WHEN LOW TECHNOLOGY IS THE ANSWER: RESPONSE TO A REMOTE OIL SEEP:

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ABSTRACT:

Emergency responders must resist the temptation to over-build our response facilities. We need to balance the inherent conflicts of safety and effectiveness versus costs and benefits. We should always try to apply the simplest, most appropriate technology to the site and its problems. This should result in the most cost-effective and least disruptive response while ensuring we keep our commitment to protecting health and the environment.

Oil seeps are common in Central California. One seep discharged up to15 bbl/week into Toro Creek. Due to the site's remote location, lack of electricity, and steep terrain, an innovative oil-water separator system was installed linking the separator by gravity to a UST (underground storage tank). These features were employed:

1. There are no moving parts. All separation and collection is by gravity;
2. Solar power runs a monitoring system and modem, which monitors system performance and phones emergency responders if there is a problem;
3. All oil is collected, conveyed, and stored within secondary containment;
4. Due to past acts of vandalism, key elements of the system are buried for greater security;
5. Only 4 hours/month is required for routine operations and maintenance activities.

EPA worked with the terrain and setting in the design and construction of this effective recovery and containment system. As a result of the application of “appropriate technology” at this oil spill, there is no longer oil in Toro Creek. This presentation will highlight the use of conventional construction methods and readily available off-the-shelf supplies and equipment to build the treatment system.

DISCUSSION:

California has many oil seeps, both inland and offshore. In 1543 Juan Cabrillo, a Portuguese sailing under the Spanish flag, recorded that the Indians along the Santa Barbara Channel used asphaltum from the area's numerous seeps to caulk their sea-going canoes and to waterproof baskets. Cabrillo followed the Indians' example, using the substance to waterproof two ships (K.A. Franks, year unknown). As early as the 1850's, American settlers in California began to tap this plentiful natural resource. By 1855, several streets in San Francisco were paved with asphalt. In 1856, still three years before Col. Drake's well was drilled in Pennsylvania, Andreas Pico was distilling oil taken from a natural seep in northern Los Angeles County for use in lighting the local San Fernando Mission (Ibid).

Oil seeps form where oil emerges at the surface from a subsurface source. Frequently, seeps are associated with water springs: oil floating to the surface of the water (A.I. Levorsen, 1967). Oil, gas, or liquid asphalt, exuded in the form of springs and seepages, may reach the surface by migration along fractures, joints, fault planes, or through any of the connected porous openings in the rocks (Ibid). Migration of oil to the surface is controlled by hydrostatic pressure, gas pressure, capillary action, differential compaction, and heat (C.W. Jennings, 1957). Seeps are transitory features, appearing and disappearing through the years on no set schedule. For the most part, this is caused by changes in the in the oil source; changes in the water table (some seeps disappearing or becoming less active during periods of drought, and reappearing or increasing their activity after periods of heavy rainfall); changes in the surface temperature; and changes in the fissure network, including seepage routes blocked by intrusions, chemical alterations, and earth movements (S.F. Hodgson, 1987). Earthquakes may account for unusually large flows from some seeps (A.I. Levorsen, 1967). Following the 1971 San Fernando Valley earthquake, several of the previously inactive oil seeps in the area resumed activity.

Site background:

Starting in 1882, Occidental Mining and Petroleum Corp. began digging a horizontal tunnel in Toro Canyon, Santa Barbara County, California at the site of a well-known local oil seep (W.A. Tompkins 1969). Horizontal oil wells were commonly used to enhance the oil flow from seeps in this area. Typically they were dug uphill at a gradient of 1% to allow the oil to flow out to the mouth of the portal for recovery, and to ensure the ore cars hauling the mine spoils would not de-rail due to high speed. Mirrors were installed at the tunnel entrance to illuminate the tunnel and to assist with the proper alignment and gradient during construction. After advancing the tunnel over 210 feet (64 meters) into the steep face, a large volume of water was inadvertently tapped. Occidental, realizing the value of fresh water in the area, abandoned the feasibility of developing the oil resource, and concentrated on conveying the water to downstream users in nearby Summerland, CA. Basic oil-water separation was employed to provide potable water to nearby residents for over 60 years, until another water source was provided.

