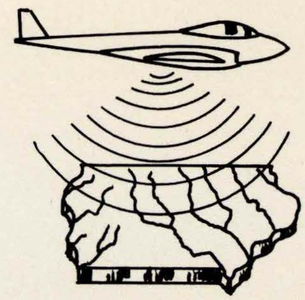
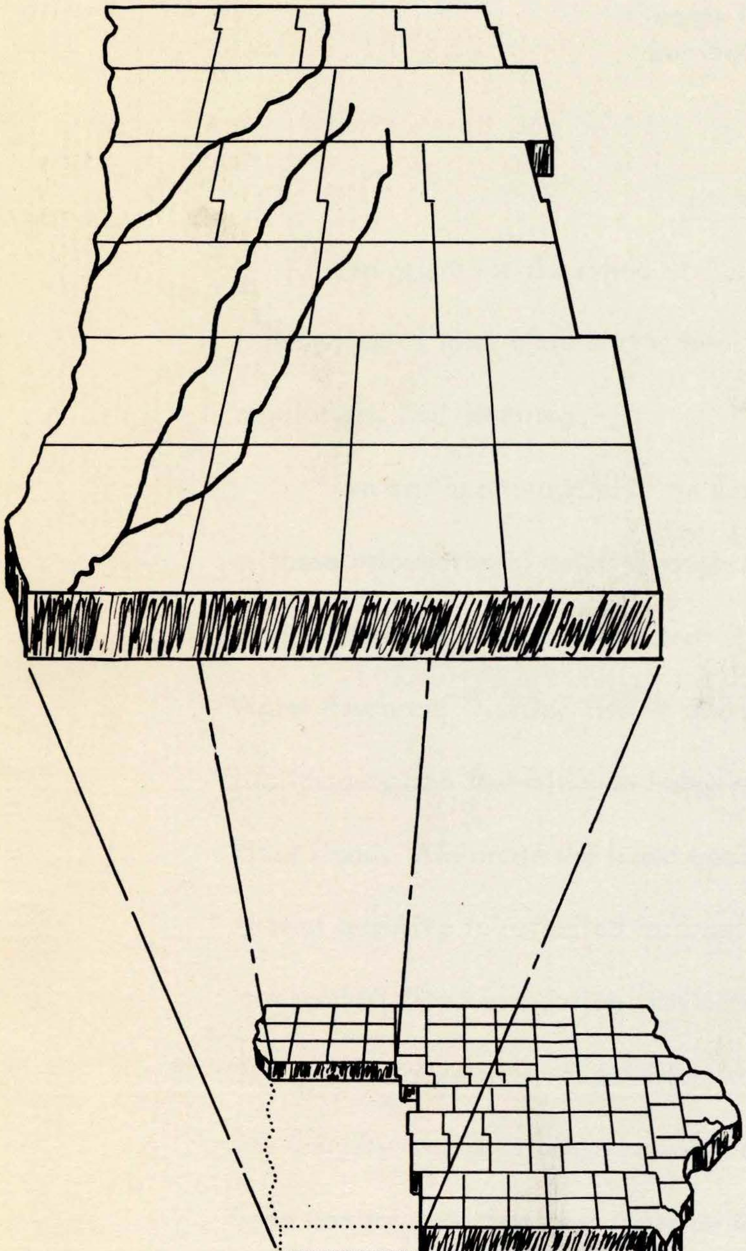
IOWA REMOTE SENSING LABORATORY





FLOOD INUNDATION MAPPING IN SOUTHWESTERN IOWA

A PRELIMINARY REPORT
FEBRUARY, 1973

Analysis of ERTS-1 Imagery

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Introduction

An operational method of flood inundation mapping is needed to provide information to Iowa state and federal agencies involved in floodplain management, regulation, and planning.

