4 ENVIRONMENTAL CONSEQUENCES

This PEA evaluates four alternatives, including a No Action alternative (see Chapter 2). The three action alternatives include the potential use of any of four WSTs at the production platforms currently operating in association with the 43 active leases on the POCS. The locations of the platforms, the active lease areas, and the potentially affected areas associated with the platforms and leases are shown in Figure 4-1. Chapter 3 of this PEA describes the nature and condition of resources that occur in the vicinity of the platforms and have the potential to be affected by WST activities on the POCS. Chapter 4 describes the environmental consequences that may occur with implementation of each of the four alternatives; a cumulative impacts analysis is provided at the end of the consequences discussion for each alternative.

The evaluation of environmental consequences presented in this PEA focuses on those resources and societal conditions most likely to be affected during WST operations under each of the action alternatives, and on potential impacts that may occur from the accidental release of WST chemicals and waste fluids or as a result of an accidental seafloor expression of hydrocarbons from a WST application.

4.1 HISTORIC USE OF WSTS IN OFFSHORE WATERS OF SOUTHERN CALIFORNIA

Each of the four WSTs included in the proposed action have been used in California and in Federal and State waters off of southern California (Long et al. 2015a,b). In onshore petroleum production in California, hydraulic fracturing often is used in low-permeability, high-porosity diatomite reservoirs of the Monterey Formation. In comparison, much of the offshore Monterey Formation has been diagenetically altered by burial to a higher density opal-CT[1] and/or quartz. As a consequence of this burial and diagenesis, the porosity of the offshore Monterrey Formation has been significantly lowered, and the resultant higher bulk density allows for greater fracturability of the formation when tectonic stresses are applied. As a result, the offshore reservoirs being produced on the POCS are much more permeable than are onshore reservoirs, and are already highly fractured and brecciated[2] (see Sections 3.2.2.2, 3.2.3.2, and 3.2.4.2). Therefore, little permeability enhancement has been required for their development, and the future use of WSTs is expected to be occasional rather than essential to hydrocarbon production from platforms on the POCS.[3]

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[1] Opal-CT is variety of opal that consists of packed microscopic spheres made up of microcrystalline blades of cristobalite and/or tridymite, with a water content as high as 10% by weight (also known as lussatite).

[2] To be "brecciated" is to be made into breccia, a rock composed of broken fragments of minerals or rock cemented together by a fine-grained matrix.

[3] Some operators have had some success increasing hydrocarbon production by performing frac-pacs (a type of hydraulic fracturing) in the sandstone reservoirs of the eastern Santa Barbara Channel.

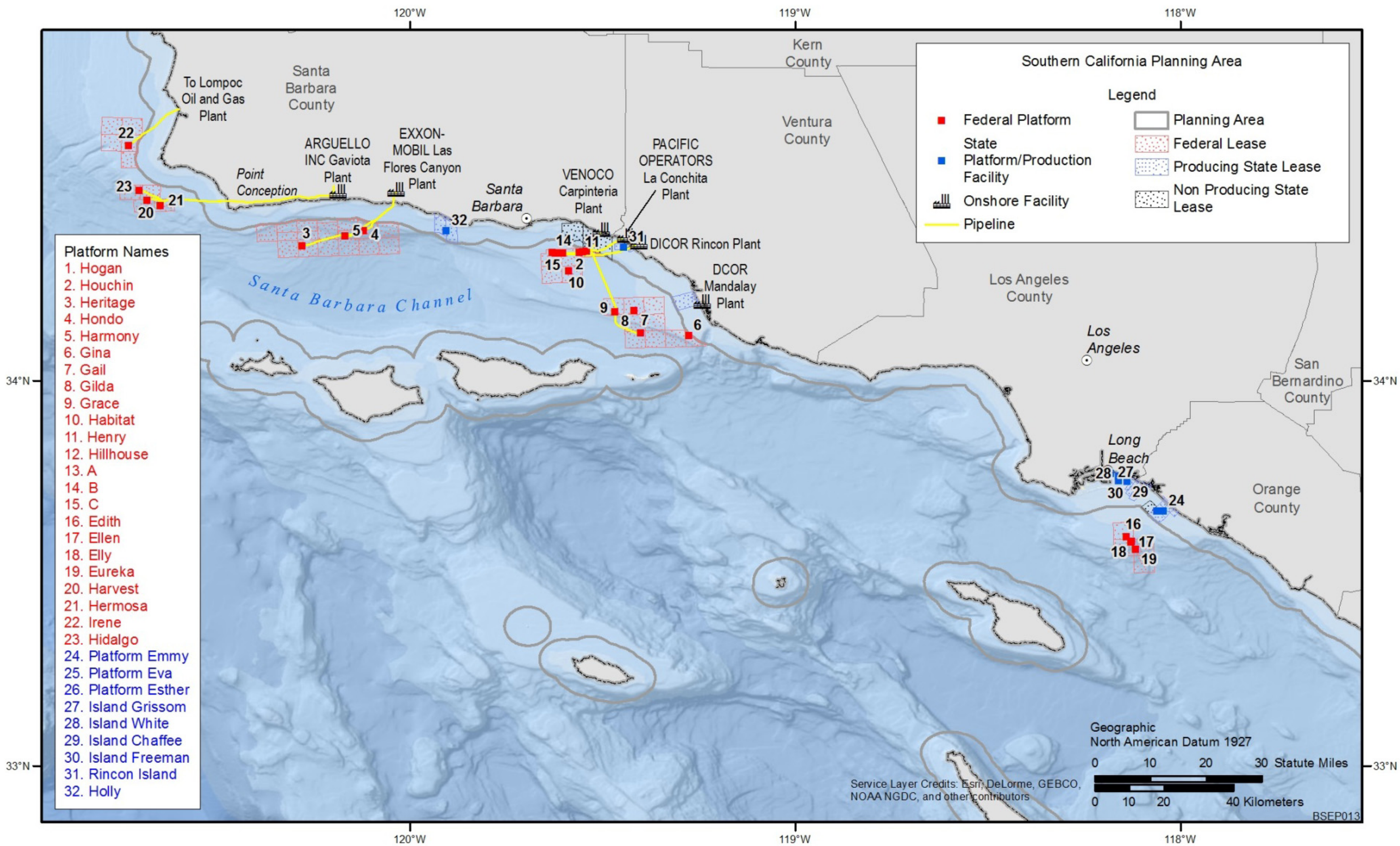

FIGURE 4-1 Locations of Current Lease Areas and Platforms Operating on the POCS (Also shown are platforms and production facilities in offshore State waters adjacent to the Federal OCS. Platforms and lease areas in Federal waters are shown in red, and those in State waters are shown in blue.)

Examination of the available data for offshore hydrocarbon operations of southern California supports this expectation (Houseworth and Stringfellow 2015). For example, more than 1,450 exploration and development wells have been drilled on the POCS. Among these, there have been only 21 hydraulically fractured completions between 1982 and 2014 (two of which were not completed), and these were conducted on only 4 of the 23 platforms in Federal waters on the OCS (Table 4-1) (BOEM 2015a; BSEE 2015a; Houseworth and Stringfellow 2015). Three of these were in the Santa Barbara Channel (Port Hueneme Unit), and the fourth was in the Santa Maria Basin (Port Arguello Unit).

An even smaller number of matrix acidizing treatments may have been conducted in OCS waters during a similar timeframe. The State of California, in its implementation of SB-4, distinguishes between the use of acid for routine well maintenance and for the matrix acidizing WST (which uses acid to increase reservoir permeability).[4] The use of acid for routine well maintenance is common at platforms on the POCS, while the use of matrix acidizing WSTs is very uncommon. The California Council on Science and Technology recently published an assessment of well stimulation in California, which identified 12 acidizing treatments (at eight different wells) on the POCS between 1985 and 2011 (see Table 2.5.3 in Houseworth and Stringfellow 2015). BSEE examined this list and was able to confirm the classification of only two of these treatments as meeting the SB-4 definition for matrix acidizing[5] plus one of undetermined classification because the volumes of acids used were not listed in the associated permit (Table 4.1). The rest would be currently classified as routine well maintenance treatments.

In comparison to past use of WSTs on the Federal OCS, there has been greater use of WSTs in State waters, although WST use is still small compared to the number of wells present in State waters. For example, there are 1,972 active or idled offshore wells in southern California State waters (DOGGR 2015; Houseworth and Stringfellow 2015). Between January 2002 and December 2013, there were 117 hydraulic fracture treatments in State waters, with most (106) conducted at production facilities on the THUMS[6] islands in San Pedro Bay off of Long Beach, California (Houseworth and Stringfellow 2015). Similarly, between June 2013 and April 2014, there were 135 acid treatments (which included both matrix acidizing [a WST] and well cleanout [as part of routine oil and gas operations]) reported from State waters in the Los Angeles Basin, with the majority of these (111) occurring on the THUMS Islands.

4.2 WST OPERATIONS AND IMPACTING FACTORS

The application of any of the WSTs included in the proposed action follows three basic steps: (1) the delivery of WST materials (i.e., WST fluids and chemicals) to a platform; (2) the

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[4] This PEA follows the definition of matrix acidizing as defined in SB-4, approved September 2013. Historic operations on the OCS employing acids have been interpreted as being either matrix acidizing WSTs or routine acid treatments (e.g., acid wash, Section 2.2.4.1).

[5] For this examination, BSEE used the California DOGGR Acid Volume Threshold calculation methodology to differentiate matrix acidizing treatments from wellbore maintenance operations that use acid (acid wash). The methodology is available from the California DOGGR at http://www.conservation.ca.gov/dog/for_operators.

[6] THUMS is the name used for five artificial islands in the vicinity of Huntington Beach and Long Beach, after the Texaco, Humble, Union, Mobil, and Shell oil companies that initially developed the islands.

TABLE 4-1 WST Applications on the POCS

Date	Platform/Well	Formation/Field	Operator
Hydraulic Fracturing			
1982	Grace/A-4	Monterey	Chevron U.S.A.
1983	Grace/A-21	Upper Repetto	Chevron U.S.A.
1984	Grace/A-3	Monterey	Chevron U.S.A.
1984	Grace/A-16	Monterey	Chevron U.S.A.
1986	Gilda/S-59	Monterey	Union Oil Co. of California
1994	Gilda/S-60	Upper Repetto	Union Oil Co. of California
1996	Gilda/S-89	Upper Repetto	Torch Operating Co.
1996	Gilda/S-62	Upper Repetto	Torch Operating Co.
1996	Gilda/S-89	Upper Repetto	Torch Operating Co.
1997	Gilda/S-87	Upper Repetto	Torch Operating Co.
1997	Hidalgo/C-1	Monterey	Chevron U.S.A.
1997	Hidalgo/C-11	Monterey	Chevron U.S.A.
1997	Gilda/S-62	Lower Repetto	Torch Operating Co.
1998	Gilda/S-28	Lower Repetto	Nuevo Energy
1998	Gilda/S-61	Lower Repetto	Nuevo Energy
2001	Gilda/S-65	Lower Repetto	Nuevo Energy
2001	Gilda/S-44	Lower Repetto	Nuevo Energy
2001	Gilda/S-62	Lower Repetto	Nuevo Energy
2010	Gail/E-8	Monterey	Venoco, Inc.
2014	Gilda/S-75	Upper Repetto	DCOR
2014	Gilda/S-33	Upper Repetto	DCOR
Matrix Acidizing			
1985	Gilda/S-44[a]	Santa Clara	Union Oil Co. of California
1988	Gilda/S-44[a]	Santa Clara	Union Oil Co. of California
1992	Gail/E-11[a]	Upper Sespe	Chevron U.S.A.

[a] Underwent matrix acidizing as defined under SB-4.

Sources: BSEE (2015a); Houseworth and Stringfellow (2015).

injection of WST fluids into the well undergoing treatment; and (3) the collection, handling, and disposal of WST-related waste fluids. It is important to note that implementation of any of the WSTs included in the proposed action would largely use existing infrastructure, would require no construction of new infrastructure (e.g., no new pipelines, no new platforms), and would not result in bottom-disturbing activities (e.g., trenching). Implementation would occur using existing infrastructure, with the possible exception of some minor equipment changes that would not entail any seafloor disturbance (e.g., replacement of existing platform injection pumps or fluid storage tanks with higher capacity equipment). New equipment may include blending units for mixing the injection fluid, additives, and proppant; and piping (the manifold) for connecting the injection pump and blender to a wellhead. Even with any such changes, no bottom disturbance would occur at the platforms. The following sections present the assumptions that were used regarding WST applications in this PEA for identifying and evaluating potential environmental consequences of the proposed action and alternatives.

4.2.1 Delivery of WST Materials

The primary materials that are used by the WSTs included in the proposed action are base fluids (such as acid solutions), proppant (such as sand), and any chemical additives (such as biocides and corrosion inhibitors). Platforms on the POCS are serviced by regularly scheduled platform service vessels (PSVs) that bring materials and supplies (such as diesel oil, food, paints, and cleaning supplies) and personnel to and from the platforms. For a WST, additional PSVs and/or trips would be needed to bring required WST-related materials to a platform. These additional trips (up to six for equipment delivery and four for WST materials delivery) represent a short-term, localized, and minor increase in PSV traffic over levels that currently occur in support of oil and gas production activities at the platforms. During delivery, all WST-related fluids and chemicals (e.g., acids, proppant, and biocides) would be transported in shipping containers designed and certified for marine and offshore transport. For example, bulk liquids would be transported in 350-gal or 500-gal stainless steel totes and non-liquid materials (e.g., proppant) would be transported in appropriate steel transport pods, all designed for marine transport and in compliance with U.S. Department of Transportation and International Maritime Dangerous Goods Code shipping requirements as identified on the Material Safety Data Sheets (MSDS) for each material being transported. In some cases, acids may be delivered in dedicated transport vessels within internal storage tanks. All transport of WST-related materials to the OCS platforms would also be done in full compliance with all appropriate U.S. Coast Guard and BSEE shipping and safety requirements.

4.2.2 WST Implementation and Operation

During a WST, chemical additives (e.g., biocides, surfactants) or proppant are mixed into a base injection fluid, filtered seawater. The seawater is sourced at each platform using seawater pumps that are present on each platform and that provide the platform with routine water needs, such as cooling water, firefighting water, and wash-down water. For each WST, the appropriate fluid is injected under the specific pressure, volume, and duration needed for the particular WST application (e.g., 4,200 gal [100 bbl] for a data-frac; 60,000 gal per stage for a hydraulic fracture treatment) as specified in the APD or APM. Pumping time will vary by the type of WST being conducted and the number of stages needed for completion. For a DFIT, pumping time may be less than 10 minutes, while the pumping time for a hydraulic fracturing treatment may be as much as 4 hr per stage.

4.2.3 WST Waste Handling and Disposal

Well stimulation treatment operations produce waste fluids containing WST-related chemicals recovered during production, and air emissions associated with the operation of WST-related equipment (e.g., injection pumps, blending units) and with the transport of WST materials and supplies to and from platforms (e.g., PSV traffic). Following completion of a WST, waste fluids containing WST-related chemicals may be collected and disposed of in a manner similar to that for produced water during routine (non-WST) oil and gas production. Hydrocarbon reservoirs generally contain naturally occurring water (the formation water) along with oil and natural gas. During hydrocarbon production (whether offshore or onshore and regardless of recovery method), water from within the formation is recovered comingled with the recovered hydrocarbons. Typically, the percentage of this comingled produced water increases as the reservoir hydrocarbons are depleted. On the POCS, hydrocarbon production is accompanied by a considerable amount of produced water. For example, annual produced water at Platform Gilda between 2009 and 2013 averaged about 54.6 million gal (1.3 million bbl) (BSEE 2015b). In 2014, approximately 5.3 billion gal (125 million bbl) of water were produced from 400 oil-producing wells on the POCS, together with about 776 million gal (18.5 million bbl) of oil, for a water-to-oil ratio of about 6.8:1 (BSEE 2015b).

On the POCS, the hydrocarbon/water emulsion ("wet oil") produced at a well is treated to separate the hydrocarbons from the produced water, either on a platform or at an onshore facility. Based on their locations and groupings, some of the OCS platforms are connected to one another by pipelines; others are also connected by pipelines to onshore facilities, and wet oil from several wells and platforms may be combined prior to processing. For example, the wet oil from Platforms Houchin and Hogan is combined at Platform Hogan and transported via pipeline to an onshore processing facility at La Conchita, where the produced water is separated and sent back to the platforms for disposal (Houseworth and Stringfellow 2015). With platform separation, the produced water is disposed of either by reinjection into the reservoir, or by discharge to the ocean under the NPDES General Permit CAG280000.[7] With onshore separation, the produced water is either disposed of by onshore injection to a reservoir, or piped back to the platforms for disposal by injection or NPDES-permitted discharge (Houseworth and Stringfellow 2015).

During the process of a WST, waste fluids (e.g., the flowback) would be comingled with the recovered wet oil. In general, the wet oil/WST waste fluid mixture undergoes oil/water separation and the WST waste fluids become part of the produced-water waste stream following separation. In some cases, the flowback may be collected separately and disposed of onshore. Table 4-2 details the transport of produced water to and from each platform on the POCS, as well as the nature of produced water disposal at each platform.

4.2.4 Impacting Factors Associated with WST Use

For each of the three steps involving WST material and fluid handling (material delivery; injection; and waste fluid collection, processing, and disposal), impacting factors were identified that have the potential to affect one or more natural, cultural, or socioeconomic resources in the area of the POCS. The WST-related impacting factors, the potentially affected resources, and the associated potential effects that were evaluated in this PEA are presented in Table 4-3.

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[7] As noted in Chapter 3, discharges from offshore oil and gas platforms on the southern California OCS are currently regulated under NPDES General Permit CAG280000, issued by EPA Region 9 effective March 1, 2014, and expiring on February 28, 2019 (EPA 2013a). The EPA uses general permits to streamline the permitting process for specified groups or types of facilities that are anticipated to discharge within the limits of the permit and for which EPA has determined thereby would not significantly affect marine environments.

TABLE 4-2 Hydrocarbon/Produced Water Separation and Produced Water Disposal on Platforms on the POCS

Platform	Produced Water Transport	Produced Water Disposal[a]
Tranquillon Ridge Field		
Irene	Sends wet oil[b] to onshore facility at Lompoc; receives treated produced water from the Lompoc facility.	Onshore and offshore injection.[c]
Pitas Point Field		
Habitat	No wet oil or produced water transport to or from the platform.	Permitted discharge under NPDES General Permit CAG280000.
Dos Cuadras Field		
Hillhouse	Receives wet oil from Platform Henry.	Permitted discharge under NPDES General Permit CAG280000.
A	Receives produced water from Platform B; sends produced water to onshore facility at Rincon. Receives treated produced water from Rincon onshore facility via Platform B.	Permitted discharge under NPDES General Permit CAG280000.
B	Sends produced water to Rincon via Platform A; receives treated produced water from Rincon onshore facility.	Permitted discharge under NPDES General Permit CAG280000.
C	Sends wet oil to Rincon via Platform B; receives treated produced water from Rincon via Platform B.	No direct discharge from Platform C; injects some produced water.
Carpinteria Offshore		
Hogan	Receives wet oil from Platform Houchin and sends wet oil to onshore processing facility at La Conchita; receives treated produced water from La Conchita and sends some produced water to Platform Houchin.	Permitted discharge under NPDES General Permit CAG280000; may be combined with treated produced water from onshore facility at La Conchita.
Houchin	Sends wet oil to Platform Hogan; no transport from platform; receives some produced water from Platform Hogan.	No direct discharge at Platform Houchin; injects some produced water.
Henry	Sends wet oil to Platform Hillhouse for separation and discharge of produced water; no transport of produced water to or from other platforms.	No direct discharge at Platform Henry.
Sockeye Field		
Gail	No transport of produced water to or from platform; receives wet oil from Platform Grace.	Injects all produced water.

TABLE 4-2 (Cont.)

Platform	Produced Water Transport	Produced Water Disposal[a]
Santa Clara Field		
Gilda	Sends wet oil to onshore facility at Mandalay; receives treated produced water from the Mandalay facility.	Permitted discharge at Platform Gilda under NPDES General Permit CAG280000 includes treated produced water from Platform Gina following onshore processing at the Mandalay facility.
Grace	No transport of produced water to or from platform; sends wet oil to Platform Gail.	No direct discharge at Platform Grace..
Hueneme Field		
Gina	Sends wet oil to Mandalay facility.	No direct discharge at Platform Gina; treated produced water disposed of at Platform Gilda (via Mandalay facility).
Point Arguello Field		
Hermosa	Receives wet oil from Platforms Hidalgo and Harvest; sends combined wet oil to onshore facility at Gaviota; some remains at the platform; no transport between platforms.	Some permitted discharge under NPDES General Permit CAG280000 at platform, some onshore injection at the Gaviota facility.
Hidalgo	Sends wet oil to Platform Hermosa; some produced water remains at the platform.	Some permitted discharge at Platform Hidalgo under General Permit CAG280000, some onshore injection at the Gaviota facility (via Platform Hermosa).
Harvest	Sends wet oil to Platform Hermosa; some remains at the platform.	Some permitted discharge at Platform Harvest under NPDES General Permit CAG280000; some onshore injection at the Gaviota facility (via Platform Hermosa).
Hondo Field		
Hondo	Sends wet oil to Platform Harmony.	No direct discharge at Platform Hondo; produced water discharged at Platform Harmony.
Harmony	Receives wet oil from Platforms Hondo and Heritage; sends combined wet oil to onshore facility at Las Flores Canyon; receives treated produced water from the Las Flores Canyon facility.	Permitted discharge of produced water under General Permit CAG280000 from Platforms Hondo and Heritage (via the Las Flores Canyon facility).
Pescado Field		
Heritage	Sends wet oil to Platform Harmony.	No direct discharge at Platform Heritage; produced water discharged at Platform Harmony.

TABLE 4-2 (Cont.)

Platform	Produced Water Transport	Produced Water Disposal[a]
Beta Field		
Eureka	Sends wet oil to Platform Elly for processing[d]; no produced water transport from platform; receives produced water from Platform Elly.	No direct discharge at Platform Eureka; injects all produced water (including water returned from Platform Elly).
Edith	No transport of produced water from platform.	Permitted discharge at Platform Edith of produced water under General Permit CAG280000; also some injection.
Ellen	Sends wet oil to Platform Elly for processing; receives produced water from Platform Elly.	No direct discharge at Platform Ellen; produced water injected
Elly	Receives wet oil for processing from Platforms Eureka and Ellen; sends produced water to Platforms Ellen and Eureka.	No routine discharge; all produced water returned to Platforms Ellen and Eureka for injection.

[a] Open water discharge is permitted from all platforms on the POCS under NPDES General Permit CAG280000, although not all platforms conduct open water discharge.

[b] "Wet oil" refers to the emulsion of crude oil and produced (formation) water produced at a well. This mixture is then processed to separate the oil and produced water.

[c] The term "injection" does not differentiate between disposal and use at any particular platform. For example, produced water may be injected solely for disposal purposes, or for formation pressure maintenance purposes.

[d] Platform Elly is a processing-only platform.

Source: BSEE and BOEM (2014).

4.3 WST-RELATED ACCIDENT SCENARIOS

There have been no reported releases of WST chemicals or fluids on the POCS (Houseworth and Stringfellow 2015), but accidental releases may occur during (1) the transport of WST chemicals and fluids to platforms; (2) WST fluid injection; and (3) the handling, transport, treatment, and disposal of WST-related waste fluids. Some accident scenarios may be applicable to each of the four WSTs included in the proposed action, while other scenarios are applicable to only some of the WSTs (i.e., only with fracturing WSTs).

The primary concern associated with a WST-related accident is the release of WST chemicals, fluids, and waste fluids (and in some accident scenarios, crude oil), and the potential effect of any such releases on exposed resources. The nature, duration, and magnitude of any resultant effects on exposed resources will depend on the location, nature, magnitude, and duration of the accidental release and the resources affected. Even in the unlikely event of a WST accident, the resource would have to be exposed to the WST-related chemicals at both a sufficient concentration and sufficient duration to result in an adverse effect.

TABLE 4-3 WST Activities, Associated Impacting Factors, and Potential Effects Included for Analysis in This PEA

WST Activity and Associated Impacting Factor	Potentially Affected Resource	Potential Effects Included for Analysis
Delivery of WST Supplies		
Transport of WST materials and supplies to the platforms	Air quality	Air emissions from WST-related PSV traffic and from onshore truck traffic delivering WST-related supplies to PSV port may reduce local air quality.
	Sea turtles and marine mammals	Injury or mortality from ship strikes with WST-related PSV traffic.
Implementation of WST		
WST fluid injection	Air quality	Air emissions from WST equipment at the platform may reduce local air quality.
	Geology/seismicity	Induced seismicity (earthquakes) with fracturing WSTs.
WST Waste Fluid Collection, Processing, and Disposal		
Injection of WST waste fluids	Geology/seismicity	Induced seismicity (earthquakes) with fracturing WSTs.
Permitted discharge of produced water containing WST waste fluids	Water quality	Localized reduction in water quality.
	Benthic resources, marine and coastal fish and EFH, sea turtles, marine and coastal birds, marine mammals	Localized exposure to potentially toxic levels of WST-related chemicals; loss of prey similarly exposed; reduced habitat quality in the vicinity of platforms discharging WST-related fluids.
	Areas of special concern, recreation and tourism	Localized decrease in water quality may affect natural resources and use of affected areas.
	Commercial and recreational fisheries	Localized reduction in abundance (catch) of fishery resources due to exposure to and effects of potentially toxic levels of WST-related chemicals.
	Environmental justice	Localized decrease in water quality could affect subsistence resources in, or reduce access to, recreational areas by low-income and minority populations.
	Socioeconomics	Localized decrease in water quality could reduce levels of commercial or recreational fishing, as well as other recreation and tourism activities.

Because WSTs on the OCS must be conducted in accordance with all BSEE, BOEM, and other regulatory agency rules and regulations dealing with safety and spill response, the potential for an accidental release to occur is low in all the accident scenarios considered in this PEA. All APDs and APMs related to WST use would be fully reviewed for safety concerns before any approval to proceed would be granted.[8] Each of the OCS platforms has systems in place to mitigate spills on the drill deck that may reach the ocean (Aspen Environmental Group 2015). In addition, required monitoring would act to maintain control over WST operations.

