# Locating Tile Drains Using Historic Air Photos


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Abstract

Land is one of the most important natural resources. Water, minerals, and biological elements are often taught explicitly as resources, with little reference to the land itself. Land use and modifying the land for greater advantages for human use has been underway for millenniums. Changing the hydrology and water content of soil has been an important part of land resource modification and land use since the early 1800s in the United States. During subsequent times, land owners, land managers, and land developers have used drainage systems to change land surface moisture conditions in order to alter land use practices. Poor documentation on drain location and development activities on such drained lands often lead to disrupted subsurface drainage systems and consequent surface land use problems. Land use planners and land developers need to know alternatives to identifying where these subsurface drains are located to avoid such problems. This research presents a method of locating

subsurface drain tiles using historical air photos. Using this approach, problem areas can be identified and potential land use issues averted.

**Key words:** Historic air photos, drain tile, land-use, tile patterns

## Introduction

When a farm owner or manager views the land with its physical surface features, farm buildings, fences, crops, and perhaps grazing animals, there is much more than meets the eye. The landscape for an experienced specialist in agriculture nearly always sees other conditions that affect the land, among them soil, slope, hydrology, and moisture content. Those latter elements greatly affect the importance of land as a natural resource. If the soil is waterlogged or has too great a water content, then a means for extracting the excess water is necessary. If there is too little moisture, then specialized farming methods and irrigation may become a necessary solution to land use. This paper focuses on soil drainage systems and the long term changes in land use resulting from drainage that have unexpected consequences.

The introduction of cultivated agriculture, scientific principles of hydrology, and the technology for using clay drainage pipes (called tiles) to remove excess water from the soil were all being used by the 2nd century BCE in Italy and elsewhere in the Mediterranean Sea region. Land use change was possible with drainage. Soil that had too much water content could be changed into dryer, more suitable conditions for growing crops. The drained land was consequently made more valuable as a natural resource for agriculture.

Land drainage was introduced to the U.S. in the early 1800s and diffused westward with the opening of new agricultural lands. Governmental jurisdictions at the county and township levels established elected or appointed drain boards and supervisors because drainage was an important aspect of public land use policy. Large areas of agricultural land use were made possible by a subsurface plumbing system that drained, transported, and discharged water. The plumbing system was important to the agricultural economy, public health, and flood management along open drainage canals, streams, and lakes.

The drainage system, however, was just the first chapter in a steadily developing account of land use change. In the latter half of the 20th century, the second chapter was underway as well drained, fertile agricultural fields became the objects of suburban residential and industrial land use. The land surface was ideal for building, but hidden beneath the surface, and often with no map or other record of when and where it was located, lay the drainage plumbing system. The following research questions emerged: How can students use place-based educational resources, such as aerial photos, to determine if prior land uses included a land drainage system? If there is a drainage system, then where is it located and what is its spatial pattern? What are the consequences for subsequent land uses? This methodology engages students in using aerial photography to study prior land uses and their soil drainage systems to predict the possible problems that may result with a change in land use.

## Draining the Land

Unidentified underground agricultural tile drains pose serious potential problems for future land development. Research on these problems in Franklin County (Columbus), Ohio, identified several instances of land use problems related to disrupted tile drains. The study found that urban development activities on tile-drained land disrupted the flow of water through the tile systems. This disruption occurred when the normal flow through the drains was impeded by tile breakage or blockage. Heavy construction equipment can compact the surface and crush sub-surface drains. Excavation can cut across drain lines causing blockage or diverting flow. A variety of problems results from such disruptions including: surface blow-outs, surface flooding, failed septic tank leach fields, impaired up-stream drainage, the development of subterranean cavities and basement flooding. In Norwich Township (part of the Franklin County study noted above), construction activities crushed a twelve-inch tile and a blow-out had developed, "...allowing sediment to clog the remainder of the tile." Water flowing through the system would rise to the surface through the blow-out and flood the surface, freezing in the winter, "allowing children to ice-skate" (Pierce, 1997).

A second landowner experienced failure of his leach system as a result of the back-up of water through a second, related tile drain. In the case of these drains, both followed a line petitioned in 1875. In another instance of drainage problems which occurred in Brown and Pleasant Townships, a tile line that was part of a system designed in 1906 to drain 1,300 acres had root clogging, leading to blowouts large enough to hold a small car (Pierce, 1997).

