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Estimating Reservoir Sediment Retention SWAT for Sustainable Dam Managem

Christian Joseph Siose , Sangjoon Bak, Yeonji Jeong, Jeongho Han, Seoro Lee, Gwanjae Lee, Kyoung Jae Lim

Master's Student Interdisciplinary Program in Earth Environmental System Science & Engineering, Kangwon National University[1]

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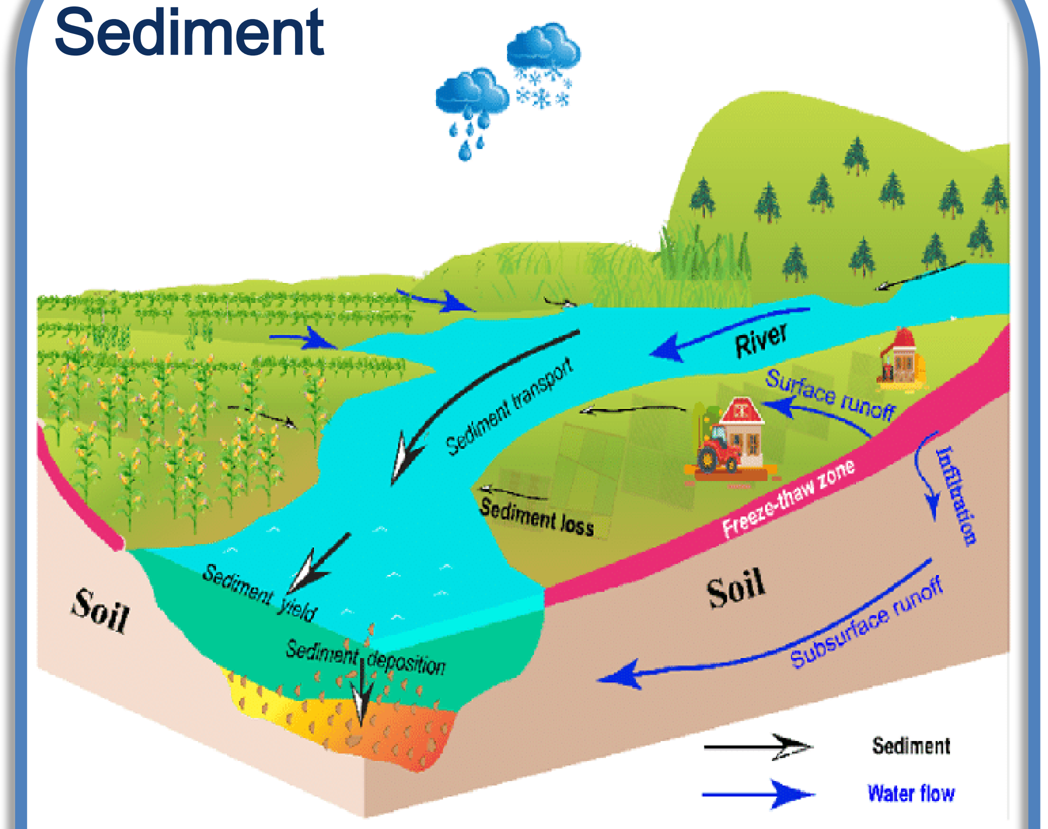
I

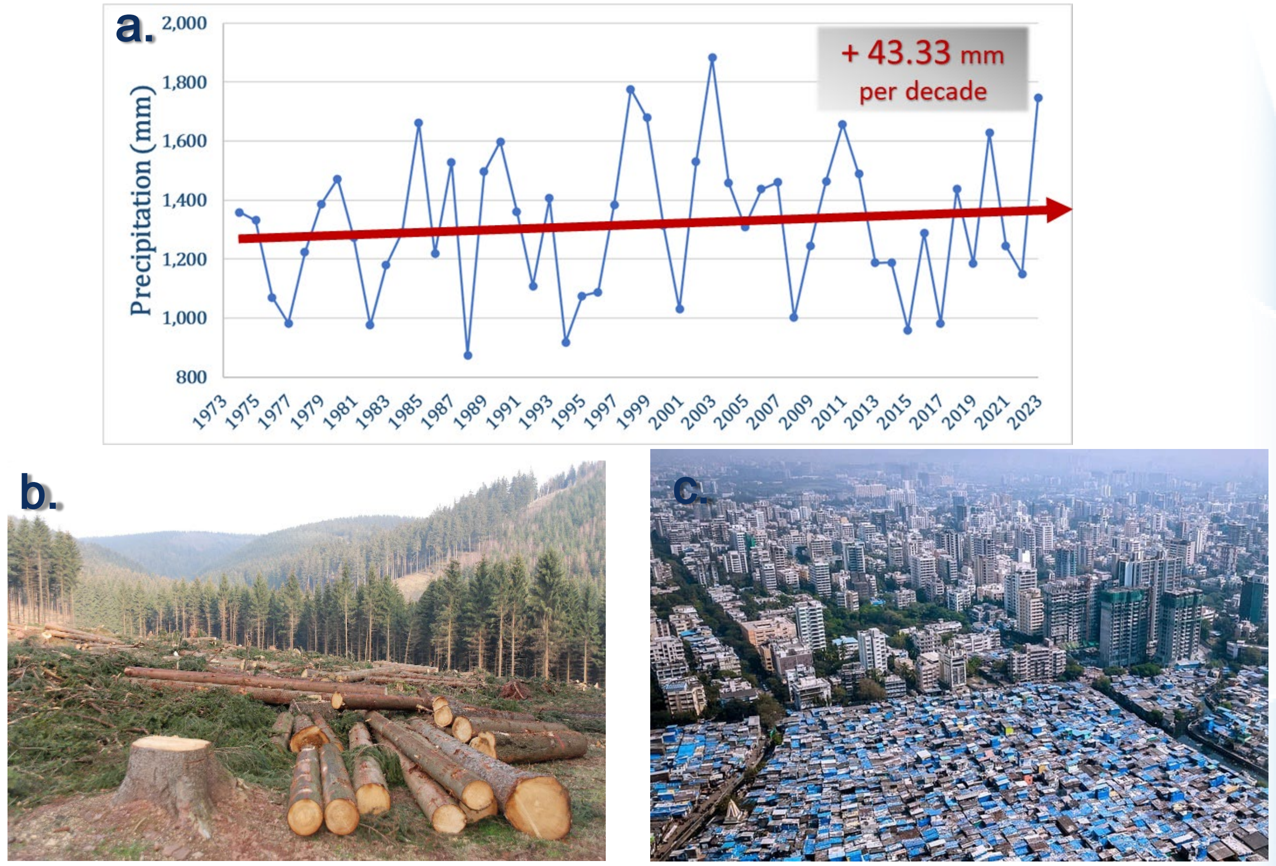
Introduction

I. Introduction

- ❖ Sediment consists of soil, sand, and mineral particles eroded and transported by river flow.
- ❖ Human activities and climate change have increased erosion and sediment runoff into rivers.
- ❖ This leads to sediment buildup in reservoirs, reducing their capacity and efficiency.



Source: Wang et. al., (2021)



a. Annual Precipitation in South Korea b. Deforestation
C. Urban Development

Source: Statista, based on data from Korea Meteorological Administration (KMA).

