2019 Annual Performance Report:

Model Criteria for Groundwater Monitoring in Areas of Oil and Gas Well Stimulation

Reporting Period: January 1, 2019 through December 31, 2019

STATE WATER RESOURCES CONTROL BOARD

June 22, 2020

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GLOSSARY

Area-specific Groundwater Monitoring Plan (GMP) – A groundwater monitoring plan submitted by the oil and gas field operator to characterize baseline water quality conditions and detect potential impacts to protected water from well stimulation treatments (area-specific). A GMP may be developed for a stimulated well or group of stimulated wells. The GMP should describe the groundwater monitoring design, as well as proposed groundwater sampling and analytical testing. An operator may propose additional wells to stimulate in an area where a GMP has been approved by State Water Board and Regional Water Quality Control Board (collectively Water Boards) staff (**addendum**).

Axial Dimensional Stimulation Area (ADSA) – The estimated maximum length, width, height, and azimuth of the area(s) stimulated by a well stimulation treatment (WST) (California Geologic Energy Management Division [CalGEM, formerly DOGGR] Well Stimulation Treatment Regulations, July 1, 2015). CalGEM approves or denies the ADSA as part of the well stimulation permitting process. After approval of the ADSA, a well stimulation permit may be issued to an operator; however, stimulation cannot occur until State Water Resources Control Board (State Water Board) staff has approved either a groundwater monitoring plan or request for exclusion from groundwater monitoring associated with the permitted well(s).

Designated Contractors – State Water Board is required to designate one or more qualified independent third-party contractors to perform property owner requested water quality sampling and testing (Pub. Resources Code, §3160, subdivision (d)(7)(B)), which interested parties must submit an application to be approved. The designated contractor must not work for or be affiliated with an oil and gas operator. A list of approved designated contactors is maintained by the State Water Board.

Exempted aquifer – As defined in 40 Code of Federal Regulations (CFR) part 146.4, an aquifer or a portion thereof which meets the criteria for an underground source of drinking water that

1) does not currently serve as a source of drinking water, and

2) it cannot now and will not in the future serve as a source of drinking water.

Refer to 40 CFR part 146.4 for regulation specifics.

Groundwater Monitoring – Monitoring of protected water in a specific area to characterize baseline water quality conditions and to assess potential effects to beneficial use waters from well stimulation treatment activities (i.e., monitoring well sampling and gauging of water levels).

Interim Groundwater Monitoring Plan (interim GMP) – GMP approved during the interim period (January 1, 2014 – July 6, 2015) prior to the State Water Board adoption of the Model Criteria.

Model Criteria for Groundwater Monitoring in Areas of Oil and Gas Well Stimulation – Outlines the methods to be used for assessment, sampling, analytical testing, and reporting of

water quality associated with oil and gas well stimulation treatments. Adopted by the State Water Board July 7, 2015.

Performance Measures – Performance measures are a means to evaluate the effectiveness and efficiency of the Model Criteria. Five (5) goals were developed through a process of meetings with stakeholder groups. Performance measures are included in the *Model Criteria for Groundwater Monitoring in Areas of Well Stimulation: Summary of Goals, Strategies, Proposed Performance Measures, and Plans for Implementation* (March 1, 2016).

Protected Water – Water with less than 10,000 milligrams per liter of total dissolved solids and located outside an exempt aquifer (meeting the criteria of 40 CFR part 146).

Regional Groundwater Monitoring Program (RMP) – As required by Senate Bill 4 (Statutes of 2013), and detailed in the Model Criteria, the State Water Board is to implement an oil and gas RMP in order to protect all waters designated for any beneficial use, while prioritizing the monitoring of groundwater that is or has the potential to be a source of drinking water. Factors considered for the RMP include well stimulation treatments, among other events or activities that have the potential to contaminate groundwater. The U.S. Geological Survey is the technical lead on the RMP.

Request for Exclusion from Area-Specific Groundwater Monitoring (request for exclusion) – A document submitted by the oil and gas field operator to request exclusion from groundwater monitoring before proceeding with well stimulation activities. Water Boards staff must provide a written concurrence to the operator for the exclusion from groundwater monitoring. Additionally, operators can submit requests to add wells to an existing exclusion. Specific submission requirements are provided in the Model Criteria.

Well stimulation treatment (WST) – A treatment procedure for a well to enhance production by increasing the permeability of the formation. WSTs include, but are not limited to, hydraulic fracturing treatments and acid well stimulation treatments. WSTs do not include steam flooding, water flooding, cyclic steaming, or routine well work.

ABBREVIATIONS AND ACRONYMS

ADSA	Axial Dimensional Stimulation Area
Annual Model Criteria Performance Report	2019 Annual Performance Report: Model Criteria for Groundwater Monitoring in Areas of Oil and Gas Well Stimulation
API	American Petroleum Institute
bbl	barrel(s) of oil
CalGEM	California Geologic Energy Management Division (formerly DOGGR)
Central Valley Water Board	Central Valley Regional Water Quality Control Board
CIPA	California Independent Petroleum Association
COGG	United States Geological Survey California Oil, Gas, and Groundwater Program (synonymous with RMP)
DOGGR	State of California Department of Conservation, Division of Oil, Gas, and Geothermal Resources
ESI	Electronic Submittal of Information
GeoTracker	GeoTracker Information System
GAMA GIS	Groundwater Ambient Monitoring and Assessment Groundwater Information System
GMP	Area-specific groundwater monitoring plan
GMR	Area-specific groundwater monitoring report associated with GMPs
MCL	maximum contaminant level
Model Criteria	Model Criteria for Groundwater Monitoring in Areas of Oil and Gas Well Stimulation
neighbor notification	CalGEM Well Stimulation Treatment Neighbor Notification Form
NWIS	National Water Information System
operator	oil and gas field operator
RMP	Regional Monitoring Program (synonymous with COGG)
Regional Water Board	Regional Water Quality Control Board
Reporting period	January 1, 2019 - December 31, 2019
State Water Board	State Water Resources Control Board
TDS	total dissolved solids
US EPA	United States Environmental Protection Agency

USGS	United States Geological Survey
USDW	Federal designation of an underground source of drinking water
Water Boards	State Water Resources Control Board and Regional Water Quality Control Boards (collectively)
WellSTAR	Well Statewide Tracking and Reporting System
WSPA	Western States Petroleum Association
WST	Well Stimulation Treatment

EXECUTIVE SUMMARY

This Annual Performance Report summarizes work performed from January 1, 2019 through December 31, 2019 by staff from the State Water Resources Control Board (State Water Board) and associated agencies to implement the *Model Criteria for Groundwater Monitoring in Areas of Oil and Gas Well Stimulation* (Model Criteria). The Model Criteria was adopted by the State Water Board on July 7, 2015 (Resolution No. 2015-0047).

State Water Board developed the Model Criteria to guide the process for assessing potential effects of well stimulation treatments (WSTs) on California's groundwater resources. It outlines groundwater monitoring requirements for area-specific groundwater monitoring conducted by oil and gas operators (operators), as well as the approach State Water Board staff will take to conduct a Regional Monitoring Program (RMP).

A WST cannot be performed until staff from the State of California Department of Conservation, California Geologic Energy Management Division (CalGEM) issues a WST permit and the State Water Board and the Regional Water Quality Control Board (Water Boards) staff have:

- approved an operator-submitted groundwater monitoring plan (GMP), or
- approved an operator-submitted request for exclusion from groundwater monitoring (request for exclusion).

If the operator proposes WST for additional wells in an area where a GMP or exclusion was previously approved, an addendum to the GMP (hereafter referred to as addendum) or a request to add wells to an existing exclusion is required.

The requirement for an GMP is limited to areas where protected water is present. Protected water is defined as:

- Water with less than 10,000 milligrams per liter of total dissolved solids, and
- Water located outside of an exempt aquifer (meeting the criteria of 40 Code of Federal Regulations (CFR) part 146.4).

Efforts performed by Water Boards staff for implementation of the Model Criteria during the reporting period (January 1, 2019 to December 31, 2019) are presented in six sections of this report, as follows, 1) introduction and background of the Model Criteria, 2) area-specific groundwater monitoring, 3) property owner's requests for water quality testing, 4) RMP, 5) performance measures, and 6) lessons learned.

Area-Specific Groundwater Monitoring. The number of GMPs (new and addenda), requests for exclusions, or requests to add wells to an existing exclusion submitted by the operators to Water Boards staff and their review status (i.e., approved, denied, or review in progress) are summarized in the table below.

Area-Specific Groundwater Monitoring Summary (January 1, 2019 – December 31, 2019)

Type of Submittal	Approved	Denied	Review in Progress / On Hold	Cancelled	Total	*Total No. of Approved WST Wells*
GMPs	3	0	3	1	**7**	***4***
Addenda	15	0	8	0	**23**	***163***
Requests for Exclusions	6	0	1	1	**8**	***6***
Requests to Add Wells to an Existing Exclusion	34	0	2	0	**36**	***173***

Property-Owner Notifications and Requested Water Sampling. Operators are required to hire an independent third-party to notify property owners, or tenants of a property, located within 1,500 feet of the well to be stimulated or within 500 feet of the surface representation of the horizontal path of the area of stimulation. A property owner that has received a notification can access a list of designated contractors on the State Water Board website. Designated contractors are required to notify State Water Board staff prior to sampling and upload the results to GeoTracker after sampling. State Water Board staff were not notified of any property owner requests for water quality testing in 2019.

Regional Monitoring Program. The goal of the RMP is to evaluate potential impacts from WST and oil field operations and characterize the risk to subsurface water designated for any beneficial use (e.g., drinking water). In 2019, the United States Geological Survey (USGS) as technical lead of the RMP continued their salinity mapping work; conducted geophysical surveys; collected well depth, casing gas, produced water, and water chemistry data; and met with oil and gas stakeholders.

Performance Measures. Under the direction of the State Water Board, staff developed performance measures for evaluation of the Model Criteria. These performance measures were prepared in collaboration with stakeholders and were presented to the State Water Board on March 1, 2016. The document includes goals, strategies, and plans for implementing the Model Criteria. A summary of the performance measures is provided below with highlights of 1) actions completed in 2019 and 2) actions planned for 2020:

- Provide transparent and available information online: New groundwater monitoring data was uploaded to GeoTracker and updates were made to the State Water Board's Oil and Gas webpage to include recent USGS publications. Feedback from operators was solicited on their experience with GeoTracker. In 2020, State Water Board staff will develop a layer in GeoTracker to display RMP data. Staff will also evaluate data sharing and opportunities to reduce duplication of data as new phases of CalGEM's Well State Tracking and Reporting (WellSTAR) are released.

- Provide clear milestones and timely deliverables: A staff workshop was held to review the definition of "Protected Water" as required by Water Code § 10783. An internal oil

and gas program procedures manual was developed, and training sessions were held to ensure consistent document reviews by staff. Also, staff evaluated the timeliness of review in the annual performance measures report. In 2020, staff will continue to update the oil and gas program procedures manual and hold training to ensure consistent reviews. Staff will also evaluate the use of available tracking tools to better monitor the status of submittals.

- Understand and mitigate impacts of well stimulation on water quality and public health: State Water Board staff hosted 1) stakeholder technical briefings on RMP activities, and 2) met with operators on the groundwater monitoring report review. Staff developed a communication strategy for the RMP and held kick off meetings with operators prior to RMP sampling. In 2020, State Water Board staff will begin its formal evaluation of the Model Criteria by seeking input from technical experts, Regional Water Boards, CalGEM, USGS, and operators. Staff will send review comments to operators on groundwater reports to ensure compliance with the Model Criteria. Finally, staff will host stakeholder meeting(s) to present technical briefings following RMP publications.

- Provide region-specific or localized flexibility: State Water Board staff did not receive alternative proposals for groundwater monitoring during the reporting period.

- Assess implementation costs: In 2019, operators spent approximately $2.9 million on implementing groundwater monitoring and $500,000 for requests for exclusion from groundwater monitoring.

1.0 INTRODUCTION

The State Water Resources Control Board (State Water Board) *Model Criteria for Groundwater Monitoring in Areas of Well Stimulation: Summary of Goals, Strategies, Proposed Performance Measures, and Plans for Implementation* (Performance Measures) specifies that the State Water Board prepare and make publicly available an "Annual Model Criteria Performance Report." This report summarizes work conducted from January 1, 2019 through December 31, 2019 (reporting period) associated with the State Water Board's Model Criteria for Groundwater Monitoring in Areas of Oil and Gas Well Stimulation (Model Criteria). Well stimulation permits are issued to operators by the State of California Department of Conservation, California Geologic Energy Management Division (CalGEM) and are required prior to performing well stimulation treatments (WSTs). The number and status of well stimulation permits can be found on CalGEM Well Statewide Tracking and Reporting (WellSTAR) website. Effective December 17, 2019, the public can use WellSTAR to find information about WST permits and disclosures.

This report is organized into six sections. This section, Section 1.0, provides a description of the establishment of the Model Criteria and Performance Measures. Section 2.0 describes the process of the area-specific groundwater monitoring plan (GMP) and results for 2019. Section 3.0 summarizes the procedures and the number of the property owner notifications sent prior to performing WSTs in 2019. Section 4.0 describes the Regional Monitoring Program (RMP) activities to date, a summary of completed activities in 2019, preliminary results, and a listing of planned activities for 2020. Performance Measures, described in Section 5.0, provides strategies and actions taken in 2019 for each of the five performance goals. Lastly, Section 6.0 summarizes the list of lessons learned and planned actions for 2020. Please note that URLs for hyperlinks can be found in the Web Link Glossary (Appendix A).

1.1 Background

California Water Code section 10783 (Senate Bill 4, Pavley, statutes of 2013) requires the State Water Board to establish and implement a comprehensive regulatory groundwater monitoring and oversight program for WSTs (including hydraulic fracturing) in areas of oil and gas operations. The State Water Board was also required to develop model criteria for groundwater monitoring in order to assess potential effects of WSTs on California's groundwater resources. The Model Criteria was adopted by the State Water Board on July 7, 2015 (Resolution No. 2015-0047). It outlines requirements for groundwater monitoring conducted by operators, as well as the approach the State Water Board will take to conduct the RMP.

Upon the passage of Senate Bill 4, the State Water Board and CalGEM developed Emergency Interim Regulations which included interim groundwater monitoring requirements. Effective January 1, 2014 through June 30, 2015, well operators were required to submit either an approved groundwater monitoring plan (interim GMP) or a letter from State Water Board staff concurring that the well(s) planned for WST does not penetrate protected water. If WSTs were planned after adoption of the Model Criteria, the operator was required to submit a GMP following the requirements of the Model Criteria. If no additional WSTs were planned in an area

with an approved Interim GMP, the operator continued monitoring under their respective Interim GMP. Therefore, there are several Interim and Model Criteria GMPs active during this reporting period. Data from both Interim and Model Criteria GMPs are uploaded to the publicly-accessible State Water Board's GeoTracker information system (GeoTracker).

The State Water Board directed staff to collaborate with stakeholders to develop performance measures for the evaluation of the Model Criteria. These performance measures were presented to the State Water Board on March 1, 2016 and included goals, strategies, and plans for implementing the Model Criteria and are found in Appendix B.

Five performance measures were identified, as provided below:

1. Provide transparent and availability of online information and documentation
2. Provide clear milestones and timely deliverables
3. Understand and mitigate impacts of well stimulation on water quality and public health
4. Provide region-specific or localized flexibility, where possible
5. Assess implementation costs

More information regarding the status of these Performance Measure goals is provided in Section 5.0 of this report.

2.0 AREA-SPECIFIC GROUNDWATER MONITORING

This section provides a summary of the GMPs submitted by operators to the State Water Board and Regional Water Quality Control Boards (collectively Water Boards) staff during the reporting period. All GMPs submitted were within the jurisdiction of the Central Valley Regional Water Quality Control Board (Central Valley Water Board).

A WST cannot be performed until CalGEM issues the WST permit and Water Boards staff have approved an operator submitted GMP, an addendum to a GMP (addendum), or request for exclusion from groundwater monitoring.

The requirement for a GMP is limited to areas where protected water is present. Protected water is defined as water:

- with less than 10,000 milligrams per liter of total dissolved solids, and
- located outside an exempt aquifer (meeting the criteria of 40 Code of Federal Regulations (CFR) part 146.4).

State Water Board staff held a public workshop on May 10, 2019 to review the definition of protected water through a public process as required by the Water Code (§ 10783(k)(2)). Representatives from industry and environmental groups gave presentations and provided feedback on the definition of protected water. Review of the definition of protected water is discussed further in Section 5.2.

If the operator proposes WST for additional wells in an area where a GMP or exclusion was previously approved, an addendum to the GMP or a request to add wells to an existing exclusion is required.

Water Boards staff review GMPs and requests for exclusion that are submitted by operators. Process flowcharts for Water Board staff review of GMPs and addenda can be found in Appendix C. The statuses of these documents are cited in this performance report as follows:

- “Approved”: Submittal was reviewed and has met the requirements of the Model Criteria.
- “Denied”: Submittal did not meet the minimum requirements of the Model Criteria.
- “Cancelled”: Submittal was retracted by the operator.
- “Review in Progress”: Submittal is being reviewed by Water Boards staff.
- “On Hold”: Water Boards staff are not currently reviewing the submittal. Submittals may be put “On Hold” for the following reasons:
    - Comments have been forwarded to the operator and the operator is working on a revised submittal.
    - Water Boards staff are awaiting approval of the Axial Dimensional Stimulation Area (ADSA) from CalGEM.
    - The GMP is on hold at the request of the operator.

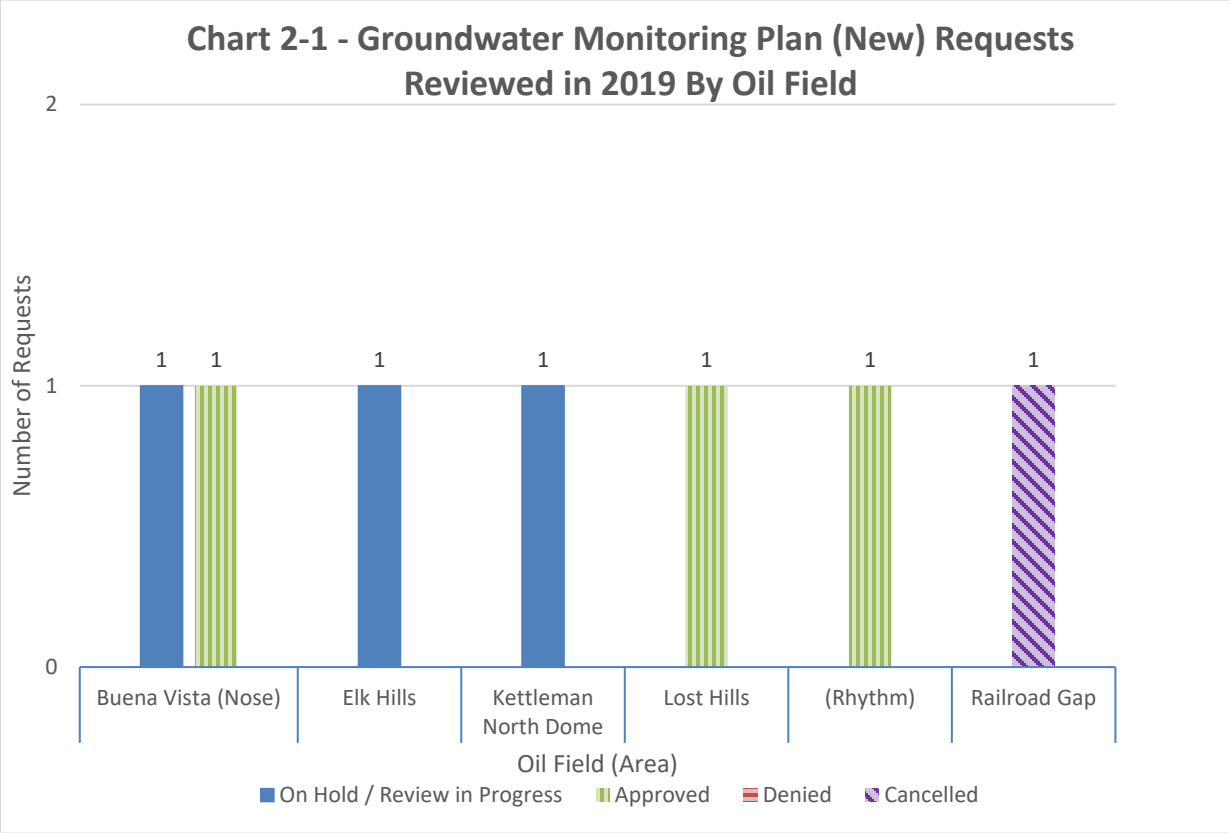
2.1 Requests for Groundwater Monitoring

This section provides a summary of the number, status, and location of GMP requests (new and addenda) submitted in 2019, and review of GMP requests which continued during the reporting period from previous years. Additionally, this section addresses the Water Boards' review process and timeline. Details on individual GMP requests are provided in Appendix D.

