

# DESIGN AND DEVELOPMENT FRAMEWORK FOR AN AIR QUALITY MONITORING WEBGIS

Katelene Panlilio<sup>1</sup>, Raymund Rhommel Sta. Ana<sup>1</sup>, Roseanne Ramos<sup>1,2</sup>, Bernadette Anne Recto<sup>1</sup>, Rodyvito Angelo Torres<sup>1</sup>

<sup>1</sup>Training Center for Applied Geodesy and Photogrammetry, University of the Philippines Diliman, Quezon City, Philippines 1101  
Email: kppanlilio@gmail.com

<sup>2</sup>Assistant Professor, Department of Geodetic Engineering, University of the Philippines Diliman, Quezon City, Philippines 1101  
Email: rvramos@up.edu.ph

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**ABSTRACT:** With the growing number of researches about air quality indices, it is only imperative to present and disseminate the scientific findings to a broader audience. This includes sharing of charts, maps, digital models, and other relevant information. An effective way to accomplish this is through a Web-based Geographic Information System (WebGIS). This study presents the design and development framework of a WebGIS that enables students, researchers, organizations and the general public to (1) access air quality monitoring stations; (2) explore various geographical factors influencing air quality, such as geographical parameters and proximity to emission sources; and (3) geo-visualize research outputs such as regression models, air dispersion models, and other maps. The methodological framework includes requirement analysis, conceptual design, survey of available hardware and software, database design and construction, acquisition of hardware and software, application development, system integration, and use and maintenance. This paper highlights the Conceptual Design's user-centric approach. User-Centered Design (UCD) encompasses both the User Interface (UI) of the platform and User Experience (UX) during its usage. It guarantees that the user's needs are the main priority of the application. To adhere to the principles of UCD, a mockup of the WebGIS was created using Figma, showcasing its core functionalities. This mockup underwent Usability Testing, a step typically done in multiple iterations to allow for discussions, collection of feedback, and evaluation of the application's functionalities. This is critical as it sets the needs and expectations of the users, ultimately saving development time and resources. The results of the testing were then compiled and assessed to determine their feasibility. It is recommended that WebGIS be developed not only to facilitate the monitoring and analysis of air quality and related integrated data but, more importantly, to play a significant role in encouraging collaboration and public involvement throughout the design and development stages, and also in addressing problems and concerns about air quality for urban planning.

## 1. INTRODUCTION

Geographic Information System (GIS) software such as QGIS and ArcGIS, are powerful applications for viewing, editing, and analysis of geospatial information. However, usage of these tools demands technical knowledge and expertise. In contrary, a WebGIS is more appropriate for a wider range of users. It is easier to share and collaborate information in a WebGIS since geospatial data can be accessed from any location with only an internet connection and a web browser. Data visualization and presentation of trends and patterns to scholars, decision-makers, and the general public may be done simply and clearly with the aid of a WebGIS.

The objective of this paper is to enhance the already existing development cycle presented in the paper entitled "WebGIS: Technologies and Its Applications" (Alesheikh et al., 2002), in such a way that it does not only focuses on the technical aspect of creating the WebGIS but also on the user-centric design aspect of it. The paper also defines the system architecture and technologies used to create the air quality monitoring WebGIS of the government-funded project Ambient Air Remote Sensing and Visualization Environment (AiRMoVE) implemented by the University of the Philippines Training Center for Applied Geodesy and Photogrammetry (UP TCAGP).

## 2. WEBGIS DESIGN AND DEVELOPMENT METHODOLOGICAL FRAMEWORK

The methodological framework of the WebGIS platform follows the development cycle established by Alesheikh et. Al. (2002). However, in this paper, this cycle has been modified in such a way that it is further classified into two (2) main aspects: the design and development and that steps 6 and 7 are interchanged. The cycle, as illustrated in Figure 1 with the

relative scope of the designer and developer, involves the following phases: (1) requirement analysis, (2) conceptual design, (3) hardware and software survey, (4) database design and construction, (5) acquisition of GIS Hardware and Software, (6) application development, (7) WebGIS system integration, and (8) WebGIS use and maintenance.

