DistanceDrawdown_Pumping–A workbook for estimating transmissivity from distance-drawdown data

Transmissivity can be estimated from multi-well aquifer-test data with the distance-drawdown method after a quasi-steady-state has been established (*Cooper and Jacob, 1946*). Most of the water released from storage originates beyond the wells that are being analyzed once quasi-steady-state conditions are established. A quasi-steady-state is reached after dimensionless time (u) is less than 0.1 at the well furthest from the pumping well. This would be $t > 2.5*r^2 S/ T$, where t is time, r is radial distance from pumping well, S is storage coefficient, and T is transmissivity in consistent length-time units. Quasi-steady-state conditions typically occur within 500 ft of the pumping wells after 6 hours of pumping from many confined aquifers. Site specific estimates for a Theis aquifer can be estimated with an analytical distance-drawdown tool.

Distance-drawdown is a simple graphical method (Weissman and others, 1977) that solves for transmissivity (T) of confined aquifers and hydraulic conductivity (K) of unconfined aquifers. The workbook DistanceDrawdown_Pumping-2019.xlsm revises the original workbook from Halford and Kuniansky (2002) to function with Excel 2013+ (Figure 1). Drawdown at distances from the pumping well are specified and plotted on a semi-log plot as drawdowns in confined aquifers and as saturated thickness squared in unconfined aquifers. A straight line initially is regressed to distance-drawdown data with the “GROSS FIT” button. Fit between straight line and plotted data can be refined visually to ignore outliers with the “ADJUST LINE” button. Transmissivity and hydraulic conductivity are reported with a user defined number of significant digits.

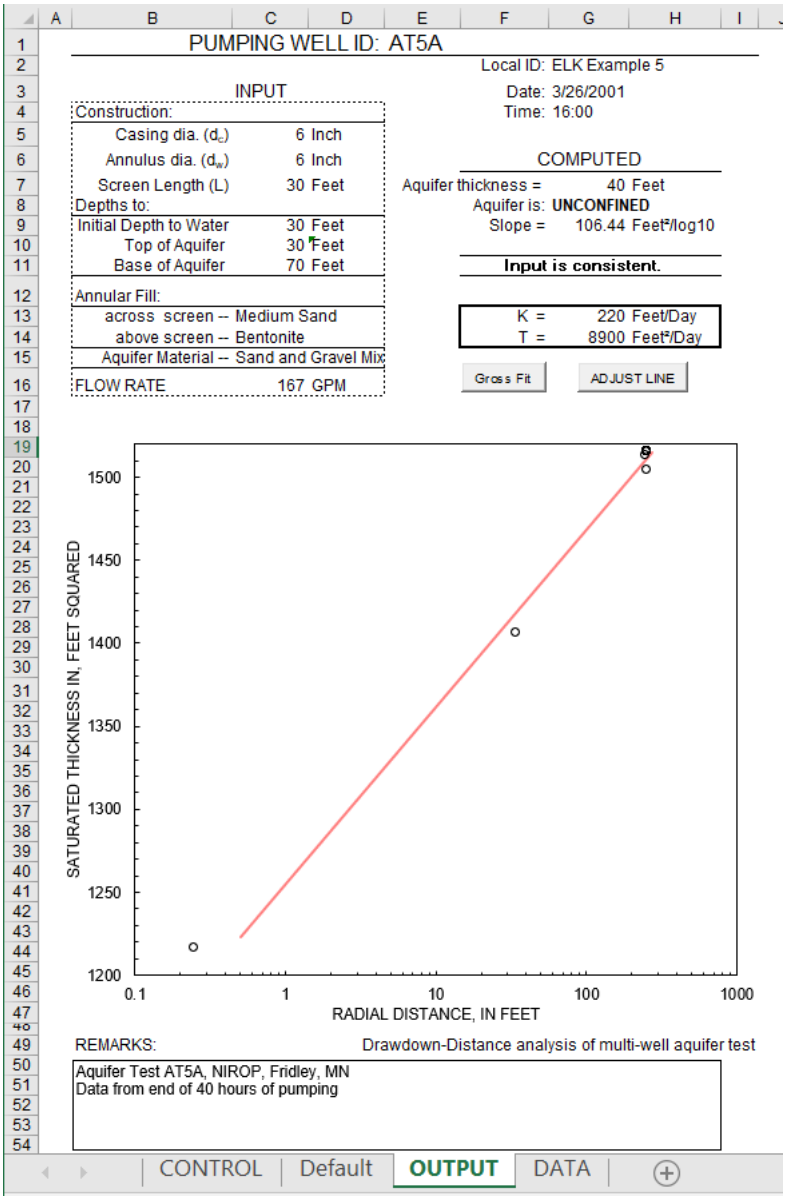


Figure 1.— OUTPUT page in DistanceDrawdown_Pumping-2019.xlsm.

