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SECTION 5.0

VEGETATION

INTRODUCTION

Plants are an integral part of the effluent treatment processes in constructed wetlands (Wetzel, 1993). Their submerged surface provides structure for the accumulation of microorganisms that are largely responsible for biological wastewater treatment. The emergent leaves provide shading and act as wind blocks. The plants also utilize nitrogen, phosphorus, and other trace constituents from the water for growth. The plants also fix atmospheric carbon into organic structures that then break down and provide inputs of different carbonaceous materials into the wastewater, in addition to those materials already present in the wastewater.

A summary of the vegetation management and monitoring program at the SCWDP from 1994 through 1998 is presented in this section. The topics covered in this section include:

- Taxonomy
- Vegetation Monitoring Program
- Vegetation Management
- Above-ground Plant Biomass
- Below-ground Plant Biomass
- Plant Density
- Plant Growth Rates
- Vegetation Tissue Concentrations
- Water Level Competition
- Tree Growth Study

Many of the topics covered were also addressed in previous Annual Reports (Nolte, 1996; Nolte, 1997; Nolte, 1998). All tables and figures are presented at the end of the section in the order referenced.

TAXONOMY

Throughout this report, reference to plant species are made using scientific names. Common names can be cross-referenced in Table 5-1, which provides a summary of plant species observed at the SCWDP between 1993 and 1998. All plant taxonomy follows the Jepson Manual (Hickman, 1993). The wetland cells were dominated by the two tall emergent macrophytes *Scirpus acutus* Bigelow var. *occidentalis* (S. Watson) Beetle and *Typha domingensis* Pers. Throughout the report the generic names, *Scirpus* and *Typha* are used in reference to these two species respectively. It should be noted that *Typha latifolia* L. is also present in all cells although in smaller numbers than *T. domingensis*. Cell 8 and the habitat

cell have large stands of *Scirpus californicus* (C. Meyer) Steudel, another tall emergent macrophyte.

VEGETATION MONITORING PROGRAM

Monitoring of vegetation characteristics can give indications of wetland health as well as provide information for comparisons between plant species, flow regimes, and other wetlands, either natural or constructed.

Vegetation monitoring at the SCWDP was performed through the use of quadrats and transects. A quadrat is a 0.5 meter x 0.5 meter PVC frame used to section off a segment of wetland vegetation for repeated observation. There are a total of 101 permanent quadrats within the 11 wetland cells. Each wetland cell, except Cells 6 and 11, has nine quadrats, five in the influent side (B-half) and four in the effluent side (A-half). Cells 6 and 11 have ten quadrats each. The quadrats are situated in the center area of each half cell. The locations of wetland cell quadrats are summarized in Table 5-2. An additional 5 quadrats are located in Laguna Creek. Two are east of the Southern Pacific Railroad tracks and three are west of the tracks. All five are located in *Scirpus acutus* vegetation zones.

Direct measurements of most vegetation parameters over a large area, such as a wetland cell or even a quadrat, are not possible due to the overwhelming quantity of material occupying that area. Typically, a parameter for which results are easily obtainable, such as plant length, is recorded and related to the unmeasurable parameter for which results are desired.

Estimates of plant biomass were made by developing a correlation between shoot length and dry weight. Two *Scirpus* plants were selected from each quadrat and measured for length, allowed to dry, and weighed to ascertain dry weight. The regression for *Typha* was generated by counting the number of *Typha* leaves within each quadrat and multiplying by the average length of the leaves measured within the quadrat. A regression analysis was performed on each data set to develop a length-to-biomass regression for each species. Therefore, the biomass measurements made within each quadrat represent the lengths of all plants observed within 0.25 m², converted to biomass, and multiplied by four to obtain results reported in g per m².

Quadrat data were taken in the late summer, when most plants were at their peak biomass. As the season progresses into fall, both *Scirpus* and *Typha* cease new shoot production and allow existing shoots to senesce (die back). In addition to shoot length, data obtained included: species composition, plant density, water depth, percent cover by floating plants (*Lemna*, *Azolla* etc.), and evidence of herbivory (consumption by plant eating animals). The number of dead *Scirpus* shoots and dead *Typha* leaves were also recorded. Once a *Typha* plant dies, its growth form allows the plant to break-up and only individual leaves can be counted.

In 1998 the methodology for estimating above ground were improved. This was accomplished by recording the percent cover of the area surrounding the quadrat that appeared to have the same plant density and plant heights as those recorded within the

quadrat. For example, if the area surrounding a quadrat was mostly open water with only 20% of the area having the plants characterized by the quadrat reading (density of 100 plants/m² with an average height of 250 cm) then the information recorded for the quadrat was multiplied by 0.2. Thus, open areas were accounted for.

VEGETATION MANAGEMENT

Although routine harvesting of vegetation is not necessary for free water surface wetlands (Reed, 1995), a number of vegetation management techniques were used at the SCWDP. The purpose of the vegetation harvesting was to assess its impact on treatment performance, system hydraulics, and vector control. The most common vegetation management techniques employed were combing, thatching, and channelizing. A summary of the annual vegetation management activities conducted at the SCWDP is presented in Figure 5-1.

Harvest Methods

The most common vegetation management techniques employed at the SCWDP were combing, thatching, and channelizing. Combing was the least invasive of the management techniques. Combing involved the removal of all dead vegetation above the water surface. A backhoe was used to comb the water surface. This procedure resulted in the removal and/or damage to some of the live plants, but shoots and rhizomes below the water surface remained intact. Combing was conducted to try and reduce the organic loading to the wetlands from the decaying vegetation.

Thatching is slightly more invasive. Thatching involved the removal of all dead vegetation above and below the water surface. Like combing, live standing vegetation was also affected, although efforts were made to leave the soil surface and rhizomes intact. Thatching was conducted to reduce organic loading as well as improve the hydraulic conductivity of the wetland.

Finally, the most invasive harvest method employed at the wetlands was channelizing. Channelizing consisted of the removal of all vegetation, both shoots and rhizomes, in four foot wide strips perpendicular to the direction of flow. The purpose of channelizing was to increase the percentage of open water areas free of vegetation. This technique also resulted in the disturbance and/or removal of the sediment layer in many areas.

An additional harvesting program conducted during April 1995 and February 1996 involved the creation of three feet deep and four feet wide channels along the perimeter of several wetland cells. These channels were created using a long-reach backhoe to provide mosquito fish access along the lengths of the wetland cells between potholes.

Vegetation management activities were scheduled when the majority of vegetation had gone into senescence and little new growth has appeared. Vegetation removed during the management events was placed in piles on fields adjacent to the wetlands. After the

harvested material had dried, it was disked into the fields. Alternative vegetation disposal methods considered were burning and co-composting with biosolids.

Harvest Results

Harvesting was not performed in 1994 during the startup period and there was no physical management or manipulation of vegetation within the treatment cells during 1998. In 1995 and 1996, sampling was conducted before and after harvest events to determine the effectiveness of the various techniques at reducing biomass. Average biomass (live plus litter) reduction for thatching and combing were 68 and 61 percent, respectively. Weight reductions ranged from 13 to 90 percent with a standard deviation of 20 percent. There was no statistically significant difference observed between the two harvest techniques. By the late summer of each year the vegetation within the cells appeared healthy and had closed canopies in most instances.

Channelization and the creation of open blocks in Cell 9 permanently reduced overall biomass. The amount of dead plant material (either *Scirpus* or *Typha*) was found to be highly variable and not dependent upon the harvest technique. An expected trend of litter build up due to not harvesting does not appear to happen. The average number of dead shoots and leaves do not continually increase in the non-harvested cells (Cell 5 and 7).

Cell 8 was originally planted with *Scirpus americanus* seeds. This was to give a comparison of tall stature plants (*S. acutus*) with shorter stature plants (*S. americanus*). By 1995, Cell 8 was dominated by *Typha domingensis* and the original comparison could not be made. In the early spring of 1996, Cell 8 was drained and allowed to dry. A bulldozer was used to remove all vegetation from the cell. In September 1996, the cell was replanted with *Scirpus californicus*, another tall macrophyte. Comparisons of growth rates between *S. californicus* and *S. acutus* were then made (see growth rate section).

ABOVE-GROUND PLANT BIOMASS

Five years of above-ground biomass data were collected. Comparison of the data was performed to assess the differences between the various treatment regimes over time and along their profile. The annual average above-ground biomass for each cell is summarized in Table 5-3. Figure 5-2 displays the average combined biomass values since 1994. Graphs of the total above-ground biomass values for each cell, over time and along the gradient are presented in Appendix A.

During 1998, there was a significant difference in the total above-ground biomass between treatment cells. Scheffe's post-hoc test showed significant differences between Cell 7 and Cells 2, 5, 8 and 3. Cell 7 had the highest average biomass value (4.53 kg/m²) and Cell 2 had the lowest (1.17 kg/m²). The well water control, Cell 5, had an average value of 1.24 kg/m².

Harvesting activity, as summarized in Figure 5-1, should be noted when examining the above-ground biomass data. Figure 5-3 presents the comparison of Cell 1 and Cell 2 (Fill

and Draw), by the five-year average of biomass along their length. Figure 5-4 presents the same comparison for Cell 3 and Cell 4 (Recycle), and Figure 5-5 compares Cell 5 and Cell 7 (Plug Flow). All cells were harvested to different degrees yet the effects on the production of biomass are not evident. Cells 1 and 2 have very similar trends in biomass production along the gradient of inflow to outflow. Cell 2, however, was thatched in 1995 and combed in 1997 whereas only half of Cell 1 was combed in the same time period. Cells 3 and 4 have production trends that are similar to each other as well, despite very different vegetation management.

While harvest technique did not appear to strongly influence biomass production, the type of flow regime appeared to have a strong influence on plant growth. This pattern is evidenced by the fact that the fill and draw cells had dramatically different biomass production than the recycle cells.

As expected, there was an obvious increase in biomass production when wastewater was applied instead of groundwater (Figure 5-5). Every year was a significant difference in the biomass produced for Cell 5 (groundwater) and Cell 7 (wastewater). These two cells have never been subjected to any treatment manipulations (harvest, water level, flow rate etc.) so the difference in biomass can only be explained by the quality of water applied. The nutrients provided by the wastewater present an obvious explanation for the observed difference.

BELOW-GROUND PLANT BIOMASS

In most herbaceous plant communities, the estimation of below-ground biomass is much more work intensive than estimation of above-ground biomass. Wetland plant communities are no exception. The overlying water column and the soil matrix make it very difficult to determine root and rhizome propagation, growth, and turnover rates. To assess live below-ground biomass of *Scirpus acutus*, large blocks from the wetland soil matrix were excavated and then smaller samples collected from them. By calculating a root (roots and rhizomes) to shoot ratio (R:S), an estimation of below-ground biomass can be made using the more easily determined measurements of above-ground biomass.

Below-Ground Plant Biomass Study Methods

To evaluate the amount of below-ground biomass in the cells, a sampling method was required to cut through the thick rhizomes without disturbing their position. A backhoe was used to pull up a large volume of the sediment with intact rhizomes and roots. Subsamples were then carved from the large block using a sharp machete. This method caused the least amount of disturbance to the roots and rhizomes, and the researcher could see the sample as it was being taken. Two backhoe bucket samples were taken at four representative locations in Cell 7 and two locations in Cell 5. The areas dug up were characterized by a uniform growth of *Scirpus acutus*. Areas that were impacted by muskrats or *Typha* were avoided.

A backhoe bucket with an opening of 81 cm by 38 cm, and a depth of 56 cm, was used to excavate a block of soil. The bucket sample was placed on the road and the orientation of the

block was determined by the location of the plant shoots and rhizomes and the orientation of the roots. The outer 20 cm was cut away using a machete. Then an approximately 7.5 x 7.5 cm block was sliced from the bucket sample, starting at the soil surface and working down as far as the bucket sample went. Samples were from 30 to 50 cm deep. Two subsamples, located diagonally from each other in the block, were taken from each bucket sample. The subsamples were divided into 10 cm increments by depth (a brick), the dimensions recorded and the bricks put into individual, labeled, ziplock bags for cold storage.

At the time of sampling, notes were taken as to the size and number of roots observed at the greatest depth of material taken by the bucket. Immediately following the backhoe sampling, above-ground biomass was measured per the previously described manner, in vegetation with the same appearance as that destroyed by the backhoe. Using a predetermined correlation between plant height and dry weight, the dry weight of the plants shoots were estimated.

The majority of below-ground subsample bricks consisted of heavy clay. The bricks were submerged in a known amount of water and their volume was determined by the amount of water they displaced. Two Cell 5 bricks were buoyant and had to be held underwater to determine their volume. The bricks were then put into a 4L Nalgene container with 10 g of Calgone and enough water to fill the container. The 4L jars were then agitated for 30 minutes. The brick was then washed by hand over a 1 mm² mesh screen to wash the roots and other organic materials free of the clay.

Plant material collected was divided by into Live Rhizomes (LRh), Live Roots (LRt), Dead Rhizomes (DRh), Dead Roots (DRt), Coarse Organic Material (COM) and Fine Organic Material (FOM). Live material had a dark reddish color (Munsell 5 R 3/6) and was somewhat rigid, whereas dead material was much darker and always limp. Several subsamples had *Typha* roots (TRt) and one had *Typha* rhizomes (TRh) so these categories were included, but not used for the root to shoot ratio calculations. Coarse organic matter was a mixture of dead plant parts, seeds and woody material from other plant species, which could be sorted out and picked up with forceps. Conversely, FOM consisted of live, fine, root hairs that broke off the roots. The more roots and the stickier the clay, the more FOM was generated due to breakage during the washing process.

Because the washing and sorting was a long and tedious process, a minimum subsample depth needed to get the majority of the below-ground plant material was determined. Using an initial set of washed subsamples that went 30 cm or deeper, it was found that the majority of the below-ground plant material was present in the top 20 cm. No roots were observed below a depth of 85 cm. Thus, only the top 20 cm were analyzed.

After washing and sorting, the below-ground samples were put into paper bags and dried at 80°C for 48 hours. Each group was then weighed. Dry weight was expressed as a function of soil volume (kg/m³) and surface area (kg/m²). Using data collected on the above-ground biomass, a ratio of live below-ground biomass to live above-ground biomass was calculated.

