Petroleum Refinery Redevelopment:
Creative Use of Technology to Save Time and Money

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The assessment and remediation of property impacted by petroleum hydrocarbons can be a lengthy and costly endeavor. This is especially true for real estate that has historically operated as a petroleum refinery, often a nexus for hazardous materials, wastes and the environment. The handling of potentially hazardous materials and wastes has significantly evolved over the past decades following the establishment of the United States Environmental Protection Agency (US EPA) in December 1970. Since then, numerous laws and regulations have been passed to ensure that human health and the environment are protected from the effects of hazardous materials and wastes released to the environment. Past practices (though possibly state-of-the-art at the time) combined with a long operational history, places the petroleum refinery in a category of high risk from a redevelopment point of view. Indeed, navigating the environmental regulations and oversight, along with the costs to mitigate identified environmental impacts to acceptable levels, often represents a lengthy and costly process. However, the use of creative investigatory techniques to supplement or in place of more traditional methods, can greatly reduce the time and costs associated with identifying and characterizing the nature and extent of contamination at a site. These techniques were developed and proven during the voluntary cleanup and redevelopment of the former Golden West Refining Co. property located in the City of Santa Fe Springs, California.

Introduction

Early in the 20th century, the demand for energy exponentially increased compared to the demands of the previous centuries. Advances in personal transportation in the first half, and rail and air transportation in the latter half of the century, as well as an overall growth in industrial activities, necessitated the development of a supply of readily available and affordable energy. In addition to coal, which had been the primary source of industrial energy, the demand related to transportation shifted in the second half of the 20th century and increasingly satisfied with the development of naturally occurring petroleum (crude oil) hydrocarbons. It was during this time that natural gas also became an important form of energy as well and was both abundant and cheap.

Unlike coal, that could be used in its present form once mined from the earth, oil required significant processing in order to break-down its many components into usable energy to meet the developing demands. The break down of oil required often massive and complex industrial facilities known as refineries, that could separate the various chemical compounds found in crude oil into usable materials such as gasoline, diesel, and heavier oils for fuel, lubrication or construction. Petroleum also became a vital source of various organic compounds used in the manufacturing of many products associated with but not limited to: aerospace, agriculture, construction, manufacturing, pharmaceutical, and of course energy industries. Indeed, the list of materials and products derived from petroleum hydrocarbons is quite substantial and varied. Many of the modern products common today are highly dependent on petroleum.

The operation of a petroleum refinery is and can be a messy operation; many of the fuels, lubricants and other materials/chemicals produced represent a variety of environmental hazards including toxicity, reactivity and flammability. The early petroleum refineries of the late 19th century was essentially a large-scale distillation process that separated the various constituents of crude oil by applying heat and condensing and collecting the resultant vapors into liquid fractions. However, in the early 20th century a thermal cracking process was developed and later improved to include catalytic cracking of heavy oils, alkylation, polymerization, and isomerization to meet the ever-increasing demands for high quality (and energy rich) fuel needs for the developing aviation market. In the latter half of the 20th century, a hydrocracking process was developed to meet the increasing demands for more gasoline and jet fuels.

Based on the time period that a particular refinery was built, the type of refining process(s) used, and the environmental laws and regulations in place during its operational life, the likelihood for releases that have impacted both soil and groundwater is very high. A typical refinery will normally include pipelines that convey the crude oil to temporary storage tanks awaiting refining, pipelines that convey the crude oil to the refining infrastructure, and pipelines that convey the refined products to temporary holding tanks pending distribution to end users via tanker trucks and/or pipelines. Although care is taken to minimize accidental release of either the crude oil or refined products into the environment, incidents do occur. Furthermore, many of the pipelines used to convey unrefined or refined petroleum hydrocarbons are placed underground for safety reasons but are then subject to corrosion due to catalytic reactions in the soil. While measures are taken to protect these pipelines from corrosion, it is difficult to eliminate even with cathodic protection; leakage into the soil and groundwater may be expected over time. This combined with accidental releases and/or poor management practices (and/or previously lax environmental regulations), often results in property that is moderately to severely impacted and must be mitigated before redevelopment will be allowed.

