Cooperative Efforts to Use *In-situ* Burning in Empire, LA, in an Intermediate Marsh Following Hurricanes Katrina and Rita

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Introduction: During Hurricane Katrina (August 29, 2005), 33,900 bbls of Louisiana Sweet Crude Oil (API 33.8, pour point – 41 C^o) were released into secondary containment areas due to a destroyed tank at the Chevron Empire facility. Chevron Empire is located at 29° 22' 9.5" North, 89° 32' 5.6" West, at mile marker 30, on the east bank of the Mississippi River in Buras, LA. As designed, most of the oil migrated to the retention pond at the facility. During Hurricane Rita (September 24th, 2005), approximately 100 – 200 bbls of oil were released into the adjacent marsh environment (Figure 1). A portion of the marsh was heavily oiled or moderately oiled (ca. 4-6 acres and 12-18 acres, respectively). On October 12 and 13th, 2005, 6 weeks after the initial spill, Chevron conducted two *in-situ* burns with support from the Unified Command and trustee agencies. The burns resulted in 80 – 90 % removal of the bulk oil and contaminated vegetation. The intermediate marsh is recovering quickly based on visual observations. However, a cooperative monitoring effort was established to quantitatively evaluate recovery in three areas: (1) oiled and burned, (2) oiled and unburned, and (3) unoiled and unburned. This paper will: 1) discuss the advantages and disadvantages of the site for conducting a burn, 2) discuss the rapid decision-making process to approve the burn, 3) describe pre, during and post burn operations and observations, 4) report lessons-learned, and 5) highlight areas of interest in monitoring the site to assess long-term recovery of the marsh habitat.

Site characteristics and extent of oiling:

Five weeks post-Katrina: During several aerial surveys since Hurricane Rita, heavily oiled marsh was observed adjacent to the Chevron Empire facility (Figure 2). On October 6th, the Environmental Unit Team, ground surveyed the impacted marsh to delineate approximate amounts of pooled or mobile oil on the water surface, vegetation, and sediment, and to provide cleanup recommendations to the Unified Command. The marsh was divided into six zones containing oiled marsh and potentially burnable areas (Figure 3). After providing cleanup recommendations to Chevron and the Unified Command, a more thorough survey was conducted on October 10th by Chevron and the Environmental Unit Team. The survey found the following:

1. Dominant species composition. The area most heavily impacted (Burn Zones 1 and 4) was an intermediate to high marsh environment dominated by *Spartina patens, Scirpus olneyi, and Distichlis spicata.* (See Figures 4-5).
2. Description of oil weathered state and oiled vegetation: The marsh contained trapped oil in the thick vegetation that was easily mobilized when agitated. Surprisingly, the oil was relatively "fresh" in characteristics such as odor, viscosity, lack of emulsification, and its propensity to remobilize off of the oiled vegetation onto the water surface. The

vegetation was heavily stained and coated with “fresh” oil. In Zones 1 and 4, oil on water thickness was estimated as 1 – 2 mm. The oiling distributions in Zones 1 and 4 were broken to continuous (estimated to be ~ 100 bbls). In Zones 2 and 5, there were pockets of pooled oil and oiled vegetation, however, there were also unoiled areas, and higher water levels (Figure 5). In Zones 3 and 6, there was no pooled oil, but contained sporadic pockets of stained vegetation, and sheening in the small canals.

3. Impacts to infauna. The area most heavily impacted (Burn Zones 1 and 4) contained high fiddler crab (*Uca spp.*) mortality, and was the most obvious invertebrate impact. It was also noted that the area was devoid of other biota expected in the marsh environments such as reptiles and birds. This was not a quantitative biological assessment, but an operational assessment for determining whether the marsh was a candidate for burning.

After the initial survey, the following options were considered by the team: (a) no action/natural recovery, (b) mechanical recovery, (c) passive recovery – sorbent pads and boom, (d) mobile sorbent material (e.g., “Gator Sorb™”, *Sphagnum* peat), and (e) *In-situ* burning.