The below-ground material was analyzed in two ways. First, the dry weight of each category was standardized by the volume of the soil matrix, resulting in kilograms of biomass per cubic meter of soil (concentration). This was done for each subsample block. The second method was to take the average surface area of the subsample (58 cm²) and calculate the dry weight of each category for the entire depth (0-20 cm). Note that roots extend below the sampling depth so both methods underestimate the actual amount of material present in the field.

Results of Below-Ground Plant Biomass Study

The percentage of total below-ground material from 0 to 10 cm and from 10 to 20 cm is presented in Figure 5-6. As indicated in Figure 5-7, the average concentration of live below-ground plant material (LRh, LRt, FOM) for half cells 7A, 7B, 5A and 5B was 52, 46, 125, and 192 kg/m³, respectively, for the top 20 cm of soil. The difference between Cell 7 and the control Cell 5 was found to be significant.

The average dry weight per area of live below-ground plant material for half cell 7A, 7B, 5A and 5B was 5.0, 4.4, 10.2, and 16.6 kg/m², respectively, for the top 20 cm of soil (Figure 5-8). Half cell 5B was found to be significantly different than the other three half cells.

The above-ground measurements taken concurrently with the below-ground sampling resulted in an average above-ground biomass value of 1.1 kg/m². There was no statistical difference between the biomass values obtained for any location, so all values were averaged. A root to shoot ratio for half cell 7A, 7B, 5A and 5B was 4.5, 3.1, 9.3 and 15.1 respectively.

Discussion of Below-Ground Plant Biomass Study

Above-ground biomass within the treatment cells at the demonstration wetland is generally high (>2 kg/m²). The wastewater is enriched in nutrients and the plants grow well. The high biomass values obtained for live below-ground biomass were enlightening. Work by Hojjati (1995) indicated root to shoot ratios for *Scirpus acutus* close to one, even in high nutrient conditions with no competition. Hojjati's work was based on plants less than one year old grown in 15 cm of soil in 30 gallon tubs, however. Ondok and Kvet (1978) determined R:S for *Phragmites communis* stands to be 1.8 - 9.9 in Czech fishponds. The 9.9 values were determined in the most nutrient rich areas of the ponds. This runs counter to the general plant ecology paradigm which proposes that plants in nutrient poor habitats should have higher root to shoot ratios since the plants need larger root systems to obtain nutrients. At the demonstration wetland it is evident that the groundwater supplied cell (Cell 5) had higher R:S (9.3-15.1) while the more nutrient rich wastewater supplied cell (Cell 7) had lower R:S (3.1-4.5).

Estimated below-ground biomass for Cells 5 and 7, based on the above-ground biomass values obtained from the quadrat readings and the determined R:S from the below-ground biomass study are presented in Table 5-4. Estimates range from 9.67 kg/m² to 23.45 kg/m².

PLANT DENSITY

Plant densities in the wetlands were measured for the two dominant macrophytes: *Scirpus* and *Typha*. Plant densities were estimated by counting the number of live plants and dead plants. In the case of *Typha*, dead leaves were counted. In general, the difference in plant densities between the two species was found to be similar to the difference in plant biomass values described previously (e.i., *Scirpus* represented the majority of plant biomass and density).

In 1998, the average live plant densities for *Scirpus* and *Typha* were 158 and 3 plants/m², respectively. The densities of dead plants for *Scirpus* and *Typha* were 117 plants/m² and 19 dead *Typha* leaves/m², respectively. Average *Scirpus* and *Typha* plant densities for 1994 to 1998 are presented in Table 5-5. It can be seen in Table 5-5 that over time, the live *Scirpus* plant density has leveled off and the dead plant density has continued to increase. Live *Typha* plant densities, however, decreased by 50% between 1997 and 1998. *Typha* dead plant density remained the same in 1998, but has experienced an overall reduction in numbers since 1994. These values include the effects of harvesting treatments.

Cell 7, the unharvested treatment control cell, was examined for effects without harvesting. Cell 7 live *Scirpus* plant density increased in 1998 by 22% and the dead plant density by 96%. Cell 7 live *Typha* plant density decreased by 28% and the dead *Typha* leaf density increased by 180%. The low plant densities observed in Cell 8 can be attributed to the replanting program that occurred to establish *Scirpus californicus*.

These overall trends may be due to the vegetation reaching a mature stage where *Scirpus* will dominate and slowly replace *Typha* by competition. There is also the possibility that the *Typha* decline is merely an artifact of the sampling design. Visual observations indicate that all cells have a substantial amount of *Typha* that is concentrated on the cell edges and at the influent end. It should be recalled that the sampling quadrats were located in the middle of the wetland cells.

PLANT GROWTH RATES

Growth of *Scirpus acutus* (SA) and *Scirpus californicus* (SC) was monitored in Cells 5, 7, 8 and the habitat cell from February 1997 to May 1998. Individual shoots were tagged and the height measured on a weekly or monthly basis. Plant heights were categorized into 50 cm increments and the individual growth rates (cm/day) averaged for each category.

A comparison of growth rates for different height categories for SA and SC are presented in Table 5-6. These values can be compared to those presented for SA in Table 4-8 of the 1996 report. The overall SA growth rates for 1997-98 were slower than the 1995-96 growth rates. Growth rates for SA were higher in most size categories than SC. The 1997-98 data have taller SA plants than the 1995-96 data. SC did not get as tall as SA in the 1997-8 event. There were no SA plants tagged that were shorter than 50 cm due to water depths of 40-45 cm in the treatment cells. Cell 8 was drawn down to 20-35 cm so shorter SC plants could be measured.

Young plants, less than 150 cm tall, were observed to have the highest growth rates, ranging from 3.69 to 4.51 cm/d. As the plants age, their growth rates slow until negative rates are reached as plant tips die and break off. Due to the draw down in Cell 8, many plants were lost to herbivory from muskrats. Large negative growth rates due to this herbivory were discarded from the data set.

When all the growth data was examined, it was found that the three tall macrophytes present at the wetlands grow fastest when they are less than one meter tall. Growth rates between 3.7 to 6.1 cm/day allow these plants to reach a height of one meter in 16 to 27 days. On average, all three species reach a zero growth rate when the plant exceeds a height of 3 meters. Of course plants do grow taller than this, but they are not the majority. In fact, individual plants of all three species were measured at heights over 4 meters tall, with several *Typha* measurements at 4.5 meters tall. *Scirpus acutus* was observed to be the fastest grower of the three species with an average rate between 4.5 and 6.1 cm/day.

VEGETATION TISSUE CONCENTRATIONS

Wetland vegetation tissue samples were analyzed for metals and nutrient content from 1993 through 1998. During the first three sampling events between 1993 and 1995, shoot and root tissue samples were combined and an average plant tissue sample concentration determined. After 1995, samples were separated by plant species (*Scirpus* or *Typha*) and shoots or roots. A description of the sampling protocol can be found in the 1997 Annual Report (Nolte, 1998). The 1998 metals and nutrient sampling program is presented in Table 5-7.

Vegetation Metals Concentrations

Average plant tissue metals concentrations for the treatment wetlands, the control Cell 5, and Laguna Creek are presented in Table 5-8. Caution should be used interpreting the results, as a direct comparison cannot be made between results from the first three sampling events and those following the September 1995 event. The earlier events used a different sampling protocol, where shoots and attached rhizomes were analyzed as a composite tissue sample. Events after the September 1995 event divided the plants into above and below-ground parts, and were analyzed separately.

Average *Scirpus* shoot and rhizome tissue metals concentrations within treatment cells are presented in Figure 5-9. For each metal tested, the difference in concentration between shoots and rhizomes is highly significant. On average, the rhizome concentration values are 2.1 times greater than shoot concentration values. For copper, chromium, lead, nickel and zinc the difference in concentration between the control cell (Cell 5) and the treatment cells were also highly significant. For all metals, except arsenic, the treatment cells have significantly higher concentrations than the control cell receiving groundwater.

It should be noted that the majority of values were below detection limits, and thus reported as one-half the detection limit. Only zinc values were regularly above the detection limit.

There are no significant differences between the 1998 tissue metals concentrations and those observed in the past.

From the data it can be concluded that metals occur at higher levels in the below-ground plant tissues, metals do not appear to be increasing over time in plant tissue, and zinc is the only metal regularly detected above the detection limit in plant tissue at the SCWDP.

Vegetation Nutrient Concentrations

Translocation of nutrients from the rhizomes to new shoots and then from mature shoots back to the rhizomes is a strategy employed by a variety of plants. Little is known about how this translocation occurs in the plant species of the SCWDP. In an attempt to quantify these fluxes, wetland vegetation was monitored over the five-year project for levels of total organic carbon (TOC), total nitrogen (TotN), total phosphorus (TP), and total solids (TS). Vegetation samples were divided up by plant location (treatment cell versus control cell), plant species (*Scirpus* versus *Typha*) and plant parts (rhizomes versus shoots). Nutrient concentration data from 1994 through 1997 can be found in their respective annual reports (Nolte, 1995; Nolte, 1996; Nolte 1997; Nolte, 1998).

In 1998, samples were collected in May and September. The May event included sampling both *Scirpus* and *Typha*, above and below-ground tissue in various life stages. Rhizomes of both species were characterized as either new or old (*Scirpus* new rhizomes=SN, *Scirpus* old rhizomes=SO, *Typha* new rhizomes=TN, *Typha* old rhizomes=TO). Shoots of *Scirpus* and *Typha* were characterized by their age: young, mature, senescent, or dead. Young shoots of both species (SY & TY) are in the growing stage with a color that is lighter green than mature shoots and they are generally shorter than the other shoots. Mature shoots (SM & TM) are those with tips that are just turning brown. Senescent *Scirpus* shoots (SS) are mostly brown, with approximately 60 cm of live material at the base of the shoot. Finally, dead shoots of both species (SD & TD) are completely brown but they are firm to the touch. These are shoots that appear to have died within a year. Dead *Scirpus* shoots that appear to have been dead for over a year, are more grey-brown than yellow-brown and are soft to the touch were designated by SR.

The September sampling event included *Scirpus* rhizomes and shoots that were analyzed for TS and TotN. The September samples were taken from Cells 5, 7 and Laguna Creek for TotN and Cells 5, 7, and 10 for TS.

The results were analyzed using a two-way ANOVA that tested the effects of the water type (Cell 5 control and Cell 7 treatment) and the plant part on the calculated results. The average concentrations of TOC, TC, TS, TotN and TP, respectively, for the various life stages and plant parts of *Scirpus* and *Typha* are illustrated in Figures 5-10 through 5-14.

For TOC there were significant differences between the control and treatment cell for SS, SR and TY (Figure 5-10). For TC there were significant differences between treatments for the majority of life stages that were examined (Figure 5-11). The TC in new *Typha* rhizomes

was significantly different than other below-ground (Figure 5-11). There were no significant differences in below-ground material for TS, however, shoots of both species had significant differences in total solids content for older, dead material (Figure 5-12).

New *Typha* rhizomes (TN) were significantly higher than all other below-ground material in TotN concentration (Figure 5-13) and in TP (Figure 5-14). Additionally, all below-ground material from Cell 5 is significantly different in TotN and TP than material from Cell 7. The TotN and TP in above-ground material can be divided into three groups with TY having the highest values, SY, SM, and TM having the middle range of values and SS, SD, SR and TD having the lowest values (Figure 5-13 and 5-14). There is a very high correlation between TotN and TP for all samples tested.

These results demonstrate that both plant species are losing the nitrogen and phosphorus as they age. Carbon remains fairly constant throughout the life of a plant. Younger rhizomes of both species have higher concentrations of N and P, *Typha* significantly so. The same is true for the above-ground shoots where the youngest shoots of *Typha* have significantly higher N and P concentrations. These high values are reduced as the plant ages. Mature shoots are grouped together, as are all shoots in the dead and dying stages. The dead and dying stages (SS, SD, SR, TD) have the lowest nutrient concentrations and the highest total solids concentrations. Generally there was a difference observed in the nutrient content depending on the quality of water applied. Plants exposed to effluent had significantly higher N and P than the control plants fed groundwater.

It is obvious that young plant tissues contain the highest nutrient concentrations. It is also obvious that the older plant materials are losing nutrients since their concentrations are reduced. These nutrients must be translocated to the rhizomes. By having the rhizomes store nutrients over the winter, the plants can immediately use them in the spring when growth starts.

WATER LEVEL COMPETITION

This study examined plant responses to varying water levels in conjunction with competition between three tall emergent species, *Scirpus acutus*, *S. californicus*, and *Typha domingensis*. In June of 1994, rhizomes of the three plant species were planted in 15 lines of varying elevation in the habitat cell. These rhizomes were irrigated until established. Any rhizomes that failed to sprout were replaced until 100 percent establishment was achieved.

The study area was surveyed in September of 1998 and the percent cover by species and water depths are presented in Table 5-9. It can be seen in Figure 5-15 that *Typha domingensis* (TD) was the dominant species in water depths from 0 to 20 cm and from 70 to 110 cm. From 30 to 40 cm water depths, *Scirpus acutus* (SA) dominates the canopy. *Scirpus californicus* (SC) was found in the greatest abundance from 50 to 60 cm water depth and then again at 115 cm of water. These results differ from the 1995 results where TD composed only 23 percent of the cover. The 1998 results indicate that TD has expanded its coverage to an average of 42 percent. *Scirpus californicus* is found primarily in the deeper water (60 to 115 cm) and SA is primarily in the shallower water (0 to 50 cm). Although the relative

portion of *Scirpus* cover was reduced from the 1995, the differentiation of SA and SC by water depths is roughly the same as in the 1995 results.

The average plant height for SA, SC and TD was 305, 334 and 350 cm respectively. This is an average increase over the past three years of 39, 17 and 41 cm, respectively. *Polygonum hydropiperoides* was present in the shallow depths of 0 to 30 cm, similar to 1995. Many of the plants in the deepest water were actually floating on the water's surface and being held upright by the surrounding plants.

The results of this study confirm what is seen in the treatment cells. The treatment cells are kept at a depth between 40 and 50 cm. This depth is very good for SA. *Typha* is commonly found along the edges of the cells where the water is shallower. Cell 8 is a monoculture of SC and is therefore free from intense competition. However, the plants could become more robust if their water depth was increased to 60 cm.

Overall, the water depth competition study demonstrated that SA was a very fast starter and dominated the plot within the first few months. After the first year SC took over and dominated the plot, especially in the deeper water. Finally, after four years, TD began to dominate the plot, especially at the shallow and the deep end. The deepest these plants can grow seems to be approximately 1.0 m. Water depths greater than 1.0 m cause the plants to uproot themselves due to the buoyancy of their aerenchymous (air-holding) tissue.

