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Evaluation of CSO impact on receiving water quality in Tokyo coastal waters

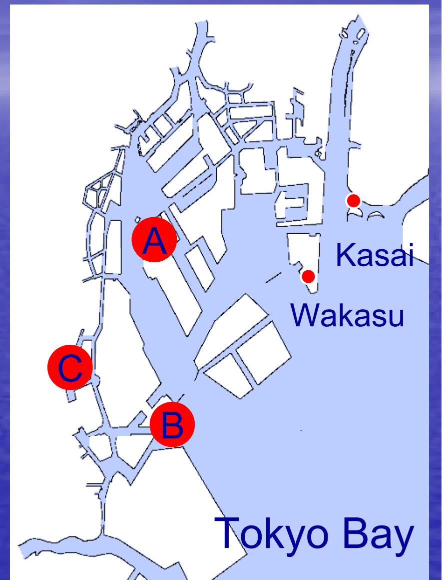
Hiroaki Furumai, Keisuke Kojima,
Akihiko Hata, Ikuro Kasuga,
Futoshi Kurisu and Hiroyuki Katayama

Research Center for Water Environment Technology,
Department of Urban Engineering
Graduate School of Engineering, The University of Tokyo

東京大学
THE UNIVERSITY OF TOKYO

Safe and confortable water front for water-amenity in coastal area of Tokyo Bay

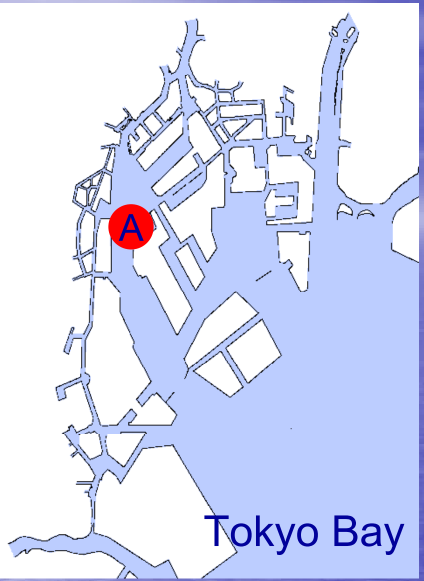
A Odaiba seaside park



B Jyonan-jima seaside park

C Ohi-pier central seaside park

Odaiba Seaside park



Area: 50.7ha (Land 7.2ha、Sea 43.5ha)

Average Depth: 3m

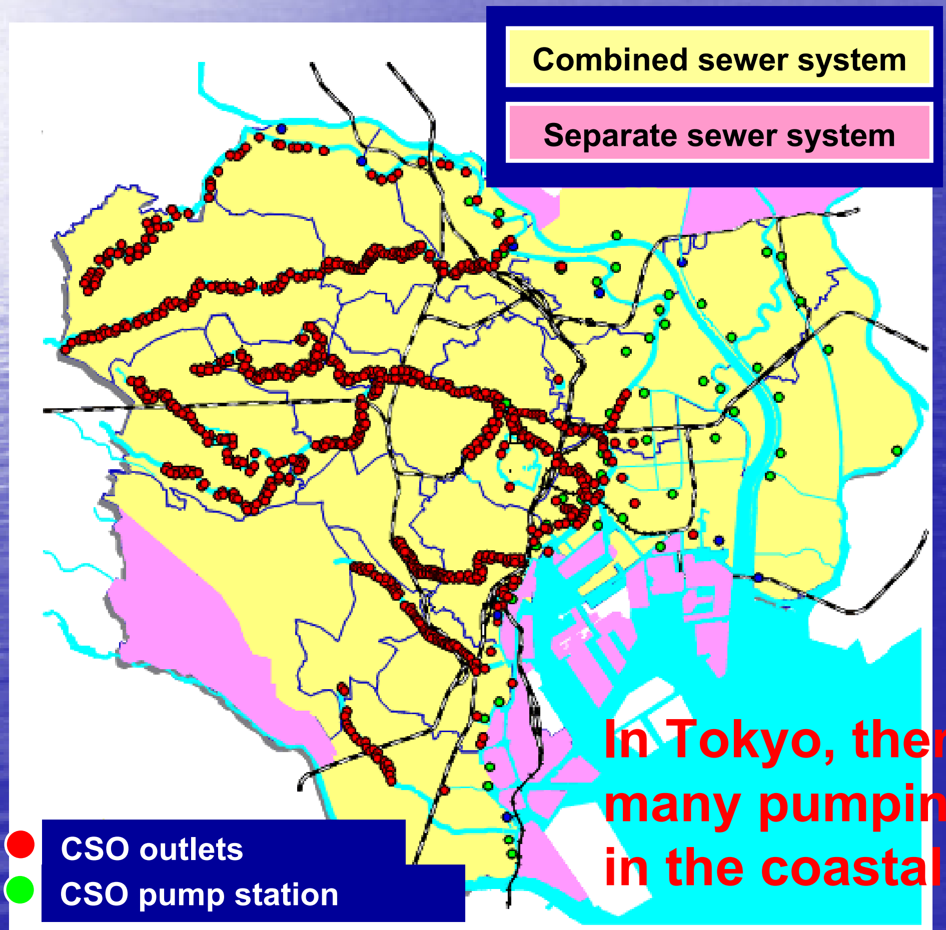
Volume: 1.40Mm^3(at ebb tide)