A Case Study

<u>Site Background</u>

Thrifty Oil Company of California was the owner of the former Golden West Refining Company (GWRC) located in the City of Santa Fe Springs, California. The refinery was built in the 1930s and was purchased by GWRC in 1983 and operated until February 1992, when crude oil processing was suspended. The property on which the refinery is situated is prime industrial/commercially zoned land with excellent access to major highways and freeways. The decision to redevelop the property was in response to growing demand for industrial space. In 1997, the Orden family, owner of Thrifty Oil Company broke ground on the first phase of a 265-acre master-planned industrial park on the former oil refinery site.

According to the Golden Springs Development Co., which is also owned by the Orden family, about 5 million square feet of new warehouse, manufacturing and retail space was now planned for the mostly dormant oil refining and distribution facility. Crude oil had been refined and stored on the site for more than 70 years.

The property was occupied by the refinery infrastructure (hydrocarbon cracking towers and other refining equipment), numerous large crude oil storage tanks and refined product storage tanks, and office buildings. The new plans called for the complete shut-down, closure and redevelopment of the site to be performed in a series of phases over a period of several years. However, as with any long-term project, concern regarding the economy and real estate market values were always a part of the decision-making process guiding the development.

In order to redevelop the GWRC property, or any potentially contaminated property for that matter, it must be thoroughly investigated and brought into compliance with current environmental regulations. Human health and safety issues and the associated risk must also be evaluated and made a part of the process as well. Assessment of the site will normally involve a thorough characterization often beginning with a review of existing data. Once completed, site characterization proceeds by implementing readily available technologies, such as soil gas surveys, boreholes to collect soil samples, and the installation of groundwater monitoring wells to collect water samples. Groundwater grab samples may be collected initially from soil boreholes to determine if groundwater media are affected prior to installing monitoring wells. Geophysical technology may also be employed, such as ground penetrating radar and/or electromagnetic surveys, as a means of identifying subsurface disturbed areas or possible underground storage tanks, that may be present but not directly observable.

The process of investigation is often performed in a series of phases. The scope of each subsequent phase being based on the data collected previously to guide the process and make the most efficient use of the resources available. The placement of boreholes may be based on a grid pattern, randomly or guided by site-specific information.

<u>Potential Contaminants</u>

The former GWRC facility refined crude oil to produce a variety of petroleum hydrocarbons for use primarily as fuels and lubricants. Crude oil is a mixture of comparatively volatile liquid hydrocarbons (compounds composed mainly of hydrogen and carbon), though it also contains some nitrogen, sulfur, and oxygen. Those elements form a large variety of complex molecular structures, which are complex mixtures of very long-chain compounds. Because such complex mixtures cannot be readily identified by chemical composition, refiners customarily characterize these crude oils by the type of hydrocarbon compound that is most prevalent in them: paraffins, naphthenes, and aromatics. In addition to the hydrocarbons, compounds of sulfur, nitrogen, and oxygen are present in small amounts in crude oils. Also found in conjunction with the hydrocarbons are typically traces of vanadium, nickel, chlorine, sodium, and arsenic. These elements may affect the safety of oil-transport systems, the quality of refined products, and the effectiveness of processing units within a refinery. Minute traces can usually be tolerated, but

SLUDGE REMOVAL DURING API SEPARATOR DEMOLITION crudes with larger amounts of these materials must be extensively treated in order to restrict their potentially harmful effects. These can also find their way into the soil and groundwater beneath the facility.

The analytical laboratory methods used to characterize the soil contaminants focused principally on petroleum hydrocarbon related constituents and heavy metals. Typical analyses included total petroleum hydrocarbon carbon chain analysis (TPHcc gas, TPHcc diesel, TPHcc oil), volatile organic compounds (VOCs), semi-volatile organic compounds (SVOC), and Title 22 (CAM 17) metals. Occasionally polychlorinated biphenyls (PCBs) and asbestos containing materials (ACM) were also analyzed depending on the situation.

