From Response to Recovery – The Story of the 2013 Colorado Floods as Experienced by the Colorado Division of Water Resources Dam Safety Branch

By: All 12 Members of the Colorado Dam Safety Branch

ABSTRACT

Have you ever been tasked with designing a dam safety scenario for an emergency action planning exercise? How about this: After a week of record hot weather, it starts raining around dark on day one. It starts raining really hard around midnight and the first evacuations are called for around 2:00 A.M. in response to reports of small dams failing. The Chief of Dam Safety and three program engineers are out of state at a conference. Before the sun rises, reports of dams failing come in from all media outlets and through the emergency management community. Reports of dam incidents extend over an area of approximately 2200 square miles. Major and minor roads are washed out and travel is hazardous or impossible to significant portions of the affected area. Calls stream in from inside the Division of Water Resources (DWR), and extend up to the Governor's office for information pertaining to the current status of all reported dam incidents. Requests from the media come in continuously for radio interviews, television interviews, and phone interviews. Volunteer engineers from within the dam community send emails, make phone calls, and write letters to DWR personnel, and even the Governor, offering their support, at no cost to the State. An analysis indicates over 200 dams lie in the area of rainfall with recurrence intervals between 25 and 1000 years. Dam safety staff in unaffected area's of the state wait with uncertainty wondering whether to come to aid without being called or stay put until further notice. The state receives a disaster declaration from the President of the United States. The exercise continues with daily injects of the above activities for a period of ten straight days.

Although hard to imagine, such was the scenario facing the Colorado Dam Safety Branch immediately following the conclusion of the Annual ASDSO Conference in 2013. Four of the twelve Dam Safety staff, including the program chief, returned to Denver on Thursday, September 12, to heavy rainfall, flooding, and stories of dam failures breaking in the news. Event detection began on September 12, and the event was not terminated and follow-up activities did not begin until September 27, 2013.

This is the story of the Colorado Dam Safety Branch (DSB) of the State Engineer's Office (SEO) as they responded to and are recovering from one of the worst natural disasters in Colorado history.

Colorado Division of Water Resources, Dam Safety Branch, 1313 Sherman Street, Denver, CO 80203, Ph: 303-866-3581, dnr_coloradods@state.co.us; http://water.state.co.us/SurfaceWater/DamSafety/

INTRODUCTION

In Colorado, there are three primary types of flood events dam safety engineers (DSE) keep an eye out for: (1) snowmelt flooding, which we worry about in the months of May and June; we can usually see these coming by monitoring Natural Resources Conservation Service (NRCS) Snowtel sites at strategic locations in the mountains; the last memorable snowmelt flooding happened in the spring of 1983; think Glen Canyon Dam; (2) flash flooding, which typically happens as afternoon thunder showers in July and August; the most catastrophic flash flood in Colorado history happened on the Big Thompson River on July 31, 1976, when a storm dropped around 12 inches of rain in three hours, resulting in flooding that took 144 lives; and (3) long duration, low-intensity rainfall associated with frontal activity (USGS, 2006); these storms are rare, but historic storms and damaging flooding in this category occurred in April 1999, May 1955 and 1969, and September 1902, 1938, and 1970.

In 2013, Colorado spring runoff was unremarkable. Two back-to-back wildfire seasons in 2012 and 2013 combined with the monsoon season to cause trouble below areas recently burned by the Hi-Park, Waldo Canyon, Black Forest, and West Fork Complex fires. No dams in or near those areas were impacted. Dam safety engineers responded to only one monsoon season rainfall-related incident in 2013 that resulted when a restricted reservoir filled unexpectedly above its restricted level. This issue was safely resolved and by the end of August, Dam Safety Branch engineers continued with their schedule of late season inspections and design review activities feeling like the worst was behind us.

As some members of the DSB prepared to attend the annual ASDSO meeting in Providence, RI, September 8-12, 2013, the Colorado weather picture was hot and dry. On Sunday September 8, the City of Boulder tied a record high temperature of 93 degrees for that date.

Weather forecasters predicted a break in the hot weather for the coming week with cooling temperatures and some rain. Scattered showers fell over Boulder on the 9th (0.25 inches) and 10th (1.02 inches), with the heaviest rainfall in northern New Mexico. During this time, the meteorological ingredients for heavy precipitation were developing along the Front Range. The large-scale atmospheric wind pattern on September 11, was characterized by a near-stationary upper-level trough over the Desert Southwest and a ridge over the mid-Mississippi Valley. Between the two weather systems, deep southerly flow east of the Front Range brought anomalous moisture north from the Gulf of Mexico. Southwesterly flow east of the upper level trough helped additional moisture transport northward from the east Pacific Ocean. At the surface, a cold front moved slowly south and had become nearly stationary across east central Colorado. (NWS, 2014)

> *"The incredible expansion of activity on Wednesday is the missing element that didn't show up ahead of time", said Bob Glancy, warning coordination meteorologist for the National Weather Service (NWS). By the evening of September 11, 1.92 inches of rain had fallen that day.*

"So, we were reacting to that with warnings on Wednesday. We were thinking on the order of 2 to 3 inches of rain causing flooding. We weren't thinking on the order of 8 inches of rain causing flooding."

These rainfall processes were different from those that often occur in intense thunderstorms that extend to high altitudes. The rainfall developed and fell mostly within the lower atmosphere, where temperatures were relatively warm. These "warm rain" processes are efficient in converting water vapor to liquid rain and are often associated with high rain rates. (NWS, 2014)

The two general sessions at ASDSO 2013 in Providence included discussions by David Cay Johnston and Thomas Moody. Mr. Johnston highlighted opportunities and pitfalls when working with the media. Mr. Moody, a survivor of the 1963 Norwich Flood and Spaulding Pond Dam Failure, showed the great impacts of a small dam failure on his family and the Norwich, Connecticut community in which they lived. As those members of the Dam Safety Branch in attendance at these presentations worked their way home after the conference, the timeliness of those two topics of discussion quickly became apparent.

The first period of high-intensity rain occurred from Wednesday night on the 11th into Thursday morning of the 12th.

Our story begins in the early morning hours of Thursday, September 12, as three of the four dam safety personnel begin to make their way back to Colorado following the conclusion of the conference in Providence, RI, one of the staff having already departed the night before.

DAY 1 – THURSDAY, SEPTEMBER 12

It is still dark outside the Omni Providence Hotel in Rhode Island as Bill McCormick, DSB Chief, gathers his things to meet Dam Safety Engineer (DSE) Kallie Bauer in the lobby to share a cab to the airport for an early morning flight. As the clock ticks over to 4:00 A.M. (2:00 A.M. in Colorado) a message comes in on Bill's phone. A posting to WebEOC (Colorado Emergency Alert Network website) reads:

"Larimer County OEM Erik Nilsson (970-222-4708) has received a POTENTIAL SAR MISSION REQUEST to the STATE EOC regarding availability of NG BlackHawk for mission support regarding IR/Nighttime aerial support.

"Current Situation of Concern is CO HWY 36 and Big Elk Meadows. At the current time field operations is reporting critical flash flooding at this location with possible small dam breaching. There are residences in the area and possible life safety issues."

All of a sudden on full alert and knowing he has only about an hour before climbing on an airplane and being out of touch, Bill immediately begins trying to make contact with DSE's in the area of concern to alert them of the issue. Making his way to the lobby, he is engrossed in his phone as he sends and leaves multiple text and voice mail messages.

Taking in the scene and a quick explanation from Bill as they meet, Kallie realizes Bill is completely preoccupied trying to make contact with people, so she immediately takes the lead on getting them to the airport. As she steers Bill into a waiting cab, through airport check-in and security, and onto the plane, emergency messages regarding flooding and dam failures continue to come in. Finally, Bill makes contact with DSE John (Johnny) Batka and informs him of the potential issue with what are now being identified as the Big Elk Meadows dams. Johnny immediately begins trying to contact the Larimer County Emergency Manager and the dam owner. As the final boarding call is made, Kallie and Bill board their plane, turn off their phones, and helplessly wait as things continue to unfold back home. The time is 5:15 A.M. EST, 3:15 A.M. MST in Colorado. Radar estimated rainfall for the storm is shown below in Figure 1.

Figure 1 - Screen capture of radar estimated rainfall during the September 2013 Colorado flooding.

An hour and fifteen minutes later, Kallie and Bill land in Newark, New Jersey for their connecting flight to Denver. While they were in the air, emergency messages continued to appear and now stories are breaking in the media. The televisions in the airport are reporting dam failures in Colorado. Bill and Kallie have less than two hours on the ground to try to find out as much information and provide as much direction as they can before boarding another plane, this time for the longer flight to Denver. As Bill continues trying to reach all Front Range DSE's, Kallie begins calling and texting dam owners for whom she has contact information in her phone. By the time they board the plane to Denver, all local DSE's have been alerted with Johnny Batka, John Hunyadi, Jeremy Franz, and Ryan Schoolmeesters plugged in, reading emails, and checking on conditions. The time is now 8:00 A.M. in Newark, still only 6:00 A.M. in Colorado.

As the plane lands at Denver International Airportfour hours later and begins taxiing towards the concourse, Bill and Kallie turn on their phones to find that all hell has broken loose. More stories are breaking in the media, phone calls begin coming in to report the status of dams and reported failures, rainfall and flooding are widespread, access is being threatened or already cut off in many areas, and flights are being delayed and cancelled.

By this time heavy rain has been falling for more than twelve hours in many places and at least six major drainages through metropolitan areas are flooding including: Boulder, St. Vrain, Sand, and Little Fountain Creeks; and the Big Thompson, Little Thompson and Cache La Poudre Rivers; as well as most, if not all, of their tributaries. Additionally, major highways and arteries are starting to be affected and it is beginning to become difficult to get into or out of certain areas. A screen capture from the Colorado Department of Transportation website in Figure 2 below hints at what travel starts to look like as things continue to develop.

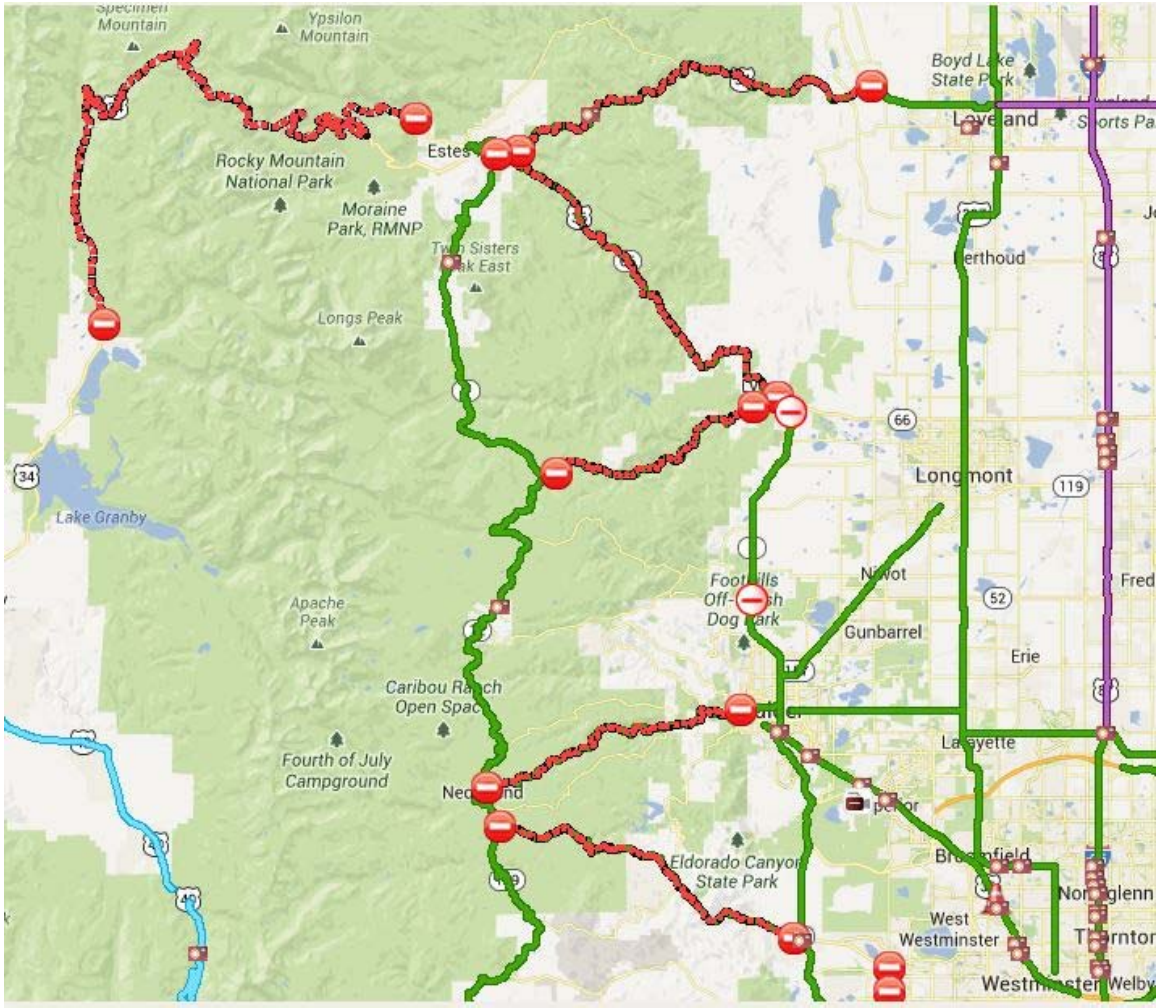


Figure 2 - Screen capture from the Colorado Department of Transportation website showing major highways west of Denver closed during and after the flooding.

In addition to the roads shown above, which will remain closed for weeks following the event due to severe damage, several other north-south arteries are closing due to the

overwhelmed drainages coming out of the foothills to the west. This includes Interstate 25, which is the main north-south connector through the state.

Colorado Dam Safety Branch

The Colorado Dam Safety Branch of the State Engineer's Office is made up of twelve engineers spread geographically throughout the state. The program chief offices out of Salida near the center of the state. A fulltime Design Review Engineer position operates out of Denver, with a shared Design Review/Construction Observation position in Grand Junction on the west side of the state. The remaining nine DSE's are responsible for the inspection and regulation of more than 1700 program dams located within seven water divisions. The dam hazard classifications are broken out as follows: 388 high hazard, 317 significant hazard, and 1032 low hazard. The DSE workload includes assignment of an average of 200 dams within their geographic area.

