Using Geospatial Information to Design and Install Drainage at the Davis-Purdue Agricultural Center

Jane Frankenberger, Agricultural and Biological Engineering
Bruce Erickson, Agricultural Economics

Introduction

The use of yield monitors and field mapping has created a renewed interest in a relatively old technology—field drainage. With the effects of drainage now quantifiable, growers can make better informed decisions about drainage installation, and validate their decisions with landowners, lenders, and farm managers. The same GPS-based technology that allows the creation of field maps can allow faster and more precise methods of assessing fields, and for designing and installing drainage systems. GPS-based technology was used at a recent drainage installation field day at the Davis Purdue Agricultural Center (DPAC) near Farmland, Indiana. This article explores how geospatial data were obtained and used to assess the land surface and existing drainage system, and aided in the planning and installation of the new system.

Technology Used for Drainage Assessment, Design, and Installation

Drainage work requires very precise elevation measurements, since the drains move water using gravitational forces. In the past 20 or so years, drainage contractors have used precision laser levels to not only map fields, but to allow precise installation when used on equipment. Unfortunately the GPS used in most agricultural applications hasn't been accurate enough, at least in the vertical direction, for drainage work. Differential GPS (code phase) has a maximum accuracy level of about 10 inches horizontal and 20 inches in the vertical direction.

Real Time Kinematic GPS, or RTK, can provide the needed accuracy, and is being used more and more for topographic mapping and drainage installation. RTK uses the carrier phase of the GPS signal to achieve accuracies of around ½ inch horizontal and 1 inch in the vertical direction. These technologies are still very new and are only beginning to be widely used. To design and implement a new or modified system, the following steps are used:

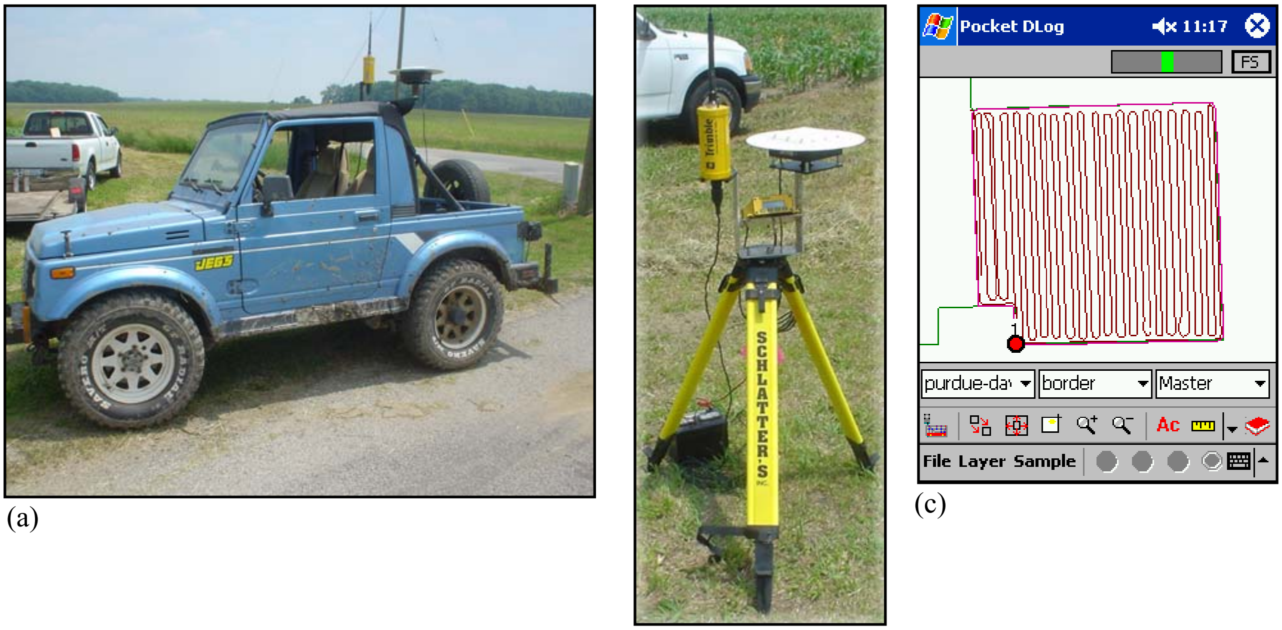
1. Create an accurate map of the land surface.
2. Map existing drain systems.
3. Design the new system.
4. Install the new system.

