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"Open Source GIS Solution: An Overview of the Architecture of Free Open Source Web GIS".

Balqies Sadoun[1], Omar Al-Bayari[1] and Suhaib Al-Tawara

[1] Department of Surveying Engineering and Geomatics Al-Balqa' Applied University, Al-Salt, Jordan

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Abstract

The advancement of modern Information and Communication Technologies (ICT) along with e-governments initiatives and the new digital world, during Covid-19, forced users to look for Free Open Source Software (FOSS) solutions, to serve different normal or specific needs, which is the real drawback of some Commercial software. The digital world is here and it needs modern management using advanced FOSS technology.

We will present an overview of the Architecture of the Free Open Source Web GIS platform to demonstrate its easiness, practicality, and ability to perform effectively and better than commercial GIS tools. The developed platform proposed will be explained based on the succession of published applications of a project which is a "Sewage Infrastructure Network". A Web Map application for the project has been developed; starting from loading the software and data collection to publishing the results on the web. The Add-ons and other complementary software tools were used for full GIS creation and functions with database management, Applications, and an easy online updating of the published data. Applications, publishing, and easy online updating at low cost are major issues to future success and the OS is the solution.

Keywords: Free Open Source Software (FOSS), Geographic Information System (GIS), Web GIS, and Database Systems.

1. Introduction

Newly available solutions which are proposed (FOSS) need to be used to prove their capabilities to replace the expensive Commercial solutions. In previous research using an Open Source (OS) GIS, we created an Application (Water Pipes) for water and sewer complaints submission, using GIS Cloud (Al-Bayari, 2018). Using the app. was expensive to the public users (as they have to pay a fee to the Cloud), which reduced its efficiency. To improve the efficiency, we devised a new solution using the GIS Web app. (Al-Bayari et al., 2020) with little cost to the government we will be able to save expensive wasted resources using FOSS possibilities.

Web mapping is the right medium to circulate your GIS data through the web and publish it. The Creation of a web map is not the same as creating a GIS. To create a web map with GIS characters, you need web programmers and FOSS tools to convert the work in GIS to web maps. Web maps are important to publish maps for their ability to adapt and display in a web browser or a mobile phone. Web maps can be static or dynamic and dynamic maps may be active or interactive. We will present the creation of an interactive web map using QGIS & other Open Source applications for a real web GIS project for the infrastructure of a sewage network

Free Open Source refers to software in which its source code is publicly accessible and users can modify and share their modifications. It opens exchange, mutual participation, clearness, and community-oriented usage and development (Kevane and Gray, 1999). The source code of FOSS is open to all users to inspect, modify, and enhance for their general or specific needs. Its source code is available to all to use, copy, learn, teach, and modify. Computer users, while exporting checking their emails, web pages, or chatting, they use open-source software to route the data to the "local" devices (Tiemann and Initiative, 2009).

The Free Open Source GIS Software was developed as a Desktop GIS, like other GIS software such as Map window but lately, the most common Desk Top GIS solution used is the QGIS (Hugentobler, 2008). QGIS maintained by volunteer developers who continuously release updates, add-ons, and bug fixes. It is used by academics and professionals and translated into over 50 languages. The application of QGIS functions as GIS software allows analyzing and editing of spatial data and information and creating and exporting graphical maps. QGIS supports vector and raster layers, where vector data is stored as point, line, or polygon features. Various formats of raster images are supported in addition to the ability to georeference images. QGIS supports shapefiles, coverage, personal geodatabases, PostGIS, dxf, MapInfo, and other formats. Web services, including Web Map Service and Web Feature Service, are also supported to allow external sources of data usage. QGIS can integrate with other open-source GIS packages, including, GRASS GIS, PostGIS, and Map-Server to offer more functions (Kevane and Gray, 1999). Plug-ins are written in Python or C++ to increase the QGIS's capabilities and usage.

* Corresponding author e-mail: balqiessadoun@bau.edu.jo

2. Discussion and methodology

2.1 Open Source Web GIS Architecture:

The WebGIS platform has different components and software to maneuver, analyze, store, broadcast, publish and envision spatial data. These components should be integrated as a dynamic system or platform using integration tools (Brovelli et al, 2017). The architecture of our proposed Free Open Source solution is presented in Figure 1, where all the main components and integration tools are defined based on the proposed application. The Desktop GIS software is the start point where GIS users can perform data cleaning, processing, structuring, and symbolizing work on their spatial data. In the working process, the spatial data should be stored properly to facilitate the communication between desktop GIS software and the middleware (server GIS software) and supports processing on the website as well (Minghini, 2014). Open-Source relational database systems with spatial extensions are the best to allow the publishing the spatial data. Then, GIS users need the middleware that connects the desktop to the web to publish the spatial data (or a subset of it) using SQL queries, as well as, needs to define the style description (Yao and Zou, 2008). The open-source middleware (server GIS software) provides web map services capability through different GIS standards to perform GIS services.

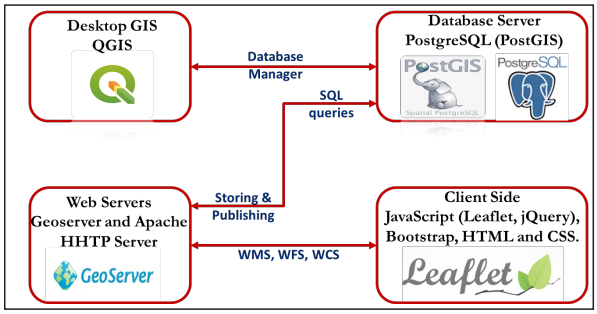

Figure 1. Platform Components and Integration Tools

There are many FOSS solutions to be used to build a WebGIS platform (Moreno-Sanchez, 2012). For demonstration and testing, we will present an easy solution to publish our spatial and non-spatial data using the WebGIS platform.

