

Technical Note

# Agentic SWMM: Auditable and Reproducible Stormwater Modelling Workflow with Skills and Model Context Protocol

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## Highlights

- A new open-source agentic runtime (aiswmm) for keeping domain knowledge in a loop
- An Agentic SWMM workflow for end-to-end SWMM modelling with aiswmm runtime, and all the modelling progress is triggered by natural language.
- Verified the equivalence of the results between command-line interface and MCP execution, Agentic SWMM and the SWMM graphical user interface execution through a real case study.
- Proposed a verification-first contract that records provenances for each run.

## Abstract

Configuring urban hydrological models, such as the Storm Water Management Model (SWMM), for operational modelling remains onerous for many models. We propose aiswmm, a SWMM-specialized Agentic runtime, together with an Agentic SWMM workflow that embeds Skills and Model Context Protocol (MCP) tools to automate GIS preprocessing, model configuration, execution, and postprocessing. Each Skill encodes a hydrologic standard operating procedure (parameter defaults, validation thresholds, metric-extraction rules), narrowing the large language model's (LLM) role from open-ended generation to constrained Skill selection. To ensure that the entire Agentic SWMM workflow is auditable and reproducible, we proposed a verification-first, provenance contract embedded into Agentic SWMM workflow, that enables byte-level audit chain to LLM-driven hydrological modelling. Each run will create an independent manifest file that documents the SWMM version used, parameter mappings, input file hashes, and quality gate (e.g., continuity diagnostics). We demonstrate the workflow on the Tod Creek watershed (located on the Saanich Peninsula, British Columbia). We validated the proposed Agentic SWMM workflow at three levels: i) a QGIS based watershed-pour-point detection that agrees with the commercial PCSWMM® method to within 0.88% of the watershed perimeter (~7.5 pixels in the digital elevation model); ii) byte-identical SWMM output files (Secure Hash Algorithm 256-bit identical) between the command-line execution and the MCP paths across 60 paired simulations, and iii) peak inflow at the watershed outlet matching to three significant digits between the manual SWMM interface and Agentic SWMM workflows. The aiswmm runtime, Skills, MCP servers, and byte-level audit chain are released as open source and remain compatible with mainstream agentic runtimes (Codex, Claude Code, Hermes, and OpenClaw) to support reproducible SWMM modelling driven by natural language.

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## 1. Introduction

### 1.1 Hydrological modelling bottleneck - physically based modelling

Hydrological modelling of urban stormwater systems remains operationally onerous[1–3]. Currently, a major pain point in hydrological modelling is that physics-based modelling software, such as Environmental Protection Agency (EPA) Storm Water Management Model (SWMM), PCSWMM® and MIKE+®, require extensive interaction between the user and the interface to constantly adjust various parameters during the modelling process [4,5]. While the visualization capabilities are excellent and the built-in physically-based formulas make the process and results interpretable, the need for multiple scenarios and simulations can result in a tedious modelling configuration process, especially during model calibration [3,6,7]. As well, users often need a significant amount of time to understand and familiarize themselves with the interface and to debug software errors [8,9].

Many useful Python packages have been developed and have made important contributions to SWMM based modelling research. For example, ‘SWMManywhere’ supports the generation of synthetic urban drainage network models and SWMM input files from publicly available geospatial data. This makes it possible to conduct preliminary urban drainage network forecasts in scarce data areas [10]. ‘PySWMM’ provides Python based access to the SWMM engine, enabling runtime interaction, parameter modification, optimization, control, and postprocessing [11]. Recent studies have also coupled PySWMM with optimization libraries such as ‘pymoo’ [12] for automatic SWMM calibration. As well, ‘swmm\_api’ (Python toolkit) can support SWMM model setup, editing, analysis, visualization, sensitivity analysis, and calibration [2]. These open-source Python packages have significantly reduced the complexity of user interface operations, but they are primarily geared towards programmers. For normal users, end-to-end configuration, operation, calibration, result extraction, and quality assurance still face efficiency challenges.

### 1.2 Machine learning alternatives

Conversely, with the development of machine learning, hydrology is currently focusing on various alternative models such as long short-term memory and physics-informed neural networks, increasing their time series recognition capabilities or adding physical constraints based on partial differential equation residuals [13–15]. This allows for the training of data-driven models that can match physics-based models in most contexts, thereby increasing operational efficiency. However, the defining weakness of these models is their poor generalization ability [16]. Their near-black-box training characteristics make accurate representation of interpretability and physical consistency very difficult, often leading to overfitting issues in data scarce situations [17–19]. Furthermore, these surrogate models may be hard to interpret in terms of the physical processes occurring in real engineering projects, flowrate estimation and locating low-impact developments [20–22]. The auditability and traceability are primary requirements in operational hydrology. Physically-based modelling cannot be, and should not be, fully replaced by other surrogate models, especially for physics informed decisions [23,24]. Machine learning model training essentially learns data mapping patterns rather than truly understanding the physics [21,25]. These limitations force future researchers to seek out methods that may compromise integrity of the physics being modelled. Therefore, since one single solution is not feasible, a complementary strategy should be sought that retains the physics-based concepts, is easy-to-operate, interpretable, and auditable hydrological model. The

modelling workflow can potentially couple the Python tools described in Section 1.1, as well as eliminating learning barriers.

### 1.3 Agentic AI, Agentic runtime, and Model Context Protocol

Currently, various Agentic AI technologies are flourishing. Unlike conventional chat-oriented systems (e.g., ChatGPT or Gemini) that primarily optimize for natural-language responses, the Agentic AI differs from a chat assistant in that it can plan multi-step actions, call external tools (e.g., web retrieval, scripts, application programming interfaces, file operations), observe their outputs, and iteratively refine planning toward a user specified goal under explicit permissions [26]. More specifically, the agentic runtime is an emerging core execution layer within Agentic AI systems, and this core determines where and how the capabilities of Agentic AI are executed, constrained, and recorded. For example, OpenClaw is a typical Agentic runtime designed for complex goals [27]. It was released by Peter Steinberger on January 29, 2026, in a GitHub repository [28,29]. As well, Hermes (v0.8.0), a type of memory-augmented agentic runtime, was released by Nous Research on April 8, 2026, in another GitHub repository [30]. The emergence of these Agentic runtimes has significantly improved the generality of large language models (LLMs). With the development of Agentic AI, some open-source software such as SWMM®, can expose communication methods to Agentic AI through Model Context Protocol (MCP), enabling software invocation [31,32]. For example, Claude Code's Agent Skills can package workflows together that an agent can recognize, thus, achieving simple migration of automated workflows [32]. The idea of automated workflows is not new [33]. Platforms such as nodemation (n8n) provide a practical example of workflow automation, which aims to create simple chatbots or trigger specific workflows at specific times [34–36]; however, the configuration process is often highly complex.

To address the current pain points in hydrological modelling, we propose an Agentic SWMM workflow based on aiswmm runtime, Skills, MCP, and the SWMM engine. This enables the configuration of SWMM and the definition of user-defined plots using natural language. In addition, we verified the consistency of the entire workflow using the Tod Creek Watershed in Saanich, BC, Canada. The results show that SWMM configured through natural language was consistent with the results configured manually through the SWMM graphical user interface (GUI). This verified that the core hydrological derivation process does not depend on the Agentic AI, but on the SWMM engine that it invokes.

This paper proposes a practical architecture that integrates the following elements:

- (i) aiswmm as a workflow execution runtime;
- (ii) Skills as reusable workflow modules;
- (iii) Model Context Protocol as a standard interface layer;
- (iv) a verification-first traceability contract for each model run;
- (v) equivalence verification between manual SWMM execution and Agentic SWMM execution.

Together, this architecture ensures that the Agentic SWMM workflow can operate the SWMM engine and the QGIS engine as well as the downstream Python scripts in a controlled and auditable manner via natural language.

## 2. Materials and Methods

The methodology is depicted in Figure 1 to indicate how the Agentic SWMM orchestrated tasks, starting with input Geo-layers data for the case study watershed. As shown in Figure 1, we present a complete workflow that packages the multi-source data (digital elevation model (DEM), landuse, soil, rainfall) required for modeling into an input package for Geographic Information System (GIS) MCP. End users can interact with SWMM by issuing commands via natural language. In the middle layer, we packaged SWMM's

commands as callable tools through MCP. Since SWMM lacks the lookup table capability to transform raw data layers into model parameters, we generate a built-in transformation lookup table through dialogue in the GIS MCP as well.

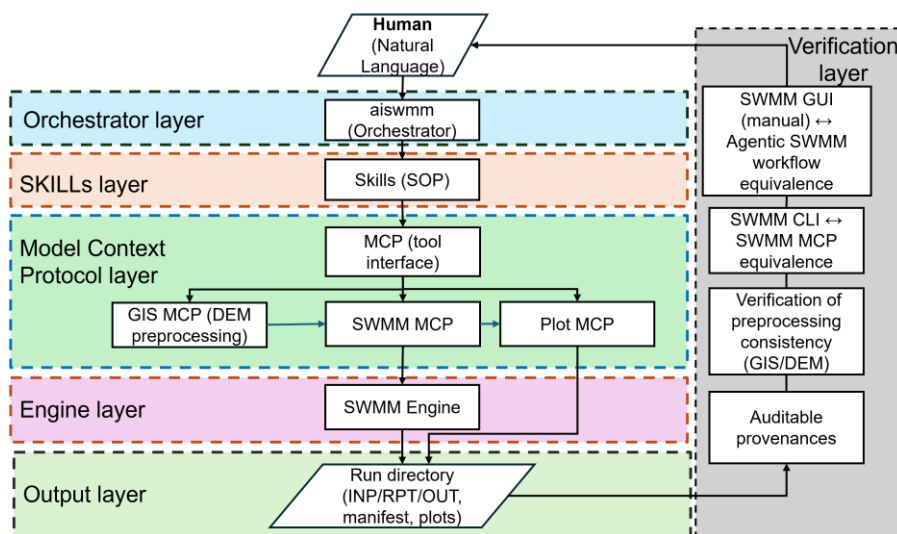
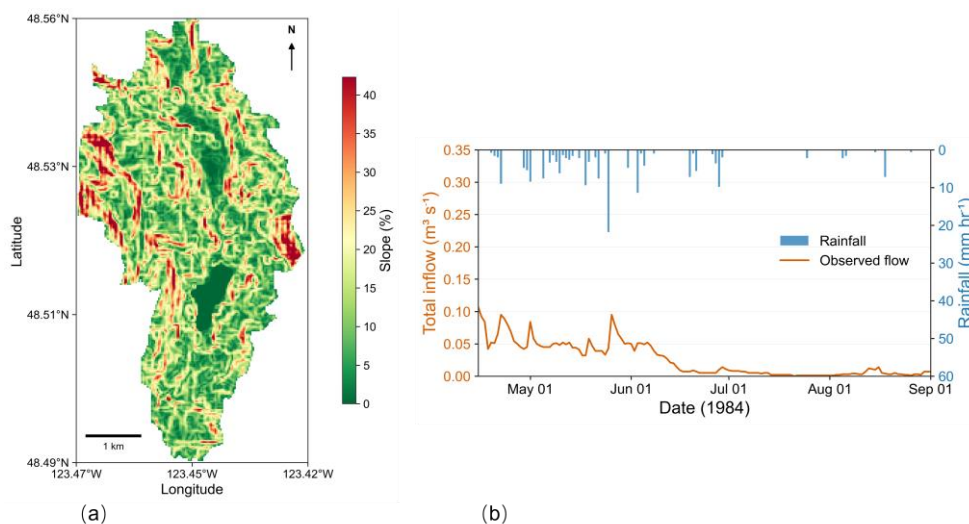
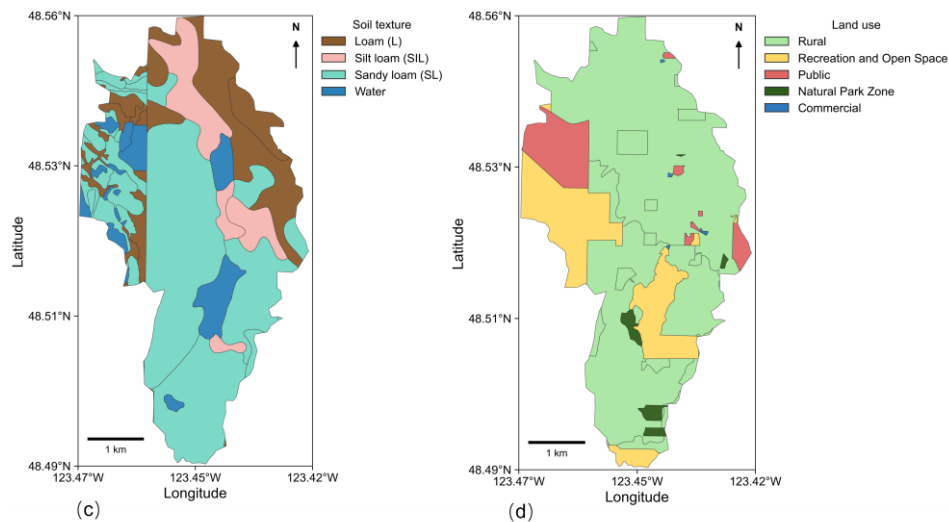


Figure 1. Methodology flowchart of the proposed Agentic SWMM workflow.

