USE OF IN SITU BURNING AT A DIESEL SPILL IN WETLANDS AND SALT FLATS, NORTHERN UTAH, U.S.A: REMEDIATION OPERATIONS AND 1.5 YEARS OF POST-BURN MONITORING

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ABSTRACT: *On 21 January 2000, a release of an estimated 100 barrels of diesel was reported from a product transportation pipeline north of Great Salt Lake in Utah. During the next few days, due to weather related conditions (freeze/thaw periods and wind), the product spread over 38 acres of salt flat and wetlands. Initial oil containment efforts were successful in reducing the risk of oil impacts to natural resources in a nearby national migratory bird refuge, but the risk remained to migratory waterfowl that were expected to arrive at the impacted wetland within approximately 6 weeks. As a result, in situ burning was proposed to remove the free-phase diesel and destroy the hydrocarbon-impacted vegetation. Upon approval of a Site Remediation Plan and Fire Management Plan, a Heli-Torch was used on 10 March, 2000 to burn the most-highly impacted 12.8 acres. The following month (late-April), 3.2 acres of remaining lightly oiled vegetation were burned using drip torches and propane wands. It was estimated that 75- 80% of the spilled diesel was burned in these operations. Because burning of the free-phase hydrocarbons and impacted vegetation would not remove product that had penetrated into the soils, bioremediation techniques were subsequently implemented, in order to further reduce hydrocarbon levels in the soil and attain the regulatory cleanup level of 20 mg/kg total polycyclic aromatic hydrocarbons.*

Introduction

On January 21, 2000, Chevron Pipe Line Company ("Chevron") was notified of a release of diesel from their 8-inch diameter pipeline on the Salt Lake City to Spokane Product Systems Pipeline near Corinne, Utah. Chevron immediately shut-off the line, implemented their emergency response system, and mobilized to the spill site. During the next three days, the pipeline was repaired and an assessment was made to determine the overall environmental impact of the release. Subsequently, a site remediation plan was prepared and reviewed by representatives of the Region 8 Regional Response Team ("RRT"), which includes representatives from several Federal and State agencies. Regulatory oversight was supervised by the designated On-Scene Coordinator from Region 8 of the U. S. Environmental Protection Agency ("EPA").

After review of all site conditions, results of extensive analytical testing on water and sediment samples from the site, and a detailed survey of the area, a final remediation plan was approved and implemented. Because the spill occurred in an area of marshes, wetlands, and salt flats, it was determined that vehicular traffic within the spill area would not be feasible. Therefore, an in-situ, controlled burn utilizing only foot traffic and helicopter access, was selected as the most effective method to remediate the site.

Project area

The pipeline leak occurred west of Corinne, in Box Elder County, Utah, U.S.A. (Figure 1), approximately 70 miles (112 km) north of Salt Lake City. The spill site is in wetlands and salt flats approximately 10 miles (16 km) north of the Promontory arm of Great Salt Lake and 4 miles (6.5 km) north of the Federal Bear River Migratory Bird Refuge.

Pre-burn staging

Given the saturated nature of the clayey soils at the site, and a desire to minimize traffic impacts, sorbent booms were deployed into the spill area using mules. The booms were removed prior to the in situ burn. Since the ignition source for the in situ burn would be deployed from a helicopter, a landing pad was cleared and marked to provide a level landing area clear of obstructions and, for safety purposes, remote from the other activities.

Emergency equipment and precautions to protect the public. Chevron's safety policy allowed only essential personnel and equipment to be in the remediation area during the in-situ