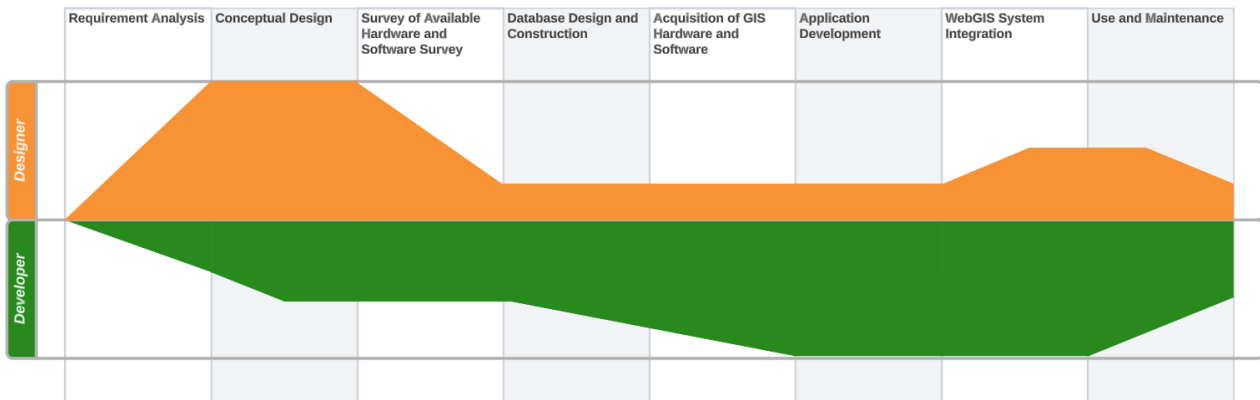


Figure 1. Design and Development Methodological Framework.

## 2.1 Requirement Analysis

In the Requirement Analysis stage, both the designer and developer delineate the scope of the project. It involves identification of the target users and their needs, laying out of the desired functionalities and features of the platform, and listing of available and needed geographical data to be used and displayed in the platform. Furthermore, this stage involves collaboration with potential partners, groups and agencies that are also engaged in monitoring the air quality in the Philippines. These collaborations and meetings allowed the team to gather useful concepts and ideas for the platform and enabled the team to know already existing platforms related to air quality monitoring.

## 2.2 Conceptual Design

Once requirements have been identified, preliminary research about data visualization of the specific products gathered and produced by the project team, the user interface designs and the user experience are conducted. Tools such as Balsamiq and Figma, which are used for creating prototype, are being investigated. Concurrently, research about how these data visualizations can be put into reality are also being conducted. Libraries such as Ant Design for charts and graphs, and React-Leaflet for maps are being explored.

### 2.2.1 Usability Testing of Prototype Using Figma

User-Centered Design (UCD) involves frequent and iterative user participation with designers and developers at various stages of the design and development process. UCD involves both the User Interface and the User Experience (UI/UX). UI refers to the visual presentation of an application, including layout and its look and feel while UX refers to the customer's journey when using the application (Antoun, 2018).

The inclusion of UCD in the methodological framework ensures that it is the target user's needs that are the priority all throughout the development process (Bhrel, 2015). Hence, upon the creation of the prototype, the team conducts usability testing sessions by inviting various participants who represent the different profiles of end users of the project's WebGIS.

The project team intends to cover three (3) main user personas:

- (a) mandated agencies or technical personnel from a government agency whose primary task is to monitor air quality data for regulatory purposes – these can be participants from the Department of Environment and Natural Resources (DENR), Environmental Management Bureau (EMB) or local government units,
- (b) researchers or people from academic and/or non-government institutions that conduct research focused on air quality studies – these are people who frequently need air quality data for their work, and
- (c) students or individuals from universities and colleges that are preferably doing thesis research on air quality or other related fields.

A testing session starts with a set of questions about the participant's background, their experience with using air quality monitoring websites, and their experience with using the internet in general. The next part of the testing then makes the participant look at the webpage without manipulating it. They are then asked about their initial impressions about the site along with their ideas on what the site is about. This is to make sure that the purpose of the site is clear to the people

accessing it as soon as they open it. The next parts are about specific questions for components like Map and Sidebar Panel and the different scenarios that must be completed by the user. The session ends with more questions about features that the participant would have liked to have included in the site to accomplish their own goals and use cases. The guide questions and scenarios are listed in the table below. After the testing session, results were compiled and shared to the team for further assessment.

