PROJECT BACKGROUND

Gore Creek and its eleven named tributaries flow directly through the heart of Vail, Colorado. Outdated topography, 1D hydraulic modeling assumptions, and inconsistent survey control throughout the valley has led the Town of Vail to request a comprehensive update of the 2-year flood line (TYFL) and 100-year floodplain within Town limits. The TYFL elevation has been adopted in the Town of Vail Code of Ordinances for regulating and protecting the riparian corridor through the designation of a "no mow" zone and riparian setbacks. These updates aim to improve the accuracy and repeatability of determining elevations in a way that is equitable to all property owners. Additionally, revisions to the 100-year floodplain are sought to better represent the existing flood hazards prior to applying for further floodplain development permits, as spring 2010 flooding had significant impacts on the channel conveyance. The Town expects that the improved data will allow property owners, surveyors, and other professionals to more accurately locate the published TYFL and 100-year flood elevations and extents on each property both physically and in GIS or other mapping platforms.

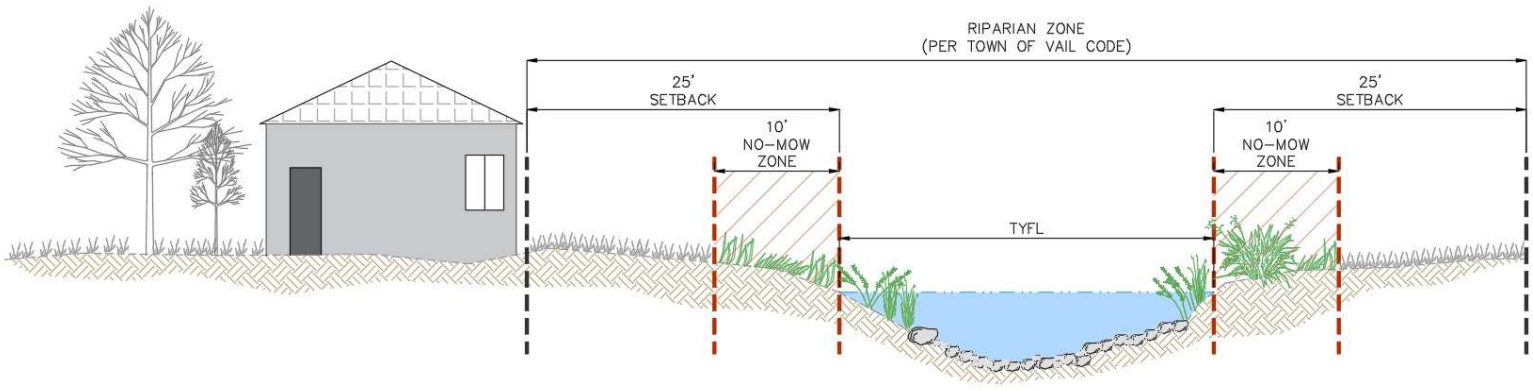
EXISTING CONDITIONS AND CONSTRAINTS

The typical practice of surveying elevations obtained from 1D modeling can be inaccurate, particularly in steep, mountainous terrain. Flood elevations between cross sections are interpolated linearly, and all calculated flood elevations must be field located by a surveyor. This approach has been common practice for practicality and repeatability reasons. However, the Effective basemapping is only accurate within 2 feet, therefore long distances between Effective Model surveyed cross sections has led to poor interpolation of the 2-year and 100-year flood elevations. The National Geodetic Survey (NGS) has also recently downgraded the local ground control network, leading surveyors to experience problems with repeatability in Vail.

In addition to issues caused by poor flood elevation resolution, field locating these flood elevations can also prove onerous. This burden may be reasonable when requiring field locating of flood elevations for building zoning and insurance requirements; however, it may not be as reasonable for private property owners attempting to comply with local riparian area protection ordinances. Requiring a surveyor-quality determination of ground elevations may not be reasonable for someone attempting, in good faith, to adjust a mowing pattern of their lawn to comply with a riparian corridor protection ordinance.

PROJECT OBJECTIVES

To address these issues, the Town of Vail sought to create a mapping line that can be used in GIS or other mapping platforms to accurately reflect the TYFL and 100-year floodplain extents associated with high-resolution LiDAR. In particular, the TYFL can be offset to show the 10-foot "no mow" buffer per the Town's riparian protection ordinance. Reliable and repeatable GIS data allows property owners to more easily identify whether they are complying with the Town's regulations without having to hire a surveyor to field locate elevations.