### 2.1 Study Site

The Tod Creek watershed, which spans about 17 km<sup>2</sup>, is situated on Vancouver Island's Saanich Peninsula in British Columbia, Canada. The covered region is mostly rural with a few small residential villages scattered throughout the watershed's undulating terrain (see Figure 2a in the digital elevation model). The 1000–1200 mm of annual precipitation is mostly concentrated between October and March of the following year. The soil types range from poorly draining clays to well-drained soils that are rich in organic matter (see Figure 2b). The resolution of the digital elevation model is 27 meters.





**Figure 2.** Tod creek watershed case study model input datasets for Agentic SWMM workflow (a) DEM-derived slope (%); (b) 1984 daily rainfall (mm) and observed streamflow ( $\text{m}^3/\text{s}$ ); (c) soil polygons; and (d) land-use polygons.

The Tod Creek database contained a) DEM; b) soil type polygons with texture attributes; c) land use polygons (zoning-style categories used as a land-use proxy); and d) 1984 rainfall records (daily totals in units of mm). For demonstration purposes, a lumped model representation of Saanich was used to validate the end-to-end workflow. The outlet location was selected algorithmically on the DEM boundary (minimum elevation candidate) to obtain a consistent reference outlet or pour point for the stormwater simulation.

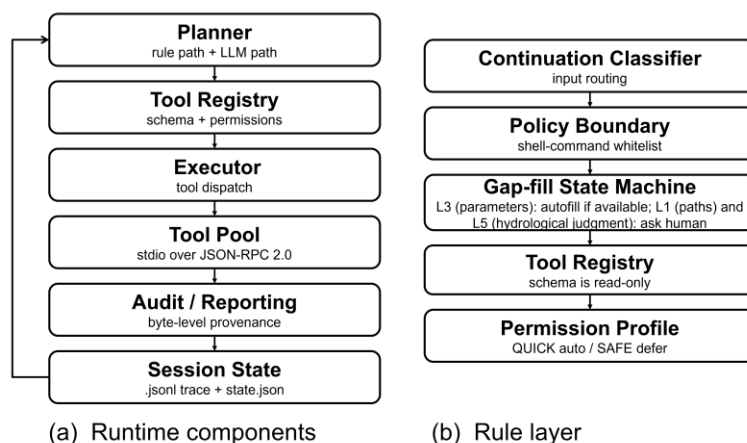
## 2.2 Methodology of Agentic SWMM System

This research compiles the SWMM command-line program (v5.2.4) from the EPA SWMM source code on macOS and executes simulations using the standard command “swmm5 <inp> <rpt> <out>”. Our SWMM Skill workflow automatically creates a separate run directory for each run, uniformly saving the input file (INP), report file (RPT), and binary output (OUT), and additionally, the swmm-runner Skill thereby generating a manifest file as shown in the Supplementary file Section S1. The biggest difference from the traditional user interface approach is that while users can see the modifications made in a GUI, this manifest, based on aiswmm (Version 0.6.4), is mandatory and written into the swmm-runner Skill. The manifest records the software version, key user configurations and parameter mappings, rainfall event information, and a summary of key results (such as continuity error, peak flow, etc.), thus, achieving transparency, reverse tracing, and auditability for each numerical experiment. There are two continuity errors that are separately tracked in the SWMM report file: the percentage mass-balance errors for runoff, and for flow routing. The magnitude of these two errors reflects the volumetric balance of surface runoff generation and the numerical stability of the hydraulic routing [37]. In addition, the same SWMM input file is run synchronously in the SWMM GUI, and the consistency of key indicators and resulting statistics is used as the basis for equivalence verification. This verification ensures that the automated command line process and the GUI run are consistent in terms of numerical behavior. After establishing this equivalence, we invoke the SWMM MCP via natural-language instructions that specify the original locations of the required datasets, trigger automated execution and call the plot Skill to generate the runoff comparison results shown in Section 3 of this paper.

### 2.2.1 aiswmm

We proposed a new Agentic runtime, called aiswmm, for reproducible SWMM modelling. The aiswmm is used as an orchestrator that executes commands, reads and writes

artifacts, and invokes external programs in a controlled environment. As shown in Figure 3a, we detail the architecture of the aiswmm runtime and its 6 core components loop. The runtime loop is inspired by ReAct [38] but emits structured tool calls (OpenAI function calling) instead of parsed text actions [39,40]. This architecture fundamentally and strongly constrains the tool-calling capabilities of LLMs. In this runtime, we force a five-layer rule system (Figure 1b) that determines when the agent may auto-execute and when it must pause and defer to the human modeler’s selection [41,42]. Hence, the aiswmm runtime cannot execute arbitrary commands, and is specifically designed for auditable, reproducible, and traceable SWMM modeling environment.



**Figure 3.** Conceptual design diagram for aiswmm runtime from structure perspective and safety control perspective for Agentic SWMM workflow (a) the aiswmm runtime structure; and (b) a five-layer rule system illustrating how the system controls tool calls and prevents uncontrolled execution.

Within this work, aiswmm does not replace SWMM, but instead standardizes the execution and bookkeeping around it. It is currently compatible with most LLMs through application programming interfaces keys, thus, enabling the analysis of complex tasks. In our case study, we use OpenAI GPT-5.5 Thinking [43], with the model identifier gpt-5.5-2026-04-23 as the primary model of aiswmm. In practice, aiswmm workflow is triggered by a natural language prompt. This will invoke the available Skills and orchestrates the MCP service to run the SWMM engine automatically and generate model outputs. The natural language prompt input format we recommend is shown in the Supplemental file Figure S1.

Note that, swmm-gis, swmm-runner, and swmm-plot in the prompts are Skill modules (tool bundles). The Skills we used were standardized as standard operating procedures; therefore, the workflow does not require high quality user prompts. The dependence on the overall prompting process is significantly reduced because the capability boundaries, parameter structure, and output formats are all “well designed” by the Skill/MCP interfaces. As a result, the LLM does not need to guess the user’s meaning, which maximizes portability and reproducibility, as well as minimizes LLM hallucination.

### 2.2.2 Model Context Protocol

MCP is a protocol that allows AI models to call external tools, read files, run models, access databases, or execute certain local functions through a unified interface [44,45]. Traditional wrappers are typically designed for developers, and they mainly aim to simplify the invocation of specific functions, commands, or software interfaces. Compared with wrappers, MCP goes beyond simply encapsulating existing software functionality one-to-one. It provides a standardized protocol layer for Agentic AI, thus, supporting not only

tool execution but also tool discovery [46,47]. The agentic runtime is able to identify available tools, understand their functional descriptions, read the input schema, and invoke different software capabilities through a unified interface. Under this design, SWMM, QGIS, Python scripts, and other external utilities are wrapped as tools. Each tool is discoverable, invocable, and orchestrable [47]. This enables cross-software communication and workflow coordination. Note that the current MCP layer runs on JSON-RPC 2.0 over stdio [32].

In this case study, mainly three MCP servers are used: a) swmm-gis-mcp for DEM data preprocessing; b) swmm-runner-mcp to generate inputs, run swmm5, extract quantities of interest and continuity metrics; and c) swmm-plot-mcp to read INP/OUT artifacts and produce figures that conform to a fixed user’s specification. Moreover, aiswmm can orchestrate MCP services after configuring the application programming interface keys of any large language model. Therefore, users can use LLM to configure the required MCP services for different analysis scenarios, such as pollutant diffusion or water quality modules. In this study, we only encapsulated the peak flows we were interested in to demonstrate the overall effect of Agentic SWMM. The MCP services can be customized, recreated, and adjusted according to the needs of end users (such as adjusting quantity of interests like water quality or any function available in any software if they have an application programming interface). However, the current validation in Section 3 mainly supports peakflow outputs and should not be interpreted as a complete validation of all SWMM outputs. Table 1 shows an interface catalogue for a SWMM-focused MCP toolchain. Table 1 lists six MCP tools designed for the entire Agentic AI workflow.

**Table 1.** MCP tool interface specification for the Agentic SWMM workflow.

MCP Server	Tool name	Required inputs	Outputs	Units / assumptions	Failure modes
swmm-gis-mcp	qgis_package_final_layers	dem (path); Geojson (path); outPng (path)	subcatchments.shp; flow.shp; slope_percent.tif; outfall.shp; overview.png;	Layers in EPSG:XXXX ; outfall manually selected in QGIS/GRASS	Required output layer missing in QGIS dir; CRS mismatch; output path not writable
swmm-runner-mcp	swm_run	inp (path); runDir (path)	JSON manifest; writes rpt/out/log/manifest	Flow units follow INP FLOW_UNITS (CMS → m <sup>3</sup> /s)	swmm5 missing; INP errors; runDir not writable; non-zero return code
swmm-runner-mcp	swm_peak	rpt (path)	JSON: node, peak, time-HHMM, source	peak in SWMM flow units; time in report time-base	RPT parse mismatch; node not found and return null; encoding issues
swmm-runner-mcp	swm_continuity	rpt (path)	JSON: runoff table; routing table; continuityErrorPct	SWMM report units; continuity in percent	Continuity blocks missing; parser mismatch across SWMM versions

swmm-runner-mcp	swm m_co mpara e	rpt (path); rpt2 (path)	JSON: aErr, bErr (head- line continu- ity)	percent (%)	Same as continu- ity; different INPs/steps and re- turn expected dif- ferences
swmm-plot-mcp	plot_r ain_r un- off_si	inp (path); out (path); outPng (path)	writes PNG; JSON: ok,outPng	Rain as mm/Δt (de- fault 5 min); flow m <sup>3</sup> /s if CMS	OUT missing/cor- rupt; TS_RAIN missing; swmmtoolbox missing; font fallback

2.2.3 Skills

Beyond MCP, Skills packages scripts, configuration, and conventions for specific tasks or workflow (e.g., SWMM input / report / binary output files Via MCP, running SWMM, extracting outputs, and producing figures). This packaging ensures the workflow can be repeated and shared with minimal manual setup. From the perspective of the Agentic SWMM workflow, the Skills are an important complement to MCP, and they work as a standard operating procedure to tell the agent what procedure should be followed. This is because MCP primarily addresses tool discovery and invocation, rather than how the tools are called in a specific order; for example, from SWMM execution to result extraction, and then to plotting. Without Skills as a soft constraint, the quality of runtime results can easily lead to a high dependence on the quality of the prompt. We adopt Skills to render commands of "what to call, in what order, using what specifications; how to implement quality gates; and how to produce reproducible workpieces" into a reusable methodology. This is shown in Table 2.

**Table 2.** Agentic SWMM capability Skills catalog (selected representative Skills, and full 14 Skills catalog provided in the Supplementary file Table S2).

Skill name	Purpose	Key scripts	Related-MCP server	Main tools	Outputs
swmm-gis	GIS/DEM pre-processing (pour point/outlet selection) for reproducible SWMM workflows	scripts/fin d_pour_p oint.py	mcp/swmm - gis/server.js	gis_find_pour_p oint	GeoJSON pour point + DEM pre- view PNG
swmm-runner	Run swmm5 reproducibly and extract peak/continuity + write manifest.json	scripts/sw mm_run- ner.py	mcp/swmm -run- ner/server.j s	swmm_run, swmm_peak, swmm_continu- ity, swmm_com- pare	run direc- tory: rpt/out/stdo ut/stderr/ma nifest.json; metrics JSON
swmm-plot	Publication-grade plotting	scripts/plo t_rain_run off_si.py	mcp/swmm - plot/server. js	plot_rain_run- off_si	figure PNG/PDF

Swmm -exper- iment- audit	Auding the Agentic SWMM runs	scripts/au- dit_run.p y	mcp/swmm -experi- ment-au- dit/server.js	audit_run	experi- ment_prove- nance.json
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In the Agentic SWMM scenario, the Skill layer:

- orchestrates the corresponding MCP to autogenerate the SWMM inputs (INPs) file;
- runs the swmm engine, and extracts indicators such as peaks and continuity;
- performs conservation/continuity checks and GUI with command-line interface (CLI) equivalence comparisons;
- includes built-in plotting specifications (units, axes, fonts, and window clipping, etc.) and automatic repair rules for common pitfalls;
- enforces standardized run directories and manifests (version, hash, parameter mapping, key results, plots, etc.).

Therefore, simply relying on MCP can easily degenerate into a set of "bare tools", which can be called but are difficult to manage and reproduce stably over a long period of time. This also makes it difficult to quickly port the entire workflow. Skill, however, organizes interface capabilities into reproducible experimental packages that are auditable, shareable, and maintainable; thus, enabling workflows to run repeatedly and be reliably reused with minimal manual setup. As well, in the data preprocessing part, because DEM-based preprocessing is often required for hydrologic model setup (e.g., identifying a pour point and delineating subcatchments) and EPA SWMM does not provide these GIS functions, we implemented a dedicated swmm-gis Skill to automate this step. We use two methods from the DEM to find candidate outlets: one is the lowest point on the boundary, and the other is the point with the largest flow accumulation. This Skill saves the pour point within the coordinate system as a reproducible geographic file, which can be directly used for SWMM model configuration.

