INVENTORY OF SURFACE WATER RESOURCES OF THE STILLWATER CREEK WATERSHED AND AN INVESTIGATION INTO THE EFFECT OF LAND USE ON WATER QUALITY

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INTRODUCTION

The immediate and long term water needs of Oklahoma are the most critical factors affecting the continued prosperity of the state. Availability of water is a primary limiting factor to population growth, industrial expansion and agricultural productivity. In short, Oklahoma's economic future may well be determined by procedures adopted now for maintaining existing water resources, and the concepts developed for water resource management in the future. At present, the lag time for water resources projects varies from a few years for a rural water district distribution system, to ten to twenty years for a major reservoir. Construction costs range from ten million to hundreds of millions of dollars (1980 dollars) respectively. Enormous investments in time and money warrant considerable efforts for efficient planning and subsequent monitoring throughout the life of the project.

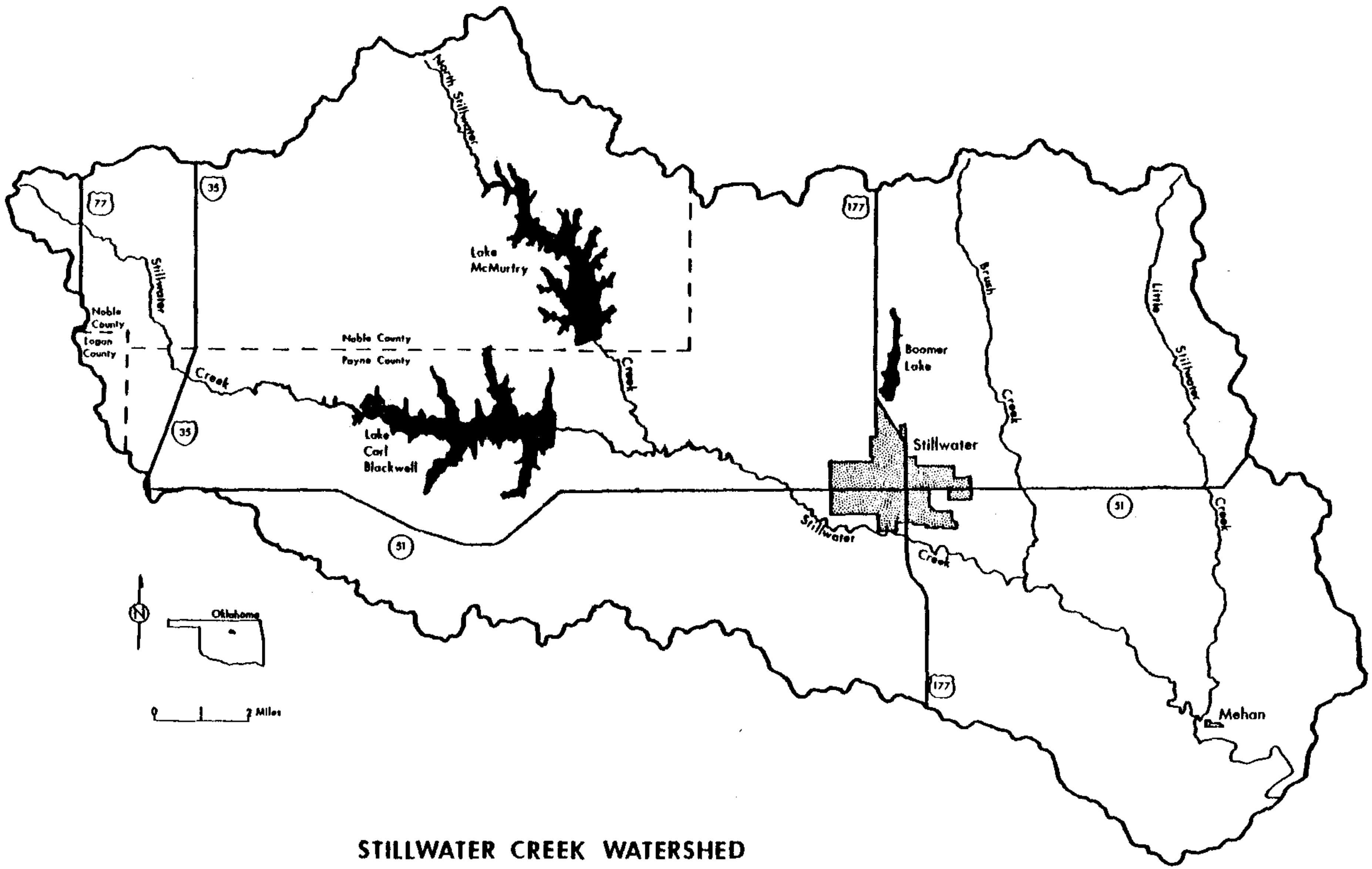
One facet of the complex water resources management problem is monitoring of environmental conditions in existing water bodies. Water quality monitoring is primarily carried out by in situ measurements over a given time period. In situ monitoring is a costly procedure with limited geographic range, especially for simultaneous monitoring. The purpose of this project is to demonstrate the applicability of satellite remote sensing to several water resources problems in Oklahoma, including water quality monitoring. The advantages of monitoring by remote sensing over exclusive in situ monitoring are: less time in the field, a large geographic area may be surveyed simultaneously, and the ability to monitor land cover and land use activities in the watershed allows an holistic approach to water quality assessment.

This project has accomplished several tasks including: 1) identification of lakes and ponds greater than 2 hectares (about 5 acres) in size; 2) an historical evaluation of water quality as affected by trophic level, suspended sediments, non-point pollution, and riparian vegetation; 3) investigation of the effects land use activities and conditions have on water quality; 4) evaluation of Landsat Multispectral Scanner (MSS) digital data as an information source for measuring water quality by an analysis of the fluctuations in trophic level, suspended sediments, non-point pollution, adjacent land use conditions, riparian vegetation, and water body size and location; and 5) evaluation of existing water resource plans and policies and the applicability of remote sensing as a data source for state-wide use.

STUDY AREA

The Stillwater Creek watershed is located in north-central Oklahoma approximately 80km (50 mi) north of Oklahoma City and 103km (64 mi) west of Tulsa (see Fig. 1). The watershed includes portions of Logan, Noble and Payne counties. Stillwater, OK is the largest urban area in the study area.

Stillwater Creek is a third order stream in the Arkansas River drainage system. The physical hydrological characteristics of the watershed are included as Table 1. The three major reservoirs in the study



STILLWATER CREEK WATERSHED

Fig. 1

Table 1. Physical hydrological characteristics of the Stillwater Creek watershed.

Area of watershed	70319 ha	(173758 ac)
Area of Lake Carl Blackwell	1370 ha	(3385 ac)
Area of Lake McMurtry	690 ha	(1706 ac)
Area of Boomer Lake	56 ha	(138 ac)
Stream density	$2.36 km/km^2$	
Length of major streams		
Stillwater Creek	66 km	(41 mi)
North Stillwater Creek	18 km	(11 mi)
Little Stillwater Creek	22 km	(14 mi)
Boomer Creek	16 km	(10 mi)
Brush Creek	16 km	(10 mi)

area are Lake Carl Blackwell, Lake McMurtry and Boomer Lake.

The watershed is located on the eastern edge of the Enid Plains physiographic region. This area is characterized by low rolling topography controlled by drainage, tall grass prairies, and forested, flat floodplains. The highest elevation is 387.1m (1270 ft) along the watershed's northern border, and the lowest elevation is 246.9m (810 ft) at the confluence of Stillwater Creek and the Cimarron River.

Geology of the study area is Permian age, red bed sandstone. These somewhat loosely consolidated rocks dip slightly to the south. Recent alluvium is found along the major streams in the watershed.[1]

Average annual precipitation for Stillwater, OK is 86.36cm (34 in) with distribution weighted to early spring and summer rains. The climate is generally mild, however, high temperatures and drought, and short periods of low temperatures and snow are not uncommon in the summer and winter seasons respectively. Average annual lake evaporation for reservoirs in the Stillwater Creek watershed is 147.32cm (58 in)[2].

Soil types in the study area range from fine sandy loams to clayey silt loams. Most of the soils have developed under prairie conditions and have clay subsoils[3]. The major soil associations occurring in the study area are presented as Fig 2.

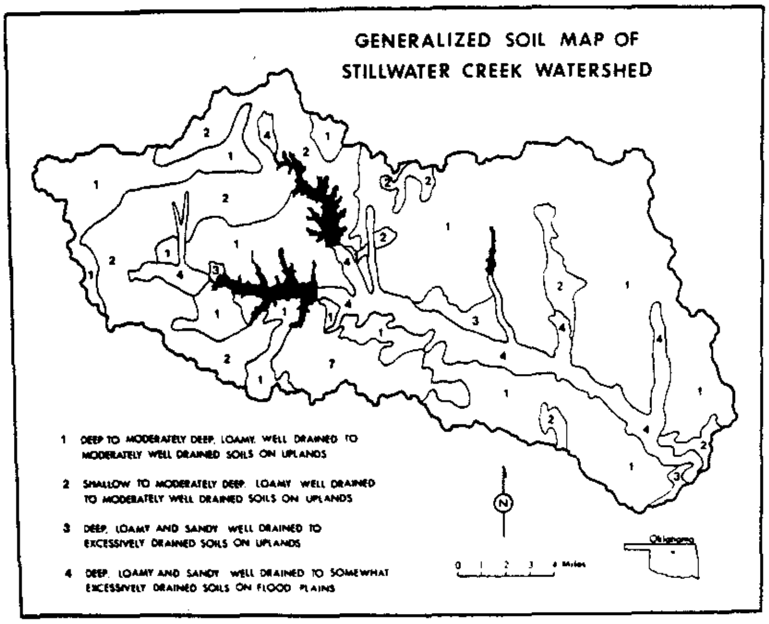


Fig. 2. Soils map.

Grasses and forbs are the dominant vegetation types in the Stillwater Creek watershed, however, a moderate amount of diversity exists in the study area. Tree species are generally classified into two distinct categories: bottomland forest and upland forest. Bottomland forests include floodplain forests and riparian forests. The floodplain forests of Stillwater Creek are very diverse tracts with high densities. The spatial distribution of these forests is controlled by the location of the floodplains, however, floodplain forests are not found exclusively adjacent to the stream channel as is the case with riparian forests.[4] The major tree and woody vegetation species of the floodplain forests are included in Appendix A.

Riparian forests are different in many respects to floodplain forests, however, riparian forests may be generally classed with floodplain forests because of their similar habitat and shared species. Riparian forests are located exclusively adjacent to stream channels and do not extend more than a few meters from the channel. A high percentage of the riparian forest species are phreatophytes (species capable of surviving long periods of inundation), and diversity is generally low, especially in a young forest. Riparian forests are typically pioneer vegetation communities colonizing sand bars and exposed banks during periods of low water.[5] The major tree and woody vegetation species of the riparian forests are included in Appendix A.

Upland forest communities are found on the sides and tops of low hills in the watershed. The frequency of upland forest lands decreases toward the west where the grasslands are dominant. Upland forests include the rapidly expanding Red cedar (Juniperus virginiana L.) forests. The major tree and woody vegetation species of the upland forests are included in Appendix A.

Tall grass prairie vegetation once covered most of the study area, however, today only small isolated remnants of true tall grass prairie exist. Commercial varieties of grasses have replaced the original species in maintained pastureland, and low value pioneer species have invaded old fields and other non-cultivated grasslands.

Wetland vegetation comprises a very small portion of the total vegetation of the watershed, but its intrinsic relationship with water makes it an important segment in the land/water biome. Three classes of wetland vegetation are found in the watershed: submerged, emergent non-forest, and emergent forest. The major tree and woody vegetation species of the wetland forests are included in Appendix A.

Agriculture is limited in the study area to pasturage and some small grain production.[6] A wider range of agricultural crops is possible now that irrigation is becoming more popular and feasible for small farms.

MATERIALS AND METHODS

Because of the interrelationship between land cover and water quality, a variety of data are required to sufficiently characterize the watershed in terms of the parameters responsible for dynamic change in the system. A variety of data collection methods are used because of the variability in the subjects to be measured.

The primary data source for all land cover, land use and lake turbidity levels is the Landsat Multispectral Scanner (MSS) digital data. The Landsat series of Earth orbiting satellites[7] circle the globe at an altitude of 920km (540 mi), and pass over the same geographic location on the surface at eighteen day intervals. The repetitive, synoptic view is a major advantage of this remote sensing system. Each of the three satellites in the series (Landsat-1 launched 23 July 1972, Landsat-2 launched 22 January 1975, and Landsat-3 launched 05 March 1978) has the same basic configuration (see Fig. 3) with the same sensor packages. The Multispectral Scanner is an electro-optical scanner that senses light reflected from the Earth's surface in four wavelength intervals or bands. Band 4 (green light) covers the range from 0.5 to 0.6 microns in the visible portion of the electromagnetic spectrum. Band 5 (red light) spans from 0.6 to 0.7 microns also in the visible range. Bands 6 and 7 (near-infrared light) range from 0.7 to 0.8 and 0.8 to 1.1 microns respectively in the portion of the spectrum just beyond human eye sensitivity.

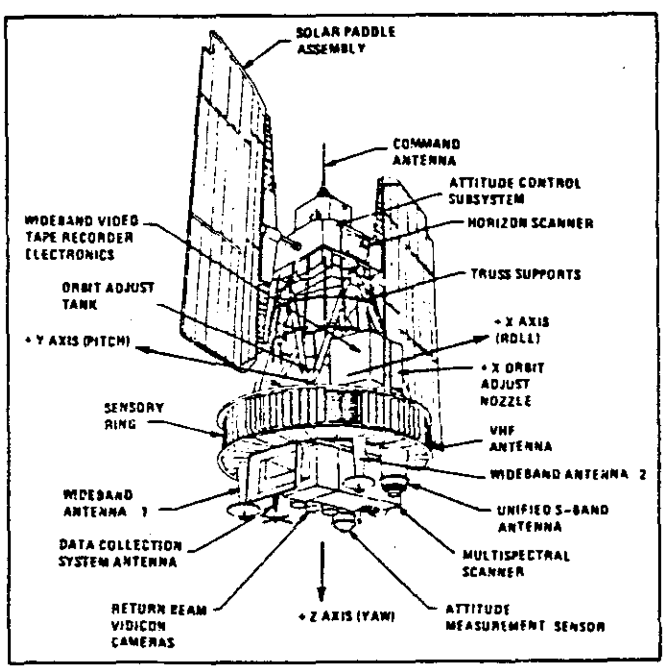


Fig. 3. Landsat satellite.

Landsat MSS spectrel data is available as computer compatible tapes (cct's) (see Fig. 4) with the digital data of all four bands for an area of 185 by 185km (115 by 115 mi). Each frame contains over ten million picture elements or pixels per band. Landsat MSS data is also available

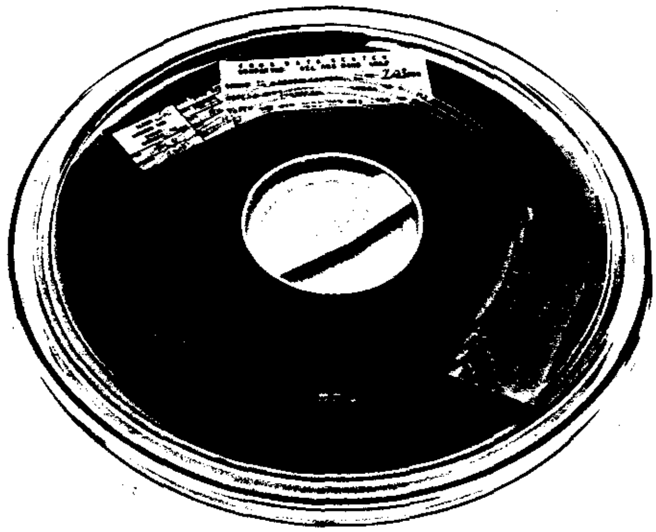


Fig. 4. A computer compatible tape (cct).

as photographic products, either as single band images or as color composites at a variety of print scales.

The Landsat MSS data for this project were acquired for the dates of 14 June 1975 and 08 April 1981 (see Fig. 5). The 1975 data set was imaged by Landsat-2 and the 1981 frame was imaged by Landsat-3. Although the gain and basic sensor performance for the two MSS devices were unavoidably different, only relative comparisons were drawn between data sets in this study and no need for calibration was warranted. Fig. 6 shows the area of coverage.

Processing of the Landsat MSS digital data was performed on the Center for Applications of Remote Sensing (CARS) Perkin-Elmer 8/32 minicomputer and Comtal image processing system. The software package used in the NASA Earth Resources Laboratory Applications Software (ELAS)[8] system. ELAS is a general purpose software package having capability to process Landsat MSS digital data from raw cct to a finished thematic map product. The data processing sequence includes four basic steps: reformat, search, classify and georeference.

The data received on the user end as a cct requires rearrangement

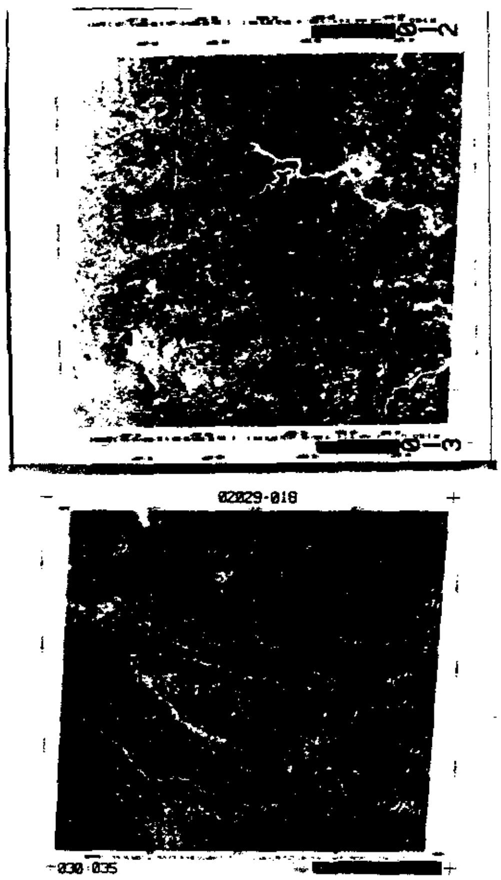


Fig. 5. Landsat MSS data.

of the data structure for more efficient use on the CARS computer. The data are reformatted from the band sequential (BSQ) or band interleaved by line (BIL) formats to a band interleaved by pixel (BIP) format (see Fig. 7). The data are also prepped for display on the Comtal image display by the addition of an eleven word preamble for image display unit control. A standard ELAS compatible header record is included as well.

At this point in the data processing procedure, a decision is made as to whether the data require additional destriping (only for BSQ format cct's). If the data show a distinct sixth line banding (due to an inconsistancy in gain settings in the detector response aboard the satellites), a destripe or detector normalization algorithm is applied to the data. The result is an image with reduced banding.

Next, a three by three element window is passed through the digital data in an automatic procedure for obtaining homogeneous training fields. Each nine element area sampled has a set of statistics computed for it including: mean, standard deviation and variance. A training

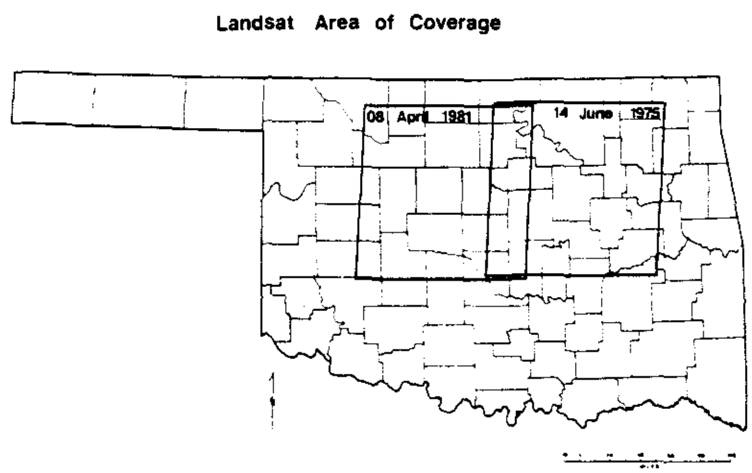


Fig. 6. Area of coverage.

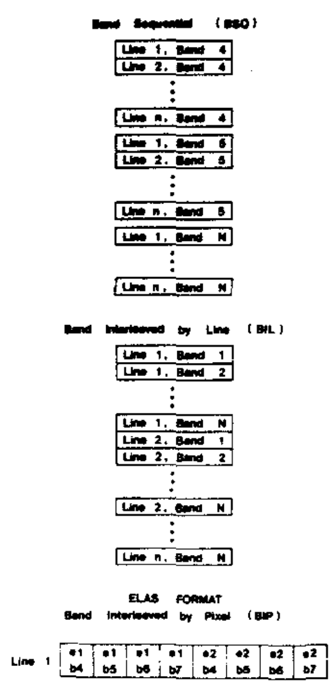


Fig. 7. Data formats.

field is defined as homogeneous when the standard deviation is between a preset standard deviation lower and upper bound range (usually 0.1 and 1.0 respectively). A set of training statistics are gathered for each data set with the result being a listing of spectrally distinct classes. The training statistics for the 14 June 1975 and 08 April 1981 data sets are included in Appendix B.

A maximum likelihood algorithm is applied to the data to convert the four channel MSS data to a single channel thematic map. Each pixel's value set (a set of values composed of one integer value for each band of Landsat data) is tested against the statistical range for each spectral class, and it is given a new value corresponding to the class it fits best. The complexity of this operation is appreciated when it is understood that the training field statistics boundary is a four dimensional ellipse. Area computations by class are included as Table 2.

Landsat MSS digital data have geometric aberrations inherent in each data set without regard to satellite platform. The most obvious aberration is skew. Skew is the result of rotation of the Earth beneath the satellite platform and the movement of the satellite along its orbit track during the time required for a single scan. Scan angle distortion results from a larger area of reflected light from the ends of the scan line than from the center reaching the scanner, and mirror velocity distortion which is due to the inconstant velocity of the scan mirror are minor aberrations, but must be corrected in order to establish a regular

Table 2. Class area results.

Class Name	Hectares		Acres	
	1975	1981	1975	1981
Agriculture	2692	3576	6651	8837
Bottomland Forest	6576	6556	16,250	16,200
Upland Forest	6281	6559	15,520	16,206
Grassland	52,925	52,283	130,777	129,191
Turbid Water	615	1076	1518	2659
Clear Water	1231	270	3042	665
Total	70,320	70,320	173,758	173,758

grid of data. A georeferencing algorithm is applied to the data (either at the reformat stage or after generation of a thematic map) to correct for the above distortions, and to transform the data to fit the Universal Transverse Mercator[9] (UTM) grid system. The data are resampled by nearest neighbor or bilinear interpolation to fit the UTM map base. Stable geographic points with UTM coordinates obtained from USGS 7.5' topographic quadrangle maps are located on the uncorrected Landsat images. Selected point pairs, UTM northing and easting coordinates and Landsat scan line and element coordinates are used as control points from which to map the resampled data.

Digital image enhancement techniques[10] were used to increase the visual acuity of the Landsat data and aid in isolating specific land cover features. A simple linear contrast stretch algorithm stated as follows:

$$Y_{ij} = \frac{X_{ij} - MIN}{MAX - MIN} \cdot C$$

where X_{ij} = input value at line i and element j
Y_{ij} = corresponding output pixel value at value (i,j) after contrast stretch

MIN, MAX = a subset of 0,127 representing the range of MIN, MAX brightness values
C = nominal value of 127

increases the visual distinctiveness between successive gray shades on the image. A haze correction algorithm given as:

$$Y_{ij} = X_{ij} - \text{Bias}$$

where X_{ij} = input pixel vale at line i and element j
Y_{ij} = enhanced pixel value at location i,j
Bias = an offset value for each spectral band (usually Bias = MIN)

is applied to bands 4 and 5 to reduce the effects of atmospheric haze and light clouds. Examples of both techniques and their respective applications are included in the RESULTS section of this report.

Change detection from data sets of different dates is accomplished with the ELAS subroutine PATD (pattern detection change). The classified, georeferenced data sets for each year are compared as to land cover types (not spectral values specifically). Those pixels having a different land cover are given a value of 0 and unchanged pixels are given a value equal to their present class value plus 100. The resulting image displays those picture elements that have changed in black and those that have remained the same in red or in class colors. Acreage and percent of total data are available from the PATD program module and are included as Table 3.

Spectral reflectance values for the water quality sample sites were extracted from the Landsat digital data in a five line by five element matrix for each band. The data were graphed and compared to Secchi disk depth data to determine which band best correlates to the in situ

Table 3. Area values from the PATD program module.

VALU	LINES FREQ	PCT.	ACRES	SQ MI	HECT.	
0	[illegible]	19.370	63353.34	98.99	25638.75	Changed Area
101	[illegible]	0.191	623.45	0.97	252.50	Agriculture
102	[illegible]	0.575	1889.06	2.95	764.50	Bottomland Forest
103	[illegible]	1.294	4232.32	6.61	1713.00	Upland Forest
104	103690	31.454	102972.75	160.89	41672.5[illegible]	Grassland
105	573	0.109	357.06	0.56	144.50	Turbid Water
106	333	0.101	329.26	0.51	133.25	Clear Water
107	[illegible]	46.474	153308.25	239.54	62043.00	
TOTAL=	329448	ACRES=	327066.44	SQ MILES=	511.04	HECT.= 132362.[illegible]

samples.

