THIRD ANNUAL REVIEW
NASA EARTH RESOURCES PROGRAM
HOUSTON, TEXAS

MEASUREMENT OF WATER DEPTH BY MULTISPECTRAL RATIO TECHNIQUES

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This work supported by NASA has been a continuation of the program started under contract to NAVOCEANO and technically monitored by Mr. John Sherman, III, Program Manager for SPOC. In previous review sessions, we discussed the results of our work in which three observables were identified that could be used by remote sensors for the measurement of water depth. The first of these was wave refraction techniques using aerial photographs and the subsequent use of the Fourier transform technique to measure the wavelength changes undergone by waves as they approach shore or shoal areas. The second was the multispectral ratio technique using data from a multispectral scanner and taking advantages of the absorption properties of different wavelengths of light and thirdly, was the use of time difference measurements from a laser ranging device which measures the time difference between the surface reflection and the bottom reflection received at the sensor.

Last year we discussed the progress made using the wave refraction technique. This year we wish to report on the work done with data from a multispectral scanner. Next year we plan to report on the use of the scanner techniques coupled with a laser depth ranging device.

In review, we note in Figure 1 (which depicts a scene taken in the Florida Keys) how the light penetrates the water in different bands. In the blue region the light scattering from particles in the water reduces the contrast of objects seen beneath. As one moves toward the blue-green wavelengths, where maximum light penetration takes place, a more detailed underwater scene can be observed at deeper depths. In the red region where water absorption is greater, only the shallow features can be observed. Finally, in the near-infrared region we find that only water and land boundaries can be distinguished. There is very little penetration of the light into the water.

Making use of this property of the selected transmission at different wavelengths an equation was developed relating the outputs of at least two channels of the multispectral scanner, to an estimate of water depth. Figure 2 shows this equation expressed by a number of variables. The alpha 1 and alpha 2 represent the extinction coefficients of water at two different wavelengths. The ρ_1 and ρ_2 represents the bottom reflection in two different bands. The K represent constants of the instrument which are known, where the H represent the incoming solar radiation which is measured by sun sensor aboard the aircraft and the voltages, V_1 and V_2 are the analog signals observed in the multispectral scanning of the shallow features.

One can see that having a priori knowledge of the alphas and the rho's one can compute an estimate of water depth since the other parameters are known by measurement. In looking at the function of absorption coefficient vs. wavelength for different kinds of water, we have found the curves to be similar but displaced so that the difference term for $(\alpha_1-\alpha_2)$ at two different wavelengths tends to be less variable than having to rely on knowing absolute values, for the different kinds of water. Also the fact that the ratio of the reflectances of the bottom material appears in the equation and that one can choose the wavelengths in this calculation, for smoothly reflecting functions, such as the reflectance of sand, this ratio tends towards one for spectral channels that are near each other. Furthermore laboratory measurements can be made and this function can be determined for commonly occuring bottom sediments. We have used this equation in a test case with data taken along the Lake Michigan shoreline. A number of calculations were made using different pairs of channels from the 12 channel spectrometer employed in The University of Michigan multispectral system. Figure 3a and b show the plot of these calculations against the known water depths. One can see how different channel pairs produced an estimate to the known depths. One can also see that the accuracy in the shallower water depths is much better than for the deeper depths. This was investigated and found to be related to the choice of values for the extinction coefficient. In order to calculate the true values for α and ρ we used the equation in reverse. Knowing the water depth at several locations we calculated the values for alpha for the fresh water situation. We also computed a reflectance for the sand from the data. Having done this for test locations for a known depth, we proceeded to apply the equation at other depths which gave more accurate estimates over the entire flight line. A digital map was then produced in which each symbol represented a depth range. This depth chart is shown in Figure 4.

In some cases, because of low signal/noise ratio a smoothing function can be used and for the case of the Lake Michigan shoreline, where one has a gradual slo~~p~~ping beach, averages over several resolution elements can be made and a more accurate depth map can be produced. An estimate of this averaging process is shown in Figure 5. We have also applied this to the Ceasar Creek area in the Florida Keys where instead of a slopping sandy beach, a situation of coral reefs occurs so that a more random set of depths are encountered and different bottom reflectances are present. The depths calculated for this case were produced as a digital printout (Figure 6) to show the various depths and in checking against the available charts for this area, reasonable correlations were found.

