VISUAL ANALYSIS OF DIGITAL IMAGES FOR STUDIES IN WATER RESOURCES

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Introduction

The ultimate aim of this work is to provide the Water Resources Engineer with a source of information on which to base designs. Remote Sensing cannot be expected to provide all the data required for a water resources study, but it can help augment other information sources and provide some data where no other data is available. This makes the technique particularly suitable for use in areas where mapping is poor and information is sparse.

There are three basic areas where remote sensing is of value in water resources engineering. One is in monitoring situations, another is in carrying out instantaneous measurements over a wide area and thus providing spatial correlation, and finally there is the measurement of parameters which do not change significantly with time. This work deals with the last of these three areas. In this area the problem is to identify what information is contained in the digital image that is of use to water resources engineers and to determine if it makes a difference as to the time of year when the data is collected. This paper looks at the first of these problems.

Background to Water Resources Engineering

If he is to design structures to store water, to transmit water, and to control flood waters the water resources engineer requires, at various levels of detail and accuracy, the following information, :

a) mean annual runoff, and monthly discharge volumes;

b) the probability distribution of flood flows and the shape of the flood hydrograph:

c) sediment yield

d) recharge to groundwater.

In some cases he has a set of historical records and actual measurements of the parameters of interest on which to base designs. This is not the usual case however. What happens in practice is that attempts are made to derive regional empirical relationships from such information that is available to provide estimates for places where there is no data.

Typical of these relationships are equations 1 and 2 taken from the U.K. Flood Studies Report[1] which give an estimate of the flood producing capacity of a catchment. Further data is used to obtain a probability distribution.

$$Q = .0213 \, .area^{.94} \, .stfrq^{.27} \, .s1085^{.16} \, .soil^{1.23} \, .RSMD^{1.03} \qquad (1)$$

$$Q = 1.459 \, . \, area^{.94} \, . \, stmfrq^{.44} \, . \, s1085^{.35} \, . \, SAAR^{.49} \qquad (2)$$

where area = catchment area; stmfrq = stream frequency;
s1085 = slope; soil = soil factor;
RSMD = rainfall-soil mloisture deficit factor;
SAAR = standard average areal rainfall.

In other cases conceptual models are used to derive estimates of river flows from rainfall and other meteorologic data. One such model, devised by Dr P Cluley[2] and Mr W Walley at the University of Aston, uses a number of parameters, together with monthly rainfall and evaporation estimates to produce a set of mean monthly flow figures for a catchment, and data on the groundwater and baseflow. This can be extended to produce actual sequences of runoff if sufficient rainfall data is available. The model parameters are based upon basic climate data related to snowmelt and a correlation with stream density, soils and land cover.

Equation 3, the Universal Soil Loss Equation, is typical of those used in estimating sediment yield.

$$E = R.K.L.S.C.P \qquad (3)$$

where E - annual soil loss, R - erosivity factor,
K - soil erodibility index, L - length of slope factor,
S - slope factor, P - rainfall factor

In all these equations, some which are recommended for use by the Institution of Civil Engineers for designing hydraulic structures and water resources schemes, catchment characteristics are used which are measurable from satellite images. These include land cover, soil type, drainage density, drainage area, catchment slope, and geology. Since they are all empirical equations the accuracy with which parameters are measued is not so important as consistency.

In looking at satellite image data from the water resources point of view, we are not so concerned with determining the actual stream density, or even the actual catchment area. We require to have a measure that is repeatable between images taken at different times and that provides a similar bias,if any, when moved in space.

It is of further significance that many of the important catchment parameters are loosely correlated with one another. This is reflected in the empirical studies that have been carried out which show that there are many correlations which give almost identical results. This is because, for example, drainage density is a function of relief, geology, soils and mean annual rainfall - since it is the end result of rainfall falling on soil and underlying geology in a given structural situation.

Processing and Presentation of Imagery

The area studied is located in North Wales and comprises some - 3,400 sq.km. - about one tenth of a full Landsat scene. The scene featured coastal flat plains through to hilly moorland areas and included forested, urban, arable and pasture land. The rainfall in the region varies from 700 mm to 2600 mm.

The only computer analysis carried out on the CCT was a contrast stretch with radiometric restoration and destripping. No allowance was made for geometric correction, this being done 'manually'. Linear features were determined by adding bands 5 and 7 and printing in black and white. Land cover was analysed with a false cover image based on mixing bands 4,5,and 7. Hard copy was obtained by photographing with panchromatic or colour film the screen of a colour monitor . The processing costs were minimal.