4.3.1 Accidents during Transport and Delivery of WST Chemicals and Fluids

An accidental release of WST chemicals could occur with any of the four WST types during the delivery of required materials and their subsequent offloading to a platform (Table 4-4). With a given application of a given WST type, required chemicals would be delivered to a platform via a PSV. They would be transported in sealed steel containers designed for marine transport and in compliance with U.S. Department of Transportation, International Maritime Dangerous Goods code,[9] U.S. Coast Guard, and BSEE packaging and shipping requirements. In some cases, acids may be delivered in dedicated transport vessels within internal storage tanks. Although the loss of individual shipping containers is not uncommon in maritime transport, such an incident on a PSV would not by itself result in the release of any WST chemicals. For a release to occur, the accident would have to include a loss of integrity of one or more shipping containers or internal storage containers. Because this would likely require a major collision with another surface vessel or a platform, such an event is not considered to be likely in the foreseeable future. Collision accidents involving commercial vessels, and especially PSVs, are very uncommon on the POCS. For example, the Ports of Los Angeles and Long Beach share common entry and exit shipping lanes. Together they experience over 5,000 vessel calls each year, yet have averaged 28 reported vessel incidents each year between 2011 and 2013 (Harbor Safety Committee 2014). Of these incidents (involving all ship types, e.g., container and bulk ships), the majority were associated with propulsion issues rather than with collisions. The U.S. Coast Guard lists only two maritime incident reports involving offshore supply vessel

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[8] When an APD or APM proposing WST operations is received in the BSEE POCS Regional Office, it is reviewed by BSEE California District Office Well Operations Section engineers to determine compliance. The required APM/APM District Production Engineering, BOP Control System Drawing, and Hydraulic Fracturing Engineering Data reviews are conducted and documented in the eWell data system. Concurrently, BSEE staff in the Regional Office of Production and Development (OPD) review the APD/APM for conservation of oil and gas resources as well as for potential geohazards. If the APD or APM is for a hydraulic fracture operation, OPD will also look at the proposed fracture in relation to active faults and the location of other wellbores, staying at least 1000 ft away from either. The OPD then documents the Geologic Review in eWell. Environmental Compliance personnel from the BSEE California District Office review the existing NEPA analysis, tiering from the relevant production plan and drilling permit, to determine whether it is adequate for the APD or APM, or whether additional NEPA analyses/findings are needed. Once completed, the review and resulting information is also documented in eWell. Upon completion of all of the above-mentioned reviews, and provided the information is compliant with all applicable standards and regulations, the District approves the permit in eWell.

[9] The International Maritime Dangerous Goods code provides international guidelines for the safe transport or shipment of dangerous goods.

TABLE 4-4 Potential Accident Events during Transport and Delivery of WST Chemicals and Fluids

WST Activity	Nature of Accident Event	Applicability	Anticipated Likelihood of Occurrence
Transport and delivery of WST chemicals to platforms	Release of relatively small quantities of WST chemicals from PSVs following loss of transport container integrity	Applicable to all four WST types	Anticipated likelihood: very low probability and not reasonably foreseeable. All WST chemicals would be transported on PSVs in approved shipping containers and transported in compliance with appropriate BSEE and U.S. Coast Guard shipping and safety regulations and requirements. Even with loss of a container overboard, because the transport containers would be sealed, release of chemicals would only occur with rupture of the shipping container.
	Release of relatively small quantities of WST chemicals during crane transfer from PSV to platform storage	Applicable to all four WST types	Anticipated likelihood: low probability but reasonably foreseeable. The transfer by crane of WST chemicals would be conducted in compliance with appropriate BSEE and U.S. Coast Guard safety regulations and requirements. For a release to occur, the accident would have to result in the rupture of the transport container.

collisions for the southern California coast between October 1, 2010, and October 1, 2015. One occurred in San Diego Harbor, where the supply vessel was backing out away from a pier and collided with a moored vessel, causing minor damage to its hull. The second collision occurred near Long Beach and resulted in minor damage to a lifeboat on the PSV (USCG 2015). Considering the very low number of incidents (about 30/yr) that occur at the Ports of Los Angeles and Long Beach (the latter of which is the second busiest port in the United States) compared to the total vessel traffic using these ports (in excess of 5,000/yr), a collision accident involving a WST-related PSV is not considered likely or reasonably foreseeable.

In contrast, there is a greater but still low likelihood of an accidental release of WST chemicals while a crane is offloading shipping containers from a PSV to a platform. Platform accidents involving cranes do occur during non-WST operations (i.e., routine oil and gas operations) on the platforms. For example, between 2005 and 2015 there were 127 crane incidents reported from platforms on the POCS (Kaiser 2015). A release of WST chemicals could occur if a shipping container is dropped during offloading, comes in contact with the platform or the PSV, ruptures, and releases its contents. Such an accident would likely involve no more than a few containers at any one time (based on the capacity of the crane and the number and size of transport containers being offloaded). This would limit the volume of materials accidentally released. For example, the U.S. Coast Guard reported the drop of a marine portable tank containing a 15% HCl solution onto the deck of a PSV at Platform Hondo on March 5, 2014 (USCG 2015). The tank was dropped when the crane failed—in this accident the tank was damaged—but there was no release of its contents. Depending on the location of the release, the rapid implementation of spill control measures on the platform and the PSV would further limit the amount of the release that would reach the ocean. This accident scenario is considered reasonably foreseeable.

Should there be an accidental release of WST chemicals during transport and delivery to a platform, a variety of resources could be affected (Table 4-5). The nature and magnitude of any effects on these resources will be dependent on the location, nature, size, and duration of the accidental release, on the materials released, and on the resources exposed.

4.3.2 Accidents during WST Fluid Injection

During WST fluid injection, the accidental release of WST-related chemicals could occur in a number of ways, although most are considered highly unlikely and not reasonably foreseeable (Table 4-6). For each of the four WSTs included in the proposed action, accidental releases of WST chemicals during implementation could occur as a result of equipment malfunction on the platform during fluid blending and injection. For the fracturing WSTs, which inject fluids at pressures exceeding the formation fracture pressure, accidental releases of WST chemicals may occur via a seafloor surface expression as a result of well casing failure during injection, or if a resultant fracture contacts an existing pathway (such as a fault or existing well) to the seafloor.

TABLE 4-5 Impacting Factors for Potential Accident Events during Transport and Delivery of WST Chemicals and Fluids

Accident Event—Impacting Factor	Resource	Potential Effect Evaluated
WST fluid release during delivery, offloading, platform storage	Air and water quality	Localized temporary reductions in air and water quality.
	Benthic resources, marine and coastal fish and EFH, sea turtles, marine and coastal birds, marine mammals	Localized lethal or sublethal effects with exposure to potentially toxic levels of WST-related chemicals; localized, temporary reduction in habitat quality.
	Commercial and recreational fisheries	Localized and temporary closure of fisheries due to health concerns. Reduction in abundance of fishing resources (i.e., fish/invertebrates) due to effects of exposure to toxic levels of WST-related chemicals.

TABLE 4-6 Potential Accident Events during WST Fluid Injection

WST Activity	Nature of Accident Event	Applicability	Anticipated Likelihood of Occurrence
WST-related platform operations (e.g., WST fluid injection)	Release of WST chemicals following malfunction of platform equipment (e.g., injection pumps, blenders). Applicable to all WSTs	Applicable to all four WST types	Anticipated likelihood: low probability and reasonably foreseeable. Relatively small, short-term releases may occur with malfunction of blending and injection equipment.
	Seafloor surface expression of WST fluids, produced water, and hydrocarbons during injection due to a well casing failure	Applicable only to fracturing WSTs	Anticipated likelihood: very low probability and not reasonably foreseeable. Real-time pressure monitoring during WST implementation would identify a decrease in pressure associated with a casing failure, and result in immediate cessation of WST fluid injection. Casing design requirements further reduce likelihood of such an event during WST use.
	Seafloor surface expression of WST fluids, produced water, and hydrocarbons following contact of new fracture with an existing pathway (e.g., fault or well) to the seafloor	Applicable only to fracturing WSTs	Anticipated likelihood: very low probability and not reasonably foreseeable. Real-time pressure monitoring during WST implementation would identify potential contact with an existing fault, fracture, or well and would result in immediate cessation of WST. Existing low reservoir pressures, together with pressure from overlying rock and seawater, would greatly limit the potential for, and the volume of, a surface expression should contact occur with an existing seafloor pathway.

Equipment malfunctions on platforms do occur. Malfunctions of blending units, injection pumps, manifolds, and other platform equipment could release small quantities of WST chemicals and result in a surface spill. Any such malfunctions would tend to be quickly detected and WST activities halted, and any releases would be quickly addressed through implementation of existing spill containment and cleanup measures. Thus, although such accidental releases may occur, they would likely result in the release of only small quantities of WST chemicals that may or may not reach the open ocean. This accident scenario is considered to have a low probability of occurrence but is still reasonably foreseeable.

During fracturing WSTs, fracturing fluids are injected at pressures that exceed the formation fracture pressure, and held at that pressure for a time. It is possible that for wells that undergo repeated fracturing WSTs, the well cement casing could fail after repeated pressurization and depressurization events. In such a scenario, the cement bond between the well casing and the formation fails after repeated application of fracturing pressures, thus providing a pathway for well fluids to pass along the outside of the well casing, migrate upward, and be released from the seafloor. All downhole wellbore operations must use pressure-tested lines and tubing, and casing that is rated (with a safety factor usually 70%) to handle the planned pressures of the operation and comply with BSEE regulations (see 30 CFR 250 subpart D, Oil and Gas Drilling Operations). In addition, injection pressures must always be within BSEE regulations (as all wellbore operations must be, not just those unique to fracturing operations). Finally, given the past limited WST use on the POCS (see Table 4-1), and the likely limited future application of fracturing WSTs, few if any wells may be expected to undergo sufficient repeated pressurization and depressurization events to affect well cement casing integrity. Such an accident scenario, while possible, is considered to have a very low probability of occurrence and is not reasonably foreseeable.

An accidental release of WST chemicals may also occur during a fracturing WST if a new fracture contacts an existing pathway (such as an existing fault or another well) to the seafloor. Such an occurrence could result in the accidental release of WST chemicals, hydrocarbons, and produced water via a seafloor surface expression, resulting in the possible exposure of a variety of resources to WST chemicals (Table 4-7). Such an accident is considered unlikely. The BSEE requires all APDs and APMs to include information on known fractures, faults, and wells in the vicinity of the proposed activity and would not approve any WST in which there is a potential for intersecting a known fault, fracture, or well. In addition, injection pressures would be continuously monitored during a fracturing operation on the POCS. A lack of pressure buildup prior to fracture initiation or a detectable pressure loss during fracture propagation would indicate that a fracture potentially has intercepted an existing pathway (e.g., fault, fracture, or well) to the seafloor[10]; injection of fracturing fluids would cease and formation pressure would be allowed to return to pre-fracturing levels. The return to pre-fracturing formation pressure, together with the pressure from the overlying rock and the overlying hydrostatic pressure, would preclude the movement of WST fluids, hydrocarbons, and formation water from the new fracture to the seafloor surface, greatly reducing the potential of a seafloor surface expression to the ocean. This accident scenario is considered to have a very low probability of occurrence and is not reasonably foreseeable.

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[10] In general, intersecting a naturally occurring fracture is not of concern, because such fractures are of short range and would not reach the seafloor. Intersecting previously induced fractures may be of concern if a pathway is created for fluid release through an improperly abandoned wellbore. Wells that have been properly abandoned and cemented will have reduced possibility of creating a pathway for fluid release to the seafloor surface.

1 **TABLE 4-7 Impacting Factors for Potential Accidents during WST Fluid Injection**

Accident Event—Impacting Factor	Resource	Potential Effect Evaluated
WST chemical release at a platform following WST equipment malfunction	Air and Water Quality	Localized temporary reductions in air and water quality.
	Benthic Resources, Marine and Coastal Fish and EFH, Sea Turtles, Marine and Coastal Birds, Marine Mammals	Localized effects with exposure to potentially toxic levels of WST-related chemicals; localized, temporary reduction in habitat quality.
	Commercial and Recreational Fisheries	Localized and temporary closure of fisheries due to health concerns. Reduction in abundance of fishing resources (i.e., fish/invertebrates) due to effects of exposure to toxic levels of WST-related chemicals.
Surface expression of WST fluids and hydrocarbons due to well cement failure from repeated fracturing jobs, or from induced fractures intercepting an existing fault or other pathway to the seafloor	Air and Water Quality	Localized (at the platform) reductions in air and water.
	Benthic Resources, Marine and Coastal Fish and EFH, Sea Turtles, Marine and Coastal Birds, Marine Mammals	Localized lethal or sublethal effects of exposure to potentially toxic levels of WST-related chemicals; localized and temporary reduction in habitat quality. Potentially longer-term effects due to hydrocarbon fraction of release.
	Commercial and Recreational Fisheries	Localized and temporary closure of fisheries due to human consumption concerns. Reduction in abundance of fishing resources (i.e., fish/invertebrates) due to effects following exposure to toxic levels of the released fluids. Potentially longer-term effects due to hydrocarbon fraction of release.
	Areas of Special Concern	If the release reaches an area of concern, localized and temporary effects on water quality and biota as above. Localized and temporary reduction in use.
	Environmental Justice	Reduce use of affected areas by low-income and minority populations.

TABLE 4-7 (Cont.)

Accident Event—Impacting Factor	Resource	Potential Effect Evaluated
	Archaeological Resources	Localized minor effects on cultural resources in affected region associated with oiling.
	Recreation and Tourism	Localized and temporary reductions in recreation and tourism.
	Socioeconomics	Local and temporary declines in commercial and recreational fisheries activities, recreation, and tourism from a crude oil release. Temporary cessation oil and gas production.

4.3.3 Accidents during Handling, Processing, and Disposal of WST Waste Fluids

Following WST fluid injection, WST-related waste fluids (e.g., the flowback fluids) are captured together with hydrocarbons and formation water as part of the production stream. They then pass through the normal processing systems that separate the crude oil, produced water, and natural gas. The WST waste fluids, which are largely seawater, are returned mixed with the produced water and handled as part of the produced water waste stream (Section 4.2.3). Although most of the chemicals present in the injection fluid remain in the formation or are consumed within the reservoir (e.g., acid solutions become neutralized), some may remain in the waste fluid and become incorporated into the produced water waste stream. An accidental release of some of these chemicals may occur if a leak occurs in a pipeline that is carrying produced water containing WST-related chemicals and this produced water is released to the ocean (Table 4-8). Should such a release occur, there is a potential for some resources to be exposed and affected (Table 4-9).

No aspects of WST use involve activities that could compromise pipeline integrity. Existing vessel traffic and anchorage restrictions along seafloor pipelines currently limit the potential for pipeline breaches due to surface vessels. In addition, pipelines undergo regular external and internal inspection per the BSEE POCS Region Pipeline Inspection and Monitoring Program (per 30 CFR 250, subpart J), which further limit the likelihood of a release from a produced water pipeline. Given the expected low frequency of WST use on the POCS in the foreseeable future, and the high volume of produced water routinely transported by the pipelines, it is highly unlikely that produced water containing WST-related chemicals would be present at the specific time and location where a pipeline leak actually occurs. Thus, although a pipeline release of produced water containing some WST-related chemicals is possible, such an accidental release has a very low probability of occurrence and is not reasonably foreseeable.

TABLE 4-8 Potential Accident Events during Handling, Processing, and Disposal of WST Waste Fluids

WST Activity	Nature of Accident Event	Applicability	Anticipated Likelihood of Occurrence
Handling, processing, and disposal of WST waste fluids.	Release of WST waste fluids following loss of pipeline integrity	Applicable to all WSTs	Anticipated likelihood: very low probability and not reasonably foreseeable. Release would require a pipeline breach at precisely the time when WST-related chemicals would be present in the produced water within the pipeline. No aspect of any WST use creates conditions for increased pipeline breach potential. Existing vessel traffic and anchorage restrictions along seafloor pipelines currently limit the likelihood of pipeline breaches from surface vessels. In addition, pipelines undergo regular external and internal inspection per the BSEE Pacific OSC Region Pipeline Inspection and Monitoring Program (per 30 CFR 250 subpart J).

TABLE 4-9 Potential Impacting Factors for Accidents during Handling, Processing, and Disposal of WST Waste Fluids

Accident Event—Impacting Factor	Resource	Potential Effect Evaluated
WST waste fluid release during collection, platform storage, and pipeline transfer between platforms and onshore facilities	Water Quality	Localized, temporary reduction in water quality.
	Benthic Resources, Marine and Coastal Fish and EFH, Sea Turtles, Marine and Coastal Birds, Marine Mammals	Localized exposure to potentially toxic levels of WST-related chemicals; localized, temporary reduction in habitat quality.
	Commercial and Recreational Fisheries	Localized and temporary closure of fisheries due to human consumption concerns. Localized reduction in abundance of fishing resources (i.e., fish/invertebrates) due to effects of exposure to potentially toxic levels of WST-related chemicals.
	Areas of Special Concern	If the release reaches an area of concern, localized and temporary effects to water quality and biota as above.
	Socioeconomics	Temporary cessation oil and gas production at platforms serviced by the leaking pipeline.

4.3.4 Effects of Response Actions

In the event of an accidental seafloor surface expression during a fracturing WST, the seafloor expression may include hydrocarbons, especially crude oil. In such an event, some resources may be secondarily affected by response actions implemented by the U.S. Coast Guard (which has jurisdictional authority for oil spill response actions) to address any hydrocarbon release (Table 4-10).

4.4 ASSESSMENT APPROACH

The environmental consequences discussed in subsequent sections of Chapter 4 address the potential impacts that could be incurred as a result of WST operations and accident events under each of the three alternatives that include WSTs. For each of these alternatives, the evaluation characterized the anticipated magnitude and duration of potential environmental effects associated with the impact-producing factors identified in Tables 4-3, 4-5, 4-7, and 4-9. The evaluations characterized potential effects with regard to how widespread any impacts might be (e.g., localized around platforms or affecting a much larger portion of the POCS), the

TABLE 4-10 Potential Secondary Effects during Response and Cleanup Activities (for accidental releases including oil)

Response/Cleanup Activity Impacting Factor	Resource Affected	Potential Effect Evaluated
Air emissions during cleanup operations	Air Quality	Temporary localized reduction in air quality due to emissions from cleanup vessels and equipment.
Increased noise associated with cleanup operations	Marine and Coastal Birds, Marine Mammals	Temporary, localized, disturbance and displacement of individuals.
Increased vessel traffic associated with cleanup operations	Sea Turtles, Marine Mammals	Temporary, localized increase in disturbance; increased potential for injury from ship strikes.
Access restrictions due to cleanup activities	Commercial and Recreational Fisheries, Areas of Special Concern, Recreation and Tourism, Environmental Justice	Localized and temporary cessation of use of fishery, recreation, and tourism areas during cleanup operations; localized and temporary cessation of areas used by low-income and minority populations.
	Socioeconomics	Local and temporary declines in commercial and recreational fisheries activities, recreation and tourism, and oil and gas production.

magnitude of any potential effect (e.g., small or large increase in air pollutants, individual biota or populations affected), and the duration of any potential effects (e.g., short term [days or weeks] or long term [months or longer]).

In contrast to Alternative 4 (No Action), Alternatives 1, 2, and 3 all include the use of the same four types of WST, and thus the nature and magnitude of any potential WST-related impacts will be relatively similar among these three alternatives, with the exception of WST-related fluid disposal under Alternative 3. The primary difference between Alternatives 1 and 2 is that Alternative 2 includes operational restrictions (minimum sub-seafloor depth requirement) that may reduce (in comparison to Alternatives 1 and 3) the likelihood of an accidental seafloor surface expression occurring. Except for the possible reduction in such a very unlikely and not reasonably foreseeable accidental release of WST chemicals (see Section 4.3), most potential impacts of WST use are similar between Alternatives 1 and 2.

In contrast, Alternative 3 differs from Alternatives 1 and 2 in that it prohibits open ocean discharge of produced water containing WST-related waste fluids, which is currently allowed at all platforms on the POCS under the NPDES General Permit CAG280000. Thus, any potential effects associated with the open water discharge of WST-related waste fluids (which could continue for Alternatives 1 and 2) would not be expected for Alternative 3. However, should the need for new injection wells be identified at some platforms for the disposal of produced water containing WST-related chemicals and fluids, Alternative 3 could include impacts (e.g., seafloor disturbance, noise impacts on marine fish and wildlife, reduction in water quality, increased air emissions) that would be associated with construction of new injection wells. Such potential impacts would not be expected under the other alternatives.

Alternative 4 differs the most from the other three alternatives, as it would completely prohibit the use of WSTs at any of the platforms on the POCS. Thus, any impacts identified from WST use identified for Alternatives 1–3, as well as any potential impacts associated with WST-related accidents, would not be expected under Alternative 4.

Incomplete or Unavailable Information. The Bureaus used the best available scientific information in the preparation of this PEA. In the following analyses of physical, environmental, and socioeconomic resources, there remains incomplete or unavailable information related to the activities contemplated in this programmatic analysis or gaps in science for particular resources or impacts, which every government agency faces in the preparation of a NEPA analysis. For the proposed action and alternatives, which are evaluated on a programmatic basis using reasonable estimates of the levels and types of activities forecast, there remains incomplete or unavailable information that may only be known when there is a specific request for WST use (e.g., the exact location of the proposed activity and amounts of chemicals used).

The subject-matter experts for each resource used what scientifically credible information was publicly available at the time this PEA was prepared. Existing and new information is included in the description of the affected environment and impact analyses throughout the PEA. Where necessary, the subject-matter experts extrapolated from existing or new information, using accepted methodologies, to make reasoned estimates and developed conclusions regarding the current baselines for resource categories and expected impacts from a proposed action. The subject-matter experts who prepared this PEA conducted a diligent search for pertinent information, and BOEM's evaluation of such impacts is based upon theoretical approaches or research methods generally accepted in the scientific community. All reasonably foreseeable impacts are considered, including impacts from accidents, even if the probability of such an accidental occurrence is low.

Although, even after this exhaustive search, the Bureaus acknowledge that there remain gaps in information relevant to the resources of the POCS and the analyses in this PEA, the subject-matter experts determined that none of the incomplete or unavailable information was essential to a reasoned choice among alternatives or in whether a FONSI could be reached. For example, the Bureaus acknowledge that the exact component chemicals of WST fluids are not definitively known at this programmatic stage and may not always be known at the time a request to conduct a WST is submitted. However, the existence of the NPDES permit program and the current WET limits that must be adhered to prior to discharge helps to ensure that the toxicity of those WST fluids (regardless of the myriad of components that could be used in combination) are adequately accounted for in the impacts analysis. In addition, the EPA regularly updates the NPDES permit, reflecting the most current information on potential chemical constituents of stimulation fluids, and taking into account the results of the monitoring that the permit requires, revising the permit as appropriate.

As new permits are submitted in the future, the Bureaus would have the option at that time to evaluate new information and information that remains incomplete or unavailable, and be in a better position to determine whether any supplementation of the PEA is appropriate, or whether an EIS is potentially warranted. For these reasons, the Bureaus have met their NEPA obligations in this PEA: to consider the best available science and information relevant to the proposed action, alternatives, and impacts analysis and to consider to what extent incomplete or unavailable information impacts that analysis, the ability to make a decision among the alternatives in light of this missing information, and whether a FONSI is appropriate in light of the available and incomplete information.

4.5 ENVIRONMENTAL CONSEQUENCES

4.5.1 Alternative 1 Proposed Action—Allow Use of WSTs

Under Alternative 1, BSEE will continue to review and approve on a case-by-case basis the use of fracturing and non-fracturing WSTs at the existing production platforms located on the 43 active leases on the POCS (Figure 4-1). Under this alternative, four WST types could be approved for use:

- Diagnostic fracture injection test;

- Hydraulic fracturing;

- Acid fracturing; and
- Matrix acidizing.

4.5.1.1 Geology/Seismicity

Induced seismicity is the primary impacting factor evaluated for the effects on geology of WSTs (Section 4.2.4), including hydraulic fracturing treatments and matrix acidizing stimulations. Between 1982 and 2014, hydraulic fracturing was used 21 times in offshore wells, with seven completions in the Monterey Formation, eight completions in the Upper Repetto sandstone formation, and six in the Lower Repetto sandstone formation (Table 4-1). The largest volume of fracturing fluid used in operations in the Monterey Formation was approximately 177,000 gal (4,200 bbl) (Gail Platform, Well E-8 in January 2010); the volumes of fracturing fluid injected into the Repetto sandstones were in the range of 10,000 to 60,000 gal (238 to 1,400 bbl) (Gilda Platform). These volumes are relatively low when compared to onshore fracturing fluid volumes completed in shale formations in California, which are reported to range from 1.75 to 10 million gal (42,000 to 238,000 bbl) per well per year between 2000 and 2010 (CCST 2015c). Matrix acidizing well stimulation treatments have been documented at the Point Arguello Field (Santa Maria Basin). Typical fluid volumes reported for these treatments were on the order of 15,000 gal (360 bbl) (Houseworth and Stringfellow 2015). By contrast, total produced water associated with offshore oil and gas activities in Federal waters off southern California in 2013 were on the order of 9 million gal (214,000 bbl) per well (based on BSEE 2014); depending on the platform, 50% or more of this volume may be disposed of by injection (Houseworth and Stringfellow 2015).

A typical large offshore hydraulic fracturing treatment would add only 4,200 bbl of injection fluid to an average well's annual injection volume of produced water of 214,000 bbl, or an increase of only 2% for a single well. When compared to the total annual produced water injection volume of 65 million bbl in 2015 on the POCS for routine operations, a large WST would add only 0.006% to total annual injection volume in the project area, an indiscernibly small increase. Given the historical very low frequency of fracturing WSTs on the POCS in the past (Section 4.1), and an expected similar level of use in the foreseeable future, total annual injection volumes from WSTs at any individual platform or for the POCS as a whole would be expected to remain a tiny fraction of that from routine operations.

Moreover, injection of well fluids on the POCS results only in maintaining formation volumes and promotes hydrocarbon flows in producing formations. Fluid injection back into the formation from which it was produced would not be expected to induce seismicity (Walsh and Zoback 2015). In onshore areas such as in Oklahoma, where induced seismicity has been observed in conjunction with increasing fracking-related injections (Petersen et al. 2016), injections tend to expand formation volume and pressure. In addition, geological conditions in California and on the POCS are quite different from areas where induced seismicity has been observed (Walsh and Zoback 2015), and by its nature the POCS is much less prone to the effects of fluid injection, as attested to by the lack of such observed activity attributable to fluid injection on the POCS or in adjacent onshore areas after decades of use. In a study of seismic activity in oilfields in the Los Angeles Basin, Hauksson et al. (2015) found no previously unidentified induced earthquakes, and concluded that the management of balanced production and injection of fluids appears to reduce the risk of induced-earthquake activity in the oil fields.

Because the volume of WST-generated fluids is very small relative to the volumes of produced water injected during normal oil and gas production operations (and small relative to onshore volumes of injected fluids overall), and because injected water only maintains formation volumes rather than expanding formation volumes or pressure, the induced seismicity hazard[11] related to the injection of WST fluids is expected to be low under Alternative 1. None of the accident scenarios identified in Section 4.2 would tend to be associated with induced seismicity.

