Instructions for computation of in-well time of travel for lowflow sampling

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Version: 6.0.1 beta (regular code)

Files = vbaprogram6.0.1_BETA.xlsm; vbaprogram6.0.1_BETA_forward1.xlsm and associated vba program for pump intake set at midpoint of screen, and vbaprogram5.1.1_BETA –nawqa.xlsm and associated vba program (for pump intake set at top of screen.

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Requirements:

[1]Excel 2013

Data solver option in Excel invoked (marco enabled-"*.xlsm").

Introduction

The vba programs to run the analytical model are embedded into the *.xlsm files. There are two main *.xlsm files vbaprogram6.0.1_BETA.xlsm, which contains the module "Module1-run8-regular.bas" with a subroutine name "GetValueL8" and . File vbaprogram6.0.1_BETA.xlsm is used for scenario where the pump intake for both purging and sampling is placed at the middle of the screen. File vbaprogram5.1.1_BETA –nawqa.xlsm, which contains the module "Module1-run9-nawqa.bas" with a subroutine name "GetVal9nw". File vbaprogram5.1.1_BETA.xlsm is used for scenario where the pump intake for both purging and sampling is placed at the top of the screen (bottom of casing).The two types of files differ only by the specification of pump position (parameter called "IP") where one is zero (nawqa) and the other is 1/2 screen (regular) length. It's just one line in the code so it's easy to miss.

The file vbaprogram6.0.1_BETA_forward1.xlsm is used for manual specification of hydraulic conductivity for evaluation of whether vertical flow in the screen is likely to occur. This is determined by specifying a

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BL of 2 ft and a BH = 0, and manually entering a LHK value in ft/d. The result is outputted as either a “0” in row 17, meaning lateral flow by the pump intake can satisfy purge requirements, or a “1” meaning lateral flow by the pump intake cannot satisfy purge requirements.

The *.xlsm include multiple sheets that are described below. The operation of the analytical model is discussed in the operation section below.

Contents of *.xlsm files

Input/Output sheet

Data are entered into the input column only on the sheet labeled “INPUTSHEET(SOLVER)”. An initial estimate of HK for high and low ranges can be specified, however, values will be recalculated when the excel solver option is invoked.

WORKSHEET FOR ESTIMATION OF LOW FLOW PURGE TIMES FOR WELLS SCREENED IN HETEROGENEOUS AQUIFERS(vBA[illegible].0.1_BETA)

Parameter	Input	Output		Calcs				Assumptions		
Well name	CPTMW03SW			qh=	0.00070[illegible]5	qtot[illegible]	0.003536768			
Date	12/19/2014			qv=	0.00275[illegible]	or qh[illegible]	0.002829415	qv=qp-(qh+qw)	or	qv=qh'*sl-2
Depth to water (DTW) in ft below ref (No data put 0)	30.75			qw=	7.81[illegible]05	qtotal'=	0.003614912			check against h3
Depth to top of screen (DTS) in ft below ref (no data put 0)	57			=b5-b6		0	10	Length of dry section; adj length of screen		
Averaged purge rate (liters/min)	0.1			0.02[illegible]50[illegible]	Gpm	0.003536768	cf/m			
Well diameter (inches)	4			0.16[illegible]67		area	0.087222222			
Length (Ls) of screen (ft)	10					ft/m	ft/m			
Drawdown (s) (ft)	0.12			=if b7 .eq. 0, then G7, ELSE H7		0.040548935	0.040316343	Piston flow velocities, ACCOU NTS FOR WELL BORE STORAGE ONLY		
Anticipated or actual purging time (mins); observed from previous stabilization data	45			4.094344562	=LN(10/rw)	0.039841582	0.039608989	Piston flow velocities, ACCOU NTS FOR HFLOW BY PUMP INTAKE		
Heterogeneity factor (HF) (x:1 where x = KH, 1 = KL)	1						7.8144E-05	Storage	qw per min	
Highest (HHK) potential Hyd. cond (ft/d)-solver	2.767021877			0.001921543	0.00176838	cf/m	0.000353677	Radial flow eqn. HIGH K; gh'; total qv = screen length - 2ft		
Thickness (bh)of high K zone (ft)	5			ft/m	0.050075	l/m		Assume .01 head grad. if drawdown = 0		
Lowest (LHK) potential Hyd. cond (ft/d)-solver	2.7670218[illegible]7			0.001921543	0.00176838	cf/m	0.000707354	Calc RADIAL flow for 2 ft around intake		
Thickness (bl) of low K zone (ft): bh+bl = Ls	5			ft/m	0.050075	l/m	0.020030025	Assume minimum b = screen length - high k b ft		