TREE GROWTH STUDY

To document the effects of treatment cell effluent on riparian habitat, a tree growth study was conducted in May 1997. The objective was to compare the growth rate of trees receiving treatment cell effluent to that of trees receiving groundwater from a nearby well. A detailed description of the water quality from the treatment cells and groundwater can be found in Section 3 of this report.

Tree Growth Study Methods

The comparison utilized three different tree species. The species included were valley oak (*Quercus lobata*), box elder (*Acer negundo*) and cottonwood (*Populus fremontii*). The study monitored fourteen similarly sized tree seedlings from each species; seven received treatment cell water and seven received groundwater. In addition fourteen cottonwoods, (also of similar size) were planted in the surrounding native soil and were managed with the same treatment. The trees were planted in four gallon nursery containers filled with planters mix, (Premium Organic Compost). The containers were randomly placed in rows of seven, approximately one meter apart. Trees were routinely watered with plastic five gallon buckets, each receiving 2.5 gallons of treatment cell effluent or groundwater. Initially the study would record height, base diameter and number of branches produced. Unfortunately, due to field constraints only height was recorded routinely. Height was measured from the soil nearest the base, to the tallest portion of the tree. Measurements and watering occurred

from May 1997 through November 1997. For growth comparison the height measurements were averaged for each species and date.

Tree Growth Study Results

The comparison of average tree height for treatment cell effluent and groundwater is presented in Figure 5-16. The results suggest that trees receiving effluent exhibit a greater average height increase and longer growing period, compared to trees receiving groundwater. For effluent watered trees the planted cottonwoods display the largest increase, averaging 23 inches and valley oaks show the smallest, averaging 2 inches. For trees receiving groundwater the planted cottonwoods exhibited the largest increase of 19 inches, while the valley oak and box elder were actually observed to decline by 1 inch over the study period. The reduction in overall average height of groundwater trees suggests that growth had stopped. Once growth of the elders and oaks stops the leaves or buds at the top fall off, resulting in a decline of height.

Tree Growth Study Conclusions

The continued increase in average height of trees water with wetland effluent suggests that trees receiving treatment cell effluent grow taller and for a longer period of time. Based on this study, it appears that treated effluent could have a beneficial impact on riparian habitat.

SUMMARY OF FINDINGS

Findings from the vegetation section are summarized below:

1. Two species of macrophytes (*Scirpus* and *Typha*) dominated the wetland vegetation at the SCWDP.
2. *Scirpus* was dominant at water depths from 30 to 60 cm. *Typha* dominated at depths below 30 cm and between 80 and 100 cm.
3. The growth rate of *Scirpus* and *Typha* were found to be up to 6 cm/d. Growth rates were found to be highest when plant height was below 1.5 m and reached a nominal rate of zero when plant heights exceeded 3 m.
4. Plant density at the peak of the growing season averaged 140 and 12 plants/m² for *Scirpus* and *Typha*, respectively.
5. The total above ground biomass at the end of the growing season averaged 2.3 kg/m² over the 5-year project.
6. Below-ground biomass, as calculated using a root to shoot ratio (R:S), was estimated to be from 3 to 15 times the above-ground biomass.
7. Three vegetation harvesting techniques were employed at the SCWDP (thatching, combing, and channelizing). Harvesting technique did not strongly influence biomass production within the wetlands.
8. Metals were found to occur at higher levels in the below-ground plant tissues.

9. Metals did not appear to increase over time in plant tissue.
10. Zinc was the only metal regularly detected above the detection limit in plant tissue.
11. Young plants were found to contain the highest nutrient concentrations. Older plants appeared to be translocating nutrients to their rhizomes for new shoot growth in the spring.
12. Trees receiving effluent from the treatment cells exhibited a greater average height increase and longer growing period than trees watered with groundwater.

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**TABLE 5-1
LIST OF SCIENTIFIC AND COMMON NAMES OF PLANTS OBSERVED AT SCWDP**

Family	Scientific Name	Common Name	Family	Scientific Name	Common Name
Aceraceae	<i>Acer negundo</i>	Box elder	Geraniaceae	<i>Geranium dissectum</i>	Geranium
Alismataceae	<i>Alisma lanceolatum</i>	Water plantain	Juncaceae	<i>Juncus accuminatus</i>	Juncus
Alismataceae	<i>Echinodorus berteroi</i>	Burhead	Lemnaceae	<i>Lemna minor</i>	Duckweed
Alismataceae	<i>Sagittaria sanfordii</i>	Sanford's arrowhead	Lemnaceae	<i>Lemna gibba</i>	Duckweed
Alismataceae	<i>Sagittaria latifolia</i>	Arrowhead	Lemnaceae	<i>Spirodela polyrrhiza</i>	Duckmeat
Apiaceae	<i>Foeniculum vulgare</i>	Fennel	Lemnaceae	<i>Wolffia</i> spp.	Water-meal
Asteraceae	<i>Aster subulatus</i>	Aster	Liliaceae	<i>Brodiaea elegans</i>	Harvest brodiaea
Asteraceae	<i>Centaurea solstitialis</i>	Yellow starthistle	Liliaceae	<i>Triteleia hyacinthina</i>	White brodiaea
Asteraceae	<i>Cichorium intybus</i>	Chicory	Lythraceae	<i>Ammania coccinea</i>	Ammania
Asteraceae	<i>Gnaphalium</i> spp.	Cudweed	Lythraceae	<i>Lythrum californicum</i>	California loosestrife
Asteraceae	<i>Hesperoxys carlescens</i>	Hogwallow starfish	Lythraceae	<i>Lythrum hyssopifolia</i>	Lythrum
Asteraceae	<i>Lactuca serriola</i>	Prickly lettuce	Malvaceae	<i>Malva parviflora</i>	Cheeseweed
Asteraceae	<i>Picris echioides</i>	Bristly ox-tongue	Malvaceae	<i>Malvella leprosa</i>	Alkali-mallow
Asteraceae	<i>Psilocarphus brevisimus</i>	Wolly marbles	Onagraceae	<i>Epilobium brachycarpum</i>	Willow weed
Asteraceae	<i>Silybum marianum</i>	Milk thistle	Onagraceae	<i>Ludwigia peploides</i>	Water primrose
Asteraceae	<i>Xanthium strumarium</i>	Common cocklebur	Papaveraceae	<i>Eschscholzia californica</i>	California poppy
Azollaceae	<i>Azolla filicoides</i>	Mosquito fern	Poaceae	<i>Alopecurus saccatus</i>	Water foxtail
Boraginaceae	<i>Amsinckia menziesii</i>	Rancher's fire weed	Poaceae	<i>Bromus carinatus</i>	California brome
Boraginaceae	<i>Plagiobothrys stipitatus</i>	Popcorn flower	Poaceae	<i>Crypsis vaginiflora</i>	Prickle grass
Brassicaceae	<i>Brassica nigra</i>	Black mustadr	Poaceae	<i>Cyadon dactylon</i>	Bermuda grass
Brassicaceae	<i>Capsella bursa-pastoris</i>	Shepard's purse	Poaceae	<i>Distichlis spicata</i>	Salt grass
Caryophyllaceae	<i>Spergularia rubra</i>	Sand spurry	Poaceae	<i>Echinochola crus-gali</i>	Watergrass
Cyperaceae	<i>Carex barbarae</i>	White root sedge	Poaceae	<i>Elymus glaucus</i>	Blue wildrye
Cyperaceae	<i>Cyperus diformis</i>	Purple nut sedge	Poaceae	<i>Hordeum brachyantherum</i>	Meadow barley
Cyperaceae	<i>Cyperus eragrostis</i>	Umbrella sedge	Poaceae	<i>Leptachola univaria</i>	Mexican sprangletop
Cyperaceae	<i>Cyperus odoratus</i>	Ferex	Poaceae	<i>Leymus triticoides</i>	Creeping wildrye
Cyperaceae	<i>Eleocharis macrostachya</i>	Spike rush	Poaceae	<i>Lolium multiflorum</i>	Annual rye grass
Cyperaceae	<i>Scirpus acutus</i>	Tule	Poaceae	<i>Paspalum dilatatum</i>	Dallis grass
Cyperaceae	<i>Scirpus californicus</i>	Bulrush	Poaceae	<i>Poa annua</i>	Annual bluegrass
Cyperaceae	<i>Scirpus fluviatilis</i>	River bilrush	Poaceae	<i>Polypogon monspeliensis</i>	Rabbit's foot grass
Cyperaceae	<i>Scirpus maritimus</i>	Scirpus	Polygonaceae	<i>Polygonum hydropteroides</i>	Smartweed
Cyperaceae	<i>Scirpus robustus</i>	Alkali bulrush	Polygonaceae	<i>Polygonum lapathifolium</i>	Willow smartweed
Euphorbiaceae	<i>Eremocarpus setigerus</i>	Turkey mullein	Polygonaceae	<i>Polygonum persicaria</i>	Lady's thumb
Fabaceae	<i>Lotus corniculatus</i>	Birdsfoot trefoil	Polygonaceae	<i>Rumex crispis</i>	Curly dock
Fabaceae	<i>Melilotus alba</i>	White sweetclover	Polygonaceae	<i>Rumex maritimus</i>	Rumex
Fabaceae	<i>Melilotus indica</i>	Yellow sweetclover	Primulaceae	<i>Anagalis arvensis</i>	Scarlet pimpernel
Fabaceae	<i>Trifolium incarnatum</i>	Crimson clover	Salicaceae	<i>Populus fremontii</i>	Cottonwood
Fabaceae	<i>Trifolium arvense</i>	Rabbitfoot clover	Salicaceae	<i>Salix</i> spp.	Willow spp.
Fabaceae	<i>Trifolium</i> spp.	Clover	Solinaceae	<i>Nicotiana quadrivalvis</i>	Tobacco
Fabaceae	<i>Viscia villosa</i>	Hairy vetch	Solinaceae	<i>Physalis</i> spp.	Ground cherry
Fagaceae	<i>Quercus lobata</i>	Valley oak	Typhaceae	<i>Typha domingensis</i>	Cattail
Geraniaceae	<i>Erodium cicutarium</i>	Red stemmed filaree	Typhaceae	<i>Typha latifolia</i>	Cattail
Geraniaceae	<i>Geranium carolinianum</i>	Carolina geranium			

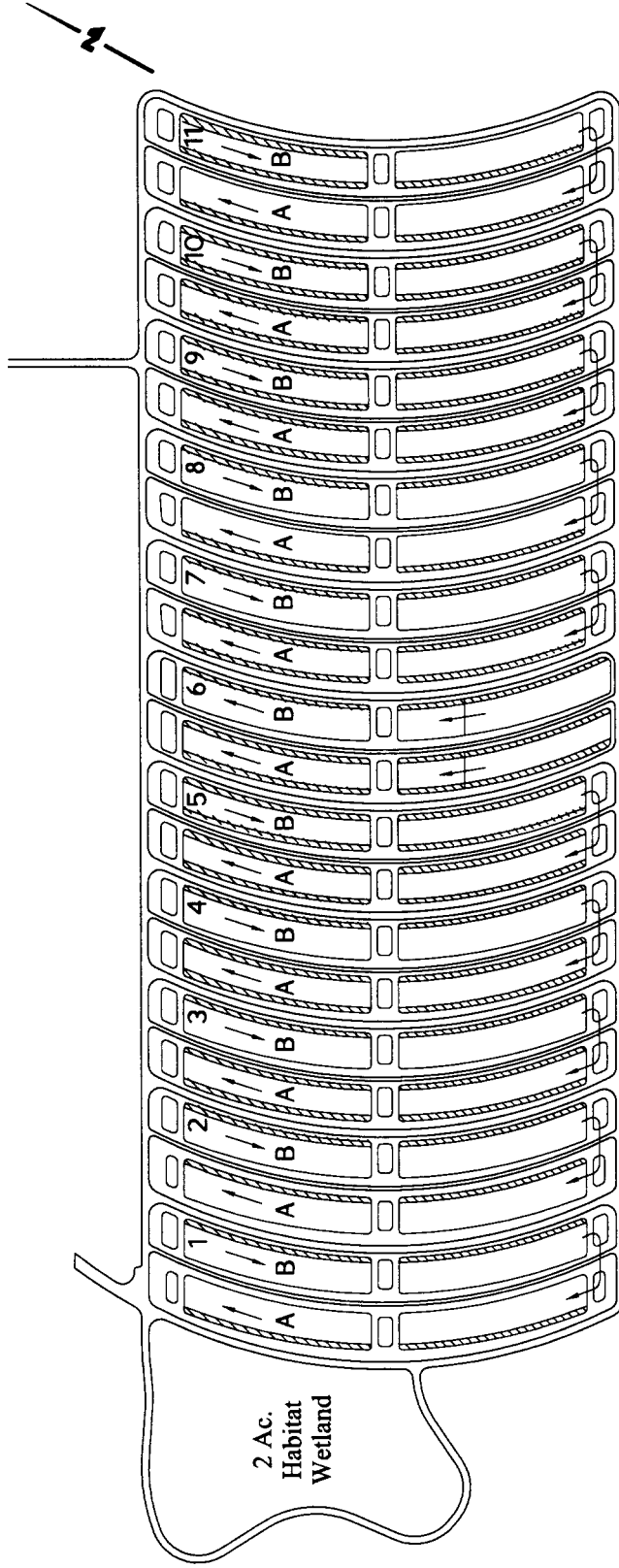
TABLE 5-2
LOCATION OF VEGETATION MONITORING QUADRATS
SACRAMENTO CONSTRUCTED WETLANDS DEMONSTRATION PROJECT

Quadrat Number	Quadrat Location, ft from wetland inlet ^a		
	Cells 1 to 5, 7 to 10	Cell 6	Cell 11
1	80	530	60
2	170	450	90
3	250	370	240
4	420	260	290
5	560	230	420
6	720	230	560
7	840	260	720
8	1,010	370	840
9	1,120	450	1,010
10	NA	530	1,120

^aTotal cell length is 1,260 ft (Cell 6 = 630 ft)

FIGURE 5-1

VEGETATION MANAGEMENT TECHNIQUES APPLIED, 1994-1998
 SACRAMENTO CONSTRUCTED WETLANDS DEMONSTRATION PROJECT



HARVEST	1A	1B	2A	2B	3A	3B	4A	4B	5A	5B	6A	6B	7A	7B	8A	8B	9A	9B	10A	10B	11A	11B
1995	C	-	TH	TH	TH	TH	C	C	-	-	CH	-	-	-	TH	TH	CH	TH	C	-	CH	TH
1996	C	C	C	C	-	-	C	C	-	-	CH	C	-	-	RE	RE	CH	CH	C	C	CH	CH
1997	-	-	C	C	C	C	C	C	-	-	CH	C	-	-	-	-	H	H	C	C	CH	CH
1998	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

KEY

- C - COMBED
- CH - CHANNELIZED
- TH - THATCHED
- (-) - NO TREATMENT
- RE - REPLANTED
- ||||| - SIDE CHANNELS
- H - HEMI-MARSH

TABLE 5-3
 AVERAGE ABOVE-GROUND BIOMASS, 1994-1998
 SACRAMENTO CONSTRUCTED WETLANDS DEMONSTRATION PROJECT

Wetland Cell	Total Biomass, kg/m ²					Average 1994-1998
	1994	1995	1996	1997	1998	
Cell 1 - Fill/Draw	1.19	2.24	3.55	2.62	1.96	2.31
Cell 2 - Fill/Draw	0.43	1.68	3.57	4.07	1.17	2.18
Cell 3 - Recycle	0.97	2.97	2.78	3.85	1.65	2.45
Cell 4 - Recycle	1.21	2.03	4.32	3.40	2.53	2.70
Cell 5 - Control	0.92	1.46	2.13	1.13	1.24	1.38
Cell 6 - Overland	1.16	1.66	2.78	1.75	2.08	1.89
Cell 7 - Plug	1.86	2.13	3.19	4.80	4.53	3.30
Cell 8 - Plug	2.12	2.86	0	0.30	1.33	1.32
Cell 9 - Plug	2.31	2.60	3.60	2.06	3.28	2.77
Cell 10 - Plug	1.49	2.41	3.79	1.68	2.50	2.38
Cell 11 - Subsurface	1.49	3.74	2.44	3.89	2.32	2.77
Average	1.38	2.34	2.92	2.69	2.24	2.31

Monitoring Dates: July 1994, September 1995; September 1996, October 1997, and August 1998.

