MEMORANDUM

To: Virginia Gazzetti and Kelly Watson, Boulder County Community Planning and Permitting (CPP)

cc:

From: Cameron Wobus and Laura Keys, Lynker Technologies

Subject: Boulder County FHZ Analysis

Date: June 30, 2022

The Boulder County Community Planning and Permitting Department ("CPP") is responsible for floodplain management within unincorporated Boulder County. Part of this role includes understanding, monitoring, and communicating flood risk for the residents of Boulder County. Recently, Boulder County was chosen as a pilot site for implementing the State of Colorado's fluvial hazard zone (FHZ) delineation protocol, which identifies areas where erosion and sedimentation hazards are most likely to occur based on a range of hydrologic and terrain characteristics. As a pilot study site, many of the fluvial hazard zones in the County's streams and rivers have now been delineated.

Lynker was retained by Boulder County to use its new FHZ delineation data to develop a better understanding of the County's risks from fluvial hazards, and to help CPP incorporate this technical information into community floodplain risk communication, management, and planning activities. Lynker also assisted CPP with a desktop-level external QA/QC of the FHZ boundaries in Boulder County, as suggested by the FHZ delineation protocol (Blazewicz et al., 2020), and investigated channel migration within Boulder County through the use of LiDAR-based elevation datasets. This memorandum summarizes the technical analysis and results of this project. A parallel, collaborative effort between Lynker and CPP generated a storymap that conveys more general information about fluvial hazards for the residents of Boulder County.

This report is accompanied by a geodatabase containing all of the spatial data included herein.

Analysis and Results

Our activities under this project were developed to translate FHZ delineations for Boulder County into information that CPP could use to understand and quantify risks from fluvial hazards, and to communicate those risks to residents. To that end, we focused our work on 1) geospatial analysis to summarize differences between the mapped FHZ and other delineations of fluvial risk in Boulder County; 2) spatial overlays to quantify the number of homes and assets at risk from fluvial hazards in Boulder County; and 3) retrospective analysis of the 2013 floods to evaluate how the extent of and damage from this event relate to the FHZ and other representations of flood risk.

Across all of these activities, we focused our analysis only on the areas where the FHZ was delineated in Boulder County. Thus, we clipped the spatial domain for all quantitative analyses to the limits of the FHZ delineations that were provided to CPP.

1. Spatial Comparisons of the FHZ and Other Metrics of Flood Risk

The FHZ provides only one of several metrics of flood risk in Boulder County. Delineations that are more commonly used by Boulder County CPP in a regulatory context include the regulatory floodway, 100-foot setbacks from active channels, and the "100-year" (1% annual exceedance probability, AEP) floodplain. Each of these flood risk delineations provides a different picture of flood risk within Boulder County. To help both CPP and the residents of Boulder County understand these different depictions of risk, we developed maps highlighting similarities and differences among these delineations. **Figures 1 and 2** provide comparisons of how each of these

delineations of flood risk relate to the 2013 flood extent in two parts of Boulder County. Blue areasdenote “hits” where the delineation matched with the presence of inundation. Red areas denote “misses” where actual inundation occurred in 2013 that was not anticipated by the respective delineation. (Note: the 2013 flood extents are based on aerial imagery from after the flood and may not always represent the actual inundation boundary.)

Figure 1. Comparisons of flood risk delineations along Left Hand Creek, with “hits” (blue) and “misses” (red) compared against 2013 flood inundation along Left Hand Creek A) FHZ, B) Floodway, and C) combined 100-year floodplain (combining 2013 and preliminary 2019 FIRMs). Note that 2013 flood inundation extent data was missing for one large stream segment, which is the cause for the large gap in each image.

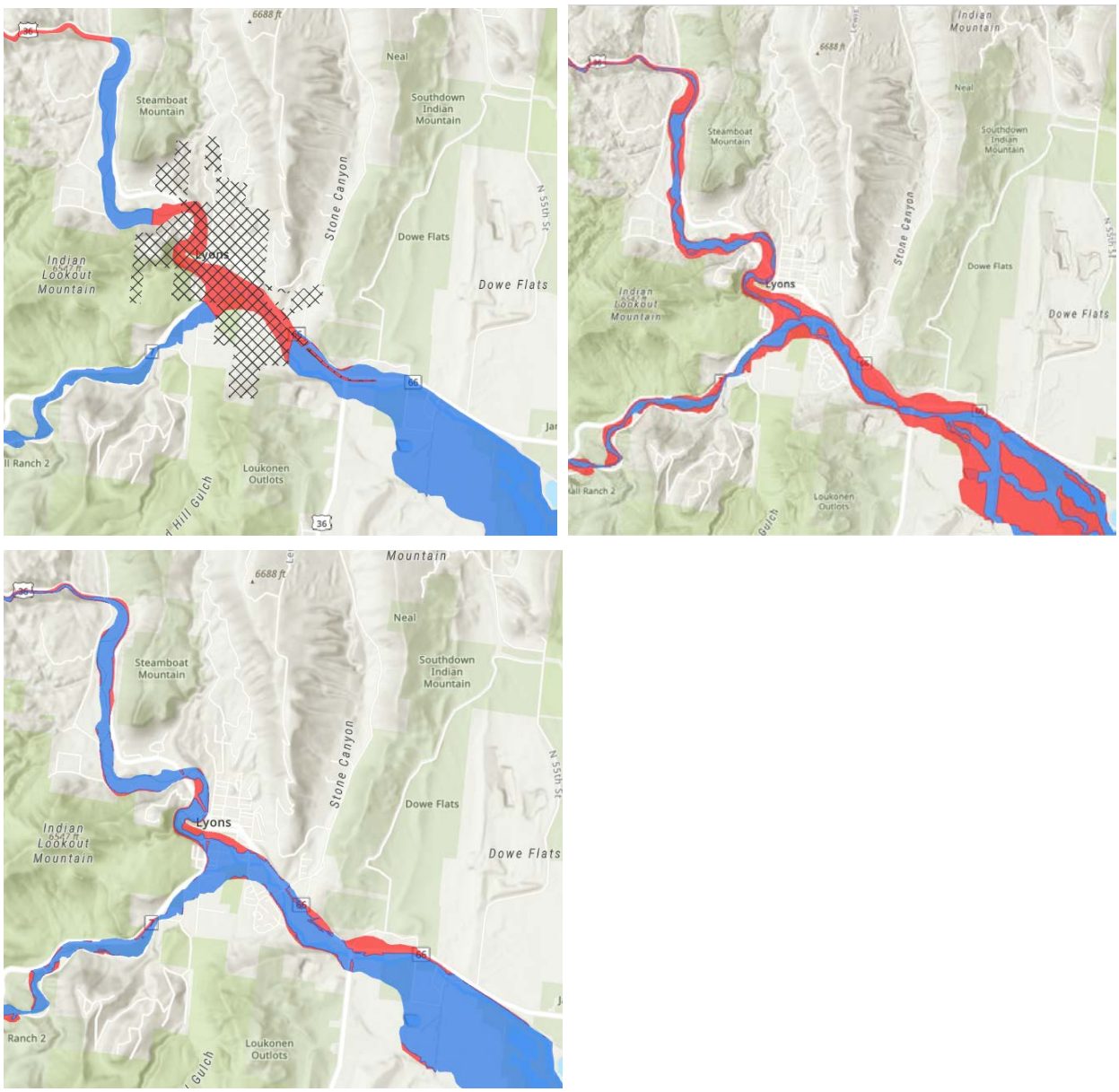


Figure 2. Comparisons of flood risk delineations, with "hits" (blue) and "misses" (red) compared against 2013 flood inundation along St. Vrain Creek. A) FHZ, B) Floodway, and C) combined 100-year floodplain (combining 2013 and preliminary 2019 FIRMs). Crosshatching in the FHZ image denotes areas that were excluded from the FHZ maps (FHZ mapping was focused on unincorporated Boulder County, which excludes Lyons city limits).

Qualitatively, as shown in Figures 1 and 2, the FHZ provides a higher degree of correspondence to the 2013 flood extent than either the floodway or the 100-year floodplain. Specifically, the floodway and 100-year floodplain each underestimate the spatial extent of flooding when compared to the 2013 floods. This is not unexpected: the fluvial hazard zone is broadly defined as "the area that a stream has occupied in recent history, may occupy, or may physically influence" (CWCB, 2020) as it transports its load of water, sediment and debris. Because the 2013 flood in Boulder County was a major event characterized by significant volumes of water and sediment, the flood occupied nearly all of the FHZ as it carried this load from the foothills to the plains.

