WELL STIMULATION TREATMENT ANNUAL REPORT

Program Assessment
NOVEMBER 18, 2024

Reporting Period: January 1, 2021, to December 31, 2021
Prepared Pursuant to Senate Bill 4 (Ch. 313, Stats. of 2013)

Gavin Newsom, Governor, State of California
Gabe Tiffany, Acting Director, Department of Conservation

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ACRONYMS, ABBREVIATIONS & UNITS

ADSA	Axial Dimensional Stimulation Area
BBLS	barrels
CalGEM	California Geologic Energy Management Division
CAP	Corrective Action Plan
CAS	Chemical Abstract Service
CARB	California Air Resources Board
CCR	California Code of Regulations
CEQA	California Environmental Quality Act
DOF-OSAE	Department of Finance – Office of State Audits and Evaluations
EIR	Environmental Impact Report
FT	feet
IWSTN	Interim Well Stimulation Treatment Notice
LLC	Limited Liability Corporation
µg/L	micrograms per liter
mg/L	milligrams per liter
pCi/L	picocuries per liter
PRC	Public Resources Code
RF	Recovered Fluid Sample
SB 4	California State Senate Bill 4 (Pavley, Ch. 313, Statutes of 2013)
SOP	Standard Operating Procedure
SRIA	Standardized Regulatory Impact Assessment
TVD	True Vertical Depth
UIC	Underground Injection Control
WST	Well Stimulation Treatment
WellSTAR	Well Statewide and Reporting System

ABOUT THE CALIFORNIA GEOLOGIC ENERGY MANAGEMENT DIVISION

The California Geologic Energy Management Division (CalGEM) prioritizes the protection of public health, safety, and the environment in its oversight of the oil, natural gas, and geothermal operations in California. To do that, CalGEM uses science and sound engineering practices to regulate the drilling, operation, and permanent closure of energy resource wells. CalGEM also regulates certain pipelines and facilities associated with production and injection.

When CalGEM was established in 1915 (then known as the Division of Oil, Gas, and Geothermal Resources), the initial focus of regulation was the protection of oil and gas resources in the state from production practices that could harm the ultimate level of hydrocarbon recovery. Early CalGEM regulations included well spacing requirements and authority to limit production rates. In 2019, CalGEM's mission focus changed to prioritize the protection of public health and safety, environmental quality, and the reduction and mitigation of greenhouse gas emissions associated with the development of hydrocarbon and geothermal resources to meet the energy needs of the state.

CalGEM operates out of three districts to best serve the needs of the state: Northern, Inland, and Southern (**Figure 1**). Each district has its own offices where staff are available to assist the public and stakeholders. CalGEM districts are responsible for all field oversight of Well Stimulation Treatment (WST) operations, including witnessing pre-WST pressure tests and chemical spot-checks during stimulation. District duties also include a review of the 72-Hour Notification form and a final review of all relevant well logs prior to the start of the treatment.

For more information about CalGEM, visit CalGEM's website at: https://www.conservation.ca.gov/CalGEM.

All WST permit applications and post-WST data submissions are reviewed and approved by CalGEM headquarters WST program staff. For more information about WSTs, visit: https://www.conservation.ca.gov/calgem/Pages/WST.aspx

For questions regarding the content of this report, contact the Department of Conservation (DOC) Public Affairs Office at pao@conservation.ca.gov.

Figure 1: CalGEM District Locations Map

1.0 EXECUTIVE SUMMARY

This annual report satisfies the legislative reporting requirements of Senate Bill 4 (SB 4) [Pavley, Ch. 313, Statutes of 2013], implemented to regulate WST activities in California. Per Public Resources Code (PRC) section 3215(c), this report covers WST programmatic activities from January 1, 2021, through December 31, 2021, but also includes data collected since the initial implementation of interim SB 4 regulations beginning on January 1, 2014, and the adoption of permanent SB 4 regulations on July 1, 2015. WST data presented in this report are derived from operator disclosures (post-WST job reports) submitted to CalGEM per the requirements stated in PRC section 3160(b)(2). Operators have one year from the date of the WST permit to begin stimulation, and 60 days from the completion of the well stimulation to submit the WST disclosure form to CalGEM (PRC sections 3160(d)(4) and 3160(g)).

As defined in PRC section 3157(a), "well stimulation treatment" means a treatment of a well designed to enhance oil and gas production or recovery by increasing the permeability of the formation. Well stimulation is a short term and non-continual process for the purposes of opening and stimulating channels for the flow of hydrocarbons. WSTs include, but are not limited to, hydraulic fracturing, acid fracturing, and acid matrix stimulation. The regulation of WSTs in California began with the passage of SB 4, which was signed into law on September 20, 2013. On January 1, 2014, interim WST regulations were issued pending the development of permanent regulations. On July 1, 2015, permanent WST regulations went into effect and in September 2016, CalGEM issued its first WST permits under the permanent WST program.

Since the establishment of California's WST regulations, the number of WST permits issued has declined —. CalGEM denied 109 permit applications in 2021. A total of 19 stimulations were completed during the reporting period. The number of permits approved and wells stimulated in a year is not one-for-one because operators have one year from the date of permit issuance during which to perform the stimulation. Of the 19 wells stimulated in 2021, 18 were permitted in 2020, with only one permitted in 2021. All 19 wells stimulated during the reporting period occurred in mature oil fields located in western Kern County. These fields have seen well stimulation activities since before the implementation of the WST regulation in California. All stimulations performed in 2021 were located farther than 1500 ft away from populated areas, and the only neighbor notifications provided, as required by regulation, were to neighboring operators. CalGEM engineers were able to witness 17 out of the 19 stimulations. The stimulations performed in 2021 were completed without any reported

spills, incidents, or well failures. There was also no known seismic activity reported during this period. As per the statutory requirements of this annual report, any well or casing integrity loss related to WST was also reviewed; as with previous years, there were no such incidents related to WST operations in 2021.

The total volume of oil produced in 2021 from wells stimulated under approved WST permits was approximately 2.02 million barrels (BBLS) of oil—approximately 1.5 percent of the 137 million BBLS of total oil produced in California in 2021. CalGEM calculated the 2021 WST production volume by taking the production data from 710 wells stimulated since the start of the permanent WST regulatory regime in 2016 through the end of 2021.

In response to the findings and recommendations from the Department of Finance - Office of State Audits and Evaluations (DOF-OSAE) report that was published in November 2020, the WST program submitted a corrective action plan (CAP) in January 2021. The CAP included updates to CalGEM's risk evaluation process and standard operating procedure as recommended by DOF. In 2021, CalGEM completed its implementation of all identified corrective actions for the WST program. Overall, the DOF-OSAE report found that CalGEM's WST program fulfills its mandate to issue WST permits in compliance with statutory and regulatory requirements.

For the first time in WST history, CalGEM took enforcement actions against two operators in 2021. CalGEM issued two civil penalties to two operators for the violation of a WST permit condition related to air monitoring requirements set by the California Air Resources Board (CARB) for WST activities completed in 2019. CalGEM collected a total of $40,000 in fines from these penalties. CalGEM also issued a civil penalty in 2022 to one operator for violations of WST permit conditions related to air monitoring requirements for WST activities completed in 2018 and 2020. CalGEM received $160,000 in fines for these violations. In total, CalGEM received $200,000 in civil penalties for these violations. By the end of 2021, CARB had concluded its audit of all the disclosures submitted under WST.

2.0 INTRODUCTION

A WST is a treatment of a well designed to enhance oil and gas production and recovery by increasing the permeability of geologic formations containing oil and gas. Hydraulic fracturing is a type of WST as well as acid fracturing (hydraulic fracturing where acid is the primary WST fluid) and acid matrix stimulation (an acid treatment of a formation at low pressure that does not create fractures). However, stimulations that include acids are rarely completed in California and have only been performed 20 times (of 2,243 stimulations) since the beginning of the WST program in 2014. The last recorded acid fracturing stimulation was completed in August 2018.

Hydraulic fracturing is the most common type of WST used in California. The hydraulic fracturing process involves injecting a mix of fluids (primarily water), sand (proppant), and chemical additives at high pressure into an oil or gas reservoir. WSTs do not include steam flooding, water flooding, or cyclic steaming, which are Enhanced Oil Recovery (EOR) techniques. Instead, WST is a well completion technique typically completed before using the well to extract oil. Compared to EOR injections, WSTs are short-term, discrete injection operations designed to increase reservoir permeability.

WSTs became regulated in California with the passage of SB 4, which was signed into law on September 20, 2013. On January 1, 2014, interim WST regulations were issued pending the development of permanent regulations. On July 1, 2015, permanent WST regulations went into effect, with new WST permit application requirements, including requirements for review by multiple state and local government agencies, neighbor notifications, CEQA review, advanced notification for witnessing by regulatory agencies, seismic monitoring, and submission of a comprehensive post-stimulation report including recovered fluid sampling. In September 2016, CalGEM issued its first WST permits under the permanent WST program.

Since the permanent WST program started in 2016 through the end of 2021, CalGEM has issued a total of 790 WST permits, with a total of 710 completed. There has been no record of incidents, spills, well, or casing integrity losses related to any of the WSTs performed. In addition, no report of seismic events related to the stimulations has been recorded.

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3.0 WELL STIMULATION TREATMENT PROGRAM UPDATE

3.1 Department of Finance - Office of State Audits and Evaluations Audit

In 2019, Governor Newsom took action to "strengthen oversight of oil and gas extraction" and ensure that state regulations protect public health, safety, and the environment. Among these was a call for the DOF-OSAE to complete an independent audit of the permitting processes for WST, which focused on process compliance with state regulations and policies and strengthening operational processes and procedures. DOF-OSAE reviewed a total of 33 WST permits issued between January 1, 2019, and October 31, 2019. The DOF-OSAE's *Final Report – California Department of Conservation, Underground Injection Control and Well Stimulation Treatment Programs, Performance Audit*, was released on November 23, 2020.

The DOF-OSAE audit concluded that CalGEM's WST permitting process complied with the WST statutes and regulations. However, the findings indicated that improvement is needed to ensure that Axial Dimensional Stimulation Area (ADSA) review and risk assessment review determinations are supported and documented consistently, with better document retention.

CalGEM's Corrective Action Plan (CAP) submitted in January 2021 included the following updates: verification of 2xADSA documentation using CalGEM's map, identification of all wells in the surface projection within the 2xADSA (including wells that do not penetrate the 2xADSA as well as those that do), updating the risk assessment template used in the WST application to incorporate the updates, and ensuring that sufficient review documentation and files supporting the evaluation of WST risk are adequately retained and accessible. The permitting process standard operating procedure (SOP) has since been updated to reflect all these recommended changes. In 2021, CalGEM completed its implementation of all corrective actions identified in response to the audit findings.

The DOF-OSAE audit report can be found here:
https://esd.dof.ca.gov/reports/reportPdf/5631D3F7-882E-EB11-9121-00505685B5D1/California%20Department%20of%20Conservation%20Underground%20Injection%20Control%20and%20Well%20Stimulation%20Treatment%20Programs%20Performance%20Audit%20November%202020

3.2 Well Stimulation Phase-out

On May 21, 2021, CalGEM released for public comment a pre-rulemaking draft of regulations to end the issuance of all WST permits by January 2024.

The public notice of the draft WST permitting phase-out rulemaking can be found here: https://www.conservation.ca.gov/index/Documents/Public%20Notice%20-WST%20permitting%20phase-out.pdf

3.3 Enforcement Action

In April 2021, CARB issued letters of permit condition violation to Aera and California Resources Elk Hills, LLC (CRC) in relation to well stimulations conducted in 2019. CARB's audit of CalGEM-required public disclosures following WST operations revealed that there were chemicals used in 2019 stimulations that were not approved or previously monitored by CARB. CARB determined that Aera had three violations and CRC had one violation in calendar year 2019. CalGEM conducted its own investigation of the case and confirmed CARB's findings. Based on these findings, CalGEM issued a civil penalty order to each operator in August 2021. CalGEM collected $30,000 from Aera (Order 1213) and $10,000 from CRC (Order 1214). Based on subsequent evaluation by CARB of WST activity in 2018 and 2020, in February 2022, CalGEM issued a civil penalty of $160,000 to Aera for violations of WST permit conditions related to air monitoring requirements for WST activities completed in 2018 and 2020 (Order 1240). In total, CalGEM received $200,000 in civil penalties for these violations. By the end of 2021, CARB had concluded its audit of all the disclosures submitted under WST.

One of the reasons for the air monitoring requirement is to assess the impact on air quality from the chemicals used during WST on the surrounding area. These violations, though related to the chemical constituents used in stimulations, were not found to have caused wide spread harm as these occurred in mature oil fields with existing air pollutants. CARB's recent publication on air monitoring concluded that background oil field emissions may have air quality/health impacts; however, emitted volatile hydrocarbon concentrations during WST activities are at levels similar to general oil and gas production emissions and due to the short-term nature of the WST activities, emissions from WSTs are indistinguishable from background oilfield emissions.

4.0 WELL STIMULATION TREATMENT DATA REVIEW

This section documents and discusses WST data relative to the 2021 reporting period and the entire period of WST regulation (beginning January 2014).

4.1 Permitting and Completions

A total of 12 WST permits were issued during the 2021 reporting period. This represents an 85.5% decrease in issued permits from the previous reporting period (83 issued in 2020). The number of WST permits issued annually has generally decreased from a high of 226 permits issued in 2018. One hundred and nine WST permit applications were denied in 2021.