FIGURE 5-2
AVERAGE ABOVE-GROUND BIOMASS FROM 1994 TO 1998
SACRAMENTO CONSTRUCTED WETLANDS DEMONSTRATION PROJECT

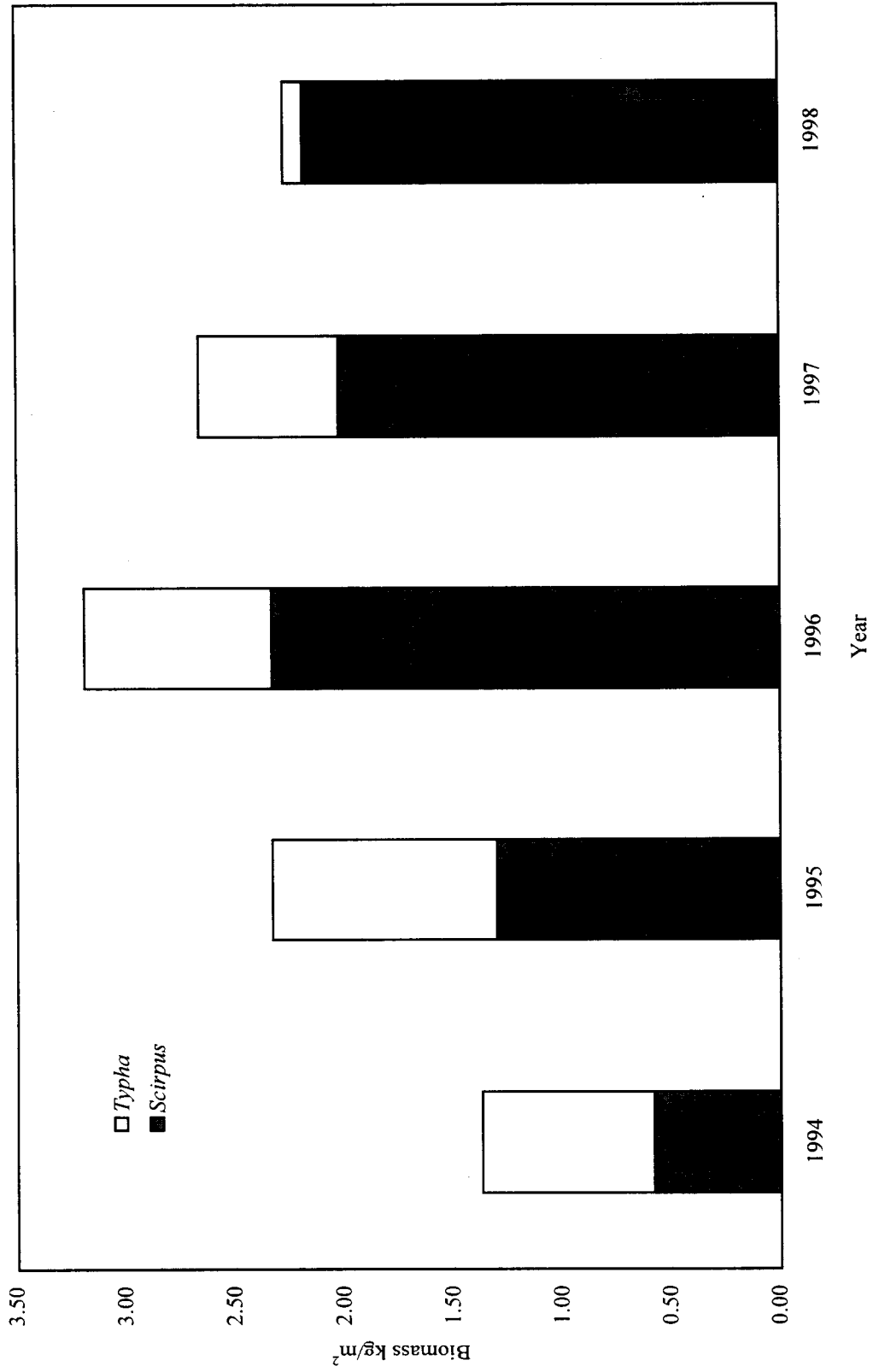


FIGURE 5-3
ABOVE-GROUND BIOMASS ALONG WETLAND PROFILE - WETLAND CELLS 1 AND 2
SACRAMENTO CONSTRUCTED WETLANDS DEMONSTRATION PROJECT

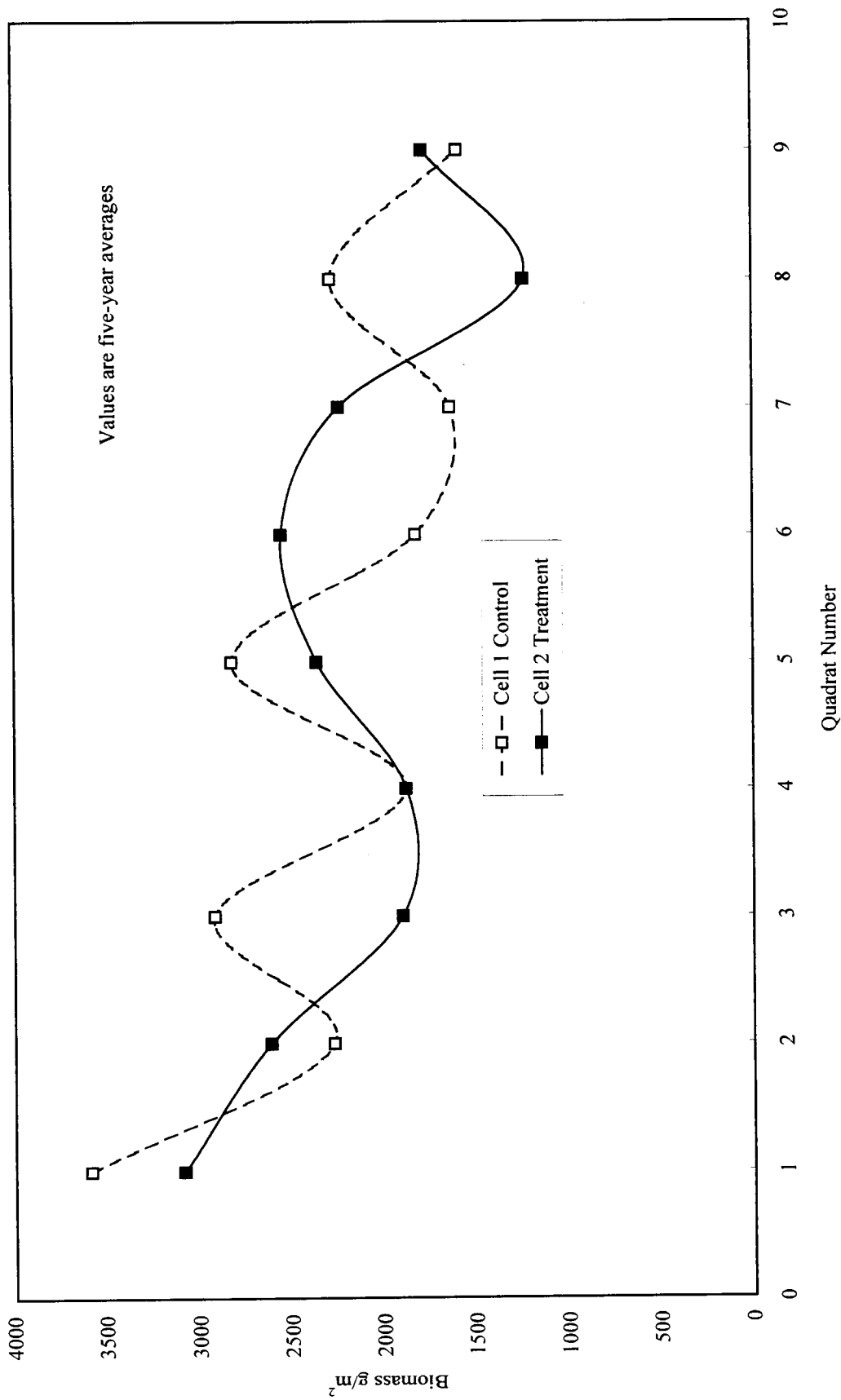


FIGURE 5-4
ABOVE-GROUND BIOMASS ALONG WETLAND PROFILE - WETLAND CELLS 3 AND 4
SACRAMENTO CONSTRUCTED WETLANDS DEMONSTRATION PROJECT

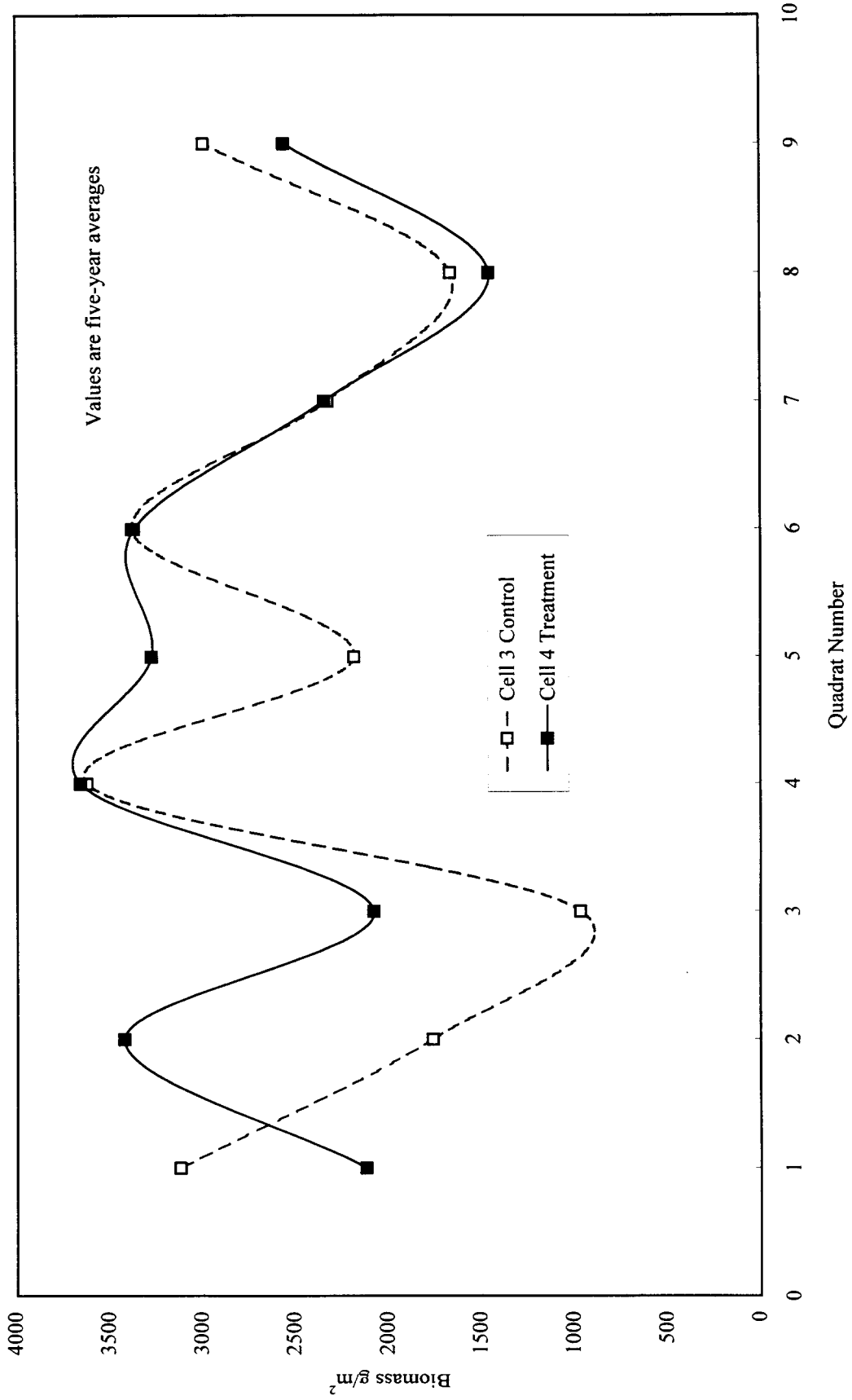


FIGURE 5-5
ABOVE-GROUND BIOMASS ALONG WETLAND PROFILE - WETLAND CELLS 5 AND 7
SACRAMENTO CONSTRUCTED WETLANDS DEMONSTRATION PROJECT