Historically, many tile locations have not been properly recorded or the records have not been maintained. This legacy of problems illustrates the importance of determining the location of tile drain systems prior to changing land uses. A question also exists as to the extent to which these problems may occur elsewhere.

To develop an understanding of the broader context of these problems, a mail questionnaire was sent to a sample of soil and water conservation district personnel in 32 Ohio counties. The questionnaire asked the recipients to indicate which tile drain issues were problems in their district (Table 1).

Based on this survey, there is clearly a set of land use problems related to disruption of tile drained land. This set of problems makes it important to develop a means of locating tile drained lands.

## *Development of the Problem*

Beginning in the early 1830s, U.S. landowners and managers followed an aggressive practice of land drainage. One of the leading proponents of drainage to enhance agricultural production was John Johnston of Geneva, New York, a tireless advocate of tile drainage who engaged in talks, correspondence, and published articles beginning in the early 1800s. Subsequent drainage in the U. S. affected thousands of acres of wetlands as they were converted to agricultural use (Weaver, 1964). Federal support for drainage was introduced through acts to enable states to reclaim the "swamplands" within their limits; thereby lending federal government support to land use changes initiated by private sector entrepreneurs. These lands were to be drained for agricultural use under provisions of the Acts and the U.S. Dept. of Agriculture maintained a policy of both financial and technical assistance to farmers to encourage drainage.[1]

Textbook authors also encouraged drainage. For example, in a soil text with a long life span (1922-1964), Buckman et al. (1964) commented on the need for farm drainage. Primary school books use also pursued this advocacy. A 1915 text, *Practical Lessons in Agriculture* (Ivins & Merrill, 1915), summarized the benefits to be derived from drainage while Bulletin Number 258 from the U.S. Department of Agriculture, "Lessons in Elementary Agriculture for Alabama Schools," detailed the need for drainage, benefits derived from drainage, and classes of drains. Manuals for guiding the drainage of land also were available for the prospective land developer.[2]

Statistics collected since 1920 on the national extent of agricultural drainage depict the continuing expansion of land drainage. According to a 1987 report, 109,680,000 acres have been artificially drained (Pavelis, 1987).

Table 1.
Problem categories identified by field staff from Ohio Soil and Water Conservation Districts in order of response frequency.

| COUNTY | BLOWOUT | SURFACE FLOODING | FAILED LEACH FIELDS | IMPAIRED UPSTREAM DRAINS | SUBTERRAIN CAVATIES | BASEMENT FLOODING | OTHER |
|---|---|---|---|---|---|---|---|
| Allen | | | | | | | |
| Auglaize | √ | √ | | √ | | | |
| Champaign | √ | √ | √ | √ | | √ | |
| Clinton | √ | √ | √ | √ | √ | √ | |
| Crawford | √ | √ | √ | √ | √ | √ | |
| Darke | √ | √ | √ | √ | | √ | |
| Defiance | √ | √ | √ | √ | √ | √ | |
| Delaware | | | | | | | |
| Erie | √ | √ | √ | | √ | √ | √ |
| Fayette | √ | √ | | √ | | | √ |
| Fulton | √ | | | | | | |
| Hancock | √ | √ | √ | √ | | | √ |
| Henry | √ | √ | | √ | | √ | |
| Huron | √ | √ | √ | √ | √ | √ | √ |
| Logan | √ | √ | √ | | | | |
| Loraine | √ | √ | | | | √ | √ |
| Lucas | | | | | | | |
| Madison | √ | √ | √ | | | √ | |
| Mercer | √ | √ | √ | √ | √ | √ | |
| Miami | √ | √ | | √ | | | |
| Ottawa | | | | √ | | | |
| Paulding | √ | √ | √ | √ | √ | √ | |
| Putnam | √ | √ | √ | | | | |
| Sandusky | √ | √ | | √ | √ | | √ |
| Seneca | √ | √ | √ | √ | √ | √ | √ |
| Shelly | √ | √ | √ | | √ | √ | |
| Union | √ | √ | √ | √ | | √ | |
| Van Wert | | | | | | | |
| Williams | √ | √ | √ | √ | | √ | |
| Wood | √ | √ | | | | √ | √ |
| Wyandot | √ | √ | √ | √ | √ | √ | √ |

*Techniques of Drainage*

Underground (subsoil) drainage systems are the preferred means of achieving field dehydration. The most common method used to reduce soil moisture has been to use clay tile, arranged two to four feet below the surface in a systematic way to enhance drainage. Tiles are placed end-to-end with a gap between adjacent tiles to permit water entry into the system. Flow is by gravity with the tile usually discharging into an open ditch. To prevent erosion at the discharge point, the tile line is usually encased in a metal or plastic pipe to carry the discharge into a receiving ditch. Recently, plastic pipe has begun to replace clay tile in field installations.

