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The geographic information system dashboard prototype of Brantas River, East Java

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Abstract. The Brantas River has vital functions, such as being a source of drinking water, as a cultivation facility, as a means of transportation, as a recreation area, and as a conservation site. Therefore, there needs to be a system that can monitor the water quality of Brantas River. The purpose of this research was to develop a prototype of the Brantas River geographic information system dashboard as a water quality monitoring system. The research stages included area study, wireless sensor network selection, system architecture design, physical data modelling, system application module development, and system implementation. The research prototype can be used as a real-time water quality monitoring system with good results from testing evaluation.

1. Introduction

Rivers have vital functions, such as being sources of drinking water, cultivation facilities, means of transportation, recreation areas, conservation sites, etc. Technological and industrial developments have provided two impacts, namely positive and negative impacts. One of the negative impacts is the disruption of the balance of natural ecosystems around industries, especially in river water. The higher the activity of the people in an area, the more likely for the level of pollution and for the spread of waste to be higher [1]. The decrease in water quality will also reduce the effectiveness and carrying capacity of the water source, which ultimately leads to the decline in the amount of natural resources.

In 2011, the Environmental Office of East Java Province (DLH-JATIM) issued a report on the results of their study that the sources of river pollution in East Java were domestic waste (50%), industrial waste (40%), and other sources (10 %) [2]. This shows that the sources of river pollution can be found in the surrounding environment.

So far, DLH-JATIM has been conducting Water Quality Monitoring (WQM) using the conventional approach. There are several weaknesses with this approach, including data acquisition that is not real-time and human error during the data acquisition process [3] [4]. Currently, research related to water quality monitoring that can be carried out automatically and real time has been developed, which is divided into two parts, namely upstream and downstream research. An example of upstream WQM is a wireless sensor network-based WQM (Wireless Sensor Network, WSN) system [5] and Internet of Things (IoT)-based WQM-WSN [6] [7].

Meanwhile, downstream research is related to spatial-temporal data visualization [8]. The following studies have integrated WSN with Geographic Information Systems (GIS) [9].

GIS is an information system that is used to enter, store, recall, process, analyze, and produce geographic or geospatial-based data to support decision-making in a planning process [10]. The use of GIS helps decision-makers (stakeholders) to point out polluted river areas.

2. Literature Review

2.1 Research area
The East Java Province is located at 111˚0 'to 114˚4' East Longitude and 7˚12 'to 8˚48' South Latitude. The total area of East Java province is 46,428 square kilometers, which is divided into four regional coordination bodies (Bakorwil), 29 regencies, 9 cities, and 658 districts with 8,457 villages / sub-districts (2,400 sub-districts and 6,097 villages).

In general, the East Java region is divided into two major parts, namely mainland East Java covering almost 90% of the total area of East Java province with 47,157.72 square kilometers and the Madura Islands region covering about 10% of the total area of East Java. In the north, the province of East Java borders the Java Sea, and in the east it borders the Bali Strait. In the south, the province borders open waters, namely the Indonesian Ocean, while in the west it borders the Central Java province.

The two most important rivers in East Java are Brantas River (290 km) and Bengawan

Solo River. The Brantas River covers nine districts, namely: Malang, Blitar, Tulungagung, Trenggalek, Kediri, Nganjuk, Jombang, Mojokerto, and Sidoarjo, as well as six cities, namely: Malang, Batu, Blitar, Kediri, Mojokerto, and Surabaya. The Brantas River has a spring in the Malang area. Arriving in Mojokerto, Brantas River breaks into two: Kali Mas and Kali Porong. Both empties at the Madura Strait. Bengawan Solo comes from Central Java and empties into Gresik [11].

2.2 Water quality monitoring
Water Quality Monitoring (WQM) is an activity to conduct periodic sampling and analysis of the conditions and characteristics of water [12]. In essence, WQM activities include monitoring water sources such as rivers, streams, lakes, ponds, springs, reservoirs, groundwater, cave water, floodplains, and wet runways, which aims to ensure that water sources are safe for living activities [5] [13] [4]. WQM is also used in monitoring water for industrial purposes [14].

