UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

REGION 6

1445 ROSS AVENUE, SUITE 1200

DALLAS, TEXAS 75202-2733

21 DEC 2017

CERTIFIED MAIL: 7007 3020 0000 1522 8625
Mr. Lanny Woods, Vice President
Jireh Resources, LLC
P.O. Box 701230
Tulsa, OK 74170

Re: Final Order
SDWA-06-2017-1110

Dear Mr. Woods:

The Environmental Protection Agency ("EPA"), Region 6, is issuing the enclosed final order pursuant to Section 1423(c) of the Safe Drinking Water Act ("the Act"), 42 U.S.C. § 300h-2(c). EPA issues this Final Order to address violations of the Act and its Underground Injection Control ("UIC") Program requirements at 40 C.F.R. Part 147, Subpart GGG at Wells No. 9, 4W and 18W in Osage County, Oklahoma. This Final Order, as proposed, was subject to public notice and comment, and an opportunity to request a hearing. A hearing was provided in Tulsa, Oklahoma, on October 11, 2017. At the hearing, you were provided an opportunity to be heard and present evidence, in accordance with Section 1423(c)(3)(A) of the Act, 42 U.S.C. § 300h-2(c)(3)(A). After considering the testimony and evidence, EPA has decided to proceed with the issuance of the Final Order as it was proposed, with some non-material revisions.

You may appeal this Final Order pursuant to Section 1423(c)(6) of the Act, 42 U.S.C. 300h-2(c)(6).

Please note that the Small Business Regulatory Enforcement and Fairness Act provides small businesses with the opportunity to submit comments on regulatory enforcement at the time of an EPA enforcement action. The attached link provides information on this right as well as information on compliance assistance.
http://nepis.epa.gov/Exe/ZyPDF.cgi/P100BYAV.PDF?Dockey=P100BYAV.PDF.

Questions regarding this Order should be addressed to Jerry Saunders at (214) 665-6470.

Sincerely,

Cheryl T. Seager
Director
Compliance Assurance and
Enforcement Division

Enclosures:

Final Order
Response to Comments
Interim Final Report
Map
Charts
Public Notice

Cc:

John L. Randolph Jr.
Pray Walker
100 West Fifth St.
Suite 900
Tulsa, Oklahoma

BIA, Minerals Branch

Osage Nation Environmental and Natural Resources Department

U.S. ENVIRONMENTAL PROTECTION AGENCY-REGION 6
ADMINISTRATIVE ORDER
In the Matter of Jireh Resources, LLC, Respondent
Docket No. SDWA-06-2017-1110

STATUTORY AUTHORITY

The following findings are made, and Administrative Order ("Order") issued, under the authority vested in the Administrator of the U.S. Environmental Protection Agency ("EPA") by Section 1423(c) of the Safe Drinking Water Act ("the Act"), 42 U.S.C. §§ 300h–2(c). The authority to issue this Order has been delegated by the Administrator to the Regional Administrator of EPA Region 6 who further delegated such authority to the Director of the Compliance Assurance and Enforcement Division. The EPA has primary enforcement responsibility for underground injection within the meaning of Section 1422(e) of the Act, 42 U.S.C. § 300h–1(e), to ensure that owners or operators of Class II injection wells within Osage County, Oklahoma, comply with the requirements of the Act.

FINDINGS

1. Jireh Resources, LLC ("Respondent") is a limited liability company doing business in the State of Oklahoma and, therefore, is a "person," within the meaning of Section 1401(12) of the Act, 42 U.S.C. § 300f(12).

2. At all times relevant to the violations alleged herein, Respondent operated injection wells which are Class II wells (collectively, "the wells") authorized to inject in the Mississippi Chat formation located in Osage County, Oklahoma, as described below:

Well No.	Inventory No.	Location				Hereinafter Referred to as
		Quarter	Section	Township	Range	
9	OS0922	Northwest	01	27 North	7 East	"Well No. 9"
4W	OS0924	Southwest	01	27 North	7 East	"Well No. 4W"
18W	OS6320	Southwest	01	27 North	7 East	"Well No. 18W"

3. Respondent is subject to underground injection control ("UIC") program requirements set forth at 40 C.F.R. Part 147, Subpart GGG, which are authorized under Section 1421 of the Act, 42 U.S.C. § 300h.

4. Regulations at 40 C.F.R. § 147.2903(a) require that any underground injection is prohibited except as authorized by rule ("ABR") or authorized by a permit issued under the UIC program. The construction or operation of any well required to have a permit is prohibited until the permit has been issued. The term "permit" is defined at 40 C.F.R. § 147.2902.

5. Regulations at 40 C.F.R. § 147.2916 require the owner or operator of a new Class II injection well, or any other Class II well required to have a permit in the Osage Mineral Reserve, to comply with the requirements of 40 C.F.R. §§ 147.2903, 147.2907, and 147.2918 through 147.2928.

6. Regulations at 40 C.F.R. § 147.2912(c), require that ABR injection wells or projects which have exhibited failure to confine injected fluids to the authorized injection zone or zones may be subject to restriction of injected volume and pressure or shut-down, until the failure has been identified and corrected.

7. Regulations at 40 CFR § 147.2920(d), require that permitted injection wells or projects which have exhibited failure to confine injected fluids to the authorized injection zone or zones may be subject to restriction of injected volume and pressure or shut-in, until the failure has been identified and corrected.

8. On April 12, 2012, EPA issued UIC permit number 06S1261P6320 ("permit") to Well No. 18W.

9. Wells No. 9 and No. 4W are regulated as ABR wells.

10. On August 16, 2016, EPA initially observed contamination in a tributary of North Bird Creek ("tributary") and North Bird Creek. Water located in the tributary at Latitude 36.8322 N and Longitude -96.4984 W, measured over 80,000 parts-per-million ("ppm") Total Dissolved Solids ("TDS"). Also residual oil was observed on the surface and along the banks of the creek. These observations are consistent with impacts associated with oil and gas operations. Since then, EPA has conducted at least 20 inspections and has observed continued contamination.

11. On October 5, 2016 and June 27 – 29, 2017, samples were collected for cation/anion analyses in order to help identify the source(s) of contamination. Grab samples were taken at certain locations including the following: several locations throughout the tributary and North Bird Creek; and Jireh Resources, LLC well 18W. Cation/anion analyses of the samples show a correlation between the tributary samples and produced fluids from this well. In addition, EPA noted elevated temperatures at the bottom of the water column of the tributary and North Bird Creek.

12. On May 25, 2017, in-stream fluid monitoring began in the tributary and North Bird Creek. In-stream monitors were placed in the tributary at ten different monitoring locations measuring the levels of TDS and temperature in the tributary and North Bird Creek.

13. Based on data from in-stream monitors, several stations continue to show elevated TDS and temperature levels. The patterns of TDS and temperature readings, the quick rebound of TDS and temperature levels to pre-event levels after precipitation events, and cyclical variations seen in the data indicate that the presence of the elevated TDS and elevated temperature are consistent with oil field related activities.

14. From June 9 – 20, 2017, a coordinated "static shut-in" of the six closest injection wells in the area occurred which included Respondent's 9, 4W and 18W Wells. The following are the observations which resulted from the shut-in:

(a) Due to the measured static fluids in injection wells being 500 – 750 feet below ground surface, the static fluids cannot migrate from depth to the surface without additional pressure buildup, which was provided by the injection operations.

(b) A correlation was seen between injection operations and in-stream water quality TDS before and after the coordinated shut-in event.

(c) Amplitude (degree of variability) of short term concentration fluctuations at some stations diminished during the shut-in period.

15. From EPA investigations including those discussed in paragraphs 10 through 14 of this Order, EPA has made the determination that injected fluids from Respondent's wells are no longer confined to the authorized injection zone.

16. Therefore, Respondent violated regulations at 40 C.F.R. §§ 147.2912(c) and 147.2920(d) by exhibiting failure to confine injected fluids to the authorized injection zone.

17. On August 4, 2017, EPA Region 6 issued a proposed order to Respondent and provided Respondent an opportunity to request a hearing on the order pursuant to Section 1423(c) of the Act, 42 U.S.C. § 300h-2(c).

18. On August 8, 2017, EPA Region 6 provided public notice of its proposal to issue an order for compliance in this matter in accordance with Section 1423(c) of the Act, 42 U.S.C. § 300h-2(c).

19. On October 11, 2017, EPA Region 6 administered a public hearing on this matter in Tulsa, Oklahoma, which provided Respondents and persons who had commented on the proposed order a reasonable opportunity to be heard and to present evidence in accordance with Section 1423(c) of the Act, 42 U.S.C. § 300h-2(c).

20. EPA summarized its determinations in its Interim Final Bird Creek Investigation and Injection Well Response Action Plan dated August 4, 2017, and its Overview and Response to Comments dated December 21, 2017.

SECTION 1423(c) COMPLIANCE ORDER

21. Based on the foregoing findings, and pursuant to the authority of Section 1423(c) of the Act, 42 U.S.C. § 300h-2(c), EPA Region 6 hereby orders Respondent to:

Immediately shut-in and/or shut-down and disconnect injection pipelines from the wellhead for Well Nos. 9, 4W and 18W until the Respondent can prove that the injected fluids are being confined to the authorized injection zone.

GENERAL PROVISIONS

22. This Order does not constitute a waiver, suspension, or modification of the requirements of 40 C.F.R. Parts 144, 146, and 147, Subpart III, which remain in full force and effect.

23. Issuance of this Order is not an election by EPA to forego any civil or criminal action otherwise authorized under the Act.

24. Violation of the terms of this Order after its effective date or date of final judgment as described in Section 1423(c)(6) of the Act, 42 U.S.C. § 300h-2(c)(6), may subject Respondent to further enforcement action, including a civil action for enforcement of this Order under Section 1423(b) of the Act, 42 U.S.C. § 300h-2(b), and civil and criminal penalties for violations of the compliance terms of this Order under Section 1423(b)(1) and (2) of the Act, 42 U.S.C. § 300h-2(b)(1) and (2).

EFFECTIVE DATE

25. This Order becomes effective thirty (30) days after issuance unless an appeal is taken pursuant to Section 1423(c)(6) of the Act, 42 U.S.C. § 300h–2(c)(6).

12-21-17
Date

Cheryl T. Seager
Director
Compliance Assurance and
Enforcement Division

CERTIFICATE OF SERVICE

I certify that the foregoing Administrative Order was sent to the following persons, in the manner specified, on the date below:

Original hand-delivered:

Regional Hearing Clerk (6RC-D)
U.S. EPA, Region 6
1445 Ross Avenue, Suite 1200
Dallas, TX 75202-2733

Copy by certified mail
return receipt requested:

Mr. Lanny Woods, Vice President
Jireh Resources, LLC
PO Box 701230
Tulsa, OK 74170

First class mail:

John L. Randolph Jr.
Pray Walker
100 West Fifth St.
Suite 900
Tulsa, Oklahoma 74103

Copy by email:

Jann Hayman, Director
Osage Nation Environmental and Natural Resources
jannhayman@osagenation-nsn.gov

Robin Phillips, Superintendent
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kristen.kokinos@sol.doi.gov

Dated: 12/21/2017

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 6
1445 ROSS AVENUE
DALLAS, TEXAS 75202

IN THE MATTER OF:	)	
	)	Docket No.:
Jireh Resources, LLC	)	SDWA-06-2017-1110
Warren American Oil Company, LLC	)	SDWA-06-2017-1111
Novy Oil and Gas, Inc.	)	SDWA-06-2017-1112
	)	
	)	**EPA'S RESPONSES**
	)	**TO PUBLIC COMMENTS**
	)	

I. SUMMARY

On August 4, 2017, the U.S. Environmental Protection Agency, Region 6 ("EPA") proposed issuance of administrative orders for compliance ("Proposed Orders") pursuant to Section 1423(c) of the Safe Drinking Water Act ("SDWA"), 42 U.S.C. § 300h-2(c) to Novy Oil and Gas, Inc., Warren American Oil Company, LLC, and Jireh Resources, LLC ("Respondents") for violating the SDWA's Underground Injection Control ("UIC") program requirements at 40 C.F.R. Part 147, Subpart GGG. The public comment period on the Proposed Orders began August 8, 2017 and closed on September 6, 2017. EPA announced the public comment period through a public notice published on the EPA Region 6 website.

EPA's public notice of the Proposed Orders also provided the Respondent and public with notice of the availability of a hearing on the Proposed Orders in accordance with Section 1423(c) of the SDWA.

During the comment period, EPA received eight comment letters including three from the three Respondents which included a request for a hearing.

On September 21, 2017, the EPA Region 6 Regional Judicial Officer provided the three Respondents with notice that a hearing ("Hearing") on the Proposed Orders would be held on October 11, 2017, at 9:15 AM in Tulsa, Oklahoma.

EPA Region 6 Presiding Officer, Thomas Rucki, administered the Hearing. During the Hearing, the following commenters provided comment and entered testimony:

1. Robert Winter, attorney for Jireh Resources, LLC
2. David House for Jireh Resources, LLC
3. Lanny Woods for Jireh Resources, LLC

4. Steve McNamara, attorney for Warren American Oil Company, LLC
5. Doug Norton for Warren American Oil Company, LLC
6. John Tucker, attorney for Novy Oil & Gas, Inc.

II. EPA'S RESPONSE TO COMMENTS

EPA has addressed the written comments on the Proposed Orders received by the EPA Region 6 Regional Hearing Clerk in response to the public notices as well as the comments provided at the October 11, 2017 Hearing. See attached Overview and Response to Comments.

III. REVISIONS TO PROPOSED ORDERS

Based upon the comments and other considerations, the following revisions to the Proposed Orders were made and incorporated into the Final Orders.

The three Final Orders are fundamentally the same as the three Proposed Orders other than the following paragraphs that were added: 1) reference to the issuance of the Proposed Orders, 2) reference to public notices of the Proposed Orders, 3) the October 11, 2017 Hearing and 4) references to the Interim Final Bird Creek Investigation and Injection Well Response Action Plan dated August 4, 2017 and the Overview and Response to Comments dated December 21, 2017.