In subsequent years, the existing OWS (oil-water separator) fell into disrepair. Numerous spills to Toro Creek occurred over the years, culminating in a major spill in 1992. At that time the California Department of Fish and Game (DFG) responded by cleaning up the oil in Toro Creek and requiring the property owner to install and operate an effective OWS. During this period, the United States Coast Guard became aware of oil in the Pacific Ocean near the mouth of Toro Creek during rainy weather. Downstream residents grew less tolerant of oil in Toro Creek.

Initial assessment:

In July 1997, a vandal disabled the OWS, resulting in a major spill of over 3,000 gallons (13,200 liters) of oil to Toro Creek. From the oil seep to the Pacific, Toro Creek was oiled for its full 4.5-mile (7.24 km) length. DFG again responded to the oil spill, but exhausted available response funds before completing the response. On July 24, 1997 United States Environmental

Protection Agency (EPA) responded at the request of DFG. Figure 1 shows a heavily oiled portion of Toro Creek on July 24, 1997. The EPA Federal On-Scene Coordinator (OSC) determined that a release of oil to Toro Creek was on-going, that Toro Creek was a water of the United States, and that other parties were unable to address the oil spill. This determination brought the oil spill under the authority of the Oil Pollution Act of 1990 (OPA), and allowed response funds to be authorized from the Oil Spill Liability Trust Fund.

The response was conducted under a Unified Command, with EPA and DFG serving jointly as Incident Commanders. This structure assured that decisions were jointly made and that response actions were well coordinated. EPA assumed the lead in trying to stop the oil release. An OSC typically focuses on stopping a spill at or near the source and controlling the source early in the response. Engineering geologists were tasked with examining the feasibility of stopping the oil flow at the source: the oil tunnel. The geologists believed that, because the tunnel had collapsed many years before, and that the slope where the tunnel had been was so steep and subject to slides and rock-falls, any attempt to re-open the tunnel would be too hazardous. The geologists further advised against attempting to drill a vertical shaft into the tunnel from above for the same reasons. Finally, they recommended against attempting to plug or seal the collapsed tunnel because such sealing methods, when employed at similar oil tunnel seeps in the area, had merely resulted in the re-establishment of the oil seep (but sometimes at different and unpredictable locations). The OSC concluded that there were no acceptable response options to stopping the flow, at least in the short-term.

Without the option of actually stopping the oil flow, attention turned to managing the flow, keeping the oil out of Toro Creek, and providing for a cost-effective long-term approach to the Toro Creek oil spill. An engineer was assigned to quickly design a system with these criteria:

1. The system must be able to be built in an area of limited vehicular access quickly;
2. Conventional off-the-shelf supplies and equipment should be used;

3. Oil must be handled safely, in secondary containment at all times, in an area prone to wild fires, earthquakes, landslides, and vandalism;
4. Construction must preserve and protect the headwaters of Toro Creek, a critical wildlife habitat and rare perennial stream in the area;
5. The design must consider the lack of electrical power, require minimal maintenance, and take into account the system's unattended operation.

System design and construction:

The initial design was completed within two days, subject to continual modifications through final construction. At an early stage, it became apparent that, in order to protect the critical habitat, the OWS would need to be built very near the seep, rather than further downstream where construction would have been more convenient. Had the OWS been constructed at the downstream location, over 0.2 miles (.032 km) of Toro Creek would have been essentially de-watered. This uppermost section was considered the most critical wildlife habitat. The seep appeared at the ground surface at the base of a 60° slope. The flow of water and oil was approximately 28 gpm (gallons per minute) (128 liters per minute). The oil portion of the flow varied from 1-2 bbl (barrels) (185-370 liters) per day. Although the amount of oil produced by the seep was relatively minimal, it was very conspicuous due to the small size of Toro Creek. The flow rates were determined to be relatively stable over a 10-day period, but local residents advised that both the water and oil rates varied seasonably. Toro Creek's oil seep was located at an elevation of 1,600 feet (488 meters) above sea level, on a south-facing slope. This orientation was favorable for the orographic enhancement of rainfall. A nearby resident who kept rainfall data advised us that the area received about 60 inches (1,524 mm) of rain annually primarily during the rainy season from November through March.