Conclusions. Based on the expected very low frequency of WST use anticipated for the reasonably foreseeable future, together with the comparatively low volumes of WST fluids that could be used for any single WST application, the conduct of any of the three fracturing WSTs (DFIT, hydraulic fracturing, and acid fracturing) or of the non-fracturing WST (matrix acidizing) is not expected to result in any increase in seismicity of the POCS and adjacent coastal counties.

4.5.1.2 Air Quality

WST Operations. Potential impacts of WST use on ambient air quality and climate change under the Alternative 1 Proposed Action would be associated with air emissions from all direct and support activities related to implementing WSTs. Emission sources include engine exhaust from diesel injection pumps, venting or flaring of gases or vapors produced during WST use, engine exhausts from PSVs, and emissions from on-land facility operations and material transport.

Reactive organic gases (ROGs) along with NO_x, are precursors of ozone and secondary PM, which contribute to smog. ROGs, if present in WST fluids, would be controlled per APCD regulations, which require that WST flowback fluids not be sent to open-top tanks or systems vented to atmosphere. Thus, ROG emissions could be controlled through vapor controls on temporary tanks in which WST flowback fluids are stored; flaring of WST vapors would not be employed. Although no measured data on evaporative emissions of chemicals from liquids used during WSTs are available (CCST 2014), such emissions would likely be very small, even in the absence of vapor controls. By comparison, current ROG emissions from oil and gas production accounted for about 1% of the total ROG emissions for the four coastal counties adjacent to the

[11] One commenter to the draft PEA raised concerns regarding potential tsunamis as a result of WST activities. Because this concern appears to be related to concerns over induced seismicity, such risk is exceedingly low. There has never been a record of a tsunami believed to be caused by WST activities. Seismic activity, regardless of the cause, has only resulted in tsunamis a handful of times in the United States. Such an occurrence is considered extremely unlikely as a result of WST activities on the POCS and not reasonably foreseeable under any of the action alternatives.

project area (ARB 2015). Because evaporative emissions from WST liquids would represent a tiny portion of all regional ROG emissions of oil and gas production, they would not adversely impact ozone air quality (CCST 2014).

Emissions from diesel pumps used to perform WSTs, therefore, are the only emissions with the potential to impact air quality and the only emissions treated quantitatively in this analysis. Incremental air emissions from diesel pumps used in WST activities are compared with total regional emissions to assess the potential impacts of WSTs on ambient air quality and climate change.

Currently, some CA counties are in nonattainment for ozone and $PM_{2.5}$ NAAQS and for ozone, PM_{10}, and $PM_{2.5}$ CAAQS (see Table 3-2). As for any oil and gas operations on the OCS platforms, WST operations would emit criteria and toxic air pollutants and greenhouse gases (GHGs). Emissions from diesel engines include NO_x and a small amount of primary PM, ROGs, and CO. Fugitive emissions of ROGs in flowback fluid would be negligible, as noted above. Particulates from engine exhaust are typically less than 1 μm and thus are included with $PM_{2.5}$, which is regulated out of concern for deep lung penetration of small particles. With respect to GHGs, diesel engines contribute CO_2 exhaust emissions, and small fugitive emissions of methane (CH_4), which is a potent GHG.

Based on estimated fuel use[12] of 926 gal (22 bbl) of diesel for pumping during a 250,000-gal (6,000-bbl) WST and using an ARB emission factor for diesel equipment, estimated total emissions for a fracturing WSTs on the POCS would be about 185 lb (0.09 ton) for NO_x and 9.7 lb (0.005 ton) of PM. These emissions are up to about 0.014% of total emissions from offshore oil and gas production activities (Houseworth and Stringfellow 2015), and 0.00004% of total emissions from the four coastal southern California counties (see Table 3-3). Thus, estimated WST-related emissions are negligible compared with those for offshore oil and gas production activities and compared to all emissions in coastal counties.

Based on an emission factor of 22 lb of CO_2/gal of diesel for pumping (CCST 2014), CO_2 emissions from diesel equipment during a 250,000-gal WSTs would be about 9.3 MT, which is negligible compared to CO_2-equivalent GHG emissions from both offshore crude production activities (140,118 MT/yr; Detwiler 2013) and all activities in California (459 MMT/yr; see Section 3.3.2.4). Methane emissions from WSTs are uncertain, but likely far smaller than the direct CO_2 emissions from oil and gas extraction (CCST 2014). Per the ARB inventory, CH_4 emissions accounted for less than 10% of total GHG emissions, on a CO_2 equivalent basis, from all oil and gas production. Sources of ROGs and fugitive CH_4 emissions

[12] This fuel use would only occur on platforms that were not electrified via a cable from the shore. No air emissions would be generated from activities on platforms that were electrified via a cable. Published estimates for the Eagle Ford and Marcellus shales (typically about 21,000 gal of diesel fuel over a 2-day period to pump about 135,000 bbl of fracturing fluid [Rodriguez and Ouyang 2013]) located outside of California are employed as the best available data, to which fuel use for WSTs on the POCS waters is assumed to be linearly proportional (CCST 2014). Using the ARB emission factor for diesel equipment, emissions for NO_x and $PM_{2.5}$ were estimated to be about 4,200 and 220 lb, respectively, which falls within the Litovitz et al. (2013) range of estimates derived using similar methodology.

associated with WSTs would be controlled according to the APCD requirement for vapor controls on flowback fluids.

Air emissions would be controlled through best available control technology and good engineering practices. Historically, WSTs have occurred less than once per year on the POCS (Table 4-1), and have employed typical fracturing fluid volumes in the range of 10,000 to 60,000 gal (238 to 1,429 bbl), with a peak of 177,072 gal (4,215 bbl) at Platform Gail in January 2010; this is smaller than the fluid volume used for emission estimates. Therefore, potential impacts of WST activities on ambient air quality and climate change would be anticipated to be minor, even if several fracturing jobs would occur annually.

With respect to any WST-related toxic air emissions from the facilities in Federal waters, because platforms are more than 3.7 mi offshore of the corresponding coastlines, such emissions would have minor to negligible public health effects; studies indicate that public health risks from exposures to toxic air contaminants (such as benzene and aliphatic hydrocarbons) are greatest within 0.5 mi of active oil and gas development (Houseworth and Stringfellow 2015). Any such emissions would follow the prevailing wind direction in the project area, which is from the west or northwest (Section 3.3.1). WST activities would occur any time of the day, both during the daytime hours when meteorological conditions are favorable for air dispersion and during the nighttime hours when land breeze blows offshore to the ocean under weak synoptic flow.

Accordingly, potential impacts of the offshore WST activities on ambient air quality, mostly ozone and PM pollution, and from toxic air pollutants in coastal communities, would be negligible. In addition, potential effects of WST-related PM emissions on visibility and other AQRVs in the nearest Federal Class I areas (which are located some distance inland) would be negligible as well.

With respect to specific WST technologies, under Alternative 1 total fracturing fluid volumes are assumed to be about 4,200 gal (100 bbl) for diagnostic fracture injection test (DFIT) and typically 250,000 gal (5,952 bbl) for fracturing WSTs (hydraulic fracturing and acid fracturing) and non-fracturing WSTs (matrix acidizing). Emissions estimated here at the 250,000-gal level would scale linearly to larger or smaller injection volumes. Overall, given the small estimated emissions for criteria pollutants and GHGs, none of the WSTs anticipated under Alternative 1 are expected to result in any noticeable impacts on ambient air quality or climate change. This includes reasonably anticipated larger injection volumes, which would at most double the emissions evaluated here.

Downstream Consumption. The Bureaus acknowledge that the use of WSTs would increase the quantity of OCS petroleum and gas produced and consumed through enhanced recovery; therefore BOEM acknowledges that WSTs could have a small impact on GHG emissions from the consumption of OCS oil and gas recovered as the result of WST use. However, even with the use of WSTs for enhanced recovery, oil and gas produced on the OCS continues to decline. For example, the average daily production of oil from the POCS has steadily declined from a peak in 1995 of about 200,000 bbl per day to about 39,000 bbl per day in 2015. Historically, WSTs have been used infrequently on the OCS (approximately 21 times in the past). While this PEA conservatively estimates that the practice could increase in the future, the Bureaus still only expect a handful of WSTs to be proposed per year.

Given the infrequent use of future WSTs expected to be proposed on the California OCS (i.e., up to approximately five times per year), this incremental increase in production is expected to be small compared with production on all remaining POCS wells and reservoirs (i.e., 441 producing wells [as of 2015] at 22 production platforms) and the annual GHG emissions from petroleum in California as a whole (217.7 million metric tons of carbon dioxide in 2013) (EIA 2015). The number of WSTs expected and the number of active production platforms and wells on the OCS are exceedingly small compared to all other petroleum operations in California in State waters and onshore (with over 50,000 currently active wells and over 2000 authorized WSTs in California from December 2013 to June 2015[13]) (DOGGR 2015). In fact, historic use of WSTs on the OCS is only 1% of the WSTs authorized by the State in just an 18-month period. If the State's authorization of WSTs continues at the current pace (assuming approximately 1500 State approvals per year), the five annual WSTs projected on the California OCS per year would represent only one-third of 1% (0.33%) of the annual state authorized WST activities. Thus, all of the available information indicates that emissions related to future WST use on the OCS in California would be only a very small percentage of GHG emissions from petroleum production and consumption in California (including, but not limited to, those related to state authorized use of WSTs) and would not result in significant impacts to the current or projected levels of GHG emissions, either in the State or globally. Should WSTs not be approved on the OCS in the future, the OCS oil and gas production foregone as a result would not necessarily reduce GHG emissions from consumption, as demand may be met by substitute crude sources either from within California or outside of the State. Any increase in GHG emissions attributable to downstream consumption of OCS oil and gas resulting from the use of WSTs is expected to be very small, as described above, and it would be impossible to tease out the impacts related to the proposed action or alternatives from the global climate change impacts attributable to all other sources. BOEM nevertheless acknowledges that these emissions as well as direct emissions from the proposed action could contribute to those impacts globally; however, that contribution is expected to be *de minimis* compared to all other WST use in California (i.e., State-approved WSTs) and emissions in the State generally.

WST-Related Accident Scenarios. Accidents may occur during the transport of WST chemicals and fluids to platforms, during WST fluid injection, and during the handling, transport, treatment, and disposal of WST-related waste fluids (Section 4.3). Accident consequences of primary concern to air quality are related to releases of ROGs, which could contribute to smog. Accidents on platforms or service vessels that result in surface water spills of WST chemicals or flowback fluids would cause negligible air quality degradation as a result of evaporation of ROGs, because these are absent in, or at most very minor components of, WST

[13] From DOGGR Interim Well Stimulation Treatment Notice Index, available at http://www.conservation.ca.gov/dog/pages/IWST_disclaimer.aspx.

fluids. Therefore, surface water releases would cause a negligible decrease in air quality from evaporation of ROGs in WST fluids.

Although not reasonably foreseeable, an accidental seafloor surface expression could release crude hydrocarbons to the sea. A lack of pressure buildup prior to fracture initiation or a detectable pressure loss during fracture propagation would indicate that a fracture potentially has intercepted an existing pathway (e.g., fault, fracture, or well) to the seafloor (Section 4.3.2). In such an event, injection of fracturing fluids would cease and formation pressure would be allowed to return to pre-fracturing levels. The return to pre-fracturing formation pressure, together with the pressure from the overlying rock and the overlying hydrostatic pressure, would preclude the movement of WST fluids, hydrocarbons, and formation water from the new fracture to the seafloor surface, greatly reducing the potential of a seafloor surface expression. Potential impacts on ambient air quality and human health as a result of such releases would depend on the location (proximity to coastal populations), size, and duration of releases. Any ROG releases could potentially affect air quality over a few days to weeks, depending on the size and duration of the release. Any resulting degradation in air quality would be localized and temporary.

A DFIT operation employs such small fluid volumes (typically 4,200 gal [100 bbl]), and such short applications of fracturing pressures, that an accident resulting in a seafloor surface expression is not reasonably foreseeable. Non-fracturing WSTs (matrix acidizing) would also be unlikely to pose risks of surface expression accidents, while the potential impacts of a surface accident would be similar for all WST technologies.

Conclusions. Based on the expected very low frequency of WST use anticipated for the reasonably foreseeable future, together with the relatively short duration of any single WST application, the conduct of any of the three fracturing WSTs (DFIT, hydraulic fracturing, and acid fracturing) or of the non-fracturing WST (matrix acidizing) is not expected to result in any noticeable impacts on ambient air quality of the project area and adjacent coastal counties, or to noticeably contribute to climate change. Potential impacts of the offshore WST activities on ambient air quality, mostly ozone and PM pollution, would be negligible under any of the fracturing and non-fracturing WSTs. Potential effects of WST-related PM emissions on visibility and other AQRVs in the nearest Federal Class I areas (which are located some distance inland) would be negligible as well.

4.5.1.3 Water Quality

WST Operations. Water quality could be affected in the vicinity of platforms that discharge WST fluids recovered after use. Recovered WST fluids are typically combined with produced water, processed, and, at various platforms, discharged to the ocean or reinjected into producing formations. Recovered WST constituents, which range from less than 5% to up to 50–70% of the quantity of WST fluids injected in onshore applications in California (CCST 2015b), are combined with and diluted in produced water, which typically originates from multiple other wells that are not conducting WSTs, as described in Section 4.1. Produced water containing WST constituents is discharged under NPDES General Permit CAG280000, which applies concentration limits at the boundary of a 100-m mixing zone. Because permits limits are requirements, no effects on water quality from such discharges are expected beyond the 100-m mixing zone; any discernable effects would be confined to the mixing zone, where WST constituent concentrations would be higher. Because permit limits generally employ a margin of safety, somewhat higher concentrations that could occur within the 100-m mixing zone would not necessarily be harmful to the ecosystem, but data is not available to support a determination of a total absence of effects.

Table 4-11 presents the general types of hydraulic fracturing fluid constituents, their functions, and example chemicals that have been used in onshore applications in California. Water or brine typically makes up over 80% of hydraulic fracturing fluids by mass, with proppant—typically sand—present on the order of 15% of total mass. Other chemicals shown in Table 4-11 make up only on the order of 1% of the hydraulic fracturing fluid mass.

With respect to specific chemicals used, a review of chemical additives used in 1,406 onshore hydraulic fracturing treatments conducted in California between January 30, 2011, and May 19, 2014, found a median of 23 individual components—including base fluids, proppants, and chemical additives—used per treatment (CCST 2015b). A separate recent EPA review of disclosures to "Frac Focus"[14] found a median of 19 chemical additives used in California hydraulic fracturing treatments based on 585 disclosures for treatments performed January 1, 2011, and February 28, 2013 (EPA 2015). Median water use for hydraulic fracturing treatments during the same period in California counties ranged from roughly 15,000 gal (360 bbl) (Colusa County, three disclosures) to 350,000 gal (8,330 bbl) (Ventura County, 12 disclosures), with Kern County with 677 of 718 total disclosures in California reporting a median volume of 77,000 gal (1,833 bbl) per treatment (EPA 2015). Although these disclosures could include offshore treatments, the vast majority would be onshore.

Table 4-12 presents the 20 most commonly reported hydraulic fracturing components used in onshore treatments in California, excluding base fluids (water and brines) and inert minerals (proppants and carriers), based on records from 1,623 hydraulic fracturing treatments (CCST 2015b). Offshore treatments would presumably use the same or similar chemicals.

Table 4-13 presents hydraulic fracturing fluid composition from onshore treatments as reported to DOGGR[15] (Houseworth and Stringfellow 2015). All treatments were for diatomite

[14] The Frac Focus Chemical Disclosure Registry (referred to as "FracFocus") is a publicly accessible website (www.fracfocus.org) where oil and gas production well operators nationwide can disclose information about the ingredients used in hydraulic fracturing fluids at individual wells. Frac Focus was developed by the Ground Water Protection Council (GWPC) and the Interstate Oil and Gas Compact Commission (IOGCC) in response to public interest in the composition of hydraulic fracturing fluids (EPA 2015).

[15] California Department of Conservation, Department of Oil and Gas and Geothermal Resources (DOGGR). Within 60 days following the cessation of an onshore well stimulation treatment, DOGGR requires that specified information regarding the composition and disposition of well stimulation fluids, including, but not limited to, hydraulic fracturing fluids, acid well stimulation fluids, and flowback fluids, be entered into a Chemical Disclosure Registry that is accessible to the public. The Registry is available at http://www.conservation.ca.gov/dog/Pages/WellStimulationTreatmentDisclosure.aspx.

1 **TABLE 4-11 Chemical Composition of Additives in Fracturing Fluids**

Additive Type	Description of Purpose	Examples of Chemicals
Proppant	"Props" open fractures and allows gas/fluids to flow more freely to the wellbore.	Sand (sintered bauxite; zirconium oxide; ceramic beads)
Acid	Removes cement and drilling mud from casing perforations prior to fracturing fluid injection.	Hydrochloric acid (HCl, 3% to 28%) or muriatic acid
Breaker	Reduces the viscosity of the fluid in order to release proppant into fractures and enhance the recovery of the fracturing fluid.	Peroxydisulfates
Bactericide/biocide/ antibacterial agent	Inhibits growth of organisms that could produce gases (particularly hydrogen sulfide) that could contaminate methane gas. Also prevents the growth of bacteria that can reduce the ability of the fluid to carry proppant into fractures.	Gluteraldehyde; 2,2-dibromo-3-nitrilopropionamide
Buffer/pH adjusting agent	Adjusts and controls the pH of the fluid in order to maximize the effectiveness of other additives such as crosslinkers.	Sodium or potassium carbonate; acetic acid
Clay stabilizer/control/KCl	Prevents swelling and migration of formation clays that could block pore spaces, thereby reducing permeability.	Salts (e.g., tetramethyl ammonium chloride potassium chloride (KCl)
Corrosion inhibitor (including oxygen scavengers)	Reduces rust formation on steel tubing, well casings, tools, and tanks (used only in fracturing fluids that contain acid).	Methanol; ammonium bisulfate for oxygen scavengers
Crosslinker	Increases fluid viscosity using phosphate esters combined with metals. The metals are referred to as crosslinking agents. The increased fracturing fluid viscosity allows the fluid to carry more proppant into the fractures.	Potassium hydroxide; borate salts
Friction reducer	Allows fracture fluids to be injected at optimum rates and pressures by minimizing friction.	Sodium acrylate-acrylamide copolymer; polyacrylamide (PAM); petroleum distillates
Gelling agent	Increases fracturing fluid viscosity, allowing the fluid to carry more proppant into the fractures.	Guar gum; petroleum distillates
Iron control	Prevents the precipitation of metal oxides that could plug off the formation.	Citric acid
Scale inhibitor	Prevents the precipitation of carbonates and sulfates (calcium carbonate, calcium sulfate, barium sulfate) that could plug off the formation.	Ammonium chloride; ethylene glycol
Solvent	Additive that is soluble in oil, water, and acid-based treatment fluids; used to control the wettability of contact surfaces or to prevent or break emulsions.	Various aromatic hydrocarbons
Surfactant	Reduces fracturing fluid surface tension thereby aiding fluid recovery.	Methanol; isopropanol; ethoxylated alcohol

Source: CCST (2014).

TABLE 4-12 Most Commonly Reported Hydraulic Fracturing Components in California

Chemical	CASRN	Treatments Using This Chemical
Guar gum	9000-30-0	1,572
Ammonium persulfate	7727-54-0	1,373
Sodium hydroxide	1310-73-2	1,338
Ethylene glycol	107-21-1	1,227
2-Methyl-3(2H)-isothiazolone	2682-20-4	1,187
Magnesium chloride	7786-30-3	1,187
Magnesium nitrate	10377-60-3	1,187
5-Chloro-2-methyl-3(2H)-isothiazolone	26172-55-4	1,184
Isotridecanol, ethoxylated	9043-30-5	1,171
Hydrotreated light petroleum distillate	64742-47-8	1,167
Distillates, petroleum, hydrotreated light paraffinic	64742-55-8	1,129
2-Butoxypropan-1-ol	15821-83-7	1,119
Hemicellulase enzyme	9025-56-3	1,098
1,2-Ethanediaminium, N1,N2-bis[2-[bis(2-hydroxyethyl)methylammonio]ethyl]-N1,N2-bis(2-hydroxyethyl)-N1,N2-dimethyl-, chloride (1:4)	138879-94-4	1,076
1-Butoxypropan-2-ol	5131-66-8	973
Phosphonic acid	13598-36-2	790
Amino alkyl phosphonic acid	Proprietary	668
Boron sodium oxide	1330-43-4	666
Sodium tetraborate decahydrate	1303-96-4	520
Enzyme G	Proprietary	480

Source: CCST (2015b).

but two, which were for Pico/Repetto sandstone, a more likely type of lithology offshore than diatomite. The table shows constituents by mass percent for the fracturing fluid with the highest reported chemical load and notes those for which toxicity data was available (Houseworth and Stringfellow 2015). The gelling agents, (guar gum and petroleum distillates) represent the largest (non-proppant) chemical component by mass.

Acid fracturing or matrix acidizing treatments typically use on the order of 10–20% strong acids, frequently as 12% hydrochloric and 3% hydrofluoric acid, along with roughly 1% of other chemicals. Some of the additives used in matrix acidizing are the same as those used in hydraulic fracturing (CCST 2015a), presumably serving the same purpose in both treatments.

Acid fracturing, like hydraulic fracturing, uses gelling agents and cross linkers to thicken a water-based “pad” used to initiate fractures. Acids are then pumped in to etch and to create worm holes connecting fractures. The acid is normally gelled, cross linked, or emulsified to minimize fluid leakoff. Fluid loss control is a key function of many of the additives used in acid fracturing.

TABLE 4-13 Hydraulic Fracturing Fluid Composition[a]

Chemical Constituent	CAS	Maximum Percentage by Mass
Crystalline silica: quartz (SiO_2)	14808-60-7	29.08368%
Guar gum	9000-30-0	0.25305%
Paraffinic petroleum distillate	64742-55-8	0.12652%
Petroleum distillates	64742-47-8	0.12652%
Oxyalkylated amine quat	138879-94-4	0.04739%
Methanol[b]	67-56-1	0.03048%
Diatomaceous earth, calcined	91053-39-3	0.02959%
Sodium chloride[b]	7647-14-5	0.02564%
1-Butoxy-2-propanol	5131-66-8	0.02109%
Isotridecanol, ethoxylated	9043-30-5	0.02109%
Cocamidopropylamide oxide	68155-09-9	0.01588%
Cocamidopropyl betaine	61789-40-0	0.01588%
Boric acid (H_3BO_3)[b]	10043-35-3	0.01524%
Methyl borate	121-43-7	0.01524%
Ammonium persulfate[b]	7727-54-0	0.00667%
Nitrilotris (methylene phosphonic acid)	6419-19-8	0.00444%
Quaternary ammonium chloride	61789-71-7	0.00444%
Hemicellulase enzyme concentrate	9025-56-3	0.00379%
Potassium bicarbonate	298-14-6	0.00311%
Glycerol	56-81-5	0.00159%
Caprylamidopropyl betaine	73772-46-0	0.00159%
Acid phosphate ester	9046-01-9	0.00148%
Vinylidene chloride-methylacrylate polymer	25038-72-6	0.00062%
5-Chloro-2-methyl-4-isothiazolin-3-one[b]	26172-55-4	0.00049%
Magnesium nitrate	10377-60-3	0.00049%
2-Butoxy-1-propanol	15821-83-7	0.00042%
2-Methyl-4-isothiazolin-3-one	2682-20-4	0.00024%
Magnesium chloride[b]	7786-30-3	0.00024%
Phosphonic acid	13598-36-2	0.00015%
Ethylene glycol[b]	107-21-1	0.00015%
Crystalline silica: cristobalite	14464-46-1	0.00005%
Hydrated magnesium silicate	14807-96-6	0.00002%
Poly(tetrafluoroethylene)	9002-84-0	0.00001%

[a] Stimulation fluid for well API 411122247, Ventura Oil Field.

[b] Chemical with toxicity data.

Source: Houseworth and Stringfellow (2015).

Matrix acidizing is typically used to repair near-wellbore damage caused by sediment plugging by dissolving mineral particles that interfere with flow into the wellbore. Table 4-14 presents matrix acidizing fluid compositions as reported to DOGGR for onshore applications in California (Houseworth and Stringfellow 2015). The table presents three distinct fluids that are commonly used sequentially for acidizing: (1) an HCl acid preflush fluid; (2) a main acidizing fluid that was generated from mixing hydrochloric acid and ammonium bifluoride to produce an HCl/HF mud acid (some operations use mud acid, while some operations primarily use 15% HCl); and (3) an ammonium chloride overflush fluid. This table also indicates the constituents for which toxicity data is available (Houseworth and Stringfellow 2015).

Many of the chemicals listed in Tables 4-13 and 4-14 would be present at low concentrations in produced water discharges associated with WSTs. Because WST flowback fluids are mixed and diluted with much greater volumes of produced water, concentrations of WST fluids at platform discharge points would be low and would appear infrequently, while in some cases WST flowback fluids are captured separately and sent to shore for treatment and disposal. Effects on water quality would be of most concern near platform outfalls; no effects would be expected after dilution within the 100-m mixing zone.

Potential Marine Effects Mediated by Discharges to Water. Although a discussion of the toxicity of WST chemical constituents in produced water discharges to marine organisms may not be strictly an issue of water quality, such effects are touched on here as part of an overarching evaluation of the effects of such discharges on the marine environment mediated by water. More detailed discussions of marine toxicity are presented in the appropriate resource sections that follow.

Due, in part, to the lack of toxicity data for many constituents of WST fluids, potential effects on marine life within the mixing zone are not fully understood. Some recent studies have been conducted to address potential effects within the mixing zone of produced water discharges, which may or may not have included WST constituents. Little effect on water quality was found in the immediate vicinity of the platforms in a study of discharge plumes (Applied Ocean Science 2004). There were no differences in salinity, temperature, or turbidity between background locations and locations within 25–50 m of platforms. The study also reported no measurable impact to temperature, salinity, density, or turbidity of the receiving waters within the zone of initial dilution (i.e., within 100 m) (Section 3.4.2.1).

