Appendix E. Hydrographs and analysis of water-level data

Part 1. Historical USGS water-level data.

The on-line U.S. Geological Survey's National Water Information System was queried for all wells in and near the study area for which at least 10 water level measurements were in the system (see Figure E-1). These data range between 1954 to 1990. Additionally, water levels from a recorder-equipped monitoring well that is not contained in the on-line system is available from Glass (1987).

Understanding historic water level fluctuations in the Sand Lake area is important because pumping of groundwater up to about 18 million gallons per day in Anchorage affected water levels across a wide area (Patrick and others, 1989), including the Sand Lake area. Also, the records provide information about seasonal and multiyear fluctuations in both confined and unconfined aquifers beyond the data that were collected during this project. Water levels in some wells were also affected by the March 27, 1964, Alaska earthquake, sometimes with long-lasting effects (Waller, 1966).

Water level in the confined aquifer system in the Sand Lake area declined between 0 and 10 feet between 1955 and 1969 (Moran and Galloway, 2006; Miller and Whitehead, 1999; and Barnwell and others, 1972). More recently, an unpublished map by Dearborn (1983) (Attachment E-1) showed that historic water levels declined up to 20 feet in the eastern part of the Sand Lake study area through 1980. Since the Eklutna Water Project came on-line in the late 1980's, Anchorage now gets most of it water from Eklutna Lake and groundwater pumpage has declined to minimal levels (https://www.awwu.biz/about-us/awwu-overview). It is likely that groundwater levels in the Sand Lake area have largely returned to mid-1950s levels, although available data are too sparse to confirm this.

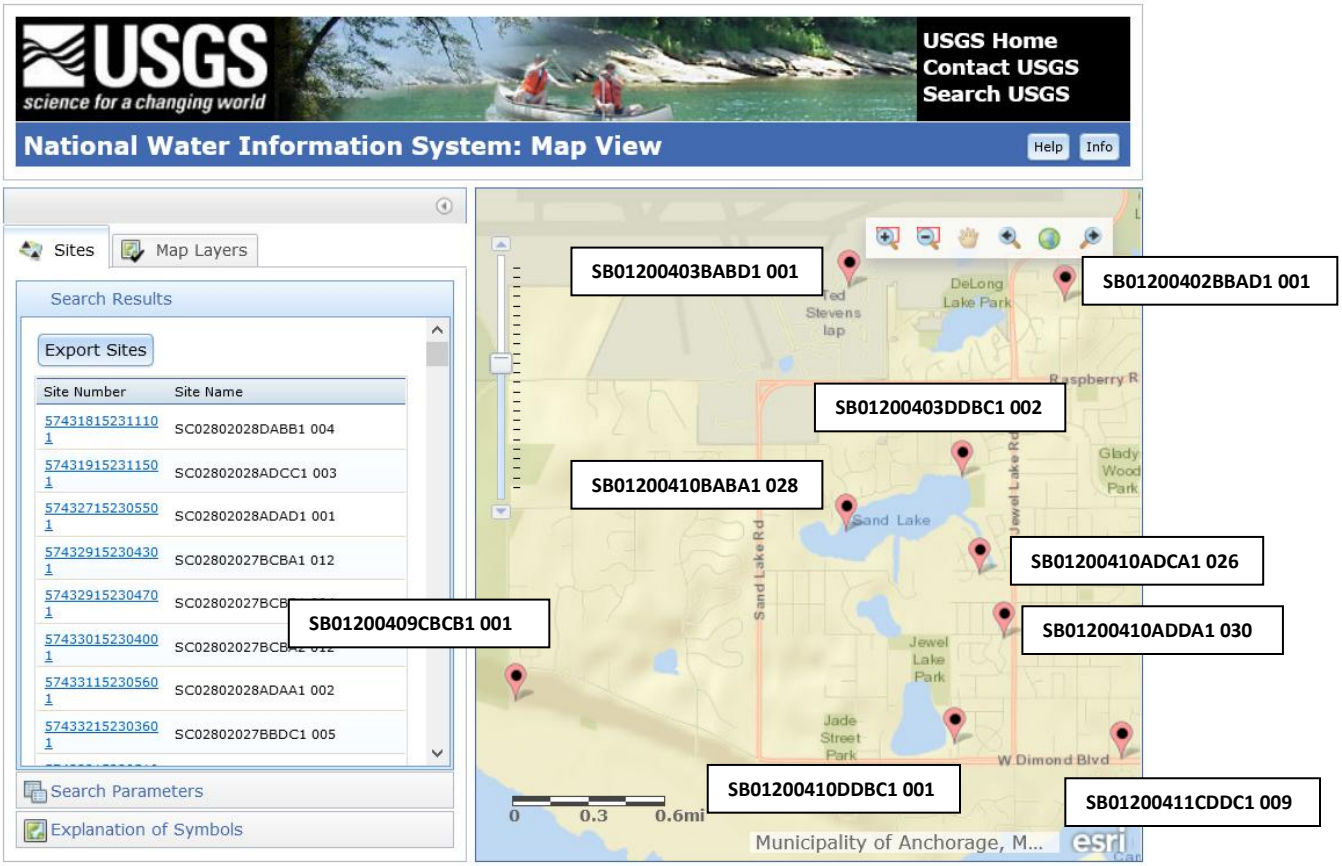

Figure E-1. Locations of wells with 10 or more groundwater level readings with data available from the USGS National Water Information System.

(Source:https://maps.waterdata.usgs.gov/mapper/nwisquery.html?URL=https://nwis.waterdata.usgs.gov/ak/nwis/gwlevels?gw_count_nu=10&format=sitefile_output&sitefile_output_format=xml&column_name=agency_cd&column_name=site_no&column_name=station_nm&date_format=YYYY-MM-DD&rdb_compression=file&list_of_search_criteria=obs_count_nu&column_name=site_tp_cd&column_name=dec_lat_va&column_name=dec_long_va&column_name=agency_use_cd)

Well Shady Birch

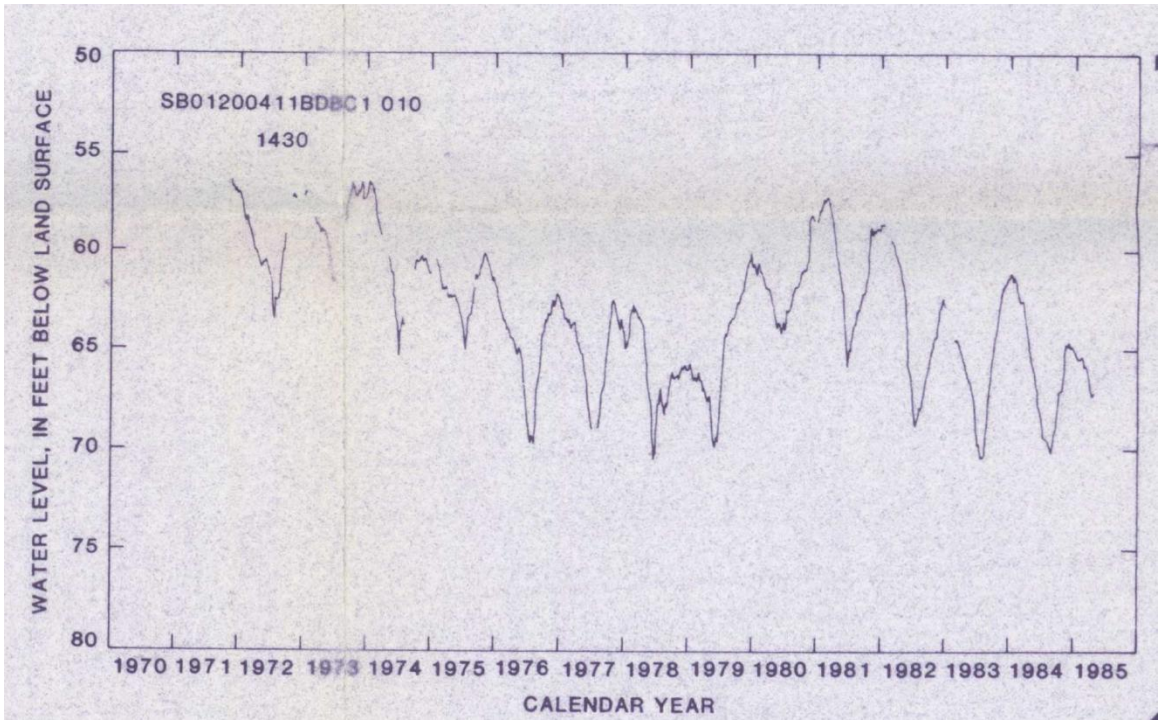

Figure E-2. Hydrograph of Well Shady Birch (SB01200411BDBC1 010)
(Source: Glass, 1987)
(See Glass (1987) or Figure 2 (Shady Birch well) for well location)

Summary of data
WELTS Log ID: 18617
Appendix A Well ID: Shady Birch
Aquifer tapped: middle zone, Anchorage confined aquifer system
Total Depth: 307 feet
Land surface elevation 112 feet

This well was operated with a water-level recorder (Glass, 1987), likely from a drum-type recorder using a float and pulley wheel that produced pen-and-ink strip charts. Digital data are not available on the USGS on-line system. These data show a recurring annual fluctuation of approximately 5-10 feet. Glass (1987) observed that "Intermittent high pumping rates of wells completed in confined aquifers cause large water-level fluctuations. These fluctuations are commonly greater than 30 ft throughout much of the midtown and downtown areas...". Thus, it is not clear whether the seasonal water-level fluctuations observed in this well are the result of seasonal pumping variations or seasonal variations in recharge, however it seems likely that variations in pumping were at least partially responsible. The data from Glass (1987) reflect conditions that were occurring prior to the delivery of water to Anchorage from the Eklutna Water Project and the subsequent reduction in pumping from Anchorage Municipal wells.

