# DOCUMENTING REVEGETATION SUCCESS FOR BOND RELEASE THROUGH MEDIUM FORMAT AERIAL PHOTOGRAPHY[1]

by

Wayne M. Grip[2] and Kent T. Brakken[2]

Abstract. Aerial photography is very useful in monitoring the progress of reclamation operations on surface mines. This technique is effective on both large and small mines and in both wet and arid climates. The authors have developed a procedure which uses a small single-engine airplane and medium format film and video cameras to obtain vertical stereo color and color infrared aerial photography of minesites. The accurate, low-cost procedures proposed provide sufficient information to satisfy bond release eligibility documentation requirements, as well as provide other benefits to the user.

Additional Key Words: revegetation success, reclamation bond release, medium format aerial photography.

Conventional black and white, color, and color infrared aerial photography is the most useful and cost effective form of remote sensing commonly applied to surface mining and reclamation. Both mine operators and regulatory authorities routinely use aerial photography to monitor the progress of mining, to create a permanent record of mining and reclamation, and to make management decisions. In contrast to conventional 9- x 9-inch vertical aerial photography, the method proposed here is medium format 70-mm vertical stereo aerial photography used to evaluate revegetation success in both (1) monitoring the current status of revegetation, and (2) effeciently collecting information for reclamation bond release.

Depending on the size of the mining operation and climatic conditions within the mining region, mine operators face different needs for aerial photography. Operators of the larger Western mines, where precipitation is limited and erratic, generally face more difficult revegetation problems than their Midwestern and Eastern counterparts, where there is much more precipitation. Due to the variable nature of the precipitation and the generally larger size of the mines, operators of Western mines need more timely and specific information. Vertical stereo aerial photography combined with ground truthing can meet this need. Furthermore, use of color infrared film can provide critical information on plant vigor and be an important avenue to monitor drought stress, the presence of toxic overburden conditions, and a lack of required micronutrients or macronutrients. In the case of plant nutrient deficiencies, an operator can establish large-scale nutrient application test plots, monitor vegetation vigor improvements with aerial photography, and have visually conclusive data back in weeks rather than months.

Smaller coal operations of the Midwest and East face a different set of problems. Although their reclamation is easier than that in the arid West, owing to their receiving more precipitation, these operations face greater overhead cost restrictions than their Western counterparts. Frequently, one environmental engineer will handle all environmental permitting and compliance problems, including revegetation success monitoring. These operators need a reliable, cost-effective way of monitoring revegetation progress. Color stereo photography and color infrared photography, flown as close as possible to the peak growth of the cool-season grass species and later at the peak seasonal growth of the warm-season species, can provide a valuable visual record. This photography is acquired during peak production for the two following reasons: (1) That is when the production data must be collected for bond release and it is logical to collect cover data at the same time, and (2) from a monitoring standpoint, that is when the vegetation will show nutritional stress detectable by color infrared photography, if such stress is present.

Concerning revegetation progress monitoring, as contrasted to bond release data collection, aerial photography can provide a valuable cost-effective alternative for any size mining operations.

Regarding reclamation bond release, vegetation cover data must be collected under relatively strict statistical limitations; in most cases, 90 percent statistical confidence. Over large bond release areas, with properly planned and executed ground truthing, aerial photography can be used to extrapolate the number of vegetation samples and reduce overall costs. This is generally more applicable to larger mining operations.

But well-executed photography can provide substantial benefits to smaller operations which plant trees and shrubs. These operations must generally ensure that 450 live trees and/or shrubs are growing and surviving at the end of the bond release period. By flying the minesite at the proper time of the day, when shadows are created, aerial photography can provide an accurate estimate of surviving trees and shrubs. Furthermore, this type of inventory once each year provides a permanent visual record for bond release purposes. Aerial photography shrub inventory applies equally well to large

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[2]Wayne M. Grip is Vice-President of the Aero-Data Corporation, Baton Rouge, Louisiana. Kent T. Brakken is a Project Leader with the U.S. Department of the Interior, Office of Surface Mining Reclamation and Enforcement, Denver, Colorado.

