# USING CPNOZZLE FOR SPRINKLER
# FOR SPRINKLER PACKAGE SELECTION

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## INTRODUCTION

Center pivots have been adapted to operate on many different soils, to traverse extremely variable terrain, and to provide water to meet a number of different management objectives. Consumers have access to an array of different sprinkler types. For some fields, many packages will perform adequately. Other fields will have a limited number of to choose from. Sprinkler package selection should be based upon accurate field based information, and careful consideration how the package will interact with cultural practices and system management.

### What flow rate?

The system flow rate determines how a number of factors impact system operation. For example, if the flow rate is greater than necessary, the peak water application rate may cause runoff toward the outer end of the pivot lateral but the system can recover from unplanned system downtime. If the flow rate is too low, runoff may be eliminated, but unexpected breakdowns can result in significant yield losses.

There are three important considerations when estimating flow rate requirements: a) environmental factors; b) system downtime; and d) the soil water holding capacity. The most important environmental considerations are the likelihood of rainfall and the peak crop water use rate. NebGuide G89-932 *Minimum Center Pivot Design Capacities in Nebraska* presents a procedure for the determining the minimum net system capacity for Nebraska conditions. A similar procedure can be used for Colorado and Kansas.

Estimated crop water use rates, soil water holding capacity and rainfall data were evaluated for different locations in Nebraska. The analysis identified areas where the system flow rate should be increased to account for lower annual precipitation and greater peak ET rates. Our best estimate is that systems located west of the 20-inch annual precipitation line should have greater flow rates. Table 1 presents the estimated minimum net system capacity required to meet crop demands 90% of the time for regions in Nebraska. The last line in the table provides the system capacity necessary to meet peak water demands 100% of the time. That calculation is based on Equation 1:

$$Q_p = ( 18.9 \times ET_p \times A \times t_i ) / ( E_i \times t_f ) \qquad \textbf{Equation 1}$$

where:
- $Q_p$ = irrigation system flow rate, gpm
- 18.9 = units conversion constant
- $ET_p$ = peak water use rate, in/day
- $A$ = irrigated area, acres
- $t_i$ = irrigation interval, days
- $E_i$ = irrigation efficiency, decimal
- $t_f$ = irrigation time per event, days

**Table 1.** Minimum net system capacities to meet crop water demands 90% of the time for the major soil texture classifications and regions in Nebraska[1].

| Soil Texture | AWC In/ft | Region 1 gpm/ac | Region 2 gpm/ac |
|---|---|---|---|
| Loam, silt loam or very fine sandy loam | 2.5 | 3.85 | 4.62 |
| Sandy clay loam, loam | 2.0 | 4.13 | 4.89 |
| Silty clay loam, fine sandy loam | 2.0 | 4.24 | 5.07 |
| Silty clay | 1.6 | 4.36 | 5.13 |
| Clay, sandy loam | 1.4 | 4.48 | 5.19 |
| Loamy sand | 1.1 | 4.83 | 5.42 |
| Fine sand | 1.0 | 4.95 | 5.89 |
| **Peak ET** | | **5.65** | **6.60** |

[1] Data taken from NebGuide G89-932 *Minimum Center Pivot Design Capacities in Nebraska*.

The values in Table 1 need to be adjusted for system downtime and the water application efficiency of the center pivot. Downtime can result from regularly scheduled maintenance, load control, system failure, or labor restrictions (manager takes Sunday's off). The downtime experienced due to system failure depends on the current age of the components and how frequently the system is checked. Operators with a shutdown phone alarm will have immediate knowledge when the system shuts down while others may not be aware that the system is down for 8 hours or more. If the system is operated 24/7, each 12 hours of down time requires a flow rate increase of 6%.

Once the net capacity has been adjusted for down time, the gross flow rate required is determined by dividing by the estimated water application efficiency. The system water application efficiency depends on the sprinkler package (sprinkler type and position). Some potential water application efficiencies are provided in Table 2. They are listed as potential efficiencies because they assume that runoff does not occur. Thus, the field conditions will determine the actual water application efficiency.