An aerial photographic technique was developed that could satisfy many of these informational needs through the cooperative efforts of the Iowa Geological Survey, Remote Sensing Laboratory (IGSRSL), and the U. S. Geological Survey, Water Resources Division (Hoyer and Taranik, 1973). Comparison of ERTS-I satellite imagery and low-altitude imagery of the September, 1972, East Nishnabotna River flood, reinforced the basic conclusion of the low-altitude study: imaging systems sensitive to reflected infrared energy can be used, in the Midwest, to map late summer flood inundation. In addition, ERTS-I imagery extended the allowable time period for imagery acquisition to seven days following flood recession. Satellite imagery also provided a method for mapping flood inundation and assessing flood control programs on a regional basis. This preliminary report includes results of flood inundation mapping in Iowa and indicates the potential of current remote sensing technology to aid flood study and evaluation. A more complete review of remote sensing methods for flood inundation mapping is in preparation and will be published as IGS Public Information Circular Number 6, available May, 1973. This future publication will incorporate results from ground investigation, low-altitude imagery interpretation, and orbital imagery interpretation, and will evaluate techniques useful for operationally mapping flood inundation.

Summary Review of East Nishnabotna River Flood Study

A major storm in western Iowa produced rainfall amounts in excess of 20 inches on September 10, 11, and 12, 1972. Most of the resulting surface runoff went into the Nishnabotna River system, where overland flooding was widespread, and into the Boyer River basin, where flooding was confined by levees.

Low altitude aerial photography was obtained by IGSRSL along the East Nishnabotna River on September 14-15, 1972. This timing provided comparison of imagery produced during flood crest and following flood recession. Different film-filter combinations were utilized in a variety of cameras: black and white and color film was exposed in a mapping camera; color and color infrared film was exposed in 35mm cameras; and black and white infrared film was exposed in an I^2S multiband camera. This multiband camera simultaneously records the same scene as four separate images. Each image records blue, green, red, and infrared energy, respectively, as it is reflected from the landscape. Multispectral images are examined in a viewer which allows each image to be viewed singly or in combination. The viewer allows false-coloring the images to enhance interpretation. The multispectral system allows the evaluation of the unique reflectance properties of flooded areas. Film-filter combinations most suitable for operationally mapping flooded areas can be determined from this type of multispectral comparative analysis.

Imagery interpretation in conjunction with ground information analysis confirmed that aerial photography could be successfully utilized to map midwestern, late summer floods for a minimum of three days following flood recession. Success of the aerial photographic technique proved dependent on the use of an infrared sensitive film. Areas of standing water and saturated soils reflect less infrared radiation than adjacent areas. Likewise, flood stressed plants reflect less infrared radiation than unaffected plants. Thus, less infrared energy is reflected to the camera system from flooded areas than from non-inundated areas. Stereoscopic viewing also proved helpful, as it aids interpretation in areas that are not well discriminated on the basis of reflectance properties. Blue reflected energy contains information for flood discrimination (table 1). Flooded areas reflect more blue energy than adjacent non-flooded areas. The best flood delineation resulted from false coloring the blue and infrared multispectral images, blue and red respectively. For operationally mapping flood inundation, a color infrared film is suggested to simplify data handling and maximize imagery utility for various state agencies.

Earth Resources Technology Satellite

The Earth Resources Technology Satellite (ERTS-I) was launched by the National Aeronautics and Space Administration (NASA) on July 23, 1972. The satellite orbits the earth at an altitude of approximately 570 statute miles. ERTS-I is in a near-circular, near-polar, sun-synchronous orbit. This orbit allows an area of 115 miles square to be imaged repetitively every 18 days, at approximately the same time of day. The spacecraft carries two sensor systems: a three-camera Return Beam Vidicon (RBV) and a four- channel Multispectral Scanner (MSS). This

Table I. Suitability of low-altitude multispectral photographic images for late summer flood mapping in the Midwestern Region.

