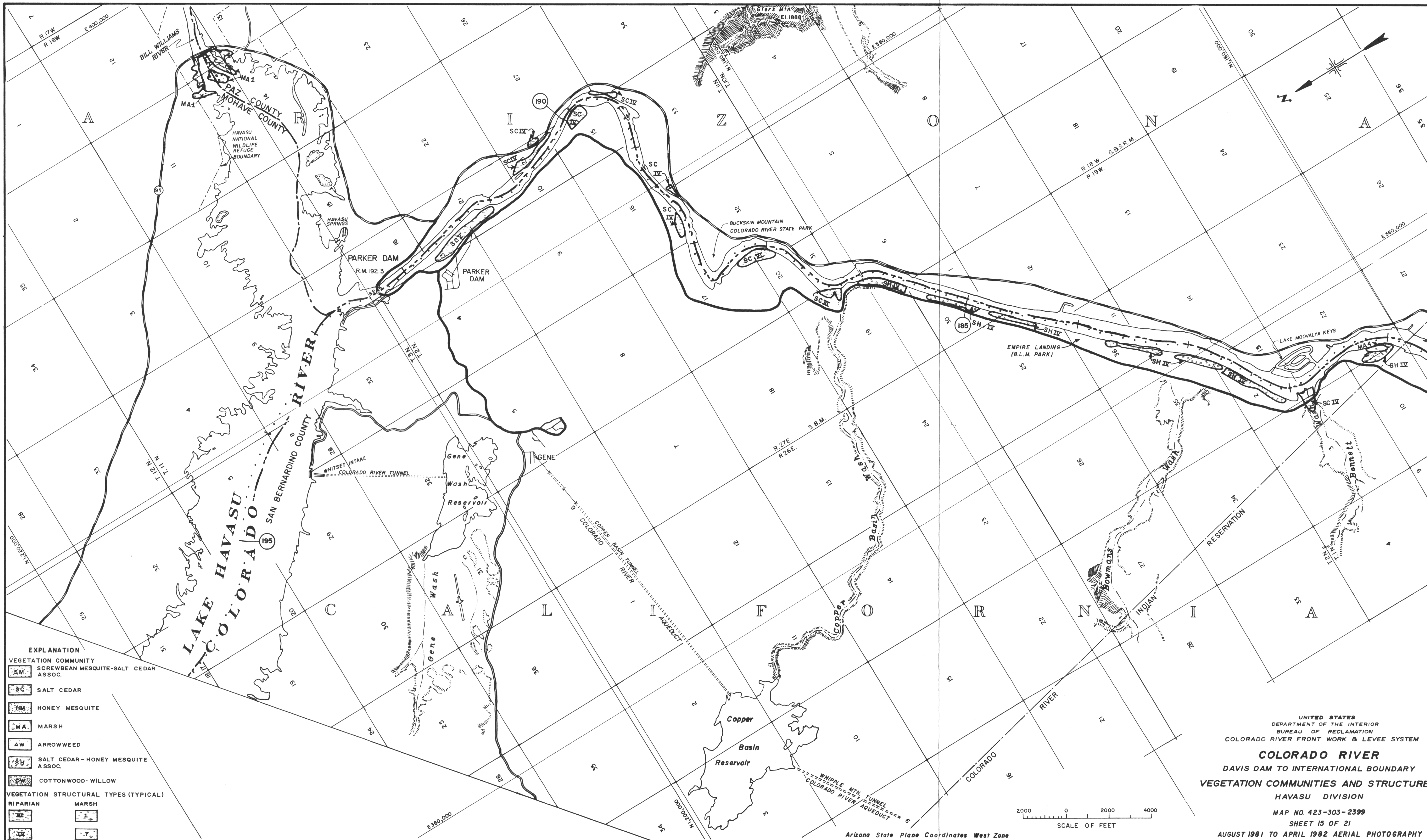

ARIZONA
LA PAZ COUNTY
PARKER-POSTON HIGHWAY (Mohave Road)
COLORADO RIVER INDIAN RESERVATION
EXPLANATION
VEGETATION COMMUNITY
SM SCREWBEAN MESQUITE-SALT CEDAR ASSOC.
SC SALT CEDAR
HM HONEY MESQUITE
MA MARSH
AW ARROWWEED
SH SALT CEDAR-HONEY MESQUITE ASSOC.
CW COTTONWOOD-WILLOW
VEGETATION STRUCTURAL TYPES (TYPICAL)
RIPARIAN
MARSH
III
IV
I
7
R.22W. G.&S.R.M.
R.21W.
T.7N.
T.6N.
T.5N.
COLORADO RIVER
HALL ISLAND
LOWER LEVEE
QUIEN SABE POINT
Big Wash
Slaughter Tree Wash
T.2S.
T.3S.
T.4S.
CALIFORNIA
RIVERSIDE COUNTY
SCALE OF FEET
Arizona State Plane Coordinates West Zone
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
COLORADO RIVER FRONT WORK & LEVEE SYSTEM
COLORADO RIVER
DAVIS DAM TO INTERNATIONAL BOUNDARY
VEGETATION COMMUNITIES AND STRUCTURES
PARKER DIVISION
MAP NO. 423-303-2395
SHEET 11 OF 21
AUGUST 1981 TO APRIL 1982 AERIAL PHOTOGRAPHY


