DREDGING TECHNIQUES USED TO DEVELOP A MAN-MADE LAKE ON A DEEP ORGANIC PROFILE

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ABSTRACT

A portable, 40.6 centimeter (16 inch), cutter-head dredge played a key role in the development of a 14 hectare (35 acre) man-made lake during the grading for EPCOT Center at Walt Disney World, Florida.

The site for the lake was underlain with peat and soft organic muck to depths exceeding 18.3 meters (60 feet). Therefore, conventional excavation methods for creating the lake were not considered practical or economical. In addition, there were strict environmental constraints, which limited the options for disposal of excavated organic material.

As an alternate, an innovative procedure involving a carefully planned and controlled surcharge program was used to take advantage of the high compressibility of the organics. Integral to this procedure was the use of a portable cutter-head dredge. The dredge was first used to excavate and backfill a containment "collar" trench around the perimeter of the site, and then to uniformly place the initial thin lifts of the sand surcharge to avoid overstressing the organics and creating a mud wave.

Eventually, up to 7.3 meters (24 feet) of surcharge was placed. During an 8 month holding period, the organic profile was compressed vertically up to 4.6 meters (15 feet). This placed the top of the organics below the bottom level planned for the lake, thus avoiding the need for significant excavation and disposal of organics.

SITE CONDITIONS

Walt Disney World is located in central Florida, about 24 kilometers (15 miles) south of Orlando (Figure 1). The Disney World property contains about 109 square kilometers (42 square miles). Much of the area is covered with dense vegetation and there are large low lying, swampy areas underlain by peat and highly organic muck.

During grading for EPCOT Center in 1980, a large man-made lake, covering 14 hectares (35 acres) was planned within the limits of a broad organic area. The site was located in an area where, in the

FIGURE 1 - LOCATION MAP

geologic past, coalescing sinkholes had created a local depression which, over the next 100,000 to 1 million years, was gradually filled in with layers of organic materials. Near the center of the area, layers of organics were found as deep as 30.5 meters (100 feet). Using information from exploratory borings and hand probes, it was found that a continuous organic profile extended to depths generally ranging from 9.1 to 18.3 meters (30 to 60 feet). Below the organics, there were fine sands. As shown in Figure 2, about two-thirds of the lake site was underlain by organics. The balance of the site was underlain from the surface by sands.

PROPERTIES OF THE ORGANICS

The surface of the site contained a heavy growth of mature bay, pine and cypress trees and there was a thick concentration of palmetto plants around the perimeter. The photograph of Figure 3 shows the typical vegetation prior to construction.

The ground surface was underlain to a depth of 0.3 to 1.5 meters (1 to 5 feet) by a "rootmat" of living and partially decomposed root systems. The rootmat layer contained a large percentage of voids and little mineral soil. The interwoven roots provided a natural reinforcement, which, if left undisturbed, could support light vehicles with low ground pressure tracks.

