Field Scale Evaluation of Center Pivot Systems

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The three states of Kansas, Nebraska, and Colorado have over fourteen million irrigated areas, of which eight million are irrigated by sprinkler irrigation systems. In the past decade, center pivot systems became the dominant sprinkler system type in the region. The growth of center pivot irrigated acreage is due to conversion of existing surface irrigated land to center pivot irrigation. A number of factors contribute to this conversion trend. Possibilities include:

1. Desire by irrigators to reduce irrigation labor requirements,
2. Desire by irrigators to conserve water through improved irrigation efficiency
3. Desire by irrigators to adopt reduced or low to no tillage production systems, and/or
4. Desire by irrigators for chemigation capability.

One of the underlying assumptions by irrigators regarding center pivot packages is that the water is being uniformly distributed across the field, so that all plants have an equal opportunity to the irrigation water applied. Irrigators have recognized that differences in irrigation efficiency exist between various sprinkler packages. Sprinkler package efficiency differences are due to a variety factors including differences in drift losses and canopy evaporation and the potential runoff.

In general, center pivot sprinkler packages are designed, installed and operated without much field verification of performance, either initially or over-time. Systems equipped with flow meters and pressure gauges can indicate that the systems are operating at design flow and pressure and, if so, are assumed to be operating at design specifications. While flow and pressure monitoring is a good and recommended best management practice, monitoring alone does not assure the over-all system performance is good.

Numerous center pivot nozzle devices and installation configurations have been developed along with use recommendations. However, testing of the performance along an entire full sized field center pivot system has been relatively infrequent for a variety of reasons; some of which are certainly the labor requirement and the wet messy condition for data collection immediately following irrigation in a field.

In 1995, irrigators from south central Kansas requested assistance from K-State Research and Extension personnel to establish a long-term project to promote adoption of best irrigation management practices with special emphasis on ET-based irrigation scheduling. The irrigators also wanted a major educational component of the project to include demonstrations using on-farm field sized irrigation systems. A research trial was also established at the Sandyland Experiment Field that had goals complimentary to the on-farm demonstration sites.

Irrigation scheduling is a process by which the timing and amount of irrigation water application to meet a specific management goal is determined. A parallel in today's business philosophy context for resource and product inventory control is "just enough, just in-time". In irrigation scheduling, control is in reference to water.

One concern to the irrigator is that the individual plants within a crop have equal access to water. This is especially important for high-yielding, full-irrigation scenarios. Therefore, part of the demonstration project and research study effort was directed towards evaluation of the sprinkler package performance in terms of irrigation distribution uniformity.

Sprinkler package uniformity evaluation involves catching of the applied water along the center pivot or lateral move irrigation system. The collection interval is determined by the distance between nozzles. The collection devices are positioned so that there is no interference by the crop canopy. The tests are usually done before or early in the growing season to avoid canopy interference. Measurement of the catch must be accomplished quickly after collection in order to minimize evaporation losses from the catch device.

Large diameter black feed pans were purchased and used to test the linear move sprinkler system at the Sandyland Experiment Field. A second catch was made simultaneously using large white-painted coffee cans. The sprinkler package had just been retrofitted with 6 psi LDN nozzles, spaced at 6 feet and positioned approximately at canopy height of fully grown corn. The initial purpose of the test was to verify the distribution uniformity of the new sprinkler package, which was assumed to high since it was a new, pressure-regulated package, designed and installed to the manufacturers recommendations. The test was also conducted to compare the results of the performance evaluation between the two catch can devices. The white coffee cans meet or exceeded ASAE catch can criteria, while the black feed pans did not. However, the black pans were preferable to the white cans because they could be nested together for better transport and storage efficiency. This was an important consideration in preparation for testing of multiple full size systems where the devices would have to be hand carried into and out of field.

The surprise from the evaluation, as shown in Figure 1, was that the new package did not result in high uniformity. The range of application depth was from one-half to nearly twice the average. However, the results between types of catch cans were similar, as is shown in Figure 2. The comparison included various pan spacings, catch can devices and application rates. The flowrate from each nozzle was caught separately and verified that each nozzle was discharging at the proper rate. Figure 2, as with other test data not shown, indicated that consistent performance evaluation occurred regardless of whether the can or the pan was used.

Based on this information, black pans were used when field scale evaluations were performed. However, the results of evaluation raised some concern since low pressure LDN nozzle packages are popular in the region.

The field evaluation of uniformities have resulted in discovery of a number of package deficiencies. Figure 3 represents a system that did not have the overhang portion of the package installed according to the design. One nozzle has been omitted and several other nozzle orifices were undersized. This resulted in an application depth in this portion of the system at only about one-half of the reminder of the system. The deficiently watered portion of the field represented approximately 20 acres. Yield losses due to the reduced water could potentially be as much as 40 bushels/acres. Annual losses due to the non-uniformity could exceed $1,600. The cost to correct this deficiency would be minimal.

A second example is shown in Figures 4a and 4b. This is a system package which included an end gun. The end gun was known to have an operational problem and during the test it was rotating 360°. This, of course, resulted in additional water being thrown back onto water pattern of the end tower. As seen in Figure 4a, excess application was being applied to the outer end of the system. This is an example of how an operational or maintenance problem can impact uniformity.

The same system was evaluated with the end gun off and shows the end portion of system has a defective application pattern (Figure 4b). Examination of the nozzle package revealed that during installation the series of nozzles for the two outside spans of the system had been reversed. The repair of the end gun and switching of reversed nozzle orifices would greatly improve uniformity of this system.

This system is equipped non-pressure regulated sprinkler package on a field with a large elevation charge. The system was tested on a relatively flat portion of the field. An additional evaluation on a sloped portion would be useful in evaluating the impact of elevation on the uniformity.