A total of 19 wells were stimulated during this reporting period (a 67% decrease from the 58 stimulations performed during the 2020 reporting period). This is also the lowest number of stimulations that have been completed in a calendar year since the implementation of the WST regulation in 2014. Additional information about permits issued and wells stimulated during the 2021 reporting period is provided in **Table B1**.

Since CalGEM started collecting WST data in 2014, the maximum number of stimulations completed occurred in 2015, with 730 stimulations (all performed under Interim Well Stimulation Treatment Notices [IWSTNs]). Under the permanent regulatory period, the largest number of stimulations completed annually under a WST permit was 245 in 2018. Overall, the number of wells stimulated annually has fluctuated throughout the regulated period but has decreased significantly since implementation of the interim WST regulations in 2014. The decline in completed stimulations results from many factors, including financial decisions made by operators in response to the per barrel price of oil. In addition, the October 2021 court suspension of Kern County's oil and gas zoning ordinance[1] has impacted the issuance of new permits in Kern County, where well stimulations are predominately performed in California, and as such, has reduced the number of WST permit applications received by CalGEM.

[1] On October 22, 2021, the court in Vaquero Energy Inc. v. County of Kern, Kern County Superior Court Nos. BCV-15-101645-GP, -10053-GP, and 100536-GP, ordered Kern County to suspend operation of the March 2021 Revisions to the Kern County Zoning Ordinance (2021 Ordinance), and to cease reviewing and approving oil and gas permits under the 2021 Ordinance unless and until the court determines that the 2021 Ordinance complies with CEQA requirements.

A total of 2,243 stimulations have been completed since the implementation of WST regulations in 2014. A total of 1,533 stimulations (68.3% of the total) were completed under IWSTNs between January 2014 and June 2016. A total of 710 stimulations have been completed under permits issued during the permanent WST program, which went into effect July 1, 2015. The first permit under the permanent WST program was issued in September 2016.

Figure 2 depicts permits issued annually from 2016 to 2021. This chart also includes counts of permits that have been canceled by operators or denied by CalGEM. **Figure 3** depicts counts of well stimulations performed annually from 2014 to 2021 based on whether the stimulation was performed under an IWSTN or WST permit.

Figure 2: Well Stimulation Treatment Permit Status (2016 – 2021)

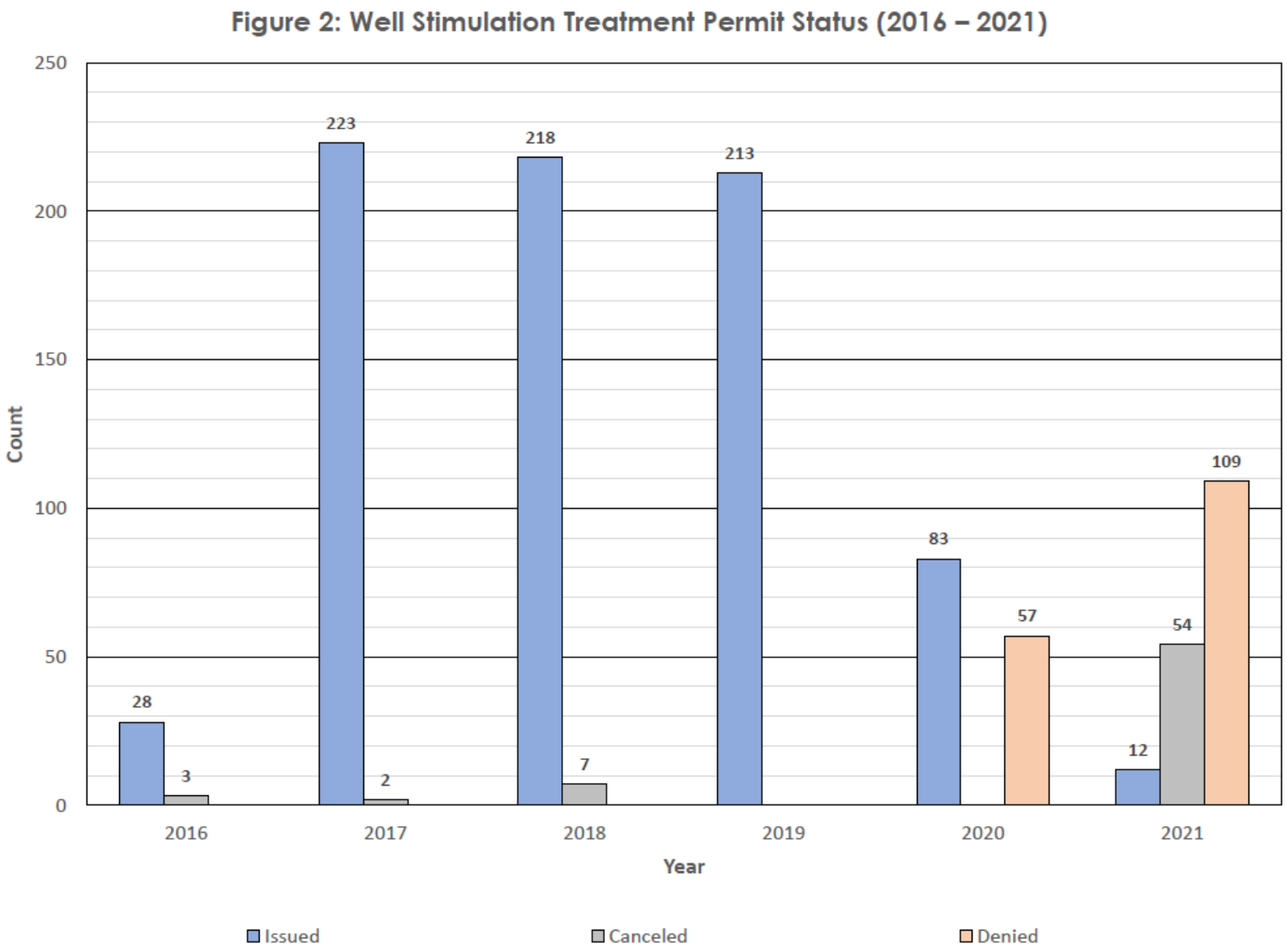

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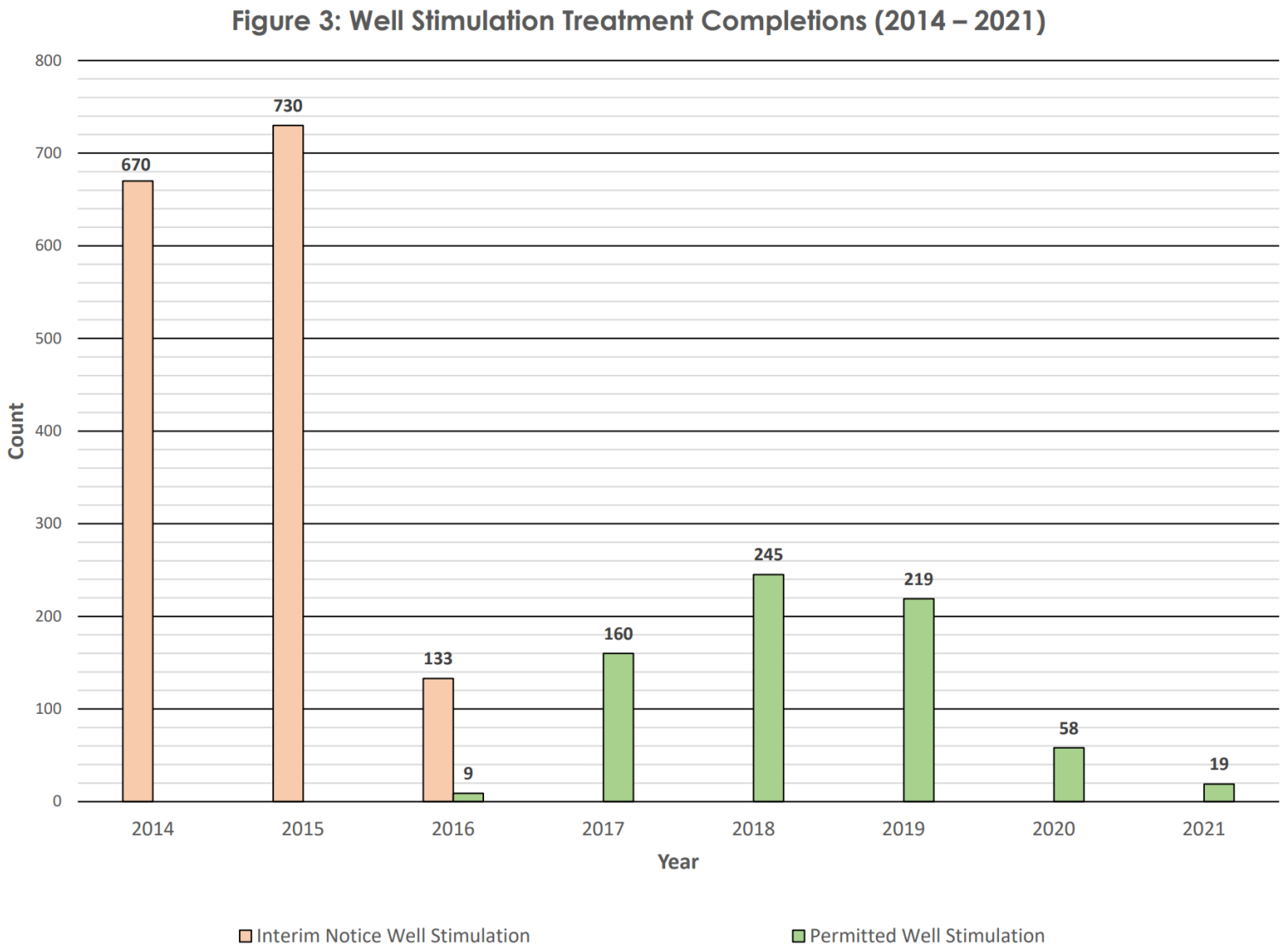
Figure 3: Well Stimulation Treatment Completions (2014 – 2021)



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4.2 Well Stimulation Treatment Locations

Oil and gas operators use well stimulations to improve the flow of fluids and gasses because the pore spaces in the rocks making up these reservoirs are too small and disconnected to allow continuous flow to the well (more geologic detail can be found on these formations in Section 4.8). In 2021, stimulations were limited geographically to three mature oil fields in western Kern County, located within CalGEM's Inland District. Of the19 wells stimulated during the reporting period, 12 were completed in the Lost Hills field, one in the North Belridge field, and six in the South Belridge field. WSTs were performed in these fields due to the low permeability of these oil reservoirs' geologic formations. Without the assistance of stimulation, it is not feasible to produce oil from portions of these fields.

Figure 4 graphically depicts the number of stimulations completed by field during the reporting period, as well as during the entire WST regulation period (beginning in 2014). As shown, the number of oil fields where WSTs have been completed has decreased since the implementation of SB 4 regulations.

The North Belridge and South Belridge fields are relatively remote, with wells stimulated in 2021 located further than five miles from populated areas. However, the stimulations completed in the Lost Hills field are in proximity to the town of Lost Hills, located in Kern County. Of the stimulated wells in 2021 in this field, the closest is approximately 2,100 feet from the nearest potential receptor. **Figure 5** provides a regional map showing all WST locations completed in 2021. **Figures 6 through 8** illustrate the detailed views of each stimulated field.

Each field-specific map provides the wellhead locations of well stimulations completed in 2021, with locations color-coded by the operator that performed the stimulation. Each location is bounded on the map by a 1,500-feet boundary, which depicts the Neighbor Notification area identifying the location of landowners or tenants to whom notification must be sent that a WST is occurring in the area. This required Neighbor Notification also provides the opportunity to request water sampling of existing wells or surface water bodies (Neighbor Notifications are discussed in more detail in Section 5). As is shown in each field-specific map, notification areas are fully encompassed by existing oil field boundaries and do not overlap any populated area boundaries. This indicates populated areas are a minimum of 1,500 feet (approximately 0.25 miles) from all wells stimulated in 2021.