EXPLANATION
VEGETATION COMMUNITY
SM SCREWBEAN MESQUITE-SALT CEDAR ASSOC.
SC SALT CEDAR
HM HONEY MESQUITE
MA MARSH
AW ARROWWEED
SH SALT CEDAR-HONEY MESQUITE ASSOC.
CW COTTONWOOD-WILLOW
VEGETATION STRUCTURAL TYPES (TYPICAL)
RIPARIAN
MARSH
A R I Z O N A
YUMA COUNTY
Twelvemile Slough
PARKER - POSTON HIGHWAY (Mohave Road)
G&S.R.M.
R.20W.
R.21W.
Poston Drain
Poston Wasteway
LOWER LEVEE
UPPER LEVEE
AGNES ROAD
WILSON ROAD
R.M. 161.8
SECTION I SECTION II
COLORADO RIVER
Lost Lake Resort
COLORADO RIVER INDIAN RESERVATION
SAN BERNARDINO COUNTY
RIVERSIDE COUNTY
Vidal Wash
SAN BERNARDINO BASE LINE
A.T.&S.F.
C A L I F O R N I A
R.24E. S.B.M.
R.23E.
C.R.I.R.
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
COLORADO RIVER FRONT WORK & LEVEE SYSTEM
COLORADO RIVER
DAVIS DAM TO INTERNATIONAL BOUNDARY
VEGETATION COMMUNITIES AND STRUCTURES
PARKER DIVISION
MAP NO. 423-303-2396
SHEET 12 OF 21
AUGUST 1981 TO APRIL 1982 AERIAL PHOTOGRAPHY
2000 0 2000 4000
SCALE OF FEET
Arizona State Plane Coordinates West Zone