Regulatory Oversight

Since the property had been historically operated as a petroleum refinery for over 70 years, a list of potential constituents of concern (PCOC) associated with this type of activity was developed along with the appropriate US EPA SW846 test methodologies to be used and corresponding screening or cleanup levels. The primary Lead Regulatory Agency was the Regional Water Quality Control Board – Los Angeles Region (RWQCB-LA). Since they were already addressing the groundwater contamination beneath the former refinery with the issuance of a Corrective Action Order (CAO), and that the suspected soil contamination at the site would also pose a threat to groundwater, the RWQCB-LA continued their Lead position. Moreover, it was the use of Waste Discharge Requirements (WDR) issued by the RWQCB-LA that was the principal guidance to establish cleanup levels for the former refinery property prior to completion of a site-wide human health risk assessment based on site data. The site-specific risk-based cleanup levels subsequently issued by the Department of Toxic Substances Control (DTSC) supplemented some of the WDRs and in many cases raised action levels. The day-to-day regulatory oversight function was delegated to the Santa Fe Springs Fire Department as the acting Certified Unified Program Agency (CUPA).

Methods of Investigation

Initially, site investigation work included the usual methods of placing soil borings in locations suspected of being impacted by past site operations. These areas would become available to investigation as the refinery-related infrastructure was removed by the demolition contractor. Typical infrastructure removal included but was not limited to aboveground storage tanks (ASTs), pipelines (both above and below ground), buildings, crude oil heating units, underground storage tanks (USTs) and the main refinery processing unit structures. Some areas that represented a potential for contamination were not well defined; randomly place borings or the use of a systematic grid pattern was employed in these situations.

In consideration of the developer's desire to be able to generate capitol during ongoing site cleanup, the property was divided into zones. These zones included the massive storage ASTs associated with crude oil, those associated with finished product storage, and the main refinery facilities. Once a zone was fully investigated and remediated, it was released for construction. Site investigation and remediation work then mobilized to the next zone and the process was repeated. Depending on the size of the zone, both site investigation/remediation and construction activities could and did at times occur simultaneously. Per agreement, the Lead Agency and the other agencies allowed for interim closures of individual zones to allow for development to continue before the entire facility had been completed. However, there was a risk that additional work could be required in an area developed under interim closure following review of the final closure documentation. Consequently, care was taken during remedial action activities to be more conservative in addressing impacts to soil (and soil vapor) to reduce this risk to acceptable levels.

Subsurface soil sampling was accomplished using direct push technology (DPT). Only a limited number of borings used hollow stem auger (HSA) drilling rig technology. Since nearly all the suspected petroleum hydrocarbon contamination at the site was related to releases from the surface (or very near surface), DPT proved to be a relatively cost-effective and timely method of investigation. It also generated significantly less waste soil than HSA methodology. Typically, the subsurface exploration depths associated with the characterization of potential petroleum hydrocarbon and metals impacts to soil was limited to approximately 20 feet or less below surface grade (bsg). However, deeper samples were occasionally collected where soil impacts based on laboratory data were indicated. Laboratory analytical turn-around times were routinely ranged between two- and four-days due to the often-accelerated pace of development required by the project owners (Golden Springs Development Co.).

The depth of first groundwater is characterized as a semi-perched aquifer at a depth of approximately 22 feet bsg. This aquifer is discontinuous laterally. A second significant aquifer is the Artesia that occurs at a depth of approximately 75 feet bsg and is laterally pervasive. Free phase petroleum hydrocarbons (gasoline, diesel and aviation fuel) are present in groundwater in both aquifers. Impact to groundwater associated with refinery operations is already being address by the RWQCB-LA under a separate Order, and therefore is not a part of site assessment and remediation activities directly associated with redevelopment. A series of monitoring wells, both on and off site, is already in place at the time of the refinery shutdown and subsequent redevelopment; consequently, the need for deeper drilling capabilities requiring the use of an HSA to reach groundwater was not necessary.

After about a year of site investigation and remediation work, the latter providing a measure of how effective the former was in delineating the impacted soil, it became increasingly apparent that the practice of relying heavily upon DPT discrete-point sampling was not producing the expected results. The nearly exclusive use of DTP was not effectively locating or delineating areas of soil contamination. Often, the delineated area of soil impact would expand during remediation and/or once site grading activities had begun. Discovery of additional contaminated soil during remediation (typically excavation) would delay release of the area to further development and increase expected costs. However, discovery during the rough grading phase proved to be much more costly as construction activities would have to be stopped resulting in standby costs until the additional contaminated soil was removed, and the excavation certified and released. These delays would often have a “ripple effect” throughout the ongoing remediation and redevelopment schedules.