*Aerial Photographic Resources for Drain Tile Location*

In order to avoid the disruption and subsequent problems identified earlier, it is important to determine where beneath the landscape such tile drainage systems are located. In many instances there are no maps of the drainage systems and local land use knowledge may not include the location of subsurface drainage systems.

One approach to determining the location of sub-surface tile is through the use of historic aerial photography. Comprehending such legacies is important to an understanding of the contemporary landscape. A recent study noted that "... site history is embedded in the structure and function of all ecosystems [and] environmental history is an integral part of ecological science, and that historical perspectives inform policy development and the management of systems" (Foster et al., 2003, p. 77-78).

Historical air photos provide a visual link between the currently observed landscape and the past land uses. Aerial photos also permit access to lands that may have been converted from agriculture to another use (junk yards, recreation) but are not experiencing problems. Studies about the use of air photos as an aid in solving environmental problems in general and locating subsurface drainage are found in a variety of sources including the geographic, agricultural, engineering, and environmental literature.[3]

## Photo Analysis

Since the 1930s, the United States Department of Agriculture has been aerial photographic inventorying the counties of the U.S. in an effort to monitor agricultural program compliance. The first flights were conducted in 1935 and most of the country was inventoried, producing photos at a scale of 1:20,000. Other agencies also began aerial photographic inventorying procedures at various scales during the 1930s, including the Soil Conservation Service, Forest Service, Geological Survey, and Bureau of Reclamation.

Three advantages to using this early photography for locating fields with tile drains include: 1) the quality of the photography is very good; if the photographs have been stored under normal photographic storage conditions the imagery is sharp and visual identification is not complex, 2) the cost is very low; in many cases a search of existing local government, library, or university files may locate imagery that can be made use of for little or no charge, and, 3) the photos can provide the visual evidence necessary to identify the extent of tile-drained agricultural areas.

### *Tile Drain Patterns and Tones*

The successful location of subsurface drain-tile is based on the use of several of the standard attributes of air photos: geometric pattern and tone. Drain tiles are installed in several different patterns based on landscape conditions. The interpreter can use these patterns as a means of identifying landscapes with subsurface tile drainage (for examples of diagrams of common patterns see Figure 1). Landscapes with a rolling topography and low lying swales are often drained with the tile pattern characterized as random. After tiling the swale bottoms, the lowest areas are linked to the larger drainage system. Landscape surfaces which are gently rolling to flat are usually drained by laying the tile in patterns that are best suited to the local topography and field shape. Photo interpreters can use these patterns as a guide to tile location when they appear on photos.

### *Soil Moisture and Pattern Contrast*

In addition to the geometric patterns displayed by the tile drainage, there are also tonal differences between drained and un-drained soil that helps to identify tile locations. Drained soils are drier, which makes them more reflective. This greater reflectivity produces tile lines which appear lighter in tone than the surrounding landscape against which they are seen.

These tonal contrasts are enhanced if there was a precipitation event just prior to the date of the photography. An event of about one quarter of an inch