Water bodies were located on the Landsat MSS digital data by using band 7 exclusively (see Fig. 8). Electromagnetic radiation in the near-infrared region of the spectrum (band 7, 0.8 - 1.1 microns) is either absorbed in the top few centimeters of the water column, or is reflected at a right angle from the light source by the water surface. In either case, very little near-infrared light is reflected

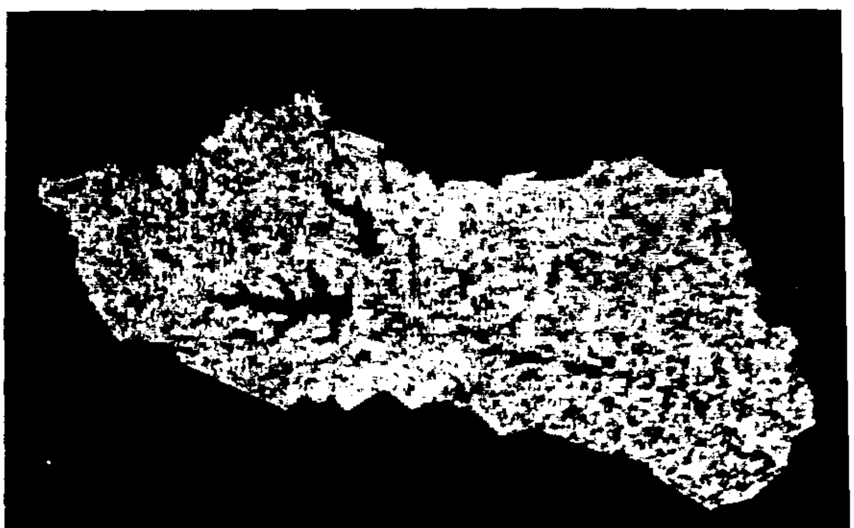


Fig. 8. Land/water interface on band 7 image.

back to the satellite scanner system, therefore, low values are expected for water on band 7 images. The low values are tested to determine the maximum value for free water by visual sampling. Those values are then isolated from the data set to obtain statistics for the surface area of water bodies in the watershed.

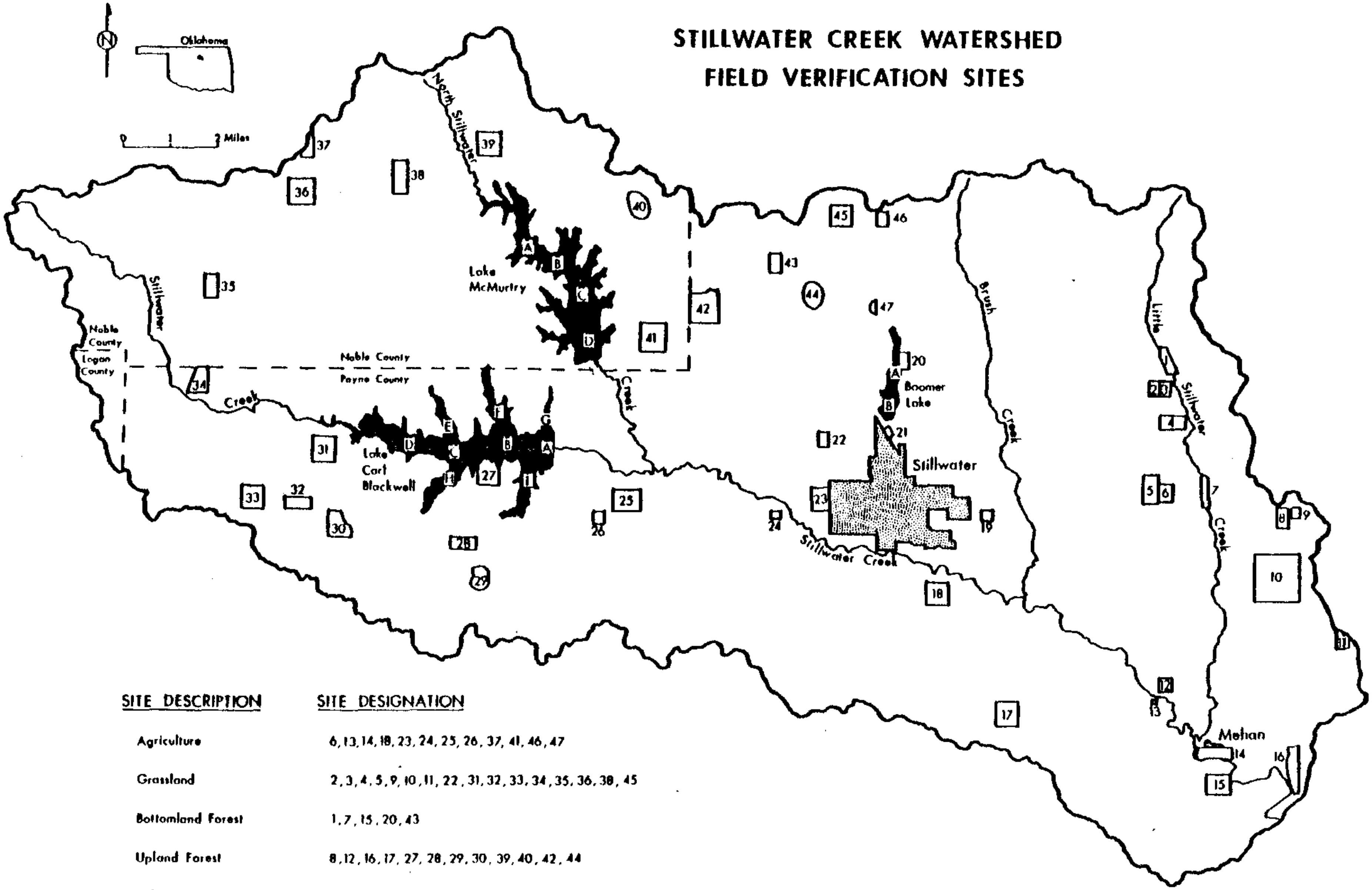
Ground truth data were collected to verify the Landsat MSS computer generated land cover classification.[11] Terrain sampling included site location and description in the field. Potential ground truth sites were first located on USGS 7.5' topographic quadrangle maps with the aid of black and white aerial photography of the watershed. Areas of 4 ha (10 acres) or larger in size showing an homogeneous land cover were selected for field survey. A map of the ground truth sample locations is included as Fig. 9.

In situ water quality data were collected for Lakes McMurtry and Boomer by CARS personnel and for Lake Carl Blackwell by Dr. Jerry Wilhm and Greg Howick of the OSU Department of Zoology. Fig. 9 includes the water quality sample sites for all three lakes.

The single most important water quality parameter in this study was turbidity expressed as the concentration of suspended sediments in free water. Other water quality data collected to assess the trophic level status were dissolved oxygen, carbon dioxide, nitrate level, phosphate level, and total hardness. Water quality data are included as Appendix C.

Secchi disk depth readings for each sample site in the three large reservoirs were collected in lieu of actual turbidity sample values from a turbidimeter. Toetz (1973)[12] demonstrated a qualitative relationship between Secchi disk depth and turbidity in Oklahoma lakes, and this relationship is assumed valid here.

STILLWATER CREEK WATERSHED
FIELD VERIFICATION SITES



SITE DESCRIPTION	SITE DESIGNATION
Agriculture	6, 13, 14, 18, 23, 24, 25, 26, 37, 41, 46, 47
Grassland	2, 3, 4, 5, 9, 10, 11, 22, 31, 32, 33, 34, 35, 36, 38, 45
Bottomland Forest	1, 7, 15, 20, 43
Upland Forest	8, 12, 16, 17, 27, 28, 29, 30, 39, 40, 42, 44
Urban	19, 21
Water	
Lake Carl Blackwell	A, B, C, D, E, F, G, H, I
Lake McMurtry	A, B, C, D
Boomer Lake	A, B

Fig. 9.

RESULTS

Task 1

The identification and mapping of water bodies greater than 2 ha (5 acres) was accomplished using Landsat band 7 digital data. Fig. 10 shows the location of surface water bodies in the Stillwater Creek watershed. The total surface area is 2394 ha (5916 acres) or about two percent of the watershed's total area.

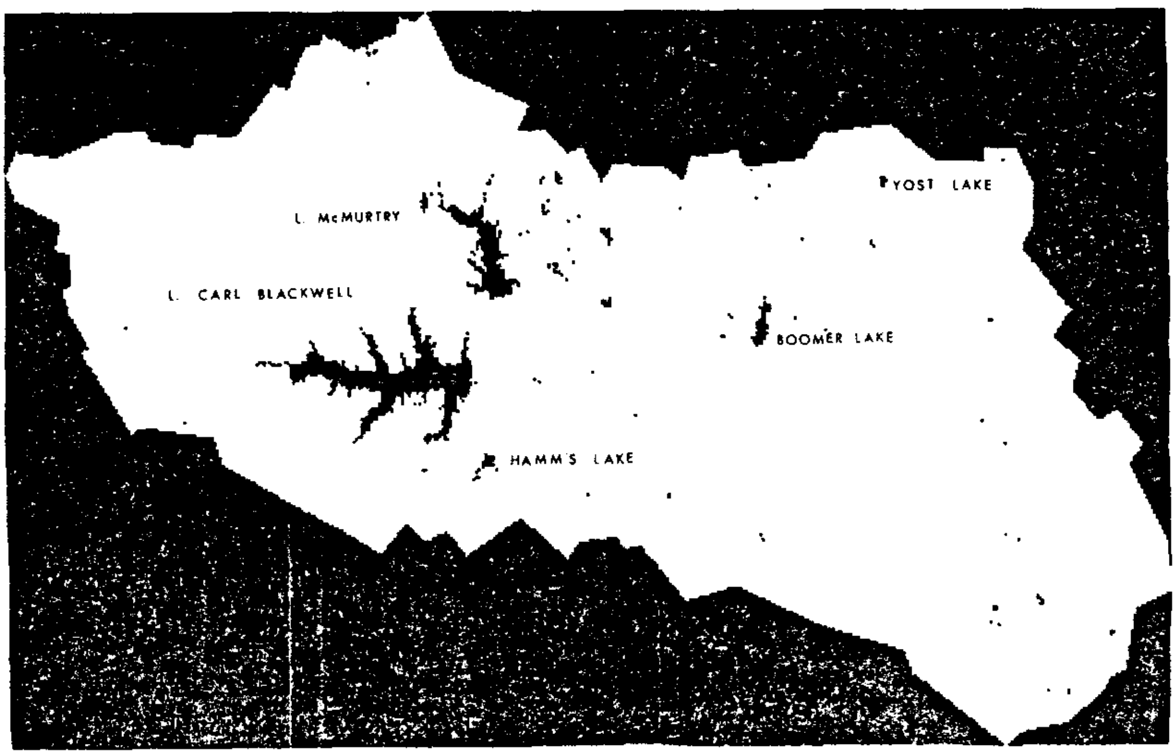


Fig. 10. Stillwater Creek watershed surface water bodies.

Task 2

Water quality in the Stillwater Creek watershed is generally good with the exception of high turbidity levels in the lakes and ponds. A large amount of data has been collected for Lake Carl Blackwell because of its availablitiy as a test site for OSU research studies.

Lake Carl Blackwell was completed in 1937 but did not fill until eight years later. In 1948 the spillway was lowered from 288.3 m (945.9 ft) to 287.8 m (944.2 ft). The lake has historically had fluctuations in water level, sometimes in the extreme.

High turbidity is a deleterious characteristic of Lake Carl Blackwell and the lake's potential for recreation has suffered because of it. Turbidity levels experience seasonal rises with the highest levels in spring and early summer and lowest levels in winter. Montmorillonite clay particles comprise the bulk of the material responsible for the high turbidity levels.[13] This fact, and the significant correlation between annual rainfall and annual maximum turbidity suggests that turbidity is due to agricultural runoff.[14] Sedimentation in the lakes is high with six percent of Lake Carl Blackwell's total volume lost in the first twenty years of its existence.[15]

The historical baseline water quality data is not available for Lake McMurtry as it is for Lake Carl Blackwell. The lake was completed in the late 1960's and the planned uses were for a municiple water supply, flood control and recreation. Generally, Lake McMurtry closely follows the annual patterns of turbidity, water level fluctuations and agricultural runoff shown in Lake Carl Blackwell with the exception that Lake McMurtry is less turbid and has less of a runoff problem. The lower turbidity is a function of the differences in land use and land cover conditions in the Lake McMurtry drainage basin as compared to those conditions on Stillwater Creek west of Lake Carl Blackwell. Forest covers a greater area and more land is in permanent non-tilled (or rarely tilled) pasture along North Stillwater Creek than along Stillwater Creek. The ability of vegetation to slow down water resulting in deposition of sediment load decreases the amount of soil reaching Lake McMurtry.

Boomer Lake serves as the cooling water supply for a city owned power station and for recreation for the city of Stillwater. Turbidity in Boomer Lake is very high because of large expanses of bare soil in its drainage area, due primarily to construction and urban expansion which release soil during periods of rainfall.[16]

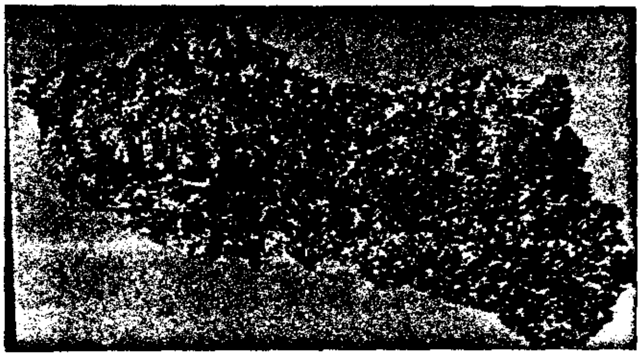
Task 3

Land use change in the Stillwater Creek watershed has not affected a majority of land areas over the six year period of the study, however, the changes that have occurred are significant in terms of their effects on water quality in the lakes. The results of the pattern detection change program (PATD) module (see Table 3 and Fig. 11) show 19 percent of the total land area has undergone change. The values in Table 3 are representative of the total watershed, however, the drainage areas for all three lakes is less than one-half of the total area. Although the major land cover categories are evenly distributed throughout the watershed, some trends are significant. Fig. 12a shows the dominance of grassland, agriculture and bottomland forest in the

Black denotes areas undergoing change

Stable land covers in red

a



Stable land covers in class colors

b

CHANGE DETECTION MAP 1975 AND 1981
(Key on next page)

Fig. 11.

Interpretation Key for

Change Detection Map, 1975 and 1981

Land Cover	Color
Agriculture	Green
Grassland	White
Upland Forest	Blue
Bottomland Forest	Orange
Turbid Water	Purple
Clear Water	Light Blue

14 JUNE 1975

a

08 APRIL 1981

b

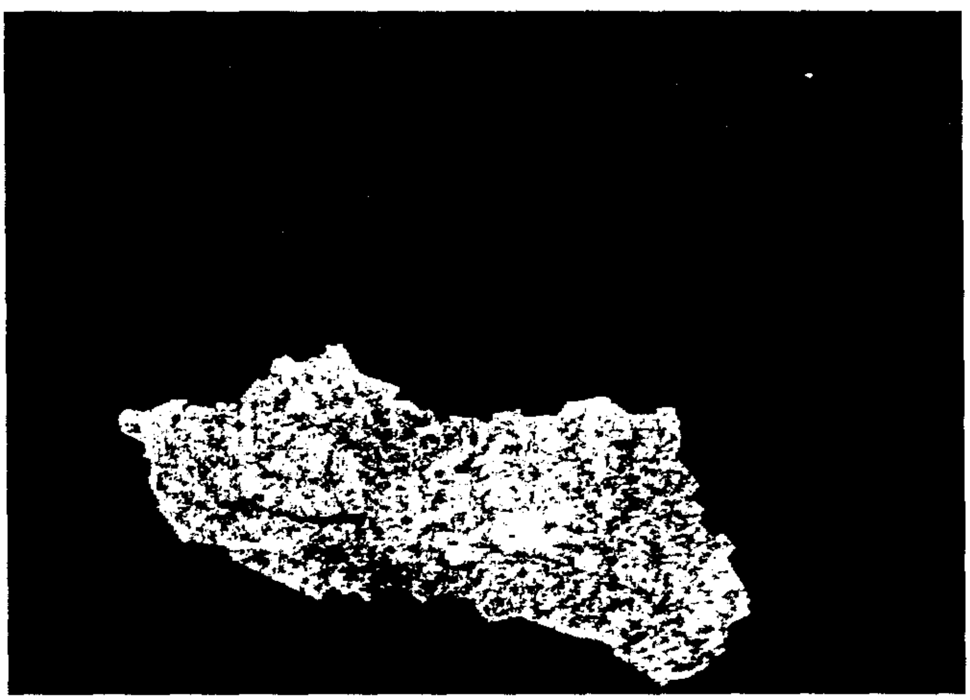


Fig. 12. LAND COVER CLASSIFICATION
(Key on next page)

Interpretation Key for

Land Cover Classifications

Land Cover	1975	Color	1981
Agriculture	White		Bright Green
Grassland	Pink		Pink
Upland Forest	Green		Red
Bottomland Forest	Dark Green		Light Red
Turbid Water	Light Blue		Blue
Clear Water	Blue		Dark Blue

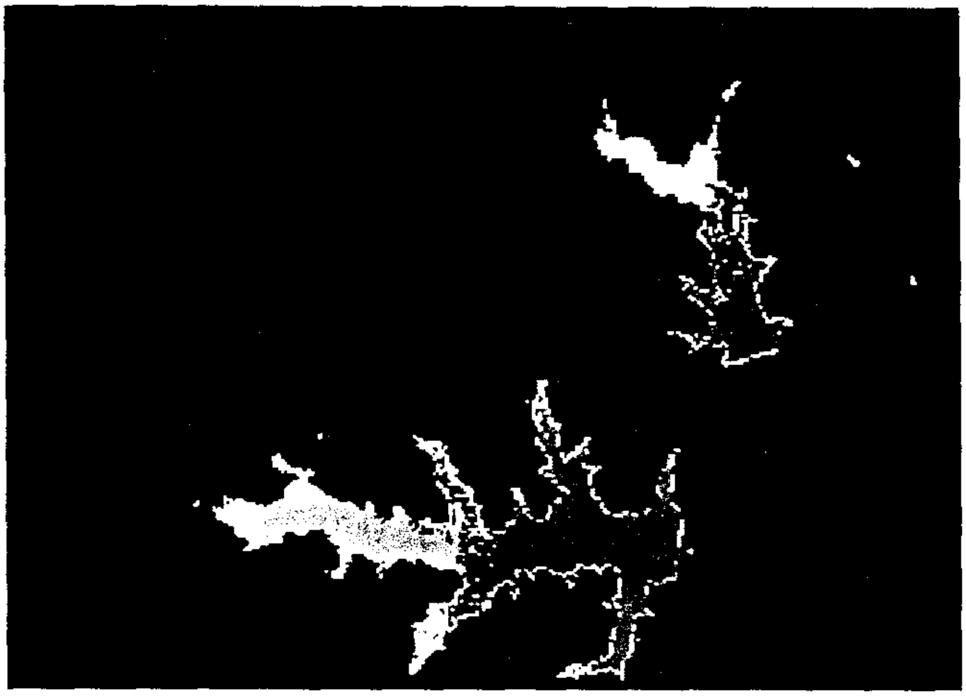
Lake Carl Blackwell drainage basin. Lake McMurtry's drainage area has a similar makeup except for a large area of upland forest to the north and east of the lake, and less agriculture.

Water quality, especially turbidity has been effected by changes in land use. Specifically, an increase in agricultural land primarily at the expense of grassland, and an increase in irrigated agricultural land have added to the source of free sediments in the basin. This in turn has caused an increase in turbidity in the lakes. Turbidity data (actual turbidimeter values) collected by the OSU Water Treatment Plant show a gradual increase in turbidity since about 1965.[17] Figures 13a and 13b and 14a and 14b show the turbidity patterns in the three major lakes in the watershed at 14 June 1975 and 08 April 1981. Climatological records indicate the increase in turbidity is not due to an unusual rainfall incident or other anonmalous meterological events. The two dates of Landsat data for this project were selected because they were within the time span of maximum annual turbidity, had very similar climatological years preceding the overpass dates, and although phenologically dissimilar (early spring and late spring), showed the major vegetation classes distinctly. These similarities were planned to eliminate as many variables as possible in the search for causes in the increase in lake turbidity.

Correlation of lake turbidity levels with the Landsat reflectance data was good for band 6 (see Figs. 15 and 16). These findings and reports in the literature[18,19,20] support the use of Landsat MSS data for tur-

14 JUNE 1975

a



08 APRIL 1981

b

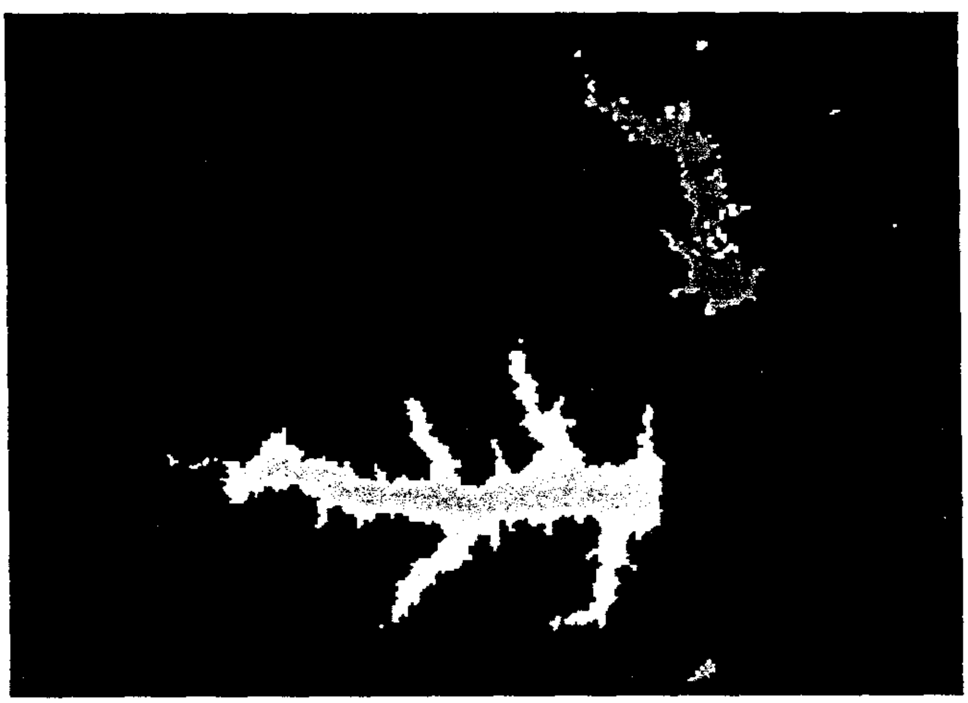


Fig. 13.
LAKE CARL BLACKWELL AND LAKE McMURTRY TURBIDITY LEVELS
(Key on next page)

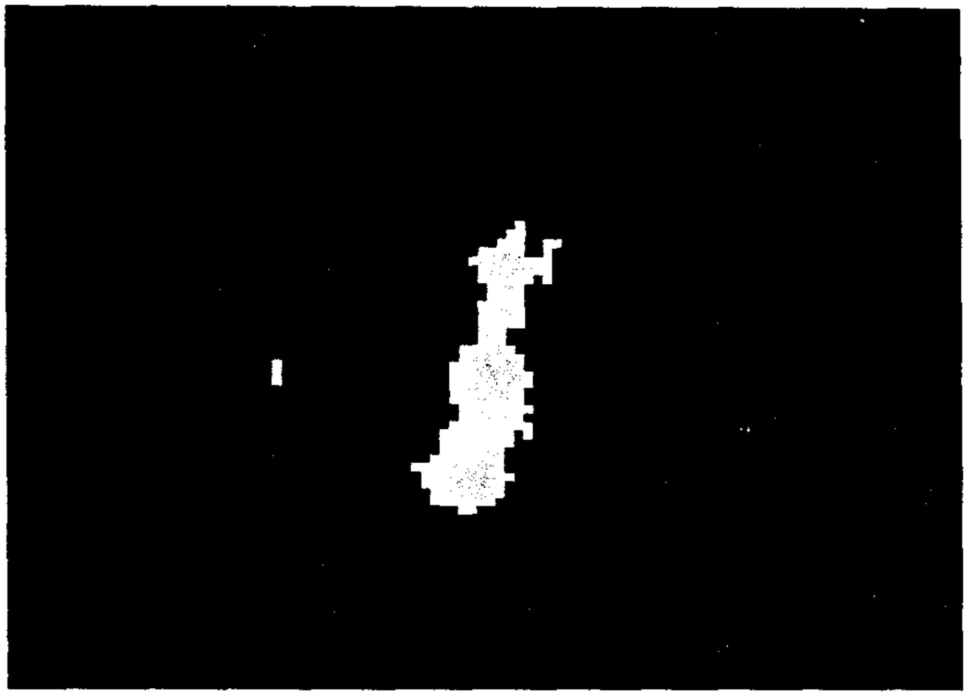
Interpretation Key for

Lake Carl Blackwell and Lake McMurtry Turbidity Levels

Level	1975	Color	1981
High	Bright Blue		Bright Blue
Low	Dark Blue		Dark Blue

14 JUNE 1975

a



08 APRIL 1981

b

Fig. 14. BOOMER LAKE TURBIDITY LEVELS
(Key on next page)

Interpretation Key for

Boomer Lake Turbidity Levels

Level	1975	Color	1981
High	Bright Blue		Bright Blue

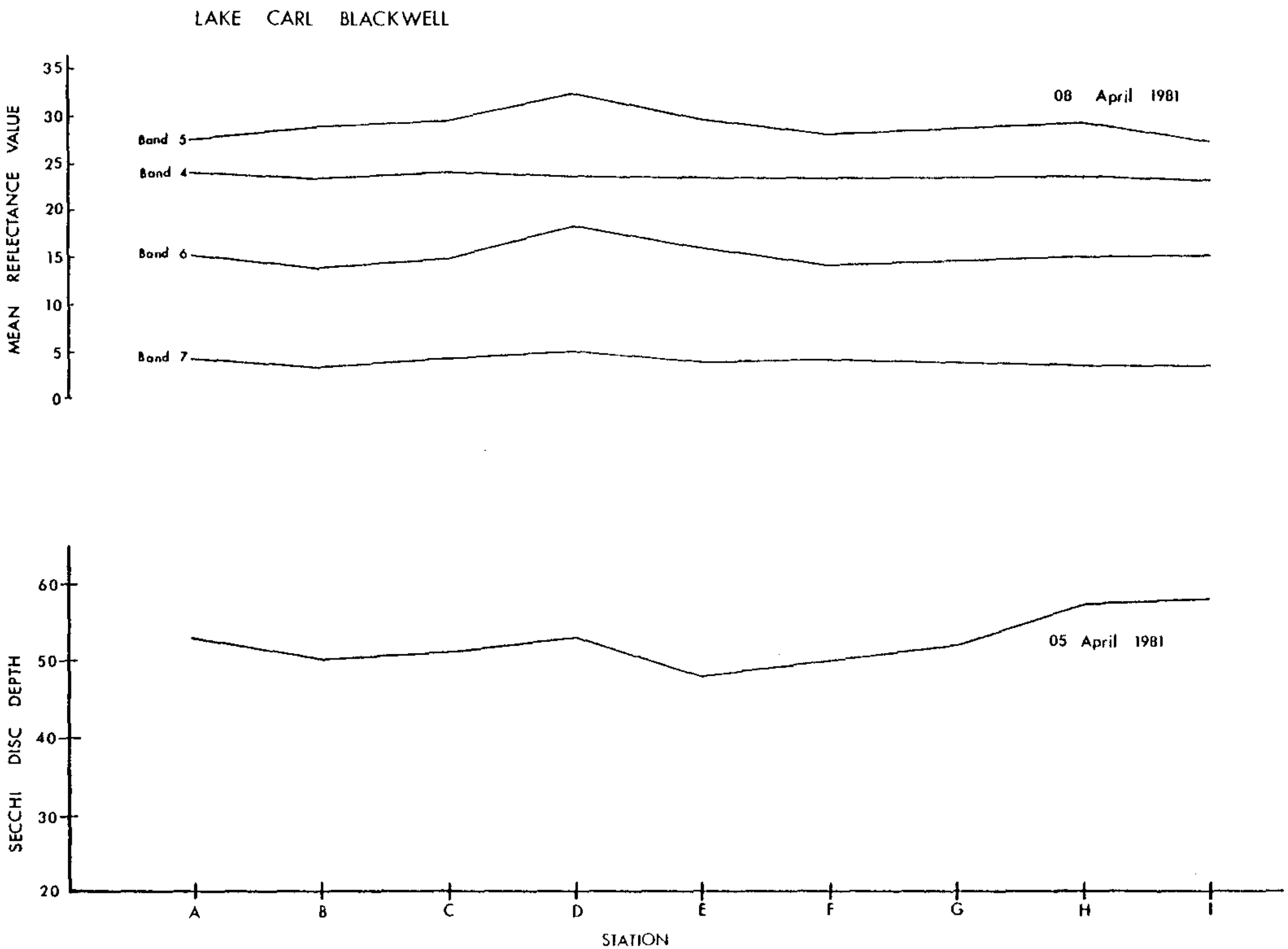


Fig. 15. Landsat MSS spectral data and Secchi disk depth value correlations.

