Drainage Plow Tubing Installation: Field Evaluation of Pull-Behind Plows1

Curtis Knueven, Larry C. Brown, Norman R. Fausey, Eric Stauffer, John J. Downey and James L. Fouss2

Summary

The overall purpose of the research is to evaluate the installation performance of subsurface drainage installation equipment. The Ohio State University and the USDA Agricultural Research Service (ARS) are working together to conduct this research. Our results should assist in the development and field testing of monitoring equipment and testing procedures to evaluate the accuracy of the placement of drain pipes by drainage plows, including, but not limited to, the newer pull-behind drainage plows that are intended for use by farmers inexperienced in design and installation of water management systems. The paper presents a summary of the experimental procedures and some field observations in 2001.

Introduction

The Ohio State University and the USDA Agricultural Research Service have recently initiated research on drainage plow installation performance. The purpose of the research is to evaluate the performance of subsurface drainage installation systems including the drainage plow, towing vehicle, grade control feature, and operator. The results should be useful in the development and field testing of monitoring equipment and testing procedures to evaluate the accuracy of the placement of drain pipes by drainage plows, including, but not limited to, the newer pull-behind drainage plows that are intended for use by farmers inexperienced in design and installation of water management systems. The results should also guide the development of educational materials and programs for owner / operators of this type of drainage equipment.

The field research is being conducted by Curtis Knueven, an M.S. Graduate Research Associate in the Environmental Sciences Graduate Program and the Department of Food, Agricultural, and Biological Engineering (FABE), at The Ohio State University. Dr. Larry C. Brown (Ohio State University FABE) and Dr. Norman R. Fausey (USDA-ARS Soil Drainage Research Unit, Columbus) serve as Curtis' research advisors. Mr. John Downey

1 This work is being supported, in part, by the USDA-ARS Soil Drainage Research Unit; the Overholt Drainage Education and Research Program and Department of Food, Agricultural, and Biological Engineering at The Ohio State University; Spectra-Precision; Ohio State University Extension; Ohio Land Improvement Contractors Association; and participating agencies and cooperators. Additional funding is being sought to further expand the research and educational efforts associated with this project and associated regional projects.

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(Spectra-Precision, Dayton, Ohio), Dr. James L. Fouss (USDA-ARS Baton Rouge, LA), and selected Ohio Land Improvement Contractors (LICA) and drainage plow manufacturers serve as project technical advisors.

Additionally, a pilot companion study was initiated to supplement, and possibly extend, our field data collection efforts. Eric Stauffer initiated a simulation study focused on the Liebrecht drainage plow, and this work is being presented in a companion paper at this meeting. The modeling work follows that conducted in the 1970's by Jim Fouss. The installation data we collect will be used to help calibrate and evaluate the simulation model. The simulation model will then allow us to evaluate drainage plow design and performance over a much larger possible range of site, topography, soil and operating conditions.

At present, evaluations are based on data from a GeoStar system mounted above the outlet of the tubing boot on each plow. The GeoStar system has an accuracy level of +/- .015'. Therefore, the absolute difference between two readings has to be greater then 0.03' in the negative direction before the grade is said to be negative, and subsequently improperly installed.

We plan to work with as many cooperators as possible. Since the process is somewhat time consuming, we usually plan to be at the observation site several days to work with those drainage plows that arrive early and are prepared to mount our instrumentation. We usually work with the cooperators to make some preliminary data collection runs, work out instrumentation and mounting bugs, interpret and discuss the results, and help ensure successful data collection.

In order for us to properly collect and record data on-the-go with these plows, the plow system must have a laser grade control system. In addition, we require the manufacturer/owner/operator to make several small modifications that will allow us to mount our instrumentation. Spectra-Precision has loaned us a GeoStar Mast system, which allows us to collect data on tubing installation depth independent of the machine's laser grade control system. To properly mount the GeoStar Mast, a mounting bracket must be installed at the rear of the plow, directly above the end of the plow's tubing placement boot. Also, a separate bracket at the end of the boot must be installed, onto which we mount our video camera. Both brackets must be installed to our specifications before arriving at the site, and we provide diagrams and suggestions for constructing and mounting these two brackets. We collect data <u>only</u> from those drainage plows that have the brackets in place prior to arriving at a site. Also, it is very important that the cooperators follow our drainage installation plan. We have developed the data collection instrumentation and procedures to properly collect very good data in a fair and consistent manner.

