THE TRI-COUNTIES, CALIFORNIA AS TECHNOLOGICAL INNOVATION MOTIVATOR

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ABSTRACT

Innovation is something that holds special significance for a technologically intensive endeavor such as petroleum extraction. Frequently through its history, continued production has hinged on the promulgation of new technologies to meet new demands. In this paper, I recount the part the Santa Barbara Channel and surrounding region (San Luis Obispo, Santa Barbara, and Ventura counties, California) has played in this innovation process. The innovations that the channel has sponsored have been "motivated" by three primary factors: first, aesthetic or pollution control demands; second, environmental/geophysical and; third, economic cycles. Each of these factors have forced and enabled the industry to address what were new problems and in so doing learn new ways to produce. This in turn has sponsored new industry standards and proven useful to production in other regions.

Keywords: Abandonment, decommissioning, environmental compliance, offshore oil, petroleum extraction, pollution control, remediation, Santa Barbara Channel.

INTRODUCTION

Unlike many of the other oil producing regions in the U.S., California in general and the tri-counties (San Luis Obispo, Santa Barbara, and Ventura counties) in particular have been the scene of a rather unique struggle between would-be oil producers and a citizenry that does not unconditionally support industry desires. Residents of the central coast of California have a strong connection with their natural environment, especially ocean and coastal resources (see Molotch et al. 1996; Freudenburg and Gramling 1994). This cultural disposition has sensitized the public to the prospect of industrial development; oil has the unenviable status of being a primary target of their concern. With the push to develop offshore tracts in the late 1950s through the 1960s, the visibility of oil production became more pronounced; platforms, processing plants, and a handful of accidents[1] lent to an already extant local opposition an urgency which spawned organized protest. Events such as lease sales, proposed platform installations, and the construction of onshore facilities became points for resistance as locals vied for control over the development direction of the region.

This local opposition has caused the oil industry a good deal of difficulty; according to industry advocates it has retarded the continued development of the region's petroleum industry by making large scale oil production unprofitable (Beamish et al. 1998). For the industry, resistance to oil-related development has often translated into: the denial of and long delays in permitting and installation of needed facilities, increased operation costs, and development of costly technological innovations to meet federal, state, and local requirements. Echoed throughout industry references to the tri-counties region are allusions to the distinct set of parameters they must contend with when producing oil. As early as 1958, Richfield Oil Corporation had to address such concerns when constructing their Rincon Island drill platform located approximately 10 miles south of the city of Santa Barbara and 20 miles north of Ventura. Because state law forbade what were referred to as "Texas-style oil towers," Richfield was forced to construct their drill platform as an island[2]. Furthermore, to appease a handful of ocean view hotels and homes along the coast the man made island was landscaped with palm trees (Ventura Star Free Press Magazine 1965).

In more recent times, in response to the 1969 Santa Barbara Channel oil spill (see Beamish et al. 1999) and growing concerns over air quality, the industry has had to address increasingly stringent pollution control standards, areas designated as officially off limits to oil development, and a population that is generally suspicious of oil development. Throughout industry references to the region are characterizations of a place unfriendly to oil. In the following trade

[1]The 1969 Santa Barbara oil spill was the most notorious.

[2]In the 1950s, state law required that all aspects of such island structures had to be built from natural materials such as sand and stone. Other islands similar to Richfield's at Rincon also went in off the coast of Long Beach CA, and were also decorated with palm trees, facades, and camouflage for their drill rigs (see Offshore Magazine 1958; Pratt 1997).

journal excerpt, the constraints posed by the area on oil development are acknowledged, with the author adding in uncertain terms that "some sort of buffer zone" will be enforced to preserve the area's scenic beauty:

> "Industry reports that more than 700,000 acres, and perhaps as much as 1,000,000 acres, have been nominated for the October (lease) sale. (The) Only area sure to be excluded from the sale is some sort of buffer zone just beyond the no-drilling sanctuary immediately in front of the city of Santa Barbara. Here the state banned drilling to preserve the beauty of the coastline, prohibiting offshore oil operations between Goleta point, west of Santa Barbara and Summerland to the east" (Offshore Magazine 1967:73).

