Thomas L. Erb
Warren R. Philipson
William L. Teng
Ta Liang
School of Civil and Environmental Engineering
Cornell University
Ithaca, NY 14853

Analysis of Landfills with Historic Airphotos*

The availability of one or more dates of aerial photography permits a temporal assessment of landfill existence, land use and land cover, and the physical environment.

Abstract: *Landfill-related information that can be derived from existing, or "historic," aerial photographs is reviewed. This information can be used for temporal assessments of landfill existence, land use and land cover, and other elements of the physical environment. Analysis of low cost, readily available aerial photographs can thus provide important, objective input to landfill inventories, assessing contamination or health hazards, planning corrective measures, planning waste collection and facilities, and development of inactive landfills.*

Introduction

The inventory and assessment of active and inactive landfills for environmental contamination is receiving much attention in the wake of several well-publicized health emergencies. The use of aerial photography and thermal scanner data for landfill monitoring and management has been documented (Souto-Maior, 1973; Garofalo and Wobber, 1974; Philipson and Sangrey, 1977; Sangrey and Philipson, 1979). Major emphasis in these studies was placed on the use of newly acquired remote sensor data, collected specifically for landfill monitoring. In this paper, the value of *existing* aerial photographs for waste management, including landfill monitoring, is examined.

"Historic" Aerial Photographs

At least one date of aerial photographic coverage exists for the entire land area of the United States and most of the world. This coverage can normally be obtained at low cost from the organization which acquired the photography or, in the case of pre-1941 U.S. government aerial photography, from the National Archives. Most of the photography is panchromatic, with stereoscopic coverage, 7 by 9 in. (18 by 23 cm) or 9 by 9 in. (23 by 23 cm) format, at a range of scales, but most commonly 1:20,000.

Information Derivable from Historic Photos

For analyzing landfills, the availability of one or more dates of aerial photography permits a temporal assessment of (1) landfill existence, (2) land use and land cover, and (3) the physical environment (Table 1).

Existence

Assessment of landfill existence includes documenting the location, extent, and possible nature of a landfill. The dates, scales, and quality of available aerial photographic coverage of the landfill will determine the extent to which a complete landfill history can be ascertained. Similarly, the capacity to extract information regarding the na-

* Revised version of paper presented at the ASCE-ASP Specialty Conference on Civil Engineering Applications of Remote Sensing, University of Wisconsin, Madison, August 1980.

Photogrammetric Engineering and Remote Sensing,
Vol. 47, No. 9, September 1981, pp. 1363-1369.

0099-1112/81/4709-1363$02.25/0

TABLE 1. LANDFILL-RELATED INFORMATION DERIVABLE FROM HISTORIC AERIAL PHOTOGRAPHS

- EXISTENCE location, extent, and possible nature of landfill
- LAND USE/LAND COVER natural and artificial
- PHYSICAL ENVIRONMENT geology, soils, and drainage

ture of waste materials in a landfill will depend on the ability to detect and identify features such as metal drums or abandoned vehicles.

One important use of historic aerial photographs involves inventorying landfills which are presently inactive and possibly developed with other land uses. In Figure 1, for example, it can be seen that a water-filled trench, in 1938, was being filled in 1951, and had been completely filled and the site developed by 1966. Little evidence of the landfill can be found in the most recent coverage.

Similarly, the value of historic aerial photographs for documenting landfill boundaries is shown in Figure 2, where the expansion of an active landfill is traced over a 40-year period.

LAND USE AND LAND COVER

Landfill existence is only one type of airphoto-derived information which can be obtained on land use and land cover on or near an active or inactive landfill. Historic aerial photographs can be analyzed to obtain general or detailed land-use and land-cover information.

The importance of recognizing land use and land-use change is illustrated in Figure 1, where the specific dates and locations of landfilling versus the dates and locations of residential construction might be of major significance in trying to ascertain any relationship between landfill leachate and health problems. In designing a leachate sampling scheme, it is critical to recognize that the parking facility for the recreational center pictured in Figure 3 was built on a landfill which was formerly a gravel pit. Because of the gravel pit, ground water contamination becomes a major consideration.

