

# Development of a Water Quality Management Decision Support System Using a 3D Platform and SWAT Model

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## A large blue circle containing the word "PART" in white, bold, uppercase letters. Below the word is a large, white, stylized number "1" that is partially cut off by the right edge of the circle.

# Introduction

# 01 Introduction

## ❖ Point source pollution and Non-point source pollution in Urban Watershed



- Problems in water quality management due to point and non-point pollution sources in urban watersheds.

→ Continuous monitoring is necessary.

# 01 Introduction

## ❖ Limits of monitoring

- Due to the high cost required for monitoring, watershed models are used for watershed management.
- Various watershed models (SWAT, HSPF, etc.) are being used for modeling.
- The SWAT model is considered as one of the most suitable models for predicting long-term impacts of land management measures on water, sediment, and agricultural chemical yield in large complex watersheds with varying soils, land use, and management conditions

**water**

Article

### The Effect of Rice Straw Mulching and No-Tillage Practice in Upland Crop Areas on Nonpoint-Source Pollution Loads Based on HSPF

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Academic Editor: Kelly T. Morgan  
Received: 18 January 2016; Accepted: 8 March 2016; Published: 17 March 2016

**Abstract:** This study evaluates the watershed-scale effects of non-point-source (NPS) pollution by caused by rice straw mulching and no-tillage applications in upland crop areas using the Hydrologic Simulation Program-Fortran (HSPF) model. The study area is the Dujinui-chon watershed (1.21 ha) of South Korea. Hourly rainfall, discharge and stream water quality data were collected for 49 years (2011–2013) at the watershed outlet. The HSPF model under conventional (no rice straw mulching or tillage) conditions was calibrated and validated using 20 rainfall events for runoff, 14 rainfall events for stream water quality (sediment, TN and TP). The average Nash-Sutcliffe model efficiency value for runoff was 0.61, and determination coefficients for runoff, sediment, total nitrogen (TN) and total phosphorus (TP) were 0.70, 0.56, 0.58 and 0.61, respectively. The results of experiments with slopes of 3% and 8% for radish and sesame cultivation showed decreases in runoff ratio, sediment, TN and TP of 8.0%, 95.9%, 22.6% and 43.3% for rice straw mulching 8% and 22.5%, 67.8 and 70.6% for no-tillage plots. The HSPF model parameters soil infiltration capacity (INFLT), soil bulk density (BD), wilting point (WP) and field capacity (FC) were control for the upland crop areas during the evaluation of the rice straw mulching and no-tillage effect. The HSPF evaluation using the application of Best Management Practices (BMPs) showed that watershed runoff ratio, sediment, TN and TP values were reduced by 10.4%, 68.7%, 31.6% and 41 using rice straw mulching and 21.5%, 83.4%, 51.9% and 60.2% under no-tillage conditions compared with conventional conditions. The land use change scenarios for the baseline (upland crop area 3%), Scenario 1 (upland crop area 10%) and Scenario 2 (upland crop area 30%) were applied in model. The results of the evaluation show that the proportion of NPS pollution loads increased a ratio approximately equal to that of the increasing upland crop area.

**Keywords:** HSPF watershed modeling; nonpoint source pollution; rice straw mulching; no-till upland crop areas

September 2010 International Agricultural Engineering Journal Vol. 31, No. 2, 22

### Modeling of point and non-point source pollution of nitrate with SWAT in the Jajrood river watershed, Iran

Mahdi Jamshidi, Masoud Tajrishy, Mahdi Maghrebi

(Environment and Water Research Center (EWRC), Department of Civil Engineering, Shahrood University of Technology, Sahrood, Iran)

**Abstract:** The Lajan dam reservoir is one of the most important drinking water sources for Sahrood. Since it is a major water quality problem in this reservoir. The Jajrood River, the most important water source for the reservoir, discharges large amount of nitrate to a river year including high levels of nitrate, a pollution of public concern. This study presents the results obtained from simulating different point source and nonpoint source inputs on the land and drainage of nitrate in the 470 km<sup>2</sup> Jajrood watershed using the Soil and Water Assessment Tool (SWAT) model version 2009 (SWAT2009). The SWAT model was calibrated and validated over an extended time period (1970–2008) for the watershed before evaluating the effects of various management practices on nitrate loading on Jajrood River. The results of monthly calibration, Nash-Sutcliffe coefficient of efficiency (E) and R<sup>2</sup> for runoff at the watershed outlet were 0.92 and 0.91 respectively, and for the validation, these statistics were 0.77 and 0.69 respectively. The values for calibration of daily nitrate load at the watershed outlet were 0.10 and 0.79 respectively and for the validation these statistics were 0.16 and 0.76 respectively. The statistical results indicate that nonpoint source and loading of both point sources are the main sources of nitrate loading to the Jajrood river system. Runoff from orchards is the other significant source of nitrate. Moreover, monitoring indicates that the maximum flow rate and nitrate load in the Jajrood River occur from February to June, which implies that at high flow rates the nitrate load increases in the river.

**Keywords:** SWAT2009; watershed modeling; nitrate; point and non-point source

© Chaitan, Mahdi Jamshidi, Masoud Tajrishy, and Mahdi Maghrebi. 2010. Modeling of point and non-point source pollution of nitrate with SWAT in the Jajrood river watershed. Iran. International Agricultural Engineering Journal, 19(2): 21–26.

### 1 Introduction

During the last decade in Iran, costly measures have been taken to reduce water pollution caused by point sources. These measures included installation of wastewater treatment for major cities and some towns. However, lack of proper treatment system in most Iranian towns and villages has resulted in pollution emissions from these point sources, which has resulted in these point sources being an important source of pollution to watersheds. In addition, nonpoint pollution also occurs from nonpoint sources, including cropland and forest tree orchards.

The Lajan dam reservoir is one of the most important drinking water resources for Sahrood, the capital city town, which supports a population of over 8 million in metropolitan area. The reservoir provides about 60% of Sahrood's freshwater. The latest report indicates that nitrate pollution is a leading cause of contamination in the Lajan reservoir, much of which transported to the reservoir by different nitrate sources. This is especially true for the Jajrood river, which discharges considerable amounts of nitrate (as phosphorus) to the reservoir on an annual basis.

Since the Jajrood River flows from a wide variety of sources that vary greatly in magnitude, to meet decades nitrate concentrations in the Jajrood river has increased significantly due to a lack of sufficient management and uncontrolled application of fertilizers in agricultural production, and entrance of nitrate

### Analysis of non-point source nitrogen pollution in watersheds based on SWAT model

Xiaoli Zhang<sup>1,2,3</sup>, Peng Chen<sup>1</sup>, Ji Shengyan Dai<sup>1</sup>, Yonghua Han<sup>1</sup>

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<https://doi.org/10.1016/j.aspen.2022.100881>

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### Highlights

- Based on SWAT model and different scenario settings.
- Quantitative identification of nitrogen pollution sources.
- Analysis of the causes of change over time and under different land use.
- The main source of non-point source pollution TN is atmospheric dust.
- The main land type of non-point source pollution TN is dryland.

