060102

AERIAL PHOTOGRAPHY FOR
WESTERN AUSTRALIAN FIELD STAFF

INVENTORY AND PLANNING
MANJIMUP

CONTENTS

AERIAL PHOTOGRAPHY IN FOREST MANAGEMENT

1. INTRODUCTION

Photogrammetry can be defined as the art, science and technology of obtaining reliable information about physical objects and the environment through the process of recording, measuring and interpreting photographic images and patterns of recorded radiant electromagnetic energy.

Included in the definition of photogrammetry are two distinct areas;

(a) "metric" photogrammetry which involves precise measurement and computation to determine the size and shape of objects and

(b) "interpretive" photogrammetry, which deals with the recognition and identification of objects. The use of Aerial photographs can greatly reduce the amount of field work that would otherwise be required to establish the detailed inter-relationships that exist in a forest and are important to the forest manager. However, to obtain the maximum benefit from photos the forest manager must be fluent in the techniques involved in measuring and interpreting photos.

2. TAKING AERIAL PHOTOGRAPHS

Normal photographs are taken with the camera pointing vertically downwards at the moment of exposure. The properties of these photographs are little affected as long as the camera does not deviate more than 3^{o} from the true vertical, and with modern equipment this limit is seldom exceeded.

Black and White photographs are usually taken on panchromatic film, which is about equally sensitive to all parts of the visible spectrum. The shorter wave lengths which produce blue light are readily scattered by dust and other impurities in the atmosphere (hence the

If this overall haze light enters the camera it reduces the contrasts in the amount of light reflected by other objects and results in a less sharp picture, so aerial photographs are generally taken through a "minus blue" filter which excludes blue light.

The advantage of colour photographs for interpretational purposes is debateable, and processing is more troublesome and costly; however, the use of colour negative film from which either colour or black and white prints can be made overcomes this drawback to some extent.

When aerial photographs are taken for survey purposes the intervals between exposures are arranged to give approximately 60% overlap between successive photographs along the line of flight. As a result every feature on the strip of photographs is recorded from at least two camera positions. This provides a means of linking together the photographs for the production of an accurate map, and also enables the photographs to be viewed stereoscopically to present a three dimensional model of the overlap area.

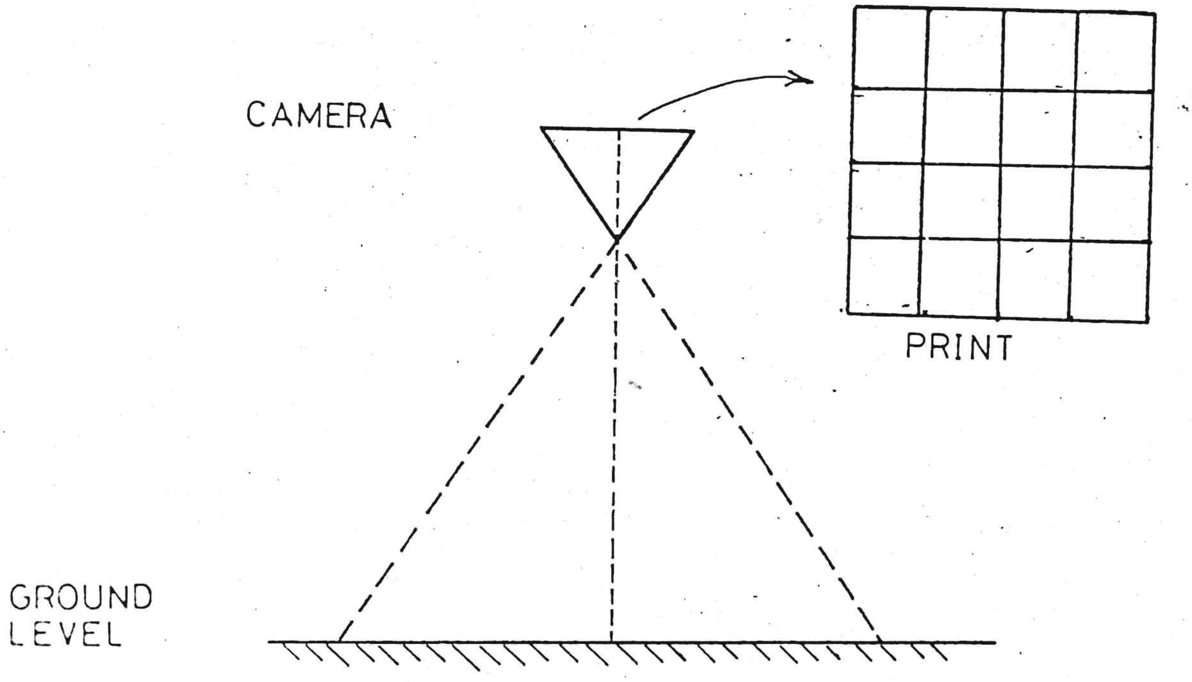
To ensure that there are no gaps in the coverage and to provide linkage between adjacent strips of photographs an overlap around 20% to 30% is prescribed between strips. On big jobs in Australia it is customary to take strips of photographs running east and west.

3. TYPES OF AERIAL PHOTOGRAPHS

3.1 Vertical Photographs

Vertical photographs are actually only near vertical. Since there is no economically practical means of holding the camera axis exactly vertical at the instant of exposure, each so called vertical exposure is in fact, tilted to some degree from the true vertical. This is the type of photo which we will mainly be dealing with.

