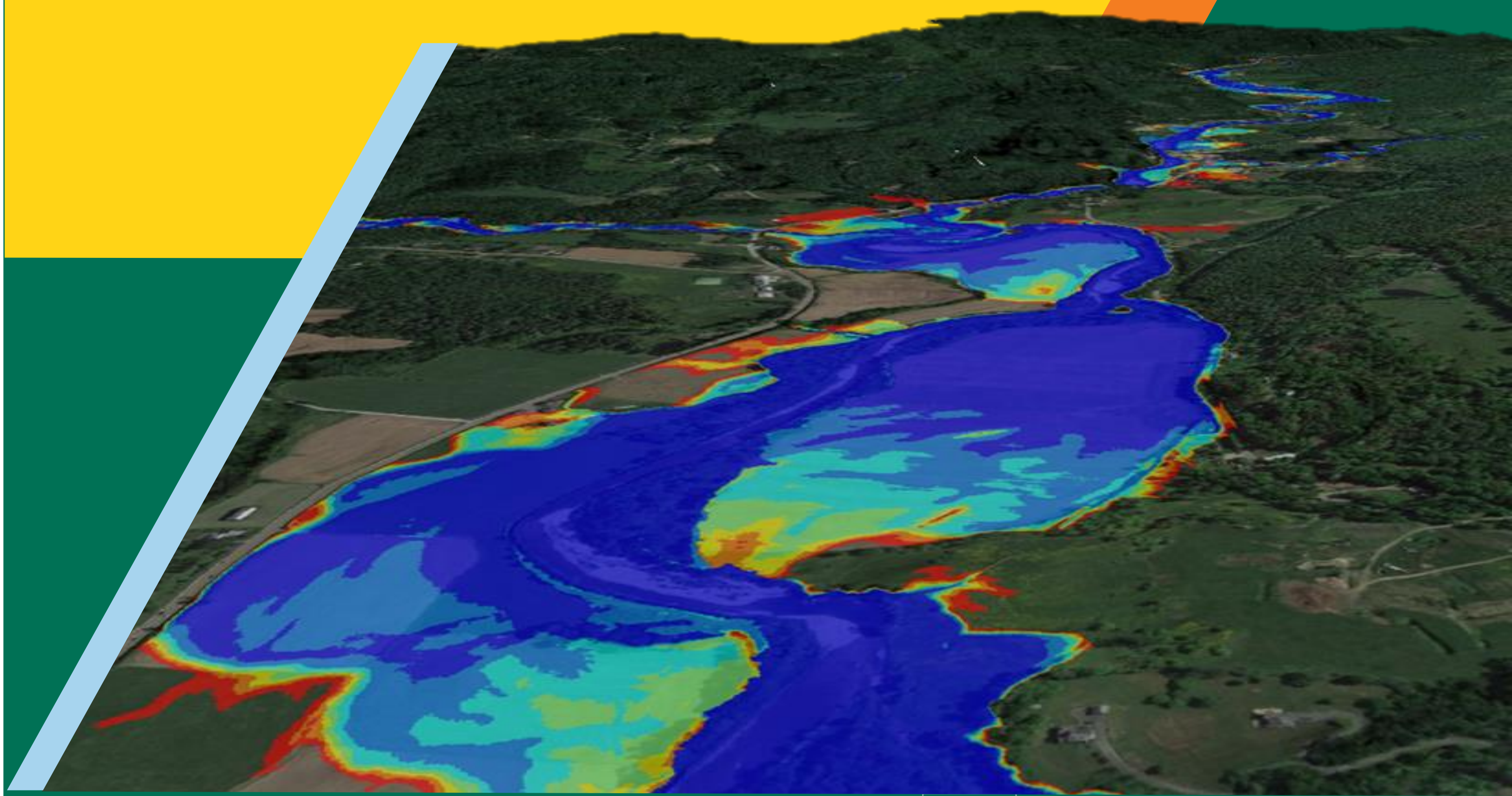
Topographically-defined Floodplains

Relative inundation for conservation and restoration planning in the Lake Champlain Basin, Vermont



Version 2.0, released May 2022

The University of Vermont

Topographically-defined Floodplains: Relative inundation for conservation and restoration planning in the Lake Champlain Basin, Vermont

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Topographically-defined Floodplains: Relative inundation for conservation and restoration planning in the Lake Champlain Basin, Vermont

Statement of Purpose (Abstract)

The Topographically-defined Floodplains were generated from high-resolution topographic data along rivers draining greater than 2 square miles in the Vermont portion of the Lake Champlain Basin. These floodplains are intended for planning and research use by government, academic, commercial and non-governmental agencies; they are not a substitute for FEMA Flood Insurance Rate Maps and are not intended for regulatory use. A greater geospatial coverage of floodplains in the basin will support analyses of floodplain and wetland processes and restoration and conservation planning for improved water quality, enhanced flood and climate resilience, and expanded habitat and ecosystem functions. Lateral extents of flooding for storms of recurrence intervals ranging from 2 to 500 years are represented in the dataset.

Floodplain Dataset Description and Intended Use

The Topographically-defined Floodplain dataset described in this document is a high-resolution raster that communicates the extent and frequency of flood inundation along rivers that drain 2 square-miles or more in the Lake Champlain Basin, Vermont. Inundation information was derived from a low-complexity hydraulic model that simplifies the characterization of water movement across the landscape. This modeling approach requires less rigorous site-scale data development than other comparable floodplain products, and instead relies upon high-resolution Digital Elevation Models (DEMs) available for the region. Consequently, a greater spatial coverage of floodplains for the region was able to be generated, as well as a representation of variable inundation extents for a suite of peak discharges ranging from events that are common (e.g., 2-year flood with a 50% probability of occurring in any given year) to those that are rare (e.g., 500-year floods with 0.2% probability). Eight modeled storm sizes are represented in this dataset (2, 5, 10, 25, 50, 100, 200, and 500 year peak floods) informed by regional regression analyses built from Vermont watershed characteristics and the historical hydrology of the region (Olson, 2014). Details of the modeling approach and recent improvements undertaken for this release of the floodplain dataset are provided in Technical Appendix A.

The specific low-complexity model developed for this application (probHAND; Diehl et al., 2021a) incorporates a probabilistic approach that accounts for the uncertainty in input values. Resulting model outputs for a given event include a range of probable inundation extents including the 95^{th}, 90^{th}, 75^{th}, 50^{th}, 25^{th}, 10^{th} and 5^{th} percentiles. This Floodplain dataset consists of the most representative (50^{th} percentile) inundation extent for each of eight storms sizes (2, 5, 10, 25, 50, 100, 200, and 500 year floods).