**Table 2.** Potential water application efficiencies for different sprinkler packages.

| Sprinkler/ Nozzle Type | Potential Application Efficiency |
|---|---|
| High Pressure Impact | 80-85 |
| Low Pressure Impact | 82-85 |
| Low Pressure Spray up top | 85-88 |
| Low Pressure Spray at truss | 87-92 |
| Low Pressure Spray at 3-7 feet | 90-95 |
| Low Pressure Spray Bubble mode | 95-98 |

## Field data collection

The Soil Survey provides one source of estimates for average water infiltration rates, field slopes and soil water holding capacities. Request that the NRCS provide the soil intake family, and record the average field slope, infiltration rate and the soil water holding capacity information on each mapping unit from the local soil survey book. Record them in a table similar to Table 3.

Some sprinkler packages are selected and installed without a site visit by the sprinkler system provider. Though soil mapping units give some indication of average field conditions, the data may not be sufficiently accurate to make a decision. Therefore, a rough grid topography map ( at least 200' x 200') will determine if areas mapped as 7 to 11% slopes are closer to 7% or 11%.

Finally, the site visit can provide valuable information related to tillage and planting practices. A field farmed on the contour can safely use a sprinkler package that would be unsuitable if farmed up-and-down hill. Crop residues left on the soil surface can absorb the impact energy of rainfall and irrigation. Thus, the soil infiltration rate would be more consistent throughout the season. Each of these factors may cause you to make a slightly different decision.

Sprinkler packages should be selected that do not result in runoff. Too often the desire to reduce pumping costs clouds over selecting the most appropriate sprinkler package. The zero runoff goal requires that the sprinkler package be carefully matched to field conditions and to the operator’s management scheme. This requires that the water application pattern of the sprinkler be compared to the soil infiltration rate.

**Table 3.** Summary of soil characteristics for each mapping unit in a quarter section of land in Pierce County, NE.[1]

| Mapping Unit | Drainage Group | Soil Water Capacity (in/ft) | Field Slope (%) | Intake Family | Land Area (Acres) |
|---|---|---|---|---|---|
| Co | Moderately Slow High Water Table | 2.4 | 0-1 | 0.3 | 42.1 |
| He | Well | 2.4 | 0-1 | 1.0 | 23.9 |
| CsC2 | Well | 2.4 | 1-7 | 1.0 | 11.0 |
| HhC | Well | 2.4 | 1-7 | 1.0 | 36.8 |
| MoC | Well | 2.3 | 1-7 | 0.5 | 5.3 |
| CsD2 | Well | 2.4 | 7-11 | 1.0 | 28.0 |
| NoD | Well | 2.4 | 7-11 | 1.0 | 1.8 |
| CsE2 | Well | 2.4 | 11-17 | 1.0 | 11.1 |

[1] Data taken from Pierce County Soil Survey

## ESTIMATING RUNOFF

The **CPNOZZLE** computer program was converted to Visual Basic to provide an opportunity to estimate of how well suited the sprinkler is to field soils and slopes. The program is useful in predicting how much the design criteria should be changed to eliminate a potential runoff problem. For example, if a sprinkler package with a 40-foot wetted diameter produces runoff, the program can be used to determine a wetted diameter that produces no runoff. If you are in the process of retrofitting an old system with a new sprinkler package, the program can be used to select an appropriate system flow rate and sprinkler wetted radius.

Based upon research conducted at the University of Nebraska, the program develops an elliptical shaped water application pattern depending upon the position on the system, wetted diameter of the package, and the system flow rate. The program uses the NRCS Intake Family to estimate the weighted potential runoff for various positions along the system. Data inputs include: 1) system length in feet; 2) system capacity in gpm; 3) application amount in inches; 4) wetted diameter of the sprinkler in feet; 5) soil intake family; 6) field slope in %; and 7) percent residue cover in %. The data inputs can be saved to a file or they will be printed with the output information. When all inputs are entered, the program output can be viewed by clicking on results (Figure 1).

