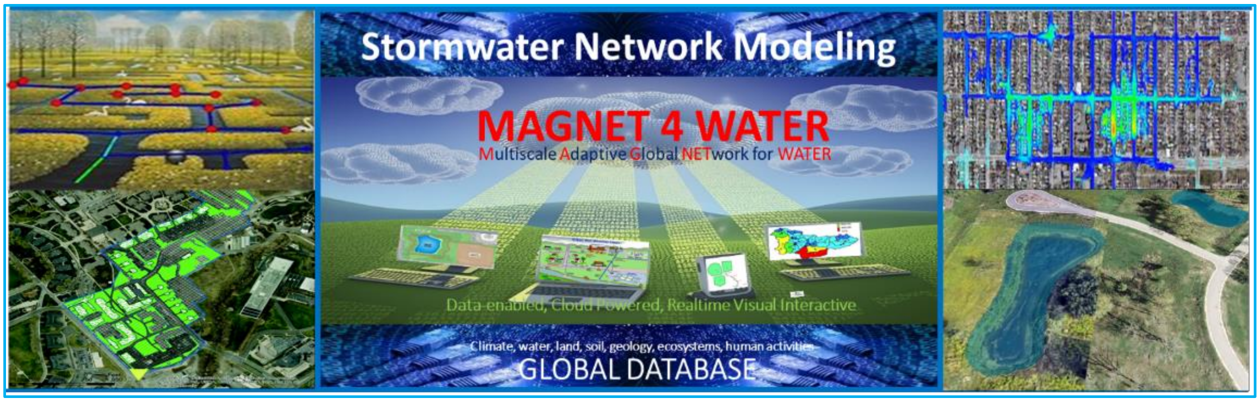
Stormwater Network Modeling
MAGNET 4 WATER
Multiscale Adaptive Global NETwork for WATER
Data-enabled, Cloud Powered, Realtime Visual Interactive
Climate, water, land, soil, geology, ecosystems, human activities
GLOBAL DATABASE

Contents

INTRODUCING STORMNET

Leveraging the ongoing global digital transformation, especially the global spatial data revolution, we introduce a next-generation global digital twin modeling technology for integrated urban water systems, including:

- Stormwater and sanitary drainage systems, including combined sewer overflow systems
- Water distribution and stormwater harvesting systems
- River systems modeling and flood inundation mapping
- Green infrastructure and low impact design

The platform, called M4W - StormNET, is part of the MAGNET 4 WATER platform that also includes five other sister global modeling platforms:

- M4W-AquaNET for realtime AQUifer System Analysis and Modeling,
- M4W-SwaNET for realtime Soil and Water Assessment and modeling,
- M4W-RiverNET for realtime river system analysis and modeling,
- M4W-PipeNET for realtime Pipe Network modeling, and
- M4W-DataNET for realtime data integration, mapping, visualization and analytics

Unique Capabilities in a Nutshell

M4W-StormNET is unique in that it is data-enabled – or live-linked to global data network supporting modeling, design, and analysis.

The data-enabled platform facilitates – for the first time – realtime, participatory modeling, visualization, analysis, reporting, and publication.

Users can zoom in anywhere in the world to build almost instantly - using big data “trimmed” to their site - a model, analysis, and visualization that can be further refined with user’s own data.

Users can instantly publish data and model results to the world, or cyber-enabled environmental observatories to showcase their capabilities and achievements - in high impact 3D visualizations, animations, and intelligent reports.

The platform further allows intelligent reporting, realtime help, and AI1-enabled situational community support.

[1] AI=Artificial Intelligence

A Smart Service System

Unlike traditional software, the M4W-StormNET technology is directly built on the data networks, eliminating the bottlenecks associated with modeling using big data that are becoming increasingly immovable. These bottlenecks include computational bottlenecks, as well as human operational bottlenecks, human cognitive bottlenecks, and network communication bottlenecks.

The platform is delivered as a service system, combining IaaS (infrastructure as a service), PaaS (platform as a service), SaaS (software as a service), and DaaS (data as a service) - accessible anywhere, anytime on demand through an internet browser.

All modeling and design tools are live-linked to a comprehensive, systematic global database system consisting of raw, processed, and simulated data from an international network of (hundreds of) data services. This includes data services provided by Hydrosimulatics, and by the a number of federal or national agencies, includes:

- United States Geological Survey
- National Aeronautics and Space Administration
- National Oceanic and Atmospheric Administration
- United States Department of Agriculture
- United States Environmental Protection Agency
- Federal Emergency Management Agency
- United States Army Corps of Engineers
- United States Fish & Wildlife Service
- Environment Canada
- British Geological Survey
- German Federal Institute for Geosciences and Natural Resources
- French Geological Survey
- Geoscience Australia
- United Nations Educational, Scientific, and Cultural Organization

Eliminating Bottlenecks

The new modeling paradigm involves no off-line post-processing and no disk writing, because results are displayed and used on the fly.

