APPENDIX A:

DECOMMISSIONING ACTIVITIES AND METHODS THAT COULD BE EMPLOYED UNDER THE PROPOSED ACTION

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APPENDIX A:

DECOMMISSIONING ACTIVITIES AND METHODS THAT COULD BE EMPLOYED UNDER THE PROPOSED ACTION

A.1 PROCESS

In general, the West Coast hosts the vendors, marine and oil industry assets, and expertise to perform many aspects of platform decommissioning, including:

- Dive companies;
- Derrick and cargo barges;
- Waste handling providers;
- Oil industry trades;
- Well plug-and-abandonment (P&A) expertise;
- Platform logistics support;
- Marine growth removal capability;
- Marine crane and transport capability; and
- Onshore port facilities.

Depending on how platform decommissioning is planned and implemented, the lift and transit capacity of the marine and onshore assets available on the West Coast may need to be augmented with additional assets such as Gulf of Mexico (GOM)-based heavy lift vessels and GOM port facilities. For example, dissembled platform components exceeding the lift capacity of West Coast ports would need to be transported via the Panama Canal to GOM port facilities for processing (InterAct PMTI 2020a).

While as many as eight platforms may be decommissioned on the POCS within the next 10 years (or almost 1 per year on average), in the GOM a two-year minimum is generally accepted by industry experts to decommission a platform (considering all the factors and moving parts involved) (Pipe Exchange 2021). Platform decommissioning of all platforms in the Pacific Outer Continental Shelf (POCS) may take several decades. Alternative technologies for each step in the decommissioning process described below will likely be developed over the extended life cycle of platform decommissioning. Advances in remote operated submersibles; mechanical shearing and cold cutting methods, for example, could speed up decommissioning.

For the purposes of this Programmatic Environmental Impact Statement (PEIS), it is assumed that decommissioning under the Proposed Action would follow a three-phased approach, as is typically followed for platform decommissioning in the GOM. The first phase (‘pre-severance’) includes the onsite mobilization of lift and support vessels, specialized lifting equipment, and the load barges necessary to receive the salvaged structure. Activities would also include those needed to prepare the target platform for severance (e.g., structure surveys; equipment shutdown, cleaning, and removal; topside and jacket bracing).

Once the pre-severance activities are completed, the next phase (‘severance’) would be initiated. Specialized contractors would deploy any of a variety of tools to cut the platform infrastructure into sections that can be safely lifted within lifting vessel capabilities and transported within cargo barge carrying capacities.

Both the pre-severance and severance phases may include a number of activities to support the actual severance of the platforms. For example, lifting pad eyes may need to be installed on sections to be severed; pipes would need be flushed, cut, and capped to prevent any residual fluid release; electrical lines would be severed; and temporary lighting and power would be required. These tasks would require a significant commitment of personnel, including crane operators, inspectors for cranes and welds, electricians, scaffolding crews, engineers, project managers, catering crews, welders, crews for boats, safety representatives, and other operations personnel.

The final phase of decommissioning (‘disposal’) consists of the lifting and loading of the severed infrastructure onto barges or other transport vessels and would be conducted concurrently with the severance phase. Once loaded onto the barges, topside materials would be transported to land-based facilities for processing, salvage (i.e., reuse, scrapping, etc.), and/or land disposal in licensed disposal sites. Severed jackets would either be transported to port for processing, salvage, and/or disposal, or be used to create artificial reefs under the Bureau of Safety and Environmental Enforcement (BSEE) and State of California Rigs-to-Reef program. Upon completion of all removal or abandonment activities, trawling and/or sonar work would be conducted in support of final site-clearance and verification, per the requirements at 30 CFR 250 Subpart Q §§ 250.1740-250.1743.

A.1.1 Pre-severance

As required under 30 CFR §250.1727, applications for platform decommissioning must include a description of the structure being removed, including descriptions of:

- Platform configuration and size;
- The number of platform legs/casings/pilings;
- The diameter and wall thickness of the platform legs/casings/pilings;
- Whether the piles are grouted inside or outside;
- A brief description of the subseafloor composition and condition;
- The sizes and weights of the jacket, topsides (by module), conductors, and pilings; and
- The maximum removal lift weight and estimated number of main lifts needed to remove the structure.

Surveys would be performed to determine structure integrity of the platform and to identify any modifications that must be made for platform decommissioning. Engineering analyses would be conducted to determine platform preparation needs, platform removal methods and transportation needs, and the activities and equipment needed for power cable and pipeline decommissioning. These engineering analyses would include reviews of:

- As-built drawings[1];
- All platform construction reports;
- All platform, pipeline, and power cable maintenance records; and
- All past platform inspection reports.

A.1.1.1 Infrastructure to be Decommissioned

Platforms. The 23 platforms on the POCS are considered fixed platforms, being constructed on concrete or steel legs that are anchored into the seabed. The platforms have from 3 to 12 legs that are anchored with piles[2] driven through the legs (referred to as main piles). Some platforms have piles that are driven into the seafloor through external skirt pile guides (referred to as skirt piles). Platforms can be constructed with main piles only, or a combination of main and skirt piles. Platform Eureka is constructed with skirt piles only (Table A-1) The platform legs are connected with vertical, horizontal, and diagonal sections made of tubular steel members (i.e., the “jacket”), some of which are also piled into the seabed.

TABLE A-1 Number of Main and Skirt Piles Associated with the POCS Platforms

Platform Name	Number of Main Piles	Number of Skirt Piles	Platform Name	Number of Main Piles	Number of Skirt Piles
Hogan	12	-[a]	Henry	6	-
Houchin	8	-	Hillhouse	8	-
Habitat	8	-	Gina	6	-
Irene	8	-	Gilda	12	-
Grace	12	8	Edith	12	24
Gail	8	12	Elly	12	-
Harvest	8	20	Ellen	8	-
Hermosa	8	20	Eureka	24	-
Hidalgo	8	8	Hondo	8	12
A	12	-	Heritage	8	26
B	12	-	Harmony	8	20
C	12	-			

Source: InterAct PMTI (2020).

[a] ‘-‘ indicates not applicable.

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[1] Generally understood to be the drawings of what was actually built. A set of drawings that are marked-up to document the original design of a project and notations to indicate any changes to the design when the project is constructed.

[2] A pile is column of timber, reinforced concrete, steel, steel pipe or steel-concrete composite that is driven into the ground. In the case of the POCS, piles are used to both fix a platform to the seabed and to provide structural strength to support the platform.

The deepest platforms in the POCS typically have several topside working decks, including: a wellhead deck, a production deck, a sump deck, a main deck, and helideck (Figure A-1). The decks contain a variety of structures and equipment needed for oil and gas production, including power generation; crew accommodations; operational control; service (e.g., heating, air compressor, control equipment, etc.); fueling systems; cranes, drilling equipment, oil and gas processing equipment; pig launching etc. (ABBB 2015). For example, Platform Grace currently has four operating decks, a jacket walkway near sea level, crew boat landings, two cranes, a control room, a galley, and personnel accommodations. This platform is supported by twelve 42-in. (1-m) diameter main piles and eight 48-in. (1.2-m) diameter skirt piles (Padre Associates 2020). All the POCS platforms have two cranes, except for Platform Irene, which has a single crane. Whether or not the cranes can be used for decommissioning activities is uncertain.

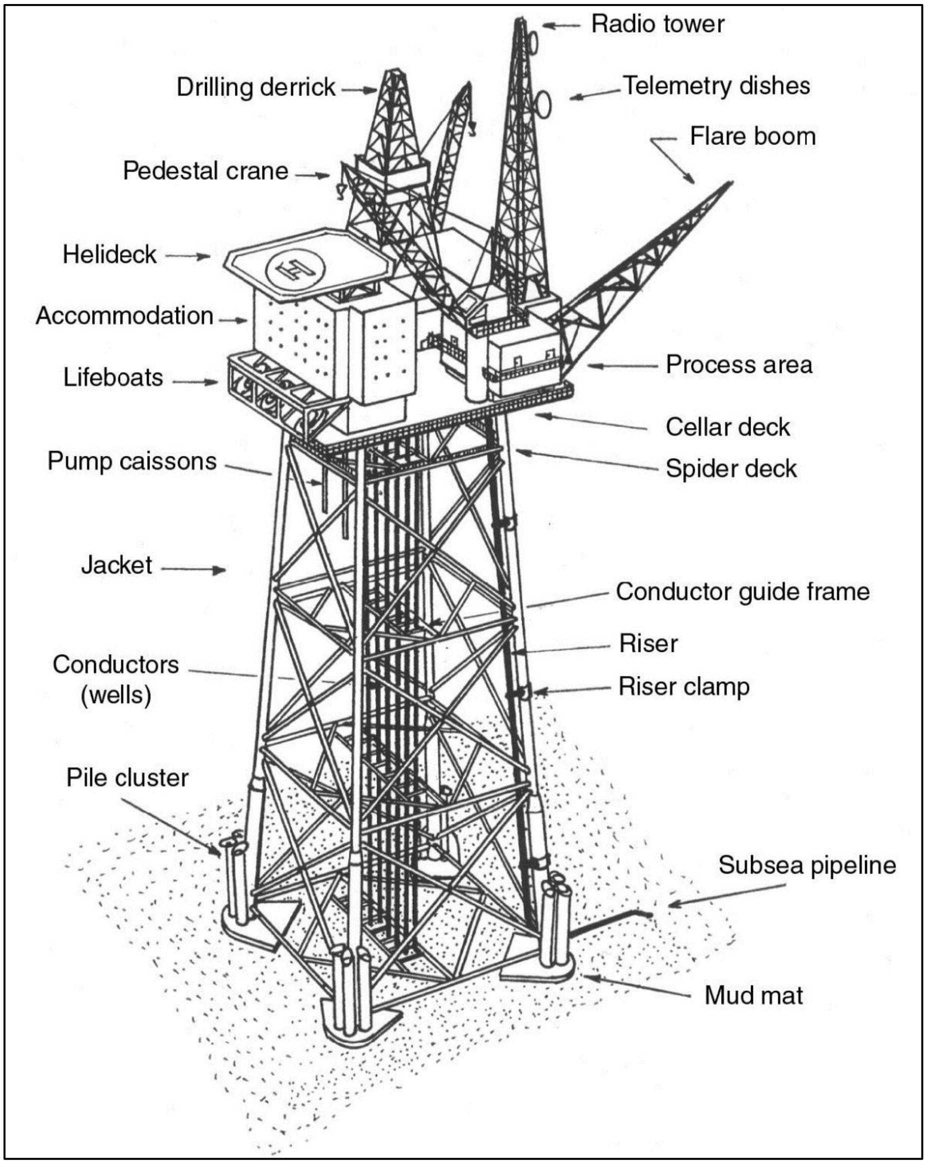

FIGURE A-1 Generalized POCS platform. (Source: PetroWiki 2015a.)

