WELL 7 FLOW TESTING JULY 5 and 8, 2006

By

Dick Benoit

July 15, 2006

INTRODUCTION

On July 8, 2006 the most complete production and interference test yet conducted at Chena hot springs was performed on Well 7 at its final completion depth of 713'. This test follows a much shorter test performed on July 5 when the well was at a depth of 616' (Benoit, 2006a). At a depth of 616' Well 7 produced enough fluid to water out the hammer tool but deepening the nearby TG-9 well from 460' to 800' in April 2006 improved the flow rate from 116 gpm to 385 gpm (Benoit 2006b). With this past experience it was anticipated that deepening would similarly improve Well 7.

On July 8 Well 7 was flowed for 7 hours and 55 minutes at rates of 240, 186, and 87 gpm. The total production was 91,000 gallons. A detailed static log Kuster log was run with stops every 2 meters in Well 7 before flow commenced. After the well was flowing the downhole pressure changes associated with start of flow, flow rate changes, and shut in were monitored with the Kuster tool. Also, two traversing logs were run in the lower part of the well during flow to document in detail the locations of the fluid-entry points with differing temperatures.

During the flow test wellhead pressures were periodically recorded by hand on wells TG-8 and TG-9. Three capillary tubing systems with Madgetech data loggers recorded the downhole pressures at sampling rates of 10 seconds to one minute in TG-1, Well 4, and Well 2. A Kuster tool was hung in TG-7 at a depth of about 485' to record the downhole pressures and was allowed to remain hanging overnight following the test. All of this instrumentation recorded at least some clear response to Well 7 flowing, demonstrating that all of the permeable wells from Well 2 and TG-7 to TG-9 are in good pressure communication with Well 7.

JULY 8 FLOW TEST CHRONOLOGY

The major activities on the flow test are shown in Table 1. The wellhead and flow line are shown on Figure 1. Zero depth on all of the Well 7 logs through July 15 is the 2" valve located on the top of the wellhead, about 3' above ground level.

TABLE 1 JULY 8 TEST CHRONOLOGY

Time	Comments
10:30 July 8	Start static Kuster downlog with 2 meter stops
12:43	Finish static downlog at depth of 713 feet and hang for flow test
13:06:10	Open well to its maximum artesian flow rate of 240 gpm
13:39	Start logging up from 713 to 658 feet for flowing log
14:00	Start logging down from 658 to 713 feet
14:19	Reach 713 feet and hang
16:27	Start logging up to 538 feet for second flowing log

16:51	Reach 538 feet
16:56	Start logging down from 538 to 713 feet
16:57	Start hanging at 713 feet
17:39	Throttle well back to flow rate of 186 gpm
19:10	Throttle well back to flow rate of 87 gpm
21:02:05	Shutin well 7
09:40 July 9	Start logging up with Kuster tool to pull out of hole
10:21	Kuster tool in lubricator

WELL 7 STATIC AND FLOWING TEMPERATURES

Well 7 Static Temperatures

The July 8 static log is very similar to the July 5 static log, but much improved by a longer equilibration time after drilling (2-3 days), being 97’ deeper, and having 6.5’ intervals between data points rather than 33’ intervals (Figure 2). There is a temperature maximum of 169 F at a depth near 590’. Below 636’ Well 7 is isothermal at a temperature of 166.9 F. This static profile certainly suggests the possibility of vertical flow within the wellbore below 636’. A second inflection on the static log indicative of a permeable interval is at a depth near 610’ which corresponds nicely with the drillers report of the hammer being watered out at a depth of 616’.

Well 7 Flowing Temperatures

The flowing logs present a complex picture of multiple inflow points with significantly different temperatures (Figure 3). The shallowest apparent inflow into the well is near a depth of 575’. No traversing flowing logs were run above a depth of 538’. The flowing temperatures at 570’ represent the overall or average fluid-entry temperature into the well. This temperature decreased from at least 165.2 to 164.4 F during the test. Given that this well was flowed only a few days after drilling was completed, it is possible that this pressure decrease represents a return of lost drilling water but it is something that needs some further observation or monitoring.

The temperature maximum depth of 590’ on the static logs is a temperature minimum on the flowing logs. This shows the importance of this interval to production as the relatively low temperatures here tend to dominate the overall flowing temperature. The difference between static and flowing temperatures at 590’ during the measurement period was as much as 5.4 F.

Below 590’ the flowing temperatures rapidly increase to 167 F at depth of 630 to 640’ with one consistent inflection on all 3 flowing logs at 616’. Below 640’ the flowing and static temperatures are basically identical with the exception of a 0.1 F cooling of all the flowing temperatures at the very bottom of the well. This implies that at least some minor permeability extends from 570’ to the bottom of the well at 713’.

The flowing temperature logs indicate the presence of significant permeable intervals at depths 570-580’, 590’, 616’, and 630-640’. Smaller permeable intervals may be present between 695 and 705’ and at 713’.

TG-8 and TG-9 Flowing Temperatures

Flow testing in April showed fluid-entry temperatures of 172.6 F in TG-8 (Figure 4) (Benoit, 2006d). These are the hottest temperatures yet measured at Chena. The TG-9 flowing temperature logs in April showed a progressive decrease of the combined fluid-entry temperatures from 162.86 to 162.1 F (Figure 4). Therefore, the presently measured temperatures of 164.4 F in Well 7 are slightly higher than those measured in TG-9 on April 18, the most recent time they were measured. It is probably realistic to expect that the Well 7 combined fluid entry temperatures may continue to decline to match those shown in TG-9 but Well 7 has not been flowed long enough to make any reliable predictions as to what the long-term fluid-entry temperature trends might be.

Well 7 Injection Temperatures

The injection log from Well 7 shows the shallowest detectable thief zone to be at 616’ (Benoit, 2006c) (Figure 5). This is also the major injection interval in the well. Other zones that accepted some fluid are at depths of 656 and 688’.

Temperature Discussion

The different types of temperatures logs show some commonality and some curious differences. For instance, the injection logs showed no trace of fluid exiting the well near a depth of 570’ or near 590’ where the flowing logs show strong inflections. At 616’ a very large fraction of the injectate clearly exits the well but there are only weak inflections shown at these depths on the flowing logs (Figure 5). This can be easily explained by any fluid entries at this depth having the same temperature as deeper fluid entries.

Combining the static, flowing, and injection logs pretty conclusively demonstrates that the primary permeability in Well 7 lies between about 570 and 616’. Intervals of lesser permeability below 620’ extend to as deep as 713’.

WELL 7 STATIC AND FLOWING PRESSURES AND PRESSURE CHANGES

Static and flowing pressures from Well 7 show a consistent 15 to 16 psi difference (Figure 6). All of the flowing logs on Figure 6 have essentially identical pressures as they were run at a flow rate of 240 gpm.

The pressure changes in Well 7 at a depth of 713’ during the entire flow test and pressure buildup are shown on Figure 7. The pressure changes are sharp and were nearly completed within 1 ½ hours of making a change in flow rate. The pressures at the end of the buildup were more or less identical to the pressures prior to the start of the test.

WELL 7 PRODUCTIVITY AND COMPARISON WITH TG-8 AND TG-9

On July 8 the well was flowed at three different rates (Table 1) so three productivity values can be calculated. The overall productivity of the well between zero flow and 240 gpm is 15.6gpm/psi. All of the July 8 productivity values are modestly higher than the July 5 value of 13.6gpm/psi so deepening the well by about 100' modestly improved the output of Well 7. The downhole productivity data are linear (Figure 8).