While the maps in Figures 1 and 2 provide a visual depiction of how the different flood risk boundaries in Boulder County compare to the actual extent of the 2013 flood, **Table 1** provides a more quantitative summary of how these different metrics of risk compare to one another. To generate Table 1, we clipped each of the regulatory

floodplain boundaries (floodway and 100-year floodplain) to the spatial extent of the FHZ, and tabulated the number of acres within the FHZ that are also contained within each regulatory boundary. Based on these data each of the regulatory floodplains is smaller than the FHZ, but the combined 2013 and preliminary 2019 100-year floodplain dataset provides the closest correspondence to the FHZ in terms of total acres of over lap.

Delineation Dataset	"Hits" area, confined to FHZ (acres)	"Misses" area, confined to FHZ (acres)	Percent correspondence of "hits"
FHZ	6,093	-	-
Floodway	2,022	4,071	33%
100-year combined floodplain	5,421	671	89%

Table 1. Comparison of areas of "hits" and "misses" against 2013 flood inundation for the FHZ, the regulatory floodway, and the 100-year floodplain. The areas are compared only within the FHZ to provide consistency among the different spatial extents and availabilities.

Collectively, the overlays between the FHZ and other metrics of flood risk demonstrate the following:

- Each of the regulatory flood boundaries used by Boulder County underestimates the area at risk of flooding when compared to the 2013 flood extent;
- Compared to the regulatory flood maps, the FHZ has a smaller "miss" rate when compared to the 2013 flood extent;
- The combined 100-year floodplain (combining 2013 and preliminary 2019 FIRMs) has approximately 90% overlap with the FHZ in areas where both maps are available.

2. Quantification of Homes and Assets at Risk

One of the key objectives of both FHZ and regulatory floodplain maps is to communicate risk to homeowners and community planners so they can both be aware of, and prepare for, future flood events. Toward this end, we overlaid building footprints, roads and bridges, culverts, and other County infrastructure with each of the different depictions of flood risk described above. The goal of these spatial analyses was to evaluate the number and nature of these assets at risk due to flooding and fluvial hazards. (Note: building flootprints are generated automatically from aerial imagery and may not be completely accurate.)

Figure 3 shows an example of building footprints within the FHZ and each of the other flood risk boundaries mapped along a segment of North St. Vrain Creek, and Figures 4-5 provide examples of bridges, roads, and culverts intersecting with each of these flood risk boundaries along two segments of Lefthand Creek. Table 2 tabulates the number of buildings, bridges and culverts, and miles of roads contained within the FHZ and each of the regulatory boundaries commonly used by CPP.

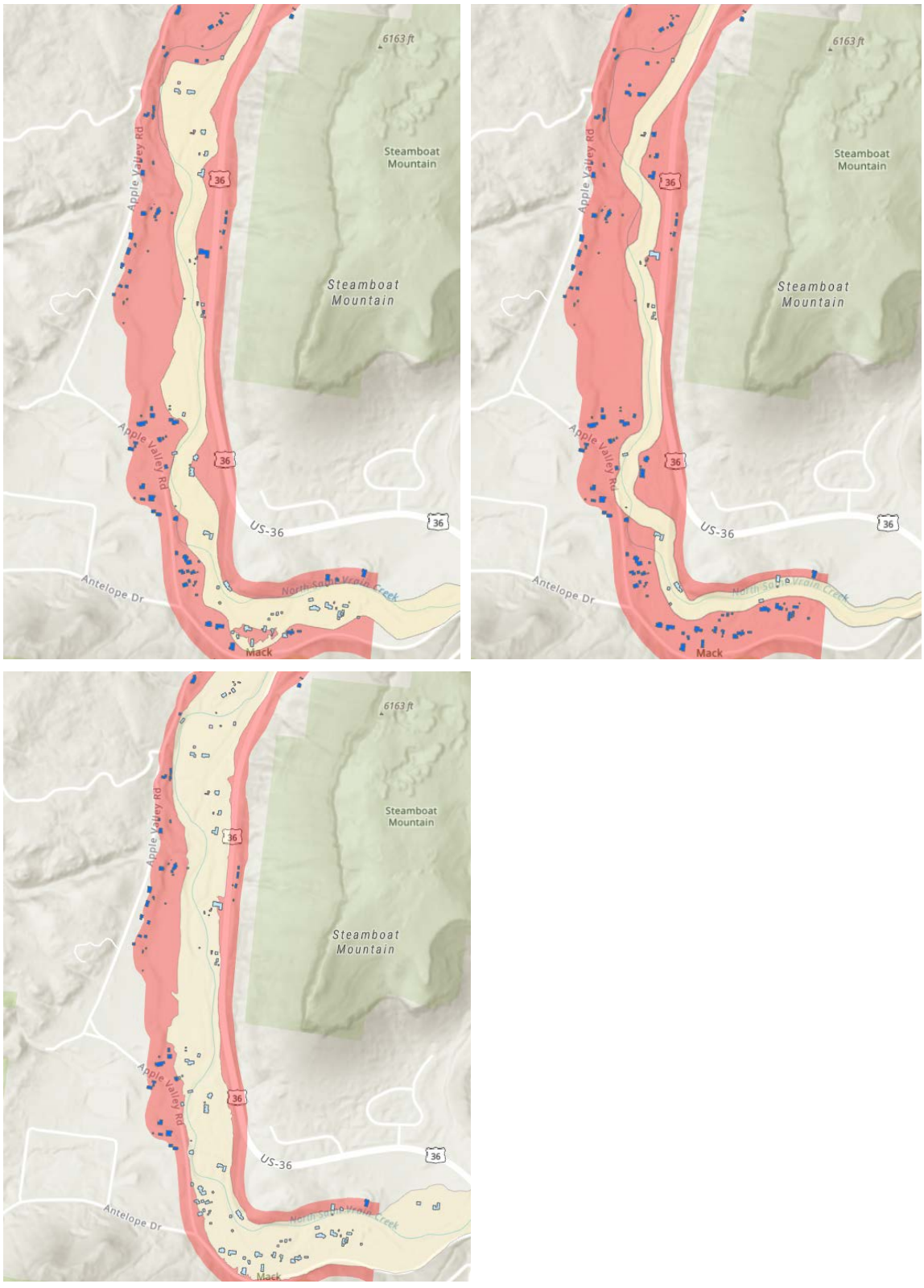


Figure 3. Buildings located along North Saint Vrain Creek in the FHZ (buildings in dark blue, zone in red) compared to buildings located in various regulatory zones (buildings in light blue, zone in light yellow). A) buildings in Floodway, B) 100-foot setbacks, and C) combined 100-year floodplain.

As shown in Figure 3 and summarized in **Table 2**, the FHZ encompasses many more buildings than the other regulatory flood risk boundaries, illustrating the extent to which there are properties at risk outside of these regulatory zones. There are a total of 1,979 buildings within the newly mapped FHZ in Boulder County. Of these, 1,604 buildings, or 81%, are outside of the floodway, and 744 buildings, or 38%, are outside of the FEMA combined 100-year floodplain. As noted above, the FHZ is defined as the area that rivers have occupied in the recent past and may occupy in the future. Thus all of the properties within the FHZ are at some risk of impact from flooding, erosion and sedimentation, or debris hazards. However, properties that lie outside the regulatory floodplain are not required by law to purchase flood insurance. Homeowners whose properties fall into the buffer between the regulatory floodplain and the edge of the FHZ may therefore bear a unique financial risk relative to those inside more traditional flood risk boundaries. Section 3 of this report describes these risks in more detail, in the context of actual losses during the 2013 flood.

The distribution of infrastructure like roads, bridges and culverts also illustrates the degree of risk outside of traditional regulatory boundaries. There are a total of 38 miles of roads and 409 bridges and culverts within the mapped FHZ boundaries of Boulder County. Of these, 31 miles of roads, or 82%, are outside of the floodway, and 19 miles of roads, or 50%, are outside the 100-year floodplain. 304 bridges/culverts, or 74%, are outside of the floodway, and 152 bridges/culverts or 37%, are outside of the 100-year regulatory floodplain.

Figure 4. County infrastructure (bridges, culverts, and roads) located along Left Hand Creek in the FHZ (infrastructure in dark blue, zone in red) compared to infrastructure located in various regulatory zones (infrastructure in light blue, zone in light yellow). A) Floodway, B) 100-foot setbacks, C) combined 100-year floodplain.