Pipelines and Power Cables. Most of the POCS platforms have subsea power cables that either connect to other nearby platforms or connect to onshore generation sources. Specifications for power cables are summarized in Table A-2. Pipelines are used to transport a variety of products, including water, oil/water mixtures and gas from the platforms to onshore processing facilities. In some locations, pipelines originating at a specific platform connect to a nearby platform where the pipeline contents are added to a different pipeline that then connects to an onshore processing facility. Among the platforms, pipeline lengths vary widely, ranging in length from 792 to 24,000 m (2,600 to 80,000 ft). Table A-3 summarizes the POCS pipeline specifications.

TABLE A-2 Power Cable Origin, Terminus, Length, and Water Depth

Platform of Cable Origin	Cable Terminus	Length m (ft)	Depth m (ft)	Platform of Cable Origin	Cable Terminus	Length, m (ft)	Depth, m (ft)
A	B	805 (2,640)	57–61 (188–200)	Harmony	Shore (2)	18,186 (59,664)	366–0 (1,200–0)
B	C	805 (2,640)	61–59 (200–193)	Harvest	-[a]	-	-
C	Shore	8,050 (26,400)	59–0 (193–0)	Henry	Hillhouse	4,023 (13,200)	52–58 (170–189)
Edith	Shore	11,265 (36,960)	46–0 (150–0)	Heritage	Harmony	11,909 (39,072)	328–366 (1,075–1,200)
Ellen	-	-	-	Heritage	Shore	31,868 (104,554)	328–0 (1,075–0)
Elly	-	-	-	Hermosa	-	-	-
Eureka	Ellen (2)	4,662 (15,297)	213–81 (700–265)	Hidalgo	-	-	-
Gail	-	-	-	Hillhouse	Shore	5,472 (17,952)	58–0 (189–0)
Gilda	Shore	11,265 (36,960)	62–0 (205–0)	Hogan	Shore	1,448 (4,752)	46–0 (150–0)
Gina	Shore	483 (1,584)	27–0 (90–0)	Hondo	Harmony (2)	14,484 (47,520)	257–366 (842–1,200)
Grace	-	-	-	Houchin	Hogan	1,158 (3,800)	54–46 (176–150)
Habitat	P/FA	5,900 (19,356)	89–57 (292–188)				

TABLE A-3 Pipeline Origin, Count, Terminus, and Length

Platform Origin	Platform Terminus (no. of pipelines in the ROW)	Length km (mi)	Onshore Facility (no. of pipelines in the ROW)	Length km (mi)
A	B (3)	1.3 (0.8)	Rincon (via subsea tie-in) (3)	18.0 (11.2)
B	A (5) (subsea tie-in for 3 lines)	0.8 (0.5)	-[a]	-
C	B (3)	0.8 (0.5)	-	-
Edith	Eva (1)	10.6 (6.6)	-	-
Edith	Ellen/Elly (1)	1.8 (1.1)	-	-
Ellen/Elly	-	-	San Pedro (1)	4.4 (15.2)
Eureka	Ellen/Elly (5)	2.6 (1.6)	-	-
Gail	Grace (3)	10.1 (6.3)	-	-
Gilda	-	-	Mandalay (3)	15.8 (9.8)
Gina	-	-	Mandalay (2)	9.7 (6.0)
Grace	-	-	Carpinteria (2)	24.6 (15.3)
Habitat	-	-	Carpinteria (1)	13.4 (8.3)
Harmony	Hondo (1)	4.7 (2.9)	Las Flores Canyon (2)	15.6 (9.7)
Harvest	Hermosa (2)	4.7 (2.9)	-	-
Henry	Hillhouse (3)	3.9 (2.4)	-	-
Heritage	Harmony (2)	10.9 (6.8)	-	-
Hermosa	-	-	Gaviota (2)	16.7 (10.4)
Hidalgo	Hermosa (2)	7.7 (4.8)	-	-
Hillhouse	A (4)	0.8 (0.5)	-	-
Hogan	-	-	La Conchita (4)	9.2 (5.7)
Hondo	Harmony (1)	4.7 (2.9)	Las Flores Canyon (1)	11.1 (6.9)
Houchin	Hogan (4)	1.1 (0.7)	-	-
Irene	-	-	Orcutt (3)	16.1 (10.0)

[a] '-' indicates not applicable.

Source: InterAct PMTI (2020a).

A.1.1.2 Platform Preparation

Inspections. Before removal of the platform structures, pipelines, and power cables begins, a comprehensive survey is conducted to ensure that the platform can be safety dissembled. "Safe" in this case involves addressing risks to workers, the environment, and decommissioning equipment. The inspection that would be performed on the topside and underwater components would include:

- A structural assessment;
- A corrosion and paint assessment;
- An assessment of equipment; and
- A safety inspection to identify hazardous materials and other safety issues related to platform disassembly.

Underwater inspections of the platform jacket, associated pipelines, and power cables would be performed by divers and/or remotely operated submersible vehicles (ROSV). These inspections would include:

- An assessment of the corrosion and structural member condition;
- An assessment of potential design or construction deficiencies;
- An assessment of the potential for environmental overloading;
- The identification of any subsea hazards;
- The identification of seafloor debris or obstructions; and
- A side-scan sonar (SSS) survey of the surrounding seafloor to establish a benchmark for the clearance stage. (InterAct PMTI 2020a).

Conductor Removal. Pre-severance activities could also include removal of conductors, which are steel tubes with internal casings that run from beneath the seafloor to platform decks, and house production tubing that carries produced hydrocarbons. Well-plugging and abandonment would occur once wells are no longer economically productive and would be completed before decommissioning begins. Conductor removal could occur prior to, or as part of, decommissioning.

Conductor removal would be completed as part of pre-severance during decommissioning under all three action alternatives, if not previously completed. Removal would involve a conductor cutting phase and a conductor extraction and sectioning phase (BOEM 2020, 2021). Abrasive and non-abrasive mechanical cutting methods would be used to sever conductor tubing and any internal casing strings at 4.6 m (15 ft) or more below the mudline. Abrasive cutting methods include using hydraulic pressure to pump an abrasive fluid composed of seawater and abrasive materials such as garnet or iron silicate to cut through conductor piping and casings. A typical conductor cut could require about 7 hours and use about 1,600 kg (3,500 lb) of iron silicate abrasive (BOEM 2021), which would be discharged. In deep water, non-abrasive mechanical cutting methods using hydraulically actuated cutter heads might be required to sever conductors. The extraction phase would involve hoisting and, using non-abrasive mechanical methods, cutting the severed conductors/casings into nominally 40-ft segments on platform decks to allow loading and transporting to shore, where the conductor segments would be loaded onto trucks for transport to a scrap recycling facility. The process is repeated for each conductor installed at a platform.

Conductor severing, hoisting, and segmenting equipment would be installed on a platform at the time of use and reinstalled at each successive platform. Conductors would be cleaned of marine growth using high-pressure water, possibly using divers for the upper submerged portions and a ring nozzle for remaining portions as they are hoisted. Marine growth would be discharged to the ocean. Vessels such as the 67.1-m (220-ft), dynamically positioned, *Harvey Challenger*, or the 68.6-m (225-ft) *Adele Elise*, would be loaded using platform cranes to transport materials to shore in regularly scheduled trips. Crews and equipment would be shuttled to platforms using a crew boat, such as the 36.5-m (120-ft) M/V *Jackie C*. Freeport-McMoRan estimated that removing 62 conductors from platforms Hidalgo, Harvest, and Hermosa in this manner would require 167 days overall. Conductor material transport would require 90 trips total, involving round trips from the platforms to the Port of Long Beach with a stop at Port Hueneme (BOEM 2020.) Chevron estimated that removing 38 conductors from platform Grace would take about 120 days and removing 28 conductors at the deeper platform Gail would take about 240 days (BOEM 2021).

As of April 2020, POCS production platforms had from 12 to 64 conductors each and 818 in all, 59 of which were empty conductor tubes (Interact PMTI 2020a). Table A-4 presents the number of conductors at each platform and total material weight for disposal. A portion of these conductors would be removed prior to decommissioning, including those mentioned in the previous paragraphs.

Platform Removal Preparation. This phase of decommissioning is labor-intensive and can involve large work crews and support staff. Staffing types can include:

- Crane operators;
- Inspectors;
- Electricians;
- Scaffolding crews;
- Engineers;
- Project managers;
- Catering crews, welders, boat crews;
- Helicopter crews; and
- Safety representatives.

Salvageable equipment would be removed prior to initiation of topside removal. Such salvageable equipment can include HVAC; living quarters; catering equipment; fresh-water generators; sewage treatment equipment; lifeboats; helideck structures; electrical generators and associated electrical utilities; fire/gas systems; air compressors; communication equipment; cranes and pedestals; drilling equipment; wellhead equipment; produced water treatment systems; and pipeline pig launchers. All liquid and gas lines, containers, tanks, and appurtenances would be flushed. Any wastes found on the platform (including waste chemicals) would be removed for licensed onshore disposal. Equipment would be shut down, including lockout/tagout where needed. The topside would then be prepared for cutting. In cutting the facility into sections, operators would design the cuts so that the lift capacity of the available cranes is not exceeded and that the cut sections will be within the carrying capacity of transport barges.

A.1.1.3 Ship and Barge Mobilization

Mobilization of support vessels (e.g., lift vessels, barges, tugboats) for Pacific Outer Continental Shelf Region (POCSR) decommissioning may involve the movement of significant assets such as heavy lift vessels (HLV) to and from the GOM via the Panama Canal, an approximate 6,400 km (4,000 nautical mi) transit. Dynamically positioned dive vessels (DPDV), if needed, could be mobilized from the Seattle area, and other equipment such as cargo barges, crane barges, tugboats, workboats, crew boats and related support vessels (part of a more routine mobilization) from a number of West Coast ports. In some cases, engine retrofits would be required in order to comply with California air quality regulations (InterAct PMTI 2020a).

TABLE A-4 Platform Conductor, Topside, Jacket, and Piling Estimated Material Volumes

Platform	Conductor Weight (tons)	Number of Conductors	Topside Weight (tons)	Topside Modules Count	Jacket Weight (tons)	Jacket Sections Count	Pile Removal Weight (tons)
A	1,343	55	1,357	4	1,500	3	584
B	1,439	57	1,357	4	1,500	3	590
C	1,354	37	1,357	4	1,500	3	597
Edith	380	29	4,134	12	3,454	5	603
Ellen	6,300	64	5,300	12	3,200	5	832
Elly	-	-	8,000	10	3,300	5	956
Eureka	12,185	60	4,700	10	19,000	22	2,198
Gail	7,519	29	7,693	8	18,300	22	2,320
Gilda	3,190	63	3,792	6	3,220	4	768
Gina	373	12	447	2	434	1	178
Grace	4,006	38	3,800	6	3,090	5	1,039
Habitat	2,063	21	3,514	6	2,550	4	849
Harmony	15,280	43	9,839	13	42,900	48	4,530
Harvest	5,050	25	9,024	10	16,633	20	2,120
Henry	845	24	1,371	4	1,311	2	283
Heritage	12,900	49	9,826	13	32,420	38	4,065
Hermosa	3,050	16	7,830	8	17,000	20	1,893
Hidalgo	2,310	14	8,100	9	10,950	14	1,340
Hillhouse	1,893	50	1,200	4	1,500	3	394
Hogan	1,410	39	2,259	8	1,263	4	429
Hondo	5,885	28	8,450	13	12,200	15	1,744
Houchin	1,370	36	2,591	9	1,486	4	407
Irene	1,800	29	2,500	5	3,100	4	760

Source: InterAct PMTI (2020a).