Figures 5a-c represent uniformity evaluations conducted on three center pivot irrigation systems all equipped with low pressure LDN nozzles, and nozzled for approximately the same system capacity. All were pressure regulated, and had drop nozzles of similar height. The major difference was the nozzle spacing.

The system shown in Figure 5a had a nozzle spraying of 5 foot and had a distribution uniformity of 90 percent, noted as CU on the graph which stands for coefficient of uniformity. Ninety percent is considered an acceptable industry standard. The system in Figure 5b had a CU of 84 percent. It had a nozzle spacing of 8 feet. The system in

Figure 5c had a CU of 87 percent with a nozzle spacing of 10 feet. The variable CU values for these three systems are consist with other research results that indicate nozzle spacing can have a large but somewhat difficult to predict impact on uniformity. Certainly a single snapshot of three systems should not be the sole basis altering system package design criteria. They do illustrate that each type of nozzle device have unique characteristics and operating constraints. These systems had been designed within recommended ranges, but at the lower end of the recommended operating pressure range. In this case, the low operating pressure made the nozzle distribution package very sensitive to the nozzle spacing. A complex relationship exists between uniformity and design parameter such as discharge rate, pressure, spacing and nozzle height. A large change of uniformity can occur due to changes in the overlap of nozzles with either small increases or decreases in nozzle spacing. The design complexity magnifies enormously when the best combination of nozzles needed for a center pivot lateral is considered since discharge rate requirement varies along the lateral.

As additional research and performance testing adds to the database, package design criteria should be improved. The effect of non-uniformity on yield also needs further examination. Non-uniformity of yields in wide spaced in-canopy systems have been noted. However, with increasing use of systems for chemigation, non-uniform water distribution would directly affect the chemical distribution applied through the water. The main point for the irrigator is that good sprinkler package design may not necessarily be the "popular" sprinkler package. Hopefully the manufacturers, dealers, researchers, etc can continue to identify and provide the best possible design. The irrigator also needs to make certain the design is properly installed, operated, and maintained.

Although the black pans were effectively used to evaluate a number of systems, the job was still a messy and labor intensive activity. Another problem associated with the irrigation demonstration projects which had sites spread out over a thirteen county area, was how to get good ground data on irrigation and rainfall when the sites were only visited periodically. What was needed was an inexpensive measuring device that would not lose caught water to evaporation. They needed to be inexpensive because of the large number of demonstration sites and the large number needed to do a center pivot distribution evaluation.

This need lead to the development of the Irrigage as shown in Figure 6. Irrigages are constructed using thin-wall low pressure drainage pipe and cap and some type of plastic bottle. The pipe is used as a sharp edged collector but the colleted water drains into the storage bottle below through a small hole. The collected water now has little opportunity to evaporate and losses are minimal; only a few percentage points in a week. An irrigator with multiple systems can use the Irrigage to catch rainfall events at the various sites and have a good reading even with a day or more delay in reaching the catch.

A second use of the Irrigage could be field verification of applied irrigation water. This would require the use of at least three irrigages being placed under the system. A great deal of variation can occur even in center pivots with good uniformity (Figure 5a) so an average of at least three readings are needed to obtain good average application estimate. If the group of three or several groups of three are moved periodically, the application depth along the entire system could be monitored over time.

Irrigages are also useful for full scale pivot evaluations. Since a large crew was required to rapidly measure catch data in order to minimize evaporation losses, a time had to be scheduled when the irrigation crew and field conditions would all allow a test. This was often a difficult scheduling problem and also usually resulted in irrigation water being applied that was not needed. The use of Irrigages addresses these problems.

First they can be installed at the evaluators convenience since they are placed on a stake and are not likely to be moved by wind. Once installed, they remain in place until an irrigation occurs. The irrigation event can be a regular event. Without a waiting crew, there is no need to run a light application to save time. In traditional evaluations, usually only the outer half of the system is tested. Since no one is waiting, the entire system could be measured if desired, if sufficient Irrigages are available.

Second, they do not have to be read immediately after an irrigation, since there is no immediate evaporation loss. Data collection can be delayed until all water is infiltrated and the surface is dry so the measurement and removal of the Irrigages can be done on firm soil. A single individual can also effectively conduct an evaluation.

Field evaluation of center pivots have indicated a need for a system review process. These evaluations can be a cost effective way to catch design, installation or maintenance errors that adversely affect center pivot irrigation system efficiency and uniformity.

Development work will continue on field evaluation of center pivots. In addition to the proto-type design of the Irrigage, a spread sheet for calculation of CU has been prepared. Guidelines for placement, measurement data entry, and other procedural issues need to be refined so that any evaluation conducted will provide an irrigator with consistent and quality information.

Figure 1.