A significant percentage of high and significant hazard dams are located up and down the front range of Colorado on the east side of the Continental Divide, where the majority of the population also lies. The majority of Colorado's water, however, comes in the form of snow in the mountains west of the Continental Divide. We refer to these two regions as the "west slope" and "east slope" or "front range," for the specific area north and south of Denver bounded by the Continental Divide to the west and the eastern plains to the east. East slope engineers include Johnny Batka and Kallie Bauer in the Greeley office, Ryan Schoolmeesters and Jeremy Franz in the Denver office, John Hunyadi in the Colorado Springs office, Mark Perry in the Pueblo office, and Bill McCormick in the Salida office. West slope engineers include Matt Gavin in the Durango office, Jason Ward in the Montrose office, Garrett Jackson in the Grand Junction office, Erin Gleason in the Glenwood Springs office, and Dana Miller in the Steamboat Springs office. 2013 was a big hiring year for the Dam Safety Branch. Ryan and Kallie began work in March and Erin began in July. While the remaining engineers each had two or more years experience in their jobs, with less than a year experience, Ryan, Kallie and Erin had yet to visit, let alone become familiar with, all of their assigned dams.

Figure 3 shows the seven water divisions within the state, and DSE office locations throughout the state.

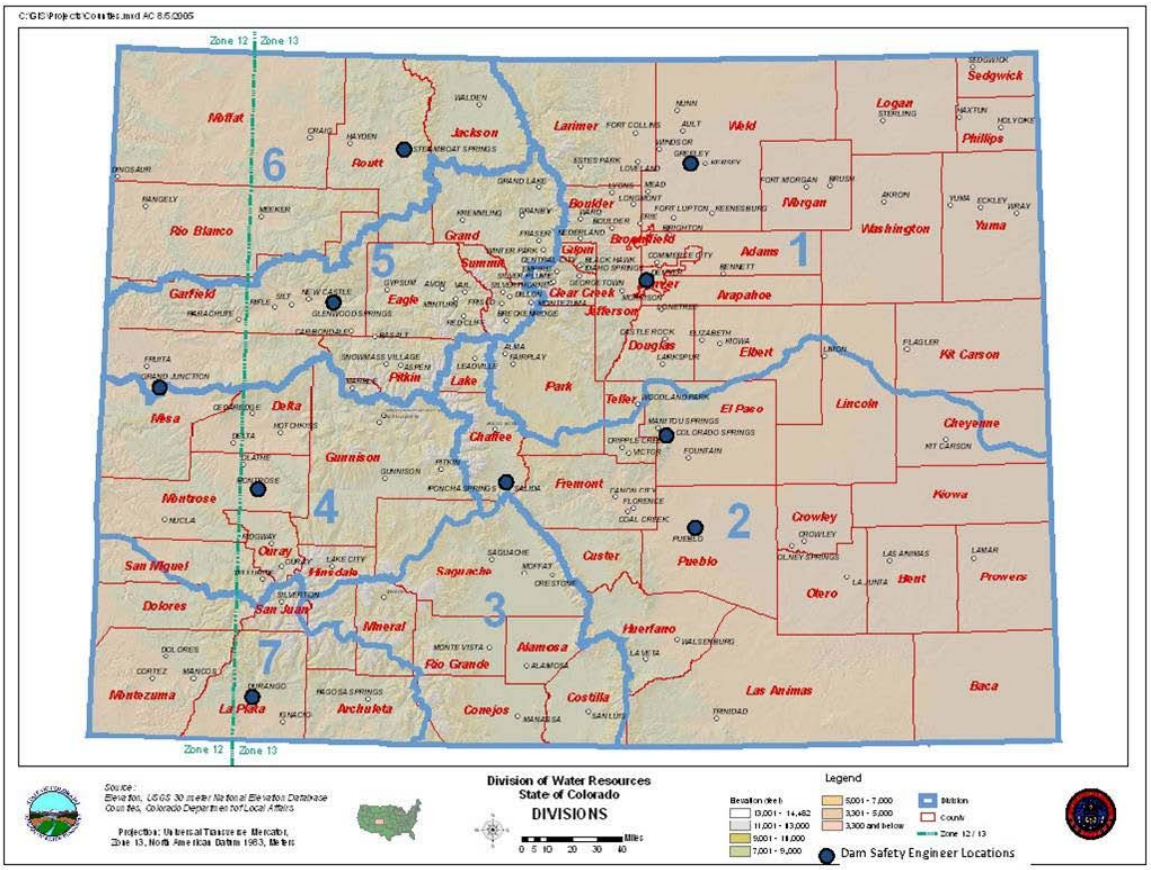


Figure 3 – Colorado Dam Safety Branch DSE office locations around the state.

One of the first major incidents to emerge from the frenzy of activity and communication is the report of dam failures in the Big Elk Meadows subdivision near the Town of Estes Park. By the time Bill lands in Denver, Johnny has been coordinating with the owner and emergency manager about the situation for nearly eight hours.

Big Elk Meadows

The Town of Estes Park sits in the mountains west of Loveland, CO and is the gateway to Rocky Mountain National Park. Big Elk Meadows is a small community in the mountains south of the town. Approximately 160 homes surround the former site of five small dams and reservoirs that were used to provide augmentation water for the subdivision's well water supply. Four of the five dams met non-jurisdictional size requirements in Colorado, with only the downstream most dam, known as Meadow Dam, being jurisdictional at about 18 feet high. The maximum cumulative volume of water stored behind the five structures was 248 acre-ft (to the dam crests).

On Wednesday, September 11, heavy rain began to fall over the mountains directly above Big Elk Meadows and by midnight the spillways of all five dams were overwhelmed and the dams were overtopping. Alerts that the dams could be in trouble went out from county emergency managers in the early morning hours of September 12.

Communication directly with the subdivision was difficult. Johnny was familiar with the five dams that were the focus of the reports that morning, but concrete information on their status was hard to come by. Telephone access to the community was lost during the night, and Johnny was finally able to reach resident Leonard Arnold, who was the only resident with cell phone access, around 8:00 A.M.. Mr. Arnold had a cell phone booster and his home became the communication center for the community for weeks to follow. Mr. Arnold was able to report that none of the dams had failed…yet. The situation was tenuous. By mid-morning and despite reports otherwise, Johnny had learned that only one of the dams had actually failed.

A return phone call from Mr. Arnold around 10:00 A.M. confirmed that the upper most dam (Sunset Lake) had given way around 8:00 A.M. The remaining dams were overtopping by several feet of water but remained intact. Mr. Arnold called back at approximately 12:30 P.M. to say that he just witnessed the failure of Willow Lake and Rainbow Lake dams. Mr. Arnold recounted the failure of Rainbow Lake saying, “I have never seen anything like this before, the dam just opened up.” At this time Mirror Lake and Meadow Lake were still intact. It was assumed that all the dams below would fail as a result, but the Meadow Lake dam held on for another hour, and Mirror Lake held on until about 2:00 A.M. the next morning.

As Johnny receives updates, he relayed all of the info to Bill and the Larimer County Emergency Manager. There is nothing either one of them can do, but watch the situation unfold.

By the time all five of the dams have failed, the flooding has already destroyed power, water, telephone service, and vehicle access to the community. The rainfall in the subdivision is so intense that even houses above the reservoirs are moved from their foundations by sheet flow alone. Thankfully, the majority of the residences are spared, but certainly the guts of the community are swept away. All vehicle access to the community is cut off and most of the residents are evacuated by National Guard helicopters. About a dozen residents stay behind, “sheltered in place”, to protect their property from further damage and begin to try to clean up and deal with what they can.

Figure 4 - Photo of Meadow Lake dam as the full breach develops at 1:40 P.M. on Thursday September 12.

Figure 5 - Photo of main access to Big Elk Meadows subdivision over the Mirror Lake dam, taken from the air on September 17..

Figure 6 - Photo of the Rainbow Lake dam breach taken on September 25, after 12 days of continuous high flows.

As Bill and Kallie depart the airport early Thursday afternoon, with Kallie heading north to Greeley and Bill heading south to downtown Denver, six fully engaged DSE's are now located up and down the front range of Colorado. On his way to the Denver office, Bill receives a call from Ryan Schoolmeesters who has deployed to Baseline Reservoir near Boulder and is monitoring a critical situation there. Ryan received a call from the owner earlier that morning reporting a 30-foot-long longitudinal crack on the downstream shoulder of the Northwest dam that had sloughed approximately one foot down slope earlier that same morning.

Baseline

Baseline Reservoir is situated near the eastern limit of Boulder, Colorado and is impounded by two High-Hazard potential dams referred to as the East and Northwest dams. Downstream of the Northwest dam sits an entire community, with a Middle School at the toe. The reservoir is off channel and typically filled by controlled ditch inflow. Complications at the diversion structure resulting from high flows on South Boulder Creek led to the reservoir receiving uncontrolled inflow well in excess of normal flows, thereby causing the reservoir to rise significantly faster than ever before.

Ryan having only been on the job six months, he had never been to the dam and was completely unfamiliar with the structure. Knowing he could use help, Bill tells Ryan to continue his work at the dam and that he will try to get him someone there to assist him ASAP. Bill first called Jeremy Franz, who had just returned from Rhode Island the night before and is at his home in Berthoud north of Boulder. Bill asked him to try to work his way toward Boulder from the north to assist Ryan. About the same time a message from Vicki Scharnhorst with Tetra Tech comes in offering whatever assistance might be needed. Knowing their proximity to Boulder, Bill called Vicki back and asks her to find a seasoned engineer to go to Baseline and assist Ryan. After talking with Vicki, Bill and Jeremy reconnect with Bill saying a closer engineer has been found, and Jeremy saying he was stopped by road closures trying to get to the dam.

At about 1:00 P.M., Dan Johnson, a veteran engineer with Tetra Tech, and Ryan's old boss, arrives on site to assist Ryan. Although neither engineer has a working history with the dam, Dan and Ryan together have over 50 years dam safety experience, and working closely with the dam owners staff, quickly strategize to mitigate the developing situation.

The first step involved assessing conditions at the Northwest Dam. As they assess the numerous apparent issues, they quickly focus on the 40-foot long, 1-foot high slump at the downstream shoulder. Initial mitigation recommendations to minimize continued destabilization of the slope included establishment of crest drainage to the upstream slope (away from the downstream slump), covering the downstream slope with tarps to minimize continued slope saturation, and establishment of makeshift monitoring systems to quickly detect future slope movement.

While the above initial steps were being established at the Northwest Dam, a discussion ensued about efforts to lower the reservoir level. The City reported that the inflows were presently uncontrollable due to overtopping of the New Dry Creek carrier canal. Inflows were reportedly around 1000 cfs that morning, however had reduced to around 400 cfs by mid-day. It is important to note that these estimates were purely guesses at the sheet flow condition overtopping the carrier canal into Baseline. At the moment, the outlet works was fully opened, releasing around 100 cfs. The reservoir was approximately 2 feet below the spillway crest and was expected to fill before nightfall. Given that the inflows were deemed uncontrollable and greatly exceeded outflows, the attention turned to the spillway and the East Dam.

A triage level assessment of the East Dam left Ryan and Dan feeling reasonably confident that the East Dam was in stable condition; their attention then returned to the Northwest Dam. In consideration of the anticipated continued rainfall, uncontrolled reservoir inflows, and the veil of night, a 24-hour monitoring program was established. Teams of two of the dam owner's staff would alternate on 6-hour shifts to visually monitor the dam, the makeshift monitoring devices, and to take piezometer readings of the piezometers at the Northwest Dam. Any rapid or notable changes would prompt an immediate phone call to Ryan.

Figure 7 - Temporary stabilization measures along the reach of the downstream slope that had sloughed at Baseline dam.

Due to quick action of the owner and engineers and to the great relief of all involved, the dam was able to "weather the storm." Digitally accessible state dam files, and the 24-hour monitoring and inspection were huge contributors to the successful outcome of a very stressful situation. However, weaknesses were revealed and a frightening near-miss was recorded. This situation has also highlighted another potential failure mode that should be considered when evaluating dam designs – intense, sustained rainfall leading to increased pore water pressure in the downstream shell, resulting in slope instability.

Figure 8 - Aerial photo of the Baseline Northwest dam with temporary stabilization measure in place and a declining reservoir level.

With Johnny monitoring the situation at Big Elk Meadows from his office in Greeley, and Ryan out at Baseline Dam, now Design Review Engineer Jeremy Franz (having just returned from ASDSO very late the night before) is stationed at his home northwest of Denver in Berthoud to monitor and help with the situation, John Hunyadi is manning the phones from his office in Colorado Springs, Kallie has made her way up to the office in Greeley, and Bill has reached the office in Denver.

With travel in the affected areas ranging from difficult to dangerous, the DSE's are doing what they can from their offices and/or mobile phones as the situation continues to grow exponentially. Unable to mobilize, they quickly become the clearing house for dam incident reporting, and begin the arduous task of confirming, clarifying, or refuting reported information. This singular task would prove to be a demanding exercise in of itself throughout the remainder of the event.

In between responding to urgent requests for information, DSE's are calling dam owners and checking on the status of structures. With frequent monitoring of National Weather Service (NWS) radar, local news reports, WebEOC, and discussions with local emergency managers, they are able to identify areas of significant reported rainfall. Armed with this information, they are contacting affected dam owners, prioritizing in order of highest hazard dams.

Calls to owners yield discussions of rainfall observed, inflow conditions, reservoir rise, imminent spillway flow, and a review of other conditions for owners to observe over the entire

structure; as well as a brief review of emergency action response. The dam owners of the high and significant hazard dams are reporting that the dams are functioning well. Reservoirs are filling but nothing alarming. Low hazard dams are also filling and are likely to start spilling soon. DSE's continue to work the phones and by Thursday afternoon the majority of dam owners have been reached.