5 ~ 1500 tons/km^2/year
in South Korea

Source: Yang et. al., (2021)

Sedimentation cleaning works in Chungnam Province, South Korea

Source: TJB News (2015)

I. Introduction

❖ Sediment accumulation in reservoirs reduces active storage capacity, directly impacting water supply, irrigation efficiency, and flood control potential and even affect the water contamination in the river

Reduced Active Water Storage in Jukrim Dam

Source: YTN News (2015)

Dam Collapses in Gyeongbuk Province

Source: MBC News (2024)

Floods in Chungbuk Due to Dam Failure

Source: KBS News (2024)

Objective of the study

This study evaluates the impact of the Dam on Total Sediment load in the Naeseongcheon Stream by applying the SWAT model

1

CASE 1

To evaluate the sediment retention in the dam by comparing the Total Sediment load at the Upstream and Downstream station of the dam

2

CASE 2

To assess the dam's impact in the downstream by comparing the Total Sediments loads at Downstream station considering With and Without the dam

II

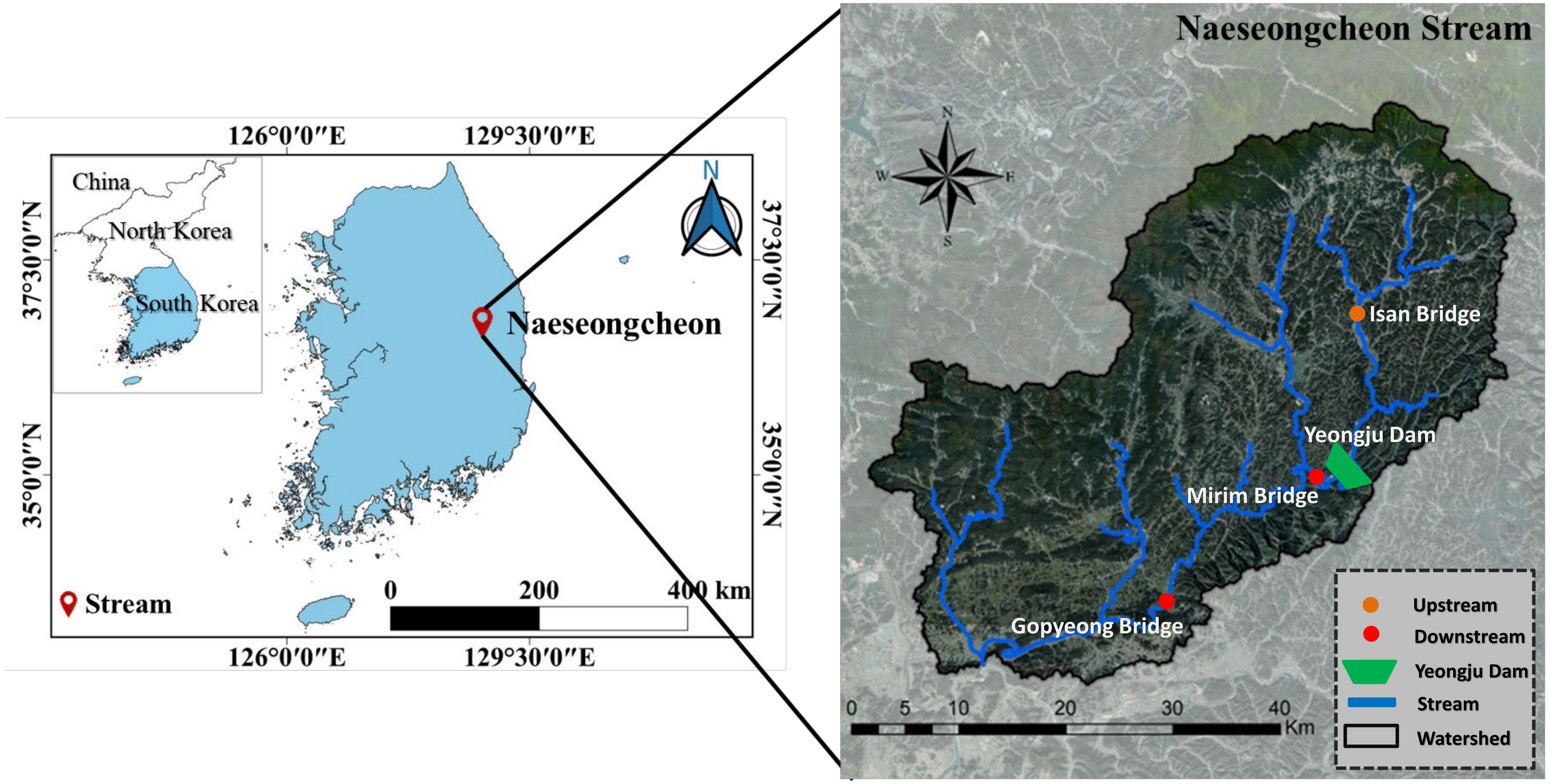
Methodology

II. Methodology – Study Area

❖ Naesongcheon Stream in Nakdong River, South Korea

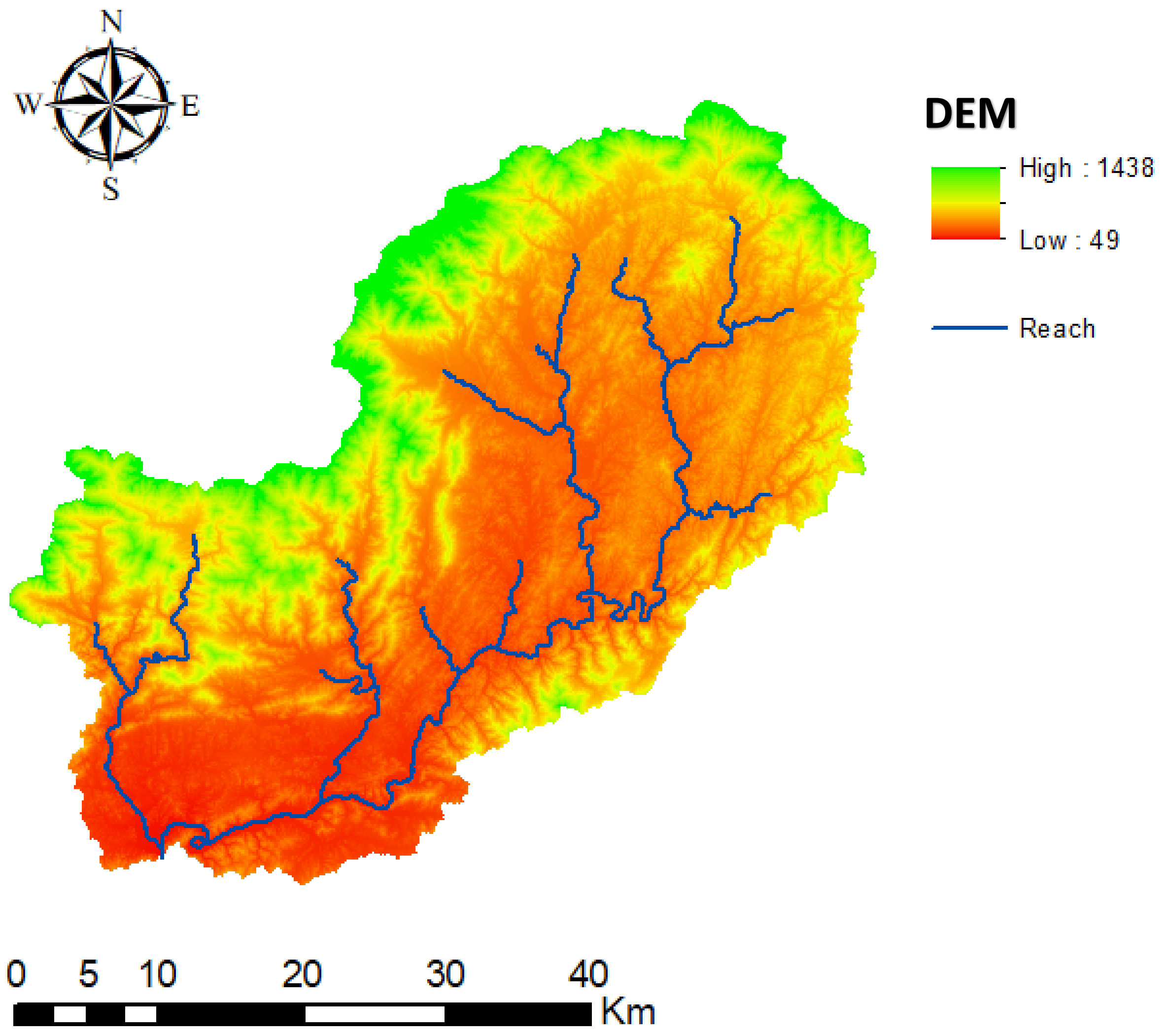
❖ Yeongju Dam is a multipurpose dam with a storage capacity of 160.4 million m^3