Given the very limited decommissioning activities conducted to date in the POCS, some services may not be available locally, necessitating either the development of expertise and technology in the Pacific region of the United States, or the mobilization of technology from the GOM or Asia. In particular, GOM vessels would be required for lift weights exceeding 500 tons. Were GOM vessels to be used, engine upgrades could be needed to meet California's air emission requirements. In addition, GOM port facilities would also be required for material disposal, since waste processing facilities on the West Coast have relatively small (50 tons) lift and processing limits. Items weighing 50 tons or less are referred to "piece-small" in the decommissioning lexicon. Loads exceeding the piece-small benchmark (the current West Coast lift and processing limit) would have to be transported through the Panama Canal for processing at Louisiana ports. Alternatively, the literature indicates that loads exceeding the West Coast lift limit could potentially be resized at offshore cutting facilities or be towed to shipyards and resized dockside (InterAct PMTI, 2020a).

The piece-small approach is a viable option for platforms in the Santa Barbara Channel. However, piece-small may not be appropriate for larger platforms in deeper water because of the need for what the Offshore Operators Committee (OOC) describes as "added engineering analysis": more complex cutting operations, increased safety and environmental concerns, and reduced decommissioning efficiencies. Only the Port of Long Beach currently has decommissioning capability at the port. Facilities there may need to be upgraded or expanded to accommodate the expected volume of materials. For some ports of entry materials may need to be transported via truck through the port to an off-site processing facility (OOC 2022).

A.1.2 Severance

A.1.2.1 Topside Removal

Topsides can be categorized as integrated, modular, or hybrid installations. Some of the POCS platforms were installed using modular construction. Modules can be thought of as rectangular boxes that are lifted for installation on the deck structure of the platform. Modular construction would have been constrained by the lift capacity of the vessels available at that time for construction. While the maximum lift capacities of derrick barges used for construction in the 1960s was 500 tons (Culwell 1997), current derrick barge lifting capacity is larger.

There are three recognized removal methods: piece-small, piece-large (also known as reverse installation), and single lift. Piece-small removal involves the removal of small platform sections, typically with weights of no more than 50 tons. Piece-large is associated with platform section weights >50 tons. Single lift involves the removal of the platform topsides as a single unit (ABBB 2015). Single-lift methods could necessitate disposal and handling at ports of entry located outside of the West Coast.

The OOC is considering what is referred to as "material recovery/reuse and/or waste disposal options" both within and outside the United States (OOC 2022). For the U.S. scenario, single-lift methods may necessitate using cargo vessels transiting to GOM via Cape Horn. For the international single-lift scenario, sites under consideration include locations in Thailand, India, and Mexico. The OOC has noted that some of said "options" may require modifications and financial investments at the receiving ports (OOC 2022).

The single-lift approach requires the use of a specialized class of HLVs not currently available for use on the West Coast. Topsides of the POCS platforms may weigh up to 9,000 tons or more (Table A-4). An HLV capable of lifting such a topside sourced from the GOM would be too large to transit through the Panama Canal and would need to travel from the GOM around Cape Horn to get to the West Coast (InterAct PMTI 2020a). Another option would be to mobilize the HLV from Asia. Since most POCS platforms are modular, for a single-lift removal, the topsides would need to be retrofitted to reinforce the structure prior to the lift. In addition, unless the single-lift load can be broken down, the West Coast onshore lift and handling capacity would be exceeded by the weight of a single lift topsides.

Reverse installation is the preferred method for modular platforms. Non-modular platforms would need to be removed in larger pieces. Piece-small and especially piece-large removal may be viable approaches for decommissioning for a subset of the platforms in the POCS. Reverse installation would have to be preceded by an engineering analysis and would include a check of the structural integrity of the modules and the reinstallation of padeyes[3] or lifting frames as needed. The piece-large dismantling approach would require moderate-capacity crane barges or heavy lift barges and cargo barges (Prasthofer 1997).

The piece-small approach can be supported by temporary deck mounted cranes, crawler cranes (as in a crane that is mobile) and standard cargo containers (Prasthofer 1997). Nevertheless, the piece-small approach may have limitations due to the hook height[4] that can be achieved by the vessels available on the West Coast. In addition, when compared to single-lift and piece-large removal, piece-small removal would involve a longer time span to complete a given topsides removal project, resulting in prolonged emissions and accumulative environmental impacts (InterAct PMTI 2020a). Table A-4 provides the module count for each of the POCS platforms.

A.1.2.2 Jacket Removal

Regardless of severance approach, jacket removal would be preceded by the removal of marine growth from top sections of the jacket, and in the case of complete jacket removal, the clearance of shell mounds. Jacket removal would be diver- and/or submersible ROV-assisted. Jackets would be sectioned using standard underwater cutting methods and lifted to the surface. Piles that have been driven through the jacket legs would be severed below the mud line. The main jacket piles may or may not allow internal access. Internal access affords the use of internal cutting and mud plug tool conveyance (Zimmerman, undated). Piles without internal access as

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[3] A padeye is a metal plate with an opening that is welded or bolted to a surface to assist in the purpose of lifting.

[4] The hook height or height of lift represents the dimensions from the crane hook at its highest position to the item to be lifted.

well as skirt piles would be externally dredged and then cut. Platform legs would also be externally dredged and cut (Zimmerman, undated). The jacket would be cut into more manageable pieces using a combination of cutting systems and shear systems (InterAct PMTI 2020a). The potential number of jacket sections for the POCS platforms ranges from 1 for Platform Gina to 48 for Platform Harmony (Table A-4).

Pile-severing and removal is typically performed internally using explosives or abrasive cutting, and the pile would be cut to 4.6 m (15 ft) below the mud line (BML). In some cases, mud may have been forced into the pile above the mudline. This mud would be removed by jetting water under high pressure into the pile, with the return water discharged to the surrounding water. If the interior of a pile cannot be accessed, the pile would need to be cut externally. An external cut must be preceded by jetting down to the target cutting depth, in order to set the cutting tool (ICF 2015).

Jacket removal may be accomplished using single lift, flotation, reverse installation, piece-small, and piece-large removal approaches. Employing the flotation approach, the severed jackets are floated to the surface and then towed to shore or lifted onto a cargo barge for transit to shore. Flotation for platform removal may be essentially the reverse of the installation process that was used at some platforms. For example, jackets on Platforms Hope, Heidi, and Hilda have large-diameter caisson legs that served as flotation devices during installation (Prasthofer 1997). However, the flotation technique would require a custom solution for each of the POCS platforms (TSB 2015).

Another technique is the piece-small to piece-large removal approach, which would be similar to that used for topside removal. The jacket would be sectioned underwater and then recovered one section at a time. Jacket removal would likely be preceded by the removal of marine growth from top sections of the jacket and clearance of shell mounds, if needed. Jacket removal could be diver- and/or ROV-submersible-assisted. Jackets would be sectioned using standard underwater cutting methods and lifted to the surface by derrick, crane, or specialized lifting barges and transported to port for further processing at onshore facilities. Currently, shore facilities in California have a 50-ton limit for recycling or otherwise preparing platforms for disposal.

Subject to the availability of an appropriate lifting system and cargo barges, it may be possible to remove the jacket in a single lift. The lifting equipment would connect to padeyes, horizontal bracing, or leg-gripping tools sufficient to support the weight of the jacket. If the weight of the single lift exceeds the capacity of the available lifting system and cargo barges, the jacket would be cut into smaller sections for removal (InterAct PMTI 2020a). Piles may need to be removed to reduce the lift weight of the jacket. Piles can be pulled by a lifting crane, a derrick barge, or some other lift system for placement onto a cargo barge. If the lifting height of the lifting system is insufficient, the pile can be pulled, cut, and removed in sections (ICF 2015). Pulled piling would be loaded onto cargo barges and transported to port for handling either at West Coast shore facilities (if the jackets can be sized to satisfy lift capacity of onshore facilities), or in the GOM or an international port if jacket sections exceed the handling capacity of West Coast ports.

One sectional removal option for jacket removal is known as progressive transport or jacket "hopping." The hopping aspect accurately describes the process. Piles are severed, the structure is rigged up and lifted vertically, and it is then moved to shallower water and set down on the seafloor. The exposed section of the jacket can then be cut without the need for a submersible ROV or diver, and the process can be repeated. After the first severance, divers or ROV-submersibles may no longer be needed. This approach was considered by the platform operators at one time, but as there would be difficulty obtaining the additional permits needed (partially due to environmental impacts), progressive transport seems unlikely (TSB 2015; OOC 2022).

A.1.2.3 Pipeline and Power Cable Removal

There are pipelines and cables running between individual platforms and onshore facilities, as well as between platforms. Per the BSEE regulations at 30 CFR §§250 1750–1754, a pipeline can be decommissioned in place if the BSEE Regional Supervisor determines the pipeline would not be a hazard to navigation or commercial fishing or have an adverse environmental effect. To decommission a pipeline in place, the pipeline must be pigged, flushed, and filled with seawater. Each end of the pipeline must be cut, plugged, and buried to a depth of 1 m (3.3 ft) below the seafloor.

Pipeline and power cable decommissioning would include divers and diving support vessels. Both human and ROV vehicles could be required for the pigging, flushing, and cutting steps. In some cases, and especially in water depths exceeding 61 m (200 ft), decommissioning could require the use of dynamic positioning (DP2) dive vessels (if anchoring at multiple locations along the pipeline pathway is a natural resource/environmental concern). A DP2 dive vessel could be mobilized from Seattle, Washington. (InterAct PMTI 2020a).

A.1.3 Disposal of Severed Infrastructure

Severed platform infrastructure would be disposed in one of two ways. All topside materials could be either transported by barge from the platform site to a port for onshore processing, salvage, and disposal. Alternately, severed jacket sections could be used to create artificial reefs under the Rigs-to-Reef programs of BSEE and the State of California. These disposal options are discussed in Section A.4.

A.1.4 Final Site Clearance

Final site clearance is a two-step process that takes place after decommissioning of a platform and its associated pipelines and power cables has been completed, when the lessee is required to verify and certify clearance. The BSEE regulation at 30 CFR §250.1740 requires the decommissioned platform site (including pipeline and power cable routes) to be clear of any seafloor obstructions. A variety of methods can be used to verify clearance:

- Trawl over the site;
- Sonar scan across the site;
- Inspection of the site using a diver; and
- Using an ROV-mounted camera to videotape the site.

For facilities in water depths less than 91 m (300 ft), the lessee must submit a certification that a site is clear of obstructions. The content of the certification includes the extent of the area surveyed, the survey method used, survey results, and a post-trawling job plot or map showing the trawled area.

