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Aerial Spill Prevention Surveillance During Sub-Optimum Weather

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September 1973

AERIAL SPILL PREVENTION SURVEILLANCE DURING SUB-OPTIMUM WEATHER

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ABSTRACT

Multi-band aerial photography was acquired during specified conditions of cloud cover and reduced visibility considered to be representative of a nearly infinite range of sub-optimum weather conditions. (For aerial photography, optimum is defined as clear skies and greater than 15 miles visibility). Basic techniques were derived from an earlier project which defined a system for strategic spill prevention surveillance (Welch, et al. 1972).

Results of this project indicated that only one film tested, a high sensitivity color positive film, provided consistently interpretable results. Rapid access techniques were also evaluated leading to recommendations for a tactical system which provide for both real-time and near real-time system update during sub-optimum aerial photographic conditions.

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SECTION I

CONCLUSIONS

TACTICAL UPDATING FOR AERIAL SURVEILLANCE SPILL PREVENTION CAN BE SUCCESSFULLY ACCOMPLISHED DURING SUB-OPTIMUM WEATHER CONDITIONS UTILIZING CONVENTIONAL COLOR FILM.

In comparison to the other film/filter combinations tested, only Kodak SO-397 positive color film (exposed through a Wratten 1A filter) provided adequate image quality regardless of time of coverage, weather conditions, or reasonable deviation from optimum exposure settings. In fact, film apparently can be utilized under any daylight conditions where an aerial photographic mission can be safely attempted. The latitude of this film combined with comprehensive flight planning adds the necessary tactical dimension needed to maintain a dynamic information file based on the strategic surveillance system specified in Welch et al. (1972). Color infrared and black and white panchromatic films which have specified surveillance applications in clear weather exhibited shortcomings which warrant recommendation against their use under less than optimum weather.

CAREFUL FLIGHT PLANNING AND COMPREHENSIVE WEATHER MONITORING ARE ABSOLUTE REQUIREMENTS FOR SUCCESSFUL MISSION PERFORMANCE.

Constraints on both the photographic system and on aircraft operations are more severe under less than optimum weather conditions. The pilot has to consider ceiling height and horizontal visibility as well as aircraft speed in order to successfully obtain low altitude photography. As altitude decreases image motion increases unless there is a compensating decrease in aircraft speed. Aircraft safety must be a major consideration in mission planning, its impact depending to a limited extent on the urgency of the mission.

Careful planning by the photographer is also required. To insure correctly exposed film and maximum possible data content, his planning should be based on a reliable source of weather information. Clouds, suspended particulates, precipitation, shadows and non-uniform illumination all require careful consideration, along with the usual factors of target characteristics and product requirements.

The importance of weather to the safety and performance of the photographic mission necessitates a source of timely, accurate weather information. Both forecasted and observed conditions for the target vicinity as well as the routes of ingress and egress should be available. FAA flight service facilities along the flight path provide a good source of enroute weather. For weather over the target the ideal source is an on-site observer in radio contact with the aircraft. Comprehensive weather information will help both pilot and photographer to perform their respective jobs effectively.

A SINGLE ENGINE, HIGH WING AIRCRAFT CARRYING A HIGH RESOLUTION CAMERA SYSTEM OF FORMAT SIZE CONSISTENT WITH AREAL COVERAGE REQUIREMENTS OFFERS MAXIMUM VERSATILITY.

The preferred vehicle for use under less than optimum weather conditions is a single-engine, high-wing monoplane carrying in vertical mode an aerial camera of format size suitable to the desired areal coverage. Single engine monoplanes are capable of the low altitude, low speed operation necessitated by operation under low clouds. The high-wing configuration is preferred because it simplifies the problem of visually alighning the aircraft on a predetermined flight line. An acquisition scale of 1:5000 provides adequate detail provided a high quality camera system is chosen.

AN INTEGRATED RAPID ACCESS SYSTEM CAN PROVIDE USEFUL REAL-TIME TACTICAL INFORMATION.

In situations requiring real-time or near real-time assessment of ephemeral conditions, such as natural disasters or catastophic spills, a properly employed rapid access photographic system can meet most information requirements which could be addressed in a routine situation by aerial photography. A rapid access operation requires coordination in all phases, but can significantly reduce the elapsed time between exposure and information dissemination. Major time reductions can be accomplished by collating the film processing, interpretation, and dissemination facilities and if possible, by overlapping processing and transport functions.

SECTION II

RECOMMENDATIONS

Film/Filter Combinations

In that aerial color film exposed through a 1A filter was the only film/filter combination which produced consistently interpretable results, it is recommended that a film of this sensitivity, color rendition, and latitude be used exclusively for tactically updating spill surveillance photography during sub-optimum atmospheric conditions.

It is recommended that a high quality photographic light meter be used by the aerial photographer to determine desired exposure. In order to calculate basic exposures, the meter should be aimed at an average subject in the ground scene during an initial pass over the target. In cases where important detail is located in darker than average areas, an increase in exposure of one "f" stop is recommended.

It is recommended that the aerial photographer develop a list of acceptable exposures for a variety of scenes and illumination conditions based on his experience with a particular camera-film-filter combination. By combining experience and light meter readings he will be able to consistently make exposures of acceptable quality.

The basic exposures used in this investigation and recommended for SO-397/1A are as follows:

Cloud Cover	Exposure
Clear	1/500 f 10
Scattered	1/500 f 8
Broken	1/500 f 6.3
Overcast	1/500 f 3.5

Where a need exists for rapid access to the data available from aerial photography it is recommended that a panchromatic film such as Kodak Plus X Type 2402 also be employed. This film can be readily processed, either during the mission or immediately upon landing, using portable equipment. The process utilized, as discussed below, yields both a negative for archiving and a positive transparency for immediate interpretation.

Film Processing

No special film processing is required for photography acquired during sub-optimum weather. Thus, conventional equipment and chemicals are recommended for processing the aerial photography so obtained.

For rapid access film processing, it is recommended that aerial color film be processed in conventional fashion using a continuous roll film processor. The special arrangements necessary for processing film immediately on delivery to the processing facility must be an integral part of planning for a rapid access capability.

It is recommended that the panchromatic film used for rapid access purposes be processed by the Bimat method. This method is a diffusion transfer development where an imbibed non-light-sensitive film is mated emulsion to emulsion with an exposed black-and-white film in a light-tight processor. After prescribed development time, the two fully processed films are separated with the original film becoming a negative and the Bimat film a positive. Because the development is self-limiting, time of processing beyond the minimum is not critical.

Both films are damp and susceptible to emulsion scratching if not dried carefully or the emulsion covered with a clear plastic cover sheet made for this purpose. Thus for archival storage it is recommended that both films be washed in running water for 10 minutes and dried carefully to prevent staining. Either film can be used without washing for several days but staining will occur after that time.

Several Bimat processors are available, each having some special characteristics. The unit used in this investigation, a Mark System, Incorporated Model 320 Bimat processor, was completely portable and manually operated and is recommended for these reasons.

Vehicle Considerations

Aircraft safety and maneuverability become critical when adverse weather conditions impose low flying speeds (80-100 knots). If an aircraft must fly at a low altitude to stay below clouds (perhaps 800-1000 feet above terrain), the plane must be flown at a low enough speed to permit camera cycling between exposures and to prevent image motion during exposure. It is therefore recommended that only those single-engine and light twin-engine aircraft capable of such performance be considered. Many heavier twin-engine and larger aircraft cannot be flown safely under the specified conditions.

Interpretation Equipment

In an operational system it is recommended that zoom stereoscopes be employed whenever possible, as they permit a more detailed interpretation due to the zoom capability and high resolution. Zoom stereoscopes also produce less eye fatigue and thus increase interpreter efficiency.

Simple stereoscopes are adequate for examination of good quality photography and are more practical for field interpretation as necessitated by a rapid access requirement.

General Considerations

Sub-Optimum Atmospheric Conditions - A carefully planned flight is essential to the smooth functioning of an aerial surveillance mission. Preparation on the ground prevents most in-flight distractions and unnecessary flight delays.

The data requestor must define his information requirements completely and accurately for the flight crew. Such data should include the following information:

Mission Timing - Aerial photographic missions should be flown with the sun angle at greater than 30° above the horizon to provide adequate illumination. Unless dynamic ground conditions, weather factors or urgent need for data dictate that photographs will be made at other times, this constraint is recommended.

Scale of Coverage - Aerial photography for spill prevention surveillance under adverse weather conditions should be acquired at a scale of about 1/5,000. Smaller scale photographs acquired at higher altitudes are often degraded by haze and cloud cover. Larger scales, which require an increased number of photographs to cover the target, are usually not necessary for detailed image interpretation.

Flight Line Direction - For most applications it is recommended that flight lines run parallel to the prevailing terrain or to the major axis of the area to be photographed. If no definite trend exists for features of interest, north-south flight lines should be specified.

Flight planners for aerial photogrpahic missions commonly use seven and one half or fifteen minute U.S. Geological Survey topographic quadrangle sheets for flight line plots. These maps are recommended for plotting both flight line location and orientation and for the post-mission plotting of areas covered by the resultant photography. For the purpose of tactical updating as detailed herein, reference should be also made to target information previously produced by the strategic spill prevention survey which presumably would have been conducted over most areas of interest.

Overlap and Sidelap Requirements - For stereoscopic viewing sixty percent forward lap between successive exposures and thirty percent sidelap between parallel flight lines are standard requirements.

Rapid Access Mission Considerations

A true rapid access system must provide support in every phase of data acquisition from flight planning through delivery of finished information, graphics and documentation. If extended delays occur at any time during the operation due to inadequate scheduling or preparation, time saved by many of the other rapid access techniques may be negated. For example, if film processing time can be reduced from four hours to one hour but the necessary trained photointerpreters are not available until the following day, then no real advantage has resulted from rapid film processing. Thus, each phase must not only be carefully planned and executed but must be well interpreted with all other phases in order to enjoy the real benefits of rapid access.

It is recommended for rapid access missions that a set of instructions and a comprehensive check list such as that shown below covering equipment requirements, functions of various staff members, arrangements for outside services and delivery of finished information, be prepared and carefully followed.

RAPID ACCESS CHECK LIST

Mission Plan

Aircraft
Cameras
Film
Accessories

Flight Operations

Crew
Camera System
Flight Plan
Aircraft and System Check
Weather Briefing
Maps

Enroute
Target

Film Processing

Laboratory Alerted
Bimat Processor and Materials
Courier for Film
Film Editor Alerted

Interpretation Operations

Facility Available
Portable Light Table
Stereoscope
Projector
Screen
Personnel
Map Sheets
References
Data Sheets

SECTION III

INTRODUCTION

The primary objective of this project was to determine the extent to which various kinds of aerial photography, when acquired of necessity under adverse weather conditions, could be used to locate and identify potential sources of spills of oil and other hazardous material. It is widely recognized that aerial photography, flown to strict specifications, can quickly and economically provide vital information on the location, qualtity and quality of various components of the natural environment. In a previous project (Welch, et al., 1972) it was shown that aerial photography could be used to identify potential sources of environmental damage from accidental spills of oil and hazardous materials, and that such information could be used in spill prevention.