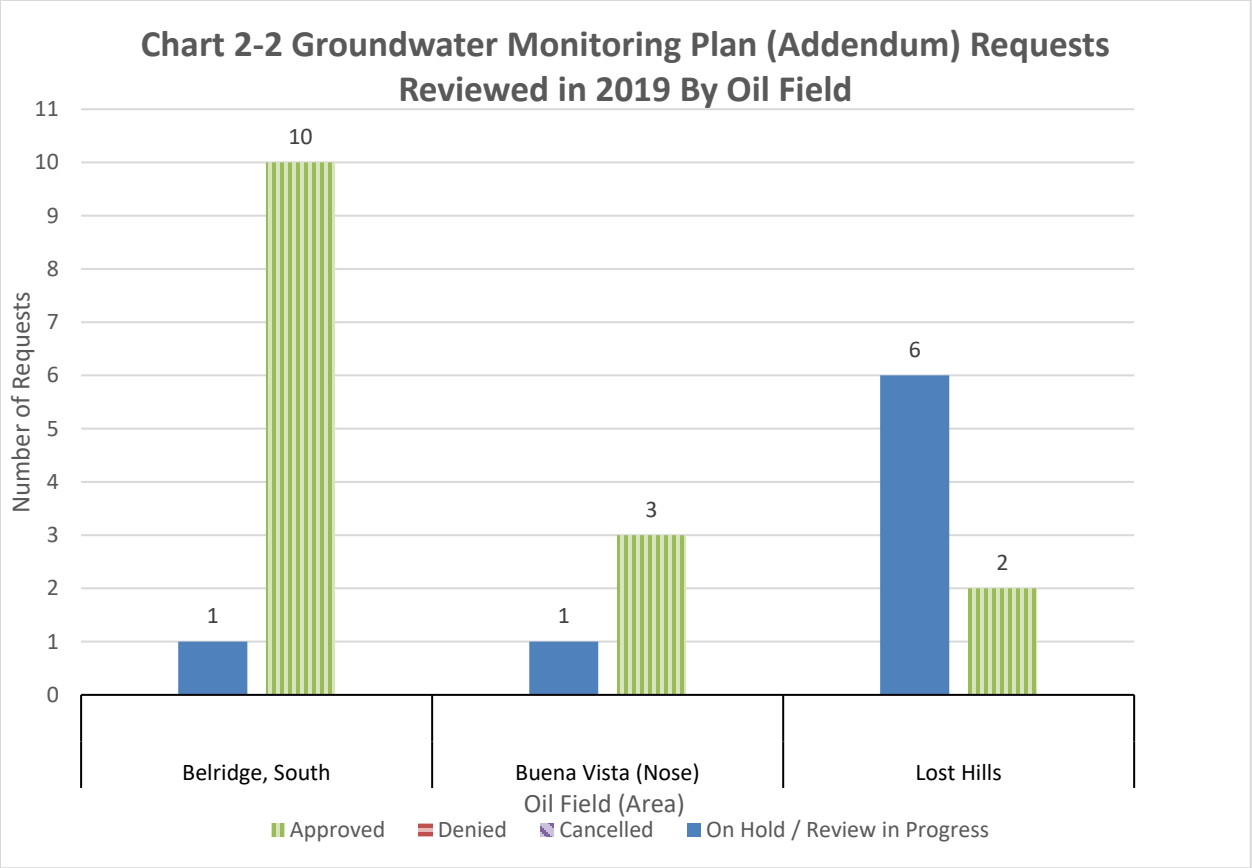
2.1.1 Groundwater Monitoring Plans Submitted for Review

Operators submitted 7 GMPs and 23 addenda for Water Boards staff review. The statuses of GMPs and addenda are summarized in Charts 2-1 and 2-2. Tables D-1 and D-2 provide a detailed summary of review timeline milestones. The locations of GMPs and addenda submitted, and wells stimulated in 2019 are shown in Figure 2-1. Locations for GMP and addenda are from GeoTracker while locations of wells stimulated are from FracFocus. FracFocus is the national hydraulic fracturing chemical registry; which is managed by the Ground Water Protection Council (non-profit organization) and the Interstate Oil and Gas Compact Commission (multi-state government entity) whose members include the governors of oil and gas producing states (including California) and their appointed representatives.

GMP and addenda submitted during the reporting period were in Kern County (Elk Hills, Railroad Gap, Lost Hills, Buena Vista (Nose), and Rhythm) and in Kings County (Kettleman North Dome). There were 167 WST wells approved in areas with GMPs and addenda.



Review time and additional details for Chart 2-1 can be found in Appendix D, Table D-1



Review time and additional details for Chart 2-2 can be found in Appendix D, Table D-2

2.1.2 Process and Timeline for Reviewing Groundwater Monitoring Plans

The process flowchart for review of a GMP is shown on Flowchart C-1 in Appendix C. Once a GMP or addendum has been uploaded to GeoTracker, Water Boards staff conduct a completeness check to assure that all required information has been submitted. Following the completeness check, Water Boards staff accept the document into GeoTracker and begin their initial review. Water Boards staff develop comments based on its operators to obtain additional information and research hydrogeologic information in areas where the direction of groundwater flow is not well understood. After review by Water Boards staff, initial comments are forwarded to the operator, the GMP may be approved, or the GMP may be denied. If Water Boards staff provide comments or deny a GMP and the operator chooses to pursue WST at that location, they are required to submit a revised GMP. The ADSA must be approved by CalGEM before a GMP or addendum can be approved. When submittals are placed “On Hold”, that time is not included in the calculation of total review time.

The average time for Water Boards staff to respond to the operator with review comments during the reporting period is summarized in Tables 2-1 and 2-2. Since 2017, Water Boards staff set a goal of 45 days for providing comments to operators. The average time for initial response to the operator increased for GMPs and addenda from initial response time in 2018. The average time to complete the entire review process also increased.

The timelines for review of GMPs increased during the reporting period for the following reasons:

- All GMPs required submittal of 3 different versions by operators prior to approval
- GMPs required multiple meetings with operators to discuss the number, location, and construction methodologies of wells.
- Water Boards staff are not able to approve a GMP until the ADSA narrative is received from CalGEM. Receipt of the ADSA narratives were delayed due to audits conducted by Lawrence Livermore National Laboratory and the California Department of Finance Office of State Audits.
- Several GMPs were in areas where 1) there was little to no hydrogeologic information, 2) there were complex hydrogeologic conditions, and 3) additional efforts to investigate and collect hydrogeologic information was required.
- Several GMPs used monitoring well construction techniques that required additional review time.
- Water Boards staff accommodated changes to operators' schedules by reprioritizing GMP reviews upon operator request.
- The number of GMPs submitted and WST wells reviewed has more than doubled since 2017.

Water Boards staff will re-evaluate the goal of 45 calendar days to respond with comments to operators in 2020, including methods for measuring those time intervals.

Table 2-1. GMP Summary

Year	Total Submittals	Submittals Approved	WST Wells Approved	Completeness Check Average (Days)	Initial Review Range (Days)	Initial Review Median (Days)	Review Process Complete Median (Days)
2017	8	5	46	ND	ND	ND	ND
2018	8	3	62	3	47 - 103	71.5	113.5
2019	7	3	4	3	47 - 132	81.5	195

Table 2-2. Addendum Summary

Year	Total Submittals	Submittals Approved	WST Wells Approved	Completeness Check Average (Days)	Initial Review Range (Days)	Initial Review Median (Days)	Review Process Complete Median (Days)
2017	4	4	11	ND	ND	ND	ND
2018	16	11	68	3	6 - 86	50	62
2019	23	15	163	4	13 - 104	50	58

2.2 Groundwater Monitoring Plans Submitted that Propose Alternative Methods

The Model Criteria allows Water Boards staff to consider proposed alternatives and modifications to the methods for GMPs based on factors such as site-specific conditions (e.g., terrain, geology, access), number and depth of aquifers containing protected water, potential pathways, and risk to receptors (e.g., groundwater resources). Water Boards staff shall provide at least fifteen days public notice and an opportunity for comments on the proposal prior to approving a proposed alternative or modification.

State Water Board staff did not receive an alternative proposal for groundwater monitoring for review.

2.3 Requests for Exclusion from Groundwater Monitoring

A GMP is required unless an operator can clearly demonstrate that the wells to be stimulated do not penetrate protected water. If Water Boards staff concur, an exclusion from groundwater monitoring requirements may be granted to the operator. Operators must also obtain approval from Water Boards staff for additional WST wells to be stimulated in an existing exclusion from groundwater monitoring. These requests for exclusion and requests to add wells to an existing exclusion are publicly available in GeoTracker.

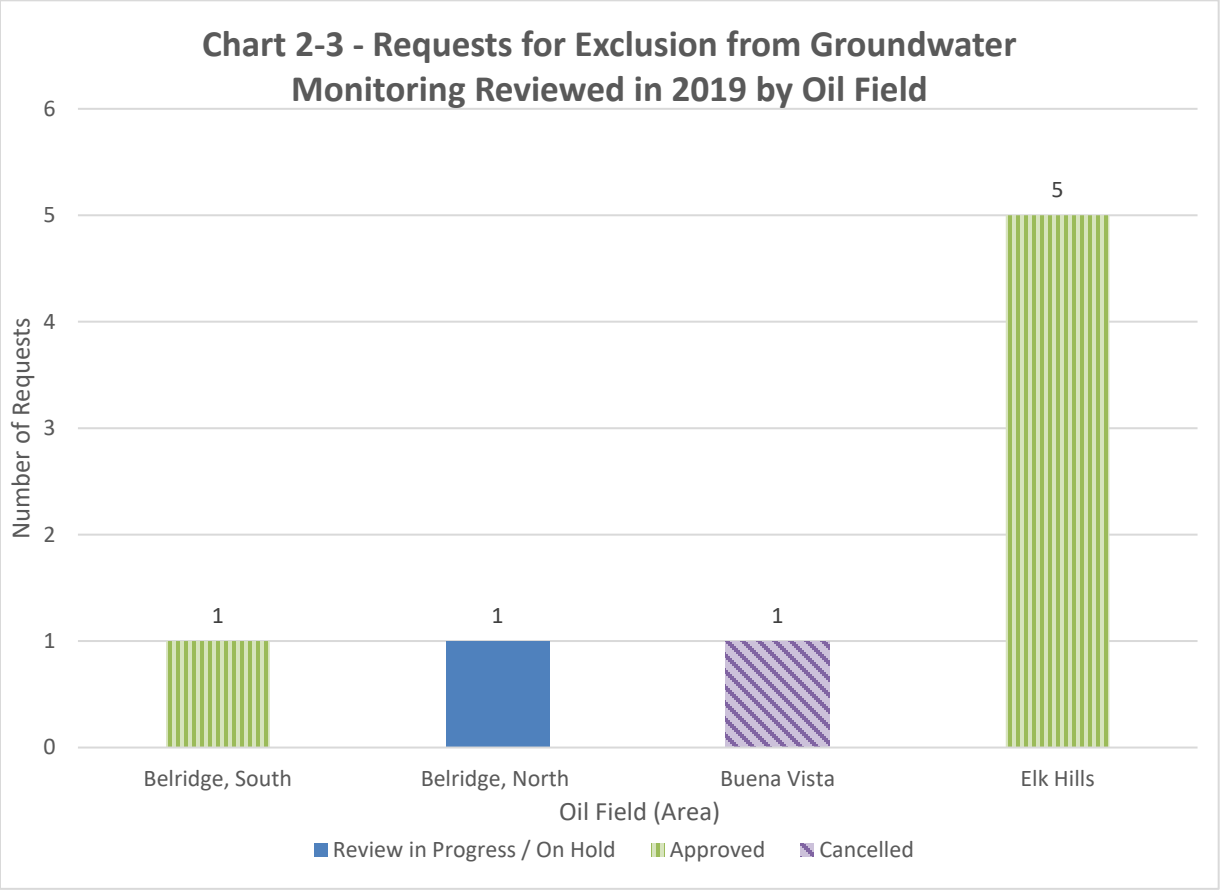
This section provides a summary of the number, status, and location of requests for exclusion and requests to add wells to an existing exclusion submitted or reviewed in 2019. The locations of requests for exclusion are shown on Figure 2-2. The process and timeline involved in reviewing a request for exclusion and request to add wells to an existing exclusion is discussed below.

2.3.1 Requests for Exclusion and Wells Added to an Existing Exclusion

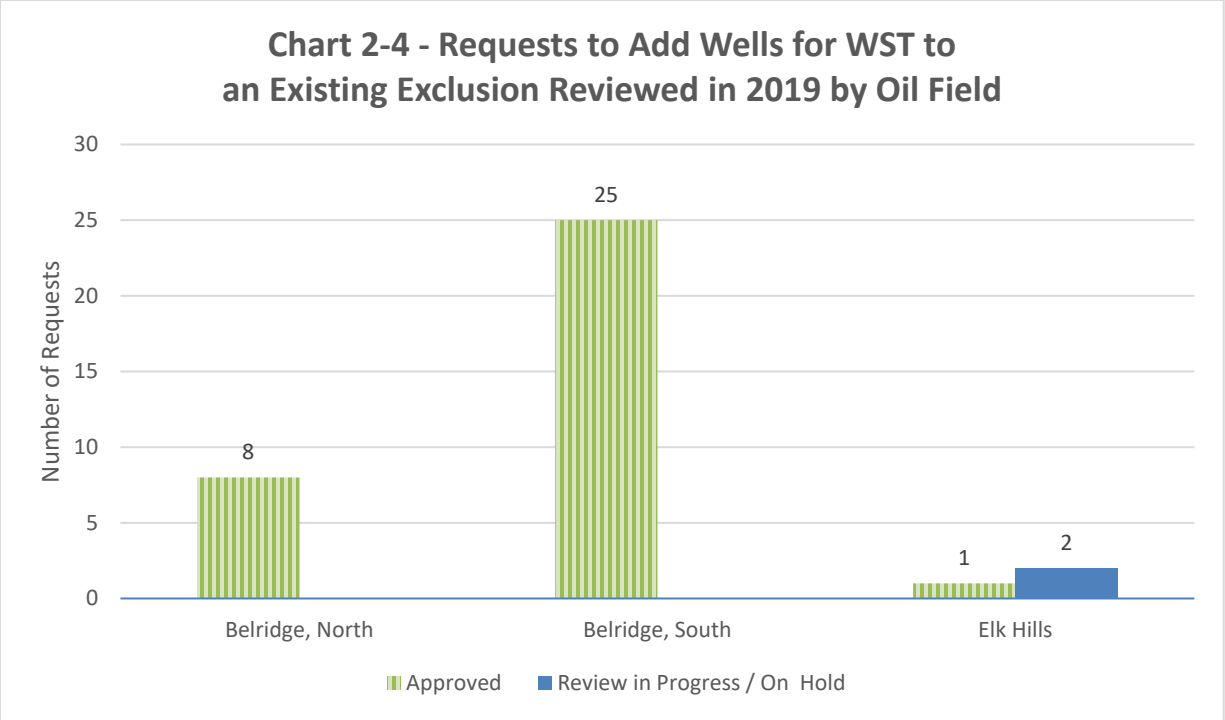
Operators submitted eight requests for exclusion and 36 requests to add wells to an existing exclusion for Water Boards staff review. The statuses of requests for exclusion and wells added to an existing exclusion are summarized in Charts 2-3 and 2-4. Tables D-3 and D-4 provide a detailed summary of review timeline milestones. The locations of these submittals as well as wells stimulated in 2019 are shown in Figure 2-2. Locations for requests for exclusion and wells

added to an existing exclusion are from GeoTracker while locations of wells stimulated are from FracFocus.

All requests for exclusion and wells added to an existing exclusion submitted during the reporting period were in Kern County (South Belridge, North Belridge, Buena Vista, and Elk Hills). A total of 173 WST wells included in requests to add to wells to an existing exclusion were approved. WST wells added to an existing exclusion increased significantly from the total WST wells added in 2018.



Review time and additional details for Chart 2-3 can be found in Appendix D, Table D-3



Review time and additional details for Chart 2-4 can be found in Appendix D, Table D-4

2.3.2 Process and Timeline for Reviewing Requests for Exclusion

The process flowchart for reviewing requests for exclusion is shown on Flowchart C-2 in Appendix C. Water Boards staff begin their review after a request for exclusion has been uploaded to GeoTracker and has been accepted as complete. The goal is to respond to the operator with initial review comments within 45 calendar days from acceptance of the submittal. After staff have completed their review, additional information may be requested, the request for exclusion may be denied, or the request for exclusion may be approved. Request for exclusion approval does not depend on CalGEM approving an ADSA but is based solely on whether sufficient technical information was submitted to indicate the absence of protected water.

The average time for Water Boards staff to respond to the operator with review comments during the reporting period is summarized in Tables 2-3 and 2-4. The average time to complete review of requests for exclusions decreased, and the average time to complete review of requests to add wells to an existing exclusion increased slightly compared to 2018.

Table 2-3. Requests for Exclusion Summary

Year	Total Submittals	Submittals Approved	WST Wells Approved	Completeness Check Average (Days)	Initial Review Range (Days)	Initial Review Median (Days)	Review Process Complete Median (Days)
2017	5	2	44	ND	ND	ND	ND
2018	4	2	2	8	28 - 78	47.5	84
2019	8	6	6	2	40 - 83	53	66

Table 2-4. Requests to Add Wells to an Existing Exclusion Summary

Year	Total Submittals	Submittals Approved	WST Wells Approved	Completeness Check Average (Days)	Initial Review Range (Days)	Initial Review Median (Days)	Review Process Complete Median (Days)
2017	43	42	140	ND	ND	ND	ND
2018	33	32	97	4	1 – 49	8	8
2019	36	34	173	8	1 – 179*	8	8

**: A significant range is reported for initial review in 2019 because one request to add wells to an existing exclusion was inadvertently overlooked.*

2.4 Groundwater Monitoring Reports

Groundwater monitoring data uploaded to GeoTracker from groundwater monitoring wells sampled as part of interim GMP and Model Criteria GMP were reviewed by Water Boards staff. From 2014 to 2019, a total of 144 sampling events of data have been collected from 10 different areas in four counties (Table 2-4). Of these sampling events, most occurred in Kern County with a total of 128 sampling events in seven areas. A sampling event consists of one or more wells sampled during a discrete period (i.e. one to multiple days of sampling depending on the number of wells). Operators may use existing wells if approved by Water Boards staff. As a result, the number of monitoring wells for each GMP (Table D-5) refers to the wells sampled to satisfy the monitoring plan requirements. This number may include wells designed and drilled for the GMP, monitoring wells shared with other operators, or wells used in other regulatory programs. Each groundwater sample is tested by an accredited analytical laboratory for a suite of chemicals as required by either the Emergency Interim Regulations (for an interim GMP) or the Model Criteria.

Table 2-5. Summary of Sampling Events Uploaded into GeoTracker by Year

Year	Total Number of Sampling Events Uploaded into GeoTracker
2014	19
2015	32
2016	21
2017	27
2018	30
2019	15

In 2019, groundwater data from a 15 sampling events were uploaded by operators into GeoTracker compared to 30 sampling events in 2018 (Table 2-4). The number of sampling events is lower in 2019 because much of the collected data are being compiled by operators. Since groundwater sampling is required on a semi-annual basis, the quarter selected for sampling alternates each year (e.g. 1st and 3rd quarter in the 1st year and then 2nd and 4th quarter in the 2nd year). As a result, if the sampling event occurred in the fourth quarter, the final report

may not be submitted until the following year. A summary of sampling events is provided in Table 2-5.

Water Boards staff reviewed area-specific groundwater monitoring data submitted by operators in 2019. Staff evaluated analytical data against regulatory thresholds (e.g. maximum contaminant levels (MCLs) for drinking water). Analytes detected above regulatory thresholds in 2019 included TDS, arsenic, barium, molybdenum, strontium, boron, selenium, radium-226, or radium-228. Increasing concentrations of TDS were also observed in one monitoring well from South Belridge. These findings were reported to the Regional Water Board and further evaluation by the operator will be required. In August 2019, State Water Board staff held an information session to meet with operators and their consultants to discuss staff review of GMRs. Operators were informed that further evaluation of potential sources for all compounds detected in samples is necessary. Additionally, all sampling events must be considered, and evaluations must include statistical analysis of trends in chemical concentrations over time. Recommended methods that can be used to identify evidence of changes in chemical constituent concentrations in groundwater are provided in the Model Criteria Section 2.1.1.

3.0 PROPERTY-OWNER NOTIFICATIONS AND REQUESTED WATER SAMPLING

Operators are required to use a third-party contractor to notify property owners, or tenants of a property, located within 1,500 feet of the well to be stimulated or within 500 feet of the surface representation of the horizontal path of the area of stimulation. CalGEM is responsible for maintaining records regarding the third-party notification process. The third party sends the property owners or tenants a Well Stimulation Treatment Neighbor Notification Form (neighbor notifications), which includes information such as the earliest date the well may be stimulated and how the property owner may request water quality testing on an existing water well or surface water suitable for drinking. Additional information regarding this process can be found on the CalGEM Well Stimulation Treatment Neighbor Notification and Water Sampling webpage. Please note, as of October 29, 2019, neighbor notification forms must be submitted through the WellSTAR electronic database.

