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date: April 27, 2021

to: WIPP Records Center

from: Dale O. Bowman II

subject: Milestone HYDRO 21-02: Progress Report that Documents CY20 Fluctuations in the WIPP Monitoring Well Network

1.0 Purpose

The Sandia National Laboratories (SNL) long-term, high-frequency monitoring program collects pressure transducer data in the Culebra and Magenta Members of the Rustler Formation, the Bell Canyon Formation, and Dewey Lake shallow subsurface wells across the Waste Isolation Pilot Plant (WIPP) facility. Programmatic groundwater measurements focus primarily on the Culebra Member of the Rustler Formation, because it is the most transmissive and laterally extensive water-bearing stratigraphic unit in proximity to the WIPP repository. Therefore, the Culebra water level fluctuations are the focus of this progress report.

The Culebra Dolomite has been identified as the most likely groundwater release pathway for potential future inadvertent human intrusion of the repository (Wagner and Hayes, 2019). Monitoring of Culebra groundwater composition, change in flow, and monitoring well water levels are to be conducted both during the pre-closure and post-closure phases of the repository (DOE, 2003). The Dewey Lake, Magenta, and Bell Canyon Members are not currently monitored as Compliance Monitoring Parameters (COMPs) and do not have Performance Assessment (PA) flow models (Wagner and Hayes, 2019). The objective of this milestone report is to present and summarize the pressure transducer data collected in Culebra wells for calendar year (CY) 2020.

2.0 Introduction

In CY2020, SNL recorded pressure data across 39 Culebra wells using calibrated pressure transducers. The transducers, which are generally installed at mid-formation depths, record water pressure at 15-minute intervals during routine monitoring. Pressure transducers provide a more complete record of the changes in hydraulic head occurring in the wells than is provided by monthly water-level measurements alone.

For the purposes of this report, these pressure data are reported in equivalent feet of fresh water (1 psi = 2.309 ft H_2O) and the first yearly value is normalized to zero. The data were also corrected for barometric and earth-tide effects using nSIGHTS v.2.50 (nSIGHTS 2013) in accordance with SP 9-13 Rev 1 (Bowman 2021). Data for each well are plotted individually and are also plotted in groups

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based on similarly sourced hydraulic head changes. A reference map of the Culebra monitoring well locations is shown in Figure 1. For completeness, Figure 1 also shows Magenta monitoring well locations.

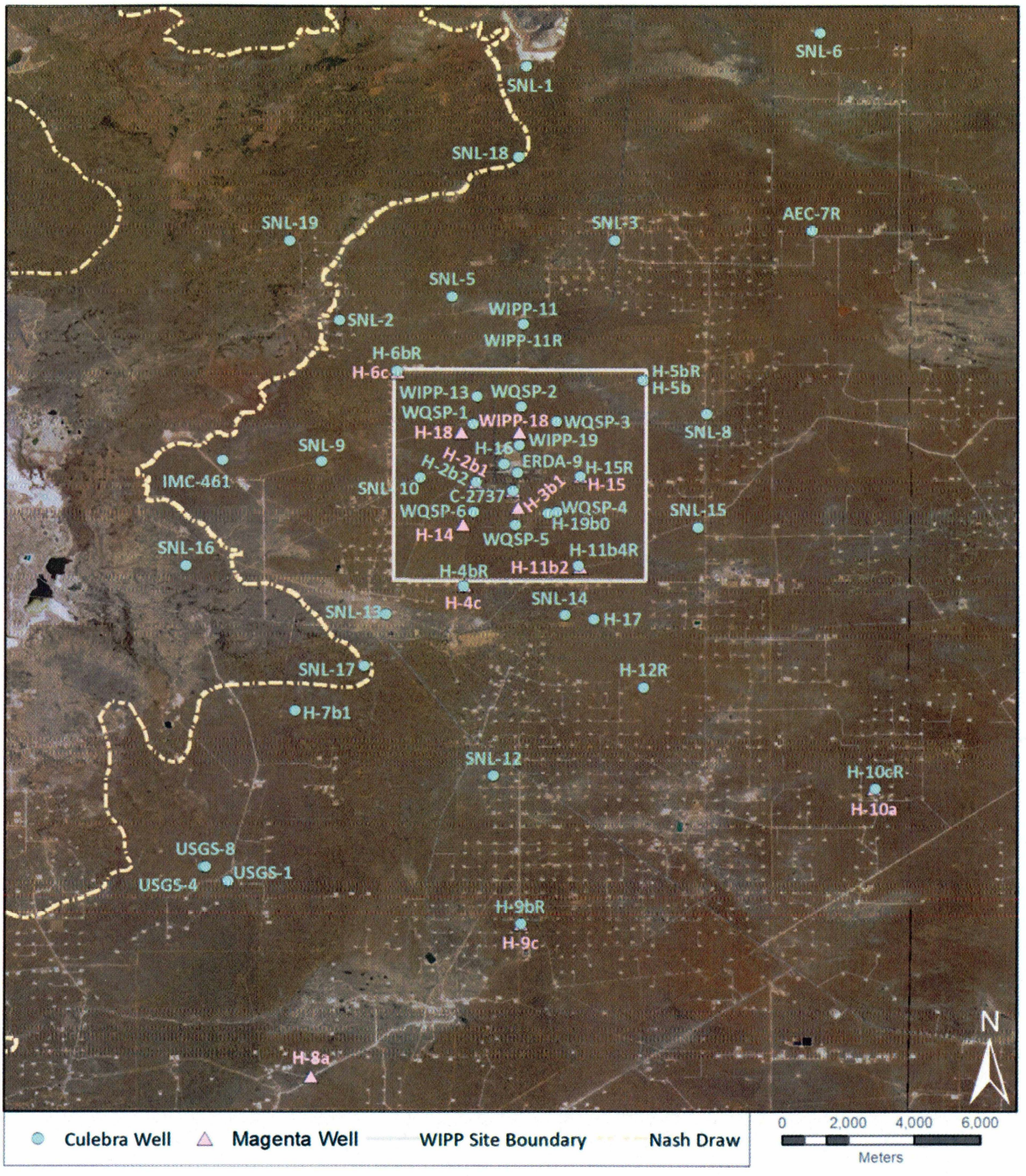

Figure 1. Locations of Culebra (blue circles) and Magenta (pink triangles) wells in the WIPP Groundwater Monitoring Network. Well C-2737 is a dual completion in both the Culebra and Magenta. The Land Withdrawal Boundary (LWB) is outlined in grey, and the approximate boundary of Nash Draw is outlined in a tan dashed line.

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Hydraulic head fluctuations for several wells include shifts, spikes, or incongruities. These fluctuations are due to various causes including adjustments to transducer depths, displacement of water during removal and replacement of transducers, transducer failures, cable stretch, or the operation of other equipment in the well. Small-scale instances of this type are not discussed in this report. Specific large-scale comments about breaks in the data or anomalous data are given on individual plots, as appropriate.

Table 1 contains a list of all monitored Culebra wells in CY2020, as shown in Figure 1, and an abbreviated description of the dominant influence(s) (the most prevalent cause(s) of change) on each well's hydraulic head. A more precise description and broader context for each of the wells and the associated influences are provided in Section 3. Table 2 contains the delta hydraulic head (Δ) change and net change of hydraulic head (both in feet of fresh water) for CY2020. Delta hydraulic head is calculated per well as the difference between the minimum and maximum recorded heads, and net change of hydraulic head is calculated as the difference between the first and last recorded head for CY2020. In circumstances where transducers were placed at different depths during CY2020 (i.e. H-6bR in Figure 12), heads were adjusted to compensate for the artificial change in pressure value. This compensation was made by aligning the last head value preceding the transducer adjustment with the first head value after the transducer adjustment. These compensations are made solely for the calculations presented in Table 2.

Table 1. Culebra Wells with Pressure Transducer Data for CY2020

Well	Dominant Influences
AEC-7R	Gravity Flow
C-2737	Recovery; Drought
ERDA-9	Recovery; Drought
H-2b2	Gravity Flow; Plugged and Abandoned
H-4bR	Recovery; Drought
H-5bR	Well Replacement; Well Development
H-6bR	Drought; Precipitation Events
H-7b1	Drought; Plugged and Abandoned
H-9bR	Drought
H-10cR	Gravity Flow
H-11b4R	Recovery; Drought
H-12R	NWR* Well Drilling/Injection
H-15R	Recovery; Drought
H-16	Recovery; Drought
H-17	Plugged
H-19b0	Recovery; Drought; NWR* Pumping
IMC-461	Drought; NWR* Pumping; Precipitation Events
SNL-1	Drought; Precipitation Events
SNL-2	Drought
SNL-3	Drought; Precipitation Events; NWR* Pumping
SNL-5	Drought; Precipitation Events
SNL-6	Long-term Recovery
SNL-8	Drought
SNL-9	Drought; Precipitation events; NWR* Well Drilling/Injection
SNL-10	Drought
SNL-12	Recovery; Drought; NWR* Pumping
SNL-13	Gravity Flow
SNL-14	Recovery; Drought; NWR* Pumping
SNL-15	Long-term Recovery
SNL-16	Drought
SNL-17	Recovery; Drought
SNL-18	Drought; Precipitation Events
SNL-19	Drought; Precipitation Events
WIPP-11R	Well Replacement; Drought
WIPP-13	Drought; Precipitation Events; NWR* Pumping
WIPP-19	Drought; Plugged
WQSP-1	Water Quality Sampling; Drought
WQSP-2	Water Quality Sampling; Drought
WQSP-3	Water Quality Sampling; Drought

*Non-WIPP Related

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Table 2. Culebra Hydraulic Head Fluctuations

Well	Δ Hydraulic Head (ft fresh water)	Net Change (ft fresh water)
AEC-7R	0.43	-0.18
C-2737	2.04	1.20
ERDA-9	2.25	0.70
H-2b2	0.20	0.07
H-4bR	3.67	-1.53
H-5bR	304.66	231.49
H-6bR*	2.09	-2.01
H-7b1	0.63	-0.18
H-9bR	11.26	-10.15
H-10cR	3.34	2.79
H-11b4R	5.03	-1.04
H-12R	18.42	4.75
H-15R	2.78	0.88
H-16	1.15	-0.65
H-17	1.65	1.57
H-19b0	3.03	1.05
IMC-461	4.60	-3.66
SNL-1	2.94	-2.90
SNL-2	2.05	-1.59
SNL-3	3.22	-3.21
SNL-5	3.83	-3.74
SNL-6*	11.23	12.63
SNL-8	0.79	-0.56
SNL-9	3.11	-2.22
SNL-10	2.02	-1.94
SNL-12	6.93	-4.71
SNL-13	0.55	0.11
SNL-14	6.64	-3.51
SNL-15	6.91	6.90
SNL-16	1.88	-1.74
SNL-17	1.20	-0.60
SNL-18	3.92	-3.85
SNL-19	2.16	-1.76
WIPP-11R	0.92	-0.89
WIPP-13	2.68	-2.56
WIPP-19	0.39	-0.30
WQSP-1	3.25	-2.39
WQSP-2	2.88	-2.83
WQSP-3	176.16	-2.37

*Period(s) of data were adjusted for calculations due to artificial changes (changes in transducer depth)

All files associated with this analysis are stored on Sandia's Concurrent Versioning System in location: /cvs/CVSLIB/WIPP_EXTERNAL/SP913_CY20.

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3.0 Dominant Influences Affecting Wells

3.1 Anthropogenic Influences

The anthropogenic impacts on the Culebra monitoring wells include:
- WQSP water quality sampling: pumping for water quality sampling at WQSP wells,
- Well maintenance activities: including development and replacement activities,
- The final remnants of recovery from Mills-Ranch pumping,
- Long-term recovery: recovery from past well development and/or nearby testing/purging/pumping that has been consistent for more than 12 months and uninterrupted in CY2020, and
- Non-WIPP related (NWR) pumping: pumping associated with industrial wells.

These human-driven impacts are discussed further in the following sections.

3.1.1 WQSP Water Quality Sampling

Sampling occurred in March 2020 for WQSP-1 and in April 2020 for wells WQSP-2 and WQSP-3. The net hydraulic head changes in these wells ranged from -2.37 to -2.83 ft fresh water (see Figures 42, 43, and 44).

3.1.2 Well Plugging, Abandonment, and Replacement

Wells H-2b2, H-7b1, H-17, and WIPP-19 were plugged and abandoned in 2020 with data collection being halted for each well in April 2020 (Figures 9, 13, 20, and 41). Wells WIPP-11 and H-5b were plugged and replaced with wells H-5bR and WIPP-11R, with data collection beginning for each well in October and June, respectively (Figures 11 and 39). Development activities at H-5bR commenced in October but have not affected other local wells.

3.1.3 Mills-Ranch Recovery

Wells C-2737, ERDA-9, H-4bR, H-11b4R, H-15R, H-16, H-19b0, SNL-12, SNL-14, and SNL-17 were in initial recovery at the start of CY2020. These wells are located in the southern half of the LWB or to the south of the LWB. Each of these wells have an increasing head for the first months of CY2020 but begin to decline as early as April 2020. The dominant effect on each of these wells transitioned from Mills-Ranch recovery to drought response, as discussed in section 3.2.1. The net recovery for these wells range between -4.71 and 1.20 ft freshwater head (Figures 7, 8, 10, 16, 18, 19, 21, 31, 33, and 36).

3.1.4 Long-Term Recovery

Wells SNL-6 and SNL-15 were drilled in areas where the Culebra contains halite cements, and the wells are still recovering from well-development activities that occurred before 2009 (DOE, 2019). The SNL-6 net recovery is 12.63 ft freshwater head (Figure 27), and the SNL-15 net recovery is 6.90 ft fresh water head (Figure 34).

3.1.5 Non-WIPP-Related (NWR) Pumping, Drilling, and Injection

Eight wells that responded to NWR pumping in CY2020 are displayed in Figure 2. These are pressure changes that are characteristic of a pumping or drilling events, but the source well and operators are many times unknown. In July 2020, there was a positive pressure event in well H-12R

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which corresponds to the drilling of oil well API# 30-015-47062 with a spud date of 7/18/2020 (Figure 17). There was a second positive pressure event in well SNL-9 characteristic of drilling or injection, but its magnitude was approximately 1 ft fresh water and its source is unknown (Figure 29). There was also evidence of pumping events in wells H-19b0, IMC-461, SNL-3, SNL-12, SNL-14, and WIPP-13. The range in pressure change for these pumping events is between 0.25 to 2.78 ft fresh water head. The net change during CY2020 in the Culebra hydraulic heads affected by NWR pumping ranged from -4.71 ft fresh water to 4.75 ft fresh water (see Figures 17, 21, 22, 25, 29, 31, 33, and 40). All wells affected by CY2020 NWR events have fully recovered.

3.2 Natural Processes

The main natural processes that impact Culebra monitoring wells are precipitation events in Nash Draw and gravity-driven flow. We acknowledge that these processes also exist in our previously described anthropogenically affected wells; however, natural processes tend to be muted under human-driven or anthropogenic hydraulic head responses. In the following sections, we discuss wells with responses dominated by natural processes.

3.2.1 Drought

Water levels in most wells had a net negative head change, and most wells that have a positive net head change for the year also have declining water levels. A negative trend in water level as a dominant influence can be seen in 30 wells: C-2737, ERDA-9, H-4bR, H-6bR, H-7b1, H-9bR, H-11b4R, H-15R, H-16, H-19b0, IMC-461, SNL-1, SNL-2, SNL-3, SNL-5, SNL-8, SNL-9, SNL-10, SNL-12, SNL-14, SNL-16, SNL-17, SNL-18, SNL-19, WIPP-11R, WIPP-13, WIPP-19, WQSP-1, WQSP-2, and WQSP-3. The net hydraulic head change in these wells ranged from -10.15 to 1.20 ft fresh water (Figures 7, 8, 10, 12, 13, 14, 16, 18, 19, 21, 22, 23, 24, 25, 26, 28, 29, 30, 31, 35, 36, 37, 38, 39, 40, 41, 42, 43, and 44). The decrease in water levels for most of the Culebra correlates with the drought status of Eddy County. Per the United States Drought Monitor, Eddy County has been in a state of drought for a majority of CY2020 (Bathke, 2021). There is agreement in our rain gauge data, which show a marked decrease in precipitation at all sites as compared to CY2019. The least impacted was the SNL-16 site with a 33% decrease in precipitation; the most impacted was the H-9 site where no precipitation was recorded. Additionally, precipitation events and typical corresponding head response were muted in CY2020.

3.2.2 Precipitation

Several wells in the vicinity of Nash Draw show relatively immediate hydraulic head responses to precipitation events. Figures 3-5 correlate precipitation data collected from rain gauges on well pads H-9, SNL-16, SNL-19, and WIPP-30 to show hydraulic head responses to precipitation events. The wells that showed a discernable, but muted, response to precipitation events did so with minimal delay (H-6bR, IMC-461, SNL-1, SNL-3, SNL-5, SNL-9, SNL-18, SNL-19, and WIPP-13). The hydraulic head fluctuations for all nine wells mentioned are consistent with precipitation fluctuations seen in previous years (Bowman & Hayes, 2019 and 2020). The net hydraulic head change in these wells ranged from -3.85 ft fresh water to -1.76 ft fresh water (Figures 12, 22, 23, 25, 26, 29, 37, 38, and 40).

3.2.3 Gravity Flow

A larger portion of wells experienced little, or no, pronounced pressure data affects from precipitation or other anthropogenic events as compared to previous years due to a lack of precipitation (AEC-7R, H-2b2, H-10cR, and SNL-13). These wells are located in areas of the

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Culebra with the largest distance from recharge, relatively low transmissivity, and other geologic factors that mute or prevent hydraulic responses observed in other wells. The net change in hydraulic heads for these wells ranged between -0.18 ft fresh water to 2.79 ft fresh water (see Figures 6, 9, 15, and 32).

4.0 Summary

Wells within the Culebra Groundwater Monitoring Network are affected by both anthropogenic influences and natural processes. The largest hydraulic head changes for CY2020 were in wells being actively developed, followed by those that are undergoing long-term recovery from pumping events. Most wells that have been predominantly affected by natural processes in past years continue to behave consistent with previous years' precipitation responses, though CY2020 was a relatively dry year, so some responses were muted and some wells that typically respond did not have any discernable response. Many of the pressure responses described in this report that are important to our understanding of the Culebra in the WIPP vicinity would not have been identifiable using only monthly water level data. The monitoring of Culebra wells using pressure transducers continues to enhance monthly water level measurements by recording high-resolution changes in hydraulic heads.

5.0 Graphs

The following section contains both composite and individual graphs of hydraulic head data from Culebra monitoring wells. Gaps and/or inconsistencies that exist in the data are described in individual well graphs, and they were evaluated under NP 16-1, Rev 7, and addressed in a Corrective Action Requests (CARs) and Corrective Action Plans (CAPs), as needed.

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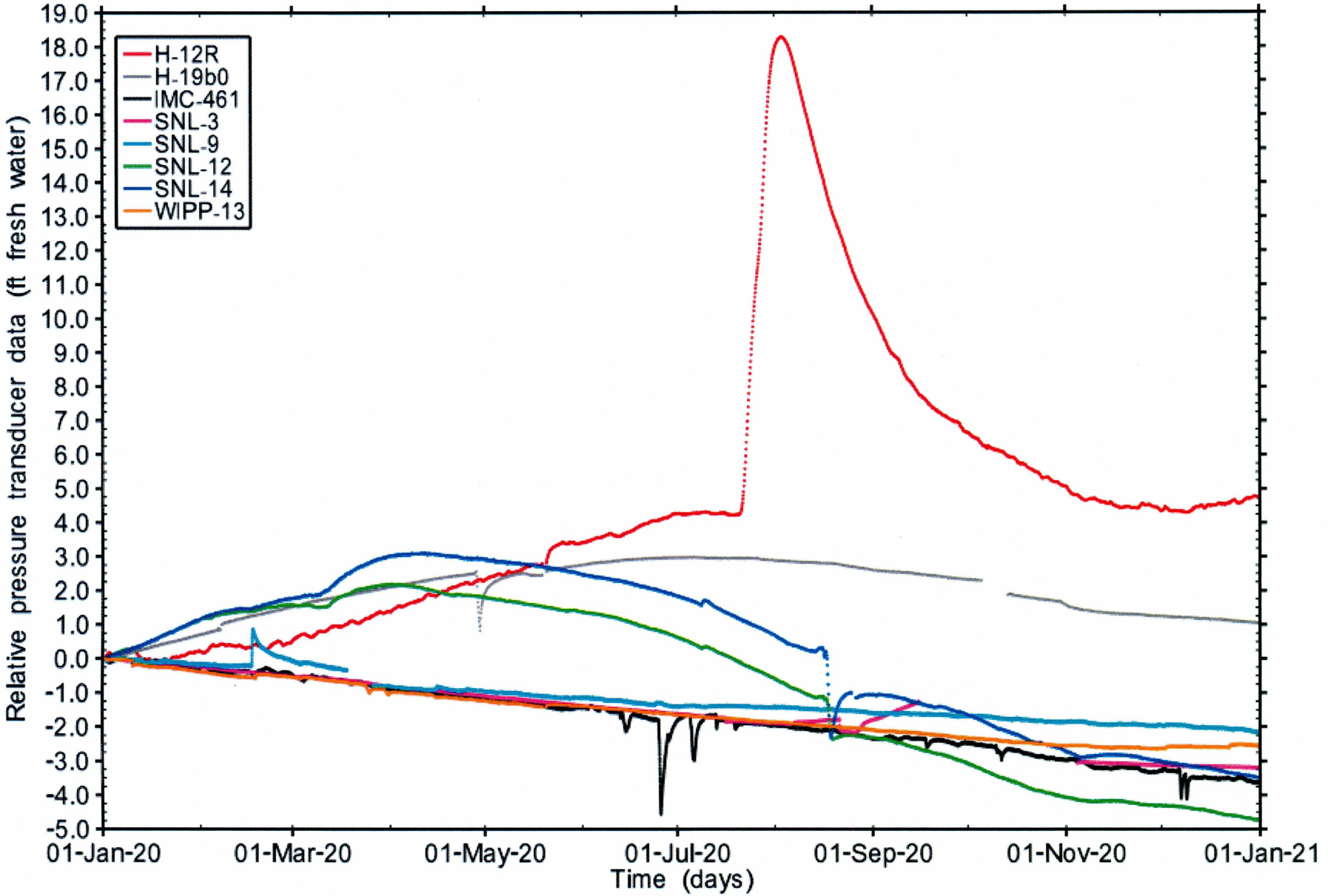

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Figure 2. Eight wells affected by NWR pumping, drilling, or injection are shown above. Note: Data gaps in CY2020 are identified in individual well graphs.

