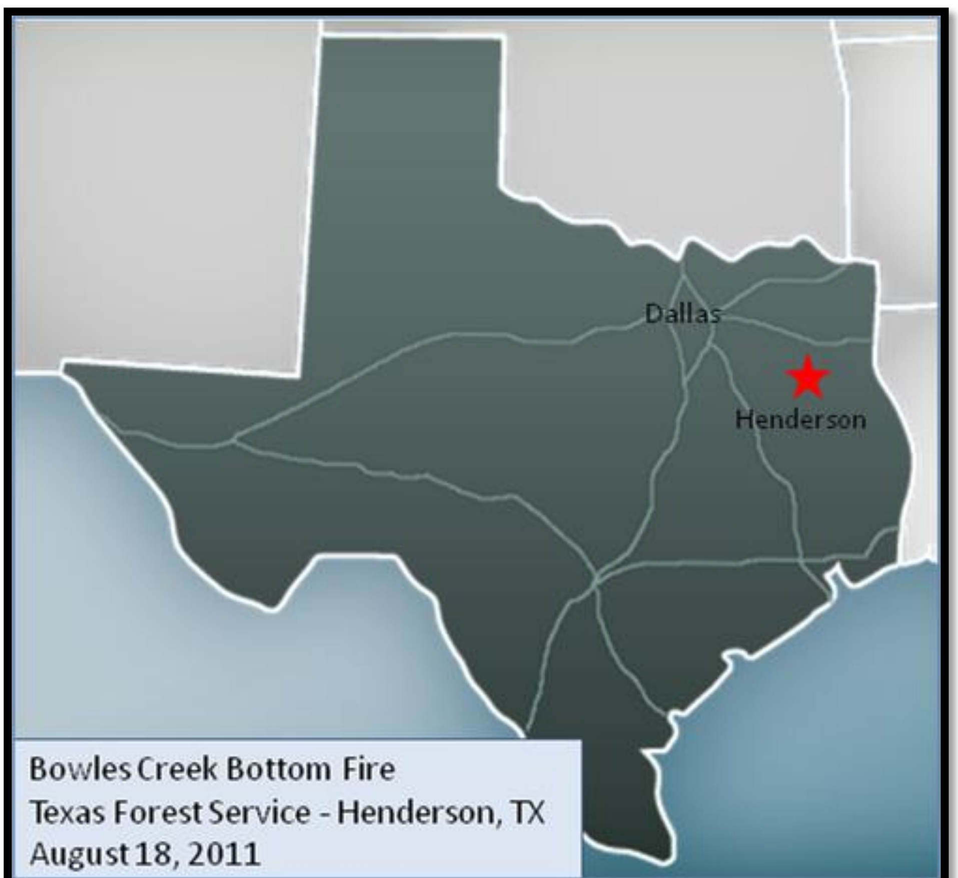
Bowles Creek Bottom Fire

Lessons Learned Review

Texas Forest Service
August 18, 2011

Contents



General overview of the area surrounding the Bowles Creek Bottom Fire.

1. Summary

slough (slōō, slou) also slew (slōō)

-noun.

1. A depression or hollow, usually filled with deep mud or mire.

2. Also slue: A stagnant swamp, marsh, bog, or pond, especially as part of a bayou, inlet, or backwater.

After months of drought conditions across the state, The Bowles Creek Bottom Fire (Fire #384) started 10 miles west of Henderson, Texas, and was reported on the afternoon of August, 18, 2011.

Initially dispatched resources included a Texas Forest Service (TFS) supervisor, two TFS Type 5 Tractor Plow Units and a U.S. Forest Service Type 6 Engine. Upon arrival, the resources found a 10 – 15 acre fire burning in a dry slough with patchy hardwood timber and surface fuels which included grass, brush, and mowed sawgrass in the open spaces between timber.

An anchor point was established at the northeastern corner of the fire, and each tractor plow took a flank and began constructing line. The Type 6 Engine was assigned to the north flank. The engine started at the anchor point and began cooling off the fire as the fire backed toward the plow line.

After working the line for 15 to 20 minutes, brief wind shifts produced several small spot fires across the constructed line on the northern flank. Initially, the engine crew and tractor plow were able to pick up the spots. A short while later, the engine moved up to help knock down some heat for the tractor plow, at which time the fire again started spotting across the line.

After initially chasing spots with the tractor plow and the hard line from the engine, the Engine Boss decided to reposition his engine away from the increased fire activity. As the Engine Boss began to back the engine out, the front end sank and the engine immediately became stuck.

The tractor plow worked quickly to pull the engine out, and after several unsuccessful attempts, a plow line was built around the engine. As the tractor plow worked, engine crewmembers attempted to extinguish spot fires beneath the engine, and as these spot fires grew, the pump quit running. After a number of tries to restart the pump, each with no success, the engine's fire extinguisher was used to contain fire burning under the engine's chassis with only minimal success.

At this point, with all engine protection options exhausted, the Engine Boss elected to depart the area due to extremely heavy smoke, building radiant heat, and increasing spot fire activity in the area surrounding the engine. The engine crew walked a short distance down their escape route to a predetermined safety zone. No crewmembers were injured. The Type 6 Engine was burned and destroyed.

The Type 6 Engine after it caught fire and burned. The soil surrounding the engine was disturbed by the tractor plow as part of the engine protection measures. Note the front wheel settling into underlying soil.