Table 1. Testing session guide questions

<b>Initial Questions</b>
<ul style="list-style-type: none"> <li>• What is your occupation? Can you tell me something about your course/work?</li> <li>• How many hours a week do you spend on the internet?</li> <li>• What kind of sites do you usually visit or use?</li> <li>• Do you have a favorite app or website?</li> <li>• Do you have any experience using sites that monitor air quality? Can you name a few?</li> <li>• If you did, what features did you like the most?</li> <li>• Do you use air quality data in research? How do you acquire these datasets?</li> </ul>
<b>Initial Impressions</b>
<ul style="list-style-type: none"> <li>• What strikes you about it?</li> <li>• What do you think it is for?</li> </ul>
<b>Questions for Map</b>
<ul style="list-style-type: none"> <li>• Which map tool did you have a hard time using or understanding?</li> <li>• What do you think the color of the markers mean?</li> <li>• Is the marker color enough to show the air quality of the area at first glance?</li> <li>• Is there anything you can think of, a better way to show the air quality?</li> <li>• What do you think needs to be added on the map that would improve air quality visualization?</li> <li>• Do you prefer to make the markers clickable? If so, what information would you expect to see on the tooltip?</li> </ul>
<b>Questions for Sidebar Filters</b>
<ul style="list-style-type: none"> <li>• Do you find this filter list useful?</li> <li>• Are you having a hard time filtering?</li> <li>• What did you think was supposed to be searched on the search bar?</li> <li>• Do you want to add another filter which you think will be relevant in filtering data on the map? If yes, what would it be?</li> <li>• What do you think the green check marks mean? (Active filters?)</li> </ul>
<b>Map View (Scenarios)</b>
<ul style="list-style-type: none"> <li>• Try to zoom in to any place in NCR</li> <li>• Show on the map the roads</li> <li>• Display an elevation layer on the map</li> <li>• If you want to see areas on the map that have high vehicular emissions, what would you do?</li> <li>• Show on the map readings of Airtoday.ph's SO2 and NO2 sensors.</li> <li>• Show on the map city boundaries.</li> </ul>
<b>Follow-up Questions</b>
<ul style="list-style-type: none"> <li>• In what way do you think this app will help with your research/work or day-to-day life?</li> <li>• Which feature did you like the least and why?</li> <li>• Were the filters helpful in searching for the information you need?</li> <li>• Was there anything that was hard to read or was straining to the eye?</li> <li>• What features do you think are missing compared to other similar sites you have used?</li> <li>• Any other thoughts, comments or opinions you would like to share?</li> </ul>

### 2.3 Survey of Available Hardware and Software

In this stage, the designer and developer have to decide the best hardware and software to be used in their respective tasks. For the design aspect, the team has decided to use Figma – a free online tool that is collaborative in nature and is used for creating mockups for software development. Other tools used that aid the project development are LucidChart – used for creating systems diagrams for the architecture and Entity Relationship Diagrams and Miro – visual collaborative tool for brainstorming of ideas.

On the other hand, for the development aspect, an important tool used is Github. It is a version control system used by the team to manage code versions and collaboration between multiple developers. It is a centralized repository hosting

service used by the team to synchronize source code among their development machines. It is also being used as the main source of code deployed on to the staging environment.

### 2.3.1 System Architecture

A schematic for the system architecture of the planned Airmove Dashboard infrastructure was created. As shown in Figure 2, the system is divided into four (4) components: Backend, Frontend, GeoServer, and Automation and Processing Tools.