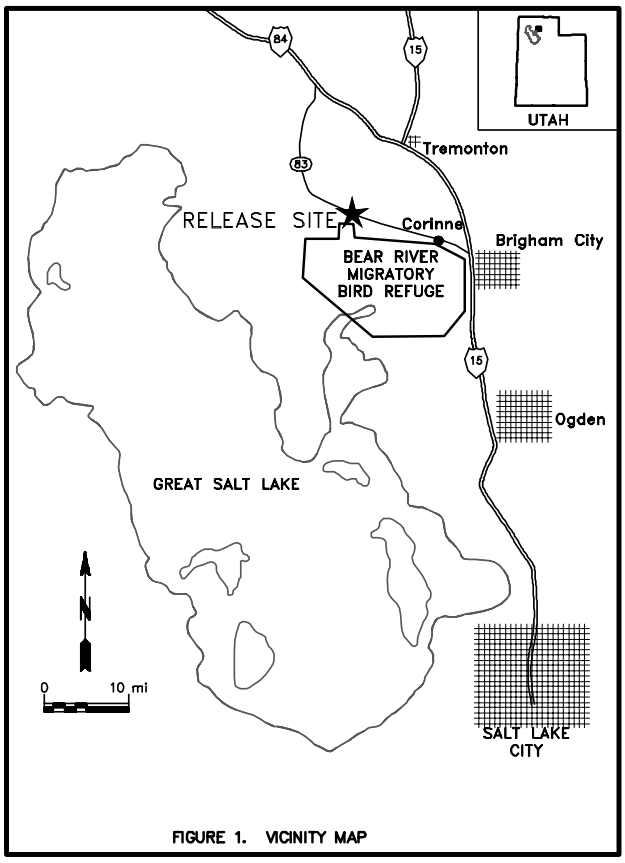

Figure 1. Vicinity map.

burn. As a result, the only vehicles at the site during the burn were County fire trucks and Chevron equipment trucks. To monitor air quality, an automated DataRam particulate air monitoring station was set up just north of the site adjacent to a public highway, prior to any burn activities. The device was not removed until after all fires had burned out and the smoke had dissipated. This device collected ambient air samples on ten-second intervals throughout the day to monitor particulates associated with smoke that may blow across the highway.

Protection of historic features.

Archeological survey – The subject pipeline was installed within the old transcontinental railroad grade east of the Golden Spike National Historic Site. As a result, the State of Utah required that an archeological survey be made of the area to assess potential impacts from remediation efforts. Several relic features associated with the construction of the railroad in the 1869 were located as well as evidence of ancient habitation of the area some 7,000 to 10,000 years ago. Overall, neither the release nor the subsequent remediation activities adversely impacted the cultural resources in the area.

Historic transcontinental railroad grade - Because of the desire to minimize impacts to the historic transcontinental railroad grade, passage of heavy equipment across the grade during the fire and post-burn activities was limited to essential vehicles only. Following the burn, the grade was restored and re-vegetated.

Railroad trestle - A historic, wooden railroad trestle exists within the impacted area. Because there were areas immediately around the structure that were impacted by the released diesel, it was necessary to burn adjacent to the trestle. To avoid fire damage to this structure, a water curtain was installed to spray water onto the trestle, thereby saturating the structure and the adjacent soil. The water curtain also protected the source pipeline and an adjacent pipeline that are suspended from the trestle.

In-situ burn operations

The burning of spilled oil often involves a relatively fresh petroleum product that is concentrated in a single region on land or on water. Ignition, therefore, can usually be completed relatively easily. This spill, however, involved a wide range of hydrocarbon accumulation within a variety of frozen and unfrozen soil, vegetation and water environments. Observations of stained vegetation and product sheens on water surfaces indicated that the impacted region covered approximately 38 acres (~15 hectares). The impacted areas were somewhat disjointed, with heavily impacted vegetation and significant product accumulation occurring over only about one-third of the total impacted area. As a result, it was determined that ignition and re-ignition of varied and somewhat separated areas would be required. Controlled in-situ burning of the spill was further complicated by the delay of approximately 6 weeks between the discovery of the spill and the final regulatory approval to burn, thereby causing the product to weather and partially infiltrate in the soil in some areas.

Pre-burn logistics & training. On February 23, 2000 the County Fire Marshall burned several fire breaks along the perimeter of the impacted area. The fire breaks were required to keep the planned Heli-torch burn from extending beyond the spill area into adjacent wetlands and grazing land.

