REMOTE SENSING SYSTEMS FOR THE GREAT LAKES

EPA/NASA MEETING
CLEVELAND, OHIO
JANUARY 5, 1978

AGENDA

GREAT LAKES WATER QUALITY MEETING

JANUARY 5, 1978

10:00 AM

I. EPA REGION V GREAT LAKES NATIONAL PROGRAM OFFICE

II. REMOTE SENSING PROGRAM FOR GREAT LAKES WATER QUALITY

- A. PROGRAM OVERVIEW
- B. FATE OF POLLUTANT MAPPING
  1. CLEVELAND HARBOR
  2. PLUARG TASK D 5 RIVER STUDY
  3. DISPERSION MODELING
  4. MILWUAKEE HARBOR
- C. BIOMASS MAPPING
  1. PHYTOPLANKTON
  2. BENTHIC ALGAE
- D. USE OF REAL TIME DATA FOR AIDING SURFACE SURVEYS
- E. SUMMARY OF REMOTE SENSING MEASUREMENT CAPABILITIES
- F. LERC PROGRAM FOR DEVELOPING CORRELATIONS
- G. LERC REMOTE SENSING FACILITIES
- H. NIMBUS G COASTAL ZONE COLOR SCANNER (CZCS)

III. EPA MEASUREMENT NEEDS

IV. FUTURE EPA REGION V/NASA LERC ACTIVITIES

V. FACILITY TOUR

- A. IMAGE PROCESSING SYSTEM
- B. AIRCRAFT SYSTEMS

REMOTE SENSING PROGRAM FOR GREAT LAKES WATER QUALITY

NASA LEWIS RESEARCH CENTER

PROGRAM OBJECTIVES:

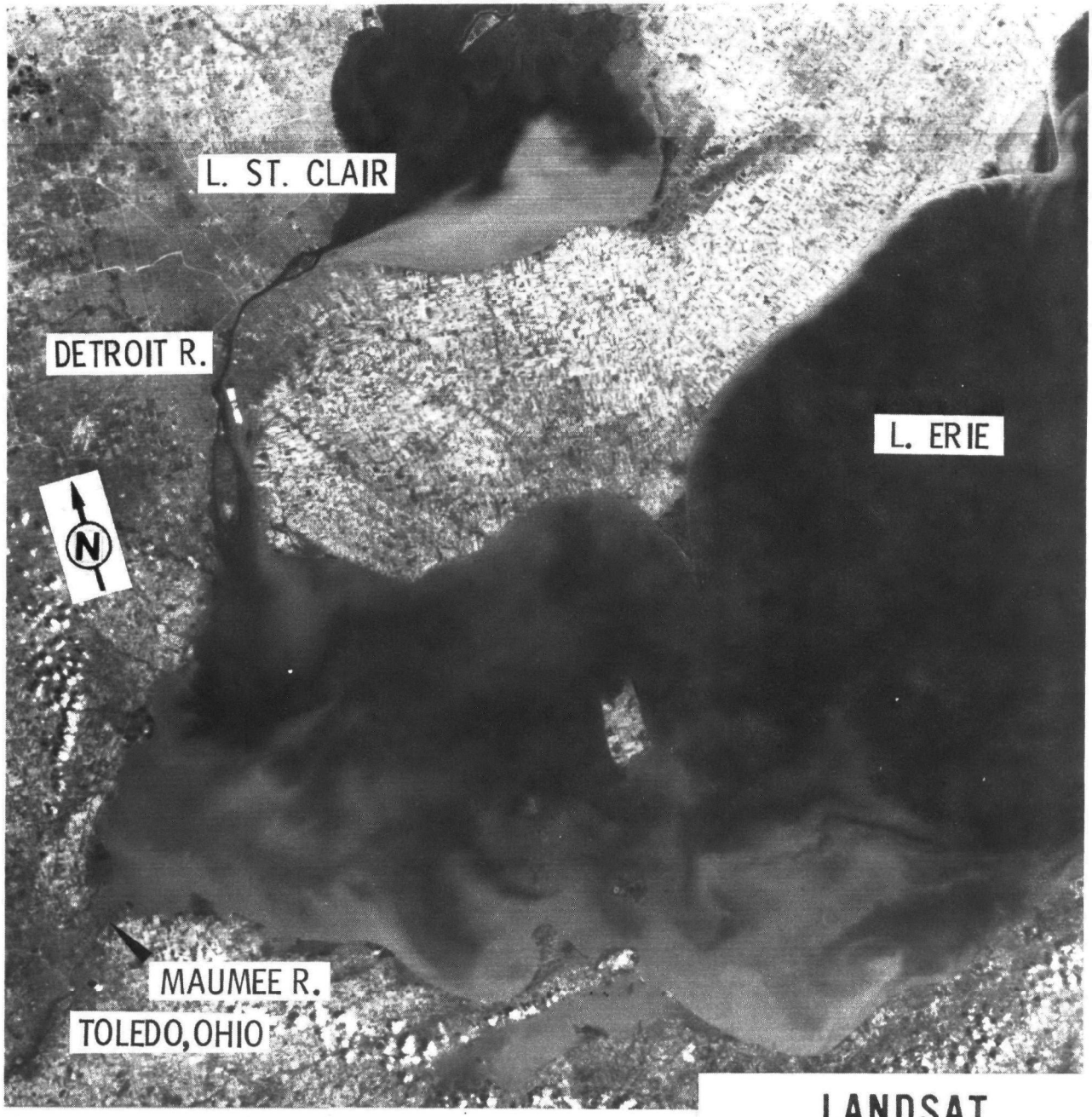
TO DEVELOP METHODS AND SYSTEMS FOR MONITORING WATER QUALITY AND OTHER LIMNOLOGICAL PARAMETERS IN THE GREAT LAKES USING REMOTE SENSING DATA. ULTIMATE GOALS WILL BE TO DEVELOP REALISTIC SYSTEMS USING DATA FROM SATELLITES SUCH AS LANDSAT AND NIMBUS-G. SYSTEMS WHICH DO NOT PROVE FEASIBLE FOR SATELLITE ALTITUDES WILL BE DEVELOPED FOR AIRCRAFT PLATFORMS.

THE CRITERIA IS THAT THE METHODS AND/OR SYSTEMS:

A. CAN EVENTUALLY BE OPERATED BY EPA TO PERFORM OPERATIONAL SURVEILLANCE OF THE GREAT LAKES.

B. ALLOW THE SURVEILLANCE TO BE PERFORMED MORE EFFICIENTLY (LESS RESOURCES) OR MORE EFFECTIVELY.

C. BE TRANSFERRED TO EPA. We don't have personnel for any surveillance



0 16 n. mi.
0 30 km.

LANDSAT
APRIL 7, 1976
BAND 5 (600-700 NM.)
IMAGE ID NO. 2441-15311
NASA

western basin
Heavier waters: longer radiance reflection
larger particular concentration
resuspended?

GREAT LAKE USES FOR REMOTE MEASUREMENTS

- EXTRAPOLATION OF SHIP MEASUREMENTS OVER LARGE AREAS (SPATIAL VARIATIONS)
- EXTRAPOLATE BETWEEN SHIP CRUISES (TEMPORAL VARIATIONS)
- PROVIDE NEAR REAL TIME AREA INFORMATION FOR SELECTING SHIP SURVEY SITES
- DETERMINE ZONE OF INFLUENCES FOR WATER INTAKES
- MONITOR NEAR SHORE VARIABILITY AND FATE OF POLLUTION SOURCES
- DETERMINE DISPERSION PATTERNS, SHORE EROSION, AND AREAS OF RESUSPENSION
- MONITOR TRANSBOUNDARY MOVEMENT
- MONITOR UPWELLING
- PROVIDE SYNOPTIC INFORMATION FOR LARGE LAKE MODELS (LAKE DYNAMICS, PARTICULATE DISPERSION, TROPHIC CONDITIONS) AND FOR PERFORMING BUDGET ANALYSES
- AID IN DETERMINING FATE OF DREDGE MATERIALS
- MONITOR INDUSTRIAL WASTES SUCH AS OIL AND ACIDS
- MONITOR MUNICIPAL WASTES
- MONITORING OF TROPHIC STATE

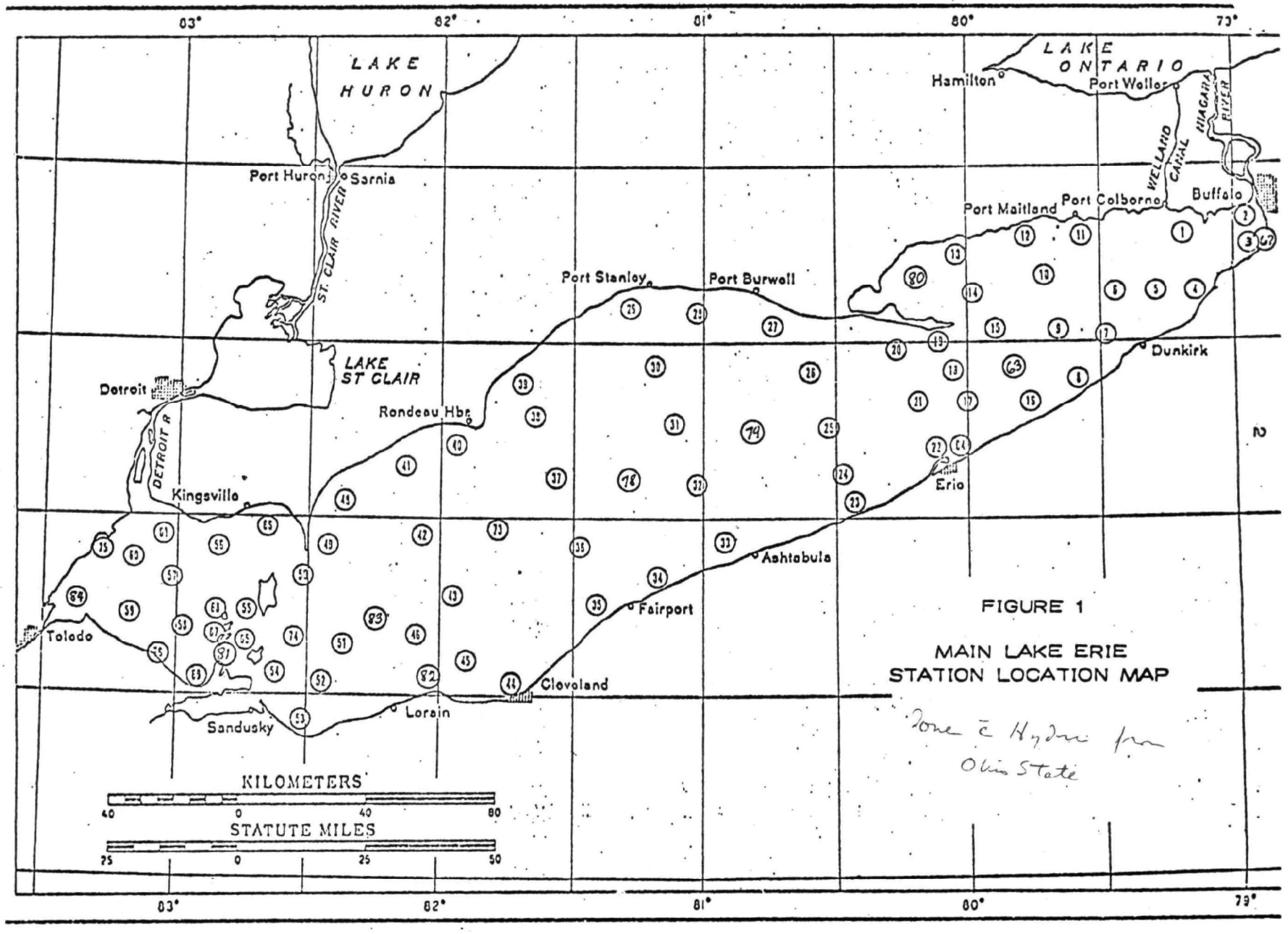
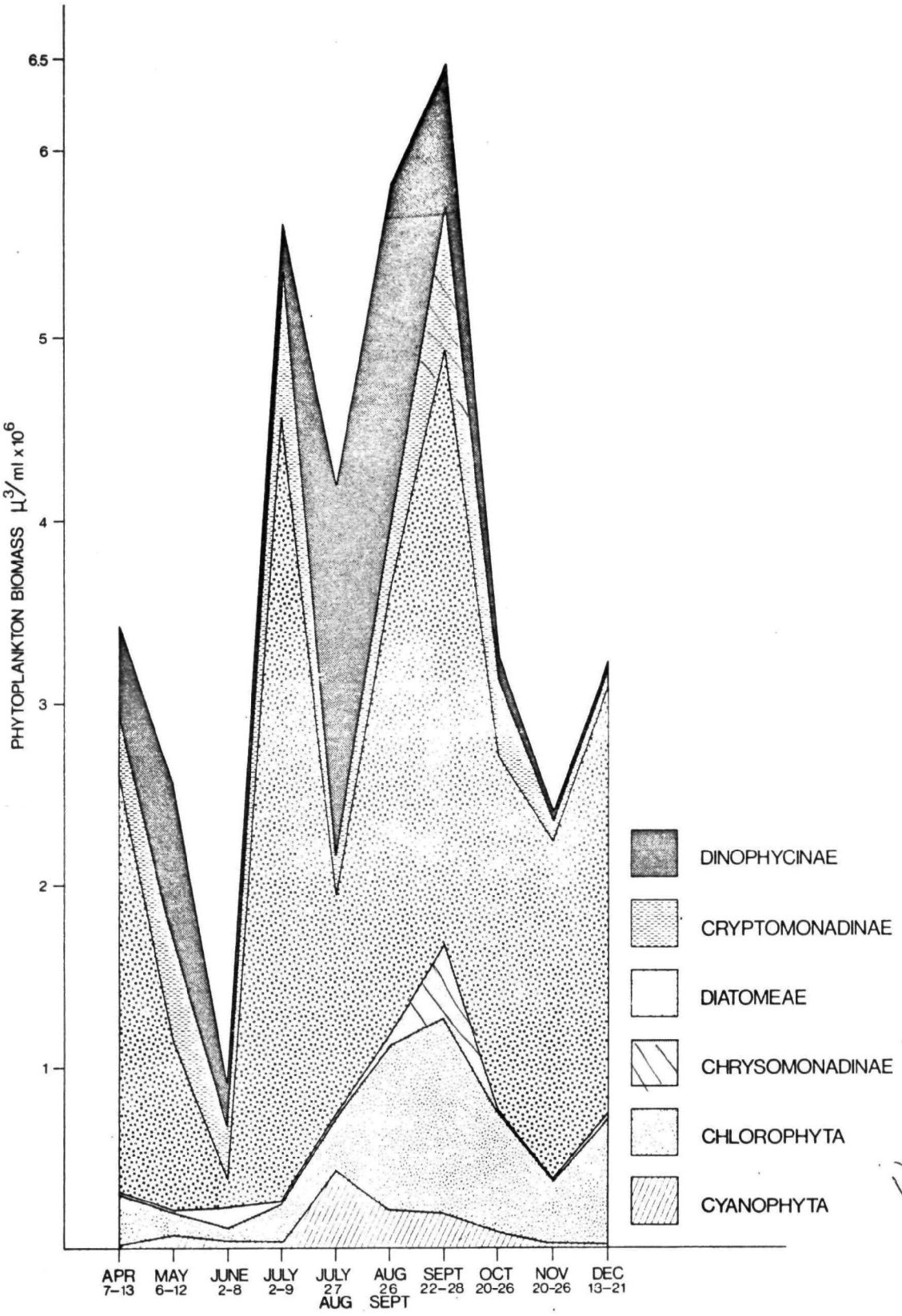