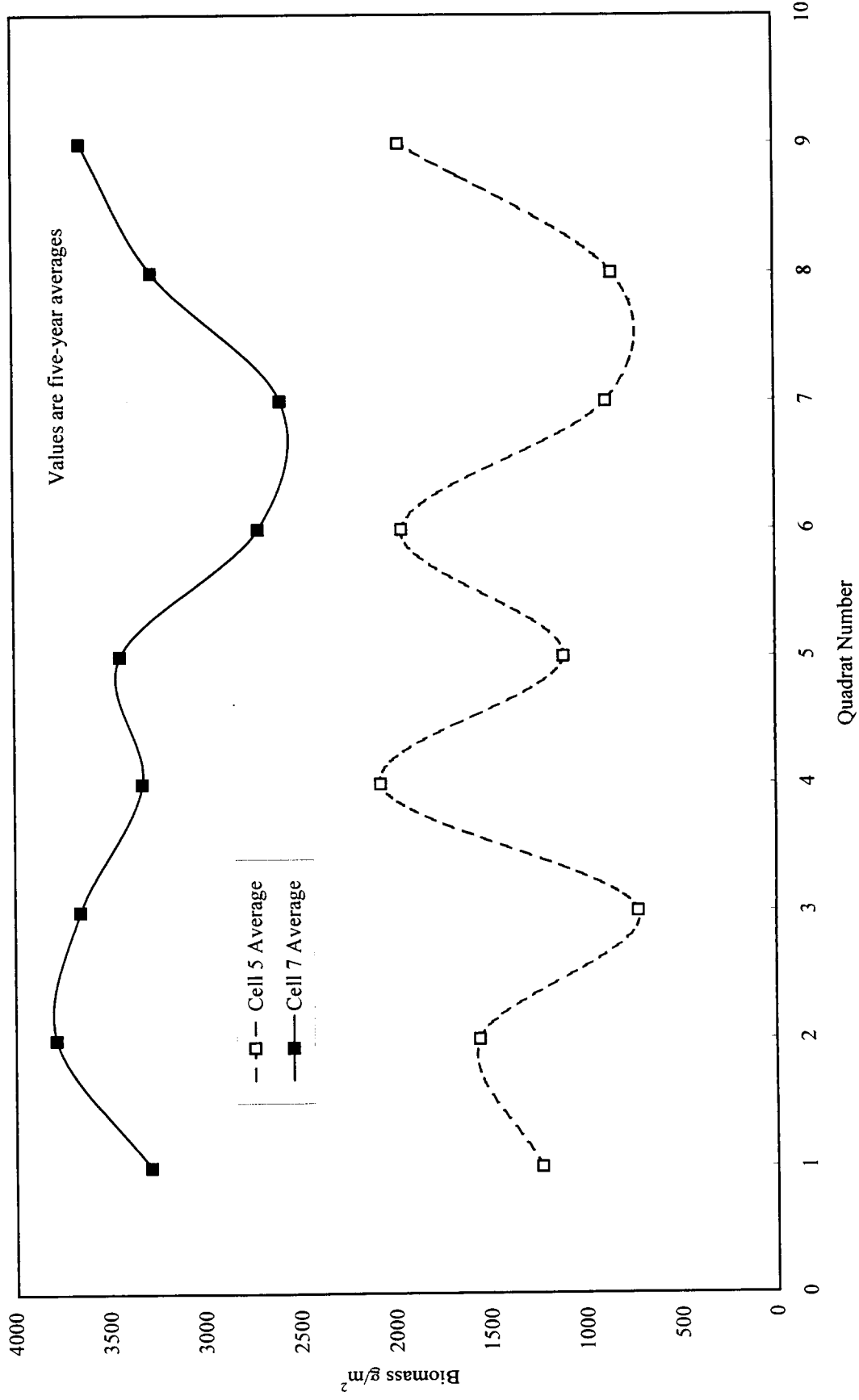


FIGURE 5-6
PERCENT OF BELOW-GROUND VEGETATION FROM 0 TO 10 CM AND 10 TO 20 CM
SACRAMENTO CONSTRUCTED WETLANDS DEMONSTRATION PROJECT

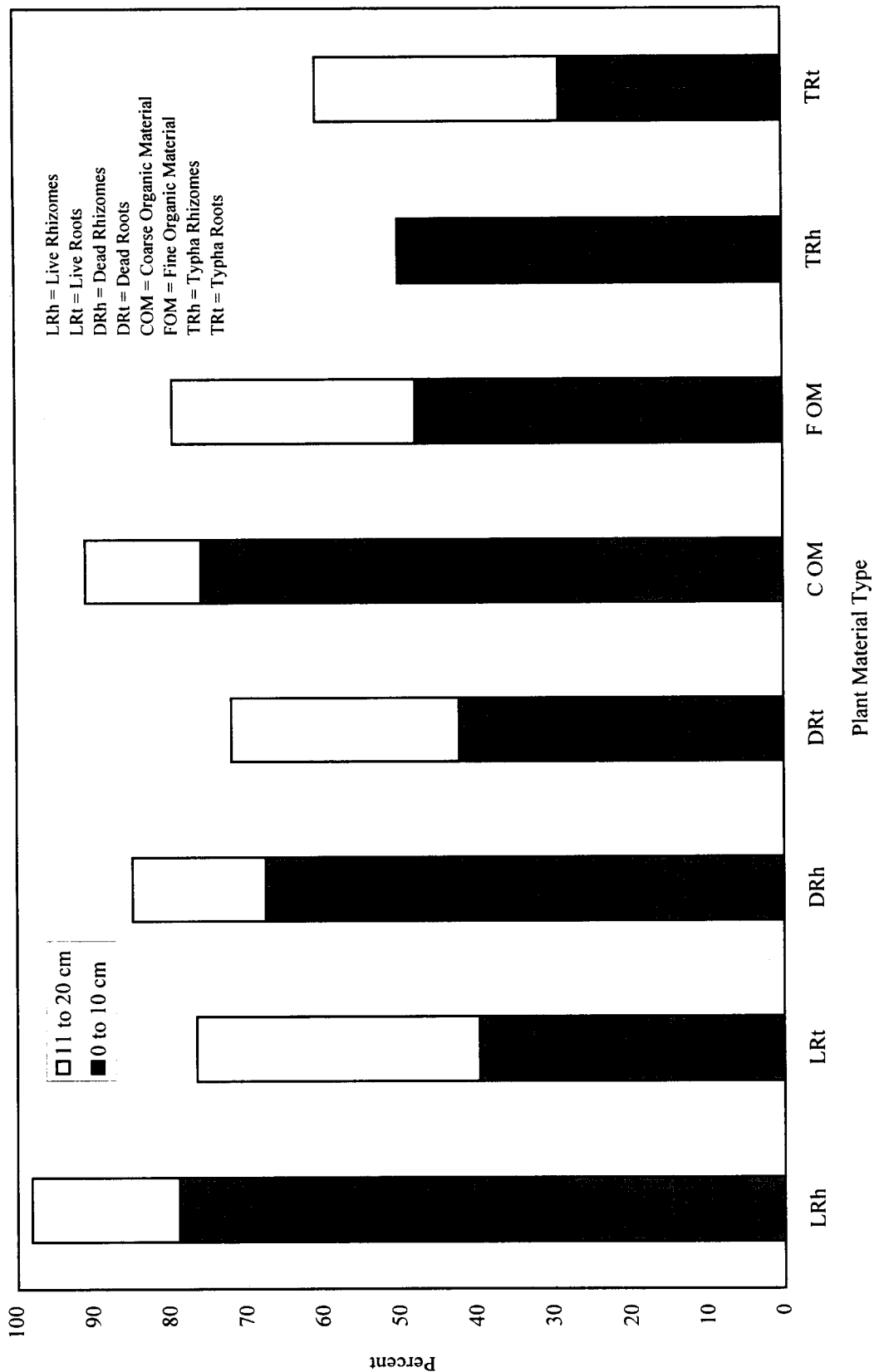


FIGURE 5-7
AVERAGE CONCENTRATION OF LIVE BELOW-GROUND BIOMASS FROM 0 TO 20 CM DEEP
SACRAMENTO CONSTRUCTED WETLANDS DEMONSTRATION PROJECT

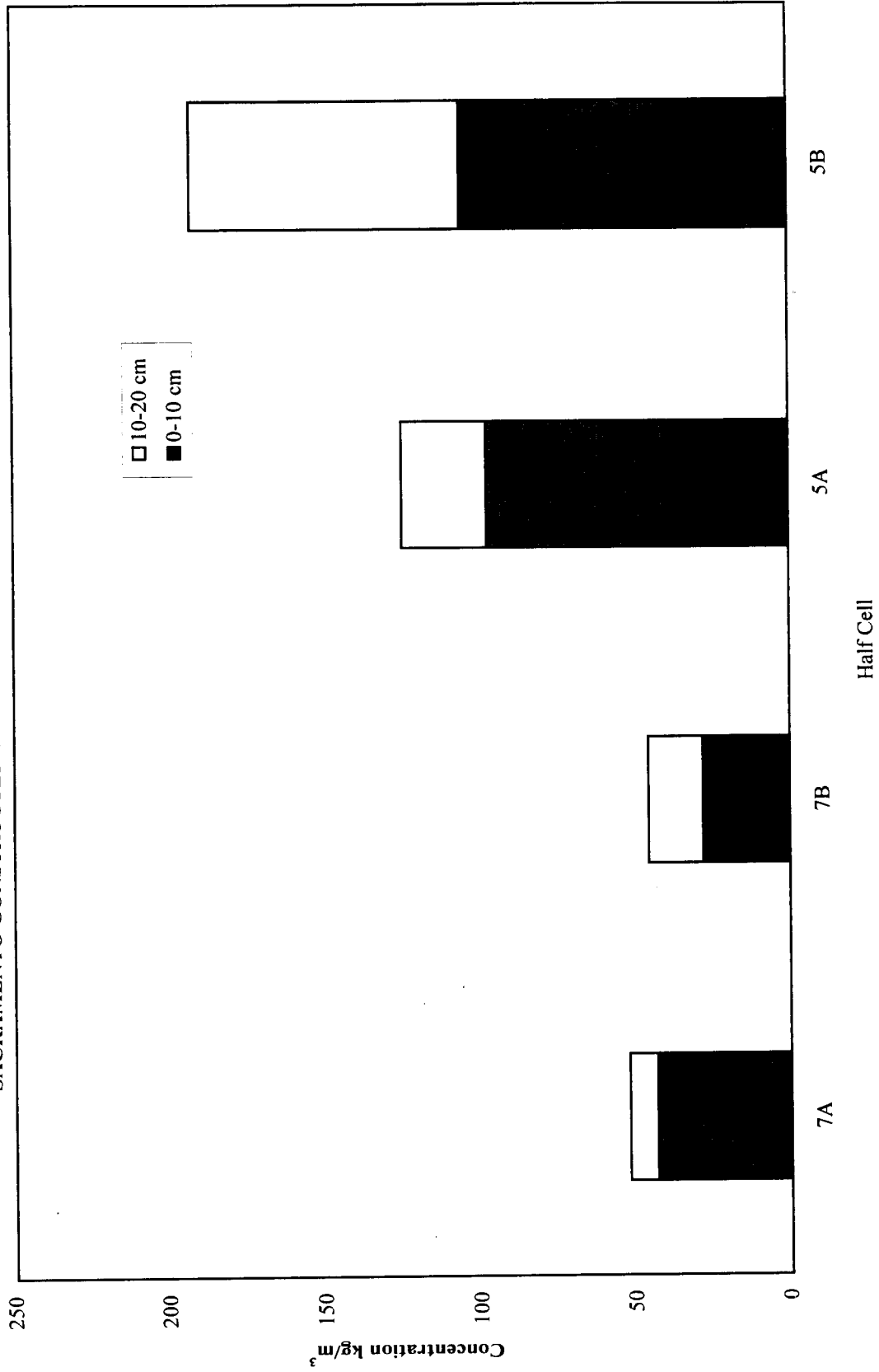


FIGURE 5-8
AVERAGE WEIGHT PER AREA OF LIVE BELOW-GROUND BIOMASS
SACRAMENTO CONSTRUCTED WETLANDS DEMONSTRATION PROJECT

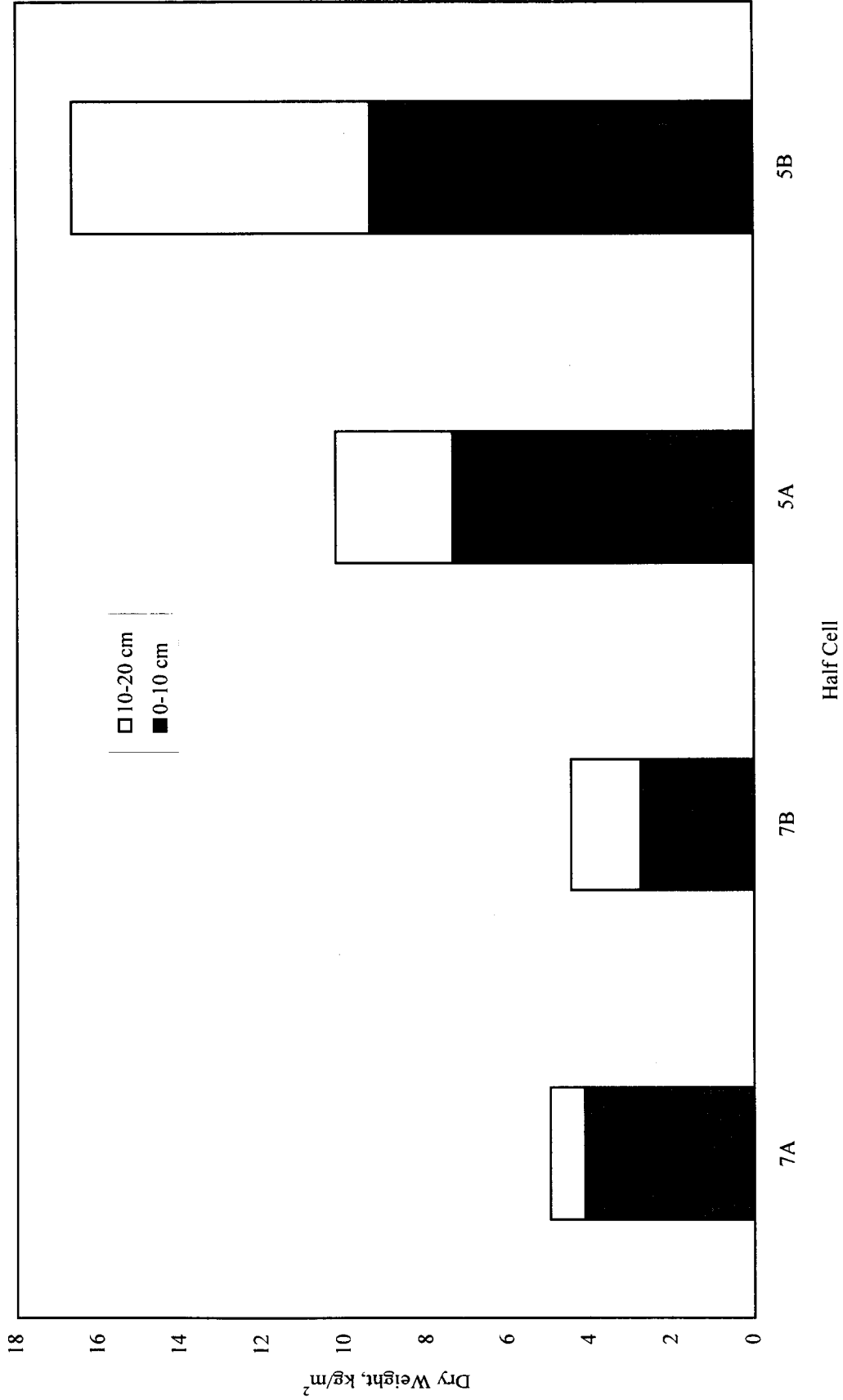


TABLE 5-4
ESTIMATE OF BELOW-GROUND BIOMASS USING ROOT TO SHOOT RATIO
SACRAMENTO CONSTRUCTED WETLANDS DEMONSTRATION PROJECT

