AUXILIARY REVIEW

In accordance with the California Public Resources Code (PRC), Section 3160 (d) (1), and California Code of Regulations, Title 14 (CCR), Section 1783 (a), oil and gas operators (operators) are required to obtain a permit before conducting any well stimulation treatment (WST) in the State of California. As part of the WST permitting process, operators are required to conduct a well stimulation treatment area analysis, described in regulation as an Axial Dimensional Stimulation Area (ADSA), (CCR § 1784).

Section 1784 of the California Code of Regulations requires operators to identify and review all wellbores located completely or partially within two times the proposed stimulated area (2x-ADSA) to ensure the geologic and hydrologic isolation of the oil and gas formation during and following well stimulation.

2x-ADSA Completeness Review

Prior to engineering review, the first step is to conduct a completeness check to ensure that all the required documents are submitted per the regulation. Below are the steps to verify that the operator has submitted sufficient data to proceed with the review.

1. Evaluate the casing design and cement details of the WST proposed well. Make sure the design complies with the regulation and field requirements (see casing diagram and cement evaluation plan).
2. Evaluate all the formations, zones, and sand markers penetrated by the well to make sure that perforations are located within the target zone (see casing diagram, and contour map and cross-section).
3. Evaluate the 2x-ADSA map provided by the operator against the CalGEM map for any discrepancy. Verify that all offset wells are included and determine whether they penetrate the 2x-ADSA.
4. Information regarding fracture geometry, azimuth, depth and other related parameters should be filled out completely for each stage in the proposed well stimulation. The proposed fracture geometry and the preferred fracture orientation/azimuth should be supported by a written narrative, separate from the application. Recently, CalGEM has implemented the model verification documentation process, where operators provide the methodology, reference data, and the calibration process of their fracture geometry determination in a written narrative. CalGEM uses the supplied information and through our contract with Lawrence Livermore National Lab (LLNL), reviews it for technical adequacy. Once an operator's model has been "approved", it will be reevaluated periodically following any change in field conditions.
5. A diagram showing the 2x-ADSA in either map view or cross-section view, or both. Examples are shown in Figures 1 and 2 (copied from different applications submitted by operators). All offset wells penetrated to the 2x-ADSA must be evaluated during the risk assessment process.