In other studies, Gale et al. (2012, 2013) compared exposures of Pacific sanddab (a flatfish), kelp rockfish, and kelp bass to petroleum hydrocarbons from seven platforms (six on the POCS and one in State waters) and from natural sites offshore Goleta, California, in the SCB. Platforms sites were found to be no more polluted than the nearby natural areas, exhibiting only low concentrations of PAHs, polychlorinated biphenyls (PCBs), DDTs, and other contaminants (Section 3.4.2.1). Likewise, Love et al. (2013) found that the concentrations of 21 elements in fish near platforms were not elevated compared to those in natural areas. These and other studies are summarized in a 2015 case study of the effects of offshore hydraulic fracturing and acid stimulation treatments in the California Monterrey formation (Houseworth and

TABLE 4-14 Matrix Acidizing Fluid Composition[a]

Stages	Chemical Constituent	CAS	Maximum Percentage by Mass
HCl preflush	Acetic acid[b]	64-19-7	0.9828%
	Citric acid[b]	77-92-9	0.8288%
	Hydrochloric acid[b]	7647-01-0	15.3241%
	Methanol[b]	67-56-1	0.0795%
	Diethylene glycol[b]	111-46-6	0.3136%
	Cinnamaldehyde	104-55-2	0.3136%
	Formic acid[b]	64-18-6	0.8317%
	Isopropanol[b]	67-63-0	0.1233%
	Dodecylbenzene sulfonic acid[b,c]	27176-87-0	0.4780%
	2-butoxyethanol[b]	111-76-2	1. 9997%
	Ethoxylated hexanol	68439-45-2	0.1514%
	Ethylene glycol[b]	107-21-1	0.0022%
	Poly(oxy-1,2-ethandiyl), a-(nonylphenyl)-w-hydroxy-b	9016-45-9	0.0088%
Main acid (HCl/HF)	Hydrochloric acid[b]	7647-01-0	14.7779%
	Ammonium bifluoride	1341-49-7	4.3887%
	Methanol[b]	67-56-1	0.0795%
	Diethylene glycol[b]	111-46-6	0.3136%
	Cinnamaldehyde	104-55-2	0.3136%
	Formic acid[b]	64-18-6	0.8317%
	Isopropanol[b]	67-63-0	0. 1215%
	Citric acid[b]	77-92-9	0.0395%
	Hydroxylamine hydrochloride	1304-22-2	0.0395%
	Silica, amorphous - fumed	7631-86-9	0.0003%
	Dodecylbenzene sulfonic acid[b,c]	27176-87-0	0.4707%
	2-butoxyethanol[b]	111-76-2	1.9687%
	Ethoxylated hexanol	68439-45-2	0.1491%
	Ethylene glycol[b]	107-21-1	0.0022%
	Poly(oxy-1,2-ethandiyl), a-(nonylphenyl)-w-hydroxy-b	9016-45-9	0.0087%
Overflush	Isopropanol	67-63-0	0.0854%
	Ammonium chloride[b,c]	12125-02-9	5.0009%
	2-butoxyethanol[b]	111-76-2	0.1685%
	Ethylene glycol[b]	107-21-1	0.0012%
	Poly(oxy-1,2-ethandiyl), a-(nonylphenyl)-w-hydroxy-[b]	9016-45-9	0.0047%

[a] Stimulation fluid for well API 403052539, Elk Hills Oil Field.

[b] Chemical with toxicity data.

[c] These chemicals exceeded the toxicity limits for some species.

Source: Houseworth and Stringfellow (2015).

Stringfellow 2015). Potential effects on marine life are discussed further in Sections 4.5.1.4 through 4.5.1.8.

Because (1) WSTs are infrequent activities, (2) WST fluids contain <1% chemical additives, and (3) recovered WST fluids are mixed and highly diluted with much greater volumes of produced water, it is unlikely that the presence of WST chemical constituents at expected levels after mixing with produced water would alter the conditions observed near platforms, as reported in these studies of produced water discharges.

Discharges under NPDES General Permit CAG280000. Discharges from all 23 platforms in the POCS are regulated under NPDES General Permit CAG280000, as discussed in Section 3.4.1. This permit includes WST fluids under discharge category for Discharge 003—Well Treatment, Completion and Workover Fluids (Part II.C), and explicitly covers well completion, well treatment operations, and well workover operations (EPA 2013a). Thus, discharges of recovered WST fluids must be in compliance with the NPDES General Permit.

The permit further stipulates that if well treatment, completion, or workover fluids are commingled with produced water, then the effluent limitations and monitoring requirements for well treatment, completion, and workover fluids do not apply; instead, the effluent limitations and monitoring requirements for produced water apply to the comingled fluids. The permit does not specify volume limits for Discharge 003, but does limit the volume of produced water (Discharge 002) discharged from platforms. Table 4-15 presents the effluent limitations and monitoring requirements for Discharge 002 and Discharge 003 under the permit.

In addition, permittees are required to maintain an inventory of the quantities and concentrations of the specific chemicals used to formulate well treatment, completion, and workover fluids. If there is a discharge of these fluids, permittees must report the chemical formulation, concentrations, and discharge volumes of the fluids, as well as the type of operation that generated the discharge in the associated quarterly Discharge Monitoring Report (DMR) submitted to the EPA, Region 9. This inventory would be available to the EPA in the event of well failure or another accident resulting in an unexpected discharge so the EPA may assess emergency response needs. This requirement was added to the permit conditions in part to address concerns regarding discharge of hydraulic fracturing fluids (EPA 2013b). The requirement also is similar to requirements for drilling muds and hydrotest water. The permit also provides that the permit may be reopened and modified if new information indicates that the discharges (including hydraulic fracturing chemicals) could cause unreasonable degradation of the marine environment (EPA 2013b). The most recent well stimulations conducted on the POCS to which the NPDES General Permit requirements were in effect were two hydraulic fracturing stimulations completed by DCOR on platform Gilda in late 2014 and early 2015.

To address the potential toxicity of unspecified WST constituents in discharges, the NPDES General Permit requires periodic toxicity testing of effluents using a whole effluent toxicity (WET) test. The EPA specifically noted in its response to comments on the draft permit that requiring the WET test for produced water will help address concerns regarding the toxicity of hydraulic fracturing chemicals (EPA 2013c). The WET test, conducted on 24-hr composite

TABLE 4-15 NPDES Effluent Limitations and Monitoring Requirements (Discharge 002—Produced Water and Discharge 003—Treatment, Completion and Workover Fluids)

Waste Type	Effluent Characteristic	Discharge Limitation	Measurement Frequency	Sample Type/Methods	Reported Values
Discharge 002—Produced Water					
Produced water	Flow rate (BWD)	N/A	Daily	Estimate	Monthly average
	Oil and grease	29 mg/L monthly average; 42 mg/L daily max.	Weekly Weekly	Grab/ Composite Grab/ Composite	The average of daily values for 30 consecutive days; the maximum for any one day.
	Whole Effluent Toxicity (WET)	N/A	Quarterly to annual	Grab/24-hr composite	Pass/fail
Discharge 003—Treatment, Completion and Workover (TCW) Fluids					
All TCW fluids	Number of jobs	N/A	Once/job[a]	Count	Type and total number of jobs
	Discharge volume (bbl)	N/A	Once/job	Estimate	Discharge volume per job
	Free oil	No discharge	Once/discharge	Grab/static sheen test	Number of times sheen observed
	Oil and grease	42 mg/L max. daily; 29 mg/L monthly average	Once/job	Grab	Max for any one day and the average of daily values for 30 consecutive days

[a] The type of job where discharge occurs (i.e., treatment, completion, workover, or any combination) shall be reported.

samples, uses three test organisms (red abalone, giant kelp, and topsmelt) to assess the toxicity of discharge waters (EPA 2013a).

In the preparation of the final permit, EPA Region 9 made changes to the monitoring frequency in the proposed permit based on input from stakeholders. For chemical constituents where reasonable potential was demonstrated for a given platform to discharge chemicals of potential concern, the monitoring frequency was increased from quarterly to monthly. For effluent toxicity, the initial monitoring frequency for the WET test was increased from annually to quarterly. After four consecutive quarters of “pass” results for a given test species, annual testing is required. Quarterly testing would resume after any “fail” result from the annual tests, until four consecutive “pass” results were again obtained (EPA 2013b,c).

The specified WET tests employ protocols from the EPA's manual, "Short-term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to West Coast Marine and Estuarine Organisms" (EPA 1995). This manual describes tests used to estimate the highest concentration of a chemical that produces no observed adverse effects, or a specified percent reduction in response, in a test organism from a chronic exposure; it also measures such responses as fish larval growth and survival rate. Using multiple test organisms increases the test's response to a wide variety of toxic chemicals with different modes of toxicity; the test organisms would be exposed to all constituents present in effluents at once and would respond to any synergistic toxicity among constituents.

Because discharge waters are sampled on a regular schedule, as specified in the General NPDES Permit, the timing of sampling for a WET test is not specifically coordinated with the conduct of WST activities. For example, depending on when a WST is conducted, WST fluid constituents may not be present in the sampled discharges when quarterly WET tests are performed. This lack of coordination has been identified as a concern for the protectiveness of the General Permit with respect to WST fluids (Houseworth and Stringfellow 2015).

This concern can be considered in light of the larger monitoring program supporting the EPA's implementation of the General Permit and the potential concentrations and toxicity of WST constituents in discharges. The EPA employs a multifaceted approach to protect marine resources from platform discharges, of which WST chemicals are one of several discharges of potential concern, which includes routine discharges of produced water and other platform effluents. In addition to periodic testing using the WET test, the permit requires oil and grease sampling, as well as visual monitoring of free oil in conjunction with each WST (Table 4-11). Such a testing strategy guards against chronic adverse conditions via the WET test, and relies on oil and grease tests and free oil observations as indicators of a loss of overall treatment system control.

With respect to WST fluid constituents in discharges, concentrations for all constituents can be estimated from quantities injected and levels of dilution in produced water, both of which are known quantities. Estimates would be upper limits, because some fraction, often a major fraction, of WST fluids are retained in the formation and not recovered. Potential toxicity can be assessed for individual constituents using toxicity values and estimated concentrations in discharges. For constituents of unknown toxicity, potential toxicity would be evaluated on the basis of reasonably representative toxicity values. This approach to toxicity assessment could reasonably be used in lieu of directly monitoring individual WSTs using the WET test, while periodic WET tests under the permit would serve as a further protective measure and would test all constituents in actual conditions and responds to potential toxic interactions. The following paragraphs further explore the approach described here.

Chemical constituents of fracturing fluids are typically present at a level of less than 1% of the injected fluid (Table 4-13). For a 60,000-gal (1,428-bbl) treatment stage, approximately 600 gal (14 bbl) of chemicals would be injected. In the formation, WST constituents may adsorb to formation surfaces and be recovered slowly, or not at all in flowback fluids, while a small portion will partition into and be recovered in the oil phase; most WST chemical additives are water soluble, and the bulk appears in the water phase of recovered fluids.

Hydraulic fracturing treatments typically return only about 5% of the injected fluids, while matrix acidizing may recover 50–70% of fluids (CCST 2015b). Recovered fluids are highly diluted in the combined produced water from the treated well and other wells. The timing of the appearance of WST constituents in produced water discharges would depend on the rate of release and recovery from the formation and the capacity and rate of treatment of the produced water treatment system. At a pumping rate of up to 20 bbl/min of injection fluid, the injection phase of well stimulation is typically completed in 4–8 hrs. Upon returning a well to production, the majority of any recovery of stimulation fluids occurs typically within 1 week. Recovered fluids mixed with produced water are typically treated within 30 hr of recovery from a well and discharged as treated produced water to the ocean after transfer back to a discharging platform within another 12 hr. WST constituents might thus be present in the combined treated produced water discharges for a week to 10 days or so after use, thus presenting a relatively small window of potential overlap when samples are taken for WET testing, which occurs at most quarterly.

Discharges would be diluted by roughly another three orders of magnitude within the NPDES 100-m mixing zone for compliance with the permit. Effluent testing for compliance with the NPDES General Permit would apply this additional dilution factor to the results of the effluent samples. Final constituent concentrations at the mixing zone boundary would be quite low (in the sub-ppm range).

Acids used in WSTs are largely spent and neutralized during use, as their purpose is to dissolve mineral materials in the formation. Flowback fluids from acid treatments typically have a pH of 2–3 or greater, approaching neutral pH. Such fluids can be further neutralized to pH > 4.5, if need be, prior to introduction to produced water treatment equipment (API 2014).

Potential Marine Ecotoxicity of Permitted Discharges. The 2015 CCST case study of the potential environmental effects of WST use in the California offshore Monterrey formation reviewed studies of the potential marine ecotoxicity of hydraulic fracturing and acid stimulation treatment constituents (Houseworth and Stringfellow 2015). The authors concluded that, although the effects of produced water have been shown to have some subtle sublethal impacts on reproductive behavior and possibly on the overall health of some species, contamination studies suggest that contaminant exposure levels, upon dilution at discharge points, have remained below levels that result in adverse impacts (Houseworth and Stringfellow 2015).

In a tabletop exercise, CCST performed a coarse toxicity screen of hydraulic fracturing fluid and matrix acidizing fluid for the respective compositions presented in Tables 4-13 and 4-14. The predicted average concentration of each chemical following dilution was compared to the lowest available acute or chronic LC50 or EC50 toxicity value[16] for 90 marine species in the following six species groups: algae, moss, fungi; crustaceans; fish; invertebrates; mollusks; and worms. The hydraulic fracturing case study included 33 chemicals, of which seven (21%) had toxicity data for marine organisms, and 26 (79%) did not. Of the seven chemicals with toxicity

[16] LC50 is the exposure concentration of a chemical that is lethal to 50% of test organisms. EC50, similarly, is the exposure concentration that results in a specific toxic response in 50% of test organisms.

data, none was predicted to occur at concentrations above acute or chronic toxicity levels. The matrix acidizing case study included 17 distinct chemicals, of which 12 (71%) had toxicity data in marine organisms, and five (29%) did not. Out of the 12 chemicals with toxicity data, two were predicted to occur at concentrations above acute or chronic toxicity levels: ammonium chloride and dodecylbenzenesulfonic acid (see Table 4-14). The study used a dilution factor of 746:1, the average of the mixing zone dilution factors for the platforms under the NPDES General Permit, to estimate concentrations at the mixing zone boundary. The study did not account for recovery of fluids after use or for any dilution in produced water. Thus, actual concentrations at the mixing zone boundary would be far lower than the values assumed in this exercise.

The biocide 5-chloro-2-methyl-3(2H)-isothiazolone (CMIT) was associated with some of the highest acute or chronic toxicity for marine species out of the chemicals screened for in this case study. However, under the conditions of the case study, CMIT would have predicted concentrations below toxic levels in surrounding waters. Note that biocides are routinely used during oil production not employing WSTs. The lack of toxicity data for 31 of the 48 distinct chemicals was identified as a problem with this evaluation approach, as was the lack of available data on chronic impacts of these chemicals in the marine environment. The authors identified these issues as critical data gaps in the analysis of potential impacts of offshore discharges of WST waste fluids to sensitive marine species (Houseworth and Stringfellow 2015).

A number of factors mitigate concerns related to unknown toxicity of WST fluid constituents. The ability of the WET test to respond to a wide variety of toxic chemicals and to mixtures of chemicals such as WST fluids, including possible toxic interactions, is discussed in some detail above. In addition, the known toxicity of a portion of the WST constituents would be expected to be fairly representative, or even conservatively representative, of the unknown portion, because toxicity studies tend to be performed on chemicals expected to be of concern (e.g., biocides), particularly chemicals used in volume. Finally, levels of WST constituents will be low in discharges—much lower than in the CCST tabletop exercise discussed above—due to the effects of retention in the formation and dilution with produced waters from multiple wells.

Well Treatment Fluids and Associated Produced Water Discharges in 2014–2015. Under the NPDES General Permit, permit holders are required to report monthly monitoring results on quarterly Discharge Monitoring Reports (DMRs). Data reported on DMRs include daily average volumes of produced water discharged at platforms, as well as the chemical formulation and concentrations of any well treatment, workover, or completion fluids used that may be ultimately become part of the produced water discharge along with the type of operation in which the fluids were used (e.g., well treatment, completion, or workover).

DMRs from 2014 and 2015 were obtained from EPA region 9 (EPA 2016) and are summarized below to provide some examples of the composition of actual well treatment fluids used on the POCS and to estimate concentrations of well treatment chemicals in produced water discharges. DMRs define well treatment fluid as “any fluid used to restore or improve productivity by chemically or physically altering hydrocarbon bearing strata after a well has been drilled.” No further information is provided as to whether the reported treatments meet the

SB-4 definitions used in this PEA to identify WSTs. Therefore, the DMRs reviewed are not limited to WSTs. The following analysis does not depend on such categorization, however; it depends only on the composition of the well treatment fluids used and the level of dilution in produced water prior to discharge.

Table 4-16 presents a summary of well treatments performed on platforms Harmony and Heritage in late 2014 and early 2015 in months for which values for produced water discharge rates are available on DMRs provided by EPA. For a given month and platform, the volumes of specific well treatment fluids for all treated wells is presented along with the daily average produced water volume for platform Harmony, which discharges all produced water from platforms Harmony, Heritage, and Hondo (EPA 2013a). The main treatment fluids used were 15% HCl and 12/3 HF 20% (mud acid). In addition, 2% ammonium chloride (NH_3Cl) was used in most of the treatments, presumably to prevent scale formation from precipitation following acid treatments. A small amount of diesel was also injected along with these main fluids in two wells on platform Harmony in April 2015.

Table 4-17 presents the composition of well treatment fluid constituents that are present at levels over 0.001% (10 ppm), as well as the estimated concentration of the constituents in produced water post-treatment after being mixed with produced water from all wells discharging at platform Harmony. Values reported would be concentrations in produced water at the point of discharge. Concentrations at the 100-m mixing zone boundary, the NPDES permit point of compliance, would be roughly 2,000 times lower, using dilution factors reported on the DMRs.

For the purpose of computing the level of dilution of well treatment fluids in produced water discharged from Harmony, a dilution factor of 130 was calculated by dividing an average daily produced water rate of 65,000 bbl/day for the 3 months reported in Table 4-16 by 500 bbl/day, a typical initial recovery rate following well treatments. No further reduction in concentration due to retention of treatment fluid constituents in the treated formation is assumed in this analysis.

Estimated concentrations of well treatment injection fluids in discharges of produced water are generally very low. Only 2-butoxyethanol and formic acid in 15% HCl injection fluid, and only 2-butoxyethanol, formic acid, and nitrilotriacetic acid in 12/3 HF 20%, mud acid, are estimated to be present in discharged produced water at concentrations exceeding 0.8 ppm. These constituents would not exceed 8 ppm and would be at similar levels to other constituents routinely present in produced water, for example, BTEX, which is present at around 0.1–1 ppm (Table 3-6).

For example, 2-butoxyethanol, a surfactant, has LC50 values of 1,500 ppm or greater in toxicity testing for fish, invertebrates and algae and is reported to be readily biodegradable (Sigma-Aldrich 2015a). Formic acid, a corrosion inhibitor, is somewhat more toxic, with an LC50 for fish of 46–100 ppm and EC50s for aquatic invertebrates and bacteria of 34 ppm and 46 ppm, respectively, and is readily biodegradable (Sigma-Aldrich 2015b). Last, nitrilotriacetic acid, an iron control agent, has an LC50 of 475 ppm in toxicity tests for fish and an EC50 value of >100 ppm for aquatic invertebrates and is readily biodegradable (Sigma-Aldrich 2015c). While only formic acid discharge concentrations potentially as high as 8 ppm approach toxic

TABLE 4-16 Well Treatment Injection Volumes and Associated Produced Water Volumes Reported on DMRs in 2014 and 2015[a]

				Treatment Fluid Injection Volumes by Well (bbl)				
Platform[b]	Date	Produced Water Rate (bbl/day)[c]	Treated Wells	Diesel[d]	15% HCl[e]	12/3 HF 20%[f]	2% NH_3Cl[g]	Totals
Harmony	Oct. 2014	65,996	HA-28	0	2274	3408	7934	13,616
			HA-26	0	28	0	341	369
			HA-20	0	372	0	1800	2172
			Totals	0	2674	3408	10,075	16,157
Heritage	Dec. 2014	72,252	HE-24	0	168	252	675	1095
			HE-29	0	297	192	812	1301
			HE-14	0	5	0	0	5
			Totals	0	470	444	1487	2401
Harmony	April 2015	56,751	HA-37	24	5174	3305	14,626	23,129
			HA-6	48	0	0	0	48
			Totals	72	5174	3305	14,626	23,177

[a] Discharge monitoring reports provided by EPA for well treatments on POCS in 2014 and 2015 (EPA 2016).

[b] Harmony discharges all treated produced water from platforms Harmony, Heritage, and Hondo (EPA 2013a); treatments of Heritage and Hondo wells are reported on Harmony DMRs.

[c] Daily average rate of produced water discharge at Harmony for the listed months during which well treatments were performed; discharge average for the 3 months listed is 65,000 bbl/day.

[d] Diesel would be recovered with oil after oil/water separation; diesel is minimally soluble in produced water.

[e] Includes <1% chemical additives, described in Table 4-17.

[f] Includes roughly 16% HCl plus 4% hydrofluoric acid and <1% chemical additives, described in Table 4-17.

[g] Contains no other chemical additives; NH3Cl would be recovered in produced water.

TABLE 4-17 Composition of Well Treatment Injection Fluids and Estimated Constituent[a] Concentrations in Produced Water Discharged from Platform Harmony from Recent Well Stimulation Treatments

CAS No.	Chemical Name	Injection Concentration (mass fraction and ppm[b])	Maximum Discharge Concentration[c]
15% HCl: Contains water, inhibitor aid, corrosion inhibitor, acid, iron control agent, mutual solvent, demulsifier			
–	Water	~85%	–
7647-01-0	Hydrochloric acid	~15%	–[d]
111-76-2	2-butoxyethanol	<0.1% (<1000 ppm)	<0.0008% (<8 ppm)
64-18-6	Formic acid	<0.1% (<1000 ppm)	<0.0008% (<8 ppm)
67-56-1	Methanol	<0.01% (<100 ppm)	<0.00008% (<0.8 ppm)
139-13-9	Nitrilotriacetic acid (NTA)	<0.01% (<100 ppm)	<0.00008% (<0.8 ppm)
61790-12-3	Fatty acids; tall oil	<0.01% (<100 ppm)	<0.00008% (<0.8 ppm)
68527-49-1	Thiourea, polymer with formaldehyde and 1-phenylethanone	<0.01% (<100 ppm)	<0.00008% (<0.8 ppm)
12/3 HF 20% (mud acid): Contains water, inhibitor aid, acid, iron control agent, mutual solvent, emulsion/sludge preventer, acid intensifier			
–	Water	~80%	–
7647-01-0	Hydrochloric acid	~16%	–[d]
1341-49-7	Ammonium hydrogendifluoride (HF)	~4%	–[d]
111-76-2	2-butoxyethanol	<0.1% (<1000 ppm)	<0.0008% (<8 ppm)
139-13-9	Nitrilotriacetic acid (NTA)	<0.1% (<1000 ppm)	<0.0008% (<8 ppm)
64-18-6	Formic acid	<0.1% (<1000 ppm)	<0.0008% (<8 ppm)
27176-87-0	Dodecylbenzene sulfonic acid	<0.01% (<100 ppm)	<0.00008% (<0.8 ppm)
67-56-1	Methanol	<0.01% (<100 ppm)	<0.00008% (<0.8 ppm)
127036-24-2	Poly(oxy-1,2-ethanediyl), alpha-undecyl-omega hydroxy-	<0.01% (<100 ppm)	<0.00008% (<0.8 ppm)
61790-12-3	Fatty acids; tall oil	<0.01% (<100 ppm)	<0.00008% (<0.8 ppm)
68527-49-1	Thiourea, polymer with formaldehyde and 1-phenylethanone	<0.01% (<100 ppm)	<0.00008% (<0.8 ppm)
67-63-0	Propan-2-ol (isopropanol)	<0.01% (<100 ppm)	<0.00008% (<0.8 ppm)
6381-77-7	Sodium erythorbate	<0.01% (<100 ppm)	<0.00008% (<0.8 ppm)

Footnotes on next page.

TABLE 4.17 (Cont.)

[a] Includes all additives present above 0.001% (10 ppm); other additives would be present in discharge at less than 0.001% (<0.08 ppm), a level assumed to be below potential concern.

[b] Parts per million on a mass basis (mg/kg).

[c] Maximum discharge concentration is computed by applying a dilution factor of 130 to the injection concentration; this dilution factor is based on a typical initial pumping rate of flowback fluids following well stimulation treatment of 500 bbl/day and an average daily produced water rate of 65,000 bbl/day discharged at Harmony (Table 4-16). These concentrations are considered maximum possible levels because values are reported as upper limits in the injection fluids and no loss of constituent concentration is assumed for retention in the formation; reduction in discharge concentrations is computed only on the basis of dilution in produced water from other wells discharging at Harmony.

[d] Strong acids (HCl and HF) are assumed to be spent and consumed by reaction with formation minerals (CCST 2014); in addition, any residual acidity would be diluted in produced water prior to discharge by a factor of 130, or by more than 2 pH units.

thresholds for aquatic organisms, such concentrations would be diluted well below levels of concern within a very short distance of the discharge point, reducing the possibility of toxic exposures, while discharge concentrations would be reduced by a factor of roughly 2,000 at the 100-m mixing zone boundary.

With respect to the major acid constituents of these treatment fluids, HCl and HF, it is assumed that these acids are entirely or nearly entirely consumed by reaction with formation minerals (CCST 2014). Any residual acid in flowback fluids would be similarly diluted by a factor of 130 when combined with produced water from all wells on Harmony, a factor that would raise residual pH by 2 additional pH units (1 pH unit for each factor of 10), and be completely neutralized by the highly buffering seawater.

These results may be compared with those for routine well treatment chemicals reported by Hudgins (1991) in a summary of chemical treatments in offshore oil and gas production that was considered in the development of the NPDES program. Hudgins estimated discharge concentrations for scale inhibitors, biocides, reverse breakers, surfactant cleaners, corrosion inhibitors, emulsion breakers, and paraffin inhibitors in the low ppm range, with LC50 values overlapping the high end of the range or exceeding discharge concentrations. Thus, recent well treatment discharges on the POCS from Harmony would be at most at the low end of the range of discharge concentrations of stimulation and workover chemical additives historically reported in the industry and considered in the development of the current NPDES permit program for offshore produced water discharges.

A 2014 CCST study of onshore WSTs in California found that well treatment flowback fluid is a combination of injected fluids and produced water from the formation, the exact proportions of which vary and are uncertain, but that increase in produced water fraction as pumping goes on after a treatment is completed. Well treatments are expected to have little effect on the eventual produced water composition from treated wells. The study reported that initial flowback may be enriched in trace metals, organics, and radionuclides mobilized from formation rock by the action of WST chemicals, including acids, while concluding that more studies are needed in California to assess whether produced waters from wells undergoing stimulation are different from those from routine operation and to determine the overall recovery of flowback fluids (CCST 2014).

While acids and other chemical additives can mobilize trace metals, organics, and radionuclides within formations and enrich their levels in flowback fluids, most of the available information on the levels of such natural contaminants in flowback fluids has been obtained from the Marcellus and Bakken formations in other regions of the United States. Although the Monterey formation is relatively high in trace metals and radionuclides compared to world average shales, the 2014 CCST review found no data available on trace metals and radionuclides in WST flowback fluids in California and identified this as a major data gap in evaluating the potential environmental effects of onshore WSTs in California. Similarly, a 2010 review of oil and gas operations on the POCS by Kaplan et al. (2010) concluded that studies of the levels of radium isotopes in produced waters offshore was warranted.