### 2.3 Verification, Reproducibility and Repeatability

#### 2.3.1 Verification-first provenance generation

The aiswmm runtime automatically generates two complementary provenance files via Skill during each SWMM run, as shown in Table 3: a) a runner-level manifest.json (written directly by the swmm-runner Skill upon SWMM execution) and b) an audit-layer provenance file experiment\_provenance.json (written by the swmm-experiment-audit Skill in Table 1). Together, the two files record the Secure Hash Algorithm 256-bit (SHA-256) hashes of every input INP, binary OUT, and report RPT artifact, together with the outcome of a deterministic quality assurance gate suite (including continuity errors, peak-metric integrity, SWMM return code, and eight SWMM specific screening rules). This ensures that every workflow step can be traced back to a byte-identifiable run (more details are provided in the Supplementary file S1 and section S3 shows an example).

Because the Skill-level Python scripts in every Agentic SWMM run generate both files automatically and mandatorily, they are produced independently of the agent runtime (aiswmm, Codex, OpenClaw, Claude Code, or any other orchestrators). This independent mechanism makes sure that the provenance files are documented regardless of which agent triggers the workflow.

**Table 3.** Two provenance files written automatically on every Agentic SWMM run. Note that this is a simplified table, and full lists are in the Supplementary file S1.

File type	Group	What is included
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manifest.json	files	INP path + SHA-256 hash, SWMM5 version + return code, absolute paths of rpt, out, stdout, stderr
manifest.json	results	Peak inflow (node, value, time, report-section source) and two continuity errors with mass-balance sub-tables
experiment_provenance.json	run context	Schema version, workflow mode, natural-language objective
experiment_provenance.json	environment	Git branch + HEAD commit + working-tree status, Python and SWMM versions
experiment_provenance.json	artifact index	Every run file by id, role, paths, SHA-256, producer, downstream use
experiment_provenance.json	verification	Quality Assurance checks (pass/fail), eight SWMM screening rules, human-decision slot

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### 2.3.2 Verification of DEM-based Preprocessing

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Because EPA SWMM does not provide necessary GIS pre-processing utilities, we implemented an automated pour-point detection routine as an independent SWMM-GIS MCP and Skill (as shown in Table 1 and Table 2) to reproduce key preprocessing steps in a traceable, script-driven workflow, and to verify consistency against a conventional GUI-based approach (PCSWMM). Its pseudocode implementation logic has been included in Section S2 of the Supporting file.

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### 2.3.3 Repeatability: equivalence validation between CLI and MCP

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In this section, we tested whether the results produced by the packaged MCP service are numerically consistent with a direct SWMM CLI execution under identical model inputs. Our baseline model is a lumped model with a timestep of 5 minutes, representing the Chicago design storm (which is the same SWMM input structure and parameters for hydrology/hydraulics). Note that Chicago design storm is a synthetic hyetograph with a single peak placed at a prescribed fraction  $r$  of the storm duration [48,49]. Two different tests were performed. In Test 1, a total of 30 parameter configurations were conducted where the Chicago storm-shape parameter  $r$  (time to peak  $r \in [0.30, 0.50]$ ) is increased from 0.30 by an increment of  $(0.50-0.30)/30$  in each run while holding all other model settings constant [50]. Test 2 is similarly 30 parameter configurations where the percentage of imperviousness ( $I$ ) is varied by a factor ranging from  $[0.9, 1.1]$  while holding all other model settings constant. Note that these parameter configurations aimed to verify the equivalence between the CLI and MCP paths, not a hydrological result. The parameter ranges and sample size only need to cover diverse, realistic SWMM inputs. Because the equivalence is verified at the byte level, the conclusion does not depend on their exact values. Since there are 30 configurations in each test, and we run the test in two different ways (CLI and MCP), there is a total of 120 SWMM runs. We then compare the degree of agreement of the computed peak flow at the outlet for each run using  $R^2$  and the Nash and Sutcliffe Efficiency (NSE). Theoretically, if the execution between CLI and MCP are equivalent, then  $R^2$  and NSE should both be exactly 1, as the SHA-256 values of the SWMM input and output files (Section 2.3.1) should be byte-identical (excluding timestamp fields).

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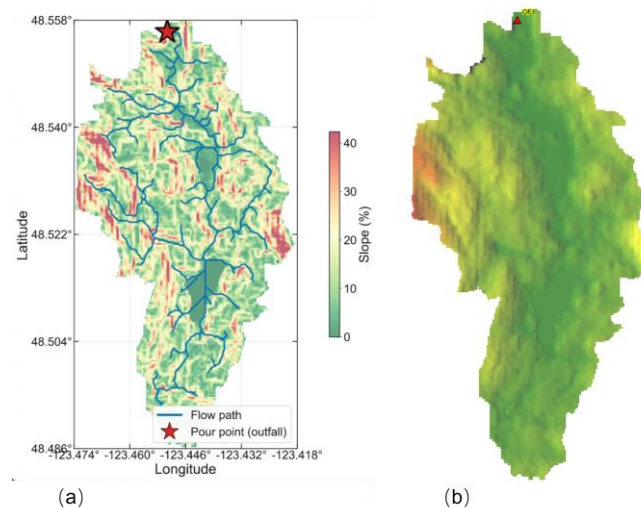
### 2.3.4 Reproducibility: SWMM GUI vs Agentic SWMM

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To verify cross-system consistency, we manually recreated the baseline model in the SWMM GUI and note that the baseline model is generated by the Agentic SWMM from the user prompt. After the manual configuration, we ran the SWMM GUI and compared the results with the Agentic AI generated baseline model to verify whether its ability to automate configuration using natural language was consistent with manual configuration.

### 3. Results

#### 3.1 Verification of data preprocessing tools

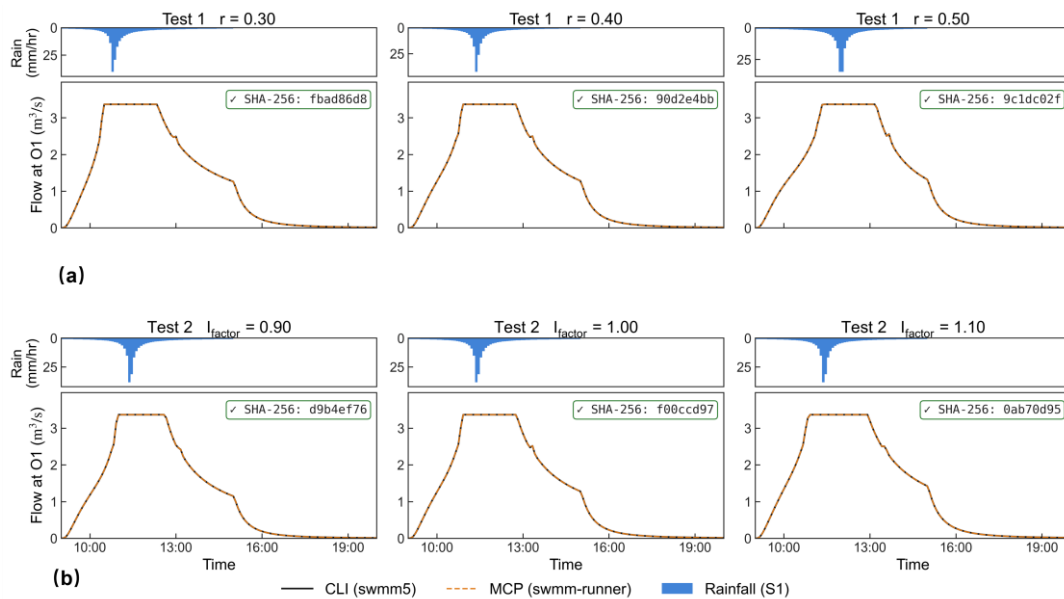


**Figure 4.** The comparison of the boundary outlet detection and plot (a) pour-point generation via Agentic SWMM via swmm-gis Skill; and (b) the pour-point generated with the PCSWMM graphical user interface.

Because SWMM itself does not integrate DEM related GIS preprocessing functions, we implemented "automatic pour point identification" as an independent SWMM-GIS Skill to extract key spatial features before modeling. Specifically, we used QGIS Processing (grass:r.watershed invoked through Agentic SWMM) to compute D8 flow direction and accumulation across the DEM and select the stream cell with the maximum upstream accumulation as a candidate pour point, which is automatically output as a point.

Figure 4(a) shows the DEM visualization generated by the Agentic SWMM-GIS Skill. The automatically identified candidate pour point is shown as a red mark. The right panel visualization of the pour point location in the same area was generated in PCSWMM using manually identified pour points from [49]. The results show that the two methods exhibit high consistency (with 0.88% error and within approximately 7.5 DEM pixels) in spatial location and topographical consistency, indicating that Skill can stably produce pour point results similar to those of the traditional GUI workflow.

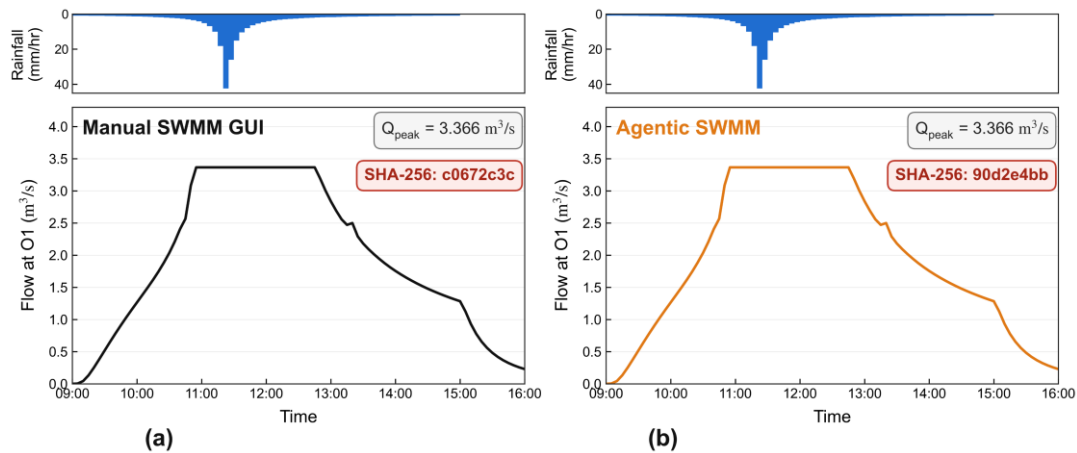
#### 3.2 Repeatability: SWMM CLI and SWMM MCP



**Figure 5.** Computed hydrographs at the outlet from six parameter configurations, demonstrating the byte-identical (excluding the timestamps) between Model Context Protocol (orange dash line) and command-line interface (black line) execution modes: (a) the three parameter configurations result pairs for Test 1; and (b) the three parameter configurations result pairs Test 2 using the methodology described in Section 2.3.2. The complete set of results of 60 pairs (120 runs) is provided in the Supplementary File Figures S2 and Figurer S3.

The CLI execution results are shown as black solid lines and the MCP results are orange dashed lines overlaid on top. The complete set of 60 pairs simulation plots is provided in the Supplementary file Figure S2 and S3, and all the models .out file pass the audit text and SHA-256 byte identical. Figures 5(a) and 5(b), and Figure S2 and S3 in the Supplementary file show that the evaluation metrics,  $R^2$  and NSE are all identically 1.0 (SHA-256 byte identical, and tolerance = 0), demonstrating consistent predictions across all 60 simulation pairs. Therefore, we can reasonably conclude that the model called by the MCP server, and the model used via the command line through the CLI port are consistent, and that the core hydrological computation based on aiswmm is entirely based on the SWMM engine rather than the large language model itself. Furthermore, the SHA-256 hashes of the manifest.json files for both tests are all identical; the return code is all 0, and  $\max|\Delta Q_{peak}| = 0.0$ , proving that the CLI and MCP have completely identical INPs (same hash). Further indications of the robustness of the MCP service are shown in Table S2 in the Supplementary file.

### 3.3 Reproducibility: Agentic SWMM and SWMM GUI



**Figure 6.** (a) Equivalence between manual SWMM graphical user interface execution; and (b) natural language driven Agentic SWMM execution at the Tod Creek watershed outlet (node O1, 1984-05-25 Chicago design storm with peak-time  $r = 0.40$ ). Peak inflow matches to three significant figures.