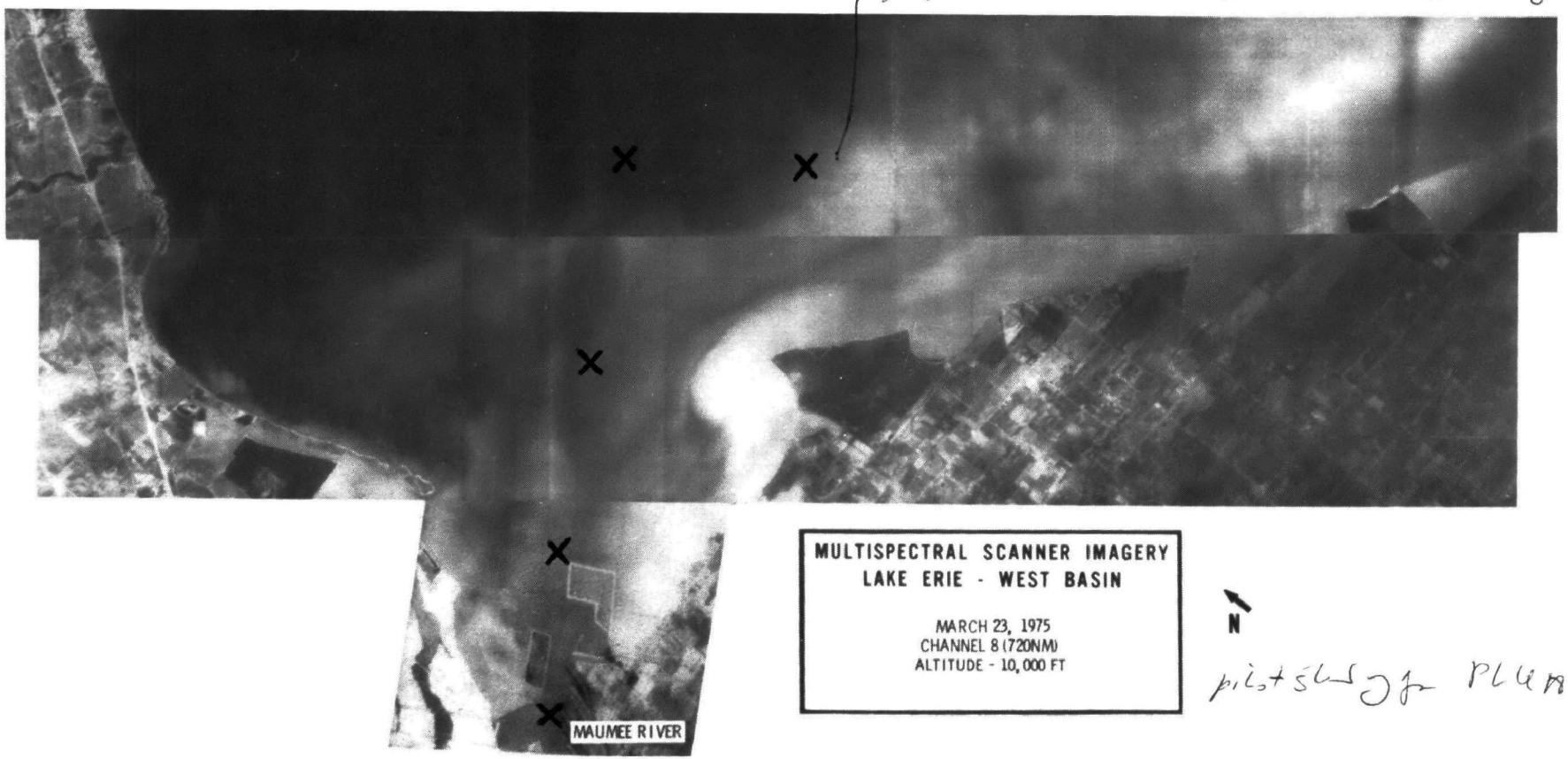
FIGURE 1

MAIN LAKE ERIE
STATION LOCATION MAP

Zone & Hydro from
Ohio State



SEASONAL CYCLE OF PHYTOPLANKTON BIOMASS BY MAJOR TOXONOMIC GROUPS IN LAKE ERIE



MULTISPECTRAL SCANNER IMAGERY
LAKE ERIE - WEST BASIN

MARCH 23, 1975
CHANNEL 8 (720NM)
ALTITUDE - 10,000 FT

N

ship verified resuspension
bottom
surface

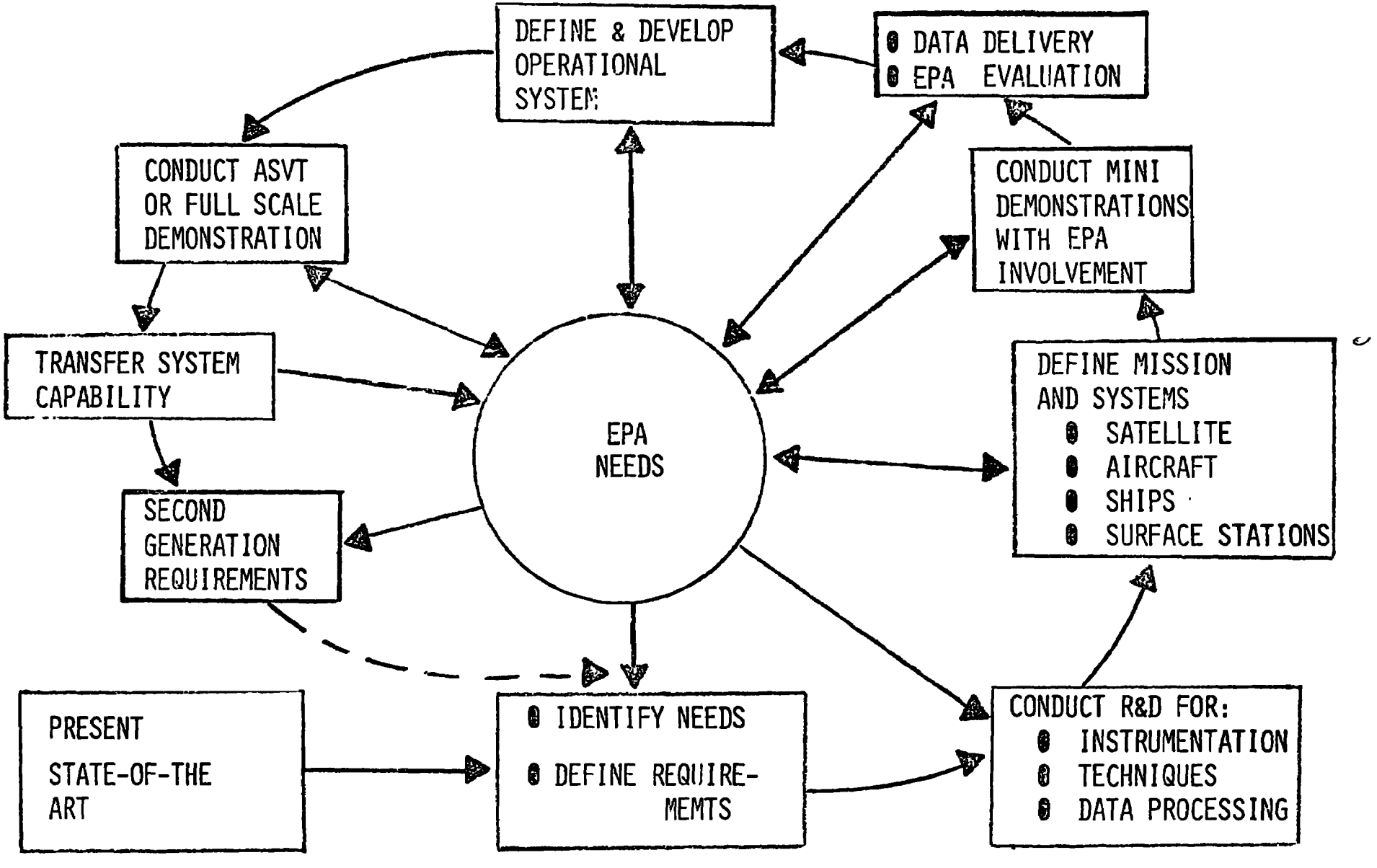
pilot ship for PLUMES

if transmittal to ship:
" and buoy 53 area of interest

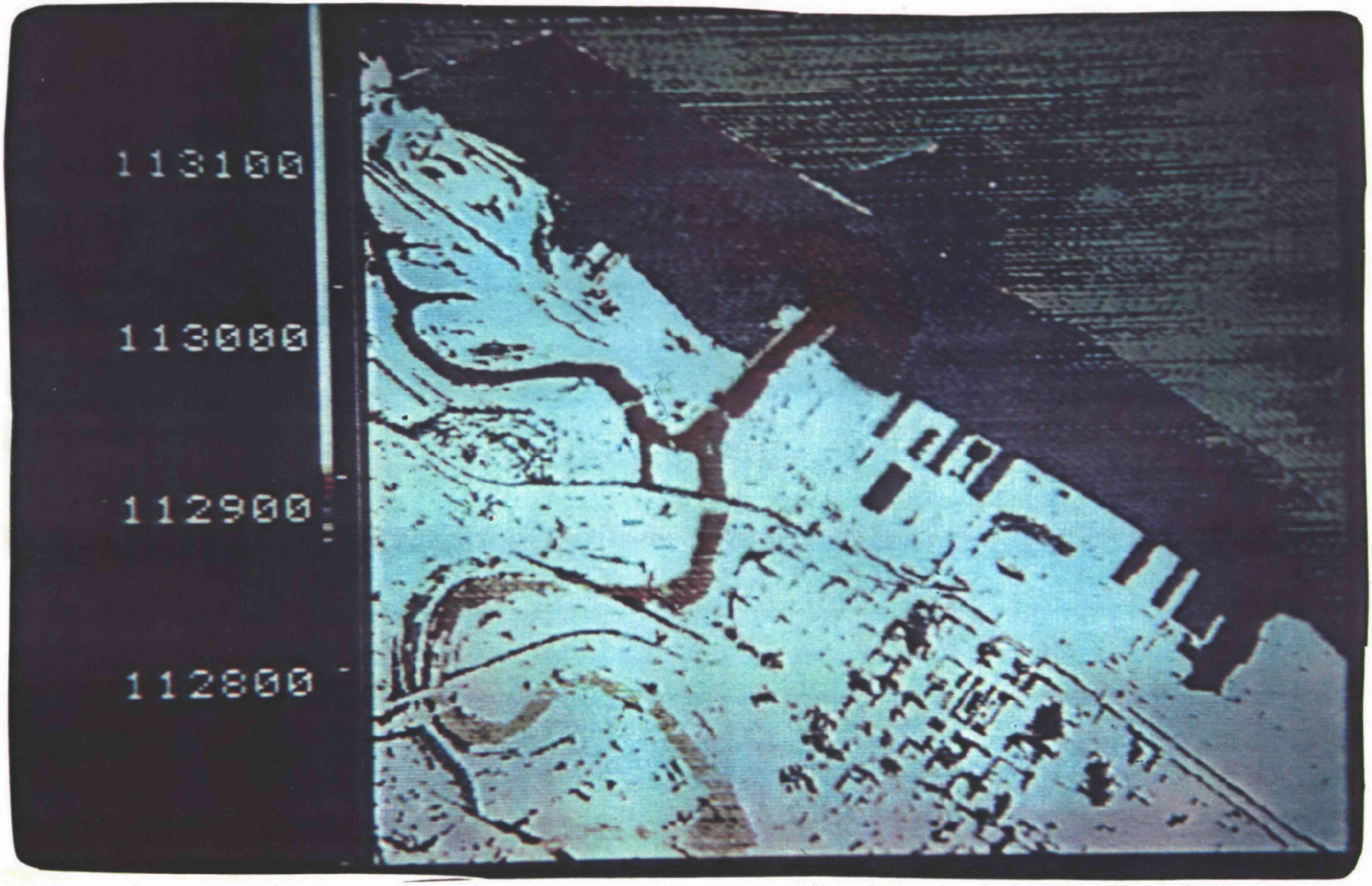
J

JOINT EPA/NASA

REMOTE SENSING SYSTEM DEVELOPMENT



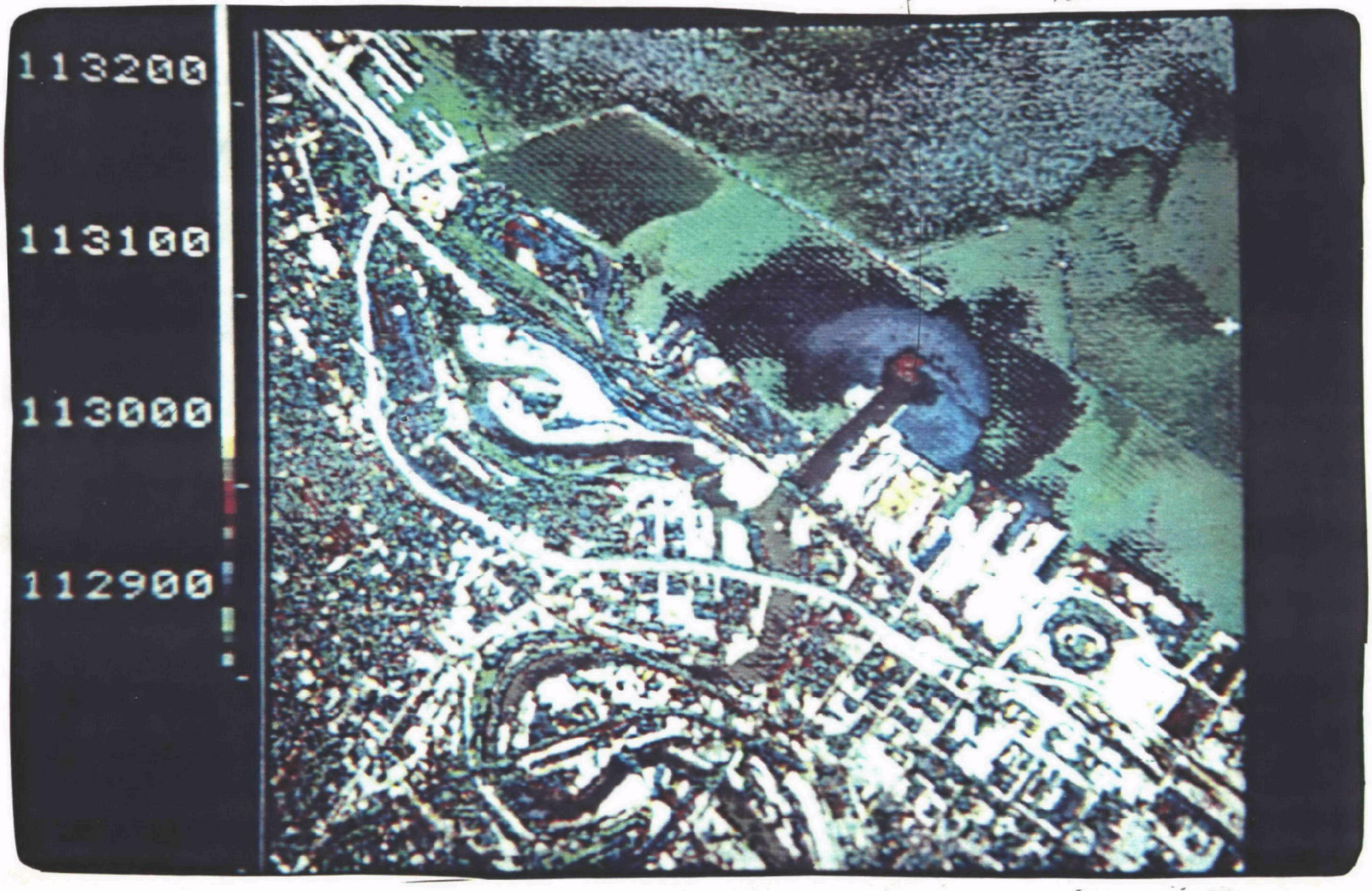
brighter : warmer temp.



Cleveland Hurricane study

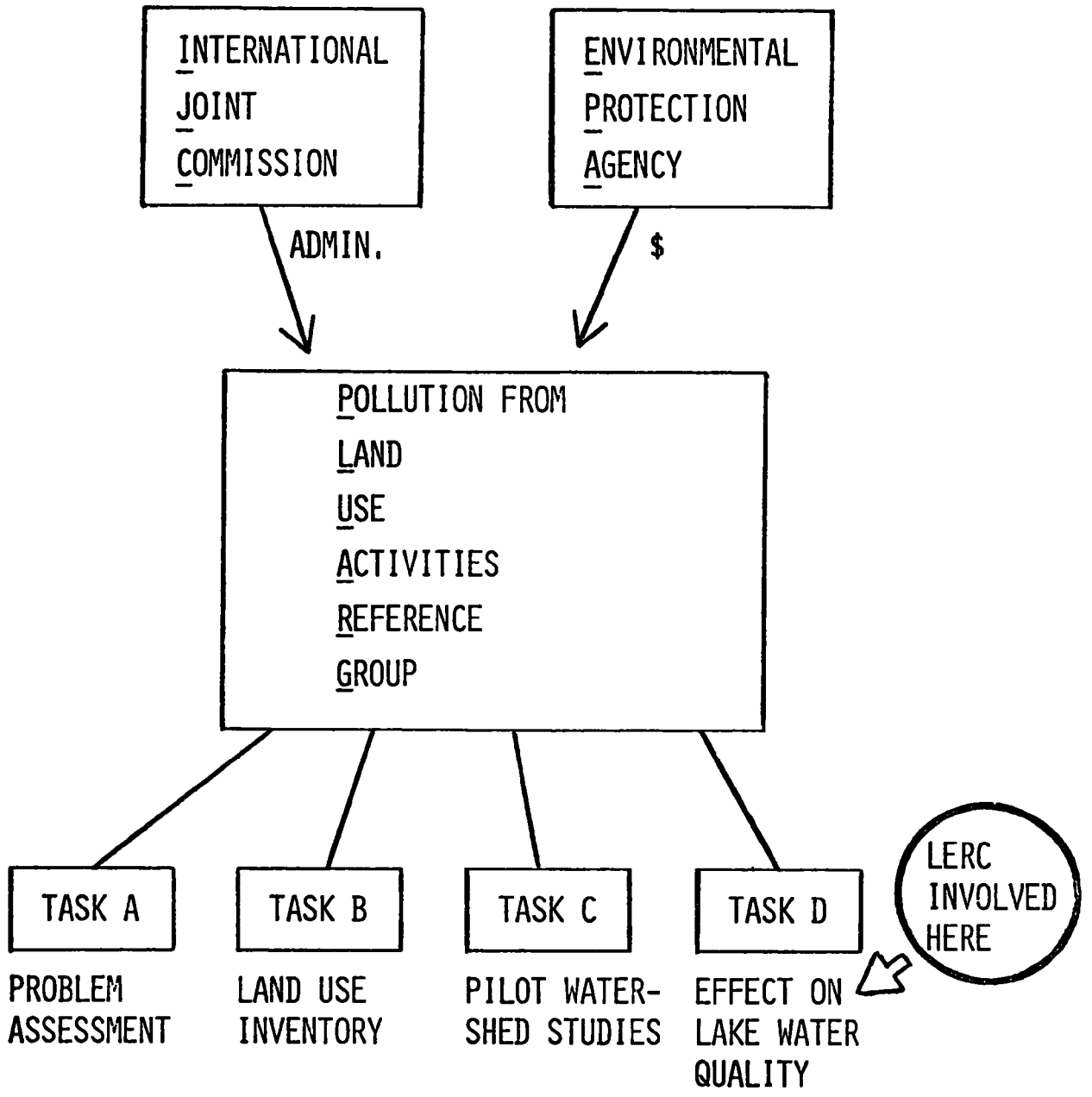
for Gene Ole

Case
Ohio State
NASA



640 meters

colors represent increase in intensity


INTERNATIONAL JOINT COMMISSION
ENVIRONMENTAL PROTECTION AGENCY
ADMIN.
$
POLLUTION FROM LAND USE ACTIVITIES REFERENCE GROUP
TASK A
TASK B
TASK C
TASK D
LERC INVOLVED HERE
PROBLEM ASSESSMENT
LAND USE INVENTORY
PILOT WATER-SHED STUDIES
EFFECT ON LAKE WATER QUALITY

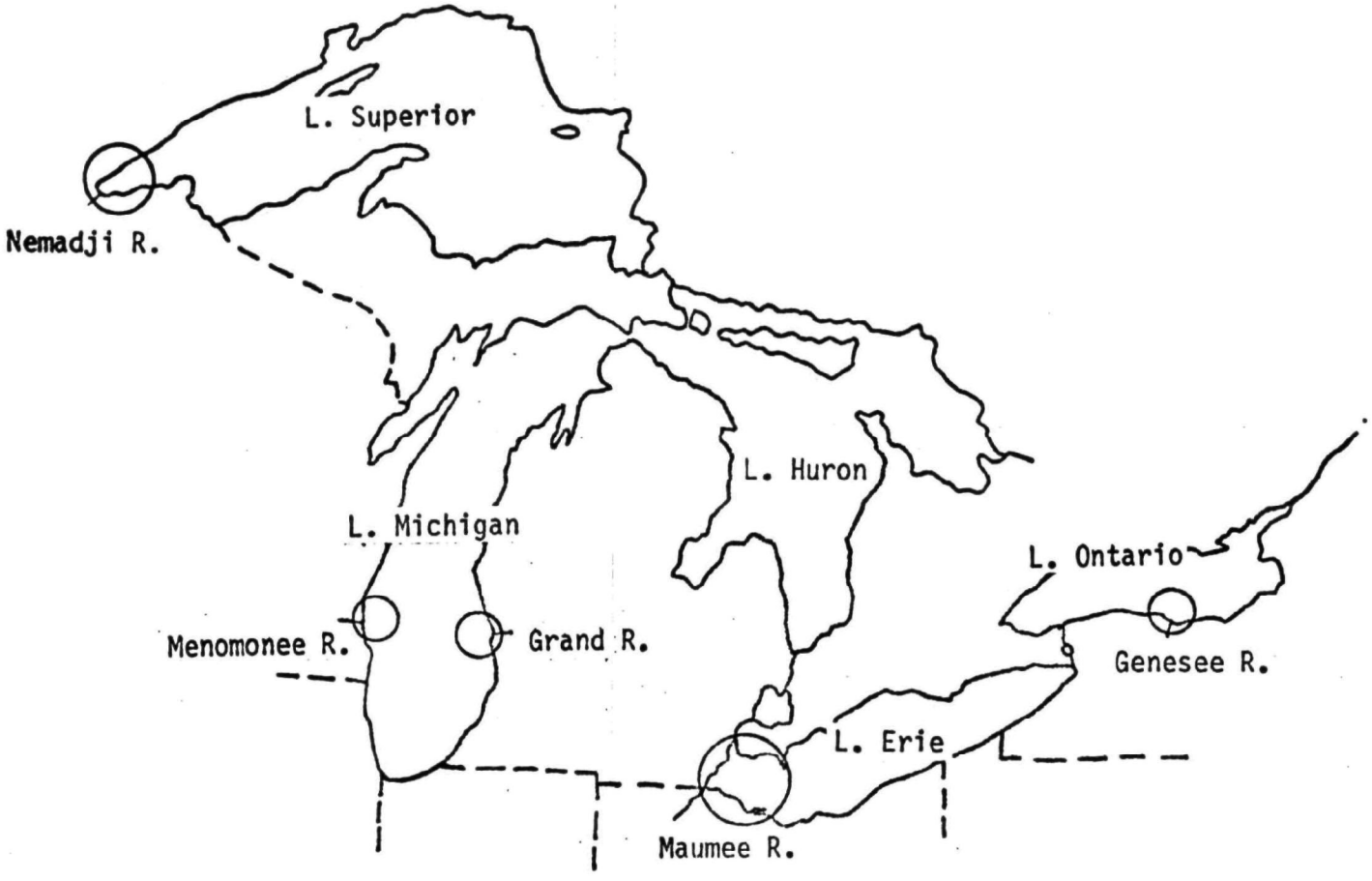
I. PLUARG TASK D OBJECTIVES - ACTIVITY 3

A. DETERMINE KINDS AND QUANTITIES OF CONTAMINANTS ENTERING LAKES, PARTICULARLY UNDER 'EVENT' CONDITIONS, eg. Spring run-off

1. SEDIMENTS
2. NUTRIENTS
3. TOXIC SUBSTANCES
4. DISSOLVED MATERIALS

B. IDENTIFY DISTRIBUTION PATTERNS AND TRANSPORT MECHANISMS OF CONTAMINANTS.

C. ASSESS IMPACT ON ENTIRE LAKE SYSTEM.



SITE	SHIP SURVEY RESPONSIBILITY
Maumee R./L. Erie - W. Basin	Ohio State Univ. - Center for Lake Erie Area Research
Genesee R./L. Ontario	State Univ. N.Y. at Buffaco - Great Lakes Laboratory
Menomonee R./L. Michigan	Wisconsin Department of Natural Resources
Grand R./L. Michigan	Great Lakes Environmental Research Lab (NOAA)
Nemadji R./L. Superior	University of Minnesota at Duluth

Study sites and organizations having ship survey responsibilities.

Spring - Summer 76

TABLE 1. OVERALL SUMMARY OF AIRCRAFT AND SHIP ACTIVITY

M-A-May 76

SITE	PERIOD OF AIRCRAFT FLIGHTS	PERIOD OF SHIP SURVEYS	PLANNED SITE COVERAGE	NO. AIRCRAFT FLIGHTS REPORTED	NO. SHIP SURVEY DAYS REPORTED	NO. DAYS BOTH AIRCRAFT & SHIP COVERAGE
MAUMEE	2/17-6/5	2/18-6/23	17	16	15*	8
GENESEE	2/24-9/24	3/31-9/24	4	6	7	2
MENOMONEE	2/20-6/7	2/13-9/9	4	7	7	2
GRAND	2/23-4/2	2/25-7/2	4	9	9	3
NEMADJI	4/1-7/8	3/31-5/21	4	9	10	5
			33	47	48	20

*15 TOTAL CRUISES REPORTED, MOST WERE MULTIPLE DAY CRUISES

WEST BASIN–LAKE ERIE

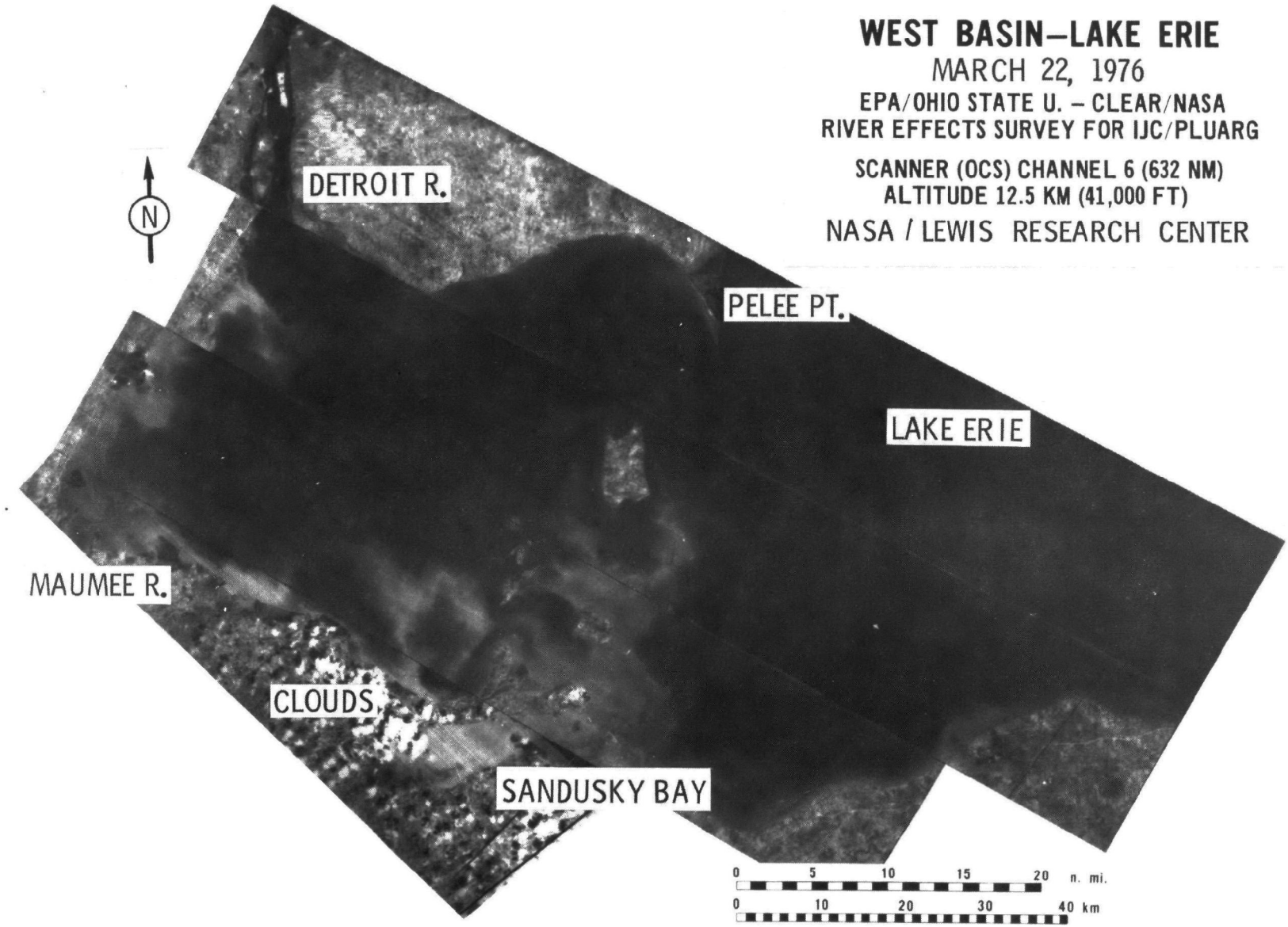
FEBRUARY 23, 1976

EPA/OHIO STATE U. – CLEAR/NASA
RIVER EFFECTS SURVEY FOR IJC/PLUARG

SCANNER (OCS) CHANNEL 6 (632 NM)
ALTITUDE 12.5 KM (41,000 FT)

NASA / LEWIS RESEARCH CENTER

Dark: little sediment
time of maximum flow. Clearing near off


WEST BASIN–LAKE ERIE
MARCH 22, 1976
EPA/OHIO STATE U. – CLEAR/NASA
RIVER EFFECTS SURVEY FOR IJC/PLUARG
SCANNER (OCS) CHANNEL 6 (632 NM)
ALTITUDE 12.5 KM (41,000 FT)
NASA / LEWIS RESEARCH CENTER
N
DETROIT R.
PELEE PT.
LAKE ERIE
MAUMEE R.
CLOUDS
SANDUSKY BAY
0 5 10 15 20 n. mi.
0 10 20 30 40 km

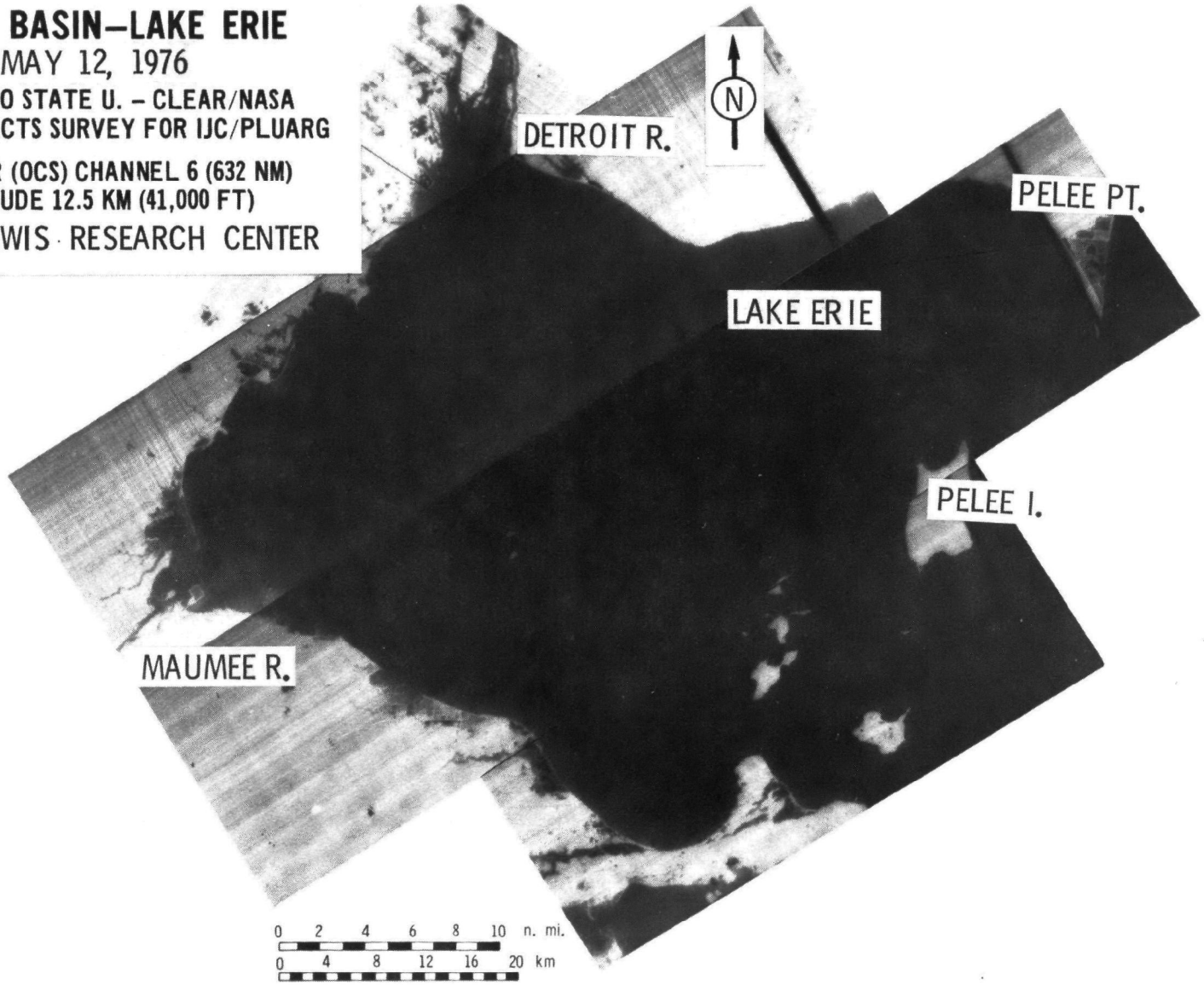
WEST BASIN–LAKE ERIE

MAY 12, 1976

EPA/OHIO STATE U. – CLEAR/NASA
RIVER EFFECTS SURVEY FOR IJC/PLUARG

SCANNER (OCS) CHANNEL 6 (632 NM)
ALTITUDE 12.5 KM (41,000 FT)

