River Morphology Information System: A Web Cyberinfrastructure for Advancing River Morphology Research

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Abstract

The study and management of river systems are increasingly challenged by the complexity and volume of data required to understand and predict river morphology changes. The River Morphology Information System (RIMORPHIS) is introduced as a transformative solution to these challenges, serving as an open-access web-based cyberinfrastructure designed to enable advanced research in river morphology dynamics and support integrated, multidisciplinary analysis of riverine environments. Built upon the robust framework of the National Hydrography Dataset Plus High Resolution, RIMORPHIS integrates publicly available bathymetry data and third-party resources, offering a comprehensive and cohesive database architecture for real-time use and analysis. This platform is structured around a PostgreSQL database with PostGIS extension, providing tools for Geospatial visualization using Deck.GL, data analytics with Python-based geospatial processing, and the integration of eHydro Cross Section Surveys via API. This paper presents the development and functionalities of RIMORPHIS, highlighting its unique contributions to the field of hydrological information systems, with a specific focus on river morphology. By providing on-demand access to relevant datasets, coupled with tools for data analytics and geospatial visualization, RIMORPHIS addresses critical gaps in data accessibility, interoperability, and the integration of disparate data sources. Our contribution extends beyond the technical implementation, aiming to foster a self-sustained community platform that encourages collaboration among researchers, educators, and practitioners. Through this initiative, RIMORPHIS not only enhances our understanding of river systems but also supports informed decision-making in river basin management.

Keywords: river morphology, hydrological information system, data analytics, geospatial visualization, WebGL, 3D Visualization, river basin management.

1. Introduction

The advent of hydrological information systems (Ames et al., 2009; Tarboton et al., 2009; Piasecki et al., 2010, Muste, 2014) marks a significant milestone in the environmental sciences domain, facilitating the complex task of managing, analyzing, and disseminating vast quantities of hydrological data (Rigon et al., 2022). These systems are crucial in addressing the challenges posed by the increasing volume and complexity of data generated by modern hydrological studies (Yang et al., 2021). The demand for on-demand access and analytics is propelled by the need to make informed decisions swiftly in managing water resources, predicting hydrological events, and understanding environmental changes (Xu et al., 2022). As such, hydrological information systems have become indispensable tools in synthesizing and leveraging big data for scientific research, policy-making, and practical applications in water management (Kim and Muste, 2012; Mount et al., 2023; Nardi et al., 2022).

The significance of river morphology within the broader context of hydrological studies cannot be overstated (Van Appledorn et al., 2019, Dey et al., 2019), since rivers, as dynamic and complex systems, are central to the hydrological cycle, influencing water quality, ecosystem health, and flood dynamics (Li et al., 2024; Alabbad & Demir, 2022). The literature on river morphology is rich, underscoring the intricate interactions between river flow dynamics, sediment transport, and channel formation processes (Kemper et al., 2023). Advances in remote sensing, geographic information systems (GIS), and computational modeling have greatly enhanced our ability to study these processes in detail (Hou et al., 2020; Li & Demir, 2022). Yet, despite these advancements, the field faces ongoing challenges related to data accessibility, interoperability, and the integration of disparate data sources (Langat et al., 2019; Sagheer et al., 2018). Studies highlight the need for more holistic and user-friendly platforms that can aggregate, analyze, and visualize river morphology data to support comprehensive river basin management and research (Muste et al., 2014; Rodrigues da Silva et al., 2023; Wood and Boyd, 2020; Sit et al., 2021).

The burgeoning complexities of riverine systems under the simultaneous pressures of natural phenomena and anthropogenic activities necessitate advanced methodologies for understanding and managing river morphology (Cox et al., 2024). Recognizing this imperative, the River Morphology Information System (RIMORPHIS)project was conceived to address the critical gap in the accessibility, organization, and analysis of river morphology data (Merwade et al., 2024). The project is rooted in the recognition that river morphology data, fundamental in studying hydrodynamics, sediment transport, and aquatic habitat, are often dispersed, inconsistently formatted, and not readily accessible for comprehensive analyses.

This paper introduces RIMORPHIS, a contribution aimed at bridging the gap in the accessibility and analysis of river morphology data. RIMORPHIS represents a novel approach within the realm of hydrological information systems, focusing specifically on river morphology. By leveraging the National Hydrography Dataset Plus High Resolution (NHDPlus HR) as a foundational framework, RIMORPHIS integrates a wide array of data sources into a cohesive and user-friendly platform. The research contribution lies not only in the development of a unique database structure but also in the provision of advanced tools for on-demand data analytics, visualization, and the facilitation of interdisciplinary research. RIMORPHIS aims to empower researchers, policymakers, and practitioners with a comprehensive tool that enhances our understanding of river systems and supports effective river basin management.

This paper is organized as follows. Section 2 details the methodology, including the background and scope of the RIMORPHIS project, data resources and organization, the data referencing system, and the integration of external data resources. Section 3 presents the system architecture, including the platform's frontend and backend, web services API, relational database, and file system, as well as the tools and services integrated into the cyberinfrastructure. Section 4 discusses the results, including the data web service and API, web platform features, and stakeholder evaluation. Finally, Section 5 concludes with a summary of the findings and a discussion of future directions for the RIMORPHIS platform.

2. Methodology

The study and management of river morphology require an integrated approach that can handle vast and diverse datasets, facilitate real-time analysis, and support interdisciplinary research. The presented framework was developed to address these needs by providing a robust cyberinfrastructure that integrates high-resolution datasets, advanced geospatial tools, and data sharing capabilities. This section outlines the methodological framework underpinning RIMORPHIS, detailing the project's background, scope, data resources, and system architecture to demonstrate how it meets the demands of modern river morphology research.

2.1. Background & Scope

The scope of RIMORPHIS is delineated by its overarching vision to create an open, integrated, and user-friendly cyberinfrastructure that enables the aggregation, visualization, and analysis of river morphology data (Cox et al., 2023). This vision is propelled by the need for a unified platform that transcends institutional and geographic boundaries, facilitating the harmonization of diverse datasets into a coherent structure. The project aims to cater to a wide array of stakeholders, including but not limited to hydrologists, geomorphologists, hydraulic and environmental engineers, water resource managers, and policy-makers, who are directly involved in river research, management, and education.

Central to the RIMORPHIS project is the development of a web-based platform that provides tools for data discovery, access, and processing. This cyberinfrastructure seeks to integrate high-resolution, multi-dimensional river morphology data from various sources, including federal and state agencies, academic researchers, and private entities. The platform is designed to support the ingestion and organization of data in diverse formats (Kim et al, 2008; Ramirez et al., 2024a), offering tools for geospatial visualization, analysis, and modeling. In doing so, RIMORPHIS addresses the critical challenges of data fragmentation and inaccessibility, fostering a collaborative environment for river morphology research.

Moreover, the project scope encompasses the establishment of community engagement mechanisms that facilitate the active participation of stakeholders in the co-development of the RIMORPHIS platform. Through workshops, surveys, and direct consultations, stakeholders contributed insights into the platform's functional and operational requirements, ensuring that RIMORPHIS evolves as a community-driven resource (Cox et al., 2023). This participatory approach underscores the project's commitment to addressing the real-world needs of its users, promoting the exchange of knowledge and best practices among the river morphology research and management communities.

2.2. Data Resources and Organization

The platform is structured around a database system that centralizes and organizes a vast array of river morphology data. This system is pivotal for the platform's capability to provide comprehensive access to, and analysis of, river morphology information. At the core of this organization is the strategic integration of data resources, which includes both publicly available bathymetry data and data from external third-party resources.