These revisions reflected in the Final Orders constitute a logical outgrowth of the issues and solutions presented in the Proposed Orders. None of the revisions were material or outside the scope of the Proposed Orders. The revisions reflected in the Final Orders do not rise to the level of significance to potentially prompt a new notice and comment period. The revisions were made in direct response to written and oral comments received by EPA in response to the public notice and at the October 11, 2017 Hearing and based upon other available information, and concern matters that the parties and interested persons knew to be at issue.

Cheryl T. Seager
Director
Compliance Assurance and
Enforcement Division

12-21-17
Date

OVERVIEW AND RESPONSE TO COMMENTS

SDWA-06-2017-1110

SDWA-06-2017-1111

SDWA-06-2017-1112

U.S. Environmental Protection Agency, Region 6

December 21, 2017

Overview

On August 4, 2017, the U.S. Environmental Protection Agency (EPA) issued three proposed Administrative Orders to the operators of seven "Class II" deep underground injection wells regulated by EPA under its direct implementation authority for the Underground Injection Control (UIC) program in Osage County, Oklahoma.[1] See Section 1423(c) of the Safe Drinking Water Act, ("the Act"), 42 U.S.C. §§ 300h-2(c); 40 CFR §147.2900. These seven wells represent a cluster of injection wells that are closest to an area of brine contamination in a surface water stream (primarily a tributary of North Bird Creek) in Osage County.[2] The seven wells inject brine wastewater from oil production operations into the Mississippi Lime geologic formation about 2300 feet belowground.[3] The ongoing contamination found in the surface water stream consists of brine-like fluids with elevated levels of "total dissolved solids" (TDS) with component concentrations that match the brine in the Mississippi Lime Formation – *i.e.*, the brine contamination in the surface water stream is identical to brine from the Mississippi Lime Formation. During a time of temporary shut-in of the seven wells (*i.e.*, temporary cessation of injection), the brine contamination in the surface water stream decreased in some of the surface water monitoring locations at the site.

The three proposed Administrative Orders would order for permanent shut-in (*i.e.*, cessation of use) of these seven deep underground injection wells. During the public comment period and at the public hearing in Tulsa, Oklahoma on October 11, 2017, EPA received comments from multiple commenters, including both those supporting and opposing the proposed action.

Issuance of Orders here is based on a 15-month EPA study that included review and analysis of the:

- Area of contamination and the physical site area, including the fractured nature of the Mississippi Lime geologic formation that can convey underground pressure over long horizontal distances, and the likely

[1] Class II injection wells inject fluids associated with oil and natural gas production into deep geologic formations in a manner which should be isolated from underground sources of drinking water. Class II fluids are primarily brine which is brought to the surface as a wastewater during oil and gas production. The brine is separated from the hydrocarbons and then reinjected into a deep geologic formation for disposal.

[2] The seven Class II UIC deep underground injection wells are Grayhorse/Novy Well B-15 (OS5258); Jireh Wells 18W (OS6320), 9 (OS0922) and 4W (OS0924); and Warren America Wells B-8 (OS0921), 9B (OS5133) and B7-D (OS0920). These wells range in distance from .5 mile to 1.5 miles to the area[s] of contamination in the surface stream. (See map.)

[3] For simplicity, the references here are to the Mississippi Lime geologic formation. The injection/production formation of primary focus in this case is commonly referred to as the Mississippi Lime or Mississippi Chat.

existence of unplugged abandoned wells from over a century of oil and gas production, resulting in vertical conduits from the Mississippi Lime formation up to the surface;
- construction and operating histories of the seven injection wells; and
- environmental monitoring and other data collected by EPA staff and others.

The study includes over 20 inspections or site visits by EPA technical personnel. For more information about the study, *see e.g.* EPA's Interim Final report "Bird Creek Investigation and Injection Well Response Action Plan" dated August 4, 2017, which includes EPA's conceptual site model that considered conceivable explanations for the contamination.

Based on this 15-month study, EPA concludes that the seven subject injection wells cause or significantly contribute to the brine contamination in the surface water stream. The three well operators have not met their burden of showing brine is contained in and not escaping from the Mississippi Lime formation. This conclusion is supported by the following observations and data.

- In June 2017, a temporary shut-in of five of the seven injection wells (one of the wells had already permanently shut-in, one well was shut-in for mechanical integrity failure) was conducted for several days to determine background or static pressure in the Mississippi Lime geologic formation in this area when the injection wells were not operating.
    - When not in operation, the injection well pressure should be close to the static reservoir pressure. The static or background formation pressure of the Mississippi Lime was measured from multiple injection and production wells located near the contamination area. This pressure was determined by measuring the depth to the fluid level in these wells. The results generally showed a range from 500' to 750' below the surface of the ground.
    - These measurements confirm that the background condition in the Mississippi Lime geologic formation – *i.e.*, without operation of injection wells – does not have sufficient pressure to cause upward flow of water all the way up to the surface, including in and around the area of surface water contamination.
    - By contrast, while the five injection wells were operating, the Mississippi Lime formation pressure was higher, with sufficient pressure to push brine water up to the surface in the contamination area.

- The June 2017 temporary shut-in confirmed that injection well operations in this area are the only reasonable source of pressure increases in the Mississippi Lime formation that could cause upward flow of deep formation brine water to the surface in/near the contamination area.

- The seven injection wells are a cluster representing the nearest injection wells and they are within approximately 1.5 miles of the contamination area in the surface water stream. EPA's approach to target the cluster of nearest injection wells is consistent with injection well pressure buildup equations – *i.e.*, pressure buildup from injection wells is highest at the base of injection well and decreases with distance from the injection well. This approach is also consistent with the strategies in other Underground Injection Control (UIC) programs for responding to similar injection pressure situations. This includes UIC programs that focus on the nearest disposal wells to earthquake epicenters for suspected injection-induced seismicity.

- The surface water contamination was discovered in August 2016. Since that discovery, EPA has inspected or visited the site area over 20 times and implemented a monitoring plan. The results include:

- Rain events: Several monitoring station locations continued to show rebounding of high levels of total dissolved solids (TDS) even after rain events of five or more inches. The ongoing presence of high TDS immediately after significant rain events indicates an ongoing source of brine contamination.[4]
- Surfactant suds: Operating records for some of the injection wells indicate that they used surfactants (sudsy agents) to facilitate oil production. Probable surfactant suds were observed in the surface water stream months after the August 2016 discovery of the contamination, which also points to an upward discharge from the Mississippi Line formation.
- June 2017 temporary shut-in of five wells: During this shut-in, the recorded water quality data for TDS at several stations in the surface stream indicated that TDS levels diminished (decreased and flattened). This indicates use of the wells causing ongoing flow of brine from the Mississippi Lime injection zone into the surface water stream.

- Following the September 2016 repair of one of Jireh's wells (Blackland-McComb 18W) to repair a mechanical integrity failure, field measurements showed significant decreases of TDS in the hotspot that had the highest concentration of TDS in the surface stream.
  - After this repair, starting in September 2016, TDS values at a monitoring location in the surface stream (also known as Monitoring Station 2) declined from an original high of over 80,000 parts per million (ppm), down to 15,800 ppm on May 9, 2017, an average decline of approximately 8,000 ppm/month. This is a 90% drop.
  - These results likely show that significant leaks of brine from this well had been contaminating the surface stream.

- One of the three operators here already decided to permanently shut-in its well, and the shut-in immediately resulted in a drastic decrease in surface stream contamination.
  - On May 9, 2017, Novy permanently shut-in its injection well (Osage "B" #15). During the period immediately following the permanent shut-in, the TDS in a stream monitoring location dropped from 15,800 ppm on May 9, 2017 to 4,900 ppm on May 18, 2017. This is a 60% drop in 9 days.
  - EPA considered whether this decline alternatively could be explained by a 1.53" rainfall event on May 11, 2017 (measured at the Foraker weather monitoring station), which presumably caused a flushing of the monitoring location at this time. EPA compared this May 11, 2017 rainfall event to other rainfall events over an 8-month period, including a number of larger rainfall events shortly before the May 9 to May 18 period, and observed that these other rainfall events did not result in a prolonged drop in TDS concentrations such as observed after shut-in of this Novy well. As a result, the permanent shut-in of the Novy well also indicates that the active injection wells are also pushing brine up to the surface.

- Stream monitoring data taken <u>before and after</u> the June 2017 temporary shut-in test showed fluctuations of measured stream contaminations in some monitoring stations consistent with varying operation of injection wells. By contrast, stream monitoring data taken <u>during</u> the June 2017 shut-in test showed a reduction and flattening in concentration levels at some stations. (See attached charts.)
  - EPA's stream monitoring network began monitoring water quality at six station locations on May 25, 2017, and four additional stations on June 1, 2017. The stations were placed along a tributary of North Bird Creek and North Bird Creek. One station was placed upstream of an original

[4] See also EPA's Osage/Bird Creek Trip Report for December 5-6, 2017, Pump Down Procedure (EPA initial observations of a pump-out procedure by one of the well operators to repeatedly pump out brine from Monitoring Station 6; the brine promptly returned).

monitoring location near some culverts and the remaining were placed downstream. The distance between the first station and the last one is about 5 stream miles.

- The monitoring network takes readings every 15 minutes for TDS and temperature.
- The June 2017 temporary shut-in test began on June 9, 2017 and lasted several days.
- The monitoring network began collecting data weeks before the June 9 shut-in and continued to collect data thereafter. The stream monitoring network continues to collect data at least as of the time of this report.
- The June 9 temporary shut-in involved five wells from operators Jireh and Warren. Operator Novy had already permanently shut-in its Well 15 and one Jireh well was shut in due to mechanical integrity failure.
- Prior to the June 9 temporary shut-in of the five active wells, the stream monitoring data showed cyclic variations of TDS in some of the monitoring stations. When plotted, this data commonly showed a pattern consisting of a sharp increase in TDS value, followed by a plateau of relatively steady TDS readings at the high level, followed by a sharp drop in TDS value. These cyclic variations are consistent with the normal cycle of starting and stopping well injection operations. In sum, the cyclic pattern of stream TDS contamination is consistent with the cyclic/intermittent pattern of operation of injection wells.
- During the June 9 temporary shut-in, the stream monitoring data showed surface stream TDS contamination dropped at some stations. This drop of surface stream TDS contamination was consistent with cessation of operation of the five injection wells.
- After the June 9 temporary shut-in, when the five injection wells returned to their usual operation, the stream monitoring data once again showed increased levels and cyclic variations of TDS in some of the monitoring stations, just as it had prior to the June 9 temporary shut-in. In sum, the return to the pre-June 9 cyclic pattern of stream TDS contamination is consistent with the restart of the cyclic/intermittent pattern of operating injection wells.
- In sum, the pattern in surface stream TDS contamination data matches the pattern expected in cyclic/intermittent operation of the five brine injection wells. The matching patterns indicate the five wells are causing or significantly contributing to brine contamination in the stream.

As indicated above, the 15-month study concludes that the injection site area for the seven wells has exhibited containment failure. The three operators have not provided evidence refuting that their wells are causing or significantly contributing to contamination in the surface stream, or pointed to or shown an alternative viable explanation. While there may be a lack of detailed understanding of the specific pathway(s) for contamination (*e.g.*, fractures or faults in Mississippi Lime formation, abandoned unplugged wellbores, *etc.*), the existence of ongoing surface brine contamination coming from brine in the Mississippi Lime formation, and the matching patterns between injection well operation and surface water contamination levels, have not been refuted. The Underground Injection Control (UIC) regulations plainly provide that injection well operators have the responsibility to demonstrate containment for the injection area (40 CFR Part 147.2903 (a) and (b)). The operators here have not demonstrated any such containment and the result is ongoing contamination of the surface water stream.

The Agency's further responses to public comments are below.

Further Responses to Comments

1) Comment: EPA had authorized injection pressures for some of the injection wells of concern which may have been high enough to induce fracturing in the Mississippi Lime reservoir, possibly allowing injected fluid to either escape from the reservoir, reach an abandoned well or a well with mechanical integrity issues, or reach the surface. Using the authorized injection pressure, the commenter calculated bottom hole injection pressure in these wells and Mississippi Lime formation fracture pressure, and concluded that authorized bottom hole pressure exceeds formation fracture pressure, and therefore fluid injected into the reservoir is being injected at sufficient pressure to induce fractures, thus allowing fluid to escape the injection zone.

Response: Based on geologic literature, EPA concluded the Mississippi Lime in this area is naturally fractured. Differentiating natural fractures from injection induced fractures is not realistically possible, or relevant to the current action. Moreover, federal regulations for Class II (oil and gas related) injection wells, including those specific to the Osage County UIC program, do not prohibit all injection over fracture pressure for oil and gas related injection wells. However, these regulations do prohibit injection pressures that could result in fracturing of overlying confining strata, i.e., lack of containment, for an injection reservoir. See 40 CFR Part 147.2912 (b).

For those wells of concern with the highest authorized injection pressures, EPA had established injection pressure limits using an equation set forth in the federal regulations for the Osage UIC program. According to the preamble to these regulations (**Federal Register / Vol. 49, No. 222 / Thursday, November 15, 1984 / Page 45304**), the equation is based on conservative estimates of the fracture pressure gradient.

Nevertheless, EPA reviewed the last five years of operational records for the wells in the area of interest with the highest authorized injection pressures. The highest reported surface injection pressure for any of these wells over the last five years was 250 psi, well below the equation-based authorized pressures and any conservative estimates of fracture pressure for limestone at the depth of the Mississippi Lime in the area of concern.

2) Comment: EPA's interpretation of the surface water monitoring data is flawed. The variations are related to daily fluctuations in temperature and precipitation events.

Response: EPA acknowledges that some factors impact the measured TDS in the tributary and creek. These include precipitation events, which can impact both runoff and ground water recharge into the creeks for extended times after the event, and daily temperature fluctuations. However, the change in character in some of the concentration curves before, during, and after extended shut-in of all of the seven nearby wells that are the focus of EPA's current decision significantly corresponded to what would be expected with shut-in of the wells and their return to operation.

As mentioned above, EPA's decision is largely based on the following facts:

- static injection reservoir pressure measured during the well shut-ins demonstrated the Mississippi Lime is not able to flow to the surface in the area of contamination without induced pressure in the formation;
- injection wells are the only reasonable cause for pressure buildup in the formation that would result in flow to/near the surface in the contamination area;
- instream monitoring data show ongoing seepage of higher TDS waters into the stream that do not correlate consistently to temperature and precipitation events; and
- EPA's approach to target the nearest injection wells is consistent with injection well pressure buildup equations that indicate nearby wells are the most likely source of pressure influence.

