APPENDIX A

FLORIDA KEYS SITE DESCRIPTIONS

Coral Shores Estates - The Coral Shores Estates site resulted from illegal dredge-and-fill in a former mangrove area. Canals that had been dug were refilled with the scrapedown material, which was primarily marl mud. Red mangrove seedlings (one year old?) were planted around the margin of the scrapedown in a strip approximately eight meters wide; they were completely exposed at low tide. The total scrapedown was not surveyed because of the young age of the site. The remainder of the site had shallow, standing water in spots at low tide and was unvegetated. Adjacent mangroves occurred at elevations (+0.21 to +0.27 m NGVD) similar to most of the elevations in the planted area. Plants installed at lower elevations (+0.01 to +0.14 m) may have had slightly better survival. Some plants used at this site were cultured two-to-a-pot and then ripped apart for planting; this improper handling prior to installation probably caused the death of some plants. Plants that had been grown one-to-a-pot had almost 100 percent survival. Another problem encountered at this site was that roots of plants cultured in peat tended to be restricted to the peatball after planting, resulting in a dwarfing or bonsai effect when installed in marl mud. Even though the planting was less than one year old, some root growth into the surrounding medium should have occurred within that time. One characteristic, which was also common to all mangrove plantings surveyed in this study, was that the planting density was too low (one meter O.C.) to result in effective coverage within a reasonable time frame. Unlike the rapid coverage achieved by rhizomatous grasses and other herbaceous plants, mangroves are slower growing, especially in the Keys, and do not produce equivalent coverage as rapidly.

Locale: Little Torch Key; Monroe County
Latitude/longitude: 24°41'18"N / 81°23'54"W
Permit numbers: **FDER** None; **ACOE** 77-4528 (enforcement case no.)
Age: <1 yr
Size: 0.2 ha planted (3.2 ha total scrapedown)
Species present: Rhizophora mangle
Status: Failure

Cross Street - At the Cross Street site, illegal fill material was removed in an attempt to reestablish elevations conducive to natural colonization by propagules produced by surrounding mangroves; no planting was attempted. The site was roughly rectangular in shape and sloped gradually from the higher elevations near Cross Street to the lower elevations at the back

of the site. A concrete culvert under a lateral road connected the site at the low end to the marine system. The higher elevations near the road were exposed limerock, but the majority of the site was composed of marl mud. Even at low tide, standing water was present in the lower elevations of the site; the presence of widgeon-grass (Ruppia maritima L.) suggests that the standing water may have been at least seasonal. Most plant colonization occurred in the cracks and shallow depressions of the exposed limerock. Adjacent undisturbed mangrove elevations were higher than most of the scrapedown area. At this site, better plant colonization occurred in areas that were at approximately the same elevations as adjacent mangroves or a little higher.

Vegetation colonization was impaired by the low elevations in most of the site. Standing water can become too warm in the summer, impairing survival of mangroves that may have colonized in the previous fall. In another part of this site, the exposed limerock was a poor substrate for colonization. Covering the limerock with a thin veneer of marl would create a more even substrate for colonization by grasses and forbs. Vegetation colonization could be enhanced by filling the site to the level of surrounding mangroves and by dispersing propagules.

Locale: Stock Island; Monroe County
Latitude/longitude: 24°36'06"N / 81°44'42"W
Permit numbers: **FDER** None; **ACOE** 81A-37-071
Age: 2 yrs
Size: 0.70 ha
Species present: Avicennia germinans, Laguncularia racemosa, Ruppia maritima, Salicornia bigelowii
Status: Failure

Florida Keys Aqueduct Authority - The Florida Keys Aqueduct Authority restoration was an attempt to partially revegetate backfill following installation of a large water supply line. The disturbed mangrove area was approximately ten meters wide and paralleled U.S. Highway A1A for several miles. An unknown number and arrangement of mangrove propagules and smooth cordgrass plugs were planted along an unknown extent of the site. The survey began at the first accessible area from the north along A1A and extended for a predetermined distance of ten sample points at regular interplot distances (total length approximately one kilometer).

