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Basic Guide to Small-format Hand-held Oblique Aerial Photography

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Users' Manual 81-2
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Abstract

The content of this manual is appropriate for the use of farmers, foresters, environmentalists, civil engineers and others who wish to make use of low-cost aerial photography to monitor local environments or to acquire permanent historical records. It provides a general overview of small-format oblique aerial photography, including pilot selection, flight planning, aircraft, cameras, films, filters and photo scale calculations. Appendices supply additional data on spectral curves of selected filters, and recommendations on film exposure and weather considerations. An annotated bibliography directs readers to sources of more detailed technical information.

Résumé

Le présent manuel s'adresse aux agriculteurs, aux gestionnaires des forêts, aux spécialistes de l'environnement, aux ingénieurs civils, et à d'autres personnes qui désirent utiliser des photographies aériennes de faible coût pour surveiller les environnements locaux ou acquérir des dossiers hsitoriques permanents. Il donne un aperçu global des photographies aériennes obliques de petit format, y compris des données sur le choix des pilotes, la planification des vols, les aéronefs, les caméras, les films, les filtres et les calculs relatifs à l'échelle des photographies. Les appendices contiennent des données supplémentaires sur les courbes spectrales de certains filtres, des recommandations sur l'exposition des films, et des considérations météorologiques. Une bibliographie annotée dirige les lecteurs vers des sources de renseignements techniques plus détaillés.

In Memoriam

Whereas there are many reports on the subject of small-format aerial photography, locating these studies and assessing their usefulness has been difficult and time consuming. Jack Fleming believed that a comprehensive document on 35 mm and 70 mm aerial photography was required in the remote sensing field. Such a document would provide enough information for a novice in remote sensing to obtain useful aerial photography as well as an overview of available information concerning more complex 35 mm and 70 mm format techniques. Unfortunately, Jack suddenly died on August 4, 1980 before this report was fully completed. We hope the above goal has been achieved in the final document.

Apart from this report, Jack contributed significantly to the CCRS Small-Format Photography project as well as to many other CCRS projects. Through his technical expertise, persistence and a vigorous analytical work, Jack has also made a lasting contribution to methods of acquiring and processing high-quality aerial photography. As a specialist and a colleague, he will be sorely missed at CCRS.

E.A. Godby
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1 INTRODUCTION

This manual has been written in response to requests for assistance from foresters, farmers, agricultural researchers, environmentalists and others whose primary interest is not aerial photography, but who recognize its potential advantages in pursuing their various professional ends. Some have sought assistance and advice in getting started; others have attempted using it but have encountered problems, particularly in connection with 35 mm colour infrared film. This manual is directed primarily to users in the categories described above. Experienced aerial photographers, although unlikely to learn anything new from it, will benefit from the collation of material into one manual.

The text deals primarily with hand-held oblique aerial photography from light aircraft, such as would be employed by occasional users who do not choose - for lack of time, resources or inclination - to become involved with the expense and complexity of fixed camera mounts, intervalometers, sophisticated navigation systems aircraft modifications and other details that are better left to professional aerial photographers. Serious researchers who need the additional information provided by stereoscopic vertical photography of extensive areas, multicamera arrays and ancillary equipment will find much that is useful in the accompanying bibliography (Section 5).

It is well to bear in mind that the object of aerial photography is not just to make pretty pictures, but to record information in a predictable and repeatable manner. It becomes a pointless exercise if the differences observed in successive photographs of a given area are due to exposure errors, processing inconsistencies, faulty film storage, film manufacturing differences, or camera malfunctions, rather than real differences within the scene. The manual attempts to point out how unwanted sources of variability may be minimized. We assume that the interested reader has access to a good small-format (35 mm or 70 mm) single lens reflex (SLR) or rangefinder camera and to a light aircraft.

2 EQUIPMENT AND MATERIALS

2.1 CAMERAS

Since we are concerned here with aerial photography from a relatively unstable and fast-moving platform, a fast shutter speed is a primary requirement to secure sharp images, unblurred by the relative motion between the aircraft and the ground. A shutter speed of at least 1/500th second is recommended for hand-held aerial photography. This consideration in turn dictates the use of relatively fast films. Although you may deviate from this general recommendation (with skill or luck) and still secure a well-exposed sharp aerial photograph, you need not do so, because fast lenses and fast films are widely available.

Specialized aerial survey cameras are of the fixed-focus type, critically focussed for maximum image sharpness of distant objects, and of rigid construction to maintain precisely the critical separation between lens and focal plane. No focus adjustment is possible or necessary. On the other hand, cameras likely to be used for the type of photography dealt with in this manual can usually be focussed to secure sharp images of objects that may range from a flower at a distance of a a few centimetres to a mountain on the horizon many kilometres away Since the focus is easily changed, and since aerial photography deals with objects that lie at a great distance from the camera (i.e., at "infinity"), the camera must be carefully focussed on distant objects before use. A strip of tape, or other form of "infinity lock", should then be applied to ensure that the focus is not inadvertently changed during use in the air.

Although a hand-wound camera is entirely adequate, a camera in which the film is automatically advanced and the shutter recocked following each exposure is more convenient. This may be accomplished electrically or by means of a spring motor. The latter costs considerably less than the battery-powered type and has no power failures, but is usually limited to about 15 exposures before having to be rewound.

An eye-level viewfinder is infinitely preferable to the waist-level, ground-glass variety, which is extremely awkward to use in an aircraft. A stout strap or other firm anchorage to secure the camera around the photographer's neck is necessary to obviate the possible embarrassment of returning from a photo flight without your camera.

2.1.1 EXPOSURE CONTROL

Most modern 35 mm cameras you are likely to use are of the single-lens reflex type with built-in, through-the-lens exposure meters. These may be of the match-needle type requiring manual adjustment of the aperture (iris diaphragm) or may be fully automatic, requiring no adjustment beyond an initial film-speed setting when the camera is loaded with film of a given speed rating.

For cameras without a built-in exposure meter, a separate exposure photometer is needed to measure the light reflected from the subject. This should be of a type whose indicator dial may be easily read while the sensor element is pointed so as to cover approximately the same field of view as the camera. The sensor should be fitted with a baffle or grid to limit the angle of acceptance to no greater than that of the camera. In use, the field of the meter must be sufficiently depressed to exclude the sky and to record only the light reflected from the objects to be photographed. A good photometer can be a surprisingly rugged instrument, but its adjustment can be deranged by mechanical shock. Hence it should be tested before it is used in the air, to ensure that it is working correctly. Additionally, inadequate baffling or careless pointing of the instrument or the camera with a meter may result in readings unduly influenced by objects outside the camera's field of view (e.g., the sky or a specular reflection from water). If such spurious readings are translated into camera settings, incorrect exposure will result.

Spot meters are excellent for ground photography of stationary objects from a stable platform, but may prove unsatisfactory for aerial use, because of the difficulty in air turbulence of holding the spot on a prescribed object long enough to get a reliable reading.

2.1.1.1 AUTOMATIC EXPOSURE CONTROL

Two systems of fully automatic exposure control may be found on modern hand cameras:

(a) aperture priority, or
(b) shutter-speed priority.

Of the two, the shutter-speed priority system is probably the better for aerial use, since you can preselect a fast shutter speed to limit image motion. The exposure is controlled by automatic adjustment of the aperture according to the average brightness of the subject seen by the exposure-metering system.

The aperture-priority system is more often encountered in hand cameras since it permits the aperture to be preset to some predetermined value to control the depth of field in closeups, the exposure being controlled in this case by automatic adjustment of the shutter speed according to the brightness seen by the exposure-metering system. This is a useful feature for pictorial photography of nearby objects but offers no advantage for aerial use, where the subject is always effectively at infinity and the depth of field is irrelevant.

Hence, if there is any choice, a fully automatic camera with the shutter-speed priority system of exposure control is recommended for oblique aerial photography. If there is no choice, the aperture-priority system may be operated in the other mode by varying the aperture setting manually until the required high shutter speed is selected by the system. This is similar to the match-needle system and can be entirely satisfactory, although no longer fully automatic. Alternatively, the aperture can be set wide open so that the shutter speed will automatically be adjusted to the maximum demanded by the existing combination of lighting and subject matter.

2.1.1.2 MEANS OF VARYING THE EXPOSURE LEVEL

Small-format hand cameras with integral exposure meters normally have three means of adjusting exposure levels:

(a) aperture setting f-stop number
(b) shutter-speed setting, and
(c) film-speed setting (ASA or DIN).

Most aperture settings are provided with "click stops" or detent positions at intervals of one full stop, although some cameras have half-stop increments. Exposure can normally be varied repeatably only by a factor of 2 by adjusting the aperture through a range of, for example,

f/2, 2.8, 4, 5.6, 8, 11, 16, 22,

in which each setting provides one-half the exposure of the preceding, that is intervals of one full stop. Similarly shutter speeds are variable, each step by a factor of 2 through a typical range of, for example, 1, 1/2, 1/4, 1/8, 1/15, 1/30, 1/60, 1/125, 1/250, 1/500, 1/1000 second,

or also intervals of one full stop. However, since films are available in a wide range of speeds, the film-speed settings of cameras with built-in exposure meters are usually in steps of one third of a stop to accommodate films with speed ratings of, typically,

ASA 25, 32, 50, 64, 80, 100, 125, 160, 200, 250, 320, 400, 500, 640, 800, 1000, etc.

Thus the film-speed setting offers the most precise means of "fine-tuning" the exposure level adjustment in cameras with built-in meters.

Approximate exposure levels required for various film types are included in Appendix B. These tables also include exposure level compensation for photography at various altitudes. The weather can affect exposure levels and change flight patterns. Appendix C lists various weather conditions and indicates how they may be compensated for by photographic exposure, film types and flight patterns.

2.1.1.3 MANUFACTURING TOLERANCES

All the aforementioned camera settings are carefully calibrated by the camera manufacturer, and are likely to be correct within small tolerances in any new camera received in good condition from a reputable supplier. However, the accumulation of tolerances, if additive, may amount to a total error of up to one-third stop, even in a well-adjusted camera. The effects of age or mishandling of a camera can cause a further shift from the calibrated values. Similarly, although the film manufacturer makes every effort to supply film of constant speed value, determined in accordance with standard criteria that are compatible with the calibration methods employed by camera manufacturers, he must also work within certain reasonable tolerances, and the characteristics of the film will also be subject to change with time and conditions of storage and handling, as well as with processing techniques.

The sum of tolerances and small errors in all phases of a complex system of light measurement, exposure control and image reproduction makes it advisable to check the output of the total system by running a series of test exposures before operating a new camera or using a new batch of film (Section 2.4). The purpose of the test should be to determine the effective speed of that batch of film, in that camera, when processed by the available means, either in a local photo-finishing plant or in your own laboratory (Section 2.2.3).

2.2 FILMS

In the interests of brevity, this text concerns itself mainly with only two general film types:

(1) "normal" colour reversal film, and
(2) "false" colour reversal film (Kodak Ektachrome Infrared).

Photographic suppliers stock a large variety of colour reversal films from several manufacturers. The choice is often based upon personal preference, since human response to colour tends to be highly subjective. This is understandable when the subject matter consists of friends, relatives and familiar scenes. Choice of a film for remote sensing applications should probably be based upon more objective criteria, some of which are considered below. Film types and manufacturers are listed in Table 2.1, along with generally followed filter recommendations.

2.2.1 FILM SELECTION CRITERIA

2.2.1.1 FILM SPEED

Since the camera platform is to be a light aircraft, the relative motion between the optical image and the film at the instant of exposure will subjet photography to several influences tending to degrade sharpness or resolution. The forward speed, which is likely to be about 75 to 100 miles an hour, causes blurring of the image and may be reduced by "panning" the camera. The light wing-loading makes the aircraft relatively unstable about its axes of rotation, requiring frequent corrections by the pilot to maintain a reasonably constant attitude. The rotating propeller and reciprocating parts of the engine generate considerable vibration which, if transmitted to the camera, will contribute to further blurring of the image.

Probably the most effective means of minimizing image degradation due to the sum of the above factors is the use of a high shutter speed, which in turn demands a fast film. Thus a film that is capable of producing superb still-life images at wide apertures and slow shutter speeds on the ground may prove quite unsuitable for use from the air. We suggest that the film for aerial use should have an effective film speed of at least ASA 100. The term ASA stands for the American Standards Association and the number provides an indication of how that film will respond to light. The film with a low ASA number (e.g., 25) will work best with very bright conditions. The film with a high ASA (e.g., 400) works best with poorer illumination. Generally the German standard DIN value for film speed rating is also shown along with the ASA value.

TABLE 2.1

Films Available for 35 mm and 70 mm Oblique Aerial Photography

Film Designation	Manufacturer	ASA (nominal)	Viewing Mode	Camera Filter Recommendation (Section 2.3)
Black-and-White Films				
Panatomic-X	Kodak	32	Prints	Haze (Wratten 1A)
Plus-X	"	125	"	"
Tri-X	"	400	"	"
Pan-F	Ilford	50	"	"
FP-4	"	125	"	"
HP-5	"	400	"	"
Normal Colour Films				
Photomicrograph*	Kodak	16	Slides	Haze (Wratten 1A)
Kodachrome 25	"	25	"	"
Kodachrome 64	"	64	"	"
Ektachrome 64	"	64	"	"
Ektachrome 200	"	200	"	"
Ektachrome 400	"	400	"	"
Kodacolor II	"	100	Prints	"
Vericolor II*	"	100	"	"
Kodacolor 400	"	400	"	"
Fujichrome R100	Fuji	100	Slides	"
Fujicolor II 100	"	100	Prints	"
Fujicolor II 400	"	400	"	"
Infrared Films				
High Speed Infrared*	Kodak	Varies (see mfr's data)	Prints	Wratten 25, 29 or 70, or 89B B + W 093
Ektachrome Infrared*	"	100	Slides	Wratten 12 or 15 (see also Section 2.3.1.5)

*Must be stored at -18°C (0°F) or colder

2.2.1.2 COLOUR CONTRAST

Aerial photography necessarily involves recording images of the ground as seen through at least several hundred (and often several thousand) feet of air. This intervening column of air, which inevitably contains varying amounts of dust, smoke, water vapour, salt and other finely divided constituents in suspension, contributes a portion of non-image-forming light (haze or fog) to the exposure of the film. This unwanted light tends to make dark shadows appear brighter than they otherwise would be. The result is a reduction of contrast. Hence for aerial use a comparatively "contrasty" material may prove advantageous to offset the contrast-attenuating effect of haze.

2.2.1.3 COLOUR RANGE

The maximum range of colours that a given colour reversal film is capable of reproducing will be determined by the nature and concentration of the chromogenic dyes used in its manufacture, and is consequently beyond the control of the photographer. However, the level of exposure, which is within the control of the photographer, will determine how much of the maximum colour range of which the material is capable will be attained in practice. Overexposure diminishes the colour range by failing to take maximum advantage of the available dyes in the film. Underexposure leaves unnecessary density in the image, making it difficult to see and reproduce, by causing the formation of more dye than is necessary to attain the maximum gamut of colour. For a given colour reversal film, the objective is to attain the maximum colour range with the minimum exposure, avoiding both under- and overexposure.

2.2.2 ACQUISITION AND STORAGE

Experience has shown that photographic films, particularly colour films and infrared-sensitive films, may exhibit significant differences in effective speed and colour balance from roll to roll, even though they are nominally of the same type and speed rating, and from the same manufacturer. The differences arise from a combination of manufacturing tolerances, effects of aging, storage and handling conditions and processing variations.

Critical users for whom consistency and predictability of response are very important, have found that variability may be minimized by purchasing many rolls of the same emulsion batch number at one time. This will ensure a reasonable degree of roll-to-roll consistency within that batch. The characteristics of that batch may then be maintained within narrow limits for an almost indefinite period by storing the film at low temperature (frozen solid at about $-18^{o}C$). Frozen film must be removed from cold storage and allowed to come gradually to equilibrium with the ambient temperature before it is removed from the sealed can or package. Otherwise, problems may arise with condensation, when moist air comes into contact with the frozen film.

A preoperational test of each batch of film in your own camera (Section 2.4) will establish the characteristics of the entire photographic system. Thereafter, your can reasonably assume a consistent response as long as all elements of the system remain unchanged. A new batch of film, a different camera, or a change of processing technique would require another test to establish the response characteristics of the new system.

2.2.3 PROCESSING FACILITIES

The practical choice of a colour reversal film for aerial photography is likely to be dictated in the final analysis by the available processing facilities. If rapid turnaround is required, so that tomorrow's decisions may be based upon today's photography, you must either process the film yourself or have access to overnight processing facilities, commercial or otherwise. If the photography is required only for archival purposes or for more leisurely study later, you may select from a much broader range of films.

Most of the larger urban centres in Canada afford overnight processing facilities for most commonly available reversal colour films. Smaller communities may also have to rely on one of these central processing laboratories and are therefore at the mercy of possible delays in postal or express services.

When you purchase film, you should ensure that it can be rapidly processed locally when necessary, and you should determine how long it will take. Otherwise, you may end up with a roll of exposed film in hand and no easy way to get at the information it contains.

The use of Ektachrome Infrared film may present a problem in some parts of Canada. This material calls for the Kodak E.4 process, which is currently being phased out by many commercial photo-finishing plants and is being replaced by the E.6, process with which Ektachrome Infrared is not compatible. For the do-it-yourselfer, E.4 processing kits will probably continue to be available for the foreseeable future. Alternatively the EA.5 process may be employed. This is the process by which aerial colour reversal film is developed in continuous-process machines. It is available in Canada only at the Reproduction Centre of the National Air Photo Library in Ottawa.* A minimum charge for 25 feet of film is applicable; hence it is not economically attractive unless several 35 mm rolls are submitted for processing at the same time. If you use this service, the exposed film frozen and packed in dry ice in an insulated container, should be shipped to Ottawa via prepaid Air

* NAPL/RC 2464 Sheffield Rd., Ottawa, Ontario, K1A 0Y7. 613-993-3450.

Express or courier service. Notify the processing lab of its impending arrival, quoting the waybill number, and ensure that it will arrive in Ottawa not later in the week than Friday morning, lest it sit over the weekend, possibly in the unsuitable environment of a warehouse or delivery truck.

2.2.4 EKTACHROME INFRARED FILM

Ektachrome Infrared film exhibits a variety of attributes, some advantageous, others requiring unusual care in acquisition, storage, handling, exposure and filtration. Failure to observe the limitations may nullify the film's advantages.