1. Mapping the Field Surface

The first step in drainage design is to create an elevation map of the field. This is done by collecting elevations at a number of points within the field, then interpolating those points to create an elevation surface.

At DPAC, elevation data were collected using a vehicle-mounted Trimble Ag214 RTK GPS system, interfacing with an iPaq[1] hand-held computer using Pocket DLog[2] software. A base station was established on the edge of the field, with data points collected in paths 35 feet apart (Figures 1a, 1b, and 1c). More data points (i.e., narrower swaths) normally lead to a more accurate surface, although no specific recommendation is widely agreed for how close data points should be to achieve the needed accuracy for field drainage installation.

[1] iPaq is a trademark of the Compaq company
[2] Pocket DLog is a trademark of Delta Data Systems



(a) (b) (c)

Figure 1. (a) The roving vehicle with RTK GPS. (b) Base station set at the edge of the field. (c) The path of the roving vehicle, mapped on a PDA in the field *(Graphics in Figures 1, 3, and 4 courtesy Joey Schlatter).*

Elevation point data captured via GPS were imported into a TilePro® drainage design software package[3]. All standard geographic information system (GIS) packages have algorithms for estimating between points, or interpolating. One of the most common algorithms is inverse distance weighted, in which the value is determined for an unknown point based on the surrounding points, but with decreasing influence for those points further away. The software user can set the rate at which their influence decreases with distance, influencing the resulting grid map. The spline method is another way to interpolate, which relies more on the trends indicated in the relationships among points, providing more of a "rubber sheet" effect. The method of interpolation can have a significant effect on the accuracy of the resulting surface. Users may aim for a "smooth" surface, but the real goal should be to use the method which most closely resembles the actual landscape. Research is needed to better establish under what conditions various methods and parameters yield the most accurate elevation surface.

2. Mapping existing drains

Many fields have existing tile systems in various degrees of function, and these should be mapped and incorporated into the new systems wherever feasible. New drains may tie into existing drains, so it is important to get accurate measurements of existing systems.

At DPAC, tile drains were already present in the southeast quadrant of the field, as well as one drain in the northeast quadrant (mapped in green in Figure 2a). A county regulated drain existed in the field as well (red in Figure 2a). Because of its location and condition, the main drain was also replaced as part of the project, with cooperation from the County Surveyor who has authority over regulated drains.

[3] Tile Pro is a trademark of Delta Data Systems.

To obtain the elevations of existing drains, drain depths were measured (Figure 2b) and subtracted from the elevation calculated in the interpolated elevation surface. This 2-step process, using an interpolated surface rather than direct measurements, may have introduced more error than directly surveying the existing tile line.

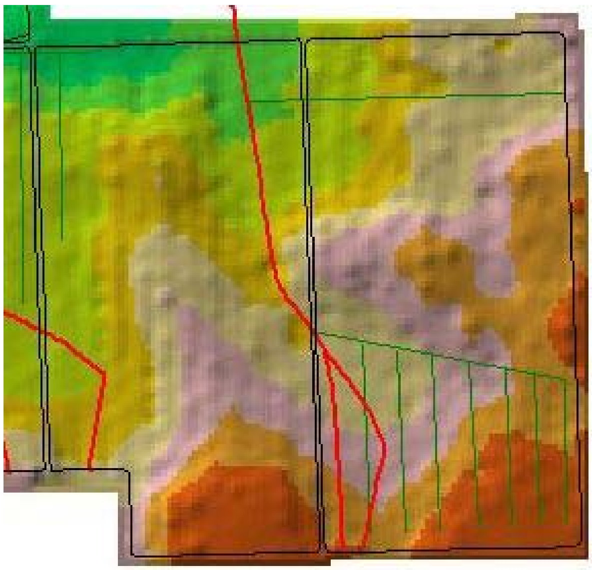


Figure 2a: Interpolated elevation surface (visualized using the "hillshade" function), with existing drains.