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Western operations reestablishing shrub communities to promote wildlife habitat improvements.

The slides made in this study were 70-mm photography cut down to 35-mm super slides. The photography was flown with a Cessna 172 Sky Hawk, the most common general aviation airplane, a single-engine high-wing airplane that cruises at a speed of 125 miles per hour. This plane is modified for aerial photography by installing two small camera ports in the belly of the plane just behind the front seats. A video camera and mount is installed in one port, and a Hasselblad 70-mm camera and mount in the other. In addition, a video monitor and tape recorder are mounted where the right front seat is normally located. Both cameras are leveled so that they are looking straight down directly beneath the airplane. In addition, the film camera mount rotates to compensate for any crab angle caused by crosswinds. New accurate gyro instruments have been installed as an aid in maintaining a level attitude during photo runs. This is very important, for if the airplane's attitude is not correct, the photographs will not be vertical. In addition, a Loran C navigation radio, programmed with the latitude and longitude of the sites to be photographed, is used as an accurate and fast guide to the correct sites. Once at the minesite, the video monitor is used to determine groundspeed, shutter interval, crab angle, and minor course corrections.

The photo runs over an active surface mine in Louisiana were made at photoscales of 1:24,000, 1:12,000, and 1:6,000. At a photo scale of 1:24,000, this Hasselblad system provides coverage on the ground of a square area 4,200 feet on a side. Using Ektachrome ASA 64 film, an object on the ground the size of a basketball can be seen. This scale is preferred for most mining applications since it allows a pilot to fly at an altitude of 6,300 feet above terrain, where the air is usually both smooth and cool, and at the same time provides a fairly large area of coverage at an adequate resolution. For very large surface mines, as many as five flight lines may be necessary to provide complete coverage of all disturbed areas.

Photo processing of the 2¼- x 2¼-inch Ektachrome transparencies is usually done on the day of the flight and takes 2 hours or less. If color infrared film is used instead, the processing, including shipping to the photo lab and return, takes 3 days.

A Krones projecting mapping device is used to trace accurate maps to a precise scale from the transparencies. Photo interpretation, using a light table and pocket stereoscope, is also performed, using the added information provided by the stereo coverage of the site.

In a reclaimed area, it is very easy to count and plot the location of every tree and shrub within a bonded area. Furthermore, by using previous years' flights, it is also possible to determine how long each plant has been in place. This method is much more accurate, faster, and less expensive than using measurements taken from the ground for most minesites. If the reclaimed area is planted to grasses, and accurate ground control is provided by reference areas, then aerial photography can be used to accurately estimate the percentage of ground cover. When problem areas in revegetation occur within a site, the aerial photography can easily pinpoint the extent of the areas in need of more intensive on-the-ground investigation and correction.

Photomosaics made from Cibachrome prints of the original transparencies provide excellent planning tools and briefing graphics to be used by both the mining industry and the regulatory agencies.

Due to recent developments in the computer industry, it is now possible at low cost to digitize features of interest directly off the projected images of the medium format aerial photography and produce maps, measure areas, overlay previously digitized maps from earlier flights and produce change maps. The implementation of the Nav Star Global Positioning Satellite System and the development of new low-cost Nav Star-compatible aviation navigation receivers have done much to improve small airplane photography systems. This highly accurate positioning system, when combined with the resolution of medium format stereo aerial photography and computer digital mapping capability, provides a very accurate and cost effective means of tracking and documenting reclamation progress on disturbed areas.

In summary, medium format aerial photography provides a very cost effective alternative to accurately document shrub and tree establishment for reclamation bond release purposes and monitor revegetation status, concurrently providing a permanent visual record of revegetation progress. When used in combination with well-planned ground truthing, this photography provides an alternative to extrapolate ground cover data to larger areas, thereby significantly reducing sampling costs.

Reclamation bond release is a critical point in any coal mining operation in these days of high bond costs. Delays in anticipated release can tie up collateral planned to back bonds for upcoming permits. Well-planned, well-executed aerial photography in combination with conventional vegetation data collection may provide mine operators the best available alternative to meet mine reclamation objectives.