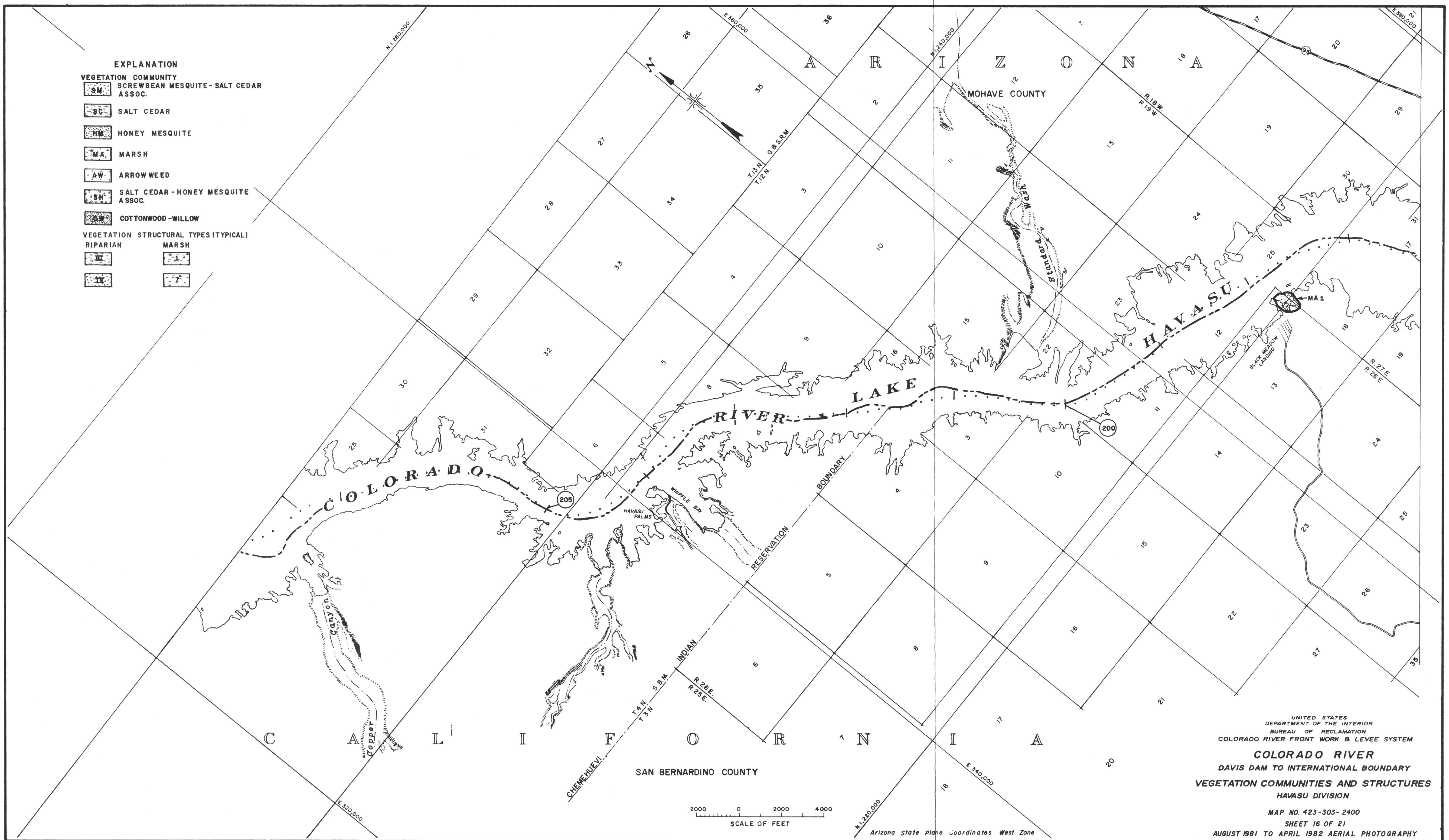


ARIZONA
LA PAZ COUNTY
CALIFORNIA
SAN BERNARDINO COUNTY
COLORADO RIVER
DEER ISLAND
Big River
BASE LINE
Parker
Blue Water Marina
HEADGATE ROCK DAM
R.M. 177.9
SM VI
Cleared
PARKER - POSTON
HIGHWAY (Mohave Road)
U.S.B.R.
A.P.O.
P.C.F.B.
A.T.& S.F.
COLORADO RIVER INDIAN RESERVATION
Osborne
Wash
Black Peak
El. 1665
R.18W.
R.19W.
R.20W.
R.21W.
R.26E.
R.25E.
S.B.M.
G.&S.R.M.
T.9N.
T.8N.
T.10N.
N.1,120,000
N.1,140,000
N.1,160,000
E.300,000
E.320,000
E.340,000
E.360,000
N
EXPLANATION
VEGETATION COMMUNITY
SM SCREWBEAN MESQUITE-SALT CEDAR ASSOC.
SC SALT CEDAR
HM HONEY MESQUITE
MA MARSH
AW ARROWWEED
SB SALT CEDAR-HONEY MESQUITE ASSOC.
CW COTTONWOOD-WILLOW
VEGETATION STRUCTURAL TYPES(TYPICAL)
RIPARIAN
MARSH
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
COLORADO RIVER FRONT WORK & LEVEE SYSTEM
COLORADO RIVER
DAVIS DAM TO INTERNATIONAL BOUNDARY
VEGETATION COMMUNITIES AND STRUCTURES
HAVASU AND PARKER DIVISIONS
MAP NO. 423-303-2397
SHEET 13 OF 21
AUGUST 1981 TO APRIL 1982 AERIAL PHOTOGRAPHY
2000 0 2000 4000
SCALE OF FEET
Arizona State Plane Coordinates West Zone


ARIZONA
MOHAVE COUNTY
YUMA COUNTY
LAKE HAVASU
N
HAVASU NATIONAL WILDLIFE REFUGE
LAKE HAVASU STATE RECREATION AREA BOUNDARY
BUCKSKIN MOUNTAINS TUNNEL
(CENTRAL ARIZONA PROJECT-UNDER CONSTRUCTION)
Havasu Springs
Fox Wash
Cave Wash
Mineral Wash
Mohave Wash
Giers Wash
Bill Williams River
COLORADO RIVER
Kohen Ranch
Ramon Esquerro Ranch
USBR 69KV
TRANSMISSION LINE
2-USBR PARKER-PHOENIX 161KV
TRANSMISSION LINES
BUCKSKIN MOUNTAINS COLORADO RIVER STATE PARK
R.18W. R.17W.
R.17W. R.16W.
T.11N. G&SRM
T.10N.
CWIII
MA1
EXPLANATION
VEGETATION COMMUNITY
SM SCREWBEAN MESQUITE-SALT CEDAR ASSOC.
SC SALT CEDAR
HM HONEY MESQUITE
MA MARSH
AW ARROWWEED
SH SALT CEDAR-HONEY MESQUITE ASSOC.
CW COTTONWOOD-WILLOW
VEGETATION STRUCTURAL TYPES (TYPICAL)
RIPARIAN
III
IV
MARSH
1
7
2000 0 2000 4000
SCALE OF FEET
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
COLORADO RIVER FRONT WORK & LEVEE SYSTEM
COLORADO RIVER
DAVIS DAM TO INTERNATIONAL BOUNDARY
VEGETATION COMMUNITIES AND STRUCTURES
HAVASU DIVISION
MAP NO. 423-303-2398
SHEET 14 OF 21
AUGUST 1981 TO APRIL 1982 AERIAL PHOTOGRAPHY