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Figure 4: Well Stimulation Treatment Completions by Field (2014 – 2021)

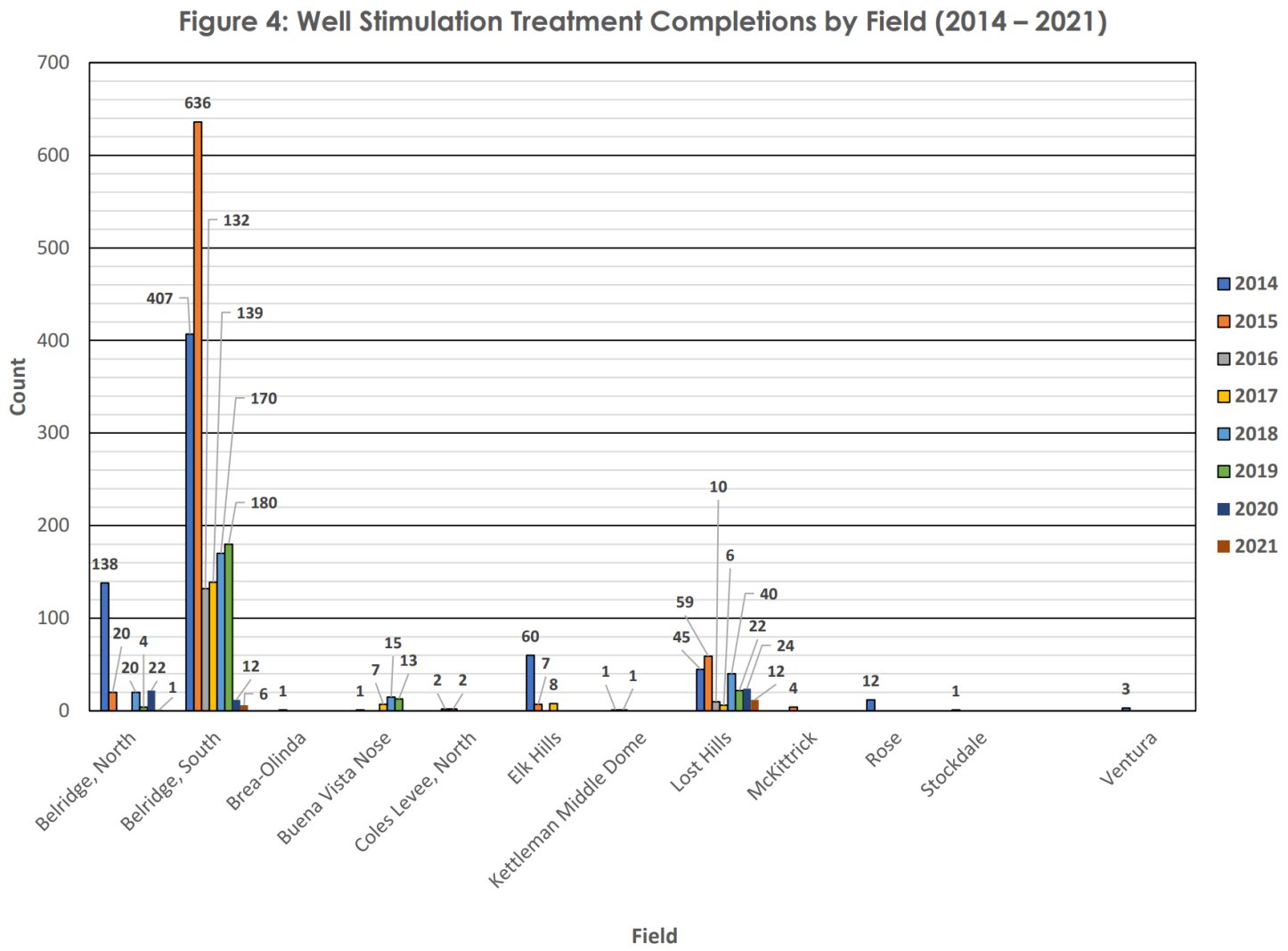

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Figure 5: Well Stimulation Treatment Locations

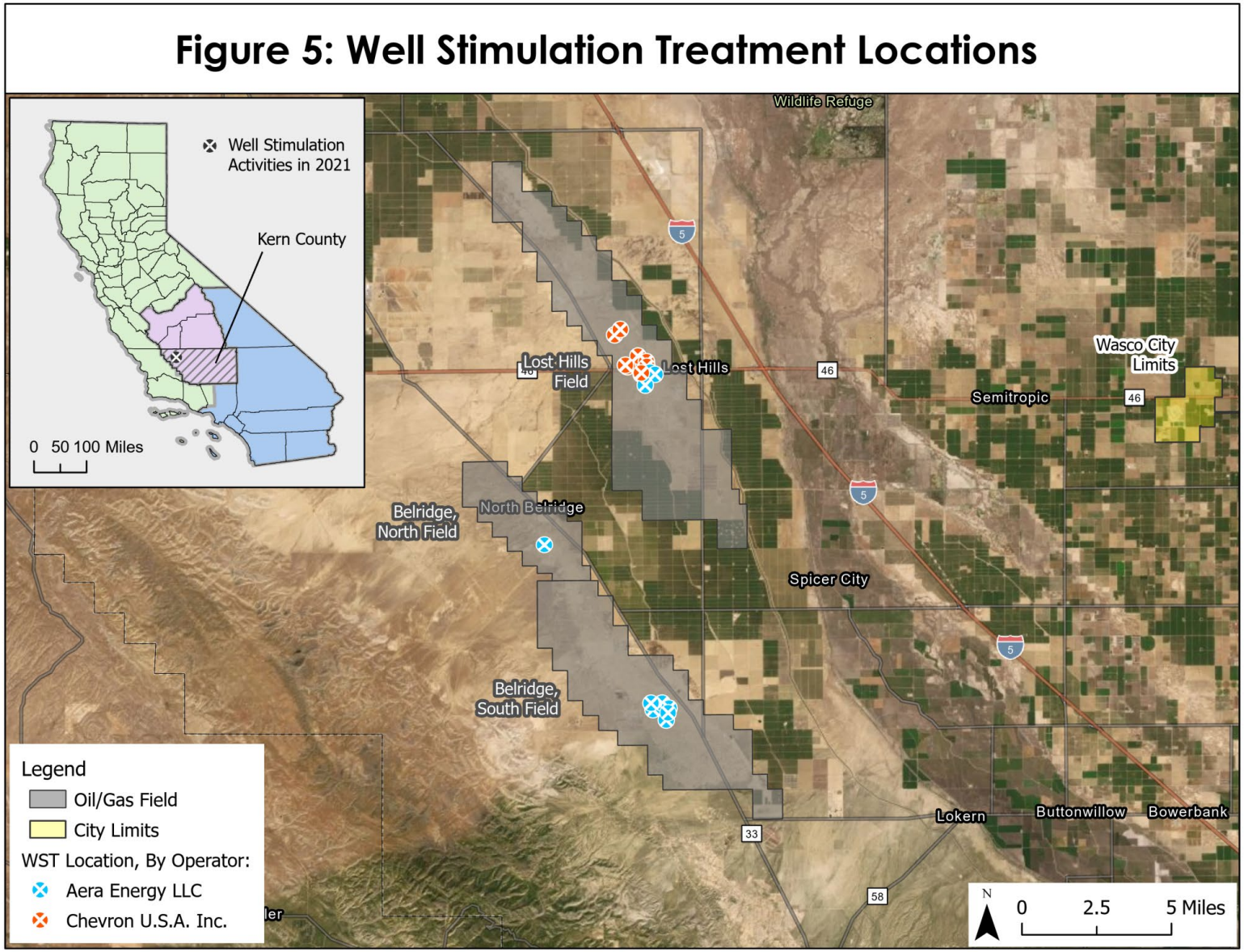

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Figure 6: Well Stimulation Treatment Locations – Lost Hills Field

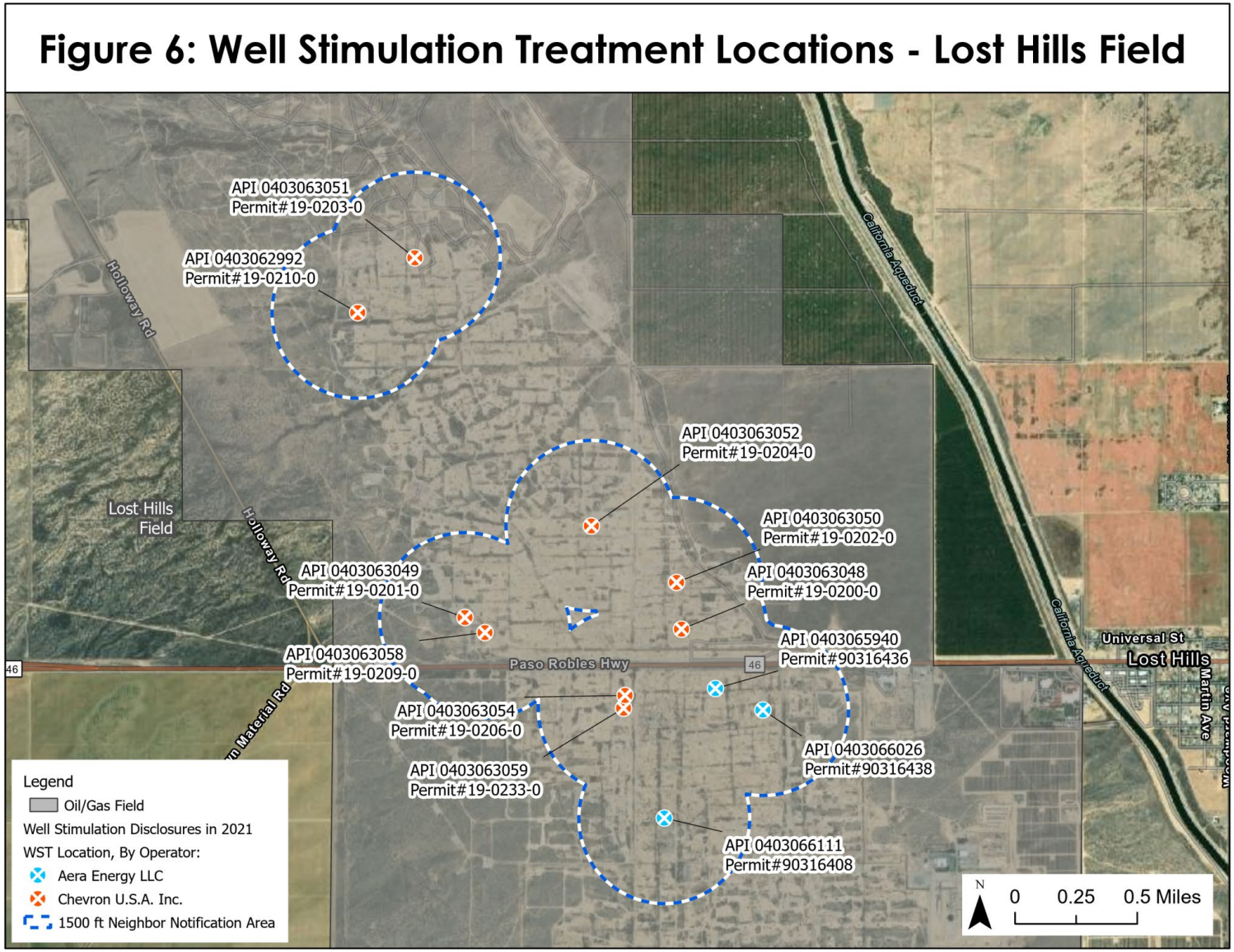

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Figure 7: Well Stimulation Treatment Locations – North Belridge Field