Similarly, the more accurate mapping of the 100-year floodplain allows property owners, surveyors, and other professionals to more accurately identify whether a building is within the flood hazard zone. The 100-year models and mapping in this effort are not yet proposed to be adopted as Effective but are being reviewed to evaluate if map updates are prudent.

AERIAL DATA ACQUISITION

RiverRestoration teamed with Quantum Spatial, Inc (NV5) for aerial data acquisition. Highly accurate (5 cm vertical error), high resolution (>20 pulses/m^2) LiDAR data was obtained for use in hydraulic modeling and mapping. Digital orthophotography was also collected simultaneously in order to obtain imagery corresponding to the LiDAR data. Pixel size (ground sample distance) of 9 cm was used and orthorectification was performed to produce a final mosaic of TIFFs across the entire flow area. Aerial data was obtained in October 2022 after leaf-fall. LiDAR data was processed to produce a raster-based digital terrain model (DEM) with a cell size of 1.5 feet by 1.5 feet. This DEM was used as the base topography for all hydraulic modeling and mapping.

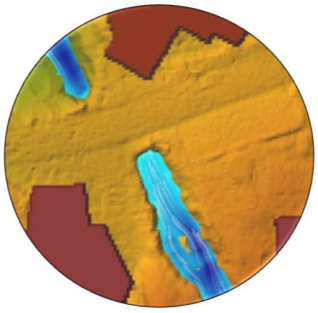
RiverRestoration hydrographic survey crews performed detailed survey and ground-truthing at hydraulic controls and crossings (culverts, bridges) to augment the DEM in areas where higher detail was required for modeling.

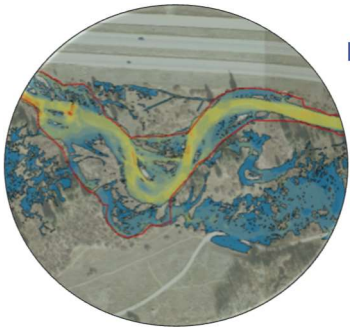
GROUND SURVEY CONTROL NETWORK

RiverRestoration teamed with Survey Systems, Inc (SSI) to update and establish a new, reliable ground control network for improved repeatability in future surveying efforts and to use the accuracy of the basemap. The ground control network is specific to the elevations and datums used to develop the revised TYFL and 100-year floodplain boundaries, and was created using the NGS Online Positioning User Service (OPUS) project platform. Using the OPUS project platform allows the ground control network and the basemapping to be updatable to future datums (the 1988 NAVD is expected to be superseded in 2023 by NATRF2022). The Town of Vail intends for the new ground control network to be required as reference for all new surveys beginning in 2025.

ENHANCEMENT OF PUBLIC HEALTH, SAFETY, AND WELFARE

Online-accessible TYFL and 100-year floodplain boundaries can enhance the public's ability to make informed decisions and ensure that individual property owners are in compliance with Town Code. Protection of the habitat and vegetation within the riparian corridor is critical to stream health and stability. Having an accurately mapped TYFL can ensure that property owners take responsibility to avoid "no mow" buffer zones and required offsets. Likewise, the revised 100-year floodplain mapping can further inform property owners of their flood risk and can assist local surveyors in determining flood elevations for future projects.





INCORPORATION OF CREATIVE, UNIQUE, AND INNVOATIVE SOLUTIONS

RiverRestoration's collaboration with NV5 and SSI demonstrate the team's dedication to providing the client with innovative solutions using state-of-the-art technology. High resolution mapping and an upgrade of the Town's entire ground control network ensures that the Town of Vail is set up for success in reviewing future planning and design projects.

A MODEL FOR OTHER COMMUNITIES

The process outlined in this project is broadly applicable to other locations and communities. Using high resolution data in a detailed modeling procedure can determine flood hazards and inundation areas for different return interval flows with much more accurate spatial resolution. When the resolution of the data and modeling procedure is able to match the accuracy needed for determining flood extents for a given ordinance, the need for field-located elevations is reduced, allowing for lower costs to landowners and higher rates of adoption of an ordinance. In the Town of Vail's case, the up-to-date, accurate mapping leads to more easily followed and enforced protection of the vegetation and wildlife utilizing the riparian corridor. This in turn benefits residents in town as well as others downstream on the Eagle River, Colorado River, and beyond.