Can vertical flow in well occur from purging based on estimated radial flow? (0=NO;1=YES)		1		"Calc from 2*unit radial flow eqn				If PUMP RATE > HFLOW BY MIDPT (2 FT THICK BASED ON LOW K UNIT)		
If drawdown> 0 and vertical flow =no, recalculate radial flow and skip below								IF NO, AND NO DRAWDOWN, WORKSHEET NOT APPLICABLE		
Minimum potential equilibrium purge rate(cf/m); if drawdown observed, this number should be less than the purge rate		0.003536768	0.100150125	L/min				Cumulative radial flow from high and low k zones = PURGE RATE		
Difference between estimated radial flow - purge rate (cf/m); should be a positive number if s>0		4.51158E-15	1.27754E-13	L/min				Does calculated radial flow > purge rate; if drawdown > 0 then recalculate; for unsteady flow and drawdown, this number should be at least equal to the casing volume /time (rate of well		
Observed volume from wellbore storage(cf)		0.010466667						Drawdown * area of well		
Potential volume from wellbore storage based on estimated radial flow (cf)		0								
Maximum vertical wellbore velocity (feet/min) with well st		0.0403		=(#REF!*O4)/(3.14*POWER(($C10/2),2))				This is maximum vertical velocity - drawdown (well storage)		
Adjusted maximum vertical wellbore veloci		0.0396						This is adjusted vertical velocity - drawdown - horizontal flow at pump intake		
Potential maximum purge time(min)		252.4679		=IF(C13=0,"NA",(B6/2)*(1/C20)				Assume pump intake at midpoint of screen; divide max. by 1/2 to account for flows from top to bottom		
Recommended maximum purge time (min); higher of anticipated or potential		252.4679		=IF((B8>C19),B8,C19)						
T of well screen		27.67021877		T=TL+TH'				This is the transmissivity of the well screen (summation of low t and high t zones)		
Average k of well screen		2.767021877		t=well screen				This is the average K of the well screen (cumulative T of well screen divided by well screen length)		
Lateral flow radius by pump intake (likely maxim um)		0.369680505		682.9355077	5918.7744	19729.248	42054.44968	Assumes n = .25		
				0.001464267	0.00016895	5.06862E-05	2.37787E-05	1,2,5,10 raddii		

The red HHK and LHK cells represent the solver determined best range of hydraulic conductivity for the respective thickness of each layer after running solver. The summation of thicknesses for the low and high HK must equal the length of screen for fully saturated conditions or the partial saturation when depths of water exceed the top of the screen interval (not for manual specification of HK). A parameter called heterogeneity factor serves to constrain ranges in HK.

Critical flags include whether vertical flow occurs (1=yes) based on whether the horizontal inflow for a 2 ft zone around the pump satisfies the purge rate **for manual specification of HK option only** ("-forward1 .xlsm"). The user can determine the HK needed to accommodate the purge rate under horizontal inflow only by specifying a 0 for the thickness for BH parameter and specifying a 2 for the BL parameter. If the resultant HK is too high based on site geology, vertical flow is likely to be the norm at most wells. <u>When solver is invoked to minimize differences between radial inflow and purge rate (cell c20; "Differences between…"), the vertical flow condition is the default.</u>

Other important output fields include average K of well screen (in red), and potential maximum purge time. The latter is an approximate value; a more precise value is determined by running the excel macro module attached to the excel file (see below).

