AQUIFER TEST IMPLEMENTATION

BILL MILLER, P.G.
SUSQUEHANNA RIVER BASIN COMMISSION

AQUIFER TEST IMPLEMENTATION

- Once your Aquifer Test Plan is approved…
  - Usually two years to complete the aquifer test
  - The majority of failed tests originate with implementation issues

WHY TEST?

The goal of the aquifer test is to produce data adequate to evaluate the short and long term impacts of the water withdrawal/use

1. Sustainable withdrawals
2. Impacts to competing groundwater or surface water users
3. Impacts to the environment

The goal of the aquifer testing is the collection of appropriate data

NOT

A task checklist

Approved Aquifer Test Plan to Failed Aquifer Test…

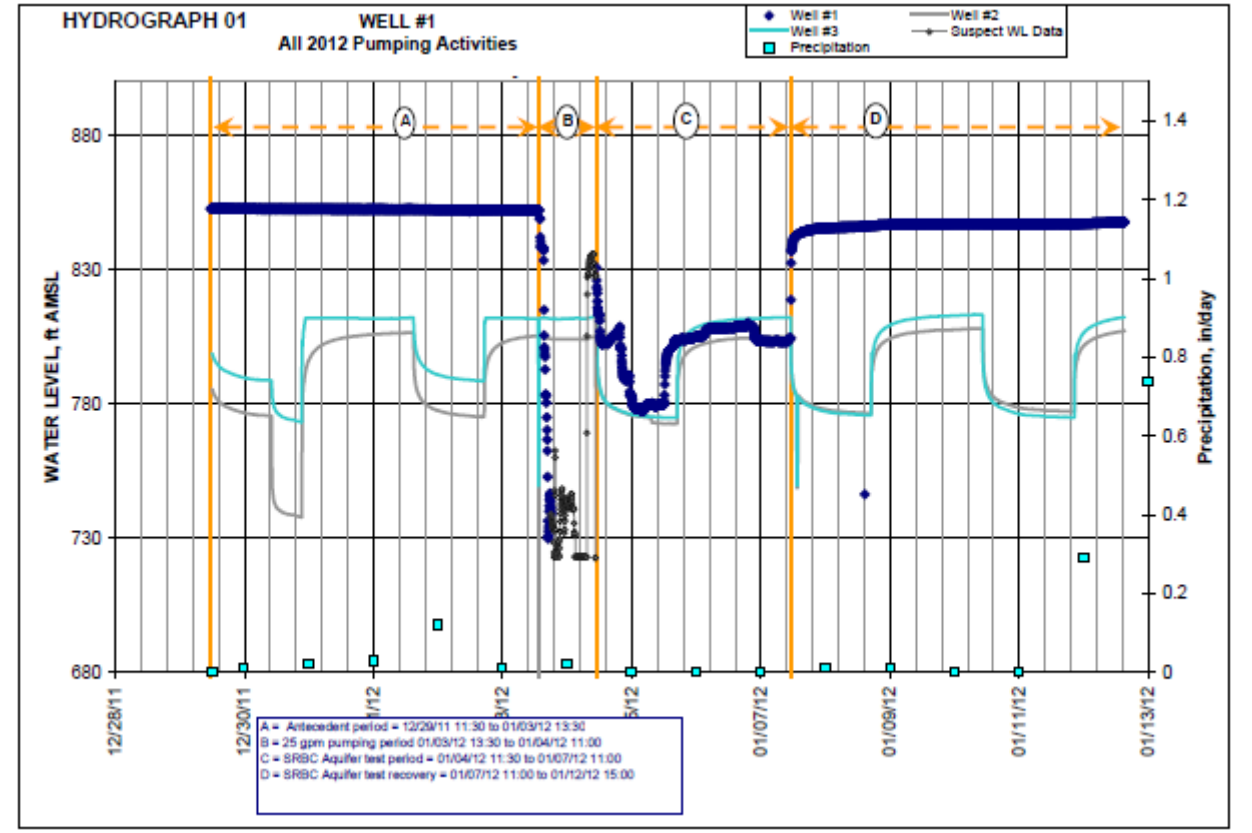
Poor Execution of a Good Plan

Rigid Execution of a Good Plan under Changing Conditions

AQUIFER TESTING IMPLEMENTATION

- Consultant should be the expert on the site
- Suggested that consultants follow the format of the guidance
- ***Minimize variables during testing – control everything that is controllable***

OVERSIGHT, DATA REVIEW AND ANALYSIS



COMMUNICATION

- Public Water System / Project Sponsor
- Consultants
- Regulatory Agency (SRBC/PADEP)

AQUIFER TESTING IMPLEMENTATION

Minimize variables during testing – control everything that is controllable

SELECTING APPROPRIATE TESTING CONDITIONS

- Evaluating both short and long term impacts
- Implications for the selection of testing conditions
  - Wetter period may be appropriate with low groundwater elevation seasonal variation
  - Dryer period typically selected – but implications for surface flow
- Could result in post-approval conditions

AQUIFER TESTING IMPLEMENTATION

- Master prognosticator
  - Finding testing window can be challenging
  - Monitoring network often in place collecting background data, waiting for opportunity to test
  - Look for periods with low probability for precipitation
  - During winter, consider the possibility of snowmelt
  - Weather.com; NOAA; Weather Underground; CoCoRaHS
- Tests may be invalidated by too much precipitation
  - Surface water monitoring points tend to be most sensitive