PHYSICAL ENVIRONMENT

Land use and land cover is only one element of the physical environment, which also includes the geology, soils, and surface as well as subsurface drainage. This is evident with the last example (Figure 3), where the land use, a gravel pit, indicates the presence of subsurface granular materials. It is also evident in Figure 2, where, with minimal airphoto interpretation skills, one can identify the abandoned stream channel and thus define a possible avenue for leachate movement. With a higher degree of airphoto interpretation in Figure 2, one could further characterize the area as being underlain by limestone (outcrops along stream, jointing, and other airphoto indicators). This type of bedrock is especially susceptible to ground water contamination.

A comparable or even greater degree of interpretive skills would be required to evaluate comprehensively the physical environment of the area pictured in Figure 1. In planning leachate detection and abatement, surface and subsurface drainage must be assessed. In this area, one must recognize the complex layering of fluvially reworked lakebed deposits, overlying dense glacial till, overlying dolomite bedrock. These interpretations can be made best from features appearing in the oldest photographs—features which are obscured or obliterated in more recent photographs (e.g., dark-toned current scars in Figure 1).

In general, historic aerial photographs can provide the most efficient, complete source of information regarding the physical environment, particularly, in the absence of soil survey or surficial geology reports.

VALUE OF HISTORIC PHOTOS

Analysis of historic aerial photographs can supply important objective information for landfill investigations. Information pertaining to existence, land use and land cover, and the physical environment can provide input to a wide range of landfill-related activities (Table 2).

FOR INVENTORY

Historical aerial photographs may be the only source of reliable information for identifying active and inactive landfills.

FOR ASSESSING CONTAMINATION/HEALTH HAZARD

Analysis of historic aerial photographs can provide unique information regarding leachate migration, especially where the landfill and surrounding area have undergone substantial change (e.g., Figures 1, 2, and 3). Analysis of historic photographs can also provide an excellent base for developing a systematic sampling plan for leachate contamination. As shown in Figure 1, information derived from the older photographs may indicate that new remotely sensed data (e.g., new aerial photographs or scanner data) will be of little value for assessing contamination.

FOR PLANNING CORRECTIVE MEASURES

Information derived through analysis of historic aerial photographs may be extremely important for planning strategies and measures to eliminate leachate contamination (e.g., Figures 1, 2, and 3). Normally, recent aerial photographic coverage is also required because of the need to relate remedial actions to existing land use and cover.