However, trace metal levels in produced water from routine operations on the POCS are available and shown in Table 3-6, with concentrations in the low microgram per liter (parts per billion) range. Even a large temporary increase in such concentrations following a WST, of say 10–100 fold, would produce concentrations approaching only 1 ppm, exposures that would not be likely to adversely affect marine life.

Similarly, Monterey shales are enriched in natural radionuclides as compared to world average shales. Although uranium concentrations in California crude are not typically high (CCST 2014), data on radionuclide concentrations in California produced waters and WST flowback fluids, either onshore or offshore, is lacking. Temporarily elevated levels of radionuclides, mainly isotopes of radium due to its higher water solubility compared to uranium and thorium, may be expected in flowback fluids following offshore WSTs, but would not be expected to result in serious adverse effects on marine life. Elevated levels would be short-lived following a WST and would be diluted in produced water from other wells and further diluted in the mixing zone, while health effects of low-level exposure to radionuclides of concern in humans, mainly cancer risk, would not be relevant to aquatic organisms. Hazards to workers and the public from radium trapped in scales formed in pipes and oilfield equipment in general are expected to be low, with little radioactivity found in surveys of the external surfaces of equipment (CCST 2014).

Considering all of the above—including the low expected concentrations of WST chemicals and expected lack of effects on marine life from potentially temporary increases in trace metals, organics, and radionuclides in flowback waters, and the additional dilution afforded by the 100 mixing zone—this analysis affirms the protectiveness of the NPDES General Permit and required monitoring to aquatic life from the effects of WSTs as they are considered in this PEA.

Potential Effects of Specific WSTs. Table 4-18 summarizes the potential environmental effects on water quality of ocean discharges of the various WSTs analyzed in this PEA. Due to the overall small volume of fracturing fluids used and the short duration of the operation, conducting a DFIT is not expected to have any effects on water quality under normal circumstances.

Typical hydraulic fracturing treatments would employ on the order of 250,000 gal (5,952 bbl) of fracturing fluid, implemented in, for example, four 60,000-gal (1,428-bbl) stages. Such treatments typically recover only on the order of 5% or less of the initial injection fluid volume in the flowback fluid (CCST 2015b); the remainder is retained in the formation. Recovered hydraulic fracturing fluids are contained in produced water, which is treated and discharged under NPDES General Permit CAG280000, or reinjected into the formation, which may be of beneficial use in maintaining formation pressure. As discussed in the foregoing sections, discharges of produced waters containing hydraulic fracturing fluids would be expected to have no discernible effects on water quality due to the very low concentrations of WST constituents that would be present in the discharged water, and the further dilution that would occur in the permit mixing zone following discharge. Monitoring conducted under the permit, including use of the WET test, would provide a further measure of protectiveness.

TABLE 4-18 Potential Effects on Water Quality of WST-Related Platform Discharges

WST	WST Fluids and Discharges	Potential Effects
Diagnostic fracture injection test (DFIT)	Injected WST fluid volume <4,200 gal (100 bbl). Composition: hydraulic fracturing fluid with roughly 1% (42 gal [1 bbl]) chemical constituents. Discharge: very low concentration of hydraulic fracturing fluid constituents.	No discernible effects expected, even close to the discharge point, due to low concentrations of WST constituents in discharge.
Hydraulic fracturing	Injected WST fluid volume typically 250,000 gal (5,952 bbl). WST composition: hydraulic fracturing fluid with roughly 1% chemical constituents. Recovery of WST fluids <5% (CCST 2015b). Discharge: low concentration of injected fluid constituents comingled with produced water, within NPDES limits.	No discernible effects on water quality indicators; potential subtle effects on some marine organisms within the mixing zone, but not possible to differentiate from effects of normal constituents of produced water.
Acid fracturing	Injected WST fluid volume: assume 250,000 gal (5,952 bbl). Chemical content: 15% HCl, 5% HF, and 1% other chemicals. Recovery of WST fluids assumed intermediate between hydraulic fracturing and matrix acidizing. Discharge: low concentration of injection fluid constituents and neutralized acids comingled with produced water, within NPDES limits.	No discernible effects on water quality indicators; potential subtle effects on some marine organisms within the mixing zone, but not possible to differentiate from effects of normal constituents of produced water.
Matrix acidizing	Injected WST fluid volume: assume less than 250,000 gal (5,952 bbl). Chemical content: 15% HCl, 5% HF, and 1% other chemicals. Recovery of WST fluids: 50–70%. Discharge: low concentration of injection fluid constituents and neutralized acids comingled with produced water, within NPDES limits.	No discernible effects on water quality indicators; potential subtle effects on some marine organisms within the mixing zone, but not possible to differentiate from effects of normal constituents of produced water.

Acid fracturing treatments contain strong acids (usually hydrochloric and hydrofluoric acid) in addition to other chemical additives such as gels and cross-linkers, which serve to thicken fracturing fluids and prevent fluid loss to large fissures in the formation. It is possible that some of the same constituents used in hydraulic fracturing or matrix acidizing presented in Tables 4-13 and 4-14, respectively, with potential toxicity to marine life are also use in acid fracturing and would present the same risks to marine life near discharge points, as described above. Overall, however, fracturing fluid chemical constituents in discharged produced water would be at very low levels and would have no more than subtle effects on marine life near discharge points. Toxicity monitoring using WET testing would protect against the discharge of WST constituents at toxic levels. Acids used in treatments would be largely neutralized by formation minerals during use and thus would produce no effects on water quality or marine life from discharges of flowback fluids combined with produced water.

Matrix acidizing fluids might contain constituents that could be toxic to marine life (Houseworth and Stringfellow 2015). As for acid fracturing, toxicity monitoring using WET testing would protect against the discharge of WST constituents at toxic levels, while acids used in treatments would be largely neutralized in flowback fluids and in discharged produced water and would have no effects on water quality or marine life.

WST-Related Accident Scenarios. Two types of accident scenarios were identified in Section 4.3 as representing plausible pathways for the release of WST fluids and hydrocarbons, surface accidents resulting in a potential release from platforms to the ocean surface (which are reasonably foreseeable but not likely to occur), and accidents resulting in a release from the seafloor, referred to as a "surface expression" (which are not reasonably foreseeable and of very low likelihood of occurrence). The potential effects on water quality of these two types of accidents are described in the following sections.

Sea Surface Accidents. Accidents at the sea surface would result in releases of a somewhat different nature than seafloor releases. As described in Section 4.3, such accidents would occur during shipping, loading, and unloading of WST materials onto and off of vessels and transfers to platforms; accidents involving WST injection fluids on platforms; and accidents involving WST flowback fluids on platforms and in pipeline transport to and from treatment facilities. Releases of WST fluids to the ocean would occur as a result of breaches of containers, tanks, or pipelines.

The volume of WST-related fluids that could be released by such accidents is limited to the size of the shipment containers used, and by the storage capacity for such fluids on platforms or on PSVs (Section 4.3). Accidental releases of recovered WST fluids post-use from pipeline leaks would be similarly limited. At a platform, recovered WST fluids would be highly diluted in produced water from the well undergoing the WST, and potentially further diluted by produced water from other wells and platforms (Section 4.2.3). Any release of WST flowback fluids from a leak in these pipelines would represent a small incremental release of WST fluid constituents contained within releases of produced water or crude oil.

Effects on water quality caused by a release of WST injection fluids or WST flowback fluids would be a temporary localized degradation of water quality near the point of the release. Effects would diminish with distance due to dilution in seawater, and would be incremental to greater effects from the release of associated produced water or crude oil. In the case of a breach of a produced water pipeline, effects on water quality would be similar to the routine discharge of produced water: minor and limited to near the discharge point. Effects of a breach of a crude oil pipeline containing WST flowback fluids would be dominated by those of released crude oil.

A direct spill of WST fluids would have potentially greater effects than a release of diluted WST constituents in flowback fluids. The effects of a direct spill are approximated by the tabletop coarse toxicity screen discussed above; concentrations of constituents with known toxicity, with a few exceptions, would be below toxic effect levels at the mixing zone boundary. Thus, due to rapid dilution at the point of release, toxic concentrations would exist over a very short range and for a short time where marine life could be exposed and affected, and mobile species would spend very little time within the toxic zone. Thus, effects on marine life from the direct release of WST fluids would be expected to be minor.

Sub-seafloor Accidents. In the event of surface expression during a hydraulic fracturing WST, which is not reasonably foreseeable, effects on water quality would depend on the size and duration of the release. Liquid and gaseous hydrocarbons released at the seafloor would rise as a plume to the sea surface, where they would form an oil slick that would be spread by currents and winds. Gaseous and volatile components of the slick would evaporate, affecting air quality, but reducing the mass of hydrocarbons in seawater. Over time, remaining hydrocarbons would oxidize and weather, forming particles that, if more dense than water, would eventually sink to the seafloor where oil would be subject to incorporation in sediments and to degradation by benthic organisms. Large oil slicks on the sea surface would likely foul coastlines, given the close proximity of the producing platforms to the coast. Potential effects on marine and coastal biota and habitats are discussed in Sections 4.5.1.4 through 4.5.1.8.

Small releases on the order of tens of barrels of crude would have short-term and localized effects on water quality. Such effects would be similar to those from natural oil seeps in the area, to which seafloor surface expression would temporarily add an additional influx of crude. Such effects include a surface oil sheen, formation of tar balls, and seafloor deposition of weather oil, as discussed in Section 3.4.2.1.2.

Larger volume releases, on the order of hundreds of barrels or more, although increasingly unlikely, would be more likely to foul beaches and coastal areas. Effects on water quality would be similar to those from historical oil spills in the project area of this magnitude, as discussed in Section 3.4.2.1. The effects of greatest concern would be on marine life, other wildlife, recreation, and commercial fishing. Effects on human health and safety, except on workers involved in cleanup, would generally not be a concern. Cleanup workers would be exposed to physical hazards, primarily. Chemical exposures would be limited via the use of personal protective equipment and by limiting exposure time. As with previous oil spills, direct effects would be mainly confined to within a few miles of the release point. However, ongoing low-level releases from oiled sediments would continue to contribute low levels of hydrocarbons to seawaters for months, to possibly years, into the future. Existing natural physical and biological degradation processes would ultimately degrade or remove hydrocarbons from seawater. Oil slicks would follow prevailing currents in the Santa Barbara channel (Figure 3-12).

Potential Effects of Specific WSTs under Accident Scenarios. The potential effects of accidental releases of WST fluids used in various WST treatments are summarized in Table 4-19. Given the small volume of fracturing fluids employed and short duration of the tests, DFIT treatments would have very low likelihood of causing a surface expression of oil from the seafloor, and it is therefore not reasonably foreseeable. Above-surface handling accidents would be unlikely due to the small volumes of fluids involved, and the impacts of any spills would be minimal.

While very unlikely and therefore not reasonably foreseeable, effects of a surface expression could include a temporary degradation of water quality through the release of crude oil and gas from the seafloor. Effects could be mitigated by cessation of the operation upon detection of a loss of pressure, thus removing the driving force for the oil release. In addition, the formations that would be fractured in the project area are mostly already depleted of formation pressure from past production, while the pressure of overlying rock and seawater would limit surface expression of crude oil. Thus, only a limited quantity of crude oil would be expected to be released in the very unlikely event of such an accident.

Surface accidents resulting in releases of WST fluids to the ocean would be possible during hydraulic fracturing treatments. The volume of fluids potentially released would be limited by the size of containers used to transport and store fluids. A direct release of fracturing fluids to the ocean would cause a short-term, localized degradation of water quality and could be toxic to marine life in the immediate area of the release. The effects of accidents resulting in the release of flowback waters would be minor and similar to the effects of permitted discharges of produce water containing hydraulic fracturing fluid constituents.

Accidents involving acid fracturing treatments would have effects similar to those of hydraulic fracturing surface accidents, and in the event of a seafloor accident, which is not reasonably foreseeable. The use of acids would not increase the effects of releases on water quality nor to marine life. Acids released directly in surface accidents would be quickly diluted and neutralized by seawater. The effects of accidental releases of flowback fluids would be similar to those of hydraulic fracturing accidental flowback fluid releases.

Matrix acidizing treatments would not incur risk of seafloor releases, given the reduced pressures used with matrix acidizing. The effects of surface accidents would be similar to those of other WSTs, because similar volumes and handling and storage of treatment fluids would be involved. In a direct spill, acids would be quickly diluted and neutralized by seawater, while some other matrix acidizing chemicals might be at levels toxic to marine life in the immediate vicinity of a spill, as discussed above. Any effects on water quality would be localized and short lived.

TABLE 4-19 Potential Effects on Water Quality of WST-Related Accidents

WST	Accidental Releases of WST fluids or Crude Oil	Potential Effects on Water Quality
Diagnostic fracture injection test (DFIT)	Surface expression of crude from a potential seafloor accident.	No effects expected due to short duration of tests and low likelihood of surface expression; not reasonably foreseeable.
	WST fluid release during vessel delivery, offloading, platform storage, pipeline delivery, or injection.	No effects expected due to very low volume of WST fluids used and secure containers.
	Release of WST flowback fluid during collection, storage, or pipeline transfer to and from shore.	Minor effects, at most, are possible, and would be incremental to (and likely not discernible from) the effects of release of associated produced water.
Hydraulic fracturing	Surface expression of crude from a potential seafloor accident.	Minimal effects expected due to monitoring and mitigation measures in place, combined with an absence of reservoir pressure that would support a surface expression; not reasonably foreseeable.
	WST fluid release during vessel delivery, offloading, platform storage, pipeline delivery, or injection.	Minor effects at most due to relatively small potential releases from small unit volumes used offshore and rapid dilution of any released fluids.
	Release of WST flowback fluid during collection, storage, or pipeline transfer to and from shore.	Minimal effects due to dilute concentrations, and further rapid dilution following any release.
Acid fracturing	Surface expression of crude from a potential sub-seafloor accident.	Same as for hydraulic fracturing; not reasonably foreseeable.
	WST fluid release during vessel delivery, offloading, platform storage, pipeline delivery, or injection.	Same as for hydraulic fracturing, but with additional hazards from acids, mainly to workers.
	Release of WST flowback fluid during collection, storage, or pipeline transfer to and from shore.	Similar to hydraulic fracturing, assuming that the same non-acid chemical additives are used. Injected acids would be mostly neutralized in the formation; minor effects.
Matrix acidizing	Surface expression of crude from a potential sub-seafloor accident.	No risks of a surface expression expected.
	WST fluid release during vessel delivery, offloading, platform storage, pipeline delivery, or injection.	Similar to hydraulic fracturing and acid fracturing, but effects on marine life could be greater from some matrix acidizing constituents with higher toxicity than the fracturing additives.
	Release of WST flowback fluid during collection, storage, or pipeline transfer to and from shore.	Reduced compared to accidents prior to injection due to dilution and neutralization of acids; minor effects.

Conclusions. Under Alternative 1, the proposed action, the use of fracturing (DFIT, hydraulic fracturing, and acid fracturing) or the non-fracturing WSTs (matrix acidizing) is not expected to adversely affect water quality. Recovered WST fluids would be mixed with produced water, treated, and discharged under NPDES General Permit CAG280000. Effluents would be routinely monitored for specific constituents, for free oil, and for oil and grease assay, and would be subjected to WET testing for general toxicity. Due to the permit limits and monitoring, it is expected that marine life protected under such measures would be effectively protected from any adverse effects of WST constituents in permitted discharges. The accidental release of WST-related chemicals is largely considered unlikely and not reasonably foreseeable, with the possible exception of a platform accident. In the event that an accidental release occurs, the release would likely be small and any effects would be limited and short term. Above-surface accidents resulting in the direct release of WST fluids or of flowback fluids containing WST constituents would have at most minor, localized, and temporary effects on water quality and marine life, and any such effects would be limited by the small quantities of transported or stored WST fluids needed and present at any one time or location, the ability to limit releases once started, and rapid dilution of released fluids in seawater.

4.5.1.4 Ecological Resources

Benthic Resources.

WST Operations. Under Alternative 1, potential WST impacting factors applicable to benthic organisms and their habitats are associated with the permitted platform discharge of produced water containing WST fluids (Section 4.2.4). Although hydraulic fracturing WST fluids make up only a small fraction of the total produced water, several compounds that are toxic to benthic organisms may be present in the discharge, such as biocides, acids, salts, hydrocarbon solvents, and surfactants (Houseworth and Stringfellow 2015). Similarly, matrix acidizing WSTs may release acids and ammonium compounds, which can be toxic to benthic organisms at high enough doses. Potential impacts from the discharge of produced water containing WST fluid chemicals could include localized exposure of benthic organisms to toxic levels of WST chemicals through direct contact with contaminated water or from ingestion of contaminated food.

At platforms on the POCS, produced water containing WST fluid constituents can be disposed of through reinjection to a reservoir or through permitted discharge to the ocean. Properly reinjected produced water would not impact benthic organisms or habitat. In contrast, surface discharge of produced water (including WST chemicals) into the ocean could affect benthic resources, although exposure of benthic resources to toxic levels of WST chemicals would not be expected with compliance with the NPDES permit. Because of the infrequent use of WSTs at platforms on the POCS, the discharge of produced waters containing WST chemicals would also occur infrequently (although acid cleanup treatments are more common) and on relatively few platforms.

In addition, the waste water that is discharged from platforms is regulated by NPDES General Permit CAG280000 (see Section 4.5.1.2), which requires that contaminants in the discharged water not exceed concentrations specified in the permit within 100 m of the discharge point. Although non-exceedance concentrations for WST-related chemicals are generally not specified, NPDES General Permit CAG280000 requirements include toxicity testing with two common benthic species, red abalone (*Haliotis rufescens*) and giant kelp (*Macrocystis pyrifera*). To date, wastewater discharged from platforms on the POCS has passed all toxicity tests (Houseworth and Stringfellow 2015). However, few of the potential WST fluid constituents have toxicological bioassay data available (Tables 4-13 and 4-14).

The composition and toxicity of many WST fluid constituents have not been studied with regard to marine invertebrates, and chronic or acute toxicity concentrations have not been established (Houseworth and Stringfellow 2015). For example, Houseworth and Stringfellow (2015) modeled the discharge concentrations of several WST constituents and generally found the concentrations were below levels associated with chronic and acute toxicity to marine organisms (including invertebrates). However, a toxicity screening of WST constituents found at least two commonly used constituents of matrix acidizing fluids to be potentially acutely toxic to marine organisms (Stringfellow et al. 2015). However, acids used in acid matrix WSTs would be largely neutralized by formation minerals and thus would produce minimal effects on benthic organisms. Despite the potential toxicity of WST constituents, the potential for release and the potential volume released would be very small. Consequently, exposure of biological communities to toxic levels of WST constituents is unlikely. The potential marine toxicity of WST fluids is discussed in more detail in Section 4.5.1.2.

Some biological surveys around oil and gas platforms in California, as well as laboratory toxicity tests using produced water from offshore platforms, do suggest localized, temporary, species-specific impacts on marine invertebrates, although the abundance of some species appears to be greater near discharge points (Osenberg et al. 1992; Neff et al. 2011; Houseworth and Stringfellow 2015). However, these were studies of produced water and are not necessarily applicable to WST fluids alone, which would constitute a very small fraction of any discharged produced water. In addition, platforms on the POCS are in water where the depth ranges from about 130 to 1,197 ft (40 to 365 m), so considerable dilution would be expected to occur before the produced waters with WST chemicals would reach benthic habitats and their biota. Consequently, WST-related waste fluids discharged under these permits are unlikely to adversely affect benthic organisms and habitat.

WST-Related Accident Scenarios. The accidental release of WST fluids could occur during vessel delivery, offloading, and injection, while the accidental release of produced water containing WST-related fluids could occur during their collection or pipeline transfer between platforms and to shore (Section 4.3). While many of these types of accidental releases are unlikely and not reasonably foreseeable, potential impacting factors associated with such accidents that could affect benthic resources are primarily associated with the accidental release of WST fluids, WST-related waste fluids, and crude oil (Tables 4-5, 4-7, and 4-9). If an accidental release from surface operations were to occur, the quantity of WST fluid released would be small due to the quantity of WST fluids involved; any such release would result in a localized, temporary reduction in water quality (Section 4.5.1.2) , which would dissipate quickly with dilution the open ocean.

In an accident resulting in a surface expression, which is very unlikely and not reasonably foreseeable (Section 4.3.2), the potential quantities of hydrocarbons or WST fluids exiting the seafloor to the overlying water column would not be expected to have appreciable impacts on benthic resources for several reasons. First, the surface expression of biologically significant concentrations of WST fluids is unlikely because real-time pressure monitoring during WST implementation would identify potential contact with an existing well or active fault with a connection to the seafloor, and result in immediate cessation of WST. In addition, existing low reservoir pressures—together with pressure from overlying rock and seawater—would greatly limit surface expression, should contact with a well or active fault occur. Therefore, appreciable quantities of WST fluids are unlikely to exit the seafloor to the overlying water column. Similarly, release at the seafloor due to cement failure at the injection well would be highly unlikely because pressure detectors would signal well failure and result in termination of WST action.

Conclusions. Under Alternative 1, only negligible impacts on benthic habitats and biota are expected to result under any of the three fracturing WSTs (DFIT, hydraulic fracturing, and acid fracturing) or under the non-fracturing WST (matrix acidizing). The discharge of flowback fluids from acid matrix WSTs would occur infrequently and in small amounts, and acids used in WSTs would be largely neutralized by formation minerals and therefore would produce minimal effects on benthic organisms. The surface discharge of produced water containing WST-related chemicals and waste fluids is also expected to have negligible impact on benthic habitats and biota because of the infrequent discharges of produced water containing WST-related chemicals, the small amounts of WST-related chemicals that would be discharged, the dilution of any WST-related chemicals from the surface discharge point to the seafloor, and the fact that all discharges will be regulated under NPDES permitting, which limits the concentration of discharged WSTs. Properly reinjected produced water containing WST fluids would not impact benthic organisms or habitats. Although accidental seafloor surface expressions could occur with fracturing WSTs, and produced water pipeline leaks with both types of WSTs, such accidents have a very low probability of occurring and are not reasonably foreseeable.

Marine and Coastal Fish.

WST Operations. Under Alternative 1, produced water containing WST fluid constituents can be disposed of through reinjection to a reservoir or through permitted discharge to the ocean after treatment. Reinjected waste fluids will not come in into contact with aquatic biota and is not expected to affect marine and coastal fish. Therefore, the primary potential impacting factor applicable to fish and EFH is the permitted platform discharge of produced water containing WST fluids (Table 4-3). WST fluids can contain biocides, acids, salts, hydrocarbon solvents, and surfactants (Houseworth and Stringfellow 2015), and potential effects from their discharge could include exposure to toxic levels of WST chemicals through direct contact or from ingestion of contaminated food. Similarly, matrix acidizing WSTs may release acids and ammonium compounds, which can be toxic to benthic organisms at high enough doses. For example, at high enough concentrations acids can damage gill tissue, resulting in lethal or sublethal effects, while metals can damage organs and act as neurotoxins.

Despite the potential toxicity of WST fluid constituents (see discussion in Section 4.5.1.2), there is little evidence that prior WST operations on the POCS have resulted in impacts on fish communities or EFH. Although WST fluids were not specifically examined, studies of fish collected off the California coast indicate contaminant concentrations from fish collected around platforms were low and similar to levels in fish collected from reference areas (Gale et al. 2012; Love et al. 2013). Similarly, Love and Goldberg (2009) found no evidence of significant reproductive impairment in Pacific sanddab (*Citharichthys sordidus*) collected from around platforms on the POCS. Houseworth and Stringfellow (2015) modeled the discharge and dilution of 19 potential WST constituents on marine organisms (including several species of fish) and predicted that only two would exist at concentrations above levels associated with chronic and acute toxicity. However, few of the potential WST fluid constituents could be evaluated due to lack of bioassay data.

Overall, platforms act as artificial reefs and support diverse and productive communities of structure-associated fish. Several studies indicate that the abundance, growth, and productivity of several species of reef fish is higher at POCS platforms and infrastructure than in nearby natural hardbottom habitat (Love et al. 2003; Love and York 2005; Claisse et al. 2014). This includes those platforms that have practiced hydraulic fracturing. Although these studies do not address the impacts of WSTs directly, they do suggest that oil and gas production activities (including WST use) at the platforms have not been detrimental to fish communities.

WST-Related Accident Scenarios. The accidental release of WST chemicals could occur during vessel delivery, offloading, platform storage, and injection, while the accidental release of produced water containing WST chemicals could occur during collection, platform storage, and pipeline transfer between platforms and to and from onshore processing facilities (Section 4.3). Potential impacting factors that could affect marine and coastal fish are primarily associated with the accidental release of WST chemicals, WST-related fluids, and crude oil (Tables 4-5, 4-7, and 4-9). If an accidental release were to occur, the quantity of WST chemicals released would be small due the quantities of chemicals transported, stored, and used, but it may result in a localized, temporary reduction in water quality.

In the unlikely event of a surface expression (Section 4.3.2), though not reasonably foreseeable, the potential quantities of hydrocarbons or WST fluids exiting the seafloor to the overlying water column would not be expected to have appreciable impacts on marine and coastal fish. The surface expression of biologically significant concentrations of WST fluids is unlikely because real-time pressure monitoring during WST implementation would identify potential contact with wells and an active fault and result in immediate cessation of WST. In addition, existing low reservoir pressures—together with pressure from overlying rock and seawater—would greatly limit surface expression, should contact with an active fault or well occur. Therefore, appreciable quantities of WST fluids are unlikely to reach exit the seafloor to the overlying water column. Similarly, release at the seafloor by cement failure would be highly unlikely because pressure detectors would signal well failure and result in termination of the WST action. The accidental release of WST-related chemicals in produced water mixtures would also be expected to have little appreciable effect, owing to the greatly diluted concentrations of WST chemicals that may be in the released produced water mixtures and the subsequent additional dilution that would occur upon release to the ocean.

Overall, given the small quantity of fluids used during a WST and the remote chance of an accidental release of WST-related fluids, the use of WSTs under Alternative 1 is not expected to result in adverse impacts on fish species (including ESA-listed species), or in a loss or modification of EFH.

Conclusions. Under Alternative 1, only negligible impacts on fish and EFH are expected to result under any of the three fracturing WSTs (DFIT, hydraulic fracturing, and acid fracturing) or the non-fracturing WST (matrix acidizing). There is a potential for some individuals to be temporarily exposed to highly diluted concentrations of WST-related chemicals that may be present in produced water being discharged under the NPDES permit, although such discharges (and associated exposures) would occur infrequently and would be localized and of short duration. Because of the anticipated infrequent use of WSTs in the foreseeable future, the infrequent discharge of WST-related waste fluids, the small amounts of WST-related chemicals that would be discharged with any single WST application, and the fact that all discharges will be regulated under NPDES permits, which require the rapid dilution of chemical constituents within the vicinity of the discharge point, impacts on marine and coastal fish and to EFH are expected to be minimal. In addition, acids used in matrix acidizing (a non-fracturing WST) would be largely neutralized by formation minerals and natural seawater buffering, and therefore would have minimal effects on fish and EFH. Although accidental seafloor surface expressions could occur with fracturing WSTs, and produced water pipeline leaks with WSTs, such accidents have a very low probability of occurring and are not reasonably foreseeable.

