577608

Sandia National Laboratories

Operated for the United States Department of Energy
by National Technology and Engineering Solutions
of Sandia, LLC.

Albuquerque, New Mexico 87185-0101
Livermore, California 94551-0969

date: June 30, 2022

to: WIPP Records Center

from: Dale O. Bowman II

subject: Milestone HYDRO 22-02: Progress Report that Documents CY21 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, as 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) 2021.

2.0 Introduction

In CY2021, SNL recorded pressure data across 34 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

Information Only

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 the Magenta monitoring well locations.

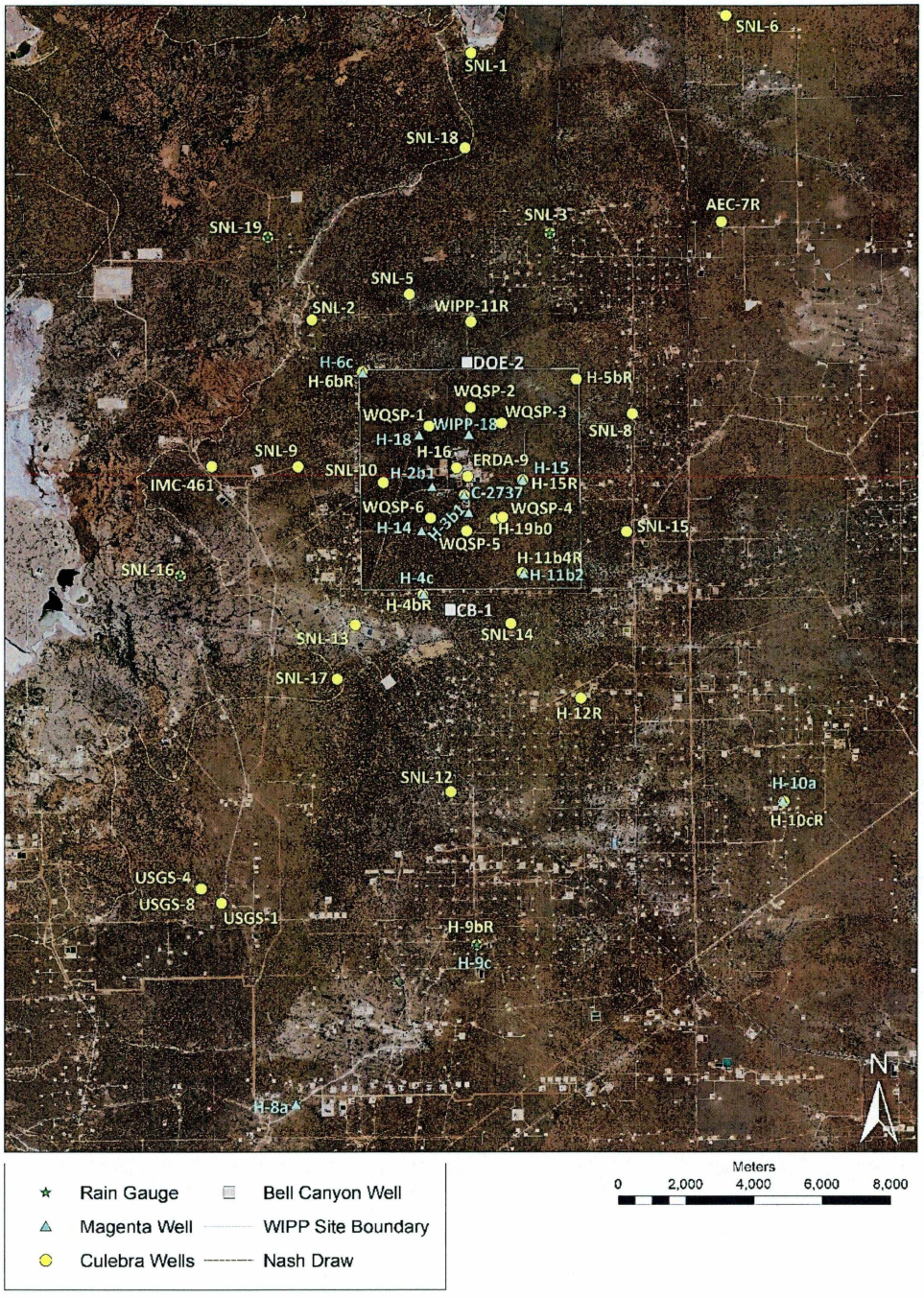

Figure 1. Locations of Culebra (yellow circles) and Magenta (blue triangles) wells in the WIPP Groundwater Monitoring Network. Well C-2737 is a dual completion in both the Culebra and Magenta. The Land Withdrawal Boundary (LWB) is outlined in grey, and the approximate boundary of Nash Draw is outlined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

Exceptional Service in the National Interest
Information Only

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 CY2021, as shown in Figure 1, and an abbreviated description of the dominant influence(s) (the most prevalent cause(s) of pressure 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 3.0. Wells WQSP-4, WQSP-5, and WQSP-6 are excluded as transducers had not yet been installed in those wells. Table 2 contains the delta hydraulic head (Δ) and net change of hydraulic head (both in feet of fresh water) for CY2021. 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 CY2021. In circumstances where transducers were placed at different depths during CY2021 (i.e. AEC-7R in Figure 5), 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 CY2021

Well	Dominant Influences
AEC-7R	Gravity Flow
C-2737	NWRA*; Precipitation Events
ERDA-9	NWRA*
H-4bR	NWRA*; Precipitation Events
H-5bR	Well Testing and Development; Recovery
H-6bR	NWRA*; Precipitation Events
H-9bR	NWRA*
H-10cR	Recovery
H-11b4R	NWRA*
H-12R	NWRA*
H-15R	NWRA*
H-16	Gravity Flow
H-19b0	NWRA*
IMC-461	NWRA*
SNL-1	Precipitation Events
SNL-2	Precipitation Events
SNL-3	NWRA*; Testing; Precipitation Events
SNL-5	NWRA*; Testing
SNL-6	Long-term Recovery
SNL-8	Gravity Flow
SNL-9	NWRA*; Precipitation Events
SNL-10	Well Maintenance*
SNL-12	NWRA*
SNL-13	Gravity Flow
SNL-14	NWRA*
SNL-15	Long-term Recovery
SNL-16	Gravity Flow
SNL-17	NWRA*; Precipitation Events
SNL-18	Precipitation Events
SNL-19	Precipitation Events
WIPP-11R	Well Replacement; Purging; Testing
WQSP-1	Water Quality Sampling; Observation Response
WQSP-2	Water Quality Sampling; Observation Response
WQSP-3	Water Quality Sampling

*Non-WIPP Related Anthropogenics

Exceptional Service in the National Interest
Information Only

Table 2. Culebra Hydraulic Head Fluctuations

Well	Δ Hydraulic Head (ft fresh water)	Net Change (ft fresh water)
AEC-7R*	0.90	0.50
C-2737	2.91	-2.58
ERDA-9	2.33	-2.05
H-4bR	5.76	-0.47
H-5bR	419.81	-16.72
H-6bR	1.60	-0.74
H-9bR	3.93	0.26
H-10cR	6.23	5.72
H-11b4R	10.49	-1.45
H-12R	8.27	-0.43
H-15R	3.81	-2.52
H-16	1.71	-1.48
H-19b0	3.90	-2.64
IMC-461	1.43	-0.33
SNL-1	0.77	0.40
SNL-2	1.31	-0.40
SNL-3	2.34	-1.39
SNL-5	1.93	0.98
SNL-6*	9.56	9.38
SNL-8	0.81	-0.07
SNL-9	3.50	-1.88
SNL-10	6.79	-0.92
SNL-12	14.66	-0.13
SNL-13	1.41	-1.02
SNL-14	23.84	-1.49
SNL-15	5.49	5.38
SNL-16	0.57	-0.06
SNL-17	2.11	-1.33
SNL-18	1.50	0.77
SNL-19	1.35	-0.22
WIPP-11R	33.66	-2.50
WQSP-1	6.74	-0.23
WQSP-2	13.45	-1.33
WQSP-3	0.76	-0.47

*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_CY21.

3.0 Dominant Influences Affecting Wells

Exceptional Service in the National Interest
Information Only

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, replacement, and pumping activities,
- 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 CY2021, and
- WIPP and Non-WIPP related anthropogenic affects.

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

3.1.1 WQSP Water Quality Sampling

Sampling occurred between March and early June 2021 for wells WQSP-1 through WQSP-6. The net hydraulic head changes from sampling were not well captured due to failed transducers, but water level changes were observed in other monitoring wells.

3.1.2 Well Testing

Wells H-5bR (Figure 9) and WIPP-11R (Figure 35) were tested in CY2021. WIPP-11R was purged in August for approximately 2 hours and subject to a constant-rate test in September for approximately 24 hours. Well H-5bR was purged four times between March and August. In October, a long-term water quality test was performed on H-5bR, followed by a slug-withdrawal test in December.

3.1.3 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). Wells H-10cR and H-5bR, which were more recently constructed are also still recovering from their testing activities and are likely to take a greater than average amount of time due to the low transmissivity in each well. The SNL-6 net recovery is 9.35 ft freshwater head (Figure 23), the SNL-15 net recovery is 5.38 ft freshwater head (Figure 30).

3.1.4 Non-WIPP-Related Anthropogenic (NWRA) Affects

Seventeen wells that responded to NWRA affects in CY2021 are displayed in Figures 2 and 3. Graphically, the events are separated into those that are associated with a singular large-scale NWRA event that began in late July 2021 and those that are independent of that singular event. In late July, there was a negative pressure event nearest wells H-11b4R, SNL-12 and SNL-14 that lasted approximately two weeks followed by recovery for the rest of the calendar year. Less prominent responses from the same event are seen in wells H-4bR, H-9bR, H-19b0, and SNL-17. Two water wells presently located near this grouping of monitoring wells are the possible source of drawdown (NMOSE 2022). Well C-02258 (production) is owned by Devon is allotted 3 AFY and is located approximately 2 miles east of SNL-12. The second well, BLM livestock well C-03351, is co-located on the same well pad as SNL-14 and is the more likely source of drawdown given the sharp pressure response at SNL-14.

Exceptional Service in the National Interest
Information Only

The other NWRA wells (C-2737, ERDA-9, H-6bR, H-12R, H-15R, IMC-461, SNL-3, SNL-5, SNL-9, and SNL-10) exhibited pressure changes that are characteristic of pumping or drilling events, but the drilling source or source well are mostly uncertain. Well H-12R was subject to the most prominent positive pressure event in January of 2021, which did not largely affect other wells. Three new oil wells (BELLOQ 11 2 FEDERAL STATE COM #611H, #711H, and #811H) were drilled within the site of the H-12 pad in a similar time frame (EMNRD 2022). The remaining NWRA wells experience smaller, isolated effects.

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 anthropogenic hydraulic head responses. In the following sections, we discuss wells with responses dominated by natural processes.

3.2.1 General Water Level Decline

In 2020, water levels in most wells (30) had a net negative head change, and most wells that had a positive net head change for the year still had declining water levels. The net hydraulic head change in 2020 ranged from -10.15 to 1.20 ft fresh water. The decrease in water levels correlated with the drought status of Eddy County but also had possible contributions from far-field aquifer use. In 2021, we still see a decline in water levels, but in smaller magnitude than in 2020. The net hydraulic head change in 2021 ranged from -2.64 to 5.72 ft fresh water. This also corresponds to an increase in measured precipitation with an average of 10.89 in of rain in 2021 as opposed to 3.09 in in 2020. Cumulative change in head in 2020 (excluding test/developed wells and wells that were plugged and abandoned) was -29.02 ft while in 2021 cumulative head change was -11.53 ft.

3.2.2 Precipitation

Several wells in the vicinity of Nash Draw show relatively immediate hydraulic head responses to precipitation events. Figure 4 correlates precipitation data collected from rain gauges on well pads H-9, SNL-3, SNL-16, SNL-19, and WIPP-30 to show hydraulic head responses to precipitation events. The hydraulic head fluctuations for all nine wells mentioned (C-2737, H-6bR, SNL-1, SNL-2, SNL-3, SNL-9, SNL-18, SNL18, and SNL-19) are consistent with precipitation fluctuations seen in previous years (Bowman & Hayes, 2019 and 2020).

3.2.3 Gravity Flow

Five wells experienced minimal pronounced pressure data affects from precipitation or anthropogenic events (AEC-7R, H-16, SNL-8, SNL-13, and SNL-16). AEC-7R and SNL-8 are located in areas of the Culebra with the largest distance from recharge, relatively low transmissivity, and other geologic factors that mute or prevent hydraulic responses observed in other wells. Wells H-16, SNL-13 and SNL-16 were uncharacteristically unaffected by precipitation events.

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 CY2021 were in wells being developed and tested, followed by those affected by the July NWRA event. Most wells that have been predominantly affected by natural processes in past years continue to behave consistent

Exceptional Service in the National Interest
Information Only

with previous years' precipitation responses. CY2021 was a wetter year than 2020 in regard to precipitation, the water levels in a majority of the observation wells are still in decline. All cases of pressure response to anthropogenic or precipitation events should be considered short-term events as:

1) full recovery is achieved post event in relatively short time spans and
2) similar events in previous years fully recovered in a similar fashion.

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.

An effect that has begun to emerge and is being corrected as identified is the replacement of cables suffering from stretch due to long term use and/or deployment depth. In several pressure profiles in 2021, the cable replacement results in an artificial offset in pressure. These cases are labeled as "Replacement Cable Offset".

Information Only

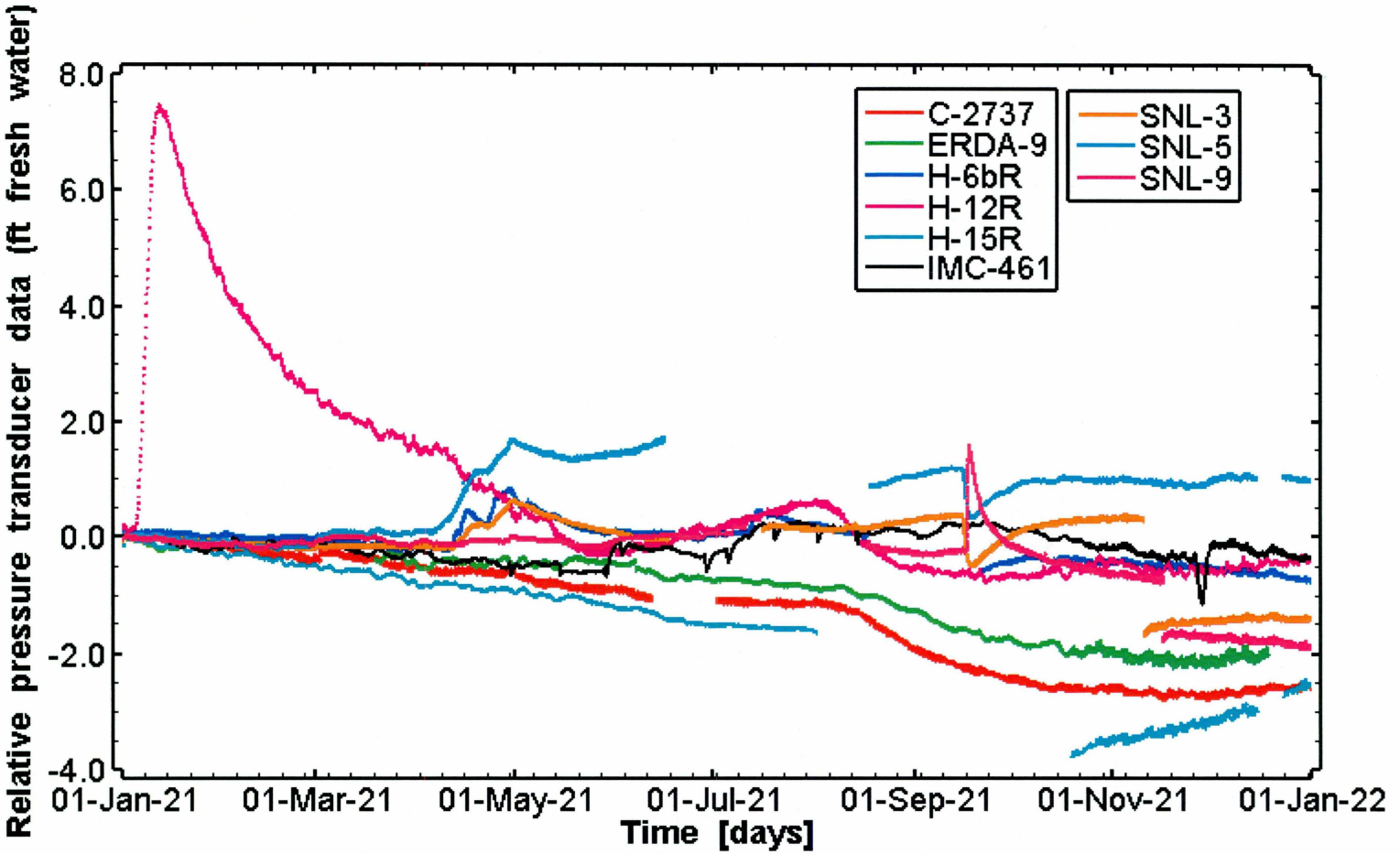

Figure 2. Ten wells affected by NWRA effects. Note: Data gaps are identified in individual well graphs.

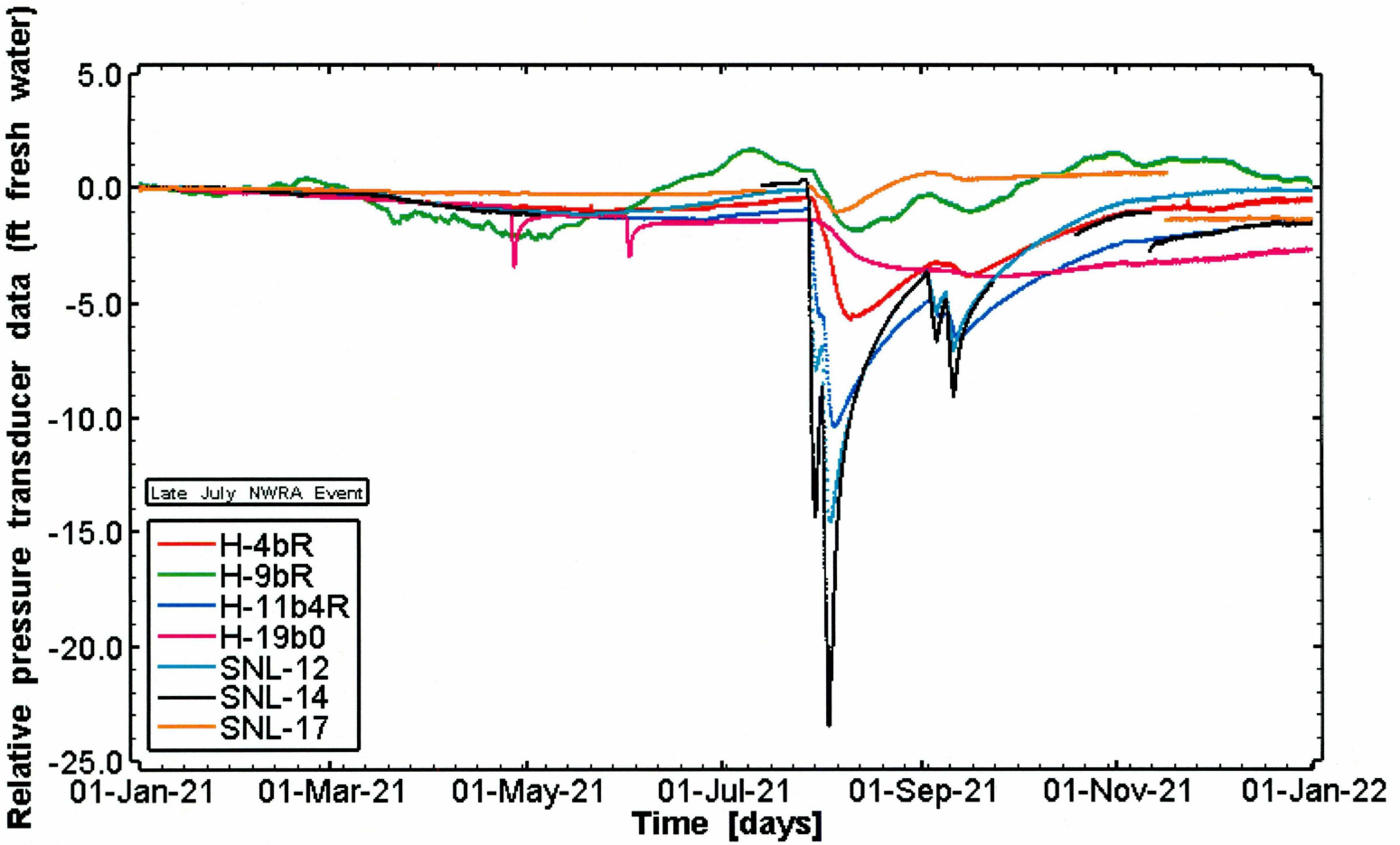

Figure 3. Seven wells affected by a single NWRA event beginning in late July 2021. Data gaps are identified in individual well graphs.

