

HeatMap CU:

A Dashboard for Analyzing Champaign-Urbana's Urban Heat Islands

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EXECUTIVE SUMMARY

Extreme temperatures contribute to the Urban Heat Island (UHI) effect, in which urban areas experience much higher temperatures than surrounding areas due to the prevalence of asphalt, concrete, large buildings, and a lack of greenery and airflow. As global temperatures rise, urban areas will continue to experience the worsening effects of the phenomenon. This design proposal's solution concerns the cities of Champaign and Urbana, Illinois, where no system to analyze UHI impacts is currently in place among the area's city planning, public health, or environmental management groups. In the proposed system, infrared sensors will feed data into a spatial decision-support system for highlighting areas in need of heat mitigation. Residents and urban planning professionals alike will access data and contribute their own observations (e.g., air and surface temperatures, observed weather conditions, and public cooling locations). In long-term management, maintenance can be tracked using the GIS field app QField to document the development and upkeep of rooftop gardens, reflective roofing, newly planted trees, and other UHI mitigation measures. The proposed solution is the HeatMap CU Dashboard: a geographic information system (GIS) for monitoring the UHI effect. This platform will bridge the gap between data and action by implementing a system for temperature reporting and plotting mitigation efforts in an interactive, accessible dashboard that will provide public planning professionals and the community as a whole with actionable insights to mitigate the UHI effect in Champaign-Urbana.

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NEEDS ASSESSMENT & USER ANALYSIS

Background & Problem Definition

Excessive heat poses a significant public health challenge, disproportionately affecting urban areas. During the summer months, extreme temperatures contribute to heat-related illnesses and exacerbate existing issues for populations without access to shade or other adequate cooling resources (Gabbe et al. 2023, 8; Harris and Albrecht 2024, 634-637). These dangerous heatwaves contribute to the Urban Heat Island (UHI) effect. This is the phenomenon in which urban areas experience much higher temperatures than surrounding rural areas, leading to “consequences for the health and well-being of people living in cities”, with some neighborhoods experiencing worse effects than others (Mohajerani et al. 2017, 522; Gronlund et al. 2018, 56). The UHI effect is more pronounced in urban than in rural areas due to extensive urban development. Paved surfaces and large buildings are the main contributors to this effect. UHI is a danger to urban residents in that it has “significant consequences for the liveability in our cities”, including increases in energy demand and pollution, “thermal stress” on the public, negative impacts on both our human living environment as well as broader urban ecosystems, and a dangerously “increased level and risk of morbidity or illness due to heat” (Mohajerani et al. 2017, 524). However, there is hope for mitigating the UHI effect. Standard mitigation measures include reflective roofs, green spaces, increased air flow, water bodies, and “cool pavements,” which absorb less thermal energy than traditional pavement materials (Mohajerani et al. 2017, 528).

Currently, there is no system in Champaign-Urbana, Illinois, to track the Urban Heat Island effect or monitor the outcomes of mitigation efforts. Geospatial solutions have proven their merit in tracking and mitigating UHI effects worldwide. The City of Philadelphia, the

Republic of Singapore, and Helsinki, Finland, for example, have each conducted geospatial analyses and leveraged geographic information systems to monitor and mitigate this issue (Smargiassi et al., 2009; Tan et al., 2022; Vaz et al., 2020). Currently, Champaign-Urbana lacks a system to identify areas most affected by UHI effects to gauge necessary mitigation efforts.

The proposed solution, a GISystem for monitoring the Urban Heat Island effect, would provide a starting place for city planners, GIS professionals, and the public to mitigate these adverse effects in the Champaign-Urbana area. This system would identify the hardest-hit areas and most at-risk neighborhoods during extreme heat events. There exists a schism between GIS data collection and actionable policy at the municipal level. This platform would bridge the gap between data and action by implementing a system for aerial imagery collection, temperature reporting, and plotting mitigation efforts in an interactive mapping environment that even the average, non-GIS-oriented citizen can use.

The primary objectives of the Urban Heat Island effect monitoring and mitigation GISystem dashboard are to provide both public planning professionals and the Champaign-Urbana community as a whole with actionable insights toward UHI effect mitigation. A secondary objective is to promote public engagement in the community through open-access data visualization and dashboard tools that uncover UHI effects in their own neighborhoods and provide a starting point for heat mitigation efforts.

The GISystem will analyze satellite imagery, land cover, and infrared sensor data, feeding the results into a spatial decision-support system to highlight areas most in need of heat mitigation. An interactive map will be integrated into a real-time dashboard to simplify viewing statistics alongside the map. A survey form will be integrated into the dashboard to facilitate public submissions of new data and attract public interest, promoting transparency during the

monitoring and mitigation endeavor. More specific functionality will include GPS-enabled field data capture, the use of surface thermometers and anemometers, and mobile app comment and photo submissions from field technicians and concerned citizens alike. By introducing a GIS dashboard to monitor UHI-effect area identification and mitigation efforts, city planners, GIS professionals, and Champaign-Urbana residents will be able to work together in an interactive environment that promotes communication, data sharing, and civic responsibility within their community.

User Analysis

This GISystem design proposal employs the “scenario-based design” method, popular for its user-centered approach in designing an experience through an iterative process. This method involves creating “user interaction scenarios” through personas (Rosson and Carroll 2002). Three personas are presented as broad characterizations of the most common potential users of this GISystem. These personas ground the GISystem in the real-world objectives and context of the intended users, highlighting their distinct needs and meeting them with an intuitive design.

City Planner – “Bonnie”

Bonnie works for the City of Champaign’s Department of Planning and Development as an Urban Planner. Her role involves engaging with community organizations and local agencies to design and implement urban development projects that will improve the community. Within her department, she specializes in climate resilience. Bonnie’s initiative to paint the roofs of city-owned buildings with an anti-thermal, reflective coating was recently implemented by her department. With the success of this program, she now wants to implement a larger program to reduce heat stress in her city. However, thermal data and quality aerial imagery are hard to come

by. The current system for hearing residents' heat-stress issues is to collect anecdotes at community meetings. With the proposed GISystem dashboard, Bonnie could access an organized array of relevant data collected from across the city. With this system, the city would no longer have to rely on anecdotal evidence for deciding where to direct heat mitigation initiatives. Not only would this system provide more accurate data, but users could access new data in real-time as the database is updated, allowing Bonnie and the city to plan a more effective strategy for climate resilience.

Geospatial Expert – “Dr. Connie”

Dr. Connie is an environmental data scientist at the University of Illinois. Her area of expertise lies in climate-conscious development and urban sustainability. She often relies on her PhD students to collect local data for various climate resilience studies and projects in the city. However, she usually uses thermal data from the USGS and satellite datasets from Sentinel Hub, since local organizations do not collect any data. These static datasets make Dr. Connie's workflow long and tedious, requiring data cleanup to extract only her area of interest. With the proposed GISystem dashboard, Dr. Connie's workflow would be cut to a fraction of the time it currently takes her. Additionally, she would no longer have to worry about converting national datasets to the local coordinate system. For many purposes, she would no longer need to download and analyze data on her computer's software, since the data and tools would be available in the dashboard. Furthermore, Dr. Connie would prefer more accurate, real-time data rather than waiting for new national datasets to be released.

Stand-Up Citizen – “Lonnie”

Lonnie is a lifelong resident of Champaign and has been a bus driver for the past fifteen years. He makes efforts to reduce his carbon footprint by biking to and from work daily, and enjoys connecting with his community during work. Lonnie has noticed that the heat in downtown Champaign seems more intense than in his shaded neighborhood. He has frequently wished for more shade in the hotter areas of downtown Champaign during the summer, and wonders about the heating effects of the large asphalt and concrete parking areas he sees daily. He is unsure if city planners are concerned about these issues, and feels disconnected from local decision-makers. The proposed GISystem would give Lonnie an outlet for voicing his concerns about urban heat hotspots in the downtown area, as well as an ability to submit photos and locations of potential sites for new green spaces. The platform would bridge the gap between decision-makers and the public, offering more transparency and opportunities for civic engagement.

All in all, these personas highlight the need for an integrated, interactive, and engaging GISystem—an accessible dashboard for monitoring the Urban Heat Island effects and mitigation efforts in Champaign-Urbana. Decision makers, geospatial experts, and community members alike would be able to contribute their unique perspectives and expertise in improving their community—a mutually beneficial outcome for all.

Needs Assessment

Meeting the distinct needs of each stakeholder is paramount to the GISystem's success and adoption, as even technically robust applications can fail to meet user needs if feedback is not provided throughout the design process (Wells et al. 2023, 2-8). A needs assessment questionnaire will be used to gauge the technical skills and the established persona groups' comfort levels with using geographic information systems (GIS) applications. Questions will include awareness of the UHI effect, confidence in data literacy, willingness to participate in community-driven aspects of the GISystem, and an open-ended question on additional functionality. The answer formats for these questions will include yes/no, Likert scale, and open-ended responses. These methods will identify any potential schisms between the persona user and the application to be revised before the next round of testing.

Semi-structured one-on-one interviews will follow the assessment questionnaire. These interviews will capture the human motivations, attitudes, and challenges that are not apparent through a simple questionnaire. Following the interviews will be a participatory design session in which stakeholders will give their feedback on alternative designs (Rosson and Carroll 2002, 18). This session will help uncover any essential system features that have yet to be discussed and will build stakeholders' trust in the design process and final product.

The survey questions in Table 1 are inspired by and designed with Getto and Moore's methods for usability testing in mind (Getto and Moore 2017).

Table 1. Survey Questions.

Question	Answer Type
1. Have you ever interacted with a geographic information systems (GIS) mapping application?	Yes / No
2. Do you have prior knowledge of the Urban Heat Island (UHI) effect?	Yes / No
3. Do you consider yourself comfortable with new technology?	Yes / No
4. Have you ever used a mobile device for field data collection (e.g., via Survey123)?	Yes / No
5. I am confident using complex interactive maps.	Likert scale 1 - 5
6. I prefer maps with high-contrast color schemes.	Likert scale 1 - 5
7. The ability to filter map data by location, date, or data type is important to me.	Likert scale 1 - 5
8. It would be helpful to receive alerts when new data is submitted for approval or added to the map.	Likert scale 1 - 5
9. I would be willing to contribute data (e.g., photos, facility ratings, temperature readings) to a GISystem.	Likert scale 1 - 5
10. Please describe any functionality you would find helpful in an urban heat-tracking GIS system.	Open-ended answer

CONCEPTS CONSIDERED

The Concepts Considered

HeatMap CU (Champaign-Urbana) is an integrated GIS system that combines mobile data collection with online mapping and dashboard applications. Mobile functionality is paramount to the success of HeatMap CU, as field technicians and community members alike will be able to submit data through a volunteered geographic information (VGI)-enabled system. This data gathering and submission via the mobile application is the first step in the HeatMap CU workflow, a cardinal component of the entire system. This data will then be uploaded to a web server that hosts the GISystem's database. Backend users will quality-check field data submissions and maintain quality control over the data layers and the integrity of the publicly available dashboard.