Ground control was provided by 1:50,000 Ordnance Survey maps. These provide adequate data on catchment area and drainage density but not on land cover. But since drainage density and catchment area were regarded to be of greater importance this was regarded as adequate. Visits were made to the site and terrestrial photographs were taken of the different land cover types.

Analysis of Imagery

Relevant spectral and linear features were traced from the imagery onto transparent acetate overlays. The work was carried out on photographs of the landsat imagery, produced at a scale of about 1:100,000, this was found to be most suitable. Actual scale variations were from 1:111,538 to 1:125,086. The benefit of using geometrically corrected images is stressed as the manhour costs in overcoming distorted images soon pay for the cost of letting the machine correct the data.

On the linear features it was surprising that streams of only a few metres wide could be detected. This was attributed to the fact that in this terrain and climate many streams are lined with trees. A simple trial of using two interpreters was tried to test whether significant differences would occur. In fact discrepancies of only 6% were recorded, and with further training these discrepancies can be reduced. These discrepancies are similar to those which can occur when using maps.

The control data for linear river features was traced from the 1:50,000 maps and reduced to the same average scale as the imagery. The colour composite was also used in an attempt to detect linear features, but with little success. The analysis of the Black and White, the False Colour images and the map data are presented on Figures 1, 2 and 3 respectively.

Land cover was analysed using a visual technique. Figure 4 shows the results. A machine interpretation was carried out but the results were poor compared with the human interpretation of the false colour image.

The following data were abstracted from the processed images :

1. the total area of each land category
2. the total length of river identified
3. the total length of river identified from B/W image
4. the total length of river identified from CIR image

Table 1 shows the result of the interpretation of linear river features, comparing O/S map data with image data.

TABLE 1. Total river lengths

	RIVER DETAILS		LENGTH km	%
1.	Ordnance Survey map reference	Figure 3	3860.89	100
2.	Total interpreted on B/W Imagery	Figure 1	1822.43	47.2
3.	Total interpreted on CIR imagery	Figure 2	1240.08	32.1
4.	Correct B/W interpretations (*)		881.58	22.8
5.	Correct CIR interpretations (*)		629.32	16.3
6.	Incorrect B/W interpretations		940.85	24.4
7.	Incorrect CIR interpretations		610.76	15.8
8.	Agreement between B/W and CIR		369.18	9.6
9.	Correct B/W plus CIR		1141.72	29.6

CIR colour infra red B/W black and white
* after allowing for misclassification

The overall result was that about 30% of the river channels were identified compared with that shown on the Ordnance Survey Map. However, the Ordnance Map shows streams down to one or two metres in width. When only the major channels are considered, the agreement is much better, as shown in Table 2. Other linear features which were easily identified - such as roads - were eliminated by noting their straightness and association with towns, which were also easily found.

TABLE 2 : Major River Lengths. With stream width greater than 5m.

RIVER	REPRESENTATIVE MAP		
	Black & White	Colour Composite	Ordnance Survey
Dee	136.40 km	136.05 km	139.80 km
Vyrnwy	35.53 km	33.53 km	40.86 km
Elwy	21.02 km	19.51 km	33.62 km
	192.95 km	189.09 km	214.28 km
% of O.S.	90.0 %	88.2 %	100.0

Tables 3 and 4 show the analysis of land use data using a visual interpretation of the colour composite (CIR) image and a computer classification. The results are adequate for watershed modelling techniques, which require landcover. When combined with drainage density the land cover provides most of what is required for many empirical techniques.

TABLE 3 : Grouping of manual categories resolved by the computer.

GROUP HEADING compiled by computer	CATEGORY compiled by visual method
Woodland	Deciduous woodland
	Coniferous " pine
	" " young fir
	" " mature fir
	Unknown
Moorland	Straw coloured reed grass
	Rough grassland
	Boundary moors
	Redish moorland
	Purple heather
Urban	Towns
	Bare soil (2 types)
Agriculture	Rich pasture and arable land
Harvest (White areas)	Hay fields/open cast quarries
Unknown	None

TABLE 4 : AREAS OF CATEGORY BY MANUAL AND COMPUTER ASSISTED CLASSIFICATION TECHNIQUES

CATEGORY	CLASSIFICATION AREAS			
	Computer Assisted		Manual	
	Sq.km	(%)	Sq.km	(%)
Woodland	99	(15.0)	83	(12.7)
Moorland	150	(22.9)	182	(27.8)
Agricultural	205	(31.3)	382	(58.3)
Unclassified	201	(30.6)	0	(0)
Urban	0.6	(0.1)	8	(1.2)
Harvest areas	0.6	(0.1)	0	(0)

Conclusions

It has been shown that using Landsat imagery (with 85 by 75 metre pixels) usable data for water resource studies can be obtained. Black and White band 5 plus band 7 was shown to provide the best enhancement for determining by visual means drainage density and catchment area in temperate hilly terrain. A false colour composite of bands 4 , 5 and 7 was shown to give the best estimates of ground cover. With limited ground control visual analysis proved to be better than pure machine classification in identifying actual ground cover.