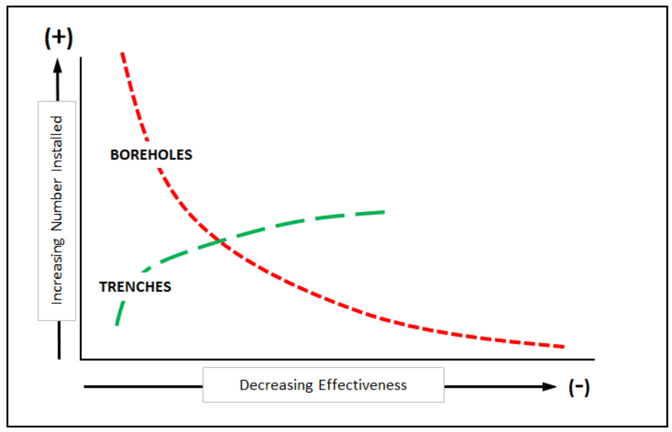
Initially, to address this problem, the number of borings were increased to provide better coverage in areas suspected of containing contaminated soil. However, it was soon realized that the number of borings needed to increase site coverage, and the associated increase in the number of laboratory analyses performed, was causing both excessive time delays and an increase to costs while not providing a corresponding improvement in assessment effectiveness. As a result, another method of investigation that would prove more effective and efficient in locating and delineating areas of petroleum hydrocarbon contamination in soil needed to be developed if the project were to be completed within an acceptable timeframe and cost desired by the project owner.

<u>Innovation and Adaptability</u>

As more knowledge regarding the lateral and vertical distribution of contaminated soil at the site was gathered and evaluated, it was decided that a different approach other than just relying on soil borings alone could to be implemented to improve the efficacy of the soil contamination delineation process.

After consideration of the potential options, a novel approach was developed and tested. This approach proved to be very effective in locating areas of soil contamination resulting from surface (near surface) releases and could be used to guide additional investigation using combinations of more traditional methodology.

The selected approach utilized a standard backhoe to excavate relatively shallow trenches over extended linear distances. Depending on the area or historical use being investigated, trench depths rarely exceeded four feet and were often around two feet bsg. These trenches were excavated with a small bucket to minimize the amount of soil removed and thus expedite the speed at which they could be advanced across an area of concern. Several trenches would typically be excavated in a suspect area, in a grid-like pattern but arranged in such a way to still allow access to most of the area being investigated. This method permitted both visual inspection of the soil being excavated, monitoring for VOCs, and/or easy access for collecting soil grab samples. This method proved very effective for both locating and roughly delineating or confirming poorly documented areas of petroleum hydrocarbon contamination in soil associated with buried pipelines, historical releases to the surface soils subsequently buried, beneath ASTs and old structure remnants. The effectiveness of trenching compared with the installation of boreholes is demonstrated by the graphic to the right. As the number of boreholes used to locate and delineate contamination in soil decreases, their effectiveness also decreases rapidly in a non-linear way. In contrast, the number of trenches required to achieve the same level of effectiveness is significantly less, also being non-linear. In other words, a relatively few trenches can achieve the same results required by many boreholes. Once the contamination has been located and roughly defined, boreholes would now be used as the most efficient method to complete the vertical and lateral delineation.



As with most industrial areas with a long history of operation, particularly prior to the establishment of environmental laws in the latter half of the 20th century (i.e.: U.S. EPA), various hazardous materials and wastes were handled much differently than today. This proved to be particularly true for the former GWRC petroleum refinery property. While some of the contamination in soil was placed with the understanding that it was the best management practice at the time (e.g.: burial of organic lead tank bottoms), many of the discovered sources of heavy petroleum hydrocarbons in the soil were either a result of an unauthorized release or were placed intentionally. For example, the large (>200,000 BLs) crude oil storage tanks would be cleaned out periodically and the tank bottom fraction removed for disposal. However, it was discovered that facility operators would from time-to-time excavate a trench adjacent to the AST drain and empty this material directly into the trench and then cover with two to three feet of soil. Apparently, this was done as much for convenience as it was for a cost-savings measure. Unfortunately, there was no real way to discover these buried pools of "goo" (aka: highly viscous long-chain aliphatic petroleum hydrocarbons) in the soil until their subsequent "emergence" during site grading. This was particularly problematic if an area had been released for construction, rough and sometime final grading had occurred, and then potentially significant excavations would be required that would often greatly impact the construction schedule. Although not completely effective, trenching, when implemented as part of the site investigation, did identify most of these burial pits that would normally have been missed using only soil borings.

