PB88-183470

Evaluation of Riparian Vegetative Trends in the Grand Canyon Using Multitemporal Remote Sensing Techniques

(U.S.) Glen Canyon Environmental Studies
Flagstaff, AZ

26 Mar 86

U.S. DEPARTMENT OF COMMERCE
National Technical Information Service
NTIS

EVALUATION OF RIPARIAN VEGETATIVE TRENDS IN THE GRAND CANYON USING MULTITEMPORAL REMOTE SENSING TECHNIQUES

Terrestrial Biology

of the

Glen Canyon Environmental Studies

By

Michael J. Pucherelli
Bureau of Reclamation
Denver, Colorado

March 26, 1986

ABSTRACT

In response to the proposed upgrade of Glen Canyon Dam for the generation of additional hydro-electric power, a multiagency environmental study was initiated in 1983. More specifically, the study was directed to assess the effects that increased fluctuation in flows of the Colorado River would have on sedimentation, vegetation, wildlife, and recreation in the Grand Canyon. The present paper discusses the evaluation of riparian flora. Historically, periodic flooding of the Colorado River was a common occurrence in the Grand Canyon. Natural succession was disturbed in low areas closest to the river by the scouring action of floodwaters. It is theorized that at the same time, the floodwaters helped to sustain a high zone of native vegetation (Carothers, unpublished data). With the control of floodwaters of the Colorado River in Grand Canyon, brought about by Glen Canyon Dam, (1963) it is believed by some that the high zone riparian habitats are diminishing in size, whereas those in the low zone are increasing (Carothers et al., 1976, Turner and Karpiscak, 1980). To assess the trends of riparian vegetation in the low and high zones, eight study sites were selected in the canyon. Large scale aerial photography covering the study sites was acquired for 1965, 1973, 1980, and 1985, interpreted and digitized into a digital data base. Tabular acreage summaries and computer-generated map plots were produced in terms of river miles. Resultant data suggests that trends in the riparian system to be very different in low zone-high zone situations. Essentially, the low zone vegetation was on the increase since the installation of Glen Canyon Dam and received a 39 percent reduction in habitat from the flood of 1983. The high zone vegetation was basically in a constant state until 1980 and now appears to be on the decline.

INTRODUCTION

The Colorado River riparian habitat in Grand Canyon National Park has changed during the last 23 years as a result of the installation of Glen Canyon Dam. Fluctuating flows from the dam's peaking power operation determine water elevations in the canyon. Controlled water regimes have reduced flooding and have dictated new areas of riparian habitat. Historically, periodic flooding occurred in the Grand Canyon. This activity scoured away low zone vegetation, the habitat closest to the river. Carothers' theory indicates that while the flooding scoured the low zone areas, it also provided water to the native high-zone vegetation. In some areas of the canyon, native high-zone habitats appear to be senescent or growing at a very slow rate, and in some cases dying out. Since the installation of Glen Canyon Dam, wildlife has been adapting to the low-zone habitats as this vegetation has shown a large increase in area.

OBJECTIVE

This study is intended to examine and quantify vegetational trends in the low and high zone riparian areas of selected sites in the Grand Canyon (figs. 1A and 1B). To achieve these objectives, current and historic aerial photography have been acquired. Riparian vegetation changes on eight select study sites in the canyon of the Colorado River between Glen Canyon Dam and Lake Mead were examined by comparing aerial photographs. Available photography from four dates has been interpreted for vegetation, digitized and reported by river miles.

BACKGROUND

Since 1963 many investigators have noted changes in the riparian zone of the Grand Canyon. Turner and Karpiscak (1980) reported the most obvious vegetation changes as revealed by comparison of oblique photographs, was the increased density of exotic species. Carothers et al. (1976) found that the construction of Glen Canyon Dam has permitted the development of a new riparian community. This community is typically characterized by salt cedar, arrowweed, coyote willow, desert broom, and seep willow. Johnson et al. (1983) noted similar changes.

In June of 1983, the Remote Sensing Section was requested to conduct a pilot study designed to quantify these changes. One raft trip in September of 1983 facilitated gathering of the ground reference information. Interpretation, digitization, and computer analysis were completed and accurate cost estimates were submitted to the terrestrial members of the biological study team.

FIGURE 1A- The Grand Canyon as viewed from the South Rim

GLEN CANYON ENVIRONMENTAL STUDY

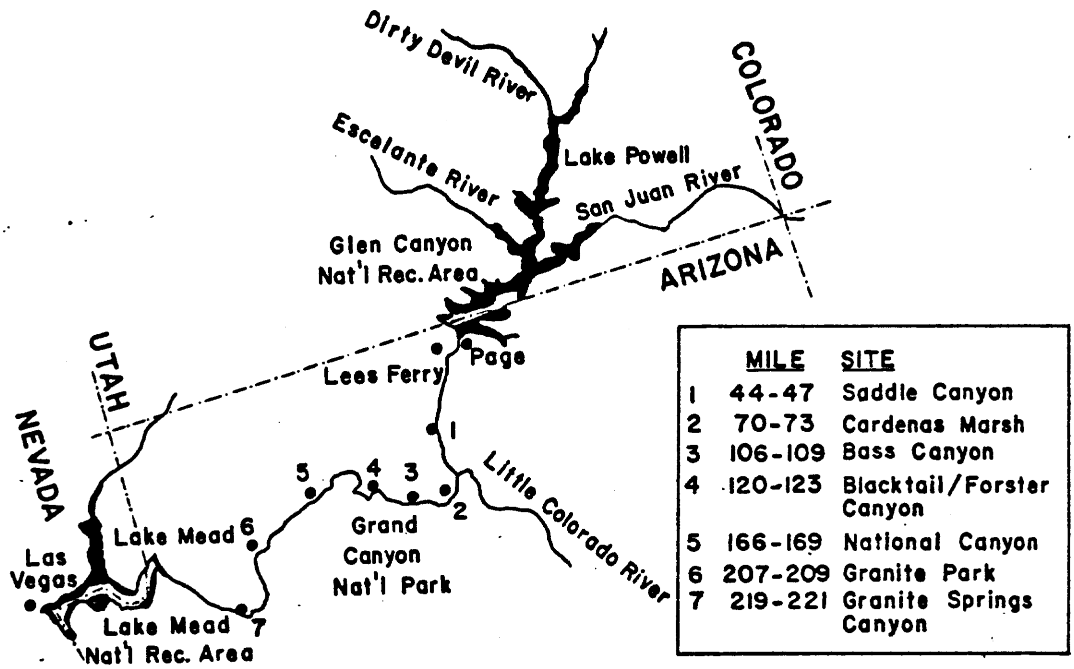


Figure 1B - Location Map

Upon completion of this task, it was determined to allocate monies to work seven study sites of approximately 3 miles each, using four dates of photography. Later in the study, an additional site above Lee's Ferry was added. The available dates of existing photographs were May 1965, black and white; June 1973, black and white; and July 1980, color infrared. The final set of color infrared photographs was flown under contract from the U.S. Bureau of Reclamation office, Salt Lake City, in June of 1985. Scales of photography varied; 1965 - 1/12000, 1973 - 1/7300, 1980 - 1/4800-1/3600, and 1985 - 1/4800. The Duck Island study site was added later during this study. Existing color photographs from 1979 at a scale of 1:3000 were also used.

Black and white photography is difficult to interpret for vegetation assessment; however, this is all that was available and the quality was fairly good. All interpretation was done on transparent mylar sheets overlaid directly on the 9- by 9-inch photographs, with the exception of the 1965 data. To facilitate interpretation at such a small scale, a map-o-graph was used to optically enlarge the photographs approximately 2X, equalling at scale of approximately 1/6000.

The vegetation was interpreted in two major associations: (1) the vegetation that was basically introduced after the installation of Glen Canyon Dam; this is referred to as low zone vegetation since it is closest to the river, and (2) the native vegetation or high zone vegetation; this zone is marked by the old historical flood line (see fig. 2).

The major plant species in the low zone are: desert broom (Baccharis sp), willows (Salix sp), saltcedar (Tamarix chinensis), and arrowweed (Pluchea sericca). The major plant species in the high zone consist of apache plume (Fallugia paradoxa), redbud (Cercis occidentalis), hackberry (Celtis reticulata), honey mesquite (Prosopis glandulosa var. torreyanna, acacia (Acacia greggii), and in the lower reaches of the canyon Creosote bush (Larrea divaricata). It should be noted that these are the major species included in the interpretation, but by no means are they complete. While ground truthing, additional vegetation was noted such as marshes with cattails; also, areas exist with grasses, forbs, vines, brittlebush, cacti, ocotillo, mormon tea, camelthorn, thistle, and more.

Eight sites were chosen to be evaluated in this study. The eight study sites are located by river miles in the list below:

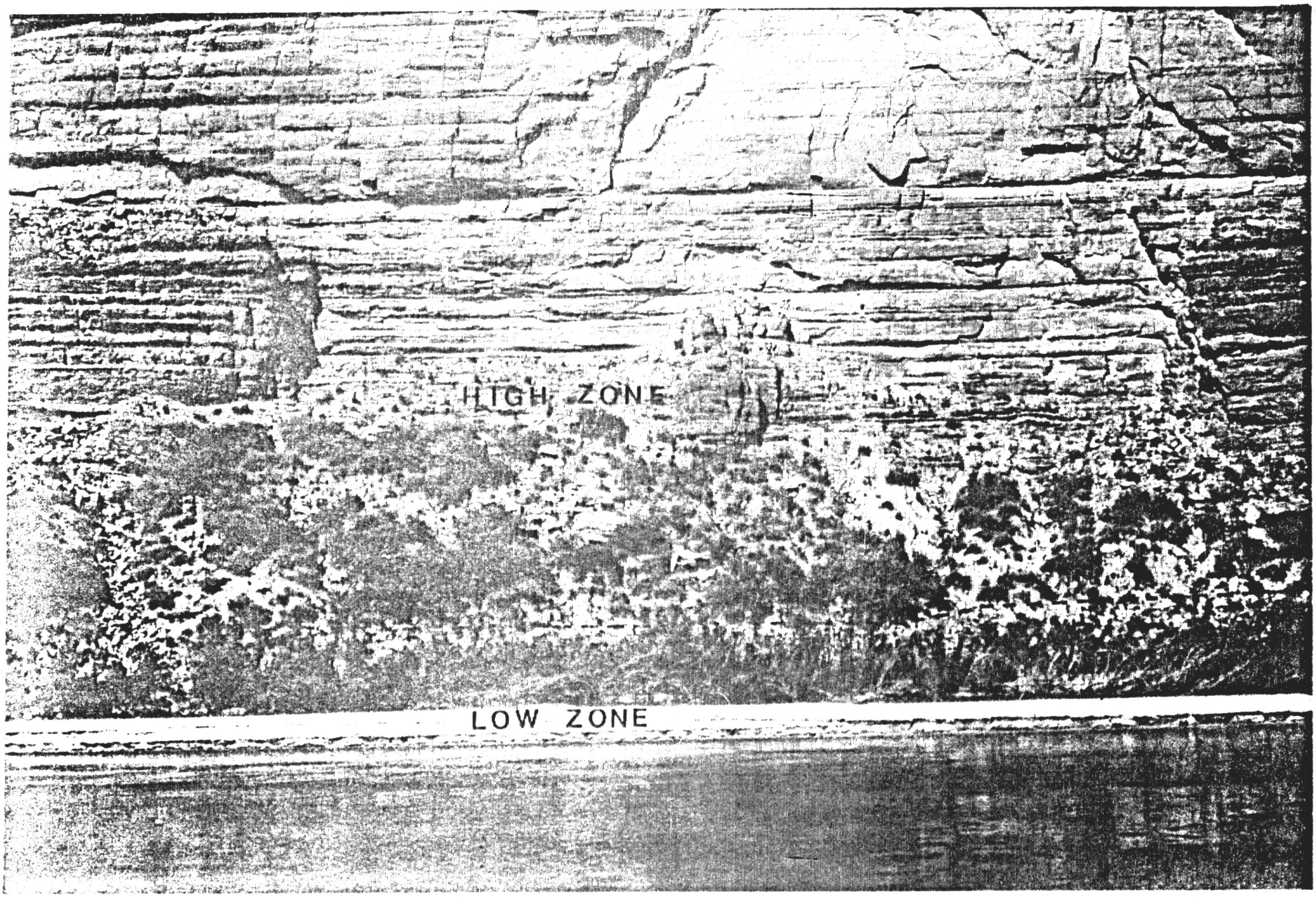


FIGURE 2- Delineation of Low Zone and High Zone

Site	Approximate river mile	Site name
1	9-14 miles above Lee's Ferry	Duck Island
2	44-47	Saddle Canyon
3	70-73	Cardenas Marsh
4	106-109	Bass Canyon
5	120-123	Blacktail/Forster Canyons
6	166-169	National Canyon
7	207-209	Granite Park
8	219-221	Granite Springs Canyon

Note: River miles in the Grand Canyon begin with 0 mile at Lee's Ferry. This area is located about 15 miles below the Glen Canyon Dam, Arizona. The river continues to Pierces Ferry, mile 280, in Lake Mead, Nevada (also see location map - fig. 1B).

Study site locations are areas of interest selected nonrandomly by the National Park Service in conjunction with the biological study group. Sites were selected because of the importance to wildlife, visitor use, and access for gathering ground reference data.

METHODOLOGY

Upon developing the interpretation criteria, work began by classifying vegetation categories and preparing map bases for digitization. A rafting trip for gathering ground reference information was taken in April 1984 (see figs. 5, 6, and 7). This trip facilitated the interpretation process. In most cases, low and high zone categories were easily distinguishable using Dietzgen portable stereoscopes (see figs. 3 and 4). However, in some cases where vegetation from the two zones overlapped, ground truth information was invaluable (see figs. 8 and 9).

Vegetation polygons were drawn on transparent mylar sheets overlaid on the photography. A polygon density was applied using a density scale. The density scale is viewed by the interpreter as he examines the photographs in stereo, and densities are applied to the polygon by making comparisons to the standard chart. Categories of 20, 40, 60, 80, and 100 percent density were applied to polygons in both low and high zone situations. This better enabled comparisons of actual vegetation changes among photography. Upon completion of this task, photographic mosaics were made of each river reach. Normally, we would then transfer

FIGURE 3-4- Example of aerial photography used in this study
The site is Granite Park located at Mile 206

Upper left photo-color infrared
Upper right photo-black and white

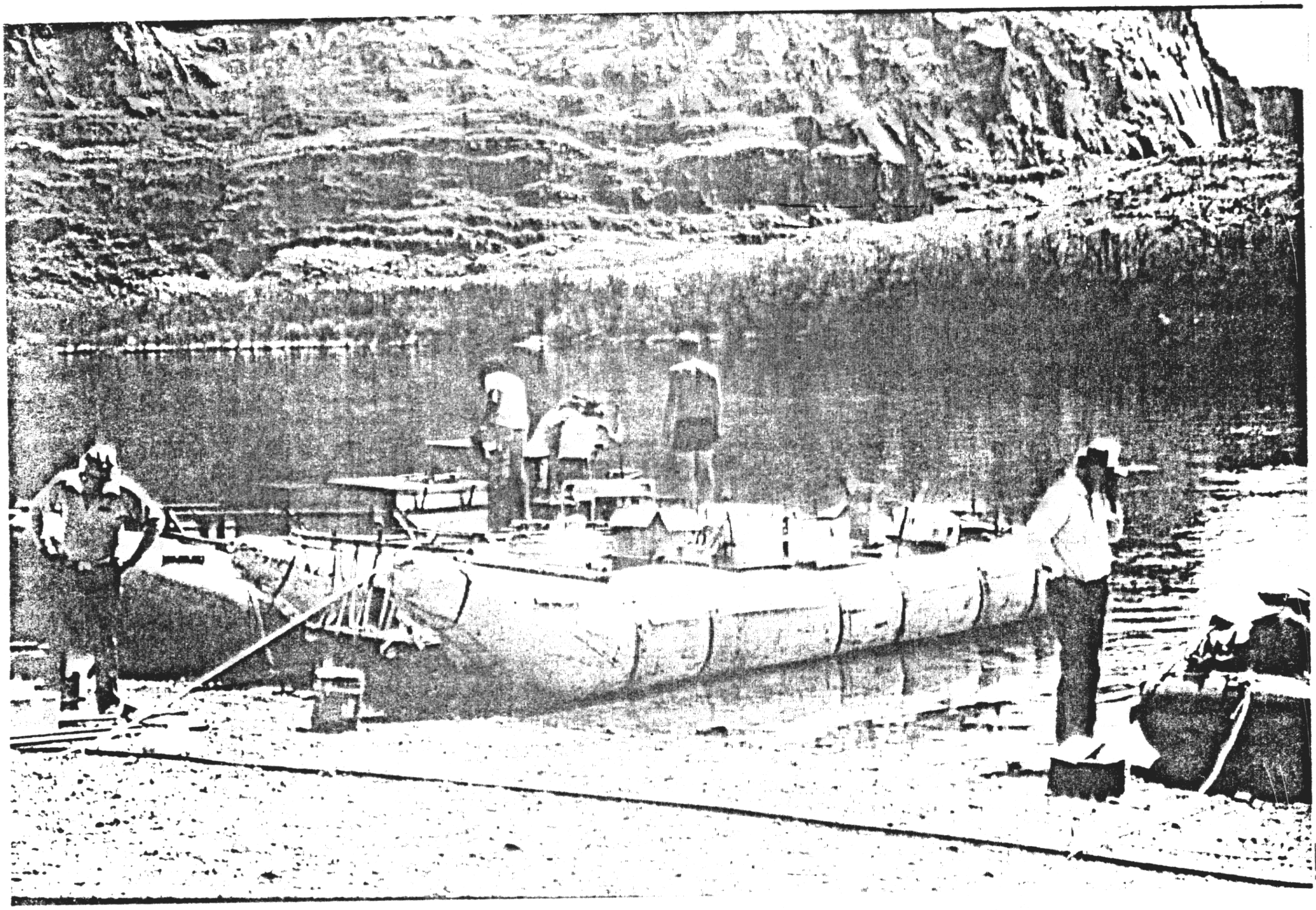


FIGURE 5- Rigging up the rafts at Lee's Ferry

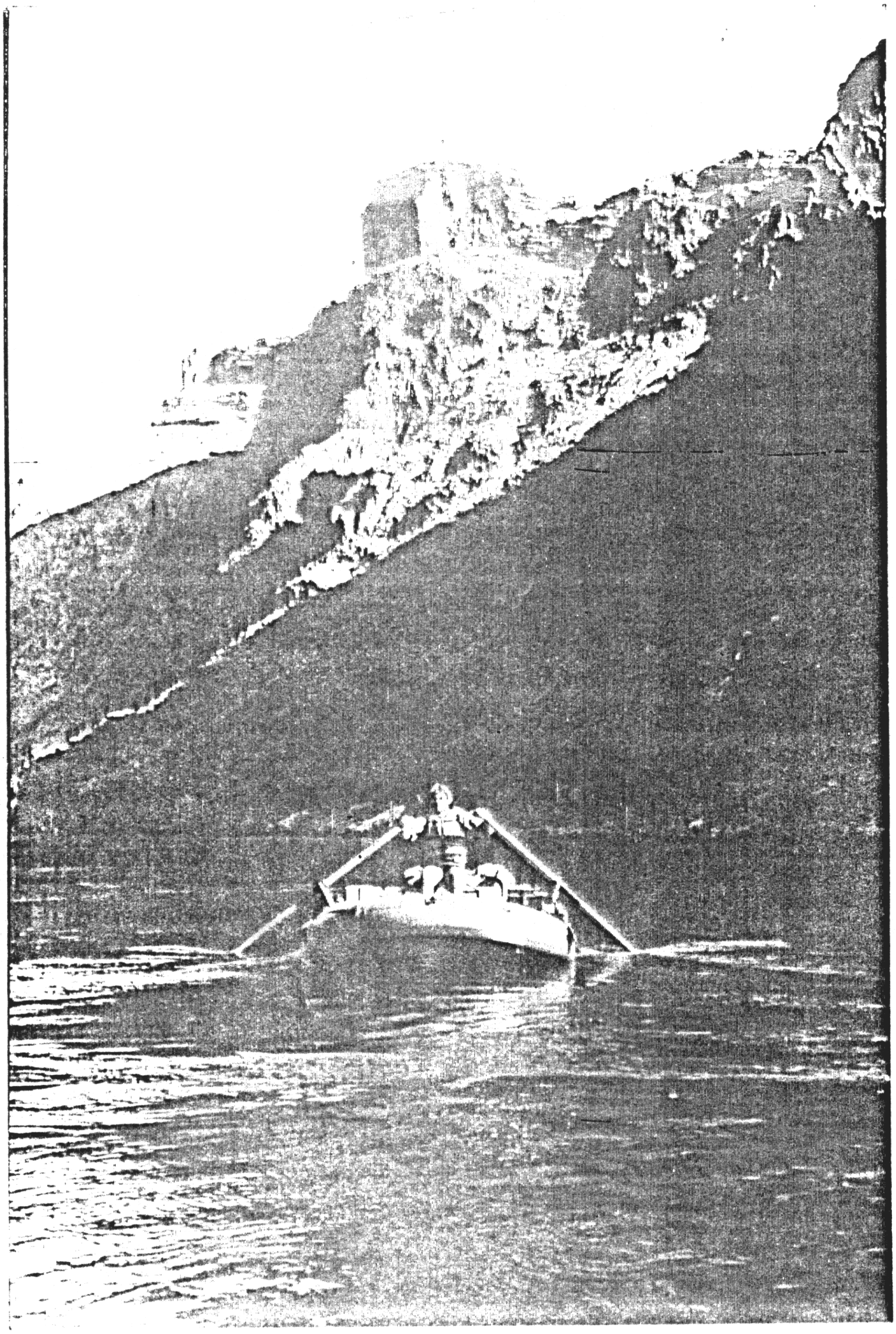


FIGURE 6- Moving from one study site to the next in slow running water

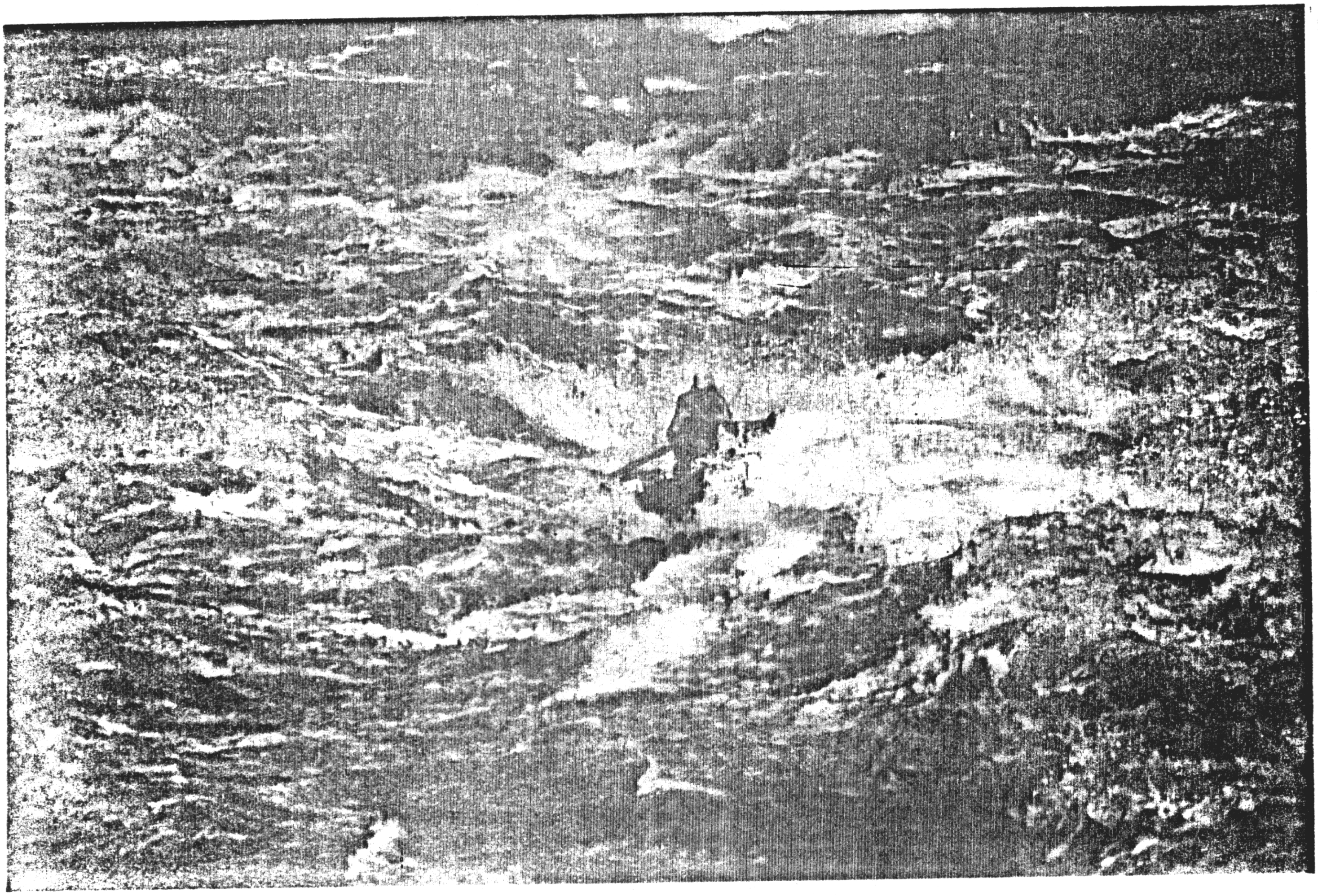


FIGURE 7- Moving from one study site to the next in Rapid conditions (Lava Falls Rapid)