The previous project demonstrated that high altitude color infrared photographs taken at scales of 1/40,000 to 1/60,000 were useful in regional surveys for locating industrial activities that could be expected to produce spills of oil and other hazardous materials. After these areas have been delineated on small scale photographs, color aerial photography flown at larger scales of 1/5,000 to 1/10,000 can be taken of selected areas for more detailed analysis in order to locate specific potential threats and actual spills of these materials. Strategic information gained in this manner could be used to prevent spills by early detection of careless practices which lead to undesirable releases of oil and hazardous materials into waterways. Furthermore, quick action by an organized force using accurate data on the location, extent and direction of spread of a spill can greatly reduce the harmful effects of such an event. It is frequently the case that circumstances mediating a tactical approach combine to present an update problem at a time when atmospheric conditions are not conducive to aerial photography. For example, an extended heavy rainfall could produce flooding and soil saturation, jeopardizing earthen revetments. Such a protracted storm is also likely to result in residual cloud cover, necessitating a delay in updating unless specific procedures for such an eventuality have been previously defined.

If the weather factors restricting the acquisition of aerial photography are known and if methods to overcome and control these factors are understood, it is possible to increase the time during which aerial photography can be obtained successfully and thus provide an even more valuable data acquisition tool for use by resource managers.

Existing camera systems, films, filters, and processing and interpretation techniques can be manipulated in a variety of ways to provide acceptable photography under various lighting conditions. In investigating these methods for use in spill prevention, it was hypothesized that even in critical situations where weather was not ideal, acceptable aerial photography could be obtained.

This study was undertaken to provide a means for acquiring high quality information for spill prevention under a variety of sub-optimum aerial photographic weather conditions. Optimum conditions are taken to be clear skies with at least 15 miles horizontal visibility. Thus, the term "sub-optimum weather conditions" applies to any situation resulting in sky cover (clouds) or reduced visibility. In addition, several rapid access techniques useful for minimizing the time necessary for acquisition and dissemination of useful information were investigated.

SECTION IV

METHODS

Weather-Type Selection

Cloud and haze conditions under which aerial photographic surveillance was to be attempted were chosen so as to be representative of conditions which commonly occur over industrial areas. Weather parameters considered were divided into two categories -- clouds and haze -- each of which offers different problems in acquisition of high quality photography. For purposes of discussion, haze is considered to describe a general set of circumstances resulting in decreased horizontal visibility due to smoke, dust, photo-chemical smog or other particulates, but differing from, although frequently occurring with clouds. Further, interaction between sun angle (angle above horizon) and haze was analyzed because the effective path length of the illuminating source (a function of angle above the horizon) is critical in selecting photographic parameters. In heavy haze, the difference of a few hours) may allow considerable more flexibility in photo acquisition.

Table 1 summarizes the cloud and visibility conditions chosen for analysis. These conditions were considered representative increments of weather conditions which vary continuously over a nearly infinite range. The increments specified were utilized as data acquisition guidelines in attempting to analyze the effects of combinations of the weather types listed on interpretability of ground features.

Test Site Selection

The existence of numerous aerial photography previously obtained of sites in the San Francisco Bay Area under near-optimum conditions (as part of the original aerial surveillance spill prevention project) suggested the continued use of certain of these same sites for the present project. An analysis of meteorological records for the Bay Area revealed that the chosen meteorological conditions occurred there with sufficient frequency to permit the project to be successfully completed within a reasonable period. For example, through the use of statistics available from the National Weather Service for the period 1948-1965, the following description of the test area was derived at the outset:

°Smoke and/or haze was reported daily at least

TABLE 1

WEATHER TYPES SELECTED FOR INVESTIGATION

(X = example obtained)

(E = no example obtained)

Sky Cover (amount in tenths)	Cloud Base (height in feet) 1,000	5,000	10,000	20,000+
Overcast (10)	X	X	X	X
Broken (5-9)	X	X	X	X
Scattered (1-4)	X	X	X	X

Haze Type (visibility in miles)	Sun Angle 20°	40°	60°
Medium (2-4)	X	X	X
Heavy (<2)	X	X	X

50% of the time from October to January, but less than 20% of the time from March to August.

°The ceiling was less than 20,000 approximately 30% of the time during June, July, and August.

°During these same months the mean sky cover (in tenths) was approximately 3.5.

Test areas previously utilized were chosen for continued overflight during this program. These areas, and the reasons for their selection, were:

°Avon Refinery

The complex of unrevetted storage tanks and pipelines lying adjacent to Pacheco Creek (Figure 1) in the center of the refinery area was designated the prime target area. The complex nature of this pipeline array provided an excellent permanent feature for analysis of portrayal on the film/filter combinations specified.

°Richmond Navy Dock

The holding pond for oily bilge wastes located at the Navy fuel oil transshipment dock (Figure 2) was chosen as a sub-area for this project as it is a dependable site for imaging oil on water. It also represents one of the most important types of hazard (oil waste holding pond situated in an area of high rainfall runoff) juxtaposed to a waterway that the surveillance system should be designed to detect.

°Richmond Scrap Steel Yard

The scrap steel yard at Richmond (Figure 3) was also selected as it represented a continual, complex source of hazardous materials entering San Francisco Bay. The large accumulation of materials also provides a dynamic site for detail analysis.