2.2.1. Data Referencing System

RIMORPHIS adopts a data referencing system that leverages NHDPlus HR for structuring and organizing river morphology data. This system is pivotal for ensuring that data from diverse sources can be integrated and accessed in a coherent and systematic manner, thereby facilitating the analysis and visualization processes within RIMORPHIS. The hierarchy within this referencing system is organized around Hydrologic Unit Codes (HUC) at level 4-8-12 (HUC4-8-12) Catchments, NHD Catchments, and the delineation of Flowlines and Junctions (Figure 1).

At the core of the RIMORPHIS referencing system is the NHDPlus HR catchment, which is designed by further partitioning areas delineated by HUC 12 into smaller catchments. Flowlines within the NHDPlus HR system are defined concerning their associated catchments and come with a wealth of associated data distributed across multiple tables (Moore et al., 2019). Each flowline is identified by a unique NHDPlusID, and its geometric properties, including length in kilometers, are cataloged. Junctions, or nodes, represent the most upstream point of the flowline geometry, serving as critical reference points within the river network. These nodes are categorized into types such as within network, network start, network end, and nonflowing, each carrying specific implications for the flow characteristics and network connectivity.

The RIMORPHIS referencing system utilizes several key tables and fields from the NHDPlus HR dataset to organize and reference river morphology data effectively. These include identifiers such as hydrologic unit code (HUC), and shape data for catchments and flowlines, as well as detailed attributes like flow direction, path length, slope, and the geometric properties of catchments. This suite of data attributes enables a rich, multidimensional analysis of river morphology characteristics.

To illustrate the extensive scale of the NHDPlus HR dataset, we reference the data statistics for HUC2 watersheds such as the Upper Mississippi (HUC 07) and Ohio (HUC 05). For example, the Upper Mississippi, the catchment data occupies 4.47 gigabytes and comprises 1,148,826 records, the flowline dataset is 462 megabytes with 627,746 records, and the junction dataset amounts to 14 megabytes with 623,616 records. Similarly, in the Ohio watershed, the catchment dataset is significantly larger, totaling 8.55 gigabytes and encompassing 2,194,880 records, the flowline dataset expands to 1.96 gigabytes with 2,214,488 records, and the junction dataset increases to 60 megabytes holding 2,182,492 records. These figures highlight the considerable volume and detail of the reference data that forms the foundation of the RIMORPHIS system, illustrating the complexity and breadth of river morphology information available for analysis.

Currently, the RIMORPHIS database integrates Catchment 0701 from the Upper Mississippi for demonstration purposes. However, a workflow has been established to retrieve, process, and consume NHDPlus HR data for the future expansion of the RIMORPHIS database. This workflow involves the use of QGIS for processing HUC, NHD catchments, and flowlines, followed by the consumption of these data through a Python script into a PostgreSQL database with a PostGIS plugin installed. This technical approach ensures that RIMORPHIS can efficiently handle and reference the extensive and detailed river morphology data provided by NHDPlus HR.

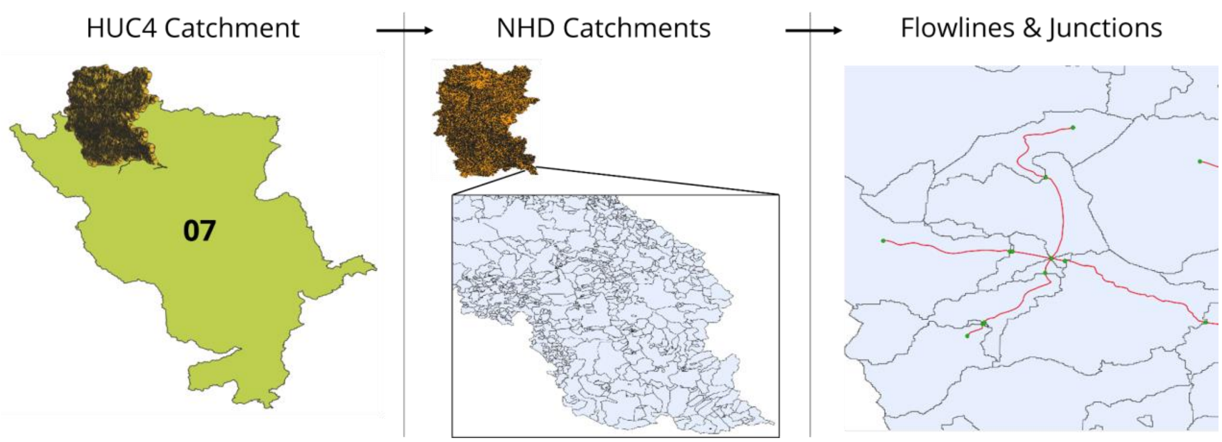


Figure 1: NHDPlus HR Data Referencing System

2.2.2. Data Model

The RIMORPHIS data model is designed to represent the complex hierarchical and relational structure of river morphology data in a comprehensive and coherent manner (Merwade et al., 2024). This model integrates various levels of HUCs, NHD catchments and flowlines, cross-section surveys, and additional data such as sedimentation and roughness measurements. The data model is structured to facilitate the storage, retrieval, and analysis of river morphology data, supporting a wide range of research and management applications (Figure 2).

Geospatial data are integral to the RIMORPHIS data model, with geometric attributes stored for catchments, flowlines, and cross-section points. These spatial data enable the visualization and analysis of river morphology within geographic information systems (GIS). Temporal data attributes, such as survey timestamps, allow for the analysis of changes in river morphology over time.

Some relationships, tables, and functions have been omitted for brevity in this description. However, the data model's implementation involves the use of PostgreSQL as the database management system, with the PostGIS extension enabling the handling of spatial data. The model's design allows for the efficient processing and querying of large datasets, supporting the RIMORPHIS platform's objectives of providing accessible, detailed, and actionable river morphology data.

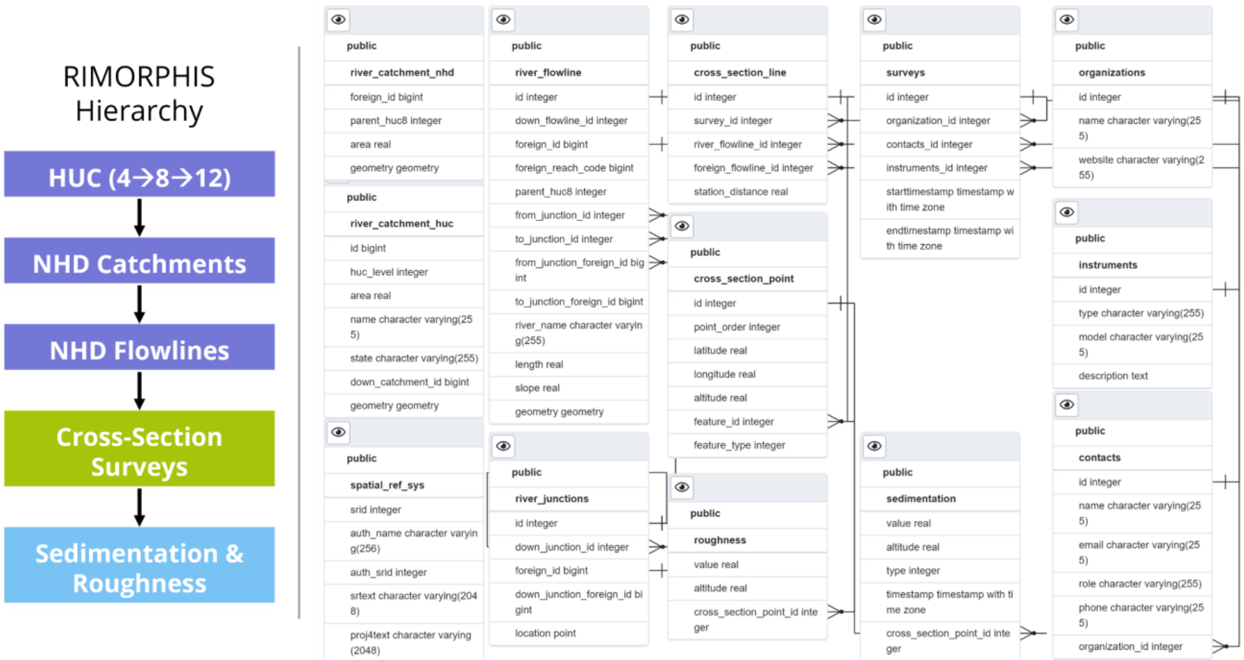


Figure 2: RIMORPHIS Data Object Model (DOM) and Metadata Specification

2.2.3. External Data Resources

RIMORPHIS incorporates a strategic integration of third-party Application Programming Interfaces (APIs) and resources to enrich its data ecosystem. One of the pivotal external data resources integrated into RIMORPHIS in this initial stage is the eHydro Cross Section Surveys provided by the United States Army Corps of Engineers (USACE) Hydrographics Surveys (Niles, 2013). These surveys offer a wealth of river morphology data crucial for a wide array of scientific and management purposes.