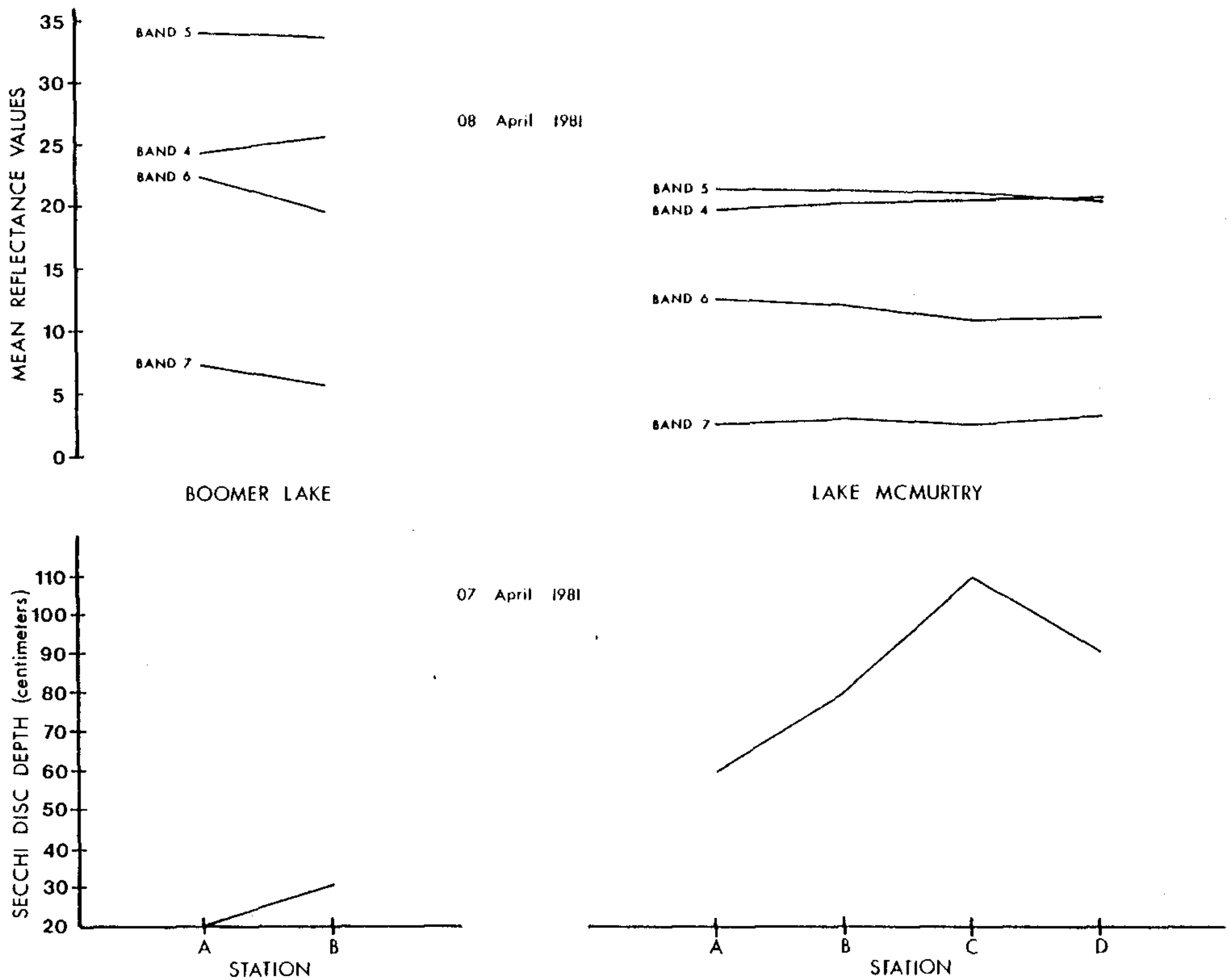


Fig. 16. Landsat MSS spectral data and Secchi disk depth value correlations.

bidity measurement.

The high concentrations of suspended sediments in the watershed's lakes reflect light in the green and red bands (bands 4 and 5) to a high degree. Landsat MSS data is sufficiently detailed to observe flow and mixing patterns in the lakes' turbid and less turbid zones. The band 5 image in Fig. 17 shows turbidity levels as varying shades of gray. Less turbid water corresponds to the darker shades and light gray denotes high levels of suspended sediments.

The clearest water is found near the dams on both lakes. This is an expected phenomenon as the deepest water is generally found near the earthen dams in this type of reservoir. Turbidity gradually increases in Lake McMurtry as distance from the dam increases. The upper reaches of the lake where North Stillwater Creek enters is especially turbid due tc the influx of sediment laden runoff water during and immediately after rainfalls, and the shallow water in the north end of the lake is easily mixed by wind wave action. Overall, the shallowness of all lakes in the watershed make them susceptible to rapid mixing by wind.

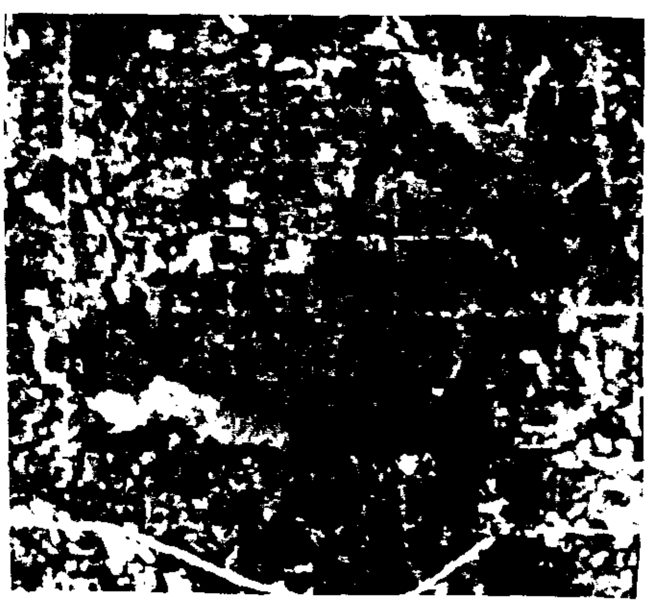


Fig. 17. Turbidity levels.

Wind conditions were noted during the in situ water quality sampling trips, however, a more quantitative measure of mixing due to wind is supplied by the dissolved oxygen test data. Winds were calm for the in situ sample dates and the Landsat overpass dates. Dissolved oxygen values are not unusually high, therefore, it is assumed that minimal mixing was occurring in the lakes. (See Appendix C.)

Lake Carl Blackwell's turbidity pattern is more complex than Lake McMurtry's, but the controlling factors are similar. The different morphology of the lakes produces differing turbidity patterns. The flooded channels extending north and south of the lake's main body are typically high turbidity zones, as are the upper reaches of the lake where Stillwater Creek flows into the lake. Wind is responsible for some mixing, but is not as severe a problem in Lake Carl Blackwell because the long east-west axis of the lake is perpendicular to the dominant wind direction. Lake McMurtry's long axis is north-south and presents a large fetch area to the prevailing wind.

Task 4

Landsat MSS data has been used to successfully identify and monitor water quality parameters in lakes (see LITERATURE CITED). This project has demonstrated the ability to monitor turbidity on a seasonal basis as well as over a span of years. Identification and mapping of water bodies as small as 2 ha (5 acres) has also been accomplished using Landsat data.

Automatic computer generated land cover classification of Landsat MSS data is a rapid, accurate technique for obtaining a thematic map, complete with area computations for a defined region. This technique requires the availablity of a digital computer, an image display device and applicable image processing software which limits the user pool sigificantly.

Digital image enhancement of Landsat MSS data increases the interpreter's ability to identify specific land covers, or to extract specific physical features from the background image. Figs. 18 and 19 show the western half of the Stillwater Creek watershed as an unenhanced band 5 image (Fig. 18), and as a contrast stretched band 5 image (Fig. 19). Riparian forests are important vegetation buffers for reducing the velocity of water to decrease the sediment carrying capacity prior to entering a lake. The unenhanced band 5 image does not sufficiently discriminate upland forest, riparian forest and grassland because their

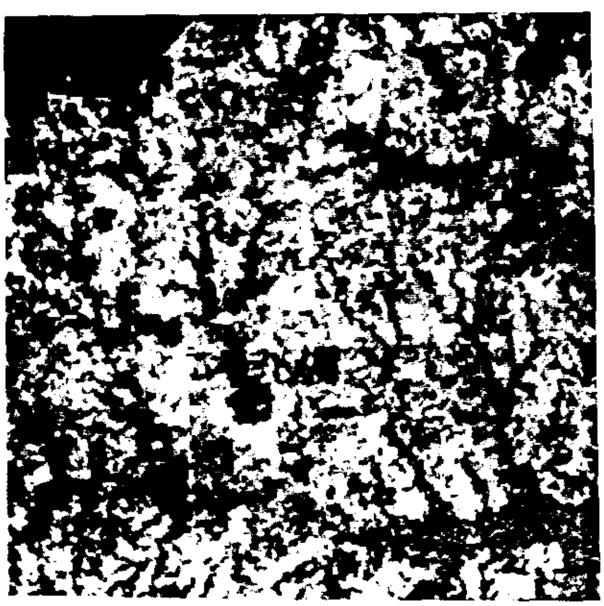


Fig. 18. Unenhanced band 5.

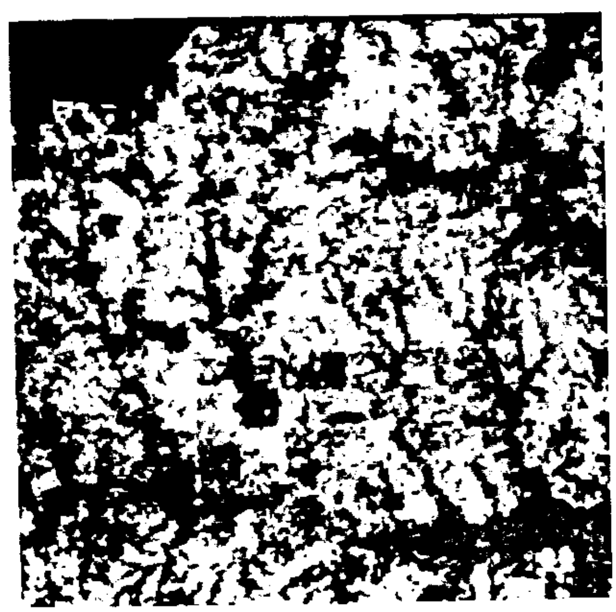


Fig. 19. Enhanced band 5.

spectral signatures are not markedly dissimilar. The widest spectral range is from grassland to riparian forests. Grasses have a high silica content and a relatively low water content. They reflect more light in the red portion of the spectrum than do the more moist broadleaved riparian forest trees. Community morphology is also responsible for the different spectral values. Both riparian and upland forests have high crown closure percentages serving to reduce the amount of red light scattered back to the satellite platform, but upland forests are typically even height trees with less species and morphological diversity than riparian forests. Grasslands allow a high percentage of light reflected from the soil to be sensed, therefore, especially in band 5, high spectral signatures are common.

A linear contrast stretch applied to the data increases the spectral distance between each land cover type exaggerating the differences in tonal representation. Grasslands appear as light grays and white, and riparian forests are black or very dark gray on the enhanced image. The heightened contrast produces a graphic image with the dark tone riparian forest visually distinctive against the bright tone grassland.

Other bands and enhancement techniques are used to isolate other land cover or physical features as demonstrated here with riparian forests.

The use of Landsat data is not without hazards. Cloud cover may render data of a specific date unuseable, however, a haze correction algorithm is available to reduce the effects of haze and thin clouds (see

Figs. 20 and 21). Another algorithm completely eliminates clouds and their shadows from an image by changing the cloud values and the cloud shadow values to values representative of neighboring pixels. Obviously, this technique is limited to very small areas.

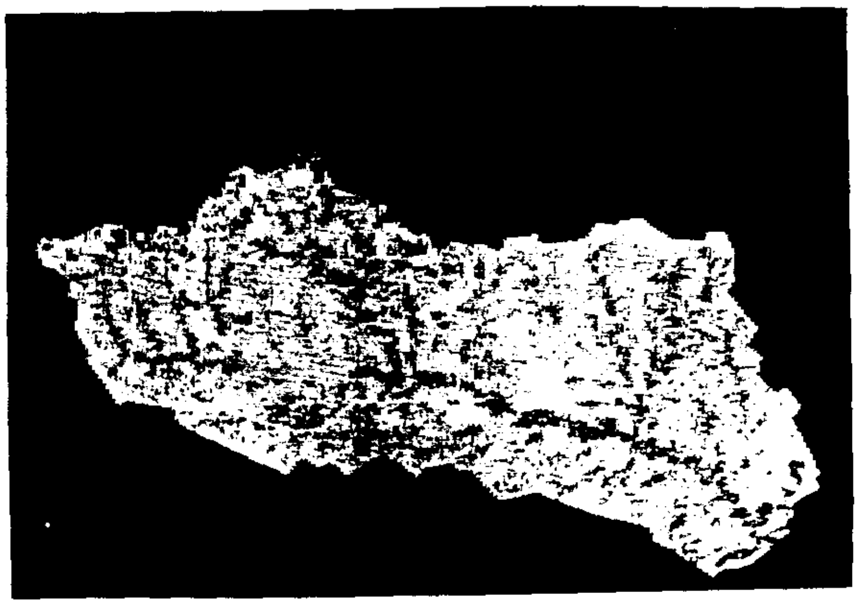


Fig. 20. Band 5 without haze correction.

Fig. 21. Band 5 haze correction applied.

Technical problems aboard the remaining two functioning satellites have caused the data stream to be inconsistent for more than a year. Acquisition of recent data is sometimes difficult because of the satellite problems and long delays at the processing facility.

Task 5

The need for economically efficient and environmentally wise management of Oklahoma's surface water resources is desirable for the present and imperative for the future. Oklahoma has taken a progressive stance in recognizing the problems of allocation, exploitation, pollution and conservation of water resources. The development of the Oklahoma Comprehensive Water Plan[21] is a step toward state-wide management of water resources in Oklahoma. The Plan identifies many specific problem areas where responsible management is necessary, however, the report does not offer a detailed methodology for water resource management or for management alternatives.

This project has demonstrated the use of Landsat MSS digital data for land cover mapping and water quality monitoring over a six year period. The basic methodologies are unaffected by size of the study area, therefore, expansion to a state-wide system requires only the addition of storage space on the computer for the proportional increase in data. Processing time is not directly proportional to the size of a region, but actually becomes more efficient as the area increases.

The advantages of using satellite remote sensing for water resources monitoring are consistency in the data format, rapid turnaround time from project start to finished output product, high visiblity products that are easily interpreted, and a stable data archive for change detection from season to season or over a decade.

SUMMARY

This project has monitored land use change and its effect on water quality in north-central Oklahoma. Landsat Multispectral Scanner digital data is the primary data source. In situ water quality data and field verification information of the automatically classified Landsat land cover thematic map were collected as well.

Satellite data for two dates, 14 June 1975 and 08 April 1981 were used to map land cover and assess land use changes occurring in the watershed over a six year period. The data were processed at the OSU Center for Applications of Remote Sensing using state of the art digital image processing software and hardware. Resulting thematic maps were displayed as full color and black and white images on the image display device, and photographed for inclusion in this report. Area totals for each land cover category were generated for each year. A special change detection algorithm was used to obtain area totals for areas undergoing land cover change.

In situ water quality data were collected to measure Secchi disk depths, dissolved oxygen, carbon dioxide, nitrate level, phosphate level and total hardness. The Secchi disk depth samples were correlated to Landsat spectral values for the sample sites. All other measured water

quality parameters were collected to develop a profile status of the water bodies.

In conclusion, land use change, especially the type of change experienced in this watershed has contributed to an increase in annual turbidity in the lakes. Landsat MSS digital data is a rapid, accurate tool for monitoring land use change, relative turbidity levels in water bodies and identification and mapping of water bodies 2 ha (5 acres) in size.

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Appendix A

Vegetation Checklist

Trees and Woody Plants of the Upland Forests

Genus species	Common name
1. Acacia angustissma	Acacia
2. Bumelia lanuginosa	Chittamwood
3. Campsis radicans	Trumpet vine
4. Carya texana	Black hickory
5. Ceanothus americanus	New Jersey tea
6. Celastrus scandens	American bittersweet
7. Celtis occidentalis	Common hackberry
8. C. reticulata	Netleaf hackberry
9. Cercis canadensis	Eastern redbud
10. Clematis pitcheri	Bluebell
11. Cocculus carolinus	Carolina moonseed
12. Diospyros virginiana	Persimmon
13. Gleditsia triacanthos	Honey locust
14. Hypericum punctatum	Spotted St. John's-wort
15. Ilex decidua	Holly
16. Juglans nigra	Black walnut
17. Juniperus virginiana	Red cedar
18. Lonicera sempervirens	Honeysuckle
19. Lycium halmifolium	Loxthorn
20. Melia azedarch	Chinaberry
21. Parthenocissus quinquefolia	Virginia creeper
22. Prunus angustifolia	Chicksaw plum
23. Quercus macrocarpa	Burr oak
24. Q. marilandica	Blackjack oak
25. Q. muehlenbergii	Chinquapin oak
26. Q. prinoides	Dwarf chinquapin oak
27. Q. stellata	Post oak
28. Q. velutina	Black oak
29. Rhus aromatica	Sumac
30. R. copallina var. copallina	Red sumac
31. Ribes odoratum	Clove currant
32. Robinia pseudo-acacia	Black locust
33. Rubus enslenii	Dewberry
34. R. ostryfolius	Blackberry
35. Sapindus drummondii	Western soapberry
36. Smilax bona-nox	Saw greenbriar
37. Toxicodendron radicans	Poison ivy
38. Ulmus rubra	Slippery elm
39. Viburnum prunifolium var. ferrugineum	Black haw
40. Yucca glauca	Beargrass

Trees and Woody Plants of the Bottomland Forests

Genus species	Common name
1. *Ampelopsis cordata*	Heartleaf ampelopsis
2. *Carya codiformis*	Bitternut hickory
3. *C. illionesis*	Pecan
4. *Catalpa speciosa*	Northern catalpa
5. *Celtis laevigata*	Southern hackberry
6. *Fraxinus pennsylvanica* var. *subintegerima*	Red ash
7. *Gymnocladus dioica*	Kentucky coffee-tree
8. *Ilex decidua*	Holly
9. *Maclura pomifera*	Osage orange
10. *Morus nigra*	Black mulberry
11. *M. rubra*	Red mulberry
12. *Platanus occidentalis*	American sycamore
13. *Prunus americana*	Wild plum
14. *Ptelea trifoliata*	Hoptree
15. *Pyrus ioensis*	Prairie crabapple
16. *Quercus shumardii*	Shummard oak
17. *Sambucus canadensis*	Elderberry
18. *Smilax tamnoides*	China root
19. *Symphoricarpos orbiculatus*	Indian currant
20. *Ulmus americana*	American elm
21. *U. rubra*	Slippery elm
22. *Viburnum prunifolium* var. *ferrugineum*	Black haw
23. *Vitis vulpina*	Frost grape

Trees and Woody Plants of the Riparian Forests

Genus species	Common name
1. *Acer negundo*	Box elder
2. *Catalpa bignonioides*	Southern catalpa
3. *Crataegus crus-galli*	Cockspur hawthorn
4. *Populus deltoides*	Cottonwood
5. *Salix nigra*	Black willow
6. *Smilax bona-nox*	Saw greenbriar
7. *S. tamnoides*	China root
8. *Tamarix gallica*	Salt cedar
9. *Vitis vulpina*	Frost grape

Trees and Woody Plants of the Wetland Forests

Genus species	Common name
1. *Cephalanthus occidentalis*	Buttonbush
2. *Cornus drummondii*	Dogwood
3. *Crataegus viridis*	Green hawthorn
4. *Euonymus atropurpureus*	Burning bush
5. *Sambucus canadensis*	Elderberry
6. *Smilax bona-nox*	Saw greenbriar
7. *Viburnum prunifolium* var. *ferrugineum*	Black haw

Appendix B

Training Statistics

STAT 1 CHNS 4 PTS= 5553 APR= 4.9839

	CH 1	CH 2	CH 3	CH 4	CH
MEAN	28.07179	38.45888	45.49554	18.96042	
S.D.	1.18224	1.80048	1.97019	1.00449	
C.V.	4.21149	4.68156	4.33052	5.29784	

CORRELATION MATRIX

1.398	0.387	0.185	-0.076
0.824	3.242	0.209	-0.015
0.430	0.742	3.882	0.431
-0.091	-0.026	0.353	1.009

COVARIANCE MATRIX

STAT 2 CHNS 4 PTS= 21798 APR= 7.0153

	CH 1	CH 2	CH 3	CH 4	CH
MEAN	29.37737	40.53749	50.80525	21.79013	
S.D.	1.37804	2.38959	2.93071	1.40548	
C.V.	4.69081	5.89477	5.76852	6.45006	

CORRELATION MATRIX

1.899	0.568	0.350	0.202
1.370	5.710	0.289	0.103
1.415	2.022	8.589	0.743
0.391	0.346	3.062	1.975

COVARIANCE MATRIX

STAT 3 CHNS 4 PTS= 5724 APR= 5.0219

	CH 1	CH 2	CH 3	CH 4	CH
MEAN	25.60078	33.80853	41.79227	17.41394	
S.D.	1.32074	2.39324	2.17896	1.13719	
C.V.	5.15900	7.07880	5.21379	6.53035	

CORRELATION MATRIX

1.744	0.544	0.319	0.195
1.719	5.728	0.402	0.275
0.919	2.098	4.748	0.649
0.293	0.749	1.607	1.293

COVARIANCE MATRIX

STAT 4 CHNS 4 PTS= 1332 APR= 3.4879

	CH 1	CH 2	CH 3	CH 4	CH
MEAN	20.56308	20.58786	59.22227	30.21469	
S.D.	1.23094	1.11595	3.21786	1.85783	
C.V.	5.98617	5.42044	5.43353	6.14877	

CORRELATION MATRIX

1.515	0.161	0.199	-0.083
0.222	1.245	-0.156	-0.331
0.789	-0.561	10.355	0.734
-0.189	-0.686	4.391	3.452

COVARIANCE MATRIX

STAT 5 CHNS 4 PTS= 54783 APR= 8.8328

	CH 1	CH 2	CH 3	CH 4	CH
MEAN	24.19200	26.13792	55.83170	26.43192	
S.D.	1.14515	2.03959	3.35886	1.85211	
C.V.	4.73361	7.80316	6.01605	7.00711	

