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**All images courtesy of [Ayes Associates](#)*

Digital Imaging Makes Colorado Flood Imagery More Valuable

Torrential rains began falling on Colorado the week of Sept. 9, 2013, and by the weekend, deadly flood waters had inundated thousands of square miles along the Rocky Mountain Front Range from Denver up to Fort Collins and spreading into the northeast part of the state.

Boulder County alone received a year's worth of rain in five days. Statewide, three major rivers – the South Platte, St. Vrain and Big Thompson – are believed to have exceeded their 100-year flood levels while others hit the 50-year mark. One Colorado mountain town that was effectively cut off from the Front Range by flooded roads and washed-out bridges was Steamboat Springs. Ironically, the famous ski resort was playing host that week to the Colorado Association of Storm Water and Floodplain Managers Conference. Some

participants, who represented the cities and counties being hit hardest by the historic event, were prevented by the storm from immediately returning to their duties.

Most of the storm water and floodplain managers in attendance, however, remained in close communication with their offices by phone and email. They quickly realized that each of their jurisdictions was part of a much larger regional catastrophe that would require careful coordination among them. Within hours, they turned their isolation into an advantage, sharing information and planning cooperative assessment activities.

Also working in favor of the stranded flood hazard specialists was the fact that representatives from [Ayes Associates](#), an engineering and geospatial consulting firm, were marooned along with them. Based in Wisconsin, with an office in Fort Collins, Ayes had provided extensive aerial mapping services in the previous 12 months to several cities and counties that had formed a consortium for floodplain management activities in the Colorado Front Range.

- when it has to be **right** 

As the magnitude of the disaster became more apparent – and the rain continued to fall – four organizations in attendance called a hasty meeting with the Ayres team at the conference hotel late on Thursday, Sept. 12. Personnel from the Colorado Water Conservation Board, Weld County, and the cities of Fort Collins and Loveland wanted to know if an aerial imaging mission could be conducted at or near peak flood stages on Saturday, Sept. 14.

“We had purchased our first aerial sensor, a [Leica RCD30](#), the year before and used it for Colorado floodplain mapping work in fall 2012,” said Jason Krueger, an Ayres Project Manager who had flown from Wisconsin to attend the conference.

“Unfortunately, our RCD30 was deployed in another part of the country and was not available the week of the Colorado floods.”

For years prior to buying the Leica camera, Ayres had used airborne imagery and photography on numerous projects. Sub-contracting for aerial services was second nature to the firm, and Krueger was able to contact a long-time business partner that operated a [Z/I Imaging DMC](#) digital mapping camera. Remarkably, the sensor was available in the



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Denver area. Weather permitting, imagery could be collected with the DMC on that Saturday. “Time was of the essence,” said Krueger. “We wanted to collect near peak flood levels.” Mapping the high-water line at peak flow during a flood is critical in assessing the full scope of damage so that recovery can be prioritized and planned.

But peak-flow data also helps prepare for the next flood, explained Dusty Robinson, an Ayres Civil Engineer. Knowing where the water actually goes allows floodplain managers to compare their maps against reality. And if needed, they can re-calibrate their hydraulic models based on the findings, he said.

As Krueger and Robinson began planning the flood acquisition with guidance from organizations at the conference, they realized the availability of the DMC camera was quite a fortunate occurrence. Although both the RCD30 and DMC units are digital frame sensors, the large-format DMC covers a bigger ground footprint in one image than the medium-format RCD30.

“With the DMC, we could capture more imagery in a shorter period of time,” said Krueger, noting this would work in their favor because weather reports for the target acquisition



The Cache la Poudre River before (left) and after (right) the flooding. The before image was captured with the Leica RCD30 medium-format digital camera, while the after image was captured with the Z/I Imaging DMC digital mapping camera.



Damage from the flooded South Platte River is clearly visible in these images captured with the DMC camera.

day predicted only brief breaks in the clouds and rain. The consortium wanted a lot of ground to be imaged in possibly just a few hours.

