Hydrogeologic Analysis to Determine Consumptive Use

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Topic 1: Hydrogeologic Analysis

Aquifer - geologic formation that yields water in useable quantities.

Figure 1. Bedrock Aquifer in Eastern Montana

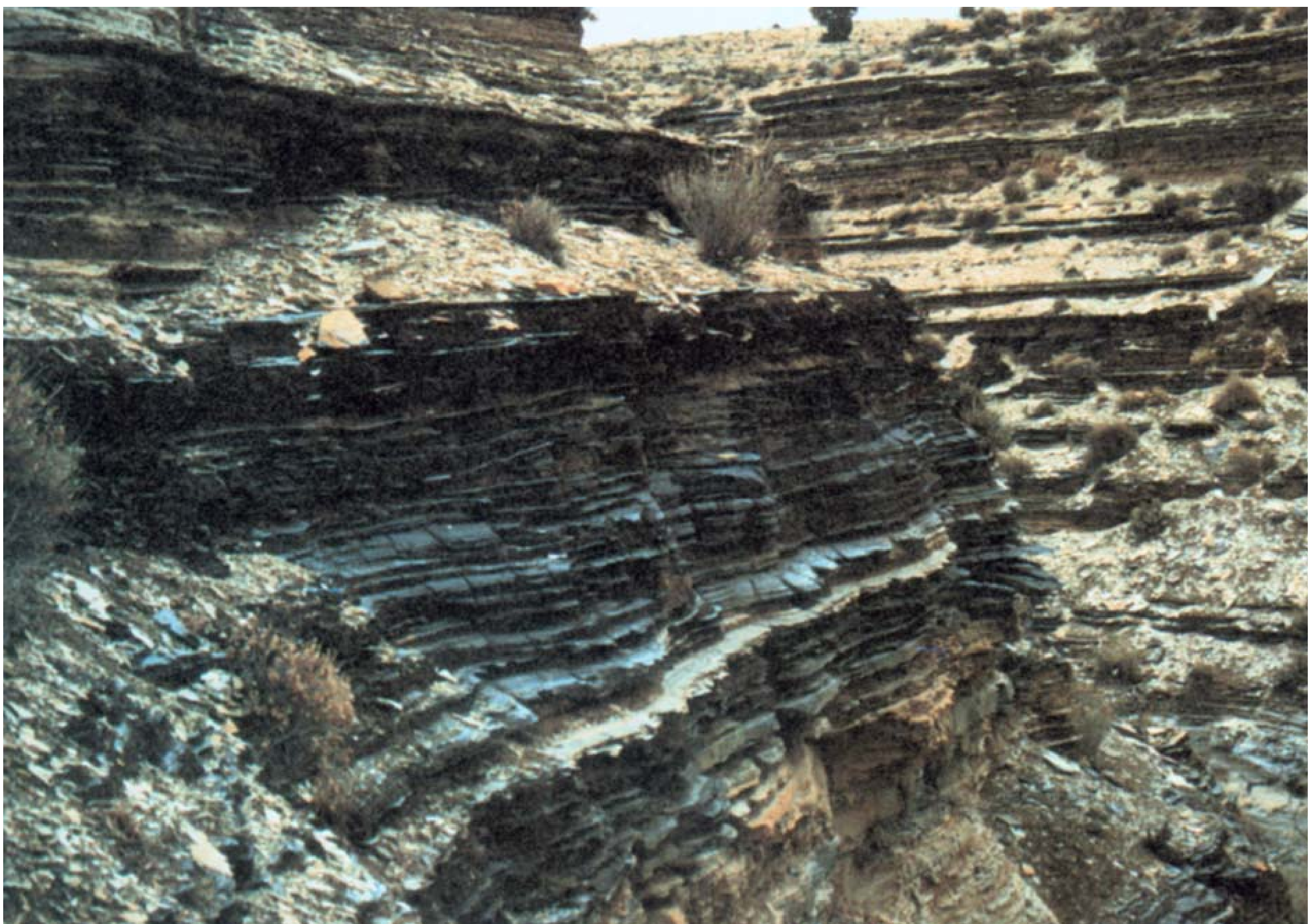


Figure 2. Alluvial Aquifer in Valleys of Montana

- typically composed of gravel, sand, silt, and clay
- unconfined because there are no extensive clay strata
- many irrigation/domestic wells completed in alluvial aquifers
- alluvial aquifer generally in hydraulic connection with surface water
- high potential for stream depletion impacts

Aquifer Test

- conducted to determine aquifer's capability to transmit and store water.

- procedure in which well is pumped to produce measurable drawdown that can be analyzed to determine aquifer hydraulic properties.

- Important testing procedures include:

  1) well pumped from 24 to 72 hours,

  2) discharge rate maintained constant,

  3) discharge rate monitored/adjusted frequently,

  4) observation well used to measure drawdown,

  5) drawdown measured at increasing time intervals that range from 30-second intervals to every 1-2 hours near end of test.

