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Subtask 2.12: AI and ML Tools to Support the Development of Blueprint

North Carolina Flood Resiliency Blueprint

Prepared for the North Carolina Department of Environmental Quality by AECOM

October 2023

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Definitions

A comprehensive list of definitions applicable to multiple Flood Resiliency Blueprint documents is provided in a separate document.

Acronyms

AI – Artificial Intelligence

AEP – Annual Exceedance Probability

BCA – Benefit Cost Analysis

FEMA – Federal Emergency Management Agency

GIS – Geographic Information System

GPS – Global Positioning System

HEC-RAS – Hydrologic Engineering Center's River Analysis System

IoT – Internet of Things

IP – Internet Protocol

LiDAR – Light Detection and Ranging

LiMWA – Limit of Moderate Wave Action

ML – Machine Learning

NC – North Carolina

RARR – Risk Assessment and Risk Reduction

ROI – Return on Investment

SIFT – Sediment Fingerprinting Tool

USGS – United States Geological Survey

WSEL – Water Surface Elevation

2D – Two-Dimensional

1 Introduction

Purpose: Subtask 2.12 – Identify Artificial Intelligence/Machine Learning (AI/ML) tools that can be used or developed to improve the North Carolina (NC) Flood Resiliency Blueprint (Blueprint) (e.g., reduce costs of updates, increase the accuracy of web-based decision tools, improve engagement and decision making).

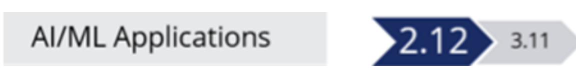
AI technologies have recently seen a surge in momentum and will become ubiquitous and integrated into floodplain management. It is not a question of when this technology will become available because much of it is already open-sourced with accompanied guidance. Leveraging existing open-source AI can have several benefits for the Blueprint, including cost savings, faster production time, flexibility and scalability of AI solutions that accommodates changing project conditions. A data governance strategy, in conjunction with a data driven decision making process will be adopted in the operation process to increase the transparency of decision makings and foster trust between users and administrators. It is essential to identify and understand the best use case and applicability to the functionality of the online data decision support tool as part of the development of the Blueprint.

The general benefits of AI include reduced information production time, rapid model adjustments, enforced data governance plan, most advanced technology adoption and cost savings. General limitations include the authority, accuracy, integrity, accessibility, and usability of data, technical expertise to develop the AI tool, domain expertise to interpret the tool and public perception of AI.

1.1 Connections to Other NC Flood Resiliency Blueprint Tasks

There are various interconnections between this Identification of AI/ML Tools for Blueprint (Task 2.12) and other tasks in the Blueprint, listed below.

- **Task 3.11** - AI/ML Utilization Recommendations



1.2 Branches of AI Applicable to Blueprint

AI is a continuously developing field that incorporates mathematics, statistics, sciences, data processing, and engineering to develop algorithms and apply rules that reach an objective. Two primary schools of thought define AI as 1) anything that replaces human intelligence is AI and 2) anything that can make predictions on unknown information based on existing and available data is AI[1]. While what is technically defined as AI remains a highly debated topic, artificial intelligence technology can essentially be broken into "branches," separated by application, including machine learning, computer vision, language processing, and robotics (Figure 1-1). It is important to note that these branches are not strictly independent of one another and often rely on or include aspects of each other. The following three branches of AI can be used or developed to improve Blueprint and are defined as…

[1] https://medium.com/@bharathkumar.h/artificial-intelligence-101-tech-terms-explained-for-non-tech-folks-3190d7e711cd

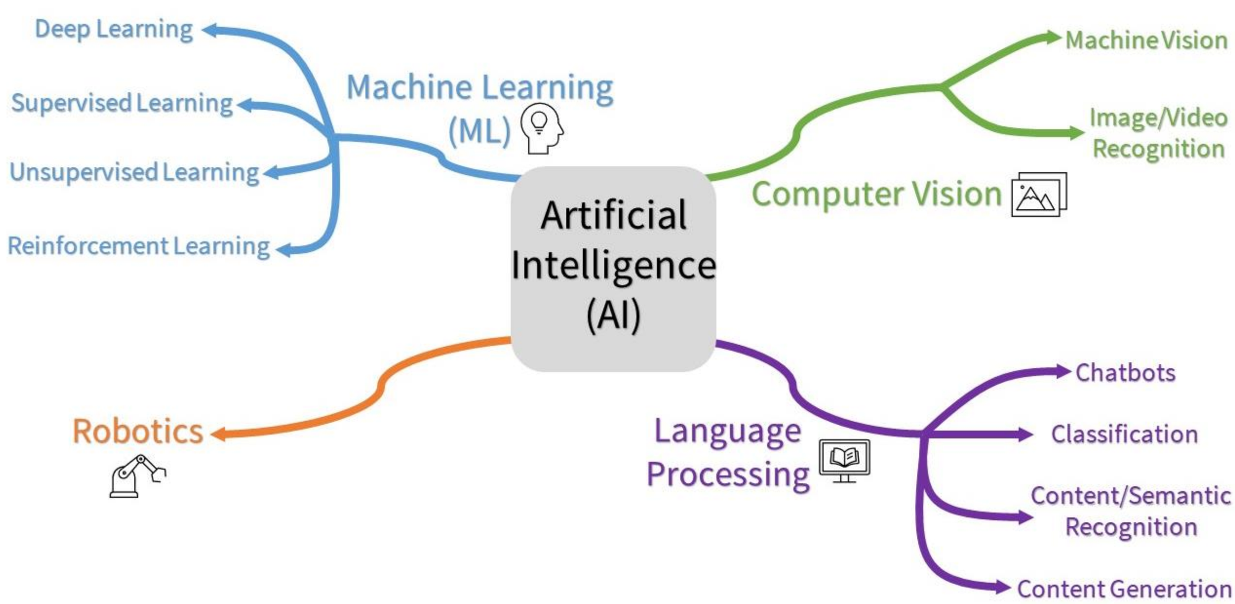


Figure 1-1: Artificial Intelligence Technology Branches

Machine Learning: "computational algorithms that are designed to emulate human intelligence by learning from the surrounding environment. They are considered the working horse in the new era of the so-called big data[2]."

Computer Vision: "artificial intelligence (AI) that enables computers and systems to derive meaningful information from digital images, videos, and other visual inputs — and take actions or make recommendations based on that information. If AI enables computers to think, computer vision enables them to see, observe and understand.[3]"

Language Processing: "combines computational linguistics—rule-based modeling of human language—with statistical, machine learning, and deep learning models. Together, these technologies enable computers to process human language in the form of text or voice data and to 'understand' its full meaning, complete with the speaker or writer's intent and sentiment.[4]"

In this report we apply these three AI branches to four specific Blueprint use cases including improved data enhancement & cost savings, data sharing & interagency collaboration, improved engagement & decision making, and digital twin.