Given the sensitivity of the marsh, the oiling conditions, the marsh conditions and location, and the appropriate weather window, *in-situ* burning was deemed the most environmentally appropriate option. Other options were less advantageous due to the amount oil and oiled vegetation left in the marsh to further impact, the sensitivity of the marsh, and limited access for crews and equipment. Any kind of mechanical recovery would be too intrusive and destructive to the marsh environment, and would increase subsurface penetration, thus retarding natural processes (e.g., microbial degradation). Deploying recoverable sorbents also required large amounts of manpower accessing the marsh, potentially causing more harm than the oil itself. Mobile sorbents, and non-recoverable sorbents, were not appropriate as a primary action, but were considered for polishing actions post-burn.

Chevron Empire site advantages and disadvantages for the ISB option:

Site-specific advantages:

- Site location: Remote location, therefore population centers were not threatened by the smoke plume. The site is bound by water (canals) on three sides (East, North and West), and the facility’s retention pond (South).
- Limited access for removing the oil with other active recovery methods without causing more physical injury to the marsh, or penetrating oil into sediments.
- Oil conditions: There was adequate mass of oil to fuel a burn, although it did not meet the continuous 2 mm oil thickness burn criterion. However, the team thought there was adequate oiling of the vegetation to sustain the burn.
- Environmental conditions: The water level was adequate (10 – 20 cm) so that the vegetation root systems would be insulated during a burn (Lin et al., 2002). The winds were forecasted to be favorable (less than 10 mph, from the N/NE with temperatures forecasted for high 80’s F).
- Recovery potential of the vegetation: burning will quickly remove the oil hazard, will retain marsh nutrients, and past burns in similar environments have successfully recovered post-burn (Lin et al., 2002, Michel et al., 2003, Henry et al., 2003, and API

2004). The land owner has conducted prescribed burning in the area in the past. Without an action such as ISB, the vegetation would not likely recover fully.

Site-specific disadvantages:

- Controlling the burn was a major concern. The team assumed worst-case, which meant the fire could burn to the water-boundaries (~120 acres). The facility is in close proximity.
- Oil penetration: there was a potential to increase oil penetration into the substrate where the water was too low (< 2 in) (Lin et al., 2002).
- Damage to biota: the ground survey revealed dead fiddler crabs, and was devoid of other biota, thus the main risk to biota was to areas that burned (un-oiled) containing viable crab and other infauna populations.
- Residues: there is likely to be oily residue from the oil type, and may be difficult to remove (API, 2004).

With support from the Environmental Unit, Chevron pursued the ISB option as most viable and acceptable, and submitted a draft burn plan on October 8th, 2005. Once agreement was reached that *in-situ* burning was a viable and the most advantageous option, Unified Command approval was received for development of an ISB plan. After several discussions with all stakeholders, the revised plan adequately addressed site safety and fire control plans, and the final plan was approved by the Unified Command. After several discussions with the Environmental Unit Team and Incident Command staff, the RRT was quickly convened via conference call. The RRT quickly granted pre-approval to the Federal On-Scene Coordinator (FOSC) to make the final decision on whether to approve the plan. The FOSC approved the plan in writing at 0700 on October 11th. Thus, through cooperative efforts, rapid and continuous communications, and buy-in at all levels, it took less than five days to plan approval and mobilization of fire control teams and equipment under complex logistical situations. The key was that the plan was being developed and amended in parallel to conducting pre-burn surveys, and mobilizing essential resources so that once approved, implementation would be immediate.

In-situ **Burn Operations and Observations:**

Day 1 (October 12, 2005): The burn plan was initiated at 1300. The weather conditions were adequate for the burn to proceed (variable N/NE wind, less than 10 mph, partly cloudy, 85^{o}F). The tidal conditions were such that there was adequate water in the marsh. In the upper marsh salinity was ~ 1 – 6 ppt (parts per thousand), and 1 ppt in the lower marsh. Fire teams had marked out Zones and created fire breaks with air boats on October 11th. The site was clearly marked out with flagging at each corner to aid with reference and communication, and to provide wind direction information to the teams. Prior to the burn, fire teams were deployed to their respective stations, and began wetting down the east berm of Zone 1, and the berm of the retention pond. As a safety precaution, all other activities at the facility were ceased on burn day, and the cleanup crews were staged onboard vessels located on the Mississippi River to the South of the Facility (Figure 1, Zone 1). After areas were wetted down, the “go” signal was given via VHF radio at 1330.