By definition, a vertical air photo has a tilt of less than 3°.

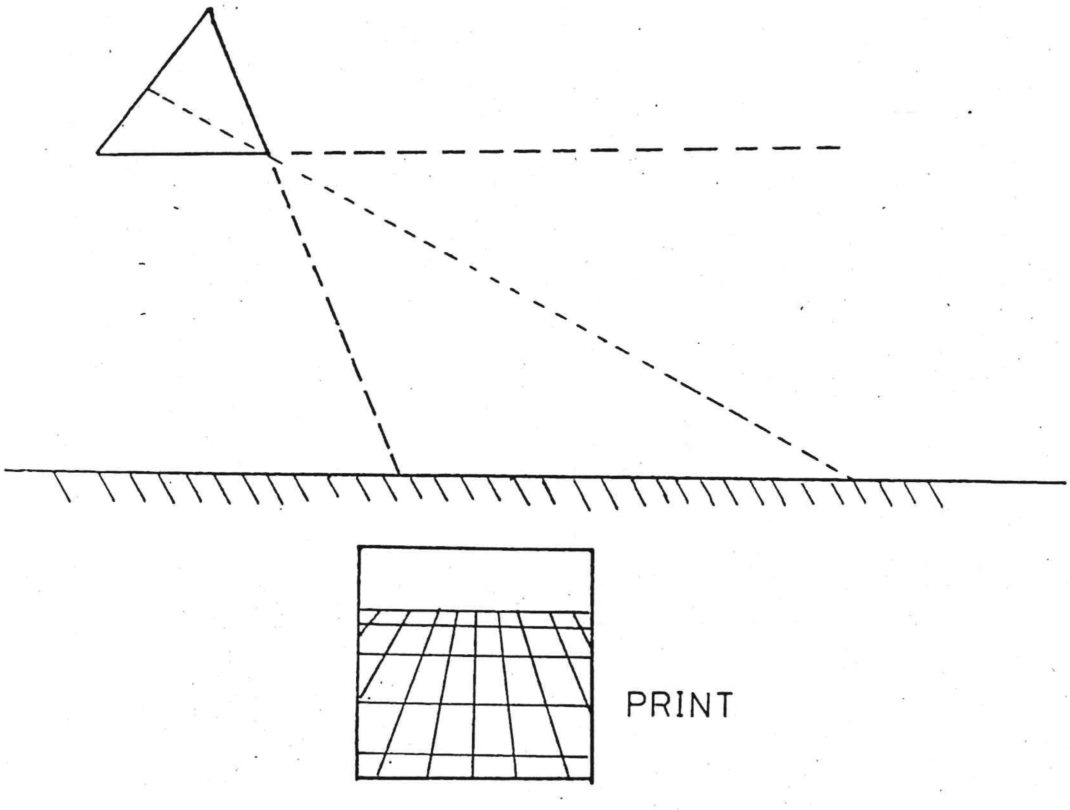


3.2 Oblique Photographs

Obliques fall into two categories.

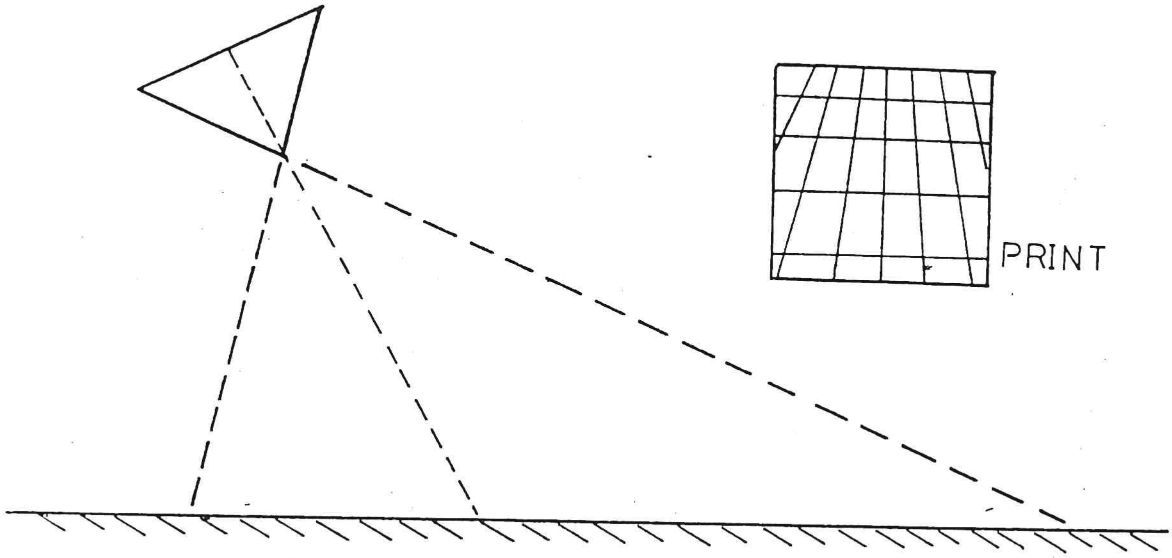
3.2.1 High Oblique

These have a relatively high angle of deviation from the vertical and include the horizon. These are seldom used for forest management.