Perishability

All photographic materials are perishable to some degree, depending upon the type, and demand careful handling to minimize the risk and rate of deterioration. Infrared-sensitive emulsions are particularly perishable, so that infrared-sensitive films must at all times be protected from high temperatures to inhibit the loss of speed, the increase in base fog, and the loss of infrared sensitivity.

High temperatures can adversely affect the various sensitivities of colour film at different rates, thereby upsetting the delicate balance among the colour-sensitive layers. Ektachrome Infrared film, being both infrared-sensitive and colour sensitive, is therefore especially susceptible to less than optimum conditions of storage and handling. A consistent product is difficult to manufacture; it should be shipped and stored in the frozen state, or at least under refrigeration. For long-term storage (more than a few weeks) it should be kept frozen at temperatures at least as low as -18°C (0°F) and preferably much lower. Fortunately, most household freezers are capable of maintaining suitable storage temperatures.

Infrared Sensitivity

Ektachrome Infrared is unique among colour reversal films in having one of its dye layers sensitized to infrared radiation. Variations in the intensity of infrared reflected from a subject appear as variations in the intensity of red in the processed image. Since the intensity of the infrared reflection of a given plant type tends to vary with the health and vigour of its vegetative growth, Ektachrome Infrared has been used to monitor the condition of forests or field crops and to map the areal extent of disease or insect infestation (Section 5). It may be employed also to observe the result of applying fertilizers or herbicides or other factors affecting the vigour of vegetative growth. It may be useful also in assessing relative surface soil moisture levels since infrared radiation is strongly absorbed by moisture. The high-contrast characteristic of the film, coupled with its infrared sensitivity and colour differentiation, make it possible to detect quite small differences of infrared reflectance.

Blue Sensitivity

In common with other colour films, Ektachrome Infrared includes three sensitive layers, each sensitized to a different band of the spectrum -- in this case, to infrared, red and green. Each layer is also sensitive to blue. Hence, if the three layers are to differentiate among green, red and infrared, the blue light must be prevented from reaching the film. This is accomplished by use of a minus-blue filter such as a Wratten 12 or 15 to absorb the blue portion of the spectrum.

High Contrast

The slope of the straight-line portion of the characteristic curve of Ektachrome Infrared film is much steeper than for normal colour films. Its numerical value is around 2.5, or about twice that of other aerial films. The high-contrast characteristic of Ektachrome Infrared exaggerates the differences of reflectance, which on ordinary colour film may be too subtle to be readily apparent.

The same high-contrast characteristic is accompanied by decreased exposure latitude. Ektachrome Infrared is relatively intolerant of exposure errors, so that storage, exposure and processing control become quite critical if good and consistent results are to be attained.

2.3 FILTERS

Anyone planning to carry out oblique aerial photography with a small-format camera should be equipped with a few basic filters, including:

(1) UV (ultraviolet) filter (Wratten 1A or equivalent),
(2) yellow (minus-blue) (Wratten 12 or 15 or equivalent),
(3) red (Wratten 25 or equivalent),
(4) infrared (Wratten 89B or equivalent), and
(5) colour compensating (CC10B-60B or CC10M-50M).

Spectral transmittance curves for selected filters from different manufacturers are presented in Appendix A. Kodak Wratten designated filters, Nikon and Johannes Weber B + W filters are included.

2.3.1. ABSORPTION FILTERS

2.3.1.1. ULTRAVIOLET FILTERS

Most films likely to be used for oblique aerial photography are more sensitive to radiation of short wavelengths at the blue and ultraviolet end of the spectrum than is the human eye, which has maximum sensitivity to green light. Panchromatic black-and-white films and the blue-sensitive layers of colour films tend to be highly sensitive, not only to visible blue light but also to invisible ultraviolet radiation which is recorded by the film as though it were visible blue. Hence the presence of ultraviolet radiation results in apparent overexposure of the photograph (in colour films, an excessive blueness). Since the short-wavelength portion of the spectrum is the most subject to atmospheric scattering, the use of an ultraviolet filter to absorb those wavelengths will result in a colour photograph which is not only sharper, but also of improved colour balance.

Photographers generally leave the UV filter in place on the camera at all times, on the grounds that

(a) it is always there when needed,
(b) it has no significant ill effects when not needed, and
(c) it protects the lens against dust and mechanical damage.

This sound practice is recommended to aerial photographers using ordinary colour or black and white film.

2.3.1.2 MINUS-BLUE FILTERS

A yellow (minus-blue) filter will absorb blue light that is strongly scattered by the atmosphere. Since shadows are illuminated chiefly by scattered blue light, they will be darkened by a minus-blue filter; thus the apparent contrast of the scene will be increased, and the apparent sharpness will be improved by attenuation of the non-image-forming scattered radiation. If you need to record on panchromatic black-and-white film details that lie in a shadow, remove the yellow filter so that more light from the shadowed areas can reach the film. Hence the advisability of using a minus-blue filter will be determined by the location of the details you wish to record. Generally, photographing from the air with panchromatic back-and-white film gives a more pleasing result with a minus-blue filter.

A Wratten 12 or equivalent minus-blue filter may be used with black-and-white infrared film to produce the "modified infrared" photography that is favoured by some foresters. With Ektachrome Infrared film, a Wratten 12 or similar yellow or orange filter must always be used to exclude the blue light from the film.

A wide variety of minus-blue filters is available, ranging from pale yellow to deep orange, to remove varying amounts of blue from the incoming radiation. Unfortunately, each manufacturer of filters or cameras tends to use his own filter designation, which usually tells little about the spectral transmittance characteristics of the filter. You should request spectral transmittance data from the manufacturer or dealer; otherwise it is difficult to compare filters from various sources.

2.3.1.3 RED FILTERS

When shooting with a panchromatic film from high altitudes or when photographing over very long distances (as of distant mountains), you may use a red filter to advantage to enhance the apparent contrast and sharpness. It functions much as a minus-blue filter (in this case a "minus-blue-green" filter) by absorbing the portion of the spectrum most subject to atmospheric scattering, leaving only the longer wavelengths of greater penetrating power to form the image.

A red filter may also be used with black and white infrared film to attenuate the extreme contrast that characterizes pure infrared photography (Section 2.3.1.4).

2.3.1.4 INFRARED FILTERS

Infrared filters appear opaque to the eye (e.g. Wratten 89B or B + W 093) since they absorb nearly all visible radiation while freely transmitting the near infrared. They are used in conjunction with black-and-white infrared film for "pure" infrared photography to record only the infrared portion of the spectrum.

2.3.1.5 COLOUR COMPENSATING FILTERS

Colour compensating filters maybe used to alter the colour balance* of pictures recorded on colour film or to reduce the effects of variations in the spectral quality of a light source. The filters attenuate light in one portion (red, green or blue) of the spectrum while transmitting light in one or both of the other parts of the spectrum (Eastman Kodak, 1973).

In colour infrared film, the spectral sensitivity of the infrared emulsion can change in relation to the two visible emulsions. This change can produce a film with enhanced or degraded response in the infrared film layer. To compensate for infrared enhancement or degradation, two specific colour compensating (cc) filters (blue or magenta) are used to shift the responses of the visible emulsions. The filters are designated as follows: blue-CC10B to CC60B; magenta CC10M to CC50M. The higher number indicates more attenuation in the red/green sensitive emulsions for the blue filter and more attenuation in the green layer emulsion for the magenta filter. For more detailed explanations on the use of CC filters, see Fleming (1980).

*Colour Balance

The proper intensities of colours in a colour print, positive transparency, or negative, that gives a correct reproduction of the grey scale (as faithful as can be achieved by photographic representation of the true colours of a scene) (Reeves, 1975).

2.3.2. POLARIZING FILTERS

A polarizing filter is a useful accessory for general photography on the ground. In landscape photography it may be used in cross-sun shots to darken the sky for enhanced contrast with clouds and to produce a more saturated blue sky in colour photographs. It may also be employed to reduce the effect of specular reflections from some shiny surfaces and thereby improve their colour rendition. The effectiveness of the polarizer is highly dependent upon the direction of the camera axis and the angle of rotation of the filter.

Because of the critical dependence on angular relationships, and because the sky is usually excluded, the value of a polarizing filter for hand-held aerial oblique photography from a light aircraft remains to be proven. Curran (1978) suggested that it may be of value in assessing soil moisture if close attention is paid to the horizontal viewing angle, the depression angle of the camera axis, and the rotation of the axis of polarization in relation to the elevation and azimuth angles of the sun. These factors are not easy to control precisely from an unstable camera platform such as a light aircraft.

For reliable results, before employing a polarizing filter from the air, the photographer should familiarize himself with the physical phenomenon of polarization, including the significance of the phase angle and polar distribution (Curran, 1978).

2.3.3 INTERFERENCE FILTERS

Most filters for small-format cameras, as described in Section 2.3.1, consist of dyes incorporated in glass or gelatin, which remove certain wavelengths or colours from incident radiation by selective absorption. The filter absorbs the unwanted portion of the spectrum and transmits the rest.

Interference filters function by a process of selective reflection. They reflect certain portions of the spectrum and transmit the rest. They consist of a dielectric layer or series of layers of metal or metallic salts deposited on glass. The thickness of the coating(s) is a fraction of the wavelength of light, the transmittance being controlled by the nature and amount of the material deposited.

Interference filters are not common in small-format photography because they are expensive. They are most likely to be encountered on multispectral camera arrays where they are used as band-pass filters to isolate narrow bands of the spectrum for later analysis and manipulation in multispectral viewers.

2.4 PREOPERATIONAL SYSTEM TEST

Once the films and required filters are selected for the particular study subject, then the camera(s), lenses, films, filters and film processing should be tested as a system to ensure consistent results over time. Films with the same emulsion batch number should be used for the study. If additional films are required and the batch number is different from the first set, then the film/camera test should be repeated. This is especially significant with colour infrared film.

The preoperational test will also aid in determining the best film speed (ASA or DIN) for that film because the actual film ASA may vary from the nominal ASA rating on the film box.

2.4.1 TEST CONDITIONS

Since the intended application is aerial photography, tests should be conducted at a fixed shutter speed of 1/500th or 1/1000th second.

The filter intended for use in the air should be fitted.

The range of the exposure test should encompass at least two full stops, centred on the nominal speed rating of the film. Suggested settings for a test of a film nominally rated at ASA 200 would be as follows:

Shutter speed	1/500th second
Film speeds	ASA 100, 125, 160, 200, 250, 320, 400
Aperture	as required to match needle, or as demanded by automatic exposure control
Test object	multicolour panel*, or a view from a high window to simulate an aerial oblique; front lighted by open sunlight
Processing	at normal temperatures, procedures, etc.

The resulting series of test frames should produce images ranging from obvious overexposure to obvious underexposure. The optimum lies somewhere between the two extremes, and may be determined by a critical inspection. It will often be found to lie somewhere other than at the nominal speed value. Frequently, two or more observers will not be unanimous in their opinions as to which image is "best".

2.4.2 ASSESSMENT OF TEST RESULTS

Overexposure of reversal colour film is characterized by thin, desaturated images and an overall impression of haziness.

* A Macbeth "Color Checker" Color Rendition Chart provides a useful array of carefully chosen colour chips arranged to suit the proportions of the 24mm x 36mm format of 35mm film.

Underexposure results in a dense image in which the colours can be discerned only with the aid of a very intense light source. Between the two extremes lies a range of results, some of which would be judged "acceptable" by a variety of observers. Determination of the "best" exposure within that narrowed range may be based upon personal taste, or upon objective measurement with a suitable instrument (e.g., a densitometer).

One criterion of "best" exposure is that which records the maximum range of colours that the film can reproduce at the minimum exposure required to produce that range. If the exposure is increased beyond the optimum, desaturation of the colours will result; if the exposure is decreased below the optimum, unnecessary density will be added to the image without increasing the colour range, making it difficult to see and to reproduce, whether by printing or by projection on a screen.

2.5 AIRCRAFT AND PILOT SELECTION

2.5.1 AIRCRAFT

Since oblique aerial photography requires an unobstructed field of view for the cameras, an ideal camera platform would be a sky-hook with no wings, wires, wheels or struts. The next best thing is a high-wing monoplane with a cantilever wing (no wing struts), and retractable undercarriage, having a large window capable of being fully opened in flight next to the photographer's seat. Such aircraft are not common on Canadian airfields, and you will usually have to settle for something less.

Most high-wing aircraft have a wing strut that tends to intrude into the field of view, particularly from the front seats. Hence the rear seats of a 4-seat lightplane or a tandem 2-seater may provide a better vantage point for the photographer.

You must be able to open a suitable window in flight. Photographing through the glass or plexiglass of the window itself will rarely give satisfactory results; reflections and poor optical quality will degrade the quality of the image. It is pointless to go to the trouble and expense of acquiring a camera with a high-quality lens, and then to use it to take photographs through a low-grade window.

A large window, hinged along its upper edge, which can be secured in the fully opened position by a latch on the underside of the wing is excellent. On some light aircraft the upward-opening window will not require a latch, being held against the underside of the wing by the airflow at the reduced airspeed usually most suitable for oblique photography.

On some aircraft, the entire door may be removed simply by extracting a couple of safety pins from the hinges. This provides an admirable field of view but renders the cabin very draughty, so that all loose articles, papers and maps must be stowed with particular care before takeoff. In cold weather, heavy windproof clothing and gloves are essential, though bulky and awkward for handling a camera. The photographer must be securely strapped in at all times.

2.5.2 PILOTS

Since oblique aerial photography frequently entails manoeuvring at low altitude and reduced airspeed, with the window wide open or a door removed, the photographer is well advised to be selective in choosing a pilot to operate his camera platform.

The aerial photographer will find that not all pilots, even with extensive flying experience, appreciate the requirements and limitations of flying in accordance with a pre-established pattern of flight, to record a particular target area on the ground from a specific viewpoint. If possible, you should seek a pilot experienced in flying for photography.

Some operators are reluctant to remove a door, and others are quite nervous about flying with an open window, having spent their entire flying careers in snugly enclosed cabins. In addition, manoeuvring safely at reduced airspeed requires a skill that is not often stressed in pilot training and is rarely practised thereafter.

On the subject of pilots, one established aerial photographer has expressed himself as follows, The photographer has three choices open to him; live with the way the pilot positions the aircraft (usually poorly), train him (slow), or learn to fly oneself (expensive)." This photographer has neatly solved his own problem by marrying another accomplished photographer who is also a commercial pilot. This expedient may not be open to everyone, but it serves to illustrate the lengths to which you may have to go to secure the services of a satisfactory pilot.

3 ORIENTATION OF THE CAMERA AXIS

3.1 OBLIQUES

In taking hand-held oblique photographs from the air, two general options in orientation are available, namely, high and low obliques. The choice between these options will be governed by whether you need to cover a very large area in a single photograph or a smaller area for more detailed information. For satisfactory systematic coverage of a given target for a specific purpose, that purpose must be defined beforehand and a detailed plan prepared before takeoff. Snapshots from arbitrary altitudes and directions are rarely satisfactory.

Since the scale in an oblique photograph is not uniform but varies continuously from bottom to top, reliable measurements are not easily made on obliques. If measurement is required, vertical photography will probably be more useful than oblique.

3.1.1 HIGH OBLIQUES

If the requirement is to define the location of a given field or installation relative to other identifiable but distant landmarks, a high oblique -- that is, one that includes the horizon -- may serve if some recognizable object of known position, such as a water tower, a steeple or a small community can be included in the background.

If the angle of depression of the camera's photographic axis (∂) does not exceed one half of the field of view of the lens (α) the horizon will remain visible near the top of the frame. For the purposes of this text, a high oblique is defined as one in which the angle of depression equals the semi-field angle ($\partial = \alpha$), so that the horizon is just visible. Consequently, the angle of depression for a high oblique will depend upon the focal length (f) of the lens in use and the format dimension (x) according to the expression:

$$\text{semi-field angle } \alpha = \arctan \frac{x}{2f} \quad \text{(Fig. 4.1).}$$

3.1.2 LOW OBLIQUES

If the depression angle exceeds the semi-field angle, the horizon will no longer appear in the photograph. The resulting photograph is defined as a low oblique. For detailed coverage of a limited area, the low oblique orientation is recommended.

3.2 VERTICALS

In Section 3.1.1, we defined a high oblique as one in which the depression of the camera's optical axis equals one half of the field angle. Similarly, we may define a vertical photograph as one in which the angle of depression is 90^o -- that is, the camera is looking straight down. In this case, the scale is more nearly uniform across the format, so that the photograph exhibits properties that approximate those of a map.

Section 4 presents a simple treatment of the basic geometry of the oblique photograph. Expressions are derived for the various parameters you need to know for comprehensive preflight planning. These are expressed in a form suitable for use with a programmable pocket calculator. From these formulas, parameters of scale, coverage and altitude relevant to vertical photography are easily derived by setting $\partial = 90^o$. To minimize the need for calculation, precalculated tables are included for a variety of small-format focal lengths, and format dimensions covering those most likely to be encountered in practice for high oblique, low oblique and vertical orientations. Finally, to illustrate the use of the tables a hypothetical practical example is worked in detail. A work sheet is also offered to facilitate preflight planning.

3.3 ORIENTATION RELATIVE TO THE SUN

The best photographs will be secured usually if the photographer positions the aircraft between the sun and the target so that the subject is front-lighted. This places the sun behind the camera so that it shines "over the shoulder" of the photographer. From this position the camera records those surfaces of buildings, trees, etc., that are in full sunlight. The small amount of shadow that remains visible serves to outline the sunlit objects against their background, providing enough sharp contrast to aid interpretation of the photograph by giving a sense of depth and perspective. The built-in automatic exposure control system of the camera will give best results from this position. In Canada, over-the-shoulder illumination usually means flying on the south side of the target with the camera pointed in a generally northern direction (Fig. 3.1). This rule will have to be modified somewhat if early-morning or late-afternoon photography is to be undertaken in summer.

In general, the opposite situation (or "back-lighting") should be avoided, except in special circumstances described below. If the camera is looking towards the sun, objects on the ground present their shadowed sides to the camera, and some horizontal surfaces tend to present a partly specular reflection or glare. The camera's exposure control system will be unduly influenced by the bright reflections, resulting in underexposure of the surfaces facing the camera. If the back-lighted situation is unavoidable, exposure should be increased by up to two full stops. Some modern cameras now incorporate a "backlight button" to accomplish this.