Half Cell	Root to Shoot Ratio	Biomass, kg/m ²		
		Measured	Estimated	
		Above-Ground	Below-Ground	Total
5A	9.3	1.04	9.67	10.71
5B	15.1	1.28	19.33	20.61
7A	4.5	5.21	23.45	28.66
7B	3.1	3.81	11.81	15.62

TABLE 5-5
SUMMARY OF ANNUAL PLANT DENSITIES, 1994 TO 1998^a
SACRAMENTO CONSTRUCTED WETLANDS DEMONSTRATION PROJECT

Wetland Cell	Plant Density, plants/m ²										Leaf Density, leaves/m ²									
	Live <i>Scirpus</i>					Dead <i>Scirpus</i>					Live <i>Typha</i>					Dead <i>Typha</i>				
	1994	1995	1996	1997	1998	1994	1995	1996	1997	1998	1994	1995	1996	1997	1998	1994	1995	1996	1997	1998
1A	70	218	243	160	168	38	54	150	391	97	19	0	3	0	0	91	0	0	12	0
1B	51	197	169	132	118	21	66	87	178	70	31	18	31	17	2	93	67	58	163	17
2A	45	191	154	150	141	91	38	97	69	82	6	9	17	17	2	234	5	39	30	78
2B	131	200	234	211	125	79	56	91	98	69	6	2	6	21	9	24	0	7	14	20
3A	102	152	142	158	192	64	50	74	35	116	28	32	20	7	2	131	51	106	1	9
3B	114	183	112	287	77	70	50	98	68	58	11	21	14	6	0	111	57	130	3	21
4A	111	169	148	135	188	77	58	73	26	128	27	14	13	13	3	80	29	33	9	30
4B	156	182	245	214	142	94	45	74	74	69	15	10	14	6	6	78	34	60	13	19
5A	103	121	80	103	105	59	81	109	112	81	19	21	9	1	2	44	67	85	0	5
5B	148	138	90	65	94	110	114	154	90	83	5	6	6	0	1	28	11	60	10	7
6A	78	110	104	69	182	96	70	110	73	136	31	30	10	9	3	103	166	112	32	13
6B	140	147	148	146	205	178	145	81	86	203	14	10	10	1	0	25	122	36	2	0
7A	148	175	138	155	190	70	123	122	193	347	22	3	5	0	0	66	131	30	7	0
7B	101	145	117	150	181	40	79	74	87	231	31	14	24	18	13	46	64	73	35	98
8A	3	8	NA	16	37	5	1	NA	0	10	38	50	NA	0	0	27	116	NA	0	0
8B	0	0	NA	78	162	0	0	NA	0	44	35	58	NA	0	0	61	190	NA	0	0
9A	136	132	108	135	241	42	275	148	177	173	11	10	15	1	0	16	160	157	2	4
9B	171	150	118	150	159	99	41	130	141	116	24	29	27	3	10	141	63	126	12	45
10A	103	102	163	191	231	48	86	122	97	174	27	15	9	0	0	106	57	22	4	7
10B	123	187	212	137	207	63	108	110	105	44	23	17	10	1	0	99	66	18	0	0
11A	173	232	65	148	200	63	27	25	133	146	5	24	21	18	4	55	25	32	75	33
11B	51	189	120	182	137	23	131	45	153	102	21	9	15	8	6	16	81	22	7	11
Average	103	151	146	144	158	65	77	99	108	117	20	18	14	7	3	76	71	60	20	19

^aPlant density measurements taken at peak of growing season

TABLE 5-6
GROWTH RATES OF *SCIRPUS acutus* AND *SCIRPUS californicus*
SACRAMENTO CONSTRUCTED WETLANDS DEMONSTRATION PROJECT

Plant Height, cm	Number of Samples	Growth Rate, cm/day ^a			Standard Deviation
		Average	Maximum	Minimum	
<i>Scirpus acutus</i>					
50 <H< 100	60	4.11	11.00	-0.50	2.64
100 <H< 150	98	4.50	16.33	-0.57	3.16
150 <H< 200	136	2.15	7.86	-9.86	3.08
200 <H< 250	157	1.79	13.33	-16.17	3.33
250 <H< 300	226	0.58	8.75	-10.00	2.65
300 <H< 350	60	0.53	8.75	-7.86	2.76
350 <H< 400	21	0.02	5.00	-6.07	2.64
400 <H	14	-1.27	2.50	-7.14	2.85
<i>Scirpus californicus</i>					
0 <H< 50	66	4.51	14.83	-2.71	3.46
50 <H< 100	543	3.69	11.00	-8.14	2.89
100 <H< 150	685	2.09	14.86	-11.00	2.74
150 <H< 200	590	1.20	8.13	-8.89	2.14
200 <H< 250	303	0.46	5.86	-12.14	1.70
250 <H< 300	83	0.02	4.29	-12.50	2.10
300 <H< 350	5	-2.05	0.00	-8.57	3.72

^a Based on data collected between February 1997 and May 1998

TABLE 5-7
1998 SCHEDULE FOR PLANT TISSUE SAMPLING AND ANALYSIS
SACRAMENTO CONSTRUCTED WETLANDS DEMONSTRATION PROJECT

Constituent	Abbreviation	Sample		Test Method	Cells Sampled	Distance
		Date	Laboratory			From Inflow, ft
Arsenic	As	May	CAL TEST	H6010	5, 7, 10	80, 250, 560, 790, 1120
		Sep	CAL TEST			
Chromium	Cr	May	CAL TEST	H6010	5, 7, 10	80, 250, 560, 790, 1120
		Sep	CAL TEST			
Copper	Cu	May	CAL TEST	H6010	5, 7, 10	80, 250, 560, 790, 1120
		Sep	CAL TEST			
Mercury	Hg	May	CAL TEST	H7471,H7471A	5, 7, 10	80, 250, 560, 790, 1120
		Sep	CAL TEST	H7471,H7471A		
Nickel	Ni	May	CAL TEST	H6010	5, 7, 10	80, 250, 560, 790, 1120
		Sep	CAL TEST			
Lead	Pb	May	CAL TEST	H6010	5, 7, 10	80, 250, 560, 790, 1120
		Sep	CAL TEST			
Zinc	Zn	May	CAL TEST	H6010	5, 7, 10	80, 250, 560, 790, 1120
		Sep	CAL TEST			
Total Carbon	TC	May	A & L WEST	AOAC 2.176	5, 7	80, 250, 560, 1120
		Sep	A & L WEST	AOAC 2.176	5, 7, LC ^b	80, 560, 1120
Total Organic Carbon	TOC	May	CAL LAB SVSC	H9060M	5, 7	250, 1120
Total Nitrogen	TN	May	A & L WEST	AOAC 2.058	5, 7	80, 250, 560, 1120
		Sep	A & L WEST	AOAC 2.058	5, 7, LC	80, 560, 1120
Total Phosphorus	TP	May	A & L WEST	AOAC 3.007/6	5, 7	250, 1120
Total Solids	TS	May	CAL TEST ^a	E160.3	5, 7, 10	80, 250, 560, 790, 1120
		Sep	CAL TEST	E160.3	5, 7, 10, LC	80, 250, 560, 790, 1120

^a Nutrient study analyzed by CAL L SVS using method S2540B

^bLC = Laguna Creek

FIGURE 5-9
 SUMMARY OF AVERAGE TREATMENT CELL *SCIRPUS* METALS CONCENTRATION
 SACRAMENTO CONSTRUCTED WETLANDS DEMONSTRATION PROJECT

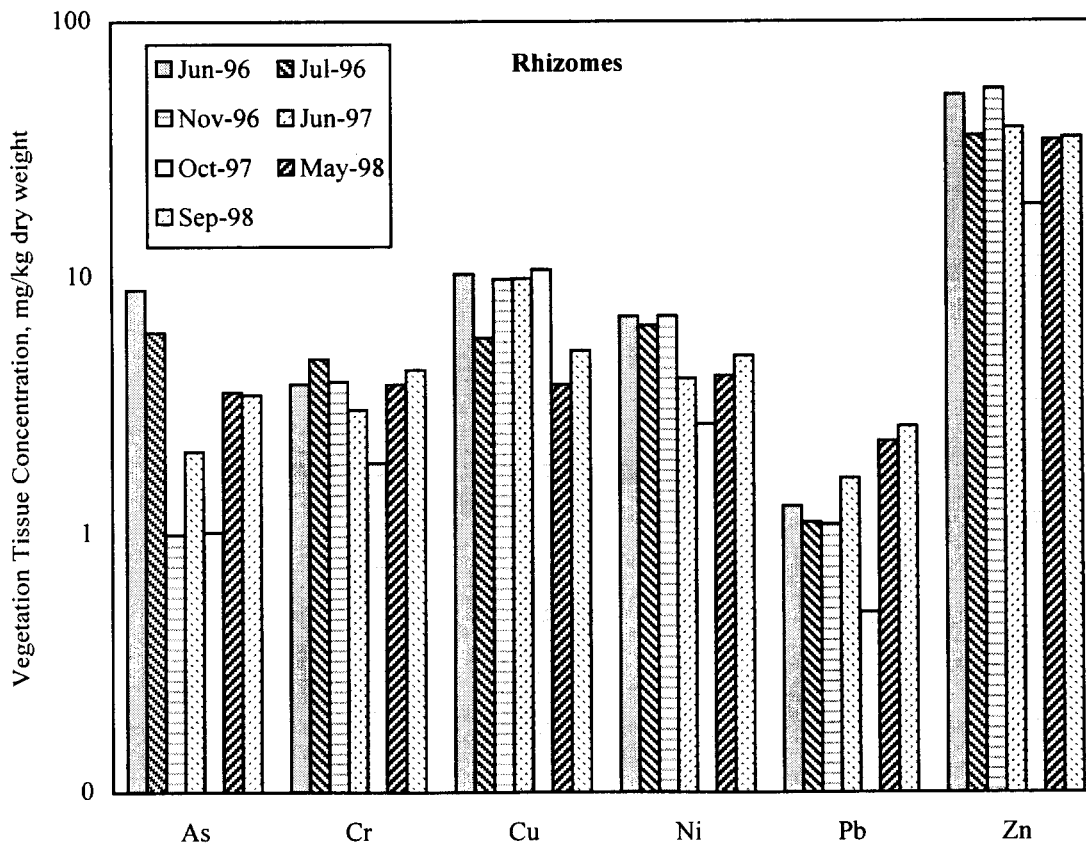
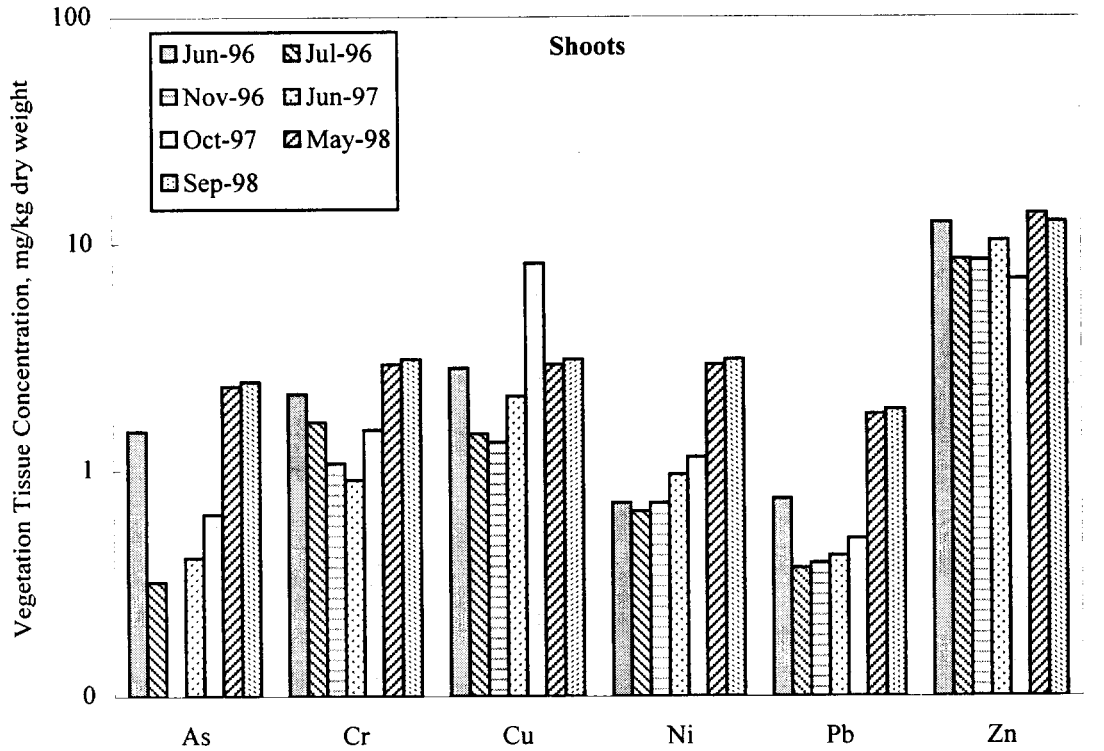


