BSC GROUP

BSC Inland Flood Risk Model for Massachusetts

FAST FACTS

Statewide, forward-looking flood data
High-resolution (10M) flood depths and extents for present and future scenarios

Cost-effective
Standardized, statewide outputs all provides efficiencies compared to bespoke, local modeling

Tailored for Massachusetts
Built upon MA-specific precipitation and geospatial data, aligned with scenarios in the ResilientMass Climate Resilient Design Standards

Comprehensive
Includes riverine and surface flooding

IDEAL FOR

Flood risk assessments
Map-based data supports complex analysis

Environmental permitting
Quickly reference future flood depths and extents as part of MEPA and other permit submittals

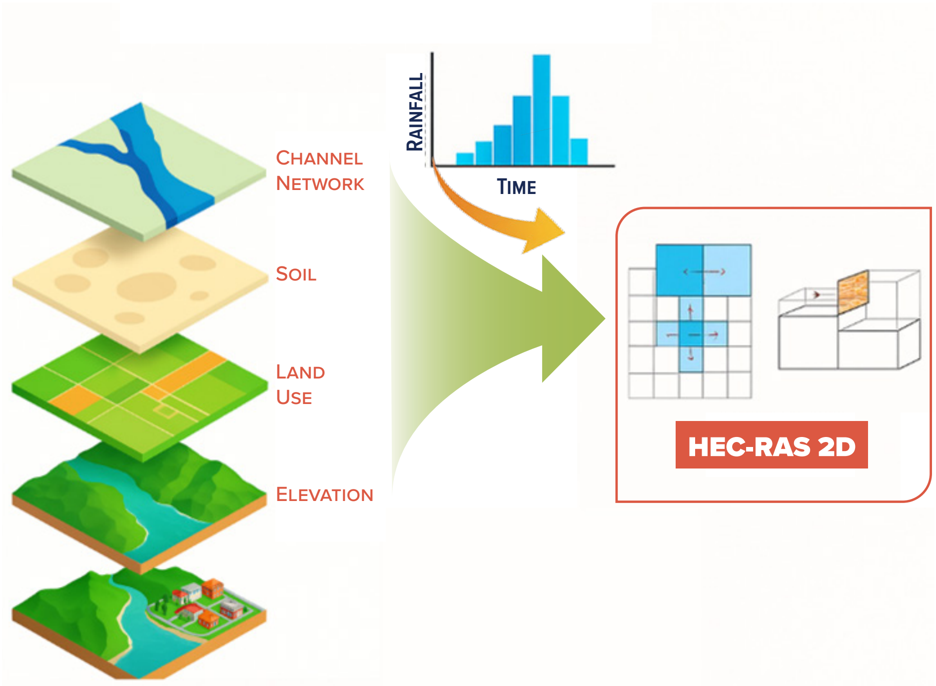
Large area planning
Inform land-use and other planning with future-oriented flood data

Basis for customization
Use as foundation for more detailed modeling or custom precipitation scenarios

The model is a statewide, high-resolution, two-dimensional inland flood simulation using HEC-RAS to support planning and flood hazard analysis for resilient communities and infrastructure across the Commonwealth.

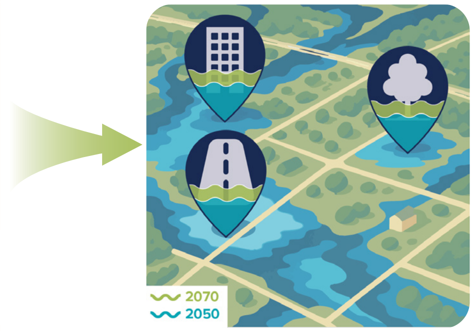
Outputs provide detailed maps of flood extents and depths, offering insights into frequent and extreme precipitation events.

KEY INPUTS



KEY OUTPUTS

Modeled Fluvial/Pluvial Flood Depths and Extents at **10-meter** Resolution for:



FEATURES SUMMARY

Statewide Coverage

Model outputs span the entire state at a 10-meter resolution, enabling comprehensive flood risk assessments for large and small areas.

Multiple Time Horizons

The model includes present-day, 2050, and 2070 precipitation values, reflecting the increases in precipitation frequency and intensity.