Floodplain maps were developed in support of research and planning efforts to: 1) create a more comprehensive inventory of floodplains as natural features along major rivers in the region, 2) identify the likely extents of flooding along the river corridor for a suite of storm sizes, 3) to add granularity to the floodplain extents by identifying the relative inundation frequency (e.g., common vs rare) of features contained within these mapped floodplains. Because of simplifications made to represent hydraulic processes in the modeling approach and uncertainties and errors in large scale model parameterization (e.g., flood peak discharges at ungauged reaches, roughness values), there are limitations to their use. These limitations are described in more detail in Technical Appendix B and attributed in the companion Topographically-defined Floodplain Reach Attribute dataset. Version 2.0 Floodplain dataset is an expansion and improvement on the original dataset (version 1.0), as described in Diehl et al (2021a) and applied to Gourevitch et al. (2022).

Example Use Cases

The following use cases describe the types of information and analyses that may be derived from the Floodplain maps in support of conservation and restoration planning.

#1: Flood and Climate Resiliency

This more comprehensive floodplain mapping inventory will highlight opportunities to enhance the region's resilience to floods and a changing climate. Floodplains and wetlands store water during floods, attenuating flood peaks, and protecting downstream communities and infrastructure (Watson et al., 2016). Water that temporarily accesses floodplains and wetlands during floods can also recharge shallow aquifers, mitigating the expected greater frequency of summer dry periods and drought (Guilbert et al., 2015). Yet, many floodplains in the Lake Champlain Basin have been disconnected, either laterally because of roads, railroads, berms, or other infrastructure, or vertically through channel incision (Kline and Cahoon, 2010). The Floodplain maps may be used to locate features (e.g., railway berms, roadways, development) that have historically disconnected portions of the floodplain (Figure 1), and to quantify improvements in floodwater storage and aquifer recharge that would be possible with restoration and reconnection (Schiff et al., 2008; Drago, 2021). Additionally, as future rainfall is anticipated to be more intense, generating larger floods (Guilbert et al., 2015), the range of inundation frequencies available in the Floodplain maps may be used to visualize areas that may be at greater future flood risk.

#2: Water Quality and Nutrient Management

Floodplains and wetlands capture, store, and transform flood-transported constituents, including sediment and nutrients, improving downstream water quality (Noe and Hupp, 2005). Research in the Lake Champlain Basin and elsewhere has established that floodplains that are more regularly inundated capture a larger amount of the total flood-transported sediment and phosphorus load (Pizzuto et al., 2016; Diehl et al., 2021b), but may also release phosphorus during flooding, notably from recently-farmed lands with legacy phosphorus (Roy et al., 2021). Relative inundation frequencies on the Floodplain maps may be used to evaluate the sediment and phosphorus storage capacity and identify opportunities to increase sediment and nutrient retention, through floodplain and wetland restoration and conservation projects.

#3: Riparian Habitat

The hydrologic regime of a river and its riparian corridor is the dominant driver of process, shaping the physical setting and determining the types of natural communities and habitats that can thrive (Poff et al., 1997). As such, Floodplain maps may be used to assess the current and potential extents of riparian habitats and can help to inform their health based on the degree of lateral and vertical connectivity. Planners may reference the full extent of the Floodplain maps (i.e., the edge of the 500 year flood) to inform town and regional growth plans, that seek to preserve linkages to upland forest blocks. Practitioners may reference inundation frequency to choose appropriate species for riparian buffer design.

#4: Environmental Justice

Initiatives to identify, and alleviate, the disproportionate impact of environmental hazards on, and limited access to environmental benefits for marginal communities are gaining momentum (e.g., Vermont's Environmental Justice Bill). The Floodplain maps may be used to evaluate the potential impact of flooding on infrastructure and property and the socioeconomic and equity consequences, in the aggregate, at a regional scale (e.g., Gourevitch et al., 2022).

Ongoing Research

Ongoing research is expected to generate future refinements of this floodplain dataset by addressing some of the limitations described in Technical Appendix B, including:

1. Using more geomorphically-consistent reaches to better resolve reach-average hydraulic geometry properties.
2. Improvements to the underlying HAND raster algorithm to reduce the frequency of artifacts generated during flow routing (e.g., HAND "cliffs").
3. Development of a post-processing algorithm to create a more seamless transition between reaches
4. Quantification of uncertainties in hydraulic geometry values associated with the channel area below the water surface.
5. Refinement of flood frequencies, or better characterization of uncertainties in flood frequencies, based on departures from regional regressions.
6. Streamlining model execution to update maps at a sufficient future frequency to capture updates in the underlying data source layers (e.g., topography, stream network, land cover) and improved predictive abilities of hydrology in ungaged basins.
7. Balancing model overprediction in areas of low topographic relief.

Acknowledgements

This dataset represents the culmination of many years of research and development and has benefited from numerus funding sources and intellectual inputs from a large group of stakeholders and researchers. We are grateful for support from the United States Geological Survey under Grant/Cooperative Agreement No. (G16AP00087) to the Vermont Water Resources and Lake Studies Center, a Lake Champlain Research Program Technical Grant, funding from the VT Department of Environmental Conservation and Watershed Investment Division under Phase 2 of the Functioning Floodplain Initiative, Lake Champlain Sea Grant, the

Nature Conservancy, and Vermont Center for Geographic Information. The project team is grateful to Jesse Gourevitch and Jeremy Matt for technical advice on HAND methodology and software; JG was partially supported by the GUND Institute for Environment and VT EPSCoR and JM was supported by a GUND Barrett Fellowship. Stephanie Drago was instrumental in dataset management and Beverley Wemple and Donna Rizzo provided feedback on the conceptual framework.

TECHNICAL APPENDICES

APPENDIX A: Updates to the probHAND model

Floodplain maps were developed using the probabilistic topographically-based low complexity hydraulic model, probHAND. The probHAND model identifies the fluvial portion of flood hazards by accounting for the maximum flooded extent for statistically-determined events. The initial formulation of this model, and its application to the Lake Champlain Basin in Vermont is described in Diehl et al (2021). Subsequent to the publication of Diehl et al (2021a), the model code and modeling approach has been updated to improve the representation of process, presentation of results, or efficiency of the code. Here we document those updates. The updated model code is available here: https://github.com/sclaw/probHAND.