A digital twin acts as a sandbox replica of real-world systems that allows users to develop, run, and test virtually modeled scenarios. While a digital twin is not AI technology, AI can be integrated to increase the predictive power of the generated models through accessing existing input data, learning, and ultimately increasing the complexity of input data by identifying and filling gaps as well as extending data's spatial and/or temporal scope.

[2] https://link.springer.com/chapter/10.1007/978-3-319-18305-3_1
[3] https://www.ibm.com/topics/computer-vision
[4] https://www.ibm.com/topics/natural-language-processing

1.3 Data Governance

To ensure the performance of AI/ML, Data Governance is the first step to ensure the data foundation is mature enough to feed into the AI/ML process. Data Governance can ensure accessibility, usability, relevance, accuracy, timeliness, integration of our data to support our decision-making with a reliable data pipeline.

Figure 1-2 shows the overall design of the data governance operation model. The data governance plan can span over multiple years, considered a long-term goal. Along the long-term plan implementation, with pain points identified, AI pilots can be implemented and applied as short-term initiatives. AI solutions can also be applied to those areas where the data foundation achieves maturity.

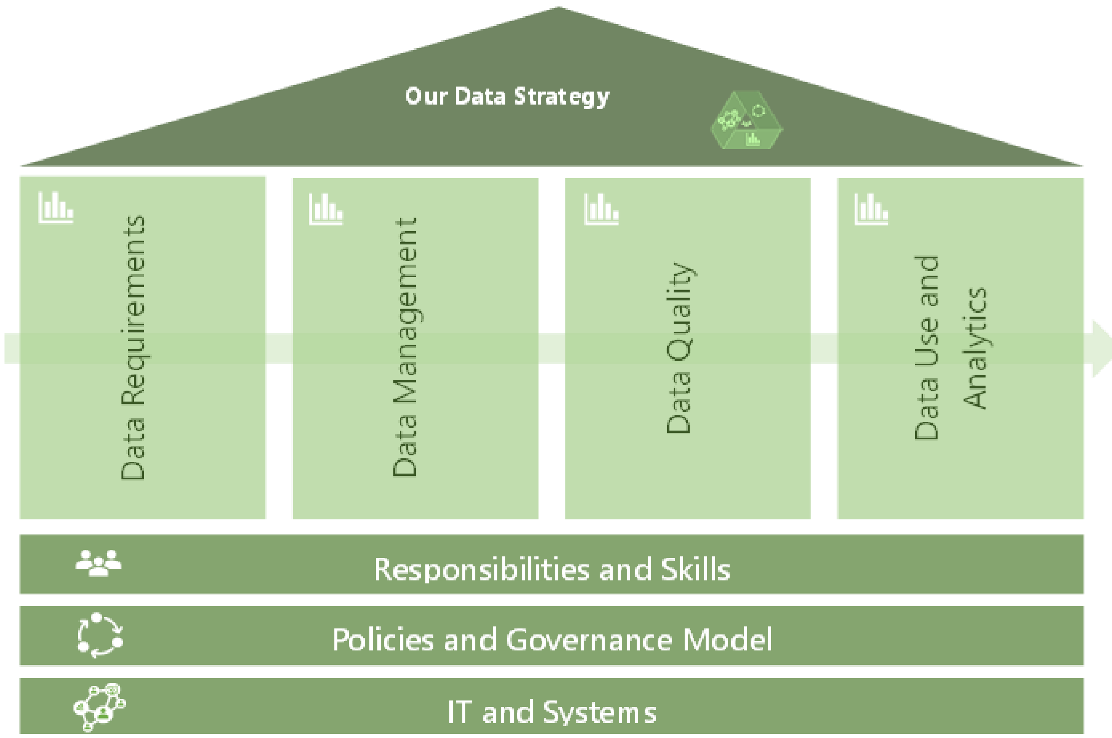


Figure 1-2: Data Strategy Operation Model

2 Data Enhancement & Cost Savings

2.1 Standard 2D Model Layers

The 2D (two-dimensional) modeling industry is not standardized, allowing a range of techniques and parameters to be acceptable. This leads to discrepancies, confusion, and distrust. Rework and duplicate work occur due to incorrect or unreasonable ranges of freedom allowed on current models. Developing statewide standards and tools will reduce the expense and redundancy of reworks.

AI technology can be used to standardize the production of infiltration layer, building footprints and stormwater networks for the following reasons:

1. AI will have a scientific process that can be reproduced as opposed to tasking a team, which would have differing engineering judgments and bias.
2. AI could continuously update these layers and verify the data.
3. AI can apply a localized and specific approach as opposed to a national approach that may relate poorly to the area.
4. AI can help close the resource gap of underserved communities by increasing the accessibility and usability of resources otherwise unavailable to them.

In summary, AI can identify patterns and trends to leverage large volumes of historical, real-time, and predicted future data to ultimately support the creation of state-wide standardized datasets. AI integration would create more accurate forecasts, optimize resource allocation, and reduce operational costs.

Some statewide layers, such as terrain, structures, and survey, do not require AI. The statewide layers that could be enhanced with AI are discussed in the following sections:

2.1.1 Infiltration Layer

The infiltration layer will contribute to the completeness of hydrology and hydraulics routing during the modeling process. The advantage of using an infiltration layer is that each cell has its own calculation instead of a single averaged calculation for the entire watershed. For example, with an infiltration layer the rain that falls on a street mostly becomes runoff, while rain that falls on sand is absorbed into the ground. Unfortunately, almost all the models for North Carolina currently average the street and the sand to be considered the same. Even more challenging is that each model uses different values for the same thing, often leading to results that do not match reality (e.g., sand specified as street). A standard layer allows all users to use the same input parameters and closes loopholes, allowing communities to use extreme parameters to achieve goals. This would provide cost savings as each study would not need to put in the effort to create its own layer while also correcting flood damage estimates from previous flawed studies.

AECOM has already created an AI–image processing tool that uses satellite imagery to determine land use at a much greater accuracy. This tool could be further expanded with LiDAR (Light Detection and Ranging) point cloud data to consider vegetation density within the land cover. It would use machine learning to produce a scientific process to calculate important model parameters such as a curve number, Manning’s n value roughness coefficient, etc. The tool could also be fully automated to continuously scan new satellite imagery to detect recent changes and adjust with the seasons. ML could be further used to calibrate the standard infiltration layer based on data such as radar rainfall, antecedent moisture conditions, gage flows and stages, etc. (see Appendix: Existing Tools - Land Use Recognition).