Multiple Return Periods

Modeling outputs account for 5-, 50-, 100-, and 500-year return periods (24-hour duration event with hourly time step).

High-Quality Data Inputs

The model incorporates datasets from USGS (topography[1], streamflow[2], Streamstat[3]), ESA land cover[4], MassGIS Statewide Coverage (Basin boundary layer[5], infrastructure[6]), NOAA Atlas 14[7], and MA-specific precipitation projections developed by Cornell University, USGS, and Tufts University on behalf of MA Executive Office of Energy & Environmental Affairs[8].

Enhanced Accuracy

Selective integration of culvert data refines water flow simulations by accounting for some manmade infrastructure effects.

TECHNICAL DETAILS

Preprocessing and Input Data

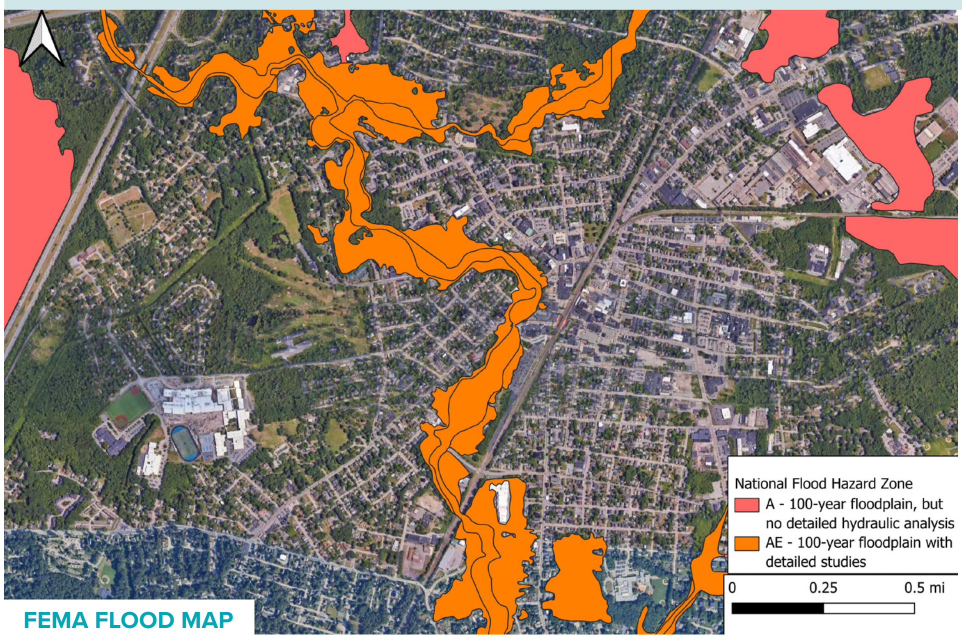
- **Topography:** 1-meter resolution digital elevation models (DEMs) from USGS and MassGIS are utilized as the base elevation input for the HEC-RAS model. The digital elevation models (DEM) are not altered in resolution and are directly used to extract terrain features, including for refining riverbed elevation and channel geometries.
- **Land Cover:** The model utilizes the 2021 ESA Landcover Map at 10-meter resolution, reclassified according to the International Geosphere-Biosphere Programme (IGBP) system to define Manning's roughness coefficients across the modeling domain. This approach enables a consistent assignment of surface resistance for overland flow simulations, while maintaining high spatial detail compatible with the 10-meter HEC-RAS computational grid.
- **Rainfall:** Design storms are derived from NOAA Atlas 14 data and the Massachusetts Climate and Hydrologic Risk Project (Phase 1) (Cornell/USGS/Tufts EEA dataset) for historical and future scenarios (2050 and 2070 horizons for the RCP8.5 scenario).
- **Hydrologic Boundaries:** Simulations are basin-specific, based on HUC12 watersheds, ensuring continuity at state boundaries. Upstream boundaries applied constant hydrographs, while inland downstream boundaries assume normal depth conditions.
- **Infiltration:** Infiltration is excluded for extreme design storms based on research indicating minimal effect during higher return periods. A referenced study[9] shows infiltration losses reduced flooded areas by only 5% at the 100-year event, compared to 33% reduction during 1-year events, confirming that excluding infiltration provides a conservative and realistic estimate for extreme flood events.