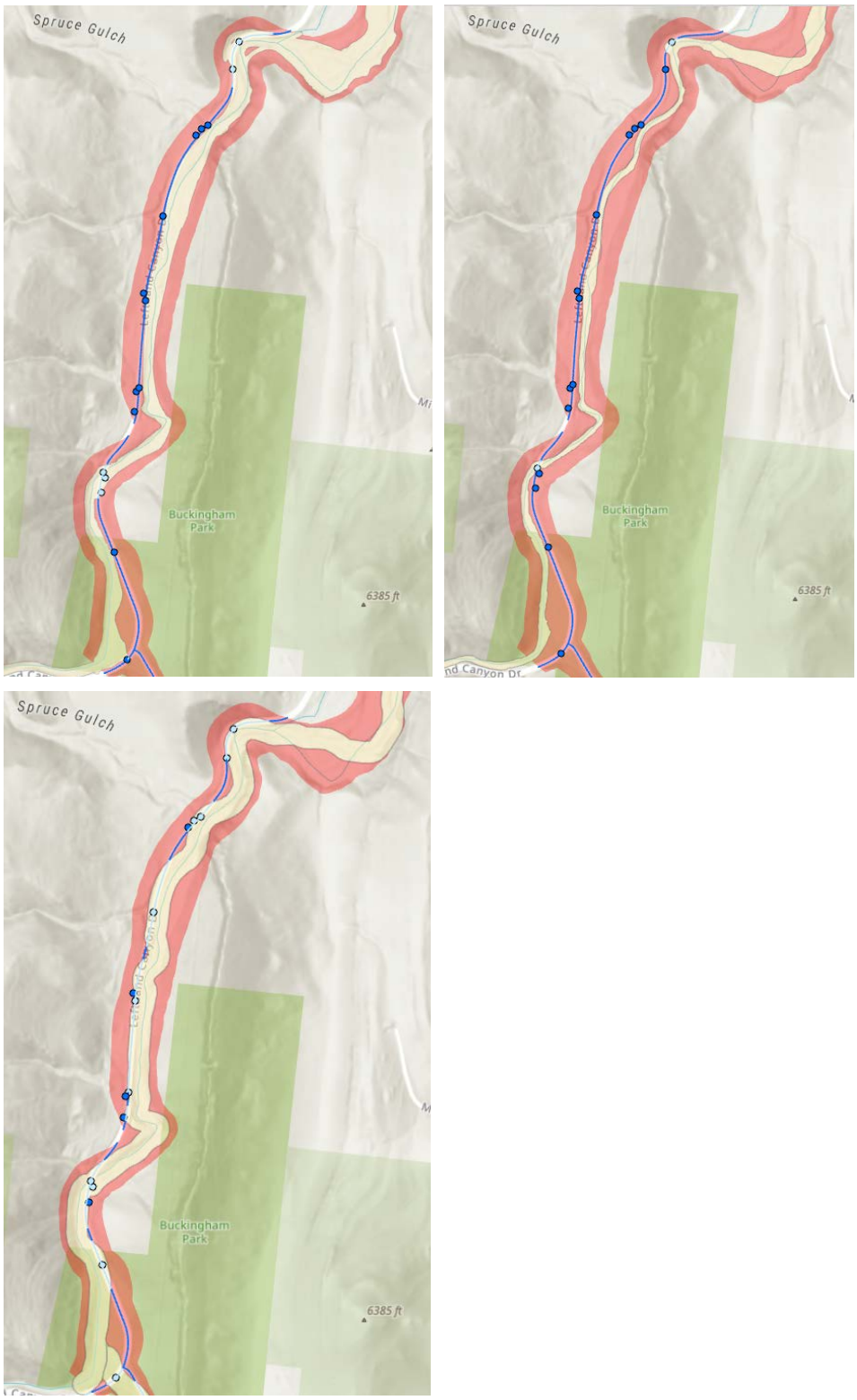


Figure 5. County infrastructure (bridges, culverts, and roads) located along Left Hand Creek in the FHZ (infrastructure in dark blue, zone in red) compared to infrastructure located in various regulatory zones (infrastructure in light blue, zone in light yellow). A) Floodway, B) 100-foot setbacks, C) combined 100-year floodplain.

Table 2. Infrastructure within the FHZ but outside of specified regulatory boundaries

Zone	Building polygons in FHZ but outside zone	Bridges/culverts in FHZ but outside zone	Road miles in FHZ but outside zone
Floodway	1,604 (81%)	304 (74%)	31 (82%)
Setbacks (100 feet)	1,778 (90%)	360 (88%)	34 (89%)
Combined Regulatory 100-year floodplain	744 (38%)	152 (37%)	19 (50%)

3. Retrospective Analysis of the 2013 Floods

The summary statistics above illustrate the degree to which roads, bridges and properties are exposed to fluvial hazards within Boulder County. While the 2013 flood was a reminder to Boulder County that floods can extend beyond the boundaries of regulatory floodplains, it also demonstrated that damage from flooding, while not always constrained by regulatory floodplain boundaries, tends to be more concentrated closer to active riverine channels than farther from those active channels. In other words, while the FHZ delineates a broader zone of exposure to fluvial hazards than that contained within the other regulatory boundaries, the degree of risk remains substantially higher inside of the regulatory floodplain boundaries than outside.

A retrospective analysis of property damage following the 2013 floods illustrates this point. Figure 6 shows data from post-disaster Substantial Damage Estimate (SDE) reports overlaid with each of the regulatory flood zones. The Floodway and 100-foot setback areas do not sufficiently cover many properties that sustained up to 100% damage, but all of the points with SDE reports fall within the FHZ. The 100-year floodplain, which includes the floodplain mapped after the 2013 flood, also appears to cover the points that sustained damage in this area on the North Saint Vrain, though the FHZ has a wider coverage area.

