INFLUENCE OF THE YUKON RIVER ON THE BERING SEA

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(Semi-annual Progress Report)
March 1987

As specified by the contract this is the third progress report concerning NAS 5-28769 entitled, "Influence of the Yukon River on the Bering Sea". The purpose of this project is to use satellite data to study relationships between discharge of the Yukon River to water-masses and biologic productivity in the northern Bering Sea.

Amended specific objectives are:

1. to develop thermal and sediment surface maps using TM data of the discharge of the Yukon River and the Alaska Coastal Current during the ice free season;
2. to develop a historical model of the distribution of the Yukon River discharge and the Alaska Coastal Current using Landsat MSS and NOAA satellite imagery;
3. to use high resolution TM data to define the surface dynamics of the front between the Alaska Coastal Current and the Bering Shelf/Anadyr Current; and
4. to verify TM and other image analyses with field data - cost to be shared with other projects in the area.

The development of chlorophyll surface maps using the TM data has been eliminated as an objective. The western limit of TM data transmission has prevented the acquisition of data in areas where chlorophyll concentration is high and thus could be analyzed. In the Norton Sound area where TM data has

N87-19877

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(NASA-CR-180356) INFLUENCE OF THE YUKON RIVER ON THE BERING SEA Semiannual Progress Report (Alaska Univ., Anchorage.) 15 p CSCL 08C

been acquired the water is highly turbid masking signatures that would be related to chlorophyll production. The presence of high concentrations of suspended sediments and low salinity also hinder chlorophyll production in that area. However, ISHTAR (Inner Shelf Transfer and Recycling) project investigators are measuring the distribution and abundance of chlorophyll in the water column and the results will be incorporated in the NASA project.

The latest efforts for this project have concentrated on image analysis of TM data, review of 1986 ship board measurements collected by ISHTAR investigators and completion of the inter-annual and intra-annual analysis of turbid water. TM data recorded on July 5 and 22 1985 of the Yukon Delta and Norton Sound area were analyzed.

The July 5 data is a night-time pass over the boundary of the Alaska Coastal and Bering Shelf water-masses, and the Yukon Delta. The thermal band is the only usable channel due to the timing of the pass. Subsections were extracted from the data to experiment with digital enhancement techniques that will display structures in the water. A fourier-gaussian filtered image (fig. 1) significantly improved the visual perception of these structures. The data is being used to study the mixing of the two water masses. Field measurements acquired by ISHTAR investigators and the image data will be used to analyze the water-mass boundary.

The July 22, 1985 TM data is a day-time pass over Norton Sound. A subsection was extracted from the data that included turbid Yukon water. Several digital techniques were applied to the data to enhance structures and boundaries in the turbid water including: piece-wise contrast stretches, a variety of color composites, fourier-transform edge-enhancement, band ratios and principal components analysis. The color composites, of the first four principal components and the ratio of band 1 to 3 best displayed structures in

the turbid water (fig. 2 & 3). Some of these structures appear to be related to factors other than variations in the concentration of suspended sediments. The structures provide information on flow characteristics and may also be related to the presence of shoals and aquatic vegetation. Field data from ISHTAR investigations needed to identify these structures is limited due to very shallow waters this close to the delta.

An ISHTAR sponsored workshop, for investigators studying the Bering Sea was held during January in Florida. Tentative results of the remote sensing project were presented and compared to ship-board measurements and oceanographic models presented by ISATAR and OCSEAP (Outer Continental Shelf Environmental Assessment Program) investigators. As discussed in the previous progress report (October 1986), the water masses delineated on the imagery correlate with the distribution of nitrate, chlorophyll, water temperatures and salinity measured in the water column. The geometry of the distribution of the water-column data is very similar to the patterns observed on the thermal imagery (fig. 4). The boundaries of the water-masses on the images do not precisely correlate with the water column values for several reasons:

1) the image data records sea surface or near surface values while ship-based measurements are acquired throughout the water column;
2) the satellite data is an instantaneous recording of the surface while water column measurements are acquired over a 10-15 day time interval;
3) water-masses are determined by temperature and salinity (i.e. density) so distribution does not always correlate with temperature only;

4) the satellite sensor records sea-surface temperatures or reflected solar energy while ship-board measurements evaluate different parameters such as chlorphyll or nitrate; and

5) the density-sliced satellite image gives the illusion of a distinct solid boundary while in reality it is gradational and dynamic.