Spectral Band (s)	Appearance of Flooded Areas Versus the Appearance of Unaffected Areas	Suitability for Flood Mapping
Blue	Lighter	Fair
Green	Lighter or Darker	Very Poor
Red	Lighter or Darker	Poor
Infrared	Darker	Good
Green, red, infra-red--false colored as blue, green, & red, respectively.	Darker Red, grading to Green, Blue, or Grey	Very Good
Blue, infrared--false colored as blue & red, respectively.	More Blue to Purple	Excellent

report concerns the evaluation of data from the MSS system. It simultaneously records energy reflected from the landscape, in four sharply defined wavelength bands. The MSS channels do not coincide with the bands of the IGSRSL I^2S multiband camera (table 2). The MSS records reflected green and red visible energy on channels 4 and 5, and has two channels, MSS 6 and 7, in the invisible infrared portion of the spectrum. It should be noted that the MSS is not a camera because it records reflected energy electronically. The MSS signal is later broadcast to recording stations on the earth, where it is transformed into an image on film or is stored on computer tapes.

General Analysis of ERTS-I Imagery

Since the satellite's launch, several high quality images of southwestern Iowa have been received (table 3). Analysis of this repetitive imagery, acquired from July through October, allows a positive determination that the Nishnabotna flood is depicted on the imagery. The major perennial streams in southwestern Iowa have very similar appearances on the July, August, and October imagery. The Nishnabotna River valleys do not appear different than the Boyer or Willow River valleys on any of the ERTS bands for these months.

The September 18 and 19 images were produced as much as six and seven days after the crest of the Nishnabotna flood (table 4). Major streams in the area appear similar in the green (MSS 4) and red (MSS 5) band images. However, the flooded areas in the Nishnabotna valleys and in other areas are readily apparent on the infrared bands, MSS 6 and 7. The area has sharply reduced infrared reflectance because of standing water, excessive soil moisture, and stressed plants. The flooded areas are most clearly defined on the MSS 7 image, and this was the imagery utilized for mapping the inundated area (Plate 1).

Table 2. Spectral band configuration of IGSRSL I^2S Multiband Camera and ERTS-I Multispectral Scanner.

IGSRSL Multiband Camera			ERTS-I Multispectral Scanner		
Band No.	Spectral Band	Wavelengths (nanometers)	Band No.	Spectral Band	Wavelengths (nanometers)
1	Blue	400 - 465	---	---	---
2	Green	480 - 570	4	Green	500 - 600
3	Red	595 - 685	5	Red	600 - 700
4	Infrared	740 - 900	6	Infrared	700 - 800
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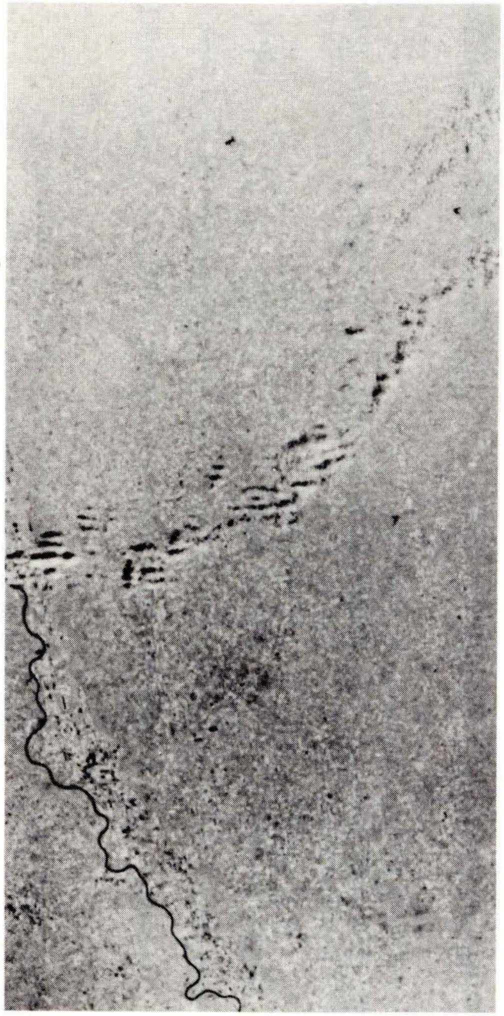
Table 3. ERTS-I satellite imagery of Southwestern Iowa utilized by IGSRSL. All images taken at approximately 10:30 A.M., Central Standard Time.