3.2.2 Low Oblique

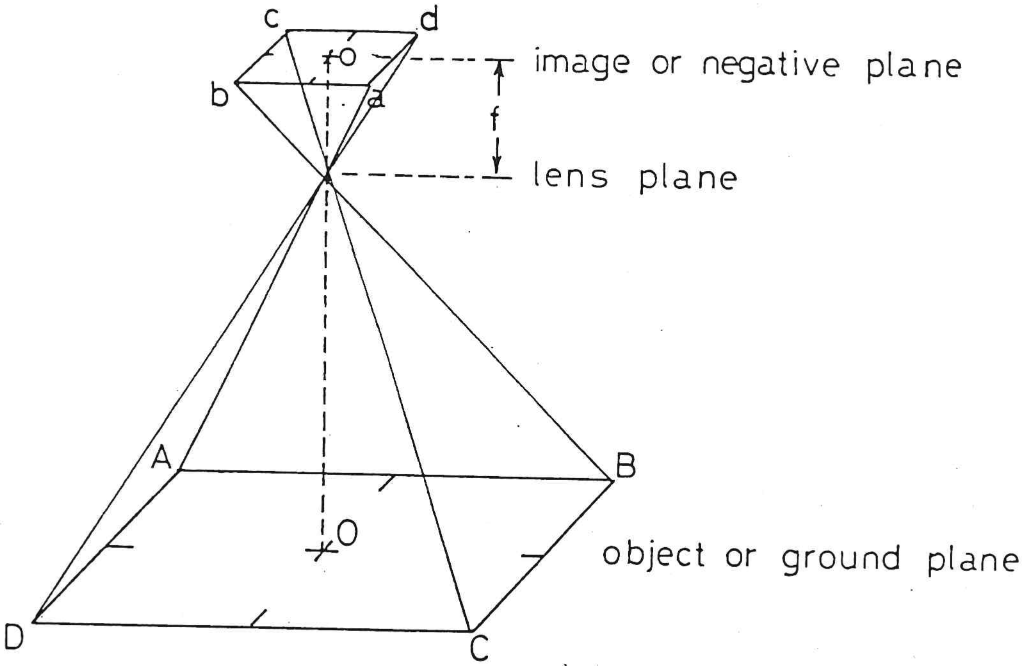
These have a relatively small angle of deviation from the vertical and do not include the horizon. These have been used extensively in forest management, particularly in coupe control in the past.



4. CHARACTERISTICS OF AERIAL PHOTOGRAPHS

4.1 Camera Geometry

Like any photograph taken through a lens, an aerial photograph provides a perspective projection of the features which it depicts.



In figure 4.1 it can be seen that all rays from the object ABCD and O pass through the lens L, before reacting the negative plane on the other side. The point where the optical axis intersects the ground plane, denoted by O, is called the ground principal point, which the same optical axis intersects the image plane at O and is simply called the principal point.

A most important calibration factor in an aerial camera is the focal length. This is LO in figure 4.1 and is denoted by the letter f. The lenses of aerial photographic cameras normally have focal lengths of between 90 and 300mm. For the same size of negative a shorter focal length will give a wider angle of coverage, and, while maintaining the standard 60% overlap, the photographs can be taken from positions which are further apart. Such photographs will show a greater amount of displacement due to height differences, and will give a more vivid 3-D effect when viewed stereoscopically than photographs taken with lenses of longer focal length.