The main objectives of this GISystem are described in three parts, in no particular order of importance. The first objective is to provide a high-quality public-facing dashboard and accompanying mobile application that allows community members to submit data and view UHI effect zones. The second objective is to build this system with a robust analytical backend, enabling expert backend users to manage, visualize, and upload temperature and surface data, and to tweak the visualizations to include additional data as needed. The third objective is to provide a dashboard that is useful not only for the public but also for external analytical experts and interested policy-makers, such as by including widgets that visualize descriptive statistics for urban planning and decision-making.

Candidates considered for the GISystem were chosen for their distinct differences, allowing an objective assessment of their strengths, weaknesses, and unique features. The three candidates scrutinized for such a system are ArcGIS Online, an integration of Leaflet and

CARTO, and the QGIS web suite with PostGIS. Technical documentation, journal articles, and whitepapers on ArcGIS Online, CARTO, Leaflet, PostGIS, QGIS, Lizmap, and QField informed these concepts, shown in Table 2 (3Liz 2025; CARTO 2025; Esri 2025a; Graser, Sutton, and Bernasocchi 2025; OPENGIS.ch 2023; Steiniger 2012).

Table 2. Comparative Evaluation of System Features.

System	Environment(s)	Strengths	Weaknesses
ArcGIS Online	Web (cloud) / Mobile	Easy deployment & integration / Offline capability	Costly, with different pricing tiers
Leaflet & CARTO	Web	Simple UI / Intuitive functionality	Limited backend
QGIS Web Suite & PostGIS	Web (cloud) / Desktop / Mobile	Offline capability / Open source	Involved setup / Learning curve

ArcGIS Online

Today, the Environmental Systems Research Institute, Inc. (ESRI) is ubiquitous with geographic information systems (GIS). Esri is known worldwide for its robust, capable software and online geospatial suite, including ArcGIS Online and Survey123, a form creation and collection application available on desktop and mobile devices. ArcGIS Dashboards, another extension of the ArcGIS Online suite, provides a platform for the HeatMap CU dashboard, with seamless integration with Esri's extensive suite of products and services. A custom Survey123 form will serve as the field data collection method for community members. At the same time, IR thermometer readings will be processed through ArcGIS Velocity, a tool that handles Internet of Things (IoT) sensor data (Esri 2025b; Esri 2025c). This data will be updated in the ArcGIS Online feature layer and thus synced with the ArcGIS Dashboard in real time. The main

strengths of Esri's ArcGIS Online suite are its easy integration and deployment, as well as its offline capability. Esri's platforms are lauded for their relative ease of use when compared with code-heavy alternatives, but pricing can be a barrier for many (Esri 2025a). Esri's pricing and licensing systems can be complex and expensive, with some features locked behind more costly tiers.

Leaflet & CARTO

The second candidate is a fusion of Leaflet and CARTO—two of the most well-known and robust mapping solutions available. Leaflet is an open-source JavaScript library that boasts high customizability (Steiniger 2012). The CARTO Platform provides cloud data storage and management, data processing, and spatial analytics. It offers a collaborative environment for geospatial experts and analysts. Base layers (satellite data, basemaps) can be imported into CARTO alongside field data submissions and processed with the SQL API. However, CARTO does not offer any accompanying field collection mobile applications. A custom mobile app using SQL API would allow data to be submitted from personal devices to the CARTO cloud. The CARTO backend is limited compared to the extensive capabilities of ArcGIS Online and similar Esri platforms, but implementing a Leaflet and CARTO solution is much cheaper (CARTO 2025a; CARTO 2025b). Like ArcGIS Online, licensing and pricing tiers can be confusing, with some features available only in higher-priced tiers.

QGIS Web Suite

The third candidate, QGIS Web Suite with a PostGIS backend, provides an entirely FOSS ecosystem. For backend database needs such as concurrent access, real-time updates, and remote access, PostGIS offers an excellent solution. With PostGIS integration, stationary IR thermometers will be able to send readings, stakeholders will be able to access data concurrently, and mobile users will be able to submit field data through QField, pushing updates to PostGIS (OPENGIS.ch 2023). Automated processing would be handled by the PostGIS database, with scheduled jobs running hourly to update it (Steiniger 2012). The Lizmap Web Client, a tool for publishing QGIS maps as web maps, will be leveraged to publish and update a dashboard with an interactive map, community reports, and statistics tables and charts (3Liz 2025; Graser, Sutton, and Bernasocchi 2025).

The Concept Selection

After considering each candidate, along with cost, backend operability, and multi-platform integration, the hybrid system of QGIS Web Suite with PostGIS has been selected as the implementation concept. This decision was made due to HeatMap CU's need for a near-real-time data pipeline, a mobile data-collection method, and an interactive, online dashboard available to all stakeholders. Additionally, integrating QGIS, QField, and Lizmap provides a robust, feature-rich open-source solution with offline capabilities and extensive customization, leaving room for the system to evolve as needed (3Liz 2025). Although the moderately involved setup of this FOSS system is a drawback, its strengths vastly outweigh this weakness. While ArcGIS Online and CARTO offer comparable services and customer support, the pricing models, which dictate feature availability, are far too limiting for a city-level project.

IoT sensors, such as IR thermometer sensors, will transmit data in JSON packets from their stationary locations. In contrast, data gathered with QField will be collected both online and offline (QField users will push the data when they finish collecting). This data will then sync back to the central PostGIS database. The database will house tables including, but not limited to, the sensor data, community-volunteered QField data, location metadata, and aerial imagery. This data will support spatial queries such as mean surface temperature and heat clusters. Layers will be configured in QGIS and published to the web as a dashboard using the Lizmap Web Client, which will display an interactive map, summary, and descriptive statistics charts and tables, allow spatial analysis, and enable the user to download data.

The offerings of the QGIS Web Suite and PostGIS best align with the HeatMap CU implementation's goals and financial constraints. With complete control over feature integration, data pipelines, and scalability to meet future needs, this concept is the best option for community volunteers, geospatial experts, and city planners alike. With this concept's implementation, HeatMap CU will bridge the gap between data and action by leveraging a robust analytical backend to foster public engagement and drive positive environmental changes through a high-quality dashboard and mobile application designed for community members, geospatial experts, and policy-makers alike.

WIREFRAME DESIGN & COGNITIVE WALKTHROUGH

Purpose

The wireframe design is tailored to its target users: city planners, geospatial experts, and community members alike. City planners will be able to use the dashboard for quick access to data when making decisions regarding the city's urban heat island (UHI) issues. Geospatial experts will appreciate the ease of access to the data and the ability to download individual layers and tables for analysis. Community members will be able to navigate a simple interface with an optional guided tutorial and submit data directly through the dashboard. We present wireframe designs to illustrate and educate the purpose and operation of HeatMap CU's dashboard, along with its accompanying widgets and forms. The first wireframe of the HeatMap CU Lizmap dashboard is shown in Figure 1.

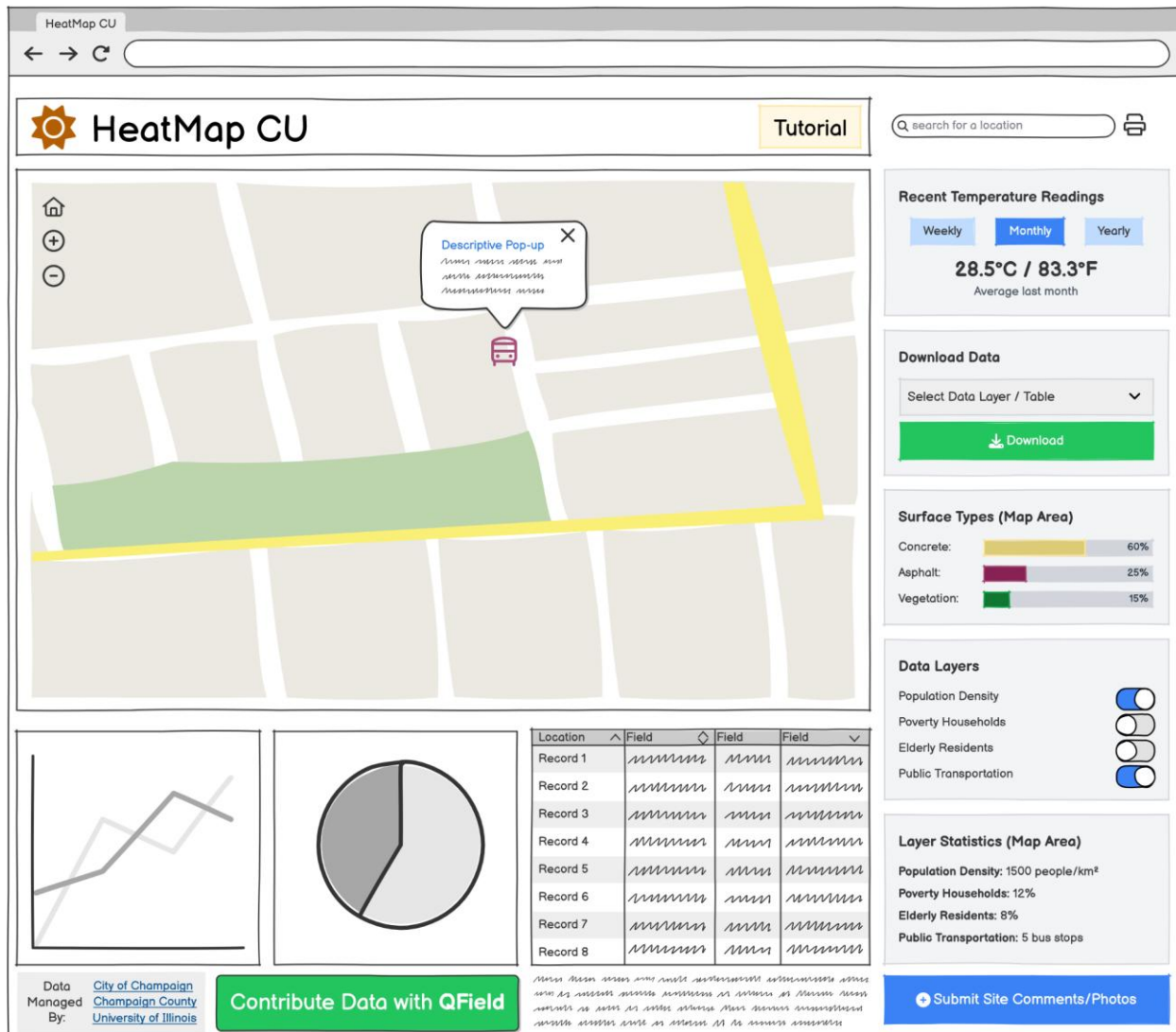


Figure 1. Interactive Dashboard

HeatMap CU's interactive dashboard provides a one-stop resource for professionals and community members alike to access the city's urban heat island data.