Figure 2b: The tiles were located and uncovered to measure depth (Photo: DPAC staff)

3. Designing the New System

After elevation and existing drains are mapped, design of the new system begins. Individual drains must have at least 0.1% grade, and should usually be installed between 2 and 4 feet below the soil surface. If tiles are too shallow, they may be vulnerable to surface pressure, causing them to bend or collapse with the weight of equipment. At DPAC, the desired depth was 3.5 feet on the mains and submains, and 3 feet on the laterals. Figure 3 shows a typical lateral profile, with the top line representing the soil surface, and the blue lines representing the maximum and minimum allowable depth. If the drain cannot stay in this zone with a constant grade, then a change in grade can be designed.

At Davis, once the outlet elevation and the design layout were determined, the slope and elevations for each main and lateral were created. This site had an unusual design because it was being used for research into a new drainage technology called *drainage water management*. With drainage water management, water levels are regulated to help store water for potential use during summer dry periods, and to minimize excessive tile flow in the winter which can contain pollutants. The field was therefore divided into four sections (Figure 4), with a control structure in each section. A 45-foot spacing between laterals was used to match existing research plots.

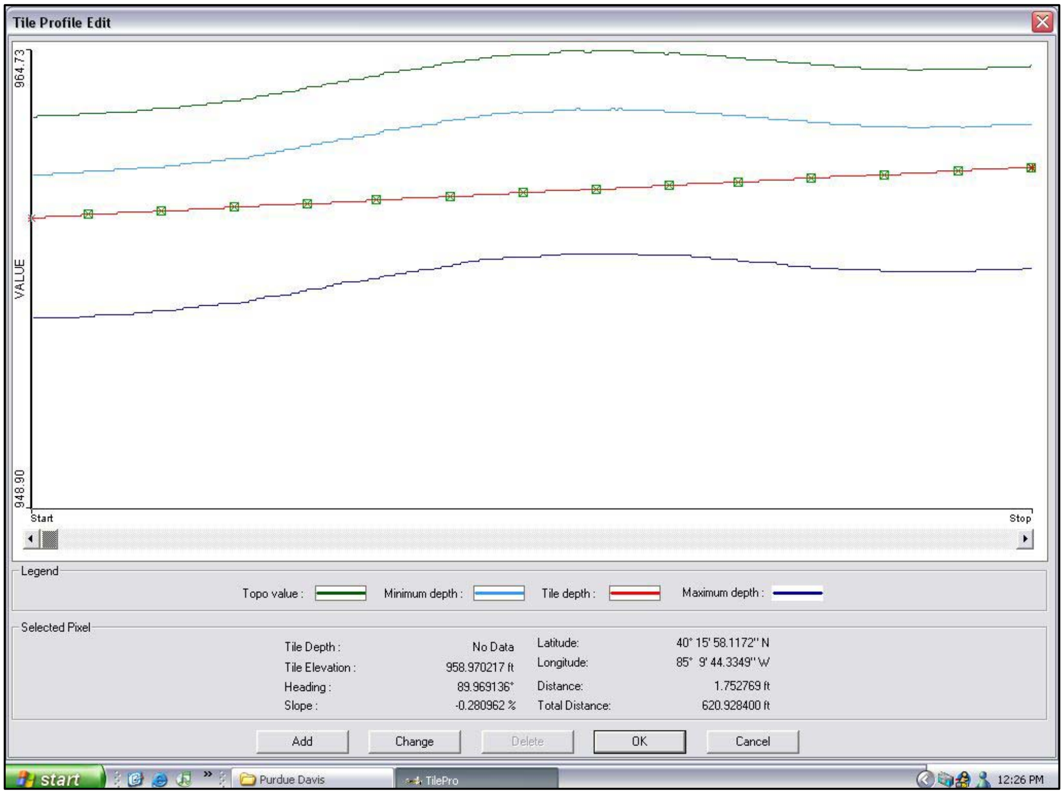


Figure 3: Lateral drain profile showing (from top) soil surface, minimum tile depth, planned tile location, and maximum depth.