4.2 The Principal Point

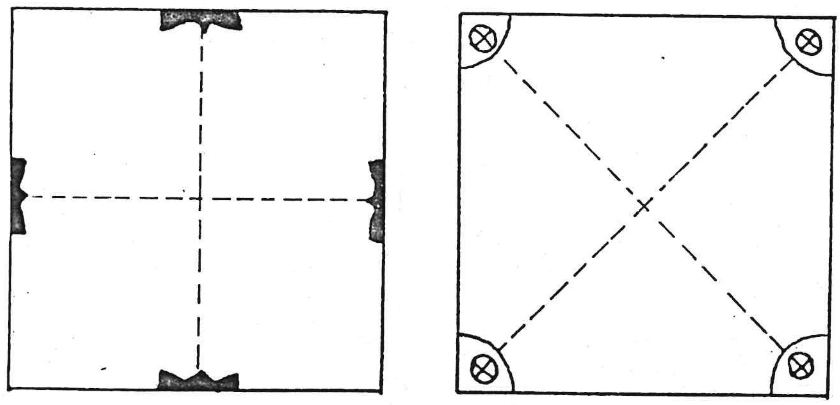


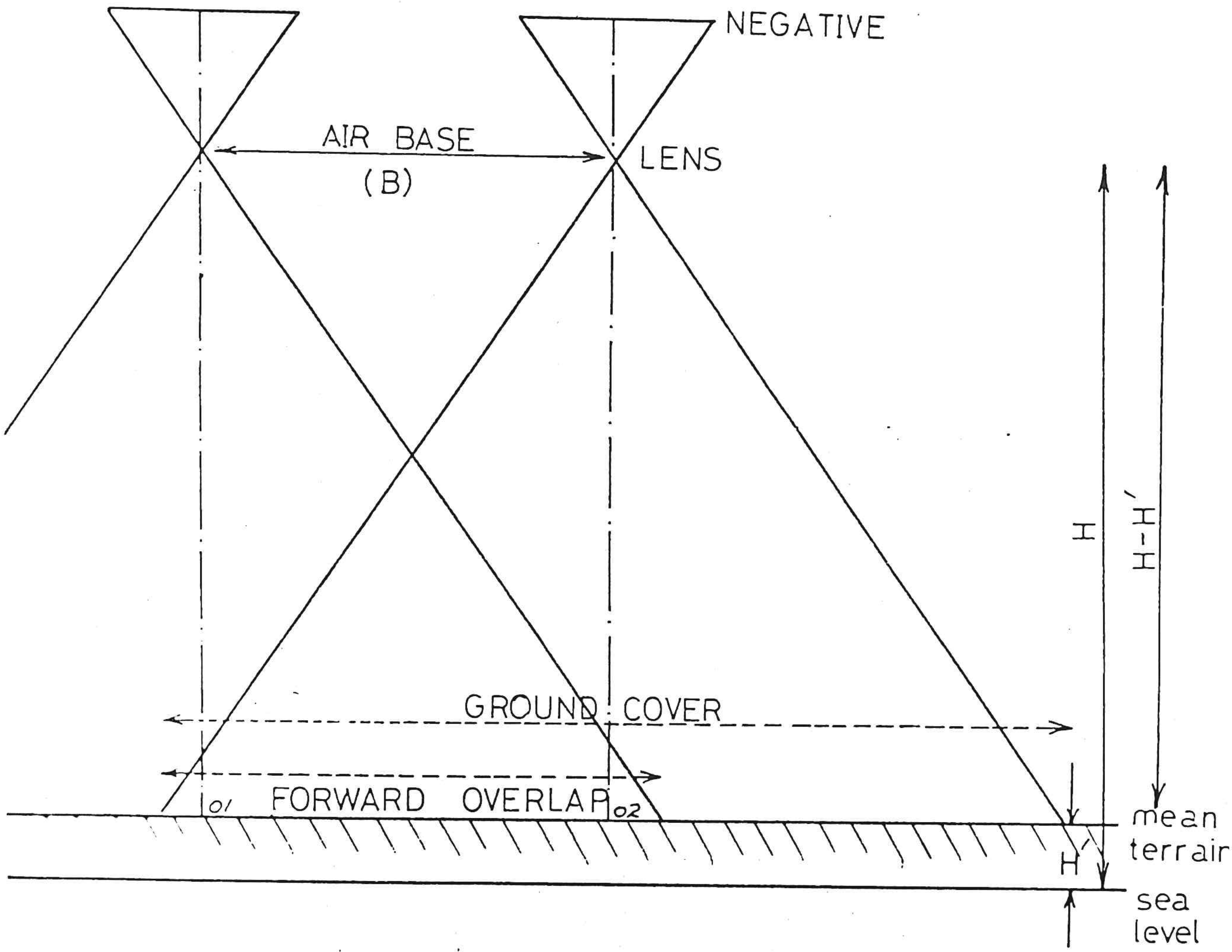
Figure 4.2 shows the usual square format of the air photograph and the fiducial marks. These marks are located within the camera and are exposed onto the negative as each photo is taken. During camera calibration the fiducial marks are adjusted so that when opposite marks are joined they:

(i) intersect at the principal point.

(ii) intersect at right angles.

So for photography from a properly calibrated camera the principal point is found by joining the opposite fiducial marks.

4.3 Forward Overlap



In Figure 4.3 the horizontal or flat terrain lies in a plane above the datum which is mean sea level. The distance between the two planes is denoted by H' and may be referred to as the mean terrain height. The aircraft is flown at an altitude above mean sea level so its exposure altitude is H. We are particularly interested in the distance from the lens to the mean terrain height, this is denoted by H - H' and is called flying height.

Aerial photographs are taken with a 60% overlap. To achieve this, each exposure is taken from an exposure station indicated by L_1 and L_2 separated by a distance called the air base (B).

4.4 Format and Legend

The standard size for survey photography is approximately 230 x 230mm (9"x9"), but smaller formats are sometimes used.

Contact prints of the same size are normally made; the negatives are usually capable of considerable enlargement, but prints larger than the standard size are awkward to view stereoscopically. Each photograph carries a legend or titling strip, giving all or most of the following information.

(a) general geographic or territorial location of the area.

(b) number of the run.

(c) serial number of the photograph.

(d) date of photography.

(e) time of photography.

(f) focal length of camera lens.

(g) flying height above sea level.

(h) approximate direction of north.

Some of this information will be in print but some may be recorded by photographing instruments in the aeroplane.

5091 WA 2043 KARRI AREAS - PEMBERTON RUN 1 (5090 - 5104) SCALE 1:25000 152.

The number 5091 is the unique number of the photo frame. However, the number 5 in the thousands position is common to all photos taken in Western Australia.

The number WA2043 is the aerial film number and is a vital part of the identification of a photo. Aerial films are usually 120m in length and are kept intact and stored in a labelled container.

Following the film number is the project or job name. In this case "Karri areas - Pemberton". On the standard 1:50,000 or 1:40,000 scale photo the job name will be something like "Pemberton 1:250,000 as shown in example 2. below.