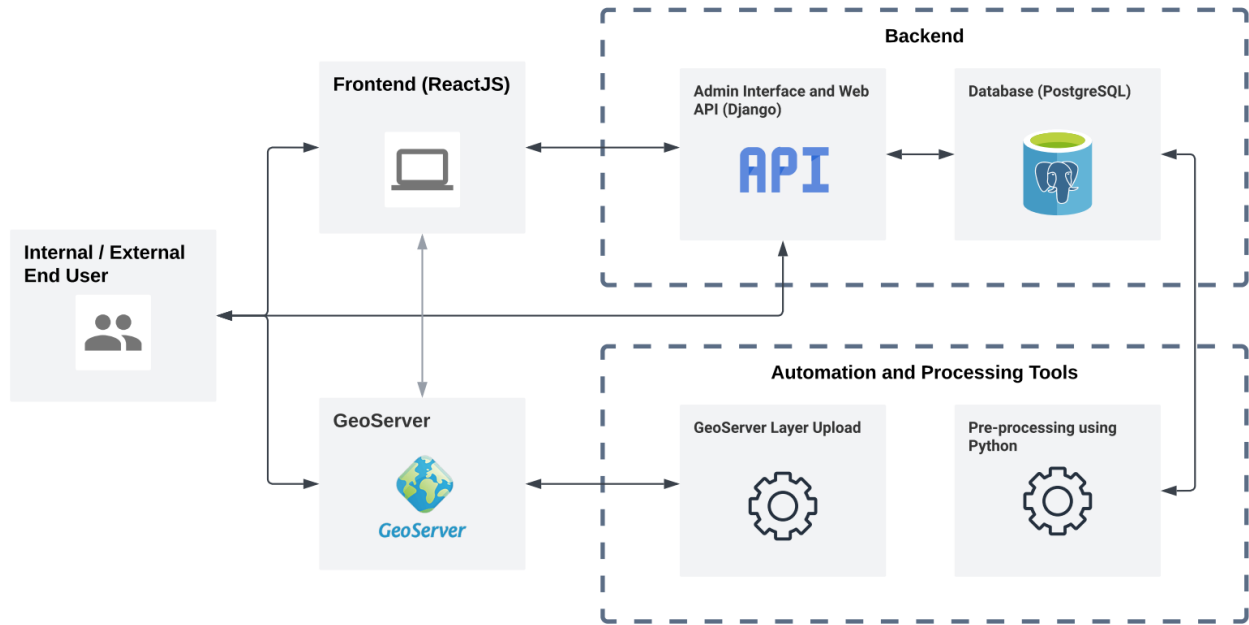


Figure 2. Airmove’s WebGIS System Architecture.

**Backend – Database:** The team developed a structure in which a centralized database system is utilized to host all geospatial information. It is crucial that this centralized system be free and open source to encourage continuous operations and to minimize operational costs. This would also ensure interoperability with other systems that could take advantage of the project’s output. For this, PostgreSQL will be used as a database management system (DBMS) due to its full featured support for geospatial datasets and its strict compliance with the Open Geospatial Consortium (OGC) specifications.

**Backend – Web Application Programming Interface (Web API):** A web-based application programming interface (Web API) is necessary for making the data discussed available to frontend applications. This component will be called the Airmove API. The developers have decided to go with the most commonly used Representational State Transfer (REST) protocol. This will be handled by the Django REST Framework -- a plugin for Django that allows developers to quickly build standard REST endpoints.

**GeoServer:** GeoServer is a Java-based software that implements Open Geospatial Consortium (OGC) Compliant services such as Web Feature Service (WFS) and Web Mapping Service (WMS) that allows for storage, presentation, and sharing of geospatial data for serving raster and vector data types.

**Frontend:** The Airmove Dashboard will be the user-facing component of the system. It will contain features that would allow stakeholders to explore data collected and generated by the project. This component uses a combination of HyperText Markup Language (HTML), Cascading Style Sheet (CSS), and JavaScript (JS) and is built using ReactJS framework – a free and open source front-end Javascript library used to build user interfaces. The Ant Design library is used to display components like bar chart and table while React-Leaflet is used to accommodate map functionalities.

**Automation and Processing Tools:** The team will develop ingestion scripts for pre-processing and uploading of data into the online database. In the ingestion step, data will be formatted in the standards required by the database system.

## 2.4 Database Design and Construction

Database design includes defining how files and geographic layers will be structured and how the different geographic formats (raster, vector) will be presented. In research projects, data is often acquired from various primary and secondary

sources. This phase includes integration and standardization of the data to be presented and visualized (uploading of data to GeoServer, application of styles, naming convention). Database construction involves the actual setting up of the database and map server and development of data models/ schema.

## 2.5 Acquisition of GIS Hardware and Software

Most of the components used in the WebGIS development are free and open source. The server from which the websites are to be deployed is the main concert in the acquisition. Initially, an AWS instance was setup to host the WebGIS Platform. Later on, though, it will be migrated to a hardware server.

## 2.6 Application Development

This step comprises of the actual setup and development of the components of the WebGIS platforms: the backend, frontend, GeoServer, and processing tools. Detailed process of setting up these components can be found in a separate technical documentation prepared by Project AiRMoVE.

## 2.7 WebGIS System Integration

The objective of this step is to integrate the different components of the hardware and software, to connect the backend APIs to the frontend user interfaces and to make sure they function accordingly. The frontend dashboard uses Fetch API to provide an interface for accessing and manipulating requests and responses from the backend API from Airmove and from other external APIs. Consequently, deployment of the application and a series of unit testing are also executed in this step. The purpose of it is to test the system specifications and validate whether they are functioning as expected.

## 2.8 WebGIS Use and Maintenance

This phase involves deployment of actual WebGIS, transfer of repositories and ownership to DENR-EMB and technology transfer. The end goal of this cycle is to put the system to use and maintain support and service to users, and system maintenance.

# 3. RESULTS AND DISCUSSION

## 3.1 Requirement Analysis

During the requirement analysis, the team has identified that target users are personnel from mandated agencies, researchers whose study focuses on air quality, students from universities and non-governmental organizations. Also, a checklist for the recommended design of website applications for air quality monitoring is drafted as a reference for the features that are important to have in an environmental monitoring application.