**Figure 1.** Sample input table for the CPNOZZLE program.

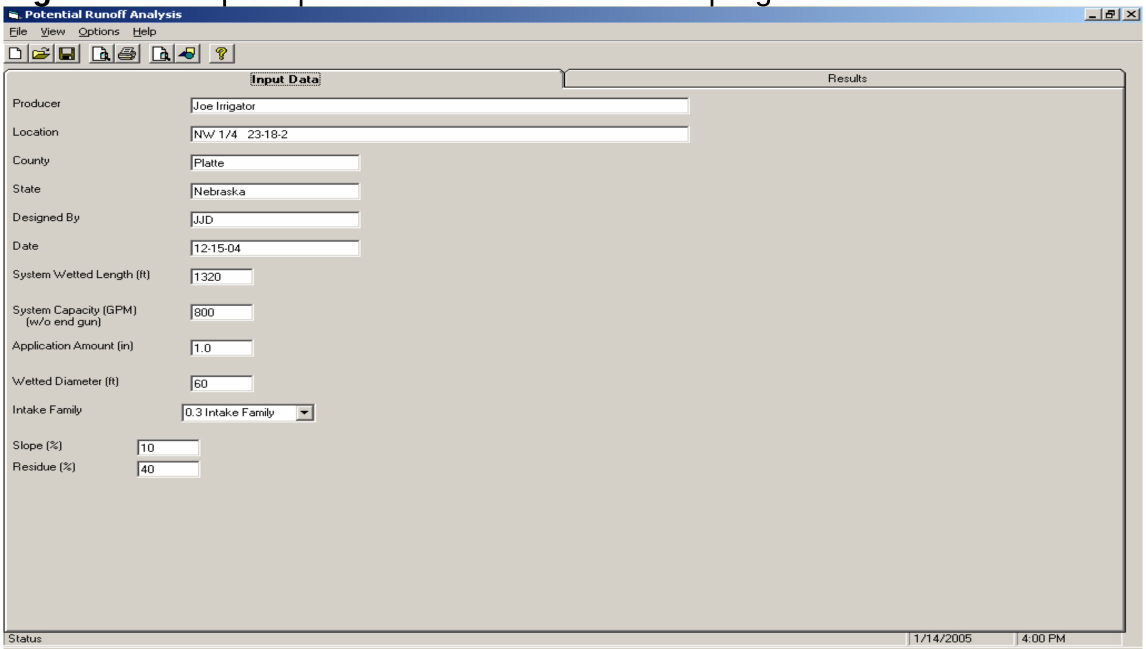
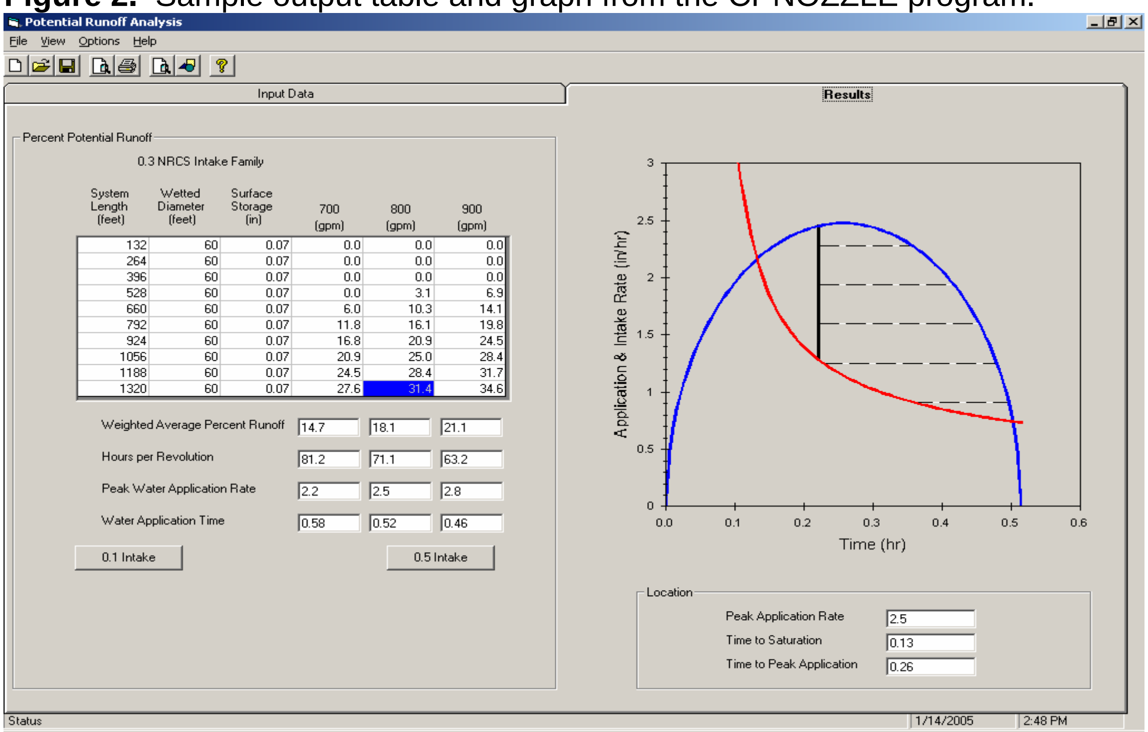