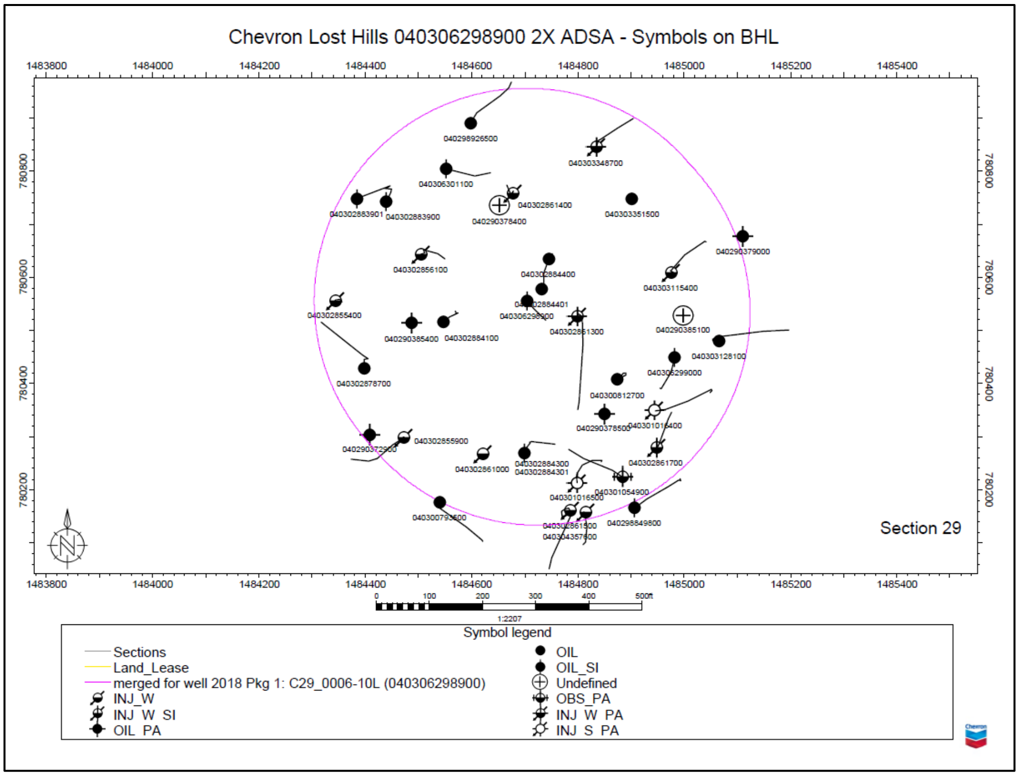

Figure 1. 2x-ADSA provided by an operator in map view

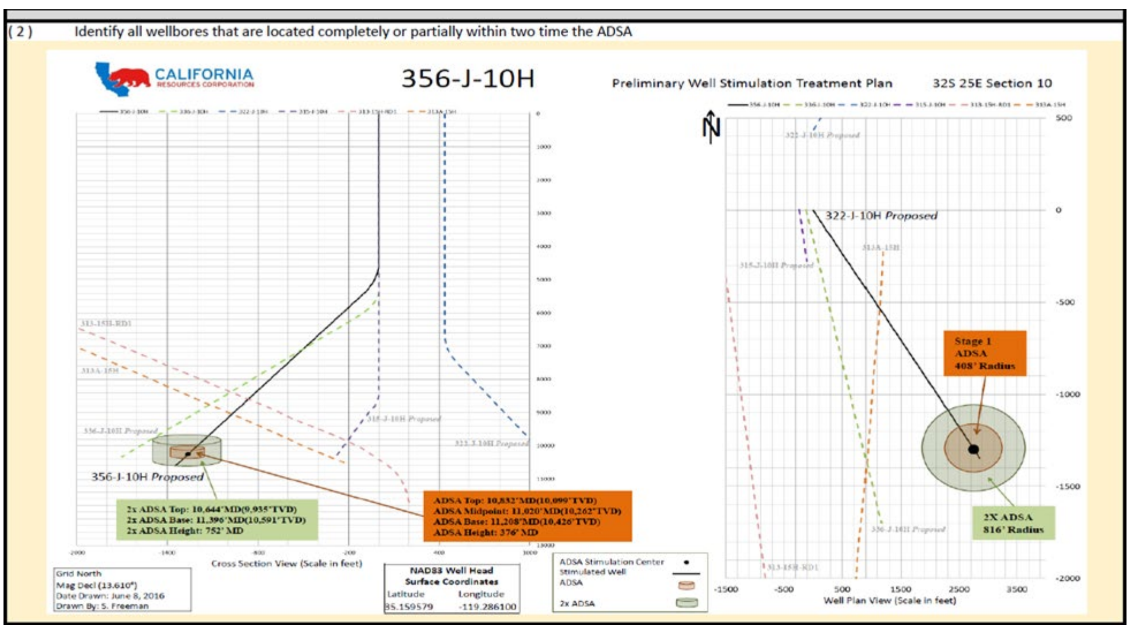

Figure 2. ADSA model showing 360-degree 2x-ADSA.

Review of 2x-ADSA

Once all required information is reviewed for completeness, the WST application undergoes an engineering review, outlined below. This review will analyze the various risk factors of all nearby wells within two times the proposed stimulated area (2x-ADSA).

Risk Assessment Spreadsheet

A CalGEM engineer will review all offset wells that penetrate the 2x-ADSA to ensure that the oil and gas zones are isolated according to statutes and regulations, and that there are no conduits to allow fluid migration out of the intended injection zone. Any wells identified as potentially providing a conduit out of the intended zone must be addressed. Please note that this includes active wells, idle wells, and any plugged and abandoned wells. Options to address any potential problem wells include having the operator conduct remediation to fix the problem, plug the well, modify the interval perforation, adjust the fluid volume so that the stimulation fluid will not reach the well with the potential issue, or reject the proposed well stimulation project if the problem cannot be resolved.

The engineer will use the "Risk Assessment Spreadsheet" to gather information and identify risk. The risk assessment spreadsheet includes two types of offset wells (Figure 8 a and b):

- Active wells (Non-Abandoned Wells), and
- Abandoned wells.