Back-lighting, or photographing towards the sun, may prove of value when the purpose is to record the presence of surface water or other liquid effluent. In this case the strongly specular reflection from the mirrorlike surface of the liquid may be useful in detecting and delineating the extent of run-off, whether it be to trace the course of a small stream, or to pinpoint the source of some liquid pollutant flowing from a factory or accident site.

For many purposes, satisfactory results may be secured by photographing under an overcast sky. Under these circumstances the lighting will be diffused with no sharp shadows, thereby reducing overall contrast. The total illumination is usually quite adequate for fast films (even Ektachrome Infrared), and details that might otherwise be lost in dark shadows may now be visible.

We suggest that you avoid taking photographs when the sun is behind you and directly in line with the camera axis (Fig. 3.1). The shadow of the photo aircraft as it traverses the ground may be seen at the centre of a bright spot that appears to travel across the ground at the speed of the aircraft. This phenomenon is due to the apparent absence of shadows in that direction, since every object at the "shadow point" conceals its own shadow from the observer and the

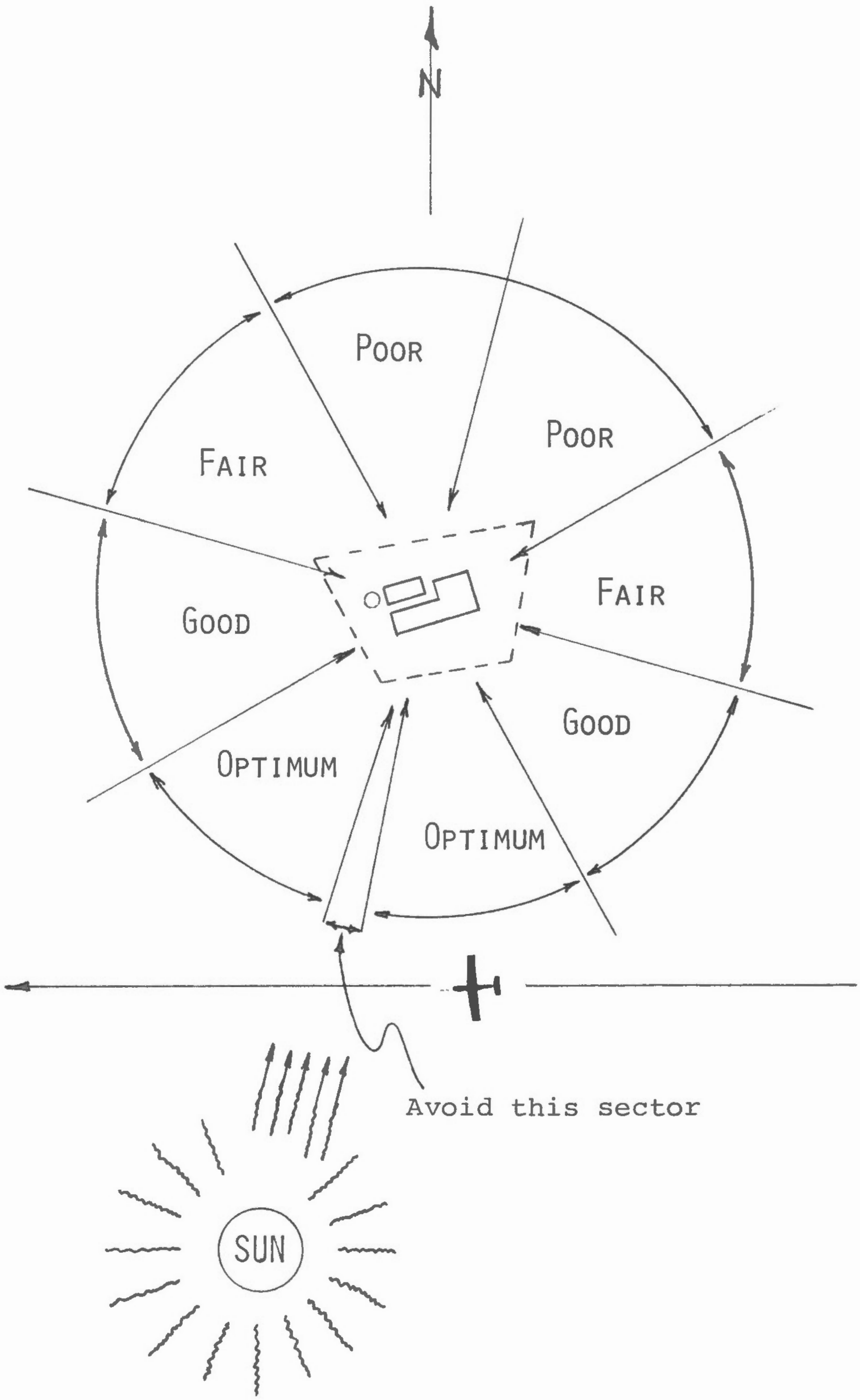


FIG. 3.1 Choice of viewpoint for oblique aerial photography relative to sun and target.

camera. The result is a loss of apparent contrast accompanied by a tendency to overexposure, which makes it difficult to discern details at that point. If a photograph were exposed at the instant the shadow point traversed the target, there would be a loss of information in the target area.

3.4 ORIENTATION FOR STEREOSCOPIC OBLIQUES

Up to this point we have been considering oblique aerial photographs only as single images. However, if photos are taken in pairs to be viewed under a stereoscope for a three-dimensional image, much more useful information can usually be extracted from the images.

The stereo pairs are obtained simply by taking two photographs of the same object approximately at right angles to the flight path, separated by only 2 to 4 seconds. The optimum time separation will vary with speed and height but should not be extended unduly; otherwise viewing conditions will become difficult and tiring to the eyes under increasing angles of convergence.

3.4.1 ORIENTATION FOR CONVERGENT OBLIQUES

The requirement is simply to secure two slightly different views of the same object from two slightly different viewpoints having a small horizontal separation. If the same ground points appear in the centre of each image, the two convergent fields of view will cover approximately the same ground (the overlap is nearly 100%) and the entire common area may be viewed in three dimensions under a pocket stereoscope (Fig. 3.2). Alternatively, enlarged prints may be used with a larger mirror stereoscope.

3.4.2 ORIENTATION FOR PARALLEL AXIS OBLIQUES

Complete stereoscopic coverage of an extended linear feature that is longer than the field of view covered by a single stereo pair (e.g., a road, power line, or river bank) may be secured by a series of overlapping obliques taken with the camera axis at right angles to the flight path while the platform is flown along a path parallel to the centre line of the feature and at a prescribed distance from it (Fig. 3.3).

If the linear feature follows an irregular meandering course, it may be necessary to fly a series of straight-line segments so that the outer reaches of the feature do not exceed the field of view in each segment (Fig. 3.4).

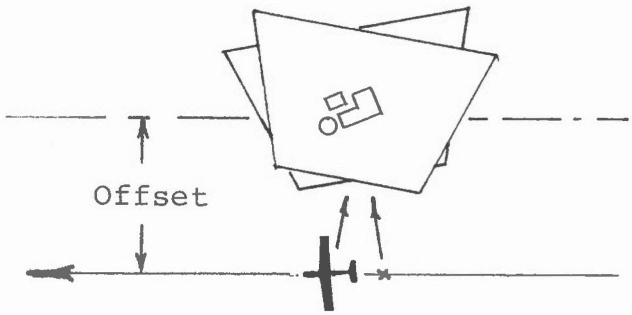


FIG. 3.2 Convergent stereo obliques of localized target area.

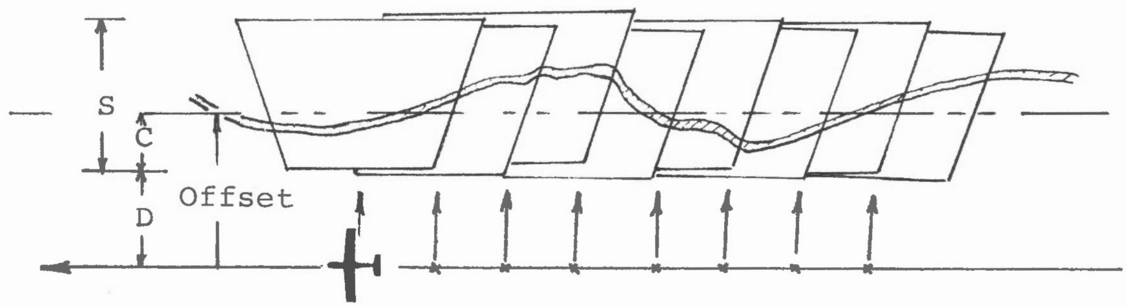


FIG. 3.3 Overlapping stereo obliques along a linear feature.

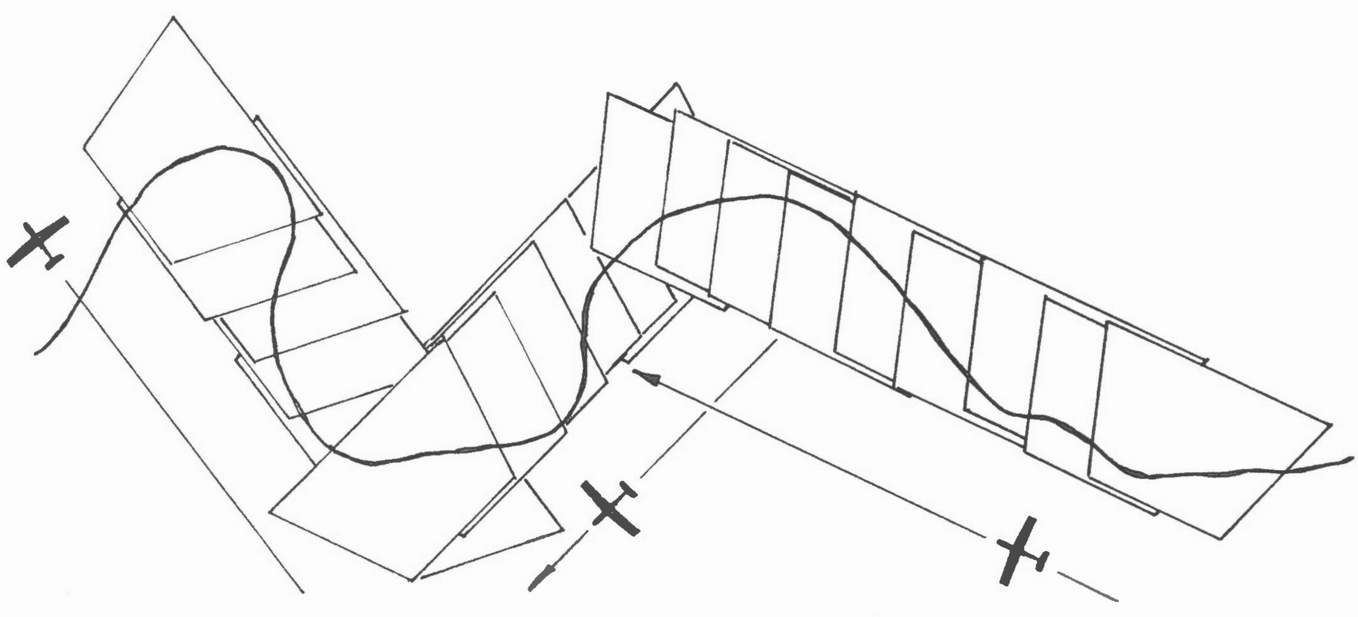


FIG. 3.4 Overlapping stereo obliques following a meandering feature.

4 PREFLIGHT PLANNING

4.1 BASIC GEOMETRIC CONSIDERATIONS

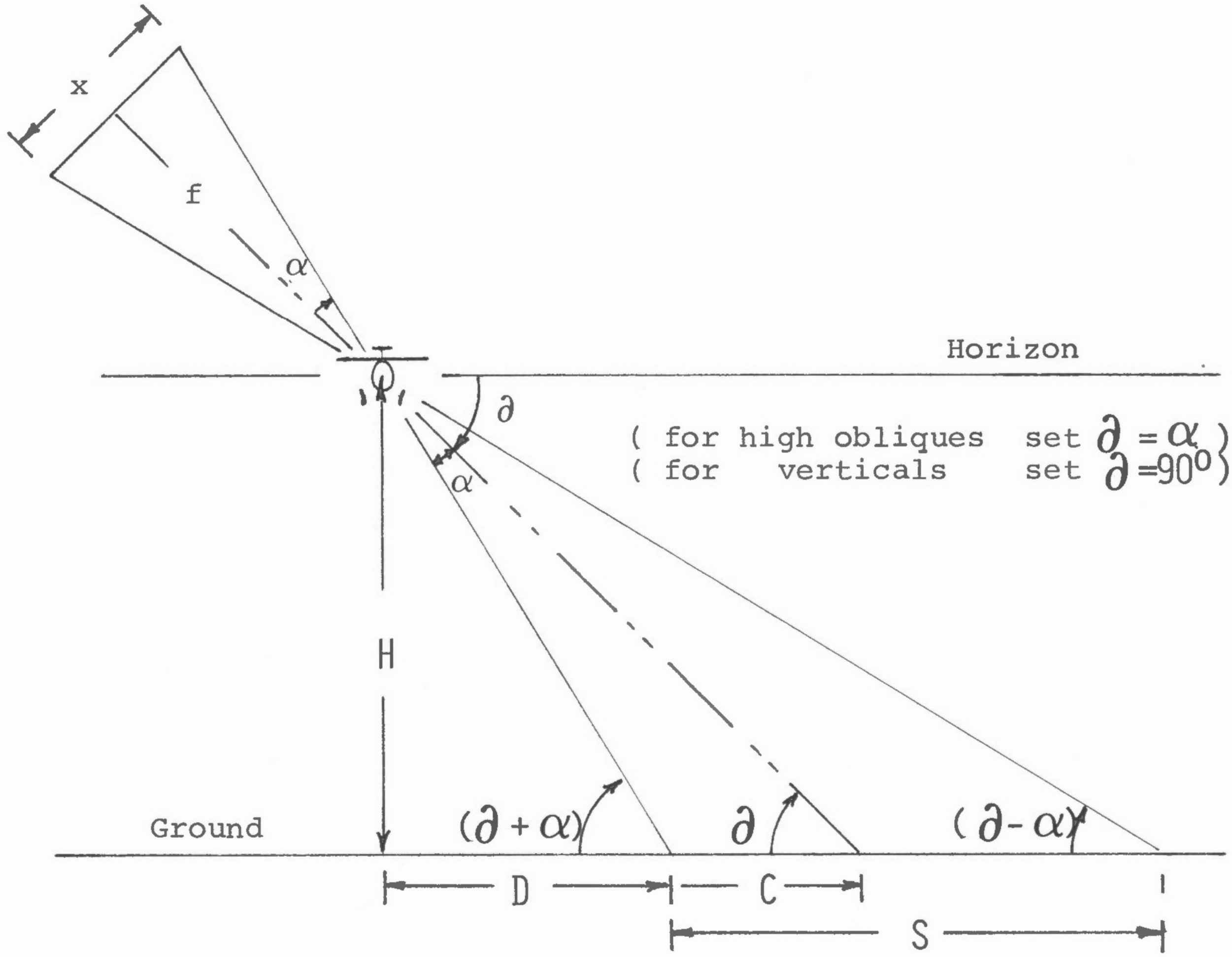
Figure 4.1 illustrates a practical and useful orientation when a standard 35 mm camera with a commonly used focal length of 50 mm is pointed at an angle of depression of 45° -- that is, the axis of the lens is directed downward at an angle of 45° below the horizontal. Since the angle of depression is 45°, it follows that the offset distance from the plumb point directly below the aircraft (nadir) to the ground point appearing in the centre of the photograph is equal to the flying height above ground, H. Some elementary trigonometry reveals that at the same time the ground distance D from the nadir to the nearest edge imaged in the photograph is 0.61H (i.e. approximately 60% of the altitude above ground) and the ground distance S covered by the shorter dimension of the 35 mm format (x = 24 mm) is 1.02H, or very nearly equal to the flying height. Thus preflight planning is very straightforward for low obliques with the 50 mm lens used at a 45° depression angle.

Tables 4.1 and 4.2 list values of semi-field angle, D/H, C/H, offset/H and scale factors for a wide range of available focal lengths for 35 mm cameras, with the format oriented horizontally (x = 24 mm), or vertically (x = 36 mm), and for 45° low obliques high obliques, and verticals. The tabulated values are expressed as decimal fractions (or multiples) of the flying height above ground. Table 4.3 lists similar factors for 70 mm photography whose format dimensions are 57 mm x 57 mm. The same format is applicable to 120 format film (2¼" (57 mm) square). The tabulated values are calculated on the basis of Fig. 4.1. Therefore, they represent critical or limiting values which include no margin for error, nor do they consider the effects of atmospheric refraction or of radial distortion that may be present to a significant degree in wide-angle lenses in particular. In practice, for flight planning purposes one should increase the tabulated minimum values of D and H by 10 to 25% to allow for imprecise navigation and "guesstimation" of the 45° depression angle. (See worked example in Section 4.2 in text and following tables.)

4.2 AN EXAMPLE

The following step-by-step procedure illustrates how the foregoing tables are used to preplan photographic coverage of a meandering river course, with stereoscopic low obliques (depression angle 45°) using a lens of 40 mm focal length on a standard 35 mm camera with the format oriented horizontally.

The area to be covered is identified on a 1:50 000 map (Fig. 4.2) as that section of the river lying between the two encircled points.