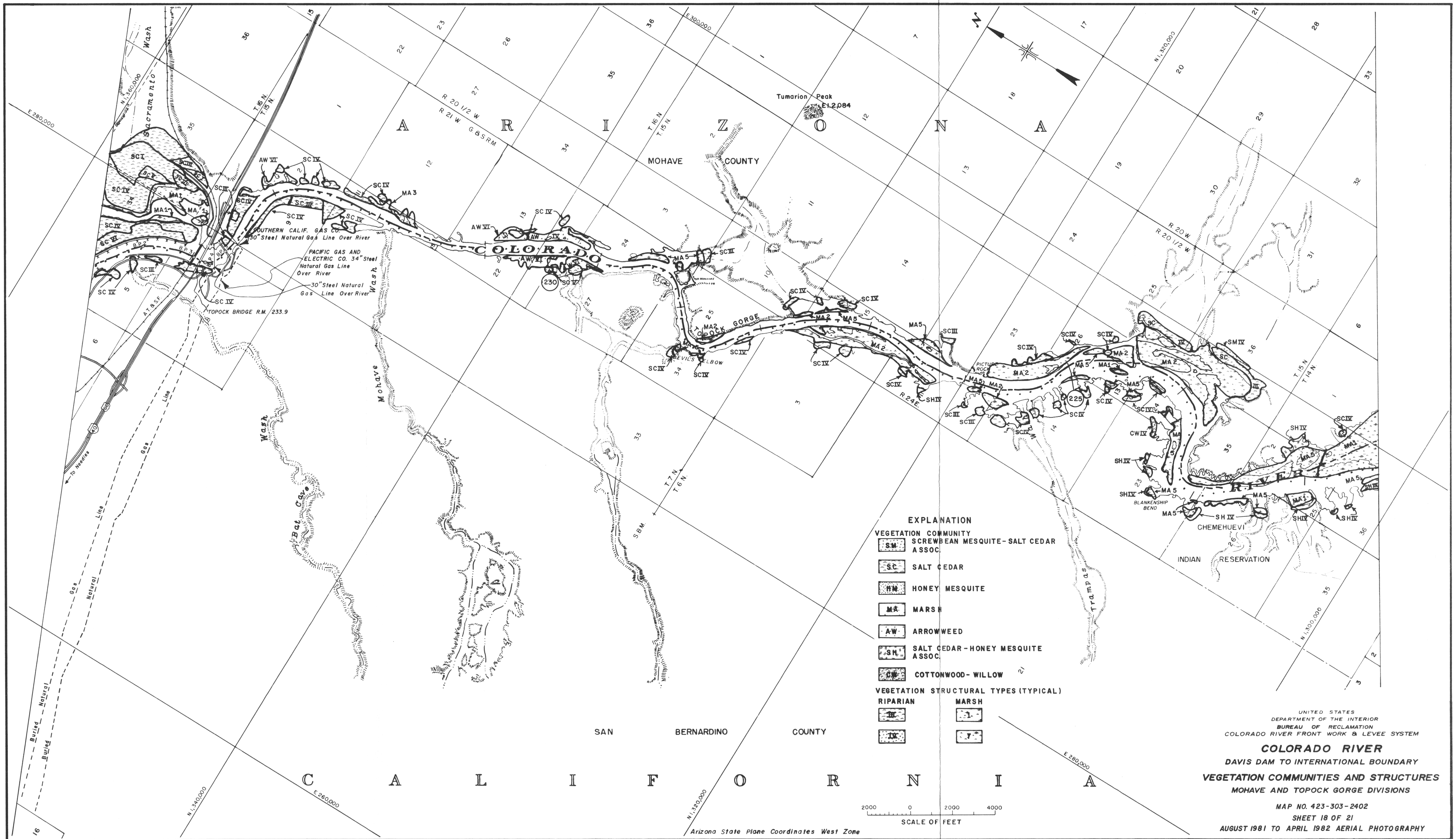


UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
COLORADO RIVER FRONT WORK & LEVEE SYSTEM
COLORADO RIVER
DAVIS DAM TO INTERNATIONAL BOUNDARY
VEGETATION COMMUNITIES AND STRUCTURES
HAVASU DIVISION
MAP NO. 423-303-2399
SHEET 15 OF 21
AUGUST 1981 TO APRIL 1982 AERIAL PHOTOGRAPHY
SCALE OF FEET
2000 0 2000 4000
Arizona State Plane Coordinates West Zone
EXPLANATION
VEGETATION COMMUNITY
SM SCREWBEAN MESQUITE-SALT CEDAR ASSOC.
SC SALT CEDAR
HM HONEY MESQUITE
MA MARSH
AW ARROWWEED
SH SALT CEDAR-HONEY MESQUITE ASSOC.
CW COTTONWOOD-WILLOW
VEGETATION STRUCTURAL TYPES (TYPICAL)
RIPARIAN
MARSH
ARIZONA
CALIFORNIA
LAKE HAVASU
COLORADO RIVER
BILL WILLIAMS RIVER
LA PAZ COUNTY
MOHAVE COUNTY
SAN BERNARDINO COUNTY
HAVASU NATIONAL WILDLIFE REFUGE BOUNDARY
HAVASU SPRINGS
PARKER DAM
R.M. 192.3
GENE
Gene Wash Reservoir
Gene Wash
WHITSET INTAKE
COLORADO RIVER TUNNEL
COPPER BASIN TUNNEL
COLORADO RIVER AQUEDUCT
Copper Basin Reservoir
Copper Basin Wash
WHIPPLE MTN. TUNNEL
COLORADO RIVER AQUEDUCT
Giers Mtn. El. 1888
BUCKSKIN MOUNTAIN
COLORADO RIVER STATE PARK
EMPIRE LANDING (B.L.M. PARK)
LAKE MOOVALYA KEYS
Bowmans Wash
Bennett Wash
COLORADO RIVER INDIAN RESERVATION
R.18W. G&SRM
R.19W.
R.27E. S.B.M.
R.26E.
R.17W
R.18W
T.11N
T.10N
T.12N
T.13N
E 400,000
E 380,000
E 360,000
N 180,000
N 200,000
N 220,000
N