The eHydro API facilitates access to a comprehensive collection of hydrographic surveys conducted by various USACE Districts across the United States. As of March 2024, the eHydro system boasts a total of 96,697 surveys, encompassing detailed morphological data from districts spanning the continental United States and beyond, including Puerto Rico, Alaska, and Hawaii. These surveys provide data in several formats, including Geodatabase (GDB), Esri TIN, XYZ, and KMZ, thus offering flexibility in data usage depending on the specific requirements of the analysis at hand. It is important to note, however, that the hydrographic surveys are intended for informational purposes only and should not serve as a navigational aid. This disclaimer underscores the dynamic nature of channel conditions and the need for caution in interpreting the surveys' accuracy.

Each survey job within the eHydro system is uniquely identified and comes with rich metadata, including a textual description of the data location, survey type, channel area identifier, and the source data location URL. These metadata are crucial for understanding the context and scope of the data, supporting effective integration and utilization within RIMORPHIS. The range of data provided in the surveys includes XYZ file formats that contain spatial coordinates (X, Y) and Z values (depth in feet), which are essential for constructing river cross-sections. Additionally, Shapefile (SHP) formats provide sounding points and contour lines with X, Y coordinates in the WGS84 spatial reference system and depth values, enabling detailed morphological analyses.

To efficiently incorporate eHydro survey data into RIMORPHIS, the workflow involves retrieving data via the API, processing it on the fly, and subsequently consuming it in a way that is compatible with the RIMORPHIS database. This process ensures that the data are accurately mapped to the RIMORPHIS data model, including matching eHydro surveys with NHD flowlines to place them correctly within the hierarchy. Individual users can also bring their own data into RIMORPHIS, allowing for flexible integration and analysis of diverse datasets.

2.3. System Architecture

The RIMORPHIS cyberinfrastructure is architectured to provide a robust, scalable, and user-friendly platform for accessing, visualizing, and analyzing river morphology data. The system architecture is designed to handle large-scale data and provide intuitive interactions for users. The architecture is divided into the platform's frontend and backend, alongside a dedicated API and an optimized database system, all running on an NGINX server (Figure 3).

Platform Frontend: The RIMORPHIS frontend is built using a React application framework, which supports a dynamic and responsive user interface. For geospatial data visualization, the platform employs Google Maps Vector version and Deck.GL for 3D visualization capabilities. This setup allows users to interact with various levels of data resolutions, from broad HUC4 areas down to detailed eHydro surveys, through an intuitive visual browsing experience. This experience is enhanced by several optimizations that ensure a seamless transition between different data resolutions and types as users zoom in and out on the vector map.

Platform Backend: The backend of RIMORPHIS is developed in NodeJS and incorporates a Python ecosystem for handling GIS operations, leveraging the strengths of both technologies for efficient data processing and management. Geospatial tools and functions are primarily based on Python but are executed through the NodeJS environment to ensure coherence and seamless integration with other backend processes. This backend setup also includes API access to the database and handling of parameters and checks for the cross-section tool, enabling complex river morphology analyses.

Web Services API: The RIMORPHIS API uses PostgREST to automatically generate an OpenAPI Specification. This specification, in turn, feeds into PostGUI, an open-source library that provides a graphical interface for intuitive database interactions (Purohit, 2020). Users can browse, filter, and download data in various formats through this interface. Rate limiting is implemented within the API to prevent excessive use and ensure system stability and availability for all users.

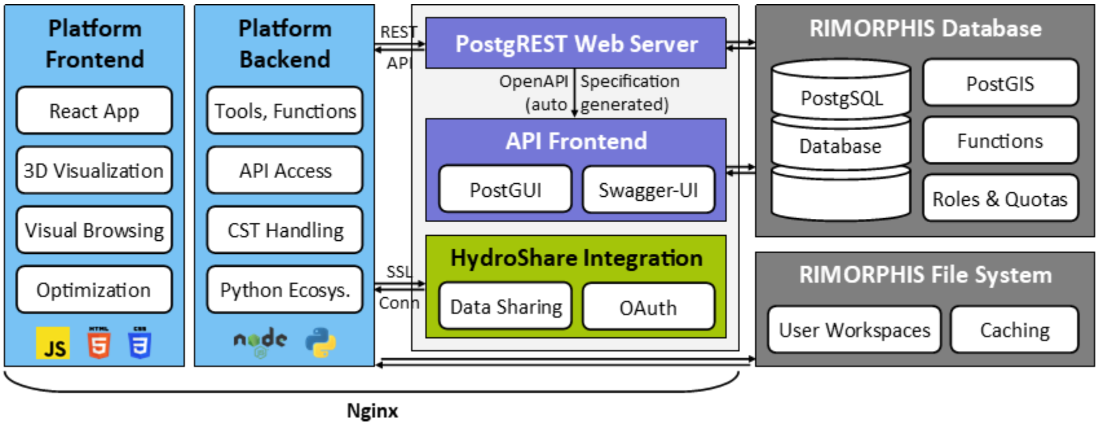


Figure 3: RIMORPHIS Cyberinfrastructure Architecture

Relational Database: At the core of RIMORPHIS is a PostgreSQL database with PostGIS enabled for geographical operations. The database is configured with multiple roles and quotas to support different levels of access from the web platform and the API. Additionally, several functions are defined at the database level to facilitate the retrieval of GeoJSON data within specified boundaries, enhancing the platform's data querying capabilities.

File System: The backend also manages a dedicated file system designed to create, manage, and clean user workspaces for data processing tasks. This workspace management system includes an auto-delete feature for efficient storage utilization. Furthermore, a caching mechanism is implemented for frequently accessed eHydro surveys, with the cache duration adjustable based on access frequency to optimize system performance and user experience.

2.4. Tools and Services

The RIMORPHIS cyberinfrastructure integrates a suite of advanced tools and services developed within a Python ecosystem to cater to the preferences and requirements of GIS professionals. This integration acknowledges the widespread use of Python in the GIS community, leveraging the extensive libraries and packages available for geospatial data processing and analysis. The tools and services are designed to enhance the platform's capabilities in generating, analyzing, and visualizing bathymetry data and river morphologies.

Bathymetry Cross-sections and Mesh Generation: A critical functionality within RIMORPHIS is the capability to generate bathymetry cross-sections and surface meshes from survey points (Liang et al., 2021). This function addresses the need for converting raw bathymetry data, often collected through single- or multi-beam surveys, into formats usable for either 1D or 2D scientific analysis. The Python-based implementation applies a curvilinear coordinate system (s, n) to account for the anisotropy in bathymetry of a river. This tool can automatically select “ideal” locations of cross-sections based on the density of survey points along the streamflow direction (s axis). Users also have the flexibility to specify cross-section locations manually. Following the identification, the cross-sections are linearly interpolated to create a bathymetry mesh (Merwade et al., 2008), facilitating comprehensive morphological analyses. This tool, detailed in previous research, exemplifies the integration of Python's geospatial capabilities within RIMORPHIS, making sophisticated analyses accessible to users through the platform's interface.