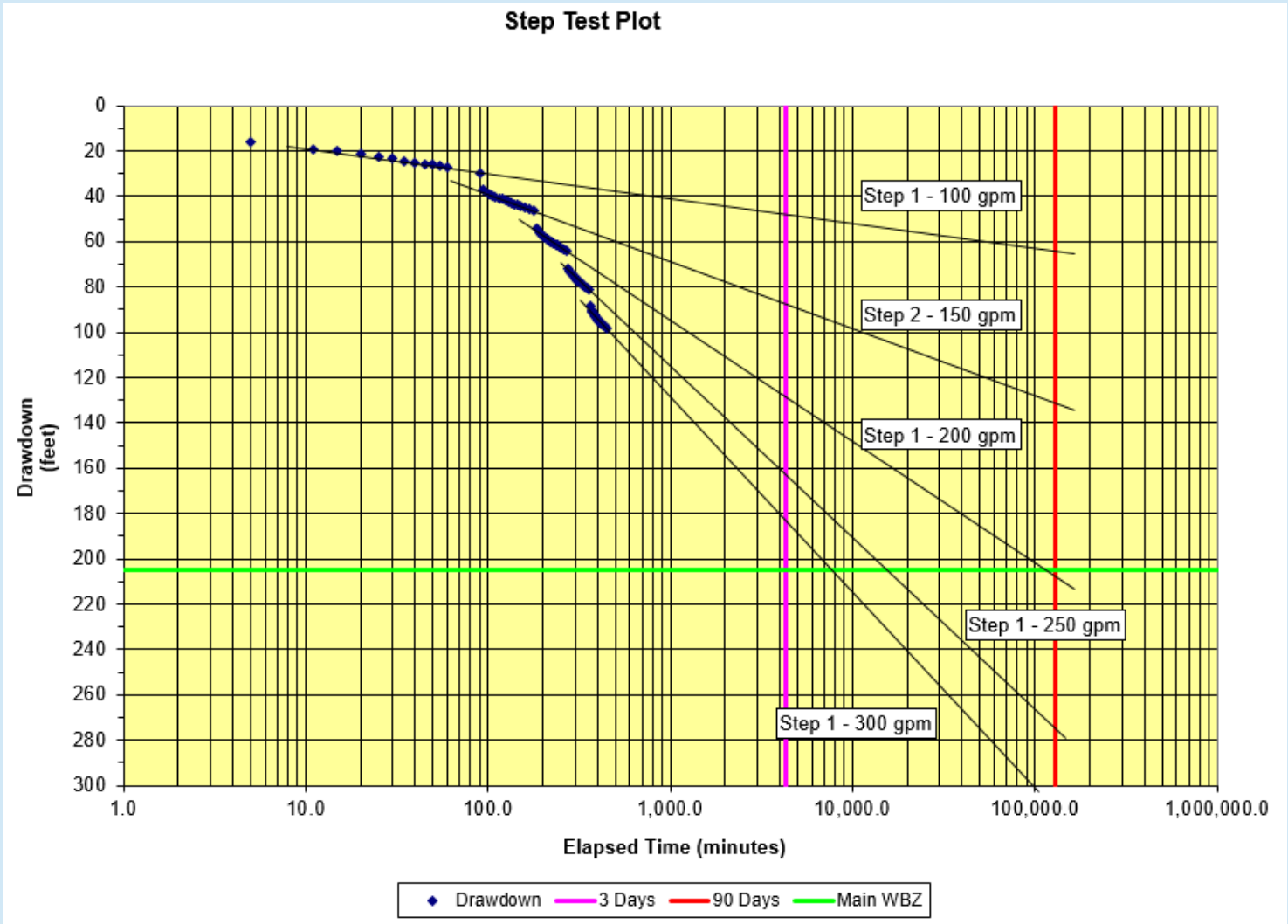
Aquifer Testing

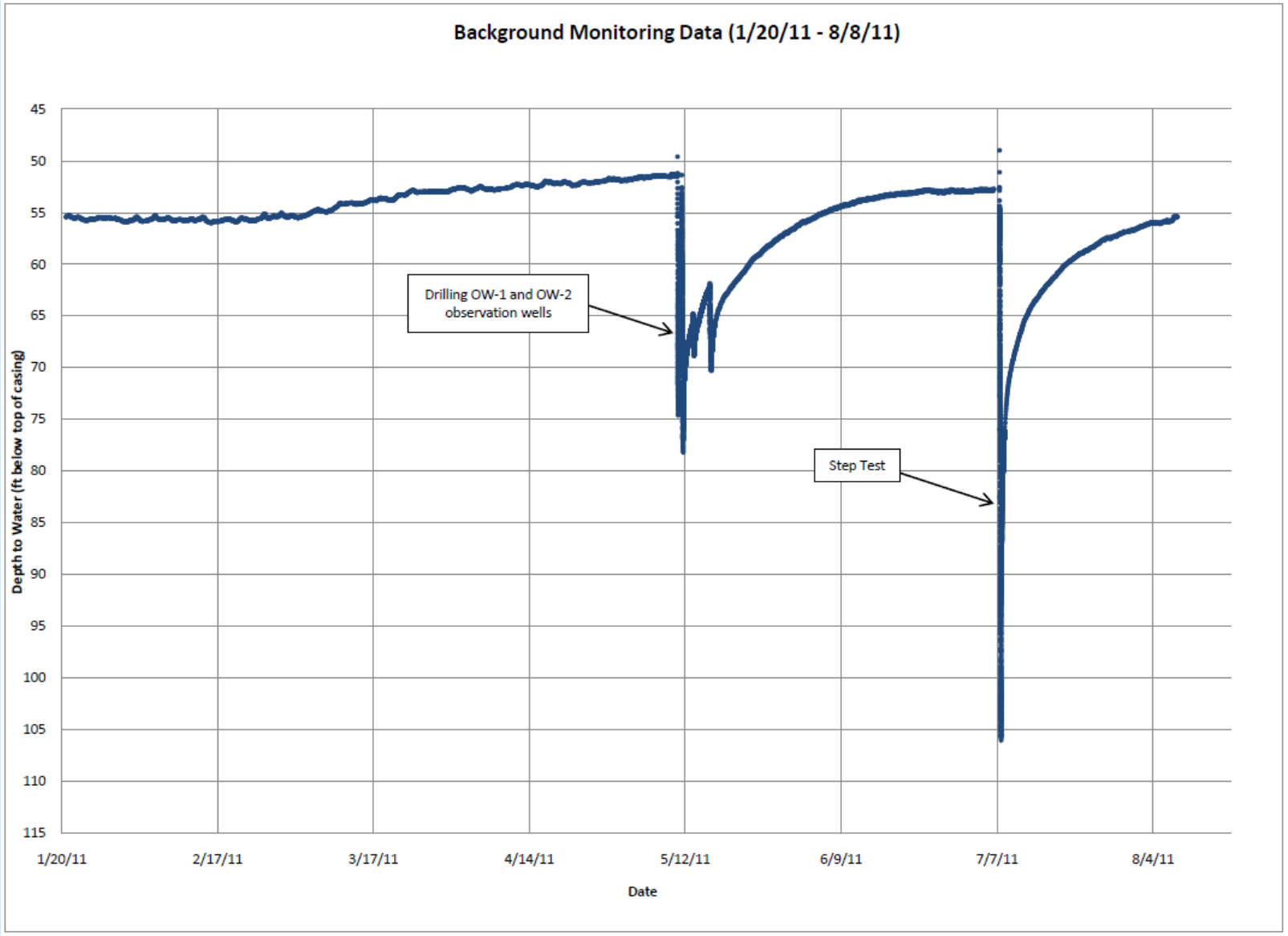
- Step Test
- Background Monitoring
- Constant-Rate Aquifer Test
- Recovery Test