Planning for a Window

On Friday, Krueger and Robinson made a break for Fort Collins so they could plan the flight lines in Robinson's office. Driving a circuitous route from Steamboat through Wyoming, they were halted by closed bridges across the Poudre River from Fort Collins in Laporte. Just a few miles from the Ayres office, they planned the flights using Leica MissionPro software and Google Earth on a laptop computer in a coffee shop that Friday night.

The flight plan focused on the South Platte River and its major tributaries, the Cache la Poudre and Big Thompson, because they cover such a large portion of the northern Front Range area and carry water through large population centers. The South Platte flows north through downtown Denver and up to Greeley where it merges with the Cache la Poudre before continuing northeast. The Big Thompson passes through the city of Loveland and into the South Platte south of Greeley. Also on the flight plan were Boulder Creek and the St. Vrain River north of Boulder.

"The plan was to fly the South Platte and its tributaries at two altitudes to capture DMC imagery at 12- and 18-inch ground sample distance (GSD)," said Krueger.

When Saturday arrived, the local weather forecasts proved correct. Much of the northern Front Range area received a four-hour respite from the downpours. While the weather still remained overcast with high clouds, the flight team went to work flying the Z/I Imaging DMC camera aboard a twin-engine Piper Cheyenne II. Again, the availability of the DMC sensor proved fortuitous. The digital camera's high dynamic range and forward motion compensation using time-delayed integration enable it to collect clear, crisp imagery even in low-light conditions under high clouds.

"The acquisition conditions were not ideal," said Krueger.



Greeley, Colo., before (left) and after (right) the flooding. The before image was captured with the Leica RCD30 medium-format digital camera, while the after image was captured with the Z/I Imaging DMC digital mapping camera.

The initial altitude was 10,000 feet AGL as the aircraft began the first flight lines at 12-inch GSD over the South Platte River from Denver up to Greeley and northeast to Sterling, Colo. That section totaled 230 linear miles, and with the ceiling dropping, the crew knew the 18-inch imagery at the higher altitude couldn't be collected in time. They elected to continue acquisitions at 12-inch GSD over as much of the remaining target area as possible, eventually capturing imagery for the Poudre River in Fort Collins and Big Thompson River in Loveland.

"We weren't able to get everything we wanted because it was a short window," said Ayres' Robinson. "It started clouding up before we could get the St. Vrain and Boulder Creek."

In total, however, the DMC camera collected 608 images on 25 flight lines covering 410 linear miles in less than four hours. The data sets were flown that night to Ayres' Madison, Wisc., office where image processing began immediately in the Intergraph ImageStation suite of software. Remarkably, the firm was able to start delivering imagery with minimal processing by Tuesday through its Fort Collins office to the participants.

"They were raw .tif files that weren't georeferenced or orthorectified. We also created prints for the people [making

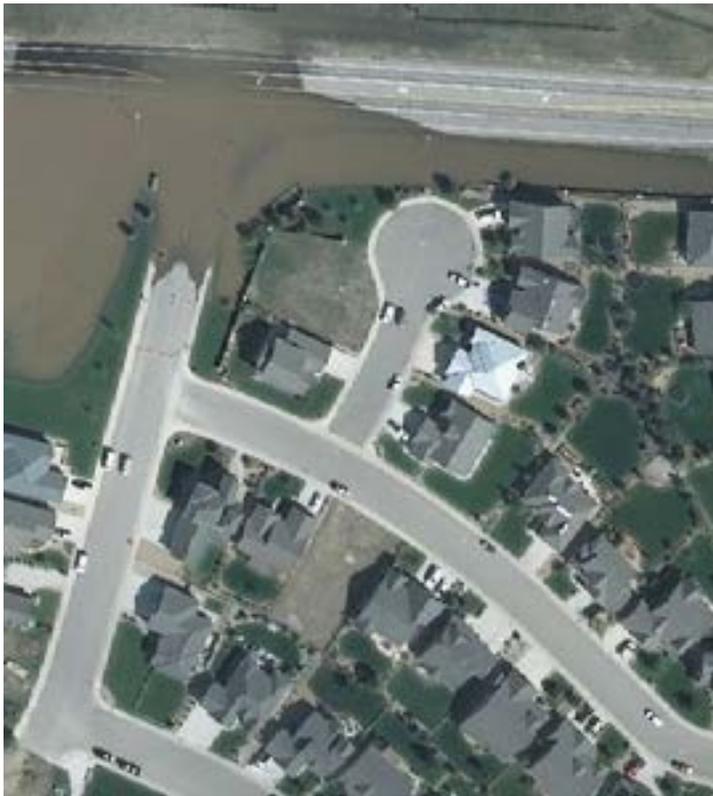
assessments] in the field," said Robinson. "The first images were delivered to the Colorado Water Conservation Board, Weld County, and cities of Loveland and Fort Collins."

