REMOTE SENSING ANALYSIS OF LAKE LIVINGSTON AQUATIC PLANTS

1975 FINAL REPORT

by

Arthur R. Benton, Jr.
Robert M. Newnam

March 1976

supported by
National Aeronautics and Space Administration
Grant NGL-44-001-001

and
Trinity River Authority
State of Texas

TEXAS A&M UNIVERSITY
REMOTE SENSING CENTER
COLLEGE STATION, TEXAS

TEXAS A&M UNIVERSITY
REMOTE SENSING CENTER
COLLEGE STATION TEXAS 77843

College of Agriculture
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INTRODUCTION

The major objective of remote sensing monitoring is to provide a workable method for detecting, identifying and delineating a condition or phenomenon which would be impossible or prohibitively expensive to monitor by ground methods alone. In the case of aquatic plants, infestations tend to occur in out-of-the-way places and the rates and directions of spread often go unobserved. Periodic remote sensing observation of susceptible areas permits monitoring of the presence, extent and condition of aquatic plants, thus providing the sort of management information essential to a plant control program.

The Remote Sensing Center made its initial system tests on Lake Livingston during 1974, a year of bumper crops of waterhyacinth and also a year when the extent of hydrilla outbreak was still somewhat limited. The mild winter of 1973-1974 permitted much of the 1973 waterhyacinth crop to winter over. The result, by April of 1974, was explosively

rapid early spread over the entire length of the Jungle and upper White Rock Creek. Efforts at herbicide control were simply too little and too late, hyacinth growth being essentially unchecked as it filled the confines of the Jungle and White Rock Creek. Growth downlake was much less extensive, reaching the level of heavy infestation in only a few scattered areas such as Brushy Creek and Kickapoo Creek.

Hydrilla, possibly unnoticed in the early months of 1974, had by late fall reached heavy concentrations in Beacon Bay and Brushy Creek, at the least. Further, an infested area had been discovered at the southeast tip of the Jungle.

Coontail did not seem in 1974 to be greatly in evidence although in hindsight, on re-examination of 1974 imagery of the Jungle's interior, it may have been present in rather considerable amount.

By late 1974 all indications were that the 1975 crop would simply pick up where 1974 left off and the spread would continue. For this reason the 1975 contract effort concentrated on the 1974 areas of known infestation, making allowance for enlargement of those working areas when and where the anticipated spreads of infestation occurred.

The 1975 work provided sequential total coverage of the Jungle and White Rock Creek plus coverage of smaller areas of localized infestation downlake, including Brushy Creek, KOA Kampground Marina, Penwaugh Slough, Memorial Point Marina, the Beacon Bay marinas and Pine Island. A mid-March date for initial photography was scheduled in order to obtain "before" baseline data in anticipation of April emergence of the various species.

THE 1975 PROGRAM

The winter of 1974-1975 was very much colder than the previous winter. Instead of the dormant hyacinth mat's wintering over as before, a totally different set of conditions prevailed. A minimum of two hard freezes hit Lake Livingston by mid-January of 1975, resulting in a massive stress impact on the hyacinth mat. The plants withered and sank because of the disintegration of the floatation cells.

The first photography of the 1975 field season was taken on 24 March. There was essentially nothing to be seen. Perhaps 50 percent of that part of the Jungle covered by hyacinth in 1974 still contained remnants of the 1974 mat. There was no indication of youthful aquatic plants anywhere on the lake with the exception of a tiny patch of hyacinth next to the road embankment in Brushy Creek.

Because of the lack of targets it was decided to hold off the next photographic sequence until a reasonable amount of spring growth had emerged. This resulted in the second flights being made on 1 June 1975 more than two months after the initial flight. Thereafter the flights were made on a monthly basis, generally about a month apart except for the month and a half separation between the 3 September and 17 October flights. In this latter case there were two intervening flights; by NASA on 25 September and by NOAA on 29 September, this imagery serving to fill the gap.

The imagery was generally good, photographic exposure being increased as the season progressed in order to obtain better pictures of the submersed vegetation. Two regrettable gaps in the imagery occurred. The first was on 9 July when we ran out of color infrared film before the marinas downlake could be photographed. The second was on the following flight when broken clouds obscured all of the Jungle and White Rock Creek plus some of the areas downlake. The result, in the second case, is lack of a record of the major initial spurt of growth of the hyacinth bed at the west end of the Jungle.

General Findings

A great deal was learned from the 1975 work; about the effects of hard winters of aquatic plants, about the plants themselves and their growth characteristics, and about the changing species makeup of the various infested areas. Concentrating on the relationship of the plants to their habitat, it might be better to consider the general 1975 program results in terms of the major lake areas under study.

Jungle - White Rock Creek - It was a very different year from 1974. Aside from the late initial growth of the hyacinth crop there was also a considerable change in species percentages and in mid-season areal coverage by species.

Only in the west and southeast tips of the Jungle was the late-season hyacinth coverage at all remeniscent of the previous year. For the most part the waterhyacinth growth was late, sparse, and limited in extent. An interior population of coontail and naiad showed up in early summer, flourished briefly and vanished mysteriously well before the onset of serious winter weather.

In over half of the Jungle area in which so much hyacinth grew last year, none was produced this year. The

lack of hyacinth was made up in part by the extensive spread of hydrilla in the southeast tip. Further, the infestation seems to be moving steadily downstream along the southwest shoreline toward the Highway 190 bridge.

In White Rock Creek there was almost no recurrence of hyacinth where it had been so widespread last year. The spoil areas off Westwood Shores marina produced an abundance of coontail and potamogeton early on but this too diminished with the onset of fall. Above Skaines Lake there was no serious emergence of anything resembling a hyacinth crop, due at least in part to the efforts of the Texas Parks and Wildlife Department (TP&WD) spray crew.

The extensive areas of coontail seen last year above Skaines Lake were next-to-nonexistent this year, for reasons not fully understood.

Brushy Creek - This was the year for hydrilla in Brushy Creek. The main feature of interest was the substantial increase in hydrilla coverage and density over last year, coupled with the late summer test of herbicides by the Texas Parks and Wildlife Department. Waterhyacinth, even though it developed relatively early here compared to the rest of the lake, simply wasn't a dominant factor in the pattern of plant coverage.