For small catchment areas the drainage density and particularly catchment area determinations, are of low quality. After allowing for drainage density measurements being about 30% of the value obtained by using 1:50,000 scale maps one would expect good results from using empirical relations based upon such data. For example in equation 1, if it were known that the stream frequency using a satellite image was 30% of that obtained from a map then it is only necessary to change the coefficient by a factor of $.3^{-.44}$ (equation 2).

The potential value for these studies is very good. For example it can be expected that the quality of data from SPOT and Landsat 4 will produce data on drainage density equivalent to the 1:50,000 scale maps. This means that in zones with good drainage density catchment areas can be determined from the images with sufficient accuracy for use in empirical water resources relationships.

Further studies being carried out at Aston involve investigating the direct relationship between image statistics and water resources data. This has promise because the statistics of the image embody soil, relief and land cover parameters. Watershed models using image statistics as determinants of model parameters are currently being developed.

References

1. Flood Studies Report NERC. 1975
2. The Estimation of Mean Monthly River Flows Using Limited Meteorological Data and Catchment Characteristics, P.Cluley, Ph.D. Thesis, Aston 1984

Note : Figures not to scale.

Date of imagery: JUNE 1975; SCALE: 1 - 117 454

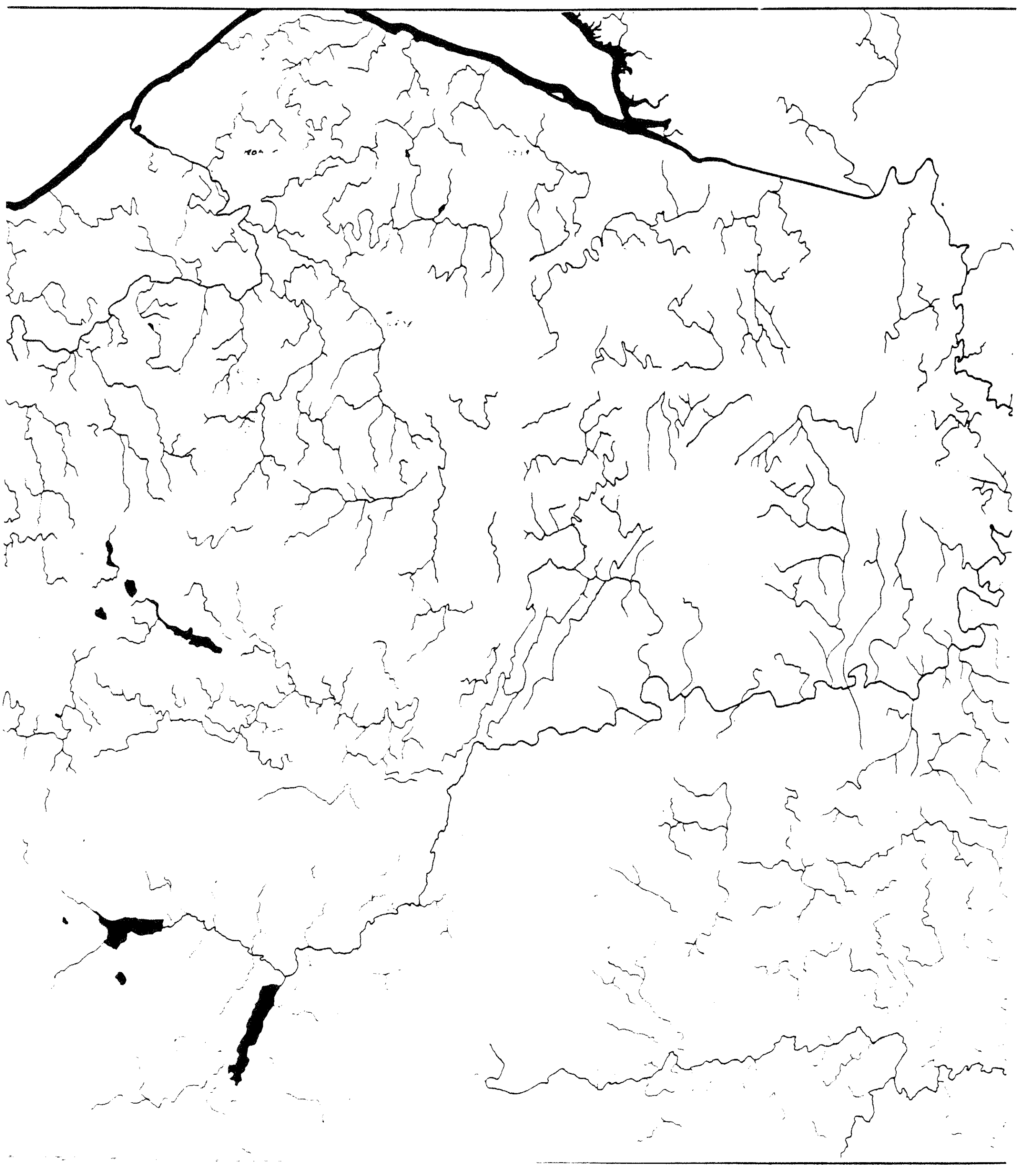

Figure 1. River Channels from B/W image.