Table 1
Well 7 July, 2006 Productivity Data

Date	Flow Rate(gpm)	Downhole Pressure (psi)	Change in Pressure (psi)	Productivity Index (gpm/psi)
July 5, 2006	220		16.2	13.58
July 8, 2006	0	321.3	0	0
July 8, 2006	87	316.8	4.5	19.33
July 8, 2006	186	309.6	11.7	15.90
July 8, 2006	240	305.9	15.4	15.58

On July 5, when Well 7 was at a depth of 615' a brief flow test showed that the well would produce about 220 gpm with a downhole pressure drop of 16.2 psi, giving a productivity of 13.6 gpm/psi (Table 1). There was no time on July 5 for flowing the well at differing rates.

Comparison of the Well 7 productivity with TG-8 and TG-9 are shown on Table 2. TG-8 has the lowest productivity of the deep wells in the area at 9.3gpm/psi while TG-9 has the highest productivity at 25.7gpm/psi. This demonstrates that the local permeability distribution varies considerably.

Table 2
Well 7 Area Productivity Index Data

	Well 7	Well 7	TG-8	TG-9	TG-9
P. I. (gpm /psi)	13.6	15.6	9.3	8.5	25.7
Date	July 5, 06	July 8, 06	April 8, 06	April 9, 06	April 18, 06
Depth (feet)	616'	713'	604'	460	800
Flow Rate (gpm)	220	240	158	142	450
Delta P (psi)	16.2	15.4	17	16.7	15

TG-8 AND TG-9 WELLHEAD PRESSURE RESPONSES TO WELL 7 FLOWING

The TG-8 and 9 wellhead pressures were recorded by hand at irregular intervals with emphasis on getting more numbers as soon as possible after flow rate changes and just before flow rate changes (Figure 9). These two wells respond immediately to Well 7. The TG-8 pressures were dropping before the Well 7 valve could be completely opened.

The nearby TG-9 well showed the greatest response to Well 7 flowing with a maximum wellhead pressure decline of 7.7 psi. TG-8 showed a wellhead pressure drop of 6.2 psi and a much smaller annular pressure drop of 3.45 psi. The difference between the TG-8 wellhead and annular pressures are that the wellhead pressure measures pressures below a depth of 360' while the annular pressures are from above a depth of 360'. This same relationship was discovered in April 2006 when TG-9 was flowed and TG-8 was monitored.

By the end of the monitoring period the TG-8 annulus pressure was actually higher than it was before the test while the TG-8 and 9 wellhead pressures were about one psi lower than before the start of the test.

DOWNHOLE PRESSURES CHANGES IN TG-1, TG-7, AND WELL 2

TG-7

The most consistent downhole pressure interference data collected during the July 8 flow test was from the Kuster tool hung in TG-7 at a depth of about 485' (Figures 10 and 11). The TG-7 data shown on Figures 10 and 11 are a 3 point moving average which covers 20 seconds of time. This tool was run in the hole just after 10:00 on the morning of the flow test. The TG-7 DHPs in the two hours prior to starting the flow test were reasonably steady at about 206.58 psi. The start of the pressure decline in TG-7 occurred between about 13:14:30 and 13:18:30 (Figure 11). It can not be picked more precisely by eyeball, even when a 5 point moving average is utilized. Taking the average of these two inflection times gives a start of 13:16:30 which is 10 minutes after Well 7 began flowing.

The total pressure decline in TG-7 was 0.475 psi but the pressure had not quite fully stabilized when Well 7 was first throttled (Figure 10). This first throttling from 240 to 186 gpm resulted in a period of stabilization of the TG-7 downhole pressure. After the second throttling from 186 to 87gpm the TG-7 downhole pressures increased. Ultimately the TG-7 downhole pressures increased to about 206.75 psi or slightly above the pressures at the start of the flow test.

With the clear responses of TG-7 in hand the more obtuse responses of the capillary tubing systems in TG-1, Well 2, and Well 4 to the flow test can be more clearly recognized.

TG-1, WELL 2, and WELL 4

TG-1, Well 2, and Well 4 all have virtually identical downhole pressure variations with considerable character and several sharp inflections during the flow test (Figure 10). Most of these sharp inflections are presumably due in large part to diurnal or solar impacts on the cap tubing systems. During late May and June the cap tubing systems always showed at least one psi of diurnal change during the day and occasionally as much as 2 psi.

The inflections associated with the initiation of flow are clearly shown by all three of the cap tubing systems (Figure 11). Unfortunately, during the period of 240 gpm flow there are at least six other sharp unexplained inflections, resulting in both increasing and declining pressures (Figure 10). None of these six inflections are recognizable on the TG-7 Kuster tool downhole pressures.

The timing of the TG-1, Well 2, and Well 4 inflections at the start of the flow test is consistent with the distance of the wells from Well 7 and with the response seen in TG-7 by the Kuster tool. TG-1, the closest of these wells to Well 7, shows a sharp response at 13:09:04 which is 2 ½ minutes after the start of flow. Well 4 shows a fairly sharp response at 13:13:47 or 7 ¼ minutes after the start of flow. The Well 2 response to the start of flow is more subdued, occurring between 13:14 and 13:20 which averages at 13:17 or about 10 ½ minutes after the start of flow. The Well 2 response time is virtually identical to the 10 minutes noted in TG-7.

The slopes of the pressure changes during the first 50 minutes of the flow test are consistent with the onsets of pressure decline in that TG-1 closest to Well 7 has the highest rate of pressure decrease and TG-7 and Well 2, which are furthest have the lowest rates of pressure decrease. Unfortunately at about 14:00 there is a major inflection in the TG-1, Well 4, and Well 2 data which is not obviously related to the flows from Well 7 (Figure 10).

After about 18:00 the three cap tubing systems more closely track the TG-7 Kuster pressure data with rising trends, suggesting that this part of these curves is being controlled by the pressure rebound near Well 7.

TG-3

TG-3 was not specifically monitored during the July 8 flow test other than to observe that the amount of water flowing over the casing slowed to a trickle after Well 7 had been flowing for a while. However, on July 5 TG-3 had a pressure bomb installed while Well 7 flowed and recorded only a 0.2 psi pressure decline with a 26 minute delay of the onset of the decline. Interestingly, this 26 minutes could correspond to a round trip time of the pressure wave from Well 7 to the TG-7 area and back again.

Because of this weak response the cap tubing system was moved from TG-3 to Well-4 for the July 8 flow test.

CONCLUSIONS

The July 8 Well 7 flow test was successful in many aspects but due to its relatively small flow rate and duration of flow there are some questions remaining to be answered about the well.

The well is now well characterized at modest flow rates. The primary permeable interval in the well is at a depth of 616’ but there are indications of permeability as shallow as

570' and as deep as 713'. The overall fluid-entry temperature declined during the flow test from165.25 to 164.4 F. This is about 2 F hotter than the overall TG-9 fluid-entry temperature but also about 7 F lower than the overall TG-8 fluid-entry temperature. There is no way to predict precisely what the long-term average fluid-entry temperature will be in Well 7. Hopefully this decline is due to fluid lost during drilling and will soon stop or perhaps even increase. The fluid-entry points are hundreds of feet below the alluvial groundwater flow and should not be quickly impacted by inflows of cold water.