Date (1972)	Cloud Cover (%)	NDPF I.D. Number*	Comments
26 July	20	1003-16334	Stream valleys
	30	1003-16341	uniform in
14 August	0	1022-16382	appearance on all
	0	1022-16384	bands. Best defined on band 5.
18 September	5	1057-16315	Flood inundated
	0	1057-16332	areas are
	10	1058-16383	apparent on
	0	1058-16390	infrared bands.
07 October	0	1076-16384	All floodplains
	0	1076-16381	apparent on infrared bands.

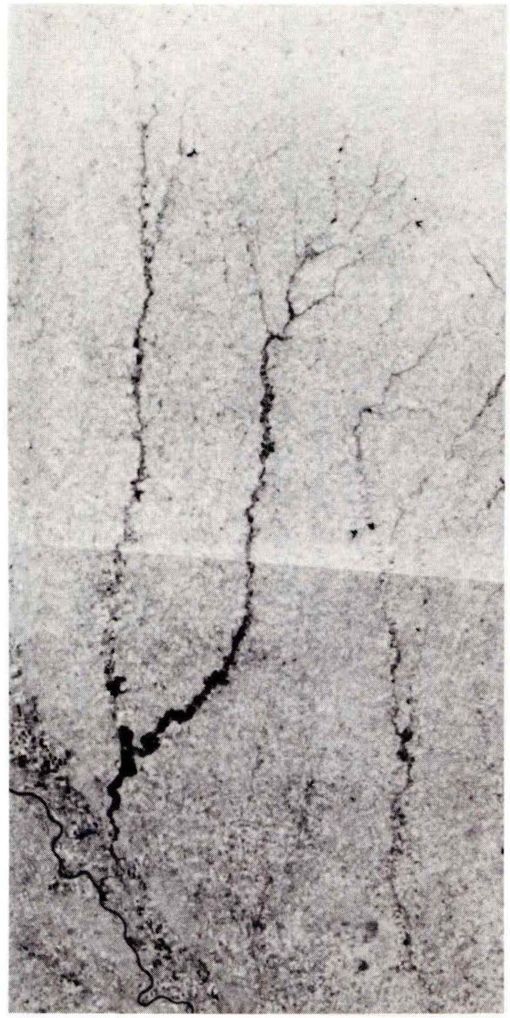
* The NASA Data Processing Facility (NDPF) I.D. Number is a catalogue reference number for a particular ERTS image. They are used for referring to a particular image and are necessary for ordering imagery. Information for ordering ERTS imagery may be obtained from the EROS Data Center, Sioux Falls, South Dakota 57198.

Table 4. Flood crest data for the September, 1972, flood along the Nishnabotna Rivers, from U.S.G.S., Water Resources Division.

River	Crest Date	Discharge (cubic feet per second)	Recurrance Interval (years)
West Nishnabotna River			
at Hancock	13 Sept.	26,400	100
near Randolph	14 Sept.	18,500	7
East Nishnabotna River			
near Atlantic	12 Sept.	26,700	120
at Red Oak	13 Sept.	38,000	100
Near Hamburg	15 Sept.	25,200	4



AUGUST 13, 1972
MSS 0.8-1.1μm BAND



SEPTEMBER 18, 1972
MSS 0.8-1.1μm BAND

PLATE I

CHANGES OBSERVED FROM ERTS-I AS A RESULT OF THE SEPTEMBER 11-15, 1972 FLOOD IN WEST CENTRAL IOWA ON THE WEST AND EAST NISHNABOTNA RIVER

Analysis of the ERTS-I imagery reinforced the basic conclusions of the IGSRSL analysis; near-visible infrared sensing systems can be used to map the extent of major midwestern floods in late summer. The ERTS data demonstrated that floodmapping can be accomplished one week after the recession of high water. The MSS does not have a blue channel, so no comparison can be made with the multiband camera for this band.