2.1.2 Building Footprints

While multiple building footprint sources already exist, the challenge is keeping these sources accurate and up to date with new construction and demolition activities. AI – image processing can scan new satellite imagery and LiDAR to detect these changes and update the layer, as previously discussed, with the infiltration layer. The reason to standardize this as a statewide layer is that the models should account for these changes, but currently do not most of the time. Additionally, having a standard of hydraulically accounting for these buildings would be beneficial.

2.1.3 Stormwater Networks

Large-scale modeling typically ignores that flooding, especially in urban areas, is often diverted and conveyed through stormwater drainage networks. It is important to capture these systems as they significantly affect model results as most mitigation projects are in areas with stormwater networks.

The initial task would be to compile a GIS (geographic information system) database of all municipal and state operated stormwater systems as a unified, statewide layer. However, there are many private systems and many municipalities that may not have readily available data. These missing segments could be generated with AI tools. Culverts, outfalls, storm drains, and other structures could be identified and estimated with aerial imagery through image processing. Many of these would be simple culverts under driveways, roads, railroads, etc. These strategies would save costs as they would reduce the need to manually modify and rework layers to account for missing segments.

2.1.4 Automatic Mesh Creation Tool

A large expense is required to refine a 2D model's mesh, which few, if any, of North Carolina's models are at the needed stage of advancement. There are no practical layers to assist this process. For example, the North Carolina Department of Transportation's transportation lines layer often follows aerial imagery and not the terrain. Models will need to be refined and would benefit from an AI tool assisting with this task instead of manually creating them for the entire state. A refined mesh is particularly important, especially in local applications such as a mitigation project's return on investment (ROI). Refined meshes include aligning cell faces with the direction of flow, aligning cell faces to extraneous features in the terrain (often via breaklines), variation in cell size (often via regions) and shape, and cell placement within the appropriate averaged calculation.

Image processing approach could be used to determine the breakline locations instead of drawing them manually. It can save a lot of labor hours. Leveraging the breakline auto creation, 2D mesh can be created or enhanced from there. The task of 2D modeling is costly and presents a significant hurdle for future flood management. A high quality, refined mesh is one solution that would increase cost savings, efficiency, and overall data accuracy.

2.2 Probabilistic Modeling

The existing standard practice of deterministic modeling only provides the "worst-case scenario" simulation. The modeling approach is conservative. In contrast, the probabilistic approach uses a Monte Carlo simulation, generating a range of simulated events. The probabilistic approach applies the proper weight to each simulated event and can return much more realistic results than the deterministic approach. The probabilistic approach was applied to FEMA's Flood Risk 2.0 program. With completed simulation results, ML can learn the data trend and predict the simulation results from targeted events, thus, this process can significantly reduce the operation cost of model simulations.

3 Improved Data Sharing & Interagency Collaboration

Flood resiliency management is a complex and multi-faceted operation that requires coordinated efforts across various government agencies and related Non-Governmental Organizations (NGOs), to prepare, prevent, and recover from flood events. The rapid advancement of the AI sector via a comprehensive suite of machine learning applications often unsettles traditional project management practices. There is an imperative need for regulators to efficiently streamline the data-sharing process and stay updated to continuously develop resiliency strategies to be more incrementally optimized in cost as the latest technology allows.

Advantages of committing to well-sought interagency collaboration for improved data sharing include comprehensive data collection for more holistic risk assessments that go beyond flood management for better prevention and recovery. Furthermore, there is the ability to strategize a timely, real-time emergency response and long-term resiliency planning via effective communication/quality control of resource allocations among different programs. By leveraging the power of language processing, flood resiliency planning can integrate resources such as text analysis for large complex datasets, ensuring scalability, which humans relatively lack the ability to adequately process in time. It can also offer sentiment analysis (e.g., citizen science on Twitter) to tailor specific community needs locally as a swift “bottom-up” response approach, as opposed to the “top-down” method of tediously running through the entire chain of commands of distinct entities to enact.

To streamline the multi-agency decision-making process, language processing can be applied to automate the above various assessments and ultimately provide an AI-powered chatbot to serve as the definitive source of information. The chatbot could automatically facilitate valuable, unified insights in a short-term and long-term timeframe with 24/7 support, which otherwise may have required stringent permitting via multiple meetings, detailed manual analyses of numerous standards/guidelines, and much larger funding requirements merely to come up with an agreement. An available service like Kapa.ai already exists today, which the teams at OpenAI and others are actively using to create a project tailored “ChatGPT” to help reduce the need for internal support or save labor costs. The product not only reduces human reliance, but also identifies gaps in the existing documentation and products by analyzing the generated answers. Similarly, the chatbot can automate the data sharing and cleaning from all associated stakeholders’ inputs, which may be extracted from multiple databases, in a consistent manner to improve the decision-making process for better accountability and fair distribution of available resources.

4 Improved Engagement & Decision-Making Processes

As complexity in floodplain management increases, so will the need for a simple product. Mutual understanding needs to be established between the public, government, and practitioners. Programs are trending towards an authoritative and "black box" approach. The "black box" approach works as a device or system which will return final products to the end users without enough understanding of the internal working logic. This is a concern for Floodplain management advises, which can be extremely complicated, especially without transparent and clear communication of how and what decisions been made. By setting the level of understanding and engagement at a public level, other levels such as federal or private will also be able to understand and govern well. To reach this level of understanding AI will play a key role in simplifying the communication and representation of stakeholders by deploying a strategic data governance plan, which can be easily shared and interpreted by decision-makers. AI also enables the Blueprint platform to offer 24/7 communication to users. It can effectively convey flood information based on extensive data-driven methods, in more straightforward or complex terms to be understandable by users with a wide range of expertise, depending on the details of the requested prompt.

The Blueprint online decision support tool, supported by AI technology, can allow users to make more informed and equitable floodplain management choices by providing clear visuals and reporting of how North Carolina is managing flooding. A common challenge communities face is the ability to make flood mitigation decisions that fully account for ongoing and/or existing projects in their applicable hydrologic service areas. Progress of flood management can be accounted for with factors such as, but not limited to, risks of current property (including recently developed), cost of mitigation efforts minus the benefits (cost expenses avoided), upward mobility, etc. This would be a human-intensive effort subject to bias and external influences. An AI system would be best to account for these complex factors being data-driven and able to recognize patterns not seen by a human analyst. AI would allow continual, transparent feedback to ensure responsible governance on how funds are distributed and how well funds are used relative to project goals. An AI system could account for a holistic overview and allow Blueprint to set goals and see progress in reaching those goals.