2.3 Wireless sensor network
Wireless Sensor Network (WSN) is an ad-hoc network system consisting of several low-cost components with low sensing power consumption. The capability of the WSN is to sense, calculate, and transmit data [15]. Thus, WSN has the components of data acquisition, wireless transmission networks, and data processing centers. The data acquisition section is equipped with sensors, processing modules, and communication [16].

2.4 Geographic information system
Geographic Information System (GIS) is a computer system that manages spatial-temporal data [17] [18]. GIS consists of 5 components, namely hardware, software, people, methods, and data [19]. The details are as follows:

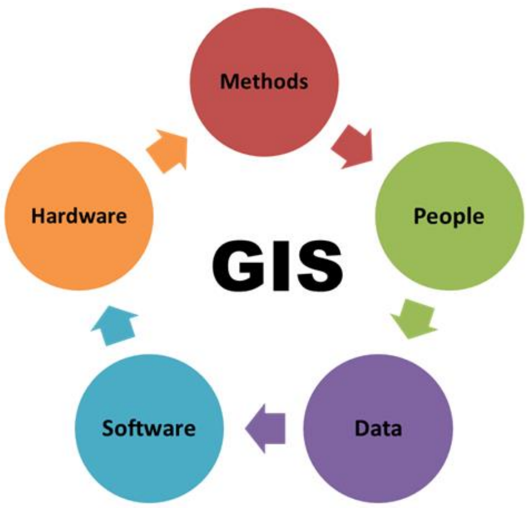


Figure 1. GIS components

1. Hardware
   Computer devices used to store, manage, and display data.
2. Software
   The GIS software provides functions that are used to store, analyze, and display geographic information.
3. People
   Users who use GIS software.
4. Methods
   The success of GIS management depends on good planning and business processes that adjust the needs of users/organizations
5. Data
   The most important component of GIS is data. Geographical data or other related data can be stored inside or outside the organization. GIS will integrate spatial data with other data sources and can involve a Database Management System.

Geospatial technology is a very important part of information systems by providing detailed information about the spatial attribute data of objects in the real world. The Google Earth API library is widely used to develop GIS. Google through Google Map API provides code blocks that can be used to modify maps according to user needs [20].

The purpose of this study was to build a prototype of the Brantas River Geographical Information System Dashboard (DSIG) architecture in East Java, Indonesia.

3. Research Methods

3.1 Area study

As shown in Figure 2, the Brantas River Flow Area (DPS) is located in the western part of East Java Province. The main river flow is circular, starting from Sumber Brantas on the slopes of Mount Anjasmara and from the western slope of Mount Semeru. The two streams meet in the mountainous area under the jurisdiction of Batu City. From the lower reaches of Karangkates Reservoir, the Brantas River flows towards the west through Kota Blitar and turns north towards Kediri. From Kediri, the river flows through Nganjuk, turning east through Jombang, then Kertosono, until it reaches Mojokerto. In the downstream of Mojokerto City, the Brantas River is split into Kali Mas and Kali Porong.

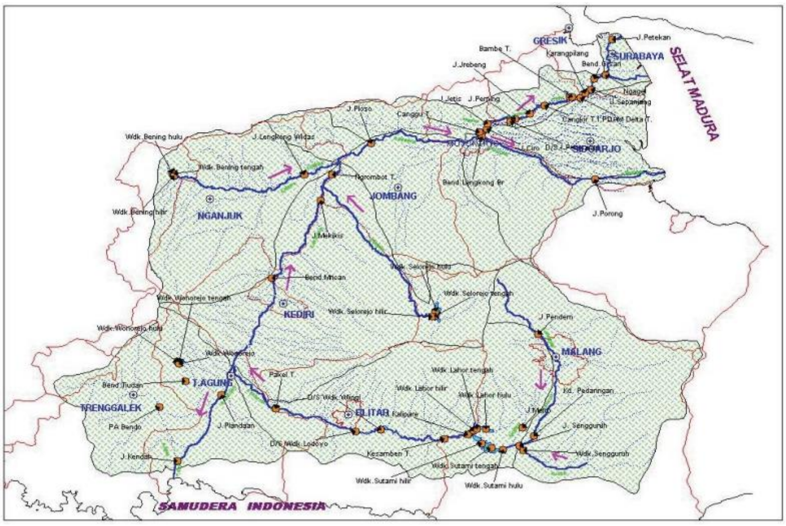


Figure 2. Brantas river flow area (Source: Perum Jasa Tirta I)

