TECHNICAL NOTE

WATER PENETRATION STUDY

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WATER PENETRATION STUDY

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SUMMARY

Nine film-filter combinations have been tested for effectiveness in recording water subsurface detail when exposed from an aerial platform over a typical water body. An experimental 2-layer positive color film, a 2-layer (minus blue layer) film, a normal 3-layer color film, a panchromatic black-and-white film, and an infrared film with selected filters were tested.

Results have been tabulated to show the relative capability of each film-filter combination for

- Image contrast in shallow water (0 to 5 feet)
- Image contrast at medium depth (5 to 10 feet)
- Image contrast in deep water (10 feet plus)
- Water penetration; maximum depth where detail was discriminated
- Image color; the spectral range of the image
- Vegetation visible above a water background
- Specular reflections visible from the water surface
- Visual compatibility; ease of discriminating image detail.

Recommendations for future recording over water bodies are included.

INTRODUCTION

Investigators in the fields of hydrology, oceanography, limnology and related fields use aerial photography as a basic investigative tool. Differentiation of water surface and subsurface detail is essential to these investigators for acquiring data on phenomena such as industrial effluents, plant life and tidal effects. Photographic penetration of the water surface to record detail is dependent upon a match of the subject's spectral and brightness character with the photographic system spectral sensitivity and sensitometric character.

The Photographic Science Office of the NASA Photographic Technology Division at the Johnson Space Center evaluated nine film-filter combinations (Table 1) for water depth penetration.

TABLE I

EXPERIMENT 047 FILMS AND FILTERS

Roll Number	Film	Wratten Filter
1	2-Layer Experimental* †	3
2	SO-397 (4-mil base Ektachrome EF)	64 + 2E
3	SO-426 (Red and Green layer SO-397)	none
4	SO-397	12
5	SO-397	3
6	2402 (Kodak Plus-X Aerographic)	64 + 2E
7	2402	3 + 47
8	2402	21 + 57
9	2424 (Kodak Infrared Aerographic)	89B

* A 2-layer color positive film as proposed by Gaylord A. Helgeson in a February 1970, Photogrammetric Engineering paper, "Water Depth and Distance Penetration", and produced by Eastman Kodak Company.

† The 2-layer color positive film was described in an April 1973, Photogrammetric Engineering paper, "New Color Film for Water Penetration", by M. R. Specht, D. Needler, N. T. Fritz.

Film Characteristic Data Sheets are included as Appendix B.

Imagery was obtained in a six camera 70mm Hasselblad system during December 1972, at an altitude of 4800 feet over a well documented area adjacent to the Scripps Institution of Oceanography. The mapped water depth in this area varied from zero on the beach to 50 meters within 1 kilometer of the shoreline.

The typical spectral character of this water body is shown in Figure 1. Maximum relative transmittance is centered between 500 nm and 550 nm.

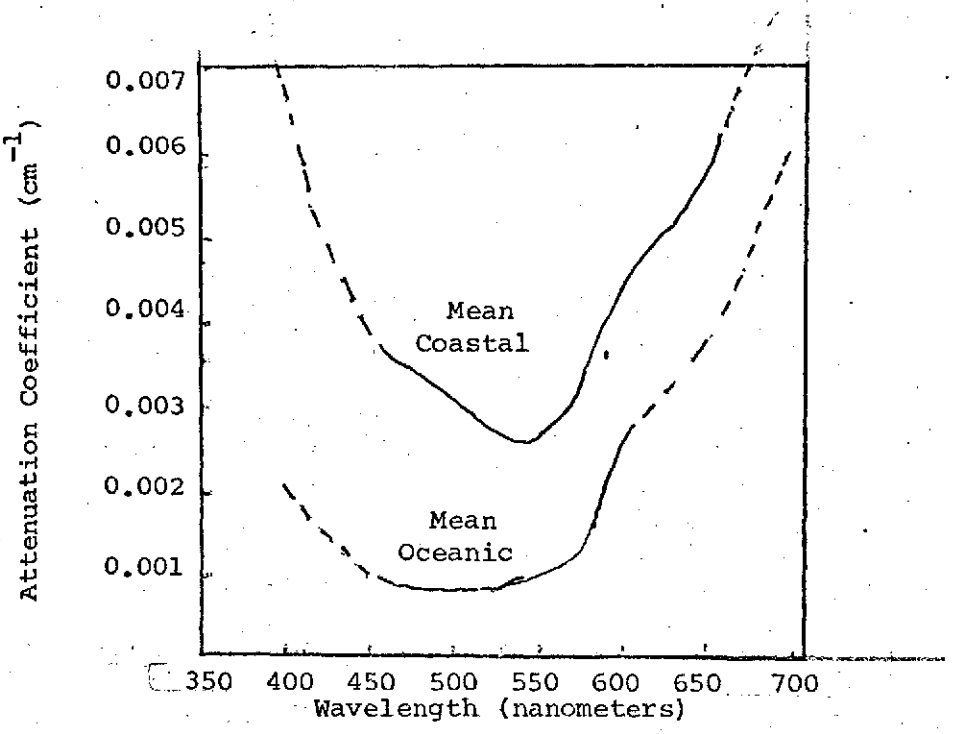

FIGURE 1

Water Attenuation Coefficient
(from Mairs and Clark, P.E.1973)

The spectral character of water bodies does vary. This experiment was designed to study photographic effects of films and filters with peak sensitivities covering the maximum water transmission region, as well as blue and near infrared.

Information obtained from this experiment will be used in determining films and filters for future photographic missions over water bodies. Criteria for the evaluation included:

- Image contrast in shallow water (0 to 5 feet)
- Image contrast at medium depth (5 to 10 feet)
- Image contrast in deep water (10 feet plus)
- Water penetration, maximum depth of detail discriminations
- Image color; the spectral range of the image
- Vegetation visible above the water surface
- Specular reflections visible from the water surface
- Visual compatibility, ease of discriminating image detail.

SECTION I

TEST PROCEDURES

The spectral sensitivities of the film-filter combinations in Table 1 are shown in Figures 2 through 10. These combinations were chosen to provide imagery resulting from peak film sensitivity across the visible and near infrared spectra.

Six records (the color films plus 2402 film with 64 plus 2E filters) were exposed in the Hasselblad system simultaneously on 2 runs along the subject coastline. The remaining records were obtained minutes later in a single run along the same coast line such that the maximum depth variation was included in the imagery. Identical subject matter appears in all nine sets of imagery. (See Appendix A - Photographic Flight Log). The imagery was processed and printed by the Photographic Technology Division.

Mapped water depths and reference points, Figure 11, were correlated with the imagery for depth determinations. Images were analyzed subjectively on a standard viewing table using the evaluation criteria listed above. A table of results with a relative scaling (1=high; 10=low) to denote performance was prepared.

Results were correlated with spectral sensitometric data to estimate subject spectral character and to study effects of spectral sensitivity variations.