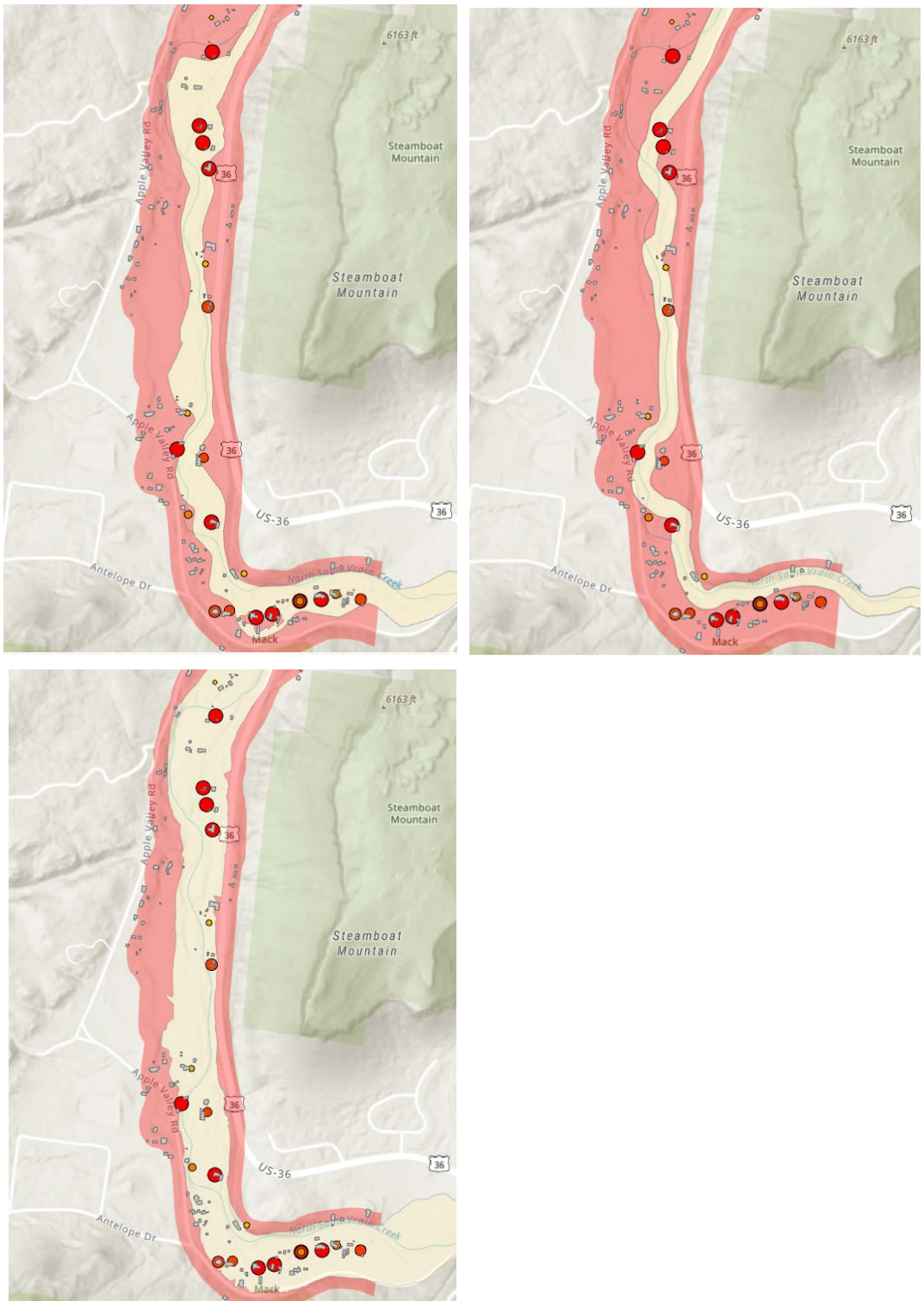


Figure 6. Damage estimates from the 2013 floods along North Saint Vrain Creek, with larger redder points meaning more complete damage and smaller orange and yellow points meaning less damage. The damage estimates are shown overlaid with the various regulatory zones (light yellow) and the wider FHZ (light red). All building footprints in the FHZ are shown in light grey. A) Floodway, B) 100-foot setbacks, C) combined 100-year floodplain.

Figure 7 shows the SDE information graphically, illustrating the distribution of 2013 damage data within the FHZ and each of the different regulatory boundaries within Boulder County. Within the area of the mapped FHZ in Boulder County, there are a total of 59 properties that sustained damage and reported this information on SDE reports. Of these, 30 properties (51%) were within the floodway. These properties sustained losses ranging from 10% to 100%, with an average loss of 59%. 12 properties (20%) were outside of the floodway but inside the 100-year floodplain. Those properties also sustained losses ranging from 10% to 100%, with an average loss of 49%. Finally, seven properties (12%) were within the FHZ but outside of all regulatory boundaries. Those properties sustained losses ranging from 20% to 50%, with an average loss of 34%.

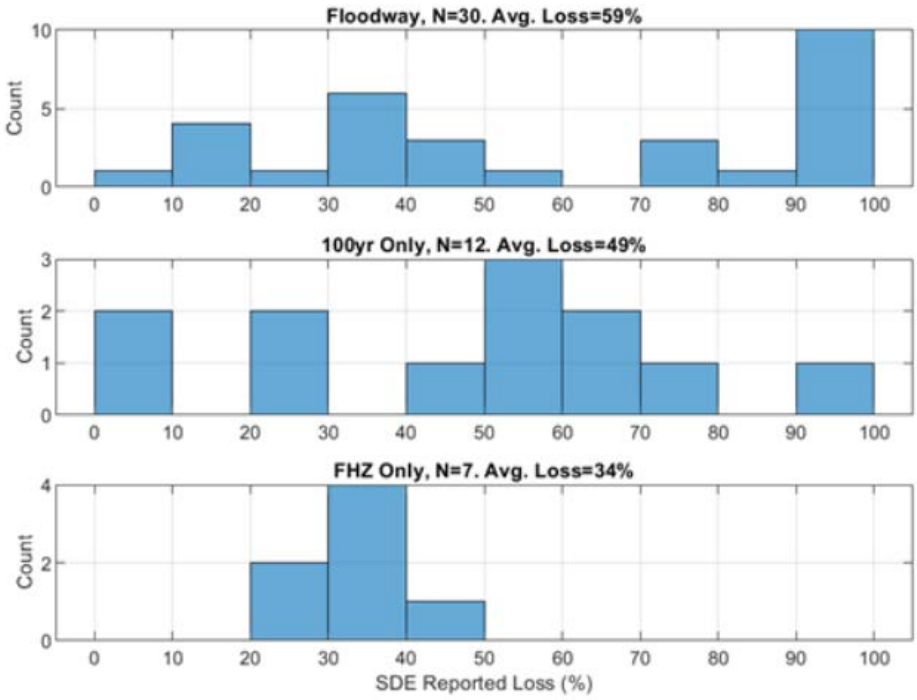


Figure 7. Distribution of all property damage estimates from the 2013 floods within the FHZ based on their location relative to regulatory boundaries A) properties within the floodway, B) properties outside the floodway but within the 100-year floodplain; C) properties outside all regulatory boundaries but within the FHZ.

Collectively, the information contained in Figures 6 and 7 demonstrate that Boulder County properties that lie within the FHZ but outside of regulatory boundaries like the floodway and the 100-year floodplain are at potential risk of damage from large flood events. However, the degree of risk is not uniform within the FHZ: more than half of the homes in the FHZ that reported damage from the 2013 floods were within the floodway, and nearly three quarters of the damage reports came from homes within the 100-year floodplain. While the FHZ delineates a broader zone of flood risk than these regulatory boundaries, the probability of a home sustaining damage from flooding, and the degree of damage that is likely to be sustained, increases with proximity to the active stream channel and associated mapped regulatory floodplains.

4. Post-2013 Channel Change

Boulder County provided Lynker with LiDAR datasets that were collected in 2013 after the Boulder County flooding and an updated one collected in 2020. We analyzed differences in the datasets and found that the stream channels exhibited high amounts of migration and dynamism over the seven years, during which time no major floods occurred. Such channel movement can be seen in the example in Figure 8, where a clear shift in Boulder Creek's stream path is visible in the eastern section of the image.