Deep Learning for River Geometry Estimation: Another innovative tool implemented in RIMORPHIS leverages deep learning (DL) techniques to estimate river geometry in data-sparse regions (Liang and Merwade, 2023). Utilizing Python's robust machine learning libraries, this tool is pre-trained on river reaches with available survey bathymetry data and can be deployed on river reaches that exhibit similar river characteristics but do not have river bathymetry data available. This approach allows for the continuous improvement and expansion of the model as more bathymetry data become available, reducing model uncertainty and enhancing the accuracy of river morphology predictions within the platform.

System for Producing River Network Geometry (SPRING): SPRING is an automated geospatial tool for improving 3D representations of river channels in regions lacking bathymetric data based on easily available data such as river centerline and a digital elevation model (DEM) (Dey et al., 2021, 2022). SPRING delineates the area of missing bathymetry in a DEM and replaces it with conceptual bathymetry based on user preferences. It is flexible in terms of the level of detail being incorporated in the bathymetry and can process entire river networks in a watershed with minimal user intervention making it appropriate for large-scale applications as well. Developed within the Python ecosystem, SPRING demonstrates the platform's capability to integrate sophisticated geospatial analyses, enhancing the morphological characterizations available to users.

Integration of Bathymetry with DEM: To support applications including riverbed surface and riverbanks, such as river hydraulic modeling for flooding simulation, RIMORPHIS includes functionality to integrate bathymetry mesh with DEMs. This integration is crucial for creating continuous “topo-bathy” DEMS encompassing both river bathymetry and surrounding floodplain topography. Utilizing Python's geospatial processing libraries, RIMORPHIS can access and clip DEMs, perform raster operations to merge bathymetry data, and complete partial bathymetric cross-sections with bank height data from DEMs. This tool exemplifies the seamless incorporation of external geospatial datasets into the RIMORPHIS framework, enabling comprehensive environmental modeling and analysis.

2.5. Data Sharing

The RIMORPHIS platform incorporates a comprehensive data sharing mechanism that facilitates seamless interaction between users and their datasets. Central to this mechanism is the integration with HydroShare, a collaborative environment for sharing hydrologic data and models (Tarboton et al., 2023). Through OAuth authentication, users can conveniently log into the RIMORPHIS platform using their HydroShare credentials. This integration not only simplifies the login process but also fosters a secure and efficient way to manage user identities and access permissions.

Upon choosing to log in via HydroShare, users are redirected to authorize RIMORPHIS to access their HydroShare profile. This authorization is a one-time process that ensures RIMORPHIS can interact with HydroShare on behalf of the user. After successfully logging in, users have the flexibility to customize various profile settings within RIMORPHIS. This customization includes setting preferences for data visualization, analysis tools, and notifications. Additionally, users can manage their data sharing settings, determining which datasets are private, shared with specific users, or made publicly available. Future users can search for and access data that the current user has shared. These customizable settings empower users to tailor the RIMORPHIS platform to their specific workflow and collaboration requirements.

3. Results

3.1. Data Web Service and API

The RIMORPHIS platform leverages a sophisticated API architecture to facilitate seamless interaction with its extensive river morphology data. This API, utilizing the capabilities of the PostGUI framework, offers an intuitive and flexible interface for querying, accessing, and manipulating data stored within the RIMORPHIS PostgreSQL database. The integration of PostGUI, a React web application designed for PostgreSQL databases, significantly enhances the user experience by adapting to the platform's database schema automatically and providing a visual query builder (Figure 4).

The RIMORPHIS API, through PostGUI, introduces a set of features that are pivotal for both GIS professionals and educational purposes. It supports data compatibility across various domains by automatically adapting to the client's database schema, making it a versatile tool for querying and sharing tabular datasets. Moreover, the API incorporates a high-performance data table for query results, capable of sorting columns by values and editing individual cell values, provided the edit feature is enabled. This capability is crucial for users looking to make real-time adjustments to the data directly from the interface. Additionally, users can download loaded data in formats such as CSV, JSON, and XML, enhancing the platform's utility for data sharing and analysis.

The RIMORPHIS API caters to a wide array of use cases, from incorporating data into existing cyberinfrastructures to enabling educational classroom tutorials. For GIS professionals, the API's integration with PostGUI offers a database-first approach that allows for the sharing of complex river morphology datasets in a user-friendly manner. This capability is especially beneficial for collaborative projects that require real-time data manipulation and sharing across teams.

In the educational domain, the API enables the creation of classroom tutorials that leverage real-world river morphology data. Educators can design interactive sessions where students use the visual query builder to explore datasets, understand river dynamics, and conduct analyses directly within the RIMORPHIS platform. This hands-on approach to learning, supported by the ability to download and manipulate data, provides students with valuable insights into GIS and river morphology.

3.2. Web Platform Features

The RIMORPHIS web platform is designed as a comprehensive tool for river morphology research, offering capabilities across data discovery, geospatial visualization, and data analytics.

Utilizing advanced web technologies and GIS principles, the platform facilitates an intuitive environment for users to explore, analyze, and visualize river morphology data.

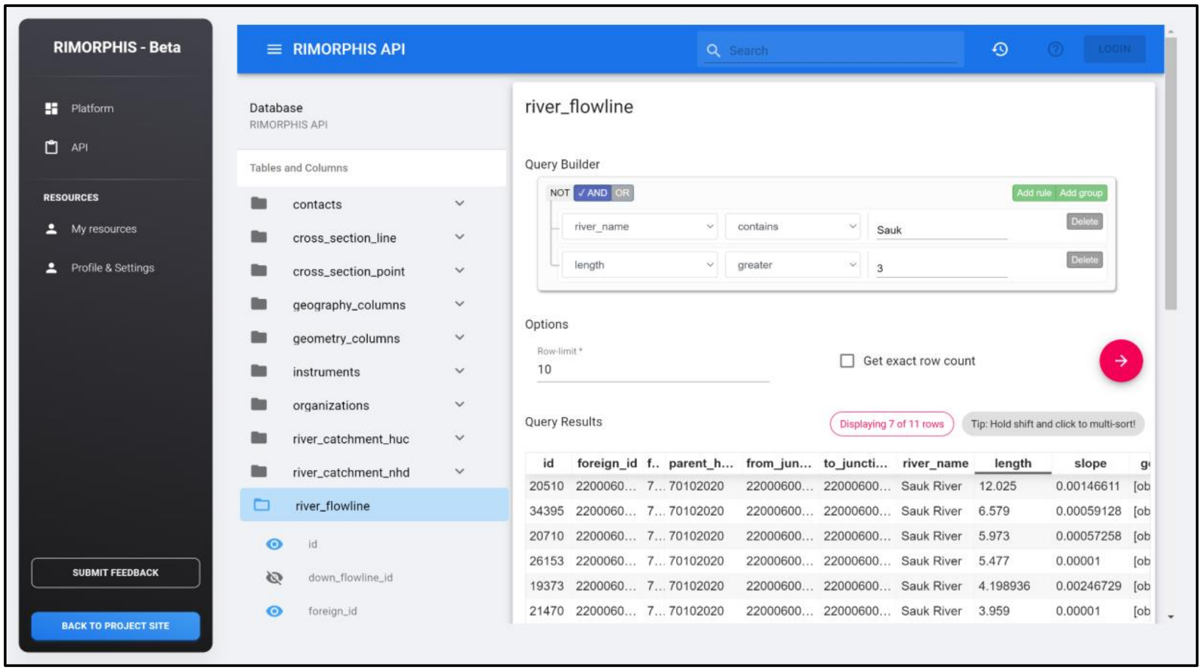


Figure 4: RIMORPHIS API Dashboard and User Interface

Data Discovery: At the heart of the platform is the data discovery feature, which empowers users to intuitively discover available data through visual browsing. The interface is engineered to dynamically populate available data resources based on the geographic context set by the user's viewport. This is accomplished by implementing different zoom levels that reveal data granularity from broad HUC to more detailed NHD catchments and flowlines, down to specific eHydro surveys (Figure 5). This approach ensures that users can efficiently navigate through vast datasets to find the information most relevant to their research needs.