Table 2. Checklist of features to be included in the WebGIS

<b>Spatial Navigation</b>
Are users able to see a spatial or geometry aspect in the website space (e.g., background map)?
Are users able to use any map tools (e.g., zoom, pan, overview, etc.)?
Are users able to see the spatial distribution of air quality monitoring stations?
<b>Temporal Navigation</b>
Are users able to view historical air quality data?
Are users able to specify a time range for viewing air quality data?
Are users able to view air quality data at a different frequency (e.g., hourly, daily, monthly, annual, etc.)?
<b>Thematic Navigation</b>
Are users able to view legends or descriptions of the values presented?
Are users able to filter individual air pollutants to show on the map?
Are users able to view different visualization tools utilizing air quality data (e.g., line plots, scatter plots, etc.)
Are users able to view different data (e.g., meteorological data or geographical parameters)?
<b>Other Features</b>
Are users able to download air quality data (csv data and charts)?
Are users informed of health recommendations based on air quality index values?
Are users able to leave messages for feedback?
Are users able to print the map?
Are users able to search for a location or automatically determine user's location?

### 3.2 Conceptual Design

#### 3.2.1 Data Visualization

The AiRMoVE Dashboard will allow end users to visualize different datasets relating to air quality and its effects in the community. Possible visualization options for each product were classified.

**Air quality parameters and indices:** These are datasets that describe concentrations of different air pollutants. We will support two main types of air quality parameter datasets: (1) In-situ are parameters measured directly from air quality monitoring stations and sensors. (2) Remote sensing products are measurements done using remotely sensed data such as satellite imagery.

Table 3. List of datasets to be supported under Air Quality Parameters

Product	Visualization
Reference grade stations	Plot station/sensor locations with readings on map Upon clicking on station/sensor location: <ul style="list-style-type: none"> <li>- Show tooltip with current sensor readings</li> <li>- Show historical data</li> <li>- Link to Mapillary or Google Street view</li> <li>- Show recent satellite view</li> <li>- Display images for station and points of interest (eg. factories, roads, etc)</li> <li>- Display recent site photos or video feed if available</li> </ul>
Remote sensing products (SO <sub>2</sub> , NO <sub>2</sub> , PM <sub>2.5/10</sub> )	Gradient maps of air quality indices; Contour maps

**Observational Meteorological Parameters:** Meteorological data are physical parameters measured by instrumentation that can be used by dispersion models. This point information can also be visualized on a map.

Table 4. List of datasets to be supported under Observational Meteorological Parameters

Product	Visualization
Point sources (includes details about temperature, pressure, precipitation, humidity, solar radiation, etc)	Plot as points
Wind speed and direction	Show animation care of api.windy.com
Dispersion model output	Gradient maps; Contour maps

**Geographical Parameters:** Geographical information such as land use, land cover, Digital Elevation Models (DEM), solar radiation, and albedo that will be used by our higher-level data products can also be displayed on the web map. We will also include some supporting geographical parameters such as roads, administrative boundaries, and buildings to help give the viewer context to the model outputs and indices.

Table 5. List of datasets to be supported under Geographical Parameters

Product	Visualization
Buildings	Tiled basemap; Vectors
Roads	Tiled basemap; Vectors
Land use and land cover	Gradient; Vectors
Digital Elevation Models (DEM)	Gradient
Administrative boundaries	Vectors
Solar radiation and albedo	Gradient

**Emission Inventory:** Emission inventories are databases used to map known pollutants found in an area across a period of time.

Table 6. List of datasets to be supported under Emission Inventory

Product	Visualization
Point sources (Location of powerplants and factories)	Plot as points; Link to street view upon clicking
Line sources (Mobile sources such as cars, motorcycles, trucks and buses)	Plot as lines
Area sources (construction activities, kaingin)	Plot as polygons

### 3.2.2 Creation of Mockup Using Figma

An initial mockup was prepared before the actual development process to allow the team to present planned layout and demonstrate the features of the WebGIS to the collaborating agencies such as DENR-EMB, Airtoday, Philippine Space Agency, and Partnership for Clean Air, Inc. during the consultation meetings. The wireframes have been crucial in identifying concerns that our partners may have.