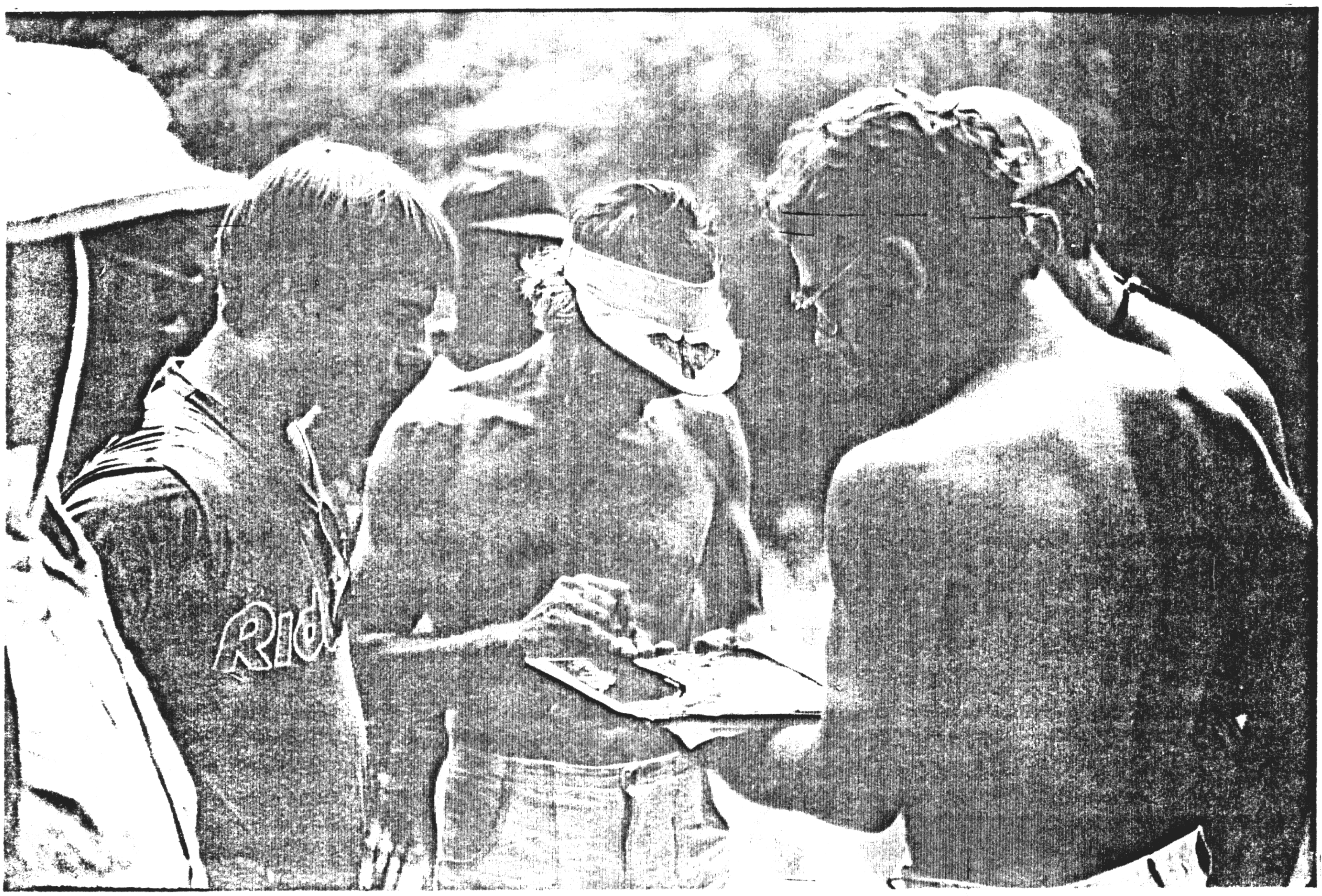


FIGURE 8- Ground truthing aerial photography in the field

FIGURE 9- Choosing a high vantage point aids in gathering ground reference information

the polygon data to map bases; however, in most areas of the Grand Canyon, 7-1/2-minute U.S. Geological Survey quadrangle maps are unavailable. For this work, available 15-minute quadrangle sheets were much too small of a scale to use. Keep in mind that the mapping resolution in some cases were 9-m^2 polygons. This was too much detail to transfer accurately onto a 1:62500 quadrangle map base.

The approach then taken was to make pseudo-UTM (Universal Transverse Mercator) grids of a scale of the 1980 photography, this being 1/4800. The 1980 date was chosen because it had the most detail and also subsequent 1985 photography was to be flown at this scale. This meant that the data would be digitized on an arbitrary UTM grid not referenced to ground coordinates; however, it would be to scale for accurate vegetation acreage tabulation. Therefore, in order to match four dates of photography on one grid, a control point file was built. Reference points were picked from each date of the photography sets. The points used in most cases were rocks and sometimes bushes. With this method employed, the river corridor's vegetation could be mapped using multitemporal data sets and digitized into our GIS (Geographic Information System) for an accurate trend analysis. By definition, a GIS is a system in which information associated with the land referenced by geographic coordinates is entered and stored by a digital computer for later retrievals, analyses, displays, and outputs for aids to modern resource decisionmaking (Koeln and Cook).

We are aware of minor scale differences, photodistortion, and mosaicing problems. However, we believe this is the best way to address this issue of digitizing and preparing vegetation overlays without proper base maps being available. Since this project was initiated, efforts by the U.S. Geological Survey to map the Grand Canyon have begun and are scheduled for completion in 1988. Any future work on this project could be referenced to these maps. Another method for georeferencing the data could be to use modern aerial photogrammetry. This method is accurate, although very expensive.

River miles were then digitized into the data base for reporting acreage statistics. The river miles were transferred from Buzz Belknap's Grand Canyon River Guide. The product of the digitizing effort is area tabular listings of vegetation in the low- and high-zone areas, with densities applied referenced by date and river mile. This product can be found in Appendix 1. Successional trends in the form of graphs were also developed and are found in Appendix 2 and 3. Map plots were produced for all dates at all study sites. An example of this product is reproduced in Appendix 4.

The digitization was accomplished by in-house contracting personnel. The digitizer used was a Calcomp 9000 table linked to a Tektronix 4014-1 display screen. This system is run by the Interactive Digital Image Manipulative Software package and the HP-3000 Computer system that is fully dedicated to remote sensing and GIS functions.

Digitization was done in vector format. This is point and line data. After digitization, computer functions ALLCOORD, TRNSFORM, STRATA, and BLDSTRAT were run to transform these data into a raster format. Rasterized data are essentially in image format. This was done to facilitate image processing and data manipulation. At this point, we were ready to apply density values, report acreage totals by river miles, and stratify out the 1965 subsets and ornithological sample plots. At one point in the study, our plans were to apply a high water mask to all dates of photography. This in turn would enable better comparison conditions among multitemporal data, as water elevations fluctuate with the operations of Glen Canyon Dam. As previously discussed, the registration process uses a control point file. The points picked are in a collinear fashion dictated by the reaches of the river chosen. This gives a poor distribution of control points with a transformation of lesser order than desired. Therefore, the water mask of one date applied to another does not fit properly and will not be used in this analysis. I will note that when we tried the water mask application on the Saddle Canyon area, it was determined that the 1980 high water image (+33,000 ft^3/s) inundated small amounts of vegetation, but some large shrubs protruded above the water and, therefore, were tabulated in the 1980 statistics. Applying this water mask to the 1973 data assumes that all vegetation under water will not be tabulated and this would be incorrect. In concluding on this issue, it should be noted that when comparing four dates of vegetation on a river environs such as the Colorado River in the Grand Canyon, water elevations should be considered if possible. For our analysis with a lack of proper base maps, the data would be improperly biased. Work completed by other study team members on beach inundation using riverflow data could aid in clarifying this issue.

In concluding the methodology section, the rasterized data are completed after applying the densities. We then extract subset data by using the river mile overlay and report it accordingly for the three complete dates; 1973, 1980, and 1985. The 1965 subset was handled by applying a substrata to extract only that portion of vegetation that was interpreted on the 1965 imagery. Because of funding not available to do the entire reach and also the poorer quality of this black and white small-scale photography (1/12000) hindering photographic analysis, very small reaches were analyzed on the 1965 imagery (approximately one-half mile of river per subset). To summarize, the subset was used as a separate strata to extract associated data from the other three dates. By using this computer technique, we have compared a small area using four dates of photography spanning 20 years of changes. (Appendix 1 & 2)

ORNITHOLOGICAL REPORT

The vegetation acreages reported in this paper will also be used in an ornithology study conducted by Bryan Brown of the Cooperative Park Service Unit at the University of Arizona, Tucson. Mr. Brown supplied me with study site boundaries plotted on the 1980 aerial photography. I had those areas digitized into separate overlays and created a strata that was used to extract that area of vegetation in the coincident imagery of 1973 and 1985. In this fashion, the vegetation in the ornithology study areas can also be compared on three different dates of photography.

The resultant data are reported on appendix 5. Any additional information regarding the ornithology research and methodology should be referred to Mr. Bryan Brown at the Cooperative Park Service Unit in Tucson, Arizona.

RESULTS AND DISCUSSION

The vegetation trends have been quantified. The author believes that trends from this study cannot be applied to the Grand Canyon as a whole. The Grand Canyon riparian area is a very dynamic system. Variables such as microclimates, tributaries, and substrate play an important role with respect to natural succession of vegetation in the Grand Canyon. These variables and others need to be taken into account before we determine trends of the entire system.

The study sites were selected nonrandomly and deemed to be important for the Glen Canyon environmental study. The results are accurate as they apply to the selected sites and probably to areas with similar environmental factors.

From 1965 to 1973, a large increase in low zone vegetation occurred. This change was tabulated as +0.491 acre/river-mile/year. Since the dam was installed in 1963, flooding conditions ceased and growth on nonnative vegetation began. Around 1973, the growth rate slowed down but was still increasing, this being at a rate of approximately +0.264 acre/river-mile/year. This slowdown of growth after 10 years could be attributed to the low zone reaching or approaching a climax state. Our data then indicate that since 1980 there was a drastic decline in the low zone vegetation. This decline was directly related to the flood of 1983. The data in Appendix 1 and graphs in Appendix 3 show the decline beginning in 1980. We used 1980 photography for preflood conditions and then 1985 data for postflood conditions. We know that the flood was in 1983; however, the data indicate a decline in growth starting in 1980. The trend in vegetation should still be increasing until 1983. Keeping this in mind, we can say that conservatively, the low zone vegetation lost -0.518 acre/river-mile/year since 1980. This rate would be higher knowing that the losses occurred since 1983, and also that growth occurred between 1980 and 1983.

In summary of the low zone trend, the 1973 analysis indicated 76.647 acres of non-native vegetation in our 19.2 miles of river surveyed. Then in the 1980 survey, we tabulated a significant increase of 35.501 acres yielding 112.148 acres of low zone vegetation in the riparian community. Reiterating the fact that the flood was in 1983, and applying the growth rate from this study, the vegetation then should have been approximately 127.206 acres assuming that the system did not reach climax conditions. The flood was directly responsible for a significant loss 49.684 acres of vegetation bringing the low zone vegetation back to 77.522 acres or 1973 conditions. The question is will the low zone vegetation rejuvenate in 10 years and is there sufficient enough substrate to support this growth? The scenario just described is based on the assumption that no flooding occurred between 1965 and 1983. We do know that tributaries frequently flash flood, impeding growth in those areas. Refer to Table 1 and Table 2 for information on growth trends in both low zone and high zone areas pertaining to specific study sites.

The native high zone trend, from the 1965-1973 period, appears to be increasing, but at a rate 5 times slower than that of the low zone vegetation (+0.102 acre/river-mile/year). From 1973-1980, this trend was slightly less at +0.094 acre/river-mile/year. A significant observation occurred when analyzing the 1980 to 1985 data being a negative growth rate equaling a decline of -0.227 acre/river-mile/year. It should be noted that 17 out of the 23 study plots showed a negative growth rate. In summary of the high zone trend, the 1973 analysis indicated 112.35 acres of native vegetation in our 19.2 miles of river surveyed. Then in the 1980 survey, we tabulated an insignificant increase of 12.626 acres, yielding, 124.976 acres of native vegetation in the riparian community. The 1985 data then tabulates 103.21 acres of native vegetation or a significant loss of 21.766 acres in the native high zone. See table 3 for t-test results indicating where significant changes occurred.

During the course of this study, I was fortunate to visit the Grand Canyon three times. Personal observations indicate that a dieback of the natives is occurring. Since the flood of 1983, positive response in growth of native vegetation is apparent. This growth is not yet detectable on the aerial photography. Another inventory with 1990 aerial photography would verify these trends.

After analyzing the trend of the native plants, one can only hypothesize that if floods were the only variable in sustaining native riparian vegetation in the Grand Canyon, then a major flood is necessary once every 15 years or sooner depending on the positive effects of the flood.

Many other issues should be researched before any such action is recommended.

1. Has the wildlife adapted to the nonnative plants; if so, what are the impacts of flooding on the wildlife in the low zone?

2. What are the impacts of the fisheries in flooding conditions?

3. Assuming less sediment input to the system, will 15-year flood increments deteriorate beaches for recreation and low zone growth?

Future recommendations for monitoring the vegetation trends are: (1) to continue these methods in 5- to 7-year increments, (2) to use map bases if they become available, and (3) to address the trends in the entire Grand Canyon. A random sample for new study sites should be developed to arrive at an extrapolatable data set. We could then determine total vegetation and trend analysis in the entire Grand Canyon riparian system.

ACKNOWLEDGMENTS

This study was supported by the Upper Colorado Regional Office of the U.S. Bureau of Reclamation. I commend Mr. Dave Wegner on the excellent job he has done coordinating among the many subteams involved in the Grand Canyon Environmental Study. It has been especially rewarding being a member and working with all the members of the Biological Study Team. The entire staff was very helpful, courteous, and professional. I thank the boatmen for their help in experiencing the Grand Canyon. I acknowledge the special efforts of Lori Sims, Joanne Halls, and Pam Cruze for digitizing the data. I also thank Mr. Gerald Teter for assisting with a flow chart of computer functions and many hours of guidance with computer analysis.

Copy to: D-150
D-400
D-842B
D-1522
D-1524
D-1524 (Pucherelli)

BIBLIOGRAPHY

[1] Carothers, S. W., and others, "An Ecological Survey of the Riparian Zone of the Colorado River Between Lees Ferry and Grand Wash Cliffs," Final Research Report No. 10, USDI, 1976.

[2] Johnson, R. A., and others, "Digitization and Resource Monitoring of Colorado River Beaches in Grand Canyon National Park, Arizona," Final Research Report Cooperative Agreement No. CA-8001-82-10, USDI, NPS, 1983.

[3] Koeln, G. T., and E. A. Cook, "Applications of Geographic Information Systems for Analysis of Radio Telemetry Data on Wildlife," Proceedings of the 1984 Pecora Symposium, Sioux Falls, South Dakota.

[4] Turner, R. M., and Karpiscak, Martin, "Recent Vegetation Changes Along the Colorado River Between Glen Canyon Dam and Lake Mead, Arizona," USGS publication 1132-1980.

APPENDIX I

Saddle Canyon Area

Vegetation Association

River miles	TV	HZ	LZ
SC-1985			
44-45	8.095	4.394	3.701
45-46	7.992	1.994	5.998
46-47	14.737	3.316	11.421
47-47.5	8.164	4.827	3.337
Study site totals	38.988	14.531	24.457
SC-1980			
44-45	10.176	3.359	6.816
45-46	9.771	3.225	6.545
46-47	17.959	5.923	12.033
47-47.5	10.518	5.632	4.882
Study site totals	48.424	18.139	30.276
SC-1973			
44-45	9.104	3.718	5.386
45-46	8.429	3.061	5.367
46-47	15.822	4.834	10.986
47-47.5	6.912	3.925	2.986
Study site totals	40.267	15.538	24.725

Note: All areas reported in acres.

APPENDIX I

Saddle Canyon Area

Vegetation Associations

River miles	V65 Sub (1)			V65 Sub (2)		
	TV	HZ	LZ	TV	HZ	LZ
SC-1985						
44-45				2.818	1.491	1.327
45-46				3.600	0.916	2.684
46-47	0.320	0.200	0.120			
47-47.5	4.707	3.073	1.634			
Study site totals	5.027	3.273	1.754	6.418	2.407	4.011
SC-1980						
44-45				2.148	0.385	1.763
45-46				4.328	1.342	2.986
46-47	0.799	0.312	0.486			
47-47.5	6.285	3.593	2.691			
Study site totals	7.084	3.905	3.177	6.476	1.727	4.749
SC-1973						
44-45				2.118	0.417	1.701
45-46				3.675	1.460	2.214
46-47	0.578	0.206	0.371			
47-47.5	3.598	2.450	1.148			
Study site totals	4.176	2.656	1.519	5.793	1.877	3.915
SC-1965						
44-45				0.673	0.218	0.454
45-46				1.656	1.585	0.071
46-47	0.456	0.456	0.000			
47-47.5	4.215	4.018	0.196			
Study site totals	4.617	4.474	0.196	2.329	1.803	0.525

Note: All areas reported in acres.

APPENDIX I

Cardenas Marsh Area

Vegetation Associations

River miles	TV	HZ	LZ
CA-1985			
70-71	21.322	12.347	8.975
71-72	9.405	2.014	7.391
72-73	19.317	13.247	6.071
Study site totals	50.044	27.608	22.437
CA-1980			
70-71	27.971	12.344	15.627
71-72	16.386	3.724	12.638
72-73	23.324	13.712	9.613
Study site totals	67.681	29.780	37.878
CA-1973			
70-71	23.533	13.061	10.471
71-72	14.651	5.263	9.388
72-73	25.318	17.361	7.955
Study site totals	63.502	35.685	27.814

Note: All areas reported in acres.

APPENDIX I

Cardenas Marsh Area

Vegetation Associations

River miles	V65 Sub (1)			V65 Sub (2)		
	TV	HZ	LZ	TV	HZ	LZ
CA-1985						
70-71				0.180	0.107	0.073
71-72				5.409	1.087	4.322
72-73	10.410	5.152	5.257			
Study site totals	10.410	5.152	5.257	5.589	1.194	4.395
CA-1980						
70-71				0.432	0.073	0.358
71-72				8.263	1.380	6.833
72-73	8.853	3.026	5.827			
Study site totals	8.853	3.026	5.827	8.695	1.453	7.241
CA-1973						
70-71				0.268	0.084	0.183
71-72				8.153	1.876	6.278
72-73	10.254	4.904	5.349			
Study site totals	10.254	4.904	5.349	8.421	1.960	6.461
CA-1965						
70-71				0.154	0.102	0.511
71-72				4.161	1.427	2.734
72-73	5.207	3.506	1.700			
Study site totals	5.207	3.506	1.700	4.315	1.529	3.245

Note: All areas reported in acres.

APPENDIX I

Bass Canyon Area

Vegetation Associations

River miles	TV	HZ	LZ
BA-1985			
105.5-106	0.547	0.483	0.063
106-107	1.000	0.978	0.021
107-108	0.817	0.760	0.008
108-108.4	0.405	0.223	0.182
Study site totals	2.769	2.444	0.274
BA-1980			
105.5-106	0.757	0.479	0.277
106-107	1.427	1.228	0.199
107-108	1.009	0.541	0.466
108-108.4	0.683	0.254	0.428
Study site totals	3.876	2.502	1.370
BA-1973			
105.5-106	0.257	0.231	0.025
106-107	0.744	0.663	0.081
107-108	0.645	0.377	0.272
108-108.4	0.588	0.204	0.384
Study site totals	2.234	1.475	0.762

Note: All areas reported in acres.

APPENDIX I

Bass Canyon Area

Vegetation Associations

River miles	V65 Sub (1)			V65 Sub (2)		
	TV	HZ	LZ	TV	HZ	LZ
BA-1985						
105.5-106						
106-107						
107-108	0.084	0.075	0.009			
108-108.4				0.293	0.112	0.181
Study site totals	0.084	0.075	0.009	0.293	0.112	0.181
BA-1980						
105.5-106						
106-107						
107-108	0.188	0.033	0.155			
108-108.4				0.487	0.187	0.299
Study site totals	0.188	0.033	0.155	0.487	0.187	0.299
BA-1973						
105.5-106						
106-107						
107-108	0.123	0.036	0.086			
108-108.4				0.467	0.165	0.302
Study site totals	0.123	0.036	0.086	0.467	0.165	0.302
BA-1965						
105.5-106						
106-107						
107-108	0.018	0.015	0.003			
108-108.4				0.103	0.075	0.028
Study site totals	0.018	0.015	0.003	0.103	0.075	0.028

Note: All areas reported in acres.

APPENDIX I

Forster/Blacktail Canyon Areas

Vegetation Associations

River miles	TV	HZ	LZ
F0-1985			
120-121	1.007	0.792	0.215
121-122	0.491	0.437	0.054
122-123	3.211	1.526	1.685
Study site totals	4.709	2.755	1.954
F0-1980			
120-121	2.018	1.091	0.926
121-122	0.756	0.465	0.291
122-123	5.392	1.706	3.684
Study site totals	8.166	3.262	4.901
F0-1973			
120-121	0.525	0.266	0.260
121-122	0.597	0.425	0.172
122-123	3.065	1.212	1.853
Study site totals	4.187	1.903	2.285

Note: All areas reported in acres.

APPENDIX I

Forster/Blacktail Canyon Areas

Vegetation Associations

River miles	V65 Sub (1)			V65 Sub (2)		
	TV	HZ	LZ	TV	HZ	LZ
FO-1985						
120-121				0.417	0.365	0.052
121-122						
122-123	1.047	0.595	0.452			
Study site totals	1.047	0.595	0.452	0.417	0.365	0.052
FO-1980						
120-121				0.968	0.597	0.370
121-122						
122-123	1.510	0.593	0.916			
Study site totals	1.510	0.593	0.916	0.968	0.597	0.370
FO-1973						
120-121				0.113	0.050	0.063
121-122						
122-123	0.836	0.356	0.481			
Study site totals	0.836	0.356	0.481	0.113	0.050	0.063
FO-1965						
120-121				0.013	0.013	0.000
121-122						
122-123	0.478	0.008	0.469			
Study Site totals	0.478	0.008	0.469	0.013	0.013	0.000

Note: All areas reported in acres.

