Alberta Small Scale Aerial Photography 1980-1990: Influences, Changes, and Evolution of Image Quality

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Abstract

Changes in the Alberta Government's small scale aerial photography program are reviewed through the 1980s, with emphasis placed on image quality. The effect of atmospheric haze, filtration, scale change, film changes, and specification change, are outlined and illustrated with respect to the continual development in the small scale product quality. A densitometric statistical evaluation of four specific time periods during the decade is also used to evaluate differences in the small scale image quality. Recommendations for modifications in the future use of small scale aerial photography are outlined.

Introduction

High quality aerial photography at scales of about 1:40 000 or smaller depends on several physical and technical factors whose manipulation require a good understanding of the aerial photographic process. Atmospheric attenuation of contrast, average gradient and exposure control, filtration, film resolution, film spectral sensitivity, these and other factors render image quality a sense of the sly.

During the past decade the Alberta Government's small scale aerial photographic acquisition program has been going through a continual evolution of product improvement. Films, average gradients, filters, and photoscales have all been investigated with the goal of finding solution to problems involved in high altitude photography. There have been successes and failures over the course of the ten years, and the experience accumulated has provided invaluable information for future planning. This article is a review of the program(s) and tests implemented, the environmental drawbacks encountered, the materials and processes used, the products produced, and the state of image quality throughout the period.

Purpose

Why the use of small scale aerial photography, especially in view of its operational drawbacks? The question is essentially answered by economic factors: more coverage equates to less photography, and less photography equals less effort in compiling the final product. Therefore, the smaller the scale the greater the economic optimizing factor becomes. The critical element in striving for operational economy becomes image quality. At what point is image quality sufficiently hindered as to render a scale, a film, a process, unusable? This question must consider the primary purpose of the images; in this sense multipurpose use is often a liability.

Between 1980 and 1985 Alberta's small scale aerial photography program was designed to meet the requirements of the Province's digital base mapping program. The aerial photography represented the source of information from which all other mapping products would be derived. The acquisition scale of this photography was determined to be 1:60 000, changed from the previous scale of 1:50 000 that conformed with the federal N.T.S. system. The choice of scale coincided mainly with the ease by which the dimensions of a township (6 $mi.^2$) could be represented by a standard aerial photograph. The photoscale was still theoretically appropriate to map at 1:20 000 (Ghosh 1987), that being the target map scale.

The negative imagery was used to produce two essential products:

- Contact paper prints for photogrammetric identifiable control location.
- Diapositive prints for photogrammetric control location, topographical, and base mapping, where not only geometric integrity was to be maintained, but also visual rendition of the ground was to be optimal. The diapositive would also be used to produce secondary photographic map products such as orthophotos.

The 1:60 000 small scale photography had another application, the updating of access features on pre-existing maps (1:50 000). The activity involved mostly the mapping of new roads (type), trails, seismic lines, cut lines, and also changes in vegetation cover. This application was performed exclusively using contact paper prints.

A third application of this photography could be included under the general heading of 'others'. The product demand of this group often surpassed that of the original user in quantity of reproduction requests since it included all other interested users in the province. The public nature of the photography facilitated a decision to make it accessible to all government departments and the general public. The applications in this domain were as diverse as the number of users which requested the imagery! The products most often requested in this category were paper contact prints and paper enlargements.

In 1986, the primary purpose of small scale aerial photography was converted from base mapping to updating existing maps. Image quality and scale therefore became more relevant to interpretation specialists often working with two power magnification stereoscopes than to the photogrammetrists and their stereoplotting instruments who preceeded them. Visibility, often through contrast,texture, and size enhancement, was a major requirement for the interpretation group, while the photogrammetrists' requirements were often centred on resolution, granularity, and good shadow detail rendition. The 1:60 000 scale was consequently dropped and replaced with the 1:40 000 scale to improve visibility. This scale has continued to be the operational small scale to the present. Experimentation with smaller scales during the decade has also continued to be of interest, specifically, testing with a scale of 1:110 000 using an 88 mm. (3.5") lens and aerial photographic images obtained at 1:130 000 using a 152 mm. (6") lens with NASA's ER-2 aircraft (Moore and Polzin 1990). Primary purpose in both these cases was to improve the cost effectiveness factor.

Small Scale Imaging Factors

The major efforts in the ten year period studied have been to resolve three major areas of mediocre image quality, namely:

- Lack of contrast in the reproductions.
- Lack of clarity and/or sharpness in spatial detail.

- Poor visibility of terrain objects.

The main causes were identified as:

- Natural Factors

  - Atmospheric effects and contrast attenuation
  - Object size
  - Terrain luminance

- Procedural Factors

  - film and print contrast (average gradient and density range)
  - film resolution: spectral and spatial

It is in these areas that much of the research and development activities have concentrated.

Atmospheric Effects. The atmosphere affects the visibility of objects on the ground in two basic ways. The first is by increasing the opacity of object detail by scattered radiation; typical scattering varying as λ^{-4} for molecular scattering and from λ^{1} to λ^{-3} for aerosol scattering (Kaufman 1988). The scatter, being more prominent with shorter wavelengths, is significant in the blue portion of the spectrum and produces the modification of tones associated with haze (Figure 2). The general effect is to decrease the ratio of ground luminances and therefore decrease contrast (Illustration 1). A minus blue filter is commonly used in black and white aerial photography to absorb this scattered, non-image, blue light (Kodak 1981). Figure 1 graphically shows both the magnitude of scattering and the effect of filtration, which has been investigated by Fleming (1974) and by Polzin (1977).

The scattering of upward image radiation is the second prominent effect observed in small scale aerial photography. This phenomena causes a diffusion of the image light and is especially pronounced in adjacent areas of higher contrast. The effect is to cause an apparent degradation of image sharpness by lowering its acutance value (Brock 1970; Illustration 3; appendix). The diffusion of upward luminance is particularly evident and problematic in the 1:60 000 scale aerial photography acquired between 1983 and 1985 (Illustrations 4 and 5). In photogrammetric applications, the difficulty of positioning the elevation contouring dot on the ground of the stereoscopic image pair is a trait of this diffusion effect, while in reconnaissance, complaints center on the lack of contrast and edge sharpness.

All the small scale aerial photography flown for the Alberta Government has had the minus blue filter utilized to compensate for the scattering effect. In addition, some experimentation with red filtration at the 1:60 000 scale has also been attempted, but the increased image tonal detail expected was not significant enough to justify a change (Illustration 2). Also, the emulsion being used at the time (Kodak Plus-X) lacked the sensitivity required with the eight filter factor exposure compensation of the red filter.