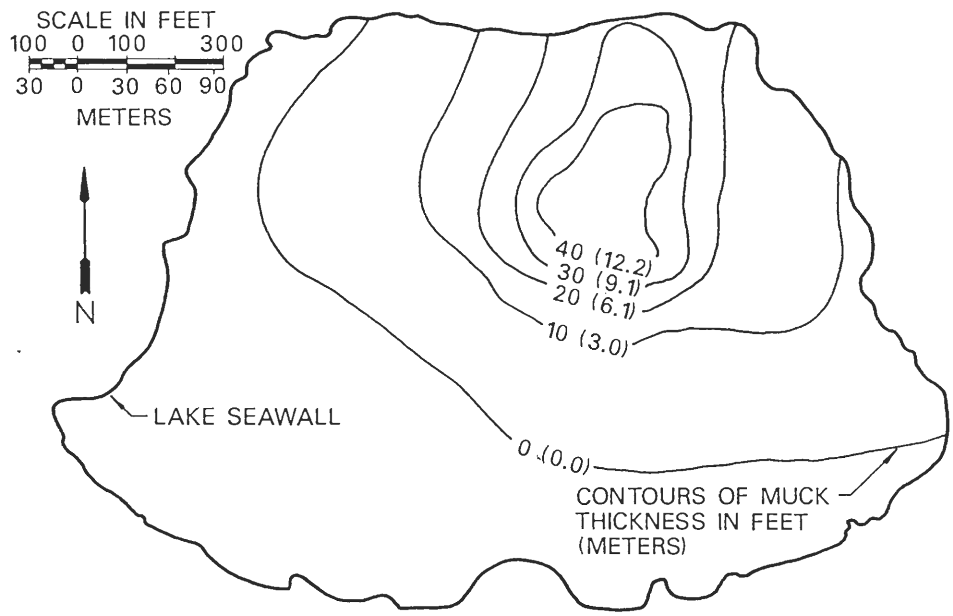

FIGURE 2 - LAKE SITE PLAN

FIGURE 3 - PRECONSTRUCTION SITE

Below the rootmat, the peat ranged from partially to highly decomposed rootlets to materials which contained equal amounts of organics and mineral soils. Very fine root fibers, having a diameter of 0.4 to 0.8 millimeter (1/64 to 1/32 inch), could be seen in this material. However, the fiber structure was highly decomposed and could be completely destroyed by rubbing across it using light finger pressure. The typical ranges in the physical properties of the organic muck are listed in Table 1. The material was typically about 50 to 95 percent water, based on wet density, and had very low shear strengths.

TABLE 1 - PHYSICAL PROPERTIES

Property	Typical Range of Test Results
Wet Density	1.0 to 1.3 g/cm^3
Moisture Content	140 to 1200 percent (based on Dry Density)
Dry Density	0.06 to 0.5 g/cm^3
Organic Content	50 to 95 percent (based on Dry Weight)
Ash Content	5 to 50 percent (based on Dry Weight)
Shear Strength	<4.8 to 18.6 kPa

Laboratory consolidation tests showed that the organics were highly compressible. Test samples compressed from one-fourth to one-half of their initial thickness under moderate loads. A summary plot of primary consolidation (expressed as vertical strain) versus the log of the applied load is shown in Figure 4. Although a general increase in stiffness can be noted when comparing samples from progressively deeper depths, there were also interbedded stiffer and softer layers, suggesting deposition in a fluctuating shallow water environment.