FIGURE 5-10
TOTAL ORGANIC CARBON (TOC) OF BELOW- AND ABOVE-GROUND MATERIAL FOR SCIRPUS AND TYPHA AT VARIOUS LIFE STAGES FROM CELLS 5 AND 7, 1998

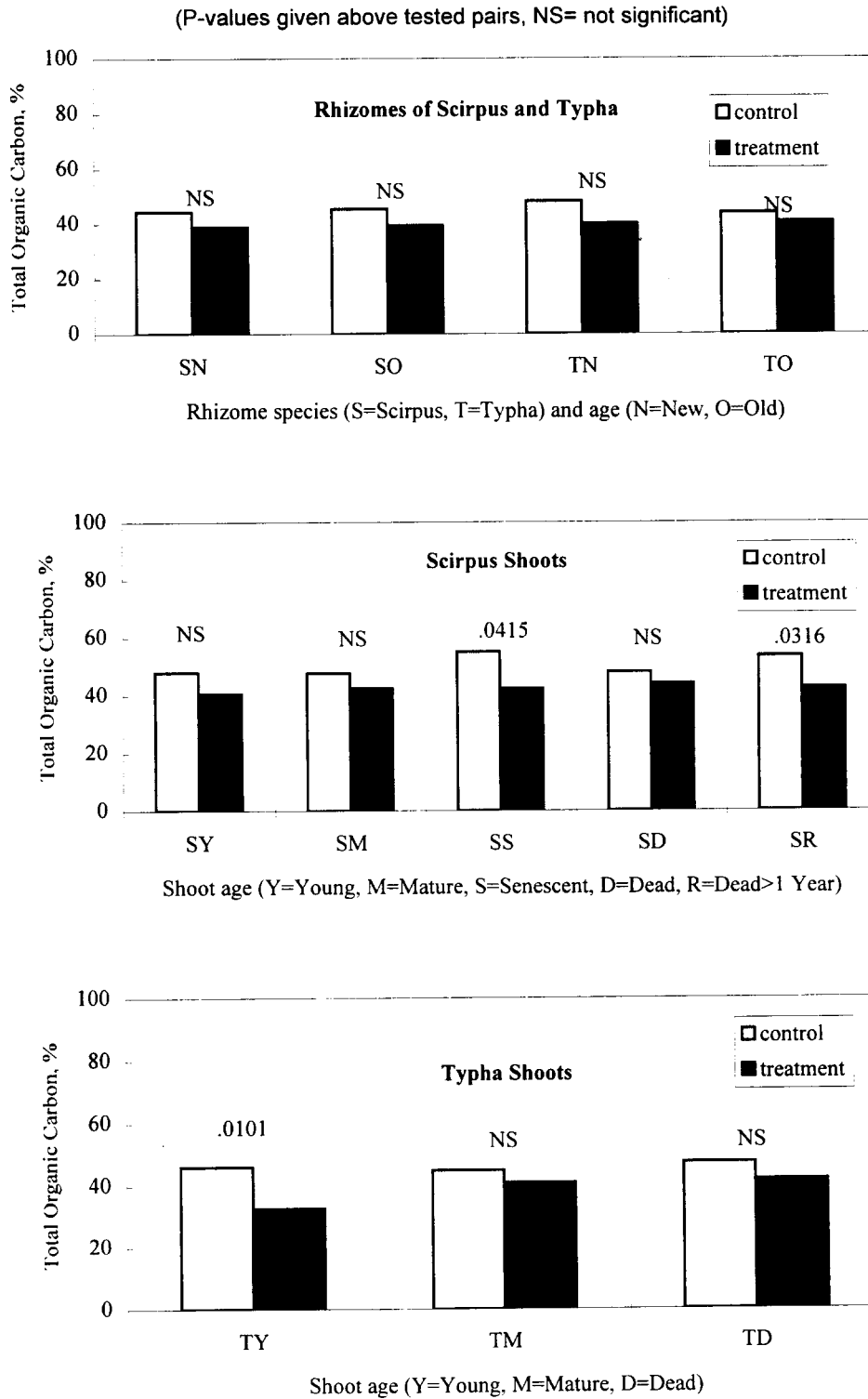
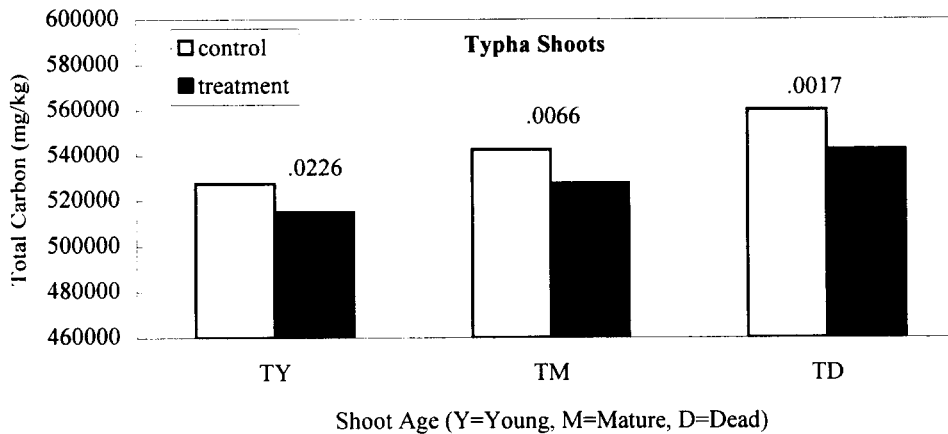
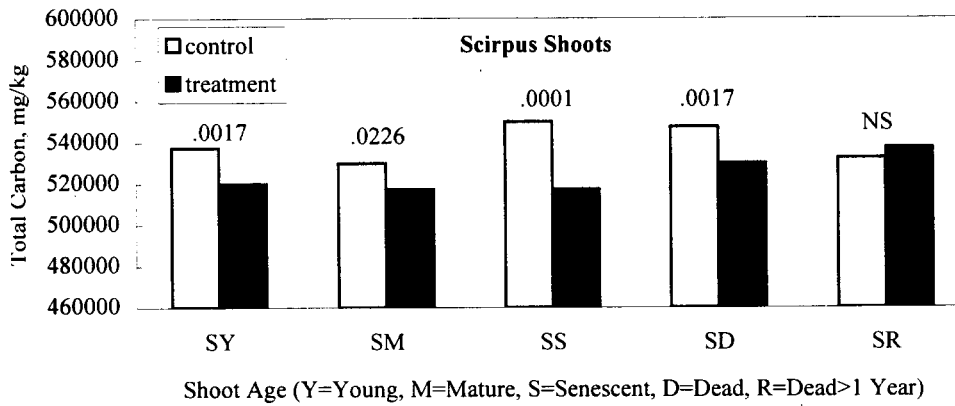
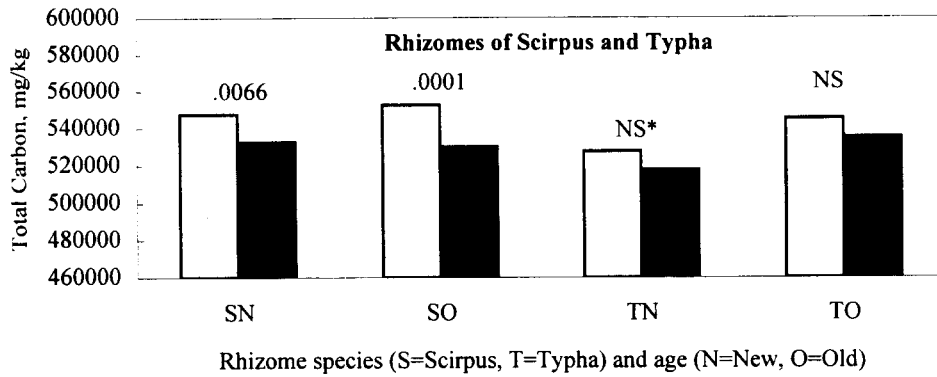
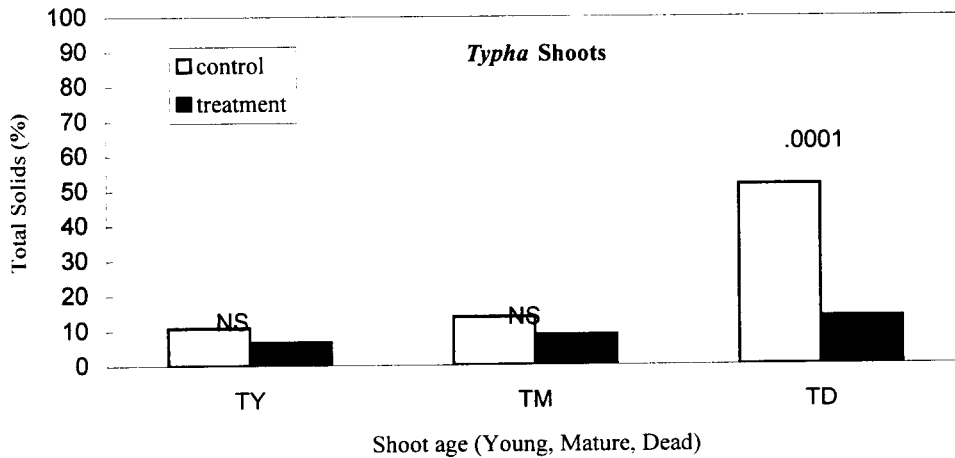
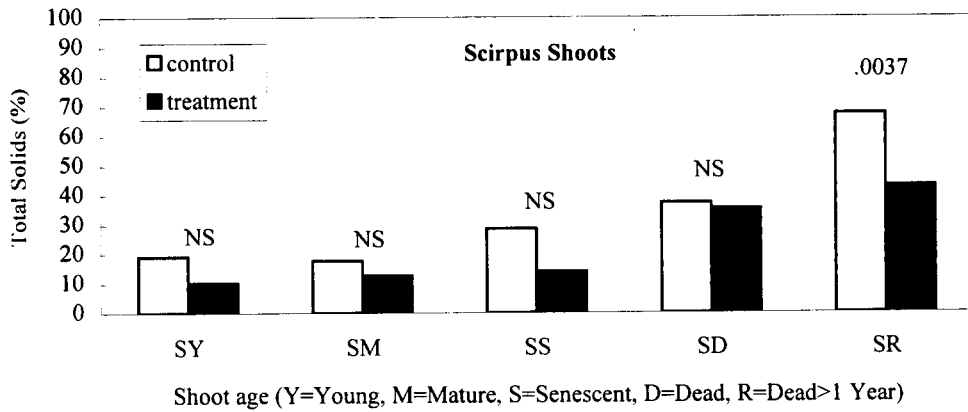
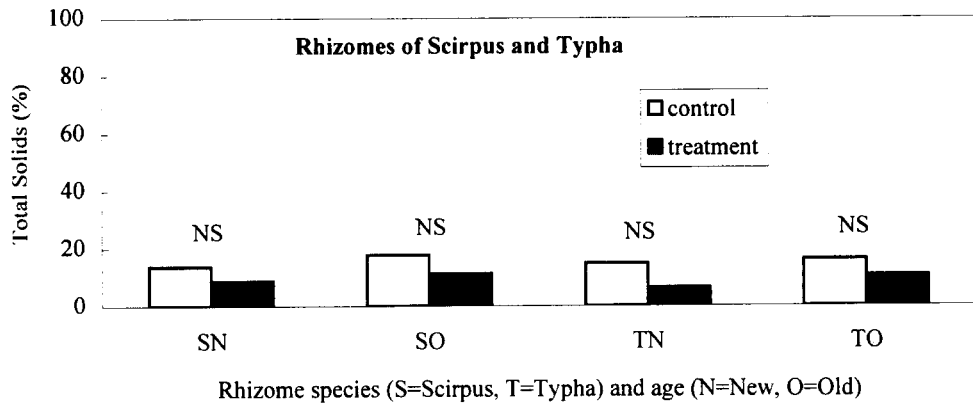