System Selection

Cameras

A basic requirement for aerial cameras considered for this study

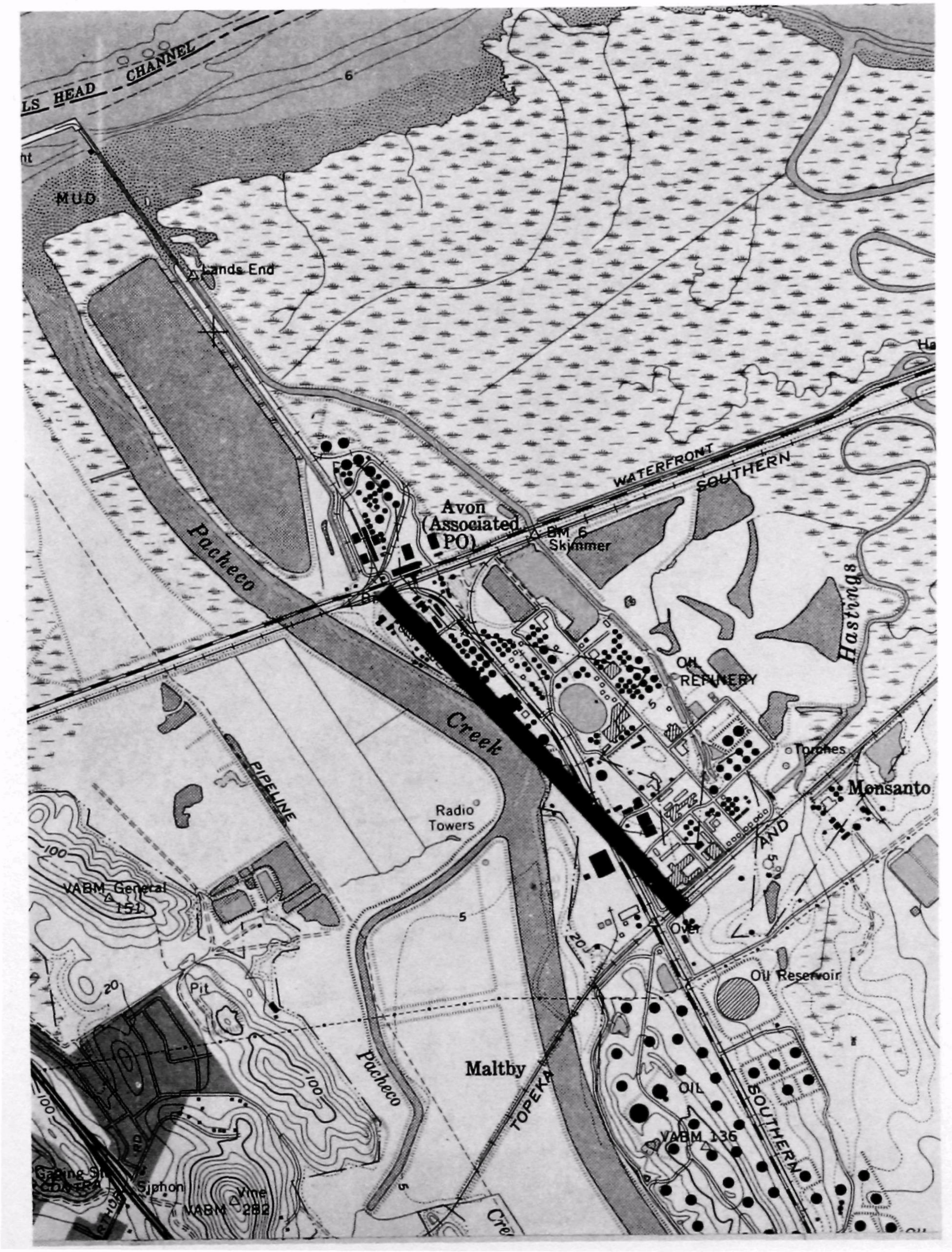


FIGURE 1. AVON SUB-SITE AND FLIGHTLINE

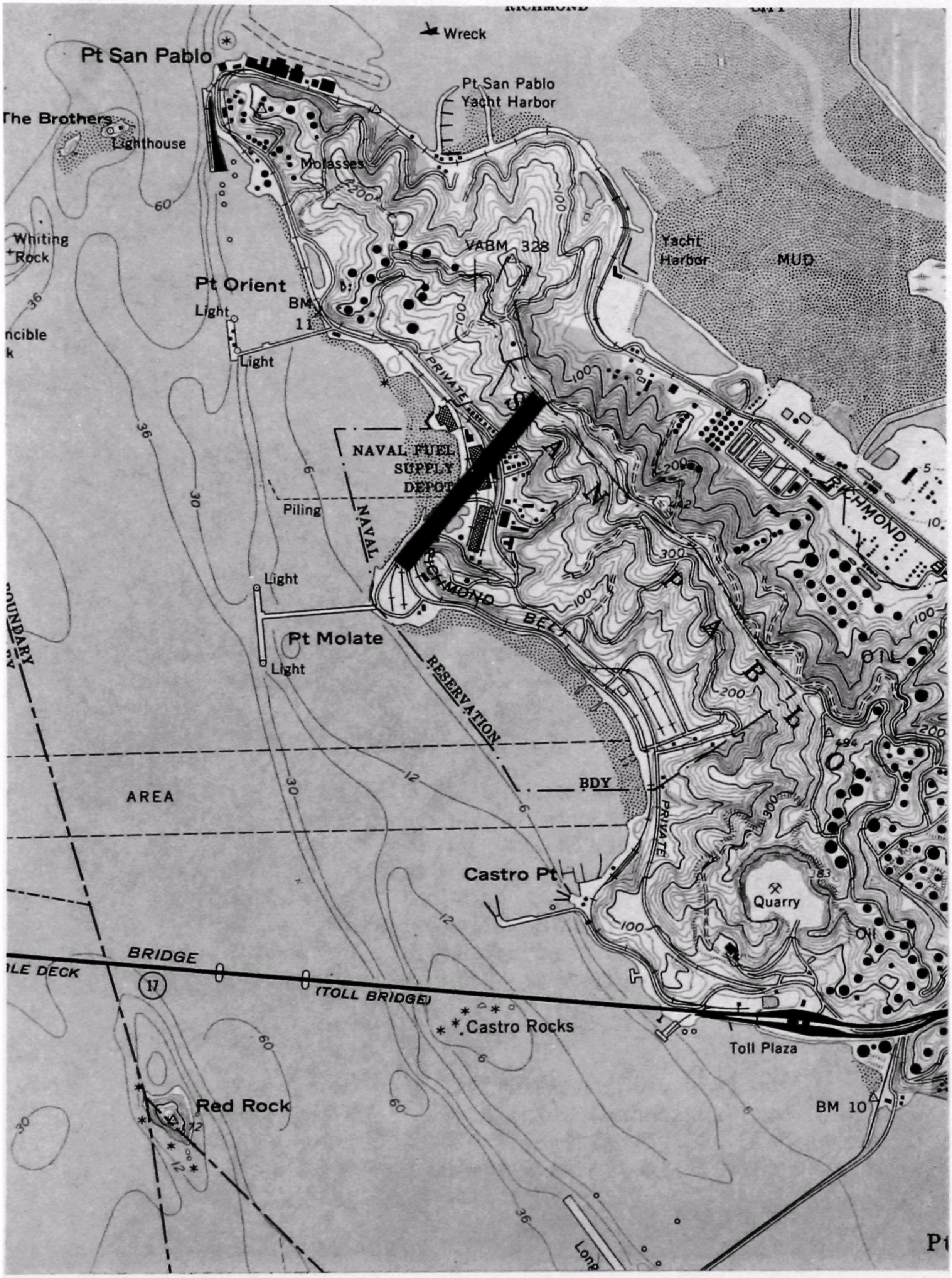


FIGURE 2. RICHMOND NAVY DOCK SUB-SITE AND FLIGHTLINE

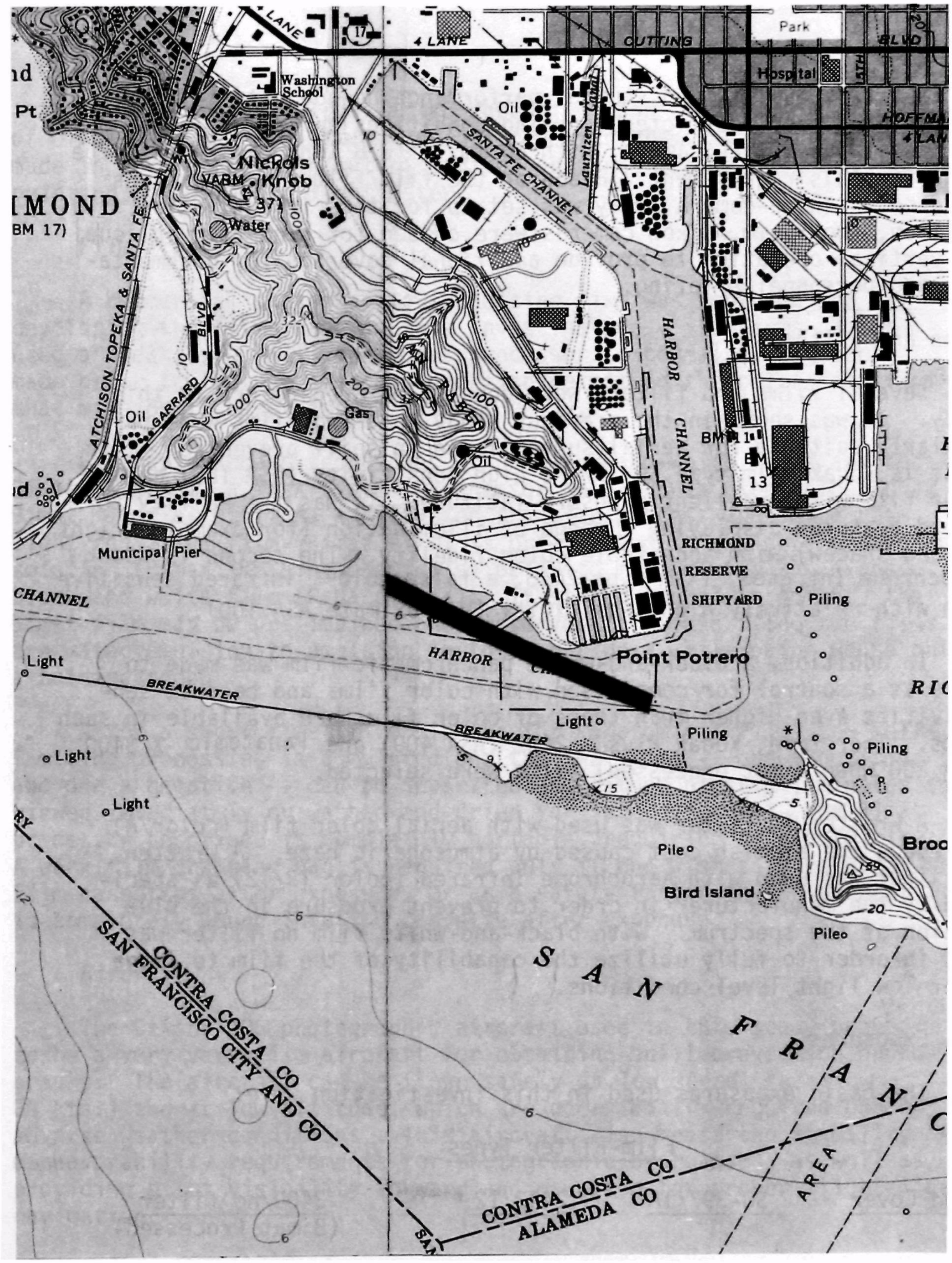


FIGURE 3. RICHMOND SCRAP STEEL YARD SUB-SITE AND FLIGHTLINE

was that lens quality and shutter performance be adequate to take photographs under restricted lighting conditions during daylight hours. The Hasselblad 500 EL camera, with 80 mm., f 2.8 lens was known to be ideal for this requirement. Based on the film/filter combinations selected, a three-camera array was set up for this investigation. In addition, two 35 mm. Nikon cameras were chosen for hand-held oblique and vertical operation to provide additional coverage for documentation and personnel briefing.

Films and Filters

Several films and filters were considered preparatory to this study. It was shown in the previous study that two films were particularly suitable for aerial surveillance in spill prevention. The first is Kodak film type SO-397, a high sensitivity (ASA 160) aerial color film with excellent exposure latitude. It has the ability to record features displaying a range of illumination (for example bright sun and shadow) with acceptable color fidelity. The second is Kodak Aerochrome Infrared, film type 2443, a false color, infrared sensitive film with relatively high sensitivity (approximate ASA 100).

In addition, a black-and-white panchromatic film was made to serve as a control for comparison with color films and because sensitivities even higher than those of color films are available in such films. Therefore, Kodak Plus X 2402 (ASA 400) and Panatomic -X 3400 (ASA 200 when Bimat processed) films were selected.

A Wratten 1A filter was used with aerial color film (color/A) to reduce the blueish cast caused by atmospheric haze. A Wratten 12 filter was used with Aerochrome Infrared (color 1R/12) as specified by the manufacturer in order to prevent exposure in the blue portion of the spectrum. With black-and-white film no filter was used in order to fully utilize the capability of the film to image under low light level conditions.

Exposures

The basic exposures used in this investigation were:

	Film-Filter Types		
Cloud Cover	SO-397/1A	2443/12	3400/no filter (Bimat Processed)
Clear	1/500 f 10	1/500 f 6.3	1/500 f 11
Scattered	1/500 f 8	1/500 f 5.6	1/500 f 10
Broken	1/500 f 6.3	1/500 f 3.5	1/500 f 8
Overcast	1/500 f 3.5	1/500 f 2.8	1/500 f 4

These exposure values varied depending upon height and density of clouds and haze conditions associated with them. Variations were made in accordance with meter readings obtianed from a downward pointing photographic light meter.

Film Processing

A commercial photographic processing firm was employed for developing the films used in this investigation. The firms chosen used a Kodak Type 1411 continuous processor. Special arrangements made prior to the rapid access exercise permitted the color film from that mission to be processed without delay.

For rapid access techniques using black-and-white films and Kodak Bimat material, a Mark Systems Processor No. 230 was used. The Kodak Bimat material utilizes a diffusion transfer process whereby a non-light-sensitive film (Bimat film) is pre-imbibed in a single processing solution (Bimat imbibing chemicals) prior to mating with the exposed black-and-white film (Panatomic-X). If stored at 35° to 45° F., the Bimat film may be pre-imbibed and preserved for weeks. The two films are mated emulsion to emulsion in total darkness while being wound onto a holding spoon.

After a short time (five minutes for Panatomic-X film) the self-limiting processing is completed and the two films -- one a positive and one a negative -- can be separated and either plastic laminated and viewed immediately or washed and dried for later viewing. The Bimat processor described is completely portable, requiring no electricity. A dark film changing bag is required only if one wishes to rethread the film cassettes after exposure, or as a safety factor in the event film is completely wound into the cassette after exposure.

Aircraft

The Cessna 206 photographic aircraft used in this study proved to be a very versatile aircraft for obtaining spill prevention photography. The aircraft can be flown safely at low speeds (as slow as 80 kts.) and at low altitude, which are occasionally required under adverse weather conditions. This aircraft also meets the stability and maneuverability requirements for photographic overpasses, as well as providing pilot visibility forward and downward for proper flight line navigation.

Interpretation Equipment

Conventional stereoscopic viewing equipment was used for interpreting images obtained in this study. Levels of magnification from

2X to 30X were used to evaluate the detectability of fine image detail. A dual strand light table was used to permit simultaneous viewing of two 70 mm. film strips for comparison of photo quality.

Ground Truth Design

Ground truth, collateral information derived from sources other than the imagery currently under interpretation, is a necessary adjunct to image interpretation. The degree of ground truth required for a particular interpretation depends on the nature of the imagery, skill of the interpreter, target characteristics, and product requirements.

The philosophy of aerial surveillance is the supportive ground truth should be minimized, with as much of the needed information as possible being derived from image interpretation. Extensive ground truth collection partially negates several of the advantages usually cited for aerial surveillance: cost, timeliness, access to denied areas, single source of data. In photointelligence operations, the image acquisition and interpretation phases are manipulated to optimize compatibility with product requirements and target characteristics.

In the design of the present project, need for acquisition of additional ground truth information was minimized by design through dependance upon the data archive available as a result of the previous aerial spill surveillance project.

Specific Interpretation Techniques

Imagery acquired during photographic flights was annotated and catalogued, then independently interpreted by three image interpreters to determine the merits of each film/filter combination under the weather conditions selected for this test Each roll of imagery was cut into stereo triplets (more frames were included in those instances where photo scale exceeded 1:5000) covering the three selected target areas. The best quality color /1A triplet for each scene was subjected to a detailed interpretation under a high resolution zoom stereoscope in order to extract the maximum available information about features to be compared throughout the test. The features selected for use in the test include many examples of past or potential hazards as stated in the report by Welch, et al., 1972. Results of the detailed interpretation plus the existing data base and weather information formed the ground truth for the interpretation.

Most interpretation was made with 2x/4x simple stereoscopes on conventional light tables in order to approximate the level of equipment sophistication likely to be used with missions requiring image acquisition under less than optimum conditions. Also, use of simple equipment established a minimum level of information which might be extracted.

Three interpreters, working independently analyzed the images in unordered sequence, rating the photographic quality of the imagery and the interpretability of the preselected features. Interpretability was rated on a scale of one, two, three and zero. A summary of the image rating criteria is given below.

Category	Description
1	Objects of all contrasts are detectable
2	Objects of medium or higher contrast detectable
3	Only objects of high contrast detectable
0	No objects of any contrast detectable
E	No example

Exposure ratings provided a means for the interpreter to express his oninion concerning the reason for the indicated level of interpretability. The basis for this response was purely subjective because the interpreter did not know the conditions under which the imagery was obtained. If the imagery "looked good" to him in terms of exposure, latitude and sharpness, and in no way affected the interpretability of the image he marked "g". However, if the imagery looked dark or too light to him, "pi", "po" or "pc" was recorded. A summary of exposure ratings follows:

Category	Description
G	Imagery of good quality; exposure, latitude sharpness
Pu	Imagery poor due to underexposure
Po	Imagery poor due to overexposure
Pc	Imagery poor even when correctly exposed; indicated limitations inherent in film type or camera utilized.