Substrates ranged from soft mud to an occasional rocky outcrop. The predominant plant species at this

site were smooth cordgrass and black mangrove. The range of elevations colonized by black mangroves was slightly higher than that for smooth cordgrass, but these species overlapped through most elevations. The greatest overall densities occurred within a range of approximately 0.09 m in the middle elevations. The cable roots of black mangrove had trouble penetrating the substrate and were arched like the prop roots of red mangrove, probably indicating a hard surface just under the mud. Standing water, present along much of the length of the survey, was very warm. Undisturbed, adjacent mangroves were approximately three meters tall, and the topography under them was even, unlike in the restored area where substrates varied in elevation. Vegetation was found mostly on the higher elevations. Variable elevations, possibly due to uneven settling of heterogeneous fill material, resulted in poor drainage from some areas. The back-fill material may have been too coarse--that is, composed of large boulders--to allow proper root penetration by mangroves.

Locale: Key Largo; Monroe County
Latitude/longitude: 25°06'39"N / 80°24'52"W
Permit numbers: **FDER** 13- and 44-28299; **ACOE** 80M-0276
Age: 5-6 yrs
Size: 3.5 ha
Species present: Avicennia germinans, Conocarpus erectus, Fimbristylis castanea, Lagun cularia racemosa, Rhizophora mangle, Spartina alterniflora
Status: Mixed success

Florida Keys Land Trust, Inc. - The Florida Keys Land Trust, Inc. site consisted of illegal road fill that was removed to restore natural sheet flow to the scrub mangrove area; no planting was attempted. The most landward portion of the site had higher elevations that descended to a muddy depression colonized by black mangroves. The topography on either side of the scrape-down rose to a scrub mangrove/high-marsh plant association that was rooted in a veneer of marl mud overlying limerock; the scrapedown exposed the underlying rock. The rock gave way to gradually decreasing elevations of marl mud covered with standing water. At the seaward end, standing water was as much as 0.3 m deep at low tide. Colonization in the marl-mud area was limited to a few scattered red mangroves (not in our sample plots) and black mangrove seedlings, except in the low area landward of the rock zone. All of the vegetation was in the upper 27 percent of the elevations, despite most of this area being rock. Rhizoma-

tous and stoloniferous grasses and forbs predominated on the rock elevations. In the adjacent undisturbed area, larger red mangrove plants had developing propagules that may colonize the site at a later date. All colonizing plants at this site were depauperate.

Although the scrapedown of the road improved tidal sheet flow in this area, vegetation establishment at this site was reduced because much of the site was graded too low and therefore did not drain properly. Also, drainage was further impeded by a mature mangrove fringe, which served as a berm. This fringe could block propagule transport into the site. Another problem resulted from the lack of substrates appropriate for colonization. When the site was scraped down, the veneer of marl was completely removed down to limerock, which impeded colonization by shallowly rooted grasses and forbs. Vegetation establishment at this site could be improved by filling the low areas to a level equal to the surrounding areas; breaching the mangrove fringe with a shallow, broad creek; planting the soft mud with red mangroves; and covering the rock with two to three centimeters of marl. Mangrove colonization failure at this site, even after four years, highlights the need to provide appropriate elevations and propagules for proper vegetation establishment to occur.

Locale: Big Pine Key; Monroe County
Latitude/longitude: 24°42'45"N / 81°22'10"W
Permit numbers: **FDER** None; **ACOE** None
Age: 4 yrs
Size: 0.2 ha
Species present: Avicennia germinans, Batis maritima, Borrichia arborescens, Monanthochlöe littoralis, Salicornia bigelowii, S. virginica, Sporobolus virginicus
Status: Failure

Hammer Point - The Hammer Point site was a scrapedown of illegal fill that had been placed between a series of canals to extend a housing project. The canals divided the restoration site into four separate areas. The coral rock substrate was of even elevation, and at low tide, the lower elevations were under approximately 0.2 m of water; the higher elevations had some standing water but were probably exposed at the lowest tides. The substrate was so hard that the red mangroves had to be hosed into the substrate. Most of the red mangroves were in the sapling class (>0.3 m); however, at installation they were already over 0.3 m tall. Because elevations designed for this project were low, a green

alga (Batophora sp.?) carpeted the substrate. The presence of shoal-grass (Halodule wrightii Aschers.) also indicated that most of the site remained permanently inundated. Survival of planted red mangroves at this site can be attributed, in part, to good water quality and to lower planting elevations in the hard substrate. However, the rate of plant growth was slow, possibly because of the poor substrate. The major growth impairment was probably due to constriction of the mangrove roots within the peat rootball, which caused a dwarfing or bonsai effect. Even after two years, the planted mangroves could easily be lifted from the substrate, and the original shape of the rootball could be observed.