APPENDIX I

National Canyon Area

Vegetation Association

River miles	TV	HZ	LZ
NA-1985			
166.1-167	7.150	5.905	1.245
167-168	5.359	2.924	2.435
168-168.7	4.108	3.953	0.155
Study site totals	16.617	12.782	3.835
NA-1980			
166.1-167	15.305	9.432	5.869
167-168	10.210	4.648	5.561
168-168.7	7.749	5.602	2.146
Study site totals	33.264	19.682	13.576
NA-1973			
166.1-167	9.499	6.549	2.948
167-168	6.665	3.606	3.059
168-168.7	3.062	2.455	0.607
Study site totals	19.226	12.610	6.614

Note: All areas reported in acres.

APPENDEX I

Granite Park Area

Vegetation Associations

River miles	TV	HZ	LZ
GP-1985			
207-208	24.221	19.363	4.858
208-209	18.820	16.074	2.746
209-209.2	3.152	2.649	0.503
Study site totals	46.193	38.086	8.107
GP-1980			
207-208	33.469	24.500	8.969
208-209	24.888	15.819	9.068
209-209.2	4.880	3.422	1.457
Study site totals	63.237	43.741	19.494
GP-1973			
207-208	28.069	23.042	5.027
208-209	19.002	12.625	6.376
209-209.2	4.428	3.374	1.054
Study site totals	51.499	39.041	12.457

Note: All areas reported in acres.

APPENDIX I

National Canyon Area

Vegetation Associations

River miles	V65 Sub (1)			V65 Sub (2)		
	TV	HZ	LZ	TV	HZ	LZ
NA-1985						
166.1-167				0.697	0.506	0.191
167-168	1.896	1.073	0.823	0.087	0.087	0.000
168-168.7	0.149	0.123	0.026			
Study site total	2.045	1.196	0.849	0.784	0.593	0.191
NA-1980						
166.1-167				1.649	0.786	0.862
167-168	3.088	1.354	1.734	0.157	0.149	0.007
168-168.7	0.456	0.367	0.089			
Study site total	3.544	1.721	1.823	1.806	0.935	0.869
NA-1973						
166.1-167				1.371	0.732	0.638
167-168	2.049	1.088	0.961	0.115	0.115	0.000
168-168.7	0.221	0.196	0.025			
Study site totals	2.270	1.284	0.986	1.486	0.847	0.638
NA-1965						
166.1-167				0.444	0.426	0.018
167-168	1.477	1.305	0.171	0.000	0.000	0.000
168-168.7	0.450	0.450	0.000			
Study site totals	1.927	1.755	0.171	0.444	0.426	0.018

Note: All areas reported in acres.

APPENDIX I

Granite Park Area

Vegetation Associations

River miles	V65 Sub (1)			V65 Sub (2)		
	TV	HZ	LZ	TV	HZ	LZ
GP-1985						
207-208				1.659	1.205	0.454
208-209	6.496	5.119	1.377			
209-209.2						
Study site totals	6.496	5.119	1.377	1.659	1.205	0.454
GP-1980						
207-208				2.909	1.957	0.951
208-209	8.034	5.205	1.443			
209-209.2						
Study site totals	8.034	5.205	1.443	2.909	1.957	0.951
GP-1973						
207-208				2.460	1.679	0.781
208-209	6.076	4.401	1.674			
209-209.2						
Study site totals	6.076	4.401	1.674	2.460	1.679	0.781
GP-1965						
207-208				0.744	0.651	0.092
208-209	5.299	4.958	0.340			
209-209.2						
Study site totals	5.299	4.958	0.340	0.744	0.651	0.092

Note: All areas reported in acres.

APPENDIX I

Granite Springs Aaea

Vegetation Associations

River miles	TV	HZ	LZ
GS-1985			
218.6-219	0.230	0.051	0.179
219-220	3.776	3.315	0.461
220-220.6	2.398	1.638	0.760
Study site totals	6.404	5.004	1.400
GS-1980			
218.6-219	0.369	0.038	0.331
219-220	7.212	4.875	2.336
220-220.6	4.928	2.959	1.986
Study site totals	12.509	7.872	4.635
GS-1973			
218.6-219	0.277	0.132	0.144
219-220	4.364	3.468	0.896
220-220.6	3.454	2.503	0.950
Study site totals	8.095	6.103	1.990

Note: All areas reported in acres.

APPENDIX I

Granite Springs Area

Vegetation Associations

River miles	V65 Sub (1)			V65 Sub (2)		
	TV	HZ	LZ	TV	HZ	LZ
GS-1985						
218.6-219						
219-220	2.690	2.441	0.249			
220-220.6	0.431	0.353	0.078	0.476	0.402	0.074
Study site totals	3.121	2.794	0.327	0.476	0.402	0.074
GS-1980						
218.6-219						
219-220	5.365	4.179	1.185			
220-220.6	1.011	0.777	0.233	0.798	0.579	0.219
Study site totals	6.376	4.956	1.418	0.798	0.579	0.219
GS-1973						
218.6-219						
219-220	3.036	2.697	0.338			
220-220.6	0.696	0.644	0.052	0.789	0.578	0.210
Study site totals	3.732	3.341	0.390	0.789	0.578	0.210
GS-1965						
218.6-219						
219-220	1.091	0.959	0.132			
220-220.6	0.317	0.281	0.037	0.363	0.363	0.0
Study site totals	1.408	1.240	0.169	0.363	0.363	0.0

Note: All areas reported in acres.

APPENDIX I

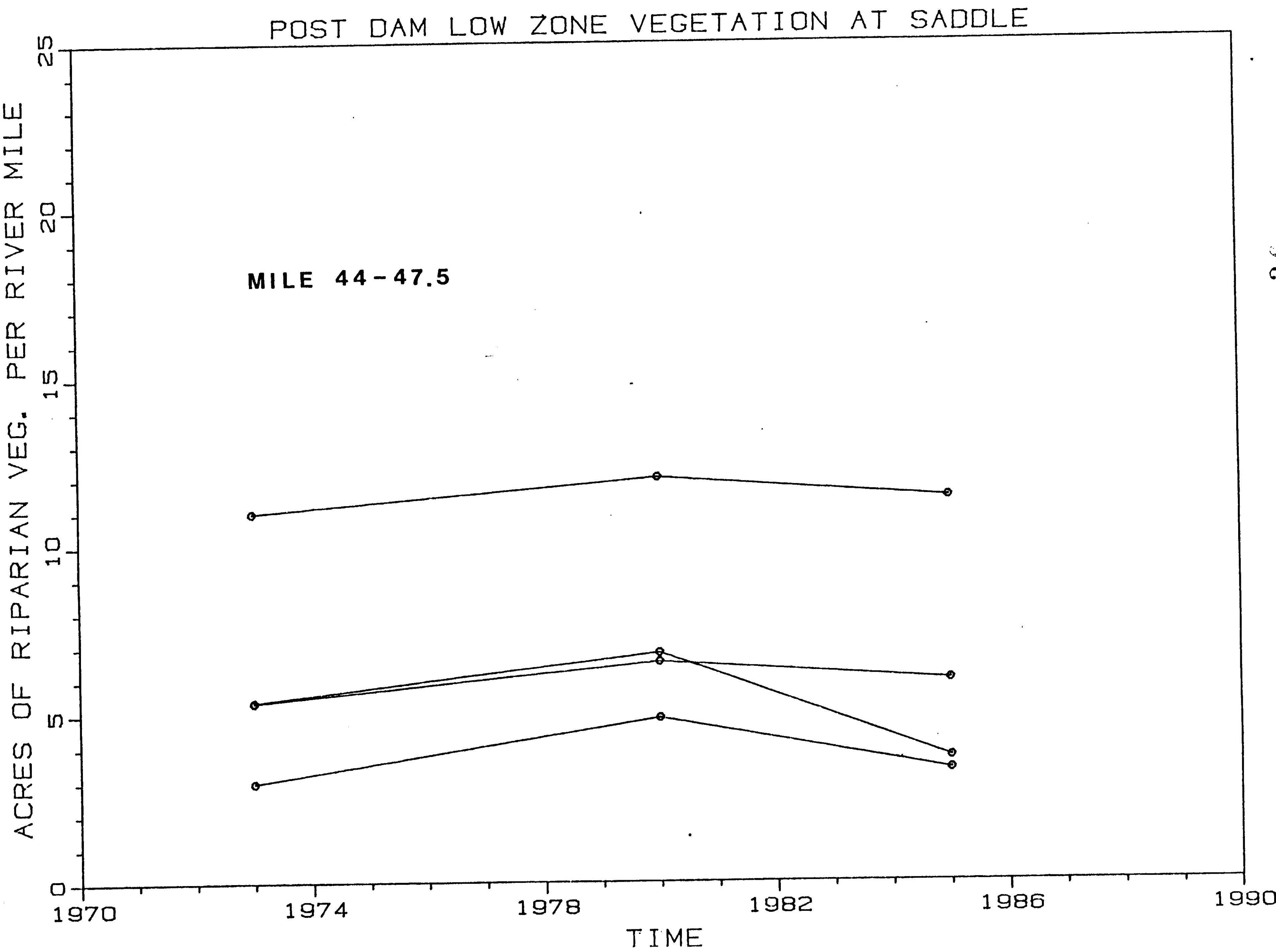
Duck Island Area

Vegetation Associations

River miles	TV	HZ	LZ
DU-1985			
-9.3 - -10	12.632	2.806	9.826
-10 - -11	14.082	2.395	11.687
-11 - -12	7.577	1.360	6.217
-12 - -13	13.303	3.533	9.777
-13 - -14	9.183	3.057	6.127
Study site totals	56.777	13.151	43.633
DU-1979			
-9.3 - -10	16.277	3.582	12.695
-10 - -11	19.733	4.168	15.565
-11 - -12	8.322	1.166	7.156
-12 - -13	15.219	2.645	12.574
-13 - -14	18.788	2.934	15.854
Study site totals	78.339	14.495	63.844

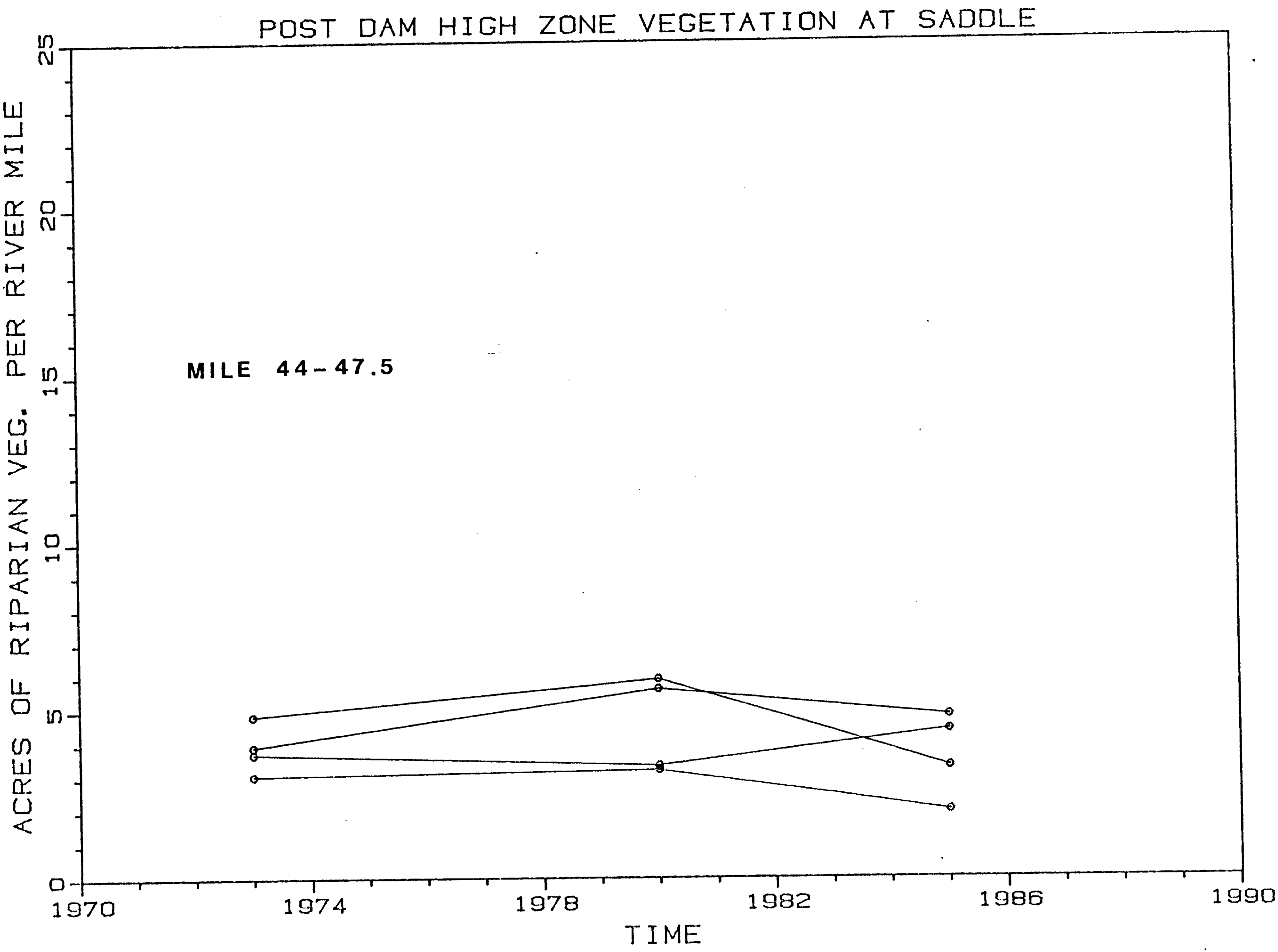
Notes: All areas reported in acres.
No 1965 subset was evaluated in this site.

APPENDIX 2



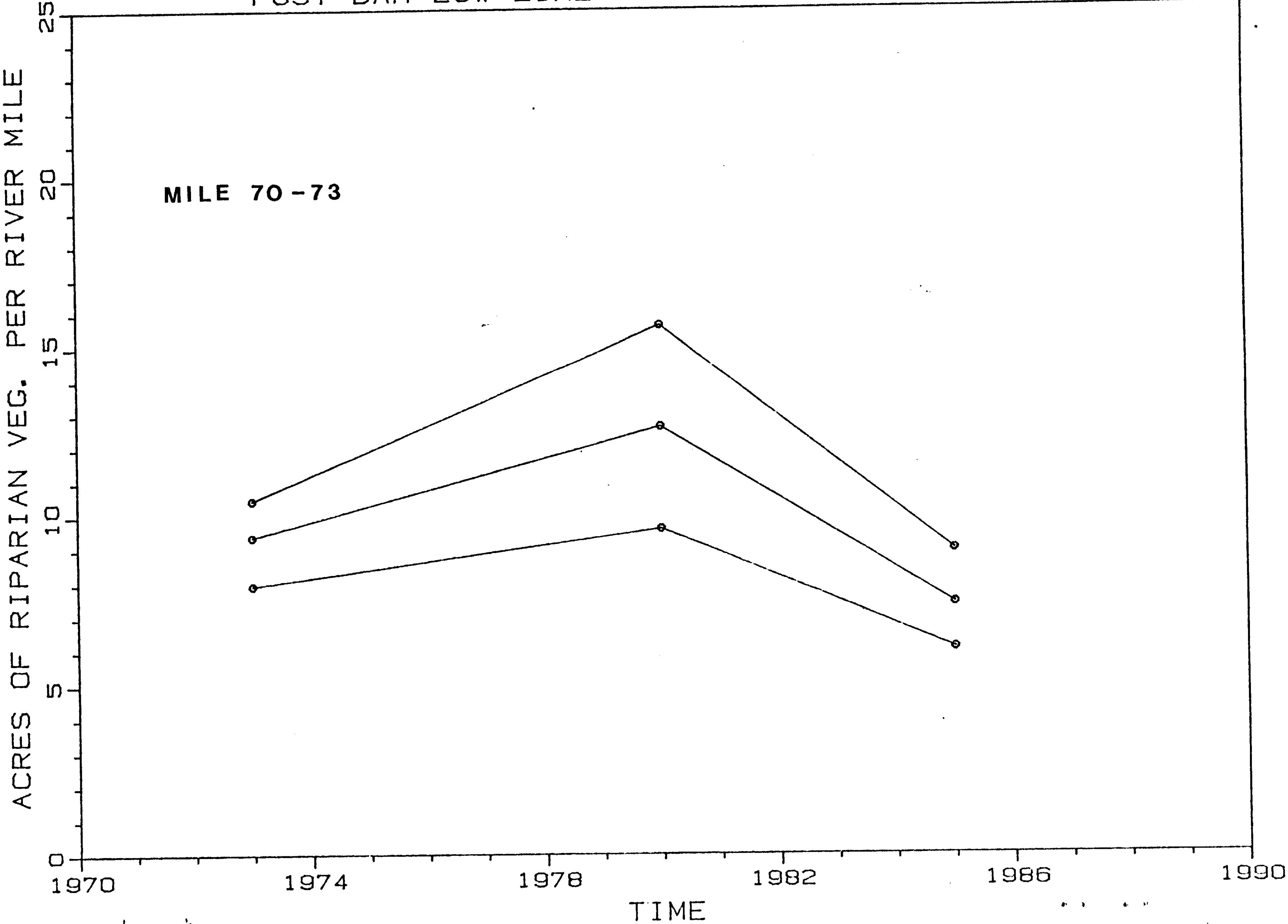
POST DAM LOW ZONE VEGETATION AT SADDLE
MILE 44-47.5
ACRES OF RIPARIAN VEG. PER RIVER MILE
0
5
10
15
20
25
1970
1974
1978
1982
1986
1990
TIME

APPENDIX 2

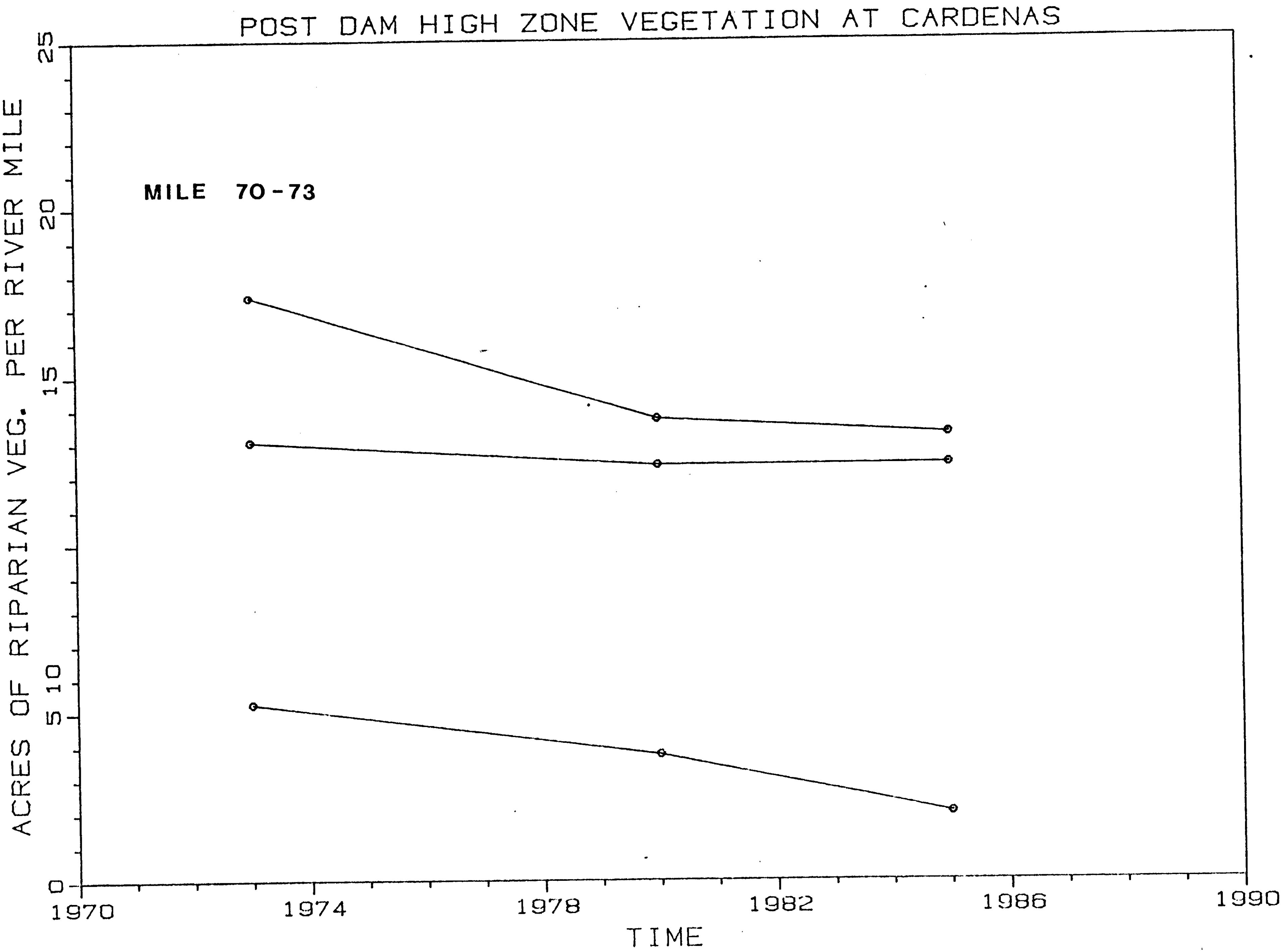

POST DAM HIGH ZONE VEGETATION AT SADDLE
MILE 44-47.5
ACRES OF RIPARIAN VEG. PER RIVER MILE
0
5
10
15
20
25
1970
1974
1978
1982
1986
1990
TIME

APPENDIX 2

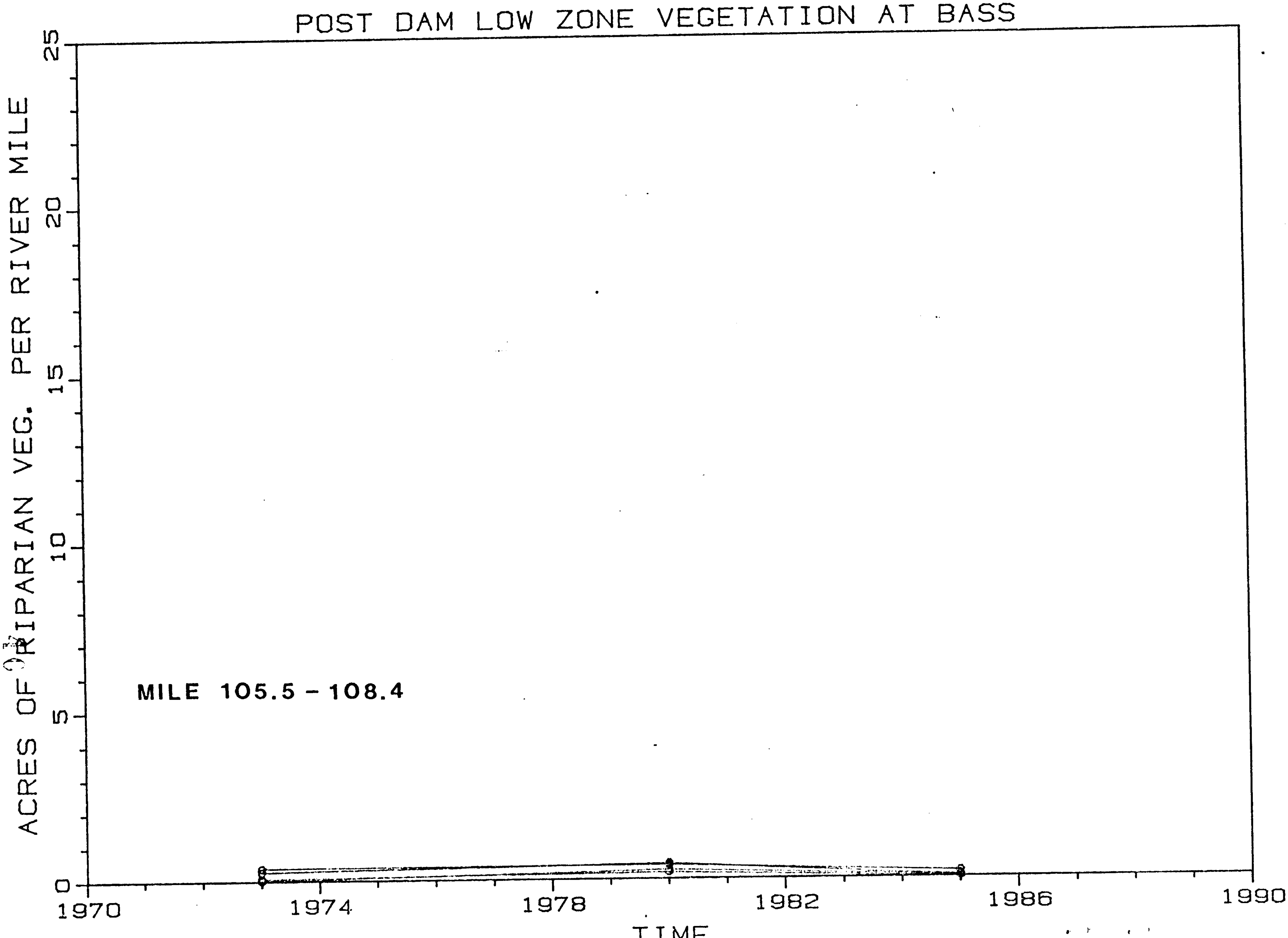
POST DAM LOW ZONE VEGETATION AT CARDENAS