4.1 Engagement at Varied Scales of Complexity

A virtual assistant powered by AI can clarify the concept of a 1% AEP (annual exceedance probability) storm event as the terminology can be confusing even for professionals in the field, tailored to the specific user's needs. For example, the virtual assistant might define the 1% AEP event by presenting historical photos from a comparable flooding incident, using the user's IP (internet protocol) address for geospatial information. It could then, through a series of automated data networking and calculations, inform the user that their area of interest faces a 30% chance of flooding over the course of a 30 years.

4.2 Engagement with Public Platforms

Most residents of North Carolina have a camera phone or the ability to document and communicate flooding and many freely share this information through social media. There are also many cameras for security, monitoring, or other purposes that can capture flooding. In addition, there are historical newspapers and other records documenting flooding and help with the human perception of flooding. Overall, there is a vast wealth and dense network of existing and developing documented flood information that is rarely used that would further densify the network and may be a useful source to document flooding.

People often use social media platforms during an event to post about their experiences and seek help. Image and video processing and ML algorithms can be used to analyze these posts and identify the areas where people most need help. For example, suppose people are posting about being stranded on the roof of their house or about being trapped in a flooded area. In that case, AI algorithms can identify these posts and alert emergency responders. This information can be used to prioritize rescue efforts and allocate resources more effectively. This is wider than just an event. AI can continually look at historical social media posts to mine data and improve floodplain management.

A common weakness in floodplain management is the lack of validating sources to establish ground truth. The high costs of acquiring and operating many gauges and sensors prohibit the establishment of a dense network. The typical solutions to high costs are to obtain more funding and/or find cheaper alternative sensors (also often increasing maintenance costs). However, there may be an out-of-the-box solution to the traditional sensors using photographs (in combination with other sources).

AI tools (such as AECOM's tool) that translate the photos of flooding to locations and inundation extents can be expanded to determine depth, time, and other variables. This AI tool would enable the vast wealth of photos to become low-cost sensors with a dense urban network (See Appendix: Existing Tools – Flood Recognition for more detail).

4.3 Funding Solutions

AI, specifically machine learning and language processing technology, can efficiently identify, continuously learn about, and update project funding opportunities for flood resiliency projects. By populating project or program profiles specific to North Carolina, these solutions can provide matching and scoring for alignment of existing funding, perform a gap analysis on funding, and identify where more funding is needed. Additionally, these solutions provide users with the expert guidance and program insights required to navigate the rigorous requirements of the Infrastructure Investment and Jobs Act and the federal commitments of the Justice40 Initiative.

Most projects need to be justified, often accomplished by seeing if the benefits outweigh the costs. Having the ability to provide a rough estimate for a ROI analysis will allow projects to progress to further stages. Otherwise, expenses must be paid upfront that may be wasted if the ROI is too low. AI could produce ballpark ROI or identify areas that would have large benefits. For example, single-access neighborhoods that become flooded or washed out, trap people inside and make it difficult for outside help to access the area. Mitigation is one relatively low-cost solution where the benefits typically outweigh the costs (for example, upsizing a culvert). Identifying areas in the model that experience flooding, single access neighborhoods, and underserved communities could lead to mitigation efforts in previously overlooked communities.

AI could then identify and prioritize potential mitigation sites, having calculated the cost to replace a road and the associated loss of service (flooding often causes a loss of service to transportation, utilities, employment, schooling, emergency services, etc.). The expense of the loss of services is usually not considered for large-scale planning purposes. Even without mitigation, identification of the risk alone would prepare damage cost at the time of a major event and assist stakeholders in making decisions with an optimal ROI.

4.4 Reporting

It is expected that various agencies and users would want reports covering project accounting material. An applicable example of this strategy in action is the City of Charlotte's Flood RARR (Risk Assessment and Risk Reduction) tool, which calculates the cost saved from mitigation such as home elevation when real storms occur. Charlotte's RARR tool also displays a graph of flood risk decreasing over the years. AI powered chatbot can be used to return answers to users' questions and provide automatic reports based on users' needs. That information can be used for inter-agencies communications and public education. Thus, this will improve the transparency of the decision-making process.

5 Digital Twin

A digital twin is the "holy grail" of floodplain management, a sandbox replica of the real world. All the AI/ML tools discussed within this report, as well as the sources of Blueprint could power the digital twin. A major advantage of the digital twin is that the range of what it can be widely varies, allowing it to be phased and designed as needed. While the initial cost to develop a digital twin is high, the benefits far outweigh the costs as a long-term investment.

5.1 Agile System of Continuous, Automatic Updates

The main advantage of a digital twin is that it is dynamic; automatically interpolating a myriad of information. For example, a digital twin continuously scans satellite imagery to detect new land development, new building footprints, forest fires, risk of debris jams, or other major changes to flood risk. This allows for good housekeeping as data is quickly updated and can be linked to automatically update flood risk (with the assistance of human supervision). The functionality of real-time flood risk updates starkly contrasts the traditional study based on course, outdated national datasets and engineering judgement. There are a plethora of examples of potential automatic updates and data inputs. Suffice it to say that a digital twin is agile and able to continuously progress with future demands.

5.2 Phasability, Synergy, and Packability

A digital twin can be created in phases allowing flexibility in costs and schedule. A digital twin can start small and straightforward, including no more capability than what a normal study would entail. As resources become available, more can be built upon the previous work. For example, a FEMA (Federal Emergency Management Agency) study of a 2D (Two-Dimensional) model (Specifically for NC the 2D Advisory Flood Hydrologic and Hydraulic Modeling) could be uploaded as the foundation of digital twin. Data such as terrain, flood hazard data layers, property value data, property damage lost data coupled with flood insurance quotes, flood control facility dataset can be all uploaded to build the digital twin to show the flood risk related information to the agencies and public. When funds become available the digital twin could be taught to establish machine learned parameters. These learned parameters could then allow for quick flood risk assessments and bridge the gaps between flood events. In a later phase, a city could create a digital database of their stormwater networks and use the digital twin to create a 2D model of the networks, improving the planning ability of urban areas (or as the technology improves such as the next version of HEC-RAS).

The ability to phase the digital twin enables these phases to be packaged and shared with others. More importantly it allows each community to decide what is important for them. For example, a city struggling to control development with discontent and frustrated residents. This city could invest in the digital twin to display flood risk through an immersive virtual reality/augmented reality teaching experience that would better communicate the communities flood risk. A further example, where a city lacks flood depth gages and decides to instead invest in using historic and public photographs to determine urban flood depths. Each of these developments could be packaged and applied to other cities at a fraction of the cost because most of the work has been done by an interested party. In many instances shared interest can lead to synergy in developing these packages. Third party packages also can be incorporated from private companies or other states and nations. To ensure the data quality uploaded to the digital twin, a well-established data governance plan needs to be in place to ensure the data quality, integrity and timeliness.