1. New more efficient Thiessen polygon algorithm

The probHAND model averages hydrologic, hydraulic, and geometric characteristics within discrete units of the landscape to characterize inundation patterns on a reach basis. These units are defined by vertices of NHDPlus reaches, and delineated using Thiessen polygons (Underwood, et al., 2021). A new more computationally-efficient method for generating Theissen polygons was selected for this updated version of the Floodplain dataset. In the new method, infinite Voronoi regions were generated from vertex points using Python's SciPy library (Virtanen et al., 2020). Finite approximations of the Voronoi regions were made by replacing any infinite polygon vertices with the intersection of the infinite ray and the watershed boundary (HUC-12).

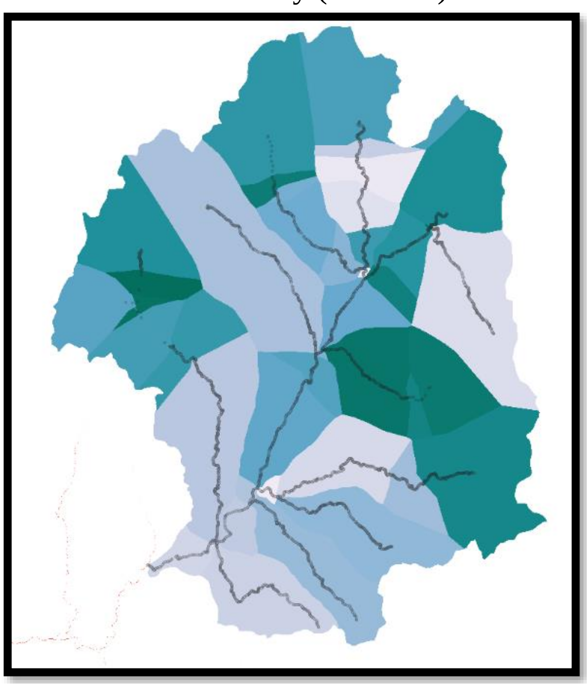


Figure A1. Example watershed discretized into units defined by the Thiessen polygon method along the river centerline of each reach. Model parameters are averaged for each spatial unit to characterize inundation.

2. New algorithm to appropriately map dominant flooding sources at confluences

Discretizing the landscape into spatial units defined by stream reaches precludes inundation from sources other than the reach associated with that unit. In reality, confluences are within the floodplains of two rivers, and they are subject to risk of inundation from both flooding sources. The artificial boundaries associated with Thiessen polygons may introduce large errors in inundation patterns near confluences, particularly where small tributaries enter larger rivers, (e.g., Figure A2). To more accurately represent this backwater effect on tributaries, a post-processing algorithm was introduced that projects the flood depth on the dominant river up the length of the non-dominant reach (i.e., smaller tributary) at each river confluence (Figure A2).

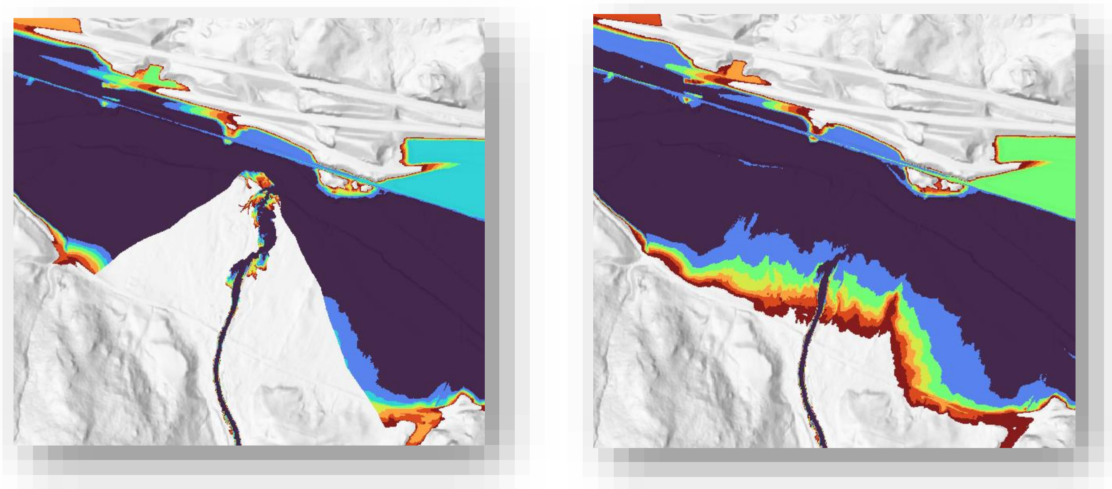


Figure A2. Example of errors in flood inundation extents introduced by Theissen polygon artifacts at the confluence of two unequally-sized rivers (left), and the resulting improvement in inundation with application of the backwater algorithm (right).

To implement this algorithm, a database of river reaches was manually compiled using a binary tree structure. Confluences were identified by querying the tree for all parent reaches containing two children. Maximum reach stages were extracted from the probHAND model run data for the two child reaches at all modeled recurrence intervals. For each recurrence interval, the maximum flood depth of the two children was found and this value was stored as the confluence D_{max}. Backwater water-surface elevations ($EL_{backwater}$) and backwater depths (Dbackwater) were calculated for each tributary reach and each recurrence interval as

$$EL_{backwater} = EL_{min\_reach} + D_{max}$$
$$D_{backwater} = D_{max}$$

where EL_{min_reach} is the minimum topographic elevation along the reach's centerline.
To find the extents of backwater inundation within each tributary reach, three filters were applied.

i. The Thiessen Polygon for the relevant tributary reach was selected

ii. Areas where the topographic elevation was less than $EL_{backwater}$ were selected to reflect the backwater effect of the confluence.
iii. Areas where the HAND elevation was less than $D_{backwater}$ were selected to both keep with the HAND modeling paradigm and to remove any flooding far away from the channel (Thiessen fringes) in topographic low areas.

Logical conjunction (i.e. an AND function) was used on these three filters to generate the final backwater footprint. Depths within the backwater footprint were calculated as

$$D_{backwater\_inundation} = EL_{backwater} - \text{Topographic elevation}$$

Finally, those backwater inundation depths were used to overwrite any areas of the model output where backwater inundation depth was greater than the base model inundation depth.

It is worth noting that assuming the risk of inundation from the dominant flooding source will still underestimate risk within confluence areas. A more robust analysis would analyze the joint probability of inundation from either flooding source. Under the current formulation of the probHAND model such an analysis would be intractable, so it was not pursued.