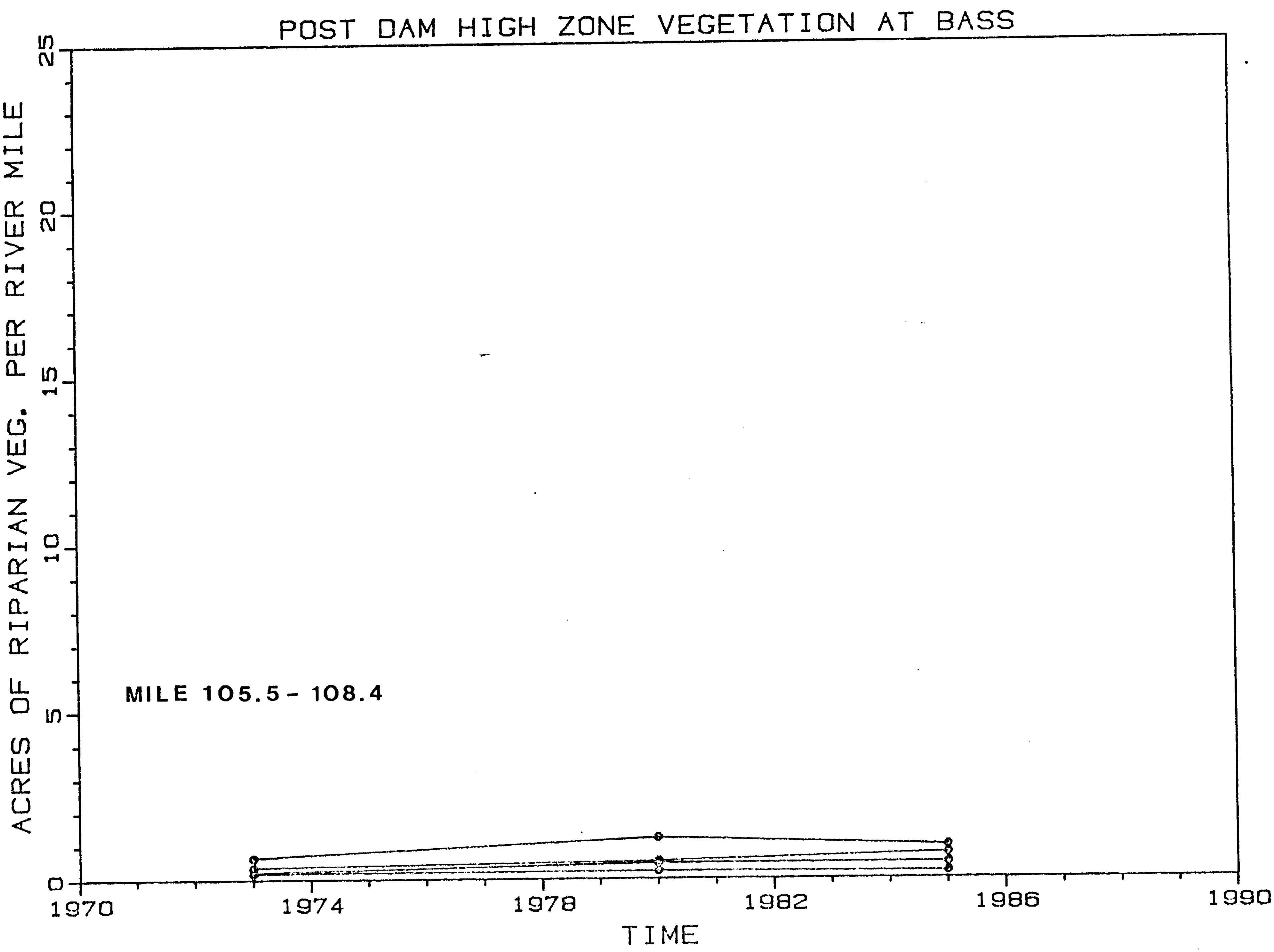
APPENDIX 2


POST DAM HIGH ZONE VEGETATION AT CARDENAS
MILE 70-73
ACRES OF RIPARIAN VEG. PER RIVER MILE
25
20
15
10
5
0
1970
1974
1978
1982
1986
1990
TIME

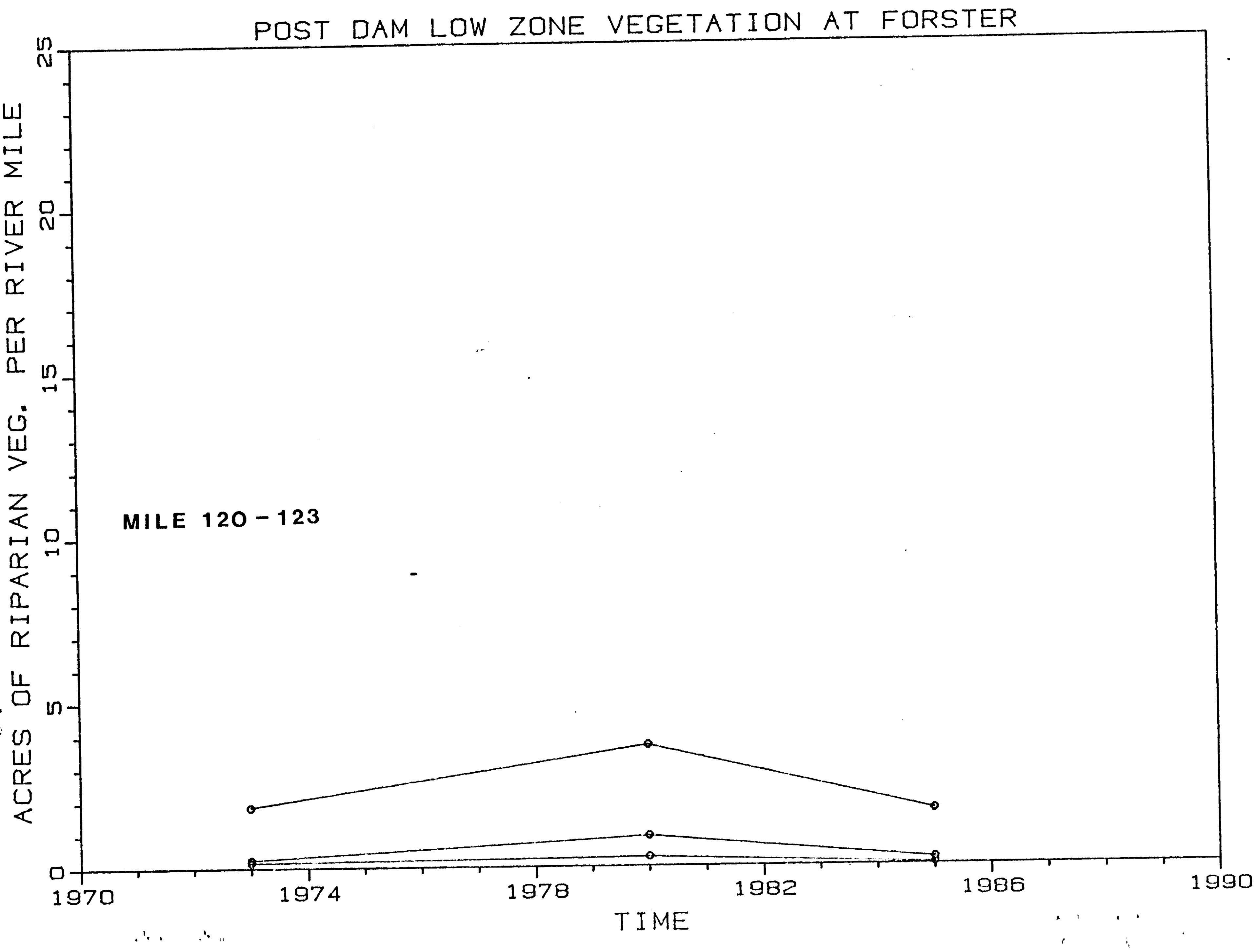
APPENDIX 2

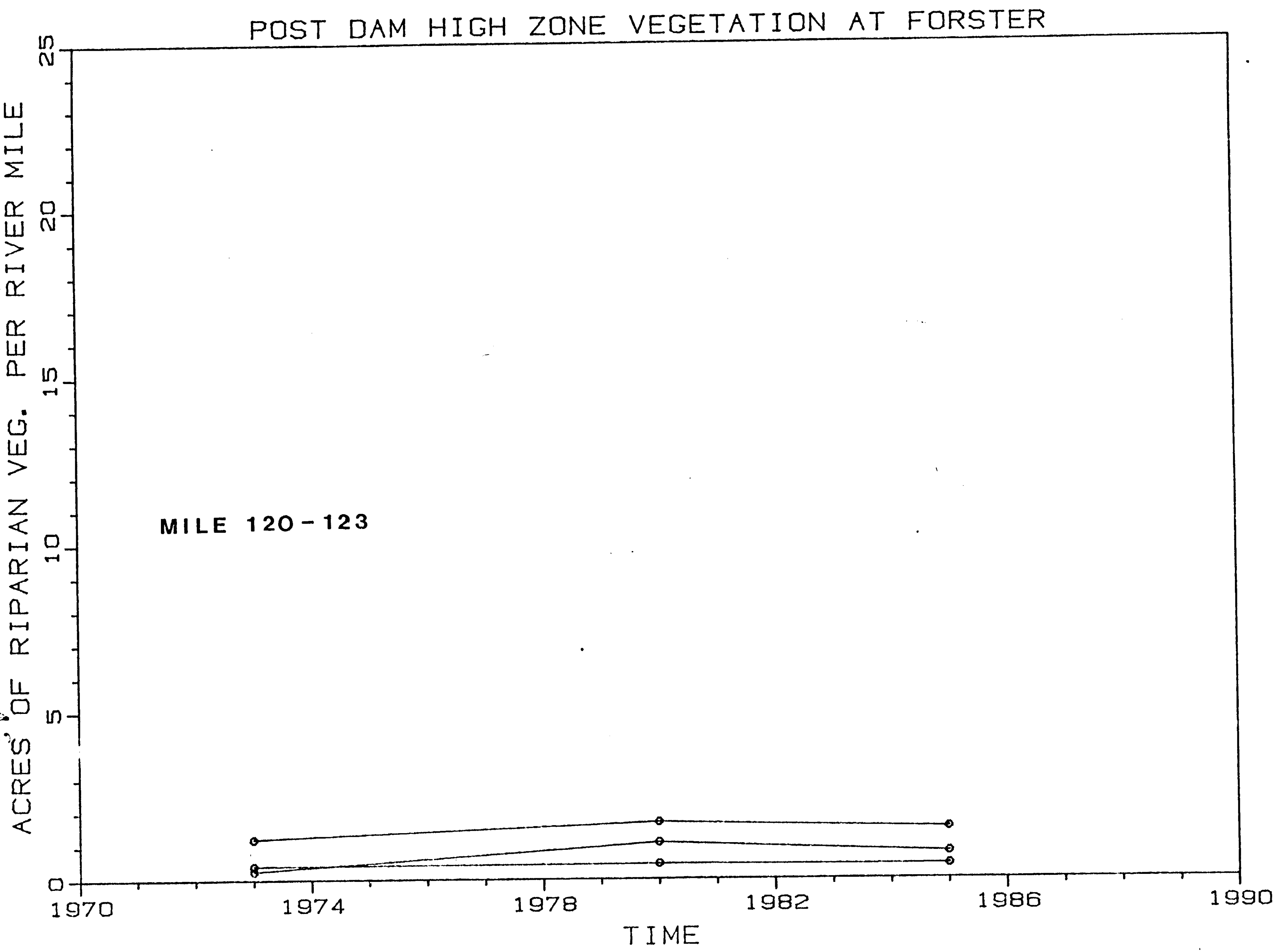

POST DAM LOW ZONE VEGETATION AT BASS
ACRES OF RIPARIAN VEG. PER RIVER MILE
0
5
10
15
20
25
1970
1974
1978
1982
1986
1990
TIME
MILE 105.5 - 108.4

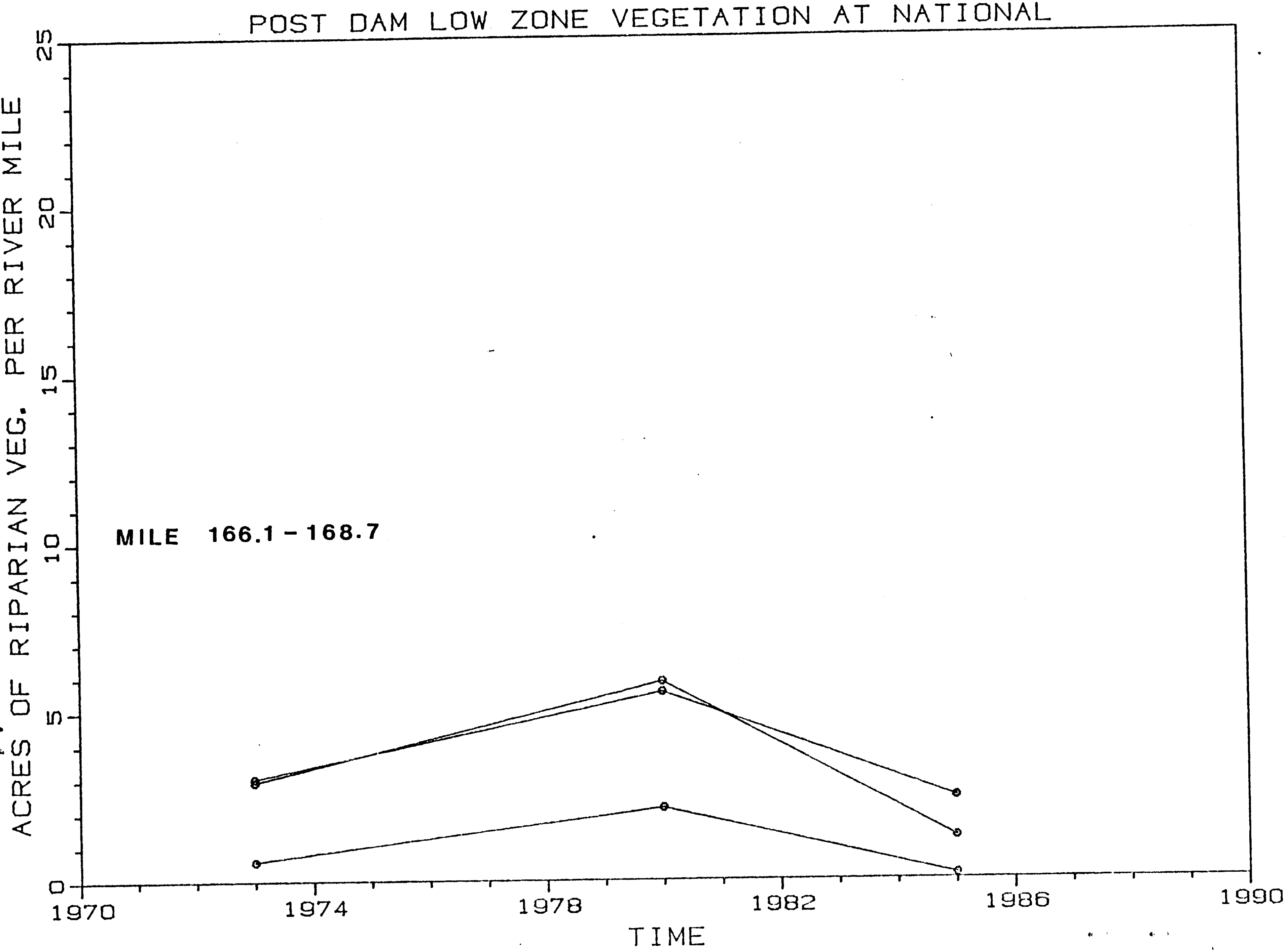
APPENDIX 2



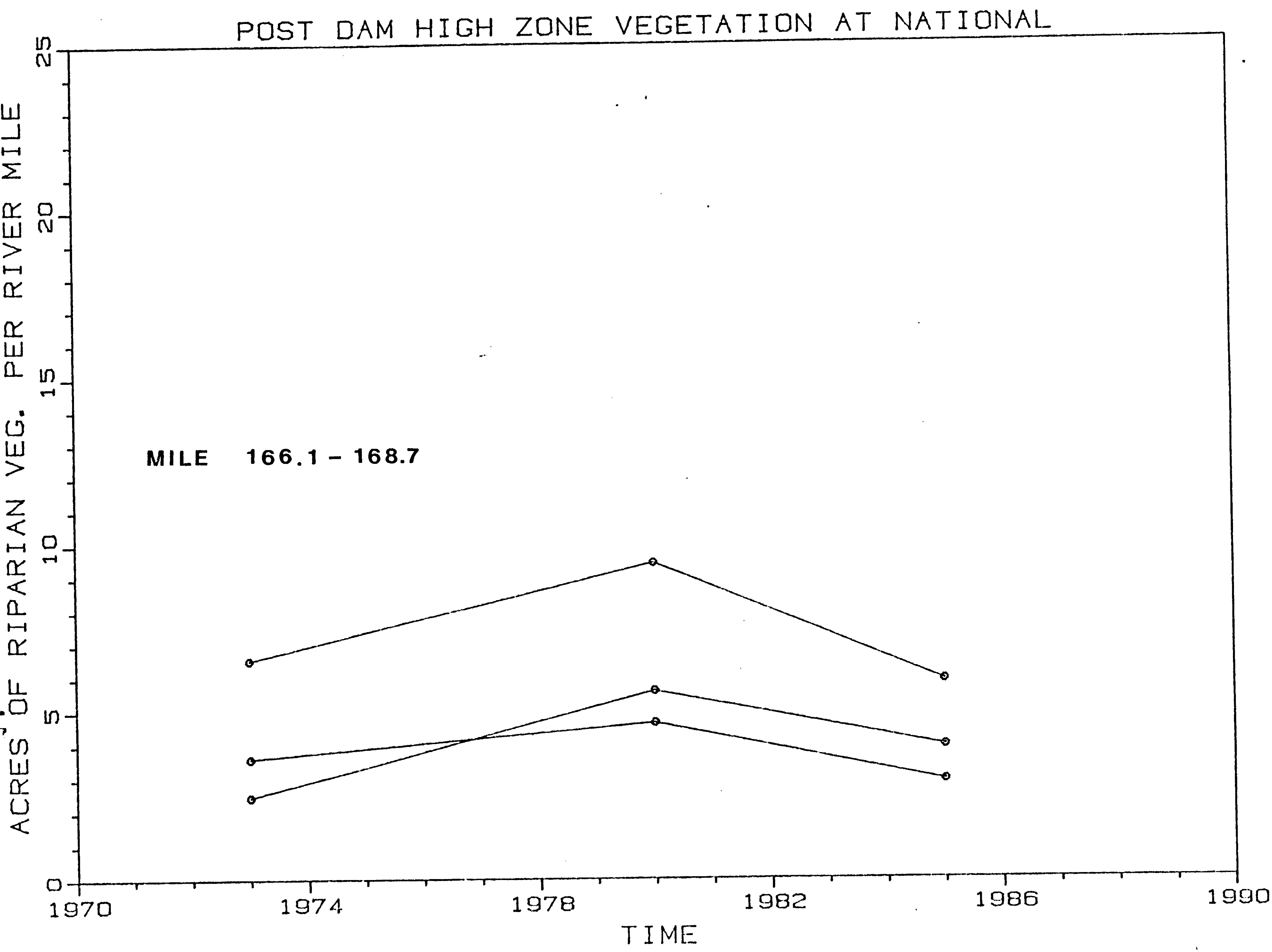
POST DAM HIGH ZONE VEGETATION AT BASS
ACRES OF RIPARIAN VEG. PER RIVER MILE
25
20
15
10
5
0
MILE 105.5 - 108.4
1970
1974
1978
1982
1986
1990
TIME


POST DAM LOW ZONE VEGETATION AT FORSTER
MILE 120 - 123
ACRES OF RIPARIAN VEG. PER RIVER MILE
0
5
10
15
20
25
1970
1974
1978
1982
1986
1990
TIME


POST DAM HIGH ZONE VEGETATION AT FORSTER
MILE 120-123
ACRES OF RIPARIAN VEG. PER RIVER MILE
0
5
10
15
20
25
1970
1974
1978
1982
1986
1990
TIME


POST DAM LOW ZONE VEGETATION AT NATIONAL
ACRES OF RIPARIAN VEG. PER RIVER MILE
25
20
15
10
5
0
MILE 166.1 - 168.7
1970
1974
1978
1982
1986
1990
TIME