The plan was to burn only Zones 1, 2, 4 and 5, all in one day. Given the wind direction, the burn order was supposed to be Zones 1, 4, 2, 5. The original plan was to conduct a back burn at the facility fence line. However, the control burn became “the burn” (Figure 6). The source of ignition was a propane torch. The fire started immediately, and quickly became a sustained fire producing large amounts of black smoke (Figure 7). Because of the intensity, loft and direction of the smoke plume, Chevron had moved all of the crew members to the MSRC GULF RESPONDER, and moved further down-river for the duration of the burn.

The fire quickly engulfed the oiled area and burned rapidly to the west from Zone 1 into Zone 4. The burn speed was more controlled as it burned upwind (north across Zone 1 to Zone 2, and across Zone 4 to 5). At 1440 (1.1 hours into the burn), 90% of Zone 1, and 25% of Zone 5 had burned (Figure 7). Flames were observed to be as high as 30 feet, continuous across the burn Zone, with a plume loft of approximately 500 – 1000 feet (See Figure 7). Around 1500, the burn was progressing faster to the west, and with more intensity than predicted, and all teams were evacuated to a safe zone inside the facility, according to the plan. The burn crossed the power lines, and burned ~100 feet beyond the original fire break on the west edge of Zone 4. However, once the fire ran out of pooled oil, and oiled vegetation, it quickly turned to white smoke, and burned out. After the fire was mostly out, airboats snuffed out the remaining flames.

Day 2 (October 13, 2005): During the operations debrief the evening after the first burn, there were two main lessons that needed to be acted upon in the second burn. First, the first burn was larger and hotter than predicted, and the responders were very aggressive in trying to control the burn. At the onset fire-control measures were a large factor in the plan and were deemed necessary to ensure the fire spread was minimized. However, due to the fire extinguishing itself when it ran out of oil as a fuel source, it was agreed that control actions for the second burn did not have to be as aggressive to ensure personnel were not placed in excessive risk. Thus, on Day 2, the responders were instructed to relax control. Second, communications were increased for Day 2. All fire teams had a safety officer, and VHF radios, as on Day 1. However, to alert all crew members that the burn had commenced, the command post blew an air horn to ensure all members were alerted.

Prior to the second burn, crews re-established fire breaks with air boats, and were pre-positioned to wet down the levee (east boundary of burn site). The NOAA Scientific Support Team advocated and supported not burning Zone 3 or 6. However, there was concern on Day 1 that Zone 3 should also be burned. Thus, the environmental team quickly re-assessed that area and re-confirmed that Zones 3 and 6 should not be burned because of sporadic oiling that was not a substantial threat to wildlife, the water level, and the diversity of the vegetation and biota.

After the teams finished wetting down the east levee, the second burn started at 1145 in the SE corner of Zone 2. The burn was again started with propane torches. The winds were out of the N/NE, and ranged from 5 – 10 mph throughout the burn period. Visibility was high, with no clouds, and a sunny 80-85^{o}F throughout the burn period. The burn behavior was considerably different than the first burn (Day 1). In comparing Figures 6 and 12, one-minute post ignition, the Day 1 fire started much more quickly, produced blacker smoke, and continued to burn without any other manual ignitions. In comparing Figures 7 and 13, the Day 1 fire was more intense, self-sustained, and produced a larger, blacker and denser smoke plume. The difference in burn behavior was due to several factors: higher water level, less gross oiling, and higher water content in vegetation (a function of less oiling).