The last few rows is an approximate calculation of lateral capture of purge water at the pump intake interval as measured along radial distances from the well. This feature is only available from version 6.0.1 and above.

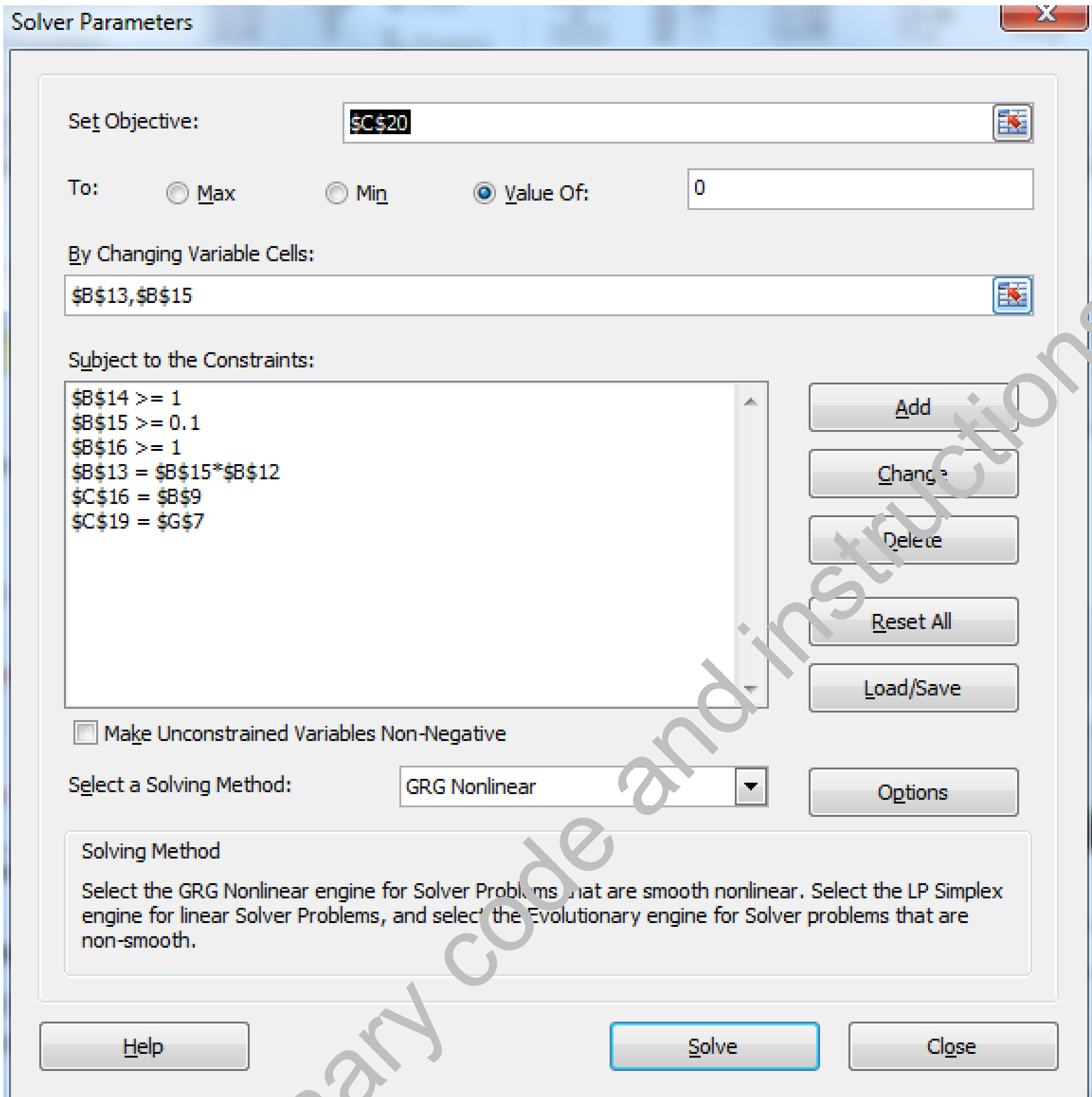
Operation

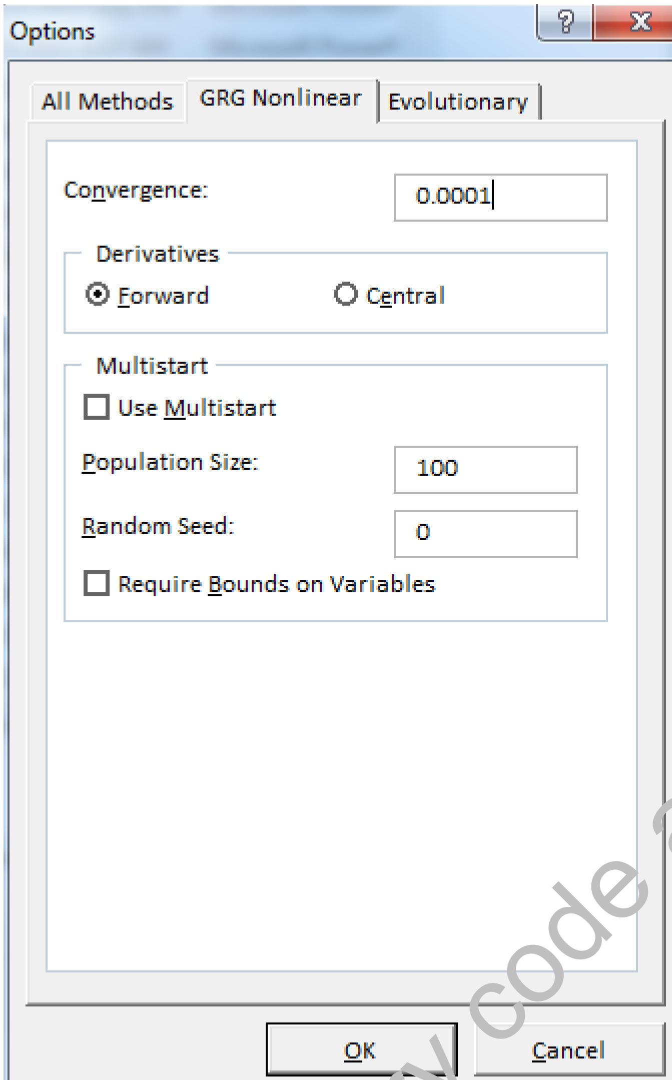
There is a two step process for running the program as outlined below.

Step 1

The solver program is run on the inputsheet(solver) sheet of the excel file. The solver add-in must be specified in the excel options menu for the program to work. The solver is invoked on the Data Analysis Tab. Use the overwrite function in solver during running.

Solver constraints include the summation of flow from the LHK and HHK must be equal to purge rate (or minimized; field C20). Other constraints include model layer thicknesses and differences between LHK and HHK based on the heterogeneity factor. The GRG nonlinear solver option with forward derivatives are used.


Solver Parameters
Set Objective:
C20
To:
Max
Min
Value Of:
0
By Changing Variable Cells:
B13,B15
Subject to the Constraints:
B14 >= 1
B15 >= 0.1
B16 >= 1
B13 = B15*B12
C16 = B9
C19 = G7
Add
Change
Delete
Reset All
Load/Save
Make Unconstrained Variables Non-Negative
Select a Solving Method:
GRG Nonlinear
Options
Solving Method
Select the GRG Nonlinear engine for Solver Problems that are smooth nonlinear. Select the LP Simplex engine for linear Solver Problems, and select the Evolutionary engine for Solver problems that are non-smooth.
Help
Solve
Close



Step 2

A vba macro program (module 1) is invoked under the Developer Tab of excel in the *.xlsm file. The program is run on the inputsheet(solver) sheet of the excel file after solver is invoked. The program module calculates horizontal and vertical flow per 1 ft increments across the screen using the solver HK values. Vertical flow is calculated from summation of the horizontal flows away from the pump intake (outside of a 2 ft zone around the pump). The program is applicable when the initial program indicates vertical flow is occurring. Results are printed to the output sheet. [You must clear contents field in gray area on output sheet]. For the regular code where the pump is set at the midpoint, the module subroutine is called GetValuer8 and for the nawqa code where the pump is set at the top of the screen it is called GetValuer9.