No. of Visitors: 1.67 Million in 2001

Background (CSO events in Tokyo: about 30 times per year)

Combined Sewer Overflow (CSO)

- In rainfall events, untreated sewage is often discharged into receiving water with dilution by rainwater



- BOD loading by CSO accounts for about 40% of total loading on receiving water

- In receiving waters, there is concern about CSO impact on health risk and hygiene issue at water front with water amenity activities

In Tokyo, there are about 800 CSO outlets and many pumping stations along urban rivers and in the coastal area.

Ref. Ministry of Land, Infrastructure and Transport

Research Purposes

- To investigate the distribution of pathogenic indicator, *Escherichia Coliform(E coli.),* at a coastal region of Tokyo Bay after a CSO event
- To develop a numerical model describing the behavior of *E coli.* and to calibrate the model with the monitoring data

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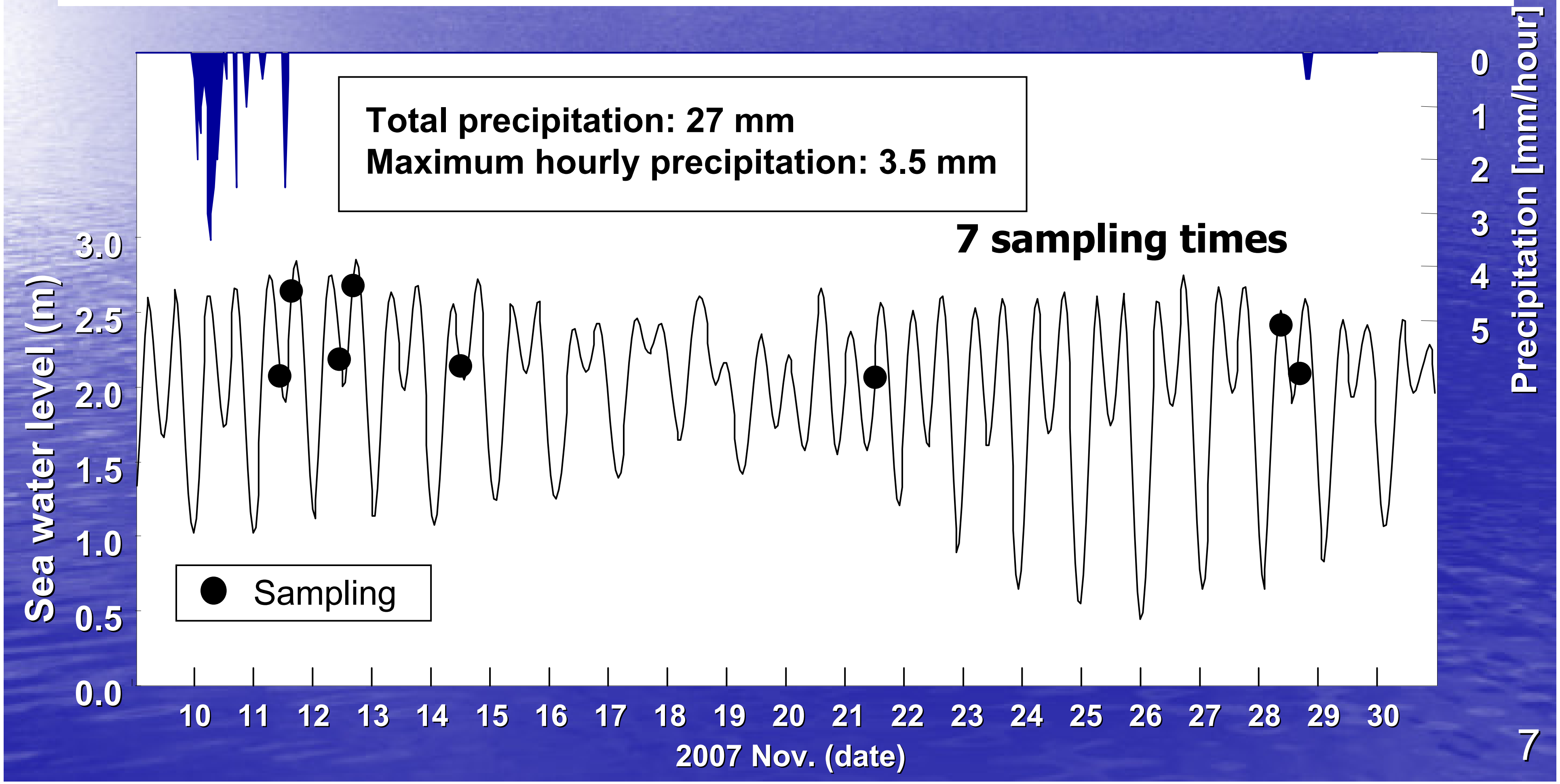
- ◆ Monitoring is necessary to understand the impact of the CSOs on water pollution at a seaside park
- ◆ Numerical model for the behavior of *E coli*. would be helpful to evaluate pathogenic pollution level quantitatively.
- ◆ Calibrated model can be used to predict pollution level and to identify the most important pollutant loads. It is also applicable to explore countermeasures for water pollution control and to evaluate their effectiveness.