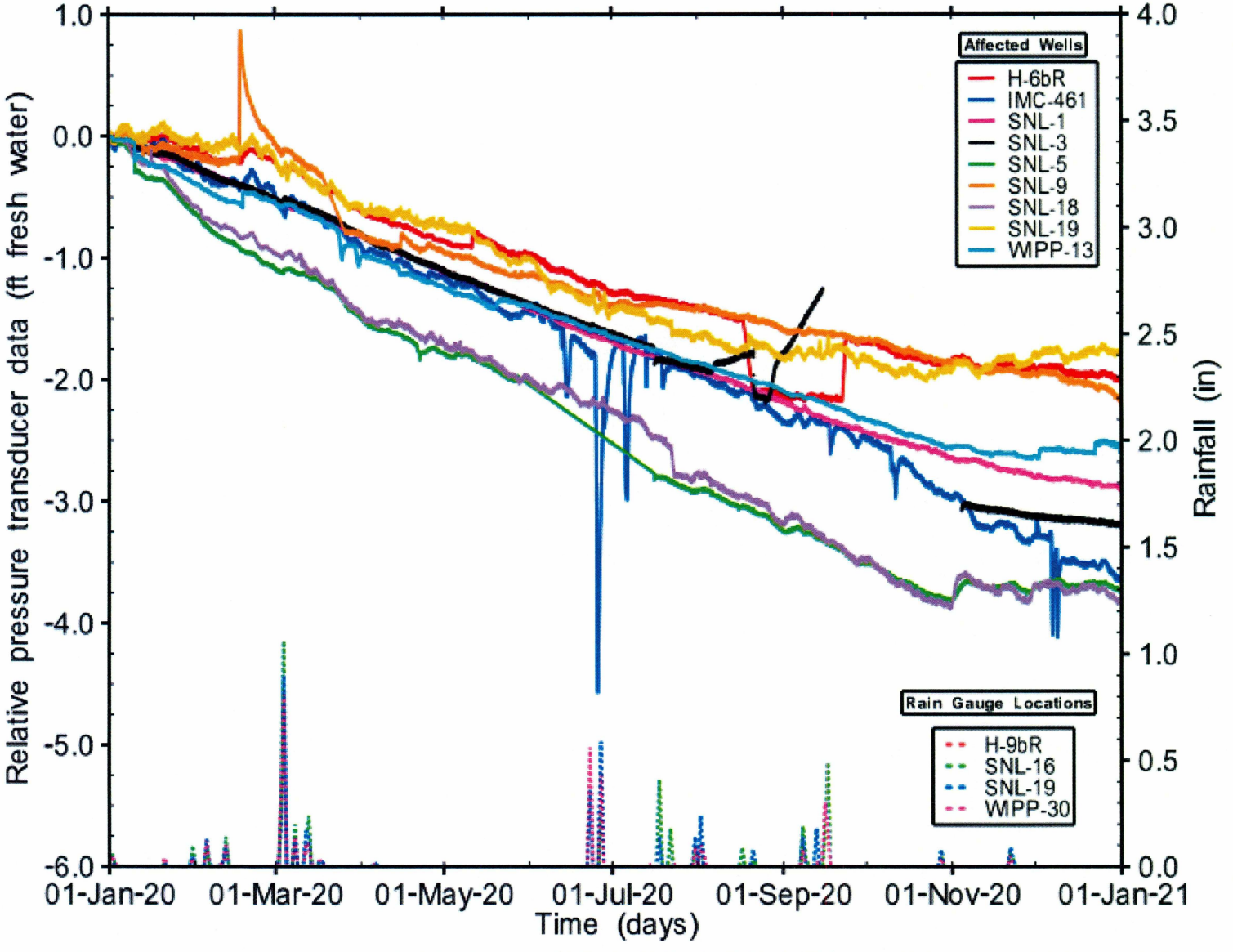

Figure 3. A group of nine Culebra wells (H-6bR, IMC-461, SNL-1, SNL-3, SNL-5, SNL-9, SNL-18, SNL-19, and WIPP-13) that demonstrate responses to precipitation events. Daily precipitation totals from four rain gauge sites are plotted as dotted lines.

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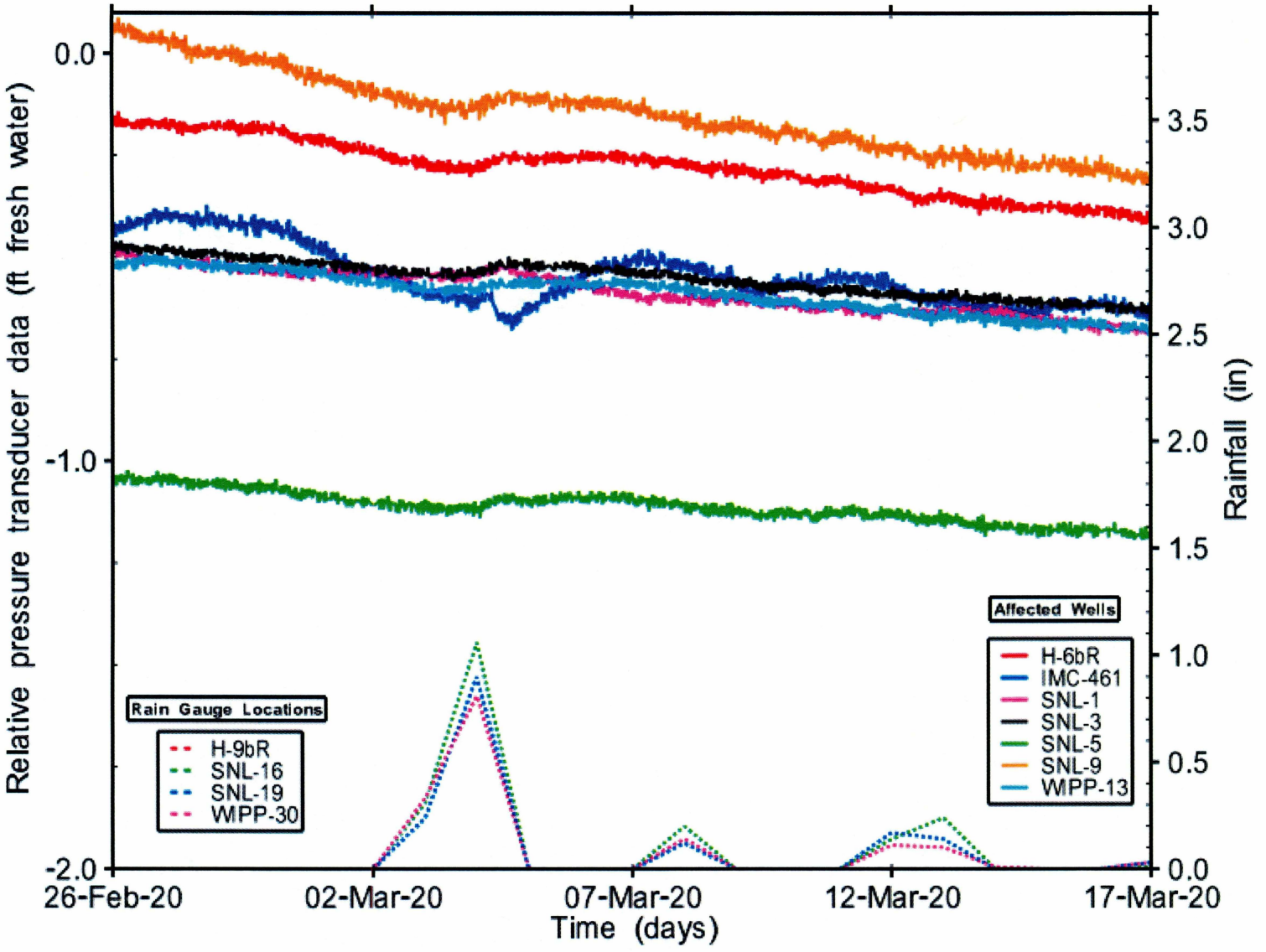

Figure 4. A subset of wells from Figure 3 that show response to the precipitation event in early March 2020.

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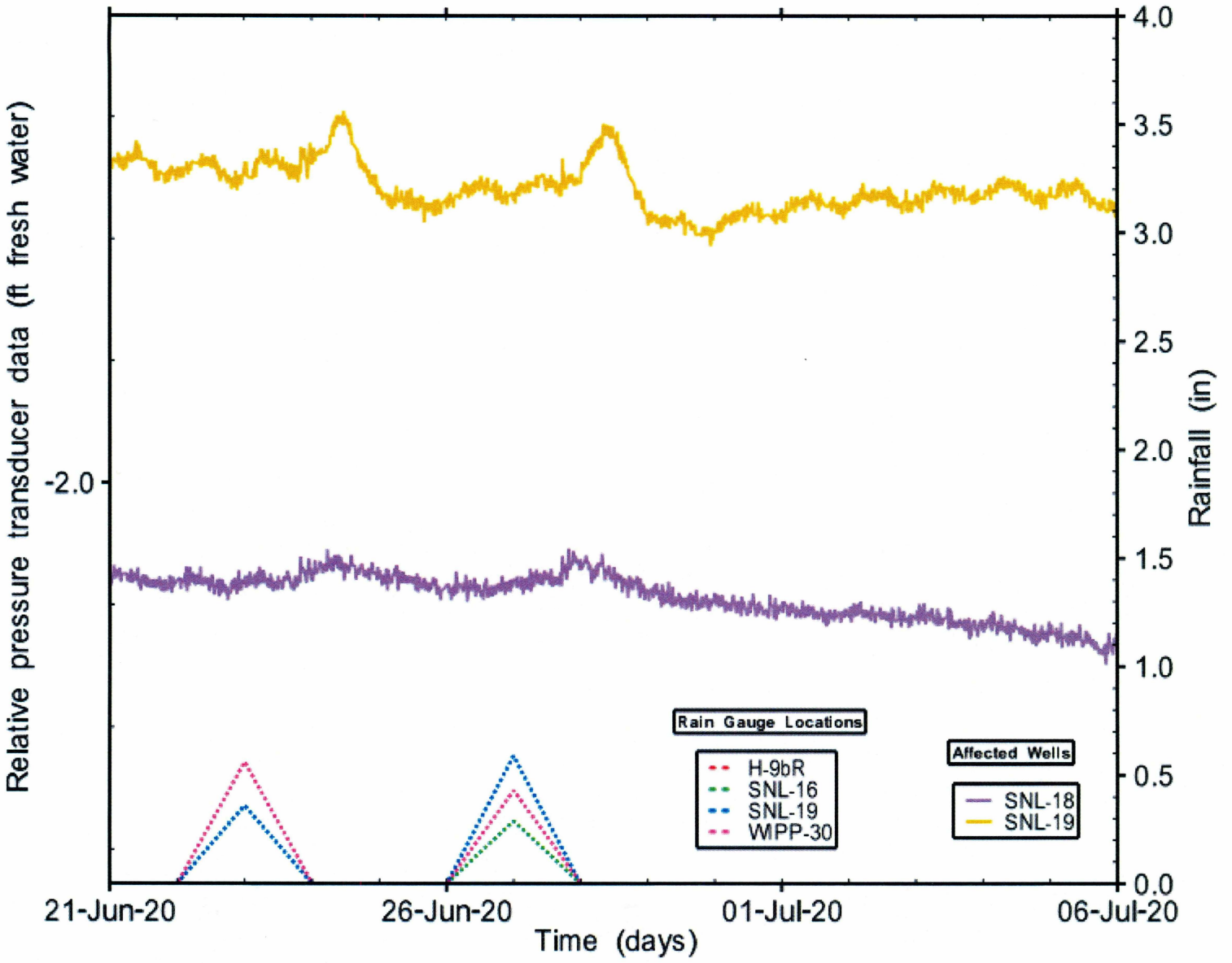

Figure 5. A subset of wells from Figure 3 that show response to the precipitation event in late June 2020.

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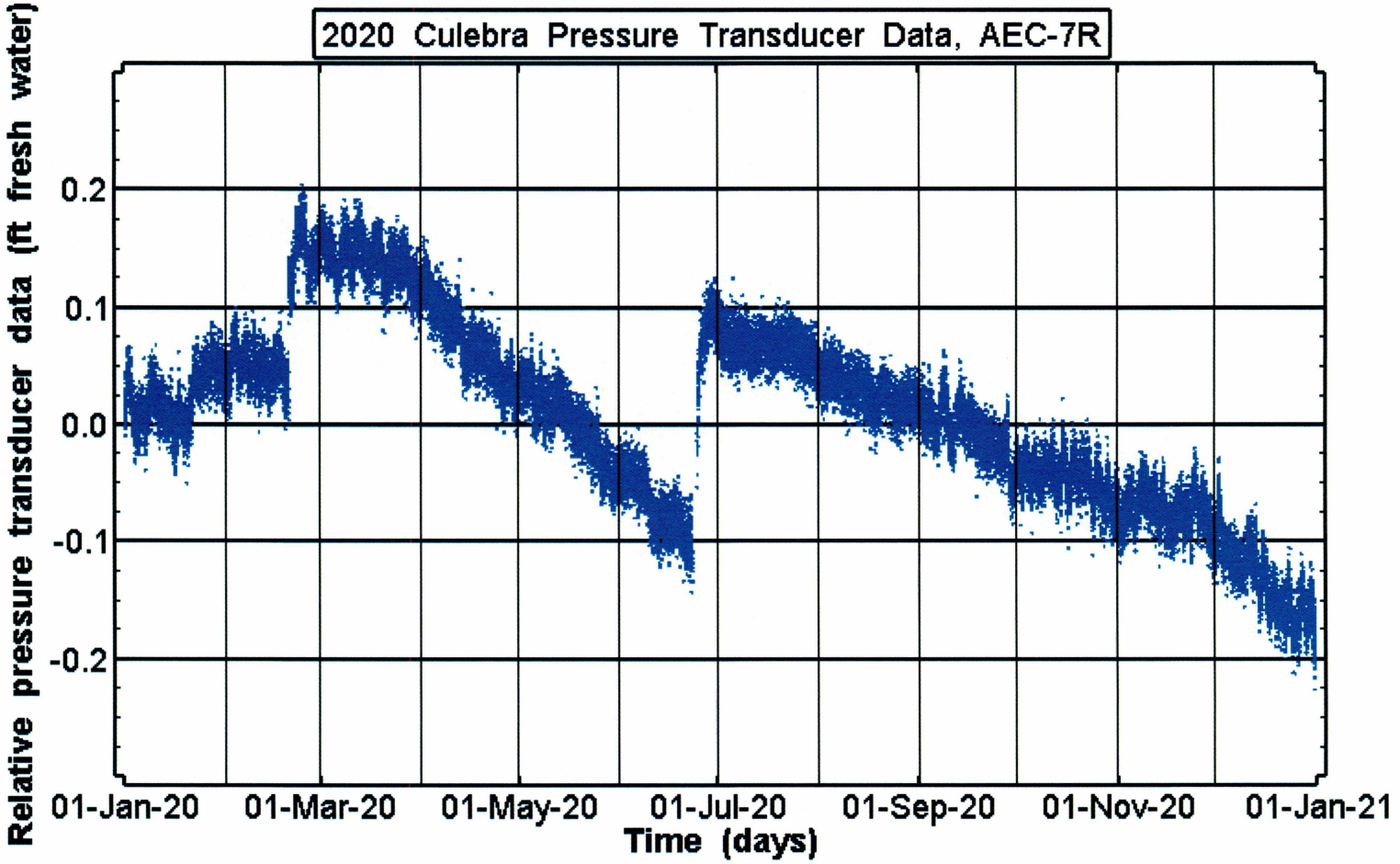

Figure 6. Well AEC-7R experienced a net change in hydraulic head of -0.18 ft fresh water in 2020.

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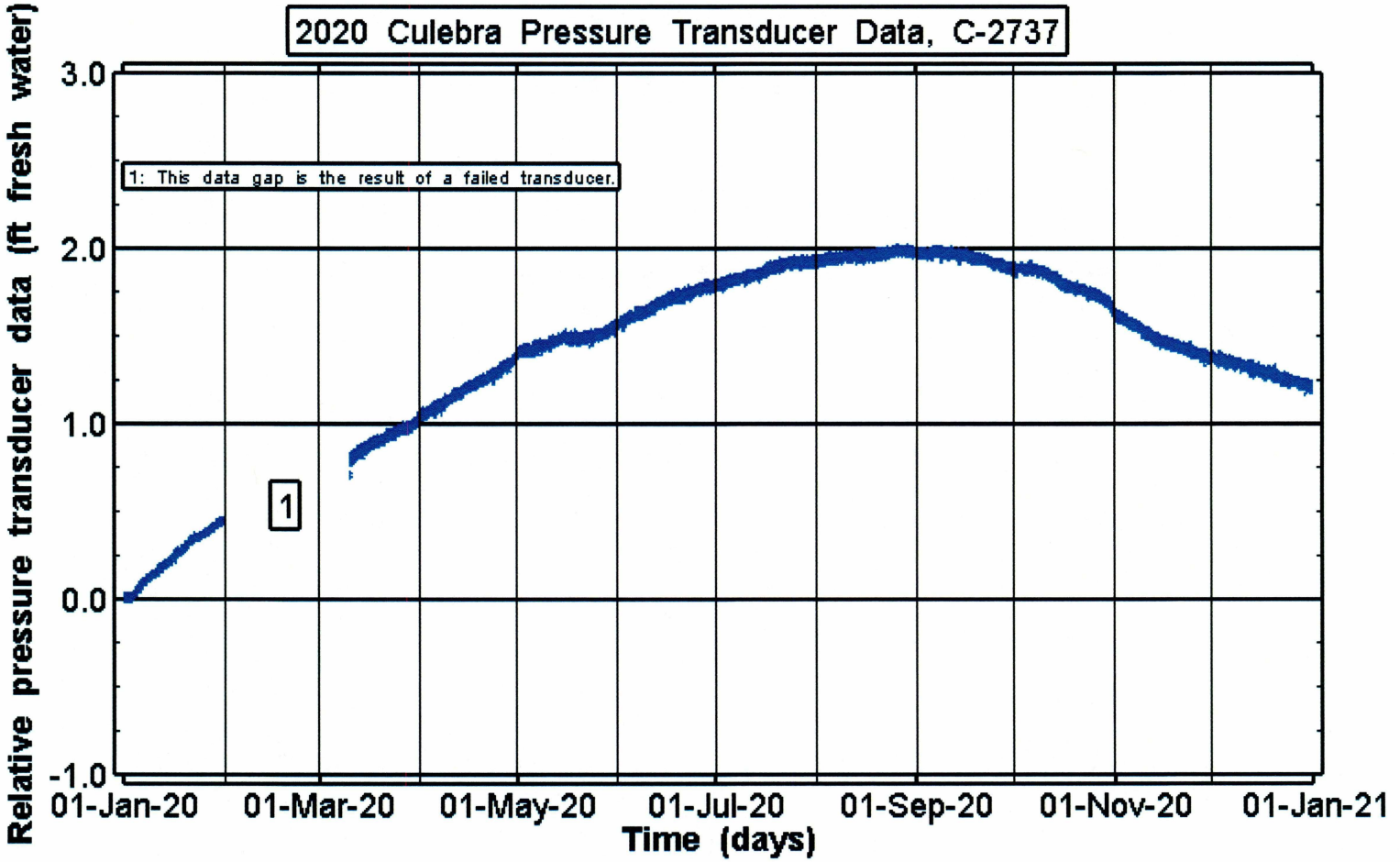

Figure 7. Well C-2737 experienced a net change in hydraulic head of 1.20 ft fresh water in 2020. This well was in recovery prior to drought effects.

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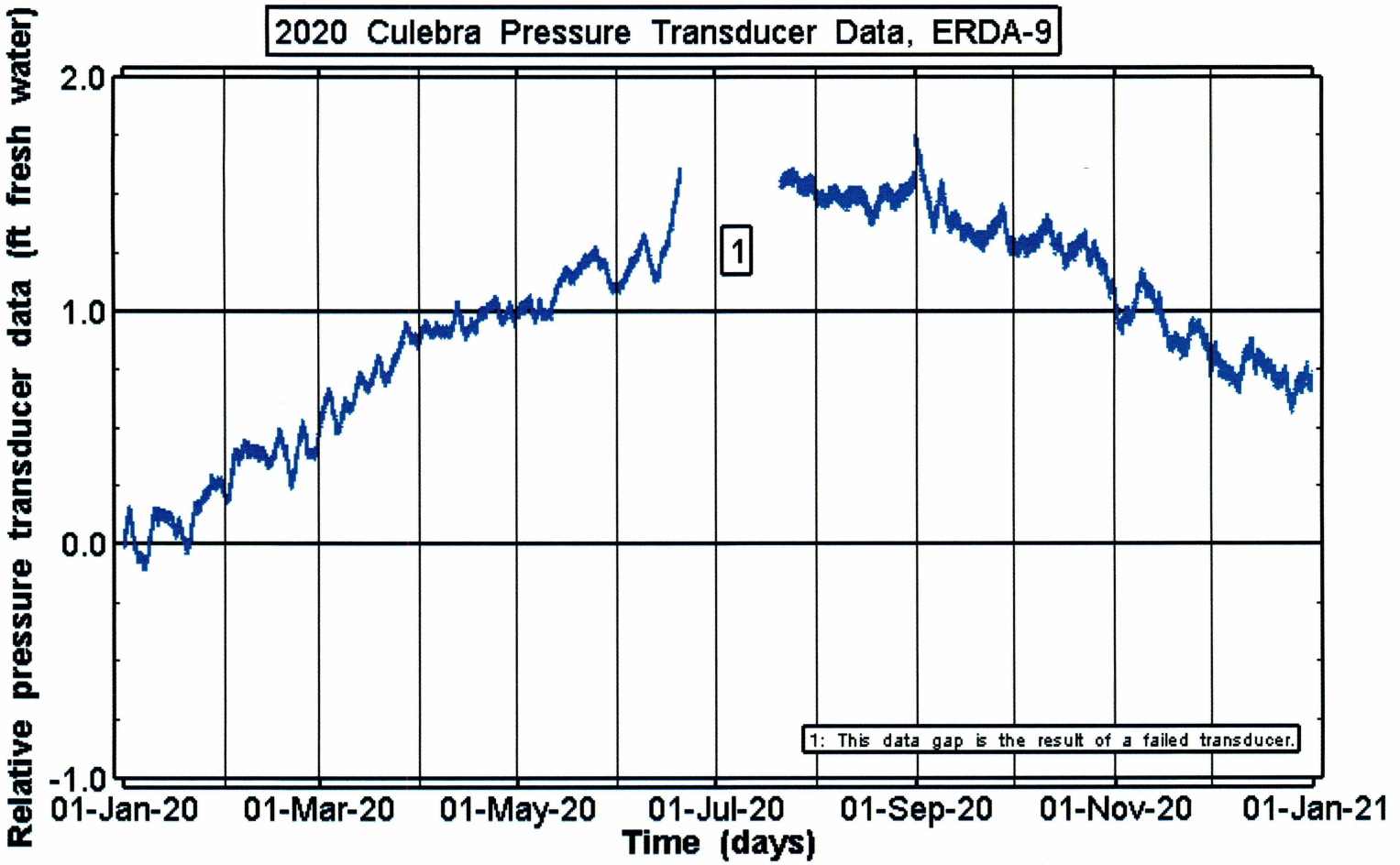

Figure 8. Well ERDA-9 experienced a net change in hydraulic head of 0.70 ft fresh water in 2020. This well was in recovery prior to drought effects.