A.2 SUPPORT VESSEL DESCRIPTIONS

A.2.1 Barges

A barge is a ship (e.g., a large vessel) with a flat-shaped hull that is usually towed or tugged by other vessels. Barges can be classified by their cargo capacity and by the way the barge is used. A typical inland barge is size is 59 by 11 m (195 by 35 ft) in size and has a carrying capacity of about 1,500 tons of cargo. Newer barges are slightly larger (64 by 15 m [209 by 50 ft]) and have a carrying capacity of about 3,000 tons (Archway Marine Lighting 2021). West Coast port vessel companies have confirmed that cargo barges capable of carrying up to 6,000 tons are available.

Some barges are self-propelled, but most barges require tugs for maneuvering, transiting to and from port, and for anchoring. Decommissioning will likely require the use of a variety of barge types, including cargo, crane, derrick, derrick lay, and lifting barges. Loads below the sea surface (e.g., platform jacket pieces) can be brought to the surface by a lifting barge or by a derrick barge. The derrick barge is the workhorse of decommissioning support barges (Culwell 1997). Offshore derrick barges have lift capacities in the range of 500 to 2000 tons (TSB 2015). The lift capacity of a derrick barge is constrained by the depth of the lift. For example, the derrick barge DB 4000 achieved a 1,600-ton lift from a depth of 91 m (300 ft) (TSB 2015). A derrick barge can be teamed with a lifting barge to transfer loads from a lifting barge to a derrick barge, especially if the working depth exceeds the reach of the derrick barge. In some cases, a load could be transferred to a cargo barge. Alternatively, a crane barge or a derrick barge may be used to both lift and transport a load to port for disposal.

Crane, derrick, and lifting barges are described below in the section on cranes and lifting systems. Derrick lay barges are described in the section on pipeline/cable ships. Cargo barges range in size from 55 to 91 m (180 to 300 ft), with carrying capacities ranging from 2,200 to 8,800 tons (2,000 to 8,000 metric tons) (Bhuvan 2022).

A.2.2 Tugboats

A tugboat is a vessel that maneuvers other vessels by either pushing or towing them. There are three general categories of tugboats: seagoing tugs, harbor tugs, and river tugs. Tugs move ships that either cannot (e.g., a cargo barge) or should not move independently (e.g., a large container vessel coming to berth) .

Tugs can also be categorized by methods of propulsion. Conventional tugs are equipped with diesel engines, one to three propellers and a rudder. Single-propeller tugs can be further distinguished as either right-handed or left-handed. The center of a conventional tug is fitted with a towing hook. Azimuth stern drive (ASD) tugs are fitted with thrusters at the aft of the ship. The thrusters can rotate 360 degrees. Azimuth thrusters can have either a fixed or controllable pitch propeller. The towing point is close to the stern on an ASD tug. A third type of tug is a tractor tug. Tractor tugs are fitted with azimuth thrusters forward of midships (Nautical Class 2018). Tractor tugs are considered to be extraordinarily maneuverable, with enhanced versatility, since the tug's towline can be worked from a winch drum on the tug (Marine Insight 2022).

Tugboat engine size varies, with seagoing tugs having engines with power ratings up to 27,200 horsepower (hp), while smaller tugs have power ratings ranging from 680–3400 hp (Marine Insight 2022). By way of example, a 500-ton capacity derrick barge with a 91-m (300-ft) length may require a 3,000-hp tug for towing, set up, and anchor handling. In the North Sea, a derrick barge with a 5,000-ton capacity required a 25,000-hp tug to set up and operate (Culwell 1997).

Towing can be broken down to at least five different techniques, all of which could have applicability during platform decommissioning:

- Harbor towing;
- Emergency towing;
- Escort towing;
- Pull back towing; and
- Canal transit towing.

Harbor towing occurs in sheltered waters (such as harbors) as part of moving another vessel to and from a berth. Emergency towing is performed in support of a vessel that has lost propulsion. Escort towing is used as a precautionary measure to protect a vessel being towed and other nearby vessels. Pull back towing is used to assist a ship that is moored at the bow. It is a kind of anchoring approach. For a pull back tow, a tug is connected to the vessel in question at the stern, thus preventing the ship from running over the front mooring and keeping the ship stationary while performing required tasks. Canal transit towing supports vessels transiting a canal or waterway (Nautical Class 2018).

A.2.3 Supply Vessels

Offshore supply vessels used support of oil and gas production operations could also be used to support decommissioning. Supply vessels range from 50–100 m (160–330 ft) in length and can have up to 36 crew members. These vessels are used for logistics support and for the transportation of goods, tools, equipment, and personnel to and from offshore platforms. Types of supply vessels include the following:

- Platform supply vessels (PSV);
- Multipurpose supply vessels (MPSV);
- Fast Supply Intervention Vessels (FSIV);
- Crew Boats;
- Line Handling (LH) Vessels;
- Tug Supply (TS) Vessels; and
- Oil Spill Response Vessels (ORSV).

The PSVs have a high capacity for transiting cargo to and from platforms. MPSV are vessels typically equipped with a small crane that can serve a variety of purposes and may also be equipped with submersible ROVs for supporting underwater tasks. The FSIVs and crew boats are used transport personnel, and in the case of an emergency intervention, FSIVs are capable of high speeds (25 knots). The roles of LH, TS, and ORSV are self-explanatory.

A.2.4 Cranes and Lifting Systems

The Occupational Safety and Health Administration (OSHA) defines a crane as being a machine used for lifting and lowering a load and moving it horizontally, with the hoisting mechanism an integral part of the machine (29 CFR §1910.179(a)(1)). Some barges are constructed with a pedestal crane. As described below, in some cases a mobile crane can be moved onto a barge for a lifting task. A derrick crane (and thus a derrick barge) is distinguished as having a vertical mast (the derrick).

Derrick cranes are also used at onshore facilities for loading and off-loading of ships and barges. Commonly used onshore marine derrick cranes have a lifting capacity in the range of 50 to 400 tons. An offshore derrick barge has a significantly greater lifting capacity, ranging from 500 to 1,500 tons. One offshore derrick barge with two cranes was reported to have a total lifting capacity of 14,000 tons (Abdallah El-Reedy 2020). A derrick barge such as the *DB Thor*, which has a lifting capacity 1,750 tons, is most likely to be used for POCS platform decommissioning (InterAct PMTI 2020a).

The crane and derrick could be integral to the design of barges used for a task (hence the terms derrick barge or crane barge). For example, a crane barge is a barge with an onboard pedestal crane. Mobile cranes can be placed on barges to support conductor, jacket, pipeline, and cable removal. Crawler cranes (i.e., cranes with either wheels or tracks) have a lift capacity ranging from 100 to 1,000 tons (Sterett Crane and Riggins 2015).

An additional lifting system is based on having the lifting point directly over the load (e.g., a jacket piece) with the "legs" of a gantry/cantilever or a truss straddling the load. The "legs" of the system would be situated on barges or other vessels. One example is the Versabar VB 4000 system, which can lift 10,000 tons at the surface, and up to 4,000 tons from what is referred to as a "seabed lift" (ICF 2015). Figure A-2 shows the Versabar Bottom Feeder system lifting a 3,200-ton jacket piece (Versabar, Inc. 2017). Sometimes, as in the case of the Siapem 7000 and the Hareerema Thialf vessels, cranes are positioned on semi-submersibles in order to provide stability (ICF 2015).

FIGURE A-2 Versabar bottom feeder lift system (Source: Versabar, Inc. 2017.)

An approach that may hold promise for decommissioning the POCS platforms is the deep-water lowering system (DLS) owned by Subsea7 (InterAct PMTI 2020a). This system is used to install jackets during platform construction, and possibly could be used to retrieve jackets during decommissioning. The DLS can be containerized for shipping and installed on a domestic vessel. The DLS has been used to lower up to 1,050 tons from depths of over 1,300 m (4,200 ft). Such a DLS system could be used to bring jackets close enough to the surface that the near-surface lifting class (e.g., crane and derrick) barges could then retrieve the load for subsequent handling (InterAct PMTI 2020a). Assuming jackets can be cut or disassembled as planned, jacket section "lifts" could range from 423 to 988 tons/section, thus not exceeding the 1,047-ton benchmark lift limit.

Buoyancy bag devices (BBD) could also be used to lift jackets ('floats') or jacket sections. BBDs have proven to be successful for a 3,000-ton lift capacity. This inexpensive and environmentally friendly approach is counterbalanced by uncertainties regarding the control of jacket ascent and surfacing (ICF 2015). Difficulty inflating bags at depth is an additional concern. Lifting systems that rely on neutral buoyancy hold promise but need to be proven. Buoyancy is discounted for single lift and for lifting jackets by sections because of safety concerns and the need to engineer each lift (InterAct PMTI 2020a)

HLVs can be broadly categorized into three main classes: semi-submersible vessels, open-deck cargo ships, and project cargo carriers. Semi-submersible vessels (SSV) use ballast water to increase draft and lower the ship into the water until the working deck is submerged a few meters below the water surface. Items can be floated on top of the submerged portion. The ballast water can then be removed, allowing the SSV to rise above the water with the cargo resting on the working deck.

Open-deck cargo ships require cargo to be placed onto the working deck. Open-deck ships typically have a large, flat deck. Cargo wider than the ship can loaded. Open-deck cargo ships can be used to transport large, heavy structures. Project cargo carriers are used to carry “project cargo,” a term that refers to large and heavy goods. Project cargo carriers have their own cranes to lift cargo. (Menon 2020).

A.2.5 Remotely Operated Vehicles (ROVs)

ROVs (also referred to as ROSVs) can be thought of as unoccupied machines operated from the surface. An ROV is typically operated from the surface via an umbilical cord that is attached to a cage or garage from which the ROV may travel for about 30 m (100 ft) (PetroWiki, 2015b). ROVs can have a role in all three phases of decommissioning. They can be used to perform pre- and post-decommissioning SSS surveys and video surveys, support pipeline pigging, and together with divers, have a role in cutting platform piles and jackets.

A.2.6 Pipeline/Cable Ships

Pipelines could be removed or abandoned in place. Even if a pipeline is abandoned in place, the pipeline will need to be cleaned (for example, by progressive pigging), and filled with seawater. Even partial removal would require support from vessels (e.g., the use of an ROV to install a pig launch system). If abandoned in place, vessels will be needed to support capping and burying the pipeline ends, and, if needed, the installation of concrete mattresses. If portions of the pipeline are to be removed, the main vessels would be lay barges, reel barges, and barges modified for towing recovery.

A reel barge, which may be towed or self-powered, is a vessel that is used to lay submarine pipelines that are carried as extended lengths coiled on a reel (DrillingFormulas.com 2016). Reel barges contain either a vertical or horizontal reel that the pipe is wrapped around (Figure A-3). The reel barge may also be used for pipeline removal (in a reverse operation) to pull a pipeline from the sea floor onto the vessel mounted reel.

FIGURE A-3 A vertical reel barge. (Source: DrillingFormulas.Com 2016.)

A reel barge is not designed to handle large-diameter pipe. Larger diameter pipe is installed, and thus could be removed, using a lay barge. Distinguishing characteristics of such a vessel include deck area to store and assemble pipe, a system for cutting the retrieved pipe, and a “stinger” that provides open water subsurface pipeline support and guides the pipe transiting from the seafloor to the water surface (John Brown Engineers 1997).