CORRELATION MATRIX

1.311	0.504	0.144	0.050
1.178	4.160	-0.201	-0.330
0.553	-1.376	11.282	0.839
0.107	-1.245	5.217	3.430

COVARIANCE MATRIX

STAT 6 CHNS 4 PTS= 747 APR= 3.0183

	CH 1	CH 2	CH 3	CH 4	CH
MEAN	24.58632	29.69211	44.16330	19.50200	
S.D.	1.16249	1.94321	2.03291	1.14444	
C.V.	4.72818	6.54453	4.60316	5.86831	

CORRELATION MATRIX

1.351	0.464	0.291	0.188
1.047	3.776	0.130	-0.083
0.687	0.515	4.133	0.501
0.250	-0.135	1.164	1.310

COVARIANCE MATRIX

STAT 7 CHNS 4 PTS= 2421 APR= 4.0498

	CH 1	CH 2	CH 3	CH 4	CH
MEAN	29.61833	40.71829	56.93143	24.87436	
S.D.	1.36787	2.41654	2.53741	1.23365	
C.V.	4.61833	5.93478	4.45695	4.95954	

CORRELATION MATRIX

1.871	0.386	0.174	0.084
1.275	5.840	0.153	-0.051
0.605	0.936	6.438	0.684
0.143	-0.151	2.140	1.522

COVARIANCE MATRIX

STAT 8 CHNS 4 PTS= 288 APR= 2.3784

	CH 1	CH 2	CH 3	CH 4	CH
MEAN	24.01736	29.56944	36.76736	14.87500	
S.D.	1.13677	1.36229	1.50421	0.77752	
C.V.	4.73312	4.60709	4.09114	5.22699	

CORRELATION MATRIX

1.292	0.549	0.245	0.160
0.351	1.856	0.119	0.169
0.419	0.245	2.263	0.499
0.142	0.179	0.584	0.605

COVARIANCE MATRIX

14 June 1975 Class Stats

STAT 9 CHNS 4 PTS= 1107 APR= 3.3302

	CH 1	CH 2	CH 3	CH 4	CH
MEAN	32.33968	46.23033	57.20418	24.33783	
S.D.	1.76745	2.21617	2.52044	1.18945	
C.V.	5.46526	4.79375	4.40604	4.88724	

CORRELATION MATRIX

3.124	0.319	0.166	0.070
1.251	4.911	0.240	0.217
0.738	1.342	6.353	0.674
0.148	0.571	2.020	1.415

COVARIANCE MATRIX

STAT 10 CHNS 4 PTS= 15561 APR= 6.4484

	CH 1	CH 2	CH 3	CH 4	CH
MEAN	23.41200	22.16927	62.25027	30.88196	
S.D.	1.01518	1.13410	3.37342	2.02494	
C.V.	4.33615	5.11564	5.41912	6.55704	

CORRELATION MATRIX

1.031	0.296	0.101	0.050
0.341	1.286	-0.236	-0.276
0.344	-0.902	11.380	0.829
0.104	-0.634	5.660	4.100

COVARIANCE MATRIX

STAT 11 CHNS 4 PTS= 3627 APR= 4.4805

	CH 1	CH 2	CH 3	CH 4	CH
MEAN	26.82246	34.54813	48.88806	21.59337	
S.D.	1.38156	2.00055	3.00253	1.46187	
C.V.	5.15077	5.79062	6.14164	6.77000	

CORRELATION MATRIX

1.909	0.277	0.279	0.185
0.765	4.002	-0.003	-0.097
1.156	-0.018	9.015	0.761
0.374	-0.283	3.341	2.137

COVARIANCE MATRIX

STAT 12 CHNS 4 PTS= 1107 APR= 3.3302

	CH 1	CH 2	CH 3	CH 4	CH
MEAN	24.38031	31.29993	32.77325	7.97471	
S.D.	0.91834	1.78273	1.53471	0.95907	
C.V.	3.76674	5.69563	4.68281	12.02638	

CORRELATION MATRIX

0.843	0.322	0.198	0.047
0.527	3.178	0.369	-0.244
0.279	1.009	2.355	0.167
0.041	-0.417	0.246	0.920

COVARIANCE MATRIX

STAT 13 CHNS 4 PTS= 8505 APR= 5.5444

	CH 1	CH 2	CH 3	CH 4	CH
MEAN	24.62822	25.60612	61.80540	30.23195	
S.D.	0.93006	1.39576	2.68405	1.54007	
C.V.	3.77638	5.45086	4.34275	5.09419	

CORRELATION MATRIX

0.865	0.323	0.154	0.065
0.419	1.948	-0.061	-0.182
0.385	-0.229	7.204	0.704
0.093	-0.391	2.910	2.372

COVARIANCE MATRIX

STAT 14 CHNS 4 PTS= 90 APR= 1.7783

	CH 1	CH 2	CH 3	CH 4	CH
MEAN	35.47777	52.73334	62.17778	26.85556	
S.D.	1.71739	2.85524	2.52877	0.91858	
C.V.	4.84076	5.41449	4.06700	3.42046	

CORRELATION MATRIX

2.949	0.732	0.428	0.528
3.590	8.152	0.573	0.572
1.859	4.138	6.395	0.654
0.834	1.500	1.520	0.844

COVARIANCE MATRIX

STAT 15 CHNS 4 PTS= 558 APR= 2.8061

	CH 1	CH 2	CH 3	CH 4	CH
MEAN	23.61652	21.27779	73.03227	38.24907	
S.D.	1.16439	1.41786	3.83783	2.19837	
C.V.	4.93042	6.66356	5.25497	5.74750	

CORRELATION MATRIX

1.356	0.542	0.204	0.156
0.894	2.010	0.049	0.061
0.913	0.267	14.729	0.802
0.399	0.191	6.763	4.833

COVARIANCE MATRIX

STAT 16 CHNS 4 PTS= 5508 APR= 4.9738

	CH 1	CH 2	CH 3	CH 4	CH
MEAN	26.01549	30.51257	57.05374	26.46310	
S.D.	1.38207	2.08647	3.08042	1.74568	
C.V.	5.31228	6.83808	5.39916	6.59666	

CORRELATION MATRIX

1.910	0.422	0.123	0.040
1.216	4.353	-0.180	-0.340
0.523	-1.155	9.489	0.303
0.095	-1.239	4.319	3.047

COVARIANCE MATRIX

STAT 17 CHNS 4 PTS= 2907 APR= 4.2394

	CH 1	CH 2	CH 3	CH 4	CH
MEAN	18.12939	15.95631	58.49158	31.59991	
S.D.	0.68209	0.95267	2.72337	1.61047	
C.V.	3.76233	5.97050	4.65600	5.09643	

CORRELATION MATRIX

0.465	0.418	-0.080	-0.130
0.272	0.908	-0.213	-0.198
-0.149	-0.553	7.417	0.741
-0.143	-0.304	3.252	2.594

COVARIANCE MATRIX

STAT 18 CHNS 4 PTS= 369 APR= 2.5304

	CH 1	CH 2	CH 3	CH 4	CH
MEAN	26.46613	44.15446	45.83740	11.92412	
S.D.	1.47425	2.17727	2.47717	1.37710	
C.V.	5.57032	4.93102	5.40426	11.54886	

CORRELATION MATRIX

2.173	0.409	-0.119	-0.229
1.314	4.740	0.290	-0.083
-0.435	1.566	6.136	0.506
-0.465	-0.249	1.727	1.896

COVARIANCE MATRIX

STAT 19 CHNS 4 PTS= 189 APR= 2.1407

	CH 1	CH 2	CH 3	CH 4	CH
MEAN	24.78835	24.51323	67.28043	34.57672	
S.D.	0.90415	1.42020	2.76759	1.89080	
C.V.	3.64748	5.79359	4.11352	5.46843	

CORRELATION MATRIX

0.817	0.189	0.065	-0.012
0.243	2.017	-0.019	-0.079
0.162	-0.075	7.660	0.697
-0.020	-0.212	3.647	3.575

COVARIANCE MATRIX

STAT 20 CHNS 4 PTS= 539 APR= 2.9023

	CH 1	CH 2	CH 3	CH 4	CH
MEAN	17.85443	15.04695	64.59940	35.89983	
S.D.	0.69945	0.88044	2.54736	1.63064	
C.V.	3.91749	5.85129	3.94331	4.54220	

CORRELATION MATRIX

0.489	0.232	0.128	0.085
0.173	0.775	-0.011	-0.037
0.229	-0.024	6.489	0.703
0.097	-0.053	2.022	2.659

COVARIANCE MATRIX

STAT 21 CHNS 4 PTS= 1026 APR= 3.2676

	CH 1	CH 2	CH 3	CH 4	CH
MEAN	22.08376	22.56435	54.33046	26.15698	
S.D.	1.39328	1.20785	2.63430	1.25348	
C.V.	6.30906	5.35292	4.84865	4.79216	

CORRELATION MATRIX

1.941	0.334	0.277	0.156
0.563	1.459	-0.090	-0.243
1.016	-0.286	6.940	0.744
0.273	-0.368	2.457	1.571

COVARIANCE MATRIX

STAT 22 CHNS 4 PTS= 1305 APR= 3.4701

	CH 1	CH 2	CH 3	CH 4	CH
MEAN	26.58087	29.15704	64.16479	31.26820	
S.D.	1.39612	1.50460	3.15475	1.71067	
C.V.	5.25235	5.16032	4.91664	5.47095	

CORRELATION MATRIX

1.949	0.414	0.352	0.185
0.870	2.264	0.139	-0.026
1.552	0.662	9.952	0.758
0.441	-0.066	4.091	2.926

COVARIANCE MATRIX

STAT 23 CHNS 4 PTS= 90 APR= 1.7783

	CH 1	CH 2	CH 3	CH 4	CH
MEAN	23.47777	23.10001	13.76667	1.91111	
S.D.	1.08359	1.31576	0.86181	0.53305	
C.V.	4.61537	5.69592	6.26011	27.89238	

CORRELATION MATRIX

1.174	0.407	0.253	-0.159
0.581	1.731	0.516	-0.099
0.236	0.585	0.743	0.052
-0.092	-0.070	0.024	0.284

COVARIANCE MATRIX

STAT 24 CHNS 4 PTS= 90 APR= 1.7783

	CH 1	CH 2	CH 3	CH 4	CH
MEAN	28.42223	49.81111	43.62222	8.15556	
S.D.	0.86074	1.81074	3.00398	1.24440	
C.V.	3.02840	3.63522	6.88635	15.25837	

CORRELATION MATRIX

0.741	-0.006	0.027	-0.062
-0.009	3.279	0.290	0.183
0.071	1.579	9.024	0.737
-0.066	0.412	2.756	1.549

COVARIANCE MATRIX

STAT 25 CHNS 4 PTS= 774 APR= 3.0453

	CH 1	CH 2	CH 3	CH 4	CH
MEAN	18.97931	18.94313	54.18991	28.04262	
S.D.	0.73733	1.35255	2.59814	1.74227	
C.V.	3.88494	7.14007	4.79451	6.21293	

CORRELATION MATRIX

0.544	0.355	0.321	-0.122
0.354	1.829	-0.137	-0.354
0.040	-0.481	6.750	0.692
-0.157	-0.834	3.135	3.035

COVARIANCE MATRIX

STAT 26 CHNS 4 PTS= 36 APR= 1.4142

	CH 1	CH 2	CH 3	CH 4	CH
MEAN	19.72223	21.19446	44.11111	22.11111	
S.D.	0.77848	0.98010	1.98251	1.03575	
C.V.	3.94721	4.62434	4.49436	4.68428	

CORRELATION MATRIX

0.606	0.334	-0.017	-0.386
0.255	0.961	-0.026	-0.107
-0.026	-0.051	3.930	0.592
-0.311	-0.108	1.216	1.073

COVARIANCE MATRIX

STAT 27 CHNS 4 PTS= 288 APR= 2.3784

	CH 1	CH 2	CH 3	CH 4	CH
MEAN	30.74306	44.86807	62.72917	27.61458	
S.D.	1.80302	2.56929	2.93661	1.28547	
C.V.	5.86480	5.72633	4.68142	4.65505	

CORRELATION MATRIX

3.251	0.363	0.213	0.279
1.683	6.601	0.274	0.190
1.129	2.068	8.624	0.692
0.646	0.628	2.613	1.652

COVARIANCE MATRIX

STAT 28 CHNS 4 PTS= 81 APR= 1.7321

	CH 1	CH 2	CH 3	CH 4	CH
MEAN	28.29630	33.75308	67.46913	32.61729	
S.D.	1.56883	1.93346	3.47165	1.63960	
C.V.	5.54430	5.72826	5.14554	5.02678	

CORRELATION MATRIX

2.461	-0.140	0.573	0.579
-0.426	3.738	-0.115	-0.436
3.122	-0.770	12.052	0.307
1.493	-1.334	4.594	2.648

COVARIANCE MATRIX

STAT 29 CHNS 4 PTS= 216 APR= 2.2134

	CH 1	CH 2	CH 3	CH 4	CH
MEAN	28.06482	43.79630	35.43982	5.80556	
S.D.	1.18334	1.68311	1.79299	0.86759	
C.V.	4.21645	3.84304	5.05926	14.94408	

CORRELATION MATRIX

1.400	0.418	0.079	-0.074
0.832	2.833	-0.018	-0.339
0.167	-0.054	3.215	0.381
-0.076	-0.496	0.593	0.753

COVARIANCE MATRIX

STAT 30 CHNS 4 PTS= 198 APR= 2.1657

	CH 1	CH 2	CH 3	CH 4	CH
MEAN	27.43434	28.01517	72.29797	36.54041	
S.D.	1.40826	1.83971	2.93711	1.87582	
C.V.	5.13319	6.56682	4.06250	5.13356	

CORRELATION MATRIX

1.983	0.468	0.142	-0.228
1.211	3.385	0.032	-0.295
0.586	0.172	8.627	0.624
-0.601	-1.019	3.738	3.519

COVARIANCE MATRIX

STAT 31 CHNS 4 PTS= 54 APR= 1.5651

	CH 1	CH 2	CH 3	CH 4	CH
MEAN	21.94444	18.20370	80.07408	43.14815	
S.D.	1.29466	1.01645	3.85513	2.60917	
C.V.	5.89973	5.58374	4.81445	6.04701	

CORRELATION MATRIX

1.676	0.080	0.281	0.321
0.106	1.033	-0.302	-0.424
1.401	-1.185	14.862	0.835
1.084	-1.125	8.403	6.808

COVARIANCE MATRIX

STAT 32 CHNS 4 PTS= 162 APR= 2.0598

	CH 1	CH 2	CH 3	CH 4	CH
MEAN	30.24074	39.53087	66.06790	30.61111	
S.D.	2.07263	2.31698	2.71670	1.21200	
C.V.	6.85378	5.86120	4.11198	3.95935	

CORRELATION MATRIX

4.296	-0.058	0.254	0.196
-0.277	5.368	0.274	-0.130
1.431	1.727	7.330	0.510
0.492	-0.364	1.679	1.469

COVARIANCE MATRIX

STAT 33 CHNS 4 PTS= 153 APR= 2.0305

	CH 1	CH 2	CH 3	CH 4	CH
MEAN	21.47713	20.52942	12.26144	1.78431	
S.D.	1.34293	0.85101	0.87187	0.44339	
C.V.	6.25283	4.14534	7.11064	24.84930	

CORRELATION MATRIX

1.803	0.031	0.252	-0.224
0.035	0.724	0.025	0.165
0.296	0.018	0.760	-0.177
-0.133	0.062	-0.068	0.197

COVARIANCE MATRIX

STAT 34 CHNS 4 PTS= 54 APR= 1.5651

	CH 1	CH 2	CH 3	CH 4	CH
MEAN	32.03703	50.50000	69.07408	30.55556	
S.D.	1.73719	2.13462	2.82718	1.05791	
C.V.	5.42245	4.22697	4.09297	3.46226	

CORRELATION MATRIX

3.018	0.254	0.257	0.235
0.943	4.557	0.200	0.217
1.262	1.208	7.993	0.673
0.432	0.491	2.014	1.119

COVARIANCE MATRIX

STAT 35 CHNS 4 PTS= 747 APR= 3.0183

	CH 1	CH 2	CH 3	CH 4	CH
MEAN	28.32799	36.74562	60.55295	27.66669	
S.D.	1.27695	2.24133	2.57597	1.40142	
C.V.	4.51481	6.10095	4.25372	5.06537	

CORRELATION MATRIX

1.636	0.207	0.224	0.100
0.595	5.026	0.153	0.026
0.739	0.883	6.641	0.656
0.178	0.081	2.370	1.964

COVARIANCE MATRIX

STAT 36 CHNS 4 PTS= 54 APR= 1.5651

	CH 1	CH 2	CH 3	CH 4	CH
MEAN	23.92592	26.83334	16.18518	2.48148	
S.D.	0.94895	1.20903	1.38884	0.54047	
C.V.	3.96619	4.50569	8.57782	21.77995	

CORRELATION MATRIX

0.901	0.252	0.254	-0.223
0.289	1.462	0.457	0.067
0.335	0.767	1.927	0.156
-0.115	0.044	0.117	0.292

COVARIANCE MATRIX

STAT	1	5553.	28.07	38.46	45.50	18.96
STAT	2	21798.	29.38	40.54	50.81	21.79
STAT	3	5724.	25.60	33.81	41.79	17.41
STAT	4	1332.	20.56	20.59	59.22	30.21
STAT	5	54783.	24.19	26.14	55.83	26.43
STAT	6	747.	24.59	29.69	44.16	19.50
STAT	7	2421.	29.62	40.72	56.93	24.87
STAT	8	288.	24.02	29.57	36.77	14.88
STAT	9	1107.	32.34	46.23	57.20	24.34
STAT	10	15561.	23.41	22.17	62.25	30.88
STAT	11	3627.	26.82	34.55	46.89	21.59
STAT	12	1107.	24.38	31.30	32.77	7.97
STAT	13	8505.	24.63	25.61	61.81	30.23
STAT	14	90.	35.48	52.73	62.18	26.86
STAT	15	556.	23.62	21.28	73.03	38.25
STAT	16	5508.	26.02	30.51	57.05	26.46
STAT	17	2907.	18.13	15.96	58.49	31.60
STAT	18	369.	26.47	44.15	45.84	11.92
STAT	19	189.	24.79	24.51	67.28	34.58
STAT	20	639.	17.85	15.05	64.60	35.90
STAT	21	1026.	22.08	22.56	54.33	26.16
STAT	22	1305.	26.58	29.16	64.16	31.27
STAT	23	90.	23.48	23.10	13.77	1.91
STAT	24	90.	28.42	49.81	43.62	8.16
STAT	25	774.	18.98	18.94	54.19	28.04
STAT	26	36.	19.72	21.19	44.11	22.11
STAT	27	288.	30.74	44.87	62.73	27.61
STAT	28	81.	28.30	33.75	67.47	32.62
STAT	29	216.	28.06	43.80	35.44	5.81
STAT	30	198.	27.43	28.02	72.30	36.54
STAT	31	54.	21.94	18.20	80.07	43.15
STAT	32	162.	30.24	39.53	66.07	30.61
STAT	33	153.	21.48	20.53	12.26	1.78
STAT	34	54.	32.04	50.50	69.07	30.56
STAT	35	747.	28.33	36.75	60.55	27.67
STAT	36	54.	23.93	26.83	16.19	2.48

14 June 1975 Class Means

DIVERGENCE MATRIX FOR STATS 1 TO 36

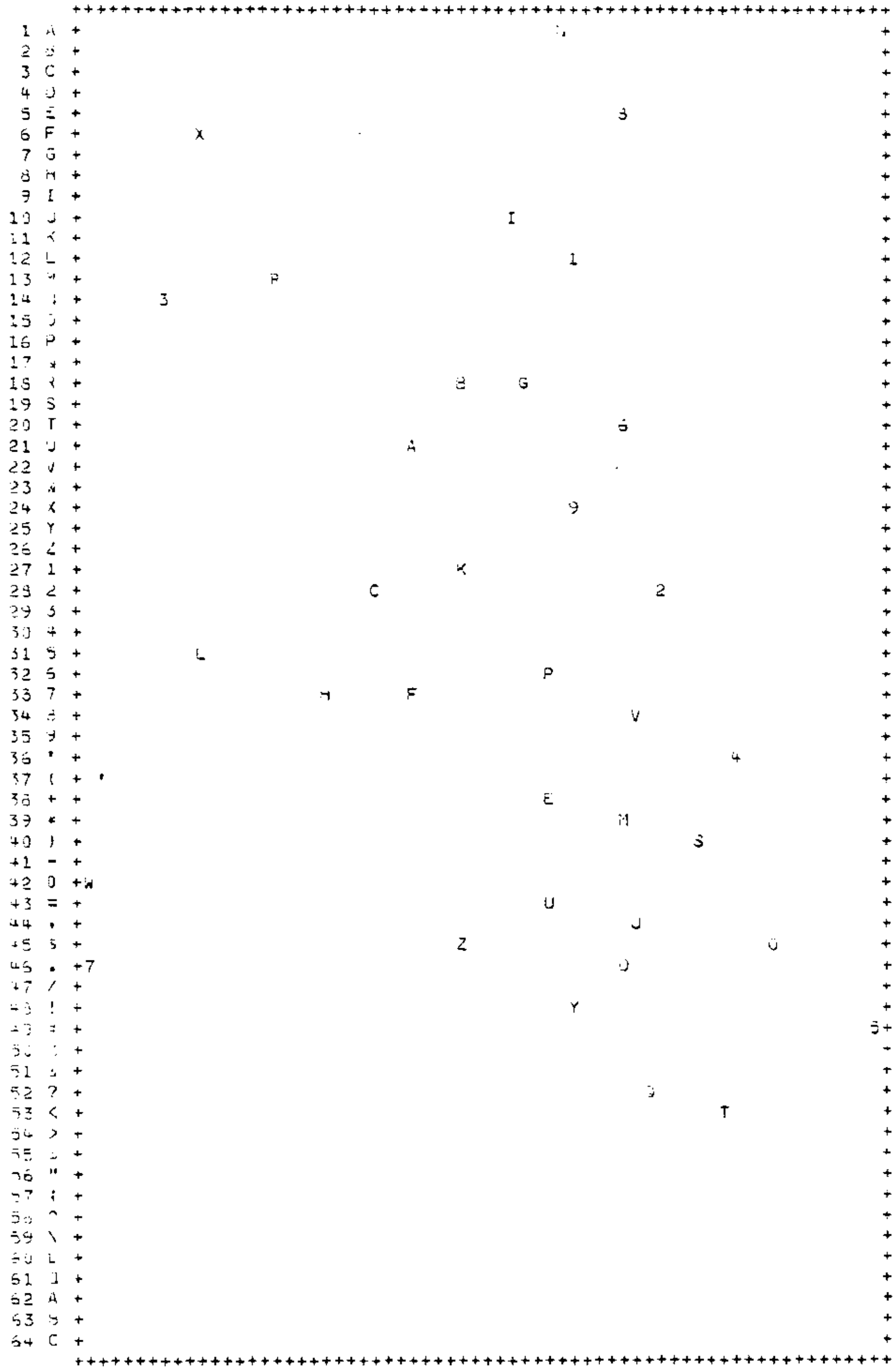
	1	2	3	4	5	6	7	8	9	10	11
2	[illegible]										
3	3	20									
4	270	243	202								
5	31	54	71	25							
6	23	31	9	117	34						
7	36	6	54	235	46	58					
8	65	106	18	339	175	36	193				
9	47	10	64	403	105	90	6	230			
10	239	194	187	8	12	105	182	347	330		
11	11	9	14	135	24	11	16	72	39	103	
12	170	223	97	502	325	143	357	72	377	518	190
13	170	113	152	28	7	90	94	321	190	8	62
14	106	29	106	632	159	139	24	365	8	533	73
15	396	250	352	27	47	243	217	636	361	14	170
16	60	30	63	61	5	38	23	179	63	38	13
17	479	463	355	26	97	225	462	493	718	67	291
18	65	80	69	377	166	92	120	165	125	375	38
19	265	167	241	36	25	161	137	494	256	11	106
20	639	631	544	44	150	369	603	763	916	87	419
21	162	150	117	12	8	55	151	206	268	14	74
22	157	36	148	61	15	97	63	339	135	33	50
23	1393	1725	1067	3224	2526	1386	2385	850	2332	3481	1649
24	181	196	200	762	381	256	256	364	258	717	232
25	251	238	180	9	43	107	258	286	392	37	143
26	227	268	127	65	67	62	308	133	484	107	143
27	82	22	92	332	79	105	8	304	10	266	42
28	169	71	178	139	46	144	44	434	94	93	60
29	212	264	176	670	368	228	394	237	413	667	251
30	278	136	273	80	47	204	102	591	180	43	106
31	637	449	536	44	93	387	422	994	678	40	295
32	143	54	158	229	65	143	25	398	46	171	61
33	2184	2739	1663	4611	3640	2044	3649	1261	3703	4949	2524
34	173	64	179	532	161	215	40	519	33	443	107
35	75	26	37	163	32	73	9	249	34	116	24
36	846	1022	631	2020	1514	846	1421	518	1412	2131	975