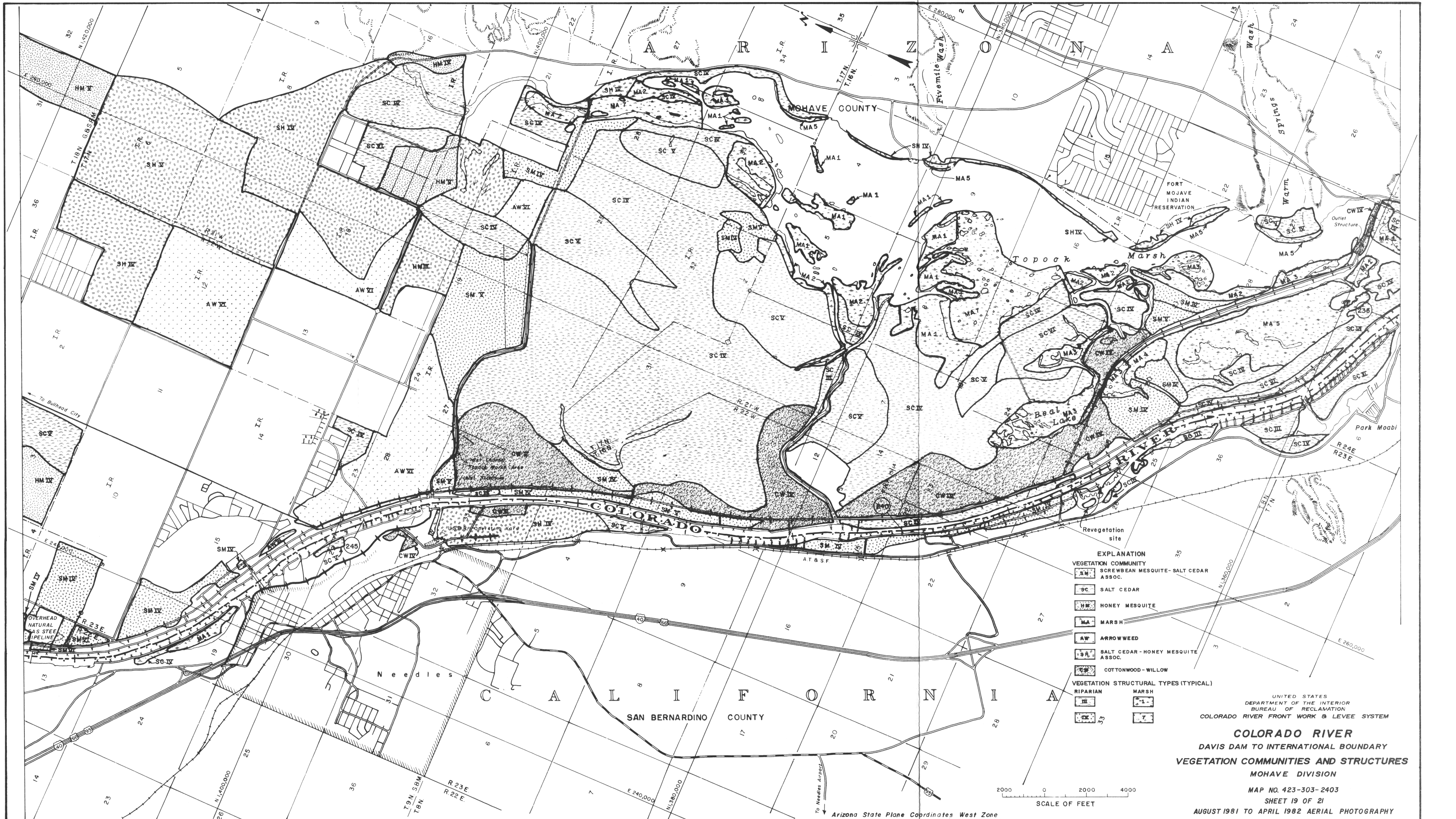


EXPLANATION
VEGETATION COMMUNITY
SM SCREWBEAN MESQUITE - SALT CEDAR ASSOC.
SC SALT CEDAR
HM HONEY MESQUITE
MA MARSH
AW ARROWWEED
SH SALT CEDAR - HONEY MESQUITE ASSOC.
CW COTTONWOOD - WILLOW
VEGETATION STRUCTURAL TYPES (TYPICAL)
RIPARIAN
MARSH
ARIZONA
MOHAVE COUNTY
CALIFORNIA
SAN BERNARDINO COUNTY
LAKE HAVASU
COLORADO RIVER
Standard Wash
Copper Canyon
BLACK MEADOW LANDING
MA 1
WHIPPLE BAY
HAVASU PALMS
CHEMEHUEVI INDIAN RESERVATION BOUNDARY
T.13N. T.12N. G&SRM
T.4N. T.3N. S.B.M.
R.18W. R.19W.
R.27E. R.26E.
R.26E. R.25E.
N.1,280,000
N.1,240,000
N.1,220,000
E.380,000
E.360,000
E.340,000
E.320,000
200
205
95
2000 0 2000 4000
SCALE OF FEET
Arizona State Plane Coordinates West Zone
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
COLORADO RIVER FRONT WORK & LEVEE SYSTEM
COLORADO RIVER
DAVIS DAM TO INTERNATIONAL BOUNDARY
VEGETATION COMMUNITIES AND STRUCTURES
HAVASU DIVISION
MAP NO. 423-303-2400
SHEET 16 OF 21
AUGUST 1981 TO APRIL 1982 AERIAL PHOTOGRAPHY

ARIZONA
MOHAVE COUNTY
LAKE HAVASU CITY
LONDON BRIDGE
Site Six
COLORADO RIVER
LAKE HAVASU
CASTLE ROCK BAY
CLEAR BAY
CATFISH BAY
Havasu Landing
HAVASU LAKE
CHEMEHUEVI INDIAN RESERVATION BOUNDARY
Chemehuevi Wash
CALIFORNIA
SAN BERNARDINO COUNTY
Arizona State Plane Coordinates West Zone
R19W G&SRM
R20W
R 20 W
R 20½ W
R.25E. S.B.M.
R.24E
T.15N.
T.14N.
T.6N.
T.5N.
T.14N
T.13N
E 320,000
E 300,000
N 1,300,000
N 1,280,000
N 1,260,000
210
215
220
MA1
MA5
SH IV
EXPLANATION
VEGETATION COMMUNITY
SM SCREWBEAN MESQUITE-SALT CEDAR ASSOC.
SC SALT CEDAR
HM HONEY MESQUITE
MA MARSH
AW ARROWWEED
SH SALT CEDAR-HONEY MESQUITE ASSOC.
CW COTTONWOOD-WILLOW
VEGETATION STRUCTURAL TYPES (TYPICAL)
RIPARIAN
MARSH
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
COLORADO RIVER FRONT WORK & LEVEE SYSTEM
COLORADO RIVER
DAVIS DAM TO INTERNATIONAL BOUNDARY
VEGETATION COMMUNITIES AND STRUCTURES
TOPOCK GORGE AND HAVASU DIVISIONS
MAP NO. 423-303-2401
SHEET 17 OF 21
AUGUST 1981 TO APRIL 1982 AERIAL PHOTOGRAPHY
2000 0 2000 4000
SCALE OF FEET