A matrix was devised on which to record the final results of image analysis. For each meteorological condition encountered, each film/filter combination was paired with the eight classes of features (Table 2) which were examined during the test. In this manner the evaluation of each film/filter type is graphically displayed.

Consistent interpretation cirteria were defined by discussing the appearance of each object type and how these appearances affected the level of interpretability. For example, after discussion it was decided that oil on water was to be identified by:

°Presence of blue, black or rainbow colors

TABLE 2

INTERPRETATION CRITERIA UTILIZED BY INTERPRETERS

Item of Interest	Interpretation Criteria
counting of tanks	Detection of tanks present; contrast of detectable tanks; evaluate tank-like objects for supportive information
leaks or seepage	Black, blue or rainbow coloration; characteristic shape of oil covered area; reflectivity
oil on water	Black, blue or rainbow coloration; shape of oil covered area; obscuration of bottom or water features, reflectivity
condition of dikes	observed dike or earth revettment; noted resolvable items, (pebbles, rocks, boulders, etc.) relief; color
trash and debris	Size, shape, color
effluents	Detectability of effluent, presence of outfall structure; size; total tone and color contrast; diffusion rates
water quality	Ability to see beneath surface; color and tone contrast
tracing pipelines	Size; shape; coloration; relief; allow for probably continuity due to linear characteristics

°Reflection (not shadows) of clouds or other objects
°Definitive shape
°Suppression of waves on surface

In addition, level of interpretability was to be determined by the various types of contrast previously discussed. For example, if oil was present and it was very black, highly reflective and stable in shape it was considered to be of high contrast. If the oil present showed only a gossamer blue or rainbow effect and had little definite shape it was considered to be of low contrast. The criteria for all targets analyzed are also shown in Table 2.

Data Acquisition During Sub-Optimum Weather

In accordance with the specific conditions listed as guidelines in Table I, photography acquisition was initiated whenever suitable conditions prevailed over one or more test areas. At these times, the photographic flight crew acquired photography over each test area, utilizing the flight tracks shown for each area in Figures 1 to 3.

Welch, et al. (1972) recommend a large scale (1:10,000 to 1:5,000) for detailed analyses. The difficulties in interpretation imposed by sub-optimum conditions prompted the use of the larger scale (1:5,000) as the standard acquisition scale in this project. The image scale varied substantially only when cloud ceiling necessitated flying at less than the altitude required to produce the desired scale (1,310 feet above terrain using 80 mm. length lenses). Therefore, all imagery was acquired at a scale of 1:5,000 or greater.

Weather conditions at time of acquisition were observed from the photographic aircraft directly as well as through queries directed towards local airport tower personnel. Exposure indices were determined by use of a downward looking exposure meter.

In this manner, nearly all preselected conditions were investigated, with the exception of sun angles of 20° and 40° during heavy haze (Table 1).

Rapid Access Experiment Design

In the performance of the rapid access experiment it was assumed that data similar to that obtained during the sub-optimum weather phase were needed quickly. These data could be interpreted from photos of the area taken at the same scale and on the same flight line as other parts of the investigation.

For this exercise an automobile and driver were waiting at the airport to carry the color film to the processing laboratory while the black-and-white film was processed in an office at the airport.

Rapid film processing techniques for both color and black-and-white film were investigated, with elapsed time monitored separately for each film to permit comparison of data access time. Manufacturer's suggested processing time and ancillary data for various panchromatic films were:

Film Type	Bimat Processing Time (minutes)	ASA Film Speed	Aerial Film Speed (When Bimat processed)
Panatomic - X 3400	5	200	64
Plus X - 2402	15	400	200

The aerial color film was processed in a Kodak Model 1411 processor operated by a commercial photographic processing firm. Special arrangements for immediate processing as soon as the film was delivered to the laboratory were made prior to the flight. The facility was located about one mile from the airport, less than a five-minute drive by automobile.

Interpretation of both films took place at the airport using a portable light table, pocket stereoscope, and tube magnifier.

SECTION V

RESULTS

Our analysis shows that of the films tested only Kodak SO-397 film exposed through a Wratten 1A filter consistently provided usuable imagery under the meteorological conditions extant at the time of acquisition of the test imagery. This film has a relatively high sensitivity, ASA 160, and a wide latitude of acceptable exposure, perhaps one to one and a half stops either side of an ideal exposure setting. This factor provides usuable images in shadow as well as sunlit areas and in areas of low albedo and high albedo when such contrasts appear on the same film frame. It is recommended that Kodak SO-397 or equivalent film be used exclusively in any operation requiring high resolution coverage under less than optimum weather conditions.

A serious shortcoming of both panchromatic and color infrared films is that under sub-optimum weather conditions the contrast between oil on water and unpolluted water is decreased, and with degradation of weather differentiation between water with and without floating oil becomes impossible. Since oil is a hazardous substance commonly introduced into waterways, the inability to monitor its presence is a serious drawback in a spill monitoring and prevention program.

Panchromatic film suffers a general loss of contrast as the weather degrades. This decreased contrast particularly hinders the analysis of dike and revetment conditions and interpretation of small, low contrast objects such as pipes and debris.

Table 3 shows selected results from the interpretation testing. The results presented are only a representative sample of the complete test results shown in the Appendix. Selected images from these film strips have been used to illustrate this report. This was done in order to facilitate comparison of photographic characteristics and interpreter performance. The table presents the judgment of three interpreters for each film type, area and characteristic of interest. This array indicates absolute results and interpreter consistency, which determines the validity of the absolute results. Interpreter consistency is fairly high, especially when one compares trend; however, the responses vary somewhat, a problem which always arises when several interpreters, all having different backgrounds and training, are employed.

Since the interpreters are qualitatively uniform in their responses, the interpretability of the various film/filter combinations can be evaluated.

Actual Weather Conditions	Frame No.	Film Type	No. of Tanks			Leaks or Seepage			Oil on Water		
			D	T	W	D	T	W	D	T	W
Clear	10-6,7,8	Color	1	1	1	1	1	1	E	E	E
		CIR.	2	1	1	2	2	2	E	E	E
	9-9,10, 11	Color		1	1		1	1		1	1
		CIR		1	1		2	2		2	2
		Pan			1			3			3
Light Haze	4-42,43, 44	Color	1	1	1	1	1	1	1	1	1
		CIR	2	1	1	2	1	2	0	2	3
		Pan	2	2	2	0	2	3	0	0	3
1000' Over-cast with Light Rain	1-44,45, 46	Color	1	1	1	1	1	1	1	1	1
		CIR	1	1	2	1	1	2	2	2	3
		Pan	2	2	3	3	2	2	0	0	3
1200' Over-cast with Drizzle	7-6,7,8	Color	1	1	1	1	1	1	1	2	1
		CIR	2	2	3	2	2	3	1	3	3
		Pan	2	2	2	3	2	2	0	0	3
		Bimat Pos.	2	1	2	3	2	2	3	0	2
5000' Over-cast with Light Rain	1-58,59, 60	Color	1	1	1	3	1	2	E	E	E
		CIR	2	2	3	0	3	3	E	E	E
		Pan	1	2	1	0	2	2	E	E	E

Key: D = S. Daus; T = O.R. Temple; W = R.I. Welch

Table 3. Summary Results

Actual Weather Conditions	Condition of Dikes			Trash and Debris Present			Location of Effluents			Water Condition Near Plants			Tracing Pipeline Routes		
	D	T	W	D	T	W	D	T	W	D	T	W	D	T	W
Clear	1	1	1	1	1	1	E	E	E	E	E	E	1	1	1
	2	2	1	2	1	2	E	E	E	E	E	E	1	1	2
		1	1		1	1		E	E		1	1		1	1
		2	2		2	2		E	E		2	1		2	2
			1			2		E	E			0			1
Light Haze	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	2	1	2	2	1	2	3	2	2	2	2	2	1	1	2
	2	2	2	2	2	2	0	3	3	0	3	3	2	2	2
1000' Over-cast with Light Rain	2	1	1	2	1	1	1	1	1	1	1	1	2	1	1
	3	2	2	3	2	2	0	0	2	3	3	2	2	1	2
	3	2	2	2	2	2	0	0	2	0	0	3	2	2	2
1200' Over-cast with Drizzle	2	1	2	2	1	2	E	E	E	2	2	1	1	1	1
	2	2	3	3	2	3	E	E	E	3	3	3	1	2	2
	3	2	2	2	2	2	E	E	E	0	3	3	2	2	2
	3	1	2	3	1	2	E	E	E	3	3	2	2	2	2
5000' Over-cast with Light Rain	2	1	2	E	E	E	E	E	E	E	E	E	1	1	2
	0	3	3	E	E	E	E	E	E	E	E	E	3	3	3
	0	3	3	E	E	E	E	E	E	E	E	E	1	2	2

Table 3. Continued

From the small sample in Table 3, it is fairly obvious that under all weather conditions the color /1A combination was superior. This combination has excellent color contrast, grain characteristics, and sensitivity.

The color IR/12 was, at times, equal to the color film in interpretability. Usually, however, it was inferior due to reduced exposure latitude.

Although panchromatic photography occasionally exhibited good sharpness and detail, it was definitely inferior to the color /1A due to the absence of color contrast. In order to interpret this photography, it was necessary to rely on subtle grey scale differences considerably reducing the utility of the photography.

The following figures illustrate the general conclusion that color /1A gives highly interpretable results regardless of the weather conditions tested. Furthermore, no other film/filter type, of those tested, provided more information than the color in any of the situations evaluated. The figures show the entire sequence, whenever possible of color, color infrared, and panchromatic photography. The imagery is illustrative of the various weather conditions encountered, ranging from clouds with 1,000 foot base and rain to clear, high visibility weather. The latter conditions approximated those considered optimum, so that the resulting photography could serve as a standard against which the sub-optimum photography could be compared. As such it represents the conditions exent at the time of acquisition of all photography dealt with in Welch, et al. (1972). More specific comments will be made concerning the relative advantages and disadvantages associated with interpreting each of the various categories of objects for each combination of weather and film type in the following discussions of each figure.

Figures 4a, 4b, and 4c are a sequence taken over the Avon, California oil refinery under clear sky and high visibility (optimum) conditions at about 1040 PDT on August 31, 1972. Figure 4a illustrates the complex of oil storage and transportation facilities chosen for analysis of detail under sub-optimum conditions. From such a high quality frame as this, where all contrasts are interpretable, contrast examples illustrating criteria in Table 2 can be selected and used throughout the entire testing procedure. Emphemeral features and characteristics such as oil spills and leakage and condition of dikes are also interpretable. Frequently, it was found necessary to use the higher quality color image of a sequence first in order to establish the contrasts of the emphemeral features present in a scene; then, the remainder of the images (color infrared and panchromatic) were analyzed in sequence in relation to these initial contrasts.