Another concern was related to the emission of nuisance petroleum hydrocarbon and other refinery-sourced vapors (sulfur-based compounds) into the atmosphere. The property is surrounded by various commercial and industrial properties and some residential development nearby. Concern was expressed by the South Coast Air Quality Management District (SCAQMD) regarding these fugitive emissions and their effect on the surrounding businesses and residences. Consequently, every effort was made to control these fugitive emissions, including dust, when performing site demolition or remediation activities.

There were also concerns regarding the release of VOCs to the atmosphere during excavation and removal of petroleum hydrocarbon impacted soil, negatively contributing to the overall air quality in the basin. An innovative solution to this challenging problem included the construction of a truck and trailer mounted high-pressure misting system that could be staged near ongoing soil excavation activities to control the vapor emissions. The system design included the use of very high-pressure mists from special spray nozzles, that would create a "water mist curtain" above the excavation and/or associated stockpile or loading areas. A patented commercially available odor-capturing liquid was added to the water and then sprayed to produce an effective vapor trapping barrier.

For highly odoriferous materials, such as sulfur-contaminated soils, a low-permeability cellulose-based material would be applied using a standard water truck nozzle and pressure to produce a layer that would seal in the odors. This technology proved very valuable one late Friday afternoon while the demolition contractor was clearing a site in the former sulfur recovery area of the refinery. Disulfide-impacted soil near the former hydrocracking tower was uncovered and the exposed soil was so odoriferous that all work in this area was immediately terminated, site personnel were evacuated, adjacent businesses were evacuated and the SCAQMD, Santa Fe Springs Fire Department and Los Angeles Sheriff's Department were notified and mobilized to the site. Subsequent excavation and transport to a licensed landfill facility was only possible by using these odor suppressing technologies.

Waste streams generated during site remediation activities included soil impacted by RCRA hazardous (Federal), non-RCRA hazardous (State), and non-hazardous (but regulated) concentrations of TPH (gasoline, diesel, oil), VOCs, SVOCs, and heavy metals (Title 22) and organic lead. Where in-situ soil was clearly defined with respect to waste classification, direct loading into trucks for transport to an offsite licensed facility was an option. However, where waste streams were first stockpiled prior to transport, systematic and statistically valid sampling was performed to classify (or verify) the waste and prepare the waste manifests. This was particularly important for metals waste profiling since in-situ soil with varying concentrations could be co-mingled during the excavation process. Unlike VOCs, real-time monitoring of metals-impacted soil during excavation is more problematic. Where soil impact is predominantly of one waste classification type, segregation is relatively straight forward. However, where soil boring data indicated metals concentrations of differing waste classifications, segregation during excavation is generally not practical unless the delineation of waste types is clearly defined and, on a scale, appropriate to the excavation method(s) being used. The resulting stockpile could represent a different waste than what was measured in-situ from soil boring samples. Consequently, the true resultant concentration of the stockpile could have the potential to be classified differently based on the discrete samples collected from boreholes. Systematic sampling of stockpiled soil that could not reasonably be segregated during the excavation process proved to be an acceptable approach for the receiving licensed landfill facilities for their waste profiling requirements. However, considerable care was still expended to segregate "hot spots" whenever/whenever practical. In addition, as was often the case, many individual stockpiles were internally segregated into their appropriate waste classification based on the results of the stockpile samples.