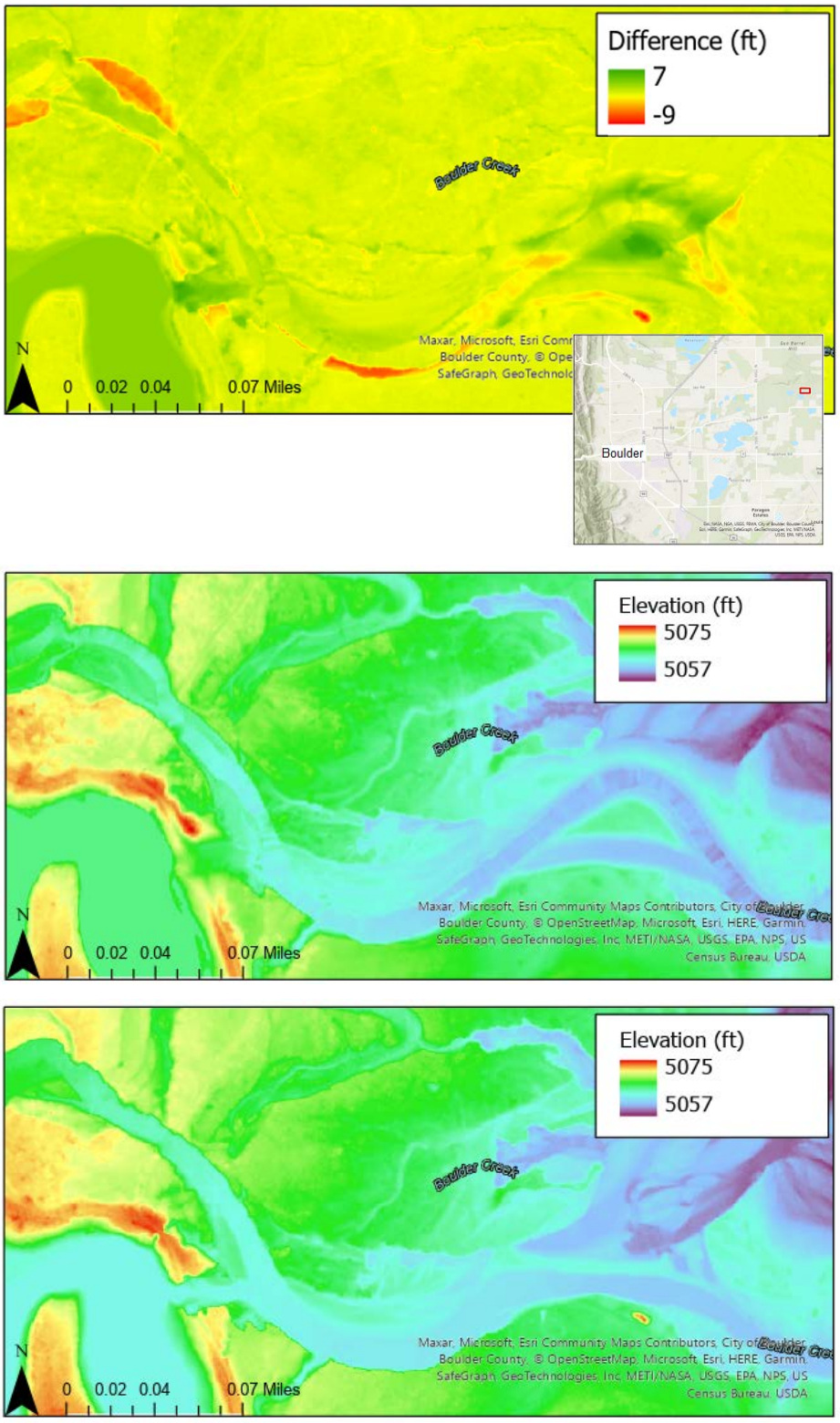
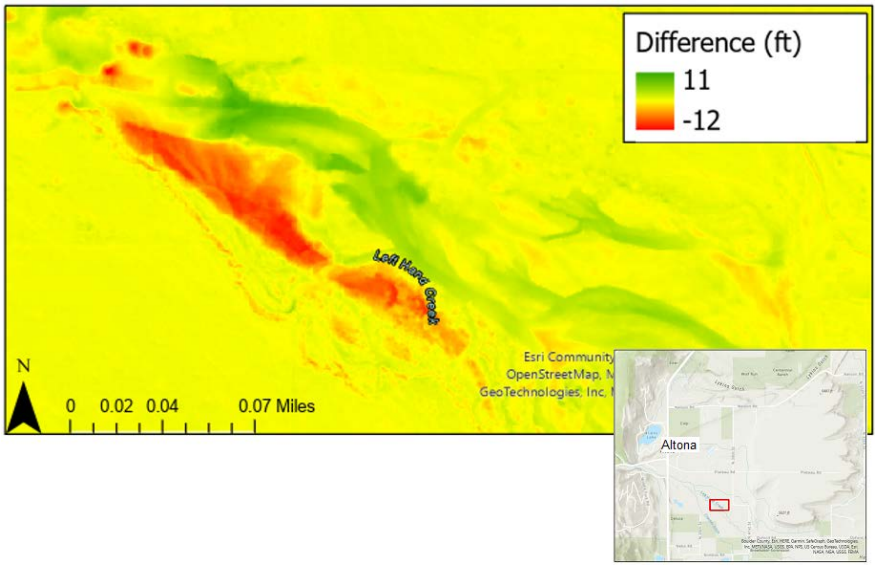
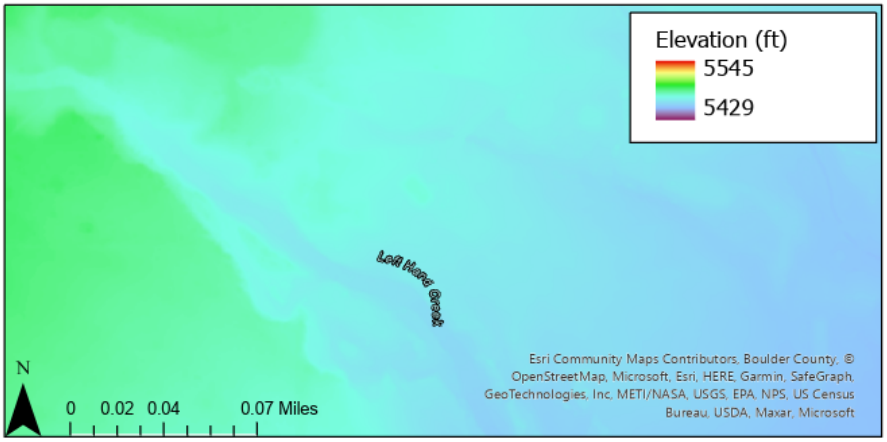


Figure 8. Channel movement along Boulder Creek. Top: Difference between 2020 and 2013 LiDAR data, with location shown relative to the City of Boulder in red rectangle. Positive values indicate higher elevation in 2020 than in 2013, and negative values indicate lower elevation in 2020. Middle: 2020 elevation data. Bottom: 2013 elevation data.

Similarly, **Figure 9** shows sediment movement between 2013 and 2020 across the plains area of Left Hand Creek. A similar pattern emerged generally across the plains areas of the FHZ, wherein streams in 2013 appeared to have a more braided appearance with spread-out fans of sediments, which then collated into a more singly-defined channel in the 2020 dataset.





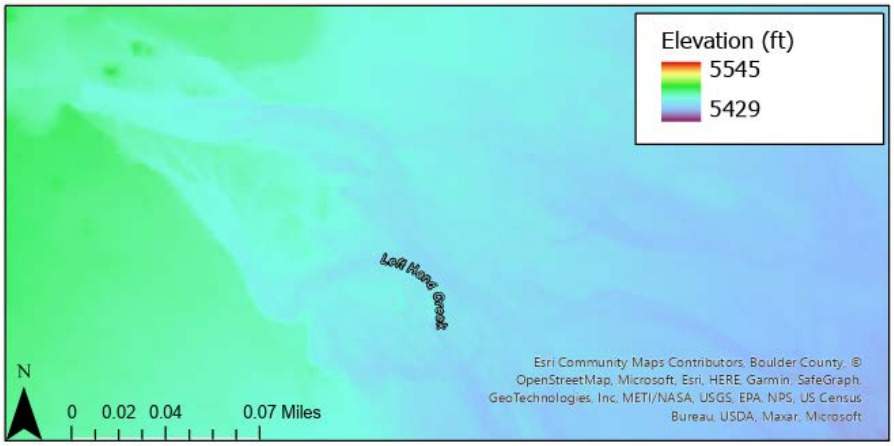


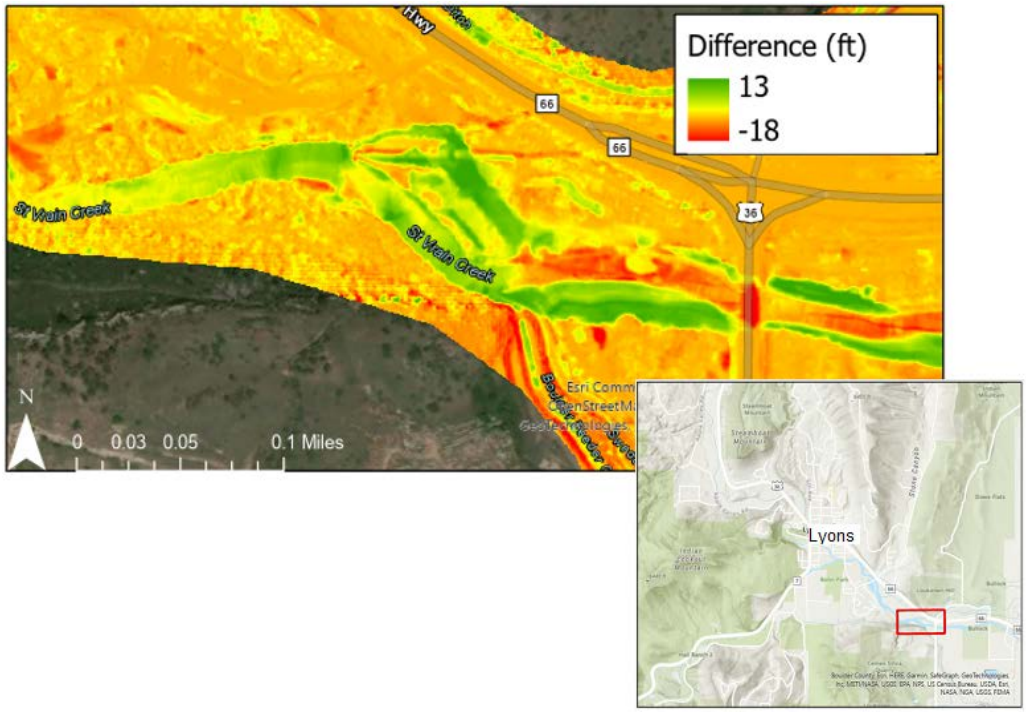
Figure 9. Channel movement along Left Hand Creek. Top: Difference between 2020 and 2013 LiDAR data, with location shown relative to Altona in red rectangle. Positive values indicate higher elevation in 2020 than in 2013, and negative values indicate lower elevation in 2020. Middle: 2020 elevation data. Bottom: 2013 elevation data.