South Central Kansas Irrigation Management Project

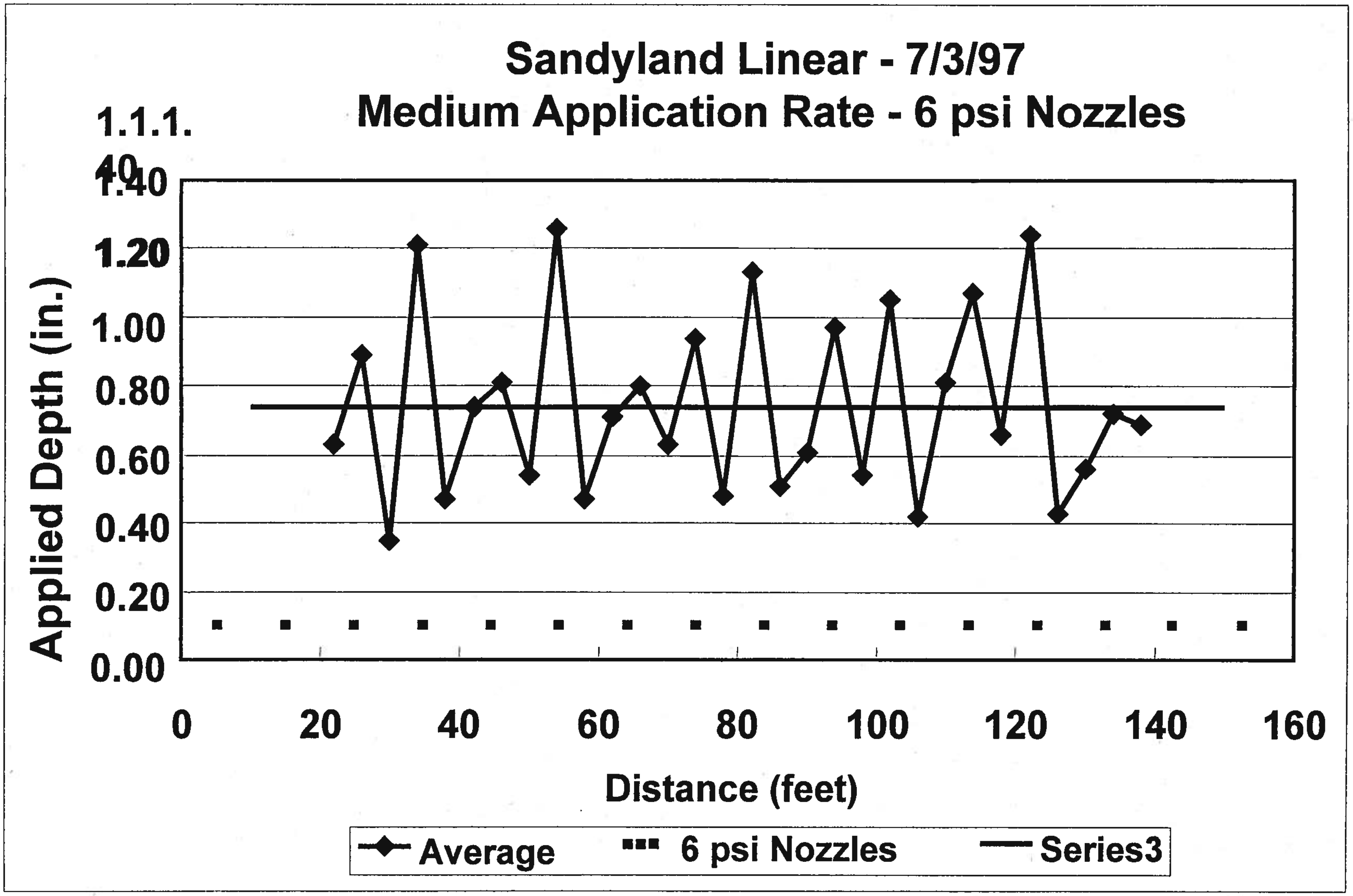
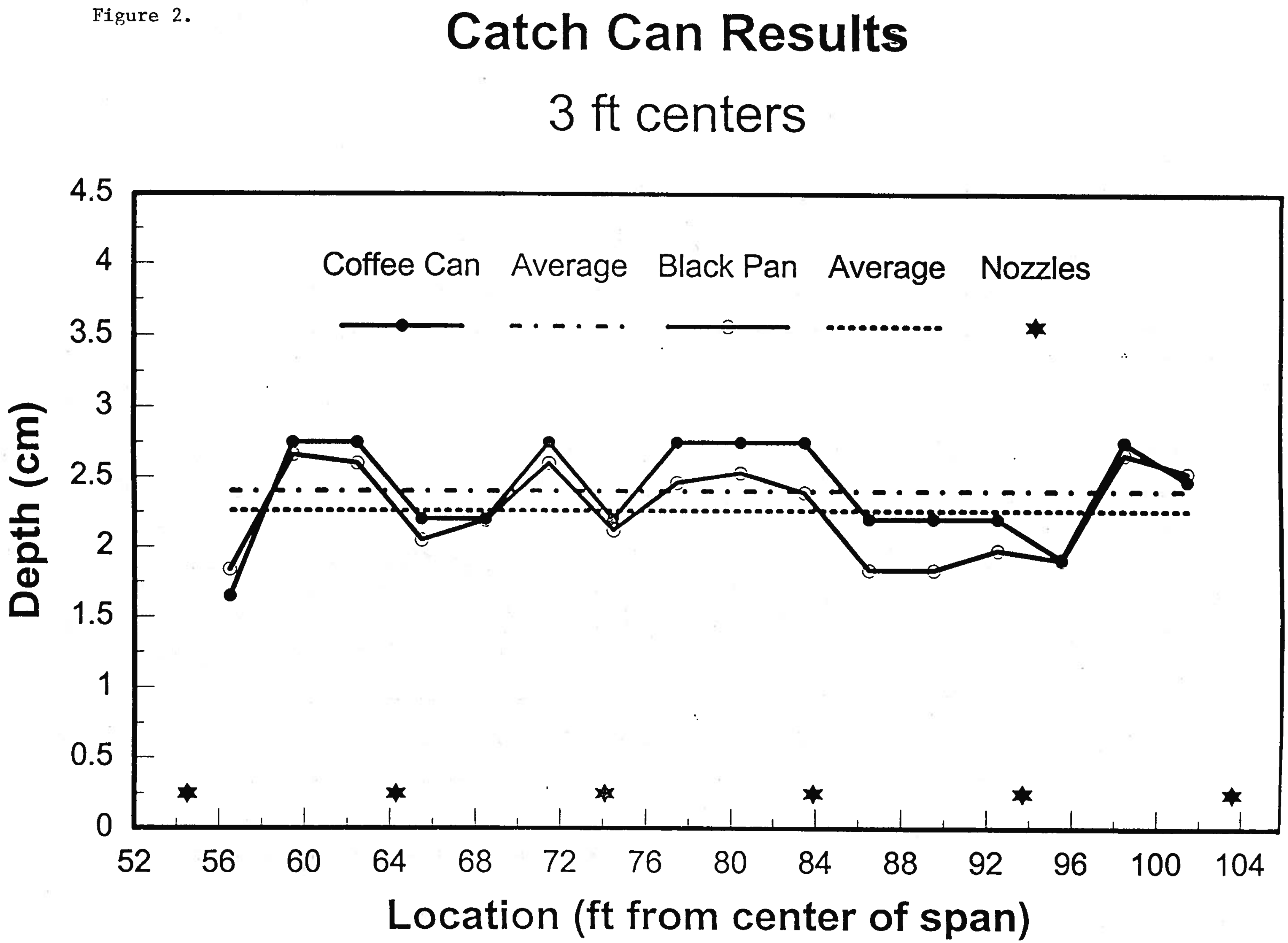


