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UTILIZATION OF ERTS-1 DATA TO MONITOR AND CLASSIFY EUTROPHICATION OF INLAND LAKES

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ABSTRACT

A technique is being developed for use of ERTS in estimating and monitoring trophic levels of inland lakes. Preliminary findings are that Michigan lakes and ponds of one acre or more are resolvable in bands 5, 6 and 7 of NASA MSS imagery under fair conditions (haze and 70% cloud cover). In processed imagery (CCT) smaller features, including water color patterns, are evident within some lakes of 40 acres or more. Image distortion of lake size, shape, orientation, etc. is minimal; discrimination of lakes and ponds from various wetlands is good. Subsequent ERTS and aircraft imagery will be correlated with detailed ground truth of water color and quality in eutrophic test lakes.

1. INTRODUCTION

Eutrophication or nutrient-organic enrichment is responsible for losses in water quality, property values and recreational uses of inland lakes. Lakes in urban and suburban areas are being degraded rapidly by large inputs of sewage and fertilizer nutrients. Algal blooms, macrophyte growths and high turbidity result from increasing productivity in these waters. Since the attendant discoloration of lakes is detectable by remote sensors, water color is the mediating factor between ERTS imagery and water quality.

In a study of 530 Wisconsin lakes Juday and Birge (1933) established empirical relationships between water transparency (turbidity) and its plankton content and color (platinum-cobalt scale). A similar relationship was found between water color and its organic carbon content. Thus as a lake becomes more productive (eutrophic) it undergoes a series of color changes from blue to green, yellow, brown and even red (Hutchinson, 1957). These color changes must be accounted for in terms of other trophic state indicators before color itself can be used to gauge water quality. Lake water colors also must be identified in remote imagery. Finally, repetitive monitoring is essential to recognize long-term trophic changes

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as distinct from short-term or seasonal variations. ERTS provides a means for regular surveillance of lake trophic levels and rates of enrichment. The present study focusses on the practical correlation of ERTS data and water quality in lakes.

2. GROUND MONITORING AND TEST SITE AREA

Six glacial lakes (40-1280 acres), varying from mildly to highly eutrophic, are under study in Oakland County, Michigan. Biological and chemical factors in four of these have been surveyed for the previous three years. While water color has been highly variable in each lake, average differences in color and quality between lakes allow them to be ranked in order of increasing productivity. A program of in situ and laboratory measurements has been designed to characterize water and lake color and to define trophic levels at the time of ERTS passes. These measurements include: water transparency (turbidimetry), water color (platinum-cobalt and Forel-Ule scales), particulate color (reflectance spectra), particulate ash/dry weight ratios, organic carbon, nitrogen and phosphorus, chlorophyll, plankton (qualitative and surface-sky radiometry. Transient factors, such as pH, temperature and blooms, will be noted as well. Ground monitoring will begin as soon as the lakes are ice-free.

Figure 1 presents the test area and five of the test lakes (Cass, Orchard, Lower Long, Forest and Island). The map is based upon data in USGS maps (1965), aerial photos and ground observation.

3. REMOTE MONITORING

Despite unfavorable weather locally since ERTS launch, one set of usable imagery is available for the study area. In this scene (Figure 1) for September 28, 1972 five of the six study lakes are visible through 70% cloud cover within the indicated 50-square-mile area. This area includes numerous other lakes and ponds that also have been useful for analyzing ERTS resolution of small water bodies and their discrimination from various wetlands. The smallest ponds (or channels) that can be resolved are approximately 200 ft. in diameter or slightly less than one acre in area. These appear as gray spots in the B/W imagery. Elongated ponds or channels that are approximately 100 ft. in width are also evident but have no definite shape in the imagery.

Larger ponds that appear as black (full density) images are at least 550 ft. in diameter, or approximately 5 acres in area. Their greater