The collection vault and OWS were sized for a maximum flow of oil and water of 125 gpm (550 LPM), five times the average flow. The initial seep flow was piped into the first of three separation chambers in a concrete industrial water clarifier. This clarifier was readily available because industrial wastewater dischargers in the area commonly used it. The clarifier was transported up the dirt road in a sling suspended from an excavator and installed mostly below-grade. Figure 2 shows the OWS clarifier being positioned. Oil was separated by gravity in the primary and secondary chambers prior to flowing into a chemically resistant two-inch (5.1 cm) hose. This hose was encased within a 4-inch (10.2 cm) schedule 80 polyvinyl chloride (PVC) pipe. Figure 3 shows the hose inside the PVC pipe. This arrangement provided secondary containment in case the chemical hose ruptured. This pipeline was buried 24 inches (61 cm) deep under the dirt access road. Figure 4 shows the pipeline trench. The pipeline ran 900 feet (275 meters) downhill to a buried underground storage tank (UST). The vertical drop for this run of pipe was just over 300 feet (91.5 meters), almost a 30% gradient. This tank, a 6,000-gallon (26,400 liters) capacity conventional double-walled fiberglass tank, provides secondary containment and is typical of those being installed currently at gasoline stations in the US. Buried to provide security both from vandals and the threat of wild fire, the UST uses conventional pipe fittings. Figure 5 shows the UST being installed. The void between the walls provides the ability to detect leaks and collect oil should the inner tank leak.

The seep water, after flowing through the two separation chambers, flows into a third chamber where it can be observed and sampled (if necessary) prior to its discharge to the headwaters of Toro Creek. Figure 6 shows the oil layer that accumulates in the first separation chamber of the OWS.

The OWS system has no moving parts, and any elements not buried were enclosed in security fencing. High level and overflow alarm switches were installed in the clarifier and UST. These are connected to a data collector and telephone dialer that phones responders in case of problems. The electrical power necessary to operate the alarm and phone dialer equipment is provided by a 50-watt solar panel. The solar panel, constantly charging a 12-volt battery, has provided sufficient power year-round.

When 4,000 gallons (17,600 liters) of oil is accumulated, a vacuum truck removes the oil from the UST and transports it to a nearby oil refinery for use in asphalt products such as roofing tar, shingles, and road asphalt. Figure 7 shows the oil being removed prior to transportation to a refinery.

Typically, a person conducts routine inspections and maintenance every 3-4 weeks for two hours. Twice annually, routine repairs are made to the dirt access road to ensure that heavy equipment can access the OWS if necessary.

Construction lasted just 20 days. Certainly, the use of commonly available equipment and materials, and the ability to constantly modify the design in the field were critical factors in the rapid start-up of the treatment system.

Problems encountered:

Although the collection system was sized for five times normal flow 125 gpm (473 LPM), it proved inadequate for heavy rains associated with the El Nino storms of February 1-3, 1998, when 9.48 inches (241 mm) of rain fell at Toro Creek. This deluge caused landslides, flash flooding, and greatly increased flows to the OWS estimated to be in excess of 800 gpm (3520 LPM). The enormous flow ruptured the concrete vault that conveyed seep fluids into the OWS. Figure 8 shows the blowout that occurred in the collector vault. High flows also overwhelmed the OWS in both separation chambers forcing water, instead of just oil, to flow down the pipeline to the UST. This situation quickly over-filled the UST with storm water. Fortunately, the UST was piped to function as an OWS when excessive water flowed into it. Slides and flooding eroded several sections of the buried secondary pipeline, exposing but not breaking it. Figure 9 shows this erosional damage. The alarm systems functioned as designed, alerting responders to the malfunctions. However, area roads were inaccessible for two days after this event, causing a delay in response.