Manufacturers, owners, and/or operators who cooperate with our project may benefit in several ways. First of all, we will furnish each cooperator with a nice summary of their machine's performance data (see again the attached example for the Liebrecht drainage plow) and videotape once we have properly reduced, documented, and evaluated the data. We hope to provide input to each cooperator about potential problems and solutions regarding proper installation of agricultural drainage tubing. Secondly, working with us may provide each cooperator additional opportunities to demonstrate and market their plows. We believe these data will be very useful to drainage plow manufacturers, owners,

and operators, their potential customers, and others across the Midwest. We are interested in working with any number of drainage plow owners and manufacturers.

During the next 12 to 24 months, we anticipate conducting a number of routine field installation evaluations at selected drainage demonstration field days in Ohio and possibly elsewhere in the Midwest. These efforts will focus primarily on the performance of the various farmer-owned/operated drainage plows currently on the market. We plan to work with selected drainage plow manufacturers, owners, and/or operators cooperatively to conduct these field installation evaluations. With cooperator help, we hope to be able to record installation data on-the-go and evaluate drainage plow performance for the field day site conditions.

With cooperator help, we hope to be able to record installation data on-the-go and evaluate drainage plow performance for field day site conditions. We plan to conduct more in-depth evaluations of one or more drainage plows during 2001 and 2002. We will develop one or more installation field sites with a number of less uniform soil and topographic conditions and features. We will also impose a range of field operation parameters (speed, tractor draft, etc.). These evaluations may be somewhat similar to the types of site and soil conditions used in the Ontario, Canada, installation equipment field tests. Although the work currently being conducted is specific to Ohio soils, we anticipate that the overall project will be linked with related efforts by universities and LICA chapters in Ohio, Minnesota, Iowa, and elsewhere.

Initial evaluations were conducted in 2000 at the following field days: J + M Farms, Leipsic, OH, June 10-11; The Ohio State University's Ohio Agricultural Research and Development Center at Wooster, OH, June 16; Liebrecht Field Day, Kieferville, OH July 19; Lorain County Subsurface Drainage and Tillage Field Day near Oberlin, Ohio September 7; and Farm Progress Show in Cantrall, IL, September 26- 28. At the Lorain County Ohio four different plows were observed in operation. Several plows were evaluated in Missouri in July of 2001.

The following sections of this paper include a summary of the features of the four plows observed at the Lorain County Field Day; a summary of some selected problems for pull-behind drainage plows observed over a range of field days (not restricted to any particular field day); and a summary of some of the representative results for each machine operated at the Lorain County Field Day.

For further information, please contact Mr. Curtis Knueven (knueven.8@osu.edu; 614-292-1406), Dr. Larry C. Brown (brown.59@osu.edu; 614.292.3826) and/or Dr. Norman R. Fausey (fausey.1@osu.edu; 614.292.9806). Please note that our work is intended to provide an un-biased evaluation and summary of drainage installation performance, and does not constitute an endorsement of any product.

Features of Pull-Behind Drainage Plows at the 2000 Lorain County Field Day

Gold Digger

Contact Information: 4501 E. Old Ft. Harrison; Terre Haute, IN 47805; Toll-free 888-SoilMax (764-5629); 812-466-0088; dbell@soilmax.com http://www.soilmax.com (Denny Bell).

Soil Max's Gold Digger sells as either a three-point model or a pull type model although our testing has only been with the 3-point model. The Gold Digger has a proportional valve that gives more or less hydraulic fluid to the plow depending upon how much the plow is off grade. This is done to help ensure no over or under correction will occur. This was the only plow observed at this field day to have this feature. When installing different size pipe, the boot and the point of the plow are changed to reduce the draft requirement while pulling the smaller 4-inch pipe. This plow has a trapezoidal bottom that meets the ASTM 449-97 specification, and can install 4, 5, 6, and 8-inch pipe. When mounted using a three point hitch, the system may act as a parallel linkage when in the float position, and help transfer the draft forward of the rear axle of the towing vehicle. This model had no pipe feeder. We have observed the Gold Digger plow with the GeoStar system five times, at three different sites, pulled with a John Deere 8410, 8400, and 8300, respectively.

Split Pines

Contact Information: 4685 McGrane RD; Romulus NY 14541; 315-585-2225; (Kevin Swartley).

The Split Pines Farms' Pine Swartly Plow from the state of New York was by far the smallest of the plows at this field day. The plow had a V-bottom that keeps with the ASTM 449–97 specification. This plow had a maximum depth of only 4.5 feet and this model sells only with a 4-inch boot. The plow has a three-point linkage that is not in float, and therefore has some manual control. This model had no pipe feeder. We have observed the Split Pines plow with the GeoStar system three times at one site, while pulled with a John Deere 8410.

Winthrup Welding Works

Contact Information: Box 87; Winthrop IA 50682; 319-935-3385 or 319-935-3747; (Roger Winthrup).