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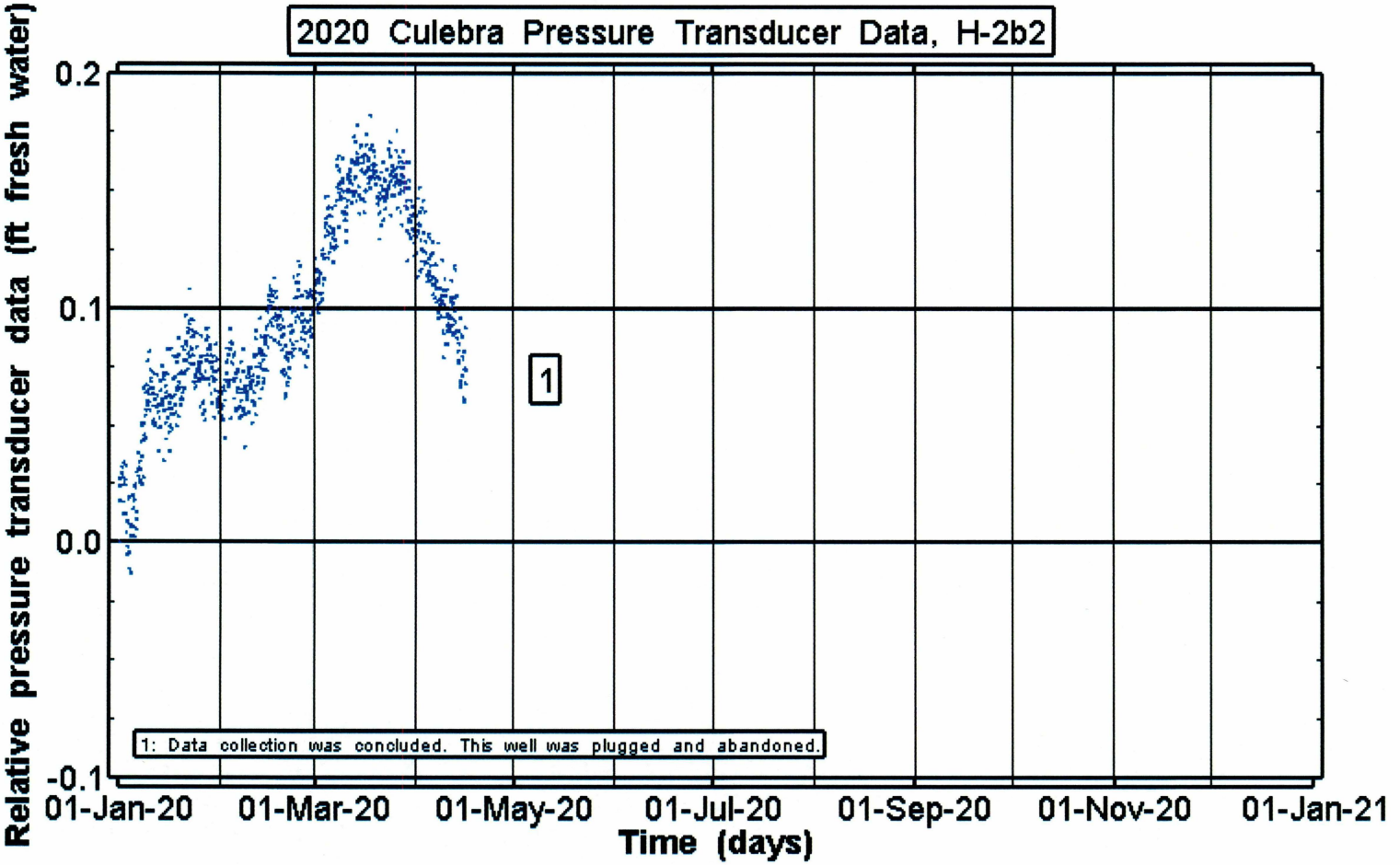

Figure 9. Well H-2b2 experienced a net change in hydraulic head of 0.07 ft fresh water in 2020.

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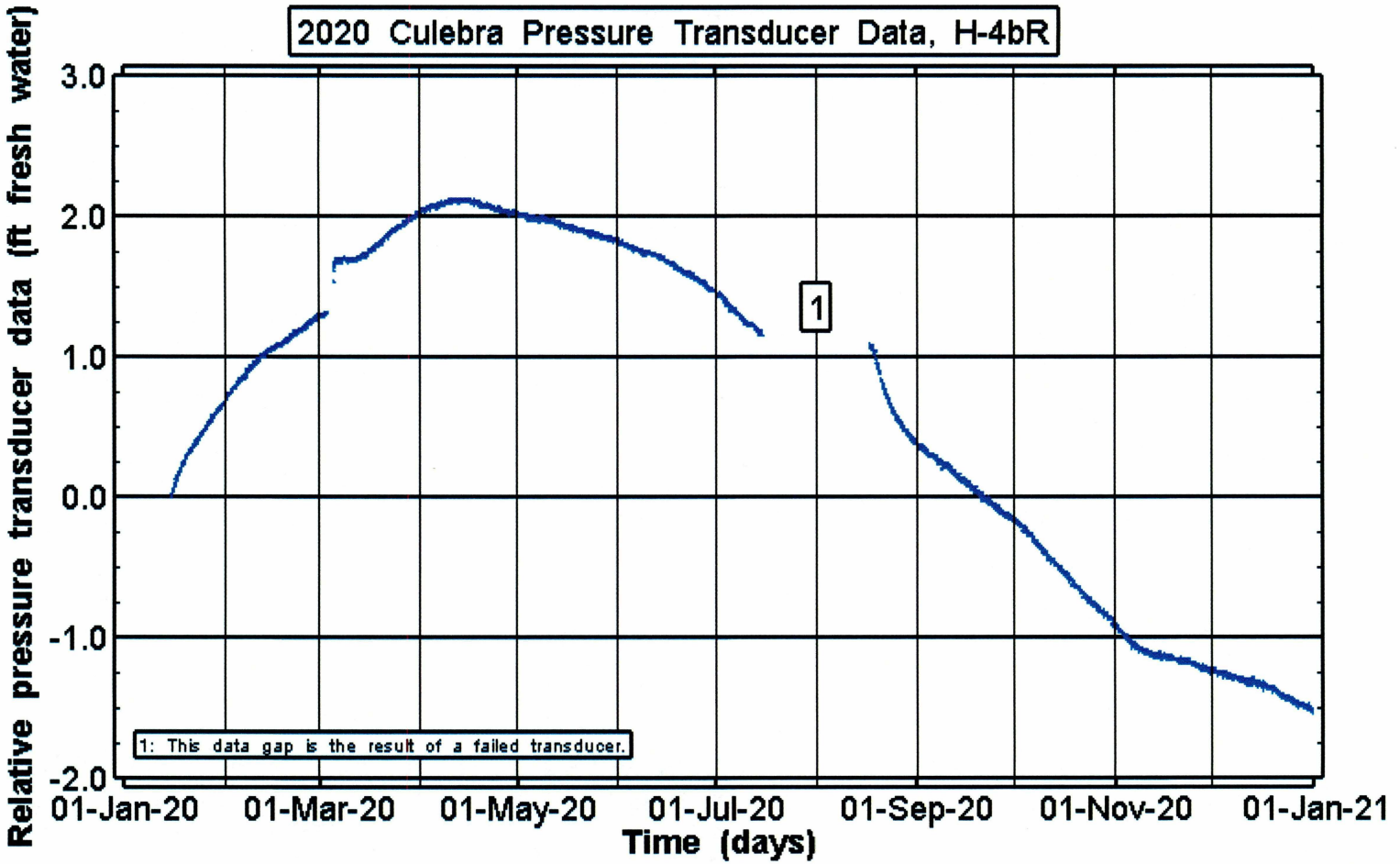

Figure 10. Well H-4bR experienced a net change in hydraulic head of -1.53 ft fresh water in 2020. This well was in recovery prior to drought effects.

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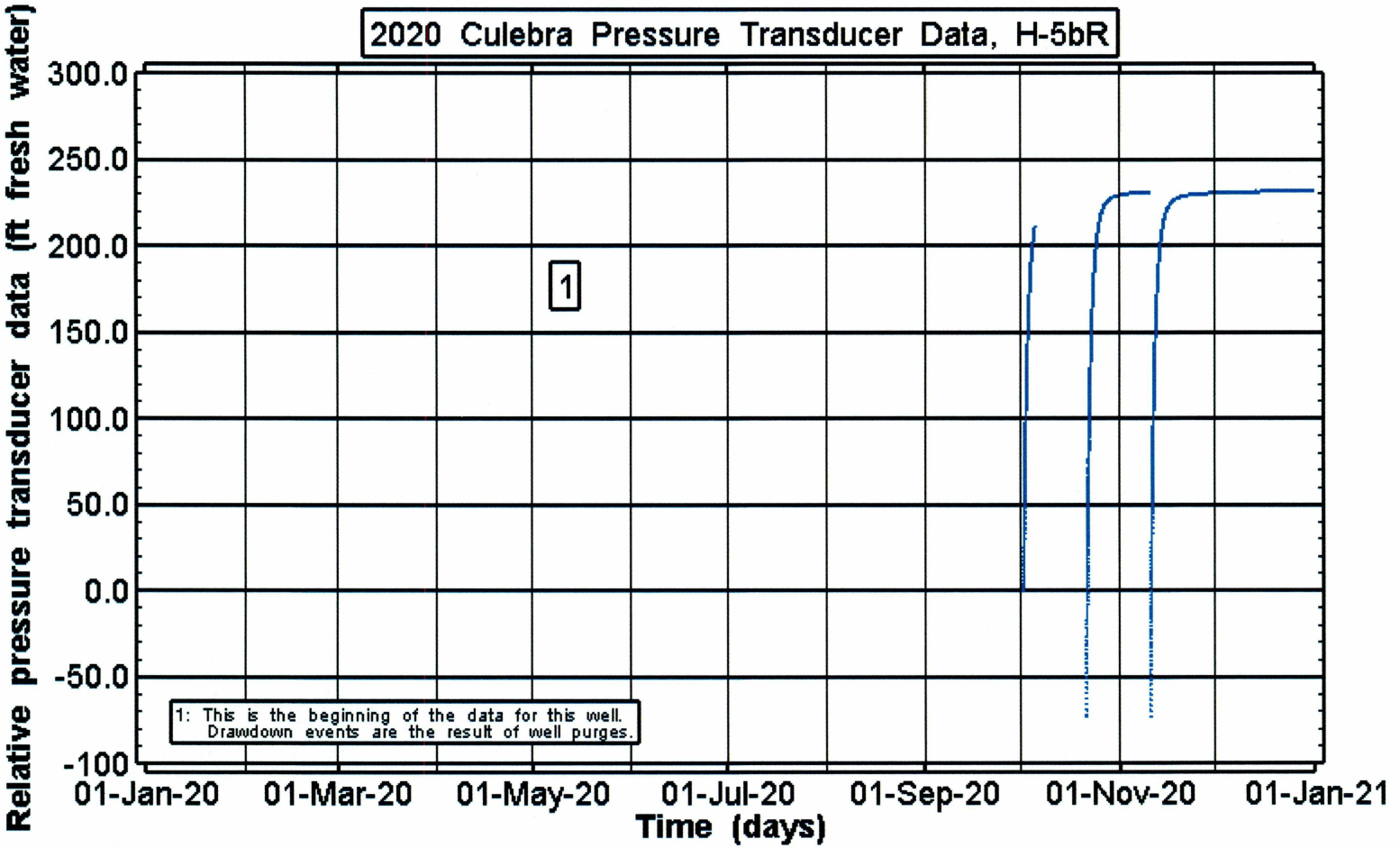

Figure 11. Well H-5bR experienced a net change in hydraulic head of 231.49 ft fresh water in 2020. This well has been subject to hydrologic purges as part of well development exercises.

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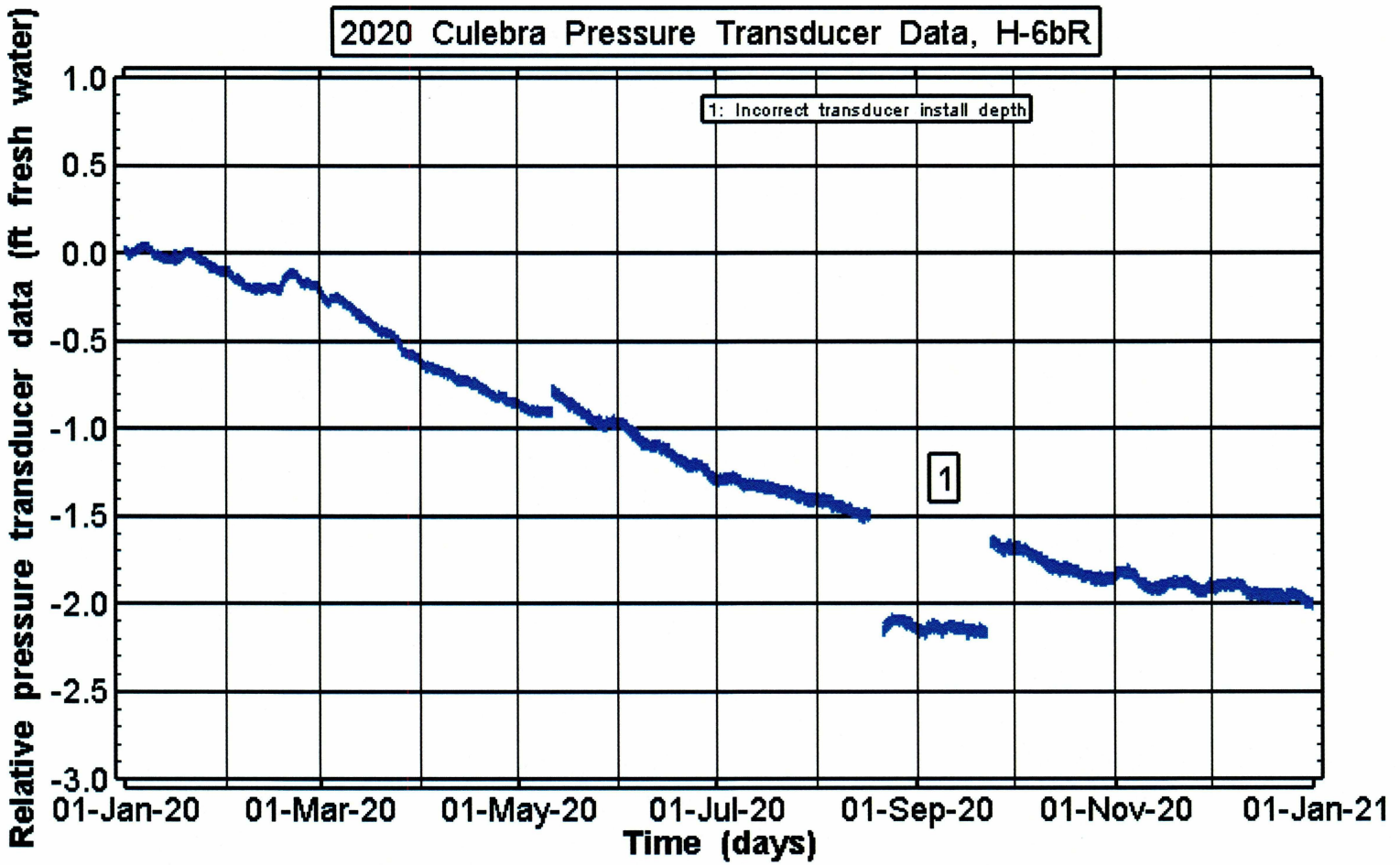

Figure 12. Well H-6bR experienced a net change in hydraulic head of -2.01 ft fresh water in 2020.

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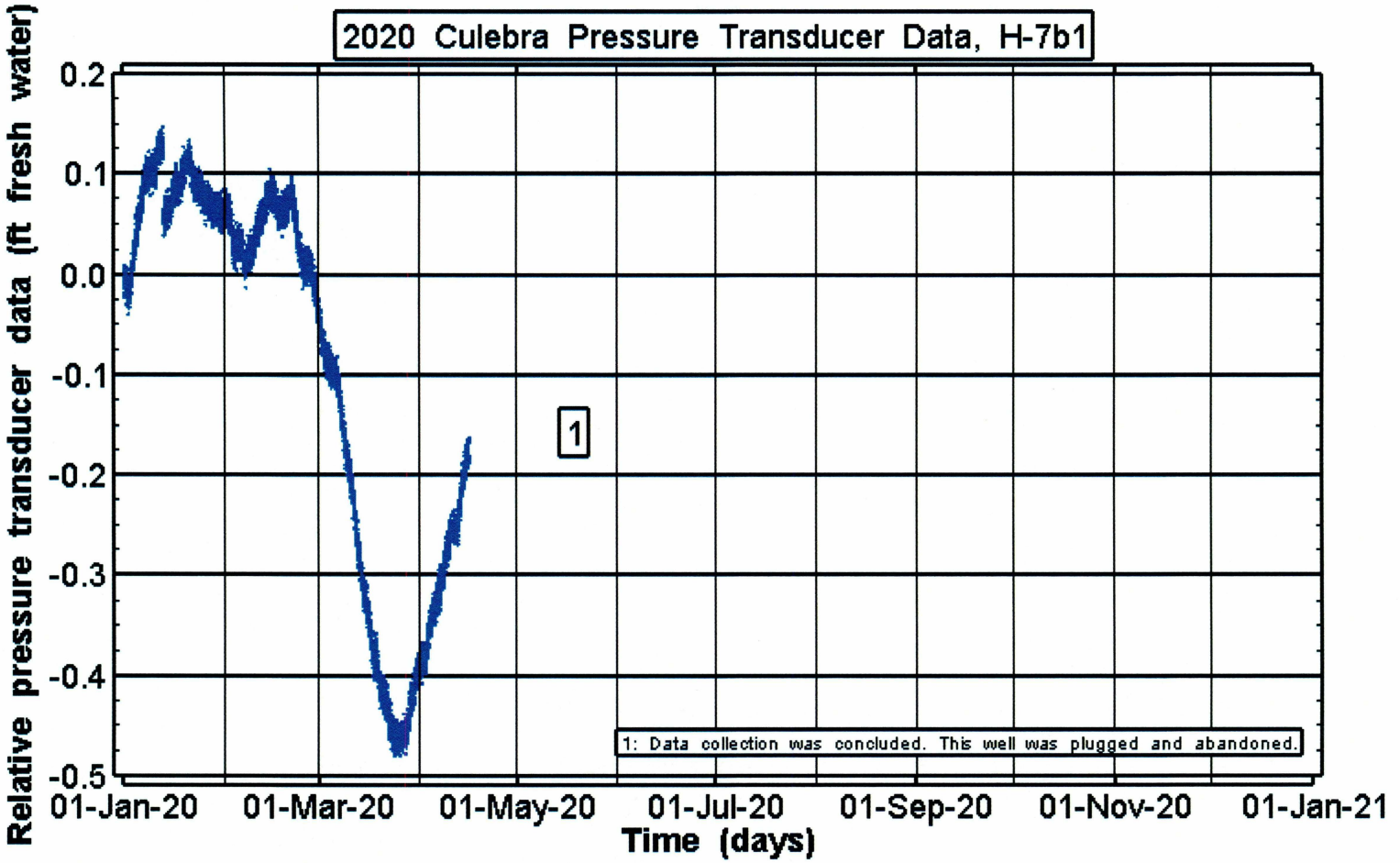

Figure 13. Well H-7b1 experienced a net change in hydraulic head of -0.18 ft fresh water in 2020.

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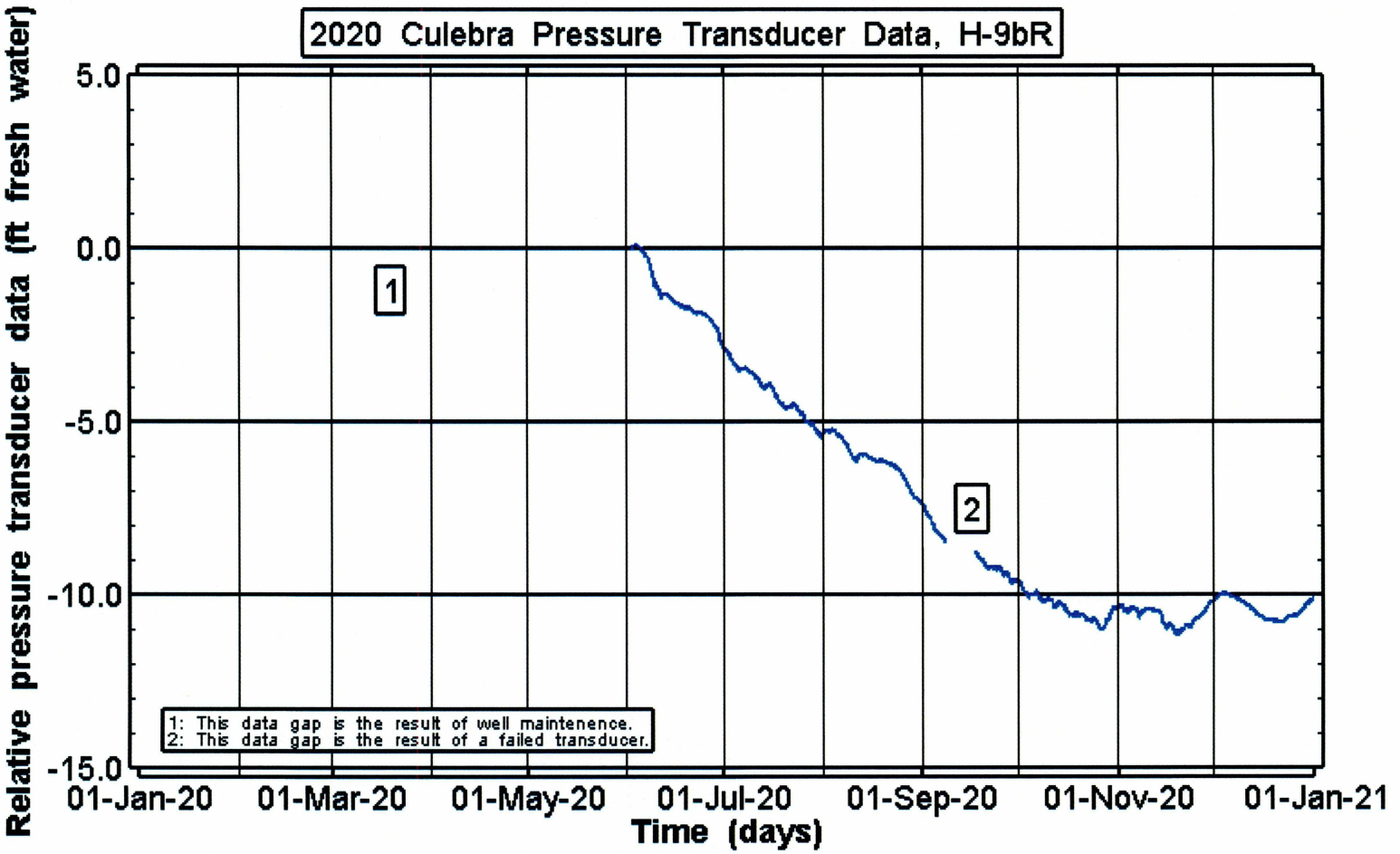

Figure 14. Well H-9bR experienced a net change in hydraulic head of -10.15 ft fresh water in 2020.