The industry has had to confront an increasing number of pollution abatement measures across the nation, but it is in California and the tri-counties (Santa Barbara Channel in particular) that these measures and community concerns have effected change in the ways the petroleum industry operates and presents itself.[3] While the push to reduce pollution has gained a national audience with powerful lobbies, it is in areas such as the tri-counties that the "frontier" of pollution control has been pushed the farthest. Hand-in-glove with such pollution controls, operators have also had to aesthetically modify their plans by developing ways to visually hide their operations from a tri-county population that can be sensitive to them.

Santa Barbara County has been especially effective in this regard, using their permit control over proposed onshore support and refining facilities to influence proposed developments, even those out of their jurisdiction in federal waters. In order to appease local fears, petroleum operators have gone so far as to paint their platforms to match the environments within which they have been installed, promise to camouflage land-based facilities with extensive landscaping, and paint, and in some cases have located facilities out of plain view. Another petroleum trade journal excerpt provides an account of platform Hogan's installation (offshore in the Santa Barbara Channel). Herein, an industry spokesperson notes the new equipment which defines the platform as distinct from similar ones installed or in use at that time. Under the title, "First Development of Channel Acreage Begins: Painted a Hazy Blue, Phillips' Hogan, Designed To Drill 66 Wells, Fight Pollution," the article recounts industry awareness of the special requirements they confront when producing in the Channel:

> "(The) First development of a federal lease in Santa Barbara Channel Calif., is underway from Philips Petroleum Co. Platform Hogan, situated in 151 ft of water some 4 miles offshore. . .
>
> A hazy blue. . . Both aesthetic and anti-pollution considerations play a large role in the operation. Both platform and the two rigs on it are painted a "blue haze" color to blend with sky and sea. The platform has been designed to eliminate all possible sources of water pollution during drilling and producing operations. . . Beautification does not stop with the platform. At the processing plant, trees, shrubs, and ground cover will be utilized to screen the facility. Also all vessels and tanks are painted a natural green to blend with surroundings. . .
>
> Air kept pure. . . Settling tanks, wash tanks, and storage tanks are equipped with vapor recovery units to prevent air pollution. Under normal operating conditions no gas will be flared. Produced gas and vapors will be processed to remove water vapor and heavy hydrocarbons . . . Produced water will be processed through a skimmer and flotation unit to remove any oil. Water then will be filtered to remove solids and minute traces of oil prior to disposal in the ocean" (Offshore Magazine 1968).

As one may surmise, painting a rig hazy blue or planting shrubbery around a refinery to spruce it up was something that was relatively new for an industry that usually got its way, on its own terms. In the Gulf of Mexico, where much of the offshore technology was first developed, these kinds of innovations were unnecessary, due to geophysical and topographic differences as well as cultural ones (Freudenburg and Gramling 1994). When offshore discoveries in the channel began, a new set of criteria had to be addressed if the industry was going to do business in the region. Even before the 1970s, the era conventionally identified as the beginning of modern "environmentalism" (Colella 1981; Enloe 1975; Pratt 1978, 1981; Pratt et al. 1997) these aesthetic and pollution concerns held salience for local residents and were a source of tension between industry and community relations (Molotch et al. 1996). During the 1980s and '90s these concerns amplified with the general growth in environmental consciousness, further forcing the industry to elaborate on existing technologies, and to create new lower-impact extraction methodologies, and/or mitigate their potential negative affects.

The novelty that such aesthetic and pollution control concessions represent is apparent when the industry's historical resistance to such demands is recounted. Their attitude toward these demands has historically been one characterized by recalcitrance; open resistance to regulation and regulatory compliance in general, especially those regulations that are superfluous to production, has been the norm (Pratt 1978, 1980). According to historian Joseph Pratt the

[3]Enforcement largely began in the late 1960s (see Beamish et al. 1998; Pratt 1978, 1980).

industry enjoyed unchallenged dominance in government-business relations until the 1970s, a dominance it has exhibited by historically flouting local, regional, and national authorities' attempts to stem what had become, at least in the Gulf of Mexico, pervasive petroleum based degradation. According to Pratt:

> "Through an ideological lens of "free competition," oil executives in the spindletop era viewed government suspiciously, as a potential usurper of corporate power and a threat to corporate autonomy. Politicians were usually seen as meddlers who were both opportunistic and incompetent. . . The resulting distrust of government did not disappear. Of course, such attitudes did not prevent business from cooperating with government measures that were beneficial to it. But when government attempted to assert power in areas previously controlled solely by the corporation, cooperation became most difficult. Pollution control was one of the most volatile issues" (Pratt 1978:7).