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This means that the job was standard photo cover of the whole Pemberton 1:250,000 map sheet area. Standard photography at 1:40,000 or 1:50,000 scale is always related to the 1:250,000 map sheet area which becomes the project area.

The Run number appears next and is self explanatory. It is followed by the frame numbers at the beginning and end of the run. Used with a flight diagram the run number is an aid to quickly finding the map area covered by the photograph.

The next statements on the legend are; the NOMINAL SCALE of the photograph, the focal length of the lens used, the date on which the job was photographed, the Lands and Surveys job number and a north point.

4.5 Nominal Scale of a Photograph

The Nominal Scale of an aerial photograph is an average scale derived simply from the relationship between the focal length of the camera (f) and the flying height $(h - H^1)$ see figure 4.3.

The equation is Scale $= \dfrac{f}{H - H^1}$

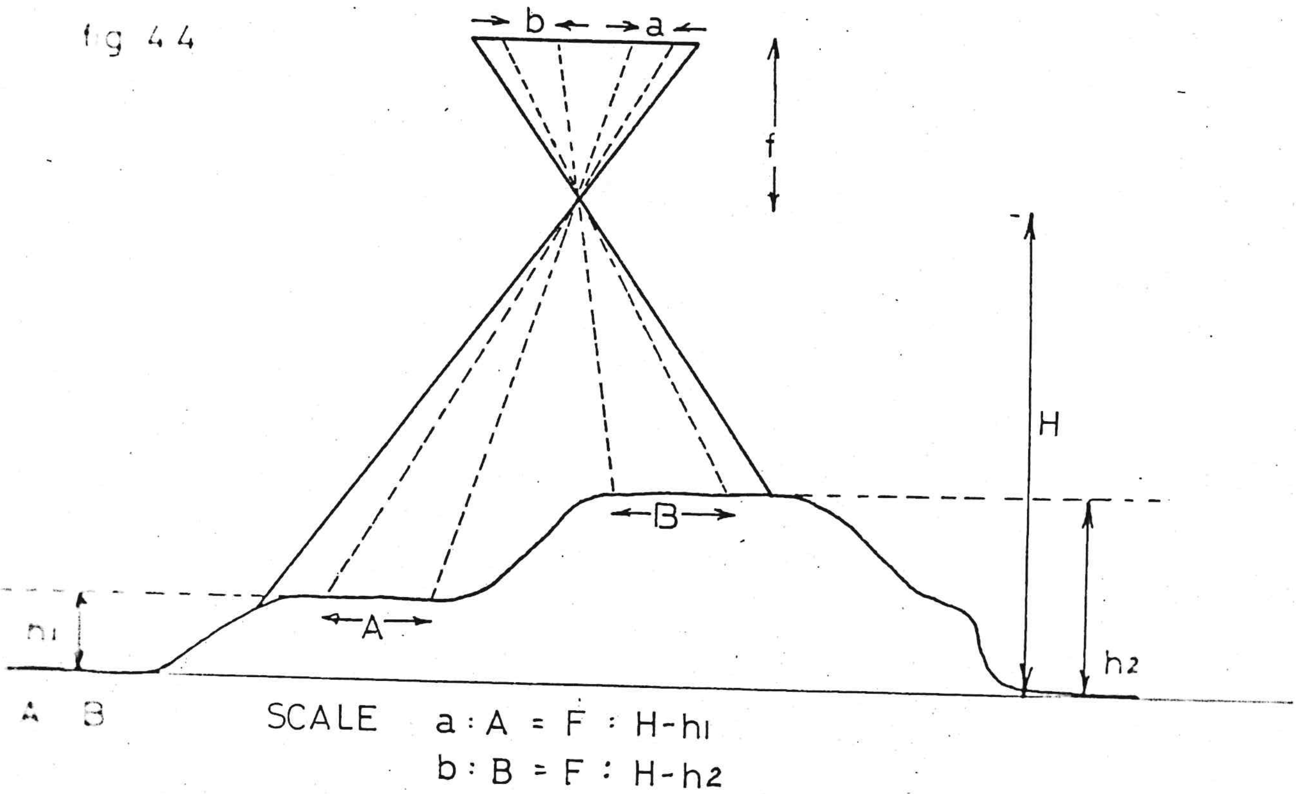
While many factors influence the accuracy of the nominal scale of a photograph, they are unimportant because nominal scale is only a good guide to the average of a number of scales which will exist on the photograph. It should be noted that precise scale on the photograph will vary continuously due to the effects of relief displacement and tilt.

4.5.1 Relief Displacement

See Figure 4.4

It is clear from the diagram how images on the photograph are displaced according to variations in elevation. Relief displacement is the most significant cause of such displacement.