We analyzed building footprints within the FHZ to locate buildings that are active, under construction, or planned, that are within 10 feet of areas where significant changes in elevation occurred between 2013 and 2020. **Table 3** contains the results of these numbers for each regulatory zone. These elevation changes refer to both positive and negative changes, where positive changes correspond to a buildup of sediment and negative values correspond to scouring or removal of sediments over time. Within each regulatory zone, the number of buildings located near areas of 5-feet or more elevation change is markedly lower than the number of buildings within range of 1-foot elevation change. The FHZ contains far more building footprints for each category than any of the other regulatory zones, better capturing the risks related to sediment movement across Boulder County.

Table 3. Buildings within regulatory zones and bounded by the FHZ within 10 feet of areas of elevation change

Zone	Building footprints near elevation change of 0.5 feet or more	Building footprints near elevation change of 1 foot or more	Building footprints near elevation change of 5 feet or more
Floodway	379	264	11
Setbacks (100 feet)	200	161	21
Combined Regulatory 100-year floodplain	1,223	865	38
FHZ	1,850	1,355	62

We also found numerous examples of sediment buildup and scouring that occurred near infrastructure such as bridges and streambanks near roads. **Figure 10** shows an example of channel deepening that occurred around a bridge over St. Vrain Creek near Lyons. The pattern noted above in the plains areas is also relevant in this example, with spread-out sediments deposited by the 2013 flood eventually being worked into a single, more defined channel.


Difference (ft)
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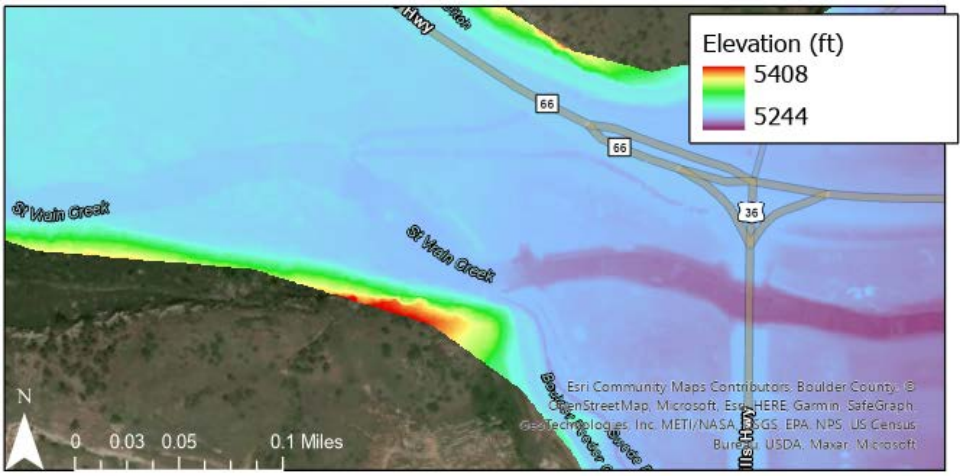
-18
St Vrain Creek
St Vrain Creek
66
66
36
N
0 0.03 0.05 0.1 Miles
Lyons


Elevation (ft)
5408
5244
St Vrain Creek
St Vrain Creek
66
66
36
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0 0.03 0.05 0.1 Miles
Esri Community Maps Contributors, Boulder County, © OpenStreetMap, Microsoft, Esri, HERE, Garmin, SafeGraph, GeoTechnologies, Inc, METI/NASA, USGS, EPA, NPS, US Census Bureau, USDA, Maxar, Microsoft

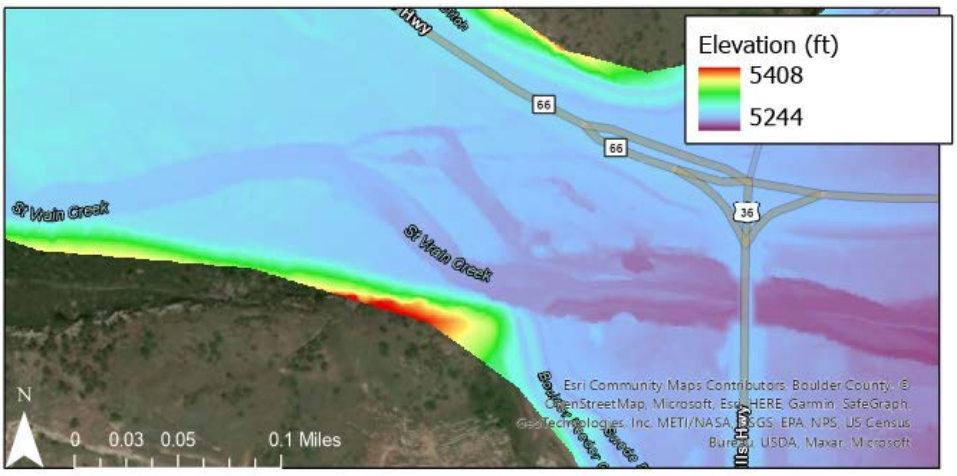
Elevation (ft)
5408
5244
St Vrain Creek
St Vrain Creek
66
66
36
N
0 0.03 0.05 0.1 Miles
Esri Community Maps Contributors, Boulder County, © OpenStreetMap, Microsoft, Esri, HERE, Garmin, SafeGraph, GeoTechnologies, Inc, METI/NASA, USGS, EPA, NPS, US Census Bureau, USDA, Maxar, Microsoft

Figure 10. Channel deepening at bridge across St. Vrain Creek, with location shown relative to Lyons in red rectangle. Top: Difference between 2020 and 2013 LIDAR data. Positive values indicate higher elevation in 2020 than in 2013, and negative values indicate lower elevation in 2020. Middle: 2020 elevation data. Bottom: 2013 elevation data.

The differences shown by these repeat LiDAR datasets highlight the fact that the stream channels in Boulder County are not the same as they were when the regulatory maps, such as 100-year floodplain, were developed. These datasets reveal large changes in the terrain that are located within close range of many active infrastructure installations and emphasize the need to consider risks associated with sediments in addition to water.

5. External QA/QC of Boulder County FHZ Boundaries

Per request from Boulder County CPP, Lynker conducted a screening-level QA/QC of the FHZ boundaries that were provided to the County as part of this FHZ pilot study. This was a desktop exercise, as we did not have the scope to complete any field-based analyses. Our QA/QC included the following steps:

Comparison of FHZ to other regulatory layers

We created "agreement" layers to compare the FHZ to the regulatory Floodway, 100-foot setbacks, and the combined 100-year floodplain (combining 2013 FIRM and 2019 Preliminary FIRM). These layers visualize where the FHZ and various layers matched, and where only one was delineated. We visually assessed the agreement layers to find locations where the FHZ was smaller than the respective regulatory layer and then compared these areas to other datasets to see whether the FHZ or regulatory layer's information seemed more reasonable. Note that while there can be instances where the FHZ is narrower than regulatory floodplain boundaries (see Blazewicz et al., 2020 Figure 1.2), we would generally expect the FHZ to be broader than the regulatory floodplain in the high gradient river systems that are typical of Boulder County.

The FHZ was at least as wide as the regulatory floodplain in the St. Vrain Creek area of Boulder County and in the western mountainous area of Left Hand Creek. In the far east area along Left Hand Creek, east of Haystack Mountain Golf Course, the FHZ was smaller in a few areas than the Floodway (**Figure 11**). The FHZ has narrower boundaries than the Floodway near the eastern FHZ boundary, close to Erie. Comparing these results to underlying imagery, the FHZ seems to follow the terrain and erodibility of the area fairly well. Both the FHZ and Floodway offer reasonable extents despite the FHZ being less conservative.

Figure 11. Left: Left Hand Creek FHZ versus Floodway, with some very small segments where the FHZ has a smaller extent (purple areas show presence of Floodway only, red is FHZ only, and yellow is both FHZ and Floodway coverage). Right: Boulder Creek near Erie, with FHZ and Floodway having some inconsistency but the FHZ extent still appearing reasonable.

The FHZ was at least as wide as the 100-foot setbacks in the mountainous areas of St. Vrain, most of Left Hand Creek, and all of Boulder Creek. There were a few small sections where the setback extends beyond the FHZ, but the FHZ appears to better match the underlying terrain. In this case, the FHZ probably more accurately reflects risk from fluvial hazards, since it is more physically-based than the setback layer.