Date of imagery: JUNE 1975; SCALE: 1 - 119 453

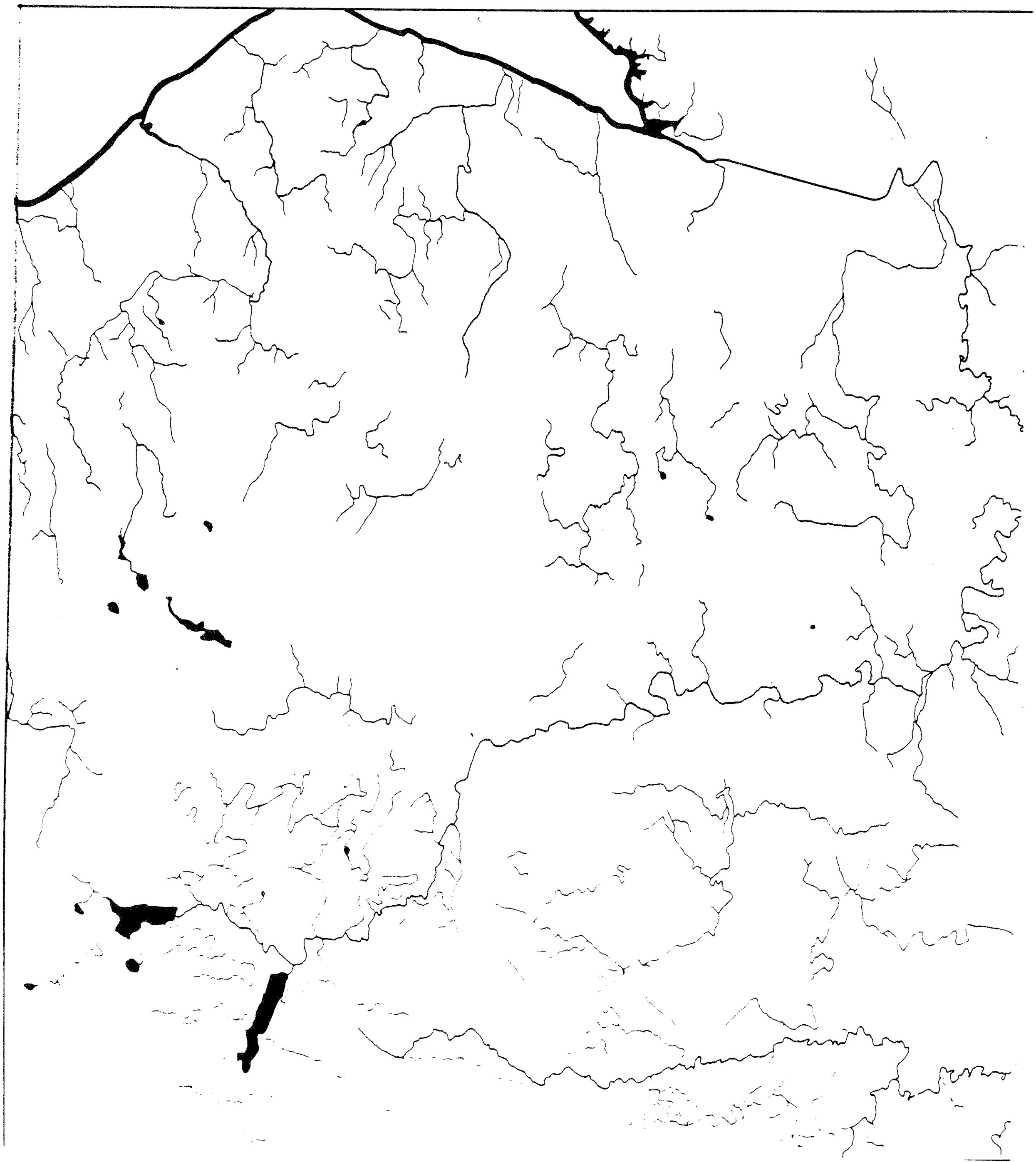

Figure 2. River Channels from CIR image.

Details of water bodies & streams taken