The pressure falloff and buildup data and the pressure changes associated with the flow rate changes were sharp and clean giving an overall productivity of 15.6 gpm/psi. This is intermediate between the values for TG-8 and TG-9. The pressure data suggest that a pump setting depth of about 200' should give close to a 100% allowance for an unexpectedly large fluid level decrease at a pump rate of 1000 gpm.

Well 7 is best connected with TG-9. It is also very well connected with the deeper pressure regime in TG-8 but less well connected with the shallow pressure regime in TG-8.

A downhole pressure decline of 15.4 psi in Well 7 produced wellhead pressure declines of 7.7 psi in TG-9, 6.2 psi in the deep pressure regime in TG-8, and 3.4 psi in the shallow pressure regime in TG-8. At the far end of the field a maximum pressure decline of 0.475 psi was measured in TG-7. Unfortunately the total pressure declines in Wells 2 and 4 and TG-1 are uncertain due to the presence of several relatively large pressure fluctuations in the cap tubing systems.

The timing of the pressure response to the start of flow in the wells is consistent with the magnitude of the overall change. Pressure changes were basically instantaneously in TG-8 and TG-9 and required about 10 minutes to reach Well 2 and TG-7, the furthest instrumented wells from Well 7.

LIST OF REFERENCES

Benoit, D., 2006a, Well 7 flow test, July 5, 2006, Report for Chena Hot Springs Resort, 3 p + figures.

Benoit, D., 2006b, April 2006 flow tests of TG-9, Report for Chena Hot Springs Resort, 7 p. + figures.

Benoit, D., 2006c, Well 7 injection logging July 11, 2006, Report for Chena Hot Springs Resort dated July 13, 2006, 3p. + figures.

Benoit, D., 2006d, April 8, 2006 flow testing and logging of TG-8, Report for Chena Hot Springs Resort dated April 14, 2006, 5p. + Figures.