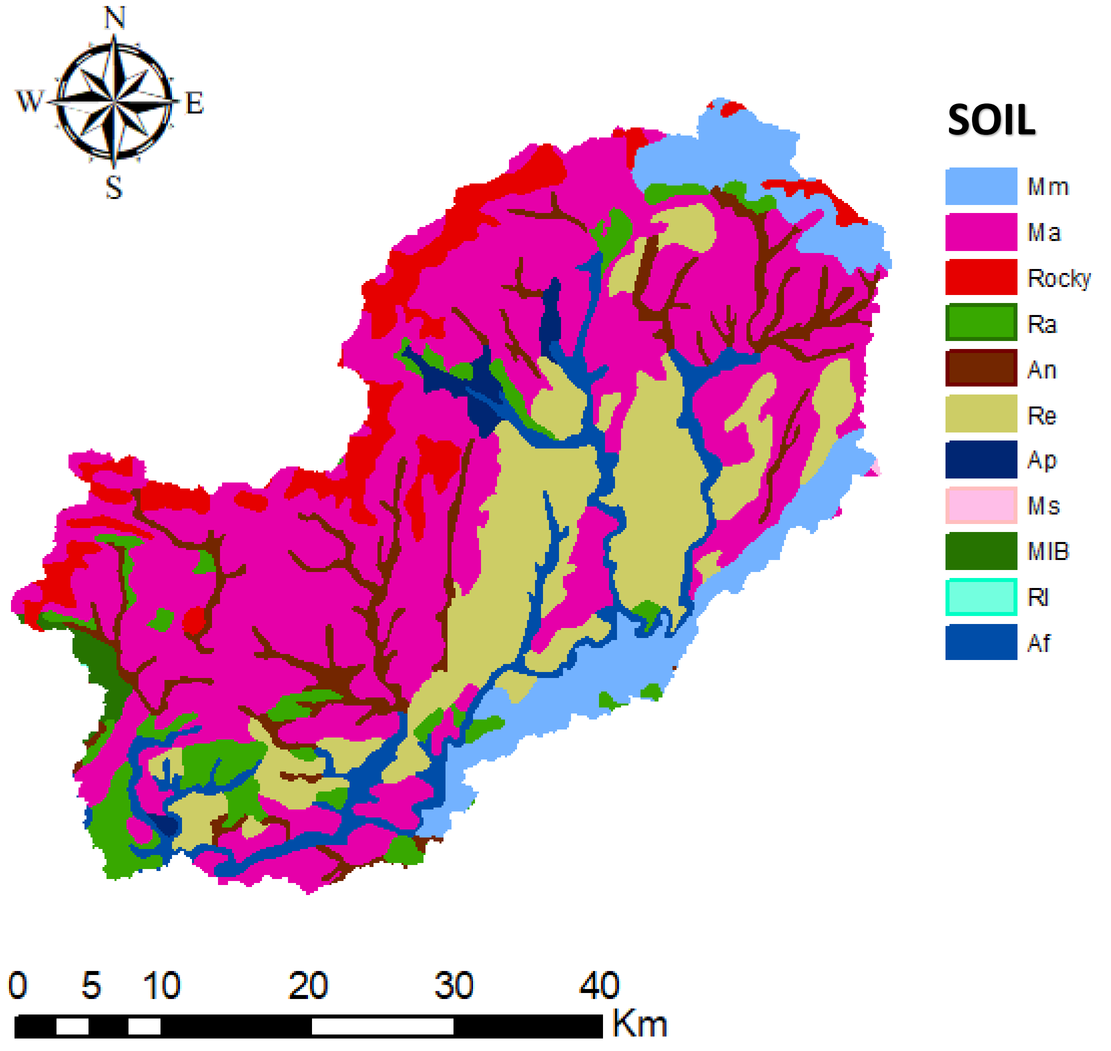
- ✓ Dam's Construction started in 2009 and was completed in 2016