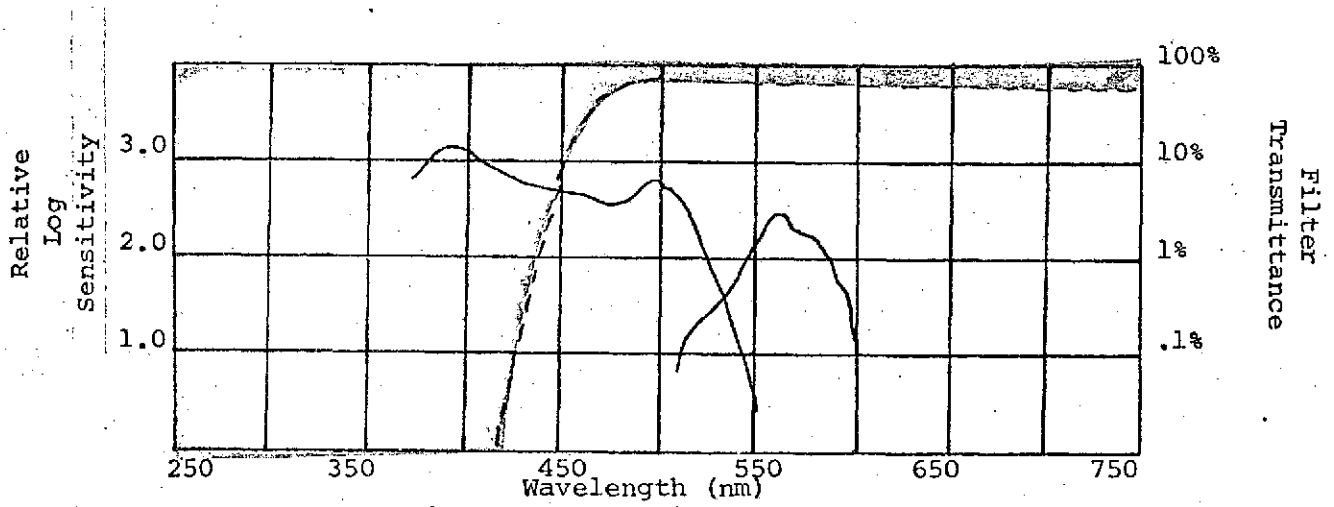

Figure 2. Experimental 2-Layer Color w/Wratten 3 Filter

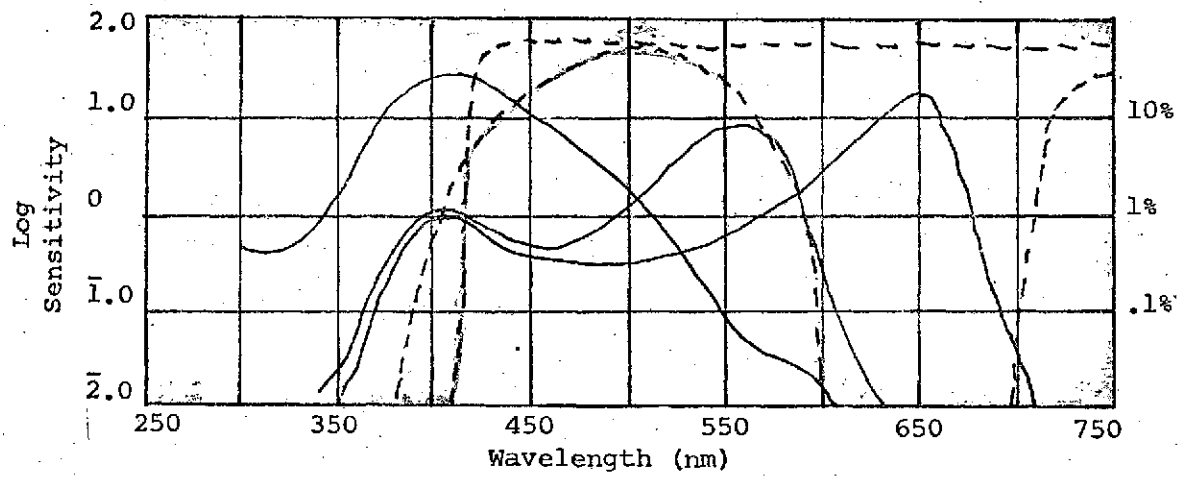

Figure 3. SO-397 w/Wratten 64 + 2E

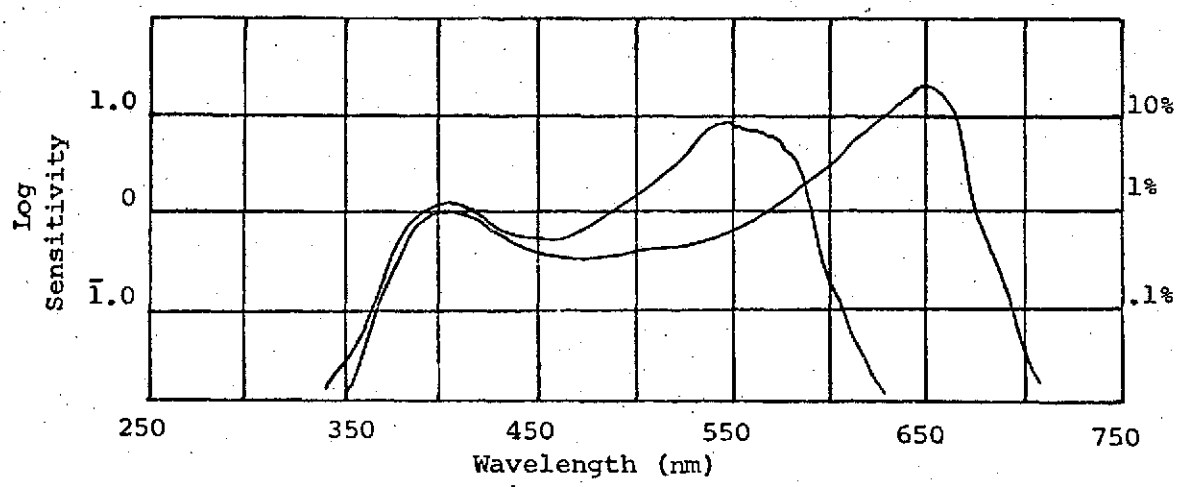

Figure 4. SO-426, No Filter

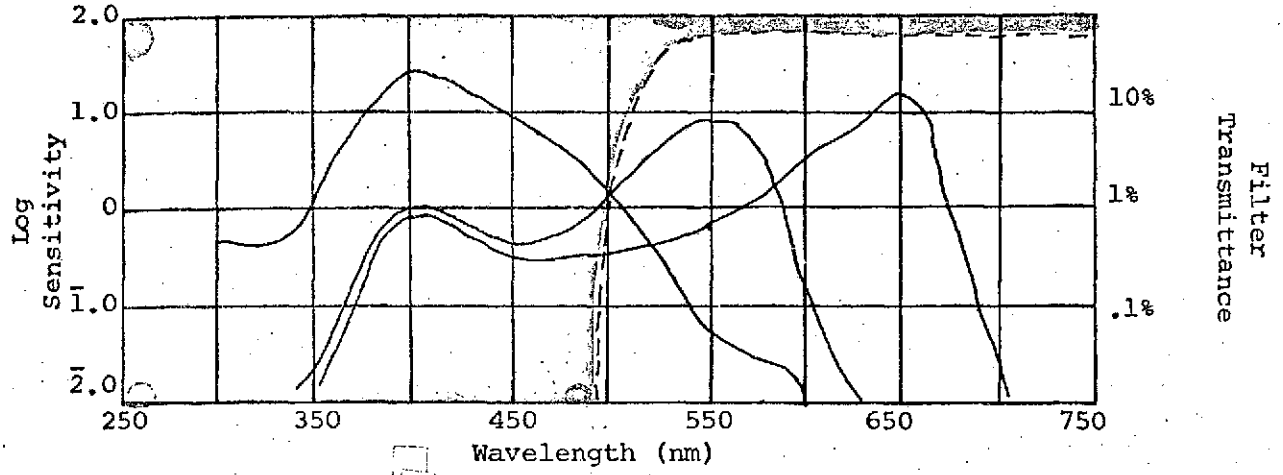

Figure 5. SO-397 w/Wratten 12

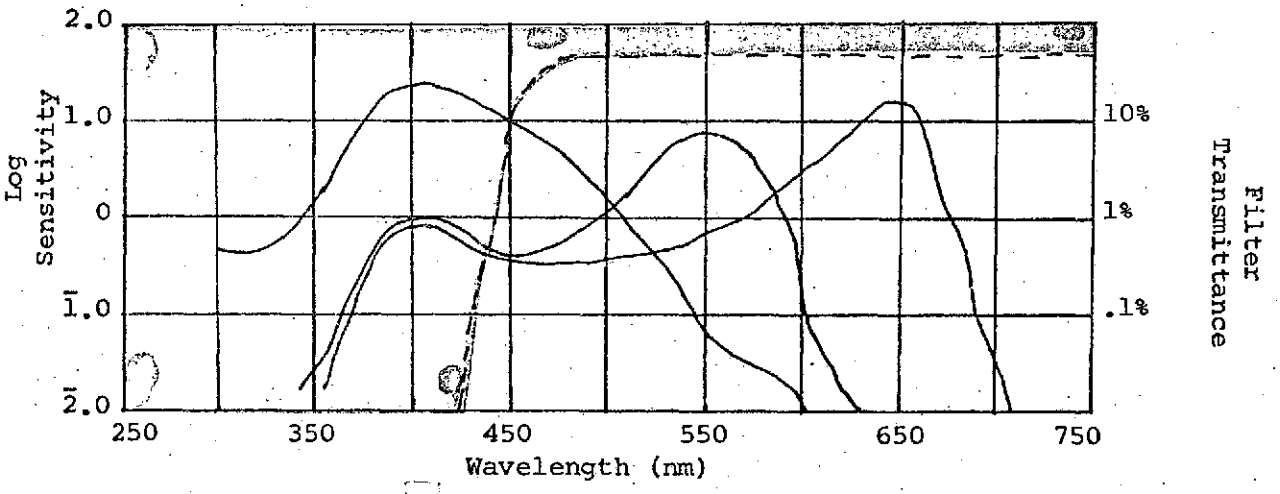

Figure 6. SO-397 w/Wratten 3

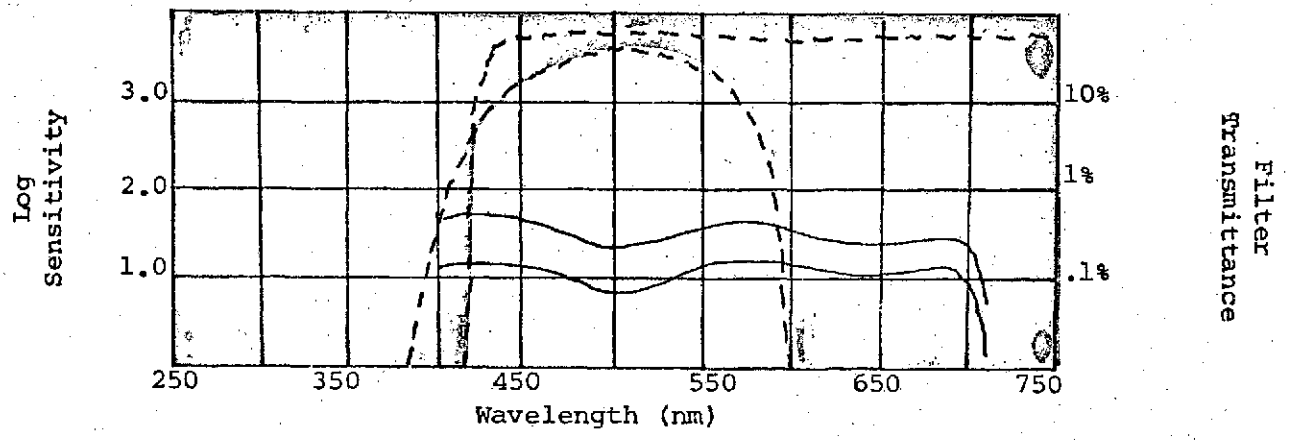

Figure 7. 2402 w/ Wratten 64 + 2E

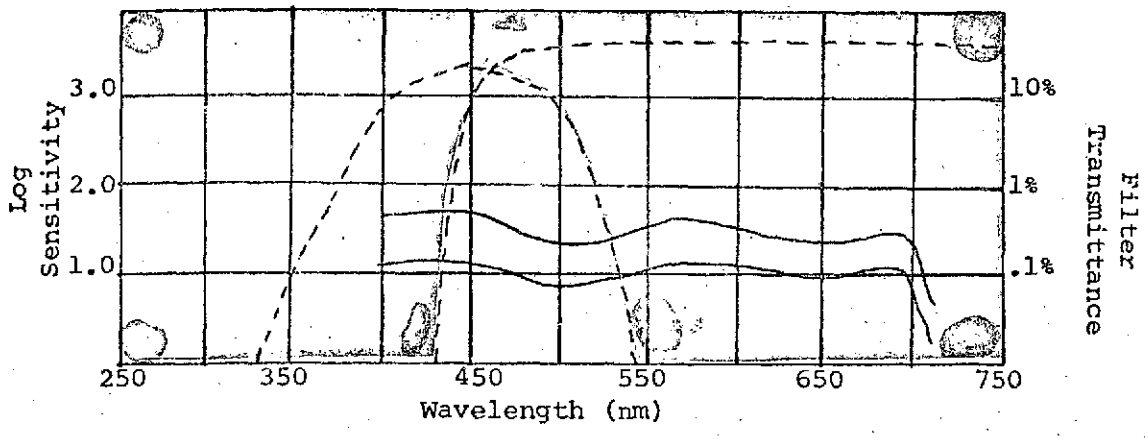

Figure 8. 2402 w/Wratten 3 + 47 Filters

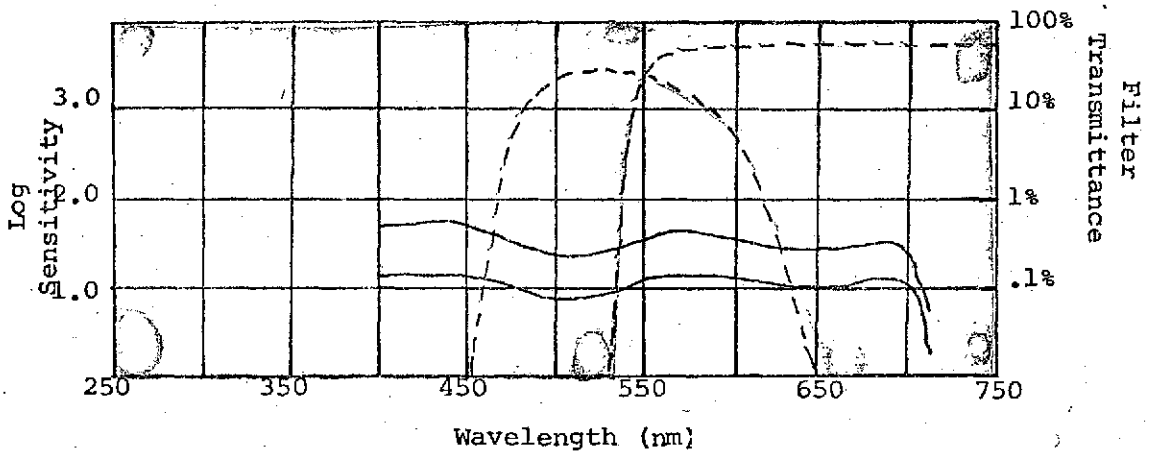

Figure 9. 2402 w/Wratten 21 + 57 Filters

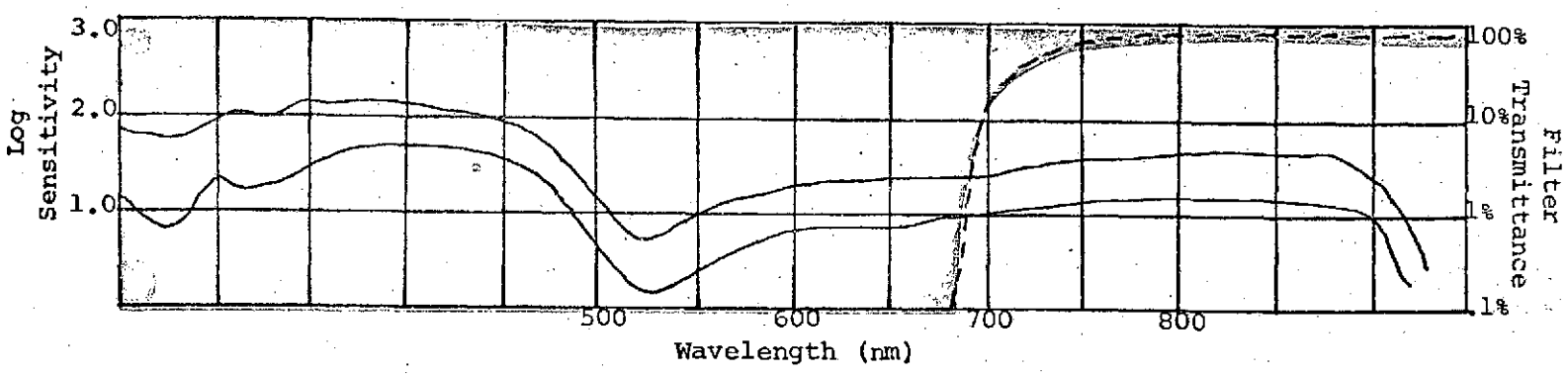

Figure 10. 2424 w/Wratten 89B Filter

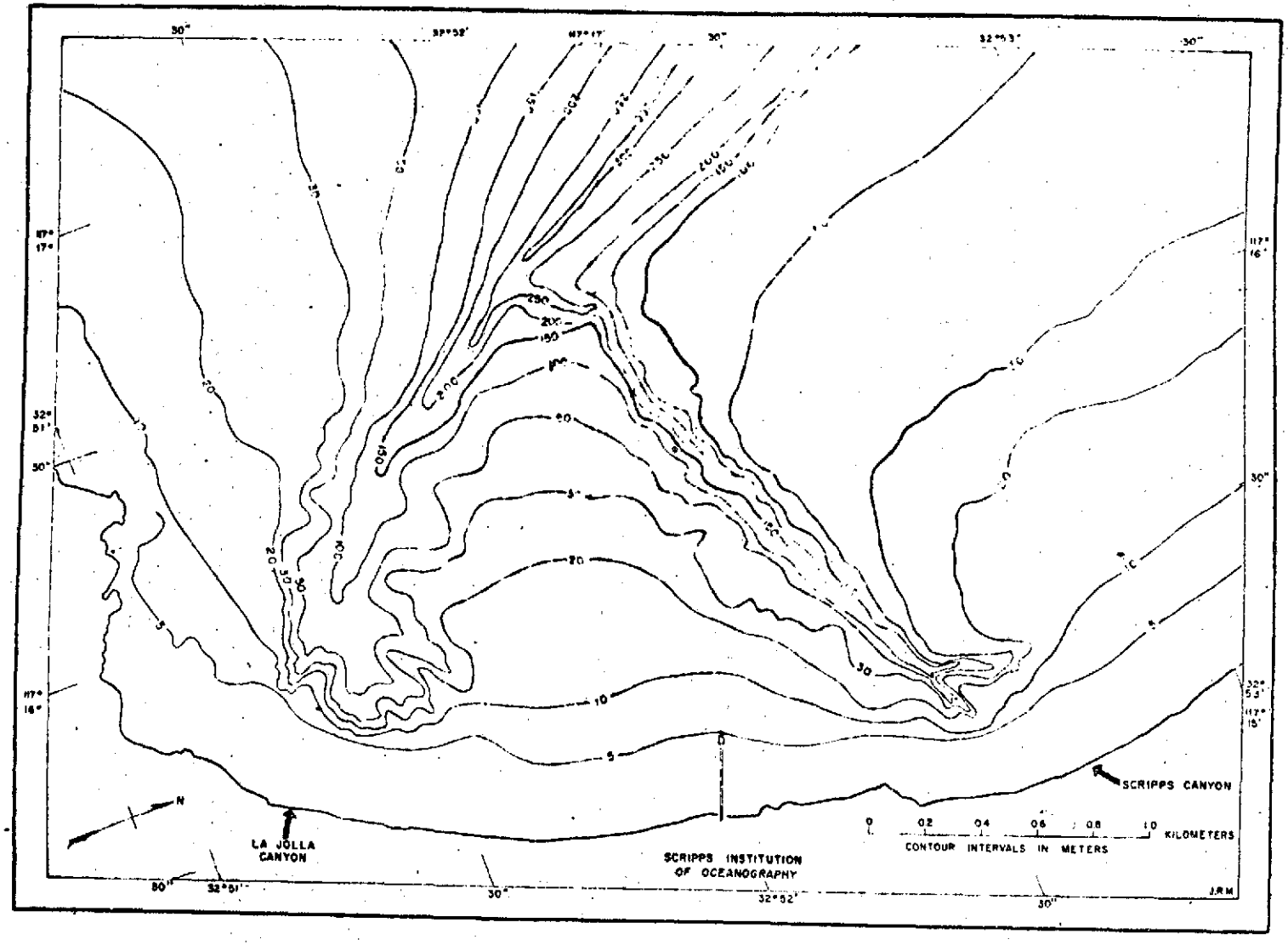

FIGURE 11. Subject Area Map
Reference

SECTION II

TEST RESULTS

A tabulated subjective analysis of the nine film records is as follows in Table 2, Experiment Results.

FILM NUMBER / FILM / FILTER	SHALLOW COLOR CONTRAST/ COLOR SCALE	MEDIUM COLOR CONTRAST/ COLOR SCALE	DEEP COLOR CONTRAST/ COLOR SCALE	WATER PENETRATION (meters)/ RANK	COLOR	SURFACE VEGETATION	SURFACE REFLECTIONS	VISUAL COMPATIBILITY
No. 1	3	2	1	10 to	Magenta	4	4	2
Experimental 2-layer		Mag.		14'	to			
Wratten 3	Magenta	to Neut.	Neutral	2	near Neut.			
No. 2	5	5	6	3 to	Green	10	2	5
SO-397				5'				
Wratten 64 + 2E	Green	Green	Green	6				
No. 3	4	3	3	6 to	lt. Mag.	3	3	4
SO-426	lt.	lt.		8'	to			
None	Mag.to C	Cyan to B	Blue	4	Blue			
No. 4	2	2	3	10 to	Yellow	1	4	3
SO-397				14'	to			
Wratten 12	Yellow	lt. G.	dk. G.	2	Green			
No. 5	1	1	1	10 to	Y/G	2	4	1
SO-397				14'	to			
Wratten 3	lt. Y.	Y-G	Green	1	Green			
No. 6	3	3	4	3 to		10	3	2
2402				5'	B & W			
Wratten 64+ 2E	B&W	B&W	B&W	6				
No. 7	4	4	2	5 to		10	n/a	2
2402				8'	B & W			
Wratten 3 + 47	B&W	B&W	B&W	5				
No. 8	4	4	1	10 to		10	n/a	2
2402				14'	B & W			
Wratten 21 + 57	B&W	B&W	B&W	1				
No. 9	10	10	10	0		4	n/a	3
2424					B & W			
Wratten 89B	B&W	B&W	B&W	7				

TABLE 2

Experiment Results

(See Table 2 Criteria Key on following page)

TABLE 2 CRITERIA KEY

Shallow Color Contrast -	Visual color or density differences in water at map positions indicating 5 feet or less.