By 1240, roughly an hour after the start of the burn, thirty percent of Zone 2 had burned. This was determined during an overflight, and quickly communicated back to the ground crew to make sure they were oriented correctly within their zones. The fire was continuously re-started throughout the day. The burning was ceased at 1500 after it was determined that most of the combustible oil/oiled vegetation had been burned. Eighty-five percent of Zone 2 was burned, and only about 50% of Zone 5 was burned (Figure 16). The total burned area was about 28 acres.

Discussion:

Overall, the burn was successful in terms of removing heavily oiled areas with a burn efficiency estimated to be roughly 80-90% removal. The burn confirmed visual characterization of the oil as burnable, however, this was also due to the oiled condition of the vegetation. The above ground vegetation in Zone 1 and 4 was dead and dry due to the oiling duration and concentration. Thus, the burn was sustained by the oil on the vegetation, and the dry state of the vegetation itself. This is confirmed by comparing Zones 2 and 5 where the oiling was moderate and the vegetation was variable in that there were pockets of dead vegetation within areas of live vegetation. See Figure 2, pre-burn conditions and Figure 16, post-burn conditions.

Small amounts of mobile oil remained in the original pools. This was most prevalent in Zones 1 and 4. The residual oil was not burnable because its change in chemical composition (loss of lower molecular weight compounds), and burn residue was observable. However, the remaining oil was recoverable with sorbent material or netting. The remaining residue was “sticky” and presented a hazard to wildlife, especially opportunistic birds that will prey on the crab carcasses and live crabs that no longer have pre-burn protection from vegetation. Immediately after the smoke abated, shorebird individuals were observed to forage in Zone 1.

In Zones 1 and 4, subsurface oiling was observed, mainly in crab burrows. This oil was not burned, and cannot be burned, and will remain in the environment. Removing this oil would require excavation of the top 5 cm of sediment, and is NOT recommended because of physical destruction of the marsh structure. The subsurface oiling will be agitated from tidal action, and light sheening will be expected. Recovery should be through passive means, and foot traffic should be minimized. Foot traffic will drive the oil deeper into the substrate, delaying the natural removal and degradation of the remaining oil. This phenomenon is not as prevalent in Zones 2 and 5, but is in discrete pockets (Figures 14 and 15). Most of the above ground remaining vegetation contained water content that prevented total combustion. Obviously, there is more above ground vegetation remaining in Zones 2 and 5 than 1 and 4 (Figure 16). This is due to different degrees of oiling, water content of the vegetation, standing water levels, and differences in fire intensities (a function of the degree of oiling and plant water content). Despite the more acute effects in Zones 1 and 4, the root systems of the plants were observed to be unburned (Figure 9). Because the root systems were left in tact, the prediction for recovery of vegetation is high.

Monitoring and Post-burn Recovery: This site presents a tremendous opportunity for ongoing study because it contains adequate reference sites. Three treatment transects were established oiled and burned marsh, oiled and unburned marsh, and unoiled and unburned marsh. Within each treatment, three sampling sites were established (pre-burn). The monitoring plan will be implemented in accordance with Louisiana Oil Spill Coordinator's Office (LOSCO) guidelines. Post-burn monitoring includes a time series of aerial photography, composite sediment samples of total petroleum hydrocarbons (TPH), and quantification of numbers of stems per square meter along transects. This information will be available to the Unified Command and interested trustees. NOAA continues to coordinate with Chevron and its research team to conduct detailed recovery studies to improve decision-making decisions for future spills.

Preliminary observations (photo-documentation) show signs of rapid recovery suggesting that burning was the most appropriate decision. NOAA has continued to monitor the site opportunistically during overflight missions for marine debris and hazardous debris cleanup operations. See Figure 17.

NOAA continues to work with Chevron during its monitoring events. To date, two monitoring events have occurred: Dec 2, 2005 and Apr 20, 2006. The intermediate marsh is recovering quickly based on visual observation. However, the team established a sampling grid to quantitatively evaluate recovery. Overall, three, five-station transects were designated within the marsh. The transects were placed in three areas: (1) oiled and burned, (2) oiled and unburned, and (3) unoiled and unburned (i.e., reference). At each transect, a 1-m quadrat was used to collect data on average stem height, stem counts, percent cover, and species composition. A soil/sediment sample was collected adjacent to the quadrat for later analysis to quantify differences in PAH degradation among treatments. The data on endpoints other than photodocumentation have not been released to date.