Prior to the main burn, a test burn was conducted on March 8, 2000 on a portion of the impacted area to evaluate the ignition requirements and the nature of any sustained combustion that could be achieved in a wetland area. The test burn was started with a diesel drip torch under the direction of the County Fire Marshall, and the fire's area, height, intensity, spread rate and smoke characteristics were monitored. Approximately 2 acres (~0.8 hectare) were burned in less than 15 minutes. The test burn validated the belief that ignition would be possible, and that the Heli-torch would be needed to safely and efficiently reach the various areas of impact.

The Heli-torch for the main burn was provided by Elastec/American Marine, Inc. (Carmi, Illinois) while Spiltec (Woodinville, Washington) provided onsite training and support throughout the Heli-torch burn operations. Classic Helicopters provided a Bell 206-4 "Long Ranger" helicopter and U.S. Forrest Service certified pilot for deployment of the Heli-torch.

Heli-torch preparations. The Heli-torch was received, assembled and tested prior to its deployment at the spill site on March 10, 2000. Prior to the burn day, packets of Sure-Fire™, consisting of a powdered mixture of alumina and gelatin, were prepared so that drums of gasoline could be mixed with the powder rapidly near the landing pad and transferred, as needed, to the Heli-torch frame. Even with air temperatures only slightly above freezing, drums of gasoline were mixed using internal mixing paddles, gelled within 30 to 40 minutes and then attached to the torch frame in less than 5 minutes. Prior to each lift-off, ground personnel ensured that the torch and its electrical and propane-igniter connections were armed and that all connections to the helicopter cargo hook were secure and free of the landing gear (Figure 2).

Figure 2. Ground support crews prepare the Helitorch for deployment on March 10, 2000.

Figure 3. Helicopter with heli-torch burn areas impacted by diesel. Note differences in the color of smoke between burning oiled areas (black) and unoiled vegetation (white).

Burn operations.

Heli-torch burns – On the morning of March 10, 2000, the first Heli-torch flight was conducted, resulting in the successful ignition of spilled diesel within one of the most heavily impacted areas. Working at safe distances and with radio communications, ground crews simultaneously worked with propane torches in areas where no significant quantity of diesel had accumulated but the soil or vegetation was visually stained. Ground crews were also helpful in directing the deployment of the Heli-torch as needed.

Before sunset, nine sorties had been flown with the Heli-torch, emptying its nearly 50-gallon (~190 liter) content of gelled gasoline during each sortie. It should be noted that the gelled gasoline remains burning after landing on water or land for several minutes, igniting any oil or other combustible material on which it lands. The gelatinous mixture burns up nearly completely, leaving only a thin crust of ash.

During the Heli-torch burns, it was readily obvious when the fire consumed relatively uncontaminated vegetation, as the smoke plume appeared light gray. When fire reached oiled areas, the smoke plume would turn dark gray in color (Figure 3). With operations from the air covering the broadest and most contaminated areas, and with ground crews burning the lighter areas of impact, it is estimated that approximately 12.8 acres (~5.2 hectares) were burned on both the north and south sides of the spill source area. The entire Heli-torch operation took about 7 hours to complete, leaving only a few regions of light contamination as stained vegetation below water and in parts of the still-frozen ground.

From observations made during and after the in situ burn, it became apparent that snow and ice can both help and hinder the use of in situ burning on land. Snow and ice can slow the spread of oil, increasing the oil thickness and the overall efficacy of the burn. However, it can also slow the heat transfer process and prevent the oil from vaporizing and burning.

Data collected and evaluated from the air monitoring station along Highway 102 and personal DataRam air monitors worn by five randomly-selected fire fighters confirmed that there were no harmful exposures to particulates associated with the burn. The evaluation considered not only the smoke particulates but also the potential hydrocarbon vapors entrained in the smoke from the diesel.