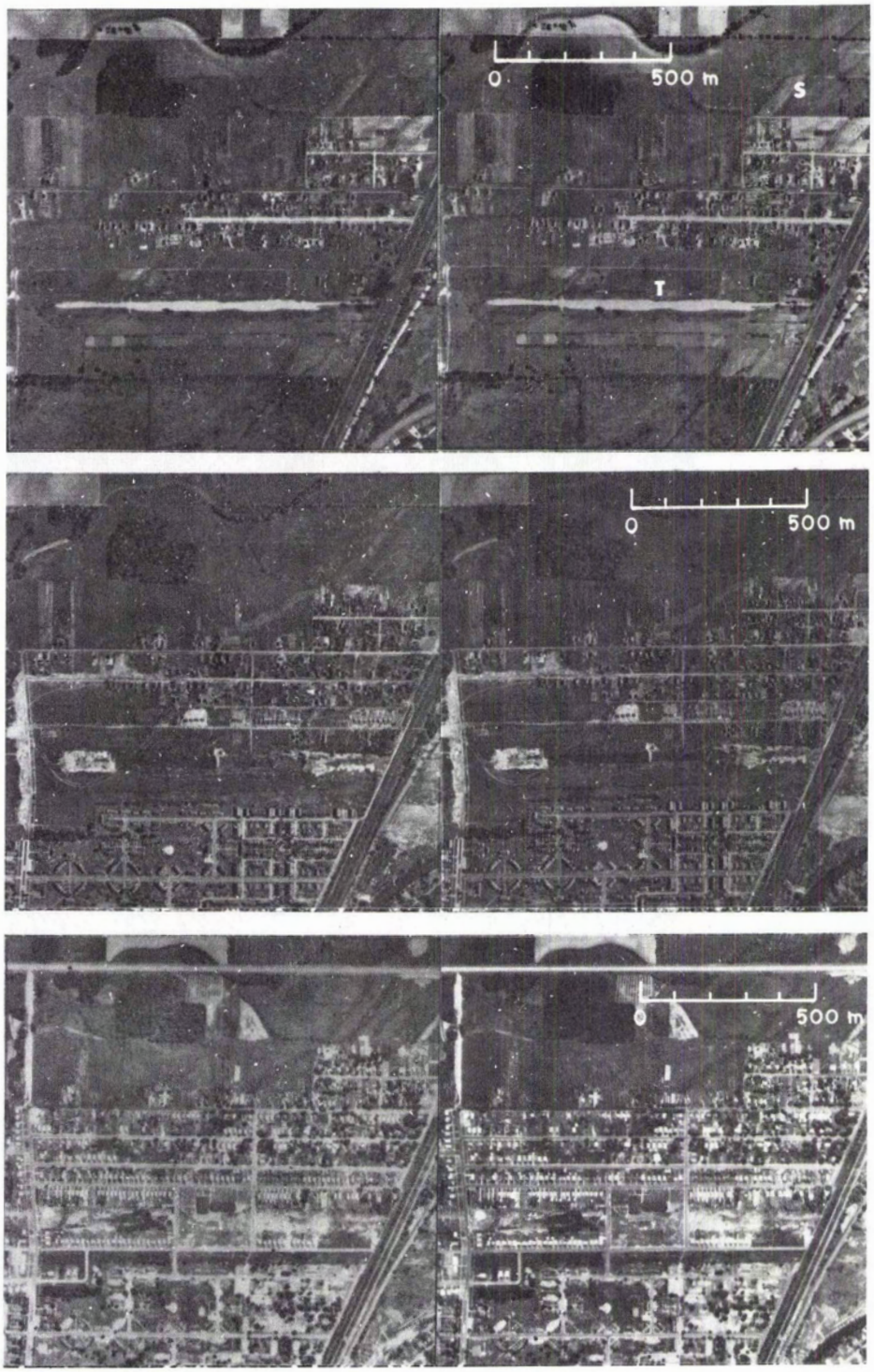

FIG. 1. Stereograms of historic aerial photographs of a landfill. The photographs were acquired in 1938 (top), 1951 (middle), and 1966 (bottom). Note water-filled trench, T, and water current scars, S, in 1938.