3. Resolving gaps in HAND Elevation rasters due to basin incongruency

The Topographically-defined Floodplain maps take advantage of the high-resolution topographic data available for Vermont and are developed at a 1-m resolution. To efficiently run the probHAND model on large files, analyses were performed on HUC12 sub-watershed units, defined by the boundaries in the Watershed Boundary Dataset (https://www.usgs.gov/national-hydrography/watershed-boundary-dataset). Because DEM data used to generate HUC12 boundaries differs from the LiDAR-derived DEMs for Vermont, cells located along the edges of the HAND Elevation Raster often did not drain to a cell within their HUC12 (Figure A3, left). The resulting gaps in many HAND Elevation rasters carried over to gaps in the Topographically-defined Floodplain maps. To fill these gaps, a coarser resolution (5-m) HAND Elevation Raster was generated for each modeled HUC-8. “nodata” areas within each HUC-12 HAND Elevation Raster were then imputed with 1m resampled data from the HUC-8 HAND Elevation Raster (e.g., Figure A3, right).

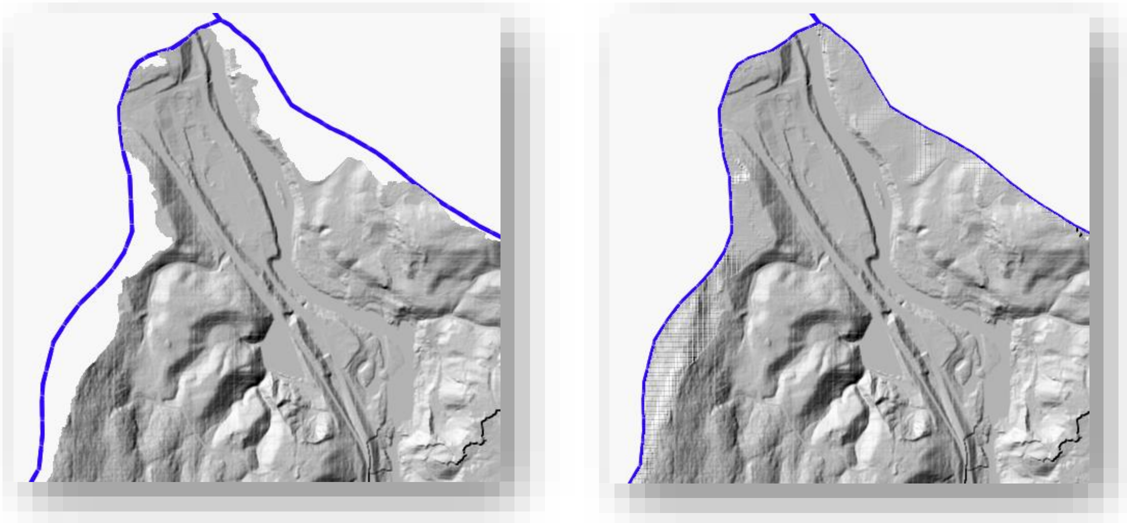


Figure A3. Missing HAND raster cells along HUC12 boundary defined by the National Watershed Boundary Dataset (left), and the resulting complete HUC12 HAND Elevation Raster after imputing raster values from a coarser-resolution continuous HUC8 raster (right).).

4. Improved Uncertainty distributions for reach slope

The probHAND model incorporates a Monte Carlo analysis for input parameters to the Manning's equation (Diehl et al., 2021a). We assume normal and truncated normal probability distribution functions for Manning's n, slope, cross-sectional area, and discharge. By simulating over 1000 iterations, we generate an empirical cumulative frequency distribution that is mapped to a probabilistic flood inundation surface for each recurrence interval.

Based on field checking of Floodplain layers, the probHAND model tends to overpredict inundation extents for higher-frequency flood events in very-low-slope channels that often naturally have lower-than-average width/depth ratios. Therefore, the Monte-Carlo sampling procedure was updated to better capture variance of channel dimensions in these stream types. for this. To generate a stratified set of distributions for slope and cross-sectional area for Monte Carlo analysis, slope and cross-sectional area values extracted from both probHAND and HEC-RAS were compared for reaches where both data sets were available (e.g., Mad River, Black Creek, Otter Creek). When the values were compared, we noted that the difference between HEC-RAS and probHAND values differed for lower vs higher slope. Differences between the two model parameters were split into two groups (HAND slope < 0.001 and HAND slope >= 0.001) and normal distributions were fitted to each of their populations.

A toggle was introduced to the model code, such that when a reach has a slope lower than 0.001 m/m, the Monte-Carlo procedure samples from the low-slope distribution for cross-sectional area and slope. When a reach has a slope higher than or equal to 0.001 m/m, the Monte-Carlo procedure samples from the high-slope distribution for cross-sectional area and slope. New distribution parameters are shown in Table 1.

Table 1. Parameters used in Monte Carlo uncertainty analysis for Lake Champlain application.

	Cross-sectional Area		**Slope**	
	Mean	***Standard Deviation***	***Mean***	***Standard Deviation***
Slope < 0.001	0.25	0.1	0.1	0.66
Slope >= 0.001	0.16	0.1	-0.25	0.45

5. Extraction of reach-based parameters for USGS Streamstats moved to downstream endpoints.

Flood frequency information (i.e., discharge associated with 8 recurrence interval flood events) is calculated for each NHDPlus reach relying on USGS Streamstats (see also B.6). This process involves delineation of an upstream watershed boundary, for extraction and calculation of drainage area, percentage of land cover characterized as wetland or open water, and average annual precipitation (Olson, 2014). The previous generation of floodplains used the reach mid-point to generate this information; this current release of Floodplain maps uses the downstream endpoint of the reach, to be more consistent with approaches used for Stream Geomorphic Assessment (VTANR, 2009) and data sets being derived under Vermont's Functioning Floodplain Initiative (https://dec.vermont.gov/rivers/ffi).

APPENDIX B: Uncertainties and Limitations of the Topographically-defined Floodplain Map Dataset

Because low-complexity hydraulic models, such as the probHAND model, simplify the representation of process, certain limitations exist to their application that translate to uncertainties in the resulting spatial representation of flooding on the landscape (e.g., Afshari et al., 2018; Diehl et al., 2021a). Additional limitations result from uncertainties in large-scale model parameterization. Some of these uncertainties are addressed broadly in the probHAND uncertainty analysis and are explored in Diehl et al. (2021a). A comparison between the Floodplain dataset and flood extents determined by a 1-dimensional hydraulic model and as depicted on FEMA's regulatory maps may be found in Diehl et al (2021a) and Underwood et al (2021). Below is a list of known errors, uncertainties, and limitations of the Floodplain dataset. A vector-dataset of reach extents (the length of river over which inundation characteristics are mapped) is included as a companion layer with the Floodplain map dataset, and attributes each reach with the associated uncertainties, and landscape characteristics (e.g., slope) relevant to these uncertainties.