	12	13	14	15	16	17	18	19	20	21	22
13	511										
14	616	315									
15	907	31	609								
16	337	13	107	68							
17	675	113	1059	78	175						
18	86	276	253	516	137	686					
19	694	8	439	10	33	120	356				
20	981	148	1359	67	241	9	893	130			
21	383	23	413	73	34	58	305	52	113		
22	538	6	233	45	9	180	260	15	222	49	
23	420	3392	3002	5281	2572	3467	996	4302	4561	2559	3572
24	129	551	462	901	317	1245	23	669	1549	630	504
25	426	63	575	68	86	10	317	85	35	17	103
26	238	132	719	253	124	93	419	214	190	35	188
27	490	136	18	266	46	615	163	176	761	233	66
28	713	40	181	35	24	310	272	43	362	120	10
29	56	600	744	1015	378	1002	54	731	1362	540	614
30	325	27	328	21	40	201	352	12	201	99	12
31	1213	63	1190	12	140	85	703	49	56	133	119
32	546	33	79	161	36	456	240	100	545	175	38
33	637	4837	4768	7507	3756	4943	1647	6166	6456	3614	5159
34	757	241	36	401	109	910	278	283	1073	410	159
35	433	50	64	139	12	350	157	76	446	108	25
36	196	2080	1932	3301	1526	2302	476	2690	3077	1539	2168

	23	24	25	26	27	28	29	30	31	32	33
24	345										
25	2727	690									
26	1662	325	35								
27	2963	312	321	447							
28	4072	492	136	314	43						
29	534	32	578	586	540	739					
30	4938	602	149	331	111	18	842				
31	6764	1204	89	362	642	210	1336	75			
32	3664	420	262	400	13	13	683	52	360		
33	12	1582	3932	2403	4567	5279	996	7076	9583	5407	
34	3516	463	497	713	9	88	330	175	816	26	5851
35	2891	322	165	259	10	13	477	53	292	8	4296
36	11	432	1757	1113	1761	2496	282	3049	4251	2236	67

	34	35
35	42	
36	2315	1726

14 June 1975 Divergence Matrix



14 June 1975 Two-space Plot

STAT 1 CHNS 4 PTS= 35833 APR= 7.9437

	CH 1	CH 2	CH 3	CH 4	CH
MEAN	25.99597	35.00023	48.89471	44.20351	
S.D.	1.68707	2.89886	2.30411	2.61019	
C.V.	6.48975	8.28240	4.71239	5.90493	

CORRELATION MATRIX

2.346	0.579	0.251	-0.058
2.332	8.403	0.204	-0.174
0.976	1.364	5.309	0.643
-0.257	-1.314	3.868	6.813

COVARIANCE MATRIX

STAT 2 CHNS 4 PTS= 648 APR= 2.9130

	CH 1	CH 2	CH 3	CH 4	CH
MEAN	17.36577	17.13426	57.72531	65.46606	
S.D.	0.95144	1.12394	2.91852	3.83105	
C.V.	5.47882	6.55959	5.05588	5.85197	

CORRELATION MATRIX

0.905	0.285	0.211	0.068
0.304	1.263	0.171	0.065
0.585	0.563	8.518	0.743
0.248	0.280	8.309	14.677

COVARIANCE MATRIX

STAT 3 CHNS 4 PTS= 3843 APR= 4.5458

	CH 1	CH 2	CH 3	CH 4	CH
MEAN	18.69527	20.15431	61.30627	67.92401	
S.D.	0.92524	1.22687	3.73598	4.51869	
C.V.	4.94905	6.08737	6.09397	6.65256	

CORRELATION MATRIX

0.856	0.339	0.114	0.106
0.384	1.505	-0.038	-0.190
0.395	-0.176	13.958	0.810
0.442	-1.055	13.680	20.419

COVARIANCE MATRIX

STAT 4 CHNS 4 PTS= 2943 APR= 4.2524

	CH 1	CH 2	CH 3	CH 4	CH
MEAN	20.10733	25.86880	36.92561	34.92085	
S.D.	1.12463	1.62543	1.98405	2.06752	
C.V.	5.59312	6.28343	5.37309	5.92059	

CORRELATION MATRIX

1.265	0.399	0.190	0.011
0.710	2.642	0.184	0.115
0.424	0.594	3.936	0.648
0.025	0.386	2.659	4.275

COVARIANCE MATRIX

STAT 5 CHNS 4 PTS= 40365 APR= 6.1935

	CH 1	CH 2	CH 3	CH 4	CH
MEAN	25.16582	33.63780	44.30016	39.18065	
S.D.	1.35122	2.18362	2.45995	2.43354	
C.V.	5.36926	6.49158	5.55291	6.21107	

CORRELATION MATRIX

1.826	0.413	0.206	0.061
1.219	4.768	0.251	0.023
0.685	1.346	6.051	0.714
0.199	0.122	4.276	5.922

COVARIANCE MATRIX

STAT 6 CHNS 4 PTS= 1953 APR= 3.8381

	CH 1	CH 2	CH 3	CH 4	CH
MEAN	22.59804	28.31798	59.32770	60.17358	
S.D.	1.42127	2.08859	3.17787	3.82895	
C.V.	6.28936	7.37548	5.35648	6.36317	

CORRELATION MATRIX

2.020	0.437	0.005	-0.152
1.297	4.362	0.034	-0.189
0.024	0.226	10.099	0.781
-0.826	-1.509	9.507	14.661

COVARIANCE MATRIX

STAT 7 CHNS 4 PTS= 6930 APR= 5.2677

	CH 1	CH 2	CH 3	CH 4	CH
MEAN	23.25854	30.36884	39.52182	35.54926	
S.D.	1.38451	2.17306	2.06007	2.33360	
C.V.	5.95270	7.15555	5.21250	6.56440	

CORRELATION MATRIX

1.917	0.551	0.052	-0.309
1.658	4.722	0.051	-0.323
0.149	0.227	4.244	0.610
-0.998	-1.640	2.931	5.446

COVARIANCE MATRIX

STAT 8 CHNS 4 PTS= 792 APR= 3.0628

	CH 1	CH 2	CH 3	CH 4	CH
MEAN	29.81693	42.52272	54.97346	48.68181	
S.D.	2.09761	2.69332	2.74311	2.84558	
C.V.	7.03497	6.33500	4.98988	5.84527	

CORRELATION MATRIX

4.400	0.124	0.240	-0.046
0.703	7.257	0.221	0.002
1.382	1.633	7.525	0.660
-0.277	0.015	5.152	8.097

COVARIANCE MATRIX

08 April 1981 Class Stats

STAT 9 CHNS 4 PTS= 238 APR= 2.3784

	CH 1	CH 2	CH 3	CH 4	CH
MEAN	16.15973	14.82292	61.81943	73.78819	
S.D.	0.86060	0.99471	2.76929	3.60410	
C.V.	5.32560	6.71059	4.47965	4.88439	

CORRELATION MATRIX

0.741	0.261	-0.049	-0.087
0.223	0.989	-0.165	-0.265
-0.118	-0.509	7.669	0.752
-0.269	-0.950	7.505	12.990

COVARIANCE MATRIX

STAT 10 CHNS 4 PTS= 2997 APR= 4.2718

	CH 1	CH 2	CH 3	CH 4	CH
MEAN	24.42543	32.08813	54.48715	52.60628	
S.D.	1.36400	2.57491	2.70853	2.79310	
C.V.	5.58433	8.02450	4.97095	5.30944	

CORRELATION MATRIX

1.860	0.285	0.211	0.049
1.000	6.630	0.238	0.046
0.778	1.658	7.336	0.685
0.186	0.328	5.181	7.801

COVARIANCE MATRIX

STAT 11 CHNS 4 PTS= 18 APR= 1.1892

	CH 1	CH 2	CH 3	CH 4	CH
MEAN	62.11111	77.61111	93.22223	79.61111	
S.D.	2.54084	3.75930	4.75889	5.38107	
C.V.	4.09060	4.84377	5.10489	6.75919	

CORRELATION MATRIX

6.456	0.762	0.582	0.489
7.279	14.132	0.926	0.891
7.033	16.559	22.647	0.932
6.691	18.015	23.857	28.956

COVARIANCE MATRIX

STAT 12 CHNS 4 PTS= 2808 APR= 4.2028

	CH 1	CH 2	CH 3	CH 4	CH
MEAN	19.96225	23.14207	58.23326	61.93661	
S.D.	1.17175	1.49563	3.51434	4.29646	
C.V.	5.86983	6.46282	6.03493	6.93687	

CORRELATION MATRIX

1.373	0.410	0.090	-0.025
0.719	2.237	-0.098	-0.238
0.371	-0.514	12.351	0.825
-0.128	-1.529	12.455	18.460

COVARIANCE MATRIX

STAT 13 CHNS 4 PTS= 3807 APR= 4.5351

	CH 1	CH 2	CH 3	CH 4	CH
MEAN	27.28030	37.16969	53.37195	49.02600	
S.D.	1.51737	2.21790	2.48786	2.71510	
C.V.	5.56215	5.96696	4.66136	5.53809	

CORRELATION MATRIX

2.302	0.140	0.053	-0.090
0.470	4.919	0.111	-0.122
0.200	0.613	6.189	0.677
-0.370	-0.734	4.576	7.372

COVARIANCE MATRIX

STAT 14 CHNS 4 PTS= 1539 APR= 3.6162

	CH 1	CH 2	CH 3	CH 4	CH
MEAN	18.07993	17.03448	65.42625	75.40482	
S.D.	0.92114	1.24103	2.98523	3.20699	
C.V.	5.09484	7.28539	4.56274	4.25303	

CORRELATION MATRIX

0.849	0.344	0.189	0.072
0.393	1.540	0.220	0.039
0.521	0.813	8.912	0.643
0.213	0.157	6.152	10.285

COVARIANCE MATRIX

STAT 15 CHNS 4 PTS= 324 APR= 2.4495

	CH 1	CH 2	CH 3	CH 4	CH
MEAN	27.75926	39.40433	59.49692	55.83025	
S.D.	1.41770	2.65324	2.70935	2.96611	
C.V.	5.10712	6.73337	4.55376	5.31273	

CORRELATION MATRIX

2.010	0.150	0.151	0.194
0.565	7.040	0.444	0.180
0.581	3.191	7.341	0.730
0.815	1.418	5.867	8.798

COVARIANCE MATRIX

STAT 16 CHNS 4 PTS= 522 APR= 2.7597

	CH 1	CH 2	CH 3	CH 4	CH
MEAN	23.12642	28.33525	45.73178	42.66093	
S.D.	1.25766	1.49106	2.39521	2.64913	
C.V.	5.43818	5.26220	5.23752	6.20973	

CORRELATION MATRIX

1.582	0.530	-0.021	-0.148
0.994	2.223	-0.115	-0.277
-0.064	-0.412	5.737	0.747
-0.494	-1.094	4.738	7.018

COVARIANCE MATRIX

STAT 17 CHNS 4 PTS= 108 APR= 1.8612

	CH 1	CH 2	CH 3	CH 4	CH
MEAN	13.26852	12.64815	12.47222	8.21296	
S.D.	0.67820	0.97936	0.88030	1.08560	
C.V.	5.11133	7.74312	7.05811	13.21809	

CORRELATION MATRIX

0.460	0.242	0.193	0.404
0.161	0.959	0.270	0.177
0.115	0.233	0.775	0.236
0.297	0.188	0.226	1.179

COVARIANCE MATRIX

STAT 18 CHNS 4 PTS= 288 APR= 2.3784

	CH 1	CH 2	CH 3	CH 4	CH
MEAN	18.66669	17.28471	72.64931	84.03473	
S.D.	0.88690	1.35733	3.82090	3.21094	
C.V.	4.75123	7.85276	5.25938	3.82096	

CORRELATION MATRIX

0.787	0.473	0.403	0.216
0.569	1.842	0.414	-0.111
1.366	2.150	14.599	0.538
0.616	-0.483	6.603	10.310

COVARIANCE MATRIX

STAT 19 CHNS 4 PTS= 63 APR= 1.6266

	CH 1	CH 2	CH 3	CH 4	CH
MEAN	18.23811	19.96825	51.03175	53.95238	
S.D.	0.83653	1.10691	2.54595	1.98736	
C.V.	4.58672	5.54333	4.98895	3.68355	

CORRELATION MATRIX

0.700	0.461	0.314	0.074
0.427	1.225	0.144	-0.037
0.569	0.405	6.482	0.641
0.124	-0.062	3.243	3.950

COVARIANCE MATRIX

STAT 20 CHNS 4 PTS= 666 APR= 2.9330

	CH 1	CH 2	CH 3	CH 4	CH
MEAN	22.00754	27.24472	51.93094	51.59308	
S.D.	1.19149	1.60638	2.52099	2.79150	
C.V.	5.41400	5.89611	4.85431	5.41061	

CORRELATION MATRIX

1.420	0.425	-0.111	-0.294
0.614	2.580	-0.040	-0.157
-0.333	-0.161	6.355	0.624
-0.973	-0.704	4.389	7.792

COVARIANCE MATRIX

STAT 21 CHNS 4 PTS= 684 APR= 2.9526

	CH 1	CH 2	CH 3	CH 4	CH
MEAN	23.69597	29.15211	14.99708	4.06433	
S.D.	0.94872	1.12436	1.12342	0.99130	
C.V.	4.00373	3.85687	7.49095	24.39020	

CORRELATION MATRIX

0.900	0.153	0.174	0.066
0.163	1.264	0.221	0.268
0.186	0.279	1.262	0.264
0.062	0.299	0.294	0.983

COVARIANCE MATRIX

STAT 22 CHNS 4 PTS= 324 APR= 2.4495

	CH 1	CH 2	CH 3	CH 4	CH
MEAN	22.32408	28.79321	35.03397	30.64813	
S.D.	1.13051	1.74463	1.36782	1.63380	
C.V.	5.06409	6.05917	3.90428	5.33084	

CORRELATION MATRIX

1.278	0.486	0.247	0.121
0.959	3.044	0.165	0.055
0.382	0.394	1.871	0.420
0.223	0.156	0.938	2.669

COVARIANCE MATRIX

STAT 23 CHNS 4 PTS= 126 APR= 1.9343

	CH 1	CH 2	CH 3	CH 4	CH
MEAN	14.98413	14.21429	14.91270	9.78571	
S.D.	1.03525	1.17035	1.09559	1.21726	
C.V.	6.90900	8.23362	7.34668	12.43915	

CORRELATION MATRIX

1.072	0.531	0.119	-0.085
0.643	1.370	0.214	0.016
0.135	0.275	1.200	0.436
-0.107	0.022	0.581	1.482

COVARIANCE MATRIX

STAT 24 CHNS 4 PTS= 153 APR= 2.0305

	CH 1	CH 2	CH 3	CH 4	CH
MEAN	30.06496	45.80392	60.03922	54.67320	
S.D.	1.98670	2.71736	2.19121	2.62038	
C.V.	6.60362	5.93193	3.64963	4.79280	

CORRELATION MATRIX

3.947	0.296	0.020	-0.025
1.596	7.332	0.149	-0.222
0.089	0.889	4.801	0.608
-0.129	-1.578	3.493	6.866

COVARIANCE MATRIX

STAT 25 CHNS 4 PTS= 180 APR= 2.1147

	CH 1	CH 2	CH 3	CH 4	CH
MEAN	19.88889	23.57777	49.72778	49.66667	
S.D.	1.12814	1.49475	2.10031	2.22472	
C.V.	5.67221	6.33968	4.22362	4.47930	

CORRELATION MATRIX

1.273	0.224	0.228	-0.315
0.377	2.234	-0.113	-0.219
0.540	-0.355	4.411	0.399
-0.791	-0.728	1.864	4.949

COVARIANCE MATRIX

STAT 26 CHNS 4 PTS= 108 APR= 1.8612

	CH 1	CH 2	CH 3	CH 4	CH
MEAN	26.54630	39.30556	28.36111	9.16667	
S.D.	1.21805	2.03460	1.84156	0.88074	
C.V.	4.58840	5.17637	6.49327	9.60806	

CORRELATION MATRIX

1.484	0.023	0.003	-0.068
0.056	4.140	0.636	0.331
0.006	2.384	3.391	0.435
-0.073	0.593	0.706	0.776

COVARIANCE MATRIX

STAT 27 CHNS 4 PTS= 54 APR= 1.5651

	CH 1	CH 2	CH 3	CH 4	CH
MEAN	31.61111	49.68520	66.37038	59.22223	
S.D.	1.41968	2.82718	2.52721	2.79930	
C.V.	4.49107	5.69018	3.80774	4.72678	

CORRELATION MATRIX

2.015	0.331	0.246	0.492
1.328	7.993	-0.116	-0.187
0.882	-0.825	6.387	0.655
1.955	-1.476	4.632	7.836

COVARIANCE MATRIX

STAT 28 CHNS 4 PTS= 72 APR= 1.6818

	CH 1	CH 2	CH 3	CH 4	CH
MEAN	18.91666	24.76389	31.00000	27.98611	
S.D.	0.86828	1.19272	1.50117	1.61410	
C.V.	4.59002	4.81639	4.84250	5.76749	

CORRELATION MATRIX

0.754	0.321	0.043	-0.021
0.332	1.423	-0.118	-0.258
0.057	-0.211	2.254	0.645
-0.029	-0.496	1.563	2.605

COVARIANCE MATRIX

STAT 29 CHNS 4 PTS= 171 APR= 2.0878

	CH 1	CH 2	CH 3	CH 4	CH
MEAN	20.47368	20.77777	10.86550	2.98830	
S.D.	1.00202	0.92554	0.83281	0.88110	
C.V.	4.89419	4.45446	7.66469	29.48489	

CORRELATION MATRIX

1.004	-0.031	0.013	0.226
-0.029	0.857	0.297	-0.018
0.011	0.229	0.694	-0.106
0.200	-0.014	-0.078	0.776

COVARIANCE MATRIX

STAT 30 CHNS 4 PTS= 117 APR= 1.8988

	CH 1	CH 2	CH 3	CH 4	CH
MEAN	21.13675	27.08548	40.26495	38.43590	
S.D.	1.26570	1.37422	1.80710	1.96686	
C.V.	5.98816	5.07363	4.48803	5.11725	

CORRELATION MATRIX

1.602	0.573	0.018	-0.239
0.997	1.888	0.272	-0.135
0.041	0.675	3.266	0.559
-0.594	-0.365	1.987	3.869

COVARIANCE MATRIX

STAT 31 CHNS 4 PTS= 252 APR= 2.3003

	CH 1	CH 2	CH 3	CH 4	CH
MEAN	24.34525	35.57541	59.18651	57.12698	
S.D.	1.30725	2.53835	2.18493	2.89658	
C.V.	5.36965	7.13513	3.69160	5.07043	

CORRELATION MATRIX

1.709	0.024	-0.009	-0.046
0.079	6.443	0.086	-0.387
-0.025	0.478	4.774	0.564
-0.176	-2.847	3.570	8.390

COVARIANCE MATRIX

STAT 32 CHNS 4 PTS= 792 APR= 3.0628

	CH 1	CH 2	CH 3	CH 4	CH
MEAN	18.81187	23.46593	33.67551	31.61366	
S.D.	0.84051	1.28709	1.58994	1.67018	
C.V.	4.46800	5.48494	4.72134	5.28310	

CORRELATION MATRIX

0.706	0.282	0.268	0.275
0.305	1.657	0.297	0.331
0.358	0.607	2.528	0.550
0.335	0.711	1.450	2.790

COVARIANCE MATRIX

STAT 33 CHNS 4 PTS= 18 APR= 1.1892

	CH 1	CH 2	CH 3	CH 4	CH
MEAN	117.11111	126.72223	126.83333	121.61111	
S.D.	8.11566	0.66697	0.38348	4.57776	
C.V.	6.92988	0.52633	0.30235	3.76426	

CORRELATION MATRIX

65.864	0.669	0.631	0.760
3.621	0.445	0.949	0.637
1.963	0.243	0.147	0.733
28.221	1.945	1.287	20.956

COVARIANCE MATRIX

STAT 34 CHNS 4 PTS= 90 APR= 1.7783

	CH 1	CH 2	CH 3	CH 4	CH
MEAN	20.07777	22.91112	64.71111	70.97778	
S.D.	0.85110	0.94373	2.33320	2.97921	
C.V.	4.23901	4.11909	3.60556	4.19739	

CORRELATION MATRIX

0.724	0.261	-0.163	-0.252
0.209	0.891	-0.094	-0.417
-0.324	-0.206	5.444	0.416
-0.633	-1.171	2.393	8.876

COVARIANCE MATRIX

STAT 1	35838.	26.00	35.00	48.89	44.20
STAT 2	648.	17.37	17.13	57.73	65.47
STAT 3	3843.	18.70	20.15	61.31	67.92
STAT 4	2943.	20.11	25.87	36.93	34.92
STAT 5	40365.	25.17	33.64	44.30	39.18
STAT 6	1953.	22.60	28.32	59.33	60.17
STAT 7	6930.	23.26	30.37	39.52	35.55
STAT 8	792.	29.82	42.52	54.97	48.68
STAT 9	288.	16.16	14.82	61.82	73.79
STAT 10	2997.	24.43	32.09	54.49	52.61
STAT 11	18.	62.11	77.61	93.22	79.61
STAT 12	2808.	19.96	23.14	58.23	61.94
STAT 13	3807.	27.28	37.17	53.37	49.03
STAT 14	1539.	18.08	17.03	65.43	75.40
STAT 15	324.	27.76	39.40	59.50	55.83
STAT 16	522.	23.13	28.34	45.73	42.66
STAT 17	108.	13.27	12.65	12.47	8.21
STAT 18	288.	18.67	17.28	72.65	84.03
STAT 19	63.	18.24	19.97	51.03	53.95
STAT 20	666.	22.01	27.24	51.93	51.59
STAT 21	684.	23.70	29.15	15.00	4.06
STAT 22	324.	22.32	28.79	35.03	30.65
STAT 23	126.	14.98	14.21	14.91	9.79
STAT 24	153.	30.08	45.80	60.04	54.67
STAT 25	180.	19.89	23.58	49.73	49.67
STAT 26	108.	26.55	39.31	28.36	9.17
STAT 27	54.	31.61	49.69	66.37	59.22
STAT 28	72.	18.92	24.76	31.00	27.99
STAT 29	171.	20.47	20.78	10.87	2.99
STAT 30	117.	21.14	27.09	40.26	38.44
STAT 31	252.	24.35	35.58	59.19	57.13
STAT 32	792.	18.81	23.47	33.68	31.61
STAT 33	18.	117.11	126.72	126.83	121.61
STAT 34	90.	20.08	22.91	64.71	70.98

08 April 1981 Class Means

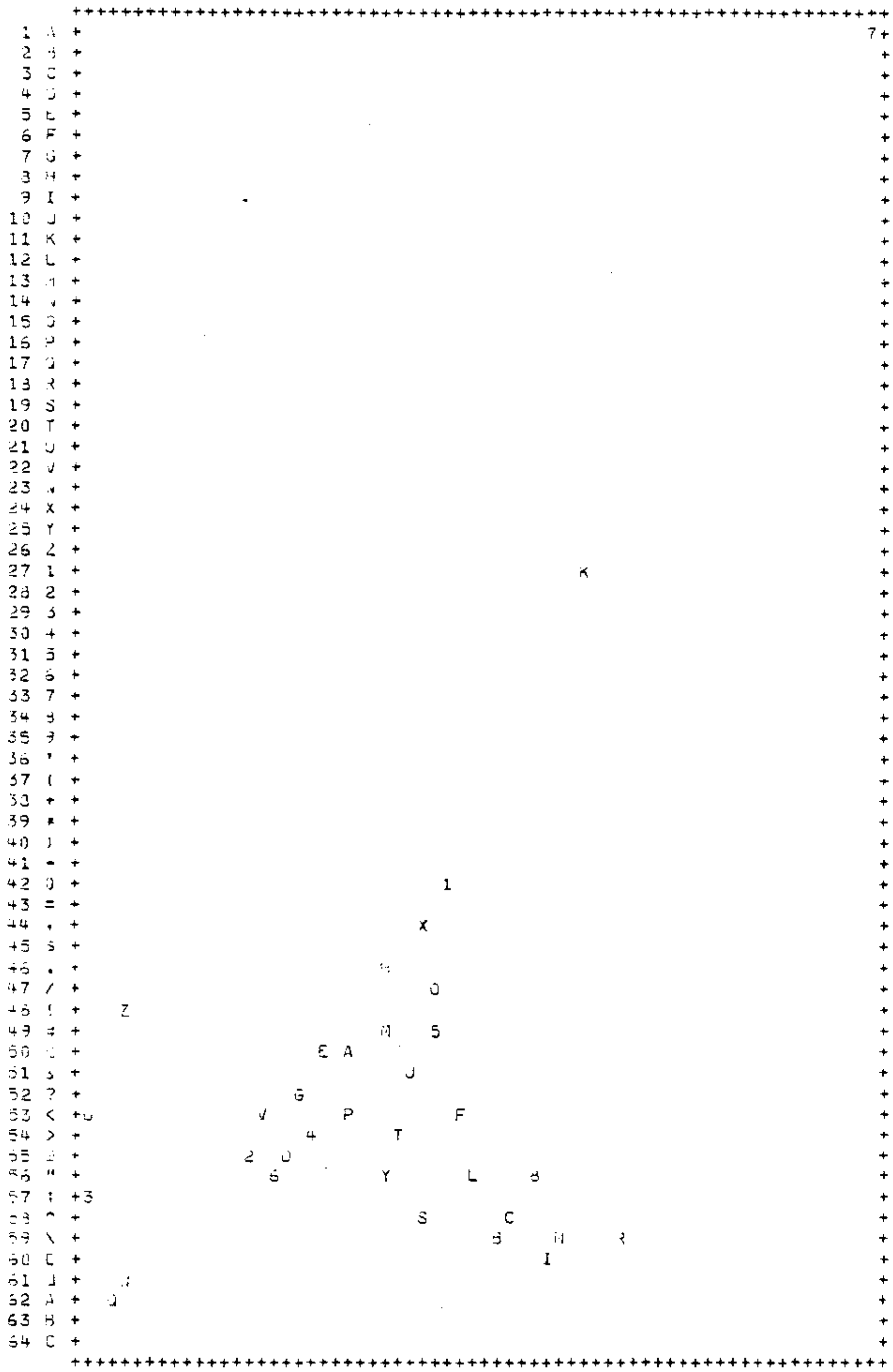
DIVERGENCE MATRIX FOR STATS 1 TO 34

0	1	2	3	4	5	6	7	8	9	10	11
2	215										
3	142	8									
4	52	212	133								
5	5	251	176	30							
6	34	73	35	116	60						
7	26	208	150	10	7	89					
8	13	377	257	133	32	54	82				
9	317	10	28	319	360	132	295	543			
10	12	145	88	80	29	9	58	25	236		
11	481	2546	2178	1263	660	794	1055	343	3760	628	
12	58	25	6	119	94	10	96	156	58	36	1363
13	6	268	169	102	20	30	61	7	383	9	612
14	261	10	11	347	325	79	309	383	9	172	2493
15	23	295	198	144	47	33	106	11	453	12	461
16	17	134	69	24	11	36	11	82	208	23	1144
17	1372	2640	2375	699	1065	2321	856	1355	3462	1316	6856
18	328	32	24	475	410	99	416	434	25	218	2746
19	133	29	30	115	153	51	126	277	85	84	2326
20	22	82	47	66	35	11	47	74	144	9	1220
21	1229	3011	3065	801	939	2304	781	1491	3803	1763	5024
22	87	438	422	12	38	273	11	180	622	173	1527
23	850	1424	1563	417	662	1350	536	1191	1858	1105	4401
24	41	426	291	220	76	60	160	8	624	34	354
25	49	59	49	62	57	38	52	143	119	37	1853
26	1037	3017	3031	719	790	2157	640	1249	3887	1600	4260
27	85	563	423	318	131	106	247	32	873	69	360
28	190	367	371	20	119	315	58	390	523	255	3013
29	2616	5309	5708	1490	2018	4608	1622	3321	6666	3589	9999
30	38	210	179	5	20	103	6	123	317	64	1383
31	31	186	111	157	60	11	117	26	291	7	849
32	113	390	375	7	76	230	38	245	597	154	2084
33	9999	9999	9999	9999	9999	9999	9999	9999	9999	9999	6913
34	169	51	13	281	209	28	227	312	86	93	3515