Well SB01200402BBAD1 001

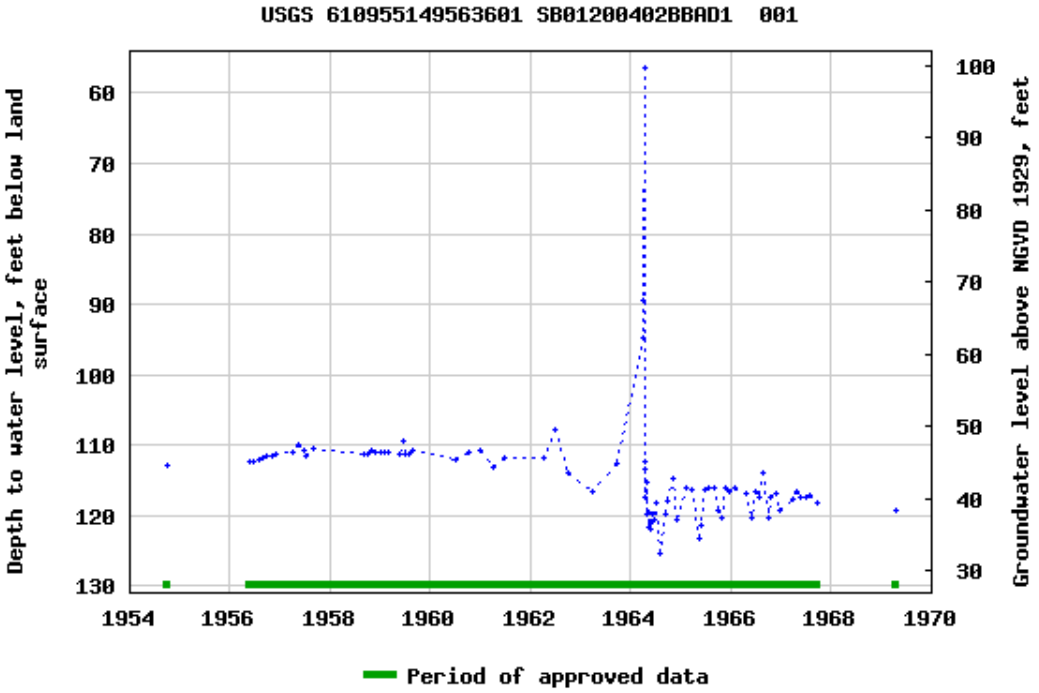

Figure E-3. Hydrograph of Well SB01200402BBAD1 001
Source:https://nwis.waterdata.usgs.gov/nwis/gwlevels?site_no=610955149563601&agency_cd=USGS&format=gif
(See Figure E-1 for well location.)

Summary of data
WELTS Log ID: none
Appendix A Well ID: none
Aquifer tapped: middle zone of Anchorage confined aquifer system
Total Depth: 349 feet
Land surface elevation 157 feet

This well, although located just outside of the Sand Lake study area, shows several things. First, there appears to be about 8-9 feet of long-term water-level decline from the late 1950's through 1969, matching Moran and Galloway's (2006) assessment. Also, there are several feet of sub-annual water-level fluctuation after 1964, but hardly any such fluctuation before 1962. The post-1964 water-level fluctuations seem likely to reflect increases and seasonal variability in pumping from the confined aquifer system. Three anomalous measurements were made during April, 1964, that are likely related to the March 27, 1964, Alaska earthquake.

Well SP-2

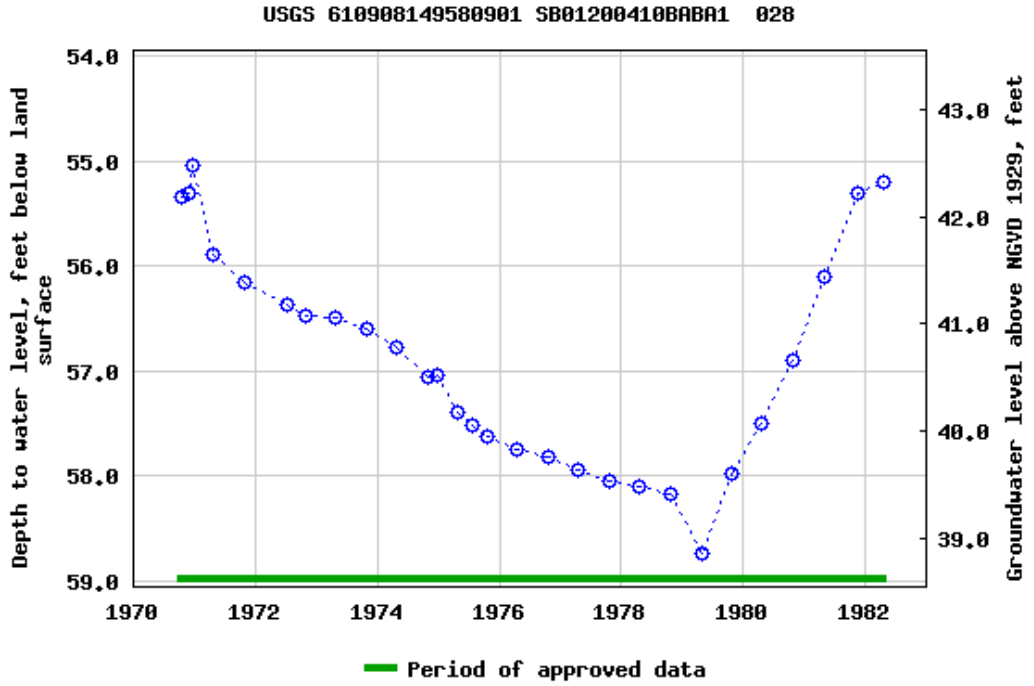

Figure E-4. Hydrograph of Well SP-2 (SB01200410BABA1 028)
(Source: https://nwis.waterdata.usgs.gov/usa/nwis/gwlevels/?site_no=610908149580901)
(See Figure E-1 for well location.)

Summary of data
WELTS Log ID: 31270
Appendix A Well ID: SP-2
Aquifer tapped: Water-table
Total Depth: 77 feet
Land surface elevation 97.55 feet

This well was drilled by the USGS as a monitoring well and taps a water-table aquifer with a water table that is approximately 50 feet below the level of Sand Lake, even though the well is located near the shore. There is a five-foot discrepancy between the land surface elevation given on the on-line-derived graph (97.55 NGVD 1929) and the land surface elevation provided on the USGS Well Schedule (92.55 ft; See WELTS Log ID 31270) that could not be definitively resolved. For this study, the on-line elevation was used to construct the water-table contour map (Figures 9, 9a) because it is likely that an error was discovered during quality assurance reviews associated with USGS data and the old paper records were not updated. Also, the 1:24,000 scale topographic map made in 1962 (Dearborn and Freethey, 1974) shows that the land surface elevation at the location of the well is likely to be very close to 100 ft above mean sea level.

The water level record for this well shows a very unusual 9-year period of decline of about 3.5 ft followed by a 3-year period of rise back to the original level. This pattern is unexplained.

Well SB01200411CDDC1 009

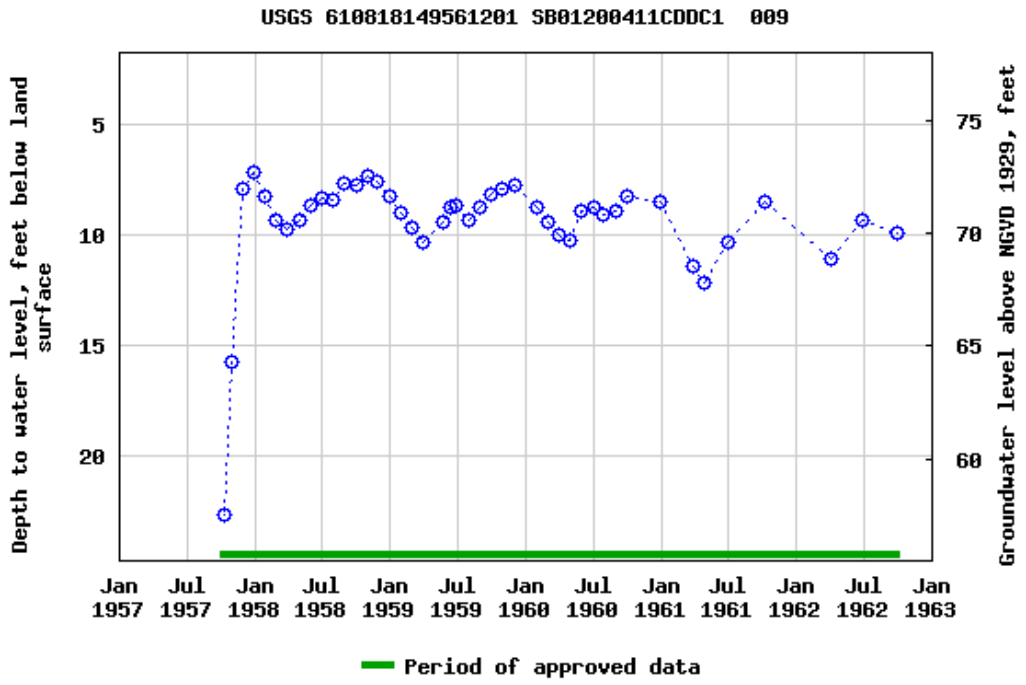

Figure E-5. Hydrograph of Well SB01200411CDDC1 009
(Source: https://nwis.waterdata.usgs.gov/usa/nwis/gwlevels/?site_no=610818149561201
(See Figure E-1 for well location.)