1. Transitions between reaches

Transitions between reaches are sometimes artificially abrupt, and do not follow topographic gradients.

Unlike flood inundation models that calculate flow depths at a point on the landscape (and are therefore much more data and computationally intensive), low-complexity models such as probHAND identify inundation extents for discrete units of the landscape, defined by river reaches (specifically, NHDPlus reaches in this application). This spatial unit is projected on the landscape using Thiessen polygons, which is a geospatial technique to define an area of influence around a sample point, such that any location inside the polygon is closer to that point than to any of the other sample points. As a result of this discretization of the landscape, artificial boundaries are sometimes present between reaches (e.g., Figure B1).

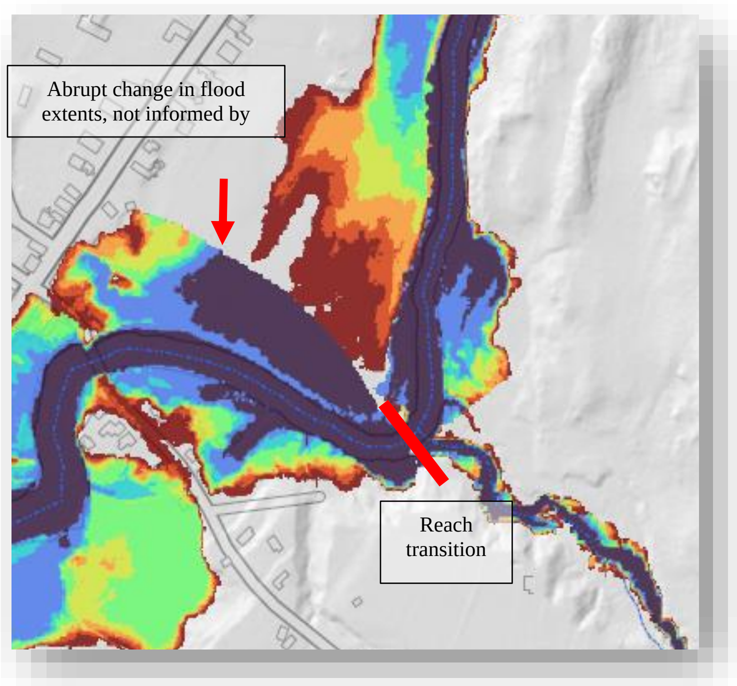


Figure B1. Example of transition between reaches that results in an abrupt change in mapped flood inundation extents.

2. Unrepresentative reach breaks

Reaches that are too long, or too short, have greater uncertainty associated with mapped flood extents. Additionally, short reaches create abrupt transitions, notably on larger floodplains.

The low-complexity model used to develop the Floodplain dataset calculates the average river geometry within a reach to develop a relationship between stage and discharge. Because of this, the probHAND model is most effective when applied to reaches with internally-consistent valley and channel geometries, as well as flow rates (Godbout et al., 2019). The Floodplain dataset relies on the NHDPlus dataset, which are hydrologically-defined reaches. Reach lengths in the NHDPlus dataset are highly variable and often span sections of river with variable valley confinement or slope (i.e., are longer than a geomorphically-consistent reach), or are too short to properly characterize slope. Additionally, short reaches, notably located in wider valleys, dissect the floodplain introducing errors and abrupt transitions (e.g., Figure B2). Short reaches, whose length is less than the width of the 500-year flood extent, are attributed in the Reach Attribute layer.

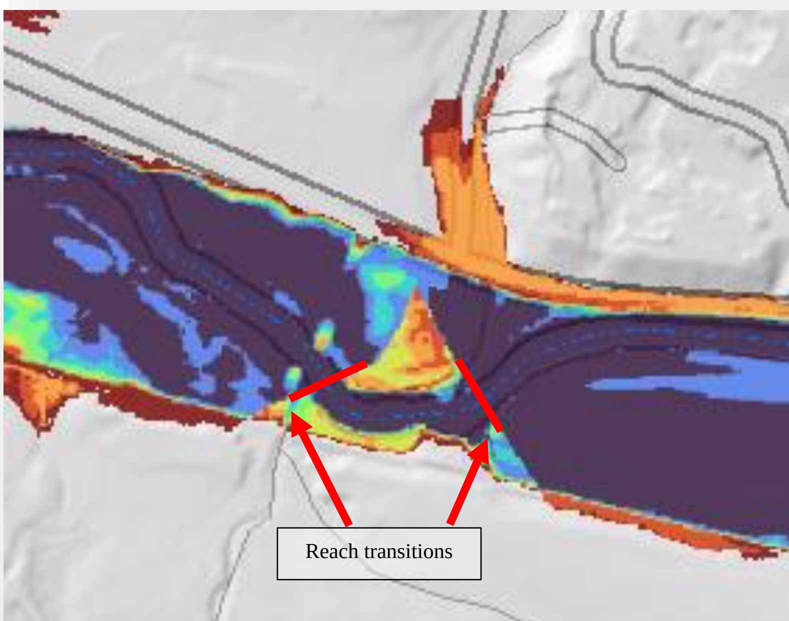


Figure B2. Short reach along large river, creates abrupt transitions in flood extents, that are not consistent with the surrounding floodplain.

3. Confluences

Floodplains around tributary junctions may have abrupt transitions and are limited in their representation of temporally variable dynamics.

Because confluences are associated with the intersection of three reaches, each with drainage area over 2 square miles (upstream mainstem, tributary, and downstream mainstem), abrupt transitions noted in section B.3 may be exacerbated. A backwater algorithm applied as a post-processing step (see A.2) reduces some of the mapped errors, but the algorithm is best suited for tributaries that meet the mainstem at a 90 degree angle, and where the topography and gradient are not highly dissimilar between the two rivers. Additionally, variability in inundation, because of differences in flood peak timing, are not well captured. Confluences of major tributaries, which drain more than 2 sq -miles, are attributed in the Reach Attribute layer.