Exceptional Service in the National Interest
Information Only

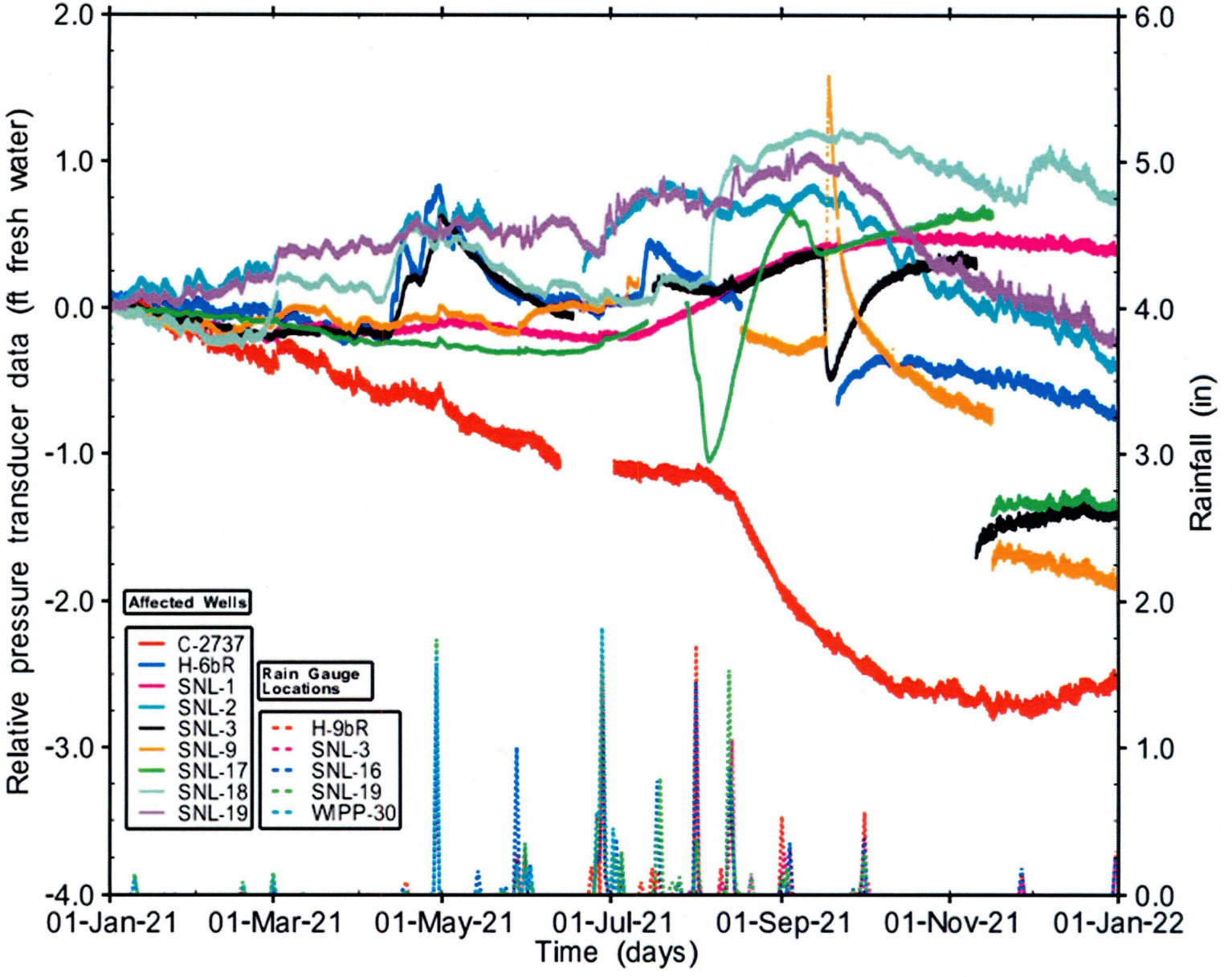

Figure 4. A group of nine Culebra wells (C-2737, H-6bR, IMC-461, SNL-1, SNL-3, SNL-9, SNL-17, SNL-18, and SNL-19) that demonstrate responses to precipitation events. Daily precipitation totals from four rain gauge sites are plotted as dotted lines.

Exceptional Service in the National Interest

Information Only

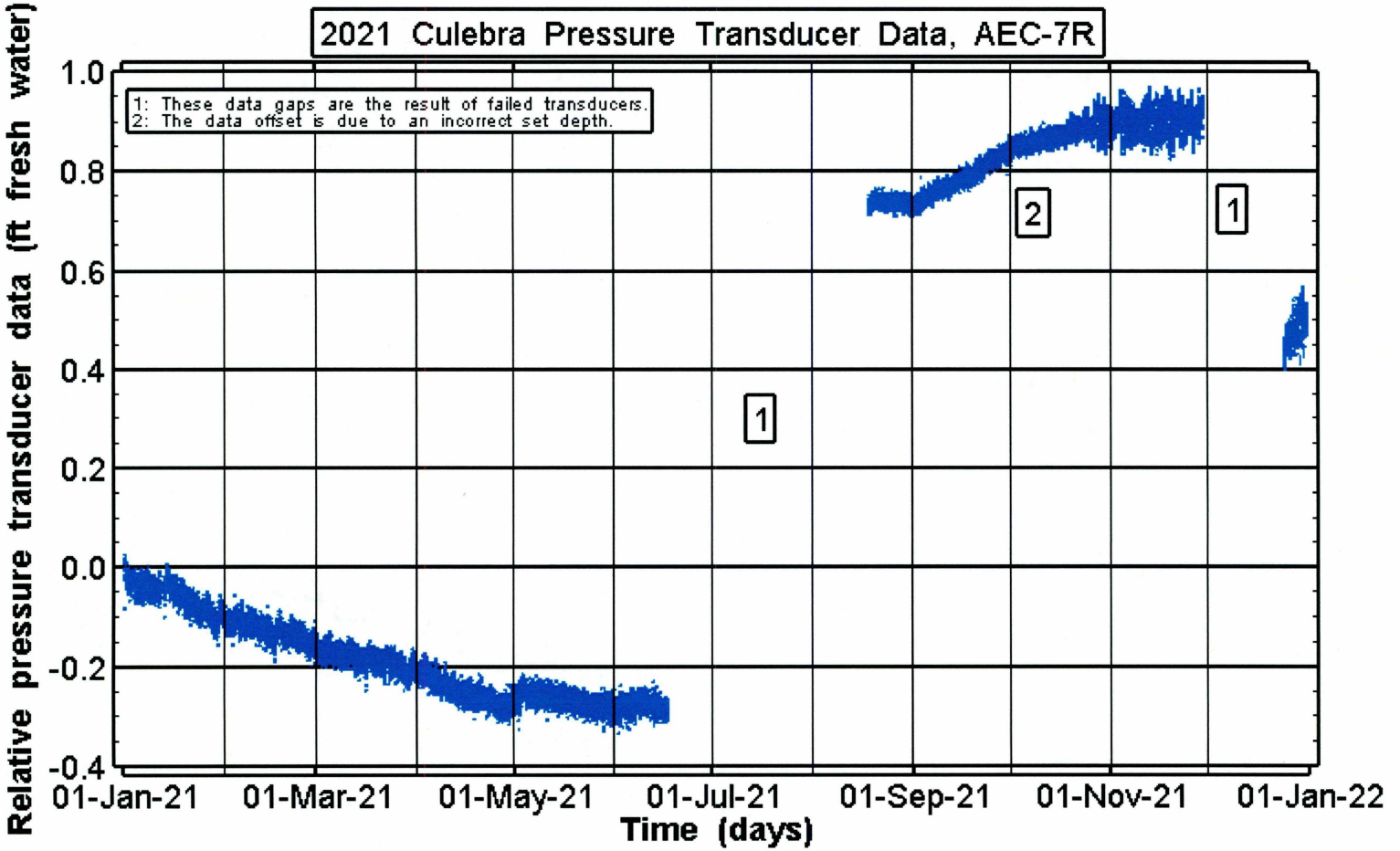

Figure 5. Well AEC-7R experienced a net change in hydraulic head of 0.50 ft fresh water in 2021.

Exceptional Service in the National Interest
Information Only

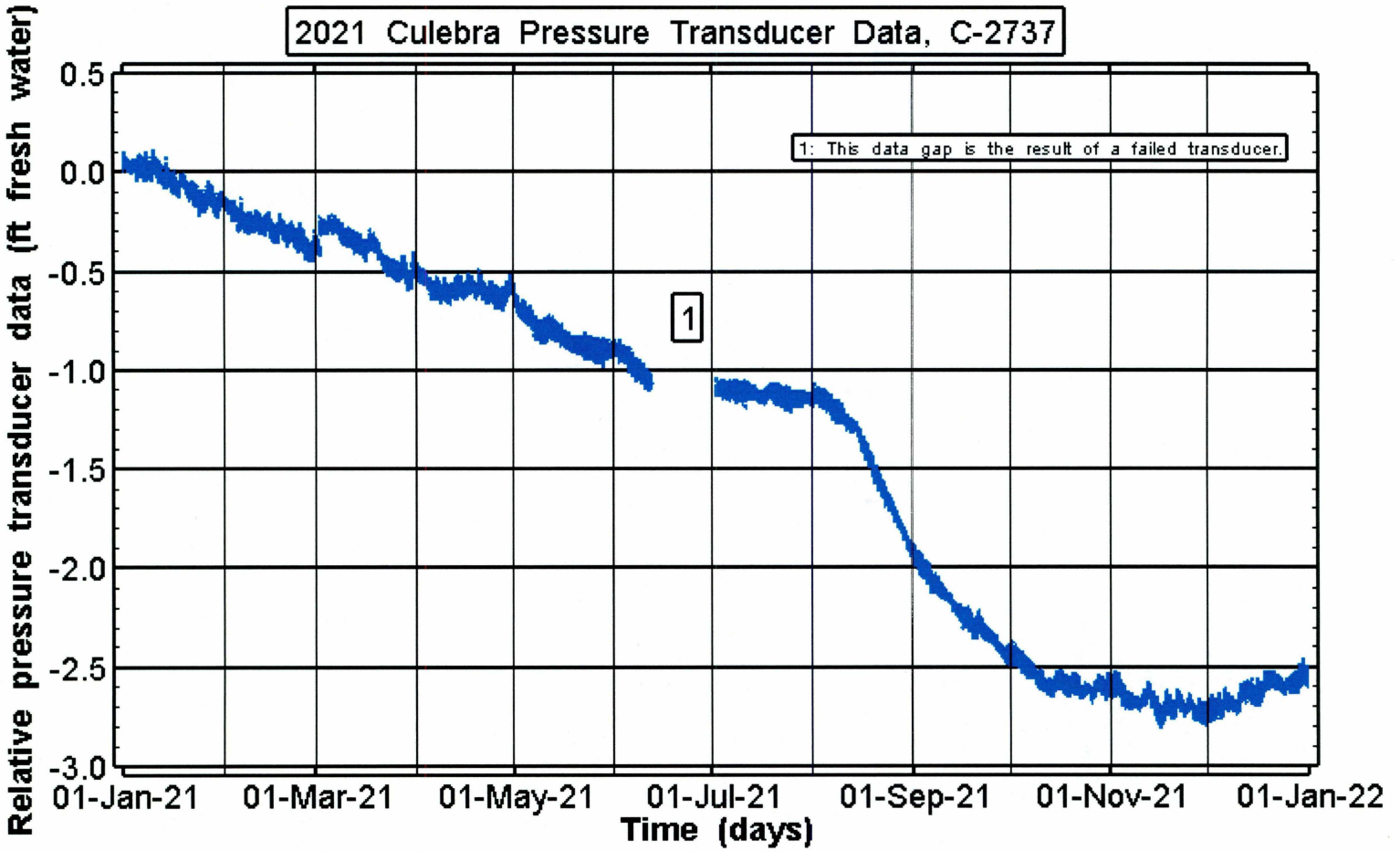

Figure 6. Well C-2737 experienced a net change in hydraulic head of -2.58 ft fresh water in 2021. This well was affected by NWRA.

Exceptional Service in the National Interest
Information Only

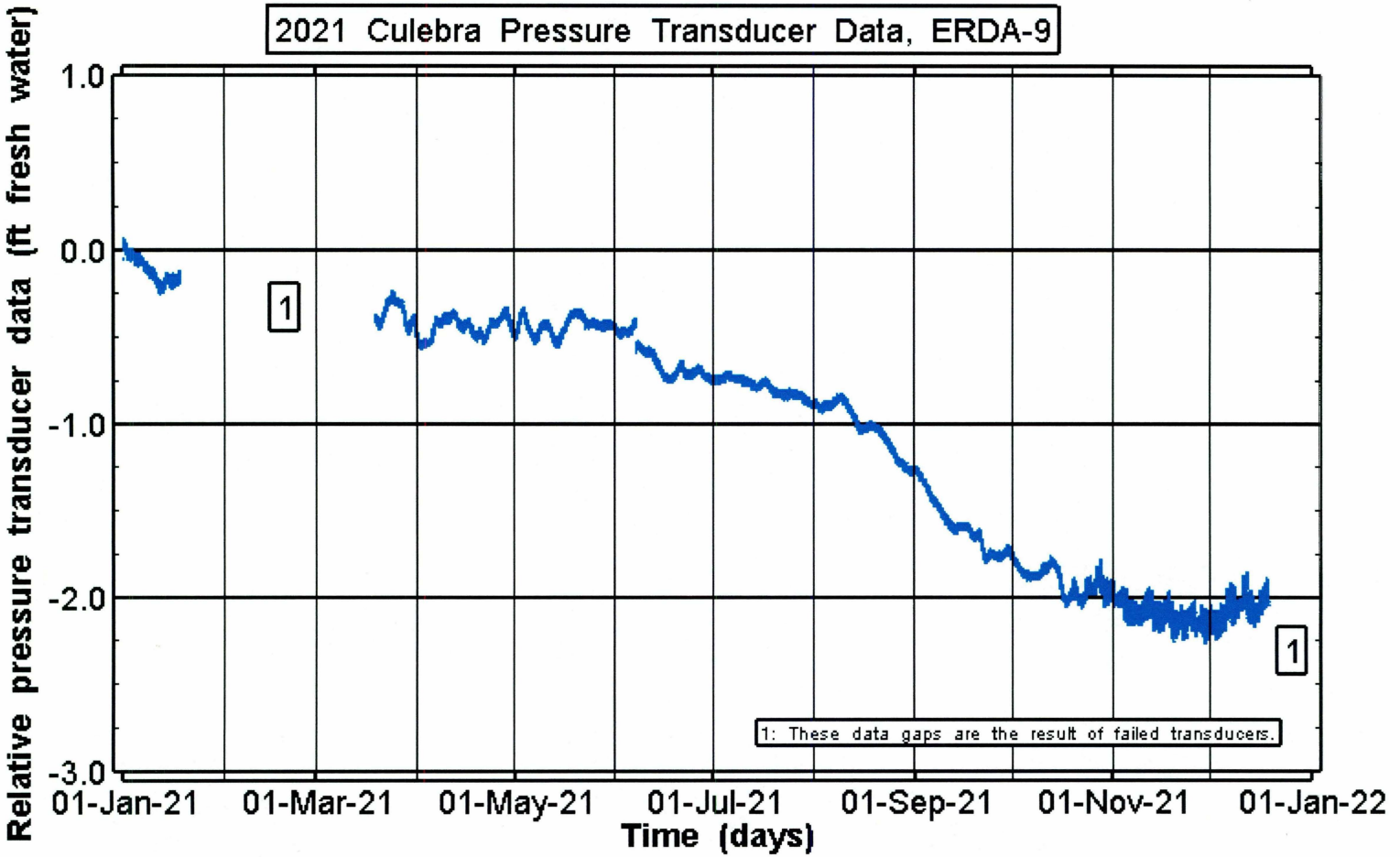

Figure 7. Well ERDA-9 experienced a net change in hydraulic head of -2.05 ft fresh water in 2021. This well was affected by NWRA.

Exceptional Service in the National Interest
Information Only

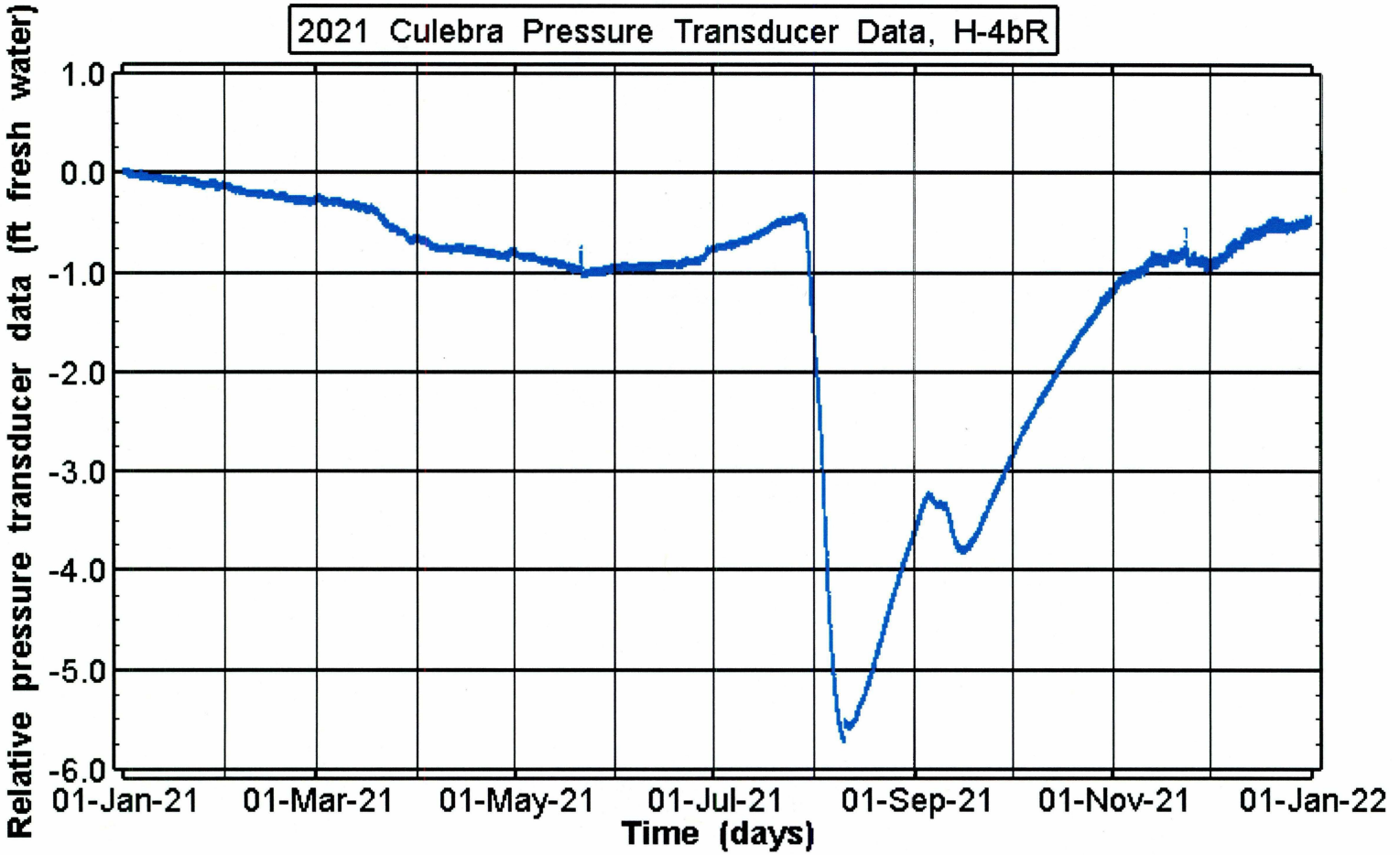

Figure 8. Well H-4bR experienced a net change in hydraulic head of -0.47 ft fresh water in 2021. This well was affected by NWRA.