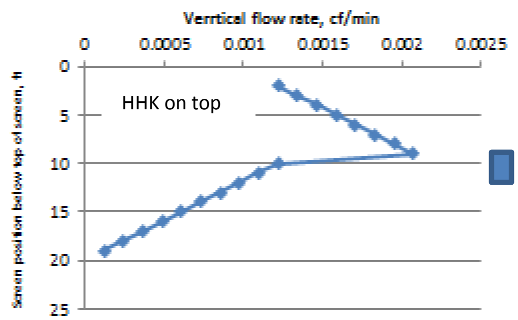
Output sheet and Graphics from Module

The output sheet lists the results of the macro program. Column A lists screen interval, column b = horizontal inflow rate, column c = vertical flow rate, column d = time of travel for that interval, column e = travel time per layer for a 1 ft thickness, column f = travel time to the pump, column g = time increment from start of pumping, column h = total inflow from recharged water captured by pump, column I = fraction of total inflow from recharge (aquifer) that is captured by the pump.

Col	a	b	c	d	e	f	g	h	i
	1	0.0012				119.07	0	0.0001	0.0345
	2	0.0001	0.0012	17.875	17.875	119.07	10	0.0001	0.0345
	3	0.0001	0.0013	16.25	34.124	101.2	20	0.0002	0.069
	4	0.0001	0.0015	14.895	49.02	84.945	30	0.0004	0.1034
	5	0.0001	0.0016	13.75	62.769	70.05	40	0.0005	0.1379
	6	0.0001	0.0017	12.768	75.537	56.3	50	0.0007	0.2069
	7	0.0001	0.0018	11.916	87.453	43.533	60	0.0009	0.2414
	8	0.0001	0.002	11.172	98.625	31.616	70	0.001	0.2759
	9	0.0001	0.0021	10.514	109.14	20.445	80	0.0011	0.3103
	10	0.0001	0.0012	17.875	505.67	0	90	0.0012	0.3448
	11	0.0001	0.0011	19.861	485.81	19.861	100	0.0013	0.3793
	12	0.0001	0.001	22.343	463.46	42.204	110	0.0015	0.4138
	13	0.0001	0.0009	25.535	437.93	67.739	120	0.0028	0.7931
	14	0.0001	0.0007	29.791	408.14	97.53	130	0.0028	0.7931
	15	0.0001	0.0006	35.749	372.39	133.28	140	0.0029	0.8276
	16	0.0001	0.0005	44.686	327.7	177.97	150	0.0029	0.8276
	17	0.0001	0.0004	59.582	268.12	237.55	160	0.0029	0.8276
	18	0.0001	0.0002	89.373	178.75	326.92	170	0.0029	0.8276
	19	0.0001	0.0001	178.75	0	505.67	180	0.003	0.8621
	20	0.0001				505.67	190	0.003	0.8621
							200	0.003	0.8621
							210	0.003	0.8621
							220	0.003	0.8621
							230	0.003	0.8621
							240	0.0032	0.8966
							250	0.0032	0.8966
							260	0.0032	0.8966
							270	0.0032	0.8966
							280	0.0032	0.8966
							290	0.0032	0.8966
							300	0.0032	0.8966
							310	0.0032	0.8966
							320	0.0032	0.8966
							330	0.0033	0.931
							340	0.0033	0.931
							350	0.0033	0.931
							360	0.0033	0.931

Graphs plotted include the following:

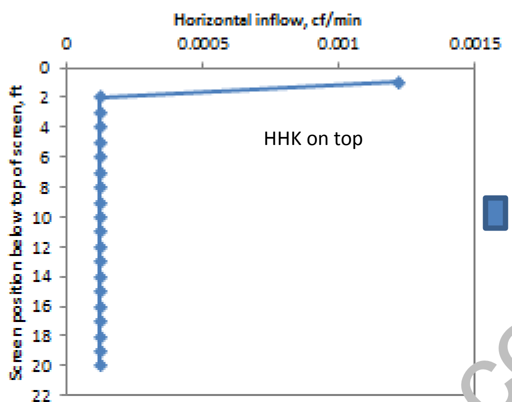
VFLOW



Pump

Vertical flow rates increase moving toward pump (blue bar). Faster on top from high HK layer.

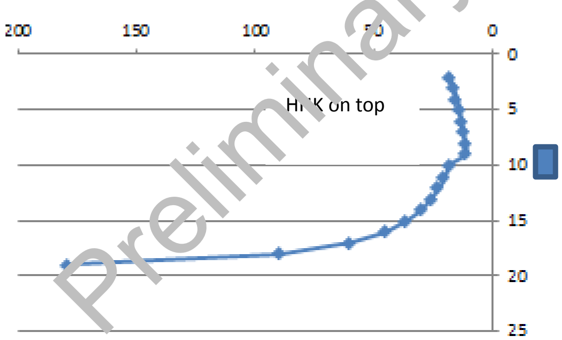
HFLOW



Pump

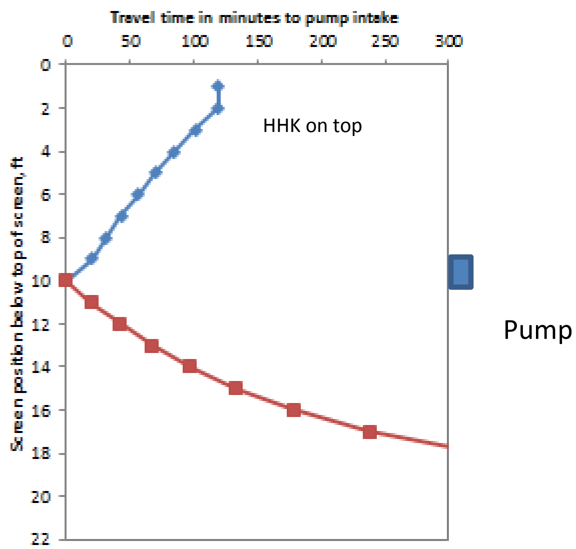
High HK at top of screen from permeable layer.

TIME

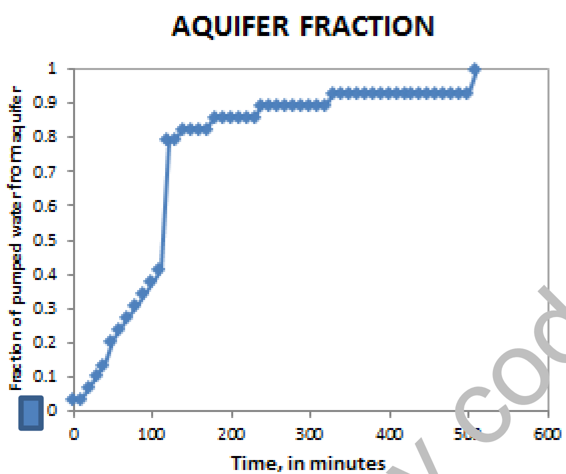


Pump

Time of travel per 1 ft distance by screen interval. Bottom layers slow because no high HK zones are present.



Time of travel to pump from screen intervals. Faster on top from high HK layer.



Amount of purge water capturing recharge water from outside well screen. In early time, most water captured is from water already inside well screen.

If specific conductance data is available, there is a another sheet where that can be entered. The graphic plot is included on the output sheet.