Pipeline removal is conducted under the following general process. Using ROV and/or diver support, a pulling head[5] is attached to the end of the pipeline (after the pipeline has undergone progressive pigging, flushing, and cleaning), and a winch is attached to the pulling head. A recovery cable is then run from the pulling head to a winch on a lay barge, which is positioned to take up the slack on the cable. The cable is then wound back onto the barge, while putting the barge in reverse. The cable pulls the pipeline into a stinger as the barge backs up. Once a targeted cut length of pipeline is achieved, tensioners[6] are installed to hold the pipeline, and the pipe is cut. The pulling head is then inserted into the newly cut end of the remaining pipe, weight is transferred from the tensioner to the recovery cable, and the pull and cut procedure is repeated. (John Brown Engineers 1997).

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[5] A pulling head is a fitting that is attached to the end of a pipe that makes it possible to pull the pipe.

[6] A device on the lay vessel that applies a horizontal tension to the pipe.

Pipelines may also be removed by what is referred to as “tow recovery.” Using a barge equipped with davits[7], tensioners, and a stinger at both ends, the pipeline is dewatered and lifted, passed through the forward stinger, and then passed through to an aft stinger. Flotation buoys are attached to the pipe as the pulling head is pulled by a tug to the desired cutting length. The pipeline can then be cut onboard the barge and the cut section of pipeline is towed to a disposal destination (John Brown Engineers 1997).

Pipeline and cable removal approaches are influenced by water depth. Pipelines and cable segments in less than 60 m (200 ft) of water can be removed by workboats and barges. DPDVs may be required in water depths in excess of 60 m (200 ft) if there is concern regarding seabed disturbance along the pipeline transect (InterAct PMTI 2020a)

A.2.7 Anchoring Approaches

During the removal of platforms, pipelines, and power cables, the decommissioning vessels will need to remain stationary while performing decommissioning tasks. This would typically be accomplished using a variety of anchoring or buoy mooring approaches. A mooring buoy is a type of buoy to which ships can be moored in deepwater areas. The mooring buoy is attached to a heavier weight located at the seafloor, which acts like an anchor to hold the buoy afloat in the water. A mooring buoy has loops or chains attached to its top, to which vessels/boats can be moored. The entire application of a mooring buoy works in such a way that the buoy is floating while the vessels are moored to a very firm support without having to use an anchor system for each vessel (Marine Insight 2022).

There are several types of anchors:

- Deadweight anchor;
- Drag anchor;
- Pile anchor; and
- Plate anchor.

Deadweight anchors are heavy objects placed on the seafloor. Drag anchors are configured like a kite and are designed to grab at the seafloor. A pile anchor is a pile installed onto the seafloor to act as an anchor. A plate anchor has a large surface area that can be jetted into or out of the seafloor (OregonWave Energy Trust 2009). Preset anchors would likely be used at platforms in water depths greater than 152 m (500 ft) (InterAct PMTI 2020a).

The types of derrick barges likely to be used for decommissioning can be anchored in waters less than 152 m (500 ft) deep. Mooring buoys could be preset with the appropriate anchorage. For pipeline and power cable decommissioning, vessels with dynamic positioning (functioning in lieu of seabed anchoring) would likely be used in order to afford needed mobility for moving along the pipelines/cables rights-of-way during removal (InterAct PMTI 2020a).

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[7] A small crane onboard a ship, especially one of a pair for suspending or lowering a lifeboat.

The number of anchors that may be needed will be affected by water depth. For example, for placement of pipelines in water depths of 305 m (1,000 ft), conventionally moored lay barges could require as many as 12 anchors (3 anchors per quarter), each weighing 50,000 lb (22,300 kg) or more (Global Security 2022). Whether or not similar anchoring would be required to decommission a pipeline is unknown.

A.3 SEVERANCE METHODS

A.3.1 Mechanical Cutting Tools

Mechanical cutting tools that could be used during decommissioning include:

- Oxy-arc cutting;
- Diamond wire cutting system (DWS);
- Guillotine saws;
- Abrasive cutters;
- Power shears; and
- Rotary mechanical cutters.

Oxy-arc cutting is a cutting process that relies on the chemical reaction of oxygen with the metals being cut. The metal is brought to the needed temperature via the heat of the arc, and a high-velocity jet of pure oxygen is directed through an electrode at the cutting site. The pure oxygen increases the temperature at the cutting surface (IMCA 2022). Oxy-arc cutting can be performed by divers or by ROVs.

A DWS has a stainless-steel wire rope loop containing small industrial diamonds. The diamond wire is rotated around the object to be cut using an externally mounted pully system. Although DWSs cannot be used to cut platform components internally, they can be used to externally cut large-diameter platform components. An ROV or diver may be used to position the DWS as needed (ICF 2015). If required, jetting can be used to clear away a sufficient amount of seabed so that there is enough space to position the DWS adjacent to the platform pilings (ICF 2015).

A guillotine saw is a hydraulically, electrically, or pneumatically powered single blade that is moved back and forth across the surface to be cut. Guillotine saws are limited to cutting pieces less than 80 cm (32 in.) in diameter. The single blade is inexpensive in comparison to the wire rope loop of the DWS. However, the guillotine saw cannot accommodate the larger-diameter platform pieces (ICF 2015).

Abrasive cutting systems rely on abrasive materials (such as such as garnet or iron silicate) in a water jet for the cutting action. The two designs are referred to as high volume-low pressure and low volume-high pressure systems. Abrasive cutting systems can cut internally or externally.

Power shears can be used to make mechanical cuts above and below the water line. Hydraulic pressure is used to open and close metals jaws with sufficient force to cut though jacket structural members. Power shears are capable of severing multi-stringer conductors up to 120 cm (48 in.) in diameter. Power shears have a large footprint so excavation or dredging would have to be performed below the mud line (ICF 2015).

A rotary mechanical cutter has blades that can cut through tubular structures. The cutting system is lowered into an open pile. The cutter can be positioned internally and rotated to cut the pile or well. (ICF 2015).

A.3.2 Explosive-Based Tools

A number of explosive severing tools have been designed for use in decommissioning operations on the OCS. Depending on their configuration, explosive charges can be deployed on almost all structural and well targets in all water depths. Historically, explosive charges have been and continue to be used in GOM often as a back-up cutter when other methodologies prove unsuccessful. In POCS, explosive severing is the option of last resort and will only be used if all other practicable severing methods (abrasive and mechanical) fail during structure-removal operations.

Explosives used for cutting and severing are considered to be safe, reliable, and cost effective. Explosives have been used in deep water primarily for well abandonment Conductors have been severed by explosives in water depths of 850 m (2,800 ft). Explosive use can reduce the amount of time divers are needed for cutting. Explosive charges can be set using ROVs, divers, or using drill strings assisted by underwater cameras. Explosive methods used for severance include bulk charges, configured bulk charges, and shaped charges. Bulk charges consist of a single mass of explosive material detonated at a single point. Configured bulk charges create more cutting power using a double-detonation bulk charge or using shock wave enhancement/centralizing device. Shape charges focus cutting action at a target

Detonator selection is influenced by depth, as hydrostatic pressure can damage the detonator and affect the sealing of the wires going into the detonators. In general, detonators in common usage are not designed for use in depths exceeding 122 m (400 ft). In some cases, there is a risk that anodic jacket protection installed to control corrosion can trigger unplanned detonation if electric detonators are used (ICF 2015).

Explosives work to sever their targets in three primary ways:

1. Mechanical distortion (ripping);
2. High-velocity jet cutting; and
3. Fracturing or “Spalling.”

Mechanical distortion is best exhibited with the use of explosives such as standard and configured bulk charges. Bulk charges use the impulse (shock) wave and outwardly expanding gases created by their detonation to apply stress to the proximal target, with the ensuing strain resulting in mass distortion and rupturing (Cooper and Kurowski, 1996). If the situation calls for minimal distortion and an extremely clean severing, most contractors rely upon the jet-cutting capabilities of shaped charges. In order to 'cut' with these explosives, specialized charges are designed to use the high-velocity forces released at detonation to transform a metal liner (often copper) into a thin jet that slices through its target at a single location or along a delineated line (CSA 2004). The least-used method of severing currently in use on the GOM OCS is fracturing. In fracturing, a specialized charge(s) is used to focus pressure waves into the target wall and use refraction forces to spall or fracture the steel on the opposing side (NRC 1996). Even if the target is not completely severed using a fracture charge, the fracturing/heat stress often allows the lift vessel to "jerk" the spall line apart.

There is a wide range of explosive materials available for use in severing charges in decommissioning activities. Severing contractors are responsible for assessing the type of material needed based upon its characteristics in relation to the target size and design, specific marine conditions, and potential methods of charge deployment. Several of the key characteristics of explosive materials are defined in Table A-5, and Table A-6 lists the specific properties of most of the commonly used explosive materials.

TABLE A-5 Key Characteristics of Explosive Materials

Characteristic	Definition as Applied to Explosive Material
Velocity of Detonation	The speed with which the explosive changes through a chemical reaction from a solid (or liquid) state to a gaseous state. *Low Velocity Explosives* change from a solid to a gaseous state over a sustained period up to 400 m/sec (1,300 ft/sec). *High Velocity Explosives* change to a gaseous state almost instantaneously at roughly 1,000 m/sec (3,821 ft/sec) to 10,300 m/sec (33,795 ft/sec), producing a very-high-pressure wave (up to 5,800,000 psi or 40 mPa).
Density	The amount of a substance contained within a specific area (the ratio of the mass of a substance to its volume). Density is an important characteristic of explosives, as the detonation rate relates directly to the square of the density (somewhat, but the higher the density in a given explosive, the higher the detonation rate).
Brisance *or* Shattering Effect	The rapidity with which an explosive develops its maximum pressure. *Brisance* is normally compared to Trinitrotoluene (TNT=1.00) and numbers >1.00 are desirable and provide an estimate of the destructive power of the given explosive on steels. Brisance is more important in bursting charges than their strength.
Specific Energy *or* Enthalpy	The heat available from a fuel, or in the case of explosives, the working performance of explosive material per kilogram.
Strength *or* Weight Strength	The ability of a given amount of explosive to perform useful work (as in rock and earth blasting) and is compared to ANFO (ammonium nitrate/fuel oil), a widely used industrial bulk explosive that has a strength of 100%.