Follow-up ground burn – After the initial Heli-torch burns, soil samples were collected to evaluate the overall effectiveness of the burn. Analytical results indicated that three small areas continued to contain elevated concentrations of total polycyclic aromatic hydrocarbons ("PAH") and that additional burning at those locations would be needed. Therefore, on April 27, 2000 a second burn was conducted with the County Fire Marshall and EarthFax representatives using a hand held propane torch. During the second burn, 3.2 acres (~1.3 hectares) were burned, of which only 0.5 acres (~0.2 hectare) were not initially burned during the initial Heli-torch operations. That portion with elevated post-Heli-torch-

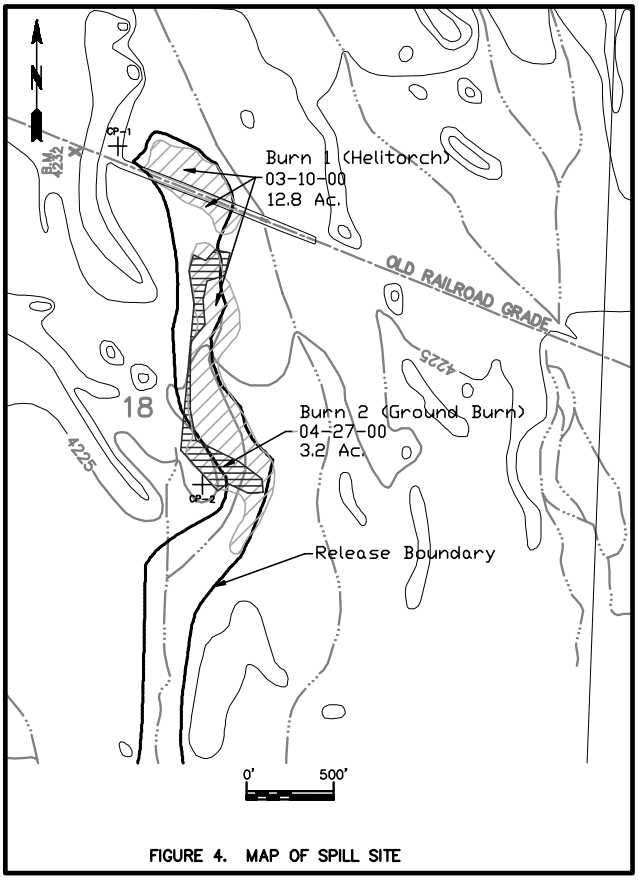

Figure 4. Map of spill site showing areas burned during the March 10 Helitorch burn and the April 27 ground burn.

burn PAH concentrations burned aggressively as most of it had been below water or frozen during the Heli-torch burns. The impacted area with the two burn boundaries is shown on Figure 4.

Post burn sampling and subsequent bioremediation efforts

Sample locations and results. Sediment samples were collected subsequent to each burn event. Overall, it was determined that over 90% of the impacted area was successfully remediated through the in-situ burn methods and the initial response efforts using booms and sorbent materials. One particular area just south of the pipeline leak continued to have elevated concentrations of certain diesel-range PAHs. In an effort to establish acceptable cleanup goals, and in consideration of the recalcitrant nature of the PAHs, Chevron conducted a post-burn ecological risk assessment for the site in August 2000. After review of this document, the EPA, in cooperation with the U. S. Fish and Wildlife Service ("USFWS"), issued a joint statement establishing two risk-based performance criteria that would need to be satisfied in order to obtain agency approval for no further action. These criteria were:

1. Total PAH concentrations shall be less than 20 mg/kg, and
2. Absence of visible sheen on any water surface.

Samples were to be analyzed not only for parent PAHs, but also alkyl homologue PAHs.

Bioremediation efforts. In accordance with the risk-based criteria, and in an effort to further reduce residual PAH concentrations, Chevron implemented a second, non-burn remediation effort. On September 9, 2000, after gaining additional approval from the RRT, approximately 7 acres (~3 Hectares) of area impacted with elevated soil PAHs were treated with 264 pounds of nitrogen-phosphate fertilizer to enhance biodegradation, and then tilled to a depth of 8 – 10 inches (~20-25 cm) using the rippers on a small dozer. The site was then left over the winter months to allow time for the natural degradation of the residual PAHs to occur.