LIST OF FIGURES

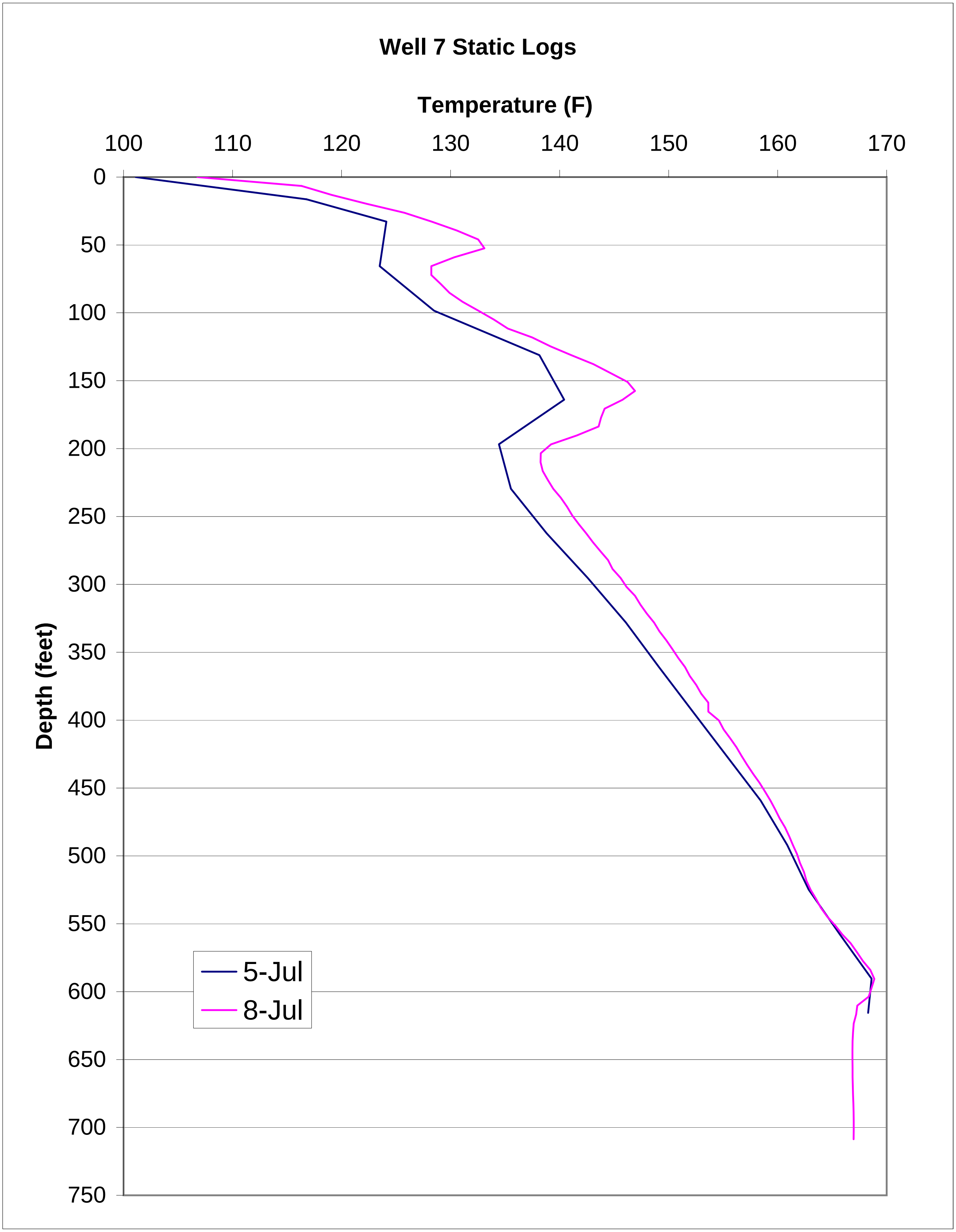
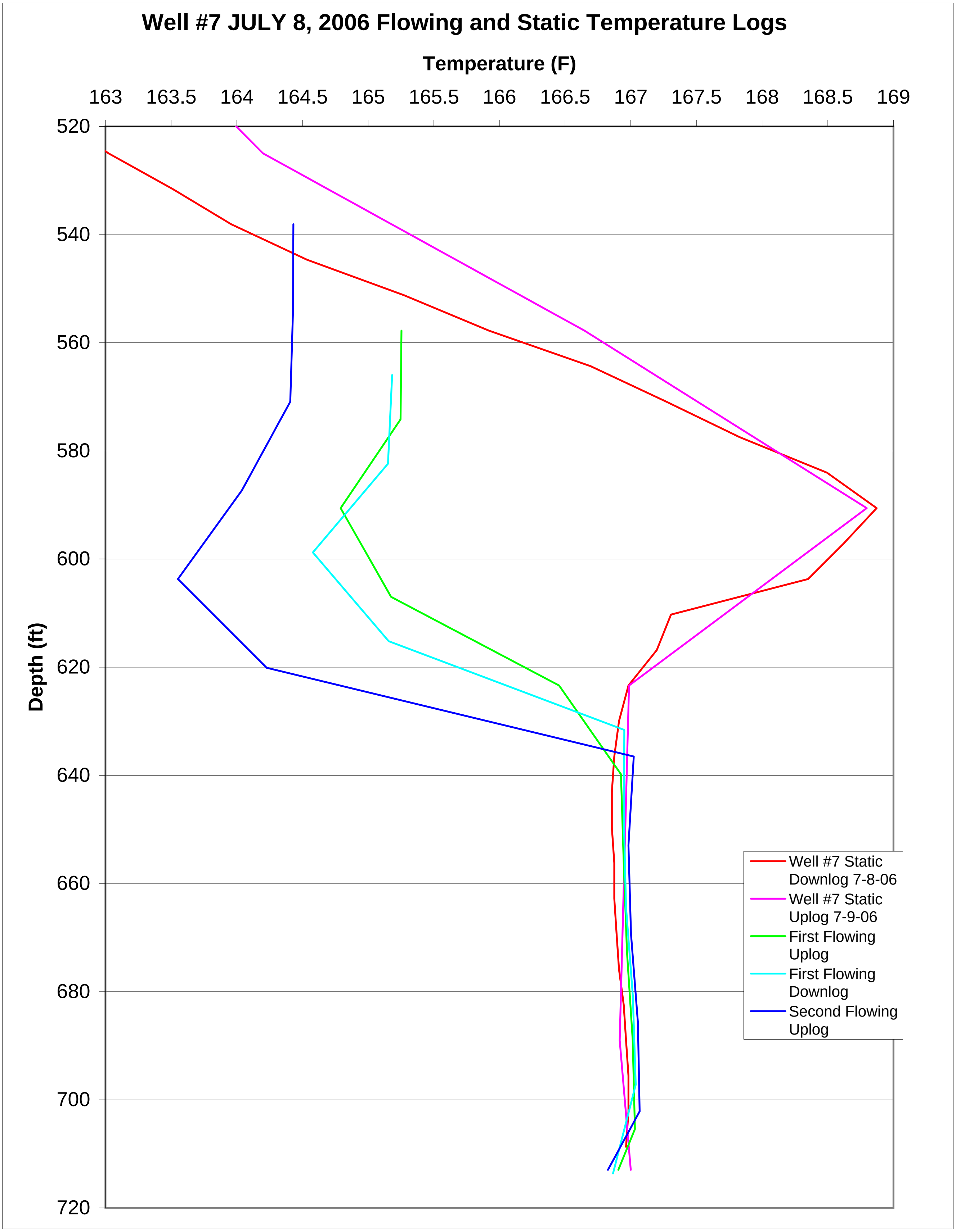
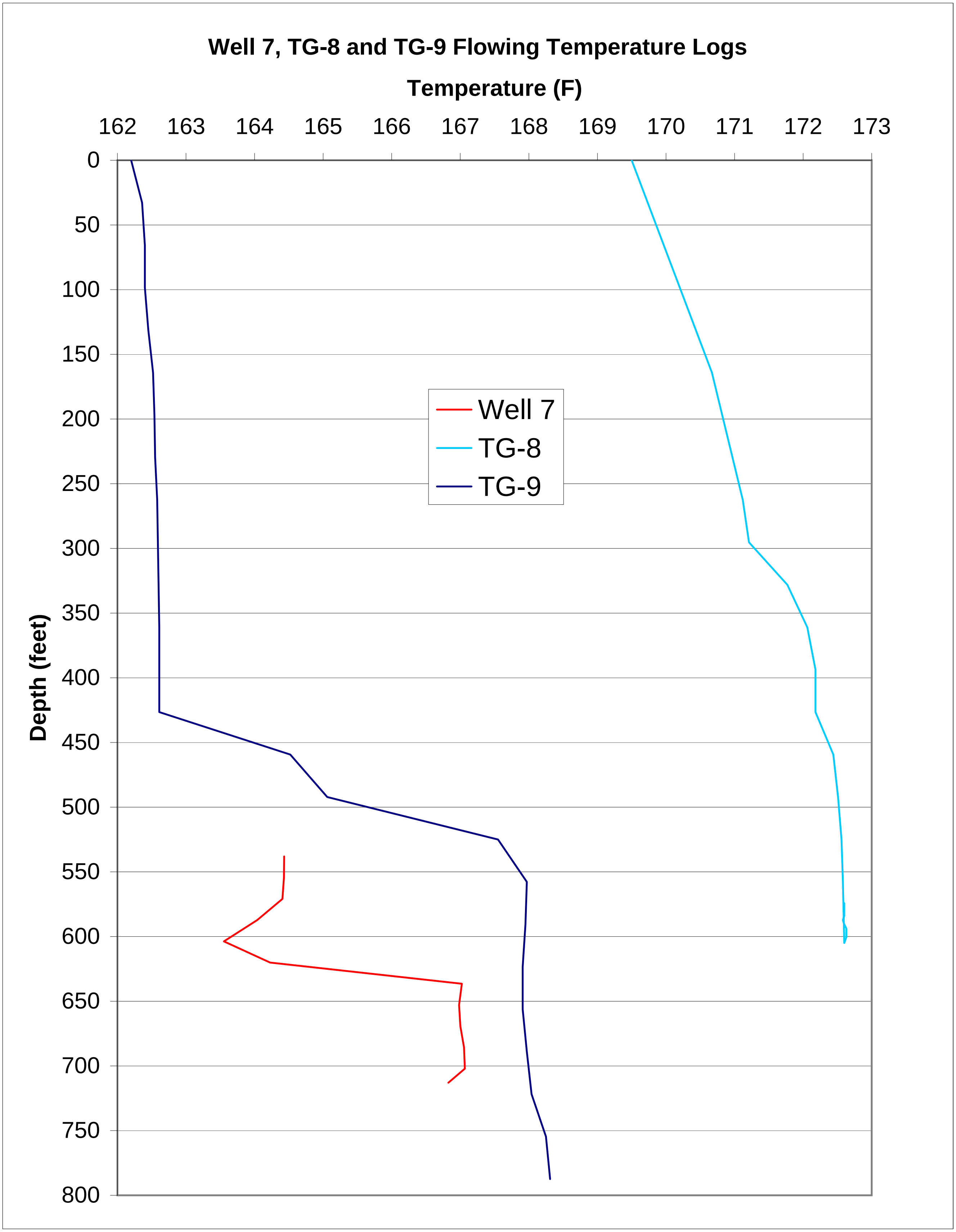

Well 7 Static Logs
Temperature (F)
100
110
120
130
140
150
160
170
Depth (feet)
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
5-Jul
8-Jul