Figure 3. Aquifer Test Setup and Drawdown

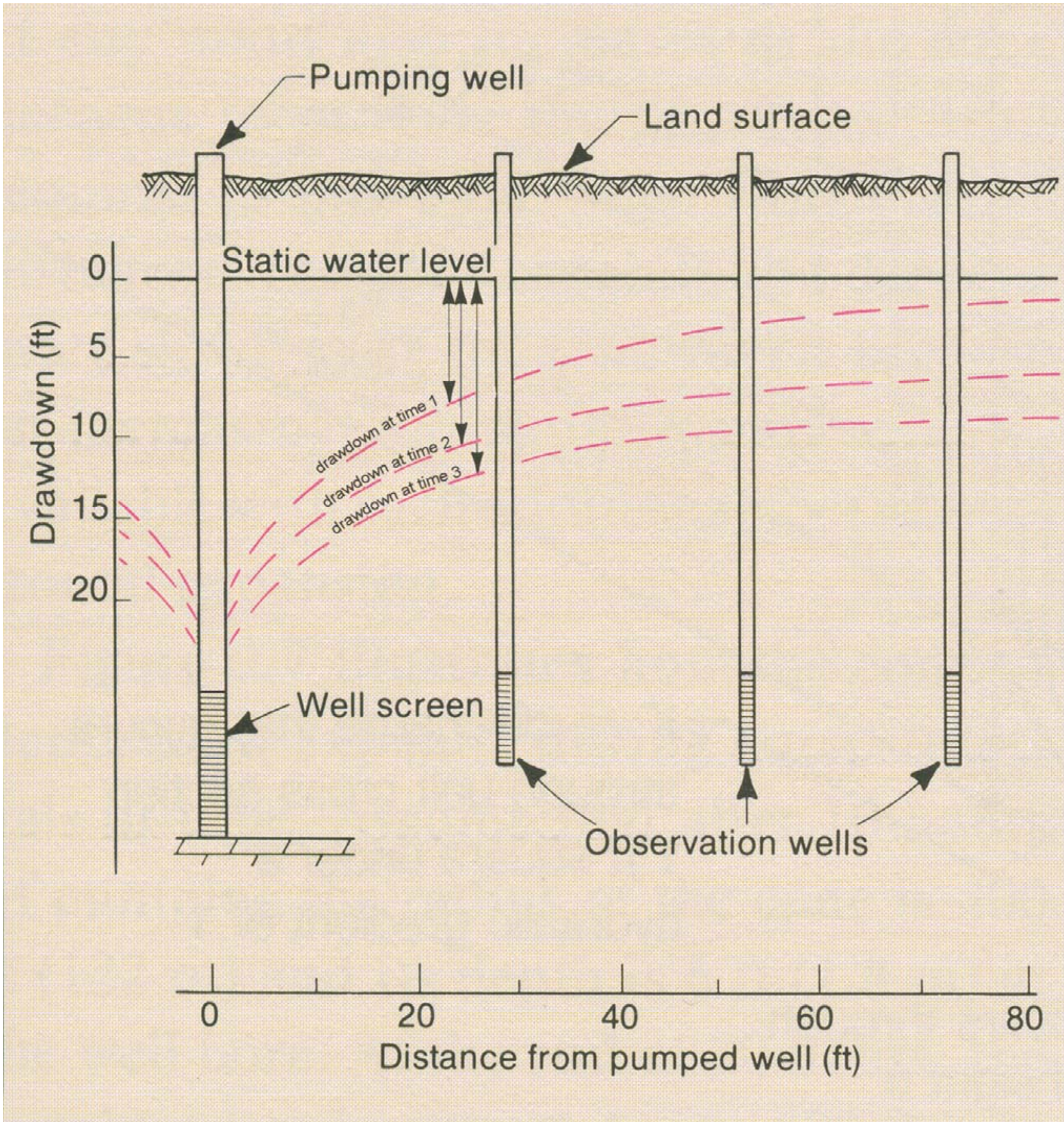