Summary of data
WELTS Log ID: none
Appendix A Well ID: none
Aquifer tapped: upper zone of the Anchorage confined aquifer system
Well Depth: 212 feet
Land surface elevation 80 feet

This well, with a depth of 212 feet, likely taps the upper zone of the Anchorage confined aquifer system. The data collected between 1957 and 1962 exhibit what is likely natural groundwater seasonal groundwater level fluctuations of about 2-3 feet. The highest water levels occur between October and December and the lowest water levels typically occur in March. There is a slight multi-year trend of declining water levels over the period of record that could reflect increasing pumping from Anchorage wells.

Well SB01200403BABD1 001

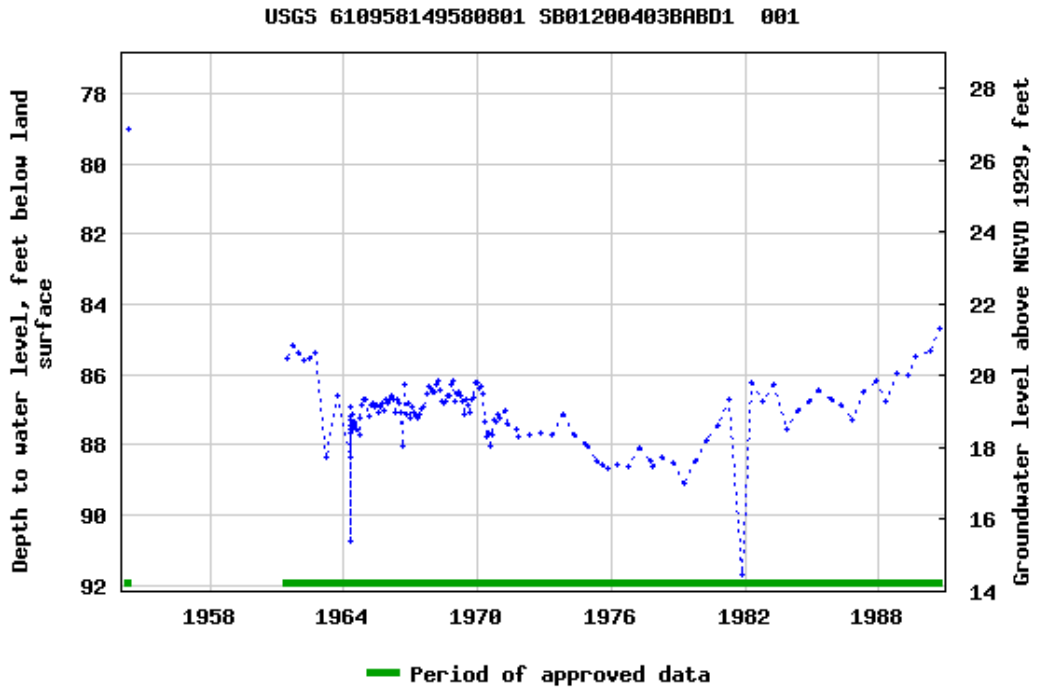

Figure E-6. Hydrograph of Well SB01200403BABD1 001
(Source: https://nwis.waterdata.usgs.gov/usa/nwis/gwlevels/?site_no=610958149580801&agency_cd=USGS)
(See Figure E-1 for well location.)

Summary of data
WELTS Log ID: none
Appendix A Well ID: none
Aquifer tapped: middle zone of the Anchorage confined aquifer system
Well Depth: 268 feet
Land surface elevation 106 feet

This well, with a depth of 268 feet, likely taps the middle zone of the Anchorage confined aquifer system. Although based on just one measurement, this wells shows a 5.5-foot decline between 1954 and 1961 and then a more gradual decline of about 3.5 feet until 1979. A low reading on April 14, 1964, likely reflects the effects of the March 27, 1964, earthquake. A partial recovery of water levels (a rise) from 1988 through the end of the period of record in 1990 likely reflects the reduction of pumping from Anchorage municipal wells as a result of delivery of water to Anchorage through the Eklutna Water Project.

Well SB01200410ADCA1 026

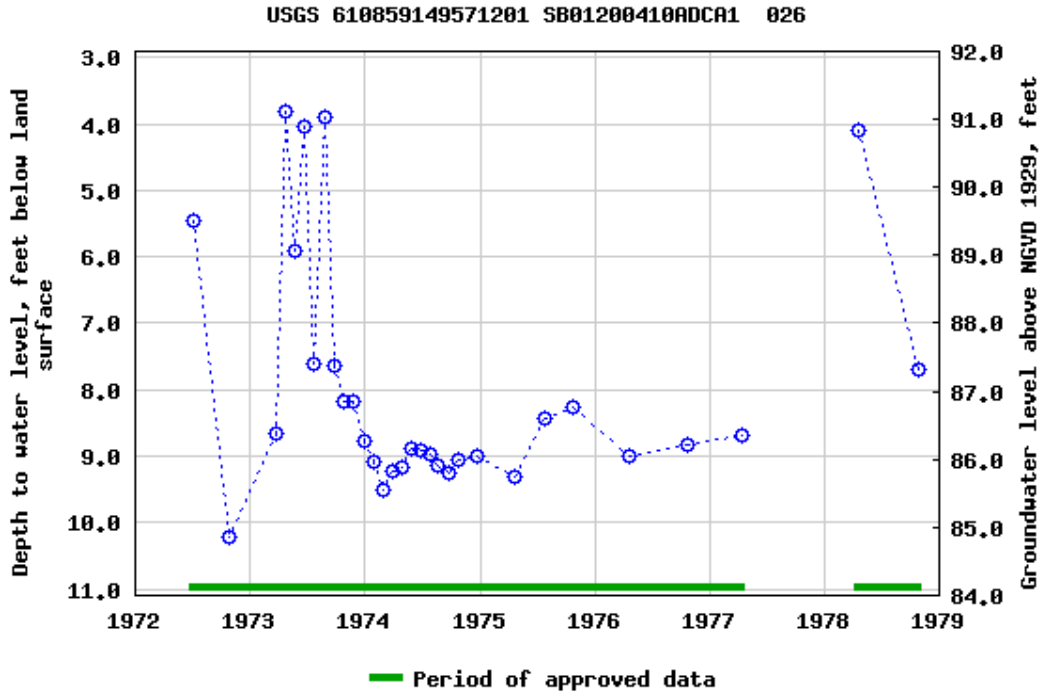

Figure E-7. Hydrograph of Well SB01200410ADCA1 026
(Source: https://nwis.waterdata.usgs.gov/usa/nwis/gwlevels/?site_no=610859149571201)
(See Figure E-1 for well location.)

Summary of data
WELTS Log ID: none
Appendix A Well ID: none
Aquifer tapped: Water-table
Total Depth: 11.5 feet
Land surface elevation 95 feet

This well, with a depth of 11.5, feet taps the water-table aquifer. Water levels showed a fluctuation of about 5 feet that occurs at irregular intervals and are likely the result of seasonal fluctuations. The approximate monthly measurements from 1973 to 1974 are unusual because the relatively large fluctuations observed in 1973 were not repeated in 1974.

Well CP4-1,2 (SB01200409CBCB1 001)

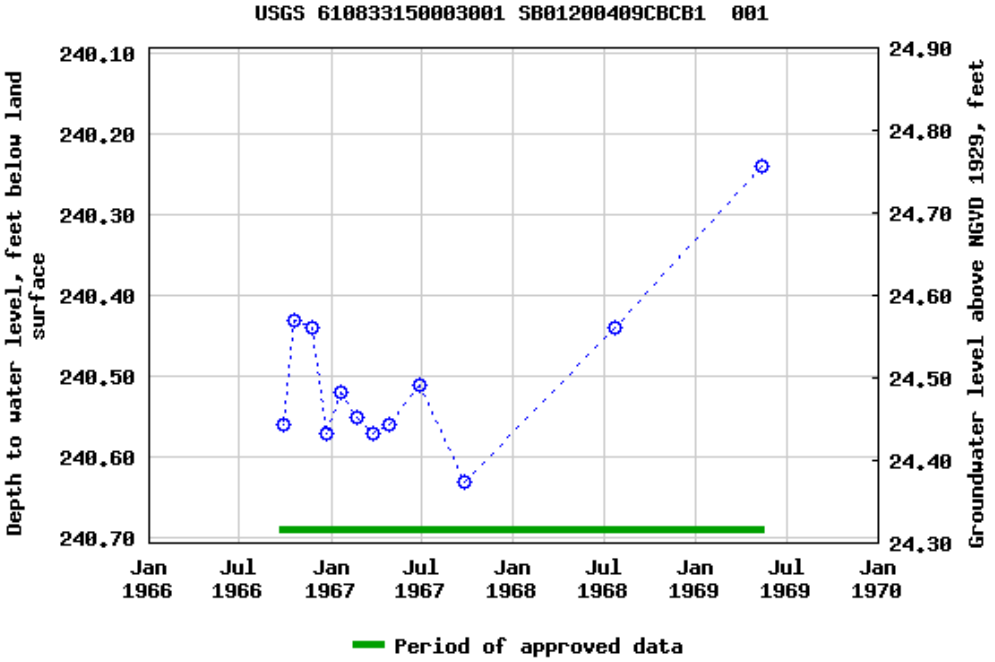

Figure E-8. Hydrograph of Well SB01200409CBCB1 001
(Source: https://nwis.waterdata.usgs.gov/nwis/gwlevels/?site_no=610833150003001)
(See Figure E-1 for well location.)

Summary of data
WELTS Log ID: 31243
Appendix A Site ID: CP4-1,2
Aquifer tapped: Water-table
Total Depth: 250 feet
Land Surface elevation 265 feet

This well, with a depth of 250 feet, taps the water-table aquifer. The water-level measurements between 1966 and 1969 are remarkably stable, with only 0.4 feet between the lowest and highest of 12 readings. The exact location of this well is unclear from the records reviewed during this investigation. The land surface elevation is also uncertain as this parcel is large and has over 20 feet of local relief. Thus, data from this well was not used in the preparation of the water table map.