The FHZ was at least as wide as the combined 100-year floodplain for the North and South St. Vrain Creeks, for most of the St. Vrain, and for most of Left Hand Creek. The largest area of discrepancy occurs in an area along the easternmost part of Left Hand Creek near the FHZ boundary (**Figure 12**). The floodplain appears to better match the terrain in this area, which also corresponds to an area of higher erodibility soils. The FHZ is possibly not conservative enough in this area east of Haystack Mountain Golf Course. Additionally, the FHZ has numerous segments in the Boulder Creek area where it has a smaller extent than the floodplain, largely in the eastern section. The large offshoot of the floodplain in the southeastern section of Boulder Creek is due to the presence of Bullhead Gulch, a non-defined channel and significant drainage area; side channels and drainages outside of the main stream channel were not included in the FHZ generation, which is why the FHZ is notably lacking in that location.

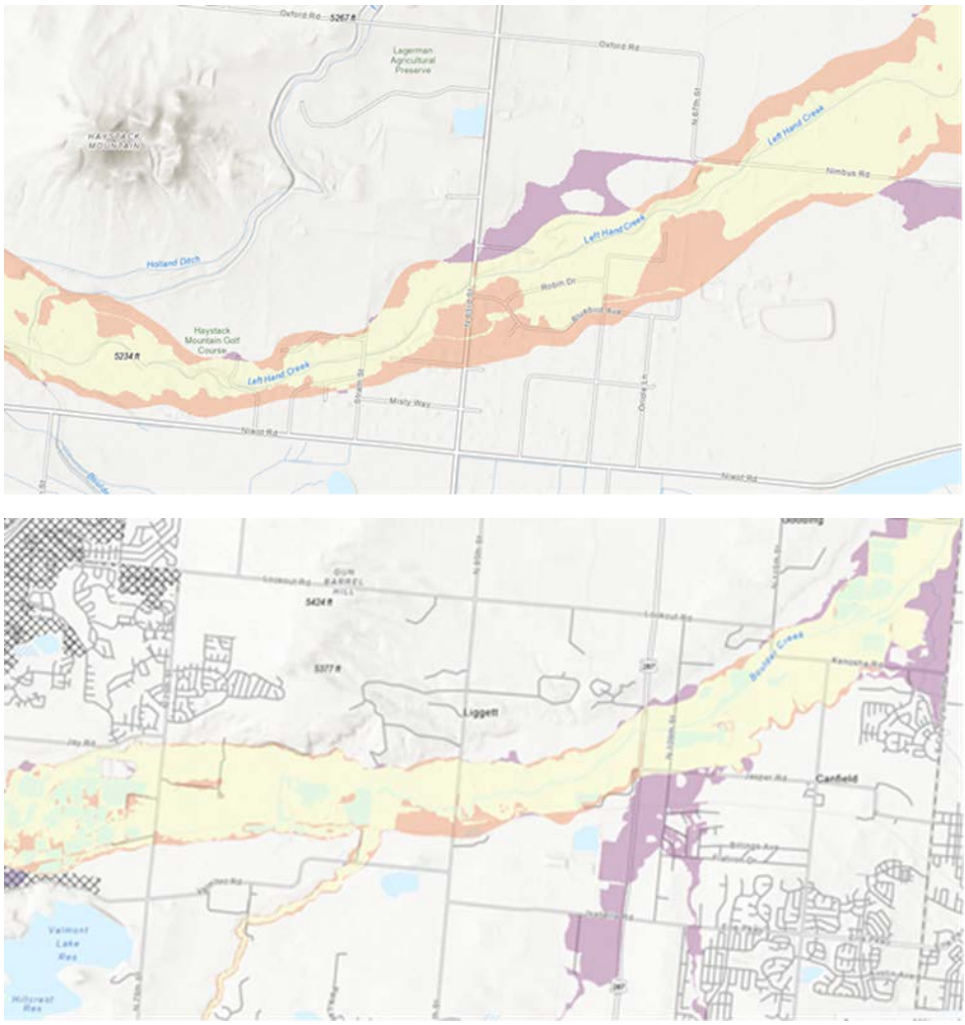

Figure 12. Top: Plains section of Left Hand Creek where the FHZ is not as conservative as the 100-year floodplain (with FHZ + floodplain in yellow, FHZ-only in light red, and floodplain-only in purple). Bottom: Boulder Creek with FHZ compared to 100-year floodplain.

In general, the FHZ is more conservative and more widely encompassing of at-risk areas than the various regulatory layers across the entirety of Boulder County. Most of the areas where the FHZ was smaller in extent than the other regulatory layers were less than an acre in size, with the largest area of difference from the 100-year floodplain along Left Hand Creek being around 20 acres in extent.

Comparison of FHZ to SSURGO erodibility index

We overlaid the FHZ layer on the SSURGO dataset to examine whether the FHZ boundaries were well aligned with soil erodibility. In general there were areas of higher erodibility outside of the boundaries of the FHZ, likely due to the scouring river action leaving only lower erodibility soils within the active stream channel (**Figure 13**).

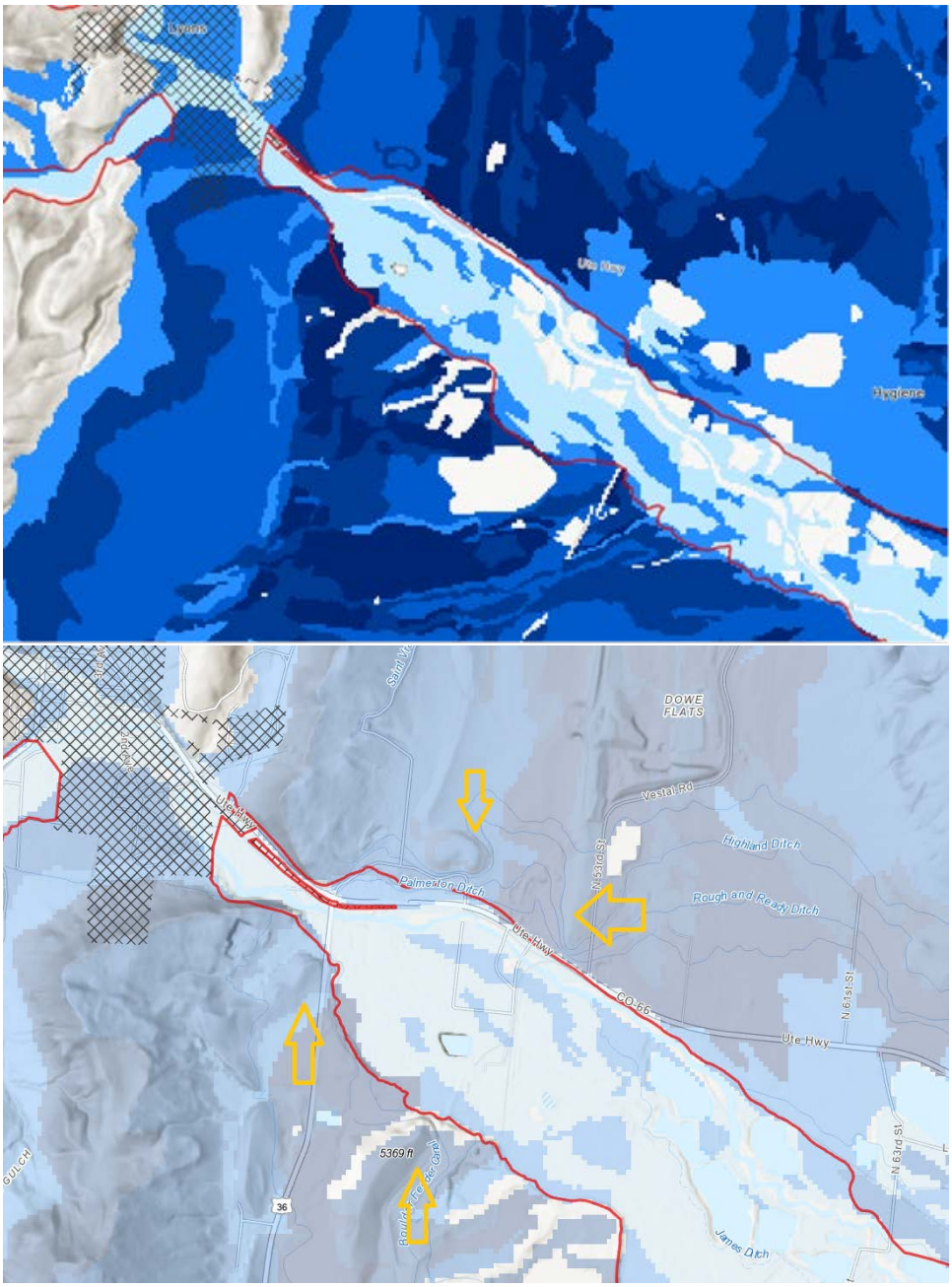

Figure 13. Top: SSURGO Soil Erodibility Index with FHZ boundaries overlaid in red, near Lyons. Lighter shades of blue are lower erodibility, darker shades of blue are higher erodibility. Bottom: Transparent SSURGO data overlaid

on terrain. Higher erodibility soils next to the FHZ tend to correspond with various higher-elevation landforms (noted by yellow arrows).