Figure 4. Cone of Depression in 3 Dimensions

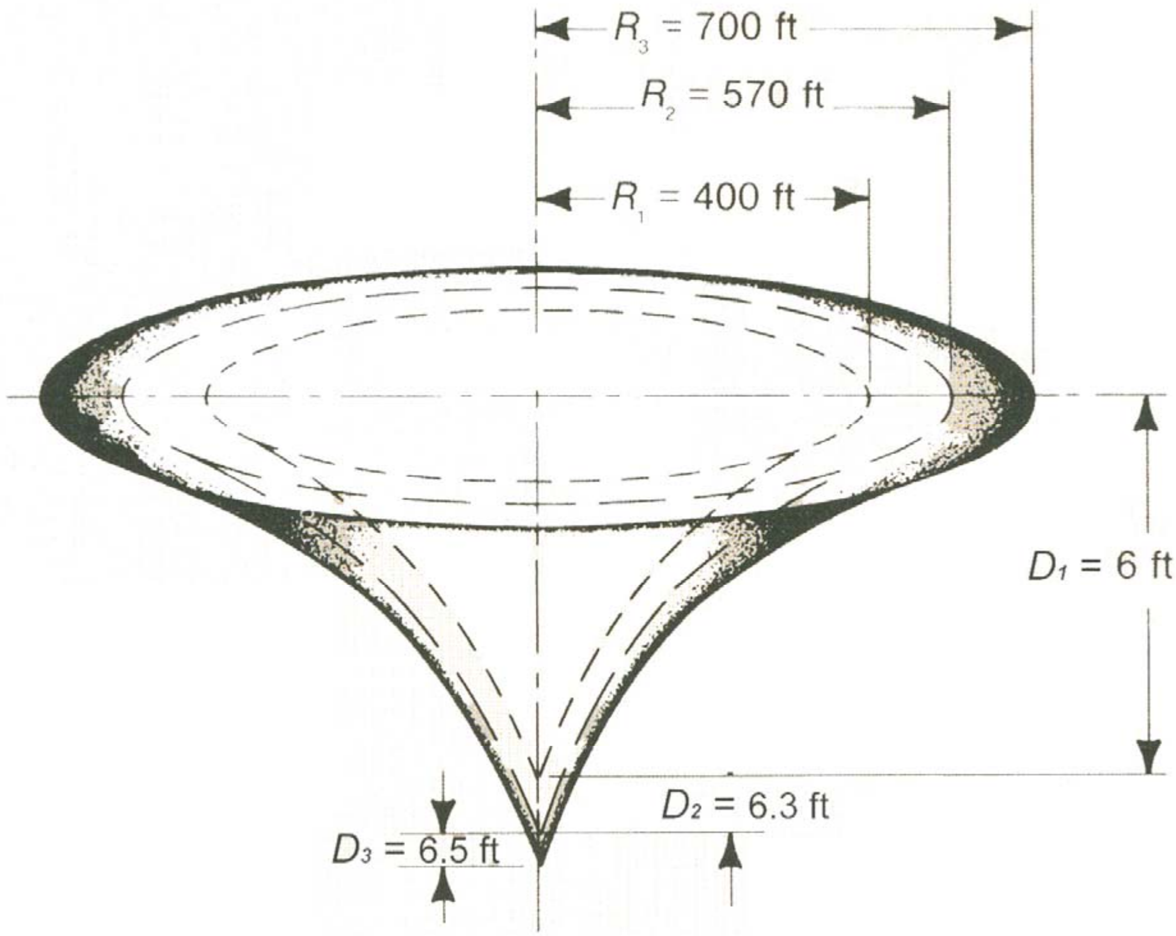


Figure 5. Time - Drawdown Graph