2.2 Desktop GIS (QGIS)

QGIS is one of the best OS desktop GIS software tools that are globally used by GIS users (QGIS, 2021). It's integrated with different geospatial software like GRASS GIS and SAGA GIS to offer more capabilities and better options. QGIS users can download many plug-INS (available online), which were developed by different GIS users. QGIS is compatible with many operating systems like Windows, Linux, Mac OS, and Android, to be easily used on all devices, especially open-source operating systems. Figure 2, presents the main window of QGIS.

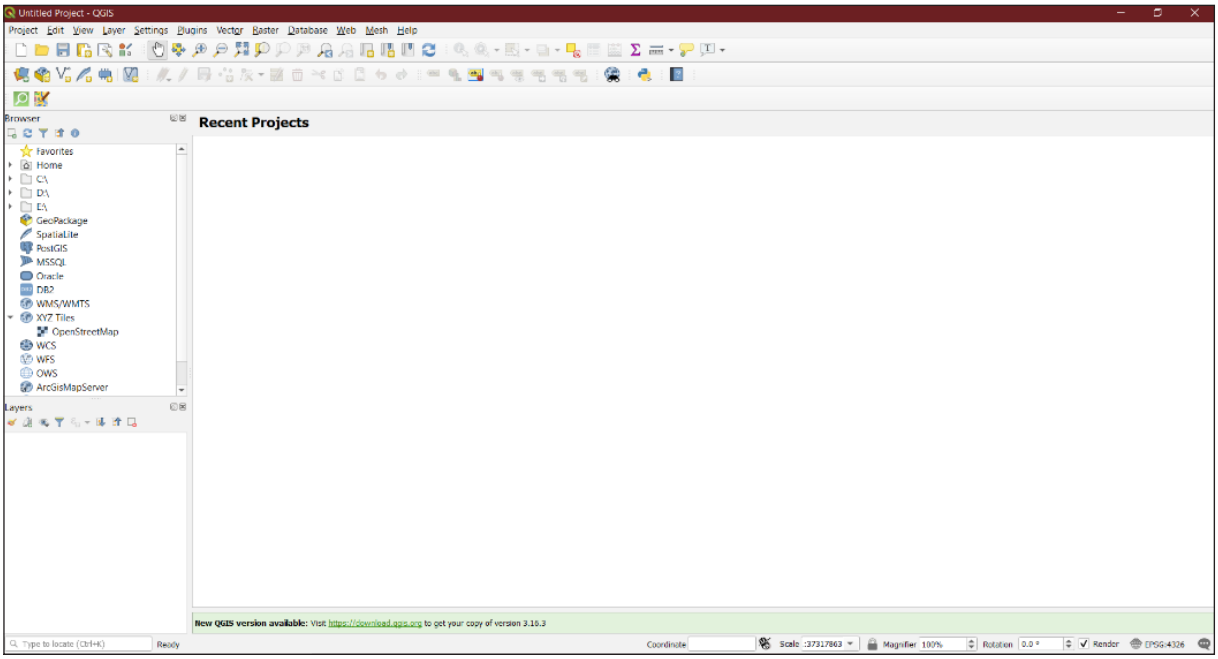

Figure 2. QGIS main Window

2.3 Database

GIS users need a well-built system that can use different data types, as well as, spatial information. PostGIS is a spatial database extender for PostgreSQL object-relational database. It supports geographic objects to allow location queries to be run in SQL. PostgreSQL is an open-source object-relational database system that uses the SQL language combined with many features that safely store and scale the most complicated data workloads (Choi et al., 2015). PostgreSQL has a reputation for its good architecture, reliability, data integrity, strong feature set, and the devotion of the open-source community to deliver great and novel solutions. PostGIS supports different geometry types like points, multi-points, lines, multi-lines, polygons, and multi-polygons (Getman, 2015). Also, it is used to store raster data (PostGIS Raster).

QGIS connects to PostGIS databases, to allow GIS users

to upload the spatial data on PostGIS to edit, update or remove spatial features that are uploaded or created on PostGIS. Using the DB manager in QGIS, the users can identify the connection parameters and start working on uploading, creating, and editing spatial data on PostGIS. Figure 3, displays the Database Manager in QGIS while importing the Shape file of our infrastructure project into PostGIS. Figure 4 displays how the PgAdmin uses the PostGIS extension to visualize, edit, analyze, update and remove spatial data using SQL language. In Figure 4, we can see a display of a part of the created Sewage Network.