Extensive Monitoring

Extensive Monitoring

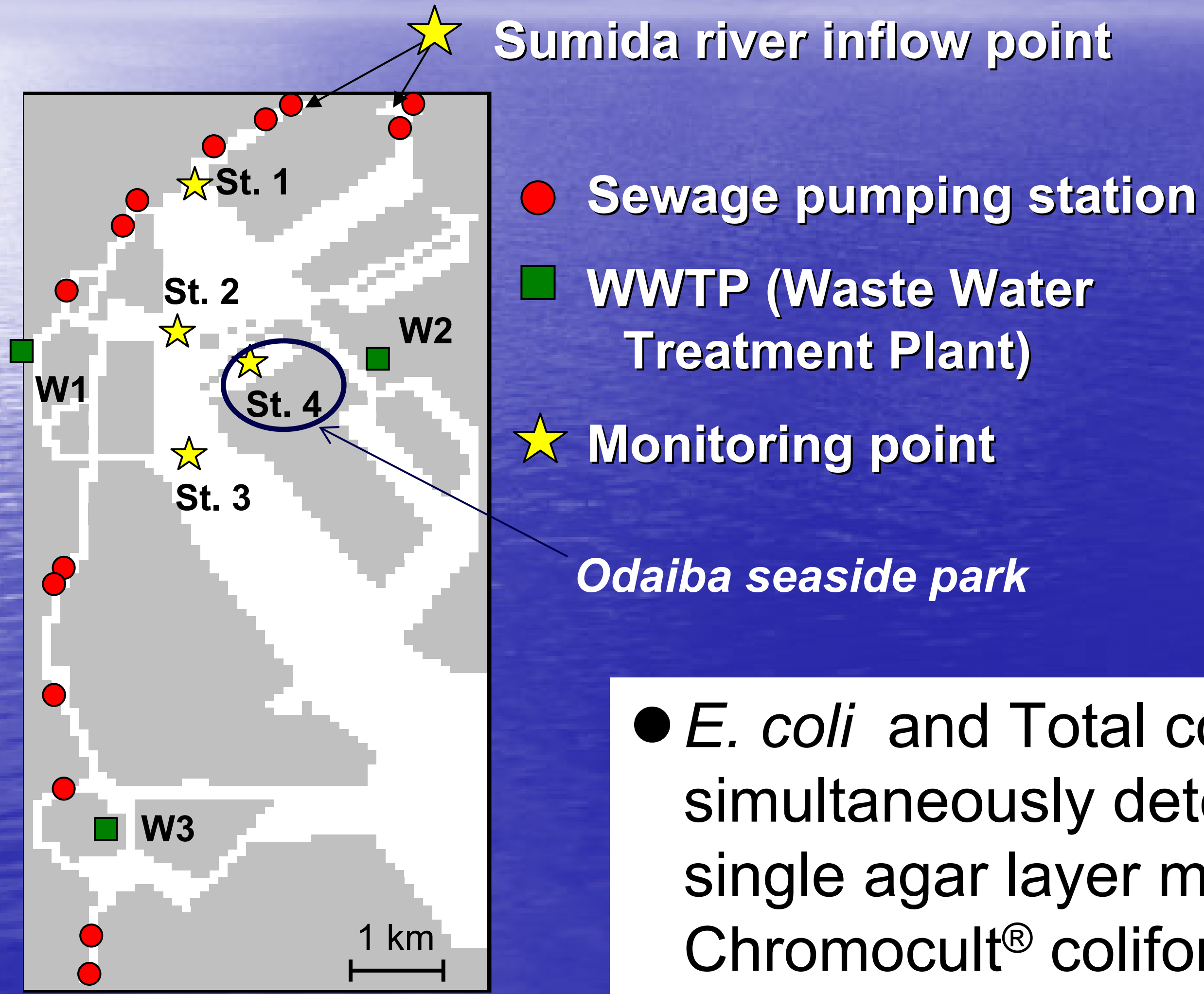
- Long term monitoring after CSO event

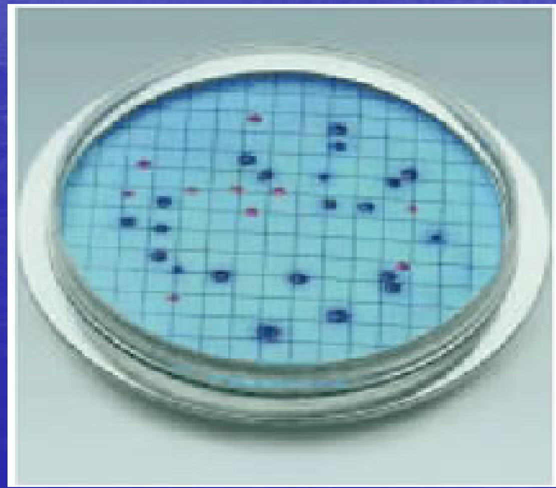
To observe the duration of pathogenic pollution at the coastal area caused by CSO



Monitoring points and analysis of coliforms

- To investigate distribution of pathogenic indicators at 5 points (river inflow point and St.1-St.4 in coastal area)





- *E. coli* and Total coliforms were simultaneously determined by a single agar layer method using Chromocult® coliform agar (Merck).

Distribution of *E. coli* concentration (Surface water)