### Abstract

By simulating and estimating non-point source pollution in Luoyang, the spatial distribution of nitrogen pollution sources in this region were revealed, provided a decision-making basis for further promoting non-point source pollution control and governance. Based on the SWAT model and different scenarios, 4 nitrogen pollution sources in Luoyang from 2009 to 2018 were quantitatively analyzed and the reasons for their changes under different pollution sources and different years were analyzed. The results show: From the analysis of different pollution types, the main sources of non-point source pollution total nitrogen (TN) are fertilizer application, atmospheric deposition and soil nitrogen reservoirs, as pollution brought by livestock and poultry breeding and rural life is relatively small. The results show: From the analysis of different land use types, the main source of non-point source pollution TN is atmospheric deposition (18.13%)>nitrogen fertilizer application (14.77%)>rural life (12.58%)>livestock (12.36%)>soil nitrogen pool (0.24%). Different pollution sources have different periods, the key period for controlling natural sources (soil nitrogen pool and atmospheric deposition) is the rainy season, while the focus for controlling

### Critical source areas' identification for non-point source pollution related to nitrogen and phosphorus in an agricultural watershed based on SWAT model

Di Chang, Zhongqiang Li<sup>✉</sup>, Shuo Li<sup>✉</sup>, Dan Li & Jun Zhou

Environmental Science and Pollution Research 28: 47162–47181 (2021) | [Cite this article](#)

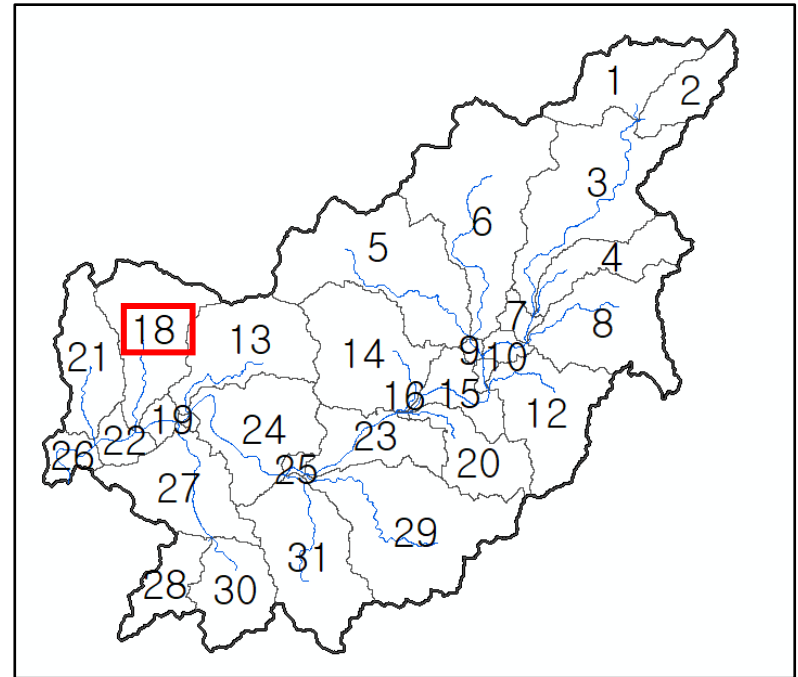
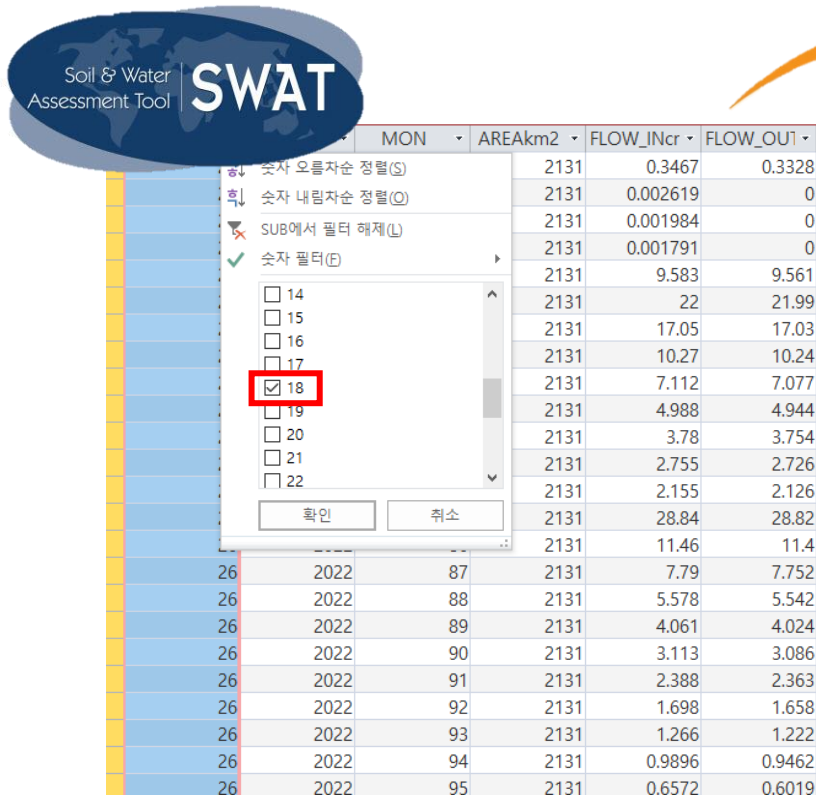
1142 Accesses | 9 Citations | [Metrics](#)

### Abstract

Water eutrophication caused by the extensive expansion of slope farming has caused the high attention of the Chinese government. We choose Lake Tianmu basin as the study area because it can represent vast majority of basins plagued by water eutrophication derived from slope village in southern China. The water ecosystem in the reservoir Daxi and Shahe within the basin has been seriously threatened by multiple pollution sources related to many intricate human activities especially agricultural production. For the first time, we identified the critical source areas (CSAs) within the basin based on nutrient load and nutrient load intensity (NLI), and on this basis, we further excavated the main causes of pollution and proposed pertinent remediation measures. The results based on the calibrated Soil and Water Assessment Tool model indicated that the TN load of each reservoir remarkably exceeded their respective water environmental capacity from 2014 to 2018. Accordingly, six main tributaries with great nutrient contributions and their corresponding sub-basins were then identified. Overall, tea and rice plantations appear to be the major nutrient contributors to reservoir Daxi. And the main nutrient sources for reservoir Shahe are tea plantations, orchards, farmland, forestland, and point sources. Regarding the CSAs identified only by nutrient load, agronomic measures such as reducing fertilizer amount, biochar application, straw incorporation, and plastic mulch coverage can be employed to improve soil water retention and curb soil erosion. Regarding the CSAs identified by nutrient load intensity (NLI), the CSAs with narrow areas should be turned directly into forestland. For the CSAs with large areas, engineering measures such as constructing ecological riparian zone, filtration, and sedimentation tank can be employed to prevent pollutants from entering downstream reaches. Overall, the research results can provide

# 01 Introduction

## ❖ Limits of SWAT Results



- While overlaying SWAT results data on a GIS map allows observation the variability of water quantity and water quality in each watershed, it is important to note that this process can be time-consuming and cumbersome, which is a drawback.
- It has a limitation that it is difficult for users who have no experience in the GIS program to proceed.