Object Size. Object size is strictly a function of scale. In some cases solar illumination also exerts a significant influence upon the visibility of object size by enhancing or subduing shadow. The identification of access features such as seismic lines and cut lines at a scale of 1:60 000 and with two power magnification stereoscopes renders the task difficult. The improbability of photographing with a clear atmosphere, insufficient object-shadow contrast, and the physical width of these features places the 1:60 000 scale at the limit of functionality for this purpose (Illustrations 4 and 5). This particular element of object size is one of the main reasons for the small scale change from 1:60 000 to 1:40 000 in 1986.

The small scale aerial photography obtained with the use of an 88 mm. (3.5") lens in

1984 (table 1) was reviewed for its effect in compensating for atmospheric opacity associated with haze. However, the image field illumination falloff, and greater degree of incursion by the anti-solar spot into the image area (illustration 6) posed problems and discouraged the use of this method. The newer lenses available today may reduce the effect of corner illumination falloff and make this procedure more attractive, but the hot-spot effects are still a concern.

In general, the viability of smaller scales, in tandem with the panchromatic-IR emulsions, have become feasible again in terms of image quality. The ER-2 tests, at a scale of 1:130 000, the photography flown by private sector firms for Manitoba, Saskatchewan, British Columbia, and I.C.A.S.'s 1990 small scale program at 1:50 000 and 1:60 000 (Landreville 1990) are all ample evidence that Alberta need not be restricted to the 1:40 000 scale, at least not with regards to image quality.

Average Gradient. The average gradient is a measure by which processing contrast can be assessed (appendix). Varying the average gradient of aerial film enables one to emphasize or subdue the luminance range of the terrain. Low luminance range terrain such as forest cover or prairie would typically be photographed and processed to a higher average gradient, while high luminance range terrain such as mountainous, urban, and certain types of agricultural areas would be photographed and processed to a lower average gradient. An average gradient of 1.0 will render the luminance ratio of the ground the same as the density ratio on the negative, consequently it may be thought as a 'normal' average gradient. Small scale aerial photography, being prone to a number of contrast attenuating factors, requires an average gradient which generally enhances the 1:1 luminance-density ratio. The photography acquired between 1980 and 1982 rarely shows an average gradient greater than 1.20, this being attributable to the densitometric specifications of the day (ICAS 1973).

In 1983, revised densitometric specifications (ICAS 1982) were introduced which emphasized obtaining proper density ranges rather than a given average gradient. The aim density range of 1.0 would be obtainable in small scales only by enhanced processing, in the range of 1.4 to 1.7 average gradient. The emulsion in use at this time, the Kodak Double-X 2405, could not be processed to such average gradients without an associated and undesirable rise in the fog density. Higher contrast alternatives were investigated (Fent 1983), (Fleming 1981) and the Kodak Plus-X 2402 film was eventually chosen to replace the previous film. The ease with which this film attains the higher average gradients, the lower fog levels, and the medium emulsion speed contributed to its use.

Spatial Resolution. The modulation transfer function (MTF) is used to associate the theoretical limits of resolution of both lenses and films (Brock 1968; appendix). This measure shows the limits to resolution are found in the camera-optical system rather than in the characteristics of emulsions. Aircraft motion, vibration, and lens MTF are cited as degenerating factors (Becker 1988). In the operational setting of the 1980s in Alberta, the spatial resolution issue was defined more by purpose and practicality; better resolving films are not necessarily the best films for small scale application. Emulsion resolution and graininess characteristics have not been particularly influential factors in reconnaissance and detection. In practice, the variations of the aerial emulsions used have not been significant enough to justify any one film over another. Theoretical calculations coupled with the ER-2 Panatomic-X photography shows potentials of better than one meter can be resolved at the

1:130 000 scale or smaller (Graham and Read 1986; illustration 7). In another comparative study of the higher resolution Kodak Panatomic-X with Plus-X (Fent 1983), the Plus-X was preferred because of its lower inherent contrast (by photogrammetrists), higher speed (by camera operators), and ease in reproduction (by lab technicians), hence, operationally more practical. The same study found that interpreters preferred the Panatomic-X for its higher contrast and apparent resolution. As noted, the Plus-X and not the Panatomic-X replaced the Double-X.

The recent ER-2 trials using Panatomic-X and Agfa Aviphot 50 also support the view that unless significant magnification is used, the lower resolving Agfa Aviphot 50 emulsion is preferred (illustration 7). These subjective quality evaluations can be associated with the density range information of the negatives which shows the more visibly pleasing Agfa Aviphot 50 film having higher density ranges (table 2), thus higher contrast and enhanced edges; the prints look sharper. However, limits to contrast enhancements do exist as less tonal gradation is reproduced (Pfenninger 1984); this may possibly be the case with the Agfa Aviphot 50 example (Illustration 7) over the urban terrain, where key highlight detail is not rendered well.

Spectral Resolution. The spectral resolution of available black and white emulsions may be classed in to four groups: panchromatic, extended red sensitive, panchromatic infrared, and infrared (Fent 1990). The use of spectrally different emulsions is associated with natural resource applications where some terrain signatures may want to be emphasized. In small scale aerial photography the spectral attributes of the film are important because of the manner in which the film is affected by the deeper atmospheric layer. Generally, the more infrared sensitive an emulsion the more transparent (appendix) a hazy atmosphere will be (figure 3; Middleton 1950). Small scale infrared photography has been suggested and tried in the Province in both cartographic and reconnaissance applications (illustration 8). The relatively coarse grain of the infrared emulsion did not contribute to its success in the mapping sector, but the emulsion is used occasionally for vegetation studies.

The Agfa-Gevaert films, whose spectral sensitivity extends to about 750 nm., are the preferred films for small scale aerial photography. These films combine panchromatic attributes with a sufficient amount of infrared sensitivity to significantly enhance the terrain detail and contrast of the small scale product. The tests on these emulsions confirm their ability to 'penetrate' haze (Fent 1986) and their consistency has been established during the four years of production use subsequent to the initial tests (table 3). We have come a long way since the early 1980s when it was thought that haze compensation was achieved by overexposure, the venerable 'punching through the haze'.

Density Range. The density range of an aerial negative is possibly the one criteria most readily visible and identifiable with overall image quality. It is influenced by atmosphere, film type, filters, average gradient, scale, and by ground luminance, all factors which are reviewed here. It is also the variable most important in the reproduction of the original negatives. Unfortunately it is an element which can not be directly manipulated in the acquisition process. Given this somewhat detached aspect of the density range, it is often evaluated at the completion of the aerial photographic process. A reliable predictor or estimator of this variable before or at the time of photography has been notably lacking in the industry (Fleming 1983; Horn and Tugwood 1984).