0	12	13	14	15	16	17	18	19	20	21	22
13	34										
14	34	280									
15	101	3	300								
16	43	43	195	77							
17	2381	1768	3666	2208	1215						
18	53	330	8	342	264	4723					
19	19	178	90	212	70	1925	166				
20	15	36	119	55	12	1752	170	36			
21	2486	1520	4020	1961	1161	470	4990	2209	1745		
22	292	157	679	255	55	672	929	256	154	567	
23	1326	1130	2036	1385	748	11	2628	1119	1052	260	426
24	160	22	401	8	149	2437	440	342	109	1987	316
25	24	36	125	123	19	1713	208	12	10	1774	152
26	2339	1312	4034	1754	1018	714	5008	2127	1593	124	514
27	251	58	542	23	241	3011	580	480	184	2451	468
28	233	304	593	428	104	519	813	232	201	553	23
29	4774	3253	7153	4181	2363	250	3996	3846	3426	84	1266
30	109	83	345	135	11	953	485	102	47	990	26
31	54	13	133	9	71	2397	211	143	54	2161	292
32	253	188	632	251	63	565	367	208	138	318	25
33	9999	9999	9999	9999	9999	9999	9999	9999	9999	9999	9999
34	11	137	34	231	119	3631	42	88	57	3496	549

0	23	24	25	26	27	28	29	30	31	32	33
24	1509										
25	1026	206									
26	398	1672	1579								
27	1992	11	320	2046							
28	323	592	174	505	616						
29	160	4299	3309	445	5291	1002					
30	593	216	45	869	327	54	1883				
31	1505	27	87	1905	63	423	4438	135			
32	336	365	132	782	505	8	1296	26	271		
33	9999	9999	9999	9999	9999	9999	9999	9999	9999	9999	
34	2134	385	94	3379	576	565	6566	254	120	520	9999

08 April 1981 Divergence Matrix



08 April 1981 Two-space Plot

Appendix C

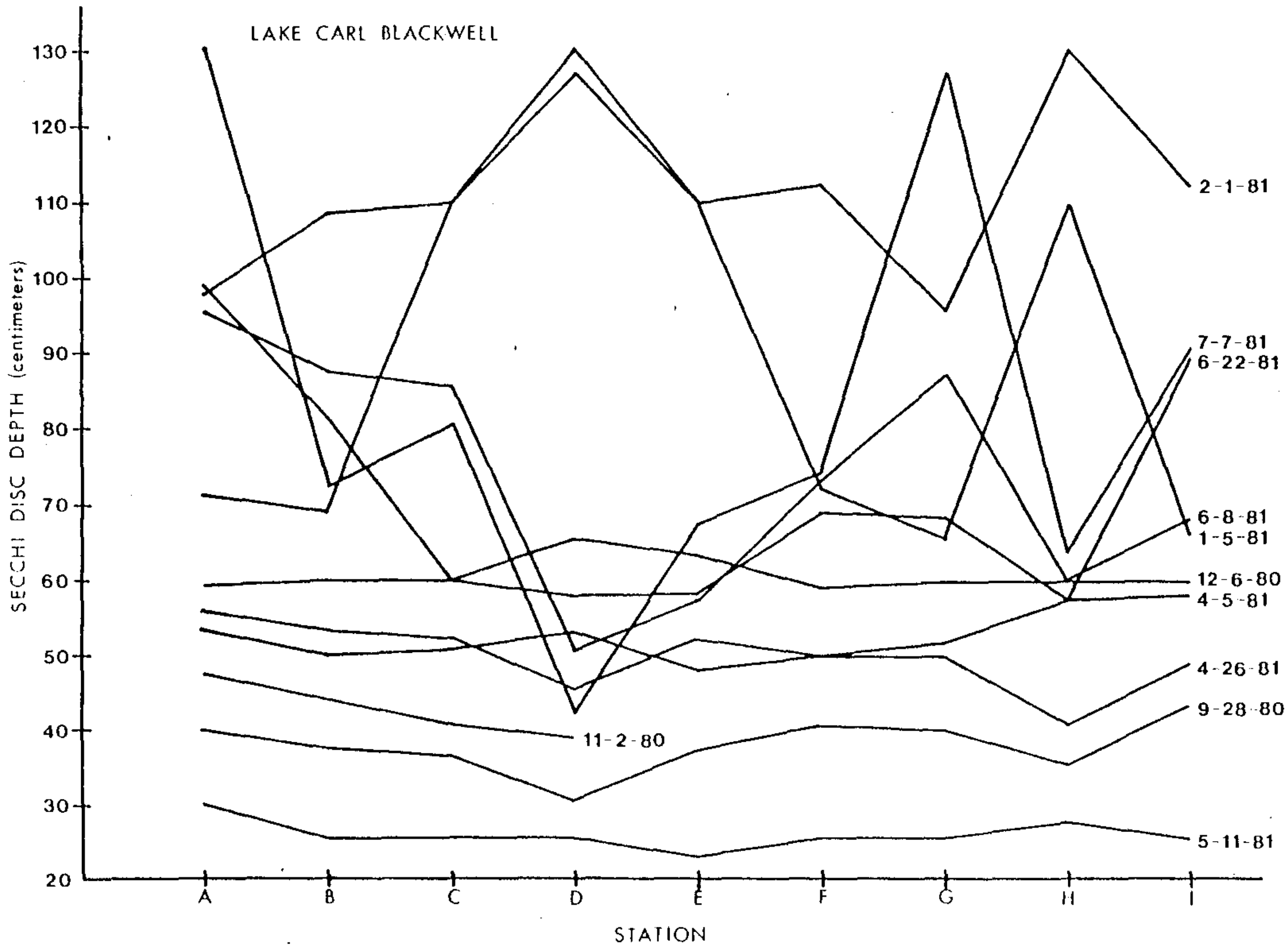
Water Quality Data

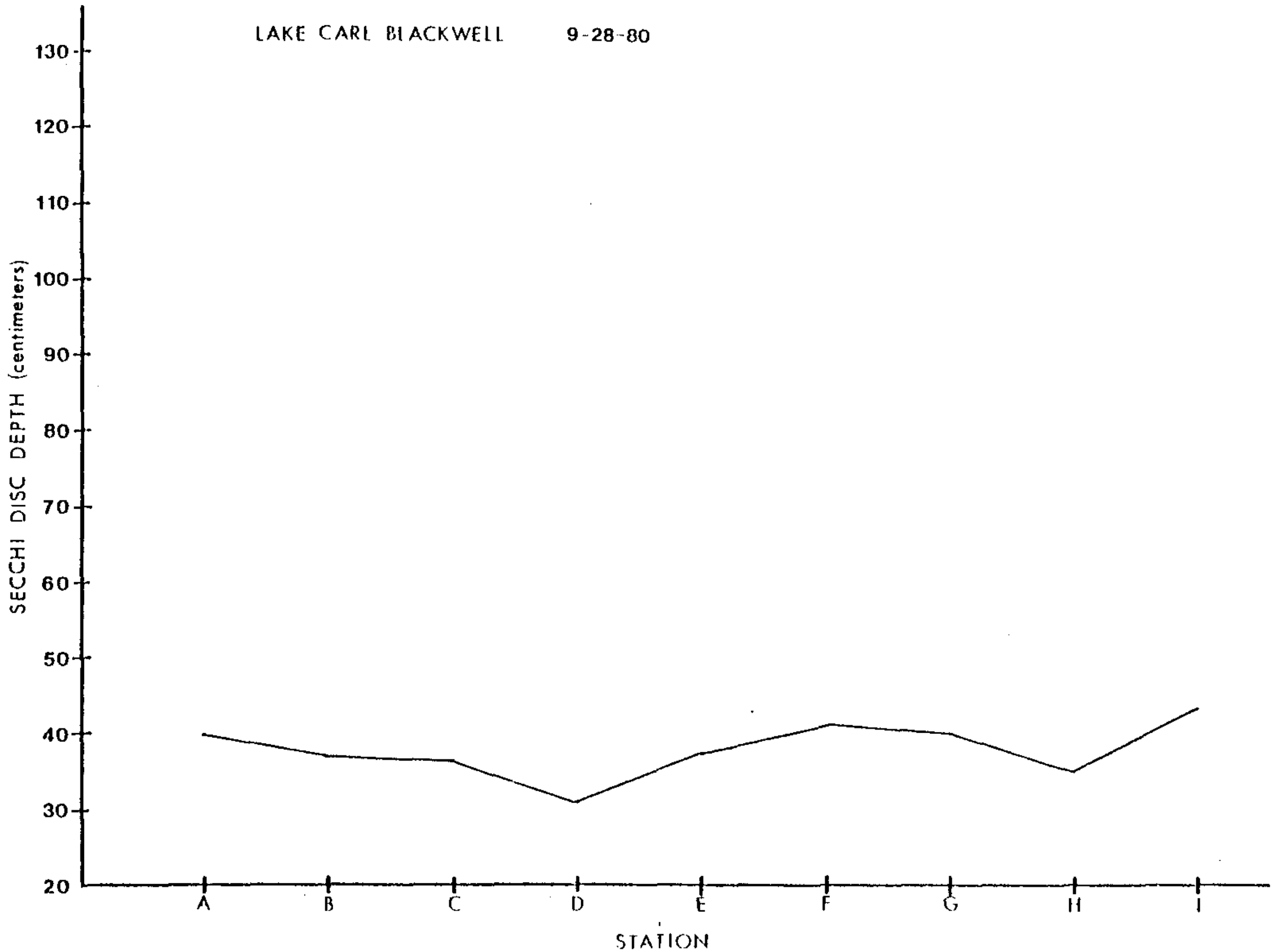
WATER QUALITY DATA FOR LAKE CARL BLACKWELL, LAKE MCMURTRY, AND BOOMER LAKE

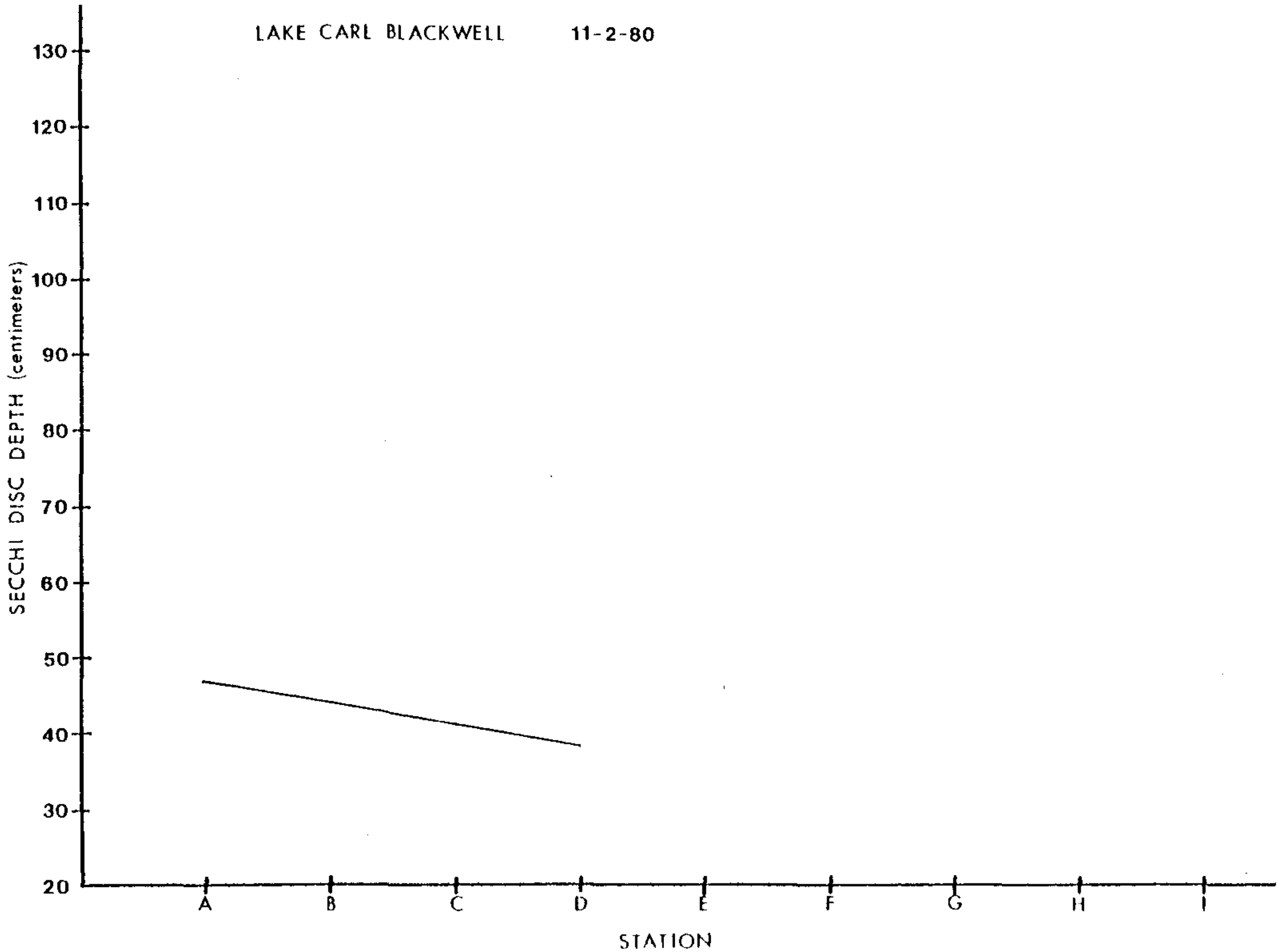
(Figures represent an average for the entire water body)

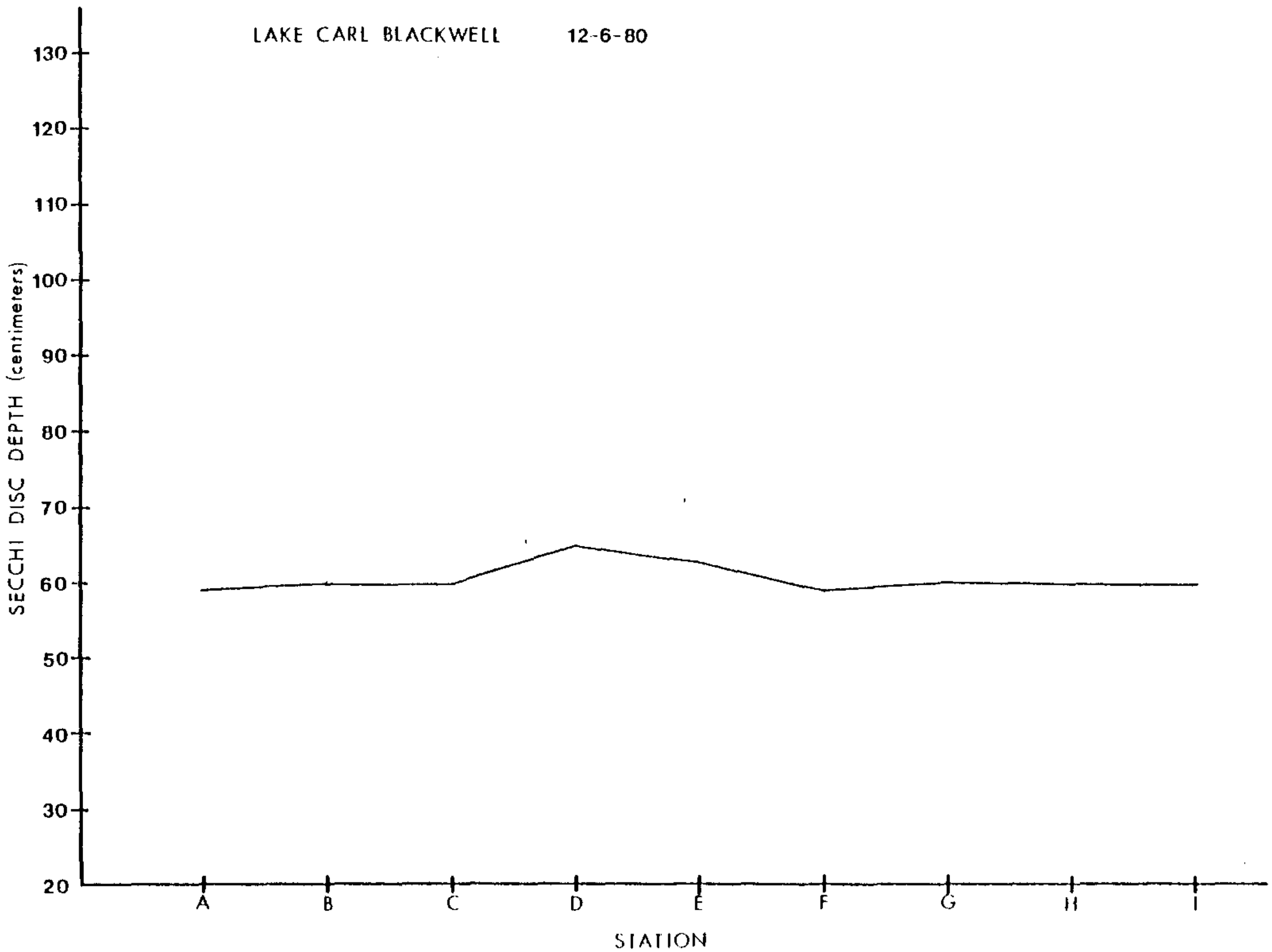
	DISSOLVED OXYGEN (ppm)	CARBON DIOXIDE (ppm)	NITRATES (ppm)	PHOSPHATES (ppm)
LAKE CARL BLACKWELL				
MARCH 8, 1981	10.0	NA	3.0*	17.0*
APRIL 5, 1981	9.0	NA	74.0*	39.0*
JULY 20, 1981	8.6	NA	NA	NA
LAKE MCMURTRY				
MARCH 25, 1981	10.0	4.0	<1.0	<1.0
APRIL 7, 1981	8.8	6.0	Trace	Trace
JULY 15, 1981	14.6	4.0	<1.0	<1.0
BOOMER LAKE				
MARCH 25, 1981	10.0	4.0	<1.0	<1.0
APRIL 7, 1981	8.6	5.0	Trace	Trace
JULY 15, 1981	14.0	4.0	<1.0	<1.0

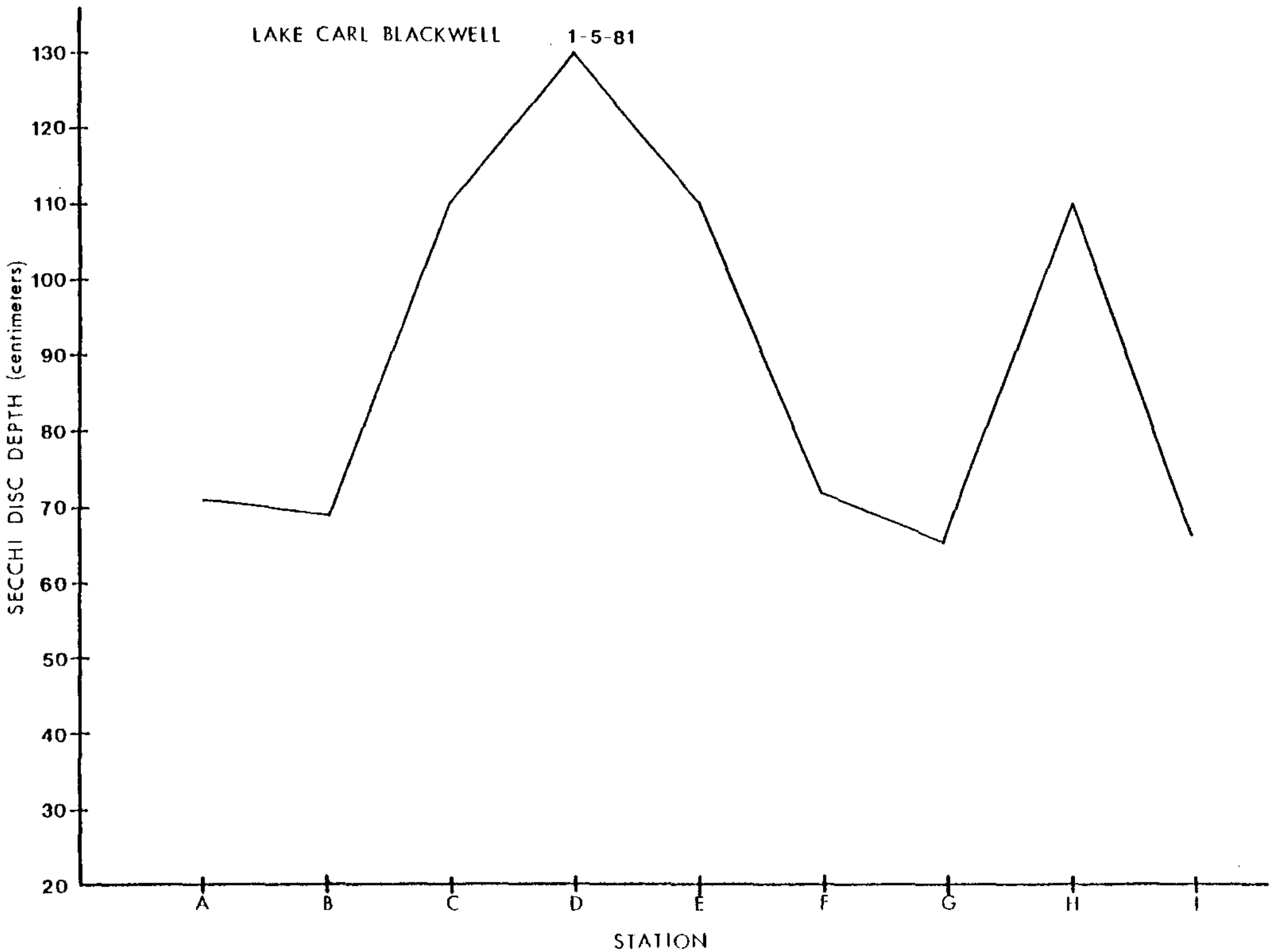
* Reported as micrograms/liter

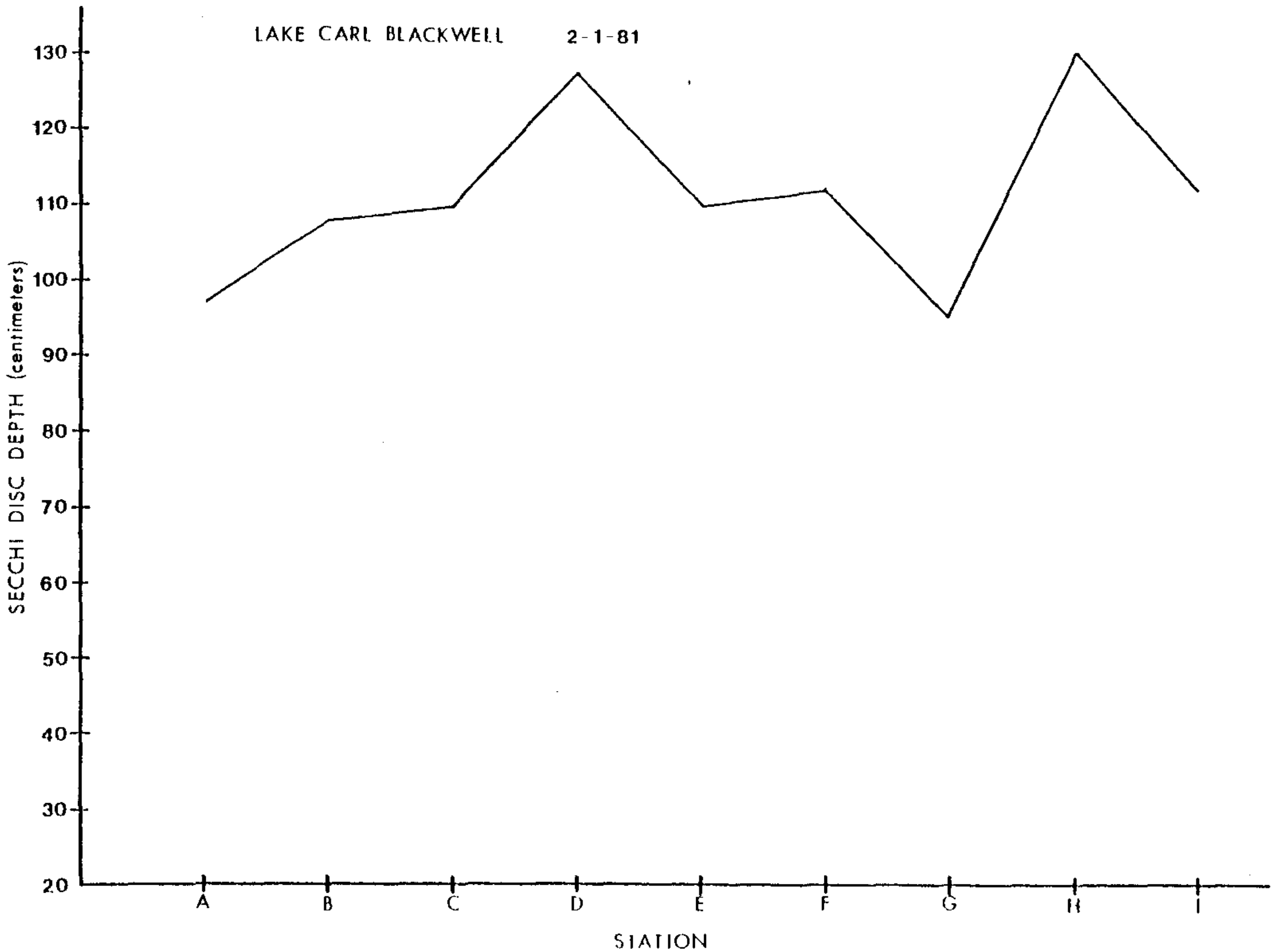

LAKE CARL BLACKWELL
SECCHI DISC DEPTH (centimeters)
130
120
110
100
90
80
70
60
50
40
30
20
A
B
C
D
E
F
G
H
I
STATION
2-1-81
7-7-81
6-22-81
6-8-81
1-5-81
12-6-80
4-5-81
4-26-81
9-28-80
11-2-80
5-11-81