Well SB01200410DDBC1 001

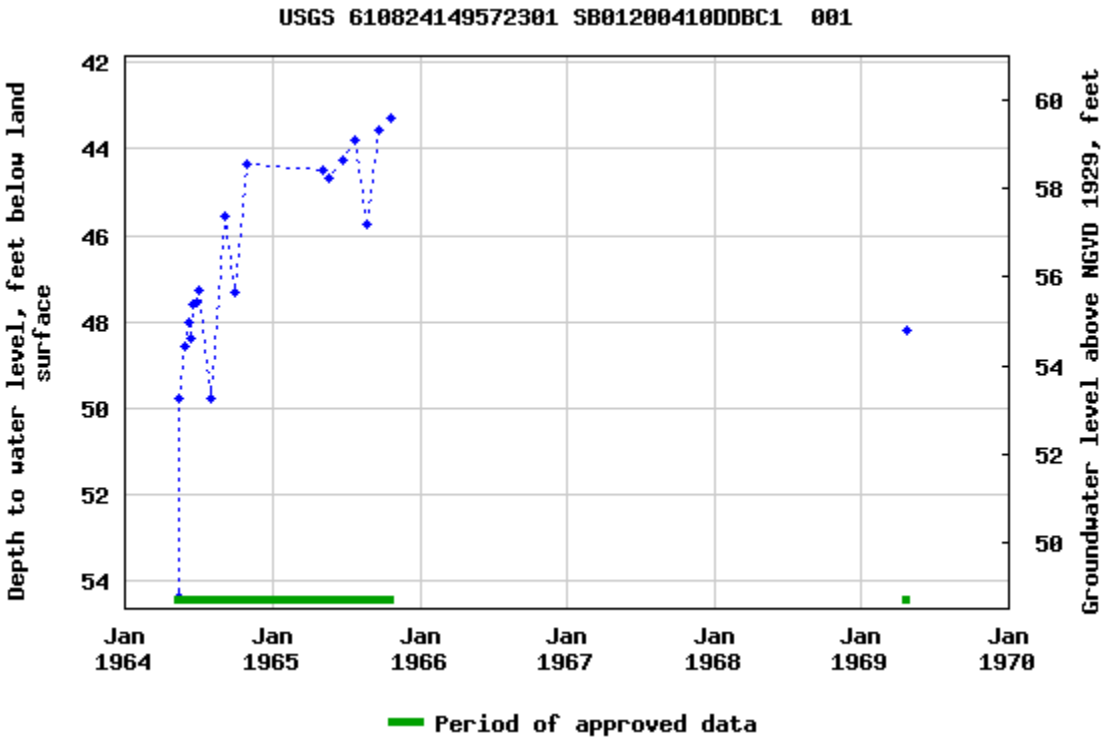

Figure E-9. Hydrograph of Well SB01200410DDBC1 001
(Source: https://nwis.waterdata.usgs.gov/usa/nwis/gwlevels/?site_no=610824149572301)
(See Figure E-1 for well location.)

Summary of data
WELTS Log ID: none
Appendix A Site ID: none
Aquifer tapped: upper zone of the Anchorage Confined aquifer system
Total Depth: 252 feet
Land Surface elevation 103 feet

This well, with a depth of 252 feet, likely taps the upper zone of the Anchorage confined aquifer system, although no well log is available. The water-level measurements start shortly after the March 27, 1964, Alaska earthquake and likely reflect the recovery of water levels from that event. Waller (1966) reported that many wells in Anchorage experience water-level drops of up to 24 feet at the time of the earthquake and most gradually recovered with about 6 months. Data from this well fits that pattern.

Well 1200403DDBC1-2

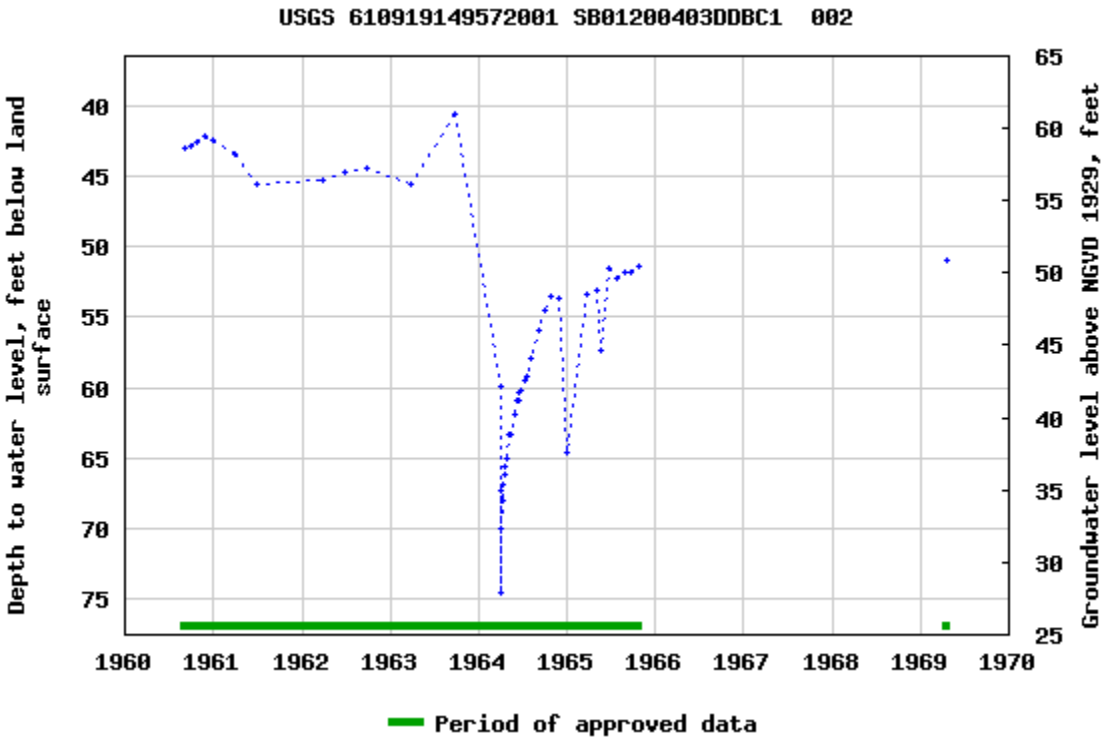

Figure E-10. Hydrograph of Well Well SB01200403DDBC1 002

Source:https://nwis.waterdata.usgs.gov/nwis/gwlevels?site_no=610919149572001&agency_cd=USGS&format=gif
(See Figure E-1 for well location.)

Summary of data
WELTS Log ID: pending
Appendix A Site ID: 1200403DDBC1-2
Aquifer tapped: middle zone of the Anchorage Confined aquifer system
Total Depth: 320 feet
Land Surface elevation 102 feet

This well, with a depth of 320 feet, taps the middle zone of the Anchorage confined aquifer system. This well experienced an apparent drop of up to 34 ft in water level as a result of the March 27, 1964, Alaska earthquake. Waller (1966) reported that some wells recovered to stable levels that were up to 15 feet lower than pre-earthquake levels. This well showed a water-level recovery to levels that appear to be 5-10 feet lower than pre-earthquake levels during a recovery period that lasted about a year and a half.

Well 1200410ADDA1-30

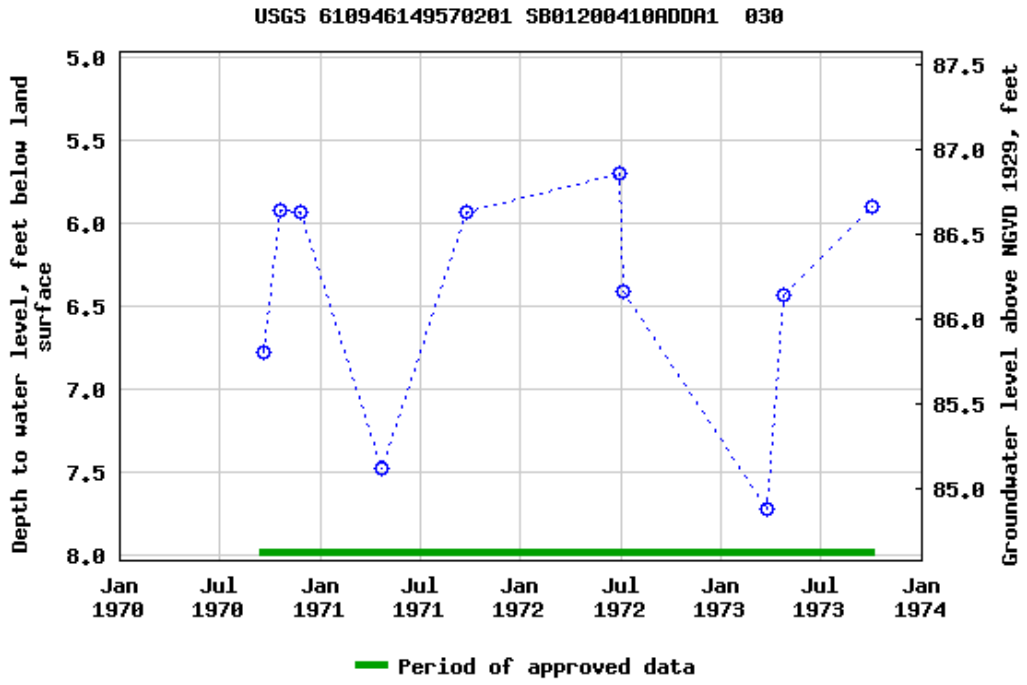

Figure E-11. Hydrograph of Well SB01200410ADDA1 030

(Source: https://nwis.waterdata.usgs.gov/usa/nwis/gwlevels/?site_no=610946149570201&agency_cd=USGS)
(See Figure E-1 for well location.)