Nevertheless, the representational nature of image quality by density range provides a suitable quantitative means by which to evaluate the various changes in small scale aerial photography occurring during the 1980-1990 study period. This period may be subdivided into four distinct groups associated with key operational changes (Table 3). The effect of these changes can be evaluated by a random sampling of the density range in each of the four groups (Figure 4). A statistical evaluation should provide a reasonable indicator of the following significant changes:

- The average gradient increased from 1.1±.1 to 1.6±.1,
  test the 1:60 000 Double-X (1980-82) vs. Plus-X (1983-85).

- The scale changed from 1:60 000 to 1:40 000,
  test the 1:60 000 Double-X (1980-82) vs. 1:40 000 Double-X (1986).

- The films changed from Kodak to Agfa at 1:40 000,
  test the 1:40 000 Kodak films (1986) with the Agfa films (1987-90).

An ANOVA comparison of the mean density range for each of the three conditions (table 3) asserts the following:

- A very significant change in image density range (from .45 to .54) occurred in the 1:60 000 scale aerial photography between the period 1980-82 and 1983-85.

- No change in the image density range (from .45 to .46) was evident from the scale change of 1:60 000 (1980-82) to 1:40 000 (1986).

- A very significant change in the image density range (from .46 to .65) of the 1:40 000 scale images occurred between 1986 and 1987-90.

The density range mean between the 1980-82 and 1983-85 intervals increased by about 20%. The higher contrast of the Kodak Plus-X is attributed to this increase, but it should also be noted that the change is also a direct result of the change in densitometric specifications criteria at the time. The 1980-82 photography reflected a requirement for an average gradient of 1.1±.1, whereas the 1983-85 photography was required to achieve a density range of 1.0 or as close to it as possible. This specification change obliged air photo acquisition firms to process to higher average gradients, thus attaining the higher density ranges.

The periods 1986 and 1987-90 show a very significant shift in the density range (approximately 40%), but here again, film type may not be the only factor involved in the amelioration. Beginning in 1987, firms acquiring aerial photography were requested to make use of the differential brightness lightmeter (Fent and Polzin 1986) developed to optimize the rendition of the ground luminance range by modifying exposure and average gradient.

An implicit assumption made in the analysis is that 'improvement' equates to higher density ranges, ideally 1.0. Although this value may be questioned by some as being too high, it should also be emphasized that the density range reduction of an original is not a compromising feat. Photographic product manufacturers produce excellent materials which alleviate many problems in this area.

Diapositive and paper printing.

Considering that both the diapositive and the contact print represent the final product from which to judge image quality, the efforts which have been placed in high quality reproduction have been relatively good in diapositive reproduction and fair in paper contact printing. The provincial specifications (I.C.S.M. 1989) require the printed product to duplicate the density range of the original negative, a practice which, fortunately, has never been adhered to. Instead, the diapositive aim density ranges have hovered around the .8 value for general diapositives (ICAS 1976) and .65 to .7 for diapositives used in producing orthophotos (Hopkinson 1980), whereas paper prints have had a value of .6 to .8 density range. In both cases, considerable effort has often been required to raise the density ranges of the originals negatives to the aim density ranges on the prints, especially with the 1:60 000 scale images (see table 2). Density range manipulation with contact prints has been easier to attain due to the greater variety of contrast grades available, but with diapositives the lack of this variety has required lab personnel to rely on careful adjustment of exposure and processing parameters to manipulate the density range.

A key goal in all print production has been to relay the concept of contrast requirement to the user. Instead of users receiving a generic printed product, they would specify the level of contrast best suited to their applications. As of yet, many users are not knowledgeable enough to properly specify the contrast ranges.

Process chemistry.

Kodak Type A and 885 chemicals were used almost exclusively to process the small scale originals. The standard Type A chemistry had been replaced by the 885 in instances where higher effective emulsion speeds were needed. This was the situation with much of the Kodak Plus-X flown in the period 1983-85 and the Panatomic-X tests flown in 1983-84. Although the Kodak 885 developer may have been advantageous to the slower films used in the small scale applications, the faster films such as Kodak Double-X showed relatively higher base and fog densities (Fleming 1983). Since the use of the Double-X film has constituted about 75% of the total film used during the decade, many contractors have resisted the conversion from Type A; however, the underexposure of the slower speed emulsions associated with overprocessing to enhance contrast has made the Kodak 885 developer attractive, and in some cases a necessity.

Other processing chemistries have been tested, namely the Kodak Duraflo and the Agfa G74c (Fent 1990), but no significant advantages have warranted a change to these products.

Color photography.

Small scale use of color emulsions has been very limited, primarily due to the added costs involved and because of the few added benefits in topographical applications (Fleming 21973). Only three projects have been flown during the decade, two 1:50 000 scale projects using color I.R. (one depicted in illustration 5) and a 1:40 000 project using color negative, both flown for special reconnaissance. The color films have not had much success in small scale applications because of a lack of illumination uniformity using the positive color I.R. film, and the bluish haze rendition of the color negative film. The three to four times added cost of the color material was also a major factor in its low use.

It may well be that negative film does have its limitations in small scale aerial photography color, but the potential with color infrared film should be significantly better, especially for reconnaissance (Gut and Höhle 1977). The Kodak 2443 emulsion has the same haze compensating attributes as the black and white infrared film and finer granularity (Kodak 1982). Combined with the negative processing technique which enhances illumination uniformity (Klimes et al. 1988), this film/process may possibly be the best **technical** approach to small scale reconnaissance.

Future Directions.

Small scale aerial photography is at a critical juncture. Whereas small scale photography was used exclusively for large mapping and reconnaissance projects in the recent past, today it is being supplemented by satellite imagery such as Landsat, Spot, and in the mid 1990s, Radarsat. In addition, airborne sensors such as the MEIS, CASI, and FLI have also viable alternatives in the reconnaissance field. However, conventional aerial photography remains the most widely used type of sensing technology even though it would seem that its days (years?) are numbered. Film technology's dominance may be attributed to several factors. The superior spatial resolution of film most definitely contributes to its use; the best silicon arrays today can approximate the resolution of ISO 1000 film, but imaging array technology continues to progress and may approach current ISO 100 film resolution by the middle-end of the current decade (Snavely 1989). Still, if high resolution digital data is required, today's scanning technology can deliver the product from the aerial film original. The flexibility in acquisition and handling of film data make it an efficient way to obtain terrain information, the photography is not subject to peripheral data processing and storage limitations as is the case with high quality digital imagery. This 'non automated' aspect of conventional photography makes it accessible to more users. A third and possibly most important reason for aerial photographic preference may be familiarity. Digital imagery, its acquisition, processing, and output is today a specialized field rather removed from the user group (photogrammetrists, natural resource specialists, planners, etc.), as such, these users' proficiency level with the digital product is lower than with the conventional product. Education, technology, and time will aid in the familiarization process with electronic image data, afterall, photography has had over 150 years of adaptation.