5.3 Mimic the Reality, Better Decisions

The concept of digital twin is to mimic the reality in a digital world. With good data governance plan in place, using proper AI tools and sensors to collect real data, the digital twin can have a much better representative of the reality. Many digital twin applications have simulation data as well; thus, the simulated data and the monitored data can supplement each other, meanwhile cross validate each other. The rich and near-real digital twin can be the trust data source for floodplain management decision making process. With the transparency of the data displayed and accessible to multiple agencies and the public, it can improve the communication on disaster mitigation and disaster responses.

The availability of big data, advanced computing power, and modern technology has removed barriers that previously limited AI/ML. Data processed in a digital twin can be looped back into the digital twin to improve itself. For example, the digital twin could take rain depths and hurricane paths and compare them to forecasts from the European and American Agencies and determine that the

European Agency provides better rain forecasts while the American Agency provides better path forecasts. The next time a hurricane is forecasted, the digital twin would have learned how to better interpret and apply this data. A digital twin can derive patterns from data to gain understanding beyond human capacity. This will have an initial cost, but eventually it will operate automatically in the background for minimal cost.

6 Conclusion

The purpose of this document is to identify AI/ML tools that can be used or developed to improve the Blueprint by reducing costs of updates, increasing the accuracy of web-based decision tools, and improving engagement and decision making. Using the AI/ML tools identified in this report, Subtask 3.11 - *Recommendations for the Utilization of Artificial Intelligence and Machine Learning to Inform Blueprint* – builds on this previous work to provide recommendations on the utilization of AI/ML to inform the development and maintenance of the Blueprint.

7 Appendix

7.1 Existing tools

The following tools are included as examples of how AI/ML can be used in flood resiliency related online tools. Each tool touches on at least one concept presented in the main body of the report while providing ground truthed methods that Blueprint can consider integrating during future phases of work.

7.1.1 Flood Recognition

AI flood recognition can locate photos from metadata, text extraction, reverse image search, user camera clustering, etc. (Figure 7-1). It can also approximate inundation extent by projecting images (focal length, GPS [Global Positioning System]) location, altitude, roll, tile, direction, and SIFT (Sediment Fingerprinting Tool)), then identify flooded areas (image thresholding and Kmeans Clustering) and convert it to a polygon. This is a proprietary solution which uses open-source packages.

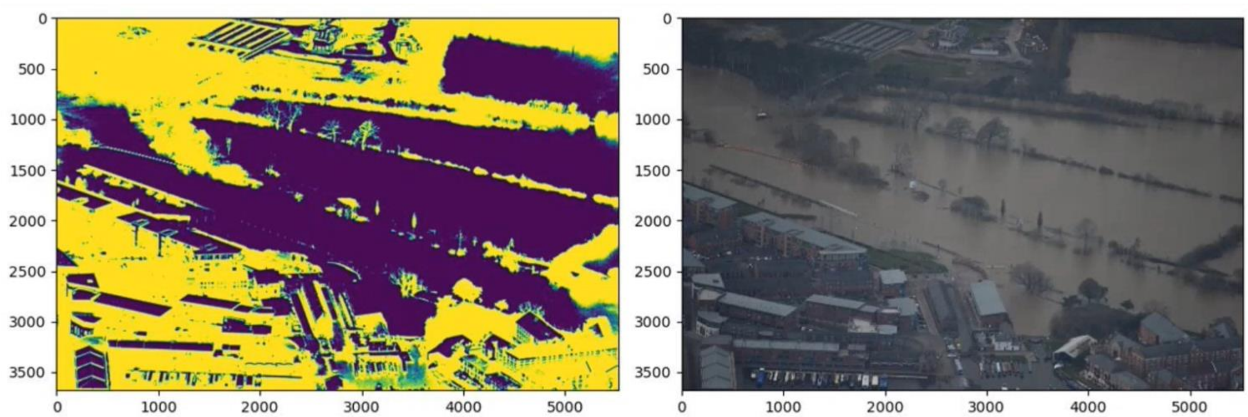


Figure 7-1: Generating Metadata via Local Satellite Imagery

- **Sources**:
  - https://www.thetimes.co.uk/article/ai-used-to-process-a-flood-of-information-lkdzf9xts
  - https://www.nature.com/articles/s41612-023-00388-1#Sec12

7.1.2 Land Use Recognition

AI land use recognition can automatically develop roughness and imperviousness data used in flood modelling by data-driven methods using imagery and LiDAR (Figure 7-2). Traditionally, practitioners have relied on a national dataset or manually digitized land use features with low detail and abundant inconsistency. AI is used to delineate features such as building extents, roads and vegetation with high precision and minimal bias at a massive scale. In 2021, the Moreton Bay Regional Council in partnership with AECOM developed an innovative approach that uses x-ray vision and point cloud data science to calculate vegetation density below the canopy. This innovative approach was successfully ground truthed and significantly improves the understanding of hydraulic roughness. This is a proprietary solution which uses open-source packages.