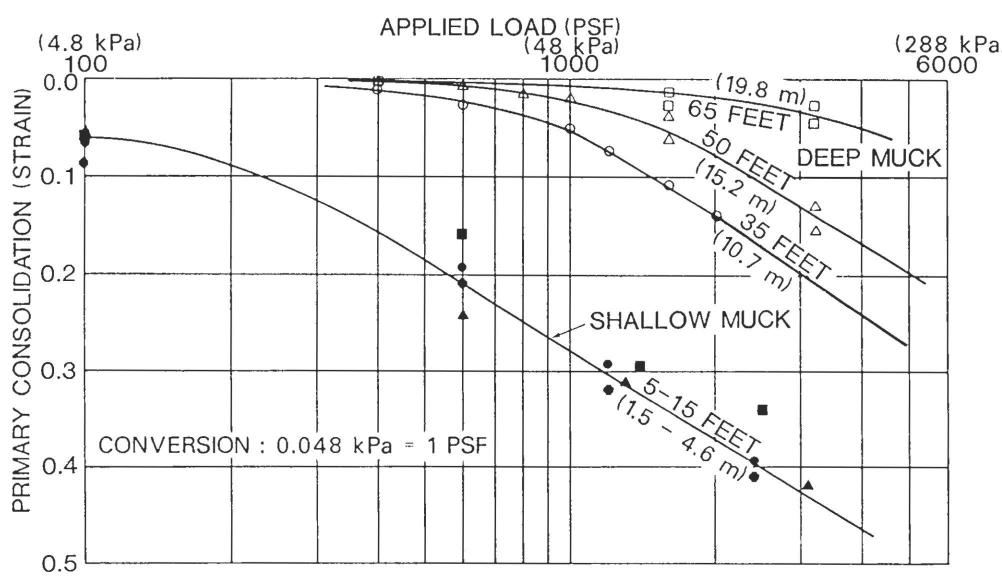

FIGURE 4 - PRIMARY CONSOLIDATION VS LOG OF APPLIED LOAD

SELECTED PROCEDURE

Since the organic profile was so thick and soft, the use of conventional excavation techniques to remove all of the organics to below the proposed lake bottom elevation were not considered practical. The rootmat could only support very light equipment and, once the rootmat was removed, the underlying muck could not even support a man's weight.

Excavation in the deeper area would also require large draglines working on mats. The excavated muck would be very difficult to handle (and re-handle) because of its very high water content and its almost complete loss of strength when disturbed. There would also be significant environmental constraints regarding its disposal.

As an alternate, an innovative approach was selected which took advantage of the high compressibility of the peat and muck. An "order of magnitude" settlement prediction was made using the laboratory data with empirical modification, based on previous experience with actual peat compressions monitored elsewhere on the property. From this, it was judged that, if the organics could be confined against lateral squeezing and the load placed uniformly, surcharging could be used to produce significant vertical compression.

The plan was to use a surcharge to compress the surface of organics below the design elevation planned for the lake bottom and, thus, avoid the need for significant excavation and disposal. However, large vertical compressions would be required, as shown on Figure 5.

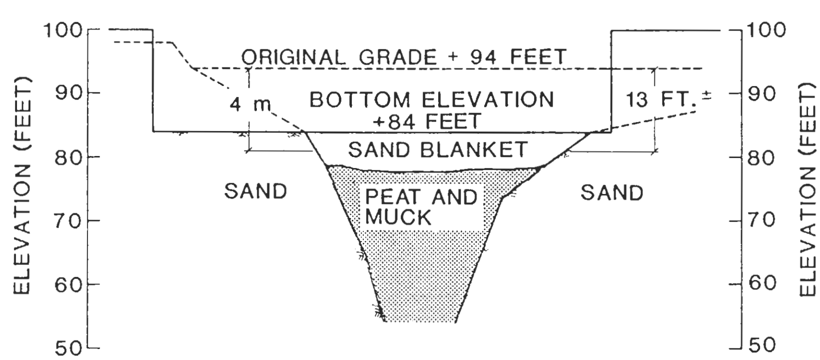

FIGURE 5 - PROPOSED FINAL GRADING

The original surface of the organics was at Elevation 94 feet and the design bottom for the lake was Elevation 84 feet. It was also planned that a 0.9 meter (3 feet) thick sand layer would be left over the bottom as a filter overlying the organics left in-place.

Therefore, the surface of the site had to be compressed from Elevation 94 feet down to Elevation 81 feet, a vertical distance of 4 meters (13 feet).

A critical consideration of the planning and construction was the marginal stability of the soft organics. The surcharge had to be placed uniformly, without creating unbalanced loadings, because of the risk of squeezing the organics laterally and causing mud waves. If a major mud wave developed, it would be very difficult, if not impossible, to regain control. For these reasons, it was decided to utilize dredging procedures to develop the site.

CONSTRUCTION PHASING

As the first step of lake construction, the trees and brush were cut and removed from the site. Draglines, working on mats, were then used to strip the rootmat from the collar area and also to excavate the organics in the shallower areas, generally to a depth of 1.5 meters (5 feet). However, the surface rootmat was left undisturbed within the central area of the site, where it served as a reinforcing layer to support the surcharge soils and minimize the tendency for local instability to occur. The construction phasing used is shown in Figure 6. The first stage consisted of excavating a containment "collar" trench around the perimeter of the area. The majority of the muck in the collar area was excavated using the cutter-head dredge.