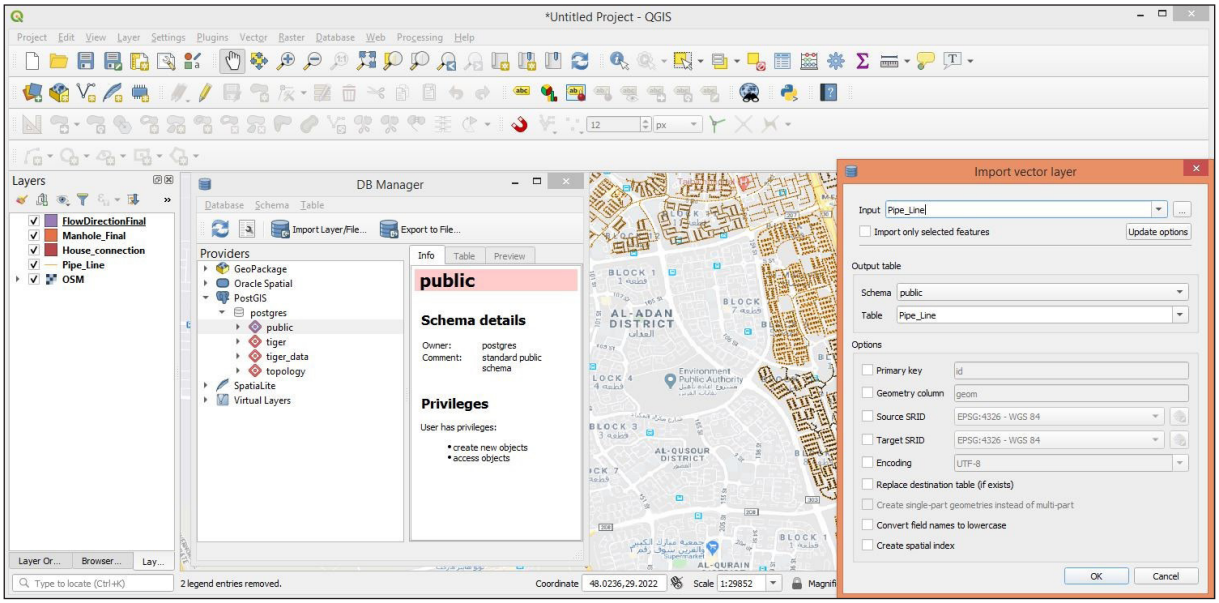

Figure 3. DB manager used to Import and Export spatial data to and from different types of spatial storage (DM Manager used to Import shape files to PostGIS).

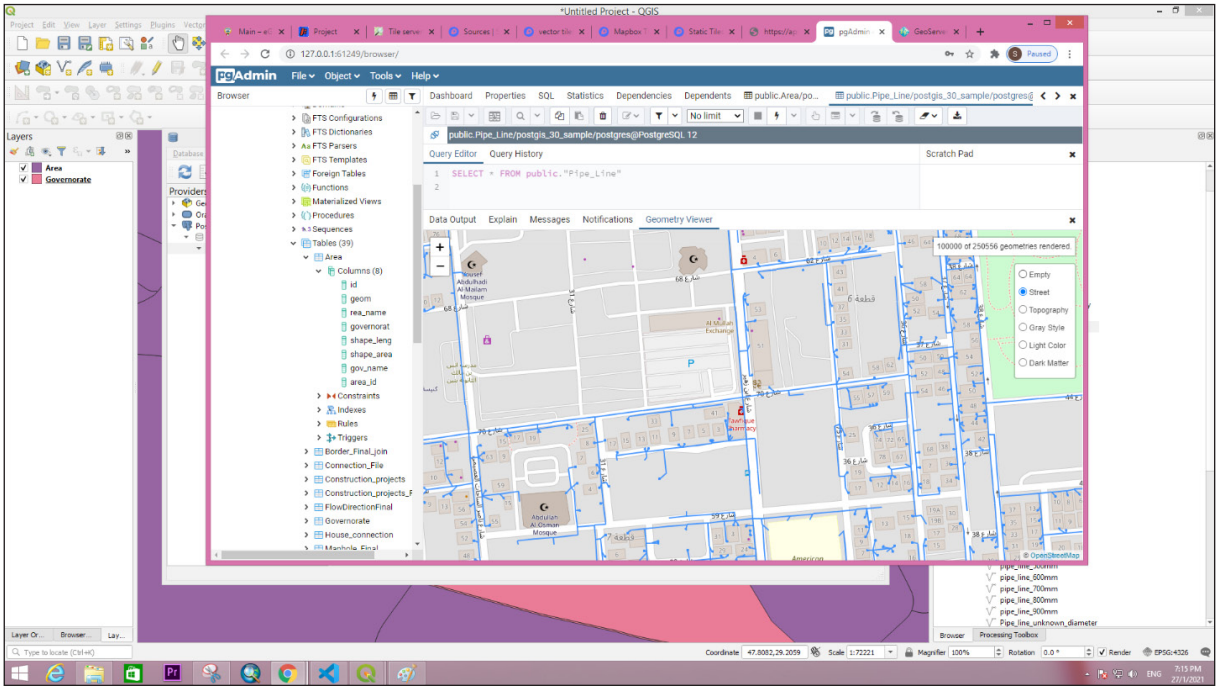

Figure 4. PgAdmin uses the PostGIS extension to visualize, edit, analyze updates, and remove spatial data using SQL language.

2.4 GeoServer

Storing spatial data in PostGIS makes the communication between desktop GIS and GIS servers easier and more efficient. OSGIS server can use PostGIS as a data source or store and can publish the spatial information on the Internet. GeoServer is an open-source server for sharing geospatial data (Yao and Zou, 2008; Garegnani, et al., 2015) It is a Java-based software server that allows users to view and edit geospatial data. GeoServer offers the facility of map creation and data sharing using open standards set out by the Open Geospatial Consortium (OGC), (Brovelli, et al., 2015). GeoServer along with Apache HTTP Server is used to publish spatial data in sync with the current HTTP standards. Apache HTTP Server is a collaborative software development effort for creating a strong, feature-full, free source code implementation of an HTTP (Web) server.