This plow uses a double linkage that helps distribute the draft of the plow to a virtual hitch point in front of the pulling implement. This plow had a round bottom with a straight cutting point, and had options of installing 4, 5, 6, 8 and 10-inch drainage pipe up to 5.0 feet deep During the Lorain County Field Day this plow was mounted on a trailer thus losing the ability to transfer weight to the towing vehicle. During the field day this plow did not have a hydraulic or electric mast making it impossible for this plow to operate through the hill that was present during the field day. This model had no pipe feeder. We have observed the Winthrup plow with the GeoStar system twice at one site, once pulled with a Case 9370 and once with a Steiger Panther.

Liebrecht

Contact Information: 17771 Rd. H-13, Continental, OH 45831; 419-596-3501; liebrech@bright.net; http://www.farmdrainage.com/**; (Jim Gordon)** jp-drain-sol@who.rr.com.

The Liebrecht Ditcher is a pull-type model that has a pipe feeder, and a tilt adjustment if it encounters ground conditions where one side of the plow is higher or lower than the other. The hydraulically controlled mast has numbers are every tenth of a foot to help the operator break grade. The mast extends well above the tractor cab to reduce the possibility of the cab interfering with the laser reception. The Ditcher plow has a Boot Pressure Regulator, which keeps 500 pounds pressure on the transport wheels in order to help the plow from sinking in

soft bottom conditions. This plow has options of installing 4, 5, 6, and 8-inch drainage pipe up to 5.5 feet deep. Instead of the ASTM 449–97 specification, this plow has a straight fracture point and a flat bottom. The bottom of the boot has a small nub which is pressed into the soil at the bottom of the plow slot to form a support for the pipe. We have observed the Liebrecht plow with the GeoStar system 12 times, at five different sites pulled with a Steiger 210 Wildcat, John Deere 8410, Case 9370, Fent 926, and Case STX 375 Quadtrax, respectively.

Problems Observed for Drainage Plows

Figure 1. Pre-ripping too deep.

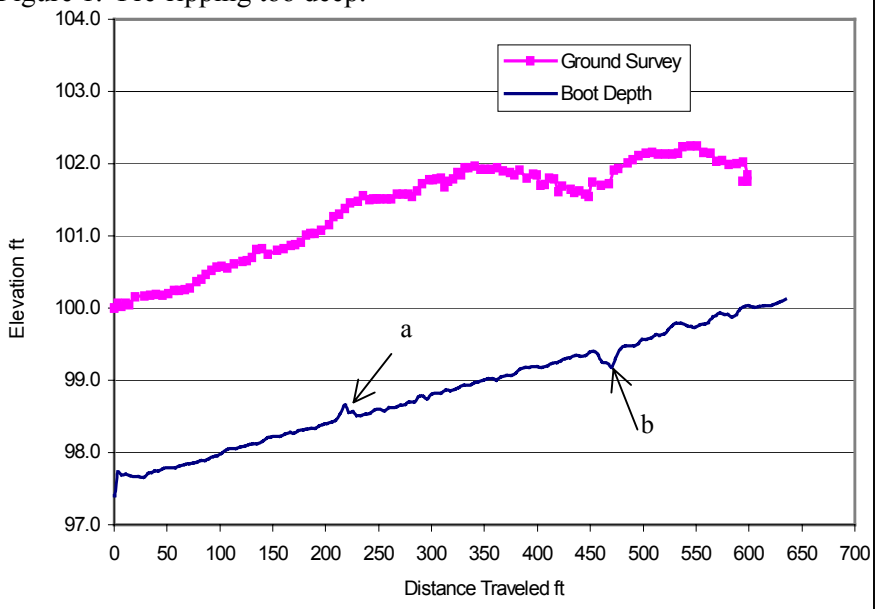


Figure 2. Incorrect transmitter setting.

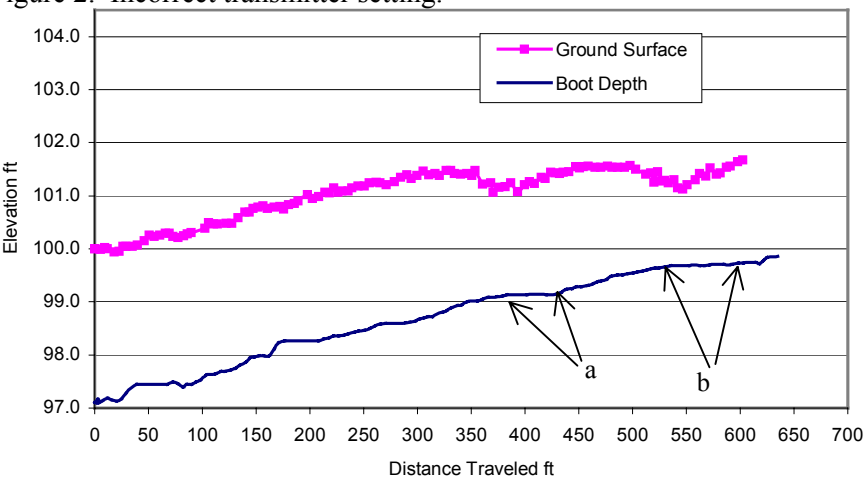


Figure 3. Untrained operator.