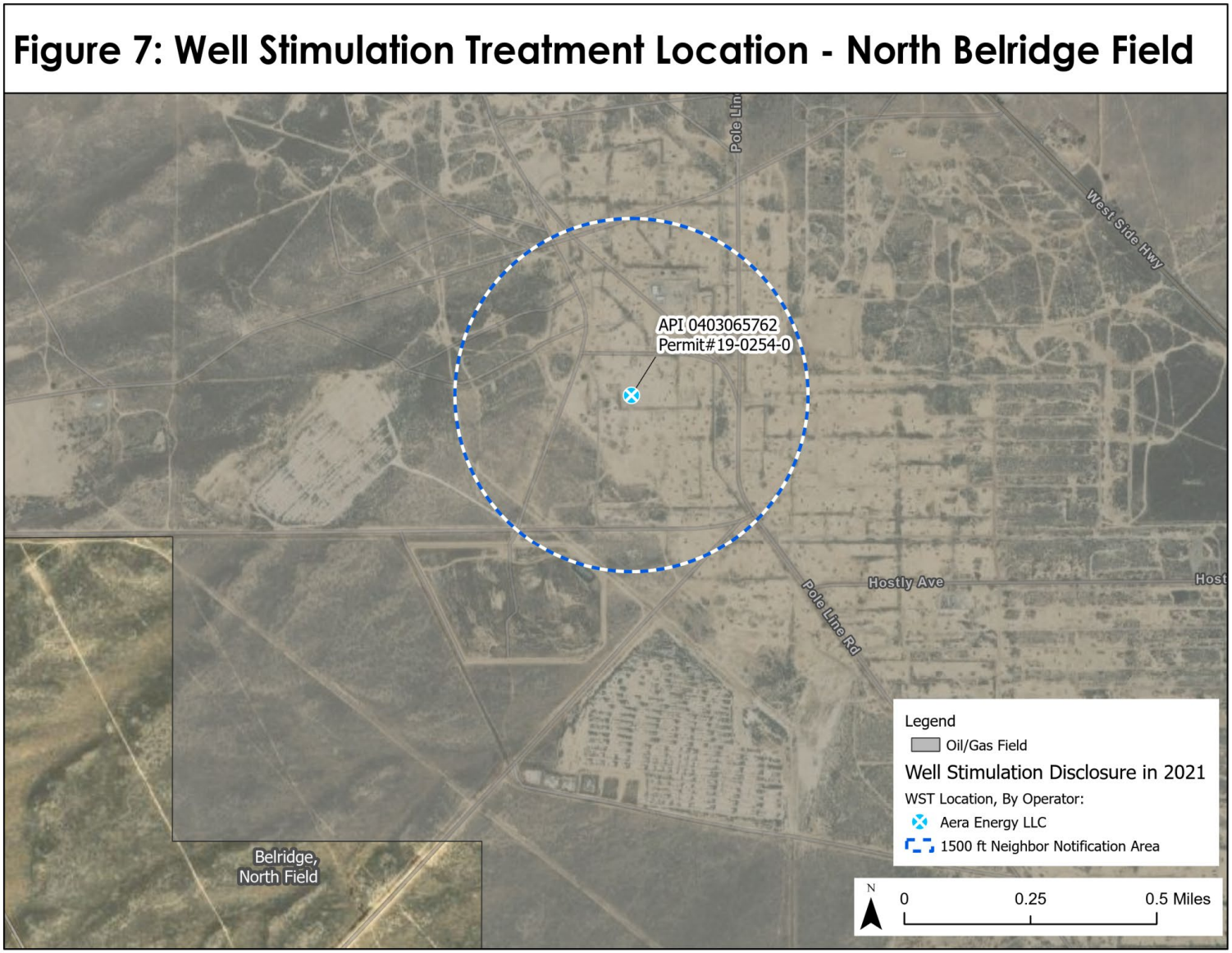

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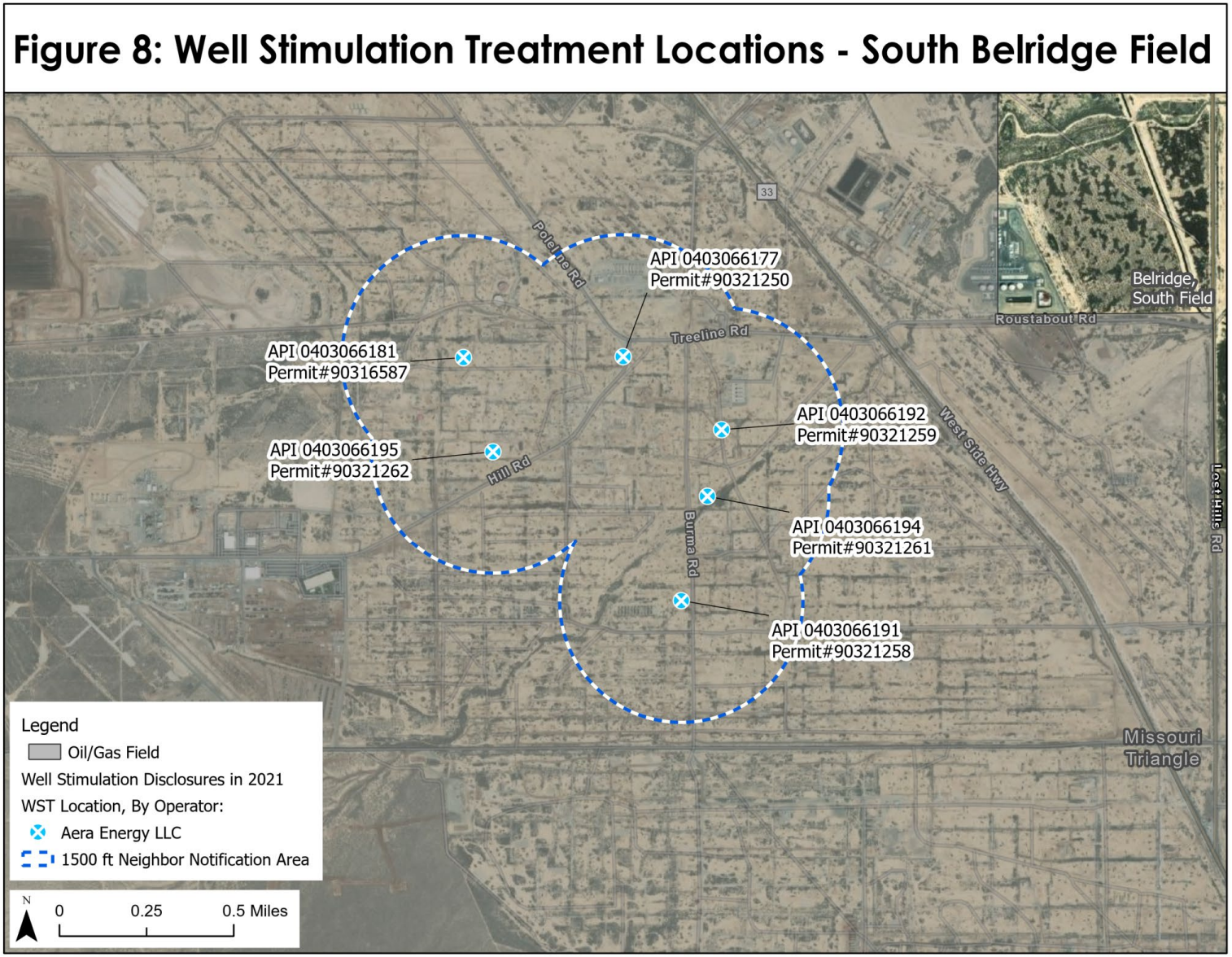
Figure 8: Well Stimulation Treatment Locations – South Belridge Field



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4.3 Well Stimulation Treatment Operators

Two operators completed all WSTs performed during the 2021 period. Aera completed a total of 10 WSTs (52% of the 19 total stimulations), which were located in the Lost Hills field, North Belridge field, and South Belridge field (as shown in **Figures 5 through 8**). Chevron conducted the remaining 9 WSTs (48% of 19 total stimulations) and only in the Lost Hills field (see **Figures 5 and 6**.)

Figure 9 depicts the number of stimulations completed by each operator annually, from 2014 to 2021, with Aera performing the most significant number of stimulations year over year. On average, Aera accounts for more than 83% of stimulations completed since 2014. The number of operators with completed stimulations since the WST regulation started has decreased from nine in 2014 to two in 2021.

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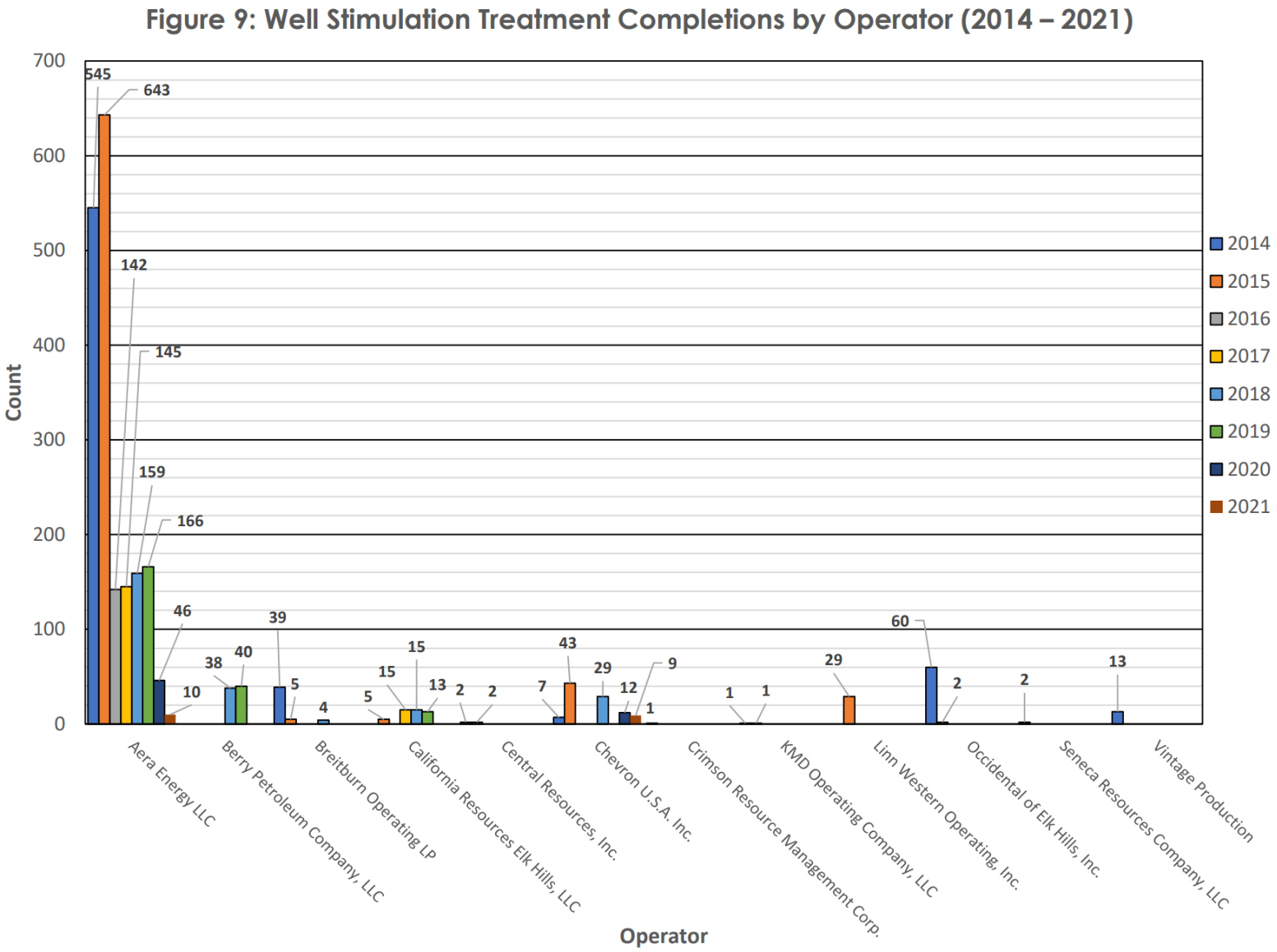
Figure 9: Well Stimulation Treatment Completions by Operator (2014 – 2021)



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4.4 Base Fluids

This section discusses the sources, volumes, and suitability for domestic or irrigation purposes of water used for WST. All WSTs completed during this reporting period exclusively used water as a base fluid. Although nitrogen, hydrocarbons, and acid have been used as base fluids in the past, they were not used during the 2021 reporting period.

4.4.1 Base Fluid Sources

Operators are required to report the sources of water used as WST base fluid in their WST permit applications, and also as part of required post-WST reporting. Operators may refer to the same source in different terminology in these submissions. Therefore, water sources used as base fluid sources during the reporting period have been categorized below under three distinct categories to provide a clear breakdown of WST base fluids based on the original water source:

Domestic Water System:

- California Aqueduct – reported by Aera

Produced Fluid:

- No produced fluid was used during this reporting period.

Operator-Owned Water Production Well:

- Tulare Water – reported by Chevron

Base fluid sources are further categorized for reporting by their suitability for irrigation or domestic purposes, meaning the water source is of a quality suitable to irrigate agricultural land or be used for indoor/outdoor household purposes, with minimal processing required. Base fluid water sources based on suitability of use are as follows:

Suitable for irrigation/domestic uses:

- Domestic Water System:
    - California Aqueduct - reported by Aera

Unsuitable for irrigation/domestic uses:

- Operator-Owned Water Production Well:
    - Tulare Water – reported by Chevron

Figure 10 illustrates the volumes of base fluids used in well stimulations by water source. The fluid volumes displayed for prior years are the total volumes reported in CalGEM's annual report. Note that the 2016 and 2017 reports covered periods greater than one calendar year, as detailed in the chart. In Appendix B, **Table B2** presents reported base fluid volumes by source, and **Table B3** presents base fluid volumes based on fluid suitability.

As shown in **Figure 10**, water quantity used for WST in 2021 was at the lowest since 2016, largely driven by the decline in WST activity.

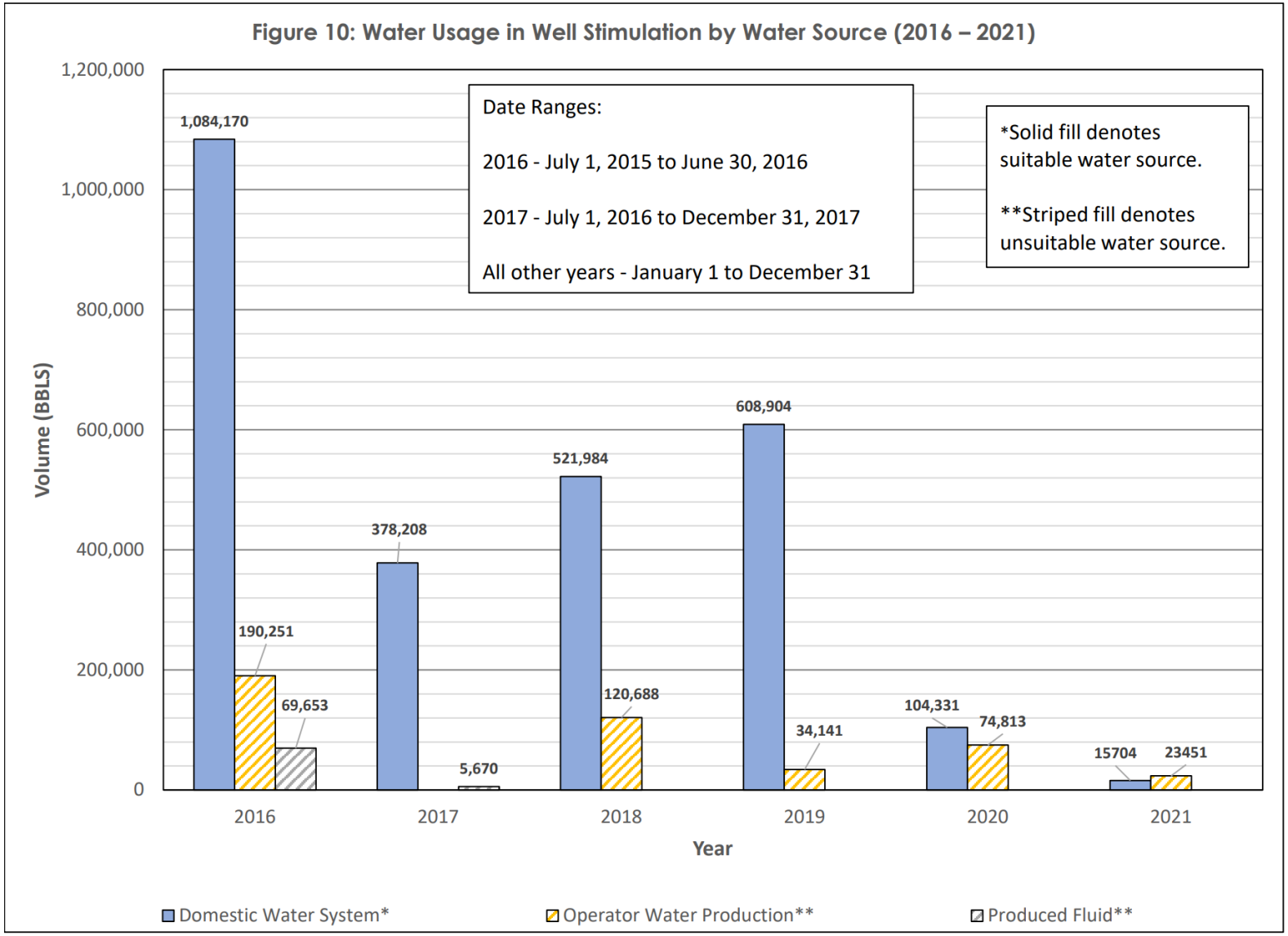
Produced fluids were not reported as used and have not been reported as used since the 2017 reporting period.