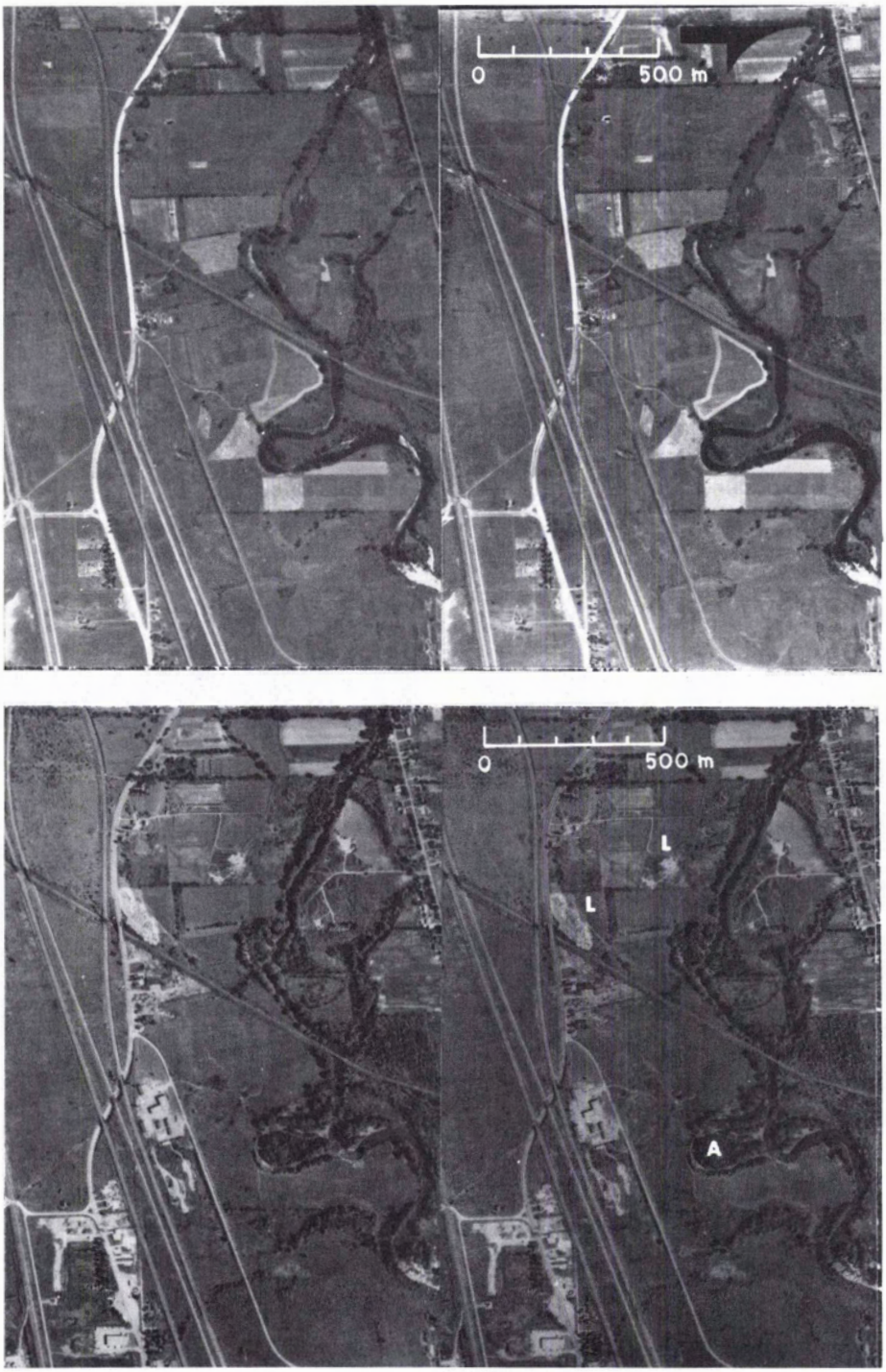

FIG. 2a. Stereograms of historic aerial photographs of a landfill (see Figure 2b). Photographs were acquired in 1938 (top) and 1958 (bottom). Note initial landfilling, L, and abandoned stream channel, A, in 1958.