Figure 1. The operator of this plow started pre-ripping from the end of the string and worked back towards the outlet. With no survey shots and no laser guidance, this operator proceeded back with little or no information about the grade or depth, just information from the previous run. At "b" during the pre-rip, the plow followed the ground surface change making the plow pre-rip too deep. Catching this mistake, the operator quickly raised the plow above the final installation depth. The boot depth graph taken during installation shows a reverse grade of 0.30', which occurred when the plow passed through this deep pre-rip area. This mistake is due to operator error, one of the numerous problems observed with inexperienced operators. This plow required some manual control and in figure 1 "a" the operator wasn't paying enough attention allowing the plow to come up 0.12' then adjusting down 0.17' producing a negative grade. In all, five negative grades can be seen in figure 1.

Figure 2 shows no apparent grade control because the operator did no set the correct grade into the transmitter. This plow operator used the grade chain and manual adjustment to keep the pipe depth close to the design depth. The boot depth graph does appear to show a negative grade but is out of the detection limit of the equipment. At letter "a" the boot depth stayed level for approximately 60 feet. At letter "b" the boot depth stayed level for approximately 90 feet. Improved installation could have occurred if this operator did not do the work hastily.

Figure 3. This graph shows numerous problems that indicate operator training and machine setup were inadequate. The pitch of the plow shank was incorrectly adjusted on this plow. The automatic grade control was unable to overcome the improper setup and the plow repeatedly produced negative grade at boot depth. The ground surface conditions and the design for this run were not difficult. These results illustrate the mistakes that can occur with improper machine setup and an inexperienced operator.

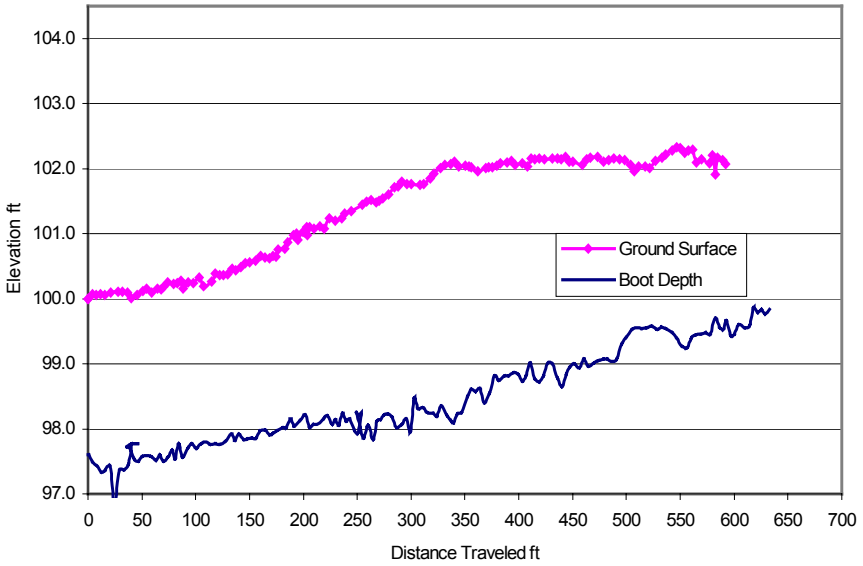


Figure 4. High wind conditions.