Marinas and Inlets - All of the marina and inlet areas under season-long study had persistent heavy infestations of some sort, usually hydrilla. This merely points up the fact that this seems to be the year when hydrilla took over as the key problem plant on Lake Livingston.

Beyond the increasing occurrence of hydrilla, and the variable success achieved by both the Trinity River Authority and the Texas Parks and Wildlife Department in coping with it, there emerged a general picture that aquatic plants have become a more widespread problem over the lake as a whole.

SPECIFIC TRENDS IN 1975

The imagery obtained this year points up some very significant differences in growth patterns, species interactions, and species dominance when compared to 1974. Then too, remote sensing procedures were rather different from 1974 to 1975. For one thing, the 1974 imagery, while sequential, was more limited in areal coverage and didn't include the marina areas downlake until relatively late in the season. For another thing, ground truth was more cursory in 1974, many features never having been checked until early-to-mid 1975.

This section will discuss the more detailed findings uncovered in 1975 plus the changes in plant community characteristics noted between the two years.

Jungle - White Rock Creek

This area was dominated by waterhyacinth and duckweed in 1974. There were additional infestations of coontail whose extent, particularly in mid-Jungle, was not well known. In 1975 the hyacinth was far less extensive. The 1975 trends, by species, are noted below.

Waterhyacinth - The initial photography on 24 March 1975 showed only the remains of the dead mat from the previous year, with no indication of emergent 1975 growt anywhere in the Jungle or White Rock Creek. The only items of interest were the dark, turbid streaks emanating from the Jungle and from White Rock Creek and sweeping off downcurrent. These streaks are now considered to be disintegrating material from the previous year's sunken mat.

By 1 June the dead mat had sunk out of sight, leaving open water over most of the Jungle and upper White Rock Creek. Small clumps and single plants of waterhyacinth were found at the south side of the west tip and at the southeast end of the Jungle during ground truth activities. These plants were too small to have shown up on the imagery. In upper White Rock Creek small patches of youthful hyacinth were seen on the imagery

along with evidence of herbicide spraying, both effects borne out by ground checks.

The imagery from 9 July showed a rather tentative emergence of relatively sizeable clumps of hyacinth at the Jungle's west tip, the southeast end, in Mill Creek, and in the slough northwest of Mill Creek. Total coverage in the Jungle at that time amounted to a very few areas, widely scattered. In White Rock Creek the most noticeable feature was the heavy herbicide spraying going on. Upper White Rock Creek had been receiving repeated doses and the Barnes Canal area, having just acquired extensive coverage of youthful hyacinth, had been sprayed as well. At this stage all of the efforts of the Texas Parks and Wildlife Department spray crew seemed to have been concentrated on White Rock Creek.

No photography or ground truth work was done in this area in August. By 3 September, the first good photographic day subsequently available, conditions in the Jungle had changed considerably. The west tip of the Jungle now had a substantial hyacinth colony in both mature and juvenile stages which was particularly lush along both sides of the approach to Shoemake Creek. A token herbicide application had been made at the north side of the west end of the Jungle. The situation at the

Jungle's southeast tip was similar, with juvenile-to-mature hyacinth spread along both sides of the channel and juvenile hyacinth found spreading northward around the southeast extremity. Of particular interest at both ends of the Jungle was the extensive beds of surfaced coontail and hydrilla and their apparent role in inhibiting the natural spread, by drift, of individual hyacinth plants and plant clusters. Mill Creek and the adjacent dammed slough had by this time become well covered by healthy hyacinth.

Meanwhile, up White Rock Creek, the TP&WD had been busy with herbicide application in most areas above Skaines Lake. No general coverage of hyacinth could be seen anywhere except at the mouth of Barnes Canal, about halfway along the northeast shoreline.

The imagery of 17 October showed a bare hint of the sort of rampant spread of hyacinth that had begun in late April of the previous year. Youthful, vigorously growing hyacinth had in one month's time leaped nearly two miles in a narrow strip extending eastward from the west end of the Jungle along the old Trinity River channel. Similarly, hyacinth in the southeast end had rapidly spread northward along the west side of the old channel. However, where extensive submersed vegetation was present, relatively little outward spread took place.

The hyacinth crop in White Rock Creek remained under close control by the TP&WD. For the first time it was noted that spray activity took place outside of White Rock Creek. During the period between the September and October flights, spray was applied in Mill Creek and the Jungle edge across from White Rock Creek bridge. The latter spray effort seemed to have been a limited one.

By 14 November very little increased hyacinth growth had occurred in the Jungle proper subsequent to the growth spurt in the September-October period. The hyacinth at the west end had for the most part reached late maturity as opposed to that in the southeast end which still appeared quite vigorous. A minor new growth showed up along the shoreline north of the west end. In both the west and southeast ends there was clear photographic evidence that spraying had taken place, but instead of the usual tan coloration the sprayed areas showed up as lime green. This created a mystery because the ground appearance was not that of 2,4-D-sprayed hyacinth either. Besides that, the TP&WD spokesman indicated that no TP&WD work had gone on in the Jungle during that month. It would almost appear that parties unknown had gone into the Jungle and sprayed extensively with an unknown liquid.

The previous heavy Mill Creek spraying had eliminated all sign of hyacinth. The plants in the adjacent slough were not sprayed and remained vigorous.

In White Rock Creek the amount of hyacinth extant remained minimal. That in the interior of the approach to Barnes Canal which had survived the earlier fringe spraying had by now begun to senesce.

By 1 December the taller, more mature stands in both ends of the Jungle had begun to senesce rapidly, a possible result of a brief period of freezing temperatures in late November. The short, youthful hyacinth, most of which was at the east end of the Jungle, remained mostly viable. It could very well be that a combination of still air and a warm water surface produced a vertical air temperature gradient such that the shorter, less mature hyacinth remained in an above-freezing zone. In general, almost all of the hyacinth bed on the west end senesced since the November flight, as well as most of that lining the south channel at the east end. The newly-emerged hyacinth south of the White Rock Creek bridge was generally in better shape while the youthful plants at the east end were the least affected of all.