Overall Conclusions or Lessons-Learned:

1) Oil that has been exposed to the environment for over five weeks can provide a burn that can remove 80 – 90% of gross oil and oiled vegetation, leaving a small amount of burn residue. The oil was originally protected by thickness of oiling in the retention pond. Once in the marsh, the vegetation provided protection from weathering, including emulsification.
2) The remaining residue was less than predicted, however, the remaining oil and residue presents a wildlife hazard and needs to be mitigated.
3) Aerial observations are important components of burn operations, and in post-burn assessments.
4) The burn removed 80 – 90% of the gross contamination.
5) Although the overall burn footprint was as precise as planned, it is unnecessary to conduct aggressive fire control if natural breaks exist for extinguishing the fire. Acceptable loss of unoiled, collateral burn, should be delineated as a means of calibrating on-scene fire-fighting control.
6) Although fire breaks worked well, the unoiled, high water content marsh on the west side of Zone 2 (Day 1) presented barriers to burning outside of the delineated burn zone.
7) Preliminary results show that recovery of the marsh based on time series photos seems to be occurring rapidly. From operational and environmental perspectives, burning was the appropriate cleanup method for this site.

8) The cooperative effort among the USCG, NOAA, Chevron, and the State of Louisiana was essential for obtaining rapid approval and for the success of the burn. This was the first burn of the Katrina-Rita responses, and set a precedent for using ISB at other sites.

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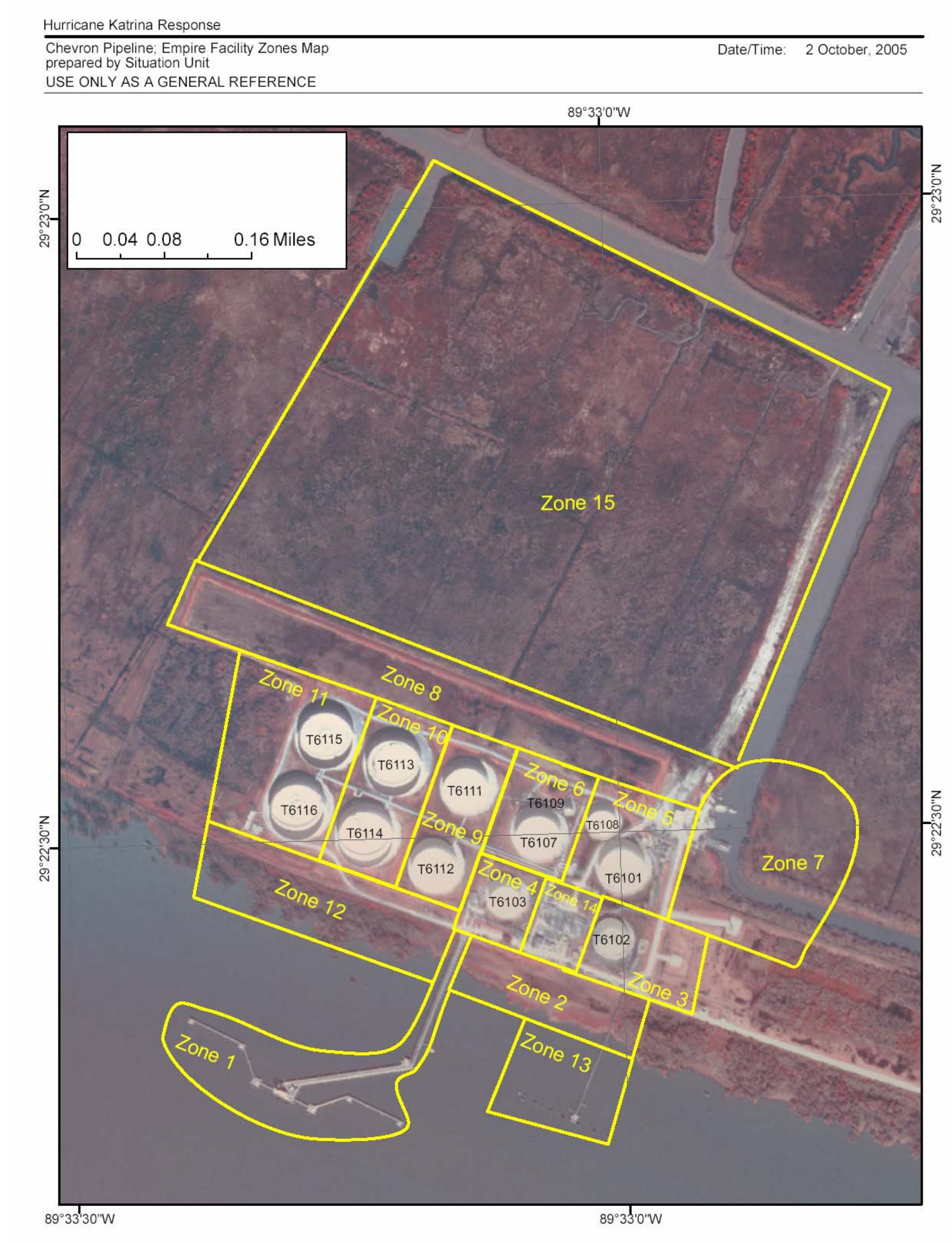