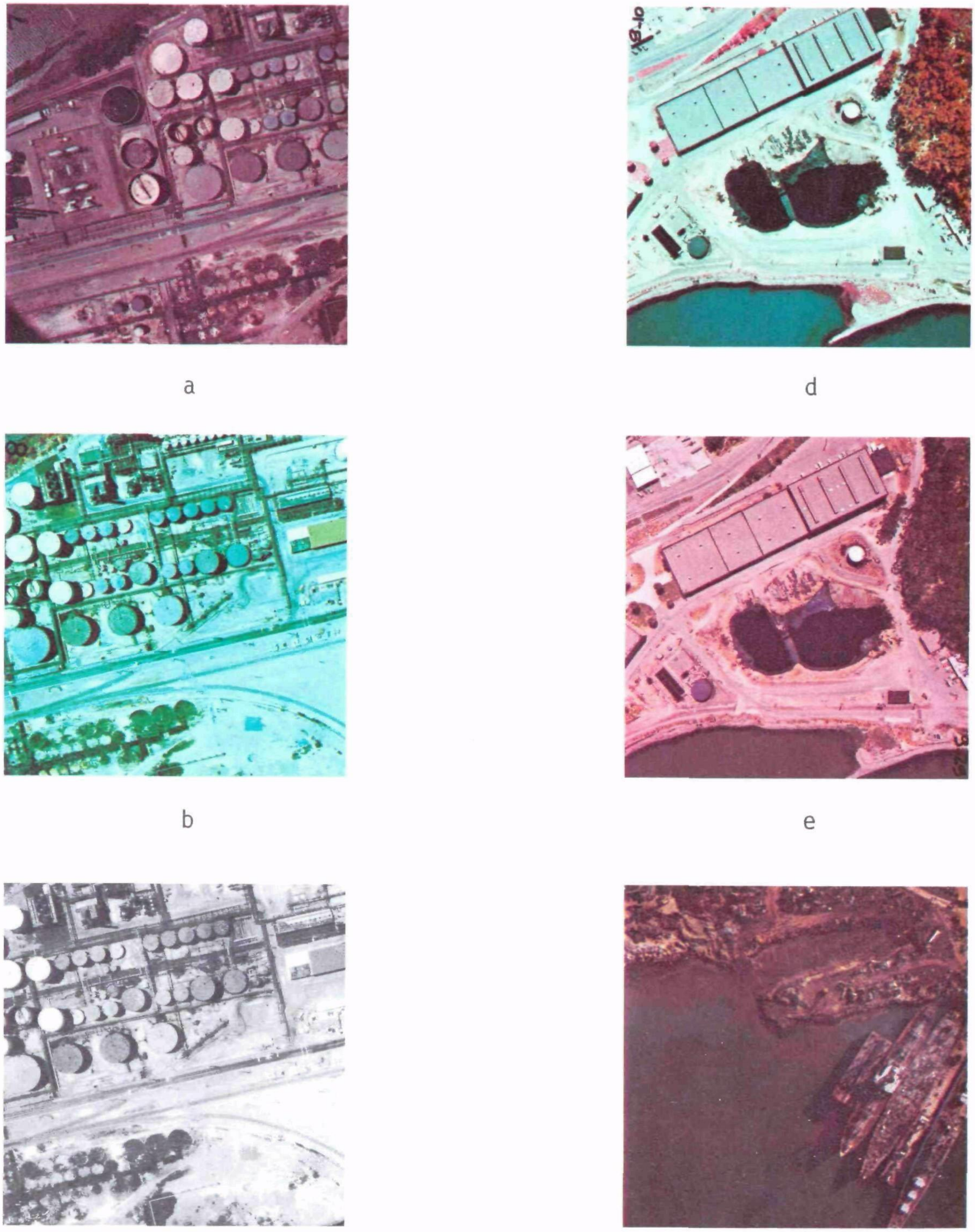


FIGURE 4. TEST PHOTOGRAPHY

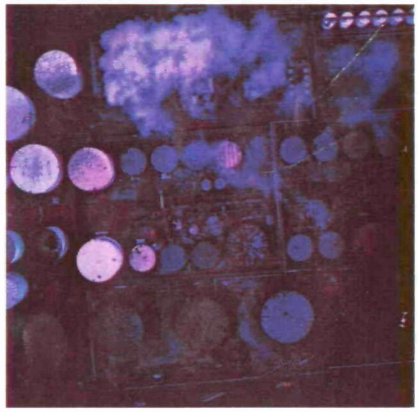
The frames in Figures 4d and 4e were exposed July 27, 1972, at 1206 PDT, and show an oil holding pond, oil separation facility and outfall structure. Panchromatic coverage was not available for this sequence; however, the color /1A and color 1R/12 are of excellent quality and were acquired under optimum weather conditions. Ephemeral features such as oil on water, effluents, and water quality are better illustrated on this frame than on the Avon frame (Figure 4a). Interpreters again found both frames to be of high quality, but found that the color yielded the greatest and most easily extractable information. In this instance relative image quality ratings were easier to establish than in the previous figure, due to the slight overexposure of the color 1R/12. This overexposure caused loss of detail in dikes, revettments, and oil stains on the ground.

Figures 4f, 5a, and 5b show a ship salvage operation near Richmond, California, and were obtained under a clear sky with medium haze at 0812 PDT on May 12, 1972. The interpreters considered this color frame to be the most readily interpretable frame acquired and attributed this to the slight under-exposure. Sharpness of this image is extremely high and color contrast seems to be optimal. This excellent image yields a wealth of information about very subtle conditions, such as the thin gossamer oil slick in the area of the ships and the bottom detail in the near shore area. The higher contrast areas are also very easily interpreted.

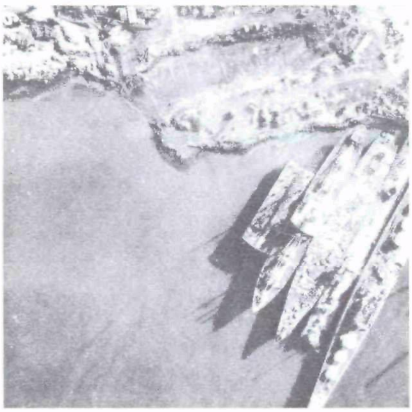
This sequence is also an excellent example of the stepwise reduction of available information as one progresses from color to color infrared to panchromatic images. The color infrared frame shows a complete loss of the subtle oil slicks which were so apparent on the color image. Furthermore, due to the reduced blue and blue-green sensitivity, much of the detail in the water is also lost. The reduced sensitivity also affected the interpretability of subtle or low contrast oil spills and seeps onto the ground. The blue tone of the older oil spills tends to merge with the bluish soil background, and may also be confused with other liquid spills or seeps which tend to have similar blue signatures. Detail in the shadows is partially obscured on the color IR, as can be seen by examining the ship shadows.

The panchromatic photograph demonstrates the drastic reduction in readily available information due to the loss of color discrimination. The inadequacy of the black-and-white tonal representative is exemplified by the oil spills and seeps on soil. Based on tonal differences alone oil spills cannot be differentiated from areas of shadow, only characteristic spill shapes allow identification. Older spills, having lost their characteristic shape, become essentially undetectable. Note also the loss of water quality information, and the complete loss of detail in shadowed areas on the panchromatic photography.

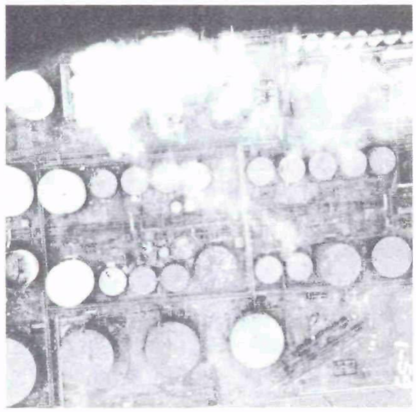
a



d



b



e

c

f

FIGURE 5. TEST PHOTOGRAPHY

Figures 5c, 5d, and 5e of the Avon refinery area were obtained on April 4, 1972, at 1407 PDT, under a 1,000 foot overcast and through a light drizzle (corresponding to visibility reduction approximating medium haze). The color imagery, although underexposed retains excellent sharpness and good color contrast, even in the cloud shadow in the upper right-hand quadrant. The companion color infrared frame is definitely inferior to the natural color image. Poor exposure latitude has created a very dark image and greatly decreased color contrasts. Reduction in image quality has resulted in loss of information about low, and even medium, contrast objects. For example, ground oil spills and seeps, very evident on the color frame, are not visible on the color infrared frame. The trend continues with the panchromatic imagery. Low light conditions have decreased tonal contrasts and have produced a very "flat" image on which the low and medium contrast features such as oil spills, dike erosion, trash and debris were extremely difficult to identify.

Figures 5f, 6a, and 6b of the Richmond Naval Yard oil pond were acquired at 1422 PDT, April 4, 1972, under overcast (1,000 feet cloud base). The absence of shadowing due to the diffuse lighting, and the excellent properties of the color emulsion combine to yield a highly interpretable image. Notable is the reflection, <u>not</u> shadow, of the cloud cover and of the photographic aircraft in the oil pool. This is indicative of the flat and highly reflective surface of the oil and leads to its positive identification. On the color frame, features of all contrast levels are easily interpretable, allowing water quality assessment. The color infrared frame has been optimally exposed, as indicated by the color balance, yet the oil pond and oil spills are rendered in the same blue tone as the oil-free tidal waters, roads and roof tops. In the absence of comparative coverage, total reliance would have to be placed on the reflective and surface characteristics of the oil pond and, if the oil pond was not imaged at or very near the principal point of the image, this technique would not generally be applicable. The same problem is apparent in panchromatic imagery, but to an even greater degree.

Figures 6c, 6d, 6e, and 6f are examples of imagery obtained during the rapid access exercise. This photography was obtained under 1,000 foot overcast at 1004 PDT on June 22, 1972. The four examples in the sequence show the color (SO-397), color infrared (2443), panchromatic (2402), and the Bimat positive. The relative levels of interpretability for these examples are basically the same as the previous examples.

The simulated rapid access photographic mission was performed as described in the methods section. Weather conditions at overflight time for the study areas were as follows:

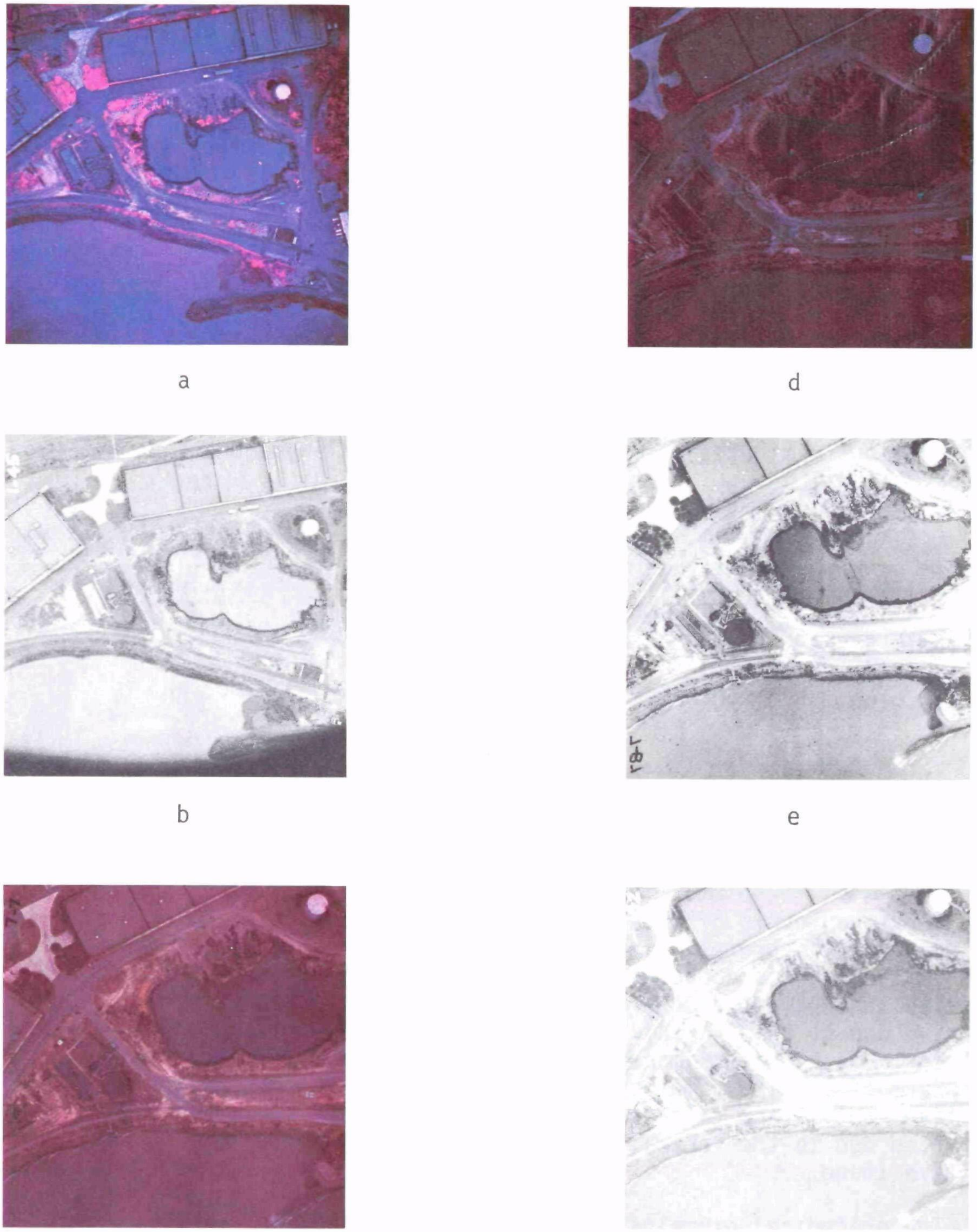


FIGURE 6. TEST PHOTOGRAPHY

Area	Sky Cover	Visibility
Richmond oil pond	Overcast at 1200; drizzle	3 miles
Richmond steel salvage	Overcast at 1500'	5 miles
Avon	Broken clouds at 2000'	15 miles

The same camera system was used for the rapid access test. The film/filter combinations used were those used throughout the investigation, with unfiltered Kodak 3400 Panatomic-X in the third camera. the 2443 Aerochrome Infrared film was not processed by rapid access but was acquired only to permit later comparison with film obtained on other flights.

Timing (in minutes) of the initial film handling operations was as follows:

	Film Left Aircraft	Start Bimat Process	Start Color Process	First Look at film at Airport
Panatomic-X	0	7	---	21
Aerial Color	0	---	5	60

Processing time included the application of a protective cover sheet on the wet emulsion side of the positive Bimat, a common practice for immediate viewing of Bimat processed film.

Relative levels of interpretability for the positive color and negative panchromatic images are basically those expected from identical exposures conventionally processed. The Bimat-processed positive transparency is more readily interpretable than the negative due to the "normal" assignment of grey levels and improved contrast. No apparent image degradation has occurred in the image transformation. The Bimat positive is a copy of the panchromatic negative, but, as in this case, the information may be more easily extracted due to the "normal" assignment of grey levels in a positive image.

The preceding examples demonstrate that a tactical aerial surveillance mission can be performed under sub-optimum weather conditions and can be designed to produce both real-time and near real-time data if careful flight planning and high quality photographic systems and materials are used.

SECTION VI

ACKNOWLEDGEMENTS

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SECTION VII

REFERENCES

Welch, R. I., Marmelstein, A. D., and Maughan, P. M., "A Feasibility Demonstration of An Aerial Surveillance Spill Prevention System," Final Report to the Office of Research and Monitoring, Environmental Protection Agency, 120 pp. (1972).

APPENDIX 1

INTERPRETATION RESULTS

Appendix Ia

Interpretation Results - Daus

Film Sequence Number	Film Type	Exposure Rating	BULK STORAGE: No. of Tanks	BULK STORAGE: Leaks or Seepage	BULK STORAGE: Oil on Water	DIKES: Condition of Dikes	DIKES: Trash & Debris	REFINERIES AND PROCESSING PLANTS: Location of Effluents	REFINERIES AND PROCESSING PLANTS: Water Condition	REFINERIES AND PROCESSING PLANTS: Pipeline Routes
3-3,4,5,6	Color/1A	G	1	1	1	1	1	E	E	1
	Color IR/12	G	1	1	1	2	2	E	E	1
	Pan/nf	G	1	1	0	3	2	E	E	1
9-35,36,37	Color/1A	G	1	1	1	1	1	E	1	1
	Color IR/12	Po	2	2	2	3	2	E	2	2
10-15, 16, 17	Color /1A	G	1	1	1	2	1	E	1	1
	Color IR/12	G	1	1	2	2	1	E	1	1
	Pan/nf	G	2	2	3	3	2	E	3	1
10-25,26,27	Color 1/A	G	2	1	1	1	1	E	1	1
	Color IR/12	G	2	2	0	2	2	E	3	1
	Pan/nf	G	2	2	0	2	2	E	0	1
6-19,20,21	Color /1A	G	1	1	1	1	1	E	1	1
	Color IR/12	PU	2	2	3	2	2	0	3	2
	Pan/nf	G	2	3	3	3	2	0	0	1
5-13,14,15	Color /1A	G	1	1	1	1	1	1	1	1
	Color IR/12	G	1	2	3	2	2	1	2	1
	Pan/nf	G	1	2	0	3	3	2	2	2
6-27,28,29	Color IR/12	G	2	2	E	3	2	E	E	2
	Pan/nf	G	2	3	E	3	2	E	E	2
11-7,8,9	Color/1A	G	1	1	E	1	1	E	E	1

Film Sequence Number	Film Type	Exposure Rating	BULK STORAGE: No. of Tanks	BULK STORAGE: Leaks or Seepage	BULK STORAGE: Oil on Water	DIKES: Condition of Dikes	DIKES: Trash & Debris	REFINERIES AND PROCESSING PLANTS: Location of Effluents	REFINERIES AND PROCESSING PLANTS: Water Condition	REFINERIES AND PROCESSING PLANTS: Pipeline Routes
	Color IR/12	G	2	2	E	2	2	E	E	2
11-22,23,24	Color IR/12	G	1	1	1	1	1	E	1	1
	Color /1A	G	1	1	1	2	1	E	2	1
11-16,17,18	Color /1A	G	1	1	1	1	1	E	1	1
	Color IR/12	G	1	0	0	2	2	E	1	2
	Pan/nf	G	2	0	0	3	2	E	3	2
11-31,32,33	Color /1A	G	1	1	E	1	E	E	0	1
	Color IR/12	G	2	2	E	2	E	E	3	2
12-1,2,3	Color /1A	Pu	1	1	1	2	2	E	E	1
12-14,15,16	Color /1A	Pu	2	1	E	1	2	E	2	1
	Pan/nf	G	2	3	E	3	2	E	3	2
12-28,29,30	Color /1A	G	1	1	1	1	1	E	1	1
	Pan/nf	Po	2	3	3	3	3	E	3	2
12-36,37,38	Color /1A	G	1	1	E	1	E	E	E	1
	Pan/nf	G	2	3	E	0	E	E	E	2
12-47,48,49	Color /1A	G	1	1	E	1	1	E	E	1
	Pan/nf	G	2	3	E	3	3	E	E	2
12-7, 8, 9	Color /1A	Pu	1	1	1	2	2	E	2	2
	Pan/nf	G	1	3	3	2	2	E	2	2
12-22,23,24	Color /1A	G	1	1	E	1	1	E	1	1

Film Sequence Number	Film Type	Exposure Rating	BULK STORAGE: No. of Tanks	BULK STORAGE: Leaks or Seepage	BULK STORAGE: Oil on Water	DIKES: Condition of Dikes	DIKES: Trash & Debris	REFINERIES AND PROCESSING PLANTS: Location of Effluents	REFINERIES AND PROCESSING PLANTS: Water Condition	REFINERIES AND PROCESSING PLANTS: Pipeline Routes
	Pan/nf	G	2	3	E	3	2	E	3	2
4-33,34,35	Color /1A	G	1	1	E	1	1	E	1	1
	Color IR/12	G	2	2	E	2	2	E	1	1
	Pan/nf	G	2	2	E	3	2	E	0	1
4-7,8,9,10	Color /1A	G	1	2	E	1	1	E	1	1
	Color IR/12	G	2	3	E	2	2	E	1	2
	Pan/nf	G	2	3	E	2	2	E	0	1
4-44,45,46,47	Color IR/12	G	2	0	E	2	2	E	3	2
	Pan/nf	G	2	2	E	3	3	E	0	1
9-28,29,30	Color /1A	G	1	1	1	1	1	E	1	1
	Color IR/12	Po	1	1	1	2	1	E	1	1
10-6,7,8	Color /1A	G	1	1	E	1	1	E	E	1
	Color IR/12	G	2	2	E	2	2	E	E	1
	Pan/nf	G	2	3	E	3	2	E	E	1
4-70,71,72	Color /1A	G	1	1	1	1	1	1	1	1
4-64,65,66	Color IR/12	G	1	1	1	2	2	1	2	1
	Color /1A	G	1	1	1	1	1	1	1	1
	Color IR/12	G	1	2	1	2	2	1	1	1
3-10,11,12	Color /1A	G	2	1	1	1	1	1	1	1
	Color IR/12	G	2	1	2	2	2	1	2	1

Film Sequence Number	Film Type	Exposure Rating	BULK STORAGE: No. of Tanks	BULK STORAGE: Leaks or Seepage	BULK STORAGE: Oil on Water	DIKES: Condition of Dikes	DIKES: Trash & Debris	REFINERIES AND PROCESSING PLANTS: Location of Effluents	REFINERIES AND PROCESSING PLANTS: Water Condition	REFINERIES AND PROCESSING PLANTS: Pipeline Routes
	Pan/nf	G	2	2	0	2	2	2	0	1
	Color /1A	Po	2	2	E	2	2	E	3	1
5-2,3,4,5	Color /1A	G	2	1	E	1	2	E	1	1
	Color IR/12	G	2	1	E	2	2	E	2	1
	Pan/nf	G	2	2	E	3	2	E	3	1
5-12, 13,14,15,16,17	Color /1A	Pc	E	1	1	1	1	1	1	1
	Color IR/12	G	1	2	2	2	1	0	0	1
	Pan/nf	G	1	3	2	3	2	0	0	2
5-23,24,25,27	Color /1A	G	1	1	1	1	1	E	1	1
	Color IR/12	G	1	1	1	1	1	E	2	1
	Pan/nf	G	1	1	0	2	1	E	2	1
5-31,32,33	Color /1A	G	1	1	E	1	1	E	1	1
	Color IR/12	G	2	2	E	2	2	E	2	1
	Pan/nf	G	2	2	E	2	2	E	3	2
4-26,27,28	Color /1A	G	1	1	1	2	1	1	1	1
	Color IR/12	PO	1	2	1	2	1	1	1	1
	Pan/nf	G	1	2	2	3	2	2	3	1
4-3,4,5	Color /1A	G	1	2	1	1	2	E	1	1
	Color IR/12	G	1	2	1	2	2	E	1	2
	Pan/nf	G	1	2	0	3	2	E	3	1