Figure 5, presents the publishing of our project in

GeoServer (GeoServer tools can publish the spatial data directly from PostGIS). Moreover, we will be able to publish updated layers or tables inside PostGIS. The Published data on GeoServer can be shared as WMS, WFS, WCS, and other standards (Steiniger and Hunter, 2012)., as shown in Figure 6, where the GeoServer presents the sewage pipelines as WMS (WMS can be linked with SLD to get a better presentation of the spatial data).

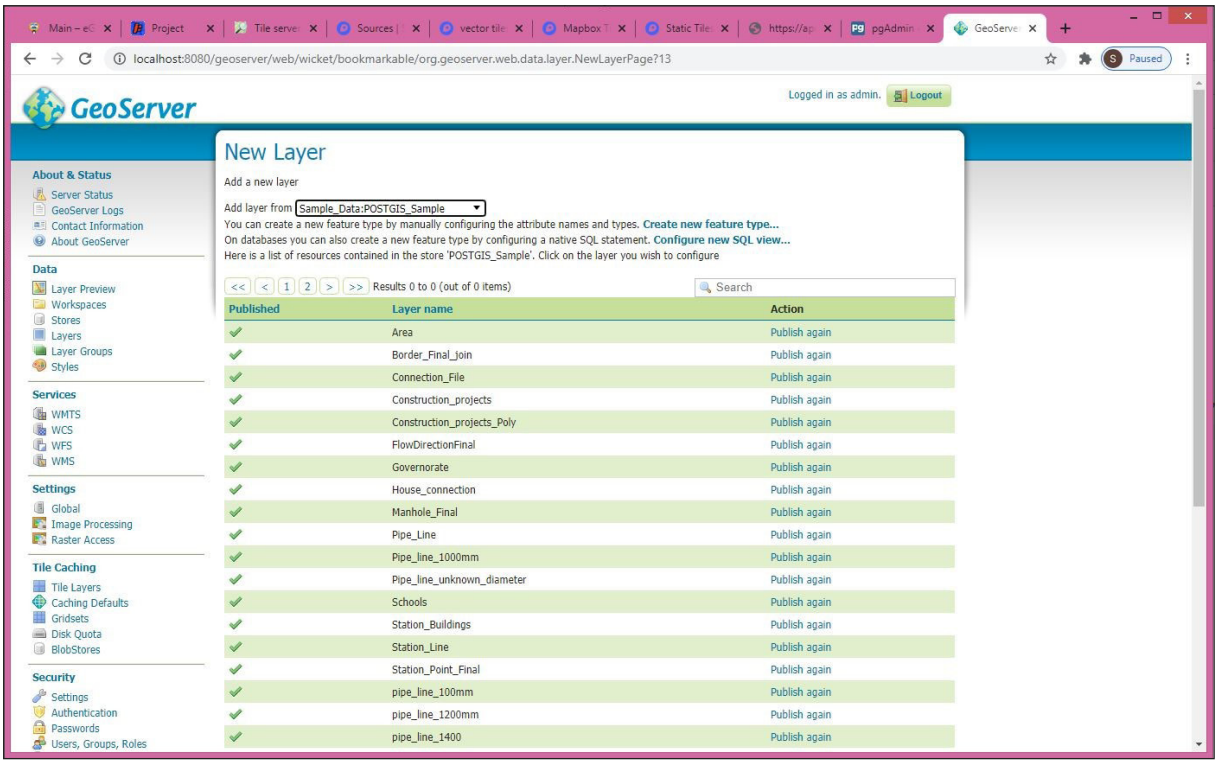

Figure 5. Geoserver can use PostGIS as a store of the spatial data and its tools to publish the spatial data directly from PostGIS or to publish any updated layer or table inside PostGIS.