There was essentially no indication of hyacinth in White Rock Creek other than the senescent mat at the entrance to Barnes Canal.

By 6 January the Jungle's hyacinth was reduced to a dead-appearing mat, including the protected slough northwest of Mill Creek as well. Two hard freezes during December seemed to have finished off the 1975 crop. The situation was the same in the Barnes Canal section, the last bastion of hyacinth in White Rock Creek.

Hydrilla - Th initial infestation of hydrilla in the Jungle occurred at the southeast tip some time during 1974. This remained the only area of known hydrilla infestation in the Jungle during 1975 and none was observed in White Rock Creek.

No hydrilla was seen in the imagery of the flights of 24 March and 1 June, nor was any found during either ground truth trip even though extensive coontail coverage was noted below the surface in June along the pipeline outlet from the Jungle.

By 9 July the hydrilla had sprung up noticeably on the imagery, taking on the near-surface deep maroon color in some places. Two major infested areas at this time were the south shoreline adjacent to the pipeline and the southeast tip of the Jungle proper, near an offlying grove of still-standing tree trunks. The hydrilla in both areas had by this time reached the surface in many different places.

The next photography of this area was on 3 September, when low altitude flight lines were initiated over the hydrilla-infested area at the Jungle's southeast end. Both the high altitude and low altitude photography showed that the hydrilla had spread extensively; to the northwest, well into the Jungle, and also southeast along the south shore of the lake, apparently beyond the edge of photography. Close examination of the imagery disclosed that the probable hydrilla coverage at this time was probably about 100 acres (40 ha).

By 17 October the hydrilla was generally lush and on the surface, more often than not overlain with algae. It had also increased in extent, as well as biomass, over the previous month. Ground truth showed that the hydrilla was mostly in flower. Moving into the Jungle along the pipeline right of way it was observed that the hydrilla was increasingly mixed with coontail over the first 100 meters. By the end of 150 meters only coontail was found. Off the southeast tip was essentially pure hydrilla, extending in diminishing clumps approximately 200 meters southeast from the middle of the tree line. Hydrilla along the shoreline was again seen to go beyond the limits of photography to the southeast.

The 14 November flight included an extended low altitude line; some 1.5 kilometers beyond the previous photography along the shoreline to the southeast. The hydrilla remained lush and vigorous, its rate of spread apparently undiminished by the onset of cooler weather. Following the extended low altitude line, hydrilla was seen along the shoreline all the way to, and across, Brown's Creek entrance, thence 0.6 kilometers further to the marina just past the overhead power transmission line. This month, perhaps for the first time, hydrilla was seen to be clearly the dominant vegetation at the southeast end of the Jungle.

The 1 December imagery showed the first indication of hydrilla decline in the southeast Jungle sector. This showed up as a slight loss of biomass and a more diffuse border. The substantial decrease in algae along with the general decrease in plant biomass permitted a better image of the interior hydrilla boundary than had been seen previously.

By 6 January the above-surface hydrilla had been decimated, undoubtedly by the interim hard freezes, leaving rather sparse indications of submersed hydrilla dimly seen in the turbid water. Ground truth showed that the hydrilla was essentially gone in the upper quarter-meter and sickly in appearance below that.

Coontail - Not a great deal is known about the total level of coontail coverage in 1974. The major interest then was in waterhyacinth and duckweed. The 1974 photo coverage was less extensive than that undertaken in 1975, as was the ground truth work. As a result we investigated the appearance of coontail near Skaines Lake, where we had photo coverage in 1974, but not in the Jungle interior or off Westwood Shores Marina where coverage had not been intended. In the 1974 mid-season, south-looking obliques off the Sebastopol area of the Jungle we often glimpsed in the background what we postulated to be a "third species", other than hyacinth and duckweed. But we were never able to obtain valid ground truth correlation because of the reluctance of our hired guides to go into the Jungle proper. One 1974 boat trip did penetrate about halfway through the pipeline from north to south. What was found at that time was a fairly extensive remnant of "tree moss" hanging in the dead branches. From this we assumed, very probably erroneously, that all of the pale gray-green background areas of the Jungle on the 1974 color infrared imagery were moss hung tree branches rather than a submersed species. We now believe otherwise.

There was no indication of coontail in the March or June photography. By 9 July, however, there was a

strong indication of extensive near-surface coontail, beginning off Shoemake Creek and continuing along the south shoreline around the corner to the west. We were so busy at the time looking for hyacinth and hydrilla that the coontail was simply overlooked.

By 3 September the coontail in the central Jungle had acquired some overlying algae and was quite easy to pick up on the imagery. In general, it filled most of the Jungle interior from the west end eastward, narrowing in offshore extent as it went around the corner of the south shoreline. Beyond that point it broadened in coverage until it met, merged with and was supplanted by the rapidly spreading hydrilla at the southeast tip of the Jungle.

Coontail was also extensively observed in September in the White Rock Creek area. Barnes Canal had a heavy growth, as did the spoil banks above Skaines Lake. The spoil banks off Westwood Shores Marina also contained dense coontail. Toward the bridge over lower White Rock Creek, the last two coves on the east side also harbored numerous lush patches of coontail

October seems to have been the high water mark for coontail. The 17 October imagery shows that the coontail coverage in the central Jungle was at least as

extensive as in September and that the sector at the south shoreline turn was perhaps better defined than before. Up White Rock Creek the general coontail coverage was greater off Westwood Shores, holding its own in Barnes Canal and in the coves north of the west end of the Highway 356 bridge.

By 14 November the coontail in the central Jungle had begun to diminish, along with the algal overstory and the accompanying naiad which had first shown up in September. In White Rock Creek the coontail was in general retreat, with the exception of the back of Barnes Canal where it was quite healthy and lush, though overlain with dead oedogonium.

By 1 December there were relatively few clumps of coontail remaining in the Jungle. In White Rock Creek there was little coontail to be seen except in Barnes Canal, with the latter sickly and much diminished.

The 6 January photography had no indication whatsoever of coontail in the Jungle or in White Rock Creek. Ground truth showed that what very little remained was rapidly disintegrating.