A manuscript entitled, "Distribution and circulation of turbid Yukon River water" is in preparation. This paper describes the inter-annual and intra-annual analysis of turbid water discharged by the Yukon River based on analysis of Landsat MSS data recorded between 1974 and 1978. After further revision the manuscript will be submitted to a refereed journal. A copy of the preliminary abstract and conclusions are included as Appendix A. An abstract has also been written and accepted for the POAC meeting (Appendix B).

Some Preliminary Findings

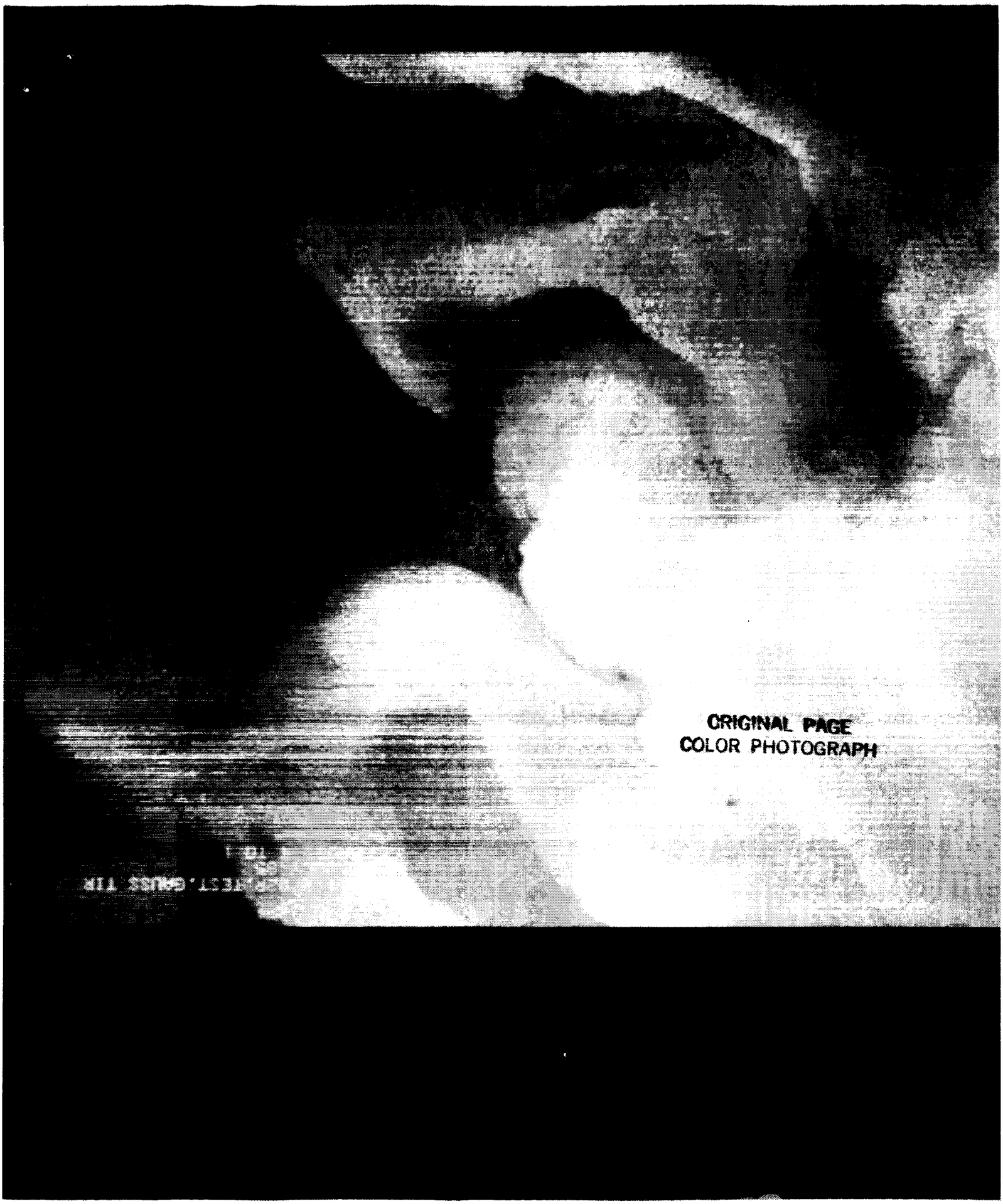
The distribution of near-surface, turbid water, discharged by the Yukon River, was studied based on analysis of satellite imagery. The interannual analyses indicates that the net flow of near-surface, turbid water is northward of the delta across the entrance to Norton Sound. Only turbid water to the east enters Norton Sound and consists of 25% of the total area based on areal measurements. Approximately 10% of that water circulates into the sound along the southern coast and is lost to view in the vicinity of Unalakleet. Suspended sediments transported by this southern circulation are primarily deposited along the southern coast. Turbid water to the northeast appears to circulate in then out of Norton Sound, possibly resulting in some deposition along the northern coast.