In California, much the same mentality has dominated industry priorities until the more recent era of stringent state and federal environmental regulation and enforcement. Take for example regulations governing platform stability in California's earthquake prone waters. The industry has not only complied with the regulations, but preemptively designed its platforms to withstand earthquakes of eight or more on the Richter Scale (Rintoul 1976; Pratt et al. 1997). In fact, the industry has addressed both platform strength and ductility in seismic proofing of their investments. The *strength* level of a platform is an assurance that the platform is designed to maintain all nominal stresses without buckling in earthquakes, for the life of the rig. The ductility of a platform, on the other hand, refers to a platform's ability to withstand earthquakes beyond its designed strength capacities. *Ductility* entails ensuring that there is enough structural resilience to absorb significant stresses beyond those anticipated in a worst case scenario (Pratt et al. 1997).

While attending to seismic concerns in California may have had a direct payoff for the industry—50 to 150 million dollars platforms and production facilities are big investments—pollution abatement presented no such incentive. The "payoff" of pollution control equipment and procedures are much less tangible in that they are long term, dispersed, and not directly tied to oil investments. The petroleum industry's externalization of "environmental costs" is a trait it has shared with other heavy industry, but the sheer size and importance of the petroleum corporations have given them a good deal of immunity for much of their history. More recently, regulatory compliance has achieved a status which even large petroleum corporations must address. Through regulation the cost of ignoring compliance has become burdensome giving it a priority status it once lacked (see Beamish et al. 1998).

However, aesthetic and pollution control considerations have not been the only motivations to drive industry innovations in the region. The Santa Barbara Channel in particular has also posed a number of new problems for those that seek to develop offshore oil tracts. Geophysically, the channel presented producers through the mid-1970s with water depths they had not yet confronted, and as mentioned earlier an earthquake-prone environment. Environmental conditions in the channel also presented operators with consistently high wave velocities as well as wind speeds at times in excess of 100 miles per hour. In a 1958 article fittingly titled, "Drilling in California will be Tough" an industry trade journal noted that the conditions that characterize California's offshore environment were vastly different than those confronted in the Gulf of Mexico where offshore operators had learned their business. The same article continued to note, "California offshore locations encounter higher everyday waves, greater water depths, fewer adequate harbors and onshore facilities" (Smith 1958). These conditions in conjunction with the region's regulatory climate sponsored a number of industry "firsts": in the development of drilling techniques for water depths over 1,000 ft, in developing production platforms able to stand in 600 and more feet of water, in transferring seals and sulfur dioxide reduction systems which would meet California and Santa Barbara Air Pollution Control District specifications, and many others.

In the following pages I touch on a number of these innovations and the contexts that have sponsored them, including: innovations that have been the outcome of regulatory requirements, advancements that address the region's distinct geophysical and environmental features, and how these innovations have promoted technologies which have set new standards for the industry and have subsequently been applied outside the region. Innovation trends have been typified by different barriers to the industry's production at different periods of time. From the late-1950s and the industry's drive to produce in ever deeper water, to current dilemmas based in abandonment (this process is also referred to as "decommissioning" in some technical and policy circles) and remediation, the story of "innovation" is a varied one based in available technologies, economic cycles, and the ingenuity of the industry itself. Taken together, aesthetic/regulatory, geophysical/environmental, and economic constraints have presented the industry with both the social and material motivations to innovate. Based on these *innovation motivators*, as I refer to them, the region has provided the impetus for new production techniques and an accompanying array of technologies (Figure 1).