Potamogeton - This plant looks rather innocuous and can hardly be classed as an exotic import. Yet it appeared

for a while during the summer of 1975 that potomogeton was making a bid to take over the shoreline of the lake. It seemed never to be the central aquatic plant of interest in any of the study areas, yet there it was, showing up on the fringe of some more "interesting" plant colony, or perhaps on the edge of a photo, growing in an area where nothing was expected to grow.

It didn't show up in the Jungle-White Rock Creek area until July, when it was seen in the cove across the highway from Galloway's Marina. By September it was well entrenched in the southeast Jungle area, showing up as a bright, dark pink patch in the general hydrilla area southeast of the tree line in open water. It also appeared, by itself, along the west shore and in Hart's Creek Cove, just west of the main project area along the north shore. It was more evident in the September imagery, off Westwood Shores Marina, than was coontail. And it continued to flourish in the cove near the Highway 356 bridge.

Potamogeton continued healthy in October in the same areas but diminished substantially by mid-November. It had diminished still more by 1 December and was nowhere in evidence on 6 January.

Brushy Creek

The Brushy Creek area in 1974 was, as far as waterhyacinth was concerned, sort of a miniature Jungle. In addition it had picked up a general infestation of hydrilla, Brushy Creek's being a popular fishing spot helping considerably in the plant's spread. Still and all, the major population in 1974 was waterhyacinth, dominating the relatively sparse, relatively unfrequent clumps of hydrilla.

Changes in 1975 - The first 1975 emergence of youthful hyacinth we found on the lake was in Brushy Creek during the March ground truth work. But healthy, widespread hydrilla was found there at the same time.

Evidence of herbicide application on hyacinth (apparently 2,4-D) was found in the 1 June imagery but its effect on hydrilla was apparently negligible. The hydrilla in Brushy Creek had by this time become dense and lush, its growth extending into the cove southwest of the bridge.

July photo-analysis was hampered by having only the single, flawed, high-altitude, color-infrared photo of Brushy Creek against which to compare the complete series of color photos. Nevertheless, the pattern was emerging of rapidly growing, healthy hydrilla interspersed

with hyacinth whose growth was inhibited by spray application and by being hemmed in by hydrilla.

By 12 August the hydrilla had essentially taken over the inlet and was in process of doing the same thing in the cove south and west of the bridge. Just outside the bridge, at the left approach, was the beginning of a competition between an established stand of potamogeton and an advancing bed of hydrilla. In most areas within the inlet the hydrilla had reached the surface and was expanding into ever-deeper water.

On 3 September, the last photographic flight before the start of the TP&WD herbicide test, the hydrilla was seen to be completely dominant in all sections, with small occasional clumps of hyacinth growing on top of the dense hydrilla understory but incapable of normal spread. An exception was the upper part of the drowned winding stream bed in which hyacinth seemed to have gotten off to a running start and which was apparently too remote to have been reached by the herbicide application crews. Elsewhere, hydrilla had increased in both spread and density, covering the bottom of many of the channels within the inlet. In contrast to the healthy potamogeton growing alone along the outer shoreline near Culp's Marina, that near the bridge approach was beginning to diminish in vigor.

The remainder of this section will be discussed in the context of the mid-September applications of herbicide on the established test plots within the inlet.

TP&WD herbicide test period - The Remote Sensing Center ground truth crew visited Brushy Creek on 6 September. Texas Parks and Wildlife Department personnel were observed at that time staking out test plots to be used during the upcoming herbicide application experiment. According to Lou Guerra, all of the test plots were treated during a two-day period in mid-September. In some plots the results were apparent in the NASA imagery of 25 September and the NOAA imagery of 29 September. In others, results weren't seen until 1 December, after it had been assumed that the main show was over.

The 25 September imagery shows the initial impact on most test plots as a highly localized increase in turbidity within the plots and in the open water immediately adjacent. In most plots this is also accompanied by loss of density.

The 29 September photography indicates a cessation of the localized turbidity except within the confines of the test plots themselves. In both the 25 and 29 September imagery the buffer zones between plots are clearly distinguishable.

At some time within the mid-September time frame there was also a general application of 2,4-D; along the north side of the approach channel to the east end of Brushy Creek Inlet, and at the base of the area known as Daffy Duck. By 25 and 29 September this had a significant impact on the hyacinth population but little or none on the hydrilla in the same area.

The 17 October Remote Sensing Center imagery showed, strangely, no turbidity whatever in the test plots and, within the now-clear hydrilla beds, relatively little in the way of diminished density or vigor. Ground truth showed that some of these areas had experienced loss of the upper part of the plants but that viable growing points were established below the deteriorated tips. In the west side of the inlet, sprayed areas were often more noticeable because of the dead hyacinth on top than they were because of dimunition in hydrilla growth. Also on the west side, it was seen that hydrilla covered most of the bottom of the main dredged channel. In the west cove outside the inlet the hydrilla continued to expand and take over the area, the hyacinth in the back of the cove having been recently sprayed, probably from the road.

The 14 November imagery showed increased loss of biomass in the centers of most test plots. The greatest impact from herbicides occurred in the area northeast of Daffy Duck. Here the plots near the water's edge consisted almost entirely of dead and defoliated stalks. Elsewhere on the east side the hydrilla had been reduced in height but the stems remain viable. On the west side of the inlet the hydrilla was less affected than on the east side. In the cove outside the inlet the stressed hyacinth mat was dead, with an overlying layer of algae having been picked up. The potamogeton patch at the bridge approach had been almost entirely infiltrated and taken over by healthy hydrilla.

By 1 December all of the hyacinth in the area had been killed off by an intervening hard freeze. The potamogeton, too, was dead or nearly so. The hydrilla was generally still healthy in the areas untouched by herbicide and not too much diminished in many of the test plots. In some treated areas there was even indication of regrowth. The odd indication on the imagery was a seemingly anachronous general area of turbidity in the extreme northeast end of the east side of the inlet. This was similar to the early post-application situation in the test plots fringing open water.