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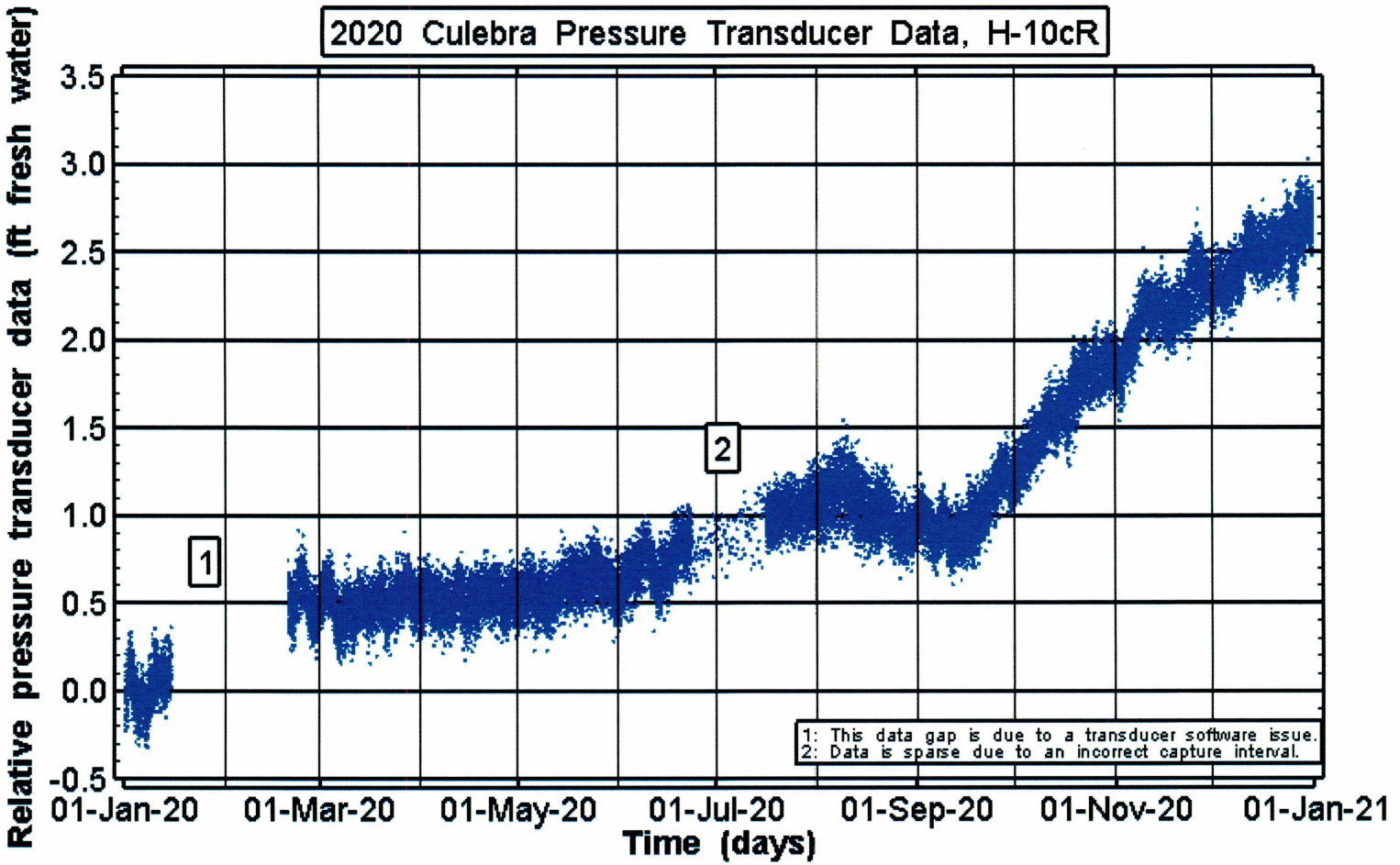

Figure 15. Well H-10cR experienced a net change in hydraulic head of 2.79 ft fresh water in 2020. The well is in long-term recovery from well development.

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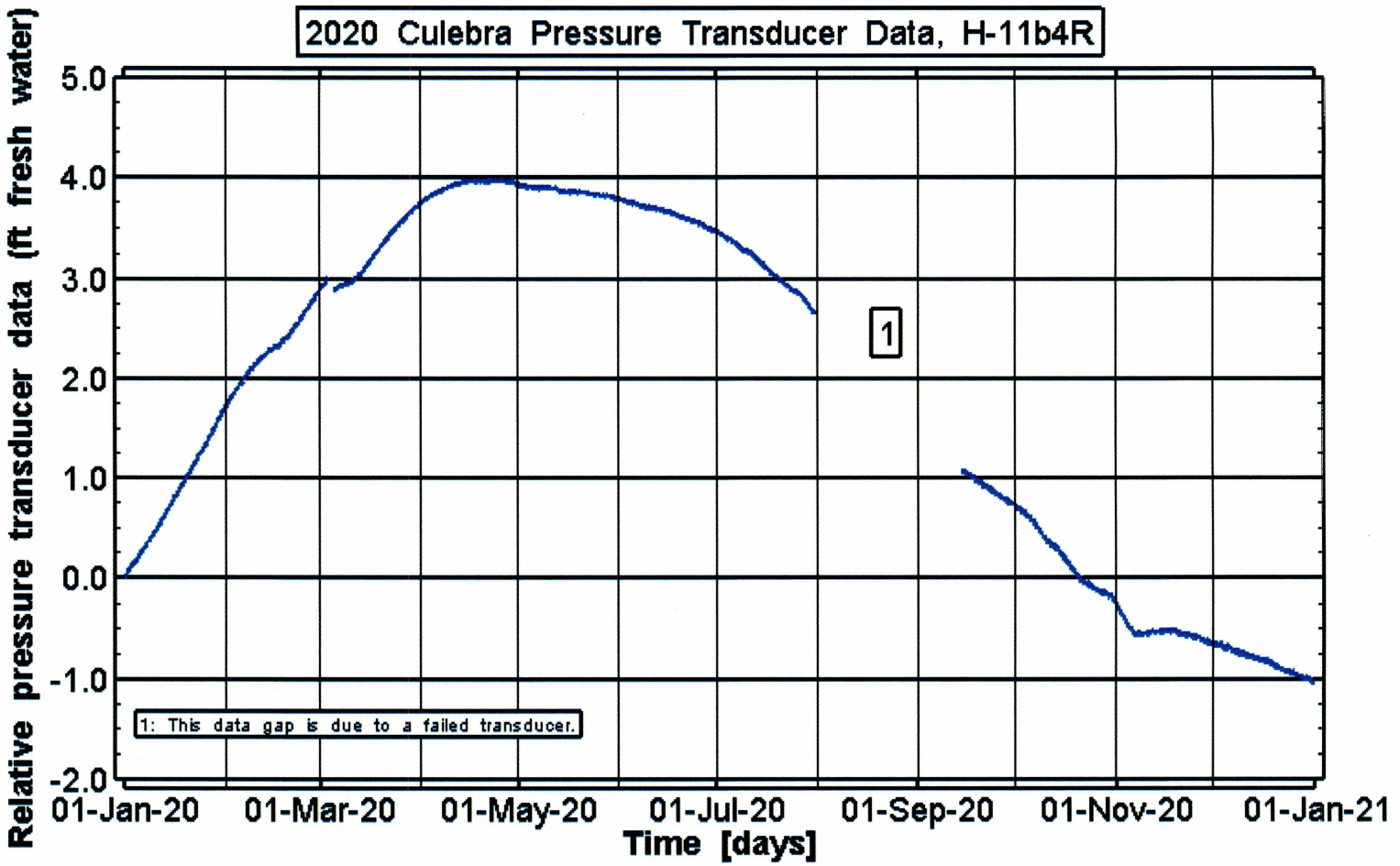

Figure 16. Well H-11b4R experienced a net change in hydraulic head of -1.04 ft fresh water in 2020. This well was in recovery prior to drought effects.

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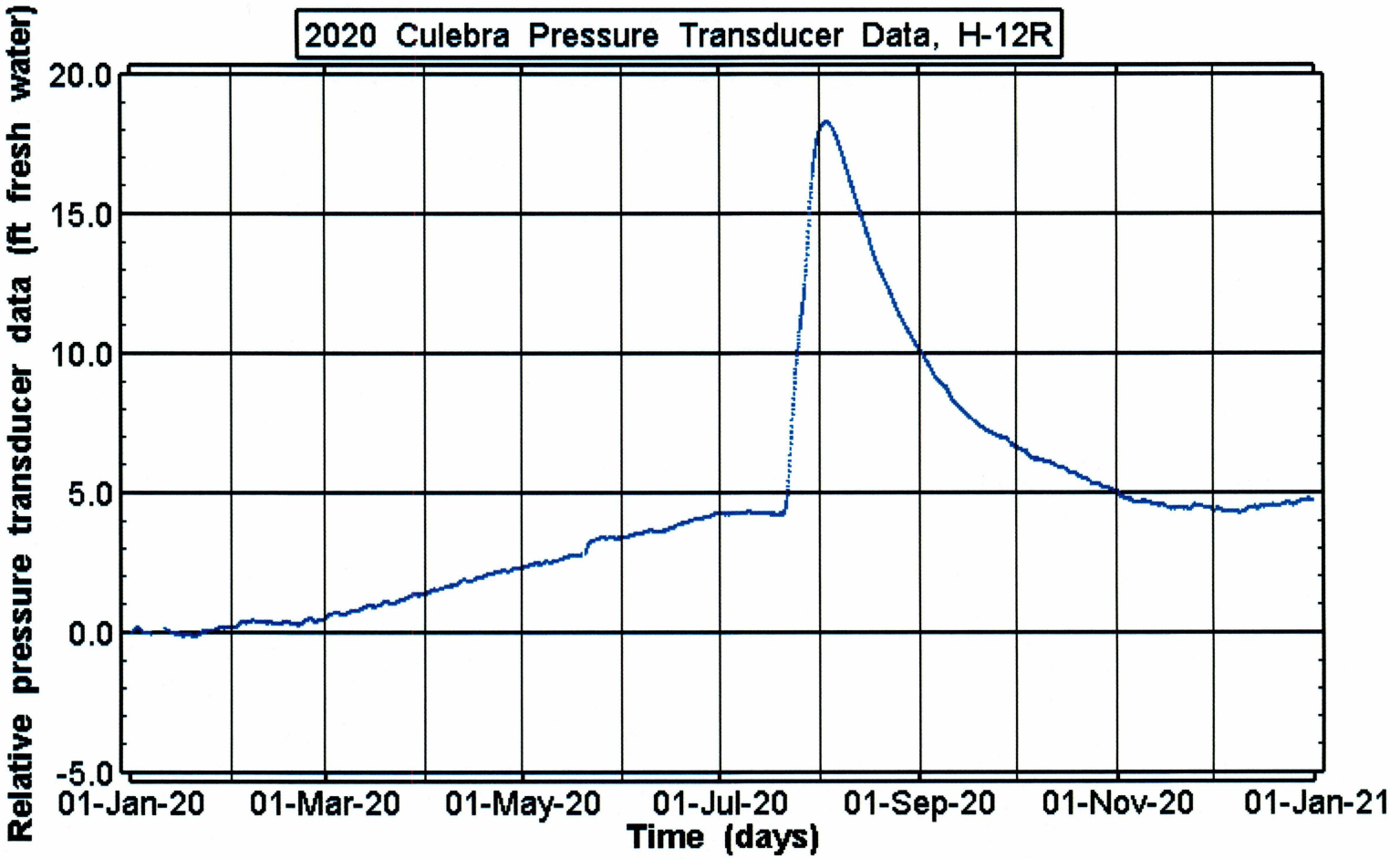

Figure 17. Well H-12R experienced a net change in hydraulic head of 4.75 ft fresh water in 2020. This well was affected by NWR well construction.

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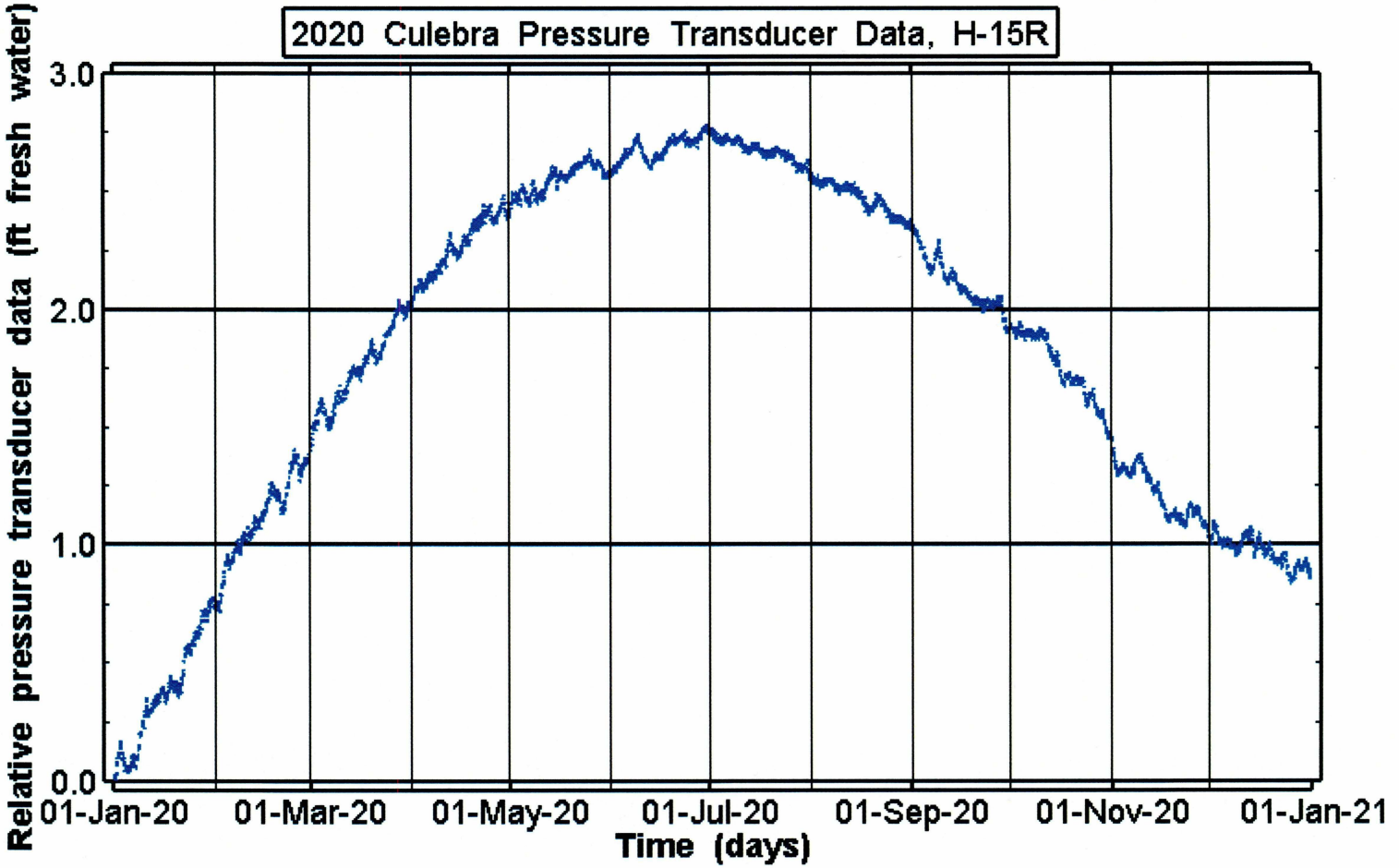

Figure 18. Well H-15R experienced a net change in hydraulic head of 0.88 ft fresh water in 2020. This well was in recovery prior to drought effects.

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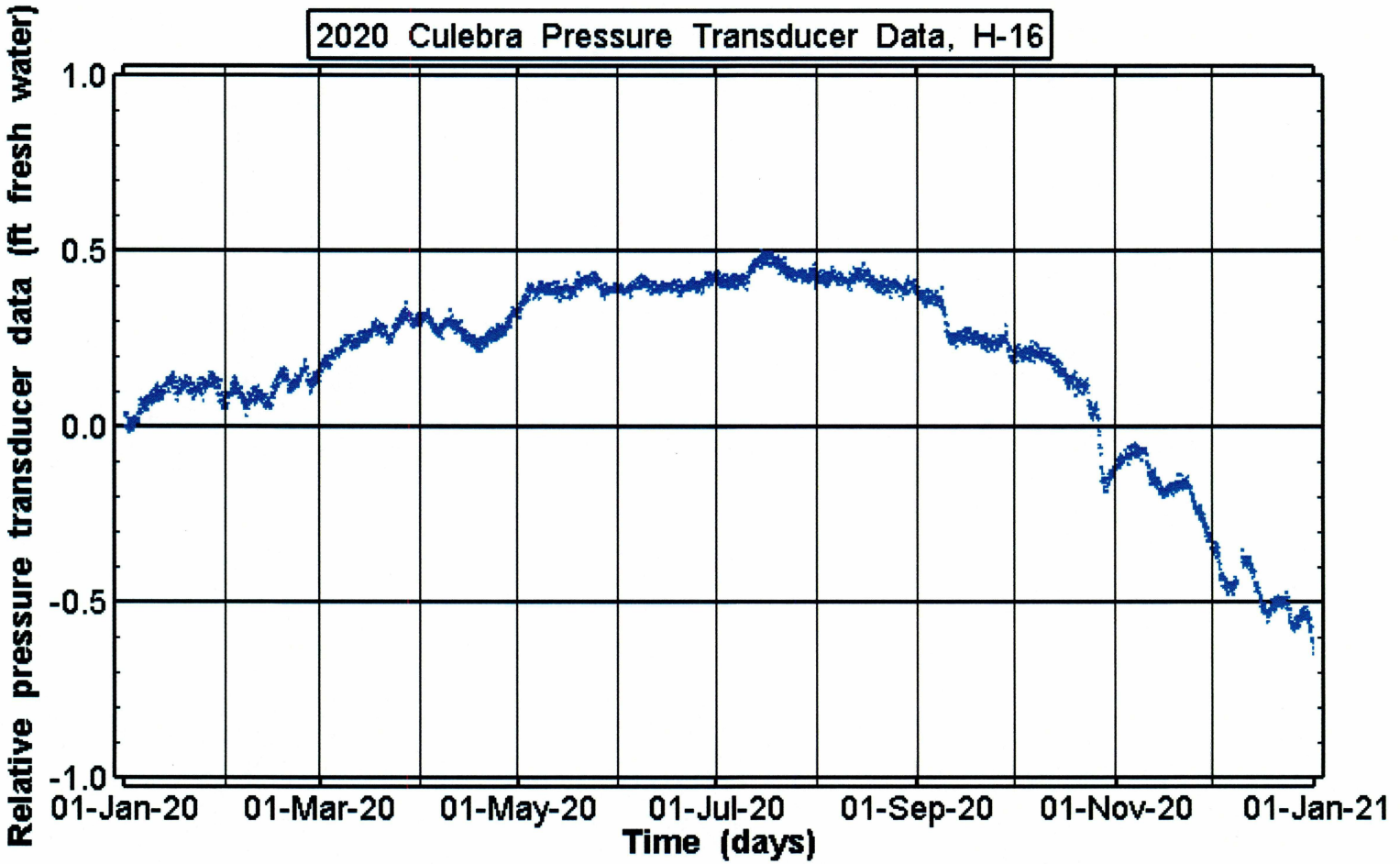

Figure 19. H-16 experienced a net change in hydraulic head of -0.65 ft fresh water in 2020. This well was in recovery prior to drought effects.

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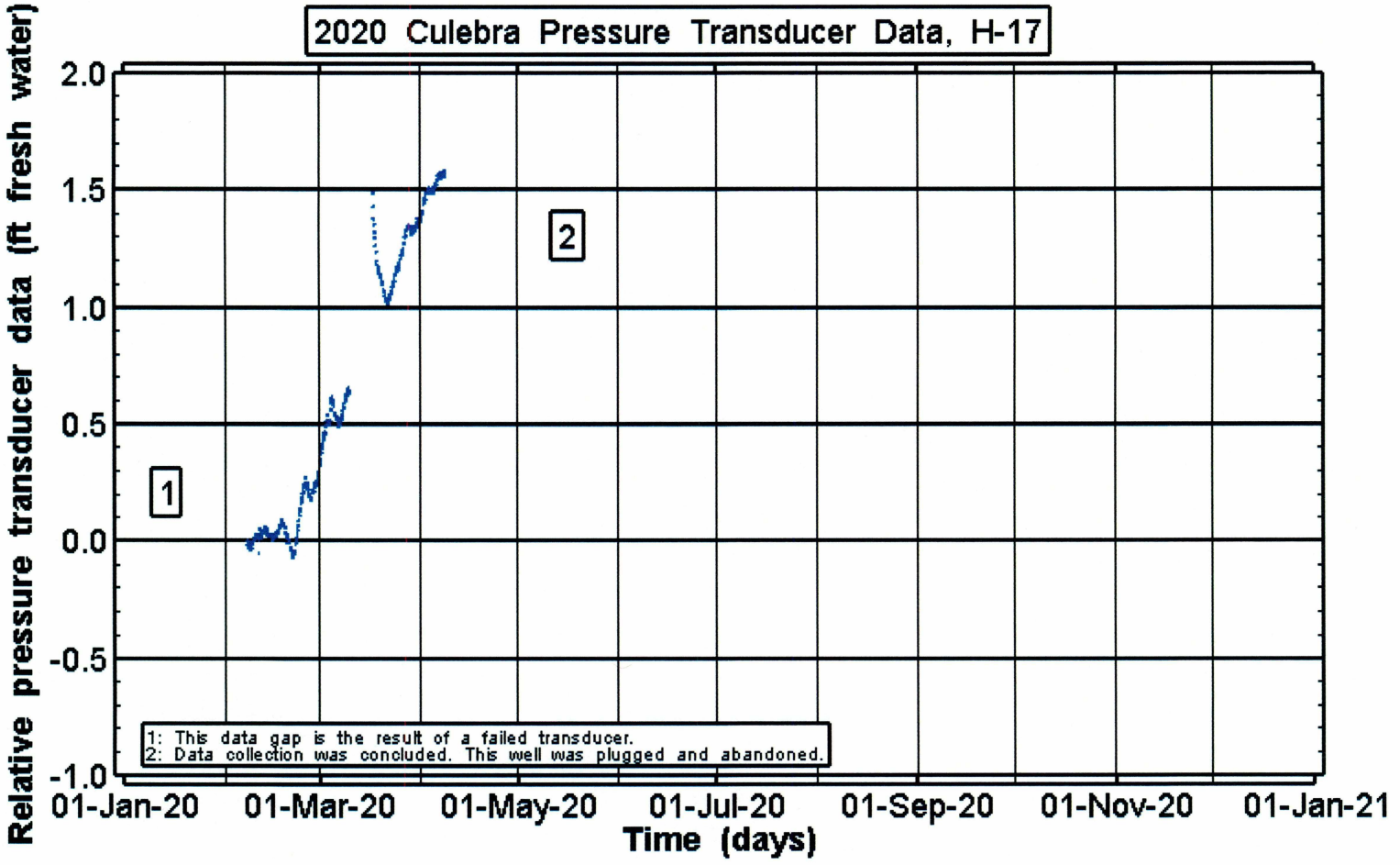

Figure 20. Well H-17 experienced a net change in hydraulic head of 1.57 ft fresh water in 2020.