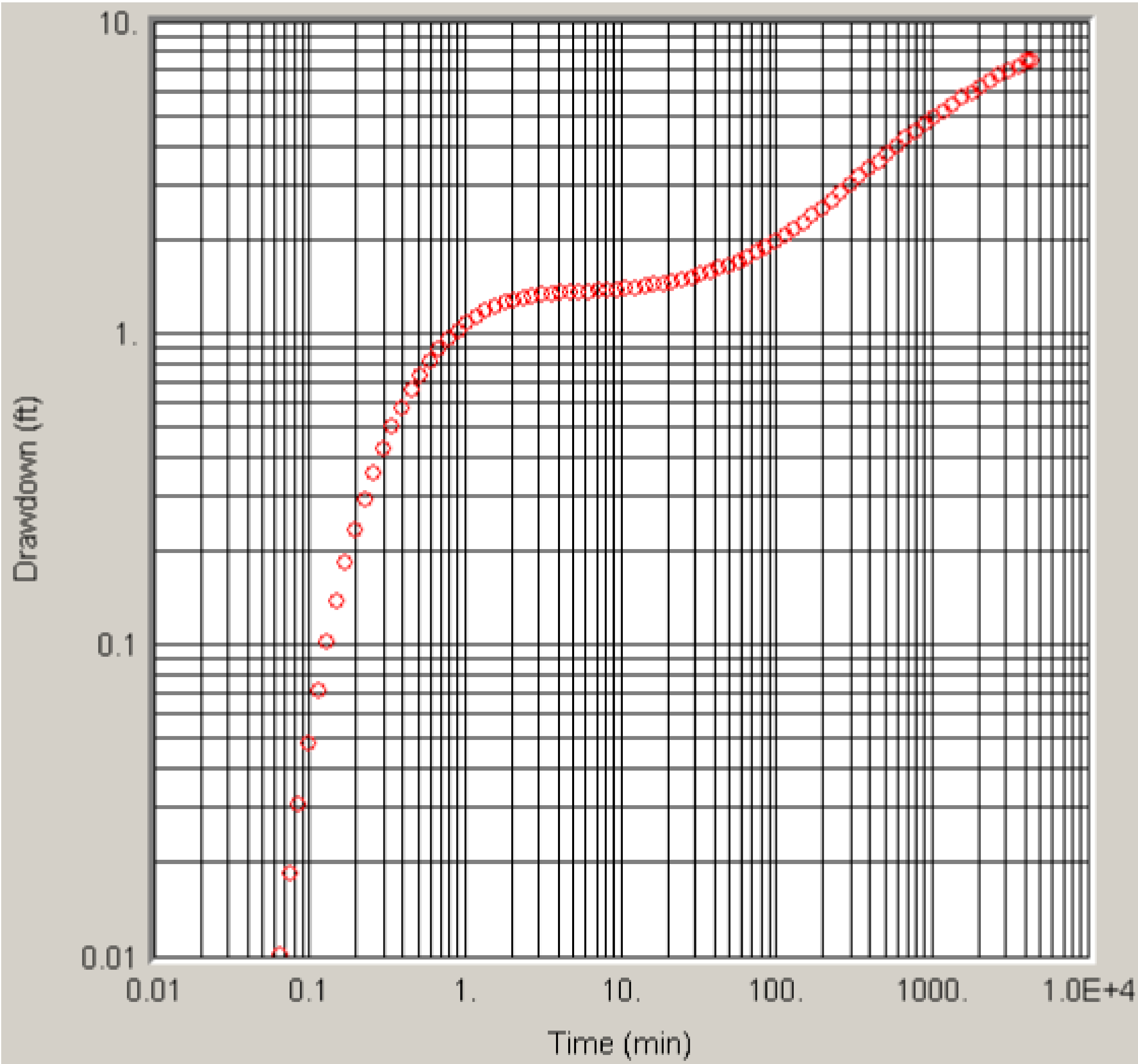
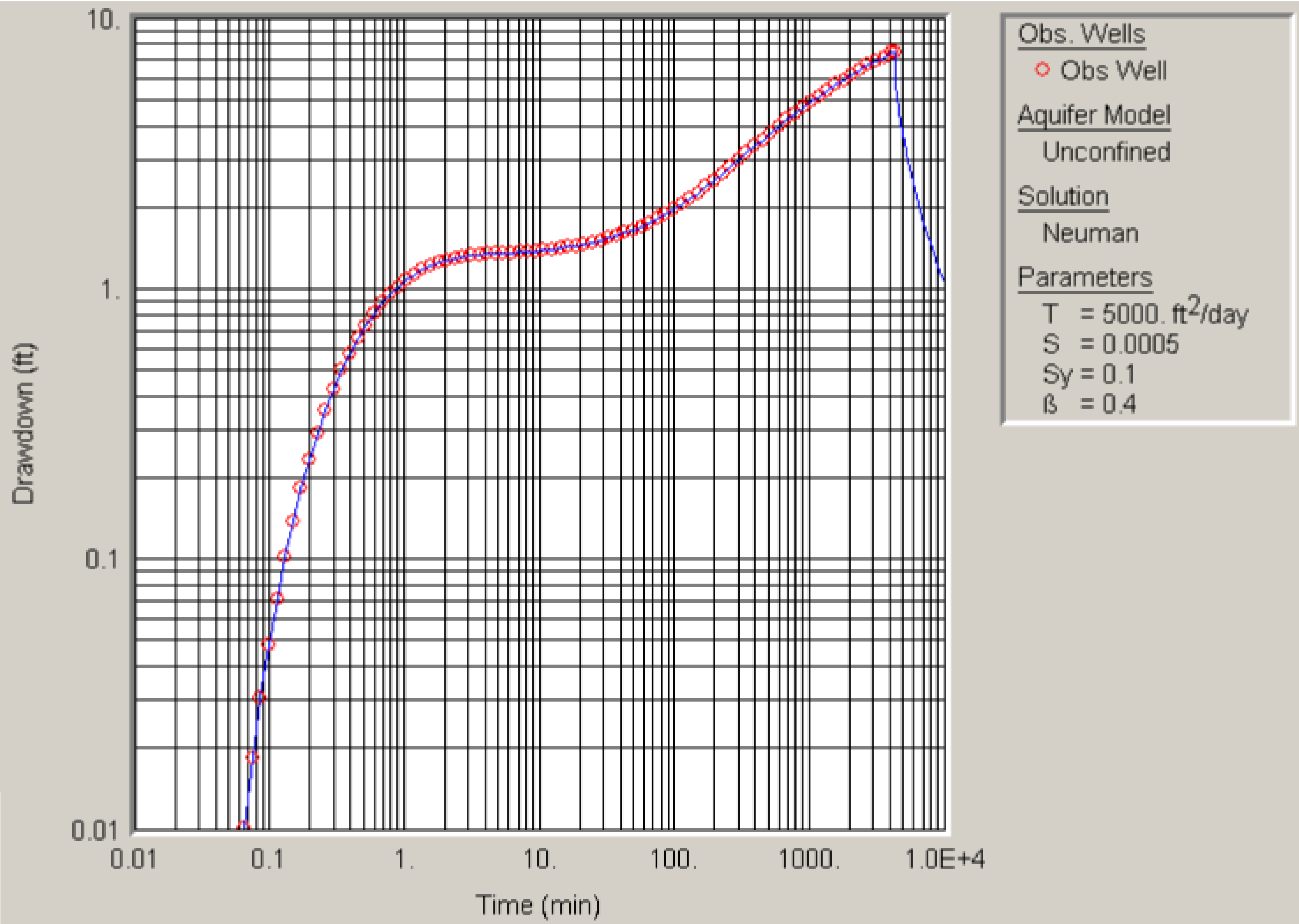