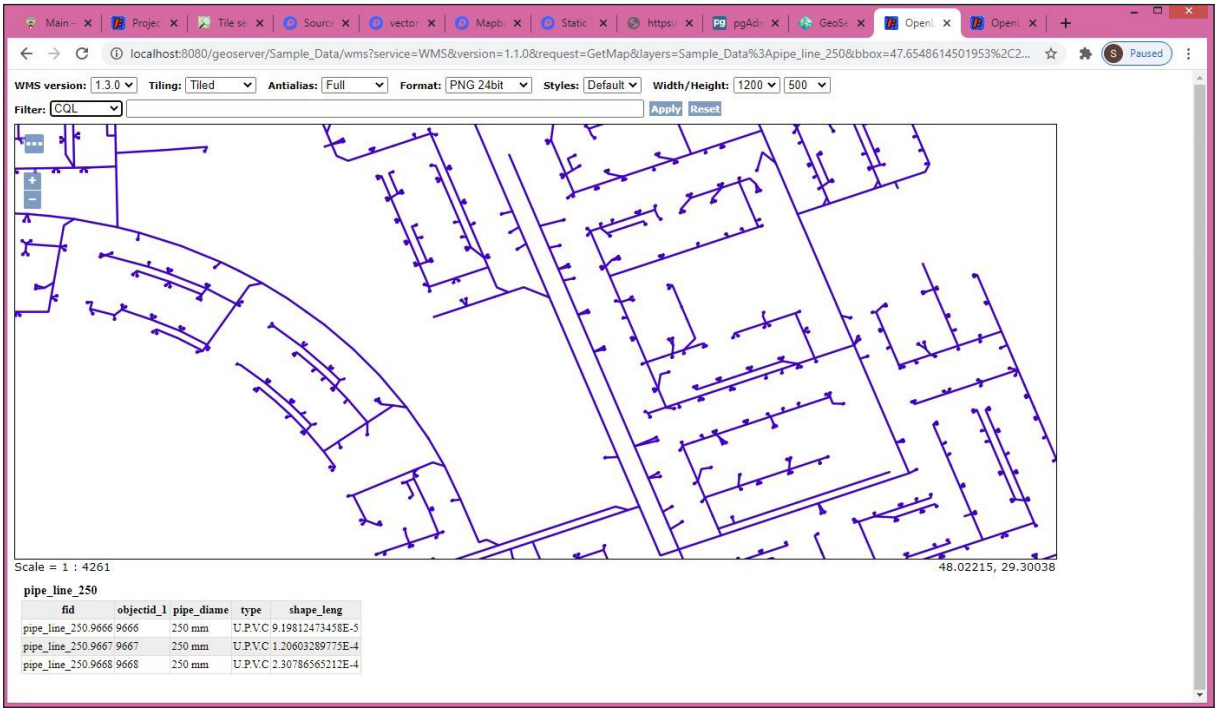

Figure 6. Published data on GeoServer can be shared as WMS, WFS, WCS, and other standards for specific purposes (WMS can be linked with SLD to have better spatial data visualization).

GeoServer serves spatial data using standard protocols established by the Open Geospatial Consortium (OGC) like WMS which supports requests for map images, WFS which supports requests for geographical feature data with vector geometry and attributes, and WCS which supports requests for coverage data (raster data). The Styled Layer Descriptor (SLD) Profile of the Web Map Service (WMS) Encoding Standard defines an encoding that extends the WMS

standard to allow user-defined symbolization and coloring of geographic features and coverage data (Cannata, et al., 2015) SLD addresses the need for users and software to be able to control the visual portrayal of the geospatial data. The ability to define styling rules requires a styling language that the client and server can both understand. SLD can be generated using QGIS and uploaded easily on GeoServer. Published spatial data can be linked with SLD and WMS will show the data with its SLD by default.

2.5 JavaScript (Leaflet, jQuery)

On the client side, JavaScript libraries (Leaflet, jQuery) as well as Bootstrap, HTML5, and CSS, are used to design the web app (client side). The leaflet is an open-source JavaScript library used to design friendly interactive maps. It has many mapping features and functions with simplicity in design. Leaflet facilitates editing, accessing, and communicating spatial data on the client side. Figure 7, presents a sample of a code developed by our team that uses JavaScript libraries, Bootstrap, HTML5, and CSS to design the client side of the GIS web application.

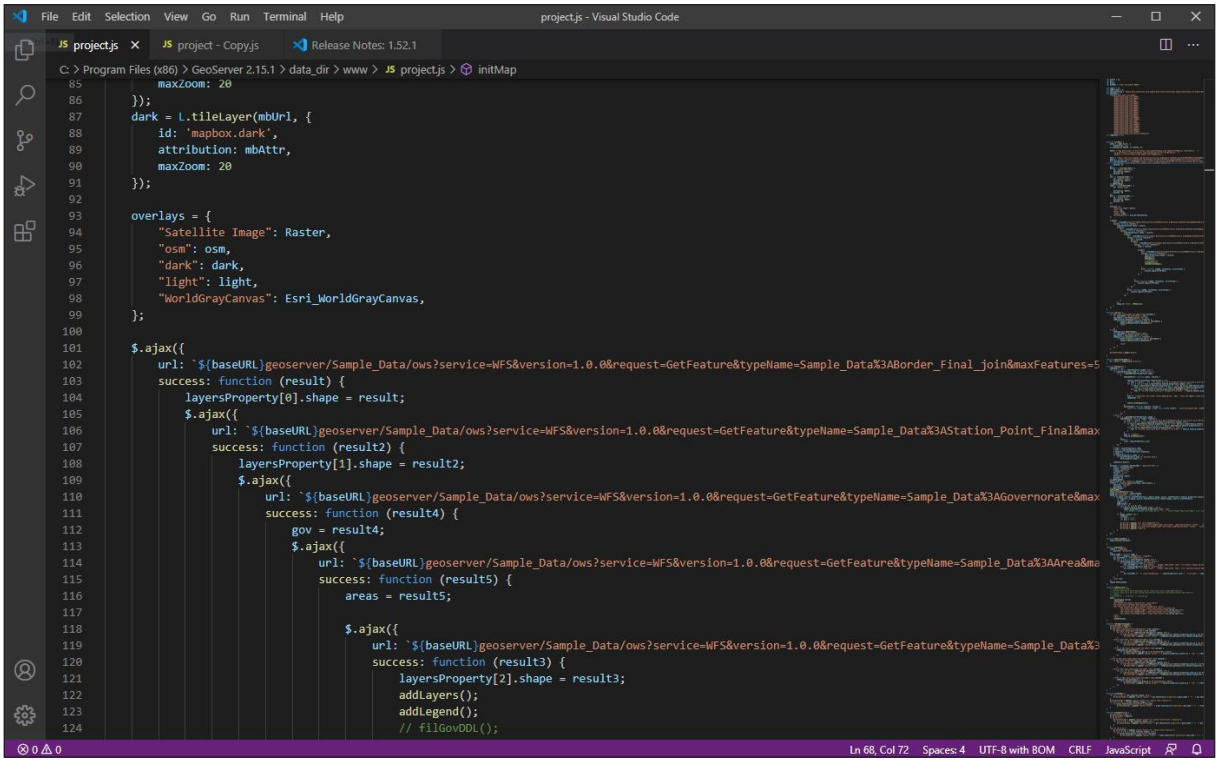

Figure 7. Sample of a code that uses JavaScript libraries, Bootstrap, HTML5, and CSS to design the client side of the GIS web application.