Film Sequence Number	Film Type	Exposure Rating	BULK STORAGE: No. of Tanks	BULK STORAGE: Leaks or Seepage	BULK STORAGE: Oil on Water	DIKES: Condition of Dikes	DIKES: Trash & Debris	REFINERIES AND PROCESSING PLANTS: Location of Effluents	REFINERIES AND PROCESSING PLANTS: Water Condition	REFINERIES AND PROCESSING PLANTS: Pipeline Routes
4-19,20,21	Color /1A	G	2	1	1	1	1	1	1	1
	Color IR/12	G	2	3	0	2	2	0	2	2
4-42,43,44	Color /1A	G	1	1	1	1	1	1	1	1
	Color IR/12	G	2	2	0	2	2	3	2	1
	Pan/nf	G	2	0	0	2	2	0	0	2
6-2,3,4	Color /1A	G	2	1	E	1	1	E	1	1
	Color IR/12	G	2	2	E	2	1	E	0	2
	Pan/nf	G	2	2	E	2	1	E	0	1
6-27,28,29	Color IR/12	G	2	1	E	2	1	E	0	1
	Pan/nf	G	2	2	E	2	2	E	0	1
2-23,24,25	Color /1A	G	1	1	1	2	2	1	1	1
	Pan/nf	G	2	3	0	3	2	0	0	2
2-33,34,35,36	Color /1A	G	1	1	1	1	1	E	E	1
	Color IR/12	G	1	1	1	3	2	E	E	1
	Pan/nf	G	2	2	0	3	2	E	E	1
2-29,30,31,32	Color /1A	G	1	1	1	1	1	1	1	1
	Color IR/12	G	2	2	3	3	2	0	3	2
	Pan/nf	G	1	2	3	2	2	0	0	1
2-40,41,42	Color /1A	G	1	1	1	1	1	1	1	1
	Color IR/12	G	2	2	3	2	2	0	2	2

			BULK STORAGE			DIKES		REFINERIES AND PROCESSING PLANTS		
Film Sequence Number	Film Type	Exposure Rating	No. of Tanks	Leaks or Seepage	Oil on Water	Condition of Dikes	Trash & Debris	Location of Effluents	Water Condition	Pipeline Routes
	Pan/nf	G	2	3	3	2	2	0	0	1
2-56,57,58	Color /1A	Pc	1	1	1	1	1	E	1	1
2-47,48,49	Color /1A	G	2	1	1	2	2	E	1	2
	Pan/nf	G	2	3	0	3	2	E	0	2
2-3,4,5	Color /1A	G	1	1	1	1	1	E	1	1
	Pan/nf	G	2	3	0	3	3	E	3	2
8-21,22,23	Color /1A	G	2	1	1	2	2	E	1	2
	Color IR/12	G	2	2	0	2	2	E	2	1
8-33,34,35	Color /1A	G	1	1	1	1	1	E	1	1
	Color IR/12	G	1	1	1	2	2	E	2	1
	Pan/nf	G	1	2	3	3	3	E	3	1
7-13,14,15	Color /1A	G	1	1	1	1	1	E	E	1
	Color IR/12	G	1	2	0	2	2	E	E	2
	Pan/nf	G	2	3	0	3	2	E	E	2
7-6,7,8	Color /1A	G	1	1	1	2	2	E	2	1
	Color IR/12	G	2	2	1	2	3	E	3	1
	Pan/nf	G	2	3	0	3	2	E	0	2
7-70,71,72	Color /1A	G	1	1	E	1	1	E	1	1
	Pan/nf	G	2	2	E	2	2	E	0	2
7-23,24,25	Color/1A	G	2	1	E	1	1	E	E	2

Film Sequence Number	Film Type	Exposure Rating	BULK STORAGE: No. of Tanks	BULK STORAGE: Leaks or Seepage	BULK STORAGE: Oil on Water	DIKES: Condition of Dikes	DIKES: Trash & Debris	REFINERIES AND PROCESSING PLANTS: Location of Effluents	REFINERIES AND PROCESSING PLANTS: Water Condition	REFINERIES AND PROCESSING PLANTS: Pipeline Routes
	Color IR/12	G	2	2	E	3	3	E	E	2
	Pan/nf	G	2	1	E	2	2	E	E	1
7-75,76,77	Color /1A	G	1	1	1	1	1	E	0	1
7-86,87,88	Pan/nf	G	1	2	2	2	2	E	0	2
7-94,95,96	Pan/nf	G	2	2	E	2	2	E	0	2
8-10,11,12	Color /1A	G	1	1	E	1	1	E	E	1

Appendix Ib

Interpretation Results - Temple

Film Sequence Number	Film Type	Exposure Rating	BULK STORAGE: No. of Tanks	BULK STORAGE: Leaks or Seepage	BULK STORAGE: Oil on Water	DIKES: Condition of Dikes	DIKES: Trash & Debris	REFINERIES AND PROCESSING PLANTS: Location of Effluents	REFINERIES AND PROCESSING PLANTS: Water Condition	REFINERIES AND PROCESSING PLANTS: Pipeline Routes
1-35,36	Color /1A	G	E	1	1	1	E	E	1	1
1-22,23,24	Color IR/12	Pc	1	1	E	2	E	E	E	2
1-5,6,7	Pan/nf	G	1	2	E	2	E	E	E	2
5-31,32,33	Color /1A	G	1	1	E	1	E	E	E	1
10-7,8,9	Color IR/12	Pc	1	1	E	1	1	E	E	1
4-53,54,55	Pan/nf	Pc	E	1	3	1	E	E	3	1
1-58,59,60	Color /1A	Pc	1	1	1	2	E	E	E	2
9-9,10,11	Color IR/12	Po	E	1	2	1	E	E	E	1
1-58,59,60	Pan/nf	G	1	3	E	2	E	E	E	1
1-27,28,29	Color /1A	G	E	1	1	1	1	1	1	E
3-18,19,20	Color IR/12	Pc	E	1	E	1	1	E	2	E
5-2,3,4	Pan/nf	G	1	1	E	1	E	E	E	1
12-1,2,3	Color /1A	Pc	E	1	2	1	E	E	E	2
11-22,23,24	Color IR/12	G	E	1	1	2	E	E	E	1
4-25,26,27	Pan/nf	Pc	E	1	1	1	E	1	2	1
7-6,7,8	Color /1A	Pu	E	1	2	1	E	E	E	1
4-7,8,9,10	Color IR/12	Pc	1	1	E	2	E	E	E	2
4-3,4,5	Pan/nf	Pc	E	2	2	1	E	E	E	1
12-36,37,38	Color /1A	G	1	1	E	1	E	E	E	1
11-7,8,9	Color IR/12	Pc	1	1	E	1	E	E	E	1

			BULK STORAGE			DIKES		REFINERIES AND PROCESSING PLANTS		
Film Sequence Number	Film Type	Exposure Rating	No. of Tanks	Leaks or Seepage	Oil on Water	Condition of Dikes	Trash & Debris	Location of Effluents	Water Condition	Pipeline Routes
4-18,19,20	Pan/nf	Pc	E	2	E	2	2	E	E	E
10-6,7,8	Color /1A	G	1	1	E	1	E	E	E	1
5-30,31,32	Color IR/12	G	1	1	E	1	E	E	E	1
2-56,57,58	Color /1A	G	1	1	E	1	E	E	E	1
8-18,19,20	Color IR/12	G	E	1	1	2	E	E	E	1
1-18,19,20	Color /1A	G	1	1	E	1	E	E	E	2
1-5,6,7	Color /1A	G	1	1	2	1	E	E	E	2
11-31,32,33	Color /1A	G	1	1	E	1	E	E	E	1
6-13,14,15,16	Color /1A	G	E	1	1	1	E	1	1	1
1-44,45,46	Color /1A	G	E	1	1	1	E	E	1	1
12-7,8,9	Color /1A	Pc	E	2	2	1	E	E	3	2
1-51,52,53	Color /1A	Pc	1	2	E	2	E	E	E	2
1-73,74	Color /1A	G	E	1	1	1	1	E	1	E
5-14,15,16	Color IR/12	Pc	E	1	2	1	2	E	E	E
10-17,18,19	Pan/nf	Pc	E	1	3	1	1	E	E	E
5-13,14,15,16,17	Color / 1A	Pc	E	1	1	1	1	E	E	E
4-67,68,69	Color IR/12	G	E	1	1	1	E	1	1	1
1-18,19,20	Pan/nf	G	1	2	E	2	E	E	E	2
8-21,22,23	Color /1A	G	E	1	E	1	1	E	E	E
7-13,14,15	Color IR/12	G	E	1	1	1	1	E	E	E

			BULK STORAGE			DIKES		REFINERIES AND PROCESSING PLANTS		
Film Sequence Number	Film Type	Exposure Rating	No. of Tanks	Leaks or Seepage	Oil on Water	Condition of Dikes	Trash & Debris	Location of Effluents	Water Condition	Pipeline Routes
7-157,158,159	Pan/nf	G	1	1	E	1	E	E	E	1
4-74,75,76	Color /1A	G	E	1	1	1	1	E	1	E
7-6,7,8	Color IP/12	Pc	E	1	2	1	E	E	E	1
7-148,149,150	Pan/nf	G	E	1	3	1	1	E	3	E
7-13,14,15	Color /1A	G	E	1	1	1	1	E	E	E
11-7,8,9	Color IR/12	G	1	1	E	1	E	E	E	1
8-27,28,29	Pan/nf	Pc	E	1	1	1	E	E	E	1
1-5,6,7	Color IR/12	Pc	1	1	E	2	E	E	2	2
7-94,95,96	Pan/nf	G	E	1	2	1	1	E	E	E
10-15,16,17	Color IR/12	Pc	E	1	2	1	E	E	E	1
9-12,13,14	Pan/nf	Pc	E	1	2	1	E	E	E	1
7-141,142,143	Pan/nf	Pc	E	2	0	2	E	E	E	2
7-75,76,77	Color /1A	G	E	1	1	1	E	E	E	1
11-16,17,18	Color IR/12	Po	E	2	3	2	1	2	2	E
1-68,69,70	Pan/nf	Pc	E	2	3	2	E	E	3	2
4-70,71,72	Color /1A	Pc	E	1	1	1	E	1	1	1
8-6,7,8	Color IR/12	Pc	E	1	3	1	1	E	3	E
2-2,3,4	Pan/nf	G	1	2	E	E	E	E	E	2
4-33,34,35	Color /1A	G	1	1	E	1	1	E	E	1
2-37c,d,e	Color IR/12	G	E	2	2	2	E	E	E	2

Film Sequence Number	Film Type	Exposure Rating	BULK STORAGE			DIKES		REFINERIES AND PROCESSING PLANTS		
			No. of Tanks	Leaks or Seepage	Oil on Water	Condition of Dikes	Trash & Debris	Location of Effluents	Water Condition	Pipeline Routes
1-44,45,46	Pan/nf	Pc	E	3	0	3	E	3	3	2
2-66,67,68	Color /1A	G	1	1	E	1	E	E	E	1
4-57,58,59	Color IR/12	G	E	2	2	1	1	2	2	E
1-35,36,37	Pan/nf	Pc	E	3	0	3	E	E	3	2
3-18,19,20	Color /1A	Pc	E	1	1	1	1	E	1	E
1-35,36,37	Color IR/12	Pc	E	2	2	2	E	E	2	2
6-26,27,28,29	Pan/nf	G	1	2	E	2	E	E	E	2
3-10,11,12	Color /1A	G	E	1	1	1	1	E	1	E
1-44,45,46	Color IR/12	Pc	E	2	3	2	E	E	3	2
1-27,28,29	Pan/nf	Pc	E	2	2	2	2	2	3	E
9-28,29,30	Color /1A	G	E	1	1	1	E	E	1	1
4-64,65,66	Color IR/12	G	E	1	1	1	E	1	E	1
10-23,24,25	Pan/nf	G	E	1	1	1	E	E	E	1
8-33,34,35	Color /1A	G	E	1	1	1	E	E	1	1
3-3,4,5	Color IR/12	G	E	1	E	1	E	E	E	1
9-20,21,22	Pan/nf	Pc	1	1	E	1	E	E	E	1
7-23,24,25	Color /1A	G	1	1	E	1	E	E	E	1
3-25,26,27	Color IR/12	Po	1	1	E	1	E	E	E	1
4-8,9,10	Pan/nf	Pc	1	2	E	1	E	E	E	2
10-25,26,27	Color /1A	G	E	1	1	1	1	E	E	E