Medium Color Contrast -	Visual color or density differences in water at map positions indicating 5 feet to 10 feet depths.
Deep Color Contrast -	Visual color or density differences in water at map positions indicating depths of 10 feet or more.
Water Penetration -	Definite density or color differences visually discriminated at depths indicated on map referenced points. This does not necessarily mean that the ocean bottom is visible.
Color -	Spectral range observed in the imagery.
Surface Vegetation -	The ability to see plant life contrasted against the water body background.
Surface Reflections -	Specular reflections observed on the water surface.
Visual Compatibility -	The effect of scene color and color differences in making visual density and color difference determinations.

The films were graded on a relative basis; 1 being excellent and 10 being poor in any category.

IMAGERY DESCRIPTION

Roll Number 1: The 2-layer experimental color positive water penetration film with a Wratten 3 filter resulted in magenta to nearly neutral imagery. Magenta is predominant in shallow water changing to neutral at greater indicated water depths (minimal exposure areas). Surface vegetation appears magenta against a nearly neutral water background. Figures 12 and 18 show the water penetration at 30 to 50 foot depths.

Roll Number 2: SO-397, low contrast Ektachrome EF aerographic film (4-mil base) with Wratten 64 and 2E filters provides light green imagery. Color contrast at all indicated water depths is poor, the overall light green color making visual determinations difficult. Surface vegetation discrimination is not possible because of poor color contrast. Figures 13 and 19 show the water penetration at 10 to 15 foot depths.

Roll Number 3: SO-426, a 2-layer color positive film (sensitivity similar to SO-397 red and green sensitive layers) with no filter resulted in light blue to blue imagery. Color contrast and saturation are inferior. Figures 14 and 20 show the water penetration at indicated depths of 20 to 25 feet.

Roll Number 4: SO-397 film with a Wratten 12 gives a yellow to green record. Saturated, bright yellow predominates