4.4.2 Base Fluid Composition

To satisfy CalGEM's reporting requirements, operators must submit base fluid composition data resulting from chemical analyses performed on water sources used as a base fluid for a WST. For base fluid water sources used in multiple WSTs within a proximal time frame, CalGEM accepts a representative sample of the water source collected and analyzed on a biannual basis (twice per year).

Tables B4 through B7 in Appendix B document the average chemical concentrations by mass of required analytes in sampled base fluid sources based on suitability type. These tables also present the percentage of samples with detections for each chemical based on the total number of samples analyzed.

Figure 10: Water Usage in Well Stimulation by Water Source (2016 – 2021)



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4.5 Additive and Chemical Usage

PRC section 3150 defines an additive as a substance or combination of substances added to a base fluid for purposes of preparing a WST fluid. An additive may, but is not required to, serve additional purposes beyond the transmission of hydraulic pressure to the geologic formation. An additive may be of any phase and includes proppant. Each additive is comprised of a unique combination of chemical constituents and, therefore, a full disclosure of the chemical constituents is required for each WST. Discussions of additives and chemicals utilized in WST fluids during the reporting period are presented below.

4.5.1 Additives

The additives used in WSTs are typically supplied by the contractor performing the operation, such as Halliburton. The following companies supplied additives for WSTs in California during the reporting period:

- Halliburton
- Operators: Chevron

Eleven different additives, not including water, were reportedly used in WST fluids during the reporting period. **Figure 11** provides a graphical representation of the average composition of a WST fluid based on additive types used during the reporting period. It must be noted that this chart presents an average of the concentrations of all uses for an additive type and is not specific to any operator or other factor.

However, the depicted additive concentrations are relatively consistent amongst WST operators, with WST fluids being comprised primarily of water and proppant. As is shown, base fluid (water) and proppant (sand) account for over 99% of the average composition of WST fluids used during the 2021 reporting period.

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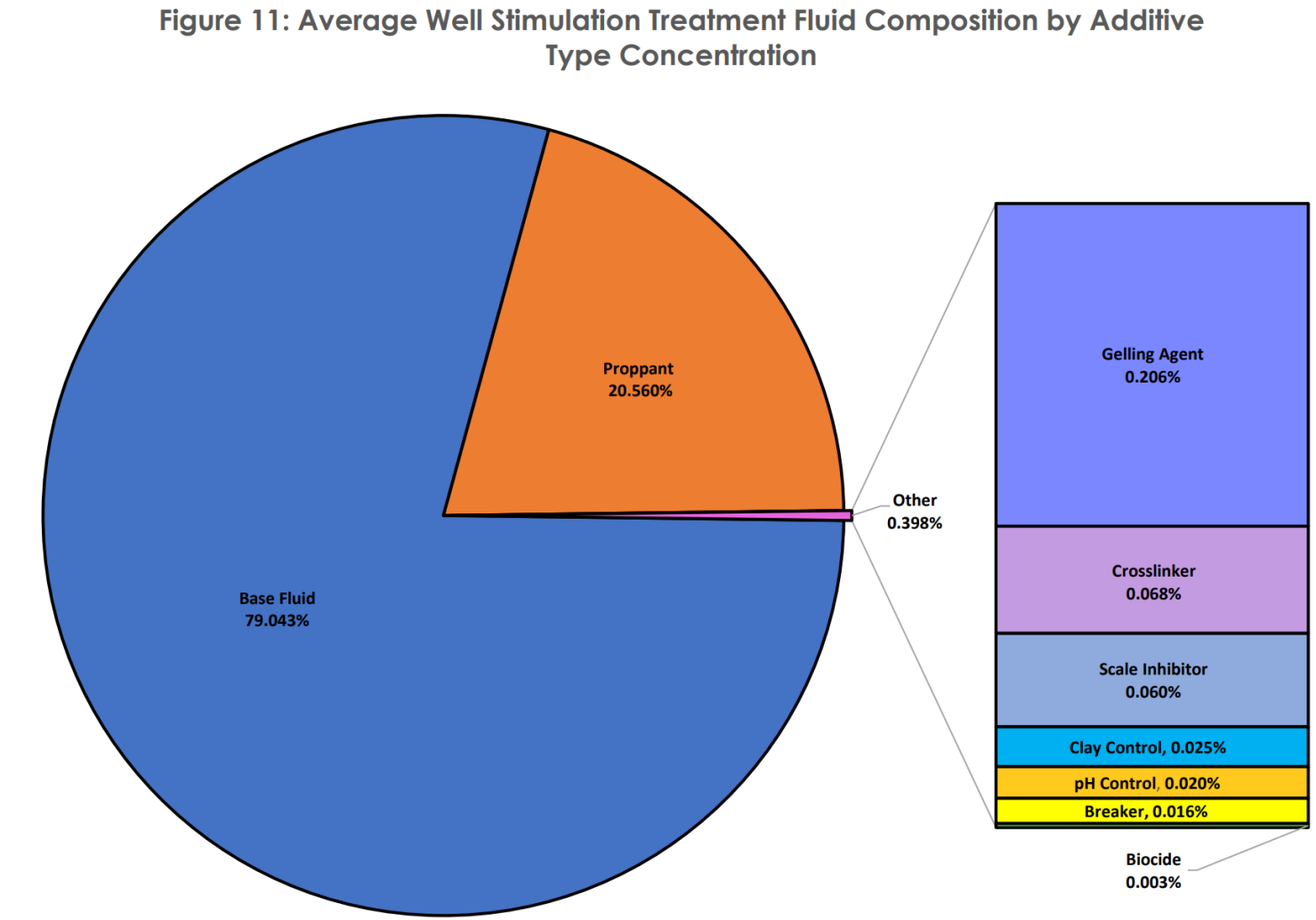
Figure 11: Average Well Stimulation Treatment Fluid Composition by Additive Type Concentration



**Values have been normalized to sum to 100%.

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Table B8 in Appendix B lists all additives used in WST fluids during the reporting period, including the number of times each additive was used, the additive supplier, and the purpose for using the additive.

Additive data specific to each WST can be accessed through CalGEM's WellSTAR disclosure database: https://wellstar-public.conservation.ca.gov/

4.5.1.1 Radiological Components

There were no radiological components or tracers used in WST during this reporting period.

4.5.1.2 Trade-secret Protection

There were no trade secret claims made by any operator for wells stimulated during this reporting period. Therefore, withholding public disclosure based on a trade secret did not occur.

4.5.2 Chemicals

Not including water, a total of 19 chemical constituents were reportedly used in WST fluids during the reporting period. **Table B9** in Appendix B provides a listing of all chemicals used in WST fluids during the reporting period, including the number of times each was used in a WST fluid, as well as a listing of the type or types of additives each chemical is commonly associated with when used in a WST fluid. Note that some of the chemical constituents were used as a component in various combinations for multiple purposes and, therefore, may be reported as used more than once per stimulation. Water was used in every WST.

Chemical data specific to each WST can be accessed through CalGEM's WellSTAR disclosure database: https://wellstar-public.conservation.ca.gov/

4.6 Recovered Fluids

Fluids produced from wells that undergo WST include petroleum, formation water, base fluid, and remaining chemical additives. Produced fluids are predominantly composed of hydrocarbons and formation water, occurring in greater quantities than fluids associated with the stimulation, such as base fluid or additives. Operators are required to collect, when possible, two recovered fluid samples for analysis after a WST has been completed. The first sample (a recovered fluid one sample [RF1]) is collected

after a calculated wellbore volume has been produced from the well but before three calculated wellbore volumes have been produced, typically after the well is placed on production. The second sample (a recovered fluid two sample [RF2]) is collected after the stimulated well has been producing for 30 days. A total of 33 recovered fluid samples were analyzed and reported to CalGEM during the 2021 reporting period, consisting of 16 RF1 and 17 RF2 samples.

Not every WST well can be sampled after stimulation, as some wells may not have enough pressure to generate flow back of WST fluids. Such situations frequently require cleanout operations prior to putting the well on production. In other instances, some of the WST fluid may have leaked off into the formation. As such, chemical analysis data of recovered fluids cannot be compared on a one-to-one basis against reported base fluid volume to establish an accurate ratio. Recovered fluid analytical data are provided in **Tables B10 through B15** in Appendix B. All chemicals detected are associated with naturally occurring petroleum compounds, produced water, and WST fluids.

All fluids recovered from WSTs completed during the reporting period were disposed of by injection into Class II injection wells, regulated separately under CalGEM's UIC program. Recovered WST fluids were not reused for subsequent treatments. There were no waste fluids other than water and petroleum-related fluids recovered during the reporting period.

4.7 Stimulation Dimensions

Well operators may estimate fracture zone lengths and heights according to sophisticated hydraulic fracturing models or previous field measured data. These estimations provide the basis for the ADSA boundaries used during risk assessment reviews. One of the key factors in estimating the fracture zone is the type of formation involved at the point of stimulation.

Figure 12 below shows the fracture length and height generated by a WST into the formation. These are key data points used to establish safety factors that denote areas in which surrounding wells are reviewed for risk (2xADSA review), and geologic features are reviewed for risk (within five times the ADSA [5xADSA review]). Safety factors are established by reviewing features within areas bounded by two times and five times the proposed fracture dimensions, thus creating a protective area around the proposed fracture zone used to make risk management and mitigation determinations. Fracture zone dimensions are also referred to in regulation as the

ADSA. The safety factors in regulation consist of evaluating wellbores or other possible migration pathways within the 2xADSA and geological features within the 5xADSA. In this report and in California's WST statutes and regulations, the terms "length" and "height" of stimulation mean the following:

Length: Generally, a hydraulic fracture is propagated on two sides of a wellbore. The horizontal length of a fracture on each side is called the fracture half-length. However, in this report, a fracture length is equal to a fracture half-length (**Figure 12**). In 2021, the average fracture length was 162 ft.

Height: For both vertical and horizontal wells, fracture height is the maximum vertical extent of a fracture growth. In other words, fracture height is the distance between the top and bottom of the fracture (**Figure 12**). In 2021, the average fracture height was 198 ft.

Fracture dimensions (as average lengths and heights) are presented in Appendix B, **Tables B16 and B17**, respectively.

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Figure 12: Use of "Height" & "Length" in Describing Well Stimulation Treatment Fractures