STEP TEST

- Only required if the proposed production well is to be used as one of the two points in a distance-drawdown analysis, but…
- Can provide information that could be helpful during the constant-rate test
  - Well efficiency at various rates
  - Can be conducted in advance of the remainder of the testing
  - Select locations can be monitored to refine the monitoring network
  - The pumping may be continued at a selected rate to provide additional information

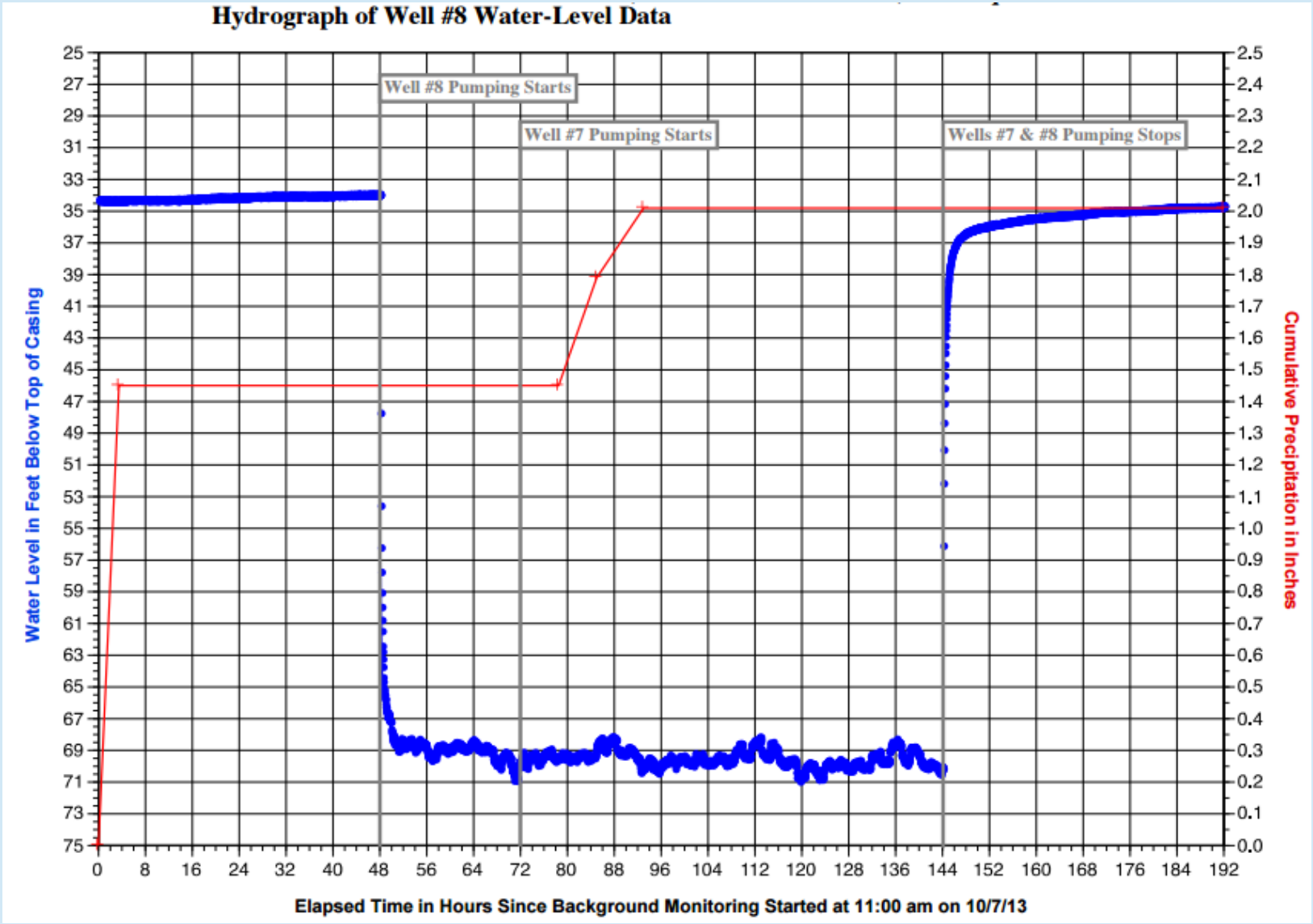
STEP TEST

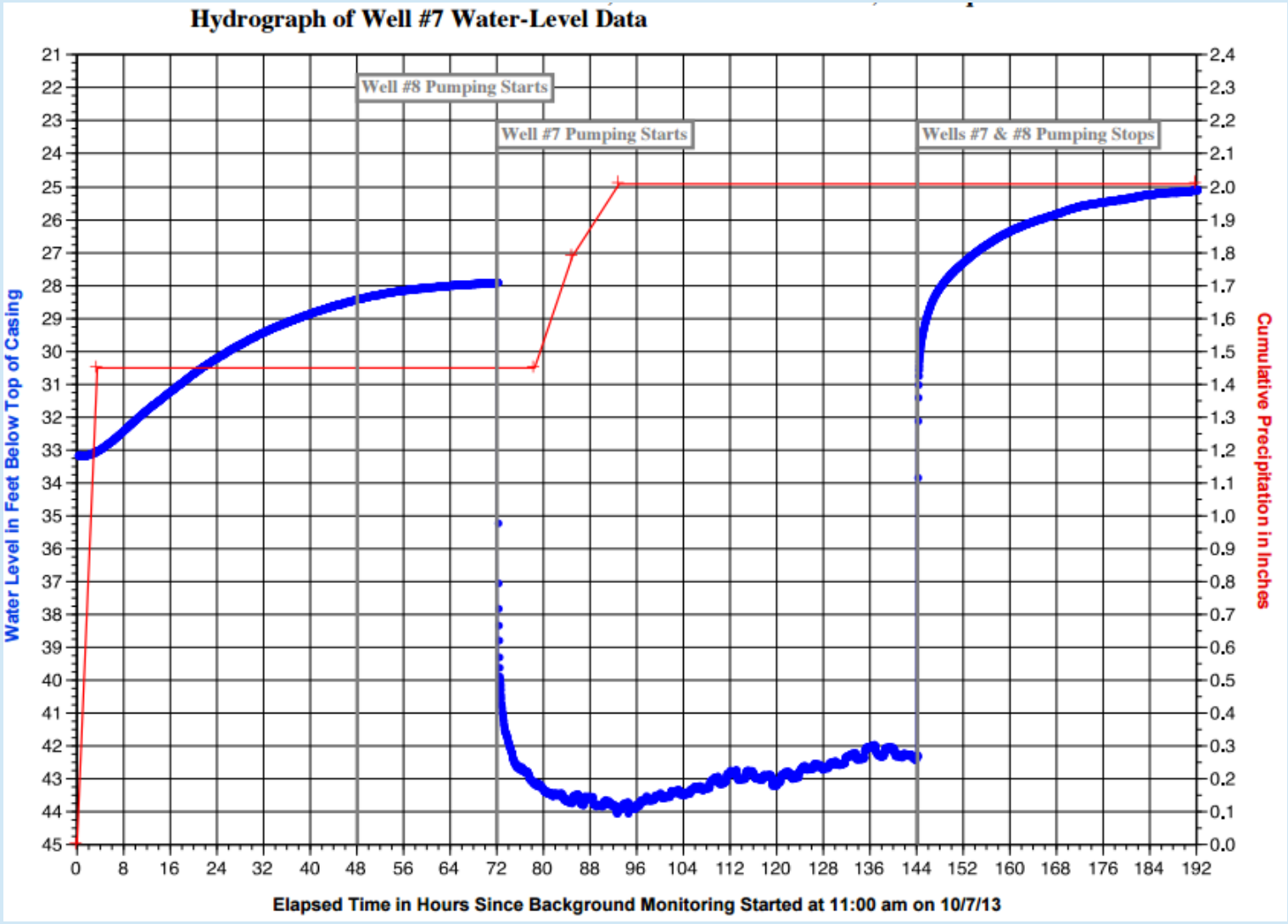

Step Test Plot
Drawdown (feet)
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
1.0
10.0
100.0
1,000.0
10,000.0
100,000.0
1,000,000.0
Elapsed Time (minutes)
Step 1 - 100 gpm
Step 2 - 150 gpm
Step 1 - 200 gpm