Exceptional Service in the National Interest
Information Only

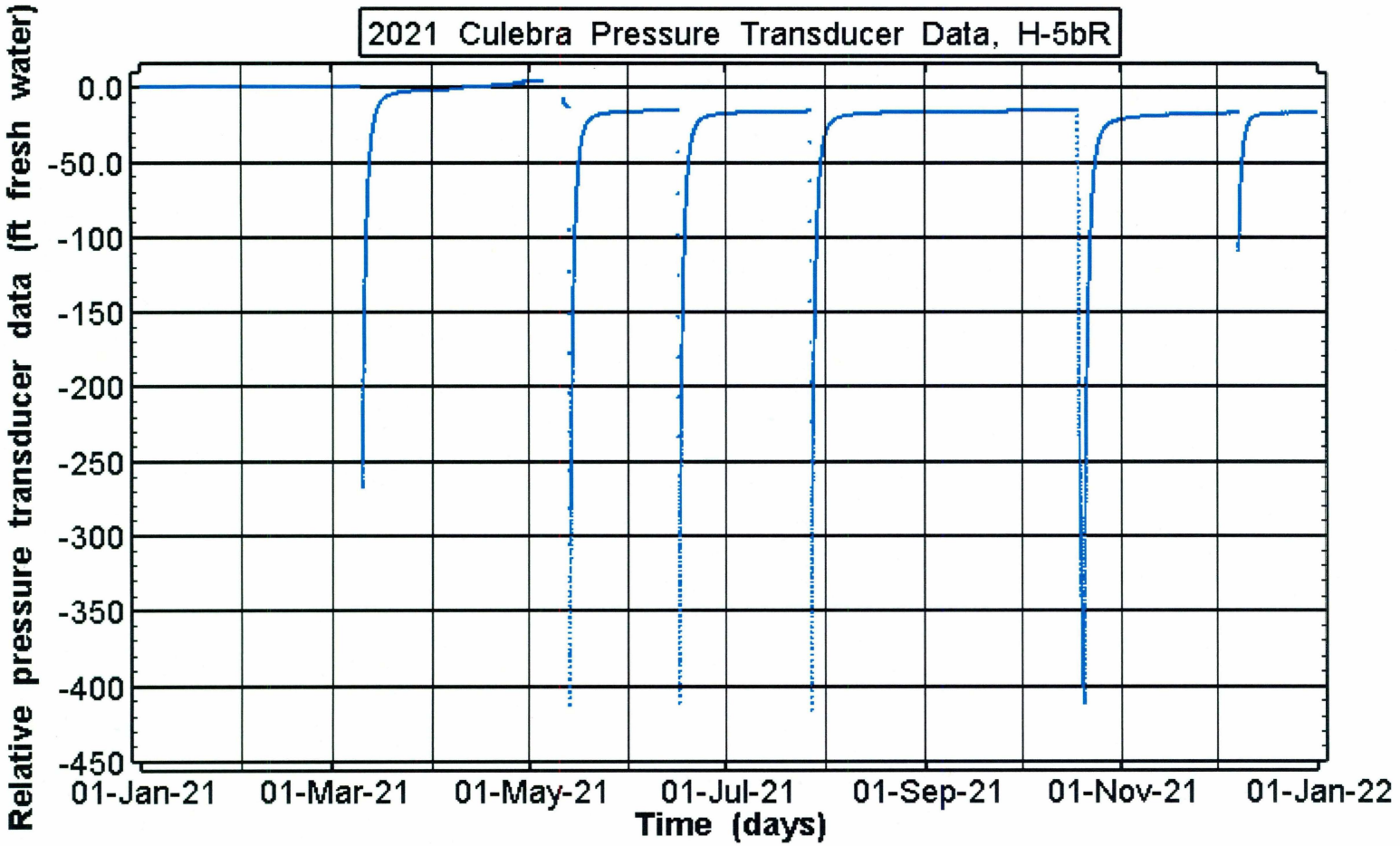

Figure 9. Well H-5bR experienced a net change in hydraulic head of -16.72 ft fresh water in 2021. This well has been subject to hydrologic purges and a slug test.

Exceptional Service in the National Interest
Information Only

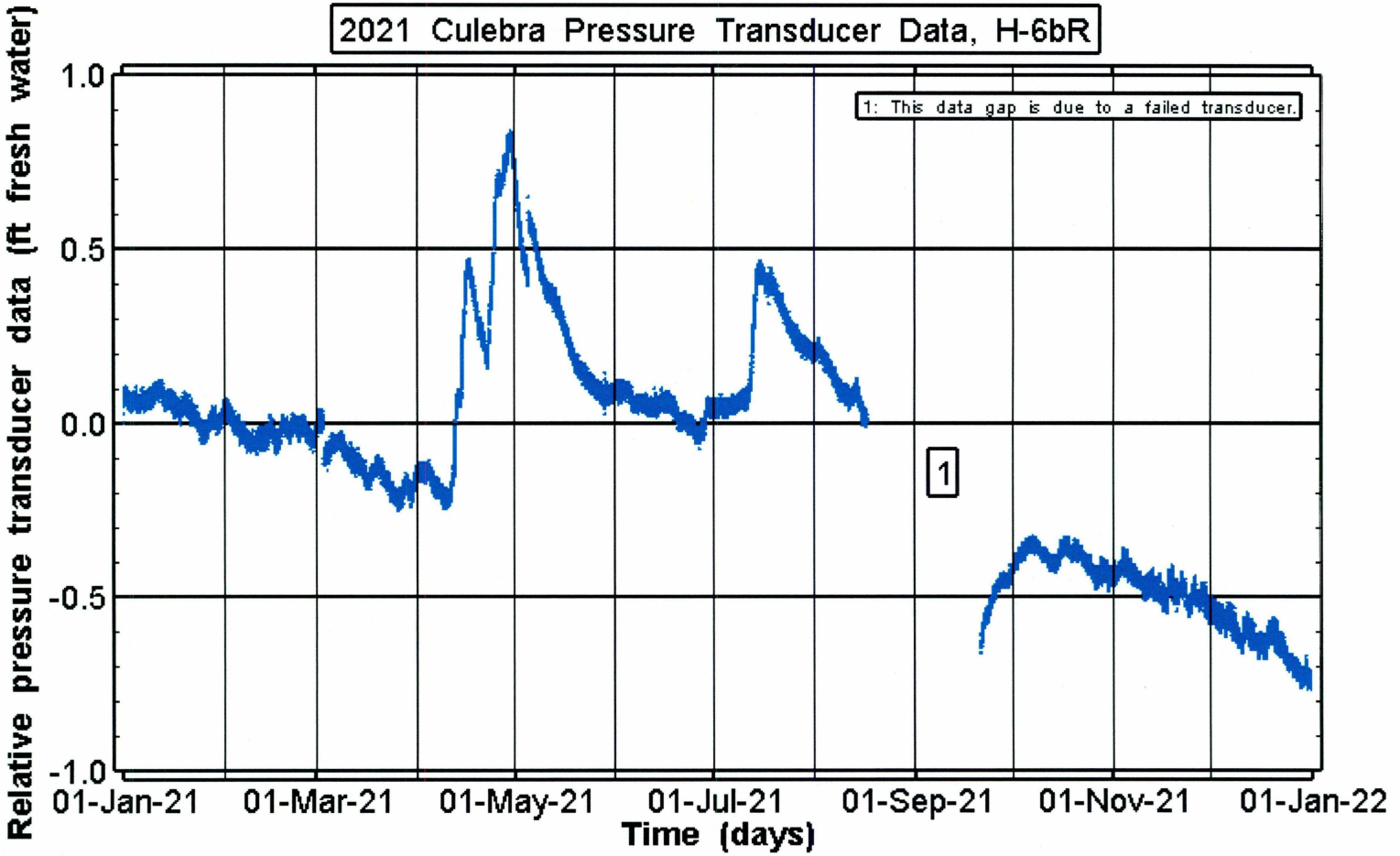

Figure 10. Well H-6bR experienced a net change in hydraulic head of -0.74 ft fresh water in 2021. This well was affected by NWRA.

Exceptional Service in the National Interest
Information Only

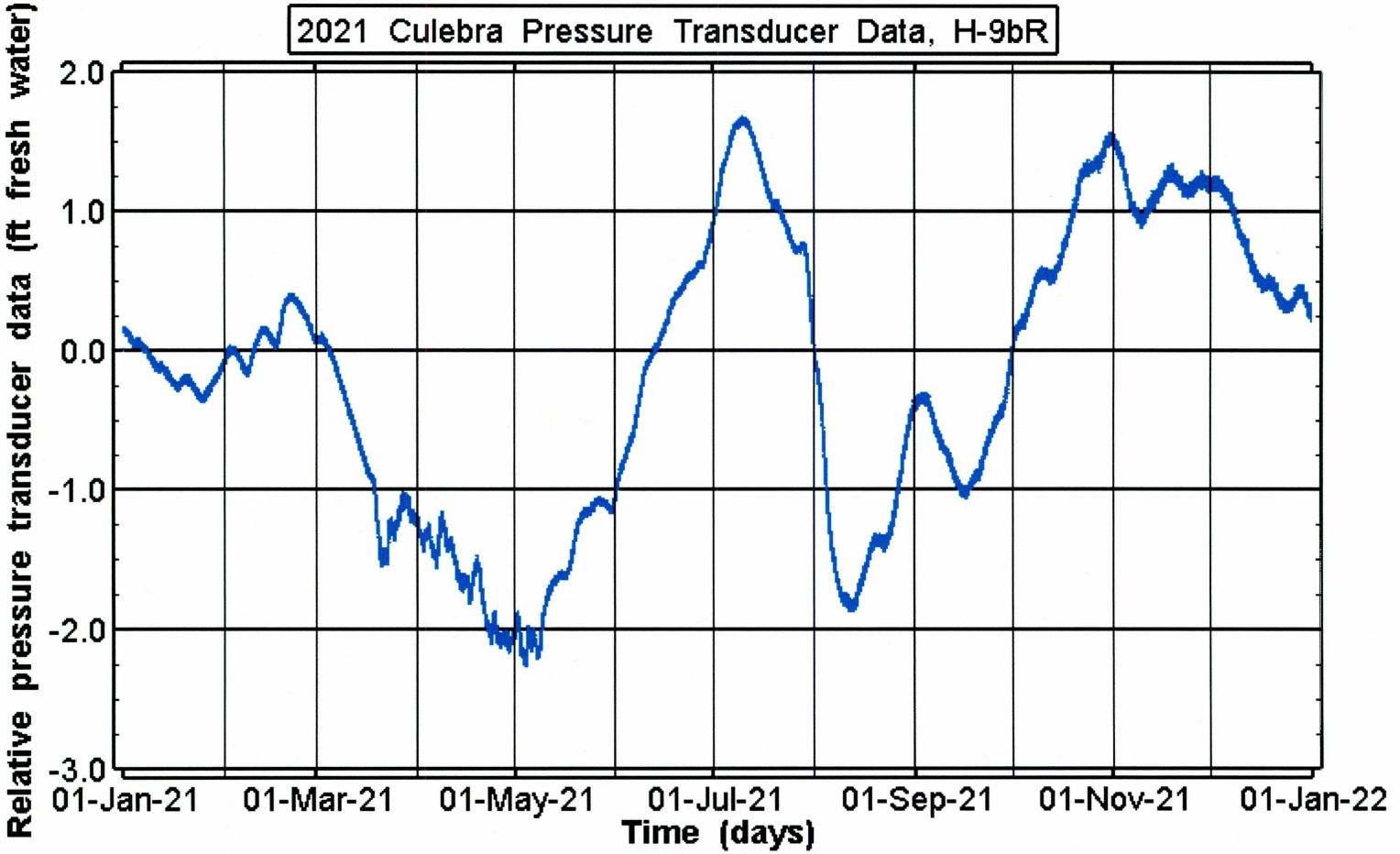

Figure 11. Well H-9bR experienced a net change in hydraulic head of 0.26 ft fresh water in 2021. This well was affected by NWRA.

Exceptional Service in the National Interest
Information Only

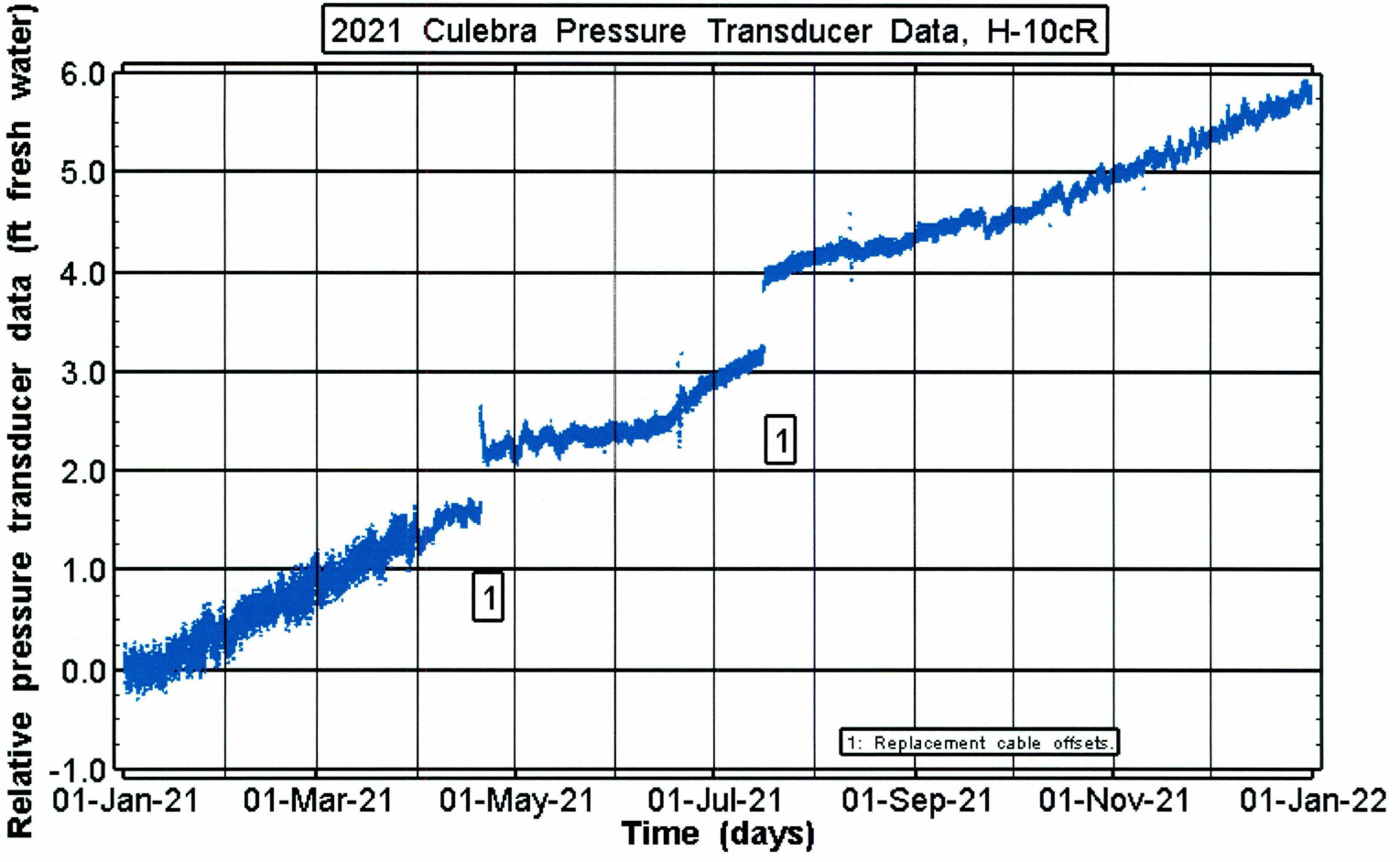

Figure 12. Well H-10cR experienced a net change in hydraulic head of 5.72 ft fresh water in 2021. The well is in long-term recovery from well development.

Exceptional Service in the National Interest
Information Only

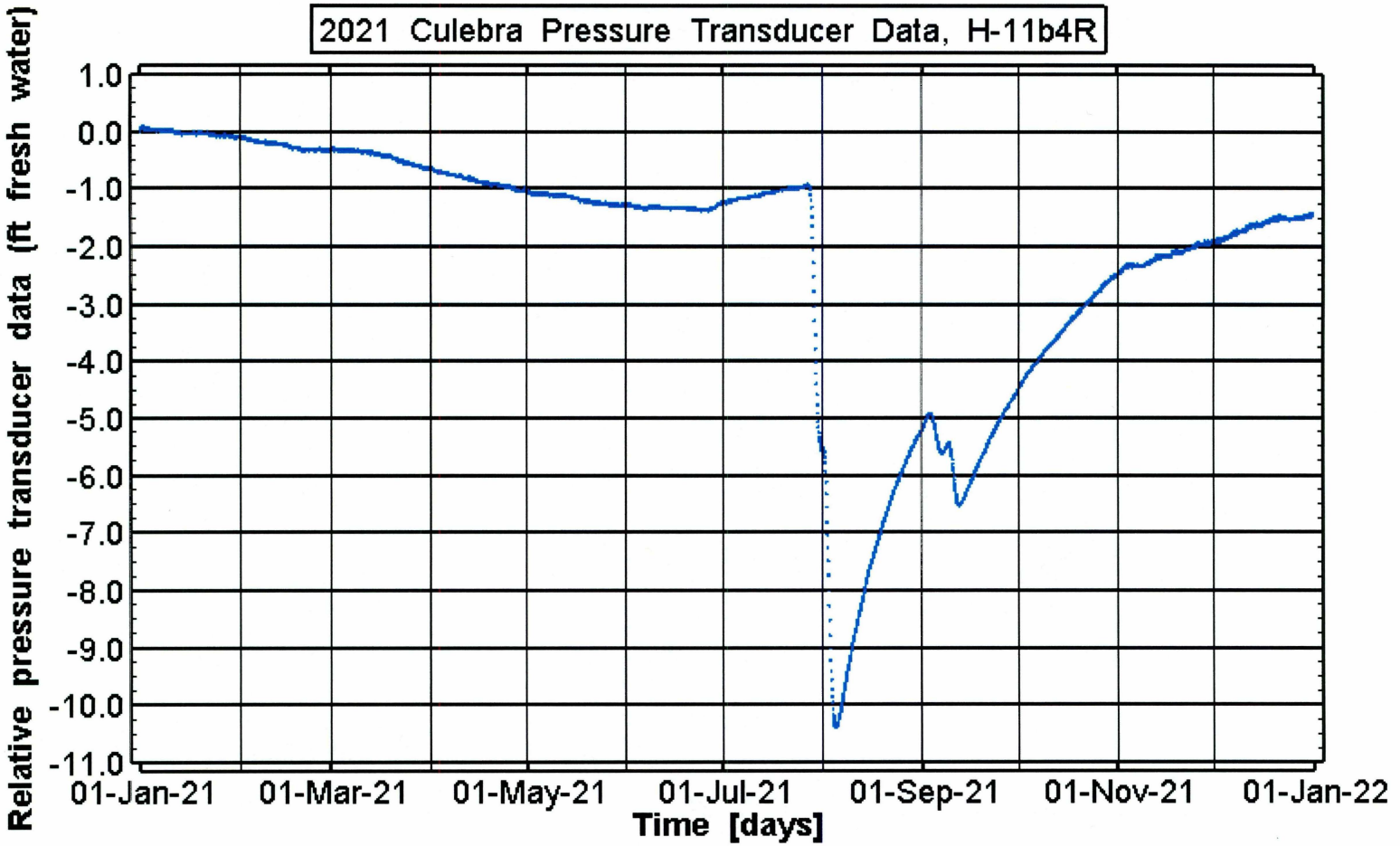

Figure 13. Well H-11b4R experienced a net change in hydraulic head of -1.45 ft fresh water in 2021. This well was affected by NWRA.