3) Comment: Calculations demonstrate that the rates and pressures used by some operators would preclude pressure influence to the surface within a few feet of the injection well.

Response: The calculations cited by the commenter were not provided and so are not part of the record, and EPA questions whether they apply to fractured formations. Fractures in injection formations can and many times do act as preferential pathways for flow and thereby transmit pressure buildup from injection more quickly and over greater distances than un-fractured formations, where flow takes place through pore spaces in the overall rock matrix. Fractures can provide a preferred flow path and result in little flow through the matrix of the rock. EPA concluded the Mississippi Lime is naturally fractured in the area of concern.

4) Comment: One commenter questions accuracy and verifiability of injection well mechanical integrity testing, as well as the mechanical integrity of wells. History of mechanical integrity test (MIT) failures, lack of MIT data availability, and mechanical integrity problems (tubing corrosion and holes) in a salt water disposal well were cited. The commenter cites accuracy and frequency of the MIT testing process, adhering to regulatory requirements for MIT testing and permitting, as well as the continued operation of well(s) that appear to lack mechanical integrity.

Response: Federal regulations for the Osage UIC program relating to mechanical integrity testing of oil and gas related injection wells require demonstration of mechanical integrity every five years, but allow for more frequent testing, if necessary. This is consistent with many state and federal oil and gas related UIC programs nationally. However, EPA agrees the highly corroded condition of the well injection tubing in one case was of concern and is considering requiring more frequent mechanical testing requirements for wells in this area.

In terms of accuracy and verifiability, EPA relies heavily on the witnessing of MITs by field inspectors for verification of this critical program requirement. EPA has two inspectors working in Osage County. In addition, the Osage Nation UIC program inspectors witness many of these tests. Also, EPA's UIC program in Osage County requires the flow-back volume of annular fluid to be measured after a pressure test is performed. This is used to confirm the entire well interval was tested down to the bottom of the casing/tubing annulus, and not just a partial length of the annulus. This requirement goes beyond most oil and gas related UIC program requirements nationally.

5) Comment: The saltwater contamination is not from injection, but was caused by a one-time event as a surface discharge and there is no ongoing pollution into the creek. The commenters note some declining concentrations over time. The commenter concludes that all observations of increased salinity can be explained by stratified flow and pool to pool transport of salts. Since saltwater has a higher density than freshwater, the areas with elevated TDS are caused by saltwater that has accumulated in deeper places in the creek that are isolated from the current. An additional commenter noted that the impacted area is an intermittent stream, some distance away from the operating leases, and no indications of stressed vegetation occurs to indicate a surface spill had occurred. One commenter also stated that the locked gate controlling access to the area was installed after the incident was discovered.

Response: EPA concluded early in its investigation that the Bird Creek contamination was not a result of surface dumping, but rather saltwater movement underground, surfacing near the area of contamination via a conduit from the Mississippi Lime. Multiple lines of evidence support this conclusion, as discussed below and elsewhere.

- Many rainfall events have been recorded in the area, some of which were heavy and caused considerable turbulent flow through the creeks. This would have repeatedly washed away salt water pooling in deeper areas, as was/is demonstrated by temporary TDS declines during/just after rain events at monitoring

locations. After rainfall events, the TDS concentrations have repeatedly rebounded with persisting levels of saltwater contamination well above background returning in some of the monitoring locations.

- Also, the area of contamination is remote and not readily accessible to trucks for dumping, regardless of the timing of the limitations on access to the area. Through an information request prior to its proposed action, EPA received records indicating surfactant was injected into at least some of the wells. Surfactant-like suds were observed in the creek months after the initial discovery of the contamination. These facts are consistent with a continued surface discharge of injected brine (with surfactant) from deep formations through a nearby unknown vertical pathway.
- Although saltwater concentrations in Monitoring Station No. 2 (MS2) have substantially dropped, corresponding with the two mechanical integrity failures described above, the monitoring data still indicate periodic fluctuations that EPA concluded are related to ongoing injection activity. Also significant contamination still exists.

Finally, the recorded water quality data indicate TDS concentrations at several stations diminished during the time of the coordinated well shut-in. This relationship indicates ongoing communication between the Mississippi Lime injection zone and the seeps entering the tributary of North Bird Creek and downstream of the confluence of the tributary of North Bird Creek.

The Agency has concluded the site has experienced a containment failure in terms of subsurface injection, and is taking actions consistent with its program responsibility to protect underground sources of drinking water. Under the UIC program, it is the responsibility of the injection well operators to demonstrate the site can contain injected fluids. The existing data indicate the site containment is compromised in the area of contamination. For reasons stated above, EPA has dismissed surface dumping as the cause of the ongoing contamination. EPA believes the fact that no substantial TDS contamination has been detected upstream of the original location indicates a conduit from deeper formations exists near the area of contamination.[5]

6) Comment: EPA observed the saltwater concentrations had elevated temperatures in the tributary and North Bird Creek. One commenter stated the temperatures correlate with the expected subsurface temperature in the Mississippi Lime reservoir, implying that surface contamination derives from fluids from this formation. A different commenter noted that the temperature anomalies observed at various depths of the tributary of North Bird Creek and downstream of the confluence of the tributary of North Bird Creek could readily be explained by solar heating of the dense saline layers. Therefore, communication with the creek and a deeper stratum would not be necessary to explain elevated temperatures at deeper, high salinity locations.

Response: EPA believes there may be two possible sources for the elevated temperatures. EPA initially posited that the high temperature of the brine was a result of the temperature in the Mississippi Lime and indicative of a quick time of travel from the injection zone to the creek (suggesting a vertical pathway is nearby because of the retention of high temperature). EPA Agency technical staff are aware of an alternative possible cause of the anomalously high temperature (higher solar heating of the brine pools in comparison to overlying shallow water). This finding opens up the possibility that the anomalous heat in the brine contamination areas is not necessarily indicative of close proximity to a vertical pathway or a short time of travel from the Mississippi Lime to the contamination areas. However, this uncertainty does not impact EPA's conclusion that the nearby injection wells are causing the surfacing brine. For either explanation for the heat, EPA's resulting action would be the same: to stop the seeps by restricting injection in the area.

[5] See also EPA's Osage/Bird Creek Trip Report for December 5-6, 2017, Pump Down Procedure (EPA initial observations of a pump-out procedure by one of the well operators to repeatedly pump out brine from Monitoring Station 6; the brine promptly returned).

7) Comment: One commenter stated that EPA did not consider rainfall levels and the effects of dilution and flushing on the stream. It was noted that MS2 records show a rapid decline after repair of one injection well and a significant rainfall event occurred soon afterwards. The commenter stated the rainfall flushed the MS2 pool which caused the concentration to decline quickly.

Response: EPA has considered rainfall episodes in its analysis of the monitoring data and some of these episodes significantly impacted salinity readings for a relatively short period of time during and after the event. TDS concentration levels in these cases rebound relatively quickly. (See also the overview above and the response to Comment 5.) EPA acknowledges the repair/shut-in of the two wells with mechanical integrity failure described above corresponded with decreases in MS2 TDS levels. However, despite numerous rainfall events, substantial contamination still exists at some of the monitoring stations. Also, as discussed above, EPA concluded from its assessment of surface water monitoring data that ongoing operations are continuing to impact the tributary and creek following the repair or shut-in of wells for mechanical integrity problems.

8) Comment: A commenter notes that there are two domestic water wells in the area which have been tested, but the operators have not yet received the results of those analyses. They assume that since they continue to be used and this indicates they have not been impacted. This was not discussed in the EPA report.

The Bird Creek area of contamination impacts or threatens the two nearby domestic private water wells. Minor fluctuations in key indicator cation elements have been noted during recent testing events. Bottled water is currently being used for drinking water purposes.

Response: According to landowner representatives, the two domestic water wells are not currently used for drinking water, and instead are used for other purposes. Also, water samples of these two domestic wells were taken on June 28, 2017 by EPA staff and analyzed. (Background samples were not collected before the contamination was discovered.) The results of the water samples have been provided to local injection well operators. The sample results are contained in the document, "United States Environmental Protection Agency, Region 6 Laboratory, Final Analytical Report, Site Name: Bird Creek," dated July 12, 2017. The sample locations for the two wells are identified as WS-11, its duplicate WS-14, and WS-12. The analyses of these water samples indicated no exceedances of EPA's drinking water standards for public water supply systems. Salinity levels of 0, 0 and 1 parts per thousand (ppt), respectively were measured. However, based on the conductivity readings, it is apparent the salinity readings are rounded to the nearest part per thousand. EPA's secondary drinking water standard for total dissolved solids (TDS, which includes salinity) is 0.5 ppt. Although these levels are not elevated to levels seen in the surface water contamination, EPA did not have historic background sample data from these wells for comparison to determine if their water quality has been impacted. Additionally, air photos and field investigations confirm there are nearby surface locations with historic and ongoing soil contamination from salt or salt water dating back to at least 1937. For these reasons, EPA is not drawing conclusions related to possible contamination of the two water wells from injection wells associated with the AOs described herein. According to landowner representatives, the two domestic water wells are not currently in use for human consumption.

9) Comment: A commenter states that the injection wells are not injecting water in high volumes, or at high pressures, anywhere close to the fracture gradient of the Mississippi Lime., More specifically, the approximately 2400 feet between the top of the Mississippi Lime and the bottom of the tributary of North Bird Creek and then downstream of the confluence of the tributary lacks sufficient reservoir pressure (even while water injection is occurring) to lift a column of fluid from the Mississippi Lime into the bottom of the tributary and then downstream of the confluence of the tributary. The commenter states that it is physically impossible that fluids injected into a well on vacuum can "make their way from this wellbore to the surface." A commenter also stated that the conclusions reached in the proposed Administrative Order are factually and scientifically incorrect, and

the data do not support the EPA's theory that the Mississippi Lime is over-pressured. The commenter states that multiple wells take water on a vacuum or operate at a very low injection pressure, and the reservoir pressure is now less than the bottom-hole pressure was 50 years ago.

It was noted by commenters that several wells dispose into both the Mississippi Lime and the Arbuckle and have always operated with negative pressure. A commenter noted that some wells use pumps to inject water, and others operate on vacuum alone meaning they are under-pressured compared to atmospheric pressure and cannot push water to the surface.

One commenter caveats that comment, saying it is true as long as the water actually enters the Mississippi Lime and does not channel up the backside of the casing.

Response: EPA does not agree it is impossible for the existing injection wells to influence the contamination area. EPA concluded the combined formation pressure buildup from one or more of these wells is sufficient to cause flow to the surface in the area of contamination of the tributary and creek. EPA concluded flow from the Mississippi Lime to the surface is happening when injection is actively taking place. EPA also notes that the surface elevation of the contamination area is significantly lower than that of the area near the injection wells. Therefore, increases in formation pressure from injection could cause upward flow to surface in lower elevation areas (e.g., the tributary and creek) with less injection pressure than that needed to cause surface flow at the injection well sites. Because the surface elevation of the contaminated area is lower than the injection well area, less pressure would be needed to lift the column of fluid from the Mississippi Lime to the tributary.

As mentioned previously, EPA concluded the Mississippi Lime is naturally fractured in the area of concern. Fractures can and have served as preferred flow paths, and commonly result in much greater lateral extent of formation pressure increases. In unfractured formations, fluid flow pathways exist as small connections between pore spaces in the rock, generally resulting in meandering and constricted flow pathways. Fluid flow is frequently much harder and slower through this type of rock than for fractured formations. Flow through unfractured formations (and resulting pressure buildup) generally occurs in all directions away from the injection well, resulting in a circular area of pressure buildup.

Fractures can and many times do serve as relatively straight easy-flow pathways for fluid through the rock and thereby act as preferential flow paths. Fractures also tend to be oriented in preferred linear directions. This results in preferential direction of flow, and an elongated and pressure buildup trend away from the injection well instead of a circular trend common in non-fractured reservoirs. Fracture dominated flow can result in rapid transmittal of formation pressure increases over great distances horizontally. EPA suspects this is the scenario in the case here. EPA is very familiar with at least one case in Texas where fracture flow resulted in very rapid communication of injection pressure at distances of over a mile (Wild Boar SWD No. 1 Interference Test Report, EPA Region 6, Harrison County, Texas, August 2004).

Based on formation pressure measured during concurrent shut-in of the seven injection wells, EPA concluded that at static condition, the Mississippi Lime is not of sufficient pressure to cause brine to flow to the surface in the contamination area. The only reasonable source for pressure to cause flow to the surface in the contamination area from the Mississippi Lime would be injection wells. Injection increases the formation pressure at the well and for some extended distance out, depending on injection formation characteristics. These impacts would decrease with lower injection pressures, but there are no data to indicate how far away from the injection wells pressure increases extend. This is especially relevant in a fractured setting for reasons discussed above.

EPA notes there is no legal differentiation for wells using pumps or gravity for disposal in the UIC regulations, as all of them are Class II UIC disposal wells. Despite not using a pump, any operation injected from a tank battery that is higher in elevation than the well location will also result in increased injection pressure at the well.

Finally, the compounding pressure buildup effects from multiple injection wells operating simultaneously may very well have contributed to the overall formation pressure buildup and resulting salt water seeps causing the contamination.

10) Comment: One commenter submitted testing which indicated that injected water from their operation is confined solely to the Mississippi Lime. While mechanical integrity failures had occurred in the past, they felt that the type of failure precluded injection to a shallower formation.

Response: The commenter refers to recent radioactive tracer surveys conducted by the operator on September 12, 2017. These surveys only determine if the injection wellbore itself is serving as a conduit for direct upward flow vertically in the space between the wellbore and outer steel casing. EPA reviewed these tests and agrees that they demonstrate that there is no significant fluid flow through vertical channels between the casing and wellbore. However, these tests only determine if the injection wellbore itself is serving as a vertical conduit and would not detect vertical conduits beyond 1-2 feet from the tested wellbore. Therefore, even proper injection, following all regulations and abiding with MIT protocols, could still contribute to the migration via an unknown pathway. EPA has concluded some combination of the seven wells are contributing to the ongoing problem and the containment capacity for this injection zone in this area is compromised.