Regarding provincial programs and applications which would make use of small scale imaging, the updating of outdated map information currently encompasses the most common practice. The accent is placed on access features such as roads, cutlines, and trails, forestry features such as cutblocks and regeneration, terrain and land use analyses. Some comparative evaluation of imaging technologies for terrain data inventories has been done (Nesby 1987; Strong 1986), but a consistent application of the technology to fit the purpose has yet to be achieved. Unfortunately, a competitive attitude often predominates proponents of the various imaging methodologies, each extolling the virtues of their proper technology. The end user is more often confused rather than enlightened as to when one methodology supersedes, or more likely, works in concert with another. Imaging options are further moderated by financial factors (Rochon et al., 1986) and may determine the ultimate basis for choice.

Conclusion.

The evolution of the small scale aerial photography product over the past decade is characterized by numerous efforts to minimize atmospheric effects while still rendering acceptable image quality coverage. In summary, factors which contribute to this goal are:

● The use of panchromatic-I.R. emulsions.
The present Agfa black and white aerial film series, the Kodak B&W IR film, and the Kodak color infrared film (negative process), all provide the necessary haze penetration required for an optimal contrast and density range. A panchromatic-infrared type film is also keenly awaited from Kodak.

● A scale change from 1:40 000 to smaller scales.
A more competitive market and the emergence of suitable films make this a realistic option. Caution should be exercised with the more exotic means of scale reduction; the ER-2 1:130 000 is prone to acquisition reliability, the use of the 88 mm. lens is subject to the incursion of the anti-solar point much earlier in the day.

● The use of higher average gradients.
The relatively low luminance ranges often encountered in small scale applications must often be enhanced in processing. Average gradients of over 1.30 should be a prerequisite while average gradients in the 1.4 to 1.7 range should be the norm. The I.C.A.S. densitometric

specification requiring a density range of 1.0 greatly aids in this goal.

- A more appropriate printing criteria.

The I.C.S.M. printing specifications must be changed. The photographic industry incorporates great latitude in its printing materials and processes to modify originals. This facility should be fully maximized, since these printed products are the basis from which users extract image information. This change would also address the requirements of those users who require lower than normal contrast reproductions such as with orthophotos.

These factors represent fundamental technical components which should be addressed in any future consideration of small scale aerial photography. The application of these recommendations will ensure that the small scale aerial photography technology is being used to its maximum potential.

Acknowledgements.

The author would like to thank Messrs. D.Thompson, T.Polzin, and J.M.Brouwer (ret.) (Alberta Forestry Lands and Wildlife) for reviewing the text and confirming the historical events, and Mr. A. Stade, (Alberta Forestry, Lands and Wildlife) for his assistance in extracting the sample density data.

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Appendix

Definition of some technical terms.

Acutance

Acutance is a measure of the microdensity profile across an edge of low to high contrast. The units which are measured are the incremental ΔDensity, ΔX (distance) at n intervals, and maximum density range DS. The complete expression is:

$$A = \frac{\Sigma \left(\frac{\Delta D}{\Delta X}\right)^2}{n(DS)}$$

Average Gradient

Average gradient defines the contrast value of an emulsion associated with a given set of processing conditions. These conditions may be chemical (developer components and concentrations) or physical (reaction rates, temp. etc.). The average gradient value is obtained by densitometric measurements of graded exposures on the emulsion, the graded exposures are obtained with a gray scale. A plot of density vs. exposure will provide a characteristic curve from which two points are chosen to define a line; the slope of this line is the average gradient. The two points are defined at .3 + base and fog density and 1.0 + base and fog density (ISO 7829). The expression is:

$$AvG. = \frac{\Delta D}{\Delta H} = \frac{D_{1.0+bf} - D_{.3+bf}}{H_{D_{1.0+bf}} - H_{D_{.3+bf}}}$$

Modulation Transfer Function (MTF)

The MTF is typically used to predict the performance of some optical system. The MTF is derived from modulating or alternating linear patterns of white and black. A microdensity profile across such a pattern will show a density variation which is sinusoidal. Thus the components of the MTF are the modulation (or wave amplitude) of density and the frequency (or wave period) the oscillating density pattern. A typical MTF plot will show frequency (in cycles/mm) on the ordinate axis and % response on the abscissa axis. The response % is the ratio of the sinusoidal test object to the processed sinusoidal image.

Transparency (atmosphere)

Atmospheric transparency is related to its *transmissivity,* denoted by $\underline{\tau}$. $\underline{\tau} = e^{-\sigma r}$, where *r* is the distance and $\underline{\sigma}$ is the <u>extinction coefficient.</u> $\underline{\sigma}$ is the sum of the absorption and scattering coefficients, *k* and *b*. Figure 1 graphically reproduces the exponential curve of this function.

Year	Description of Event	Emulsion Used	A.G.
1980	Small scale production change from 1:50 000 to 1:60 000.	Kodak Double-X 2405	1.1±.1
1982	I.C.A.S. Densitometric specifications are revised and adopted provincially.	Not specified	
1983	Kodak Plus-X and Panatomic-X are tested for higher contrast as required by the revised I.C.A.S. specifications. Plus-X set as the small scale standard production film.	Kodak Plus-X 2402 Kodak Panatomic-X 2412	1.55±.2 2.0±.2
1984	Red filtration tested to diminish attenuation of contrast by haze. Ilford FP3 also investigated.	Kodak Plus-X 2402 Ilford FP3	1.70 0.87
1984	88 mm. (3.5") lens cone tested at 1:110 000 scale.	Kodak Plus-X 2402	1.57
1986	Small scale production change from 1:60 000 to 1:40 000.	Kodak Double-X	1.20±.1
1986	Agfa-Gevaert emulsions tested using the Kodak films as control.	Agfa Aviphot 200 Agfa Aviphot 150 Kodak Plus-X Kodak Double-X	1.77 1.79 1.91 1.47
1987	Agfa Aviphot 150 set as standard small scale production film.	Agfa Aviphot 150	1.6±.2
1988	Small scale test at 1:130 000 using ER-2 aircraft. Agfa Aviphot 50 introduced.	Agfa Aviphot 50	1.30
1989	Small scale standard production film set as Agfa Aviphot 50.	Agfa Aviphot 50	1.40±.1
1990	Comparison test of Kodak Panatomic-X 2412 and Agfa Aviphot 50 obtained at 1:130 000 scale with ER-2 aircraft.	Kodak Panatomic-X 2412 Agfa Aviphot 50	1.25 1.29

Table 1. A chronology of small scale aerial photography events in the Alberta Government.