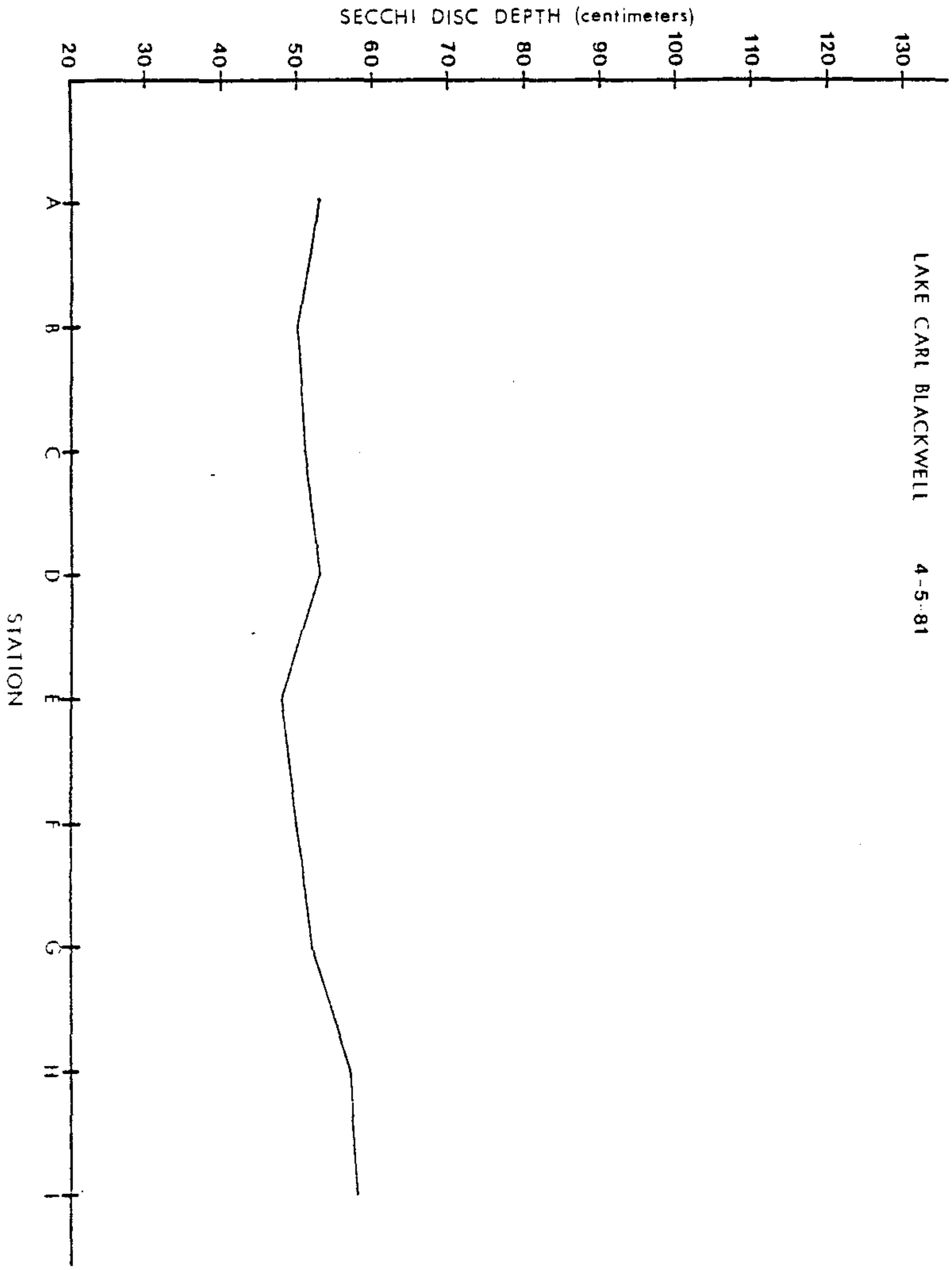

LAKE CARL BLACKWELL 9-28-80
SECCHI DISC DEPTH (centimeters)
20
30
40
50
60
70
80
90
100
110
120
130
A
B
C
D
E
F
G
H
I
STATION

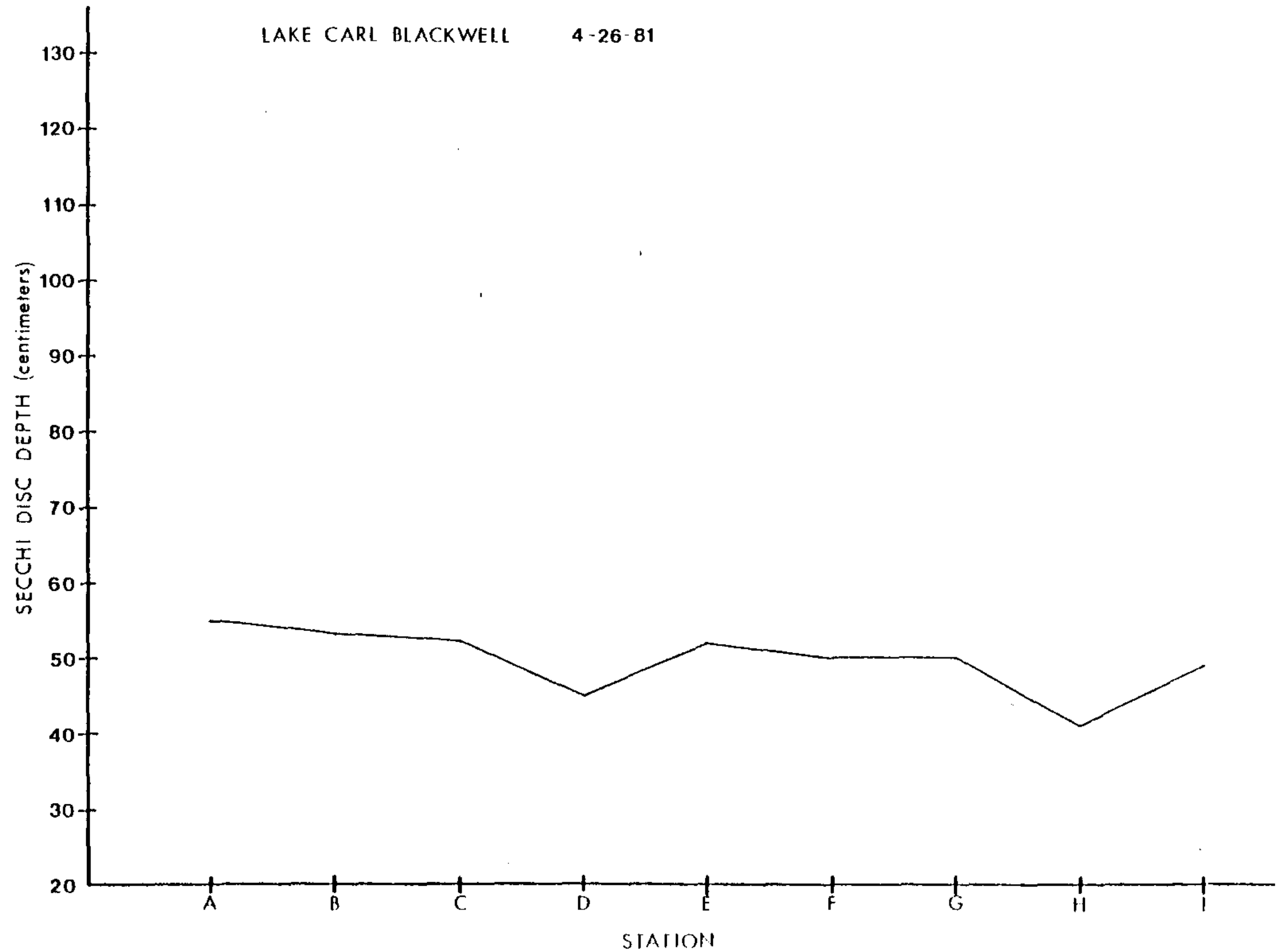

LAKE CARL BLACKWELL 11-2-80
SECCHI DISC DEPTH (centimeters)
130
120
110
100
90
80
70
60
50
40
30
20
A
B
C
D
E
F
G
H
I
STATION

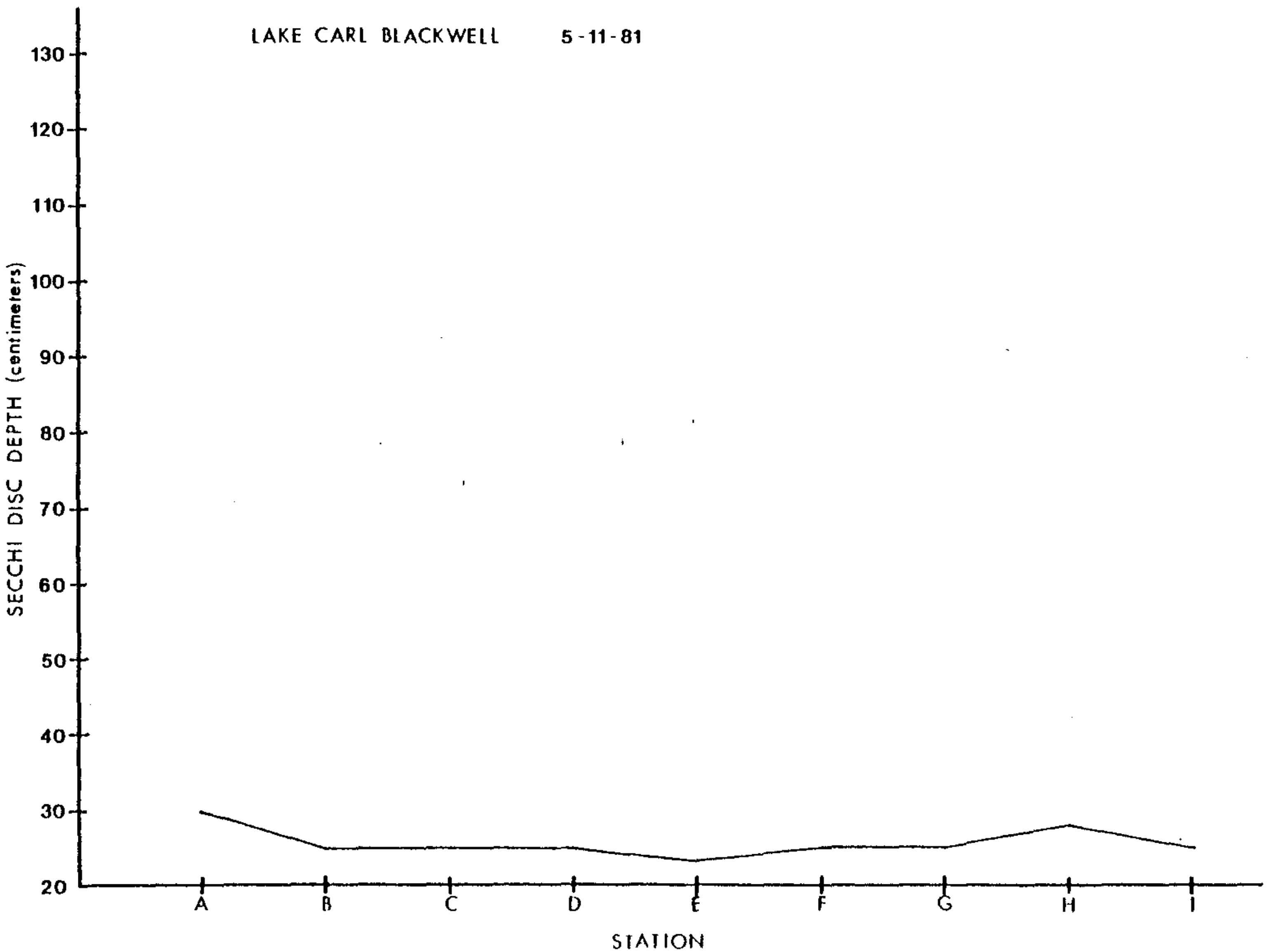

LAKE CARL BLACKWELL 12-6-80
SECCHI DISC DEPTH (centimeters)
20
30
40
50
60
70
80
90
100
110
120
130
A
B
C
D
E
F
G
H
I
STATION

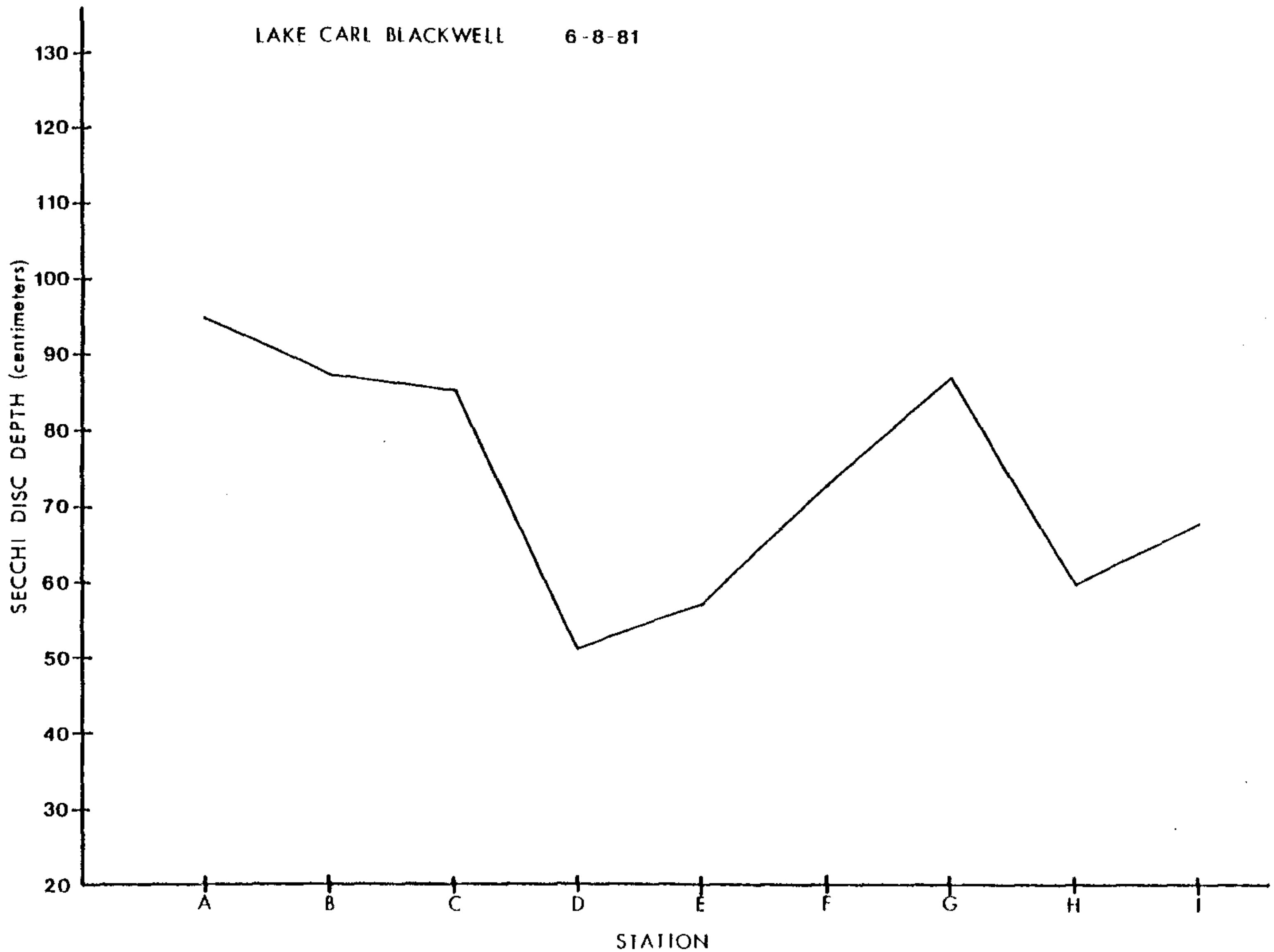

LAKE CARL BLACKWELL 1-5-81
SECCHI DISC DEPTH (centimeters)
20
30
40
50
60
70
80
90
100
110
120
130
A
B
C
D
E
F
G
H
I
STATION


LAKE CARL BLACKWELL 2-1-81
SECCHI DISC DEPTH (centimeters)
130
120
110
100
90
80
70
60
50
40
30
20
A
B
C
D
E
F
G
H
I
STATION

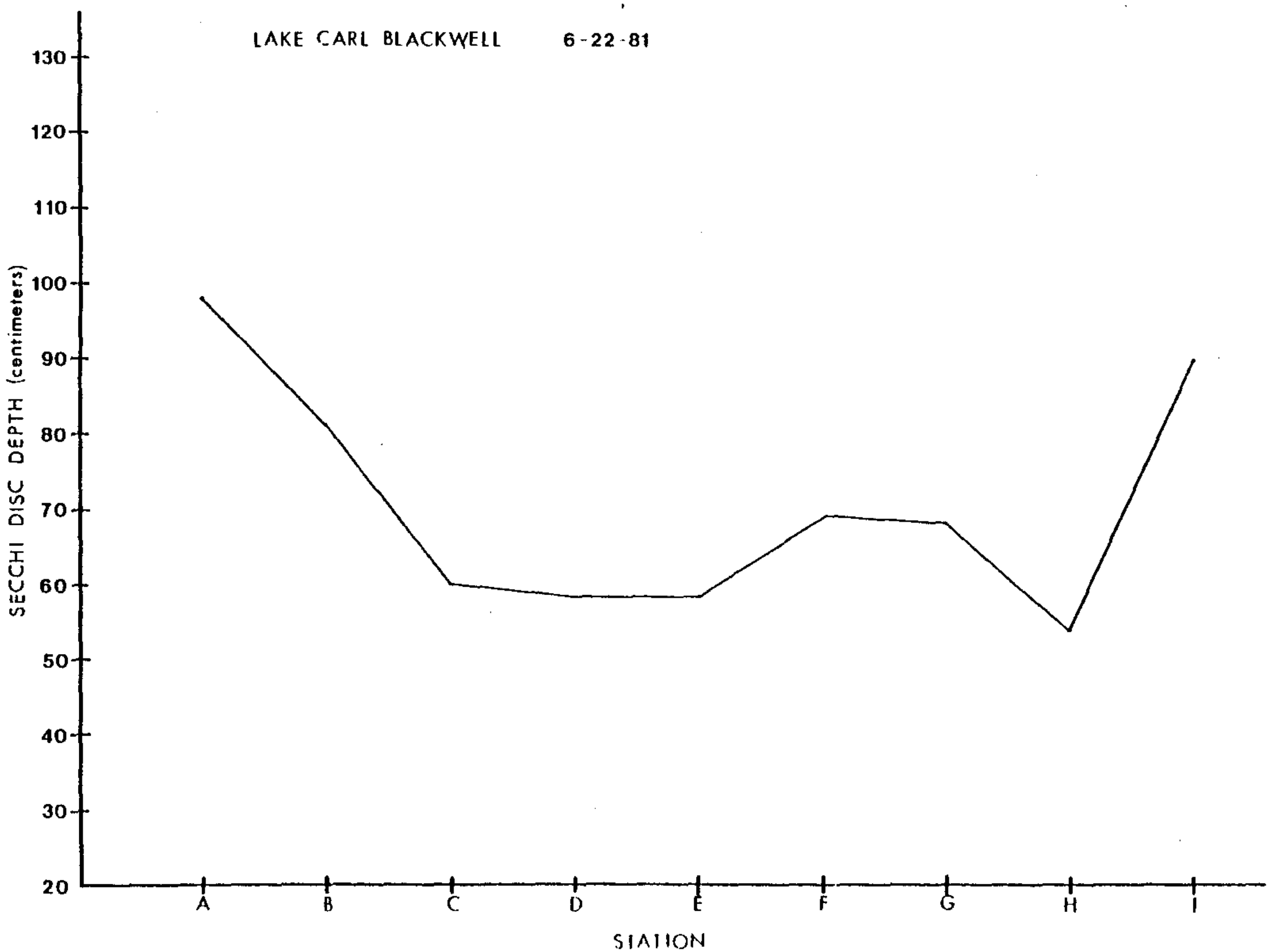

LAKE CARL BLACKWELL 4-5-81
SECCHI DISC DEPTH (centimeters)
20
30
40
50
60
70
80
90
100
110
120
130
STATION
A
B
C
D
E
F
G
H
I

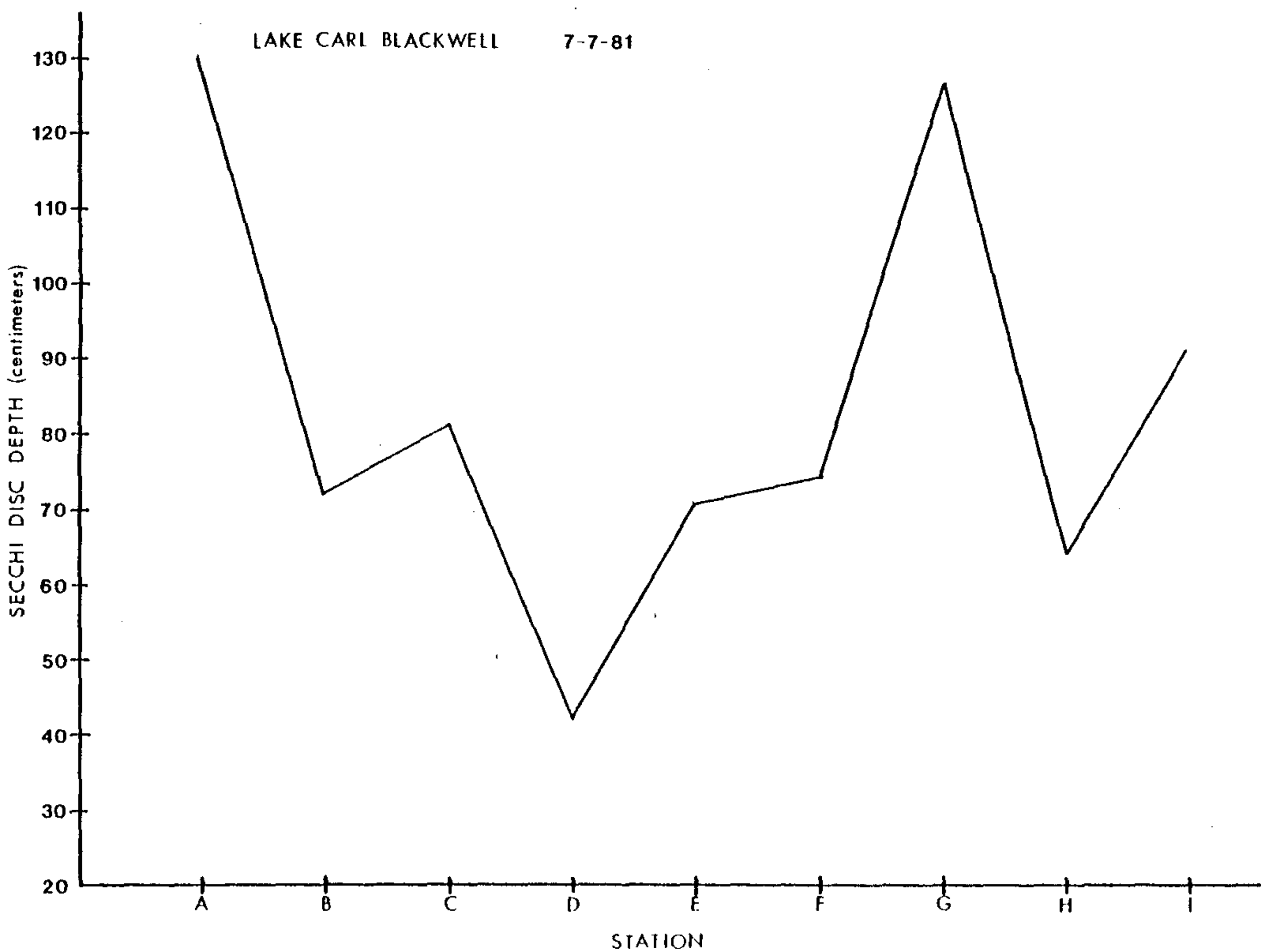

LAKE CARL BLACKWELL 4-26-81
SECCHI DISC DEPTH (centimeters)
130
120
110
100
90
80
70
60
50
40
30
20
A
B
C
D
E
F
G
H
I
STATION