Our plans for the future are to implement this technique in conjunction with a laser ranging device which would then supply a number of sample points of known water depth along the flight line. These known depths would be used to calculate the appropriate values for α and ρ and does reduce the dependency on estimates of these two particular functions. A combination of the multispectral scanner and the laser system should prove to be a unique system which would have the ability to measure rapidly the water depths and underwater topography along the coastlines. It should prove useful in updating shoreline maps, reducing hazards to navigation, and verifying the existence of shoals and changes in beaches especially after major storms each year. We look forward to the next year's research project, in which we hope to demonstrate the potential of the combination of these two systems.

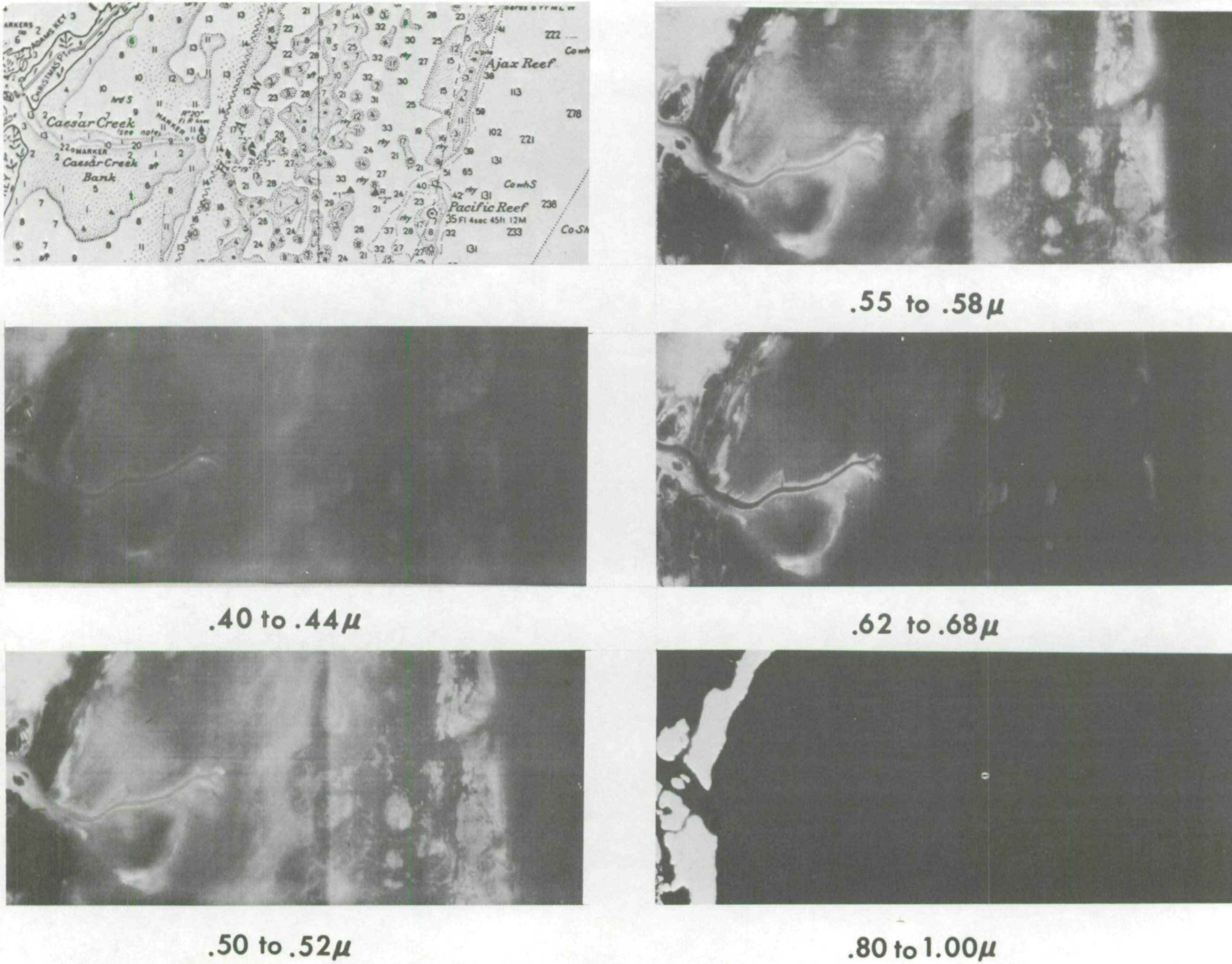
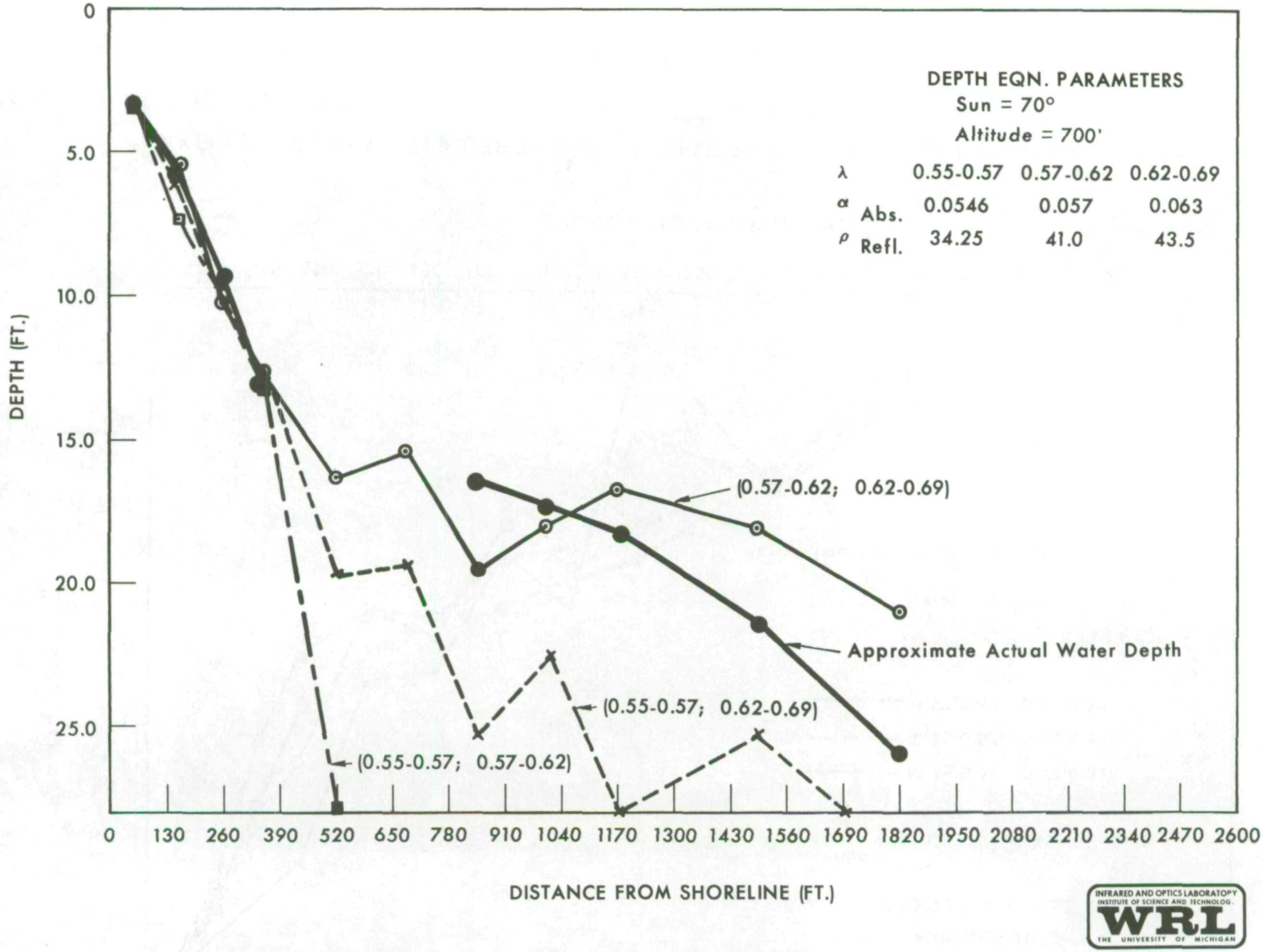

Caesar Creek
Caesar Creek
Bank
Ajax Reef
Pacific Reef
.55 to .58μ
.40 to .44μ
.62 to .68μ
.50 to .52μ
.80 to 1.00μ