Figure 2.



Sandyland - 7/03/97
High Rate

Figure 3. Center Pivot Distribution Uniformity – System PR01.

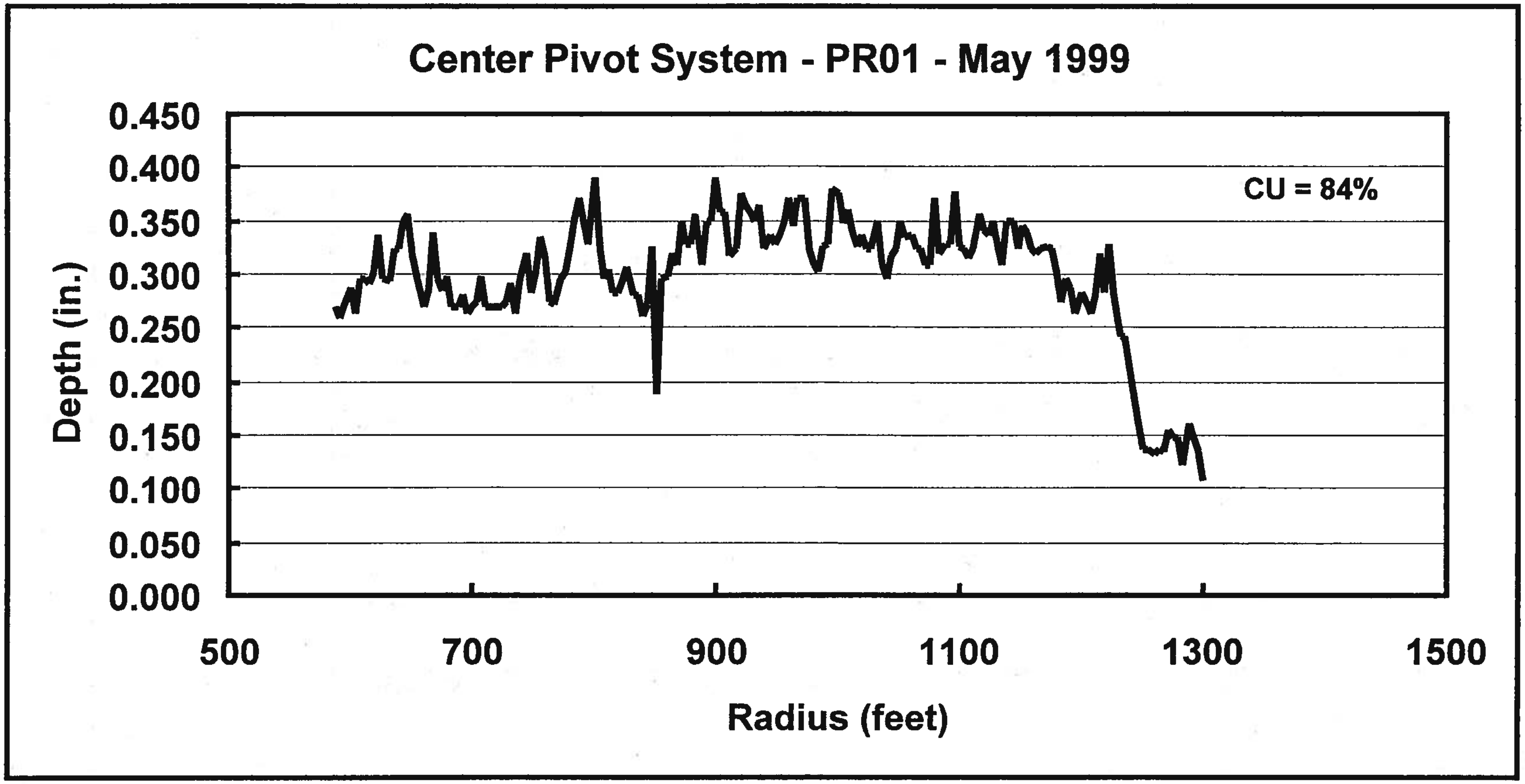


Figure 4a. Sprinkler uniformity with End-gun 'ON'
Farm No. 1, Finney County, Kansas