It eliminates the time-consuming and error-prone intermediate processing, establishing real time communication between the assumptions/concepts and final results/implications.

It eliminates the boundaries and disconnect among the different components of data-model software solutions, and creates capabilities that provide a system perspective and holistic management ability.

The platform changes the role of humans in complex modeling projects from heavily “physical” to cognitive problem solving and decision making tasks.

Unlocking Human Ingenuity

The seamless model integration, visual interactivity, and real-time processing and communication capability makes it possible for scientists and engineers to focus on critical conceptual issues and to quickly and iteratively: examine modeling approximations and hypotheses, identify dominant processes, assess data worth and model uncertainty, calibrate and validate the numerical representation, and experiment in real time with environmental sampling, management, and remedial options.

The innovations enable intelligent human-machine interactions that set big data free, unlocks human ingenuity, and enables realtime problem solving and complex water systems modeling in ways previously impractical.

It enriches the process of professional investigation and scientific discovery and transforms the way scientists and engineers conduct model-based investigations and site characterization.

Numerical Engine

The M4W-StormNET platform makes use of the EPA’s Storm Water Management Model (SWMM) – a program widely used by the international water resources community.

The underlying SWMM modeling engine solves the full Saint Venant equation for unsteady flow using the dynamic wave routing method, allow modeling diverse flow scenarios or regimes, including pressurized or unpressurized flow, backwater, surcharging, and reverse flow, as well as surface ponding, street flooding, and flood inundation, in branched and/or looped networks in response to event-based, individual storm events or long term continuous stresses and boundary conditions.

GLOBAL DATABASE

The integrated global database system supporting M44-StormNET platform contains information and data related to climate, hydrology, topography / terrain, land use and cover, soil, urban infrastructure, and roads and streets, and can be used directly for conceptual modeling / system visualization, numerical model development and calibration, result interpretation, and integrated design analysis.

Some of the most relevant datasets for Stormwater modeling include:

Climate Data

- (Historical and Present) The National Climatic Data Center (NCDC) Hourly and 15 Minute Precipitation Data (HPD) Data Service; 5,500 US National Weather Service (NWS), Federal Aviation Administration (FAA), and cooperative observer stations in the United States, Puerto Rico, the US Virgin Islands, and various Pacific Islands.
- (Historical:) NOAA PRISM database, containing seamless USA-wide climate datasets - including daily precipitation, temperature, radiation, dew point, from 1981 to 6 months ago, at 4km-resolution
- (Statistical) NOAA Precipitation Frequency Data Server *(PFDS)*, delivering NOAA Atlas 14 precipitation frequency estimates and associated information for a majority of US States (still awaiting coverage for Idaho, Montana, Oregon, Washington, and Wyoming).
- Global Climate Forecast System Reanalysis (CFSR) weather generator database, containing daily temperature, mean dew point, vapor pressure, and solar radiation, at about 38km resolution, for the period 1979 to 2018.
- (Historical, Present, and Short-term Forecasts) National Weather Service (NWS) NEXTRAD precipitation, including realtime measurements and historical time-series, based on a network of 158 high-resolution Doppler weather radars operated by the National Weather Service.
- (Historical and Present) China Meteorological Assimilation Driving Datasets v1.2, raster, Daily precipitation, temperature, and wind speed, with spatial resolution of 13 km derived from 416,000 stations (2008 to present). Data from 58,500 older stations are also available (1979 to present).
- (Historical and Present) Environment Canada climate data from over 1100 weather stations, containing hourly or daily precipitation, temperature, dew point, relative humidity, and other data in some cases (e.g., wind speed, air pressure).
- (Future Forecasts) Spatially variable precipitation and time series forecast data from the NWS Weather Prediction Center (WPC) Probabilistic Quantitative Precipitation Forecasts (PQPFs). The WPC produces 6-hourquantitative precipitation forecasts at 6-hour intervals (72-hour duration). PQPFs are computed based on a combination of WPC's 6-hour QPF and an ensemble of model forecasts.

Land Data

- Digital Elevation Model (DEM), characterizing topography at multiple resolutions: 1000m, 300m, 90m, 30m, 12.5m, and 10m
- LiDAR at sub-1m resolution, including bare-earth elevations and 3D point clouds, which are invaluable for stream and floodplain bathymetry delineation
- Land use and land cover and hydraulic properties, at 30m resolution, including historical and present, characterizing land cover and land cover change from 2001-2019, urban imperviousness, tree canopy from 2011-2016 and western U.S. shrub and grassland areas for 2016

Soil Data

- The Soil Survey Geographic Database (SSURGO) containing soil type information at scales ranging from 1:12,000 to 1:63,360. (Mostly at a scale of 1:12,000)
- USDA-NRCS gridded National Soil Survey Geographic Database (gNATSGO), providing complete coverage of the best available gridded soils information for all areas of the United States and Island Territories. It was created by combining data from the Soil Survey Geographic Database (SSURGO), State Soil Geographic Database (STATSGO2), and Raster Soil Survey (RSS) databases into a single seamless database at 10m grid resolution.