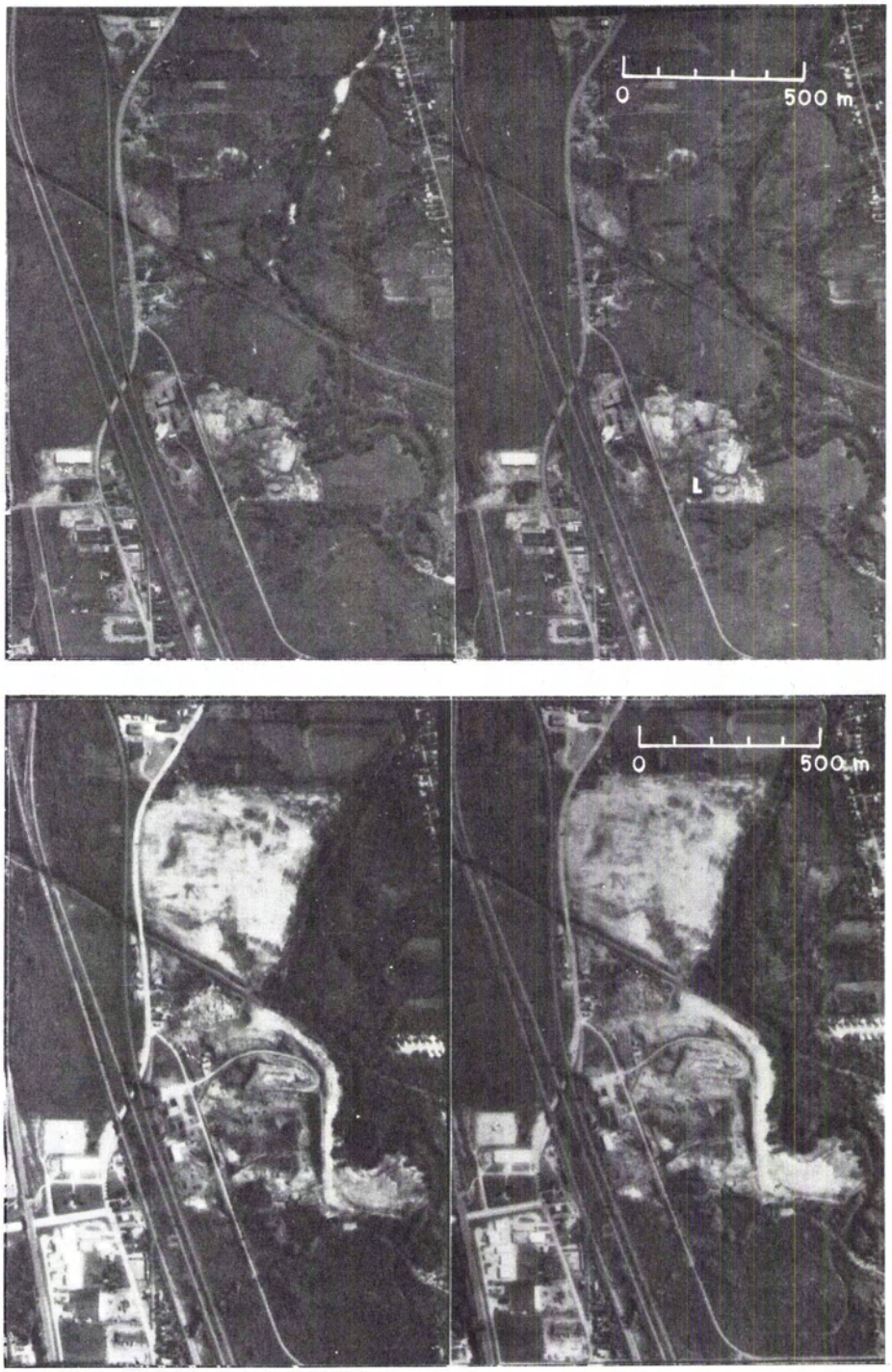

FIG. 2b. Stereograms of historic aerial photographs of a landfill (see Figure 2a). Photographs were acquired in 1968 (top) and 1978 (bottom). Note expanded landfilling.