The FHZ encompasses a range of erodibility values but mostly towards the low end of the erodibility index. Low erodibility values can be found in the main active stream channel, where loose sediments have been scoured out and transported, and higher erodibility values line the edges of many parts of the FHZ. Low erodibility values next to the FHZ could signal areas that should be added to the FHZ's coveragedue to previous presence of water that removed easily eroded sediments. In general, the Boulder County FHZ dataset and SSURGO erodibility values seemed reasonably aligned without any large discrepancies.

Comparison of FHZ to aerial imagery

We overlaid the FHZ layer onto aerial imagery (ArcGIS World Imagery, resolution up to 1m or better) and visually examined across the FHZ extent for the presence of alluvial fans which might have been left out of the additional avulsion and geotechnical datasets included with the FHZ.

There were no fans visible in imagery in the St. Vrain or Left Hand Creek areas, though there are plenty of dams, former river channels, and cutoffs visible. There were a few locations along South Boulder Creek where the creek makes very sharp turns, possibly with a fan in place (**Figure 14**). This area of Boulder County was particularly noteworthy in terms of the presence of visible historical or potential alternative paths for the stream.

Figure 14. South Boulder Creek with former flow path covered in sediment (noted by yellow arrow).

The FHZ does a good job of covering a wide area for dynamic river systems. There are not many associated avulsion hazard zones and geotechnical flags with this dataset for Boulder County, but those included appear sufficient based on available aerial imagery.

Summary of Findings and Recommendations

Our review of the fluvial hazard zone delineations produced for Boulder County focused on the degree to which the FHZ differs from the regulatory boundaries currently used by CPP in land use planning and regulations. This review supports the following key conclusions:

- When compared to regulatory boundaries like the floodway and the 100-year floodplain, the FHZ delineates a much broader zone of risk to flood hazards, and more closely matches the observed flood extent during the 2013 flood event.

- Approximately 1/3 of the Boulder County properties that are within the newly mapped FHZ are outside of regulatory boundaries like the floodway or the 100-year floodplain. Thus there are a significant number of homes that may be at risk from fluvial hazards but who do not have a regulatory mandate to act (i.e., by purchasing flood insurance or complying with Substantial Improvement requirements in the floodplain ordinance).
- Some of the homes that sustained damage during the 2013 flood were within the FHZ but outside all of the regulatory flood boundaries. However, homes within the mapped 100-year floodplain were substantially more likely to be damaged in 2013 than those between the 100-year and FHZ boundaries: almost three quarters of the properties with SDE reports were inside the 100-year floodplain, whereas only 12% of the damaged homes were within the FHZ but outside of all regulatory boundaries.
- A significant number of culverts, bridges and other county infrastructure are also within the FHZ but outside of regulatory boundaries. Approximately 1/3 of the culverts and bridges that are within the FHZ are also outside of the 100-year floodplain, and half of the roads that fall within the FHZ are also outside the regulatory floodplain.

Based on our review, it is clear that the FHZ delineates a zone of flood risk that extends well beyond the areas that Boulder County currently regulates. This zone contains a substantial number of homes and infrastructure that could be affected by future flood events. It is difficult to quantify the degree of risk for most of these assets because of the dynamic nature of rivers within the fluvial hazard zone: channel avulsions and sedimentation events are created by events that in most cases are impossible to predict, and the rivers are constantly shifting and migrating even throughout years of "normal" streamflow. However, Boulder County can take concrete steps toward minimizing risk to property and infrastructure in the FHZ by integrating fluvial hazards into its existing planning processes.

Our screening-level external QA/QC of the FHZ delineations in Boulder County found the following:

- The FHZ is more conservative and more widely encompassing of at-risk areas than the various regulatory layers across the entirety of Boulder County. Most of the areas where the FHZ was smaller in extent than the other regulatory layers were less than an acre in size, with the largest area of difference from the 100-year floodplain along Left Hand Creek being around 20 acres in extent.
- The active stream channel of the FHZ loosely corresponds to areas of lower erodibility in the SSURGO soils index, though the alignment is not perfect, with some areas of higher erodibility included along the edges of the FHZ and the FHZ boundaries stopping within some areas of lower erodibility. As erodibility is only one component of determining FHZ boundaries, the FHZ dataset for Boulder County seems reasonable in this regard.
- There are not many associated avulsion hazard zones and geotechnical flags with this dataset for Boulder County, and those included are sufficient based on available aerial imagery.

Recommendations and Next Steps

The fluvial hazard zone broadly delineates areas that are at risk from channel avulsions, erosion and sedimentation hazards, and other fluvial hazards beyond simple "clear water" flooding. Because the FHZ does not represent a regulatory boundary, however, many Boulder County residents may be unaware of these hazards CPP therefore has an opportunity to improve communication of these hazards through public outreach, and an obligation to minimize risk to its residents by incorporating the FHZ into its land use planning processes.

Land use decisions in Boulder County are guided by the Boulder County Comprehensive Plan (BCCP), which is periodically updated as new information becomes available. While fluvial hazard zones are not currently integrated into land use guidelines or recommendations for site-specific study, there are several components of the Plan that could be updated to more explicitly acknowledge and manage risks in the FHZ. Incorporating

elements of the FHZ into the BCCP is an important step in ensuring that this risk information is shared with the public and ultimately becomes used to inform development and prevent costly property damage due to floods.

With mountainous, confined stream channels transitioning into wider, flatter plains areas, Boulder County's topography and land use present an excellent case study for the use of the FHZ across varied landscapes.While traditional risk management has focused solely on inundation and water, major flood events such as that in 2013 in Boulder County and a2022 event in Yellowstone National Park make it clear that sediment and erosional risks associated with flooding must be considered in future planning. The FHZ presents a comprehensive, expanded view of risks to infrastructure associated with flooding beyond just water.

We encourage other communities to consider undertaking a similar analysis of the FHZ to understand how it could be useful for planning for hazards around the country, and adopting comprehensive flood risk management into planning and development.

References

Blazewicz, M., Jagt, K., and Sholtes, J., 2020Colorado Fluvial Hazard Zone Delineation Protocol Version 1.0. Colorado Water Conservation board, 212 pp.

Fluvial Hazards in Boulder County

Community Planning & Permitting
Floodplain Management

Legend

- Alluvial & Debris Fans
- Geotechnical Flags
- Streams with Fluvial Hazards
- Active Stream Corridor
- Disconnected Active Stream Corridor
- Fluvial Hazard Buffer
- Avulsion Hazard Zones
- Areas Excluded from Study

This map is intended to delineate the area a stream has occupied in recent history, may occupy, or may physically influence as it stores and transports water, sediment, and debris. This map does not predict the magnitude, frequency, or rate of fluvial geomorphic hazards. The intended use of this map is to inform land use planning, emergency planning, floodplain management, and stream corridor conservation efforts.

Definitions:
Active Stream Corridor: Areas that have been historically influenced by erosion and deposition.

Fluvial Hazard Buffer: Areas along the sides of the Active Stream Corridor that, though they may be elevated above a stream channel, are susceptible to erosion or hillslope/bank failure.

Avulsion Hazard Zone: Areas outside of the Active Stream Corridor that a stream channel can occupy. Avulsions occur when a stream channel suddenly abandons one pathway for another.

Alluvial Fans: Triangular landforms of sediment and/or debris that develop where a steep tributary channel meets a flatter valley. The direction of water flow over a fan can be erratic and difficult to predict.

Geotechnical Flags: Areas where hillslope failures caused by erosion may extend beyond the Fluvial Hazard Buffer due to hillslope steepness, height, or composition.

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0 2.5

1" = 2.5 miles
1:158,400