The bigger concern is that the irrigation ditches that control the inflow on many of the Front Range dams are running very full. Many reservoirs and dams in developed areas between Boulder and Lyons are off-channel structures similar to Baseline Reservoir described above. The filling of the reservoirs is typically closely controlled by gated diversion structures on the major streams located to the north and south. The water is delivered to the reservoirs via ditches that run cross-county, in some cases for miles between the stream diversions and the reservoirs. Given the level of inlet control to the ditches, these reservoirs rarely, if ever, spill. The widespread flooding overnight on Wednesday and into Thursday damages or destroys innumerable diversion structures and headgates, allowing uncontrolled inflows into irrigation ditches and causing reservoir levels to rise uncontrollably. In some cases the ditches themselves fail due to the increased flows from the flooding streams. This has a consequence of flooding developed areas downstream of the ditches. In other cases, ditches are intentionally breached at suitable locations to avoid failure in unsuitable ones. Where ditches remain intact, the receiving reservoirs fill and begin to spill. In numerous cases, this previously unseen water flowing from spillways operating for the first time in anyone's memory, leads unfamiliar residents to panic and report that the dams are failing. Communication between DSE's, dam owners, ditch owners and water commissioners is essential throughout the day to confirm or dispel these reports.

In addition to responding to requests for information and reaching out to dam owners, John Hunyadi in Colorado Springs engages with the state Emergency Operations Center (EOC) and also reaches out to the El Paso County EOC. He becomes the first DSE to plug in to the emergency response community. John engages with EOC personnel and becomes the dam safety point-of contact with State emergency managers. In this capacity, John is able to upload information from different DSE's to WebEOC to instantly communicate the status of ongoing dam incidents and reports of incidents. As the event progresses, the remaining DSE's become engaged and also participate virtually and in person at EOC's activated for Larimer, Boulder, and Jefferson Counties, as well as a State EOC located in Centennial.

Emergency Operations Centers (EOC's)

The DSB's presence at the EOC's allowed us to communicate directly with emergency managers at both the county and state levels, providing a technical resource for interpreting general and specific dam safety risks and impacts, ongoing situational awareness, and knowledge of dam structures and operations for verification of information being disseminated to the EOC's, media, and general public.

Being directly plugged into the emergency management community also gave the Dam Safety Branch (DSB) access to the full state and federal resources being applied to the emergency. Through the EOC's the DSB was able to make their own resource

requests for things such as air transport to inaccessible sites for inspection; and heavy equipment to clear spillways, lower reservoir levels, and in some cases perform controlled breaches of unsafe structures. Our integration into this community was not flawless, but proved to be critical in our ability to function as a valuable part of the response team. The lessons we learned during this sudden immersion into a real-life, large-scale emergency response situation hugely advanced recent efforts to communicate with emergency managers and learn how the Dam Safety Branch could/should fit into this important system.

In the year prior to the September 2013, event dam safety staff Bill and John had been engaging with the state emergency management community to develop relationships and be in a position work together effectively in the event of a dam safety emergency. The goal of the engagement activities was to improve the response and reduce potential consequences in the case of a dam safety emergency. The bi-monthly meetings held in the year before the floods enabled each of the organizations to learn of each other's capabilities and resources and laid the foundation for our coordination and cooperation during the flood.

The planning groundwork had also included a requirement for all DSE's to complete National Incident Management System (NIMS) training on the Incident Command System (ICS) through FEMA. While Bill and John arranged and attended regularly scheduled coordination meetings with the state and local emergency management personnel, they shared what they learned with the other DSE's. Bill and John learned about the WebEOC emergency alert system and network used in Colorado. This system connects members of the emergency management community to communicate with emergency personnel during an event; and conducting and participating in regional Emergency Action Plan (EAP) exercises.

Tying into the Emergency Management community prior to the event had, to some, seemed like an additional burden to our already heavy workload, but these coordination efforts proved to be critical. Because these efforts had been made there was awareness of our dam safety community and resources, and even without much prior practice, we were able to plug effectively into the well-oiled ICS machine, providing real value to the emergency response effort. It was reported after the event that before DSE presence in the EOC's, when dam incidents were reported the level of tension and stress increased noticeably. With the aid of DSE's technical knowledge and presence emergency mangers reported a greatly reduced level tension and stress as additional dam incident reports came in.

In addition to the Big Elk Meadows and Baseline situations, dam incident reports due to overtopping embankments and significant spillway erosion continue to stream in on no less than seven additional dams Thursday. One of these is Carriage Hills No. 2, located in the Town of Estes Park, one of the hardest hit areas.

Carriage Hills No. 2 Dam

The Fish Creek drainage basin, south of the Town of Estes Park, received as much as 16-inches of rain at elevations near 10,000 ft (AWA, 2014). Fish Creek peak flows during the event have been estimated at five times the 100-yr flow (NRCS, 2013).

On Thursday morning after hearing the reports of heavy rainfall and flooding in the Town of Estes Park, Johnny Batka got in touch with the Town of Estes Park Public Works Engineer regarding the Carriage Hills No. 1 and No. 2 dams that are owned by the Town and located on a major drainage way through town called Fish Creek. The town engineer confirmed Fish Creek was experiencing significant flooding and both dams were overtopping. He said due to the amount of flooding, the floodway along Fish Creek had been evacuated. Later, the Dam Safety Branch (DSB) would learn that in fact some residents along Fish Creek had not received the message to evacuate, adding to the frightening reality of the situation in hindsight.

Overtopping began on Thursday morning. Based on DSB forensic investigation the Carriage Hills No. 2 Dam (lower dam) failed around 10 P.M. on Thursday or early morning (2-3 A.M.) on Friday. Thankfully, no loss of life or significant property damage was documented as a result of the dam failure.

Figure 9 - Photo of Carriage Hills No. 1(upper dam) overtopping taken on Thursday September 12, 2013 by an Estes Park resident.

In addition to the stories on Big Elk Meadows, Baseline, and Carriage Hills No. 2, reports have come in on the failure of Great Western and Leyden dams. After significant time spent trying to verify or clarify the stories, DSE's are able to report that the dams are in fact spilling through the emergency spillways, and that this is per the design intent for exactly this kind of scenario. Numerous similar reports are received throughout the day, and the public is on edge.

As night falls Thursday, all of the DSE's have made their way back to Colorado; evacuations are in place below Baseline and Carriage Hills No. 2 Dams. Johnny and Kallie are coordinating with owners on what to do overnight; Ryan is stuck in the field at Baseline Dam because all hotels are full due to the evacuations and travel to his home in south Denver is considered too risky; and Bill is manning what would become the "Dam Safety Branch EOC" in the Denver office. The first of what would become a series of regular morning and evening conference calls with dam safety staff is held at 5:00 P.M., where everyone is given a chance to regroup and the remaining DSE's throughout the state are brought up to speed.

Offers to help from the remaining DSE's, Colorado Parks and Wildlife dam safety staff, and the Colorado dam engineering community in general are on the table. Although the remaining DSE's are ready to pitch in, there is some hesitance to pull them away from their own regions, leaving an entire half of the state uncovered should something else start to develop. At this point, not knowing what lay ahead, and with travel on the Front Range being limited and dangerous, it is decided that everyone should sit tight and see what the morning holds. As it would turn out, even after some indication from the day's events, there was little grasp on the enormity of the situation, how long it would go on, and how much devastation it would eventually cause.

FRIDAY, SEPTEMBER 13 (DAY 2)

Friday awakens to near panic as rain continues to fall and the full onset of the flood now hits the Front Range area. Heavy rain is falling from northern Colorado all the way to Colorado Springs, with the rainfall now reaching 100-year and greater return intervals over multiple areas. The early morning news is again reporting more dams in the process of failing and the peak runoff from the mountain rainfall is reaching the foothills reservoirs. Most of the major Front Range highways are now closed including State Highways 119, 36, 34, and 115; and Interstate 25, the main north-south artery. Travel south from the City of Greeley to the impacted areas is not possible due to closed or destroyed bridges that cross the swollen rivers. More roads are closing by the hour, and it is now difficult to tell what is open and what is closed. The Big Thompson River has overtopped Interstate 25 north of Denver, and the magnitude of the event is starting to become apparent. Figure 10 shows a screen capture of an Extreme Precipitation Index Analysis (EPI) run by MetStat, Inc. This shows the potential for precipitation up to the 500-year return interval along the northern portion of the Front Range and Denver area.

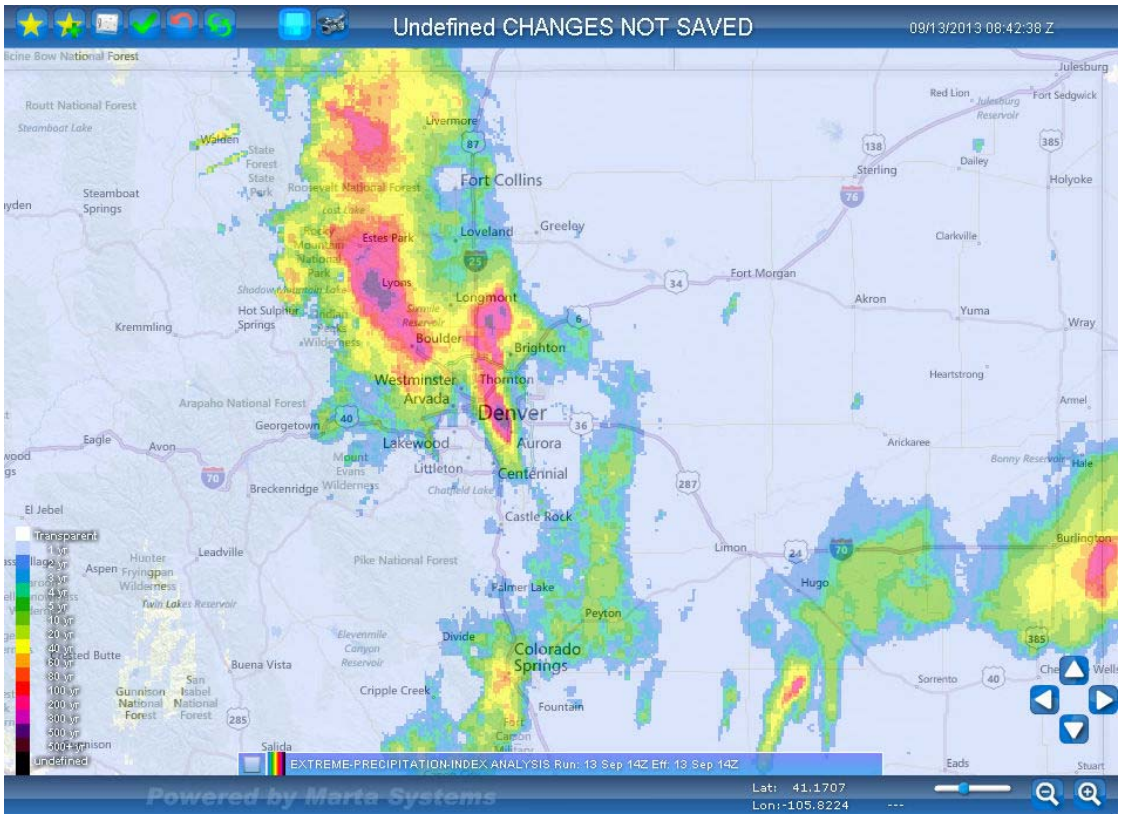


Figure 10 - Screen Capture of an Extreme Precipitation Index (EPI) Analysis run on September 13, 2013

Still barely light outside, the early morning news is reporting the failure of Blunn Dam in Arvada. At 6:30 A.M. a URS engineer sends an email to Bill inquiring about the report. By chance, Bill happens to know Jack Byers, his former boss/Deputy State Engineer, lives near the dam. Another early morning phone call and Jack is soon at the site sending a cell phone picture confirming that the emergency spillway is flowing, but the dam is not overtopping. This information is quickly forwarded to the WebEOC communication board and the emergency management community is made aware of the real situation. Another similar situation is the reported overtopping of Latham Reservoir downstream of Greeley, which leads to additional serious confusion for the general public.

Latham Reservoir

Latham Reservoir is a large sized significant hazard dam located outside of the City of Greeley. On Friday morning one of the Greeley office staff noted a Facebook post about the pending failure of the Latham Reservoir Dam and the evacuation order for the Town of Kersey which lies downstream. About the same time Kallie Bauer got a call from a man in Georgia who had heard about the Latham Dam being in trouble and was concerned about his daughter who lives in Kersey. After some checking on local news websites the following post was found;

From the Greeley Tribune

UPDATE, 11 a.m. — Residents around the Latham Dam south and west of Kersey at Weld County roads 50 and 51 are advised to evacuate immediately. The dam is overtopping by 4 feet and two gates are already lost. A reverse 911 is going out to all area residents.

Latham Reservoir is an off channel reservoir that was low before the flood began and reports of it overtopping did not make sense. The area Water Commissioner Bill Schneider was called and fortunately was in the area. He was able drive to the reservoir and confirm what we thought, that reservoir level was a couple of feet below the level of the emergency spillway and was filling slowly. However, the Latham Ditch located below the reservoir had in fact breached and was flooding farmland. DSB staff relayed this information to emergency managers and the evacuation order was called off.

Unfortunately now multiple similar mis-informed reports are in the media, leading to unnecessary panic on the part of the public. DSE's are trying to confirm and/or clarify incident reports as fast as they can; trying to reel in these false, panic-inducing messages, and replace them with their own dam safety public education message:

"Because of high flows in rivers and stream channels, many emergency spillways are flowing or activation is imminent. Although the dams are safe and functioning as intended, the large flows passing through the reservoirs will cause flooding and hazardous conditions downstream. Stay away from the spillways and out of the floodplain."

Throughout the day on Friday a constant stream of requests for information comes in from all avenues, including the Governor's Office, requesting for the latest on situational awareness (emergency incidents) involving dams, status of our response effort, etc. In the case of the Governor's Office, this information is being used by state leadership to communicate up the ladder and request assistance for the state.

Although most people and entities at this point are looking to the Colorado Dam Safety Branch for information related to dam safety, surprisingly we find that some have gone directly to the U.S. Army Corps of Engineers (USACE) or the U.S. Bureau of Reclamation (Reclamation), apparently unaware that a program exists at the state level. This discovery is made by John Hunyadi when a "resource request" is made by the Jefferson County emergency manager in WebEOC for USACE dam subject matter experts on Friday morning. John Hunyadi responds to the resource request, describing the role/capabilities of the Colorado Dam Safety Branch, and receives the response, "…well, that's exactly what I needed, I didn't know you guys existed!"