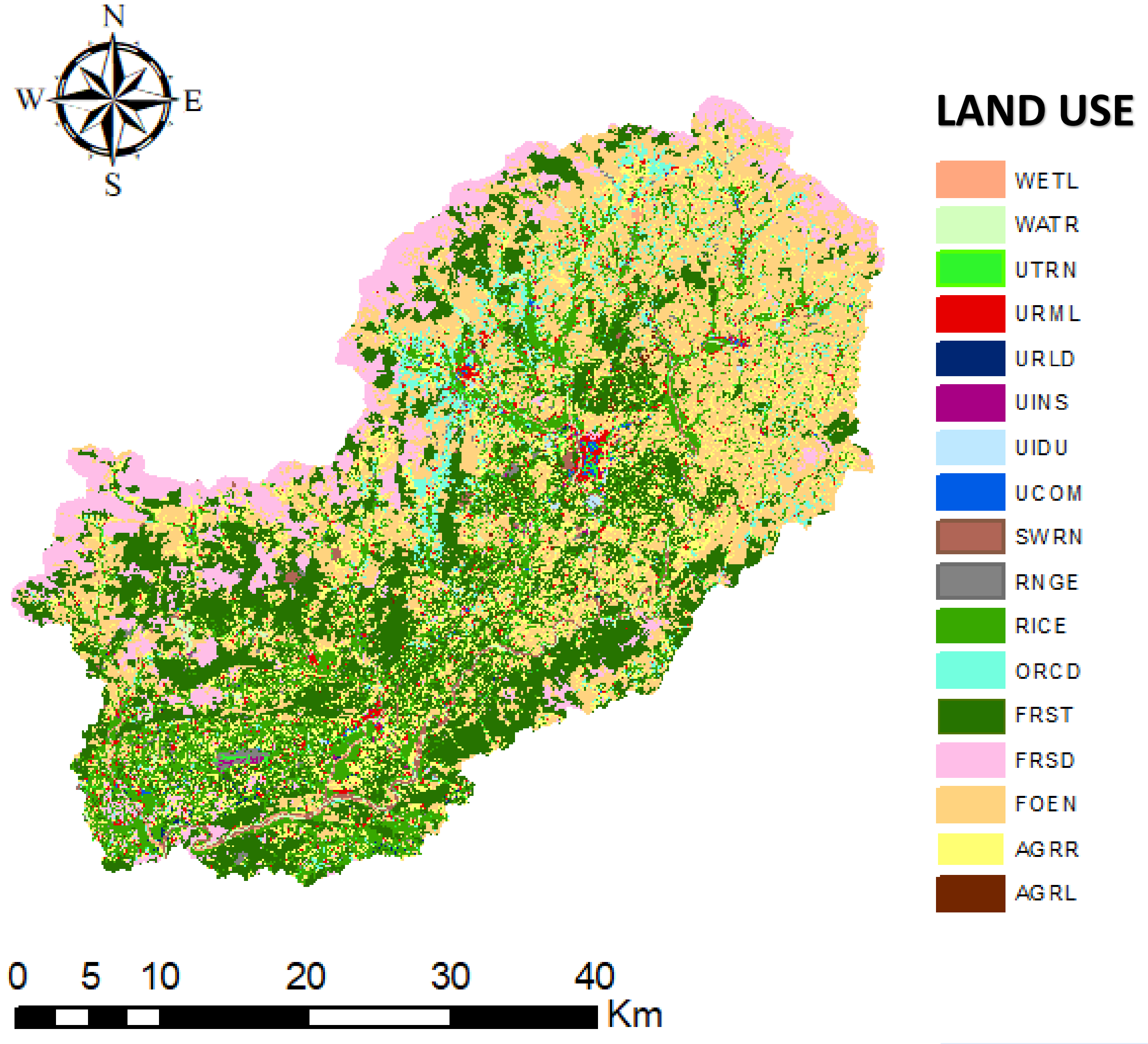


II. Methodology –Data Collection

- **Digital Elevation Model (DEM)** data with a 30-meter resolution were provided by the National Spatial Data Infrastructure Portal
- **Soil** data were provided by the Rural Development Administration
- **Land use** data were provided by Ministry of Environment







II. Methodology –Data Collection

❖ Data Collection Period

- Warm-up period (2014 ~ 2016)
- Simulation Period (2017 ~ 2020)

Meteorological Observation Data			
Data	**Source**	**Data Type**	**Description**
Precipitation	Korea Meteorological Administration (KMA)	Daily	Rainfall data from general meteorological observation stations, specifically from Automated Surface Observing System (ASOS)
Temperature (min/max)	KMA	Daily	Minimum and Maximum Temperature from general meteorological observation stations, (ASOS)
Wind Speed	KMA	Daily	Average Wind Speed from general meteorological observation stations, (ASOS)
Solar Radiation	KMA	Daily	Solar Radiation data from general meteorological observation stations, specifically from Automatic Weather Station (AWS)
Relative Humidity	KMA	Daily	Relative Humidity data from general meteorological observation stations, (AWS)

II. Methodology –Data Collection

❖ Streamflow Observation Data and Sediment Data

❑ Sediment Conversion Formula (Korean Water Resources Corporation, 2012)

✓ Assumption : Suspended Load at Inflow of Yeongju Dam and Isan Bridge is similar

Data	Source	Data Type	Description
Streamflow (m^3/s)	Water Resources Management Information System (WAMIS)	Daily	Streamflow data from general meteorological observation stations

<Suspended Sediments Data>

- Gopyeong Bridge (Upstream)

$$Q_{SS} = 0.0675Y^{1.9827}$$

- Isan Bridge (Downstream)

$$Q_{SS} = 1.4696Y^{0.9564}$$

<Total Sediment Data>

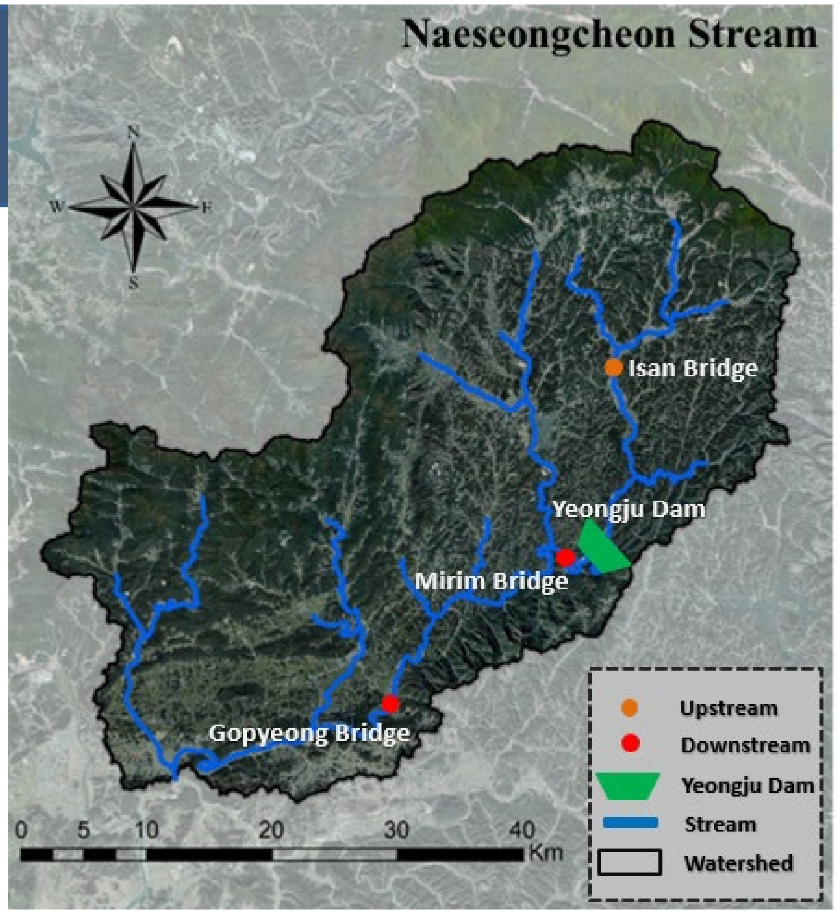
- Gopyeong Bridge (Upstream)

$$Q_{TS} = 15.56Y\,uu^{0.7703}$$

Wherein, Q	:	Streamflow (m^3/s)
Q_{SS}	:	Suspended Solids (ton/day)
Q_{TS}	:	Total Sediment (ton/day)

(Korean Water Resources Corporation, 2012)

II. Methodology



❑ Case # 1

- ✓ To evaluate the sediment retention in the dam by comparing the Total Sediment load at the Upstream (Isan Bridge) and Downstream (Mirim Bridge) of the Dam

❑ Case # 2

- ✓ To assess the Dam's impact in the downstream by comparing the Total Sediments loads at Gopyeong Bridge With and Without the Dam

Year	2014~2016	2017 ~ 2020
Case # 1 & 2	Warm-up	Modeling Simulation Period

II. Methodology —Calibration

❖ SWAT-CUP

▪ Streamflow Parameter

Parameter	Description	Variation Method	Range
CN2	SCS runoff curve number factor	Multiply by Value	-25.0 ~ 25.0
ALPHA_BF	Baseflow alpha factor (days)	Replace by Value	0.0 ~ 1.0
ALPHA_BNK	Baseflow alpha factor for bank storage	Replace by Value	0.0 ~ 1.0
GW_REVAP	Groundwater “revap” coefficient	Add	0.02 ~ 0.2
GWQMN	Threshold depth of water in the shallow aquifer required for return flow to occur (mm)	Replace by Value	0.0 ~ 5000.0
SURLAG	Surface runoff lag time	Replace by Value	0.05 ~ 24.0
SOL_AWC	Available water capacity of the soil later	Multiply by Value	-25.0 ~ 25.0
SOL_K	Saturated hydraulic conductivity	Multiply by Value	-25.0 ~ 25.0
CH_N2	Manning’s value for the main channel	Replace by Value	-0.01 ~ 0.3
CH_K2	Effective hydraulic conductivity in main channel alluvium	Replace by Value	-0.01 ~ 500.0
ESCO	Soil evaporation compensation factor	Replace by Value	0.0 ~ 1.0

▪ Suspended Sediments Parameter

Parameter	Description	Variation Method	Range
ADJ_PKR	Peak rate adjustment factor for sediment routing in the main channel	Replace by Value	0.5 ~ 2.0
PRF	Peak rate adjustment factor for sediment routing in the subbasin	Replace by Value	0.0 ~ 2.0

II. Methodology –Performance Metrics

➢ Coefficient of Determination (R^2)

- Indicates how well the model explains the variance in observed data
- Range: (0 to 1) values near 1 reflect strong model performance.