TABLE A-6 Key Properties of Explosives Commonly Used in Severing Activities (DEMEX 2003)

Explosive Type	Principal Uses[a]	Velocity (m/sec)	Density	Brisance	Water Resistance	Specific Energy (watts/g)	Weight Strength (%)
Initiating Explosives (Primary)							
Lead Azide	4	5,300	5.00	0.39	Fair	466	39
Diazodinitrophenol (DDNP)	4	6,600	1.63	0.92	Fair		76
Lead Styphnate	4	5,200	2.90	0.40	Fair	470	40
High Explosives (Secondary)							
Pentaerythritol tetranitrate (PETN)	2,3,5	8,400	1.70	1.73	Good	675	96
Cyclonite (RDX)	1,2,3,5	8,750	1.76	1.57	Good	675	93
Homocyclonite (HMX)	1,2,5	9,100	1.91	1.45	Good	664	93
Trinitrotoluene (TNT)	1,2,3,5	6,900	1.65	1.00	Good	488	74
Ammonium Picrate (Explosive D)	1,2,5	7,150	1.60	1.25	Poor	321	70
Nitroglycerin (NG)	1,5	7,600	1.81	1.81	Fair	720	96
Nitroglycol (NGC)	1,5	7,300	1.48	2.06	Fair	780	105
Nitromethane (NM)	1,2,5	6,290	1.14	1.33	Fair	533	86
Hexanitrohexaazaisowurzitan (HNIW)	1,2,5	10,300	2.10				
High Explosives (Tertiary)							
Composition B	1,2,5	7,840	1.68	1.30	Good		
Composition C-4	1,2,5	8,040	1.59	1.32	Good		
Cyclotol 70/30	1,2,5	8,060	1.73	1.31	Good		
Octol 75/25	1,2,5	8,643	1.81	1.16	Good	503	
Plastic Bonded (PBX9404)	1,2,5	8,800	1.86	1.37	Good		
Pentolite 50/50	1,2,5	7,465	1.66	1.22	Good	588	
Detasheet	1,2,5	7,300	1.62	1.12	Good	495	
Torpex (Aluminized Explosive)	1,2,5	7,500	1.81	1.64	Good	867	
Blasting Gelatin	1,2,5	7,300	1.50	1.91	Fair	740	100
HTA-3 Aluminized Explosive	1,2,5	7,870	1.90	1.19	Good	573	
Binary Explosives							
Binex 42P	1	4,000	1.50		Good		
Helex (Liquid, Solid)	1,2,5	7,100	1.14		Good		85
PLX (Liquid, Liquid)	1,2,5	6,200	1.14	1.27	Good	535	85
Kinepak (Solid, Liquid)	1,5	6,100	1.15		Good		80

[a] Principal Uses: (1) Demolition Charges; (2) Shaped Charges; (3) Detonating Cord; (4) Detonator Primer; and (5) Metal Severance.

A.3.2.1 Bulk Charges

Besides being the most common explosive cutters, bulk charges are the most-often-used severing tools used on the GOM (CSA 2004). As the name implies, the charge is made up of a bulk amount of explosive material (e.g., Composition B, C-4, HMX, etc.), designed to sever its target using the mechanical distortion and the subsequent ripping that results from the shock wave and expanding gas bubble released during the charge’s detonation. Bulk charges can be developed and engineered in several different configurations depending upon marine conditions, available support services, and target characteristics.

For internal cuts on surface-accessible or “open-pile” targets, bulk charges can be deployed by hand or with the deck crane, lowering the charge to the required cutting depth with ropes and harnesses. Divers and/or ROVs are required for the placement of externally deployed bulk charges or in cases where internal bulk cutters are needed to sever subsea targets (e.g., skirt piles, casing stubs, and well heads). Depending on the charge configuration, divers may also be necessary to deploy some bulk cutters for the internal severing of surface-accessible, large-diameter caissons.

Standard Bulk Charge. Standard bulk charge cutters rely upon minimal designs that center on a simple container that holds the main charge and booster. Depending upon the explosive material’s pliability or viscosity, the charge container may consist of a section of polyvinylchloride (PVC) pipe that is capped at both ends. A harness assembly consisting of nylon/polypropylene ropes or stainless wire line is generally fixed to the container or housing, allowing the explosive technicians (blasters) to lower the charge into the target or for guiding and positioning charges into subsea targets by ROVs or divers (Figure A-4). The rope or line also gives the blaster a place to secure the fragile detonation cord and or signal wire so that it does not become chafed or damaged during the charge placement. Once the charge is at the proper cut depth, a brace or “tbar” assembly is fastened to the rope/wire to maintain the charge’s positioning and allow the blaster (and all other personnel, equipment, vessels, etc.) to be “backed-off” the target for detonation.

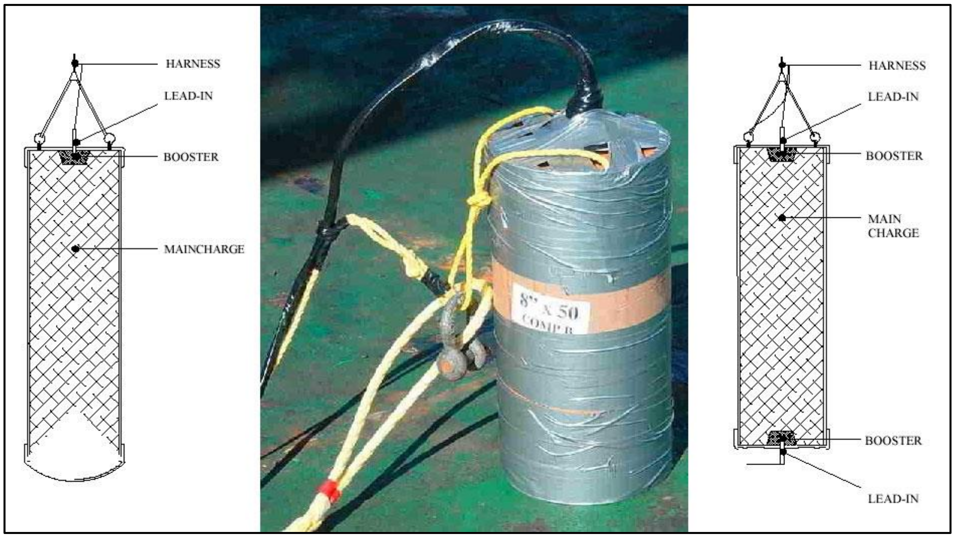

FIGURE A-4 Simple bulk charge design, rigged 50lb charge (center), and double-detonation bulk charge design (Image courtesy of DEMEX, Int.).

Double-Detonation Bulk Charge. Similar to a standard bulk charge cutter, the double-detonation bulk charge employs two or more boosters and detonation signals, often located at opposite ends of the cutter. When initiated, the forces of the dual detonations collide with one another at the midpoint of the charge, creating an outward focused force used to distort and mechanically sever its target (Manago and Williamson 1998). Like a standard bulk charge, double-detonation cutters are assembled with simple components (e.g., PVC pipe, duct tape, rope/wire harnesses, etc.) making them fairly inexpensive and easy to develop.

Ring-Configured Bulk Charge. The ring-configured charge is a bulk charge design that employs a donut or ring-shaped charge housing that allows more of the explosive to be placed closer to the target wall (Figure A-5, *left*). The increased efficiency often allows the overall charge weight to be reduced by 10–15% over standard bulk charges for the same size target (NRC 1996). Like standard bulk charge housings, the ring-configured charge form can be built from PVC tubing, making it easy to design and deploy. Borrowing from double-detonation charges, the ring charge can also be designed with multiple boosters and detonation signals, further enhancing its effectiveness. One alternation on the charge’s housing design uses flexible tubing such as semi-rigid pipe or fire hoses to form a “flexible linear” bulk charge. Deployed only by divers, the flexible charge housing is situated around the inner periphery (internal cut) or outer diameter (external cut) of a target and braced into position with fill material or sandbags (DEMEX 2003).

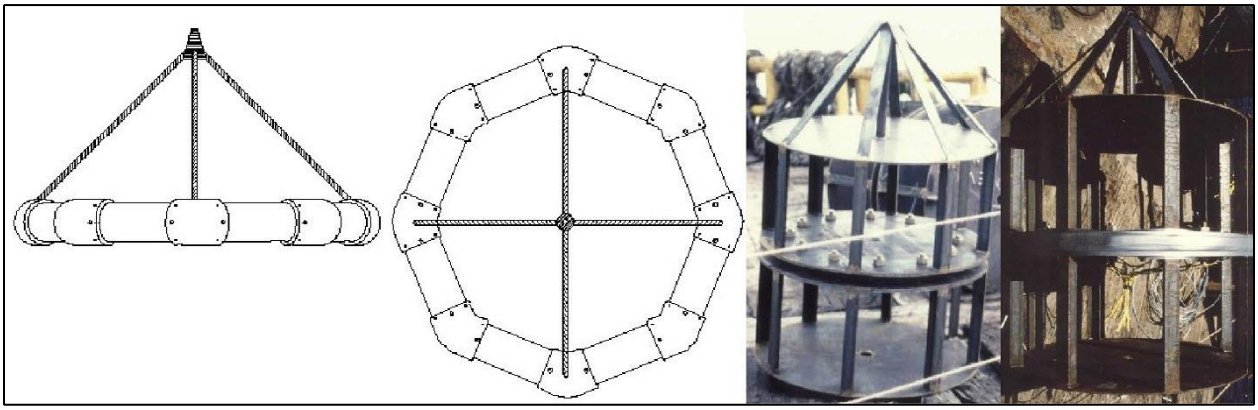

FIGURE A-5 Ring (left) and focusing-configured bulk charge (right) (Sources: DEMEX 2003 and BOEM Staff Photo).

Focusing-Configured Bulk Charge. Focusing-configured bulk charges use specifically designed charge housings to direct their explosive power towards the target in a horizontal manner; ultimately increasing the efficiency of the cut and reducing the flaring that commonly occurs in standard bulk charges (Figure A-5, *right*). These charges take advantage of the principle of “tamping” or “stemming;” an energy enhancement process that uses overlying layers of steel and or concrete in the charge housing to confine and focus the explosives (CSA 2004). Much more complex than other bulk charges, the housings for focusing charges must be specially fabricated and sized for each particular target diameter prior to mobilizing offshore.

The overall weight of the charge, housing, and tamping material often necessitates cable harnesses and handling duties are delegated to a deck crane; especially for large-diameter targets.

A.3.2.2 Shaped Charges

Unlike the ripping affect achieved by bulk cutters, shaped charges are intended to sever targets by jet-cutting. Shaped charges employ special housings that are designed to create a cavity or void between the explosive material and target wall. Employing a phenomenon known as the Monroe Effect, the shock wave produced at detonation accelerates and deforms the shaped housing into a high-velocity (24,000- 27,000 fps) plasma jet within the void space (JRC 2002). The formed jet is able to cut through steel targets of various thicknesses based upon the void shape and the “stand-off” distance to the target wall (Figure A-6). Because the “cutting” efficiency of shaped charges is several times greater than that of bulk charges, they can often greatly reduce the net explosive weight needed to sever similar-sized targets. However, since shaped charges require an air gap within the void/stand-off space for proper jet formation, waterproof casings and casing deployment devices require prefabrication several weeks in advance; ultimately resulting in four to five times higher cutter costs (NRC 1996).