In Figure 1, I graphically outline the motivators the tri-counties have presented the industry with, and the advances, that have been made to overcome them. Each of these factors as both impediments to, and sponsors of, new exploration and production technologies has effected change in the industry at different periods. In the following I recount this history of regionally sponsored technological innovation.

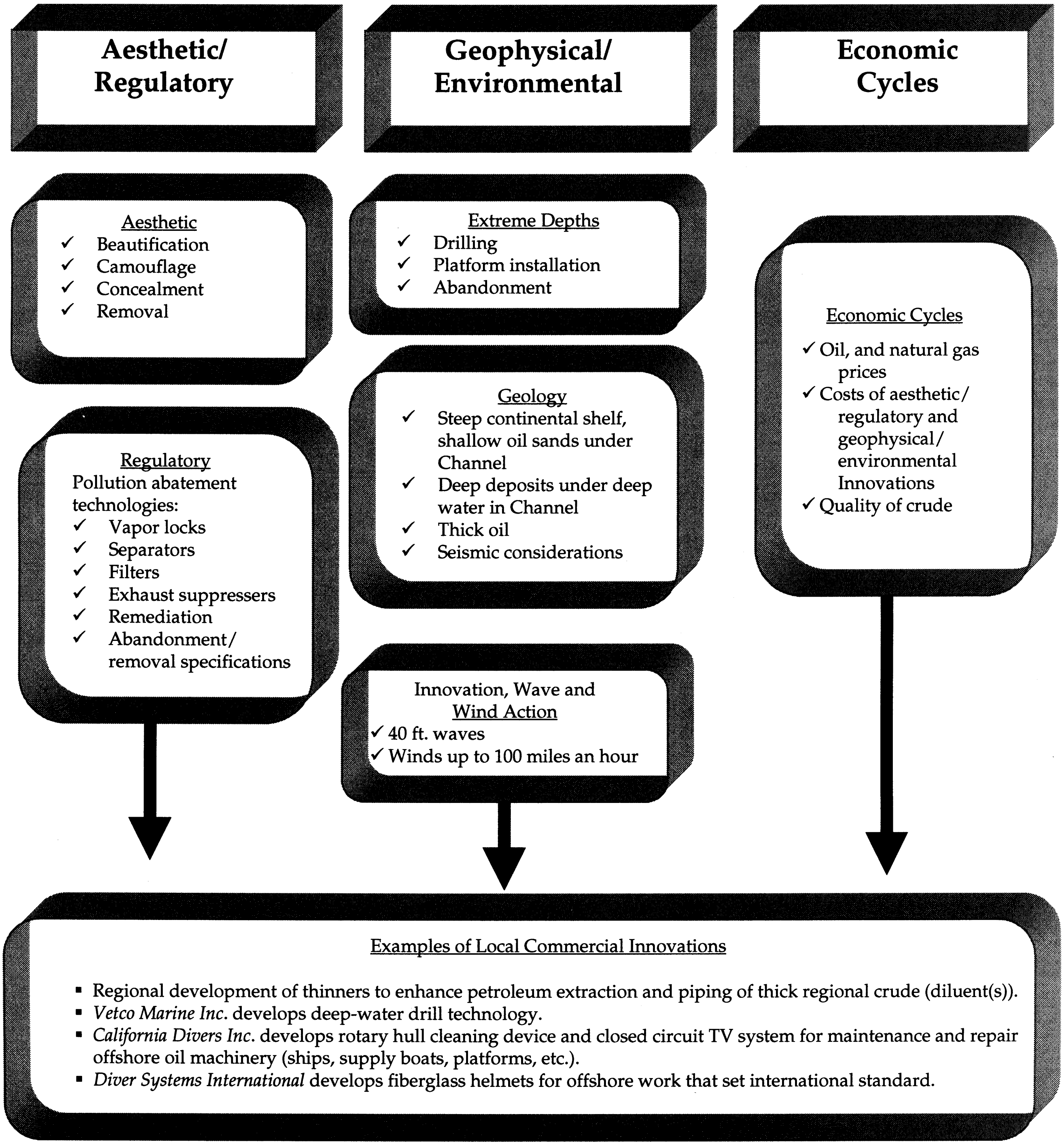


Figure 1. Tri-county technological innovation motivators.