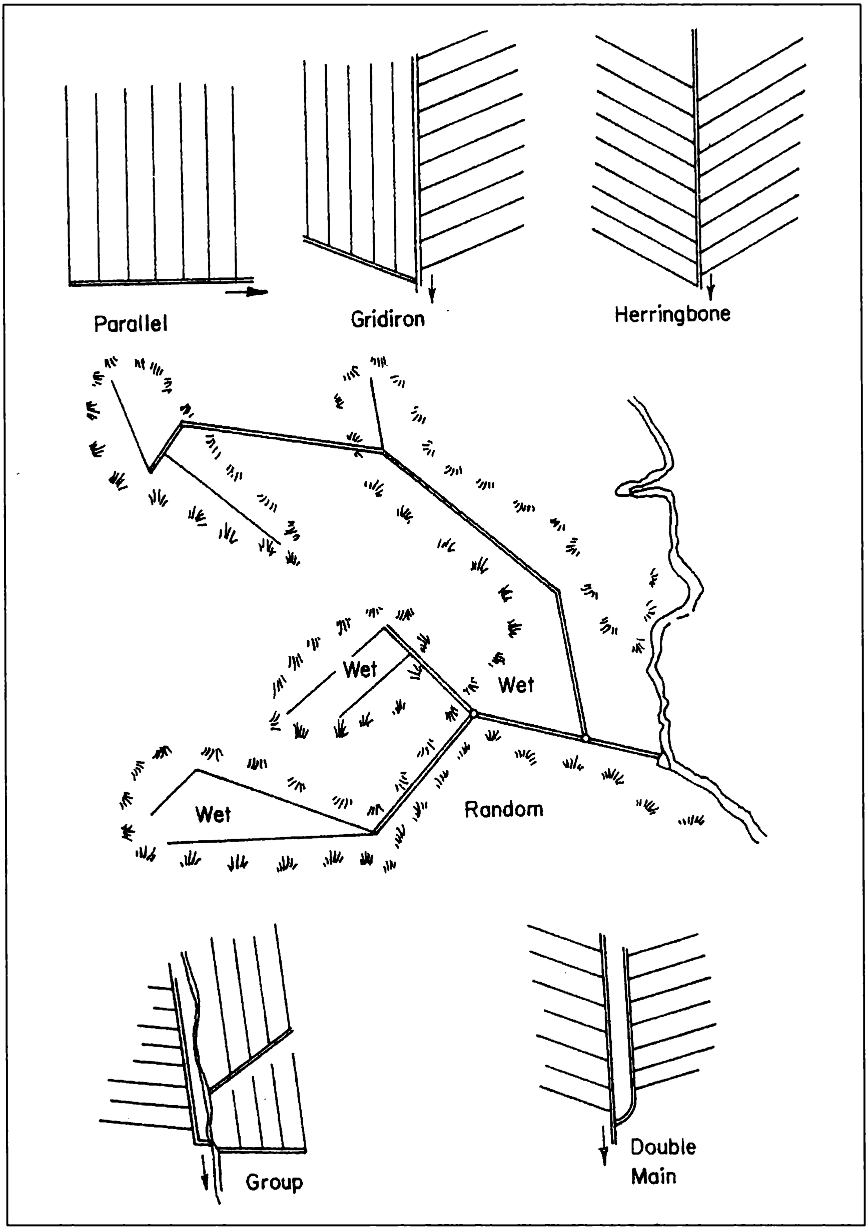


*Figure 1*. Common drainage tile patterns.

or more in the two to three days before the photographs were taken enhances the contrast between tile lines and the surrounding landscape enabling more accurate identification. In the case of the following photos, the 1938 photos were taken shortly after an event of between 0.23 and 0.28 inches of rain prior the acquisition of the photography precipitation. Air photo interpreters beginning an investigation for tile drains should access the historical weather statistics for the area in question prior to searching for photography in order to enhance the chance of success.

## Case Studies

Two case studies were undertaken to illustrate the use of historic air photos to locate sub-surface drain tile. The first set of photos, taken in Allen County, Ohio, in late October, 1956, provide characteristic examples of tile pattern arrangements which can be used as a guide to determine the location of buried drain tiles. Figure 2 depicts a combined herringbone and parallel pattern of tile placement. Figure 3 is an example of parallel and random mixed placement while Figure 4 exhibits a mixture of herringbone and parallel patterns. The crisp appearing edges on the 1956 photos suggest that the installation was completed a short time prior to the aerial photo.

Taken in Montgomery County, Ohio, in July, 1938, Figure 5 depicts a random pattern and Figure 6 shows parallel patterns. While the tonal and geometric patterns are evident in the 1938 photos, the blurring of the edges suggests that there was a more extensive passage of time between tile installation and photo acquisition than in the 1956 photos. This combination of geometric pattern and tonal differences provides the interpreter with guides to the location of the tile lines.

*Figure* 2. Example of herringbone and parallel tile placement, Allen County, Ohio, late October, 1956.