# 01 Introduction


## ❖ Digital Twin

- Digital twin technology creates a virtual replica of an object in reality, allowing for advanced predictions through computer simulations.
- Visualizing analysis results through a digital twin, it enhances visibility and enables intuitive understanding

→ Digital Twin is intuitive

### Bradford city centre 'digital twin' model to be unveiled

© 11 April 2022



Organisers say Virtual Bradford could also have other potential uses such as creating heritage trails

A virtual 3D model of a city is being built which could help with planning, air pollution and traffic management.

University staff are currently creating Virtual Bradford, a high-resolution copy of the city centre.


Due to be unveiled at a conference on Monday, it could be extended out, eventually mapping more than 60 miles (100km) of streets.

Prof Andrew Wilson said it would show "accurate levels of detail".

Part of the University of Bradford's School of Archaeology and Forensic Sciences, Prof Wilson said: "This is essentially a 3D model or digital twin of the city, capable of showing accurate levels of detail for the built environment."

### 'Largest underwater scanning project in history' gives never-before-seen view of Titanic

By Niamh Kennedy, CNN  
Updated 10:15 PM EDT, Wed May 17, 2023



Editor's Note: Sign up for CNN's Wonder Theory science newsletter. Explore the universe with news on fascinating discoveries, scientific advancements and more.

**CNN** — The mysterious 1912 sinking of the luxury passenger liner, the *Titanic*, has long served as a source of fascination for many.

Historians now believe that a new underwater scanning project may provide answers to some of the unanswered questions regarding the tragedy that killed more than 1,500 people.

A team of scientists have used deep sea mapping to create "an exact 'Digital Twin' of the *Titanic* wreck for the first time," according to a press release Wednesday from deep sea investigators Magellan and firm-makers Atlantic Productions.

By carrying out the "largest underwater scanning project in history," scientists have managed to "reveal details of the tragedy and uncover fascinating information about what really happened to the crew and passengers on that fateful night" of April 14, 1912, the press release said.

Scans of the wreck were carried out in the summer of 2022 by a specialist ship stationed 700 km (435 miles) off the coast of Canada, according to the release. Tight protocols prohibited team members from touching or disturbing the wreck which investigators stressed was treated with the "utmost of respect."

Every millimeter of its three-mile debris field was mapped in minute detail, the press statement said. The final digital replica has succeeded in capturing the entire wreck including both the bow and stern section, which had separated soon after the 1912.

### 'Digital twin' tech to cut Stirling's carbon emissions

© 8 June 2019



Project Scene

IES has helped construct a 3D digital model of the first phase of the Trent Basin development in Nottingham

By Kenneth Macdonald  
BBC Scotland Science Correspondent

A Scottish company is using "digital twin" technology to build replicas of entire communities in cyberspace.

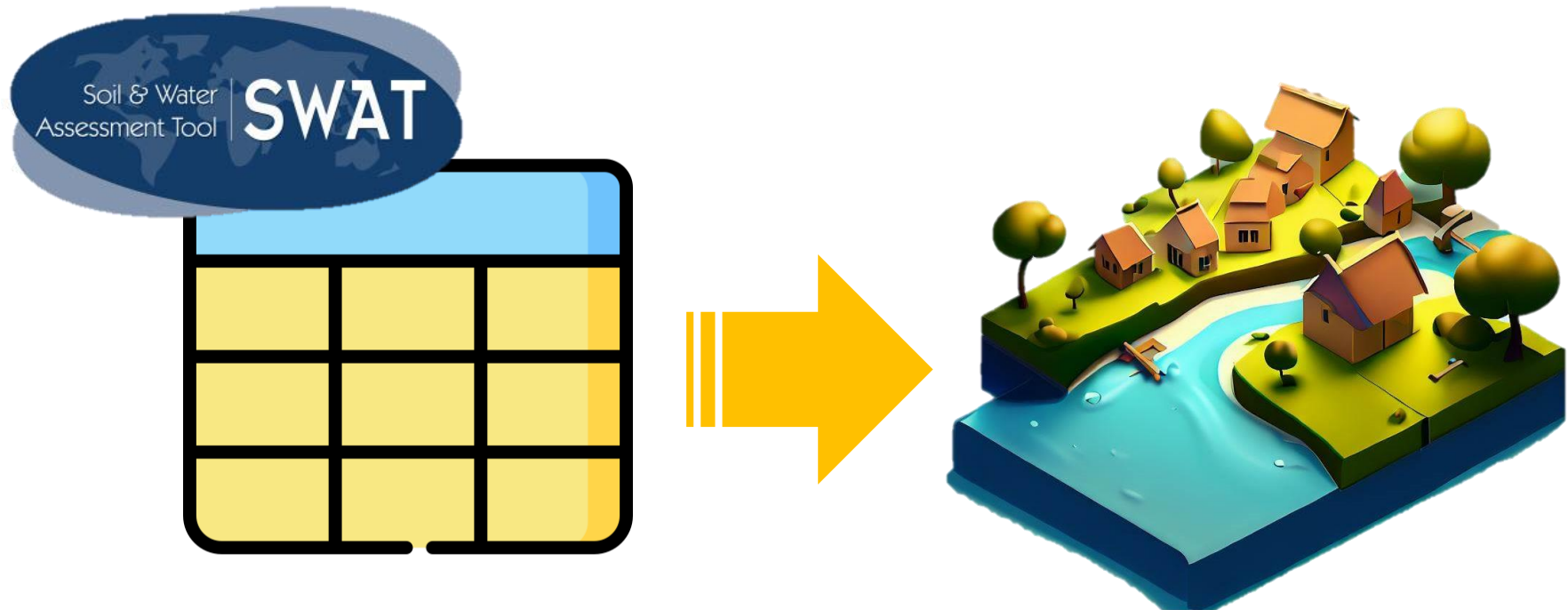
They say their aim is to help people reduce their energy bills and cut carbon emissions on a huge scale.

One plan nearing completion is a project that will create digital twins of 30 schools for Stirling Council.

# 01 Introduction

## Goals

Development of a **Water Quality Management Decision Support System** integrating SWAT and Digital Twin for simulation of various scenarios.