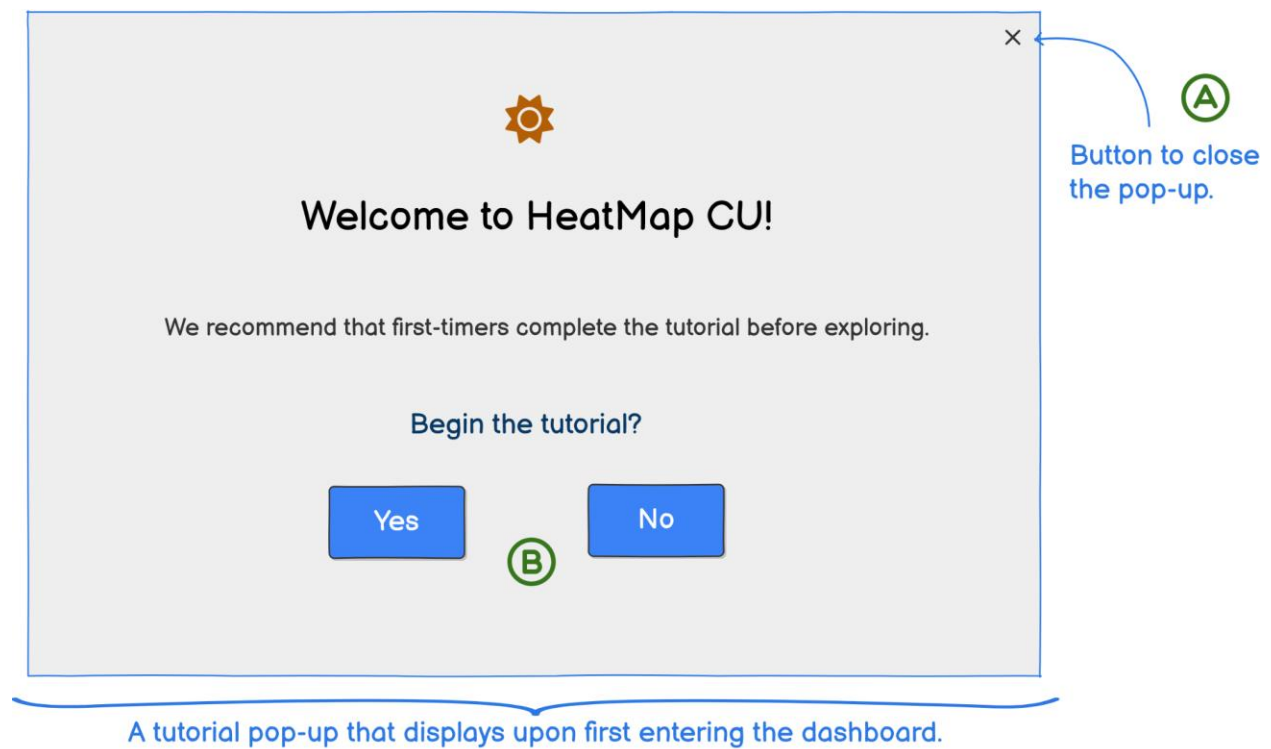
Step-by-Step Wireframes & Cognitive Walkthrough

Figure 2. Welcome Pop-up

The welcome pop-up (overlaid on the dashboard) asks the user if they would like to begin the tutorial.

User Tasks:

1. Read the welcome pop-up.
2. Begin the tutorial by selecting the 'Yes' button (B).

If the user is familiar with the welcome screen, they will close the pop-up (A).

HeatMap CU

Click anywhere to continue.

Search for a location

1 Search for a specific location here.

Recent Temperature Readings

Weekly Monthly Yearly

28.5°C / 83.3°F
Average last month

Download Data

Select Data Layer / Table

Download

Surface Types (Map Area)

Concrete: 60%

Asphalt: 23%

Vegetation: 15%

Data Layers

Population Density

Poverty Households

Elderly Residents

Public Transportation

Layer Statistics (Map Area)

Population Density: 1500 people/km²

Poverty Households: 12%

Elderly Residents: 8%

Public Transportation: 5 bus stops

Location	Field	Field	Field
Record 1			
Record 2			
Record 3			
Record 4			
Record 5			
Record 6			
Record 7			
Record 8			

Contribute Data with QField

Submit Site Comments/Photos

Data Managed By: City of Champaign, Champaign County, University of Illinois

The tutorial walks the user through each widget's purpose and operation.

Figure 3. Dashboard Tutorial

The dashboard tutorial ensures that users with varying technical competencies can navigate it confidently.

User Tasks:

1. Read each pop-up and click anywhere to continue until finished.

Note: For brevity, only the first tutorial step is included.

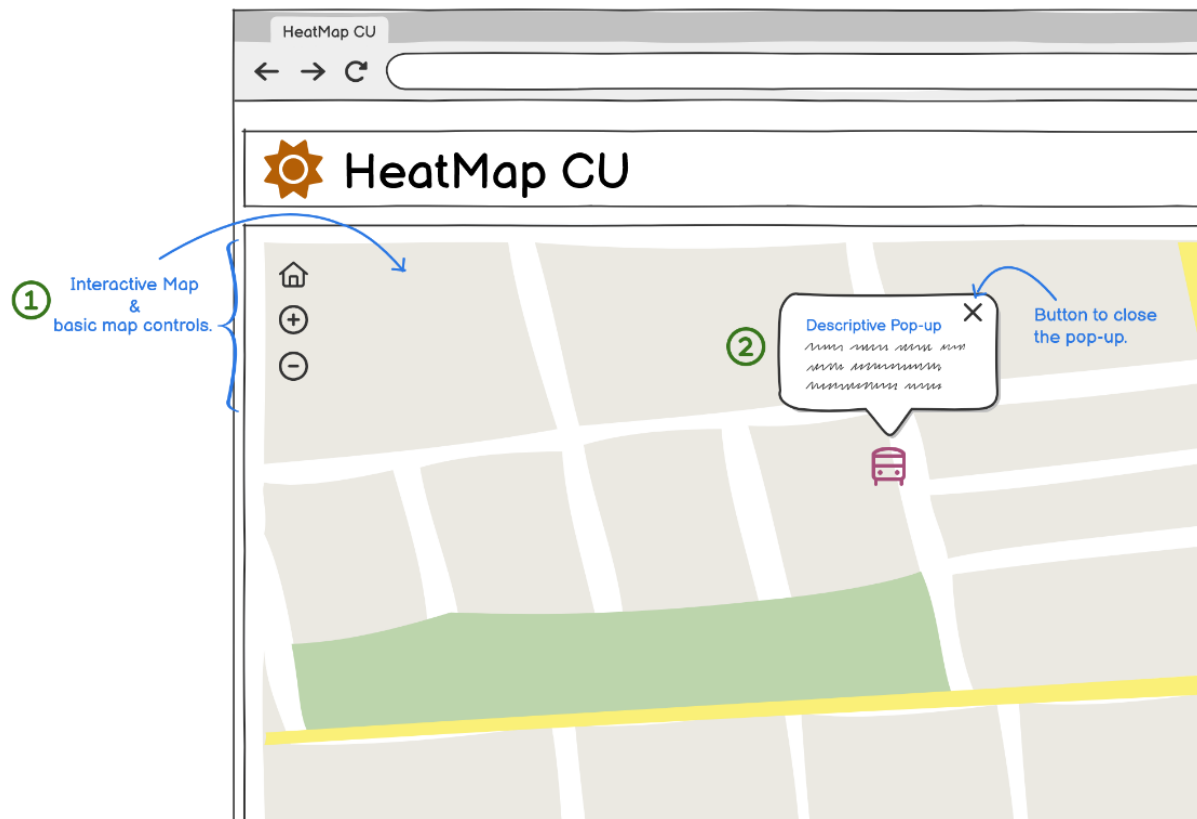


Figure 4. Interactive Dashboard in Detail – Upper Left

Caption: The top-left quarter of the dashboard displays the interactive map and its controls. Map features are clicked to reveal descriptive pop-ups.

User Tasks:

1. Locate the interactive map. Use the map control buttons to zoom in and out, then use the ‘home’ button to return the map to its default extent (1).
2. Click a feature on the map.
3. Read the descriptive pop-up, then close it with the ‘X’ button (2).

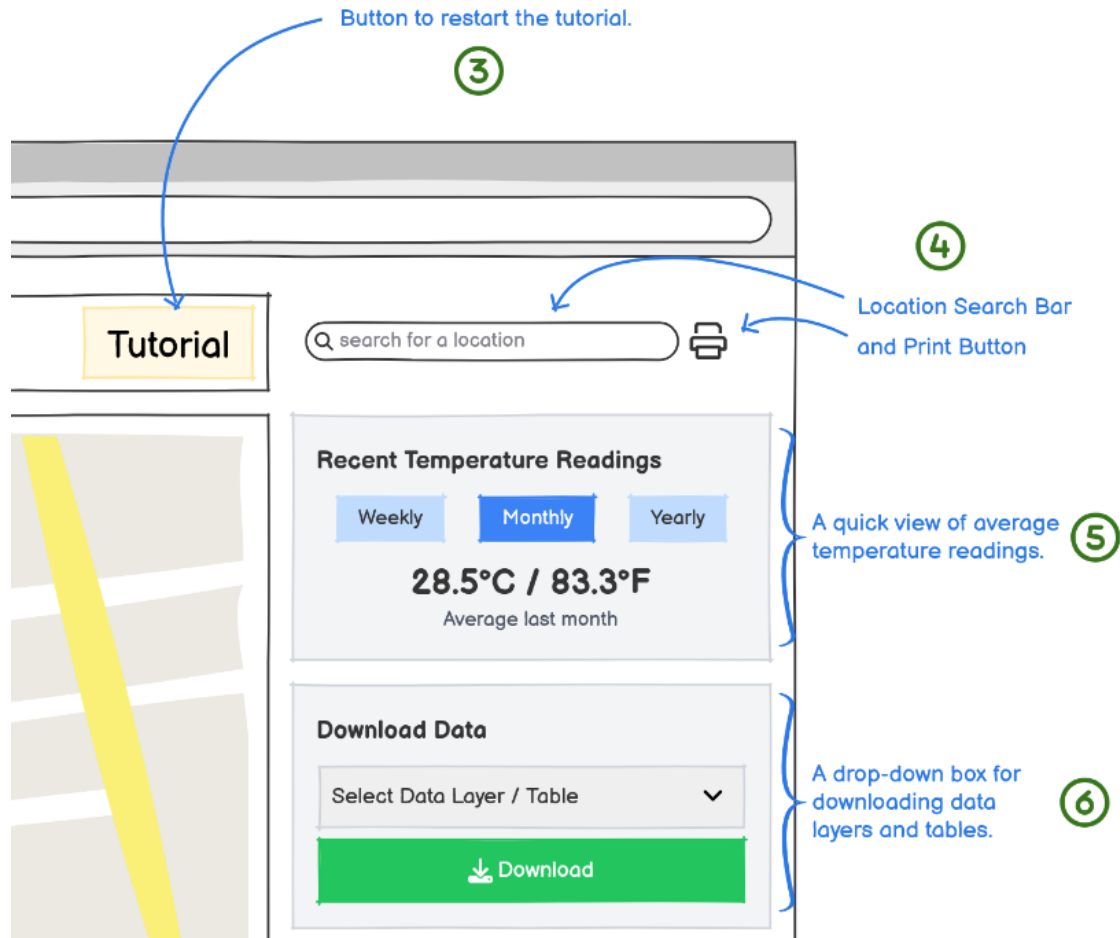


Figure 5. Interactive Dashboard in Detail – Upper Right

The top-right quarter of the dashboard includes a restart button, a search bar, a print button, and widgets to review temperature readings and download data.