1950-1968 Deep Water and Deep Pockets: Depth is Not a Limit

From the 1950s into the mid-1960s, innovation in offshore oil production centered on the development of technologies to deal with an increasing number of deep water finds. From the mid-1960s through the '70s, the offshore industry grew worldwide at a phenomenal rate, and the Santa Barbara Channel was no exception. Engineers and research and development people knew that new technologies were a must if they were to tap oil reserves beyond the conventional 300 ft pile-driven platform limits (Moore and Ridge 1982:45).

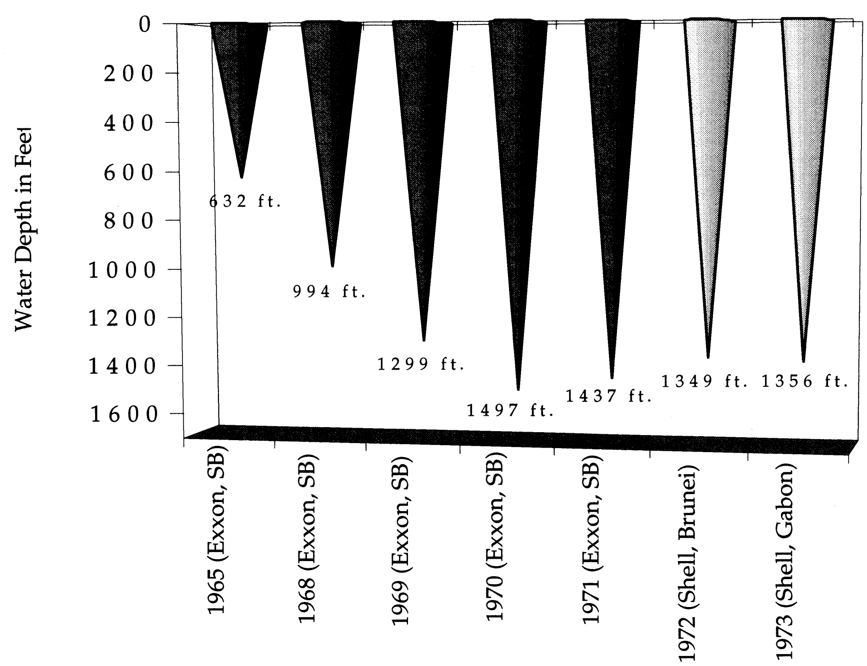
Economic considerations during this period were not an overriding concern for engineers, who were able with virtually open budgets to overcome barriers to production.

Tens of billions of dollars were spent on solutions, some of which while appearing workable later had to be scrapped. Economic projections of $40 to $50 per barrel (which turned out incorrect) appeared at the time to justify such investments. According to petroleum engineer Stuart Hall, "the offshore industry had a kind of myopic view of the real world back then . . . We were blinded by the challenges of a particular number, in this case 1,000 ft (of water)," (Moore and Ridge 1982:46).

The Santa Barbara Channel's steep continental shelf and depths dropping well over 1,000 ft provided a testing ground for such deep water technologies, especially with lease sales P-1 (1963), P-3 (1966), and P-4 (1968) in federal waters three and more miles offshore Santa Barbara County.

The period's big producers, with "limitless" resources at their disposal, coupled with their high hopes for Channel finds, financed such independent mobile drill ships as *Wodeco IV* and *Blue Water 2* to push deep water drill records routinely past the 600 ft mark.[4] The first record was set in 1965 by Exxon crews drilling in 632 ft of water off the coast of Santa Barbara (Figure 2). In setting such records and hence new standards, the industry also learned valuable lessons that were later applied off the coasts of southeast Asia, Africa, and the North Sea.