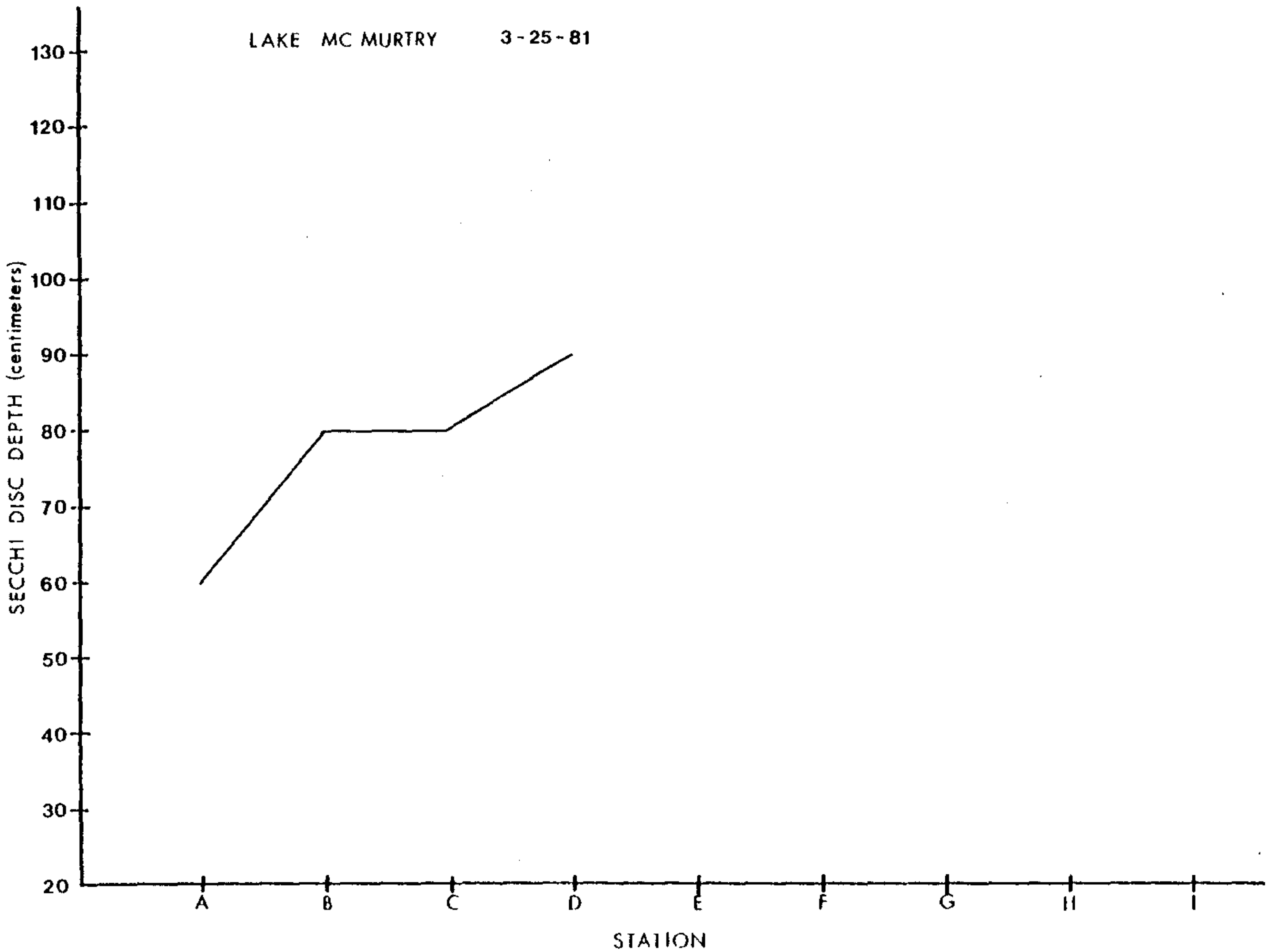

LAKE CARL BLACKWELL 5-11-81
SECCHI DISC DEPTH (centimeters)
130
120
110
100
90
80
70
60
50
40
30
20
A
B
C
D
E
F
G
H
I
STATION

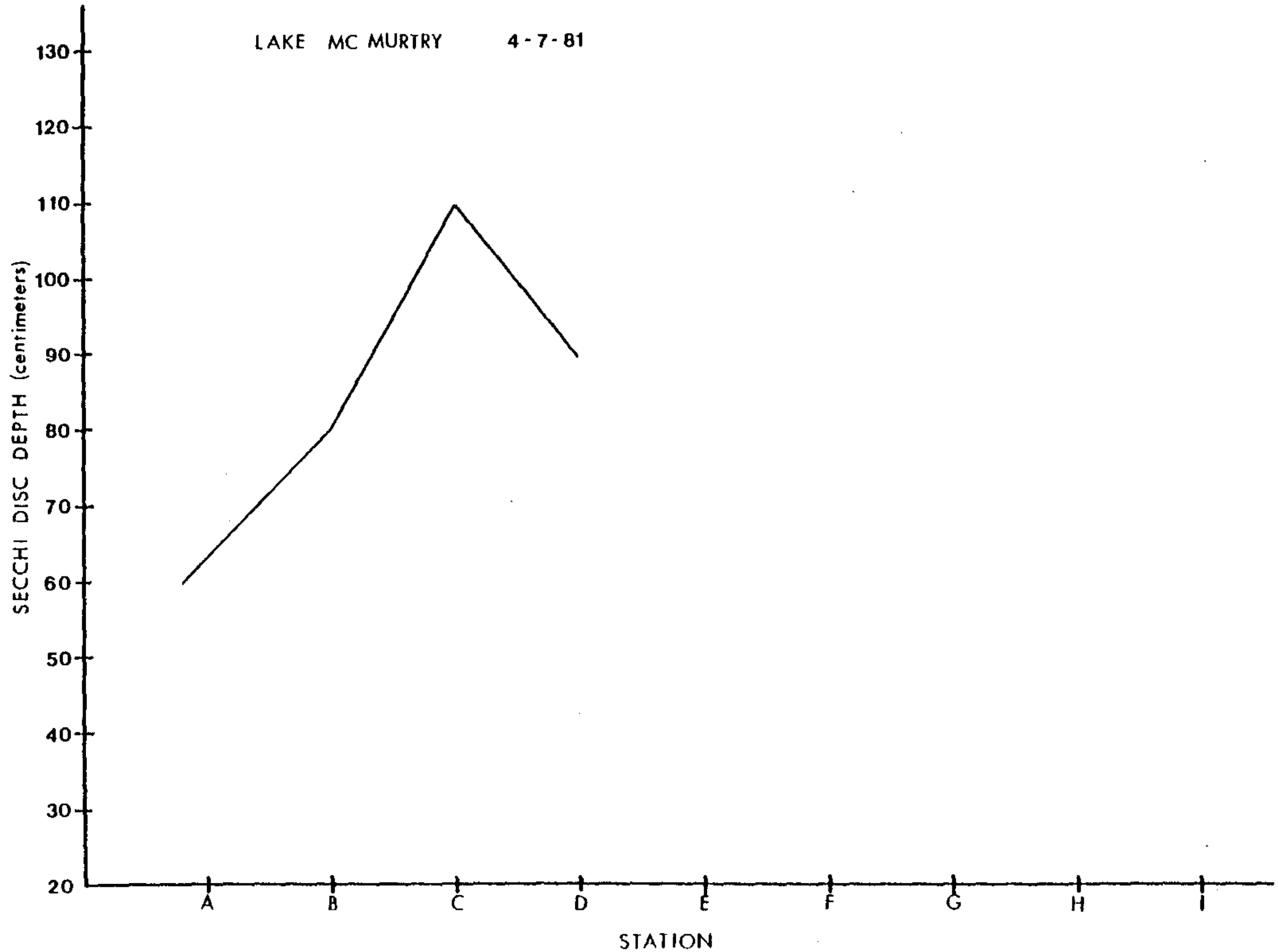


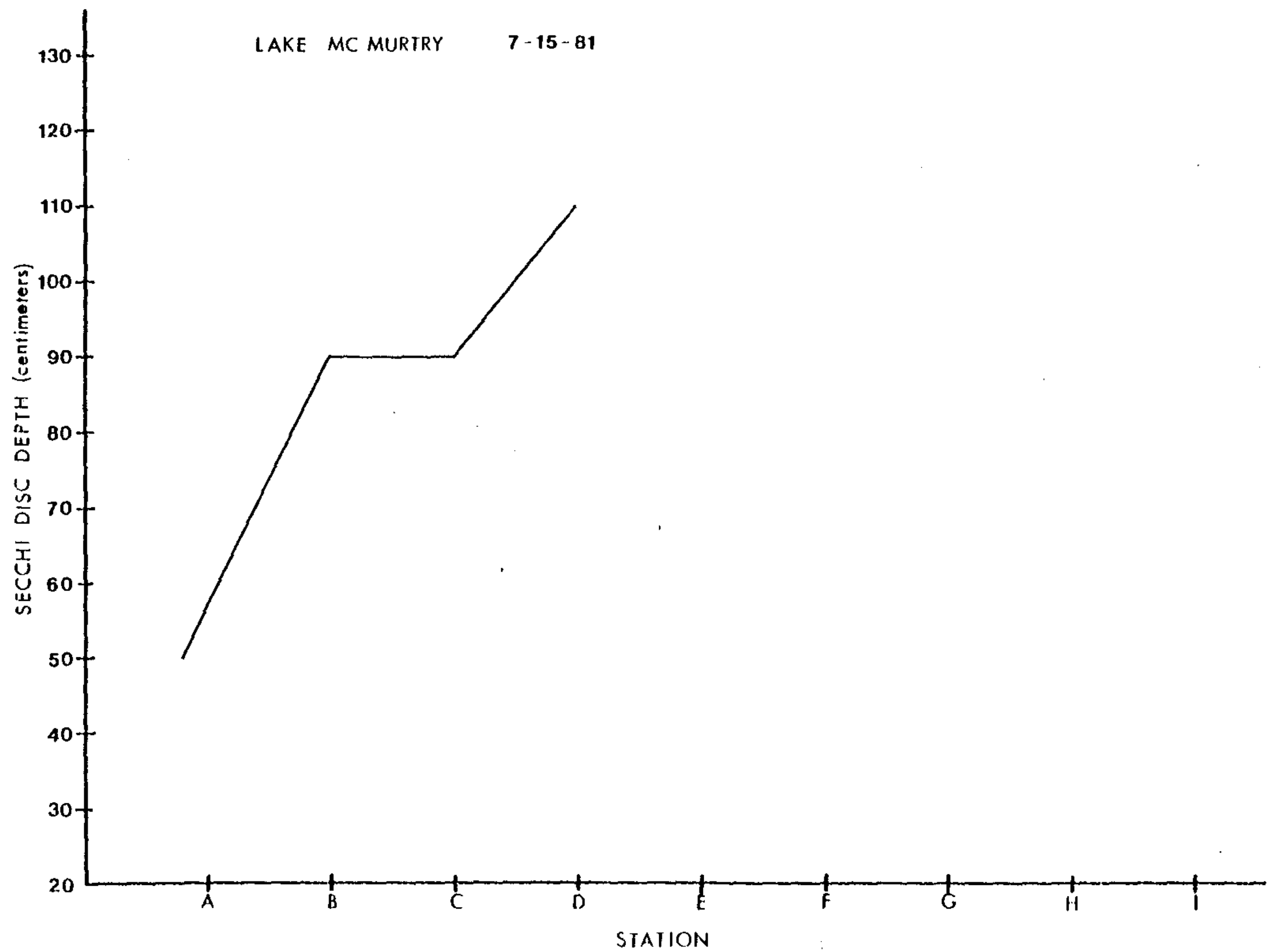
LAKE CARL BLACKWELL 6-8-81
SECCHI DISC DEPTH (centimeters)
130
120
110
100
90
80
70
60
50
40
30
20
A
B
C
D
E
F
G
H
I
STATION

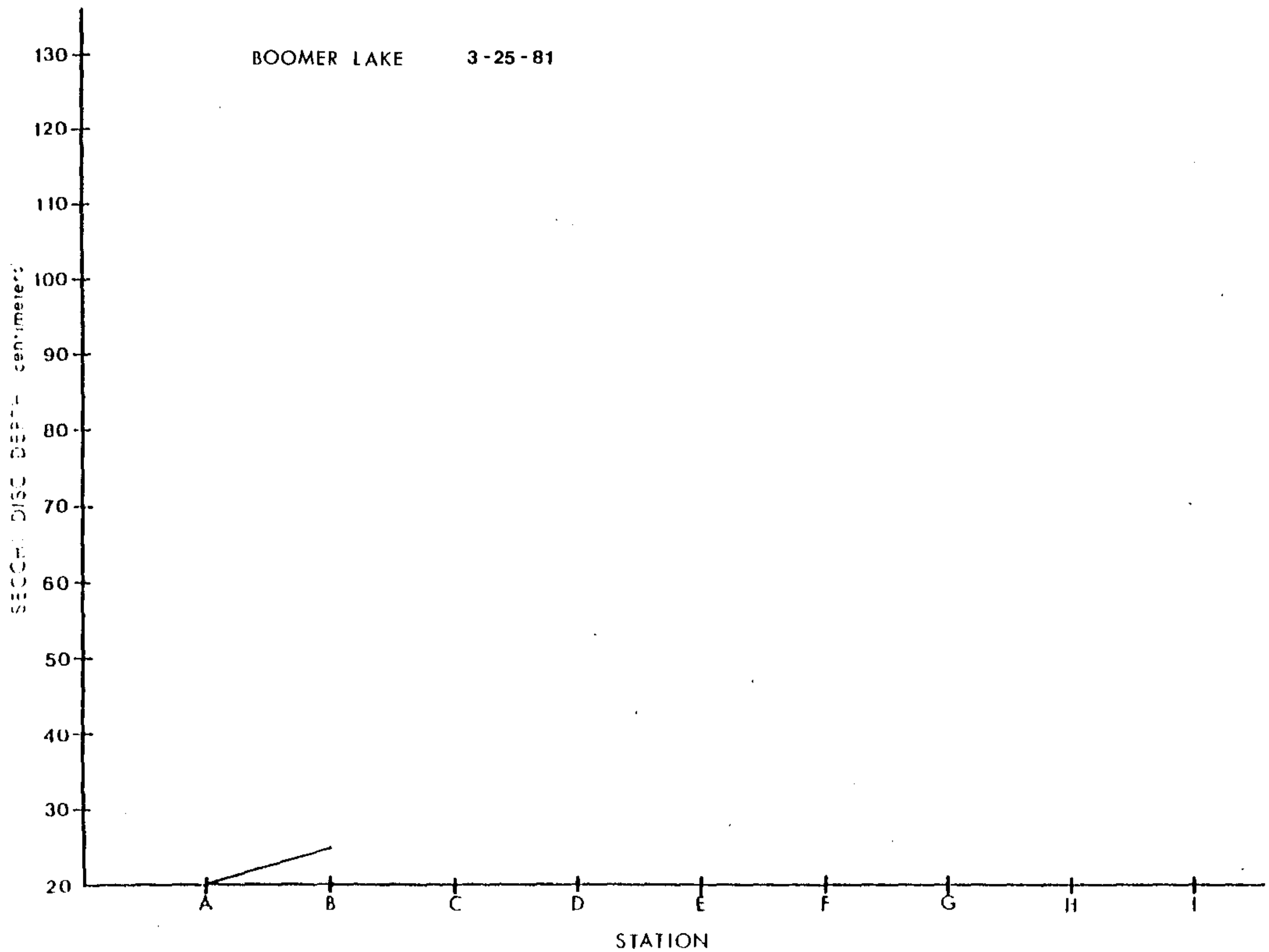

LAKE CARL BLACKWELL 6-22-81
SECCHI DISC DEPTH (centimeters)
130
120
110
100
90
80
70
60
50
40
30
20
A
B
C
D
E
F
G
H
I
STATION

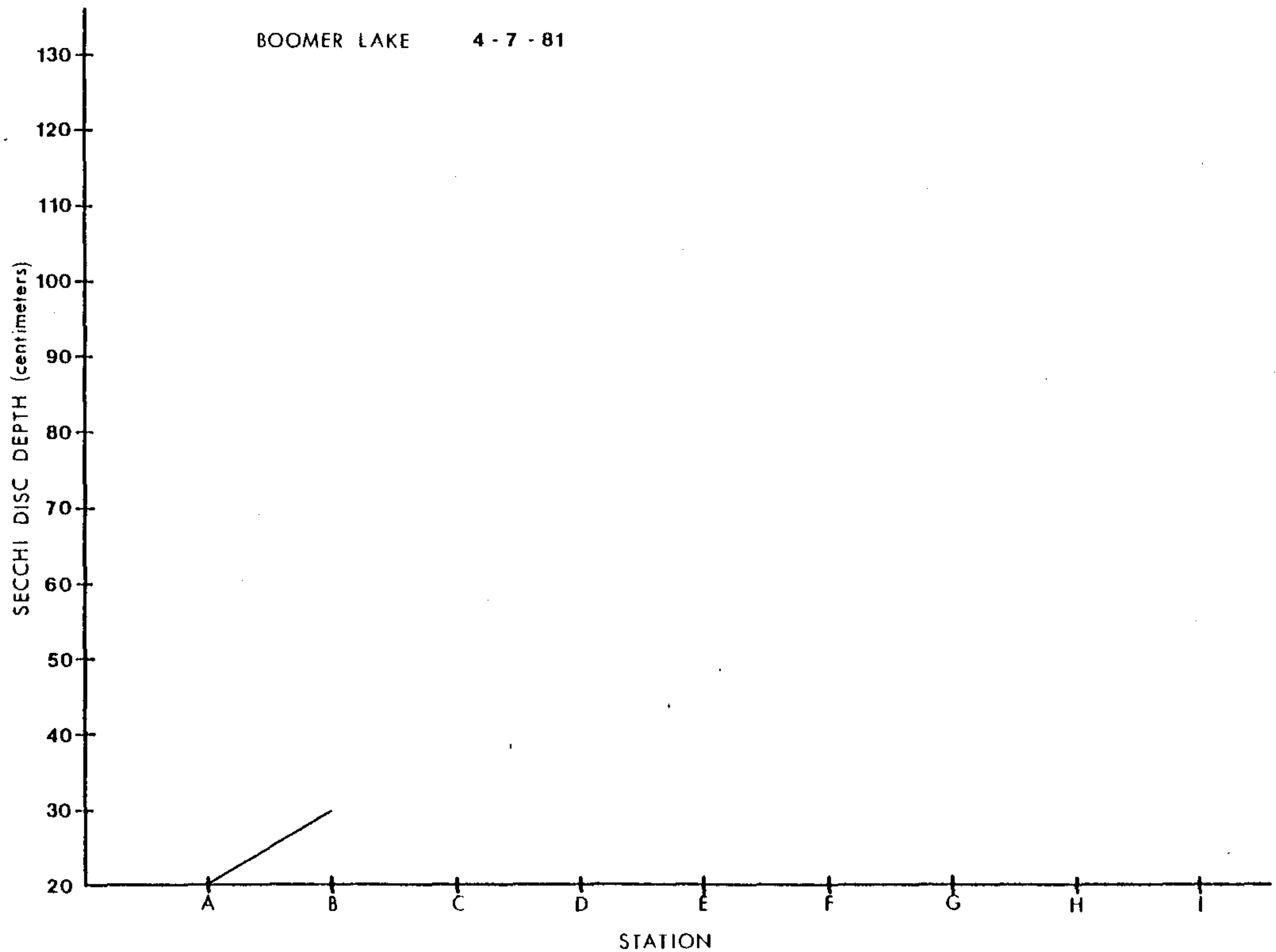

LAKE CARL BLACKWELL 7-7-81
SECCHI DISC DEPTH (centimeters)
130
120
110
100
90
80
70
60
50
40
30
20
A B C D E F G H I
STATION

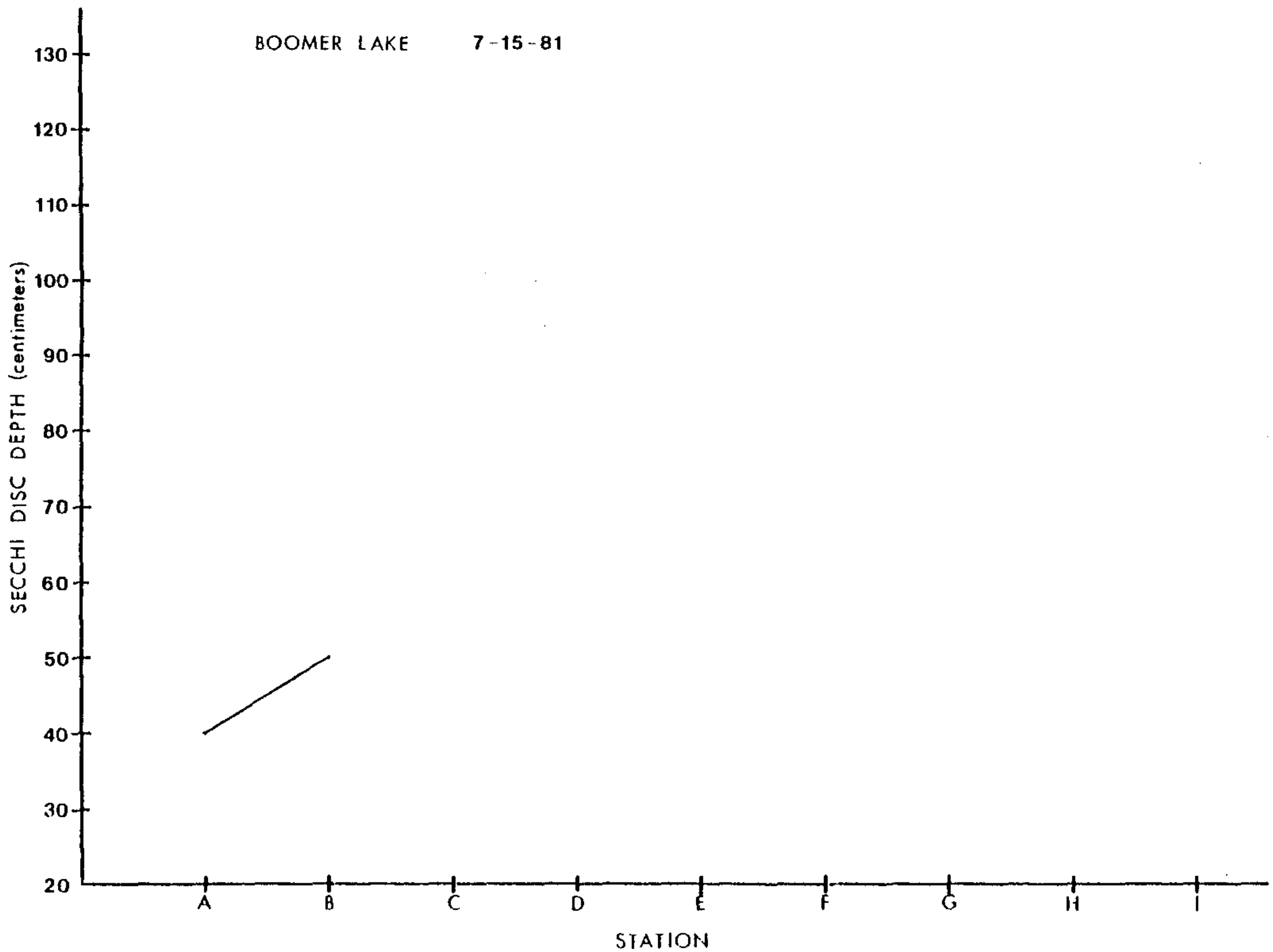

LAKE MC MURTRY 3-25-81
SECCHI DISC DEPTH (centimeters)
130
120
110
100
90
80
70
60
50
40
30
20
A
B
C
D
E
F
G
H
I
STATION


LAKE MC MURTRY 4-7-81
SECCHI DISC DEPTH (centimeters)
130
120
110
100
90
80
70
60
50
40
30
20
A
B
C
D
E
F
G
H
I
STATION


LAKE MC MURTRY 7-15-81
SECCHI DISC DEPTH (centimeters)
130
120
110
100
90
80
70
60
50
40
30
20
A
B
C
D
E
F
G
H
I
STATION


BOOMER LAKE 3-25-81
SECCHI DISC DEPTH (centimeters)
130
120
110
100
90
80
70
60
50
40
30
20
A
B
C
D
E
F
G
H
I
STATION


BOOMER LAKE 4 - 7 - 81
SECCHI DISC DEPTH (centimeters)
130
120
110
100
90
80
70
60
50
40
30
20
A
B
C
D
E
F
G
H
I
STATION


BOOMER LAKE 7-15-81
SECCHI DISC DEPTH (centimeters)
130
120
110
100
90
80
70
60
50
40
30
20
A
B
C
D
E
F
G
H
I
STATION