ARIZONA
CALIFORNIA
MOHAVE COUNTY
SAN BERNARDINO COUNTY
COLORADO
RIVER
TOPOCK GORGE
DEVILS ELBOW
Tumarion Peak El. 2,084
CHEMEHUEVI INDIAN RESERVATION
BLANKENSHIP BEND
PICTURE ROCK
SOUTHERN CALIF. GAS CO. 30" Steel Natural Gas Line Over River
PACIFIC GAS AND ELECTRIC CO. 34" Steel Natural Gas Line Over River
30" Steel Natural Gas Line Over River
TOPOCK BRIDGE R.M. 233.9
Sacramento Wash
Mohave Wash
Bat Cave Wash
Trampas Wash
Buried Natural Gas Line
To Needles
R 20 1/2 W
R 21 W G&SRM
R 20 W
R 24 E
T.16 N.
T.15 N.
T.14 N.
T.7 N.
T.6 N.
SBM
EXPLANATION
VEGETATION COMMUNITY
SM SCREWBEAN MESQUITE-SALT CEDAR ASSOC.
SC SALT CEDAR
HM HONEY MESQUITE
MA MARSH
AW ARROWWEED
SH SALT CEDAR-HONEY MESQUITE ASSOC.
CW COTTONWOOD-WILLOW
VEGETATION STRUCTURAL TYPES (TYPICAL)
RIPARIAN III IV
MARSH 1 5
SCALE OF FEET
2000 0 2000 4000
Arizona State Plane Coordinates West Zone
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
COLORADO RIVER FRONT WORK & LEVEE SYSTEM
COLORADO RIVER
DAVIS DAM TO INTERNATIONAL BOUNDARY
VEGETATION COMMUNITIES AND STRUCTURES
MOHAVE AND TOPOCK GORGE DIVISIONS
MAP NO. 423-303-2402
SHEET 18 OF 21
AUGUST 1981 TO APRIL 1982 AERIAL PHOTOGRAPHY



UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
COLORADO RIVER FRONT WORK & LEVEE SYSTEM