Locale: Key Largo; Monroe County
Latitude/longitude: 25°01'24"N / 80°30'45"W
Permit numbers: **FDER** None; **ACOE** 71-1176 (enforcement case no.)
Age: 2 yrs
Size: 1.0 ha
Species present: Halodule wrightii, Rhizophora mangle
Status: Failure

Loggerhead Lane - The Loggerhead Lane site was a scrapedown of illegal fill that had been placed in seasonally flooded wetlands. Adjacent vegetation indicated the area was probably sparsely vegetated with mangroves before filling occurred. The scrapedown resulted in uneven topography, covered mostly with standing water approximately 0.3 m deep. Supposedly, black mangroves were planted along the margin, but we observed only a few volunteer seedlings. The dominant species at lower elevations was spike-rush (Eleocharis cellulosa Torr.), which usually occurs in low salinities. Elevations of the adjacent mangroves were higher than the substrate elevations in the scrapedown area. Increasing the substrate elevations slightly may encourage reestablishment of saline-adapted vegetation.

Locale: Sugarloaf Key; Monroe County
Latitude/longitude: 24°40'10"N / 81°22'10"W
Permit numbers: **FDER** None; **ACOE** 82W-37-032 (enforcement case no.)
Age: 4 yrs
Size: 0.4 ha
Species present: Aster sp., Avicennia germinans, Bacopa monnieri, Eleocharis cellulosa, E. geniculata
Status: Failure

Rock Harbor - The Rock Harbor site was mitigation intended to offset canal construction to gain water access to a nearby development. Most fill material was removed to elevations approximating mean low water, and red mangroves were installed. The rocky marl substrate was uneven in topography. The higher elevations were exposed limerock and were littered with trash. Extensive areas of standing water were filled with shoalgrass, indicating that flooded conditions were permanent.

The planted red mangroves were spindly, and the lower two-thirds of each stem was covered with green algae. Most surviving mangroves occurred in the upper half of the substrate elevations. Survival of the planted red mangroves at lower elevations was due, in part, to good water quality. Low scrapedown elevations caused mangroves to be spindly; these planted mangroves had only a few leaves at the top of a meter-long stem. Adjacent mangrove areas were higher and had a dense fringe of robust red mangrove seedlings. The natural fringe was approximately one meter higher than the lowest areas of the scrapedown.

Locale: Key Largo; Monroe County
Latitude/longitude: 25°04'56"N / 80°26'51"W
Permit numbers: **FDER** 44-34296; **ACOE** 80J-1758
Age: 3 yrs
Size: 1.3 ha
Species present: Avicennia germinans, Halodule wrightii, Laguncularia racemosa, Rhizophora mangle, Salicornia bigelowii
Status: Failure

Sexton Cove - At the Sexton Cove site, an attempt was made to plant red mangroves following scrapedown of illegal fill and backfilling of canals. Sea-grass was installed in low areas of the cove but was not included in this survey. The substrate was hard-packed, crushed limestone rubble. The topography of the site was even, with the lowest region being in the middle of its long dimension (parallel to the adjacent road). Planting holes for the mangroves were apparently created with an auger. The few red mangroves that survived were depauperate.

All colonizing plants were found in the upper half of the elevations. At low tide, the planted area was completely dry, except for water trapped in the auger holes. High summer temperatures apparently heated the water that was retained by the auger holes at low tide, damaging the mangrove seedlings. As at other sites in

the Keys, the hard, low-nutrient substrate created a dwarfing or bonsai effect on the planted mangrove seedlings; roots never left the peatball. Unlike most of the other Keys sites surveyed in this project, overall elevations may have been too high for good mangrove growth. In hard rock substrates, survival of mangrove seedlings may depend on constant flooding during the hottest months.