NASA / LEWIS RESEARCH CENTER



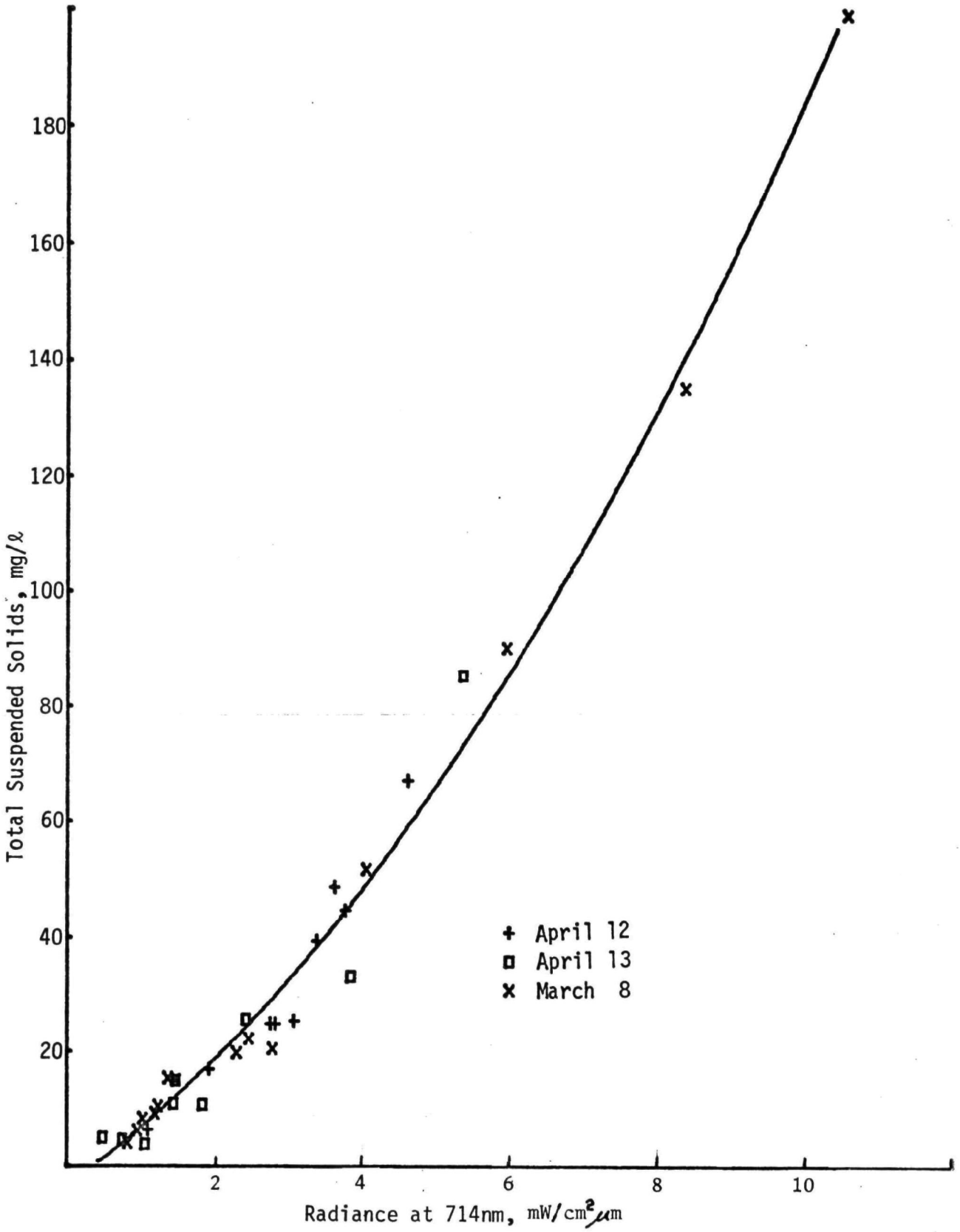
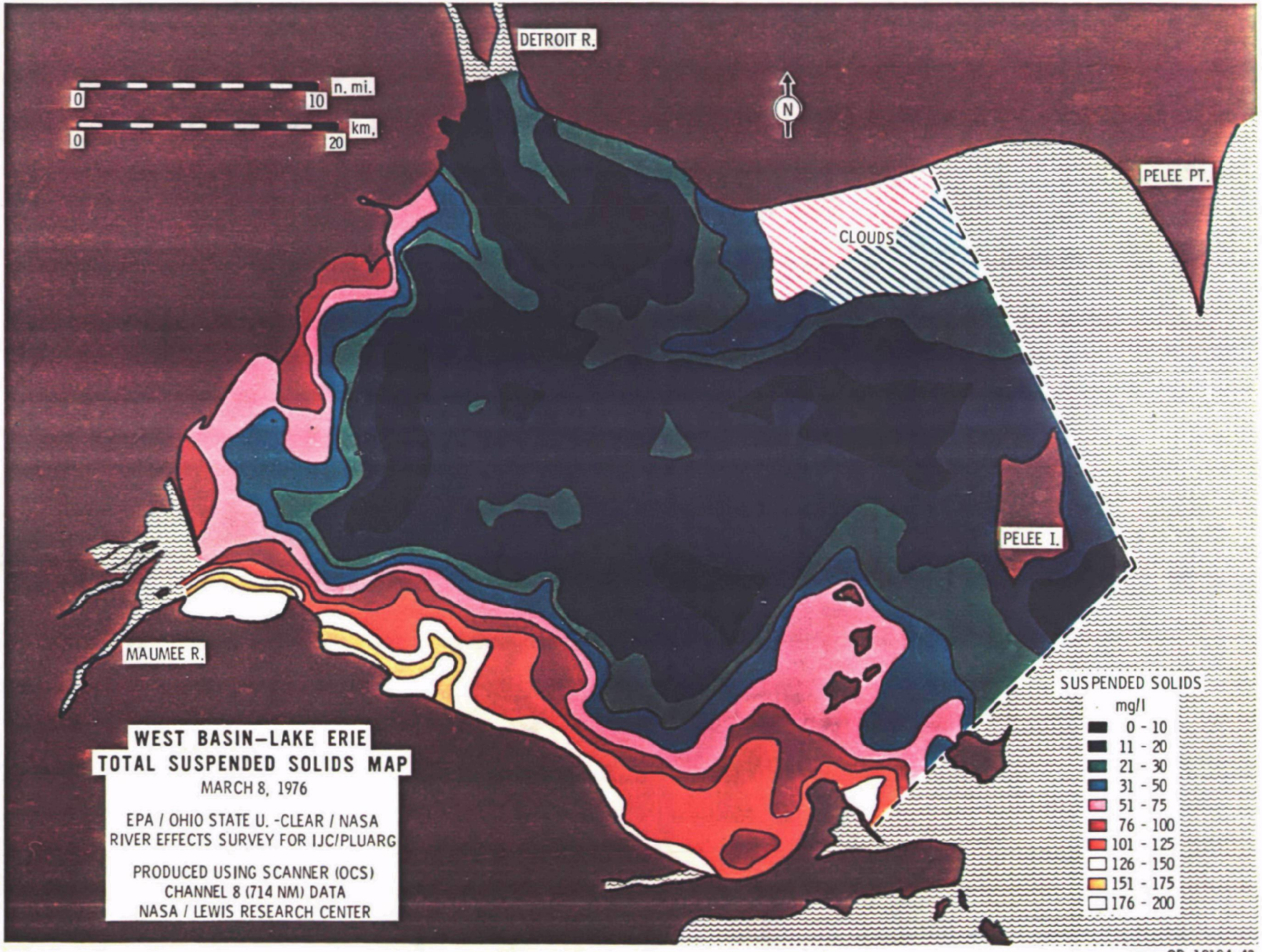


Figure 33. Generalized correlation applicable to data from multiple days.

NASA
C-77-1412



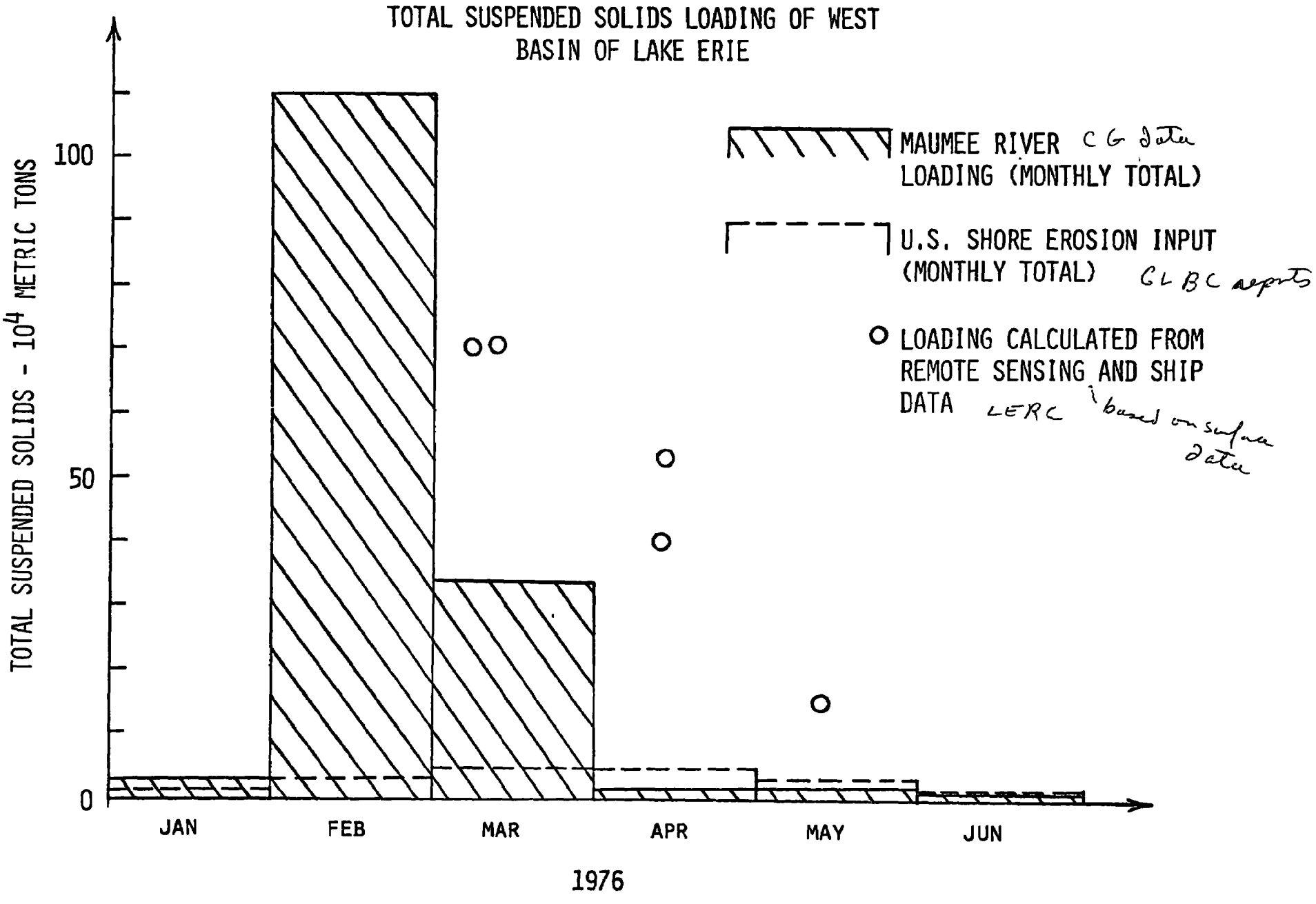
CD-12104-43

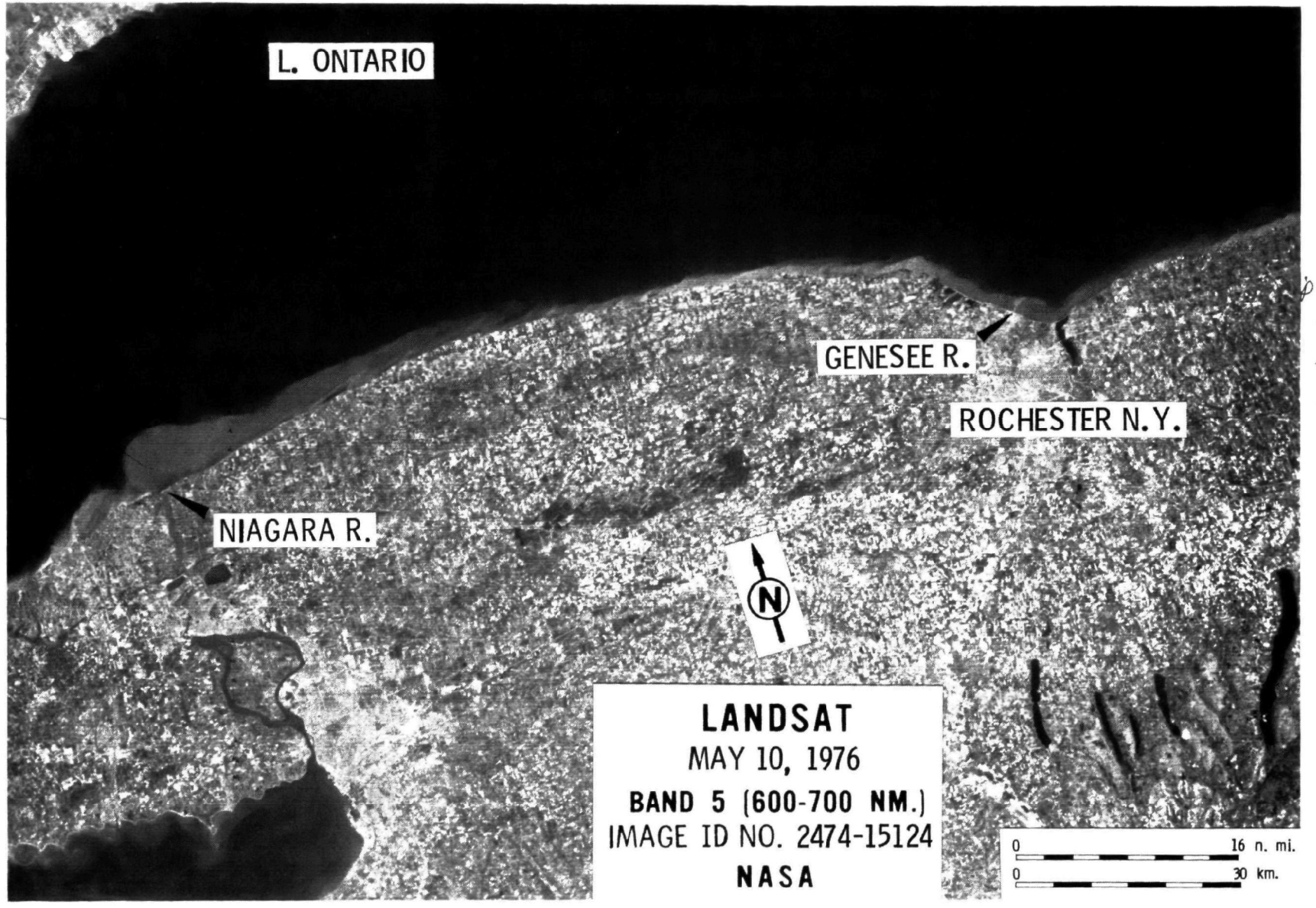
Western Arm Surface Total Organic N Values (mg/ℓ)
on April 4, 1976

indirect correlations

SUMMARY OF QUANTITATIVE CHEMICAL PARAMETER MAPS PRODUCED FOR PLUARG SURVEY (SUSPENDED SOLIDS USED AS TRACER)

RIVER	CHEMICAL PARAMETER
MAUMEE	DISSOLVED OXYGEN, TOTAL PHOSPHORUS
GENESEE	CHLOROPHYLL A
MENOMONEE	CHLORIDE, AMMONIA NITROGEN, NITRATE NITROGEN, TOTAL SOLIDS, DISSOLVED OXYGEN, TOTAL PHOSPHORUS, PARTICULATE PHOSPHORUS
GRAND	CALCIUM, MAGNESIUM, TOTAL KJELDAHL NITROGEN, CHLOROPHYLL A, SILICA, TOTAL PHOSPHORUS
NEMADJI	TOTAL PHOSPHORUS, TOTAL ORGANIC NITROGEN, SILICA, SULFATE


TOTAL SUSPENDED SOLIDS LOADING OF WEST BASIN OF LAKE ERIE
TOTAL SUSPENDED SOLIDS - 10^4 METRIC TONS
100
50
0
JAN
FEB
MAR
APR
MAY
JUN
1976
MAUMEE RIVER LOADING (MONTHLY TOTAL)
U.S. SHORE EROSION INPUT (MONTHLY TOTAL)
LOADING CALCULATED FROM REMOTE SENSING AND SHIP DATA


L. ONTARIO
GENESEE R.
ROCHESTER N.Y.
NIAGARA R.
N
LANDSAT
MAY 10, 1976
BAND 5 (600-700 NM.)
IMAGE ID NO. 2474-15124
NASA
0 16 n. mi.
0 30 km.

NUMERICAL MODELLING

- NUMERICAL MODELS FOR WIND DRIVEN CURRENTS IN GREAT LAKES HAVE BEEN SUCCESSFULLY DEVELOPED AT LERC. AT PRESENT, HOWEVER, NO FURTHER MODEL DEVELOPMENT IS BEING PERFORMED

- EPA-GROOSE ILE IS PRESENTLY DEVELOPING NUMERICAL CURRENT, DISPERSION AND ECOLOGICAL MODELS

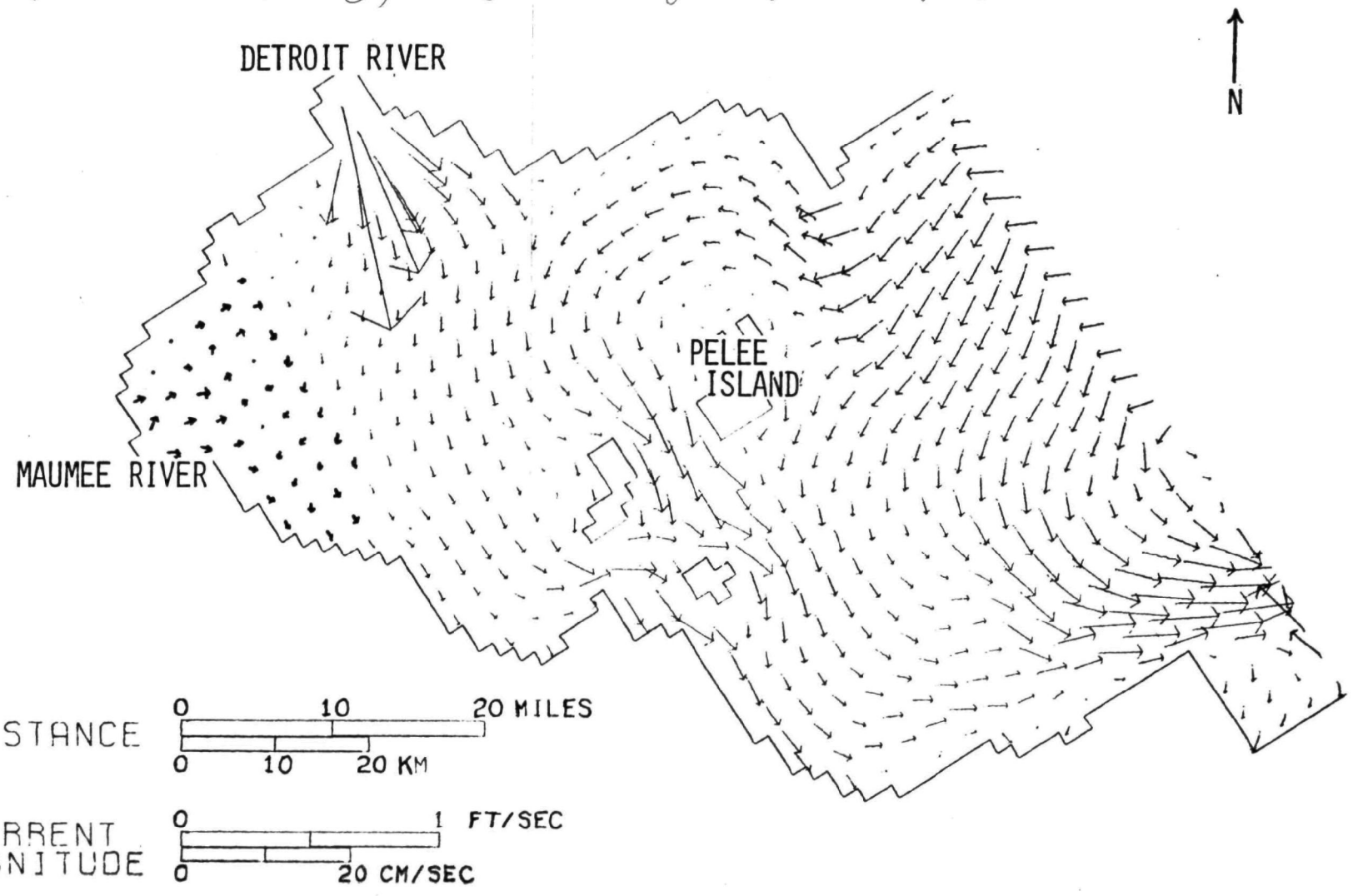
- LERC IS WORKING WITH EPA-GROSSE ILE ON THE UTILIZATION OF REMOTE SENSING DATA TO PROVIDE SYNOPTIC INPUTS FOR MODELS
  - 1975 CLEVELAND HARBOR DATA
  - 1976 PLUARG TASK D DATA