Between chasing down false messages in the media, providing rapid public education, and responding to urgent requests for information from all avenues, it is not long before the critical role communication will play in our response to this event is clear; as is the huge

demand it will place on our resources. Not only will communication within our group be important, but also the communication of clear messages to the public, media, emergency management community, and state leadership as well. We need to figure out quickly how we are going to handle this monumental beast called communication.

Communication

Knowing the importance of being able to communicate effectively internally, the DSB quickly begins to make use of technology (both familiar and new) to coordinate action items, daily schedules and responsibilities, ongoing incident status, and the tracking/logging of information and statistics.

Spreadsheets and word documents, edited by multiple people at the same time and requiring only internet access, were created on the state's relatively new cloud-based Google platform. This multi-user access and editing capability allowed real-time uploading and dissemination of information, and in turn, confidence in accurately reporting incident and emergency response status through communication lines established with state leadership, the emergency management community, the media, and the general public. Questions and answers relevant to the group as a whole were also recorded in this format to streamline the exchange of information. Morning and afternoon conference calls were held, often with the aforementioned documents being viewed on mobile devices, to check in, plan the day ahead, and regroup at the end.

Beyond internal communication, communication with the media was incredibly important, as this is where the public was getting their information on anything dam safety related. The communication of clear, concise messages that would rise to the top of the inherent drama in a breaking news story was critical if we were to get our message across. The irony and incredible timeliness of four of our engineers having just attended a well thought out and delivered presentation on how the media thinks and how best to communicate with them at the ASDSO conference just days before was not lost on the group.

We had fantastic opportunity to practice what we had learned over the course of the next 15 days. Bill provided information to various media outlets daily. A consistent message and talking points were developed and we implored the media to help us get the message out in an attempt to calm the public. The message was "the large dams are performing as designed and are not in danger, the spillways flows are causing damage so be vigilant and stay away from the streams, and be on the lookout for small dams in your neighborhoods as those are stressed beyond their design and could cause trouble." This message was discussed at the daily calls and consistency was developed through the Branch. DSE's were part of recorded and produced radio interviews; television interviews on all four major stations; daily interviews became part of published articles with news outlets across the state and country. A Denver Post writer toured the affected areas with DSB staff for a full afternoon and developed a comprehensive story for the Sunday edition. The Governor was provided with graphics

depicting dam safety incident status and response, which were used as his back drop during at least one press conference.

Due in no small part to what we had so recently learned about effective and cooperative communication at ASDOS 2013 in Providence, the media coverage was generally accurate and portrayed a positive light on the dam safety response to the historic flooding. We liked to believe the messages conveyed went some distance to reducing the general public's stress about dams. This outcome did not come through flawless execution of a well thought out communication plan, as there was none in place at the time of the disaster, but through application of a few key points garnered from the ASDSO presentation and put into practice by trial and error on the fly.

As panic is hitting the general public, the Division of Water Resources (DWR) and water community in general continue to collectively answer the call of duty, seemingly knowing what to do in the face of disaster. With major roads being closed and travel dangerous, the best course of action for the DSE's (while frustrating) is to stay put and continue to work the phones, with the better part of the day again spent chasing down reported incidents. With phone lines jammed, people seem to know not to leave phone messages, as these take precious time to retrieve. Instead it is intuitively understood that as soon as you get off the phone, you will check your caller ID and immediately return any calls you have missed.

DWR water commissioners, who administer the water rights along the rivers and streams in Colorado, are busy assessing head gates and ditches. They soon become valuable resources, as they know the water players and are able to report back on the condition of structures in their areas. Hydrologists try to estimate flows in the rivers and creeks that are well above normal operation, as they also try to save measuring devices that are threatening to be washed away.

Jeremy Franz begins working in Denver with GIS staff to put together lists and locations of spillways activated, EAP's activated, and failed dams. This effort begins to paint a picture of what areas are under the greatest impact. At this point we know the rainfall is widespread, but we need information to determine just how widespread it is to try to get ahead of the curve and find out what developing situations may not be on our radar yet. Fortunately, we have connections in the meteorology community and early on Friday, Jeremy reaches out to these contacts to start trying to define aerial extent and rainfall magnitudes as they might relate to potential dam safety concerns.

Applied Weather Associates (AWA) is quick to respond with helpful information. There is a vast array of meteorological data available on the web that is updated on a nearly real-time basis. Jeremy begins to wade through all the data in an attempt to help focus our response. Radar maps are disseminated to the DSE's to help with their situational awareness. NOAA 24-hour Storm Total Precipitation (STP) products are collected from the last five days and are incorporated into our GIS analysis of the impacted areas. By the end of the day, we are starting to get a picture of the staggering extent of the event. Figure 5 provides a graphical representation of emergency spillways already flowing or likely to activate as of 5:00 P.M. on Friday.

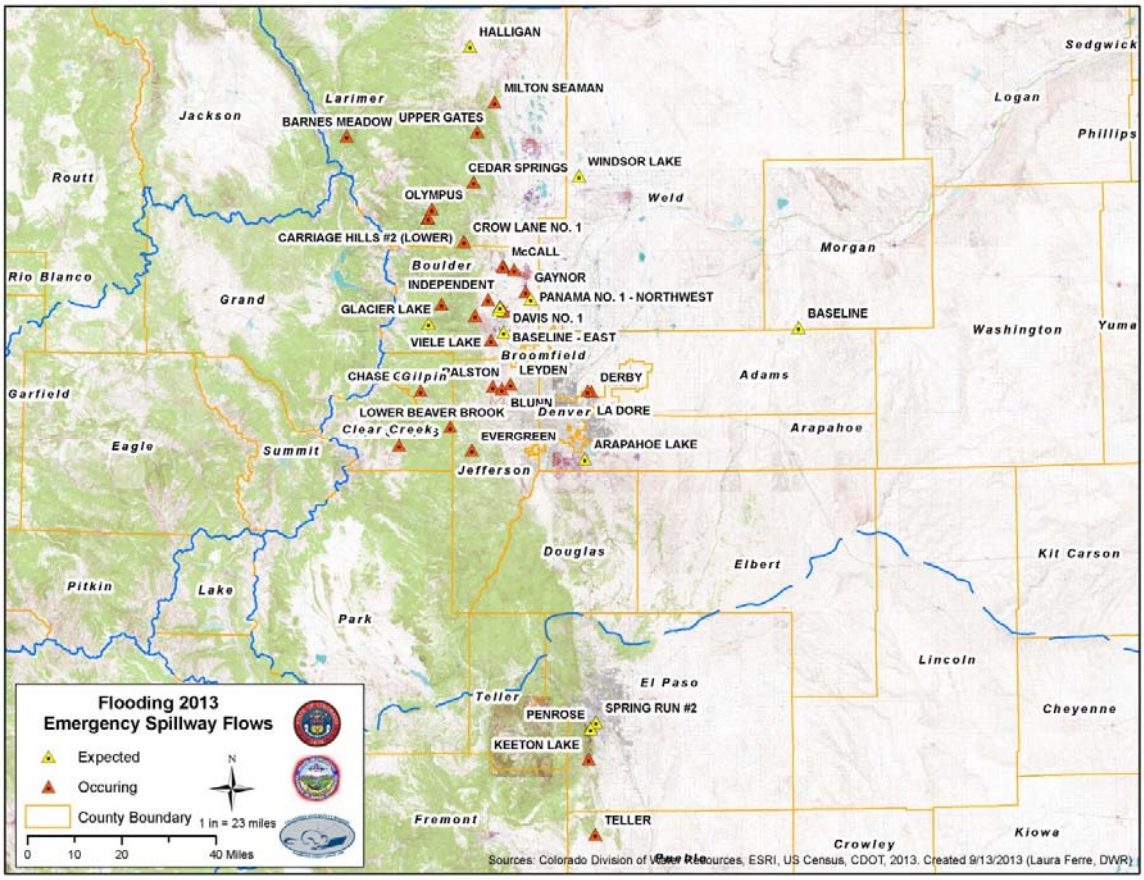


Figure 11 - GIS generated graphic showing emergency spillways flowing or likely to spill as of 5:00 P.M. Friday, September 13, 2013.

As Friday comes to a close, thankfully the weather forecast for Saturday is for clearing skies, to which the crew looks forward with relief. However this may be a temporary reprieve, as the forecast also contains an ominous prediction for more rain in the near future.

SATURDAY, SEPTEMBER 14 (DAY 3)

The weather forecast comes through and Saturday awakens to a slight reprieve from the rainfall. As skies clear, the interstate is reopened, access in general begins to open back up, and the DSE's are more than ready to get out in the field and begin immediate dam assessments. A conference call is held to discuss the approach and best course of action to tackle the task ahead.

Essentially having been chained to their desks, computers, and phones the previous two days responding to reports of dam incidents, Kallie, Johnny, Ryan, Jeremy and John are anxious to get out and put eyes on some of these structures. A long day is spent on immediate dam assessments, getting a look at as many structures as possible, with high and significant hazard dams being the highest priority.

In El Paso County, the morning is sunny for John Hunyadi and 2-year-old daughter Annika. John's wife is unfortunately out of town and John and Annika team up to and visit many of the dams in the region that were reported to have received heavy rainfall. The team finds that reservoir levels have risen significantly on numerous dams, causing spillways to flow that rarely if ever have in the past. Quick walk-through "inspections" reveals no immediate dam safety threats, although during this process John is informed of two concerns: failure of two small, "non-roster", dams (dams previously unknown to DSB) in Emerald Valley Ranch, a resort fishing area on the south slopes of Pikes Peak; and the reported failure of Stratton dam at elevation 11,800 feet above the Cheyenne Canyon neighborhood in Colorado Springs.

Emerald Valley and Stratton Dams

Access to the Emerald Valley Dams is not possible by vehicle, but a site visit is made to a Significant Hazard dam, Keeton Reservoir, just downstream. Having just undergone spillway improvements in 2007, it is evident the spillway has passed significantly high flows with no immediate dam safety concerns. However, a residential access road/bridge below the spillway channel has been completely eroded/washed out. Those home owners wishing to evacuate, are forced to hike out over a ridgeline to access rides from friends. John worked with local and state emergency managers, and FEMA, to provide necessary supplies to the remaining residents cut off from their homes below Keeton Dam.

Increasingly high flows in Cheyenne Creek, on the south slopes of Pikes Peak has led to rumors in the local emergency management community that normally dry Stratton Dam has breached. John reviews the situation with both owners and local emergency managers and determines that Stratton Dam having breached is unlikely. However, arrangements for access via helicopter are made through a resource request via WebEOC, and around 2:00 P.M. the owner boards a U.S. Army Blackhawk helicopter. Unfortunately the high altitude of the dam and impending severe weather again "scrub" the mission. A second attempt is made via helicopter on Sunday morning, but is once again scrubbed. Finally, John and the dam owner decide to depart on off-road motorcycles and ATV's for Stratton in order to lay eyes on the dam and determine its real status. By that evening, the men are finally able to see that the normally dry dam is still dry and standing in good condition. The cause of the rising creek was strictly associated with very heavy rainfall over a large, steep basin.

With the interstate re-opened and the sun shining, Johnny Batka is able to access the hardest hit areas along the St. Vrain River and Left Hand Creek to inspect the condition of the dams. He performs boots-on-the-ground inspections of 12 of the significant/high hazard dams and/or dams known to have spilled; and drive-by inspections of numerous smaller dams.

Kallie and Jeremy analyze the rainfall maps and determine upon which area around the Cache la Poudre River they need to focus. They then spend the full day trying to visit as many dams as possible, performing cursory inspections. The goal of the inspections at this point is to identify any dams that are experiencing issues or performing unusually. Kallie and Jeremy perform immediate assessment inspections on sixteen structures.

Ryan, able to leave Baseline Dam in a relatively stable condition and in good hands, coordinates with his owners to assess the damages and perform cursory inspections in his area as well. Communication and coordination with the dam owners at this point is critical to keep track of new, ongoing, misreported, and resolved incidents.

Finally, dam owners are beginning to get control of the ditches that feed many of the reservoirs and spillway flows are diminishing significantly. Damage to the dams inspected so far appears to be limited to spillway erosion and does not, in any of the cases, threaten the structural integrity of the structures. As the end of the day approaches people are beginning to feel like the storm has passed and the most critical time is over.

Feeling like things are relatively under control, Bill decides to take a few hours to go home to Salida, about 3 hours southwest of Denver, for a bit of a breather and some fresh clothes. As he makes his way into and out of areas with cell phone coverage, he finally has some time to think. From Thursday through Saturday, the DSB has received offers from engineers all over the community to help in any way they can. Thinking about how to put this untapped resource to use to help ensure public safety, the wheels slowly begin to turn.

SUNDAY, SEPTEMBER 15 (DAY 4)

Day 4 dawns with dreary skies, and eventually brings 1-3 inches more rain to the already saturated Front Range. Running almost non-stop for the past 72 hours and having felt as though we might be through the worst of it, the DSE's responding to the event are temporarily deflated as flows through the spillways increase again, flooding worsens and access again degrades. Also thinking perhaps the worst was over and now realizing otherwise, the remaining six DSE's in other areas of the state begin to make plans to head to the Front Range.

The first to arrive is Erin Gleason from her office in Glenwood Springs. Ryan has been stifled in attempts to access some of his mountain dams in Jefferson and Boulder Counties and the idea of taking advantage of Erin and her ability to approach from the west springs forth. Ryan and Erin divide up a compiled list of dams with reported issues, and attack from different directions to cover as much ground as possible. Kallie and Johnny are doing the same in their respective areas of Larimer, Boulder, and Weld Counties as the rain continues to fall. Johnny reports to the EOC in Lyons, one of the hardest hit places by the flooding, and while there becomes aware of a concern over Button Rock reservoir located upstream of Lyons on North St. Vrain Creek.

Button Rock Dam

A National Guard helicopter rescue missions pilot noted significant flow over the emergency spillway for the Ralph Price Reservoir (AKA Button Rock Reservoir dam).