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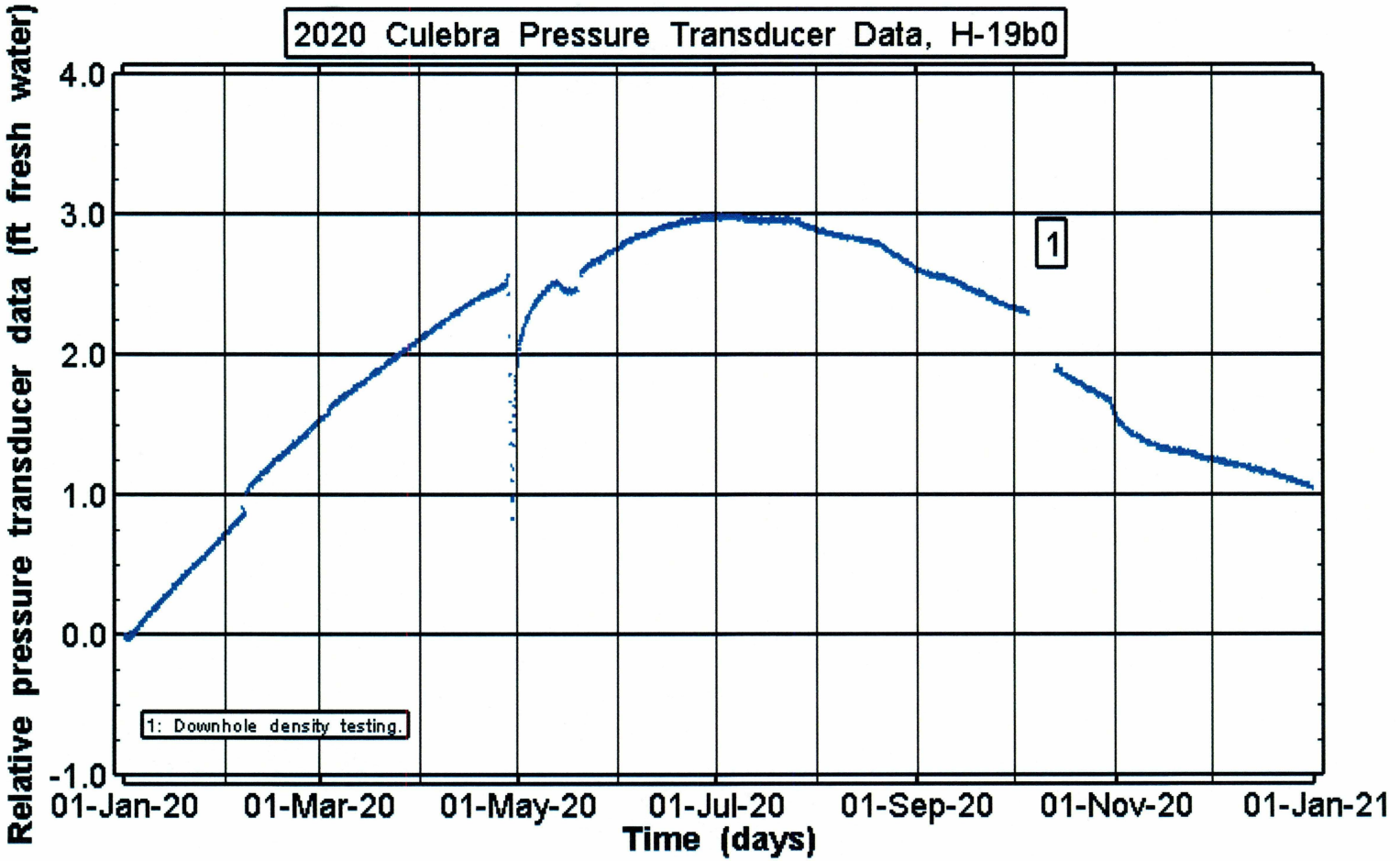

Figure 21. Well H-19b0 experienced a net change in hydraulic head of 1.05 ft fresh water in 2020. This well was in recovery prior to drought effects and is also affected by NWR pumping.

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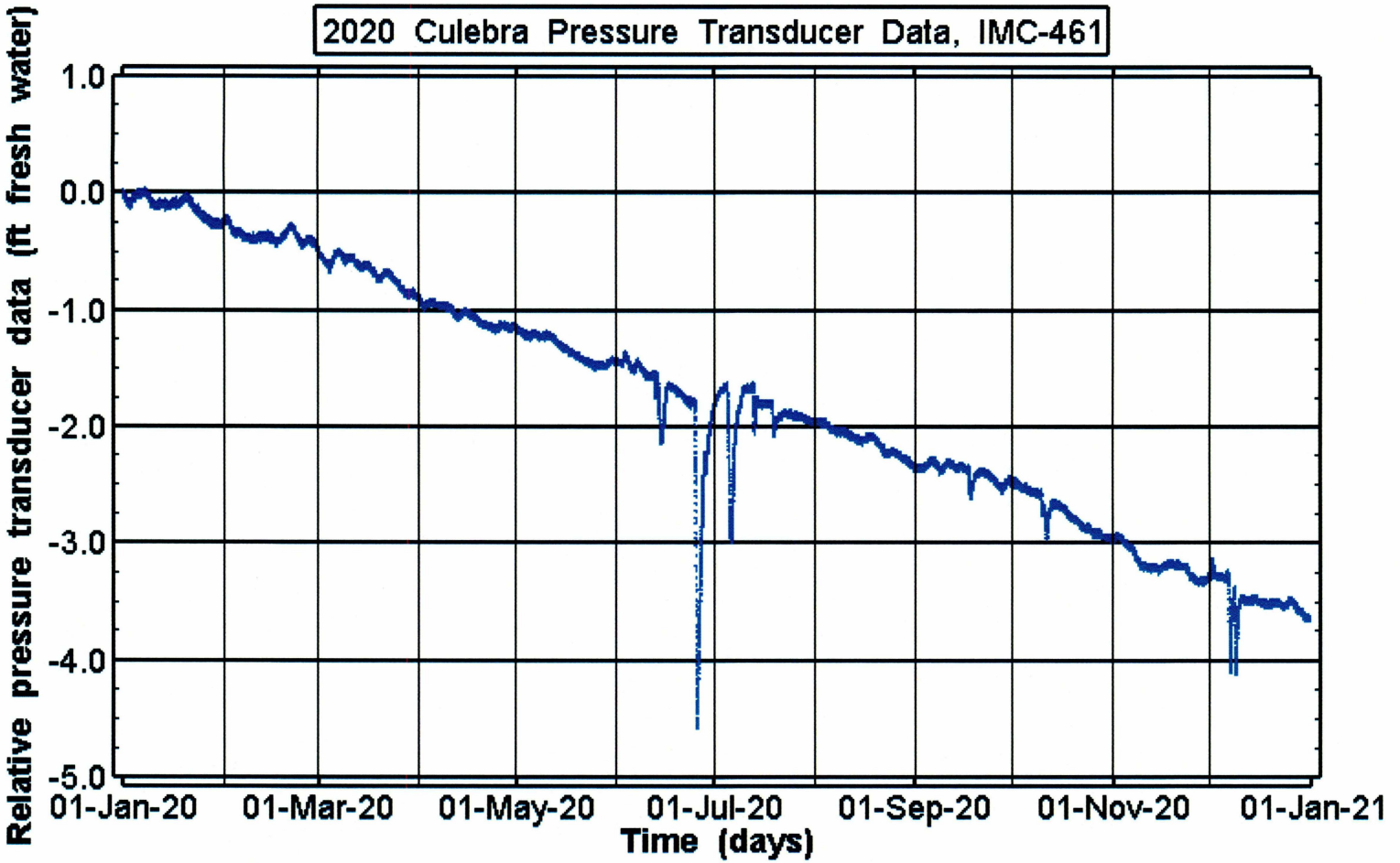

Figure 22. Well IMC-461 experienced a net change in hydraulic head of -3.66 ft fresh water in 2020. This well was primarily affected by NWR pumping.

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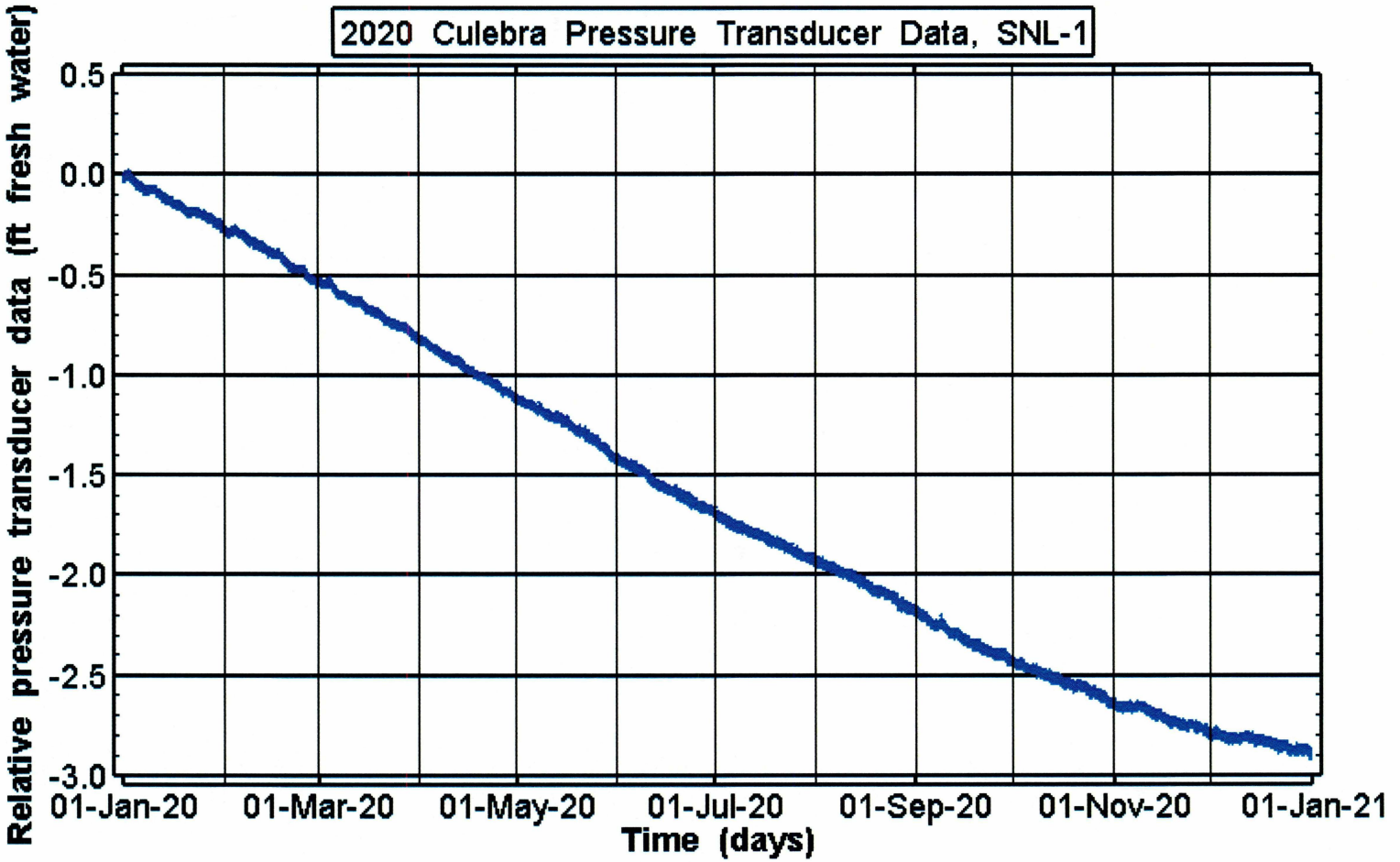

Figure 23. Well SNL-1 experienced a net change in hydraulic head of -2.90 ft fresh water in 2020.

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Figure 24. Well SNL-2 experienced a net change in hydraulic head of -1.59 ft fresh water in 2020.

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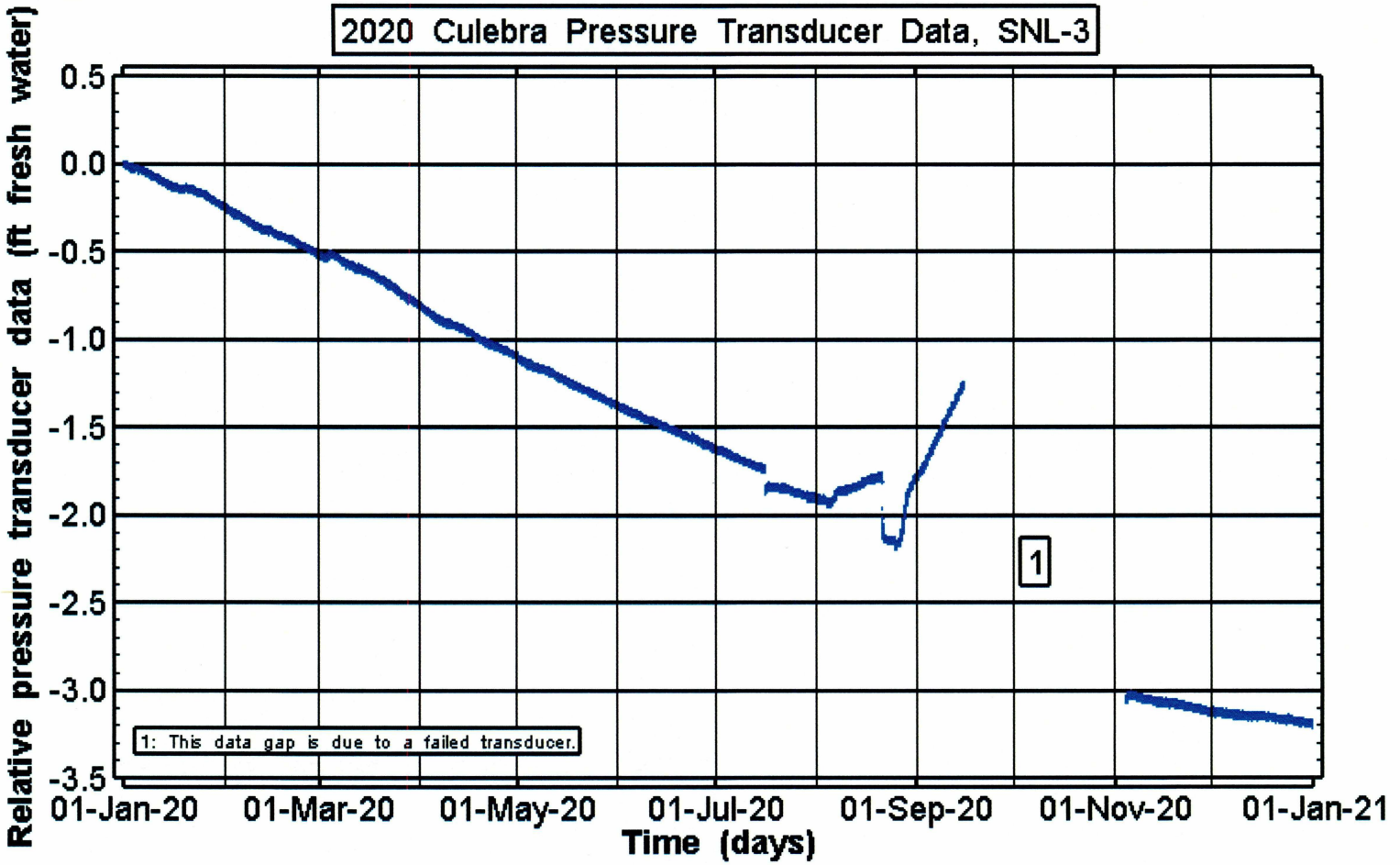

Figure 25. Well SNL-3 experienced a net change in hydraulic head of -3.21 ft fresh water in 2020. This well is affected by NWR pumping.

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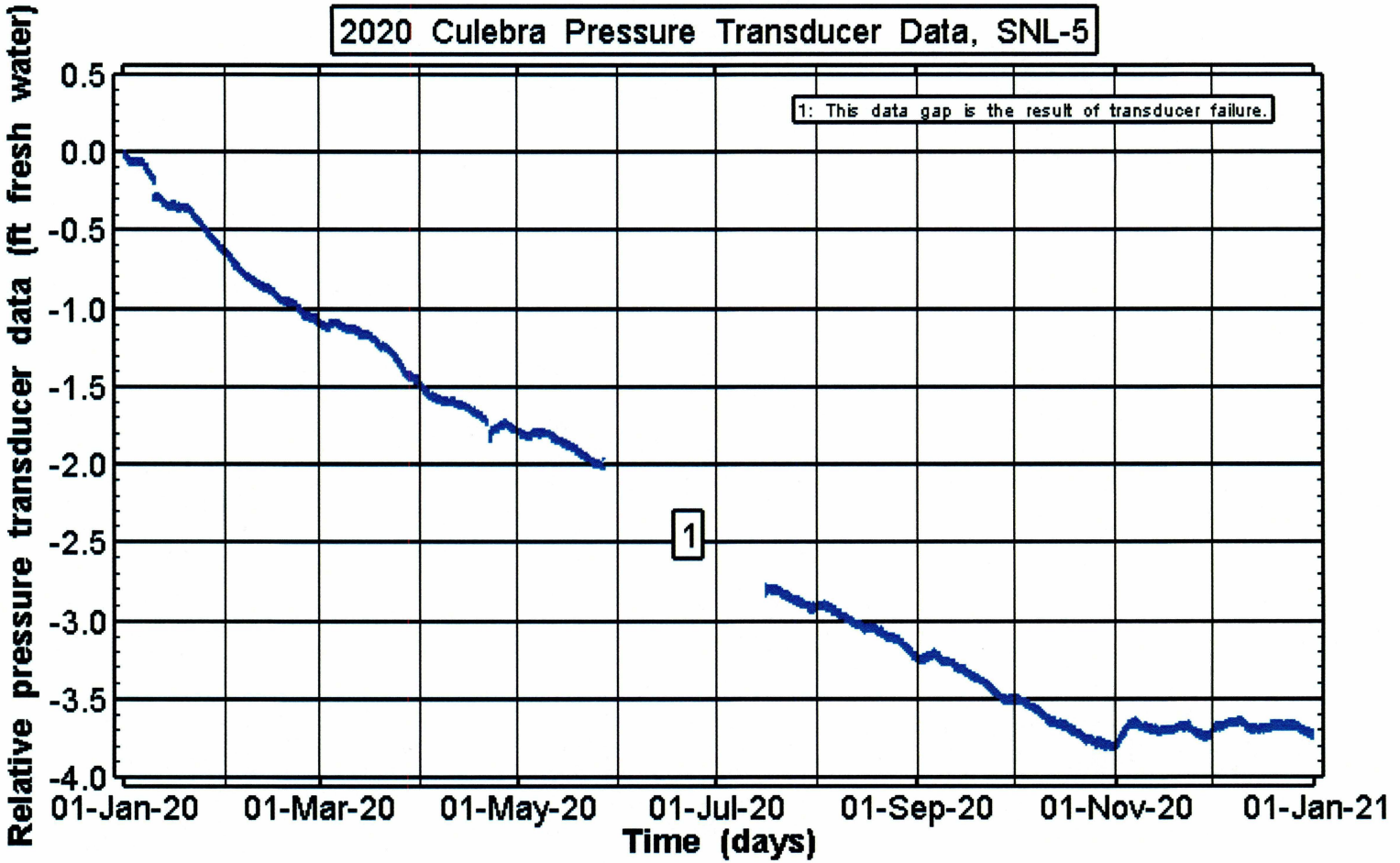

Figure 26. Well SNL-5 experienced a net change in hydraulic head of -3.74 ft fresh water in 2020.