Flood Inundation Mapping: Comparison of Results

After initial analysis of the low altitude imagery a map of the flooded area along the East Nishnabotna River was prepared, utilizing multispectral imagery and metric black and white panchromatic photography. Problems in interpretation of the low-altitude imagery were encountered in some areas because of the incomplete photographic coverage over the entire width of the flooded area. The accuracy of the mapping of the inundated area by low altitude imagery was substantiated where ground observations were available. After the low altitude analysis was completed the interpretations of the inundated area were transferred to base maps at a scale of 1:126,720 (1 inch $\approx$ 2 miles). The ERTS imagery was then used to produce a map of the inundated area. The interpretation was done directly from prints, enlarged from 70mm positive transparencies to 1:250,000 scale (1 inch = 4 miles). The two maps were produced independently by the IGSRSL interpreters.

The investigators prepared a composite map at a scale of 1:250,000 to compare the low altitude and the orbital imagery interpretations. A preliminary version of this map is shown in figure 1. The two interpretations were comparable at this scale with 80 percent of the area mapped in complete agreement. However, small areas of discrepancy exist. These areas of differences should be considered in light of certain factors. The low-altitude mapping was accomplished with incomplete photographic coverage. Multispectral imagery did not include the full width of flood inundation in many areas. At these locations the boundary had to be interpreted from stereoscopic black and white panchromatic imagery filtered to include only green and red reflected energy--the least informative spectral bands for flood mapping. Interpretive errors are possible in flat lowland areas where the border of the flooded area is very complex. Transferring interpreted data to base maps was difficult because of the almost total lack of topographic maps along the East Nishnabotna River. A further mapping complication resulted from the acquisition of the low-altitude imagery below Shenandoah up to 24 hours before flood crest. For this study, ERTS imagery resulted in fewer problems because it provided comprehensive coverage with an infrared sensitive system. In places the boundary was not sharply defined and was marked only by slight tonal differences on band 7 which caused some interpretive problems. Tonal differences were especially small in the upper portion of the basin (where flooding was earliest), in the broad floodplain of the West Nishnabotna River (where flooding was slight), and near urban areas, (especially Red Oak). Another interpretive difficulty of ERTS imagery resulted from the large amount of infrared energy reflected from lowland tree species located within the flooded region. These trees are particularly apparent near Riverton. It is assumed that these bottomland trees were not stressed as a result of inundation. This response was not a problem for low-altitude stereoscopic imagery, but proved troublesome for ERTS imagery interpretation. Where mapping differences occur between low-altitude and satellite imagery, some