Modeling Software and Approach

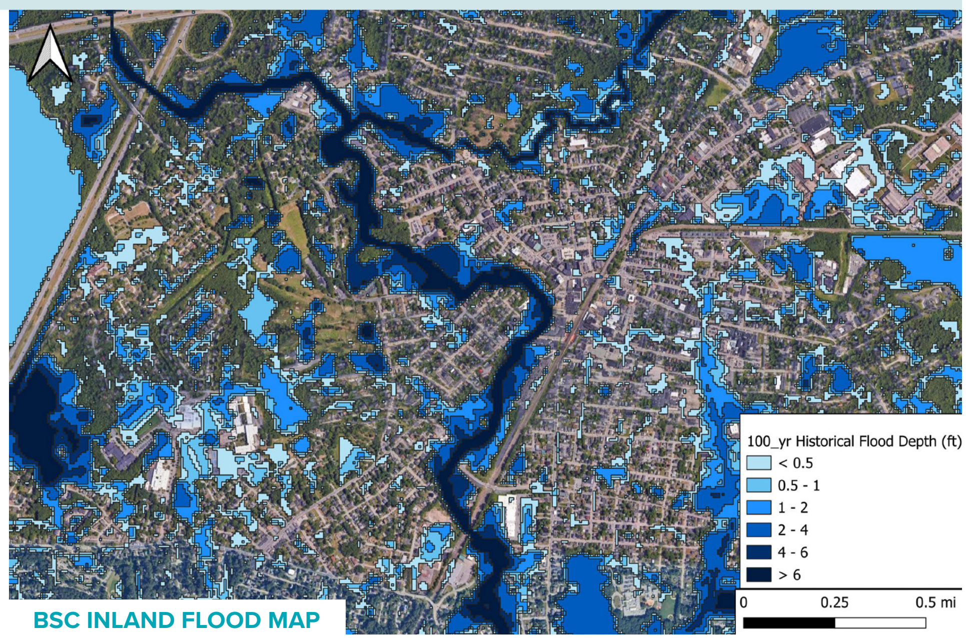
The model solves full 2D shallow water equations using HEC-RAS's diffusion wave solver. It captures dynamic interactions between rainfall-driven overland flow and fluvial processes across complex terrains and varying land cover types.

Selective culvert integration is conducted, with 842 culverts (in rivers with a width of ≥10 meters) manually burned into the DEM to correct topography and improve local hydraulic connectivity.

Access More Information, Including Pluvial (Surface) Flooding and Estimated Flood Depths, Compared to Standard FEMA Maps



FEMA FLOOD MAP



BSC INLAND FLOOD MAP

The HEC-RAS 2D platform is a widely recognized and trusted tool for flood modeling. HEC-RAS serves as an industry standard due to its:

- **Proven Accuracy:** Its methodologies are validated extensively in engineering and hydrological studies worldwide.
- **Flexibility:** The platform supports detailed, localized analyses and large-scale statewide modeling efforts, making it adaptable to various project scales.
- **Integration with Best Practices:** HEC-RAS aligns with engineering and planning norms, ensuring its results are reliable and actionable.

Compared to other tools, HEC-RAS 2D offers robust overland flow and water depth simulations, enabling detailed assessments of flood extents. Its capabilities are further enhanced by integrating high-resolution input data, such as DEMs and distributed friction maps, ensuring precise and realistic flood predictions.

This methodology enables high-detail simulations of water movement during flood events, flexibility to model both engineering-scale and statewide scenarios, and alignment with engineering and planning best practices. Including 2D overland flow modeling improves accuracy in simulating water depth and extent, bolstered by high-resolution input data such as DEMs and distributed friction maps.