Objective Function	Outflow Response	Very Good	Good	Satisfactory	Not Satisfactory
R^2	Flow	> 0.85	$0.85 \geq R^2 > 0.75$	$0.75 \geq R^2 > 0.60$	0.60≥
	Sediment	> 0.80	$0.80 \geq R^2 > 0.65$	$0.65 \geq R^2 > 0.40$	0.40≥

(Moriasi et al., 2015)

• Nash -Sutcliffe Efficiency (NSE)

- Measures the agreement between observed and simulated values
- Range: (- ∞ to 1) values closer to 1 indicate higher accuracy

Objective Function	Outflow Response	Very Good	Good	Satisfactory	Not Satisfactory
NSE	Flow	> 0.80	0.80 ≥ NSE >0.70	0.70 ≥ NSE >0.50	0.50≥
	Sediment	> 0.80	0.80 ≥ NSE >0.70	0.70 ≥ NSE >0.45	0.45≥

(Moriasi et al., 2015)

III

Results & Discussion

II. RESULTS & DISCUSSION

❖ SWAT-CUP OPTIMAL CALIBRATED PARAMETER

▪ Streamflow Optimal Parameter

Parameter	Description	Variation Method	Range	Fitted Value
CN2	SCS runoff curve number factor	Multiply by Value	-25.0 ~ 25.0	1.13075
ALPHA_BF	Baseflow alpha factor (days)	Replace by Value	0.0 ~ 1.0	0.012
ALPHA_BNK	Baseflow alpha factor for bank storage	Replace by Value	0.0 ~ 1.0	0.768
GW_REVAP	Groundwater "revap" coefficient	Add	0.02 ~ 0.2	0.027
GWQMN	Threshold depth of water in the shallow aquifer required for return flow to occur (mm)	Replace by Value	0.0 ~ 5000.0	2241.199
SURLAG	Surface runoff lag time	Replace by Value	0.05 ~ 24.0	5.556
SOL_AWC	Available water capacity of the soil later	Multiply by Value	-25.0 ~ 25.0	-7.286
SOL_K	Saturated hydraulic conductivity	Multiply by Value	-25.0 ~ 25.0	1.04604
CH_N2	Manning's value for the main channel	Replace by Value	-0.01 ~ 0.3	0.035
CH_K2	Effective hydraulic conductivity in main channel alluvium	Replace by Value	-0.01 ~ 500.0	74.425
ESCO	Soil evaporation compensation factor	Replace by Value	0.0 ~ 1.0	0.5

▪ Suspended Sediments Optimal Parameter

Parameter	Description	Variation Method	Range	Fitted Value
ADJ_PKR	Peak rate adjustment factor for sediment routing in the main channel	Replace by Value	0.5 ~ 2.0	0.4
PRF	Peak rate adjustment factor for sediment routing in the subbasin	Replace by Value	0.0 ~ 2.0	0.4