H = Altitude above ground

α = Semi-field angle = arctan $\frac{x}{2f}$

∂ = Depression angle

D = Distance, nadir to near edge of image $= H\left[\frac{1}{\tan(\partial + \alpha)}\right]$

C = Distance, near edge to centre $= H\left[\frac{1}{\tan\partial} - \frac{1}{\tan(\partial + \alpha)}\right]$

Offset = D+C = nadir to centre of photo $= H\left[\frac{1}{\tan\partial}\right]$

S = Ground coverage of photo $= H\left[\frac{1}{\tan(\partial - \alpha)} - \frac{1}{\tan(\partial + \alpha)}\right]$

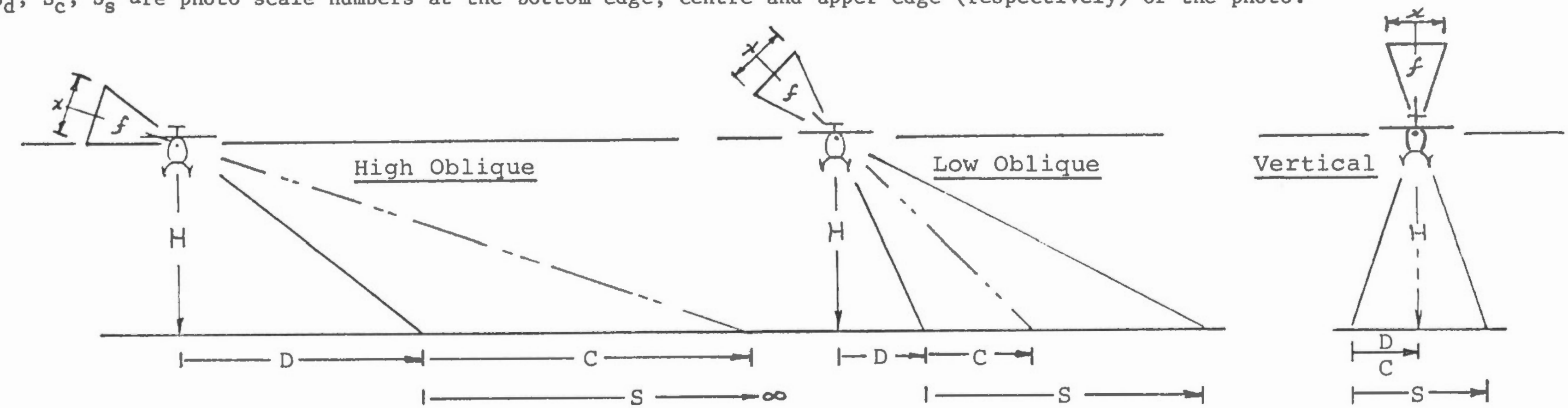
FIG. 4.1 Basic geometry of the aerial photograph —general case.

35mm CAMERA 24mm X 36mm FORMAT HORIZONTAL ORIENTATION (X = 24mm)

TABLE 4.1

		High Oblique				($\partial = \alpha$)			Low Oblique				($\partial = 45^\circ$)			Vertical	
		Ground Distance				Scale No.			Ground Distance				Scale No.			$\partial = 90^\circ$	
f (mm)	α°	D/H	C/H	Off-set /H	S/H	S_d^*/H	S_c^*/H	S_s^*/H	D/H	C/H	Off-set /H	S/H	S_d/H	S_c/H	S_s/H	S/H	S_c/H
18	33.7	.42	1.08	1.50	∞	15.3	30.5	∞	.20	.80	1.0	4.8	14.4	23.9	71.8	1.33	16.9
21	29.7	.59	1.16	1.75	"	14.6	29.3	"	.27	.73	"	3.39	13.1	20.5	47.9	1.14	14.5
24	26.6	.75	1.25	2.0	"	14.2	28.4	"	.33	.67	"	2.67	12.0	18.0	35.9	1.0	12.7
28	23.2	.95	1.38	2.33	"	13.8	27.6	"	.40	.60	"	2.10	10.8	15.4	26.9	.86	10.9
35	18.9	1.29	1.63	2.92	"	13.4	26.9	"	.49	.51	"	1.55	9.17	12.3	18.7	.69	8.71
40	16.7	1.52	1.82	3.34	"	13.3	26.5	"	.54	.46	"	1.32	8.29	10.8	15.4	.60	7.62
50	13.5	1.96	2.20	4.16	"	13.1	26.1	"	.61	.39	"	1.02	6.95	8.62	11.3	.48	6.10
55	12.3	2.18	2.40	4.58	"	13.0	26.0	"	.64	.36	"	.92	6.43	7.84	10.0	.44	5.54
85	8.0	3.47	3.61	7.08	"	12.8	25.6	"	.75	.25	"	.58	4.44	5.07	5.90	.28	3.59
100	6.8	4.11	4.23	8.34	"	12.8	25.6	"	.79	.21	"	.49	3.85	4.31	4.90	.24	3.05
110	6.2	4.53	4.63	9.16	"	12.8	25.5	"	.80	.20	"	.44	3.53	3.92	4.40	.22	2.77
135	5.1	5.58	5.67	11.3	"	12.8	25.5	"	.84	.16	"	.36	2.93	3.19	3.50	.18	2.26

*S_d, S_c, S_s are photo scale numbers at the bottom edge, centre and upper edge (respectively) of the photo.

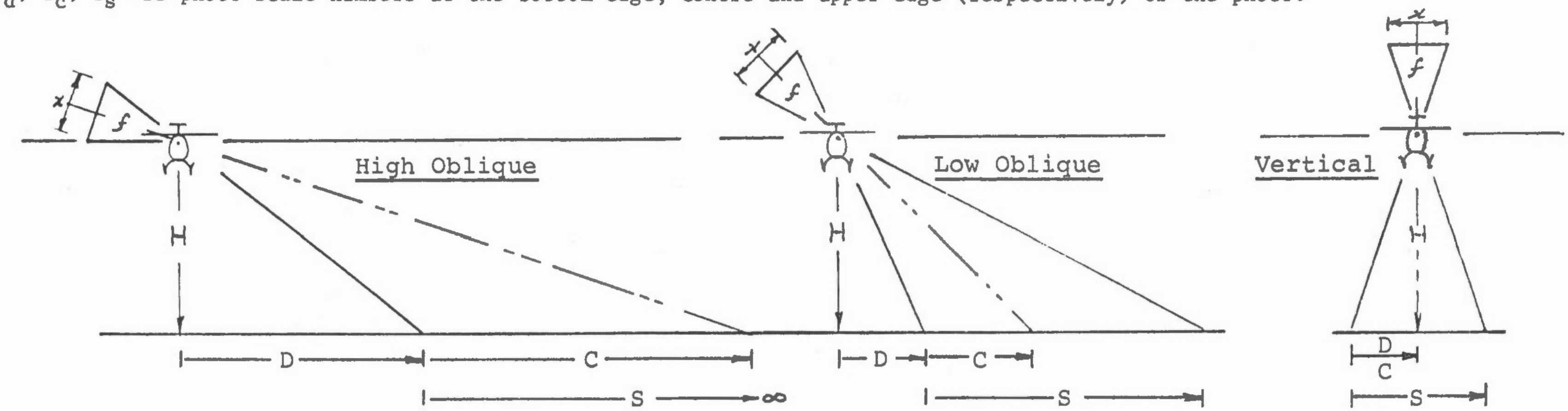


35mm CAMERA 24mm X 36mm FORMAT VERTICAL ORIENTATION (X = 36mm)

TABLE 4.2

		High Oblique				($\partial = \alpha$)			Low Oblique				($\partial = 45^o$)			Vertical	
		Ground Distance				Scale No.			Ground Distance				Scale No.			$\partial = 90^o$	
f (mm)	α^o	D/H	C/H	Off-set /H	S/H	S_d^*/H	S_c^*/H	S_s^*/H	D/H	C/H	Off-set /H	S/H	S_d/H	S_c/H	S_s/H	S/H	S_c/H
18	45	0	1	1	∞	12	24	∞	0	1	1	∞	12	24	∞	2	16.9
21	40.6	.15	1.01	1.16	"	11.6	22.3	"	.08	.92	"	12.9	11.1	20.5	144	1.71	14.5
24	36.9	.29	1.04	1.33	"	10.6	21.2	"	.14	.86	"	6.9	10.3	18	72	1.50	12.7
28	32.7	.46	1.10	1.56	"	10.1	20.1	"	.22	.78	"	4.4	9.37	15.4	43.1	1.29	10.9
35	27.2	.71	1.23	1.94	"	9.52	19.0	"	.32	.68	"	2.8	8.1	12.3	23.4	1.03	8.71
40	24.2	.89	1.34	2.23	"	9.28	18.6	"	.38	.62	"	2.3	7.4	10.8	19.6	.90	7.62
50	19.8	1.21	1.57	2.78	"	9.0	18.0	"	.47	.53	"	1.65	6.34	8.62	13.5	.72	6.10
55	18.1	1.36	1.69	3.05	"	8.9	17.8	"	.51	.49	"	1.47	5.90	7.84	11.7	.65	5.54
85	12.0	2.25	2.47	4.72	"	8.7	17.3	"	.65	.35	"	.89	4.18	5.07	6.43	.42	3.59
100	10.2	2.69	2.87	5.56	"	8.6	17.2	"	.69	.31	"	.74	3.65	4.31	5.26	.36	3.05
110	9.3	2.97	3.14	6.11	"	8.6	17.2	"	.72	.28	"	.67	3.37	3.92	4.69	.33	2.77
135	7.6	3.68	3.82	11.5	"	8.5	17.1	"	.76	.24	"	.54	2.82	3.19	3.68	.27	2.26

*S_d, S_c, S_s are photo scale numbers at the bottom edge, centre and upper edge (respectively) of the photo.

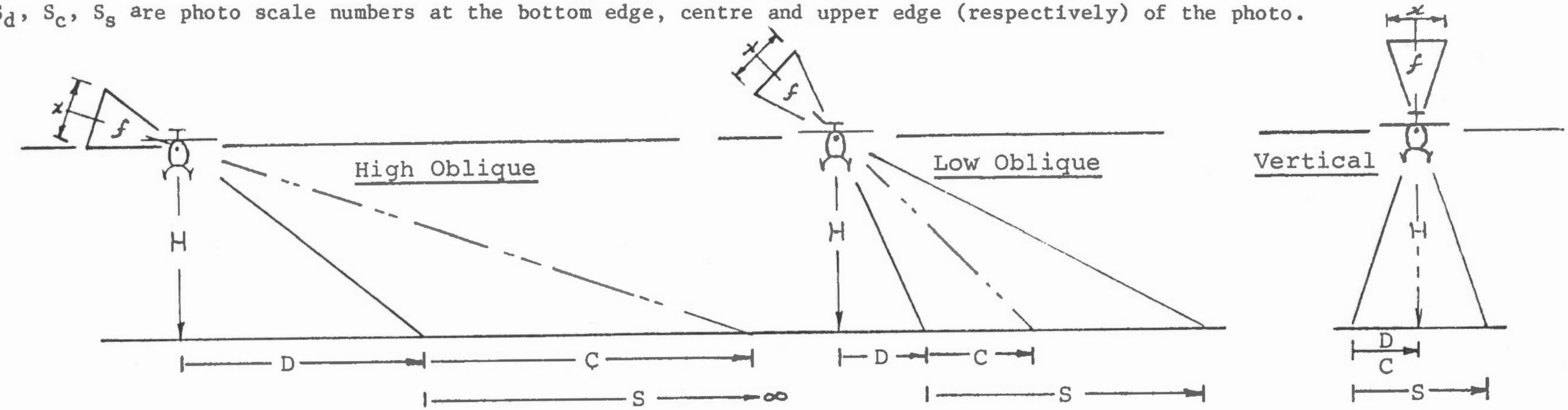


70mm CAMERA 57 mm X 57mm FORMAT (2¼" SQUARE) (X = 57mm)

TABLE 4.3

		High Oblique Ground Distance				($\partial = \alpha$) Scale No.			Low Oblique Ground Distance				($\partial = 45^{\circ}$) Scale No.			Vertical $\partial = 90^{\circ}$	
f (mm)	α°	D/H	C/H	Off-set /H	S/H	S_d^*/H	S_c^*/H	S_s^*/H	D/H	C/H	Off-set /H	S/H	S_d/H	S_c/H	S_s/H	S/H	S_c/H
38	36.9	.29	1.04	1.33	∞	6.7	13.4	∞	.14	.86	1.0	6.9	6.5	11.3	45.4	1.50	8.02
40	35.5	.34	1.06	1.40	"	6.6	13.1	"	.17	.83	"	5.8	6.3	10.8	37.5	1.43	7.62
50	29.7	.59	1.16	1.75	"	6.2	12.3	"	.27	.73	"	3.4	5.5	8.62	20.1	1.14	6.10
58	26.2	.77	1.26	2.03	"	6.0	11.9	"	.34	.66	"	2.6	4.98	7.43	14.6	.98	5.25
60	25.4	.82	1.29	2.11	"	5.9	11.8	"	.36	.64	"	2.45	4.87	7.18	13.7	.95	5.08
80	19.6	1.23	1.58	2.81	"	5.7	11.4	"	.47	.53	"	1.63	3.97	5.39	8.37	.71	3.81
85	18.5	1.32	1.66	2.98	"	5.6	11.3	"	.50	.50	"	1.51	3.80	5.07	7.63	.67	3.59
100	15.9	1.61	1.90	3.51	"	5.6	11.1	"	.56	.44	"	1.24	3.35	4.31	6.03	.57	3.05
110	14.5	1.80	2.06	3.86	"	5.5	11.0	"	.59	.41	"	1.11	3.11	3.92	5.29	.52	2.77
120	13.4	1.99	2.22	4.21	"	5.5	11.0	"	.62	.38	"	1.01	2.90	3.59	4.71	.48	2.54
150	10.8	2.54	2.73	5.27	"	5.4	10.9	"	.68	.32	"	.79	2.41	2.87	3.55	.38	2.03
250	6.5	4.33	4.45	8.78	"	5.4	10.8	"	.80	.20	"	.46	1.55	1.72	1.95	.23	1.22
303	5.4	5.27	5.37	10.6	"	5.4	10.8	"	.83	.17	"	.38	1.30	1.42	1.57	.19	1.01

*S_d, S_c, S_s are photo scale numbers at the bottom edge, centre and upper edge (respectively) of the photo.



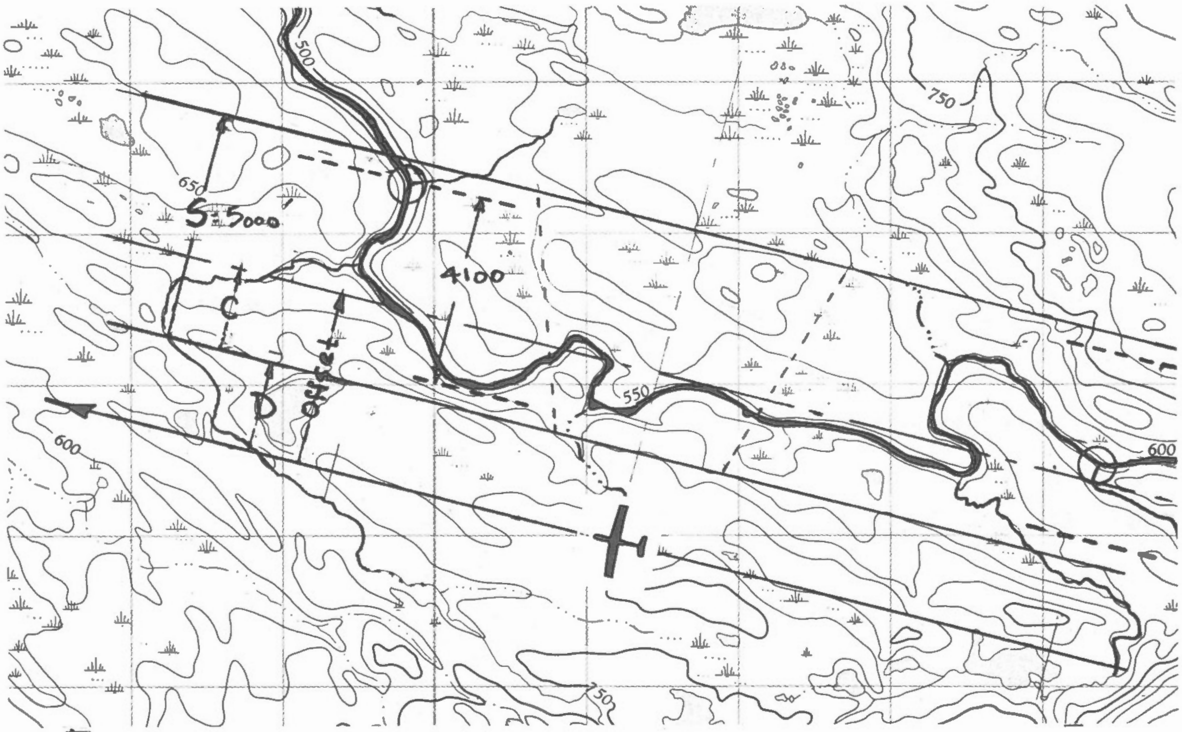


FIG. 4.2 Example of flight line and photo coverage.

(1) Draw two parallel lines completely covering the required area with minimum spacing between the lines (dashed lines, Fig. 4.2). The distance between the lines represents the minimum swath width needed to cover the area, with no allowance for error. It is wise to increase this width by at least 10%, to allow for inevitable errors in navigation and pointing the camera. An allowance of 25% would be a safer tolerance at low altitudes, particularly with an inexperienced pilot or photographer.

Increasing the swath width by 20% (for good measure) results in a width of 4920 feet, which we then round up to 5000 feet for a safe working value of S.

(2) Since $S = 5000$ feet
and $f = 40$ mm (focal length of the lens)
From Table 4.1 $S/H = 1.32$
Hence $H = 5000/1.32 = 3790$ feet above ground

(3) Since, from Table 4.1 $D/H = .54$
$D = .54 \times 3790 = 2050$ feet

(4) Since, from Table 4.1 $C/H = .46$,
$C = .46 \times 3790 = 1740$ feet

(5) The offset from the centre line is the sum of $D + C$,
i.e., Offset = 3790 feet
This is of course equal to H, since the depression angle is 45^o.

(6) The photo scale number along the bottom edge of each photo is
$S_d/H = 8.29$ (from Table 4.1)
Hence $S_d = 8.29 \times 3790 = 31,420$ feet
i.e., the photo scale along the lower edge is 1:31420.