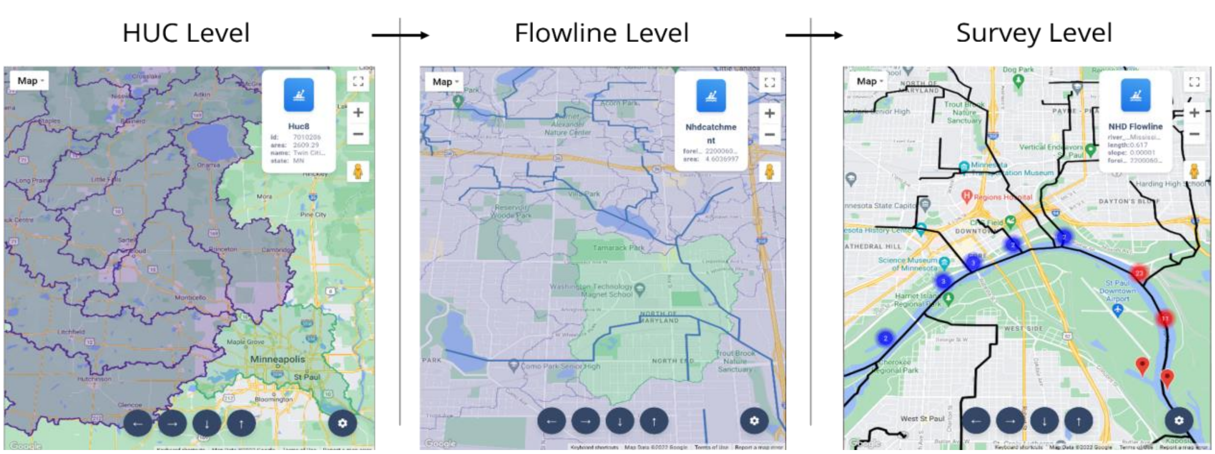
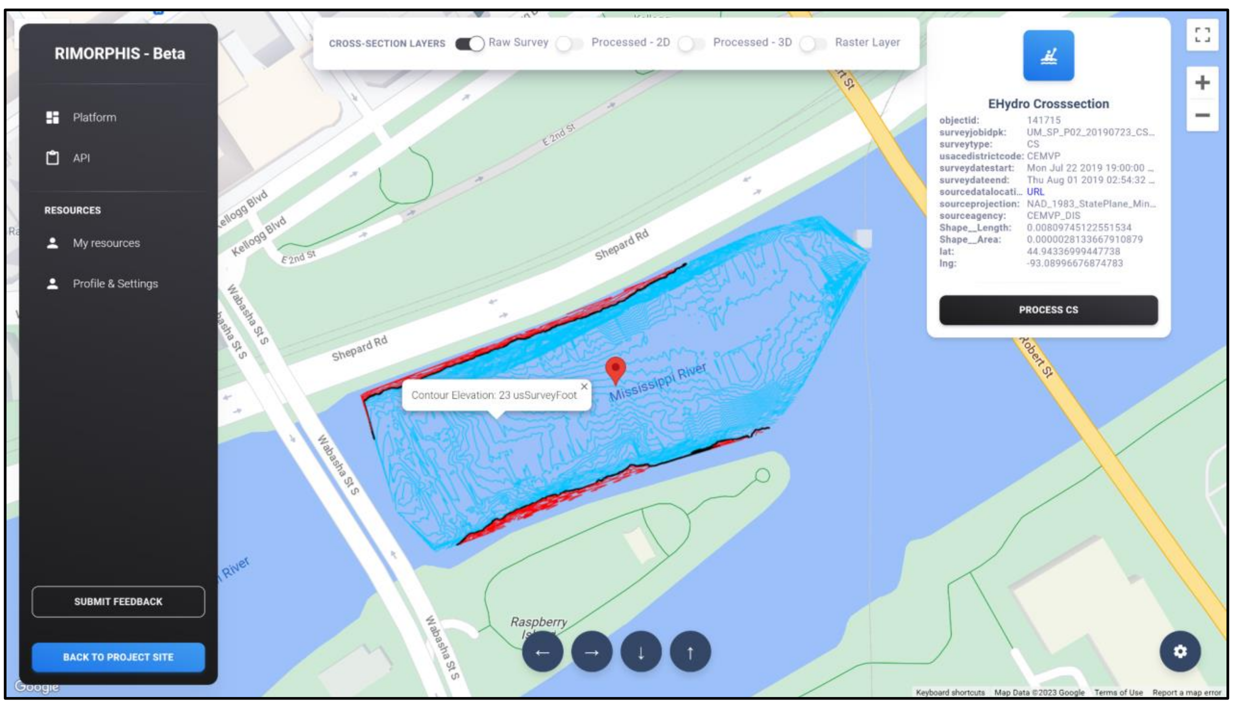


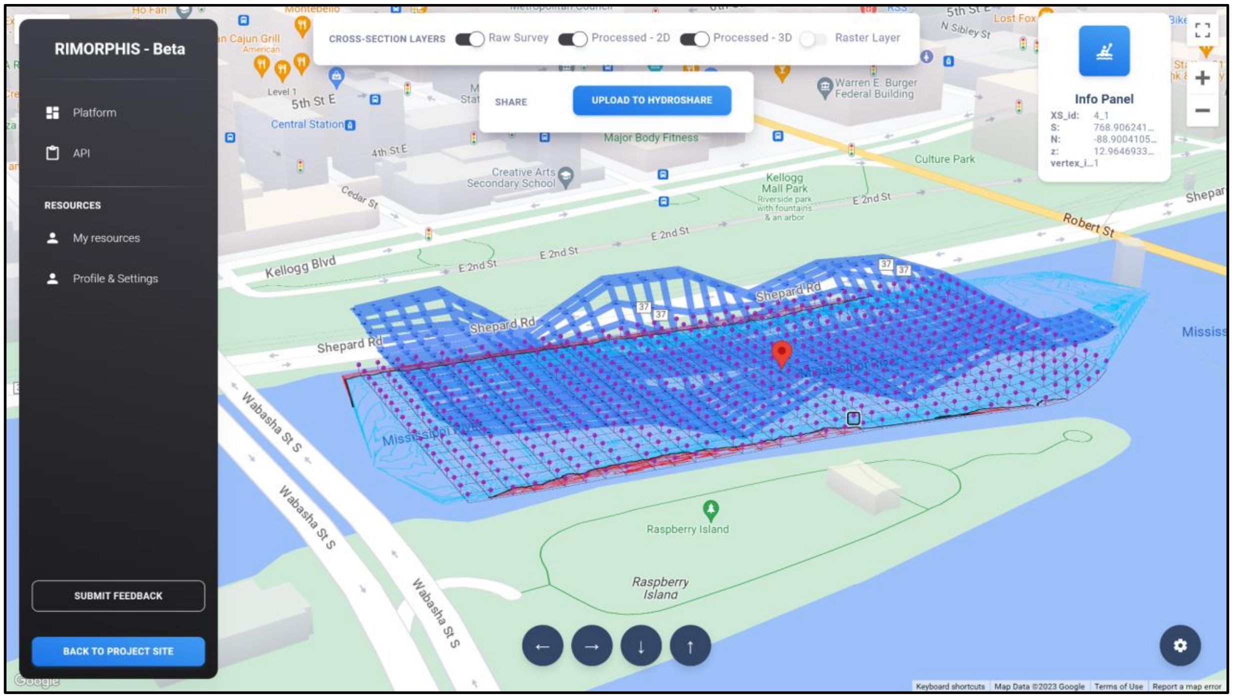
Figure 5: RIMORPHIS Interface and Map-Based Visual Browsing

Geospatial Visualization: The platform's geospatial visualization capabilities are robust, supporting both 2D and 3D models to effectively convey bathymetry data for selected river reaches on the fly. In 2D visualization, users can interact with KMZs, markers, and ground overlays for raster data, with a caching mechanism in place for cross-sections previously retrieved from eHydro, enhancing performance and user experience (Figure 6a). The 3D visualization extends the platform's capability further by offering 3D maps, buildings, mesh models, and interactive, rotatable views, with rendering processed client-side using technologies like deck.gl (Figure 6b). This dual visualization mode ensures that users can choose the most effective model for their analysis, offering both broad overviews and detailed examinations of river morphology.