COLORADO RIVER

DAVIS DAM TO INTERNATIONAL BOUNDARY

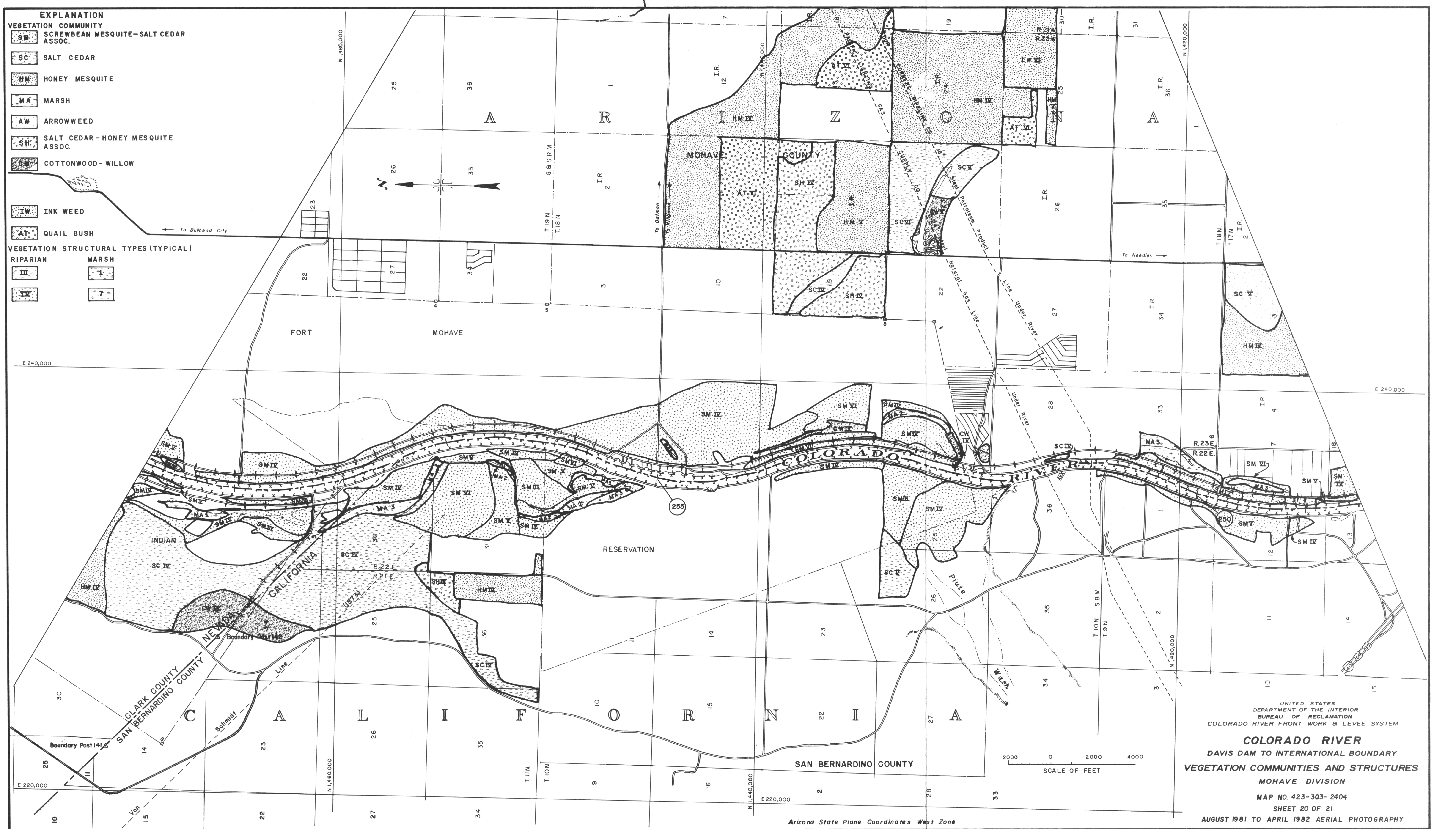
VEGETATION COMMUNITIES AND STRUCTURES

MOHAVE DIVISION

MAP NO. 423-303-2403

SHEET 19 OF 21

AUGUST 1981 TO APRIL 1982 AERIAL PHOTOGRAPHY


EXPLANATION
VEGETATION COMMUNITY
SM SCREWBEAN MESQUITE-SALT CEDAR ASSOC.
SC SALT CEDAR
HM HONEY MESQUITE
MA MARSH
AW ARROWWEED
SH SALT CEDAR-HONEY MESQUITE ASSOC.
CW COTTONWOOD-WILLOW
IW INK WEED
AT QUAIL BUSH
VEGETATION STRUCTURAL TYPES (TYPICAL)
RIPARIAN
III
IV
MARSH
1
7
To Bullhead City
To Oatman
To Kingman
To Needles
ARIZONA
MOHAVE COUNTY
FORT MOHAVE
INDIAN
RESERVATION
COLORADO RIVER
CALIFORNIA
NEVADA
CLARK COUNTY
SAN BERNARDINO COUNTY
Boundary Post 141
Boundary Post 142
Schmidt Line
Von
Piute Wash
Steel Petroleum Product Line Under River
Natural Gas Line Under River
PACIFIC LIGHTING GAS SUPPLY CO.
CORBESS PIPELINE CO.
E 240,000
E 220,000
N 1,460,000
N 1,440,000
N 1,420,000
T19N
T18N
T17N
T10N
T9N
T11N
G&SRM
SBM
R.23E.
R.22E.
R21E
I.R.
255
250
SCALE OF FEET
2000 0 2000 4000
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
COLORADO RIVER FRONT WORK & LEVEE SYSTEM
COLORADO RIVER
DAVIS DAM TO INTERNATIONAL BOUNDARY
VEGETATION COMMUNITIES AND STRUCTURES