Water / Hydrology Data

- The National Hydrography Dataset (NHD) containing the water drainage network of the United States with features such as rivers, streams, canals, lakes, ponds at 1:24,000 scale
- Watershed Boundary Dataset, containing eight levels of progressively smaller hydrologic units / catchments
- United States National Dam and Reservoir Database.
- FEMA Flood Hazard Zone Database
- Global soil moisture datasets at 0.25°x0.25° spatial resolution, including surface and subsurface soil moisture (mm), soil moisture profile (%), and surface and subsurface soil moisture anomalies
- Global MODIS datasets, containing 8-Day and yearly evapotranspiration at 1km resolution, and net 8-day and yearly evapotranspiration 8 at 500m resolution
- National Streamflow network (NSN), containing more than 11,300 USGS stream gages, including approximately 8,500 realtime gages continuously monitoring streamflow year-round
- National Ground-Water Monitoring Well Network (NGWMN), historical and realtime, 17643 water-level wells, 4066 water-quality wells

Paradigm Shift in Modeling

The intelligent platform enables modeling in new, unique ways.

The platform provides realtime tools for data-driven decision making, process-based modeling, and for planning, analysis, and design related to stormwater runoff, coupled stormwater/sanitary systems and combined sewer overflows, and other drainage systems.

It can be used for evaluating gray infrastructure control strategies for stormwater, such as pipes and storm drains, and creating cost-effective green-gray hybrid stormwater control systems that reduce runoff through infiltration and retention, and help to reduce discharges that impair waterbodies.

StormNET supports local, state, national, and international sustainable development goals in relation to clean water and creation of resilient urban water infrastructures

Typical applications include:

- Designing and sizing drainage system components for flood control
- Sizing detention facilities and their appurtenances for flood control and water quality protection
- Mapping flood plains of natural channel systems— The modeling engine *SWMM 5 is a FEMA-approved model for National Flood Insurance Program studies*
- Designing control strategies for minimizing combined sewer overflows
- Evaluating the impact of inflow and infiltration on sanitary sewer overflows
- Generating nonpoint source pollutant loadings for waste load allocation
- Controlling site runoff using green infrastructure practices as low LID controls
- Evaluating the effectiveness of best management practices and low impact development for reducing wet weather pollutant loadings.

Instant Channel

The realtime modeling technology creates a new, instant channel for research, education, consulting, management, *simultaneously benefiting* multiple segments of the environmental communities and communities related to, influenced by, and serve or served by the environmental communities, including students, educators, researchers, professors, planners and managers, and policy/decision makers.

More specifically, the platform benefits:

1) <u>students and educators</u> – by bringing real-world problem solving into the classroom on a routine basis
2) <u>consulting engineers and scientists</u> - by drastically reducing the costs of groundwater system characterization and monitoring network design;
3) <u>managers and decision makers</u> – by allowing them to evaluate and visualize management options live in realtime; and
4) <u>researchers</u> – by dramatically enhancing their ability to understand complex systems across multiple scales.

We have emphasized real-time visualization and data and results overlays because the way information is presented has an enormous effect on how a modeler can understand it and exploit it for his or her needs.

Humans have five senses, but only our sense of sight has sufficient bandwidth to permit conveyance and interpretation of the immense amount of data obtained from large-scale simulation applications.

The new software system is effective since it recognizes this physiological constraint, human perceptual and cognitive factors, and takes advantage of human's special capability to recognize patterns and images.

Virtual Site Visit

Simulation in the digital twin environment begins with a *virtual site visit*.

The platform allows users to zoom in anywhere in the world to perform a preliminary system characterization – to explore the lay of the land, to discover what lies underneath, and to characterize the water systems. The new software offers a method of seeing the unseen and understanding the invisible.

In particular, the platform allows a user to:
- understand climate extremes
- delineate catchments and drainage patterns
- map flood hazard
- analyze land use patterns and vegetation cover
- visualize urban system and imperviousness, roughness, and heat island effects
- map soil types, and infiltration potential
- locate and map the groundwater table
- visualize borehole lithologies, surficial geology,
- identify/map sites of environmental concern
- understand vulnerability

Users can create a diversity of overlays through conventional 2D mapping as well as 3D immersive visualization, taking advantage of high-fidelity 3D terrains, LiDAR, and representations of urban buildings and urban infrastructure.