Three distinct zones within the turbid water have been identified based on relative brightness levels. These zones appear to be primarily related to

differences in suspended-sediment concentrations and position of the sediments in the water column. Zone one which is adjacent to the delta has the highest suspended sediment concentrations, low bioturbation and corresponds to the submarine deltaic morphology. Suspended-sediment concentration decreases and bioturbation increases in zone two and three, which are successively seaward of zone 1. The interannual extent of turbid water and modern Yukon sediments on the sea-bottom are very similar. This similarity is the result of currents located along their boundaries in the Bering Sea and in northern Norton Sound that control their extent. These currents are at depth and near the surface.

The extent of turbid water varies seasonally. It is most extensive June through october even though discharge of the Yukon River decreases substantially after July. Some turbid water circulates into Norton Sound throughout this period. Turbid water is present in May and November but only, immediately offshore from the delta.

Figure 1. Landsat TM data recorded on 5 July, 1985. The thermal image is a subsection of the data along the boundary of the Alaska Coastal and Bering Shelf water-masses. The data have been enhanced using an edge-enhancement algorithm. Light shades are warm and dark shades are cold. Structures in the water are related to the mixing of the warm coastal and cold shelf water.



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COLOR PHOTOGRAPH

Figure 2. Landsat TM data recorded on 22 July, 1985. The image is a subsection of the data northeast of the Yukon Delta. The data have been enhanced using the principal components algorithm applied to TM bands 1-4. The first four principal components were composited to form the color image. Red is terrestrial vegetation, light blue and white is turbid water from the Yukon River and dark blue is clearer water.