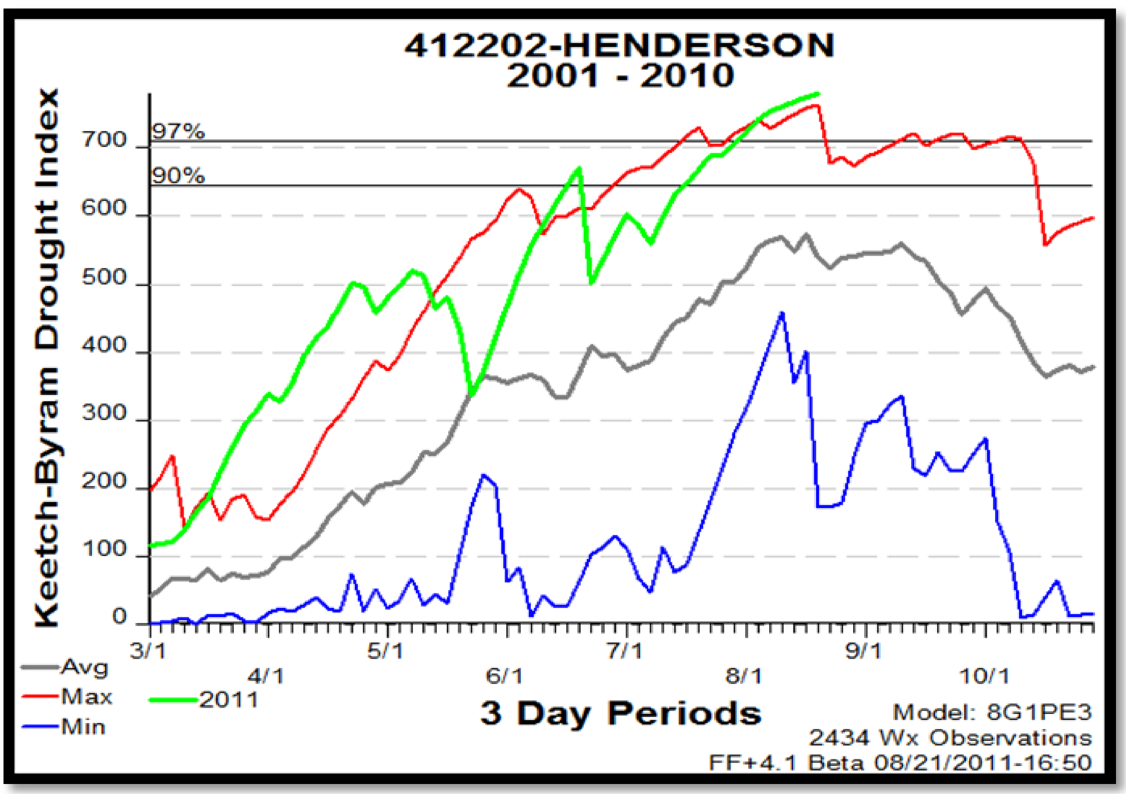
2. Background Information

March-August, 2011

Texas: The 2011 Fire Season

For Texas, the 2011 fire season began early and quickly developed into the most significant fire season on record. Most of Texas had become entrenched in one of the most severe droughts in recorded history. Local fire crews had been actively suppressing fires since March, and many Texas Forest Service crews had been working a schedule of 21 days of work followed by 2 days off.

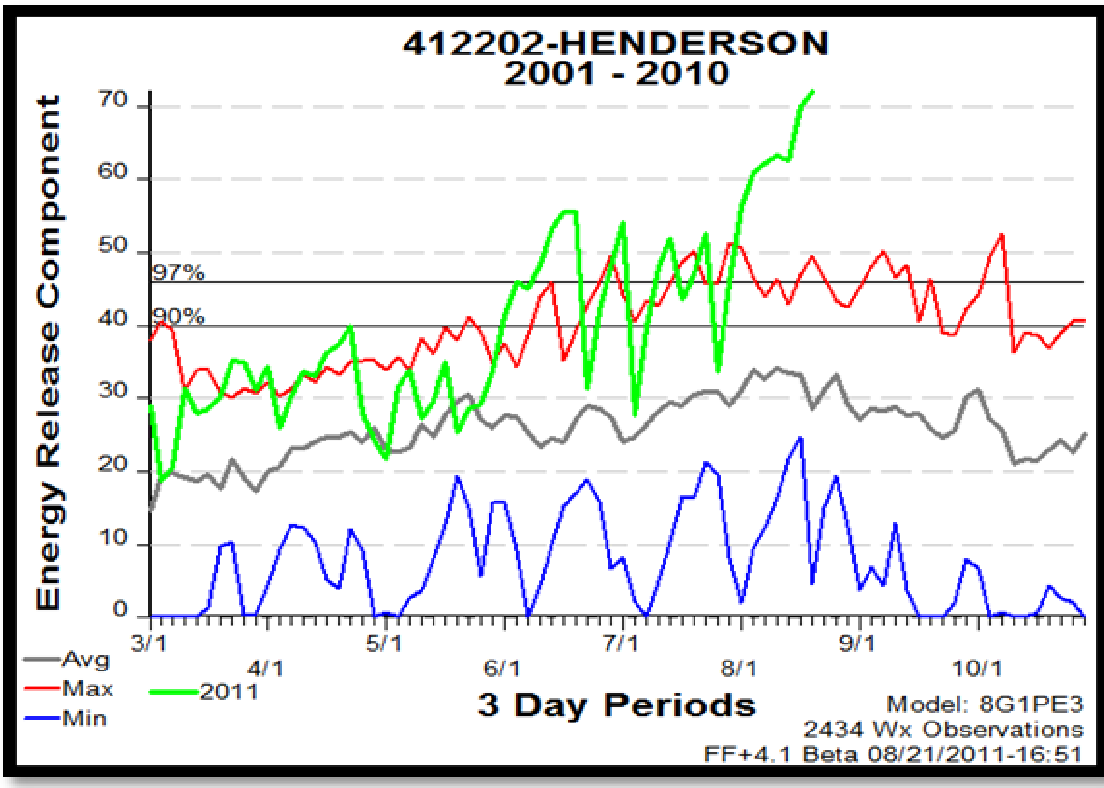
The US Drought Monitor indicated the area around Henderson, Texas was in "exceptional drought," the most severe classification. Daily temperatures had been in the triple digits much of June, July and all of early August. The Keetch-Byram Drought Index (KBDI), ranges from 0 to 800, where a drought index of 0 represents no moisture depletion 800 represents absolutely dry conditions



The Keetch-Byram Drought Index (KBDI) from ***March –August 2011*** *from the Henderson RAWS.*

By early August, KBDI readings were establishing new records on a daily basis. (Indices were taken from Henderson Remote Automated Weather Station (RAWS) located approximately 10 air miles east northeast of the fire area, which has data from 2001 to present (2011)).

Energy Release Component (ERC) is the National Fire Danger Rating System (NFDRS) index used to track the combined effects of fuel dryness on fire potential. ERC Model G was also setting new historic highs and was well above the 97th percentile for the nine years of data.