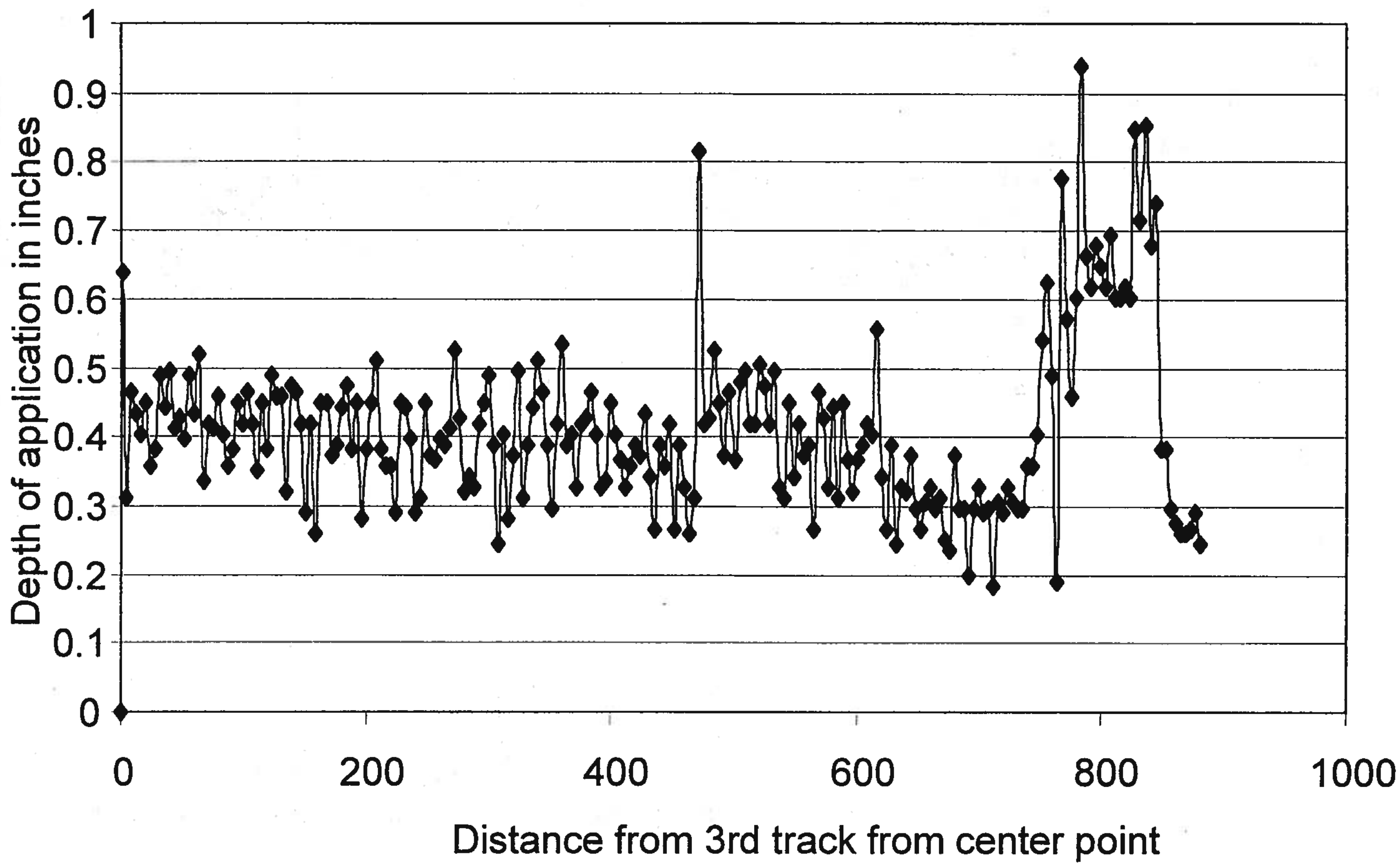


Figure 4b. Sprinkler uniformity with End-gun 'OFF'
Farm No. 1, Finney County, Kansas