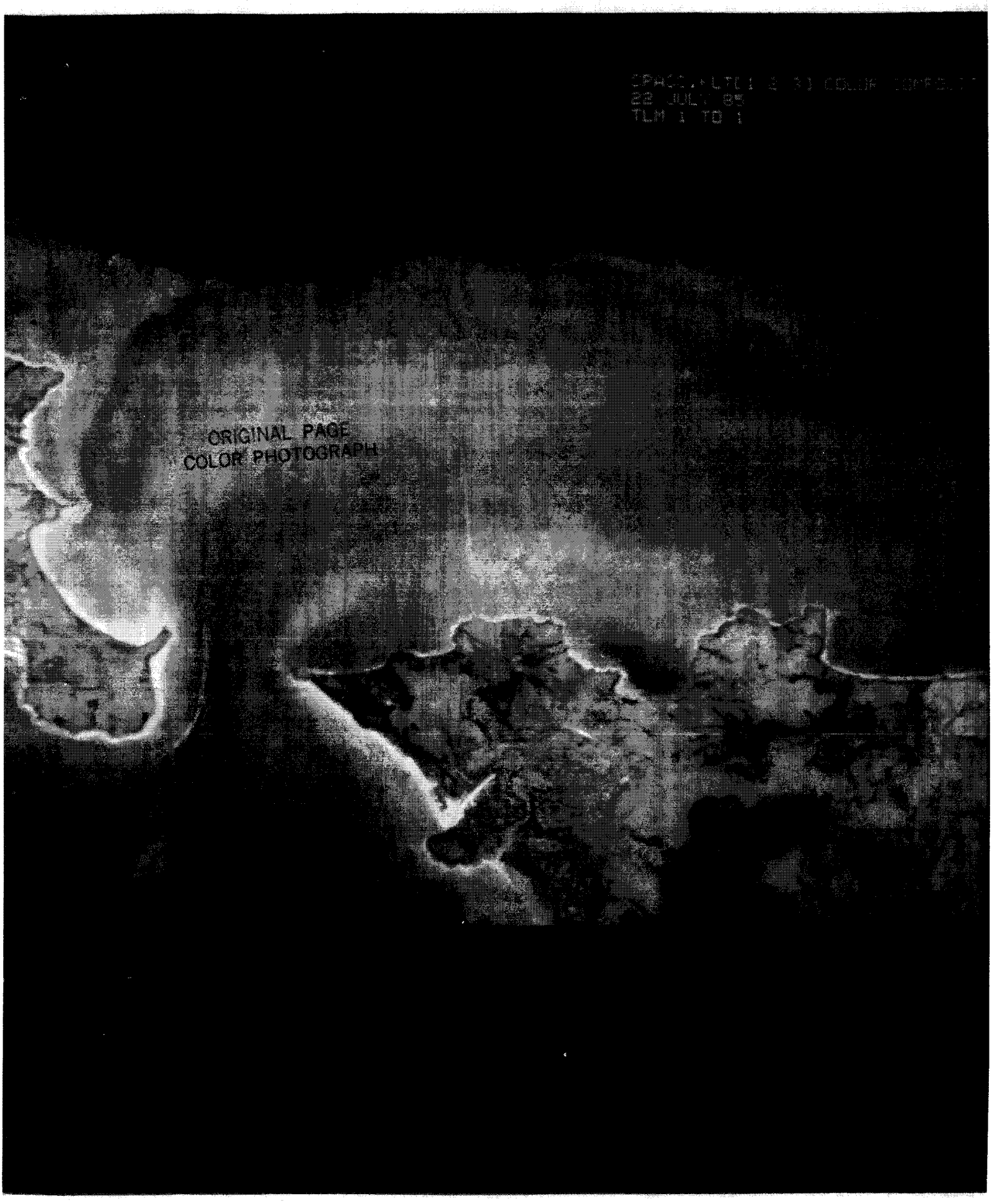
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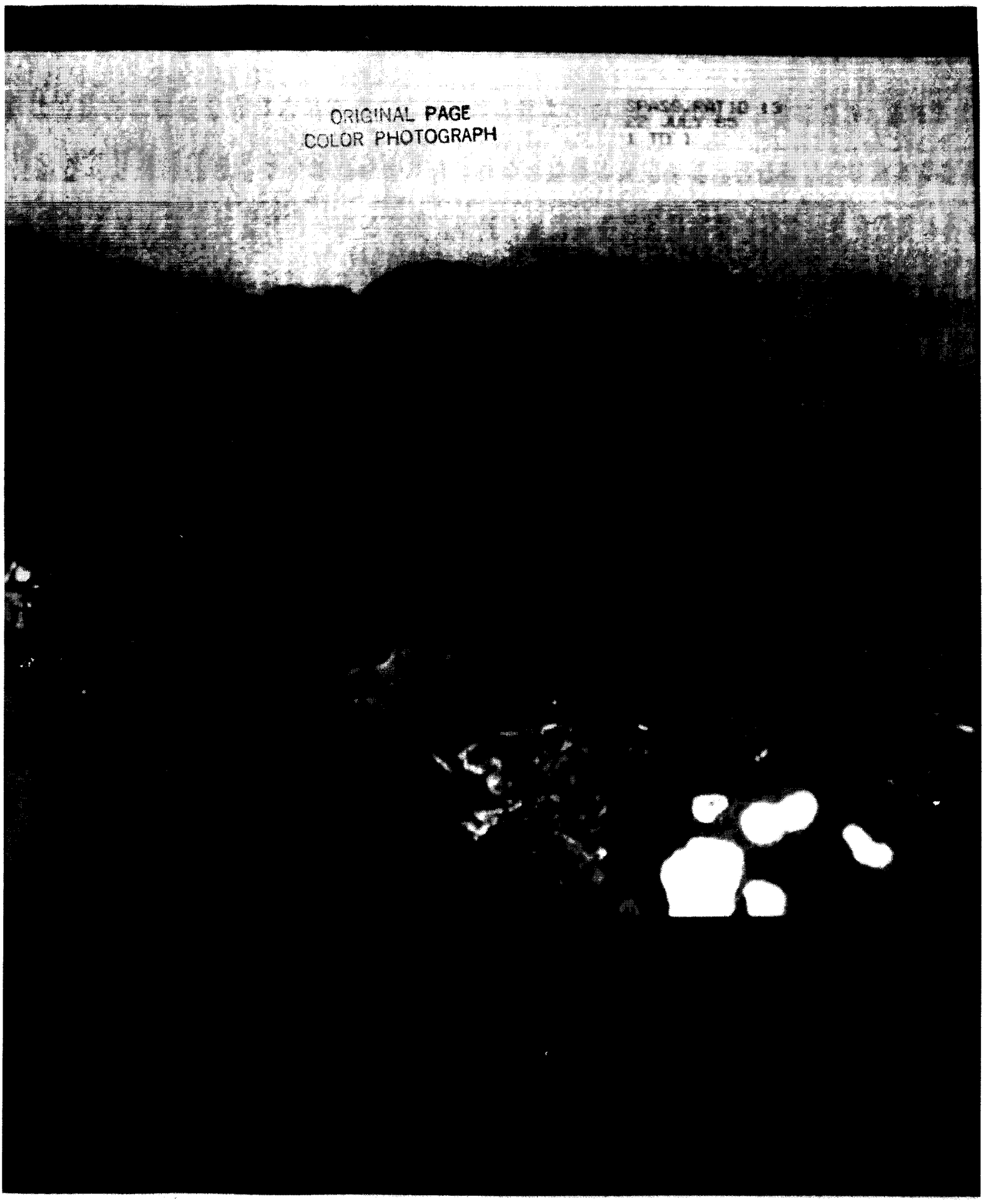
Figure 3. Landsat TM data recorded on 22 July 1985. The image is the same subsection