**Figure 2.** Sample output table and graph from the CPNOZZLE program.




| System Length (feet) | Wetted Diameter (feet) | Surface Storage (in) | 700 (gpm) | 800 (gpm) | 900 (gpm) |
|---|---|---|---|---|---|
| 132 | 60 | 0.07 | 0.0 | 0.0 | 0.0 |
| 264 | 60 | 0.07 | 0.0 | 0.0 | 0.0 |
| 396 | 60 | 0.07 | 0.0 | 0.0 | 0.0 |
| 528 | 60 | 0.07 | 0.0 | 3.1 | 6.9 |
| 660 | 60 | 0.07 | 6.0 | 10.3 | 14.1 |
| 792 | 60 | 0.07 | 11.8 | 16.1 | 19.8 |
| 924 | 60 | 0.07 | 16.8 | 20.9 | 24.5 |
| 1056 | 60 | 0.07 | 20.9 | 25.0 | 28.4 |
| 1188 | 60 | 0.07 | 24.5 | 28.4 | 31.7 |
| 1320 | 60 | 0.07 | 27.6 | 31.4 | 34.6 |

Program output includes a table presenting potential runoff for 10 positions along the system and the weighted potential runoff for the entire field. Output generated for a system with inputs of 1320 foot system, 800 gpm, 1.0 inch application, 60 foot wetted diameter, 0.3 intake family, 10% slope, and 40% residue cover are presented in Table 4. In addition to the inputs listed above, the program also prints results for the same system with a flow rate of 100 gpm more and 100 gpm less than 800 gpm. Results indicate that approximately 18 % of the water applied could move from the point of application or run off the field.

By clicking on the intake family button below the output table, the user can view output from one intake family higher and one lower than the original inputs. The purpose of the additional output is to allow comparisons between different soil intake families and flow rates because few fields have soils that fit into a single intake family. Any of the input information can be changed to perform a 'what if' style of analysis (i.e., if I increase the wetted diameter from 60 feet to 100 feet, What are the results?).