11) Comment: One commenter noted for the record that they have no alternative location for disposal of produced water, and have been told by EPA personnel that no new permits to drill a disposal well further to the north or to dispose of produced water into different formations will be approved.

Response: EPA recently expanded its assessment of injection wells beyond the approximate 1.5-mile radius encompassing the seven injection wells under this action to a 3-mile radius around the contamination area. To date, the Agency has made no decisions related to the operation of injection wells in this expanded area. However, further action may be necessary to eliminate the brine seepage to surface.

12) Comment: One commenter believes that the EPA's proposed Administrative Order to permanently discontinue disposing of produced water into the Mississippi Lime is arbitrary and capricious, and is not supported by the data.

Response: EPA disagrees with this statement. EPA's decision to order the shut-in of these seven injection wells is supported by substantial evidence and rationally connected to EPA's findings of fact. EPA has been actively working on this study since August 2016. The Agency has conducted over 20 inspections and done extensive monitoring and sampling of the site. EPA has examined all the data and relevant factors and has and considered alternative explanations of the problem. As discussed above, EPA concluded, based on a 15-month study, that the seven injection wells caused or significantly contributed to the brine contamination in the surface water stream and that injected fluid from these injection wells was no longer confined to the authorized injection zone. The well operators have not met their burden of showing brine is contained in and not escaping from the Mississippi Lime formation. The public participation process for the proposed Administrative Orders is intended in part to provide the opportunity for consideration of any new information. Based on consideration of all the available information and public comments received, EPA continues to conclude that the injection wells caused or significantly contributed to the ongoing contamination. This conclusion is based on the detailed assessment of abundant scientific data, as discussed herein.

13) Comment: Several commenters offer various ways to help address the issue of high salinity such as draining the deep pools multiple times, lowering injection pressures, increased MIT testing, or monitoring and reporting of casing pressures on a frequent basis, while continuing creek monitoring.

Response: EPA supports the concept of well operators taking action to provide more information on the ongoing contamination, but these actions are beyond the scope of the current Administrative Order process. EPA would be interested, at least in an observational role, in any further activity related to addressing the ongoing contamination. In fact, on December 5-6, 2017, EPA observed a procedure conceived and performed by two of the injection well operators to repeatedly pump out brine from Monitoring Station 6. EPA's initial observations are available in the Osage/Bird Creek Trip Report for December 5-6, 2017, Pump Down Procedure.

14) Comment: Several commenters indicate asking for additional information regarding the testing and monitoring and have not yet received all of the documents requested from the EPA through various Freedom of Information Act (FOIA) requests. The commenters request adequate time to review and respond to this information once it is received before any decision is made to shut down injection.

Response: EPA acknowledges that a significant amount of information and documentation are continuing to be provided through various FOIA requests. However, EPA also recognizes that urgent action is needed to address ongoing contamination.

15) Comment: One commenter disagrees with the EPA finding that cation/anion analyses using Stiff diagrams are strongly correlative between brine samples from the seeps and produced brine from the nearby Mississippi Lime oil production/injection operations, contending they can be ambiguous when strongly dominated by one cation/anion pair such as Na+ and Cl-. Stiff diagrams can readily demonstrate that fresh water has been impacted with a produced water. Thus with the available data, it can only be concluded that the tributary of North Bird Creek and downstream of the confluence of the tributary of North Bird Creek was impacted by produced water of some source, but the source of that water remains unknown.

Response: The commenter appears to agree EPA's testing and analyses have shown that the creek is impacted by brine from the Mississippi Lime, which is the production formation in this area. EPA agrees that it would be difficult to determine more specifically and quantitatively, the relative culpability of any specific injection well operation based on the information presented in the Stiff diagrams. Since all operators are producing from the same zone, it may not be possible to distinguish unequivocally between their respective fluids. Additionally, there have been a multitude of various enhanced recovery projects historically, which may have used produced water from both the Mississippi Lime and the Layton formation to be reinjected into the Mississippi Lime. Thus, a repeated cycle of reinjection and recycled fluid movement has been identified within the Mississippi Lime. Finding a unique marker definitively linking the contamination found in the tributary and creek samples as unequivocally from only a specific injection well is unlikely and, considering the enhanced recovery processes mentioned above, it is not likely that obtaining a unique sample from all the different formations in the area will enable distinguishing between wells. However, the impacts to the tributary and creek have been confirmed including identifying the seven specified wells as causing or significantly contributing to the contamination. After reviewing multiple lines of evidence, EPA concludes the injection well operations are causing or significantly contributing to the contamination to the tributary of North Bird Creek and downstream of the confluence of the tributary of North Bird Creek. The UIC regulations clearly place the burden for demonstrating compliance with the program requirements on the operators, and in this case operators have not demonstrated the site has sufficient containment capability for purposes of injection.

16) Comment: One commenter feels that the change in the amplitude of the TDS variations occurring immediately after the sensor was removed and replaced makes the cause of the change highly suspect. It is plausible that replacement of the sensor at a different vertical depth resulted in the change.

Response: EPA acknowledges there could be some minor anomalies possibly related to equipment. However, the Agency took these possibilities into account in its assessment of the data. Changes in TDS values immediately after the removal and replacement of the sondes (monitoring devices) within the stream to download data may be due to multiple factors, including that the sensors on the sondes are cleaned and recalibrated, and that small differences in placement may result in different values. Data are corrected to account for slight variations in readings caused by accumulation of film over the time between placement and removal/cleaning/calibration. However, the analysis of the trend of the data is more important than the absolute values of any particular data point. The fact there are multiple monitoring stations provides a level of redundancy to supplement any questionable data. The Agency also notes that no issues were experienced with most of the sondes although two were replaced due to bad connectivity during downloads. These are rare anomalies, and EPA has confidence in the overall quality of the monitoring data with respect to its conclusions and multiple lines of evidence support the Agency's action in this case, including the totality of the data from the ten monitoring stations.

17) Comments: One commenter has expressed that the Bird Creek area of contamination impacts or threatens grazing land. Due to contamination on the land and the creek, Osage Land & Cattle has a current loss of 3,500 acres of high-quality livestock cattle grazing land and livestock watering from the creek due to high total dissolved solids measurements.

The Bird Creek area of contamination impacts or threatens ecological habitat (i.e., the tall grass prairie) and aquatic life. There was a wildlife kill of fish, turtles, crayfish, and mollusks. Historic poor management of oil and gas operations results in some Osage County surface waters being listed as impaired waters by the State of Oklahoma under the Clean Water Act.

The Bird Creek area of contamination impacts or threatens City of Pawhuska drinking water. Due to contamination in the tributary of North Bird Creek and downstream of the confluence of the tributary of North Bird Creek, as a precautionary measure, and at significant expense to the City of Pawhuska, the city changed its drinking water intake from Bird Creek to Pawhuska Lake.

Response: EPA is aware that the brine seepage has impacted and continues to impact ranching operations, aquatic life (i.e., fish) and other wildlife. With respect to drinking water impacts EPA has been monitoring stream locations near drinking water sources in Bird Creek for any possible impacts to drinking water and data show that values of concern have never been above expected background levels at these stream locations. As the commenter stated, the decision by the City of Pawhuska was a precautionary one and not based on any data that has been collected. EPA also collected samples from the two private wells and sample results do not indicate any contamination that correlates with ongoing seeps in Bird Creek posing a threat to these wells. The Agency is acting within its regulatory authority under the Safe Drinking Water Act to address the cause of contamination and believes the current course of action will improve conditions. However, improvement to surface water quality will likely be gradual due to the presence of brine in the shallow formations adjacent to the creek.

18) Comment: The abundance of improperly abandoned wells, well casing corrosion, and the absence or degradation of well casing cement all could result in conduits for upward movement of subsurface fluids. These conduits can allow pollutants to migrate to groundwater aquifers or surface waters; the commenter states this is a plausible explanation for contamination of the tributary of North Bird Creek and downstream of the confluence of the tributary of North Bird Creek. Bird Creek area wells predate state regulations for well

abandonment protective of fresh water. The regulatory agencies for oil and gas development in Osage County have not historically been accountable for the disposition of abandoned wells.

Response: The requirements for oil and gas related injection wells in Osage County require an assessment of all known penetrations within a quarter mile of the proposed injection well to assure no improperly plugged or constructed wellbores exist (40 CFR Part 147.2904). This "Area of Review" radius is consistent with both federal regulations and many other oil and gas related UIC programs nationally. See 40 CFR Part 147.2904.

EPA agrees historic drilling activities have resulted in improperly constructed or plugged wells that serve as artificial penetrations to brine-bearing formations. Oil and gas drilling in Osage County has occurred since the late 19th century, increasing the likelihood of undocumented wellbores that could serve as conduits for upward brine flow from deeper formations. EPA agrees an undocumented wellbore is a plausible explanation for communication to the surface in this case. EPA performed a historical aerial photo analysis of the area of concern related to the ongoing contamination from 1937 to present in an effort to identify old drilling sites. This analysis and subsequent field verification of continued salt contamination of soil identified three persistent areas of stressed vegetation caused by brine contamination on the surface dating back to before 1937. Due to the location of the largest stressed area relative to the monitoring stations, the age and severity of the scarring at this location, and the analysis of monitoring data, the Agency suspects an old wellbore may exist in this area. An improperly abandoned historic wellbore would be a potential vertical pathway for migration from deeper formations to the surface and may be the reason for compromised containment in this case.

The Bureau of Indian Affairs may have construction and cement records of old wells.

19) Comment: Injection/disposal well permitting and monitoring in the Bird Creek area do not sufficiently consider geologic formation characteristics of the Mississippi Lime. The commenter states that the formation exhibits lateral and vertical variations in reservoir properties, is naturally fractured, and is poorly suited for large scale water disposal. The confining zone above is weathered and soft, and may lack sufficient containment ability.

Response: EPA issues permits for injection wells in Osage County according to the federal regulations specific to this Underground Injection Control Program. These rules, as with most other oil and gas injection well programs nationally, do not require rigorous geologic data requirements related to site characterization. Availability of site specific resources could be another factor. EPA is aware the Mississippi Lime exhibits some complexities, including erosional features and natural fractures, but notes the existing program requirements do not have any prohibition for injecting into these types of formations provided they have sufficient confining strata between the injection zone and the lowermost fresh water aquifers. Substantial oil deposits in the Mississippi Lime indicate there are effective confining strata over the formation in the area of the injection wells in this case. Although the formation is not generally used for large scale waste disposal in Osage or other counties in Oklahoma, enhanced oil and gas related injection is common.

20) Comment: One commenter strongly supports the proposed Administrative Orders, but also requested EPA to apply additional administrative controls in permitting, testing, and monitoring, particularly for disposal/injection well construction, permitting, monitoring, reporting, and plugged and abandoned/orphan well program management.

Response: Based on experience with the North Bird Creek contamination event and injection-induced seismicity in Oklahoma, EPA is assessing various parts of its Osage County direct implementation program for possible

areas of program enhancement. Among other enhancements, these include increased operational monitoring requirements and more frequent mechanical integrity requirements.

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INTERIM FINAL

Bird Creek Investigation and Injection Well Response Action Plan

August 4, 2017

Main point of contact: Philip Dellinger (6WQ)

ABSTRACT

In August 2016, the Bureau of Indian Affairs (BIA) informed EPA that a tributary to North Bird Creek had high levels of total dissolved solids (TDS), an oil sheen and bubbles on the surface. EPA conducted extensive investigations in an attempt to determine whether the closest seven (all within 2.0 miles) Class II UIC injection wells (Table 1, Figure 1) were causing the impacts, and if so, through what mechanism. Six of these wells are injecting into the Mississippi Formation, one is injecting into the Mississippi and Arbuckle Formations. Surface water monitoring, both manually and by the use of dedicated in-stream equipment, was conducted, as well as a shallow electrical resistivity survey, aerial photo analysis, and sampling and analysis of surface water and injected fluids. In May 2017, mechanical integrity tests (MITs) were performed on five of these wells (two were shut-in and remain shut-in due to MIT failure) and all of the Authorized by Rule wells (four) were required to submit permit applications. A coordinated shut down of these five wells was performed in June 2017.

Data acquired through multiple approaches support the conclusion that the seven nearby injection wells are causing or contributing to the brine seeps observed in a tributary to Bird Creek.

- Cation/anion analyses using Stiff diagrams (Figure 2) are strongly correlative between brine samples from the seeps and produced brine from the nearby Mississippi Formation oil production/injection operations.
- Additionally, surfactant foam observed at one the seeps is consistent with reported use of surfactants in these nearby operations.
- Mechanical integrity failure and subsequent repair of the Jireh Well 18W (OS6320) in August – September 2016 resulted in a temporary shut-in of this well (for repairs). This action corresponded to a substantial decrease of total dissolved solids over the next several months in Monitoring Station 2, the highest TDS of two "hot spots" (Monitoring Station 6 being the second).
- Mechanical integrity failure identified on the Novy/Grayhorse well in May 2017 resulted in the shut-in of this well. Total dissolved solids at Monitoring Station 2 abruptly dropped even further following the shut-in of the Novy well.
- Simultaneous shut-in of five of the seven injection wells (two of the seven were already shut-in because of mechanical integrity failure) and subsequent measurement of the injection formation pressure in June 2017, demonstrated brine from the Mississippi Formation could not have flowed to the nearby creek without pressure buildup from injection wells.
- Extensive surface water monitoring indicated correspondence of some of the seven injection well operations with surface water brine concentrations, including the simultaneous shut-in event and injection formation pressure measurements mentioned above.
- Finally, air photo analysis with follow-up field investigation confirmed substantial historic salt water contamination of soil dating back to before 1937 in an area very near the brine seeps. This contamination is likely from oil and gas operations and suggestive of a nearby

undocumented wellbore, which could be serving as a conduit resulting in, or contributing to, contamination of the nearby segment of the creek. Shallow resistivity measurements conducted by EPA in September 2016 appear to support this scenario (nearby undocumented wellbore).

While approaches are outlined below, UIC program staff and management strongly recommend and support approach 1, concurrent closure of all seven of the injection wells listed in Table 1. The analysis in this review indicates a loss of containment in the injection formation (the Mississippi Formation) in this area which not only impacts Bird Creek but also endangers the Underground Source of Drinking Water which is present between the Mississippi Formation and the surface.