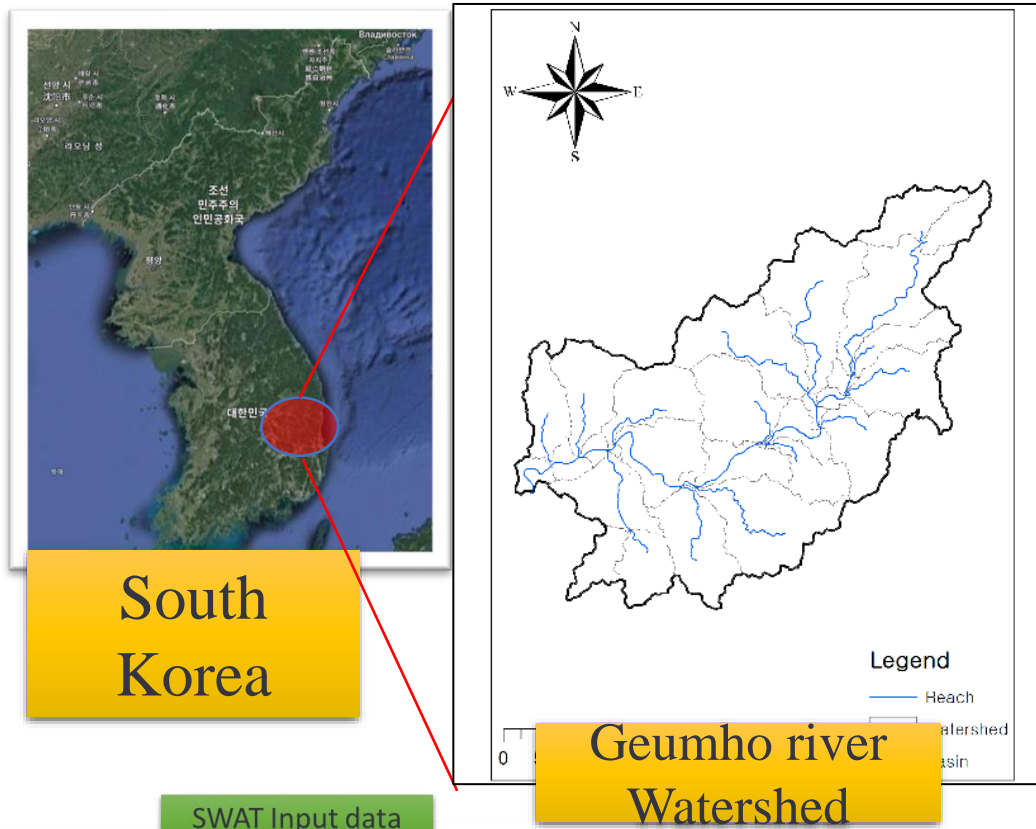


A large, dark blue circular graphic containing the word "PART" in white, uppercase letters at the top left and a large, white, stylized number "2" that overlaps the bottom right of the circle.

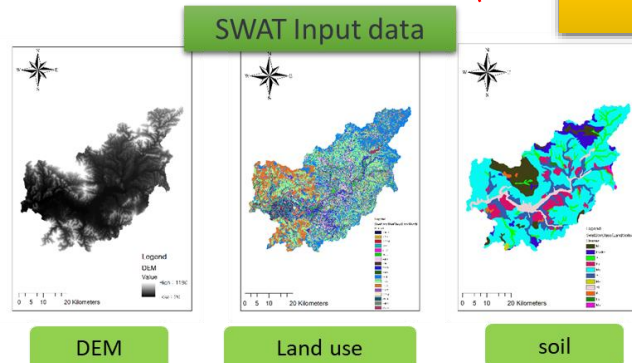
# Method and Material

# 02 Method and Material

## ❖ Study Area and SWAT Input Data



- Watershed area : 2,092 km<sup>2</sup>
- Total stream length : 6,179.43 km
- The water quality of Geumho river has deteriorated due to industrialization and urbanization
- The Korean government is making efforts to solve the water quality of the Geumho River.



- Simulation Period: 2015 – 2022
- Simulation Variables: Flow (CMS),  
Water Quality: T-P (mg/L)

# 02 Method and Material

## ❖ 3D visualization platform CESIUM



- Cesium is an open source JavaScript library for creating 3D globes and maps
- Cesium allows for interactive user engagement and real-time streaming, which is advantageous for time-based analysis
  - Analysis of changes over time is possible



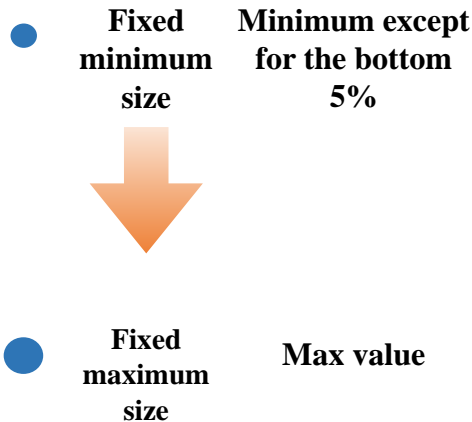
# 02 Method and Material

## Development of a Water Quality Management Decision Support System (Visualization Component – Water Quantity, Water quality)



### Water Quantity (CMS)

Express flow by changing the size of the point



### Water Quality: T-P(mg/L)

Express flow by changing the color of the point

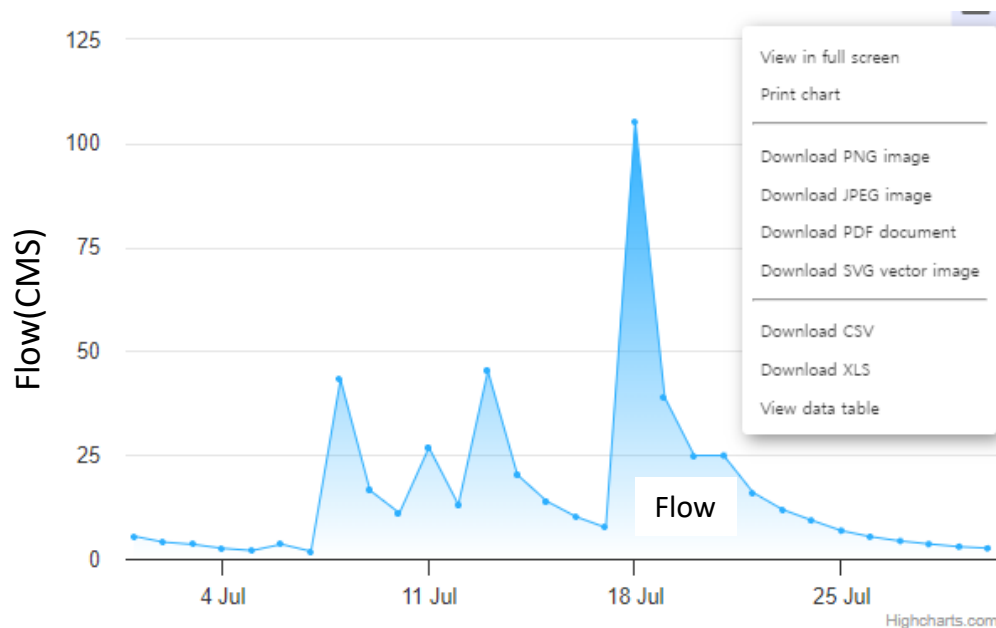
●	Excellent	0.02mg/L or less
●	Good	Above 0.02mg/L 0.04mg/L or less
●	Slightly good	Above 0.04mg/L 0.1mg/L or less
●	Medium	Above 0.1mg/L 0.2mg/L or less
●	Slightly bad	Above 0.2mg/L 0.3mg/L or less
●	Bad	Above 0.3mg/L 0.5mg/L or less
●	Very bad	Above 0.5mg/L

'Living River Water Quality Standards



## Development of a Water Quality Management Decision Support System (Additional Visualization Components – HighChart)

- HighChart is a software library for creating charts.
- Time series data (water Quantity / Water Quality) are displayed using HighChart
- HighChart enables to effectively visualize the time-dependent trends and fluctuation in the data