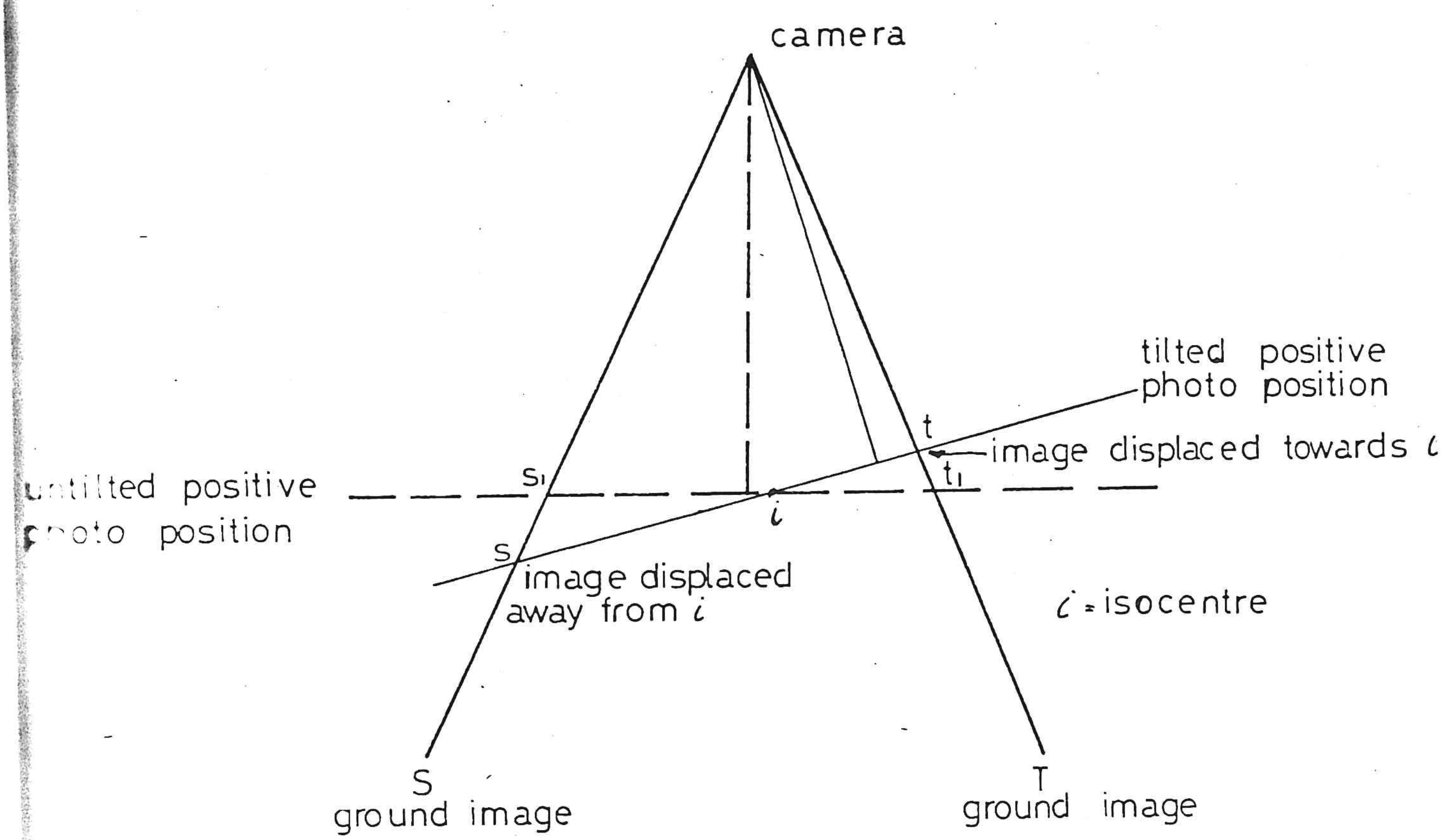
fig 4.4



4.5.2 Tilt

See Figure 4.5

So called vertical photography is not necessarily truly vertical in the sense that the ground plane and the camera negative plane are always parallel. Normal specifications require that the average tilt of the camera axis from the vertical should not exceed 1 degree nor shall the maximum tilt exceed 4 degrees. Figure 4.5 illustrates the image displacements due to tilt.



5. INTERPRETATION OF AERIAL PHOTOGRAPHS

There are two basic instruments used to view pairs of photographs (stereopairs) in three dimensions, or as it is called, stereoscopically. They are the mirror stereoscope and the pocket stereoscope. The mirror stereoscope allows the entire 60% of the overlap to be viewed at once. The pocket stereoscope only allows 35% of the overlap to [illegible] a handy instrument in the field.

5.1 Scaling a Photograph

If using standard and survey photographs the nominal scale will be shown on the legend. If, however, photos of uncertain scale are being used such as HOCS photography there are three basic methods for determining the scale of the photograph.

5.1.1 Use of a Map

(a) Select any two clearly visible points on either of the photographs which can also be clearly located on the map. It is best to select points as far away from each other as possible to avoid errors in measurement.

(b) The following formula can then be used:

$$D = \frac{d_1 \times D_1}{D}$$

Where D = scale of photograph

d = distance on the photograph

D_1= scale of map

d_1= distance on the map

5.1.2 Photographic Data

See 4.5

5.1.3 Objects on the Photograph

Working out the scale from an object of known size on the photograph. This may require going into the field and measuring the distance between two clearly visible objects. Convert the distance on the ground to centimetres. Measure the distance on the photo in centimetres. Divide the distance on the ground by the distance on the photo to obtain the nominal scale of the photograph.

eg. distance on the ground = 250 metres

= 25,000 centimetres

distance on the photo = 12.3 centimetres

$$\text{scale} = \frac{25,000}{12.3}$$

$$= 2032.5$$

Therefore, the nominal photo scale is 1:2032.5

5.2 Measuring Area From a Photograph

This particular skill is useful in determining the areas of coupes undergoing treatments by contract labour.