Step 1 - 250 gpm
Step 1 - 300 gpm
Drawdown
3 Days
90 Days
Main WBZ


Background Monitoring Data (1/20/11 - 8/8/11)
Depth to Water (ft below top of casing)
45
50
55
60
65
70
75
80
85
90
95
100
105
110
115
1/20/11
2/17/11
3/17/11
4/14/11
5/12/11
6/9/11
7/7/11
8/4/11
Date
Drilling OW-1 and OW-2 observation wells
Step Test

BACKGROUND MONITORING

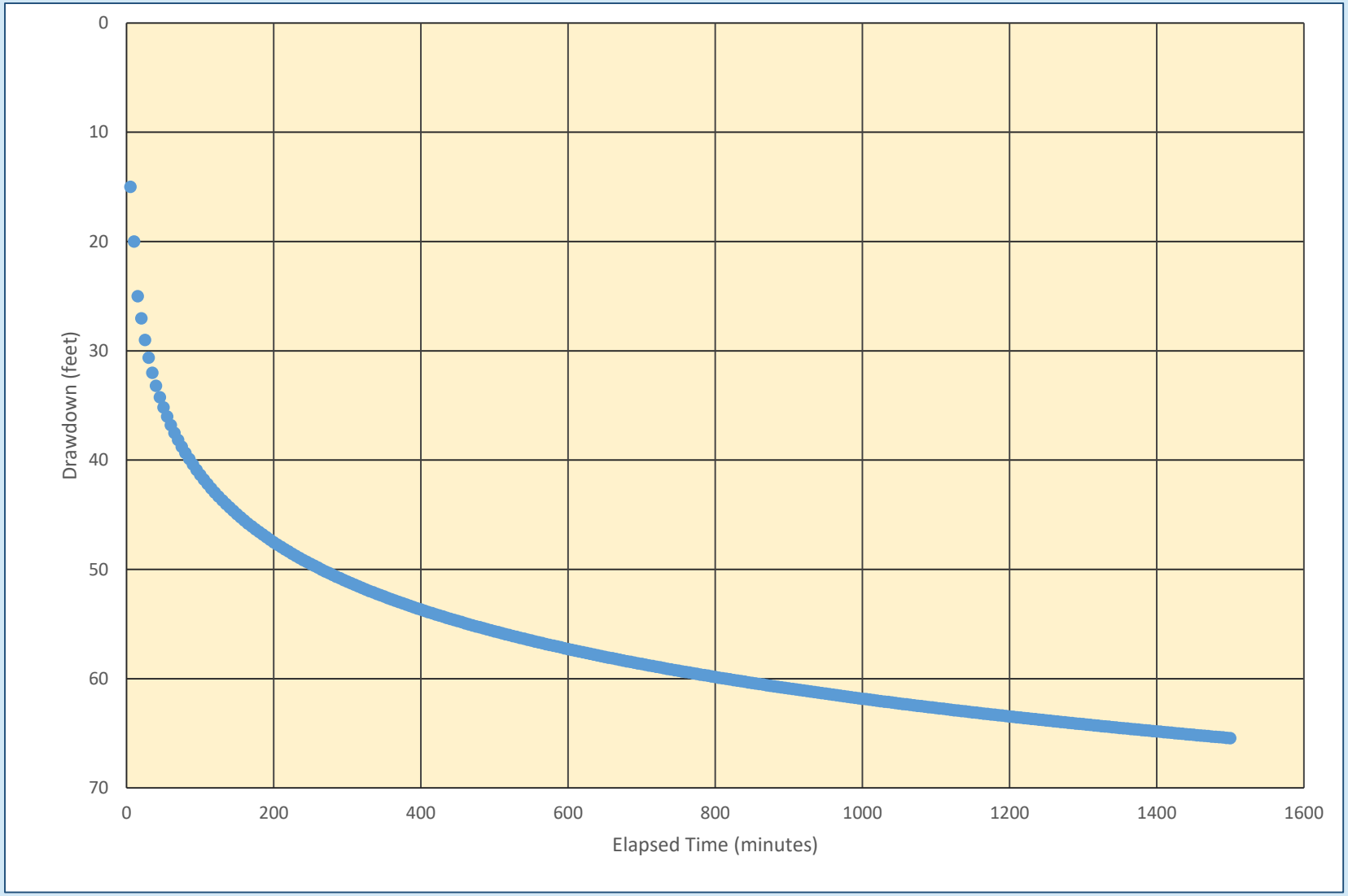
- Begins after 90% recovery from step test
- At least 48 hours (72-hours in PADEP guidance)
- Demonstrate asymptotic groundwater and recessional surface water trends (base flow) in monitoring network prior to starting test
- Additional background monitoring may be required for some projects (e.g. projects with other pumping wells)
- No pumping of test well during background period.