at depths under 5 feet changing through green at 5 feet to 10 feet to green at depths greater than 10 feet. Color contrast is good at all depths with water depth penetration indicated at map positions of 30 feet to 50 feet, Figures 15 and 21. Vegetation above water surface is imaged best by this record, bright yellow against green water.

Roll Number 5: SO-397 film with a Wratten 3 filter provides an excellent record for water depth penetration. Light yellow predominates at shallow (under 5 feet) depths, changing to a yellow-green contrast at 5 feet to 10 feet and green at depths in excess of 10 feet. Color contrast is excellent at all depths, definitely superior to other films. Water penetration is possible at indicated depths of 30 feet to 50 feet, Figures 16 and 22. Surface vegetation is identified with ease. Visual compatibility is excellent for this film-filter combination. Brightness discriminations are easily made in the yellow and green; color contrast is very good.

Roll No. 6: Black-and-white Kodak Plus X Aerographic film with Wratten 64 and 2E filters results in density differences below depths of 10 feet that are better than other black-and-white records. Detail discrimination is relatively poor at greater depths. Surface vegetation is very difficult to discriminate and water penetration is possible at 10 feet to 15 feet depths, Figures 17 and 23.

Roll Number 7: 2402 film with Wratten 3 and 47 filters provides imagery with minimal density differences at indicated depths below 10 feet and good density differences beyond 10 feet. Surface vegetation is not easily visually discerned. Figures 24, 27 and 30 show the water penetration at indicated depths of 15 to 25 feet.

Roll Number 8: 2402 film with Wratten 21 and 57 filters shows minimal density differences at depths under 10 feet but excellent gradation at depths greater than 10 feet. In deeper areas this record compares very favorably with SO-397 with a Wratten 3 filter and may show greater density differences. Penetration is possible at the 30 foot to 50 foot depths, Figures 25, 28 and 31. Surface vegetation is not easily discernable.