Kodak Panatomic-X *Average Gradient=1.25*			Date of flight: August 19,1990 Visibility: good-fair, 15 Km.	**Agfa Aviphot 50** *Average Gradient=1.29*		
Dmin	**Dmax**	**Drng**	**Description of Area**	**Dmin**	**Dmax**	**Drng**
.36	.80	.44	City of Calgary (urban terrain)	.47	1.25	.78
.24	.58	.34	Montana-Alberta border (mountainous terrain)	.41	.97	.56
.28	.55	.27	Sylvan Lake (agricultural terrain)	.58	1.08	.50
.22	.35	.13	Wabasca Lake (forestry terrain)	.34	.61	.25
.28	**.58**	**.30**	**Densitometric averages (complete phpotographic coverage)**	**.46**	**1.01**	**.55**

Table 2. Densitometric data of the 1990 ER-2 test with Kodak Panatomic-X and Agfa Aviphot 50.

Description of Event	Sample Number[1]	Mean Density Range	Standard Deviation	ANOVA F test	Type I error analysis at $\alpha = .01$
Group 1 1980-1982 Double-X 1:60 000	$n_1 = 90$	$\bar{a} = .45$	s =.17	11.99 $H_o: \mu_1 = \mu_2$	*Rejected*
Group 2 1983-1985 Plus-X 1:60 000	$n_2 = 90$	$\bar{a} = .54$	s =.16		
Group 3 1986 Double-X 1:40 000	$n_3 = 90$	$\bar{a} = .46$	s =.16	.08 $H_o: \mu_1 = \mu_3$	*Accepted*
Group 4 1987-1990 Agfa 50 & 150 1:40 000	$n_4 = 90$	$\bar{a} = .65$	s =.16	60.01 $H_o: \mu_3 = \mu_4$	*Rejected*

[1] These observations represent random sampling obtained in forested terrain. Alberta's terrain is characterized by four major features: cordilleran, forest, agriculture, and rangeland. Photographic coverage of these features varies widely among the four groups, potentially biasing the density range representation of each group. The forested terrain sample represents a relatively homogeneous condition and also the most prominent terrain feature of the province.

Table 3. Statistical summary of density range comparisons for four time periods, scales, and film conditions. Statistical test and table values from Mendenhall (1970).

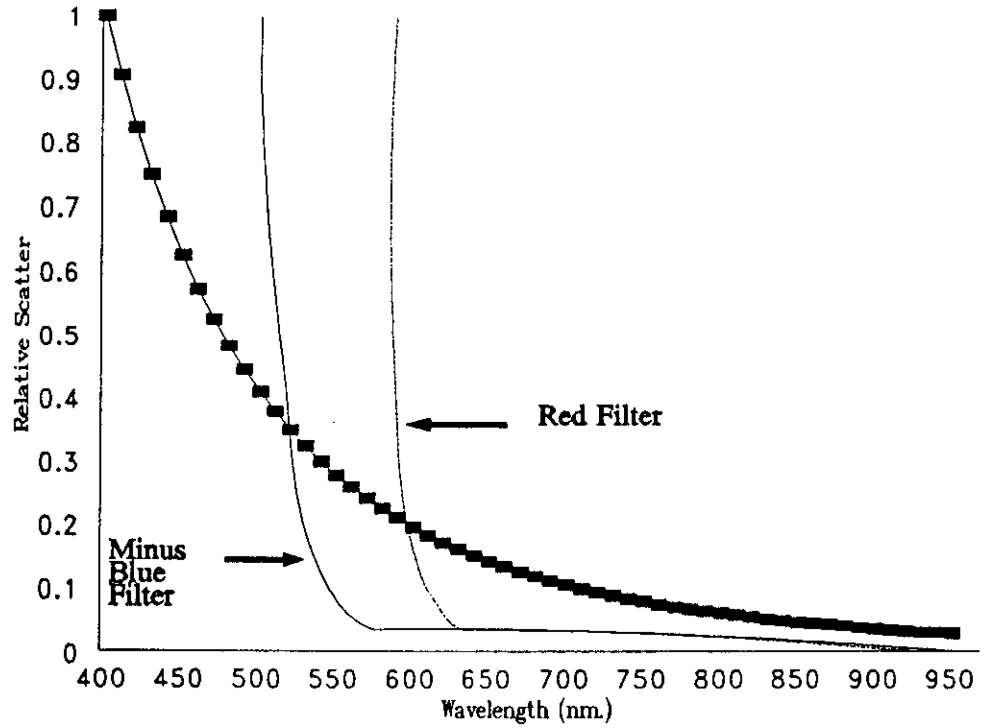


Figure 1. Scattering as a function of wavelenght and as affected by filtration.

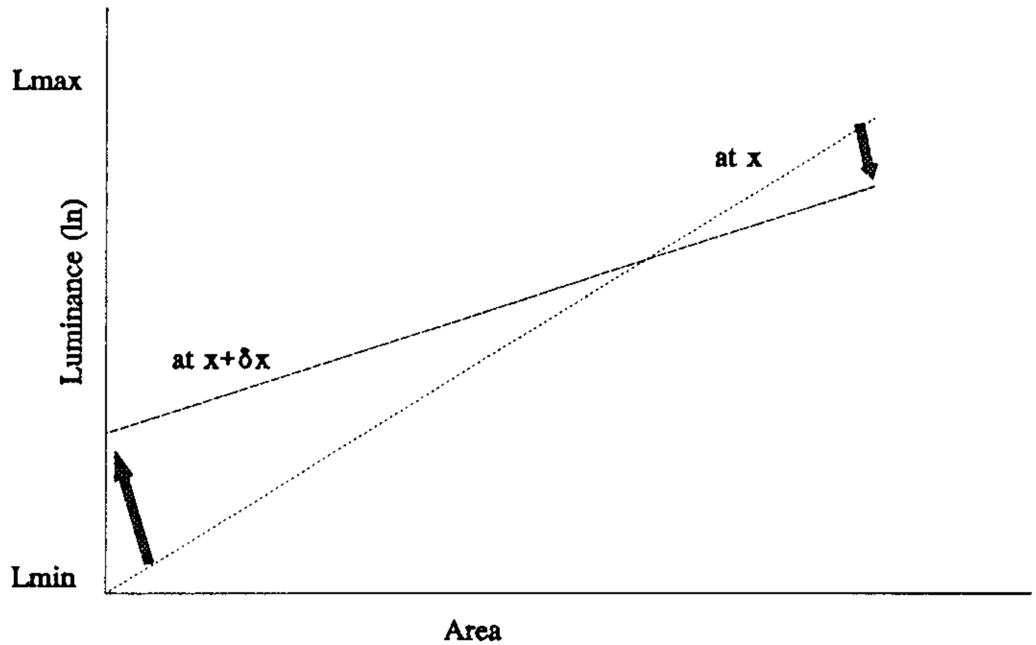


Figure 2. The scattering effect of haze. Minimum luminances are increased while maximum luminances are decreased with atmospheric distance, x+δx. (Gibbs)