11 November
(Ebb tide)

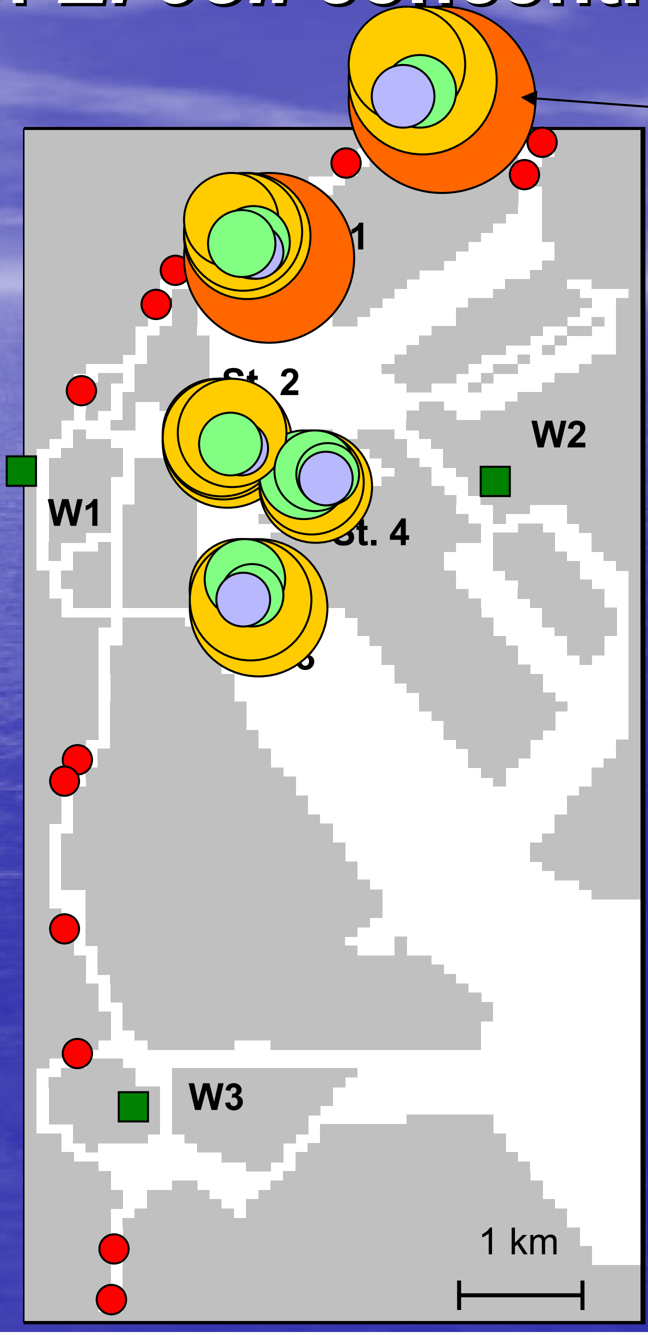
12 November
(Flood tide)

14 November
(Ebb tide)

21 November
(Flood tide)

22 November
(Flood tide)

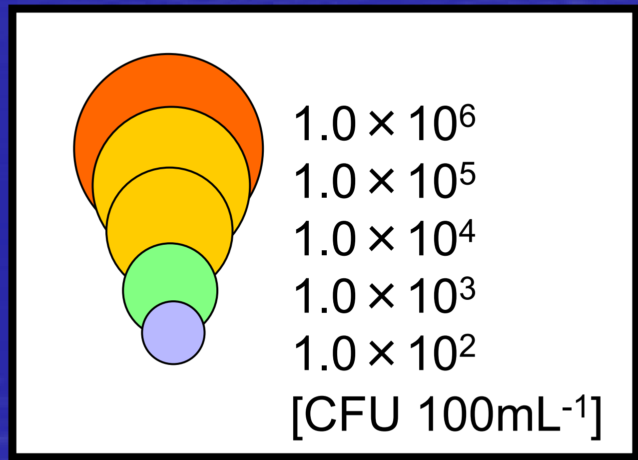
28 November
(Ebb tide)