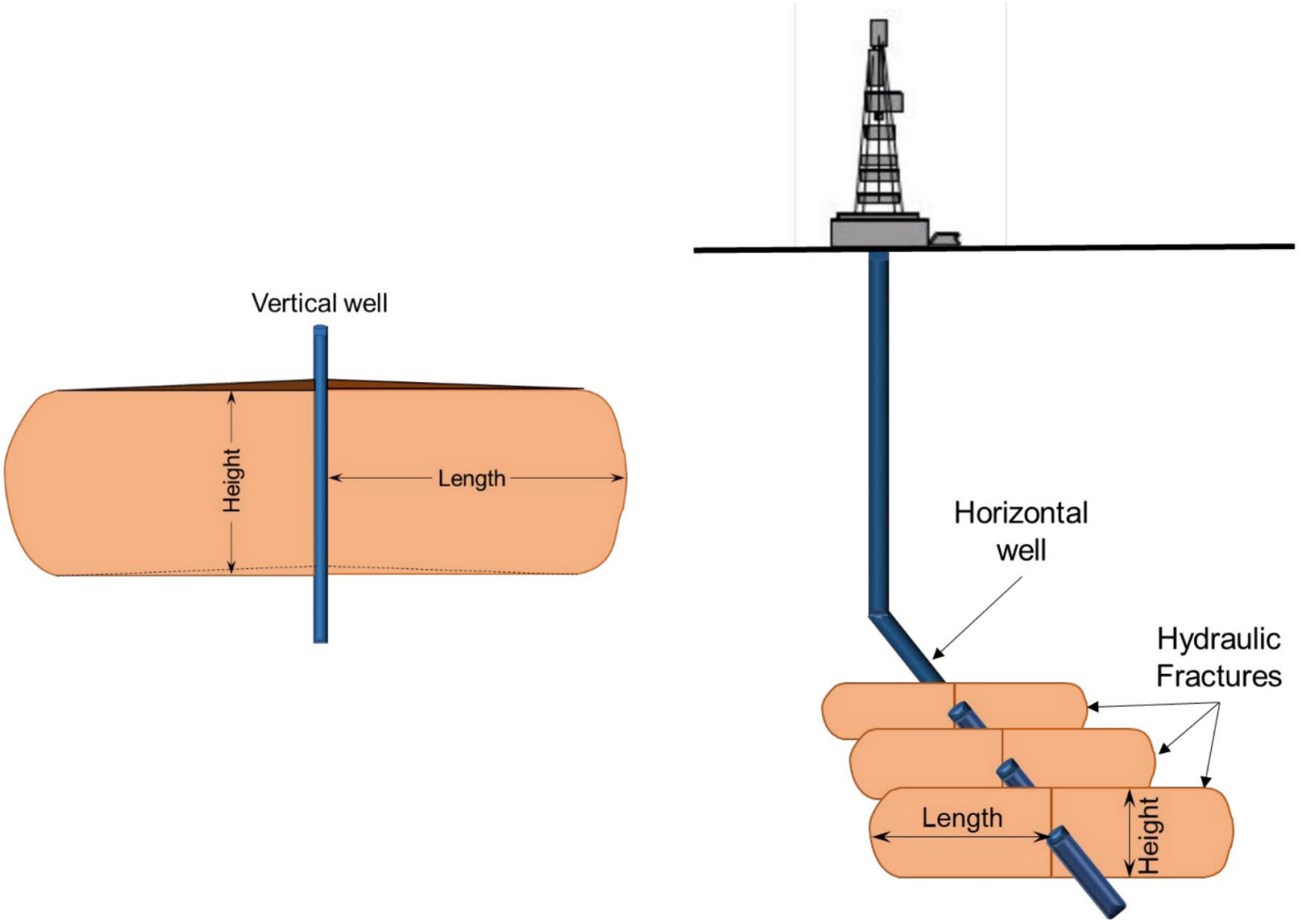

Figure 12: Use of "Height" & "Length" in describing WST Fractures in California

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4.7.1 Fracture Depths

This section presents aggregated information regarding the depths at which WSTs were performed during the reporting period. The minimum depth provided is the true vertical depth (TVD) from ground surface to the top of the uppermost stage. The maximum depth provided is the true vertical depth from ground surface to the bottom of the deepest stage. In 2021, the average minimum depth was 1,295 ft. TVD, and the maximum depth was 1,829 ft. TVD.

In Appendix B, **Table B18** presents data related to the depth to the top of proposed fractures, and **Table B19** presents data related to the depth to the bottom of proposed fractures.

4.8 Stimulated Formations/Zones

Oil and gas "zones" refer to the areas within a geologic formation where oil, gas, and water are trapped due to a geologic structure such as a fault, variable stratigraphy, or other feature that traps a resource in an area. For the purposes of this report, the stimulated formations and zone names reported by operators during the reporting period are as follows:

- Reef Ridge Formation – Reported zones:
  Reef Ridge-Diatomite

- Etchegoin Formation – Reported zones:
  Etchegoin-Diatomite

These formations/zones are comprised of low permeability rocks that, while they contain oil, do not readily transmit or readily allow the flow of oil and oil-bearing fluids. Therefore, these formations must be stimulated to be produced. A stimulation treatment creates pathways for oil-bearing fluids to migrate through, and hydrocarbon extraction becomes feasible.

Table B20 in Appendix B provides the number of times each of the formations listed above was stimulated during the reporting period.

5.0 NEIGHBOR NOTIFICATIONS

After receiving a WST permit, but before stimulation, operators are required to provide neighbor notification to surface owners and tenants of properties that are either located within a 1,500-foot radius of the wellhead receiving WST (as depicted on the WST location maps, **Figures 6 through 8**), or within 500 feet of the surface projection of the horizontal path of the subsurface parts of the well. If the neighbor notification requirement is triggered, operators are required to hire an independent third-party to perform the notification. Notified neighbors who have an existing water well or surface water on their parcel suitable for drinking or irrigation purposes may request water quality testing. Operators are required to send a copy of the water quality testing results to CalGEM.

The third-party notice provider also sends information to CalGEM detailing the surface owners and tenants notified, the date of notification, and the delivery method. Operators cannot perform a stimulation on a well until after 30 calendar days from the date surface owners and tenants are notified. CalGEM retains neighbor notification data and checks for reporting compliance prior to the well stimulation. The performance of the third-party notice providers is reviewed and subject to random audits conducted by CalGEM.

In 2021, 19 stimulations were completed with 13 stimulations requiring neighbor notifications—these notifications were all given to neighboring operators. Twelve stimulations completed in the first quarter of 2021 were based on WST permits issued in 2020 and had neighbor notifications submitted in late 2020. Another neighbor notification was submitted in early 2021 for the stimulation completed in April 2021. Though there are no nearby population close to any of the wells stimulated, any surface owners or tenants, including other oil field operators, are required to receive a neighbor notification if they are located within the notification area. The remaining 6 WST permits did not require neighbor notifications because no surface owners or tenants were located near the stimulation area. Details regarding the six stimulations that did not require neighbor notifications are presented in **Table B21** of Appendix B. There were no requests for water sampling by surface owners or tenants during the reporting period.

6.0 SEISMIC MONITORING

Pursuant to the provision of the California Code of Regulations (CCR), Title 14, section 1785.1, operators are required to monitor the California Integrated Seismic Network during and 10 days after the well stimulation for any indication of an earthquake of magnitude 2.7 or greater within the five times ADSA. If an earthquake of a 2.7 magnitude or greater is detected, the operators must notify CalGEM for further evaluation.

There have been no reports of any seismic activities triggered by well stimulation activities during the reporting period. CalGEM's WST unit reviewed 2021 earthquake data from the United States Geological Survey for the periods of hydraulic fracturing to verify the lack of correlating seismic activities. There has been no report of any seismic activities related to WST under the permanent WST program.

7.0 ENFORCEMENT

To help ensure oil and gas operators comply with California statutes and regulations, CalGEM's enforcement office works to identify violations and take actions to bring violators into compliance with the law. Enforcement actions CalGEM takes include issuing notices of violation, taking civil or criminal enforcement action, and assessing penalties.

Beginning in 2021, CARB conducted an audit of the public disclosures required following WST operations for compliance on air monitoring. As part of this audit, it was discovered that there were stimulations performed under four permits issued by CalGEM in 2019 for which a required permit condition was not met. More specifically, all of these permits contained a permit condition under which the operator was required to prepare a site-specific plan to perform air sampling and analysis using CARB's *Air Sampling and Analysis Plan for Well Stimulation Treatment Operations* on the WST if the WST includes any additional or different constituent chemicals not previously included under a previously approved Sampling Analysis Plan or not previously monitored by CARB. In coordination with CARB, CalGEM found that Aera committed three violations and CRC committed one violation in the calendar year 2019 for violating this air-monitoring permit condition. In response, CalGEM issued a civil penalty order to each operator in August 2021. CalGEM collected $30,000 in civil penalties from Aera (1213-Aera) and $10,000 from CRC (1214-CRC).

CARB issued another set of letters in July 2021 for violations related to stimulations completed in 2018 and 2020. CalGEM concluded its investigation of these violations and Aera was found to have 16 violations for stimulations completed in 2018 and 2020. In February 2022, CalGEM issued a civil penalty order of $160,000 for these violations (1240-Aera).

By the end of 2021, CARB had concluded its audit of all the disclosures submitted under WST to date. The 20 violations identified as part of this audit occurred across 20 stimulations. There were a total of 710 stimulations completed under the permanent WST regulatory period that spanned from 2016 to 2021. These violations, though related to the chemical constituents used in stimulations, were not found to have caused widespread harm as these occurred in mature oil fields with existing air pollutants. One of the reasons for the air monitoring requirement is to assess the impact on air quality from the chemicals used during WST on surrounding area. CARB's recent publication on air monitoring concluded that while background oil field emissions may have air quality/health impacts, emitted volatile hydrocarbon concentrations during

WST activities are at levels similar to general oil and gas production emissions and due to the short-term nature of the WST activities, emissions from WSTs are indistinguishable from background oilfield emissions.

7.1 Well Stimulation Treatment Witnessing

Witnessing is the term used for a site visit made by CalGEM district staff to evaluate aspects of a WST operation, including, but not limited to:

- Casing and tubing pressure testing to ensure well integrity prior to WST;
- WST surface equipment pressure testing prior to WST; and
- Observation of WST activities on the day of stimulation.

During the reporting period, CalGEM implemented health and safety measures to protect staff and limit exposure to potential sources of COVID-19. CalGEM staff were not able to witness all stimulations due to the COVID-19 health and safety measures but met the majority of witnessing obligations, witnessing 63% of stimulations (12 of the 19) completed in 2021. CalGEM staff continue to strive to meet the goal of witnessing all stimulations during a reporting period. **Table B22** in Appendix B presents the number of stimulations witnessed during the 2021 reporting period.

7.2 Chemical Spot-Checking

Spot-checking is an onsite assessment made specifically to verify that the WST fluid additives conform to the additive composition approved by CalGEM during the application review.

The ability to complete chemical spot-checks was impacted by social distancing restrictions/remote witnessing protocols that CalGEM and the operators implemented in response to COVID-19. In 2021, zero chemical spot-checks were performed during the reporting period. CalGEM's goal remains to perform chemical spot-checks at all witnessed stimulations. **Table B23** in Appendix B presents the number of chemical spot-checks performed during the 2021 reporting period.

8.0 REPORTS OF INCIDENTS/EVENTS

For public health and safety, any loss of well or casing integrity for wells that have undergone a WST is reviewed and reported by CalGEM in this annual report, along with other losses of well or casing integrity issues of all wells in California. Spills and releases associated with WSTs are also reported per the requirements stated in PRC section 3215(c).

A loss of well or well casing integrity in wells that have undergone WST is defined as a breach in any casing string utilized in WST operations or a breach of the geologic or hydrologic isolation of the formation. Loss of well or well casing integrity for all other wells is identified by any incident involving damage to a well's permanent construction indicated by inspection and/or mechanical integrity testing (MIT). Integrity losses typically develop over time, making it challenging to identify the precise point at which a loss first occurs. A failure of an integrity test is not always conclusive evidence of casing integrity loss. A determination of actual loss may require additional testing and review.

A query of CalGEM's records yielded 774 instances of possible loss of well or well casing integrity during the reporting period, including failed mechanical integrity tests, pressure tests, and reported anomalies. Records of possible well/well casing integrity loss were cross-referenced with wells that had undergone stimulation in 2021. Based on this analysis, no well or casing integrity losses were associated with WSTs identified during the reporting period. During the reporting period, there were no emergency responses to spills or releases of any liquids or regulated substances associated with WSTs.

The total number of wells experiencing casing integrity loss in 2021 decreased compared to the 1,060 recorded in 2020 (about 27% decrease). However, prior to 2021, the overall trend had been increasing from 152 reported in 2018, which is believed to be a result of transitioning to WellSTAR, which now captures all well integrity-related data within the Division, providing a more complete data set, as well as due to more stringent regulations for UIC, Idle Wells, and Underground Gas Storage programs, as these regulations required increased testing of related wells.

Any well that has possible loss of casing integrity is not allowed to be operated until it passes additional inspections/testing, or the well is reworked to remediate the issue. If a major casing loss is identified, the well may be plugged and abandoned according to the standard set in the regulations.

APPENDICES

APPENDIX A – REFERENCES/DATA SOURCES

The following were used as data sources for this report:

CalGEM Statutes and Regulations (January 2022): https://www.conservation.ca.gov/index/Documents/CALGEM-SR-1%20Web%20Copy.pdf

Well Statewide Tracking and Reporting System (WellSTAR): https://wellstar-public.conservation.ca.gov/

CalGEM WST Unit's *WST Tracker.xlsx.* This is an internal Excel workbook developed by WST unit staff specifically to track the progress of requests to perform WSTs, through notices/applications, actual stimulations, and disclosing of stimulations.

CalGEM Inland District's *WST_Tracking1.xlsx.* This is an internal Excel workbook developed by Inland District staff to schedule and track staff witnessing WST-related operations.