Key Findings

The analysis of technical data to date indicates:

- Surface water concentrations at the originally reported location (Monitoring Station 2, MS2) have declined steadily and significantly since the Jireh Resources Well 18 (OS6320) was repaired in September 2016 following an MIT failure.
- Further declines at the original location (MS2) also occurred immediately after the shut-in of the Novy/Grayhorse disposal well (OS5258) due to an MIT failure.
- Cation/Anion analysis of injected fluids and high TDS stream waters (Figure 2) show a match with the Mississippi Chat Formation (which is used for both oil production and an injection disposal zone).
- To measure the Mississippi Formation fluid pressure, a concurrent shut-in of the injection wells (Jireh and Warren) of concern (Novy/Grayhorse and Jireh Well 9 were inoperable during the shut-in) occurred on June 9, 2017. Due to the measured static fluids being 500 – 750 feet below ground surface, they cannot flow from depth to the surface without additional pressure buildup, which is provided by the injection operations.
- Monitoring at some locations indicates that despite the repair to the Jireh Well 18W (OS6320) and shut-in (termination) of the Novy/Grayhorse well, injection operations appeared to affect in-stream water quality (TDS) before and after the coordinated shut-in event, but amplitude (degree of variability) of short term concentration fluctuations at some stations diminished during the shut-in period.
    - This indicates ongoing impacts from the injection operations unrelated to the mechanical integrity failures of these two wells.
    - Information to date does not indicate relative impacts from specific injection well(s) or the mechanism of migration responsible.
    - High TDS remains at Monitoring Station 6 (MS6), ½ mile downstream of the original location.

Fresh water aquifers occur in the area down to approximately 500-650 feet, as determined by geophysical well logging techniques. Several domestic water wells were identified near the contamination area (Figure 1), and range in depth from 50-300'. Aquifers (Underground Sources of Drinking Water) are threatened by the injection activity via contamination as the brine moves vertically

upward (through wellbore or fault) to the creek from the Mississippi Formation, and as brine moves to downstream areas where the creek recharges ground water. No existing public water supply wells were identified in the immediate area as of this time. However, the City of Pawhuska has a drinking water intake in Bird Creek, downstream of the brine seeps for its public water supply. Although no impacts were detected to date, this intake has been moved to a nearby lake in a preventative response due to the upstream brine seeps. However, the Bird Creek water supply intake still exists and may be used by the City of Pawhuska at some point in the future (e.g., drought, population increase). Further, with any population growth, other locations on Bird Creek may be relied upon for drinking water.

Approaches to Address Injection

1. Concurrent Closure of All Seven Nearby Injection Wells: Issue termination of authorization to inject letters by 6EN (if possible; immediately shuts wells in) and propose denial/termination of permits (by 6WQ).
2. Staged Well Closures: Issue termination of authorization to inject letters and propose denial/termination of permits in a sequential order.
    a. Prioritize actions based on same shut-in order used in June (i.e., the high volume, closest active well (Jireh OS6320), first).
    b. Actions staged in minimum 30 day increments to determine effectiveness.
3. Permanent Termination of Novy/Grayhorse OS5258 Permit and operating restrictions on other wells;
    a. Restrict authorized injection pressure for remaining six wells to 0 psi (gravity feed only) and allow injected fluid to only include Mississippi Formation water generated at respective operational unit (no disposal, no make-up water).
4. Approach 3 with further restriction of 25% reduction in historical injection volume.
5. Approach 3 with further restriction of 50% reduction in historical injection volume.

Table 1: Well Info for seven wells within area of interest.

Inven-tory ID	Well ID	Owner/ Operator	ABR/ Permit	Permit No.	Well Type	USDW Depth (fbs)	Static Fluid Level. (fbs)	S.F.L Date	Latitude	Longitude	Distance from MS2 (ft)	Distance from MS6 (ft)	Status
OS5258	B-15	Grayhorse /Novy	Permit	06S1261P5258	SWD	540	707.35	3/9/2017	36.823458	-96.489383	4156	3943	SI
OS6320	18W	Jireh	Permit	06S1261P6320	SWD	622	668	6/12/2017	36.84119	-96.504909	3800	4948	Active
OS0921	B-8	Warren American	ABR	TBD	SWD	663	563	6/12/2017	36.845139	-96.496017	4715	6493	Active
OS0922	9	Jireh	ABR	TBD	EOR	645	555	6/12/2017	36.85202	-96.507365	7731	9030	SI
OS5133	9B	Warren American	Permit	06S1261P5133	SWD	660	504	6/12/2017	36.843278	-96.496076	4111	5884	Active

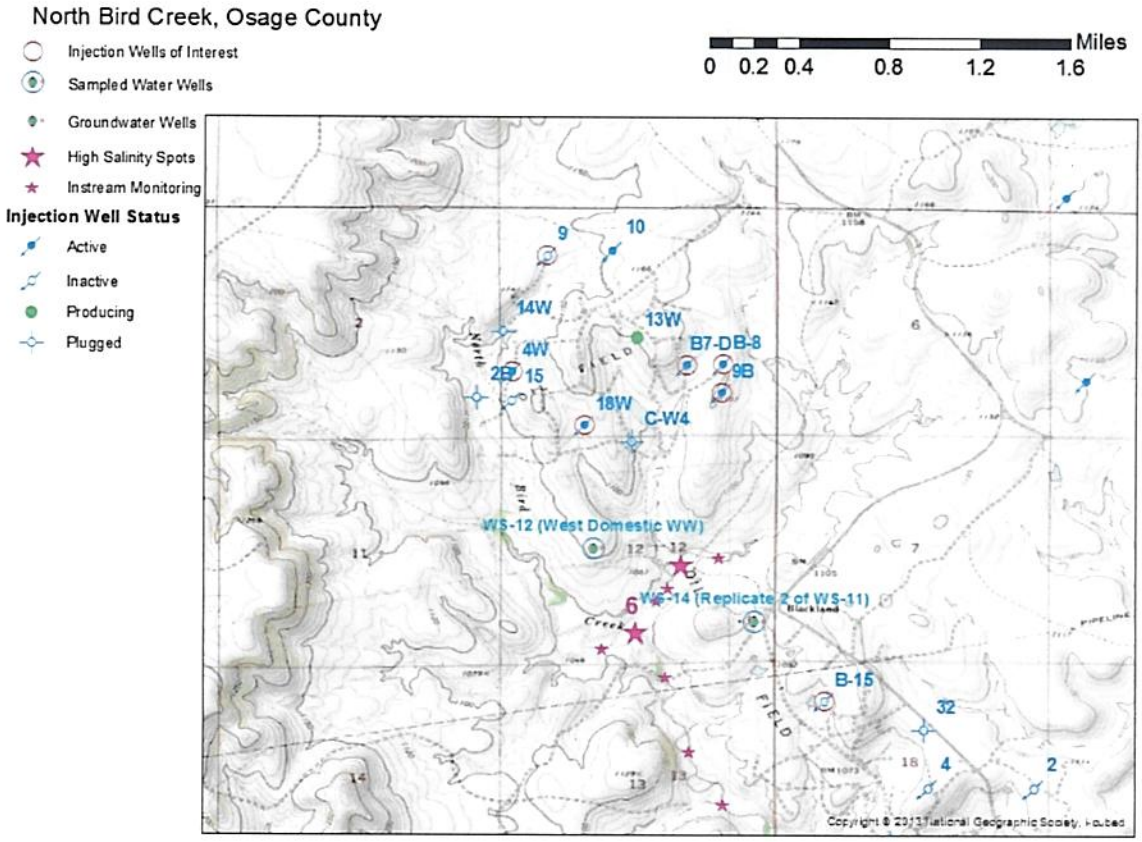
Inven-tory ID	Well ID	Owner/ Operator	ABR/ Permit	Permit No.	Well Type	USDW Depth (fbs)	Static Fluid Level. (fbs)	S.F.L Date	Latitude	Longitude	Distance from MS2 (ft)	Distance from MS6 (ft)	Status
OS0920	B7-D	Warren American	ABR	TBD	SWD	642	586	6/12/2017	36.845045	-96.4983	4715	6340	Active
OS0924	4W	Jireh	ABR	TBD	EOR	637	739	6/12/2017	36.844596	-96.509579	5568	6545	Active

fbs = feet below surface measured in injection well.

OS0920,OS0921, OS0922 have applied for a permit, but the S.F.L is above the USDW.

OS0922 is currently waiting to do a workover of the well. They have a permit from the BIA, but will not do the work if we deny the permit.
OS5133 permitted 8/8/1986 and reported fluid level of 1147' as recent as 7/8/2016
OS0920 and OS091 have applied for permits as EOR wells.

Figure 1



SUMMARY OF ACTIVITIES AND DEVELOPMENTS

Working in coordination, managers and staff from 6WQ-S and 6EN-W have developed and implemented the following activities regarding the Bird Creek area of concern. This report includes elements related to continuation of current activities and recommended next steps.

Since the confirmation of the impacts to the tributary to Bird Creek at the original location (Monitoring Station 2, MS2) near the ranch road culverts in August of 2016, a second hotspot has been identified (Station 6) and efforts have been made to address three primary questions relating to cause:

- **Are the Bird Creek impacts related to the seven nearby UIC Class II injection wells shown in Table 1?**
- **If so, can we determine the relative contributions from among the seven wells?**
- **What is the mechanism or pathway of fluid migration from them to the surface?**

Relevant efforts to date have determined:

- Fluids entering the creek are hot, high in total dissolved solids (TDS), and have had, at times, oily sheens and bubbles (which are consistent with some oilfield chemical additives). Multiple measuring locations, both upstream and downstream, have confirmed there is at least one additional location (Monitoring Station 6, MS6, approximately ½ mile downstream of MS2) with high TDS levels and temperatures. No impacts have been detected upstream from the injection wells and the original location.
- The site is remote, with limited access through locked gates. There have been no reported or observed illegal disposal activities. These factors, coupled with the long time-frame of impacts to the creek, and rebounding TDS concentrations after flushing by stormwater, eliminates a surface source due to recent dumping of produced water.
- Anion/cation analysis of the water collected from the initial high TDS location in the creek confirm a geochemical fingerprint (using Stiff diagrams, Figure 2) consistent with produced formation fluids (i.e., brine, salt water) from the Mississippian Formation, which receives injected brine for both disposal and enhanced oil recovery.
- One of the two nearest injection wells is owned by Jireh Resources (well ID 18W, OS6320). It failed mechanical well integrity (at a reported 900' below ground surface (BGS) or shallower). This well was repaired and resumed injection the first week of September 2016. It injects comparatively high volumes of brine (reported up to 80,000 barrels/month).
    - BIA salinity readings collected on a frequent basis at MS2 demonstrated declining TDS values after this repair, dropping from over 80,000 ppm in August 2016 to 15,800 ppm on May 9, 2017.
- The other nearest injection well is owned by Novy Oil and Gas well (well ID 15, OS5258). It is a brine disposal well operated by Grayhorse Operating. On May 4th, Osage Inspector Andrew Yates determined, with the operator present, that the well failed mechanical integrity and required repair. Grayhorse shut-in this well on May 9th and began attempting repairs. 6EN issued a Termination of Authorization to Inject by letter dated May 24th. The operator has not been able to repair the well as of this time. This well had injected comparatively high volumes of brine.

    - BIA salinity readings collected on a frequent basis at MS2 demonstrated declining TDS values after this repair, dropping from 15,800 ppm on May 9th (date of well shut-in) to 4,900 ppm on May 18th.
- The Novy/Grayhorse well received a termination letter from 6EN and remains shut-in as of August 1, 2017, and the operator has notified EPA by email they are likely to plug and abandon the well.
- Five of the seven injection wells in the area passed annulus pressure tests in May, except for the Novy/Grayhorse well and the Jireh 9 well. However, these tests did not address the potential for movement behind the casing in the annular space.
- All of the injection wells were shut-in on Friday, June 9th, to allow for collection of static fluid levels beginning Monday, June 12th. Mississippian formation fluid levels were measured at approximately 600-700 feet below ground surface. This confirms that under non-injecting conditions, pressure does not exist in the Mississippian Formation in this area at sufficiently high levels to cause migration of formation fluids to the surface. The operators were requested to perform a "staggered startup," with higher priority wells beginning injection first. Other injection wells were requested to restart on a 48-hour interval. It was hoped that the in-stream monitoring of water quality may show measurable impacts associated with the restart. Injection well operation delays effectively prevented the staggered startup from happening as planned. Lower post shut-in volumes being injected by operators have also been reported.
- Initial analysis of the instream monitoring data from May 25, 2017, through July 2, 2017, indicate that in at least three locations, cyclic variations in TDS concentrations appear before the shut-in period, level out during the shut-in period, then resume slowly as injection resumes and formation pressures rebuild after June 15th. These data appear to demonstrate a change in water quality in the stream occurs when injection wells are operating. The amplitude (degree of variability) of short term concentration fluctuations at some stations diminished during the shut-in period, especially at MS3. This clearly seems to indicate a correspondence with the injection activities.
- Limited field monitoring (with a hand held probe) of in-stream TDS levels during the start-up of injection activities after shut-in showed only one reading with slightly elevated levels (less than 810 ppm; background was approximately 480-500 ppm) was present in the original location (MS2), but continued to be high (approximately 46,000 ppm) at the downstream location (MS6). This is consistent with the automated in-stream monitoring data.