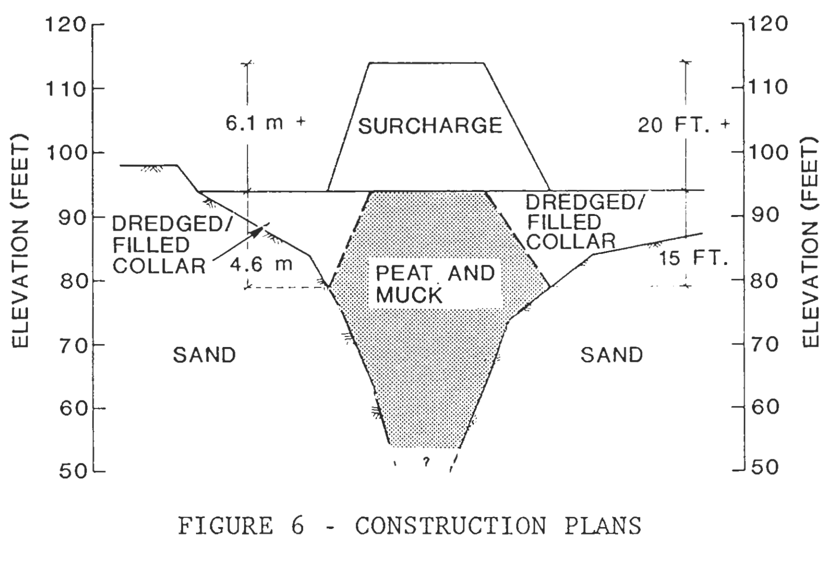

FIGURE 6 - CONSTRUCTION PLANS

Starting at the outside and proceeding inward, the peat was totally removed to a point where the bottom of the organics was about 4.6 meters (15 feet) deep. The retreating face of the muck was cut at a slope of approximately 3 horizontal to 1 vertical. After the excavation of the collar trench was completed by the dredge, the area was then backfilled with sand to provide confinement for the deep organics left within the interior against lateral squeezing. This backfilling procedure was completed by dredging in the non-organic soil areas and discharging into the collar area. This procedure is shown on Figure 7.

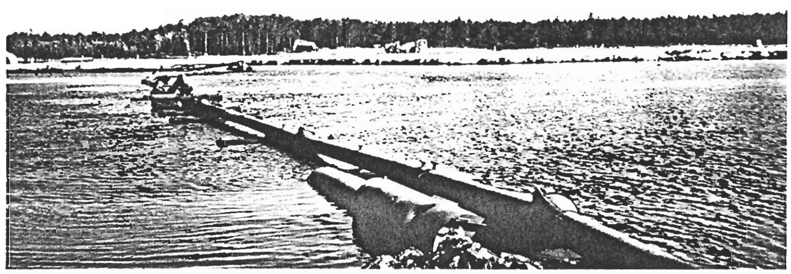

FIGURE 7 - FILLING THE COLLAR AREA

The dredge was then used to place the initial lifts of sand surcharge. The initial 0.6 to 0.9 meter (2 to 3 feet) thick sand layer was place uniformly over the peat surface by continuously moving the dredge discharge pipe. Small bulldozers were used to maintain a sand dike over the collar area to contain the next layers of dredged sand. After about 2 to 3 meters (6.5 to 10 feet) of dredged sand had been placed, conventional heavy earth moving equipment was used to place the remainder of the surcharge. The final thickness of the surcharge placed ranged from 6.1 to 7.3 meters (20 to 24 feet).