			BULK STORAGE			DIKES		REFINERIES AND PROCESSING PLANTS		
Film Sequence Number	Film Type	Exposure Rating	No. of Tanks	Leaks or Seepage	Oil on Water	Condition of Dikes	Trash & Debris	Location of Effluents	Water Condition	Pipeline Routes
1-51,52,53	Color IR/12	Pc	3	0	E	0	E	E	E	3
2-30,31,32	Pan/nf	G	E	1	1	1	1	E	E	E
6-19,20,21	Color /1A	G	E	1	1	1	1	E	E	E
1-18,19,20	Color IR/12	Pc	1	1	E	2	E	E	E	2
1-18,19,20	Pan/nf	Pc	1	2	E	1	E	E	E	1
10-15,16,17	Color /1A	G	E	1	1	1	E	E	E	1
1-27,28,29	Color IR/12	Pc	E	2	1	2	2	2	2	E
2-22,23,24,25	Pan/nf	G	E	3	0	2	E	E	E	E
12-14,15,16	Color /1A	Pc	E	1	1	1	1	E	0	E
6-26,27,28,29	Color IR/12	G	1	1	E	2	E	E	E	1
12-22,23,24	Color /1A	G	E	1	1	1	1	E	E	E
4-44,45,46,47	Color IR/12	Pc	1	1	E	1	E	E	E	2
2-44,45,46	Pan/nf	G	E	2	2	1	1	E	2	
12-28,29,30	Color /1A	Po	E	1	1	1	E	E	E	1
9-2,3,4	Color IR/12	G	E	1	1	2	2	E	E	E
11-2,3,4	Pan/nf	G	1	1	E	1	E	E	E	1
4-7,8,9,10	Color /1A	G	1	1	E	1	E	E	E	1
3-10,11,12	Color IR/12	G	E	1	1	1	1	E	1	E
10-7,8,9	Pan/nf	G	1	1	E	1	E	E	E	1
2-29,30,31,32	Color /1A	G	E	1	1	1	1	E	1	E

Film Sequence Number	Film Type	Exposure Rating	BULK STORAGE			DIKES		REFINERIES AND PROCESSING PLANTS		
			No. of Tanks	Leaks or Seepage	Oil on Water	Condition of Dikes	Trash & Debris	Location of Effluents	Water Condition	Pipeline Routes
5-23,24,25,26,27	Color IR/12	G	E	2	2	1	E	E	E	1
7-78,77,79	Pan/nf	Pc	E	1	1	2	1	E	E	E
5-2,3,4,5	Color /1A	G	1	1	E	1	E	E	E	1
6-19,20,21	Color IR/12	Pc	E	1	2	2	1	E	E	E
5-31,32,33	Pan/nf	G	1	1	E	2	E	E	E	1
12-47,48,49	Color /1A	Pu	1	1	E	1	E	E	E	1
6-13,14,15	Color IR/12	Pc	E	2	2	2	E	2	2	2
2-38,39,40	Pan/nf	G	E	2	1	2	E	E	E	1
2-76,77,78,79	Color /1A	G	E	1	1	1	E	E	E	1
5-2,3,4	Color IR/12	G	1	1	E	2	E	E	E	1
7-86,87,88	Pan/nf	Pc	E	1	1	2	E	E	E	2
3-3,4,5,6	Color /1A	G	E	1	1	1	E	E	E	1
2-32,33,34	Color IR/12	Pc	E	2	2	2	2	E	3	E
4-62,63,64	Pan/nf	Pc	2	2	E	2	E	E	E	2
4-42,43,44	Color /1A	Pc	E	1	1	1	1	1	1	E
2-38,39,40	Color IR/12	Po	E	2	2	2	E	E	E	2
6-19,20,21	Pan/nf	G	E	2	2	2	2	E	E	E
4-26,27,28	Color /1A	G	E	1	1	1	E	1	1	1
2-51,52,53	Color IR/12	G	1	2	E	2	E	E	E	2
6-13,14,15	Pan/nf	G	E	2	3	2	E	2	3	2

Film Sequence Number	Film Type	Exposure Rating	BULK STORAGE			DIKES		REFINERIES AND PROCESSING PLANTS		
			No. of Tanks	Leaks or Seepage	Oil on Water	Condition of Dikes	Trash & Debris	Location of Effluents	Water Condition	Pipeline Routes
5-23,24,25,26,27	Color /1A	G	E	1	1	1	E	E	E	1
10-25,26,27	Color IR/12	G	E	2	3	1	1	E	3	E
5-15,16,17	Pan/nf	Pc	E	2	3	2	2	3	3	E
4-83,85	Color /1A	Pc	E	1	1	1	E	1	1	1
4-32-32,33,34,35	Color IR/12	G	1	1	E	1	E	E	E	2
3-10,11,12	Pan/nf	G	E	E	1	2	1	E	2	E
8-10,11,12	Color /1A	G	1	1	E	1	1	E	E	1
7-70,71,72	Color IR/12	G	E	1	1	1	1	E	E	E
3-3,4,5	Pan/nf	G	E	1	1	2	1	E	E	1
4-3,4,5	Color /1A	G	E	1	1	1	1	1	1	2
6-2,3,4	Color IR/12	G	1	1	E	1	E	E	E	1
10-2,3,4	Pan/nf	G	1	1	E	E	E	E	E	1
6-2,3,4	Color /1A	G	1	1	E	1	E	E	E	1
4-3,4,5	Color IR/12	G	E	1	1	1	E	E	1	1
6-1,2,3	Pan/nf	G	1	1	E	E	E	E	E	1
4-19,20,21	Color /1A	G	E	1	1	E	1	1	1	E
	Color IR/12	G	E	1	1	E	1	1	1	E
4-42,43,44	Pan/nf	Pc	1	1	E	2	E	E	E	2
2-47,48,49	Color /1A	G	1	1	E	1	E	E	E	2
1-58,59,60	Color IR/12	Pc	2	3	E	3	E	E	E	3

Film Sequence Number	Film Type	Exposure Rating	BULK STORAGE: No. of Tanks	BULK STORAGE: Leaks or Seepage	BULK STORAGE: Oil on Water	DIKES: Condition of Dikes	DIKES: Trash & Debris	REFINERIES AND PROCESSING PLANTS: Location of Effluents	REFINERIES AND PROCESSING PLANTS: Water Condition	REFINERIES AND PROCESSING PLANTS: Pipeline Routes
5-24,25,26	Pan/nf	G	E	1	1	1	E	E	E	1
2-23,24,25	Color /1A	G	E	1	1	1	E	E	E	1
2-44,45	Color IR/12	Po	E	2	1	2	2	E	2	E
4-32,33,34	Pan/nf	Pc	1	1	E	1	E	E	E	1
2-33,34,35,36	Color /1A	G	E	1	1	1	E	E	E	1
4-26,27,28	Color IR/12	G	E	1	1	2	E	2	2	1
2-51,52,53	Pan/nf	Pc	1	2	E	E	E	E	E	2
22 Sep 72 A	Bimat pos	G	1	1	E	1	E	E	E	2
22 Sep 72 A	Bimat pos	G	1	1	E	1	E	E	E	1
22 Sep 72 C	Bimat pos	G	E	1	2	2	1	E	2	E
22 Sep 72 C	Bimat pos	G	E	1	2	1	1	E	2	E
22 Sep 72 B	Bimat pos	G	E	2	2	2	E	E	E	2
22 Sep 72 B	Bimat pos	G	E	1	3	1	E	E	E	1
25 Jul 72 C	Pan/nf	G	E	2	0	2	2	E	E	E
25 Jul 72 A	Pan/nf	G	1	1	E	1	E	E	E	1

Appendix Ic

Photointerpretation Results - Welch

Film Sequence Number	Film Type	Exposure Rating	BULK STORAGE			DIKES		REFINERIES AND PROCESSING PLANTS		
			No. of Tanks	Leaks or Seepage	Oil on Water	Condition of Dikes	Trash & Debris	Location of Effluents	Water Condition	Pipeline Routes
10-6,7,8	Color /1A	G	1	1	E	1	1	E	0	1
10-7,8,9	Color IR/12	G	1	2	E	1	2	E	0	2
9-2-,21,22	Pan/nf	G	1	3	E	1	2	E	0	1
9-28,29,30	Color /1A	G	1	1	1	1	1	E	1	1
9-9,10,11	Color IR/12	G	1	2	2	2	2	E	1	2
4-42,43,44	Color /1A	G	1	1	1	1	1	1	1	1
4-57,58,59	Color IR/12	G	1	2	3	2	2	2	2	2
4-18,19,20	Pan/nf	G	2	3	3	2	2	3	3	2
1-58,59,60	Color /1A	G	1	2	1	2	2	1	1	2
1-58,59,60	Color IR/12	Pu	3	3	2	3	3	2	2	3
1-58,59,60	Pan/nf	G	1	2	2	3	2	2	2	2
1-44,45,46	Color /1A	G	1	1	1	1	1	1	1	1
1-44,45,46	Color IR/12	G	2	2	3	2	2	2	2	2
1-44,45,46	Pan/nf	G	3	2	3	2	2	2	3	2
7-6,7,8	Color /1A	G	1	1	1	2	2	1	1	1
7-6,7,8	Color IR/12	Pu	3	3	3	3	3	2	3	2
7-141,142,143	Pan/nf	G	2	2	3	2	2	2	3	2
7-86,87,88	Bimat	G	2	2	2	2	2	1	2	2

SELECTED WATER RESOURCES ABSTRACTS

INPUT TRANSACTION FORM

1. Report No.

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3. Accession No.

W

4. Title

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7. Author(s)

Welch, R.I., Marmelstein, A.D., Maughan, P.M.

10. Project No.

9. Organization

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1747 Pennsylvania Avenue, N.W.
Washington, D.C. 20006

11. Contract/Grant No.

68-01-0191

13. Type of Report and Period Covered

12. Sponsoring Organization

15. Supplementary Notes

Environmental Protection Agency report number, EPA-R2-73-243, September 1973.

16. Abstract

Multi-band aerial photography was acquired during specified conditions of cloud cover and reduced visibility considered to be representative of a nearly infinite range of sub-optimum weather conditions. (For aerial photography, optimum is defined as clear skies and greater than 15 miles visibility.) Basic techniques were derived from an earlier study designed to yield strategic spill prevention surveillance. (Welch, et al. 1972)

Results indicated that only one film tested, a high sensitivity color positive film, provided consistently interpretable results. Rapid access techniques were also evaluated leading to recommendations for a tactical system providing a capability for both real-time and near real-time system update during sub-optimum aerial photographic conditions.

17a. Descriptors

Water pollution sources, oil, chemicals, remote sensing, aerial photography

17b. Identifiers

*Aerial photography, *sub-optimum weather, hazardous materials

17c. COWRR Field & Group

18. Availability

19. Security Class. (Report)

20. Security Class. (Page)

21. No. of Pages

22. Price

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