The Energy Release Component (ERC) from ***March –August 2011*** *from the Henderson RAWS.*

March-August, 2011

The USFS Type 6 Engine: The 2011 Fire Season from March to August

For the crew of the Type 6 USFS Engine, the 2011 fire season began in late April when crewmembers started their seasonal appointments. By the first week of May, all seasonal crewmembers were on duty. Local initial attack activity was relatively light during early May. Several local fire assignments occurred in the engine's area prior to the first off-district assignment that took the engine to Southern Arizona the first week of June. After that assignment, the engine remained attached to the local district due to Stage III Fire Closure restrictions that were in place on the

Forest. Fire restrictions were completely lifted the first week of August, and this made the Engine and its crew available for the off-district fire assignment to East Texas.

August 9th -August 17th, 2011

The Type 6 Engine: Mobilized to East Texas for Initial Attack Support

The Type 6 Engine was mobilized on August 9th to the East Texas Zone, which was part of the larger Initial Attack organization that covered the entire state. The crew mobilized with an Engine Boss and three fire fighters (the Assistant Engine Boss was on personal leave, and did not mobilize on this assignment, and on August 17th, one of the three firefighters de-mobilized due to minor medical issue.)

August 10th was the crew's first day of the fire assignment. Between August 10th and 18th, the crew spent a total of seven operational periods assigned to fires. The crew took their engine off-road a number of times including other dry sloughs, without any difficulties. Work days were generally 12 hours in length, with several shifts that approached 15 hours in length. After the first week of their assignment, the crewmembers reported feeling no excessive fatigue.

The Texas Forest Service Type 5 Tractor Plow that worked on the north flank of the Bowles Creek Bottom Fire. Note the plow attachment on the rear of the tractor.
Click here for a video of a tractor plow in action

3. Detailed Incident Chronology

August 18, 2011
The day of the Incident

- The Keetch Byram Drought Index (KDBI) is at **776**, the highest recorded value since 2001 (the length of records for the weather station closest to the fire).
- Morning Fire Weather Forecast includes a "slight chance for rain."

0730 Start of the crew's eighth shift on their East Texas assignment.

0800 Morning briefing at Texas Forest Service Henderson Office.

1000 Crew assigned to patrol a fire contained on August 17. The crew drives their engine in a dry slough and has no problems.

1300 Engine and crew are back in Henderson, Texas, and are standing by for Initial Attack.

A New Fire is Reported; Resources are Dispatched

**Denotes times taken from Texas Forest Service Dispatch logs. All others were approximated with direct assistance from those involved in the incident.*

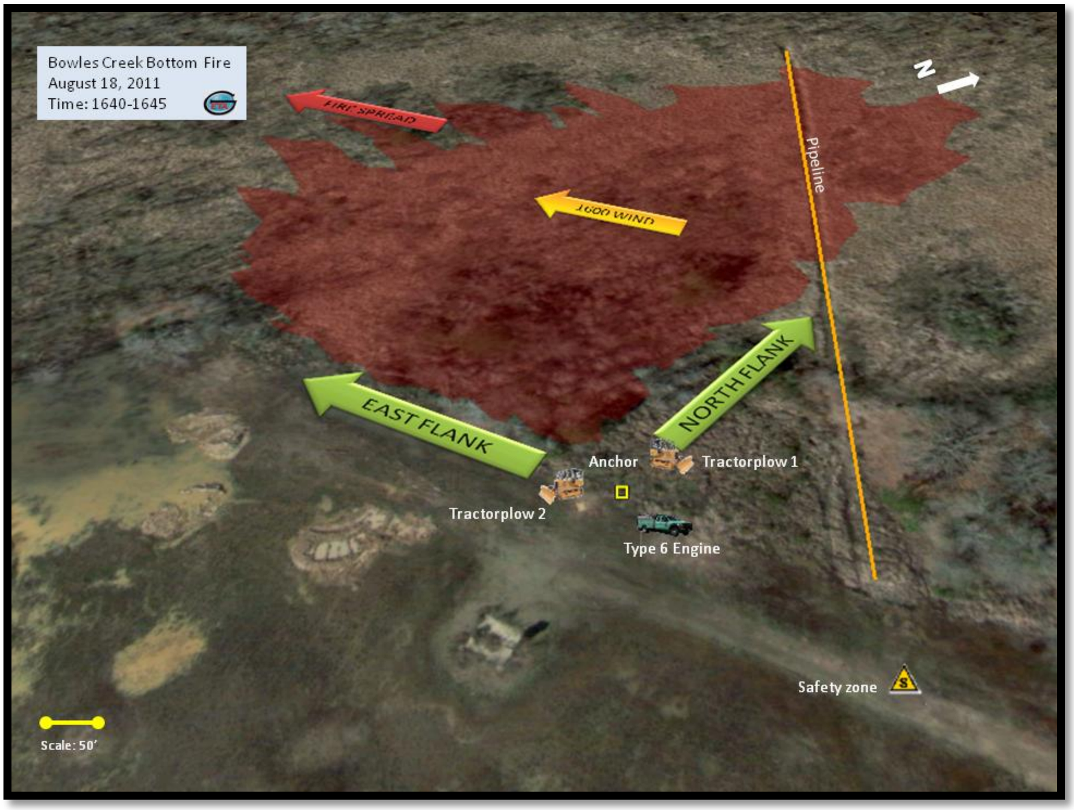
1455* A fire detection aircraft provides initial reports of a new fire, 10 miles west of Henderson, Texas. The new fire, Incident #384, becomes known as the Bowles Creek Bottom Fire.

1506* Initial attack dispatch includes a Texas Forest Service (TFS) supervisor, a TFS Type 5 Tractor-Plow, and a U.S. Forest Service Type 6 Wildland Fire Engine.

1509,* 1545* Two additional TFS Type 5 Tractor-Plows are dispatched to the fire (One each at 1509 and 1545).

1550* The first resources are on scene, including the TFS supervisor and two TFS Type 5 Tractor-Plows, as well as the USFS Type 6 Engine. Briefing takes place in an open pasture, which is a designated safety zone.

1600 Resources receive briefing and engage in line construction efforts on the northern and eastern flank. The Type 6 Engine, with a crew of 3, works on the northern flank.