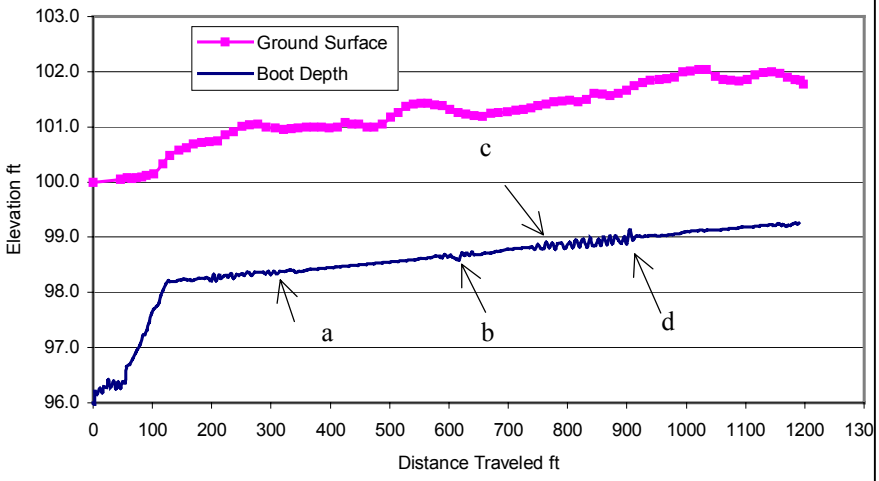


Figure 4. This boot depth graph shows the effect of wind on the laser transmitter, which was set up approximately 500' from the receiver. Before letter "a" the graph shows a little static, but the noise smoothed out from "a" to "c". At letter "b" the transmitter actually shut down and the operator changed the wind sensitivity level to 0. At "d" the transmitter was tied down to an auger, then this system operated within the detection limits of the GeoStar System, as shown on the graph after letter "d". Figure 5 and 6 show one way to firmly mount the tripod to the ground, thus helping to reducing the potential for error. The maximum deviation in grade between points "c" and "d" is 0.25', which is greater then ½ the inside diameter of the pipe being installed.

(Figure 5) Auger

Figure 5. This type of auger can be purchased from almost any local hardware store. The auger needs to be driven in the ground to approximately two feet. The benefits are tremendous when using a taller tripod.

(Figure 6) Tripod setup

Figure 6 illustrates a fully setup tripod with a come-along installed to tighten the tripod firmly with the ground anchor.

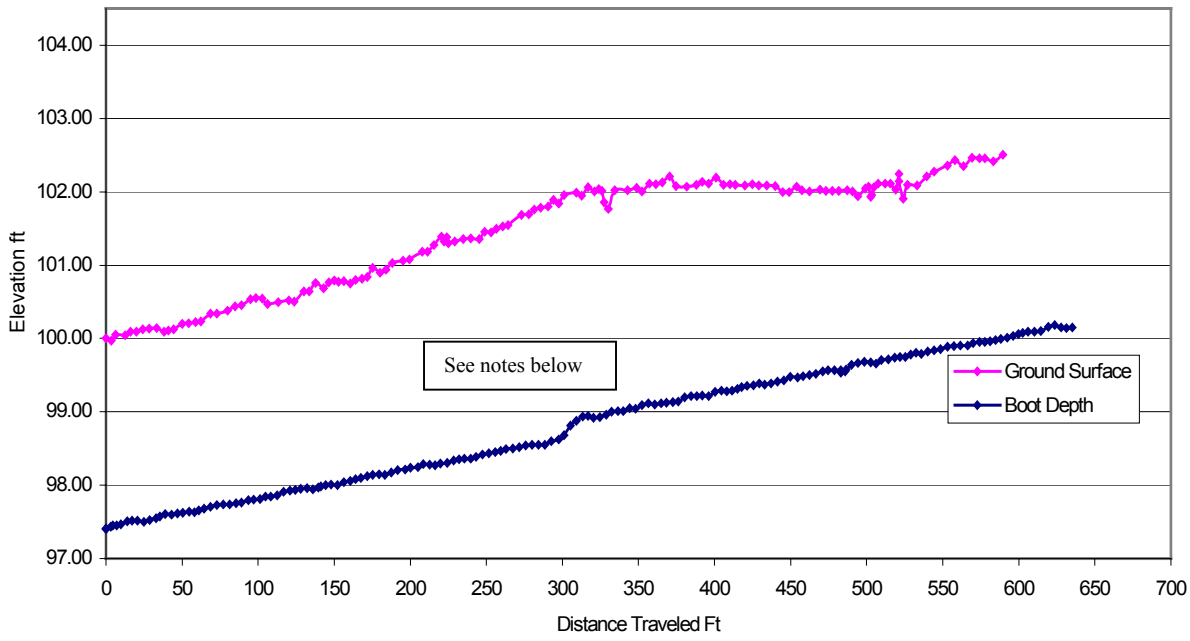
Most problems observed tend to be related to operator inexperience and lack of training.