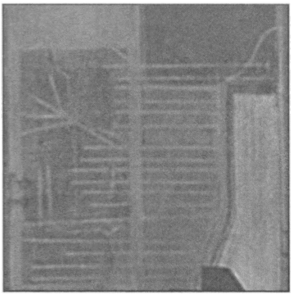

*Figure 3*. Example of parallel and random mixed tile placement in Allen County, Ohio, late October, 1956.

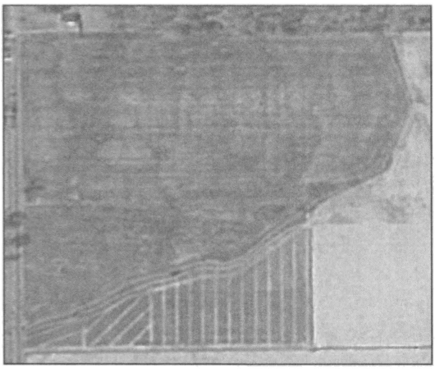

*Figure 4*. Example of mixed herringbone and parallel tile patterns in Allen County, Ohio, late October, 1956.

*Supporting Locational Evidence*

Additional supporting resources help in locating tile-drained areas. Field observation can be used to locate drain outfalls to determine if they are related to the fields identified as having tile drains. The discharge point for tile drainage systems is usually from a pipe extending beyond the side of a surface drainage ditch and can often be detected by field survey. Such discharge points can be referenced by using a GPS unit and the information can add precision to the survey.

County soil surveys can also be of assistance in locating tile drained fields. Figures 5 and 6 are both Brookston silty clay loam soils whose description indicates a need for drainage.

University of Wisconsin researchers have also conducted research that relates crop conditions in the field to tile drain locations. Corn, alfalfa, and soybean growth patterns were all noted as being useful indicators of the presence of subsurface tile drains. This knowledge combined with the photographic evidence is useful in the search for tile lines (Ruark et al., 2009).

*Figure* 5. Example of random tile placement pattern in Montgomery County, Ohio, July 1938.

## Conclusion

Draining excess water from surfaces is a common practice in many locations, both rural and urban. The use in rural places where land use changes for agricultural development is the greatest use of drainage systems. Suburban housing tracts and urban centers, however, are also vulnerable to excessive amounts of water in the soil. If a prior subsurface plumbing system for agricultural drainage was present at a prior time and becomes damaged, unexpected water problems in a residential neighborhood may result.

Students using historic air photos in combination with an assessment of drain outfall locations and a survey of the associated field soil types and their

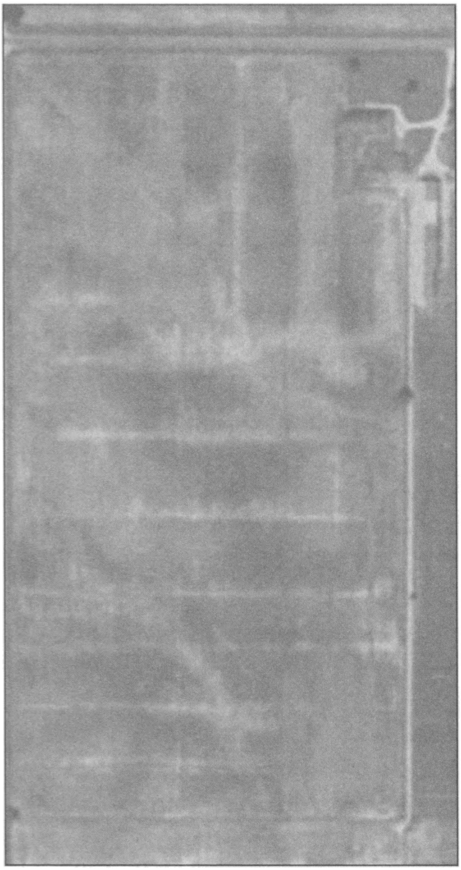

*Figure 6.* Example of parallel tile pattern in Montgomery County, Ohio, July, 1938.

hydrologic groups will be able to analyze and identify the problem. In fact, using aerial photos can help identify fields with existing drain tiles where a land use change could result in water drainage issues.

Equipped with information as to the location of existing tile fields, students can engage in research that officials in county planning offices, developers, septic tank installers, and builders can use to make appropriate adjustments to their land use plans. It is an excellent example of applying geographic research methods and analysis to specific locations, or place based learning experiences. Students would be able to participate in public discussions about problems associated with soil drainage, broken tiles, and disrupted drainage systems that occur when changes are made in land uses.