- EPA-GROSSE ILE IS USING THE LERC COMPUTER FACILITIES VIA REMOTE TERMINAL FOR RUNNING THEIR MODELS

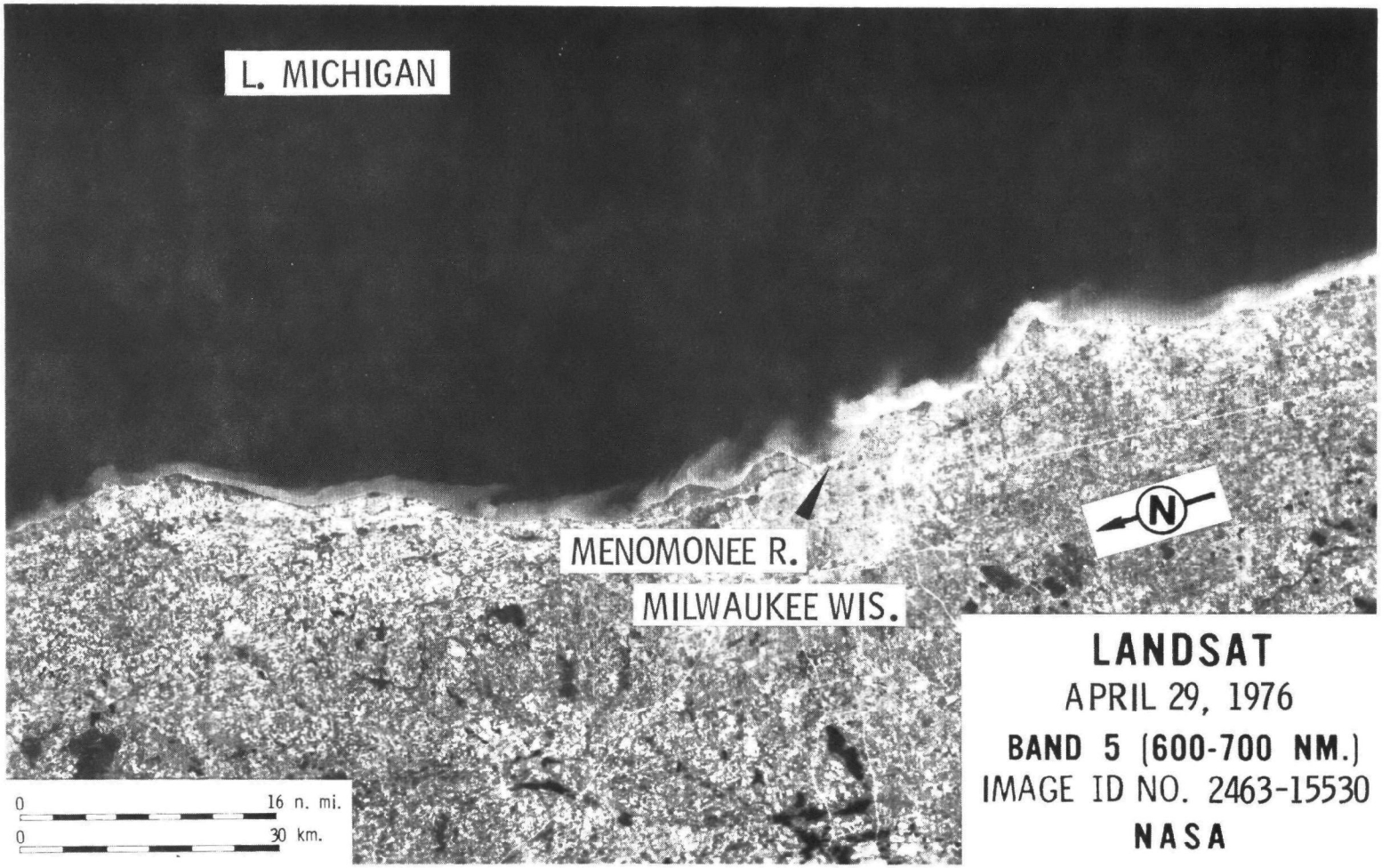
Computer generated plot

CALCULATED WEST BASIN SUBSURFACE (4.6 M) CURRENTS AT 9:00 AM, MARCH 8, 1976

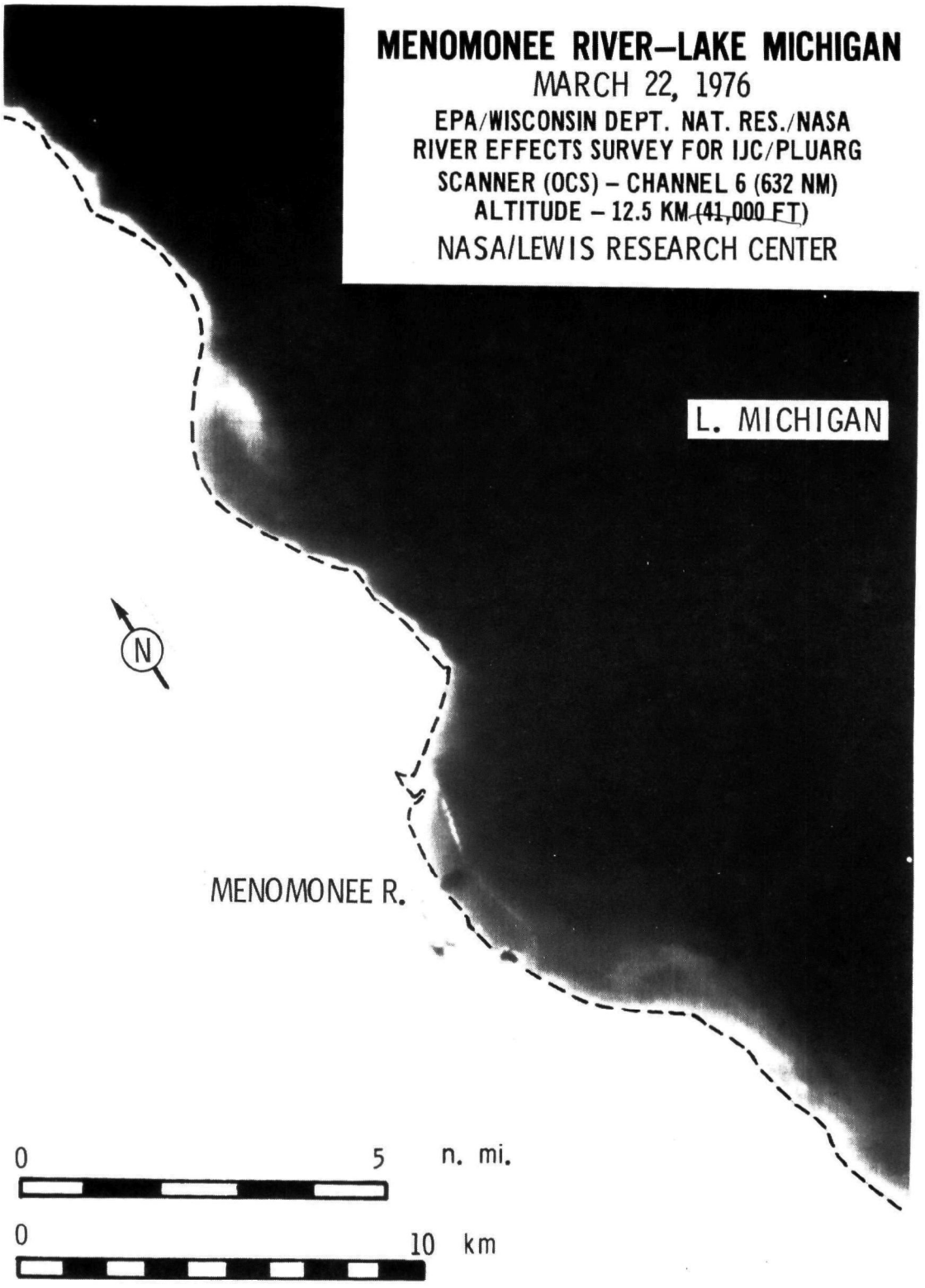
GLEP (Great Lakes Erosion plume) study now being ~~used~~ by GLBC to plug



Milwaukee Harbor



LANDSAT
APRIL 29, 1976
BAND 5 (600-700 NM.)
IMAGE ID NO. 2463-15530
NASA


MENOMONEE RIVER–LAKE MICHIGAN
MARCH 22, 1976
EPA/WISCONSIN DEPT. NAT. RES./NASA
RIVER EFFECTS SURVEY FOR IJC/PLUARG
SCANNER (OCS) – CHANNEL 6 (632 NM)
ALTITUDE – 12.5 KM (41,000 FT)
NASA/LEWIS RESEARCH CENTER
L. MICHIGAN
N
MENOMONEE R.
0
5
n. mi.
0
10
km

0 1.6 n. mi.

0 3.0 km.

MENOMONEE RIVER–LAKE MICHIGAN

APRIL 8, 1976

EPA/WISCONSIN DEPT. NAT. RES./NASA
RIVER EFFECTS SURVEY FOR IJC/PLUARG
SCANNER (M^2S) – CHANNEL 4 (560 NM)
ALTITUDE – 3.04 KM (10,000 FT)

NASA/LEWIS RESEARCH CENTER

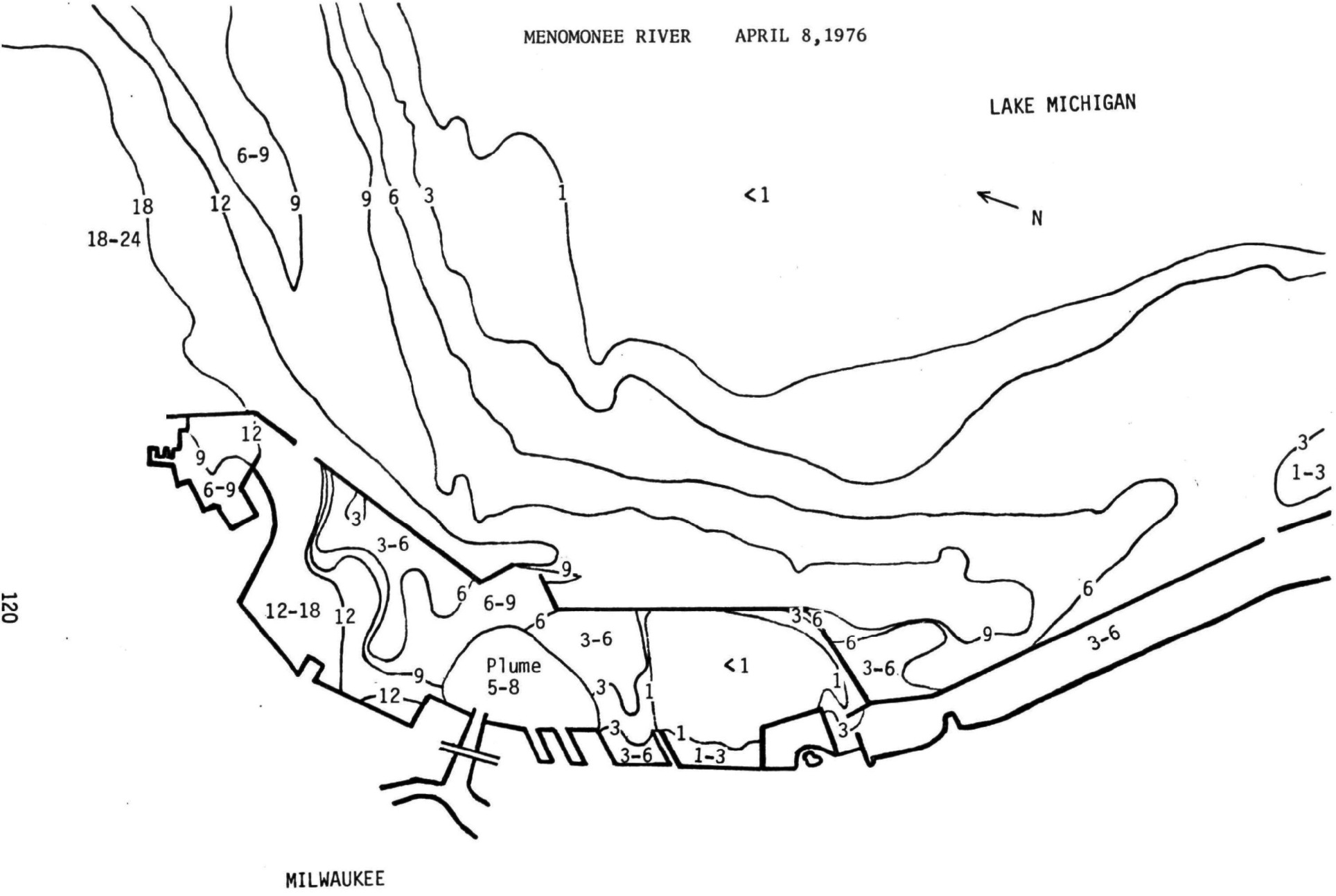
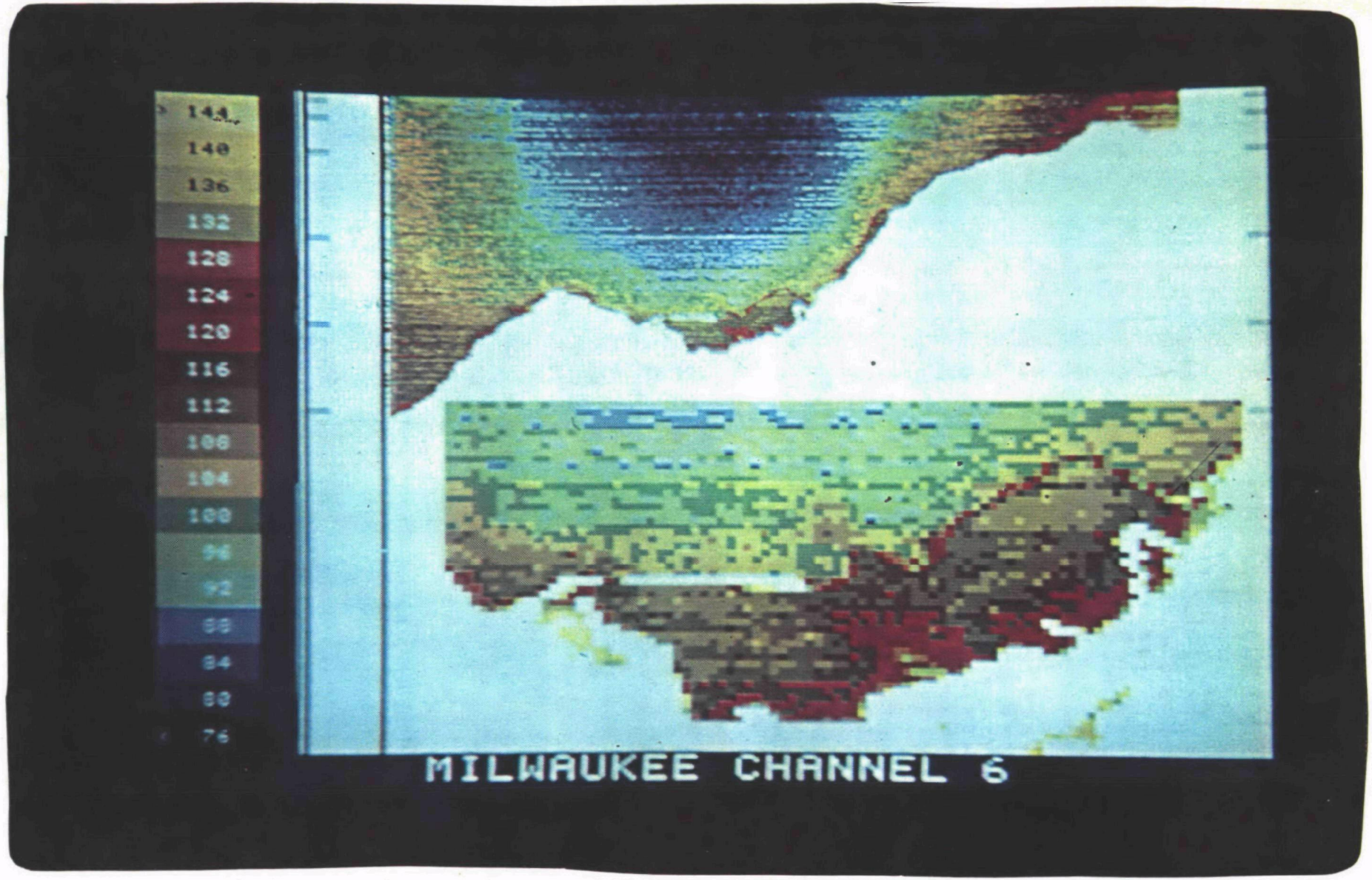
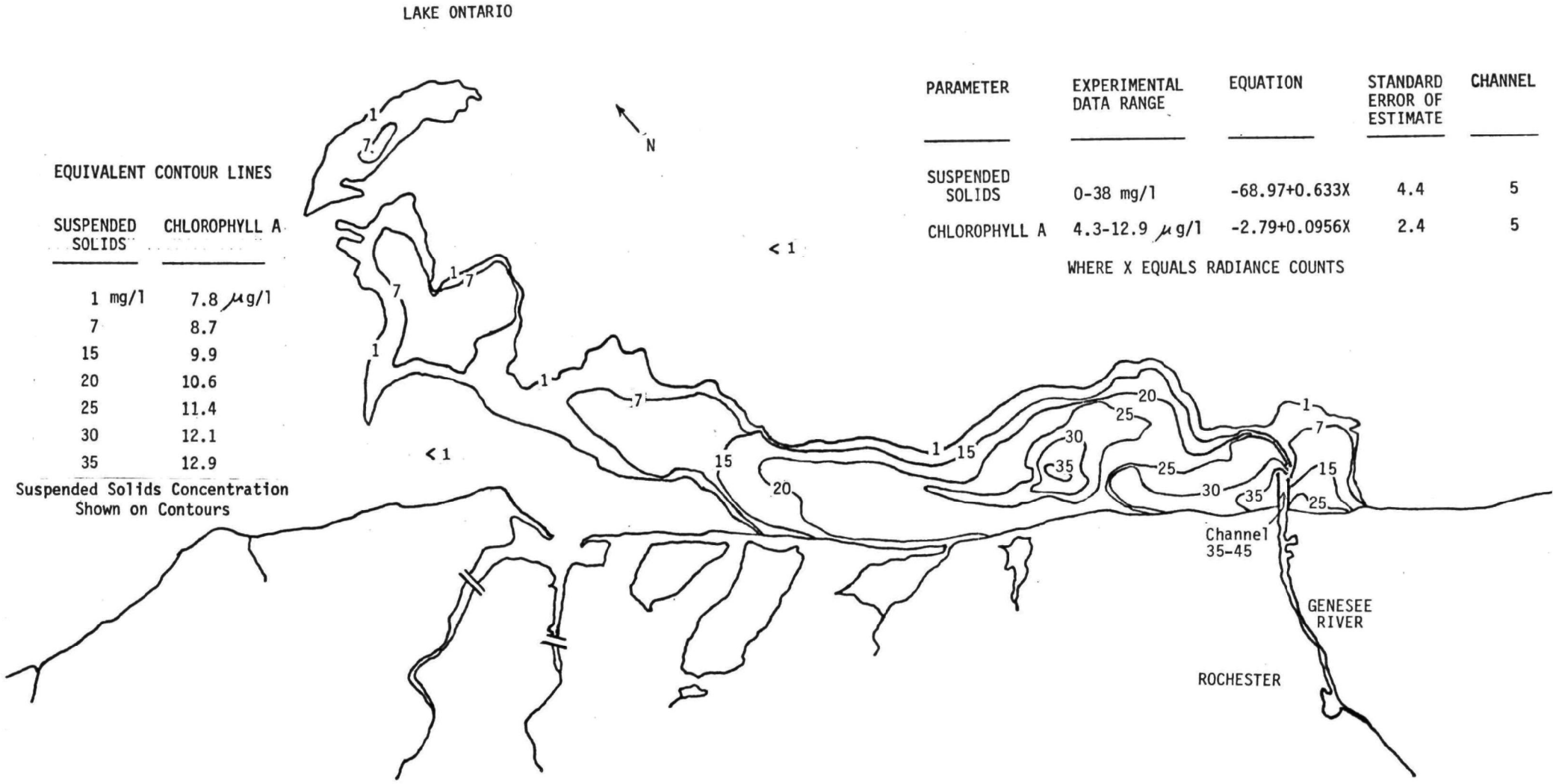


Figure 75. Contour plot of suspended solids (mg/ℓ) - see tables 10 and 11 for particulate phosphorus.


96.0
97.8
101.4
105.0
108.5
112.1
115.7
119.3
122.9
126.5
130.1
133.7
137.2
140.8
144.4
148.0
151.6
155.4
MILWAUKEE CHANNEL 9
NADIR=575 OFFSET= 500


144
140
136
132
128
124
120
116
112
108
104
100
96
92
88
84
80
76
MILWAUKEE CHANNEL 6

GENESEE RIVER AUGUST 3,1976



PARAMETER	EXPERIMENTAL DATA RANGE	EQUATION	STANDARD ERROR OF ESTIMATE	CHANNEL
SUSPENDED SOLIDS	0-38 mg/l	-68.97+0.633X	4.4	5
CHLOROPHYLL A	4.3-12.9 µg/l	-2.79+0.0956X	2.4	5

WHERE X EQUALS RADIANCE COUNTS

FIGURE 58 CONTOUR PLOT OF SUSPENDED SOLIDS AND CHLOROPHYLL A

PHYTOPLANKTON - CHLOROPHYLL MEASUREMENTS

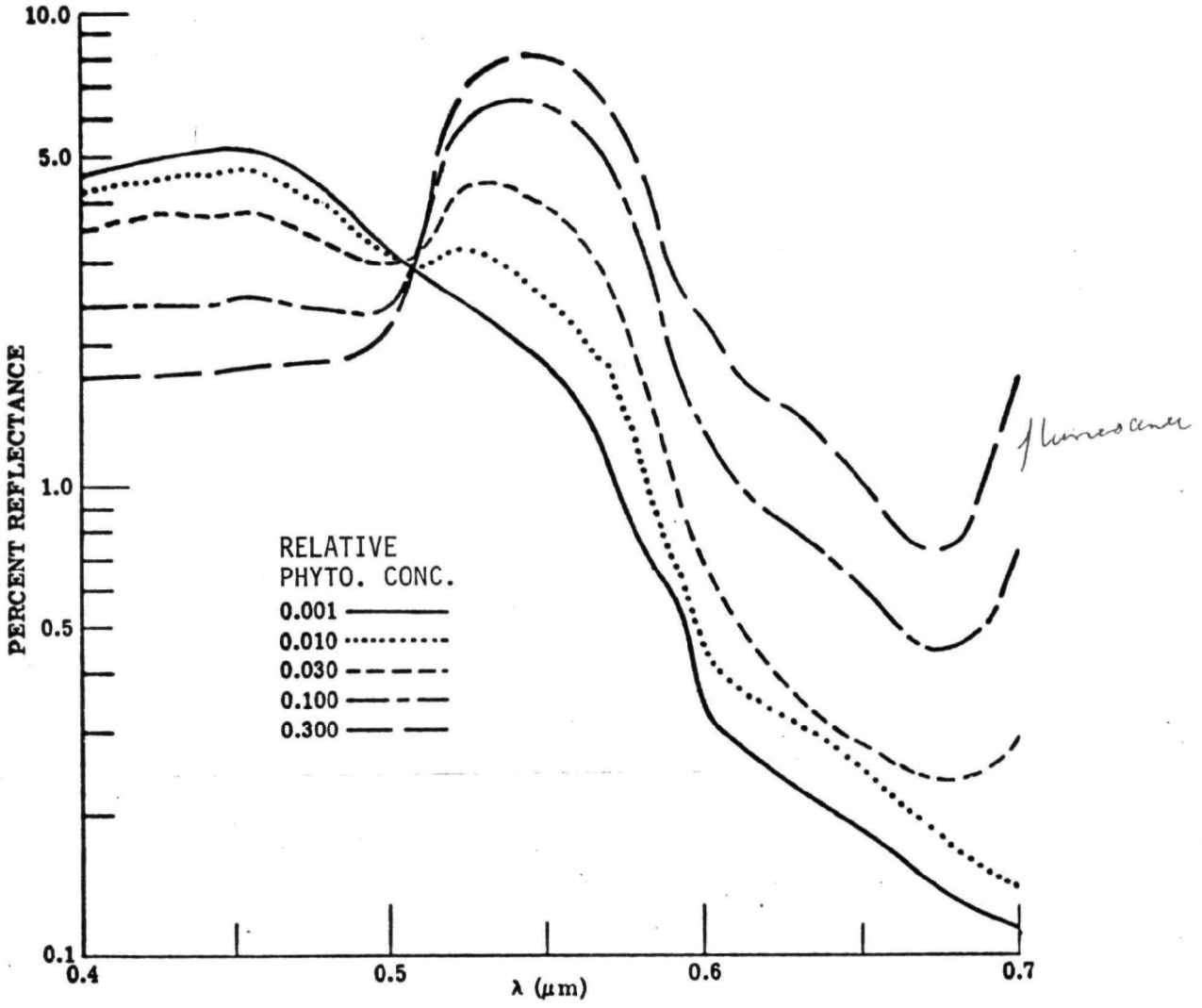
- REMOTE SENSING TECHNIQUES ARE BASED ON EFFECTS OF CHLOROPHYLL/PIGMENT LIGHT ABSORPTION AND FLUORESCENCE ON REFLECTANCE SPECTRA

- REMOTE SENSING METHODS TESTED IN GREAT LAKES

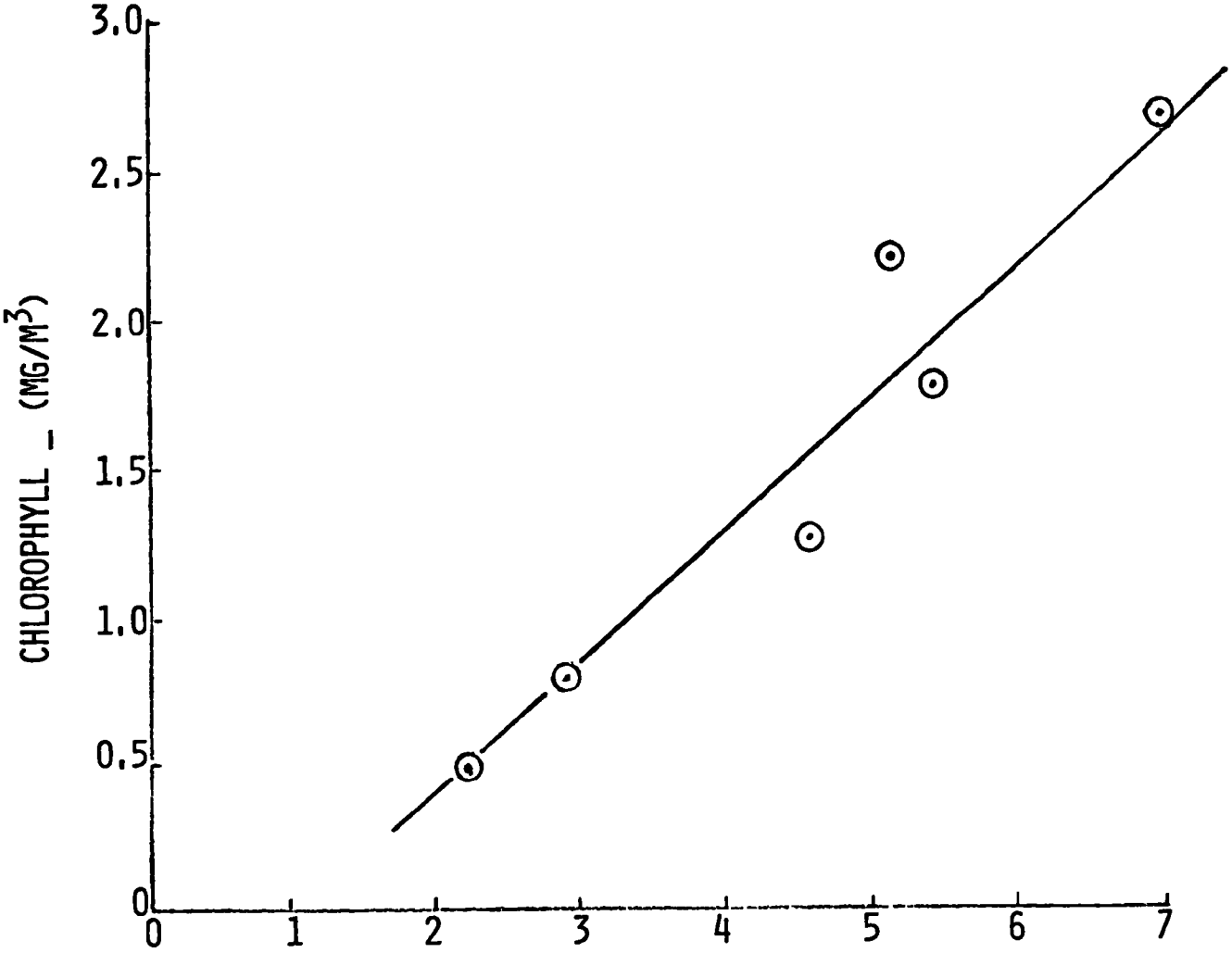
  A. RATIO OF RED AND BLUE BAND INTENSITIES
  B. DIFFERENCES OF RED AND BLUE BAND INTENSITIES
  C. SUNLIGHT INDUCED FLUORESCENCE looking at 685
  D. LASER INDUCED FLUORESCENCE flown primarily in L. Ontario