APPENDIX B – DATA TABLES

Table B1: Well Stimulation Treatment Permit Status - 2021 Reporting Period

WST Permit Number	Permit Issue Date	Stimulation Completion Date	API	Operator	County	Field	Permit Status
19-0200-0	11/20/2020	3/7/2021	03063051	Chevron	Kern	Lost Hills	Completed
19-0201-0	11/20/2020	3/10/2021	03063054	Chevron	Kern	Lost Hills	Completed
19-0202-0	11/20/2020	3/5/2021	03063048	Chevron	Kern	Lost Hills	Completed
19-0203-0	11/20/2020	3/1/2021	03063049	Chevron	Kern	Lost Hills	Completed
19-0204-0	11/20/2020	3/3/2021	03063050	Chevron	Kern	Lost Hills	Completed
19-0206-0	11/20/2020	3/13/2021	03063058	Chevron	Kern	Lost Hills	Completed
19-0209-0	11/20/2020	3/9/2021	03063052	Chevron	Kern	Lost Hills	Completed
19-0210-0	2/23/2021	4/20/2021	03062992	Chevron	Kern	Lost Hills	Completed
19-0233-0	11/20/2020	3/12/2021	03063059	Chevron	Kern	Lost Hills	Completed
19-0254-0	4/3/2020	3/19/2021	03065762	Aera	Kern	North Belridge	Completed
90316073	2/9/2021	--	03065990	Aera	Kern	North Belridge	Active
90316408	12/3/2020	3/17/2021	03066111	Aera	Kern	Lost Hills	Completed
90316436	12/3/2020	3/18/2021	03065940	Aera	Kern	Lost Hills	Completed
90316438	12/3/2020	3/18/2021	03066026	Aera	Kern	Lost Hills	Completed
90316500	2/9/2021	--	03065978	Aera	Kern	North Belridge	Active
90316522	2/9/2021	--	03065982	Aera	Kern	North Belridge	Active
90316523	2/9/2021	--	03065986	Aera	Kern	North Belridge	Active
90316524	2/9/2021	--	03065989	Aera	Kern	North Belridge	Active
90316525	2/9/2021	--	03065992	Aera	Kern	North Belridge	Active
90316526	2/9/2021	--	03065993	Aera	Kern	North Belridge	Active
90316527	2/9/2021	--	03065994	Aera	Kern	North Belridge	Active
90316528	2/9/2021	--	03065995	Aera	Kern	North Belridge	Active
90316529	2/9/2021	--	03066000	Aera	Kern	North Belridge	Active
90316530	2/9/2021	--	03066001	Aera	Kern	North Belridge	Active
90316587	12/30/2020	3/24/2021	03066181	Aera	Kern	South Belridge	Completed
90321250	12/30/2020	3/25/2021	03066177	Aera	Kern	South Belridge	Completed

WST Permit Number	Permit Issue Date	Stimulation Completion Date	API	Operator	County	Field	Permit Status
90321258	12/30/2020	3/22/2021	03066191	Aera	Kern	South Belridge	Completed
90321259	12/30/2020	3/27/2021	03066192	Aera	Kern	South Belridge	Completed
90321261	12/30/2020	3/26/2021	03066194	Aera	Kern	South Belridge	Completed
90321262	12/30/2020	3/24/2021	03066195	Aera	Kern	South Belridge	Completed

Table B2: Base Fluid Volumes by Operator and Source

Well Operator/County – District	Domestic Water System (BBLS)	Operator Water Production Well (BBLS)	Produced Fluid (BBLS)	Total Base Fluid (BBLS)
Aera	15,704		0	15,704
Chevron		23,451	0	23,451
TOTALS	15,704	23,451	0	39,155
Kern County – Inland District	15,704	23,451	0	39,155

Table B3: Base Fluid Volumes by Operator and Suitability

Well Operator/County – District	Suitable for Irrigation/Domestic Use (BBLS)	Not Suitable for Irrigation/Domestic Use (BBLS)	Total Base Fluid (BBLS)
Aera	15,704		15,704
Chevron		23,451	23,451
TOTALS	15,704	23,451	39,155
Kern County – Inland District	15,704	23,451	39,155

Table B4: Inorganic Compounds in "Suitable" Base Fluid

Required Analytes	Average Concentration Detected (mg/L)	Percentage of Samples with Detection
Silver	0	Not Detected
Alkalinity, Total	63	100%
Arsenic	0.004	33%
Boron	0.32	100%
Barium	0.053	100%
Beryllium	0	Not Detected
Bromide	1.28	100%
Calcium	69	100%
Cadmium	0	Not Detected
Chloride	270	100%
Cobalt	0	Not Detected
Chromium	0.0016	67%
Copper	0.0042	100%
Mercury	0.000012	33%
Potassium	2.79	100%
Lithium	0	Not Detected
Magnesium	10.4	100%
Molybdenum	0.0098	100%
Sodium	160	100%
Nickel	0.0014	67%
Nitrate	0.19	67%
Lead	0.0031	67%
Antimony	0	Not Detected
Selenium	0.005	33%
Sulfate	112	100%
Strontium	0.40	100%
Total Dissolved Solids	770	100%
Thallium	0	Not Detected
Vanadium	0.006	100%
Zinc	0.0011	33%

Table B5: Organic Compounds in "Suitable" Base Fluid

Required Analytes	Average Concentration Detected (µg/L)	Percentage of Samples with Detection
Benzene	0	Not Detected
Bromoform	22	33%
Dibromochloromethane	0.31	33%

Required Analytes	Average Concentration Detected (µg/L)	Percentage of Samples with Detection
Ethyl Benzene	0	Not Detected
Toluene	0	Not Detected
Xylenes	0	Not Detected

Table B6: Inorganic Compounds in "Not Suitable" Base Fluid

Required Analytes	Average Concentration Detected (mg/L)	Percentage of Samples with Detection
Alkalinity, Total	75	100%
Arsenic	0	Not Detected
Boron	3.3	100%
Barium	0.02	100%
Beryllium	0	Not Detected
Bromide	5.5	100%
Benzene	44	100%
Calcium	340	100%
Cadmium	0	Not Detected
Chloride	1,400	100%
Cobalt	0	Not Detected
Chromium	0	Not Detected
Copper	0	Not Detected
Mercury	0	Not Detected
Potassium	5.6	100%
Lithium	0.33	100%
Magnesium	51	100%
Molybdenum	0.045	100%
Sodium	1,000	100%
Nickel	0	Not Detected
Nitrate	0	Not Detected
Lead	0	Not Detected
Antimony	0	Not Detected
Selenium	0	Not Detected
Silver	0	Not Detected
Sulfate	1,300	100%
Strontium	4.9	100%
Total Dissolved Solids	4,000	100%
Thallium	0	Not Detected
Vanadium	0	Not Detected
Zinc	0	Not Detected

Table B7: Organic Compounds in "Not Suitable" Base Fluid

Required Analytes	Average Concentration Detected (µg/L)	Percentage of Samples with Detection
Benzene	44	100%
Ethyl Benzene	2.1	100%
Toluene	6.7	100%
Xylenes	5.7	100%

Table B8: Additives Used in Stimulation by Supplier & Purpose

Supplier Name	Additive Trade Name	Purpose	Number of Times Used in WST Fluid
Chevron	Water	Base Fluid	9
Halliburton	Acetic Acid	pH Control	3
Halliburton	BC-140C	Crosslinker	19
Halliburton	BE-3S BACTERICIDE	Biocide	19
Halliburton	DCA-13002	Breaker	19
Halliburton	DCA-14005	pH Control	19
Halliburton	DCA-16002	Clay Control	19
Halliburton	DCA-25005	Gelling Agent	19
Halliburton	DCA-30001	Scale Inhibitor	9
Halliburton	GBW-30 BREAKER	Breaker	19
Halliburton	SAND-PREMIUM WHITE-16/30	Proppant	18
Halliburton	SAND-PREMIUM WHITE-20/40	Proppant	11
Halliburton	Water	Base Fluid	10

Table B9: Chemical Constituents Used in Stimulation by Constituent Name

Constituent Name	CAS Number	Number of Times Used in WST Fluid
2,2 Dibromo-3-nitrilopropionamide	10222-01-2	19
2-Monobromo-3-nitrilopropionamide	1113-55-9	19
Acetic acid	64-19-7	3
Ammonium chloride	12125-02-9	19
Ammonium; diallyldimethyl-; chloride; polymers	26062-79-3	19
Crystalline Silica (Quartz),	14808-60-7	19
Guar gum	9000-30-0	19
Hemicellulase enzyme	9012-54-8	19
Lactose	63-42-3	19
Monoethanolamine borate	26038-87-9	19
Pigment Red 48:2	7023-61-2	1
Polyoxyethylene (12) polyoxypropylene (66) glyceryl ether	9082-00-2	1

Constituent Name	CAS Number	Number of Times Used in WST Fluid
Polyurethane Resin	57029-46-6	1
Sodium bisulfite	7631-90-5	9
Sodium chloride	7647-14-5	19
Sodium Hydroxide	1310-73-2	19
Sodium persulfate	7775-27-1	19
Sodium polyacrylate	9003-04-7	9
Sodium sulfate	7757-82-6	19
Water	7732-18-5	19

Table B10: Average Concentration of Inorganic Compounds Detected in Recovered Fluid by Operator

Required Analytes	Aera (mg/L)	Chevron (mg/L)
Alkalinity, Total	2,491	3,266
Antimony	0.0005	NOT DETECTED
Arsenic	0.141	0.007
Barium	8.1	7.1
Beryllium	NOT DETECTED	NOT DETECTED
Boron	114	89
Bromide	87	56
Cadmium	0.0003	NOT DETECTED
Calcium	146	3180
Chloride	12,585	17,733
Chromium	0.0008	0.0380
Cobalt	0.008	0.001
Copper	0.062	0.009
Fluoride	NOT DETECTED	0.01
Hydrogen sulfide (H2S)	NOT DETECTED	0.3
Iron	20	81
Lead	0.001	0.020
Lithium	6.2	16.9
Magnesium	116	217
Manganese	0.36	1.40
Mercury	0.0001	0.0001
Molybdenum	0.0076	0.0072
Nickel	0.030	0.032
Nitrate	NOT DETECTED	NOT DETECTED
Nitrite	0.063	NOT DETECTED
Potassium	202	550
Selenium	0.43	0.19

Required Analytes	Aera (mg/L)	Chevron (mg/L)
Silver	NOT DETECTED	NOT DETECTED
Sodium	7,477	7,472
Strontium	7.5	65.3
Sulfate	27	41
Thallium	0.0001	0.0420
Total Dissolved Solids	23,154	39,311
Vanadium	NOT DETECTED	0.004
Zinc	0.124	0.230

Table B11: Average Concentration of Inorganic Compounds Detected in Recovered Fluid by County & District

Required Analytes	Kern County – Inland District (mg/L)	Percentage of Samples with Detection
Alkalinity, Total	2,972	100%
Antimony	0.0002	10%
Arsenic	0.06	48%
Barium	7.5	100%
Beryllium	0	NOT DETECTED
Boron	99	100%
Bromide	69	100%
Cadmium	0.0001	6%
Calcium	1,908	100%
Chloride	15,574	100%
Chromium	0.022	61%
Cobalt	0.0042	45%
Copper	0.031	58%
Fluoride	0.008	3%
Hydrogen sulfide (H2S)	0.2	55%
Iron	55	100%
Lead	0.012	65%
Lithium	12.4	100%
Magnesium	175	100%
Manganese	0.96	97%
Mercury	0.00013	16%
Molybdenum	0.0073	45%
Nickel	0.031	87%
Nitrate	0	NOT DETECTED
Nitrite	0.027	6%
Potassium	404	100%
Selenium	0.29	94%

Required Analytes	Kern County – Inland District (mg/L)	Percentage of Samples with Detection
Silver	0	NOT DETECTED
Sodium	7,474	100%
Strontium	41.1	100%
Sulfate	36	61%
Thallium	0.02	26%
Total Dissolved Solids	32,535	100%
Vanadium	0.002	10%
Zinc	0.186	81%

Table B12: Average Concentration of Organic Compounds Detected in Recovered Fluid by Operator

Required Analytes	Aera (µg/L)	Chevron (µg/L)
Benzene	1,465	424
Ethyl Benzene	232	240
Guar Gum	55,846	121,500
Methane	2.1	1.2
Toluene	2,211	491
Xylenes	1,209	538

Table B13: Average Concentration of Organic Compounds Detected in Recovered Fluid by County & District

Required Analytes	Kern County – Inland District (µg/L)	Percentage of Samples with Detection
Benzene	860	100%
Ethyl Benzene	236	100%
Guar Gum	93,968	94%
Methane	1.57	100%
Toluene	1,212	100%
Xylenes	819	100%

Table B14: Average Concentration of Radioactive Compounds Detected in Recovered Fluid by Operator

Required Analytes	Aera (pCi/L)	Chevron (pCi/L)
Alpha, Gross	3.5	65.1
Beta, Gross	100.4	255.5
Radium-226	18.6	30.0
Radon	-66.3	44.3

Table B15: Average Concentration of Radioactive Compounds Detected in Recovered Fluid by County & District

Required Analytes	Kern County – Inland District (pCi/L)	Percentage of Samples with Detection
Alpha, Gross	39.3	100%
Beta, Gross	190	100%
Radium-226	25.2	100%
Radon	-0.6	100%

Table B16: Average Length of Stimulation

Well Operator/ County-District	Minimum (FT)	Maximum (FT)	Average (FT)
Aera	50	68	57
Chevron	50	200	193
Kern County - Inland District	50	200	162

Table B17: Average Height of Stimulation

Well Operator/ County-District	Minimum (FT)	Maximum (FT)	Average (FT)
Aera	91	171	126
Chevron	70	255	218
Kern County - Inland District	70	255	198

Table B18: Top Depths of Stimulation

Well Operator/ County – District	Minimum (TVD FT)	Maximum (TVD FT)	Average (TVD FT)
Aera	502	2,190	1,172
Chevron	1,149	1,734	1,432
Kern County – Inland District	502	2,190	1,295

Table B19: Bottom Depths of Stimulation

Well Operator/County – District	Minimum (TVD FT)	Maximum (TVD FT)	Average (TVD FT)
Aera	1,356	2,541	1,777
Chevron	1,657	2,146	1,888
Kern County – Inland District	1,356	2,541	1,829

Table B20: Number of Stimulations in Each Formation by County & District

County/District	Formation Name	Number of Stimulations
Kern County - Inland District	Etchegoin/Reef Ridge-Diatomite	5
	Reef Ridge-Diatomite	14
TOTAL		19

Table B21: Well Stimulation Permits Not Requiring Neighbor Notification

WST Permit Number	API	Operator	County	Field
90316587	0403066181	Aera Energy LLC	Kern	South Belridge
90321250	0403066177	Aera Energy LLC	Kern	South Belridge
90321258	0403066191	Aera Energy LLC	Kern	South Belridge
90321259	0403066192	Aera Energy LLC	Kern	South Belridge
90321261	0403066194	Aera Energy LLC	Kern	South Belridge
90321262	0403066195	Aera Energy LLC	Kern	South Belridge

Table B22: Number of Stimulations Witnessed by CalGEM

County – District	Number of WSTs Witnessed
Kern County – Inland District	12

Table B23: Number of Chemical Spot-Checks Performed by CalGEM

County – District	Number of Chemical Spot-Checks Performed
Kern County – Inland District	0

APPENDIX C – STATUTORY REQUIREMENTS FOR ANNUAL REPORT

As defined in PRC section 3157(a), "Well stimulation treatment" means a treatment of a well designed to enhance oil and gas production or recovery by increasing the permeability of the formation. Well stimulation is a short-term and non-continual process for the purpose of opening and stimulating channels for the flow of hydrocarbons. WSTs include but are not limited to hydraulic fracturing, acid fracturing, and acid matrix stimulation.