## Footnotes

[1] Extensive studies of North American drainage have been carried out by geographers, agriculture historians, and rural sociologists. A regional perspective on the Midwest is provided in H. Prince, (1997), *Wetlands of the American Midwest: A historical geography of changing attitudes*, (Chicago: University of Chicago Press). More geographically focused attention is given in the following studies: Meyer, A.H. 1935, The Kankakee 'Marsh' of Northern Indiana and Illinois, *Papers of the Michigan Academy of Science, Arts and Letters, 21*, (1935), 366-395; Meyer, A.H., 1936, The Kankakee 'Marsh' of Northern Indiana and Illinois, *Michigan Papers in Geography, 6*, 359-396. This latter is a considerably expanded version of the author's 1935 paper and includes three highly detailed maps. Hewes, L., (December 1951), The Northern Wet Prairie of the United States: Nature, sources of information, and extent, *Annals of the Association of American Geographers, 41*, 307-323; Bogue, M. B., (1951), The Swampland Act and Wet Land Utilization in Illinois, 1850-1890, *Agricultural History, 25*, 169-180; Hewes, L., and Frandson, P. E., (March 1952), Occupying the wet prairie: The role of artificial drainage in Story County, Iowa, *Annals of the Association of American Geographers, 42*, 24-50; Wooten, H. H., and Jones, L. A., (1955), Drainage of fields: The history of our drainage enterprises, *Water: The yearbook of agriculture,* (Washington: US Government Printing Office, 478-491); Kaatz, M. R., (March 1955), The Black Swamp: A study in historical geography, *Annals of the Association of American Geographers, 45,* 1- 35; Sutton, J. G., (1957), Drainage in the humid areas of the United States, *Transactions*, American Society of Civil Engineers, 122, 115-131; Bogue, M. B., (1959), *Patterns from the sod: Land use and tenure in the Grand Prairie, 1850-1900*, (Springfield, Illinois: Illinois State Historical Library, Land Series, Volume 1); Bogue, A. G., (1963), *From prairie to Corn Belt: Farming on the Illinois and Iowa Prairies in the Nineteenth Century*, (Chicago: The University of Chicago Press); Kelly, K., (1975), The artificial drainage of land in nineteenth–century Southern Ontario, *Canadian Geographer, 19*, 279-298; Winsor, R. A., (1987), Environmental imagery of the Wet Prairie of East Central Illinois: 1820-1920. *Journal of Historical Geography, 13*, 375-397; Rumer, T., (1999), *Unearthing the land: The story of Ohio's Scioto Marsh*, (Akron: University of Akron Press); Meindl, C., Alderman, D., and Waylen, P., (2002), On the importance of environmental

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[2] Buckman, H., and Brady, N., (1964), *The nature and property of soils*, (NewYork: The Macmillan Company). See also Ivins, L. and Merrill, F., (1915), *Practical lessons in agriculture*, (Cincinnati: American Book Company);, U.S. Department of Agriculture, (1915), *Lessons in elementary agriculture for Alabama schools*, Bulletin Number 258, July 13, 1915 from the U.S. Department of Agriculture; Munn, B., (1855), *The practical land drainer,* (New York: C.M. Saxton and Co.).

[3] See especially: Krusinger, A., Schwab, G., and Mintzer, O. (1971), Drainage tile location using aerial photography, A paper presented at the Winter Meeting of the American Society of Agricultural Engineers, Chicago, Illinois, December 7-10, p. 1-6. Also, Verma, A., Cooke, R., and Wendte, L. (1996), Mapping subsurface drainage systems with color infrared aerial photographs. A paper presented before the Symposium on GIS and Water Resources, American Water Resources Association, Ft. Lauderdale, Florida, September 22-26; Naz, B.S., Ale, S., and Bowling, L.C., (2009), Detecting subsurface drainage systems and estimating drain spacing in intensively managed agricultural landscapes, *Agricultural Water Management, 96*, 627-637; Goodwin, C., Green, J., Horstmeyer, S., Nolen, J., Seiler, S., and Skalley, S., (2000), Use of aerial photography to locate agricultural drain tile. A poster presented before the East Lakes Division of the Association of American Geographers Meeting, Oxford, Ohio, October 21.

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