Summary of data
WELTS Log ID: pending
Appendix A Well ID: 1200410ADDA1-30
Aquifer tapped: Water-table
Well Depth: 14 feet
Land surface elevation 92.58 feet (NGVD 1929)

This well shows up to about 2 feet of water level fluctuation that is likely a result of seasonal variations.

Part 2. Data collected during this investigation.

Water-level data were collected during this project using pressure transducers installed below the water surface in each well. A barometric pressure logger was also installed in Well SL-1 just inside the wellhead to measure fluctuations in barometric pressure. Water levels were periodically measured with an electric water-level indicator and the digital data were corrected for barometric pressure fluctuations and related to the elevation of the measuring point of each well to convert the pressure data to values of water-level elevation shown in the plots.

Several wells provided data that were useful for understanding the results of the aquifer test (Appendix F). For these wells, a short term hydrograph of data collected before, during and after the test are also provided.

Well KE-21

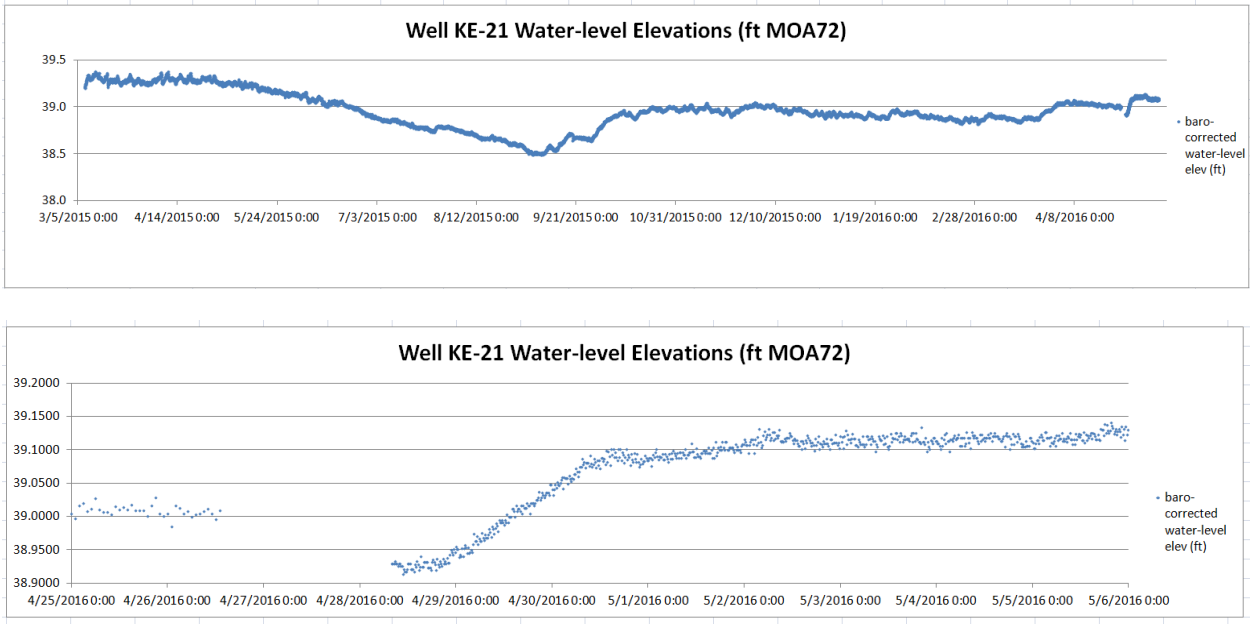

Figure E-12. Hydrographs of Well KE-21.

Well KE-21 exhibited a water-level elevation range of approximately 0.9 ft over the 14-month period of record, with the lowest levels occurring at the end of summer in early September 2015. Water levels rose between April 28-30 by about 0.15 ft, likely as a result of the discharge of water from the April 28-29, 2016, aquifer test into the South Pond. After April 30, 2016, the water level continued to rise another 0.05 feet during the next few days before resuming a declining trend.

Table E-1. Water-level measurements collected at well KE-21. See Appendix A for additional well data and for additional water-level measurements made during well sampling events.

Depth to water below top of casing (ft)	Date and time of measurement	Water-surface elevation	Method of measurement
29.21	3/7/15 10:55 am	39.22	e-tape
29.12	4/25/15 2:18 pm	39.31	e-tape
29.38	6/17/15 11:25 am	39.05	e-tape
30.25	11/20/2015 2:40 pm	38.18	e-tape
29.50	4/26/2016 2:21 pm	38.93	e-tape
29.21	5/12/2016 8:10 am	39.22	e-tape

note: top of casing elevation 68.43 feet MOA72

Well KE-22

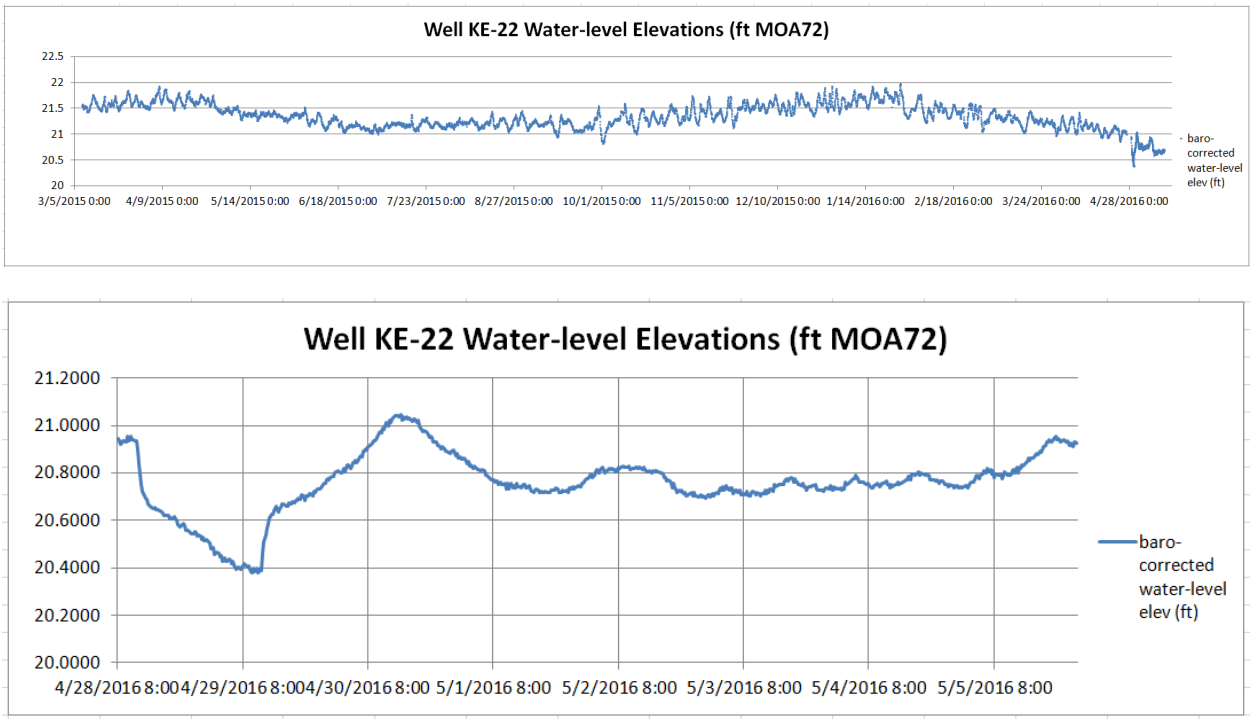

Figure E-13. Hydrographs of Well KE-22.

Well KE-22 exhibited a range of water-level fluctuation of approximately 1.4 ft over the 14 month period of record, with the lowest water levels (except for during the April 20016 aquifer test) occurring near the beginning of summer in May, 2016. The well also exhibited short term fluctuations of approximately 0.3-0.6 ft that do not correlate with barometric or tidal fluctuations. Inspection of the graph shows the effect of the aquifer test conducted April 28-29, 2016, when water levels briefly dropped below 20.5 ft elevation (MOA72).

Table E-2. Water-level measurements collected at well KE-22. See Appendix A for additional well data and for additional water-level measurements made during well sampling events.

Depth to water below top of casing (ft)	Date and time of measurement	Water-surface elevation	Method of measurement
49.32	3/7/2015 10:37 am	21.55	e-tape
49.29	4/25/2015 1:50 pm	21.58	e-tape
49.43	5/15/2015 11:15 am	21.44	e-tape
49.72	6/17/2015 10:45 am	21.15	e-tape
49.29	11/20/2015 2:30 pm	21.58	e-tape
49.00	4/26/2016 2:00 pm	21.87	e-tape
50.04	5/12/2016 8:00 am	20.83	e-tape

note: top of casing elevation 70.87 feet MOA72

Well SL-1

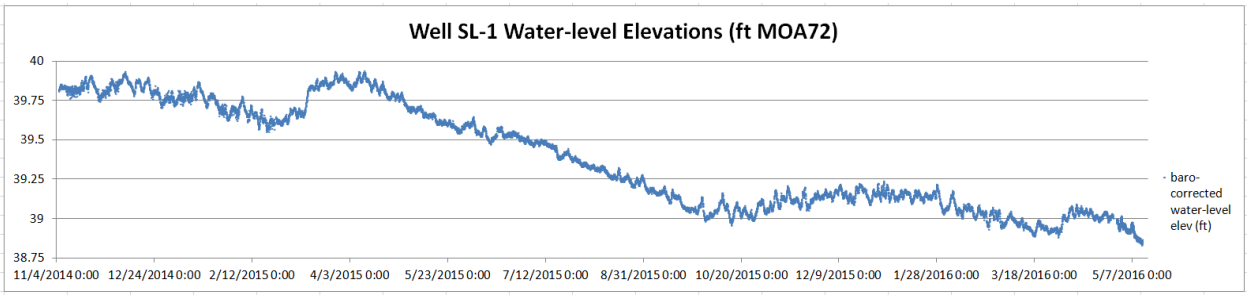

Figure E-14. Hydrograph of Well SL-1.