Figure 2



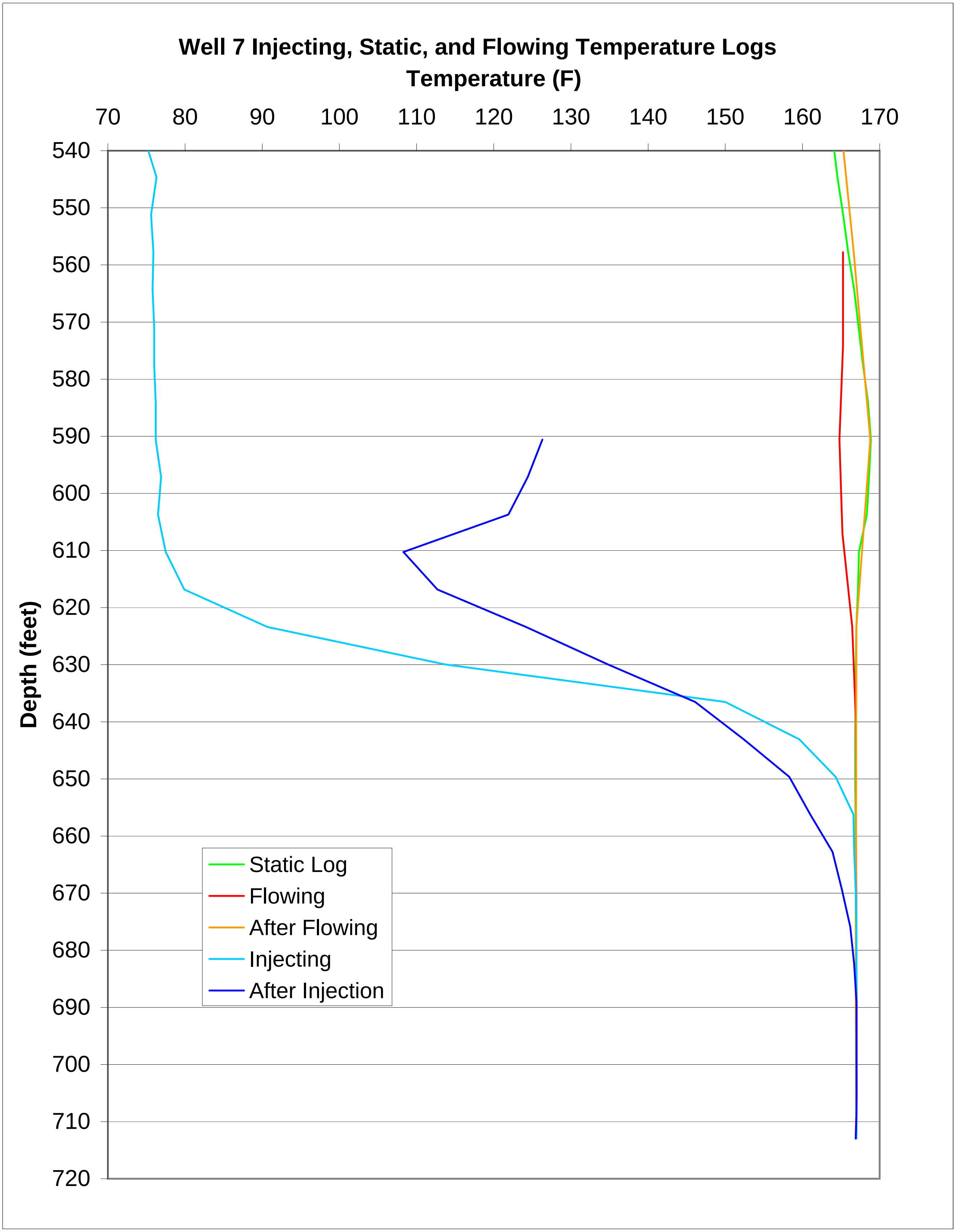
Well #7 JULY 8, 2006 Flowing and Static Temperature Logs
Temperature (F)
163
163.5
164
164.5
165
165.5
166
166.5
167
167.5
168
168.5
169
Depth (ft)
520
540
560
580
600
620
640
660
680
700
720
Well #7 Static Downlog 7-8-06
Well #7 Static Uplog 7-9-06
First Flowing Uplog
First Flowing Downlog
Second Flowing Uplog

Figure 3



Well 7, TG-8 and TG-9 Flowing Temperature Logs
Temperature (F)
162
163
164
165
166
167
168
169
170
171
172
173
Depth (feet)
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800
Well 7
TG-8
TG-9

Figure 4



Well 7 Injecting, Static, and Flowing Temperature Logs
Temperature (F)
70
80
90
100
110
120
130
140
150
160
170
540
550
560
570
580
590
600
610
620
630
640
650
660
670
680
690
700
710
720
Depth (feet)
Static Log
Flowing
After Flowing
Injecting
After Injection

Figure 5

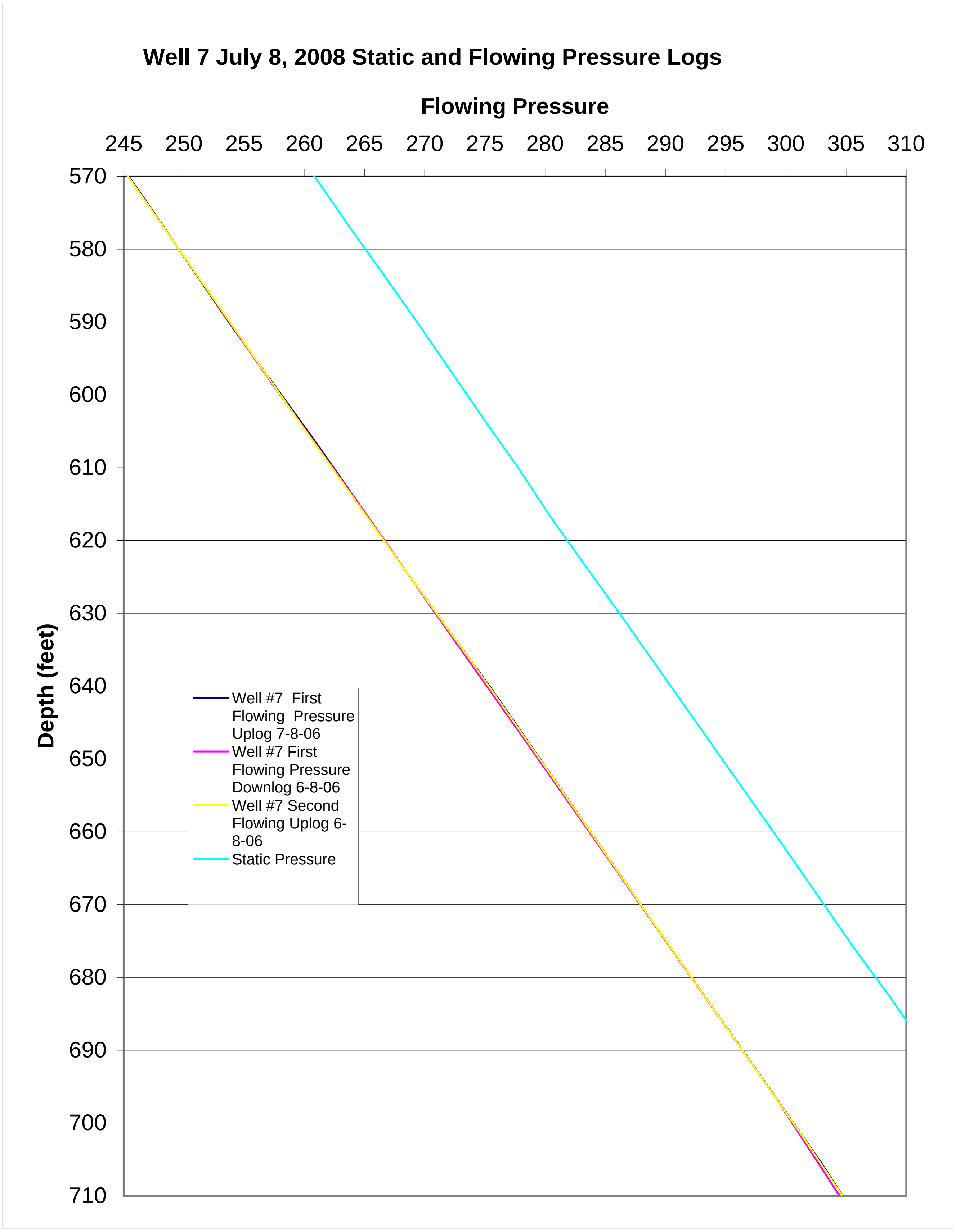

Well 7 July 8, 2008 Static and Flowing Pressure Logs
Flowing Pressure
245
250
255
260
265
270
275
280
285
290
295
300
305
310
Depth (feet)
570
580
590
600
610
620
630
640
650
660
670
680
690
700
710
Well #7 First Flowing Pressure Uplog 7-8-06
Well #7 First Flowing Pressure Downlog 6-8-06
Well #7 Second Flowing Uplog 6-8-06
Static Pressure