as in figure 2. The image was generated by rationing band 1 to band 3 to enhance turbid water features.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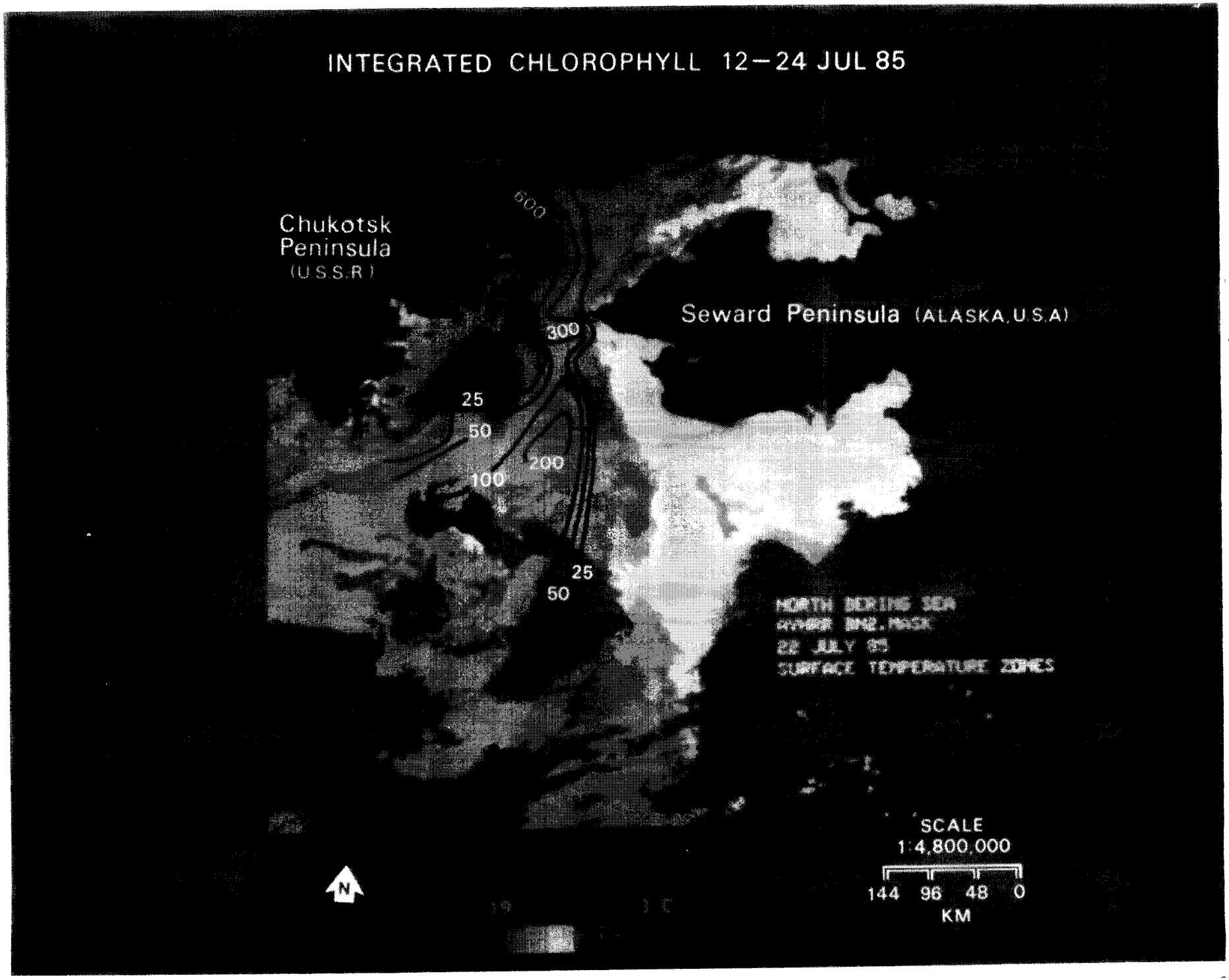
COLOR PHOTOGRAPH