User Tasks:

1. Click the tutorial button (3), and then click ‘No’ on the tutorial pop-up to exit it.
2. Locate the search bar and print button. Search for an address with the search bar (4).
3. Toggle the ‘Recent Temperature Readings’ widget to display last week’s average ‘Weekly’ temperature reading (5).
4. Click the drop-down to ‘Select Data Layer / Table’. Select a data table and download it (6).

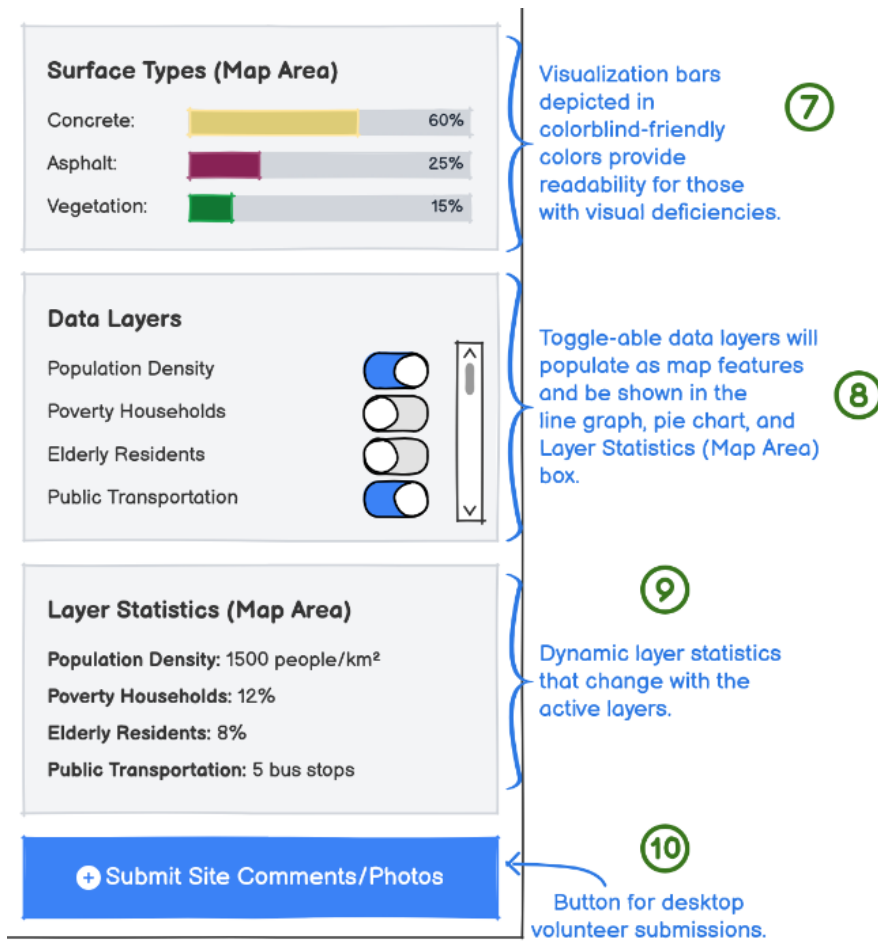


Figure 6. Interactive Dashboard in Detail – Lower Right

The bottom-right quarter of the dashboard contains surface-type visualization bars, toggleable data layers, a quick view of layer statistics, and a button for data submissions.

User Tasks:

1. Click one of the ‘Surface Types’ bars (7) to highlight the surface type on the map.
2. Toggle the population density layer off and scroll to find the 2024 Landsat surface temperature layer. Toggle it on (8).
3. Note how the ‘Layer Statistics (Map Area)’ widget changes dynamically to display the toggled data. What is the average surface temperature (9)?
4. Click the button to ‘Submit Site Comments/Photos’ (10).

Desktop Volunteer Submission Form

Submit Location Data
✕

Location (be specific)

Data to submit:

Air Temperature

Surface Temperature

Site Condition

Damaged Equipment

Other

Date/Time Observed:

/ /

📅

00 : 00 AM PM

🕒

Text Entries

Photo Entry (Optional)

Upload Photo

Full Name

City of Residence

Email Address

Submit

B Radio buttons for the user to specify what type of data to submit.

A Text box for the user to specify the location of their data to be submitted.

C Date and time pickers for the user to specify the period of their observation.

D Text box for data specifics

E Photo upload button

F Text boxes for entering personal information.

G Submit button

Figure 7. Desktop Volunteer Submission Form

The data submission form collects the user's location (where the data is collected), type of data, date and time observed, and optional photos. Users must submit their full name, place of residence, and email address.

User Task Scenario:

You notice that today is much hotter than it has been over the past several days. The thermostat outside of your apartment reads 98 degrees Fahrenheit. Shocked that it could be so hot in early July, you decide to take a photo of your thermostat and send its reading to the HeatMap CU dashboard.

User Tasks:

1. Enter the location where the data was collected (A).
2. Select the type of data collected (B).
3. Enter the date and time of the collection (C).
4. Enter specific details about the data collection (D).
5. Upload a photo to support the data (E).
6. Fill in your personal details (F).
7. Submit the form (G).

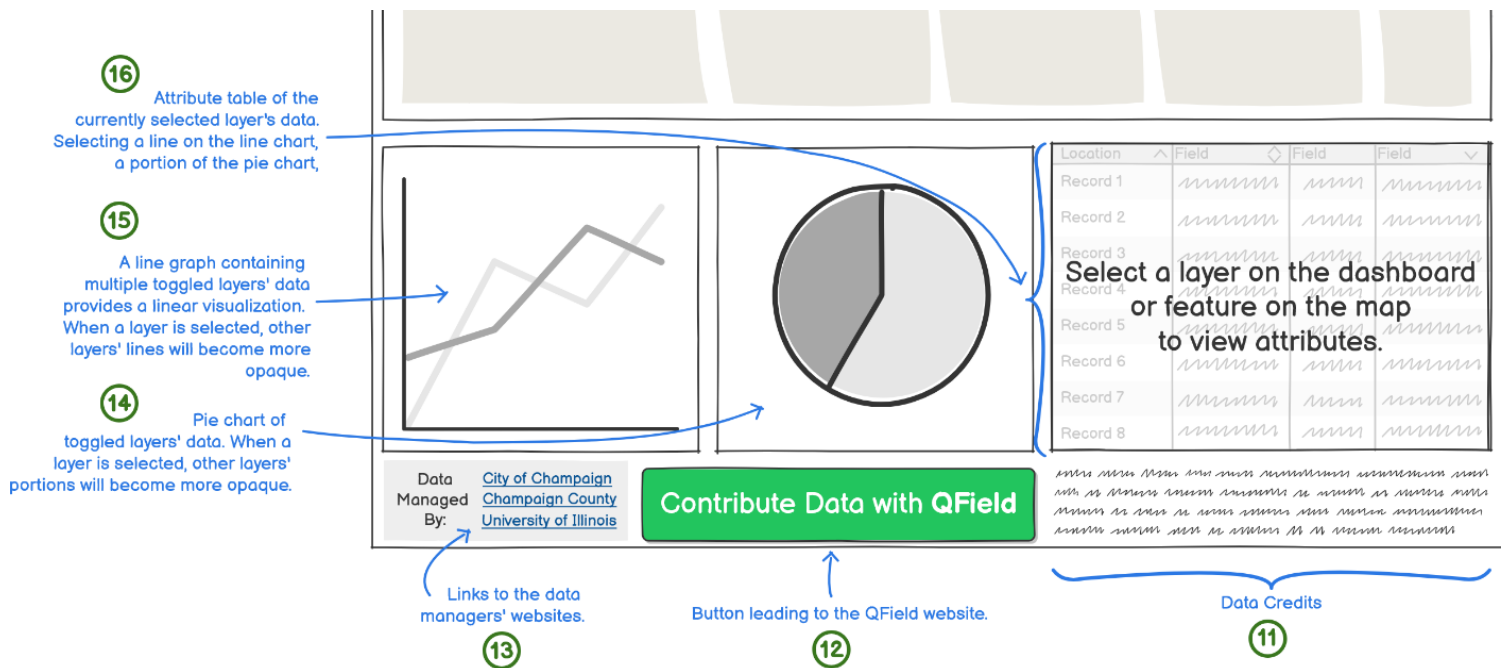


Figure 8. Interactive Dashboard in Detail – Lower Left

The lower left portion of the dashboard contains an attribute table, a pie chart, and a line chart for data visualization. Below, links to data managers' websites, a button to the QField website, and data credits are provided.

User Tasks:

1. Locate the data credits. Who is credited for providing satellite imagery (11)?
2. Click the 'Contribute Data with QField' button (12).
3. Return to the dashboard.
4. Locate the three data managers. Who are they (13)?
5. Select a portion of the pie chart to focus on a layer (14).
6. Select a grayed-out line in the line graph to focus on a different layer (15).
7. Scroll through the records in the attribute table for the selected layer (16).

Design Considerations

These wireframe designs were created with accessibility and ease of use in mind. The chosen colors are easily differentiated by people with color vision deficiency (as shown in the “Surface Types” element in Figure 6 and in the button color choice throughout the dashboard). The elements on the dashboard follow a typical layout for an interactive map dashboard, with the map as the focus, surrounded by charts and tables for further investigation if the user wishes to engage with them. The user will be able to toggle layers on/off to suit their interests and reduce clutter on the map.

SYSTEM ARCHITECTURE

Architecture Components

HeatMap CU's system architecture is arranged into a four-tier concept, including a data tier, business services tier, application tier, and presentation tier. In the data tier, data is stored in an authoritative database (PostGIS/PostgreSQL) on QGIS Cloud. This data includes media storage for QField volunteer-submitted photos, reference layers, and relational and lookup tables. In the business services tier, several things are happening simultaneously. Scheduled tasks process new data, transfer data from thermometer sensors to the database, and QGIS Server reads the data to update the Lizmap dashboard. The application tier, which consumes the services of the preceding tier, consists of three key components. Admin review of volunteer submissions via forms in QGIS falls under this tier (as well as leading back to the data tier), as do Lizmap Web Client configurations and the core QGIS project's app configurations. In the presentation tier, the Lizmap dashboard provides an interactive map and widgets for stakeholder use. Additionally, in the presentation tier, QField offers an interface for volunteers to submit their contributions. This doubles as data collection and connects back to the data tier. Figure 9 visualizes these tiers.