Exceptional Service in the National Interest
Information Only

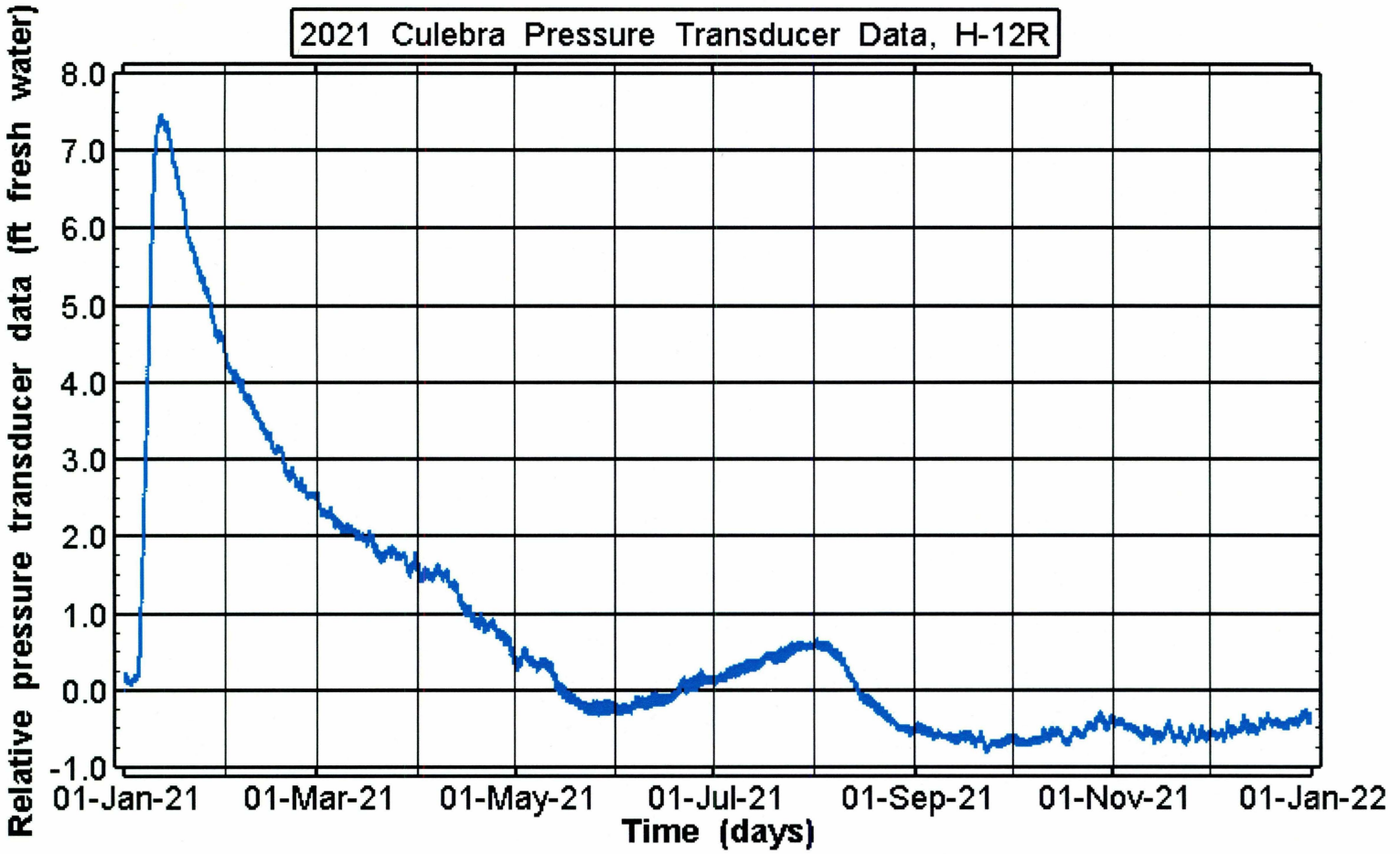

Figure 14. Well H-12R experienced a net change in hydraulic head of -0.43 ft fresh water in 2021. This well was affected by NWRA.

Exceptional Service in the National Interest
Information Only

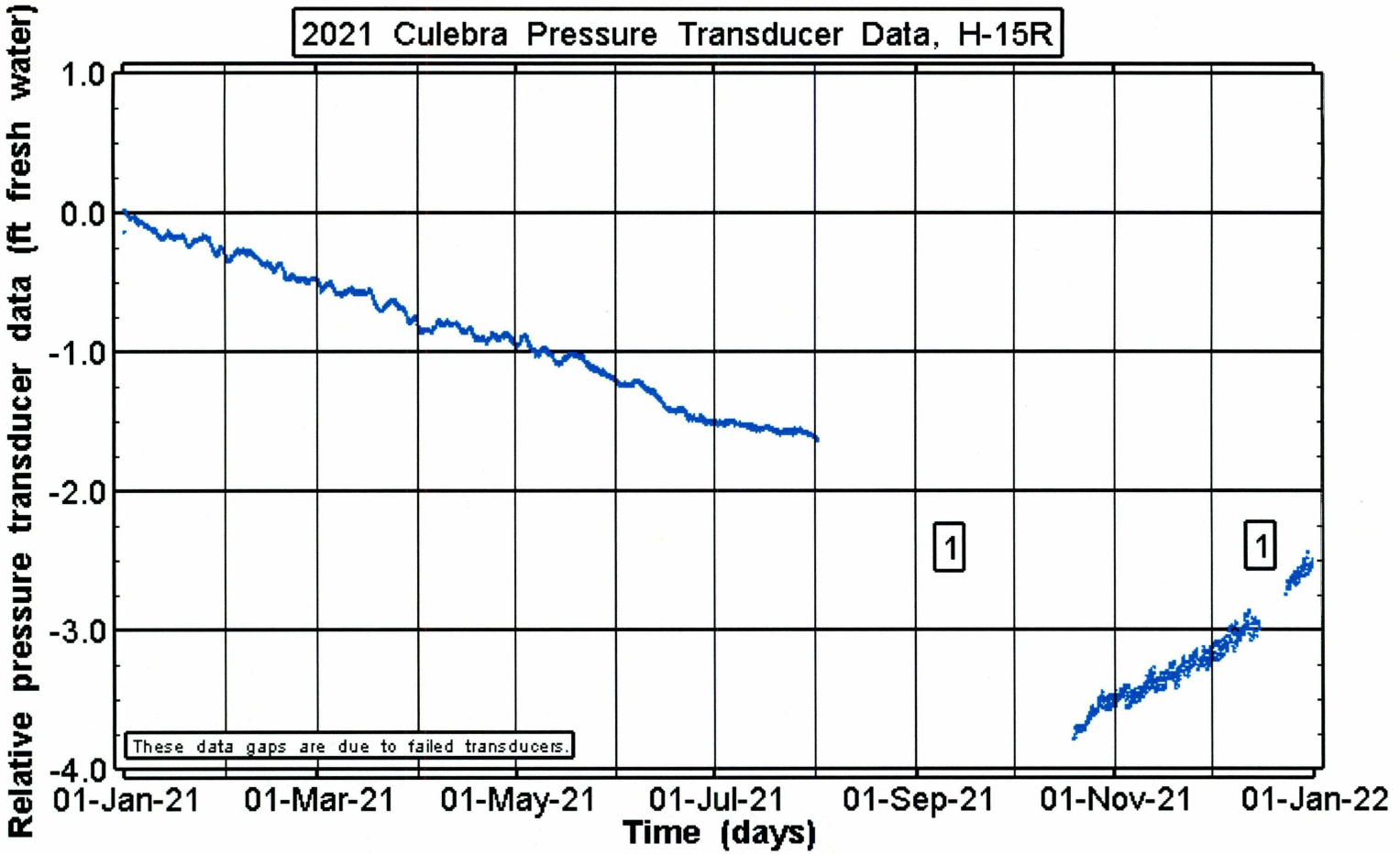

Figure 15. Well H-15R experienced a net change in hydraulic head of -2.52 ft fresh water in 2021. This well was affected by NWRA.

Exceptional Service in the National Interest
Information Only

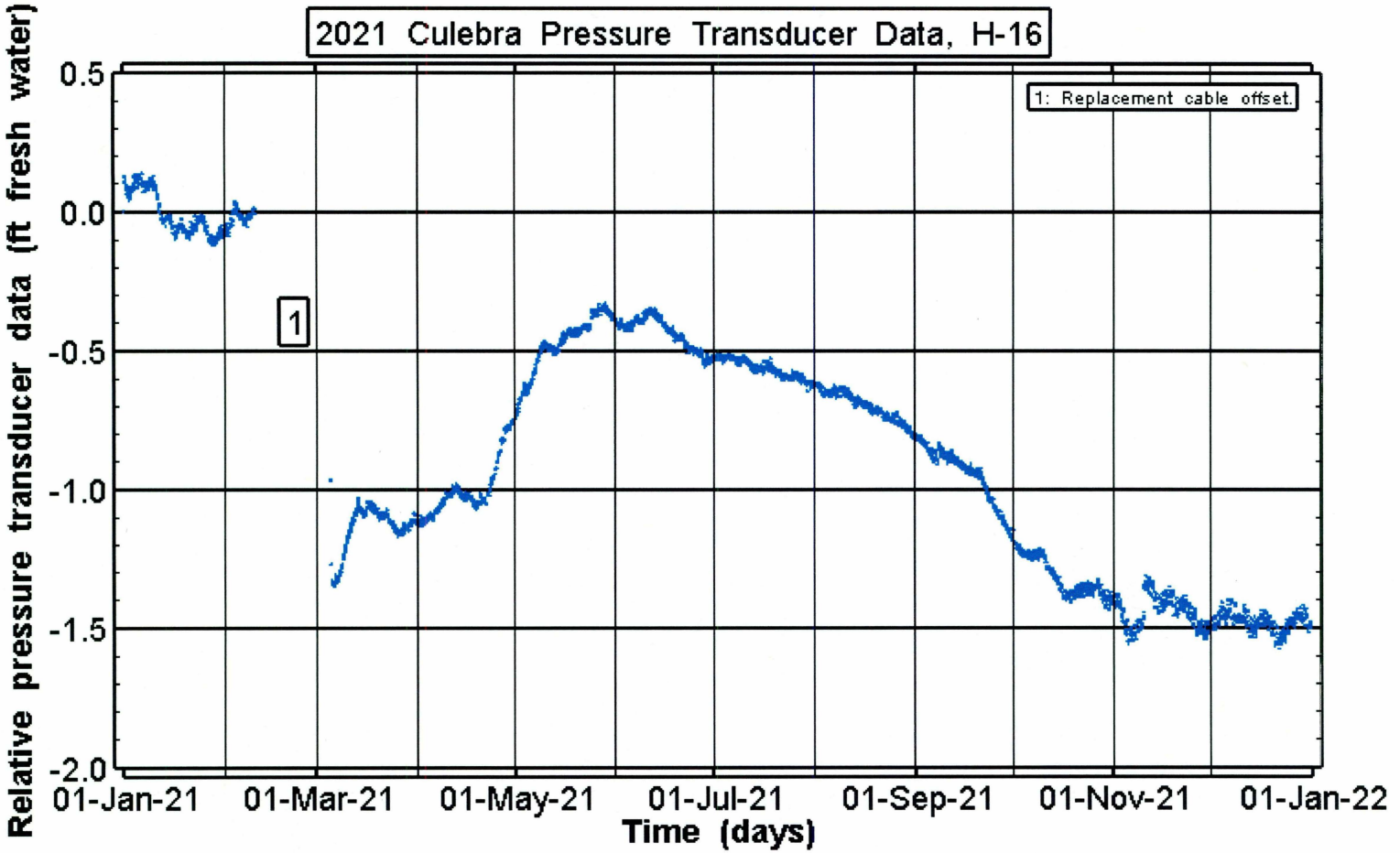

Figure 16. H-16 experienced a net change in hydraulic head of -1.48 ft fresh water in 2021.

Exceptional Service in the National Interest
Information Only

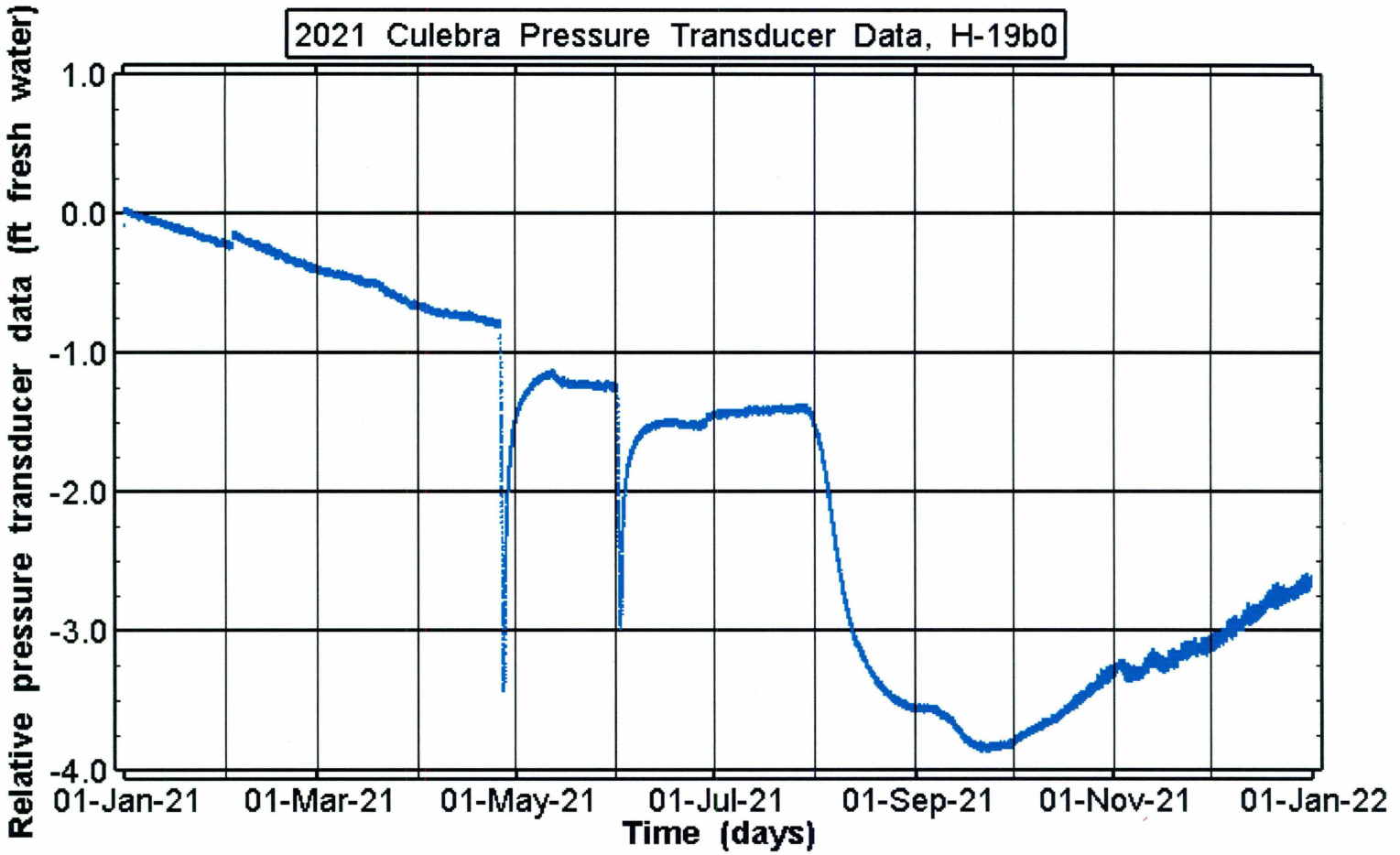

Figure 17. Well H-19b0 experienced a net change in hydraulic head of -2.64 ft fresh water in 2021. This well was affected by NWRA.

Exceptional Service in the National Interest
Information Only

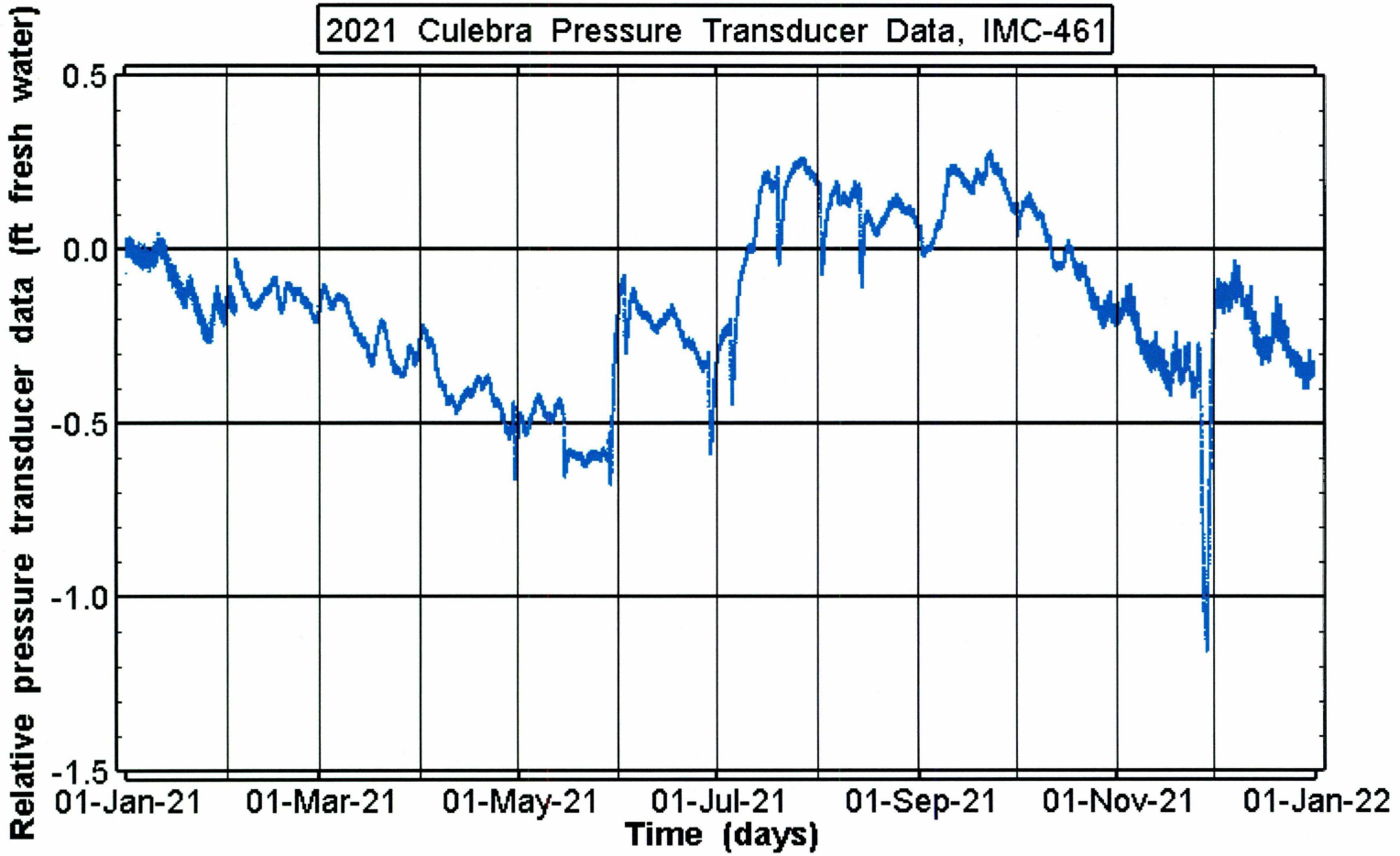

Figure 18. Well IMC-461 experienced a net change in hydraulic head of -0.33 ft fresh water in 2021. This well was affected by NWRA.