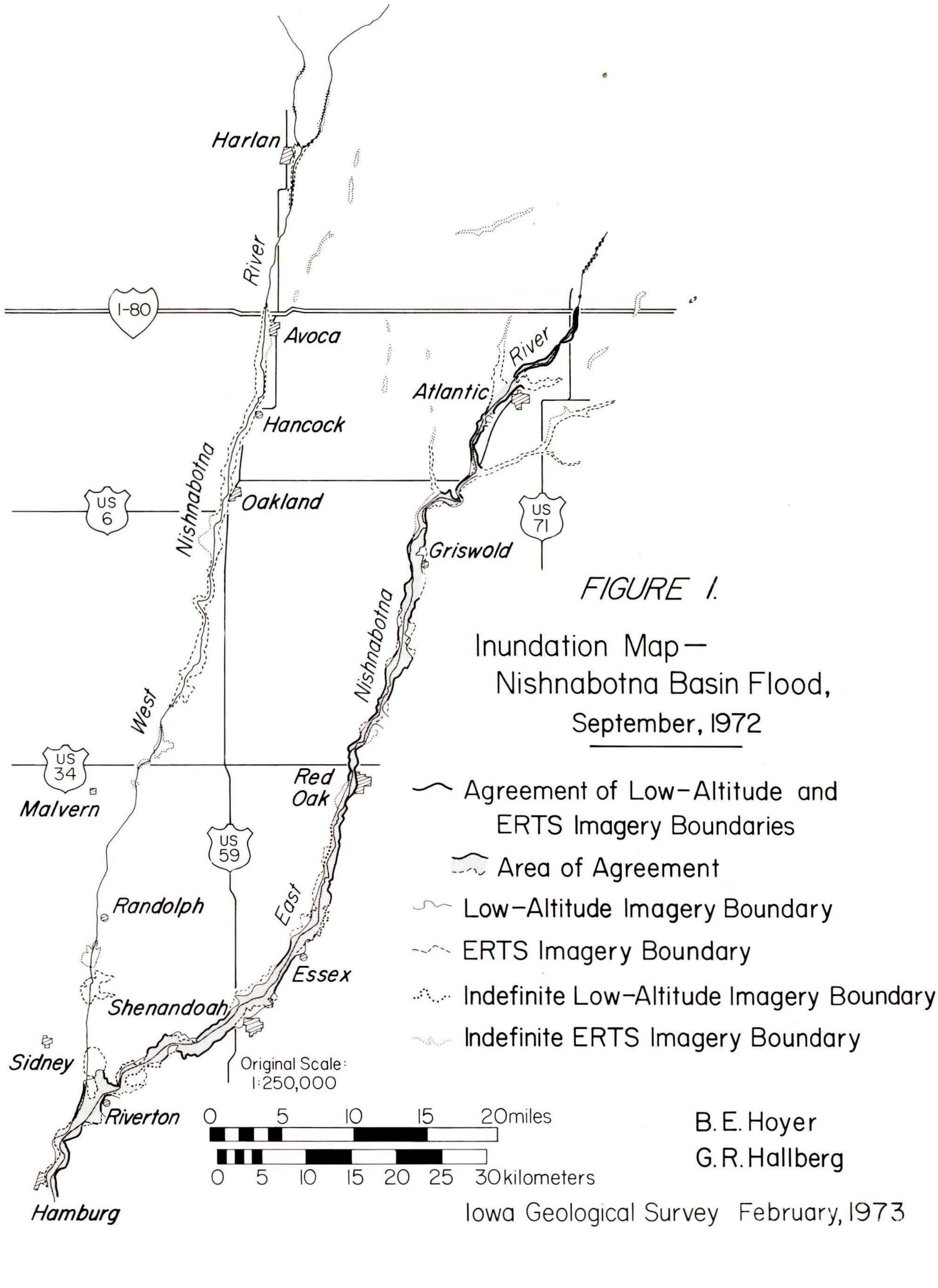


FIGURE 1.

Inundation Map — Nishnabotna Basin Flood, September, 1972 refinements of one method by the other is possible based on the interpretor's judgement and re-evaluation. The map presented does not show these possible refinements, but rather indicates the total area of dispute to eliminate interpretive bias.

Flood inundation mapping was continued into the West Nishnabotna basin because of the agreement of data in the East Nishnabotna basin. The criteria used for interpretation in the East Nishnabotna basin were also utilized in the West Nishnabotna basin, where mapping the northern portion was readily accomplished. However, no flooding could be interpreted throughout much of the southern portion, except in two highly questionable areas. Ground data supplied by the U. S. Geological Survey coinvestigators indicates that the West Nishnabotna did not breach its levees in the Malvern-Randolph area. Flood gaging records suggest this as well (table 4). The crest of the flood at Randolph exhibited a recurrence frequency* of only seven years--indicating a very minor flood stage. The crests measured along the upper portions of the West Nishnabotna and along the East Nishnabotna indicated a 100-year flood or greater.