(7) Along the centre line, photo scale number is
$S_c/H = 10.8$ (from Table 4.1)
$S_c = 40,930$ feet (scale is 1:40930)

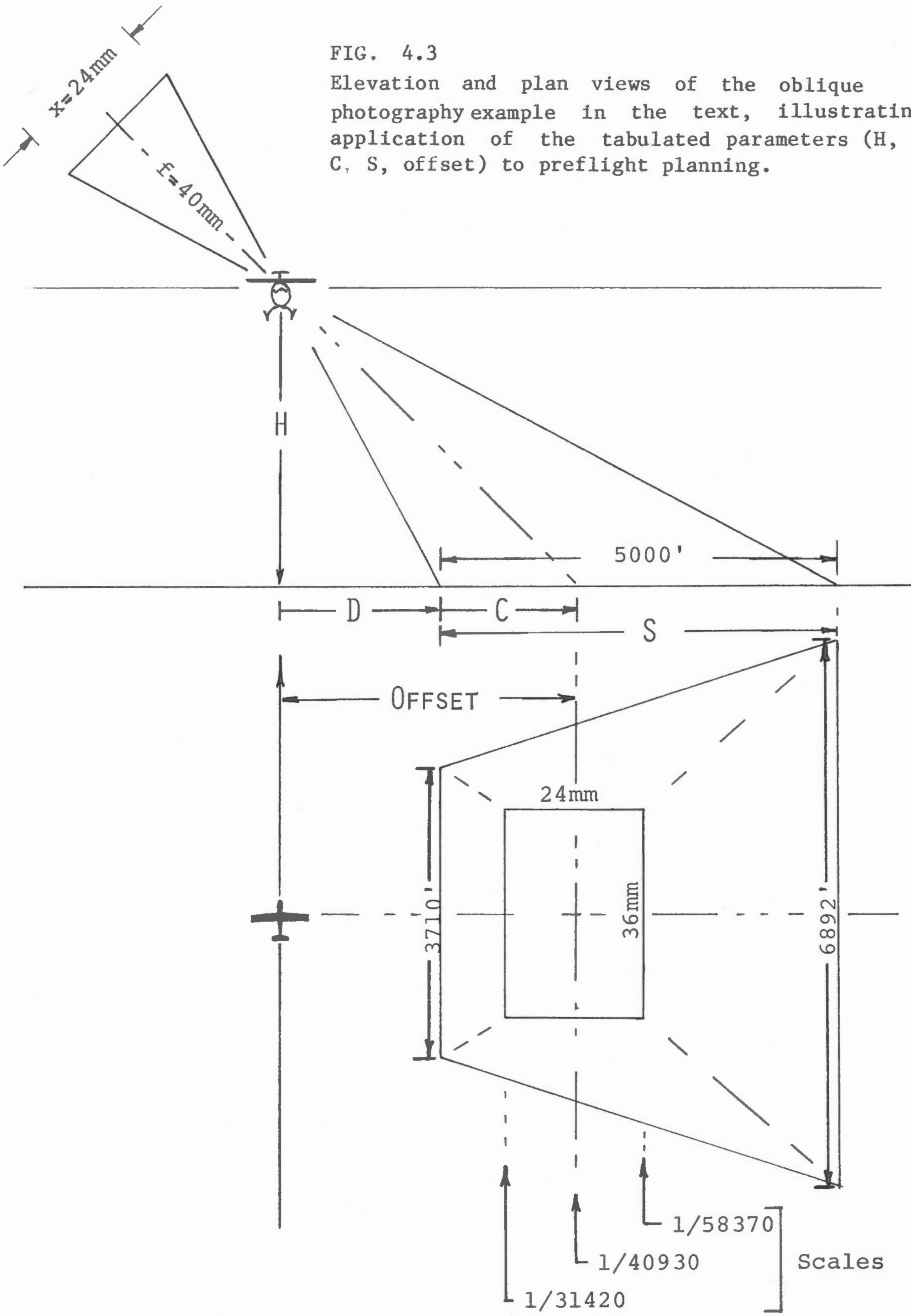
(8) Along the upper edge, scale number is
$S_s/H = 15.4$ (from Table 4.1)
from which $S_s = 58,370$ feet (scale is 1:58370).

Figure 4.3 illustrates this example, to scale, with both plan and elevation views of the situation.

(9) To secure full stereoscopic coverage, we must have at least 50% overlap of successive photographs along the lower edge. With the horizontally oriented format, that edge is 36 mm in length. From (6) above, the corresponding length on the ground is

$$\frac{36 \text{ mm} \times 31\,420}{1000} \text{ metres} \times 3.28 = 3710 \text{ feet}$$

FIG. 4.3
Elevation and plan views of the oblique photography example in the text, illustrating application of the tabulated parameters (H, D, C, S, offset) to preflight planning.



Hence we must take a photograph every 3710/2 = 1855 feet along the flight path.

(10) Since the total path length measured on the map is 16,000 feet, we shall require a minimum of nine frames to secure the required coverage, plus one additional frame at the beginning and end of the study area.

(11) If we assume a ground speed of 90 mph (132 ft/sec), then we shall require a photograph every 14 seconds (1855 ft / 132 ft / sec = 14 sec).

(12) If larger scale stereo photography of the same stretch of river were required, it would probably be advisable to divide it into several segments, treating each straight-line segment as above.

Table 4.4 is a step-by-step work sheet to facilitate the foregoing determinations and to provide a record for subsequent reference. It may be photocopied or otherwise reproduced in quantity to furnish a separate record for each site.

(It is reasonable to ask why, in this metric age, distances are expressed in feet rather than in metric units. The reason is that aircraft altimeters are calibrated in terms of feet, and by international agreement are likely to remain so for the immediate future.)

5 BIBLIOGRAPHY

5.1 INTRODUCTION

The preceding sections give an overview of the various factors involved in the acquisition of oblique aerial photography such as cameras, films, exposure, storage, coverage and scales.

The following annotated bibliography has been prepared as a guide to specific applications of small-format photography. Technical data on the design, implementation and analysis of small-format (35 mm and 70 mm) aerial photography are also included in the various reports listed.

5.2 DESCRIPTION

Anderson and Wallner's bibliography (1978) and the reports of Sherstone (1978) and Dalman (1977) provided the basis for the original bibliography document seach. Other references were located through a literature search by the CCRS Remote Sensing Online Retrieval System (RESORS). In all cases, a report was studied and placed into one of two sections, 35 mm or 70 mm film formats. Included in the first section (35 mm) are four categories along with an indication of the amount of detail and comprehensiveness of each document for categories B, C and D:

TABLE 4.4

Preflight Planning Work Sheet for Oblique Aerial Photography

(For use with accompanying tables)

AREA Minimum swath width: __________ feet

CAMERA

Format: Dimensions ____ x ____mm Orientation: Horizontal/Vertical (select appropriate table)

Focal length ____mm Semi-field angle, = ____ degrees (from table)

Depression angle, = ____ degrees

HEIGHT TO FLY

S = ______ feet (incl. tolerances). From table, $^{S}/_{H}$ = ____, H = _____ feet

Distance, nadir to near edge of oblique photo

From table, $^{D}/_{H}$ = ____, D = ____ feet

Distance, nadir to centre line of oblique photo

From table, $^{C}/_{H}$ = ____, C = ____ feet

____

OFFSET D + C = ____ feet

COVERAGE

Length of format, ____mm (from (1))

From table, $^{S_d}/_{H}$ = ____ S_d = ____

Length on ground (____mm x ____) x .00328 = _____ feet

Gain per frame for 50% overlap

(____)/2 = ____ feet per frame

Total line length _____ feet

Mim. no. of frames = ____ feet/_____ feet per frame = _____ frames

Aircraft Ground Speed ____ mph: ____ ft/sec. Photographs required _______ seconds apart.

(A) General (bibliographies, miscellaneous technical information)

(B) "Mainly" Techniques (how to utilize 35 mm aerial photography)

(C) "Mainly" Applications (applied uses and results of 35 mm aerial photography)

(D) Both Techniques and Applications

The comprehensiveness of each document in categories B, C and D has been rated subjectively on a scale of 1 to 4, with 4 indicating maximum amount of detail. For example, a report with a D.4 index should provide a potential user with sufficient detail on how to obtain aerial photographs with a 35 mm camera, and also furnishes examples and results of a particular study.

Since the bibliography is mainly concerned with 35 mm photography 70 mm format is included but the literature search was not as extensive as for 35 mm reports. Key index E identifies publications which contain material on techniques and applications of 70 mm aerial photography.

5.3 BIBLIOGRAPHIC KEY for REFERENCES

This section includes a summary (by report number) of references in each subarea as a further aid in using the bibliograpy.

35 mm Format

A - General (Documents) 3, 4, 8, 15, 29, 37, 38, 70.

B - Mainly Techniques: 5, 11, 12, 13, 39, 44, 48, 49, 50, 51, 55, 56, 57, 61, 64, 66, 67, 68 71, 72, 73.

C - Mainly Applications: 9, 16, 17, 18, 19, 21, 24, 25, 31, 34, 35, 40, 41, 45, 58, 59, 65, 74.

D - Techniques and Applications: 2, 7, 10, 14, 20, 23, 27, 32, 33, 36, 53, 54, 60, 69, 75.

70 mm Format

E - 70 mm aerial photography and applications (selected references). 1, 4, 5, 6, 12, 15, 22, 24, 26, 28, 30, 39, 42, 43, 46, 47, 51, 52, 56, 57, 62, 63, 65 66, 67, 69.

Example of Reference

Ref. No. ______ Author. Date. Title ________________ ________________. Source or Publisher ____________________________. RESORS No. (if applicable). Key index (e.g., D.4)

5.4 DOCUMENTS AND SUMMARIES

1 AIRD, W J. 1977. Remote Sensing: Airborne Mission Planning. Environmental Protection Service, Department of the Environment, EPS-6-EC-77-2, Ottawa. 201 p. RESORS No. 1011922. E.

The CCRS aerial sensor systems and the Environmental Protection Service's Light Aircraft Camera System (LACS) are presented. The Interdepartmental Committee on Aerial Surveys is outlined along with its functions. Charts and graphs are provided on most aspects of aerial mission planning, weather, flying constraints, and photographic coverages. The report also includes a basic coverage of remote sensing technologies.

2 ALFÖLDI, T.T. 1972. Remote Sensing in the Arctic for Engineering Purposes. B.A. Sc. Thesis. University of Toronto, Toronto. 51 p. RESORS No. 1018498. D.3.

This thesis, while slightly out of date in regard to specific film types and costs, provides good documentation on cameras, aircraft selection and exposures. The report deals specifically with 35 mm photography and discusses its selection over 70 mm. The entire procedure, from obtaining film to taking photos, having them processed and then analyzed, is outlined in a logical straightforward manner.

3 ANDERSON, W.H. and K.J. KROEGER. 1980. Selected Readings in Agricultural Applications of Small-Format Aerial Photography. NASA/EROS Data Centre. 87 p. RESORS Nos. 1026474-1026493; 1022714, 1008067 and 1019390. A, E.

"This collection of material has been assembled in response to a growing interest in the use of low-cost, small-format aerial photography in the management of agricultural resources. Together, these articles serve to document the prevailing level of interest in the subject and provide an insight as to what can reasonably be expected from the use of this powerful agricultural management tool" (from the Introduction of this report).

4 ANDERSON, W.H. and F.X. WALLNER. 1978. Small Format Aerial Photography: a Selected Bibliography. A report prepared for Geologic Survey Sioux Falls. 7 p. RESORS No. 1019390. A.

Prepared by Technicolour Graphic Services Incorporated, this document provides a short annotation with each article mentioned.

5 Australian Department of Agriculture. 1974. Tables for Small Format Aerial Photography in Forestry. Prepared by F.P. van der Duys, Forestry & Timber Bureau, Canberra. 25 p. RESORS No. 1020444 B.4, E.

Charts and explanations on using 35 mm and 70 mm photography at various altitudes with different focal length lenses are presented.

6 BENTON, A.R. et al. 1976. Low-cost Aerial Photography for Vegetation Analysis. Journal of Applied Photographic Engineering, 2(1) Winter 46-49. RESORS No. 1010112. E.

This report covers several examples of vegetation studies using colour and colour IR (CIR) film in two 70 mm cameras (Hasselblads). While no quantitative data are given on exposures, flying parameters, etc., the authors mention the colour variation in CIR film. A list of guidelines is provided on flying, film purchases and storage.

7 California State Water Resources Control Board. 1978. Low altitude Aerial Surveillance for Water Resources Control Manual of Practice. Prepared by G.W. Fraga. 67 p. RESORS No. 1023060. D.4.

Discussions are presented in layman terms on SLR camera selection, films, filters, lenses and aircraft selection. Mission planning and execution with examples are clearly outlined. The report is an excellent guide for potential users of small-format photography for water resource studies. See also Ontario Ministry of the Environment (1979).

8 CLEGG, R.H. and J.P. SCHERZ. 1975. A Comparison of 9 inch, 70 mm and 35 mm Cameras. Photogrammetric Engineering and Remote Sensing, 41(12): 1487-1500. RESORS No. 1008067. A.

The three formats are compared for resolution, photointerpretation potential, metric accuracy and cost for obtaining simultaneous colour and CIR photography for environmental mapping purposes.

9 DALMAN D.W. 1978. Supplementary Aerial Photography (SAP) in the Planning and Management of National Parks. Proceedings of the Fifth Canadian Symposium on Remote Sensing, Victoria: 391-395 RESORS No. 1018778. C.1.

Several studies were done to demonstrate the flexibility and applicability of SAP in assessing environmental damage and visitor population in national parks. From the work done, implementation of SAP techniques to park planning and management followed.

10 DALMAN, D.W. 1977. The Utility of Supplementary Aerial Photography in the Management of Natural Resources in National Parks: Case Study Point Pelee National Park Ontario. A report prepared for Parks Canada, Ottawa. 327 p. RESORS Nos. 1018942 - 1018953. D.4.

A thorough overview of remote sensing sensors and applications is presented. Complete aspects of SAP, such as pilot and aircraft selection, cameras, films, filters, approach to SAP mission planning, and flight plans, are covered and well documented. General interpretation techniques for analyzing remote sensing data are carefully outlined. The case study at Point Pelee specifically considers 1) census of visitor populations - their movements and locations; 2) assessment of vegetation stress; 3) the effect on the Pelee Marsh of nutrient influxes from farmlands; 4) the monitoring of geomorphic processes in the coastal zone; 5) advantages and limitations of SAP to natural resource management problems. See also Zsilinszky and Graham (1976).

11 Eastman Kodak Ltd. 1971. Photography from Lightplanes and Helicopters. Publication No. M-5, Eastman Kodak, Rochester. 25 p. B.3.

Many sample photographs demonstrating different reasons for using aerial photographs are included in this Kodak publication. Discussions on subject contrast, lighting, motion, exposures, films, filters, mission planning, aircraft and pilot selection, and vertical/oblique scale calculations are clearly presented.

12 FAGERLUND, E. and M. GUNNERHED. 1975. Systems Analysis and Development of a Mini-RPV for Reconnaissance (the "Skatan" project) FDA. Report D30021-E1, National Defence Research Institute, Stockholm. 50 p. RESORS No. 1022078. B.2, E.

Small cameras were mounted in remotely piloted small model aircraft. Film development, navigation problems and solutions are discussed. Cost limitations are also outlined. A version in Swedish, FDA Report C 30057-E1 (Gunnerhed, 1975), is available (RESORS No. 1022079) and it includes examples of photography.

13 FISHER, J.J. and E.Z. STEEVER. 1973. 35 mm Quadri-camera. Photogrammetric Engineering, 39 (6): 573-578. RESORS No. 1003291. B.2.

An inexpensive 4-camera system was developed around the Robot 35 mm camera. The Robot has a viewfinder, interchangeable lenses and a stainless-steel spring motor to give up to 50 exposures per winding. The mount holding the cameras can be hand-held at vertical or oblique angles from a high wing aircraft. Comparisons of other quadricamera systems of 70 mm and 35 mm formats are provided but there is no detail on use of filters, films and exposures.

14 GARNER, J.B. and L.J. MOUNTAIN. 1978. The Potential of 16 mm and 35 mm Time Lapse Photography taken from a Helicopter for Traffic Studies at Complex Intersections. Photogrammetric Record 9 (52): 523-535 (October 1978). RESORS No. 1017692. D.2.

Time lapse photography from a hovering helicopter by a 35 mm Robot camera and a 16 mm Vinten camera was evaluated for traffic studies. Comparisons of film types, cameras and film sizes are provided.

15 GIANNELIA, A.M. 1980. An Airborne Camera Management System. Photogrammetric Coyote 3(4) (December 8-9). 1 p. RESORS No. 1026735. A, E.

An overview of the camera systems utilized by the Ontario Centre for Remote Sensing (OCRS) (see Zsilinszky, 1979) and The Airborne Remote Sensing Group is presented. The heart of the system is a microcomputer, which acts as an intervalometer, a drift meter and a controller of other camera functions. Various combinations of cameras (35 and 70 mm) and other sensors can be used in the flexible camera mounting system. A video camera system is also used for navigation and computer monitored drift control.

16 GRUMSTRUP, P., and M. MEYER. 1977. Applications of Large Scale 35 mm Colour and Colour Infrared Aerial Photography to the Analysis of Fish and Wildlife Resources on Disturbed Lands. IAFHE-RSL Report 77-3, St. Paul. 70 p. RESORS No. 1011324. C.3.

Abandoned strip mines in Virginia were photographed by a 35 mm camera to assess the applicability of such photography to planning surface reclamation and management. The camera system used is described in Meyer and Grumstrup (1978). Benefits, costs, limitations and interpretive techniques are presented. The analysis of each site with acreage estimates for various land classes is provided.

17 GUSTAFSON, R.J., et al. 1979. Land Lost from Production under and around Electrical Transmission Line Structures. Presented at the Joint Meeting of the American and Canadian Societies of Agricultural Engineers and Engineering, Winnipeg. 16 p. RESORS No. 1021844. C 2.

A Nikon camera with a 250-exposure magazine was mounted in a port of a Cessna (206) aircraft. The photographic scale of 1:5000 was adequate to record cropping patterns and variations in farming procedures around electrical transmission towers. See also Gustafson (1978).

18 GUSTAFSON, R.J., et al. 1978. Report of an Investigation of Electric Power Transmission and Agriculture Compatibility in the MAPP Region. IAFHE-RSL Miscellaneous Publication 1713, St. Paul. 287 p. RESORS No. 1019394. C.2.

A short description of the camera system (Nikon), techniques and aircraft is provided in the report. Most of the report deals with all aspects of electric power transmission lines and their interaction with agricultural practices. Photography was vertical, through a camera bay (16 inch diameter) in a Cessna 206.

19 GUSTAFSON, T.D. and M.S. ADAMS. 1973. Remote Sensing of _Myriophyllum_ _spicatum L_ in a Shallow Lake. In _Remote Sensing and Water Resources Management_, Editors K.P.B. Thomson, R.K. Lane, S.C. Csallany, Urbana. 387-391. RESORS No. 1004071. C.1.

Two 35 mm cameras with colour and CIR film were used to acquire photographs of _Myriophyllum_ beds. The photos were used to visually interpret biomass and stem density classes. Optical density techniques were used to quantify biomass and this was found superior to visual techniques.