The 6 January imagery showed a significant change in the hydrilla in Brushy Creek, both in the treated and untreated areas. The untouched hydrilla in the cove outside the inlet was less dense and the plant tops had receded well below the surface. Within the inlet, on the west side, the hydrilla had receded and diminished even more, though it was still viable. The situation on the east side of the inlet showed most of the test areas still containing viable hydrilla as a near-bottom mat, the buffer zones being denser and closer to the surface. An exception to the relative health of most of the hydrilla crop in the east end was that portion northeast of Daffy Duck. There, particularly further in toward the back shoreline, there was no bottom mat at all, only a few random dead stems. The condition was apparent from the imagery, this being the area in which a general high level of turbidity was seen in the December photography.

Marinas and Other Downlake Areas

The 1974 work started off in the Jungle and White Rock Creek areas and didn't take in any of the marinas or inlets further down until October, when word of hydrilla infestation reached us. In 1975 these areas

were included from the beginning, some of the more interesting findings involving marinas, campgrounds and adjacent areas.

KOA Kampground Marina - This marina was typified by an infestation of hydrilla which grew within the marina and patches of potamogeton which flourished on the outside.

The first hydrilla was found during the June and July ground truth work in patches too small and too far below the surface to be picked up on the imagery. By August the potamogeton to the north was lush, expanding rapidly, and showing up as a bright peach coloration on the color infrared imagery. Two small patches of hydrilla along the bulkhead near the fuel float were also picked up on the photography.

The September imagery showed mature potamogeton to the north and a great deal of hydrilla spread about the confines of the marina. By mid-October the hydrilla had become a nearly continuous surfaced mat fringing all bulkhead areas and threatening to take over. Herbicide was subsequently applied within the marina by the Trinity River Authority (TRA).

The first flight following herbicide application was on 14 November. The reduction in hydrilla biomass was very substantial, strong remnants remaining only in the areas adjacent to the boat ramp and the fuel float. The potamogeton had by this time begun to senesce.

By 1 December the only hydrilla still faintly visible on the imagery was that adjacent to the fuel float. By 6 January even that was no longer detectable.

Penwaugh Slough - The general area contains a commercial campground which appears to generate a great deal of high-nutrient effluent into the adjacent waters. A broad, shallow inlet at the rear contained a dense crop of waterhyacinth in 1974.

Dense, flowering hyacinth was seen in the June imagery and during the associated ground truth visit. By 9 July the hyacinth was seen to be mature and very dense, with a thick algal bloom ongoing adjacent to the lakeward limit of hyacinth. A cursory spray treatment was given the hyacinth by the TRA later in the month. The August photography showed minimal resulting damage to the hyacinth and the continuation of the dense, floating algal mat. By September the situation was much the same except that the hyacinth had grown taller and the algae, a mixture of spirogyra and oedogonium, had spread further down the inlet.

The October imagery shows the hyacinth moving into the late maturity stage, with youthful hyacinth in the previously sprayed area. Down-inlet, the algae was breaking up and moving out, clumps of youthful hyacinth moving in behind and attaching to the shoreline. By mid-November the main body of hyacinth was seen to be senescing rapidly. The algae mat had broken up still more and youthful hyacinth, in scattered clumps, had progressed still further down the inlet.

By 1 December the main hyacinth area was dead and much of the late-emerging small clumps had begun to senensce. The algae mat was much less extensive and there were almost no remaining viable hyacinth clusters within it. By 6 January all the hyacinth and most of the algae was dead. Exceptions were a few scattered patches of mixed spirogyra and cladophora.

Memorial Point Marina - This marina was apparently infested with hydrilla late in 1974. The early 1975 crop grew aggressively.

Hydrilla was first seen, very faintly, on the June photography. In July a widespread infestation was seen along the short breakwater and the adjacent shoreline. By August the hydrilla was very apparent throughout the

marina inlet, overlain by oedogonium to a considerable extent. On 3 September the situation had worsened still more, with very dense, very lush hydrilla crowding the inlet and overlain by spirogyra and oedogonium.

A heavy application of herbicide was put down subsequent to the September flight and ground truth sequence. The October photography showed the heavily stressed hydrilla mostly as detached, floating mats. Some fairly extensive patches of near-bottom growth remained along the north breakwater and bulkhead but not at the boat ramp area in the back of the marina. By November most of the surface mat had disintegrated but the bottom mat described above was still apparent on the imagery, under magnification.

The 1 December imagery shows that the hydrilla had diminished to numerous, small, somewhat less dense clumps. By 6 January the clumps were extremely faint. Ground truth showed the hydrilla to be rather sparse and decimated.

Beacon Bay - The two marinas in this embayment were the site of a very dense and extensive hydrilla infestation in 1974. A late-1974 herbicide treatment may have inhibited the rate and extent of 1975 regrowth.

Hydrilla became visible on the 1 June imagery, seen rather faintly along the shoreline in the main embayment. By July it was readily seen throughout the Beacon Bay area and apparently spreading around both the flanking points of land.

By August the hydrilla had become significantly more dense in all areas, which was quite apparent on the imagery, and an extensive bottom mat had developed in rather deep water off Beacon Bay Marina entrance, which was not that apparent on the photography. The September imagery showed an increase in the surfaced hydrilla, some of it having picked up an algal overstory. By October the algae had disappeared, leaving both surfaced and submersed hydrilla clearly visible in the main embayment. Detached mats had begun to show up with Beacon Bay Marina itself, the result of recent herbicide applications.

The water was quite clear in the November imagery and numerous large dense patches were visible in deep water in the main embayment. The peripheral hydrilla patches were still mostly surfaced. Beacon Bay Marina appeared to be clear on the surface, the delayed result of the September herbicide application.

Senescence had begun prior to the 1 December photography. By 6 January the remaining hydrilla in the

outer embayment had receded well below the surface and become very sparse.

Putnam's Landing - This was a new area of investigation in 1975. Hydrilla was first observed on the imagery, in very small amounts, in June. No increase was noted in July and the area was missed in August. By September there had been no increase in growth, but by October healthy hydrilla could be seen growing luxuriantly around the entire perimeter of the inlet. From November on a plankton bloom masked the offshore extent of the hydrilla growth and possibly inhibited photosynthesis as well. By January the bloom still persisted and the hydrilla remained near the surface and relatively healthy. In addition, hydrilla had spread all the way to the dock area on the south shore of the mouth of the inlet.