Recommended Studies:

- Wind sensitivity and tripod effect
  - Height of tripod under different wind conditions
  - Various tripods under different wind conditions
  - Various transmitters with different tripods
  - How distance becomes a major factor in high wind conditions
- Economics of farmer owned pull behind plows
  - At what point will the farmer actually save money?
  - Do farmers realize all the costs involved?
- Computer modeling of other pull behind plows
  - The use of different valves to help with grade control
  - The effect of speed on plow performance
- Various power sources on various plows
  - Four-wheel drive
  - Front wheel assist with same weight and power
  - Various weighting and positioning
  - Front weights being better then rear weights
  - Various speeds
- Tractor hydraulics
  - Do these plows require a higher starting pressure?
  - Do older farm tractors have enough hydraulic pressure?

Gold Digger Plow Evaluation

Wednesday September 6, 2000
Lorain County Subsurface Drainage and Tillage Field Day, Oberlin, Ohio



These data were collected under the following conditions:

- ❖ Soils were Mahoning silt loam 0-2 % slope. Soil water content 17 – 20%.
- ❖ Plow was pulled by a John Deere 8400 (loaded with approximately 1500 lbs on front) at a speed of 0.9 mile per hour, 80 feet per minute (100 feet timed during run).
- ❖ Installation path was pre-ripped using the Gold Digger plow.
- ❖ Installation grade was established at 0.004ft/ft, and laser grade control was performed using a TopCon system. The initial depth was estimated to be 2.5 feet.

- Operator broke grade manually at the 300 ft mark. At 486 ft from the start of installation, the plow stopped (to reconnect a failed splice the pipe) and the plow settled 0.04 ft.
- GeoStar system (Spectra-Precision) mast was mounted over the rear of the tubing boot to detect the relative elevation of the pipe as it exited the tubing boot, therefore the installed pipe depth is apparent.
- Accuracy of GeoStar System was approximately 0.015 ft.

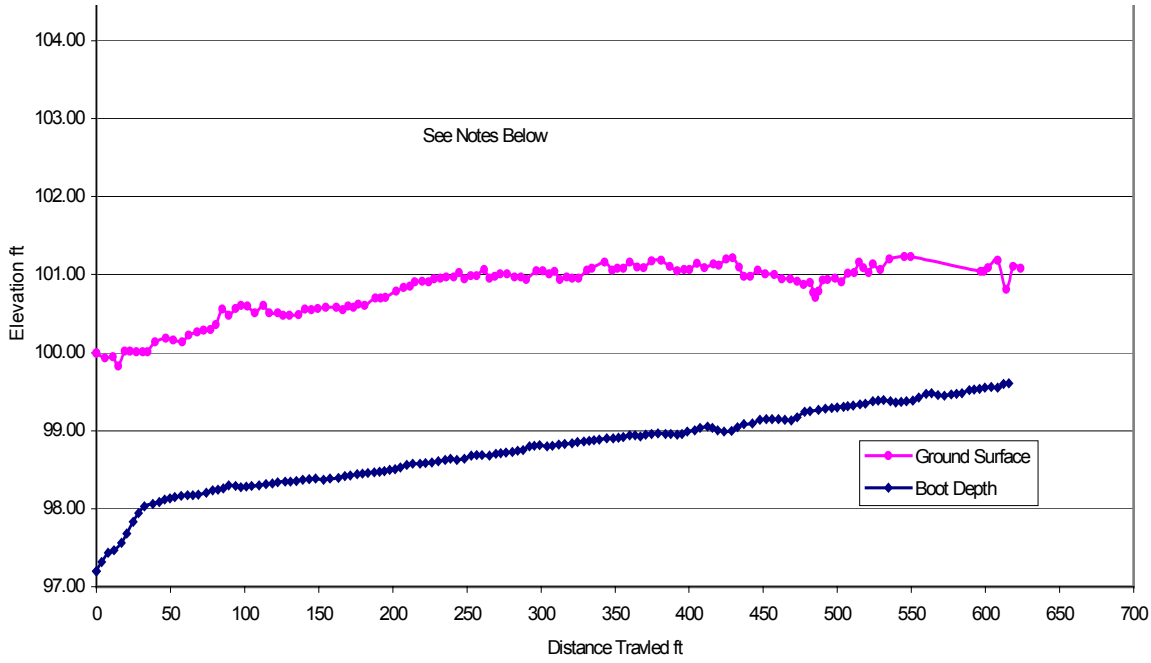
This evaluation was conducted at the Lorain County Subsurface Drainage and Tillage Field Day, Oberlin, Ohio, by Curtis Knueven, Graduate Research Associate, Environmental Sciences, Department of Food, Agricultural, and Biological Engineering, The Ohio State University (Dr. Larry C. Brown, Advisor), in Cooperation with the USDA-ARS Soil Drainage Research Unit, Columbus (Dr. Norman R. Fausey, Advisor); Spectra-Precision, Dayton, Ohio (Mr. John Downey), and Soil Max (Denny Bell). This evaluation does not constitute an endorsement of any product. For more information, please contact Mr. Curtis Knueven at (Department of Food, Agricultural, and Biological Engineering The Ohio State University: knueven.8@osu.edu).