Other innovations included technologies to address platform installation in the Channel's deep waters and extremely steep ocean floor. The depth coupled with a 600 ft contour (a precipitous sloping of the ocean floor) ranging from only two to fifteen miles offshore made platform installation a very tricky proposition (Pratt et al. 1997).[5] Complicating platform placement and stability beyond the depth and abrupt drops of the Channel floor were constant westerly winds, accompanying extreme wave conditions, and few adequate harbors or onshore facilities to fabricate, install, or service offshore platforms. Waves for instance, driven by persistent winds can reach heights of 26 ft for 12 to 36 hours at a time (Pratt et al. 1997). Such waves not only taxed the platform styles of the day, but also the techniques that producers used for installing them. An initial innovation the industry developed to meet these demands was the *gravity structure design*.[6] The gravity structure concept entailed



Source: Simmons, J.D. 1976. "Exxon Discloses its Experience in Deepwater Drilling Worldwide." Offshore Magazine. Vol. 36, May: 200-209.

Figure 2. Santa Barbara Channel drill records.

[4]Working under contract for Exxon and Esso, respectively.

[5]This is in contradistinction in the Gulf of Mexico (the standard) where the ocean floor's gradient is incredibly gradual. Platforms can be many miles offshore and still encounter relatively shallow depths and a flat ocean floor.

Table 1. Santa Barbara Channel offshore platform installation and removal chronology.[1]

1958
1. Platform Hazel installed*
2. Construction of Rincon Island*

1960
1. Platform Hilda installed*
2. Platform Helen installed*

1961
1. Platform Harry installed*

1963
1. May, Lease Sale P-1
2. Platform Herman installed*

1966
1. December, Lease Sale P-3
2. Platform Holly installed*
3. Platform Heidi installed*
4. Platform Hope installed*

1967
1. Platform Hogan installed**

1968
1. February, Lease Sale P-4
2. Platform Houchin installed**
3. Platform ‘A’ installed**
4. Platform ‘B’ installed**

1969
1. Platform Hillhouse installed**
2. January, blowout, Platform ‘A’

1974
1. Platform Harry removed

1976
1. Platform Hondo installed (self-contained deep-water platform for combined drilling and production activities).**

1977
1. Platform ‘C’ installed**

1979
1. June, Lease Sale 48
2. Platform Grace installed**
3. Platform Henry installed**

1980
1. Platform Gilda installed**
2. Platform Gina installed**
3. SALM Technology installed by Exxon to process crude from Hondo avoid environmental restrictions.**

1981
1. May, Lease Sale 53
2. Platform Habitat installed**

1982
1. June, Lease Sale 53
2. Arco’s natural gas recovery project commences (pyramid gas trap over natural gas seep receives pollution credits).

1983
1. November, Lease Sale 73

1984
1. October, Lease Sale 80

1985
1. Platform hermosa installed**
2. Platform Harvest installed**
3. Platform Irene installed**

1986
1. Platform Hidalgo installed**

1987
1. Platform Gail installed**

1988
1. Platform Helen removed
2. Platform Herman removed

1989
1. Platform Heritage installed**
2. Platform Harmony installed**

1996
1. Platform Hazel removed
2. Platform Hilda removed
3. Platform Hope removed
4. Platform Heidi removed

[1]To date 31 platforms installed, seven removed, 24 remain.
*State lands.
**Outer continental shelf, federal waters.

floating the platform jacket out to the point of intended installation and then securing the platform by gravity alone. This was accomplished by filling its caissons (or legs) with sand and cement instead of anchorage with steel piles driven into sea floor as done in the Gulf of Mexico. One of the first applications of this advanced design technique was with the installation of platforms Hope, Heidi, Hilda, and Hazel (beginning in 1958 with platform Hazel) (Table 1). The design strategy allowed the industry to pre-construct larger and more secure platforms on land in other regions (primarily the Gulf where their operations were already in place), float them to the intended destinations, and install them relatively quickly, even in rough seas. This method, having proven effective in the channel, has been used extensively in Cook Inlet (Alaska) and in the North Sea off Norway.