DistanceDrawdown_Pumping-2019.xlsm and explanatory PDF can be downloaded with the following link.

References

Cooper, H.H., and C.E. Jacob. 1946. A generalized graphical method for evaluating formation constants and summarizing well field history. American Geophysical Union Transactions 27: 526–534. https://doi.org/10.1029/TR027i004p00526

Halford, K.J. and E.L. Kuniansky 2002, Documentation of spreadsheets for the analysis of aquifer pumping and slug test data, USGS OF 02-197 https://pubs.usgs.gov/of/2002/ofr02197/

Weissman, Warren, Jr., Knapp, J.W., Lewis, G.L., and Harbaugh, T.E., 1977, Introduction to Hydrology: Harper and Row, NY, 704 p.

DistanceDrawdown_Pumping-2019.xlsm Workbook

The workbook consists of three pages, DATA, OUTPUT, and PROP, and one hidden page, CONTROL. The hidden CONTROL page contains lookup tables and code for translating coordinates, which users should not need to edit. Aquifer test information, analysis, and results are summarized on the OUTPUT page. Well construction, aquifer thickness, aquifer material, site identifier, and remarks about the test are specified on the OUTPUT page. Additional information such as a well construction diagram and pictures of the site also could be pasted on the OUTPUT page. Time series of water-level changes from data loggers or manual measurements are entered on the DATA page. Ranges of hydraulic conductivities for aquifers are specified on the PROP page. The list should be modified to include more specific information about local units in a study area.

DATA page

Wells, distances, and drawdowns are specified in columns B-E from row 8 down (Figure 2). Pumping well location and drawdown are specified in row 8. Distances can be specified as radial distances from the pumping well or as XY coordinates. Units of distances and drawdowns are specified in cells D7 and E7, respectively. Units of analyzed distances and drawdowns can differ as specified in cells G7 and H7, respectively.

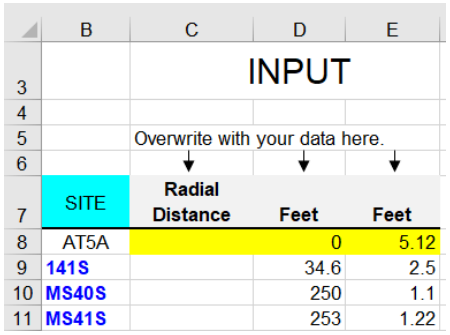
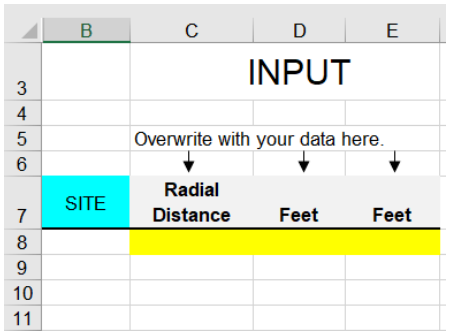
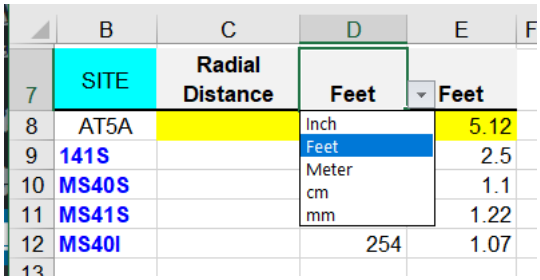
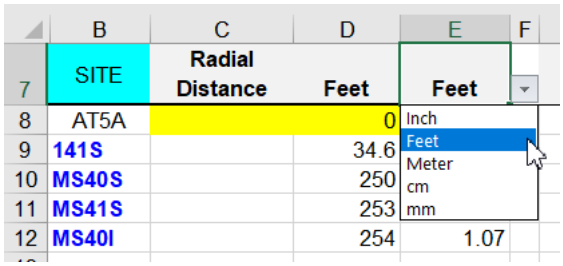
	B	C	D	E	F	G	H
1		Number of points =	5			Rmin	b
2						0.25	40
3		INPUT				Unit correction	
4						1.00	1.00
5		Overwrite with your data here.					
6		↓	↓	↓		Distance	H², Feet
7	SITE	Radial Distance	Feet	Feet		Feet	Feet
8	AT5A		0	5.12		0.25	1216.614
9	141S		34.6	2.5		34.60	1406.25
10	MS40S		250	1.1		250.00	1513.21
11	MS41S		253	1.22		253.00	1503.888