Sewage pumping station

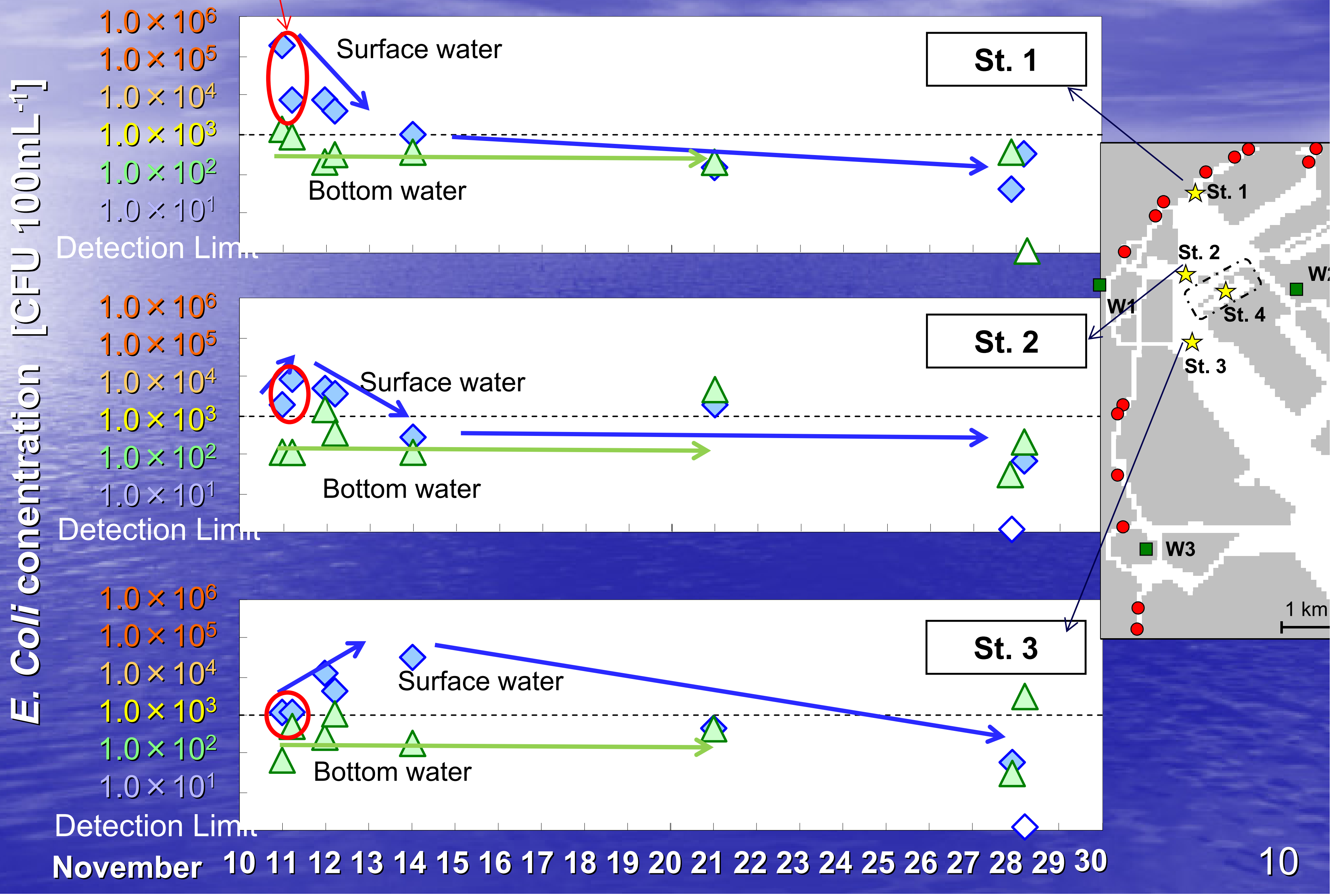
WWTP (Waste Water Treatment Plant)

Monitoring station



Temporal change of *E. coli* Concentration

Variation between ebb and flood tides



Summary (Extensive Monitoring)

- The extensive monitoring showed clear evidence of fecal contamination caused by CSO at a seaside park as well as the river inflow streamline.
- Two types of temporal variations in the *E. coli* concentration were observed. One is variation between ebb and flood tides and another is downward movement of polluted water mass by river inflow.
- Regarding to the downward movement of highly polluted water mass, there was a time lag in increase of *E. coli* concentration found at downstream station (St. 2, St. 3).
- The monitoring data showed that it took four days to decrease the contamination level to the bathing water quality criteria at St. 1, St. 2 and St. 4, while St 3 had higher contamination than other points 4 days after the event.