The September 18 ERTS imagery also revealed apparent flood inundation along other stream systems, notably in the Nodaway River and Grand River basins.

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* The recurrence interval or frequency of a flood is discussed because it is more easily comprehended than actual discharge figures. The statistic basically infers that the magnitude of the flood for a given drainage basin is inversely propo to its frequency of occurence, i.e., a seven-year flood is of much lower magnitude than a 100-year flood. The statistic 100-year flood actually means that for any given year there is one chance in 100 of a flood occurring of that magnitude.

U. S. Geological Survey, Water Resources Division, data indicate the flooding occurred in these areas also. Flood stages were reached on the Boyer River and in Mosquito Creek, but inundated areas are not apparent on the imagery. The flooding in Mosquito Creek was equal to a 200-year flood near Earling, but this took place in a very small localized area (drainage area of only 32-square miles). This particular area is obscured by clouds on both the September 18 and 19 ERTS images, so no assessment of the capabilities of the ERTS imagery is possible in this area. The Boyer River was imaged on September 19. This river has been highly channelized, and the 30-year flood recorded at Logan was contained with no significant overland flooding.

The correlation of orbital data with ground data and low altitude data indicates the possibility of regionally analyzing flood inundation in the Midwest during late summer using satellite imagery. Reasonable measurements of flooded acreage seems possible for entire river systems. Using the ERTS imagery a total flooded area of 78,000 acres has been mapped in the Nishnabotna River basins. Fifty-five thousand flooded acres were mapped in the East Nishnabotna basin and 23,000 acres were mapped in the West Nishnabotna basin. Existing levee systems also can be evaluated on a regional basis. Interpretation of the West Nishnabotna valley between Malvern and Randolph and the Boyer River valley indicated that the levees were generally adequate for this flood. Evaluation of ground studies later confirmed this interpretation. Utilizing satellite imagery to assess flooded areas could become an important tool, particularly in poorly mapped, sparsely settled, or inaccessible areas. Unfortunately, the scale of the ERTS imagery limits its usefulness where detailed information is necessary. Identification of point locations for engineering studies, or the determination of flooding on a field by field basis for legal purposes, could not be accomplished using the ERTS imagery.

Summary

In September, 1972, heavy rains concentrated in the East and West Nishnabotna basins resulted in major flooding in southwestern Iowa. The flood crest moved downstream between September 11-15. A cooperative program to evaluate the possibility of mapping flood inundation using remote sensing techniques was initiated by the Iowa Geological Survey, Remote Sensing Laboratory, and the U. S. Geological Survey, Water Resources Division. Ground data and a variety of low-altitude multiband imagery were acquired for the East Nishnabotna River on September 14-15. This successful effort concluded that a near-visible infrared sensor could map inundated areas in late summer for at least three days after flood recession. ERTS-I imagery of the area was obtained on September 18-19. Analysis of ERTS-I multispectral scanner imagery reinforced the conclusions of the low altitude study. The time period critical for imagery acquisition was increased to at least seven days following flood recession. The capability of satellite imagery to map late summer flooding at a scale of 1:250,000 is demonstrated by the agreement of flood boundaries interpreted from ERTS-I imagery with boundaries mapped by low-altitude imagery and ground methods. The synoptic coverage of ERTS-I allowed extension of the flood mapping to the West Nishnabotna River. Satellite imagery allows rapid appraisal of the areal extent of flood inundation for entire river systems, and may be used in the Midwest to map the areal distribution of major, late-summer floods, on a regional basis.

References

Hoyer, Bernard E., and James V. Taranik, 1973, Aerial Flood Mapping in Southwestern Iowa, A Preliminary Report. Iowa Geological Survey, Remote Sensing Laboratory, 11 p.

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