Ralph Price Reservoir is a large water storage facility for the City of Longmont. This reservoir is an on channel structure located on North St. Vrain Creek that had a reported peak flow of approximately 10,000 cfs through the emergency spillway. No

reliable information was available to confirm the emergency spillway was not being damaged as road access was not possible and the dam's caretaker was evacuated from the site in the midst of the storm. A helicopter flight was coordinated by the Emergency Operations Center to evaluate the condition of the spillway. After a tense night for residents below the dam, filled with rumors of dams failing and the National Guard forcing evacuations, on Monday September 16, representatives from FEMA, City of Longmont, and a DSE John Batka staff are flown to the site to assess the condition.

Figure 12 - Photo of Button Rock dam spillway flow from the left abutment, near peak (10,000 cfs) on Friday September 13, 2013.

Based on review of the geology, spillway design drawings and visual examination of the concrete spillway structure and downstream rock channel from the air, it was determined the channel is well armored by bedrock and was performing as designed. Erosion was occurring at the bottom of the spillway channel but was not endangering the structure or the dam. A significant log jam was noted in the upstream end of the reservoir which was identified as a potential safety issue during the upcoming spring runoff and was made a priority to be removed over the winter.

Figure 13 - Button Rock dam spillway flows from the air on September 16, 2013.

While Ryan, Erin, John, Kallie, and Johnny are out in the field, Kallie gets a call from the Larimer County Emergency Manager requesting that she immediately come and provide a physical presence at the county EOC to be available as a dedicated dam safety resource. In this role she would help respond to reported dam incidents and advise on evolving potential life safety issues related to dams in the rescue/response zones. As other emergency managers become aware of this resource, they too begin to request a physical presence from state dam safety officials in their own EOC's. Recognizing that this is a hugely important role to fulfill, it is also viewed as additional taxation on already stretched resources and the question soon becomes, "How can we possibly do it all?"

Figure 14 - Button Rock reservoir with log jam from the air on September 16, 2013.

As the DSE's deal with the set back of more rain, Jeremy continues to work in Denver with GIS staff and the meteorological community to get a better handle on just how many dams may have been impacted.

Rainfall Analysis

Up to this point, the NOAA STP product had been used as the primary source of information to determine which dams were most impacted by the rainfall. Querying this dataset revealed just how many dams had experienced significant rainfall amounts over the past three to four days. But we ran into a challenge: how do you know what depth of rain is significant enough to be concerned about a dam? Simply querying our dams against peak 24-hour precipitation we knew that over 500 dams had experienced 24-hour rainfall depths over 5-inches. Responding to that many dams seemed daunting at best. Compounding that challenge was the fact that the significant orographic effects of the topography in Colorado mean that a precipitation event that would be significant to a dam in the mountains or foothills may not be significant enough to worry about for a dam on the plains. This effect is easily visualized by looking at the precipitation depth maps from NOAA Atlas 14 which clearly illustrate that at higher elevations along the Front Range, the various recurrence interval rainfall depths for a given duration decrease with increasing elevation. So we knew we couldn't rely on rainfall depth alone to focus our response. We needed a way to put the rainfall depth into context.

Table 1- Precipitation Amounts Recorded at Gages September 9-12, 2013

Location	Gage Name	Gage ID	Type	Precipitation in Inches				Comparison
				24-hour[1]	48-hour[2]	72-hour[3]	96-hour[4]	
Aurora	Virginia Court	510	UDFCD	7.32	9.96	11.04	11.04	>500-year
Boulder	Lee Hill	4320	UDFCD	7.84	12.84	13.40	14.44	>500-year
Boulder	Justice Center	4360	UDFCD	5.80	11.96	12.44	13.28	>500-year
Boulder	Boulder	050848	NOAA	9.08	11.00	12.02	12.27	>500-year
Fort Collins	Fort Collins	053005	NOAA	1.99	2.81	3.47	3.53	<100-year
Loveland	Loveland 2 N	055236	NOAA	2.32	2.59	3.22	3.22	<100-year
Colorado Springs	Colorado Springs Airport	051778	NOAA	1.61	1.80	1.87	1.87	<100-year
Fort Carson	Rod and Gun Station	384053104492001	USGS	11.90	12.48	12.48	12.48	>500-year

Note: September 13, 2013 data are not included, which could change table.
1. The 24-hour event corresponds to September 12.
2. The 48-hour event corresponds to September 11 and 12.
3. The 72-hour event corresponds to September 10, 11, and 12.
4. The 96-hour event corresponds to September 9, 10, 11, and 12.

Quantifying the Rainfall Event

Through reaching out to the meteorological community, Jeremy was put in touch with Tye Parzybock with MetStat, Inc., a small meteorological consulting firm based out of Fort Collins. Tye shared with Jeremy an image from the Extreme Precipitation Index tool, (EPI), produced by MetStat and Weather Decision Technologies (WDT). This data product objectively conveys the rarity of observed and forecast precipitation in real-time. The EPI is a real-time measure of the Average Recurrence Interval (ARI) of precipitation; when the EPI is high, the likelihood of flooding is high. Utilizing WDT's gridded quantitative precipitation estimates (QPE), EPI maps/grids of the past 3, 6 and 24 hours are created and provided as online interactive maps. The QPE grids are based on high resolution, gauge-adjusted NEXRAD precipitation data. These grids are then influenced and adjusted using quality-controlled rain gauges from MetStat's proprietary real-time acquisition and QC system. Together with official precipitation frequency estimates published by the National Oceanic and Atmospheric Administration's (NOAA) Hydrometeorological Design Studies Center, the EPI is computed.

The EPI allows users to quickly interpret the significance of recent or forecast precipitation events anywhere in the state. The general public, as well as hydrologic engineers and emergency managers, often have a better sense of the consequences of a 100-year storm versus an absolute amount of precipitation, making the EPI a powerful way to convey the magnitude of storms. The EPI product was a powerful means of conveying significant precipitation and potential flooding to dam safety officials, emergency managers, and the public during the Colorado floods of September 2013. It is important to understand that the ARI/EPI of the rainfall does not necessarily equate to the same ARI of the ensuing flooding. However, the EPI clearly shows when rainfall

amounts have (or are expected to) significantly exceed climatological normal's, thereby producing flooding. The EPI complements NWS-issued Flash Flood watches, warnings and advisories by pin-pointing areas of heaviest rainfall and putting the NWS statements into an actionable perspective.

The EPI helped tremendously by defining the event in terms that could be related to the hazard classification, and thus the hydrologic design standard of the dam. Tye provided the EPI product as a Geo-referenced raster grid which, once overlaid on our dams shape file, gave us an estimate of the return interval of the rainfall occurring at a given location.

As updated rainfall recurrence interval data comes available it shows the breadth of the extreme rainfall. The knowledge that high and significant hazard dams have performed well is tempered by the knowledge that for many of these, this was a "first fill" event. Reservoirs had risen to new high levels and spillways had been tested for the first time. The reservoirs now stood full with no end of rain in sight. Numerable low hazard dams had seen rainfall in excess of their design standards and may be sitting out there also full and potentially damaged or in distress.

With requests to get more people at the EOC's, reported incidents continuing to require response, and a daunting number of dams that need more thorough emergency inspections, Bill recognizes that his staff of eleven is not going to be able to do it all. Before leaving Salida Sunday morning to head back to Denver after only a 16-hour stay, Bill sends an email to respected members of the dam safety community in and around Denver requesting a meeting to discuss the practicality and necessity of using volunteer engineers to perform mass inspection of these tested facilities. The idea being relatively new and radical, Bill and senior management need some additional confidence in the path ahead. The response to the request for some counsel was overwhelmingly positive and that afternoon Bob Huzjak, Ed Toms, Jennifer Williams, John Cyganowicz, Dick Westmore, Dan Johnson, John France, Ben Letak, and Fred Rios meet in the URS offices and listen while Bill, Scott Cuthbertson (Deputy State Engineer), and Dick Wolfe (State Engineer), describe the events to date and the offers of assistance from the engineering community at large. A conceptual emergency inspection program is discussed. The concerns regarding first fill conditions and rainfall beyond design standards are considered real and in the end the need for some form of emergency inspections is considered valid. While no plan was devised by the end of the day, DWR leadership is convinced of the need. Deciding how best to do that and potentially use outside engineers will take a bit more time and thought.

MONDAY, SEPTEMBER 16 (DAY 5)

Day 5 the weather is once again clear and we're feeling more settled than we have since the start of the event, with processes in place and things starting to go a little more smoothly. We have the "Dam Safety EOC" in the 8th floor conference room of the Denver office, which is providing a centralized location for meeting, working, lending moral support, etc. Media communication is still quite demanding and includes: daily requests from the Colorado Department of Natural Resources (parent organization) to update various news

outlets, constant calls directly from the media, requests for information from the Governor's office, and requests from the general public. The DSE's remain inundated with flood response activities, continuing to receive and respond to calls for the status of ongoing, developing, or new incidents. One of these is Gaynor Lake.

Gaynor Lake Dam

On Monday Johnny Batka is notified by Karen Martinez from Boulder County Open Space of a sinkhole that had formed over the downstream end of the outlet conduit at Gaynor Lake dam, which is classified a Significant hazard dam.

The heavy rainfall that occurred over the Longmont area between September 11, and 15, caused a significant amount of runoff to enter the reservoir which was passed through the reservoir via the service spillway and outlet conduit. With the amount of uncontrolled flow through the outlet conduit, water in the outlet ditch inundated the downstream outlet structure causing a sinkhole to form approximately halfway up the embankment. The cause of the sinkhole is not known, but it was likely caused by a combination of pressurized flow in the outlet pipe combined with a pipe defect and saturation of the embankment due to the water backing up in the outlet ditch. A defective joint in the vicinity of the outlet likely allowed the saturated embankment material to migrate into the conduit causing the sinkhole to form on the surface of the embankment.

With Johnny dealing with the questions about Button Rock Dam, Erin Gleason helps the owner gain control of the situation. Approximately 300 feet of the outlet ditch was cleaned with a large tracked excavator to improve the flow conditions, and a gravel filter was placed on the downstream slope over the sinkhole to slow the loss of embankment material. As the inflow in the reservoir decreased the outlet valve was opened to lower the reservoir level. The dam was monitored daily by Boulder County Open Space and DWR staff until it was lowered to a safe level. The reservoir was eventually drained completely.

Figure 14 - Photo of the swollen outlet channel at Gaynor Lake dam. Note location of sinkhole above the pipe.

While managing incidents as an overall team, Ryan, Erin, Kallie, John, and Johnny are also sharing rotations to keep the Boulder County, Larimer County, and State EOC's staffed. The typical schedule is to check-in the morning and evening and stay for as long as it takes to update situational awareness of on-going incidents and resolve those that they can. Jeremy continues to work on refining the list of dams that will require emergency post-flood inspections. Given the additional rainfall on Sunday, Tye with MetStat, Inc. provides an update to the EPI dataset, while Jeremy works to define a prioritization scheme that can be used to determine what dams need emergency inspections. This scheme evolves through the course of the week, but essentially consists of a tiered threshold of EPI estimated recurrence interval for low, significant, and high hazard dams. The prioritization scheme ultimately includes low hazard dams with EPI > 25-years, significant hazard dams with EPI > 50-years, and high hazard dams with EPI > 100-years. We also decide that any dam in our database tagged as non-jurisdictional[1], breached, or abandoned should be inspected just in case. Dams with existing reservoir restrictions due to previously identified safety concerns are also added to the list. Employing this philosophy, Jeremy develops a list of 207 dams having been subject to one or more of the following: rain in excess of the spillway design event, rapid loading, first fill, storing water above the normal pool, and/or saturation of the downstream shell.

[1] Non-jurisdictional dams are defined as embankments that are less than 10-feet tall, and that impound reservoirs that cover less than 20 surface acres with less than 100 acre-feet of storage. These are not regularly inspected.

With five days of record-breaking rainfall and multiple dam failures having been reported in the media (whether false or real), the general public and emergency responders are very nervous about dam incidents at this point. It is imperative that we are able to quickly and confidently report on the condition of all known structures in the affected area so the emergency responders can do their jobs and the public can begin putting their lives back together.

Armed with this tentative list of dams, as well as list of probable potential failure modes specific to this type of event and developed the previous day, we now know how we are going to utilize these volunteers. In the afternoon, Bill grants his first television interview and makes public plans for the emerging volunteer emergency inspection process.

That evening, as the Emergency Inspection Program (EIP) is presented to the DSE's during the daily wrap-up conference call, it meets with unanticipated resistance. Having put in five non-stop days, with long hours under stressful working conditions, the DSE's express a range of opinions. Some are frustrated by the fact that they have already observed many of the dams on the list and feel redoing this would be a waste of time; others feel their professional capabilities are being questioned by seeking help outside the branch for primary branch functions; still others feel that the energy spent just managing the effort will be too great to provide meaningful benefit.

Ultimately it is decided that the number of detailed inspections required, coupled with ongoing incident response, maintaining a presence in the EOC's and responding to requests for information from internal and external sources, is just too great a workload for the existing resources within the DSB. It would be in the best interest of those we serve to protect to utilize the offers of help that have been extended to us. Out of great respect, genuine friendship for one another, and for the greater good of those we serve, once the decision is made, all members of the DSB set aside their opinions and concentrate on successfully implementing the plan. A call is made to accept URS's offer to help move the plan forward and make arrangements to meet again the next day. The goal of the meeting would be to develop the scope of work and necessary documents to define the EIP.

TUESDAY, SEPTEMBER 17 (DAY 6)

Bill, Kallie, Jeremy, and staff from URS meet at 8 A.M. in the Denver office to develop an approach to the emergency inspection process, i.e. how exactly to mobilize the volunteers.

By midday several documents have been developed including a scope of work, liability waiver, inspection form, "Engineer's Inspection Report" format, initial conditions assessment sheet, and letter to the dam owners explaining the need for inspections. A timeline for completing the inspections and reports is established, as well as requirements and guidelines for the inspectors, which include two-person inspection teams, at least one of which has to be a Registered Professional Engineer in Colorado with three years of dam safety experience; and guidelines pertaining to personal safety. Bringing all the necessary pieces together in an extremely condensed timeframe is not without hiccups, stress, and issues, but as the team forges ahead they find with some surprise and relief that all of the required legislation for the

program is already in place. Having never had a reason to invoke it before now, we were not aware it existed.