Figure 6. Time - Drawdown Data Analysis



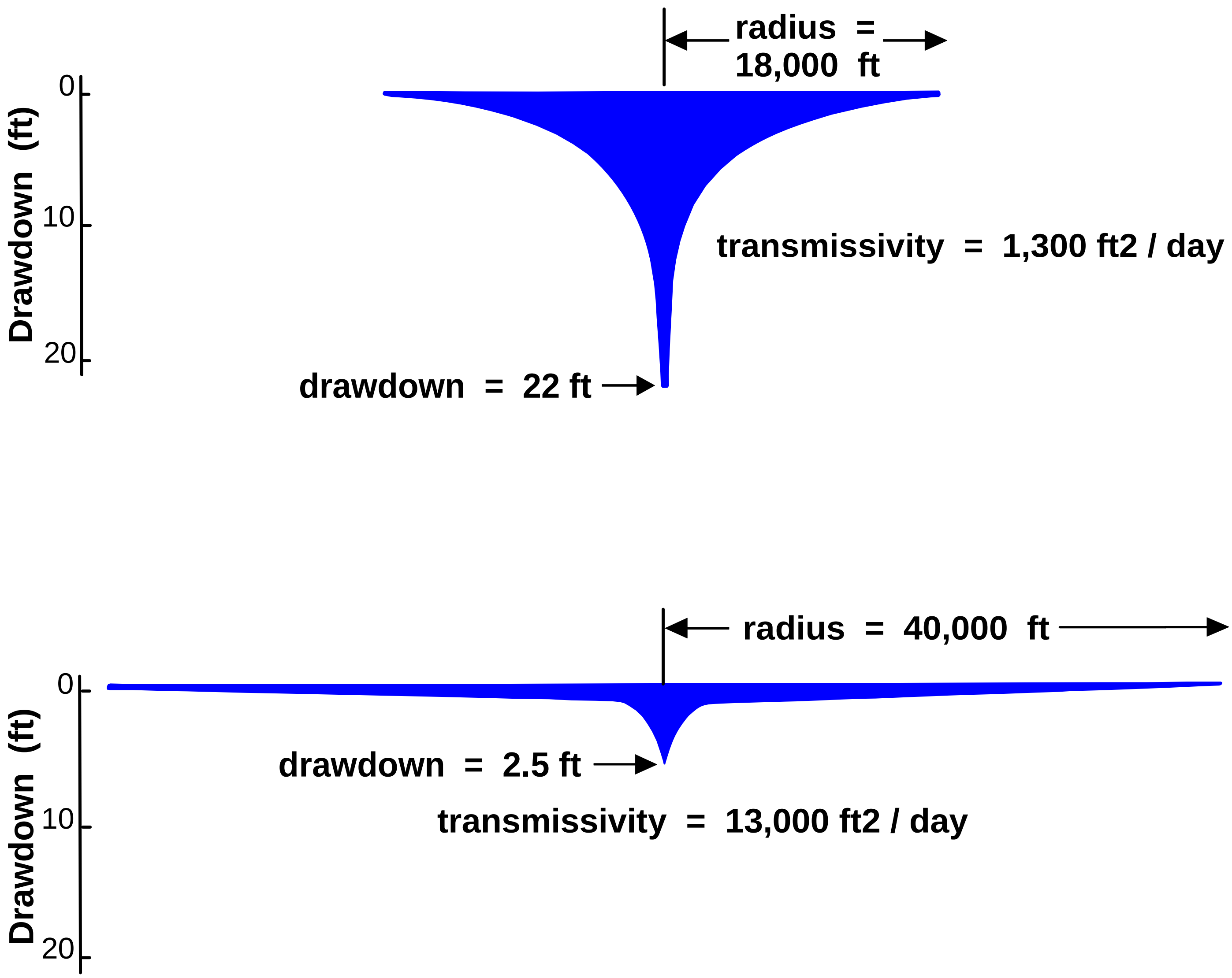
Analysis determines transmissivity = 5,000 ft²/day and storage coefficient (specific yield) = 0.10.

Aquifer properties considered conservative and representative of aquifer used for crop irrigation.

Transmissivity - measure of aquifer to transmit water.

Specific Yield - measure of aquifer to store and release water under gravity drainage.

Figure 7. Aquifer Properties Control Stream Depletion



Different T values affect depth and extent of cone of depression, given equal pumping rate and time.

Stream depletion occurs sooner for high T than for low T.

Stream depletion occurs later for high Sy than for low Sy.

Topic 2: Consumptive Use

- **Blaney - Criddle Formula developed to estimate consumptive use of irrigated crops in western U. S.**

  - crop type
  - stage of growth
  - air temperature
  - lengths of day light and growing season
  - air temperature and regional precipitation

Figure 8. Blaney - Criddle Formula available in electronic format from NRCS (formerly SCS)

SCS also published Montana Irrigation Guide.

- compiles water-use requirements for variety of crops at many locations throughout Montana.