Revision date: February 5, 2001. For release to Lorain County SWCD

Split Pine Farms Plow Evaluation

Thursday September 7, 2000

Lorain County Subsurface Drainage and Tillage Field Day, Oberlin, Ohio



These data were collected under the following conditions:

- Soils were Mahoning silt loam 0-2 % slope. Soil water content was 17–20%.
- Plow was pulled by a John Deere 8410 (loaded with approximately 1300 lbs on front) at a speed of 1.1 mile per hour, 95 feet per minute (100 feet timed during run).
- Installation grade was established at 0.004 ft/ft, and laser grade control was performed using a Spectra Physics system. The initial depth was estimated to be 2.8 feet.
- At 429 feet the system went down 0.06 feet at the edge of a wet spot.

- GeoStar system (Spectra-Precision) mast was mounted over the rear of the tubing boot to detect the relative elevation of the pipe as it exited the tubing boot, therefore the installed pipe depth is apparent.
- The accuracy of the GeoStar System was approximately 0.015 ft.

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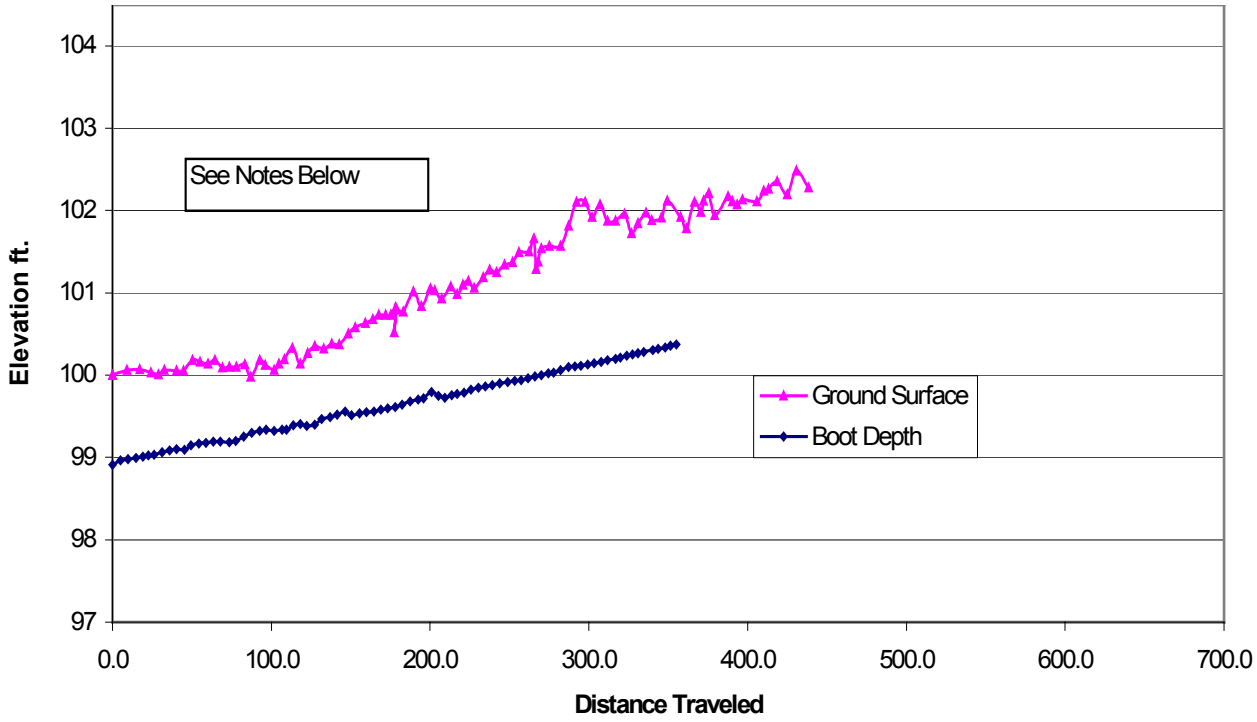
Winthrop Welding Works Yieldmaster Plow Evaluation

Date: Thursday September 7, 2000
Lorain County Subsurface Drainage and Tillage Field Day, Oberlin, Ohio



These data were collected under the following conditions:

- Soils were Mahoning silt loam 0-2 % slope. Soil water content 17 – 20%.
- Plow was pulled by a Steiger Panther KP-1325 at a speed of 0.8 mile per hour, 70 feet per minute (100 feet timed during run).
- Installation grade was established at 0.004 ft/ft, and laser grade control was performed using a Laser Alignment system. The initial depth was estimated to be 0.8 feet.
- GeoStar system (Spectra-Precision) mast was mounted over the rear of the tubing boot to detect the relative elevation of the pipe as it exited the tubing boot, therefore the installed pipe depth is apparent.
- The accuracy of the GeoStar System was approximately 0.015 ft.