Exceptional Service in the National Interest
Information Only

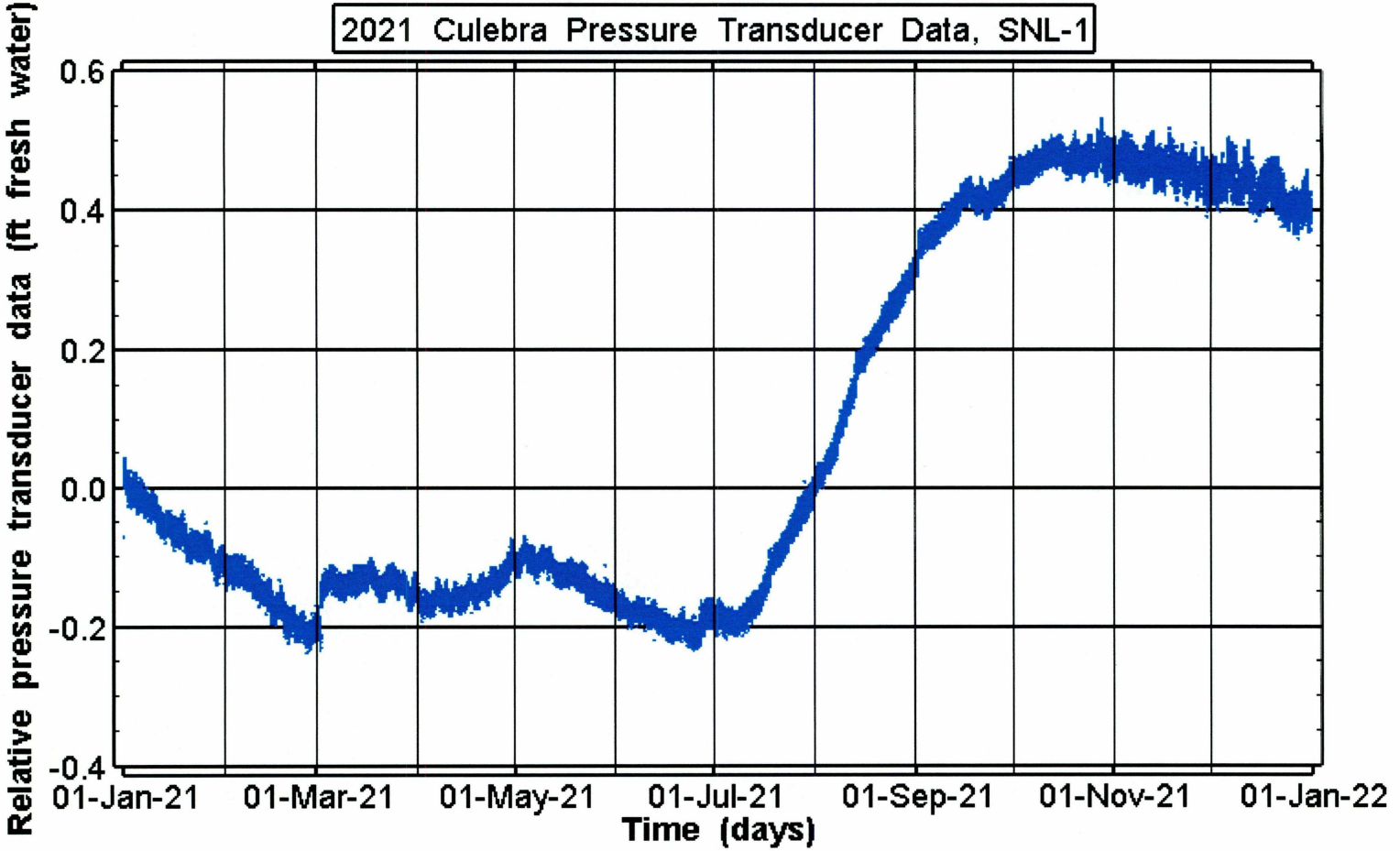

Figure 19. Well SNL-1 experienced a net change in hydraulic head of 0.40 ft fresh water in 2021.

Exceptional Service in the National Interest
Information Only

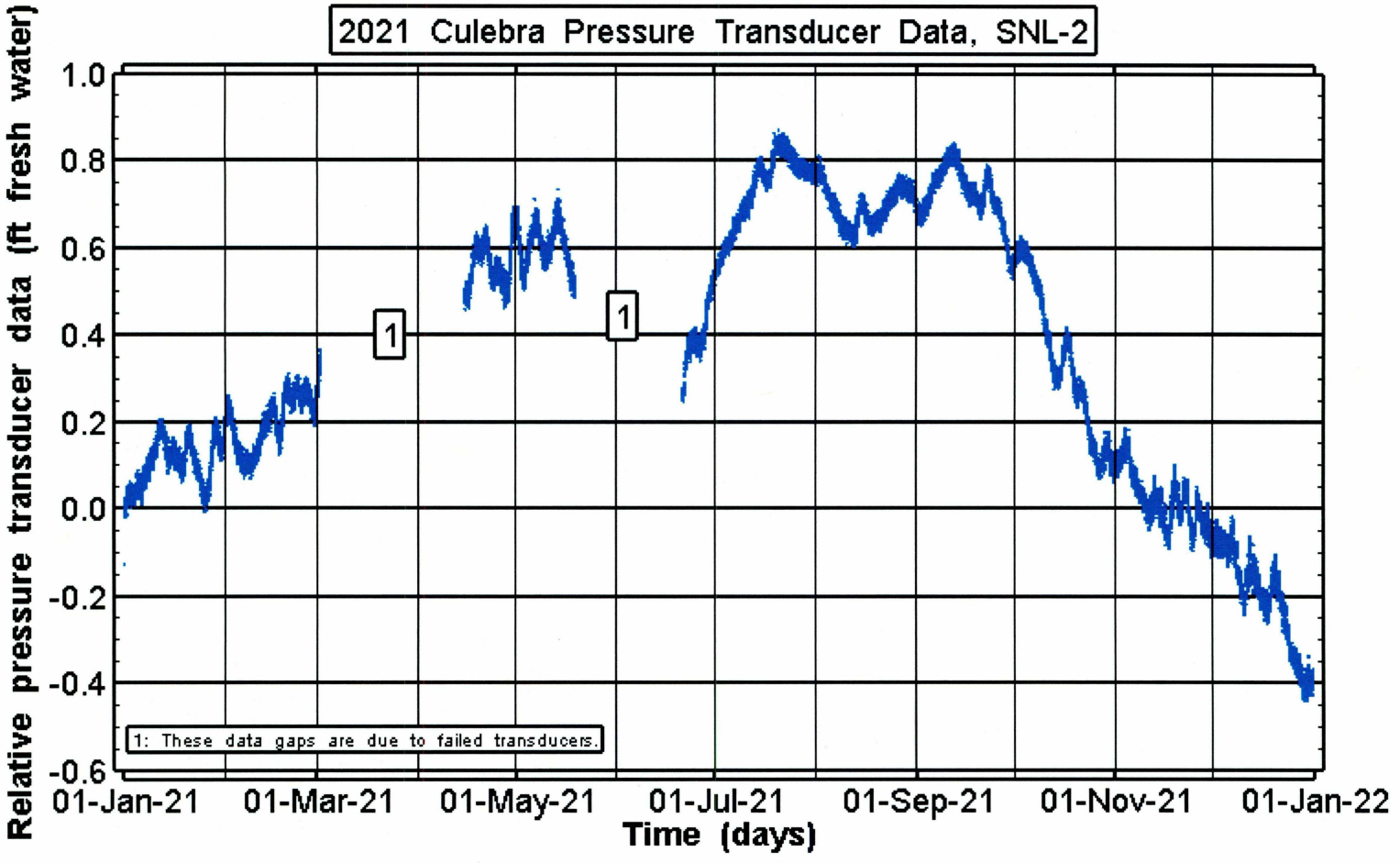

Figure 20. Well SNL-2 experienced a net change in hydraulic head of -0.40 ft fresh water in 2021.

Exceptional Service in the National Interest
Information Only

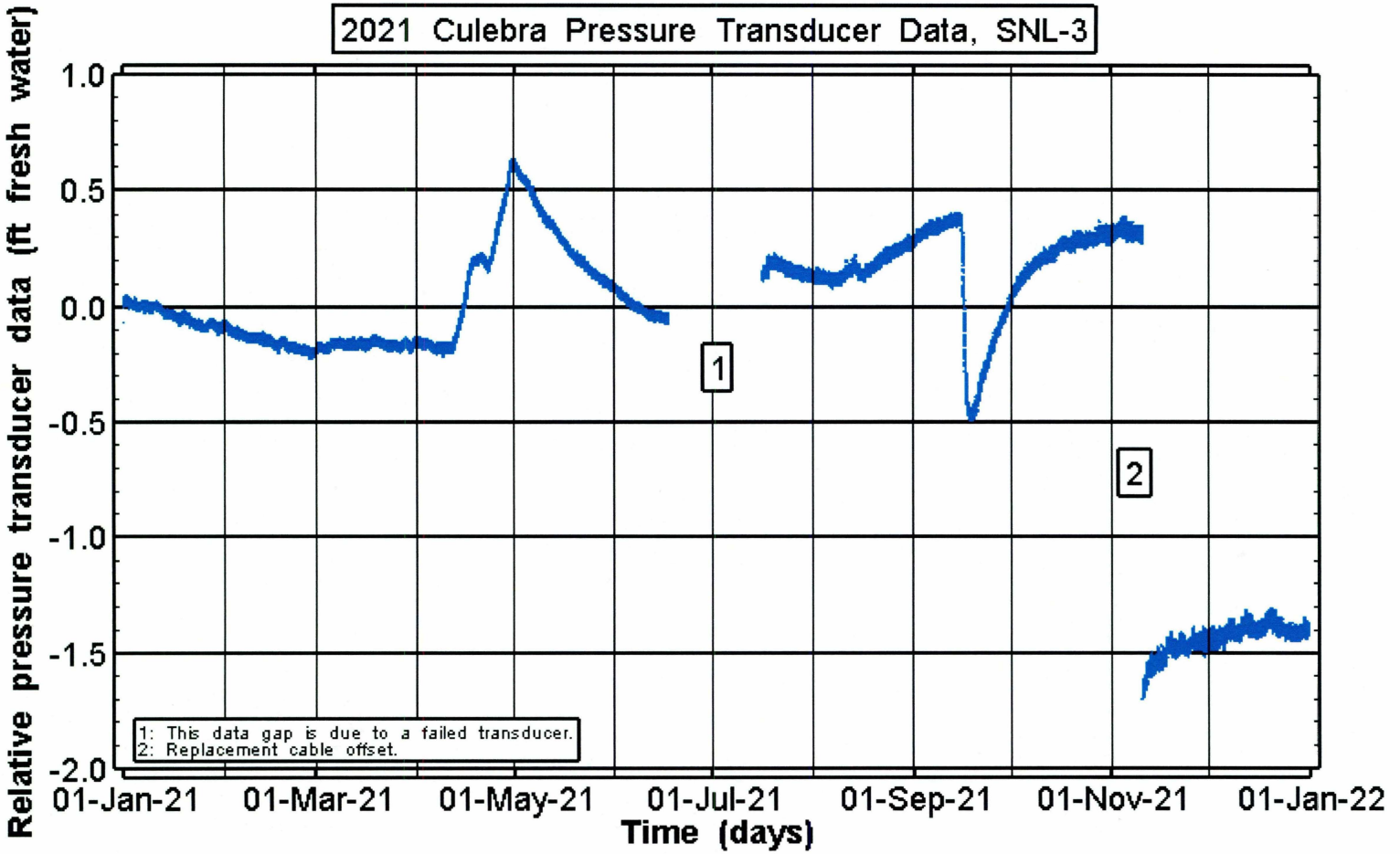

Figure 21. Well SNL-3 experienced a net change in hydraulic head of -1.39 ft fresh water in 2021. This well is affected by NWR and observation response from the WIPP-11R pumping test.

Exceptional Service in the National Interest
Information Only

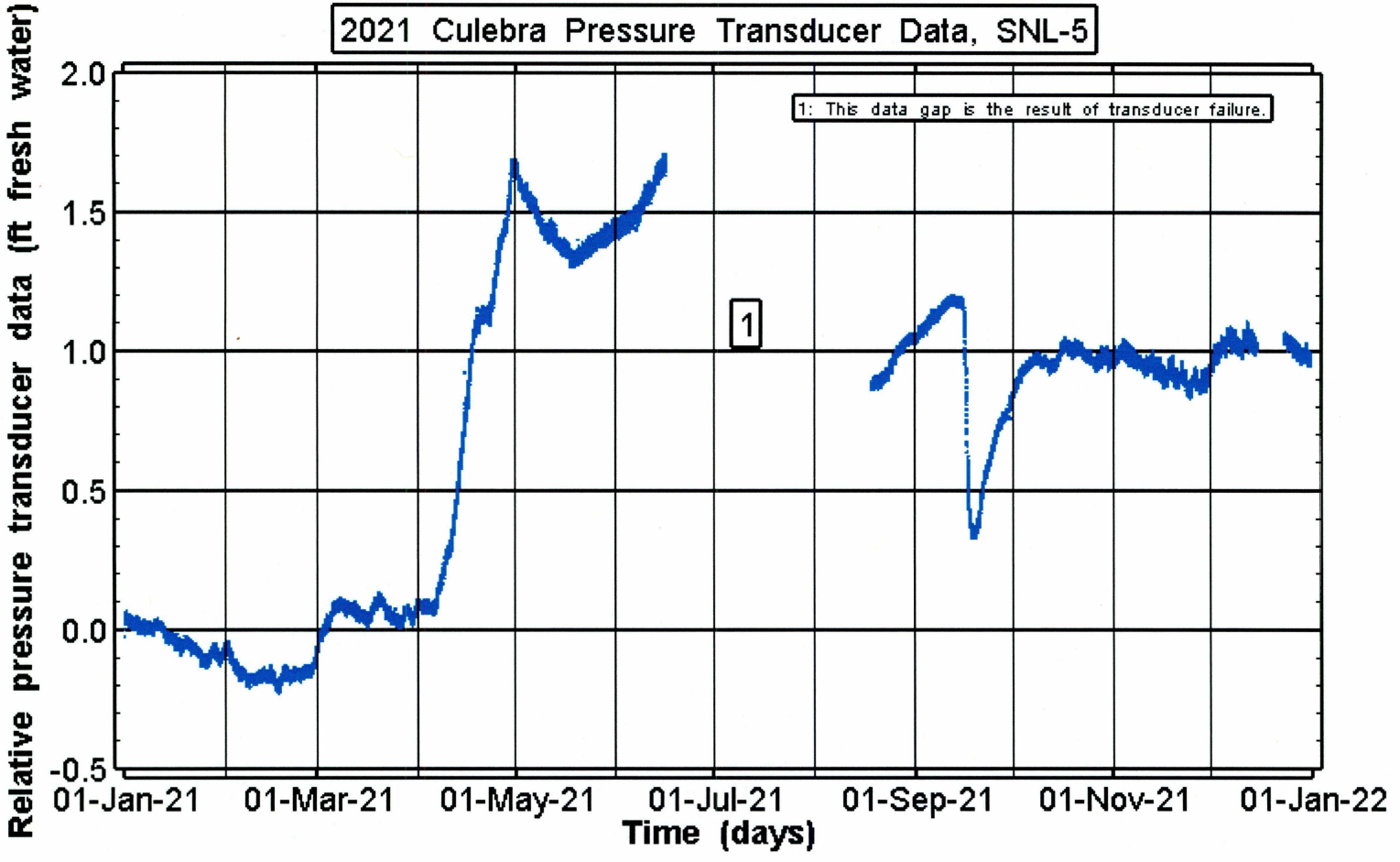

Figure 22. Well SNL-5 experienced a net change in hydraulic head of 0.98 ft fresh water in 2021. This well is affected by NWRA and observation response from the WIPP-11R pumping test.

Exceptional Service in the National Interest
Information Only

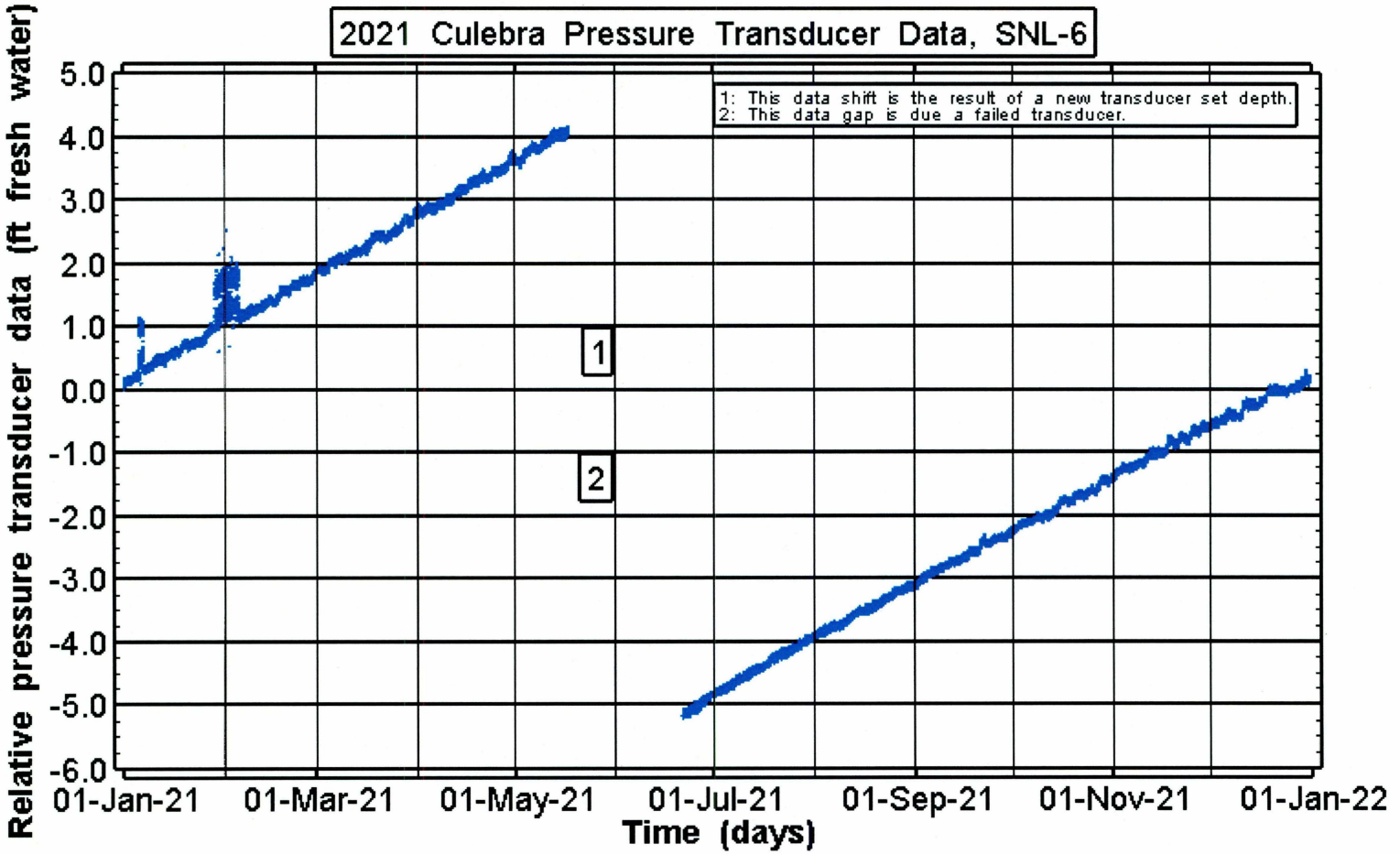

Figure 23. Well SNL-6 experienced a net change in hydraulic head of 9.38 ft fresh water in 2021. The well is in long-term recovery from well development.