Pine Island - This was also a new area for 1975 work. A hydrilla infestation had occurred in the two coves at the east end of the island. Very little of interest seems to have happened during 1975. Hydrilla was first noticed in the June imagery at the back of both inlets. The infestation increased slightly in area during mid-summer, picking up some coontail in the south inlet. The spread in both inlets progressed through August, slowing down by September

and, in the case of the north inlet, receding for no apparent reason. Hydrilla coverage was seen in October to have increased in the south cove; held its own in the north cove.

By 14 November the submersed vegetation had begun to decrease in extent, diminishing by January to very faint images of rather sparse vegetation consisting almost entirely of hydrilla.

Deep-water hydrilla clumps - An observed, but not yet photographed 1975 phenomenon is the appearance of extensive submersed clumps of aquatic plants in the very deep waters west and south of Pine Island. From aerial observation these appear to be acre-sized and larger, observable only on days when the water is relatively clear.

These observations correlate with reports we have received from commercial bait fishermen who have hauled up living hydrilla from depths of 10 to 13 meters in these same areas. It appears that hydrilla can exist in turbid water at depths significantly greater than heretofore expected. This would mean that hydrilla is capable of readily progressing across a relatively deep channel as it moves along a lake shoreline.

DISCUSSION AND CONCLUSIONS

The Florida experience of recent decades has shown that, given the intial infestation of noxious aquatic plants and the environmental conditions supportive of them, the plants will tend to take over lakes and reservoirs if left to their own devices. In the case of Lake Livingston we have a newly-formed lake fed by a river which is rich in the nutrients which promote plant growth. The modern-day mechanism for the lake-to-lake spread of aquatic plants--trailered boats--has been in operation here. Further, local boats will continue to spread the plants within the lake so long as centers of infestation continue to flourish.

During a given year the rates of growth, rates of spread, and the seasonal period of youthful emergence are modified to a considerable extent by the severity of the previous winter and by the effective level of effort of the ongoing aquatic plant control program.

Looking back on 1974 we see an explosion of hyacinth growth in the Jungle and White Rock Creek following the mild winter of 1973-1974. The control program in those areas during 1974 simply could not cope. It appeared to consist of random treatment of random areas, with results which were spotty at best.

In 1975, after a very severe winter, the emergence of meaningful amounts of youthful hyacinth was delayed from three to five months in comparison with the previous year. Further, the control effort appeared to concentrate almost exclusively on White Rock Creek, which comprises perhaps 3 percent of the total surface area of the lake. As a result the extent of White Rock Creek coverage averaged near zero.

Meanwhile, down in the Jungle and elsewhere on the lake, the spread of hyacinth continued essentially uninterrupted. Fortunately the several hard freezes of the winter of 1974-1975 kept the hyacinth from getting a good running start. And in 1975 the character of the Jungle infestation seemed to change, perhaps only temporarily, to one which is dominated by submersed plants. According to Florida investigators, this is definitely no improvement.

Further down the lake we observed, in 1974, an extremely heavy infestation of hydrilla in Beacon Bay. This was treated by the Trinity River Authority in early fall with fair-to-good short and mid-term results for the two marinas involved. Strong regrowth began in early summer in Beacon Bay and treatment was again given in early fall of 1975, but at no time did the level of infestation reach that of the previous summer.

The extent to which this inhibition in growth was due to herbicide treatment rather than weather factors is not known. It does seem certain that, barring a breakthrough in herbicide development, herbicides must continue to be applied indefinitely in Beacon Bay and in all other critical areas if a measure of localized control is to be achieved.

Standing off at a distance and looking at the total Lake Livingston problem over the 1974-1975 period, we can ask ourselves whether 1974 or 1975 is more typical of what may be anticipated over the coming years. In all probability neither one is. Instead, 1974 and 1975 are simply two consecutive years in the eutrophication process of the lake. The rapidity of eutrophication will be dependent on the vagaries of the weather, the changing quality of the lake's inflow and the things people do to promote or inhibit the future levels of infestation.

The aquatic plant problem is complex and the cause and effect relationships only partially understood. The monitoring that was carried out in 1974 and 1975 has provided a considerable amount of insight into what is happening on the lake. It has been a useful tool for detection of infestations and for assessment of the results--or lack of results--of the ongoing control efforts.

Monitoring will continue to be needed in order to track the problem on the lake, to understand the dynamics of the natural processes involved, and to determine the short-term and long-term effects of man's activities. The aquatic plant problem is essentially a management problem. As is the case with any management problem, timely and accurate management information is required for its solution. Remote sensing monitoring can provide that information at a reasonable cost.

RECOMMENDATIONS

There is a tendency to believe that the total problem on Lake Livingston is by definition encompassed by the areal extent of the 1975 photography. But occasional glimpses of other areas over which photographs were taken at random, or visual observations made, show that this is not the case. Examples include: the hyacinth-covered areas upstream from the Jungle; the progression of hydrilla infestation along the shoreline southeast of the Jungle; the potamogeton beds in the shallows between Brushy Creek and KOA Marina; the patches of submersed vegetation off Waterwood; and the huge, submersed, deepwater clumps out in mid-lake.

For one thing, these additional areas should be photographed and mapped. For another, the detailed coverage of small, critical areas should be continued.

To this end, it is recommended that:

- total coverage of all Lake Livingston shoreline areas be obtained, using large-format photography, during 1976,
- sequential aquatic plant coverage of these areas be documented on 1:24,000 scale maps, similar to Figures 1-3 accompanying this report, but rather more elegant in layout, and
- larger scale photo and map coverage be provided for selected critical areas.

In addition, it has been reported that the extensive alligatorweed infestations of the Trinity River delta area have been augmented this year by an extensive intrusion of water hyacinth. Since this too is an area of importance to the Trinity River Authority, it is recommended that:

- the Wallisville reservoir site be included in the 1976 project area, and that the photographic and cartographic output discussed above be provided for the Wallisville area as well.