Figure 6

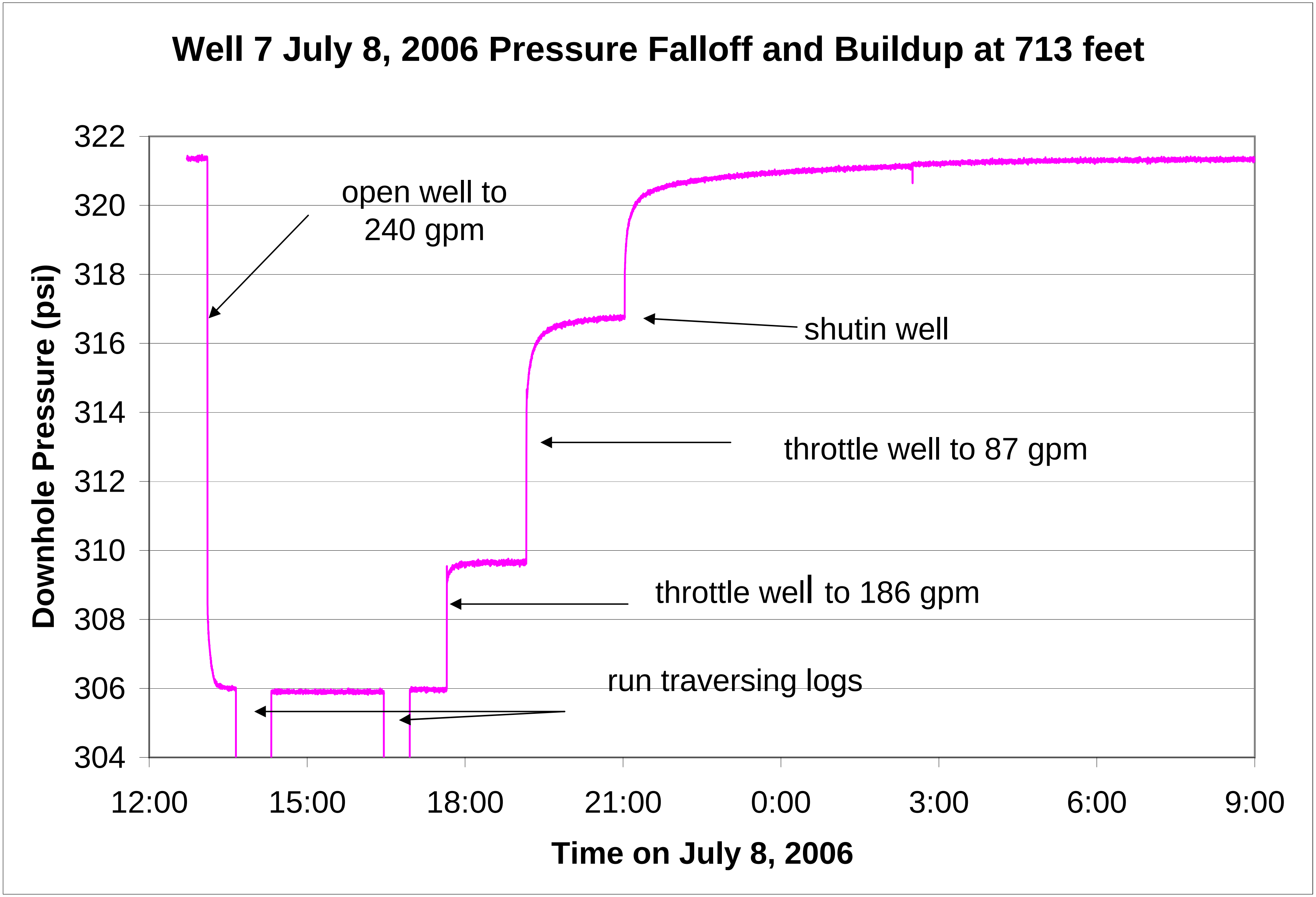
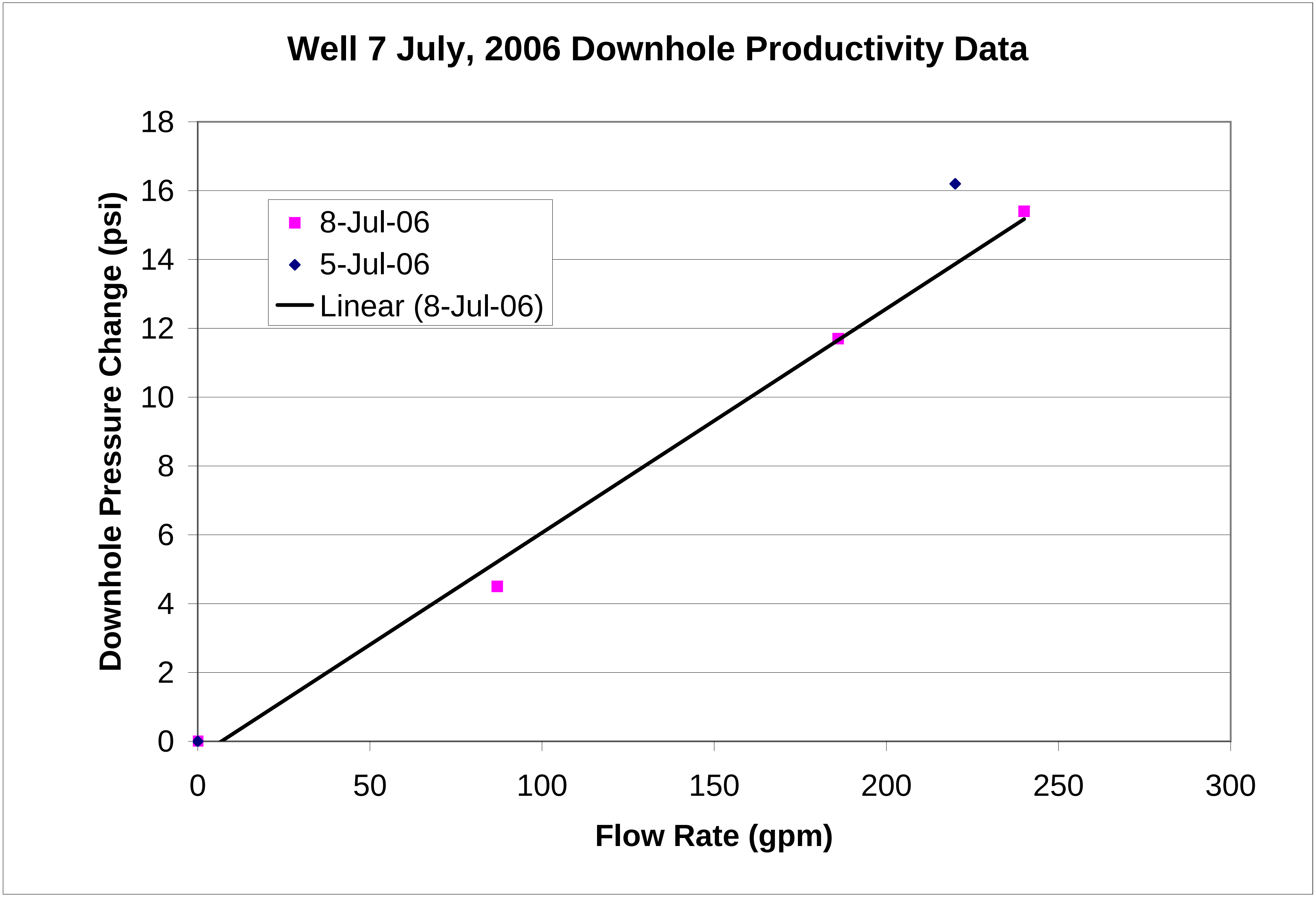
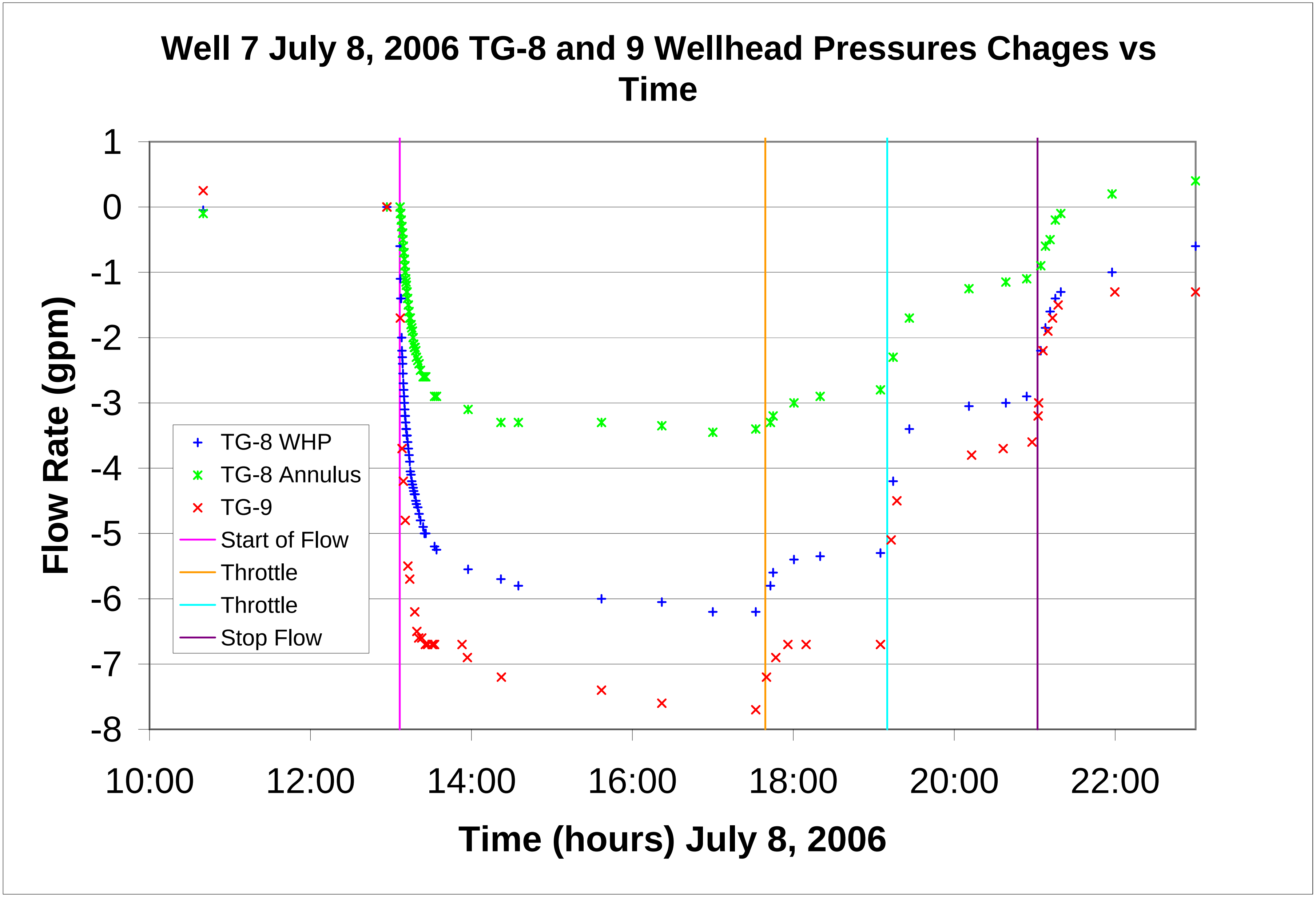