The Bowles Creek Bottom Fire, estimated at 10-15 acres in size upon arrival of Initial Attack Resources. Initial suppression action on this fire was a classic "anchor and flank" method of attack.

1615 Plow and blade line has progressed to an underground pipeline approximately 170 feet northwest of the anchor point. No plow / dozer line is installed over the pipeline due to concerns that the dozer plow could impact the pipeline.

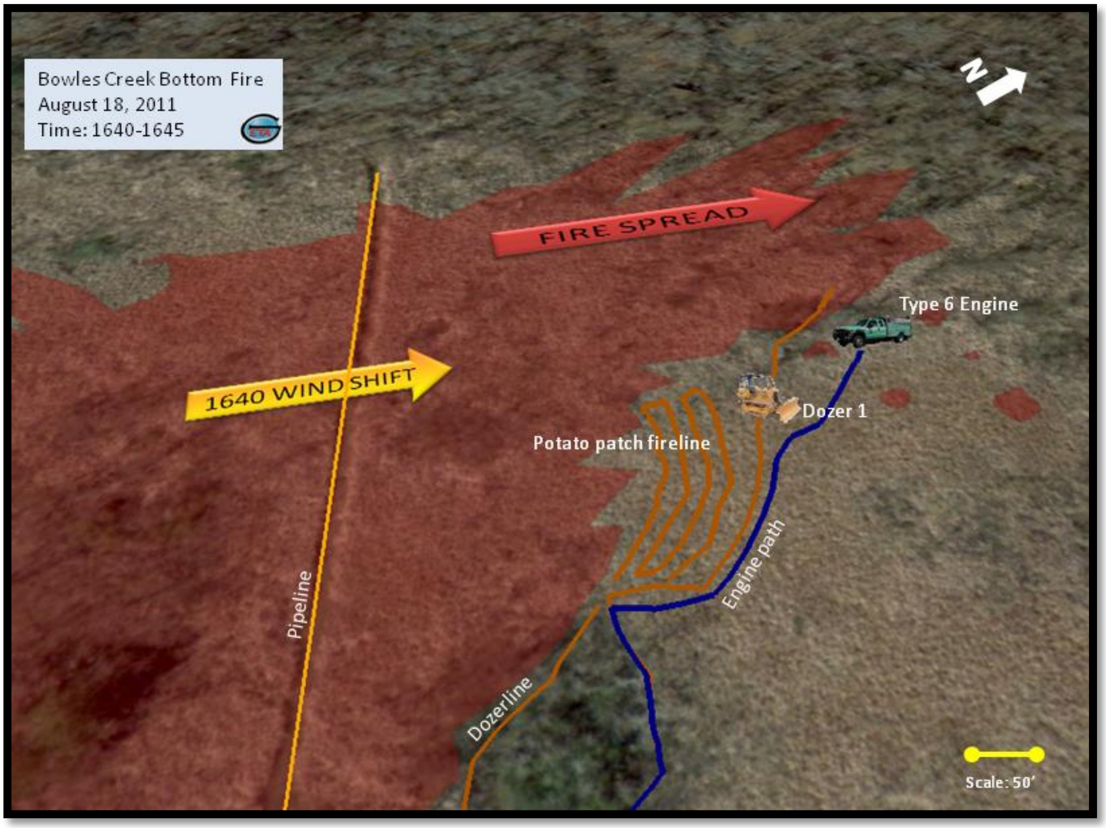
1620 The engine crew constructs a short piece of handline over the underground pipeline.

1625 After a brief wind shift, tractor operator notices several spots across line in the mowed sawgrass, and begins to "potato patch" (series of parallel plow lines) in the vicinity of these spots.

1635 Engine moves down the line to cool down some brush near the northwestern corner, which is still the heal of the fire at this point in time.

Winds Pick up and Shift 180 °; Fire Intensity and Spotting Increase.

The following events occurred in the sequence listed below. Specific time stamps are not shown because of the very narrow window of time in which these events unfolded.



The Bowles Creek Bottom Fire at approximately 1640, when the significant wind shift occurs.

1640

- The Engine Boss attempts to back up engine to reposition away from increased heat and spot fire activity. The Engine's front wheels quickly sink, and the engine becomes stuck.
- At the direction of the Engine Boss, one of the engine crewmember retrieves the tow chain to pull the engine out. The second crewmember and the Engine Boss work to suppress spot fires around the engine.
- The Engine Boss reports that the smoke is thick enough to "put me to my knees" as he works to contain spots around the engine. As he finds fresh air, he realizes he needs to step back from suppression activities and serve as a lookout for his crew and his stuck engine.
- The swamper from the tractor plow notices the engine is stuck, and directs the tractor plow to move into a position to pull the engine out.

1640

- The engine's tow chain is secured to the engine and the tractor plow, and after three attempts to free the stuck engine, the chain is disconnected.
- Tractor plows a line around two sides of the engine. Fire activity near the front of the engine prevents a complete line.
- As crewmembers work to suppress spot fires in the vicinity of the truck, and under the chassis, the pump dies. All attempts to restart the pump all fail.
- Engine Boss directs a crewmember to use engine's fire extinguisher on developing spot fires beneath engine chassis. This effort is minimally successful.

1645 With all engine protection options exhausted, Engine Boss decides to disengage from engine protection and lead crew down the escape route to the established Safety Zone (the pasture where briefing took place.)

1647 THE CREW IS IN THE SAFETY ZONE. THERE ARE NO CREWMEMBER INJURIES.

1649* Report from Bowles Creek Bottom Fire Incident Commander to Texas Forest Service Dispatch that the engine "has been destroyed."

1700 Engine Boss notifies home unit via cell phone of the incident.

4. Conditions: In Their Own Words

Diagram which shows the inter-related nature of the conditions, represented in the words of firefighters, that led up to the Type 6 Engine burning on the Bowles Creek Bottom Fire.

5. Lessons Learned

A. The following are Lessons collected from both the Type 6 Engine Crew and the Type 5 Tractor Plow personnel who were on the north flank as events unfolded.