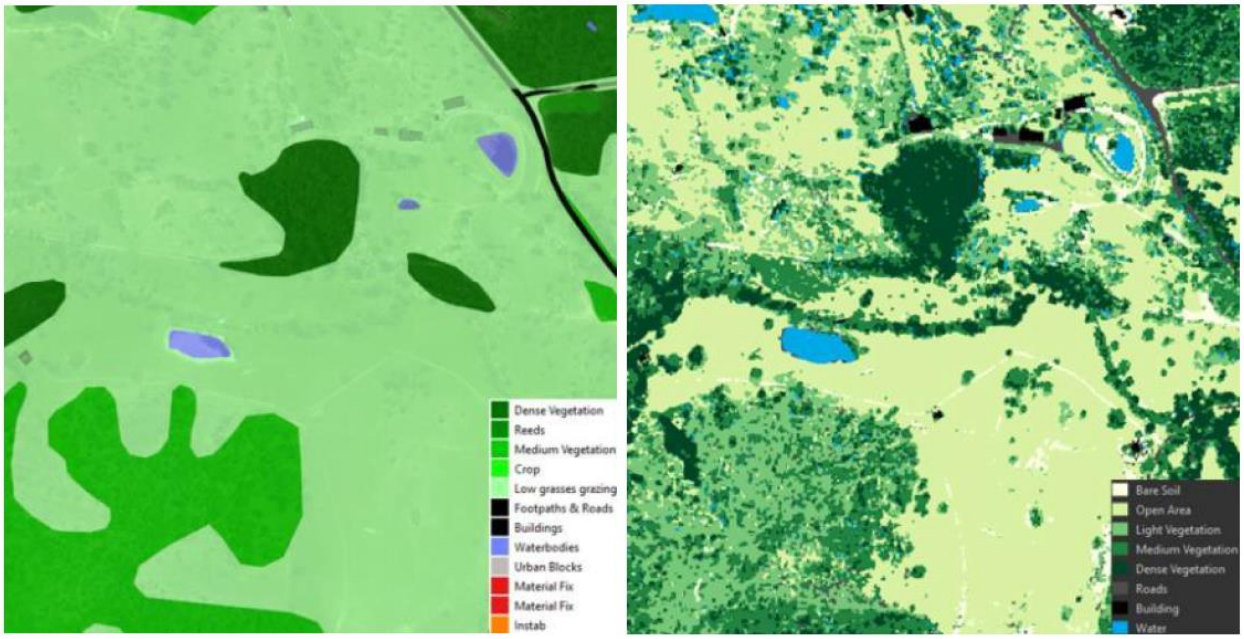


Figure 7-2: Integration of Orthoimagery and LiDAR to generate Land Use Data

- **Source**: https://www.surfacewater.biz/wp-content/uploads/2021/11/20210427_FMA21_ArtofRoughness_FINALPaper.pdf

7.1.3 2D Floodway

ML techniques are applied to limit the number of iterations to determine the floodway (most dangerous part of the river where development is very restricted) in 2D models. Being able to quickly determine where the floodway will be in 2D models will be important to restrict development as time and funding may take longer than the development.

AECOM developed a proof of concept in applying ML process to optimize the 2-Dimension Floodway Development. The ML process leveraged depth and velocity raster data to predict a better start point for engineers to begin floodway model iterations. The ML model was trained using a completed floodway simulation dataset, cross-validated internally with an accuracy of 99%. Furthermore, by applying the ML model to a different project, which is the external test, showed a successful reduction of model iteration time by 90%. This is a proprietary solution which uses open-source packages.

7.1.4 Microsoft Planetary Computer

The Microsoft Planetary Computer is an initiative by Microsoft to create a cloud-based platform that combines various forms of data from Earth's systems, such as the atmosphere, oceans, and land, to provide researchers, scientists, and policymakers with the tools and data they need to better understand and address global environmental challenges.

The platform aims to aggregate and analyze petabytes of data from sources such as satellites, scientific instruments, and social media, using advanced machine learning algorithms and artificial intelligence tools to generate insights and predictions about changes in the Earth's environment. These insights can be used to inform decision-making around issues such as climate change, natural resource management, disaster response, and urban planning.

The Microsoft Planetary Computer is built on top of the Azure cloud platform and makes use of Microsoft's extensive global network of datacenters to process and store vast amounts of data. It also incorporates a range of open-source technologies, including Jupyter notebooks, Apache Spark, and TensorFlow, making it easy for researchers to develop and share their own models and analyses.

Overall, the Microsoft Planetary Computer represents an important step forward in the use of technology to help address some of the most pressing environmental challenges facing the planet today. This is a proprietary solution which uses open-source packages.

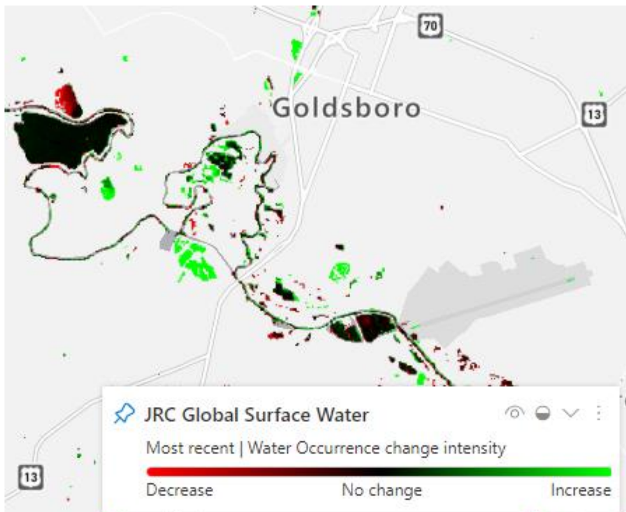


Figure 7-3: Microsoft Planetary Computer's Water Occurrence Change Intensity Layer (Goldsboro, NC)

- **Source**: https://planetarycomputer.microsoft.com/

7.1.5 Google Flood Hub

The Google Flood Hub is an online platform developed by Google that provides information and tools related to flooding and flood management. The platform was launched in 2021 as part of Google's broader efforts to support climate action and help communities prepare for and respond to the impacts of climate change.

The Google Flood Hub offers a range of resources for individuals, communities, and organizations, including:

- Flood forecasts and alerts: The platform includes real-time flood forecasts and alerts for more than twenty countries, providing users with up-to-date information on potential flood risks and impacts.
- Flood mapping: Users can access detailed flood maps that show areas of potential flooding, as well as information on flood depths and flow velocities.
- Preparedness and response resources: The platform provides guidance and resources on how to prepare for floods, including information on emergency kits, evacuation plans, and flood insurance. It also offers resources for responding to floods, such as information on sandbagging and flood cleanup.

- Data and analytics tools: The platform include a range of data and analytics tools that can be used to analyze flood risks and impacts, including satellite imagery, weather data, and flood modeling tools.

This is proprietary solution which uses open-source packages.

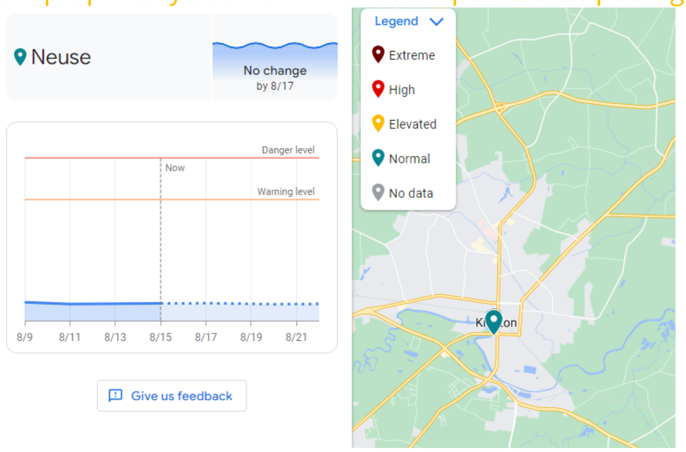


Figure 7-4: Google Flood Hub Flood Alerts & River Forecasts (Kinston, NC)

- **Source**: https://sites.research.google/floods/l/0/0/3

Overall, the Google Flood Hub is designed to help individuals, communities, and organizations better understand and manage the risks associated with flooding, and to support efforts to build more resilient communities in the face of climate change.