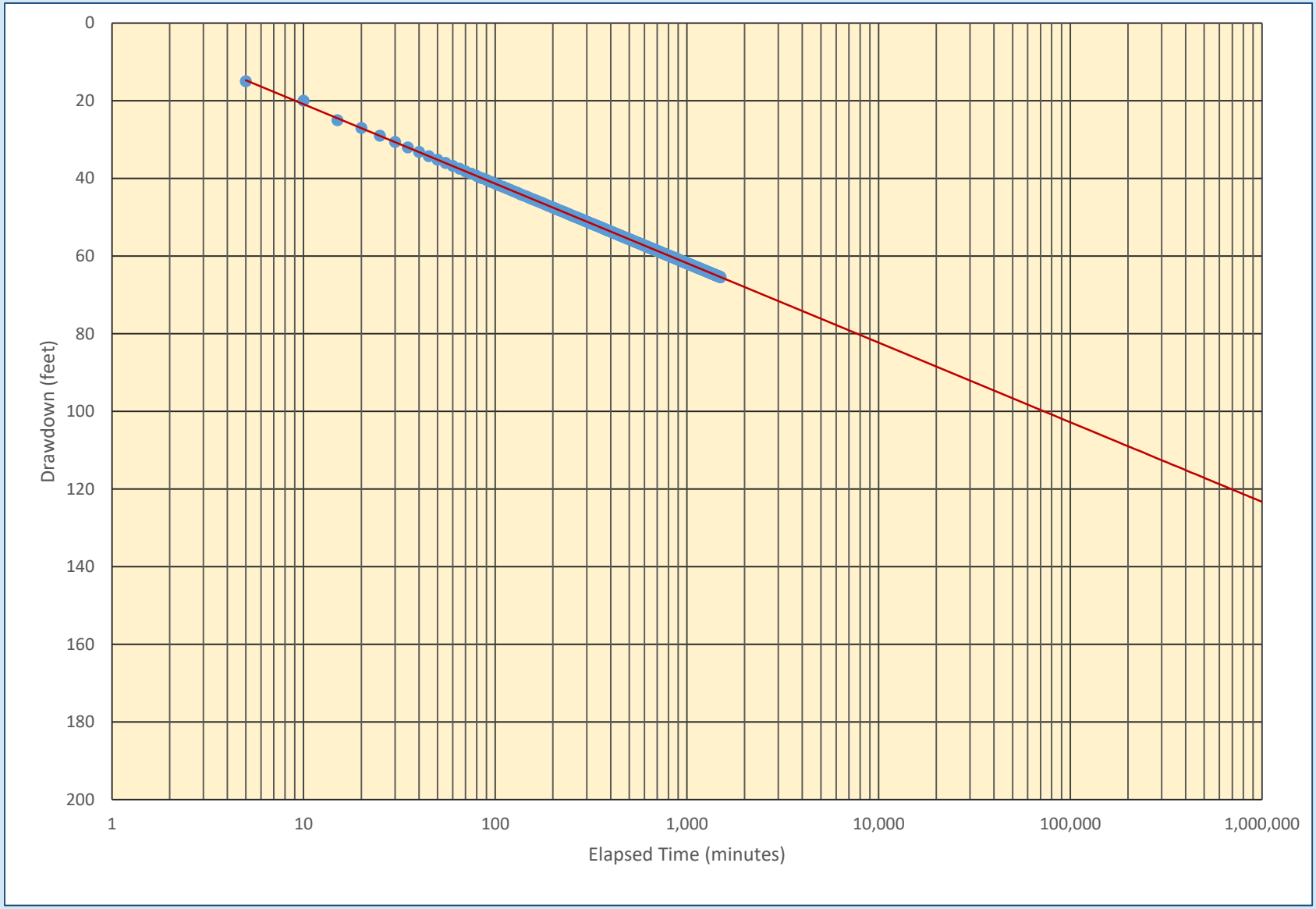

Hydrograph of Well #8 Water-Level Data
Well #8 Pumping Starts
Well #7 Pumping Starts
Wells #7 & #8 Pumping Stops
Water Level in Feet Below Top of Casing
Cumulative Precipitation in Inches
Elapsed Time in Hours Since Background Monitoring Started at 11:00 am on 10/7/13