- **Do not** assume that because a dozer, **tractor plow unit** or other piece of equipment moves across a piece of ground with no problem, that your engine will be able to do the same.
- **Do not** assume that just because you are not leaving behind ruts as you drive that you are on solid ground.
- Picture how mowed (or altered in any way) fuels would look when they were standing, ask yourself what has changed and what hasn't.
  - The crew said they would not have thought about driving in the area if it had been standing sawgrass. Just because the fuels were altered or mowed down doesn't mean the condition of the underlying soils have changed. (although potential fire behavior could).
- Know where your flammables are stored and be mindful of their location and proximity to flames or heat sources.

Which is the Heaviest?

While the Type 5 Tractor Plow is the heaviest object, at 17,300 pounds, that's just part of the story…

While the Type 5 Tractor plow *"…weighs 17,300 pounds, it exhibits a ground pressure (down force measured in pounds per square inch) of only 4.3 pounds per square inch as compared to 34.5 pounds per square inch for the apparatus which actually weighs less at 16,200 pounds. For comparison, a firefighter standing on both feet exhibits approximately 8 pounds per square inch of ground pressure."*(See Appendix B for a more detailed analysis on factors associated with the Type 6 Engine)

Here's the ground pressure rankings:

1. Type 6 Engine	2. Firefighter	3. Type 5 Tractor Plow
34.5 PSI	~8 PSI	4.3 PSI

- When returning to the scene, portions of a driptorch and window glass were found over 20 feet from the engine. The hazards associated with being anywhere near a burning wildland fire vehicle are significant, and were noted by those involved.

- Know where **all of your equipment** is stored!
  - This crew knew exactly where the tow chain was and quickly had it hooked up.
- If your unit has several similar engines/vehicles that crews switch between, set up compartments the same way.
  - The Type 6 Engine crew frequently switches between the two Engines on their home unit, and the fact that the compartments are configured similarly was an asset. This is the situation with this engine crew and it served them well.
- Have a copy of your vehicle inventory at the home unit.
  - The Engine crew did have copies of their inventory at the home unit and it turned out to be extremely helpful in the process of replacing destroyed equipment.
- Have a copy of the vehicle maintenance records and inspection logs at the home unit.
  - The Engine crew did not have copies of the vehicle maintenance records or inspection logs at a separate location.
- **Do not** hesitate to use the fire extinguisher.
  - When the pump quit working, the Engine Boss immediately instructed crewmembers to utilize the fire extinguisher to suppress surface fire burning below the engine. The crew members knew where the extinguisher was located and quickly put it to use.
- When conditions deteriorate, remember to keep a lookout posted.
  - Once the crew began to focus on engine protection, the Engine Boss realized the need for a “localized” lookout and subsequently oversaw the protection operations and monitored the surrounding fire conditions.
- When an incident like this happens, notify your home unit quickly.
  - Within minutes of the incident, the Engine Boss notified his home unit supervisor. This early notification allowed agency liaisons to travel to Texas the next day (see below). This was key to the efficient coordination with the Texas Forest Service as the review team was mobilized.
- Send representatives from the home unit to serve as advocates and liaisons.

    - In this case, a representative from the Engine crew's home District as well as a Forest level representative arrived the next day. All agreed this was essential to properly support the engine crew.
- When on assignment away from your local area, if you come upon a term or concept you are unfamiliar with, ask for clarification and ask to be shown exactly what is being described.
    - This Engine crew was not familiar with the term "slough". They did eventually ask and understand after being shown exactly what it was.
- Train on low frequency events (pulling out the chain and hooking it up quickly, for example)
- Actively build crew cohesion- it is essential to efficiency in stressful situations.
    - The engine crew credited their efficient and decisive actions to being a "tight engine"
- Have an administrative plan for how to deal with destroyed equipment.
    - In this instance the representatives from the home unit took on the task of what to do with the remains of the burned engine. In some cases the damaged equipment may need to be retained for further investigation, although not in this case. It was difficult to know where to start with required paperwork needed to properly deal with the remnants of the engine. [Those involved expressed the desire for a checklist or guidance for this situation (removal of damaged government property)]. It seemed as if nobody knew who had the authority to approve "scrapping" the engine and it was discussed throughout the chain of command several times. This could be avoided by having a discussion with your fleet manager and Agency Administrator about what the process would look like in this potential situation.

B. Lessons Developed by the Review Team

- In some situations, the ability of soil to hold weight can decrease after multiple passes. Additionally, both the visual and physical cues of foot and heavy equipment traffic may not be accurate in determining soil stability.
    - While tractor plow 1 weighs 17,300 pounds, it exhibits a ground pressure (down force measured in pounds per square inch) of only 4.3 pounds per square inch as compared to 34.5 pounds per square inch for the apparatus which actually weighs less at 16,200 pounds. For comparison, a human standing on both feet exhibits approximately 8 pounds per square inch of ground pressure.
    - Although the Type 6 engine and the Type 5 Tractor Plow are very closely matched in terms of weight, the Type 6 Engine has a much higher ground pressure.

- Emphasize the mutual responsibility and importance of thorough in-briefings for resources from outside the area. These briefings should include local hazards, tactics and terminology or jargon. As part of the briefing, exchange information about resource capabilities. In this instance, multiple tractor plow operators mentioned they had never really worked with engines before and were unfamiliar with their capabilities and what exactly they do on fires, and subsequently how to direct them on fires. This was worked out after the first couple of fires, but all agreed a thorough conversation surrounding resource capabilities would have been beneficial for both groups.

- If the pump did die from oxygen deficiency and the air quality subsequently improved enough to restart the engine, the operator would have needed to execute coordinated valve closures and a specific starting sequence. This process is generally learned from systematic hands-on training which is usually not within the scope of entry level firefighter's training.
    - Repeatedly practice problem diagnoses and restart procedures under varying conditions to create resilience during high risk, low frequency situations.
- "I look for reasons why I can engage a fire."
    - Consider the possibility that when we approach a situation that requires risk assessment ("Should I drive this section?") and we have a preferred outcome ("I want to catch this fire!"), we may tend to look for reasons why we <u>can</u> do what we want (confirming evidence),

rather than looking for reasons we shouldn't attempt it (disconfirming evidence). Counting up the reasons why "it's ok" may overpower the one good reason not to engage.

- Consider the gradual positive and negative changes in behavior after operating for extended periods of time in "non-normal" conditions. As you consider these potential changes in how you operate, think about ways to leverage and teach the desired shifts in behavior as well as identifying and addressing the undesired behaviors.