The software seamlessly and dynamically merges heterogeneous and distributed geo-spatial information into a single map - joining and viewing together separate data sets that share all or part of the same space or literally “fusing” maps together. The result of this combination is a new data set that identifies complex spatial relationships that evolve over time.

The new technology allows users’ thought processes to progress naturally and intuitively with the correct information visualized, analyzed, overlaid, and compared at the instant it is required, providing a real sense of continuous exploration.

Being able to watch natural subsurface flow and transport processes evolve over time and visualize instantaneously the complex interrelationships among hydrological and environmental variables sparks pivotal insights, giving rise to an intuitive grasp of the hydrogeological and chemical processes that can't be readily obtained otherwise.

Digital Twin Visualization

Armed with these unique insights and understanding from virtual site exploration, users begin model-based simulation.

Users can model a system interactively and iteratively, delineating, simulating, and importantly instantly visualizing model systems. Users can also model a system incrementally, beginning with a big picture, before adding more details. Or, users can also focus initially on a component, or a series of components, and gradually expand to create a more complete system, or a system of systems.

Importantly, M4W-StormNET enables instant conversion of a conceptual or numerical model representation into a high-fidelity 3D visualization or *Digital Twin*.

Users can visualize in 3D the complex water infrastructure network with 3D representations of buildings and other surface or subsurface infrastructure. StormNET enables both system-level visualization of the entire urban water system environment as well as realistic representations of model details (e.g., individual stormwater harvesting components or sub-systems).

M4W-StormnNET provides full control and flexibility with respect to visualization of different components of the digital twin environment (i.e., layers or features can be turned “on” and “off”, user can control semi-transparency renderings, etc.). Users can even customize the building “textures” using the built-in texture database, or upload textures/images of their own.

The user can create a digital twin visualization at any point during the model design, or after simulation as a static visualization or transient animation of 3D water dynamics in conduits, rivers, channels, water towers, tanks, ponds, and storage units.

Realtime interactive Digital Twin modeling and visualization allows users to manipulate and maneuver the visual presentations of the abstract results. It allows communicating with data by manipulating its visual representation during simulation. This process dramatically reduces the time needed for conducting a model-based simulation and analysis.

Real Time Conceptualization

The software continually displays results as simulations proceed. Users benefit by receiving immediate and continuous visual feedback in a form that is understandable.

In addition, the software paradigm enables complex computations to be calculated and the results intelligently processed, organized, analyzed, extracted, and displayed and overlaid in animated graphical form.

These processes dramatically reduce the time needed for conducting a model-based simulation and analysis.

The seamless model integration, visual interactivity, and real-time processing and communication capability makes it possible for scientists and engineers to focus on critical conceptual issues and to quickly and iteratively examine modeling approximations and hypotheses, identify dominant processes, assess data worth and model uncertainty, calibrate and validate the numerical representation, and experiment in real time with environmental sampling, management, and remedial options.

Modeling within the new environment becomes essentially a process of high-level interactive graphical modeling and conceptualization, as if one is drawing a picture of the site. It becomes a process of pointing and clicking to delineate the area of interest, the spatial coverage of the rivers, lakes, and wetlands, land uses, aquifer materials and properties, contamination sources, and to interactively input boreholes and wells to define aquifer framework and stresses. The user can pause at any time, including during the simulation and analysis, to interact with any aspects of the modeling process.

Specifically, the new real-time interactive environment allows a user, at any time during the modeling process:

- to graphically modify domain configuration, interactively change conceptual assumptions, aquifer structures, properties, stresses, and parameters independent of spatial and temporal discretization;

- to adaptively change numerical parameters such as time step, grid spacing, solution methods, solver parameters, and spatial interpolation techniques, without having to restart the integrated simulation;

- to introduce contamination from different sources and initiate particle tracking and contaminant transport modeling. Transport modeling is automatically activated when a contamination source is introduced. Flow is modeled only once and automatically skipped in the second time step if it is at a steady state;

- to “zoom” in one or more sub-areas and investigate local detailed dynamics by initiating one or more coupled nested subscale flow and transport models that run in parallel with the parent model. Boundary conditions for the local models are extracted from the regional/parent model dynamically at every time step online and automatically;

- to activate stochastic Monte Carlo simulation, examining the impact of heterogeneity, data limitation, and uncertainty. The probabilities at any interactively specified monitoring well and spatial statistics (means and standard deviations) are computed on-line recursively and visualized as the simulation proceeds. At any given time, best available probabilistic characterizations are presented and is recursively improved as the number of realizations increases;

- to perform, overlay, and visualize drawdown distribution, well influence areas, the area of contribution, and wellhead protection areas and to compute and instantly visualize solute mass and water budget balance over any interactively specified zones, seepage and solute flux distribution along a user specified polyline, head hydrographs and concentration breakthrough at a monitoring well; and,

- to customize the visual presentations and manipulate the results in real-time (e.g., changing the display mode, contour, vector, and line types, legends, levels of detail, ways of presentation, the number and order of parameter layers to be visualized), and thus help us to understand the results (especially the complex interrelationships) ‘on the fly’.