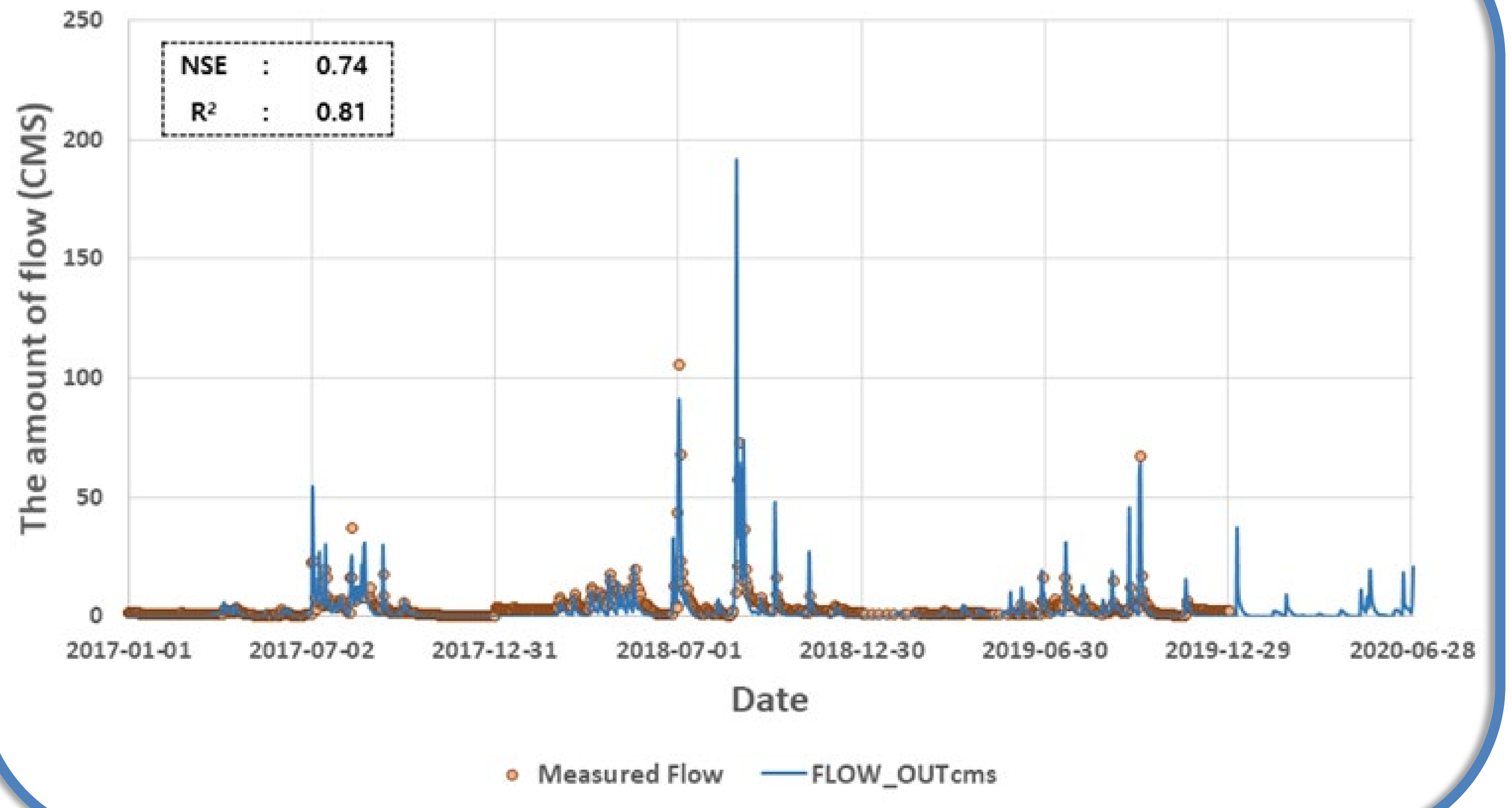
II. RESULTS & DISCUSSION

❖ Isan Bridge ~Upstream

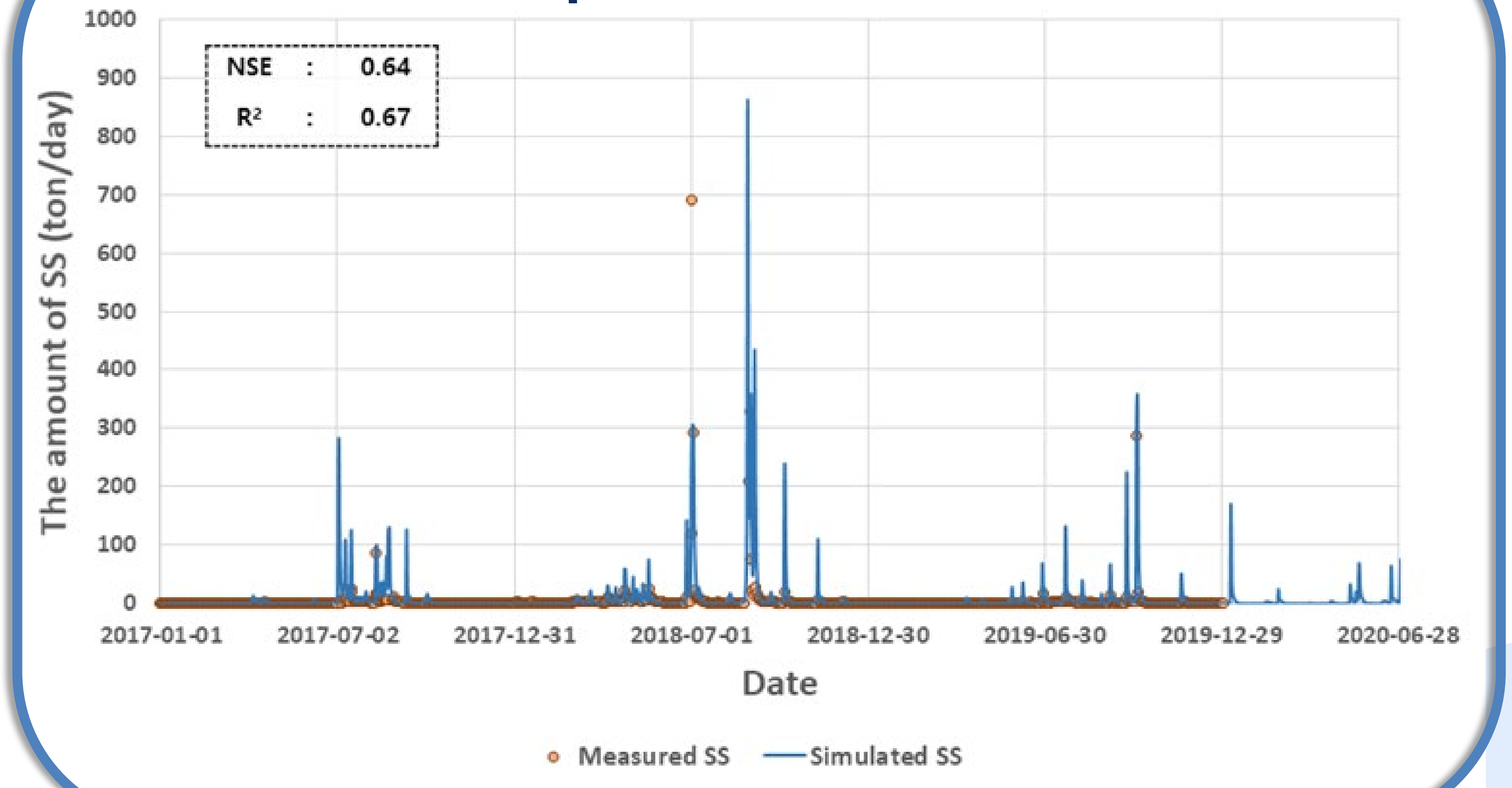
✓ The Streamflow calibration results R^2: 0.81 / NSE: 0.74 indicate a 'Good' model performance

✓ The Sediment calibration results R^2: 0.67 / NSE: 0.64 indicate a 'Good' model performance while the NSE has a 'Satisfactory' model performance