Figure 9. Montana Irrigation Guide

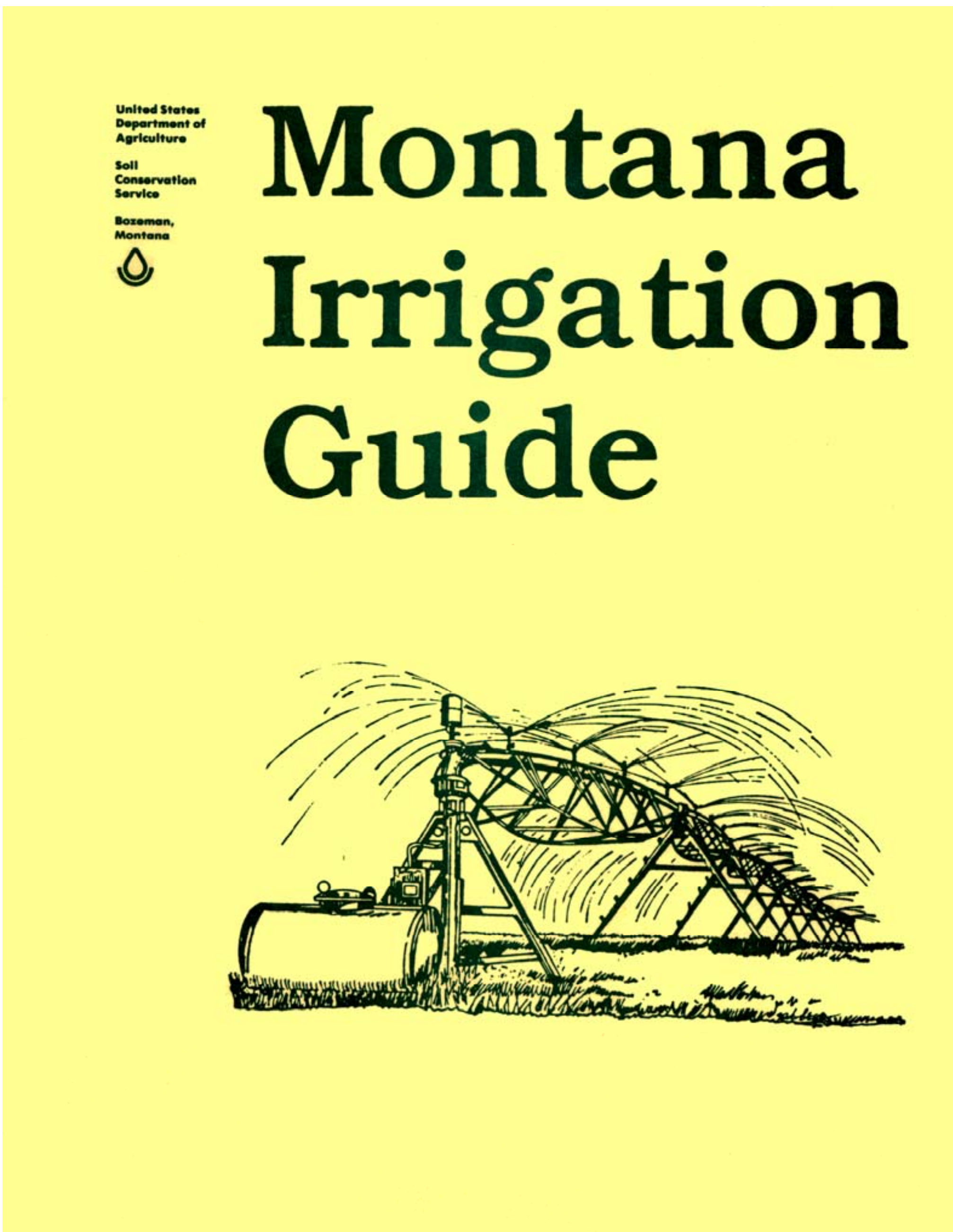


Figure 10. Data Sheet from Montana Irrigation Guide

MT IRR GUIDE — WATER REQUIREMENTS

APPENDIX B
ESTIMATED MONTHLY AND SEASONAL CONSUMPTIVE USE
(SCS, TR-21 Balaney-Criddle Method)

County: Lewis and Clark
Weather Station: Helena WSO — 4636 N, 11200 W
Climatic zone: Moderate (3) — Elevation: 3828 FT

Crop: Alfalfa — Normal net irrigation application: 2.5 in
Planting date: May 6 — Harvest date: October 5

MONTH	CONSUMPTIVE USE INCHES	EFFECTIVE PRECIPITATION: INCHES — Normal Year (50%)	EFFECTIVE PRECIPITATION: INCHES — Dry Year (80%)	NET IRRIGATION 1/ INCHES — Normal Year (50%)	NET IRRIGATION 1/ INCHES — Dry Year (80%)
JAN					
FEB					
MAR					
APR					
MAY	2.79	.93	.43	.61	.91
JUN	5.19	1.48	1.00	3.71	4.19
JUL	6.90	.85	.58	6.05	6.33
AUG	5.66	.94	.64	4.72	5.03
SEP	2.98	.54	.36	1.35	1.55
OCT	.23	.07	.05	.00	.00
NOV					
DEC					
TOTAL	23.77	4.81	3.26	16.46	18.01

Example: Consumptive Use Exercise

Assume:

- agricultural land in Helena Valley near stream
- 150 acres of alfalfa
- period of use from May 15 - Sep 15 = 123 days
- application rate requested = 2.24 ac-ft / acre
- volume requested = 336 acre-feet
- pumping rate ~ 800 to 1,000 gpm

Figure 11. Consumptive Use Excel Spreadsheet

		Stream Depletion Volume and Rate Calculator						
							# of irrig. acres	
			adj. water	normal-year	adj. effective	net	150	
	days	consumptive	require. for	effective	precip. for	consumptive	consumptive use	consumptive
month	per month	use (in)	partial month	precip. (in)	partial month	use (in)	volume (ac-ft)	use rate (gpm)
Apr								
May	**16**	**2.79**	1.44	**0.93**	0.48	0.96	12.00	**169.70**
Jun	**30**	**5.19**	5.19	**1.48**	1.48	3.71	46.38	**349.78**
Jul	**31**	**6.90**	6.90	**0.85**	0.85	6.05	75.63	**551.99**
Aug	**31**	**5.66**	5.66	**0.94**	0.94	4.72	59.00	**430.64**
Sep	**15**	**2.98**	1.49	**0.54**	0.27	1.22	15.25	**230.04**
Oct								
						16.66	**208.25**	