2.6 Web GIS Application Interface

The application interface displays the different layers, satellite images, and non-spatial data, it consists of two frames, where the main components are the navigation tools (zoom in and zoom out), and search tools (load different layers and satellite images). Figure 8, presents the main viewer displaying some pipelines and manholes in our published project "Sewage Network".

Figure 8. Sample of the final output – a web interactive map containing different services like WMS and WFS. WMS is symbolized and described by SLD attached with the spatial layers on GeoServer.

3. Sewer Network Description:

A Sewage network is composed of sewer lines that are connected at junction points, which are considered nodes. The sewer lines and nodes are treated as a geometric network. Geometric networks offer a way to model common networks water flow, manholes capacity, and pipes diameter can be modeled and analyzed using geometric networks (Najeeb, 2017). Many factors and data should be considered in the planning and design of sewage networks, such as the determination of population equivalent, peak flow, type and size of pipe, flow velocities, invert level, and outlet level, (Figure 9). Sewer Cad or excel sheet could be used to design the pressure flow and gravity flow through the pipelines and pumping stations.

The FOSS GIS platform is used to display and show old sewage networks, new networks, and designed infrastructure projects in the city, where the decision-maker can study and analyze the expansion of sewer networks based on GIS capabilities.

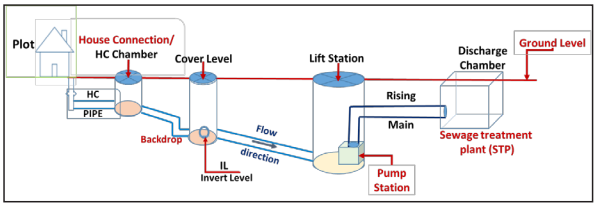

Figure 9. Sewage Network Components

4. Results and discussion

Researchers did many comparisons between commercial and OS software for different important technical points of view according to needs and functionality such as data type and data consumption, data processing, speed of processing, editing, and the type of results (Veenendaal, et al., 2017; Sandhya, 2017) to proof OS efficiency. We are presenting two new operational processes which were needed for the processing of our application, to test the effectiveness of our platform, and to set up a working process that will help future OS users follow to get the needed results for two specific tasks:

1- Data conversion, from Cad to GIS for sewer networks: the main feature of our WebGIS platform is to display the sewer networks on the WebGIS for planning and future applications purposes. It is well known that the design of Sewer Networks is done and stored in Cad design. It is not possible to upload these files into GIS without the data migration process from Cad to GIS format, for display and further analysis. Most commercial software such as ArcGIS well defined procedure for data conversion (based on the ArcGIS documentation or user manual). Commercial GIS software uses ETL tools to convert the Cad file into a GIS shapefile. Using OS software, such as QGIS the data conversion needs more time and a right well-defined setup for data conversion. Figure 10 presents the flowchart of the processing to convert the Cad files into QGIS. We get much better and correct results using the proposed process compared to when using the plug-in tools provided by QGIS (Particularly for Sewer Networks). The resulting conversion of Cad files is shown in Figure 11. As a result of our research, we set up a process (Figure 10) to convert Cad Files into GIS (Shapefile or PostGIS) using OS QGIS, for Cad files (Sewer Network data), which will better help the OS QGIS users.

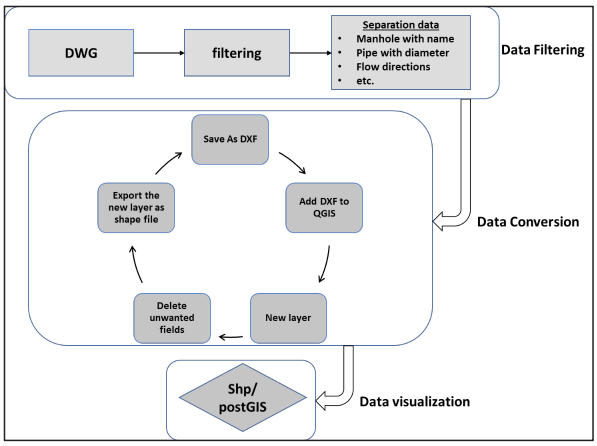

Figure 10. The flow chart of the proposed methodology of converting Cad to shapefiles using OS QGIS