<Streamflow>



<Suspended Sediments>



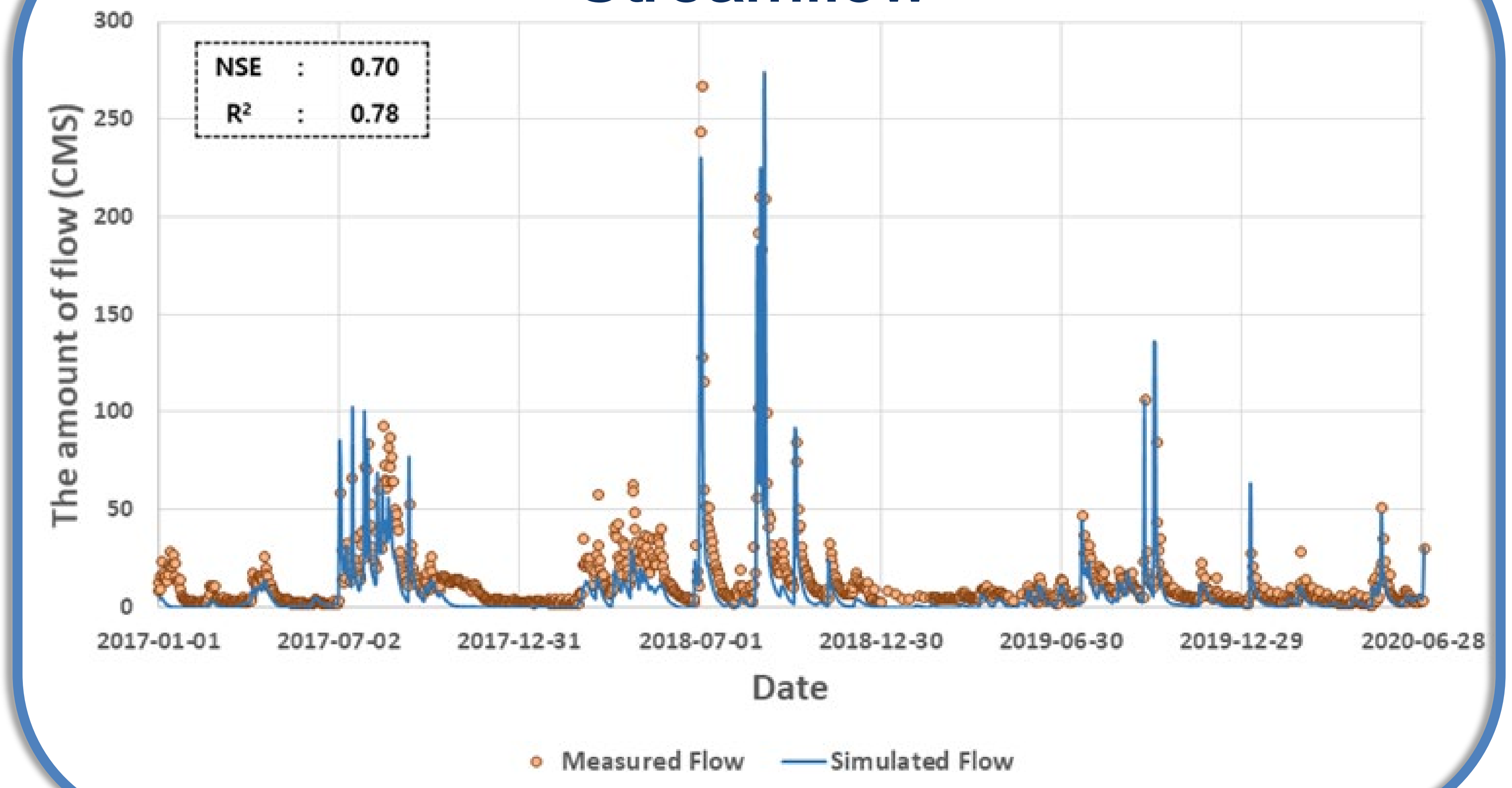
II. RESULTS & DISCUSSION

❖ Gopyeong Bridge~ Downstream

✓ The Streamflow calibration results R^2: 0.78/ NSE: 0.70 indicate a 'Good' model performance

✓ The Sediment calibration results R^2: 0.77/ NSE: 0.53 indicate a 'Good' model performance while the NSE has a 'Satisfactory' model performance

<Streamflow>



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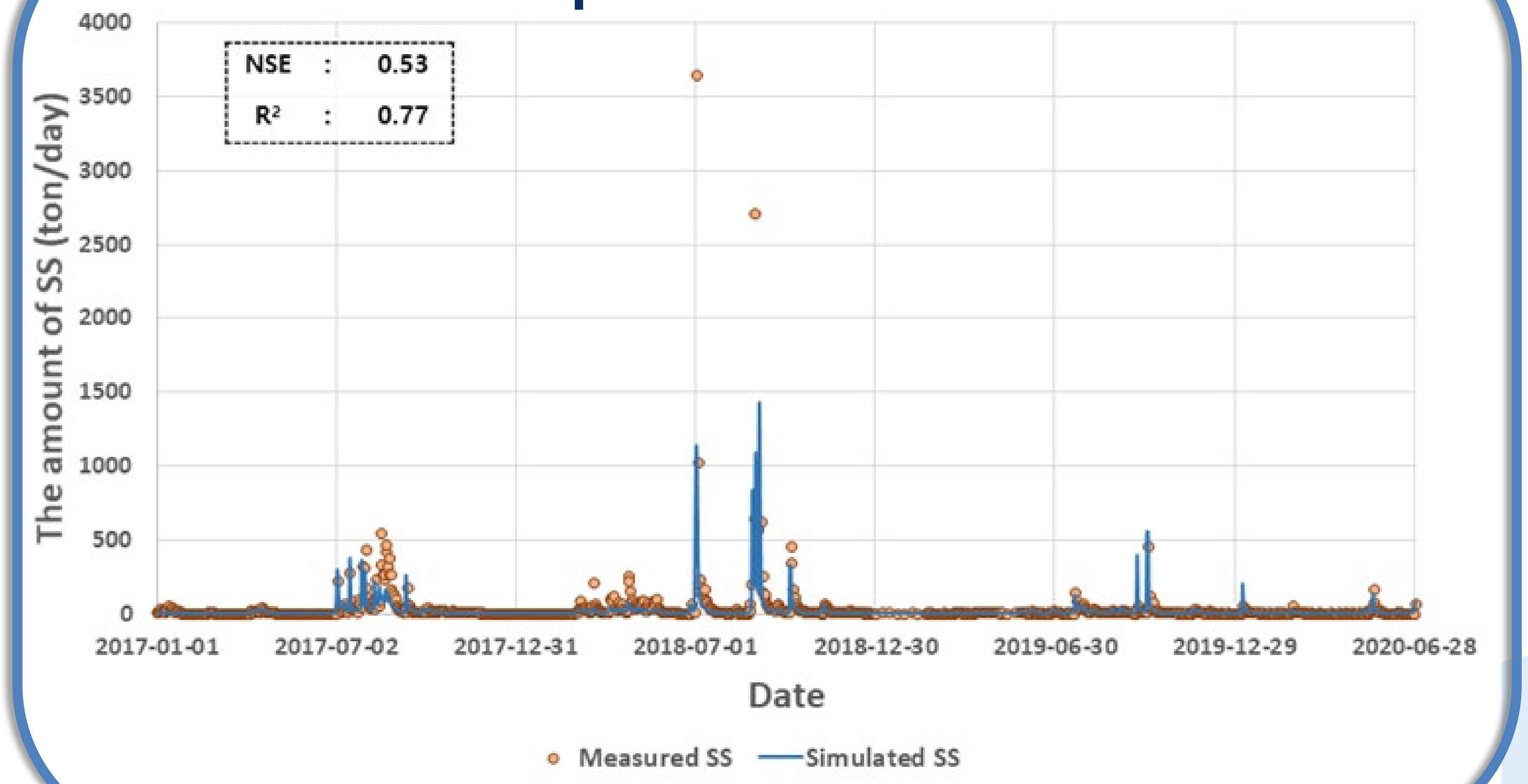
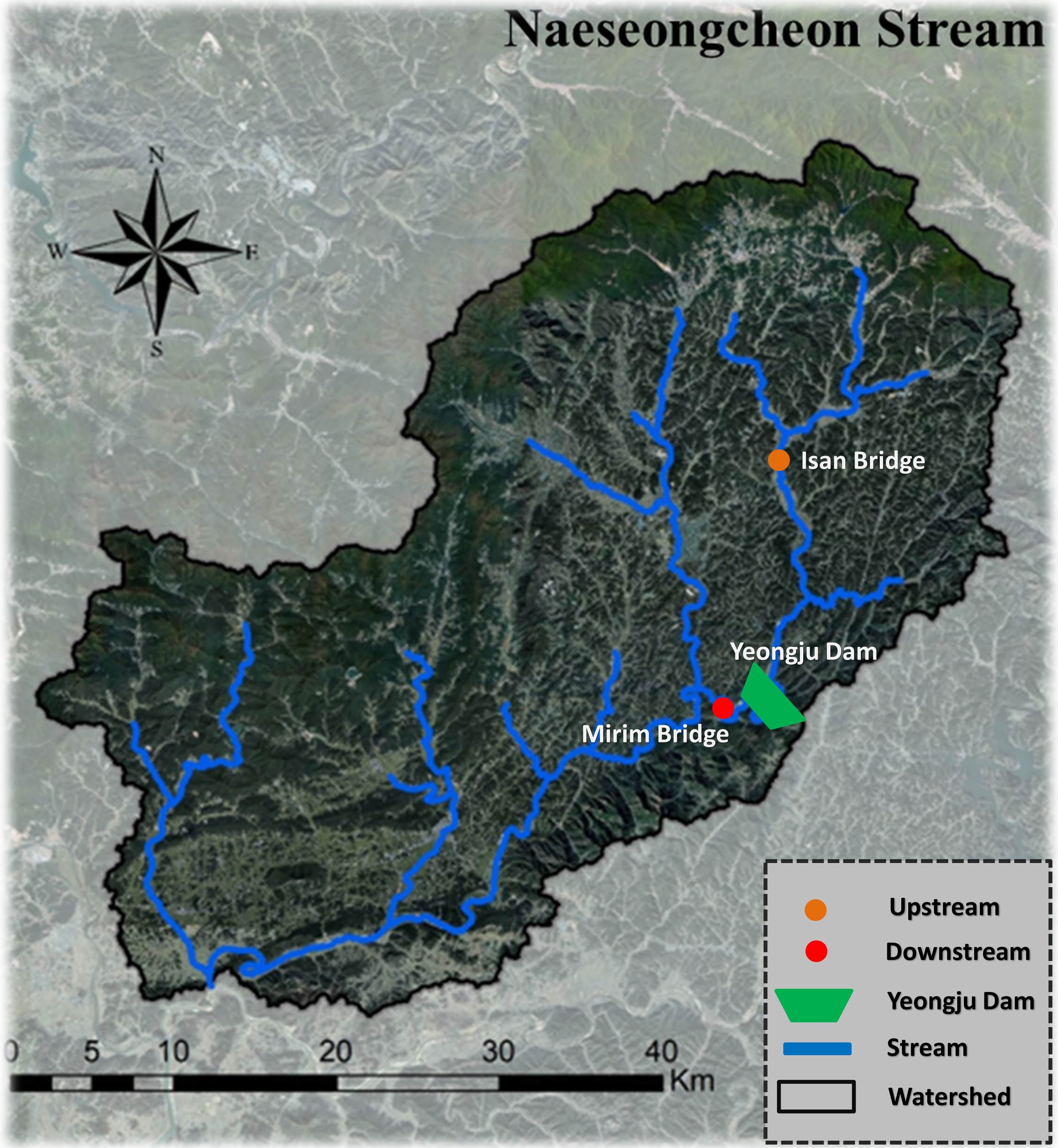