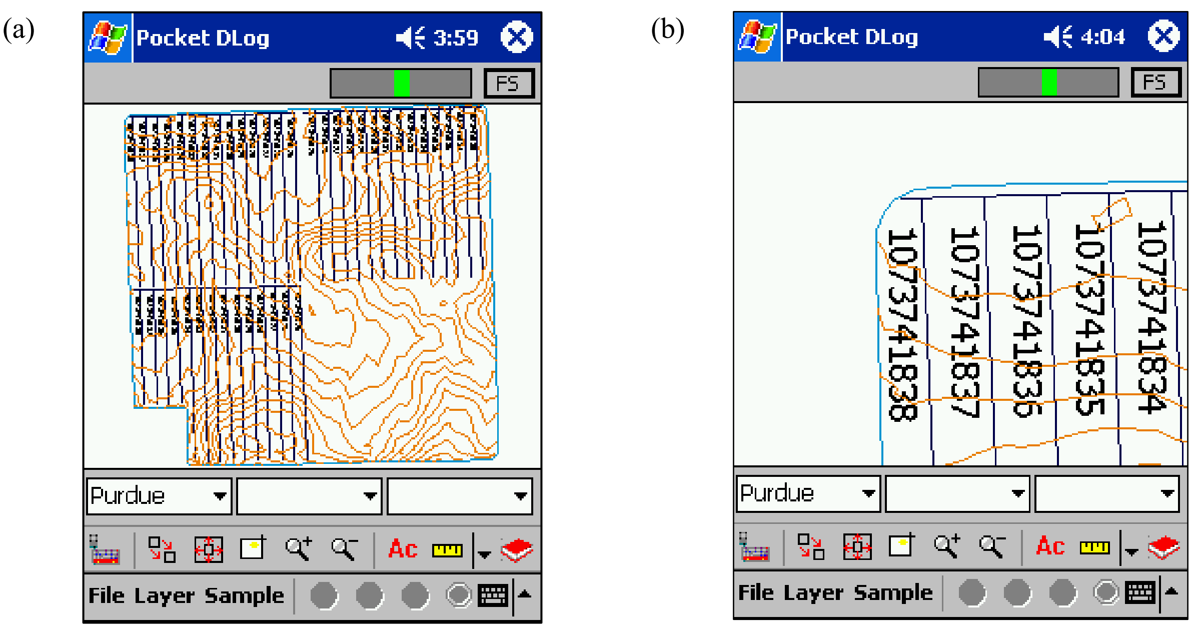


Figure 4. Drainage design used for installation. (a) The drainage system was designed with four quadrants, one for each drainage management structure. (b) A close-up of the top left field corner shows how each drain is referenced by number.

4. Drainage Installation and Mapping

The finished design was downloaded to mobile equipment for the drainage installation at DPAC. In this project, the GPS data were used for horizontal control of the drain plow. The design was fed into a lightbar to tell the operator whether to turn left or right in order to follow the designed tile locations. Vertical control was provided by a laser system.

In principle, the design could be used for vertical control as well. Software is needed to control the “boot” of the drain plow, which allows the drainage tile to be precisely installed. The accuracy of the RTK GPS, which has a root mean square error of up to one inch in the vertical direction, is less than the accuracy of a laser level which is commonly used for the installation of tile. A very small variation from grade with very gradual slopes (often 0.2% or less) can result in siltation of drainage lines, reducing capacity. However, the laser control may not actually result in more accuracy because the plow still may vary because of ground conditions, rocks, or obstructions.

An advantage of the GPS receiver on the boot of the tile is that it can also produce an “as-built” map, which shows the client exactly how tile was installed. This may include any variation from grade that may exist due to obstructions encountered along the way, or other differences between the design and actual installation. The results of this technology are still being evaluated at DPAC.

Conclusion

Newer high-accuracy GPS known as RTK can enable drainage contractors to survey a field quickly, then create an elevation surface that closely mirrors the topographic surface of the land. At the Davis Purdue Ag Center, such a map was used to design and install the new drainage system. The use of RTK GPS during installation also allows the contractor to provide an “as-built” map that provides a useful record for landowners to accompany other site-specific maps of their field.

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