Calibration

Model focused on ensuring accurate river geometry and flood surface propagation:

- **Bankfull Geometry:** Channel geometry is developed using an elevation-based approach informed by bankfull width analysis. This process involves generating terrain cross sections from 1-meter DEMs, with sampling intervals of up to 500 meters along river reaches (closer spacing is applied in complex areas).
- **Bankfull widths** is estimated using the Wolman Width-to-Depth Ratio and Bench Index (BI) methods, providing a geomorphological basis for defining channel boundaries. Wherever available, bankfull width estimates are validated using USGS Stream Stats information and regional curves. This methodology provides consistency between modeled river geometries and expected hydrologic behaviors across varying watershed conditions.
- **Riverbed Adjustments:** Riverbed elevations are calibrated to ensure that the modeled bankfull stage under the 2-year return period flood aligns with expected channel capacities. Adjustments are guided by reference data, prioritizing USGS regional curves and StreamStats-derived bankfull discharges for each river segment. In cases where local discharge data were limited or unavailable, extreme value statistical methods are applied to estimate bankfull conditions based on available hydrologic records.

  Cross-section spacing are maintained at a maximum of 500 meters to preserve geomorphic consistency, with closer spacing where channel variability warranted additional refinement.
- **Floodplain Adjustments:** Roughness modifications are prioritized over infiltration rate adjustments in pluvial areas.

Validation

Model performance is evaluated using:

- FEMA flood maps at 2-, 100-, and 500-year return periods.
- Available depth grids, flood extent datasets, and published regional flood studies, where applicable.
- USGS high-water mark observations.

Validation metrics included Critical Success Index (CSI), Hit Rate, False Alarm Rate, Error Bias, and R^2 statistics.

Limitations

- **Coastal Regions:** The model uses “normal depth” as a boundary condition, which assumes uniform flow conditions and does not account for the complex dynamics of tidal fluctuations, storm surges, and wave interactions in coastal regions. For detailed coastal flood risk assessments in MA, users should refer to the *Massachusetts Coast Flood Risk Model* or similar specialized tools.
- **Simplification of Control Infrastructure:** The model incorporates only culverts exceeding 10 meters in width, as identified on FEMA regulatory floodway maps. These culverts are burned into the DEM to ensure accurate propagation of water. However, smaller culverts, stormwater control structures, and hydraulic infrastructure are not explicitly included, which may lead to localized flow restrictions and reduced accuracy in areas with significant infrastructure complexity.
- **Stormwater and Sewer Systems:** The model does not simulate stormwater or sewer infrastructure, which can affect flood predictions, especially in highly urbanized areas. Integration of this data is possible on a project-specific basis to enhance model accuracy. BSC is able to integrate this information on a project-by-project basis. Please contact us to explore this option.
- **Soil and Saturation Effects:** The model does not dynamically account for soil saturation levels or changes in soil permeability during flood events. In real-world scenarios, pre-saturated soils can exacerbate flooding by reducing infiltration and increasing runoff, which may not be fully represented in the model outputs.

OFFICE LOCATIONS

HEADQUARTERS

Boston, MA

Andover, MA
West Yarmouth, MA
Worcester, MA
Glastonbury, CT
Manchester, NH

SERVICES

- Climate Resilience
- Civil Engineering
- Coastal
- Custom Software & Spatial Data Integration
- Ecological Science
- Flood Risk Information and Modeling
- GIS
- Landscape Architecture
- Land Surveying
- Mapping & Analysis
- Permitting & Regulatory Compliance
- Planning
- Structural Engineering
- Transportation Engineering
- Water Resources

Endnotes

[1] The National Map Data by the USGS National Geospatial Program (2022). Available at: https://apps.nationalmap.gov/downloader/

[2] National Water Dashboard by USGS Massachusetts Water Science Center, National Weather Service, and National Integrated Drought Information System (2020). Available at: https://dashboard.waterdata.usgs.gov/app/nwd/en/?aoi=default

[3] USGS Wisconsin Water Science Center and ESRI, Inc. (2018). Available at: https://streamstats.usgs.gov/ss/

[4] WorldCover 2020 v100: Zanaga, D., Van De Kerchove, R., De Keersmaecker, W., Souverijns, N., Brockmann, C., Quast, R., Wevers, J., Grosu, A., Paccini, A., Vergnaud, S., Cartus, O., Santoro, M., Fritz, S., Georgieva, I., Lesiv, M., Carter, S., Herold, M., Li, Linlin, Tsendbazar, N.E., Ramoino, F., Arino, O., 2021. ESA WorldCover 10 m 2020 v100. https://doi.org/10.5281/zenodo.5571936. Available at: https://worldcover2020.esa.int/downloader