- MEASUREMENT COMPLEXITY

  GREAT LAKES CHLOROPHYLL RANGE - .5 TO 80 MG/M^3 : none of above works over entire range
  VARIETY OF SPECIES ABUNDANT AT VARIOUS TIMES
  LARGE VARIATIONS IN VERTICAL DISTRIBUTION
  SIGNIFICANT INORGANIC PARTICULATE PRESENT AT HIGHER CHLOROPHYLL CONCENTRATIONS
  " " tends to obscure signal



CHANGE IN REFLECTANCE OF WATER WITH INCREASING CONCENTRATION OF PHYTOPLANKTON

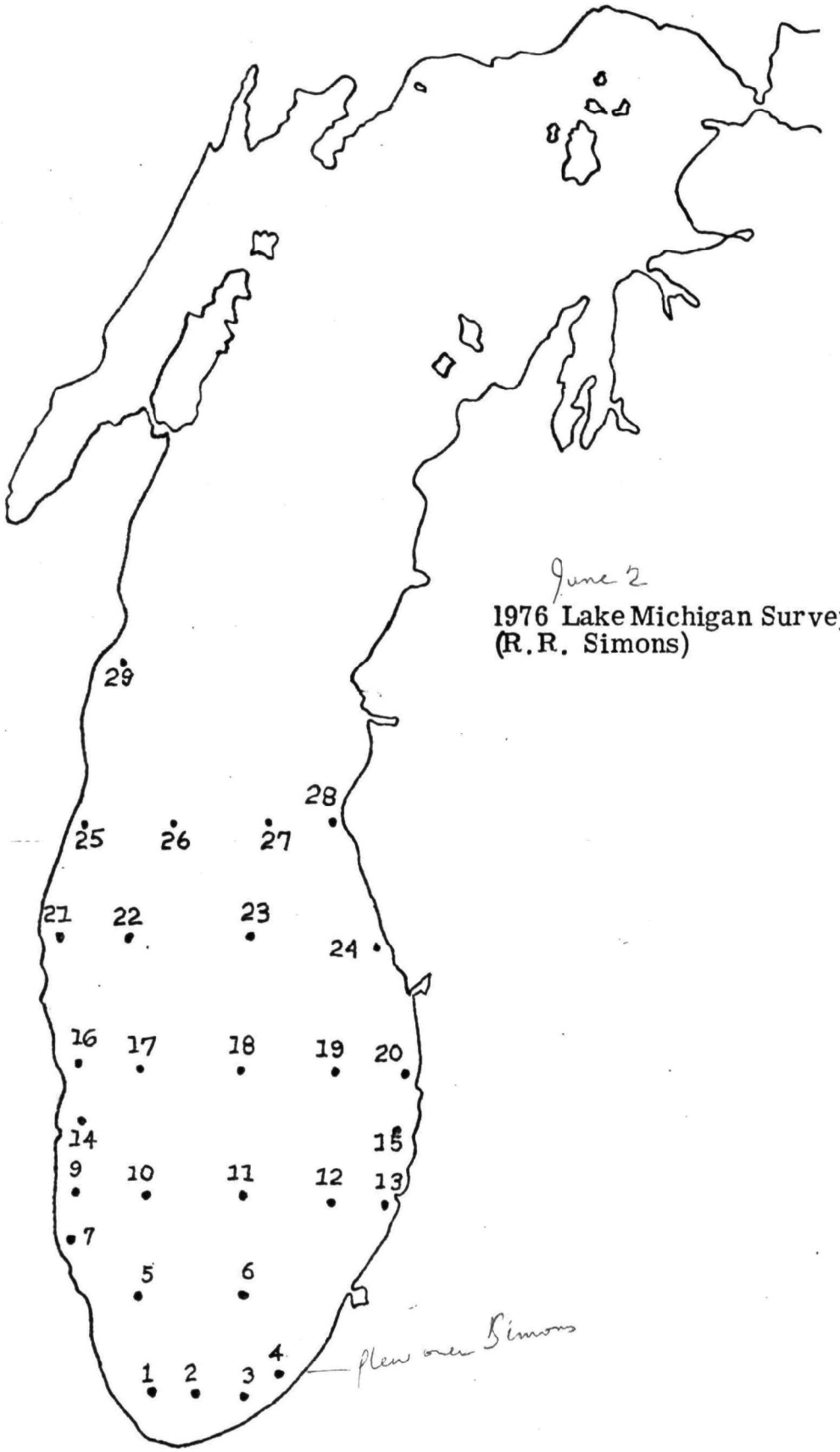


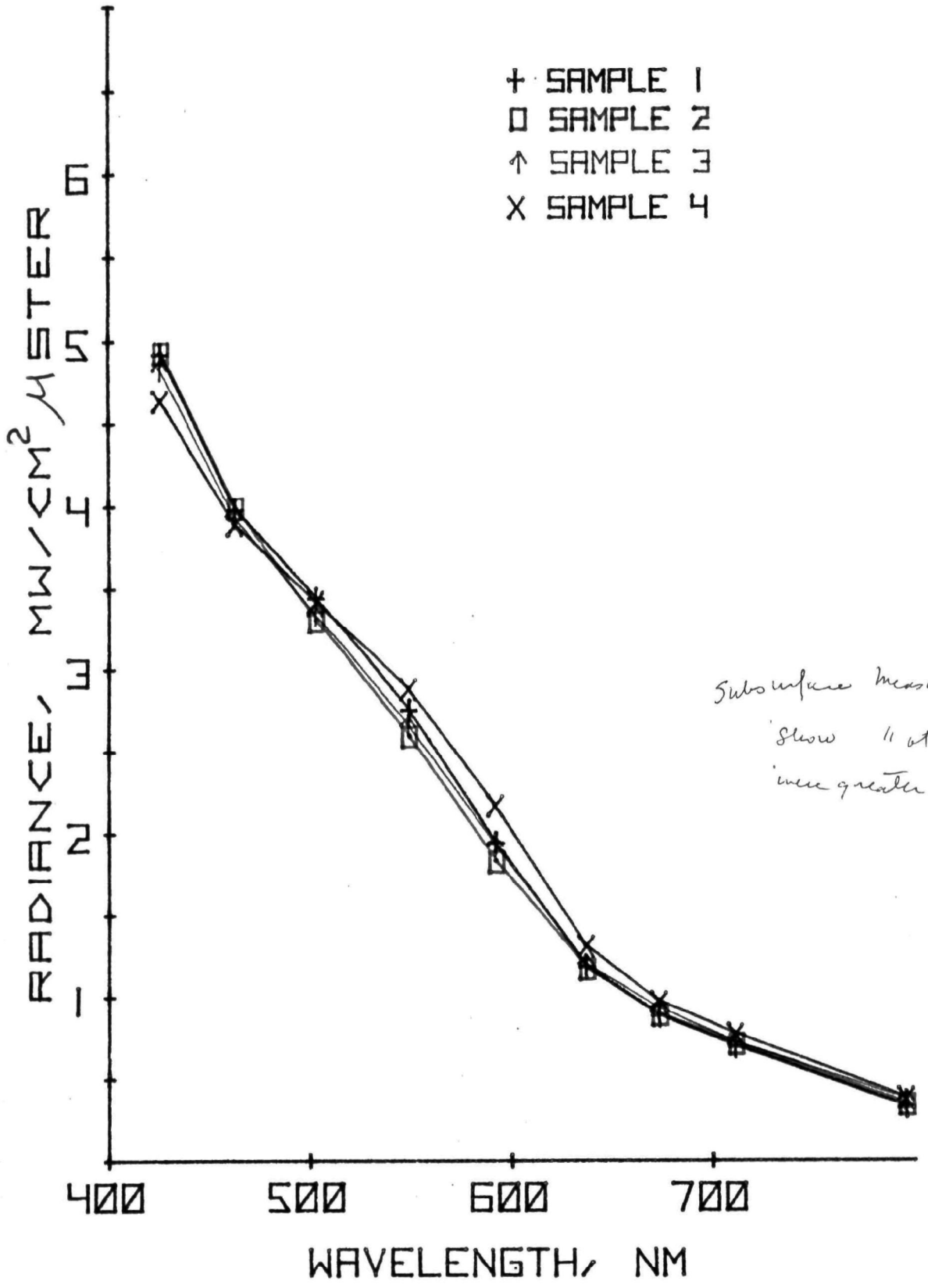
COLOR INDEX (RED/BLUE)

(DATA FROM LAKE HURON AND GEORGIAN BAY

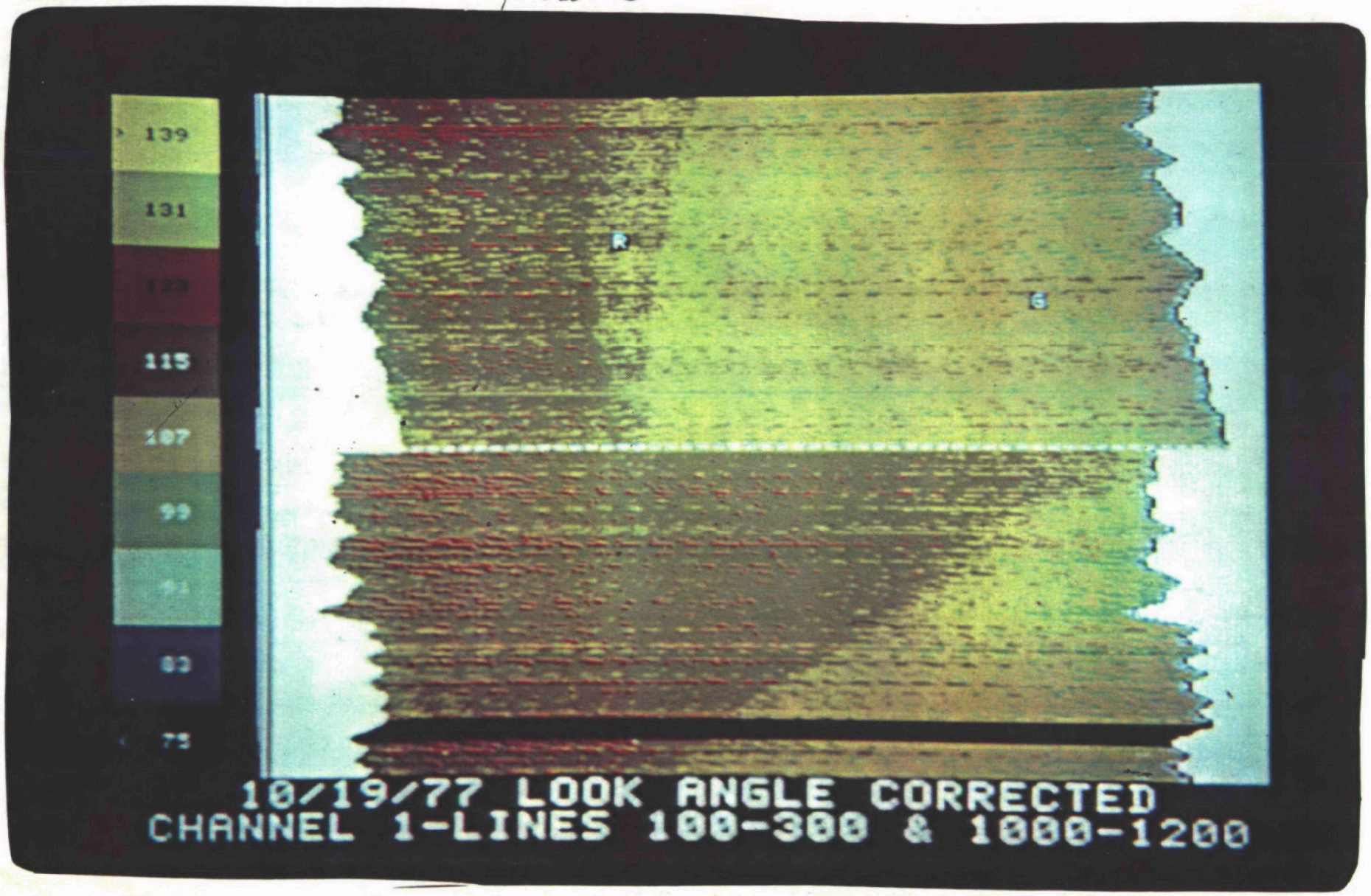
OVER A 6 MONTH PERIOD - 1974)

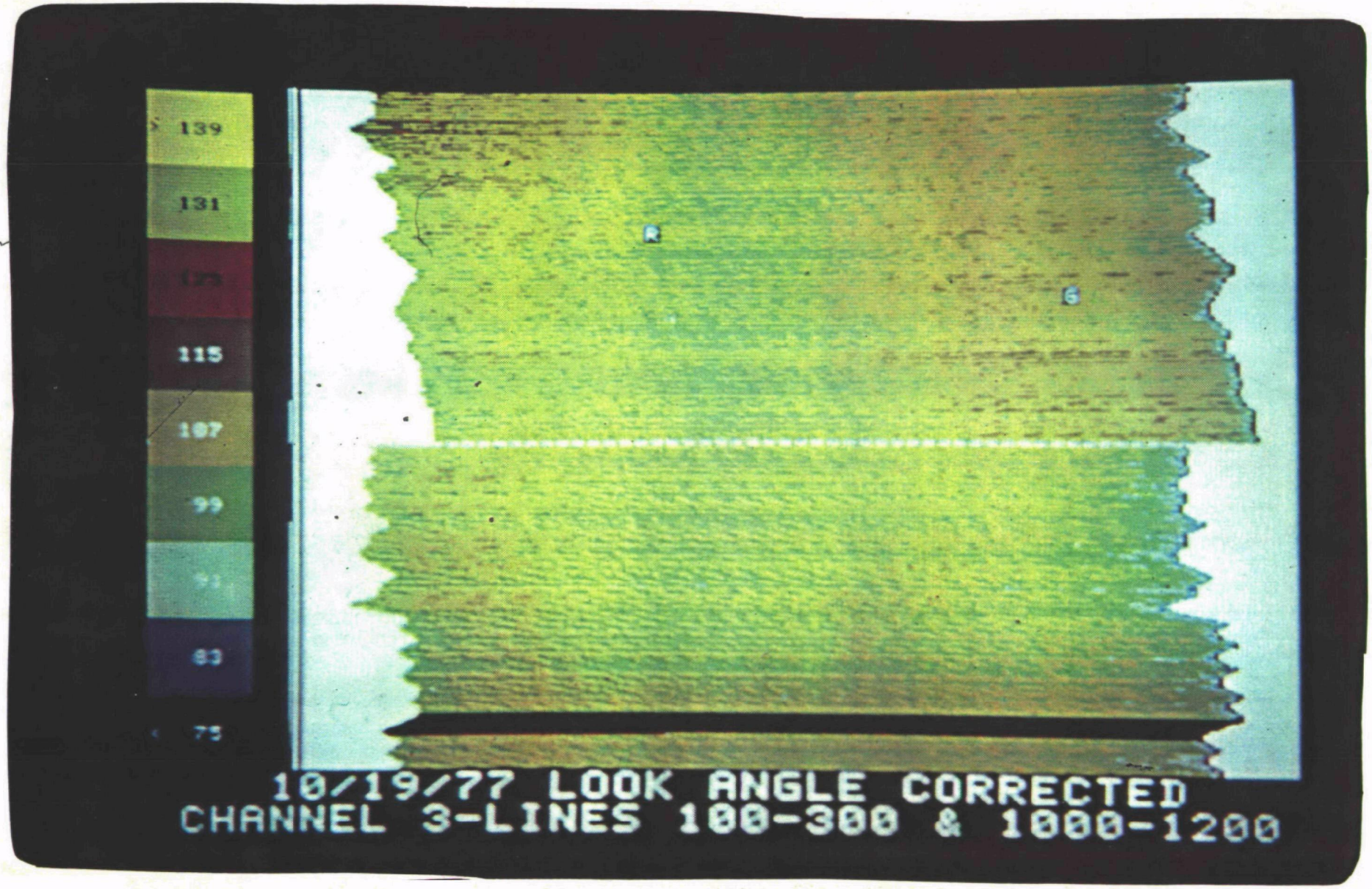
Some 140 measurements

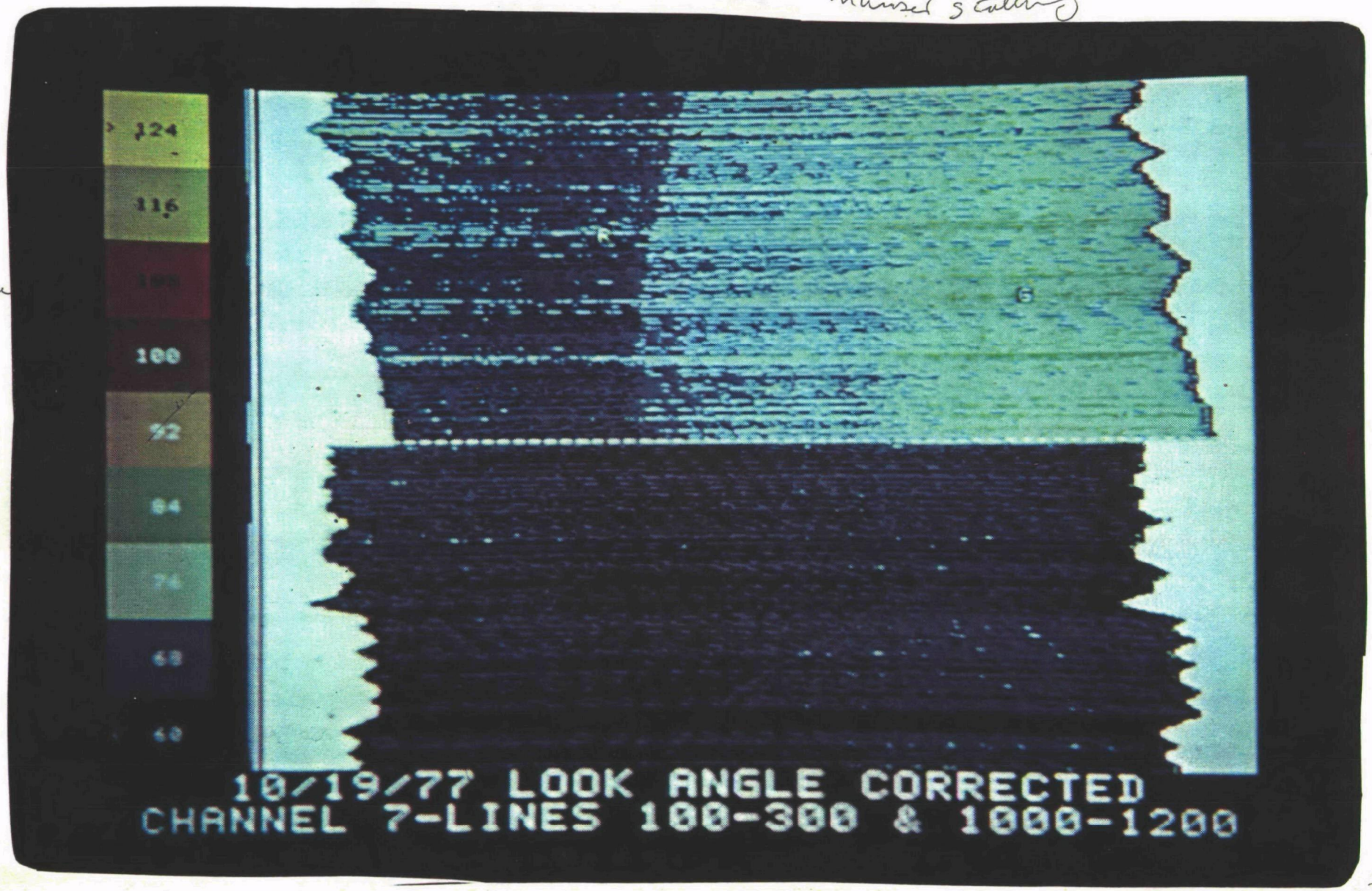

June 2
1976 Lake Michigan Survey
(R.R. Simons)
29
28
25
26
27
21
22
23
24
16
17
18
19
20
14
15
9
10
11
12
13
7
5
6
4
1
2
3
flew over Simons