Well SL-1 exhibited a range of water-level fluctuation of approximately 1 ft over the 18 month period of record, with the lowest water level occurring during May 2016. Seasonal fluctuations were generally less than 0.5 ft. A period-of-record decline of the water level trend was likely the result of a return to more normal precipitation levels after a climatic wet period.

Table E-3. Water-level measurements collected at Well SL-1. See Appendix A for additional well data and for additional water-level measurements made during well sampling events.

Depth to water below top of casing (ft)	Date and time of measurement	Water-surface elevation	Method of measurement
83.38	2/23/2015 11:45 am	39.65	e-tape
83.27	4/25/2015 12:38 pm	39.76	e-tape
83.85	11/20/2015 3:30 pm	39.18	e-tape
84.00	4/27/2016 4:11 pm	39.03	e-tape

note: top of casing elevation 123.03 feet MOA72

Well SL-2

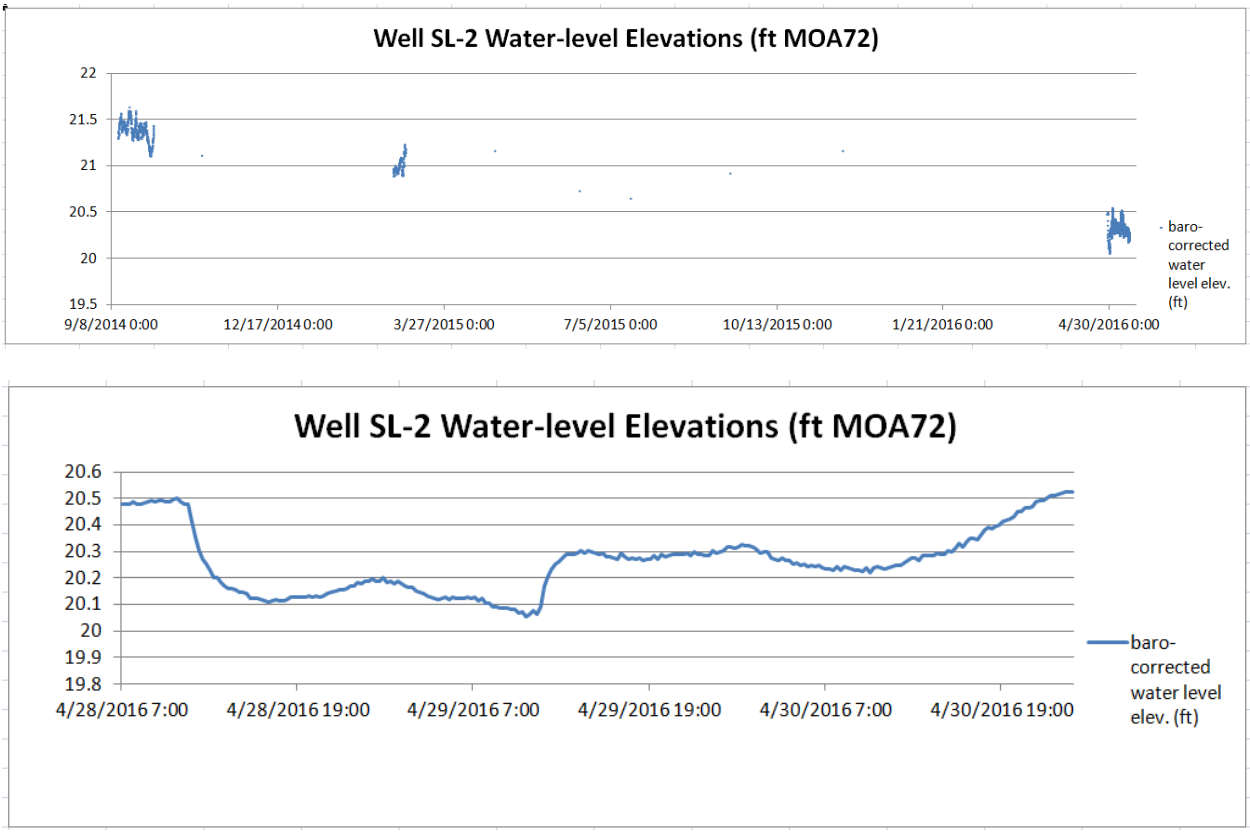

Figure E-15. Hydrographs of Well SL-2.

Well SL-2 had recurrent problems with instrumentation that resulted in mostly sporadic water-level data. The well exhibited a range of water-level fluctuation of approximately 1.6 ft over the 20-month period of record, with the lowest water level occurring during the aquifer test conducted April 28-29, 2016. Inspection of the graph shows the effect of the aquifer test conducted April 28-29, 2016.

Table E-4. Water-level measurements collected at Well SL-2. See Appendix A for additional well data and for additional water-level measurements made during well sampling events.

Depth to water below top of casing (ft)	Date and time of measurement	Water-surface elevation	Method of measurement
107.4	9/11/2014 8:00 am	21.37	Not reported
107.48	10/2/2014 4:00 pm	21.29	Not reported
107.65	10/31/2014 2:00pm	21.12	Not reported
107.8	2/23/2015 12:25 pm	20.97	Sonic sounder

Depth to water below top of casing (ft)	Date and time of measurement	Water-surface elevation	Method of measurement
108	3/15/2015 5:30 pm	20.77	Not reported
107.60	4/25/2015 12:44 pm	21.17	Sonic sounder
108.12	7/16/2015 11:50 am	20.65	e-tape
107.6	11/20/2015 4:10 pm	21.17	sonic sounder
108.29	4/27/2016 4:30 pm	20.48	e-tape
108.44	5/11/2016 4:00 pm	20.33	e-tape

note: top of casing elevation 128.77 feet MOA72

Well SL-3

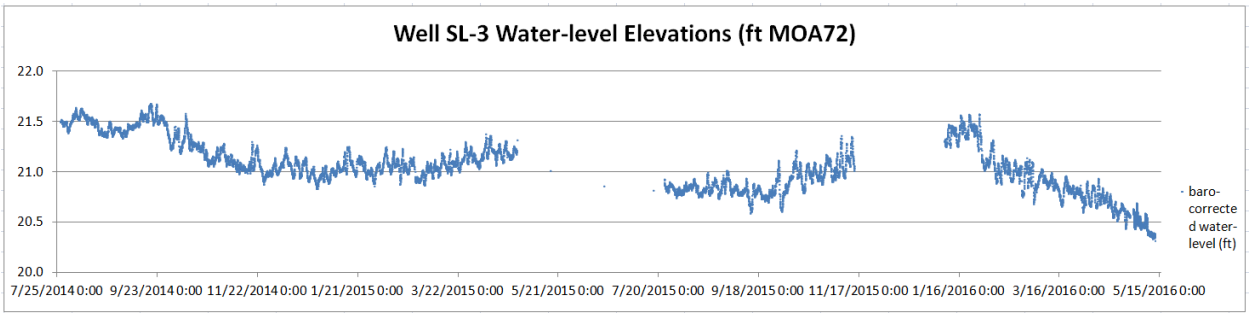

Figure E-16. Hydrograph of Well SL-3.

Well SL-3 also had some problems with instrumentation that resulted in some periods lacking data. The well exhibited a range of water-level fluctuation of approximately 1.3 ft over the 20-month period of record, with the lowest water level occurring during May 2016.

Table E-5. Water-level measurements collected at Well SL-3. See Appendix A for additional well data and for additional water-level measurements made during well sampling events.

Depth to water below top of casing (ft)	Date and time of measurement	Water-surface elevation	Method of measurement
113.17	10/2/2014 5:00 pm	21.45	Not reported
113.61	2/23/2015 1:50 pm	21.01	Not reported
113.3	4/25/2015 12:52 pm	21.32	e-tape
113.6	5/15/2015 11:36 am	21.02	e-tape
113.8	7/16/2015 10:50 am	20.82	e-tape
113.6	11/13/2015 11:30 am	21.02	e-tape
114.07	4/26/2016 1:00 pm	20.55	e-tape
114.30	5/11/2016 2:15 pm	20.32	e-tape

note: top of casing elevation 134.62 feet MOA72

Well SL-4I

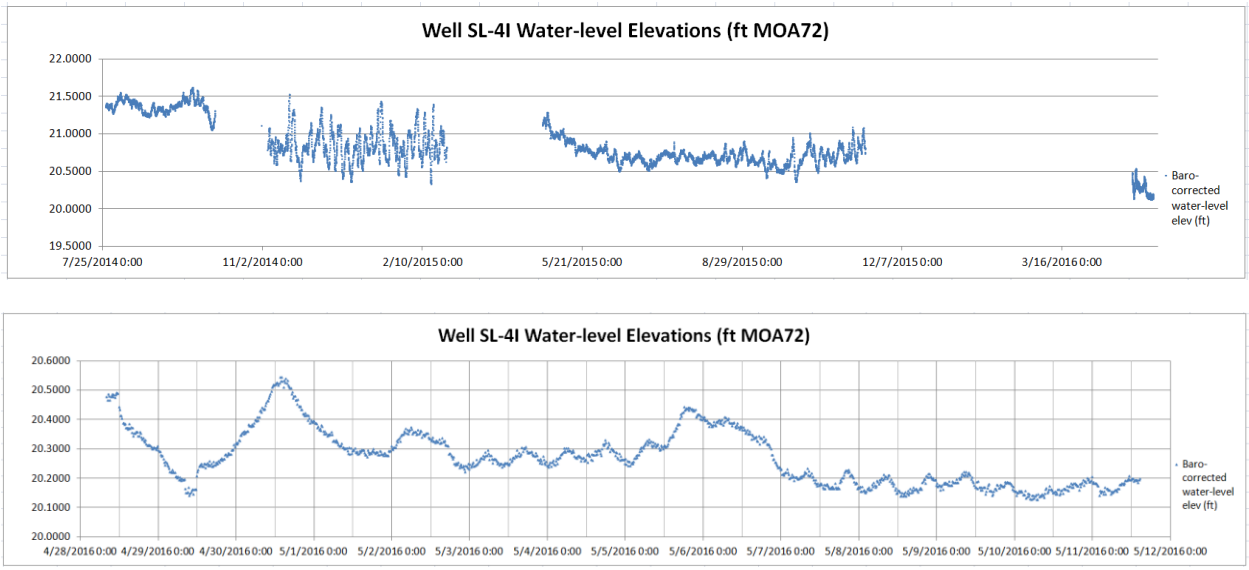

Figure E-17. Hydrographs of Well SL-4I.