1969-1986 Deep Water and Pollution Control as Innovation Incentives

Through the 1970s, deep water coupled with good economic returns for local oil producers continued to prompt technical innovation. Exxon's operations in the channel would continue, until 1974, to hold world records for open water drill depth and platform placement (Figure 2). By the early 1980s the Santa Barbara Channel's role as a deep water testing ground gave way as the majors began to apply what they had learned to drilling and production in other regions in water depths that on occasion exceeded 3,000 ft.[7]

In addition to deep water, environmental legislation following the 1969 spill acted as a spur for a new round of advances, as oil firms were forced to devise pollution control equipment to meet new regulatory demands (see Beamish et al. 1998). Innovation continued to occur and was spurred on by the constant threat of earthquake, consistently rough wave action, and high winds characteristic of the channel. In this period, new innovations to meet these environmental conditions included platform jacket jointing, development and use of flexible materials (for instance new steel alloys), and caisson support systems that could withstand these stresses; these technologies were employed on increasingly large and expensive offshore platforms.[8] Through the 1980s regulatory and pollution control issues would also continue to push producers and define for them the character of the tri-counties region. The strict regulatory climate that began to develop in California, coupled with a new array of federal controls, forced operators to address environmental impacts through innovative pollution abatement technologies.

The heavy restrictions placed on air- and-water-borne discharge from platforms and land-based facilities, for instance, forced producers to develop *advanced effluent recovery units* to assure low level waste emissions (both air and water), to use of alternative fuels to power generators, and to mitigate unavoidable impacts. Specifically, innovations developed to address these and other pollution concerns included: platforms that ran on electricity as opposed to diesel; facility installations, extraction methods, transport systems, and refining methods that developed new or applied the most advanced pollution control devices; the modification of onshore technologies for "first time use" in offshore applications (ability to accommodate multiple liquid effluents such as oil, gas, water; and muds from extraction wells and refining processes); and all other potentially detrimental effluent whose origins are the platforms (for instance, human wastes).

1987-1996 and Into the Future: Economic Downturn, Abandonment, and Post-Industrial Clean-up

Market prices for oil precipitously declined in the 1980s and with them the tri-counties region began to see the majors sell off or pull out their "unproductive" (that is, less profitable) operations. A handful of platforms were among the operations slated for removal, and these challenged the technical knowledge of the industry. Unlike the Gulf of Mexico, where such abandonments have become rather routine,[9] the decommissioning of these platforms became a hot issue and led to a (currently) continuing debate over whether platforms should be left in place, partially, or completely removed.

This first round of abandonment was in relatively shallow waters. Platforms Helen, Herman, Hope, Heidi, Hilda, and Hazel, all in state waters, were at 100 feet depths, but the size of the channel platforms changed the nature of removal as it had been accomplished up to this time. The Gulf of Mexico provides the largest base of experience and information for platform abandonment with over 1,100 platforms removed to date. However, because channel platforms tend to dwarf the average size of those removed in the Gulf, and the environmental conditions that characterize the channel are less hospitable, extraction of these platforms is more problematic. The platforms off the Santa Barbara coast are

[6]Source: Decommissioning and Removal of Oil and Gas Facilities Offshore California: Recent experience and future deep water challenges. September 23-25, 1997. Ventura, CA. Sponsored by the Minerals Management Service and the California State Lands Commission.

[7]Open water drill depths for exploratory purposes exceeded the 2,500 ft mark, but due to a drop in oil prices production at these depths was unprofitable and was never carried through.

[8]Between 1978 and 1979, the price of a platform more than doubled from $60 million to well over $100 million. Such investments were worth the added technological protection gained through extensive research and development (Offshore Magazine 1979:43).

[9]In the Gulf of Mexico.

typically in the 8,000 to 16,000 ton rage, while those in the Gulf typically weigh 3,000 tons and less. Furthermore, with only 38 of those Gulf platforms in depths over 200 ft their removal protocols differ markedly from those producers had to develop for the channel.

A number of technologies had to be developed in order to meet new abandonment challenges that entail heavier total loads and stricter regulatory restrictions than those found in the Gulf.[10] Examples of such technologies include: hydraulic grippers adapted to special buoyant lift rigging which could handle 500 ton lifts or more, the development of "A" frames which could also handle such enormous weights, as well as barges, cranes, lazer cutting devices, and other tools able to deal with unprecedented torques, corroded and overgrown sub-sea infrastructures, and metals designed specifically to withstand tremendous force. Complicating extraction beyond the technologies involved is the plain fact that all these enormous tools and their removal strategies have to be coordinated from the topside of a floating work station.