Roll Number 9: Black and white infrared aerographic film, 2424, with an 89B filter provides no water penetration. Surface vegetation may be visually discriminated and the shoreline is easily noted making this the only black-and-white record with that capability (See Figures 26, 29 and 32).

SECTION III

DISCUSSION

Four of the film-filter combinations produced imagery which demonstrated similar superior water depth penetration in water at 10 to 15 meters.

- Experimental 2-layer color with Wratten 3
- SO-397 with Wratten 12
- SO-397 with Wratten 3
- 2402 with Wratten 21 and 57 filters

This means that density or color brightness changes were visually discriminated in these map-correlated deep water areas. Visual discrimination, of course, is not the only method available to analyze aerial imagery. Where practical enhancement may be accomplished with image quantizers to produce isodensity contours or high contrast printing on a limited number of frames (See Appendix C).

Correlation of imagery with film spectral sensitivity and sensitometric data is useful for relating the effect of a water body subject transmittance on the films with given filters. The water attenuation characteristics, Figure 1, are confirmed by the imagery in this case. The SO-397 with a Wratten 3 filter, the widest spectrally sensitive combination used is the easiest to observe for demonstration purposes.

Correlating its spectral sensitivity data with the imagery results in an approximate subject transmittance curve shown as Figure 33.

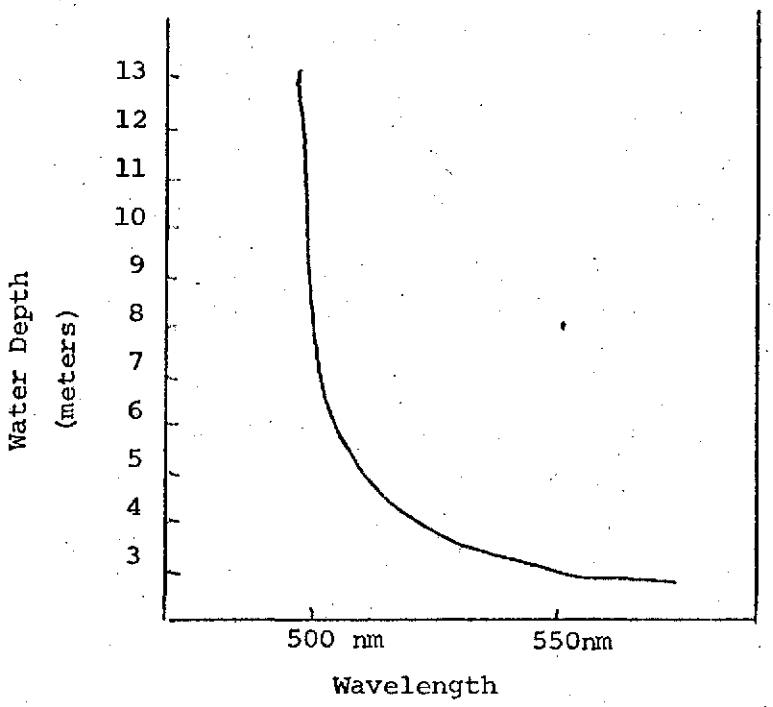

FIGURE 33.

Subject Transmittance

Maximum brightness results near the shoreline with peak transmittance of 550 nm and minimum brightness results in deep water with transmittance at 500 nm. There is little spectral change beyond a depth of 3.5 meters.

Water bodies represent a subject of overall wide brightness range, from bright shallow water to dark deep water, with minimum brightness range in deep water where detail discrimination is desirable. Color contrast, spectral sensitivity and characteristic curve shape are key factors in effective recording over water bodies.

The experimental 2-layer color film imagery is magenta near the shoreline which correlates well with spectral sensitivity at 550 nm. At 500 nm the imagery is not correlated as easily because of the low subject brightness. The imagery is nearly neutral (Red = 1.29, G = 1.36, B = 1.11), but definitely not green as might be suggested by Figure 2. This situation results in minimal color contrast or color brightness variation in the deeper water.

Film type SO-426 (the 2-layer minus blue version of SO-397) imagery correlates well with subject transmittance and spectral sensitivity. With the removal of the blue sensitive-yellow dye forming layer, the yellow filter used to control residual blue sensitivity in the lower layers apparently loses some of its efficiency. The addition of a Wratten 12 filter might be advisable to correct this problem. In shallow water at 550 nm where green is expected, the added blue produces a cyan image. At 500 nm, low exposure areas, the blue imagery correlates well with spectral sensitivity data.

Film type SO-397 with a Wratten 3 filter produced excellent imagery not only because of water depth penetration but also because of the spectral range (color contrast) in the image. Yellow in higher brightness shallow water at 550 nm contrasts well with green in the deeper water. The colors are also saturated and brightness variations are observed easily. The presence of a wider range of colors in the imagery offers a better chance for color contrast to be displayed when brightness level as well as peak spectral transmittance are factors. The same film with a Wratten 12 filter introduced excessive yellow into the imagery.

The black-and-white 2402 film imagery was influenced by exposure equally as by spectral sensitivity. Film type 2402 with green sensitivity (64 + 2E filters) received 16X less camera exposure because of its lack of sensitivity at 500 nm. The other 2402 records were exposed identically.

Poor image contrast were exhibited by all the black-and-white films in shallow water where a wider subject spectral transmittance range was present. In deeper water, 2402 with 64 + 2E filters is more sensitive than the same film with 21 + 57 filters which have

negligible sensitivity at 500 nm. The latter required 16X more exposure in this case providing better imagery. Although the 64 + 2E filters produced an excellent overall image, the exposure in the deep water low-brightness area provides too little image contrast.

Infrared sensitive film with an 89B filter would be excellent for detecting vegetation against a water background if it is exposed properly. Water is opaque in the near infrared making the contrast easy to achieve.

Water depth penetration is highly dependent upon spectral sensitivity, as well as image contrast. The problem is complex because of high brightness, wide spectral range subject (shallow water) is combined with a low brightness, low brightness range subject (deep water). To record all of the subject properly high film gamma is desirable in the low exposure area, lower gamma is desirable in the high exposure area and a wide exposure range is needed.

The visual color contrast increase available with some color film-filter combinations like the experimental 2-layer film or SO-397 with either a Wratten 12 or a Wratten 3 filter is a significant aid when making visual analyses.

SECTION IV

CONCLUSIONS

The following are concluded from this evaluation of nine films for water depth penetrating ability over a typical subject area:

1. SO-397 (low contrast Kodak Ektachrome EF Aerographic film on a 4-mil base) with a Wratten 3 filter for atmospheric haze reduction produced the best overall imagery for water depth penetration at all depths. The wide spectral sensitivity of this combination, 450 nm to 650 nm, make it an excellent choice for recording over bodies of water at this altitude.

2. The Kodak experimental color film with a Wratten 3 filter water depth penetration ability was comparable to SO-397 with a Wratten 3 filter, but its color contrast (magenta and near neutral) was inferior.

3. SO-397 film with a Wratten 12 filter was best for differentiating surface and subsurface vegetation. Yellow surface vegetation contrasted against a green water background was effective.

4. Color film imagery was superior to black-and-white imagery when a wide subject spectral range was present; e.g. shallow vs. deep water and surface vs. subsurface vegetation.

5. 2402 (Kodak Plus-X Aerographic film) with Wratten 21 and 57 filters was the most effective black-and-white film. Its ability to discriminate deep water subsurface detail was equal to SO-397 with a Wratten 3 filter.

6. 2424 (Kodak Infrared Aerographic film) with an 89B filter defines shoreline well. Water is a poor transmitter of infrared and produces no exposure on infrared film producing a clear discrimination between it and the beach or shoreline.

7. Color film should be included in water body studies. Color contrast is a definite aid in visual analysis of water surface and subsurface detail. It is increasingly important as water depth becomes less.

8. Imagery shows that deep water subsurface detail discrimination is dependent upon photographic exposure and contrast. Subject spectral range is small and subject brightness and brightness ranges are low, requiring higher contrast and film speed.

9. SO-397 with Wratten 64 and 2E filters is inferior in this application.

10. SO-426 (2-layer color positive film similar to SO-397 red and green layers) was inferior in this application.

11. 2402 with Wratten 64 and 2E filters as well as 2402 with Wratten 3 plus 47 filters were both inferior in this application.

12. Serious consideration should be given high contrast printing as an image enhancement tool for deep water penetration.