Locale: Key Largo; Monroe County
Latitude/longitude: 25°10'09"N / 80°23'02"W
Permit numbers: **FDER** None; **ACOE** 74-1067-CIV-SMA (consent agreement case no.)
Age: 2 yrs
Size: 0.2 ha
Species present: Avicennia germinans, Baccharis sp., Batis maritima, Blutaparon vermiculare, Casuarina sp., Conocarpus erectus, Heliotropium currassavicum, Laguncularia racemosa, Rhizophora mangle, Sporobolus domingensis
Status: Failure

APPENDIX B

ATLANTIC COAST SITE DESCRIPTIONS

Bella Vista, Inc. - The Bella Vista, Inc. site was a mitigation attempt to compensate for the filling of mangrove forest (0.3 ha) to install a tennis court. Information on this site was difficult to obtain and often conflicting. The original mitigation plan called for the scrapedown of over 0.1 ha and the planting of red mangroves and smooth cordgrass. The areal trade-offs at this site were inequitable, resulting in wetlands habitat loss. The substrate was a clayey mud that dried hard in the higher elevations near U.S. Highway A1A. Very few of the installed plants survived. Plant death was attributed to high elevations, so 0.07 ha of the original scrapedown was lowered further, and a drainage ditch was excavated to improve water circulation.

Following the topography changes, natural colonization by white mangroves was extensive, especially along the ditch, where they reached into the tree stratum. Over three-quarters of the white mangrove seedlings were in the upper half of the elevations, but over three-quarters of the saplings/trees were in the lower half of the elevations. This suggests that factors conducive to seedling establishment may be different from those conducive to long-term plant survival. Seedling establishment may be greater in infrequently flooded substrates, but survival and growth may be better in more frequently flooded conditions, exclusive of interspecific interference. Red mangroves can probably survive better at lower elevations because of their larger propagules, and they may exclude white mangroves from lower elevations. However, timing of colonization by each mangrove species would affect the final outcome of interspecific interactions. The high mangrove colonization rate at this site contrasts with the relative paucity of vegetation that results from low planting densities normally used in creating mangrove habitat. Frequently, natural colonization by mangroves overwhelms most mangrove plantings if appropriate elevations and circulation patterns have been established and if a propagule source is nearby.

Locale: South Hutchinson Island; St. Lucie County
Latitude/longitude: 27°16'36"N / 80°12'30"W
Permit numbers: **FDER** 560543888, 560698258; **ACOE** 81N-1253 (?)
Age: 3 yrs (?)
Size: 0.14 ha

Species present: Bacopa monnieri, Borrichia frutescens, Eleocharis albida, Laguncularia racemosa, Rhizophora mangle, Suaeda linearis

Status: Failure

Campeau Corporation - The Campeau Corporation site resulted from the illegal cutting of the mangrove fringe (principally red mangroves), which killed the severely pruned plants. Some large-diameter black mangrove trees were cut, but stump resprouting was evident on only a few trees. Mitigation in the form of scrapedown of another area and installation of culverts in an adjacent impoundment was required (FDER 560565429). A dense cover of dead red mangrove prop roots remained in the cut area.

Red mangrove propagules were planted among the existing prop roots independently (not as a mitigation requirement) by an unknown agent. Supporting stakes, which marked the locations of planted mangroves, were still in place, although all the mangroves had died. Planted mangroves died because they were installed at too low an elevation; elevations at which adult plants are usually found are too low for mangrove seedling establishment. Colonization by mangroves and other vegetation was at the approximate high-tide line, as defined by an accumulation of flotsam and jetsam. Ninety-four percent of all vegetation was in the upper half of the elevations sampled. The seaward edge of the red mangrove prop-root zone was as much as one meter below the estimated high-tide line. Dense prop roots may impede mangrove reestablishment by inhibiting colonization, especially if the prop-root zone is wide. Usually, mature red mangroves on steep shorelines migrate into deeper water by sequential prop-root extension, not by propagule colonization. The lower-elevation prop-root zone is probably a better habitat for many marine organisms. Therefore, mangrove habitat established at the higher elevations, even if equivalent in biomass to lower elevation mangroves, is not equivalent in overall quality.