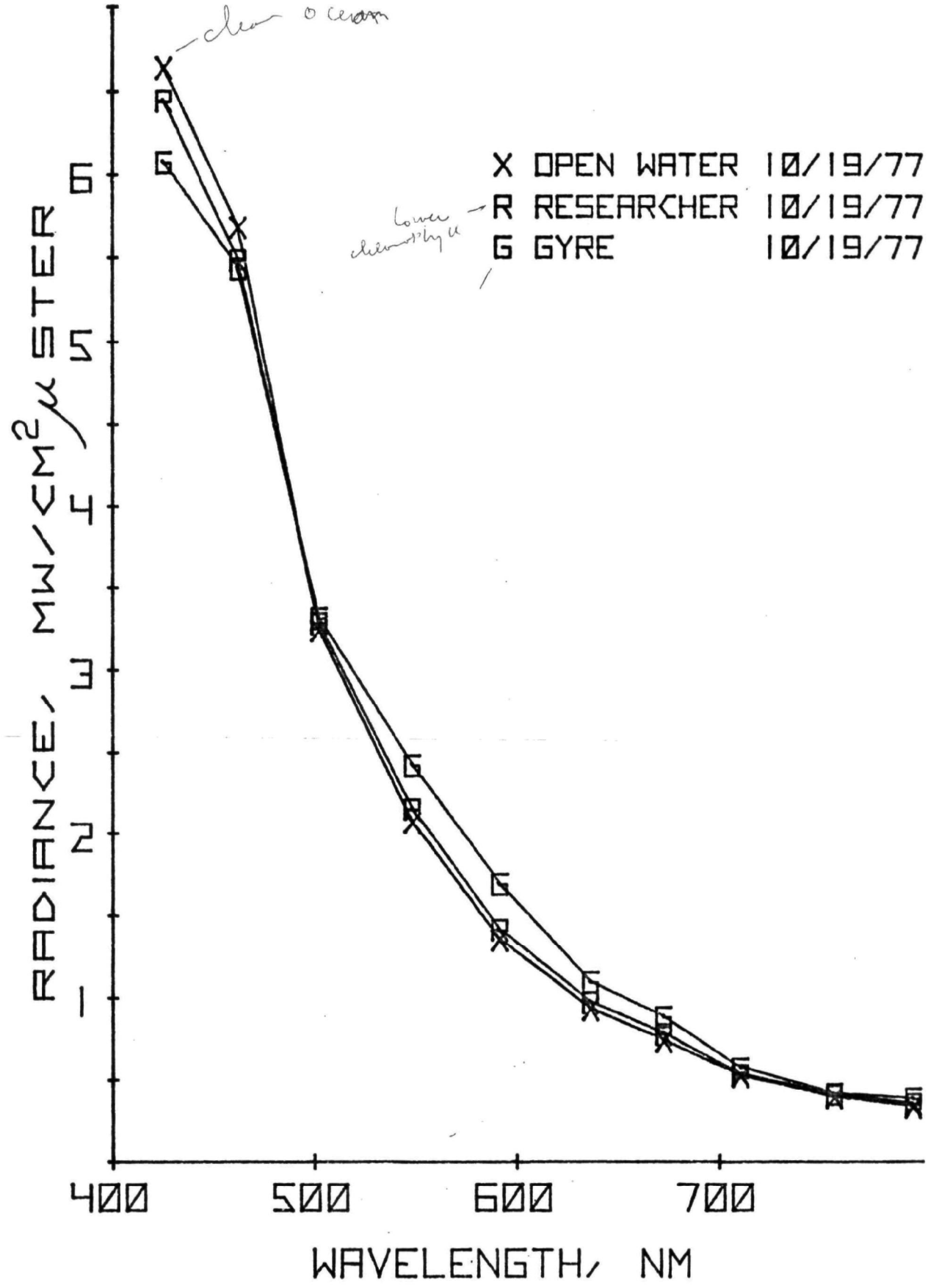


Subsurface measurements show 1 at 4 is greater


139
131
115
107
99
83
75
R
G
10/19/77 LOOK ANGLE CORRECTED
CHANNEL 1-LINES 100-300 & 1000-1200


139
131
123
115
107
99
91
83
75
R
G
10/19/77 LOOK ANGLE CORRECTED
CHANNEL 3-LINES 100-300 & 1000-1200


> 124
116
100
92
84
76
68
60
10/19/77 LOOK ANGLE CORRECTED
CHANNEL 7-LINES 100-300 & 1000-1200

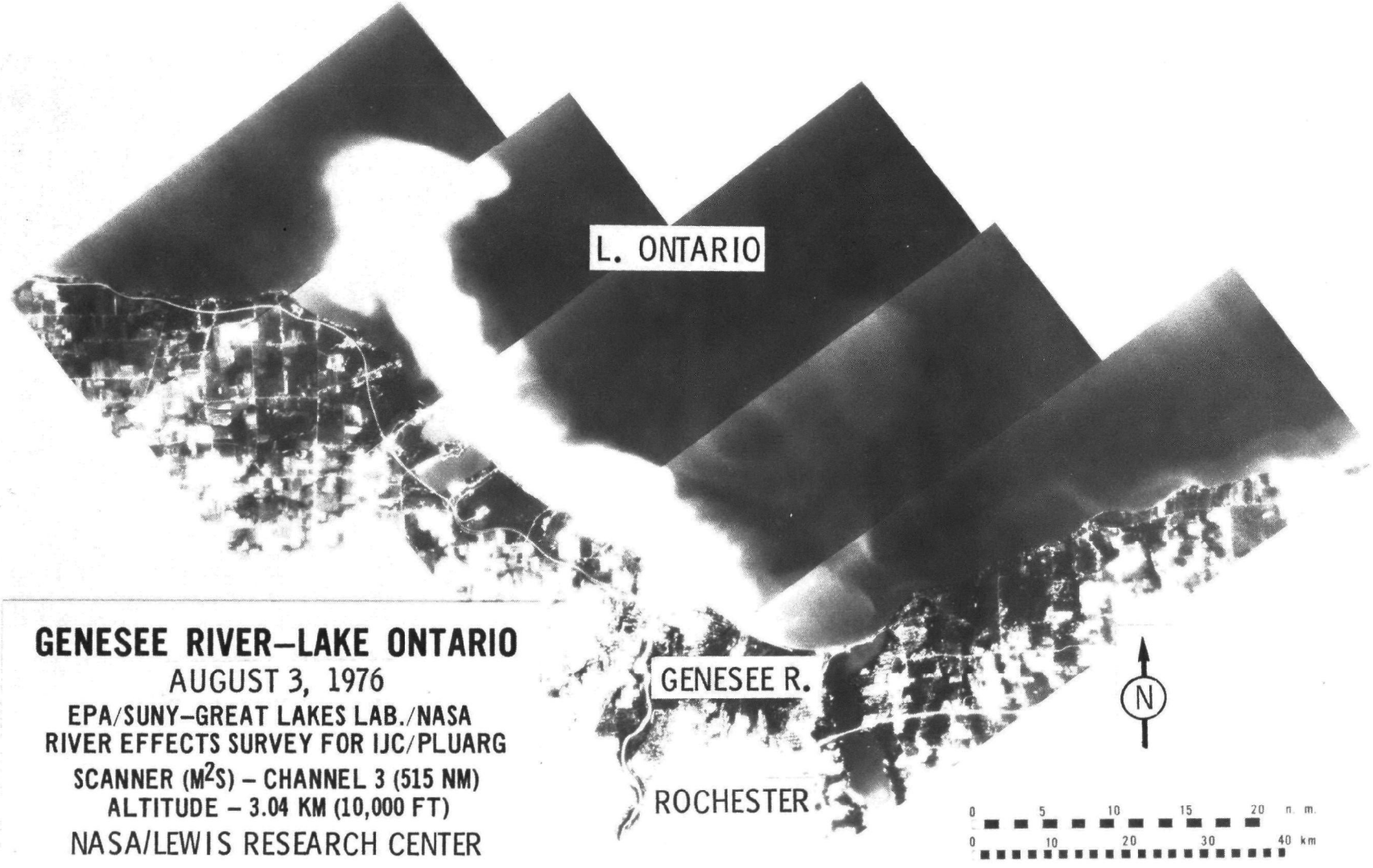

clear ocean
lower chlorophyll
X OPEN WATER 10/19/77
R RESEARCHER 10/19/77
G GYRE 10/19/77
RADIANCE, MW/CM2/MICROSTER
1
2
3
4
5
6
400
500
600
700
WAVELENGTH, NM

CLADOPHORA MAPPING

- A BENTHIC ALGAE WHICH CONTRIBUTES TO MAJOR PROBLEMS IN NEAR SHORE AREA. HIGH TOLERANCE TO TURBID WATER. INDICATOR OF NUTRIENT LOADINGS.
- REMOTE SENSING TECHNIQUES OF MONITORING BY RATIOING OF TWO ADJACENT BANDS HAS BEEN DEMONSTRATED WITH AIRCRAFT SCANNERS.
- HIGH SPACIAL RESOLUTION (40 TO 80 METERS) IS REQUIRED
- HIGH ALTITUDE REMOTE SENSING COULD EFFICIENTLY AID STUDIES ON PRODUCTIVITY IN RELATION TO LOCATION, SEASON AND OTHER ABIOTIC PARAMETERS.
- GROUND TRUTH IS NECESSARY TO ESTIMATE BIOMASS - IMAGERY COULD BE USED FOR SAMPLING SITE SELECTION.

ERIM did a study: 2 adjacent bands

When to measure?



GENESEE RIVER–LAKE ONTARIO

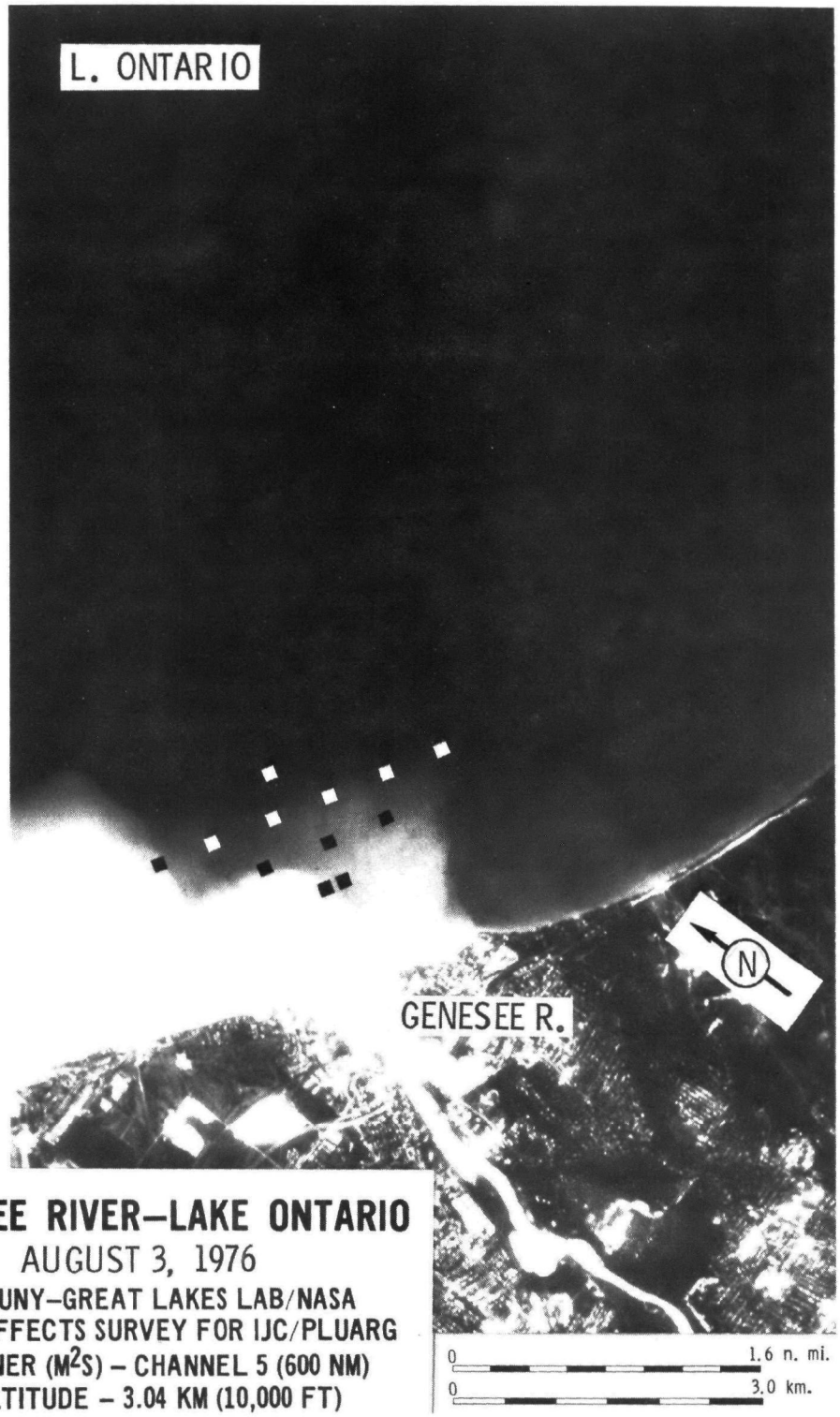
AUGUST 3, 1976

EPA/SUNY–GREAT LAKES LAB./NASA
RIVER EFFECTS SURVEY FOR IJC/PLUARG

SCANNER (M^2S) – CHANNEL 3 (515 NM)
ALTITUDE – 3.04 KM (10,000 FT)

NASA/LEWIS RESEARCH CENTER

Sampling tracks were very rigid

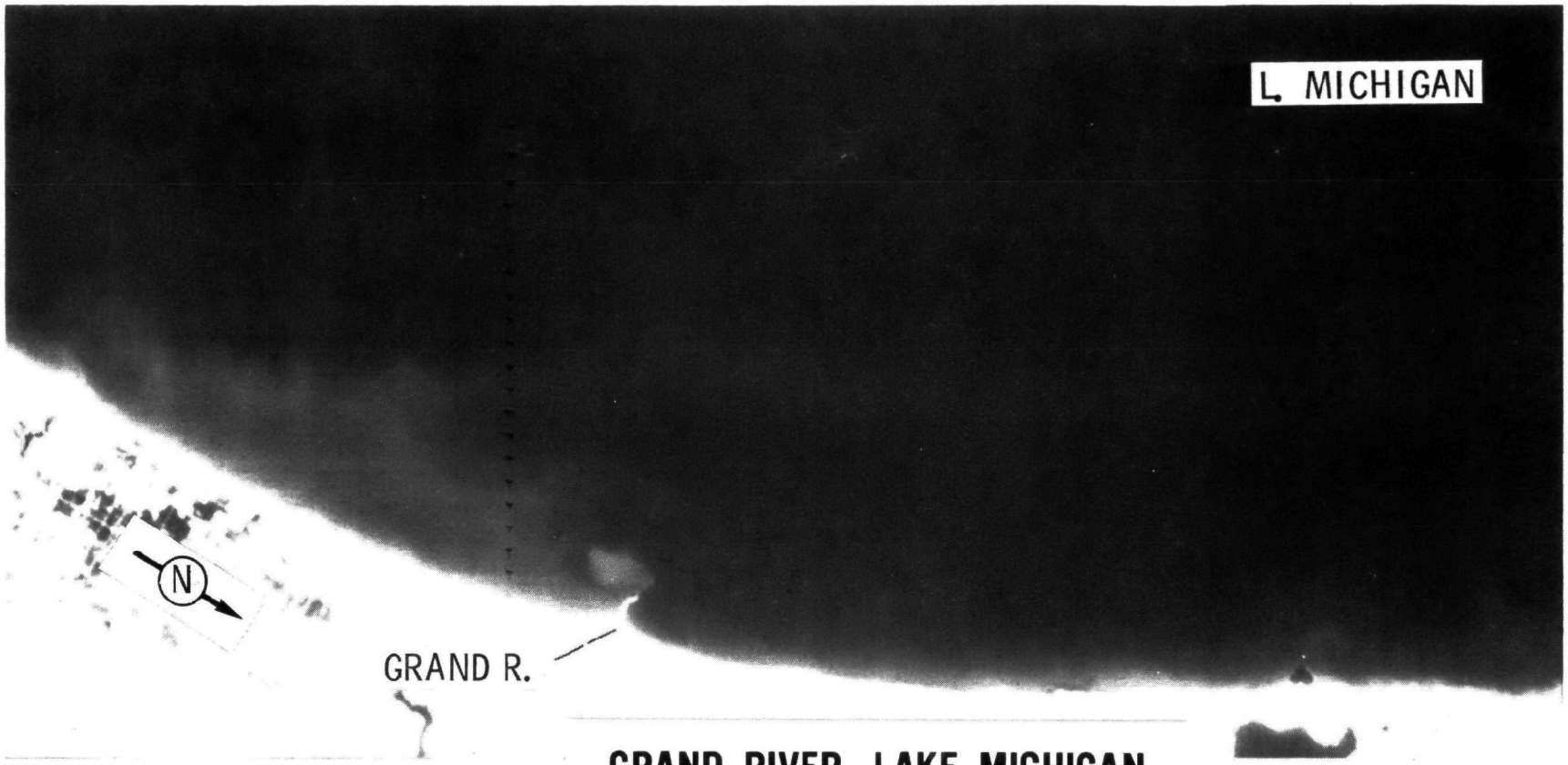


GENESEE RIVER–LAKE ONTARIO

AUGUST 3, 1976

EPA/SUNY–GREAT LAKES LAB/NASA
RIVER EFFECTS SURVEY FOR IJC/PLUARG
SCANNER (M^2S) – CHANNEL 5 (600 NM)
ALTITUDE – 3.04 KM (10,000 FT)

NASA/LEWIS RESEARCH CENTER



GRAND RIVER–LAKE MICHIGAN

MARCH 22, 1976

EPA/NOAA – GLERL/NASA
RIVER EFFECTS SURVEY FOR IJC/PLUARG
SCANNER (OCS) – CHANNEL 6 (632 NM)
ALTITUDE – 12.5 KM (41,000 FT)

NASA/LEWIS RESEARCH CENTER

took it and
transmitted to in that
right
However

GRAND RIVER–LAKE MICHIGAN

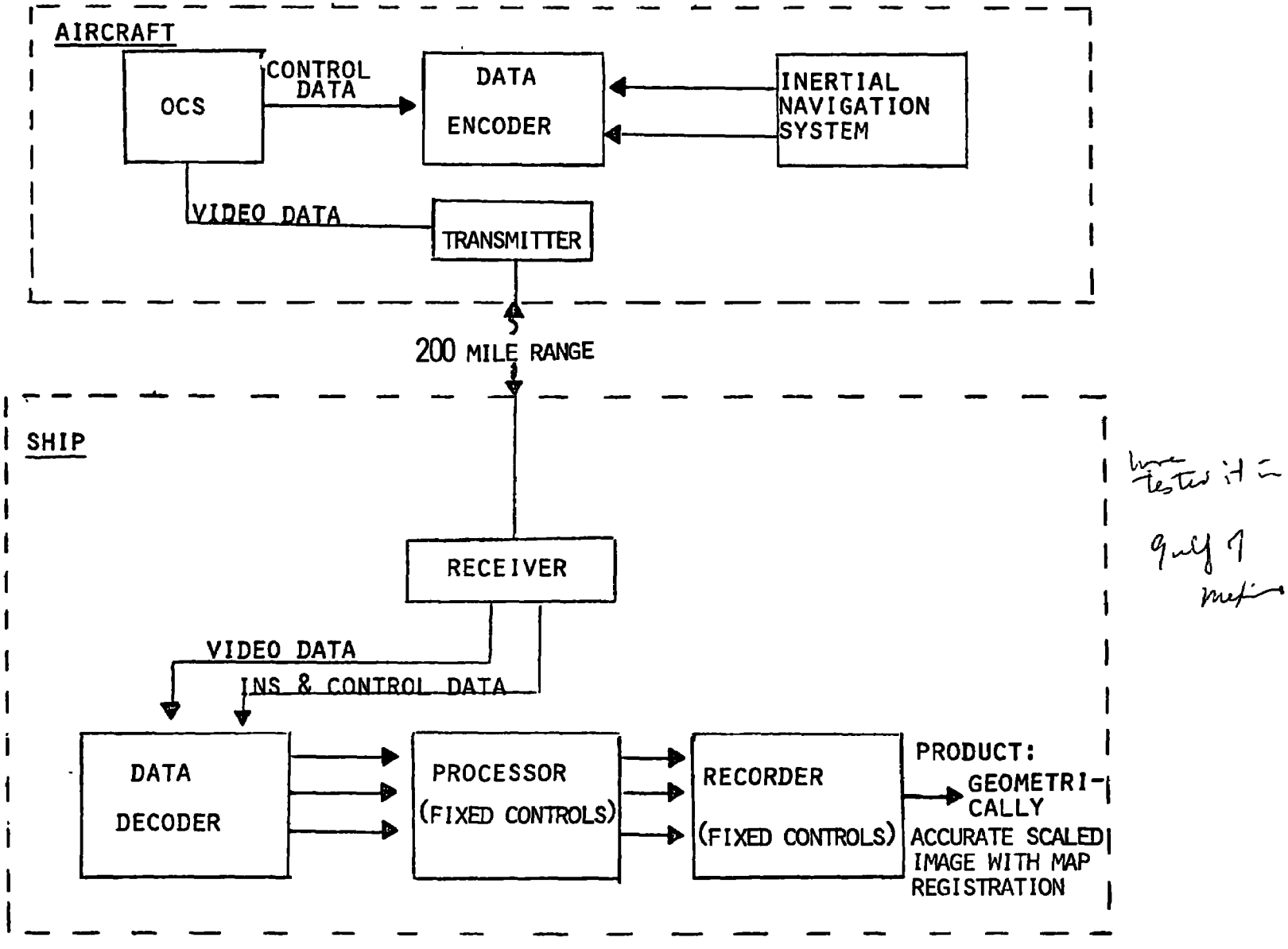
MARCH 23, 1976

EPA/NOAA – GLERL/NASA
RIVER EFFECTS SURVEY FOR IJC/PLUARG
SCANNER (OCS) – CHANNEL 6 (632 NM)
ALTITUDE – 12.5 KM (41,000 FT)

NASA/LEWIS RESEARCH CENTER

the next day
:, we set out to develop real-time transmission

REAL-TIME TRANSMISSION OF IMAGE DATA FROM AIRCRAFT TO SHIP



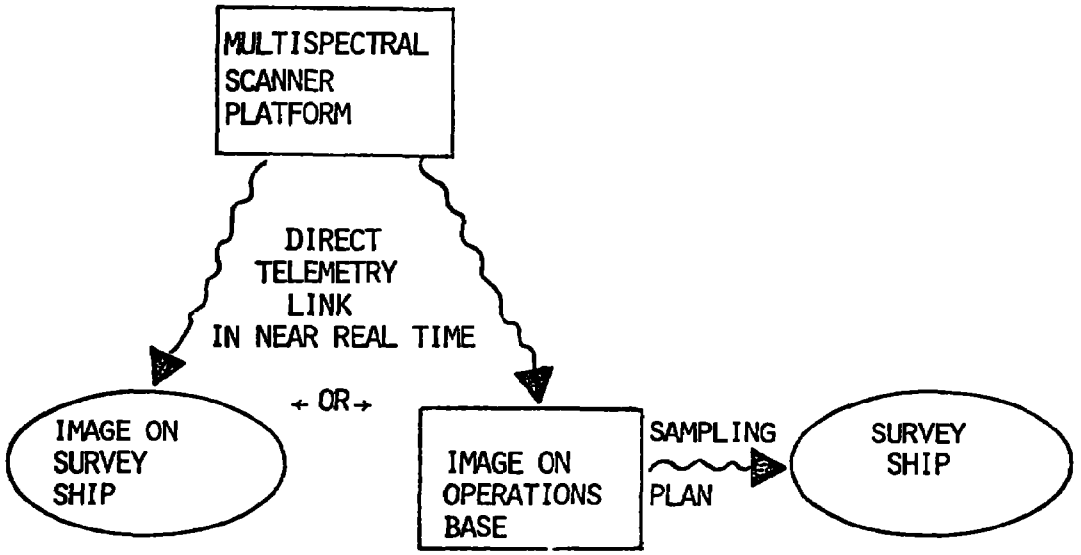


IMAGE PRODUCTS IN NEAR REAL-TIME (NOT REQ ADP)

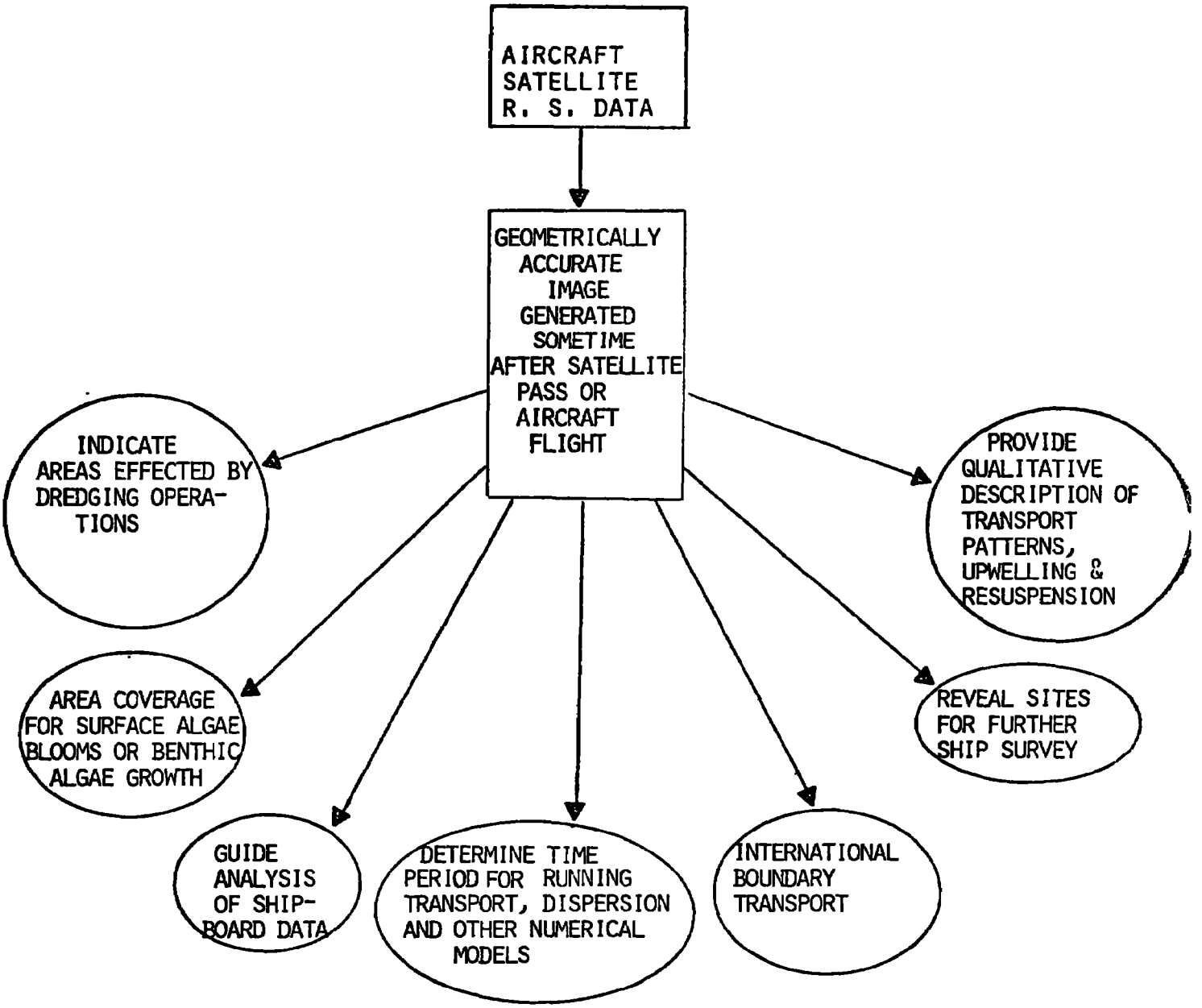


IMAGE PRODUCES (POST MISSION) NOT REQUIRING ADP

PARAMETER MEASUREMENTS FOR WHICH REMOTE SENSING CAN BE UTILIZED (NOW OR IN THE NEAR-TERM FUTURE)