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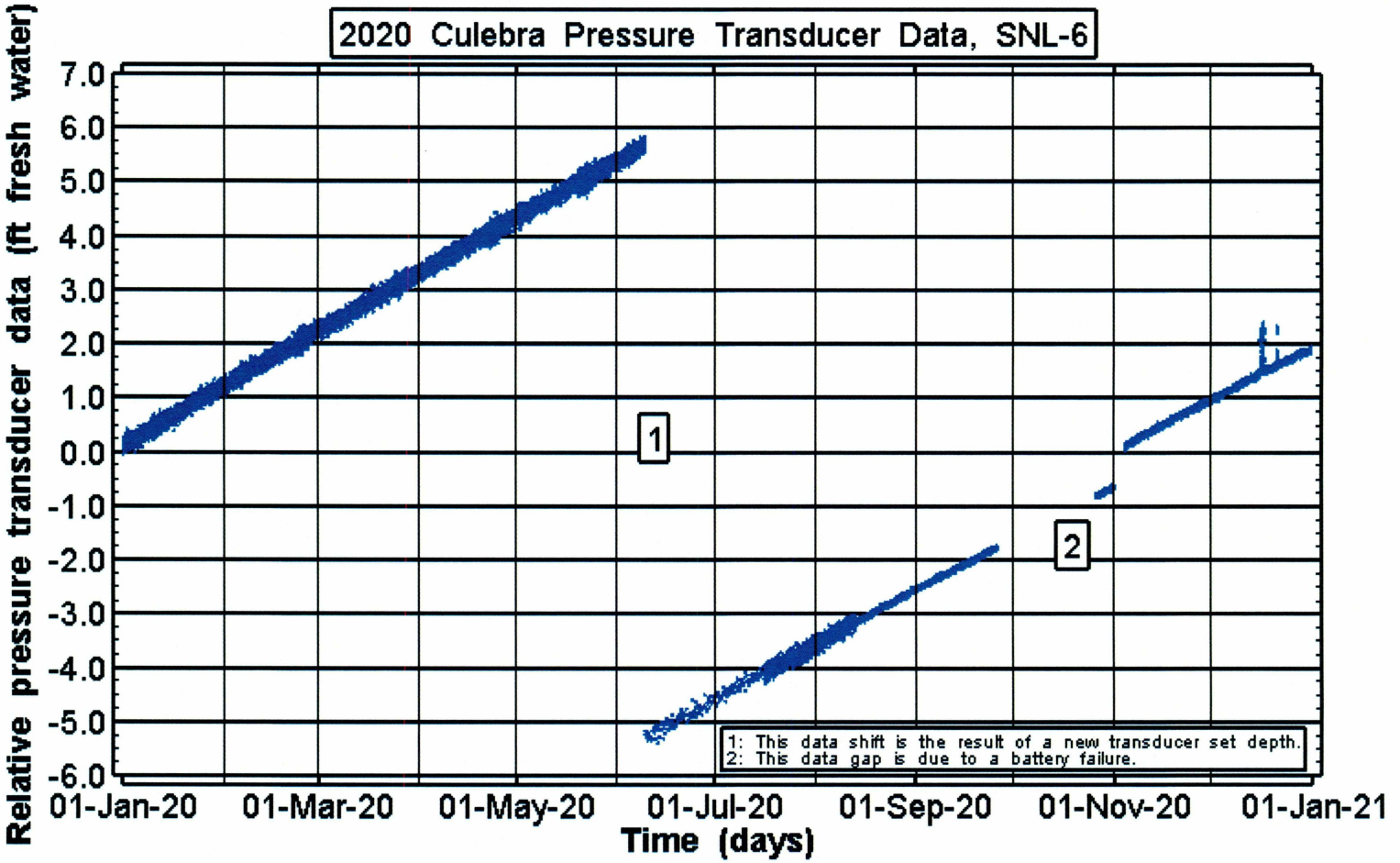

Figure 27. Well SNL-6 experienced a net change in hydraulic head of 12.63 ft fresh water in 2020. The well is in long-term recovery from well development.

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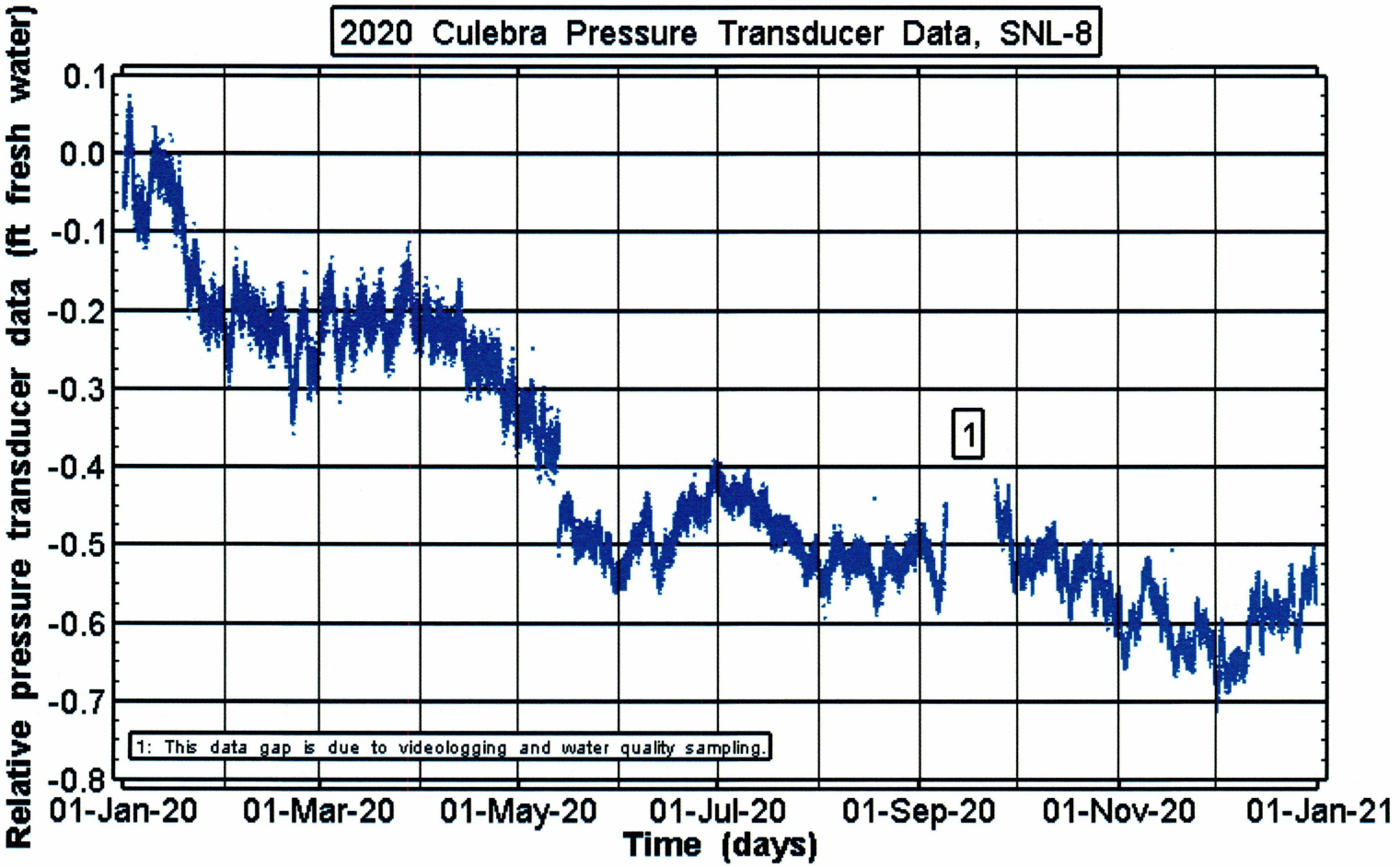

Figure 28. Well SNL-8 experienced a net change in hydraulic head of -0.56 ft fresh water in 2020.

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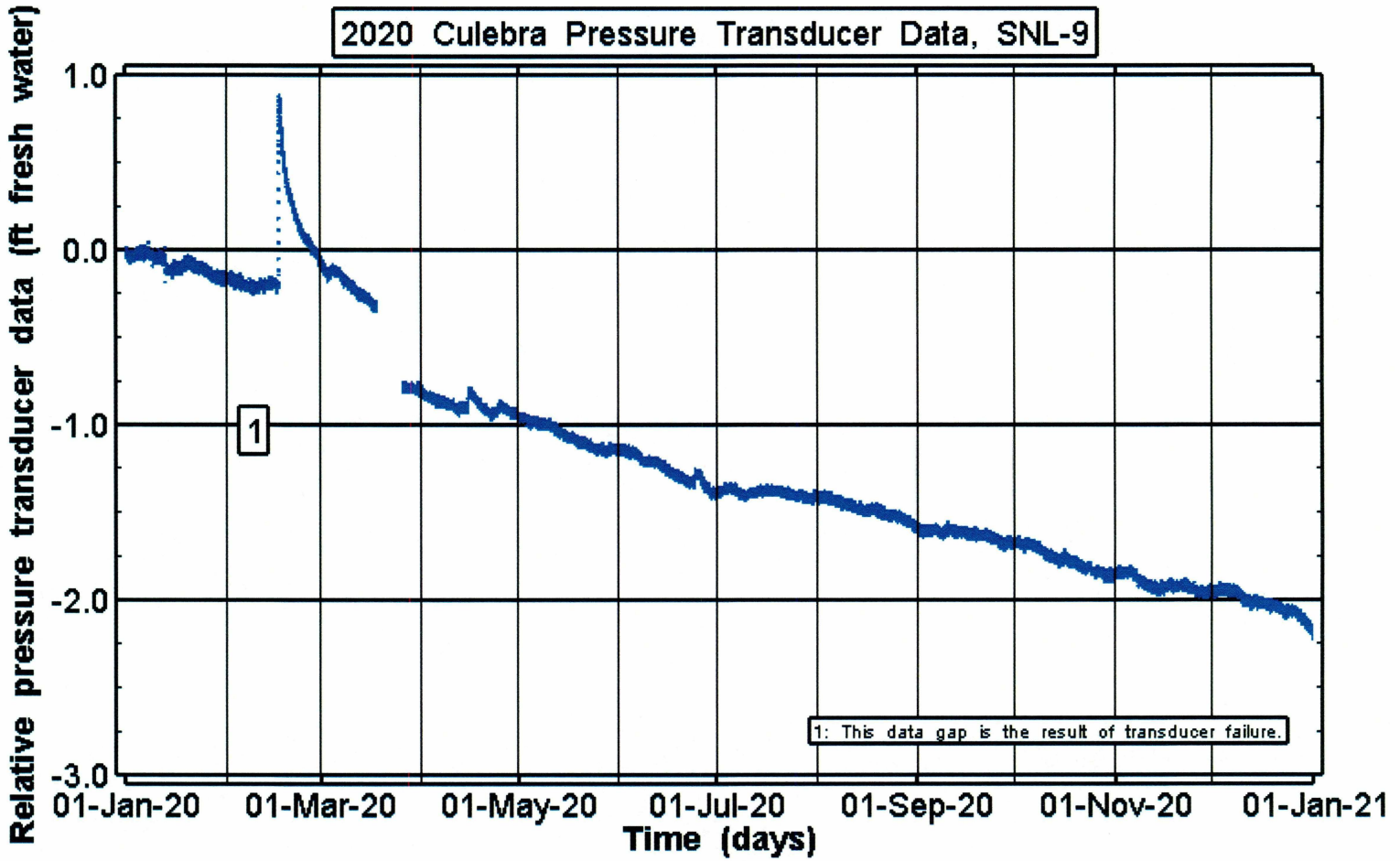

Figure 29. Well SNL-9 experienced a net change in hydraulic head of -2.22 ft fresh water in 2020. The well is affected by NWR pumping.

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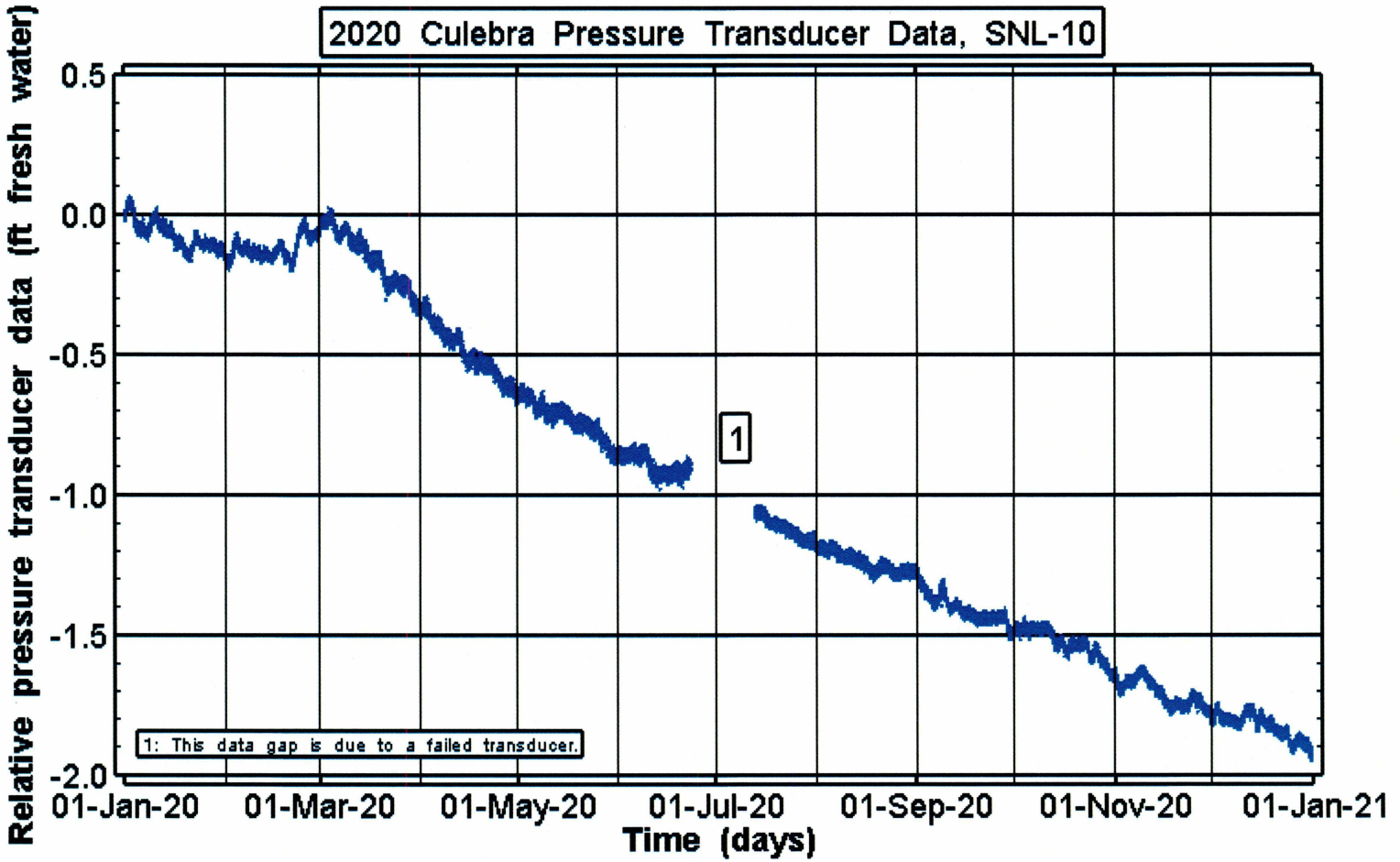

Figure 30. Well SNL-10 experienced a net change in hydraulic head of -1.94 ft fresh water in 2020.

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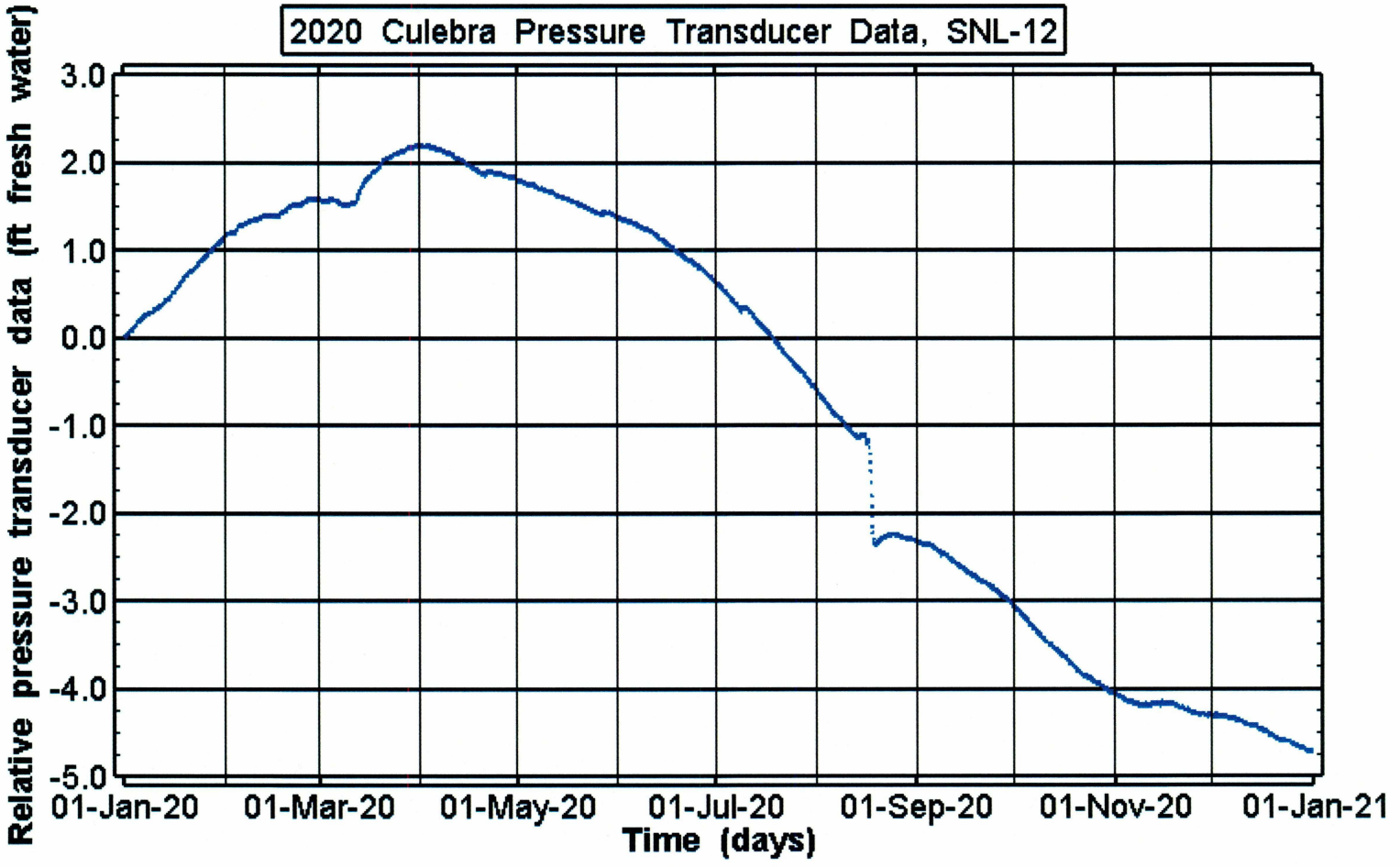

Figure 31. Well SNL-12 experienced a net change in hydraulic head of -4.71 ft fresh water in 2020. This well was in recovery prior to drought effects and is affected by NWR pumping.

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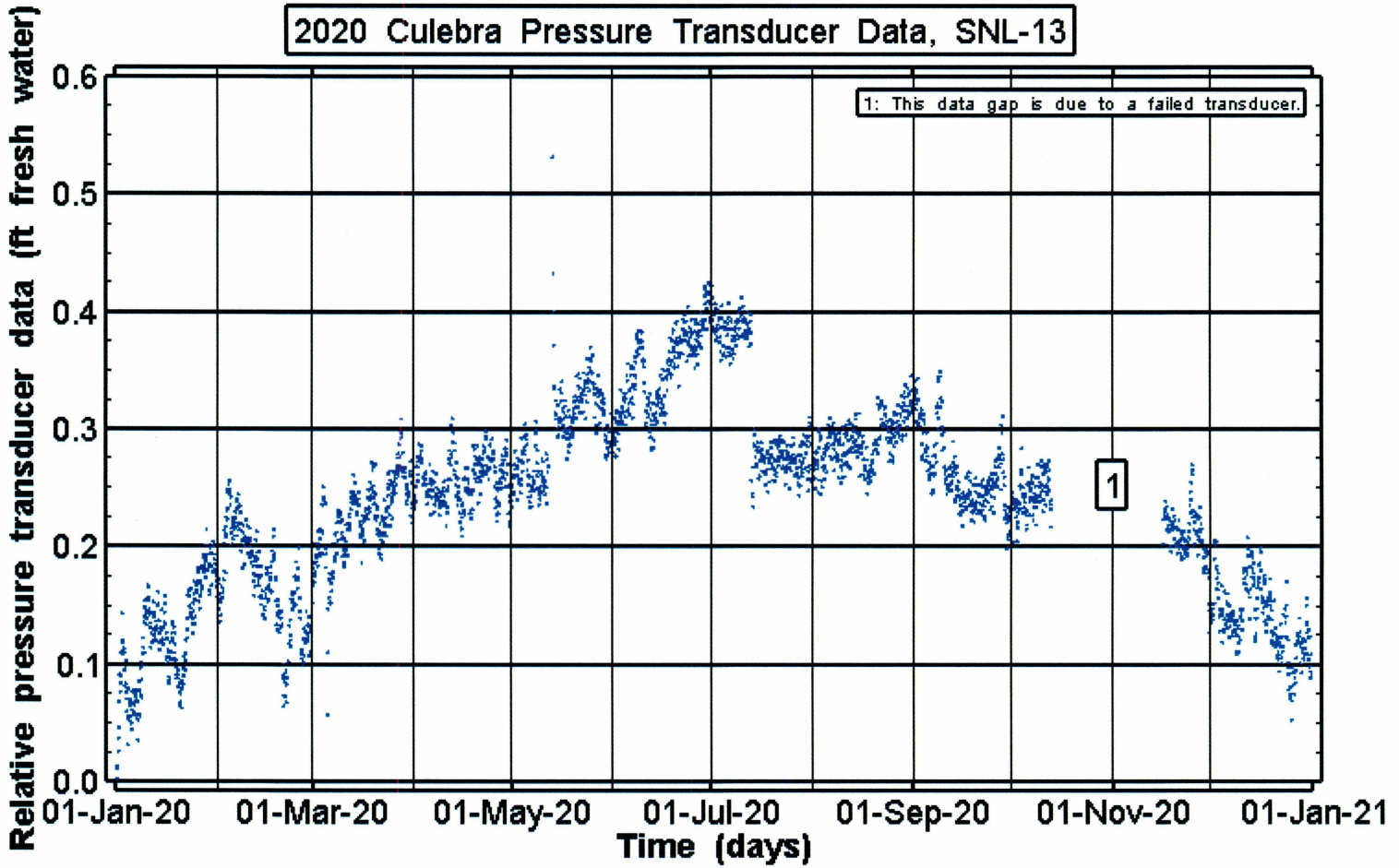

Figure 32. Well SNL-13 experienced a net change in hydraulic head of 0.11 ft fresh water in 2020.