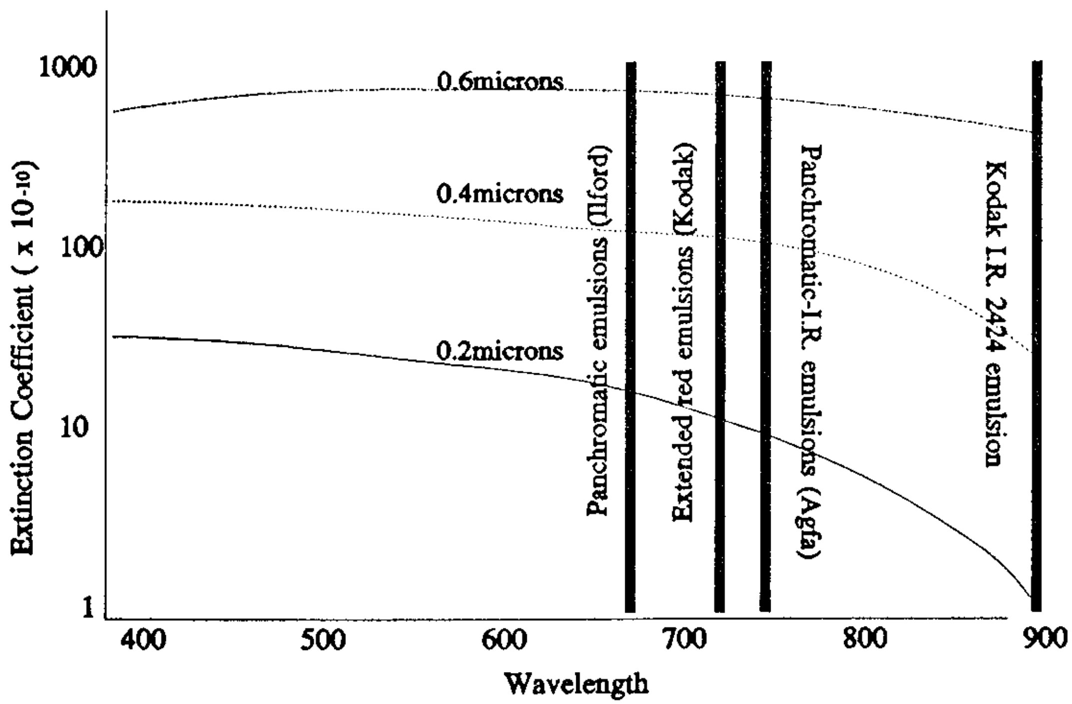


Figure 3. Extinction coefficients for three different size particles (adapted from Bricard), with spectral limits of different types of emulsions.

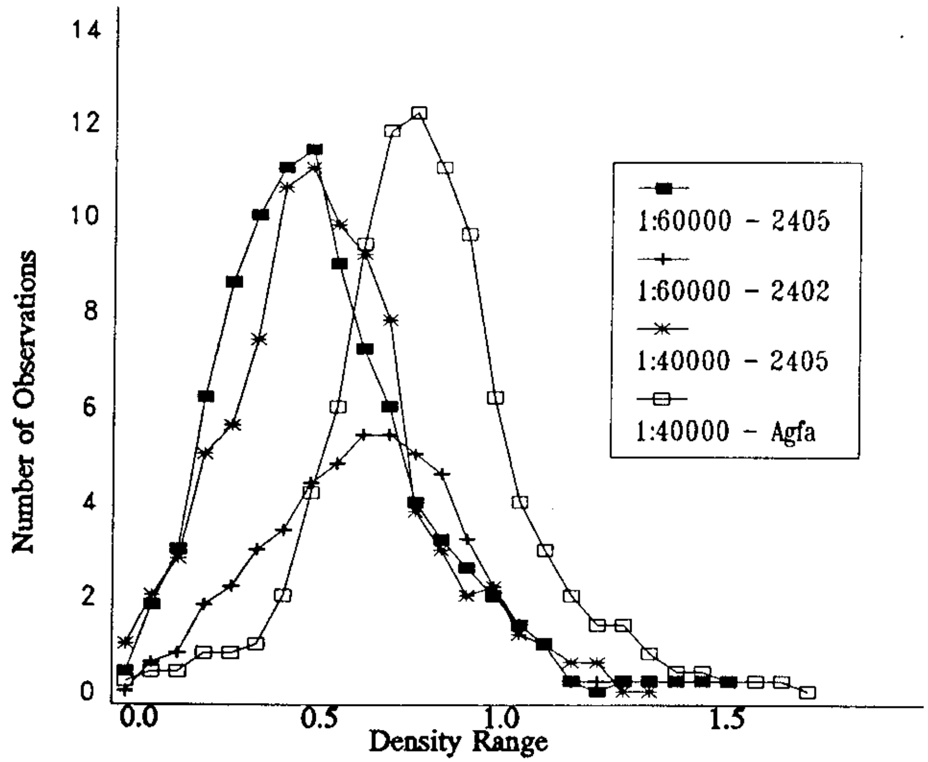
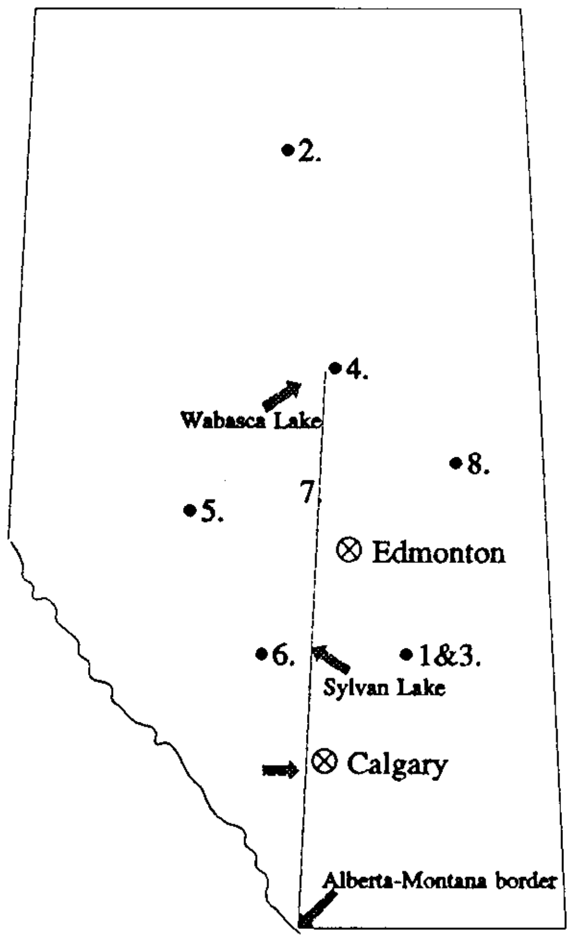


Figure 4. Frequency distributions of the densitometric data samples.