After inspecting the damage, we decided to increase the capacity of the OWS collection and treatment system to handle peak flows of 800 gpm (3520 LPM). An additional clarifier was added upstream of the existing OWS designed to handle increased flows when necessary, and act as pre-treatment for the existing OWS. The new OWS was fabricated as a bottom-less stainless steel box with underflow baffles for oil-water separation. Figure 10 shows the artesian seep just prior to the new OWS being placed on top of it. It was placed directly on top of the seep resulting in an upflow from the bottom into the new OWS. A stainless steel wire mesh coalescer was added to the bottom of the new OWS to agglomerate the finer oil particles and make them more amenable to separation.

The exposed portions of the pipeline were re-buried and a large dirt and rock berm constructed to direct high surface water flows and debris flows away from sensitive areas. Figure 11 shows the serious erosion around the buried secondary containment pipeline resulting from the El Nino storms. Figures 12 and 13 show the new OWS being placed and the final configuration of the OWS system. Figure 14 shows a schematic of the OWS system as built at Toro Creek.

Current status:

The OWS produces between 1.2-7.5 bbl (191-1192 liters) of oil per week. Since February 1998, there have been no further weather-related problems. No one can predict when the seep will decrease or increase. However, Toro Creek is free of oil for the first time in many years.

Response costs:

Estimated costs for the initial response including the Toro Creek cleanup, and system design and construction is US$187,000. Routine operations and maintenance costs average US$22,000 per year.

CONCLUSIONS:

Appropriate technology for oil spill response includes the use of minimally disruptive construction and design criteria, and the use of techniques, which most simply solve the problem. Simplicity means using basic uncomplicated designs, conventional equipment and supplies, and minimal manpower needs for long-term operations and maintenance. Simple response designs can provide high levels of environmental protection demanded by the public while providing the cost-effectiveness required by the realities of tight budgets.

BIOGRAPHY:

The author is a Federal On-Scene Coordinator for the US Environmental Protection Agency, based in San Francisco. Mr. Mandel has over 21 years experience in the environmental emergency response field. His primary professional interest is in the application of innovative treatment technologies at hazardous substance and oil responses.