3.2 Selection of wireless sensor network

Research related to wireless devices that used low power consumption and have high data acquisition capabilities has been initiated under the name Wireless Sensor Network (WSN) [21].

From the previous explanation, WSN, which is a wireless device, can also be referred to as an independent or autonomous node and with one or more sensors in it. This node is equipped with transmitters and receivers that communicate wireless with other nodes or with a gateway. The gateway is responsible for transmitting data from the sensor to the base station that is responsible for providing Wide Area Network (WAN) connectivity across the local network. The data sent is then available to the recipient via the user interface [8].

The sensor used in this design was WSN with high data acquisition performance, which is also easily programmable by users.

3.3 System architecture design

As shown in Figure 3, the Brantas River DSIG system architecture consists of 3 main parts. The explanation is as follows:

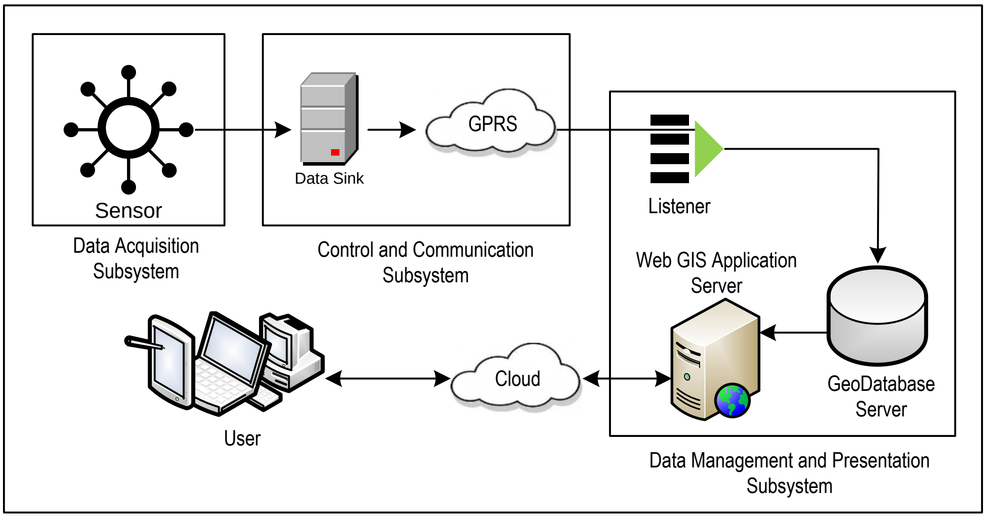


Figure 3. System architecture

a. Data acquisition: This section consists of several sensors scattered in several points of the research area. These sensors capture data based on the parameters to be analyzed.
b. Control and Communication: This section functions to collect, monitor, and control data coming from sensors and forward the data to the next section (data management and presentation).
c. Data Management and Presentation: this section periodically receives data from the system described in section b. Furthermore, these data are processed and stored in the geodatabase and then accessed by the GIS application.

3.4 Physical data model system

From Figure 4, the tables made in the Brantas River DSIG system are grouped into two parts, with the following explanation:

a. Spatial tables: tables that are equipped with spatial attributes (latitude and longitude). There are two spatial tables used by the system, namely the sensor table which stores sensor information disseminated in the research area and cluster tables which store population information such as industrial zones and residential housing in the vicinity of the research area.