Over the next few weeks, Ayres delivered fully processed orthorectified images meeting 1"=200' map scale standards. The firm also built a digital terrain model for the captured flood plains and georeferenced mosaic of the entire project area. The Ayres Fort Collins office provided engineering and field support in the weeks after the floods.

Putting Images to Immediate Use

The Colorado Water Conservation Board, which is the primary water planning body for the state, was among the first to receive DMC imagery just a few days after it was acquired. Kevin Houck, Chief of the Watershed and Flood Protection Section, said it was extremely valuable to get the imagery so fast. Although the peak may have passed, much of northeastern Colorado was still under water and assessment was underway.

"The crispness of the images made it easy to pick out details and portray what was happening on the ground," said Houck. "Real-time information [like the images] is what decisions are made on."



“As an engineer, I love to have this kind of detailed information because it really helps identify where potential problems may be.”

used to assess how well the city’s flood models held up to reality and to pinpoint any damage inflicted upon flood protection structures. Brian Varrella, the Utilities’ Floodplain Administrator, was amazed at the detail and vibrant colors that he saw in the imagery despite the hazy weather conditions. Varrella scrutinized the DMC imagery to assess flood water flow and river bank damage.

“What I enjoyed most as a hydraulic engineer is being able to see the fastest and most detrimental velocities within the watershed in real time,” said Varrella.

Varrella explained that the resolution in the color images was good enough to pick out whitewater plumes and turbulence in the Poudre River, especially where the water had flowed over its banks. He compared these features against his existing models to determine if there were places in the river where flow velocity changed unexpectedly, potentially causing damage to the embankment. Such information will enable Fort Collins to fine-tune its hydraulic models to better predict where the river bank should be enforced to prevent overflow and damage in future events.

Several of the organizations that received the first batches of imagery posted them on web portals for access by the public. Fort Collins’ Varrella hopes the visual impact of DMC flood images will compel the public to make informed choices as they begin to rebuild their homes and businesses after the devastating Colorado floods of 2013.

For more information about Ayres Associates, visit www.ayresassociates.com. To learn more about airborne sensor solutions, visit www.leica-geosystems.us.

In Weld County where the Poudre and South Platte Rivers had both swelled well beyond their banks around Greeley, the Public Works Department immediately put the imagery to work in damage assessment. Responsible for thousands of miles of gravel roads in the rural county, the department relied on the images to determine where roads had been washed out. In addition, they pinpointed the hardest hit developed areas so that crews could be dispatched to inspect homes and buildings to ensure they could be occupied.

“As an engineer, I love to have this kind of detailed information because it really helps identify where potential problems may be,” said Clay Kimmi, Weld County Public Works Senior Floodplain Engineer.

Kimmi explained that his team examined the images to prioritize road repairs based not just on the degree of damage but by each road’s importance to commerce. Because the floods occurred at harvest time, Weld County placed a high priority on roads that connected the county’s many farm communities with key transportation hubs where their crops would be transported to agriculture markets.

For Fort Collins Utilities, the imagery was primarily