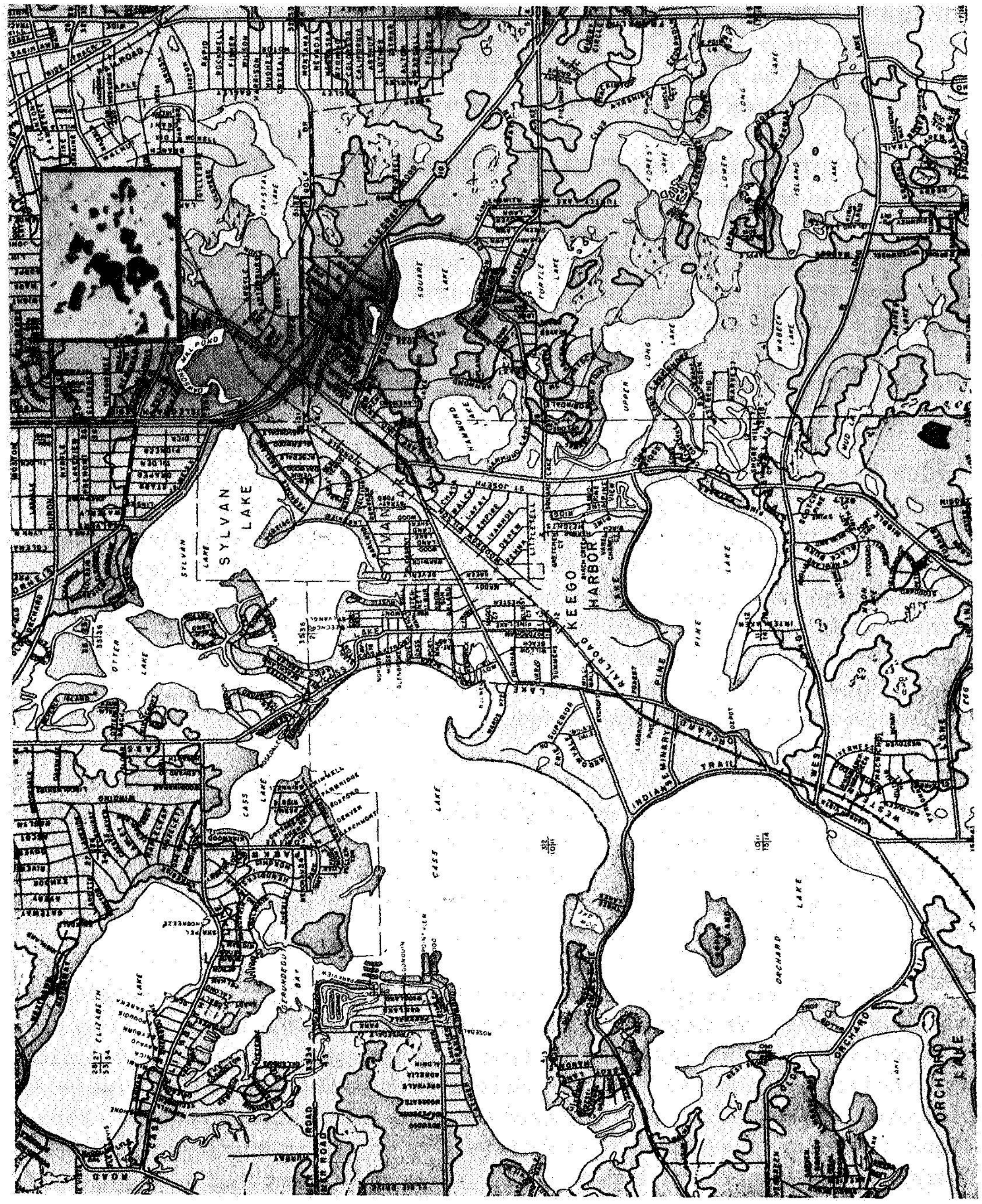

Figure 1 Oakland County Planning Commission Map of ERTS Study-Sub Area (1968) ERTS Scene 1067-15463-7 Inset Upper Left Hand Corner

image density may be a function of sensor response or, possibly, may be related to their shallow depth and generally more turbid waters. This question will be resolved later by ground truth. In any event, smallest of the study lakes (Forest, 40 acres) is visible in full image density.

No differences were noted (in Bands 6 and 7 of the NASA GSFC imagery) in the resolution of small elongated ponds that are oriented with the direction of scan (west to east) and those that are aligned normal to scan lines (north to south). Similarly, no apparent distortion or displacement of small ponds was observed in Bands 6 and 7. Some distortion (banding effect) in the imagery received from NASA was noted in Band 5, which was not evident in later imagery produced from CCT in Bendix Earth Resources Data Center (Figure 2 and Figure 3).