Data Analytics: A cornerstone of the platform is its Data Analytics feature, particularly the Cross-Section Processing Tool (CST), designed to automatically process and visualize raw surveys. The CST can handle data from external sources like eHydro in real-time, as well as data manually uploaded by the user in the form of shapefiles. This tool supports customization across several parameters, including geometry conversion, input and output types, and download formats, ensuring flexibility and precision in data analysis (Figure 7a). For example, users can convert point data into mesh models, specifying the number of bins, vertices for each cross-section, and minimum and maximum spacing for interpolated cross-sections (Figure 7b).



(a)



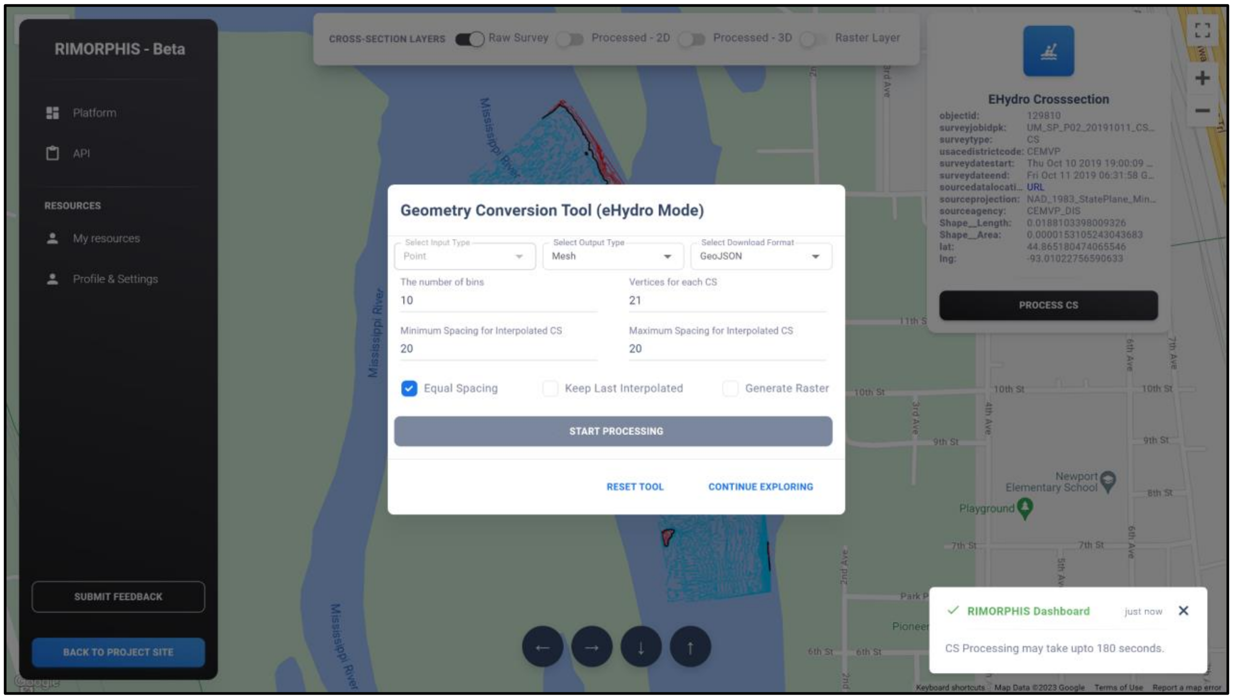
(b)

Figure 6: Geospatial Visualization Interfaces, a) 2D Mode, b) 3D Mode

Furthermore, the CST offers an option to generate raster data, activating the tool for integrating bathymetry with DEM. This feature merges local DEM with the results from the CST, returning the output as GeoTIFF and JPEG for convenient visualization on the map, along with relevant metadata (Figure 7c). This capability exemplifies the platform's commitment to providing comprehensive tools for river morphology research, enabling users to derive meaningful insights from complex geospatial data.

Data Sharing and Collaboration: A key feature of the platform is its ability to seamlessly integrate with HydroShare for data import and export (Figure 8a). Users can bring their private data repositories from HydroShare into RIMORPHIS for analysis and visualization. This feature is particularly valuable for users who have amassed extensive datasets within HydroShare and wish to leverage the analytical capabilities of RIMORPHIS. Conversely, users can also upload products and datasets generated within RIMORPHIS back to HydroShare, thereby sharing their work with the broader hydrologic community (Figure 8c). This bidirectional data flow enhances collaboration and knowledge sharing among researchers, educators, and practitioners.

The platform also accommodates users who prefer not to sign in through HydroShare or those seeking to explore the platform's capabilities before committing to an account. These anonymous users can browse publicly available data repositories on HydroShare that are compatible with RIMORPHIS and import them as needed (Figure 8b). This feature ensures that RIMORPHIS remains accessible to a wider audience, including educators looking to demonstrate river morphology concepts without requiring students to create accounts immediately and researchers seeking to explore the platform's potential for their projects.


RIMORPHIS - Beta
Platform
API
RESOURCES
My resources
Profile & Settings
SUBMIT FEEDBACK
BACK TO PROJECT SITE
CROSS-SECTION LAYERS
Raw Survey
Processed - 2D
Processed - 3D
Raster Layer
Geometry Conversion Tool (eHydro Mode)
Select Input Type
Point
Select Output Type
Mesh
Select Download Format
GeoJSON
The number of bins
10
Vertices for each CS
21
Minimum Spacing for Interpolated CS
20
Maximum Spacing for Interpolated CS
20
Equal Spacing
Keep Last Interpolated
Generate Raster
START PROCESSING
RESET TOOL
CONTINUE EXPLORING
EHydro Crosssection
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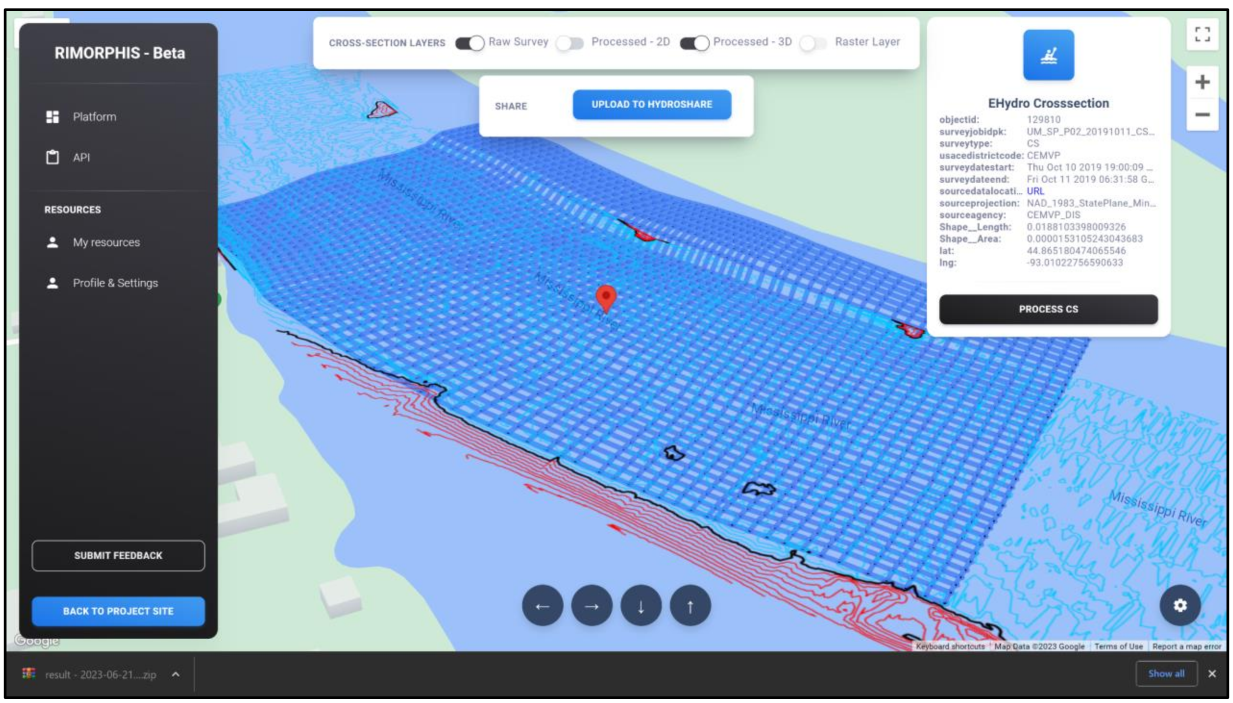
PROCESS CS
RIMORPHIS Dashboard
just now
CS Processing may take upto 180 seconds.
Mississippi River
Newport Elementary School
Playground