from 1:50 000 Ordnance Survey map.

Date of O.S. : 1979; SCALE : 1 - 102 142

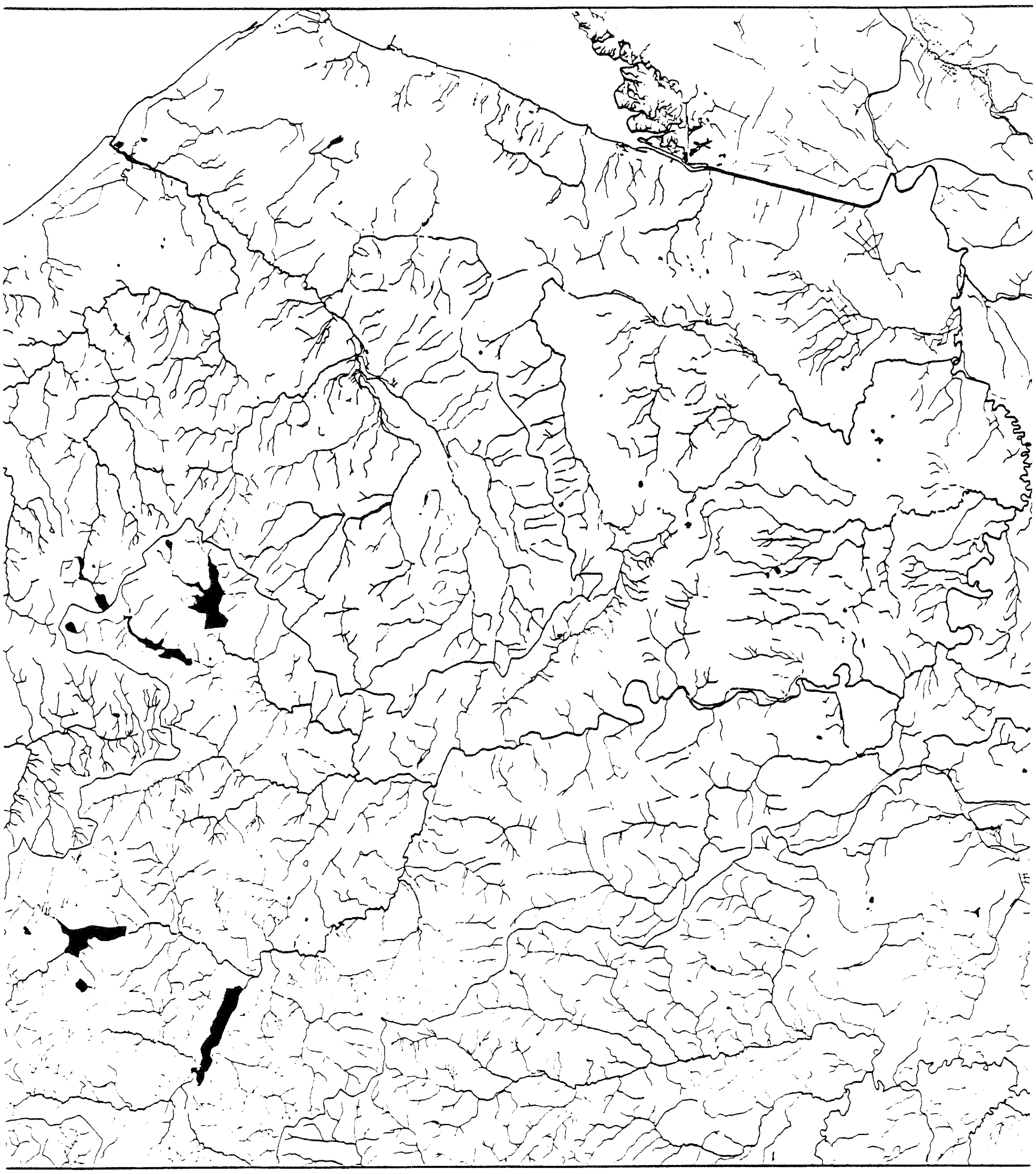

Figure 3. River Channels from 1:50,000 O.S. Map.