The numbers of neighbor notifications sent by operators are summarized in Table 3-1. Please note that the number of neighbor notifications dropped after 2015 with the passage of SB4 and has been steadily increasing since.

Table 3-1. Number of Neighbor Notifications Sent by Third-party Contractors

Operator	2014	2015	2016	2017	2018	2019
Aera Energy, LLC	818	960	29	138	250	**233**
Berry Petroleum Company, LLC	-	-	-	-	160	**219**
Breitburn Energy Co., LLC	18	-	-	-	1	**-**
Central Resources, Inc	19	-	-	-	-	**-**
Chevron USA, Inc	35	6	-	-	42	**-**
Crimson Resource Management	194	-	-	-	-	**-**
DCOR, LLC	11	-	-	-	-	**-**
Occidental of Elk Hills, Inc	57	36	-	-	-	**-**
Seneca Resources Corporation	19	4	-	-	-	**-**
Vintage Production California, LLC	108	-	-		-	**-**
California Resources Elk Hills, LLC	-	5	42	2	93	**57**
Linn Operating, Inc	-	273	-	-	-	**-**
Salt Creek Oil, LLC	-	-	2	-	-	**-**
Total	**1,279**	**1,284**	**73**	**140**	**546**	**509**

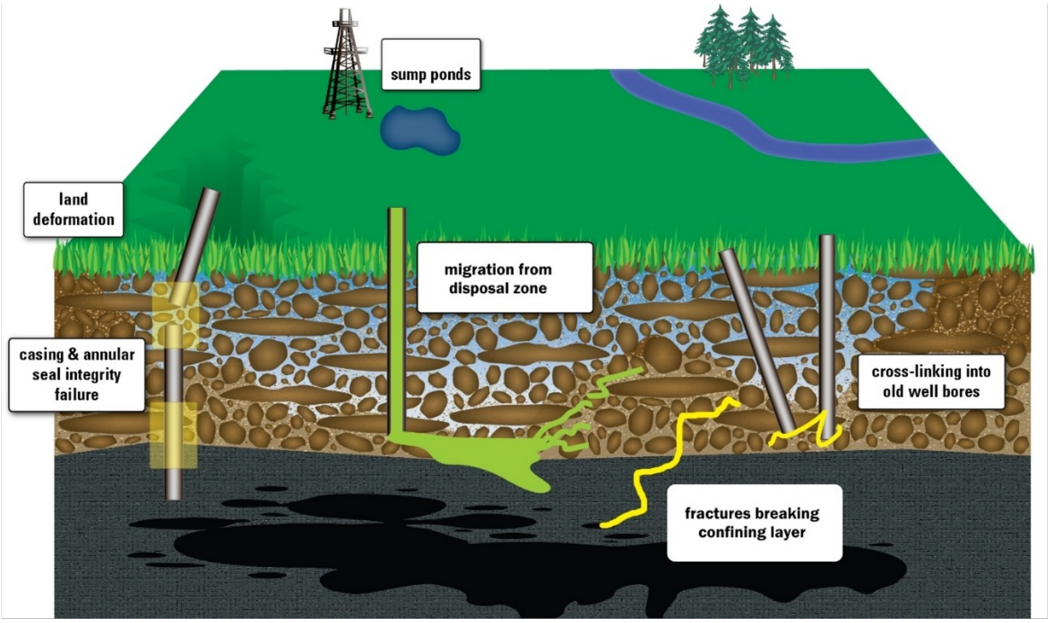
Source: State Water Board staff communication with CalGEM staff January 8, 2020.

State Water Board staff are required to designate qualified independent third-party contractors (designated contractor) to perform property owner requested water quality sampling. The State Water Board List of Designated Contractors for Water Sampling provides contact information for contractors who perform this service. Once a property owner has received a notification regarding WST from an operator, the property owner can choose a designated contractor from

the list to perform water quality sampling at their property. The designated contractor is to sample in accordance with the standards and protocols outlined in the Model Criteria. Designated contractors are required to notify State Water Board staff prior to sampling and upload the results to GeoTracker after analysis. During 2019, State Water Board staff did not receive any notifications of water sampling performed by a designated contractor. This would imply that the property owners who received a neighbor notification declined the opportunity to have their water sampled.

4.0 REGIONAL MONITORING PROGRAM

The primary goal of the RMP is to evaluate potential impacts from WST and oil field operations and characterize the risk to subsurface water designated for any beneficial use, while prioritizing the highest areas of risks to be monitored. The RMP is evaluating pathways (see illustration below) by determining which WSTs and other oil and gas operations have the potential to contaminate groundwater. Potential pathways include the injection of water and/or steam during enhanced oil recovery practices, underground oilfield water injection, leakage along improperly constructed and/or compromised wells, surface disposal ponds, or natural geologic sources.



Potential Pathways between Oil & Gas Activities and Protected Groundwater
(Source: USGS, https://ca.water.usgs.gov/projects/oil-gas-groundwater/science/pathways/)

The RMP is designed to answer the following questions:

- Where are groundwater resources?
- How close are oil and gas operations to groundwater resources, and what geologic materials (i.e., features and properties) separate them?
- Where is there evidence of fluids from oil and gas sources in groundwater? Where does evidence indicate no connections?
- When fluids from oil and gas sources are present in groundwater, what pathways or processes are responsible for observed transport?
- Have oil and gas operations contributed to overall water-quality changes in groundwater basins?

The approaches being used to answer those questions include: 1) mapping protected groundwater, 2) characterizing and monitoring groundwater in wells near oil fields, and 3) characterizing oil field fluids. Together, with site-specific information about the local geology, hydrology, and historic disposal areas, these three components will help to systematically and comprehensively collect and interpret information that will support management and protection of waters designated for any beneficial use. The United States Geological Survey (USGS) is the technical lead of the RMP. The USGS refers to the work performed under the RMP as the California Oil, Gas, and Groundwater (COGG) Program.

The RMP is conducted in a phased approach that allows findings to be assessed and future work to be refined. A "phase" depicts the compilation, review, synthesis, collection, and interpretation of data. Generally, the phases are as follows:

> **Phase 1** - Prioritizing areas for regional monitoring and collecting groundwater and produced water quality data for high priority oil fields. This phase began in 2015.
>
> **Phase 2** – Divided into four primary tasks for each oil field study area: 1) salinity mapping, 2) groundwater sampling, 3) oilfield fluid sampling, and 4) interpretative analysis of the collected data from tasks 1 through 3. Types of data used in this phase include historical water sample data, newly sampled water supply and produced water sample data, borehole geophysical logs, well construction data, and surface and airborne electromagnetics methods. This phase includes determining gaps in the data and potentially installing monitoring wells to fill-in those data gaps. This phase also includes an analysis of risks to groundwater quality. This phase began in 2016 and is ongoing.
>
> **Phase 3** – If results from Phase 2 indicate there is a high risk to protected groundwater from oil and gas operations, a sampling plan will be developed and could include the installation of groundwater monitoring wells. This phase has not yet begun.

Progress in answering the questions above in particular study areas are summarized in Sections 4.1 through 4.2 below, and all reports generated as part of the RMP are publicly available on the State Water Board Oil and Gas – Regional Groundwater Monitoring or the COGG Products webpage.

4.1 Overview of Completed Work

An overview of completed work by phases is provided below. Published products are listed in Appendix E.

Phase 1 – Initiated in 2015, Phase 1 focused on prioritizing areas for regional groundwater monitoring and compiling data from oil fields and nearby groundwater aquifers. Data obtained from underground injection control activities and aquifer exemption proposals were used in the prioritization process. About 100 oil fields with the presence of protected groundwater and active oil production and injection were given the highest priority. A summary technical report and data release documenting the prioritization work was published in 2018 by Davis and others (Appendix E, items 2 and 3).

Phase 1 work also included exploratory sampling to evaluate the utility of chemical constituents used in similar studies elsewhere in California. The USGS sampled 51 groundwater wells and 4 oil wells in and near oil fields in the Los Angeles Basin and Kern County. In addition, Phase 1 also included preliminary mapping of groundwater near 30 selected oil fields, mostly in Kern County, using historical water sample data only. This reconnaissance effort helped to highlight data gaps that need to be filled using other approaches. Reports and data releases documenting this work are listed in Appendix E–Phase 1.

Phase 2 – Phase 2 of the RMP began in 2016. USGS and State Water Board staff collaboratively selected fields for study using results from the prioritization analysis described above (Davis and others, 2018, Appendix E–item 2). Well depth and water chemistry data were compiled into numerical databases for use in the regional analyses. Work then began in each of these study fields on one or more of four major tasks 1) salinity mapping, 2) groundwater sampling, 3) oilfield fluid sampling, and 4) interpretative analysis of the collected data from tasks 1 through 3 in each of these selected fields. A summary of Phase 2 tasks initiated for each oil field is presented in Table 4-1.

- Beginning in 2016, the first oil fields identified for all four tasks were: Fruitvale, Lost Hills, South Belridge, and North Belridge. In addition, salinity mapping work began in the following fields: Elk Hills, Montebello, Poso Creek, Rosedale Ranch, and Cal Canal Gas.
- In 2017, oil fields selected for sampling included Oxnard, Elk Hills, North Coles Levee, Orcutt, and Montebello with salinity mapping proceeding in Midway-Sunset, South Coles Levee, and South Cuyama.
- In 2018, oil fields selected for sampling included: Placerita, Santa Maria Valley, Midway-Sunset, Buena Vista, San Ardo, and Kern River, with salinity mapping beginning in Yowlumne.
- In 2019, oil fields selected for sampling included: Cat Canyon, Wilmington-Torrance, and Poso Creek, with salinity mapping beginning in San Ardo and Cat Canyon.

In each of the study areas sampled, the USGS identified suitable locations of groundwater wells and oil wells/injectate sites that would meet well and oil fluid sample criteria for the RMP. Once the well locations were determined, the USGS worked with well owners to get permission to collect the samples. Samples collected include:

- 2016 – 23 groundwater samples and 17 oilfield fluid site samples in two study areas.
- 2017 – 74 groundwater samples in 6 study areas and 8 oilfield fluid site samples in 2 study areas.
- 2018 – 81 groundwater samples in 8 study areas and 16 oilfield fluid site samples in 3 study areas.
- 2019 – 79 groundwater samples in 7 study areas.

Table 4-1. Oil Fields where USGS Regional Monitoring Program Phase 2 work has been initiated: 2016-2019

Oil Field	County	Salinity Mapping	Groundwater Sampling	Oilfield Fluid Sampling	Interpretive analysis published	Publication(s) in Appendix E
Buena Vista	Kern		X	X		
Cal Canal Gas	Kern	X				
Cat Canyon	Santa Barbara	X	X	X		
Elk Hills	Kern	X	X	X		15
Fruitvale	Kern	X	X	X	X	12, 13, 19-23, 25
Kern River	Kern		X	X		
Lost Hills	Kern	X	X	X	X	9, 10, 12, 14, 16, 17, 20, 21
Midway-Sunset	Kern	X	X	X		18
Montebello	Los Angeles	X	X	X		
North Belridge	Kern	X	X	X	X	10, 12, 14, 16, 17, 20
North Coles Levee	Kern		X	X		
Orcutt	Santa Barbara		X	X		
Oxnard	Ventura		X	X		
Placerita	Los Angeles		X	X		
Poso Creek	Kern	X	X	X		24
Rosedale Ranch	Kern	X				22, 23
San Ardo	Monterey	X	X	X		
Santa Maria Valley	Santa Barbara		X	X		
South Belridge	Kern	X	X	X	X	10, 12, 14, 16, 17, 20, 21
South Coles Levee	Kern	X				
South Cuyama	Santa Barbara	X				11
Wilmington-Torrance	Los Angeles		X	X		
Yowlumne	Kern County	X				

4.1.1 Status of Work Conducted in 2019

In 2019 the USGS continued Phase 2 work, which included salinity mapping, airborne electromagnetic surveys, geologic data compilation (well depth, water chemistry, injection and production volume, well integrity, borehole geophysical, temperature, etc.), water sampling, installation of multiple well monitoring sites, analyses of historical and newly collected data, publication of manuscripts and data, and stakeholder meetings. The work conducted in 2019 is summarized below and publications are listed in Appendix E.

- In the Santa Maria Valley, San Ardo, Cat Canyon, Kern River, and Montebello oil fields, one or more of the following types of data were compiled: oil well construction data was extracted from scanned or paper records and included oil well perforation depth and drill date, types and depths of geophysical logs collected, bottom-hole temperatures, oil show and/or core properties data, depths of geologic markers, and/or oil well integrity data. Borehole geophysical logs were digitized and/or analyzed to determine salinity profiles with depth in the Poso Creek, Elk Hills, North Coles Levee, Buena Vista, and Midway-Sunset oil fields. Mud logs in the Oxnard oil field were digitized. Oil field injection records since 1977 continued to be extracted and analyzed from digital files publicly available from CalGEM.
- Well depth and water chemistry data were compiled from many sources into numerical databases for use in the regional analyses. Compilation of these data in 2019 were focused on the southwestern San Joaquin Valley, the Los Angeles Basin, and selected oil fields including Oxnard, Orcutt, Elk Hills, Kern River, San Ardo, Montebello, Cat Canyon, Poso Creek, and Wilmington-Torrance. These data have been combined with data from existing databases for analysis.
- Salinity mapping continues near high priority oil fields to evaluate groundwater quality by using water sample data, oil well borehole geophysical logs, and collecting airborne and surface geophysical surveys. A salinity mapping study of the Lost Hills/Belridge oil fields area was published. Data releases associated with salinity mapping were published for the Lost Hills/Belridge and South Cuyama study areas. Salinity mapping studies are progressing to publications in the areas of the Poso Creek, Elk Hills/North Coles Levee, Midway-Sunset, and South Cuyama oil field study areas.
- Reconnaissance surface geophysical surveys were performed in areas adjacent to the Cat Canyon, San Ardo, and Elk Hills oil fields to collect data contributing to salinity mapping in these study areas. A manuscript and data releases summarizing results of airborne electromagnetic surveys adjacent to the Lost Hills/Belridge oil fields were in the late stages of review or accepted for publication.
- Written plans for produced water sampling were prepared and submitted for five oil fields, with requests for site access going to multiple companies in each field (23 individual field/company plans submitted). USGS and State Water Board personnel participated in eleven kickoff meetings with companies to discuss these requests.
- Seventy-nine water supply and monitoring wells were sampled in seven study areas.

- Analysis of water chemistry and ancillary data and preparation of publications continued for the Lost Hills/South Belridge/North Belridge, Elk Hills/North Coles Levee, Oxnard, Orcutt, Montebello study areas and began for the Placerita, Santa Maria Valley, Midway-Sunset/Buena Vista, San Ardo, and Kern River study areas.
- Water sample and groundwater level data continued to be collected from two multiple completion monitoring well sites drilled and installed adjacent to the Lost Hills and Belridge (North and South) oil fields in 2018. Each well site was constructed with five individually cased well screens completed within the same borehole, at different depths in the aquifer. Each well site was drilled to about 1,800 ft below ground surface; geologic cuttings and borehole geophysical logs were collected; the wells were installed and developed; and data on water-level changes was collected over time. These data are publicly available on the USGS COGG Data website. A report and data release documenting the results from the Lost Hills multiple well monitoring site were published (Everett, 2020; Appendix E–items 34 and 35). A report and data release documenting the results from the Belridge multiple well monitoring site are in review (Appendix E–items 36 and 37). Two additional drill sites in the Elk Hills and Poso Creek study areas were selected for drilling in 2020-21.
- Program personnel updated stakeholders on RMP activities in a public stakeholder meeting in February 2019, as summarized in Section 5.3, Strategy #1.
- Data releases of historical produced water chemistry data compiled from publicly available CalGEM scanned records were published for the Lost Hills/Belridge and Elk Hills oilfield study areas. Similar compilations are continuing for the Kern River and other oilfield study areas.
- Manuscripts were published describing the results of groundwater quality analysis near the Fruitvale oil field and analysis of radium in groundwater in the Fruitvale and Lost Hills/Belridge study areas.

4.1.2 Regional Monitoring Program Results and Findings– 2019

A focus of RMP efforts in 2019 was publication, by the USGS, of results from the Fruitvale and Lost Hills/Belridge study areas and preparation of publications from the Orcutt, Oxnard, and other study areas. Study results were published in 2019 (Appendix E) or are in review and will be published in 2020 (Appendix E–Phase 2 Anticipated in 2020). The observations below summarize results from publications in 2019.

Salinity mapping

In 2019, a study by Gillespie and others (Appendix E–item 16) showed that groundwater near current and historic oilfield produced-water disposal areas in the Lost Hills and Belridge (North and South) oil fields indicated increases in salinity above natural levels. The study found that the salinity increases were related to the mixing of native groundwater with saline oilfield produced water discharged to surface disposal ponds and underground injection wells. This study was based on publicly available data collected from oil production wells, underground injection wells, and groundwater monitoring wells. While the groundwater near these oil fields is not currently a

source of drinking water because it is naturally brackish, some farmers use it for irrigation. The study documented regional, natural salinity gradients within the aquifer system and noted changes near produced water disposal ponds and injection wells. The results of salinity mapping have been an invaluable resource to support many decisions made by Water Boards staff, regarding produced water pond and underground injection control activities.

Groundwater sample analysis

In 2019, the USGS published a study for an area near the Fruitvale Oil Field in Bakersfield, CA where the groundwater overlying the oil producing zone is used for public water supply (Wright and others Appendix E–item 25). Oil production has occurred here for more than 90 years. Activities occurring in the oil field include enhanced oil recovery (water and steam flooding), produced water disposal, and oil refining. The results indicated that groundwater currently used for public supply was of good quality, due to the relatively rapid flushing of the aquifer system by recharge from the Kern River. Trace detections of oilfield water in two wells appear to be related to historical disposal of oilfield water in surface ponds. Trace detections of hydrocarbon gases in three wells include gas from natural microbial activity in the aquifer mixed with gas from petroleum sources in the subsurface. These results may indicate migration of gases into overlying groundwater via oilfield infrastructure and/or natural processes. The relations of groundwater quality to long-term oil production or sources in a heavily utilized groundwater system with high recharge rates may be relevant to similar settings.

A published 2019 study by McMahon and others (Appendix E–item 21) used geochemical data from 40 water wells to examine the occurrence and sources of radium in groundwater associated with three oil fields in California (Fruitvale, Lost Hills, South Belridge). Radium-rich groundwater was detected in sample locations near unlined disposal ponds, yet the radium isotopic characteristics of groundwater near ponds differed from the oilfield water in ponds. Geochemical analysis indicated that radium in oilfield water in ponds was removed by interactions with sediments in the near-pond environment but that the saline, organic-rich oilfield water subsequently mobilized radium from downgradient aquifer sediments. This study demonstrates that infiltration of oilfield water may leach radium into groundwater by changing geochemical conditions in the subsurface rather than by direct mixing with high-radium oilfield water. These processes could also control radium distribution in groundwater in other areas with surface releases of produced water.

4.1.3 Progress on addressing Regional Monitoring Program Questions

RMP studies conducted by the USGS are designed to answer questions defined in Section 4.0 by completing the four tasks associated with Phase 2. Since 2016, Phase 2 tasks have been initiated in several oil fields (Table 4-1). A brief summary of how published work addresses those questions is presented below.

Salinity mapping studies have addressed where groundwater resources are and how close groundwater resources are located to oil and gas operations. Metzger and others (2018) identified data gaps and produced preliminary mapping of groundwater salinity in 31 oilfield areas using publicly available groundwater and produced water sample data. Davis and others

(2018) performed an analysis of the intensity of petroleum resource development and proximity to groundwater resources using publicly available statewide data. Gillespie and others (2019) and Stephens and others (2018) used borehole geophysical log analysis and other data to map the distribution of groundwater with less than 10,000 milligrams per liter total dissolved solids and spatial relations to oil and gas operations near the Lost Hills/Belridge and Fruitvale oil fields, respectively.

Studies involving the collection of groundwater or oilfield fluid samples address the questions related to evidence of oil and gas fluid migration, potential transport pathways, and changes to water quality near oil and gas operations. McMahon and others (2017) used reconnaissance data to evaluate the utility of chemical, isotopic, and groundwater-age tracers for assessing sources of salinity, methane, and petroleum hydrocarbons in groundwater near oil fields. McMahon and others (2019) described the occurrence and sources of radium in groundwater in the South Belridge, Lost Hills, and Fruitvale study areas. Kulongoski and others (2018) used reconnaissance groundwater quality samples from oilfield areas of the Los Angeles basin to describe evidence for biogenic sources of high concentrations of methane in Los Angeles groundwater. McMahon and others (2018) characterized regional patterns in the geochemistry of oilfield water in the Fruitvale, Lost Hills, South Belridge, and North Belridge oil fields. Barry and others (2018) similarly explored the variability in the composition of oilfield fluids and used the noble gas composition of oil well casing gases in the Lost Hills Oil Field to trace signatures of injection in the oil reservoir; this information could be used to help identify the origin of gases in nearby aquifers in the future. Wright and others (2019) described groundwater quality of an aquifer used for drinking water overlying the Fruitvale Oil Field.