Figure 1. Chevron Pipeline; Empire Facility – Zone Map. Heaviest oiling occurred in the south-east of zone 15.

Figure 2. Oiled marsh north of facility (October 10, 2005).

Hurricane Katrina Response - Chevron Empire Burn Zones

Base Map
prepared by NOAA
USE ONLY AS A GENERAL REFERENCE

Date/Time: 04 Nov 2005
Platform: N/A
A. Merten NOAA

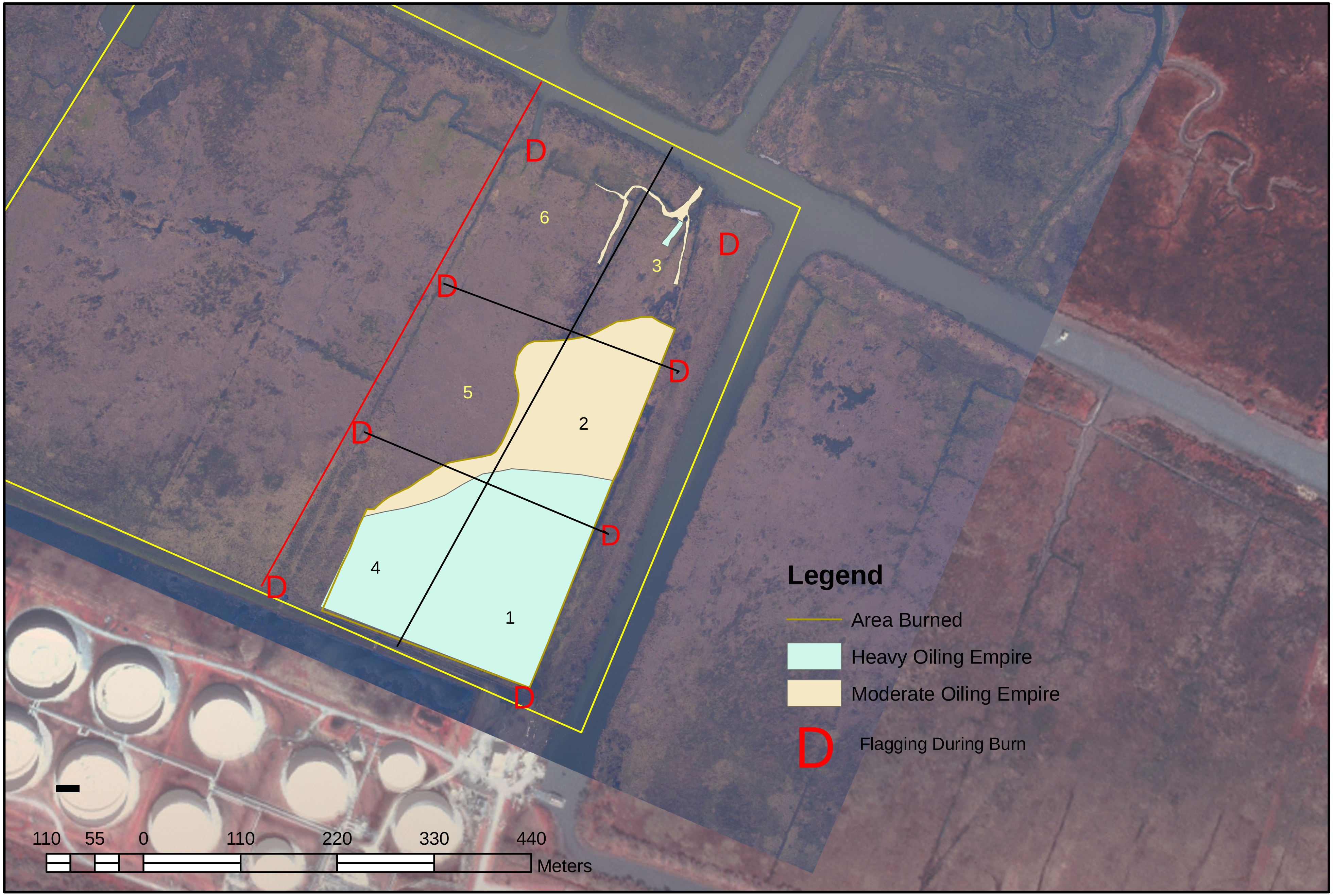

Figure 4. Two Days, pre-burn (October 10, 2005). Example of heavily oiled vegetation in Burn Zone 1. Note the lack of green vegetation.

Figure 5. Two days pre-burn (October 10, 2005), standing at the border of Zones 2 and 3, facing South overlooking Zone 2. Note the amount of green vegetation compared to Zone 1.

Figure 6. Day 1. One minute post-start of burn (October 12, 2005). Facing the oiled marsh from the Chevron Bunkhouse. The burn was started in the SE corner of burn Zone 1.

Figure 7. Aerial photo 1.25 hours into the burn (October 12, 2005). The fire has burned about a third of Zone 1, and has crossed the boundary into Zone 4. The people standing in the bottom right hand corner of the photo are behind the fire breaks of Zone 1.