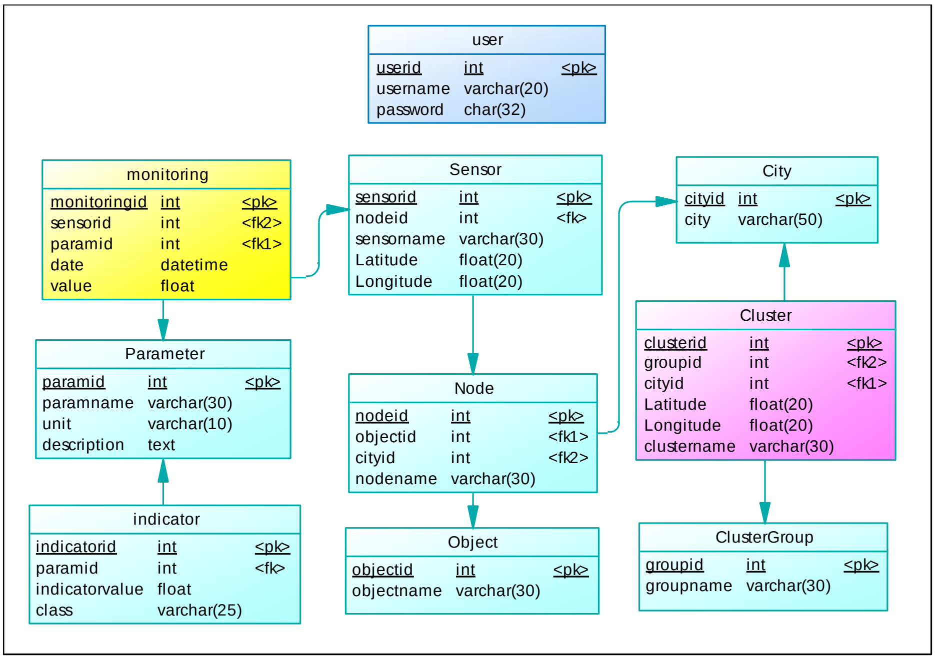


Figure 4. Physical data model system

b. Non-spatial labeling: this table has no spatial attributes. There are eight non-spatial tables created in the system. The first the indicator table that stores information on water quality indicator values such as class 1, class 2, and so on. The second is the parameter table that stores information on water parameters used in analysis such as water pH, Biological Oxygen Demand - BOD), and so on. The third is the monitoring table that stores information on the values of each parameter sent from the sensor. The fourth is the node table that holds nodes controlling the sensor. The fifth is the object table that stores information about the types of objects observed such as rivers, lakes, water sources, and so on. The sixth is the city table that stores city or regency information. The seventh is the Cluster Group, which stores information on population groups such as heavy industry, light industry, and so on. The last is the user table that stores system users' login data.

3.5 GIS application modules

From Figure 5, the GIS application has four main modules, namely:

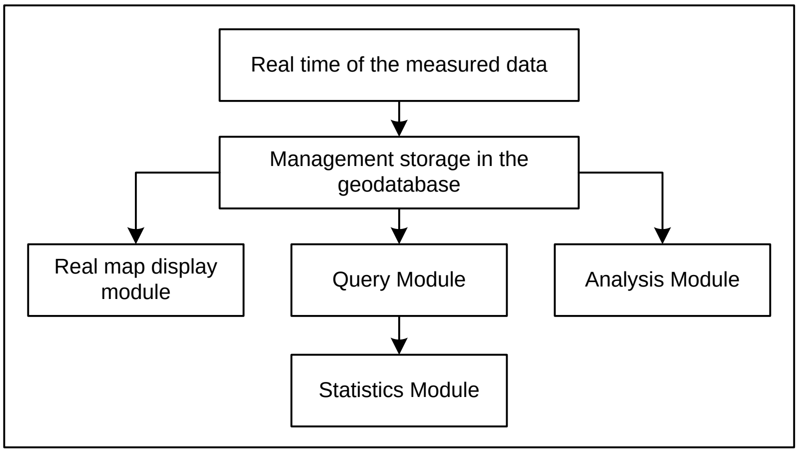


Figure 5. GIS application modules

a. Real map display: displays a map of the observation area in real time.
b. Query: finds information stored in the geodatabase according to user requests.
c. Statistics: displays outputs from the query module in the form of tables or graphs.
d. Analysis: performs calculations on the analysis parameters used in the study.