(a)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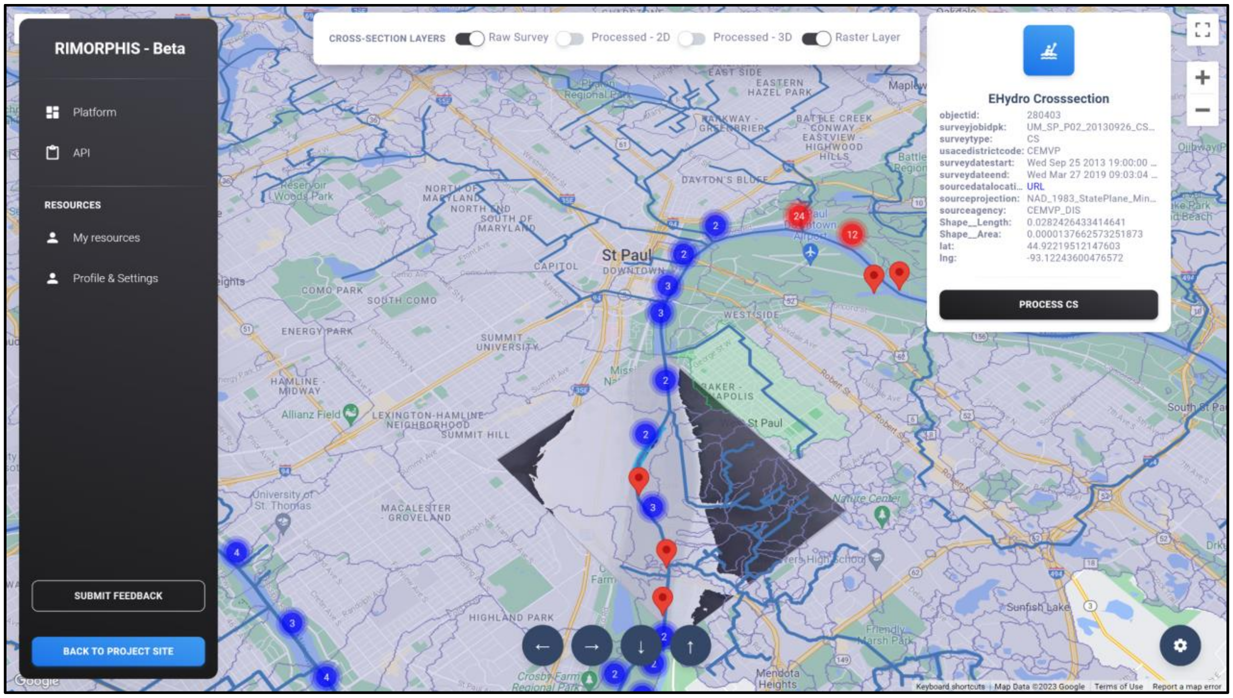
Raw Survey
Processed - 2D
Processed - 3D
Raster Layer
SHARE
UPLOAD TO HYDROSHARE
EHydro Crosssection
objectid:
129810
surveyjobidpk:
UM_SP_P02_20191011_CS...
surveytype:
CS
usacedistrictcode:
CEMVP
surveydatestart:
Thu Oct 10 2019 19:00:09 ...
surveydateend:
Fri Oct 11 2019 06:31:58 G...
sourcedatalocati...
URL
sourceprojection:
NAD_1983_StatePlane_Min...
sourceagency:
CEMVP_DIS
Shape__Length:
0.0188103398009326
Shape__Area:
0.0000153105243043683
lat:
44.865180474065546
lng:
-93.01022756590633
PROCESS CS
Mississippi River
result - 2023-06-21....zip
Show all

(b)



(c)

Figure 7: CST for Automated Processing of Reach Surveys. (a) Automated Processing Options, (b) 3D Result, (c) DEM Integration

HydroShare acts as an intuitive and GIS-compatible data sharing platform for RIMORPHIS users, facilitating the export and import of data. This integration is designed with the geospatial community in mind, ensuring that datasets retain their spatial context and metadata when transferred between the platforms. By leveraging HydroShare's robust data management and sharing capabilities, RIMORPHIS users can effectively collaborate on projects, share insights, and contribute to the collective understanding of river morphology and hydrology.

3.3. Stakeholder Evaluation

The third annual RIMORPHIS Stakeholder Workshop, held in Boulder, Colorado on June 22, 2023, provided a pivotal platform for engaging with the river morphology community. This hybrid event aimed to share updates on the development of the RIMORPHIS platform and gather valuable feedback from attendees on its current functionalities and future directions. The workshop facilitated rich discussions on various aspects of the platform, from data management and tool functionalities to design and usability, leading to insightful suggestions for enhancing the RIMORPHIS experience (Cox et al., 2023).

Data Model, Referencing, Integration, and External Services: Participants expressed interest in seeing RIMORPHIS incorporate additional datasets and data sources, such as vertical datum tools for conversion and support for GeoJSON and GPKG formats. The addition of a consistent RIMORPHIS-selected reference datum was suggested to complement the existing 2D river reference system, which would standardize data interpretation and improve accuracy. Furthermore, incorporating batch processing capabilities and the ability to merge data from various locations and time points would streamline workflows and allow users to handle diverse and complex data types more efficiently.