DREDGING EQUIPMENT AND TECHNIQUES

A portable 40.6 centimeter (16 inch) cutter-head dredge was transported to the site and assembled on-site. The dredge was "shop built" and operated by consortium of McCormack-Conduit-Buckley, and powered by a 900 horsepower GM motor. The dredge had plan dimensions of 24.4 by 6.7 meters (80 by 22 feet), and a draft of 1.4 meters (4.5 feet). The cutter-head was 3 feet in diameter and powered by a

75 horsepower motor. The ladder was 15.2 meters (50 feet), providing a maximum dredge depth of about 9.1 meters (30 feet). The suction pipe was 45.7 centimeters (18 inches) in diameter and powered with a Maddox Pump. The dredge is shown in operation in the background of Figure 8. In the foreground, a CME 45 drill rig mounted on a skid plate is performing additional exploration in an area where the organic soils will remain.

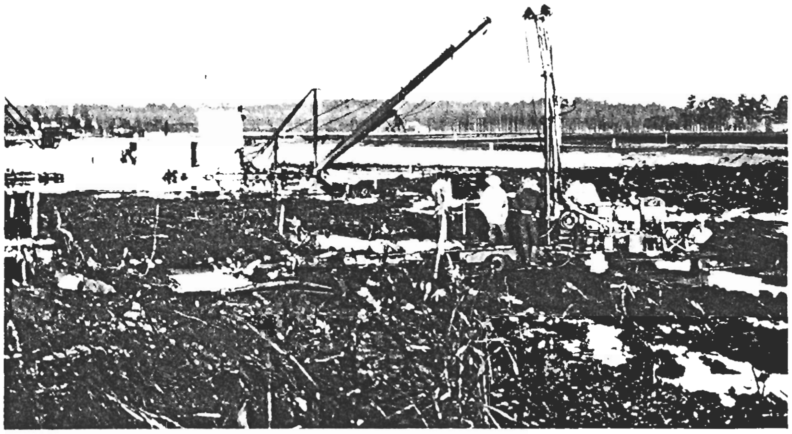

FIGURE 8 - DREDGE IN OPERATION

The primary borrow source for the EPCOT site was approximately 2.4 kilometers (1.5 miles) to the south of the lake site. This borrow area had been excavated by conventional equipment to form cells that were subsequently used for the disposal of the dredged organic soils. The effluent flowed progressively through these cells which served as settlement basins for the suspended organics. The dredging was performed using a "closed loop" system wherein the water from the last cell was returned to the site using a 16 inch Caterpillar pump powered by a 500 horsepower motor. As each cell was filled with settled dredge spoil, it was abandoned with the primary discharge moved to the next cell in line. These cells were later covered with a sand cap.

The dredge was able to cut through roots and small stumps. Occasionally, the cutter-head became clogged with these materials and was cleared by reversing the cutter-head. Large stumps, which had not been removed by the dragline, created occasional problems; essentially, that equivalent to encountering larger rocks during conventional dredging. Fortunately, very few of the larger stumps were encountered. Also, toward the end of the project, when fewer cells were available for settlement, the dredging operation was shut down for short periods of time because the return water contained too large a percentage of suspended solids. In general, these stoppages of work lasted only a few hours.

When cutting to a depth of 4.5 meters (15 feet), the control required to remove all of the organics was difficult, but fairly manageable. However, along the north perimeter of the lake, dredging was required to slightly in excess of 9.1 meters (30 feet). Control in this area was much more difficult. The dredge operator could only tell he was no longer pumping organics by noting the increase in voltage and listening to the smoother pumping action which occurred when the sands underlying the organics were encountered. In this area, the work was controlled by soundings and sampled, hand probes. Re-dredging of missed areas in this deeper zone was required more than once.

The dredging operation, once set up, was performed on a 24-hour basis with the dredge averaging 18 to 20 hours of work per day. The dredge was able to move approximately 230 cubic meters (300 cubic yards) per hour for an average daily production of 4,200 cubic meters (5,500 cubic yards). The majority of the dredging work was completed in 16 months, well under the contract time of 24 months.