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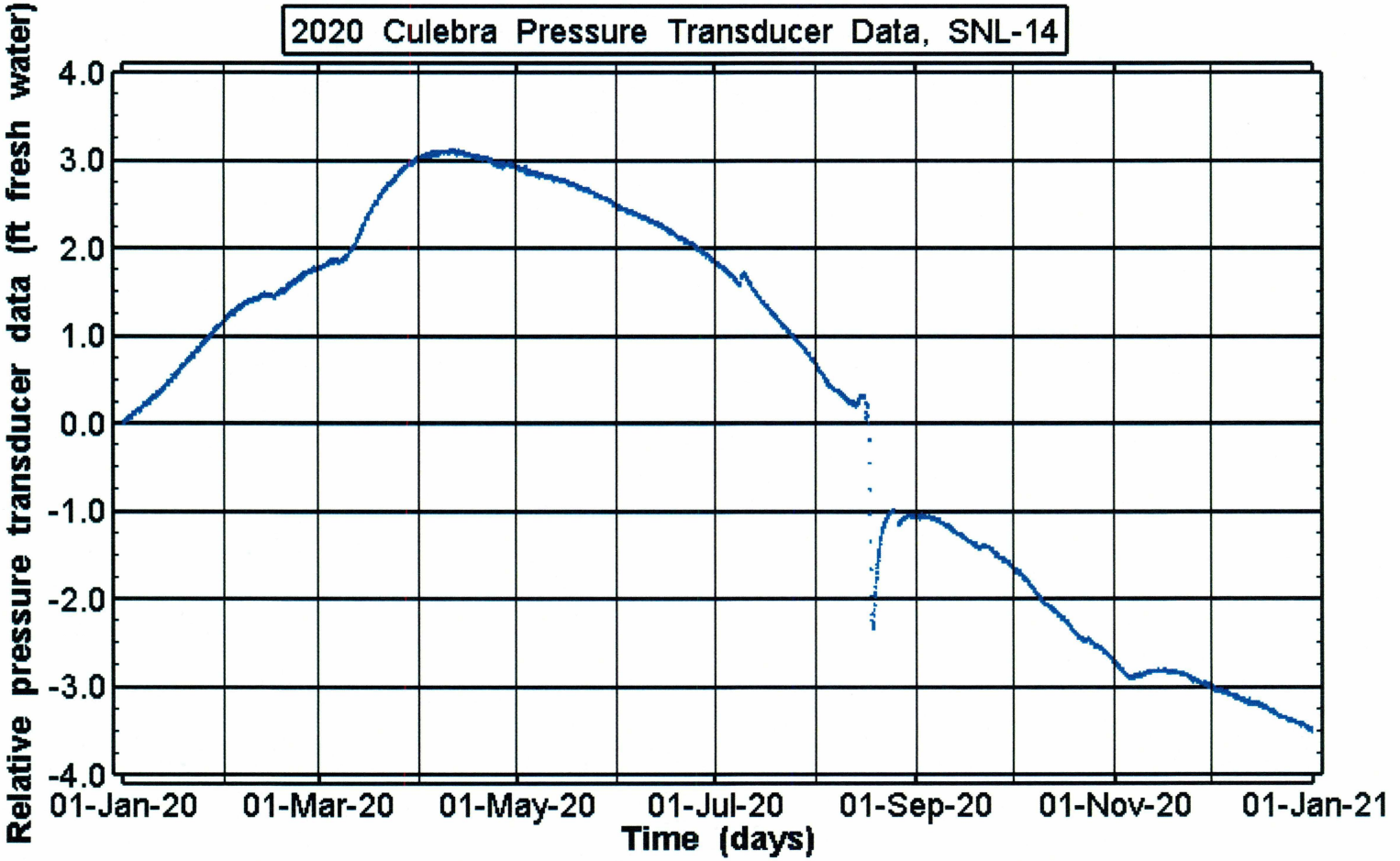

Figure 33. Well SNL-14 experienced a net change in hydraulic head of -3.51 ft fresh water in 2020. This well was in recovery prior to drought effects and is also affected by NWR pumping.

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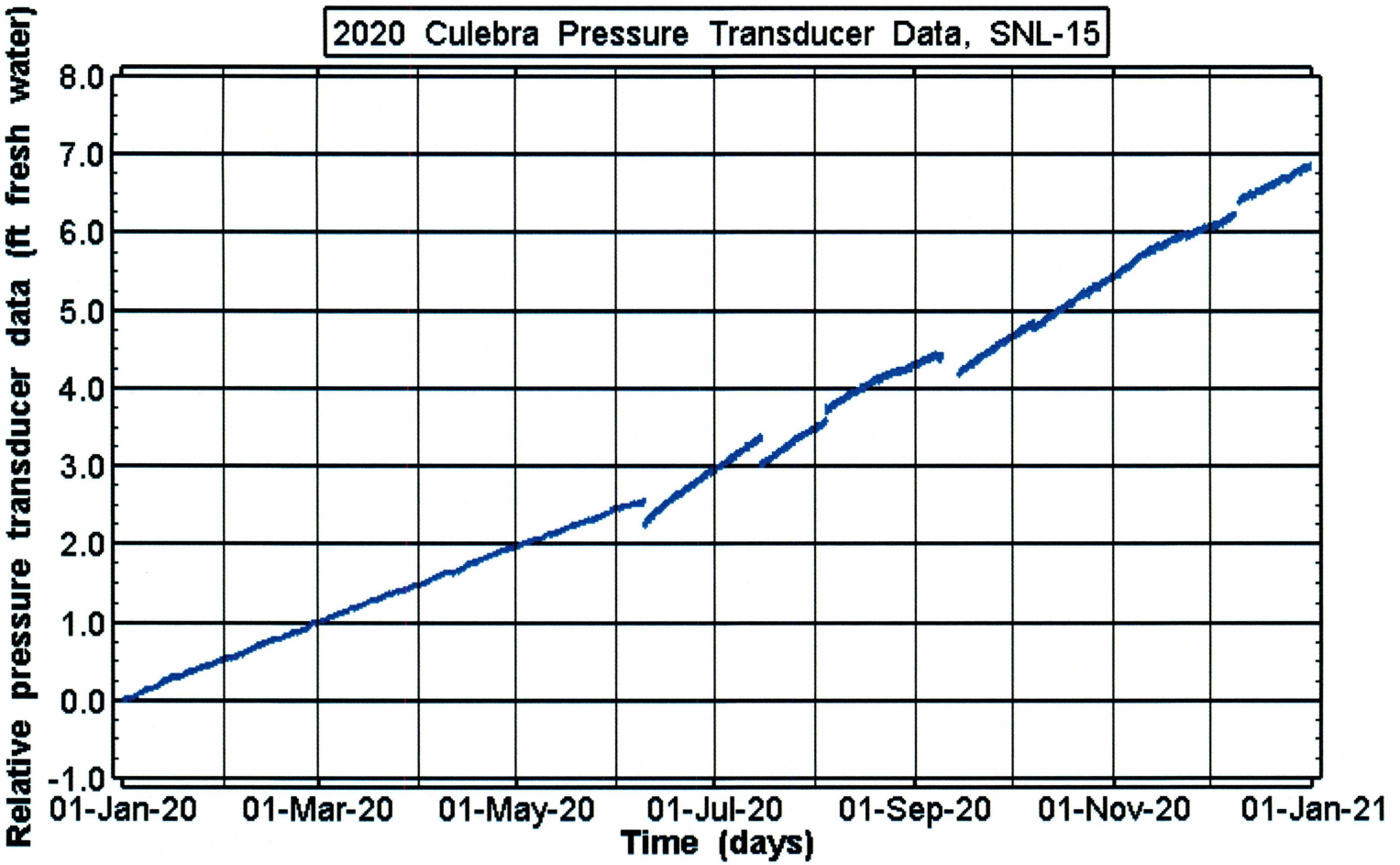

Figure 34. Well SNL-15 experienced a net change in hydraulic head of 6.90 ft fresh water in 2020. The well is in long-term recovery from well development.

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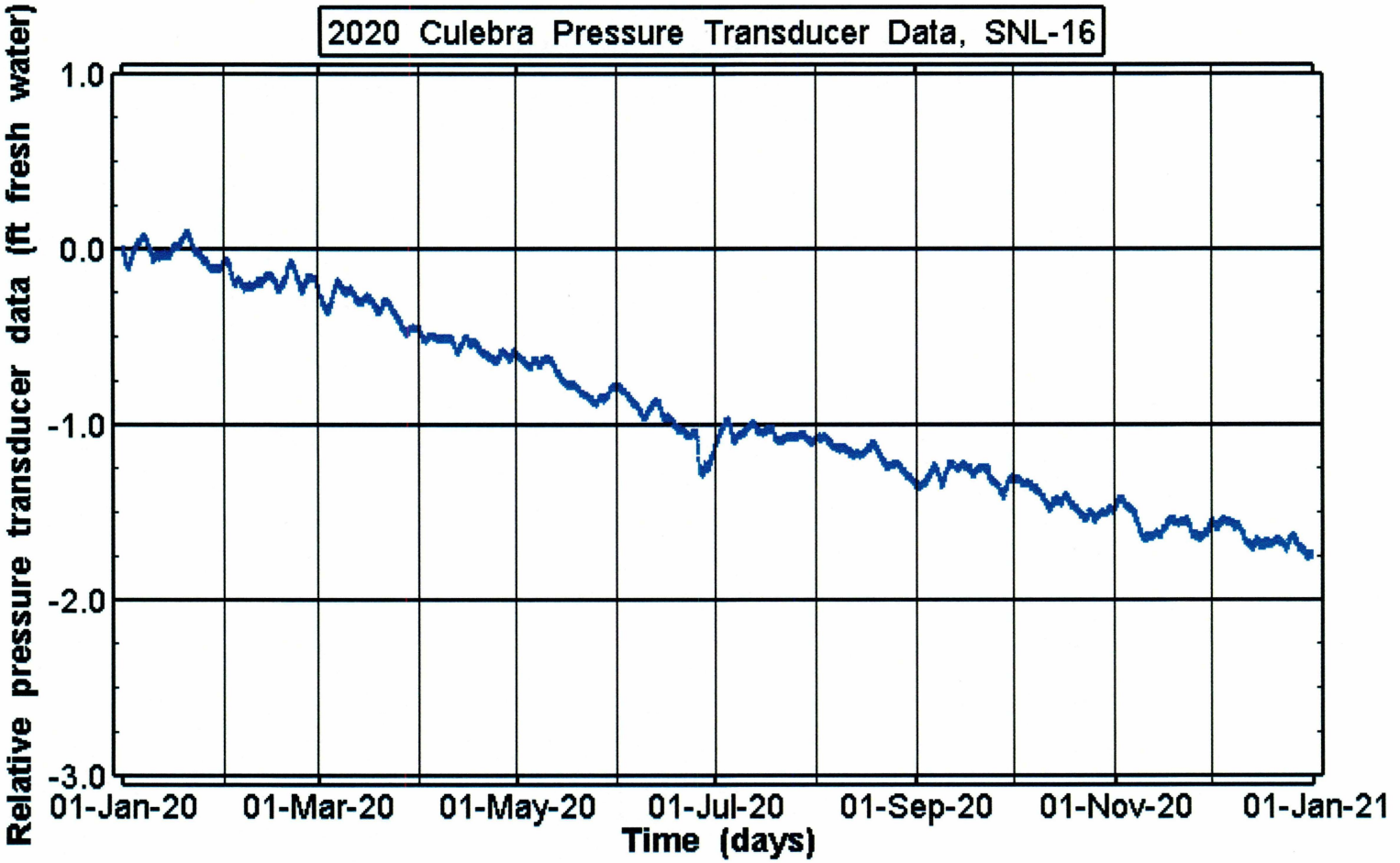

Figure 35. Well SNL-16 experienced a net change in hydraulic head of -1.74 ft fresh water in 2020.

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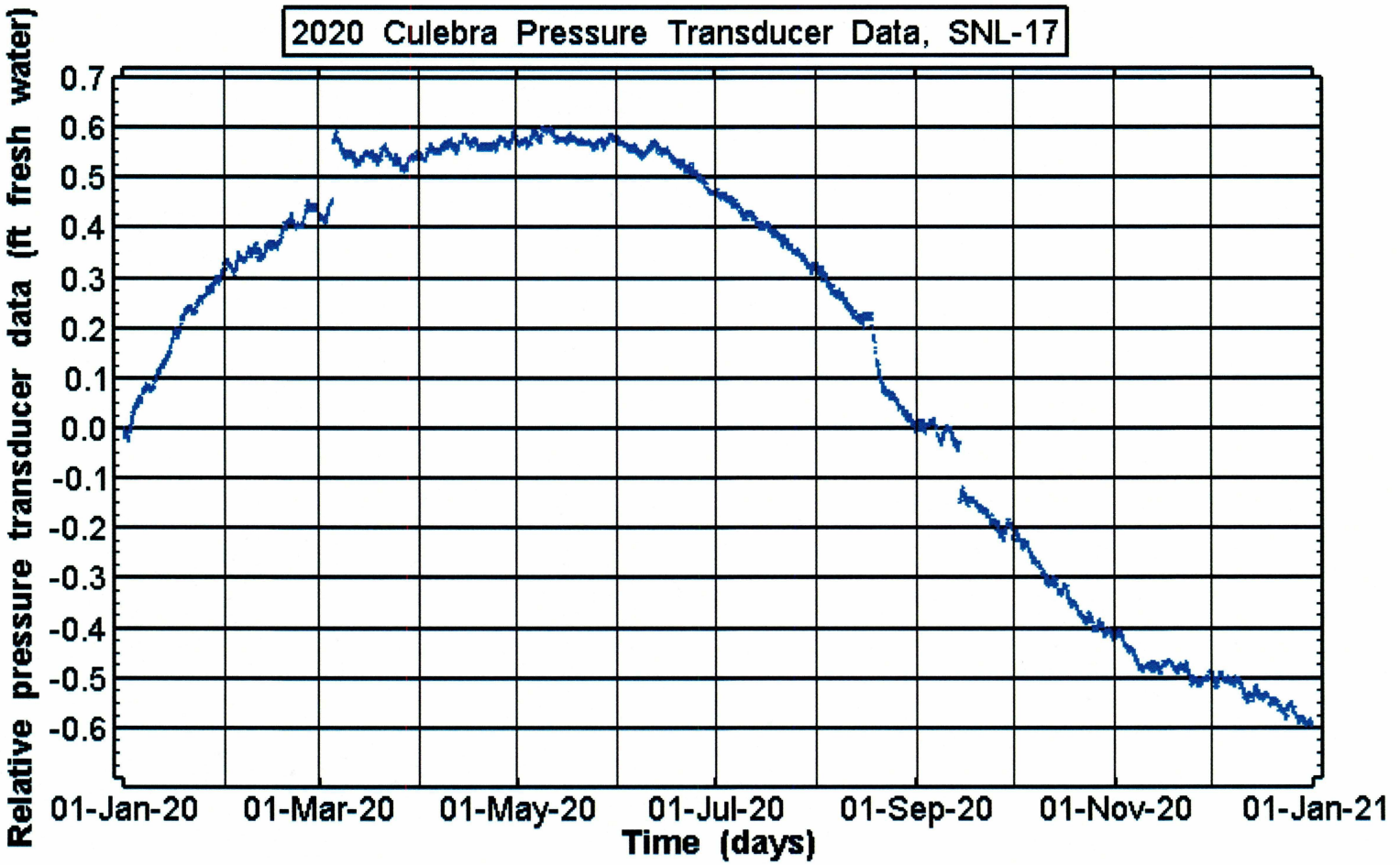

Figure 36. Well SNL-17 experienced a net change in hydraulic head of -0.60 ft fresh water in 2020. This well was in recovery prior to drought effects.

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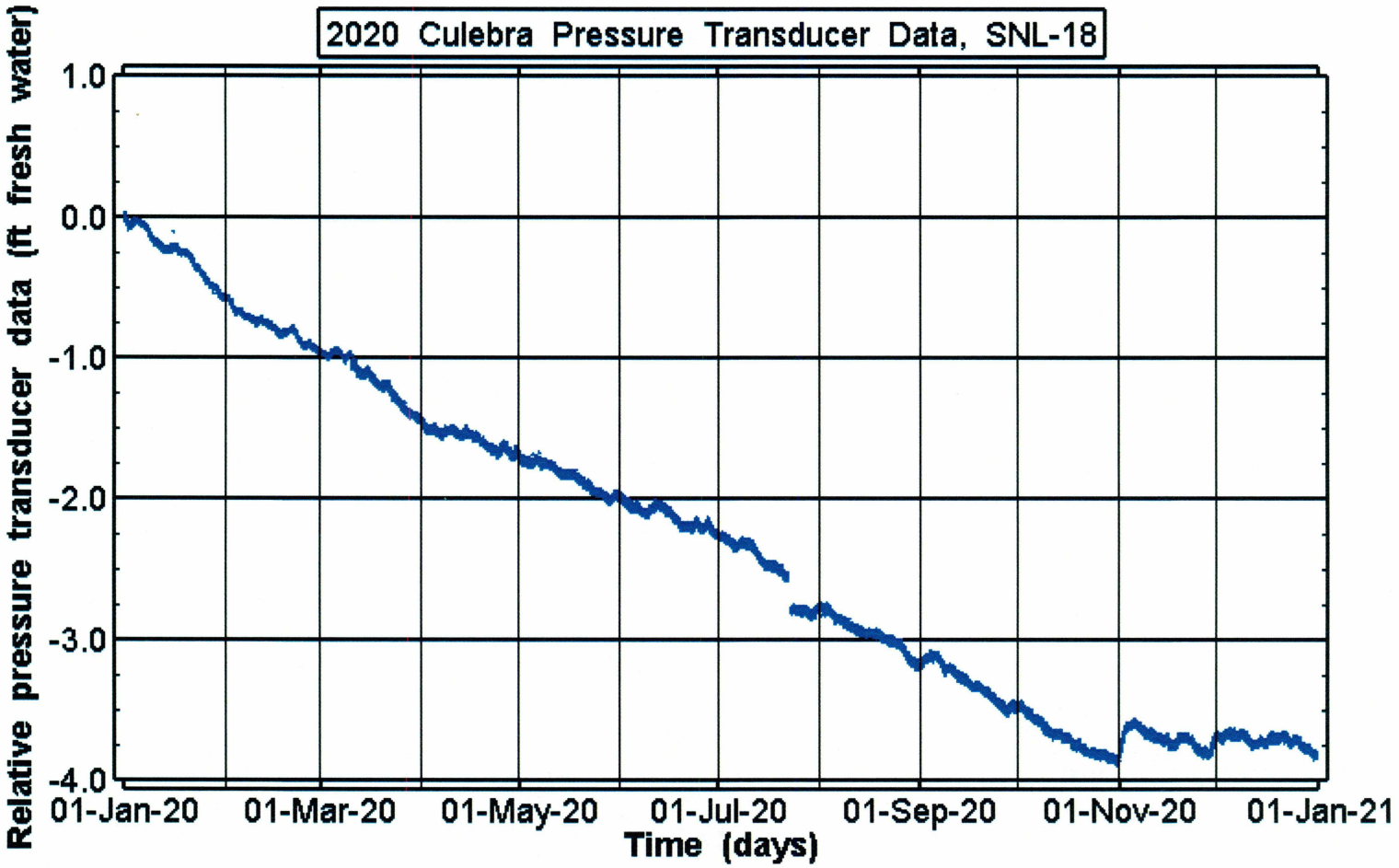

Figure 37. Well SNL-18 experienced a net change in hydraulic head of -3.85 ft fresh water in 2020.

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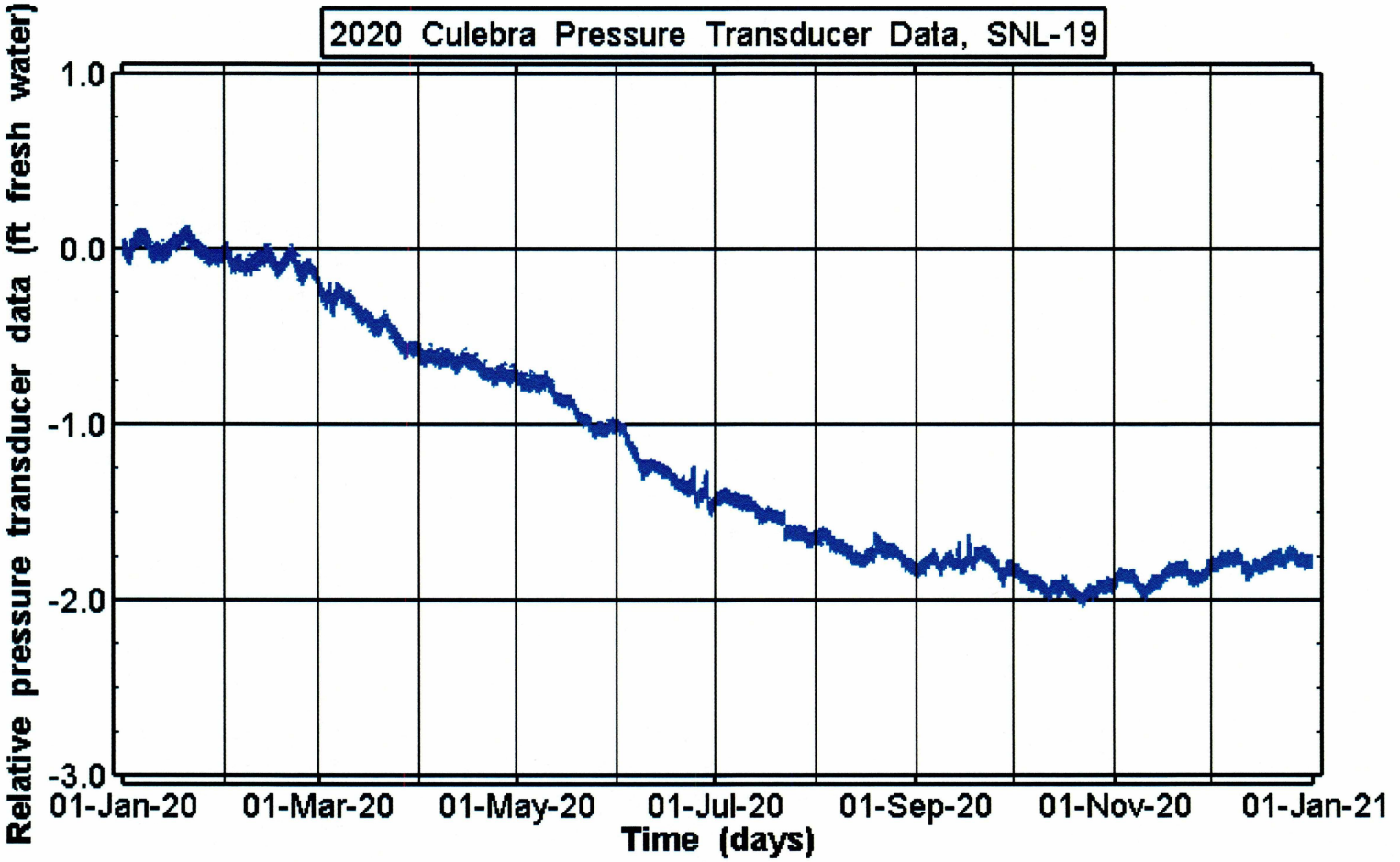

Figure 38. Well SNL-19 experienced a net change in hydraulic head of -1.76 ft fresh water in 2020.