20 HALL, W.B. and T.H. WALSH. 1977. Color Oblique Stereo Aerial (COSA) Photographs for Planning Rapid Geologic Reconnaissance and Other Types of Geologic Programs. Wyoming Geological Association Guidebook: 751-760. RESORS No. 1017387. D.3.

Advice is provided on camera types, films, lenses, exposures and framing intervals for COSA photos. Several examples of interpreted images are included. See also Walsh and Hall (1978).

21 HARRIS, J.W.E., and A.F. DAWSON. 1979. Evaluation of Aerial Forest Pest Damage Survey Techniques in British Columbia.

BC-X-198, Environment Canada, Forestry Service, Victoria. 22 p. RESORS No. 1020374. C.3.

Several examples compare aerial sketch-mapping and aerial photographic techniques. The authors feel that small format photography (35 or 70 mm) can often supplement aerial sketching when the cost of a complete aerial photographic survey could be prohibitive.

22 HARRIS, J.W.E., et al. 1978. Detecting Windthrow, Potential Focii for Bark Beetle Infestation by Simple Aerial Photographic Techniques. Bi-monthly Research Notes, 34 (5) Sept/Oct. Environment Canada, Forestry Service, Victoria. 1p. RESORS No. 1020375. E.

This short overview covers intial experiments using a hand-held 70 mm camera (Hasselblad) for detection of windthrown trees. Results indicated the technique had promise but needed some further improvements.

23 HARRIS, J.W.E. 1971. Aerial Photography (35 mm): Aid to Forest Pest Surveys. Canadian Forestry Service, Bi-monthly Research Notes 27 (3): 20. RESORS No. 1019388. D.3.

Two hand-held 35 mm cameras (Asahi Pentax) operated simultaneously were used to acquire photos for pest detection and tree damage assessment. Various types of aircraft were used to obtain both vertical and oblique images. Films used are no longer available and have been replaced by higher quality films. The 35 mm format provided some interpretation problems but generally was satisfactory.

24 JOHNSON, R.E. and J.N. MULVANEY. 1978. The Use of Low-level Oblique Aerial Photographs for Environmental Management in Elliot Lake Area. Proceedings of the Fifth Canadian Symposium on Remote Sensing, Victoria: 396-398. RESORS No. 1018779. C.1, E.

Hand-held cameras (Hasselblad and Nikon) were used to evaluate the impact of increased mining activity in the Elliot Lake area. High and low stereo obliques from helicopters recorded examples of tailing dam leakage and tailing spills. The potential value of aerial photographs as legal evidence in pollution court cases is also briefly discussed.

25 KIEFER, R.W. 1970. Effects of Date of Photography on Airphoto Interpretation Using Color and Color-infrared Films. In the Proceedings of the International Symposium on Photography and Navigation, Columbus: 100-117. RESORS No. 1019385. C.2.

Soil, crop growth patterns and flood damage were recorded at various times in the summer and fall using two 35 mm cameras (Minolta). Some information is provided on exposures but the main volume of the work is concerned with the analysis of the multitemporal photographs. See also Milfred and Kiefer (1976).

26 KIPPEN, F.W., and L. SAYN-WITTGENSTEIN. 1964. Tree Measurements on Large-scale Vertical, 70 mm, air photographs. Environment Canada, Forest Research Branch (No. 1053), Ottawa. 16 p. RESORS No. 1021843. E.

A Vinten 70 mm camera with a 12-inch lens was used for panchromatic winter photographs at a scale of 1:1200. The accuracies of species identification, height, crown width and dbh (diameter at breast height) measurements are discussed.

27 KLEIN, W.H. 1970. Mini-Aerial Photography Journal of Forestry, August: 475-478. RESORS No. 1019386. D.3.

A discussion of 16, 35 and 70 mm film formats, their advantages, limitations and applications, is presented. The main thrust of the paper is the use of a 35 mm camera (Miranda) from a Cessna aircraft, and the interpretation of the film on a stereo plotter designed for 35 mm. A portable stereo viewer was also developed for field use.

28 LYONS, E.H. 1967. Forest Sampling with 70 mm Fixed Air-base Photography from Helicopters. Photogrammetria, 22 (1967): 213-231. RESORS No. 1021846. E.

Cameras mounted on a boom on a helicopter were used to secure photographs of sample plots. These photos were analyzed to determine tree volume length, dbh and species identification, which were compared to ground measurements. The results were as good as ground measurements and were significantly cheaper. Some data is provided on exposures, camera limitations and flying heights.

29 MacDOUGALL, N. 1978. Flight Notes: General Aviation Comes through. Canadian Aviation, December: 12. A.

Coverage of the Ontario Ministry of the Environment's (OME) operation "Skywatch" is provided. "Skywatch" is a volunteer, airborne pollution-monitoring program operated by OME. See also Ontario Ministry of the Environment (1979).

30 MARLAR, T.L., and J.N. RINKER. 1967. A Small Four-camera System for Multi-emulsion Studies. Photogrammetric Engineering, 33 (11): 1252-1257. RESORS No. 1002834. E.

The camera system developed by Ulliman et al. (1970) is based on the design described in this report. Photographs, schematics, costs of the cameras and their mounts are provided. Only two cameras in the mount provide stereo coverage because their film advances in the same direction as the flight line. The film from the other two cameras must be cut and transposed to provide stereo coverage.

31 MEYER, M.P., and P.D. GRUMSTRUP. 1978. Operating Manual for the Montana 35 mm Aerial Photography System - 2nd Revision. IAFHE-RSL Institute of Agriculture, Forestry and Home Economics, Remote Sensing Laboratory, University of Minnesota, Research Report 78-1, St. Paul. 62 p. RESORS No. 1016964. C.4.

This document specifically deals with Nikon F2 or Canon F-1 camera systems to be mounted in the window of a high wing light aircraft. General information is available on filters, films, time of photography and pre-, during- and post-flight check lists. Charts for photographic scale vs. lenses and altitude and for framing intervals are provided. Also included are guidelines for processing the films, storing the film and interpreting techniques. Applications and some limitations of 35 mm photography are discussed.

32 MEYER, M.P. et al. 1975. 35 mm Aerial Photograph Applications to Wildlife Population and Habitat Analysis. Parts 1 and 2. Proceedings of the Workshop on Remote Sensing of Wildlife, Quebec. 12 p. RESORS No. 1014127. D.3.

Using the camera system outlined in Documents 31 and 33, a census was conducted on Canada geese, canvasbacks and coots in Part 1 of the study Telephoto lenses were used to increase count accuracy. Information on exposure, films and flying conditions are included. Flights took place under various types of cloud conditions in Parts 1 and 2.

Part 2 of the study was the development of a cost-effective 35 mm aerial photography system (see Scheierl and Meyer, 1976). This system was again based on Documents 31 and 33 and was designed for easy, practical use by field personnel with minimal aerial photographic experience. Part 2 was concerned with habitat analysis in Alaska while Part 1 dealt with lakes in Minnesota.

33 MEYER, M.P., and B.H. GERBIG. 1974. Remote Sensing Applications to Forest and Range Resource Surveys and Land Use Classification on the Motta District, (BLM), Montana. IAFHE-RSL Report No. 74-1, St. Paul. 36 p. RESORS No. 1010612. D.2.

This report documents the development of a 35 mm camera system, the use of small-scale 9 x 9 CIR photography and the use of Landsat imagery for field-level monitoring, large-area resource planning and extensive resource survey. The 35 mm camera system (Minolta) was the predecessor of the system in Document 31. Photography scales, films and formats are listed but no guidance on exposures is provided. This document should be used in conjunction with Document 31.

34 MILFRED, C.J. and R.W. KIEFER. 1976. Analysis of Soil Variability with Repetitive Aerial Photography. Soil Science Journal, 40 (4) July/August: 553-557. RESORS No. 1012484. C. 2.

This report utilizes the same camera system and techniques as in Kiefer (1970). The authors found that small-format aerial photography helped to improve the description, evaluation and interpretation of soil mapping units. Repetitive photography was useful to identify land use and crop type and for monitoring environmental dynamics such as flooding and erosion.

35 MILLER, W.A. 1974. The Application of the 35 mm Aerial Photography System to Resource Management on National Lands. Western Interstate Commission for Higher Education, Boulder. 50 p. RESORS No. 1019067. C.3.

The work done is with the camera system described in Meyer and Grumstrup (1978) (first edition using a Minolta camera rather than the second edition's Nikon). Various examples of range, wildlife habitat, forest and watershed management are included and evaluated. The main limitations of the system came from organization, field application and interpretation problems at the district level.

36 MINTZER, O.W. and D. SPRAGG. 1978. Mini-format Remote Sensing for Civil Engineering. Transportation Engineering Journal, November: 847-858. RESORS No. 1019393. D.2.

Two Nikon cameras were mounted side by side for hand-held photography to monitor strip mine reclamation and landslide erosion and for location of abandoned mines and field tiles. A survey of other authors' works is also included. Exposure and filter/film combinations are discussed.

37 MOSER, J.S. and N.L. FRITZ 1975. Films for Small-format Aerial Photography. Proceeding of the SPIE, Volume 58: Effective Utilization and Application of Small-format Camera Systems, Anaheim: 31-37. RESORS No. 1010599. A.

This report is an overview of various black and white and colour high-resolution "Special-Order" (SO) Kodak films. The resolving power, spectral sensitivities and sensitometric curves of these films are included.

38 MYERS, B.J. 1977. Development in the Use of Colour Aerial Photography in Australian Forestry. Australian Forestry, 40 (4): 268-273. RESORS No. 1020405. A.

This report covers various studies using 70 and 35 mm photography as a data base. Information on scales and some cost figures are provided.

39 MYERS, B.J. and F.P. van der DUYS. 1975. A Stereoscopic Field Viewer. Photogrammetric Engineering and Remote Sensing 41 (12): 1477-1478. RESORS No. 1019391. B.2.

The design and specifications of a portable stereoscopic viewer for 35 mm and 70 mm films are outlined. The unit uses no batteries or awkward viewing arrangements to illuminate the transparencies.

40 NASH, M.R., M.P. MEYER, and D.W. FRENCH. 1977. Detection of Dutch Elm Disease using Oblique 35 mm Aerial Photography. IAFHE-RSL, Report No. 77-9, St. Paul. 16 p. RESORS No. 1015343. C.1.

A motorized 35 mm camera (Nikon) was used to produce obliques through a camera port in the belly of an aeroplane. Positive normal colour slide film and CIR film with photo scales of 1:4200 to 1:8400 were used. The images were interpreted monoscopically and stereoscopically and the best results were on CIR film.

41 Ontario Ministry of the Environment. 1979. Operation Skywatch. First edition. Information Services Branch, Toronto. 79 p RESORS No. 1020863. C 3.

This report, along with the manual from the California State Water Resources Control Board (1978), should enable a potential novice user to rent an aircraft with a pilot and use them and a camera effectively to obtain good quality hand-held photographs of various environmental pollution problems In this document, the legal aspects of photographs of pollutant sources are also discussed. See also MacDougall (1978).

42 POKRANT, H.T. 1979. Supplementary Aerial Photography in Manitoba: History, Equipment and Uses. Manitoba Remote Sensing Centre, Winnipeg. 16 p. RESORS No. 1021420. E.

A history and description of the Hasselblad 70 mm camera system is profiled. Technical problems encountered and their solutions along with several applications are described. Cost comparisons between 9 x 9, 70 mm and 35 mm systems are also included.

43 RHODY, B. 1977. A New, Versatile Stereo-camera System for Large Scale Helicopter Photography of Forest Resources in Central Europe. Photogrammetria, 32: 183-197. RESORS No. 1019392. E.

Costs, some technical plans and considerations are included in this report on the use of one 70 mm camera (Hasselblad) mounted on each side of a helicopter to produce stereo images. Some results on the quality of the interpretation are discussed.

44 RINEHARDT, G.I. and J.P. SCHERZ. 1972. A 35 mm Aerial Photographic System. University of Wisconsin, Institute for Environmental Studies Remote Sensing Program, Madison, Report No. 13. 13 p. Also in Proceedings of the 38th Annual Meeting ASP, Washington: 571-579. RESORS No. 1004738. B.1.

Two Nikon motorized cameras were used for hand-held and mounted aerial photography. The system was elaborate, utilizing an intervalometer, large (250) exposure magazines, power packs and various lenses. Film processing is discussed generally but more detail is provided on indexing storage systems and viewing equipment for 35 mm film. See also Scherz et al. (1975).

45 RUKAVINA, N.A. 1978. Air-Photo Reconnaissance, Great Lakes' Shorelines. Technical Note 78-12, Hydraulics Research Division, Environment Canada, Burlington. 24 p. RESORS No. 1020419. C.1.

An extensive photographic record of portions of the shores of Lakes Erie, St. Clair, Huron (including Georgian Bay), Superior and connecting channels is included in this report. The report shows how effectively 35 mm photography can be used for baseline geographic data.

46 SABINS, F.F. 1973. Aerial camera mount for 70 mm stereo. Photogrammetric Engineering 39 (6): 579-582. RESORS No. 1003292. E.

A camera mount was designed for a Hasselblad camera to allow it to be used in several different types of aircraft (Cessna 206, Pilatus Porter, deHavilland's Beaver or Otter). Specifications for the mount are included as is

some guidance on flying techniques for aerial photographic missions.

47 SAYN-WITTGENSTEIN, L. and A.H. ALDRED. 1969. A Forest Inventory by Large Scale Aerial Photography. Pulp and Paper Magazine of Canada, 70 (Sept.-Dec.): 92-95. RESORS No. 1010974. E.

Two 70 mm cameras (Vinten) in a vertical mount were used to conduct a tree inventory in the Mackenzie River Delta. Photographs were taken of sample plots. Tree heights were measured from the photos and then correlated to ground samples to provide more accurate volume estimates.

48 SCHANTZ J.A. 1975. U.S. Navy High Resolution Small Format Camera System. Proceedings of the SPIE, Volume 58: Effective Utilization and Application of Small-Format Camera Systems, Anaheim: 8-14. RESORS No. 1014669. B.1.

Special apochromatic lenses are part of a camera system (Leicaflex) designed by Ernst Leitz Canada Limited. Data are provided on the lenses along with MTF (modulation transfer function) curves for the camera system and a precision enlarger. Sensitometric curves are provided for various high-resolution black-and-white films.

49 SCHEIERL, R. and M.P. MEYER. 1976. Evaluation and Inventory of Waterfowl Habitats of the Copper River Delta, Alaska, by Remote Sensing. IAFHE-RSL Report No. 76-3, St. Paul. 47 p. RESORS No. 1017073. D.1.

This report is the final report of Meyer et al. (1975) Part 2. It utilizes the camera system described in document 33. From the abstract: "The 35 mm aerial photography system was deemed to be practical as a field level resource monitoring tool from the standpoint of: (1) resource data collection capabilities, (2) modest cost of operation, and (3) operational feasibility under normal (often adverse) field and weather-conditions."

50 SCHERZ, J.P. R. SINGH, and G. RINEHARDT. 1975. 35 mm Photography, Viewing and Cataloguing System for Remote Sensing Data. The Canadian Surveyor, 29 (2) (June): 201-208. RESORS No., 1006330. B.2.

Standard 35 microfilm viewers and storage units are used to interpret and store data taken from a 35 mm aerial camera system (Nikon). The cataloguing system is applied not only to 35 mm data but also to 70 mm, 23 cm, thermal IR and ground survey data. A colour microdensitometer was used to analyze the films. See also Rinehardt and Scherz (1972).

51 SCHULTINK G. 1978. Light Aircraft Remote Sensing Using Small Format Cameras Draft Copy. Michigan State University, Lansing. 44 p RESORS No. 1021845. B.4, E.

Included in this report are discussions on remote sensing principles, multistage techniques and comparisons between 35 mm and 70 mm camera systems (Nikon and Hasselblad). Inexpensive camera mounts are shown along with design criteria. Film/filter and exposure problems and considerations are clearly outlined. Flight planning and aircraft selection are presented logically.

52 SEELEY, H.E. 1962. The Value of 70 mm Air Cameras for Winter Air Photography. Woodlands Review, Pulp and Paper Magazine of Canada, 63 (5): 3-6. RESORS No. 1004536. E.

70 mm black-and-white photographs from a Vinten camera were used to evaluate tree volumes and sizes with reasonable success. Some technical data is provided on flying times and conditions.

53 SEEVERS, P.M., and V.L. WIEGAND. 1978-1979. An Evaluation of Colour Infrared Photography for Monitoring of Cropping Problems; Final Reports to Farmland Industries, Inc. University of Nebraska, Lincoln, March 1978: 36 p. and March 1977: 31 p. RESORS Nos. 1019221 and 222. D. 4.

Evaluation of camera, film and aircraft types is included in this report. The storage problems of CIR film are discussed, as are various flight parameters such as timing, speed and weather conditions. This study provides excellent guidance for oblique hand-held aerial photography and interpretation techniques for local agricultural problems.

54 SHERSTONE, D.A. 1978. Small Format Camera Systems for Hydrologic Research: Background Studies and a Report on Preliminary Work within the Glaciology Division. Presented at The Fifth Canadian Symposium on Remote Sensing, Victoria. Published by Inland Waters Directorate, Department of the Environment, Ottawa. 8 p. RESORS No. 1019237. D. 2.

A camera system, using a Canon F-1 was mounted in an aircraft by adapting a Wild RC 10 mount. Positional accuracy between points on 9 x 9 and 35 mm film was found to be adequate for many tasks undertaken by the Glaciology Division. Some data are presented on film types and aircraft selection.

55 SMYTH J.R.C. 1972. Parameters and Intervals for 35 mm Aerial Photography. Ontario Ministry of Natural Resources 49 p. RESORS No. 1019241. B 4.

Charts and explanations on using 35 mm photography at various altitudes with different focal length lenses for longitudinal and transverse orientation of 35 mm film are presented clearly and logically

56 SPENCER, R.D. 1978. Map Intensification from Small Format Camera Photography. Photogrammetric Engineering and Remote Sensing, 44 (6): 697-707. RESORS No. 1016138. B.2, E.

35 mm and 70 mm (Asahi Pentax and Vinten) format cameras were used to supplement major aerial surveys to increase the accuracy of base maps for plantations. The author found these techniques were very cost effective when compared with ground surveys. Some guidance is provided on aircraft pilot selection, exposures, mapping scales and data transfer techniques.