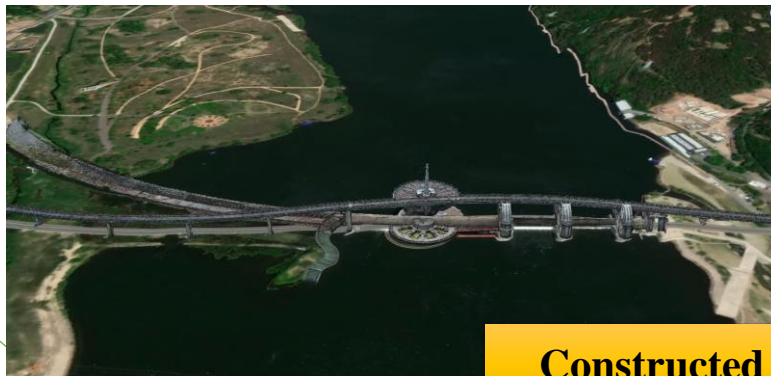


**Flow of Geumho river – 26 sub-basin**

# 02 Method and Material

## Development of a Water Quality Management Decision Support System (visualization component – Drone filming and 3D Model Construction)

- 3D model was constructed using DJI Terra and visualized in CESIUM
- It has the advantage of being able to identify pollutant sources



Constructed 3D model

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# Results and Discussion

# 03 Results and Discussion

## Development of a Water Quality Management Decision Support System Result

Data

DataBase

req date	123 1_FLOW_OUTcms	123 1_T-Pkg	123 2_FLOW_OUTcms	
183	2015-07-02	0.617	0	0.442
184	2015-07-03	0.442	0	0.324
185	2015-07-04	0.319	0	0.238
186	2015-07-05	0.232	0	0.176
187	2015-07-06	0.169	0	0.13
188	2015-07-07	1.289	1.703	0.83
189	2015-07-08	2.538	2.459	1.636
190	2015-07-09	10.95	105	6.813
191	2015-07-10	6.793	0.585	4.521
192	2015-07-11	4.788	0.013	3.277
193	2015-07-12	7.847	22.64	5.212
194	2015-07-13	5.302	0.164	3.67
195	2015-07-14	3.776	0.004	2.677
196	2015-07-15	2.712	0	1.963
197	2015-07-16	1.961	0	1.444
198	2015-07-17	1.427	0	1.066
99	2015-07-18	1.044	0	0.789
200	2015-07-19	0.768	0	0.586
201	2015-07-20	0.569	0	0.436
202	2015-07-21	0.424	0	0.325
203	2015-07-22	0.316	0	0.243
204	2015-07-23	0.238	0	0.182
205	2015-07-24	0.179	0	0.136
206	2015-07-25	0.136	0	0.102
207	2015-07-26	0.104	0	0.077
208	2015-07-27	0.08	0	0.058
209	2015-07-28	0.064	0	0.045
210	2015-07-29	0.05	0	0.034
211	2015-07-30	0.039	0	0.026
212	2015-07-31	0.031	0	0.02
213	2015-08-01	0.025	0	0.015
214	2015-08-02	0.838	1.296	0.53
215	2015-08-03	0.55	0.004	0.368
216	2015-08-04	0.389	0	0.267
217	2015-08-05	0.278	0	0.195

Visualization

HTML

Select Date

시작일자

종료일자

submit

Request data

SQL query  
(user Request data)