Marine Mammals.

***WST Operations*.** Under Alternative 1, the impacting factors potentially affecting marine mammals during use of WSTs are identified in Table 4-3. As with the previous categories of marine biota, potential effects are primarily associated with the discharge from platforms of WST-related fluids and chemicals. Exposure to WST-related chemicals in the discharged waters may occur through direct contact and though ingestion of contaminated food. However, compliance with the requirements of NPDES General Permit CAG280000 will greatly limit the potential for exposure of marine mammals to toxic concentrations of the WST-related chemicals. Because WST fluids are rapidly diluted in the open ocean, marine mammals would be expected to experience only very low levels of exposure from the water column. Acids used by some WSTs undergo chemical reactions downhole and form non-acidic components in the flowback fluids. The acids are also water soluble, so any unreacted acid will be diluted by produced water in the flowback fluids and neutralized by natural seawater buffering following discharge. Thus, WST-related chemicals, including any unreacted acids, will have a negligible impact on marine mammals.

Marine mammals may be indirectly affected if discharges containing WST-related chemicals reduce the abundance of prey species. However, because of the rapid dilution that would occur following permitted discharge, potential impacts on prey populations inhabiting the water column would be limited in extent and would not be expected to affect overall prey abundance. Field studies have shown that the concentrations of trace metals and hydrocarbons in the tissues of fishes around production platforms are within background levels (Continental Shelf Associates 1997). Thus, food chain uptake is not expected to be a major exposure pathway for fish-eating marine mammals at offshore facilities where WSTs are used. As discussed, WSTs are not expected to cause either an acute or a chronic effect on benthic organisms and fish species. Therefore, WSTs are not expected to affect the prey base for marine mammals.

The EPA (2013b), in its issuance of the final NPDES General Permit CAG280000 for discharges from offshore oil and gas facilities located in Federal waters off the coast of southern California, provided an analysis of the potential effects of regulated discharges on several Federally listed marine mammal species. The analysis concluded that no effects are anticipated for the listed marine mammals, primarily because of the very limited time any individuals may spend near a platform (Table 4-20). The EPA (2013b) did not evaluate the Federally endangered North Pacific right whale (*Eubalaena japonica*). However, sightings of this species off the California coast are rare, and there is no evidence that the western coasts of the continental United States were ever highly frequented (Reilly et al. 2008). Thus, no effects are anticipated for this species, largely because there are very few sightings of individuals off southern California and any individuals that may enter the project area would likely spend a very limited amount of time in the vicinity of any of the offshore platforms (Table 3-7).

Noise associated with PSVs used to deliver WST equipment and materials, and with WST activities conducted on the platforms, may have a short-term negligible impact on marine mammals (e.g., localized impact on their behavior and/or distribution). A minor potential exists for marine mammals to be struck by PSVs.

WST-Related Accident Scenarios. Impacting factors associated with accidents during the use of WSTs and affecting marine mammals are identified in Section 4.3. These are associated primarily with accidental releases of WST fluids and waste fluids, and crude oil. Impacts from an accidental release will depend on the magnitude, frequency, location, and date of the release; characteristics of the released materials; spill-response capabilities and timing; and various meteorological and hydrological factors. Impacts could include decreased health, reproductive fitness, and longevity; and increased vulnerability to disease. An accidental release could also lead to the localized reduction, disappearance, or contamination of prey species.

An accident during transport and delivery of WST chemicals (Table 4-4); fluid injection (Table 4-6); or handling, processing, and disposal of WST-related wastes (Table 4-8) could involve the release of WST chemicals to the water column. Impacts of WST constituents released during these activities would be minor due to the relatively small amounts of

TABLE 4-20 Potential Effects of Regulated Discharges of WST-Related Fluids from Offshore Oil and Gas Facilities on Several Federally Listed Marine Mammals

Species	Status[a]	Potential Effects[b]
Balaenoptera borealis borealis (sei whale—northern hemisphere subspecies)	E/D	No effects anticipated. Individuals spend very limited amounts of time in the vicinity of platforms.
Balaenoptera musculus musculus (blue whale—northern hemisphere subspecies)	E/D	No effects anticipated. Individuals spend very limited amounts of time in the vicinity of platforms.
Balaenoptera physalus physalus (fin whale—northern hemisphere subspecies)	E/D	No effects anticipated. Individuals spend very limited amounts of time in the vicinity of platforms.
Megaptera novaeangliae (humpback whale)	E/D	No effects anticipated. Species not expected to occur in the vicinity of the platforms.
Physeter macrocephalus (sperm whale)	E/D	No effects anticipated. Individuals spend very limited amounts of time in the vicinity of platforms.
Arctocephalus townsendi (guadalupe fur seal)	T/D	No effects anticipated. Species not expected to occur in the vicinity of the platforms.
Enhydra lutris nereis (southern sea otter)	T/D	No effects anticipated. Individuals tend to reside within 1.2 mi of shore, while platforms are 3 mi or more offshore.

[a] Status: E = endangered under the Endangered Species Act (ESA); T = threatened under the ESA; D = depleted under the Marine Mammal Protection Act.

[b] The “no effects” determinations are those provided in the source document.

Source: Modified from EPA (2013b).

WST-related materials that could occur followed by the dilution of the released WST-related chemicals (Section 4.5.1.2). In addition, a surface spill during shipping of WST chemicals or during offloading to a platform is expected to have minimal impacts because it is not likely that the entire contents of a shipping container would spill, and the small amount of released fluids would be quickly diluted by the seawater in the area of a spill. Thus, any impacts on marine mammals from the accidental release of WST chemicals or produced water containing WST-related chemicals are expected to be temporary, localized, and affect few if any individuals.

An accident from a seafloor surface expression from a fracturing WST (though not reasonably foreseeable, and not a risk for matrix acidizing) would result in only a small release of WST fluids and hydrocarbons (Section 4.5.1.3). Although a surface expression is considered to be of low probability and not reasonably foreseeable, should such a release occur, it is expected to be localized, temporary, and quickly diluted; therefore, impacts on marine mammals would be negligible. Marine mammals may also be affected if containment and cleanup activities for accidental releases are conducted. Marine mammals that may otherwise be unaffected by an accidental release may be affected by increased vessel traffic and remediation activities (Table 4-10). Vessel noise and other factors related to increased human presence would likely cause changes in marine mammal behavior and/or distribution. An increased number of response vessels could also increase the risk for vessel collisions.

Conclusions. Under Alternative 1, only negligible impacts on marine mammals are expected to result under any of the three fracturing WSTs (DFIT, hydraulic fracturing, and acid fracturing) or the non-fracturing WST (matrix acidizing). There is a potential for some individuals to be temporarily exposed to highly diluted concentrations of WST-related chemicals that may be present in produced water being discharged under the NPDES permit, although such discharges (and associated exposures) would occur infrequently and be localized and of short duration. Conduct of any of the WSTs may also result in short-term, localized disturbance in behavior and/or distribution of some individuals, but these impacts would be negligible. Negligible impacts on marine mammals are also expected from accidents related to WSTs. Although accidental seafloor surface expressions could occur with fracturing WSTs, and produced water pipeline leaks with both types of WSTs, such accidents have a very low probability of occurring and are not reasonably foreseeable.

Marine and Coastal Birds.

WST Operations. The primary impacting factor potentially affecting marine and coastal birds during WST use is the discharge of WST-related chemicals to the ocean (Table 4-3). Because materials and equipment used for WST operations will be transported to platforms on normal service vessel runs, there will be no additional impacts on birds (e.g., noise or visual disturbances) associated with vessel traffic. Pumps used for WST operations may add to noise disturbances within the immediate area of the platform. The elevated noise levels near a platform from WSTs will be negligible. This is based on only 21 hydraulic fracturing and three matrix acidizing operations reported for Federal platforms between 1992 and 2013 (Section 4.1). The number of WSTs is not expected to vary from these levels in the foreseeable future. At high enough concentrations, WST-related chemicals may be toxic to some marine and coastal birds following exposure through direct contact and through ingestion of contaminated food. Compliance with the discharge requirements of the NPDES General Permit CAG280000 sets spatial limits (328 ft [100 m]) on the concentrations of discharges. Because any discharged produced water containing WST-related chemicals would be rapidly diluted in the open ocean, marine and coastal birds would be expected to experience only very low levels of exposure to contaminants close to a platform. Acids such as HCl and HF undergo chemical reactions downhole that form non-acidic components in the flowback fluids. These acids are also water soluble, so any unreacted acid will be diluted by produced water in the flowback fluids. Thus, the use of acid WSTs are not expected to impact marine and coastal birds.

Marine and coastal birds may be indirectly impacted if WST-related discharges reduce the abundance of prey species. However, because of the rapid dilution that would occur (i.e., NPDES permit limits extend 100 m from the point of discharge), potential impacts on prey populations (see, e.g., previous analysis for marine and coastal fish) would be limited in extent and not expected to adversely affect overall prey abundance. Field studies have shown that the concentrations of trace metals and hydrocarbons in the tissues of fishes around production platforms are within background levels (Continental Shelf Associates 1997). Thus, food chain uptake is not expected to be a major exposure pathway for fish-eating birds at offshore facilities. Therefore, WST fluids and their constituents are not expected to affect the prey base for marine and coastal birds during WST applications.

The EPA (2013b), in its issuance of a final NPDES General Permit CAG280000 for discharges from offshore oil and gas facilities located in Federal waters off the coast of southern California, provided an analysis of the potential effects of regulated discharges on several of the Federally listed marine and coastal species, including birds. This analysis identified no anticipated effects, primarily because none of the ESA-listed bird species normally occur in the vicinity of the offshore platforms (Table 4-21). As stated in Section 3.5.4.4, the Marbled Murrelet (*Brachyramphus marmoratus*) feeds within 4 mi (7 km) of shore; the largest numbers of this species occur within 2 to 3 mi (3 to 5 km) of shore. Although no mortality of Marbled Murrelets is expected, some individuals may experience short-term disturbance from noise or movement of PSVs. The EPA (2013b) concluded there would be no effects on the California Least Tern (*Sternula antillarum browni*). However, because it feeds up to 2 to 3 mi (3 to 5 km) offshore, with most feeding within 1 mi (1.6 km) of shore, potential disturbance to individuals could occur from PSV traffic associated with WSTs.

TABLE 4-21 Potential Effects of Regulated Discharge of WST-Related Fluids from Offshore Oil and Gas Facilities on Select Federally Listed Marine and Coastal Birds

Species	Status[a]	Potential Effects[b]
Sterna antillarum browni (California Least Tern)	E	No effects anticipated. Habitat located near coastline or in nearshore shallow waters. Forages within about 2 mi of shore, while platforms are 3 mi or more offshore.
Charadrius nivosus nivosus (Western Snowy Plover)	T	No effects anticipated. Individuals inhabit coastal dunes and beaches, salt pans, and coastline marshes.
Brachyramphus marmoratus (Marbled Murrelet)	T	No effects anticipated. Most forage within 3 mi of shore.
Rallus obsoletus levipes (Light-footed Ridgway's Rail)	E	No effects anticipated. Individuals inhabit coastal saltwater marshes and occasionally freshwater marshes.

[a] Status: E = endangered under the Endangered Species Act (ESA); T = threatened under the ESA.

[b] The "no effects" determinations are those provided in the source document.

Source: EPA (2013b).

Accident Scenarios. A variety of accidents could occur during use of WSTs on the POCS (Section 4.3). Impacting factors associated with such accidents that could potentially affect marine and coastal birds are identified in Tables 4-5, 4-7, and 4-9. These are associated primarily with accidental releases of WST chemicals and fluids, and crude oil. Impacts from an accident depend on the magnitude, frequency, location, and timing of the accident; characteristics of the spilled material; spill-response capabilities and timing; and various meteorological and hydrological factors. Impacts could include decreased health, reproductive fitness, and longevity; increased vulnerability to disease; and increased mortality. A spill could also lead to the localized reduction, disappearance, or contamination of prey species. Most accidental releases limited to WST-related chemicals and produced water would quickly dissipate and would only affect a small amount of habitat and relatively few individuals and only for a short time after the release.

An accident at a platform or a PSV could result in the release of WST chemicals to the ocean surface. Although some WST constituents such as acids or biocides are toxic, a surface spill during shipping of WST chemicals by service vessel or during offloading to a platform is expected to have minimal impact because it is not likely that the entire contents of a shipping container would spill, and because of dilution from seawater in the area of a spill. Impacts from the release of WST constituents from a produced water pipeline would also be minimal due to the rapid dilution that would occur (Section 4.5.1.2). Any impacts on marine and coastal birds would be temporary, localized, and affect few if any individuals. However, species such as gulls and shearwaters, which are attracted to offshore platforms or often follow vessels, may be more likely to be exposed to an accidental release. These birds may be directly exposed while feeding or resting in spills originating from platforms or service vessels and could incur lethal or sublethal effects.

An accident from a seafloor surface expression from a fracturing WST (which is not reasonably foreseeable for any WST and not a risk in matrix acidizing) would result in only a small release of WST fluids and hydrocarbons (Section 4.5.1.3). Surface expression would be localized and quickly diluted; therefore, impacts on marine and coastal birds would be negligible. In the event of a seafloor surface expression that includes crude oil, marine and coastal birds may be affected during spill containment and cleanup activities (Table 4-10). Birds that may otherwise be unaffected by an accidental release may be impacted by increased vessel traffic and remediation activities. Vessel noise and other factors related to increased human presence would likely cause changes in seabird behavior and/or distribution. Potential impacts of oil spills and dispersant use are discussed in Section 4.5.1.11.

Conclusions. Under Alternative 1, only negligible impacts on marine and coastal birds are expected to result under any of the three fracturing WSTs (DFIT, hydraulic fracturing, acid fracturing) or the non-fracturing WST (matrix acidizing). Because few fracturing or matrix acidizing WSTs are expected annually at OCS platforms in the foreseeable future, WST operations under Alternative 1 are expected to have no to negligible impacts on year-round resident or seasonally occurring bird species. WST operations would have no impacts on migratory species during the months when such species do not occur in the project area. Otherwise, potential short-term negligible disturbance, mostly from noise or the presence of

PSVs, may briefly affect marine and coastal birds. Negligible impacts on marine and coastal birds are also expected from accidental release of WST chemicals. Although accidental seafloor surface expressions could occur with fracturing WSTs, and produced water pipeline leaks with both types of WSTs, such accidents are have a very low probability of occurring and are not reasonably foreseeable.

Sea Turtles.

WST Operations. Impacting factors potentially affecting sea turtles during the use of WSTs are identified in Section 4.2.4. Some WST-related chemicals may be toxic to sea turtles, depending on the level and duration of exposure. Exposure may occur through direct contact and through ingestion of contaminated food. Compliance with NPDES permit requirements will greatly limit the exposure of sea turtles to toxic concentrations of WST-related chemicals. Because WST fluids are rapidly diluted in the open ocean, sea turtles would be expected to experience only very low levels of exposure from the water column. Acids, such as HCl and HF, that are used in some WSTs undergo chemical reactions downhole, forming non-acidic components in the flowback fluids. The acids are also water soluble, so any unreacted acid will be diluted by produced water in the flowback fluids. Thus, use of acid WSTs is not expected to result in any discernible impacts on sea turtles.

Sea turtles may be indirectly impacted if WST discharges reduce the abundance of prey species. However, because of the rapid dilution that would occur, potential impacts on prey populations inhabiting the water column would be limited in extent and not expected to adversely affect overall prey abundance. Although some WST-related chemicals may reach sediments and reduce macroinfaunal abundance, the potentially affected macroinvertebrate fauna would be generally at depths beyond the diving limits of sea turtles. In addition, concentrations of WST-related chemicals in the discharged water would be further diluted before they would reach the seafloor, and thus be even less likely to affect benthic resources that are utilized by turtles.

The EPA (2013b), in its issuance of a final general NPDES permit for discharges from offshore oil and gas facilities located in Federal waters off the coast of southern California, provided an analysis of the potential effects of regulated discharges on the Federally listed sea turtle species. The EPA concluded that no effects are anticipated for any of the sea turtles as a result of discharges under NPDES General Permit CAG280000 (Table 4-22).

Noise associated with PSVs used to deliver WST equipment and materials, and with WST activities conducted on the platforms, may have a short-term negligible impact on sea turtles (e.g., localized impact on their behavior and/or distribution). A minor potential exists for sea turtles to be struck by PSVs. Because no more than 10 PSV trips would be needed for a WST treatment, and because no more than a few WSTs would be conducted per year at Federal platforms, the likelihood of a sea turtle being struck by a PSV is very low.

TABLE 4-22 Potential Effects of Regulated Discharges of WST-Related Fluids from Offshore Oil and Gas Facilities on Federally Listed Sea Turtles

Species	Status[a]	Potential Effects[b]
Caretta caretta (loggerhead turtle)	E	No effects anticipated. Occurs infrequently near platforms. Discharges from offshore oil platforms not mentioned as a threat to the species.
Chelonia mydas (green turtle)	T	No effects anticipated. Infrequently occurs near platforms. Species mostly occurs outside the project area (south of San Diego). No information found to indicate proposed discharges would affect the species.
Dermochelys coriacea (leatherback turtle)	E	No effects anticipated. Only Platform Irene falls within the area of critical habitat. No information found to indicate proposed discharges would affect the species or its critical habitat.
Lepidochelys olivacea (olive Ridley turtle)	T	No effects anticipated. Rarely occurs near platforms.

[a] Status: E = endangered under the Endangered Species Act (ESA); T = threatened under the Endangered Species Act.

[b] The "no effects" determinations are those provided in the source document.

Source: EPA (2013b).

WST-Related Accident Scenarios**.** Potential impacting factors that could affect sea turtles are primarily associated with the accidental release of WST fluids and crude oil (Tables 4-5, 4-7, and 4-9). Impacts from an accidental release depend on the magnitude, frequency, location, and date of the release; characteristics of the released material; spill-response capabilities and timing; and various meteorological and hydrological factors. Impacts could include decreased health, reproductive fitness, and longevity; and increased vulnerability to disease. A spill could also lead to the localized reduction, disappearance, or contamination of prey species. Diminished prey abundance and availability may cause sea turtles to move to less-suitable areas and/or to consume less-suitable prey.

A sea surface accident could result in the release of WST chemicals to the ocean. The accidental release of WST-related chemicals in produced water mixtures would also be expected to have little appreciable effect owing to the greatly diluted concentrations of WST chemicals that may be in the released produced water mixtures and the subsequent additional dilution that would occur upon release to the ocean (see Section 4.5.1.2). Although some WST constituents such as acids or biocides are toxic at high exposure concentrations, a surface spill during shipping of WST fluids by service vessel or during offloading to a platform is expected to have minimal impact because the entire contents of a shipping container is not likely to spill, and there would be relatively rapid dilution from seawater in the area of a spill. Any impacts on sea turtles would be temporary and localized, and, would affect few if any individuals. Any individuals in the area of a spill would be expected to avoid or leave the spill area, and no population-level effects are expected as a result of an accidental release of WST-related chemical.

An accidental release from a seafloor surface expression during a fracturing WST (which is neither expected nor reasonably foreseeable for any of the WSTs) would result in only a small release of WST fluids and hydrocarbons (Section 4.5.1.3). An accidental seafloor expression is considered to have a very low probability of occurrence and is not reasonably foreseeable. However, should such an accidental release occur, the release of WST chemicals would be localized and quickly diluted. Therefore, impacts on sea turtles would be negligible. In the event of a seafloor surface expression that includes crude oil, sea turtles may be affected during spill containment and cleanup activities (Table 4-10). Sea turtles that may otherwise be unaffected by an accidental release may be affected by increased vessel traffic and remediation activities. Vessel noise and other factors related to increased human presence would likely cause negligible changes in sea turtle behavior and/or distribution. Increased vessel traffic associated with spill response vessels could also increase the risk for vessel collisions. Potential impacts of oil spills and dispersant use are discussed in Section 4.5.1.11.

Conclusions. Under Alternative 1, only negligible impacts on sea turtles are expected to result under any of the three fracturing WSTs (DFIT, hydraulic fracturing, and acid fracturing) or the non-fracturing WST (matrix acidizing). There is a potential for some individuals to be temporarily exposed to highly diluted concentrations of WST-related chemicals that may be present in produced water being discharged under the NPDES permit, although such discharges (and associated exposures) would occur infrequently and would be localized and of short duration. Conduct of any of the WSTs may also result in short-term, localized disturbance in behavior and/or distribution of some individuals, but these impacts would be negligible. Negligible impacts on sea turtles are also expected from accidental release of WST chemicals. Although accidental seafloor surface expressions could occur with fracturing WSTs, and produced water pipeline leaks with both types of WSTs, such accidents have a very low probability of occurring and are not reasonably foreseeable.

4.5.1.5 Recreational and Commercial Fisheries

WST Operations. Under the proposed action, the primary impacting factor affecting commercial and recreational fisheries from WST operations is the permitted platform discharge of produced water containing WST-related chemicals (Table 4-3). Because WST fluids can contain compounds such as biocides, acids, salts, hydrocarbon solvents, and surfactants that can be toxic to invertebrate and fish species (Houseworth and Stringfellow 2015), there is a potential for reductions in the abundance of target species due to localized exposure to toxic levels of WST chemicals in discharges through direct contact or from ingestion of contaminated food.

As discussed in Section 4.2.3, following mixing with produced water, WST waste fluids may be disposed of by reinjection into wells or by permitted discharged from the platforms into the ocean. Waste water that is properly reinjected into subsurface reservoirs would not come into contact with fish and benthic organisms or their habitat and thus not affect fishery resources. The discharge into the ocean of treated wastewater containing WST fluids would be very limited for a number of reasons. First, discharge of wastewater containing WST fluids would occur infrequently, from relatively few platforms. In addition, the discharge of wastewater from platforms on the POCS is regulated by NPDES General Permit CAG280000, which requires that contaminants in the discharged water not exceed concentrations specified in the permit beyond 100 m of the discharge point (see Section 4.5.1.2). As described in Section 4.5.1.2, rapid dilution would be expected over a very short distance from the point of discharge and there would only be a short period of time where marine life or habitats could be exposed and affected. Thus, effects on marine life or habitats from the direct release of WST fluids would be expected to be minor. Consequently, it is anticipated that WST constituents discharged with produced water into the ocean under NPDES General Permit CAG280000 would have negligible effects on fishery species and habitats.

Under Alternative 1, the permitted mixing areas for NPDES permitted discharges would not change from current conditions (i.e., 100 m from the discharge point). Consequently, there would be no additional restrictions on areas available for fishing compared to current conditions.

It is anticipated that WST fluids and WST activities would not result in increases in platform vessel traffic compared to current conditions. As a consequence, preclusion from fishing areas due to interference with WST supply vessels is not expected to differ from levels experienced during existing routine operations.

WST-Related Accident Scenarios. Under Alternative 1, the accidental release of WST chemicals could occur during vessel delivery, offloading, platform storage, and injection (Section 4.3). In addition, the accidental release of produced water containing WST constituents could occur during collection, platform storage, and pipeline transfer of produced water (Section 4.3.3). If large quantities of WST chemicals were released during such accidents, there is a potential for localized and temporary closure of fisheries because of potential contamination, or because of a reduction in abundance of fishing resources (i.e., fish/invertebrates) due to lethal or sublethal effects following exposure to toxic levels of the released WST chemicals. There would also be a potential for localized and temporary closure of fishery areas during cleanup operations in the event of accidents resulting in releases of large quantities of WST chemicals or fluids (Table 4-10).

As of July 2015, there had been no reported spills of WST chemicals or fluids (Houseworth and Stringfellow 2015) associated with offshore activities in California, and an accidental release by the mechanisms identified above is considered very unlikely. If an accidental release were to occur, it is anticipated that the quantity of WST chemicals released would be relatively small and quickly diluted to acceptable (nontoxic) levels, although localized, temporary reductions in water quality could occur (see Section 4.5.1.2). As a consequence, adverse impacts on species or habitats important for recreational or commercial fisheries are considered unlikely.

Conclusions. Under Alternative 1, only negligible impacts on recreational or commercial fisheries are expected to result under any of the three fracturing WSTs (DFIT, hydraulic fracturing, and acid fracturing) or the non-fracturing WST (matrix acidizing). The discharge of flowback fluids from acid matrix WSTs would occur infrequently and in small amounts, and acids used in matrix acidizing WSTs would be largely neutralized by formation minerals and therefore would produce minimal effects on area fisheries. The surface discharge of produced water containing WST-related chemicals and waste fluids is also expected to have negligible impacts on fisheries resources because of the infrequent discharges of produced water containing WST-related chemicals, the small amounts of WST-related chemicals that would be discharged, the dilution of any WST-related chemicals from the surface discharge point to the seafloor, and the fact that all discharges will be regulated under NPDES permitting, which limits the concentration of discharged WSTs. Properly reinjected produced water containing WST fluids would have no impact on fisheries resources. Although accidental seafloor surface expressions could occur with fracturing WSTs, and produced water pipeline leaks with both types of WSTs, such accidents have a very low probability of occurring and are not reasonably foreseeable.

4.5.1.6 Areas of Special Concern

WST Operations. Under Alternative 1, areas of special concern (see Section 3.11) may be affected by WST operations if the permitted discharge of produced water containing WST-related chemicals were to affect the water quality at the area of special concern (Table 4-3). However, such effects are highly unlikely. Both the EPA (2010) and the California Coastal Commission (2013) contend that discharges (including those containing WST-related chemicals) from platforms on the POCS authorized by the NPDES General Permit CAG280000 will not cause significant degradation of the marine environment and are consistent with the marine protection and water quality policies of the California Coastal Act (California Coastal Commission 2013). Discharges will not compromise the biological productivity of coastal waters or inhibit the maintenance of optimum populations of marine organisms as required by Sections 30230 and 30231of the California Coastal Act (California Coastal Commission 2013). The NPDES General Permit CAG280000 provides protection against contamination expected from hydrocarbons and produced water that may contain WST-related chemicals.

Because of the distance of the 23 platforms on the POCS from any areas of special concern, permitted discharges at the platforms are not expected to affect water quality of any areas of special concern, and thus would not affect the purpose or use of those areas. For example, the nearest platform to any of the areas of special concern is Platform Gail. This platform is about 3,600 ft (1,100 m) from the outer boundary of the Channel Islands Marine Sanctuary; this sanctuary is a 6-nautical mi^2 ($11\text{-}km^2$) area surrounding the Channel Islands National Park (Section 3.7.1). Based on these distances, the dilution and natural breakdown of WST constituents following their permitted discharge in produced water should preclude any impacts on water quality at the sanctuary or the national park, as well as associated Marine Protected Areas. Similarly, the various State-protected areas (e.g., marine reserves, marine conservation areas, and special closure areas; Figure 3-19) would also not be affected by WSTs, primarily due to their distance from the platforms on the POCS.