MONITORING

As discussed previously, an important advantage of using the dredge for placing the initial lifts of the surcharge was the fact that material could be placed uniformly in level lifts. Because of the criticality of this initial filling operation, a constant "muck watch" was maintained to ensure uniform load placement and to watch for any signs of mud wave development. If signs of instability were observed, the dredging operations were stopped, the dredge pipe moved or other modifications made. Placement of the first surcharge lift is shown in Figure 9.

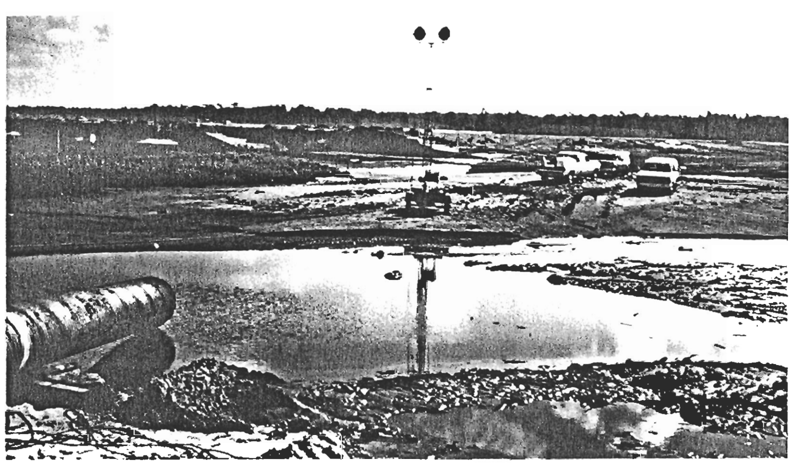

FIGURE 9 - PLACING THE FIRST SURCHARGE LIFT

After the initial layer of surcharge was in-place, settlement plates were installed to monitor the vertical compressions. The settlement plates consisted of a steel base plate 0.6 square meters (2 square feet) in plan, with a 2.5 centimeter (1 inch) diameter riser pipe. As the surcharge progressed, additional sections of pipe were added to keep the top of the pipe above the level of the surcharge. The settlement pipes were surveyed daily during the placement of the initial lifts of the surcharge to evaluate any stability problems. As the surcharge reached its design height, the monitoring was performed less frequently. The surcharge was placed over a two month period and the full surcharge remained in place for a period of four to eight months. A typical settlement curve recorded during the surcharging is shown in Figure 10.