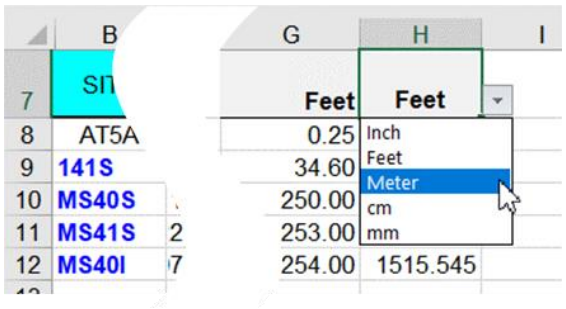
Plot Area

Prop | OUTPUT | DATA

Figure 2.—DATA page in the DistanceDrawdown_Pumping-2019.xlsm workbook where distances and drawdowns are specified.

Data Page

Clear existing data between columns B and F from row 8 to the last entry.	 Empty cells before adding your data. 
Specify units for time in cell D7.	
Specify units for measured drawdowns in cell E7.	

Specify units for distances and drawdowns that are analyzed in cells G7 and H7.	

OUTPUT page—Site Information

Construction, depths, material, and site information are specified on the OUTPUT page (Figure 3). Most of this information is descriptive and does not affect estimated transmissivities. Aquifer material defines broad ranges of permissible transmissivities, which users should expand or replace with site specific limits. Initial depth to water and top of aquifer in cells C9 and C10 determine if analysis is confined or unconfined.

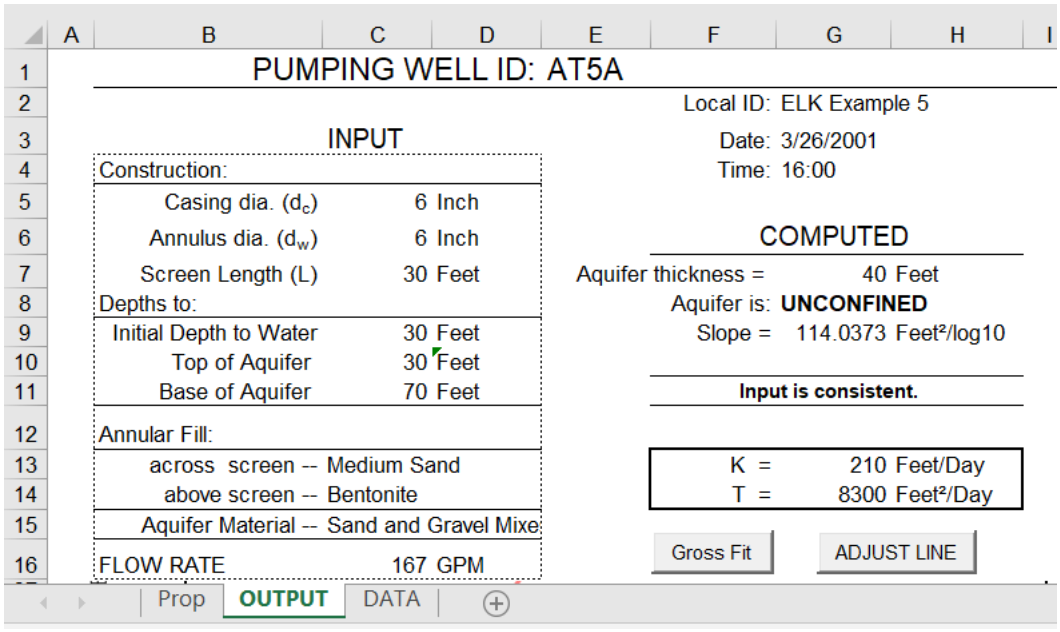
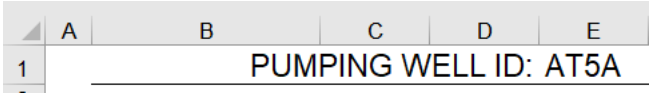
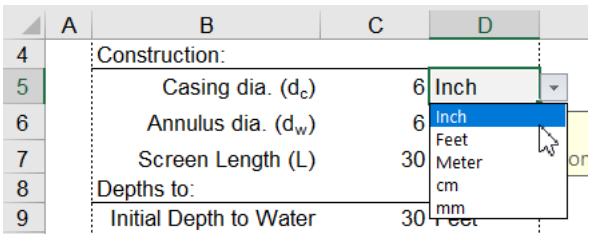
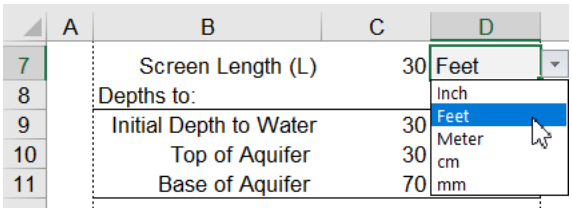
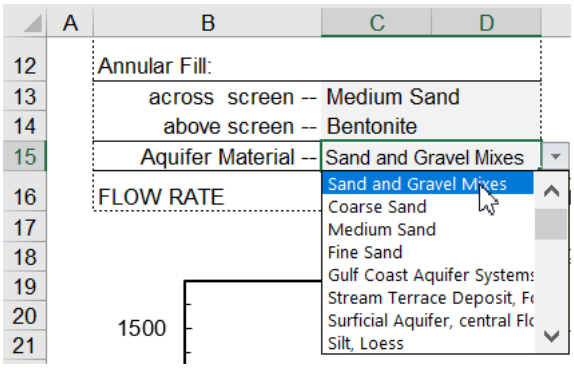
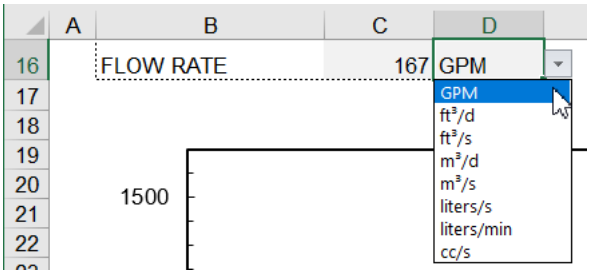