4.2 Upcoming Work in 2020

The following work is planned for the RMP as part of Phase 2 in 2020:

- Sampling of groundwater and produced water in the following oil fields (subject to receiving site access permission): Buena Vista, Midway-Sunset, Poso Creek, Kern River, San Ardo, Cat Canyon, and Wilmington-Torrance.
- In advance of sampling activities, the USGS in coordination with State Water Board staff will continue to:
    - Provide written summaries to the operators of sampling objectives, a general history of major fluid flows (e.g., water disposal, water flood, steam enhanced oil recovery, surface disposal), and proposed areas for monitoring wells
    - Request review and input from the operators' technical experts to identify sampling locations, to further document fluid flows, and specific conditions and characteristics of the site to be sampled
    - Review the information provided by the operators as input to finalizing the sampling plan and interpretation of the data
- A new list of up to three oilfield study areas for sampling in 2020 based on the Phase 1 prioritization report will be generated by State Water Board staff in collaboration with

USGS staff (Appendix E–item 1). Analysis of additional data may be used to modify the priority of oil fields. Suitable locations of water supply wells and/or oil wells/injectate sites within and near these oil fields will be identified. Once the well locations are determined, the USGS will work with well owners to get permission to collect the samples. Sampling is planned to begin in at least three new study areas.

- A multiple completion monitoring well site for monitoring fluid pressure and water quality at different depths in groundwater systems near an oil field will be drilled and installed. The multiple completion monitoring well site consists of 5 separate, discretely screened and cased wells within a single borehole. Potential monitoring well sites have been selected to fill-in priority gaps in existing data required for an initial interpretive analysis.
- Salinity mapping using borehole geophysical log analysis, water sample data, and in some cases airborne electromagnetic data will continue in the Elk Hills/North Coles Levee, Midway-Sunset/Buena Vista, Poso Creek, Montebello, South Cuyama, and San Ardo study areas.
- Additional results from the salinity mapping, groundwater quality, produced water chemistry results, and data collection efforts will be published at the Fruitvale, Lost Hills/South Belridge/North Belridge, Oxnard, Elk Hills/North Coles Levee, Midway Sunset, Orcutt, and South Cuyama study areas.
- Executive summaries of findings on the USGS COGG Findings web page will be updated.
- USGS staff will continue to update stakeholders on RMP activities in State Water Board-hosted stakeholder meetings, including presentations on results of recent publications.

Interpretative manuscripts and data releases expected to be published in 2020 are listed in Appendix E – Phase 2 Anticipated in 2020.

5.0 PERFORMANCE MEASURES

In 2015, the State Water Board directed staff to collaborate with stakeholder groups to develop performance measures for the evaluation of the Model Criteria. Performance measures were developed by stakeholders including CalGEM, Clean Water Action, Environmental Working Group, Chevron USA, California Resources Corporation, Western States Petroleum Association (WSPA), California Independent Petroleum Association (CIPA), and State Water Board staff. Performance Measures were presented to the State Water Board on March 1, 2016 and included goals, strategies, and plans for implementing the Model Criteria.

The Performance Measures identified five goals:

1. Provision of transparent and easy to access online information and documentation
2. Provision of clear milestones and timely deliverables
3. Understanding and mitigation of the impacts of well stimulation on water quality and public health
4. Provide region-specific or localized flexibility where possible
5. Assessment of implementation costs

These performance measures are a means to evaluate the effectiveness and efficiency of the Model Criteria. When the original goals and strategies were developed in 2016, it was anticipated that the performance measures and implementation plans would be periodically re-evaluated and updated through a stakeholder process. A table of the original performance measures and strategies can be found in Appendix B.

The following sections provide an overview of the five performance measures (goals), each corresponding strategy, and actions performed in 2019 to meet each goal. During the review of these performance measures, some actions were identified for 2020 and are mentioned below in ***italicized bolded*** text.

5.1 Goal #1: Transparency and Availability of Online Information and Documentation

This goal is to provide transparent, effective, and efficient access, for the public and state agencies, to online information and documentation on the permitting and approval process of well stimulation activities in California. GeoTracker provides public online access to operator submitted GMPs, requests, data, reports, and state agency correspondence. These data and information are publicly available for export and analysis. GeoTracker provides capabilities and guides for operators to upload information.

Strategies and actions to meet this goal in 2019 included the following:

Strategy #1: Improve and expand upon available data sets and the ability to analyze and manipulate that data.

Action #1: Develop/Modify/Update Tools in GeoTracker. In order to utilize GeoTracker as a data management system, continuous improvements are made based on internal and external feedback. These tools help to streamline staff review time and avoid errors.

The GeoTracker map function was enhanced to show the boundaries of approved GMPs or requests for exclusions in the legend. This enhanced function now displays the spatial boundaries of GMPs and exclusions using color to improve readability.

Action #2: Consolidate existing oil and gas data into GeoTracker. The Data Sharing Plan (further discussed under Strategy #3) identifies the need for Water Boards staff to create produced water pond sites in GeoTracker. Water Boards staff have generated facility entries in GeoTracker for all regulated produced water ponds.

Water Boards staff will continue to consolidate oil and gas data into GeoTracker in 2020.

Strategy #2: Improve online user experience with simplified and clear messaging to make data easier to access.

Action #1: Webpage Updates. Periodic updates are made to the State Water Board's Oil and Gas Monitoring Program web page. In 2019, the following information was uploaded:

- 2018 Annual Model Criteria Performance Report
- Five USGS data releases
- Three USGS Journal Abstracts/Articles
- February 2019 Stakeholder Meeting webcast
- List of designated contractors for water sampling

Additionally, the USGS regularly updates their COGG Program website to provide information on recently published studies.

Action #2: Feedback from the Operators on Information Portals. Stakeholders are asked annually for input on 1) their experiences using GeoTracker, and 2) their suggestions for improving the State Water Board information portals. Operators feedback included reducing duplication of information required for submittal in WellSTAR and GeoTracker. ***State Water Board staff will continue to ask operators for feedback annually. Staff will evaluate potential reduction of duplication between the CalGEM and Water Boards web portals.***

Action #3: GeoTracker Technical Support. In 2019, State Water Board staff provided timely support to GeoTracker users via email or phone that allows public access to accurate and complete data. ***State Water Board staff will continue to assist users by responding to user comments and questions in 2020.***

Strategy #3: Create data communication/sharing strategy to optimize data and information sharing between the State Water Board, Regional Water Boards, CalGEM, and other agencies, as appropriate.

Action #1: Sharing data. The State Water Board continues to implement the "Oil and Gas Data Communication and Data Sharing Plan for the State Water Resources Control Board and Division of Oil, Gas, and Geothermal Resources" (Data Sharing Plan). The Data Sharing Plan was developed by Water Boards staff, in collaboration with CalGEM, with the objective of outlining current oil and gas data systems, existing communication and data sharing processes, and strategies for future data sharing. The Data Sharing Plan was developed in response to these performance measures; however, it broadly outlines data sharing between CalGEM and Water Boards staff for all oil and gas programs.

Effective sharing of data and information will help streamline regulatory efforts, avoid duplicate collection and submittal requirements, facilitate data submittal processes for operators, and help provide the public easy access to the information. For example, Water Boards and CalGEM staff continue to use a secure file sharing and online storage "drop box" to easily share documents.

In 2019, Water Boards staff were kept appraised by CalGEM on the roll-out of the WellSTAR system. Water Boards staff attended CalGEM-led and internal training events to become familiar with release 4 of WellSTAR, which includes new WST functionality, starting in April 2019.

State Water Board staff provide the USGS with annual downloads of all oil and gas related data in GeoTracker. The USGS incorporates these data into related RMP studies. State Water Board staff upload groundwater data from the USGS NWIS website to GAMA GIS periodically. In 2019, State Water Board staff began development of a RMP layer in GeoTracker to display data collected by the USGS. ***In 2020, State Water Board staff plans to develop a GeoTracker layer to display USGS collected data. State Water Board and USGS staff will continue to exchange data between NWIS and GAMA GIS.***

Action #2: Coordinated Communications. Water Boards and CalGEM staff use a system for sharing data associated with WST permit applications, GMPs, addenda, exclusions, and well stimulation 72-hour notices, as outlined in the Data Sharing Plan. Water Boards staff routinely communicate with their counterparts at CalGEM as project-related questions and issues arise. Additionally, Water Boards and CalGEM met on a monthly basis in 2019 to discuss comments and questions arising from reviews of WST permit applications submitted by operators. These meetings were initiated to resolve comments or issues that could delay the permitting process. ***Water Boards and CalGEM staff will continue to hold monthly meetings in 2020 to discuss comments and explore questions arising from review of WST permit applications.***

5.2 Goal #2: Provide Clear Milestones and Timely Deliverables

This goal is to 1) report on the completion of the milestones and deliverables included within the Water Code and to 2) provide timely deliverables (i.e., staff letters) during the review of GMPs, requests for exclusion, and requests to add WST wells to an existing exclusion from groundwater monitoring.

Strategies and actions to meet this goal in 2019 included the following:

Strategy #1: Make milestones and deliverables outlined in the Model Criteria and Senate Bill 4 (Chapter 313, Statutes of 2013, including Water Code section 10783), publicly available.

Action #1: Availability of Milestone Schedule. The status of Senate Bill 4 deliverables and milestone schedule are posted on the State Water Board website. The State Water Board's final milestone was completed in 2019. In May 2019, a staff workshop was held to review the use of the United States Environmental Protection Agency's (US EPA) definition of Underground Source of Drinking Water (USDW) as containing less than 10,000 mg/L TDS and whether exempt aquifers pursuant to 40 CFR 146.4 should be subject to groundwater monitoring. The staff workshop included presentations from State Water Board staff, representatives from oil industry, and non-governmental organizations. Presentations were followed by a facilitated discussion with the public. ***In 2020, State Water Board staff will follow up on actions related to the review of the definition of protected water.***

Strategy #2: Prepare review processes, flowcharts, and timelines for reviewing groundwater monitoring plans and requests for exclusion from groundwater monitoring, including interagency collaboration and program efficiencies.

Action #1: Preparation of Annual Model Criteria Performance Report. State Water Board staff prepared and made publicly available the "2018 Annual Performance Report: Model Criteria for Groundwater Monitoring in Areas of Oil and Gas Well Stimulation" (dated April 5, 2019) for the reporting period of January 1, 2018 through December 31, 2018. This report is posted on the State Water Board, Division of Water Quality, Oil and Gas Performance Measures webpage. The 2018 Annual Performance Report: Model Criteria for Groundwater Monitoring in Areas of Oil and Gas Well Stimulation was made available on the website in April 2019. ***The Annual Model Criteria Performance Report for the 2020 calendar year will be drafted, and publication is anticipated for March 2021.***

Action #2: Updated Review Processes.

- *Created Internal Program Procedure Manual.* State Water Board staff developed an internal program procedures manual to ensure consistent and complete reviews. The program procedures manual includes a description of the staff responsibilities and processes to be followed for the review of GMPs, requests

for exclusion from groundwater monitoring, and WST permit applications. The program procedures manual also includes updated checklists and rationale for review processes.

- *Groundwater Monitoring Report (GMR) Review Process.* State Water Board staff continued to utilize the GMR review checklist. Staff evaluated GMRs submitted by operators in 2019 and identified additional information that is required from operators to be compliant with the Model Criteria. In August 2019, State Water Board staff held an information session with operators to describe additional information that is required in GMRs and to inform them of our updated review processes. ***In 2020, Water Boards staff will inform operators when submitted GMRs do not comply with the Model Criteria and submittal of revised GMRs will be required.***

- *Internal Training.* State Water Board staff completed internal training for reviewing GMPs, GMRs, and WellSTAR WST permit applications. The training was designed in large part to educate new staff on review processes and procedures.

Action #3: Prepare/Update Flowcharts. In 2019, State Water Board staff continued to update and utilize the process flowcharts for "Uploading and Reviewing Area-Specific Groundwater Monitoring Plans" and "Reviewing Requests for Exclusion from Groundwater Monitoring". Refer to Appendix C. The flowcharts detail the operator's process for uploading GMPs or requests for exclusion into GeoTracker. Additionally, the flowcharts detail the Water Boards' process for review. Estimated timelines for responding to the operator are also provided. ***In 2020, flowcharts, procedures, and checklists will be updated on an as-needed basis.***

Action #4: Evaluate Water Boards' Timeliness of Review. Sections 2.1.2 and 2.3.2 provide an evaluation of staff review times. Staff's goal is to provide initial review comments to the operator within 45 calendar days from acceptance of the GMP or request for exclusion into GeoTracker. The initial review time includes Water Boards staff acceptance into GeoTracker through to initial comments to the operator. This process may require the operator revise the submittal and re-submit. Time spent by Water Boards staff reviewing revised submittals or drafting additional comments is included in the total review time.

The average time for review of GMPs, addenda, requests for exclusion, and requests to add wells to an existing exclusion are summarized in Tables 2-1, 2-2, 2-3, and 2-4. In comparison with 2018, the average time to complete the review process for each submittal type:

- GMPs- increased
- addenda- increased
- requests for exclusions- decreased
- requests to add wells to an existing exclusion- increased slightly

The changes in review timeframes are detailed in Sections 2.1.2 and 2.3.2; detailed review timelines are provided in Tables D-1, D-2, D-3, and D-4. ***State Water Board staff will continue to use tracking systems to improve timeliness of reviews in 2020***.

Action #5: Collaborate Between Agencies. In 2019, State Water Board and Regional Water Board staff collaborated weekly on reviews of WST permit applications, GMPs, requests for exclusion, and GMRs. Water Boards and CalGEM staff held monthly meetings to discuss comments and questions from reviews of WST permit applications. These meetings have served as a collaboration between the two agencies on related issues and upcoming changes. In 2019, CalGEM staff were provided an opportunity to review draft reports prepared by the USGS for the RMP and participated in kickoff meetings with operators in advance of sampling efforts.

Action #6: Enhance Program Efficiencies. While reviewing operators' submittals, Water Boards staff communicated questions and concerns. Hydrogeologic and geologic conditions at oil fields vary in complexity and as a result, the process to develop a GMP is iterative. Examples of collaboration with operators to maintain communication channels and enhance efficiency include*:*

1) In 2019, Water Boards staff continued to schedule meetings with operators to discuss concerns from preliminary review of GMPs and requests for exclusion. Water Boards staff also developed processes and procedures to streamline GMP reviews and accommodate cases when multiple versions of GMPs are required.

2) State Water Board staff facilitated USGS interactions with operators for RMP sampling requests. Staff coordinated 11 RMP kickoff meetings for the USGS to share site-specific information and communicate with operators regarding sampling logistics. These meetings provide a line of communication for efficient RMP planning.

3) State Water Board staff have prepared an internal program procedures manual containing staff responsibilities and processes to be followed for the review of GMPs, requests for exclusions, and GMRs. The program procedures manual is available to train new staff in order to maintain efficiency.

Key communications between State Water Board staff and operators will continue to be documented and any action items will be tracked to ensure they are resolved in a timely manner.

5.3 Goal #3: Understand and Mitigate the Impacts of Well Stimulation on Water Quality and Public Health

This goal is to assess groundwater monitoring data as required in the approved GMPs and the RMP. Data associated with area specific and RMP groundwater sampling events have been uploaded into GeoTracker for sampling events conducted from 2014 through 2019 (refer to

Section 2.4 and Section 4). Strategies and actions to understand and mitigate the impacts of well stimulation on water quality and public health in 2019 include the following:

Strategy #1: Provide regular assessments of monitoring data, including pilot study results and identification of any chemicals of concern.

The Model Criteria addresses two types of activities: 1) area-specific and 2) regional groundwater monitoring. Water quality information collected by these monitoring activities will be used to evaluate groundwater and hydrogeological conditions, including establishing a baseline of water quality that will be used to assess future potential impacts. State Water Board staff will consider both the USGS and operator recommendations when assessing collected data and information.

Action #1: Regional Monitoring Program Technical Briefings. On February 25, 2019, the USGS provided a technical briefing to the public on the following subjects. The February 25, 2019 USGS technical briefing is available through the State Water Board's website.

- Update on RMP Activities
- Analysis of potential factors influencing groundwater quality near oil fields
- Results from the RMP Study of the Elk Hills, North Coles Levee, Oxnard and Orcutt oil fields
- Geochemical tools for evaluating sources of constituents in groundwater

In 2019, State Water Board staff and the USGS reviewed the process for holding technical briefings. As a result of this review, future technical briefings will be held after studies have been published. Due to this change, technical briefings will be scheduled periodically and may occur less frequently than semi-annually.

State Water Board staff will continue to host technical briefings by USGS on the RMP to stakeholders in 2020.

Action #2: Communicate with Operators. In June 2019, State Water Board staff met with operators to discuss their concerns about implementation of the RMP. In response, State Water Board staff shared a communication strategy for RMP implementation and results. Efforts included maintaining publicly available websites, publishing RMP data and studies, holding stakeholder technical briefings, and facilitating pre-sampling communication described in Action #3 below. Also, the State Water Board began issuing media releases to accompany key interpretive USGS RMP publications. ***In 2020, State Water Board staff will continue to implement the communication strategy to promote understanding of the RMP.***

Action #3: USGS Interactions with Operators in Advance of RMP Sampling. The State Water Board and USGS staff continued pre-sampling communication with operators. The objectives of these interactions are to improve transparency of the RMP, obtain technical insight from operators, and to convey the importance of the program to the

overall approach in assessing the potential effects from oil production on the groundwater resources in the state of California. A summary of State Water Board and USGS interactions with operators prior to RMP sampling efforts are summarized below.

- Email notification to operator 60 days in advance of mobilization including:
  - High level overview of the RMP
  - Scope of the sampling program/summary of samples to be collected
  - Rationale for selecting sampling points
  - Overarching goals of the sampling program
  - Logistics for sampling
  - Points of contact
  - Attachment - Written summary of sampling objectives, a general history of fluid flow, and proposed areas and depth zones for sampling
- Kickoff meeting 30 days in advance of mobilization including:
  - PowerPoint presentation of the proposed field program
  - Dialogue between State Water Board/USGS and operator regarding the proposed field program
- Follow-up 14 days in advance of mobilization including:
  - Operators provide input and feedback on the proposed sampling program
  - Iterative discussions between State Water Board/USGS and operator regarding sampling program plans and logistics

Action #4: Provide preliminary data analysis of the most significant results. A summary of groundwater monitoring data is provided in Section 2.4 for the GMP and in Section 4.1 for the RMP. USGS and State Water Board staff held regular internal meetings in 2019 to collaborate regarding groundwater data and to share findings from the RMP. In August 2019, State Water Board staff held an information session for operators regarding groundwater monitoring report contents and practices. The main topic of the information session was that operators are required to provide further analysis and interpretation of data to identify potential impacts from well stimulation as outlined in the Model Criteria. ***In 2020, State Water Board and USGS staff will continue to evaluate monitoring data collected as part of both the RMP and GMP.***

Strategy #2: Mitigate problems as they occur and share mitigation efforts with stakeholders.

Action #1: Implement Action Plan. If data demonstrates a potential water quality or public health concern, Division of Water Quality staff will expeditiously work with the appropriate Regional Water Board and/or Division of Drinking Water staff to address the issue. Data collected thus far has not necessitated action to be taken.

Action #2: Continue to work with the USGS and other state agencies to better understand which compounds used in WST fluids are the most appropriate tracer and/or indicator compounds. State Water Board staff have initiated discussions with technical experts to identify appropriate tracer and/or indicator compounds. State Water Board staff created the Produced Water Studies Interagency Coordination in 2015. These meetings allow us to interact with our sister agencies on how best to identify tracers or

indicator compounds for WST fluids. ***State Water Board staff will continue to evaluate the appropriate tracers and indicator compounds in 2020.***

Strategy #3: Develop a plan to re-evaluate the effectiveness of monitoring. Modify the scope of work and approach based on evaluation of the data collected and evaluated.

Action #1: Re-evaluate Model Criteria. State Water Board staff have begun evaluating the Model Criteria. Feedback from the Central Valley Water Board, CalGEM, USGS, and operators are being incorporated during the evaluation. Evaluation of the Model Criteria is time-intensive, and any modifications will undergo a public review process. Actions in 2019 include but are not limited to those described below.

1. **Operator Feedback**. Throughout 2019, State Water Board staff received feedback from operators regarding implementation of the Model Criteria. State Water Board staff are considering all feedback received as we contemplate potential revisions to the Model Criteria. ***State Water Board staff will continue to request feedback from operators in 2020. All feedback will be considered as the Model Criteria is re-evaluated.***

2. **Review the Definition of Protected Water**. As required by Water Code Section 10783, State Water Board staff reviewed the definition of protected water. A staff workshop was held in May 2019 to collect public input on any potential changes to the definition. ***State Water Board staff will follow up on actions related to the review of the definition of protected water***.