Visual Computational Steering

As changes in parameters become more instantaneous, the cause-effect relationships within the simulations become more evident.

Scientists and engineers not only analyze data that results from computations; they also interpret what is happening to the data during computations.

They are able to change parameters, resolution or representation, and see the effects.

They *interact* with their data.

They interact with their modeling processes

Real-time modeling and visualization makes users an equal partner with the computer to manipulate and maneuver the visual presentations of the abstract results.

They *steer* calculations in close-to-real-time;

They drive the scientific discovery, engineering design, and management problem solving process;

It allows scientists to communicate with data by manipulating its visual representation during processing.

The more sophisticated process of *navigation* allows scientists to *steer*, or dynamically modify computations while they are occurring and directly control the execution sequence of the program.

The software continually displays results as simulations proceed. Users benefit by receiving immediate and continuous visual feedback in a form that is understandable.

In addition, the software paradigm enables complex computations to be calculated and the results intelligently processed, organized, analyzed, extracted, and displayed and overlaid in animated graphical form.

The new technology allows the scientists and engineers' thought processes to progress naturally and intuitively with the correct information visualized, analyzed, overlaid, and compared at the instant it is required, providing a real sense of continuous exploration.

These processes dramatically reduce the time needed for conducting a model-based simulation and analysis.

The innovative software environment dramatically improves research productivity and reduces the time needed for conducting a modeling project.

The innovations enable intelligent human-machine interactions that set big data free, unlocks human ingenuity, and enables realtime problem solving and complex water systems modeling in ways previously impractical.

At the beginning of the simulation before there is any result generated, a few important feedbacks often significantly help in choosing correct parameters and initial values.

One can visualize some intermediate results and key factors to steer the simulation in the right direction. With computational steering, scientists are able to modify parameters in their systems on-line as the computations progress, and avoid something being wrong or uninteresting after long hours or days of expensive computations.

Major conceptual errors can be identified and fixed very early before many dependencies on the flawed concepts are created, resulting in higher-quality model representation in less calendar time.

Real-time steering can be considered as the ultimate goal of interactive computing.

Data Enabled Modeling

Critical model components are *data-enabled*, or live linked to a high-resolution database system containing information related to elevations, land use, soil, climate data, roads, and buildings.

Everything can be further *modified* throughout the modeling process, using users' own data, or big data-enabled modeling can be used to guide local data collection and integration.

Modeling Precipitation

StormNET enables automatic generation of spatially explicit rainfall time series based on 1) historical data, 2) future projections; and 3) design storm events or historical storm statistics.

The StormNET rain gage tool is live linked to the following databases:

- For Historical Events:
  - The Global Climate Forecast System Reanalysis (CFSR) weather generator database (daily precipitation, at about 38km resolution, for the period 1979 to 2018).
  - The NOAA PRISM database, containing seamless USA-wide daily precipitation, from 1981 to 6 months ago, at 4km-resolution.
  - The National Climatic Data Center (NCDC) Hourly and 15 Minute Precipitation Data (HPD) Data Service..
  - The NWS NEXTRAD precipitation, including realtime measurements and historical time-series..
  - China Meteorological Assimilation Driving Datasets containing daily precipitation data from 1979 to present.
  - Environment Canada hourly or daily precipitation data from over 1100 weather stations.
- For Future Forecasts:
  - the NWS Weather Prediction Center (WPC) Probabilistic Quantitative Precipitation Forecasts (PQPFs). PQPFs are used by forecasters and hydrologists to determine the probability of any rainfall amount at a given location. The WPC produces 6-hour quantitative precipitation forecasts at 6-hour intervals (72-hour duration). PQPFs are computed based on a combination of WPC's 6-hour QPF and an ensemble of model forecasts.
  - NOAA NEXTRAD short-term forecasts calibrated with on-the-ground rain gages
- For Design Storms:
  - the NOAA Precipitation Data Frequency Server that utilizes a map-based interface to extract rainfall depth given interactively selected location and storm duration and frequency
  - StormNET automatically converts total design rainfall to a time series, assuming a different types of statistical temporal distribution, including:

    - SCS Type I, Ia, II, and III
    - Uniform distribution
    - Triangular distribution
  - Custom time series – users can define a storm event by directly inputting precipitation data.