4. Results and Evaluation

4.1 Results

From this study, the following results have been obtained.

Figure 6 is an interface that provides information on the results of water monitoring from each city that the Brantas river passes through. Figure 7 is an interface that provides information on industrial populations or households that are around the Brantas river. Meanwhile, Figure 8 is an interface that provides information on pollution categories in each observation area.

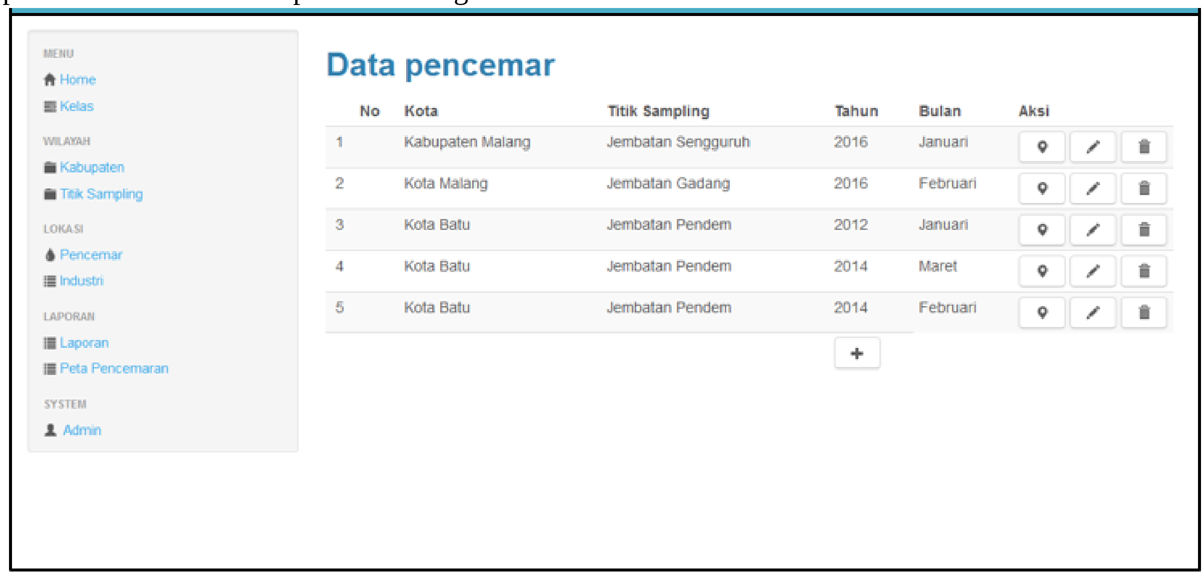
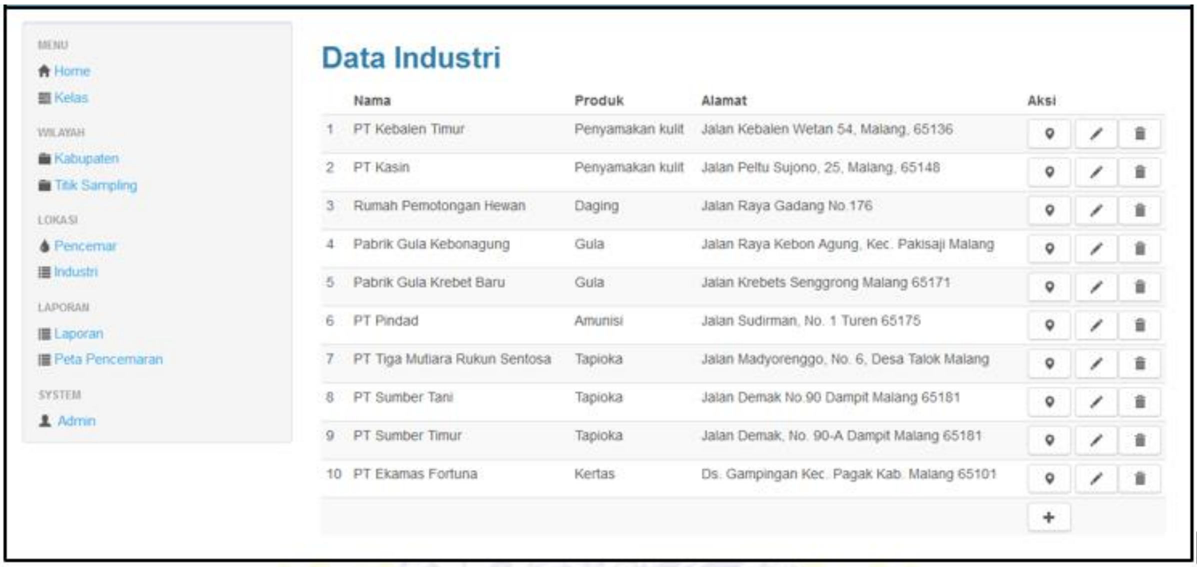
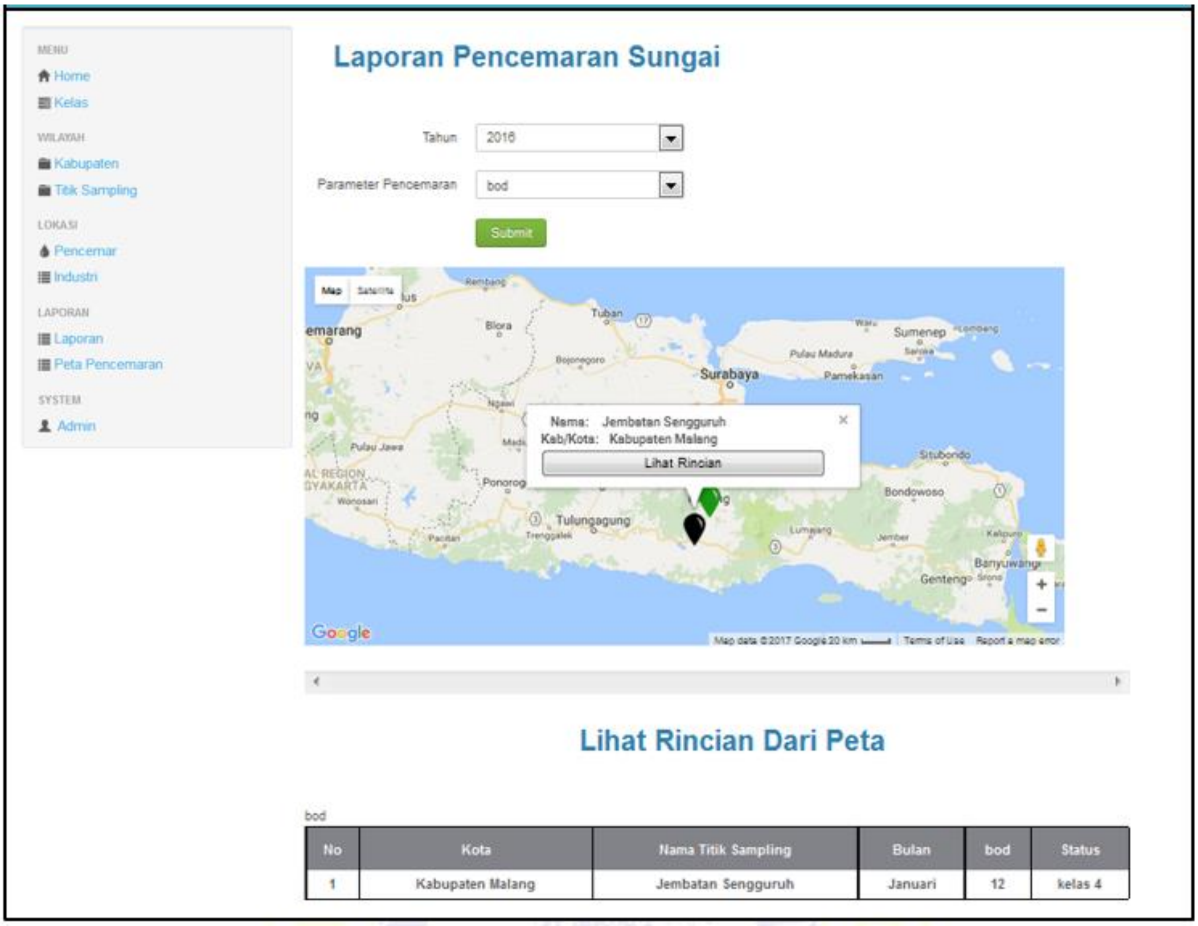