Words Have Meaning

This is an excerpt from the safety message in the Incident Action Plan two days after the incident (August 20, 2011)

> ***"Thursday we lost a Type 6 engine in a burn-over on the Bowles Creek Bottom fire in the East Zone. Fortunately the crew was able to escape to a safety zone and there were no injuries. While we do not yet know all the details, there are lessons to be learned."*** (West Texas Initial Attack IAP, August 20, 2011)

This use of the term "burn-over" in the IAP safety message had a negative effect on the people involved.

Burnover: *An event in which a fire moves through a location or overtakes personnel or equipment where there is* ***no opportunity to utilize escape routes and safety zones****, often resulting in personal injury or equipment damage.* (Definition from the NWCG Glossary of Terms PMS 205, 2011.)

The phrase '***no opportunity to utilize escape routes and safety zones'*** does not match the situation on the Bowles Creek Bottom Fire. There was much discussion amongst those involved about the terminology and connotations within the wildland fire community of the term '*burnover*'. The term has an extremely negative connotation which, intended or not, calls into question the operational capability of the resources involved. Nobody wants to be the crew that got burned over, especially if that wasn't the case.

There was similar concern with portions of the 24 hour report (August 19, 2011):

> "***While supporting fireline construction on a wildfire near Henderson, Texas, a USFS Ford F-550 Brush Truck Unit, consisting of an Engine Captain and two operators, were cut off from their safety zone due to the brush unit becoming stuck in marshy soil conditions.*" (**Texas Forest Service 24 Hour Report, August 19, 2011)

The statement that the crew was "cut off from their safety zone," which was inaccurate, had a lasting negative effect on the people involved. As with most initial notifications, the 24 Hour report included the qualifier "The following information is preliminary and subject to change." This instance illustrates what we are willing to publish in initial reports. Obviously none of this was done maliciously, but the overall impact was significant.

- A clear lesson for all of us, especially those who put widely circulated documents into print, is to be mindful of language used in these situations, particularly in initial reports where all details are not yet known. Know the definition and correctly use emotionally charged words and phrases like "Burnover", "Entrapment" and "cut off from safety zones."

6. Commendations

- **Leadership and Decision Making**
  - The Engine Boss made several critical decisions, the most important being the timely choice to cease engine protection efforts and calmly lead his crew to the safety zone.
  - The Engine Boss made another sound decision when he consciously stepped back to serve as a lookout when operational tempo increased.
  - US Forest Service Region 3 immediately sent advocates for their employees.

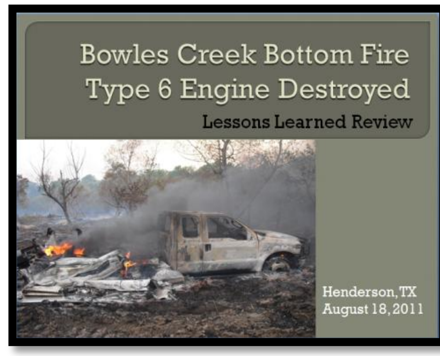
- **Crew Cohesion**
  - The engine crew displayed high levels of cohesion as they kept calm, thought clearly, and acted decisively in this high stress situation.

- **Communications**
  - The Texas Forest Service and US Forest Service Region 3 personnel quickly communicated and cooperated to take a learning rather than blaming approach with this review.

7. Further Learning Opportunities

Lessons Learned Review Presentation:

Below is a link to a presentation intended to give a brief overview of the incident as well as pertinent lessons for firefighters. This presentation was developed to aid in knowledge sharing. Not everyone has the time or interest in reading the numerous reports and reviews available. The intent is that one individual from a crew or module can read this review, become familiar with the details and then provide this presentation to their peers. In addition, there are also recommended field exercises listed at the end of the presentation. Of course, the most important piece of preparation is reading the report and being intimately familiar with the chronology and lessons.



The link is for a pdf version of the presentation. In the document is an email link to request a PowerPoint version for customization. The PowerPoint version contains some helpful notes associated with a number of slides.

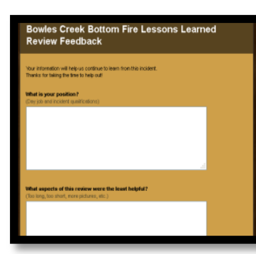
Bowles Creek Bottom Fire Lesson Presentation (Click to Follow)

Google Earth Representation

Below is a link to a Google Earth representation of the events on the Bowles Creek Bottom Fire (You'll need Google Earth to view the representation).

Bowles Creek Bottom Fire LLR (Click to Follow)

Review Feedback



Below is a link to a five question feedback form on the effectiveness of this report. Please help us improve how we review and learn from events like this

Bowles Creek Bottom Fire LLR Feedback (Click to Follow)

8. Review Process Lessons

The following items are a summary of what the Review Team Members learned about the Lessons Learned Review process itself.

Initial Response

- The Engine Boss stated he would have greatly appreciated a call from the Lessons Learned Review team leader early in the process (as soon as the team leader accepted the assignment). This call would allow the team leader to check in and let those involved know what the Lessons Learned Review process would be like. Additionally, this call would establish a connection immediately and increase the comfort level for the crew during an inherently stressful time period. **DO THIS!**
- In the delegation of authority, spell out the exact process to be followed for finalizing and publishing the document. Specify when a draft will be provided to the delegating authority and how long they have to review it and provide feedback. Note:
  - *"A copy of the final report will be submitted to the respective agency's national fire safety lead who will provide a copy to the Wildland Fire Lessons Learned Center."* (Interagency Standards for Fire and Fire Aviation Operations, January 2011)

Review Team composition

- As part of the team, include a technical expert in the area of operations involved (in this case wildland fire engines). The subject specialist on this team proved to be invaluable and added immensely to the effectiveness of this report.
- Consider adding immediate training material (presentations or exercises) to aid knowledge transfer in the field. Consider including a team member with a background in training development who would focus on developing additional learning tools.
- Include an operationally experienced geospatial technical expert.

Facilitation of group discussion

- Provide opportunity for all those involved to share their experience. Make an effort to seek out and converse with those not comfortable speaking up in a group setting.