In the Southern Region vertical photographs are taken of cutting coupes by the Aerial Photography Group. It must be emphasised that the accuracy standards of this type of photography are not as stringent as those imposed by the Department of Lands and Surveys.

The increased degree of error of the Aerial Photography Group photography stems from several sources:

(i) In taking an aerial photograph the tip and tilt of the aircraft cannot be controlled to the same exacting tollerances as the Lands and Survey photography. These errors are more obvious toward the edge of a frame. Therefore, when ordering photography from the A.P.&.I. the particular coupe of interest must be specified exactly so that the coupe can be photographed from directly above to minimise this type of error.

(ii) The lenses used by the Forests Department are not corrected to the same standards as the Lands and Surveys lenses. This produces small image errors due to radial displacement and varying atmospheric conditions but are not important unless detailed mapping information is required.

(iii) Lands and Surveys produce a negative that is 230mm x 230mm which is the same size as the print.
Forests Department photography produces a negative that is 54mm x 54mm. The final 1:15,000 scale print is an enlargement of this negative. The enlarging process can cause some image errors due to misalignment of the negative and the print paper, although every effort is made to minimise this source of error.

However, for the determination of areas these sources of error pale into insignificance when compared to the sources of error involved with a chain and compass survey.

The method involved is relatively simple and is covered in the practical exercise.

STEP 1 - Scaling the Photo

The HOCS photo is usually at an approximate scale of 1:15,000. This is only approximate, however, and the true mean scale of the photography must be found. To do this, identify several objects on the photo that appear to be in a mid slope position. Go to the field and measure between these objects and take matching measurements from the photo as explained in 5.1.3. Calculate the average scale.

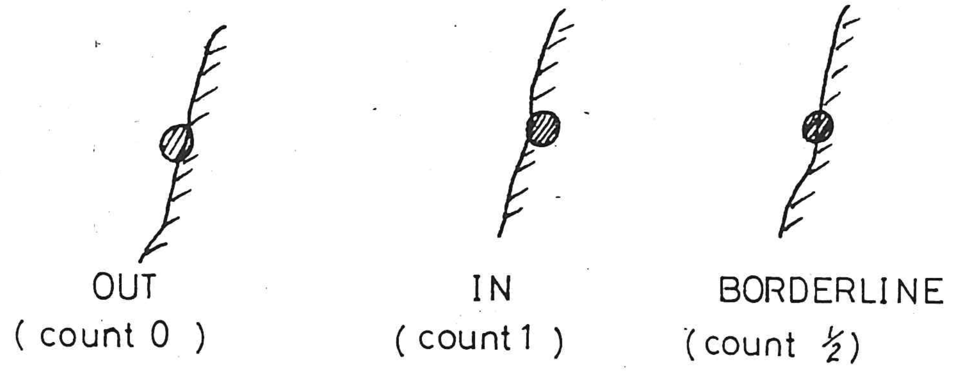
STEP 2 - Dot Grid Calibration

(i) Using the scale calculated for the photograph, determine the area enclosed by one square centimetre.

(ii) Using a fine dot grid (F.D. 1374D is recommended), determine the area represented by one dot.

STEP 3 - Dot Griding

Place the dot grid randomly over the area to be determined and count the number of dots enclosed by the boundary using the following rules for determining "in" dots and "out" dots.



Repeat this four times. Calculate the average number of dots. Multiply the average number of dots by the value of one dot to determine the total area.

5.3 Characteristics of a Photographic Image

Object recognition is based on the consideration of seven basic characteristics of a photographic image. These are shape, size, pattern, shadows, tone, texture and site.

5.3.1 Shape

Shape relates to the general outline of objects. The use of a stereoscope to view the object in 3 - D is essential. The shape of a Karri crown, a football oval or aerodrome give a clue to its identity.

5.3.2 Size

The size of objects vary with the scale of the photograph. It is important, then, to be familiar with the size of common objects at various scales. A dog kennel and a shed look very similar until the photo scale is considered.

The great height of a Karri tree is an obvious clue which permits this forest type to be readily identified from aerial photographs. This single characteristic is, however, not always sufficient to enable positive identification since there is another species, Red Tingle, which also shares the great size of the Karri tree, and which also appears similar when viewed stereoscopically. Frequently other means, including field checking, may have to be used to ensure positive identification.

5.3.3 Pattern

Pattern relates to the spatial arrangement of objects. The repetition of certain forms is characteristic of many objects and gives objects a pattern which aids the photo interpreter in recognising them. For example, orchards, market gardens and sand dunes all have a peculiar pattern. The arrangement of tree crowns often produces a pattern which enables ready identification. For example, the regular pattern of planted pines, together with their tone, gives a reasonably positive clue to their identification.

5.3.4 Tone

Tone refers to the brightness with which light is reflected from an object. In black and white photography colours are represented by shades of grey. The factors affecting tone are:

(a) the nature of the surface of the object.

(b) the sensitivity of the film.

(c) the scatter of light in the atmosphere (haze)

(d) the light transmission through the filter used.

(e) the position of the object on the ground in relation to the camera and the sun.

5.3.5 Texture

Texture may be described as the degree of regularity in the surface of an object and ranges from rough to smooth. On a photo it is revealed as the frequency of change in tone within the image. Texture is produced by an aggregate of unit features which may be too small to be clearly discerned individually on the photograph. It is a product of their individual size, shape, pattern and tone. The effect of texture tend to diminish with an increase in flying height and the associated reduction in scale.