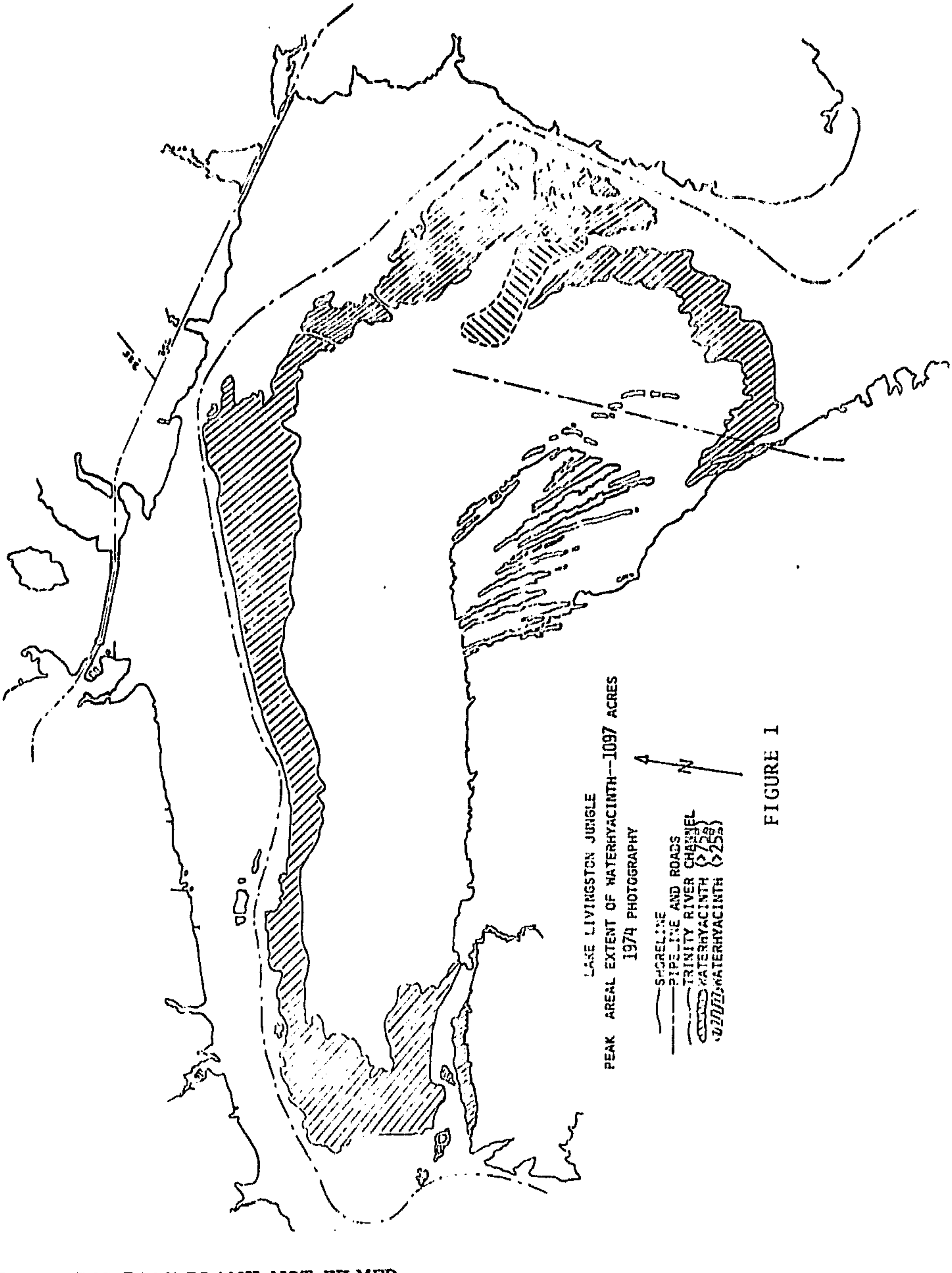

FIGURE 1

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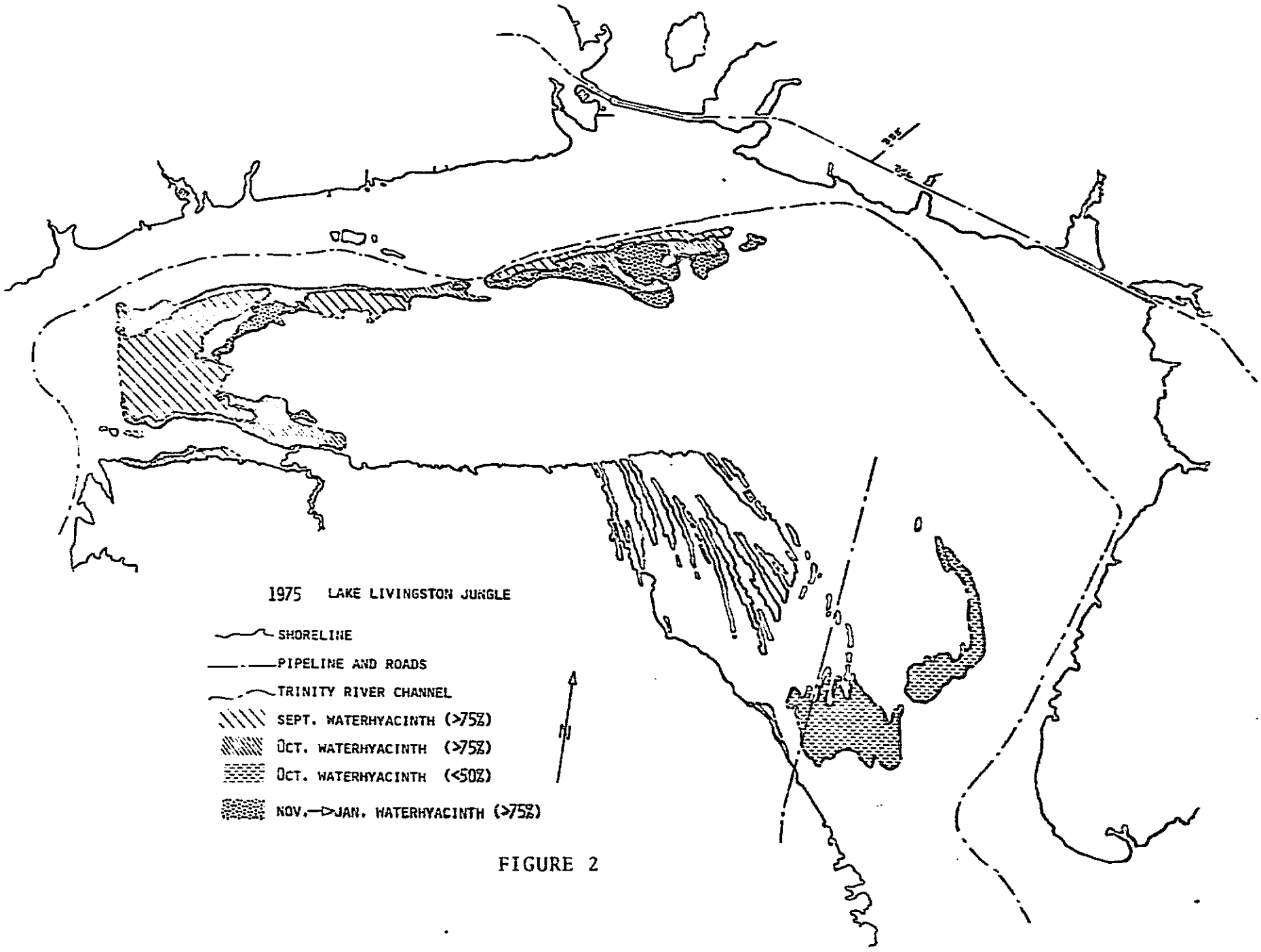
1975 LAKE LIVINGSTON JUNGLE
SHORELINE
PIPELINE AND ROADS
TRINITY RIVER CHANNEL
SEPT. WATERHYACINTH (>75%)
OCT. WATERHYACINTH (>75%)
OCT. WATERHYACINTH (<50%)
NOV.→JAN. WATERHYACINTH (>75%)
N