PHOTIC DEPTH — extinction depth; 1% extinction

TOTAL SUSPENDED SOLIDS ; turbidity can differentiate organic/inorganic

INORGANIC PARTICULATE ;

ORGANIC DETRITUS

DISSOLVED ORGANICS

LIVING BIOMASS (PHYTOPLANKTON AND BENTHIC ALGAE)

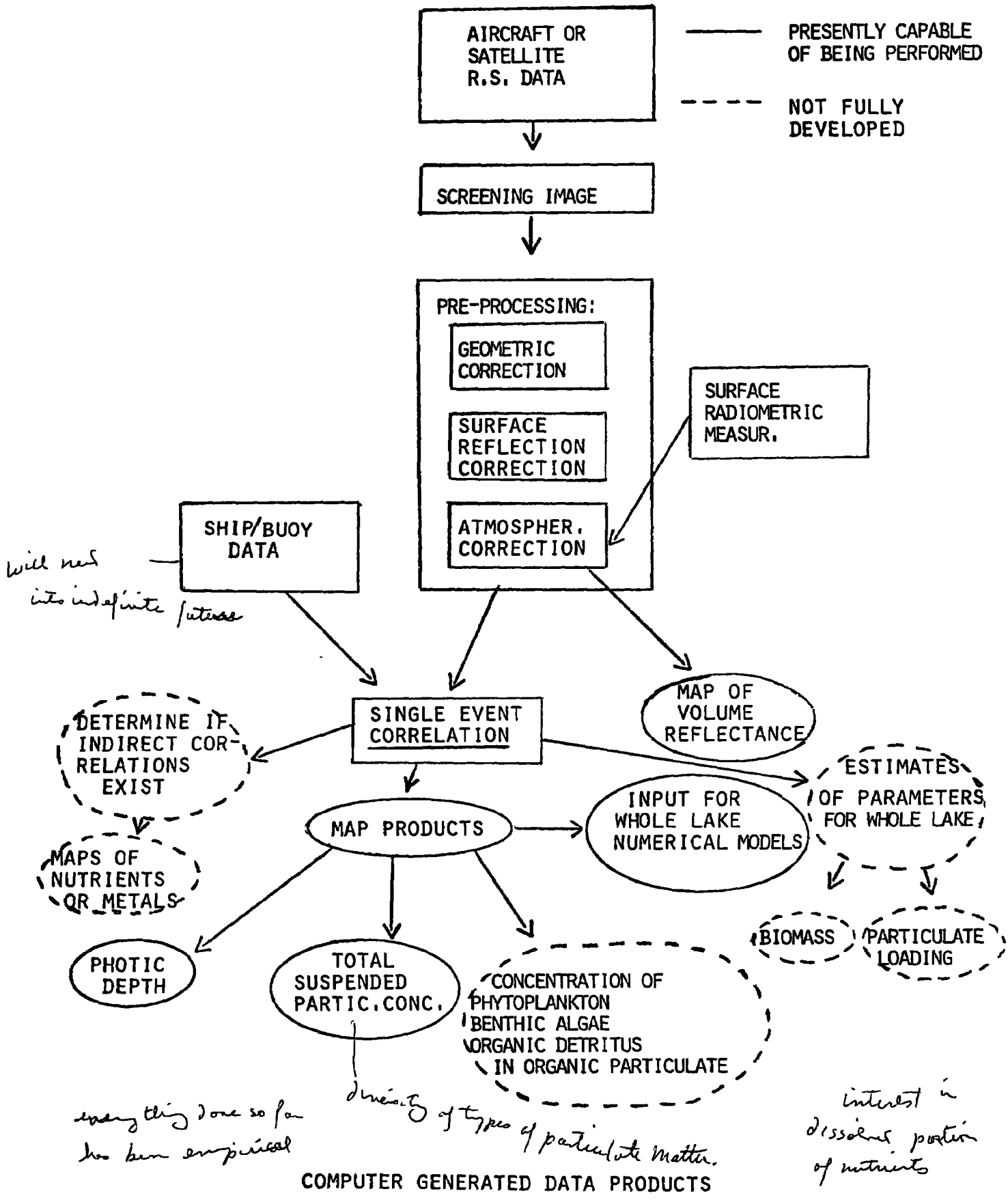
NUTRIENTS (INDIRECT) / particulate tracers

METALS (INDIRECT)

TEMPERATURE

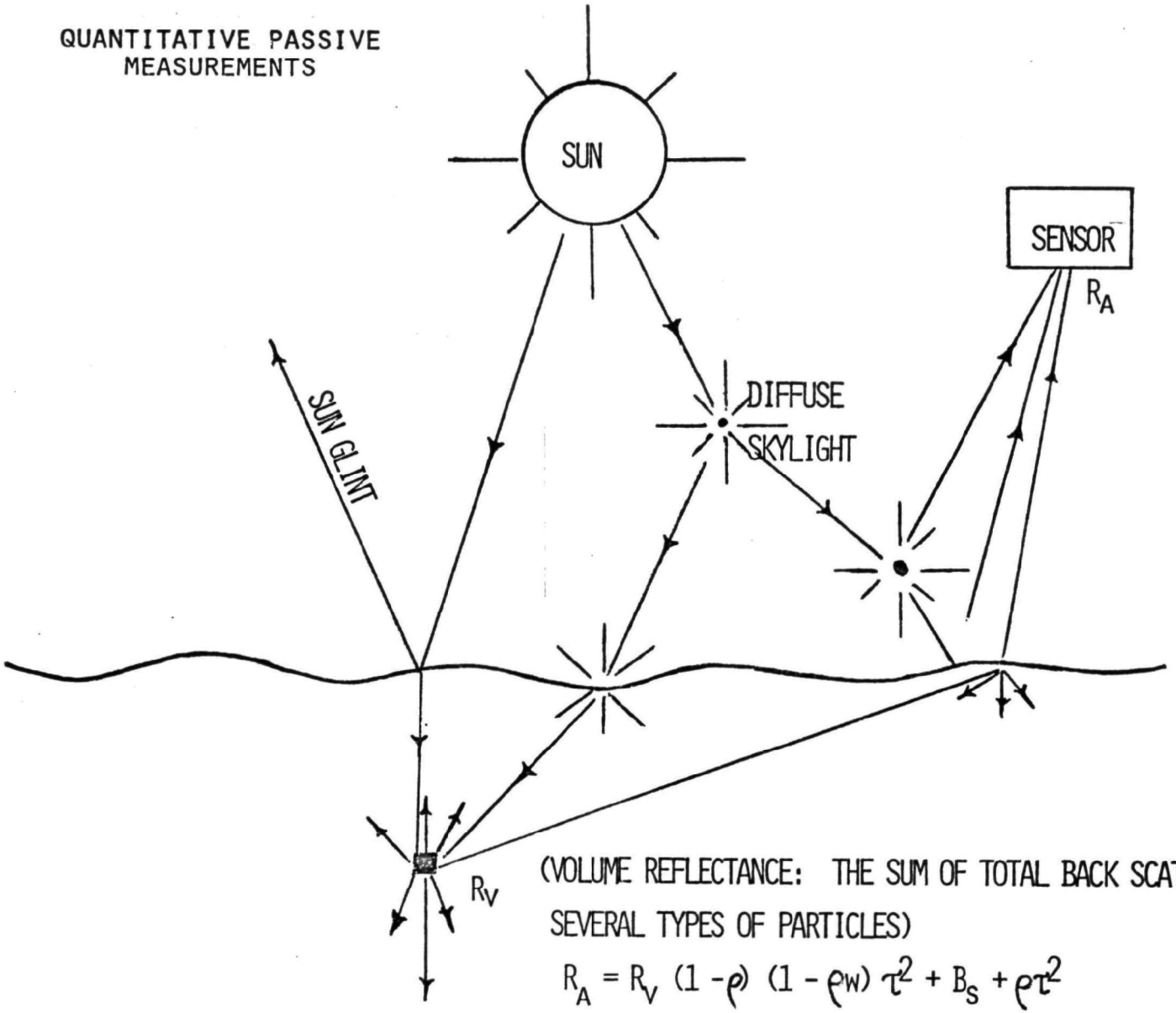
VERTICAL MIXING (SEA STATE)

OIL



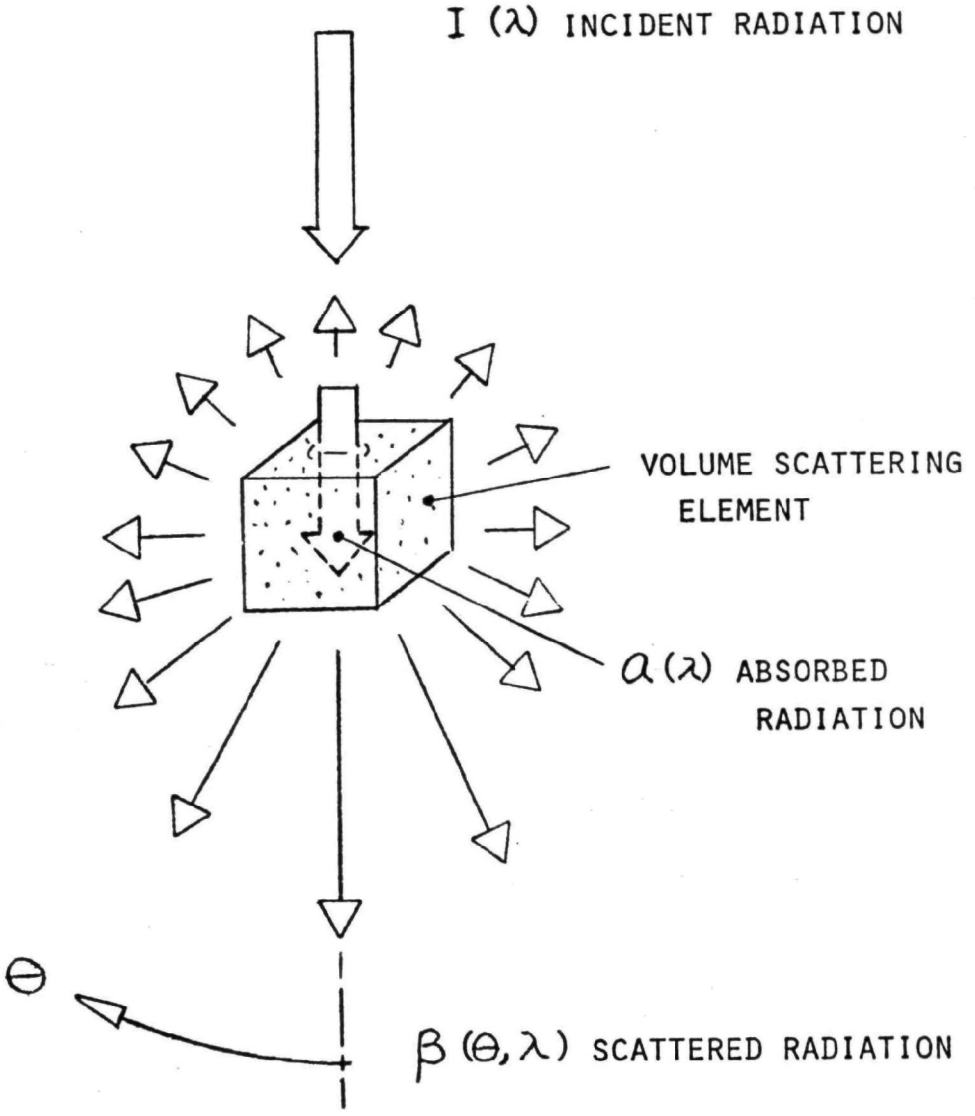
COMPUTER GENERATED DATA PRODUCTS

QUANTITATIVE PASSIVE MEASUREMENTS



(VOLUME REFLECTANCE: THE SUM OF TOTAL BACK SCATTERING FROM SEVERAL TYPES OF PARTICLES)

$$R_A = R_V (1 - \rho) (1 - \rho_W) \tau^2 + B_S + \rho\tau^2$$


I (λ) INCIDENT RADIATION
VOLUME SCATTERING ELEMENT
a (λ) ABSORBED RADIATION
θ
β (θ, λ) SCATTERED RADIATION

RADIATIVE TRANSFER EQUATIONS

$$\text{VOLUME REFLECTANCE} = R\left[a(\lambda),\ \beta\ (\theta,\lambda)\right]$$

$$= .0001 + .324\ \frac{b^*}{a+b^*} + .1425\ \left(\frac{b^*}{a+b^*}\right)^2 \ldots$$

$$\approx .33\ \frac{b^*}{a}$$

$$c = b + a,\quad b = 2\pi \int_0^{\pi} \beta(\theta)\ \sin\theta\, d\theta$$

$$b^* = 2\pi \int_{\frac{\pi}{2}}^{\pi} \beta(\theta)\ \sin\theta\, d\theta$$

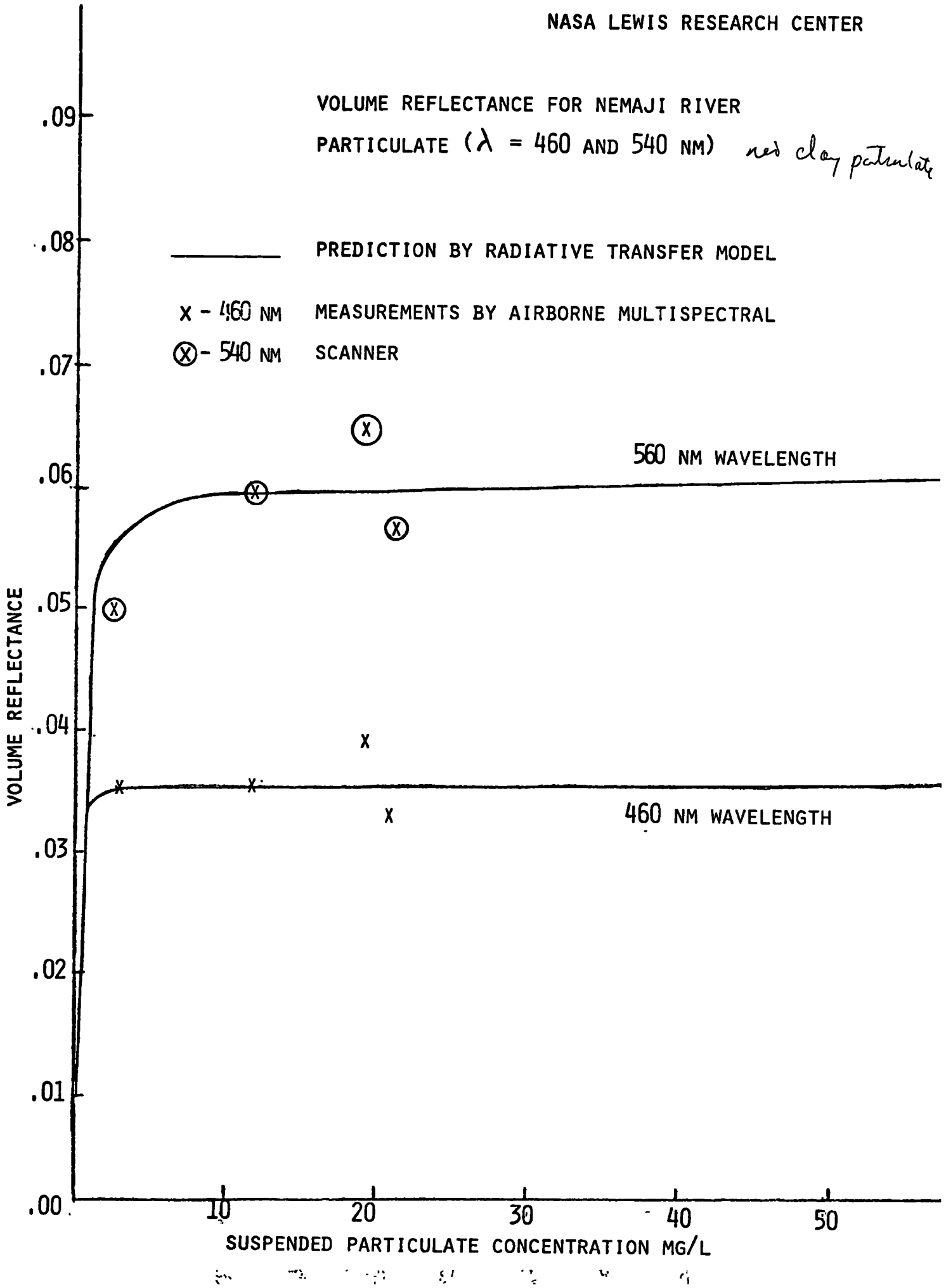
FOR A MIXTURE HAVING SPECIE CONCENTRATIONS C_1, C_2 ...

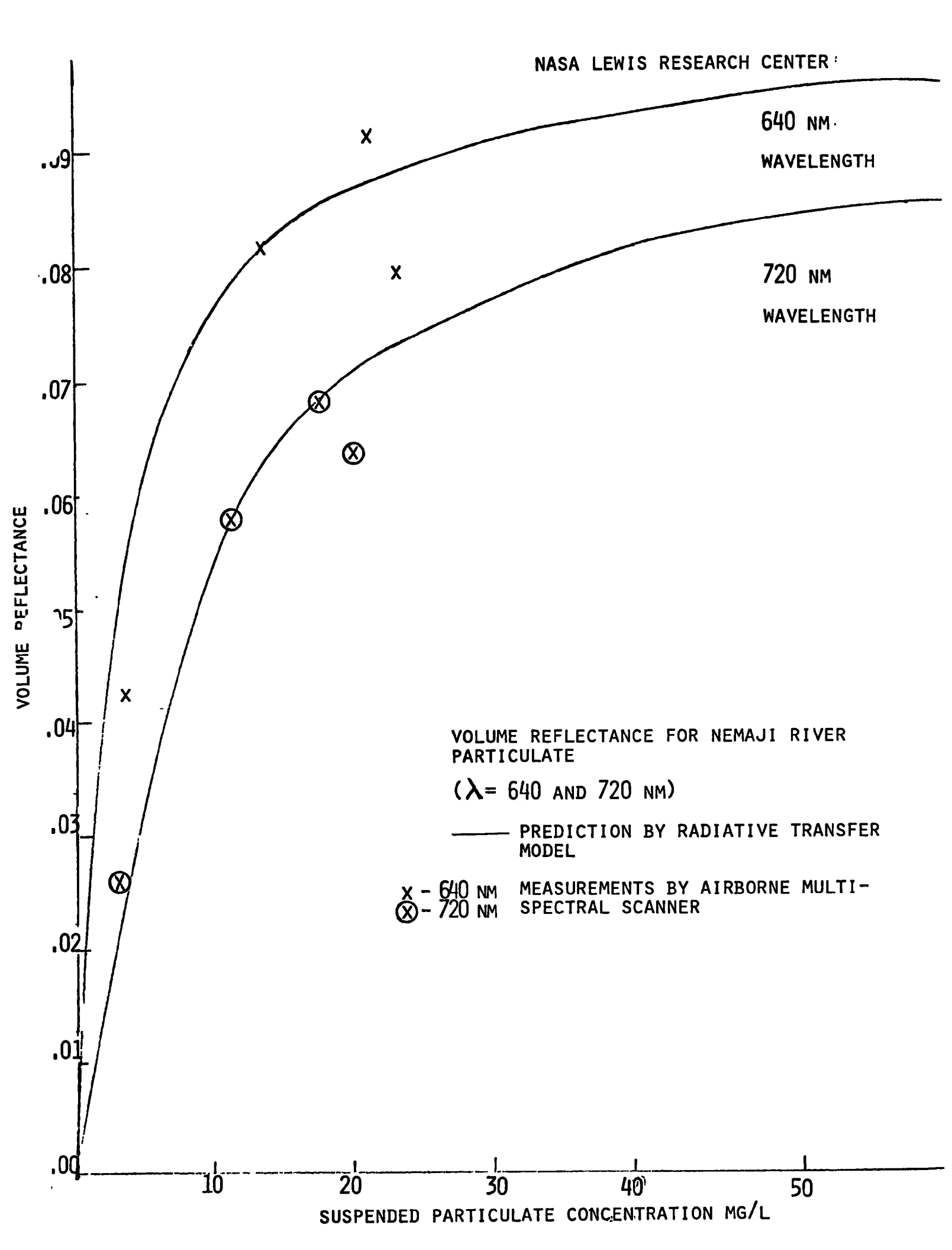
$$b^* = \sum b_w^* + b_1^* C_1 + b_2^* C_2 \ldots$$

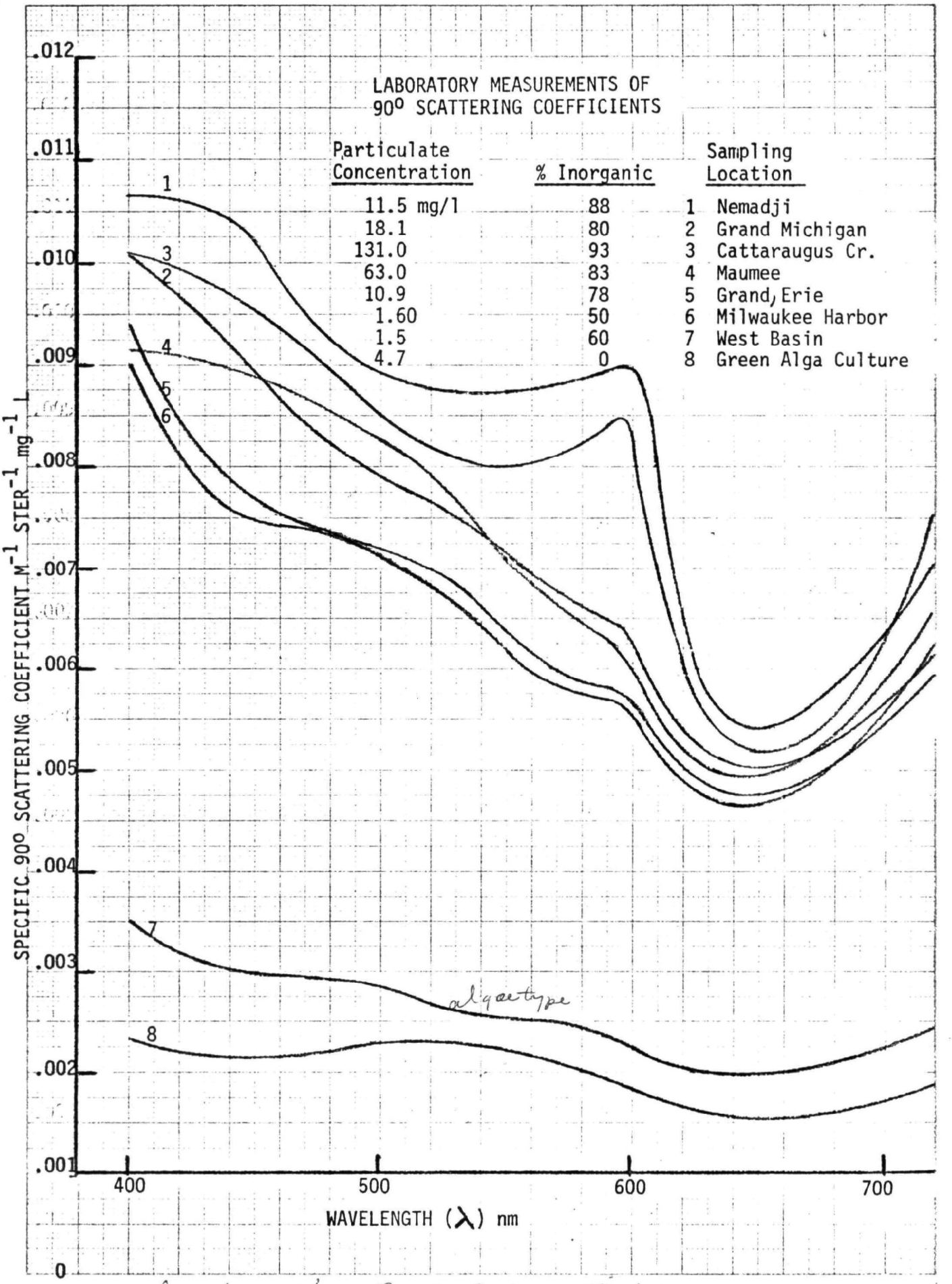
$$a = \sum a_w + a_1 C_1 + a_2 C_2 \ldots$$