Electronic enlargements of this imagery (Bendix CCT imagery), which became available just prior to this report, show improved resolution of these features (some distortion exists in Figure 2 and Figure 3 because earth rotation and other geometric errors are not corrected. Such corrections are underway). For example, swamps composed of floating and emergent vegetation are readily distinguished from the smallest lakes visible. In bands 6 and 7 swamps appear as gray areas distinct from other wooded areas. Further study will resolve the question of how much floating or emergent vegetation a lake may contain and still show the image characteristics of "open water".

One of the study lakes contains a one-acre island visible in bands 6 and 7. The conclusion is that ERTS resolution is approximately the same whether it concerns a light object in a dark field (islands on water) or a dark object in a light field (ponds on land). The first key step - determining that ERTS-1 detects and separates small inland water bodies and wetlands - has been accomplished.

The image density of lake water has been examined for variations in all four bands. In certain lakes patterns of variable density were noted, particularly in the negative transparency images. With few exceptions the variations in water "color" were evident only in Band 5 (Figure 3). However, because of partial cloud cover it was unclear whether these tonal effects represented real differences in water quality. Under better atmospheric conditions Bands 4 and 5 would be expected to record differences in water color that are within the visible spectrum (blue to red). Water colors of green, green-yellow, yellow, yellow-brown, and red-brown are common occurrences among the six study lakes. Surface phenomena, such as algal blooms (of cyanophytes) that are seen occasionally on the lakes, may well be detectable in Bands 6 and 7 (near IR)

Figure 2 Enlargement of ERTS Study Sub-Area
as Shown in Figure 1
(1067-15463 Band 7)

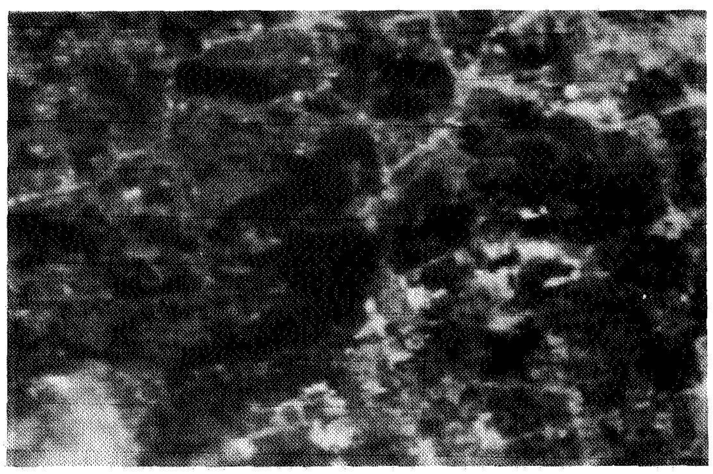

Figure 3 Enlargement of ERTS Study Sub-Area,
as Shown in Figure 1
(1067-15463, Band 5)

as well. Comparison of these images with bathymetry maps of lakes indicates that only part of the variable density is due to bottom reflection and macrophytes. Some of the variation is due to backscatter from organic and inorganic suspensions. (See Table 1) for a summary.

4. DATA PROCESSING

A series of lake water surface maps combining the CCT data of all four channels will be prepared. Preliminary statistical computer processing indicates a wide variety of color data in the four bands. The next key test now underway is the comparison (for Orchard Lake) of the bathymetry map, ERTS-1 individual band alpha numeric printouts, (CCT) ERTS-1 probability density imagery (CCT), ERTS-1 decision imagery, ERTS-1 Cal Comp water feature boundaries, and similar statistically processed imagery for an 11-channel scanner (Bendix M^2S). This study is expected to verify that ERTS-1 can detect the various causes of lake water color for smaller inland lakes - including the important backscatter from suspensions.

The final key step of correlation ERTS-1 data to trophic level and classifying lakes will be performed in the spring, summer and fall of 1973.

5. SIGNIFICANT RESULTS

ERTS-1 imagery has shown several changes (or inaccuracies) to have occurred since the Oakland County map (Figure 1) was drawn (1968). ERTS-1 and ground observation indicates the southern part of Otter Lake is a swamp. A pond was dredged to become a lake, as is now apparent in the ERTS-1 imagery[4]. Other detail corrections of the base map could be listed.[5]

More key is establishing that ERTS-1 detects lake areas of one acre and can monitor average lake colors to as small as 5 acres. In addition color features are demonstrably observable in at least 3 of the test lakes in the imagery. And of course statistical processing of the CCT is producing improved geometrical resolution and spectral separation because of the greater information present in the CCT.