Figure 3.—Site information for single-well aquifer test in the DistanceDrawdown_Pumping-2019.xlsm workbook.

Site Information

Enter site identifier in cell E1.	

Diameters of casing and annulus are specified in cells C5 and C6. Select units from pull-down menu in cell D5.	
Depths to static water level, top of screen, and bottom of screen are specified in cells B33, B34, and B35. Select units from pull-down menu in cell C33.	
Filled annular material across screen and above screen are specified in cells C13 and C14. Aquifer material is specified in cell C15 and defines range of permissible hydraulic conductivities. Select materials from pull-down menus in cells C13:C15.	
Constant flow rate is specified in cell C16 and units are selected from pull-down menu in cell D16.	

OUTPUT page —
Estimating transmissivity or hydraulic conductivity

Distances and drawdowns or saturated thicknesses squared are plotted and analyzed on the OUTPUT page (Figure 4). A straight line initially is regressed to drawdown and recovery data with the “GROSS FIT” button. Fit between straight line and plotted data can be refined visually with the “ADJUST LINE” button to ignore additional drawdown from well losses in the pumping well. Transmissivity and hydraulic conductivity are reported with a user defined number of significant digits.

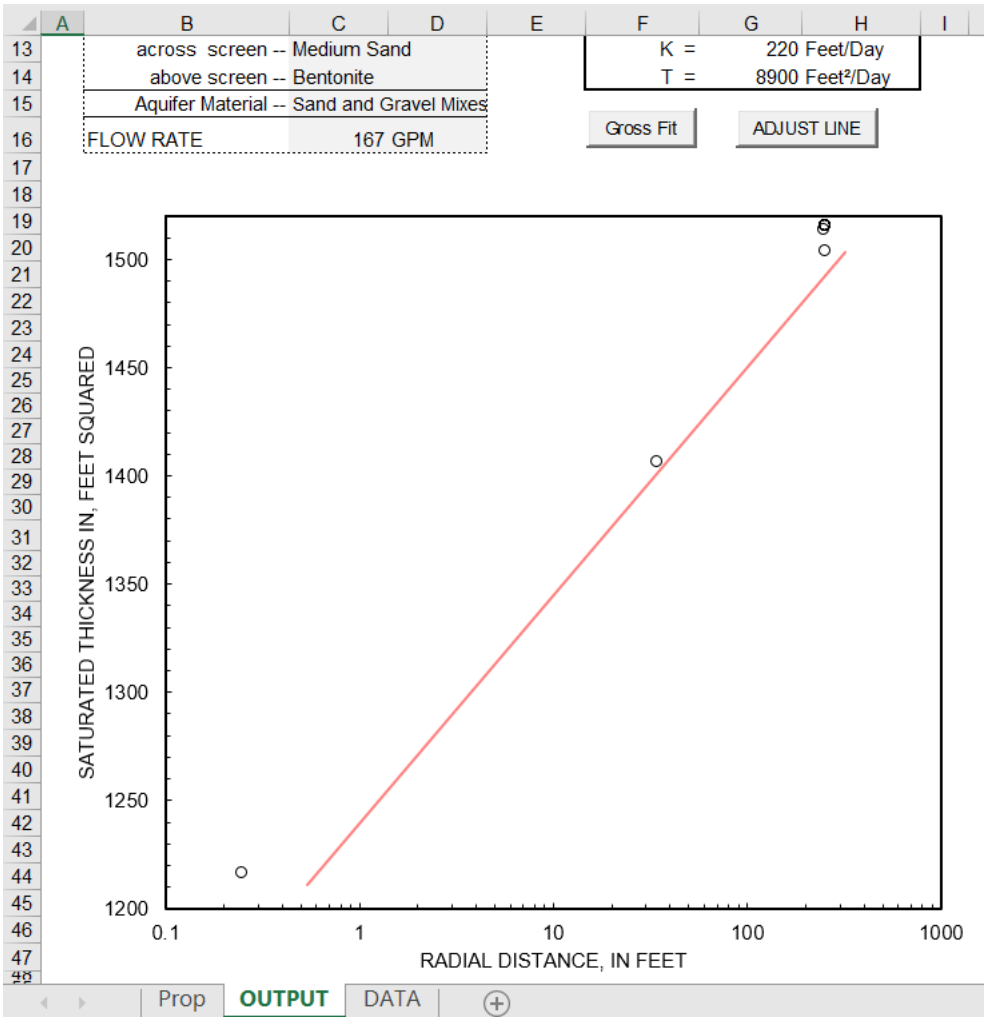
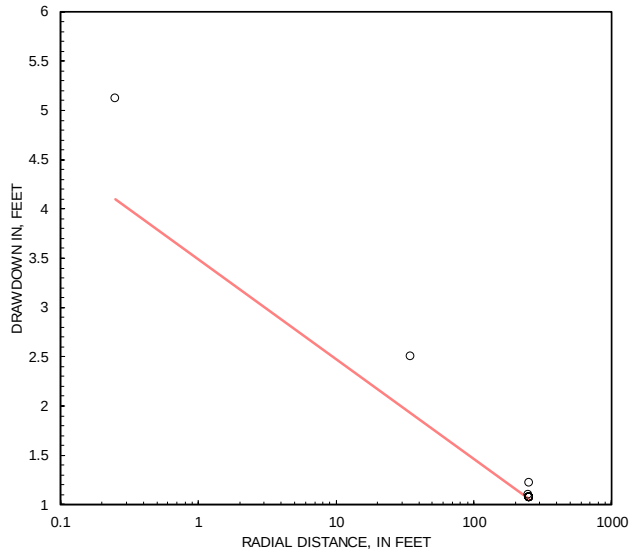
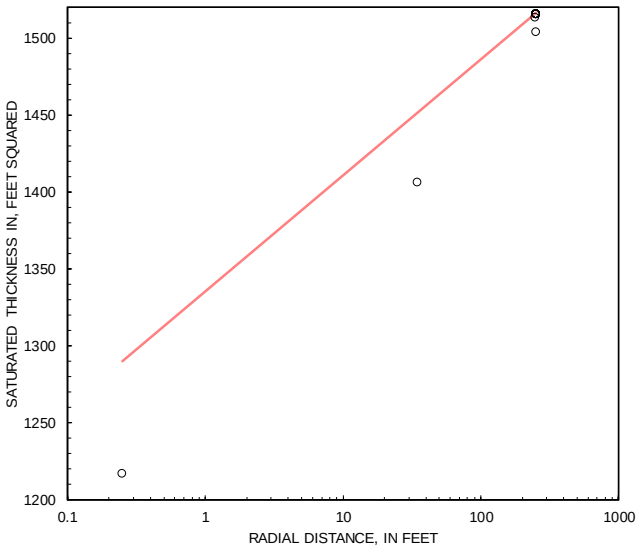
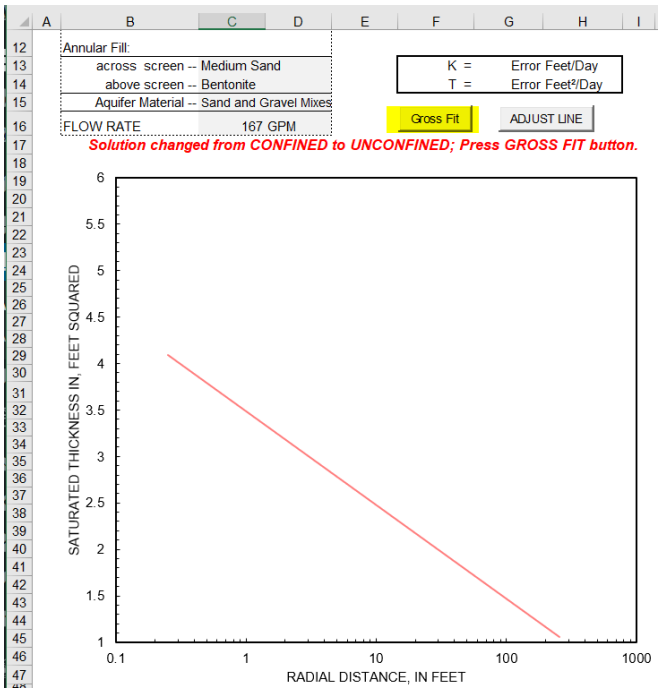
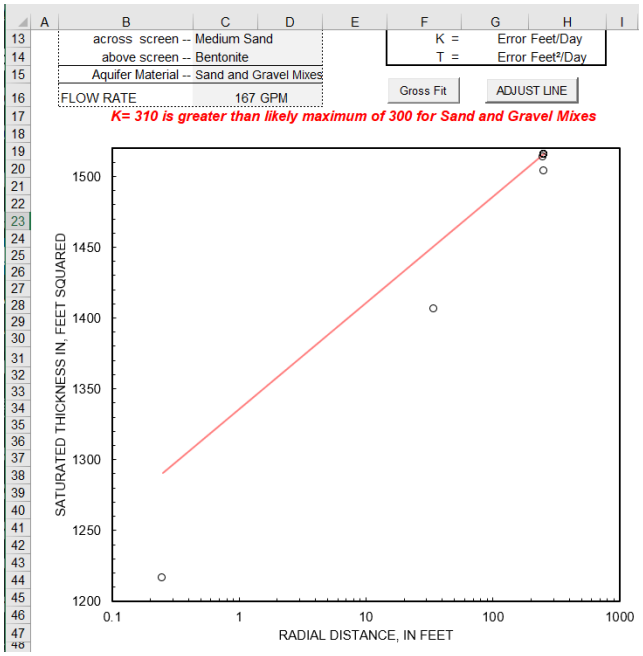
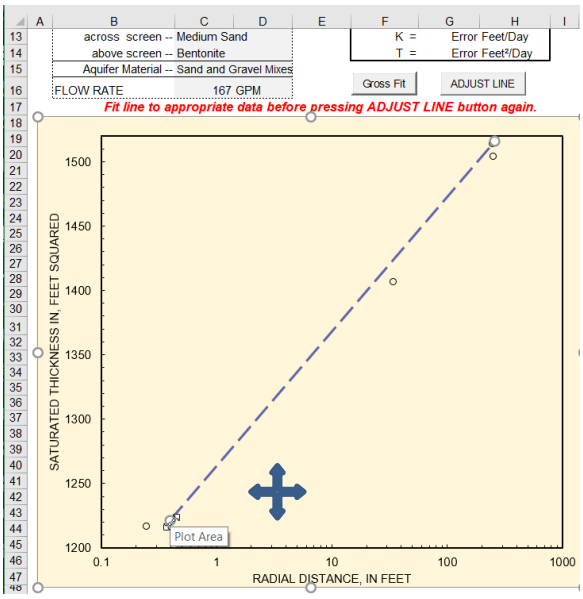
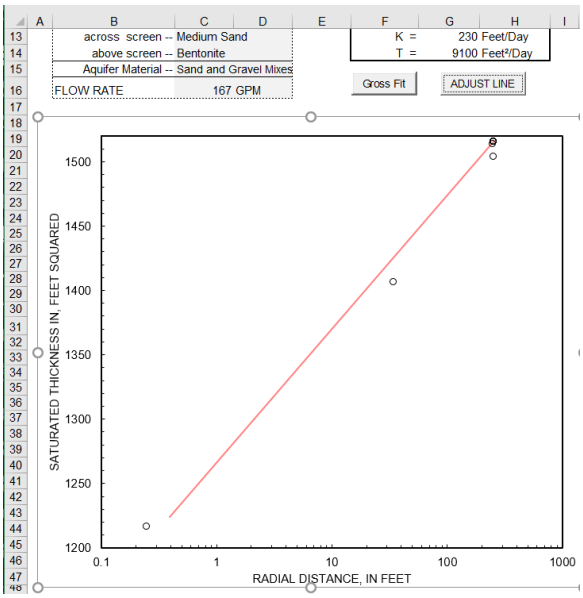
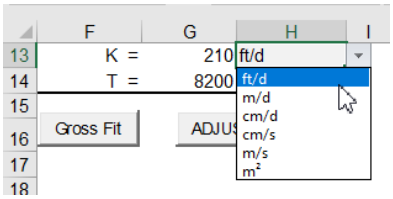
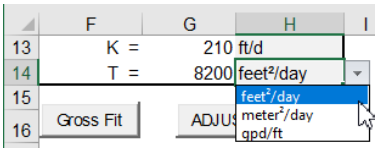