Variations in crown texture can help to distinguish one tree type from another. The Jarrah and Marri in mixed association of similar height classes, the marri may often be distinguished by its denser crown, the crown of jarrah being of rather poor, open structure, thus giving the forest canopy an irregular texture on the photograph.

5.3.6 Site

The location of objects in relation to other features can be very helpful in identification. For example, some trees are restricted to certain climatic or soil zones and are rarely found outside these fairly well defined limits. Karri is more or less confined to a small corner in the south west of the state, while Tuart is rarely seen outside a very narrow strip of limestone country which stretches between Wanneroo and Busselton. On a finer scale we see Warren River cedar along creeks in the Karri forest and the typical vegetation types of the black sand, jarrah flats.

5.3.7 Shadows

Shadows are important as they often give an oblique profile of an object which can contribute important clues.

Shadows are important where objects are small or lack tonal contrast with their surroundings. Under these circumstances the sharp tonal gradients of the shadows enable the interpreter to identify objects that are on the threshhold of recognition eg. TV and radio masts.

Unfortunately, photographic detail may be lost if the object falls into a shadow area. Objects within the shadow reflect so little light that they are virtually indiscernable. For this reason, aerial photography is usually taken within two hours of local noon so that shadows will be as small as possible.

Aerial photos are also widely used in forestry in the alignment and construction of roads,analysis of damage to forests by fire and insects, observation of areas undergoing clearing and cutting operations and to check the progress of reafforestation.

The success of forest interpretation is dependent to a large degree upon a number of factors:

(i) time of year of photography

(ii) time of day of photography

(iii) scale of photography

(iv) type of aerial film emulsion

(v) type of colour filter used

Furthermore, the success and accuracy of photographic interpretation is very much dependent upon sufficient ground truth checking. However, when a person considers all the above mentioned factors to interpret a photo he can extract a great deal more information about the locality than if he just looks at the photo.

6. PRODUCTS FROM THE AERIAL NEGATIVE

6.1 Contact Prints

These are 230mm x 230mm (9" x 9"). Usual production makes use of an electronic dodging exposure machine which applies greater exposure to dark (eg. shadows) areas and less exposure to light (bare soil) areas. By arrangement, photographs required for specific interpretation of forest types can be produced without electronic dodging.

An increasing porportion of the states annual aerial photography programme is being requested in colour. So far its use is confined to project areas. It is to be noted that colour products are 3 to 4 times more expensive than black and white photos.

6.2 Enlargements

Because of the high resolution of modern camera/film combinations, enlargements up to four times from the original nominal scale prove very useful. Enlargements five times and beyond can be made only of part frames. These partial enlargements, particularly when they are made of areas close to the edge of the original photograph, will display exaggerated radial displacement, and so, should not be used for making accurate measurements.

However, rectification of enlargements is possible. Rectification provides for a position fit of the enlargement to at least three map points of similar elevation. The fit is achieved by changing scale and tilting the copy easel. Thus, the effects of the inherent errors of a photograph are somewhat reduced. However, variation of scale within the rectified enlargement remains. Rectified enlargements are eminantly suitable for detailed planning where the background detail provided by an aerial photograph is an advantage. This facility is available through Mapping Branch when using Lands and Surveys photography.

It is not available when using HOCS photography.

6.3 Orthophoto Maps or Controlled Mosaics

An orthophoto is an aerial photo which has been differentially rectified. That is, a sophisticated scanning instrument has shifted the photographic image so that it has the same geometric properties of a map. When the photographic image is considered at ground level (eg. at the base of a tower), the errors of scale, relief displacement and tilt have been removed.

Thus, an orthophoto map is an orthophoto or mosaic of orthophotos upon which is shown a map grid and (where desired) contours. The orthophoto map is an accurate planning tool and pictorial record. The current disadvantages to large scale use of orthophoto maps is the lead time required for production.

6.4 Uncontrolled Mosaics

These are widely used in forestry for planning and management. This type of mosaic consists of photographs assembled together to give, as clearly as possible, the impression of a single large photograph. They are compiled as accurately as possible but there is no check or control on errors. The mosaic may be square or rectangular in shape and may consist of a number of photos from a number of runs. During assembly each photo is trimmed and every effort is made to obtain the best visual join between adjoining photographs. The usual procedure is to paste the central photograph to a board, then working out from the centre to the corners, the photos in the corners being laid last. Cumulative errors are carried out from the centre and may appear in the corners unless exceptional care is taken.

Mismatch between photographs because of relief, tilt and scale differences cannot be avoided, especially toward the corners of the mosaic. It should be appreciated that relief displacements increase with an increase in the radial distance from the nadir point, so it is generally desirable to use the central portion of each photograph.

In summary, it can be said that all mosaics of undulating terrain will contain errors due to relief. Relief displacement errors can be reduced by using a larger flying height while at the same time maintaining the scale by using a longer focal length. By increasing the forward and side overlap the central portion of the photos used will be smaller thus reducing relief displacement errors and improving the accuracy of the mosaics. Measured distances and directions on mosaics will be in error.

Finally, if mosaics are correctly used for investigations and qualitative studies the planimetric inaccuracies are of little consequence.