PRESENT DEFICIENCY IS LACK OF MEASUREMENTS OF b^* AND a

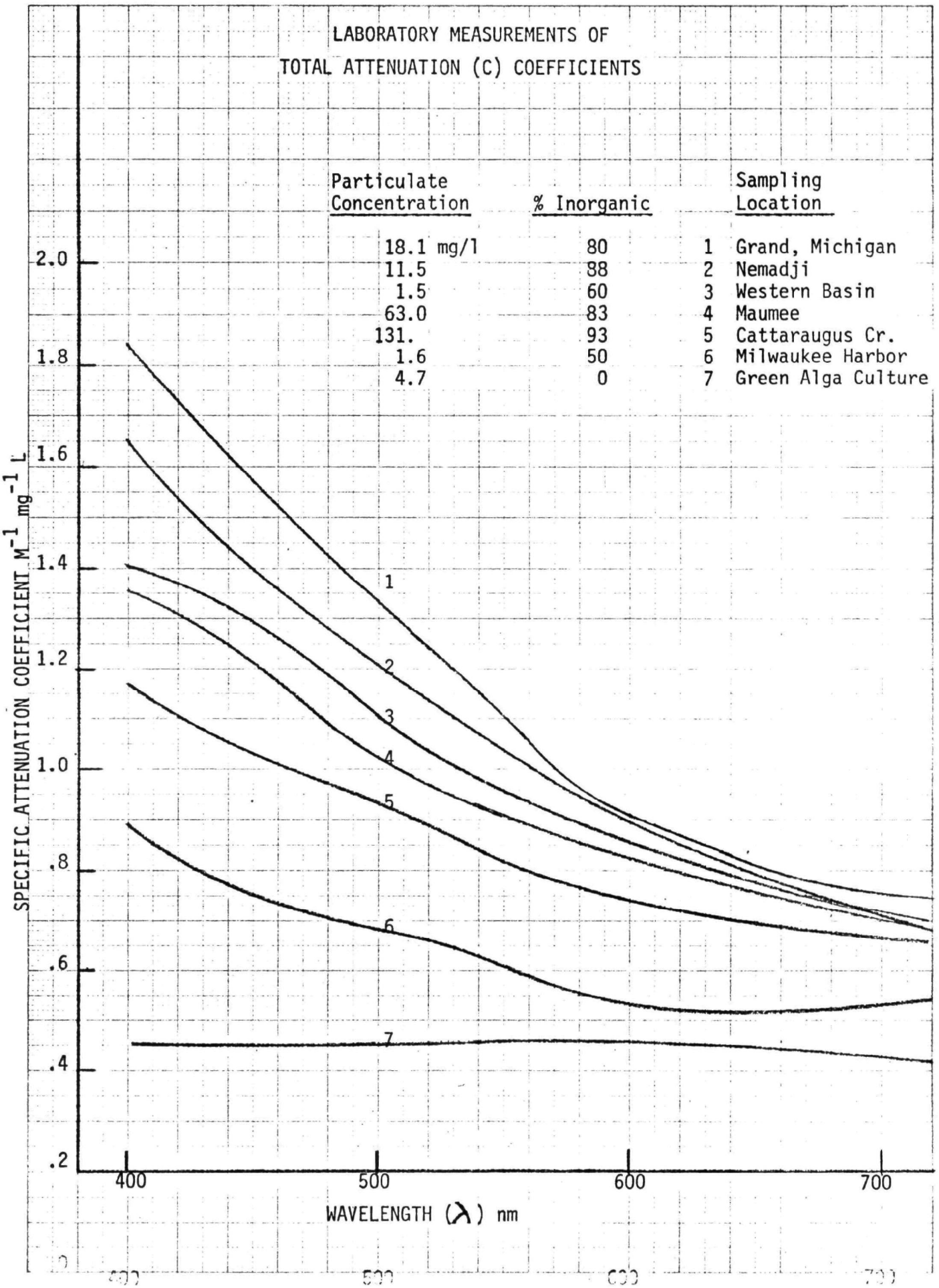
Monte Carlo solution


NASA LEWIS RESEARCH CENTER
VOLUME REFLECTANCE FOR NEMAJI RIVER
PARTICULATE (λ = 460 AND 540 NM)
red clay particulate
PREDICTION BY RADIATIVE TRANSFER MODEL
X - 460 NM
⊗ - 540 NM
MEASUREMENTS BY AIRBORNE MULTISPECTRAL SCANNER
560 NM WAVELENGTH
460 NM WAVELENGTH
VOLUME REFLECTANCE
.09
.08
.07
.06
.05
.04
.03
.02
.01
.00
10
20
30
40
50
SUSPENDED PARTICULATE CONCENTRATION MG/L


NASA LEWIS RESEARCH CENTER
640 NM
WAVELENGTH
720 NM
WAVELENGTH
VOLUME REFLECTANCE
.09
.08
.07
.06
.05
.04
.03
.02
.01
.00
10
20
30
40
50
SUSPENDED PARTICULATE CONCENTRATION MG/L
VOLUME REFLECTANCE FOR NEMAJI RIVER PARTICULATE
(λ= 640 AND 720 NM)
PREDICTION BY RADIATIVE TRANSFER MODEL
X - 640 NM
⊗ - 720 NM
MEASUREMENTS BY AIRBORNE MULTI-SPECTRAL SCANNER

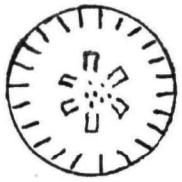


Meaning α & β of dried particulates

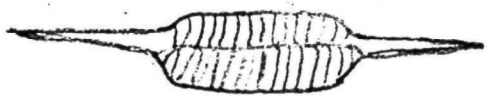

LABORATORY MEASUREMENTS OF
TOTAL ATTENUATION (C) COEFFICIENTS
Particulate Concentration
% Inorganic
Sampling Location
18.1 mg/l 80 1 Grand, Michigan
11.5 88 2 Nemadji
1.5 60 3 Western Basin
63.0 83 4 Maumee
131. 93 5 Cattaraugus Cr.
1.6 50 6 Milwaukee Harbor
4.7 0 7 Green Alga Culture
SPECIFIC ATTENUATION COEFFICIENT $M^{-1} mg^{-1} L$
2.0
1.8
1.6
1.4
1.2
1.0
.8
.6
.4
.2
0
400
500
600
700
WAVELENGTH (λ) nm
1
2
3
4
5
6
7

CORRELATION DEVELOPMENT FOR MIXTURE OF PARTICULATE SPECIES

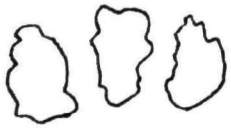
OBTAIN SINGLE SPECIE SAMPLES FOR COMMONLY FOUND MIXTURES



CYCLOTELLA



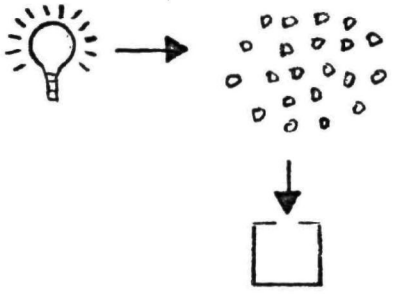
RHIZOSOLENIA



CLAY

PERFORM OPTICAL PROPERTY MEASUREMENTS FOR $a_i(\lambda)$ & $b_i(\lambda)$ CATALOGUE

PARTICULATE SAMPLE



DETECTOR

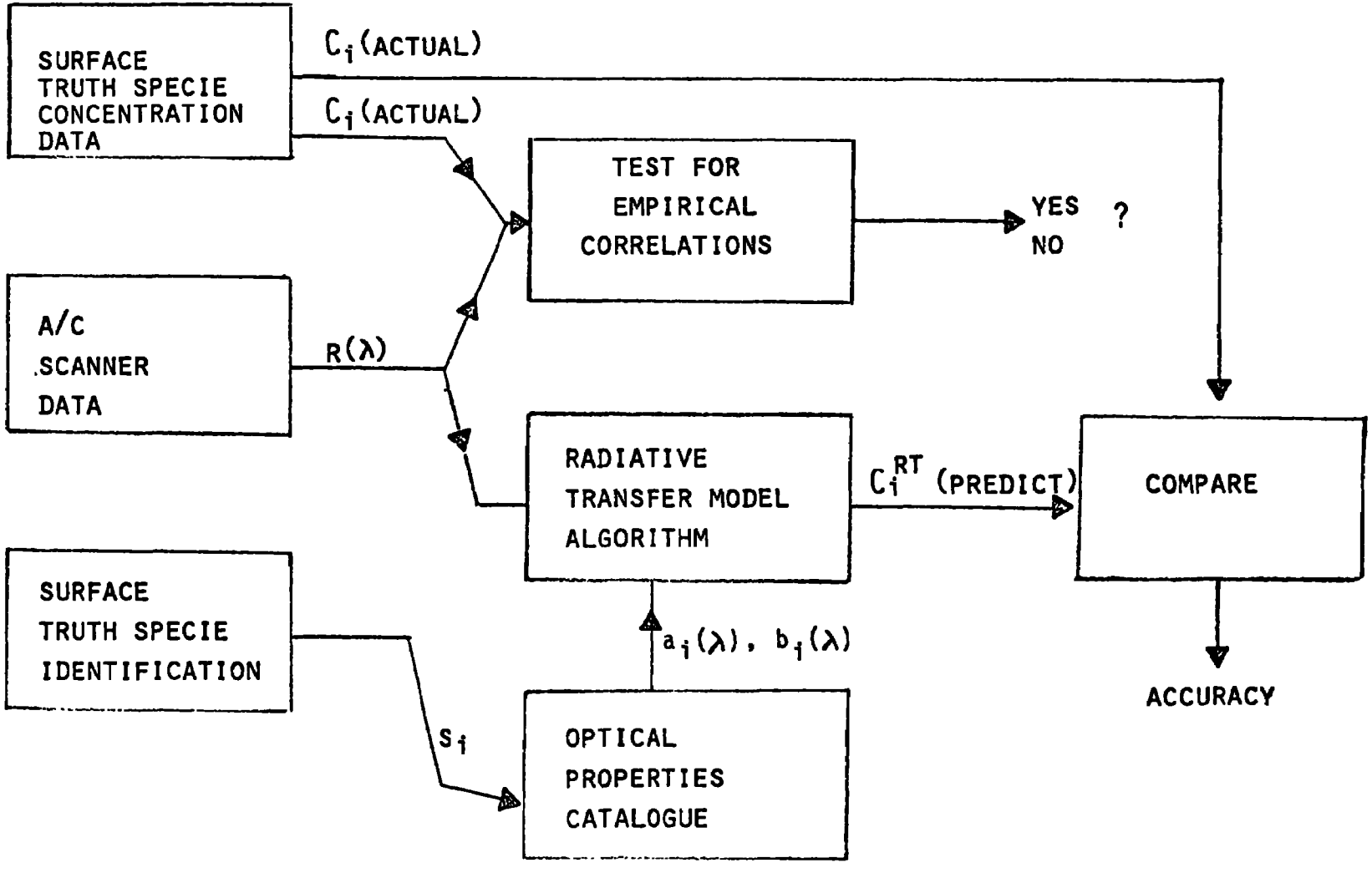
USE RADIATIVE TRANSFER ANALYSIS TO DETERMINE POSSIBLE INVERSION ALGORITHMS FOR COMMON MIXTURES

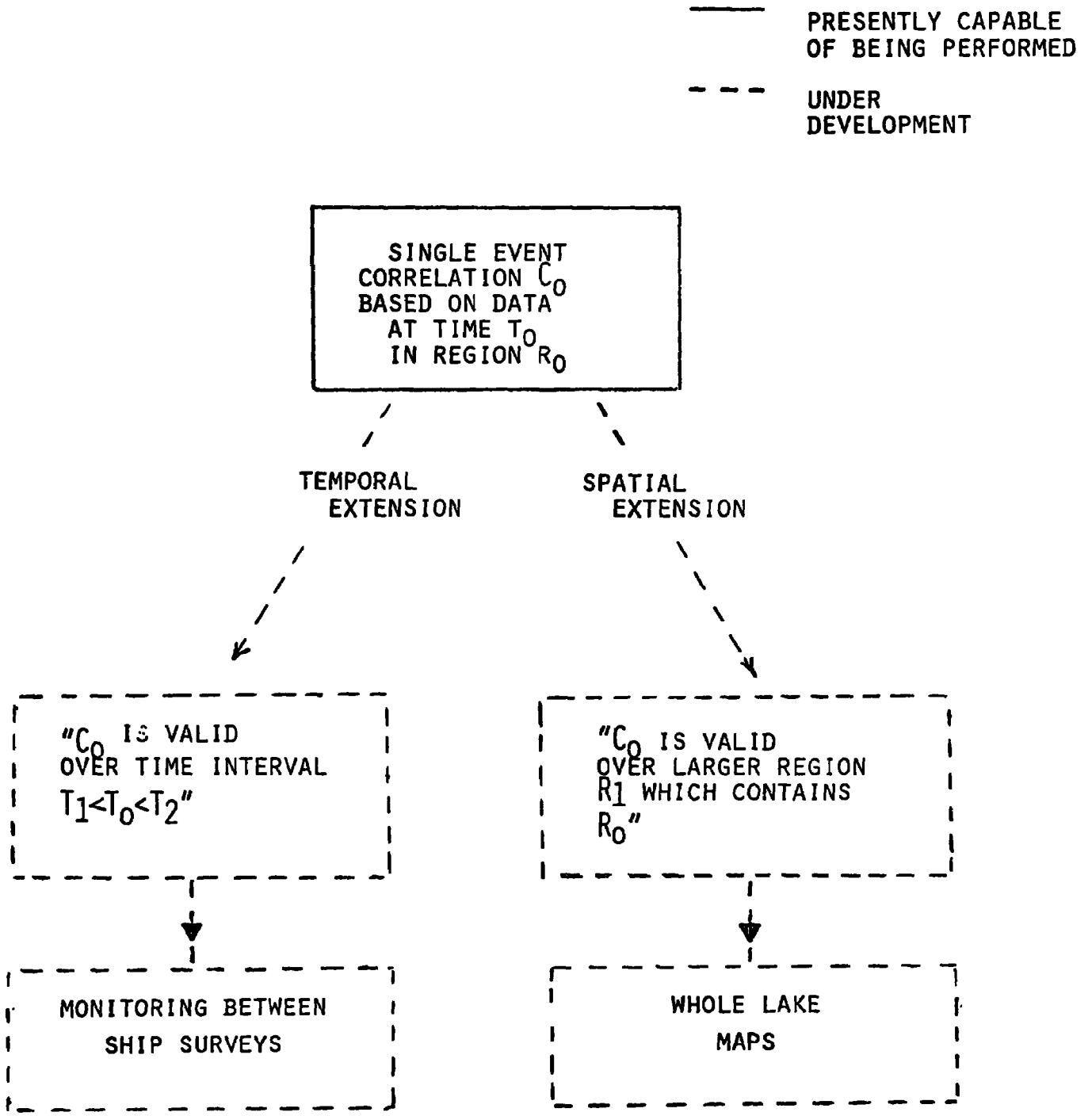
$C_i = F_i \left[R(\lambda) \right]$

C_i = SPECIE CONCENTRATION

i = 1, 2, 3 ...SPECIES

TEST CORRELATIONS UNDER ACTUAL FIELD CONDITIONS





EXTENSION OF SINGLE EVENT CORRELATIONS

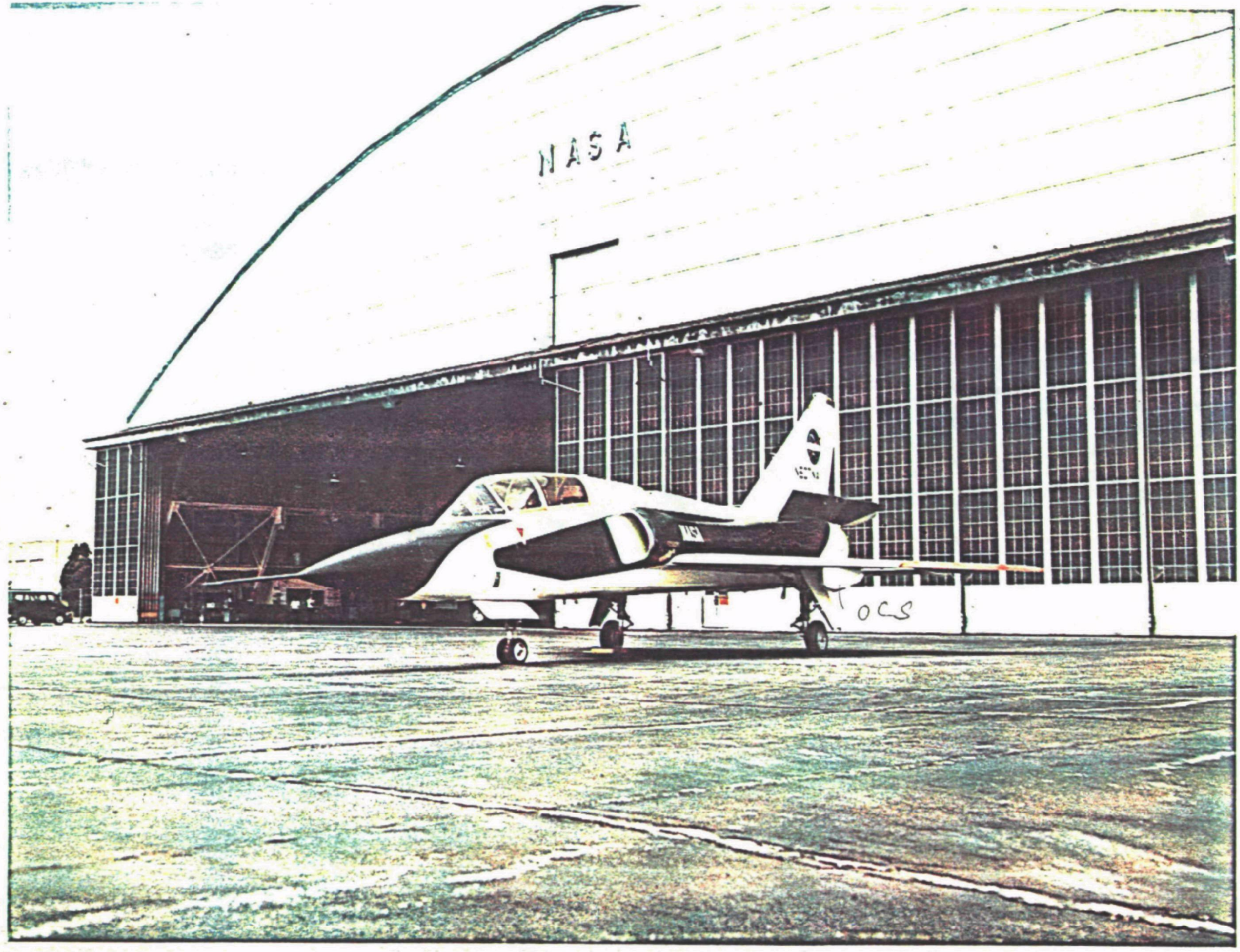
MAJOR FACILITIES
EARTH OBSERVATIONS BRANCH

1. C-131= low & medium altitude replacing C-47DC3	SLAR. M^2S - Bendix multiple spectral CAMERAS AIR-GROUND COMMUNICATIONS INS inertial navigation system
2. F-106/LEAR JET - big ill,	OCS - Ocean Color Scanner INS CAMERA AIR-GROUND DATA LINK
3. PROJECT ICEWARN (C-130)	SLAR RADAR IMAGE PROCESSOR INS SATELLITE COMMUNICATIONS AIR-GROUND COMMUNICATIONS
4. IMAGE PROCESSING COMPUTER SYSTEM	
5. OPTICAL PROPERTIES LABORATORY	SPECTRAL TRANSMISSOMETER LARGE ANGLE SCATTERING METER DUAL LASER SMALL ANGLE SCATTERING METER

9 to go in Aug 1978
Coastal Zone color scanner
NIMBUS-6

allocate f;

Global transponder : military

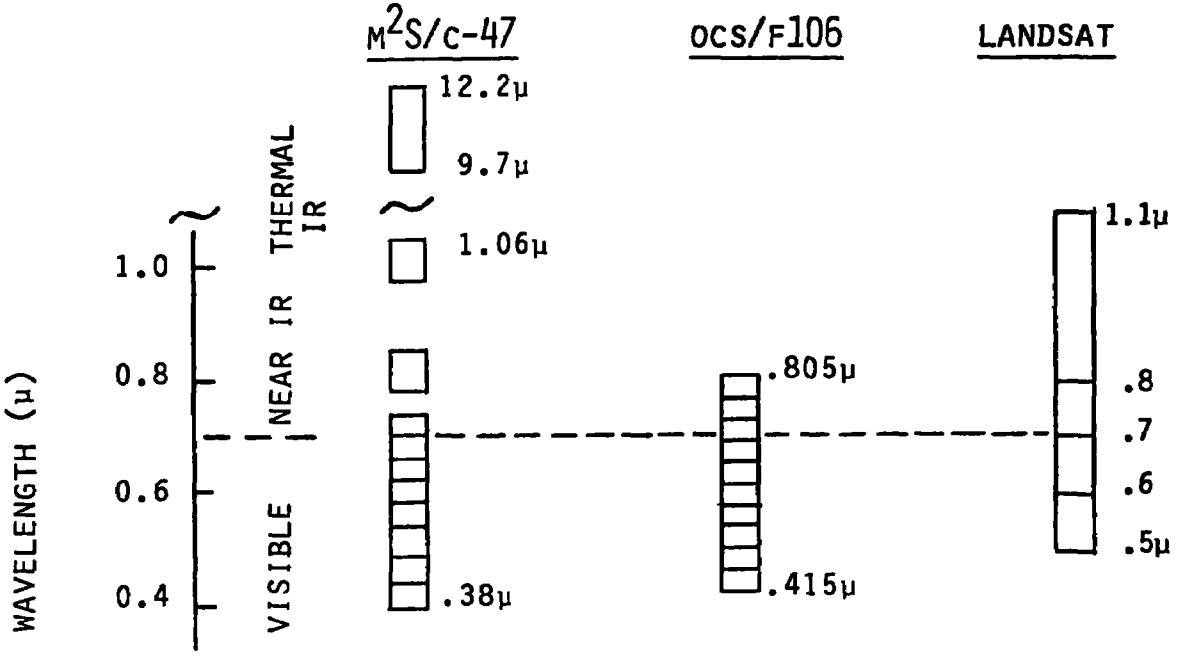


NASA
C-76-873

Lear
used on
PLUARC &
Gulfstream
experiments

NASA
C-76-1406

SCANNER SYSTEMS



	M²S/C-47	OCS/F106	LANDSAT
GROUND RESOLUTION	25 FT (AT 10,000 FT)	200 FT (AT 40,00 FT)	300 FT (AT 500 MI)
SWATH WIDTH	4.5 MI (AT 10,000 FT)	16 MI (AT 40,000 FT)	115 MI (AT 500 MI)

NIMBUS-G MISSION OBJECTIVES

August:

- OBSERVATION OF GASES OR PARTICULATES IN THE TROPOSPHERE OR STRATOSPHERE TO DETERMINE FEASIBILITY OF MAPPING SOURCES, SINKS AND DISPERSION OF ATMOSPHERIC POLLUTANTS Limb scanning in IR

- OBSERVATION OF OCEAN COLOR, TEMPERATURE AND ICE CONDITIONS, PARTICULARLY IN COASTAL ZONES, WITH SUFFICIENT SPATIAL AND SPECTRAL RESOLUTION TO DETERMINE FEASIBILITY OF:

  A) DETECTING POLLUTANTS ON WATER SURFACE

  B) DETERMINING THE NATURE OF MATERIALS SUSPENDED IN THE WATER

  C) APPLYING THE OBSERVATIONS TO MAPPING OF SEDIMENTS, BIOLOGICALLY PRODUCTIVE AREAS, AND INTERACTIONS BETWEEN COASTAL EFFULENTS AND OPEN OCEAN WATERS

CZCS

OCS - 1st on satellite to measure water quality

NIMBUS G: COASTAL ZONE COLOR SCANNER

LAUNCH:	FALL 1978
GROUND COVERAGE:	± 800 KM ABOUT NADIR
	ENTIRE GREAT LAKES SCENE IN 5 OUT OF 6 DAYS
	(SCAN ANGLE IS DIFFERENT FOR EACH DAY)
SENSOR:	SIX SPECTRAL BANDS: FIVE VISIBLE, ONE THERMAL,
	825 x 825 METER RESOLUTION AT NADIR

BANDS	λ (NM)	Δλ(NM)	OBSERVATIONS
1	443	20	CHLOROPHYLL ABSORPTION
2	520	20	CHLOROPHYLL CORRELATION
3	550	20	DISSOLVED ORGANICS
4	670	20	SUSPENDED SOLIDS
5	750	100 (LANDSAT)	SURFACE VEGETATION
6	THERMAL IR 10.5 - 12.5μ		SURFACE TEMPERATURE

Gt Lakes was not included in coastal zone → CZCS done for marine environment

want to develop Algorithms for GL

LERC CZCS ACTIVITIES

- DEVELOP ALGORITHMS FOR GREAT LAKES PARTICULATE AND DISSOLVED SUBSTANCES USING OCS/F-106 (BOTH PRE AND POST LAUNCH EXPERIMENTS)
- DETERMINE OPTIMUM CZCS GAIN AND TILT ANGLE SETTINGS FOR GREAT LAKES CONDITIONS
- DEVELOP DATA PROCESSING AND PRODUCTS NECESSARY TO UTILIZE THE AVAILABLE HIGH FREQUENCY COVERAGE AND WHOLE LAKE MAPPING POTENTIAL OF CZCS
- INVESTIGATE UTILITY OF REAL TIME DATA FOR SELECTION OF SHIP SAMPLING CRUISES AND SITE LOCATIONS