FIGURE 2

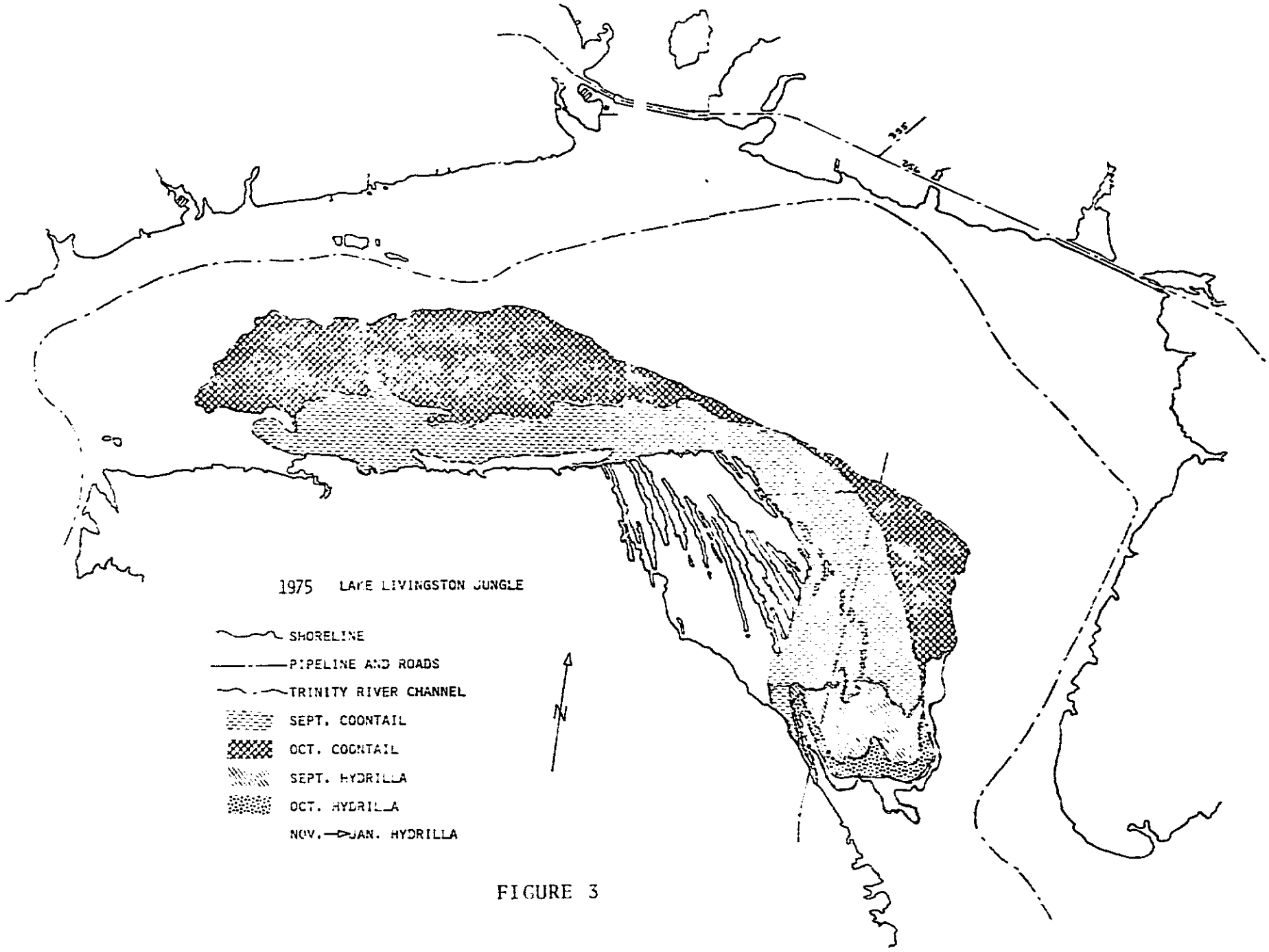
1975 LAKE LIVINGSTON JUNGLE
SHORELINE
PIPELINE AND ROADS
TRINITY RIVER CHANNEL
SEPT. COONTAIL
OCT. COONTAIL
SEPT. HYDRILLA
OCT. HYDRILLA
NOV.—JAN. HYDRILLA
N

FIGURE 3