A variety of military use areas and activities occur in the Pacific Ocean off of southern California (Section 3.11.6). The OCS platforms are located either within Military Warning Areas or between the Military Warning Areas and the coast. A Military Warning Area is airspace of defined dimensions, extending from 12 nautical mi (22 km) outward from the coast of the United States, containing activity that may be hazardous to nonparticipating aircraft. Use of these air spaces would not be affected by WST operations. This is also the case for the Point Mugu Sea Range. U.S. Navy and Marine amphibious training along the coast would not be affected by WST operations. The Vandenberg Air Force Base is located in the area of the more northern OCS platforms (Irene, Hidalgo, Harvest, and Hermosa). These platforms are several nautical miles offshore from the base; therefore, WSTs would not affect the base or interfere with its operations. WSTs would not affect either danger zones (water areas used for target practice, bombing, rocket firing, or other especially hazardous operations, normally for the armed forces) or restricted areas (water areas designated for the purpose of prohibiting or limiting public access in order to provide security for government property and/or protection to the public from the risks of damage or injury arising from the government's use of that area).

WST-Related Accident Scenarios. Accidents associated with WST use would only affect areas of special concern if accidentally released WST chemicals or crude oil were to affect the water quality, biota, and other resources that underlay the special concern status of the area, or preclude the intended purpose or use of the area (e.g., conservation of fish and wildlife, military training). The likelihood of an accidental release affecting the purpose or use of an area is remote. Any accidental surface releases of WST chemicals during delivery, platform storage, and injection (which have a low probability of occurring and may or may not be reasonably foreseeable [see Section 4.3]) would be small in size and would stay in the immediate vicinity of the platform. Any such small spills would be rapidly diluted and chemical constituents would be degraded; coupled with the distances between platforms and the areas of special concern, such small spills would not be expected to affect water quality, biota, and other aspects of the areas of special concern.

Although not reasonably foreseeable, a seafloor surface expression could include the release of crude oil, which would not be expected to undergo dilution or degradation to the same extent as WST fluid constituents. Should the crude oil reach an area of special concern, it could impact water quality and biota at the area, as well affect the purpose and use of that area.

Conclusions. Routine WST operations involving either fracturing or matrix acidizing will have no impacts on areas of special concern. No impacts on areas of special concern are also expected from accidental releases of WST fluids.

4.5.1.7 Archaeological Resources

WST Operations. As discussed in Chapter 3, cultural resources include submerged prehistoric archaeological sites and historic shipwrecks, as well as coastal prehistoric sites and architectural resources found onshore. Because WST operations would include no new onshore or offshore construction, there would be no seafloor or ground disturbing activities that could affect known or unknown archaeological resources in the area.

WST-Related Accident Scenarios. The accidental release of WST chemicals is not expected to have any effects on known or unknown archaeological or historic resources in the area. Dilution and degradation of any released WST chemicals in seawater would remove any corrosive properties of the chemicals, effectively exposing archaeological or historic resources to seawater. The greatest potential for effects on such resources would be associated, not with contact with WST chemicals or crude oil (if released during a seafloor surface expression or well casing failure), but rather with physical damage that may occur during response activities addressing the release (Bittner 1996; Reger et al. 2000).

Conclusions. No impacts on archaeological resources are expected to result under any of the three fracturing WSTs (DFIT, hydraulic fracturing, acid fracturing) or the non-fracturing WST (matrix acidizing) under Alternative 1. Should there be a release of crude oil as a result of an accidental seafloor surface expression or a well casing failure during WST injection, response activities could damage some resources. All response activities would be overseen and directed by the U.S. Coast Guard, which would be expected to consider potential impacts of selected response actions on archeological resources. However, such accidental releases have a very low probability of occurrence and are not reasonably foreseeable.

4.5.1.8 Recreation and Tourism

WST Operations. Recreation and tourism together are a major economic driver in the four coastal counties adjacent to the POCS. WST operations would have no or negligible impacts on ecological resources (Section 4.5.1.4), recreational and commercial fisheries (Section 4.5.1.5), or areas of special concern (Section 4.5.1.6); thus, no impacts on recreation and tourism (including aesthetic impacts) related to WST use are anticipated. A typical WST may occur over the course of several days and the visual character of the site where the work is performed would be largely unchanged from its pre-stimulation condition (Aspen Environmental Group 2015). No additional service vessel trips are expected that could result in a visual or noise annoyance to tourists or recreationists, or in space-use conflicts with recreational fishermen. The discharge and mixing zone currently in place for the permitted discharge of wastewater (including produced water) would not change with the use of WSTs, and thus should not affect recreational activities in the vicinity of the platforms. Truck traffic into Port Hueneme to deliver extra chemical totes, pumps, or other equipment necessary for WST operations is not expected to noticeably increase traffic in the area.

WST-Related Accident Scenarios. Among the accident scenarios identified for WST use, accidental surface releases of WST chemicals at platforms during delivery, platform storage, and injection (which have a low probability of occurring but some of which are reasonably foreseeable [see Section 4.3]) would be small in size and would stay in the immediate vicinity of the platform. Any such small spills would be rapidly diluted and chemical constituents would be degraded; coupled with the distances between platforms and areas used for recreation and tourism, such small spills would not be expected to affect activities associated with recreation and tourism. More substantive impacts would occur if crude oil was associated with a seafloor surface expression or a well casing failure (see Section 4.5.1.11); however, such accidents are very unlikely to occur and are not reasonably foreseeable.

Conclusions. Under Alternative 1, the proposed action, **t**he use of fracturing (DFIT, hydraulic fracturing, and acid fracturing) or the non-fracturing WST (matrix acidizing) is not expected to impact any areas of special concern. No impacts on areas of special concern are expected from accidental releases of WST fluids.

4.5.1.9 Environmental Justice

WST Operations. The environmental justice impact analysis evaluates the potential for disproportionately high and adverse human health and environmental effects on minority and low-income populations that could result from WST use at the platforms on the POCS. The use of WSTs is not expected to result in any adverse effects on minority and low-income populations. All WST operations would use existing infrastructure and facilities, would occur on already operating platforms, and would dispose of WST-related fluids in the same manner as currently used for wastewater disposal at the platforms (either reinjection or NPDES-permitted discharge). Truck traffic into Port Hueneme to deliver extra chemical totes, pumps, or other equipment necessary for WST operations will not be noticeably different from existing traffic levels. The permitted discharge of produced water containing WST-related chemicals is also not expected to affect any resources providing subsistence or recreational use to any area populations, including low-income or minority populations. Therefore, there will be no disproportionately high adverse health or environmental effects on minority or low-income populations from WSTs.

WST-Related Accident Scenarios. Accidents associated with WSTs may cause a localized decrease in water quality, which could reduce use of impacted areas by every ethnicity and income level, including minority and low-income populations. However, the amount of WST chemicals released would be quickly diluted in close proximity to a release. No disproportionate effects on minority and low-income populations are expected from offshore WST-related accidents.

Coastal areas will not be affected by an accidental release of WST constituents (in the event of a seafloor surface expression from a fracturing WST). An accidental release of crude oil (in the event of a seafloor expression), discussed in Section 4.5.1.11, is not likely to be of sufficient magnitude or duration to have an adverse and disproportionate long-term effect on low-income and minority communities in the four coastal counties of southern California. Although low-income and minority populations reside in some areas of the coast, in general coasts in southern California are home to more affluent groups. Thus, low-income and minority groups are less likely to bear more negative impacts than other groups.

Conclusions. Under Alternative 1, the proposed action, **t**he use of fracturing (DFIT, hydraulic fracturing, and acid fracturing) or the non-fracturing WST (matrix acidizing) is not expected to impact minority or low-income populations. Similarly, no impacts are expected from accidental releases of WST fluids. No environmental justice impacts are expected from accidental releases of WST fluids.

4.5.1.10 Socioeconomics

WST Operations. Under Alternative 1, the use of WSTs is not expected to affect employment, income, State and local tax revenues, population growth, housing, or community and social services. Any WST activities would be conducted with no increase in the workforce, using the existing workforce at the platforms and on service vessels. Because delivery of WST materials to platforms and the return of proppants and comingled fracturing fluids and produced water would make use of existing vessels and/or pipelines, no new land-based or transportation systems would be required. Because an increased workforce is not anticipated, there would be no effect on employment, income, State and local tax revenues, population, housing community, or social services. Although the use of WST fluids and materials (e.g., proppants) could benefit suppliers of these materials, WST use is expected to be very infrequent (based on past WST activity at platforms on the POCS; see Table 4-1) and thus is not expected to provide more than very minor and localized economic benefits for area businesses.

WST-Related Accident Scenarios. Unlike an oil spill, an accidental release of WST chemicals will quickly dilute and degrade by natural processes. Therefore, even a large release of WST chemicals (which is not reasonably foreseeable) is not be expected to cause a loss of employment, income, and property values; increased traffic congestion; increased cost of public service provision; or possible shortages of commodities or services. There could also be a temporary cessation of oil and gas production at the platform associated with the accidental release and subsequent cleanup. There may be short-term expenditures and an increase in the number of individuals employed if cleanup and remediation activities are required. This would be considered a short-term negligible impact.

Conclusions. Under Alternative 1, the proposed action, **t**he use of fracturing (DFIT, hydraulic fracturing, and acid fracturing) or the non-fracturing WST (matrix acidizing) is not expected to result in socioeconomic impacts. No negligible socioeconomic impacts are expected from any of the accident scenarios considered for Alternative 1, because the accidents have low probabilities of occurrence, and with the exception of a localized crane accident occurring at a platform, are not reasonably foreseeable.

4.5.1.11 Cumulative Impacts

A cumulative impact, as defined by the Council on Environmental Quality, "results from the incremental impact of [an] action when added to other past, present, and reasonably foreseeable future actions, regardless of what agency (Federal or nonfederal) or person undertakes such other actions" (40 CFR 1508.7). Repeated actions, even minor ones, may produce significant impacts over time through additive or interactive (synergistic) processes. The baseline environment for the proposed action (as described in Chapter 3), and the direct and indirect impacts that could result with implementation of any of the WSTs included in Alternative 1 (Sections 4.5.1.1 through 4.5.1.14) account for the past and present actions in the project area. The impacts identified for Alternative 1 are carried forward to the cumulative impact analysis, which also takes into account the effects of other ongoing and reasonably foreseeable future actions and trends.

A variety of past, current, and reasonably foreseeable future activities and actions contribute to cumulative impacts on the natural resources potentially affected by the use of WSTs under the proposed action, including air, water, benthic communities, fish, sea turtles, birds, and marine mammals, and also on socioeconomic and sociocultural conditions, including environmental justice and recreational and commercial fisheries in the potentially affected portions of the POCS. These other activities include, but are not limited to, oil and gas development and production activities in Federal and State waters as well as onshore; runoff from onshore industries, agriculture, transportation (fossil fuel combustion products), urban development, and sewage treatment plant discharges; commercial and recreational fishing; commercial and recreational vessel traffic; and recreation and tourism. Potential effects of these other activities may impact air and water quality, marine and coastal habitats and biota, socioeconomics (including commercial and recreational fisheries, and recreation and tourism), and have environmental justice concerns. In addition, natural phenomena such as certain weather events (e.g., El Niño events), as well as climate change, may also impact resources and socioeconomic/sociocultural conditions on the POCS and adjacent areas. The nature, extent, and magnitude of any of these anthropogenic and non-anthropogenic activities and events will vary widely, depending on the causative activity or event and its location, duration, and magnitude.

Impacting factors associated with WST activities include transport of WST materials and supplies to the platforms (potentially affecting air quality, sea turtles, and marine mammals), WST fluid injection (potentially affecting air quality and geology/seismicity), injection of WST waste fluids (potentially affecting geology/seismicity), discharge of produced water containing WST waste fluids (potentially affecting water quality, benthic resources, marine and coastal fish and EFH, sea turtles, marine and coastal birds, marine mammals, areas of special concern, recreation and tourism, commercial and recreational fisheries, environmental justice, and socioeconomics).

During WST implementation, Alternative 1 would have only negligible, localized, and temporary effects on air quality and water quality. Impacts on air quality, water quality, benthic resources, marine and coastal fish, sea turtles, marine and coastal birds, marine mammals, and recreational and commercial fisheries would be negligible. Although there would be the potential for some marine biota to be exposed within the NPDES mixing zone to very low concentrations of WST-related chemicals and formation-related trace metals, organics, and radionuclides following permitted open-water discharge, such discharges (and associated exposures) would occur infrequently, and would be very localized and of short duration. Exposure levels within the 100-m mixing zones would be highest around discharge locations, while exposure concentrations at the mixing zone boundary would be as much as 2,000 times lower than at the discharge locations due to dilution. There would be no impacts on seismicity, areas of special concern, archaeological resources, recreation and tourism, or socioeconomics. WST use would not impact minority or low income populations. The probability for an accidental release of WST-related chemicals to occur is low, and reasonably foreseeable for only two accident scenarios considered (i.e., during the transfer by crane of WST chemicals from a platform supply vessel to a platform and during injection due to platform equipment malfunction). All other accidental release scenarios were identified to have a very low probability of occurring and to be not reasonably foreseeable. In the event that an accidental release occurs, the release would likely be small and any effects would be limited and short term.

Thus, minor incremental impacts from the implementation of Alternative 1 are not expected to result in any cumulative effects on resources or socioeconomic/sociocultural conditions of the project area.

4.5.2 Alternative 2—Allow Use of WSTs with Depth Stipulation

Under Alternative 2, BSEE technical staff and subject matter experts would continue to review APDs and APMs involving the use of any of the WSTs included in the proposed action and, if determined to be compliant with the performance standards identified in BSEE regulations at 30 CFR 250, subpart D, would be approved. However, applications for fracturing WST use at depths less than 2,000 ft (610 m) below the seafloor would not be approved without further environmental evaluation and review. This limit is intended to reduce the possibility of a surface expression occurring during a fracturing treatment below the already low possibility of such an event occurring under Alternative 1. All other operational aspects and assumptions identified for Alternative 1 would apply to this alternative.

4.5.2.1 WST Operations

The effects of WST operations under Alternative 2 would be the same as those described for Alternative 1, in that the quantity and nature of WST use would be mostly the same. The use of any of the WSTs under this alternative would result in only small or negligible impacts on air quality, water quality, benthic resources, marine and coastal fish, EFH, sea turtles, marine and coastal birds, marine mammals, areas of special concern, archaeological resources, recreation and tourism, or socioeconomics. The use of fracturing WSTs under this alternative is also not expected to increase the potential for induced seismic events. No disproportionate impacts are expected on minority and low-income populations under this alternative.

4.5.2.2 WST-Related Accident Scenarios

As under Alternative 1, there is a low likelihood (i.e., very low probability of occurrence and not reasonably foreseeable) of an accidental seafloor release of crude oil and WST fluids due to subsurface expression under Alternative 2. The likelihood of an accidental seafloor release would be even less than under Alternative 1 due to the depth restriction under Alternative 2. Restricting hydraulic fracturing depths to deeper than 2,000 ft (610 m) would increase the length of any release pathway to the surface, and greater overlying formation and hydrostatic pressures that would occur under Alternative 2 would further act to suppress seafloor surface expression. Thus the potential for exposure to WST-related chemicals and released hydrocarbons due to an accidental seafloor expression would be reduced compared to Alternative 1. It is unlikely, however, that permits would be approved for WST use at shallow depths in areas with a high potential for the presence of existing faults that reach the seafloor or wells under Alternative 1 in the absence of a depth stipulation; therefore, actual differences between the two alternatives would likely be small with respect to the likelihood of a seafloor release during a fracturing WST. Alternative 2 provides an additional safety buffer in the event of an unknown fault or less well-known area.

There would be no differences between Alternative 2 and the proposed action in the potential for, and effects from, surface accidents during collection, platform storage, and pipeline transfer between platforms and to and from onshore processing facilities. Effects of such accidents would depend on the specific factors and characteristics of the accident, as described for Alternative 1.

4.5.2.3 Cumulative Impacts

The actions affecting resources and socioeconomic and sociocultural conditions in the project area, as described in Section 4.5.1.11 for Alternative 1, would continue for Alternative 2. The potential cumulative contribution of Alternative 2 to impacts affecting resources in the area will be similar to those described for Alternative 1, and could be somewhat less due to the reduced potential for an accidental seafloor surface expression with the depth restriction of Alternative 2. The contribution of WSTs to cumulative impacts of Alternative 2 in the region would be the same as identified for Alternative 1. Under Alternative 2, the contributions are considered to be negligible compared to the contributions from other sources that affect resources or socioeconomic and sociocultural conditions in the area.

4.5.3 Alternative 3—Allow Use of WSTs with No Open Ocean Discharge of WST Fluids

Under Alternative 3, APDs and APMs that include the use of any of the four WST types included in the proposed action would continue to be reviewed by BSEE technical staff and subject matter experts, and, if determined to be compliant with the performance standards identified in BSEE regulations at 30 CFR 250, subpart D, would be approved. However, in contrast with Alternatives 1 and 2, under Alternative 3 there would be no open ocean disposal of any fluids containing WST-associated chemicals. This restriction is intended to eliminate all potential impacts associated with the exposure of marine biota and habitats to surface water discharges containing WST constituents, which are currently permitted under NPDES General Permit CAG280000 and be allowed under Alternatives 1 and 2. Open ocean discharge of produced water and other operational fluids, as permitted under the NPDES General Permit would continue under Alternative 3.

4.5.3.1 WST Operations

Under Alternative 3, potential impacts of WST use would be identical to those identified for Alternatives 1 and 2, with one exception. The prohibition of open ocean discharge of WST fluids under Alternative 3 would eliminate exposure to WST chemicals in surface water discharges and any impacts associated with such exposures by benthic resources, marine and coastal fish, EFH, marine and coastal birds, sea turtles, marine mammals, and commercial and recreational fisheries. Such discharges would be allowed under Alternatives 1 and 2 under NPDES General Permit CAG280000.

Some platforms on the Federal OCS currently dispose of produced water via onshore or offshore injection (Table 4-2), and it is assumed that any produced water containing WST-related chemicals would be disposed of in a similar manner. At these platforms, no reduction in potential exposure of marine resources to produced water containing WST chemicals would be expected, while potential impacts identified from other aspects of WST use (e.g., localized and temporary reductions in air quality) for Alternative 1 would also be possible under Alternative 3.

At platforms where disposal of produced water does not involve either onshore or offshore injection (see Table 4-2), the injection of WST-bearing produced water would eliminate the exposure of marine biota and habitats to WST chemicals and any possible toxic effects of such exposures (see Sections 4.1.5.4 to 4.5.1.8). Due to the potential need to drill additional injection wells at these platforms, Alternative 3 may have some impacts that would not occur under Alternatives 1 or 2, namely impacts from the construction of new injection wells. Disturbance of the seafloor from drilling injection wells could temporarily and locally impact water quality and thereby affect benthic resources and fish, either due to sediment disturbance or from the discharge of drill cuttings. Localized disturbance of seafloor habitats for benthic resources and fish would also be expected where new injection wells are drilled. In addition, marine fish, birds, and mammals, as well as sea turtles, could be disturbed by noise during drilling of additional injection wells. Air quality could be temporarily affected from emissions from drilling rigs. Any such impacts associated with drilling new injection wells would be localized and short term, and would not be expected to result in long-term impacts on air or water quality, or on marine habitats and biota. Under Alternative 3, platform operators may incur some additional costs associated with the disposal of WST waste fluids, especially if a new injection well is deemed necessary.

4.5.3.2 WST-Related Accident Scenarios

The restriction against open ocean discharge of any WST-related fluids would not affect the potential for WST-related accidents. The potential likelihood for an accidental release of WST-related chemicals, as well as any associated impacts, would be the same under Alternative 3 as those identified for Alternative 2 for all WSTs.

4.5.3.3 Cumulative Impacts

The actions affecting resources and socioeconomic and sociocultural conditions in the project area, as described in Section 4.5.1.11 for Alternative 1, would continue to affect the project area under Alternative 3. The contribution of WSTs to cumulative impacts of Alternative 3 in the region would be the same as identified for Alternative 1; contributions would be considered negligible compared to the contributions from other sources that affect resources and socioeconomic and sociocultural conditions in the area. However, because there would be no open water discharge of WST-related chemicals and wastes under Alternative 3, there would be a very slight decrease in potential cumulative impacts associated with open water discharge. Although the construction of a small number (if any) of new injection wells would locally impact some resources, any such impacts would be very localized and short term, and not expected to appreciably contribute to impacts incurred by affected resources from other sources. Potential contributions to cumulative impacts from accidental releases would be negligible.

4.5.4 Alternative 4 No Action—No WST Use on Existing OCS Leases

Under the Alternative 4 No Action, none of the WST types identified for the proposed action would be approved for use in any current or future wells on the production platforms associated with the 43 active leases on the POCS. Drilling, production, well workover, and routine maintenance activities on the platforms and their wells would continue under Alternative 4. BSEE technical staff and subject matter experts would continue to review APDs and APMs and, if determined to be compliant with the performance standards identified in BSEE regulations at 30 CFR 250 Subpart D, these would be approved. However, no APDs or APMs that include a WST would be approved.

4.5.4.1 Operations Excluding WSTs

None of the effects on resources identified under Alternative 1, the proposed action, as specifically associated with WST operations, would be expected to occur under Alternative 4. Oil and gas drilling and production activities would continue, including the permitted discharge of produced water and other operational discharges under the NPDES General Permit. The prohibition of WSTs on existing OCS leases would have no effect on the hazard of induced seismicity relative to Alternative 1, because the hazard of induced seismicity associated with the injection of WST-generated fluids is considered to be low already (Section 4.5.1).

Under this alternative, routine oil and gas activities, such as PSV traffic and produced water waste handling and disposal, would continue to occur (as they would under each of the other three alternatives). In addition, the conduct of routine well cleaning operations, and use of enhanced oil recovery treatments (such as steam flooding), would also continue to be reviewed for approval by BSEE technical staff and subject matter experts under this alternative as they would be under the other three alternatives. Routine well cleaning operations include the use of acid or solvent treatments, water blasting, and casing scrape/surge (see Section 2.2.5).

Routine well cleaning operations using acid cleanup treatments have been conducted as needed at wells on the POCS and at wells in State waters (Houseworth and Stringfellow 2015), and there is no evidence of these treatments having resulted in any adverse environmental impacts. Acid washes are conducted on wells in the POCS on average once every other year for a given well (Kaiser 2016). Acid solutions used for routine well cleaning are similar in type (e.g., HCl, HCl-HF) and concentration (typically 15% or lower) to those used in the acid-based WSTs (see Section 2.2.1), although the volume of acid solution used for an acid wash is much less than that used for a WST. The volume used for an acid wash will depend on the length of the interval undergoing the wash, and may range from 5,000 to 10,000 gal (119 to 238 bbl). In contrast, as much as 240,000 gal (5,700 bbl) of acid solution would be used in completing a four-stage acid fracturing or matrix acidizing WST application (60,000 gal [1,430 bbl] per stage). California SB-4 WST regulations call for the calculation of an Acid Volume Threshold (AVT) to distinguish acid matrix stimulation treatments from the routine use of acids (14 CCR §1761), and the volume of acid solution used at a well for an acid wash would be much less than the calculated AVT for that well.

The effects of acid cleanup treatments for well maintenance would be somewhat similar to, but of much lower magnitude than, those for matrix acidizing or acid fracturing, which use much larger volumes of acid. In an acid wash, following injection the acid solution is allowed to remain in place to dissolve wellbore damage, during which time the acid becomes neutralized. Upon return to the surface, the wash-related fluids are managed as specified in the waste management plan and are processed accordingly. Any open-water discharges containing acid wash fluids would need to meet the requirements of the NPDES General Permit before discharge would occur. Because of the small volume of acid solution used for well maintenance, any partially neutralized acid would be fully neutralized when combined and treated with other wastewater, or rapidly diluted and neutralized within the NPDES mixing zone if discharged directly to the ocean. Fluids associated with a solvent wash would be collected, handled, and disposed of in an appropriate manner in accordance with the waste management plan. Any residuals discharged in wastewater would be quickly diluted and would meet the requirements of NPDES-permitted open-water discharge. Acid and solvent washes are conducted about once every other year for any particular well, so discharges of wash-related chemicals would occur infrequently and would be of very short duration. Thus, the use of acid washes for routine well cleanup is not expected to result in any adverse environmental impacts on the POCS.

Solvent washes are also low-volume well cleaning procedures that may occur once every other year at a well. Typically, the solvent wash volume is in the range of 2,500 to 5,000 gal (60 to 119 bbl), depending on the interval length undergoing cleaning. Solvents and other fluids collected during any of the four well maintenance activities are handled in accordance with approved waste management plans for the platforms. Any disposal of any such fluids by open-water discharge would be conducted in compliance with the requirements of the NPDES General Permit for the OCS platforms. Thus, the use of solvent washes for routine well cleanup is not expected to result in any adverse environmental impacts on the POCS.

Water blasting uses a high-pressure spray of filtered seawater to dislodge sand, scale, corrosion particles, built-up sludges, and other materials that may be inhibiting flow of oil into the well. With water blasting, no acid solutions or solvents are used, and the pressure used for blasting is well below that required for formation fracturing. Water volumes for this well cleaning operation may range from 1,000 to 5,000 gal (24 to 119 bbl), depending on the interval length and the specific type of pressure/jet wash being employed (Kaiser 2016). Water blasting operations generate relatively little waste, on the order of a few cubic yards of debris (e.g., sand scale, corrosion particles), and these wastes are collected on the platform and containerized for transport to shore for disposal (Kaiser 2016).

Depending on the type of water blasting being used, wash water containing dislodged deposits may or may not be returned to the surface (i.e., to the platform). If returned, the wash waters are collected and screened to remove solid deposits, which are containerized and then transported to shore for disposal, while the wastewater (primarily seawater) is recycled for additional use in well cleanup operations, or disposed of per the waste management plan. Wash waters not immediately returned would be treated as ordinary well fluids. Ocean discharge of any wastewater would meet NPDES permit requirements. Thus, the use of water blasting for routine well cleanup is not expected to result in any adverse environmental impacts on the POCS.

Casing scrape/surge involves the mechanical removal of scale, corrosion particles, sludge, and other materials without any application of acid solutions or solvents. Relatively little waste (on the order of a few cubic yards of solid debris) is generated, and these wastes are containerized on the platform and transported to shore for disposal. Any wastewater collected during this operation would be handled per the waste management plan, and waste liquids meeting the requirements of the NPDES General Permit could be discharged to the open ocean. Because there is no open-water disposal of solid waste materials, and wastewater would only be discharged if NPDES permit requirements are met, the use of casing scrape/surge for well maintenance is not expected to result in any environmental impacts.