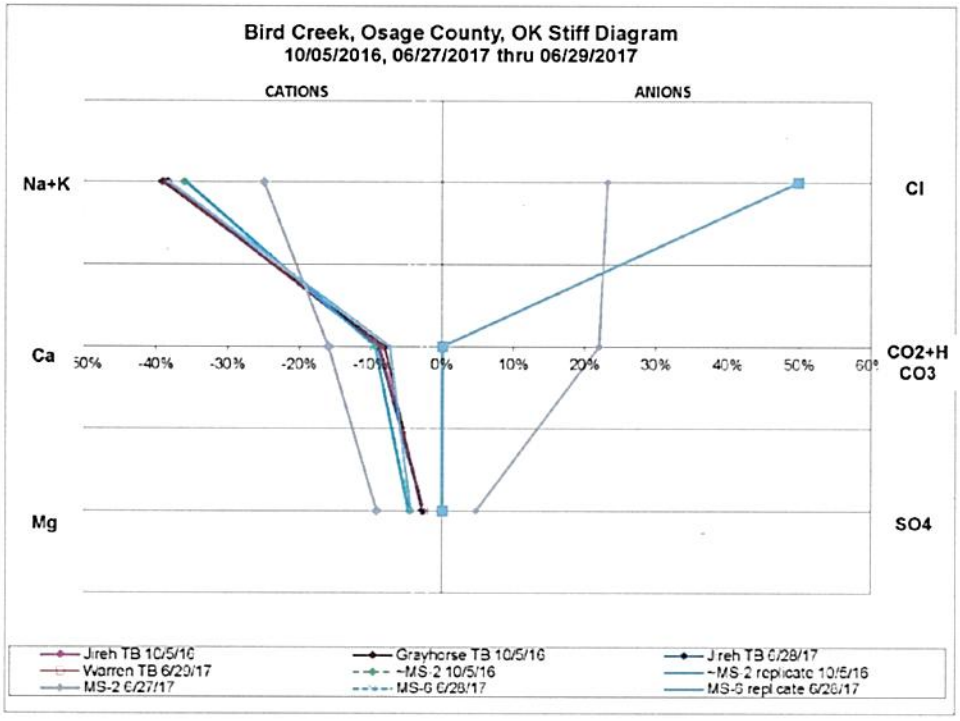
At this point, the first question (Are these impacts related to the seven nearby UIC Class II injection wells shown in Table 1?) has been answered with reasonable certainty. Yes.
Based on multiple lines of evidence, EPA has concluded that the formation fluids are migrating to the surface under pressure caused by injection well operations.

- The anion/cation samples of brine collected from MS2 (the original location of in-stream impacts) and two of the injection wells is a geochemical match to the Mississippian Formation fluids as indicated by a Stiff diagram (Figure 2).
- Due to the static fluid levels being well below ground surface, Mississippi Formation water cannot migrate from depth to the surface without additional pressure, which can be provided by injection operations.

- The observed oil sheen and bubbles on the surface of the creek are consistent with oilfield additives.
- Based on the remote location with limited access, the persistence of the impacts, the reappearance after flushing by heavy rainfall events, and the lack of any stressed vegetation or witnesses reporting any suspicious activities, recent surface dumping has been eliminated as a potential source. Historic surface dumping prior to 1937 is indicated by aerial photo analysis, but is not considered the primary source of recent contamination events.
- In-stream monitoring data show declining concentrations at MS2 after repair of one injection well and cessation of another. Both wells had failed MITs.
- In-stream monitoring data before, during and after the shut-in of injection operations appears to show a correspondence at multiple locations between cyclic pulses of TDS concentration variations and injection well activities.

At this time, EPA is unaware of any information which contradicts this conclusion.

Figure 2



Page 1 of 2

Note: some lines on diagram not discernable because of overlap.

Activities which have been, or may be in the near future, conducted by EPA.

- In-stream monitoring of the tributary to Bird Creek by automated equipment (i.e., sondes) began in May 2017. Ten monitoring stations (MS) have been established, with data being collected every 15 minutes for conductivity and temperature. At eight of stations, which are located in the deeper parts of the creek, the height of the water column is also being measured by a second, deeper sonde to assess stream flow conditions. Data is recorded within the sondes' onboard memory storage and requires a manual retrieval and download. The first data download occurred the week of June 26th. Additional data downloads are expected monthly.
- Water quality samples from the stream were collected the week of June 26th to continue to assess impacts for refinement of the conceptual site mode, trend analysis, and exposure control.
- Responses from the information requests sent to operators are being used to select analytes that may help discern whether specific injection wells are sources.
- Surface mapping of electrical resistivity (using the Geometrics OhmMapper™) in the shallow subsurface soils/rock near the original impacted location was conducted on a limited scale in October 2016. Additional mapping with the OhmMapper™ device may be planned for areas of interest in August. This will include targeting the two identified in-stream hot spots (MS2 and MS6), and at least one of three areas identified through aerial photos as having stressed vegetation and high soil salinity levels.
    - Oil and gas drilling in Osage County has occurred since the late 19th century, increasing the likelihood of undocumented wellbores that could serve as conduits upward brine flow from deeper formations (http://www.okhistory.org/publications/enc/entry.php?entry=OS006). Utilizing historical aerial photography dating as far back as 1937, several local areas of persistently stressed vegetation were identified, possibly indicating past oilfield activity. In recent (June 2017) field screening evaluations at three of these locations, anomalously high salt concentrations (up to 3,300 ppm in solute) were found in shallow soil samples, and salt crystals were observed in the soil at one location. This location (on top of a hill near MS2) is suspected to be in close proximity to an improperly plugged wellbore.
- Soil sampling of the areas with stressed vegetation and high soil salinity levels is planned in conjunction with the electrical resistivity survey.
- Regional staff may utilize a down-hole camera to inspect the casing of the Novy/Grayhorse well (OS5258).
- Research staff at EPA's Ground Water and Ecosystems Restoration Division at the Robert S. Kerr Lab staff in Ada, OK, were consulted on June 27th to review information gathered to date and evaluate future actions to identify potential individual sources and migration pathways.
    - Both regional and Ada staff believe dye/tracer studies are unlikely to be useful due to the depth and distances involved in this project, along with numerous geologic uncertainties. The potential for false negatives is very high.
    - It was agreed that utilizing resistivity surveys to identify high conductivity areas due to brine contamination, and/or metallic signatures of well bores, would be preferred. Identifying where the brine is migrating to surface will allow a better understanding of the pathway, potential impacts and risks, and guide further actions.
    - A phased approach initially utilizing Regional personnel and equipment (i.e., the OhmMapper™) could be used to evaluate the areas around the two impacted creek

locations and multiple surface targets identified through historical aerial photograph analysis.

- After results of the shallow resistivity are reviewed, if appropriate areas of interest are identified, a second phase of investigation may be planned, if resources are available. This could be conducted by Ada staff or through Oklahoma State University (contractor support). This phase of investigation will use a traditional resistivity array of very long cables with electrodes fixed into the ground every 10-20 feet. The Ada system (which may not be functional) is capable of evaluating to depths of ≈ 180 feet or more, while OSU can reach depths exceeding 300 feet.

The second and third questions ("If so, can we determine relative contributions from among the seven wells?" and "What is the mechanism or pathway of fluid migration from them to the surface?") have not been answered conclusively, but information gathered to date is useful in guiding further efforts. ***Note: It may not be possible to answer these two questions with reasonable certainty with the currently available resources.***

Information that led to the conclusion that the breakouts of brine are related to the injection well operations also informs the Conceptual Site Model (CSM) development. There are two broad initial concepts, both of which involve a horizontal migration from the injection wells to a location nearer the surface impact sites, and then vertical migration, likely through a preferential pathway:

CSM Approach 1: Injection of produced brine back into the Mississippian Formation raises the hydrostatic pressure to the point that brine is capable of being pushed to the surface from the Mississippi Formation. Pressure increases causing purges to the creek are believed to originate from multiple injection wells, and under this model would have been transmitted horizontally within the injection zone then vertically along a conduit near the creek. Possible conduits include undocumented wellbores or a fault.

CSM Approach 2: Loss of mechanical integrity in injection wells allowed injected brine to enter into a shallower zone (casing leak) and migrate horizontally and possibly vertically, via a preferential pathway(s), to the surface locations. Mechanical integrity can be lost internally (casing, tubing, or packer leaks) or externally (failure of cement behind casing that allows upward flow along the injection wellbore). Internal mechanical integrity is determined by annulus pressure tests, which were conducted on all five of the seven suspect wells in May 2017. UIC Class II program requirements allow cement records for well construction to meet the external mechanical integrity requirement. Region 6 records indicate all seven suspect wells meet the minimum standard for casing cement. The fact that the seep samples so closely match Mississippi Formation water indicates there was little mixing with other formation fluids, as would be expected with great distances of travel through a shallower formation. However, external mechanical integrity failure cannot be ruled out. Other external mechanical integrity testing methods exist and could be required on the suspect wells.

Since no ground surface purges have been identified, the loss of mechanical integrity scenario would require this shallower zone to be a confined or semi-confined formation in order for the injected fluids to transmit enough pressure horizontally to initiate flow to the creek via a nearby vertical conduit. Two of the wells, Jireh Resources EOR well 18W (OS6320) and Novy/Grayhorse disposal well 15 (OS5258) have both lost internal mechanical integrity in the timeframe of interest. The Jireh well was repaired in September 2016, shortly after the confirmation of the surface water impacts by EPA in August. The

Novy/Grayhorse disposal well was found by a field inspector to not have internal well integrity in on May 4, 2017, ceased injections on May 9th, and was issued a termination of authorization to inject on May 24th. The operator attempted to pull the tubing, but due to massive corrosion, the tubing string broke several hundred feet below the ground surface and the lower section has not been able to be retrieved. The well has not been able to be repaired and remains out of service. The condition of the casing is unknown, but the demonstrated level of corrosive effects on the tubing, along with potential damages during attempts to retrieve the broken injection tubing string, raise serious concerns about the casing integrity.

Factors Common to Both CSM Approaches:

- Geologic maps of the area show the presence of multiple faults, supporting the existence of secondary porosity and permeability features (fractures) within the Mississippian formations, which could serve as preferential pathways of injection fluid migration.
- The forensic match (Stiff diagram, Figure 2) shows the in-stream brine originated in the Mississippian.
- Disposal of produced fluids at the surface has been ruled out due to multiple factors.
- The high temperature of the brine in the stream may show it migrates from depth (where it is hot due to the geothermal gradient) to the surface fairly quickly. This would necessitate the presence of a preferential pathway(s) to the surface, which could be an unknown, improperly plugged well bore (or well bores), or an unknown fault or fracture system.
- An alternative explanation of the high temperature in the stream comes from high-salinity solar ponds. Dense brine has been shown to absorb solar radiation much better than fresh water, and has been used as a solar heating system for electrical power generation plants. This solar heating may be creating a pool of hot, dense water in the deeper areas of the stream, thus potentially eliminating the need for a quick migration to the surface from depth through a preferential pathway. However, solar ponds typically use significantly higher salinity concentrations and achieve significantly higher temperatures. Evaluation of temperatures through seasons (and thus shorter vs. longer days and corresponding variations in incoming solar radiation) could help determine the potential for this mechanism to explain the high instream temperatures. If this is the mechanism for heating, a release into the shallow ground water would not require a preferential pathway or confined shallow aquifer zone to explain the high temperature.
- Based on in-stream monitoring before, during and after the shut-in testing, and two mechanical integrity failures (Jireh Well 18W and Novy/Grayhorse (OS5258) well), it appears both the mechanical integrity pathway, and the formation pressure pathway, may be contributing to TDS concentrations in the stream.
- The observed correspondence between brine concentrations in some of the monitoring stations and the nearby injection well operations, considered with recent (May 2017) successful mechanical integrity demonstrations for all operating wells, appears to confirm that a hydrologic connection to the creek exists via a conduit from the injection formation near the creek (undocumented wellbore or fault).

In summary, multiple scenarios exist in terms of pathways from the injection wells to the creek. Due to complexities in the nature of the reservoir (fracture flow), multiple possibilities for conduits, (failed

MITs, undocumented wellbores or faults, etc.), and substantial costs and time, continued efforts to definitively identify the pathway are not feasible.

Communication Strategy

EPA will be contacting the following to ensure that the interested/affected parties are informed: Landowners, operators, Osage Nation, Osage Minerals Council, Solicitor's Office, BIA, City of Pawhuska, Osage County, Cattlemen's Association and Producer's Association.

Other Considerations

- It will likely take a significant amount of time once the source wells are addressed for all salt water seeps to decrease.
- For all response approaches, investigation of additional injection wells (beyond the current seven wells) may be needed if creek salinity levels don't moderate to acceptable level.
- Impacts to all stakeholders (e.g., tribes, operators, landowners) should be considered.
- If impacted oil operators can address the non-containment of the site, they can resume injection operations by re-applying for a permit.
- Annual mechanical integrity tests will be required on any of the seven suspect wells that continue to operate.
- Responsibility for conducting the in-stream monitoring of water quality in the future needs to be determined.

Does EPA have the authority to order shut-in of Class II injection wells?

Underground injection cannot result in the movement of contaminants into an underground source of drinking water. As such, the regulations clearly authorize EPA to order shut-in at both "authorized by rule" (ABR) and permitted wells if the wells fail to confine fluids to its authorized injection zone. The regulations also authorize EPA to terminate a permit if the permitted well activity endangers the environment.

40 CFR 147.2903 – Prohibition of unauthorized injection

- 40 CFR 147.2903(a) – any underground injection, except as authorized by permit or ABR, is prohibited.
- 40 CFR 147.2903(b) – No owner/operator shall construct, operate, maintain, convert, plug, or abandon any inject well or conduct any other injection activity
    - in a manner that allows *the movement of fluid containing any contaminant into underground sources of drinking water,*

- if the presence of that contaminant may cause the violation of any *primary drinking water regulation under 40 CFR Part 142 or may otherwise adversely affect the health of persons.*
- The *applicant for a permit shall have the burden of showing* that the requirements of this paragraph are met.

40 CFR 147.2912(c) - wells authorized by rule

- Injection wells or projects which have exhibited failure to confine injected fluids to the authorized injection zone or zones may be subject to restriction of injection volume and pressure, or shut-down, until the failure has been identified and corrected.