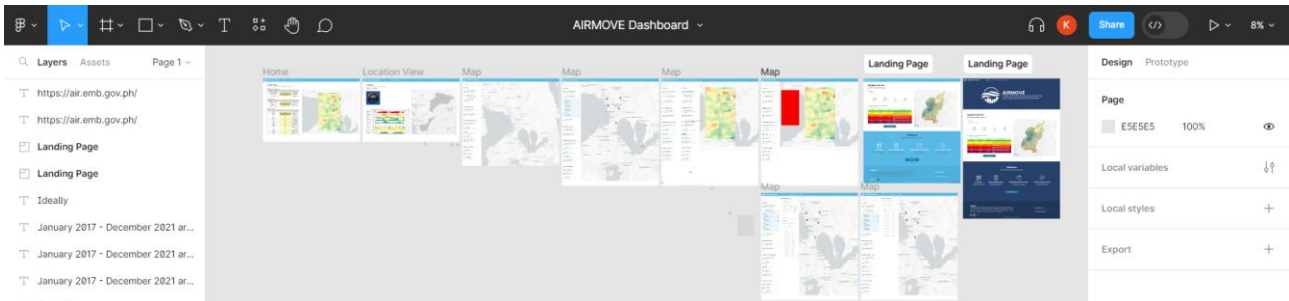


Figure 3. Figma design pages.

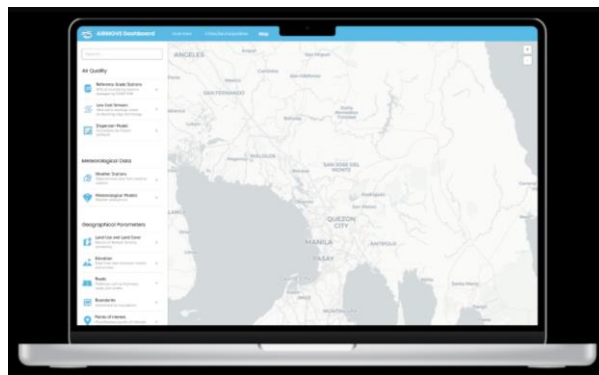
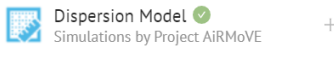


Figure 4. Figma mockup of the map page.

### 3.2.3 Results of Usability Testing

A set of pain points for the users were listed and assessed if they can be addressed feasibly. Below are some of the issues that were identified during the sessions.

Table 7. Usability testing issues and probable solution

Component / Feature	Problem	Solution
Search bar	The search bar feature on the sidebar is used for filtering the datasets. It is not intended to search for a location on the map. Two out of three participants thought that this feature is for location searching.	Update labels on the text box to clearly state what it is for. The team changed the placeholder from “Search...” to “Search datasets...”.
Green check mark 	The green check mark beside a dataset indicates which dataset is active. This could be confusing during testing since it is not fully functional. Maybe through a series of testing or design changes, this feature will be clear.	This feature can be confusing during testing since it is not fully functional. The team believes that this feature will be more obvious once the application progresses in development. This will be confirmed during future testing sessions.
Satellite image	The basemap layer used is CartoDB Light which cannot be used to check vegetation on the map.	Added a selection of basemap layers (OSM, CartoDB-Dark, Carto-DB-Light, ESRI) from which the user can choose from.
Tooltip Information/ Additional Information	Points only show the color of the marker. Users want to display more information about the point	Tooltip shows the current reading from DENR-EMB’s API. Additional information can be displayed upon

	(aggregated data daily, weekly, monthly) and allows filtering.	clicking of the “View downloadable files” icon beside the layer name on the side panel or upon clicking a point on the map.
Interface for filters and downloading of data (CSV, PNG, TIFF)	There is no way yet to filter aggregated data (daily, monthly, yearly) using date range and to download it.	Adds a secondary sidebar that displays the aggregated data with filtering options and download buttons for CSV and PNG file format.

### 3.3 WebGIS Platform

**Backend – Database:** The current database contains Air Quality Stations, Station Types, Parameters, Air Quality Reports (daily, monthly, yearly), Weather Stations, and Meteorological Parameters.