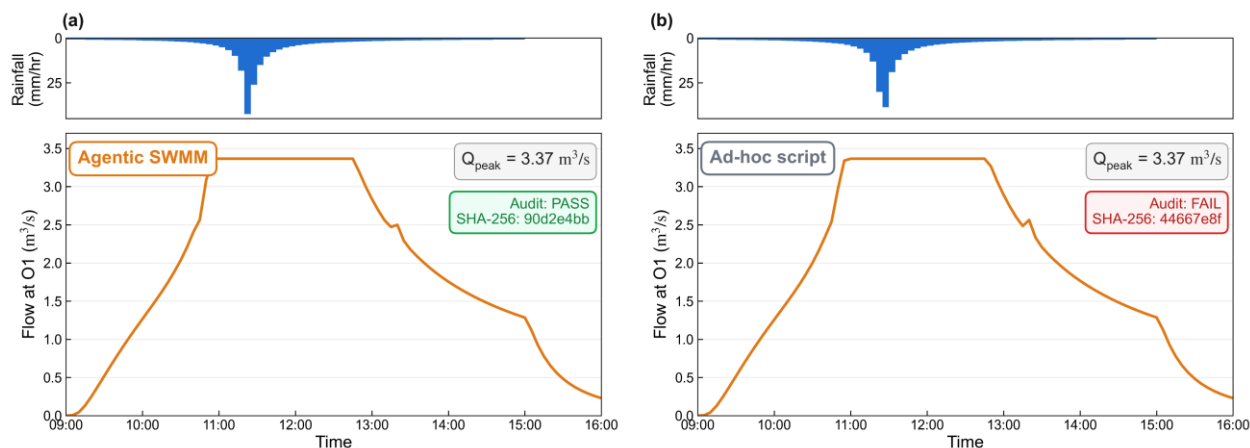
Using identical INP files we conducted equivalence verification on two execution paths. Figure 6(a) shows the GUI display obtained through manual parameter configuration and execution using the traditional SWMM graphical user interface. Figure 6(b) shows the workflow from Figure 1, entirely driven by aiswmm through a natural language dialogue, utilizing the SWMM Skill and MCP toolchain. Agentic AI automatically generates/verifies inputs from the original dataset, calls swmm5 to execute simulations, and extracts key outputs. As the comparison in Figure 6(a) shows, the peak flow results obtained from both paths are completely identical indicating that the aiswmm driven SWMM modeling approach is consistent with SWMM GUI execution. Not surprisingly, the two approaches yield identical peaks to three decimal places, but they are not bit identical. This is because of the subtle differences in node naming, junction name, and modeling procedures during manual modeling that can lead to different SHA-256 values. This indicates that in the current AI age, the Agentic SWMM workflow can produce peak values that are identical with SWMM GUI execution (to within three decimal places) thereby, greatly expanding the model's usability. To test the scalability of the Agentic SWMM workflow's generic modeling process beyond the Tod Creek case study, we additionally validated its core modules on three external SWMM benchmarks:

- (i) the Tecnopolo January-1994 prepared-input case from [51,52];
- (ii) the TUFLOW-SWMM Module 03 coupled benchmark [53]; and
- (iii) the Generate\_SWMM\_inp INP-derived adapter case [54].

In each benchmark, we audited the artifacts: manifest.json and experiment\_provenance.json against the published reference outputs. The validation scope and conclusions are reported in the Supplementary file Section S4.

### 3.4 Verification-first provenance

Figure 7 is an additional audit example showing the SHA-256 comparison between Figure 7(a) and Figure 7(b). The inconsistencies observed are caused by LLM scripts generation level. Both panels were labelled as  $r = 0.40$  and appeared visually consistent, while the SHA-256 prefixes were different ('90d2e4bb...' versus '44667e8f...').



**Figure 7.** The auditing process detected a Secure Hash Algorithm 256-bit byte level inconsistency caused by LLM hallucination (a) byte-level consistency check between the original Model Context Protocol execution mode and command-line interface; and (b) inconsistency between the LLM-generated Python script way and command-line interface execution results.

After reviewing the manifests, we found that two independently generated Python scripts selected different nearest parameter values at the Tod Creek watershed outlet (node O1, 1984-05-25 Chicago design storm with peak-time  $r = 0.40$ ). Figure 7(a) selected  $r = 0.39655$ , and Figure 7(b) used  $r = 0.40345$  (details in the supplementary file Section S5). Both values were rounded to  $r = 0.40$  in the figure labels, which masked the underlying difference. This finding shows that the two manifests (provenance) are not only a passive record of model execution but can also detect inconsistencies before they are entered into the final scientific record, hence, we call this a verification-first. This result also proves our MCP is more stable than an ad-hoc Python script. There are further auditing/testing case reports that can be found in the supplementary file Table S3 (unit inconsistencies) and Table S4 (different observation time).

## 4. Discussion

### 4.1 The explainable and auditable results

The interpretability of our results does not arise from Agentic AI itself or from the underlying LLM. Rather, interpretability is grounded in the physical model and its explicit, inspectable input/output files. In our framework, SWMM constitutes the computational core: all hydrologic calculations are executed by SWMM, while the Agentic layer is responsible for orchestration, tracking, and standardized output generation. To mitigate LLM hallucinations, we first established the full end-to-end workflow prototype and then performed manual checks to confirm consistency between automated and reference runs.

Not surprisingly, all LLM-driven workflows, including aiswmm and other agentic runtimes such as Codex, Claude Code, and OpenClaw, inherently translate natural language prompts into tool calls in non-deterministic ways [55,56], which may lead to subtle but real inconsistencies in the executed workflow [57]. This is a well-documented characteristic of LLM-driven systems. Therefore, we designed a verification-first provenance mechanism (as described in the two audit files included in Section 2.3.1 and Supplementary File S1) that records the identify source of each execution run using SHA-256. The two JSON files ensure that the key information of each run is documented and can be traced, facilitating reproducibility.

The aiswmm runtime mechanism also makes the entire workflow become auditable and reproducible. The aiswmm runtime loop shown in Figure 3(a) was built specifically for the SWMM engine, and Figure 3(b) tells the runtime when to stop and when to ask

users for more input, rather than having an arbitrary runtime. Beyond the two audit files, as shown in Figure 3(a), the runtime also produces a session\_state.json capturing the agent loop state (goal, plan, tool calls, failures) for cross-session referencing.

#### 4.2 Minimized LLM model hallucinations in hydrology domain

LLMs must be applied to stormwater hydrology in a safe manner [58,59], and a purely black-box approach for using Generative AI may violate physical laws due to LLM hallucinations [20,21,40,60–62]. In our work, as shown in Figure 1, the LLM hallucination is minimized through three layers of defense: a) the runtime layer that hard constrains the LLM's action space to a registered, schema-validated tool list; b) the MCP interface layer that declares structured tool signatures the LLM can reason about, and c) the Skill layer that encode SWMM-specific domain contracts; for example, 'the peak is always read from Node Inflow Summary, never from Node Depth Summary'. Hence, the runtime will execute the deterministic Python implementations rather than the one temporally generated by LLM. The aiswmm runtime orchestrates which Skill to invoke, and then the Skill decides how the SWMM operation is performed. In this work, we also packaged the entire Agentic SWMM workflow as a standardized Skill with mandatory artifacts and quality gates (e.g., continuity diagnostics and consistent quantity of interests definitions), improving portability and substantially reducing the error from LLM hallucination. In practice, while poor prompting can lead to variability in how non-expert users specify tasks [63], the Skill constrains execution to validated procedures and specifications, thereby minimizing the workflow from failures caused by ambiguous or low-quality prompts. Also, Skills and MCP are portable [32], they can run with any Agentic runtimes (Codex, Claude code, Hermes, OpenClaw, and etc.). However, these constraints are still soft, and they may still operate at the prompt-injection level for the AI agent or LLM [63,64].

The goal is not to replace SWMM or the modelers, but to make SWMM-based modelling easier to reproduce, audit, remember, and trust. Hydrologists' experience and judgment can and must be extended to aiswmm existing runtime as needed (as shown in Figure 3(b)), which means we not only need to verify the report but also need to track the Agentic runtime computational behavior [65]. We can add new deterministic SWMM diagnostic rules to make the agentic runtime traceable, transparent, and trustworthy. However, a trade-off between flexibility and stability needs to be considered and properly designed [42]. For example, should shell permissions be granted to the runtime? [66,67]? Should we relax the permissions to allow the LLM to automatically complete extremely important urban drainage network information, such as invert elevation? Should we let the model run first and then review the record afterward? [68] We need to balance this tradeoff within an acceptable level of LLM hallucination [69] for hydrological field.

#### 4.3 Limitation

First, the Agentic SWMM workflow is still under active development and testing. This work focuses on the operational layer of SWMM-based modelling rather than its theoretical formulation. We built the Agentic SWMM workflow around the SWMM engine, and none of the SWMM governing equations or numerical schemes have been modified; all hydraulic and hydrologic computations remain those of EPA SWMM 5.2.4. We do not seek to replace SWMM or software assembly but rather attempt to propose a new pipeline for hydrological modelling in the current Agentic AI age in a safe manner.

Second, in this latest research, we found that building the urban pipeline network system presents some challenges. This is not only due to the scarcity of real urban pipeline network data, but also because expert experience is needed to estimate parameters, such as the parameter mapping tables. Therefore, modelers may need to participate in re-customizing the existing Skills and MCP. As the hallucination of LLM comes from its gener-

ation mechanism [70] and training method, it cannot be eliminated just by prompts injection or changing the hyperparameters (eg., temperature) [40]. The runtime, MCP tool whitelist, parameter schema, audit logs, and continuity checks essentially restrict the free-flowing behavior of LLM within an inspectable, traceable environment, thereby minimizing and tracking errors to satisfy the needs of operational hydrology or computational hydrology.

Third, aiswmm is a memory-informed runtime (we developed a memory layer for it). It can not only perform general text-based lesson memory, similar to Hermes, but also implements a SWMM domain-specific quantitative memory layer, as well as bidirectional connectivity with the audit layer. Therefore, logically, it forms a closed loop: aiswmm memory layer -> aiswmm decision layer -> SWMM execution -> audit -> aiswmm memory layer. The data from the memory layer are stored as plain text files (JSONL, YAML, and Markdown), with SQLite used only as an optional index for large stores rather than as the primary store. The audit layer can now produce Markdown format documents, thereby competing subsequent analysis using Obsidian. However, the verification of the effectiveness for this memory informed structure needs time and real SWMM project data support. Therefore, although we have built this memory-informed framework in aiswmm v0.6.5, it has not yet been sufficiently validated. Therefore, it was not completely demonstrated in the paper.

Finally, uncertainty quantification was not demonstrated in the main results. The open-source repository already provides preliminary support; however, an uncertainty quantification (such as a watershed-entropy based metric [72]) module needs to be incorporated with current workflow. Additionally, Skills and MCP need to be established and extended for subcatchment partition.

## 5. Conclusion

The overall Agentic SWMM workflow described in this paper suggests that Agentic AI offers great operational potential for hydrological modelling in place of traditional GUI modes of parameter modification. Agentic AI runtime can orchestrate tool-based workflows (via Skills and MCP) and potentially across multiple software to execute, verify, and reproduce hydrological modelling tasks beyond conversational responses. This paper details how the aiswmm architecture, leveraging mainstream MCP services and Skills, can potentially replicate the previously manually driven GUI operation process. This application-level implementation greatly facilitates subsequent researchers or users unfamiliar with model deployment and operation to configure and audit their own hydrological models in a very short time.

Our novelty lies in proposing an automated, auditable, and reproducible Agentic SWMM framework for stormwater modelling. Our work is not only designing the MCP tools and Skills for SWMM, but also verification the equivalence between Agentic SWMM and manual SWMM GUI workflow. Also, the verification-first mechanism can better help researchers understand the performance of Agentic AI and use AI in a safe manner for hydrological modelling in the current AI age.

The contributions of this work are not only in making the hydrological modelling configuration process simpler and more trustworthy, but also in providing a suitable and appropriate for leveraging the capabilities of Agentic AI in the hydrological modelling domain. Potentially, transferring the orchestration capabilities of Agentic AI into our field can better support the understanding of hydrological modelling processes. This is a practical attempt to integrated agentic AI with hydrological modelling that is both automated and auditable, rather than treating automation and reproducibility as competing goals.

Future work will focus on letting the Agentic SWMM workflow learn from its own audited history (memory-informed), turning past modelling experience into guidance for new watersheds.

## 6. Data Availability Statement

Agentic SWMM is a pre-1.0 project under active development. The open-source Agentic SWMM (0.6.4) so far provides overall 14 Skills, 11 MCP servers, and 45 MCP tools supporting raw GIS preprocessing, parameter mapping, climate/rainfall preprocessing, pipe network assembly (Alpha), model building (INP file), SWMM execution, plotting, model calibration (Alpha), model sensitivity and uncertainty analysis, experiment audit, and cross-run model informed memory. Four Skills and six MCP tools are used to test the equivalence and validation for the demonstration propose. All the source code is released for future researchers under MIT license for free of use.

The source codes are available for downloading at the link:

<https://github.com/Zhonghao1995/agentic-swmm-workflow>.