The dilemmas these removals present do not end with the platforms, the water depths, or their difficult removal. They also present an environmental double bind which has proven difficult if not impossible for the industry to overcome. Even if equipment of the right size and horsepower is developed and used, the pollution emitted would violate California and regional (e.g., tri-county) air quality standards, making removal virtually impossible.[11]

Still, in the near future the abandonment of the channel's offshore rigs looms as the viability of several of the outer continental shelf (OCS) petroleum reservoirs are depleted. All the remaining 24 platforms in the channel, with the exception of platform Holly (in state waters), are in federal waters. The extreme water depths in which these platforms stand, coupled with their immensity, pushes the limits of existing knowledge and technology, providing the impetus for a new round of innovation. It is important to stress that the removal process is one that is derivative of and embedded in a social context. The region continues to be concerned with issues of pollution abatement and environmental impact. Experts believe the channel will be the first location to have structures of this size, in these depths, and in such a heavily regulated environment to be removed. From the industry's perspective, the conditions that surround the removal of these platforms makes their extraction not only arduous, but expensive (requiring expenditures that can rival those of the initial installations). Yet a strategy will have to be devised, because state and federal law as it is currently written calls for the complete removal of those platforms when production has been discontinued.

In addition to offshore innovation, a number of onshore fields, of which the abandoned Guadalupe oil field is the most significant, provide another incentive for a new array of remedial technologies (see Beamish et al. 1998). In Guadalupe's case, a petroleum thinner called diluent (pronounced dil-'ú-ent)—or K-9 thinner as it is referred to by the oil industry—was spilled, accumulating under the sands of the Nipomo-Guadalupe Dunes reserve that surrounds the oil field. Estimates put the spilled product between 8.5 and 30+ million gallons. Much like kerosene or diesel fuel, diluent is a relatively clear petroleum by-product that is used to thin the heavy crude characteristic of the central and south coast of California. As a thinning agent, diluent was an early regional innovation that made possible the pipeline transport of the areas thick crude from extraction wells to local refining and storage facilities (Stormont 1956:127).

Because the spill is hard to access, as it is primarily underground on the water table and in the middle of California's last intact coastal dunes and marsh ecosystem, new remediation techniques are being implemented that promise lower impacts than those associated with traditionally conceived excavation techniques. Bioremediation technologies include an array of largely untested strategies for the clean up of petroleum contaminated sites. New clean up strategies and technologies include: installation of high integrity physical barriers to impede hydrocarbon drift (technically referred to as bentonite walls), vacuum enhanced drop tube technologies (use of high vacuum drop tube techniques to pull hydrocarbons out and push oxygen in which "enhances" the growth of petroleum eating microbes), and biosparging (which entails forcing air and microbes underground into contaminated areas, promoting the growth of introduced biogenetically engineered micro-organisms which live on such hydrocarbons). These are being developed and used for the first time, at least at this kind of scale, and will be used in other areas as similar sites are found in the tri-counties and elsewhere.

CONCLUSION

In the preceding pages we have looked at how the tri-counties and the Santa Barbara Channel in particular have motivated innovations in the petroleum industry. These have been the outcome of regionally based regulatory requirements, advancements made that address the region's distinct geophysical features, and environmental conditions that put new stresses on what were time were inadequate technologies. Furthermore, we have also touched on how these innovations have promoted technologies that have set new standards for the industry and have subsequently been applied

[10]Source: Decommissioning and Removal of Oil and Gas Facilities Offshore California: Recent experiences and future deep water challenges. September 23-25, 1997. Ventura, CA. Sponsored by the Minerals Management Service and the California State Lands Commission.

[11]Diesel exhaust is heavily regulated.

outside the region. Taken together, aesthetic/regulatory, geophysical/environmental, and economic constraints have presented the industry with both the social and material motivations to innovate. Based on what I refer to as *innovation motivators,* the region has sponsored new production techniques and an accompanying array of technologies that have changed how the industry produces oil and presents itself. Those changes have not only had ramifications for local production, but at times have had applications outside the region.

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