Exceptional Service in the National Interest
Information Only

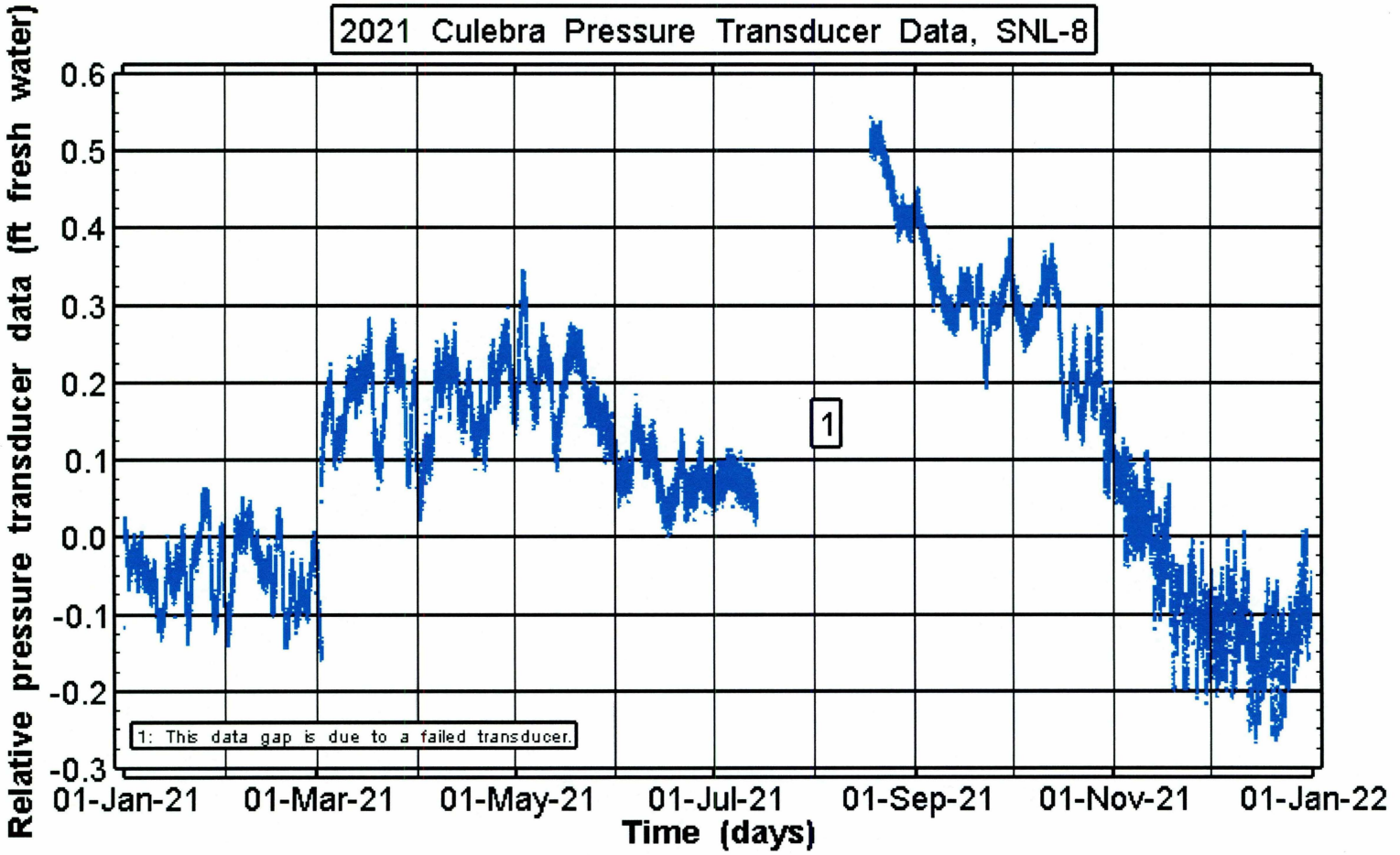

Figure 24. Well SNL-8 experienced a net change in hydraulic head of -0.07 ft fresh water in 2021.

Exceptional Service in the National Interest
Information Only

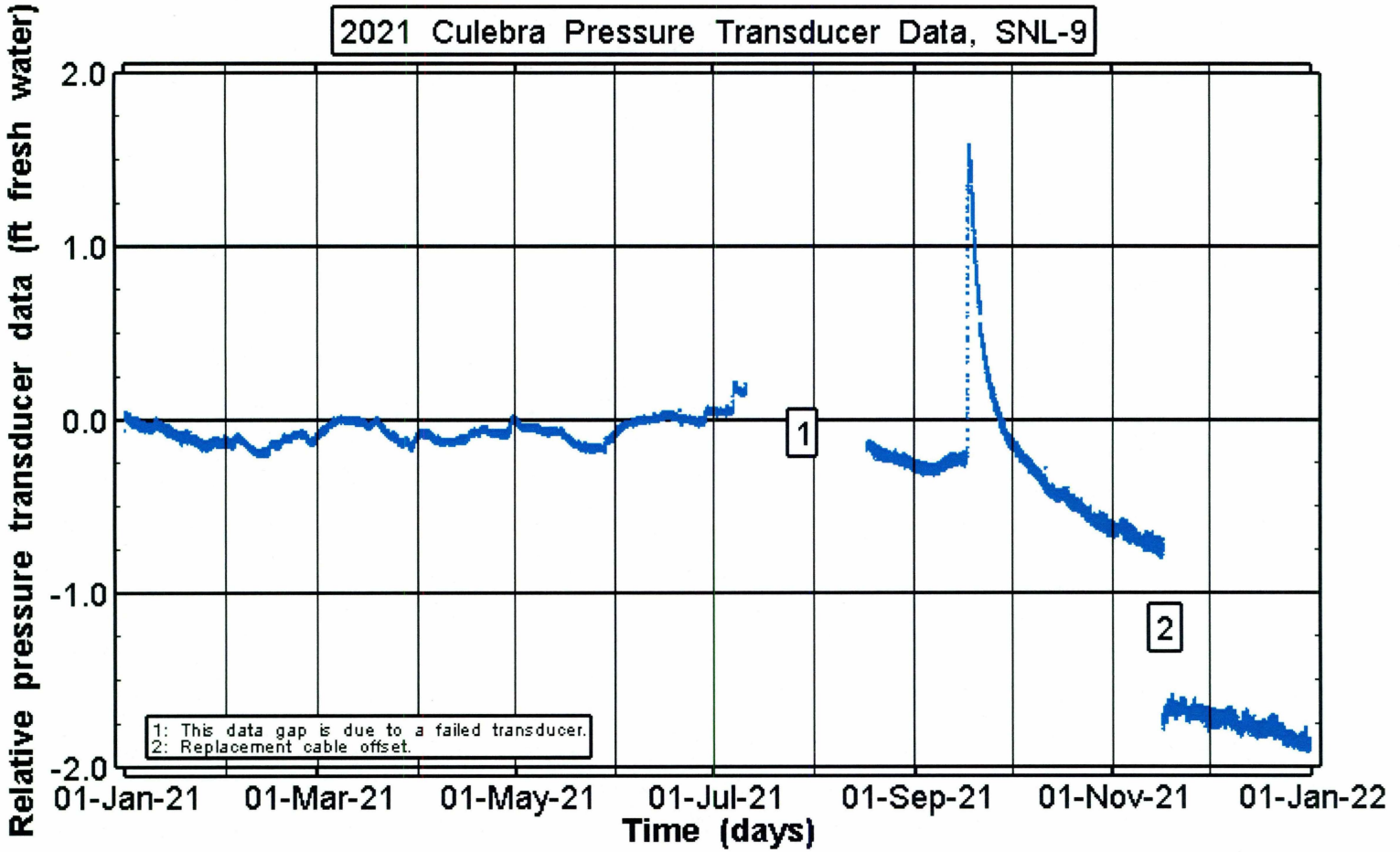

Figure 25. Well SNL-9 experienced a net change in hydraulic head of -1.88 ft fresh water in 2021. This well was affected by NWRA.

Exceptional Service in the National Interest
Information Only

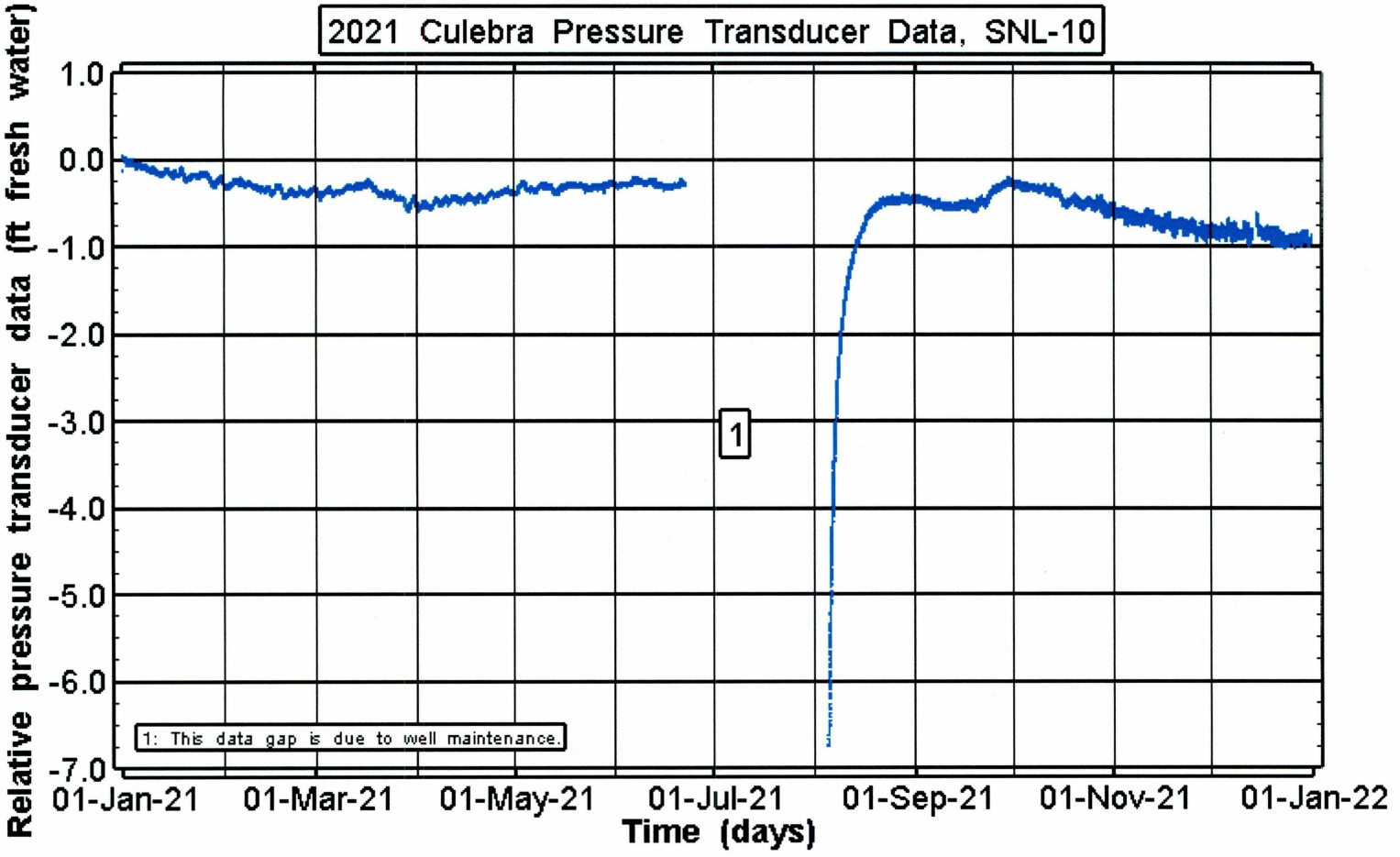

Figure 26. Well SNL-10 experienced a net change in hydraulic head of -0.92 ft fresh water in 2021. This well was affected by NWRA.

Exceptional Service in the National Interest
Information Only

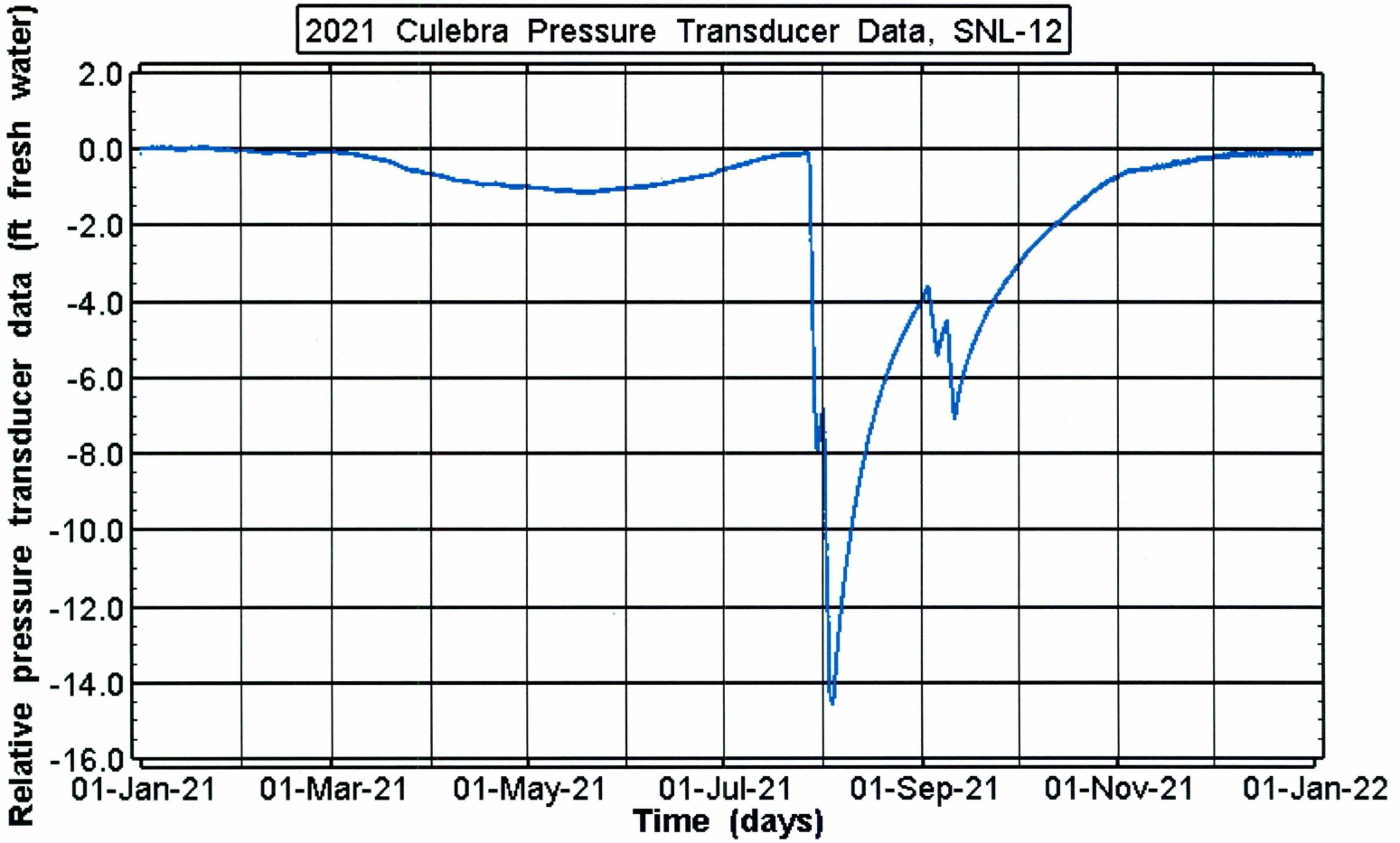

Figure 27. Well SNL-12 experienced a net change in hydraulic head of -0.13 ft fresh water in 2021. This well was affected by NWRA.

Exceptional Service in the National Interest
Information Only

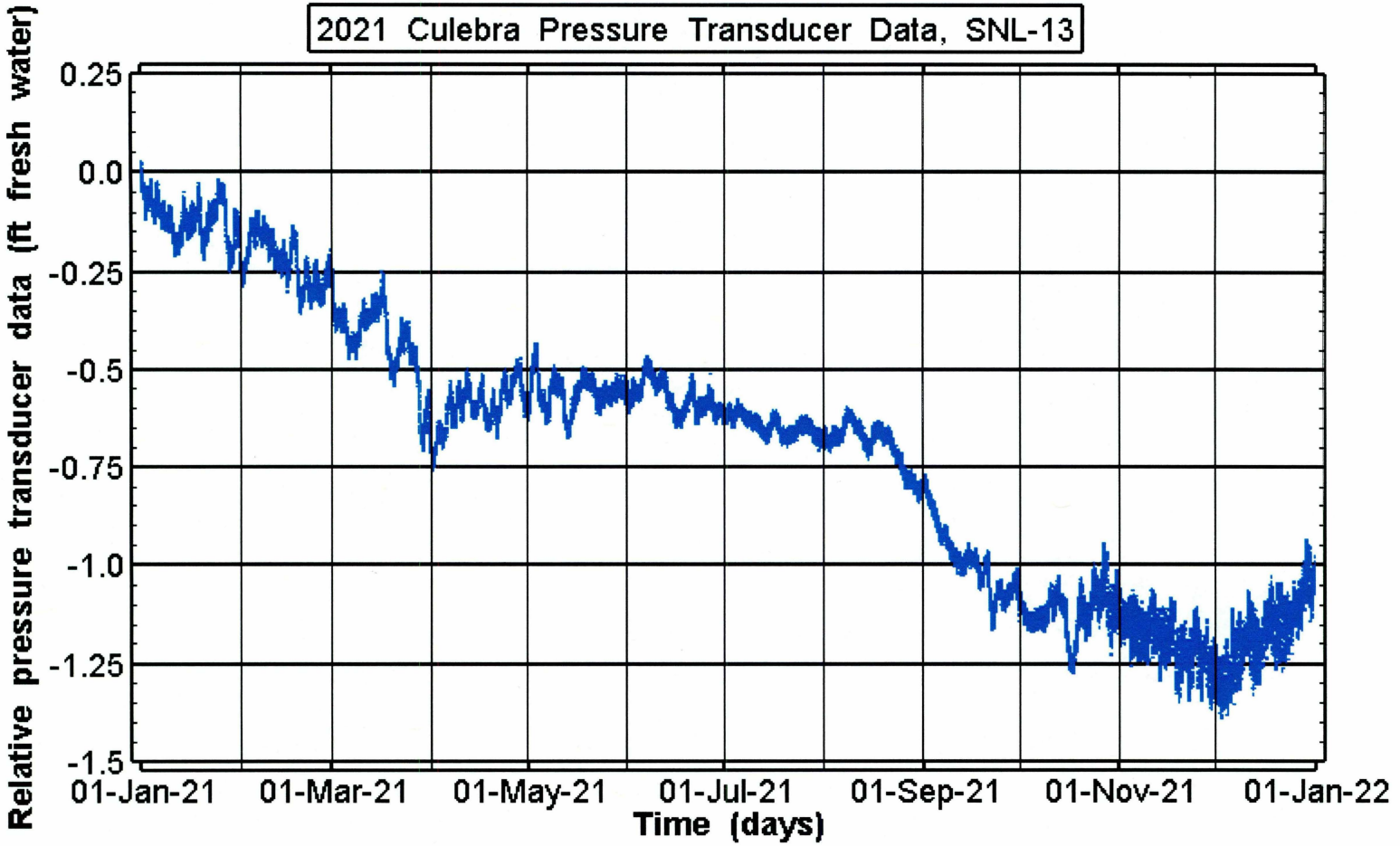

Figure 28. Well SNL-13 experienced a net change in hydraulic head of -1.02 ft fresh water in 2021.