Additional output can include a graphical presentation of the comparison between the water application pattern and the soil infiltration rate curves. By clicking on any of the potential runoff estimates in the table, a graph will appear on the right side of the screen. For example, if the user moves the computer mouse and clicks on the number 25.0 under the 800 gpm column, a graph will appear specifically for the position on the system. In the best-case scenario, the two curves do not intersect.

**Table 4.** Output table from the CPNOZZLE program for a site in Platte Co., NE

| System length feet | Wetted diameter feet | Surface storage Inches | 700 gpm | 800 gpm | 900 gpm |
|---|---|---|---|---|---|
| 132 | 60 | 0.07 | 0.0 | 0.0 | 0.0 |
| 264 | 60 | 0.07 | 0.0 | 0.0 | 0.0 |
| 396 | 60 | 0.07 | 0.0 | 0.0 | 0.0 |
| 528 | 60 | 0.07 | 0.0 | 3.1 | 6.9 |
| 660 | 60 | 0.07 | 6.0 | 10.3 | 14.1 |
| 792 | 60 | 0.07 | 11.8 | 16.1 | 19.8 |
| 924 | 60 | 0.07 | 16.8 | 20.9 | 24.5 |
| 1056 | 60 | 0.07 | 20.9 | 25.0 | 28.4 |
| 1186 | 60 | 0.07 | 24.5 | 28.4 | 31.7 |
| 1320 | 60 | 0.07 | 27.6 | 31.4 | 34.6 |

| | 700 gpm | 800 gpm | 900 gpm |
|---|---|---|---|
| **Weighted Average Percent** | 14.7 | **18.1** | 21.1 |
| Hours per revolution | 81.2 | 71.1 | 63.2 |
| Peak Water Application Rate | 2.2 | 2.5 | 2.8 |
| Water Application Time | 0.58 | 0.52 | 0.46 |

Agency and irrigation distribution companies may wish to develop a series of graphs to represent conditions in their area. For example, Figure 3 presents weighted potential runoff comparisons for a range of NRCS intake families when the water application depth increases from 0.5 inches to 2.0 inches per revolution for a 1320 foot center pivot. Inputs of flow rate, sprinkler wetted diameter, field slope, and residue cover were consistent and are presented under the table heading. Note that as application depth increases the potential for runoff increases. However, fields with greater than 5% slope, the application depth cannot be reduced to eliminate runoff without surface storage for soils in the 0.1 to 1.0 NRCS intake family.

Should runoff be predicted, one option is to reduce the system flow rate. Figure 4 presents results for reducing the system flow rate from 800 gpm to 600 gpm. Increasing the wetted diameter of the sprinkler from 40 to 60 feet also helps reduce the potential for runoff. However, though not shown in graphical format, when slopes are above 5% and no crop residues are present, the potential for runoff from low infiltration rate soils is great for the 0.1 to 0.5 Intake Family soils. Impact sprinklers are a better option for fields with steep slopes and low infiltration rate soils.