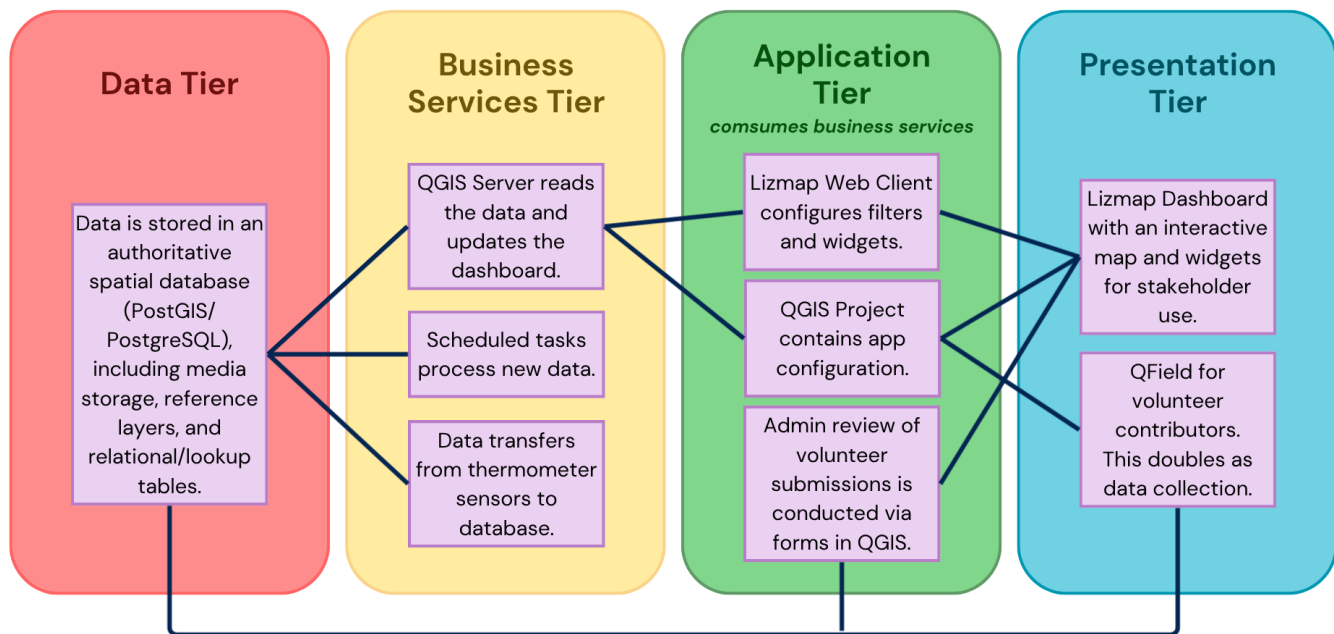


Figure 9. HeatMap CU System Architecture. The architecture is visualized as four interconnected tiers: the Data Tier, Business Services Tier, Application Tier, and Presentation Tier.

GIS Software

The Concept Selection section of this proposal details an integration of QGIS Web Suite (including Lizmap), QField, and PostGIS (through a QGIS Cloud PostgreSQL database) as the selected implementation concept for HeatMap CU. This architecture provides a purely FOSS ecosystem with backend capabilities for concurrent access, remote connectivity, and scheduled task automation. IR thermometer sensors transmit readings to the database, which stakeholders can view in near real-time. Community volunteers can submit field data through QField, which is then sent directly to the QGIS Cloud database. The QGIS Web Suite and Lizmap Web Client provide the tools for publishing QGIS projects as web maps through QGIS Server on a virtual machine, which will be leveraged to publish and update dashboard maps and widgets.

QGIS and Lizmap are both software accessible using a desktop computer. Additionally, QField can be used on a desktop if needed, although it is primarily designed for mobile devices. It is worth noting that QGIS, as an open-source project, has no official system requirements. Table 3 shows recommended specifications. The table's contents reflect the latest versions of browsers and operating systems compatible with the applications.

Table 3. Application System Requirements.

Application	Requirement Type	Requirement / Recommended Specification
QGIS v.3.44.4	Browser	A web browser is required to download QGIS. Recommended web browsers include: <ul style="list-style-type: none"> ● Microsoft Edge v.142.0.3595.65, 2025 ● Google Chrome v.142.0.7444.61.x, 2025 ● Mozilla Firefox v.145, 2025 ● Apple Safari v.26, 2025 ● Opera (Opera Software) 123.0.5669.47, 2025
	Operating System - Desktop	The QGIS Community Team specifies these operating systems as functional with QGIS (QGIS.org 2025): <ul style="list-style-type: none"> ● Windows 11 64-bit, v.25H2, 2025 ● macOS v.26.1 Tahoe, 2025 ● GNU/Linux: <ul style="list-style-type: none"> ○ Debian v.13, 2025 ○ Ubuntu v.25.10, 2025 ○ Fedora v.43, 2025 ○ NixOS v.25.05, 2025 ○ openSUSE v.16, 2025 ○ Mandriva v.Lx 6.0, 2025 ○ Slackware v.15.0, 2022 ○ Arch Linux v.6.17.6, 2025 ○ Flatpak v.1.16.1, 2025 ○ Spack v.1.0.2, 2025 ● BSD <ul style="list-style-type: none"> ○ FreeBSD v.14.3, 2025 ○ OpenBSD v.7.9, 2025
QField v.3.7.9	Operating System - Desktop	<ul style="list-style-type: none"> ● Windows 11 64-bit, v.25H2, 2025 ● macOS v.26.1 Tahoe, 2025
	Operating System - Mobile	<ul style="list-style-type: none"> ● Android 16 v.16.0.0_r2, 2025 ● iOS 26, v.26.1, 2025

Table 3. Application System Requirements.(continued)

Lizmap Web Client v.3.9.3	Browser	<ul style="list-style-type: none"> ● Microsoft Edge v.142.0.3595.65, 2025 ● Google Chrome v.142.0.7444.61.x, 2025 ● Mozilla Firefox v.145, 2025 ● Apple Safari v.26, 2025 ● Opera (Opera Software) 123.0.5669.47, 2025
Lizmap Web Client (Mobile Mode)	Operating System - Mobile	<ul style="list-style-type: none"> ● Android 16 v.16.0.0_r2, 2025 ● iOS 26, v.26.1, 2025

GIS Hardware

As with the operating system specifications for QGIS, it is worth noting that QGIS, QField, and Lizmap do not have official hardware requirements. Therefore, the hardware requirements for ArcGIS Pro 3.5 have been adopted as benchmarks for the general needs of GIS software, as QGIS and ArcGIS Pro perform many similar, if not identical, geospatial operations (Esri 2025d). The contents of Table 4 reflect the minimum and recommended hardware specifications for running QGIS, Lizmap, and QField.

Table 4. Application Hardware Specifications.

Application	Hardware	Requirement
QGIS v.3.44.4 (hardware requirements adapted from those of ArcGIS Pro 3.5)	CPU	<u>Minimum</u> : 2 cores, simultaneous multithreading, 64-bit <u>Recommended</u> : 4 cores, 64-bit
	RAM/Memory	<u>Minimum</u> : 8 GB <u>Recommended</u> : 32 GB
	Storage	<u>Minimum</u> : 32 GB free <u>Recommended</u> : 32+ GB on a solid state drive (SSD)
	Screen Resolution	<u>Minimum</u> : 1024x768 <u>Recommended</u> : 1080p or higher
	Graphics	<u>Minimum</u> : Supported CPU with integrated graphics <u>Recommended</u> : Dedicated GPU with 4+ GB
QField v.3.7.9 (Desktop) / Lizmap Web Client v.3.9.3	CPU	<u>Minimum</u> : 2 cores <u>Recommended</u> : 4 cores
	RAM/Memory	<u>Minimum</u> : 8 GB <u>Recommended</u> : 16 GB
	Storage	<u>Minimum</u> : 32 GB free <u>Recommended</u> : 32+ GB free
	Screen Resolution	<u>Minimum</u> : 720p <u>Recommended</u> : 1080p
	Graphics	<u>Minimum</u> : Integrated graphics <u>Recommended</u> : Dedicated GPU
QField (Mobile) / Lizmap (Mobile Mode)	CPU / Graphics	<u>Minimum</u> : Apple A11 / Adreno 610 (Snapdragon 680) <u>Recommended</u> : Apple A16 / Adreno 740 (Snapdragon 8 Gen 2)
	RAM/Memory	<u>Minimum</u> : 4 GB <u>Recommended</u> : 8 GB
	Storage	<u>Minimum</u> : 64 GB total <u>Recommended</u> : 128 GB total
	Screen Resolution	<u>Minimum</u> : 720p <u>Recommended</u> : 1080p

Network Resources

For uploading data to the QGIS Server, an uplink bandwidth of at least 10 Mbps (25 Mbps recommended) is required to ensure timely data synchronization and avoid any lag in dashboard updates. For the average user, a minimum Wi-Fi download speed of 10 Mbps is sufficient for loading maps, while a minimum upload speed of 2 Mbps is required for uploading small, text-only form submissions. These minimum requirements support loading tiled basemaps, viewing one or two data layers simultaneously, making simple submissions through the community form, and fundamental dashboard interactions. Higher speeds enable downloading map data, refreshing time-enabled layers, and uploading larger data (such as photos) in the community submissions form. For cellular connectivity speed, a minimum of 5 Mbps download and 1 Mbps upload is required for basic functionality. These minimums support the synchronization of offline edits with QField, basic map navigation, and small data uploads. However, a higher cellular connectivity speed is needed to load dashboard updates and photos, as well as to continuously sync data with QField.

Slow connections may fail to load all map tiles, leaving “blank” regions as you pan across the map. This is mitigated by using cached tiles on the server. Photo submissions, whether via QField or the dashboard’s community submission form, may fail to upload to networks with high latency and low bandwidth. Additionally, limited storage may limit device caching abilities, causing slow performance and memory-related errors, such as tile refresh and reload.

Database Design & Requirements

Figure 10 illustrates the database schema of HeatMap CU, stored in QGIS Cloud, which includes tables for identifying neighborhoods, sensors, users, and surface types, as well as tables for sensor readings and community observations.

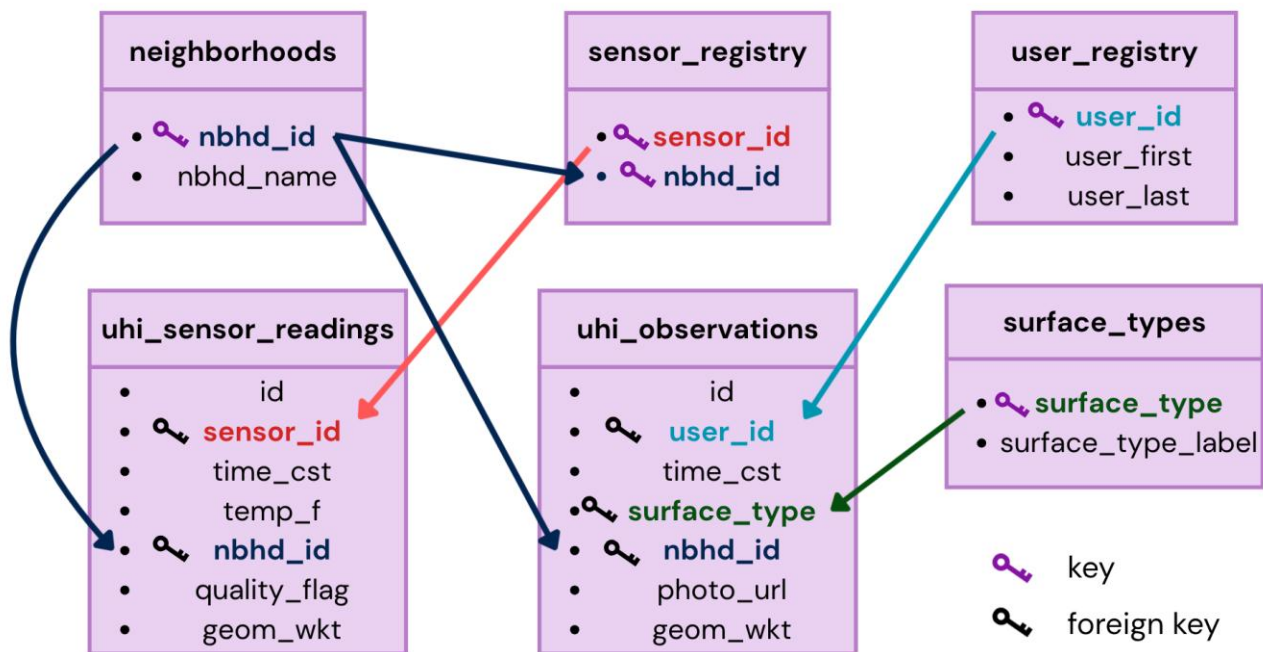


Figure 10. HeatMap CU Database Schema. Necessary Tables include those for storing neighborhood IDs, sensor IDs, user IDs, sensor readings, volunteer observations, and surface types. All tables necessary for the entire workflow of the HeatMap CU system (e.g., raw sensor data) are not shown.