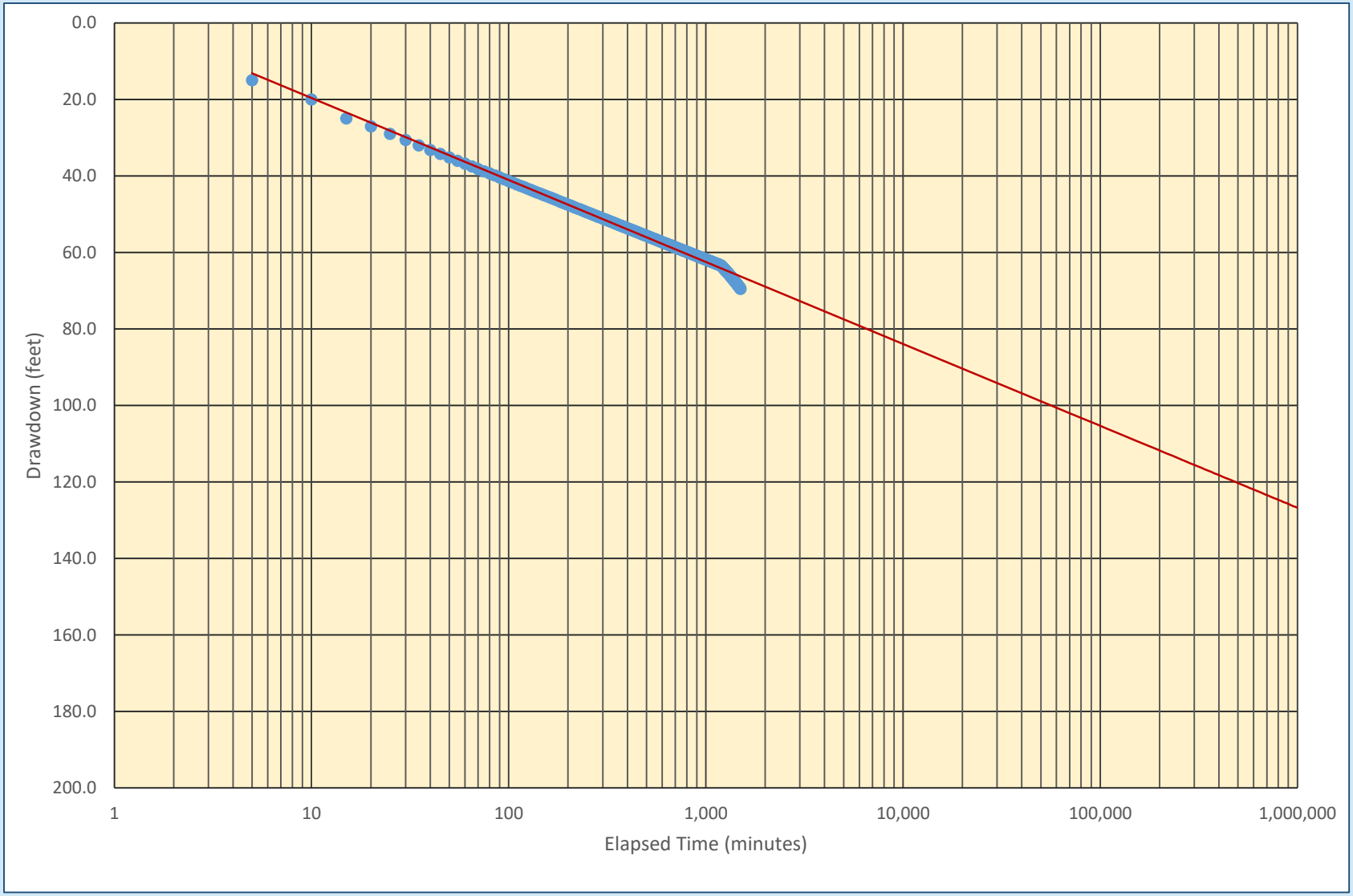

Hydrograph of Well #7 Water-Level Data
Well #8 Pumping Starts
Well #7 Pumping Starts
Wells #7 & #8 Pumping Stops
Water Level in Feet Below Top of Casing
Cumulative Precipitation in Inches
Elapsed Time in Hours Since Background Monitoring Started at 11:00 am on 10/7/13

CONSTANT-RATE AQUIFER TESTING

- Begins immediately after background period
- Assess sustainability
- Evaluate the potential for adverse impacts
- Predict impacts from long-term pumping


0
10
20
30
40
50
60
70
Drawdown (feet)
0
200
400
600
800
1000
1200
1400
1600
Elapsed Time (minutes)


0
20
40
60
80
100
120
140
160
180
200
Drawdown (feet)
1
10
100
1,000
10,000
100,000
1,000,000
Elapsed Time (minutes)


0.0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
160.0
180.0
200.0
Drawdown (feet)
1
10
100
1,000
10,000
100,000
1,000,000
Elapsed Time (minutes)

RECOVERY TEST

- Immediately follows constant-rate test
- At least 24-hours and until aquifer has recovered to at least 90% of pretest levels, minus groundwater recession
- Useful in assessing sustainability of proposed withdrawal

GENERAL PERFORMANCE REQUIREMENTS

GENERAL PERFORMANCE REQUIREMENTS

1. The generally recommended length of the aquifer constant-rate test is 72 hours. A longer or shorter test may be appropriate to evaluate aquifer and well capabilities, as well as potential impacts to existing water supplies and the environment. The project hydrogeologist must recommend an adequate pumping test length demonstrating due diligence for site characterization and long-term protection of the resource, and provide a rationale for that recommendation. However, the duration may need to be increased during the test in response to ongoing test results.

- A shorter duration test may be appropriate, particularly under changing conditions.

- Test duration may need to be extended in response to test results and changing conditions (Monitor test results).

Extending Constant-Rate Test Duration

- Test interruptions
  - Pump problems
  - Generator/power problems
  - Other Murphy's Law considerations

- Generally, test should be extended by the amount of time to re-establish the pumping level and drawdown trend.

- **Data review and analysis during testing.**

GENERAL PERFORMANCE REQUIREMENTS

2. Aquifer tests must be performed on wells that are considered to be completed and fully developed. Wells exhibiting incomplete development characteristics (i.e., turbidity spikes or unexplained water level fluctuations) may require an extension of the pumping phase or retesting. In carbonate, unconsolidated, or deeply weathered formations, continuous turbidity monitoring will be necessary, and the proposed monitoring methodology should be described in the aquifer test plan. Wells exhibiting well development episodes during the testing must demonstrate development-free performance during the last 72 hours of testing.

- May result in extended constant-rate test duration
- Development and turbidity issues can be evaluated during step testing
- **Data evaluation during testing**

GENERAL PERFORMANCE REQUIREMENTS

3. Discharge from the proposed production well must be routed such that recirculation does not occur. This typically results in a discharge point 300 to 500 feet down dip (bedding, schistosity, etc.) from the proposed pumping well, but may be 2,000 feet or more in karst-prone carbonate formations. Recirculation will invalidate the test and will require retesting.

- Inspect discharge pipe/hose at test start-up and periodically during the test.
- Use appropriate energy dissipation devices at discharge point

GENERAL PERFORMANCE REQUIREMENTS

8. The proposed production well may be pumped at any rate desired, but must be pumped at a constant rate for the test duration specified in the approved plan (recommended 72 hours). The Commission will not approve the well for operation at a rate higher than the average tested rate.