Modeling Evaporation and Snowmelt

StormNET models time-varying evaporation of standing surface water as part of the simulation process, using the Hargreaves approach.

StormNET models the accumulation, removal, and melting of snow over three types of sub-areas within a catchment:

- The Plowable snowpack area consists of a user-defined fraction of the total impervious area. It is meant to represent such areas as streets and parking lots where plowing and snow removal can be done.
- The Impervious snowpack area covers the remaining impervious area of a catchment.
- The Pervious snowpack area encompasses the entire pervious area of a catchment.

Both evaporation and snow dynamics depend strongly on temperature which can be automatically extracted from the following climate databases:

- the global CFSR climate generator database (about 38km resolution) containing temperature for the period 1979 to 2018.
- the NOAA PRISM database containing seamless USA-wide temperature datasets, from 1981 to 6 months ago, at 4km-resolution (with 800m coming soon).
- the China Meteorological Assimilation Driving Datasets containing temperature data with spatial resolution of 13 km derived from 416,000 stations (2008 to present).

Users can also load their own time series data that is more site-specific.

Modeling Infiltration into Unsaturated Soil

StormNET models infiltration into unsaturated soils using one of the following methods: 1) the Horton method, 2) the Modified Horton method, 3) the Green and Ampt methods, 4) the SCS Curve Number method.

Users can take advantage of automatic extraction of infiltration parameters from the following databases

- Worldwide FAO soil database (400m spatial resolution)
- USA wide gNASTGO soil database for United States, latest version, at 10m resolution

- USA wide gSSURGO soil database, or discretized SSURGO on a 10m grid with missing data / gaps filled by data from STATSGO and Raster Soil Surveys (RSS) – the best updated, modern soil dataset available for the USA.

Parameters extracted for georeferenced modeling and / or visualization include:

- Hydrologic Soil Group and SCS runoff curve number (needed for Curve Number infiltration method)
- Saturated hydraulic conductivity (needed for Horton, Green-Ampt and Curve Number method)
- Wilting point (Horton)
- Soil porosity (Horton, Green Ampt)
- Residual moisture content (Green Ampt)
- Moisture content at field capacity (Green Ampt)

Modeling Groundwater Inflow

StormNET allows modeling groundwater inflow into the stormwater drainage system, through subcatchment outlets.

Groundwater inflow from subcatchments areas to subcatchment outlets (receiving nodes such as storage units) – or "subsurface runoff" – requires specification of an initial groundwater level and surficial aquifer thickness, although site-specific information is typically lacking or sparse.

In StormNET, users may assign an initial groundwater level and aquifer thickness for each subcatchment directly from model outputs of MAGNET Groundwater: a water table interpolated from groundwater level data; or a simulated water table based on a process-based groundwater model.

Modeling Runoff

StormNET models surface runoff or overland flow for each of the subcatchments using nonlinear reservoir routing based on an effective sheet flow model.

Ponding on the subcatchments is computed using a water balance analysis, accounting for precipitation, evaporation and evapotranspiration, infiltration, interception, and outflow.

The outflow (runoff) is computed from an "effective" Manning's equation utilizing effective subcatchment slope, length and width calculated from the georeferenced subcatchment geometry and DEM (or design elevations). As a default, Manning's roughness is based on the site-specific land use extracted from the global land use / land cover database.

The runoff model is live linked to the following databases:

- 10m Digital Elevation Model (DEM) for the United States
- DEM at 90m for the world
- LiDAR for North America at sub-1m resolution, including bare-earth elevations and 3D point clouds, which are invaluable for stream and floodplain bathymetry delineation
- Land use and land cover and hydraulic properties, at 30m resolution, including historical and present, characterizing land cover and land cover change from 2001-2019, urban imperviousness, tree canopy from 2011-2016 and western U.S. shrub and grassland areas for 2016

Modeling Green Infrastructure

StormNET enables modeling green infrastructure or Low Impact Development (LID) that promotes infiltration and evapotranspiration (and therefore reduce runoff). The LID features that can be simulated include: bioretention cells, rain gardens, permeable pavements, green roofs, infiltration trenches, rain barrels, vegetative swales, and rooftop-disconnects.

StormNET models and visualize LIDs as spatially explicit features or as an implicit portion of an existing subcatchment.

A link to the Interactive EPA National Groundwater Calculator is available for LID cost estimation.

Modeling Stormwater Drainage System

StormNET enables simulates unsteady flow in conduit networks of unlimited size and complexity, including branched and looped networks. Utilizing the dynamic wave routing method, a diverse range of flow regimes can be simulated, including pressurized flow, gravity flow, backwater flow, reverse flow, and surcharging.