APPENDIX

PHOTOGRAPHIC FLIGHT LOG

MISSION FCF | SITES Proj 047 | DATE 12-12-72 | PHOTOGRAPHER Gray-Lucero

CAMERA / POSITION	HASS 3	HASS 4	HASS 5	HASS 6	HASS 7	HASS 8		3	6	5
LENS / SERIAL NO.	80MM	80MM	80MM	80MM	80MM	80MM		80MM	80MM	80MM
FILM / EMULSION NO.	Kodak Exp	50397 17-1	5042L 1-1	50397 17-1	50397 17-1	2402 144-1		2402	2402	2424 29-M
FILTER / SERIAL NO.	W3	64+2E	NONE	W12	W3	64+2E		W3+47	21+57	898
SHUTTER SPEED	1/250	1/125	1/250	1/250	1/250	1/250		1/60	1/60	1/250
f/STOP	5.6	4	8	4	5.6	5.6		2.8	2.8	11
OVERLAP	20%	20%	20%	20%	20%	20%		30%	30%	30%
ROLL NUMBER	1	2	3	4	5	6		7	8	9

NOTES: A/C con. skidded A/C to follow the beach.

#4 Cable ON HASS-Bro used Spare-

FT - Film Test

METER 14,1

SITE / FLIGHT NO.	LINE	RUN	START / STOP	START / STOP	START / STOP	START / STOP	START / STOP	START / STOP	START / STOP	START / STOP	START / STOP	START / STOP	TIME	IVLR. SEC.	ABS. ALT.	DRIFT	TRUE HEAD.	GS
336 FT	1	1	1 / 25	1 / 25	1 / 25	1 / 25	1 / 25	1 / 25					180935 / 181335	10	4.9	1L	167	1
336 FT	2	1	26 / 42	26 / 42	26 / 42	26 / 42	26 / 42	26 / 42					181740 / 181940	7	4.9	1L	083	
336 FT	1	2	43 / 56	43 / 56	43 / 56	43 / 56	43 / 56	43 / 56					182750 / 182925	7	4.8	2R	037	
336 FT	1	3								1 / 55	1 / 55	1 / 55	184845 / 185355	7	4.8	1R	030	

APPENDIX B

FILM CHARACTERISTICS DATA SHEETS

KODAK EKTACHROME EF FILM TYPE SO-397

(Estar Base)

(This material was obtained from manufacturers published information unless a specific test source is referenced)

FILM CHARACTERISTICS

A medium speed, color reversal aerial camera film for low-to-medium altitude reconnaissance applications. This film has low contrast, medium resolving power and extremely fine grain. The film can also be used as a comparison film in conjunction with black-and-white films used for multispectral serial photography.

BASE

This film has a 4-mil base with a fast-drying backing. Total film thickness is 4.9 mils.

EXPOSURE

Effective aerial film speed is 64, based on normal development. PTD* standard ASA speed with an HF-3 filter is 160.

IMAGE STRUCTURE CHARACTERISTICS; EA-5 chemicals at 115°F

CHARACTERISTIC	VALUE
Resolving Power	
Test-Object Contrast 1000:1	80 lines/mm
Test-Object Contrast 1.6:1	40 lines/mm
RMS Granularity (at gross diffuse density 1.0)	15

MECHANIZED PROCESSING

The 1811 Color Versamat can be used to process this film using EA-5 chemistry; processing temperature at 115°F at 9 feet per minute.*

*PTD information

KODAK MINUS BLUE LAYER FILM TYPE SO-426

(Estar Base)

(This material was obtained from manufacturers published information on SO-397 unless otherwise specified)

FILM CHARACTERISTICS

SO-426 is a minus-blue layer version of Kodak Ektachrome EF Film Type SO-397. It is a medium speed, color reversal aerial camera film for low-to-medium altitude reconnaissance applications. The film has low contrast, medium resolving power, and extremely fine grain. Its design purpose was for water penetration.

BASE

This film has a 4-mil Estar base.

EXPOSURE

For aerial recording an effective aerial film speed of 128 may be used.* PTD* speed used was 2X SO-397.

IMAGE STRUCTURE CHARACTERISTICS

None available.
Reference may be made to SO-397.

MECHANIZED PROCESSING

The 1811 color Versamat can be used to process this film using EA-5 chemistry; processing temperature at 115°F at 9.5 feet per minute.*

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* PTD information.

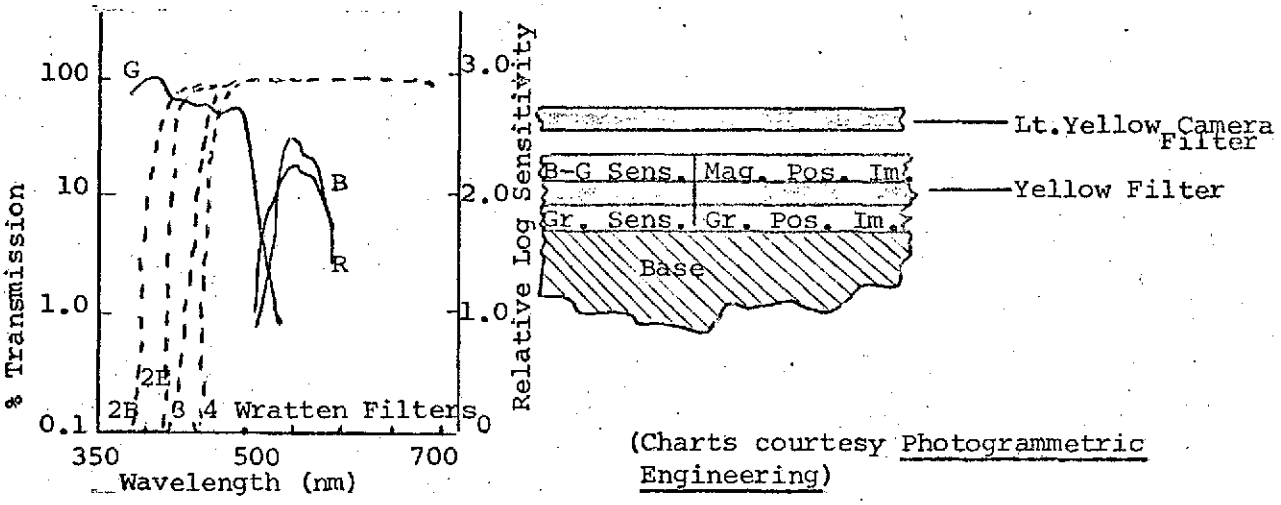
KODAK EXPERIMENTAL WATER PENETRATION FILM

This material is based on information from published journal articles and PTD test information. This film was described in a paper by Norman L. Fritz (Photogrammetric Engineering, April 1973, pp 359), a photographic scientist in the Kodak Research Labs.

The code number for the film tested here was 4J 227810.

FILM CHARACTERISTICS

A medium speed, color reversal camera film for aerial reconnaissance over water. The film has 2 color layers and special sensitivity to match water transmittance:



(Charts courtesy Photogrammetric Engineering)

EXPOSURE

The authors suggest an aerial film speed of 40.

PTD tests were conducted at a speed equal to SO-397 or AFS 64*.

IMAGE STRUCTURE CHARACTERISTICS

CHARACTERISTIC	VALUE
Resolving Power	
Test Object Contrast 1000:1	100 lines/mm
RMS Granularity	21

MECHANIZED PROCESSING

The 1811 color Versamat can be used to process this film using EA-5 chemistry; processing temperature at 115°F at 9.5 feet per minute.*

---

* PTD information

KODAK PLUS-X AEROGRAPHIC FILM TYPE 2402

(Estar Base)

(This material was obtained from manufacturer's published information unless a specific test source is referenced).

FILM CHARACTERISTIC

A panchromatic negative film that has medium speed, medium-high contrast and extended red sensitivity. It can be processed in the Kodak Versamat Processor, Model 11C-M. This film is designed for general use in mapping and reconnaissance aerial photography at medium to high altitudes.

BASE

This film has a 4.0-mil Estar polyester base with a fast-drying backing. Nominal thickness is 4.3 mils.

EXPOSURE

Aerial Exposure Index for this film is 80. Aerial exposure indexes are not equivalent to, and should not be confused with, the conventional film speeds used in pictorial photography.

IMAGE STRUCTURE CHARACTERISTICS:

CHARACTERISTIC	VALUE
Resolving Power	
Test-object Contrast 1000:1	112 lines/mm
Test-object Contrast 1.6:1	50 lines/mm
RMS Granularity	
(at net density of 1.0)	30

MECHANIZED PROCESSING

The Versamat Model 11C-M can be used to process this film; MX-641 chemicals with processing temperature of 85°F , 2 Tanks, 12 feet per minute.