Topic 3: Stream Depletion Modeling

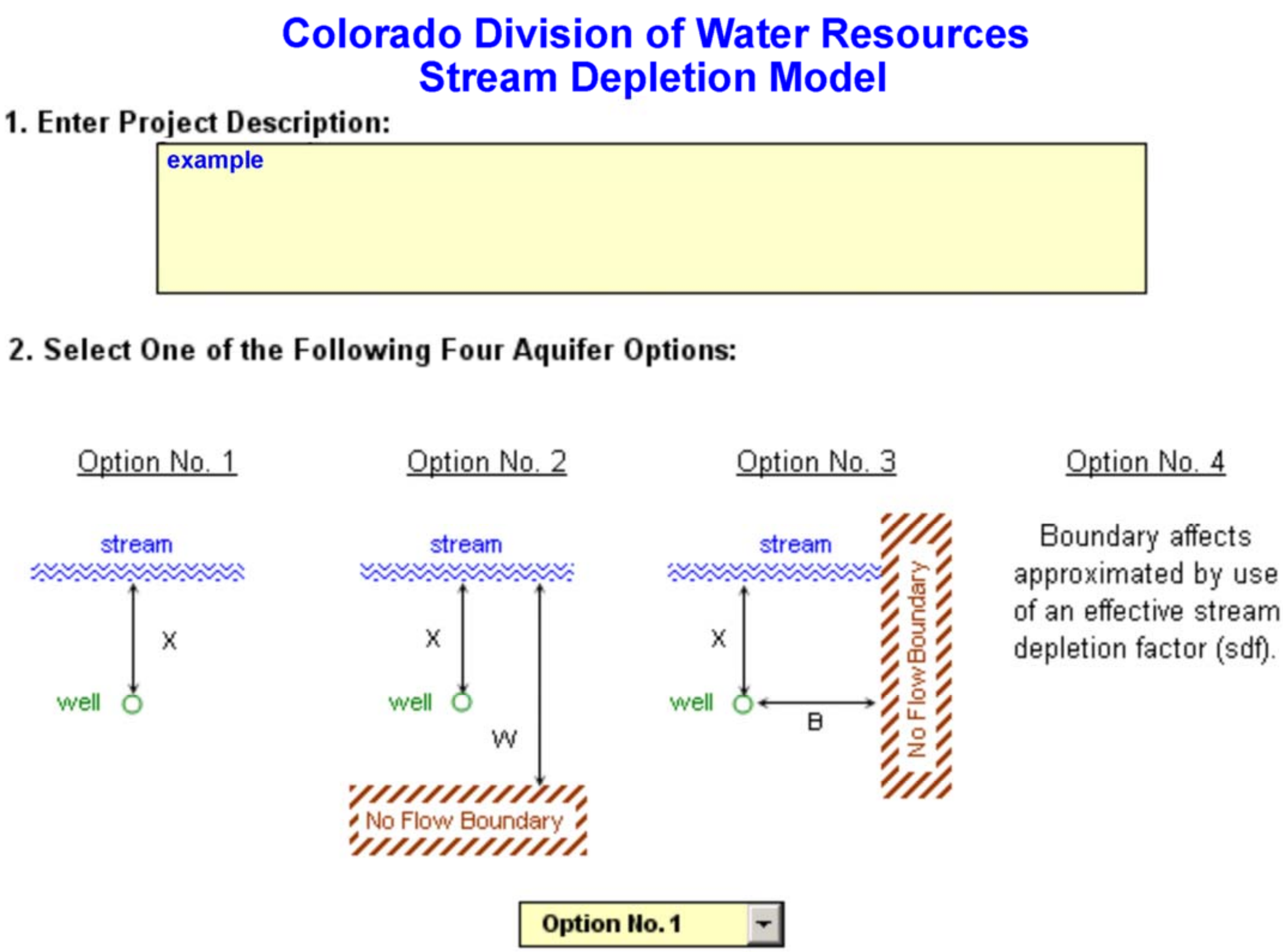
- **Model is computer software that mathematically simulates natural processes.**

Model Types:

<u>Analytical</u> - simple, limited input and data requirements

<u>Numerical</u> - complex, extensive data requirements, time consuming to design

Figure 12. Colorado Stream Depletion Model



3. Enter Physical Characteristics:

Aquifer Transmissivity (ft^2/day):	5,000	(Required for Option Nos. 1, 2, or 3 only)
Aquifer Specific Yield:	0.10	(Required for Option Nos. 1, 2, or 3 only)
Distance X (feet):	750	(Required for Option Nos. 1, 2, or 3 only)
Distance W (feet):		(Option No. 2 only)
Distance B (feet):		(Option No. 3 only)
sdf:		(Option No. 4 only)

4. Select Time Units:

3) Months

5. Enter Number of Pumping Periods: 120

Notes: Can not be greater than 3,600 periods.

6. Enter Starting Date: 1/1/2008

(e.g., enter 12/01/1950 for December 1, 1950)