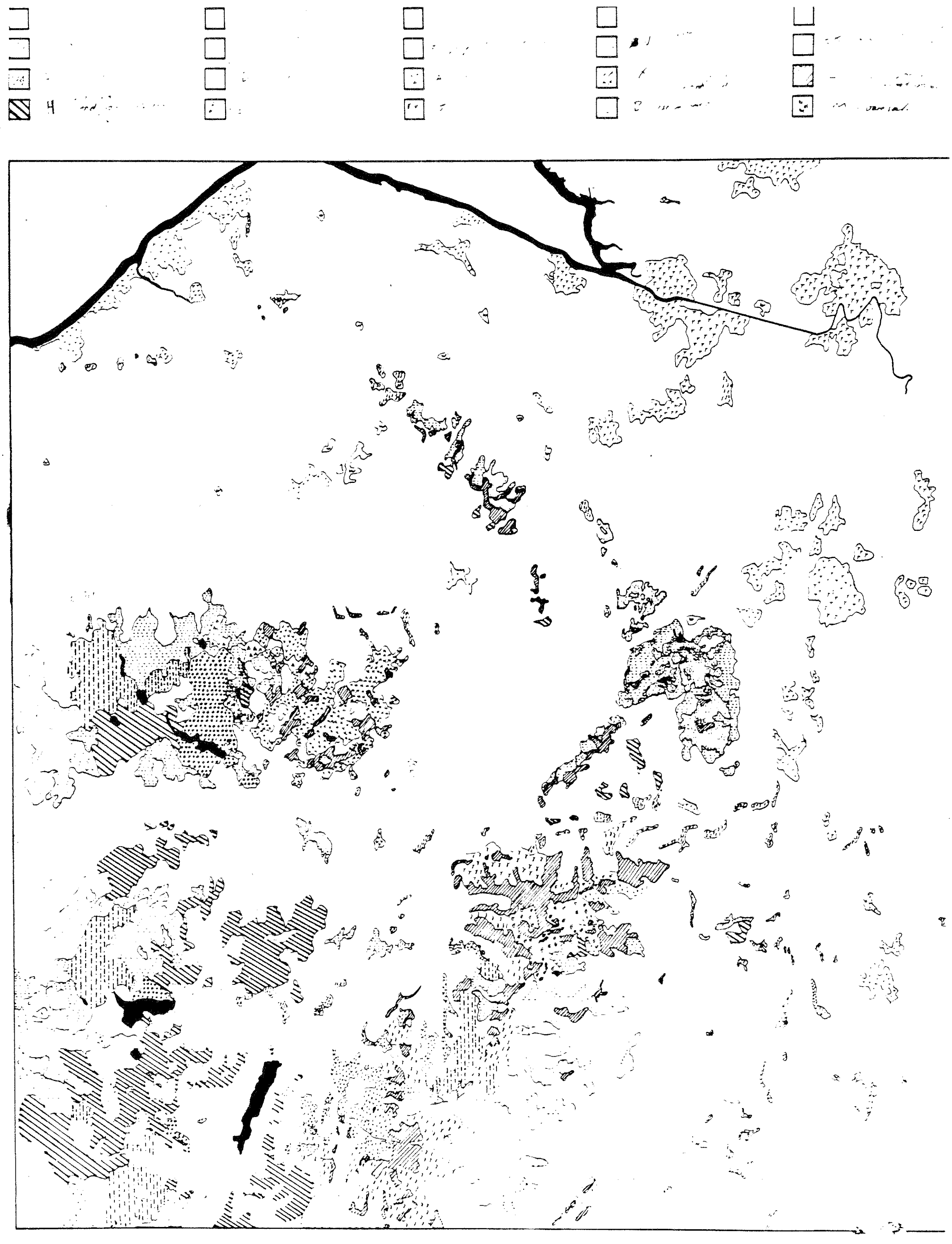

Figure 4. Landuse from CIR image.