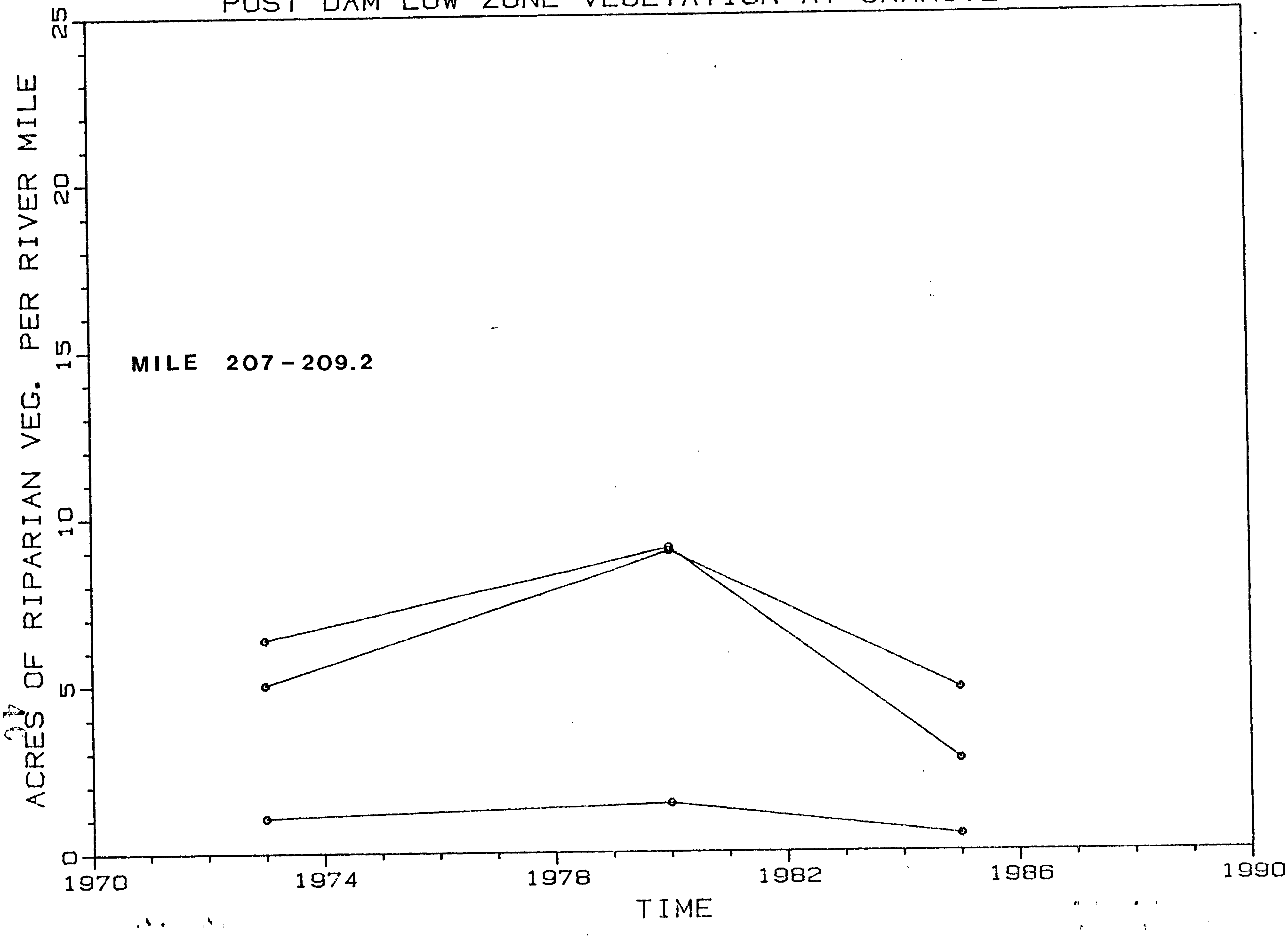
APPENDIX 2



POST DAM HIGH ZONE VEGETATION AT NATIONAL
MILE 166.1 - 168.7
ACRES OF RIPARIAN VEG. PER RIVER MILE
0
5
10
15
20
25
1970
1974
1978
1982
1986
1990
TIME

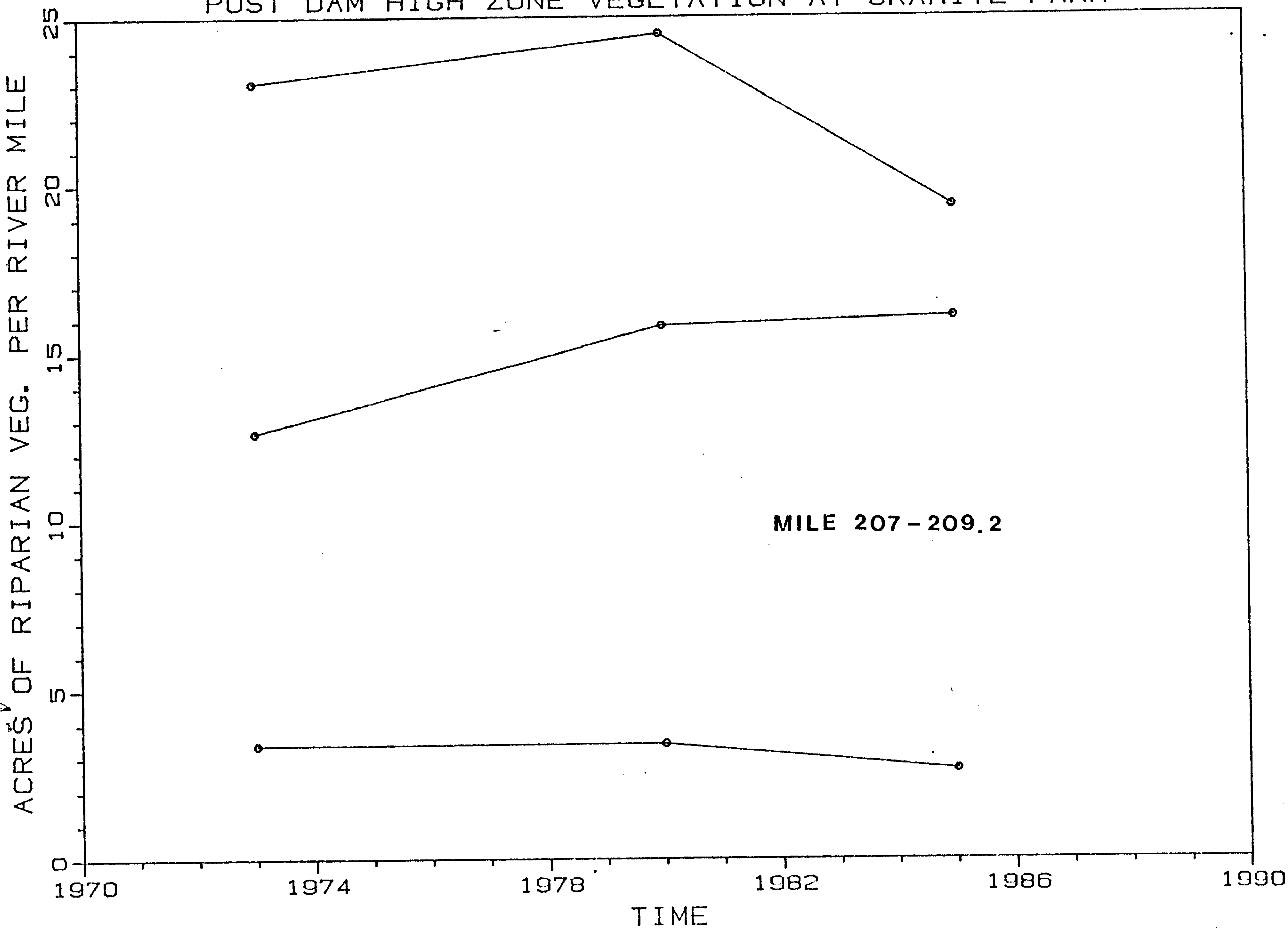
APPENDIX 2

POST DAM LOW ZONE VEGETATION AT GRANITE PARK

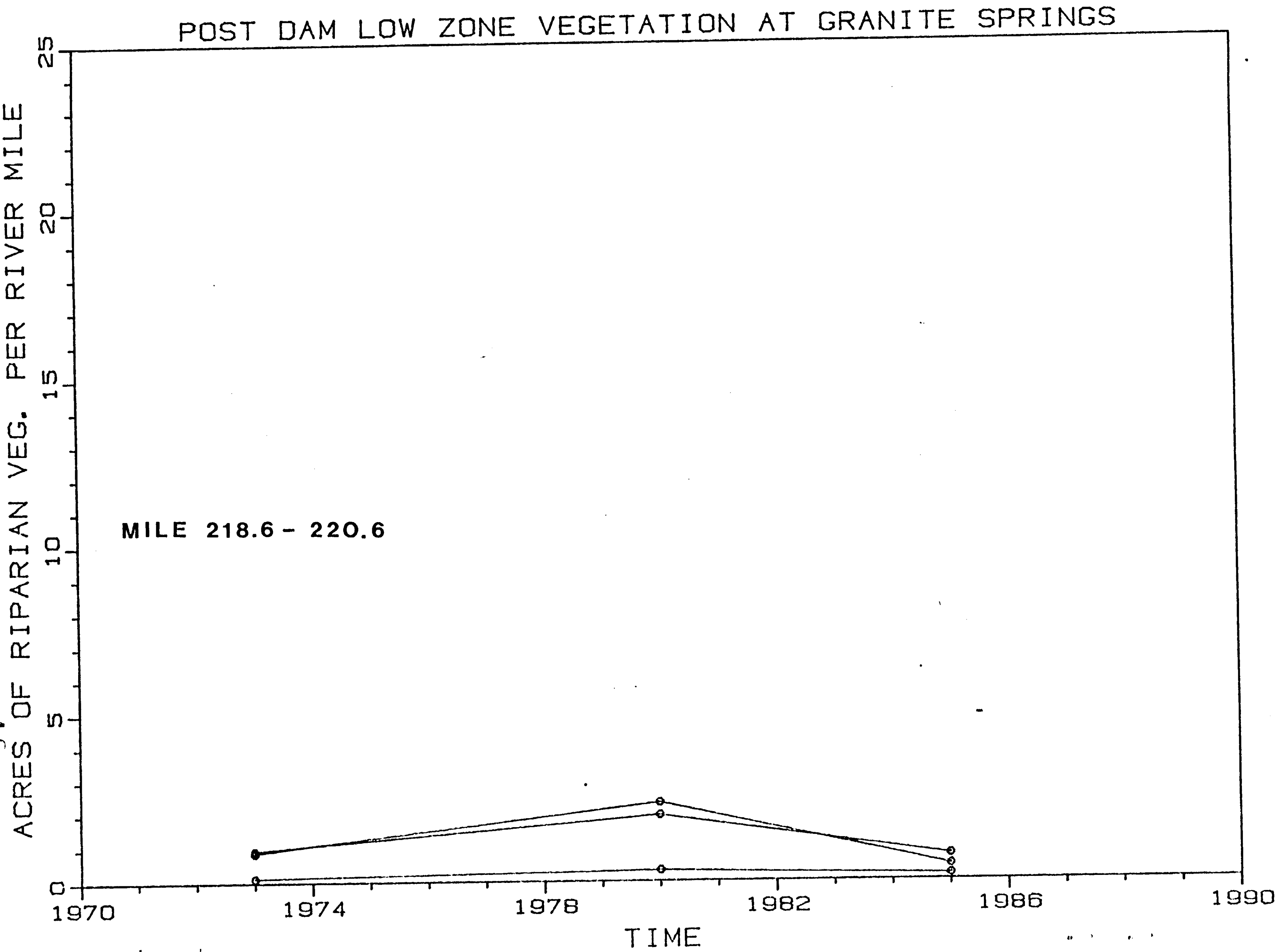


APPENDIX 2

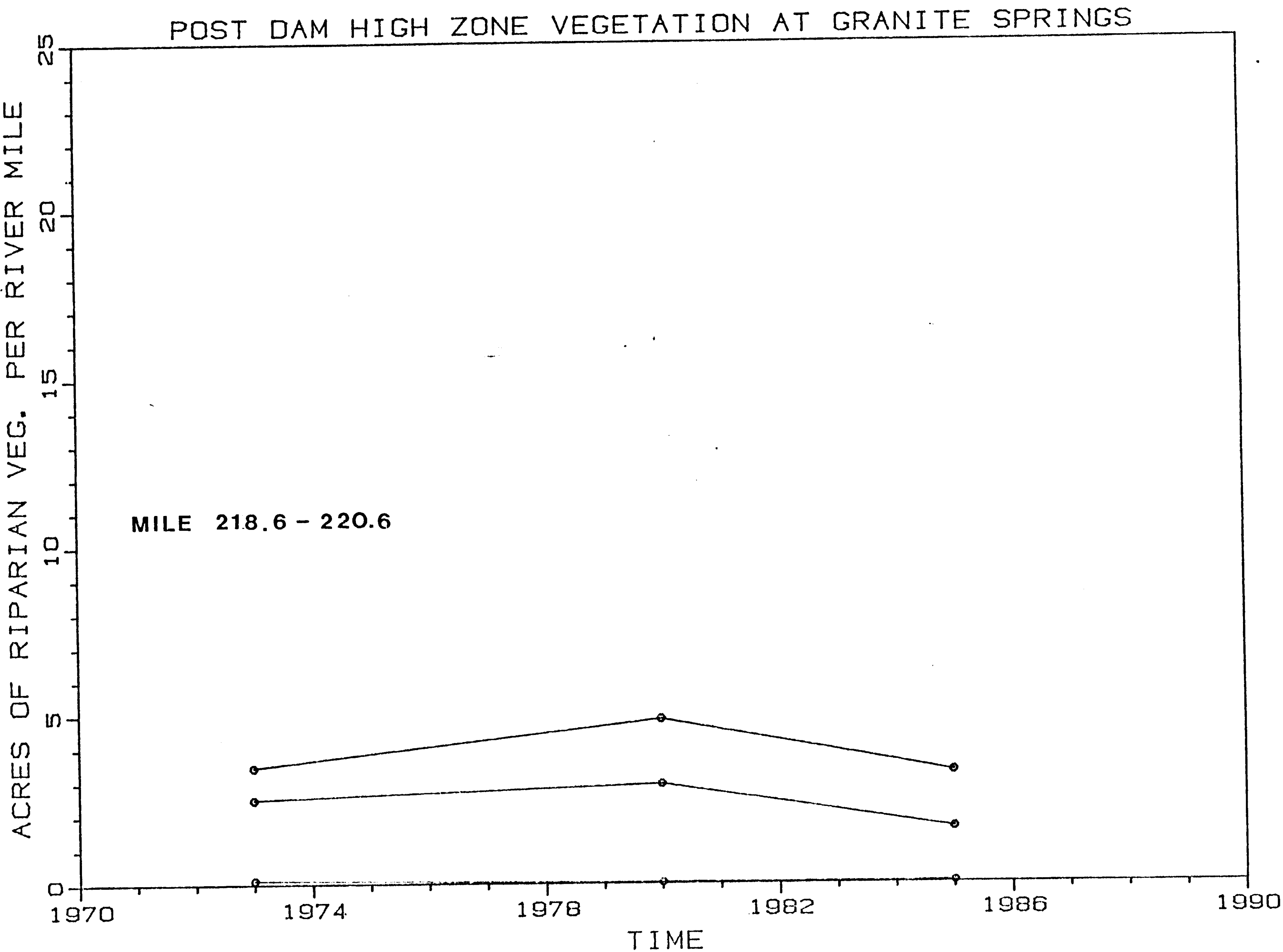
POST DAM HIGH ZONE VEGETATION AT GRANITE PARK



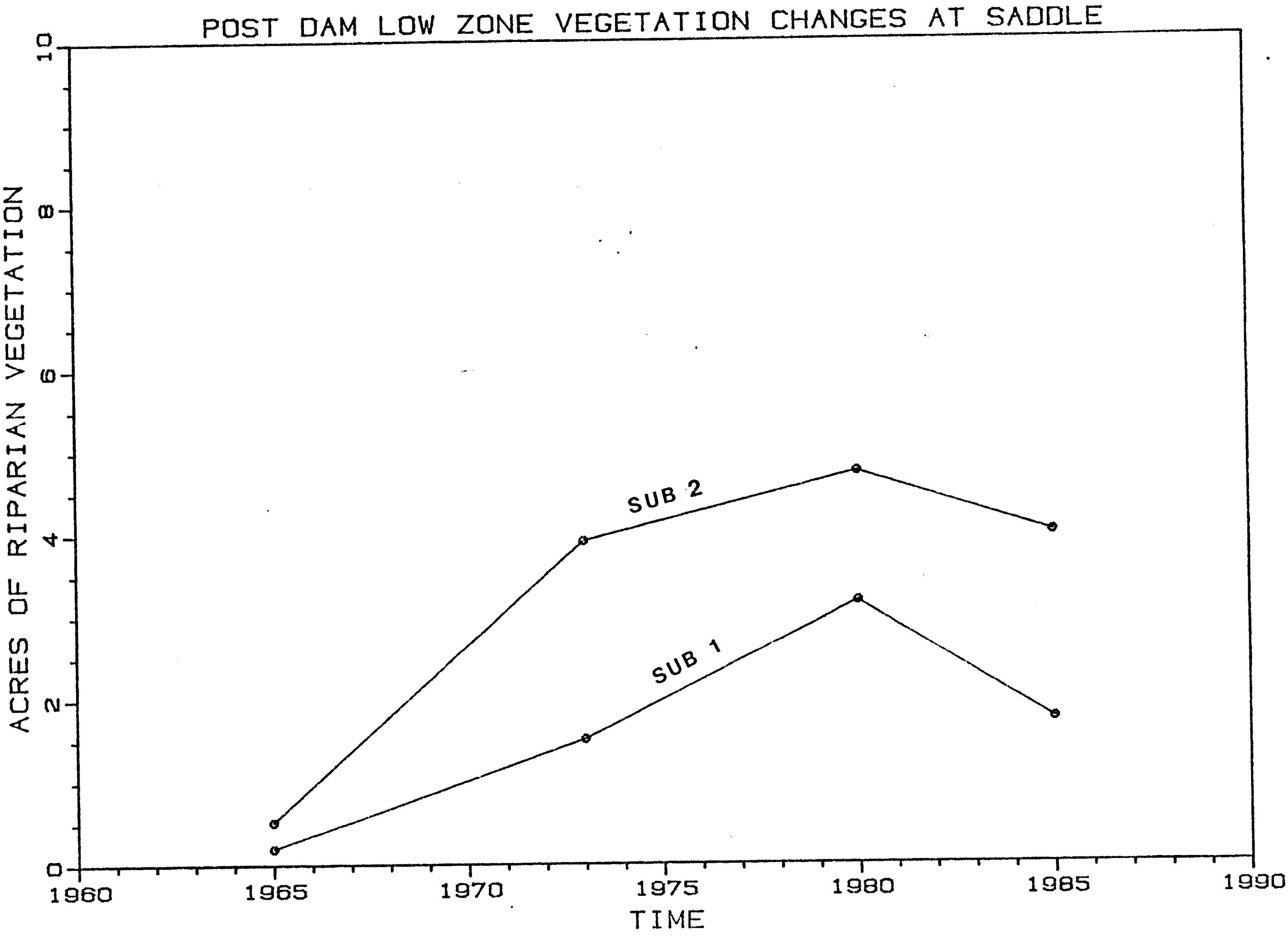
APPENDIX 2



POST DAM LOW ZONE VEGETATION AT GRANITE SPRINGS
ACRES OF RIPARIAN VEG. PER RIVER MILE
0
5
10
15
20
25
MILE 218.6 - 220.6
1970
1974
1978
1982
1986
1990
TIME

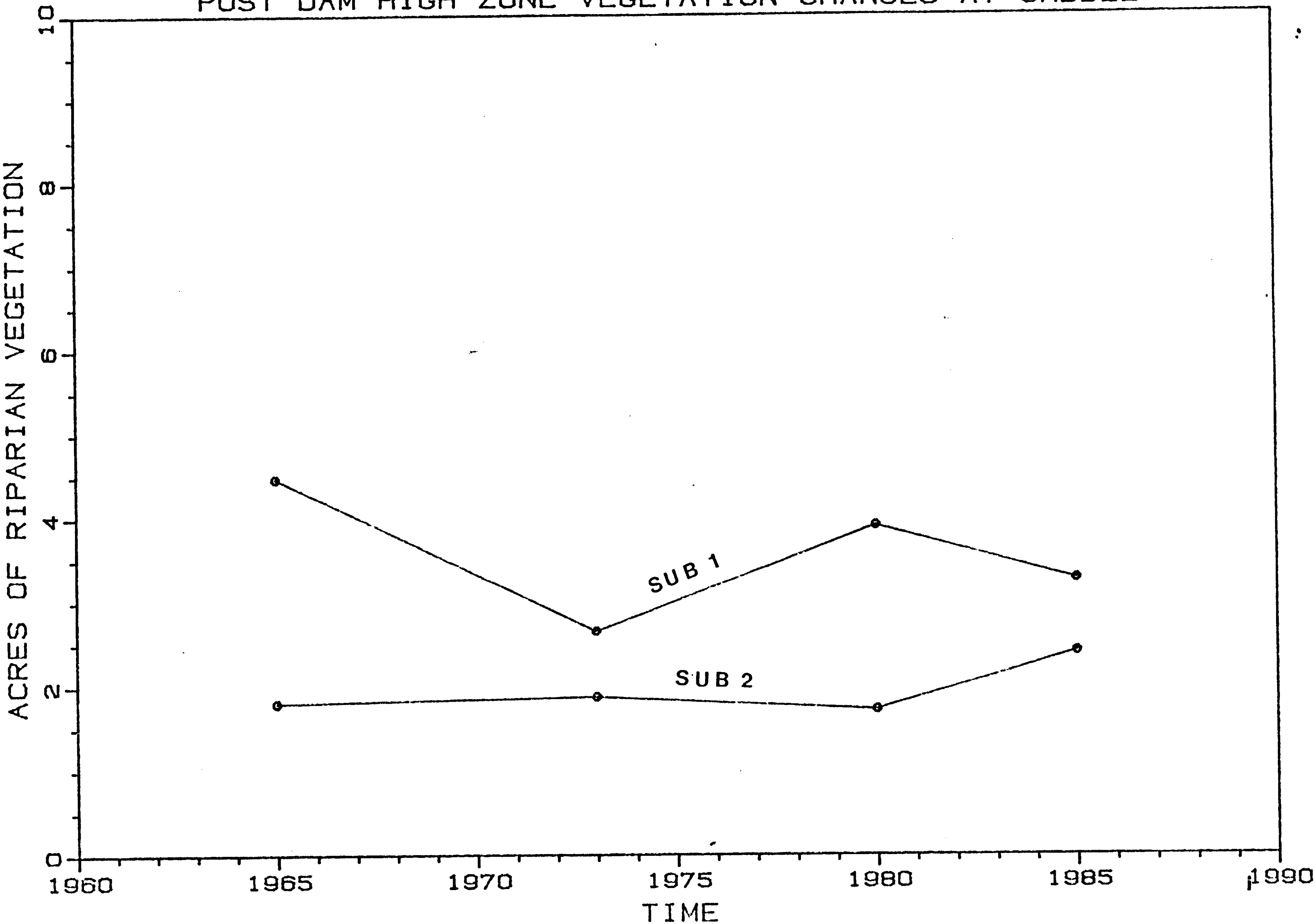

POST DAM HIGH ZONE VEGETATION AT GRANITE SPRINGS
ACRES OF RIPARIAN VEG. PER RIVER MILE
25
20
15
10
5
0
1970
1974
1978
1982
1986
1990
TIME
MILE 218.6 – 220.6