- PyPI version: aiswmm (0.6.4)
- Docker image (GHCR): ghcr.io/zhonghao1995/agentic-swmm-workflow:v0.6.4
- Git tag: v0.6.4 (commit a0650e9)
- LLM Model: gpt-5.5-2026-04-23

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## 7. Abbreviations

The following abbreviations are used in this manuscript:

EPA	Environmental Protection Agency
SWMM®	Storm Water Management Model
MCP	Model Context Protocol
CLI	command-line interface
GUI	graphical user interface
DEM	digital elevation model
GIS	Geographic Information System
INP / RPT / OUT	SWMM input / report / binary output files
LLM	large language model
SHA-256	Secure Hash Algorithm 256-bit

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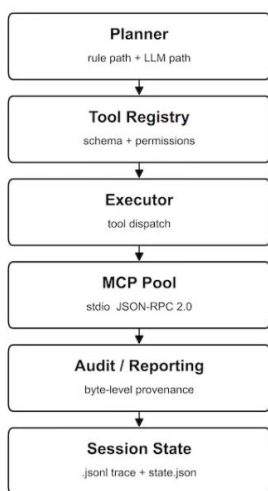
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**Supplementary file**  
**Section S0 runtime description**



```

zhonghao — aiswmm — 106x35
Last login: Sat May 16 06:47:49 on ttys002
zhonghao@Zhonghao's-Mac-mini: ~ % AISWMM_CONFIG_DIR=/tmp/aiswmm-demo-$$ aiswmm

AISWMM

Welcome to AISWMM!

I'm an agentic stormwater modeling assistant. I can help you:
- Build EPA SWMM input files from your GIS, climate, and network data
- Run SWMM simulations and audit the results automatically
- Calibrate model parameters against observed flow data
- Quantify uncertainty in your stormwater predictions
- Remember lessons across modeling sessions

Things to try:
- "Run the tecnopolo demo"
- "Show me what skills you have"
- "Help me build an INP for my project"

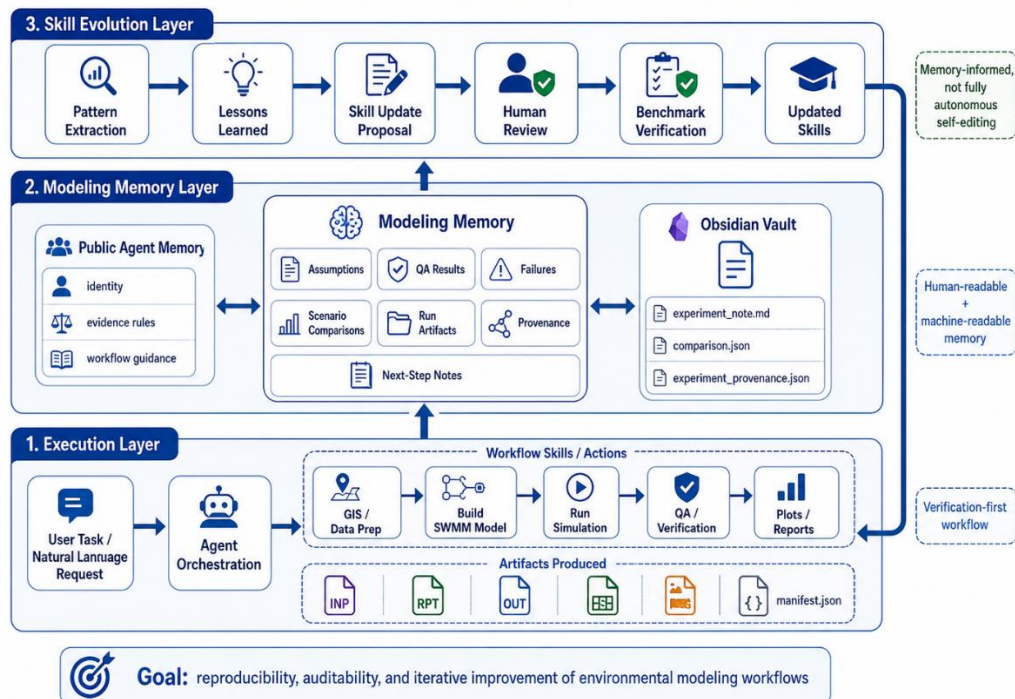
I'll always tell you what I've actually verified vs. what's still uncertain.

Type /help anytime. Let's get started -- what would you like to do?
aiswmm> aiswmm interactive (session=065846, runs/2026-05-16, profile=quick) - /exit, /new-session
you>
  
```

732

# Agentic SWMM: Modeling Memory and Skill Evolution

From workflow execution to auditable memory to controlled skill refinement



**Figure S0.** aiswmm (v0.6.4 alpha) architecture and CLI as well as model informed memory layer for future research, and flowchart (by GPT image 2.0) on github.

## Section S1 Manifest Schema

**Table S1.** Run Manifest Schema for Reproducible SWMM Execution

Field	Type	Required	Description
manifest_version	string	YES	Manifest schema version.
created_at	string (ISO-8601)	YES	Timestamp when the run record was created.
swmm5.cmd	string	YES	Command used to invoke SWMM engine (e.g., swmm5).
swmm5.version	string/null	RECOMMEND	SWMM engine version if detectable (e.g., 5.2.4).
inp	string (path)	YES	Path to the SWMM input file (.inp).
inp_sha256	string	YES	SHA256 hash of the input INP to guarantee input equivalence (GUI vs CLI).
files.rpt	string (path)	YES	Path to SWMM report file (.rpt).
files.out	string (path)	YES	Path to SWMM binary output (.out).
files.stdout	string (path)	YES	Captured stdout from swmm5 execution.
files.stderr	string (path)	YES	Captured stderr from swmm5 execution.
metrics.peak.node	string	YES	Node/outfall identifier used for peak extraction (e.g., O1).
metrics.peak.peak	number/null	YES	Peak flow value parsed from SWMM report; unit follows INP FLOW_UNITS (paper uses m <sup>3</sup> /s).
metrics.peak.time_hhmm	string/null	YES	Time of peak in HH:MM if available in report summary.
metrics.peak.source	string/null	YES	Which SWMM report section provided the peak (e.g., Node Inflow Summary).
metrics.continuity	object	YES	Parsed continuity blocks including continuity_error_percent and underlying tables.
return_code	integer	YES	Return code from swmm5 (0 indicates success).

This table defines the required and recommended fields of the run-level manifest used to record provenance and key metrics for each SWMM simulation by using OpenClaw. The manifest captures execution metadata (timestamp, engine command/version), input identity (INP path and SHA256 hash), generated artifacts (RPT/OUT and logs), extracted peak-flow metrics, continuity check results, and return status, enabling auditable reproduction and GUI–CLI equivalence verification. As well, the Json file is provided as following:

<https://gist.github.com/Zhonghao1995/f5050e26f0da1ee28f115192659d15fd>

The full list of **Section 2.3.1** Manifest json file and experiment\_provenance.json are also available at:

<https://gist.github.com/Zhonghao1995/f5050e26f0da1ee28f115192659d15fd>

“Run the full Agentic SWMM workflow using your GIS, SWMM runner, and plotting skills. My input data folder is located at <PROJECT\_ROOT>:

Use swmm-gis to select an outlet (document the method) and export the outlet (GeoJSON + preview).

Use swmm-runner to build and run a baseline SWMM simulation from the provided inputs and assumptions and save a self-contained run folder with all artifacts and a manifest.json.

Use swmm-plot to generate figures for the QoIs on dd-MM-YYYY.

Return: the output folder path, the manifest.json path, and a short list of assumptions (if you have).”

**Figure S1.** The natural language prompt input format.

This prompt was successfully tested with OpenClaw version 2026.4.11. Please install the corresponding Skills and MCP servers before running the test, or simply provide the GitHub repository link <https://github.com/Zhonghao1995/agentic-swmm-workflow>

for your runtime, and the current Agentic SWMM version, v0.6.1, is still in the **Alpha** testing stage.

**Table S2.** Complete OpenClaw SWMM capability catalog: 14 skills, 11 MCP servers (3 skills are pure orchestration / retrieval and intentionally do not expose an MCP wrapper

#	Skill name	Purpose	Key scripts	MCP server	Main tools	Outputs
1	swmm-gis	GIS/DEM preprocessing & subcatchment delineation	find_pour_point.py, preprocess_subcatchment_s.py, basin_shp_to_subcatchments.py	mcp/swmm-gis/server.js (swmm-gis-mcp)	gis_preprocess_subcatchments, qgis_load_layers, qgis_validate_crs, qgis_normalize_layers, qgis_overlay_landuse_soil, qgis_extract_slope_area_width, qgis_import_drainage_assets, qgis_export_swmm_intermediates, qgis_package_final_layers, qgis_area_weighted_params, basin_shp_to_subcatchments (11)	builder-ready subcatchment CSV, GeoJSON, DEM/layer previews
2	swmm-params	Land-use / soil -> SWMM runoff & Green-Ampt parameters	landuse_to_swmm_params.py, soil_to_greenampt.py, merge_swmm_params.py	mcp/swmm-params/server.js (swmm-params-mcp)	map_landuse, map_soil, merge_params	merged parameter JSON
3	swmm-network	Build/validate/route SWMM pipe network from shapefiles or CAD/GIS	network_to_inp.py, network_qa.py, snap_pipe_endpoints.py, infer_outfall.py, reorient_pipes.py	mcp/swmm-network/server.js (swmm-network-mcp)	import_network, import_city_network, snap_pipe_endpoints, reorient_pipes, infer_outfall, assign_subcatchment_outlets, prepare_storm_inputs, qa, summary, export_inp (10)	INP-ready network JSON; pipe-network QA report
4	swmm-climate	Rainfall CSV -> SWMM [TIMESERIES] + [RAINGAGES] snippets	format_rainfall.py, build_raingage_section.py	mcp/swmm-climate/server.js (swmm-climate-mcp)	format_rainfall, build_raingage_section	SWMM-ready timeseries text + raingage JSON
5	swmm-builder	Assemble runnable SWMM INP + manifest from CSV/JSON inputs	build_swmm_inp.py, subcatchments_shp_to_csv.py	mcp/swmm-builder/server.js (swmm-builder-mcp)	build_inp	INP file + manifest JSON (hash, version, parameter mapping)
6	swmm-runner	Run swmm5 reproducibly; extract peak/continuity; emit manifest.json	swmm_runner.py	mcp/swmm-runner/server.js (swmm-runner-mcp)	swmm_run, swmm_peak, swmm_continuity, swmm_compare	run directory (rpt/out/stdout/stderr/manifest); metrics JSON
7	swmm-plot	Publication-grade rainfall-runoff figures	plot_rain_runoff_si.py	mcp/swmm-plot/server.js (swmm-plot-mcp)	plot_rain_runoff_si	figure PNG/PDF
8	swmm-	KGE-based search / SCE-UA	swmm_calibrate.py, sceua.py, dream_zs.py	mcp/swmm-calibration/server.j	swmm_calibrate, swmm_calibrate_search	calibrated parameter set;

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	calibration <sup>62</sup>	/ DREAM-ZS calibration + validation <sup>62</sup>	iterative_calibration.py, metrics.py <sup>62</sup>	s (swmm-calibration-mcp) <sup>62</sup>	swmm_calibrate_sceua, swmm_calibrate_dream_zs, swmm_sensitivity_scan, swmm_validate (6) <sup>62</sup>	KGE / r / alpha / beta; posterior samples <sup>62</sup>
9 <sup>62</sup>	swmm-uncertainty <sup>62</sup>	Parameter / forcing uncertainty propagation + sensitivity analysis <sup>62</sup>	uncertainty_propagate.py, sensitivity.py, rainfall_ensemble.py, source_decomposition.py, monte_carlo_propagate.py <sup>62</sup>	mcp/swmm-uncertainty/server.js (swmm-uncertainty-mcp) <sup>62</sup>	swmm_sensitivity_oat, swmm_sensitivity_morris, swmm_sensitivity_sobol, swmm_rainfall_ensemble, swmm_uncertainty_source_decomposition (5) <sup>62</sup>	hydrograph envelopes; Morris/Sobol' indices; uncertainty_source_decomposition.json <sup>62</sup>
10 <sup>62</sup>	swmm-experiment-audit <sup>62</sup>	Byte-level audit + Obsidian provenance after every run <sup>62</sup>	audit_run.py, init_obsidian_vault.py <sup>62</sup>	mcp/swmm-experiment-audit/server.js (swmm-experiment-audit-mcp) <sup>62</sup>	audit_run <sup>62</sup>	experiment_provenance.json (v1.3 schema); audit notes <sup>62</sup>
11 <sup>62</sup>	swmm-modeling-memory <sup>62</sup>	Summarize repeated assumptions / failure patterns / lessons across runs <sup>62</sup>	summarize_memory.py <sup>62</sup>	mcp/swmm-modeling-memory/server.js (swmm-modeling-memory-mcp) <sup>62</sup>	summarize_memory <sup>62</sup>	memory summary markdown + skill-update proposals <sup>62</sup>
12 <sup>62</sup>	swmm-rag-memory <sup>62</sup>	RAG retrieval over audited runs & memory notes <sup>62</sup>	retrieve_memory.py, build_memory_corpus.py, answer_with_memory.py, rag_memory_lib.py, refresh_after_run.py, generate_failure_advice.py, record_resolution_memory.py <sup>62</sup>	(none -- pure Skill, invoked in-process) <sup>62</sup>	-- <sup>62</sup>	memory-grounded answer; retrieved evidence list <sup>62</sup>
13 <sup>62</sup>	swmm-lid-optimization <sup>62</sup>	LID scenario generation + placement / combination optimization <sup>62</sup>	lid_scenario_builder.py, entropy_lid_priority.py <sup>62</sup>	(none -- pure Skill) <sup>62</sup>	-- <sup>62</sup>	LID scenario JSON; Pareto candidates <sup>62</sup>
14 <sup>62</sup>	swmm-end-to-end <sup>62</sup>	Top-level orchestration over the other 13 skills <sup>62</sup>	mcp_stdio_call.py <sup>62</sup>	(none -- pure Skill, orchestrates other MCP servers) <sup>62</sup>	-- <sup>62</sup>	end-to-end run manifest aggregating downstream outputs <sup>62</sup>

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## Section S2 Automatic Pour Point Detection Algorithm

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Algorithm: FindPourPoint\_BoundaryMinElev\_ImageFrame(Z, M, T)

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Input : Z[H,W], M[H,W] (True=valid), affine transform T

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Output: (r\*, c\*), (x\*, y\*), z\*

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$B \leftarrow \{(r,c) \mid r \in \{0, H-1\} \text{ OR } c \in \{0, W-1\}\}$

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$V \leftarrow \{(r,c) \in B \mid M[r,c]=\text{True AND isfinite}(Z[r,c])\}$

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if  $V = \emptyset$ :

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raise "No valid boundary cells"

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$(r^*, c^*) \leftarrow \operatorname{argmin}_{\{(r,c) \in V\}} Z[r,c]$  (optional: tie-break by first / min r / etc.)