The data presented in this report are derived from operator disclosures submitted to CalGEM per the requirements stated in PRC section 3160(b)(2). Operators have one year from the date of issuance of a WST permit to begin a stimulation and 60 days from the completion of the well stimulation to submit the WST disclosure form to CalGEM (PRC sections 3160(d)(4) and 3160(g)).

PRC section 3215(c)(1)-(8) requires that this report address the following items:

1. Aggregated data detailing the disposition of any produced water from wells that have undergone WST.
    - Review Section 4.6 of this document.

2. Aggregated data describing the formations where wells have received WSTs, including the range of safety factors used and fracture zone lengths.
    - Review Section 4.8 of this document

3. The number of emergency responses to a spill or release associated with a WST.
    - Review Section 8.0 of this document.

4. Aggregated data detailing the number of times trade secret information was not provided to the public in the preceding year by county and company.
    - Review Section 4.5.1.2 of this document.

5. Data detailing the loss of well and well casing integrity for wells that have undergone WST in the preceding year. Data detailing the loss of well and well casing integrity in the preceding year for all wells shall also be provided for comparative purposes. The cause of each well and well casing failure, if known, shall also be provided.

- Review Section 8.0 of this document.

6. The number of spot-check inspections conducted pursuant to PRC section 3160(l), including the number of inspections where the composition of well stimulation fluids was verified and the results of those inspections.
   - Review Section 7.2 of this document.

7. The number of WSTs witnessed by CalGEM.
   - Review Section 7.1 of this document.

8. The number of enforcement actions associated with WSTs, including, but not limited to, notices of deficiency, notices of violation, civil or criminal enforcement actions, and any penalties assessed.
   - Review Section 7.0 of this document.

PRC section 3215(c) also calls for the inclusion of "aggregated data of all the information required to be reported" under PRC section 3160, consisting of the provisions described under PRC 3160(b)(2)(A)-(G) which are addressed in this report:

A. The date of the WST.
   - WSTs completed between January 1, 2021, and December 31, 2021. This is the reporting period covered in this report.

B. A complete list of the names, Chemical Abstract Service (CAS) numbers, and maximum concentration, in percent by mass, of each and every chemical constituent of the WST fluids used.
   - Review Section 4.5.2 of this report.

C. The trade name, the supplier, concentration, and a brief description of the intended purpose of each additive contained in the WST fluid.
   - Review Section 4.5.1 of this report.

D. The total volume of base fluid used during the WST and the identification of whether the base fluid is water suitable for irrigation or domestic purposes, water not suitable for irrigation or domestic purposes, or a fluid other than water.
   - Review Section 4.4 of this report.

E. The source, volume, and specific composition and disposition of all water, including, but not limited to, all water used as base fluid during the well stimulation treatment and recovered from the well following the well stimulation treatment that is not otherwise reported as produced water pursuant to PRC section 3227. Any repeated reuse of treated or untreated water for well stimulation treatments and well stimulation treatment-related activities shall be identified.

- Review Section 4.6 of this report.

F. The specific composition and disposition of all WST fluids, including waste fluids, other than water.

- Review Section 4.6 of this report.

G. Any radiological components or tracers injected into the well as part of, or in order to evaluate, the WST, a description of the recovery method, if any, for those components or tracers, the recovery rate, and specific disposal information for recovered components or tracers.

- Review Section 4.5.1.1 of this report.

H. The radioactivity of the recovered well stimulation fluids.

- Review Section 4.6 of this report.

I. The location of the portion of the well subject to the WST and the extent of the fracturing or other modification, if any, surrounding the well induced by the treatment.

- Review Section 4.7 of this report.

APPENDIX D – GLOSSARY

TERM	DESCRIPTION
Acid Fracture Stimulation	The combined use of acid and fracturing to increase the permeability of (stimulate) a portion of rock or sediment formation intercepted by a well.
Acid Matrix Stimulation	The use of acid to dissolve mineral material to increase the permeability of (stimulate) a portion of rock or sediment formation intercepted by a well.
Additive	One or more substances added to a base fluid to make up a WST fluid.
Base Fluid	A liquid (or potentially a gas) into which additives are mixed, to make up a WST fluid.
Base Fluid Source	The source or origin of a base fluid.
Base Fluid Suitability	The suitability of water base fluid for domestic use (e.g., human or livestock consumption) or irrigation (e.g., agricultural use).
California Code of Regulations (CCR)	The official compilation and publication of the regulations adopted, amended or repealed by state agencies pursuant to the Administrative Procedure Act. WST is regulated within title 14, sections 1751 through 1789 of the California Code of Regulations.
Chemical Abstract Service Registry Number	A unique identification number assigned by the Chemical Abstract Service (CAS) for every chemical compound or mixture of chemical compounds described in scientific literature.
Class II (Injection) Well	Class II wells in California are approved and regulated by CalGEM for the injection of fluids produced as byproducts of the recovery or production of oil or gas, or for storage of hydrocarbons pursuant to CalGEM's UIC program. See *Underground Injection Control (UIC)*.
Confidential Well	A temporary well status approved by CalGEM to protect certain information about a well from disclosure to public and presumably competing operators.
Constituent	A chemical used in a WST additive or base fluid; a chemical component of a WST fluid.

TERM	DESCRIPTION
Diatomite	A rock of very high porosity and usually low permeability that may contain oil or gas. Diatomite is found within the Monterey Formation and other petroleum-bearing rock formations in California and elsewhere.
Directionally Drilled Well	A well that has been intentionally constructed away from vertical, on or close to a pre-planned pathway. Some directionally-drilled wells are curved upward during drilling to be finished as horizontal wells.
Disclosure	The electronic report of a WST submitted to CalGEM under WST regulations.
Disposition	Term used in WST statutes for the management or disposal of water or other wastes from WST operations.
District	An administrative regional CalGEM office.
Gas	Natural gas. Natural gas consists of methane and other simple hydrocarbon molecules that are gasses rather than liquids at room temperature and pressure. Natural gas is present both dissolved in oil and in pore space above oil, within the Earth.
Hydraulically Fracture Stimulation	Refers to the intentional, short-term injection of fluid at sufficient pressure to break apart rock to enhance the permeability of (stimulate) a portion of rock or sediment formation intercepted by a well.
Measured Depth	The distance along the actual path of wellbore, from the ground surface, drilling mat, kelly bushing, drill floor, or other aboveground reference point used during drilling. Measured depth can be thought of as the total length of drill pipe in the ground to reach the end of a wellbore, no matter how curved and twisted the well bore path may be from the reference point.
Monterey Formation	The name used in much of California for a portion of the Miocene-aged, fine-grained sedimentary rock (i.e., commonly shale) deposited and still present along the margin of the Pacific Ocean.

TERM	DESCRIPTION
Neighbor Notification	The requirement and process to notify landowners and occupants of parcels of property located within specified distances of a well where a WST is to be performed. The notification allows landowners or occupants to request that ground or surface waters that are suitable for drinking or irrigation be sampled and tested to assess possible impact from WST.
Notice of Violation	Written notification made to an oil or gas well operator from the State Oil and Gas Supervisor of violation of a regulation or statute. A Notice of Violation is commonly the first formal correspondence to an operator preceding an Order or other potential enforcement action.
Notice to Operators	A written clarification, transmission of, or request for information made by CalGEM to oil and gas well operators about a specific topic.
Notification	The process of providing information about an upcoming action, an opportunity, or an action taken, made in writing, to a party. See *Neighbor Notification* for one example of a notification required by SB 4.
Operator	A party that owns or has legal responsibility for the maintenance and operation of an oil or gas well or other well that falls within the jurisdiction of CalGEM.
Permeability	The property of or rate at which a solid can or does transmit oil, water, air, or other fluids. See *Porosity*.
Porosity (Pore Space)	The presence within and amount of a solid that is void (potentially empty) space. Pore space within rocks and soil is filled with oil, water, air or other gasses or fluids. See *Permeability*.
Pressure Testing	The requirement implemented July 1, 2015, that an operator notify CalGEM of and record pressure tests of all well casings and tubings to be used in a WST operation. See *Zonal Isolation* and *Well Integrity*.

TERM	DESCRIPTION
Produced Water	Water that is extracted from beneath the ground surface as a byproduct of oil or gas production. In mature oil fields such as those common in California, most of the fluid that is pumped from the ground is produced water. In California, most produced water is naturally salty.
Public Resources Code (PRC)	One of 29 groupings of California statutes (laws). The Public Resources Code contains key statutes affecting oil and gas resources, wells, and operations. SB 4 added language primarily to the PRC to give CalGEM greater authority and responsibility to regulate WST.
Recovered Water or Fluid	Fluids (e.g., water, oil, and gas) that come out (either naturally or by pumping or other assistance) of an oil or gas well after WST and prior to the routine production or other stabilized use and flow of fluids from a well. SB 4 requires operators to chemically test and provide information to CalGEM about recovered fluids.
Rulemaking Process	The procedure used by any component of the Executive Branch (of the State of California government) in adopting regulations and rules that will have the force of law. CalGEM followed both the emergency rulemaking process and regular rulemaking process in implementing SB 4.
Senate Bill 4 (SB 4)	California State Senate Bill 4 (Pavley, Chapter 313, Statutes of 2013) was passed by the Legislature and signed by Governor Jerry Brown in September 2013 to better regulate WST.
Spot-Check (Inspection)	The term used in SB 4 to describe a visit by CalGEM staff to a WST operation for the specific purpose of comparing the additives, chemicals, and base fluid at the WST location with the information about the additives, chemicals, and base fluid that was supplied in the Notice.
Stage	A subset or smaller portion of the total interval or portion of a well that is stimulated. A typical WST has several to more than ten stages that are performed in rapid succession in a single effort.

TERM	DESCRIPTION
Trade Secret	The withholding of certain information about one or more WST additives from the public and presumably competitors. SB 4 allows an operator to request trade secrecy from CalGEM through a rigorous and formal process.
True Vertical Depth	The straight-line extent of a well vertically down into the Earth, calculated without regard to actual twists, curves or intentional deviations of the well bore. It is measured from the ground surface, drilling mat, kelly bushing, drill floor, or other aboveground reference point used during drilling.
Underground Injection Control (UIC)	CalGEM has responsibility and authority to regulate the injection of any fluid into the ground via any oil or gas or other well under its jurisdiction. CalGEM's UIC regulations and authority conform to and were granted by federal authority in compliance with the federal Safe Drinking Water Act of 1974. See "Class II well."
Wellbore	A hole that is drilled to aid in the exploration and recovery of natural resources including oil, gas, or water.
Well (Casing) Integrity	The reliability of a well to perform its functions. This includes intact and functioning casing and cement that can durably resist all foreseeable changes (such as pressures, corrosive fluids or earth settlement or lateral shift) in conditions within and outside the well and ensure zonal isolation. See *Zonal Isolation*.
Well Stimulation	The brief and intentional application of pressure, chemicals, or other method to rock or sediment intercepted by a well, to increase the rock or sediment permeability to enhance oil or gas production, or potentially to increase water production or the ability of rock or sediment to accept injection water or other fluid.
Well Stimulation Treatment (WST)	Any treatment of a well designed to enhance oil and gas production or recovery by increasing the permeability of the formation. WSTs include, but are not limited to, hydraulic fracturing treatments and acid well stimulation treatments.
Witnessing (Inspection)	The term used in SB 4 to describe a general or all-purpose visit by CalGEM staff to a WST operation to observe, monitor, or verify any regulated or required aspect of the WST.

TERM	DESCRIPTION
Zonal Isolation	The principal of constructing, verification-testing, and maintenance of a well to ensure that fluids are not migrating along or inside a well from one zone to another. Zones of concern that are protected from contamination of one another include oil or gas-bearing zones, zones of abnormally high pore pressures, zones of fresh water, zones of water of actual or potential beneficial use, zones of saline water, and zones of water contaminated by human activity.

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CALGEM DIVISION CONTACT INFORMATION

HEADQUARTERS

715 P Street, MS 1803
Sacramento, CA 95814
Phone: (916) 445-9686
Fax: (916) 319-9533

NORTHERN DISTRICT

Sacramento Office

715 P Street, MS 1804
Sacramento, CA 95814
Phone: (916) 322-1110
Fax: (916) 445-3319

Orcutt Office

195 S. Broadway, Suite 101
Orcutt, CA 93455
(805) 937-7246
Fax: (805) 937-0673

Ventura Office

1000 S. Hill Road, Suite 116
Ventura, CA 93003
(805) 937-7246
Fax: (805) 654-4765

INLAND DISTRICT

11000 River Run Blvd.
Bakersfield, CA 93311
(661) 322-4031
Fax: (661) 861-0279

SOUTHERN DISTRICT

3780 Kilroy Airport Way, Suite 400
Long Beach, CA 90806
(562) 637-4400
Fax: (562) 424-0166