9. The pumping rate of the proposed production well must be monitored with an appropriate flow measurement device that is accurate to within 5 percent. The flow rate should be held constant to within 5 percent of the target flow rate for the duration of the test or the test will likely not qualify as a constant-rate test and may have to be rerun.

10. Valving must allow adjustment of the pumping rate to within the required tolerances.

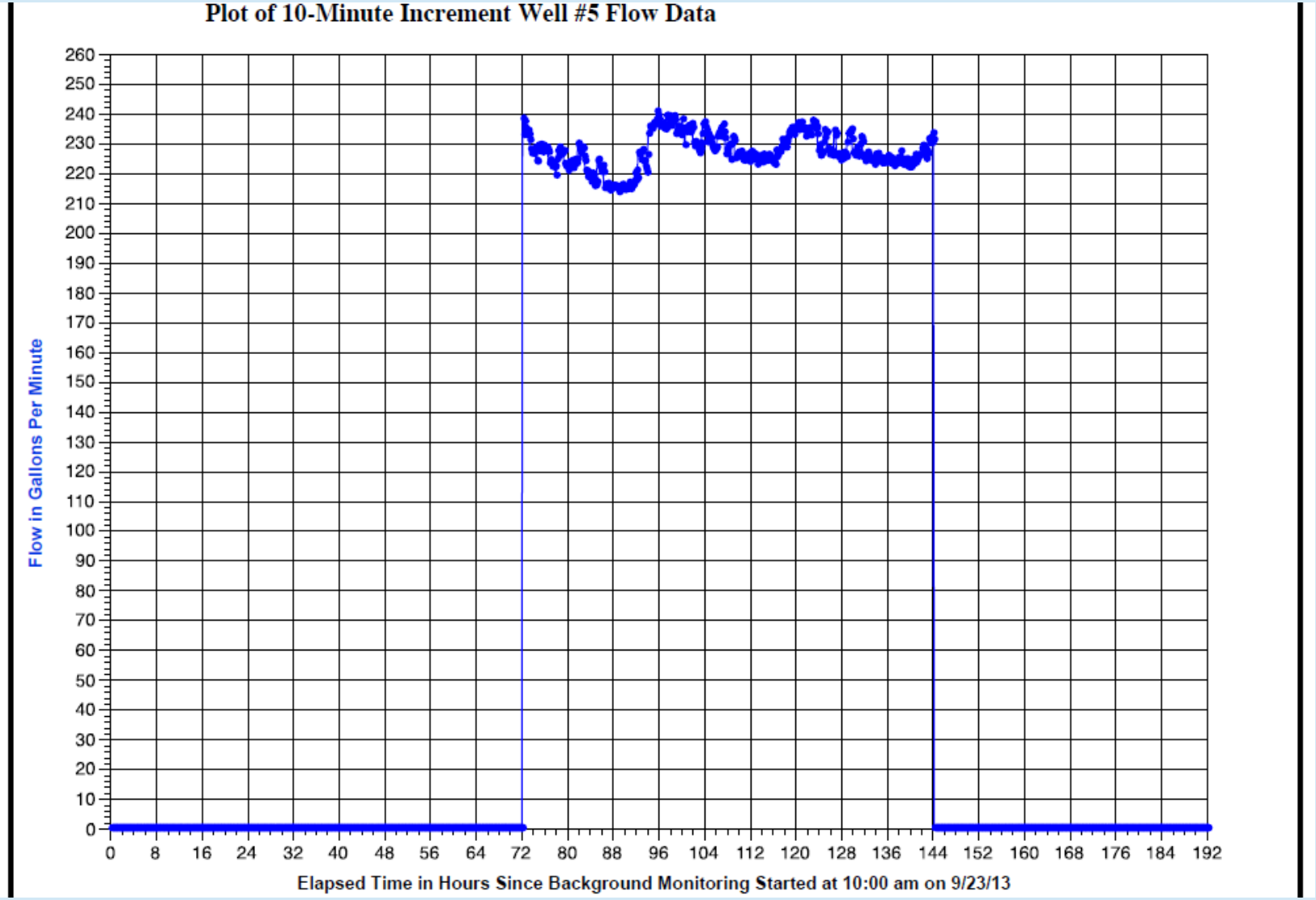
    - Make sure that the test is not started at maximum valve settings. Must be able to adjust to maintain rate with falling head.

5 % of the target flow rate

- Considerations:
  - Under-developed well
  - Sustainable yield over-estimated based on blown yields
- Step Tests can be very useful to refine target aquifer test rates
- Pumping rate is one of the data trends that should be evaluated in addition to being documented.

SYSTEM OPERATION DURING TESTING

- Refer to Aquifer Test Plan. Check implementation.
- Communicate plans to all parties.
- Communicate with SRBC staff if any changes are necessary.
- Goal is to isolate impacts as a result of pumping the test well
- Extended background periods may be needed to establish steady-state or near steady-state conditions
- **May be extremely important part of plan – often overlooked or not adequately considered**


Plot of 10-Minute Increment Well #5 Flow Data
Flow in Gallons Per Minute
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220
230
240
250
260
0
8
16
24
32
40
48
56
64
72
80
88
96
104
112
120
128
136
144
152
160
168
176
184
192
Elapsed Time in Hours Since Background Monitoring Started at 10:00 am on 9/23/13

GENERAL PERFORMANCE REQUIREMENTS

11. The flow rate (gallons per minute) and cumulative flow (total gallons pumped) should be recorded at a minimum of once per hour. Do the math!

12. All flow rate adjustments must be documented with a measurement of flow before and after adjustment, the time at which the adjustments were made, and a rationale for the adjustment. This information must be included in the hydrogeologic report.


1 3 5 6 4 1 0
Gallons
Model
25
Recordall
13836 • 007
0596
ANALOG

GENERAL PERFORMANCE REQUIREMENTS

13. If a well exhibits unexpectedly excessive drawdown, testing should be suspended. After full recovery, the test should be restarted.

15. A test with a declining pumping rate due to excessive drawdown or inadequate pump capacity will be considered a failed test and will require retesting.