Product

- Take on the responsibility of quickly providing review products for those in the field who operate in similar situations as those depicted in the incident review.
- Be very mindful of terminology and remember that words have meaning.
- Ask participants if they have photos or video they are willing to share and to be included in review products.

Learning In Action:

Based on the outcome and lessons learned on the Bowles Creek Bottom Fire, as of August 24th, 2011:

1. Texas Forest Service will be positioning a new safety officer in East Texas to provide in depth local knowledge briefings to out-of-area resources.
2. Local Texas Forest Service units plan to utilize this report and presentation in training they provide to Volunteer Fire Departments.

The Lessons Learned Review Team

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The Review Team would like to acknowledge the Texas Forest Service as well as USFS Region 3 personnel for their cooperation and support as we worked to gather these lessons. In addition, we truly appreciate the openness and candor demonstrated by those involved with the Bowles Creek Bottom Fire. Paul Keller provided invaluable editorial feedback.

Appendices

Appendix A – Weather and Fire Behavior

Weather 8/18/2011: Observations were taken from the Henderson Remote Automated Weather Station (RAWS). At the time of the incident temperatures were 102°F, relative humidity 24%, winds were initially 5 miles per hour (mph) out of the north northeast. Sometime between the 1600 and 1700 observations, winds shifted to southwest and increased to 12 mph. The Henderson RAWS recorded 0.01 inches of precipitation on the 1700 observation, however only a few drops of precipitation were noted at the fire.

Personnel at the fire noted a large cumulus thunder cell located northeast of the fire when arriving at the safety zone. This thunder cell was not visible at the engine location due to smoke and trees obscuring visibility. Based on the direction of this wind shift(southwest), outflow winds from thunder cells located to the *south* of the fire, rather than those to the northeast were likely responsible for this shift[1]. The Morning Fire Weather Forecast used in morning briefing on August 18th gave very little indication of potential thunderstorm activity. The Afternoon Fire Weather Forecast did indicate the potential for thunderstorms, but this forecast was not issued until 1600.

Fuels: The fire area was a dry slough. During normal years, the area would have held standing water. Overall fuels in the area consisted of mowed sawgrass with pockets of mixed hardwoods and un-mowed sawgrass immediately surrounding these pockets. The area where the engine became stuck consisted of mowed sawgrass which created a continuous fuel bed of fine cured biomass, similar to fuels found in masticated areas, only this material is lighter weight, herbaceous in origin and more abundant. The fuel bed averaged 3 inches in depth the upper ¾ of the fuel bed was dry and fluffy. The lower ¼ of the fuel bed in contact with the soil was perceptibly moist. The mowed sawgrass is a modified fuel bed that is now compact (less available oxygen) and would burn more slowly exhibiting relatively low flame lengths and low rates of spread, but long duration combustion, and more receptivity to ember ignition. A modified moderate load timber litter best represents fire behavior in this fuel bed. The higher fuel moisture in the lower ¼ of the fuel bed prevented the

[1] Based on communications with the National Weather Service(NWS), in Shreveport, Louisiana, which is the NWS office responsible for fire weather forecasting in this part of Texas. This office reviewed radar imagery from August 18 gathered at the time of the observed windshift.

entire fuel strata from being consumed. Fine dead fuel moisture was calculated to be 5% and probability of ignition 71% at the time of the incident.

Fire Behavior: When arriving at the heal of fire, personnel noted fire behavior consisting of backing fire with flame lengths less than 1 foot. Hardwood, un- mowed grass areas were burning with slightly higher intensities up to 2 foot flame lengths, with occasional torching. When winds shifted from northerly to southerly and increased, personnel noted frequent short range spotting across the plow line in the vicinity of the engine, and flame lengths in the mowed fuels of 1 to 1 ½ feet. Fire in the un-mowed sawgrass and hardwood patches exhibited greater flame lengths (near 4 feet) with frequent torching. During the period of time from the engine becoming stuck and the crew leaving the engine, head fire had formed north of the engine as a result of spot fires and began to actively move north.

Appendix B – Detailed Analysis of the Type 6 Engine

(Note: In this section, the Type 6 Engine is referred to as an 'apparatus' to avoid confusion given the extensive discussion associated with the 'pump engine' and the 'truck engine')

The incident location was in a dry slough consisting of soil with a high organic content and mowed sawgrass approximately 3 inches thick which readily support surface fire. The location in which the apparatus became immobilized was recently mowed, visibly dry and had previously supported travel by a tractor plow. Additionally, personnel were walking through the general area without any noticeable effect on the underlying soil. The apparatus stopped short of a timbered area because of increased fire behavior and engaged in direct support of the tractor plow. When the wind shifted to the southwest and fire behavior increased, the Engine Boss placed the apparatus in reverse.

Prior to the reversal of the apparatus, when the wheels initially rolled forward over the organic soil, voids beneath the soil surface were compressed as the wheels rolled forward. Once the weight of the apparatus had moved past, these void re-filled by capillary action with water from below. (It might be helpful to think of how a compressed sponge responds when placed in a shallow container of water.) When the apparatus moved backwards, the front tires rolled over and sank into this newly re-wetted soil. This same capillary action made it impossible to retrieve the apparatus after 3 attempts with the tractor plow which subsequently experienced the beginning of the same sinking effect.

While tractor plow 1 weighs 17,300 pounds, it exhibits a ground pressure (down force measured in pounds per square inch) of only 4.3 pounds per square inch as compared to 34.5 pounds per square inch for the apparatus which actually weighs less at 16,200 pounds. For comparison, a human standing on both feet exhibits approximately 8 pounds per square inch of ground pressure.

As deduced, the ability of soil to hold weight can decrease with re-absorption that could render the ground unstable on subsequent passes. Additionally, both the visual and physical cues of foot and heavy equipment traffic may not be accurate in determining soil stability, given the much higher ground pressure associated with the apparatus.

Initial Pump Failure

During the attempt to retrieve the apparatus with the tractor plow, the pump stopped running. Reasonable potential causes of the initial pump failure include:

Electrical component failure – The pump engine has several electrical circuits and associated devices that control the pump engine operation. There is no history of electrical malfunctions with this series of pump engine or this particular pump engine. Given that personal accounts reflect that all pump engine controls were working properly, as well as the fact that the pump engine briefly restarted utilizing said controls, indications are that if an electrical malfunction was present it would be intermittent in nature. Therefore, the probability of this being a causal factor is indeed possible, however not probable.