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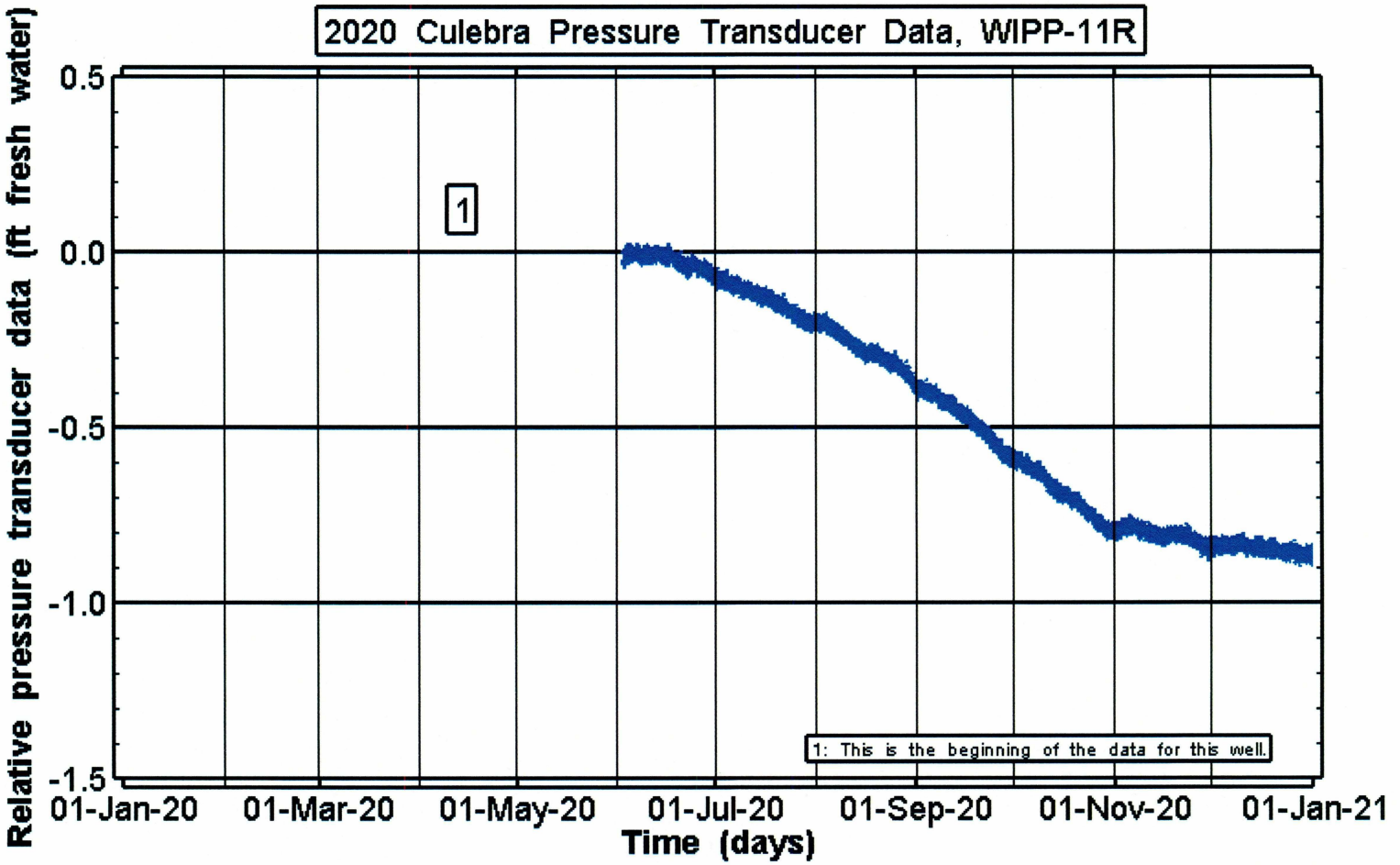

Figure 39. Well WIPP-11R experienced a net change in hydraulic head of -0.89 ft fresh water in 2020.

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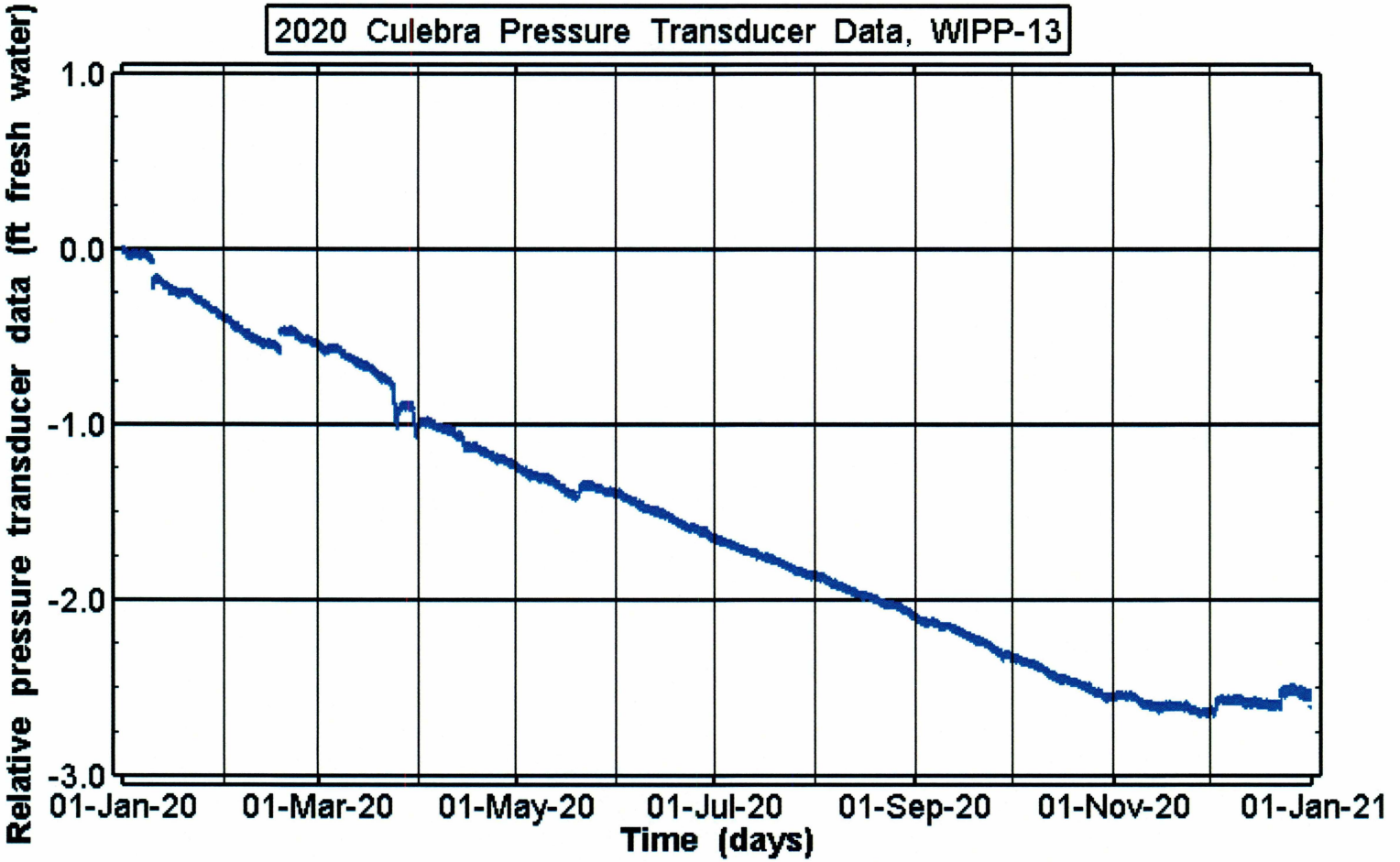

Figure 40. Well WIPP-13 experienced a net change in hydraulic head of -2.56 ft fresh water in 2020. The well is affected by NWR pumping events.

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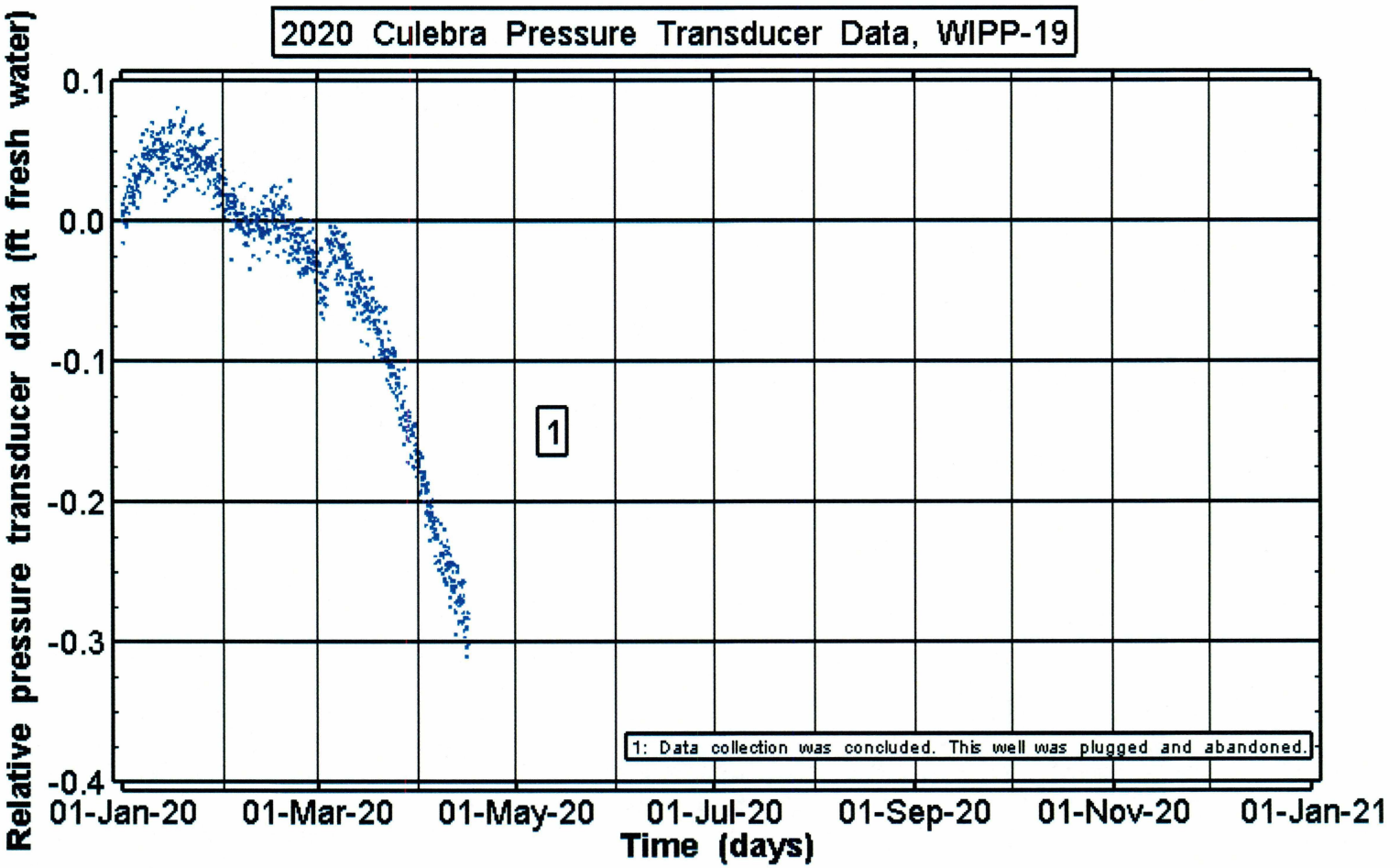

Figure 41. Well WIPP-19 experienced a net change in hydraulic head of -0.30 ft fresh water in 2020. This well was plugged and abandoned.

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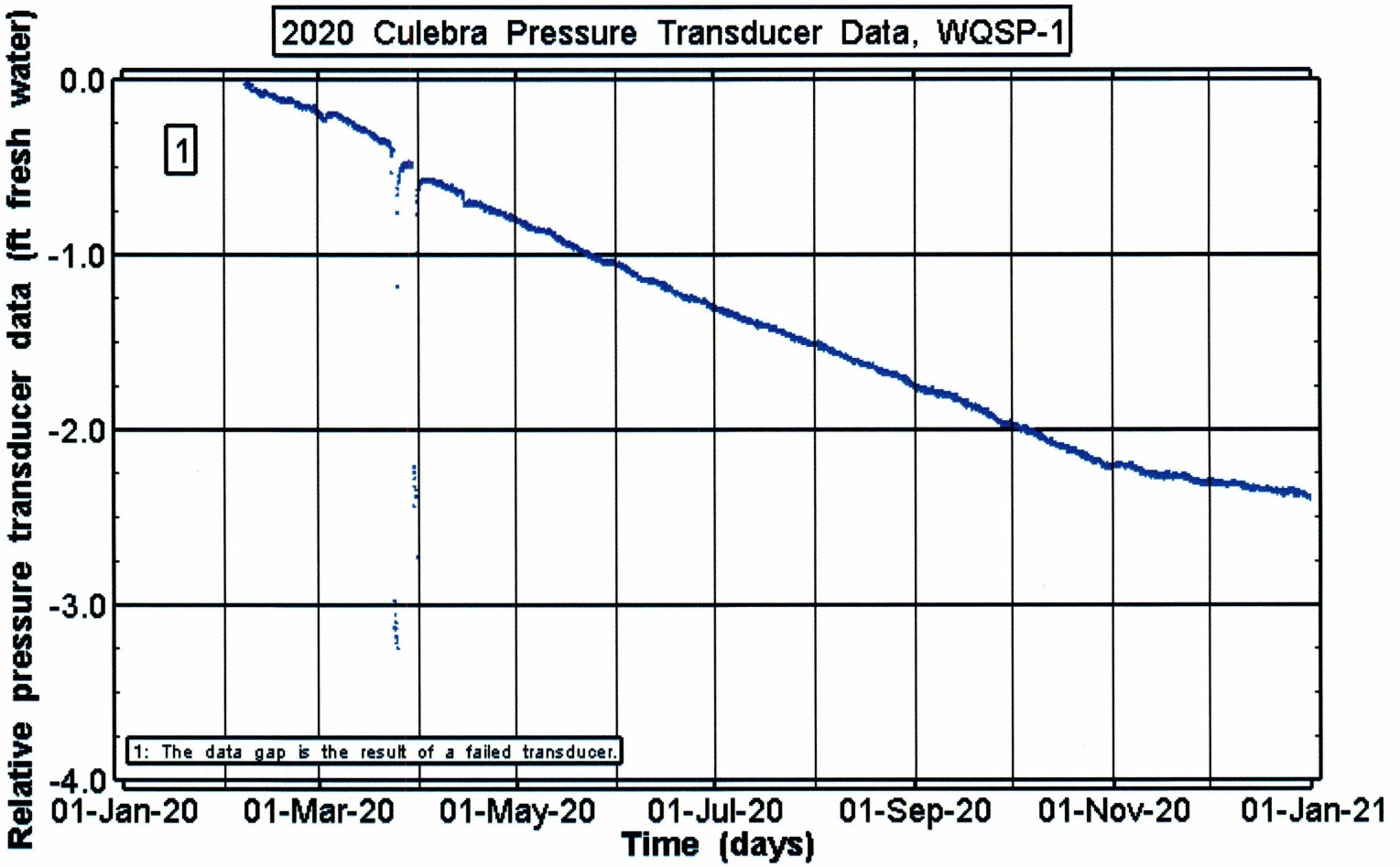

Figure 42. Well WQSP-1 experienced a net change in hydraulic head of -2.39 ft fresh water in 2020. This well was sampled in March 2020.

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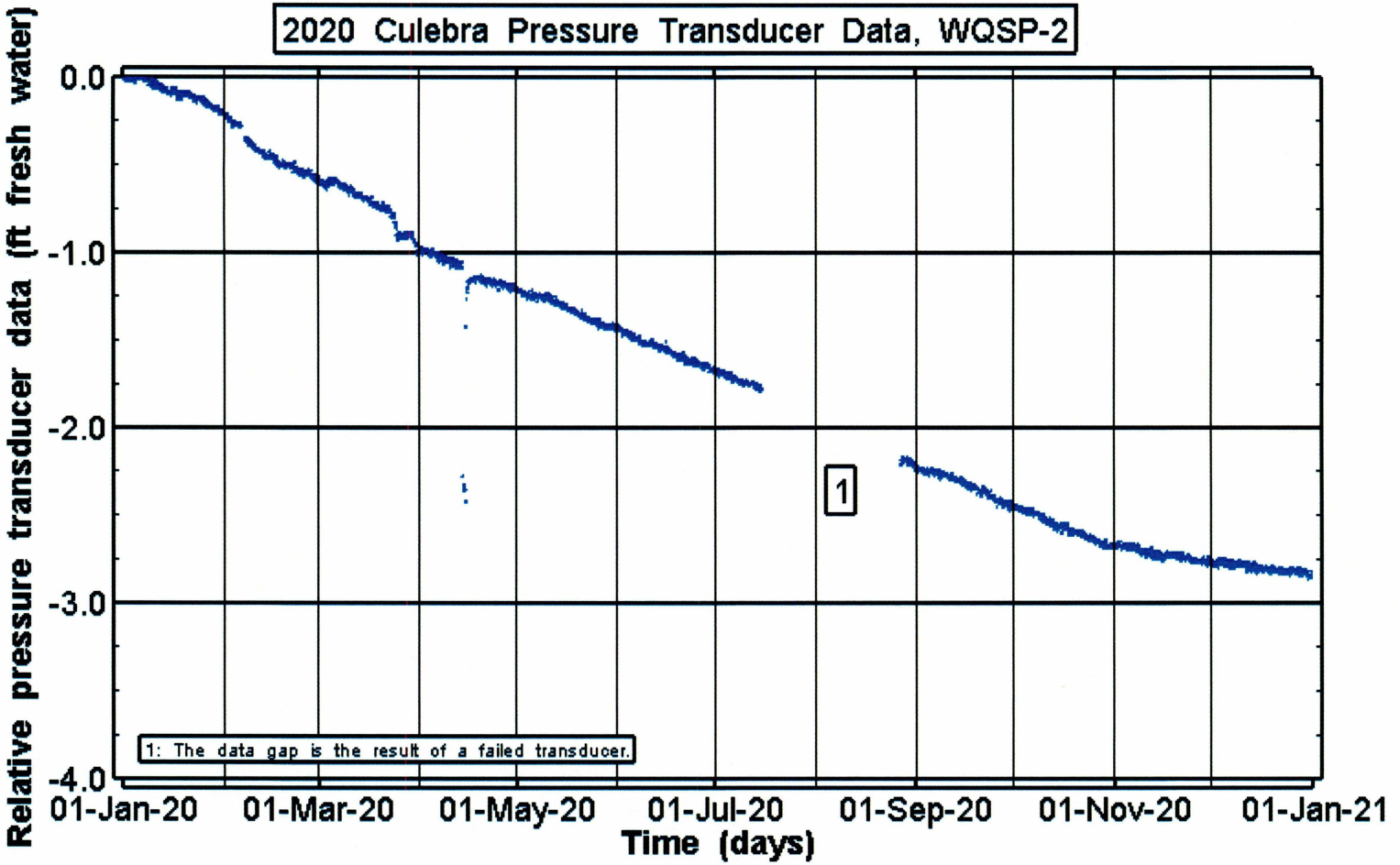

Figure 43. Well WQSP-2 experienced a net change in hydraulic head of -2.83 ft fresh water in 2020. This well was sampled in April 2020.

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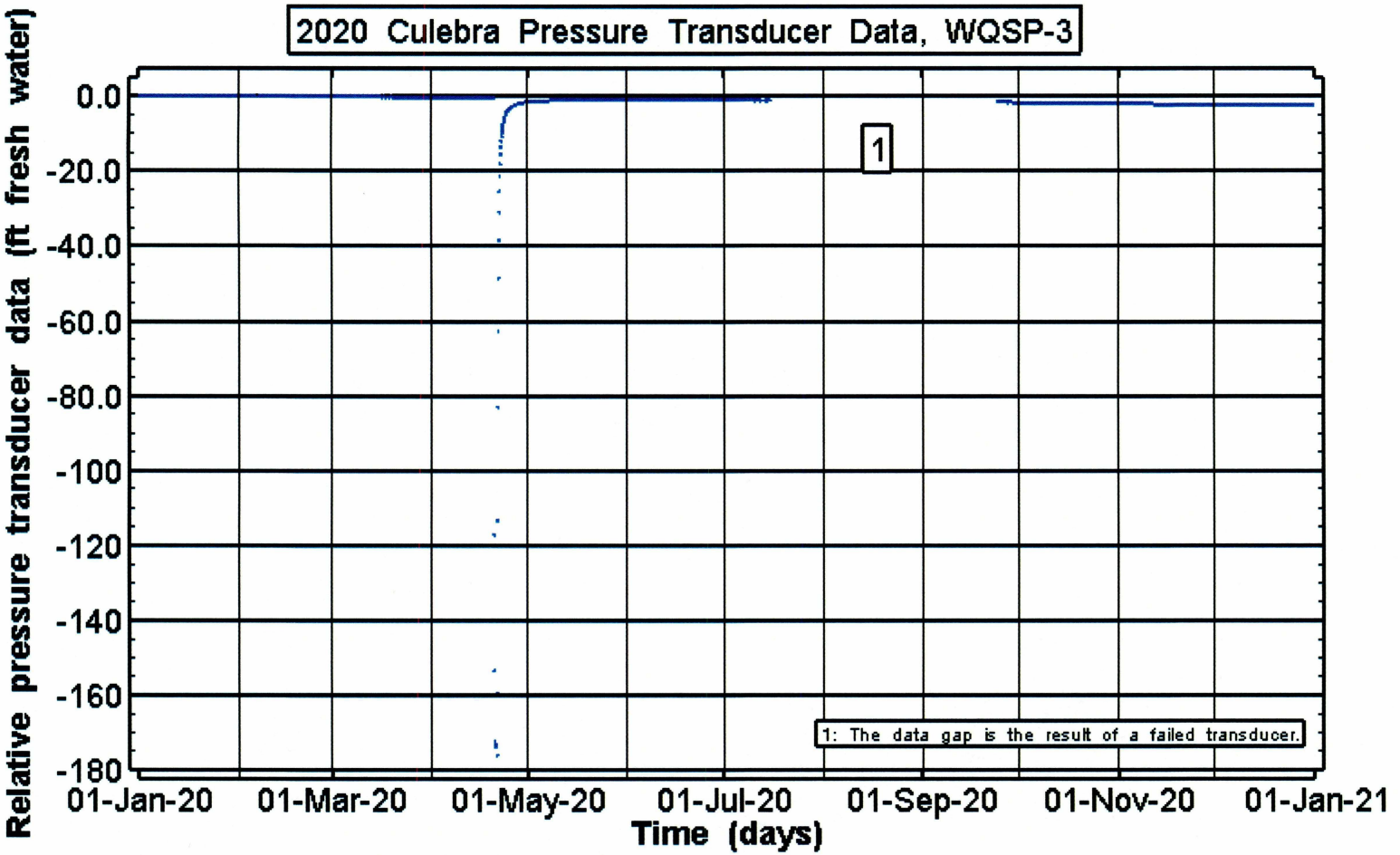

Figure 44. WQSP-3 experienced a net change in hydraulic head of -2.37 ft fresh water in 2020. This well was sampled in April 2020.

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