3. **Evaluate Area-Specific and Regional Groundwater Monitoring.** Results from area-specific and regional groundwater sampling, along with the composition of the well stimulation fluids, will be evaluated to assess if the required list of analytes provided in the Model Criteria should be modified. State Water Board staff will consult with the USGS to provide technical input for potential revision(s) to the Model Criteria. ***State Water Board staff plan to initiate discussions with technical experts and stakeholders in 2020 to evaluate the effectiveness of both monitoring programs and prepare a summary report of the findings.***

Action #2: Compliance to Area-Specific Monitoring Program. In August 2019, State Water Board staff held an information session to inform operators of updated groundwater monitoring report review processes to bring GMRs into compliance with the Model Criteria. ***State Water Board staff will provide written comments to operators regarding GMRs to ensure compliance with the Model Criteria.***

Strategy #4: Coordinate with other agencies to identify risk.

Action #1: Gather, Consolidate, and Publish Significant Findings. The USGS provided significant findings from the RMP to date are summarized in Section 4.1 of this report and a list of current publications is provided in Appendix E.

Action #2: Gather, Consolidate, and Publish Lessons Learned. State Water Board staff requested a list of lessons learned from the staff at the Regional Water Boards, USGS, and CalGEM. The accumulated lessons learned during this reporting period are provided in Section 6.0 of this report.

5.4 Goal #4: Provide Region-Specific or Localized Flexibility Where Possible

Water Boards staff consider localized conditions (i.e., geologic, hydrogeologic, land use restrictions, access restrictions, monitoring frequency) when reviewing GMPs or requests for exclusion. The strategies for this goal include:

1) Consider local conditions when reviewing GMPs
2) Clearly communicate why region-specific activities are occurring
3) Use consistent flexibility criteria for monitoring

The Model Criteria allows for alternative GMPs. As discussed in Section 2.2, Water Boards staff did not receive any requests to consider an alternative method during 2019. Water Boards staff will continue to provide localized flexibility as needed.

5.5 Goal #5: Assess Implementation Costs

State Water Board staff, in cooperation with operators and representatives from CIPA and WSPA, developed a list of information needed to assess operator costs. CIPA, in collaboration with WSPA, used a third-party aggregator to collect and report operator costs associated with the implementation of the Model Criteria.

5.5.1 Operator Costs

Estimated operator costs are summarized in Table 5-5. The total costs reported by operators for groundwater monitoring increased in 2019. The number of GMPs developed and the cost to install monitoring wells increased due in large part to GMP development and deeper monitoring well installation. The total costs reported by operators for requests for exclusion increased in large part due to the collection of data from soil borings to support the absence of protected water.

The estimated groundwater monitoring cost per sample; groundwater monitoring cost per barrel of oil; and average cost of compliance per monitoring well are summarized in the operator provided table below.

Table 5-5. Estimated Operator Costs (*Provided by CIPA and WSPA*)

Groundwater Monitoring Plans	2014 - 2016 (1)	2017	2018	2019
Number of GMPs Developed	19	7	16	20
GMP Cost	$517,250	$207,843	$131,719	$864,872
Wells Installed	19	12	8	5
Well Installation Cost	$5,806,232	$2,000,673	$351,744	$1,450,014
Samples Collected	105	85	106	95
Reports Submitted	28	12	12	20
Sampling and Reporting Cost	$990,000	$418,702	$273,423	$293,253
Samples Analyzed	86	80	106	95
Sample Analysis Cost	$172,500	$188,490	$288,345	$243,469
Other Subcontractor and Consultant Fees	$111,969	$150,000	$98,601	$20,000
Total Cost (Capital + Operating Expenses)	$7,597,951	$2,965,708	$1,143,831	$2,871,608

Requests for Exclusion	2014 - 2016 (1)	2017	2018	2019
Requests for Exclusion	11	7	29	32
Requests for Exclusion Cost	$73,710	$76,075	$46,400	$525,600

Regional Monitoring Program	2014 - 2016 (1)	2017	2018	2019
RMP Estimated Total Operators Cost	$15,000	$18,000	$265,525	$0

Well Stimulation Treatments and Production	2014 - 2016 (1)	2017	2018	2019
WSTs Performed - GMP	176	34	129	96
Oil Production from WSTs - GMP (bbl)	1,362,969	451,478	312,501	362,810
WSTs Performed - Exclusions	1,089	122	115	70
Oil Production from WSTs - Exclusions (bbl)	9,438,976	296,336	523,299	166,875

Summary	2014 - 2016 (1)	2017	2018	2019
Oil Produced subject to Model Criteria Requirements (bbl)	10,801,945	747,814	835,800	529,685
Estimated Groundwater Monitoring Cost per Sample	$72,361	$34,891	$10,791	$30,227
Groundwater Monitoring Cost per bbl of oil	$5.57	$6.57	$3.66	$7.91
Average Cost of Compliance per Monitoring Well	$43,170	$87,227	$8,867	$29,913

Note: (1) Reporting period equal to 2.5 years.

5.5.2 State Water Board Costs

Statewide, 14 Water Boards staff positions are dedicated to SB4 related activities at an estimated annual cost of $2.45 million per year, and the RMP annual costs are $7.4 million. Both are funded via the Oil, Gas and Geothermal Administrative Fund.

6.0 LESSONS LEARNED AND PLANNED ACTIONS FOR 2020

This section summarizes lessons learned from State Water Board, CalGEM, Central Valley Water Board, and USGS staff this past year. Please note that GMPs and requests for exclusion reviewed this year were all located within the Central Valley Regional Water Quality Control Board's boundaries.

Tables 6-1 through 6-5 organizes the lessons learned to align with the five Performance Measure goals: transparency and availability of online information and documentation; clear milestones and timely deliverables; understand and mitigate the impacts of well stimulation on water quality and public health; provide region-specific or localized flexibility; and assess costs of implementation. These tables describe the lessons, the relative impact to the Model Criteria program, and the next steps or actions planned for 2020.

Table 6-1. Model Criteria - Lessons Learned and Planned Actions for 2020

Goal #1: Transparency and Availability of Online Information and Documentation	
Lesson	Next Steps/Actions for 2020
GeoTracker updates for the public portal are periodically needed.	State Water Board staff will complete development of a GeoTracker layer to display RMP data collected by the USGS. Existing GeoTracker functions will be updated periodically as needed.
Operator's perspective of the Water Board's information portals (i.e., GeoTracker, GAMA GIS, State Water Board's Oil and Gas Monitoring Program website) should be evaluated.	State Water Board staff will continue to ask operators for feedback and collaborate in 2020 to reduce duplication across respective web portals.
GeoTracker and WellSTAR provide operators online access to their data. Any unnecessary overlap or data gaps in data systems should be evaluated.	State Water Board and CalGEM staff will continue to discuss future well stimulation data sharing between GeoTracker and WellSTAR to leverage existing capabilities, reduce redundancies between agencies, and meet the Model Criteria data needs.
Data sharing and coordinated communications amongst the Water Boards, USGS, and CalGEM are necessary to provide effective data exchange and collaboration between the organizations.	State Water Board and the USGS will continue to exchange data between the agencies respective databases. Water Boards and CalGEM staff will continue to hold teleconferences in 2020 to discuss comments and explore questions arising from reviews of well stimulation permit applications. Additionally, CalGEM and the Water Boards are establishing a Data Sharing Team to create efficiencies between WellStar and GeoTracker.

Goal #1: Transparency and Availability of Online Information and Documentation	
Lesson	Next Steps/Actions for 2020
CalGEM has identified the need to better track approval of GMPs and exclusions by API number.	Water Boards staff will track approvals of GMPs and exclusions by API number in communications to CalGEM.
Water Boards staff must ensure that monitoring requirements are consistently applied to all operators.	State Water Boards staff will conduct a review of approved GMPs and exclusions to assure that the Model Criteria requirements are applied fairly and consistently to all operators.

Table 6-2. Model Criteria - Lessons Learned and Planned Actions for 2020

Goal #2: Provide Clear Milestones and Timely Deliverables	
Lesson	Next Steps/Actions for 2020
Annual performance evaluation is a necessary step for continuous improvement of the program.	State Water Board staff will prepare the 2020 Annual Model Criteria Performance Report. Final publication is anticipated in March 2021.
It is important to develop, update, and train staff on standard procedures, to assure statewide consistency and efficient program implementation.	For the purpose of streamlining reviews and avoiding duplicative efforts between Water Boards staff and CalGEM staff, State Water Board staff will conduct periodic review of the Oil and Gas Program Procedures Manual, which includes checklists and flowcharts. This document will be used to train staff.
The process of compiling the review timeline for GMPs, addenda, requests for exclusions, and requests to add wells to an existing exclusion on an annual basis could be improved	Key communications between State Water Board staff and operators will be documented, and any action items will be tracked to ensure they are resolved in a timely manner.
Hydrogeologic and geologic conditions that exist at oil fields can be very complex; thereby, review time may exceed goal.	Water Boards staff will continue to hold meetings with operators during the review process to proactively communicate any of the Water Boards' concerns.

Table 6-3. Model Criteria - Lessons Learned and Planned Actions for 2020

Goal #3: Understand and Mitigate the Impacts of Well Stimulation on Water Quality and Public Health	
Lesson	Next Steps/Actions for 2020
Transparency of data and findings of the RMP are essential.	State Water Board staff will implement the oil and gas operator communication strategy for the RMP. Findings will be communicated to stakeholders in technical briefings following publication of the data. Preliminary information will no longer be released prior to product publication. In addition, staff will issue media releases to accompany key USGS RMP publications.
There is a significant time interval between collection of data as part of the RMP and final publication of the results. Additional opportunities to transfer knowledge to Water Boards staff would be beneficial to the program.	USGS staff will continue to provide internal briefings to Water Boards and CalGEM staff on preliminary RMP findings. In 2020, Water Board staff will also organize technical working sessions with the USGS to provide additional opportunities for meaningful transfer of technical knowledge gained from the RMP.
Technical nomenclature must be defined and used consistently.	USGS and Water Boards staff will assure that technical nomenclature, such as “produced water” and “oilfield fluids”, is used accurately and consistently.
The operators have valuable site-specific data and knowledge that improves the design of the RMP sampling program.	The USGS will continue to solicit input from operators’ technical experts prior to RMP sampling. In addition, technical experts from CalGEM will be invited to review of RMP findings.
Implementation of the Model Criteria from the operator’s perspective is important.	State Water Board staff will compile and evaluate feedback from operators regarding the implementation of the GMPs and suggested modifications to the Model Criteria.
Preliminary data requires further analysis.	State Water Board and USGS staff will continue to evaluate monitoring data collected as part of both the RMP and the area-specific monitoring programs.
A better understanding of tracer and/or indicator compounds is needed to determine the persistence of WST fluids.	State Water Board will continue to meet periodically with the Produced Water Studies Interagency Coordination group and other technical experts to evaluate tracer and/or indicator compounds.

Table 6-3. Model Criteria - Lessons Learned and Planned Actions for 2020 (Continued)

Goal #3: Understand and Mitigate the Impacts of Well Stimulation on Water Quality and Public Health (Continued)	
Lesson	Lesson
The Model Criteria should be re-evaluated based on lessons learned.	State Water Board staff will continue evaluation of the Model Criteria in 2020, continue to request feedback from operators and initiate discussions with technical experts and stakeholders to evaluate the effectiveness of both monitoring programs and prepare a summary report of the findings.
The Model Criteria should be reviewed to ensure there are guidelines for all elements of the SB-4 program.	During re-evaluation of the Model Criteria, State Water Boards staff will develop guidance for activities that are not currently addressed in the document such as adding wells to an existing exclusion and decision criteria for discontinuation of groundwater monitoring.

Table 6-4. Model Criteria - Lessons Learned and Planned Actions for 2020

Goal #4: Provide Region-Specific or Localized Flexibility where Possible	
Lesson	**Next Steps/Actions for 2020**
Lessons will be evaluated on a case-by-case basis.	Water Boards staff will consider alternative GMPs submitted by operators.

Table 6-5. Model Criteria - Lessons Learned and Planned Actions for 2020

Goal #5: Assess Implementation Costs	
Lesson	**Next Steps/Actions for 2020**
Implementation costs are reported annually and included in the Performance Measures report.	Future implementation costs will be compiled and reported annually.

FIGURES

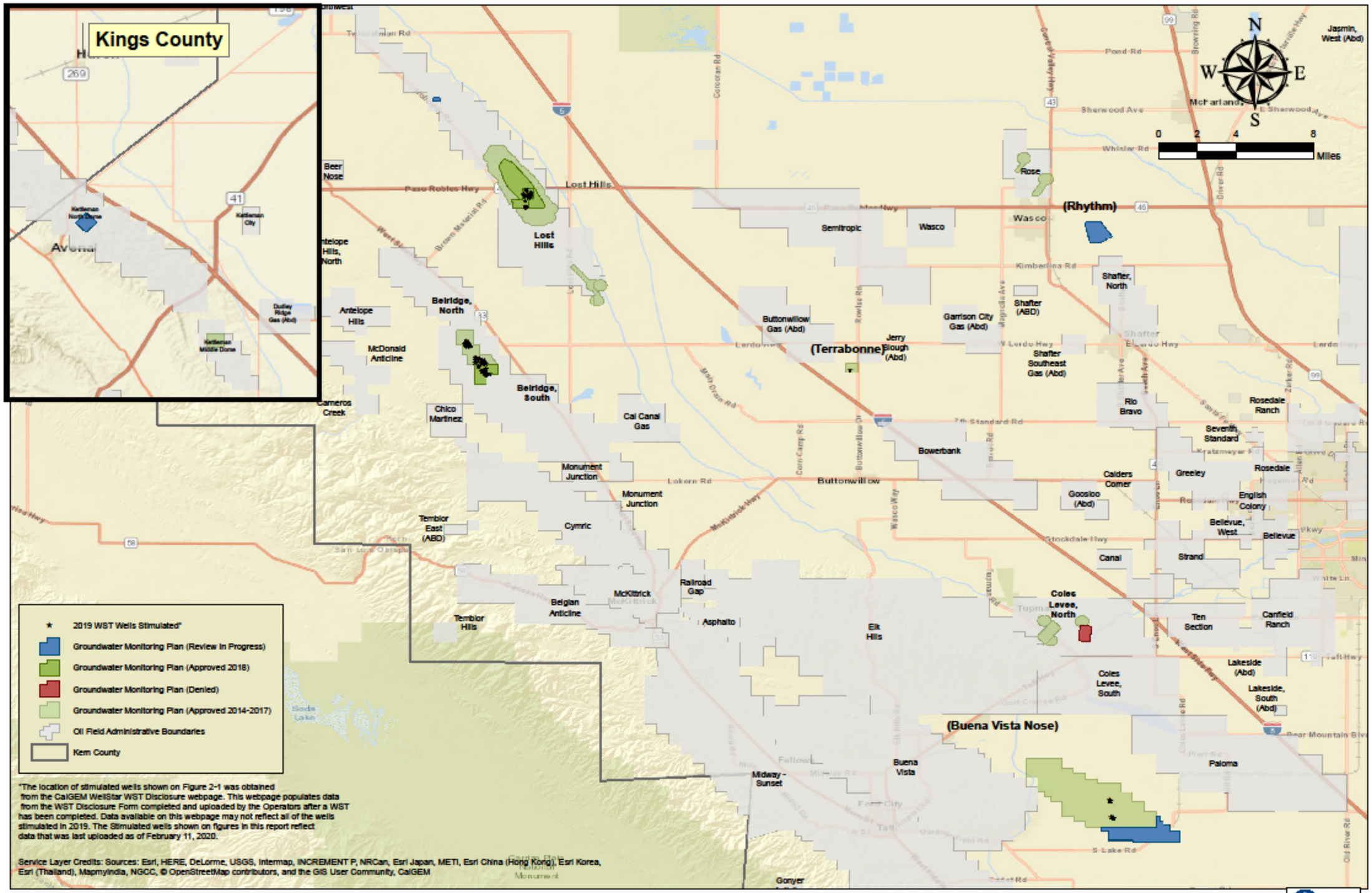


Figure 2-1. Groundwater Monitoring Plans and Wells Stimulated (January 1, 2019 - December 31, 2019)

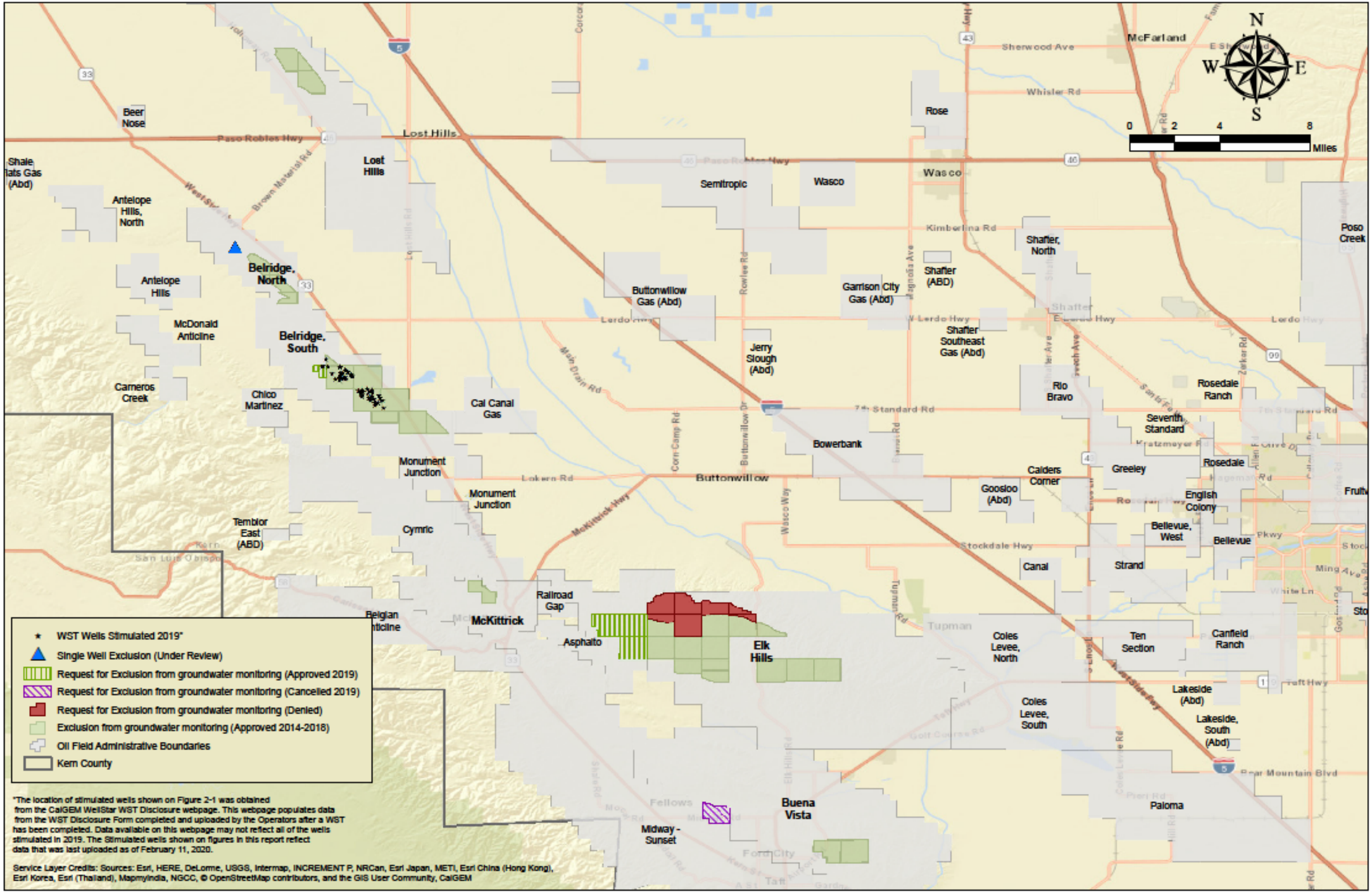


Figure 2-2. Requests for Exclusion from Groundwater Monitoring and Wells Stimulated (January 1, 2019 - December 31, 2019)