Figure 4. NOAA-AVHRR image recorded on 22 July, 1985. The thermal image has been density sliced to display water-masses in the Bering Sea. Contoured data are intergrated chlorophyll mg/m^2 collected by ISHTAR investigators. High concentrations of chlorophyll are located in the Bering Shelf water-mass seen as shades of green on the image. Bright colors are the warm coastal water and dark blue is cold oceanic water that upwells near the Siberian coast.



APPENDIX A

DISTUBUTION AND CIRCULATION OF TURBID YUKON RIVER WATER

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Abstract

The interannual and intra-annual distribution and circulation of turbid water was studied in the northeast Bearing Sea. This turbid water results from discharge of the Yukon River which is the primary component in the development of the Alaska Coastal Current in the area. Landsat MSS satellite imagery and ship-based measurements were used to map the distribution of turbid water and to analyze flow characteristics. Most of the turbid water is transported and deposited northward from the delta across the entrance to Norton Sound June through October. Approximately 10% is transported and deposited into southern Norton Sound. The extent of turbid water is very similar to the distribution of modern bottom sediments derived from the Yukon River. Within the turbid water three zones have been identified based on brightness levels. These zones appear to result from the concentration and position of suspended sediments in the water column and influence submarine biologic activity.

APPENDIX B

SATELLITE OBSERVATIONS OF WATER MASSES IN THE NORTHERN BERING SEA

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Physical and biological oceanography are being studied in the northern Bering Sea using satellite data and ship-board measurements. The satellite data, recorded in 1985 and 1986, were acquired by the NOAA-AVHRR sensor (Advanced Very High Resolution Radiometer), and Landsat Multi-spectral Scanner (MSS) and Thermatic Mapper (TM) sensor. Satellite data was computer-enhanced to optimize the distribution of water-masses, suspended sediments, and flow characteristics. Ship-board measurements acquired by scientists working on the Inner Shelf Transfer and Recycling project (ISHTAR) provided field-data and "ground truth."

Three distinct north-flowing, water-masses occur in the area during the ice-free season: Anadyr, Bering Shelf and Alaska Coastal. The Anadyr water-mass is located in the western Bering Sea and is derived from water that upwells adjacent to the Siberian coast. This water is cold (0-5°C), highly saline and nutrient rich. In contrast, the Alaska Coastal water-mass is located in the eastern Bering Sea and is strongly influenced by river discharge, primarily the Yukon and Kuskokwim Rivers. This water is warm (10-20°C) has low salinity and is nutrient poor but has high concentrations of suspended sediments especially in the vicinity of the Yukon Delta. Between the eastern and western water-masses is the Bering Shelf water. This water has intermediate temperatures (5-10°C) and nutrient concentrations but has the highest levels of phytoplankton productivity or biomass.

Remote sensing data only records near-surface water temperatures and turbidity. Due to the distinct characteristics of each water mass, the satellite data accurately depicts their general distribution, boundaries and flow characteristics. This analysis provides baseline information of a pristine shelf environment, with abundant marine life, that is destined for petroleum and harbor development.