Locale: Hutchinson Island; St. Lucie County
Latitude/longitude: 27°25'47"N / 80°16'40"W
Permit numbers: **FDER** None; **ACOE** None
Age: 1 yr (?)
Size: 0.1 ha

Species present: Avicennia germinans, Baccharis sp., Borrichia frutescens, Cyperus ligularis, Heliotropium curassavicum, Laguncularia racemosa, Rhizophora mangle, Sporobolus domingensis, Vigna luteola

Status: Failure

Costa del Sol - The Costa del Sol site was a scrapedown mitigation to offset wetlands encroachment related to nearby development. The site was located next to a condominium development and its associated stormwater-runoff basins. A large mound of soil (10 meters high) was located next to the site; erosion of this mound was carrying soil into the mitigation wetlands. Although both red mangroves and smooth cordgrass were planted--apparently around the margin of the site--only smooth cordgrass was observed within the site proper. The first planting effort failed, so the site was replanted in the second year. The species composition of this site indicated that considerable freshwater input was occurring, and selection against saline vegetation was probable. Southern cat-tail (Typha domingensis Pers.) had invaded and was aggressively replacing the saline-adapted species. The area outside the narrow entrance to the site had a higher elevation than the site interior, which had been scraped lower, ostensibly to prevent rapid filling of the site. This narrow entrance, with its higher elevation, probably prevented adequate flushing of the interior. Coupled with freshwater runoff from the stormwater catchment basins, the lack of proper flushing is causing the intended saline-adapted vegetation to be replaced by other species. Possibly, saltmarsh bulrush (Scirpus robustus Pursh.) and southern cat-tail will eventually be the dominant vegetation. Already, saltmarsh bulrush was prevalent in the lower, vegetated elevations but was only a minor component of the higher smooth cordgrass zone.

Although plant diversity was high relative to many of the other sites and although many fish, birds, and other wildlife were observed at this site, the original mitigation objective was only temporarily achieved. Maintaining saline habitats is unlikely in interior sites such as this, unless sufficient flushing is incorporated in the design. In addition, this site exemplifies the failure to plan for movement of saline vegetation inland with sea-level rise or land subsidence. Future sea-level rise will compress the vegetation into narrow bands around the steep slopes of the site. Creating gradual slopes that allow vegetation

movement is not suited to this type of interior scrapedown because the extent of uplands--which equals revenue--that is required for creating gentle slopes is greater than for steep slopes.

Locale: Banana River Lagoon; Brevard County
Latitude/longitude: 28°22'15"N / 80°36'18"W
Permit numbers: **FDER** 050770284; **ACOE** None
Age: 4 yrs (replanted)
Size: ca. 0.4 ha
Species present: Amaranthus sp., Ammania latifolia, Bacopa monnieri, Cyperus ligularis, C. odoratus, Echinochloa walteri, Eleocharis albida, Eustoma exaltatum, Iva frutescens, Paspalum vaginatum, Pluchea odorata, Ruppia maritima, Salicornia bigelowii, Scirpus robustus, Spartina alterniflora, Suaeda linearis, Typha domingensis
Status: Failure

Fountain Cove - The Fountain Cove site was a mitigation scrapedown to replace wetlands damaged by condominium construction nearby. The site was crescent-shaped and had outlets at either end connecting it to the Banana River. Stormwater runoff from roads and parking lots was funneled into the center of the site through a culvert pipe. Sprinkler-system runoff from the adjacent lawn also flowed into this site. The interior elevations were much lower than the outlets, causing impaired flushing. Central elevations were approximately 0.76 m lower than that of the edges, where smooth cordgrass grew best.