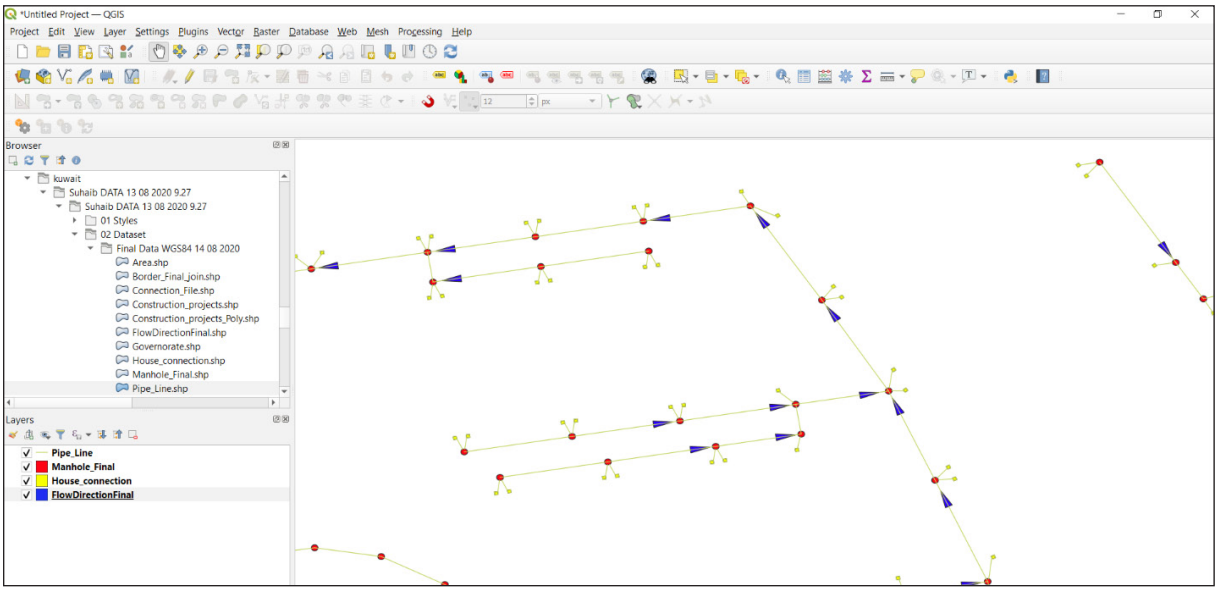

Figure 11. Sewer Network converted from CAD to GIS in QGIS

2- Dynamic update of published data on WebGIS using QGIS: Most Commercial software such as ArcGIS Enterprise can update the GIS database through direct connection with Desktop applications, the process of updating, and publishing data is very difficult and needs GIS experts. In our OS Application we set a much easier procedure to be followed by the GIS users, (Figure 12). OS offers the possibility to developers to master the GIS concepts and direct the functions to get the needed results from the Application. To update the GIS data, we edit the PostGIS spatial data in QGIS and then the data is published directly in Geoserver (Figure 13). Similar to the archiving process using ArcGIS enterprise tools, PostGIS can be used to track the edit history on the spatial tables using the trigger system, so it should be easy to see how has the data changed between two dates, who made the changes, and where did they occur?

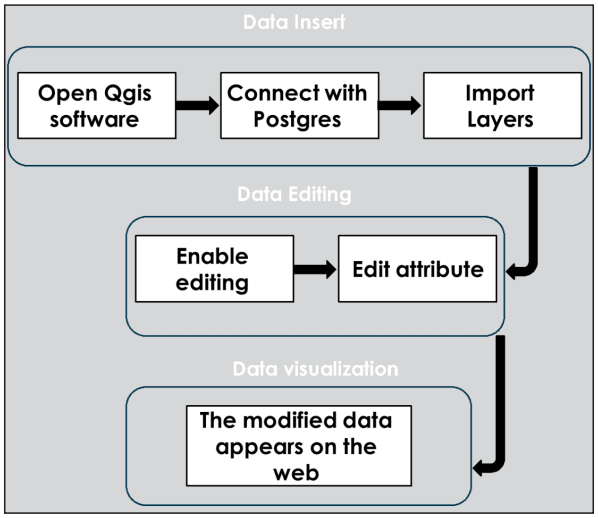

Figure 12. Flow chart process for updating data using OS Web GIS (Geoserver) and QGIS

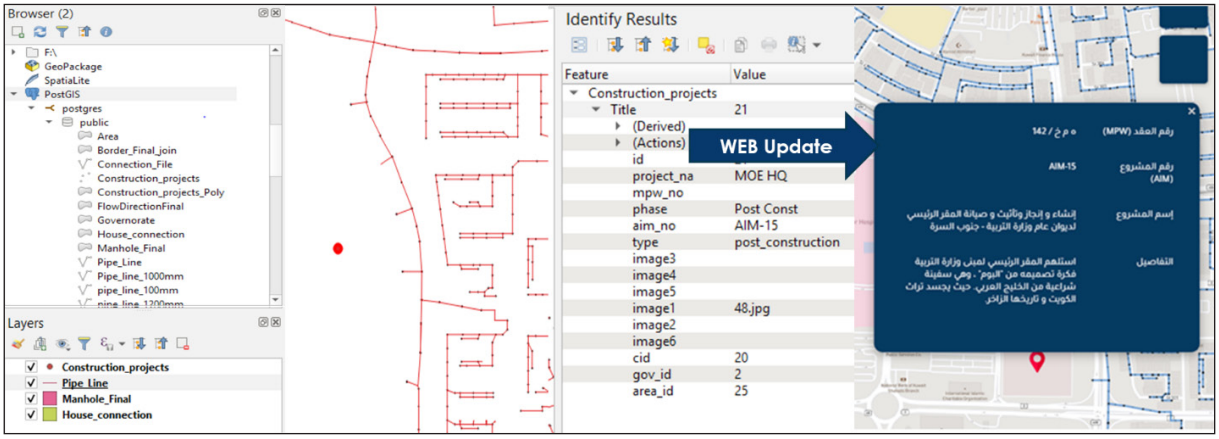

Figure 13. Example of update GIS Data on Geoserver using QGIS

4. Conclusions

We concluded with the following comments:

- OS software could be modified for general and specific needs, which is the real drawback of some expensive commercial software. It is constantly developing and under-verifying due to its open nature. OS solution offers the possibility-free of charge Applications.
- QGIS is an Open Source GIS that offers an easy-to-use solution at no cost and in no time. It is easy to install for MS Windows and Mac OS X. QGIS has an easy-to-use graphical user interface (GUI), providing common functions and features. It supports different raster and vector data formats and a new format is easily added using the plugins. QGIS is released under the GNU General Public License (GPL), so you can inspect and modify the source code, and guarantees that you have access to a GIS program as long as you need (stability).
- Publishing the data on the GeoServer allows for creating a Web Map Application. We can build the Code of the Web Map Application by Leaflet js. To allow the code to identify the linked data (from Geosphere) we had to alter the settings of the GeoServer by (Enable CORS). Enable CORS: The standalone distributions of GeoServer include the Jetty application server. Enable Cross-Origin Resource Sharing (CORS) allows JavaScript applications outside of your domain to use GeoServer.
- In this work we offered the methodology to follow using OS QGIS to acquire the following: a) An easiness and freedom in serving specific needs while using the available data (Cad files), b) more correct data conversion than using QGIS plug-ins, c) the creation of an efficient application and its web mapping processing, using QGIS OS, d) The ability and ease of the online updating of the published GIS without the need to a GIS expert contrary to the situation in case of using the QGIS plug-in tools, and finally e) we were able to do it all at a third of the cost when using Commercial software. We believe the future will be the use of the OS anywhere at any time.

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References

Al-Bayari, O. (2018, July). GIS cloud computing methodology. In 2018 International Conference on Computer, Information and Telecommunication Systems (CITS) (pp. 1-5). IEEE.

Al-Bayari, O., Sadoun, B., & Shatnawi, N. (2020). An Internet and wireless networking-based water pipes web application for fault reporting. International Journal of Communication Systems, 33(8), e4363.

Brovelli, M. A., Minghini, M., & Zamboni, G. (2015). Public Participation GIS: a FOSS architecture enabling field-data collection. International Journal of Digital Earth, 8(5), 345-363.

Brovelli, M. A., Minghini, M., Moreno-Sanchez, R., & Oliveira, R. (2017). Free and open source software for geospatial applications (FOSS4G) to support Future Earth. International Journal of Digital Earth, 10(4), 386-404.

Cannata, M., Antonovic, M., Pozzoni, M., & Graf, A. (2015, April). Open Source and Open Standard based decision support system: the example of lake Verbano floods management. In EGU General Assembly Conference Abstracts (p. 11233). (accessed: 10 March 2021)

Choi, J., Kim, H., Ahn, J., & Kim, J. (2015). FOSS4G for rapidly urbanizing cities and UN sustainable development goals (SDGs); SDG 11 cities and human settlement. In Seoul, Korea: LH-OSGeo Joint Seminar: Open Source GIS for UN and Developing Countries.

Denver, September 24, 2015.

Garegnani, G., Geri, F., Zambelli, P., Grilli, G., Sacchelli, S., Paletto, A., Curetti, G. ,Ciolli, M., and D. Vettorato, (2015). "A new open source DSS for assessment and planning of renewable energy: r. green" Geomatics Workbooks, Vol. 12, pp. 39–49

Getman, Dan. 2015. "Visualization and Analysis of Spatiotemporal Data Using Free and Open

Hugentobler, M. (2008). Quantum GIS. In S. Shekar and H. Xiong (Eds.), Encyclopedia of GIS (pp. 935–939). New York: Springer.

Kevane, M., & Gray, L. C. (1999). A woman's field is made at night: Gendered land rights and norms in Burkina Faso. Feminist Economics, 5(3), 1-26.

Minghini, M. (2014). Multi-dimensional GeoWeb platforms for citizen science and civic engagement applications.

Moreno-Sanchez, R. (2012). Free and Open Source Software for Geospatial Applications (FOSS4G): A mature alternative in the geospatial technologies arena.

Najeeb, Z. (2017). Evaluation of Combined Sewer Network Design Using GIs and Multi-Criteria Decision Making (MCDM). Al-Nahrain Journal for Engineering Sciences, 20(5), 1143-1153.

QGIS, (2021), https://qgis.org/en/site/ (10 March 2021)

Sandhya, M. C. (2017). Exploring opportunities with open source GIS.

Sandinska, Y. (2016, June). Technological Principles and Mapping Applications of Web GIS. In 6th INTERNATIONAL CONFERENCE ON CARTOGRAPHY AND GIS (p. 287).

Source Software at the National Renewable Energy Laboratory." Presented at GIS on the Rockies,

Steiniger, S., & Hunter, A. J. (2012). Free and open source GIS software for building a spatial data infrastructure. In Geospatial free and open source software in the 21st century (pp. 247-261). Springer, Berlin, Heidelberg.

Tiemann, M., & Initiative, P. O. S. (2009). How open source software can save the ICT industry one trillion dollars per year. retrieved July 3, 2009.

Veenendaal, B., Brovelli, M. A., & Li, S. (2017). Review of web mapping: Eras, trends, and directions. ISPRS International Journal of Geo-Information, 6(10), 317.

Yao, X., & Zou, L. (2008). Interoperable internet mapping—an open source approach. Cartography and Geographic Information Science, 35(4), 279-293.