Server



Data

Viewer



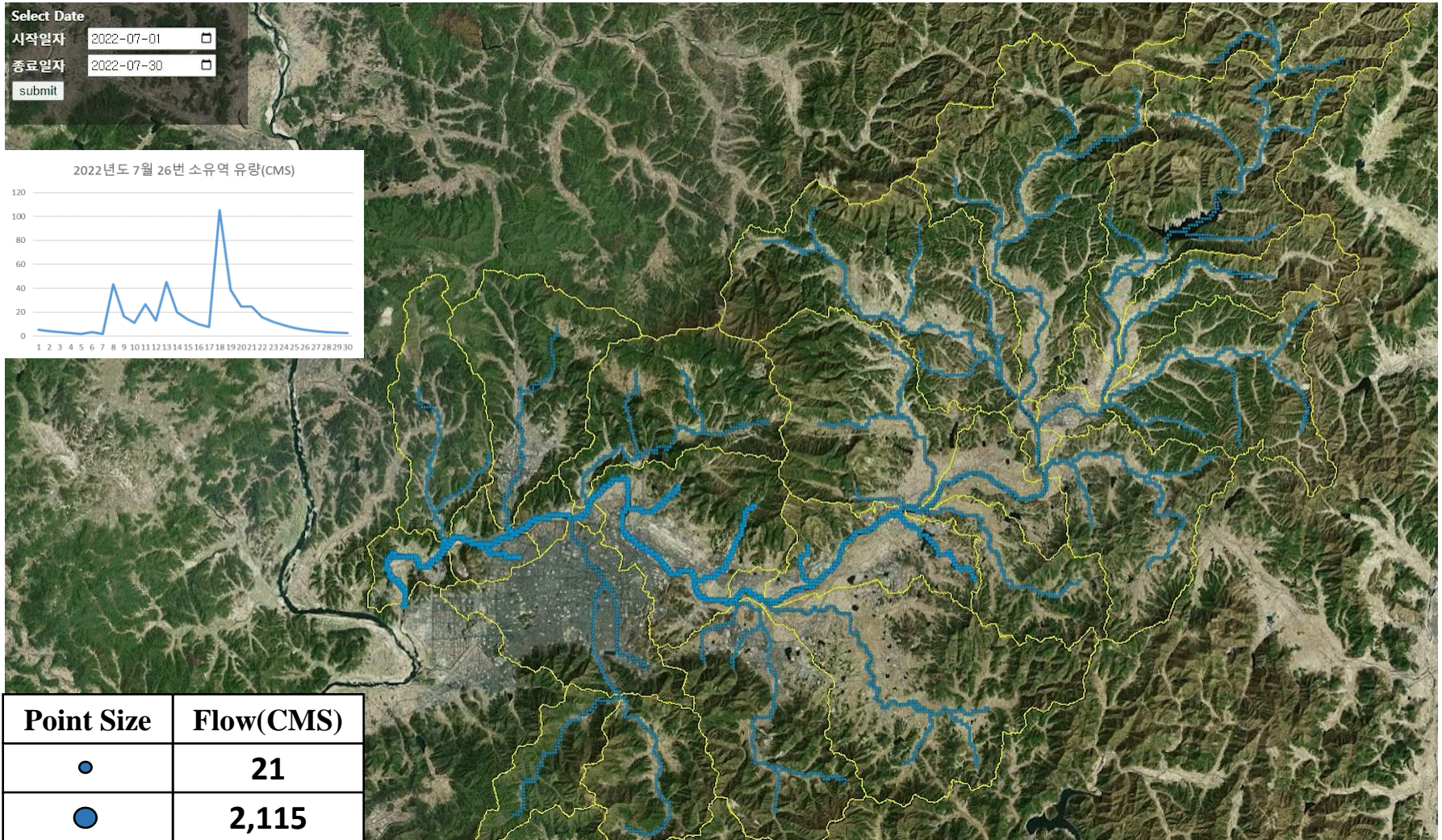
SWAT result

Reconstructed Flow and  
Water Quality values in DB



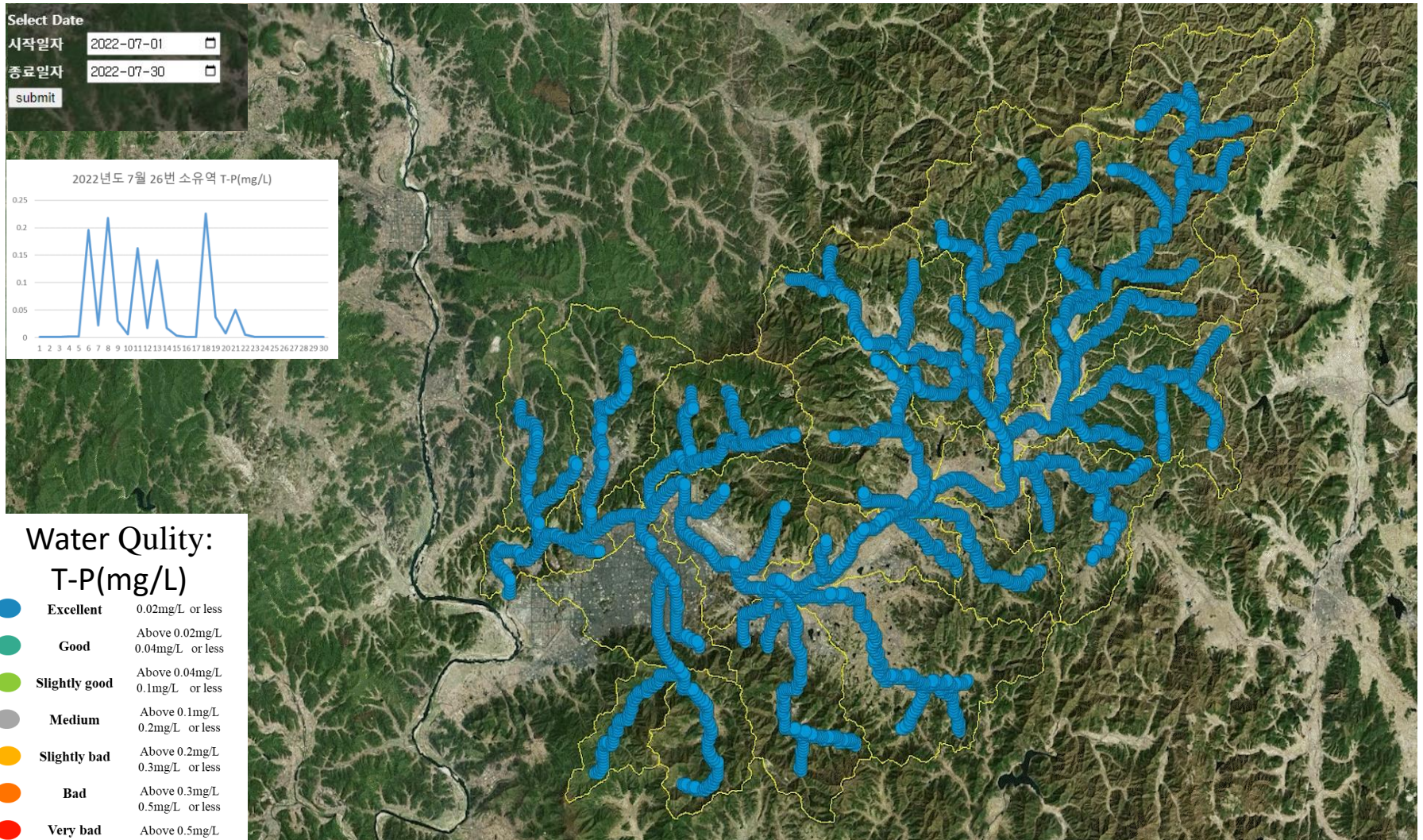
# 03 Results and Discussion

## ❖ Flow visualization result of SWAT Model



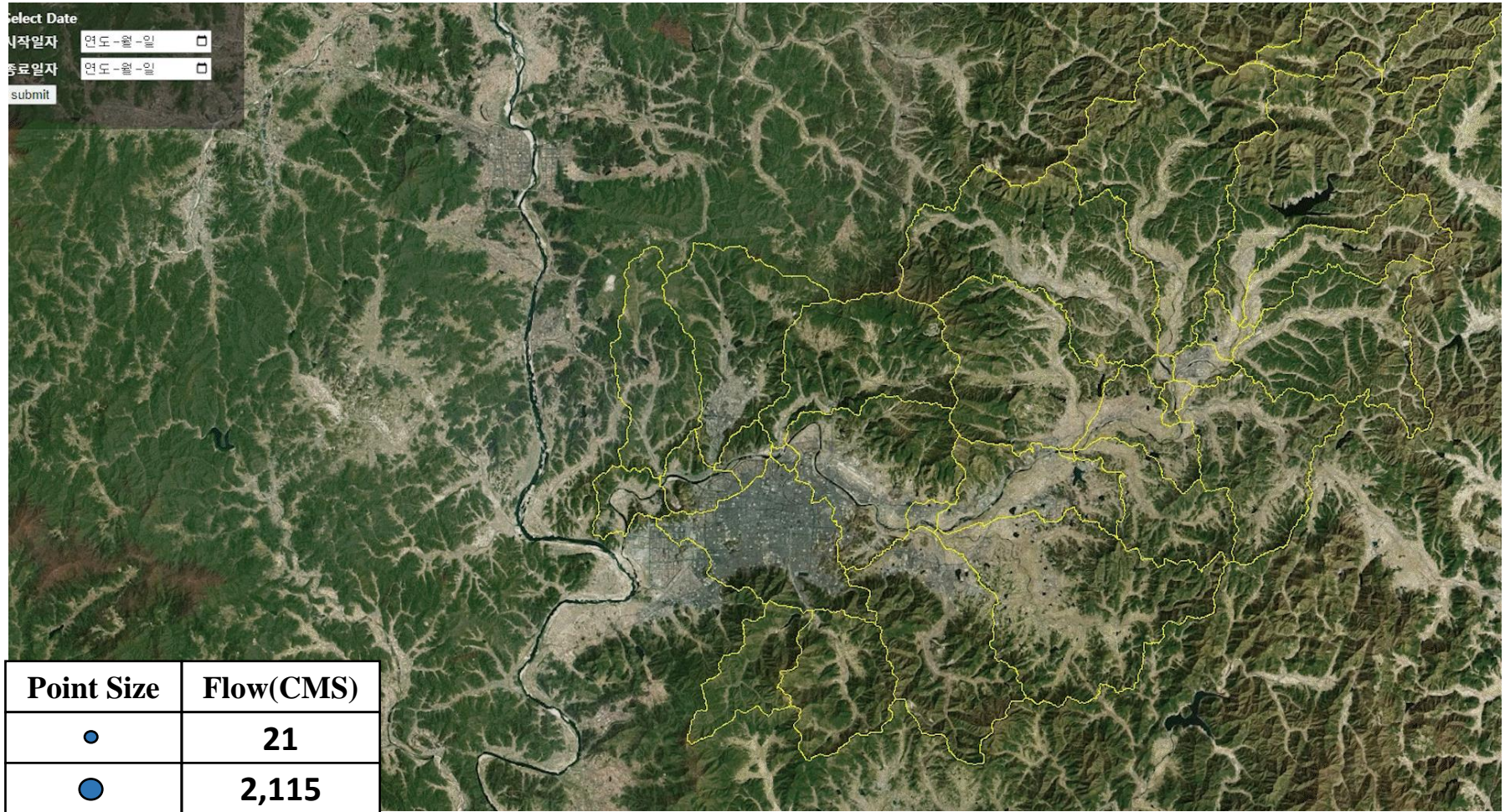
# 03 Results and Discussion

## ❖ Water Quality Visualization Result of SWAT Model



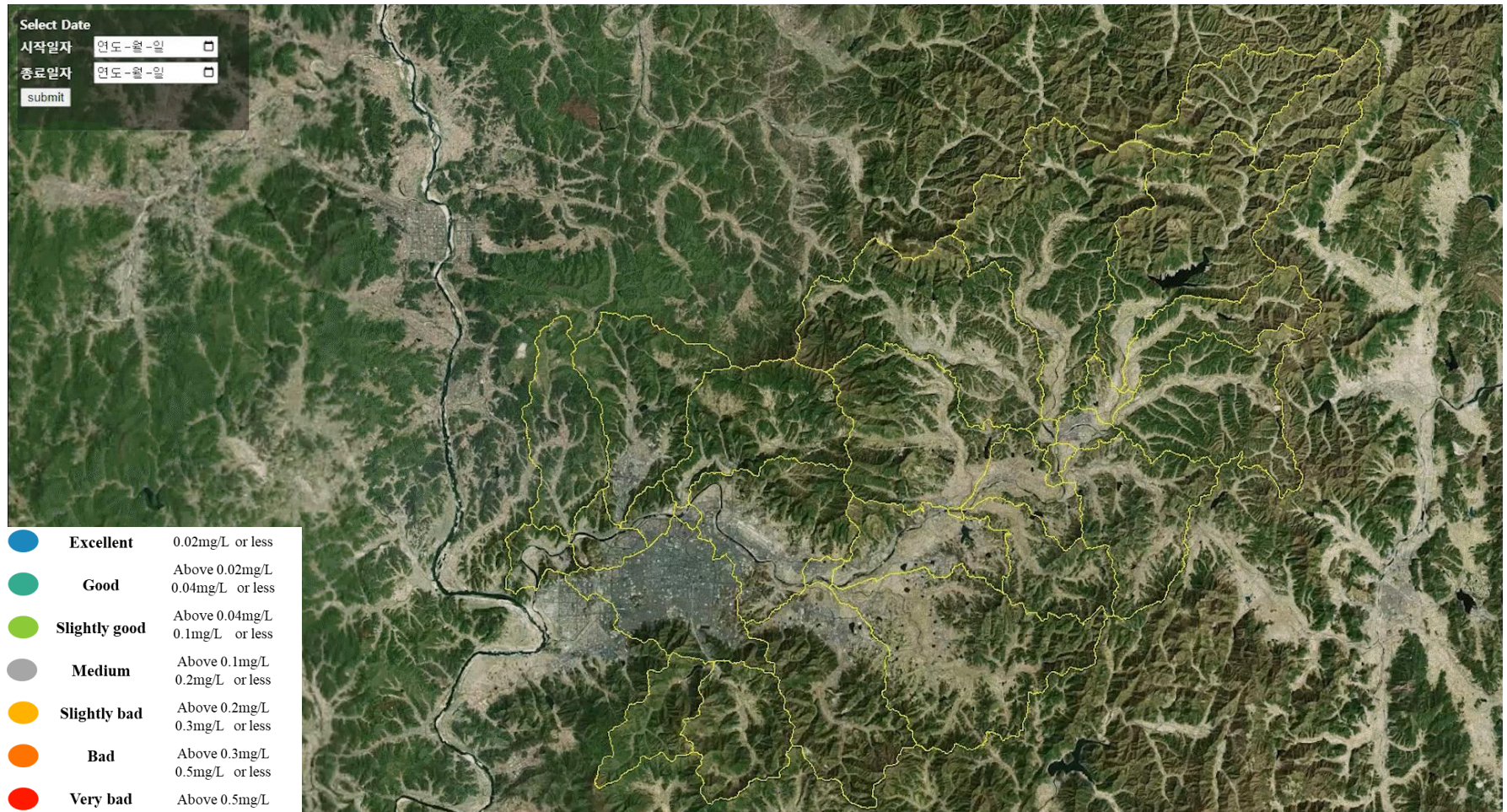
# 03 Results and Discussion

## ❖ Display of Time Series Flow Data of SWAT Model Using HighChart



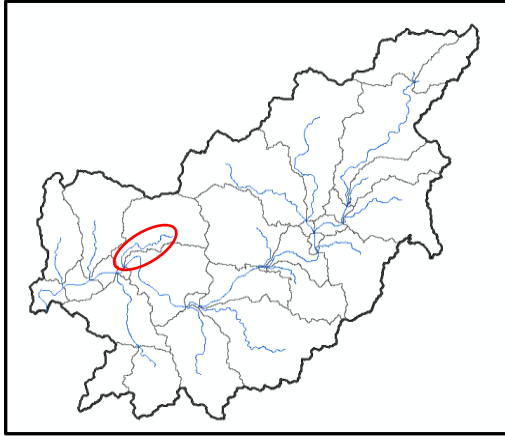
# 03 Results and Discussion

## ❖ Display of time-series water quality Data of SWAT model using HighChart



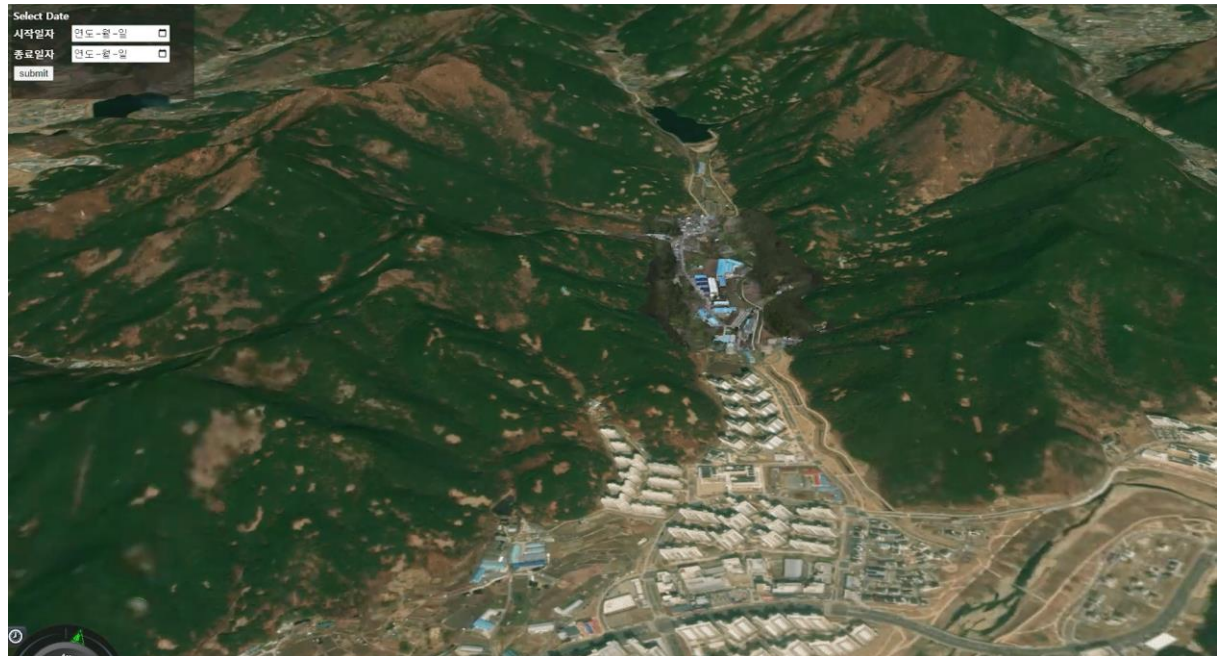
# 03 Results and Discussion

## ❖ Construction 3D objects using drones



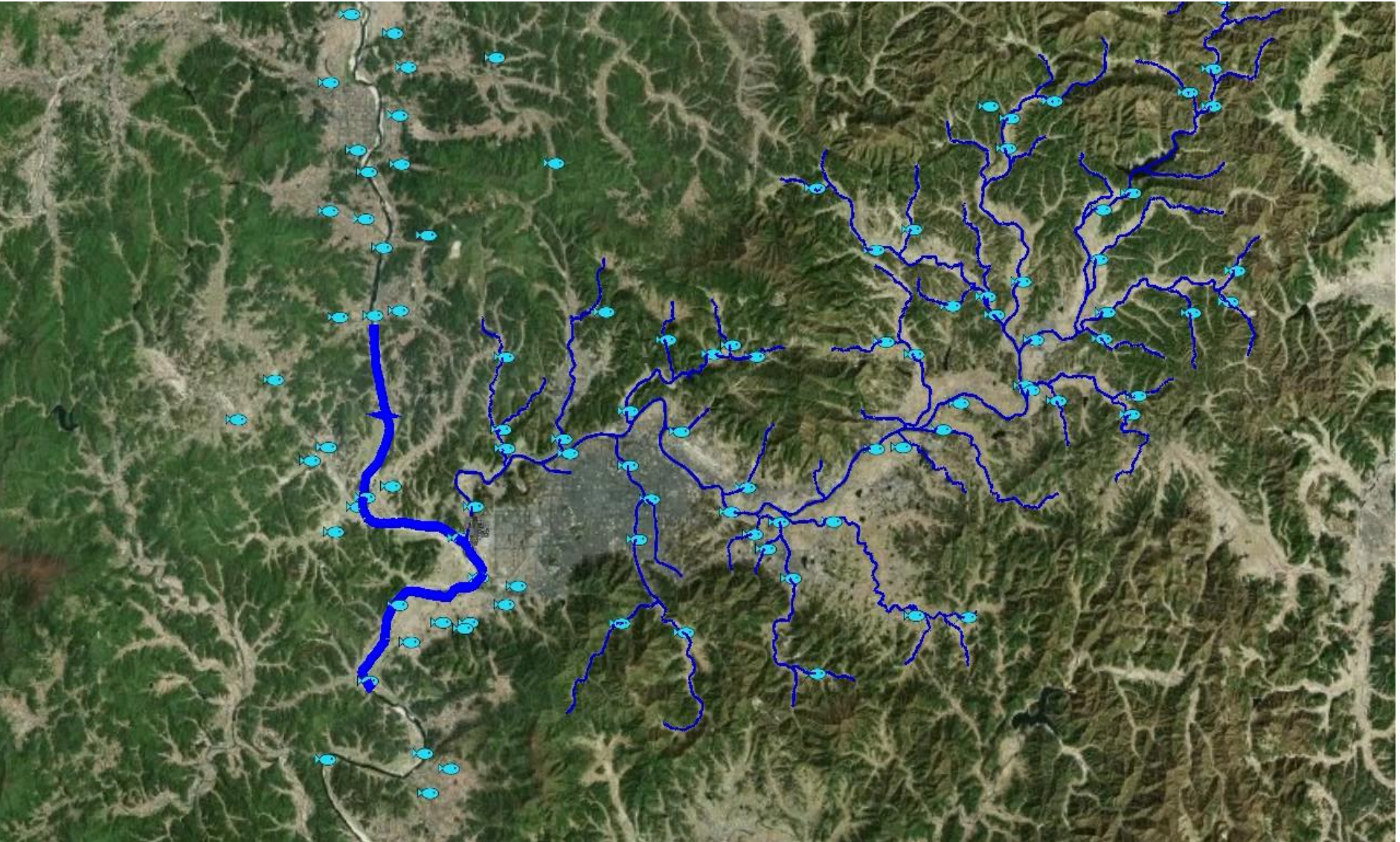