7.1.6 Fathom Flood

Fathom Flood is a web-based platform developed by Fathom, a data visualization and analytics company, which provides flood risk assessments for properties in the United Kingdom. The platform was launched in 2018 and is designed to help property owners and insurance companies better understand and manage flood risk.

Fathom Flood uses a combination of data sources, including satellite imagery, topographic data, and flood models, to create detailed flood risk assessments for individual properties. The platform considers a range of factors, such as the likelihood of flooding, the potential depth and extent of flooding, and the impact of flooding on the property and surrounding area.

Users of the platform can enter an address or postcode to generate a flood risk report for a specific property that includes information on flood risk levels, flood history, and potential impacts on the property. The report also includes recommendations for flood prevention measures that can be taken to reduce the risk of flooding and minimize potential damage.

Fathom Flood is designed to be user-friendly and accessible to a broad range of users, including property owners, insurers, and local authorities. The platform is intended to help users make more informed decisions about flood risk management and prevention, and to support efforts to build more resilient communities in the face of climate change. This is a proprietary solution which uses open-source packages.

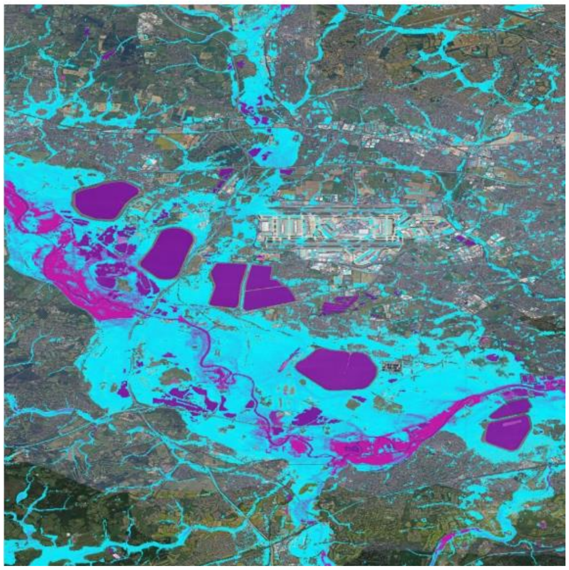


Figure 7-5: Fathom Flood's Relative Risk Product

- **Source**: https://www.fathom.global/

7.1.7 Streamflow Prediction

Hydroforecast is a company using science-guided AI solution to do streamflow prediction. It learns to represent hydrologic processes by identifying relationships between satellite observations, basin characteristics, meteorological forecasts, and streamflow measurements. The product can be used for hydropower operations, energy trading, dam safety, emergency preparedness, water supply management, restoration, and conservation. This is a proprietary solution which uses open-source packages.

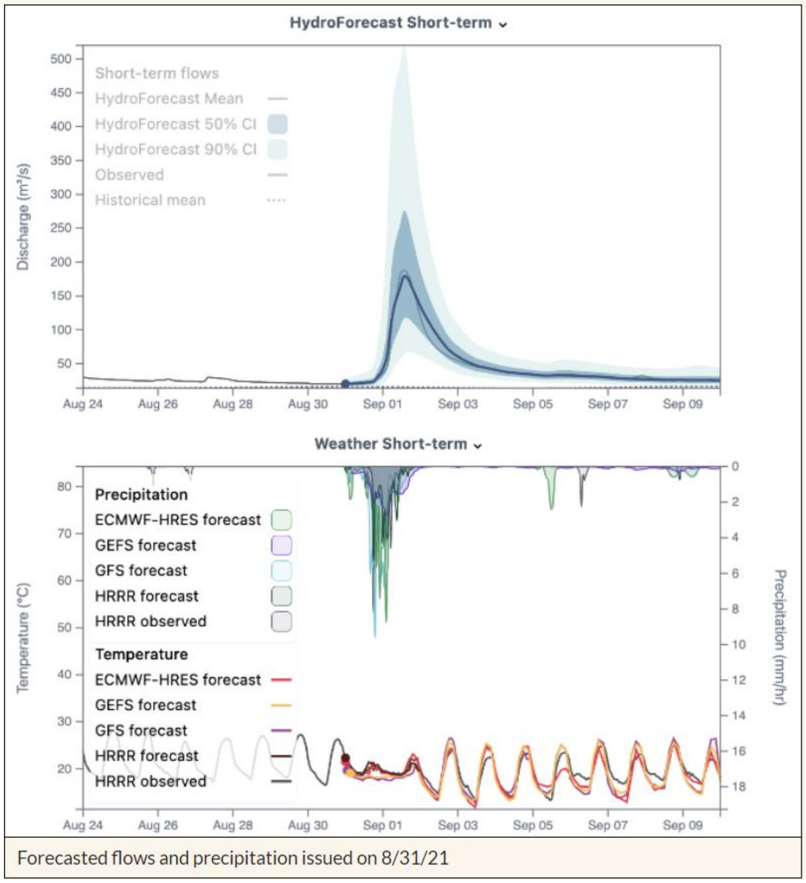


Figure 7-6: Prediction of Hurricane Ida at Little Tennessee at Needmore

7.1.8 FloodMapp

FloodMapp is a software platform that uses real-time data and machine learning algorithms to provide flood forecasts and alerts to help people and organizations better prepare for floods. The platform, founded in 2017, is based in Australia.

FloodMapp uses a variety of data sources, such as rainfall data, river levels, and topographic data, to generate flood forecasts and alerts. The platform uses machine learning algorithms to analyze this data and provide highly accurate and up-to-date flood risk assessments for specific locations. This allows people and organizations to take appropriate action to prepare for floods and minimize the risk of damage and loss of life. This is a proprietary solution which uses open-source packages.

Figure 7-7: FloodMapp PostCast Flood Inundation Impact Product

The FloodMapp platform includes a range of features, such as real-time flood warnings, flood depth and velocity modeling, and impact assessment tools. The platform is designed to be user-friendly and accessible to a broad range of users, including emergency services, local authorities, and businesses.

FloodMapp is designed to help individuals, communities, and organizations better understand and manage the risks associated with flooding, and to support efforts to build more resilient communities in the face of climate change. The platform is currently being used in Australia and is expanding to other parts of the world.