APPENDIX 2

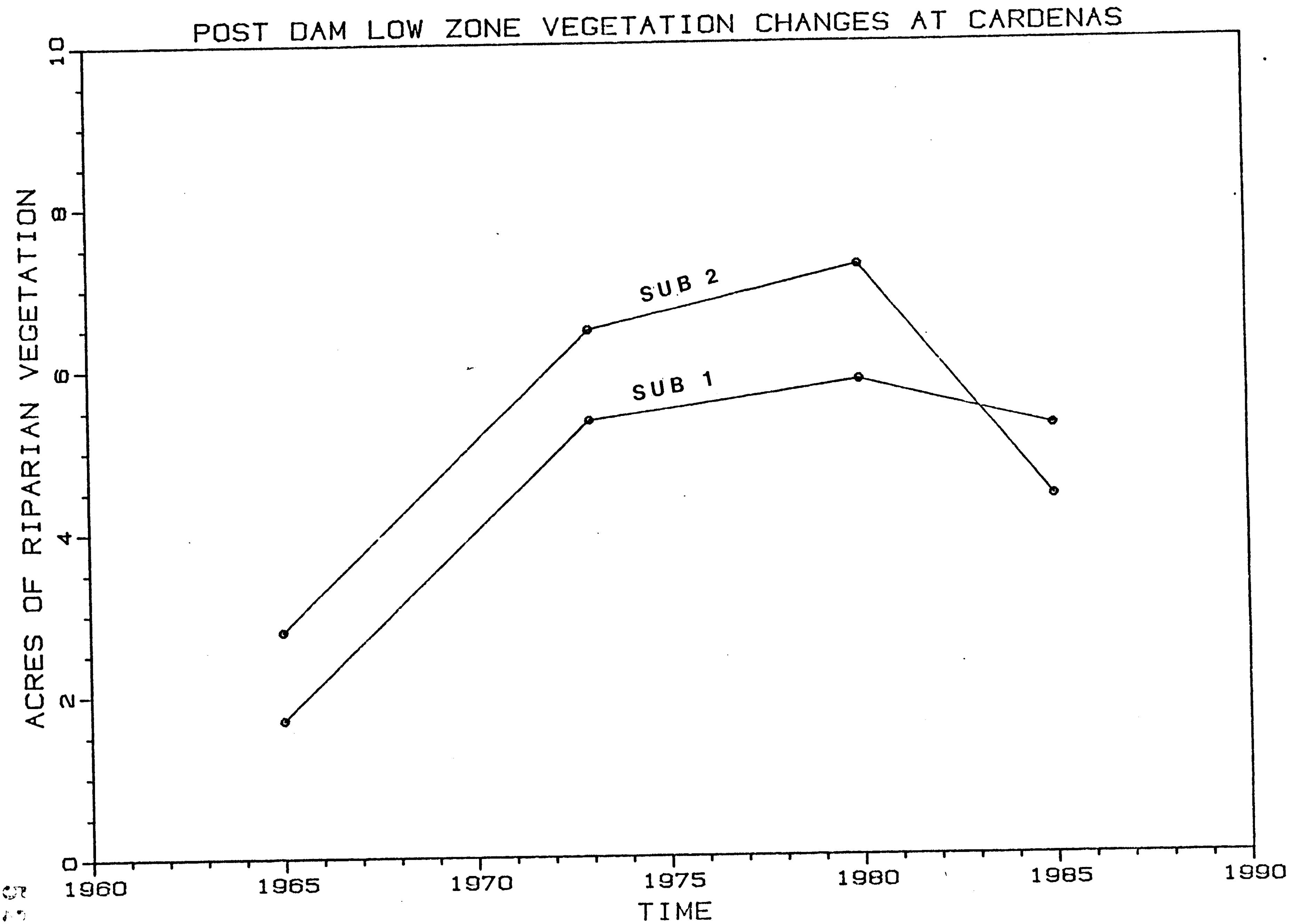

POST DAM LOW ZONE VEGETATION CHANGES AT SADDLE
ACRES OF RIPARIAN VEGETATION
0
2
4
6
8
10
1960
1965
1970
1975
1980
1985
1990
TIME
SUB 2
SUB 1

APPENDIX 2

POST DAM HIGH ZONE VEGETATION CHANGES AT SADDLE

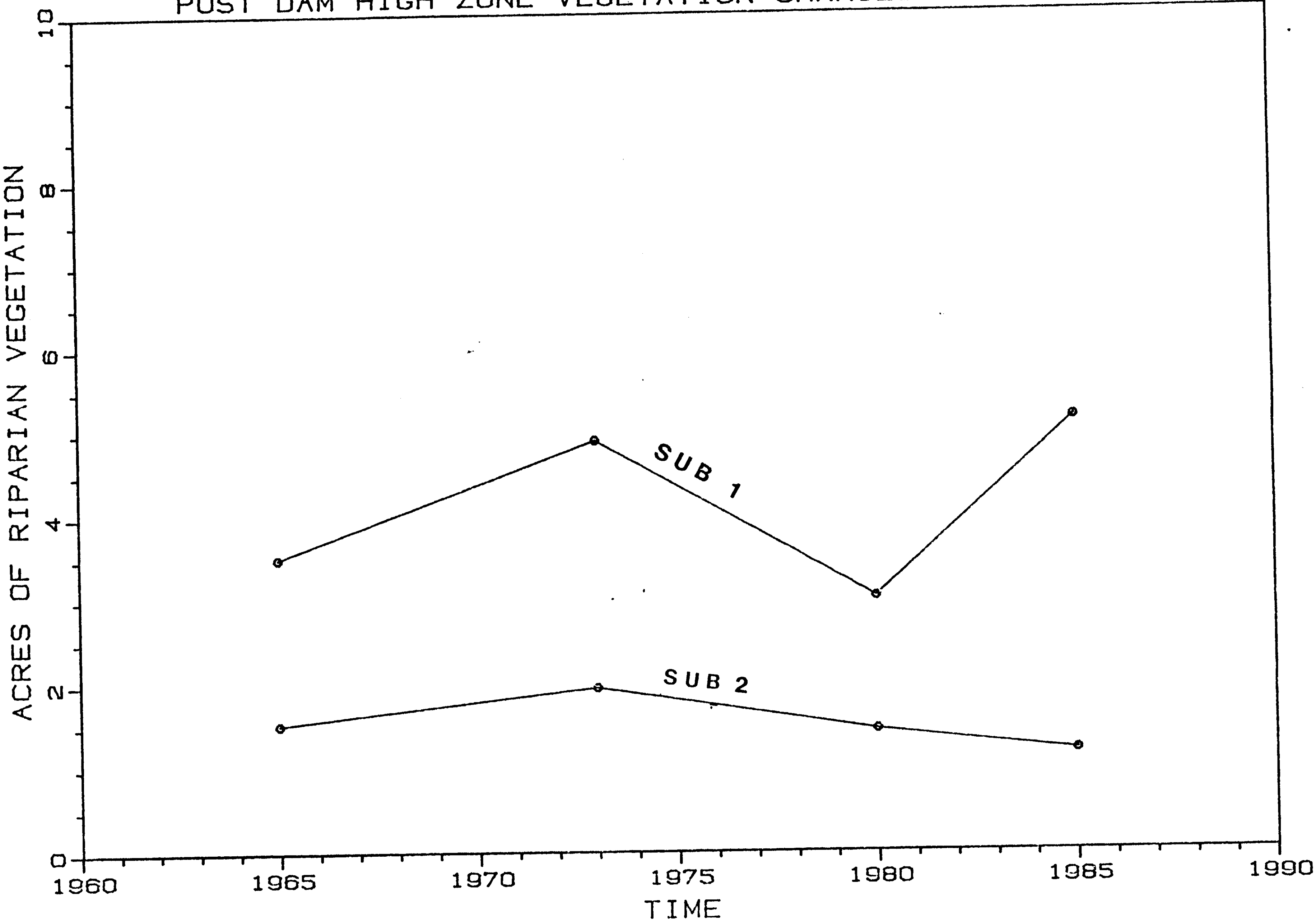


APPENDIX 2

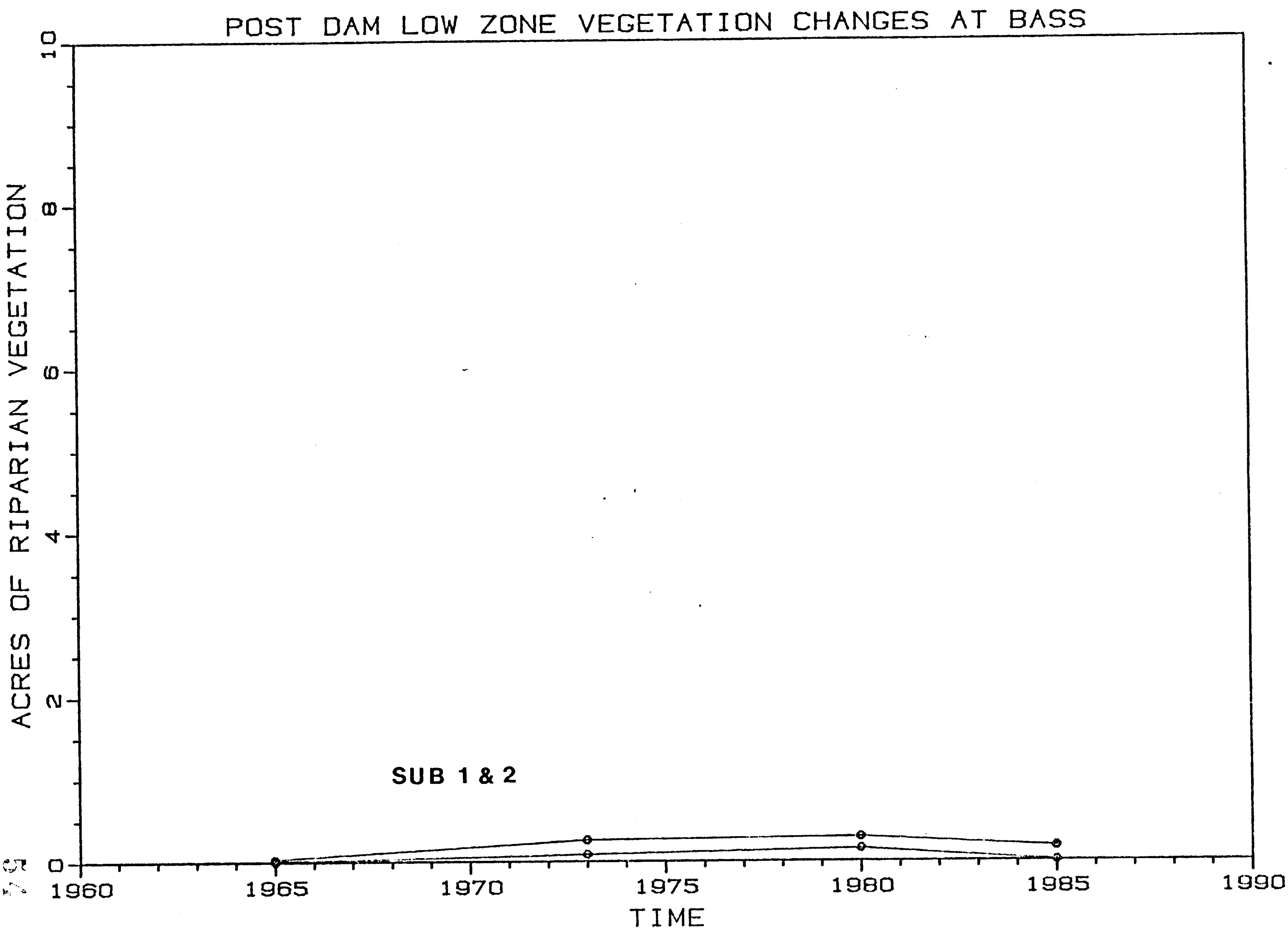

POST DAM LOW ZONE VEGETATION CHANGES AT CARDENAS
ACRES OF RIPARIAN VEGETATION
0
2
4
6
8
10
SUB 2
SUB 1
1960
1965
1970
1975
1980
1985
1990
TIME

APPENDIX 2

POST DAM HIGH ZONE VEGETATION CHANGES AT CARDENAS

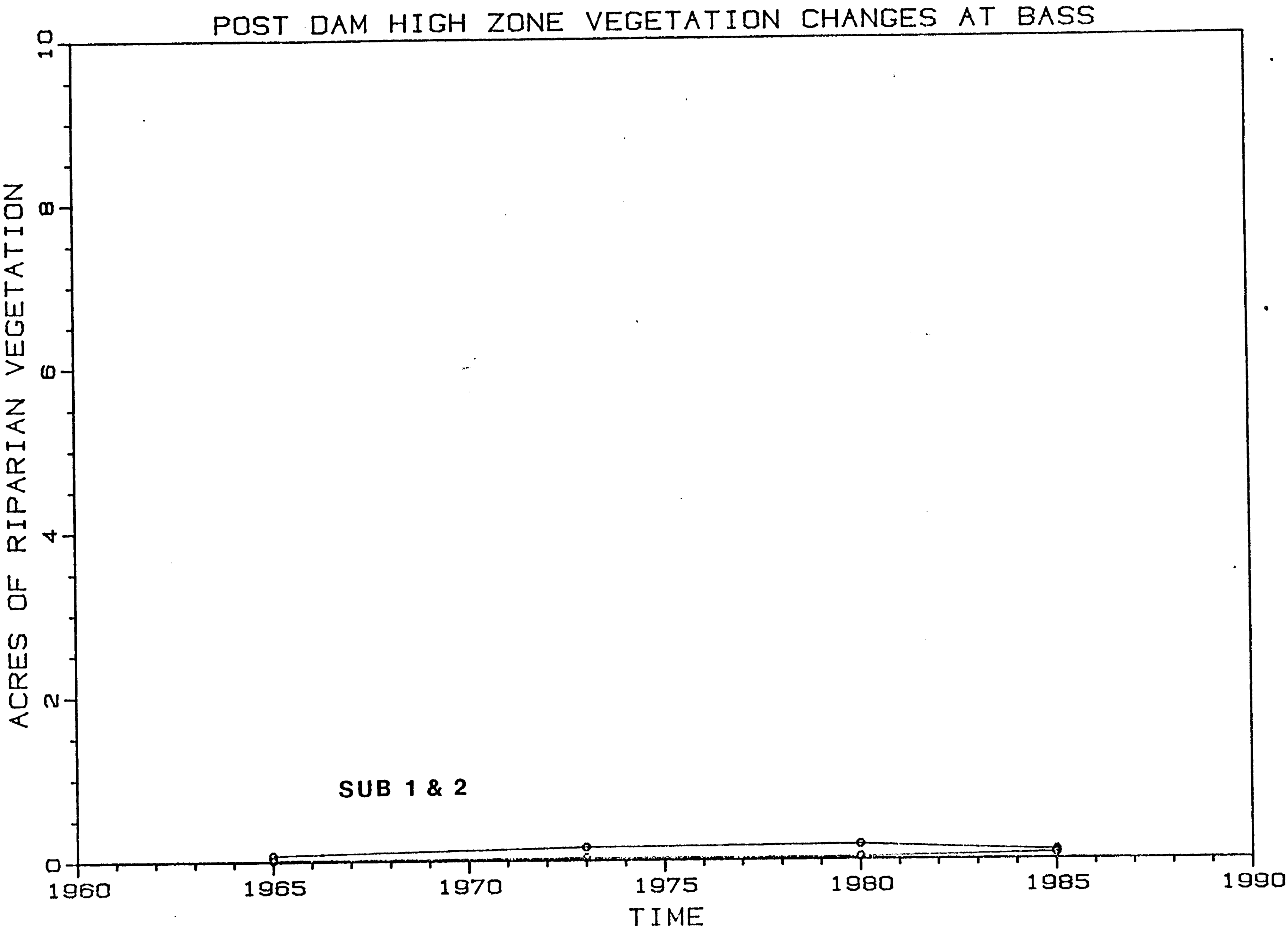


APPENDIX 2

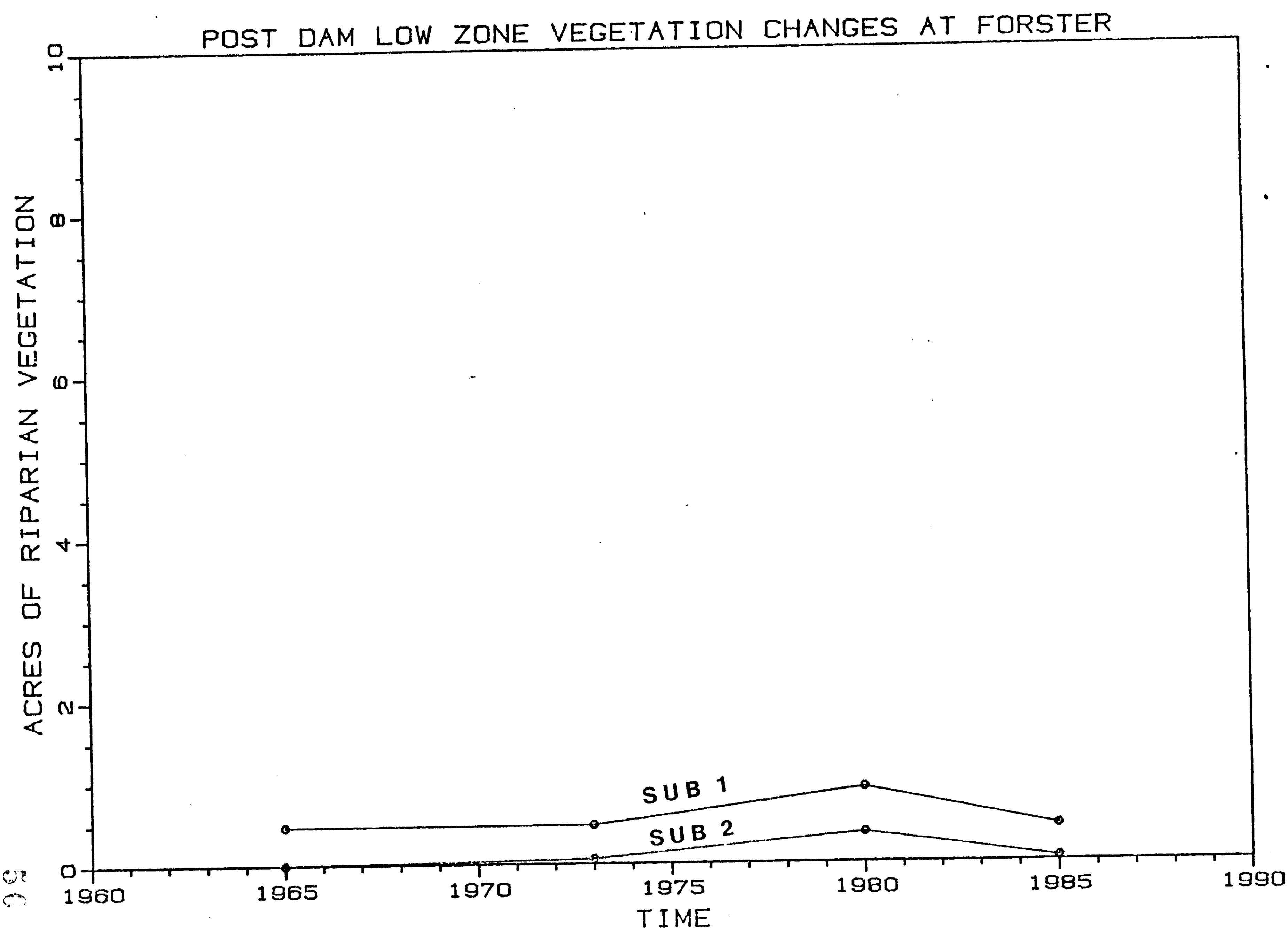


POST DAM LOW ZONE VEGETATION CHANGES AT BASS
ACRES OF RIPARIAN VEGETATION
0
2
4
6
8
10
1960
1965
1970
1975
1980
1985
1990
TIME
SUB 1 & 2

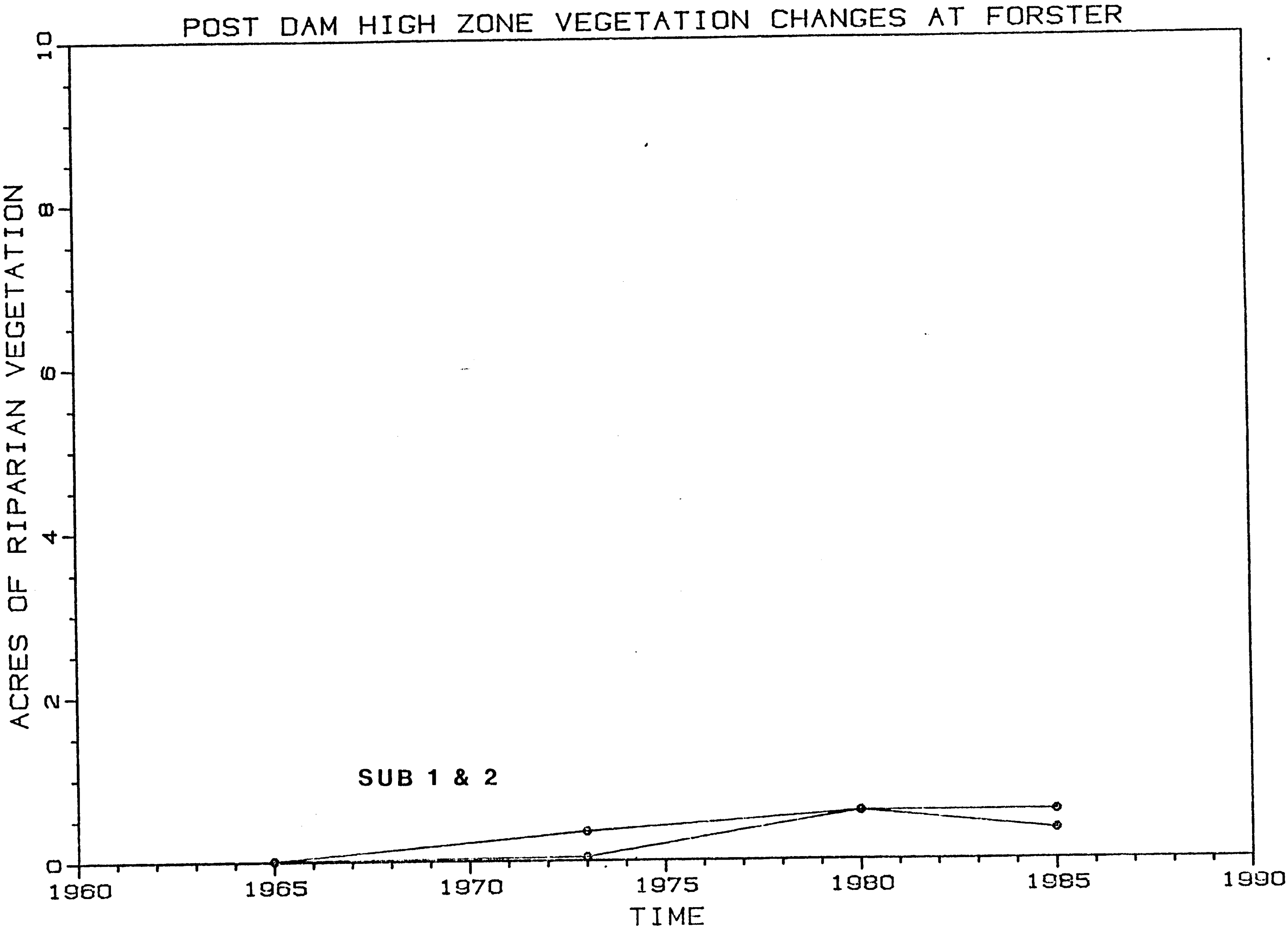
APPENDIX 2


POST DAM HIGH ZONE VEGETATION CHANGES AT BASS
ACRES OF RIPARIAN VEGETATION
0
2
4
6
8
10
SUB 1 & 2
1960
1965
1970
1975
1980
1985
1990
TIME