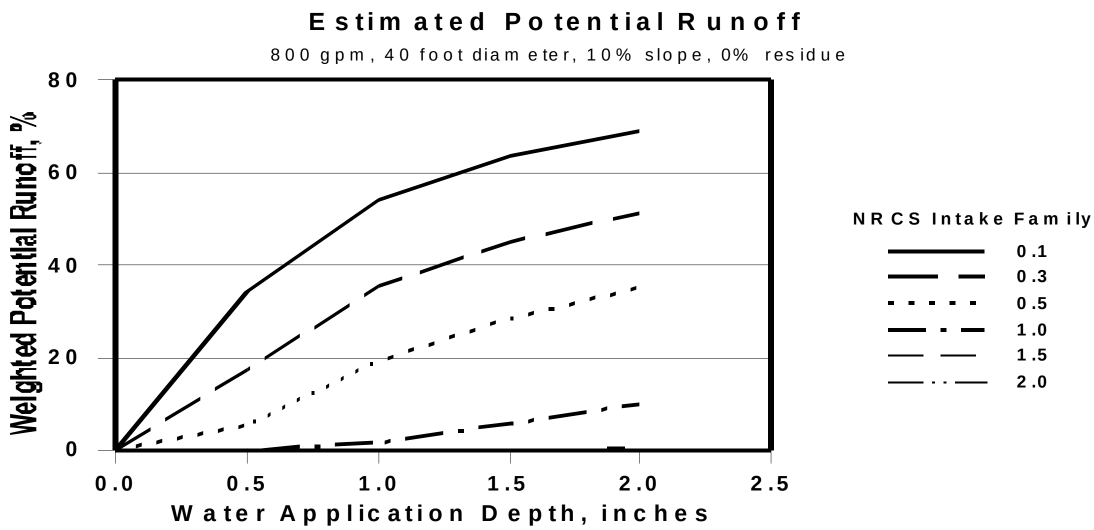



**Figure 3.** Effect of soil intake family and water application depth on weighted potential runoff for a 1320 foot center pivot with a sprinkler package wetted diameter of 40 feet and a flow rate of 800 gpm.

## SUMMARY

Center pivot buyers have a vast array of sprinkler packages to choose from. Selecting the most appropriate sprinkler package for an individual field should be based upon collection of accurate field based information for soils, slopes, and cropping practices. The final selection should not be based on energy costs alone. Rather the system should first apply water uniformly without generating runoff. The new Visual Basic version of the **CPNOZZLE** computer program provides an opportunity to perform 'what if?' sort of analyses prior to making a sprinkler package purchase.

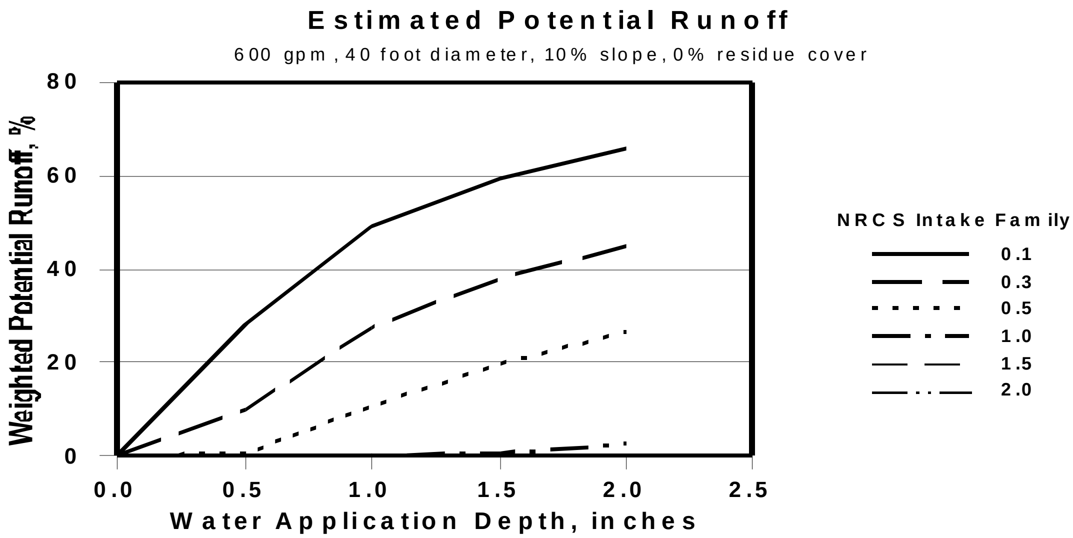



**Figure 4.** Effect of soil intake family and water application depth on weighted potential runoff for a 1320 foot center pivot with a sprinkler package wetted diameter of 40 feet and a flow rate of 600 gpm.

## REFERENCES


Kranz, Bill, Lackas, Greg, and Derrel Martin. 1989. Minimum center pivot design capacities in Nebraska. NebGuide G89-932-A. UNL Cooperative Extension.