57 SPENCER, R.D 1978. Film Trials of Aerial Photography for Forestry in Victoria, Australia. Photogrammetric Record 9 (57): 391-403 (April) RESORS No. 1017859. B.3, E.

Four rangefinder 35 mm cameras (Yashica) and two 70 mm cameras (Vinten) were used to evaluate several types of Kodak Infrared (8443, 2443), colour negative, colour positive, and black-and-white negative films. Exposure values for overcast and clear skies are given. Discussions of vegetation appearance on CIR film are included.

58 STEVENS, A.R. 1972. Application of Small Format Color and Color Infrared Aerial Photography to Dutch Elm Disease Detection. Proceeding of the 38th Annual Meeting of the ASP, March, Washington: 349-357. RESORS No. 1004700. C.1.

Three 35 mm cameras (Minolta), manually advanced, were used in a hand-held mode to record elm trees with Dutch Elm Disease. The affect of the disease on the trees was evaluated by means of densitometric readings taken over the trees. The conclusions recommend a motor-driven, 250-exposure magazine, and a two camera system in a vertical mount.

59 STEPHENS, P.R. 1976. Comparison of Color, Color Infrared and Panchromatic Aerial Photography. Photogrammetric Engineering and Remote Sensing, 42 (10): 1273-1277. RESORS No. 1012089. C.1.

This is an extension of the author's 1975 thesis (Document 60). The three 35 mm film types were assessed

for their capability to distinguish alignments, fault plug zones and seepage areas, eroded surfaces, erosion types and processes, vegetation types and conditions, and damage patterns. CIR film appeared to be the most effective.

60 STEPHENS, P.R. 1975. Determination of Procedures to Establish Priorities for Erosion Controls as Determined in the Southern Rushine Ranges, New Zealand. Msc. Thesis, Massey University, New Zealand. 140 p. RESORS No. 1024728-34. D.4.

All the analysis and results presented in this document have been obtained from ground and aerial surveys, in particular using 35 mm colour, colour infrared and panchromatic films. Descriptions on the camera types (Asahi Pentax), lenses and exposures are included. There is also a literature review on the use of conventional earial photography for erosion and related studies. The normal colour films used in this study are no longer available but their replacements would provide comparable results.

61 STRANDBERG, C.H. 1964. 35 mm Aerial Photography for Measurement Analysis Presentation - second edition. U.S. Public Health Service, Division of Water Supply and Pollution Control. 61 p. RESORS No. 1019223. B.3.

A detailed document on all important aspects of aerial photography related to using 35 mm format. The equipment and films illustrated are now out of date but the techniques are still useful. Geometry and rectification of oblique and vertical photography are discussed extensively.

62 ULLIMAN, J. J., and D.W. FRENCH. 1977. Detection of Oak Wilt with Color IR Aerial Photography. Photogrammetric Engineering and Remote Sensing, 43 (10): 1267-1272. RESORS No. 1015017. E.

The camera system described in Document 63 was used to obtain data on oak wilt infection centres. Various films, scales and filter configurations were used and evaluated.

63 ULLIMAN, J.J., R.P. LATHAM and M.P. MEYER. 1970. 70 mm quadricamera system. Photogrammetric Engineering, 36 (1): 49-54. RESORS No. 1002618. E.

A four-camera system (Hasselblad) and mount were developed for low- and medium-altitude aircraft and also for Lear jets. Equipment capabilities and operational problems are outlined. See also Ulliman and French, 1977.

64 WALSH, H.T., and W.B. HALL. 1978. Pocket Guide for Making Colour Oblique Stereo Aerial (COSA) Photographs with 35 mm Cameras. University of Idaho, Moscow 10 pp. RESORS No. 1020431. B.3.

This guide is concise and to the point in providing the information needed to take colour oblique stereo photographs. It can easily be adapted to vertical stereo photographs. Data are given for film types, exposures and analysis equipment. See also Hall and Walsh (1977).

65 WILLETT, A.M., and B.K. WARD. 1978. Forest Insect and Disease Surveys by Remote Sensing. Bulletin of the Remote Sensing Association of Australia, 4 (1) (September): pp. 11-12. RESORS No. 1020437. C.2, E.

Both 35 mm (Nikon) and 70 mm (Vinten and Hasselblad) cameras mounted in various high-wing aircraft are discussed in relation to forest surveys. Some specific examples are cited along with particular film/filter combinations for the best detection of dieback disorders.

66 WILLIAMS, P.G. 1975. A Light Aircraft Remote Sensing System. Proceedings on the Workshop on Remote Sensing of Wildlife, Quebec: 7 p. RESORS No. 1014128. B.1, E.

A camera system consisting of two 70 mm cameras (Vintens), two 35 mm cameras (Nikon) and a 16 mm camera was used in vertical mount in a Cessna 180 aircraft. Control is exercised by a master intervalometer mounted in the instrument panel.

67 WOODCOCK, W.E. 1976. Aerial Reconnaissance and Photogrammetry with Small Cameras. Photogrammetric Engineering and Remote Sensing, 42 (4): 503-511. RESORS No. 1010280. B.2, E.

This report is concerned mainly with the quality of black and white film taken with 70 mm (Hasselblad) and 35 mm (Leica) cameras for mapping, not remote sensing purposes. The cameras are vertically mounted in a light aircraft.

68 WRACHER, D.A. 1973. Small Format Aerial Photography. Mining Engineering 27 (November). 47-48. RESORS No. 1019389. B.3.

Guidance is provided on scale, exposure and flying conditions with appropriate examples. Some cost calculations are included.

69 ZSILINSZKY, V.G. 1979. A User's Notes on Remote Sensing Application. International Symposium on Remote Sensing for Natural Resources, Moscow. 18 p. RESORS No. 1020888. D.3, E.

Various photographic and video cameras and their mounting systems are summarized. The system includes a microcomputer to control the camera firing intervals and a video display for navigating. This report also covers applications and interpretations from SAP as well as 70 mm and 23 cm photography. See also Giannelia (1980).

70 ZSILINSZKY, V.G. A.M. GIANNELIA and M.J. RAFELSON. 1979. A Review of the Supplementary Aerial Photography Program of the Ontario Ministry of Natural Resources. Presented at the Remote Sensing Symposium Canada - Ontario Joint Forest Research Committee, Toronto. 8 p. RESORS No. 1020889. A.

This paper summarizes the Supplementary Aerial Photography (SAP) program of the Ontario Centre for Remote Sensing. It discusses the problems encountered in obtaining aircraft, training personnel and standardization of equipment. The results presented in this paper were based on a questionnaire completed by Ontario government personnel utilizing SAP techniques.

71 ZSILINSZKY, V.G. and C.W. GRAHAM. 1976. Instruction Manual of Supplementary Aerial Photography. Ontario Centre for Remote Sensing, Toronto. 76 p. and appendices. NOT AVAILABLE FOR DISTRIBUTION; OCRS TRAINING COURSE MATERIAL. B.4.

An extensive and comprehensive document on all aspects of 35 mm aerial photography, specifically referring to the OCRS Nikon photographic system. See also Dalman (1977).

72 ZSILINSZKY, V.G. 1972. Camera Mounts for 35 mm Mono and Multi-spectral Photography. Proceedings of the First Canadian Symposium on Remote Sensing, Ottawa: 441-450. RESORS No. 1001969. B.2.

Four-camera mounts (for 1, 2, 3 or 4 cameras) for use in the deHavilland Beaver or Otter aircraft are described. The mounts are more fully described in Williams (1975).

73 ZSILINSZKY, V.G. 1972. Fisheye Lens for Plot Location. Photogrammetric Engineering, 38 (8): 773-775. RESORS No. 1004746. B.2.

A fisheye lens (focal length 7.5 mm) optically aligned with a 55 mm sampling lens is used to provide the location of the sample area imaged by the 55 mm lens. Both lenses are attached to 35 mm format cameras (Nikon).

74 ZSILINSZKY, V.G. 1972. Resource Surveys with Miniature Cameras. Proceedings of the Twelve Congress I.S.P. Commission 7, July-August, Ottawa: 14 p. RESORS No. 1002037. C.1.

An overview of forestry applications in which supplementary aerial photography has provided a useful and viable role. Some guidance is presented on the actual techniques needed to acquire information on tree heights, diameters, crown cover, animal populations, etc.

75 ZSILINSZKY, V.G. 1969/70. Supplementary Aerial Photography with Miniature Cameras. Photogrammetria, 25 (1969/70): 27-38. RESORS No. 1005037. D.2.

SAP can be used very economically as an addition to conventional aerial photography for map revision, when the SAP is performed from a light aircraft with a vertical camera mounting systems. Selection of proper focal length lenses can ensure a close scale match to 23 x 23 cm photographs and high-quality enlargers can provide acceptable prints from SAP to compare with the larger format's contact prints. A camera (Nikon) mount system for use in an aircraft with a belly hatch is presented.

6 REFERENCES

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Dalman, D.W 1977. The Utility of Supplementary Aerial Photography in the Management of Natural Resources in National Parks: Case Study, Point Pelee National Park, Ontario. A report prepared for Parks Canada, Ottawa. 327 p. RESORS Nos. 1018942-1018953.

Fleming, J. 1980. Standardization Techniques for Aerial Colour Infrared Film. Interdepartmental Committee on Air Surveys and Surveys and Mapping Branch, Department of Energy Mines and Resources, Ottawa. 28 p. RESORS No. 1022226.

Eastman Kodak. 1972. Kodak Aerial Films and Photographic Plates, Volume 1 (M-61). Eastman Kodak Company, Rochester. 28 p.

Eastman Kodak. 1973. Kodak Filters for Scientific and Technical Uses; B-3. Eastman Kodak Company, Rochester. 91 p.

Reeves, R.G. 1975. Glossary. In: Manual of Remote Sensing, Volumes I and II, R.G. Reeves, Editor. American Society of Photogrammetry, Falls Church. 2144 p.

Zsilinszky, V.G., and C.W. Graham. 1976. Instruction Manual of Supplementary Aerial Photography. Ontario Centre for Remote Sensing, Toronto. 76 p. and appendices.

7 APPENDICES

7.1 APPENDIX A

Selected Filter Data and Response Curves

Spectral transmittance curves of selected filters that can be used for aerial photography are presented in Figures A1 to A5. The manufacturer's designation and the filter's colour are given for each filter. The relevant text sections are:

Figure A1 - (2.3.1.2)
Figure A2 - (2.3.1.2)
Figure A3 - (2.3.1.2) and (2.3.2)
Figure A4 - (2.3.1.2), (2.3.1.3) and (2.3.1.4)
Figure A5 - (2.3.1.2) and (2.3.1.3)

- Courtesy of the Ontario Centre For Remote Sensing and The National Research Council.

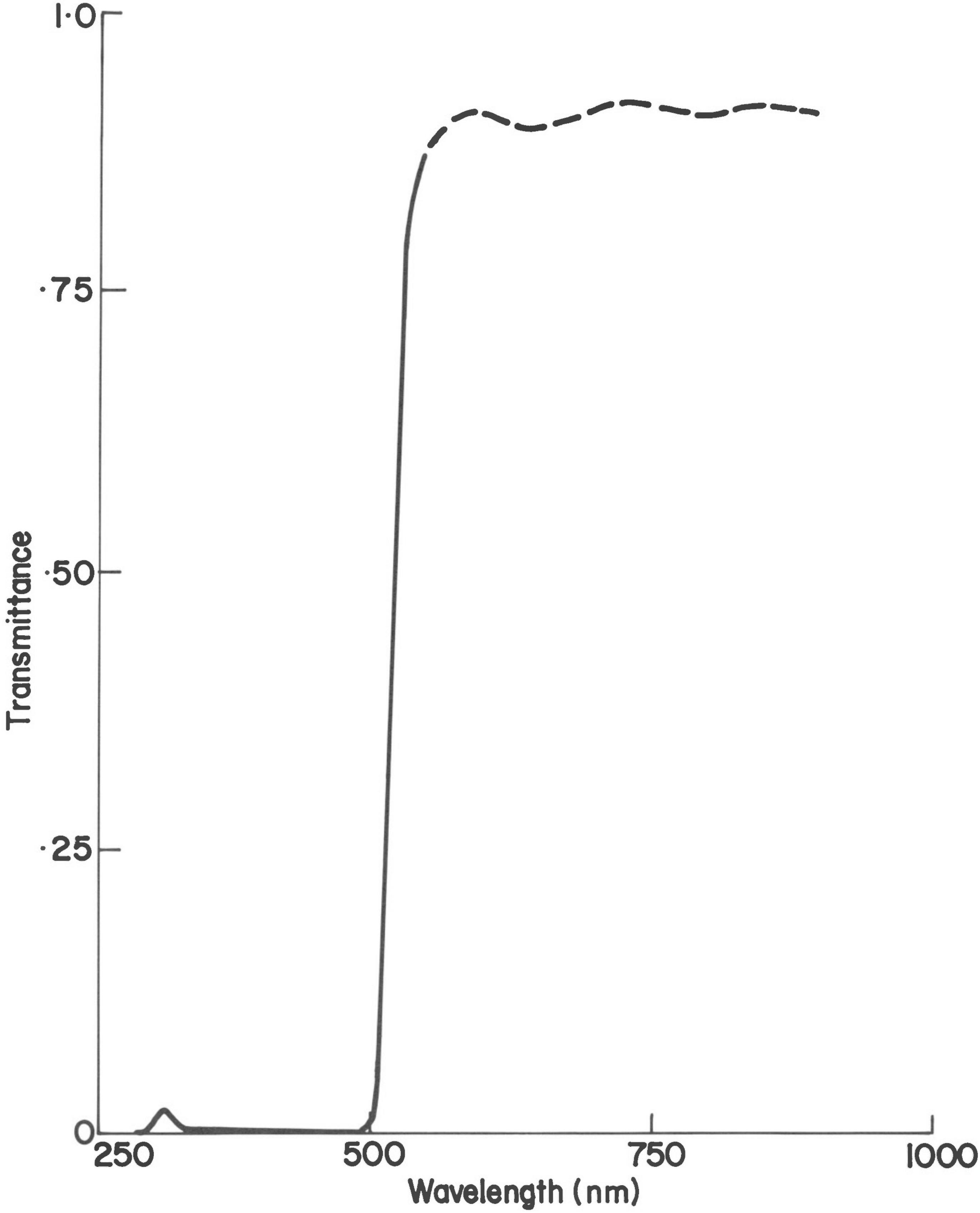

FIG. A1

Kodak Wratten 12 (Med. Yellow)

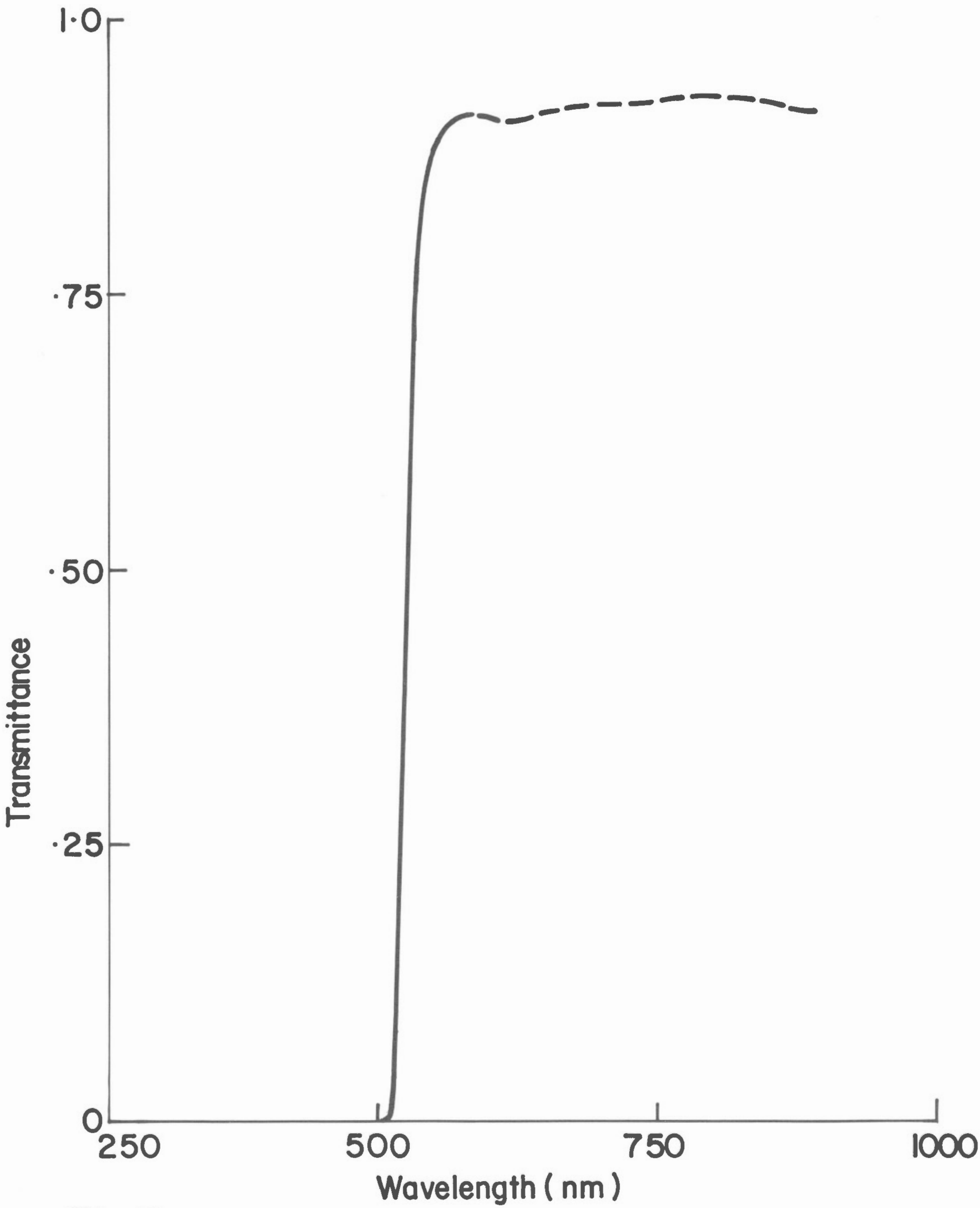

FIG. A2
Kodak Wratten 15 (Deep Yellow)