Figure 1

$$V_\lambda = K_\lambda \rho_\lambda H_\lambda e^{-\alpha_\lambda Z(\cos^{-1}\theta + \cos^{-1}\phi)}$$

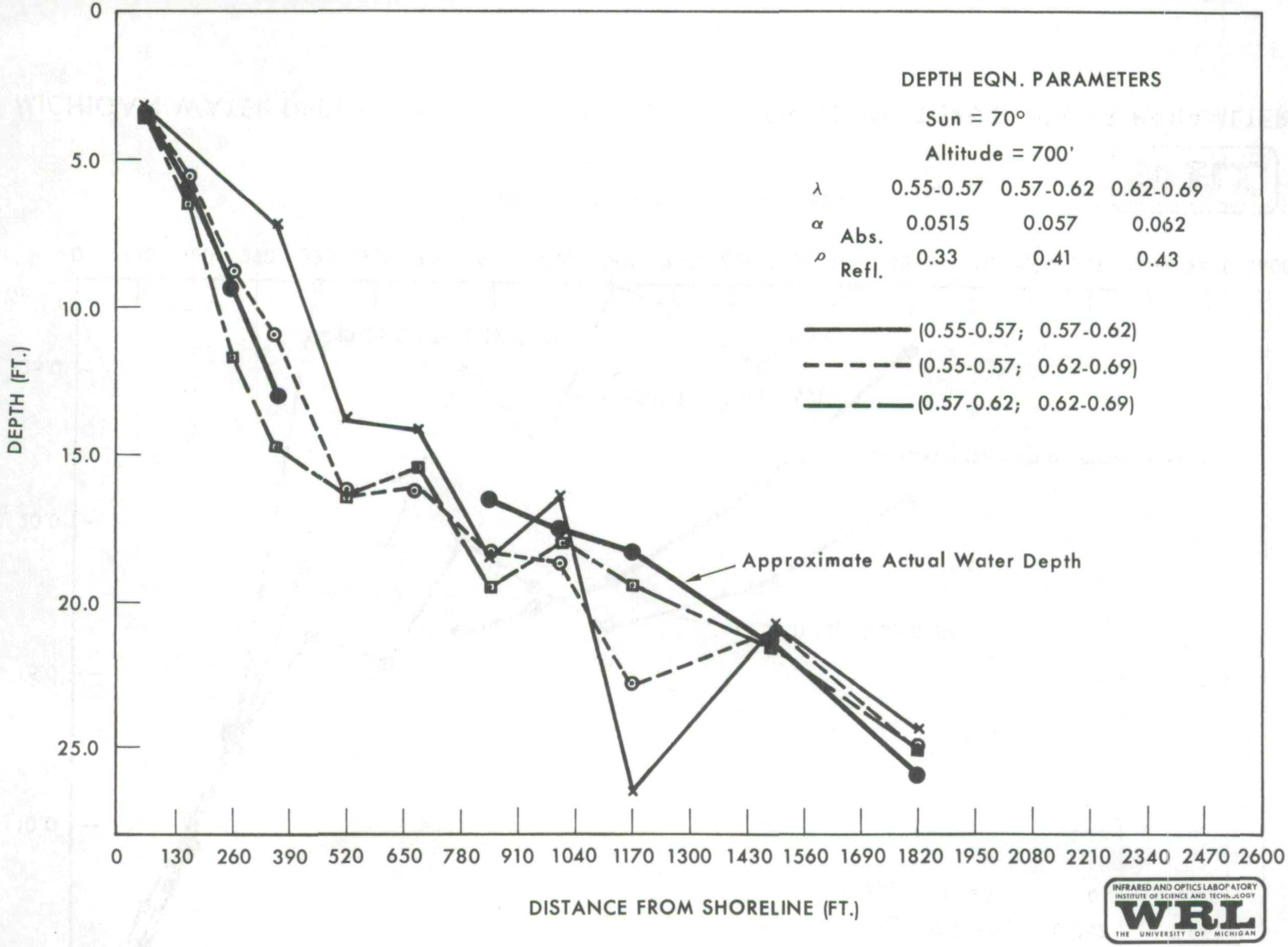
$$\boxed{Z = \frac{1}{(\alpha_{\lambda_2} - \alpha_{\lambda_1}) f(\theta, \phi)} \ell n \frac{V_{\lambda_1} K_{\lambda_2} \rho_{\lambda_2} H_{\lambda_2}}{V_{\lambda_2} K_{\lambda_1} \rho_{\lambda_1} H_{\lambda_1}}}$$

Figure 2.