State Water Board, March 2020

Appendix A WEB LINK GLOSSARY

LINK TEXT	URL ADDRESS	SECTION
MODEL CRITERIA FOR GROUNDWATER MONITORING IN AREAS OF WELL STIMULATION: SUMMARY OF GOALS, STRATEGIES, PROPOSED PERFORMANCE MEASURES, AND PLANS FOR IMPLEMENTATION	https://www.waterboards.ca.gov/water_issues/programs/groundwater/sb4/performance_measures/index.shtml	1
MODEL CRITERIA FOR GROUNDWATER MONITORING IN AREAS OF OIL AND GAS WELL STIMULATION	https://www.waterboards.ca.gov/water_issues/programs/groundwater/sb4/well_stimulation/index.shtml	1
WELLSTAR	https://wellstar-public.conservation.ca.gov/	1
GEOTRACKER	https://geotracker.waterboards.ca.gov/	1
FRACFOCUS	https://fracfocus.org/	2
MCLS FOR DRINKING WATER	https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/MCLsandPHGs.shtml	2
CALGEM WELL STIMULATION TREATMENT NEIGHBOR NOTIFICATION AND WATER SAMPLING	https://www.conservation.ca.gov/calgem/Pages/WSTNeighborNotificationAndWaterSampling.aspx	3
STATE WATER BOARD LIST OF DESIGNATED CONTRACTORS FOR WATER SAMPLING	https://www.waterboards.ca.gov/water_issues/programs/groundwater/sb4/docs/list_of_designated_contractors_sept_2019.pdf	3
GROUNDWATER AMBIENT MONITORING AND ASSESSMENT PROGRAM GROUNDWATER INFORMATION SYSTEM	https://gamagroundwater.waterboards.ca.gov/gama/gamamap/public/	3
STATE WATER BOARD WATER QUALITY IN AREAS OF OIL AND GAS PRODUCTION – REGIONAL GROUNDWATER MONITORING	https://www.waterboards.ca.gov/water_issues/programs/groundwater/sb4/regional_monitoring/index.html	
USGS' COGG PROGRAM	https://ca.water.usgs.gov/projects/oil-gas-groundwater/	
USGS COGG FINDINGS	https://ca.water.usgs.gov/projects/oil-gas-groundwater/finding	
STATE WATER BOARD'S OIL AND GAS MONITORING PROGRAM WEB PAGE	https://www.waterboards.ca.gov/water_issues/programs/groundwater/sb4/	
DATA SHARING PLAN, JUNE 1, 2016	https://www.waterboards.ca.gov/water_issues/programs/groundwater/sb4/docs/data_sharing_plan_06012016.pdf	
USGS FUNDAMENTAL SCIENCE PRACTICES	https://www.usgs.gov/about/organization/science-support/science-quality-and-integrity/fundamental-science-practices	6

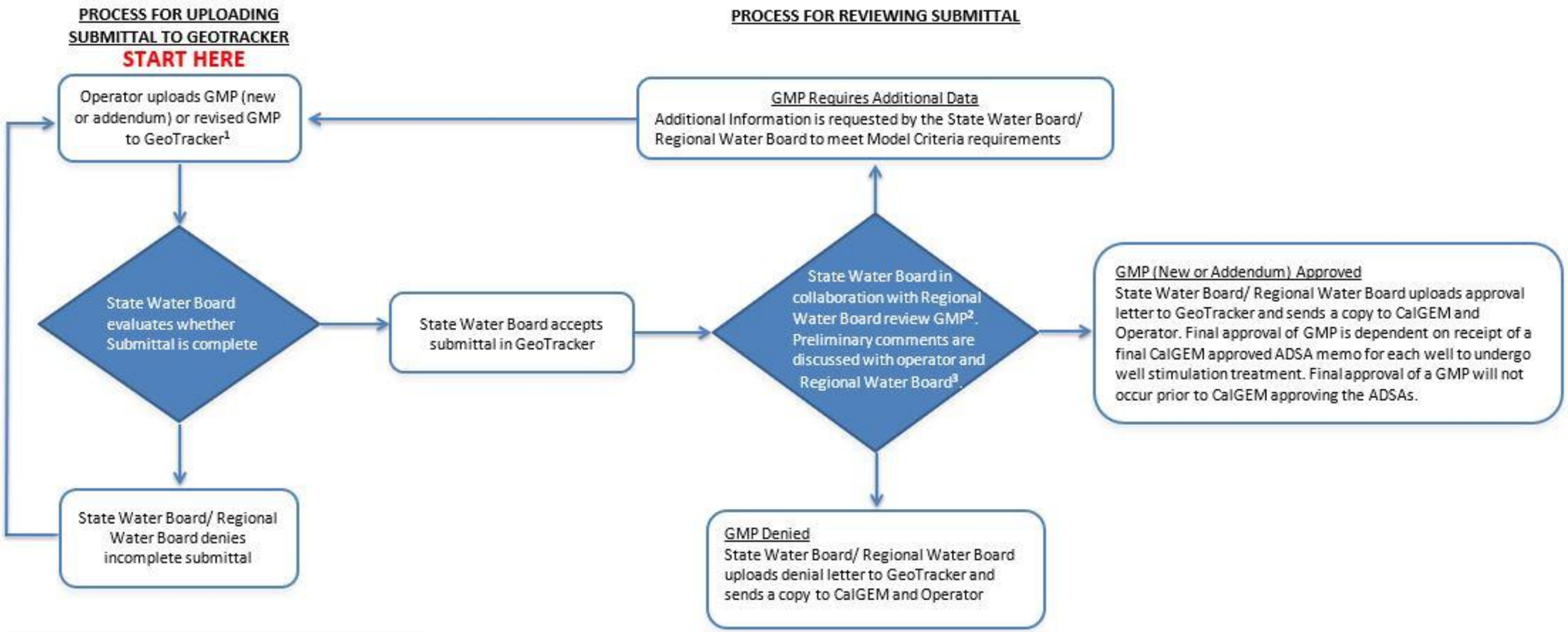
Appendix B ORIGINAL PERFORMANCE MEASURES

Goals	Strategy
Goal #1: Transparency and availability of online information and documentation.	1.1 Improve and expand upon available datasets and the ability to analyze and manipulate that data.
	1.2 Improve online user experience with simplified and clear messaging to make data easier to access.
	1.3 Create data communication/sharing strategy to optimize data and information sharing between the State Water Board, Regional Water Boards, CalGEM, and other agencies, as appropriate.
Goal #2: Provide clear milestones and timely deliverables.	2.1 Make milestones and deliverables outlined in the Model Criteria and Senate Bill 4 (Chapter 313, Statutes of 2013, including Water Code section 10783), publicly available.
	2.2 Prepare review processes, flowcharts, and timelines for reviewing GMPs and requests for exclusion from groundwater monitoring, including interagency collaboration and program efficiencies.
Goal #3: Understand and mitigate impacts of well stimulation on water quality and public health.	3.1 Provide regular assessments of monitoring data, including pilot study results and identification of any chemicals of concern.
	3.2 Mitigate problems as they occur and share mitigation efforts with stakeholders.
	3.3 Develop a plan to re-evaluate the effectiveness of monitoring. Modify the scope of work and approach based on evaluation of the data collected and evaluated.
	3.4 Coordinate with other agencies to identify risk.
Goal #4: Provide region-specific or localized flexibility where possible.	4.1 Consider local conditions when reviewing groundwater plans.
	4.2 Clearly communicate why region- specific activities are occurring.
	4.3 Use consistent flexibility criteria for monitoring.
Goal #5: Assess implementation costs.	5.1 Assess implementation cost for the State Water Board and stakeholders.

Appendix C PROCESS FLOWCHARTS

LIST OF FLOWCHARTS

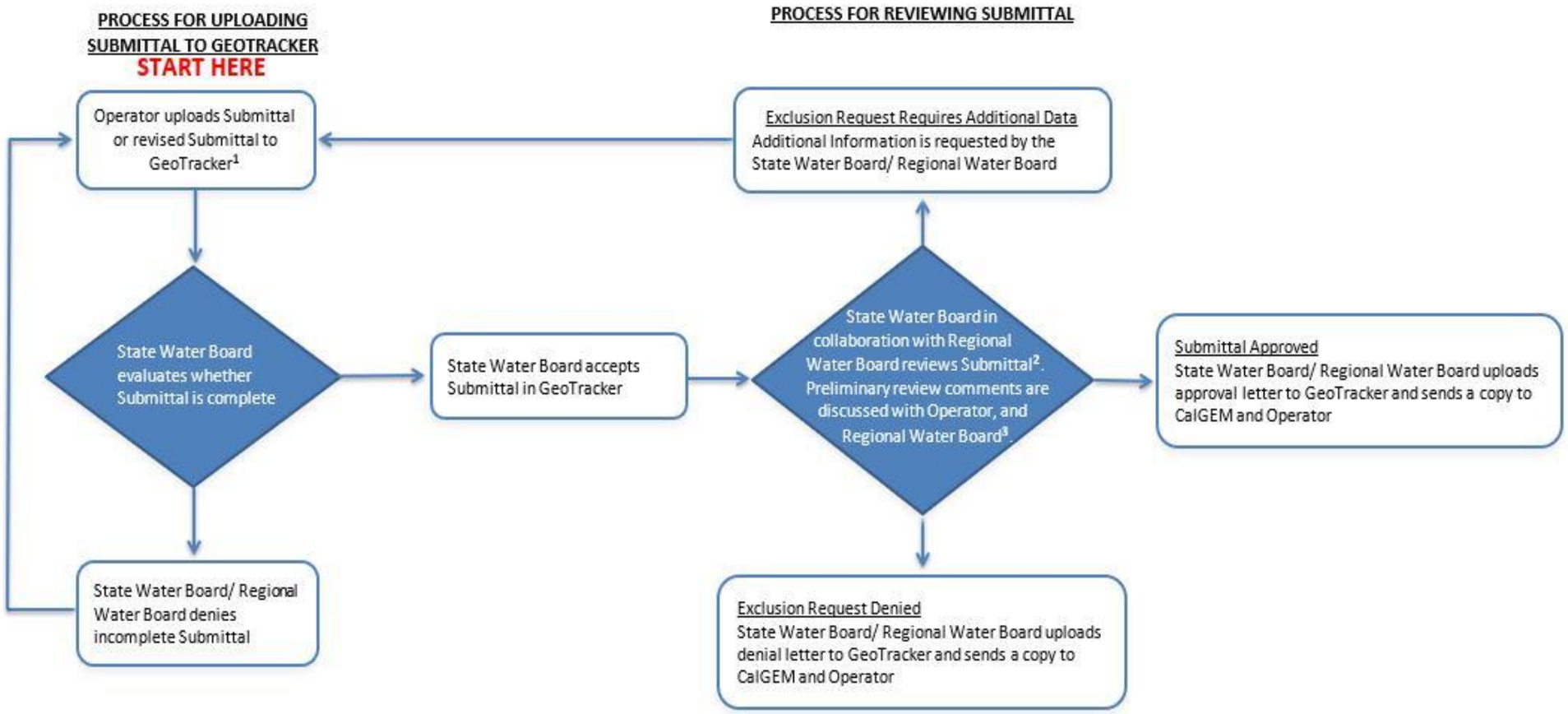
Flowchart C-1. Process Flowchart for Uploading and Reviewing Area-Specific Groundwater Monitoring Plans (New or Addendum)
State Water Resources Control Board
Oil and Gas Monitoring Unit



DEFINITIONS
ADSA = Axial Dimensional Stimulation Area
CalGEM = California Geologic Energy Management Division (formerly DOGGR)
GMP = Groundwater Monitoring Plan
Regional Water Board = Regional Water Quality Control Board

FOOTNOTES
1. New monitoring plans, or addendums to existing monitoring plans, submitted after July 7, 2015 must follow the requirements outlined in the Model Criteria for Groundwater Monitoring in areas of Oil and Gas Well Stimulation (Model Criteria).
2. It is the Water Boards goal to respond to the Operator in 45 calendar days from acceptance of a complete GMP.

Flowchart C-2. Process Flowchart for Reviewing Request for Exclusion from Groundwater Monitoring
State Water Resources Control Board
Oil and Gas Monitoring

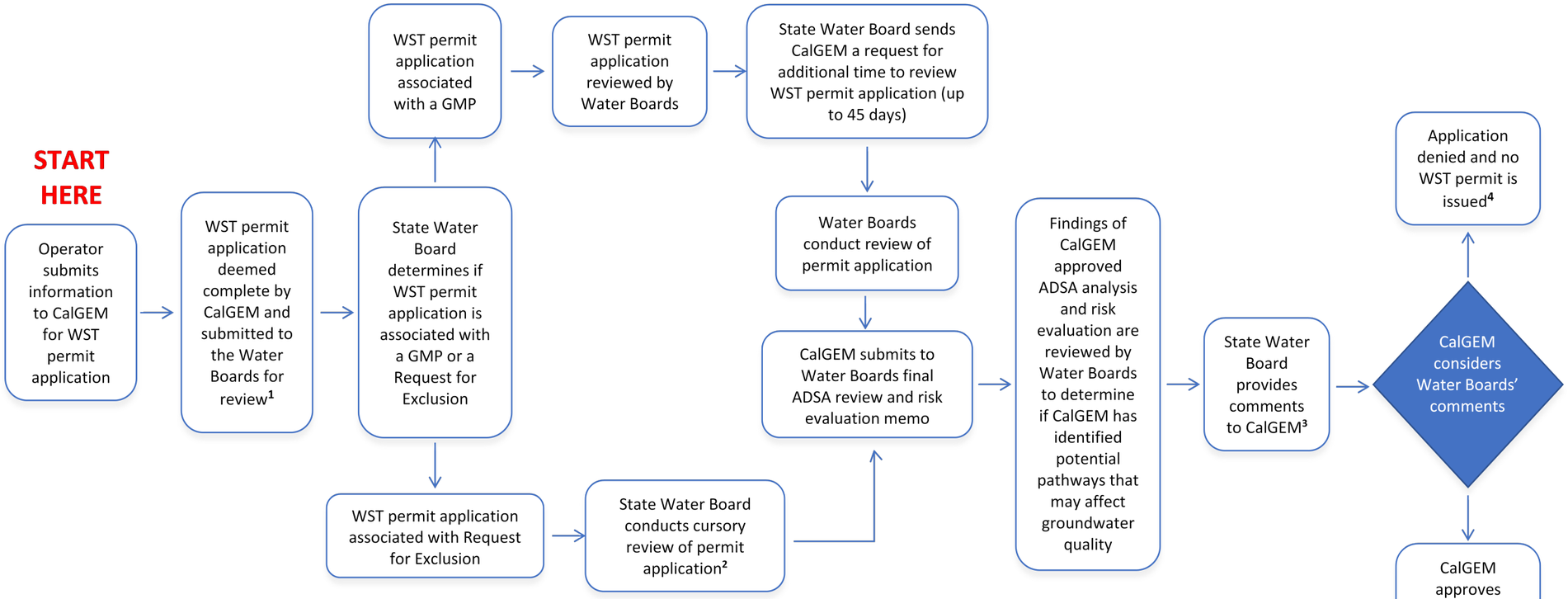


DEFINITIONS
CalGEM = California Geologic Energy Management Division (formerly DOGGR)
Regional Water Board = Regional Water Quality Control Board
Submittal = Request for Exclusion from Groundwater Monitoring
State Water Board = State Water Resources Control Board

FOOTNOTES
1. Requests for exclusion from groundwater monitoring submitted after July 7, 2015 must follow the requirements outlined in the Model Criteria for Groundwater Monitoring in areas of Oil and Gas Well Stimulation (Model Criteria). If future information indicates the potential presence of protected water in an area granted exclusion from groundwater monitoring, the State Water Board/ Regional Water Board will re-evaluate its determination.
2. It is the Water Boards goal to respond to the Operator in 45 calendar days from acceptance of complete submittal.

Flowchart C-3. Process Flowchart for Reviewing Well Stimulation Permit Applications

State Water Resources Control Board
Oil and Gas Monitoring Unit



DEFINITIONS
ADSA = Axial Dimensional Stimulation Area
CalGEM = California Geologic Energy Management Division (formerly DOGGR)
GMP = Groundwater Monitoring Plan
Request for Exclusion = Request for exclusion from groundwater monitoring
State Water Board = Water Resources Control Board
Water Boards = State Water Resources Control Board and Regional Water Quality Control Board
WST = Well Stimulation Treatments

FOOTNOTES
1. Reviewed independently from GMP or Request for Exclusion. Well stimulation cannot occur until a WST permit is issued by CalGEM and a GMP or Request for Exclusion has been approved by the Water Boards.
2. Where 5X ADSA extend into a non-excluded area, the Regional Board will also review permit application.
3. Regional Board staff forwards their comments on the permit applications and associated ADSA narratives that they review to State Water Board staff. State Water Board writes a memo to CalGEM staff that summarizes review comments.
4. If CalGEM denies a WST permit application, then WST activities at that well cannot proceed.
5. Well stimulation activities cannot proceed until Water Boards approve a GMP or Request for Exclusion.

Appendix D TABLES

LIST OF TABLES

Notes and Acronyms for all tables:

-- = not applicable
ADSA = Axial Dimension Stimulation Area
CalGEM = California Geologic Energy Management Division – Department of Conservation
GMP = Groundwater Monitoring Plan
WST = well stimulation treatment
Bbl = Barrel(s) of oil

Timelines for evaluation of submittals that extended beyond the reporting period are accurate as of February 10, 2020.

1. Located in Kern County, unless otherwise noted.
2. Date of Revised Plan submission to GeoTracker or other action by Operator.
3. On Hold indicates that Water Board staff are waiting on additional information from the operator or the approved ADSA from CalGEM. Denied indicates that the GMP did not meet the minimum requirements in the Model Criteria.
4. Days to complete the process equates to the elapsed time between the "GMP Date Accepted" to "Status/Determination Date". For GMPs (new and addenda) with multiple revisions, days to complete the process equates to the sum of days to review the original submittal and the days to review each of the revisions. This time includes communications with the operator, Regional Water Board staff, and CalGEM, review of data and the submittal, and preparation and review of agency correspondence. Refer to Flowchart C-1 - Process Flowchart for Uploading and Reviewing GMPs (new or addenda) in Appendix A for the detailed flowchart of the GMP review process.
5. Days to complete the process equates to the elapsed time between the "Request for Exclusion Accepted Date" to "Status/Determination Date". For Requests for Exclusions with multiple revisions, days to complete the process equates to the sum of days to review the original submittal and the days to review each of the revisions. This time includes communications with the operator, Regional Water Board staff, and CalGEM, review of data and the submittal, and preparation and review of agency correspondence. Refer to Flowchart C-2. Process Flowchart for Reviewing Requests for Exclusion from Groundwater Monitoring in Appendix A for the detailed flowchart of the Exclusions from Groundwater Monitoring review process.
6. Days to complete the process equates to the elapsed time between the "Date Accepted Request of Additional WST Wells" to "Status/Determination Date". For Requests of Additional WST Wells with multiple revisions, days to complete the process equates to the sum of days to review the original submittal and the days to review each of the revisions. This time includes communications with the operator, Regional Water Board staff, and CalGEM, review of data and the submittal, and preparation and review of agency correspondence. Refer to Flowchart C-3. Process Flowchart for Reviewing Well Stimulation Permit Applications.
7. Interim GMPs were approved by CalGEM. Sampling events are required pre-well stimulation and post well stimulation. Events may be zero because well stimulation was not performed, sampling was not performed, or sampling reports have not been uploaded to GeoTracker

Table D-1. Groundwater Monitoring Plans Reviewed (January 1, 2019 – December 31, 2019)

GeoTracker Global Identification	or (Area)	Township (T), Range (R), Section (S)[1]	Operator	GMP Date Accepted	Days for Initial Response	Interim Review Actions	Status/ Determination[3]	Number of WST Wells Approved	Status/ Determination Date	Days to Complete Process[4]	Comments
GAOG10009209	Buena Vista (Nose)	T32S, R25E, S13-16 T31S, R25E, S22-24	California Resources Corporation	9/13/2018	56	--	On Hold	--	--	--	Southeast expansion. GMP was accepted on 9/13/2018. Water Boards staff held a meeting to discuss comments with the operator on 10/15/2018. Water Boards staff sent a comment letter on 11/8/2018. Review is on hold due to information deficiencies in operator submitted GMP.
GAOG10009209	Buena Vista (Nose)	T32S, R24E, S1 T31S, R24E, S36 T32S, R25E, S3-11, S14-17 T31S, R25E, S31	California Resources Corporation	3/1/2019	132	Operator submitted revised GMPs (11/12/2019 and 1/9/2020)	Approved	2	1/17/2020	195	Northeast expansion. GMP was accepted on 3/1/2019. A drinking water well survey and new downgradient monitoring well were required as part of this expanded GMP. Water Boards staff discussed comments regarding installation methods proposed for the monitoring well and drinking water well survey results with the operator in coordination meetings on: 3/4/2019, 4/2/2019, 6/3/2019 and 6/24/2019. Water Boards staff sent comment letter to operator on 7/11/2019. Revised GMP accepted on 11/12/2019. A phone meeting was conducted on 11/29/2019 to discuss further comments from Water Boards staff. Water Boards staff contacted operator regarding information submitted within GMP's water well survey on 12/6/2019. Water Boards staff sent a comment letter to operator on 1/7/2020. Operator submitted a revised GMP on 1/9/2020. Issued approval letter on 1/17/2020.
GAOG10013748	Elk Hills	T30S, R24E, S36	California Resources Corporation	10/31/2019	78	--	On Hold	--	--	--	GMP was accepted on 10/31/2019. Water Boards staff discussed questions from review of groundwater data presented in the GMP during coordination meetings held on 11/18/2019, and 12/16/2019. Coordination meetings included operator presentations addressing staff concerns from GMP review. Water Board staff sent comment letter to operator on 1/17/2020.
GAOG10011823	Kettleman North Dome	T22S, R17E, S11	California Resources Corporation	7/23/2018	85	Operator submitted a revised GMP (2/11/2019) Operator placed the project on	On Hold	--	--	--	GMP was accepted on 7/23/2018. Water Boards staff held internal discussions regarding the nonstandard monitoring well construction proposed in the GMP. Water Boards staff sent comment letter on 10/16/2018. Water Boards staff accepted revised GMP on

GeoTracker Global Identification	or (Area)	Township (T), Range (R), Section (S)[1]	Operator	GMP Date Accepted	Days for Initial Response	Interim Review Actions	Status/ Determination[3]	Number of WST Wells Approved	Status/ Determination Date	Days to Complete Process[4]	Comments
						hold (4/9/2019)					2/11/2019. Water Board review complete on 2/22/2019, but issuance of approval on hold without receipt of ADSA narrative. Operator placed the project on hold on 4/9/2019.
GAOG10011556	Lost Hills	T26S, R20E, S11	California Resources Corporation	4/19/2018	92	Operator submitted revised GMPs (9/12/2018 and 1/31/2019)	Approved	1	9/25/2019	252	GMP was accepted on 4/19/18. Operator's initial GMP submittal proposed an alternative groundwater monitoring network with two groundwater monitoring wells as an alternative to Model Criteria methods. GMP included converting of a previously uncompleted oil well as a groundwater monitoring well. Preliminary meeting with operator to discuss initial GMP comments held on 5/8/2018. Comment letter sent to operator on 7/20/2018. Meeting with operator to discuss comments held on 8/7/2018. Operator submitted a revised GMP on 9/12/2018. Water Boards staff sent a comment letter on 12/3/2018. Operator submitted a revised GMP which Water Board staff accepted on 1/31/2019. Water Board staff discussed review of GMP at meeting with operator held on 3/4/2019. Water Board staff sent conditional approval pending receipt of ADSA narrative on 3/14/2019. Water Board Staff received ADSA narrative on 8/20/2019. Issued approval letter on 9/25/2019.
GAOG10012724	Railroad Gap	T30S, R22E, S15	California Resources Corporation	2/20/2019	--	--	Cancelled	--	--	--	Operator completed project phase of redrilling well for stimulation, and informed Water Boards staff of cancellation of GMP due to lack of production on 4/3/2019.
GAOG10011753	(Rhythm)	T27S, R25E, S8, S9, S16, S17	California Resources Corporation	6/21/2018	47	Operator submitted revised GMPs (8/16/2018 and 4/18/2019)	Approved	1	7/30/2019	192	Water Boards staff sent comment letter to operator on 8/7/2018. Operator submitted revised GMP on 8/16/2018. Water Boards staff drafted a second iteration of comments and sent letter on 10/8/2018. Operator submitted a second revised GMP on 4/18/2019. Water Boards staff completed review after receipt of ADSA narrative on 7/1/2019. Issued approval letter 7/30/2019.