Each of these wells has different factors with assigned values (points) that define the risk potential for each case. The list of the factors for each type is:

<u>Active wells (Non-Abandoned Wells)</u>

- Well Type, (Idle, Injector, or Other active well)
- Previously Stimulated, (Stimulated or Non-Stimulated)
- Damage Type, (None, Parted casing or hole, Dogleg, or Other)
- Damage Location, (None, In and Out of Zone, In Zone, Out of Zone)
- ADSA Location, (A, B, and C), See Figure 8 and 9
- USDW Present, (Yes or No)
- Point Total, (this is sum of the points assigned to above factors)
- Comments, (Perf location and any damage or fish in the well is commented here)

<u>Abandoned wells</u>

- Abandonment Info (clean out depth), (Bottom Perforation, Into Top Perforation, Into Stimulated Formation, above (<20 ft) Stimulation Formation with >1x Cement Pumped, Above (>20 ft) Stimulation Formation with <1x Cement Pumped, or Above Overlying Formation)
- Damage Location, (None / at or Above clean out depth, Below clean out depth and in of zone, or Below clean out depth and out of zone)
- USDW Present, (Yes or No)
- Perforation Location, (Not in 2x-ADSA, A, B, or C)
- Location in ADSA, (A, B, and C), See Figure 8 and 9
- Point Total, (this is sum of the points assigned to above factors)
- Comments, (Perf location and any damage or fish in the well is commented here)

The well summary of offset wells and the application information are used to gather these data. Specific points (risk values) have been assigned to each of the subfactors which are used for risk evaluation. The sum of all points assigned to subfactors for every single offset well is shown in "Point Total" (sum of each row) which is used for applying further conditions and recommendations in a WST permit. A high value of "Point Total" means a higher risk possibility in the offset well during the WST job.

Non-Abandoned Wells

API	Well Number	Well Type	Previously Stimulated	Damage Type	Damage Location	ADSA Location	USDW Present	Point Total	Comments
03024999	7238-4	Other Active Wel	Stimulated	None	None	C	YES	2	
03038369	7213B-4	Idle Well	Stimulated	None	None	A	YES	6	Idle since 05/2015; no test records due; very close to proposed WST well; may need to be abandoned prior to WST
03046827	8214B-4	Idle Well	Stimulated	Parted Casing or Hole	In Zone	C	YES	11	WF; Idle since 04/2015; no test records due; 02/09/2015: RA survey indicates a possible csg hole on short string @1980'; diat @1954'
03046830	8239A-4	Injector Well	Stimulated	None	None	B	YES	4	
03059895	8214D-4	Injector Well	Stimulated	None	None	B	YES	4	

Note:

(yellow)	Selected monitoring well(s)
(green)	Poorly abandoned

Figure 3(a). Factors for risk assessment of Active wells (Non-Abandoned Wells)

Abandoned Wells

API	Well Number	Abandonment Info (c/o Depth)	Damage Location	USDW Present	Perforation Location	Location in ADSA	Points	Average	Comments
02984067	257-4	Above Overlying Formation	Above C/O Depth	YES	B	B	10	8	Dogleg @644'; junk: 2.375" tbg & pkr @840' - 1968'; perfs @1214' - 2864'; diat @1998'; ret @630'; cem 630' - 5'/w 485 cf
03018878	7213-4	Bottom Perforation	Above C/O Depth	YES	A	A	9	7.5	Dogleg @731'; junk: 36 jts of 2.875" tbg & (41) 0.75" rods at uknown depth; perfs @1210' - 2290'; diat @1980'; c/o @2470'
03018915	8239-4	Into Top Perforation	Above C/O Depth	YES	B	B	7	7	Csg damage@1946'; junk: 8 jts of 2.875" tbg & pkr @2244'; perfs @1300' - 2230'; diat @1957'; c/o @1988'
03018918	8214A-4	Bottom Perforation	Above C/O Depth	YES	B	Not in ADSA	5	7	Dogleg @1188'; csg hole @1240'; junk: 15 jt 2.375" tbg @1766'; perfs @1460' - 2240'; diat @1946'; c/o @2148'
03024465	7213A-4	Bottom Perforation	Above C/O Depth	YES	A	A	9	9	Dogleg @1966' & 2066'; perfs @1570' - 2150'; diat @1965'; c/o @2024'

Figure 3(b). Factors for risk assessment of Abandonment wells

The prepared spreadsheet (Figure 3 a and b) is used for risk assessment of wells inside 2x-ADSA.

Each offset well is evaluated and reviewed on a case-by-case basis using the Risk Assessment Spreadsheet. The Risk Assessment Spreadsheet acts as a guideline to assist the analysis performed by reviewing engineers, increase visibility of risks, and inform discretionary permitting decisions. A couple of possible examples/scenarios are explained below.