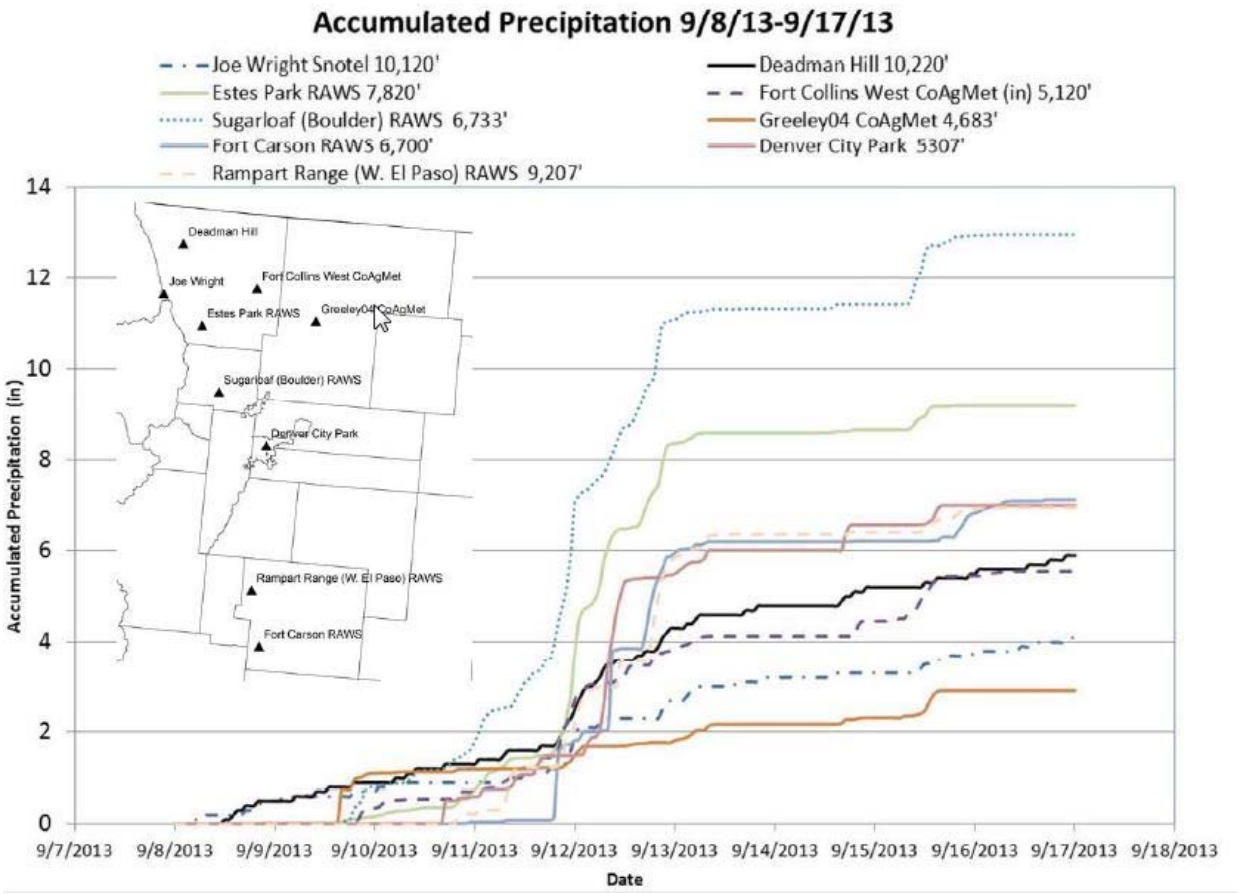


Figure 15 - Plot of accumulated rainfall at various rain gages along the front range, provided on September 18th.

The preamble to the waiver includes references to the state statutes that protect the agency's volunteers from being sued by the dam owners or others. The state Attorney General is consulted in developing language that will protect not only the state, but also the dam owners, and the volunteers. While the primary purpose of the waiver is to protect the state from being sued by the volunteers, we also try to use the language to educate the volunteers as to their immunity from liability. The final purpose of the waiver is to keep the volunteers from suing the dam owners so that the owners will hopefully be more comfortable with the volunteers entering their property for the emergency inspections.

Legality and liability issues aside, the practical execution of the EIP still lay ahead. With a list of over 200 dams, spread throughout 10 counties, and a list of over 100 engineers, approximately 50 teams, standing by to help, the question becomes, "How *do* we correlate all of this?"

A final mapping effort is made to assist with the process. First, the volunteers are split among ten of the DSE's to create a management structure for reporting, and providing any

necessary assistance to the volunteers. A database is then created linking the dams needing inspection with the DSE managers and the volunteer engineers. This is then linked to a shape file containing the geographical location of the dams. This mapping exercise facilitates the spatial logic that will be used to assign the volunteers to the dams. To the extent practical, each pair of volunteers will be assigned dams that reside in the same county and water district, and will be managed by one DSE. As Jeremy concentrates on ironing out the details, Kallie begins working with administrative staff in Greeley to print, collate, and mail notices explaining the impending emergency inspection process to all dam owners. In order to expedite the inspections and help avoid any potential private property and/or trespassing issues, a copy of each of these letters will be provided to the inspecting engineers to have on their person when they arrive for the inspections. Also, so that the engineers will have some background before arriving on site, Kallie also begins compiling electronic copies of the last regular inspection report and construction drawings where available for each of the dams. These will be uploaded to a FTP site, where they will be made available for download by the inspecting engineers. With Jeremy, Kallie, the Greeley administrative staff, and others working furiously to organize the information and documents necessary for the EIP, the remaining DSE's continue to work issues and incidents in the field, and man the EOC's.

As clear tasks and responsibilities related to the EIP begin to emerge, the role of the remaining DSE's is recognized, and they quickly mobilize to the Front Range. Up to now there has been hesitation to bring the others in because, in addition to not being sure about leaving half the state uncovered, the current staff has been so overwhelmed, they haven't had time to think about how they might use the others. Now with more clearly defined goals and objectives, and renewed confidence in what they could accomplish with more people, the front range staff is anxious for help and ready to put their colleagues to work.

In addition, the goals and objectives that had been evolving over the first five days of the storm are defined into three succinct objectives and become known as our "Overarching Goals"

1. *Support the EOC's so they have situational awareness of any slowly or quickly developing dam safety threats that might affect field personnel access and/or safety*
2. *Continue to work to be in the best possible position to be able to respond to incidents, i.e. reports of dams failing, or dams in distress*
3. *Finalize details and implement the emergency inspections plan*

With these three objectives now clearly defined, the process that had seemed so overwhelming the first several days somehow begins to feel manageable. As if validating our previous feelings of being overwhelmed, and providing some scope of the enormity of the event, we learn that Colorado has received the Presidential Disaster Declaration, making federal funding available for emergency relief and reconstruction assistance.

WEDNESDAY, SEPTEMBER 18 (DAY 7)

The last of the remaining DSE's stationed throughout the state, Dana Miller, Mark Perry, Jason Ward, Matt Gavin, and Garrett Jackson, arrive from their respective regions, and the entire Dam Safety Branch is now assembled on the Front Range. As Jason, Mark, Matt, and Garrett are quickly delegated to incident response, Dana heads to Greeley where she steps in and begins to help Kallie make preliminary dam assignments and compile historical inspection reports and construction drawings, with calls related to incidents, people offering to help, or just wanting information continuing to come into the office.

As the EIP is advanced, new incidents continue to develop, most notable of which is at Flatirons Vista near the City of Boulder.

Flatirons Vista Dam

Flatirons Vista dam is located on and owned by City of Boulder Open Space. Yet another dam never reported to the Dam Safety Branch or the Division of Water Resources Water Commissioner and therefore "non-roster". A phone call from the City of Boulder Water Resources Department indicated that Flatirons Vista Dam had overtopped during the storm but had not failed. The water surface was within a couple feet of the dam crest and draining through a small spillway. The dam had an outlet, but the gate has reportedly never been operated and it was unclear if it would work, not to mention that the manual operator was inaccessible except by boat.

The dam was located on a dry gulch approximately 0.25 miles upstream of Highway 93, which serves as a 2-lane primary thoroughfare between the cities of Golden and Boulder. The City of Boulder Open Space maintains public access on multi-purpose trails throughout Flatirons Vista Open Space and a parking area located between the dam and Highway 93. It was unclear whether failure of the dam would jeopardize the parking area or Highway 93. However as the dam had signs of overtopping, a downstream slope failure, inoperable outlet and possible sinkhole above the outlet conduit, to be safe, emergency response measures were deemed necessary.

The reservoir was immediately drawn down to a few feet above the outlet and monitored. Drawdown was accomplished through pumping with two truck-mounted 6-inch pumps, and took a couple days to reach the desired elevation. Once drawdown was complete, the owner provided labor and a small track-hoe to excavate a breach through the embankment along the outlet works alignment to approximately one foot above the present water surface. This work was deemed necessary to prevent the reservoir from rising to a level that could threaten the safety of Highway 93. Figure 16 illustrates some of the issues of concern.

Over the next few weeks, the inoperable upstream outlet gate was removed and the reservoir was allowed to drain down to near the outlet elevation, and the breach depth was increased to approximately 1-2 feet above the outlet crown.

Figure 16 - Photo of a slope failure caused by embankment saturation due to overtopping of the Flatirons Vista dam. The weakened dam was eventually breached.

Towards the end of the day, feeling organized enough to embark upon the EIP, an official call is made for volunteers. At 4:05 P.M. Dick Wolfe sends an email to a compiled list of would be volunteers with the following message:

> *"This email is being sent to your attention either because of your gracious offer to assist the State of Colorado with response to the disastrous flooding last week, or because you were specifically considered by our staff for this effort. Thank you in advance.*
>
> *"There are approximately 200 dams we have identified in the impacted area. We are hoping to field enough teams to inspect these dams by September 27, 2013. Attached to this email are:*
>
> - *a list of the dams that need inspection*
> - *a scope of work that details the inspection process and information required*
> - *an engineer's inspection report and cover letter to use in reporting the inspection results*
> - *a waiver of liability for both the State of Colorado and property owner*
> - *Colorado Statute CRS 13-21-108.3*

"If you are willing to assist us in this endeavor, ***please send an email to dnr_coloradods@state.co.us*** *with the list of dams that you would volunteer to inspect and a copy of the signed waiver for each party participating. We would encourage you to select dams with which you are already familiar as those associations will be made whenever possible. Other dams and any conflict between requests to inspect dams for which you have an existing relationship will be assigned on a first come, first assigned basis.*

"There will be an orientation meeting at 10:00 AM this Friday, September 20, at 1313 Sherman St (Room 318), Denver, CO or by conference call at (303) 866-3581 ext 7616 for anyone wanting clarification or additional information.

"Thank you for your assistance in our attempts to most effectively respond to this emergency."

The response to this email is quick; and tremendous. The vast majority of individuals and companies have little problem returning the completed waivers; however in reality, there are a small number of companies that are unable to reconcile perceived legality/liability issues within such a short timeframe, much to the terrible chagrin of the perched and waiting would-be volunteer(s).

Wednesday comes to a close with Bill running command from the "DSB EOC;" Ryan manning the State EOC; Mark monitoring conditions in Estes Park; Jeremy, Dana, and Kallie working in Greeley and Denver to assemble information for the volunteer inspectors and beginning to make specific dam assignments; and Johnny, Garrett, Jason, Matt, and John continuing to investigate/monitor reported incidents.

THURSDAY, SEPTEMBER 19 (DAY 8)

Day breaks with still more incidents continuing to stream in. Having had the chance to recalibrate a little bit, part of the team transitions to reconnaissance efforts in the Estes Park/Big Elk Meadows/Boulder County area. Jeremy, Dana, and Kallie continue preparations for the volunteer inspection meeting the following day. Garrett, John, Jason, Erin, and Matt continue to follow up on incidents and man the county EOC's; and Ryan is manning the State EOC.

Mark is tasked with inspecting known dams in the Estes Park area, as well as non-roster (previously unknown) dams at the Salvation Army's Longs Peak Inn. Due to road closures and a forgotten cell phone charger, Mark's two hour trip turns into a six hour odyssey. Mark immediately plugs into the Town of Estes Park EOC (technically an Incident Command Center) and works with the Town Engineer and the Logistics Specialist. The Town is concerned about the status of U.S. Park Service's Lily Lake Dam, which Mark is able to inspect and finds no problems. Mark also takes the opportunity to inspect the Carriage Hills No. 1 and No. 2 Dams mentioned previously and confirms reports that the No. 2 dam failed during the flood. Mark performs initial forensic investigations and directs the Town Engineer to clear willows and remove a rock weir from the spillway to increase capacity.

Finally, after an arduous but satisfying trip, Mark begins to make his way back to Denver late Thursday afternoon. Not far down the road he observes Aspen Lodge Dam, still another previously unknown non-roster dam that is sitting with its emergency spillway completely blocked and low level outlet clogged by a massive debris flow from the 11,400 ft Twin Sisters Peak.

Aspen Lodge

The night of 9/12-9/13, Aspen Lodge Resort was hit with a debris flow off the west side of the Twin Sisters Peaks. The slide caused extensive damage to their facilities and clogged the Aspen Lodge Dam spillway with mud and debris (including a 10-ft propane tank). The dam overtopped the night of 9/12-13 and into the day on 9/13. The owner was able to get a small notch cut through the spillway debris, enough to stop the dam from overtopping. When Mark found the dam a week later, the spillway was still clogged and the reservoir level was about 4-inches below the dam crest. The floods had washed out two U.S. Highways into Estes Park, and the sole remaining access into the town was CO Highway 7, There sat Aspen Lodge Dam with a clogged spillway and dangerously high water level about 400-ft upstream of a 3.5 foot-diameter culvert beneath State Highway 7.

The dam owner's lodge had been ravaged and they had no remaining capacity to deal with the dam emergency. By statute, the Colorado State Engineer has authority to take control of an unsafe dam and employ measures to protect life and property, and Mark took emergency action.

A multi-day effort ensued to procure construction resources in a disaster area with limited access. This effort led us through multiple agencies, aborted efforts, false leads, and finally down a canyon road late one night where a local contractor worked in the dark to restore access to stranded residents. With additional rain in the forecast, a handshake deal was made and early the next morning Mark directed a controlled breach of partially failed dam downstream and then debris removal and emergency spillway enlargement at the Aspen Lodge Dam. All the while a steady convoy of emergency supplies passed on the highway below.