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$z^* \leftarrow Z[r^*, c^*]$

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$(x^*, y^*) \leftarrow \operatorname{CellCenter}(T, r^*, c^*)$

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return  $(r^*, c^*), (x^*, y^*), z^*$

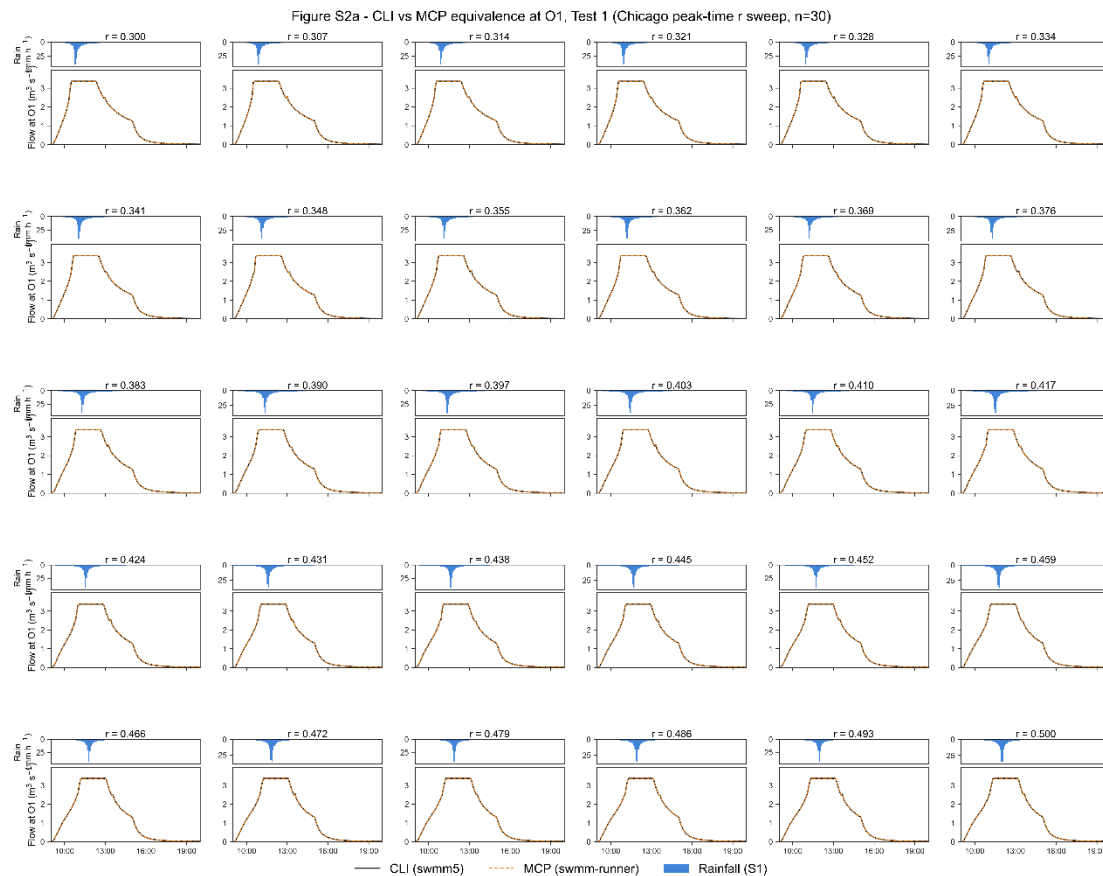
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Case 01 r = 0.300 NSE = 1.000000 R <sup>2</sup> = 1.000000	Case 02 r = 0.307 NSE = 1.000000 R <sup>2</sup> = 1.000000	Case 03 r = 0.314 NSE = 1.000000 R <sup>2</sup> = 1.000000	Case 04 r = 0.321 NSE = 1.000000 R <sup>2</sup> = 1.000000	Case 05 r = 0.328 NSE = 1.000000 R <sup>2</sup> = 1.000000	Case 06 r = 0.334 NSE = 1.000000 R <sup>2</sup> = 1.000000
Case 07 r = 0.341 NSE = 1.000000 R <sup>2</sup> = 1.000000	Case 08 r = 0.348 NSE = 1.000000 R <sup>2</sup> = 1.000000	Case 09 r = 0.355 NSE = 1.000000 R <sup>2</sup> = 1.000000	Case 10 r = 0.362 NSE = 1.000000 R <sup>2</sup> = 1.000000	Case 11 r = 0.369 NSE = 1.000000 R <sup>2</sup> = 1.000000	Case 12 r = 0.376 NSE = 1.000000 R <sup>2</sup> = 1.000000
Case 13 r = 0.383 NSE = 1.000000 R <sup>2</sup> = 1.000000	Case 14 r = 0.390 NSE = 1.000000 R <sup>2</sup> = 1.000000	Case 15 r = 0.397 NSE = 1.000000 R <sup>2</sup> = 1.000000	Case 16 r = 0.403 NSE = 1.000000 R <sup>2</sup> = 1.000000	Case 17 r = 0.410 NSE = 1.000000 R <sup>2</sup> = 1.000000	Case 18 r = 0.417 NSE = 1.000000 R <sup>2</sup> = 1.000000
Case 19 r = 0.424 NSE = 1.000000 R <sup>2</sup> = 1.000000	Case 20 r = 0.431 NSE = 1.000000 R <sup>2</sup> = 1.000000	Case 21 r = 0.438 NSE = 1.000000 R <sup>2</sup> = 1.000000	Case 22 r = 0.445 NSE = 1.000000 R <sup>2</sup> = 1.000000	Case 23 r = 0.452 NSE = 1.000000 R <sup>2</sup> = 1.000000	Case 24 r = 0.459 NSE = 1.000000 R <sup>2</sup> = 1.000000
Case 25 r = 0.466 NSE = 1.000000 R <sup>2</sup> = 1.000000	Case 26 r = 0.472 NSE = 1.000000 R <sup>2</sup> = 1.000000	Case 27 r = 0.479 NSE = 1.000000 R <sup>2</sup> = 1.000000	Case 28 r = 0.486 NSE = 1.000000 R <sup>2</sup> = 1.000000	Case 29 r = 0.493 NSE = 1.000000 R <sup>2</sup> = 1.000000	Case 30 r = 0.500 NSE = 1.000000 R <sup>2</sup> = 1.000000

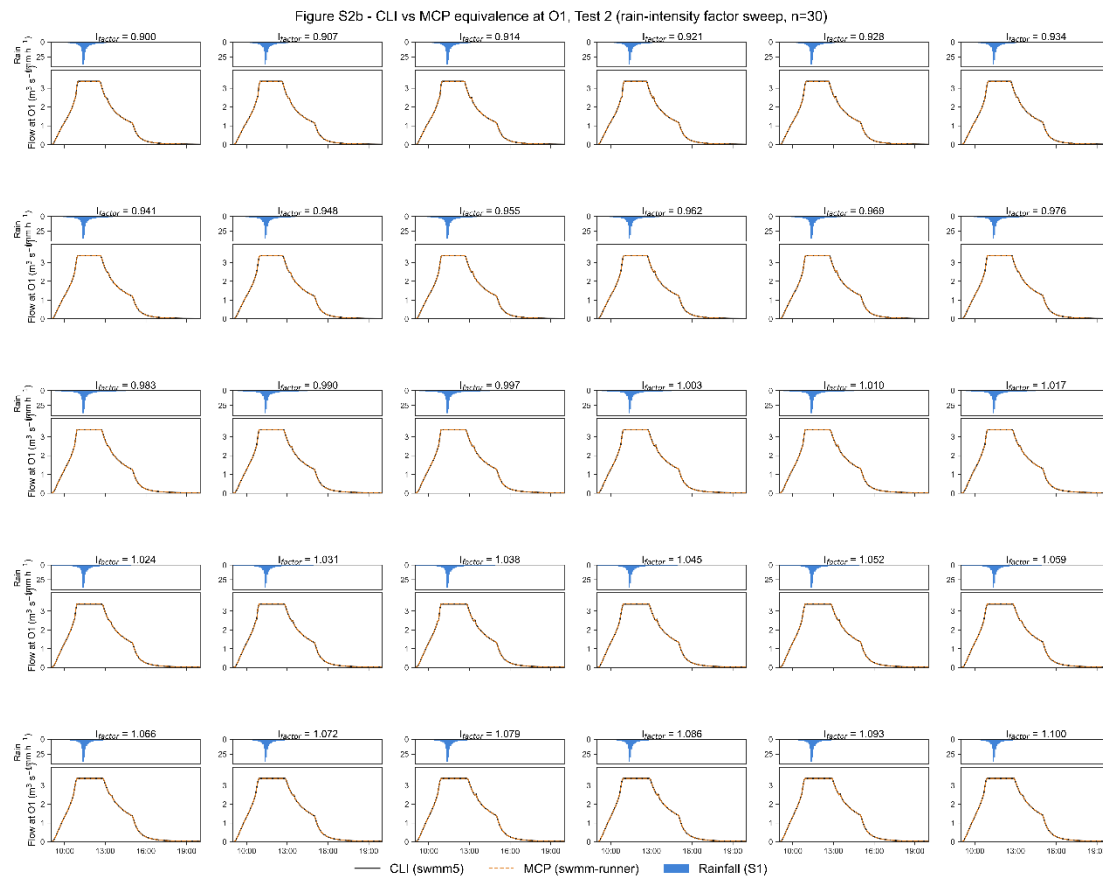
Figure S2. The NSE R2 value for Scenario A, compared with SWMM CLI and SWMM MCP via aiswmm.

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(a)

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(b) **Figure S3.** Computed hydrographs at the outlet for the upper and lower limit for 30 runs with hyetograph shown in blue on the left axis (inverted) for (a) Test 1 top panel; and (b) Test 2 downside panel. CLI results are shown as black solid lines and MCP results are orange dashed lines overlaid on top

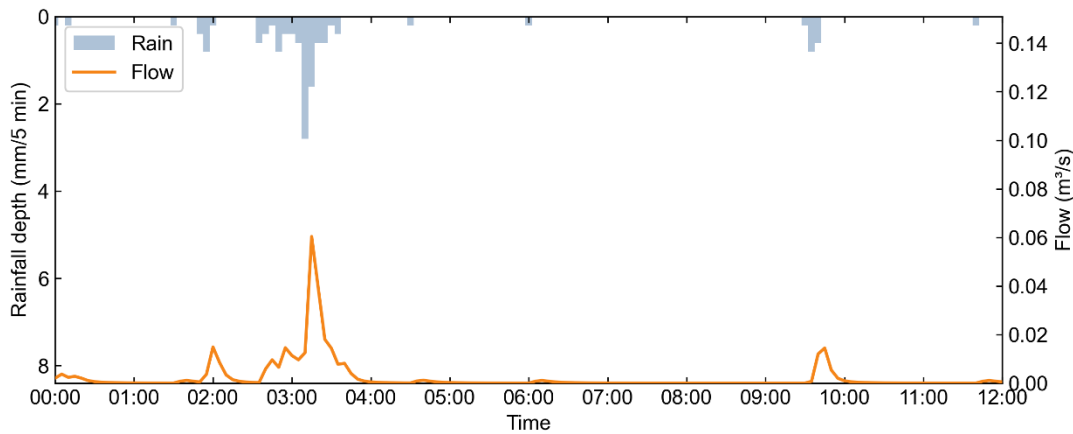
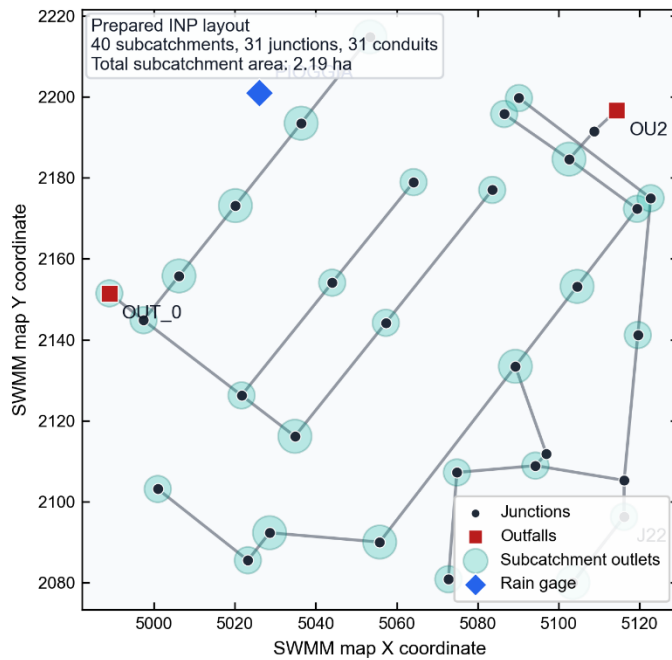
**Section 3** Verification-first provenance