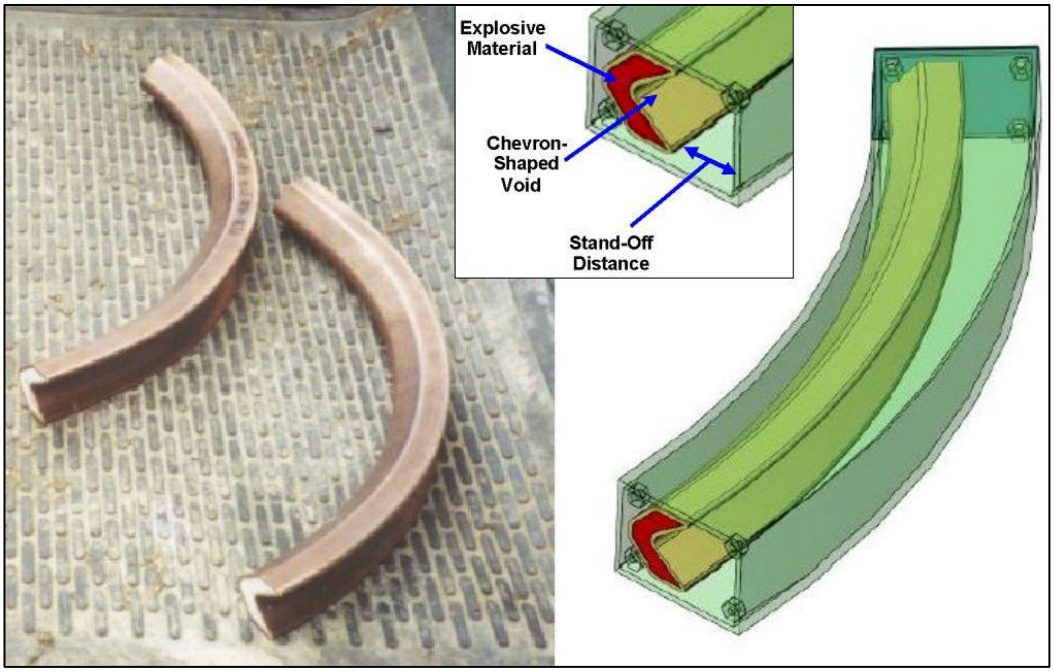

FIGURE A-6 Internally deployed LSCs and casing diagram (Source: Saint-Arnaud et al. 2004).

Conical-shaped charges (CSCs) contain a cavity in the shape of a cone, designed to cut round holes and penetrate deep into targets. Industry’s primary use of CSCs has occurred in the development of perforating guns, which incorporate multiple CSC assemblies placed down boreholes and detonated to penetrate through the drill casing and into the surrounding geologic strata for the extraction of hydrocarbons. Linear-shaped charges (LSCs) contain a void shaped into a chevron or inverted "v" along its entire length, and they are designed to cut linearly through their target. Subcontractors use LSCs on a wide range of decommissioning targets in many different configurations depending on cutting requirements.

Internally Deployed Shaped Charges. If LSCs are deployed to sever piles, the charge housings are required to be curved to a specific arc (depending upon the inner diameter (ID) of the target) with the void space on the convex surface (Figure A-6). Likewise, the waterproof casing(s) require the same orientation to lie perfectly against the inner periphery of the target wall, holding fast to the charge housing inside while accounting for the proper stand-off distance (Saint-Arnaud et al. 2004). Since most severing targets are not entirely concentric and are often fabricated with "stabbing guides" (internal alignment braces within piles), the LSC housing and respective casing cannot be constructed or deployed as a single, 360º component. For this reason, some internal LSCs are designed to be deployed via a charge-delivery device that can be inserted into a target retracted, then navigated past any obstructions to the required cutting depth, and then mechanically actuated to position the casings (generally two or four) tightly against the target wall (Figure A-7).

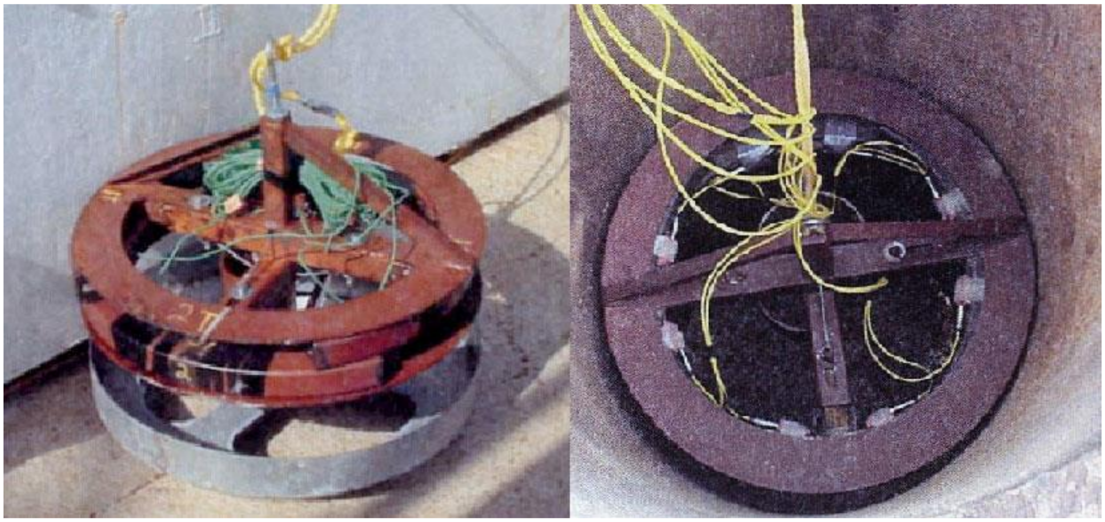

FIGURE A-7 LSC Delivery system with retracted casings (*left*) and a similar design being lowered into a pile (Image courtesy of Explosive Services International; Saint-Arnaud et al., 2004).

Another common practice relies upon divers to deploy each component (i.e., charge housing, det-cord, and bracing), especially when used to sever large-diameter caissons. Once at the proper cutting depth and oriented, the diver braces the charge housing snug to the target with simple turnbuckle rigging.

When LSCs are used for internal severance of conductors, "casing cutter" devices have been designed and prefabricated with compensation/tolerances for the specific ID of most of the common casing sizes. Though used in some small-pile decommissioning work, the primary use of casing cutters in the GOM is for well-workover operations and P&A activities. Some activities necessitate severing the smaller, internal casings that are pulled to allow larger casing cutters to sever the outer casings or conductor itself. Because of the small ID of most casings, most of the charges use less than 1.4–1.8 kg (3–4 lb) of explosives to achieve effective cuts.

Externally Deployed Shaped Charges. Linear shaped charges can also be used to conduct external severance. As with internally deployed LSCs, externally deployed charge housings are required to be curved to a specific arc, but in this case, dependent upon the target's outer diameter (OD). The void space must be formed on the concave surface so that its cutting jet is directed inward. Similarly, the casing(s) are oriented in the same manner with the proper stand-off distance figured into its design, depending upon the wall thickness of the intended target. Since external LSCs generally encounter fewer obstructions, the housings and waterproof casings are often constructed in two-piece designs, which can be deployed either by divers or via specialized ROV configurations (Figure A-8). This feature is highly beneficial for AML cutting, but as with other external BML severing methods, operators must first employ sediment jetting around the target to allow for diver/ROV access and charge deployment.

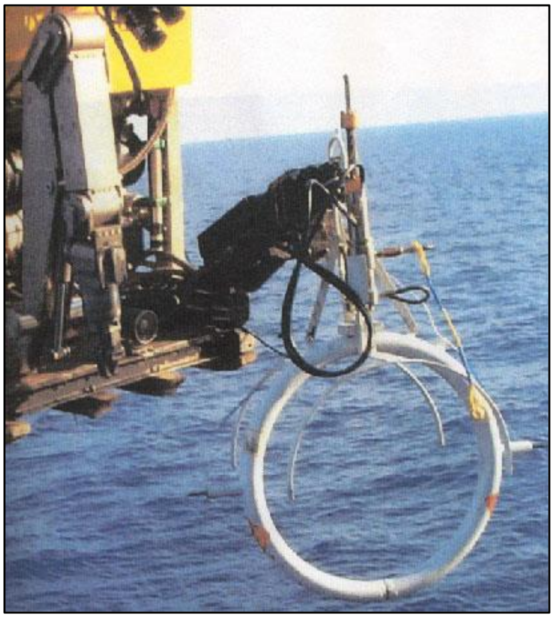

FIGURE A-8 Externally deployed LSC mounted to ROV (JRC 2002).

A.3.2.3 Fracturing Charges

Fracturing charges are currently the least-used explosives cutting tools on the GOM and most likely not be used in POCS. Generally available as "plaster" or shock-refraction cutters, fracturing charges sever targets by taking advantage of the reflected shock wave resulting from the initial force developed during detonation (NRC 1996). The wave propagation results in spalling or fracturing of the target wall opposite of the charge, with the ensuing gas bubble expanding and causing the completion of the cut. Not very effective on wells or grouted piles, fracturing charges are primarily available in the form of an adhesive-backed tape, which has always required divers for deployment (CSA 2004). Severing contractors are currently working on improvements to the charges, including charge delivery systems that could negate the need for divers.

A.3.3 Sub-Seafloor Tools

For complete platform removal, pile sections need to be removed to a depth of 4.5 m (15 ft) below the seafloor surface. Pile sections can be removed using either internal or external cutting methods. Internal pile cutting requires the removal of any seafloor sediments that may be present inside the pile. In general, any such sediments that have entered the pile are typically removed to 6.1 m (20 ft) below the seafloor surface, to ensure access for the cutting tool of choice. This method is frequently called “jetting.” During such jetting, the removed sediment is discharged to the open water.

In some cases, an internal obstruction may preclude the placement of the internal jetting equipment and or prevent placement of the cutting tool at the target-cutting depth. If internal severance is not possible, the pile must be severed externally. External severance necessitates the removal of the seafloor sediment from around the pile, in order to provide access to the external cutting tool. This removal would include any shell mound materials in the immediate area and would create a conical-shaped depression surrounding the pile footing. External jetting can be performed by divers and/or small suction dredges (Zimmerman Undated).

Pipelines may or may not be buried. The removal of pipelines with burial depths less than 0.6 m (2 ft) can occasionally be overcome without excavation. Greater burial depths may necessitate excavation. Pipeline excavation may also be required if either the vessel pulling/lifting capacity has been reached, or if pipeline integrity is in question. Excavation can be performed by a diver (Zimmerman Undated).

A.4 DISPOSAL

A.4.1 Land Disposal

Off-loading of waste will be constrained by a general 50-ton load limit at the West Coast port waste/recycling facilities. Conductors, power cables, and pipelines could be disposed of at West Coast facilities since those waste would likely be within the 50-ton lift limits of vessel and dockside lift systems. Transportation to port would occur via cargo barges. Likely ports receiving severed platform materials include the San Pedro Bay Port Complex (comprised of the Ports of Long Beach and Los Angeles) and possibly, the ports of Oakland, Portland, and Tacoma.

In general, scrap facilities are not set up for the reduction of large packages. Scrap reduction is costly and waste products from scrap reduction, as well as wastes generated from platform preparation activities, would need to be disposed of properly. In the past, decommissioned pipelines were not typically recycled because of the high cost of removing pipeline coatings. In some instances, the recovered pipelines had to be sized to 1.8-m (6-ft) lengths in order to be accepted at a disposal site (Prasthofer 1997).