3-Dimensional simulation

3-Dimensional Flow and WQ Model

Input data

- Bathymetric feature
- Meteorological Data
  air pressure, vapor pressure, temperature, relative humidity, wind speed, wind direction, cloud amount, solar radiation, precipitation
- River discharge (inflow)
- Open boundary data such as sea level, water temperature, salinity
- Sewage (CSO) discharge at the pumping stations and Effluent discharge at the wastewater treatment plant

Model structure

3Dimensional model

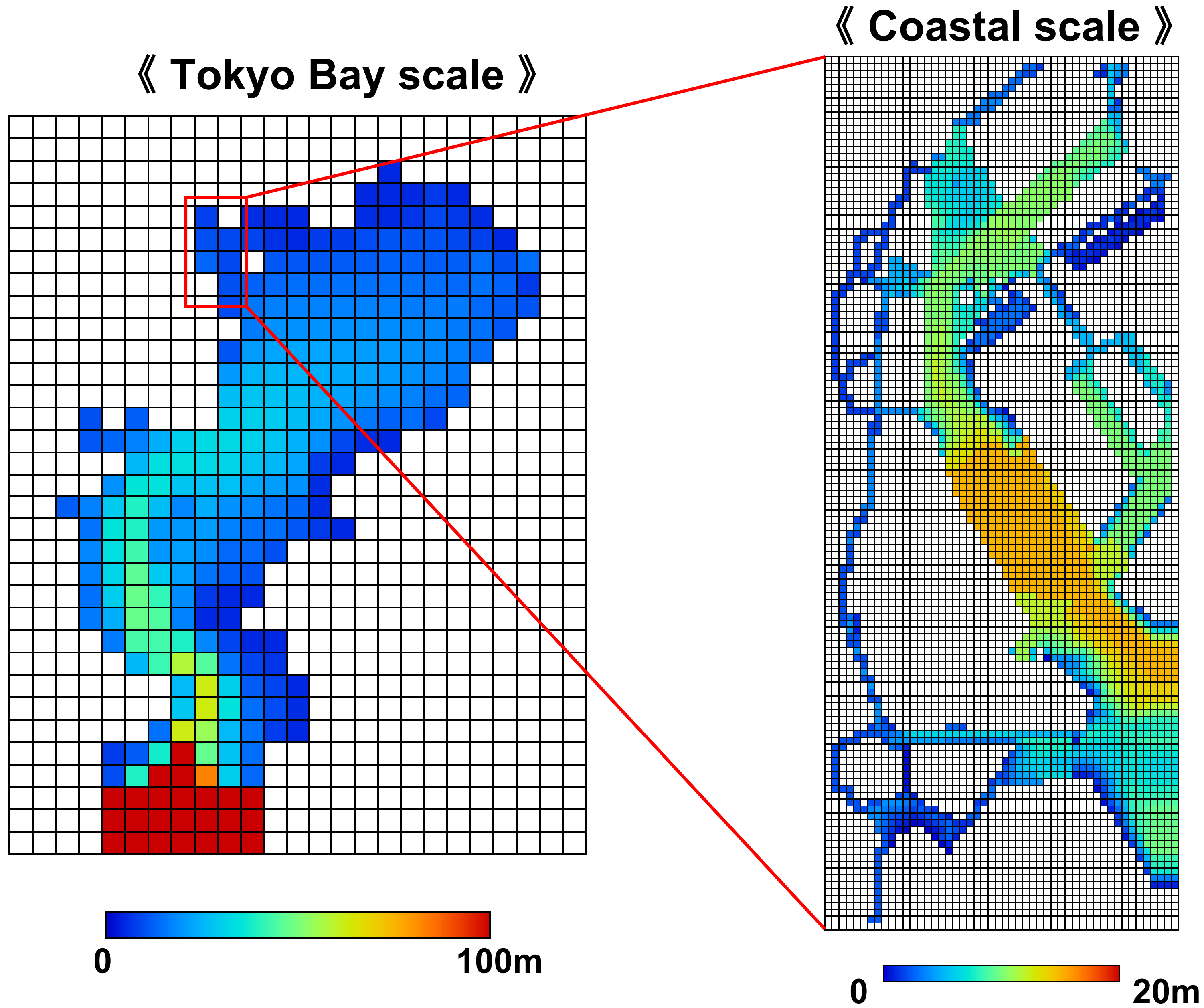
(σ -coordinates)