On May 16, 2001 four compliance sample locations were selected by representatives of Chevron, EPA and USFWS within the area that was tilled the prior September. Sediment samples from the top 4 inches (~10 cm) were then collected at these locations and analyzed for total PAHs. At this same time, those present documented that there was no visible sheen on any water surface in the release area.

Analytical results from one of the locations sampled on May 16 failed to meet the 20 mg/kg stipulation. Thus, the site was tilled again, without the addition of fertilizer, on August 2, 2001. Compliance samples were again collected from the same four sample locations on October 30, 2001. Of these, another location, other than the one sampled on May 16, failed the 20 mg/kg criteria. Nutrient analysis in samples from the site confirmed that there were concentrations of nitrogen and phosphate adequate to promote biodegradation, indicating that degradation would likely continue with more time. Consequently, it was decided to let the site remain undisturbed over the winter months to allow degradation to continue.

On March 7, 2002 the single sample location that had failed in October 2001 to meet the 20 mg/kg limitation was re-sampled. Analysis of that sample indicated a total PAH concentration of less than 20 mg/kg. This last sample result satisfied the requirements set forth by the RRT, as well as independent requirements of the EPA and USFWS. An agreement was reached with the RRT to issue to Chevron a letter of no further action upon submission of all final reports and data summaries.

Oil degradation between the release and final remediatoin

Soil samples collected near the release site showed increased concentrations of total PAHs from pre-burn to post-burn periods prior to bioremediation. The post-burn samples contained alkylated homologues for some of the PAHs in ratios similar to the fresh product, although at significantly lower concentrations (Figure 5). Since the PAHs in samples containing pyrogenic-sourced hydrocarbons are depleted in alkylated homologues (Wang, et al, 1998), the increase in total PAH concentrations was not a result of combustion. It is possible that the post-burn increase in PAHs was caused by "wicking" of oil that had penetrated, prior to burning, into the sediments. The sediments in this area dry out during the summer months and form deep desiccation cracks, providing an avenue for diesel to have penetrated into the sediments prior to remediation. This deeply penetrated oil could not burn, but it may have been drawn to the surface by the heat of the fire.

The PAHs in the samples collected in 2001 were characterized as moderately weathered because of the presence of naphthalenes even as late as October 2001. Microbial degradation rates are a function of the amount and surface area of the oil, nutrient availability, moisture content, and temperature. In areas that dry out during the warm summer months, degradation rates were likely slow.

Figure 5 shows the distribution of PAHs in the fresh, spilled diesel as well as in soil samples collected approximately 20 months and 24 months after the initial burn. This area was tilled once approximately 6 months after the initial burn. The scales of the three plots in Figure 5 have been expanded for each sample so that the pattern in the PAH distribution can be seen. Total PAH concentration in the October 2001 sample was 48 mg/kg, compared to 0.2 mg/kg in the March 2002 sample. The 2-ringed PAHs (naphthalenes and fluorenes) were nearly completely degraded by March 2002, two years after the release and burns. The more- recalcitrant 3-ringed PAHs (phenanthrenes and dibenzothiophenes) have exhibited 99%+ decrease in concentration and will likely degrade further due to natural microbial activity.

Conclusions

The challenge of dealing with spilled oil in a wetland and salt flat environment, compounded by winter weather conditions and the impending arrival of sensitive waterfowl, was dealt with in an effective and safe manner. The in situ burn, the subsequent ground burn and all other activities completed at the site were performed without any safety incidents or consequential impact to cultural resources at the site. In addition, overall impact to the habitat of wildlife in the area was limited. Notwithstanding the period of time that elapsed between initial discovery, obtaining regulatory approval and remediation, the success of this effort clearly demonstrates that the use of in situ burning is an efficient, cost effective tool for remediating inland oil spills.