[5] MassGIS, Bureau of Geographic Information (2003). Available at: https://www.mass.gov/info-details/massgis-data-major-drainage-basins

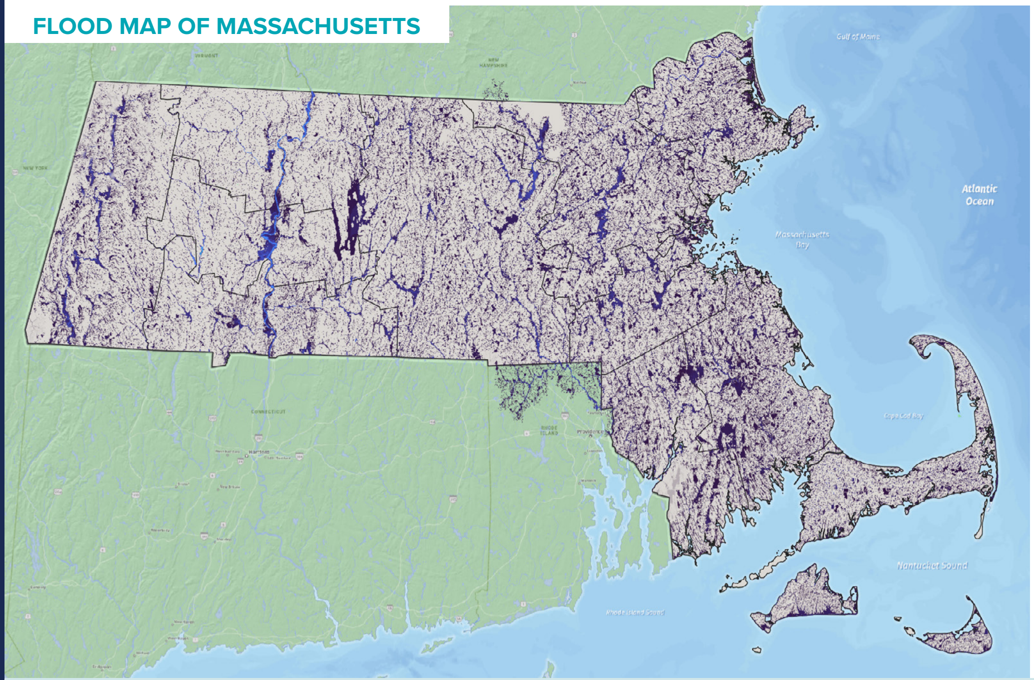
[6] MassGIS, Bureau of Geographic Information (2020). Available at: https://gis.data.mass.gov/datasets/MassDOT::culverts/explore?location=42.433257%2C-71.592418%2C9.38

[7] NOAA Atlas 14 (2011). Available at: https://hdsc.nws.noaa.gov/pfds/

[8] MA Executive Office of Energy and Environmental Affairs, Cornell University, U.S. Geological Survey, Tufts University (2021). Watershed Scale Temperature and Precipitation Projections. Available at: https://resilientma-mapcenter-mass-eoeea.hub.arcgis.com/

[9] Barbosa, S.A., Wang, Y. and Goodall, J.L., 2025. Exploring infiltration effects on coastal urban flooding: Insights from nuisance to extreme events using 2D/1D hydrodynamic modeling and crowdsourced flood reports. Science of The Total Environment, 968, p.178908.

FLOOD MAP OF MASSACHUSETTS



Disclaimer

The BSC Inland Flood Risk Model for Massachusetts shows the estimated pluvial (surface water) and fluvial (riverine) flooding at given time horizons based on USGS data for topography and streamflow, MassGIS for landcover and infrastructure, and NOAA Atlas 14 and projections of extreme precipitation frequency estimates provided in the ResilientMass Climate Change Projections Dashboard. BSC Group does not develop and is not responsible for such data and projections, which are subject to constant change and are provided "as is," without any guarantees or warranties of any kind. Data are modeled at 10-meter resolution and are not intended for specific engineering design. Any use of or reliance upon this map and the underlying data presented herein is at the sole risk of the user. The projected flood extents and depths may be used to inform plans and designs, but they are not to be considered final or appropriate for constructions documents without supporting engineering analyses.

For more information, visit BSC:

https://www.bscgroup.com/services/flood-risk-information-modeling/

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