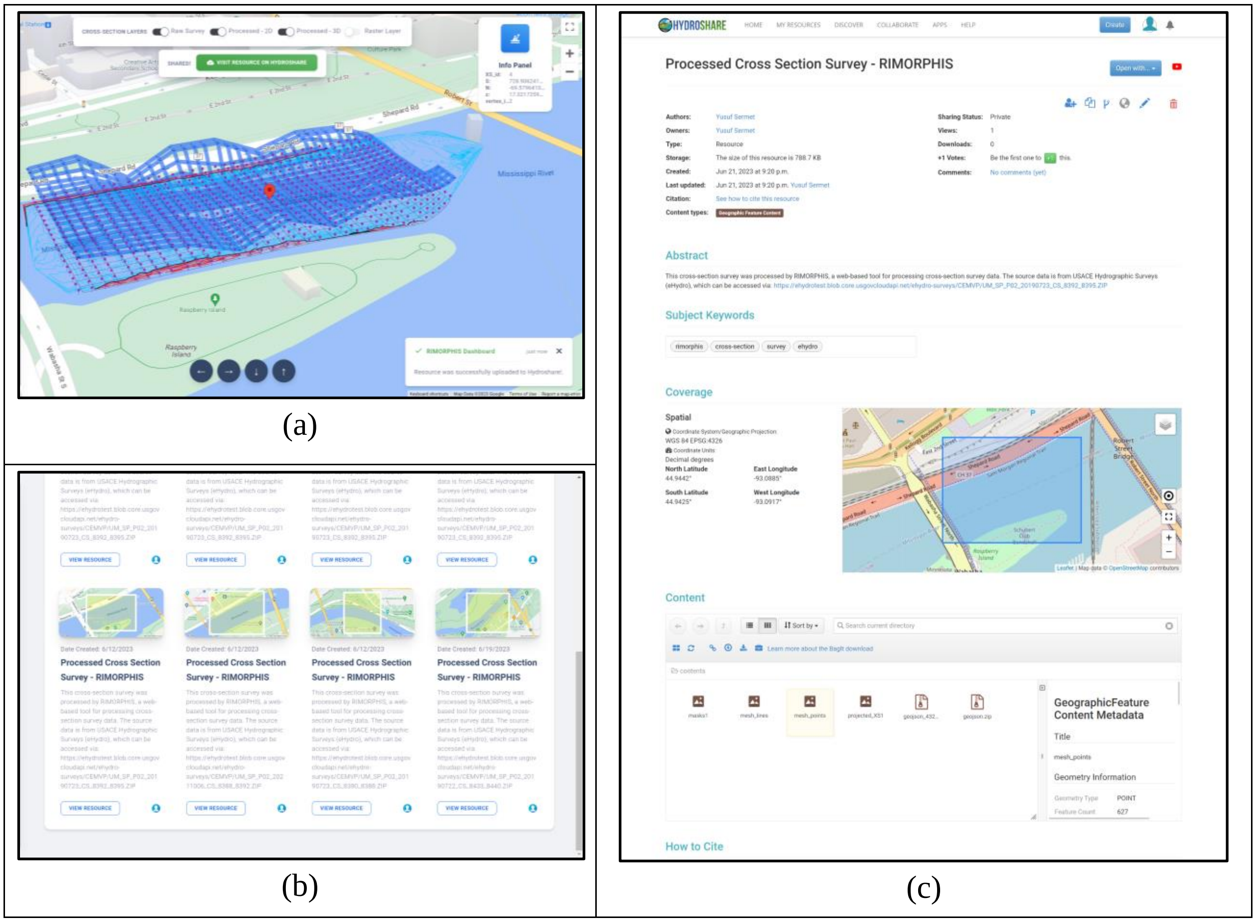


Figure 8: Data Sharing Features. a) Data Upload Process, b) Compatible Data Browsing, c) Uploaded Data

Tools, Functionality, and Capabilities: Feedback on tools and functionalities centered around the desire for vertical datum conversion tools, historical bathymetry conversion tools, and the ability to merge multiple surveys into a single dataset. Introducing these tools would enable users to work with a broader range of data types and historical data, enhancing their ability to conduct comprehensive analyses. Participants also suggested improvements for fusing different datasets to develop composite surface datasets, which would provide a more complete and accurate representation of river morphology. The addition of a 'most-recent bathymetry' feature would allow users to quickly access the latest available data, ensuring their analyses are based on up-to-date information. The potential for incorporating advanced analytics capabilities, such as machine learning or AI, to interpolate between multiple datasets was discussed enthusiastically, as these technologies could significantly improve the accuracy and depth of river morphology research.

Feedback on Interface and Usability: Participants encountered some processing errors and recommended clearer documentation and tutorials to support new users. Implementing comprehensive documentation and step-by-step tutorials would lower the barrier to entry for new users, making the platform more accessible. Suggestions to improve the interface's intuitiveness included making units more apparent in the geometry conversion tool and providing clearer initial steps for uploading data. These changes would reduce user error and enhance the overall user experience. Labeling steps sequentially was also proposed to make the platform more user-friendly, which would guide users through complex processes more effectively.

Collaboration and Data Sharing: The discussions underscored the importance of robust documentation for the original data sources and the steps used to merge or sub-sample datasets. Implementing such documentation would enhance data transparency and reliability, making it easier for users to understand the origins and transformations of their data. An automated log of steps used to generate final datasets was suggested to better support collaboration among researchers and organizations. This feature would facilitate joint analyses and communication by providing clear records of data provenance and processing, ensuring that all collaborators have a consistent understanding of the data.

Design, Usability, and Future Development: Challenges in sorting through different datasets and visualizing overlapping datasets by recency or elevation were highlighted. Developing tools to address these challenges would simplify data management and allow users to more easily observe and analyze channel changes over time. Participants expressed a need for such tools, which would enhance the platform's usability and analytical capabilities. The discussion also touched upon the potential for RIMORPHIS to support community science initiatives by encouraging crowd-sourced depth of flow data to enrich the platform's dataset. This would broaden the scope of data available for analysis.

4. Conclusions

The RIMORPHIS platform represents a significant advancement in the field of river morphology research. By providing an open-access web platform equipped with ancillary tools, RIMORPHIS aims to support scientific discovery related to river morphology progression and foster integrated multidisciplinary research on riverine environments. The platform's development has been guided by the vision of creating a self-sustained community platform that not only facilitates access to extensive datasets and sophisticated analytical tools but also promotes collaboration among researchers, educators, and practitioners.

Through the years, RIMORPHIS has evolved, incorporating feedback from the community to enhance its data model, referencing system, tools, functionality, and overall user experience. The platform's integration with HydroShare for seamless data import and export has been a key feature, enabling users to leverage their existing datasets for further analysis and visualization within RIMORPHIS, as well as to share their work with a broader audience. The platform's capabilities in geospatial visualization, data analytics, and collaboration have positioned it as a valuable resource for advancing river morphology studies.

In the endeavor to further enhance the RIMORPHIS platform, future developments will concentrate on broadening the spectrum of data sources and formats accessible to users. This expansion aims to encompass a wider array of research needs and methodologies within the river morphology community. Emphasis will be placed on integrating tools that facilitate the conversion of vertical datums and allow for the seamless merging of datasets from varied origins. Such advancements are expected to significantly augment the platform's versatility and applicability across diverse research scenarios.

Parallel to expanding data compatibility, the enhancement of tools and functionalities stands as a pivotal aspect of future work. The introduction of innovative tools for converting historical bathymetry data and creating composite datasets from multiple surveys will address specific community needs. Additionally, the exploration of advanced analytics, leveraging machine learning or AI (Pursnani et al., 2023), promises to unlock new potentials in river morphology research, enabling users to tackle more complex questions with greater precision and insight (Ramirez et al., 2024b).

Improvements in the platform's interface and usability will be pursued with the goal of fostering a more intuitive and efficient user experience. By refining the user interface and developing comprehensive documentation and tutorials, the project aims to lower the barrier to entry for new users and enhance the overall usability of the platform (Shahid et al., 2023). Strengthening feedback mechanisms will further ensure that user issues and suggestions are promptly addressed, driving continuous improvement in platform design and functionality.

The promotion of collaboration and data sharing remains a cornerstone of the RIMORPHIS initiative. Future efforts will be directed towards ensuring transparent documentation of data sources and processing steps, thereby facilitating collaborative research efforts and joint analyses. Moreover, the platform will seek to support community science initiatives, encouraging the contribution of crowd-sourced data, which will enrich the platform's datasets and broaden its application scope.

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