Conduit cross-sectional shapes of storm drainpipes can be custom designed based on a user-defined, tabular entries of cross-section geometry, or selected from a number of predefined regular parameterized cross-sectional shapes.

StormNET is live linked to 10m resolution digital elevation models and all invert elevations are defined relative to the ground elevations.

Conduit slope calculations are, by default, based on DEM elevations automatically extracted at node locations in the model network (users can overwrite with design elevations, too). Conduit/pipe lengths are automatically based on geographic coordinates from the georeferenced map display.

Modeling Water Distribution Network

StormNET allows simulation and visualization unsteady flow in water distribution network systems. StormNET is capable of handling complex networks with extremely large numbers of nodes and links. The nodes that can be simulated include surface reservoirs and groundwater wells, storage structures such as water towers (predefined, or custom designed), general aboveground and underground storage tanks, and treatment units. The links that can be simulated include conveyance structures such as pressurized pipes, as well as special controls such as regulators and valves, and pumping systems characterized by different characteristic pump curves.

For conveyance and storage structures users have the option to apply commonly used, pre-defined shapes, or they can use a tabular interface to define general shapes.

StormNET utilizes by default Hazen-William equation to simulate the head loss.

StormNET also allows simulating unsteady flow dynamics in combined stormwater drainage and water supply systems (e.g., used in applications related to stormwater harvesting and reuse)

Modeling Sanitary Sewer Network

StormNET allows modeling “dry weather” gravity sanitary sewer systems transporting wastewater or sewage flow. StormNET also allows modeling “wet weather” combined sewer overflow systems that convey both sanitary sewerage and stormwater through the same pipes.

During periods of moderate or heavy rainfall, the wastewater volume in the combined sewer system can exceed the capacity of the gravity-driven sanitary system or the wastewater treatment plant. Because of this, combined sewer overflow systems are designed to discharge the excess wastewater directly to a nearby water body via diversion regulators (note that StormNET allows modeling diversions dynamically).

Flow during dry weather (no precipitation) is dry-weather flow. Base flow consists of groundwater infiltration and direct inflows, which can include underground springs, flow from sanitary side sewer lateral connections, and others sources.

StormNET allows applying external flow and water quality inputs from surface runoff, groundwater interflow, rainfall-dependent infiltration/inflow, dry weather sanitary flow, and user-defined inflows.

Modeling River System

StormNET offers powerful tools for simulation, visualization, and analysis of river systems and channels, including:

- Uniform open channel flow modeling, for any cross-sectional shapes including rectangular, trapezoidal, triangular, circular, or any general cross-sectional shapes defined by users.
- Irregular natural stream and floodplains modeling, with automated generation of cross-sections based on high resolution DEM and/or interpolation of key “anchoring” cross-section defined by user inputs / design elevations,

Natural stream delineations are DEM enabled and cross-sections and floodplains are interactively / automatically generated based on high resolution DEM, including LiDAR DEM; the number of cross-sections along streams and the number of points along cross-sections used to define natural stream variability are interactively specified.

Storment allows specifying different manning roughness within and outside the main channel. The manning’s roughness outside of the main channel width (e.g., in the flood plains) is automatically extracted from the global land use database.

StormNET enables high-fidelity, immersive flood inundation mapping leveraging high resolution world land terrain, digital surface model, and a global 3D buildings database.

Modeling Storage Routing

StormNET simulates coupled water level dynamics in a network of storage units connected through conduits, canals, and rivers.

Storage units (e.g., water towers, storage tanks, above ground and underground detention facilities, lakes, wetlands, ponds, depressions) and their inlets and outlets (e.g., risers, spillways, weirs, orifices, culverts) are DEM-enabled and represented / designed spatially explicitly. The SU shapes (i.e., the area-depth relationships) can be custom designed interactively through a tabular interface or selected from a diversity of predefined shapes.

A unique option for spatially explicit storage representation is available for features such as ponds, lakes, wetlands, depressions, detention, aboveground and underground storage tanks – with geometries following predefined regular shapes and general irregular shapes.

The tool allows interactively delineating natural and manmade ponds with DEM-enabled storage curve and automatic calculation of surface areas, while allowing the user to make design modifications.

StormNET allows mapping and visualizing spatially explicitly water level in these storage units. Users can observe water level or inundation dynamics in animation individual storage tanks or in ponds, wetlands, depressions, and detention facilities.

Hydraulic Structures and Dynamic Control Rules

StormNET enables modeling a variety of hydraulic control structures such as street inlets, storage and treatment units, flow dividers, pumps, weirs, and orifices. Users can also represent in detail: bridges, culverts, roadway weirs, outfalls, and regulators / diversions.

Spatially explicit inlet and outlet locations can be specified, for features such as risers, dams, weirs, orifices, gates, spillways, and values. Options for specifying general internal boundary conditions and rating curves are also available.