- The drone used for filming (Metrice 300 RTK)

- 3D object model has been constructed using drone filming. This is expected to help identify the source of pollution.



# 03 Results and Discussion

- ❖ Visualization of aquatic ecosystem Observed data in 2022 of the Geumho River



A large, dark blue circular graphic containing the word "PART" in white, uppercase letters above a very large, white, stylized number "4".

# Conclusion and Future Plan

# 04 Conclusion and Future Plan

## ❖ Conclusions and limitation

- In this study, developed a Water Quality Management Decision Support System based on a watershed model and 3D platform system.
- The system visualizes water quantity and water quality data, which is traditionally presented in table format, allowing for intuitive understanding.
- However, there is an issue where some point source pollution values appear lower than the actual measurements due to the inability of the SWAT model to account for point source pollution.



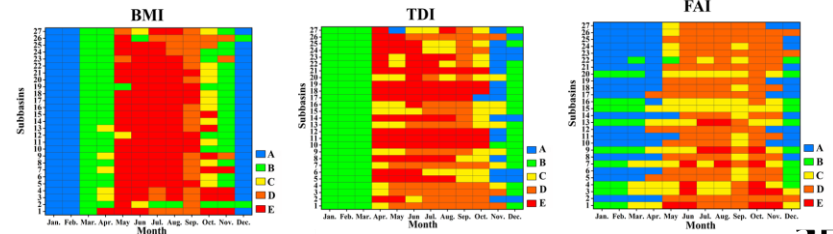
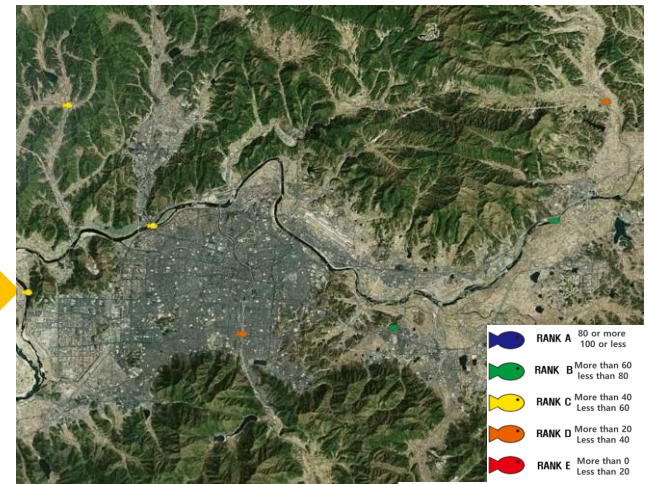
# 04 Conclusion and Future Plan

## ❖ Prediction of Aquatic Ecosystem Health through SWAT and Machine Learning Models

- We plan to display the prediction results of aquatic ecosystem health based on watershed environment, not only water quantity and water quality, in the 3D-based decision support system, by utilizing a machine learning model and the SWAT model for predicting aquatic ecosystem health.



**Visualization of prediction data for changes in aquatic ecosystem health according to watershed environment**



# Thank you for listening!

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