Figure 6. Pollution data



	Nama	Produk	Alamat	Aksi
1	PT Kebalen Timur	Penyamakan kulit	Jalan Kebalen Wetan 54, Malang, 65136	
2	PT Kasin	Penyamakan kulit	Jalan Peltu Sujono, 25, Malang, 65148	
3	Rumah Pemotongan Hewan	Daging	Jalan Raya Gadang No.176	
4	Pabrik Gula Kebonagung	Gula	Jalan Raya Kebon Agung, Kec. Pakisaji Malang	
5	Pabrik Gula Krebet Baru	Gula	Jalan Krebets Senggrong Malang 65171	
6	PT Pindad	Amunisi	Jalan Sudirman, No. 1 Turen 65175	
7	PT Tiga Mutiara Rukun Sentosa	Tapioka	Jalan Madyorenggo, No. 6, Desa Talok Malang	
8	PT Sumber Tani	Tapioka	Jalan Demak No.90 Dampit Malang 65181	
9	PT Sumber Timur	Tapioka	Jalan Demak, No. 90-A Dampit Malang 65181	
10	PT Ekamas Fortuna	Kertas	Ds. Gampingan Kec. Pagak Kab. Malang 65101	

Figure 7. Industry data



No	Kota	Nama Titik Sampling	Bulan	bod	Status
1	Kabupaten Malang	Jembatan Sengguruh	Januari	12	kelas 4

Figure 8. Pollution report

4.2 Evaluation

System evaluation was carried out using ISO 9126 quality standard testing, which has four characteristics, namely functionality, reliability, use, and efficiency. There were 7 respondents who filled out the questionnaire to test the quality of the Brantas River DSIG. The respondents' responses to the Brantas River DSIG quality level according to ISO 9126 can be measured using the formula equation 1.

$$\% \text{ Actual Score} = \frac{\text{Actual Score}}{\text{Ideal Score}} \text{ x } 100\% \quad (1)$$

where:
- the actual score is the answer of all respondents to the questionnaire that had been submitted.
- the ideal score is the highest score, or all respondents are assumed to choose the answer with the highest score.

Afterwards, the interval value was calculated to determine the rating category by the formula in equation 2.

$$\text{I} = \frac{100\%}{\text{Number of score criteria (likert)}} \quad (2)$$

Finally, the results were calculated and processed with the criteria set out in table 1, namely:

Table 1. Criteria for Percentage of Respondents' Responses to Ideal Score [22].

% Total score	Criteria
0% - 24.99%	Insufficient
25% - 49.99%	Satisfactory
50% - 74.99%	Good
75% - 100%	Very Good

The Brantas River DSIG software testing is viewed from several aspects, namely functionality, reliability, use, and efficiency. Th test results by aspect are as follows:

a. The majority of respondents strongly agree that the Brantas river GIS has good criteria for all aspects.
b. The percentages of respondents' scores for each aspect are s follows: functional aspects with 76%, reliability with 73%, usage with 75%, and efficiency with 77%.

5. Conclusion

Based on the results of the research described earlier, the conclusions obtained are as follows:
a. the prototype of the Brantas River Geographic Information System Dashboard architecture can be used as a a water quality monitoring system in real time.
b. Software testing results of the Brantas River Geographic Information System Dashboard yields a good qualification.

Suggestions based on the results of this study are as follows:
a. Sensor selection needs to consider the battery capacity.
b. The election of a sampling points needs to consider the strength of the communication signal

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