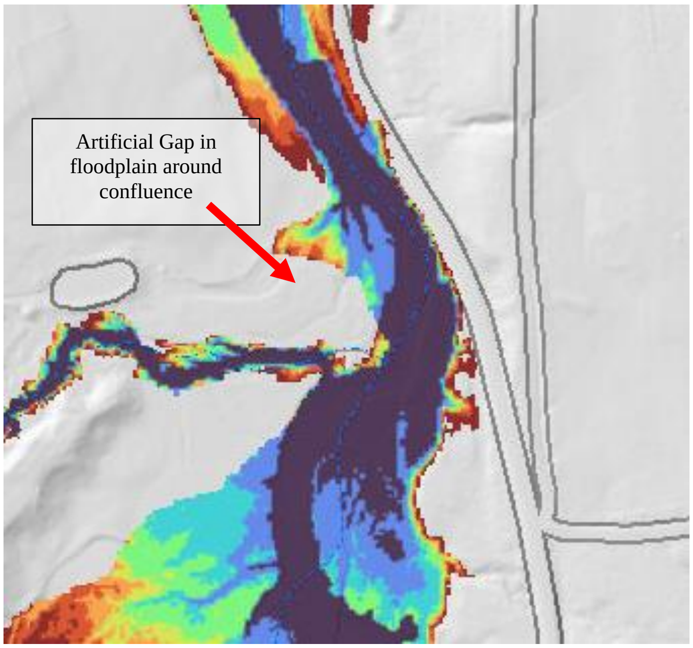


Figure B3. Tributary junction results in an artificial gap in likely inundated surfaces.

4. Backwaters and Hydraulically Complex Areas

Flood inundation patterns have greater uncertainties where flows are hydraulically complex and backwaters exist, such as in urban areas, upstream of bridges, and with abrupt changes in valley or channel width because of natural (e.g., bedrock outcrops) or manmade (e.g., bridges) barriers.

Because it is difficult to fully attribute these uncertainties, only significant, and apparent barriers, such as stream crossings, are attributed in the Reach Attribute layer.

5. Low Gradient, Low Relief Settings

Lower slope valleys, that tend to have lower topographic relief, are likely to have greater uncertainties in inundation extents particularly for high-frequency, low-magnitude floods. These uncertainties tend to translate to overpredictions of flooded extents.

Uncertainties in inundation extents associated with low gradient, lower relief settings may be attributed to a variety of uncertainties and simplifications in the mapping process. Measurement of channel geometry from LiDAR-derived data (that does not penetrate the water surface), can result in underestimates of channel area. Because of the low width/depth ratio commonly associated with low-gradient channels, errors in the LiDAR assessment of channel geometry are likely exacerbated, overestimating the stage (i.e., depth) associated with a given discharge. Additionally, the assumption of channel slope as the energy grade slope in the Manning's equation, also inflates the overestimation of stage in these settings. Small errors in stage in low relief settings, translate to larger errors than in settings with more substantial changes in elevation across the river valley (Johnson et al., 2019). These uncertainties are addressed, to some degree, in the uncertainty analysis (see A.4 above), but remain an issue in this present release of the FLOODPLAIN dataset (e.g., Figure B4). Channel slope used in the probHAND model for each reach is attributed in the Reach Attribute layer.

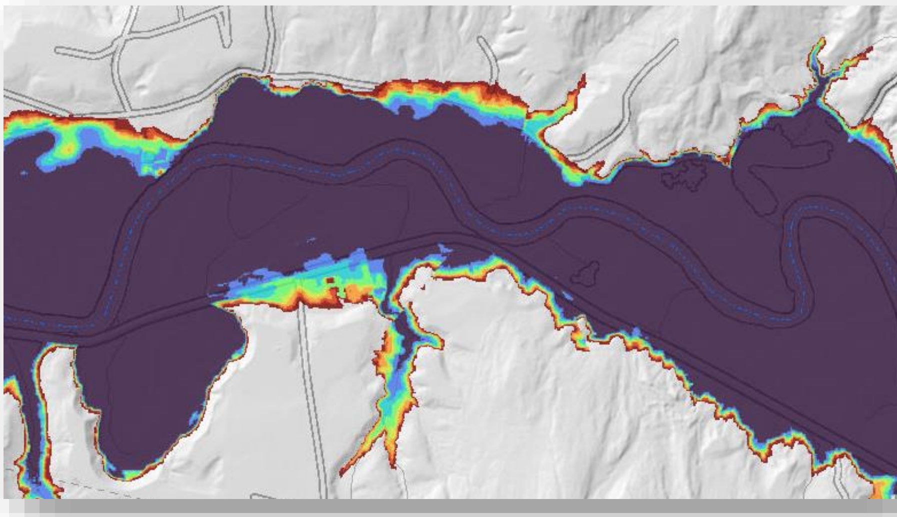


Figure B4. Example of likely over-prediction of flood extents in low gradient, low relief setting. Dark blue symbolizes the 2yr flood, which is unlikely to fill the valley bottom and overtop the road located at the valley wall.

6. Peak Discharge Estimates Associated with Flood Frequencies

Uncertainties in peak discharges may be great, especially along regulated rivers and those for which substantial access to floodplains and wetlands upstream attenuate flood peaks.

Peak discharges for each reach were estimated from a multiple linear regression model of Olson (2014) that underlies USGS Streamstats (https://streamstats.usgs.gov/ss/) in the Vermont region. This source uses a set of equations for various return intervals to estimate peak discharge for ungauged sites on rivers minimally affected by flow regulation (e.g., withdrawals, impoundments, diversions). Final regression equations reflect a relationship between peak discharge and the following three independent variables: drainage area, percent wetlands/water, and mean annual precipitation. A comparison of estimated peak discharges with discharges determined through a flow frequency analysis at gauged reaches in the Lake Champlain Basin demonstrates the limitations and challenges of using regional regressions for ungauged basins (Figure B5). In particular substantial over-estimation occurs on regulated rivers and where there is significant opportunity for water storage within the river corridor, such as on the Otter Creek that has a large wetland complex upstream of the Middlebury gage. The probHAND uncertainty analysis incorporates the standard error of the regional regressions, addressing some of the variability around the 1:1 agreement, but not fully addressing settings whose discharge does not scale to the input variables.