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TABLE 1. NAMED LAKES VISIBLE IN ERTS-1 IMAGERY (Sept. 28, 1972) OF OAKLAND COUNTY (Scene 1067-15463)

Lake Name	ERTS Band Visibility				Area (Acres)	Max. Depth (Feet)	Shore Length (Miles)	Ref. Number*	Lake Shape	Shape Fit: Image/Map	Lake Islands: Present/ Absence	Lake Islands: ERTS Band Visibility		Var. Image Density (Band 5)
	4	5	6	7								5	6	
Cass	+	+	+	+	1280	123	11.5	331	Elliptical	Good	No			Yes
Orchard	+	+	+	+	788	110	5.7	344	Circular	Good	1	+	+	Yes
Union	+	+	+	+	465	102	4.0	232	Elliptical	Good	No			
Sylvan	+	+	+	+	458	---	4.7	329	Triangular-	Good	No			Yes
Pine	+	+	+	+	395	90	4.3	347	Elliptical	Good	No			Yes
Elizabeth	+	+	+	+	363	90	3.3	925	Rectangular	Good	No			Yes
Upper Straits	+	+	+	+	323	96	5.5	359	Elongate	Good	No			Yes
Walnut	+	+	+	+	232	101	3.2	381	Square	Good	No			
Lower Long	+	+	+	+	178	95	3.7	411	Elongate	Good	No			Yes
Middle Straits		+	+	+	171	55	4.1	263	Elongate	Good	No			Yes
Green		+	+	+	166	---	3.0	340	Elongate	Good	No			
Upper Long	+	+	+	+	108	---	2.5	348	Elongate	Good	No			
Island	+	+	+	+	101	35	2.0	444	Triangular	Good	3	-	-	Yes
Square	+	+	+	+	94	67	1.4	405	Square	Good	No			
Crescent		+	+	+	90.4	40	2.3	918	Elongate	Fair	2	+	+	
Hammond	+	+	+	+	85	---	1.5	330	Circular	Good	No			
Otter		+	+	+	81	---	1.8	934	Elliptical	Poor	No			
Crystal	+	+	+	+	51	---	2.2	969	Elongate	Good	No			
Forest		+	+	+	40	55	0.8	410	Circular	Good	8	-	-	Yes
Turtle	+	+	+	+	37	65	1.4	406	Elliptical	Good	No			
Orange			+	+	37	---	1.1	416	Elliptical	Good	No			
Wabeek		+	+	+	25	---	0.9	447	Rectangular	Good	No			
Geneva		+	+	+	19.2	---	0.8	921	Elliptical	Good	No			
Darby		+	+	+	16.5	---	0.7	334	Square	Good	No			
Simpson			+	+	13.2	---	0.5	337	Elliptical	Fair	No			
Crawford			+	+	13.0	---	0.5	453	Elliptical	Good	No			
Morse			+	+	13.0	---	0.9	371	Rectangular	Fair	No			
Mirror		+	+	+	11.0	25	0.5	367	Elliptical	Fair	No			
Sodon			+	+	10	19	0.4	446	Circular	Fair	No			
Landers			+	+	9.6	---	0.6	342	Rectangular	Good	No			
Scotch		+	+	+	9.3	---	0.6	338	Elliptical	Good	No			
Dawson's Mill Pond			+	+	8	---	1.1	970	Elongate	Poor	No			
Fiddle			+	+	7.5	---	0.6	920	Elongate	Poor	No			
Cross			+	+	7.3	---	0.6	337	Elliptical	Good	No			
Dow			+	+	6.5	---	0.4	346	Square	Poor	No			
Mud			+	+	6.2	---	0.5	349	Rectangular	Fair	No			
Egg			+	+	5.6	---	0.3	356	Elliptical	Fair	No			
Haines			+	+	5.5	---	0.4	449	Triangular	Fair	No			

6. REFERENCES

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2. Hutchinson, G. E. (ed.) 1957. A treatise on limnology. Vol. 1. Geography, physics and chemistry. John Wiley and Sons, Inc. New York. 1015p.

3. Juday, C. and E. A. Birge. 1933. The transparency, the color and the specific conductance of the lake waters of northeastern Wisconsin. Trans. Wisc. Acad. 28:205-259.

4. The new 'lake' lies on a line between Wabeek and Pine Lake in Figure 2.

5. Golf courses and cemetaries are particularly visible in Figure 2.

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