- **Monitor and evaluate during testing**

GENERAL PERFORMANCE REQUIREMENTS

14. Any change in the trend of the time-drawdown curve, such as might be caused by a positive/recharge boundary or negative/barrier boundary encountered during the test, must have a record of at least 24 hours. Therefore, any boundary condition encountered during the last 24 hours of pumping will require that the test be extended.

GROUNDWATER MONITORING GUIDANCE

- Don’t request that wells in use change their usage patterns. Groundwater elevation data still useful and can also be used to better evaluate impacts to other wells.

- Monitoring devices

AUTOMATIC WATER RECORDERS (PRESSURE TRANSDUCERS)

- Two cable types – vented and unvented.
  - Vented – Make sure to use desiccants. Install with end connection pointing downward so water does not collect and migrate down vent line.
  - Unvented – Sealed, so no condensation/water issues, but a barometric transducer MUST also be used. Barometric compensation MUST be conducted for any submitted data.

- They can and do fail. ALWAYS collect manual back-up measurements.

AUTOMATIC WATER RECORDERS (PRESSURE TRANSDUCERS)

- Operation of transducers should be verified prior to background monitoring and then rechecked prior to the constant-rate test.
  - Check battery levels
  - Check units and test programming
- Transducers should be downloaded and data evaluated during testing phases. Direct read cables are recommended.
- Any time a transducer is deployed, disturbed or removed, a manual measurement should be collected before and afterwards.

AUTOMATIC WATER RECORDERS (PRESSURE TRANSDUCERS)

- Select appropriate PSI ratings
- Install to monitor expected groundwater range
- If groundwater level falls below transducer, the transducer should be lowered – again, collect a manual measurement before and after adjustment.
- Installation of a stilling tube can dampen pump effects and ease deployment and retrieval.

SURFACE WATER MONITORING GUIDANCE

- Ponds and wetlands without flow:
  - Install hydraulically separated piezometers

- Flowing surface water (including pond and wetlands discharges as well as springs and streams)
  - Quantitative analysis (instrumented weir or flume) when the proposed withdrawal exceeds 10% of the flow at the time of testing (DIRECT MEASUREMENT)
  - Streambank piezometers may be used when the proposed withdrawal rate is less than 10% of the flow at the time of testing (INDIRECT MEASUREMENT)

WEIRS AND FLUMES

- Reliable measure of 10% of the proposed withdrawal or natural flow rate, whichever is smaller
- 10% change in flow must correspond to at least 0.01 feet of change in the device (1/8 inch)
- Must be suitable for range of flows expected during testing

WEIR SELECTION

- Minimum water depth for V-notch weirs is 2.9 inches to measure 10% change in flow as at least 1/8 inch in level change.
- Minimum water depth for rectangular weirs is 1.8 inches
- V-notch angles and rectangular weir width determine the minimum flow rate measurable.
- Select appropriate weir angle/width or flume throat size for anticipated flow volume.

V-Notch (Triangular) Weir Calculator

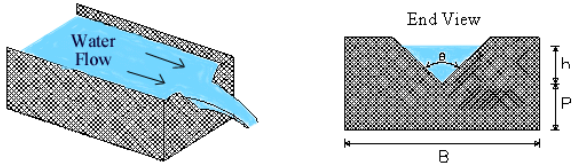
Discharge and Head Calculations, Equations, and Guidelines for water flow measurement in streams and channels.

V-Notch weir (triangular weir) calculation is mobile-device-friendly as of January 21, 2014

Solve for: Discharge ▾ | Click to Calculate | Initial Values

Discharge, Q:	32.282204	gal/min (gpm) ▾
Head, h:	0.24	ft ▾
Notch Angle, θ:	90	degrees ▾
Discharge Coefficient, C:	0.57790489	
Head Correction Factor, k:	0.0029025168	ft

 http://www.LMNOeng.com



Units in V-notch weir calculation: ft^3=cubic foot, gal=US gallons, m^3=cubic meter, mm=millimeter, s=second

To:
LMNO Engineering home page (more calculations)

Related calculations:

Weirs:
Rectangular
Cipoletti

End Depth Method:
Circular
Rectangular
Triangular

Flumes:
Parshall (submerged)

Parshall, Trapezoidal, Rectangular, and U shape

http://www.lmnoeng.com/Weirs/vweir.php


9
8
7
6
5
4
3
2
1
1.0
9
8
7
6

PRECIPITATION MONITORING

- On-site instrumentation is recommended, to nearest 0.1 inches
- 12-hour interval through all phases of testing
- Note the duration of any precipitation events
- Rain gages should be unobstructed
- Snow should be recorded as a liquid equivalent

SUMMARY

- Collect manual back-up measurements. Automated equipment and systems can fail. Monitor equipment operation.

- Evaluate all collected data during the test. Compare the results against the General Performance Guidelines.

- Select a testing period that minimizes variables and maximizes the collection of direct measurements of the tested variables.

- Communicate changing conditions, unexpected results.

EXTENDING THE CONSTANT-RATE TEST

- Constant-rate test interruptions due to pump, power of other concerns.
- Unexpected precipitation once the test has started.
- Changes in the rate of drawdown in the last 24 hours of the test.

POTENTIAL FAILED TEST SITUATIONS

- Recirculation of discharged water.
- Pumping rate variation in excess of 5% of the target withdrawal rate.
- Excessive drawdown
- Decreasing pumping rate due to excessive drawdown and inadequate pump capacity (a constant-level instead of a constant-rate test).
- Precipitation

How to Find a Geologist

- References
- Referrals
- Pennsylvania Department of State
  - https://www.pals.pa.gov/#/page/search
  - Search for Engineers as Profession Type

Big Firms vs. Local Experience

- Local experience can be valuable – assess against the potential increased resources of a large firm
- Can depend on the work scope
- Plumber vs. Electrician
- Interview and assess the project team to be assigned to your work.

Other Considerations

- Listen to your consultants
  - But, if something doesn't feel right…
- Your project – your water. Stay involved
- Aquifer testing has value
  - Can guide operations – rates and duration of pumping. Well operating rotation.
  - Provides a baseline to which future well performance can be compared.

SRBC Staff Observations

- Poor advice on project and application requirements.
- Choosing consultant based on pre-conceived impressions.
- Poor knowledge of local conditions.
- Consultant recommendation of unnecessary work.
- Communicate with Commission staff early and often through the project.

QUESTIONS ?