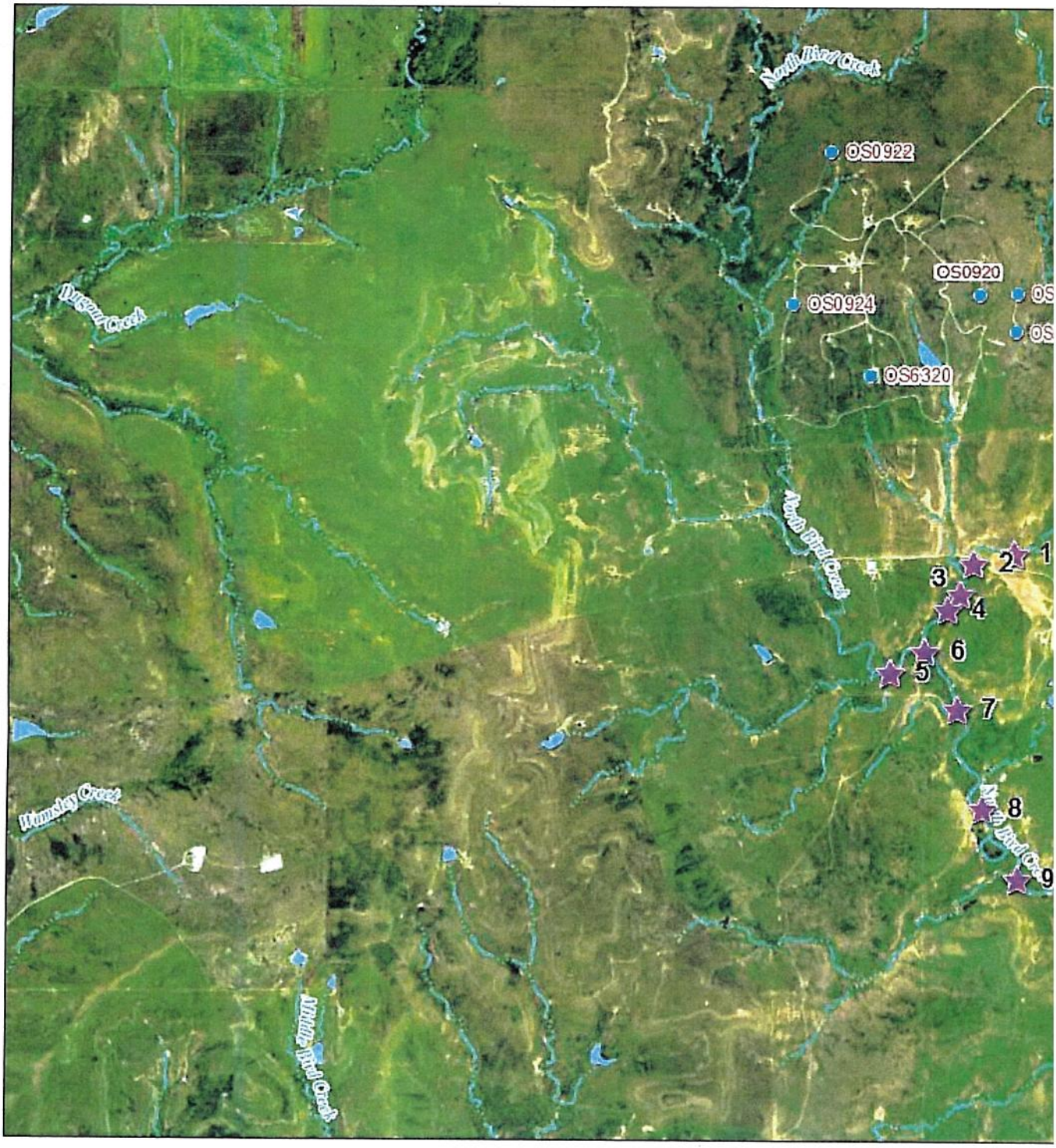
40 CFR 147.2920(d) – wells authorized by permit

- Injection wells or projects which have exhibited failure to confine injected fluids to the authorized injection zone or zones may be subject to restriction of injection volume and pressure, or shut-in, until the failure has been identified and corrected.

40 CFR 147.2928 – permit termination

- 40 CFR 147.2928(a)(3) – permit may be terminated if there is a determination that the permitted activity endangers human health or the environment.

Monitoring Station Locations and Injection Wells wit



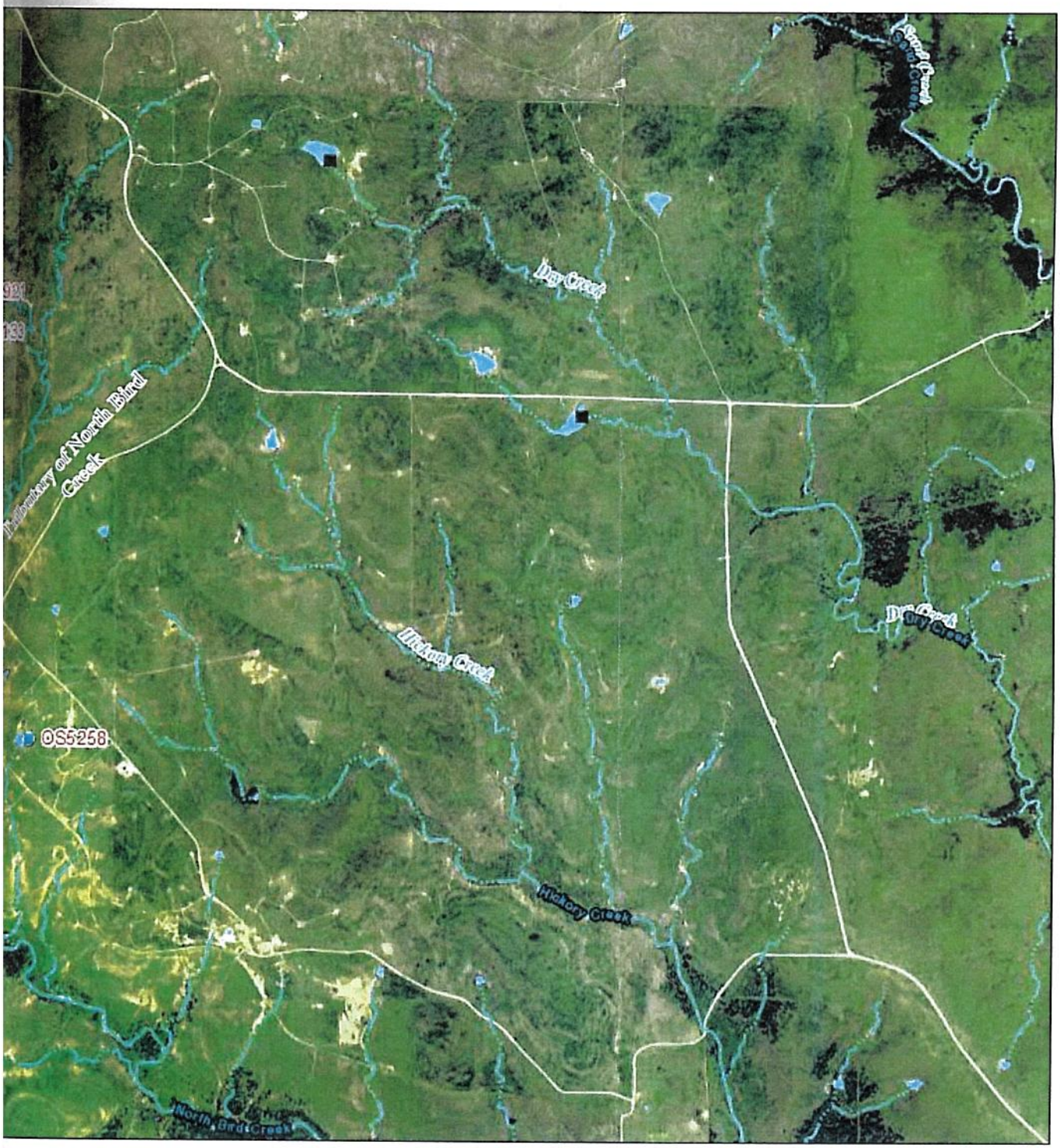
December 20, 2017

Injection Wells of Concern

In-Stream Monitoring Station

Note: The in-stream Monitoring Station No. 10 location is not shown on this map.

in North Bird Creek Area, Osage County, Oklahoma



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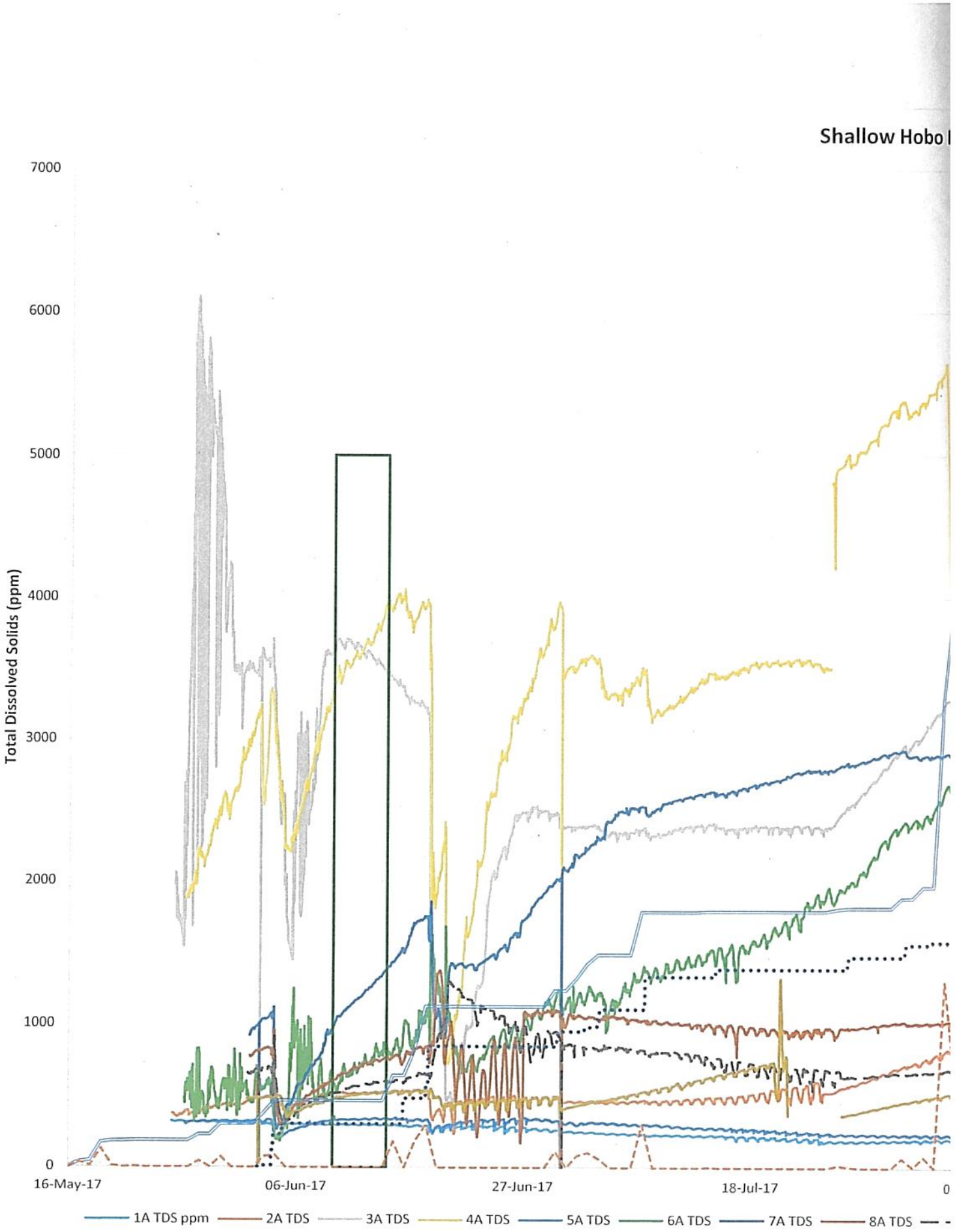
USGS The National Map: National Hydrography Dataset. Data Refreshed October, 2017.
Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, and the GIS user community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics,

U.S. Environmental Protection Agency, Region 6
Microsoft | USGS The National Map: National Hydrography Dataset. Data Refreshed October, 2017. | Esri, HERE, Garmin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16-May-17
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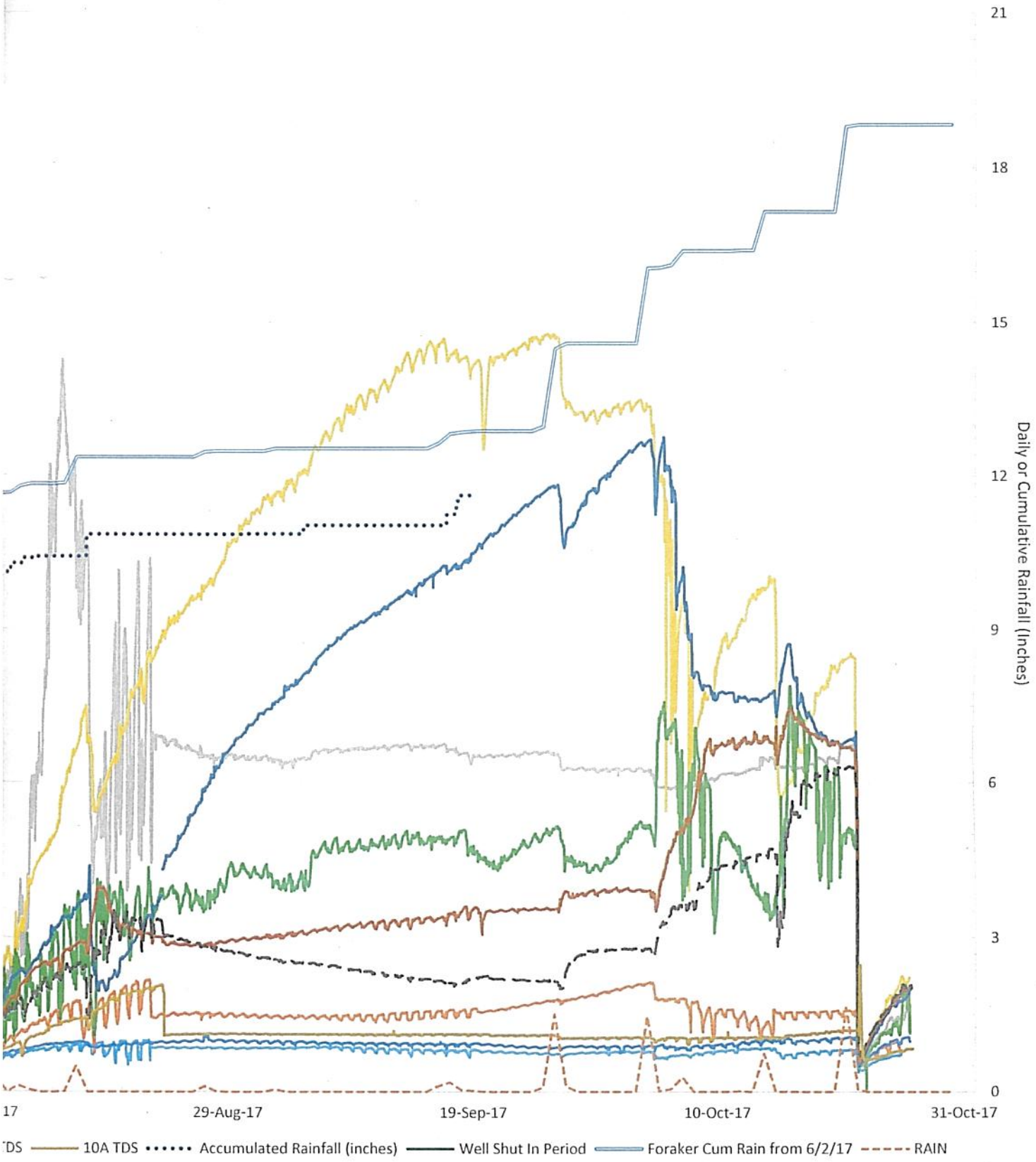
ta at Bird Creek