The deterministic Quality Assurance (QA) gate suite in swmm-experiment-audit evaluates eight rules in sequence after every SWMM execution, and the overall QA verdict is pass only if all eight rules pass. The eight rules are: (1) runner\_return\_code\_zero — the SWMM 5 binary must exit with return code 0; (2) runner\_outputs\_exist — the report file (.rpt) and binary output file (.out) declared in the runner manifest must exist on disk; (3) peak\_metric\_present — the peak inflow at the configured node must be successfully parsed from the Node Inflow Summary section of the RPT; (4) peak\_matches\_report — the peak inflow value recorded in manifest.json must equal, to three decimal places, the value re-parsed from the same RPT section, providing an internal consistency cross-check; (5) continuity\_error\_runoff — the absolute continuity error of the runoff-quantity block must remain below the configured threshold (default 3 %); (6) continuity\_error\_routing — the absolute continuity error of the flow-routing block must remain below the same threshold; (7) conduit\_slope\_plausibility — every conduit slope inferred from end-node inverts and conduit length must fall within the physically plausible interval (default  $1 \times 10^{-5}$  to 1.0 m/m); and (8) invert\_elevation\_sanity — no junction or outfall may carry a negative or sentinel invert elevation. Each rule emits a structured (id, status, evidence) record into experiment\_provenance.json, so the resulting QA verdict is reviewable artifact-by-artifact rather than as a single opaque pass/fail flag. Note that this description is generated by LLM (Claude code 4.7 opus), but the description has been verified.

scenario	case	inp_sha21	inp_sha256	inp_sha384	inp_sha512	inp_sha768	inp_sha1024	inp_sha1536	inp_sha2048	inp_sha2560	inp_sha3072	inp_sha3584	inp_sha4096	inp_sha4608	inp_sha5120	inp_sha5632	inp_sha6144	inp_sha6656	inp_sha7168	inp_sha7680	inp_sha8192	inp_sha8704	inp_sha9216	inp_sha9728	inp_sha10240	inp_sha10752	inp_sha11264	inp_sha11776	inp_sha12288	inp_sha12800	inp_sha13312	inp_sha13824	inp_sha14336	inp_sha14848	inp_sha15360	inp_sha15872	inp_sha16384	inp_sha16896	inp_sha17408	inp_sha17920	inp_sha18432	inp_sha18944	inp_sha19456	inp_sha19968	inp_sha20480	inp_sha20992	inp_sha21504	inp_sha22016	inp_sha22528	inp_sha23040	inp_sha23552	inp_sha24064	inp_sha24576	inp_sha25088	inp_sha25600	inp_sha26112	inp_sha26624	inp_sha27136	inp_sha27648	inp_sha28160	inp_sha28672	inp_sha29184	inp_sha29696	inp_sha30208	inp_sha30720	inp_sha31232	inp_sha31744	inp_sha32256	inp_sha32768	inp_sha33280	inp_sha33792	inp_sha34304	inp_sha34816	inp_sha35328	inp_sha35840	inp_sha36352	inp_sha36864	inp_sha37376	inp_sha37888	inp_sha38400	inp_sha38912	inp_sha39424	inp_sha39936	inp_sha40448	inp_sha40960	inp_sha41472	inp_sha41984	inp_sha42496	inp_sha43008	inp_sha43520	inp_sha44032	inp_sha44544	inp_sha45056	inp_sha45568	inp_sha46080	inp_sha46592	inp_sha47104	inp_sha47616	inp_sha48128	inp_sha48640	inp_sha49152	inp_sha49664	inp_sha50176	inp_sha50688	inp_sha51200	inp_sha51712	inp_sha52224	inp_sha52736	inp_sha53248	inp_sha53760	inp_sha54272	inp_sha54784	inp_sha55296	inp_sha55808	inp_sha56320	inp_sha56832	inp_sha57344	inp_sha57856	inp_sha58368	inp_sha58880	inp_sha59392	inp_sha59904	inp_sha60416	inp_sha60928	inp_sha61440	inp_sha61952	inp_sha62464	inp_sha62976	inp_sha63488	inp_sha64000	inp_sha64512	inp_sha65024	inp_sha65536	inp_sha66048	inp_sha66560	inp_sha67072	inp_sha67584	inp_sha68096	inp_sha68608	inp_sha69120	inp_sha69632	inp_sha70144	inp_sha70656	inp_sha71168	inp_sha71680	inp_sha72192	inp_sha72704	inp_sha73216	inp_sha73728	inp_sha74240	inp_sha74752	inp_sha75264	inp_sha75776	inp_sha76288	inp_sha76800	inp_sha77312	inp_sha77824	inp_sha78336	inp_sha78848	inp_sha79360	inp_sha79872	inp_sha80384	inp_sha80896	inp_sha81408	inp_sha81920	inp_sha82432	inp_sha82944	inp_sha83456	inp_sha83968	inp_sha84480	inp_sha84992	inp_sha85504	inp_sha86016	inp_sha86528	inp_sha87040	inp_sha87552	inp_sha88064	inp_sha88576	inp_sha89088	inp_sha89600	inp_sha90112	inp_sha90624	inp_sha91136	inp_sha91648	inp_sha92160	inp_sha92672	inp_sha93184	inp_sha93696	inp_sha94208	inp_sha94720	inp_sha95232	inp_sha95744	inp_sha96256	inp_sha96768	inp_sha97280	inp_sha97792	inp_sha98304	inp_sha98816	inp_sha99328	inp_sha99840	inp_sha100352	inp_sha100864	inp_sha101376	inp_sha101888	inp_sha102400	inp_sha102912	inp_sha103424	inp_sha103936	inp_sha104448	inp_sha104960	inp_sha105472	inp_sha105984	inp_sha106496	inp_sha107008	inp_sha107520	inp_sha108032	inp_sha108544	inp_sha109056	inp_sha109568	inp_sha110080	inp_sha110592	inp_sha111104	inp_sha111616	inp_sha112128	inp_sha112640	inp_sha113152	inp_sha113664	inp_sha114176	inp_sha114688	inp_sha115200	inp_sha115712	inp_sha116224	inp_sha116736	inp_sha117248	inp_sha117760	inp_sha118272	inp_sha118784	inp_sha119296	inp_sha119808	inp_sha120320	inp_sha120832	inp_sha121344	inp_sha121856	inp_sha122368	inp_sha122880	inp_sha123392	inp_sha123904	inp_sha124416	inp_sha124928	inp_sha125440	inp_sha125952	inp_sha126464	inp_sha126976	inp_sha127488	inp_sha128000	inp_sha128512	inp_sha129024	inp_sha129536	inp_sha130048	inp_sha130560	inp_sha131072	inp_sha131584	inp_sha132096	inp_sha132608	inp_sha133120	inp_sha133632	inp_sha134144	inp_sha134656	inp_sha135168	inp_sha135680	inp_sha136192	inp_sha136704	inp_sha137216	inp_sha137728	inp_sha138240	inp_sha138752	inp_sha139264	inp_sha139776	inp_sha140288	inp_sha140800	inp_sha141312	inp_sha141824	inp_sha142336	inp_sha142848	inp_sha143360	inp_sha143872	inp_sha144384	inp_sha144896	inp_sha145408	inp_sha145920	inp_sha146432	inp_sha146944	inp_sha147456	inp_sha147968	inp_sha148480	inp_sha148992	inp_sha149504	inp_sha150016	inp_sha150528	inp_sha151040	inp_sha151552	inp_sha152064	inp_sha152576	inp_sha153088	inp_sha153600	inp_sha154112	inp_sha154624	inp_sha155136	inp_sha155648	inp_sha156160	inp_sha156672	inp_sha157184	inp_sha157696	inp_sha158208	inp_sha158720	inp_sha159232	inp_sha159744	inp_sha160256	inp_sha160768	inp_sha161280	inp_sha161792	inp_sha162304	inp_sha162816	inp_sha163328	inp_sha163840	inp_sha164352	inp_sha164864	inp_sha165376	inp_sha165888	inp_sha166400	inp_sha166912	inp_sha167424	inp_sha167936	inp_sha168448	inp_sha168960	inp_sha169472	inp_sha170000	inp_sha170512	inp_sha171024	inp_sha171536	inp_sha172048	inp_sha172560	inp_sha173072	inp_sha173584	inp_sha174096	inp_sha174608	inp_sha175120	inp_sha175632	inp_sha176144	inp_sha176656	inp_sha177168	inp_sha177680	inp_sha178192	inp_sha178704	inp_sha179216	inp_sha179728	inp_sha180240	inp_sha180752	inp_sha181264	inp_sha181776	inp_sha182288	inp_sha182800	inp_sha183312	inp_sha183824	inp_sha184336	inp_sha184848	inp_sha185360	inp_sha185872	inp_sha186384	inp_sha186896	inp_sha187408	inp_sha187920	inp_sha188432	inp_sha188944	inp_sha189456	inp_sha189968	inp_sha190480	inp_sha190992	inp_sha191504	inp_sha192016	inp_sha192528	inp_sha193040	inp_sha193552	inp_sha194064	inp_sha194576	inp_sha195088	inp_sha195600	inp_sha196112	inp_sha196624	inp_sha197136	inp_sha197648	inp_sha198160	inp_sha198672	inp_sha199184	inp_sha199696	inp_sha200208	inp_sha200720	inp_sha201232	inp_sha201744	inp_sha202256	inp_sha202768	inp_sha203280	inp_sha203792	inp_sha204304	inp_sha204816	inp_sha205328	inp_sha205840	inp_sha206352	inp_sha206864	inp_sha207376	inp_sha207888	inp_sha208400	inp_sha208912	inp_sha209424	inp_sha209936	inp_sha210448	inp_sha210960	inp_sha211472	inp_sha211984	inp_sha212496	inp_sha213008	inp_sha213520	inp_sha214032	inp_sha214544	inp_sha215056	inp_sha215568	inp_sha216080	inp_sha216592	inp_sha217104	inp_sha217616	inp_sha218128	inp_sha218640	inp_sha219152	inp_sha219664	inp_sha220176	inp_sha220688	inp_sha221200	inp_sha221712	inp_sha222224	inp_sha222736	inp_sha223248	inp_sha223760	inp_sha224272	inp_sha224784	inp_sha225296	inp_sha225808	inp_sha226320	inp_sha226832	inp_sha227344	inp_sha227856	inp_sha228368	inp_sha228880	inp_sha229392	inp_sha229904	inp_sha230416	inp_sha230928	inp_sha231440	inp_sha231952	inp_sha232464	inp_sha232976	inp_sha233488	inp_sha234000	inp_sha234512	inp_sha235024	inp_sha235536	inp_sha236048	inp_sha236560	inp_sha237072	inp_sha237584	inp_sha238096	inp_sha238608	inp_sha239120	inp_sha239632	inp_sha240144	inp_sha240656	inp_sha241168	inp_sha241680	inp_sha242192	inp_sha242704	inp_sha243216	inp_sha243728	inp_sha244240	inp_sha244752	inp_sha245264	inp_sha245776	inp_sha246288	inp_sha246800	inp_sha247312	inp_sha247824	inp_sha248336	inp_sha248848	inp_sha249360	inp_sha249872	inp_sha250384	inp_sha250896	inp_sha251408	inp_sha251920	inp_sha252432	inp_sha252944	inp_sha253456	inp_sha253968	inp_sha254480	inp_sha254992	inp_sha255504	inp_sha256016	inp_sha256528	inp_sha257040	inp_sha257552	inp_sha258064	inp_sha258576	inp_sha259088	inp_sha259600	inp_sha260112	inp_sha260624	inp_sha261136	inp_sha261648	inp_sha262160	inp_sha262672	inp_sha263184	inp_sha263696	inp_sha264208	inp_sha264720	inp_sha265232	inp_sha265744	inp_sha266256	inp_sha266768	inp_sha267280	inp_sha267792	inp_sha268304	inp_sha268816	inp_sha269328	inp_sha269840	inp_sha270352	inp_sha270864	inp_sha271376	inp_sha271888	inp_sha272400	inp_sha272912	inp_sha273424	inp_sha273936	inp_sha274448	inp_sha274960	inp_sha275472	inp_sha275984	inp_sha276496	inp_sha277008	inp_sha277520	inp_sha278032	inp_sha278544	inp_sha279056	inp_sha279568	inp_sha280080	inp_sha280592	inp_sha281104	inp_sha281616	inp_sha282128	inp_sha282640	inp_sha283152	inp_sha283664	inp_sha284176	inp_sha284688	inp_sha285200	inp_sha285712	inp_sha286224	inp_sha286736	inp_sha287248	inp_sha287760	inp_sha288272	inp_sha288784	inp_sha289296	inp_sha289808	inp_sha290320	inp_sha290832	inp_sha291344	inp_sha291856	inp_sha292368	inp_sha292880	inp_sha293392	inp_sha293904	inp_sha294416	inp_sha294928	inp_sha295440	inp_sha295952	inp_sha296464	inp_sha296976	inp_sha297488	inp_sha298000	inp_sha298512	inp_sha299024	inp_sha299536	inp_sha300048	inp_sha300560	inp_sha301072	inp_sha301584	inp_sha302096	inp_sha302608	inp_sha303120	inp_sha303632	inp_sha304144	inp_sha304656	inp_sha305168	inp_sha305680	inp_sha306192	inp_sha306704	inp_sha307216	inp_sha307728	inp_sha308240	inp_sha308752	inp_sha309264	inp_sha309776	inp_sha310288	inp_sha310800	inp_sha311312	inp_sha311824	inp_sha312336	inp_sha312848	inp_sha313360	inp_sha313872	inp_sha314384	inp_sha314896	inp_sha315408	inp_sha315920	inp_sha316432	inp_sha316944	inp_sha317456	inp_sha317968	inp_sha318480	inp_sha318992	inp_sha319504	inp_sha320016	inp_sha320528	inp_sha321040	inp_sha321552	inp_sha322064	inp_sha322576	inp_sha323088	inp_sha323600	inp_sha324112	inp_sha324624	inp_sha325136	inp_sha325648	inp_sha326160	inp_sha326672	inp_sha327184	inp_sha327696	inp_sha328208	inp_sha328720	inp_sha329232	inp_sha329744	inp_sha330256	inp_sha330768	inp_sha331280	inp_sha331792	inp_sha332304	inp_sha332816	inp_sha333328	inp_sha333840	inp_sha334352	inp_sha334864	inp_sha335376	inp_sha335888	inp_sha336400	inp_sha336912	inp_sha337424	inp_sha337936	inp_sha338448	inp_sha338960	inp_sha339472	inp_sha340084	inp_sha340596	inp_sha341108	inp_sha341620	inp_sha342132	inp_sha342644	inp_sha343156	inp_sha343668	inp_sha344180	inp_sha344692	inp_sha345204	inp_sha345716	inp_sha346228	inp_sha346740	inp_sha347252	inp_sha347764	inp_sha348276	inp_sha348788	inp_sha349300	inp_sha349812	inp_sha350324	inp_sha350836	inp_sha351348	inp_sha351860	inp_sha352372	inp_sha352884	inp_sha353396	inp_sha353908	inp_sha354420	inp_sha354932	inp_sha355444	inp_sha355956	inp_sha356468	inp_sha356980	inp_sha357492	inp_sha358004	inp_sha358516	inp_sha359028	inp_sha359540	inp_sha360052	inp_sha360564	inp_sha361076	inp_sha361588	inp_sha362100	inp_sha362612	inp_sha363124	inp_sha363636	inp_sha364148	inp_sha364660	inp_sha365172	inp_sha365684	inp_sha366196	inp_sha366708	inp_sha367220	inp_sha367732	inp_sha368244	inp_sha368756	inp_sha369268	inp_sha369780	inp_sha370292	inp_sha370804	inp_sha371316	inp_sha371828	inp_sha372340	inp_sha372852	inp_sha373364	inp_sha373876	inp_sha374388	inp_sha374900	inp_sha375412	inp_sha375924	inp_sha376436	inp_sha376948	inp_sha377460	inp_sha377972	inp_sha378484	inp_sha378996	inp_sha379508	inp_sha380020	inp_sha380532	inp_sha381044	inp_sha381556	inp_sha382068	inp_sha382580	inp_sha383092	inp_sha383604	inp_sha384116	inp_sha384628	inp_sha385140	inp_sha385652	inp_sha386164	inp_sha386676	inp_sha387188	inp_sha387700	inp_sha388212	inp_sha388724	inp_sha389236	inp_sha389748	inp_sha390260	inp_sha390772	inp_sha391284	inp_sha391796	inp_sha392308	inp_sha392820	inp_sha393332	inp_sha393844	inp_sha394356	inp_sha394868	inp_sha395380	inp_sha395892	inp_sha396404	inp_sha396916	inp_sha397428	inp_sha397940	inp_sha398452	inp_sha398964	inp_sha399476	inp_sha400088	inp_sha400600	inp_sha401112	inp_sha401624	inp_sha402136	inp_sha402648	inp_sha403160	inp_sha403672	inp_sha404184	inp_sha404696	inp_sha405208	inp_sha405720	inp_sha406232	inp_sha406744	inp_sha407256	inp_sha407768	inp_sha408280	inp_sha408792	inp_sha409304	inp_sha409816	inp_sha410328	inp_sha410840	inp_sha411352	inp_sha411864	inp_sha412376	inp_sha412888	inp_sha413400	inp_sha413912	inp_sha414424	inp_sha414936	inp_sha415448	inp_sha415960	inp_sha416472	inp_sha416984	inp_sha417496	inp_sha418008	inp_sha418520	inp_sha419032	inp_sha419544	inp_sha420056	inp_sha420568	inp_sha421080	inp_sha421592	inp_sha422104	inp_sha422616	inp_sha423128	inp_sha423640	inp_sha424152	inp_sha424664	inp_sha425176	inp_sha425688	inp_sha426200	inp_sha426712	inp_sha427224	inp_sha427736	inp_sha428248	inp_sha428760	inp_sha429272	inp_sha429784	inp_sha430296	inp_sha430808	inp_sha431320	inp_sha431832	inp_sha432344	inp_sha432856	inp_sha433368	inp_sha433880	inp_sha434392	inp_sha434904	inp_sha435416	inp_sha435928	inp_sha436440	inp_sha436952	inp_sha437464	inp_sha437976	inp_sha438488	inp_sha439000	inp_sha439512	inp_sha440024	inp_sha440536	inp_sha441048	inp_sha441560	inp_sha442072	inp_sha442584	inp_sha443096	inp_sha443608	inp_sha444120	inp_sha444632	inp_sha445144	inp_sha445656	inp_sha446168	inp_sha446680	inp_sha447192	inp_sha447704	inp_sha448216	inp_sha448728	inp_sha449240	inp_sha449752	inp_sha450264	inp_sha450776	inp_sha451288	inp_sha451800	inp_sha452312	inp_sha452824	inp_sha453336	inp_sha453848	inp_sha454
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an external SWMM model, compare workflow outputs against direct swmm5 execution, inspect both an outfall and an internal junction, generate rainfall-runoff figures, and emit audit-ready artifacts.