FIGURE 5-11
SCIRPUS AND TYPHA - CELLS 5 AND 7
SACRAMENTO CONSTRUCTED WETLANDS DEMONSTRATION PROJECT



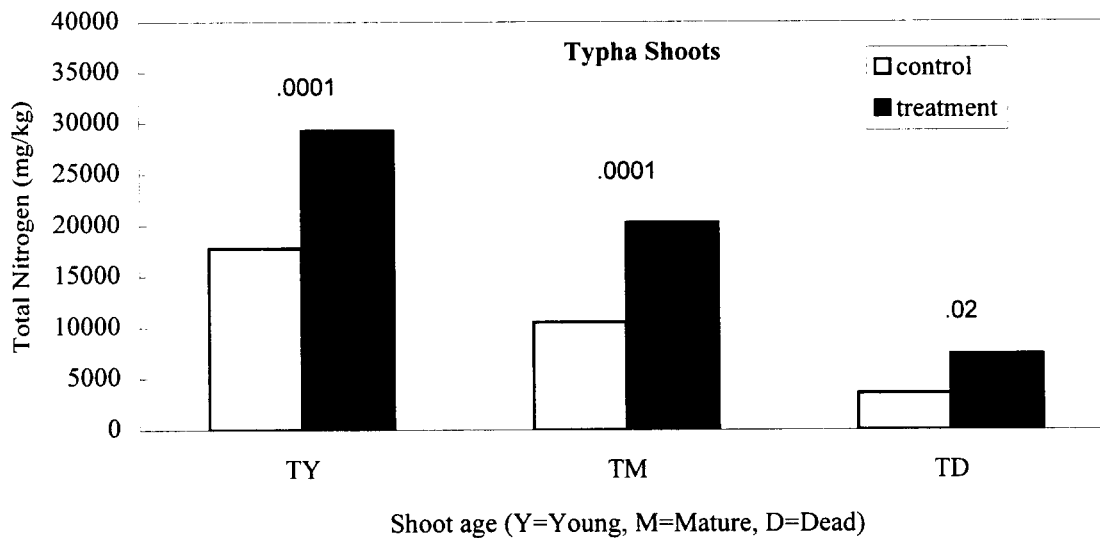
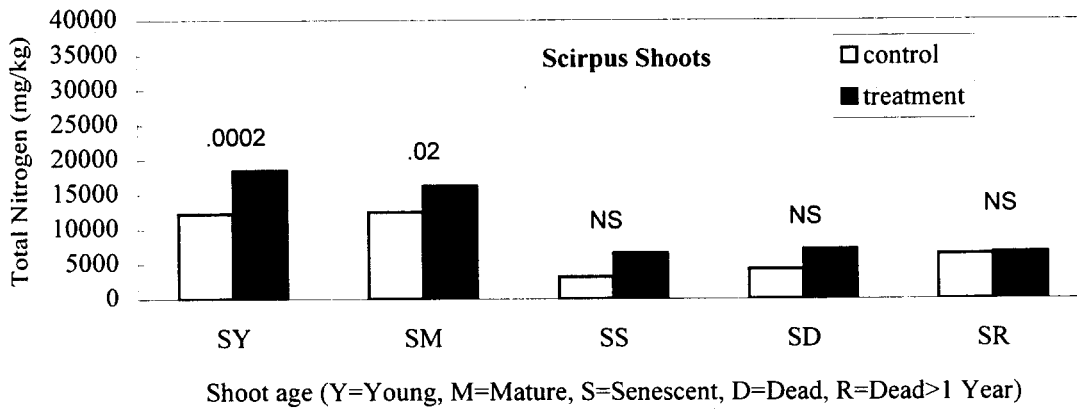
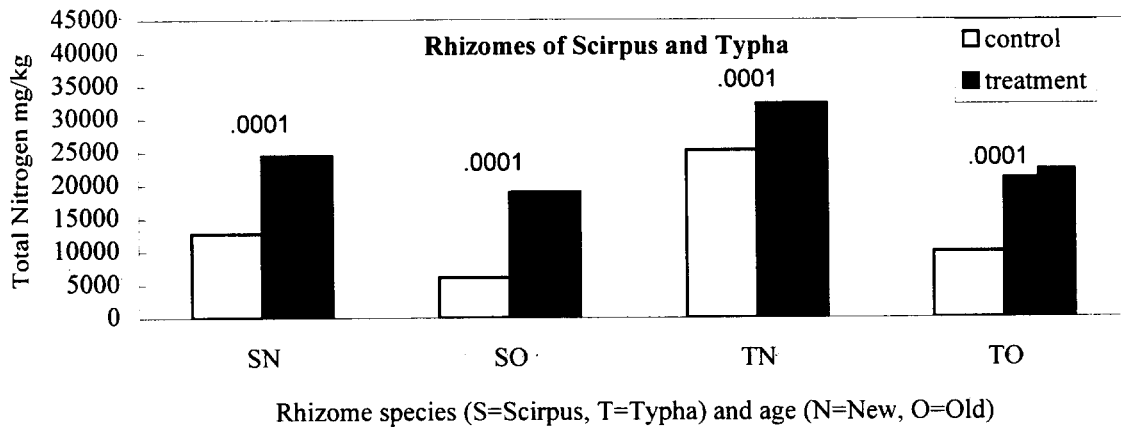
Notes: P values above tested pairs. NS = Not significant
 *Life stage significantly different than others

FIGURE 5-12
TOTAL SOLIDS (TS) OF BELOW- AND ABOVE-GROUND BIOMASS - CELLS 5 AND 7.
SACRAMENTO CONSTRUCTED WETLANDS DEMONSTRATION PROJECT



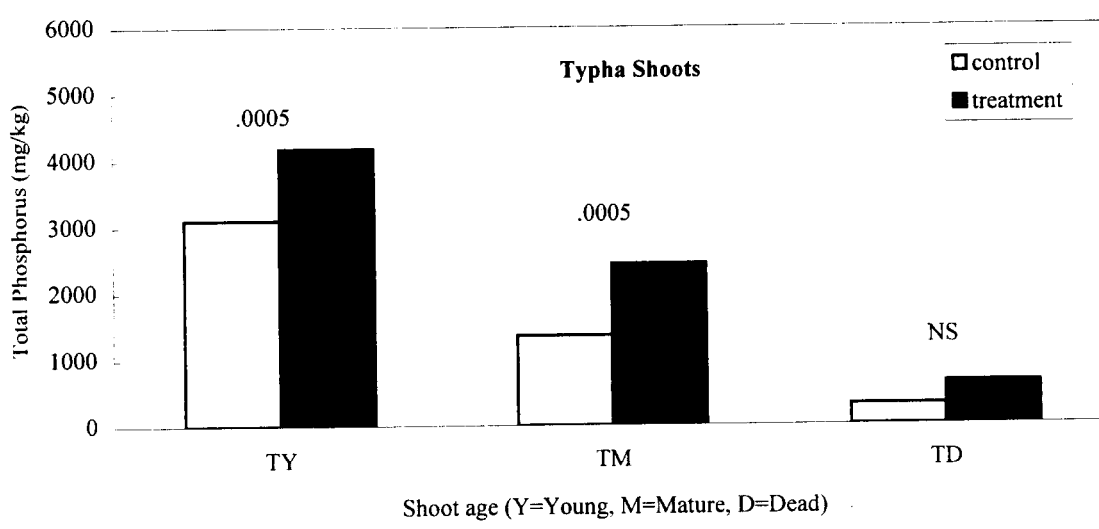
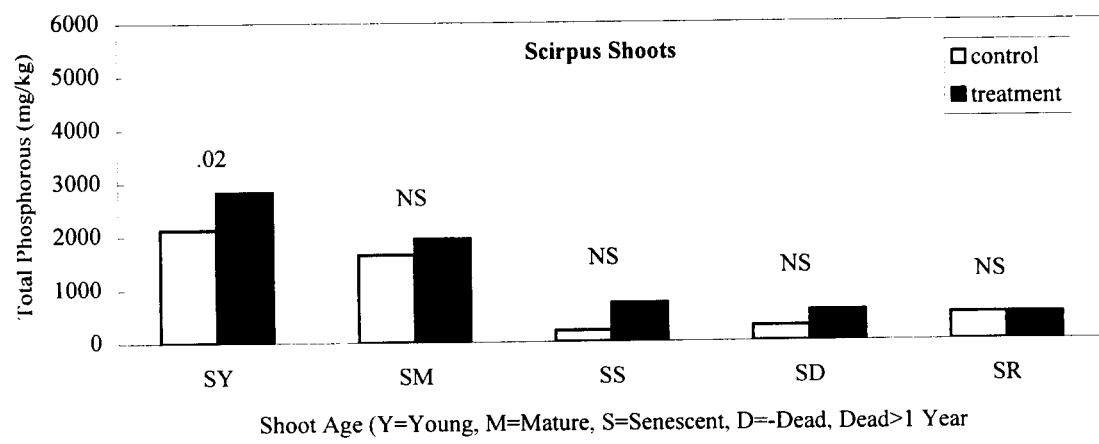
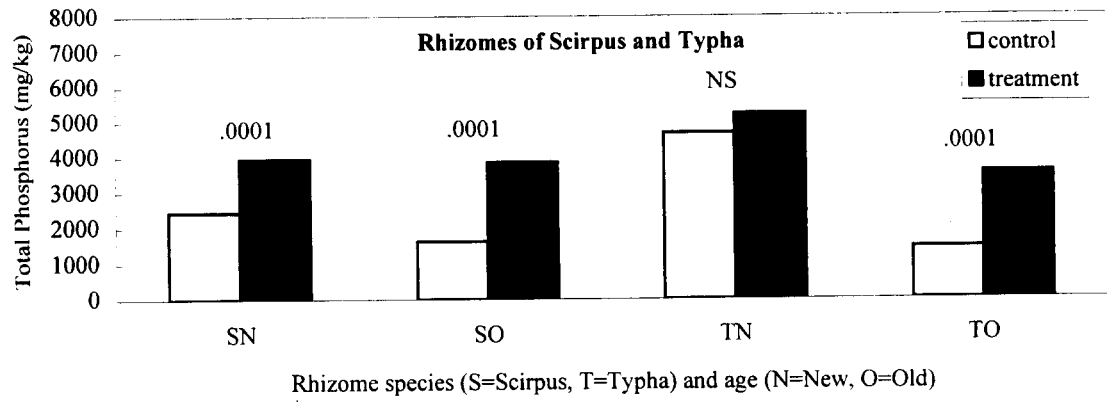
P-values given above tested pair. NS = not significant.

FIGURE 5-13
TOTAL NITROGEN (TN) IN BELOW- AND ABOVE-GROUND BIOMASS - CELLS 5 AND 7
SACRAMENTO CONSTRUCTED WETLANDS DEMONSTRATION PROJECT



P-values given above tested pair. NS = not significant.
 *=Life stage significantly different than all others.

FIGURE 5-14
TOTAL PHOSPHORUS (TP) OF BELOW- AND ABOVE-GROUND BIOMASS - CELLS 5 AND 7
SACRAMENTO CONSTRUCTED WETLANDS DEMONSTRATION PROJECT



Note: P-values given above tested pair. NS = not significant.

TABLE 5-9
HABITAT CELL WATER LEVEL COMPETITION DATA, SEPTEMBER 1998
SACRAMENTO CONSTRUCTED WETLANDS DEMONSTRATION PROJECT

Water Depth, cm	Percent Cover, %			
	<i>Scirpus acutus</i>	<i>Scirpus californicus</i>	<i>Typha domingensis</i>	Open Water
10 ^c	21.9	0.0	53.1	6.3
20 ^c	29.4	0.0	47.1	8.8
30 ^c	51.6	3.2	41.9	0.0
40	54.3	25.7	20.0	0.0
50	11.8	51.0	37.3	0.0
60	0.0	45.9	32.4	21.6
70	0.0	29.3	48.8	22.0
80	0.0	17.6	41.2	41.2
90	0.0	28.9	63.2	7.9
100	0.0	21.2	45.5	33.3
115	0.0	50.0	37.5	12.5
Shallow Average ^b	0.0	29.4	47.2	23.4
Deep Average ^a	28.2	21.0	38.6	6.1
Total Average	15.4	24.8	42.5	14.0

^a Deep average for water depths between 60 and 115 cm

^b Shallow average for water depths between 10 and 50 cm

^c *Polygonum hydropiperoides* also present at these depths

FIGURE 5-15
PERCENT COVER BY THREE PLANT SPECIES ALONG WATER DEPTH GRADIENT IN HABITAT CELL
SACRAMENTO CONSTRUCTED WETLANDS DEMONSTRATION PROJECT

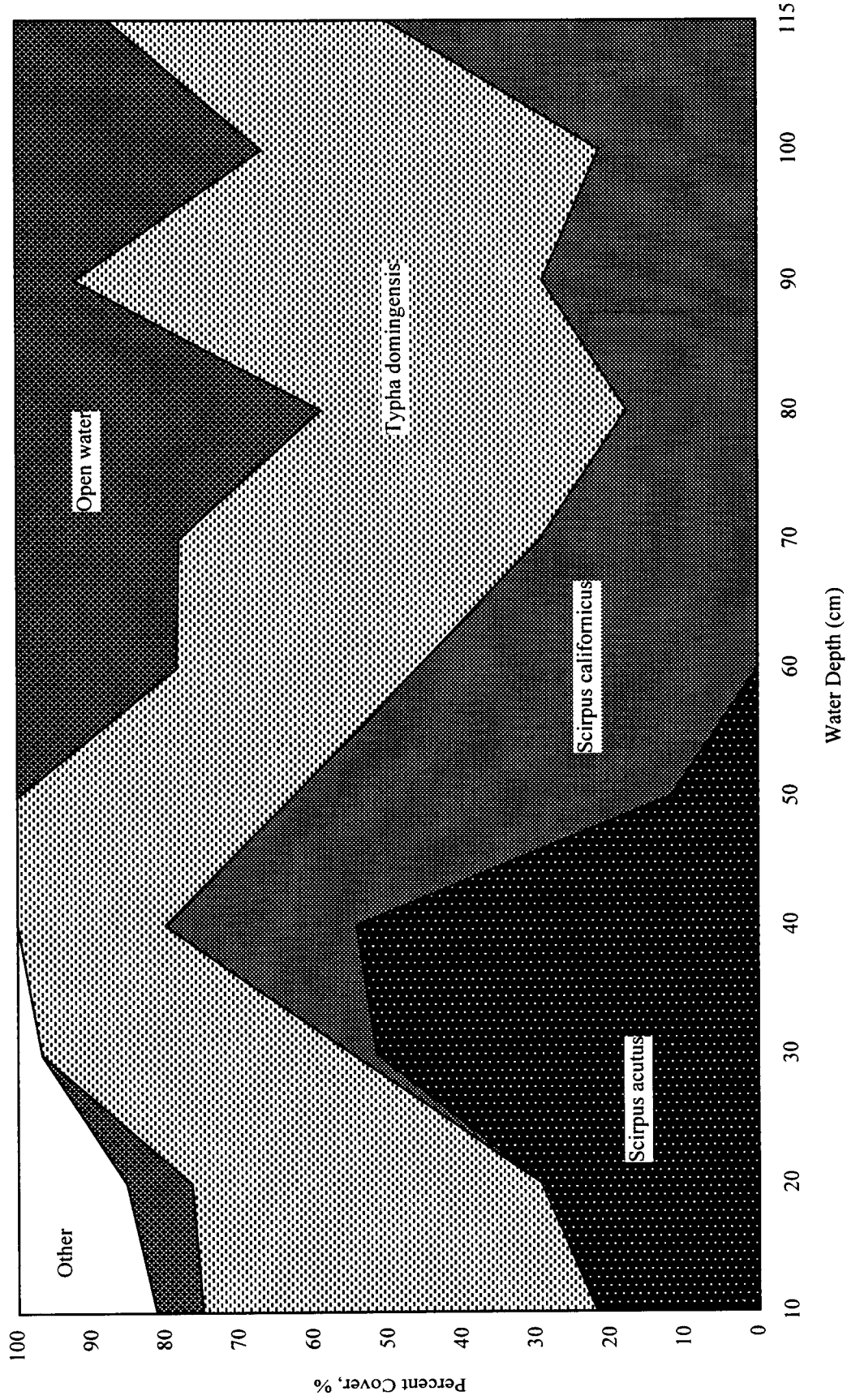


FIGURE 5-16
 SUMMARY OF TREE GROWTH STUDY RESULTS
 SACRAMENTO CONSTRUCTED WETLANDS DEMONSTRATION PROJECT