In general, piece-small items, or piece-large items that can be rendered into piece-small sizes, could be processed at West Coast ports. For platform pieces exceeding 50 tons (e.g., piece-large jacket sections and some modular topside pieces), cargo barges and tugs would be used to transport such materials through the Panama Canal to processing facilities in the GOM (InterAct PMTI 2020a). Multiple 75-day round trips through the Panama Canal would likely be required (InterAct PMTI 2020b). Alternatively, scrap could be processed at international receiving ports in Asia or Mexico if such ports can be identified and have the needed disposal handling capacity (OOC 2022)

A.4.2 Rigs-to-Reef Disposal

Rigs-to-Reefs (RTR) is a process, managed by federal and state agencies under the National Artificial Reef Plan, in which operators choose to donate rather than scrap decommissioned O&G platforms to coastal states to serve as artificial reefs. The California Marine Resources Legacy Act authorizes the state of California to take title to a decommissioned offshore O&G structure that has been converted into an artificial reef. Donation of a decommissioned platform as an artificial reef is a lessee decision (BOEM 2017). Approval of an RTR decommissioning plan is up to BSEE and the appropriate State and local agencies.

California has experience with artificial reefs, with over 20 such reefs off of Southern California (Lewis and McKee 1989), many of which were developed using quarry rock (e.g., the Pendleton, Carlsbad, and Wheeler North Artificial Reefs). While the creation of artificial reefs is an accepted habitat enhancement/creation approach in California, to date no RTR-based artificial reefs have been created from O&G platforms that have been decommissioned in State waters. In State waters, platforms Harry, Helen, Herman, Hope, Heidi, and Hilda were decommissioned using a complete removal approach. During the decommissioning of platform Hazel, associated caissons[8] were left in place due to their excessive weight and concerns regarding seafloor disturbance (Bull and Love 2019). In the GOM, about 11% of the decommissioned platforms have been used to create artificial reefs under various State RTR programs.

There are three methods generally used in RTR artificial reef creation:

- Tow-and-place;
- Topple-in-place; and
- Partial platform removal.

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[8] Typically, a caisson is a watertight chamber, open at the bottom, from which water is evacuated and kept out by air pressure. Work can be carried on within the caisson.

Of these, only partial platform removal is considered for the POCS platforms.

With partial removal, the lower portion of the platform (that part below a depth of 26 m [85 ft]) would remain fixed on the seafloor and the upper portion would be moved from the platform site to a State-approved artificial reef site.

A.4.2.1 Transport Methods

The severed jacket structures to be used in a RTR disposal would be transported from the platform location to the artificial reef site either by cargo barge or by floating the severed portion and towing it to the desired location.

A.4.2.2 Placement Methods

Upon arriving at the new artificial reef site, the jacket would be placed on the seafloor. Jacket placement would be analogous to how the platforms were constructed in the first place. A lifting system, such as a vessel with a pedestal crane, mobile crane, or derrick crane would lift the severed jacket off of the barge and place it on the sea floor in a horizontal position. Alternatively, if the severed section has been floated and towed, the jacket could be lowered from the vessel doing the towing.

A.5 REFERENCES

AABA. Undated.

ABBB. 2015. Offshore Oil and Gas Decommissioning. Available at https://library.e.abb.com/public/d689c2f70f0c447586610ac566c9aa7e/ABB-Offshore-Oil-and-Gas-Decommissioning-2015.pdf.

Abdallah, El-Reedy, M. 2020. “Fabrication and installation, Offshore Derrick Barges.” In Offshore Structures, Design, Construction and Maintenance, (Second Edition,) Science Direct. Elsevier Inc. Available at https://www.sciencedirect.com/book/9780128161913/offshore-structures.

Archway Marine Lighting. 2021. Exploring the World of Barges. Available at https://www.archwaymarinelighting.com/inland-waterway/exploring-the-world-of-barges/.

BOEM. 2017. Decommissioning and Rigs to Reefs in the Pacific Region Frequently Asked Questions. Available at: https://www.boem.gov/sites/default/files/oil-and-gas-energy-program/Leasing/Regional-Leasing/Pacific-Region/Leasing/Decomissioning/Decommissioning-and-Rigs-to-Reefs-in-the-Pacific-Region.pdf.

BOEM 2020. Environmental Assessment, Point Arguello Unit Well Conductors Removal Offshore Santa Barbara County, California, July.

BOEM 2021. Final Environmental Assessment Santa Clara Unit (Platforms Grace and Gail) Conductor Removal Program, OCS EIS/EA 2021-040, May

Bull, A. S. and M.S. Love. 2019. “Worldwide oil and gas platform decommissioning: A review of practices and reefing options.” Ocean and Coastal Management. Volume 168, 1 February 2019, Pages 274–306.

Bhuvan, J. 2022. Different Types of Barges-Uses and Differences. Marine Insight. Available at https://www.marineinsight.com/types-of-ships/different-types-of-barges-used-in-the-shipping-world/.

Continental Shelf Associates, Inc. (CSA). 2004. Explosive removal of offshore structures: Information synthesis report. U.S. Dept. of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA. OCS Study MMS 2003-070.

Cooper, P. and S. Kurowski. 1996. Introduction to the Technology of Explosives. New York, NY: Wiley-VCH, Inc.

Culwell, A.S. 1997. “Removal and Disposal of Deck and jacket Structures.” Pages 48-65 in Minerals Management Service, 1997, Proceedings: Public Workshop, Decommissioning and Removal of Oil and Gas Facilities Offshore California, Recent Experiences and Future Deepwater Challenges, September.

DEMEX Division of TEiC Construction Services, Inc. 2003. Explosive technology report for structure removals in the Gulf of Mexico. DEMEX Office, Picayune, MS DrillingFormulas.com. 2016. Reel Lay Pipeline Installation Methods. Available at https://www.drillingformulas.com/reel-lay-pipeline-installation-method/. Accessed on April 14, 2022.

Global Security. 2022. Pipelaying, S-Lay Method by Conventionally Moored Lay Barges. Available at Pipelaying (globalsecurity.org).

ICF. 2015. Decommissioning Methodology and Cost Evaluation, Prepared for BSEE by ICF Incorporated, Fairfax, VA.

IMCA International Marine Contractors Association (IMCA). 2022. Available at https://www.imca-int.com/imca-publishes-guidelines-for-oxy-arc-cutting/#:~:text=%E2%80%9COxygen%2Darc%20cutting%20is%20an,IMCA's%20Technical%20Director%2C%20Jane%20Bugler.

InterAct PMTI. 2020a. Decommissioning Cost Update for Pacific Outer Continental Shelf Region Facilities, Volume 1. Prepared for BSEE, Ventura, CA, September.

InterAct PMTI.2020b. Decommissioning Cost Update for Pacific Outer Continental Shelf Region Facilities, Volume 2. Prepared for BSEE, Ventura, CA, September.

Jet Research Center (JRC). 2002. ROV placed explosive shaped charges. Victoria, TX: Jet Research Center, Specialty Explosive Services Group.

John Brown Engineers. 1997. The Abandonment of Offshore Pipelines, Methods and Procedures for Abandonment. Prepared for the UK Health and Safety Executive. Available at https://www.hse.gov.uk/research/othpdf/500-599/oth535.pdf.

Lewis, R.D. and K.K. McKee. 1989. A Guide to the Artificial Reefs of California. Updated 2001. California Department of Fish and Game. Available at https://wildlife.ca.gov/Fishing/Ocean/Artificial-Reefs/Guide.

Manago, F. and B. Williamson, eds. 1998. Proceedings: Public workshop; Decommissioning and removal of oil and gas facilities offshore California: Recent experiences and future deepwater challenges. OCS Study MMS 98-0023. Marine Science Institute, University of California, Santa Barbara, CA. 275 pp.

Marine Insight. 2022. “What is a Mooring Buoy.” Available at https://www.marineinsight.com/marine-navigation/what-is-a-mooring-buoy/#:~:text=Mooring%20buoys%20are%20a%20type,the%20bottom%20of%20the%20sea. Accessed March 24, 2022.

Menon, A. 2020. Understanding Heavy Lift Vessels (HLVs): Design, Operation and Types, Marine Insight. Available at Understanding Heavy Lift Vessels (HLVs): Design, Operation And Types (marineinsight.com). Accessed February 23, 2022.

Nautical Class. 2018. Marine Examination Guide, What are the types of tugs and use? Available at https://nauticalclass.com/what-are-the-types-of-tugs-and-use/.

Mineral Management Service (MMS) 2005. Structure-Removal Operations on the Gulf of Mexico Outer Continental Shelf, Programmatic Environmental Assessment. OCS EIS/EA MMS 2005-013. U.S. Department of the Interior, Mineral Management Service, Gulf of Mexico OCS Region. New Orleans, LA.

National Research Council (NRC). 1996. Marine board committee on techniques for removing fixed offshore structures. An assessment of techniques for removing offshore structures. Washington, DC: National Academy Press.

Offshore Operators Committee (OOC). 2022. BSEE/BOEM Pacific Decom PEIS Discussion Meeting, March.

OregonWaveEnergy Trust. 2009. Advanced Anchoring and Mooring Study. Available at https://tethys.pnnl.gov/sites/default/files/publications/Advanced_Anchoring_and_Mooring_Study.pdf.

Padre Associates. 2020. Santa Clara Unit (Platforms Grace and Gail) Conductor Cutting Program, prepared for Chevron West Coast Decommissioning Program, Ventura, California, September.

PetroWiki. 2015a. Fixed steel and concrete gravity base structures. Available at https://petrowiki.spe.org/Fixed_steel_and_concrete_gravity_base_structures.

PetroWiki, 2015b, Remotely operated vehicles, https://petrowiki.spe.org/Remotely_operated_vehicles_(ROVs).

Pipe Exchange. 2021. Lessons from the Gulf of Mexico: Expediting an offshore platform's decommissioning. December. Available at: https://pipexch.com/lessons-from-the-gulf-of-mexico-expediting-an-offshore-platforms-decommissioning/.

Prasthofer, P. 1997. "Offshore Production Facilities: Decommissioning of Topside Production Equipment." In Minerals Management Service, 1997, Proceedings: Public Workshop, Decommissioning and Removal of Oil and Gas Facilities Offshore California, Recent Experiences and Future Deepwater Challenges, September.

Saint-Arnaud, D., P. Pelletier, W. Poe, and J. Fowler. 2004. Oil Platform Removal Using Engineered Explosive Charges: In-Situ Comparison of Engineered and Bulk Explosive Charges. Final Report. U.S. Dept. of the Interior, Minerals Management Service, Technology Assessment and Research Program, Herndon, VA

Sterett Crane and Riggins. 2015. Crawler Cranes. Available at https://www.sterettcrane.com/crawler-cranes/.

TSB 2015

Zimmerman. Undated. Letter from Offshore Operators Committee to BOEM during Scoping, "Appendix A. Subject Dredging and Excavation."

Versabar, Inc. 2017. Project History — Bottom Feeder. Versabar, Inc., New Orleans, LA. Available at https://www.vbar.com/project_history-vb10000/index.php?ProjectType=Bottom+Feeder. Accessed April 14, 2022.

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