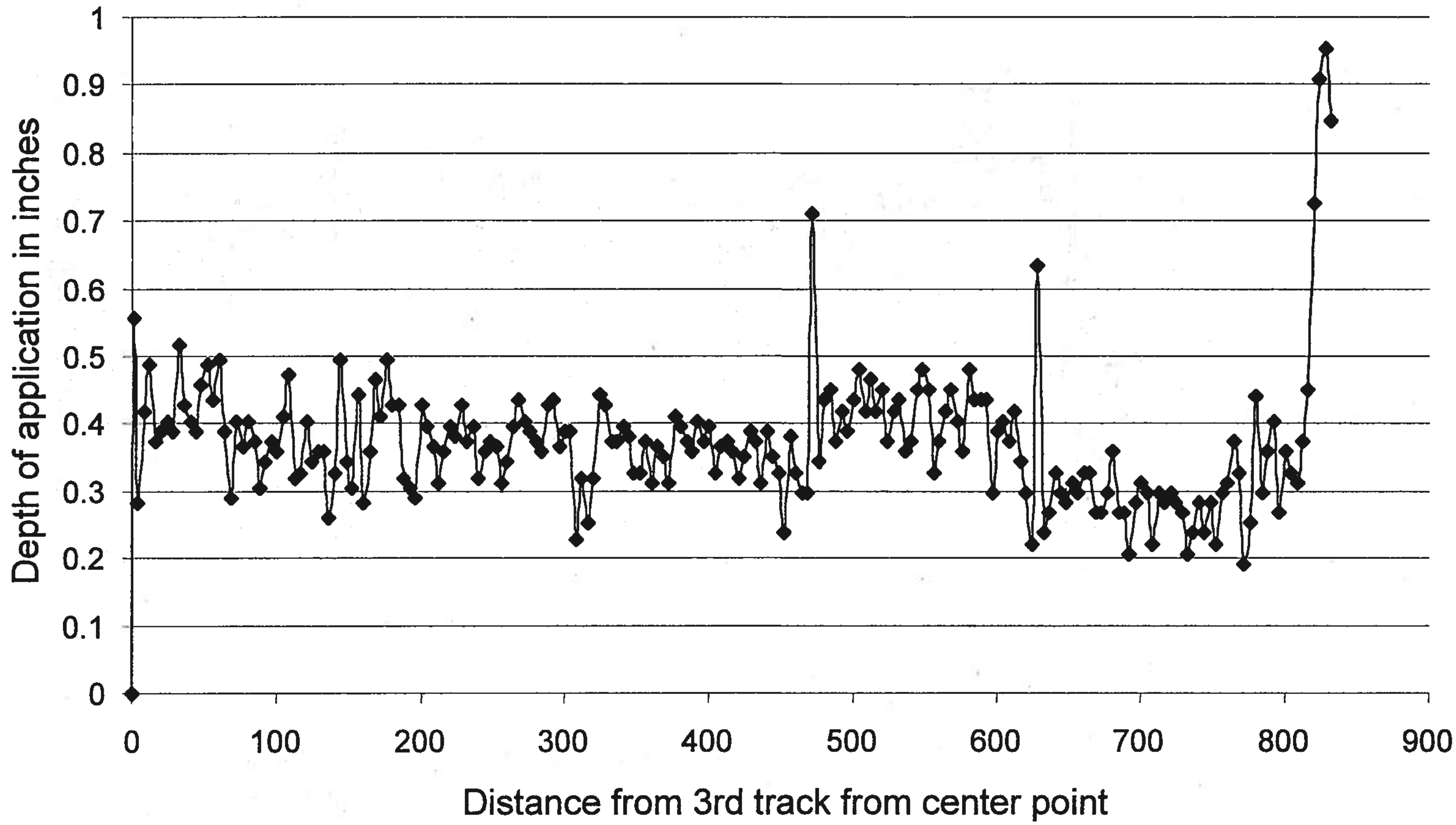


Figure 5a. Center Pivot Distribution Uniformity – KI01.

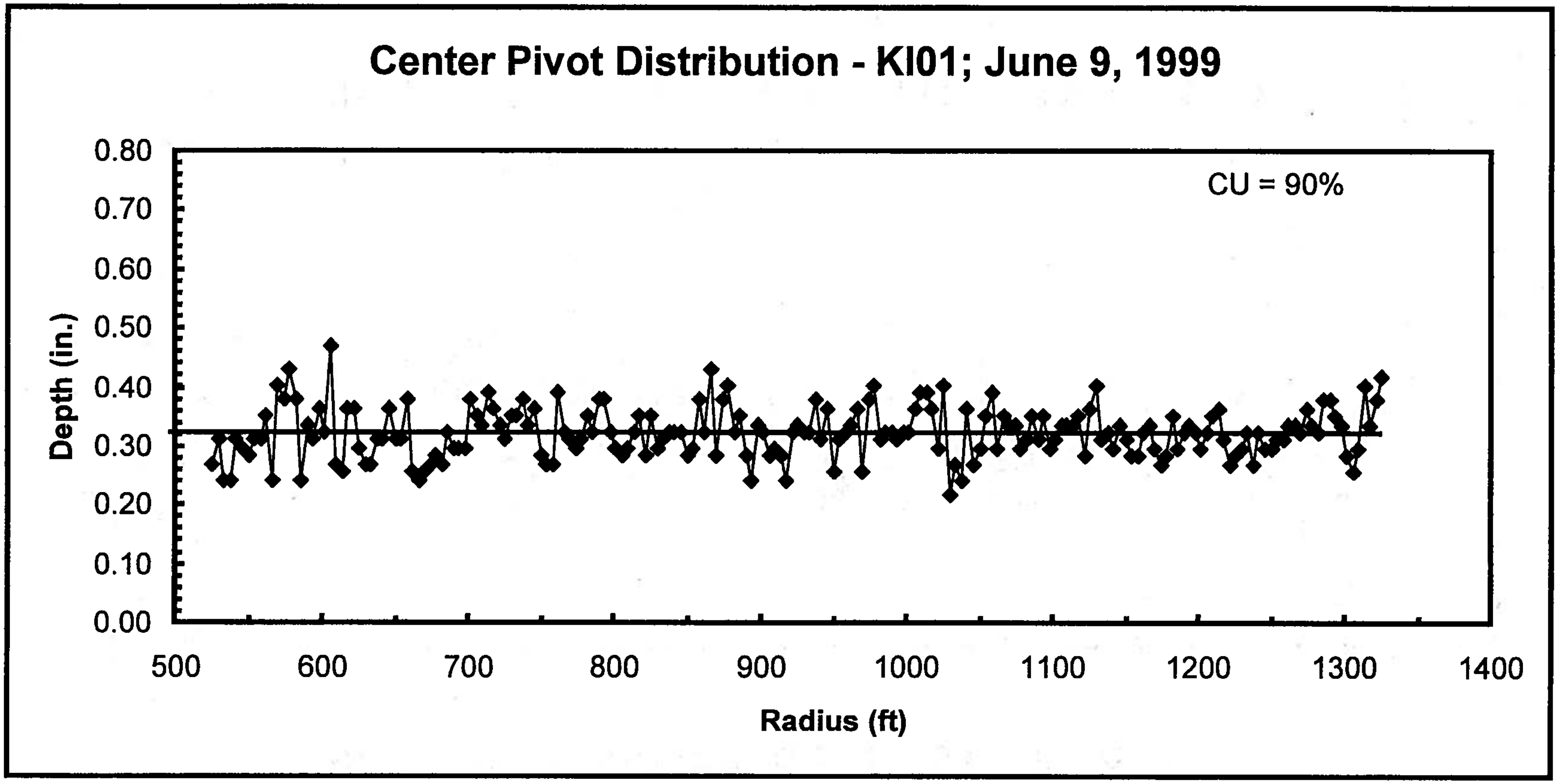


Figure 5b. Center Pivot Distribution Uniformity – System ED01.