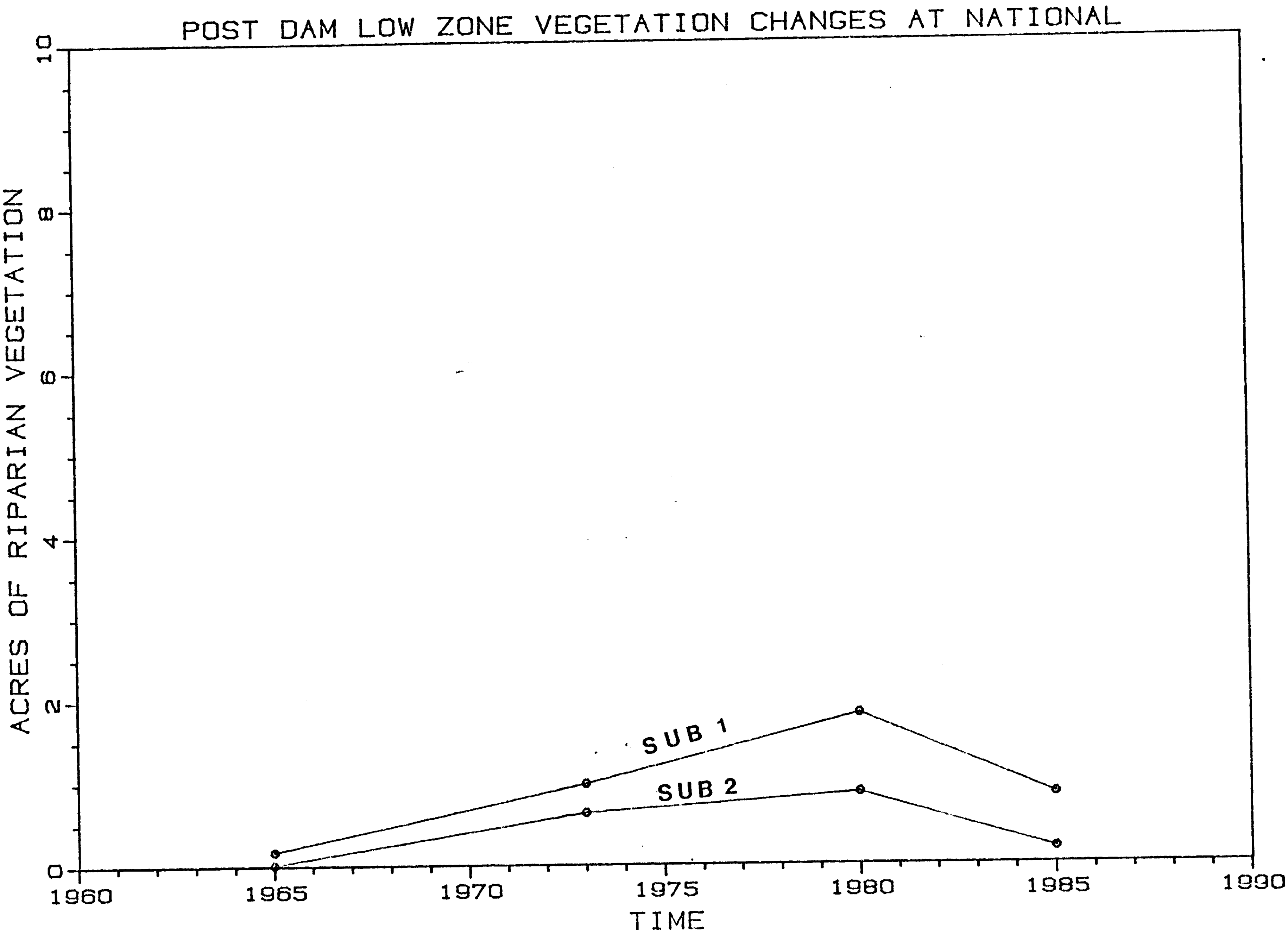
APPENDIX 2


POST DAM LOW ZONE VEGETATION CHANGES AT FORSTER
ACRES OF RIPARIAN VEGETATION
0
2
4
6
8
10
1960
1965
1970
1975
1980
1985
1990
TIME
SUB 1
SUB 2

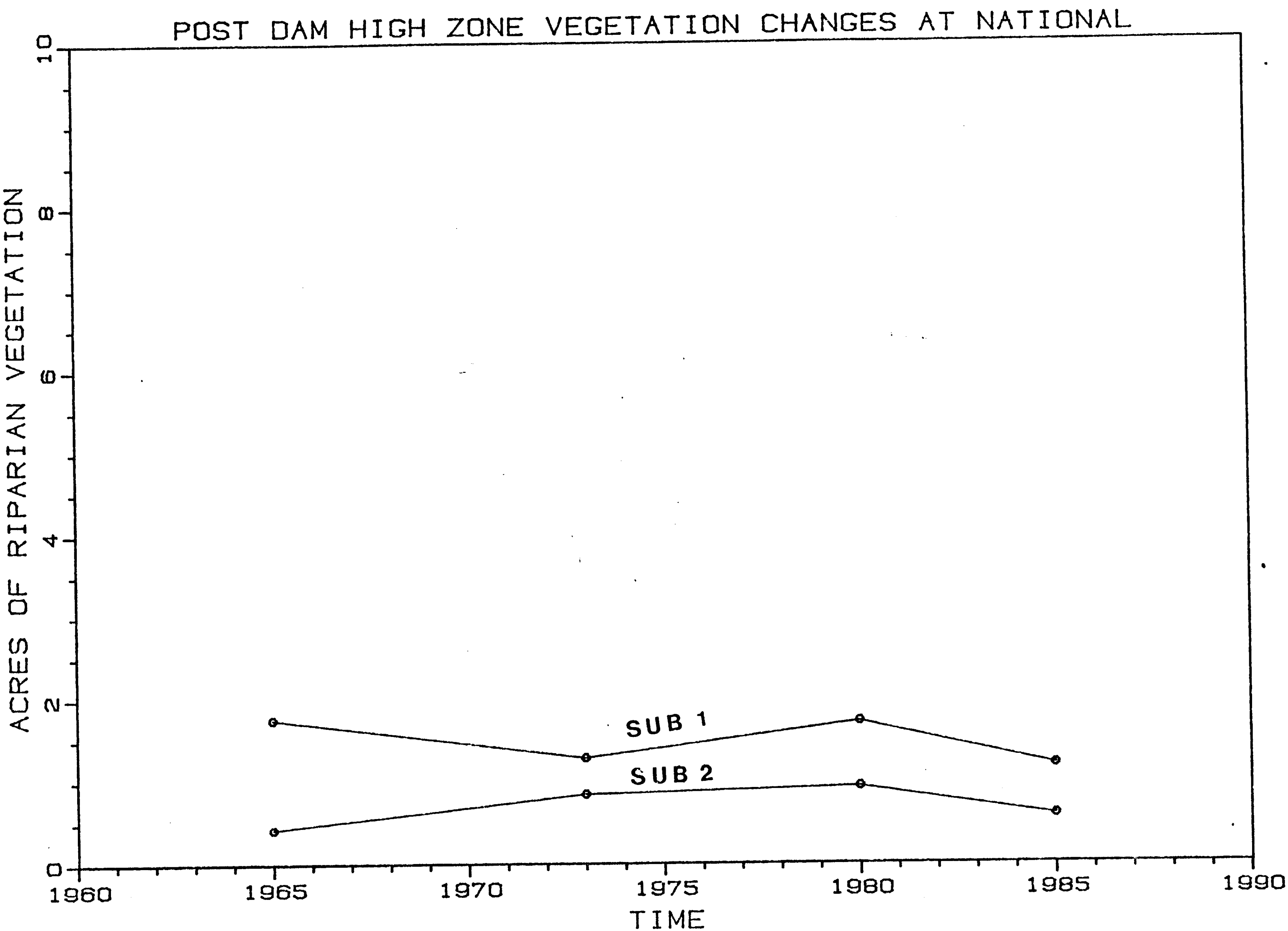
APPENDIX 2


POST DAM HIGH ZONE VEGETATION CHANGES AT FORSTER
ACRES OF RIPARIAN VEGETATION
0
2
4
6
8
10
SUB 1 & 2
1960
1965
1970
1975
1980
1985
1990
TIME

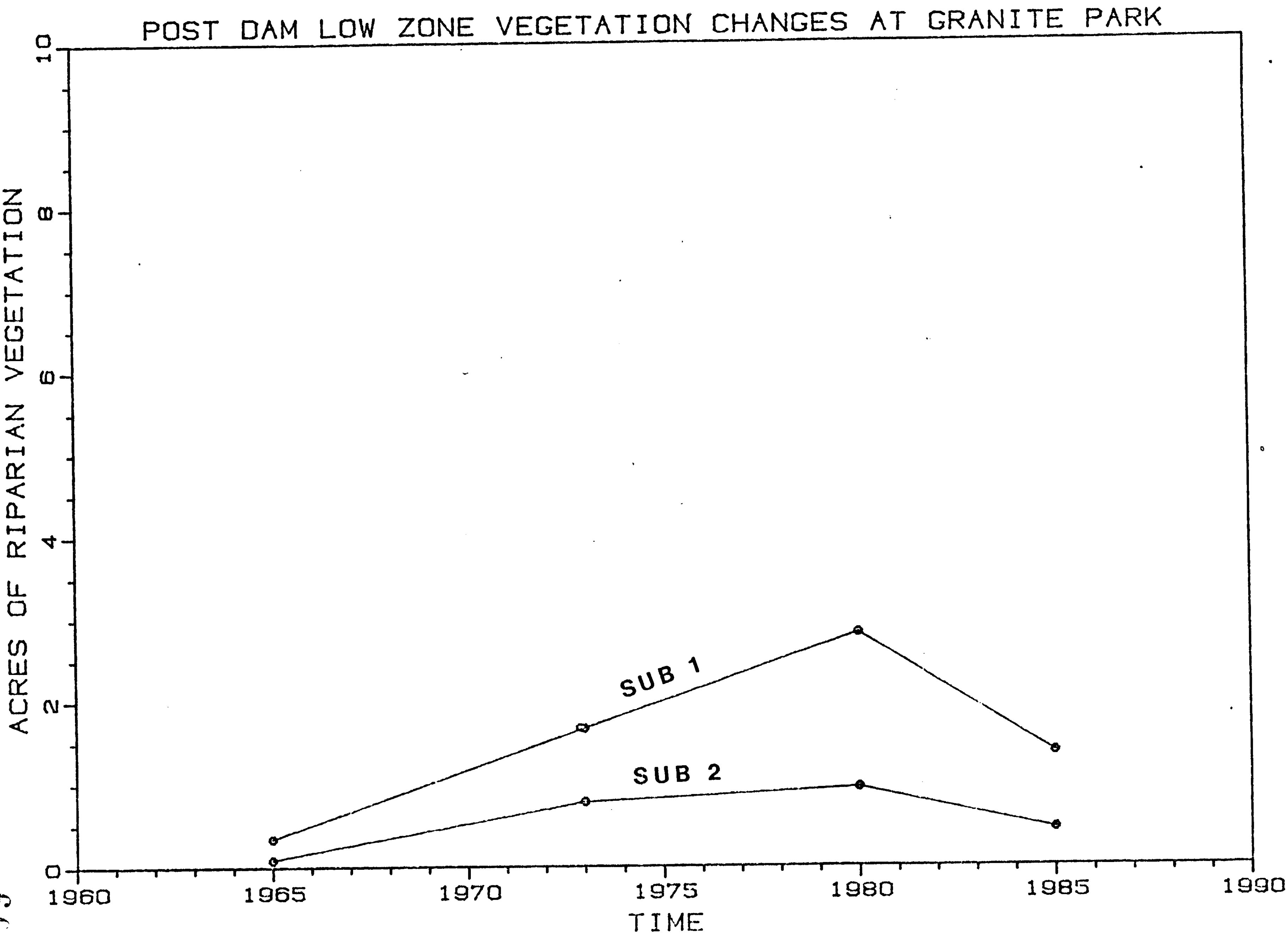
APPENDIX 2


POST DAM LOW ZONE VEGETATION CHANGES AT NATIONAL
ACRES OF RIPARIAN VEGETATION
0
2
4
6
8
10
SUB 1
SUB 2
1960
1965
1970
1975
1980
1985
1990
TIME

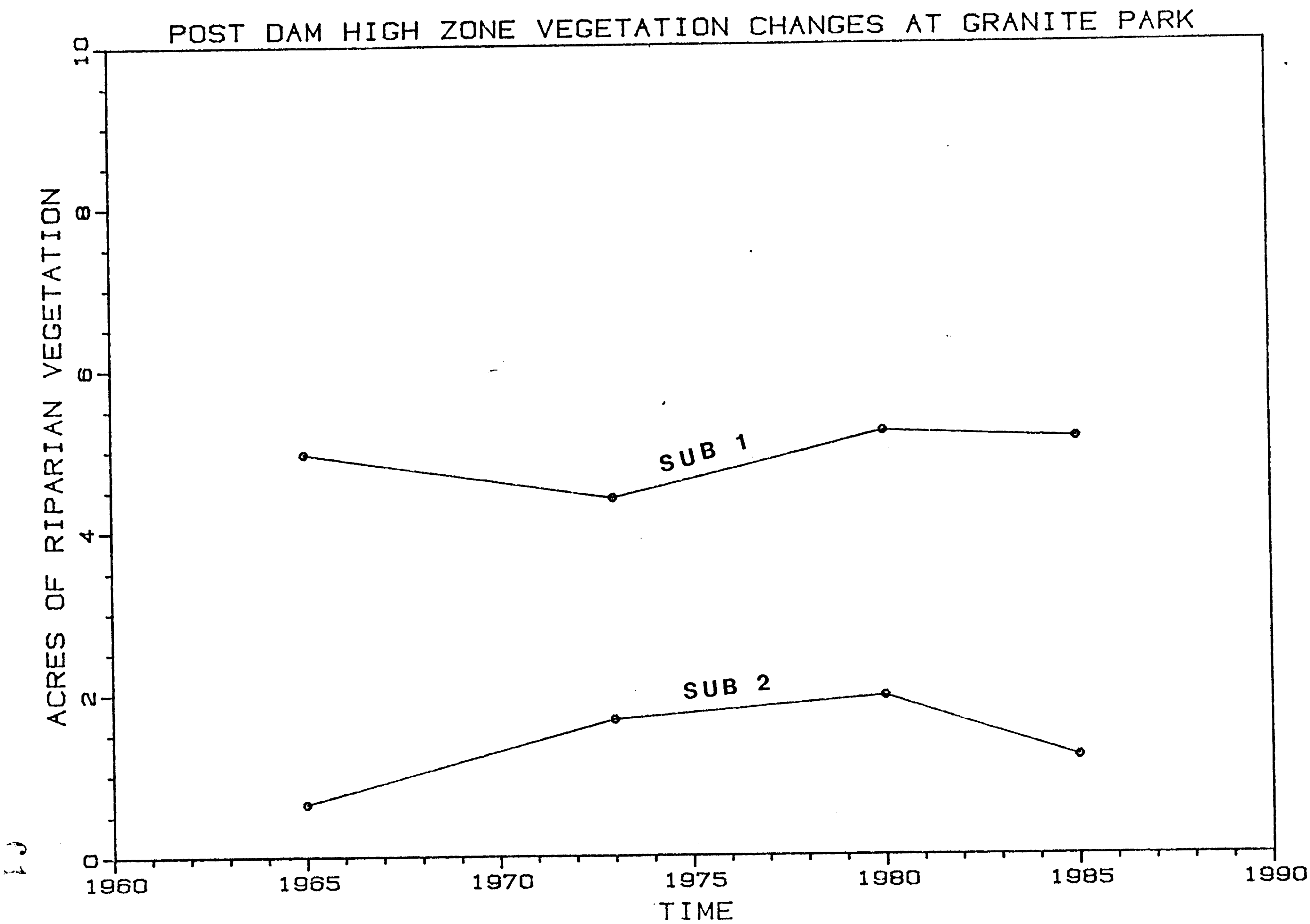
APPENDIX 2


POST DAM HIGH ZONE VEGETATION CHANGES AT NATIONAL
ACRES OF RIPARIAN VEGETATION
0
2
4
6
8
10
SUB 1
SUB 2
1960
1965
1970
1975
1980
1985
1990
TIME

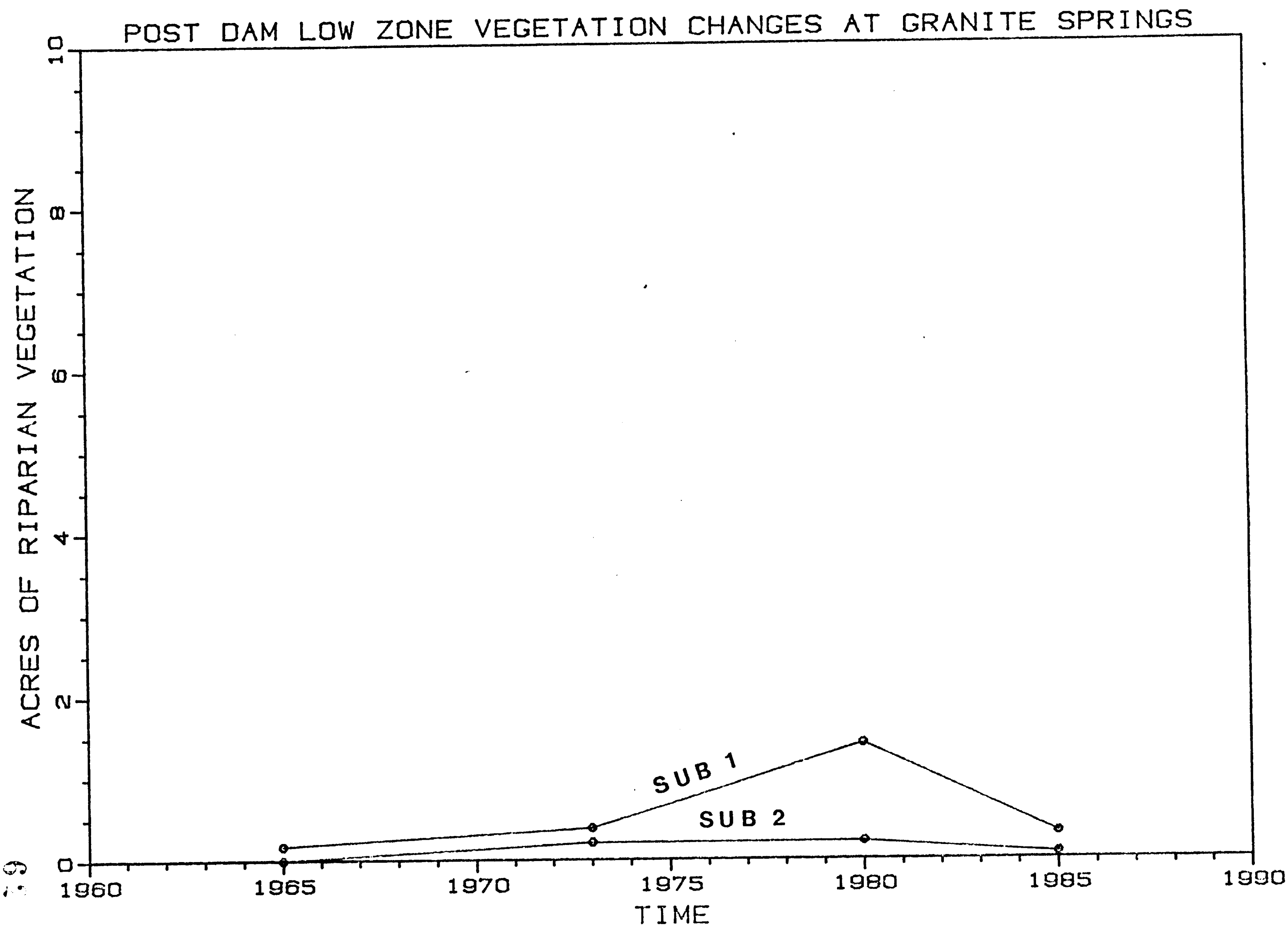
APPENDIX 2


POST DAM LOW ZONE VEGETATION CHANGES AT GRANITE PARK
ACRES OF RIPARIAN VEGETATION
0
2
4
6
8
10
1960
1965
1970
1975
1980
1985
1990
TIME
SUB 1
SUB 2

APPENDIX 2

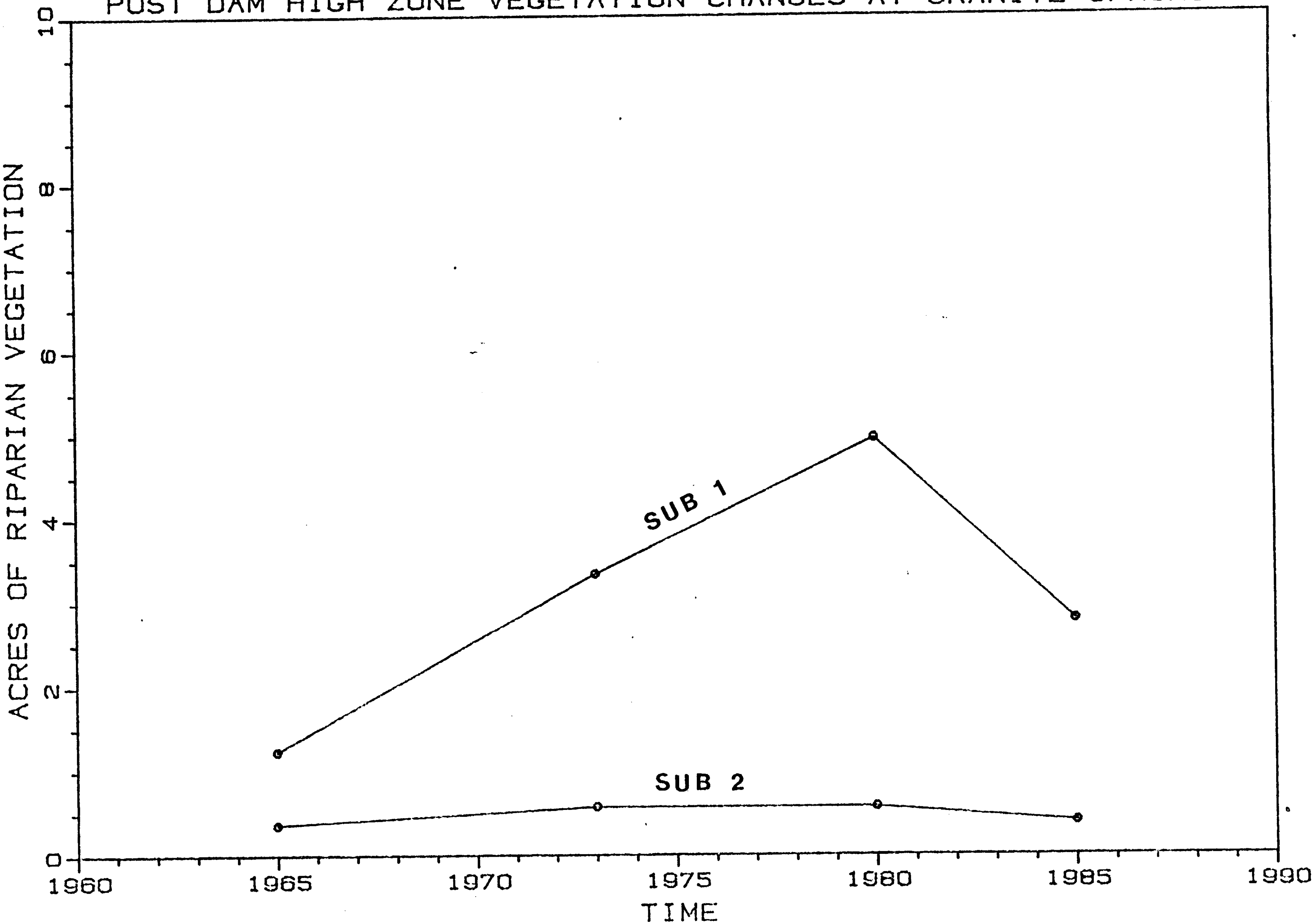

POST DAM HIGH ZONE VEGETATION CHANGES AT GRANITE PARK
ACRES OF RIPARIAN VEGETATION
0
2
4
6
8
10
SUB 1
SUB 2
1960
1965
1970
1975
1980
1985
1990
TIME