Exceptional Service in the National Interest
Information Only

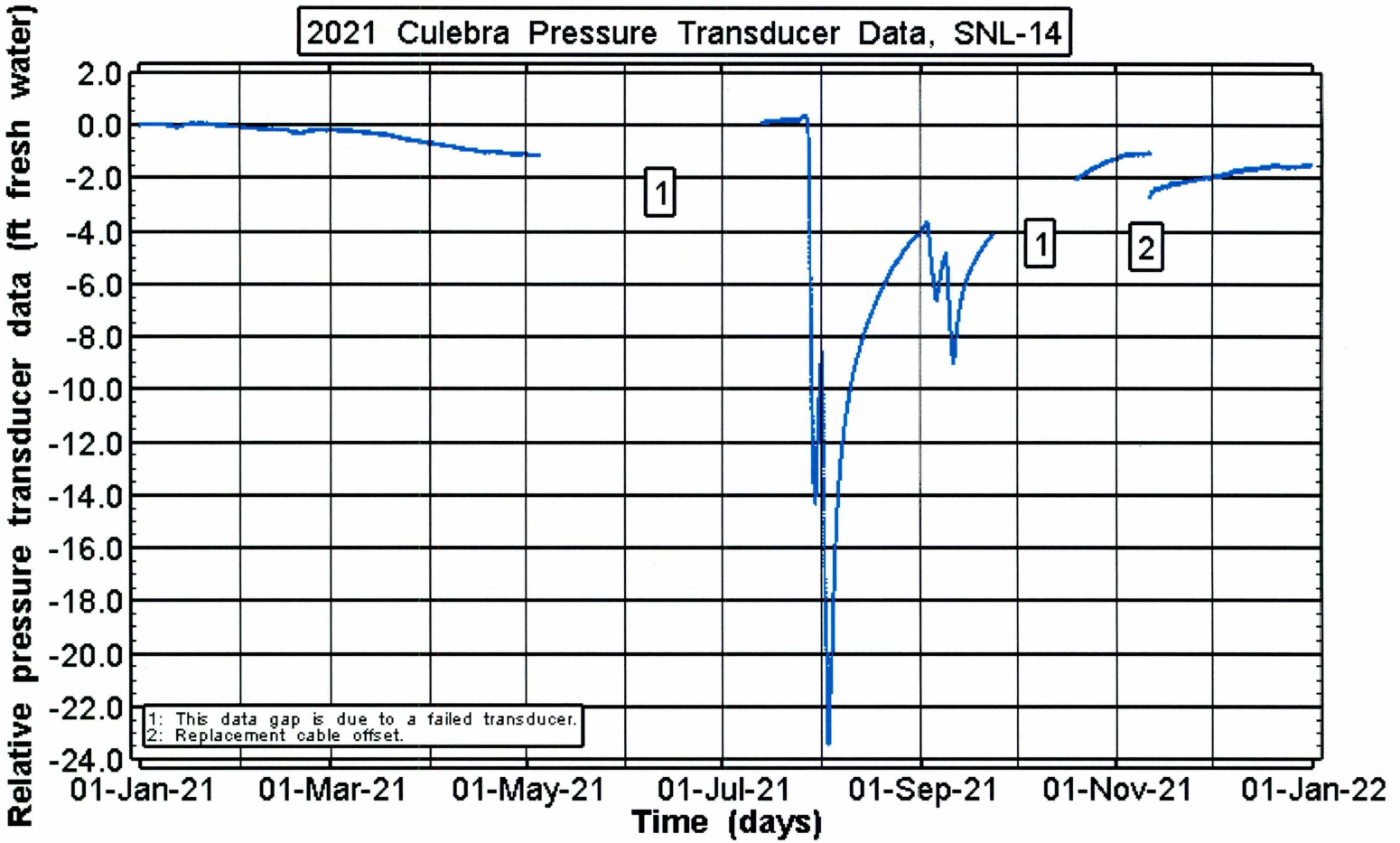

Figure 29. Well SNL-14 experienced a net change in hydraulic head of -1.49 ft fresh water in 2021. This well was affected by NWRA.

Exceptional Service in the National Interest
Information Only

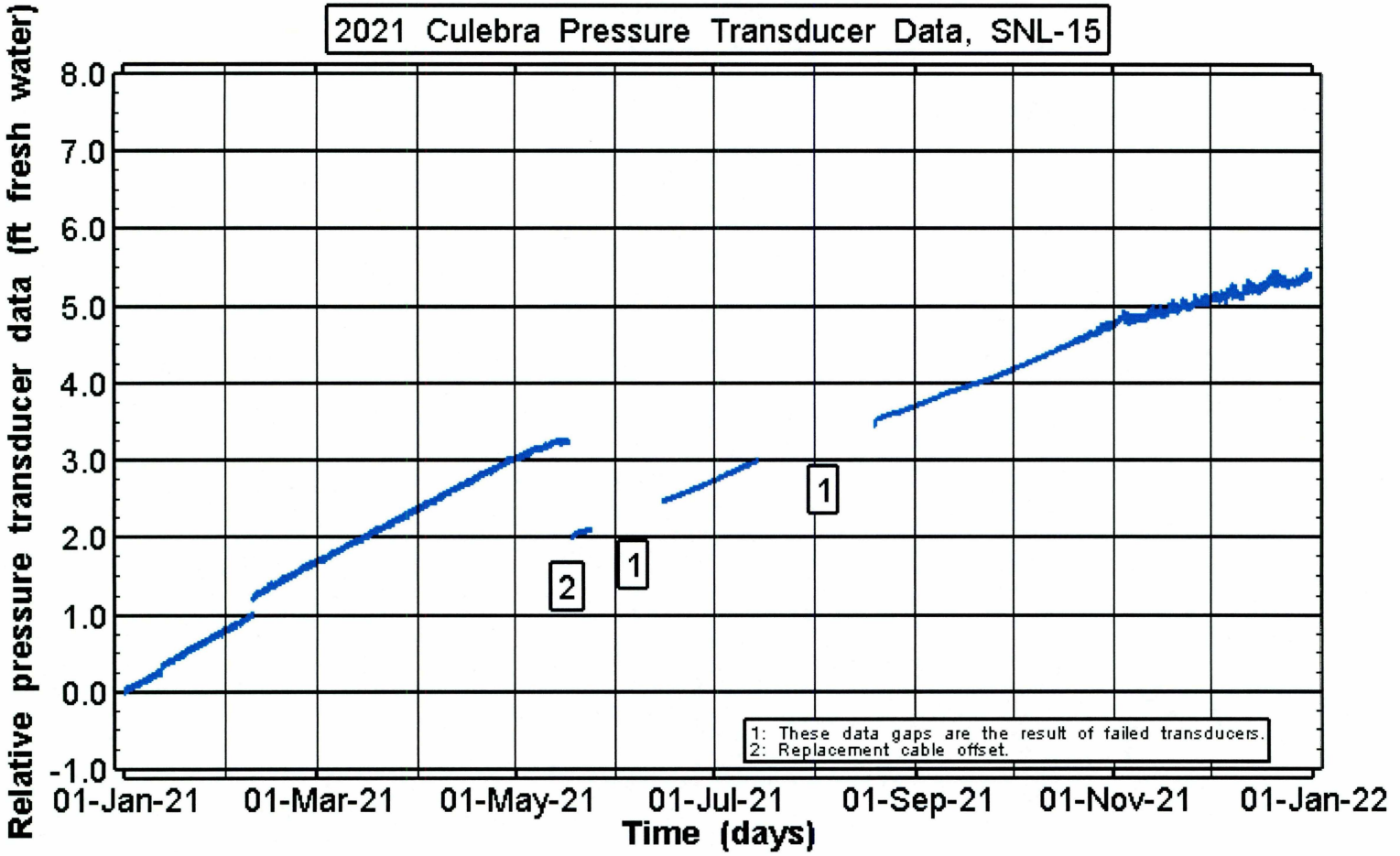

Figure 30. Well SNL-15 experienced a net change in hydraulic head of 5.38 ft fresh water in 2021. The well is in long-term recovery from well development.

Exceptional Service in the National Interest
Information Only

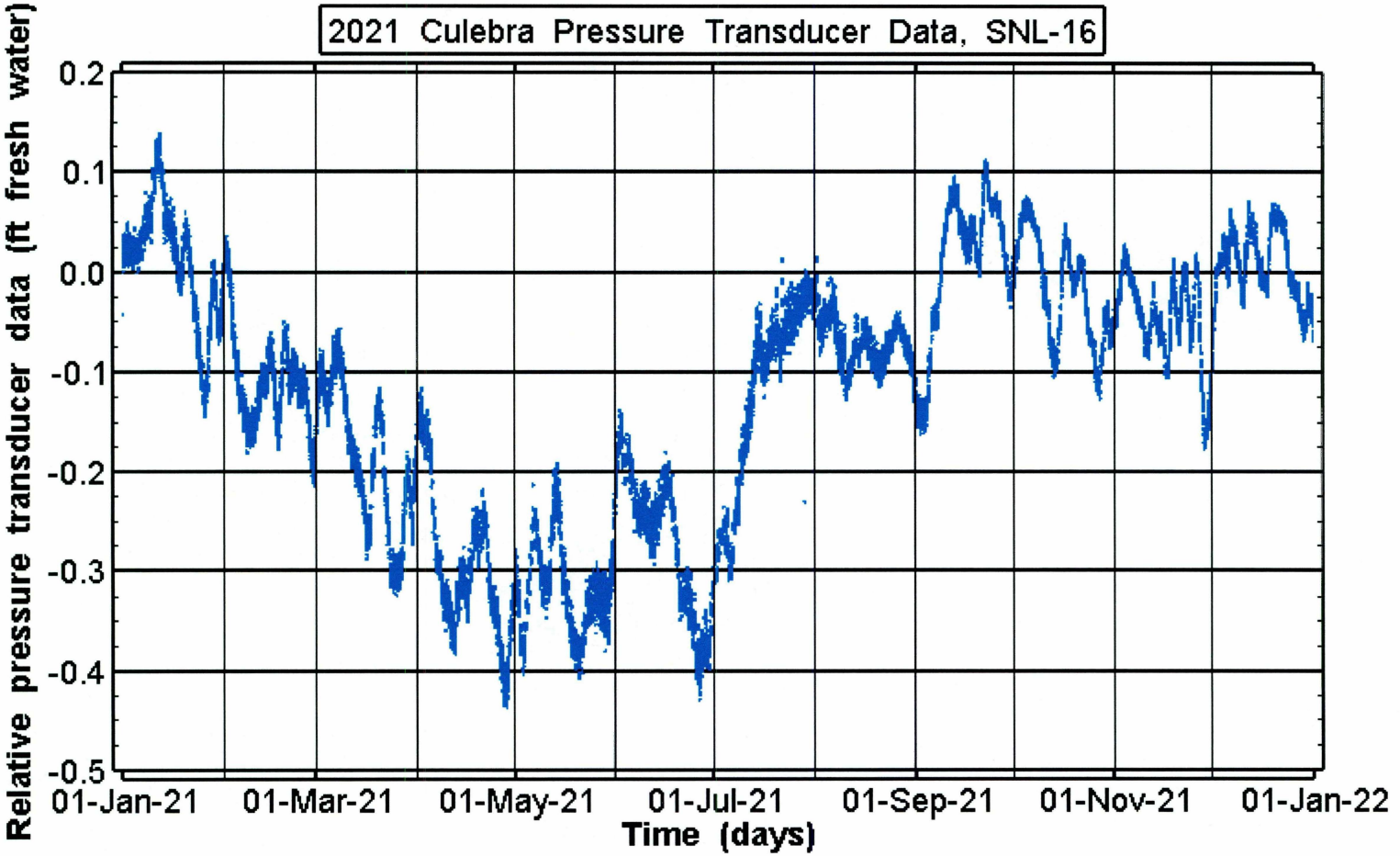

Figure 31. Well SNL-16 experienced a net change in hydraulic head of -0.06 ft fresh water in 2021.

Exceptional Service in the National Interest
Information Only

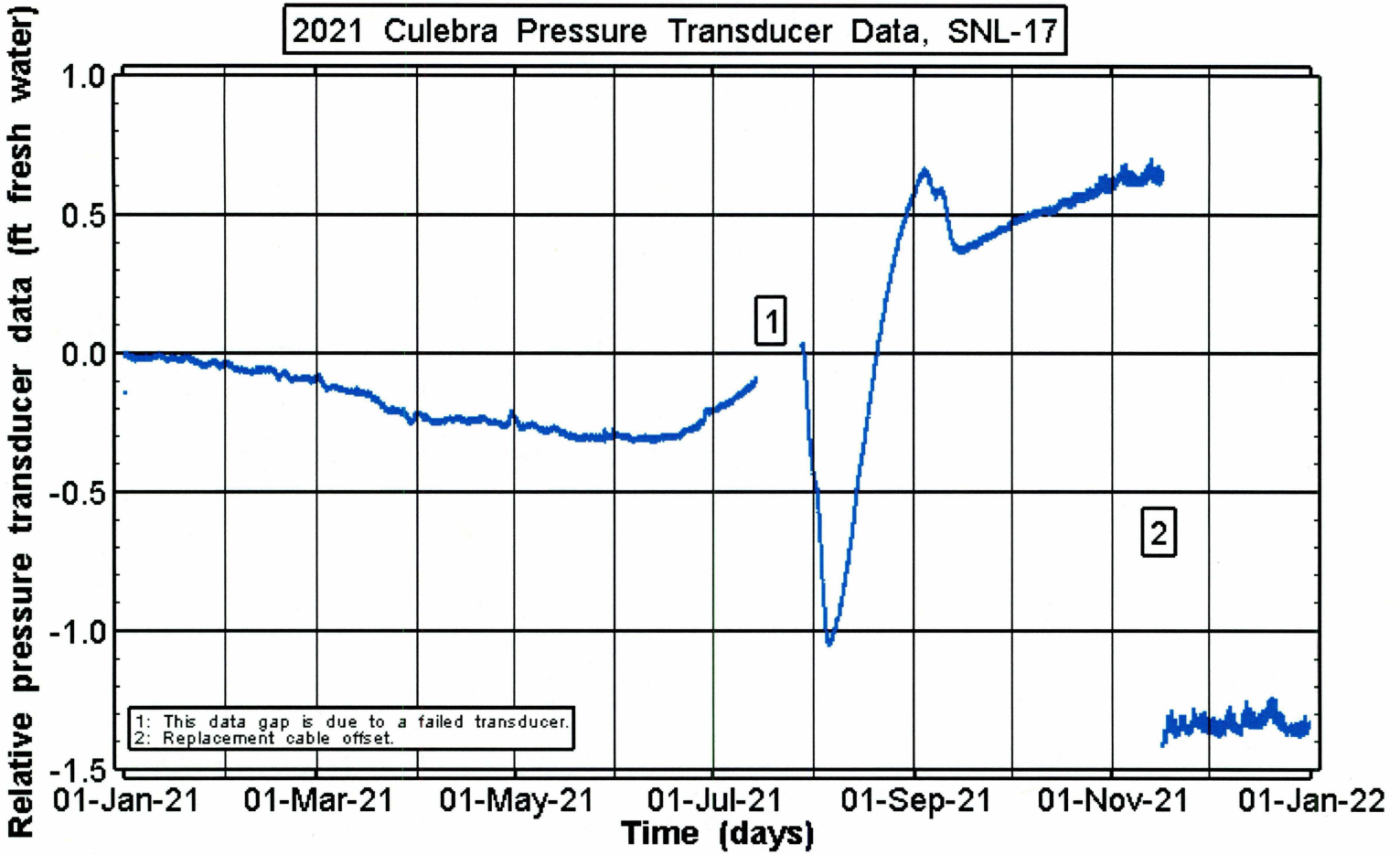

Figure 32. Well SNL-17 experienced a net change in hydraulic head of -1.33 ft fresh water in 2021. This well was affected by NWRA.

Exceptional Service in the National Interest
Information Only

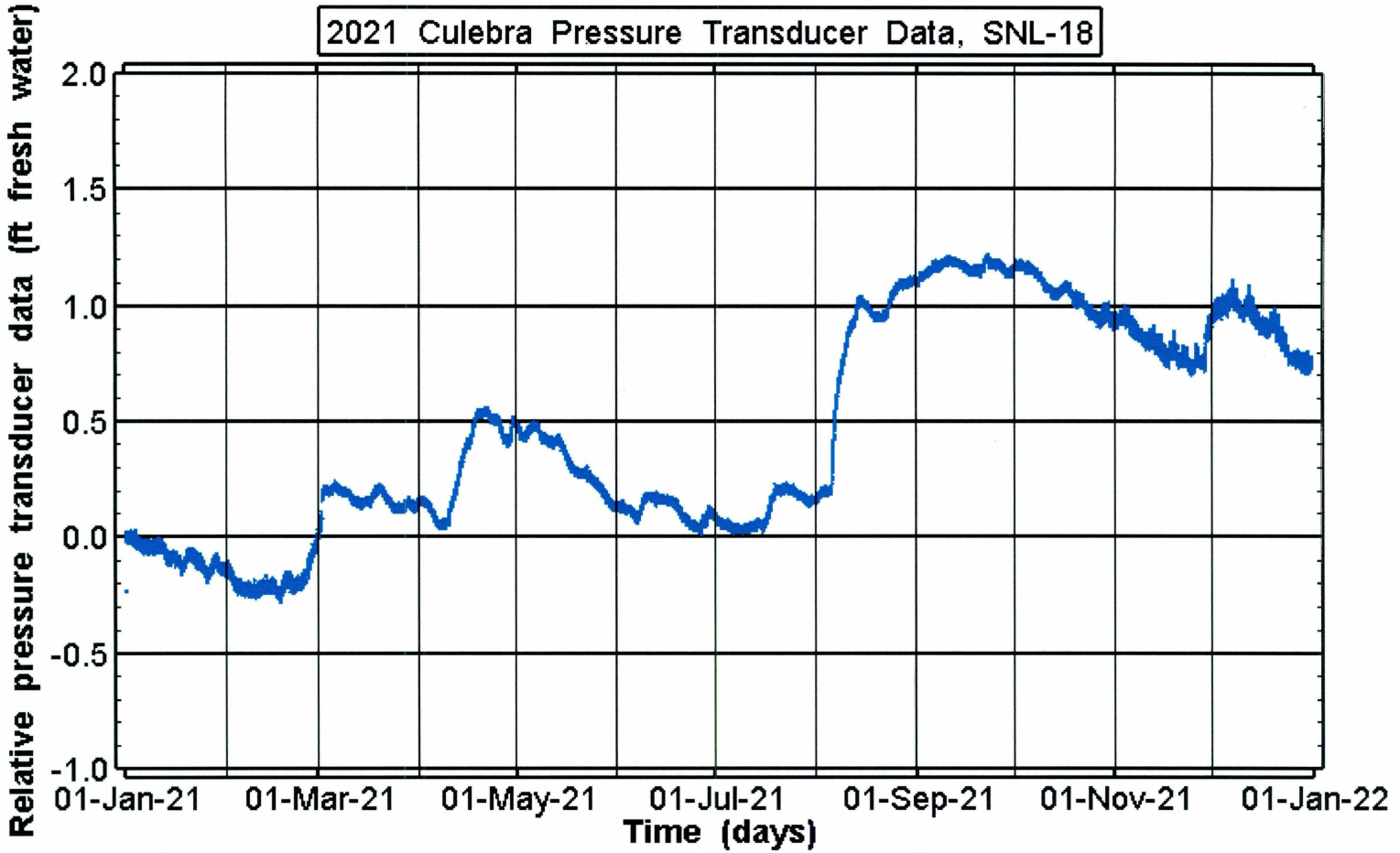

Figure 33. Well SNL-18 experienced a net change in hydraulic head of 0.77 ft fresh water in 2021.

Exceptional Service in the National Interest
Information Only

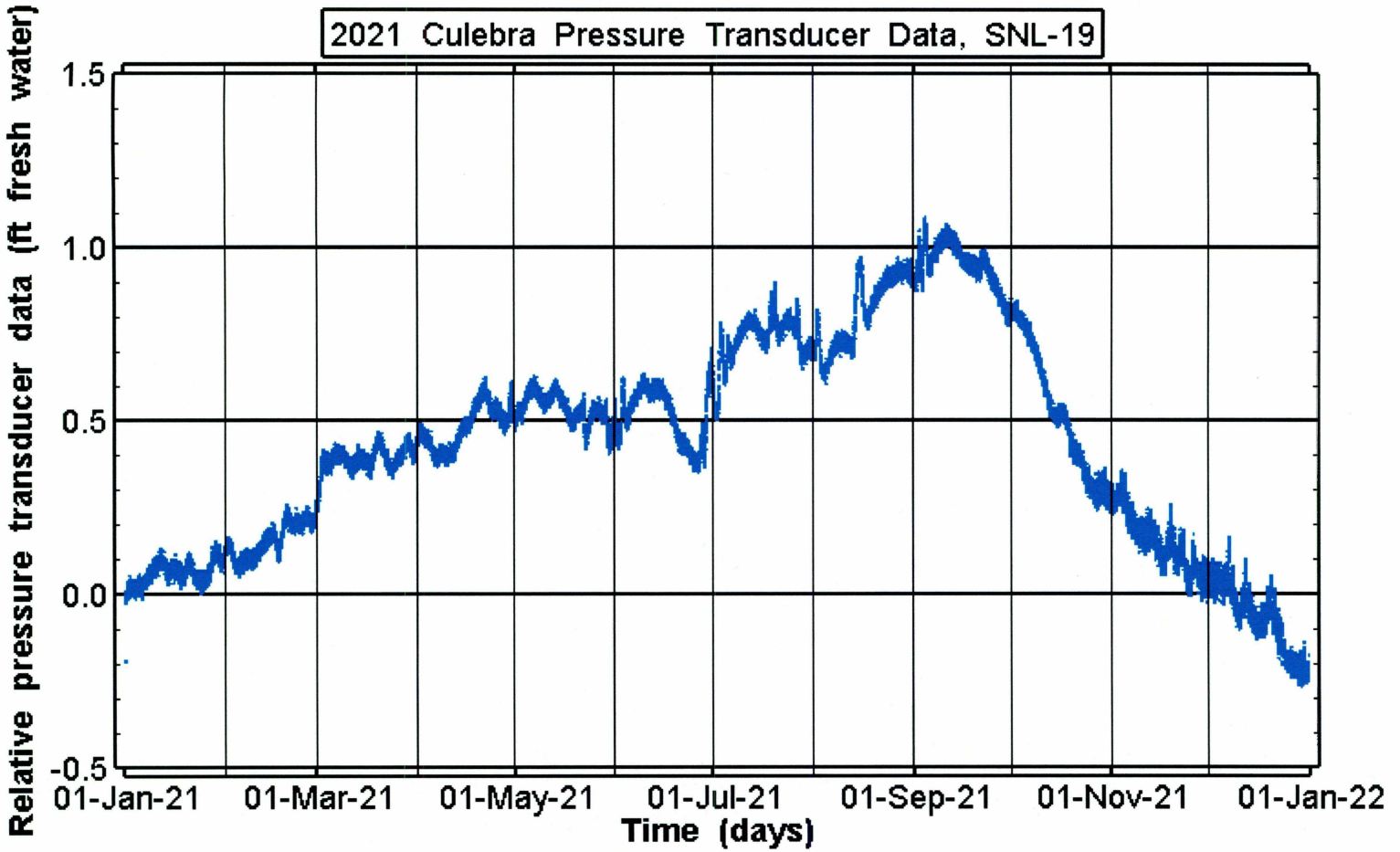

Figure 34. Well SNL-19 experienced a net change in hydraulic head of -0.22 ft fresh water in 2021.