MOHAVE DIVISION
MAP NO. 423-303-2404
SHEET 20 OF 21
AUGUST 1981 TO APRIL 1982 AERIAL PHOTOGRAPHY
Arizona State Plane Coordinates West Zone

ARIZONA
MOHAVE COUNTY
FORT MOHAVE
INDIAN RESERVATION
NEVADA
CLARK COUNTY
COLORADO RIVER
DAVIS DAM
RM 276.0
Lake Mohave
POWER PLANT
SOUTHERN CALIFORNIA EDISON
BULLHEAD CITY EL 550
Secret Pass Canyon
Silver Creek Wash
Montana Wash
To Oatman
To Needles
Lake Mead National Recreation Area Boundary
MESA PIPELINE INC.
Telephone Line
Buried Pipeline
SOUTHWEST GAS CORP.
20" Steel Natural Gas Line Over River
SOUTHWEST GAS CORP
20" Steel Natural Gas Line Under River
275
270
265
260
EXPLANATION
VEGETATION COMMUNITY
SM SCREWBEAN MESQUITE - SALT CEDAR ASSOC.
SC SALT CEDAR
HM HONEY MESQUITE
MA MARSH
AW ARROWWEED
SH SALT CEDAR - HONEY MESQUITE ASSOC.
CW COTTONWOOD - WILLOW
VEGETATION STRUCTURAL TYPES (TYPICAL)
RIPARIAN
MARSH
2000 0 2000 4000
SCALE OF FEET
Arizona State Plane Coordinates West Zone
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
COLORADO RIVER FRONT WORK & LEVEE SYSTEM
COLORADO RIVER
DAVIS DAM TO INTERNATIONAL BOUNDARY
VEGETATION COMMUNITIES AND STRUCTURES
MOHAVE DIVISION
MAP NO. 423-303-2405
SHEET 21 OF 21
AUGUST 1981 TO APRIL 1982 AERIAL PHOTOGRAPHY