The denser widgeon-grass elevations were approximately 0.21 m lower than the denser smooth cordgrass elevations. Thick mats of blue-green algae were floating on the surface, possibly as a result of fertilizer runoff from the lawn coupled with reduced tidal flushing. The large number of brackish-water and freshwater plant species indicated that the site was moving toward eventual selection against saline vegetation. The margins of this site were too steep to allow vegetation to migrate inland as sea level rises. The deep center area, coupled with the steep slopes, provided very little vegetated wetlands habitat.

Locale: Banana River Lagoon; Brevard County
Latitude/longitude: 28°20'47"N / 80°36'32"W
Permit numbers: **FDER** None; **ACOE** None
Age: 3 yrs

Size: 0.12 ha
Species present: Ambrosia artemisiifolia, Eclipta prostrata, Eustoma exaltatum, Galium sp., Paspalum vaginatum, Pluchea odorata, Ruppia maritima, Spartina alterniflora, Stenotaphrum secundatum, Vigna luteola
Status: Failure

Melbourne Harbour, Ltd. - The Melbourne Harbour, Ltd. site was designed to curtail erosion and to mitigate for habitat damage resulting from condominium construction. Part of the site was a long fringe of smooth cordgrass fronted by coquina rock to break boat wakes and waves; subsequent earthgrading had pushed soil into the mitigation area and had obliterated most of the fringe.

The part of the site surveyed in this study was a broad area behind a berm and away from ongoing construction. The berm was not part of the initial construction but formed secondarily on the seaward edge of the area planted with smooth cordgrass. The berm was densely covered with salt jointgrass (Paspalum vaginatum Sw.) and seashore dropseed (Sporobolus virginicus (L.) Kunth). Elevations behind the berm were relatively even, and smooth cordgrass cover was homogeneous; the elevation range of smooth cordgrass was 0.46 m. The site had a broad exposure to the Indian River Lagoon and flushed completely at low tide. The overall elevation range appeared to be mostly within the upper-middle tidal range. Peripheral areas were planted with seashore dropseed, marsh-hay (Spartina patens (Ait.) Muhl.), saltgrass (Distichlis spicata (L.) Greene), and red mangrove. The mangroves were killed by a severe freeze.

Locale: Indian River Lagoon; Brevard County
Latitude/longitude: 28°04'36"N / 80°35'52"W
Permit numbers: **FDER** 050924-4; **ACOE** SAJ-44
Age: 4-5 yrs
Size: ca. 0.2 ha
Species present: Sesuvium portulacastrum, Spartina alterniflora
Status: Mixed success

Seagrove - The Seagrove site was part of a scrapedown mitigation project to offset filling a short canal along the Indian River Lagoon. Part of the mitigation area was a narrow fringe behind large mangroves and was not surveyed. The main site was drained by a horse-

shoe-shaped channel, which connected at both ends to the Indian River Lagoon. Because of the channel, flushing was excellent, and planted portions of the marsh drained completely at low tide. The site was planted with smooth cordgrass. The center, lower portion was not vegetated as densely as the higher perimeter; greater smooth cordgrass culm density occurred between +0.37 and +0.50 m NGVD. Black mangrove saplings were observed in the slightly lower central area (+0.47 m), but most colonization occurred above +0.58 m NGVD.

Although the channel aided drainage of the upper marsh area, it was deeper than the outlets into the Indian River Lagoon; complete flushing at low tide requires that interior ditch elevations be at least as high as the outlets. However, standing water is often designed into a site to provide feeding areas for birds, etc. This site had many design characteristics that resulted in production of a highly vegetated habitat in minimum time. The substrate slopes were gradual and provided for good drainage and potential colonization, and the channel ensured good flushing of the planted areas.

Locale: Indian River Lagoon; Indian River County
Latitude/longitude: 27°37'10"N / 80°21'20"W
Permit numbers: **FDER** 057-760-4; **ACOE** None
Age: 1 yr
Size: 0.2 ha
Species present: Avicennia germinans, Baccharis sp., Bacopa monnieri, Fimbristylis spathacea, Flaveria floridana, Laguncularia racemosa, Limonium carolinianum, Paspalum vaginatum, Rhizophora mangle, Salicornia virginiana, Spartina alterniflora, Sporobolus virginicus
Status: Successful