II. RESULTS & DISCUSSION

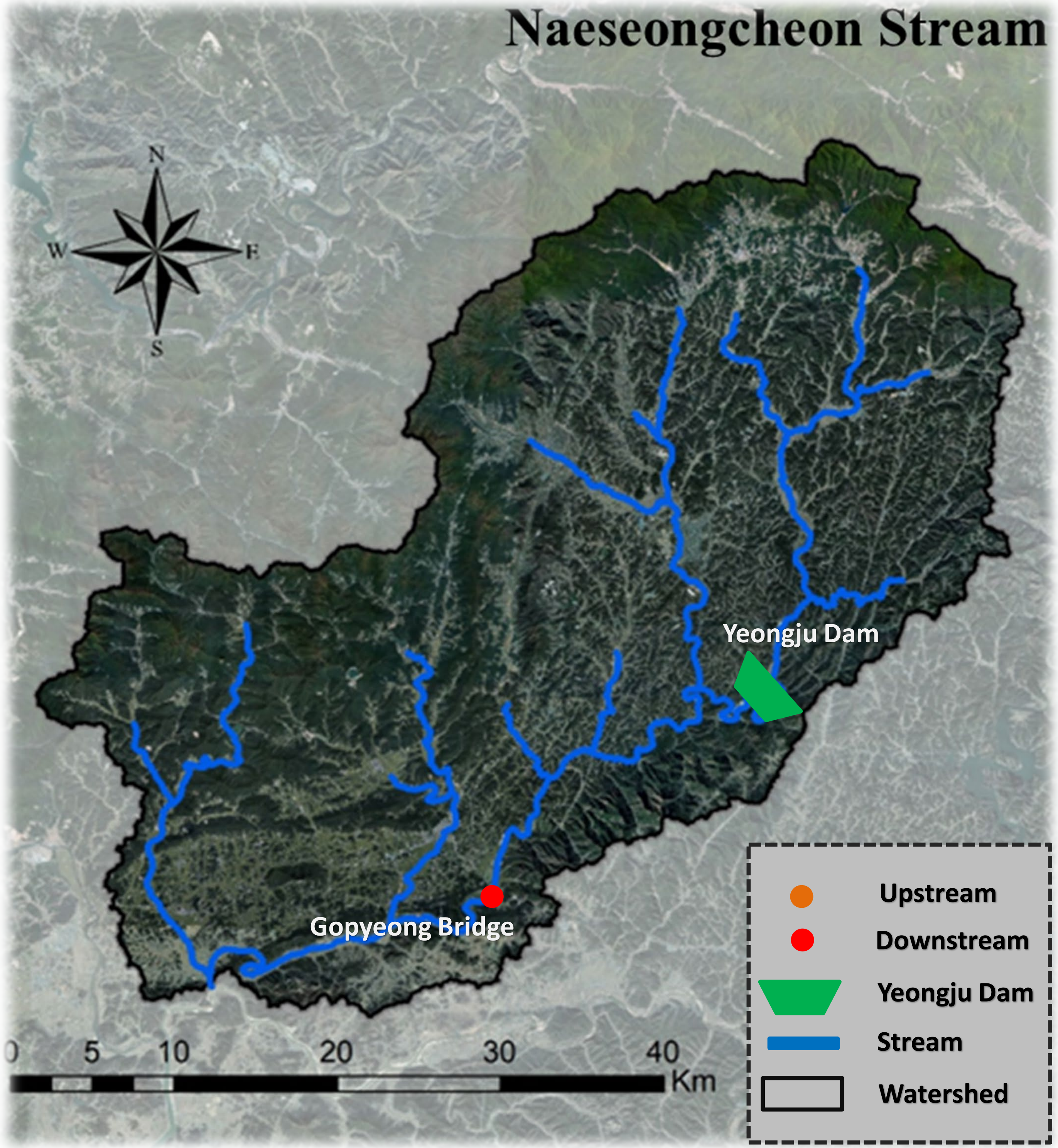
❖ Case # 1

✓ The Total Sediment Retention Rate in the Dam is 13.6% by comparing the Upstream (Isan Bridge) and Downstream (Mirim Bridge) Dam

Year	Total sediment load (ton/year)		
	Isan Bridge (Upstream)	Mirim Bridge (Downstream)	Retention Rate
2017	8,285	13,979	-68.7%
2018	19,780	16,615	16.0%
2019	9,205	3,599	60.9%
2020. 01~06	3,844	1,342	65.1%
Total	41,114	35,536	13.6%



II. RESULTS & DISCUSSION



❖ Case # 2

✓ The Total Sediment Change Rate at Gopyeong Bridge is 16.5% by considering With and Without the Dam

Year	Total sediment load at Gopyeong Bridge site (ton/year)		
	Without Yeongju Dam	With Yeongju Dam	Change Rate
2017	19,502.77	19,447.28	0.3%
2018	33,198.50	28,012.07	15.6%
2019	16,269.77	11,620.52	28.6%
2020. 01~06	7,099.25	4,470.26	37.0%
Total	76,070.29	63,550.14	16.5%

IV

Conclusion

V. Conclusions

❖ Conclusions

❖ The SWAT model, calibrated with reliable flow and sediment data, was used to evaluate the impact of Yeongju Dam on total sediment transport.

- ✓ Case 1 showed a 13.6% retention rate, indicating sediment accumulation within the reservoir.
- ✓ Case 2 showed a 16.5% reduction in downstream sediment load, confirming the Dam's impact on sediment transport

❖ Overall, the results demonstrate that the construction and presence of the Yeongju Dam have a measurable effect on sediment dynamics, both within the reservoir and downstream.

❖ These findings provide a methodology for future sediment management strategies in dam-affected river systems.

❖ Future Works

- ✓ Apply climate change scenarios (SSP1–2.6 to SSP5–8.5) to simulate future rainfall impacts on Total sediment transport for improved dam management.

Thank you for your Attention!