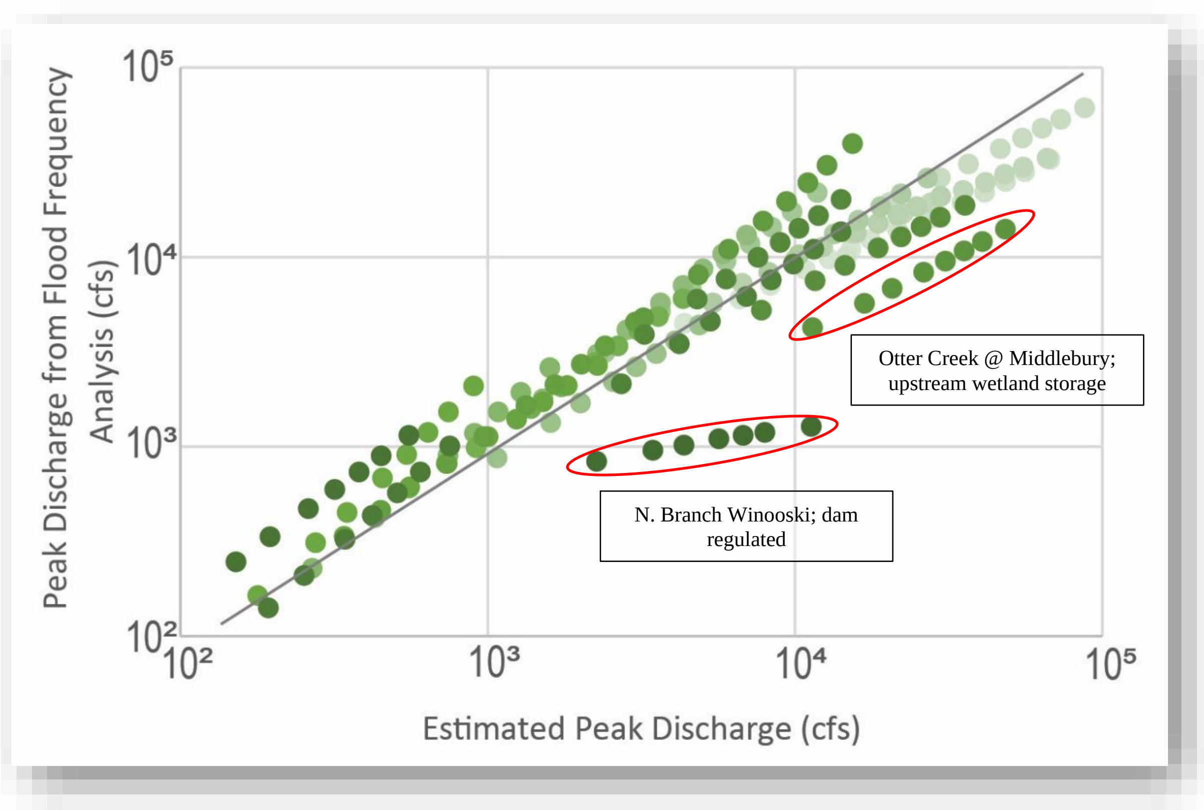


Figure B5. Relationship between estimated peak discharge (from regional regressions; Olson 2014) and those determined through a flood frequency analysis at gauged reaches for the 2, 5, 10, 20, 50, 100, 200, and 500 year recurrence interval floods.

7. Instream Waterbodies

Waterbodies that occur along the river corridor, including lakes, ponds, and reservoirs are not well represented in the Floodplain dataset

The probHAND model is intended to delineate flooded extents within the valley bottom associated with fluvial (river-derived) flooding. This current version of the Floodplain dataset includes water bodies (i.e, ponds, lakes, or reservoirs) that intersect the stream center line; however, floodplains along these impounded reaches are not accurately mapped using probHAND procedures. Reaches with waterbodies are attributed in the Reach Attribute layer to flag the uncertainty in floodplain extents for these impounded reaches.

8. Persistent Barriers to Flow on Small Tributaries

Inundated areas connected by culverts or bridges along small tributaries may be more frequently inundated than the maps indicate.

Hydro enforcing was performed on barriers to flow along the channels draining greater than 2 square miles. Thus, barriers to flow persist in the underlying topography where bridges or culverts convey small side tributaries to the main stem. These are often prevalent in urban settings. Consequently, some floodplain locations depict inundation only at higher flood stages (i.e., when road berms are overtopped), when in reality they may inundate at lower flood stages as facilitated by these under-road culverts (e.g., Figure B6).

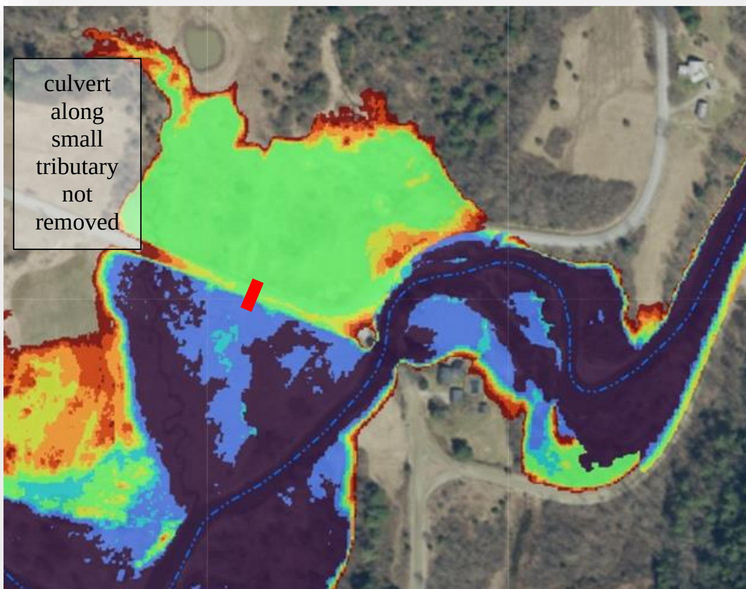


Figure B6. Example of likely under-representation of flood inundation frequency on portion of floodplain dissected by roads. While elevated road crossings were removed along major tributaries during hydro enforcing of the DEMs, they remain along small (drainage area <2 sq-miles) tributaries.

9. Currency of Underlying Datasets

Topographically-derived floodplains are based on the most recent dataset and may display inaccurate data if the landscape has changed.

The Floodplain maps represent the flood inundation extents as they are topographically represented at time of the most recent LIDAR data collection flight, which varies from 2013 to 2017. Because of this, there may be occasions where the NHDPlus stream line (2011) is offset from the mapped floodplains, or where the known stream centerline today is offset by both the mapped floodplain and the NHDPlus stream line, or where the inundation is not representative of current patterns. Often this occurs when there has been some disturbance(s) of the floodplain and/or channel that altered local hydrology in the intervening time period, such as (i) a flood event resulting in channel avulsion, (ii) flood recovery efforts, (iii) progressive channel migration, (iv) channel restoration activities, or (v) land use change impacting channel position. The Reach Attribute layer documents the approximate LiDAR flight date.

10. Flow Dispersion in Small Streams

Floodplains along small, headwater streams may contain gaps

Stream network generation was performed using a D-infinity flow accumulation algorithm. D-infinity algorithms divide the outflow of each cell amongst its two downslope neighbors, and because of this, they are able to reflect flow dispersion patterns within the topography. The probHAND model classifies cells as stream cells when the cell's flow accumulation exceeds the 2 square mile threshold. Flow in headwater reaches may disperse and dip below the accumulation threshold, leading to a gap in the stream network. With low flood stages in these areas already, these stream network gaps typically present as gaps in the floodplain.