For examples of HeatMap CU's attribute table schemas, see APPENDIX: ATTRIBUTE TABLE EXAMPLES, on page 54.

Enterprise GIS Components

The HeatMap CU GISystem operates as a small-scale enterprise deployment, supporting concurrent users, integrating multiple data sources, and running background-scheduled processes. This is accomplished through an authoritative database (PostGIS/PostgreSQL) on QGIS Cloud that stores and manages sensor readings, volunteer contributions, and reference layers and tables. QGIS Server reads and publishes this data as web map services (WMS) and web feature services (WFS). Lizmap then consumes this data and provides an interactive dashboard. Behind the scenes, IR thermometer readings are pushed from the sensors to the database for validation and summarization. Geospatial analysts and administrators utilize QGIS Desktop to configure project settings and review volunteer submissions. The shared database, QGIS Desktop, QGIS Server, Lizmap, and continuous background tasks all work in tandem to provide an established enterprise system for HeatMap CU.

Performance Considerations

Performance limitations in the HeatMap CU enterprise system may arise from server and database storage constraints and the need to expand storage. The storage needs of the GISystem are ever-growing, as the system constantly ingests IR thermometer sensor readings and stores continuous submissions from QField. Insufficient disk space may lead to slower queries and affect the system's ability to refresh views. Additionally, WMS and WFS requests may time out if the data complexity is too large. To mitigate these issues, photo submissions are limited to 15 MB per submission, and raw sensor data is routinely archived. Although HeatMap CU is a small project, growing demand may necessitate future upgrades to the database and server storage.

Download speed limitations occur when users access web map services over slow Wi-Fi or cellular networks, leading to delayed loading, missing map tiles, and reduced functionality. Although the application may be accessible with a download speed of less than 10 Mbps over Wi-Fi or less than 5 Mbps when using the system’s mobile applications, higher speeds support better performance and significantly reduce complications.

Maintenance Considerations

Routine maintenance is essential for any successful enterprise environment to ensure optimal performance and data stability. Weekly tasks are run on the weekend, while no edits are being made to the data, to confirm that services are running correctly and that disk space remains ideal. Monthly maintenance is required to ensure data integrity through several operations detailed in Table 5.

Table 5. Monthly Maintenance Schedule

January	Full system audit Test database backup restore Review disk usage Remove old debug logs
February	Run <i>vacuum analyze</i> on PostgreSQL database Review and update SSL certificates if necessary Quarterly stakeholder meeting to assess and meet needs
March	Apply any security patches to OS, PostgreSQL, QGIS Desktop, QGIS Server, and Lizmap
April	Review IR sensor performance
May	Test database backup restore Review disk usage Quarterly stakeholder meeting to assess and meet needs
June	Review bandwidth and response times of dashboard

Table 5. Monthly Maintenance Schedule. (continued)

July	Inspect tables for bloat Run <i>vacuum full</i> on PostgreSQL database if necessary Review IR sensor performance
August	Apply full updates to OS, PostgreSQL, QGIS Desktop, QGIS Server, and Lizmap Quarterly stakeholder meeting to assess and meet needs
September	Test database backup restore Test disk usage Apply any new project layer configurations
October	Review QGIS Server error logs Review and test QField offline and online workflows
November	Update documentation if necessary Quarterly stakeholder meeting to assess and meet needs
December	Evaluate software and hardware needs for the next year Archive old logs Update metadata Reorganize schema if necessary

Security Considerations

Security measures must be taken to protect data access and user authentication. The database will be restricted to only connections from QGIS Server, authorized admin workstations, and the IR thermometer sensor's ingestion API. The GISystem's web traffic must use HTTPS/TLS to encrypt and authenticate communication. Users will have role-based permissions, with administrators, analysts, and contributors having separate levels of access to the data. Administrative tools will require strong passwords and multifactor authentication, while IR sensors will authenticate using unique device tokens. Routine software security patches will

be necessary to reduce vulnerabilities, while automated backups stored separately from the central database protect against data loss.

DATA

Background

The HeatMap CU GISystem integrates infrared (IR) sensor data, community observations, high-resolution imagery, and surface types to provide the foundation for professional and amateur analysis of Champaign-Urbana's urban heat island (UHI) patterns. The system relies on IR temperature data, provided in near real time via the ingestion API running on the QGIS Server. In addition to sensor data collection, community members submit temperature readings via QField, which are reviewed and added to a separate layer for comparison. Both sensor readings and field collection reports, as well as the surface types layer, neighborhood boundaries, and imagery, are managed in QGIS Desktop. Tools in QGIS are available to analysts for contextualizing and symbolizing data before publishing. At the same time, the interactive dashboard consolidates published data into a single place for stakeholders to view, analyze, and download.

Data Source Descriptions

The infrared (IR) sensors provide temperature data to the database through an ingestion API. This raw data is then processed into an easily-read format during regularly scheduled tasks, and the 'IR Sensor Readings' layer is updated with the processed data. The attributes for this layer include sensor ID, time in CST, temperature in Fahrenheit, neighborhood ID, quality flag, and coordinates in well-known text (WKT). Special care must be taken during the very hot summer months to ensure the sensors are working correctly and not overheating.

Volunteer observations are stored separately from the ‘IR Sensor Readings’ data. While this aspect of the GISystem promotes community engagement, its entries require admin review before being appended to the main ‘Volunteer Observations’ layer to maintain data integrity. The data’s attributes include location, time of observation, surface temperature, air temperature, and comments.

The Champaign County GIS Consortium provides imagery for the area. This aerial, orthorectified imagery is very high resolution, with one pixel per six inches in the real world. High-quality imagery is crucial to the dashboard's success, as it provides the context needed to understand the other data layers. Unlike the different data layers, this proprietary layer is not available for download via the dashboard.

The ‘Neighborhoods’ layer is created with US Census blocks. Rather than representing true neighborhoods as residents would understand them, these census blocks serve as statistical units for easily observing and quantifying changes in an area and for comparing blocks.

The ‘Surface Types’ layer is created in QGIS with the QuickOSM plugin by querying OpenStreetMap features with the ‘surface’ key and specifying the desired surface type (3Liz 2025). This layer contains the features of each identified surface type, along with their corresponding labels and IDs. Surface types provide a crucial basis for understanding how certain land cover materials influence surface temperature, enabling geospatial analysis.

Table 6 summarizes these data layers and provides additional information.

Table 6. Data Summary.

Data Layer	Source	Spatial Info*	Collection Method	Interval / Date	Citation	Big Data	Real-Time	VGI	Access
IR Sensor Readings	IR Thermometers	Point	Ingestion API	Updated hourly	IoT IR Sensors	No	Yes	No	Open
Volunteer Observations	Volunteers via QField	Point	Manual entry	Timestamp recorded with each record	QField form, dashboard form (www.example.org)	No	No	Yes	Open
Imagery	Champaign County GIS Consortium	Raster, 6 inch	Aerial Orthoimagery	3 years	CCGISC (https://www.ccgisc.org/DataAndServices.aspx)	No	No	No	Proprietary
Neighborhoods	US Census Bureau, NHGIS	Polygon	Manual mapping	Decennially	NHGIS, (https://data2.nhgis.org/main)	No	No	No	Open
Surface Types	OpenStreetMap	Polygon	Manual mapping	Quarterly	OpenStreetMap (www.openstreetmap.org)	Yes	No	Yes	Open

* All data is in (or projected into) the NAD83 Illinois East coordinate system.

UML DESIGN

The UML design for HeatMap CU, shown in Figure 11, includes public users, the QField app, and IoT IR Sensors as the “Data Producer” actors. Opposite these actors are the decision maker (analyst/planner) and GIS admin, or “Data Managers and Decision Makers” — those who maintain and/or use the data to run analyses and make decisions. Both the public user and the decision maker review the interactive map, download data, and generate reports. The decision maker also has access to data analysis tools, while the GIS admin manages users and data. Public users, the QField mobile app, and IoT IR sensors all submit data (which is either verified or displays an error message or error log, depending on the actor) to the GISystem. The GIS admin reviews these submissions, either by reviewing individual user submissions or by scheduling tasks that process the raw data from the IR sensors and publish the cleaned data.

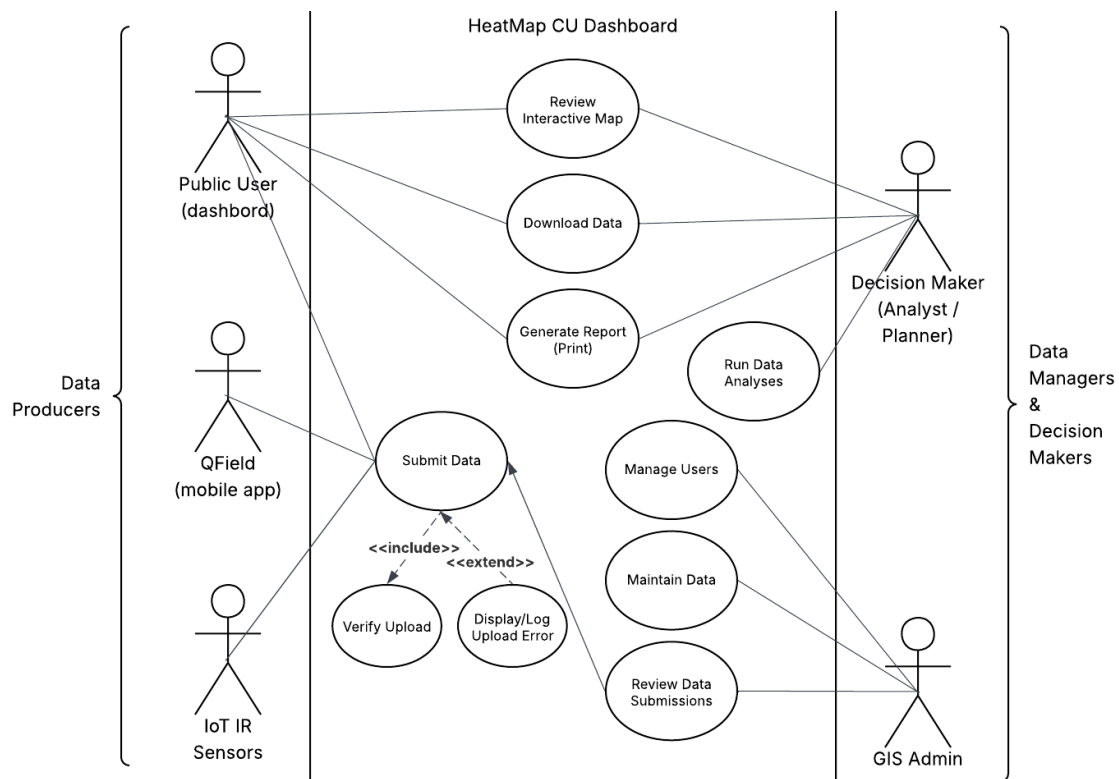


Figure 11. UML Diagram for the HeatMap CU Dashboard. Primary use cases are shown in the center, while actors contributing data are shown on the left, and actors managing data are displayed on the right.