LAKE MICHIGAN WATER DEPTH CURVES GENERATED FROM SHALLOW, TURBID WATER PARAMETERS

Figure 3a



LAKE MICHIGAN WATER DEPTH CURVES GENERATED FROM DEEP WATER PARAMETERS

Figure 3b

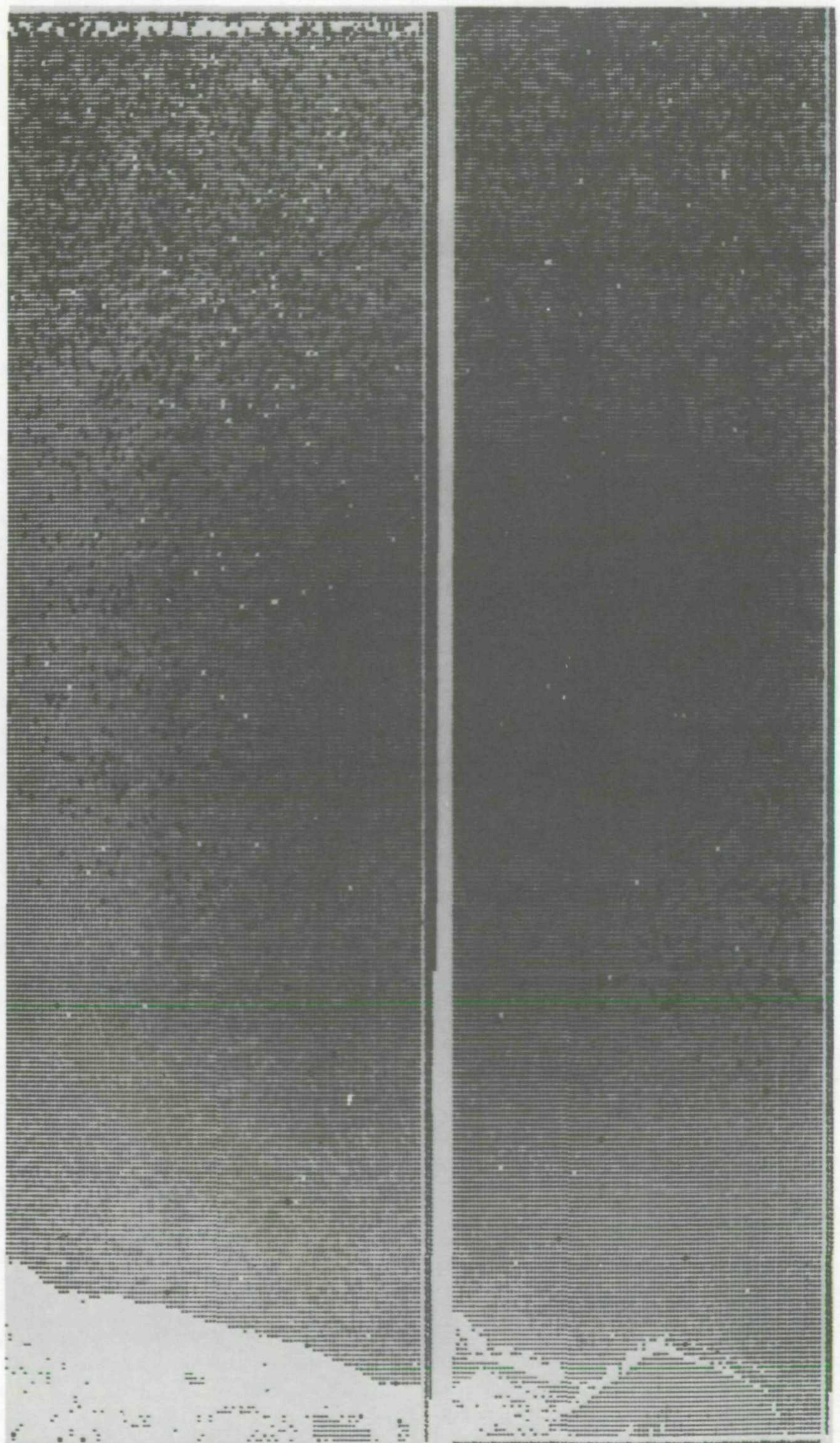


Figure 4.