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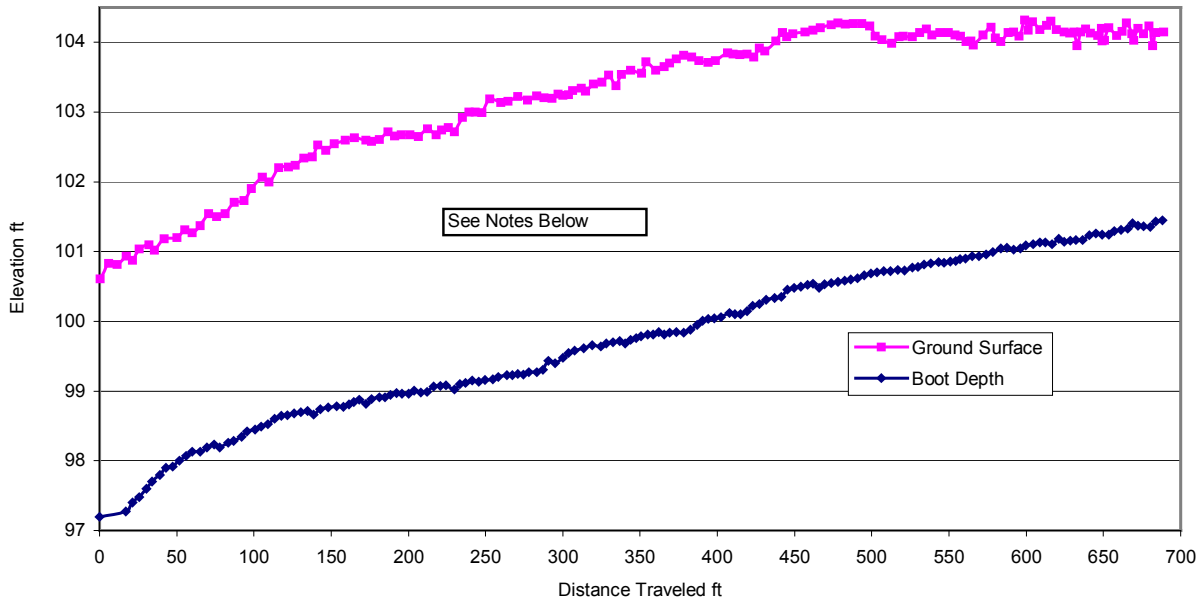
Liebrecht Ditcher Plow Evaluation

Thursday September 7, 2000
Lorain County Subsurface Drainage and Tillage Field Day, Oberlin, Ohio



These data were collected under the following conditions:

- Soils were Mahoning silt loam 0-2 % slope. Soil water content 17–20%.
- Plow was pulled by a Case 9370 (loaded with approximately 3000 lbs on the rear) at a speed of 1.6 mile per hour, 140 feet per minute (100 feet timed during run).
- Installation grade was established at 0.004 ft/ft, and laser grade control was performed using a Laser Alignment system. The initial depth was estimated to be 2.8 feet.
- At 245 feet something in the soil was hit causing the pipe to go down 0.02ft. At 280 and 380 feet the operator manually broke grade.
- GeoStar system (Spectra-Precision) mast was mounted over the rear of the tubing boot to detect the relative elevation of the pipe as it exited the tubing boot, therefore the installed pipe depth is apparent.
- The accuracy of the GeoStar System was approximately 0.015 ft.

This evaluation was conducted at the Lorain County Subsurface Drainage and Tillage Field Day, Oberlin, Ohio, by Curtis Knueven, Graduate Research Associate, Environmental Sciences, Department of Food, Agricultural, and Biological Engineering, The Ohio State University (Dr. Larry C. Brown, Advisor), in Cooperation with the USDA-ARS Soil Drainage Research Unit, Columbus (Dr. Norman R. Fausey, Advisor); Spectra-Precision, Dayton, Ohio (Mr. John Downey), and JP Drainage Solutions (Jim Gordon). This evaluation does not constitute an endorsement of any product. For more information, please contact Mr. Curtis Knueven at (Department of Food, Agricultural, and Biological Engineering The Ohio State University: knueven.8@osu.edu). Revision date: February 5, 2001.