Well SL-4I also had some problems with instrumentation that resulted in some periods lacking data. The well exhibited a range of water-level fluctuation of approximately 1.5 ft over the 22-month period of record, with the lowest water level occurring during May 2016. Inspection of the graphs shows the effect of the aquifer test conducted April 28-29, 2016, and lesser fluctuations caused by tides.

Table E-6. Water-level measurements collected at Well SL-4I. See Appendix A for additional well data and for additional water-level measurements made during well sampling events.

Depth to water below top of casing (ft)	Date and time of measurement	Water-surface elevation	Method of measurement
112.71	10/2/2014 5:00 pm	21.32	Not reported
112.91	10/31/2014	21.12	Not reported
113.20	2/24/2015 1:00 pm	20.83	Not reported
112.90	4/25/2015 3:04 pm	21.13	e-tape
113.25	5/15/2015 12:00 pm	20.78	e-tape
113.32	7/16/2015 10:34 am	20.71	e-tape
113.10	11/13/2015 11:39 am	21.17	e-tape
113.64	4/26/2016 1:00 pm	20.39	e-tape
113.83	5/11/2016 2:45 pm	20.20	e-tape

note: top of casing elevation 134.03 feet MOA72

Well SL-4D

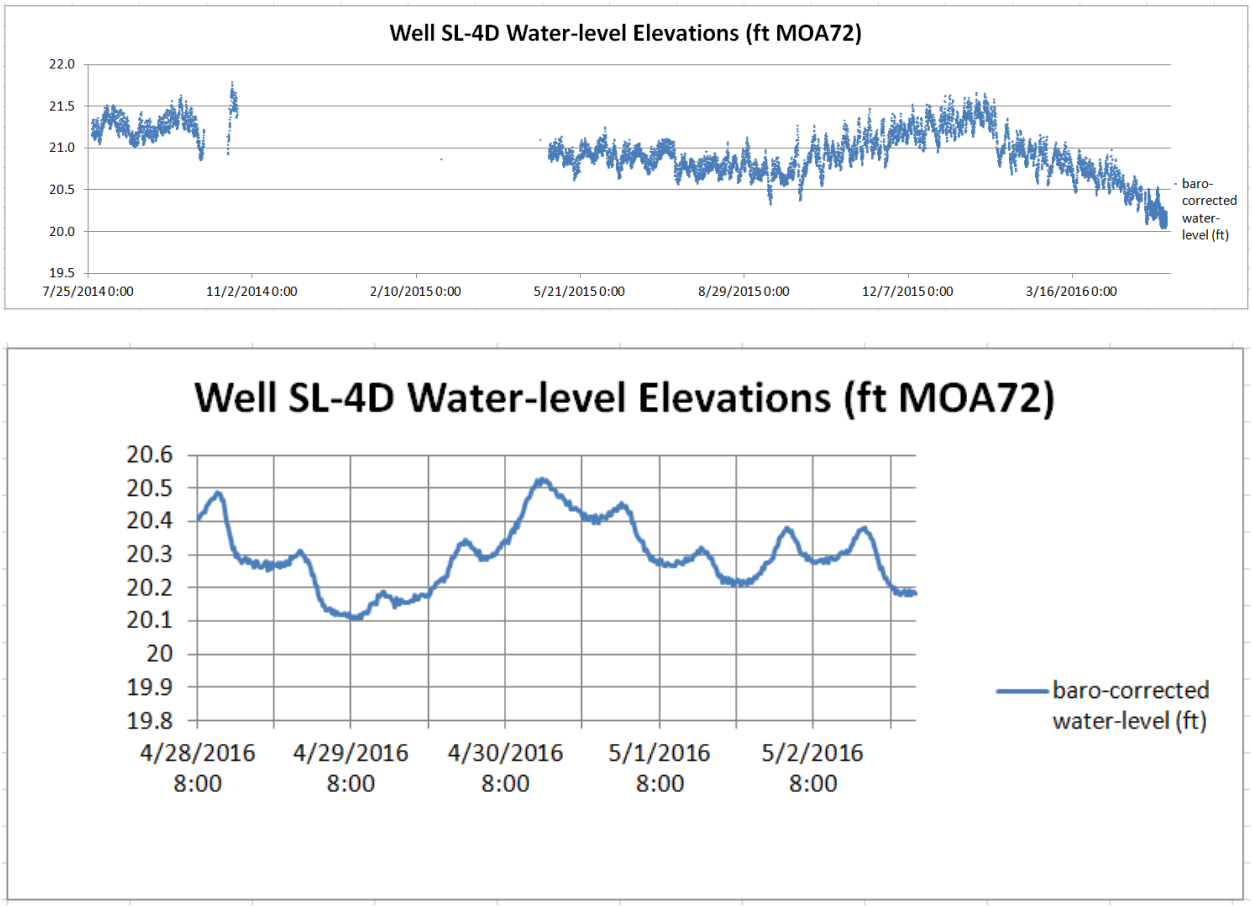

Figure E-18. Hydrographs of Well SL-4D.

Well SL-4D also had some problems with instrumentation that resulted in some periods lacking data. The well exhibited a range of water-level fluctuation of approximately 1.8 ft over the 22-month period of record, with the lowest water level occurring during May 2016. Well SL-4D exhibited the strongest tidal-response fluctuations compared to any of the other wells monitored. Inspection of the graphs shows the effect of the aquifer test conducted April 28-29, 2016, and lesser fluctuations caused by tides.

Table E-7. Water-level measurements collected at Well SL-4D. See Appendix A for additional well data and for additional water-level measurements made during well sampling events.

Depth to water below top of casing (ft)	Date and time of measurement	Water-surface elevation	Method of measurement
112.73	10/2/2014 6:00 pm	21.21	Not reported
113.06	2/24/2015 1:00 pm	20.88	Not reported
112.83	4/25/2015 2:53 pm	21.11	e-tape
113.11	5/15/2015 11:58 am	20.83	Not reported
113.21	5/19/2015 10:34 am	20.73	Not reported
113.26	7/16/2015 10:54 am	20.68	e-tape
112.69	11/20/2015 12:20 pm	21.25	e-tape
113.60	4/26/2016 1:15 pm	20.34	e-tape
113.82	5/11/2016 3:00 pm	20.11	e-tape

note: top of casing elevation 133.94 feet MOA72

Well SL-5S

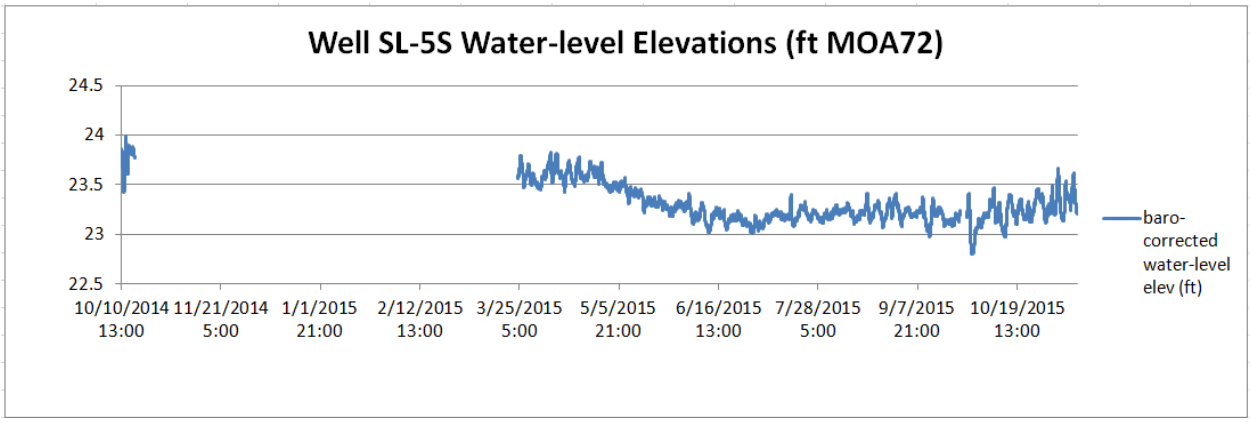

Figure E-19. Hydrograph of Well SL-5S.

Well SL-5S also had some problems with instrumentation that resulted in a period lacking data. The well exhibited a range of water-level fluctuation of approximately 1.2 ft over the 13-month period of record, with the lowest water level occurring during late September/early October 2015.

Table E-8. Water-level measurements collected at Well SL-5S. See Appendix A for additional well data and for additional water-level measurements made during well sampling events.