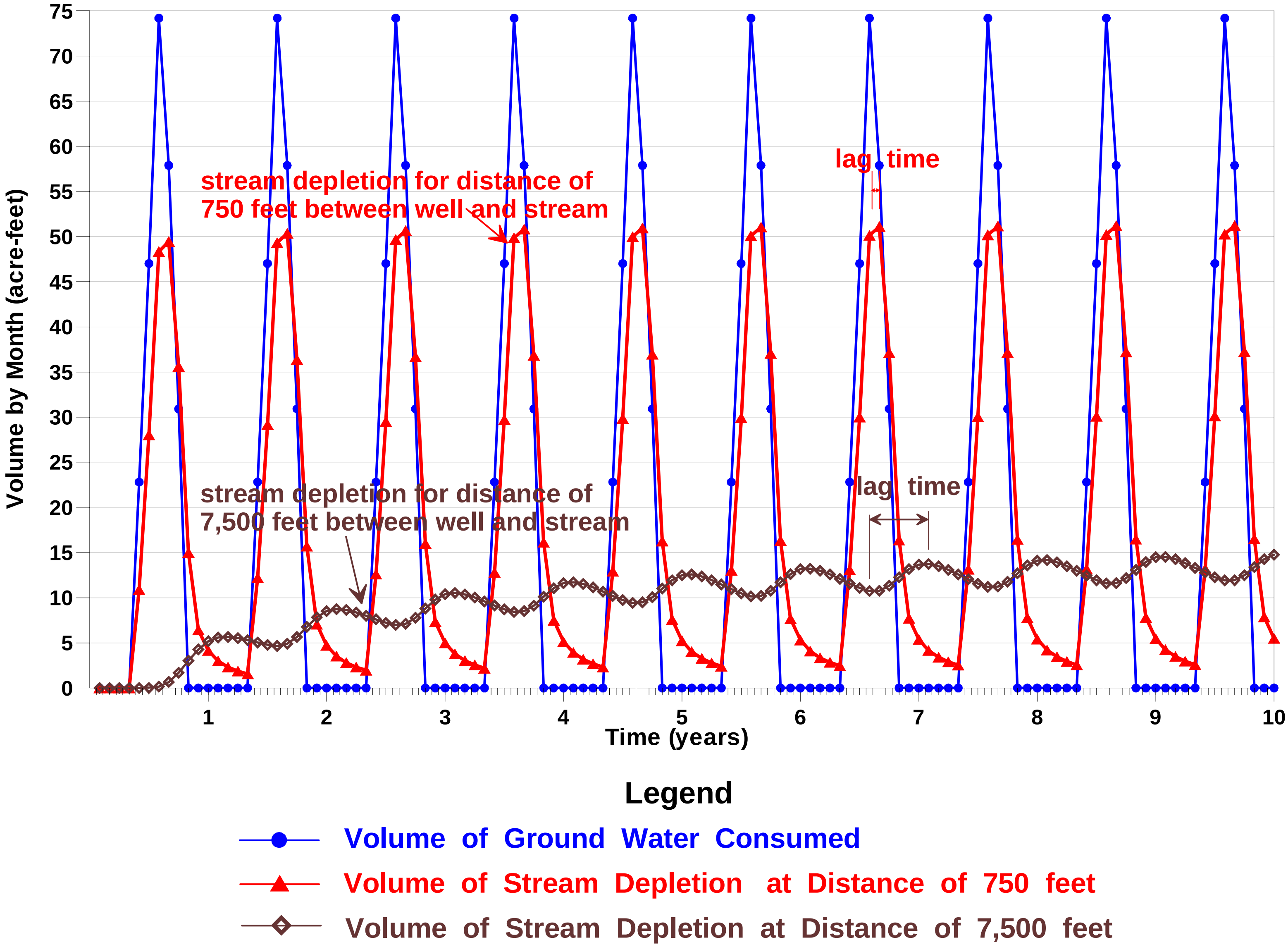
7. Pumping Schedule and Depletion Results:

Below, enter the Pumping Rate (Col C, yellow cells) corresponding with the associated Pumping Period. After the data have been entered, click on the button below to calculate the resulting stream depletion.

Calculate Stream Depletion

Pumping Schedule			Pumping Summary		Depletion Summary		
Date	Pumping Period (months)	Pumping Rate (gpm)	Volume Pumped This Period (acre-feet)	Cumul. Volume Pumped (acre-feet)	Depletion Rate (gpm)	Volume of Depletion (acre-feet)	Volume of Depletion This Period (acre-feet)
1/1/2008	1	0.00					
2/1/2008	2	0.00					
3/1/2008	3	0.00					
4/1/2008	4	0.00					
5/1/2008	5	169.70					
6/1/2008	6	349.78					
7/1/2008	7	551.99					
8/1/2008	8	430.64					
9/1/2008	9	230.04					
10/1/2008	10	0.00					
11/1/2008	11	0.00					
12/1/2008	12	0.00					
1/1/2009	13	0.00					
2/1/2009	14	0.00					
3/1/2009	15	0.00					
4/1/2009	16	0.00					
5/1/2009	17	169.70					
6/1/2009	18	349.78					
7/1/2009	19	551.99					
8/1/2009	20	430.64					
9/1/2009	21	230.04					
10/1/2009	22	0.00					
11/1/2009	23	0.00					
12/1/2009	24	0.00					
12/1/2016	108	0.00					
1/1/2017	109	0.00					
2/1/2017	110	0.00					
3/1/2017	111	0.00					
4/1/2017	112	0.00					
5/1/2017	113	169.70					
6/1/2017	114	349.78					
7/1/2017	115	551.99					
8/1/2017	116	430.64					
9/1/2017	117	230.04					
10/1/2017	118	0.00					
11/1/2017	119	0.00					
12/1/2017	120	0.00					

Figure 13. Stream Depletion Graphs



T = 5,000 ft^2/day
Sy = 0.10
Acres Irrigated = 150 acres

Requested Volume = 336 acre-feet
Consumptive Use = 208.25 acre-feet
Period of Use = May 15 - Sep 15

Summary Comments

- Hydrogeologic analysis consists of aquifer testing from which aquifer properties are evaluated.

- Consumptive crop use determined with Blaney - Criddle Formula and published by NRCS.

- Stream depletion software uses aquifer properties and consumptive use data to approximate stream depletion impacts.

  - T, S, and distance from well to stream control development of stream depletion,

  - stream depletion develops quickly when well is near stream (i.e. within days to weeks),

  - stream depletion develops slowly when well is far from stream (i.e. within months to decades),

  - stream depletion stabilizes when depletion during one cycle equals depletions during succeeding cycles,

  - equilibrium occurs when stream depletion equals consumptive use.