Low oil pressure – The apparatus has an automatic cut-out that protects the pump engine in case of a fatal loss of oil pressure below 4.26 (+- 1.4) pounds per square inch (psi). A manual momentary over-ride switch exists to facilitate the start-up of the engine. A low oil pressure condition was unlikely, as the oil level was checked daily including the morning of the event.

Low water pressure – The pump engine has a manual select toggle switch that protects the pump in the case of a fatal water pressure loss usually when the tank emptied or a loss of vacuum is experienced. The switch must be in the off position to start the engine, and a minimum of 10 psi must be maintained once the switch is in the on position. Only 1 nozzle flowing 35 gallons per minute (gpm) was being utilized and the engine was reported to have had 3/8 of a tank of water at the time. Re-creation of the event indicates that the pump performance of this apparatus series would overcome the minimum pressure threshold of 10 psi with a 35gpm nozzle fully open, negating the position of the low pressure over-ride switch during start-up. It is therefore unlikely a low water pressure condition caused the initial failure.

Air restriction - The air induction assembly on diesel engines are sized to deliver the ideal air / fuel ratios to obtain maximum engine efficiency. The air filter and assembly were cleaned 2 days prior to this event with negligible visible dust present. It is plausible, although unlikely, that particulate impaction could have independently or in conjunction with the depletion of oxygen, (as a result of the heavy smoke) initiated an immediate pump engine failure.

High pump engine temperature - The apparatus has an automatic cut-out that protects the pump engine in case of critically high engine coolant temperature in excess of 238 degrees. The recorded air temperature 10 miles East of the fire was 102 degrees Fahrenheit. The local resources indicate that they have overheated their equipment occasionally (specifically tractor plows) this year due to the abnormal and extreme operating conditions. Consistent with this apparatus, these series of engines do not have a history of overheating. It is plausible that in conjunction with the active fire environment; a critical temperature condition could have been achieved.

Oxygen starvation - Internal combustion engines are inherently susceptible to decreased performance in connection with low oxygen levels. Research suggests that there are significant differences in air induction requirements and combustion efficiencies among diesel engines. Based on personal accounts on this incident, the air quality limited physical activity to the point of impairment at the time of pump failure. For reference, documented cases of fire apparatus exhibiting oxygen starvation exists in Australia. Additionally, local resources claim that local fire departments have historically experienced apparatus losses in which the casual factor was determined to be a lack of oxygen. Oxygen starvation could have been a causal factor.

Fuel line failure - It is consistent with all accounts that fire was established under the apparatus at the time of pump engine failure, specifically at the left front and left rear of the apparatus. It was noted that while the tractor plow was attempting the pull, the rear of the apparatus also sank bringing the undercarriage and components closer to the ground where flame lengths exceeding 1 foot were reported. Rubber hoses and components generally have a relatively low ignition temperature and flame impingement on the pump fuel line located in the left rear corner could have caused a loss of fuel availability to the pump engine.

This Region 3 Model 54 apparatus had monthly and daily inspection and maintenance records indicating a history without significant repairs other than a pump seal replacement. Through personal accounts and technical criteria it is possible to speculate on causal factors with a moderate degree of accuracy. However, due to the final condition of the apparatus it is impossible to definitively state a cause of the initial and /or subsequent pump engine failures.

Successive Starting Attempts

Three successive attempts to re-start the pump engine were un-successful. Each time the pump engine would momentarily re-start, and then cut-out shortly after release of the oil pressure / coolant temperature override switch. Due to time elements involved in the incident, it is not feasible to determine if the over-ride switch was directly correlated to the pump engine cut-out. Ultimately, the override and starter were both held in the start position for a last unsuccessful attempt to keep water flowing.

Based on the afore-mentioned list of potential causes, only a correction of the air quality and subsequent water pressure correction would have resulted in an opportunity for a sustained pump engine re-start given the time constraints of the incident. In this instance the air quality was degrading rapidly rather than improving. However, it is important to note the truck engine did continue to run until the crew departed the area.

If the oxygen deficiency did improve enough to support combustion, the operator would have needed to execute coordinated valve closures and a starting sequence resulting from either knowledge based training and / or a conditioned response from systematic hands-on training which is usually not within the scope of entry level firefighter training. During the apparatus protection, crewmembers switched off operating the pump engine as the Engine Boss was working to free the apparatus and arrange the tractor plow pull.

To see an example of a pump re-start procedure that was developed by operators of USFS Type 6 Engines see this link: TYPE 6 (643U) Pump Procedures (Click to Follow)

Apparatus Involvement

Surface fire was observed under the apparatus from all sides. Furthermore, substantial radiant heat with 48 inch flame lengths was observed within 17 feet off the drivers' side front corner. Personal accounts indicate the drivers' side rear of the apparatus appeared to "have a lot of fire under it". Suppression action taken by the tractor plow before the apparatus was completely involved resulted in a berm push against the driver side rear where fire was most evident. Partial plow line construction also occurred around the apparatus with exception of the front which was impacted by increased fire behavior. Burn patterns on the cab indicate burning from drivers' side to passenger side which consistent with the observed wind direction when the crew departed the area. Once involved, the apparatus, equipment and flammables stored on the vehicle posed a significant risk to human safety. The composite body contains fire resistant resin that starts to degrade at 250 C° and becomes gaseous. Melted side window glass was located 13 feet from the apparatus, possibly propelled by the air bag deployment. Substantial drip torch parts were located 21 feet from the apparatus, carrying elements of the compartment with it as a result of the drip torch bleve.

The location of flammables stored on the apparatus were as follows:

- 2 partially fueled chainsaws in compartment # 2
- Dolmar, 7 full sigs, and chainsaw bar oil in compartment # 8
- 2 drip torches (1 full and one ¾ full) in compartment #8
- Portable pump with full 1 gallon plastic can in compartment # 5
- Jetboil™ fuel canister and FireQuick™ rounds in compartment # 1
- Road flares in compartment #7
- Aerosol window cleaner in compartment # 6

The actual fire involvement of the vehicle was not witnessed due to the degrading fire environment as the crew walked to their previously identified safety zone.