StormNET users can add hydraulic regulators that dynamically control flow and pressures in the model network. Users define and apply controls through an interactive interface to simulate the dynamic operation of, for example, pumps, orifice openings, and weir crest levels..

Water Quality Modeling

StormNET can estimate the production of pollutant loads associated with stormwater runoff. The following processes can be modeled for any number of user-defined water quality constituents:

- Dry-weather pollutant buildup over different land uses.
- Pollutant wash-off from specific land uses during storm events.
- Direct contribution of rainfall deposition. Reduction in dry-weather buildup due to street cleaning.
- Reduction in wash-off load due to best management practices (BMPs).
- Entry of dry weather sanitary flows and user-specified external inflows at any point in the drainage system.
- Routing of water quality constituents through the drainage system.
- Reduction in constituent concentration through treatment in storage units or by natural processes in pipes and channels.

SIMULATION GALLERY

3D Immersive Visualization

StormNET users can perform 2D or 3D inundation mapping in lakes, wetlands, open channels, and natural rivers, including as an animation over time.

Users can also create powerful 3D CAD visualizations of hydraulic structures such as dams, detention ponds, weirs, culverts, road crossings, and bridges. The CAD visualization can be utilized during the model-building process (pre-simulation) or after simulation to view the water quantity dynamics (water levels/storage in different objects over time).

Visualization of 3D buildings and sub-catchments is enhanced with a built-in texture database.

Flood Inundation Mapping

Results from flood inundation modeling can be automatically displayed in the map display or in a 3D visualization with bank lines, surface features, buildings, and/or a background map.

The ability to visualize in realtime surface water flow in real life setting provides an an intuitive grasp of implications of management actions and policy decisions that can't be readily obtained otherwise.

Flow Profile Visualization

Users can interactively select network objects along a flow path to visualize the water quantity dynamics in profile-mode, including along conduits, channels, and rivers.

Flow Cross-section Visualization

StormNET enables simultaneous display of a water dynamics animation on multiple cross-sections along a selected flow path, including along conduits, channels, and rivers.

Time Series Visualization

Users can visualize model inputs and model outputs as time-series at nodes and in storage units and links and subcatchments. They can also add observed data to aid in model evaluation and calibration.

Mapview Visualization

Immediately after simulation, the map objects (subcatchments, links, and nodes) are color coded to represent parameter values that changes as a function of time.

An interface is available for users to select different time-steps or parameters to show in the display, and to turn on/off certain display options.

Users can also control the flood inundation mapping through this tool in StormNET.

Process Connectivity and Water Budget Visualization

StormNET provides an intuitive/informative "Sankey" chart, allowing use to visualize process connectivity and "water budget dynamics at the overall system level, or nested subsystem level. In particular, the chart allows users to characterize:

- Where does water come from? (e.g., precipitation on impervious surfaces, precipitation on pervious surfaces, initial water storage)
- Where does water go? (e.g., to evapotranspiration, infiltration, storm sewers, low-impact-design treatment, or to downstream receiving water)
- The relative importance of different hydrologic processes
- The effectiveness/performance of LID controls
- The numerical accuracy or mass balance errors (which is helpful in iterative modeling and design)

The water budget process visualization can be applied to the whole model system, or just to runoff continuity, flow routing continuity, or low impact design processes.

AI ENABLED SUPPORT

AI Assistant

(Coming soon). StormNET employs AI "chatbots" to answer questions regarding modeling, data, science, and the M4W software.

The chatbots are "trained" with the M4W documentation database and other information gathered from internal systems. Their training, combined with user-specific information/inputs, enables AI chatbots to quickly provide relevant answers and links to additional resources.

In turn, this enables the M4W team to focus on more complex issues and improve the overall capabilities and functionality of the StormNET platform.

Situational Help

StormNET user reference material is situationally embedded inside the modeling platform interfaces and submenus; real-time help buttons provide instant access to sub-pages explaining how to use different options or features.

The Realtime Help Pages are continuously improving and will include not only technical reference material, but also links to related scientific material (e.g., typical parameter values, numerical / computational aspects, etc.). Eventually, our goal is for intuitive modeling that allows users to ‘model without a manual’.

Intelligent Reporting

The M4W system automatically and instantly converts “incomprehensible” low-level StormNET model inputs/options/settings into a high-level report summary with tables for easy assimilation by others. The system also facilities creating detailed, professional-grade reports that automatically extracts relevant model information into appropriate places of existing report templates

Instant Publication

StormNET is directly linked to the MAGNET Global Model Network, allowing users to share selectively their model results (images, plots, animations, or reports) and/or the model file itself and/or its data (inputs and outputs). Users are offered the flexibility to determine what and how much to make public.