Figure 8. Post-Burn, Day 1 (October 12, 2005),, standing in the Zone 1. This was a heavily oiled pocket of floating oil, and the remaining above vegetation (*Scirpus*).

Figure 9, Post Post-Burn, Day 1 (October 12, 2005), standing in the Zone 1. Note the green roots (*Distichilis*).

Figure 10. Post Burn, Zone 4 (October 13, 2005). Note root stumps (*Scirpus*) and residual oil/residue on the surface of the water.

Figure 11. Post-Burn Day 1 (October 12, 2005). All zones are clearly visible. Burned Zones: 1 and 4. Oil contamination visible in Zones 2 and 5. Zones 3 and 6 are in the fore front.

Figure 12. Day 2. 1 minute post-start of burn (October 13, 2005).

Figure 13. Aerial photo 1.1 hours into the burn (October 13, 2005). The fire is in Zone 2. The leading edge is almost in Zone 5. Note the difference in smoke volume, density and color from Day 1.

Figure 14. Post-Burn, Day 2 (October 13, 2005), Zone 2. Note the amount of remaining, unburned vegetation and water levels.

Figure 15. Post-Burn Day 2, Zone 2.

Figure 16. Final Footprint of the burn area. Note Zone 2 is about 85% burned, but Zone 5 only about 50% is burned.

Figure 17. Aerial photo of burn site, March, 16, 2006, 5 months post-burn. Photo credit: Gary Shigenaka (NOAA)