- **Source**: https://www.floodmapp.com/

7.1.9 Premonition

Premonition is a company that uses data analytics and machine learning algorithms to help identify potential disease outbreaks, including those caused by mosquito-borne viruses like Zika and Dengue fever. The company was founded in 2013 and is based in Miami, Florida.

Premonition collects data from a variety of sources, including social media, news articles, and government data, and uses machine learning algorithms to analyze the data for patterns and trends that may indicate the emergence of a disease outbreak. The company's algorithms can detect outbreaks earlier than traditional surveillance methods, allowing public health officials to respond more quickly and effectively to prevent the spread of disease.

In addition to disease surveillance, Premonition also offers a range of other data analytics services, such as predictive modeling and risk assessment, to help clients make more informed decisions and reduce risk.

Premonition's technology has been used to identify potential disease outbreaks in several countries around the world, including Brazil, India, and the United States. The company's work has been recognized by the World Health Organization and other international organizations as a valuable tool in the fight against infectious diseases. This is a proprietary solution which uses open-source packages.

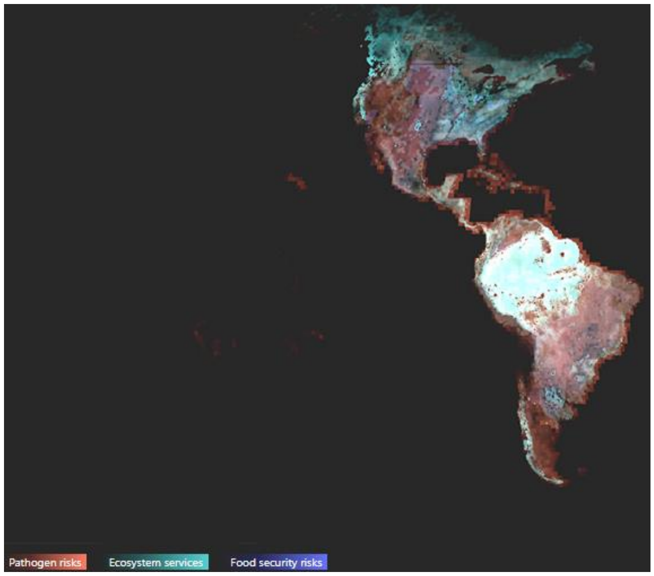


Figure 7-8: Microsoft's Premonition Platform

- **Source**: https://www.microsoft.com/en-us/research/product/microsoft-premonition/

7.1.10 IBM's Water Management Platform

IBM's Water Management Platform is a cloud-based platform that uses Internet of Things (IoT) technology, data analytics, and machine learning algorithms to help organizations manage water resources more effectively. The platform was launched in 2018 and is designed to help organizations better understand water usage, identify areas of inefficiency, and optimize water management strategies.

The Water Management Platform collects data from a variety of sources, including sensors, weather data, and satellite imagery, and uses machine learning algorithms to analyze the data for patterns and trends that may indicate water management challenges. The platform can also help organizations monitor water quality, detect leaks, and manage irrigation systems.

In addition to its core water management capabilities, the platform also includes features for predictive maintenance, asset management, and environmental monitoring. The platform is designed to be scalable and customizable, making it suitable for a wide range of organizations, from small businesses to large municipalities.

IBM's Water Management Platform has been used in a variety of applications around the world, including in agriculture, industry, and urban water management. The platform is intended to help organizations reduce water waste, improve operational efficiency, and build more sustainable water management systems. This is a proprietary solution which uses open-source packages.

- **Sources**:

- https://www.ibm.com/blogs/think/2018/11/49707/
- https://portal.mwater.co/#/resource_center

7.1.11 Aquantix

Aquantix is a software and data analytics company that provides solutions for water utilities and organizations that manage water resources. The company, founded in 2017, is based in Melbourne, Australia.

Aquantix offers a range of software platforms and services to help water utilities improve their operations and reduce costs. The company's platforms use advanced data analytics and machine learning algorithms to optimize water usage, detect leaks, and monitor water quality in real-time. Aquantix also provides consulting services to help utilities design and implement more efficient water management strategies.

One of Aquantix's flagship products is WaterWorX, a cloud-based software platform that uses machine learning algorithms to optimize water treatment processes and reduce energy consumption. WaterWorX provides utilities with real-time data on water quality, flow rates, and chemical dosing, allowing them to make more informed decisions about their operations.

Aquantix also offers a range of other software platforms and services, such as leak detection, asset management, and billing management solutions. The company's solutions are designed to help water utilities and organizations improve their efficiency, reduce costs, and ensure a reliable supply of safe and clean water for their customers. This is a proprietary solution which uses open-source packages.

- **Source**: https://www.aquantix.ai/

7.1.12 Flood.io

Flood.io is a cloud-based load testing platform that helps developers and businesses assess their websites, applications, and APIs (application programming interface) for performance under heavy traffic and high load conditions. Flood.io was founded in 2014 and is based in Australia.

The platform allows users to simulate real-world traffic scenarios by generating massive user loads from around the world. Users can create and run load tests with thousands or even millions of virtual users, and measure how their systems perform under different conditions. The platform also provides real-time monitoring and analysis of performance metrics, allowing users to quickly identify and troubleshoot issues.

Flood.io's load testing platform is designed to be flexible and customizable, allowing users to configure and fine-tune their load tests to match their specific needs. The platform supports a wide range of protocols and technologies, including HTTP, WebSockets, and JMeter.

Flood.io's load testing platform has been used by businesses of all sizes, from startups to Fortune 500 companies. The platform is intended to help businesses ensure their websites, applications, and APIs can manage high traffic loads and provide a smooth user experience, even under peak load conditions. This is a proprietary solution which uses open-source packages.

- **Source**: https://www.flood.io/

7.1.13 Digital Twin and AI

A recent project led by AECOM engineers and planners developed digital twins with integrated AI solutions to enhance stakeholder engagement efforts in an Australian community experiencing chronic flooding. The project team developed the digital twin with hydrologic variables and AI generated underlying data, including buildings and vegetation, to depict 2-4m^2 (5-10km^2), 3D models of the community environment. During the engagement process, participants navigated a model of a simulated flood path from a recent storm event where they validated the model's accuracy and identified aspects the digital twin may have missed like surcharging sewer maintenance holes. The engagement effort further used the 3D modeled flood event simulation to walk through potential flood risk management strategies such as stream restoration and open space establishment/preservation with participants. This is a proprietary solution which uses open-source packages.

Figure 7-9: AECOM's Digital Twin's Australian Community Model

- **Source**: https://digital.aecom.com/article/using-artificial-intelligence-and-digital-twins-to-inform-our-most-vulnerable