Activities and issues that came up and were addressed included: Confusion over the resource request for equipment to mitigate the hazard; authorization of the work by the Larimer County Sheriff; coordination activities for local resources identification at the Estes Park EOC; hand labor with Larimer County and FEMA personnel to free the plugged outlet works; pumping the reservoir down with a fire department pumper truck and public works department pumps; finding a local contractor and securing a handshake deal to meet at the next morning to breach some dams; Notifying DWR Water Commissioner and the IC of possible increased flows downstream of the dams during breaching; Successfully breaching the lower Swiss Lakes Dam; Recruiting a group of Mormon disaster recovery volunteers to monitor the Highway 7 culvert

throughout the breaching process; Removing debris from the spillway and enlarging it so it could be comfortably left with more rain in the forecast for the next day.

Mark's emergency actions prevented two dams from failing uncontrollably and provided needed protection of the sole remaining access to a town of over 6,000 people in the midst of a crisis.

Figure 17 - Photo of fire truck utilized as a last resort to begin to lower reservoir level at Aspen Lodge dam.

While Mark is dealing with the situations in Estes Park, great progress is made in the "Dam Safety EOC," where logistics are finalized for the EIP, preparations are wrapped up for the kickoff meeting the following morning, and the majority of dam/engineer assignments are made. Liability waivers are being recorded as they are received, and DSE's are each assigned a list of engineers/dams that they will manage during the inspection effort.

With Jeremy, Kallie and Dana fully in control of the EIP process, Bill and Scott take Johnny up on an offer to tour the affected areas in Boulder County. In the interest of cooperating with the media, they invite a Denver Post reported who had been communicating daily regarding dam related inquires. For about 4 hours, the group tours one of the areas devastated by the flooding. It is an eye opening experience for all. Being truly candid with the reported the entire time, there is some trepidation over what sort of story he will write. During the tour Bill picks the reporters brain for the wording to a needed social media post regarding the upcoming inspections. Between them they come up with:

"Emergency dam inspections are required for public safety in South Platte Basin. Will begin 9/21/13 and go for 10 days. Attempts will be made to contact owners. Cooperation for access is requested. Contact dam safety engineers for questions."

In the end a generally positive story comes out in the Sunday edition of the Denver Post. Reports are the Governor's Chief of Staff is "beside herself" with the positive coverage of State employees acting on behalf of fellow citizens. Another trial of cooperative communication with the media proves successful and another lesson from the ASDSO conference proves essential.

FRIDAY, SEPTEMBER 20 (DAY 9)

Friday dawns with some excitement and final preparations for the EIP orientation meeting that will really set the process in motion. At 10:00 A.M. Dick Wolfe addresses the eager group of 30+/- engineers who attend the meeting in person, with an unknown number listening in by phone. Mr. Wolfe provides an introduction and expresses gratitude and pride in the Colorado engineering community on behalf of the state for its willingness to help in a time of need. He then turns the floor over to Bill who provides the current known status of the area impacted by flooding from a dam safety perspective, and explains the urgency behind the need for more detailed inspection, damage assessment, and categorization. Based out of fear that the EIP could spin into disaster, Bill makes the following impassioned plea to the volunteers:

"I implore you to interpret what we need from the scope, not get hung up on the details, not badger your group manager with distracting questions; work logistical things out in the field using creative and resourceful thinking, and do it safely. We simply need you to take what we have put together and get out there as soon as possible, with the best information available; make your observations, interpret those observations using your best engineering judgment, and report back to us on the current level of safety of those dams as soon as possible.

"We simply need to know and be able to state with confidence that the dams in Colorado impacted by this event are as safe as the rest of the dams in Colorado. If we can do this, we may be able to make those people hit so hard by the devastation from this event see that it can be mitigated, and maybe then people can begin to feel like they have a chance of getting their lives back. I believe we can provide that service to the citizens who have been hit the hardest by this event. We are all working for them."

The objective of the inspection process is to compile a list of dams, each rated with a "response level" relating the urgency of any response required due to damage received by the flooding. The levels are defined as follows:

Level 0: Safe for normal operation
Level 1: Functional; some repairs needed; no dam safety concerns
Level 2: Potential dam safety issue(s) exist(s); dam requires immediate evaluation
Level 3: Urgent; failure imminent or in progress; requires 911 notification immediately

Most of the volunteers at the meeting are provided a tentative list of their assignments, with the last few still being finalized. Most are also given the name and contact information of the DSE to whom they will report, and provided a link to the FTP site where they will be able to download the latest inspections and, in some cases, construction drawings for the dams they are assigned.

Shortly following the meeting, Jeremy is able to finalize the inspection assignments, exports his shape file to a Google Earth compatible KMZ file, and emails this to the volunteers so they can begin coordinating their site visits. With this final detail completed, the EIP is off and running.

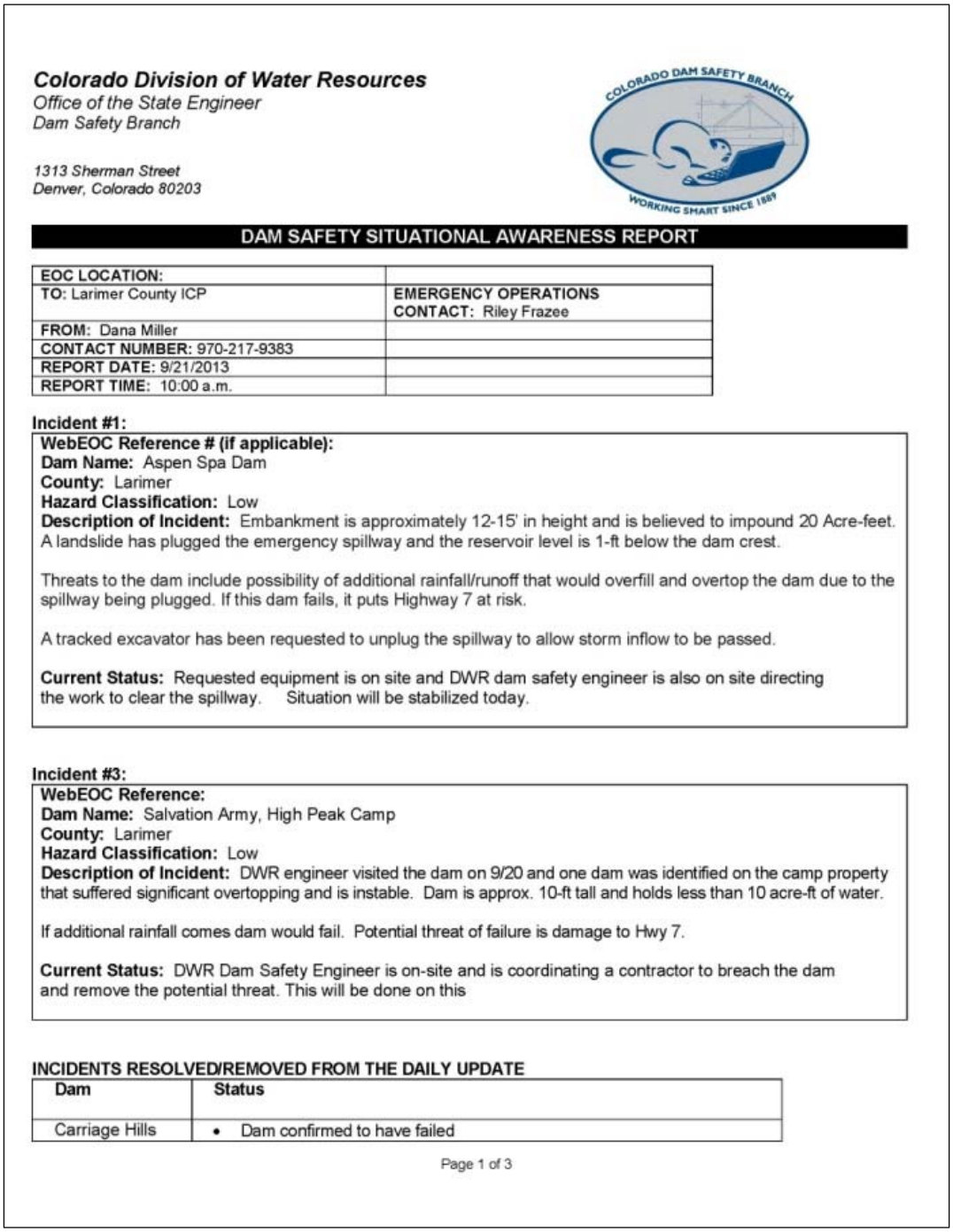
Throughout the day, DSE's continue to respond to incidents and staff the EOC's, where political figures, including Vice President Joe Biden, are beginning to make appearances. Dana takes the opportunity to converse with U.S. Senator Udall regarding our program's response to the flooding including a subtle pitch to support the National Dam Safety Act, in response to his question of "how can he help".

SATURDAY/SUNDAY, SEPTEMBER 21 & 22 (DAYS 10 & 11)

Going into the weekend activities are much the same with issue resolution and EOC attendance being the primary focus. By this time we have developed a Situational Awareness form to use in WebEOC communication, an example of which is shown in Figure 18. The DSE assigned to the particular EOC reports the status of known dam safety incidents each morning to the County or State Emergency Manager, and the form is then posted on WebEOC so that emergency management personnel are aware of any potential dam safety hazards in their area. Google Earth is also used to show the locations of any dams of interest, as well as provide a visual of potential impact areas downstream.

In addition to regular situational awareness reporting at the EOC's, the branch has also begun a more regimented scheduling of activities and personnel for manning EOC's, following up on incidents, checking on dams of concern, preparing for forensic investigation activities and performing dam inspections in areas with no access (requiring helicopter access).

With the volunteer inspection force mobilized, DSE's also begin fielding calls from the engineers as they gear up for inspections or, in some cases, are already reporting from the field.



Colorado Division of Water Resources
Office of the State Engineer
Dam Safety Branch

1313 Sherman Street
Denver, Colorado 80203

COLORADO DAM SAFETY BRANCH
WORKING SMART SINCE 1887

DAM SAFETY SITUATIONAL AWARENESS REPORT

EOC LOCATION:	
TO: Larimer County ICP	**EMERGENCY OPERATIONS CONTACT:** Riley Frazee
FROM: Dana Miller	
CONTACT NUMBER: 970-217-9383	
REPORT DATE: 9/21/2013	
REPORT TIME: 10:00 a.m.	

Incident #1:

WebEOC Reference # (if applicable):
Dam Name: Aspen Spa Dam
County: Larimer
Hazard Classification: Low
Description of Incident: Embankment is approximately 12-15' in height and is believed to impound 20 Acre-feet. A landslide has plugged the emergency spillway and the reservoir level is 1-ft below the dam crest.

Threats to the dam include possibility of additional rainfall/runoff that would overfill and overtop the dam due to the spillway being plugged. If this dam fails, it puts Highway 7 at risk.

A tracked excavator has been requested to unplug the spillway to allow storm inflow to be passed.

Current Status: Requested equipment is on site and DWR dam safety engineer is also on site directing the work to clear the spillway. Situation will be stabilized today.

Incident #3:

WebEOC Reference:
Dam Name: Salvation Army, High Peak Camp
County: Larimer
Hazard Classification: Low
Description of Incident: DWR engineer visited the dam on 9/20 and one dam was identified on the camp property that suffered significant overtopping and is instable. Dam is approx. 10-ft tall and holds less than 10 acre-ft of water.

If additional rainfall comes dam would fail. Potential threat of failure is damage to Hwy 7.

Current Status: DWR Dam Safety Engineer is on-site and is coordinating a contractor to breach the dam and remove the potential threat. This will be done on this

INCIDENTS RESOLVED/REMOVED FROM THE DAILY UPDATE

Dam	Status
Carriage Hills	• Dam confirmed to have failed

Page 1 of 3

Figure 18 - Example of form developed to update EOC's on situational awareness.

THE FOLLOWING WEEK, 9/23-27 (DAYS 12-16)

Dam safety staff move into volunteer force management, fielding questions from the engineers and owners; receiving and processing reports; and forwarding critical information as necessary. A summary of the volunteer workforce that was fielded for the EIP process is shown below in Table 3.

Table 2- EIP Participation Statistics

Emergency Inspections Program (EIP) Statistics		
Participants	**Number**	**Comments**
Volunteer Engineers	113	Teams of two, all lead by a Colo. Professional Engineer
Federal Agencies	4	NRCS, USACE, USBR, FERC
State Agencies	1	Wyoming
Engineering Firms	27	From up and down Front Range

Again, documents within the state's relatively new cloud-based Google Drive platform are used extensively to track incidents, tasks and responsibilities, common questions and answers, and progress and real time results of the EIP. These spreadsheets are also used to house consultant contact information, inspection assignments, etc. from which all of the DSE's can work concurrently. This system is invaluable in reporting the progress of the inspection process, as at this point it has garnered the attention of the Governor's Office and the media.

Bill and Deputy State Engineer Scott Cuthbertson are able to go into the spreadsheets at any time and view real time data on how many inspections have been performed, and the response level distribution. This system is used to quickly identify any structures that may pose an immediate hazard. The system and reporting methods allow the most critical structures to be identified and quickly mitigated. As inspection reports come in, the DSE's normally responsible for the regions that experienced the flooding begin the process of aligning dam owners with potential resources for repairing their structures, and working through the regulatory process.

Owing to what can best be described as the volunteers' solemn understanding of the critical nature of the task; an application of the highest level of professionalism and selflessness; and a sense of duty to help where their skills can be put to good use; a high percentage of emergency inspection condition assessments are completed within six days of the initial kick off meeting, and within 15 days of the start of the event. As is shown below in Table 3, the Dam Safety Branch is quickly able to confidently report to state leadership, the emergency management community, and the citizens of Colorado that all identified and inspected dams are safe for recovery work to commence.