11. HAND "Cliffs"

Floodplains may be constrained at an artificial barrier to flow.

To develop the HAND raster, each cell on the DEM is traced downslope until a stream cell is encountered. In some instances, cells will trace substantially down-valley before encountering a stream cell. This will tend to exaggerate HAND elevation, relative to the nearest drainage as judged by Euclidean distance, and will likely mis-represent inundation frequencies. This flow accumulation algorithm can lead to underestimation of inundation extents and/or inundation frequency. Specifically, in some areas inundation frequency may be under-estimated, and in others, the floodplain will appear constrained at nonexistent barriers (i.e., a HAND "cliff"; Figure B7). This phenomenon is particularly pronounced in areas where the vertical distance from the river channel to floodplain is pronounced such as where rivers are incised or where berms or levees exist.

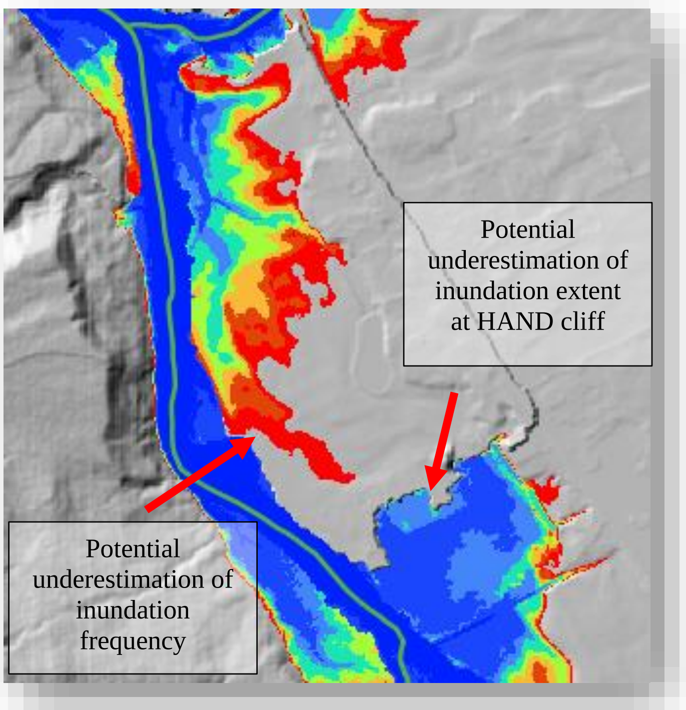
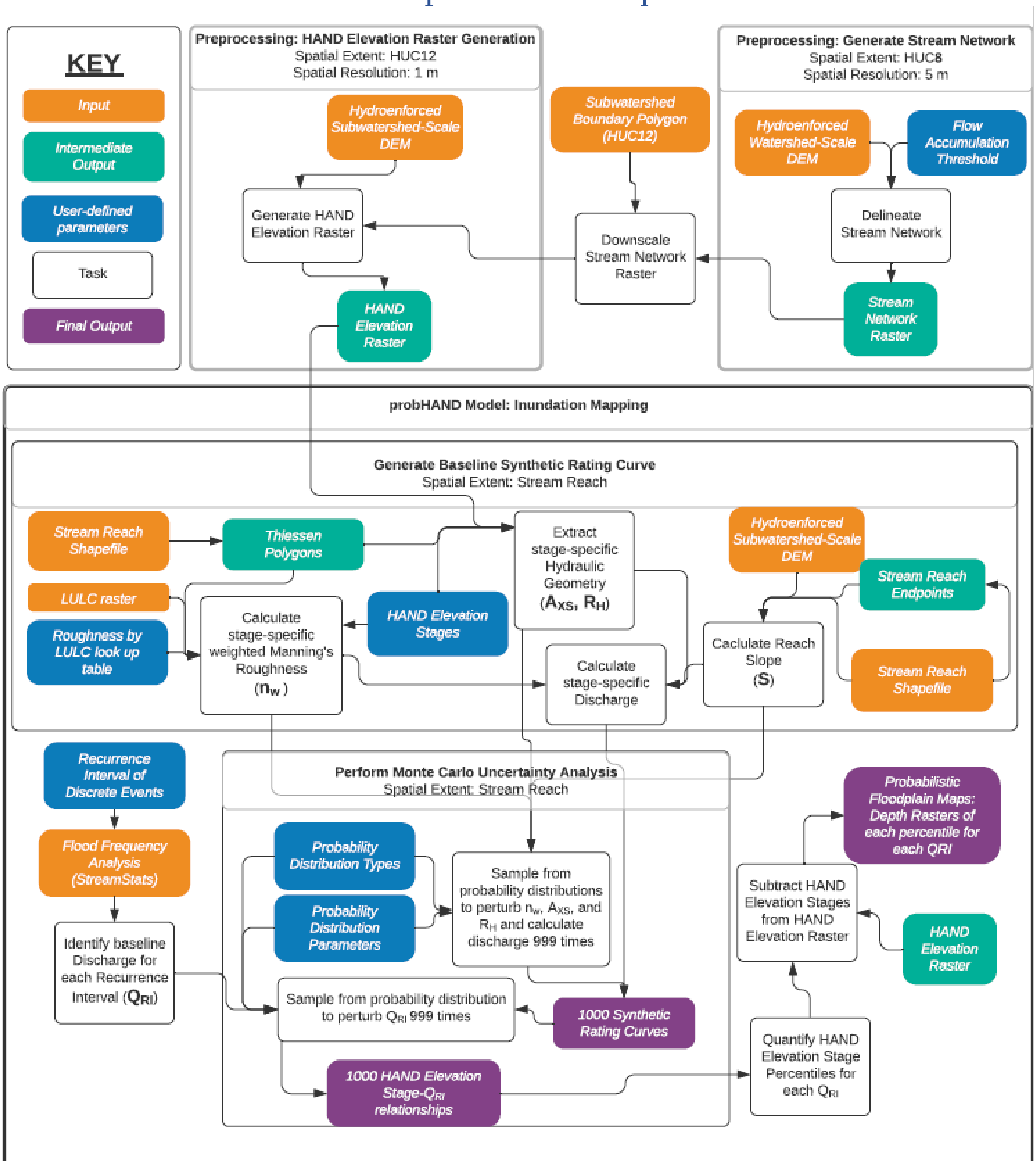


Figure B7. Example of HAND "cliffs", or artifacts of the algorithm used to develop the HAND raster. Floodplain maps are overlain on a hillshade of the HAND raster to highlight the "cliffs", or barriers to flow.

APPENDIX C: Flow chart of probHAND Implementation



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