EVALUATION METHODS

A heuristic evaluation, user testing sessions, and a system usability questionnaire will help assess the functionality and effectiveness of the HeatMap CU GISystem.

Heuristic Evaluation

The heuristic evaluation will help experts identify major issues in the system before it is presented to end-users. The goal of this method is to ensure that the GISystem adheres to Nielsen's ten usability heuristics. These heuristics provide a guide for identifying and remedying user experience (UX) issues in complex applications such as HeatMap CU. The ten usability heuristics include, but are not limited to, user control, consistency, error prevention, efficiency, aesthetic design, and access to help (Kaplan 2021).

By focusing on these key heuristics during development, we reduce the need for future updates to address errors and other issues. This will save both time and money, as fewer resources will be required if the proper time and effort are put into creating a high-quality application that serves all stakeholders from the beginning.

Following the heuristic evaluation, task-based user testing will be conducted with stakeholders.

User Testing Sessions

After making adjustments based on the heuristic evaluation, user testing sessions will be conducted both indoors with the HeatMap CU dashboard and in the field with the QField app. These testing sessions will be conducted with scripts for each respective environment. A

facilitator will observe the user's performance in a controlled space with a stable network (when indoors) and proper hardware, ensuring that all hardware, software, and network needs are met before testing. In both table-top and field-testing sessions, participants will perform tasks that reflect real-world workflows. During these sessions, an evaluator will be present to provide instructions and record any issues during testing. After testing, participants will complete a System Usability Scale (SUS) questionnaire.

Simulating real users interacting with the system in realistic conditions, user testing sessions will elucidate issues and provide direct evidence of how well the system functions for both professionals and community members. Observing real users offers unparalleled insight into how accessible and efficient the GISystem's user experience is.

Example Usability Tasks for Analysts (table-top)

1. **Task:** Your organization is conducting a study on poverty and the potential connection with urban heat island effects. Use the dashboard to find and select a neighborhood with a high poverty rate and high temperature readings.
Success: The participant can locate and select an appropriate neighborhood.
2. **Task:** Examine the shifts in temperature between the different surface types. What patterns, or lack thereof, do you notice?
Success: The participant can pan around the map and record their observations.
3. **Task:** Use the dashboard widgets to investigate whether there are any apparent relationships between high concentrations of elderly residents, surface types, and temperature patterns.
Success: The participant can gather insights into surface types and temperatures in areas with high numbers of elderly residents.

Example Usability Tasks for the General Public (table-top)

1. **Task:** Zoom out to the full extent of the map. Toggle the layers so that only the “Poverty Households” layer and “Sensor Readings” layer are visible (in addition to the basemap). What do you notice about these two data layers?
Success: The participant can use the map navigation tools to zoom to the full map extent, toggle the correct layers, and note data details.
2. **Task:** Locate a place of personal interest on the map and examine the data presented in the widgets. What surface type is dominant in the vicinity?
Success: The participant can locate their place of interest and gather the necessary information.
3. **Task:** Locate the tool for printing the dashboard’s contents.
Success: The participant can locate the print button with no difficulty.

Example Usability Tasks for Mobile Users (QField)

1. **Task:** Navigate to the Community Project “HeatMap_CU”.
Success: The user can find and open the HeatMap CU project file.
2. **Task:** Zoom in to your current location and toggle “Digitize Mode”.
Success: The user can zoom in to their locations and navigate to / toggle “Digitize Mode”.
3. **Task:** Select the “Air Temperature” layer. Click the (+) button to add a new record to the layer.
Success: The user can open the form to add a new record to the correct layer at the proper location.

System Usability Scale Questionnaire

A survey will be conducted with all personnel who complete the user testing sessions. A pre-test questionnaire will precede a System Usability Scale (SUS) survey. To properly assess the system usability score of HeatMap CU and compare it with that of other complex applications, the system usability scale's questions and wording are not altered from those in the Nielsen Norman Group's system usability questionnaire (Laubheimer 2018).

Pre-Test Questionnaire – Before SUS Questionnaire

1. What is your job title?
2. What is your age?
3. Do you have experience using geographic information systems (GIS) beyond navigation tools like Google Maps?
4. Do you consider yourself comfortable with new technology?
5. Do you have any disabilities or other conditions that could affect your use of the application (color blindness, loss of sight, or other physical difficulties in operating a computer)?

System Usability Survey

Participants evaluate the System Usability Scale statements using the following answers: *Strongly Disagree (1), Disagree (2), Neutral (3), Agree (4), and Strongly Agree (5).*

1. I think that I would like to use this system frequently.
 2. I found the system unnecessarily complex.
 3. I thought the system was easy to use.
 4. I think I would need the support of a technical person to use this system.
 5. I found the various functions in this system were well integrated.
 6. I thought there was too much inconsistency in this system.
 7. I would imagine that most people would learn to use this system very quickly.
 8. I found the system cumbersome to use.
 9. I felt very confident using the system.
 10. I needed to learn a lot of things before I could get going with this system.
-

COST/BENEFIT ANALYSIS

The HeatMap CU GISystem requires a modest financial investment for essential operations, maintenance, and personnel. Primary expenses include hosting a QGIS Server via a small-scale virtual machine and a PostGIS database with a low-cost QGIS Cloud subscription (Sourcepole, n.d.). Additional costs include the upkeep of stationary IR thermometers and contract labor dedicated to the system's initial configuration and automation, validating community submissions, and maintaining system integrity through regular maintenance. Contract labor, or personnel resources, is the most significant portion of recurring annual costs, followed by storage and network expenses.

The costs of the HeatMap CU GISystem support centralized data storage and collection, reduce long-term labor costs through automation, and improve data accuracy and consistency by using IR sensors and monitored QField submissions. For the residents of Champaign-Urbana and the many university students, researchers, and GIS organizations in the area, these costs represent better-informed heat-mitigation investments, potentially reduced emergency response costs (e.g., by implementing solutions such as cooling centers or water stations to reduce heatstroke, lessening the burden on first responders and emergency staff), and more efficient planning.

HeatMap CU will drive solutions for the greater good of Champaign-Urbana by integrating IR sensor readings, land cover classifications, and community-sourced observations into a unified geospatial database. The system provides evidence that allows city staff to prioritize heat-mitigation measures, such as tree planting, shade structure installations, or

resurfacing existing pavement with cool, reflective pavement. With HeatMap CU, planning uncertainty is reduced by directly highlighting the contributors to the Urban Heat Island (UHI) effect. This leads to more strategic planning and resource allocation, and to more substantial justification for grant funding and budget requests. The costs of the system are well justified by the benefits of reduced emergency costs, more efficient city planning, and a more comfortable, safer city for all residents. Table 7 shows a cost-benefit summary for the HeatMap CU GISystem. Note that these costs are estimates only and represent the system in a nascent state. Future scaling measures may be needed if user demand, data volume, or concurrent access increases.

Table 7. HeatMap CU Cost-Benefit Analysis.

Category	Estimated Annual Cost	Benefit
QGIS Server (virtual machine)	\$1,000	Centralized data storage and real-time updates
IR thermometer deployment and automation set-up (20 sensors, initial development)	\$2,500	Continuous temperature monitoring
GIS Analyst (contract labor)	\$10,000	Data QA/QC, layer updates, community submissions review
Developer setup (one-time cost)	\$3,000	System configuration and automation
PosGIS Database and backups (QGIS Cloud Pro)	\$200	Long-term data retention
Community training sessions and collection support	\$1,000	Increased public participation and higher-quality submissions
Dashboard configuration and updates (contract labor)	\$1,000	Public communication and accessibility of data
Total	\$18,700	

FUTURE WORK

The development and anticipated work schedule for HeatMap CU are broken into four major milestones, or “phases”: “System Stabilization”, “App Enhancement”, “Testing & Evaluation”, and “Maintenance”, shown in Figure 12.

Early work during the System Stabilization phase will focus on finalizing the ingestion pipeline and installing the IoT IR sensors in key areas, followed by performance optimization of the QGIS Server and PostGIS environment. Once the foundation for this system is stabilized, work will shift to enhancing the Lizmap dashboard with core visualizations, including the land-cover dataset and aerial imagery. In a calendar year starting in January, this phase would run from the beginning of January to the end of March.

Once the system is stabilized with its core basemap and land-cover dataset, the App Enhancement phase begins by integrating Lizmap widgets, charts, and statistics. Running in parallel with this task will be improvements to mobile responsiveness for Lizmap mobile mode (mobile web browser view) and the QField app. The final task in this phase is to integrate the neighborhood block layers and ensure that metadata for all datasets is appropriately configured. This phase is scheduled to run from the beginning of March until mid-May.

The third phase, Testing & Evaluation, focuses on a heuristic evaluation and the resulting system tweaks. User testing sessions are conducted next, followed by compiling feedback and implementing improvements based on the results. This phase is scheduled to run from the beginning of May until mid-July.

From July onward, the Maintenance phase marks the beginning of HeatMap CU’s public deployment and the start of the maintenance schedule, including monthly data updates, quarterly

stakeholder meetings, and other monthly tasks according to the maintenance schedule outlined in the “System Architecture” section of this proposal. Remaining unresolved issues include ensuring long-term scalability and balancing real-time updates with system performance.