Figure 4.—Estimating transmissivity or hydraulic conductivity from distance-drawdown data in the DistanceDrawdown_Pumping-2019.xlsm workbook.

Estimating Transmissivity or Hydraulic conductivity

Drawdowns appear on the semi-log plot if confined conditions are analyzed.	
Saturated thicknesses squared appear on the semi-log plot if unconfined conditions are analyzed.	

Changing solution from confined to unconfined or vise-versa triggers a warning in row 17. Press “GROSS FIT” button (cell F16) to correct as instructed in row 17.	
After pressing “GROSS FIT” button (cell F16) regresses a straight line to drawdown and recovery data. Minimum and maximum values of Y-axis are redefined to bracket drawdown or saturated thickness data and fitting line.	

Pressing the “ADJUST LINE” button (cell G16). Converts the regression line in the chart to a graphical line that can be moved and adjusted. Background color changes and remains changed while in fitting mode. An error condition exists while graphically fitting line.	
Pressing “ADJUST LINE” button (cell G16) again. Reverts graphical line to regression line and restores background color of chart.	
Units of reported hydraulic conductivity (K) are selected from pull-down menu in cell H13	
Units of reported transmissivity (T) are selected from pull-down menu in cell H14.	

PROP page

Annular fill, grouts, and hydrogeologic units are specified on the PROP page (Figure 5). Annual fill and grout are descriptive lists in columns A and B that can be edited by the user. Aquifers define a range of permissible hydraulic conductivities for each unit. The default list was defined in Halford and Kuniansky (2002). The list of aquifers should be adapted to specific information from a user's study area.

	A	B	C	D	E	F	G	H	I	J
1										
2		Significant Digits =		2						
3					Common Rock Properties					
4					Extreme	Likely	Likely	Extreme		
5	Annular Fill	GROUTS		Aquifer Material	Kmin, ft/d	Kmin, ft/d	Kmax, ft/d	Kmax, ft/d	Rock Type	References
6	Gravel	Bentonite		Gravel	90	300	3000	3000	Unconsolic	1,5
7	Coarse Sand	Cement		Sand and Gravel Mixes	1	30	300	300	Unconsolic	1
8	Medium Sand	Backfill		Coarse Sand	50	70	300	300	Unconsolic	1
9	Fine Sand	Open Hole		Medium Sand	1	20	70	200	Unconsolic	1,5
10	Open Hole			Fine Sand	0.05	3	20	20	Unconsolic	1,5
11				Gulf Coast Aquifer Systems (6603 values)	2	30	200	800	Unconsolic	2

Prop | OUTPUT | DATA

Figure 5.—Annular fills, grouts, and ranges of transmissivities on the PROP page in the DistanceDrawdown_Pumping-2019.xlsm workbook.