List of Illustrations

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2. Cariboo Mountains.
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6. Rocky Mountain House area.
7. ER-2 flight line and photo location.
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Figure 5. Geographic locations of air photos

Illustration 1. The effect of haze on luminance range. The density range difference (negative) between the two conditions is .30. Film average gradient is 1.21 and the paper grade is #3.

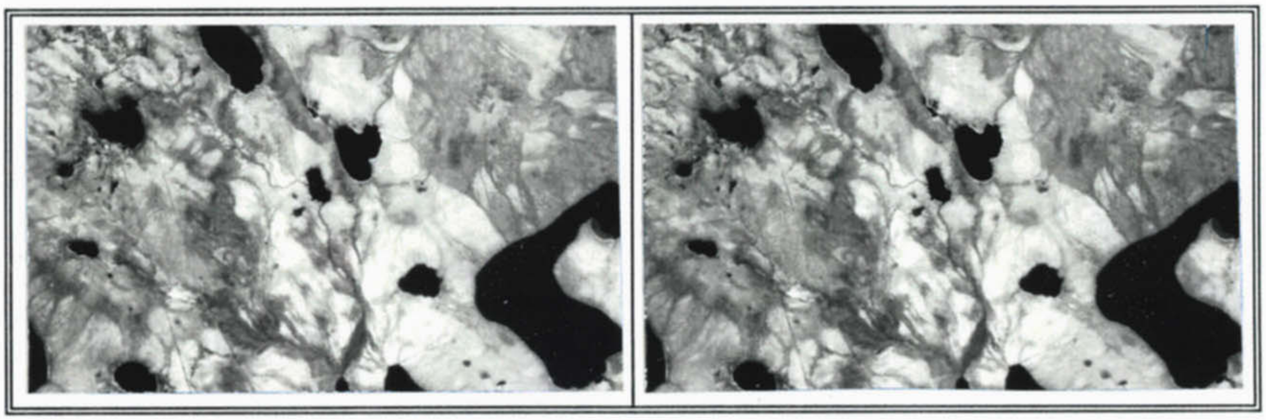


Illustration 2. 1:60 000 scale photography exposed with a minus blue filter (left) and a red filter (right). The density range difference (negative) is .13. Film average gradient is 1.14 and the paper grade is #3.

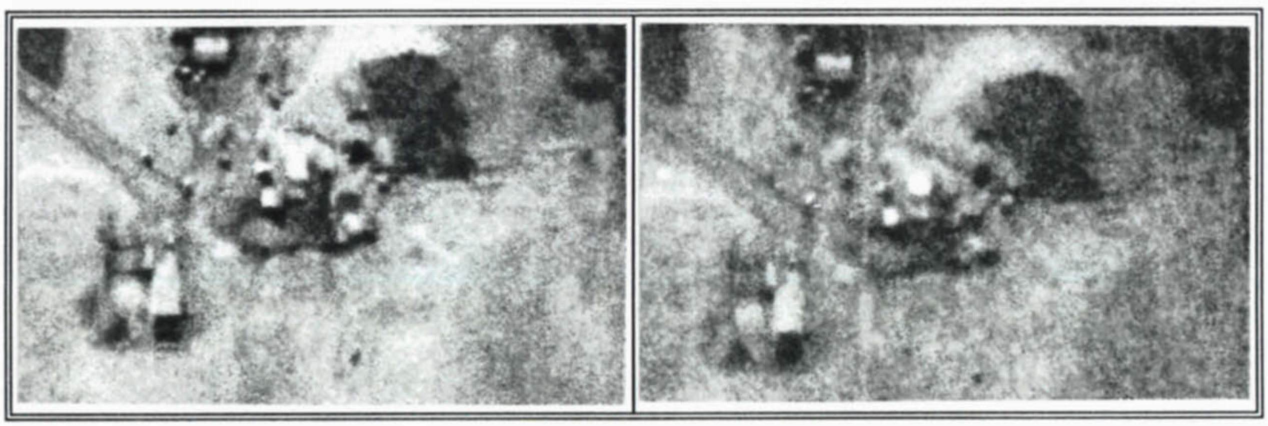


Illustration 3. 1:60 000 scale photography enlarged 18X. Note the degradation in apparent sharpness of the buildings caused by haze.

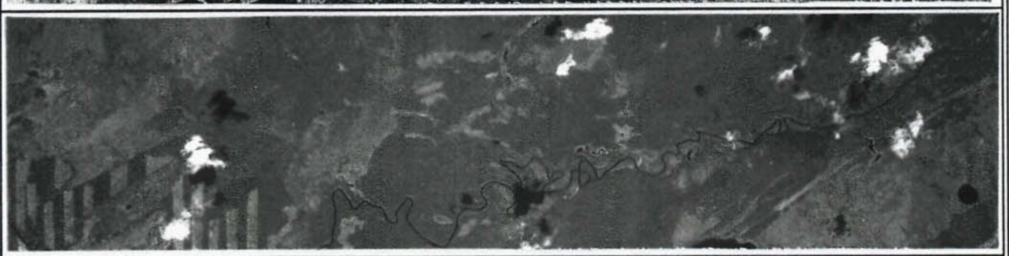
1980 1:60 000 Double-X Av.G.= 1.14	
1984 1:60 000 Plus-X Av.G.= 1.66	
1986 1:40 000 Double-X Av.G.= 1.30	
1989 1:40 000 Agfa 150 Av.G.= 1.80	
1990 1:130 000 Agfa 50 Av.G.= 1.29	
1990 1:130 000 Panatomic-X Av.G.= 1.25	