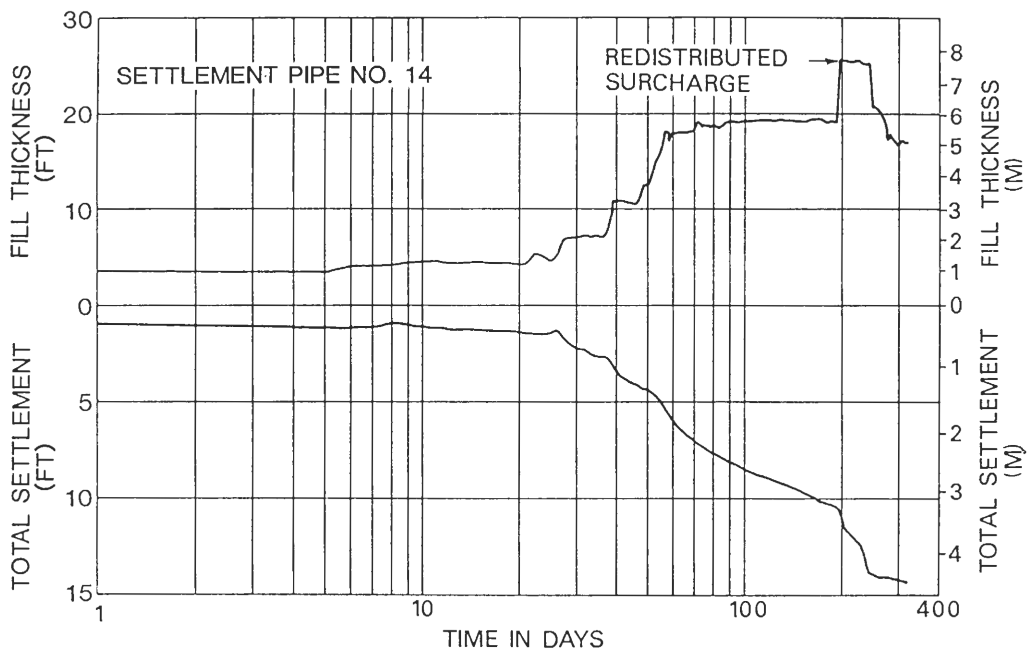

FIGURE 10- TYPICAL SETTLEMENT PLOT - LAKE AREA

Under the full surcharge, the surface of the peat compressed vertically up to 4.6 meters (15 feet). After the required compression occurred, the surcharge was removed, leaving a minimum of 0.9 meter (3 foot) blanket of sand overlying the compressed peat. As the surcharge was removed, the measured rebound was generally less than 5 centimeters (2 inches). To accelerate the settlement, after the desired compression had occurred in an area, the surcharge was removed and added in other areas to create additional load. Ultimately, the surcharge material was used as fill in other portions of the project.

A picture of the completed lake is shown in Figure 11 (note Space Ship Earth in the background).

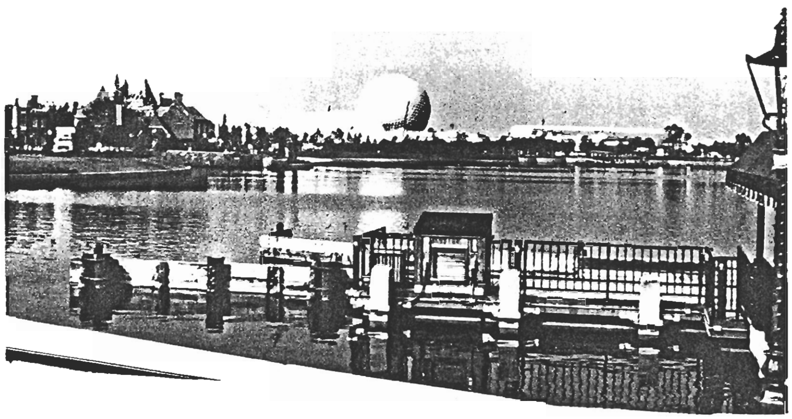

FIGURE 11 - COMPLETED LAKE (SHOWCASE LAGOON)

CONCLUSION

With the exception of two localized areas which remained about 0.9 meters (3 feet) higher than planned, the entire surface of the peat was compressed to the design elevation. These two areas were subsequently excavated and backfilled with sand using conventional equipment.

The procedure described took direct advantage of the high compressibility of the organic profile. Central to the success of this innovation construction approach was the use of the portable cutter-head dredge. Without the dredge, the construction would have been considerably more difficult, if not impossible to complete. The use of the dredge provided a practical means for placement of the surcharge, while controlling the stability of the area. This unique site development approach resulted in considerable savings in time and construction expense by significantly reducing the amount of organic material requiring excavation and eliminating the related disposal problems.

REFERENCES

(1) Swantko, T.D., et al., (1984), "Experience with the Development of Peat Deposits at Walt Disney World, Florida", Symposium on Construction in Difficult Terrain, Transportation Research Board Record 928, pp. 60-67.

(2) Swantko, T.D. and Berry, S. W., (1988), "Creation of a Lake Over Peat by Precompression", Proceedings of the Second Baltic Conference on Soil Mechanics and Foundation Engineering, Tallin, USSR.

(3) Personal Communication, Robert R. Buckley, Buckley and Company, Inc., 3401 Moore Street, Philadelphia, PA 19145