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FIGURES

Figure 1

Figure 2

Figure 3

Figure 4

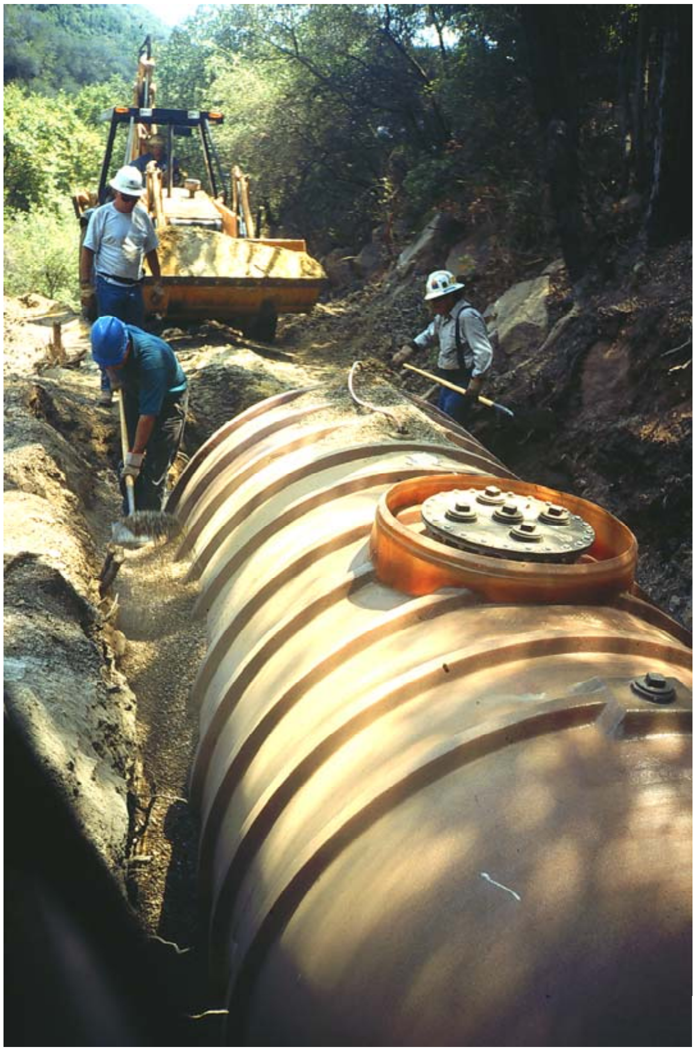


Figure 5

Figure 6

Figure 7

Figure 8

Figure 9

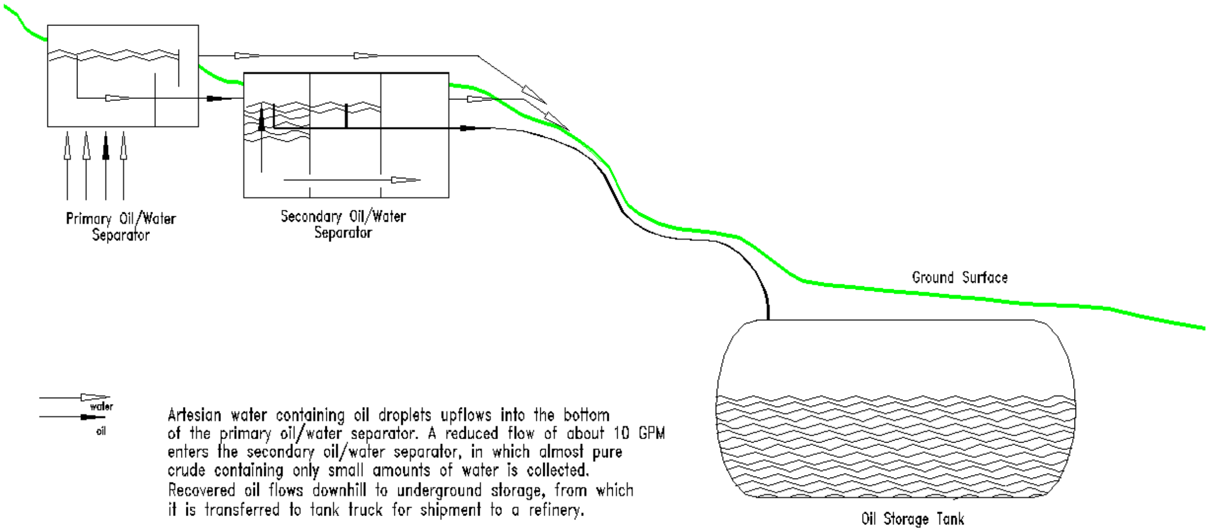
Figure 10


Toro Creek
4 Mar 98
Severe erosion
exposed pipeline buried
2 ft deep in Aug 97

Figure 11

Figure 12

Figure 13



Artesian water containing oil droplets upflows into the bottom of the primary oil/water separator. A reduced flow of about 10 GPM enters the secondary oil/water separator, in which almost pure crude containing only small amounts of water is collected. Recovered oil flows downhill to underground storage, from which it is transferred to tank truck for shipment to a refinery.

Figure 14

CAPTIONS:

Fig 1: A heavily oiled portion of upper Toro Creek during July 1997.
Fig 2: Workers set the 3-chambered OWS clarifier in position.
Fig 3: The chemical hose holding the oil is enclosed within the PVC pipe to provide secondary containment.
Fig 4: Pipeline trench containing the secondary containment hose and electrical wiring for the high level alarm.
Fig 5: The UST is installed.
Fig 6: Here is the thick oil layer that accumulates in the primary separation chamber.
Fig 7: Vacuum truck removes oil from the UST periodically.
Fig 8: El Nino flows ruptured the concrete intake structure upstream of the OWS.
Fig 9: An example of erosional damage resulting from the El Nino storms.
Fig 10: The artesian flow of the seep at Toro Creek prior to the installation of the new primary OWS.
Fig 11: Badly eroded pipeline trench required re-burial and the construction of surface diversion berms.
Fig 12: New primary clarifier in place directly over the seep.
Fig 13: Current OWS system configuration.
Fig 14: Diagram of final as-built for the OWS system at Toro Creek.