METHOD AND RESULTS

HYDROLOGY

100-year discharge for the main stem of Gore Creek and its 11 named tributaries; Buffehr Creek, Red Sandstone Creek, West Mill Creek, East Mill Creek, Middle Creek, Spraddle Creek, Booth Creek, Pitkin Creek, Bighorn Creek, Black Gore Creek, and Upper Gore Creek were obtained from FEMA's Eagle County FIS dated December 4, 2007. 2-year discharge was calculated based on gage analysis and StreamStats data in 2022. RiverRestoration analyzed both the 1.5-year and 2-year flood lines to determine the ordinary high water line (OHWL). The TYFL was selected to conservatively represent the OHWL and the connection of riparian areas for use in the Town's ordinance.

MODELING AND MAPPING

Hydraulic modeling of Gore Creek and its tributaries was performed with two-dimensional (2D), quasi-steady flow in HEC-RAS v6.3.1. RiverRestoration created 13 separate meshes to analyze flood extents for the main stem and each tributary (an additional model was created upstream of the East Mill and West Mill Creek split).

The 2D modeling approach allowed for increased resolution in the mapping of the 2-year and 100-year flood boundaries. In-channel hydraulic mesh resolutions were on the order of 3-5 feet cell sizes and floodplains were on the order of 8-20 feet cell sizes. Breaklines were used to target and accurately represent flow constraining topographies based on the 1.5 feet cells of the LiDAR. Additionally, the 2D model allows for the integration of culverts and crossings where they occur in the mesh. Spatially variable Manning's N roughness coefficients were assigned to the channel and overbank areas in a manner consistent with Effective 1D model. 1D normal depth solutions were used as the downstream boundary condition. The 2-year and 100-year flood boundaries were exported as ESRI shapefiles and processed for mapping. In areas where model domains overlapped at tributaries' confluences with Gore Creek, the areas with greater flood extent were reported.

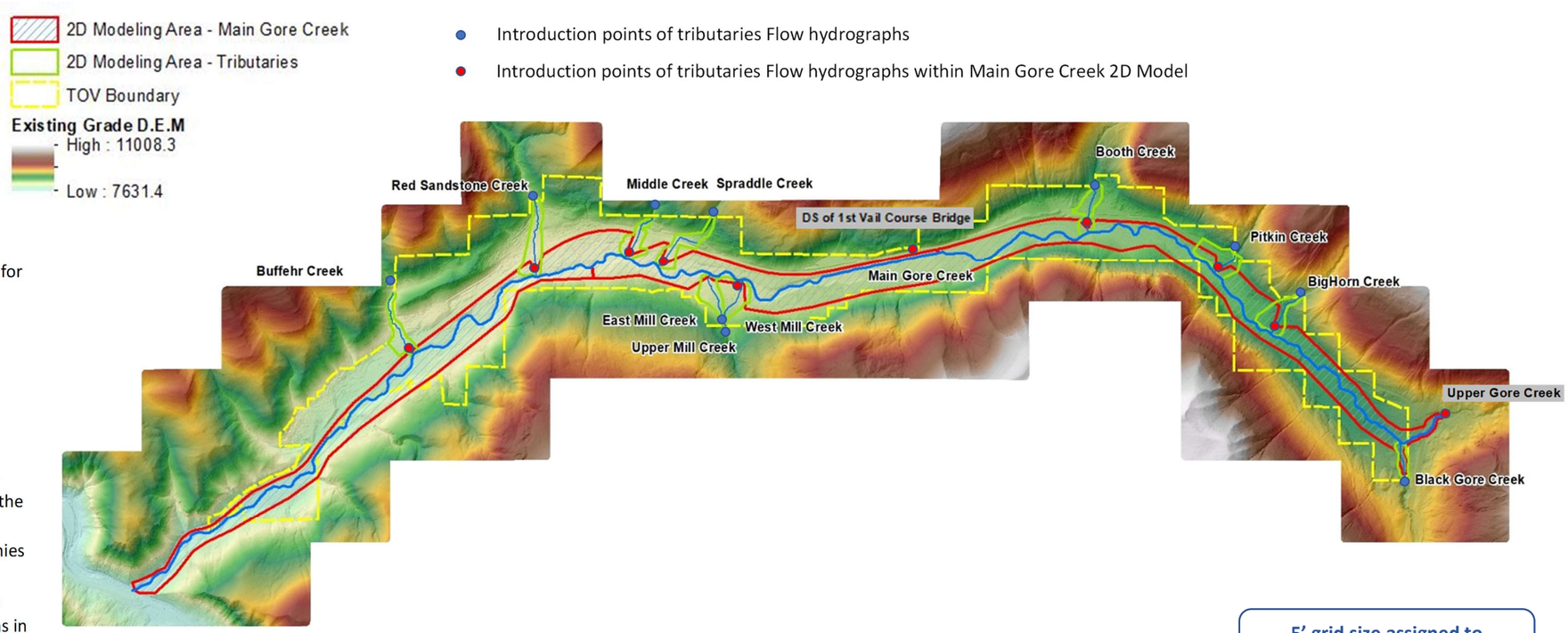


Figure 1. Total 2D modeling area from confluence with Eagle River to Upper Gore Creek