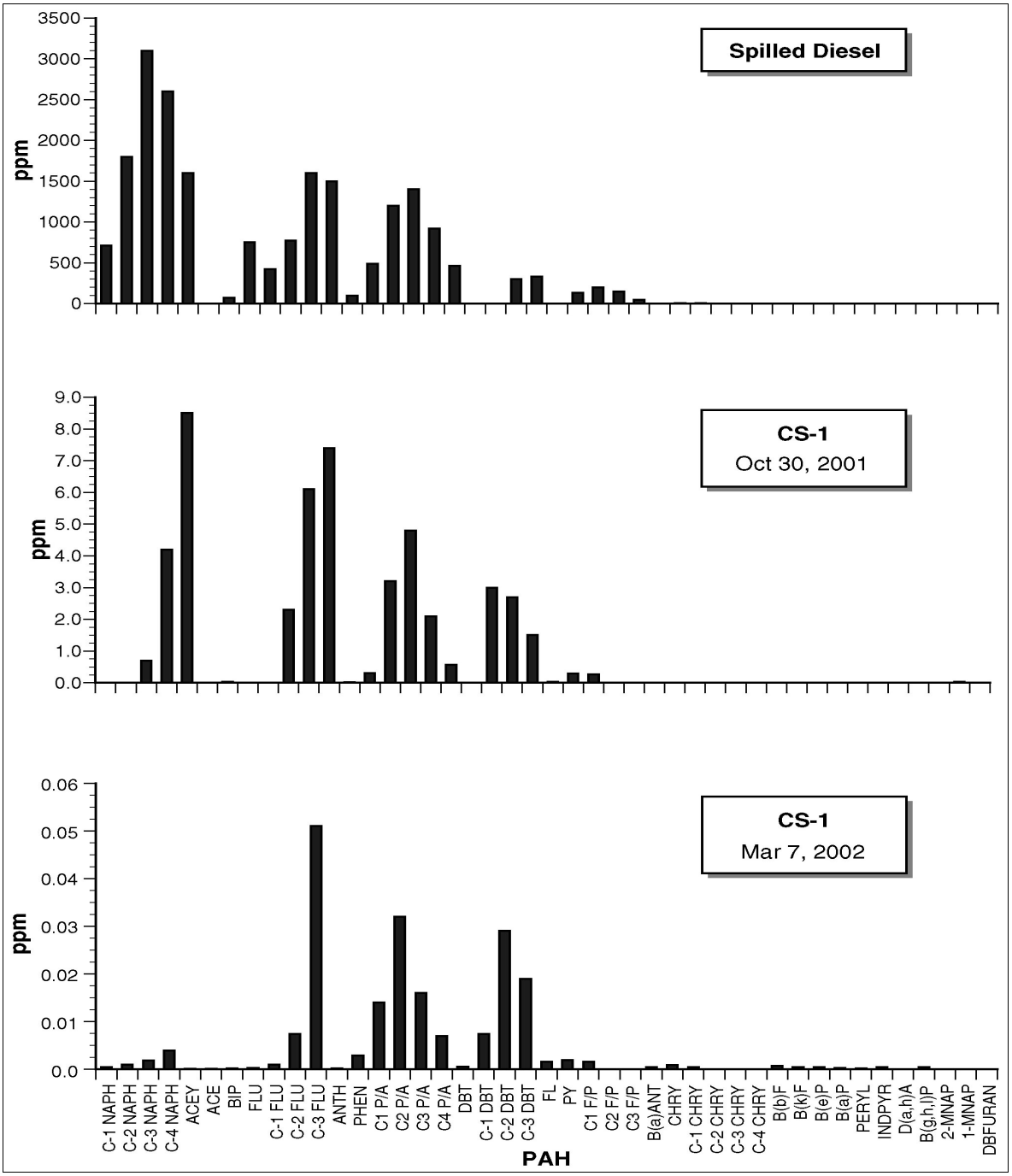

Figure 5. PAH distribution in the spilled diesel and in soil samples from a site sampled in October 2001 and March 2002. Note the large differences in the concentration scale for the plots. Nearly all of the 2-ringed PAHs had degraded within 2 years post-spill.

Biography

Galen W. Williams, P.G. Mr. Williams is an engineering geologist with EarthFax Engineering, Inc. in Salt Lake City, Utah. He holds a BS and MS from the University of Utah. He has worked as an environmental consultant to Chevron Pipe Line Company and Chevron Products Company full time for the past 12 years.

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