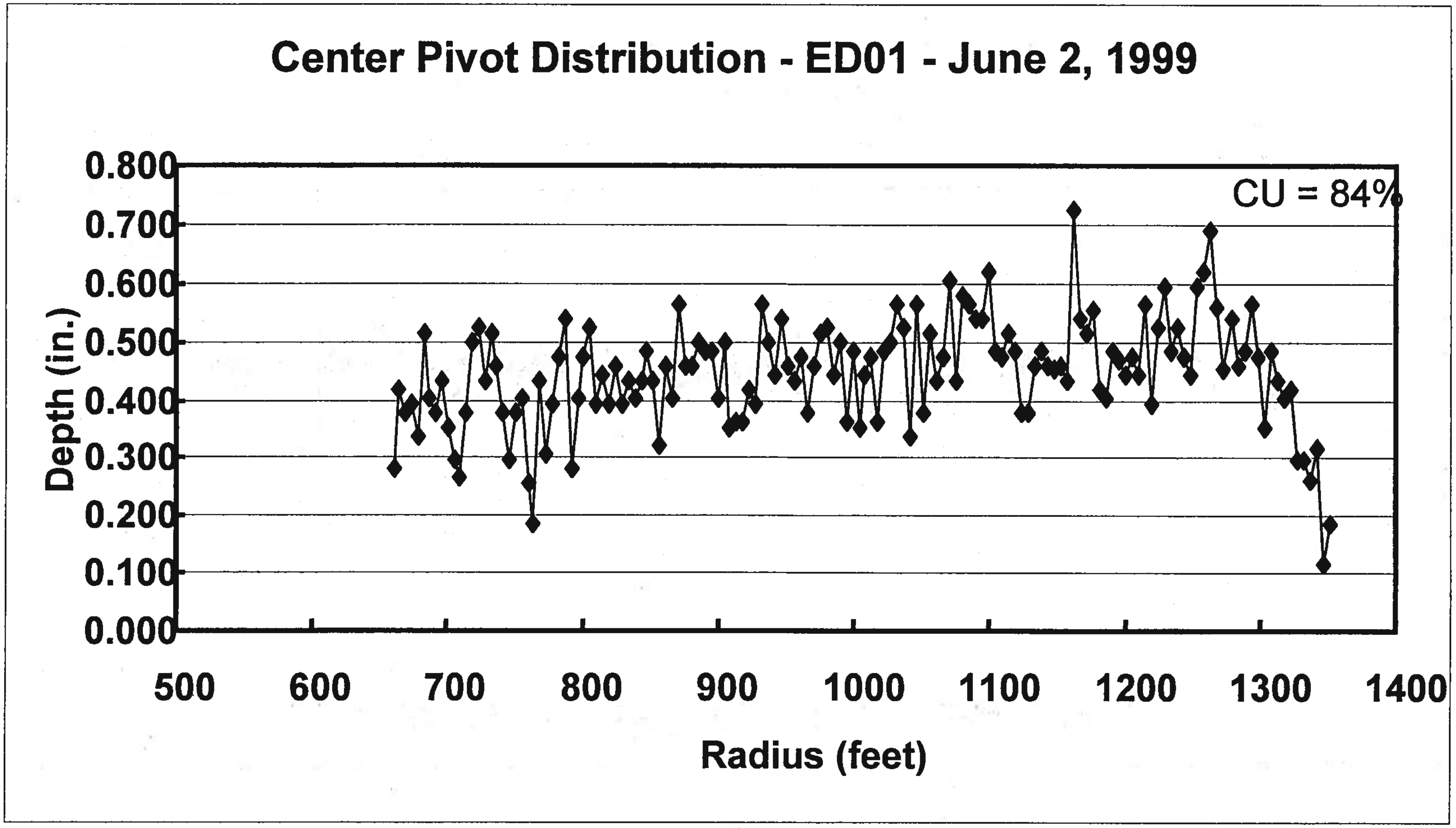


Figure 5c. Center Pivot Distribution Uniformity – System ED01.