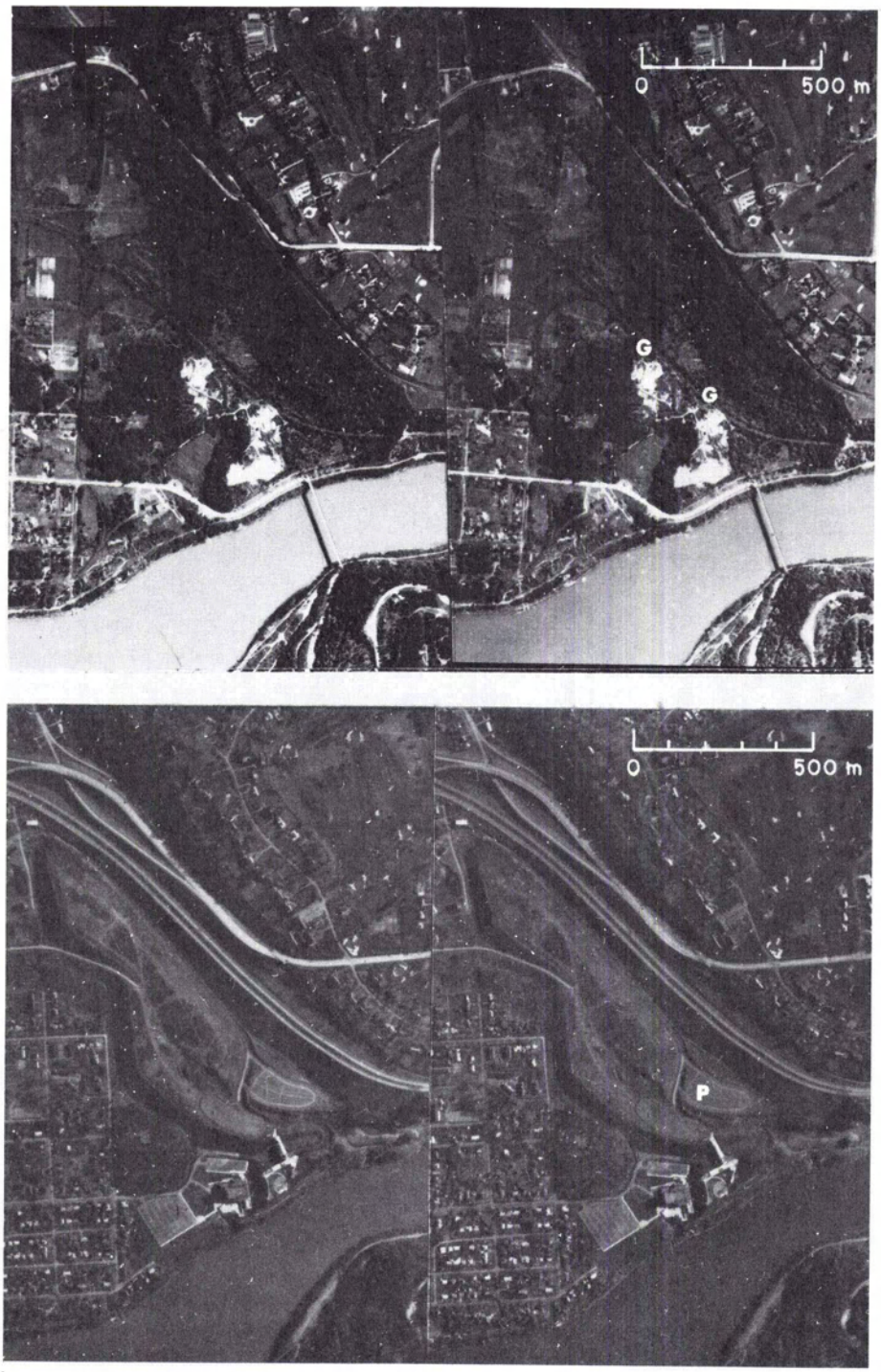

FIG. 3. Stereograms of historic aerial photographs of a landfill. Photographs were acquired in 1938 (top) and 1974 (bottom). Note gravel pit, G, in 1938 and parking lot, P, in 1974.

TABLE 2. SUMMARY OF THE VALUE OF HISTORIC AERIAL PHOTOGRAPHS FOR LANDFILL ACTIVITIES

Activity	Relative Value
Inventory	Critical
Assessing Contamination/ Health Hazard	May be critical, especially if site has been altered
Planning Corrective Measures	May be critical, especially if site has been altered
Planning Waste Collection and Facilities	Of little value if new airphotos are available
Developing on Inactive Landfills	May be critical
Other	Variable

FOR PLANNING WASTE COLLECTION AND FACILITIES

Aerial photographs are excellent sources of information for planning waste collection or new facilities; however, recent photographs are required because the area may have changed from the time of the older photographs and be unavailable for development.

FOR DEVELOPING ON INACTIVE LANDFILLS

This includes both knowingly and unknowingly developing an inactive landfill (e.g., for biogas extraction). In general, any development on or of a known landfill site should be preceded by an analysis of historic aerial photographs of the site. The analysis may point out the extent of filling as well as other items of importance (e.g., nature of the fill). Additionally, any site or route selection problem which might inadvertently encounter a former landfill would also benefit from an analysis of historic coverage.

FOR OTHER SPECIFIC LANDFILL INVESTIGATIONS

Possible activities include those related to research and development of improved land-filling operations, as well as those related to legal actions. Depending on the activity or purpose, the analysis of historic aerial photographs may be of real or little value.

CONCLUSION

Information derived from historic aerial photographs is often invaluable for landfill investigations. Although appreciable amounts of time may be required to locate, order, receive, and catalog all available site coverage from the U.S. Government as well as from commercial agencies, only selected coverage may be required. In general, historic aerial photographs are readily available and, compared to the costs for acquiring field data or new aerial photography, they are inexpensive.

ACKNOWLEDGMENTS

This study was supported, in part, by the National Aeronautics and Space Administration (NASA Grant NGL 33-010-071) and by the New York State Department of Health. Photographs used in the figures were flown by the U.S. Department of Agriculture, except for Figure 2b (top) which was obtained from Lockwood Mapping Company of Rochester, N.Y., and Figure 3 (bottom) which was obtained from McIntosh and McIntosh, Inc., of Lockport, N.Y.

REFERENCES

Garofalo, D., and F. Wobber, 1974. Solid waste and remote sensing, *Photogrammetric Engineering* 40(1):45-59.

Philipson, W. R., and D. A. Sangrey, 1977. Aerial detection techniques for landfill pollutants, in *Proc. 3rd Annual EPA Research Sym. on Management of Gas & Leachate in Landfills*, held St. Louis, E.P.A., Washington, D.C. 11pp.

Sangrey, D. A., and W. R. Philipson, 1979. *Detecting landfill leachate contamination using remote sensors*, Research Report EPA-600/4-7-060, E.P.A., Las Vegas, Nevada, 67 p.

Souto-Maior, J., 1973. Applications of thermal remote sensing to detailed ground water studies, pp. 284-298 in *Proc. of Symp. on Remote Sensing and Water Resources Management* (K. Thomson, R. Lane & S. Scallany, eds.), Amer. Water Resources Assoc., Minneapolis, Minn.

(Received 8 October 1980; revised and accepted 5 March 1981)