Symbol	Depth
—	0 - 4'
=	4 - 8'
*	8 - 12'
θ	12 - 16'
⋇	16 - 20'
[illegible]	20'

DIGITAL PRINTOUT OF WATER DEPTH OVER LAKE MICHIGAN

INFRARED AND OPTICS LABORATORY
INSTITUTE OF SCIENCE AND TECHNOLOGY
WRL
THE UNIVERSITY OF MICHIGAN

Figure 5

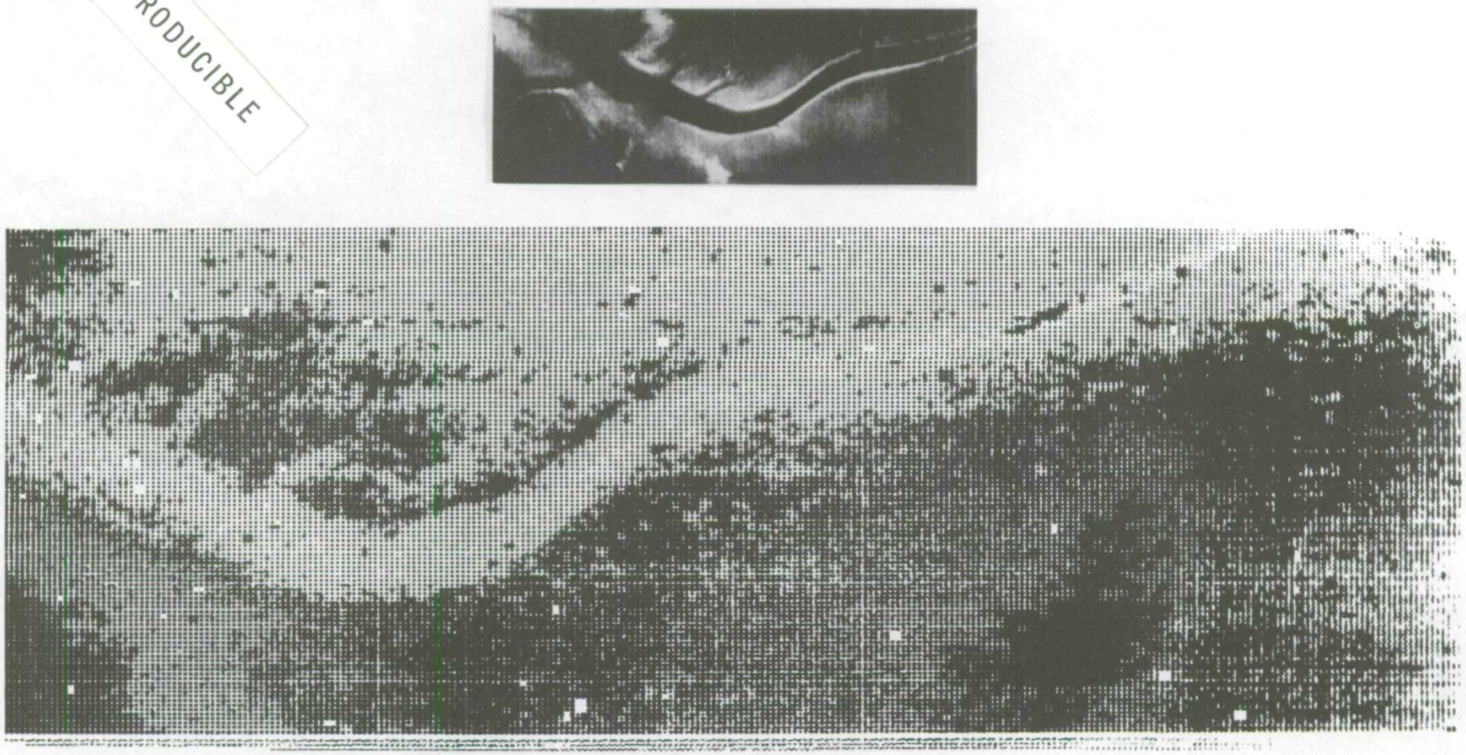


Figure 6.- (Repeated) depth chart - Caesar Creek - obtained by digital processing of multispectral scanning.