If an active offset well has been stimulated, the risk of fluid communication will be higher. In addition, a well located within 1x-ADSA (see Figure 4) at the direction of the fracture azimuth (Zone A), has higher risk than a well that located outside the 1x-ADSA and not in the direction of the azimuth (zone C). If the well has been idle for a long period of time, the risk is greater. For those wells in which the casing has holes/parted or dogleg that occurred in and out of zone of interest, the risk will be even greater. For non-abandoned (active or idle) offset wells that can be considered a high risk, CalGEM will require the operator to monitor well pressure during stimulation or remediate the well prior to stimulation.

In addition, if the non-abandoned offset well includes damage outside the zone (but close to top of the fractured zone), CalGEM will ask the operator to abandon it prior to the stimulation (if possible). If none of the above decisions resolve the issue, CalGEM will request the operator to shift the target stage of the stimulation or change the frac design in order to reduce the risk.

For an abandoned well, an analysis must be performed to determine if the well abandonment fulfilled CalGEM's requirements (CCR §1723.1). Factors to consider include the location of cement placement, clean out depth, perforation location, damage location (within the zone or outside the zone), and if USDW is present. For example, if clean out depth of an abandoned well is above the top of the zone and unable to squeeze any cement, with casing holes below clean-out depth that happened to be above the zone, it is considered a relatively high-risk well. As mentioned, depending on the location of the well, the risks associated with an individual well may be very different. For instance, if a poorly abandoned well is located at the zone C with a monitor well in-between, the possibility of conduit from the offset well to the proposed stimulation well is small.

Note: Any hazardous offset wells shall be abandoned or remediated prior to well stimulation. "*Hazardous well" means an oil and gas well determined by the supervisor to be a potential danger to life, health, or natural resources and for which there is no operator determined by the supervisor to be responsible for its plugging and abandonment under Section 3237 (Source: PUBLIC RESOURCES CODE - PRC).*"

For determining the risk of offset wells based on the fracture azimuth and distance from the WST perforations, the diagram in Figure 4 is used as a guide to evaluate the risk. The risk zones are in order of decreasing risk. If the fracture azimuth proposed in the application is 45°, a line is drawn according the proposed orientation. The high-risk zone is Zone A, which is a circle (from 0° to 360°) with one time radius of ADSA with the proposed stimulation well in the center. The next is Zone B, which is from 0° to 90° and 180° to 270° located within the 2x-ADSA radii of the proposed well, located symmetrically with respect to the fracture azimuth. Zone B is considered as a moderate-risk zone. And, any other zone outside zones A and B will be considered low-risk zones (*Zone C*). The zones are shown in Figure 4 below.

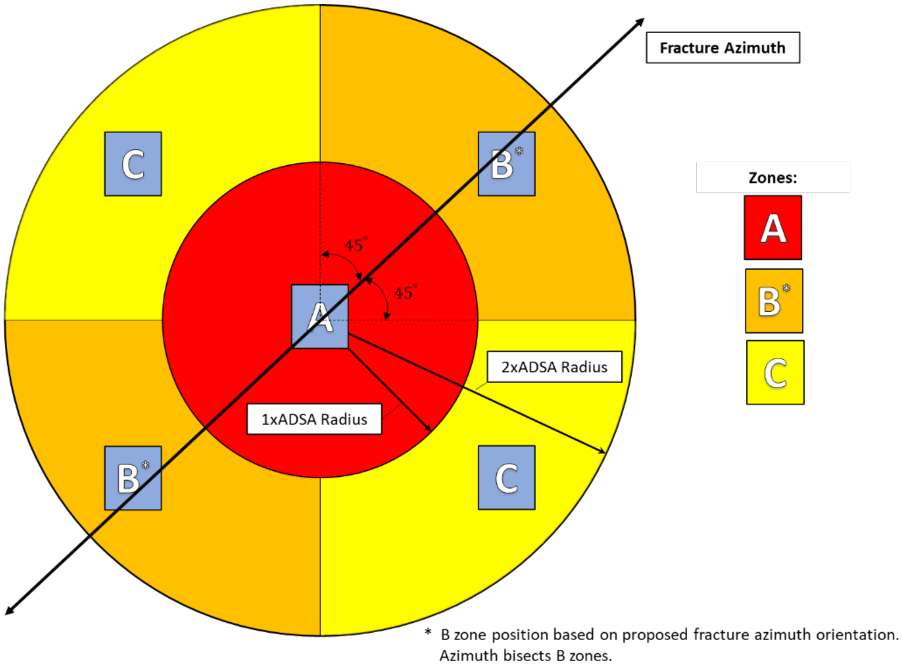

Figure 4. 2x-ADSA zones that are categorized based on fracture azimuth and distance from the WST stages.