In areas where lighter fraction petroleum hydrocarbons (gasoline) had been released to the soil, and site investigation indicated contamination at depths greater than could be excavated, a different approach was applied that allowed construction activities to move forward. VOCs vapors in the soil associated with the gasoline plume represented a potential health risk to the occupants in the proposed building above it. As a result, mitigation measures were needed and implemented to address issues of vapor intrusion. Following grading activities, soil vapor extraction wells were installed but capped; the system of wells remained in place with lateral pipelines installed and protected as the building was being constructed. In addition, a plastic vapor barrier was placed over a sand bed beneath the building's floor slab. Once the building construction was completed, thermal oxidation equipment (electro-catalytic) was installed and connected to the wells. The system was then operated and optimized until the soil vapors had been removed. Because the soil vapor extraction equipment was situated within an enclosure matching the building architecture, visibility was minimal and not very noticeable. What could have been a significant impact to site redevelopment at this location was effectively mitigated allowing construction and occupation to move forward.

Benefits Realized

Over a five-year period of performance, approximately 235,000 cubic yards (317,000 tons) of impacted soil was excavated and transported to landfills and/or recycling facilities in California, Arizona and Nevada. Emphasis was placed on recycling wherever possible resulting in over 35% of all material recycled. Most of the recycled soil was generally impacted by petroleum hydrocarbons in the gasoline and diesel range. This soil was transported offsite and subjected to thermal oxidation and then transported back to the refinery to be used as fill material. To save money, trucks would haul impacted soil to the licensed treatment facility and then return with a load of “clean” treated soil, reducing the amount of soil that would need to be purchased as makeup soil to backfill the remediation excavations. As a result of this effort, the project owner (Golden Springs Development Co.) received recognition and awards for exceeding targeted recycling goals.

CATALYTIC CRACKING TOWER BEFORE BEING TOPPLED

Redevelopment was on a high-level “fast-tracked” approach that required negotiation and regular interaction with the RWQCB-LA, DTSC and CUPA staff to enable the timely flow of information and address concerns as they arose. The negotiated use of the interim closure approach allowed construction to proceed prior to submittal of final closure documentation. Incorporating this approach would ultimately save an estimated three to five years off the originally projected completion timeline and allow for the timely develop of the property within a favorable real estate market.

The application of the innovative methods used for the site investigation activities at the former GWRC property proved valuable in the redevelopment process in terms of reducing both costs and schedule. Since the delineation of site contamination can be a time-consuming process, with potentially several iterations of sample collection and laboratory analysis needed to fully characterize an area of concern, any investigative methodology that can be utilized to make the overall process more efficient is valuable. The subdivision of the larger parcels of the refinery property into individual smaller zones proved very beneficial and strategic. By doing so, site investigation and remediation could proceed on a scale that was much more compatible with the interim closure concept, but large enough to allow for construction and site investigation/remediation activities to proceed often concurrently. Indeed, it was not uncommon for a large distribution warehouse to be under construction while remedial action was proceeding nearby, all within the same zone. Of course, this approach required great care in ensuring that all site investigation and remediation activities were in total compliance with the regulatory agreements in place and that everything was thoroughly documented. Once an area was redeveloped it would be very costly if additional work were required by the oversight agencies.

CATALYTIC CRACKING TOWER AFTER BEING TOPPLED SHOWING SOIL BERM CUSHION (at right)

Lessons Learned – The Take Away

Redevelopment of the former GWRC property was performed at a high level "fast-tracked" pace that required the incorporation of less traditional approaches to site characterization in order to meet critical construction schedules. Application of other new or emerging technologies were used to address difficult and unforeseen site conditions that had the potential to greatly affect the success of the project. Flexibility and adaptability were key to being able to respond quickly to challenges as they arose. Every effort was made to develop a "team" approach amongst the demolition, waste transporters and waste/recycling facilities; the analytical laboratories; and the subconsultants involved with the project. All participants in this redevelopment activity understood their function in the process and importance to its overall success.

Negotiation and regular interaction with the RWQCB-LA, DTSC and CUPA staff was paramount in establishing a mechanism that allowed for submittal of interim closure documentation, enabling construction activities to proceed prior to submittal of final closure documentation. Regular meetings were held with the CUPA agency to keep them informed of planned/ongoing demolition, site investigation findings, and remediation progress. Other agencies were informed as needed when appropriate. The effective flow of information between developer and regulator proved to be a very important aspect contributing to the ultimate success of the project. A significant benefit was that this approach saved an approximately three to five years off the total originally estimated project lifespan and proved that, with the proper application of technology and project management, redevelopment of high-risk property is not only possible but profitable.