Table D-2. **Groundwater Monitoring Plans (Addendum) Reviewed (January 1, 2019 - December 31, 2019)**

GeoTracker Global Identification	Oil Field or (Area)	Township (T), Range (R), Section (S)[1]	Operator	GMP Date Accepted	Days for Initial Response	Interim Review Actions	Status/ Determination[2]	Number of WST Wells Approved	Status/ Determination Date	Days to Complete Process[3]	Comments
GAOG10009277	Belridge, South	T28S, R20E, S12, S13, T28S, R21E, S18	Aera Energy, LLC	1/10/2019	13	Operator submitted revised addendum (1/23/2019)	Approved	35	1/25/2019	15	Water Board staff sent comments to operator on 1/22/2019. Operator submitted revised addendum on 1/23/2019. Issued approval letter 1/25/2019.
GAOG10009277	Belridge, South	T28S, R20E, S12, S13, T28S, R21E, S18	Aera Energy, LLC	2/20/2019	37	--	Approved	15	3/29/2019	37	Issued approval letter 3/29/2019.
GAOG10009277	Belridge, South	T28S, R20E, S12, S13, T28S, R21E, S18	Aera Energy, LLC	3/18/2019	49	--	Approved	14	5/6/2019	49	Water Board staff contacted operator regarding information deficiencies on 5/1/2019. Operator provided additional information on geophysical logs on 5/1/2019. Issued approval letter 5/6/2019.
GAOG10009277	Belridge, South	T28S, R20E, S12, S13, T28S, R21E, S18	Aera Energy, LLC	3/18/2019	50	--	Approved	9	5/7/2019	50	Water Board staff contacted operator regarding information deficiencies on 5/1/2019. Operator provided additional information on geophysical logs on 5/1/2019. Issued approval letter 5/7/2019.
GAOG10009277	Belridge, South	T28S, R20E, S12, S13, T28S, R21E, S18	Aera Energy, LLC	3/27/2019	41	--	Approved	1	5/7/2019	41	Issued approval letter 5/7/2019.
GAOG10009277	Belridge, South	T28S, R20E, S12, S13, T28S, R21E, S18	Aera Energy, LLC	4/10/2019	28	--	Approved	14	5/8/2019	28	Issued approval letter 5/8/2019.
GAOG10009277	Belridge, South	T28S, R20E, S12, S13, T28S, R21E, S18	Aera Energy, LLC	7/8/2019	--	--	Review in Progress	--	--	--	Addendum is under Water Board staff review but cannot be completed without receipt of ADSA narrative.
GAOG10011328	Belridge, South	T28S, R21E, S19	Berry Petroleum Company, Inc	12/4/2018	70	Operator submitted revised addendum (2/18/2019)	Approved	10	3/6/2019	86	Permit Group 6. Water Board staff sent comments to operator on 2/12/2019. Operator submitted a revised addendum on 2/18/2019. Issued approval letter 3/6/2019.
GAOG10011328	Belridge, South	T28S, R21E, S19	Berry Petroleum Company, Inc	12/14/2018	53	Operator submitted revised addendum (2/27/2019)	Approved	10	3/18/2019	72	Permit Group 5. Water Board staff sent comment letter to operator on 2/5/2019. Waterboard Staff accepted revised addendum on 2/27/2019. Issued approval letter 3/18/2019.

GeoTracker Global Identification	Oil Field or (Area)	Township (T), Range (R), Section (S)[1]	Operator	GMP Date Accepted	Days for Initial Response	Interim Review Actions	Status/ Determination[2]	Number of WST Wells Approved	Status/ Determination Date	Days to Complete Process[3]	Comments
GAOG10011328	Belridge, South	T28S, R21E, S19	Berry Petroleum Company, Inc	12/14/2018	60	Operator submitted revised addendum (4/2/2019)	Approved	10	4/24/2019	82	Permit Group 7. Water Board Staff sent comment letter to operator on 2/12/2019. Water Board Staff accepted revised addendum on 4/2/2019. Issued approval letter 4/24/2019.
GAOG10011328	Belridge, South	T28S, R21E, S19	Berry Petroleum Company, Inc	4/15/2019	30	Operator submitted revised addendum (5/21/2019)	Approved	9	6/13/2019	53	Permit Group 8. Water Board staff sent comments to the operator on 5/15/2019. Water Board Staff received revised addendum on 5/21/2019. Issued approval letter 6/13/2019.
GAOG10009209	Buena Vista (Nose)	T32S, R24E, S1, T31S, R24E, S36 T32S, R25E S3-11,14-17 T31S, R25E, S 31	California Resources Corporation	10/22/2018	57	Operator submitted revised addendum (3/12/2019)	Approved	5	5/8/2019	114	Addendum 7. Water Board staff held comment meeting with operator on 12/18/2018. Operator informed by email of pending approval contingent on Workplan approval on 1/11/2019. Water Board staff sent comment memo to operator regarding outstanding issues to be addressed in future revised addenda on 1/16/2019. Water Board staff accepted revised addendum on 3/12/2019. Issued approval letter 5/8/2019.
GAOG10009209	Buena Vista (Nose)	T32S, R24E, S1, T31S, R24E, S36 T32S, R25E S3-11,14-17 T31S, R25E, S 31	California Resources Corporation	1/11/2019	39	Operator submitted revised addendum (2/28/2019), Operator submitted a second revised addendum (3/28/2019)	Approved	2	4/11/2019	75	Addendum 8. Water Board staff compiled comments from review of addendum on 2/19/2019. Water Board staff received revised addendum from operator on 2/28/2019. Water Board staff sent comments to operator regarding revised addendum on 3/22/2019. Operator submitted a second revised addendum 3/28/2019. Issued approval letter 4/11/2019.
GAOG10009209	Buena Vista (Nose)	T32S, R24E, S1 T31S, R24E, 36 T32S, R25E, S3-11, S14-17, T31S, R25E, S31	California Resources Corporation	2/13/2019	58	Operator submitted revised addendum (4/22/2019)	Approved	2	5/30/2019	96	Addendum 9. Water Board staff sent comment letter to operator on 4/12/2019. Operator submitted revised addendum 4/22/2019. Issued approval letter on 5/30/2019.

GeoTracker Global Identification	Oil Field or (Area)	Township (T), Range (R), Section (S)[1]	Operator	GMP Date Accepted	Days for Initial Response	Interim Review Actions	Status/ Determination[2]	Number of WST Wells Approved	Status/ Determination Date	Days to Complete Process[3]	Comments
GAOG10009209	Buena Vista (Nose)	T32S, R24E, S1 T31S ,R24E, 36 T32S, R25E, S3-11, S14-17 T31S, R25E, S31	California Resources Corporation	6/27/2019	83	--	On Hold	--	--	--	Addendum 10. Water Board staff sent comment letter to operator on 9/18/2019. Addendum review is on hold pending additional information submission from operator.
GAOG10010391	Lost Hills	T26S, R21E, S29, S32, S33 T27S, R21E, S4, S5	Chevron USA, Inc	9/13/2018	50	Operator submitted revised addendum (12/15/2018) Operator submitted a second revised addendum (5/9/2019)	On Hold	--	--	--	Addendum 1. Comment letter sent to operator on 11/2/2018. Revised addendum submitted on 12/15/2018. Operator informed Water Board staff of intent to revise addendum on 1/24/2019. Second revised addendum submitted on 5/9/2019. Comment letter sent to operator on 6/20/2019. Review process on hold pending receipt of ADSA narrative, comments sent to operator regarding addendum and status of ADSA narrative on 8/20/2019.
GAOG10010391	Lost Hills	T26S, R21E, S29, S32, S33 T27S, R21E, S4, S5	Chevron USA, Inc	5/28/2019	104	Operator submitted revised addendum (8/8/2019)	On Hold	--	--	--	Addendum 2. Operator informed Water Board staff of intent to revise addendum on 8/4/2019. Operator submitted revised addendum on 8/8/2019. Review process on hold pending receipt of ADSA narrative. Water Board staff contacted operator via email on 9/9/2019 with comments, and status of ADSA narrative.
GAOG10010391	Lost Hills	T26S, R21E, S29, S32, S33 T27S, R21E, S4, S5	Chevron USA, Inc	6/10/2019	71	--	On Hold	--	--	--	Addendum 3. Waterboard staff completed review of submitted addendum on 7/23/2019. Review process in on hold pending receipt of ADSA narrative. Waterboard staff sent comment letter regarding addendum and ADSA narrative to operator on 8/20/219.
GAOG10010391	Lost Hills	T26S, R21E, S29, S32, S33 T27S, R21E, S4, S5	Chevron USA, Inc	8/8/2019	32	--	On Hold	--	--	--	Addendum 4. Water Board staff sent a comment letter regarding addendum, and status of ADSA narrative on 9/9/2019. Water Board staff review in progress.

GeoTracker Global Identification	Oil Field or (Area)	Township (T), Range (R), Section (S)[1]	Operator	GMP Date Accepted	Days for Initial Response	Interim Review Actions	Status/ Determination[2]	Number of WST Wells Approved	Status/ Determination Date	Days to Complete Process[3]	Comments
GAOG10009406	Lost Hills	T27S, R21E, S4, S5	Aera Energy, LLC	2/13/2019	41	--	Approved	15	5/7/2019	58	Regional Water Board staff verbally relayed addendum comments to operator on 3/26/2019. On 4/2/2019 operator provided additional documentation to address Water Board staff comments. Regional Water Board staff confirmed that additional information addressed comments on 4/10/2019. Operator notified by email that addendum approval could not be completed without receipt of ADSA narrative on 4/12/2019. Water Board staff received ADSA narrative on 4/30/2019. Issued Approval Letter on 5/7/2019.
GAOG10009406	Lost Hills	T27S, R21E, S4, S5	Aera Energy, LLC	7/8/2019	--	--	Review in Progress	--	--	--	Addendum is under Water Board staff review but cannot be completed without receipt of ADSA narrative.
GAOG10009406	Lost Hills	T27S, R21E, S4, S5	Aera Energy, LLC	5/17/2019	60	Operator submitted revised addendum (8/5/2019) Operator submitted second revised addendum (12/13/2019)	Approved	12	1/24/2020	201	Operator revised bottom hole location for well in addendum on 7/16/2019. A revised addendum was submitted on 8/5/2019. Water Board staff sent comment letter to operator on 11/6/2019. Operator submitted a second revised addendum on 12/13/2019. Issued approval letter on 1/24/2020.
GAOG10009406	Lost Hills	T27S, R21E, S4, S5	Aera Energy, LLC	8/15/2019	83	Operator submitted revised addendum (12/17/2019)	On Hold	--	--	--	Water Boards staff sent comment letter to operator on 11/6/2019. Water Board staff received a revised addendum on 12/17/2019. Operator notified on 2/7/2020 that Water Boards staff review of addendum complete, but approval cannot be issued without receipt of ADSA narrative.

Table D-3. Requests for Exclusion Reviewed (January 1, 2019 - December 31, 2019)

GeoTracker Global Identification	Oil Field	Township (T), Range (R), Section (S)	Operator	Request for Exclusion Accepted Date	Days for Initial Response	Interim Review Actions	Status/ Determination	Number of WST Wells Approved	Status/ Determination Date	Days to Complete Process[4]	Comments
GAOG10012394	Belridge, North	T27S, R20E, SE 1/4 of S27	Aera Energy, LLC	12/12/2018	51	--	On Hold	1	--	--	Water Boards staff sent comment letter on 2/1/2019. Water Board staff review is on hold due to information deficiencies in operator provided documentation.
GAOG10012000	Belridge, South	T28S, R21E, NE 1/4 S30	Aera Energy, LLC	8/22/2018	44	Operator submitted a Revised request for exclusion (1/25/2019)	Approved	2	2/13/2019	63	Water Boards staff sent comment letter on 10/05/2018. A meeting between Water Boards staff and operator was held on 10/10/2018. Operator submitted a revised request for exclusion on 1/25/2019. Issued approval letter on 2/13/2019.
GAOG10013169	Buena Vista	T31S, R23E, S34B (portion) T32S, R23E, S3C (portion)	California Resources Elk Hills, LLC	7/11/2019	--	--	Cancelled	--	--	--	Operator submitted request for exclusion on 07/10/2019. Operator retracted request in email correspondence on 08/29/2019.
GAOG10011793	Elk Hills	T30S, R23E, S16R-501 ACRE	California Resources Corporation	5/31/2019	40	--	Approved	4	7/10/2019	40	Issued approval letter on 7/10/2019.
GAOG10012808	Elk Hills	T30S, R22E, Portion of S24Z	California Resources Elk Hills, LLC	3/15/2019	53	--	Approved	--	5/7/2019	53	Issued approval Letter on 05/17/2019.
GAOG10013167	Elk Hills	T30S, R23E, S19R	California Resources Elk Hills, LLC	7/10/2019	69	--	Approved	--	9/17/2019	69	Issued approval Letter on 09/17/2019.
GAOG10013229	Elk Hills	T30S, R23E, S30R	California Resources Elk Hills, LLC	7/30/2019	73	--	Approved	--	10/11/2019	73	Issued approval Letter on 10/11/2019.
GAOG10013274	Elk Hills	T30S, R22E, S25Z-162-acre portion	California Resources Elk Hills, LLC	8/14/2019	83	--	Approved	--	11/5/2019	83	Issued approval letter on 11/5/2019

Table D-4. Requests to Add WST Wells to Existing Approved Areas of Exclusion (January 1, 2019 - December 31, 2019)

GeoTracker Global Identification	Oil Field	Township (T), Range (R), Section (S)	Operator	Date Accepted Request of Additional WST Wells	Days for Initial Response	Status/ Determination	Number of WST Wells Added to Approved Exclusion	Status/ Determination Date	Days to Complete Review Process[6]
GAOG10010818	Belridge, North	T28S, R20E, S1	Breitburn Operating LP	8/20/2019	8	Approved	11	8/28/2019	8
GAOG10010818	Belridge, North	T28S, R20E, S1	Breitburn Operating LP	8/20/2019	2	Approved	10	8/22/2019	2
GAOG10010818	Belridge, North	T28S, R20E, S1	Breitburn Operating LP	8/29/2019	6	Approved	12	9/4/2019	6
GAOG10011107	Belridge, North	T28S, R20E, S1	Aera Energy, LLC	5/14/2019	16	Approved	1	5/30/2019	16
GAOG10011107	Belridge, North	T28S, R20E, S1	Aera Energy, LLC	5/14/2019	16	Approved	10	5/30/2019	16
GAOG10011107	Belridge, North	T28S, R20E, S1	Aera Energy, LLC	7/29/2019	8	Approved	13	8/6/2019	8
GAOG10011108	Belridge, North	T27S, R20E, S35	Aera Energy, LLC	4/16/2019	8	Approved	10	4/24/2019	8
GAOG10011109	Belridge, North	T27S, R20E, S36	Aera Energy, LLC	4/16/2019	8	Approved	2	4/24/2019	8
GAOG10008913	Belridge, South	T28S, R21E, S28	Aera Energy, LLC	6/28/2019	4	Approved	2	7/2/2019	4
GAOG10008915	Belridge, South	T28S, R21E, S34	Aera Energy LLC	12/21/2018	17	Approved	2	1/7/2019	17
GAOG10008892	Belridge, South	T28S, R21E, S33	Aera Energy, LLC	12/27/2018	8	Approved	7	1/4/2019	8
GAOG10008892	Belridge, South	T28S, R21E, S33	Aera Energy, LLC	1/24/2019	41	Approved	10	3/6/2019	41
GAOG10008892	Belridge, South	T28S, R21E, S33	Aera Energy, LLC	4/16/2019	8	Approved	3	4/24/2019	8
GAOG10008892	Belridge, South	T28S, R21E, S33	Aera Energy, LLC	7/3/2019	0	Approved	14	7/3/2019	0

GeoTracker Global Identification	Oil Field	Township (T), Range (R), Section (S)	Operator	Date Accepted Request of Additional WST Wells	Days for Initial Response	Status/ Determination	Number of WST Wells Added to Approved Exclusion	Status/ Determination Date	Days to Complete Review Process[6]
GAOG10009503	Belridge, South	T28S, R21E, S29	Aera Energy, LLC	1/24/2019	40	Approved	3	3/5/2019	40
GAOG10009503	Belridge, South	T28S, R21E, S29	Aera Energy, LLC	2/28/2019	5	Approved	3	3/5/2019	5
GAOG10009503	Belridge, South	T28S, R21E, S29	Aera Energy, LLC	3/7/2019	0	Approved	1	3/7/2019	0
GAOG10009503	Belridge, South	T28S, R21E, S29	Aera Energy, LLC	3/26/2019	3	Approved	3	3/29/2019	3
GAOG10009503	Belridge, South	T28S, R21E, S29	Aera Energy, LLC	3/26/2019	3	Approved	12	3/29/2019	3
GAOG10009503	Belridge, South	T28S, R21E, S29	Aera Energy, LLC	3/28/2019	1	Approved	2	3/29/2019	1
GAOG10009503	Belridge, South	T28S, R21E, S29	Aera Energy, LLC	3/28/2019	1	Approved	2	3/29/2019	1
GAOG10009503	Belridge, South	T28S, R21E, S29	Aera Energy, LLC	4/15/2019	9	Approved	2	4/24/2019	9
GAOG10009503	Belridge, South	T28S, R21E, S29	Aera Energy, LLC	6/28/2019	4	Approved	3	7/2/2019	4
GAOG10009503	Belridge, South	T28S, R21E, S29	Aera Energy, LLC	7/3/2019	5	Approved	1	7/8/2019	5
GAOG10009503	Belridge, South	T28S, R21E, S29	Aera Energy, LLC	7/25/2019	8	Approved	7	8/2/2019	8
GAOG10009503	Belridge, South	T28S, R21E, S29	Aera Energy, LLC	7/25/2019	8	Approved	2	8/2/2019	8
GAOG10009503	Belridge, South	T28S, R21E, S29	Aera Energy, LLC	7/29/2019	179	Approved	1	1/24/2020	179
GAOG10009503	Belridge, South	T28S, R21E, S29	Aera Energy, LLC	8/5/2019	0	Approved	6	8/6/2019	1
GAOG10009592	Belridge, South	T29S, R21E,1/2 S3	Aera Energy, LLC	4/15/2019	9	Approved	4	4/24/2019	9