Description	Gore Creek 1D Station	Gore Creek Main Channel Q_2 (cfs)	Tributary Input Q_2 (cfs)
Upper gore Creek	231	282	282
Black Gore Creek	221	185	185
Bighorn Creek	205	570	103
Pitkin Creek	199	674	104
Booth Creek	188	823	149
East Mill Creek	160	882	59
West Mill Creek	158.4	941	59
Spraddle Creek	153.6	964.2	23.2
Middle Creek	151.4	1030	65.8
US Red Sandstone Creek	145	1078	48
Red Sandstone Creek	144	1192	114
Buffehr Creek	131	1241.2	49.2

Description	Gore Creek 1D Station	Gore Creek Main Channel Q_{100} (cfs)	Tributary Input Q_{100} (cfs)
Upper Gore Creek (*)	231/218	1350	1350
Black Gore Creek			640
Bighorn Creek	205	1470	280
Pitkin Creek	199	1670	290
Booth Creek	188	1840	370
DS of 1st Vail Course Bridge (*)	174	1930	
Upper Mill Creek upstream of Split			300
East Mill Creek	161	2100	150
West Mill Creek			150
Spraddle Creek	155	2150	170
Middle Creek	151	2310	140
Red Sandstone Creek	144	2620	490
Buffehr Creek	131	2650**	220

(*) Based on Effective Model
(**) Flow in FIS Report table but not in effective 1D Model. Used in 2023 2D modeling

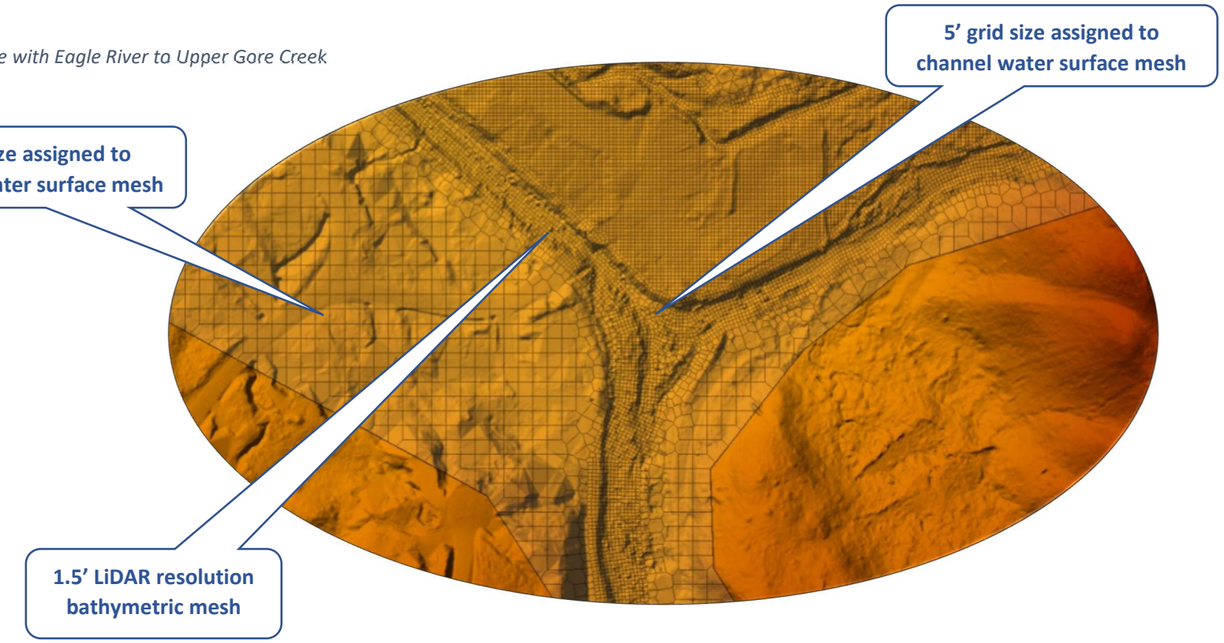


Figure 2. Varying mesh resolution at upstream confluence of Upper Gore Creek and Black Gore Creek