Table 3- EIP Execution Statistics

Emergency Inspections Program Progress Summary				
Inspection Activity	**Number**	**Percent Complete**		
		9/27/13	**10/1/13**	**10/10/13**
Inspections Required	207	100%	100%	100%
Inspections Assigned	207	100%	100%	100%
Assignments Confirmed	207	100%	100%	100%
Inspections Scheduled	207	100%	100%	100%
Condition Assessments Submitted		66%	93%	100%

We are also thrilled and quite honestly relieved to report shortly following the incident that all of the High hazard and Significant hazard dams have performed as designed and intended during the event, with spillways adequately and safely passing the inflows. Incidents that did occur on high and significant hazard dams were caused by embankment saturation due to the heavy and sustained rain, and uncontrolled inflow from ditches. As would be expected, downstream channels were severely scoured and much infrastructure lost, but the dams remained protected, which was our highest priority. This was a huge validation of the regulatory design review process that is intended to ensure that dams in Colorado are designed and built safely.

The nine dams that failed during the event were considered small or non-jurisdictional, structures with low hazard ratings. Their spillways were appropriately sized according to design standards for the 25 or 50-year events. The rainfall that occurred between September 11, 2013 and September 17, 2013 far exceeded these design criteria.

Throughout this week, DSE's continue issue resolution, and daily contact with the EOC's. The need for physical attendance at the EOC's begins to wane around the beginning of the week, as they reduce staff and start moving into recovery mode. Three emergency inspections performed this week by volunteer engineers are accompanied by state dam safety personnel and attended by TV crews and reporters continuing to follow the event and progress of inspections. Each of the inspections results in interviews that end up on the evening news, as shown in Figures 19-21.

Figure 19 - Fox News Channel 31 Interview with DSE Jeremy Franz.

Figure 20 - NBC Channel 9 News Interview with DSE Kallie Bauer.

Figure 21 - CBS Channel 4 News Interview with DSE Ryan Schoolmeesters.

Also this week a resource request is made through WebEOC for helicopter assistance to transport DSE's to inaccessible areas to perform dam inspections and begin forensic work. DSE's perform forensic investigations on the nine known dams that failed during the event, as well as one overtopping incident that led to another controlled breach.

Overall, the EIP involved a mammoth initial organizational and administrative effort and even greater follow up because, as was largely unavoidable, dams that were not in good condition to begin with, yet had not received major damage from the floods, were now identified and thrown into the mix as needing significant work.

It is easy to look at this process and think that the real push and focus of the effort was on getting a mess of volunteers out to canvas the flooded area in a short amount of time. This is true, but what may easily be lost sight of, and what the DSB was not entirely prepared for, was the huge amount of follow up work that this process would generate. The emergency inspections were really just the first step in the recovery process, and it turns out, just the tip of the iceberg in terms of the total effort that would ultimately be required before DSE's could feel like they might be "back to normal" schedules.

Once inspections and reports were completed by the volunteer engineers the DSE's assembled a package to be sent to the individual owners. These packages included the assessment rating, inspection report, photos, steps for issue resolution, and potential funding sources; which of course in turn, generated follow up questions and discussion.

The DSE's are not new to this process and it is in fact business as usual during a normal inspection season where we might see 65-70 dams over a period of 10-12 months, only a percentage of which need significant work or repairs. Table 4 below shows the final condition assessment results for the emergency inspections, which gives an idea of the amount of follow up work that might be required.

Table 4- EIP Condition Assessment Results

Emergency Dam Inspections Status - 11:30 10/10/13			
Condition Assessment Categories	Definition	Number	Percent of Total
Response Level 0 –	Safe for normal operation	130	63%
Response Level 1 –	Functional; some repairs needed; no dam safety concerns	62	30%
Response Level 2 –	Potential dam safety issue exists; needs immediate evaluation	15	7%
Response Level 3 –	Urgent; failure is imminent or in progress; notify 911 immediately	0	0%
	(207 dams to be inspected) Totals	**207**	**100%**

To have 207 dam inspection reports come in all at once, about 37 percent of which indicate some form of repairs are needed, over a geographical area covered by only four DSE's, was overwhelming and generated a monumental amount of follow up work.

The Colorado Dam Safety Branch and staffing are not set up to handle the huge influx of projects, owner questions, public questions, construction, etc. within such a short period of time. We are continuing to respond the best we can, with the unfortunate case being that those DSE's who were running around the most during the flooding, also are doing the heaviest lifting when it comes to the follow up. The most intense follow up to the immediate flooding response effort, which included transmitting the reports to all the owners, continued through about 45 days from the start of the event. On November 7, 2013 the DSB was pleased to announce that all emergency EIR's had been sent to their respective dam owners. This, however did not signal a return to "normal" operations. It was an important milestone, but it was just the beginning. At that point a full two months of a yearly schedule had been completely lost. Getting those two months back remains a work in progress, almost a year after the event.

During this time the most critical, high-priority projects were handled; which then transitioned to less critical projects and rehabilitation, with concurrent efforts including data collection and analysis, and professional incident reports for the dams that failed, which in some cases resulted in the need to participate in public meetings.

With most of the immediate follow up work generated by the inspection process and the event in general completed, the DSB continues to feel repercussions, and likely will for some time.

The response effort for this event had a significant impact on our 2013 inspection season, and carries over to 2014 as well. As is the case with the ongoing overall recovery efforts statewide, the DSB remains in recovery mode, with it being difficult to say when we will be back to business as usual.

All told, the initial response effort put forth by the DSB staff of twelve during the September 2013 flooding resulted in:

- Immediate calls to over 200 dam owners as the incident was unfolding

- Response to over 40 dam safety incidents in a 10-day period
- Response to continuous media and state leadership requests for information, as well as countless false incident reports
- Immediate perfunctory assessment of over 150 dams prior to deploying the EIP
- Daily staffing of five EOC's (3 manned, 2 virtual)
- Nine forensic investigations
- Oversight of the controlled breach of two dams, and emergency spillway cleanout and lowering of one other
- Organization of over 100 engineers who performed over 200 official emergency dam safety inspections

Over 70 dams spilled as a direct result of this event, keeping in mind that many of these reservoirs were significantly drawn down due to the time of year, and first had to fill before spilling; 11 EAP's were activated, thankfully all at the lowest level, typically described as the detection of an unusual situation that requires monitoring, and/or significant spillway flows; and twenty four Colorado counties were affected, as demonstrated by those that received the Presidential Disaster Declaration, shown in Figure 22.

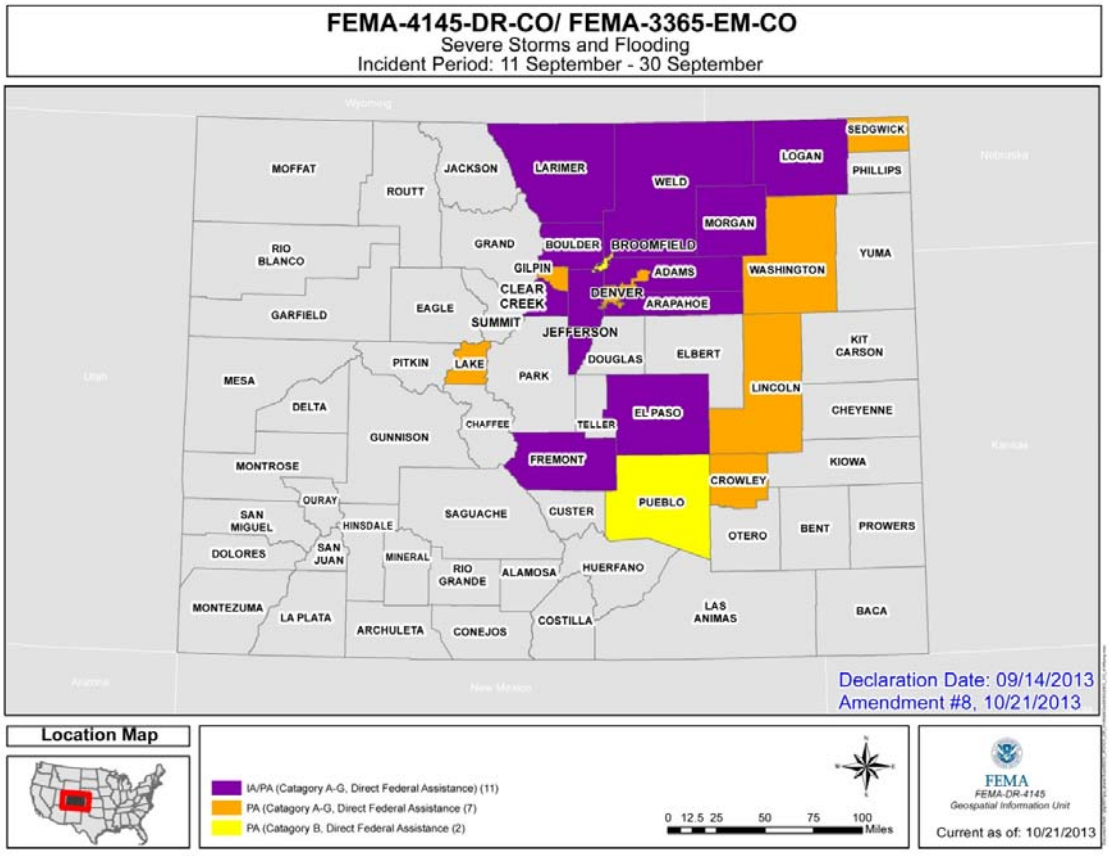


Figure 22 - Counties receiving the presidential disaster declaration as a result of the September 2013 Colorado flooding.

DISCUSSION/LESSONS LEARNED

Prior to this event, the Colorado Dam Safety Branch was reasonably confident in our incident response capabilities, given historical knowledge and experience with what we will now call “typical” incident response. However, this was unprecedented, and caught us unprepared to handle an event of this magnitude with such widespread consequences. By the end of the storm and out of pure necessity, we had developed an emergency response model that we believe can be applied to future widespread flooding situations, with the objective being to allow quicker organization and delegation of duties, and effective and efficient use of all resources available.

The trial and error process we went through in shaping this effort provided plenty of trials and plenty of errors by which to learn. In the hopes of capturing all that we did learn, the Dam Safety Branch is in the process of developing emergency communication guidelines for a more deliberate and effective (and less stressful) means of communication during the next dam safety incident in Colorado. One important lesson learned that will have a huge impact in the next widespread dam safety incident is the need for a separate Public Information Officer (PIO) to handle even just the media’s need for updates and requests. The time and energy it took to respond to this constant need inhibited our ability to respond where we could really provide the most value and highest resource. Even more importantly, we learned that effective communication *overall* is the key to effective emergency response.

Following the event, an after action review or ‘hotwash’ session for just the Dam Safety Branch was facilitated by members the Colorado Office of Emergency Management to capture lessons learned, processes or procedures that were missing, and ways in which the branch might be better prepared for the next dam safety incident that will surely come. Take-away’s from this experience include:

- Large dams functioned as intended due to design criteria based on high return interval events
- Smaller dams proved to be the biggest safety concern due to spillways that are sized for smaller events; a low hazard structure rating does not mean no hazard
- Increase awareness of programs or legislation that already exist within your own state to secure resources or assistance in the case of a widespread emergency
- Look outside your own state for help, both to gain assistance, and to provide valuable opportunity for experience to other programs; mechanisms are in place to allow other states to assist, e.g. Emergency Management Assistance Compact (EMAC)
- Promote internal awareness of resources available through the emergency management network and the process for garnering these (e.g. resources request process for access to heavy equipment, communication radios, transportation, etc.)
- Use common communication platforms (e.g. smart phones, social media, WebEOC, Google Drive, etc.)

- Increase awareness of our organization's capabilities (to the public, other state agencies, etc.)
- Always have on hand current contact information for emergency managers and dam owners
- Foster relationships between state dam safety engineers, emergency managers (local and state), and dam owners
- Develop lists of locally available resources (i.e. heavy equipment, materials, specialty equipment and/or expertise, etc.)
- Develop an internal Emergency Response Plan (ERP) to include how to organize internally, when and how to activate different support networks, when and how to procure resources, and emergency training
- Have a designated Public Information Officer (PIO) in the case of a widespread emergency to handle media requests, public inquiries, etc. while dam safety personnel are able to focus on the situation
- Call on internal resources sooner; it's better to have too much help than not enough
- Develop internal protocols for communication and the flow of information during emergency events
- Development a permanent volunteer consultant database, certification, implementation process, etc.
- Provide public education regarding dam safety vocabulary
- Develop a method for internal emergency notification and guidelines for availability (e.g. middle of the night phone calls when cell phone ringers or the phones themselves might be off…)
- Develop and maintain current WebEOC system knowledge
- Develop and maintain current understanding of emergency management functions and our role
- Establish communication lines with federal agencies like the U.S. Army Corps of Engineers, U.S. Bureau of Reclamation, etc.
- Tools that allow the central coordination of information are extremely useful (Google Drive)
- Educate and familiarize dam owners with their Emergency Action Plans
- Develop (or fine tune) methods for real time monitoring using radar overlays on basins compared to design events
- Have a "go kit" at work or home packed with muck boots, a change of clothes, flashlights, and other field tools
- Develop ways to interface more with emergency managers, e.g. inviting them on inspections of high hazard dams

- Maintain current contacts for non-jurisdictional dams in our database
- Work on capturing all “illegal” or “non-roster” dams
- Hold more regional/basin-wide dam safety exercises and discussion
- Develop general email addresses, e.g. Chief of Dam Safety, etc.
- Relationships were huge: within the branch, with DWR water commissioners, with past DWR employees, with local engineers, with the meteorological community, and with dam owners and caretakers
- Access to electronically stored files proved efficient and extremely useful
- Clean up our database
- Repercussions go on longer than might be anticipate, be patient with your own programs recovery.
- Incidents that did occur on high and significant hazard dams were caused by embankment saturation due to the heavy and sustained rain, and uncontrolled inflow from ditches.
- Site access – understand your agencies authority / official capacity as defined by statutes.

The 2013 flooding event was the 7th historic flood in Colorado since 1902, suggesting a frequency of about once every 16 years. This suggests that every dam safety engineer planning on a career of 20 years or more can reasonably expect to be involved in such an event and therefore should make preparations for it. The Colorado DSB was not as prepared as we could have been at the onset of this event. Through application of various lessons learned before and during the event, we made it through successfully. Like the dams exposed to previously unseen loadings, members of the DSB were tested and stressed. We wonder, could we have reduced that stress and maybe accomplished more had we been more diligent with our planning and preparations? We are hopeful other state dam safety programs will take the lessons and information from our shortcomings and our successes and do their best to protect the safety of their citizens the next time a historic flood event hits their state.

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