Case 2: The Tecnopolo benchmark



The Tecnopolo benchmark validates the prepared-input path using an external 40-subcatchment SWMM model derived from a public Zenodo dataset.

It checks that the workflow can execute an external SWMM model, compare workflow outputs against direct swmm5 execution, inspect both an outfall and an internal junction, generate rainfall-runoff figures, and emit audit-ready artifacts.

**Validation snapshot**

The repository includes runnable benchmarks and research previews with different evidence boundaries. The README keeps only the index; figures, commands, and boundary notes live in [Validation evidence](#).

Path	What it shows	Evidence boundary
<a href="#">Information-loss-guided subcatchment partition</a>	QGIS-to-Agentive SWMM preprocessing using entropy and fuzzy-similarity concepts from Zhang & Valeo's <a href="#">Journal of Hydrology paper</a>	GIS preprocessing concept, not a calibrated SWMM performance claim
<a href="#">Raw GeoPackage-to-INP benchmark</a>	Public TUFLOW GeoPackage layers converted into SWMM-ready artifacts, QA, and audit	Structured raw GIS path, not arbitrary CAD/GIS recognition
<a href="#">Prepared-input SWMM benchmark</a>	External 40-subcatchment Tecno polo model execution, plotting, and direct <code>swmm5</code> comparison	Prepared INP validation path
<a href="#">Prior Monte Carlo uncertainty smoke</a>	Tecno polo HORTON parameter perturbation and hydrograph envelope preview	Prior uncertainty smoke, not calibration
<a href="#">Optional INP-derived raw adapter benchmark</a>	Raw-like inputs extracted from a public SWMM fixture and rebuilt through the modular path	Adapter handoff check, not greenfield watershed generation

Examples: [TUFLOW](#) and [Tecno polo](#).

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### Section S5 auditing

Tracing the discrepancy revealed that the inconsistency originated from the natural-language-driven figure-preparation process at the LLM-to-shell-command translation level: the two figure-preparation Bash invocations were issued in separate Agentive SWMM sessions, and each time the language-model agent translated the natural-language phrase  $r = 0.40$  into Python code, it produced subtly different file-selection logic — one session generated a generic selector function `np.argmax(|r - 0.40|)` (which, with NumPy's first-occurrence tie-break, returns  $r = 0.39655$ ), while the other session hard-coded the explicit directory name `r_0.4034` (returning  $r = 0.40345$ ). The choice of selector implementation was an LLM-level decision at code-generation time, not a runtime artefact — once each Python script ran, it executed deterministically. Both  $r$  values rounded to 0.40 under `:.2f` formatting, masking the underlying inconsistency at the figure-label level. The two INP files are themselves different. Each of the 30 sweep points produces its own INP file with a distinct [TIMESERIES] `TS_RAIN` block reflecting the corresponding Chicago hyetograph. A direct diff of `inp_test1_v2/r_0.3966.inp` and `inp_test1_v2/r_0.4034.inp` shows that all 72 5-minute rainfall intensity values differ. For example, around the storm peak at 11:20 on 1984-05-25, the rainfall rate is 42.44 mm/hr in the  $r = 0.39655$  storm but a different value in the  $r = 0.40345$  storm because the Chicago peak position shifts by  $\approx 3$  minutes between the two cases. The SHA-256 hashes of the two INP files themselves are therefore already distinct (`a2c644b4...` versus `8971c40f...`), and the corresponding binary `model.out` files inherit this distinction (`90d2e4bb...` versus `44667e8f...`). The chain of distinct hashes — from input INP to output `.out` — is a chain of byte-level identifiers that makes every step of the divergence traceable. Any reader can independently verify each link of this chain from the public artifact archive.

**Table S3.** More Audit\_Tamper\_Comparison

**Table S<sub>3</sub>. Audit-layer detection of intentional input tampering**

Subcatchment S1 %Imperv modified (25.24 → 30.00) in an otherwise byte-identical SWMM input. Both runs executed through the live MCP swmm-runner transport at commit 2b99264 on 2026-05-15. SHA-256 digests truncated to the first 10 hexadecimal characters; full digests are available in the run manifests under /tmp/figure4\_mcp\_live/(baseline,tampered)/.

Check	Baseline	Tampered	Result	Interpretation
status	pass	pass	same	swmm5 return code (both runs converged).
git_head	2b99264d3f...	2b99264d3f...	same	Code version captured by the run manifest.
model_inp_sha256	a2c644b4d6...	30799f5412...	changed	SWMM input model identity.
runner_out_sha256	90d2e4bb0c...	f605b11528...	changed	SWMM binary output identity.
runner_rpt_sha256	580bd10ea9...	4d336bb121...	changed	SWMM text report identity.
peak_flow at O1 (m <sup>3</sup> /s)	3.366	3.366	same	Contract-defined headline metric; deceptively unchanged because the outfall is rate-limited by saturation of the J1→O1 conduit.
peak_source_section	Node Inflow Summary	Node Inflow Summary	same	Source-of-truth section enforced by the metric-source contract.
peak_matches_report	True	True	same	Recorded peak equals the value re-parsed from the source section (within-run self-consistency).
time_of_peak at O1	day 2, 11:00	day 2, 10:54	changed	Peak time advanced by -6 min under the perturbation.
total_volume at O1 (10 <sup>4</sup> L)	50.3	55.4	changed	+10.1 % under tampering, despite identical peak rate.
peak_flow at J1 (m <sup>3</sup> /s)	35.667	40.049	changed	Upstream peak +12.3 % — the unmasked tamper signature.
continuity_error (runoff, %)	-0.003	-0.003	same	Within solver tolerance; solver-health unchanged.
continuity_error (routing, %)	-0.001	0.000	same	Within solver tolerance; solver-health unchanged.
<b>Comparison warnings</b>				
<ul style="list-style-type: none"> <li>model_inp_sha256 changed: the SWMM_inp differs between baseline and current run — input was modified, not merely rerun.</li> <li>runner_out_sha256 changed while peak_flow at O1 is unchanged: the outfall is rate-limited (conduit saturation); upstream peak at J1 shifted by +12.3 % and total inflow volume at O1 by +10.1 %.</li> </ul>				
<b>Verdict</b>				
All four artifacts in the audit chain (INP → manifest → model.out → model.rpt) flipped under a single-parameter perturbation. The contract-defined headline metric (peak_flow at outfall O1) would have failed to discriminate the two runs because the outfall is hydraulically saturated; this is precisely the failure mode the byte-level audit layer is designed to back-stop. Adjacent metrics (J1 peak, O1 total volume, time-of-peak) together with the SHA-256 chain provide an unambiguous tamper signature even when the published headline number is masked.				

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**Table S<sub>4</sub>. The issue of unit conversion was captured from the auditing note.**

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Check	Baseline	Current	Result	Interpretation
status	pass	pass	same	Overall audit status.
git_head	c9689b21ce1b...	c9689b21ce1b...	same	Code version captured by the run manifest.
model_inp_sha256	272557d26e8a...	272557d26e8a...	same	SWMM input model identity.
runner_out_sha256	c68c63002224...	c68c63002224...	same	SWMM binary output identity.
runner_rpt_sha256	27faf67e6b31...	f025a44738c4...	changed	SWMM text report identity; may differ because reports include timestamps.
peak_flow	98.54	0.007	changed	Recorded peak-flow metric.
peak_source_section	Node Inflow ...	Node Inflow ...	same	Report section used for peak-flow extraction.
peak_matches_report	False	True	changed	Whether the recorded peak value matches the value re-parsed from the source report section.
continuity_error	{'flow_routi...	{'flow_routi...	same	Parsed continuity errors.

Comparison warnings:

- baseline peak-flow record does not match the value parsed from its source report section.
- Peak flow changed while the SWMM input hash is unchanged; check parser version, metric source, or report records.

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