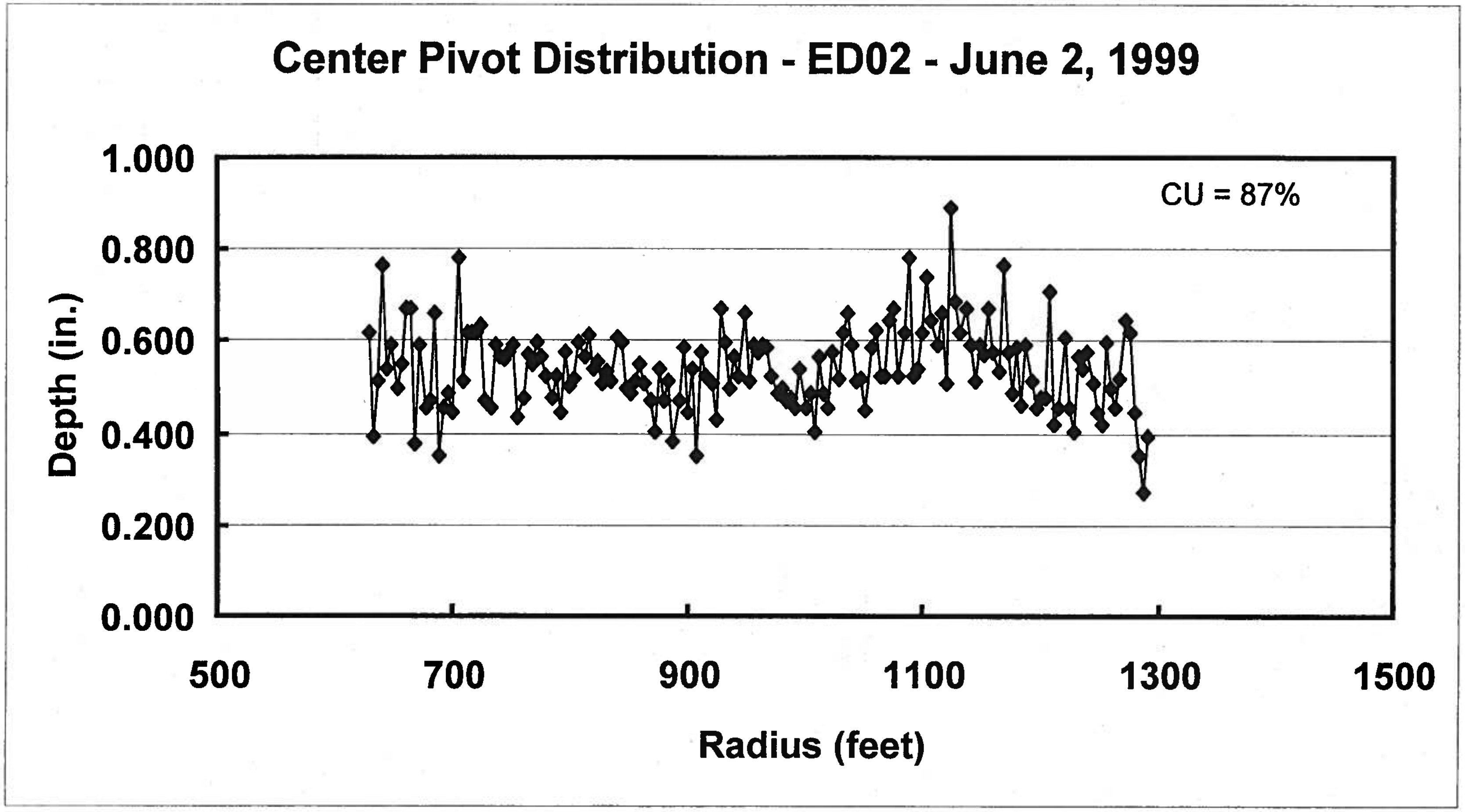


Figure 6.

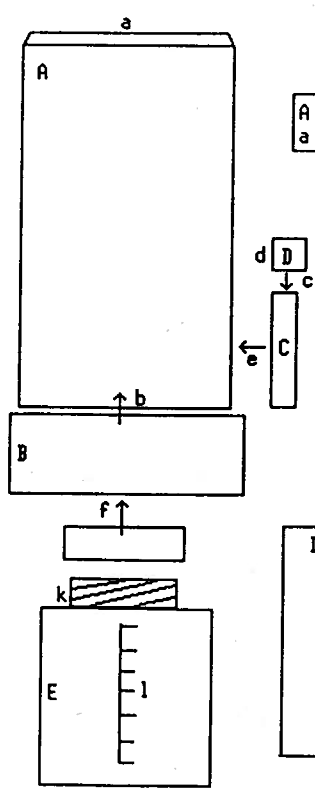
♦IRRIGAGE♦

Bill of Materials - Each

a) 11 inch length of 4" PVC Sewer Pipe (Irrigage Body)
b) One 4" PVC Sewer Cap (Irrigage Body end cap)
c) 4 inch length of 1/2" PVC Schedule 40 Pipe (Irrigage Hanger tube)
d) One 1/2" PVC Cap (Irrigage Hanger end cap)
e) One graduated, plastic bottle with screw cap (Collection Bottle)
f) PVC Cleaner and Cement
g) 2 - #6 X 1/4" Sheet metal screws
h) 1/4", 1/8", and 7/64" drill bits
i) Silicon Sealant

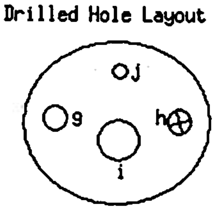
Plan of Procedure

a) Bevel one end of the gauge body on a disc sander
b) Glue the end cap onto the other end of the gauge body
c) Glue the hanger cap onto the hanger tube
d) Flatten one side of hanger assembly on a disc sander
e) Glue the hanger assembly to the side of the gauge body
f) On a belt sander, flatten a spot on the bottom of the gauge body and the top of the collection bottle cap
g) Center the collection bottle cap on the bottom of the gauge body end cap, then mark and drill pilot holes for the screws with the 7/64" drill bit.
h) Silicon seal the collection bottle cap to the gauge body end cap, and secure with the two #6 X 1/4" sheet metal screws.
i) After silicon has cured, drill a 1/4" hole through the bottle cap and the gauge body end cap
j) Drill a 1/8" breather hole through the bottle cap and the gauge body end cap
k) Screw on collection bottle
l) Mark graduated scale in tenths of an inch (see volume conversions)



A = Part Description
a = Procedure Description

Drilled Hole Layout



Inches	Millileters	Ounces
0.1	21	0.7
0.2	41	1.4
0.3	62	2.1
0.4	82	2.8
0.5	103	3.5
0.6	123	4.2
0.7	144	4.9
0.8	165	5.6
0.9	185	6.3
1.0	206	7.0
1.1	226	7.7
1.2	247	8.4
1.3	267	9.1
1.4	288	9.8
1.5	309	10.5
1.6	329	11.2
1.7	350	11.9
1.8	370	12.6
1.9	391	13.3
2.0	411	14.0
2.1	432	14.7
2.2	453	15.4
2.3	473	16.1
2.4	494	16.8
2.5	514	17.5