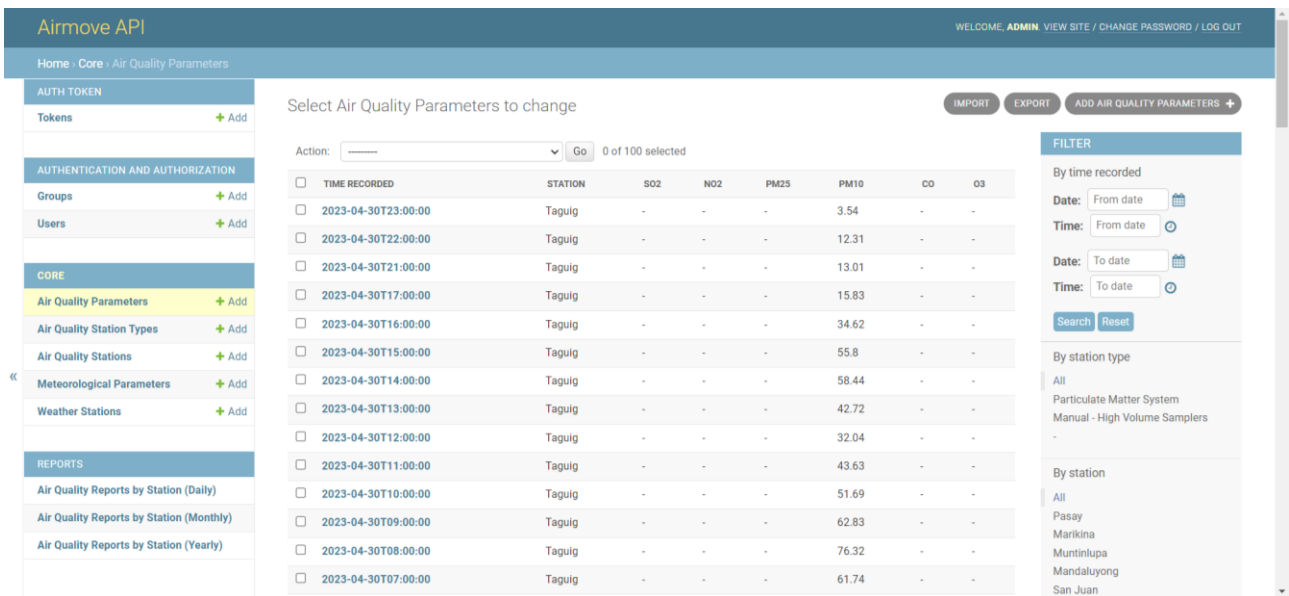


Figure 5. WebGIS Admin Interface.

**Backend - Web Application Programming Interface:** The Web API currently houses seven (7) REST endpoints as shown below, each of which allows exchanging of information in a standard JSON format.

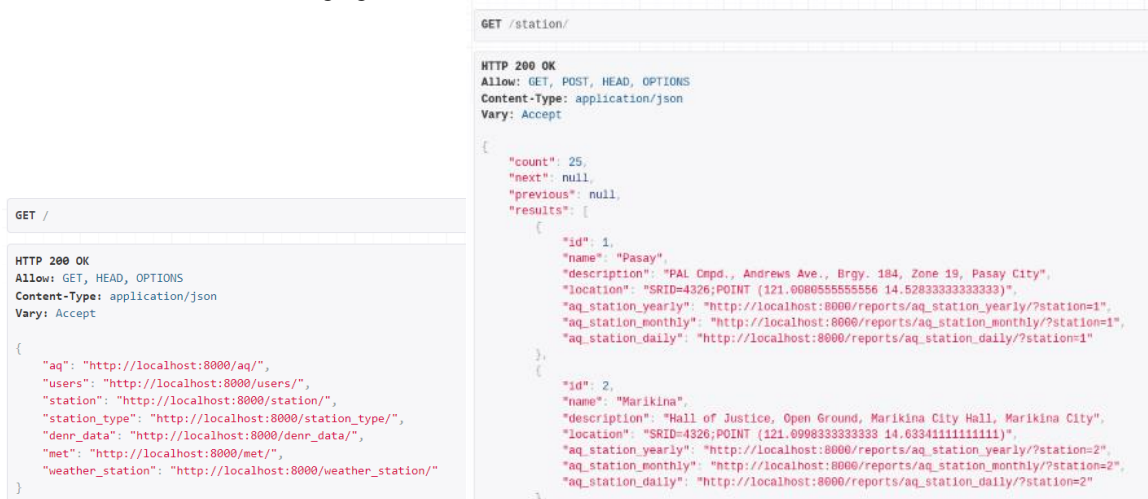


Figure 6. An example output of the root and /station/ endpoint of the Airmove API showing a list of stations loaded in the database.

**GeoServer:** GeoServer currently houses the raster and vector files under the Geographical Parameters such as the land use and land cover, administrative boundaries, and roads. Their corresponding styles can be found and edited in the Styles



section located in the left panel of the page. These layers are fetched in frontend using the leaflet-geoserver-request package which can be found here <https://github.com/iamtekson/leaflet-geoserver-request>.



Figure 7. Geographical parameters uploaded in GeoServer.

**Frontend:** The Airmove Frontend now contains a landing page, a data hub page and a map page. The map page of it is shown in the figure below.