Exceptional Service in the National Interest
Information Only

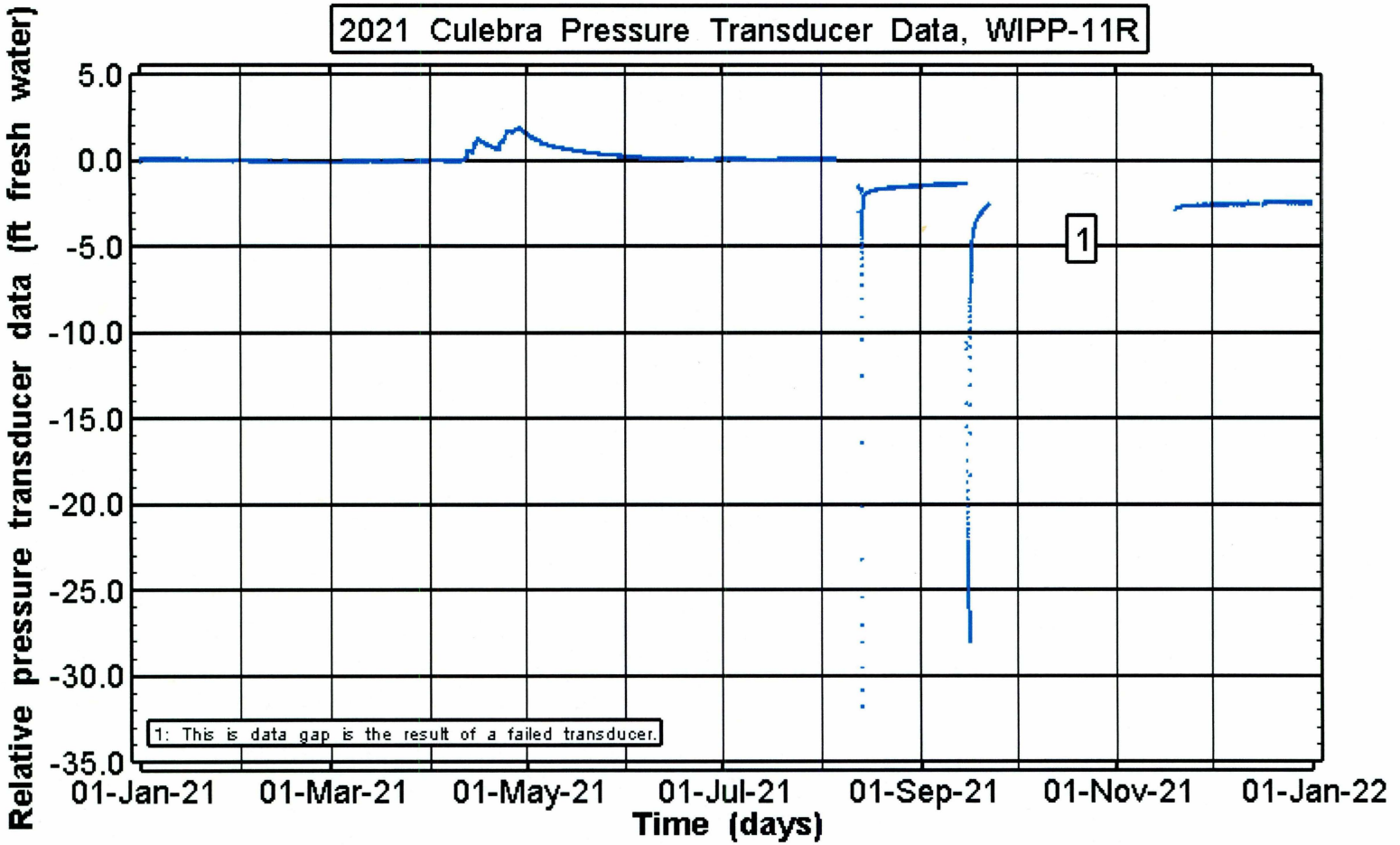

Figure 35. Well WIPP-11R experienced a net change in hydraulic head of -2.50 ft fresh water in 2021. A purge of WIPP-11R was conducted in mid-August of 2021. A constant-rate pumping test was conducted in WIPP-11R in mid-September of 2021.

Exceptional Service in the National Interest
Information Only

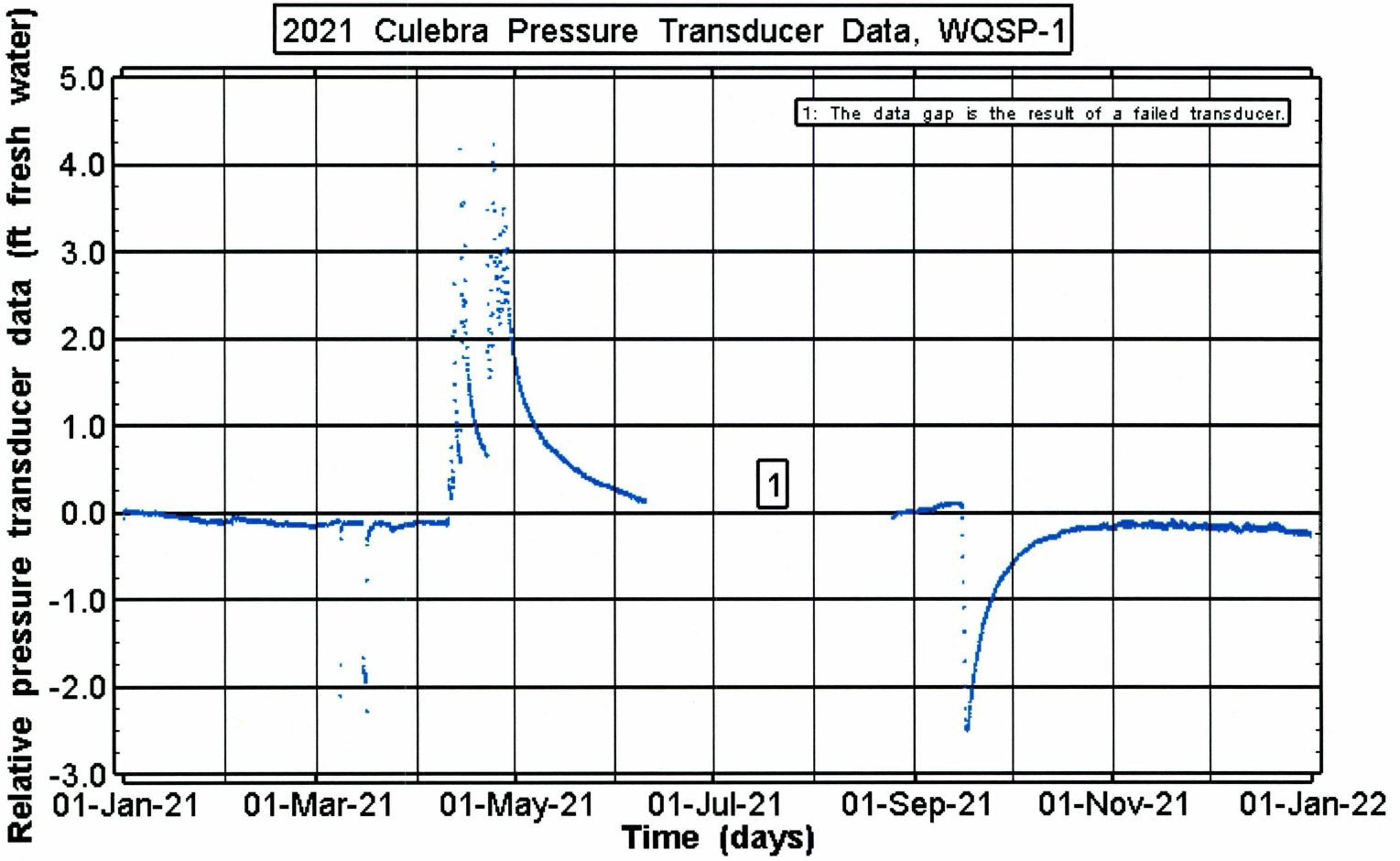

Figure 36. Well WQSP-1 experienced a net change in hydraulic head of -0.23 ft fresh water in 2021. Observation response to pumping in well WIPP-11R occurred in mid-September.

Exceptional Service in the National Interest
Information Only

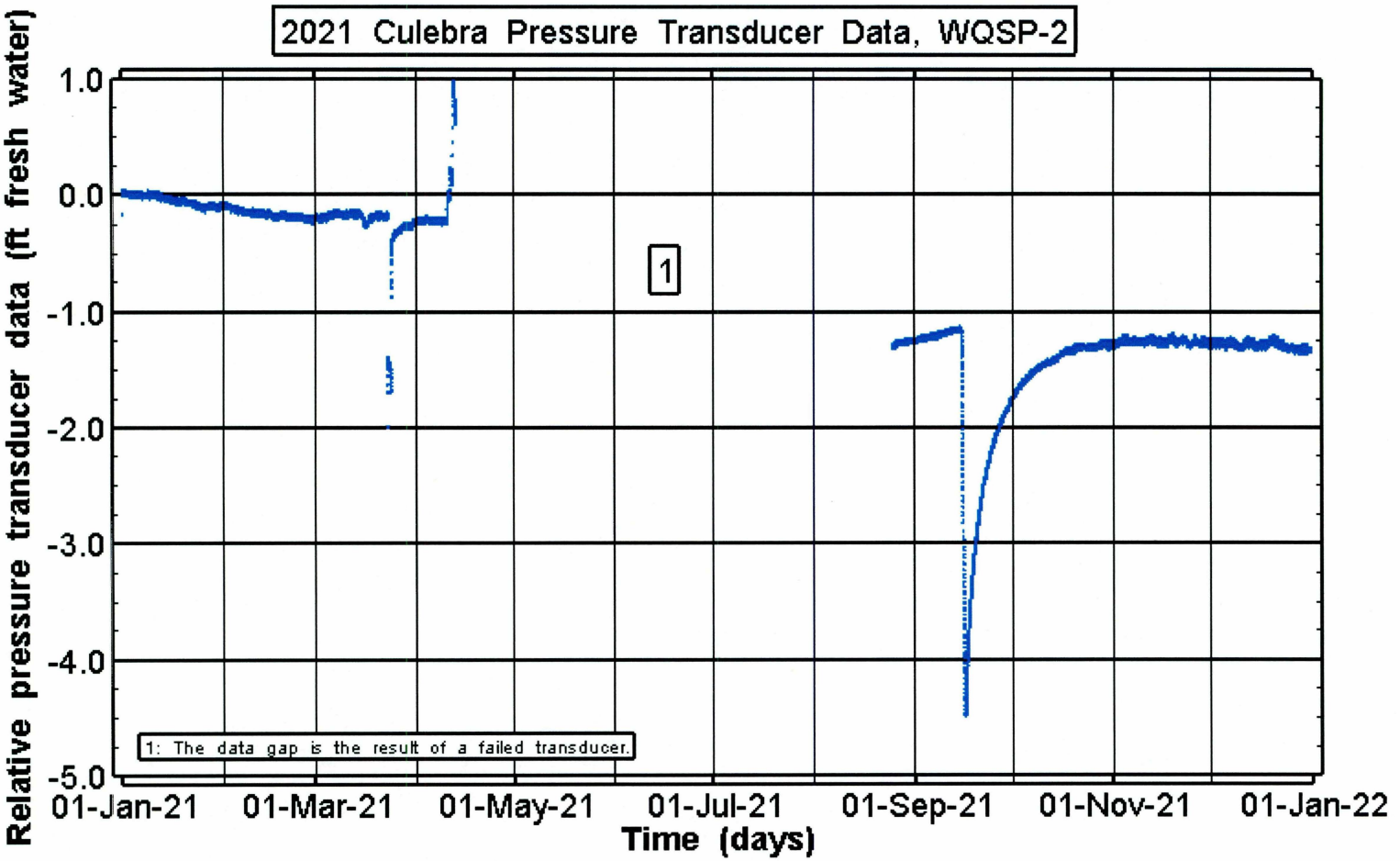

Figure 37. Well WQSP-2 experienced a net change in hydraulic head of -1.33 ft fresh water in 2021. Observation response to pumping in well WIPP-11R occurred in mid-September.

Exceptional Service in the National Interest
Information Only

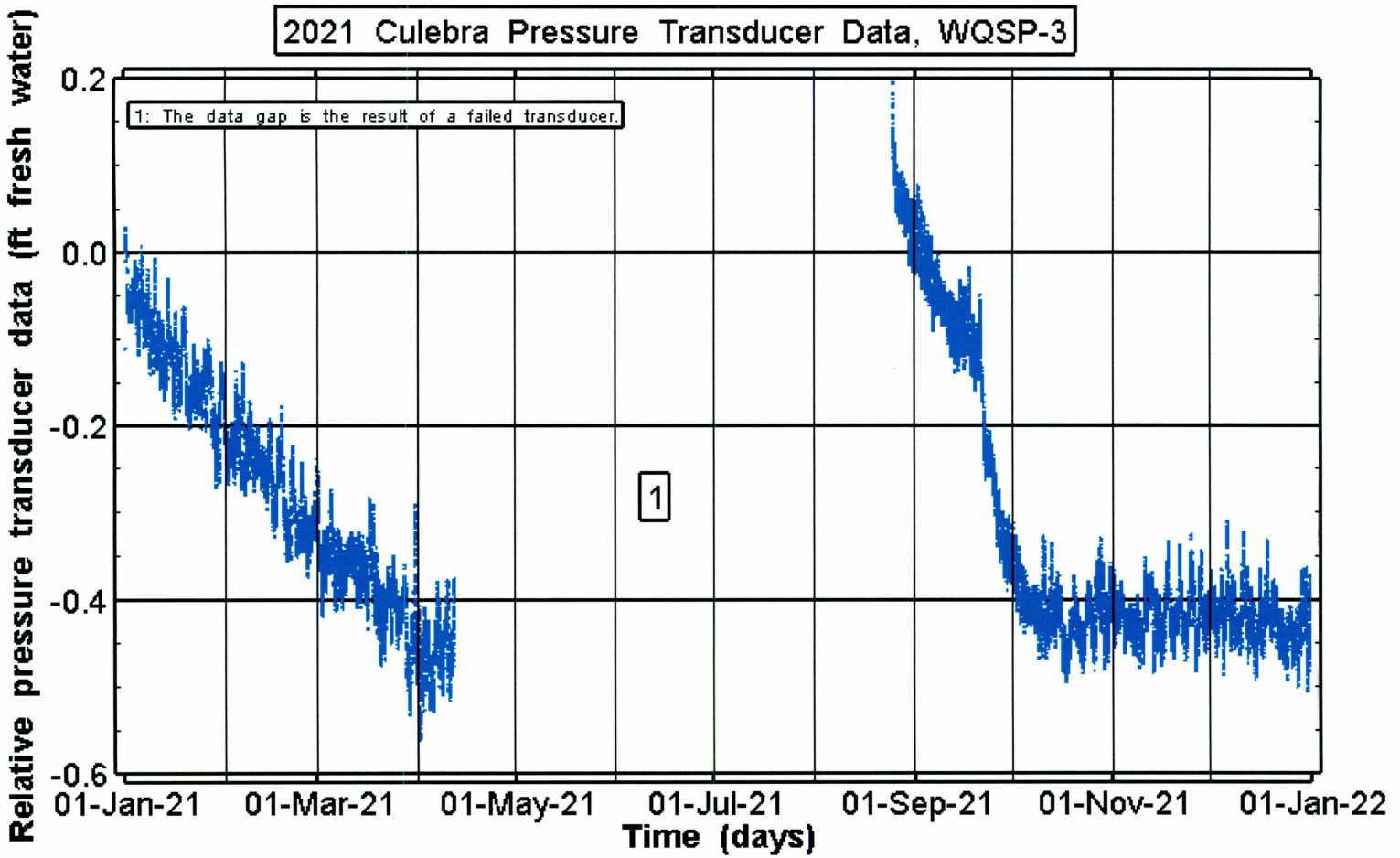

Figure 38. Well WQSP-3 experienced a net change in hydraulic head of -0.47 ft fresh water in 2021.

Exceptional Service in the National Interest
Information Only

Internal Distribution

MS-1395	D.O. Bowman	Org. 8882
MS-1395	A. Hayes	Org. 8882
MS-1395	P.B. Johnson	Org. 8882
MS-1395	O.W. Lofton	Org. 8882
MS-1395	P.E. Shoemaker	Org. 8880
MS-1395	C. Miller	Org. 8882

References

Bowman, D.O. 2021. SP 9-13 Data Thinning and Removal of Barometric and Earth Tide Effects from Water-Level Data, REV 1. Sandia National Laboratories. Carlsbad, NM ERMS 574997

Bowman, D.O. and Hayes, A. 2019. WIPP Milestone Report: 2018 Culebra Monitoring Network Groundwater Level Fluctuations. Sandia National Laboratories. Carlsbad, NM. ERMS 571630

Bowman, D.O. and Hayes, A. 2020. WIPP Milestone Report: 2019 Culebra Monitoring Network Groundwater Level Fluctuations. Sandia National Laboratories. Carlsbad, NM. ERMS 573306

Energy Minerals and Natural Resources Department 2022. https://www.emnrd.nm.gov/ocd/ocd-gis-and-maps/

New Mexico Office of the State Engineer 2022. https://gis.ose.state.nm.us/gisapps/ose_pod_locations/

nSIGHTS v. 2.50 covered under NSIGHTS Version 2.41a User Manual Version 2.41a., 2013. Sandia National Laboratories. Carlsbad, NM. ERMS 555653

U.S. Department of Energy (DOE) 2003. Strategic Plan for Groundwater monitoring at the WASTE Isolation Pilot Plant. Carlsbad Field Office. Carlsbad, New Mexico. DOE/WIPP-03-3230

U.S. Department of Energy (DOE) 2019. Title 40CFR Part 191 subparts B and C Compliance Recertification Application 2019 for the Waste Isolation Pilot Plant: Appendix HYDRO-2019 Hydrological Investigations. Carlsbad Field Office. Carlsbad, New Mexico. DOE/WIPP-19-3609

Wagner, S. and Hayes, A. 2019. Sandia National Laboratories Compliance Monitoring Parameter Assessment for 2018. Sandia National Laboratories. Carlsbad, New Mexico. ERMS 570837

WIPP:4.4.2.3.1:TD:QA-L:RECERT:5466636

Exceptional Service in the National Interest

Information Only