With respect to potential effects other than those related to routine well maintenance operations, under Alternative 4, there would be no disproportionate effects on minority and low-income populations related to the prohibition of WST use on the POCS. However, a prohibition of offshore WST use may lead to additional onshore use of WSTs, which could have adverse environmental justice impacts (Aspen Environmental Group 2015).

Potential WST-related socioeconomic impacts for Alternative 4 would be associated with the potential closure of wells that become unproductive and could benefit from the implementation of a WST (i.e., WST use may prolong oil production), but are prohibited from doing so. This could lead to drilling of additional wells offshore and/or onshore, earlier-than-expected decommissioning of platforms, and/or increased importation of oil and gas from elsewhere in the United States or from foreign sources. These would have potentially major economic consequences that are beyond the scope of this PEA. However, an earlier-than-expected closure of wells and platform decommissioning is not expected in the foreseeable future.

4.5.4.2 Accident Scenarios Excluding WSTs

None of the WST-related accident scenarios identified for Alternative 1 would be expected under Alternative 4, and thus none of the potential WST accident-specific effects on resources identified under Alternative 1 would be expected to occur under Alternative 4. As for anticipated accidental releases during the transfer of acids from PSVs to the platforms or on platforms during WSTs, which are considered reasonably foreseeable but unlikely (see Section 4.3), similar reasonably foreseeable but unlikely accidental releases of acids and solvents could occur during acid and solvent wash well cleaning operations. Such releases may affect water quality as well as marine biota in the immediate vicinity of the release. However, any accidental releases would be of much smaller volumes than those of accidental releases associated with WSTs. In the event of an accidental release during an acid or solvent wash operation, the release would be of small volume and duration, would be quickly diluted, and thus would result in negligible impacts.

4.5.4.3 Cumulative Impacts

The actions affecting resources and socioeconomic and sociocultural conditions in the project area, as described in Section 4.5.1.11 for Alternative 1, would continue to affect the project area under Alternative 4. There would be no potential direct cumulative contribution of WSTs under Alternative 4 because there would be no WST use. If no WSTs are allowed, the possibility exists that the lifespan of the existing offshore oil wells on the POCS may be shortened (although not in the foreseeable future), and the maximum practical production of oil and gas from the reservoirs under the OCS would be less.

Assuming that the level of oil and gas consumption does not change, implementation of Alternative 4 may lead to the drilling and production of new wells offshore and/or onshore, increase WST use at onshore wells, and/or increase the need to import more gas and oil. These could all increase environmental and societal cumulative impacts. For example, increased use of WSTs at onshore sites may have environmental justice impacts and increase the potential for induced seismicity hazards (Aspen Environmental Group 2015). The prohibition on the use of the WSTs under Alternative 4 may also increase domestic production of electricity using generation alternatives such as coal or alternative energy (e.g., solar and wind). However, none of the potential scenarios described above are considered reasonably foreseeable outcomes of the implementation of Alternative 4, and consequently do not contribute to the analysis of environmental impacts in this environmental assessment.

4.6 SUMMARY OF ENVIRONMENTAL EFFECTS

The use of WSTs at platforms on the Federal OCS has the potential to affect a variety of resources. Given the type and the expected frequency of use of WST activities that are reasonably foreseeable for the Federal OCS, none of the three action alternatives are expected to result in adverse impacts on the environment (Table 4-23). While an accidental release of WST chemicals during conduct of a WST may also affect a variety of resources, all three alternatives have a similarly low and not reasonably foreseeable potential for the accidental releases of WST-related chemicals (Table 4-24). During WST implementation, Alternatives 1–3 would have only very small, localized, and temporary effects on air and water quality, while Alternatives 1 and 2 also have the potential for some marine biota to be exposed to highly diluted concentrations of WST chemicals in the NPDES mixing zones of platforms following NPDES-permitted open water discharge. Additional localized and temporary impacts on air and water quality, marine biota, and archaeological resources could be incurred under Alternative 3 (Table 4-23). These additional impacts would be associated with the construction of any new injection wells that may be needed as a result of the prohibition of open water discharge of produced water containing WST-related chemicals. Overall, there are relatively few differences among the action alternatives (or between fracturing and non-fracturing WSTs) regarding the nature and magnitude of the environmental effects (Table 4-23), which remain small under any of the action alternatives.

Under Alternative 3, there would be no open water discharge of WST waste fluids. As a result, operators at platforms may have to install offshore injection wells in order to dispose of any produced water containing WST chemicals or waste fluids. Such activities would include localized, temporary bottom-disturbing activities. Well drilling would disturb seafloor habitats, potentially affect seafloor archaeological artifacts, reduce overlying water quality, and disturb local biota. The operation of associated surface support vessels and equipment would result in increased air emissions and also disturb local biota. Platform operators would also incur additional costs with any new injection well construction.

None of the potential effects associated with WST use (including waste disposal) identified for Alternatives 1–3 would be expected under Alternative 4. In contrast to Alternatives 1–3, Alternative 4 may have economic effects associated with the decommissioning of wells that become unproductive in the absence of WST use.

Because WSTs on the OCS would be conducted in accordance with all BSEE, BOEM, and other regulatory agency rules and regulations dealing with safety and spill response, the probability for an accidental release to occur is low and reasonably foreseeable for only a single accident scenario considered in this PEA (i.e., during the transfer by crane of WST chemicals from a PSV to a platform). All other accident scenarios were identified to have a low or very low probability of occurring and not reasonably foreseeable. With regard to reducing the likelihood of a WST-related accident occurring, there is relatively little difference among the three action alternatives (Table 4-24). However, Alternative 2 differs from the other WST alternatives with regard to reducing the risk of an accidental seafloor surface expression during WST fluid injection. The depth stipulation of this alternative may even further decrease the likelihood of a surface expression of hydrocarbons should a fracture contact an existing pathway (e.g., a surface

1 **TABLE 4-23 Summary Comparison of Potential Effects among Alternatives[a]**

Resource	Alternative 1 Proposed Action – Allow Use of WSTs	Alternative 2 – Allow Use of WSTs with Depth Stipulation	Alternative 3 – Allow Use of WSTs with No Open Water Discharge of WST Fluids	Alternative 4 – No WST Use on Existing OCS Leases
Air quality	No noticeable WST-related impacts on regional air quality expected. Negligible emissions of greenhouse gases.	Same as Alternative 1.	Same as Alternative 1. Additional temporary and localized air emissions if new injection well construction occurs.	No WST-related impacts.
Water quality	No WST-related impacts expected; although slight localized reduction in water quality at surface water discharge location.	Same as Alternative 1.	Similar to Alternative 1, but no reductions in water quality from WST chemicals in discharges to surface water. Temporary and localized reduction in water quality if new injection well construction occurs.	No WST-related impacts.
Induced seismicity	Very low or negligible potential for induced seismicity.	Same as Alternative 1.	Same as Alternative 1.	Same as Alternative 1.
Benthic resources	No WST-related impacts expected.	Same as Alternative 1.	Same as Alternative 1. Localized and temporary benthic habitat disturbance likely if new injection well construction occurs.	No WST-related impacts.
Marine and coastal fish; sea turtles, marine and coastal birds, marine mammals	No WST-related impacts expected; potential for subtle toxic effects in some species from some WST chemicals occurring within the NPDES discharge mixing zone from discharges of WST waste fluids to surface water.	Same as Alternative 1.	Similar to Alternative 1, but with no potential for exposure to WST chemicals in discharges to surface water. Localized and temporary habitat disturbance and/or displacement of individuals likely if new injection well construction occurs.	No WST-related impacts.

2

TABLE 4-23 (Cont.)

Resource	Alternative 1 Proposed Action – Allow Use of WSTs	Alternative 2 – Allow Use of WSTs with Depth Stipulation	Alternative 3 – Allow Use of WSTs with No Open Water Discharge of WST Fluids	Alternative 4 – No WST Use on Existing OCS Leases
Commercial and recreational fisheries	No WST-related impacts expected.	Same as Alternative 1.	Same as Alternative 1. Localized and temporary habitat disturbance and/or displacement of individuals likely if new injection well construction occurs.	No WST-related impacts.
Areas of special concern, recreation and tourism, archaeological resources, environmental justice	No WST-related impacts expected.	Same as Alternative 1.	Same as Alternative 1. Localized and temporary habitat disturbance and/or displacement of individuals likely if new injection well construction occurs.	No WST-related impacts.
Socioeconomics	No WST-related impacts or benefits expected.	Same as Alternative 1.	Same as Alternative 1. Platform operators may incur additional costs if new injection wells are needed.	No WST-related impacts. Decommissioning costs may be incurred at some wells that become unproductive in the absence of WST use.

[a] A comparison of the likelihood of various accidents under the alternatives is provided in Table 4-24.

TABLE 4-24 Comparison of Likelihood of Occurrence of WST-Related Accidents among Alternatives

	Likelihood			
Accident	Alternative 1 Proposed Action – Allow Use of WSTs	Alternative 2 – Allow Use of WSTs with Depth Stipulation	Alternative 3 – Allow Use of WSTs with No Open Water Discharge of WST Fluids	Alternative 4 – No WST Use on Existing OCS Leases
WST chemical release during transport following loss of transport container integrity	Applicable to all four WST types. Very low probability and not reasonably foreseeable.	Same as Alternative 1.	Same as Alternative 1.	Will not occur.
WST chemical release during crane transfer	Applicable to all four WST types. Low probability and reasonably foreseeable.	Same as Alternative 1.	Same as Alternative 1.	Will not occur.
WST chemical release during injection from platform equipment malfunction	Applicable to all four WST types. Low probability and reasonably foreseeable.	Same as Alternative 1.	Same as Alternative 1.	Will not occur.
Seafloor expression of WST chemicals due to well casing failure	Applicable only to fracturing WSTs. Very low probability and not reasonably foreseeable.	Same as Alternative 1.	Same as Alternative 1.	Will not occur.
Seafloor expression of WST chemicals due to fracture intercept with existing surface pathway	Applicable only to fracturing WSTs. Very low probability and not reasonably foreseeable.	Reduced probability compared to Alternative 1.	Same as Alternative 1.	Will not occur.
Release of WST chemicals due to rupture of pipeline conveying produced water containing WST chemicals	Applicable to all WSTs. Very low probability and not reasonably foreseeable.	Same as Alternative 1.	Same as Alternative 1.	Will not occur.

fault) to the surface. Such a seafloor expression is considered to be a very low probability event and not reasonably foreseeable under any of the action alternatives to begin with, and even less so under Alternative 2 (Table 4-24). None of the WST-related accident scenarios could be realized under Alternative 4.

In conclusion, neither the proposed action nor any of the action alternatives are expected to result in more than short-term, localized impacts on the environment. Potential impacts of WST use would be similar in nature and magnitude among the action alternatives, although Alternative 3 would reduce potential exposure of marine biota to WST-related chemicals in surface water. Compared to the other action alternatives, Alternative 3 would also have some additional localized and temporary impacts should construction of new injection wells be needed for disposal of produced water containing WST-related chemicals. With the exception of a crane accident resulting in the release of WST chemicals at a platform, the other accident scenarios that could result in the release of WST chemicals are considered to be unlikely and not reasonably foreseeable for the three action alternatives, while Alternative 2 has the potential to further reduce the already very low likelihood of an accidental release of WST chemical via a seafloor surface expression.

4.7 REFERENCES

API (American Petroleum Institute), 2014, *Acidizing Treatment in Oil and Gas Operations*.

Applied Ocean Science, 2004, *Produced Water Discharge Plumes from Pacific Offshore Oil and Gas Platforms*, prepared for the Mineral Management Service, POCS Region, Feb.

ARB (Air Resource Board), 2015, *Emission Inventory Data*, California Environmental Protection Agency. Available at http://www.arb.ca.gov/ei/emissiondata.htm. Accessed May 18, 2015.

Aspen Environmental Group, 2015*, Draft Environmental Impact Report Analysis of Oil and Gas Well Stimulation Treatments in California*, State Clearinghouse No. 2013112046, prepared for California Department of Conservation, Jan.

Bittner, J.E., 1996, "Cultural Resources and the *Exxon-Valdez* Oil Spill: An Overview," in *Proceedings of the* Exxon-Valdez *Oil Spill Symposium*. American Fisheries Society Symposium 18:814–818.

BOEM (Bureau of Ocean Energy Management), 2012, *Gulf of Mexico OCS Oil and Gas Lease Sales: 2012-2017; Western Planning Area Lease Sales 229, 233, 238, 246, and 248; Central Planning Area Lease Sales 227, 231, 235, 241, and 247. Final Environmental Impact Statement*, OCS EIS/EA BOEM 2012-019, Gulf of Mexico OCS Region, New Orleans, LA, July.

BOEM, 2015a, *Offshore Oil and Gas Wells*. Available at http://www.boem.gov/Oil-and-Gas-Energy-Program/Mapping-and-Data/Pacific.aspx.

BOEM, 2015b, *Pacific Region Facts and Figures*. Available at http://www.boem.gov/BOEM-Newsroom/Offshore-Stats-and-Facts/Pacific-Facts-and-Figures.aspx. Accessed July 24, 2015.

BSEE (Bureau of Safety and Environmental Enforcement), 2014, *POCSR Production and Development Statistics 2013*, July.

BSEE and BOEM (Bureau of Safety and Environmental Enforcement and Bureau of Ocean Energy Management), 2014, *Map and Infrastructure Information for the Pacific OCS*. Available at: http://www.boem.gov/pacific-ocs-map.

CCST (California Council on Science and Technology), 2014, *Advanced Well Stimulation Technologies in California: An Independent Review of Scientific and Technical Information*, Aug. 28.

CCST, 2015a, *An Independent Scientific Assessment of Well Stimulation in California, Volume I. Well Stimulation Technologies and their Past, Present, and Potential Future Use in California*, Sacramento, CA, Jan.

CCST, 2015b, *An Independent Scientific Assessment of Well Stimulation in California: Volume II. Potential Environmental Impacts of Hydraulic Fracturing and Acid Stimulations*, July.

CCST, 2015c, *An Independent Scientific Assessment of Well Stimulation in California, Volume III. Case Studies of Hydraulic Fracturing and Acid Stimulations in Select Regions: Offshore, Monterey Formation, Los Angeles Basin, and San Joaquin Basin*, Sacramento, CA, July.

Claisse, J.T., D.J. Pondella II, M. Love, L.A. Zahn, C.M. Williams, J.P. Williams, and A.S. Bull, 2014, "Oil Platforms off California Are among the Most Productive Marine Fish Habitats Globally," *Proceedings of the National Academy of Sciences*.

Continental Shelf Associates, 1997, *Gulf of Mexico Produced Water Bioaccumulation Study Executive Summaries*, prepared for Offshore Operators Committee, New Orleans, LA, April. Available at http://www.deq.louisiana.gov/portal/Portals/0/permits/lpdes/pdf/EPA%20Executive%20Summaries.pdf. Accessed Aug. 4, 2015.

Detwiler, S., 2013, *2007 Oil and Gas Industry Survey Results Final Report (Revised),* California Environmental Protection Agency, Air Resources Board, Sacramento, CA. Available at http://www.arb.ca.gov/cc/oil-gas/FinalReportRevised.pdf.

DOGGR (Division of Oil, Gas, and Geothermal Energy), 2015, *Environmental Impact Report: Analysis of Oil and Gas Well Stimulation Treatments in California*, California Department of Conservation, Sacramento, CA. Available at: http://www.conservation.ca.gov/dog/SB4DEIR/Pages/SB4_DEIR_TOC.aspx.

DOGGR, 2015, *Online Production and Injection Query*, California Department of Conservation, Sacramento, CA. Available at http://opi.consrv.ca.gov/opi/opi.dll/Search?UsrP_ID=100175545&FormStack=Main%2CField&Fld__Code=849&Action=%3C%3C+Back++&PriorState=Encoded%3DTrue.

EIA (U.S. Energy Information Administration), 2015, *Energy Related Carbon Dioxide Emissions at the State Level, 2000-2013*, U.S. Department of Energy, Washington DC. Available at http://www.eia.gov/environment/emissions/state/analysis/pdf/stateanalysis.pdf.

EPA (U.S. Environmental Protection Agency), 1995, *Short-term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to West Coast Marine and Estuarine Organisms*, EPA/600/R-95-136, Aug.

EPA, 2013a, *Authorization to Discharge under the National Pollutant Discharge Elimination System for Oil and Gas Exploration, Development, and Production Facilities*, General Permit No. CAG280000 0, Dec. 20.

EPA, 2013b, *Addendum to Fact Sheet, Final NPDES Permit No. CAG280000 0 for Offshore Oil and Gas Exploration, Development and Production Operations off Southern California*.

EPA, 2013c, *Response to Public Comments Reissuance of National Pollutant Elimination System (NPDES) General Permit No. CAG280000 for Offshore Oil and Gas Exploration, Development and Production Operations off Southern California*, Dec. 11. Available at http://www.epa.gov/region9/water/npdes/pdf/ca/offshore/response-public-comments.pdf. Accessed July 26, 2015.

EPA, 2015, *Analysis of Hydraulic Fracturing Fluid Data from the FracFocus Chemical Disclosure Registry 1.0. Office of Research and Development*, EPA/601/R-14/003, Washington, DC.

EPA, 2016, Harmony Platform, OCS-P-0190, NPDES General Permit No. CAG280000, Discharge Monitoring Report for fourth quarter 2014, dated Jan 26, 2015; and second quarter 2015, dated July 28, 2015, submitted by ExxonMobil Production Company to EPA, Region 9.

Gale, R.W., M.J. Tanner, M.S. Love, M.M. Nishimoto, and D.M. Schroeder, 2012, *Comparison of Concentrations and Profiles of Polycyclic Aromatic Hydrocarbon Metabolites in Bile of Fishes from Offshore Oil Platforms and Natural Reefs along the California Coast*, Open-File Report 2012–1248, U.S. Department of the Interior, U.S. Geological Survey.

Gale, R.W., Tanner, M.J., Love, M.S., Nishimoto, M.M., and Schroeder, D.M., 2013, *Comparison of Aliphatic Hydrocarbons, Polycyclic Aromatic Hydrocarbons, Polychlorinated Biphenyls, Polybrominated Diphenylethers, and Organochlorine Pesticides in Pacific Sanddab (*Citharichthys sordidus*) from Offshore Oil Platforms and Natural Reefs along the California Coast*, Open-File Report 2013–1046, U.S. Geological Survey.

Harbor Safety Committee, 2014, "Minutes of the 148th Meeting of the LA/LB Harbor Safety Committee, Wednesday, February 2014." Maritime Exchange of Southern California, San Pedro, CA.

Hauksson, E., T. Göbel, J.-P. Ampuero, and E. Cochran, 2015, "A Century of Oil-field Operations and Earthquakes in the Greater Los Angeles Basin, Southern California," *The Leading Edge* 34(6):650–652, 654–656. Available at http://library.seg.org/doi/abs/10.1190/tle34060650.1. Accessed May 6, 2016.

Houseworth, J., and W. Stringfellow, 2015, "A Case Study of California Offshore Petroleum Production, Well Stimulation, and Associated Environmental Impacts," Chapter 2 in *An Independent Scientific Assessment of Well Stimulation in California, Volume III*, California Council on Science and Technology.

Hudgins, C.M., Jr., 1991, *Chemical Treatments and Usage in Offshore Oil and Gas Production Systems*, paper OTC 6528, presented at the 23rd Annual Offshore Technology Conference, Houston, Texas, May 6–9.

Kaplan, B., C.J. Beegle-Krause, D. French McCay, A. Copping, and S. Geerlofs (eds.), 2010, *Updated Summary of Knowledge: Selected Areas of the Pacific Coast*, OCS Study BOEMRE 2010-014, U.S. Dept. of the Interior, Bureau of Ocean Energy Management, Regulation, and Enforcement, Pacific OCS Region, Camarillo, CA.

Kaiser, J., 2015, personal communication, *Unpublished crane incidence reports, 2006 – 2015*, from J. Kaiser, Acting District Manager California District, Well Operations Lead, to I. Hlohowskyj, Argonne National Laboratory; December 15.

Kaiser, J., 2016, personal communication from J. Kaiser (Acting BSEE District Manager, Bureau of Safety and Environmental Enforcement, POCS Region, Camarillo, CA), to I. Hlohowskyj (Argonne National Laboratory, Argonne, IL), Jan. 15.

Litovitz, A., A. Curtright, S. Abramzon, N. Burger, and C. Samaras, 2013, "Estimation of Regional Air-quality Damages from Marcellus Shale Natural Gas Extraction in Pennsylvania," *Environ. Res. Lett.* 8:014017. DOI:10.1088/1748-9326/8/1/014017.

Long, J.C.S., L.C. Feinstein, J. Birkholzer, P. Jordan, J. Houseworth, P.F. Dobson, M. Heberger, and D.L. Gautier, 2015a, *An Independent Scientific Assessment of Well Stimulation in California, Volume I, Well Stimulation Technologies and Their Past, Present, and Potential Future Use in California*, California Council on Science and Technology, Sacramento, CA, Jan. Available at http://ccst.us/publications/2015/2015SB-v1.pdf. Accessed Aug. 21, 2015.

Long, J.C.S., et al., 2015b, *An Independent Scientific Assessment of Well Stimulation in California, Volume II, Potential Environmental Impacts of Hydraulic Fracturing and Acid Stimulations*, California Council on Science and Technology, Sacramento, CA, Jan. Available at http://ccst.us/publications/2015/2015SB-v2.pdf. Accessed Aug. 21, 2015.

Love, M.S., and S.R. Goldberg, 2009, "A Histological Examination of the Ovaries of Pacific Sanddab, *Citharichthys sordidus*, Captured at Two Oil Platforms and Two Natural Sites in the Southern California Bight," *Bulletin of the Southern California Academy of Sciences* 108(2), Article 1. Available at http://scholar.oxy.edu/scas/vol108/iss2/1.

Love, M.S., and A. York, 2005, "A Comparison of the Fish Assemblages Associated with an Oil/Gas Pipeline and Adjacent Seafloor in the Santa Barbara Channel, Southern California Bight," *Bulletin of Marine Science* 77:101–118.

Love, M.S., D.M. Schroeder, and M.M. Nishimoto, 2003, *The Ecological Role of Oil and Gas Production Platforms and Natural Outcrops on Fishes in Southern and Central California: A Synthesis of Information*, MMS 2003-032, OCS Study.

Love, M.S., M.K. Saiki, T.W. May, and J.L. Yee, 2013, "Whole-body Concentrations of Elements in Three Fish Species from Offshore Oil Platforms and Natural Areas in the Southern California Bight, USA," *Bulletin of Marine Science* 89(3):717–734. Available at http://dx.doi.org/10.5343/bms.2012.1078.

Neff, J., K. Lee, and E.M. DeBlois, 2011, "Produced Water: Overview of Composition, Fates, and Effects," pp 3–54 in *Produced Water Environmental Risks and Advances in Mitigation Technologies*, K. Lee and J. Neff (eds.), Springer, New York.

Osenberg, C.W., R.J. Schmitt, S.J. Holbrook, and D. Canestro, 1992, "Spatial Scale of Ecological Effects Associated with an Open Coast Discharge of Produced Water," pp. 387–402 in *Produced Water: Technological/Environmental Issues and Solutions*, Plenum Press, NY.

Petersen, M.D., C.S. Mueller, M.P. Moschetti, S.M. Hoover, A.L. Llenos, W.L. Ellsworth, A.J. Michael, J.L. Rubinstein, A.F. McGarr, and K.S. Rukstales, 2016, *2016 One-year Seismic Hazard Forecast for the Central and Eastern United States from Induced and Natural Earthquakes*, Open-File Report 2016–1035, U.S. Geological Survey. Available at http://pubs.usgs.gov/of/2016/1035/ofr20161035.pdf. Accessed May 6, 2016.

Reger, D., D. Corbett, A. Steffian, P. Saltonstall, T. Birkedal, and L. Yarborough, 2000, *Archaeological Index Site Monitoring: Final Report, Exxon Valdez Oil Spill Restoration Project Final Report (Restoration Project 99007A)*, Alaska Department of Natural Resources, Anchorage, AK. Available at http://dnr.alaska.gov/commis/evos2/documents/99007a.pdf. Accessed March 23, 2012.

Reilly, S.B., J.L. Bannister, P.B. Best, M. Brown, R.L. Brownell, Jr., D.S. Butterworth, P.J. Clapham, J. Cooke, G.P. Donovan, J. Urbán, and A.N. Zerbini, 2008, "*Eubalaena japonica* (North Pacific Right Whale)," *The IUCN List of Threatened Species*. Available at http://www.iucnredlist.org/details/41711/0. Accessed Sept. 27, 2015.

Rodriguez, G., and C. Ouyang, 2013, *Air Emissions Characterization and Management For Natural Gas Hydraulic Fracturing Operations In the United States*, University of Michigan, School of Natural Resources and Environment, Master's Project Report, Apr. Available at http://deepblue.lib.umich.edu/bitstream/handle/2027.42/97418/Air Emissions Hydraulic Fracturing_04-23-2013.pdf?sequence=1.

Sigma-Aldridge 2015a, Safety Data Sheet, 2-butoxyethanol, July 22. Available at http://www.sigmaaldrich.com/catalog/search?term=111-76-2&interface=CAS%20No.&N=0+&mode=partialmax&lang=en&region=US&focus=product. Accessed April 30, 2016.

Sigma-Aldridge 2015b, Safety Data Sheet, formic acid, August 25. Available at http://www.sigmaaldrich.com/catalog/search?term=64-18-6&interface=CAS%20No.&N=0+&mode=partialmax&lang=en&region=US&focus=product. Accessed April 30, 2016.

Sigma-Aldridge 2015c, Safety Data Sheet, nitrilotriacetic acid, December 28. Available at http://www.sigmaaldrich.com/catalog/search?term=139-13-9&interface=CAS%20No.&N=0+&mode=partialmax&lang=en&region=US&focus=product. Accessed April 30, 2016.

Stringfellow, W.T., H. Cooley, C. Varadharajan, M. Heberger, M.T. Reagan, J.K. Doman, W. Sandelin, M.K. Camarillo, P.D. Jordan, K. Donnelly, S.C.T Nicklisch, A. Hamdoun, and J.E. Houseworth, 2015, "Impacts of Well Stimulation on Water Resources," Chapter 2 in *An Independent Scientific Assessment of Well Stimulation in California: Volume II. Potential Environmental Impacts of Hydraulic Fracturing and Acid Stimulations*, California Council on Science and Technology.

USCG (U.S. Coast Guard), 2015, *Incident Investigation Reports*, USCG Maritime Information Exchange. Available at https://cgmix.uscg.mil/IIR/IIRSearch.aspx.

Walsh, F.R., III, and M.D. Zoback, 2015, "Oklahoma's Recent Earthquakes and Saltwater Disposal," *Science Advances*, 1(5):e1500195. DOI: 10.1126/sciadv.1500195.