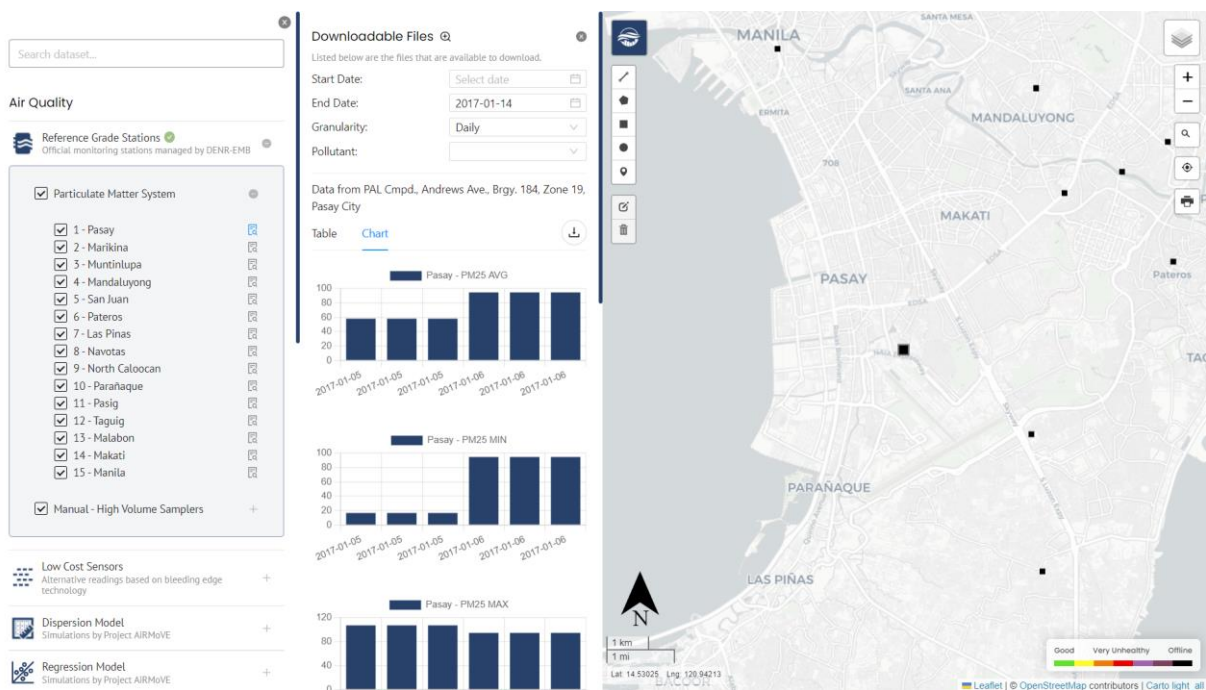


Figure 8. Map page of Airmove Frontend.

Features that have currently been developed in the WebGIS Frontend are the following:

Table 8. Developed components and functionalities of WebGIS

Component	Functionalities
Map	Zoom controls Elements: North arrow, scale, legend Basemap layer Search location Locate me
Sidebar	Shows lists of datasets Shows active/ inactive layers Button to shows historical data of points; Zoom to point Opacity slider for Geographical Parameters
Secondary sidebar (other functionalities)	Table and Chart for Historical Data of monitoring stations Export to CSV for Tables Export to PNG for Charts

Layers that are acquired, pre-processed, and presented in the dashboard are the following:

Table 9. List of datasets already supported under Air Quality Parameters

Product	Visualization
Reference grade stations	Plot station/sensor locations with readings on map Upon clicking on station/sensor location: <ul style="list-style-type: none"> <li>- Show tooltip with current sensor readings</li> <li>- Show historical data</li> </ul>

Table 10. List of datasets already supported under Geographical Parameters

Product	Visualization
Land use and land cover	Vectors
Roads	Vectors
Administrative boundaries	Vectors

#### 4. CONCLUSION

In conclusion, this paper presents a streamlined methodological framework in building a WebGIS. It discusses the design aspect of it which highlighted the importance of prototype, UI/UX, and iterative usability testing. This approach allowed the team to continually recalibrate the system in accordance to users' requirements and expectations. Further, this paper presents also the development aspect including the system architecture and the different technologies, frameworks, and libraries that are utilized. Furthermore, it suggests that WebGIS be developed as more than just a tool for analysis and monitoring of air quality indices. It promotes the idea that WebGIS can be a catalyst for scientific communication and public participation, promoting stakeholder's engagement throughout the different stages of WebGIS creation.

#### 5. ACKNOWLEDGEMENTS

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