Well 7 July 8, 2006 Pressure Falloff and Buildup at 713 feet
322
320
318
316
314
312
310
308
306
304
Downhole Pressure (psi)
open well to
240 gpm
shutin well
throttle well to 87 gpm
throttle well to 186 gpm
run traversing logs
12:00
15:00
18:00
21:00
0:00
3:00
6:00
9:00
Time on July 8, 2006

Figure 7



Well 7 July, 2006 Downhole Productivity Data
Downhole Pressure Change (psi)
0
2
4
6
8
10
12
14
16
18
0
50
100
150
200
250
300
Flow Rate (gpm)
8-Jul-06
5-Jul-06
Linear (8-Jul-06)

Figure 8



Well 7 July 8, 2006 TG-8 and 9 Wellhead Pressures Chages vs Time
Flow Rate (gpm)
1
0
-1
-2
-3
-4
-5
-6
-7
-8
TG-8 WHP
TG-8 Annulus
TG-9
Start of Flow
Throttle
Throttle
Stop Flow
10:00
12:00
14:00
16:00
18:00
20:00
22:00
Time (hours) July 8, 2006

Figure 9

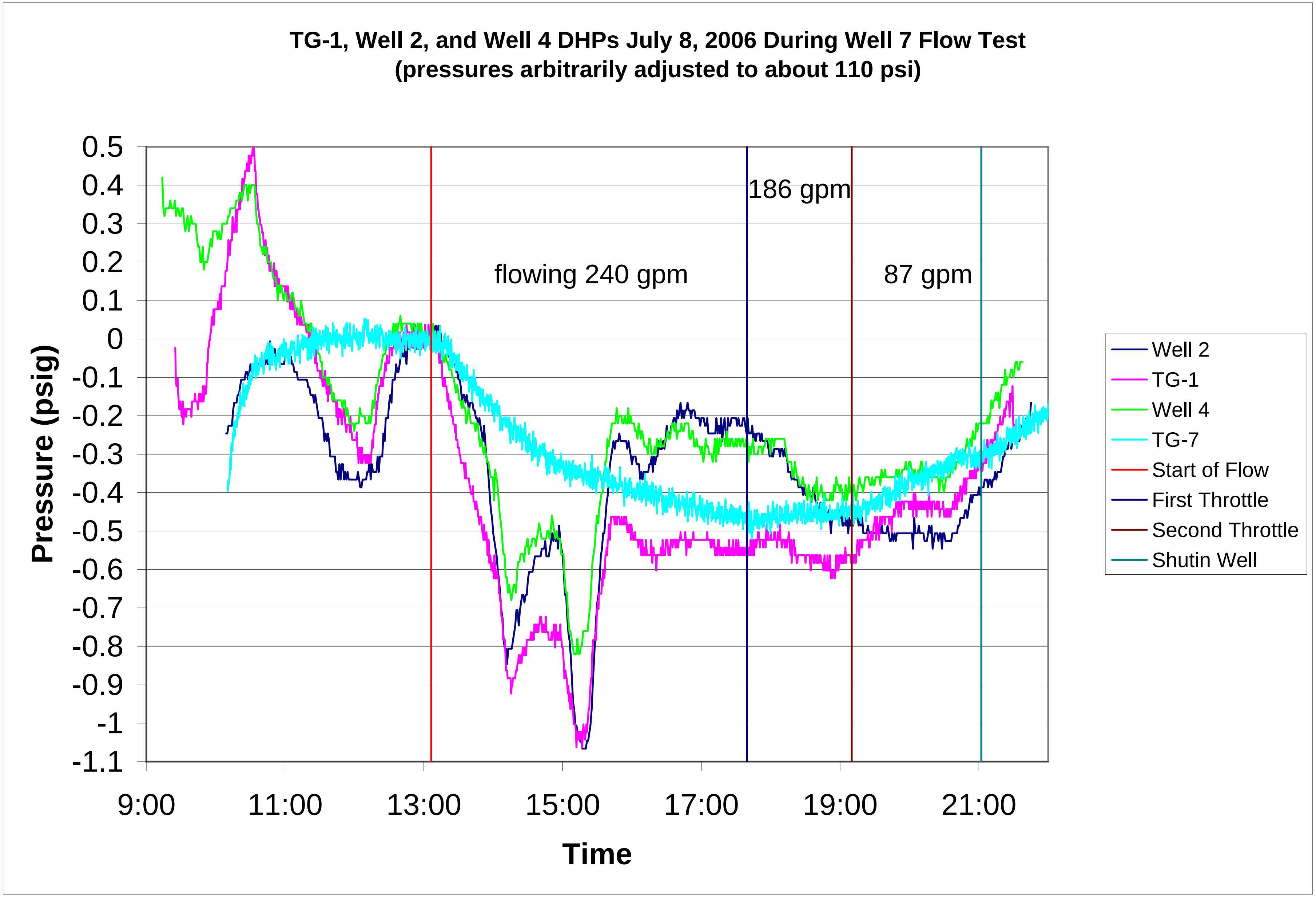
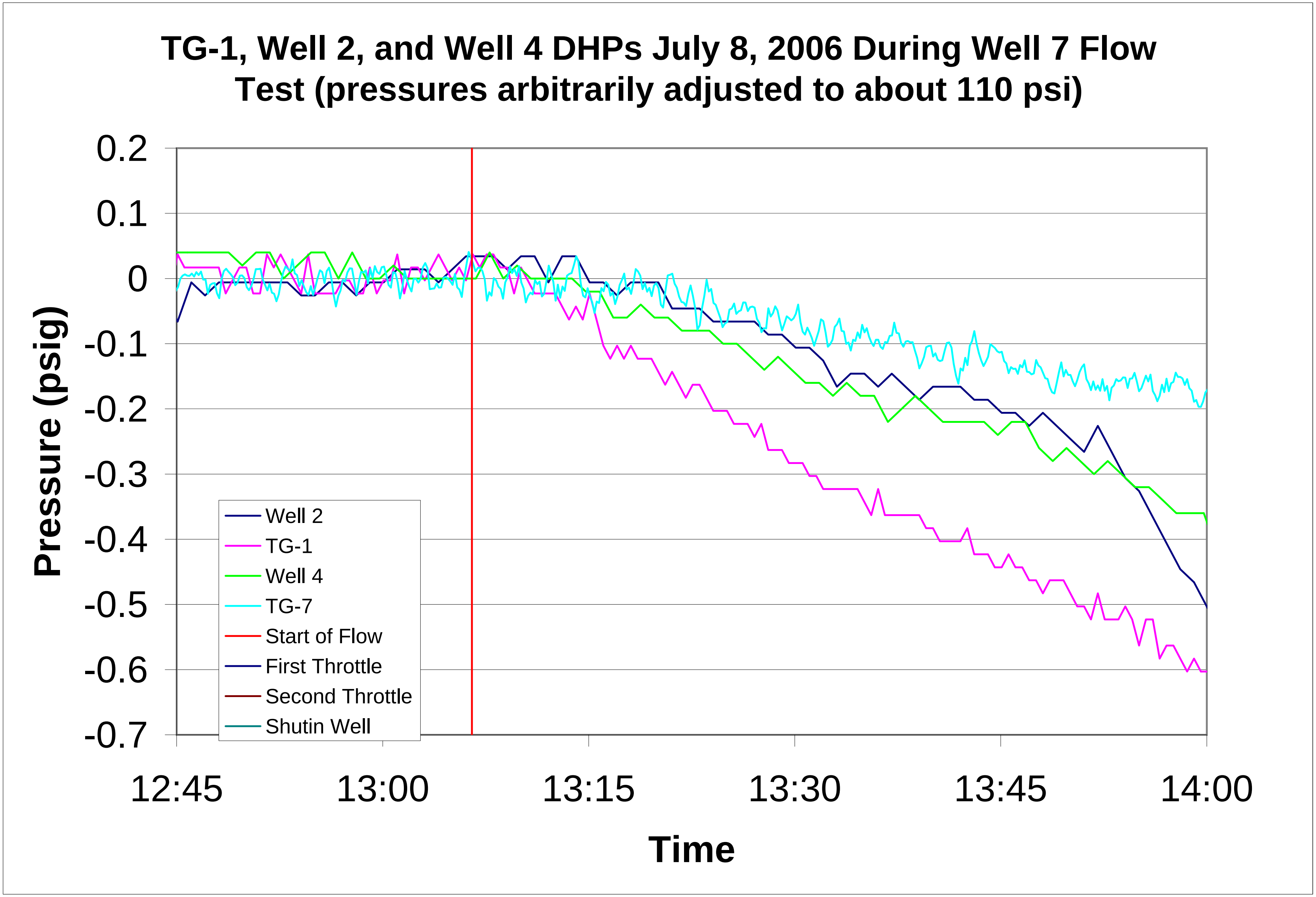

TG-1, Well 2, and Well 4 DHPs July 8, 2006 During Well 7 Flow Test
(pressures arbitrarily adjusted to about 110 psi)
Pressure (psig)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
-0.8
-0.9
-1
-1.1
9:00
11:00
13:00
15:00
17:00
19:00
21:00
Time
flowing 240 gpm
186 gpm
87 gpm
Well 2
TG-1
Well 4
TG-7
Start of Flow
First Throttle
Second Throttle
Shutin Well

Figure 10



TG-1, Well 2, and Well 4 DHPs July 8, 2006 During Well 7 Flow Test (pressures arbitrarily adjusted to about 110 psi)
Pressure (psig)
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
Well 2
TG-1
Well 4
TG-7
Start of Flow
First Throttle
Second Throttle
Shutin Well
12:45
13:00
13:15
13:30
13:45
14:00
Time

Figure 11