APPENDIX C

IMAGE ENHANCEMENT TECHNIQUES

Imagery may be enhanced or displayed to aid investigators interested in water depth penetration.

Graphic displays of density data may be achieved using an iso-densitracer which produces a two dimensional plot of image density. For ease in interpreting the eight displays included the density increments noted below each plot are represented by three symbols; lines, dots and blanks. Density is increasing when the pattern order is lines-dots-blank. This method has one severe restriction; i.e. each plot of about 1 square inch required a machine time of 24 hours.

Contrast enhancement is a fruitful technique which may be used. In deeper water where brightness differences are small increased contrast may separate items of interest in the imagery. This technique is more easily accomplished, requiring only a critical specification of exposure, film stock and process. Sample contrast enhanced images are included.

DATE October 1973 RECORDING NO. _____ IDENTIFICATION Water Penetration Study SO-397 film/Wratten 3 Filter

SPOT HEIGHT	1.1 mm	WEDGE NUMBER	F	RATIO ARM	10	OPERATOR	
SPOT WIDTH	1.1 mm	Δ D INCREMENT	0.03			COMMENTS:	
OBJECTIVE	X 10 /	TABLE SPEED	22	RECORD SPACING	0.5 mm		
CONDENSER	X 10 /	PEN DAMPING	1.1	SAMPLE SPACING	50 μ		

Tech ape
TECHNICAL OPERATIONS INCORPORATED
REGIONAL OFFICES
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Santa Clara, California 95050
111 Terrace Hall Avenue
Burlington, Massachusetts 01803
6124 Milwaukee Avenue
Chicago, Illinois 60646

ISODENSITY Isodensitracer RECORDING

TECHNICAL OPERATIONS, INCORPORATED RADIATION PRODUCTS DIVISION NORTHWEST INDUSTRIAL PARK BURLINGTON, MASSACHUSETTS 01803

DATE October 1973 RECORDING NO. _____ IDENTIFICATION Water Penetration Study
SO-397 Film/Wratten 12 Filter

SPOT HEIGHT	1.1 mm	WEDGE NUMBER	F	RATIO ARM	10	OPERATOR	
SPOT WIDTH	1.1 mm	Δ D INCREMENT	0.03			COMMENTS:	
OBJECTIVE	X 10 /	TABLE SPEED	22	RECORD SPACING	0.5 mm		
CONDENSER	X 10 /	PEN DAMPING	1.1	SAMPLE SPACING	50μ		

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REPRODUCIBILITY OF THE
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DATE October 1973 RECORDING NO. _____ IDENTIFICATION Water Penetration Study SO-426 Film (minus blue layer) No filter

SPOT HEIGHT	1.1 mm	WEDGE NUMBER	F	RATIO ARM	10	OPERATOR	
SPOT WIDTH	1.1 mm	Δ D INCREMENT	0.03			COMMENTS:	
OBJECTIVE	X 10 /	TABLE SPEED	22	RECORD SPACING	0.5 mm		
CONDENSER	X 10 /	PEN DAMPING	1.1	SAMPLE SPACING	50 μ		

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ISODENSITY Isodensitracer RECORDING

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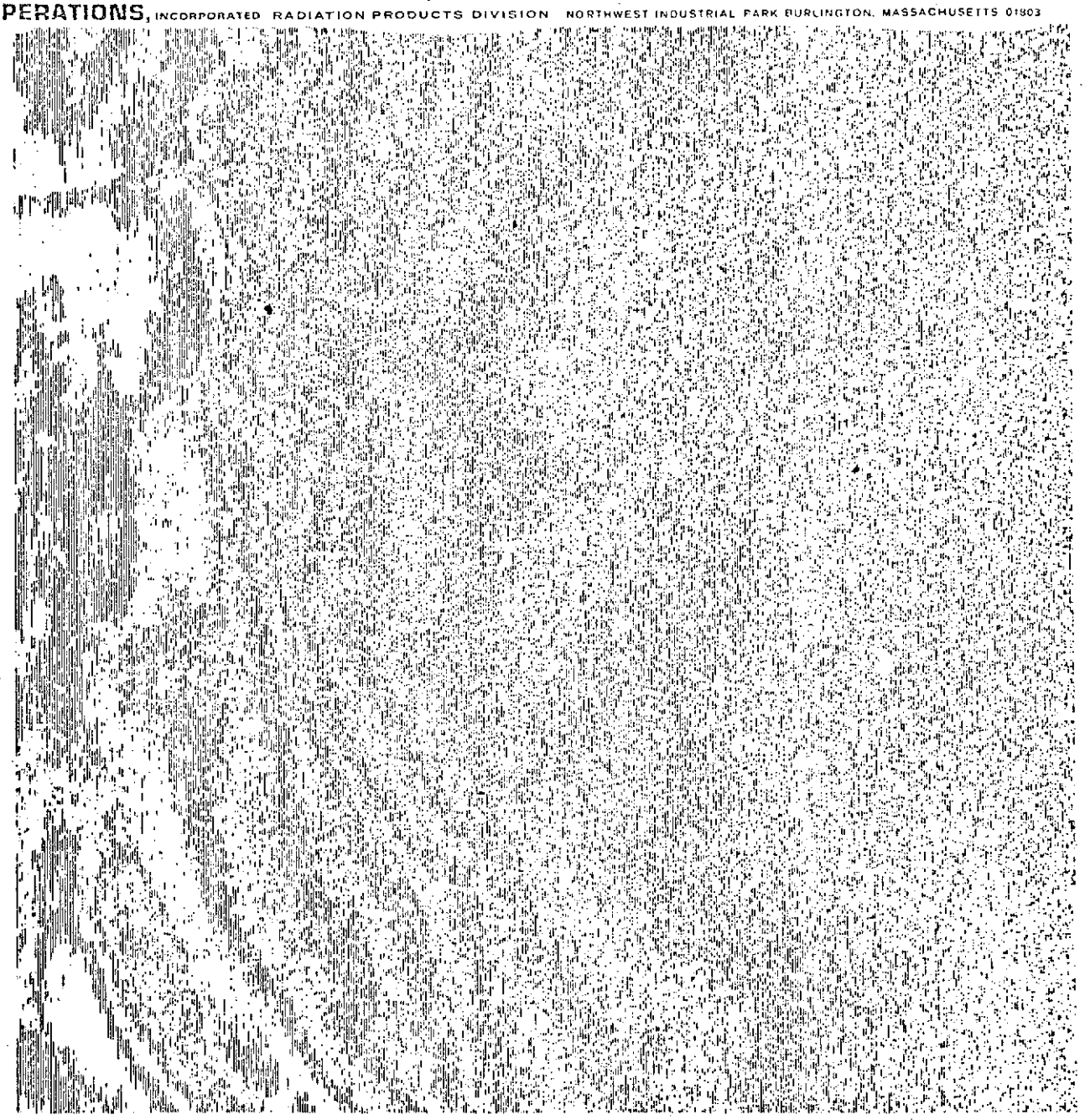

DATE October 1973 RECORDING NO. _____ IDENTIFICATION Water Penetration Study
Experimental 2-Layer
Color Film/Wratten 3 Filter

SPOT HEIGHT	1.1 mm	WEDGE NUMBER	F	RATIO ARM	10	OPERATOR	
SPOT WIDTH	1.1 mm	Δ D INCREMENT	0.03			COMMENTS:	
OBJECTIVE	X 10 /	TABLE SPEED	22	RECORD SPACING	0.5mm		
CONDENSER	X 10 /	PEN DAMPING	1.1	SAMPLE SPACING	50μ		

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ISODENSITY Isodensitracer RECORDING

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DATE October 1973 RECORDING NO. _____ IDENTIFICATION Water Penetration Study
2402 Film/Wratten 64+2E Filters

SPOT HEIGHT	1.1mm	WEDGE NUMBER	F	MAGNIFICATION:	10 →	OPERATOR	
SPOT WIDTH	1.1mm	ΔD INCREMENT	0.08		10 ↑	COMMENTS:	
OBJECTIVE	x10	DIFFERENTIAL CONTROL		SCALE: ONE INCH=			
CONDENSER	10	PEN DAMPING	1.1	ONE CENTIMETER =			