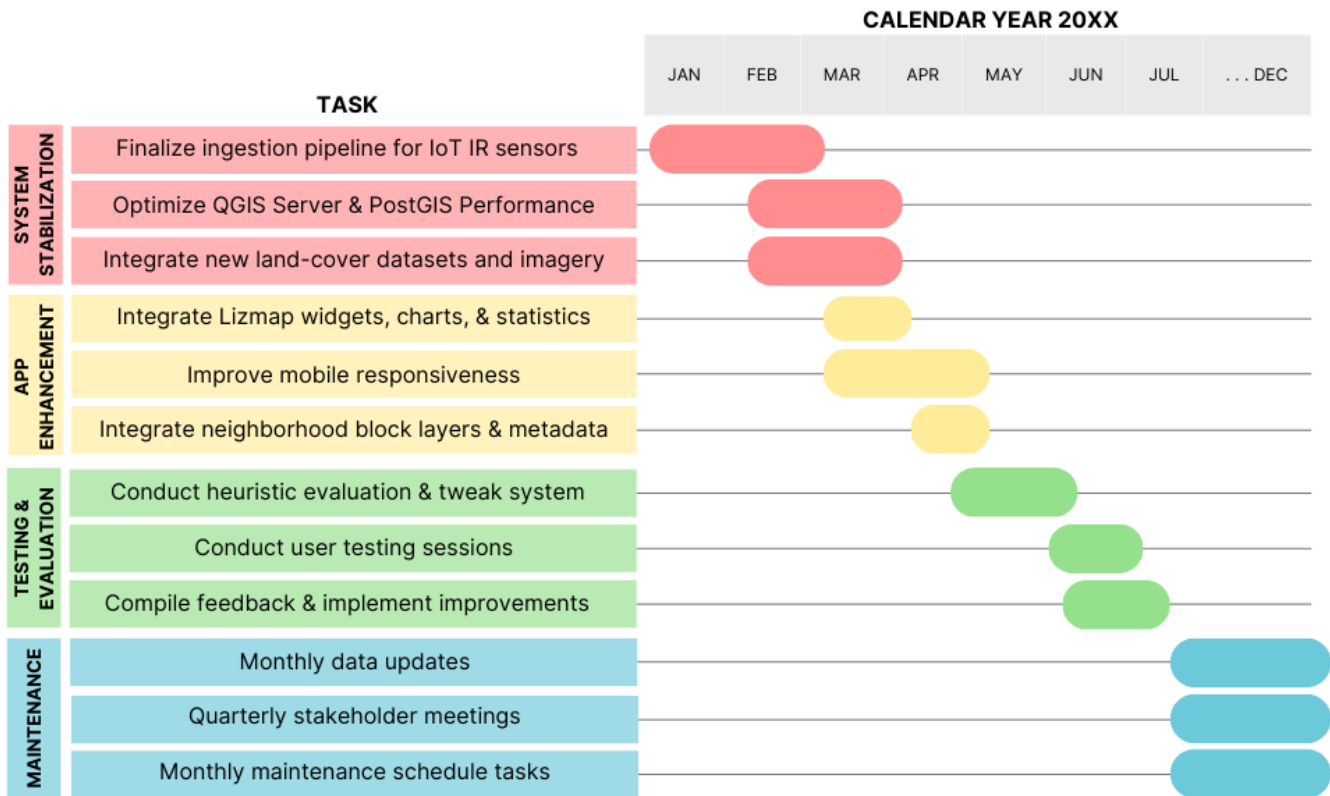


Figure 12. HeatMap CU Gantt Chart. Major milestones in the system’s development are sectioned into four phases: System Stabilization, App Enhancement, Testing & Evaluation, and Maintenance.

BIBLIOGRAPHY

- 3Liz. 2025. *QGIS and QGIS Server*. Lizmap Documentation. Accessed October 27, 2025. <https://docs.lizmap.com/current/en/introduction.html#qgis-and-qgis-server>.
- 3Liz. 2025. *QuickOSM Documentation*. Accessed November 18, 2025. <https://docs.3liz.org/QuickOSM/>.
- CARTO. 2025. *CARTO Pricing Page*. Accessed October 27, 2025. <https://carto.com/pricing>.
- CARTO. 2025. *The Future of GIS Education: A Cloud-Based, Open Source GIS & Mapping Solution for Education*. https://go.carto.com/hubfs/Education_Whitepaper-1.pdf.
- Esri. 2025a. *Introduction to ArcGIS Online*. Accessed October 27, 2025. <https://doc.arcgis.com/en/arcgis-online/get-started/what-is-ago1.htm>.
- Esri. 2025b. *Introduction to ArcGIS Velocity*. Accessed October 27, 2025. <https://doc.arcgis.com/en/velocity/get-started/what-is-arcgis-velocity.htm>.
- Esri. 2025c. *Pricing for ArcGIS Online User Types*. Accessed October 27, 2025. <https://www.esri.com/en-us/arcgis/products/arcgis-online/buy>.
- Esri. 2025d. *ArcGIS Pro System Requirements*. ArcGIS Pro Documentation. Accessed November 2025. <https://pro.arcgis.com/en/pro-app/latest/get-started/arcgis-pro-system-requirements.htm>.
- Champaign County GIS Consortium (CCGISC). 2025. *Data and Services*. Accessed November 18, 2025. <https://www.ccgisc.org/DataAndServices.aspx>.
- Gabbe, C. J. 2023. "Reducing Heat Risk for People Experiencing Unsheltered Homelessness: A Case Study of the San Francisco Bay Area." *The Lancet Regional Health – Americas* 21: 100479. <https://doi.org/10.1016/j.lana.2023.100479>.
- Getto, Giulia, and Chris Moore. 2017. "Mapping Personas: Designing UX Relationships for an Online Coastal Atlas." *Computers and Composition* 43: 15–34. <https://doi.org/10.1016/j.compcom.2017.04.001>.

- Graser, Anita, Tim Sutton, and Marco Bernasocchi. 2025. "The QGIS Project: Spatial Without Compromise." *Patterns* 6 (7): 101265. <https://doi.org/10.1016/j.patter.2025.101265>.
- Gronlund, Carina J., Kyle P. Sullivan, Yonathan Kefelegn, Lorraine Cameron, and Marie S. O'Neill. 2018. "Climate Change and Temperature Extremes: A Review of Heat- and Cold-Related Morbidity and Mortality Concerns of Municipalities." *Environmental Research* 161: 1–15. <https://doi.org/10.1016/j.envres.2017.10.002>.
- Harris, Amanda W., and Albrecht, Jennifer. 2024. "Association between Homelessness and Temperature-Related Emergency Department Visits in the United States." *Weather, Climate, and Society* 16 (4): 633–638. <https://doi.org/10.1175/WCAS-D-24-0009.1>.
- IPUMS. 2025. *National Historical Geographic Information System: NHGIS Data Portal*. Accessed November 18, 2025. <https://data2.nhgis.org/main>.
- Kaplan, Kate. 2021. "10 Usability Heuristics Applied to Complex Applications." Nielsen Norman Group. August 15, 2021. <https://www.nngroup.com/articles/usability-heuristics-complex-applications/>.
- Laubheimer, Page. 2018. "Beyond the NPS: Measuring Perceived Usability: The System Usability Scale (SUS)." Nielsen Norman Group. February 11, 2018. <https://www.nngroup.com/articles/measuring-perceived-usability/>.
- Mohajerani, Abbas, Jason Bakaric, and Tristan Jeffrey-Bailey. 2017. "The Urban Heat Island Effect, Its Causes, and Mitigation, with Reference to the Thermal Properties of Asphalt Concrete." *Journal of Environmental Management* 197: 522-538. <https://doi.org/10.1016/j.jenvman.2017.03.095>
- OPENGIS.ch. 2023. *QField Concepts*. Accessed October 27, 2025. <https://docs.qfield.org/get-started/concepts/>.
- OpenStreetMap. 2025. *OpenStreetMap: Collaborative Map Database*. Accessed November 18, 2025. <https://www.openstreetmap.org>.
- QGIS.org. 2025. "Installation Guide." Accessed November 2025. <https://qgis.org/resources/installation-guide/>.

- Rosson, Mary Beth, and John M. Carroll. 2007. "Scenario-Based Design." In *The Human-Computer Interaction Handbook*, 1067–1086. CRC Press.
<https://doi.org/10.1201/b11963-ch-48>.
- Smargiassi, Andrea, Mylene Fournier, Ying Zhou, Pierre Plante, Caroline Goudreau, Madeleine Bourque, and Tom Kosatsky. 2009. "Assessing Vulnerability to Heat: A Geospatial Analysis for the City of Philadelphia." *Journal of Exposure Science and Environmental Epidemiology* 19 (3): 246–57. <https://doi.org/10.1038/jes.2008.29>.
- Sourcepole, n.d. "Plans." QGIS Cloud. Accessed November 26, 2025.
<https://qgiscloud.com/pages/plans?locale=en>.
- Steiniger, S. 2012. "The 2012 Free and Open Source GIS Software Map." *Computers, Environment and Urban Systems* 36 (2): 73–77. <https://doi.org/10.3390/ijgi9020090>.
- Tan, Zhenyu, Zhi Huang, and Jun Yang. 2022. "Urban Heat Island Mitigation: GIS-Based Analysis for a Tropical City Singapore." *Urban Climate* 46: 101314.
<https://pubmed.ncbi.nlm.nih.gov/36231216/>.
- Vaz, Eric, and Miguel Nijkamp. 2020. "Zoning and Weighting in Urban Heat Island Vulnerability and Risk Mapping in Helsinki, Finland." *Regional Environmental Change* 20 (3): 83. <https://doi.org/10.1007/s10113-019-01491-x>.
- Wells, Rebecca, Emily Grant, Tim Chang, and John Anderson. 2021. "Evaluating the Usability and Acceptability of a Geographical Information System (GIS) Prototype to Visualise Socio-Economic and Public Health Data." *BMC Public Health* 21 (1): 2104.
<https://bmcpublichealth.biomedcentral.com/articles/10.1186/s12889-021-12072-1>.
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APPENDIX: ATTRIBUTE TABLE EXAMPLES

Tables 3 through 9 contain example data representing the attribute tables of the HeatMap CU database.

Table A1. Neighborhoods

nbhd_id	nbhd_name
1	Lincoln Square
2	Victory Park
3	South Philo

Table A2. Sensor Registry

sensor_id	nbhd_id
IR-001	1
IR-002	2
IR-003	3

Table A3. Surface Types

surface_type_id	surface_type_label
1	Pavement
2	Rooftop
3	Vegetation

Table A4. UHI Sensor Readings

id	sensor_id	time_cst	temp_f	nbhd_id	quality_flag	geom_wkt
1	IR-001	2025-11-12 12:00:00	42	1	3	POINT(40.110701 - 88.205230)
2	IR-002	2025-11-12 12:00:00	45.7	2	3	POINT(40.111407 - 88.196979)
3	IR-003	2025-11-12 12:00:00	41.9	3	3	POINT(40.086195 - 88.190273)

Table A5. UHI Observations

id	observer_id	time_cst	surface_type	nbhd_id	photo_url	geom_wkt
1	user_1	2025-11-12 12:00:00	1	6	https://example.org/photo.jpg	POINT(40.089660 - 88.199147)
2	user_2	2025-11-12 12:00:00	3	6	https://example.org/photo.jpg	POINT(40.089686 - 88.201511)
3	user_3	2025-11-12 12:00:00	2	4	https://example.org/photo.jpg	POINT(40.112910 - 88.208048)

Table A6. Pivot Table – Neighborhood Temperature Averages by Hour

nbhd_id	time_cst	avg_temp_f	readings_count
4	2025-11-12 11:00:00	47.6	3
4	2025-11-12 12:00:00	47.5	3
5	2025-11-12 10:00:00	43.1	2

Table A7. Pivot Table – Observed Surface Types by Neighborhood

nbhd_id	vegetation_count	pavement_count	rooftop_count
1	1	2	1
4	1	6	2
2	4	2	0