APPENDIX 2

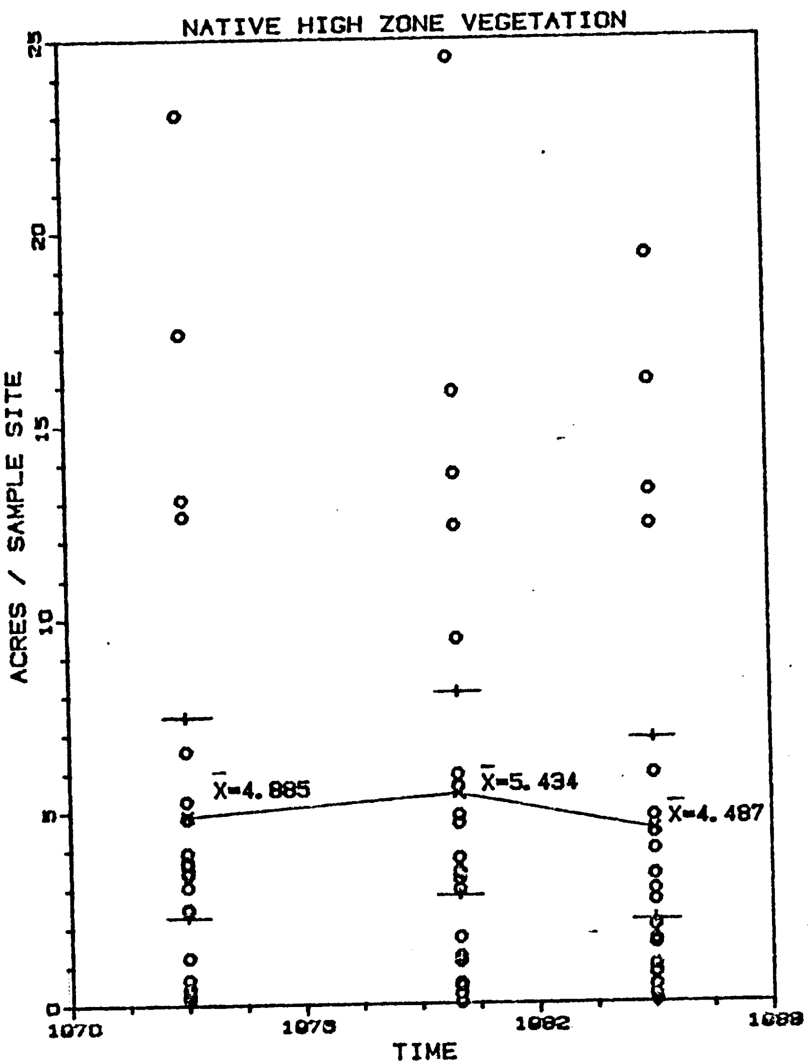

POST DAM LOW ZONE VEGETATION CHANGES AT GRANITE SPRINGS
ACRES OF RIPARIAN VEGETATION
0
2
4
6
8
10
1960
1965
1970
1975
1980
1985
1990
TIME
SUB 1
SUB 2

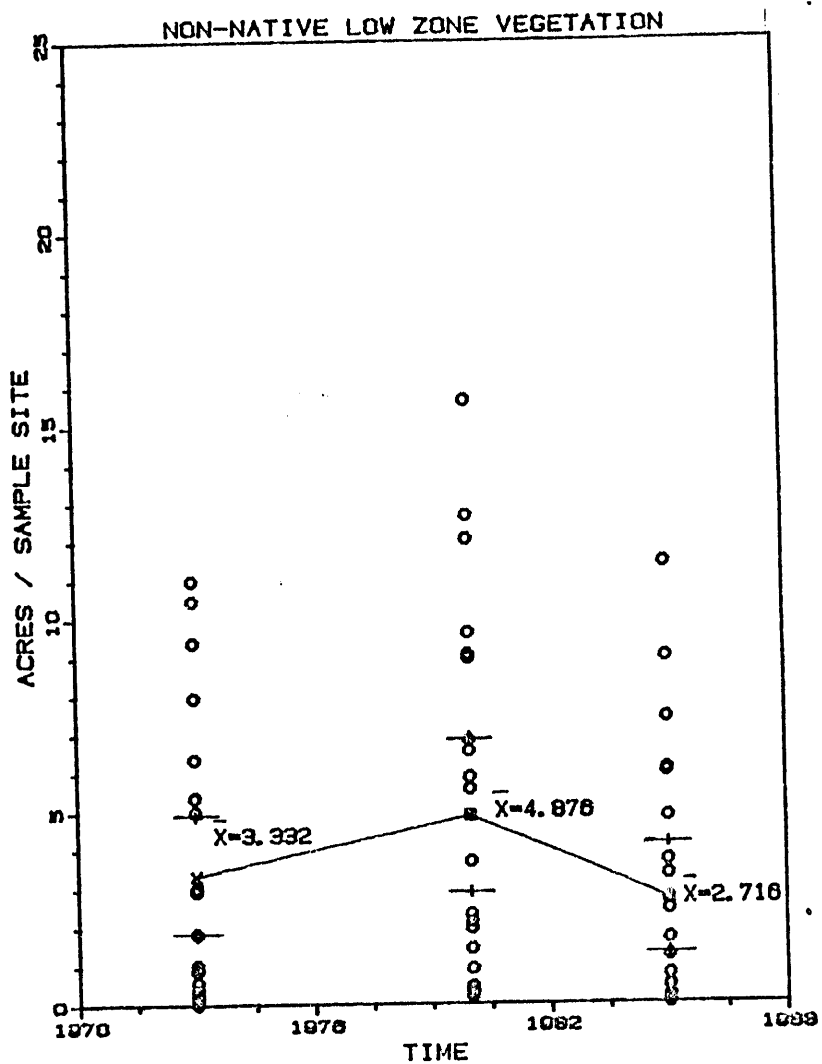
APPENDIX 2

POST DAM HIGH ZONE VEGETATION CHANGES AT GRANITE SPRINGS

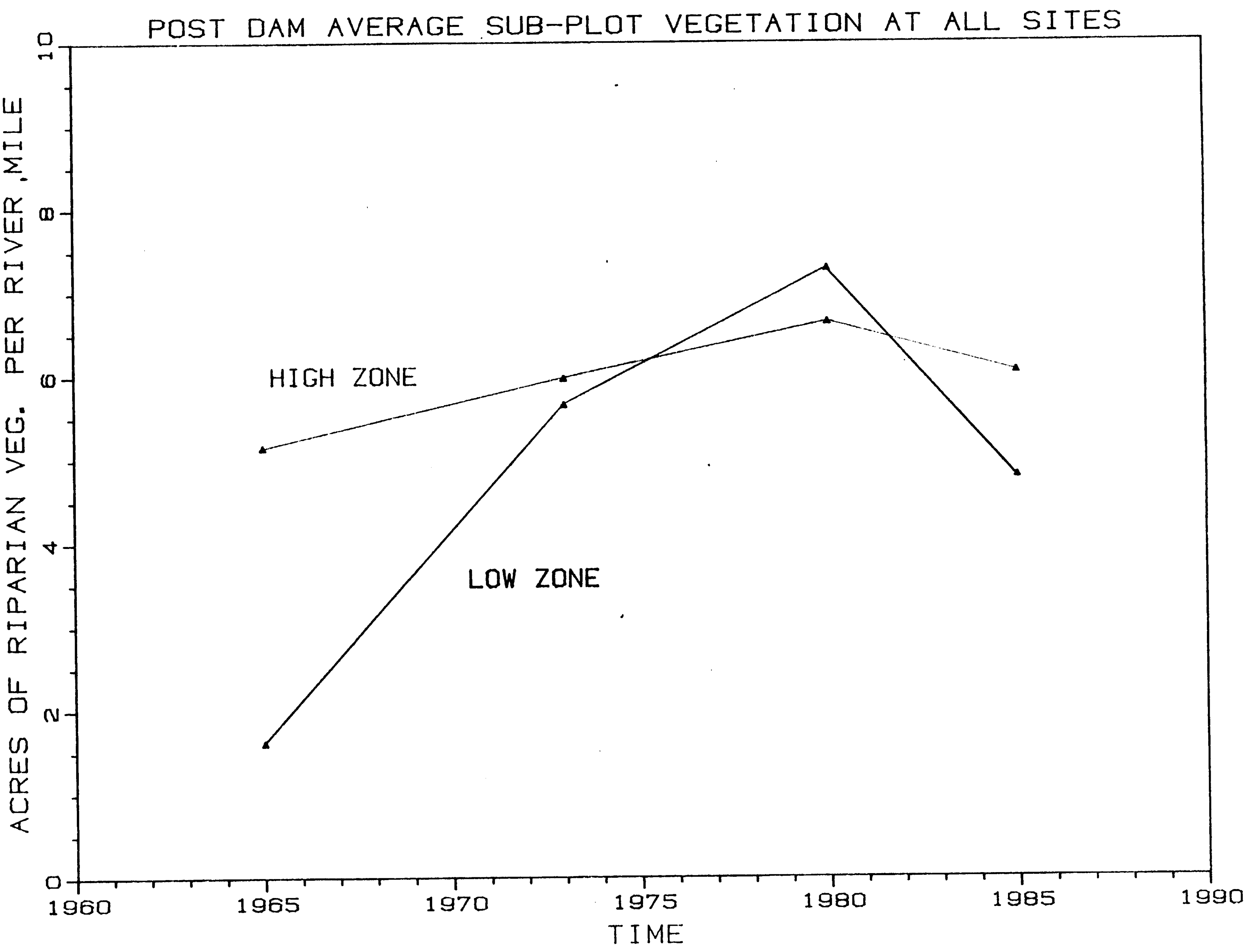


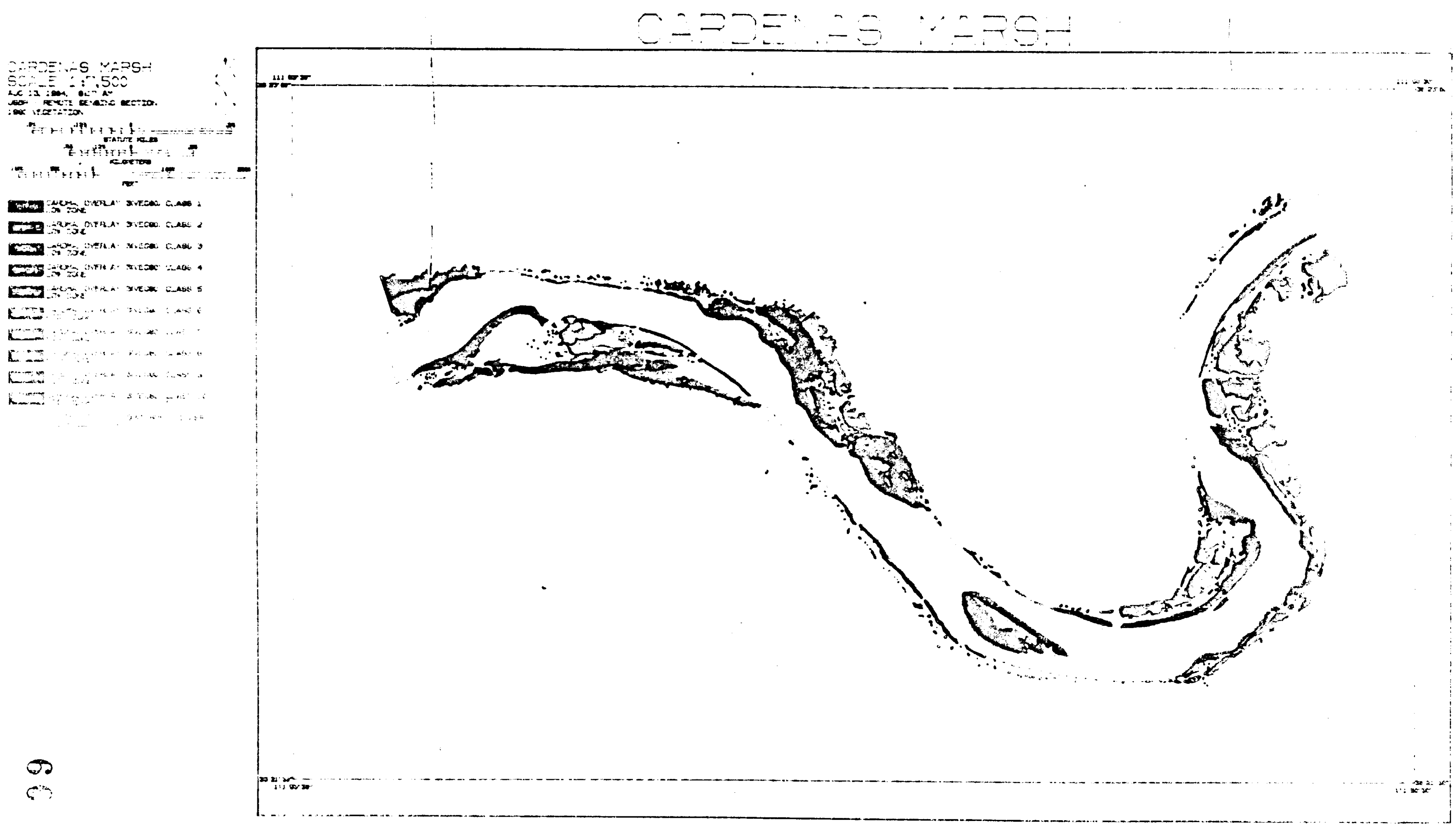
APPENDIX 3


NATIVE HIGH ZONE VEGETATION
ACRES / SAMPLE SITE
0
5
10
15
20
25
$\bar{X}$=4.885
$\bar{X}$=5.434
$\bar{X}$=4.487
1970
1976
1982
1988
TIME


NON-NATIVE LOW ZONE VEGETATION
ACRES / SAMPLE SITE
0
5
10
15
20
25
$\bar{X}$=3.332
$\bar{X}$=4.876
$\bar{X}$=2.716
1970
1976
1982
1988
TIME

APPENDIX 3


POST DAM AVERAGE SUB-PLOT VEGETATION AT ALL SITES
ACRES OF RIPARIAN VEG. PER RIVER MILE
0
2
4
6
8
10
HIGH ZONE
LOW ZONE
1960
1965
1970
1975
1980
1985
1990
TIME



A reproduction of a map plot near mile 70-73 of the Grand Canyon. This plot was produced by digitizing interpreted data from 1980 color infrared aerial photography. The native vegetation associations (HZ) are plotted in green and the introduced vegetation associations (LZ) are plotted in red.

APPENDIX V

Saddle Canyon Area

Vegetation Associations

River miles	NZ (02-B) Orno plot (1)			OHWZ (02-A) Orno plot (2)		
	TV	HZ	LZ	TV	HZ	LZ
SC-1985						
44-45						
45-46						
46-47	5.172	0.007	5.164			
47-47.5				2.875	2.557	0.318
Study site totals	5.172	0.007	5.164	2.875	2.557	0.318
SC-1980						
44-45						
45-46						
46-47	6.066	0.033	6.033			
47-47.5				2.632	2.390	0.242
Study site totals	6.066	0.033	6.033	2.632	2.390	0.242
SC-1973						
44-45						
45-46						
46-47	3.883	0.573	3.310			
47-47.5				1.762	1.618	0.144
Study site totals	3.883	0.573	3.310	1.762	1.618	0.144

Note: All areas reported in acres.

APPENDIX V

Cardenas Marsh Area

Vegetation Associations

River miles	NZ (03-B) Orno plot (1)			OHWZ (03-A) Orno plot (2)		
	TV	HZ	LZ	TV	HZ	LZ
CA-1985						
70-71				2.859	2.583	0.276
71-72	3.637	0.077	3.560			
72-73						
Study site totals	3.637	0.077	3.560	2.859	2.583	0.276
CA-1980						
70-71				2.774	2.347	0.426
71-72	5.849	0.161	5.688			
72-73						
Study site totals	5.849	0.161	5.688	2.774	2.347	0.426
CA-1973						
70-71				3.475	2.734	0.740
71-72	5.358	0.019	5.340			
72-73						
Study site totals	5.358	0.019	5.340	3.475	2.734	0.740

Note: All areas reported in acres.

APPENDIX V

Bass Canyon Area

Vegetation Associations

River miles	NZ (04-B) Orno plot (1)			OHWZ (04-A) Orno plot (2)		
	TV	HZ	LZ	TV	HZ	LZ
BA-1985						
105.5-106						
106-107						
107-108						
108-108.4	0.142	0.0	0.142	0.073	0.050	0.023
Study site totals	0.142	0.0	0.142	0.073	0.050	0.023
BA-1980						
105.5-106						
106-107						
107-108						
108-108.4	0.237	0.0	0.237	0.064	0.037	0.026
Study site totals	0.237	0.0	0.237	0.064	0.037	0.026
BA-1973						
105.5-106						
106-107						
107-108						
108-108.4	0.205	0.0	0.205	0.052	0.035	0.016
Study site totals	0.205	0.0	0.205	0.052	0.035	0.016

Note: All areas reported in acres.

APPENDIX V

Forster/Blacktail Canyon Areas

Vegetation Associations

River miles	NZ (05-B) Orno plot (1)			OHWZ (05-A) Orno plot (2)		
	TV	HZ	LZ	TV	HZ	LZ
FO-1985						
120-121						
121-122						
122-123	0.783	0.0	0.783	0.588	0.545	0.043
Study site totals	0.783	0.0	0.783	0.588	0.545	0.043
FO-1980						
120-121						
121-122						
122-123	1.211	0.0	1.211	0.488	0.465	0.022
Study site totals	1.211	0.0	1.211	0.488	0.465	0.022
FO-1973						
120-121						
121-122						
122-123	0.332	0.032	0.300	0.267	0.247	0.020
Study site totals	0.332	0.032	0.300	0.267	0.247	0.020

Note: All areas reported in acres.

APPENDIX V

National Canyon Area

Vegetation Assocations

River miles	NZ (06-B) Orno plot (1)			OHWZ (06-A) Orno plot (2)		
	TV	HZ	LZ	TV	HZ	LZ
NA-1985						
166.1-167 167-168 168-168.7	0.484	0.00	0.484	1.918	1.918	0.000
Study site totals	0.484	0.000	0.484	1.918	1.918	0.000
NA-1980						
166.1-167 167-168 168-168.7	0.695	0.008	0.686	2.188	2.183	0.004
Study site totals	0.695	0.008	0.686	2.188	2.183	0.004
NA-1973						
166.1-167 167-168 168-168.7	0.547	0.044	0.503	1.552	1.552	0.000
Study site totals	0.547	0.044	0.503	1.552	1.552	0.000

Note: All areas reported in acres.

APPENDIX V

Granite Park Area

Vegetation Associations

River miles	NZ (09-B) Orno plot (1)			OHWZ (09-A) Orno plot (2)		
	TV	HZ	LZ	TV	HZ	LZ
GP-1985						
207-208 208-209 209-209.2	0.742	0.040	0.701	8.691	8.554	0.137
Study site totals	0.742	0.040	0.701	8.691	8.554	0.137
GP-1980						
207-208 208-209 209-209.2	1.443	0.082	1.362	8.242	8.109	0.132
Study site totals	1.443	0.082	1.362	8.242	8.109	0.132
GP-1973						
207-208 208-209 209-209.2	0.507	0.000	0.507	6.873	6.391	0.481
Study site totals	0.507	0.000	0.507	6.873	6.391	0.481

Note: All areas reported in acres.

APPENDIX V

Granite Springs Area

Vegetation Associations

River miles	NZ (09-A) Orno plot (1)		
	TV	HZ	LZ
GS-1985			
218.6-219			
219-220	1.375	1.362	0.013
220-220.6	0.186	0.177	0.009
Study site totals	1.561	1.539	0.022
GS-1980			
218.6-219			
219-220	2.360	2.233	0.127
220-220.6	0.354	0.293	0.060
Study site totals	2.714	2.526	0.187
GS-1973			
218.6-219			
219-220	1.281	1.248	0.034
220-220.6	0.167	0.167	0.0
Study site totals	1.448	1.415	0.034

Note: All areas reported in acres.

Table 1 . - Post Dam vegatation changes in the Grand Canyon, 1973-1985 using aerial photography 19.2 River miles surveyed

River mile segment	7 year change 1973-1980		5 year change 1980-1985	
	LZ	HZ	LZ	HZ
44-45	+1.430	-0.359	-3.115	+1.035
45-46	+1.178	+0.164	-0.547	-1.231
46-47	+1.047	+1.089	-0.612	-2.607
47-47.5	+1.896	+1.707	-1.545	-0.805
70-71	+5.156	-0.717	-6.652	+0.003
71-72	+3.250	-1.539	-5.247	-1.710
72-73	+1.658	-3.649	-3.542	-0.465
105.5-106	+0.252	+0.248	-0.214	+0.004
106-107	+0.118	+0.565	-0.178	-0.250
107-108	+0.194	+0.164	-0.458	+0.219
108-108.4	+0.044	+0.050	-0.246	-0.031
120-121	+0.666	+0.825	-0.711	-0.299
121-122	+0.119	+0.040	-0.237	-0.028
122-123	+1.831	+0.494	-1.999	-0.180
166.1-167	+2.921	+2.883	-4.624	-3.527
167-168	+2.502	+1.042	-3.126	-1.724
168-168.7	+1.539	+3.147	-1.991	-1.649
207-208	+3.942	+1.458	-4.111	-5.137
208-209	+2.692	+3.194	-6.322	+0.255
209-209.2	+0.403	+0.048	-0.954	-0.773
218.6-219	+0.187	-0.094	-0.152	+0.013
219-220	+1.440	+1.407	-1.875	-1.560
220-220.6	+1.036	+0.456	-1.226	-1.321
Total river miles surveyed 19.2	+35.5010	+12.6230	-49.6840*	- 21.768
Ave. change/yr in 19.2 river miles	+5.0716	+1.8033	-9.9360*	-4.352
Ave. change/river mile	+1.8490	+0.6574	-2.5877*	-1.134
Ave. change/yr/river mile	+0.2641	+0.0939	-0.5175*	-0.227

* This decrease is mainly related to the flood of 1983.

Table 2. - Post dam vegatation changes in the Grand Canyon, 1965-1985 using aerial photography - 4.05 river miles surveyed

Area	1965-1973				1973-1980				1980-1985			
	Subplot 1		Subplot 2		Subplot 1		Subplot 2		Subplot 1		Subplot 2	
	LZ	HZ	LZ	HZ	LZ	HZ	LZ	HZ	LZ	HZ	LZ	HZ
Saddle Canyon	+1.323	-1.818	+3.39	+0.074	+1.658	+1.249	+0.834	-0.15	-1.423	-0.632	-0.738	+0.68
Cardenas	+3.649	+1.398	+3.216	+0.431	+0.478	-1.878	+0.78	-0.507	-0.57	+2.126	-2.846	-0.259
Bass Canyon	+0.083	+0.021	+0.274	+0.09	+0.069	-0.003	-0.003	+0.022	-0.146	+0.042	-0.118	-0.075
Forster	+0.012	+0.348	+0.063	+0.037	+0.435	+0.237	+0.307	+0.547	-0.464	+0.002	-0.318	-0.232
National	+0.815	-0.471	+0.62	+0.421	+0.837	+0.437	+0.231	+0.088	-0.974	-0.525	-0.678	-0.342
Granite Park	+1.334	-0.557	+0.689	+1.028	-0.231	+0.804	+0.170	+0.278	-0.066	-0.086	-0.497	-0.752
Granite Springs	+0.221	+2.101	+0.210	+0.215	+1.028	+1.615	+0.009	+0.001	-1.091	-2.162	-0.145	-0.177
TOTALS	+7.437	+1.022	+8.462	+2.296	4.274	2.461	2.328	0.279	-4.734	-1.235	-5.34	-1.157

Total river miles surveyed	1965-1973		1973-1980		1980-1985	
	LZ	HZ	LZ	HZ	LZ	HZ
4.05	15.892	3.318	6.602	2.74	-10.074*	-2.392
Ave. change/yr in 4.05 miles	+1.9865	+0.4148	+0.9431	+0.3914	-2.0148*	-0.478
Ave. change/ river mile	+3.924	+0.8193	+1.6301	+0.6765	-2.4874*	-0.5906
Ave. change/yr/ river mile	+0.4905	+0.1024	+0.2329	+0.0966	-0.4975*	-0.118

* This decrease is mainly related to the flood of 1983.

Table 3

Paired t-Test

1. Calculations

$$\bar{x} = \frac{1}{n} \sum x$$

$$s^2 = \frac{1}{n-1} \{\sum x^2 - \frac{1}{n} (\sum x)^2 \}$$

$$t = \frac{\bar{x} - \mu}{s/\sqrt{n}}$$

2. Results of paired t-test

Nonnative riparian zone			Native riparian zone		
1965-73 LZ	1973-80 LZ	1980-85 LZ	1965-73 HZ	1973-80 HZ	1980-85 HZ
n = 13	n = 22	n = 22	n = 13	n = 22	n = 22
t = 3.25*	t = 5.46*	t = 5.05*	t = 0.96	t = 1.77	t = 3.25*

*Indicates significant changes between the means at the 95 percent probability level (P = .05).