GeoTracker Global Identification	Oil Field	Township (T), Range (R), Section (S)	Operator	Date Accepted Request of Additional WST Wells	Days for Initial Response	Status/ Determination	Number of WST Wells Added to Approved Exclusion	Status/ Determination Date	Days to Complete Review Process[6]
GAOG10009592	Belridge, South	T29S, R21E,1/2 S3	Aera Energy, LLC	4/25/2019	11	Approved	3	5/6/2019	11
GAOG10009914	Belridge, South	T28S, R21E, S20	Aera Energy, LLC	2/28/2019	47	Approved	1	4/16/2019	47
GAOG10010731	Belridge, South	T29S, R21E, S2	Aera Energy, LLC	4/15/2019	9	Approved	2	4/24/2019	9
GAOG10010731	Belridge, South	T29S, R21E, S2	Aera Energy, LLC	4/25/2019	11	Approved	4	5/6/2019	11
GAOG10011093	Elk Hills	T30S, R22E, Portion of S29R	California Resources Elk Hills, LLC	12/19/2019	20	Approved	2	1/8/2020	20
GAOG10012808	Elk Hills	T30S, R22E, Portion of S24Z	California Resources Elk Hills, LLC	12/9/2019	--	Review in Progress	7	--	--
GAOG10012808	Elk Hills	T30S, R22E, Portion of S24Z	California Resources Elk Hills, LLC	12/12/2019	--	Review in Progress	2	--	--

Table D-5. Sampling Events for the Area-Specific Groundwater Monitoring Program (January 1, 2019 - December 31, 2019)

GeoTracker Global Identification	Oil Field or (Area)	Interim GMP or GMP	Township (T), Range (R), Section (S)	County	Operator	Number of Groundwater Monitoring Wells	2014	2015	2016	2017	2018	2019	Total	Comments
GAOG10010818	Belridge, North and South	GMP	T28S, R20E, S1, S12	Kern	Breitburn Operating, LP	3	NA	NA	NA	NA	2	NA	**2**	GMP approved on 10/24/17. Stimulation occurred from 4/2/2018 through 8/4/2018. Exclusion approved on 8/28/2018.
GAOG10011328	Belridge, South	GMP	T28S, R21E, S19	Kern	Berry Petroleum Company, LLC	7	NA	1	1	2	2	2	**8**	GMP approved on 7/12/2018. Sampling data includes interim sampling events since 2015. Stimulation occurred starting on approximately 8/9/2018 and is ongoing.
GAOG10009277	Belridge, South	GMP	T28S, R20E, S12, S13, S18	Kern	Aera Energy, LLC	4	1	3	3	4	6	3	**20**	GMP approved on 4/11/2017. Sampling data includes interim sampling events since 2015. Stimulation started on 1/2/2014 and is ongoing.
GAGW10000050	Brea-Olinda	Interim GMP	T3S, R9W, S6	Orange	Bridge Energy, LLC	2	0	2	1	1	1	0	**5**	Interim GMP received on 4/3/2014. Stimulation occurred on 9/23/2015 to 9/24/2015.
GAOG10009209	Buena Vista (Nose)	GMP	T32S, R24E, S1; T31S, R24E S36; T32S, R25E, S3-11, 14-17; & T31S, R25E, S31	Kern	California Resources Corporation	16	2	2	1	3	3	1	**12**	GMP approved on 11/18/2016. Sampling data includes interim sampling events since 2014. Stimulation started on 10/27/2014 and is ongoing.
GAGW10000018	Coles Levee, North	Interim GMP	T30S, R25E, S29, 30	Kern	California Resources Corporation	2	2	3	2	2	2	1	**12**	Interim GMP received on 8/19/2014. Stimulation occurred on 10/24/2014 to 10/26/2014 and 11/7/2014 to 11/9/2014.
GAGW10007872	Coles Levee, North	Interim GMP	T30, S25E, S31	Kern	California Resources Corporation	1	0	3	2	2	2	1	**10**	Interim GMP received on 9/19/2014. Stimulation occurred on 6/19/2015 to 6/20/2015.
GAOG10010467	Coles Levee, North	GMP	T30S, R25E, S30	Kern	California Resources Corporation	3	NA	NA	NA	0	0	0	**0**	GMP approved on 10/24/17. No wells stimulated.

GeoTracker Global Identification	Oil Field or (Area)	Interim GMP or GMP	Township (T), Range (R), Section (S)	County	Operator	Number of Groundwater Monitoring Wells	2014	2015	2016	2017	2018	2019	Total	Comments
GAGW10000042	Hopper Canyon	Interim GMP	T4N, R18W, S13	Ventura	DCOR, LLC	2	1	0	0	0	0	0	**1**	Interim GMP received on 5/22/2014. Pre-stimulation/baseline sampling only conducted in 2014. No wells stimulated.
GAGW10000040	Kettleman Middle Dome	Interim GMP	T23S, R19E, S19	Kings	California Resources Corporation	1	1	3	0	3	2	1	**10**	Interim GMP received on 6/11/2014. Stimulation occurred on 11/23/2014 to 11/28/2014 and 2/16/2015 to 3/13/2015. Post stimulation sampling was not performed in 2016.
GAOG10009406	Lost Hills	GMP	T27S, R21E, S4 and S5	Kern	Aera Energy, LLC	9	2	6	3	2	3	3	**19**	GMP approved on 5/14/2018. Sampling data includes interim sampling events since 2014. Stimulation started on 6/4/2014 and is ongoing.
GAGW10000039	Lost Hills	Interim GMP	T27S, R21E, S36	Kern	Seneca Resources Corporation	1	3	2	2	2	2	1	**12**	Interim GMP received on 3/10/2014. Stimulation occurred on 10/13/2014 and 10/20/2014.
GAOG10010391	Lost Hills	GMP	T26S, R21E, S29, S32, S33 & T27S, R21E, S4 & S5	Kern	Chevron USA, Inc	13	1	2	2	2	2	1	**10**	GMPs approved on 9/20/2017 and 8/10/2018. Sampling data includes interim sampling events since 2014. Stimulation started on 3/17/2014 and is ongoing.
GAGW10000032	Rose	Interim GMP	T26S, R24E, S36	Kern	California Resources Corporation	1	1	2	2	2	2	1	**10**	Interim GMP received on 5/5/2014. Stimulation occurred on 9/16/2014 to 9/22/2014. Pre-stimulation (baseline) sampling event was not performed.
GAGW10000031	Rose	Interim GMP	T26S, R24E, S26	Kern	California Resources Corporation	2	3	3	2	2	1	0	**11**	Interim GMP received on 2/18/2014. Stimulation occurred on 10/7/2014 to 10/8/2014.

GeoTracker Global Identification	Oil Field or (Area)	Interim GMP or GMP	Township (T), Range (R), Section (S)	County	Operator	Number of Groundwater Monitoring Wells	2014	2015	2016	2017	2018	2019	Total	Comments
GAGW10000041	Stockdale	Interim GMP	T30S, R27E, S22	Kern	Crimson Resources	1	2	0	0	0	0	0	**2**	Interim GMP received on 7/15/2014. Approved Interim GMP proposed a baseline sampling event and one post-stimulation sampling event. Stimulation occurred on 11/17/2014 – 11/21/2014.

Appendix E REGIONAL MONITORING PROGRAM PUBLICATIONS

Phase 1

1. Davis, T.A., Landon, M.K., and Bennett, G.L., 2018, Prioritization of oil and gas fields for regional groundwater monitoring based on a preliminary assessment of petroleum resource development and proximity to California's groundwater resources: U.S. Geological Survey Scientific Investigations Report 2018–5065, 115 p., https://doi.org/10.3133/sir20185065

2. Davis, T., Bennett, G., Metzger, L., Kjos, A., Peterson, M., Johnson, J., Johnson, T., Brilmyer, C., and Dillon, D., 2018, Data analyzed for the preliminary prioritization of California oil and gas fields for regional groundwater monitoring: U.S. Geological Survey data release, https://doi.org/10.5066/F7FJ2DV3

3. Davis, T.A., Kulongoski, J.T., and McMahon, P.B., 2016, Produced water chemistry data for samples from four petroleum wells, Southern San Joaquin Valley, California, 2014: U.S. Geological Survey data release. https://www.sciencebase.gov/catalog/item/57a50c48e4b0ebae89b6d87f

4. Dillon, D.B., Davis, T.A., Landon, M.K., Land, M.T., Wright, M.T., and Kulongoski, J.T., 2016, Data from exploratory sampling of groundwater in selected oil and gas areas of coastal Los Angeles County and Kern and Kings Counties in southern San Joaquin Valley, 2014–15: California Oil, Gas, and Groundwater Project, U.S. Geological Survey Open-File Report 2016–1181, 24 p. https://pubs.er.usgs.gov/publication/ofr20161181

5. Metzger, L.F., and Landon, M.K., 2018, Preliminary groundwater salinity mapping near selected oil fields using historical water-sample data, central and southern California: U.S. Geological Survey Scientific Investigations Report 2018–5082, 54 p., https://doi.org/10.3133/sir20185082

6. Kulongoski, J.T., McMahon, P.B., Land, M.T., Wright, M.T., Johnson, T.A., and Landon, M.K., 2018, Origin of methane and sources of high concentrations in Los Angeles groundwater, Journal of Geophysical Research: Biogeosciences. 123. https://doi.org/10.1002/2017JG004026

7. McMahon, P.B., Kulongoski, J.T., Wright, M.T., Land, M.T., Landon, M.K., Cozzarelli, I.M., Vengosh, Avner, and Aiken, G.R., 2017, Preliminary results from exploratory sampling of wells for the California oil, gas, and groundwater program, 2014–15 (ver 1.1, January 2017): U.S. Geological Survey Open-File Report 2016–1100, 8 p., http://dx.doi.org/10.3133/ofr20161100

8. Metzger, L.F., Davis, T. A., Peterson, M.F., Brilmyer, C.A, and Johnson, J.C., 2018, Data used for preliminary regional groundwater salinity mapping near selected oil fields in central and southern California: U.S. Geological Survey data release, https://doi.org/10.5066/F7RN373C

Phase 2

9. Barry, P.H., Kulongoski, J.T., Landon, M.K., Tyne, R.L., Gillespie, J.M., Stephens, M.J., Hillegonds, D.J., Byrne, D.J., and Ballentine, C.J., 2018, Tracing enhanced oil recovery signatures in casing gases from the Lost Hills oil field using noble gases. Earth and Planetary Science Letters, 496, 57-67. https://doi.org/10.1016/j.epsl.2018.05.028

10. Davis, T.A., Teunis, J.A., McCarlson, A.J., Seitz, N.O., and Johnson, J.C., 2018, Water chemistry data for samples collected at groundwater and surface-water sites near the Lost Hills and Belridge oil fields, November 2016–September 2017, Kern County, California: U.S. Geological Survey data release, https://doi.org/10.5066/F7NS0T5M.

11. Everett, R.E., Fenton, N.C., Hill, J.M., Stephens, M.J., Francisco, D.M., Metzger, L.F., Gans, K.D., and Qi, S.L., 2019, Geochemical and geophysical data for selected wells in and surrounding the South Cuyama oil and gas field: U.S. Geological Survey data release, https://doi.org/10.5066/P9KTYCNC.

12. Gannon, R.S., Saraceno, J.F., Kulongoski, J.T., Teunis, J.A., Barry, P.H., Tyne, R.L., Kraus, T.E.C., Hansen, A.M., and Qi, S.L., 2018, Produced water chemistry data for the Lost Hills, Fruitvale, and North and South Belridge study areas, Southern San Joaquin Valley, California: U.S. Geological Survey data release, https://doi.org/10.5066/F7X929H9

13. Gans, K.D., Metzger, L.F., Gillespie, J.M, and Qi, S.L., 2018, Historical produced water chemistry data compiled for the Fruitvale Oil Field, Kern County, California: U.S. Geological Survey data release, https://doi.org/10.5066/F72B8X8G

14. Gans, K.D., Metzger, L.F., Gillespie, J.M., and Qi, S.L., 2019, Historical produced water chemistry data compiled for the Lost Hills and North and South Belridge Oilfields, Kern County, California: U.S. Geological Survey data release, https://doi.org/10.5066/F7F18Z12.

15. Gans, K.D., Metzger, L.F., Gillespie, J.M., and Qi, S.L., 2019, Historical Produced Water Chemistry Data Compiled for the Elk Hills Oilfield, Kern County, California: U.S. Geological Survey data release, https://doi.org/10.5066/P9Z8ZSVS.

16. Gillespie, J.M., Davis, T.A., Stephens, M.J., Ball, L.B., and Landon, M.K., 2019, Groundwater salinity and the effects of produced water disposal in the Lost Hills-Belridge oil fields, Kern County, California, AAPG Environmental Geosciences, v. 26, no. 3, 77-96. http://archives.datapages.com/data/deg/2019/EG032019/eg18009/eg18009.html

17. Gillespie, J.M., Davis, T.A., Ball, L.B., Herrera, P.J., Wolpe, Z., Medrano, V., Bobbitt, M., and Stephens, M.J., 2019, Geological, geochemical, and geophysical data from the Lost Hills and Belridge oil fields: U.S. Geological Survey data release, https://doi.org/10.5066/P90QH6CI.

18. Haugen, E.A., Finney, D.M.N., Ducart, A., Stephens, M.J., and Shimabukuro, D.H., 2018, Geophysical and geochemical data for salinity mapping in the Midway-Sunset oil field area: U.S. Geological Survey data release, https://doi.org/10.5066/P9I0Q1B2

19. McCarlson, A., Wright, M. T., Teunis, J.A., Davis, T.A., Johnson, J., and Qi, S.L., 2018, Water chemistry data for samples collected at groundwater sites near the Fruitvale oil field, September 2016–February 2017, Kern County, California, https://doi.org/10.5066/F7ZW1K7T.

20. McMahon, P.B., Kulongoski, J.T., Vengosh, A., Cozzarelli, I.M., Landon, M.K., Kharaka, Y.K., Gillespie, J.M., and Davis, T.A., 2018. Regional patterns in the geochemistry of oil field water, southern San Joaquin Valley, California, USA. Applied Geochemistry, https://doi.org/10.1016/j.apgeochem.2018.09.015

21. McMahon, P.B., A. Vengosh, T.A. Davis, M.K. Landon, R.L. Tyne, M.T. Wright, J.T. Kulongoski, A.G. Hunt, P.H. Barry, A.J. Kondash, Z. Wang, C.J. Ballentine, 2019. Occurrence and sources of radium in groundwater associated with oil fields in the southern San Joaquin Valley, California. Environmental Science & Technology, 53 (16), 9398-9406, https://doi.org/10.1021/acs.est.9b02395.

22. Stephens, M.J., Shimabukuro, D.H., Gillespie, J.M., and Chang, W., 2018, Groundwater salinity mapping using geophysical log analysis within the Fruitvale and Rosedale Ranch oil fields: Kern County, California, USA. Hydrogeology Journal, https://doi.org/10.1007/s10040-018-1872-5

23. Stephens, Michael J., Shimabukuro, David, Gillespie, Janice, Metzger, Loren, Ducart, Ashley, Everett, Rhett, and Gans, Kate, 2018, Geochemical and geophysical data for wells in the Fruitvale and Rosedale Ranch oil and gas fields; Kern County, California, USA: U.S. Geological Survey Data Release, https://doi.org/10.5066/F7S181PH

24. Stephens, M.J., Haugen, E.A., Shimabukuro, D.H., Gillespie, J.M., Sowers, T.A., Ducart, A., and Medrano, V., 2018, Geochemical, geological, and geophysical data for wells in the Poso Creek oil and gas field, Kern County, California: U.S. Geological Survey data release, https://doi.org/10.5066/P9RR9UYN.

25. Wright, M.T., McMahon, P.B., Landon, M.K., Kulongoski, J.T., 2019, Groundwater quality of a public supply aquifer in proximity to oil development, Fruitvale oil field, Bakersfield, California, Applied Geochemistry, 106, 82-95, doi: https://doi.org/10.1016/j.apgeochem.2019.05.003.

Phase 2 Anticipated in 2020

26. Anders, R.A. and others, in preparation, Occurrence of brines and thermogenic gas in groundwater near the Orcutt Oil Field, California, Journal Article

27. Ball, LB., and others, in review, Probabilistic groundwater salinity mapping from airborne electromagnetic data adjacent to the Lost Hills and Belridge Oil Fields, Southwestern San Joaquin Valley. California, Journal Article

28. Ball, L.B., in press, Airborne electromagnetic and magnetic survey data, San Joaquin Valley near Lost Hills, California, October 2016: U.S. Geological Survey Data Release.

29. Ball L.B., and others, in press, Supporting groundwater salinity data used for salinity mapping adjacent to the Lost Hills and Belridge oil fields, Kern County, California: U.S. Geological Survey Data Release

30. Ball L.B., in preparation, Poso Creek airborne electromagnetic survey results: U.S. Geological Survey Open-File Report

31. Ball L.B., in preparation, Poso Creek airborne electromagnetic survey data: U.S. Geological Survey Data Release

32. Chang, W., and others, in preparation, A neural network for mapping groundwater salinity using deep borehole geophysical logs, Journal Article

33. Davis and others, in preparation, Geochemical processes controlling groundwater quality in a densely-developed area of petroleum exploration, Lost Hills and Belridge Oil Fields, Kern County, California, Journal Article

34. Everett, R.R. and others, in press, Multiple-well monitoring site adjacent to the Lost Hills Oil Field, Kern County, California: U.S. Geological Survey Open-File Report 2019-1114.

35. Everett, R.R. and others, in press, Aquifer test data for multiple-well monitoring site (LHSP), Kern County, California: U.S. Geological Survey Data Release.

36. Everett, R.R. and others, in review, Multiple-well monitoring site adjacent to the North and South Belridge Oil Fields, Kern County, California: U.S. Geological Survey Open-File Report

37. Everett, R.R. and others, in review, Aquifer test data for multiple-well monitoring site (LHSP), Kern County, California: U.S. Geological Survey Data Release.

38. Everett, R.R. and others, in preparation, Salinity mapping near the South Cuyama Oil Field: U.S. Geological Survey Scientific Investigations Report.

39. Gans, K.D., and others, in preparation, Historical produced water chemistry data compiled for the Kern River oil field, Kern County, California: U.S. Geological Survey Data Release

40. Gillespie, J.M., and others, in preparation, Groundwater salinity mapping near the Elk Hills oil field, Kern County, California. Journal Article

41. Gillespie, J.M., and others, in preparation, Data used in groundwater salinity mapping near the Elk Hills oil field, Kern County, California: U.S. Geological Survey Data Release

42. Karolyte, R., and others, in review, Noble gas constraints of the mechanisms of hydrocarbon occurrence in shallow aquifers in the San Joaquin Basin, USA, Journal Article

43. Lorah, M., and others, in preparation, Volatile organic compounds in produced water from four oil fields in California: Journal Article

44. McCarlson A., and others, in preparation, Water chemistry data for samples collected at groundwater sites near the Elk Hills and North Coles Levee Oil Fields, 2017-18, Kern County, California, U.S. Geological Survey Data Release

45. McCarlson A., and others, in review, Water chemistry data for samples collected at groundwater sites near the Orcutt Oil Field, 2017-18, Santa Barbara County, California, U.S. Geological Survey Data Release

46. McMahon, P.B., and others, in preparation, Vulnerability of groundwater associated with oil fields estimated from groundwater age tracers: Journal Article

47. Metzger, L.M., and others, in press, Inorganic chemistry data for groundwater wells near selected oil fields in the southwestern San Joaquin Valley, central California: U.S. Geological Survey Data Release.

48. Metzger, L.M., and others, in review, Historical produced water chemistry data compiled for the Orcutt and Oxnard oil fields, Santa Barbara and Ventura Counties, southern California: U.S. Geological Survey Data Release.

49. Metzger, L.M., and others, in review, Historical produced water chemistry data compiled for selected oil fields in Los Angeles and Orange Counties, southern California: U.S. Geological Survey Data Release.

50. Rodriguez, O., and others, in review, Water chemistry data for samples collected at groundwater sites near the Oxnard Oil Field, 2017, Ventura County, California, U.S. Geological Survey Data Release

51. Rosecrans, C., and others, in review, Groundwater quality of aquifers overlying the Oxnard Oil Field, Ventura County, California, Journal Article

52. Seitz, N.O., and others, in review, Produced water chemistry data collected from the Orcutt Oil Field, February 2018, Santa Barbara County, California: U.S. Geological Survey Data Release

53. Shimabukuro, D. and others, in preparation, Understanding potential fluid migration pathways related to injection in and around select Kern County (California) oil fields using fluid volume balance analysis, Journal Article

54. Shimabukuro, D. and others, in preparation, Idle well fluid level data used in fluid volume balance analysis in selected oil fields, Kern County, California: U.S. Geological Survey Data Release

55. Stanton, J.S., and others, in preparation, Groundwater quality in the vicinity of the Montebello oil field, Los Angeles County, California: U.S. Geological Survey Scientific Investigations Report

56. Stephens, M.J., and others, in preparation, Along-strike variability in fault seal shown from groundwater salinity modeling in the Poso Creek oil field, Kern County, California, Journal Article

57. Stephens, M.J., and others, in review, Mud logs from the Oxnard oil field, Ventura County, California: U.S. Geological Survey Data Release

58. Warden, J.F., and others, in preparation, Regional groundwater monitoring results near the Elk Hills and North Coles Levee Oil Fields, Journal Article