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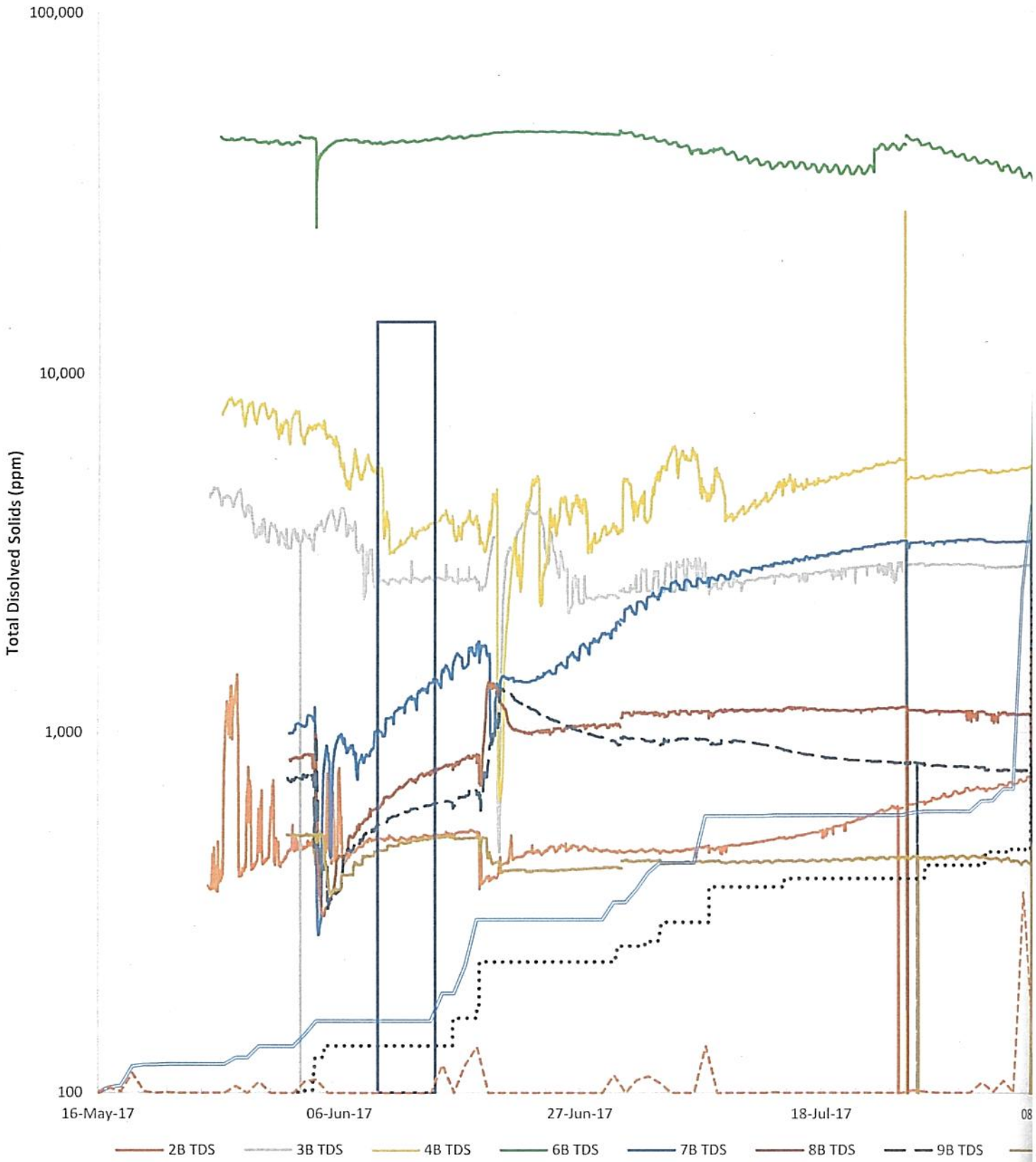
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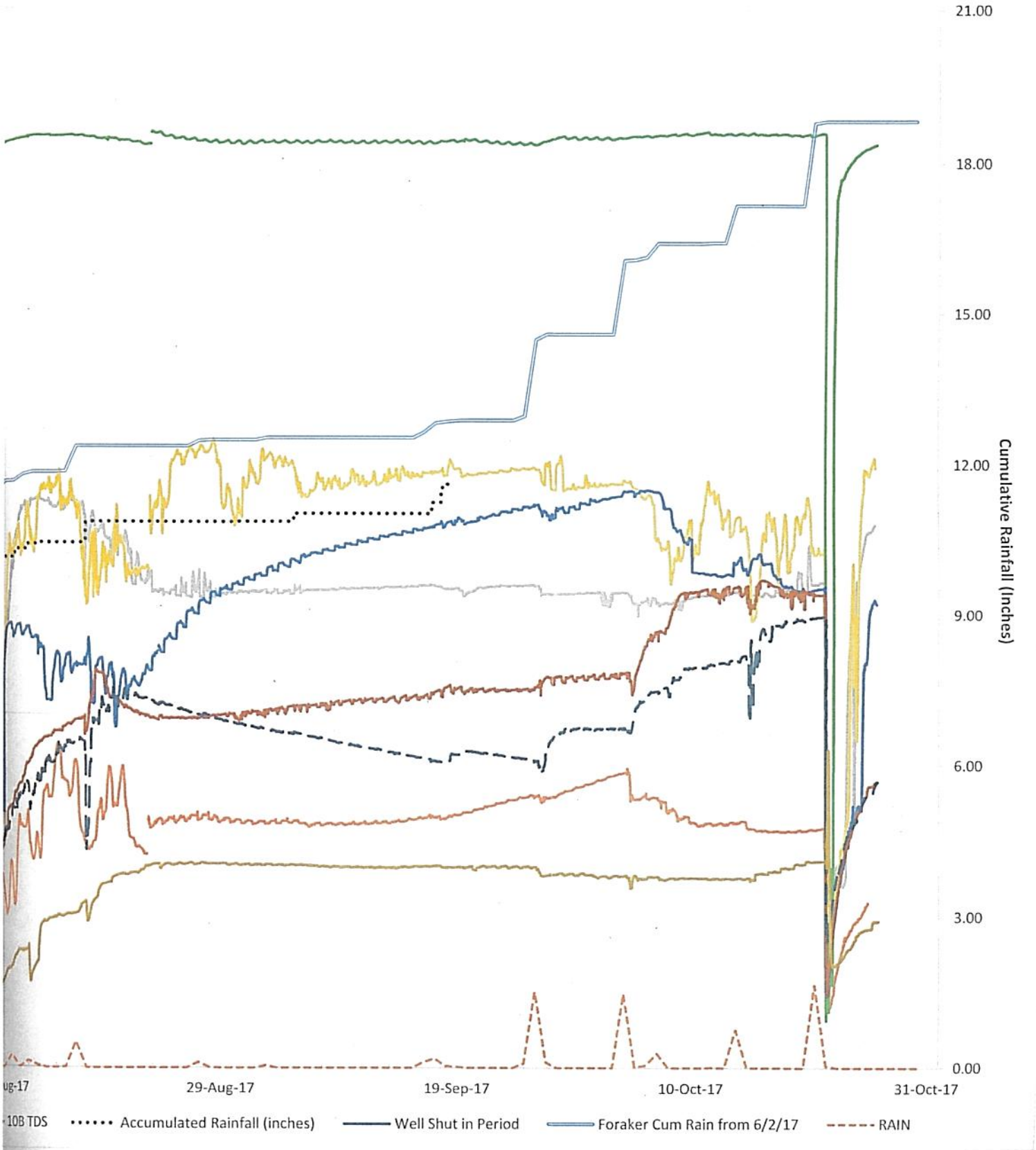
Total Disolved Solids (ppm)
16-May-17
06-Jun-17
27-Jun-17
18-Jul-17
2B TDS
3B TDS
4B TDS
6B TDS
7B TDS
8B TDS
9B TDS

at Bird Creek



UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 6
1445 ROSS AVENUE, SUITE 1200
DALLAS, TEXAS 75202-2733

PUBLIC NOTICE

Date Posted: AUG 0 8 2017

Comment Period Close Date: SEP 0 6 2017

Date Removed: SEP 0 6 2017

This is to give notice that the Environmental Protection Agency (EPA), Region 6, has proposed an administrative order (AO) to the Respondent shown below.

The AO is proposed by authority of the Safe Drinking Water Act (SDWA) which authorizes EPA to issue AO's for violations of Underground Injection Control (UIC) regulations. Relevant information concerning the proposed AO follows:

Docket Number: SDWA-06-2017-1110

Respondent: Jireh Resources, LLC
PO Box 701230
Tulsa, OK 74170

Inventory No.	Well No.	Location	Injection Formation
OS0922	9	NW/4, Sec. 01, T27N, R 7E	Mississippi Chat
OS0924	4W	SW/4, Sec. 01, T27N, R 7E	Mississippi Chat
OS6320	18W	SW/4; Sec. 01, T27N, R 7E	Mississippi Chat

Alleged Violations: Failing to confine injected fluids to the authorized injection zone [40 C.F.R. §§ 147.2912(c) and 147.2920(d)].

Proposed Penalty: None

Any person may review the AO and administrative record and submit written comments. Any person who comments on the AO will receive written notice of any public hearing on the AO and have a reasonable opportunity to be heard and present evidence at the hearing.

The AO and administrative record are available for review Monday through Friday between 8:00 a.m. and 4:00 p.m. at the address shown below:

U.S. EPA, Region 6
1445 Ross Avenue, Suite 1200
Dallas, TX 75202-2733

Written comments and requests for a public hearing must be submitted within the comment period shown above to:

Regional Hearing Clerk (6RC-D)
U.S. EPA, Region 6
1445 Ross Avenue, Suite 1200
Dallas, TX 75202-2733

The Respondent in this action may request a public hearing. If the Respondent requests a hearing, those persons who have commented during the comment period will be notified of the hearing and may appear at the hearing to present evidence on the appropriateness of the AO and penalty assessment. A final order will be issued after the close of the comment period unless a public hearing is requested by the Respondent. The final order will be effective 30 days after issuance unless a person who commented on the AO appeals the final order.

Additional information may be obtained by sending a written inquiry to the EPA at the address shown above or by telephoning (214) 665-7328.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 6
1445 ROSS AVENUE, SUITE 1200
DALLAS, TEXAS 75202-2733

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The AO is proposed by authority of the Safe Drinking Water Act (SDWA) which authorizes EPA to issue AO's for violations of Underground Injection Control (UIC) regulations. Relevant information concerning the proposed AO follows:

Docket Number: SDWA-06-2017-1111

Respondent: Warren American Oil Company, LLC
6585 S. Yale Ave., Suite 800
Tulsa, OK 74136

Inventory No.	Well No.	Location	Injection Formation
OS0920	B7	SE/4, Sec. 01, T27N, R 7E	Mississippi Chat
OS0921	B8	SE/4, Sec. 01, T27N, R 7E	Mississippi Chat
OS5133	B9	SE/4, Sec. 01, T27N, R 7E	Mississippi Chat

Alleged Violations: Failing to confine injected fluids to the authorized injection zone [40 C.F.R. §§ 147.2912(c) and 147.2920(d)].

Proposed Penalty: None

Any person may review the AO and administrative record and submit written comments. Any person who comments on the AO will receive written notice of any public hearing on the AO and have a reasonable opportunity to be heard and present evidence at the hearing.

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REGION 6
1445 ROSS AVENUE, SUITE 1200
DALLAS, TEXAS 75202-2733

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The AO is proposed by authority of the Safe Drinking Water Act (SDWA) which authorizes EPA to issue AO's for violations of Underground Injection Control (UIC) regulations. Relevant information concerning the proposed AO follows:

Docket Number: SDWA-06-2017-1112

Respondent: Novy Oil and Gas, Inc.
651 South 247th St. West
Goddard, Kansas 67052

Inventory No.	Well No.	Location	Injection Formation
OS5258	15	NW/4, Sec. 18, T27N, R 8E	Mississippi Chat

Alleged Violations: Failing to confine injected fluids to the authorized injection zone [40 C.F.R. §§ 147.2912(c) and 147.2920(d)].

Proposed Penalty: None

Any person may review the AO and administrative record and submit written comments. Any person who comments on the AO will receive written notice of any public hearing on the AO and have a reasonable opportunity to be heard and present evidence at the hearing.

The AO and administrative record are available for review Monday through Friday between 8:00 a.m. and 4:00 p.m. at the address shown below:

U.S. EPA, Region 6
1445 Ross Avenue, Suite 1200
Dallas, TX 75202-2733

Written comments and requests for a public hearing must be submitted within the comment period shown above to:

Regional Hearing Clerk (6RC-D)
U.S. EPA, Region 6
1445 Ross Avenue, Suite 1200
Dallas, TX 75202-2733

The Respondent in this action may request a public hearing. If the Respondent requests a hearing, those persons who have commented during the comment period will be notified of the hearing and may appear at the hearing to present evidence on the appropriateness of the AO and penalty assessment. A final order will be issued after the close of the comment period unless a public hearing is requested by the Respondent. The final order will be effective 30 days after issuance unless a person who commented on the AO appeals the final order.

Additional information may be obtained by sending a written inquiry to the EPA at the address shown above or by telephoning (214) 665-7328.