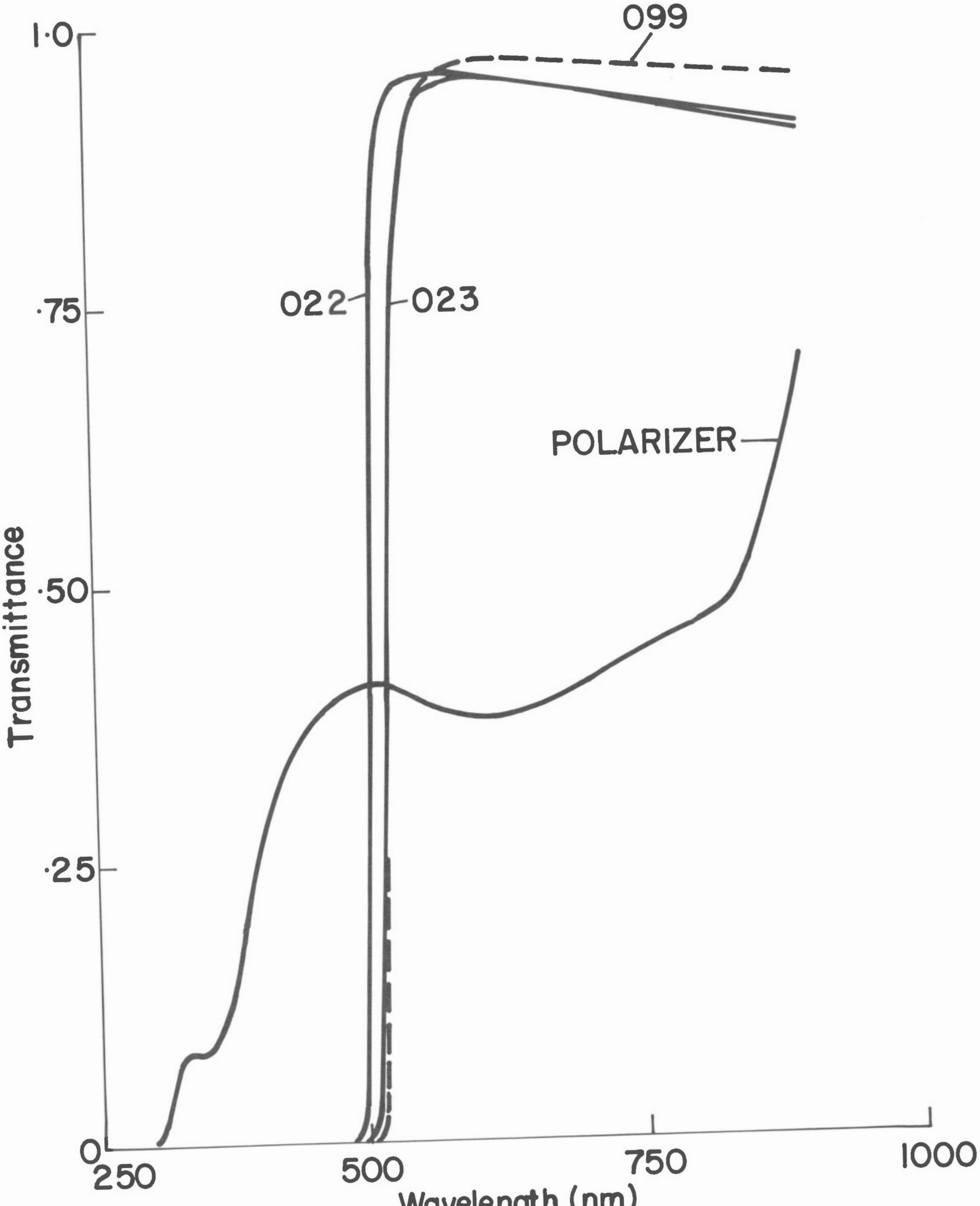

FIG. A3

B + W 022(Med.Yellow), 023(Deep Yellow) and 099(Orange), Polarizer

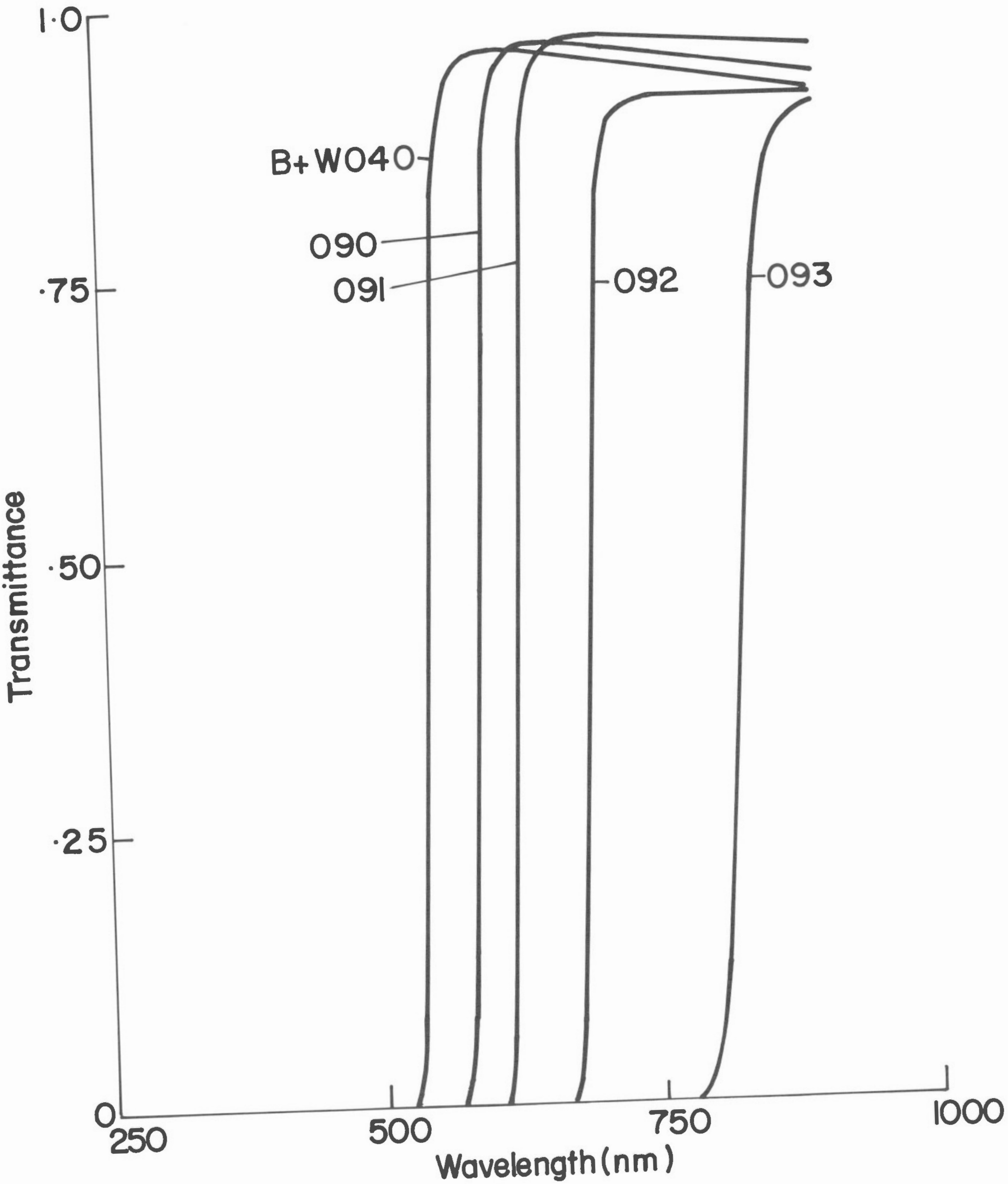

FIG. A4 B + W 040 (Yellow/Orange), 090 (Light Red), 091 (Dark Red), 092 (Deep Dark Red), 093 (Black)

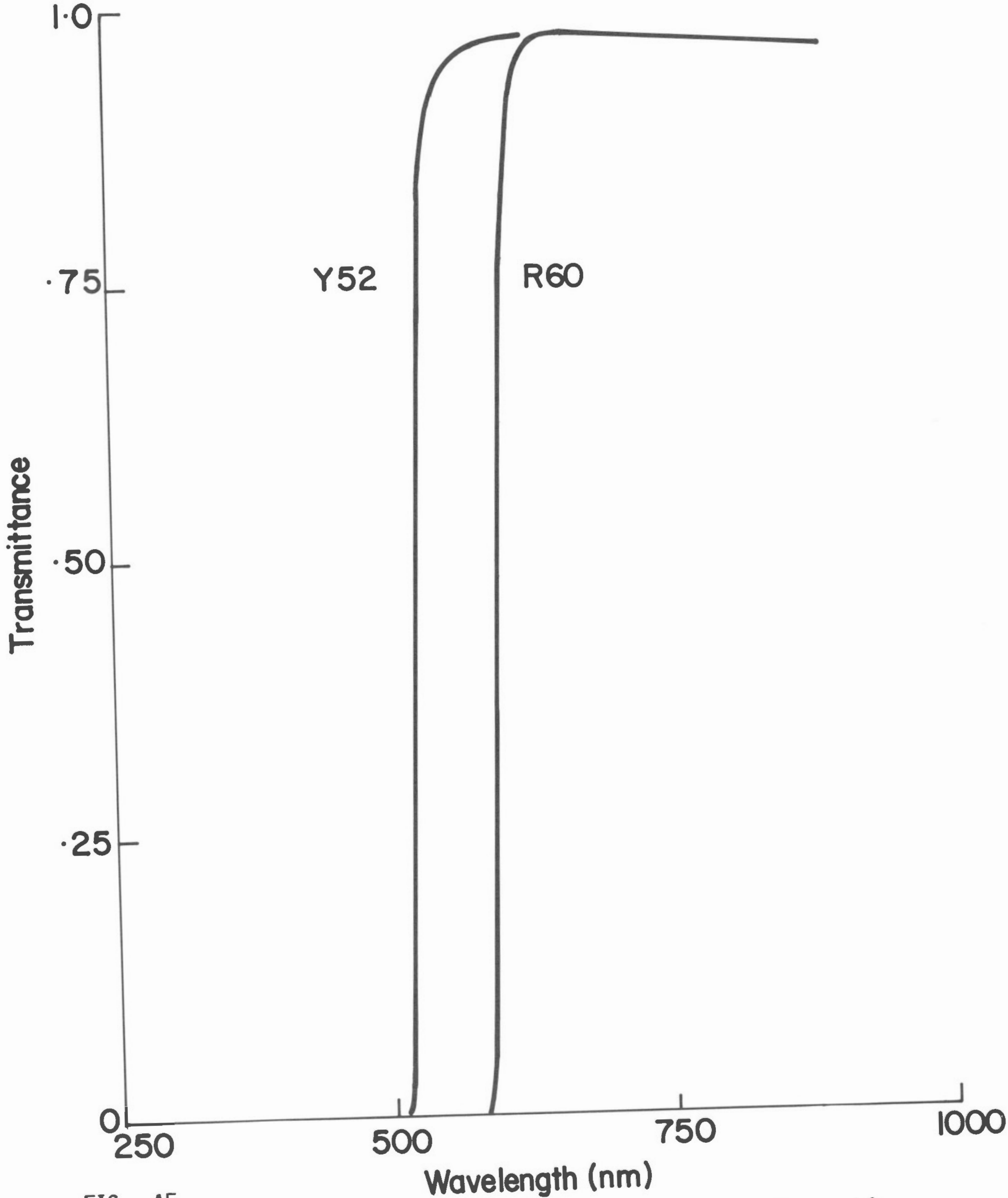

FIG. A5
Nikon Y52 (Deep Yellow) and R60 (Red)

7.2 APPENDIX B

Recommendations for Aperture, Shutter Speeds and Filter Combinations for Supplementary Aerial Photography (SAP)

Source: Adapted from V.G. Zsilinszky and C.W. Graham (1976).

: Adapted from D.W. Dalman, (1977).

NOTE: All filters are designated by the Kodak Wratten filter system, e.g., W12 = medium yellow

TABLE B-1 APERTURE, SHUTTER SPEEDS AND FILTER COMBINATIONS AT ALTITUDES ABOVE GROUND FOR SELECTED PANCHROMATIC B. & W. FILM - CONDITIONS CAVU* - FOREST OR GROUND COVER - NORMAL HAZE

FILM	ASA	500-1500 (feet)	Filter	1500-3000 (feet)	Filter	3000-5000 (feet)	Filter	5000-12000 (feet)	Filter
			See Section 2.3 & Appendix A						
TRI-X PAN	400	f8-1/1000	-	f8-1/500	W12	f8-f11-1/500	W12	f11-1/500	W12
PLUS-X PAN	125	f5.6-1/1000	-	f5.6-1/500	W12	f5.6-f8-1/500	W12	f8-1/500	W12
PANATOMIC X	32	f2.8-1/1000	-	f4-1/500	W12	f4-f5.6-1/500	W12	f5.6-1/500	W12
H & W CONTROL	50-80	f3.5-1/1000		f4.5-f5.6-1/500		f5.6-f7-1/500		f8-1/250	

*CAVU-Ceiling and visibility unlimited

TABLE B-2 APERTURE, SHUTTER SPEEDS AND FILTER COMBINATIONS AT ALTITUDES ABOVE GROUND FOR SELECTED COLOUR FILMS - CONDITIONS CAVU - FOREST OR GROUND COVER - NORMAL HAZE

FILM	ASA	500-1500 (feet)	Filter*	1500-3000 (feet)	Filter* See Section 2.3	3000-5000 (feet)	Filter*	5000-12000 (feet)	Filter*
PHOTOMICROGRAPHY No. 2483	16	f2.0- 1/1000	-	f2.8- 1/500	-	f3.5- 1/500	-	f4-1/500	-
KODACHROME 25	25	f2.8- 1/1000	-	f4- 1/500	-	f4-f5.6- 1/500	-	f5.6-1/500	-
KODACHROME 64 EKTACHROME 64	64	f2.8- 1/1000	-	f4.f5.6- 1/500	-	f5.6- 1/500	-	f5.6-1/500	-
KODACOLOR II	100	f3.5- 1/1000	-	f5.6- 1/500	-	f5.6-f8- 1/500	-	f5.6-f8- 1/500	-
EKTACHROME INFRARED	100	For exposures and filters see Aerochrome Infrared 2443 (Table B-3)							
EKTACHROME 200	200	f4-f5.6- 1/1000	-	f5.6- 1/500	-	f8- 1/500	-	f8-1/500	-
VERICOLOUR II	100	f2.8- 1/500	-	f4- 1/500	-	f5.6- 1/500	-	f5.6- 1/500	-
EKTACHROME 400	400	f5.6- 8-1/1000		f8- 1/500		f11- 1/500		f11- 1/500	- -
KODACOLOR 400	400	f5.6- 8-1/1000		f8- 1/500		f11- 1/500		f11- 1/500	- -

* All films in this chart should be used with a Wratten 1A or equivalent haze filter.

TABLE B-3 APERTURE, SHUTTER SPEEDS AND FILTER COMBINATIONS AT ALTITUDES ABOVE GROUND FOR SELECTED AERIAL FILM - CONDITIONS CAVU - FOREST OR GROUND COVER - NORMAL HAZE

FILM	ASA	500-1500	Filter	1500-3000	Filter	3000-5000	Filter	5000-12000	Filter
AEROCHROME INFRA-RED 2443-3443	ASA 100 EAFS-40 AEI-10	f4-f5.6-1/500	W12+ CC10M W15	f4/5.6 1/500	W12+ CC10M W15	f5.6/8 1/500	W12+ CC10M W15	f8-1/500	W12+ CC10M W15
AEROGRAPHIC INFRA-RED 2424	EAFS-200 AEI-100	f4-f4.5-1/1000 f4.5-1/1000 f8-1/1000	W25 W89B W12 W15	f8-1/500 f8-1/500 f8-1/500	W25 W89B W12 W15	f8-1/500 f11-1/500 f8-f11-1/500	W25 W89B W12 W15	f11-1/400 f11-1250 f11-1/500	W25 W89B W12 W15
AEROCOLOUR NEG. FILM 2445	EAFS-100 AEI-32	f3.5-1/1000		f5.6-1/500	Haze (W1A)	f6.7-1/400 f8-1/500	2XA.V. Haze (W1A)	f7-1/500	Haze (W1A)

* AEI - Aerial exposure index. The reciprocal of twice the exposure (in metre-candle-seconds) at the point on the toe of the characteristic curve where the slope is equal to 0.6 gamma. Now replaced with the effective aerial film speed (EAFS) (Eastman Kodak, 1972).

EAFS - Effective aerial film speed. One and half times the reciprocal of the exposure (in metre-candle-seconds) at the point on the characteristic curve where the density is 0.3 above gross fog. ANSI Standard PH 2.34-1969 (Eastman Kodak, 1972).

7.3 APPENDIX C

Weather Considerations

Weather conditions are important to the successful completion of a photographic mission because they affect the selection of the aircraft, the skill level and experience required of the pilot, the flying height and lens that must be used to obtain the desired contact scale and the type of film and filter that may be used.

Source Adapted from D.W. Dalman (1977)

TABLE C 1 Adjustments Required in a SAP* Mission in Selected Meteorological Conditions

Weather		Adjustment
Atmospheric haze:	normal	- none
	hazy	- change of filter and possibly film type
Precipitation:		- mission usually abandoned
Cloud Cover: (per cent)	10	- none
	10-15	- open aperture (stop) and/or decrease shutter speed
	50	- decrease shutter speed and/or open aperture
	> 50	- possible film type change or abandonment of mission
Ceiling: (feet)	1000 or less	- may affect Visual Flight Regulations (VFR) and pilot, aircraft, instrumentation required may have to be altered
	1000 to 5000	- possible change in focal length of lens to achieve desired contact scale
Wind Speed: (mph)	10	- minor adjustments for crab
	10-20	- experienced pilot required to fly prescribed straight line
	> 20	- major adjustments in crab - only short burst of photographs can be suitably referenced, long flight lines will meander in light aircraft - possible change in size of aircraft and pilot skills
Wind Direction:		- depending on wind speed, possible change in flight line direction - depending on topographic relief and flying height, possible abandonment of mission
Turbulence:		- mission could be abandoned, if too severe (take along a sick bag!)
Sun Angle: (degrees)	< 30	- long shadows obscure ground detail - weak lighting; possible change in film type or shutter speed/aperture settings - desirable for some photography (e.g., over water bodies)
	> 30	- generally no adjustments except over highly reflective surfaces

* SAP - Supplementary aerial photography.