Depth to water below top of casing (ft)	Date and time of measurement	Water-surface elevation	Method of measurement

Depth to water below top of casing (ft)	Date and time of measurement	Water-surface elevation	Method of measurement
162.58	10/10/2014 1:00 pm	23.86	Not reported
163.07	2/24/2015 2:30 pm	23.37	Not reported
162.88	3/24/2015 1:45 pm	23.56	Not reported
162.87	4/25/2015 1:33 pm	23.57	e-tape
163.25	6/17/2015 2:10 pm	23.19	e-tape
163.15	11/13/2015 4:04 pm	23.29	e-tape
163.5	4/26/2016 2:50 pm	22.94	Not reported
163.6	5/11/2016 3:00 pm	22.84	Not reported

note: top of casing elevation 186.44 feet MOA72

Well SL-5D

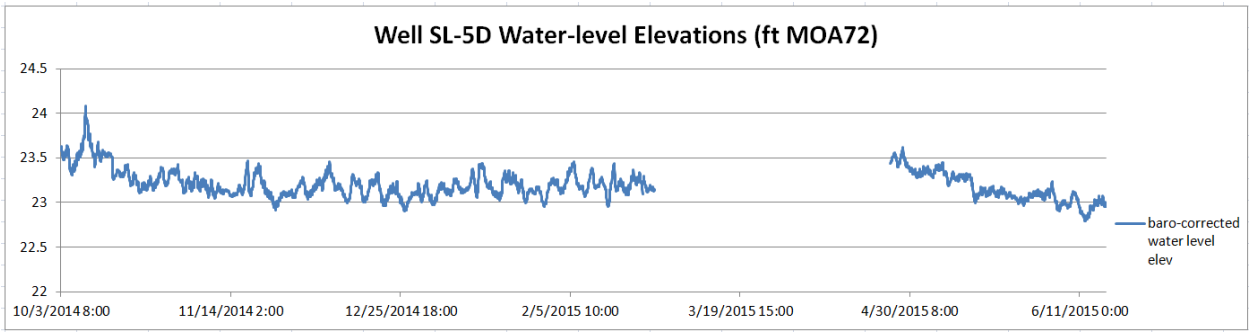

Figure E-20. Hydrograph of Well SL-5D.

Well SL-5D also had some problems with instrumentation that resulted in a period lacking data. The well exhibited a range of water-level fluctuation of approximately 1.3 ft over the 20-month period of record, with the lowest water level occurring during June 2015.

Table E-9. Water-level measurements collected at Well SL-5D. See Appendix A for additional well data and for additional water-level measurements made during well sampling events.

Depth to water below top of casing (ft)	Date and time of measurement	Water-surface elevation	Method of measurement
162.84	10/2/2014	23.65	Not reported
163.29	2/26/2015 2:15 pm	23.20	Not reported
163.05	4/25/2015 1:23 pm	23.44	e-tape
163.47	6/17/2015 1:15 pm	23.02	e-tape
163.32	11/13/2015 4:00 pm	23.17	e-tape
163.6	4/26/2016 3:30 pm	22.89	e-tape
163.79	5/11/2016 11:00 am	22.70	e-tape

note: top of casing elevation 186.49 feet MOA72

Tidal influences and vertical gradients

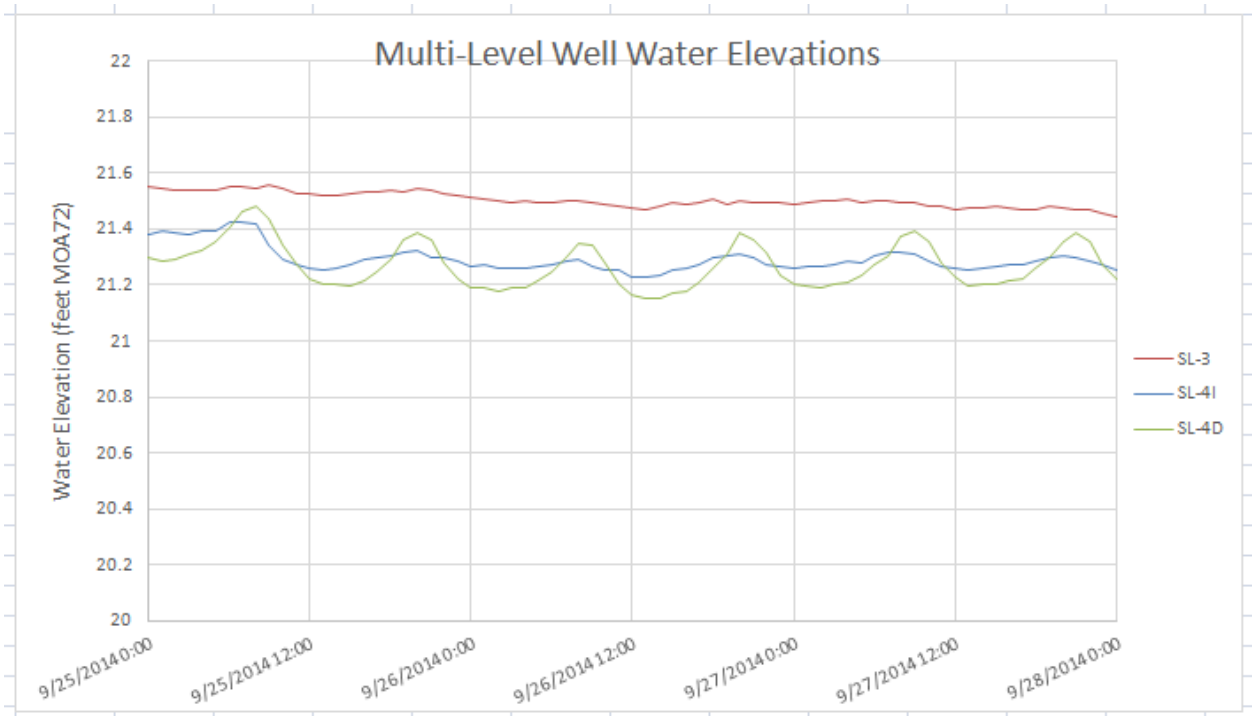

Figure E-21. Example of water-level data from Well SL-3, SL-4I, and SL-4D over several tidal cycles.

Figure E-21 shows a representative sampling of water-level data from three wells drilled at the same site near Lucy Street. Well SL-4D tapping the lower zone of the confined aquifer system, exhibits the largest response to tides, with a more muted response noted in Well SL-4I, which taps the upper zone. Well SL-3, which taps the water table aquifer at the site, does not show a response to tides. There is a consistent downward vertical gradient from the water table aquifer to the confined aquifer system. The vertical gradients between the upper and lower zone are relatively flat, however, vary from being slightly upward to being slightly downward, depending on the tidal cycle.

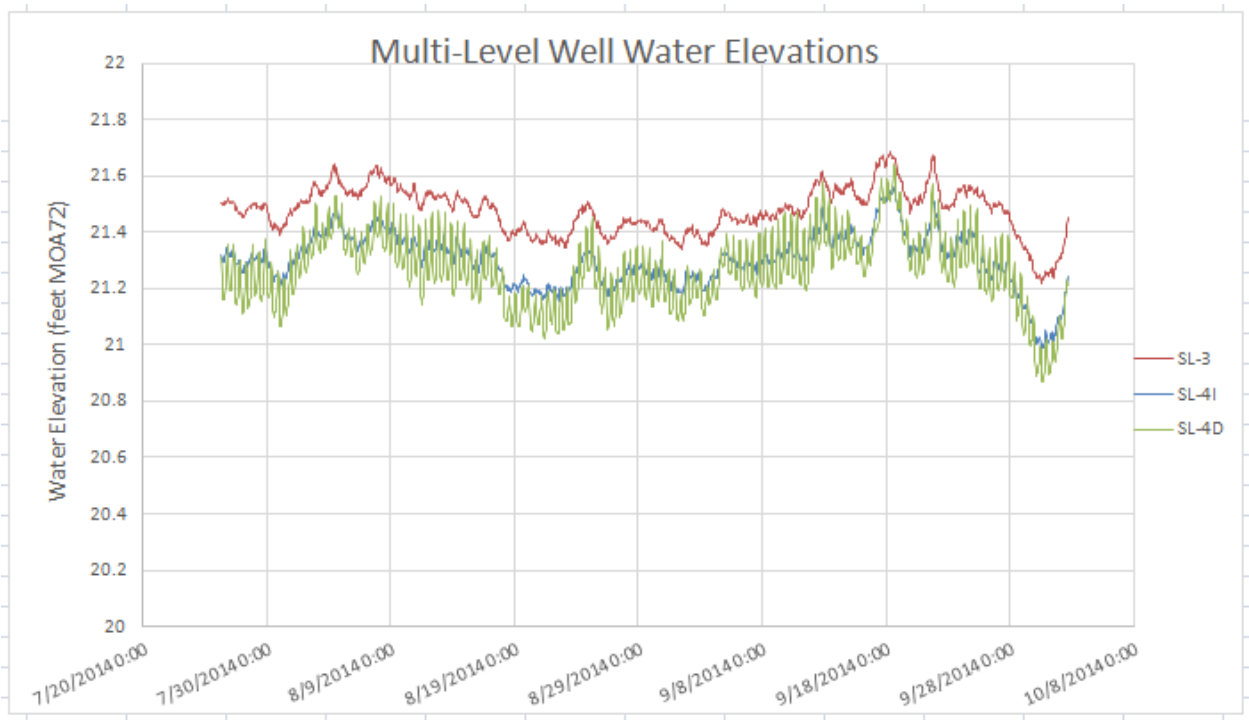

Figure E-22. Water-level data from Well SL-3, SL-4I, and SL-4D

Figure E-22 shows that a longer length of record also illustrates the relationships observed in Figure E-21.

SUMMARY

The summary of findings from the water level data contained in this appendix is in the main text of the report and is not repeated here.

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ATTACHMENTS

Attachment E-1. Dearborn 1983 Anchorage Asphalt well report