Illustration 4. Photography of the Wabasca Lake area

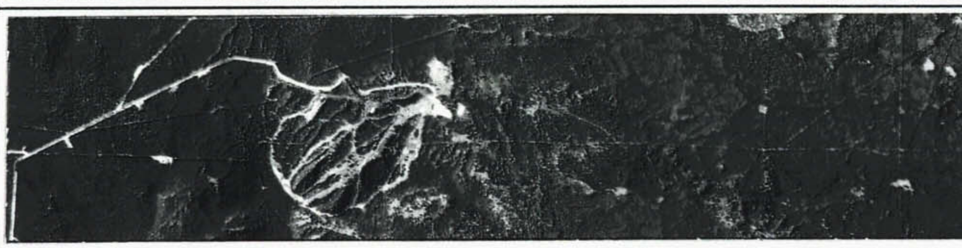
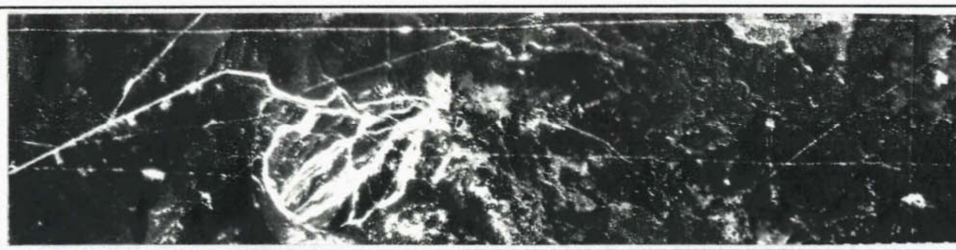
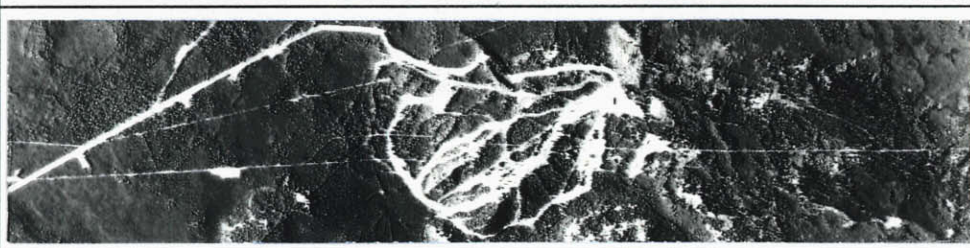
1977 1:50 000 Double-X Av.G.= 1.26	
1981 1:60 000 Double-X Av.G.= 1.15	
1983 1:50 000 I.R. 2443	
1985 1:60 000 Plus-X Av.G.= 1.50	
1986 1:40 000 Double-X Av.G.= 1.47	
1986 1:40 000 Agfa 200 Av.G.= 1.77	

Illustration 5. Photography of the Edson area (Silver Summit ski hill).

Illustration 6. 1:110 000 photography photographed with the 88 mm. lens (left is corner, right is center).

1987 1:40 000 IR 2424 Av.G.= 1.43	
1988 1:40 000 Agfa 150 Av.G.= 1.51	

Illustration 8. Small scale use of Infrared film for vegetation studies. Compared here with the Agfa panchromatic-I.R. product used in general survey applications.

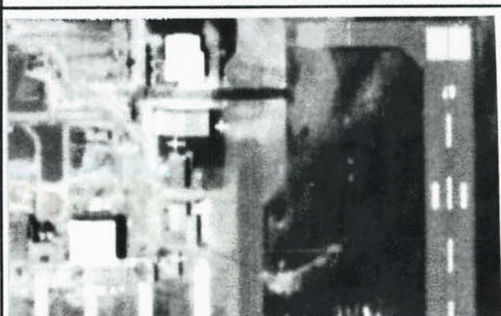
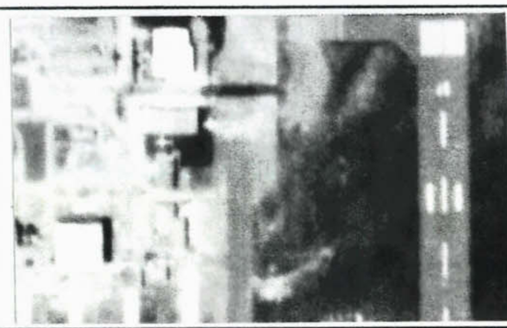
Location	Kodak Panatomic-X 2412	Agfa Aviphot 50
Wabasca Lake (forested)		
Montana-Alberta border (mountain)		
Sylvan Lake (cultivated)		
City of Calgary (urban) Circle indicates location of 18X enlg.		
City of Calgary (airport) 18X enlg.		

Illustration 7. ER-2 simultaneous photography exposed at 1/150 s. f/5.6, printed on grade 3 paper.

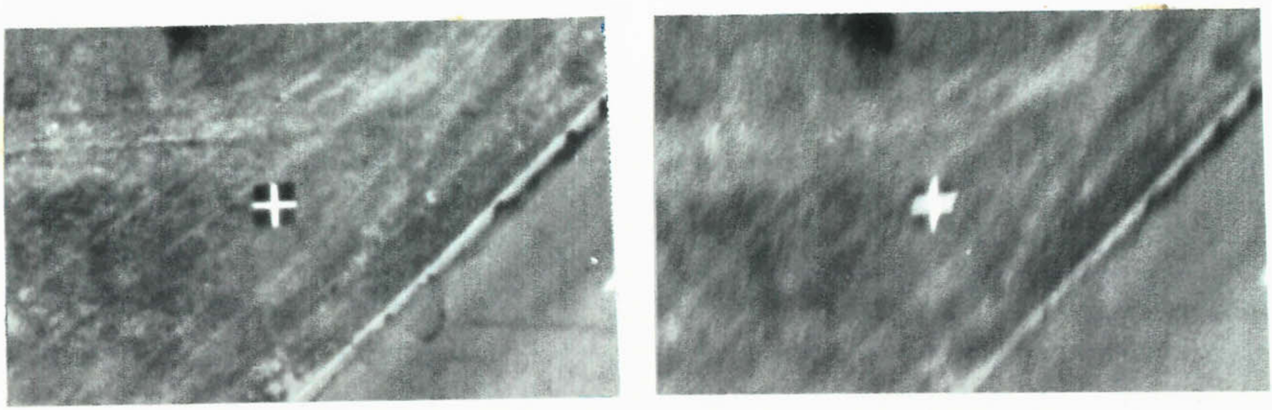


Figure 13. Photography with forward motion compensation used but exhibiting lateral motion blur in the right side frame. Direction of flight is from left to right, Original scale 1:5000 enlarged 18X. Courtesy of City of Edmonton, Mapping and Graphics Section.