ISODENSITY Isodensitracer RECORDING

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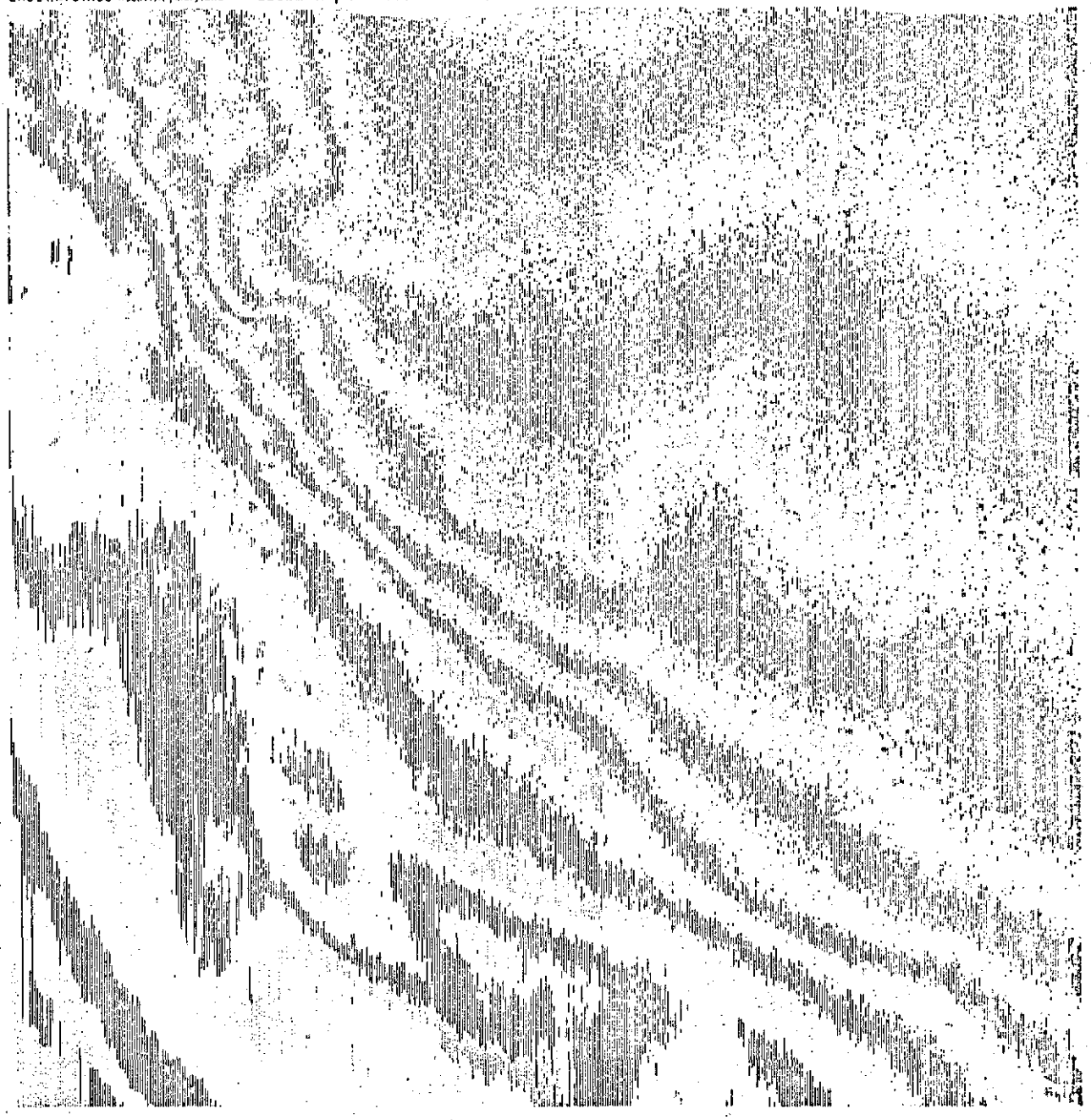

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DATE October 1973 RECORDING NO. _____ IDENTIFICATION Water Penetration Study
2402 Film/Wratten 21 + 57 Filte

SPOT HEIGHT	1.1mm	WEDGE NUMBER	F	MAGNIFICATION:	10 →	OPERATOR	
SPOT WIDTH	1.1mm	ΔD INCREMENT	0.08		10 ↑	COMMENTS:	
OBJECTIVE	x 10	DIFFERENTIAL CONTROL		SCALE: ONE INCH=			
CONDENSER	10	PEN DAMPING	1.1	ONE CENTIMETER =			

ISODENSITY Isodensitracer RECORDING

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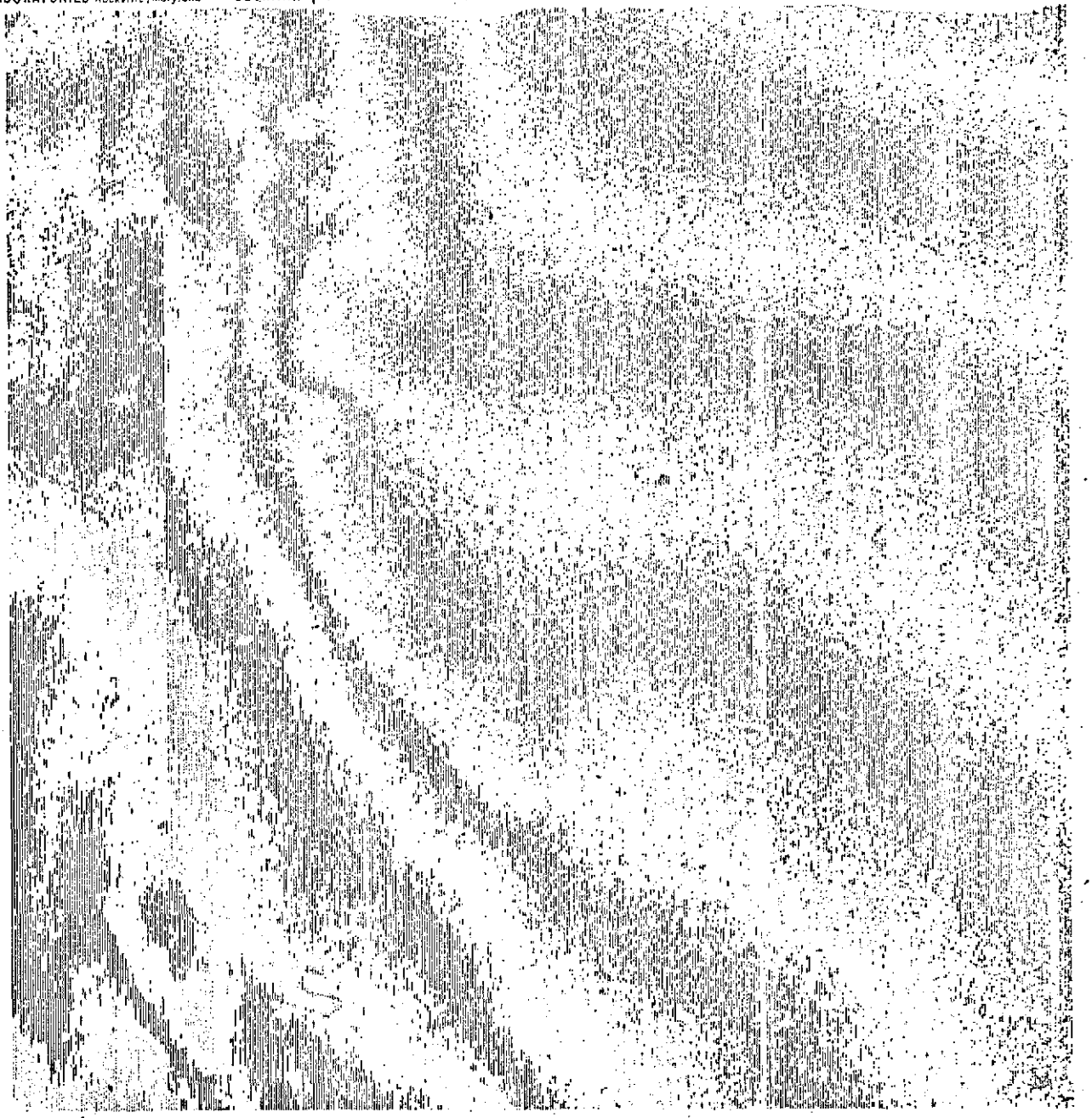

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DATE October 1973 RECORDING NO. _____ IDENTIFICATION Water Penetration Study
2402 Film/Wratten 3 + 47 Filte

SPOT HEIGHT	1.1mm	WEDGE NUMBER	F	MAGNIFICATION:	10 →	OPERATOR	
SPOT WIDTH	1.1mm	ΔD INCREMENT	0.08		10 ↑	COMMENTS:	
OBJECTIVE	x 10	DIFFERENTIAL CONTROL		SCALE: ONE INCH=			
CONDENSER	10	PEN DAMPING	1.1	ONE CENTIMETER =			

tech ops

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