- Navie-Stokes equation
- Mass balance equation with advective diffusion, settling and decay of *E. coli*

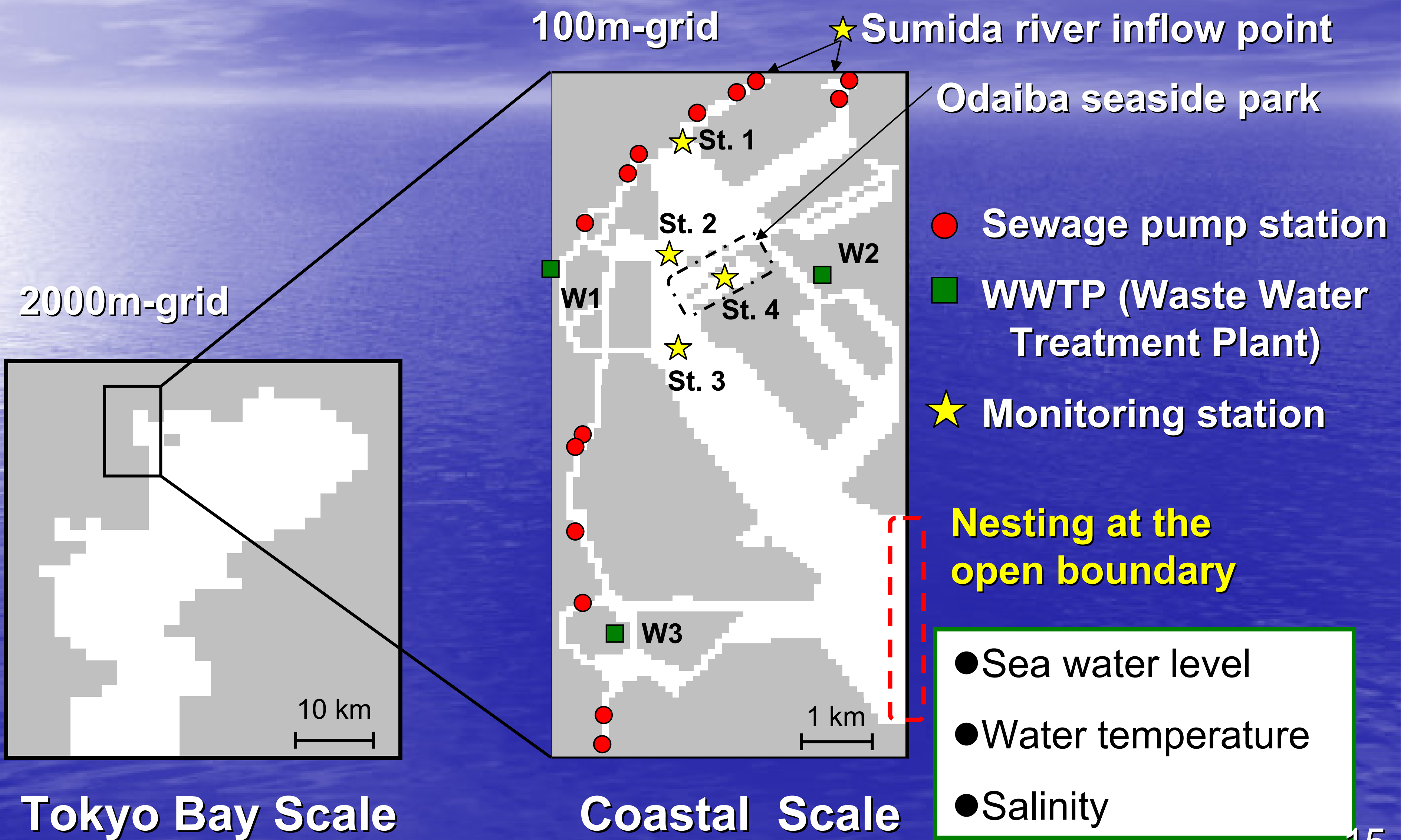
Output data

- Water velocity, sea water level
- Water temperature, salinity
- *E. coli* conc.

Bathymetric feature



3-Dimensional Simulation Area



Advection-diffusion equation (*E. coli*)

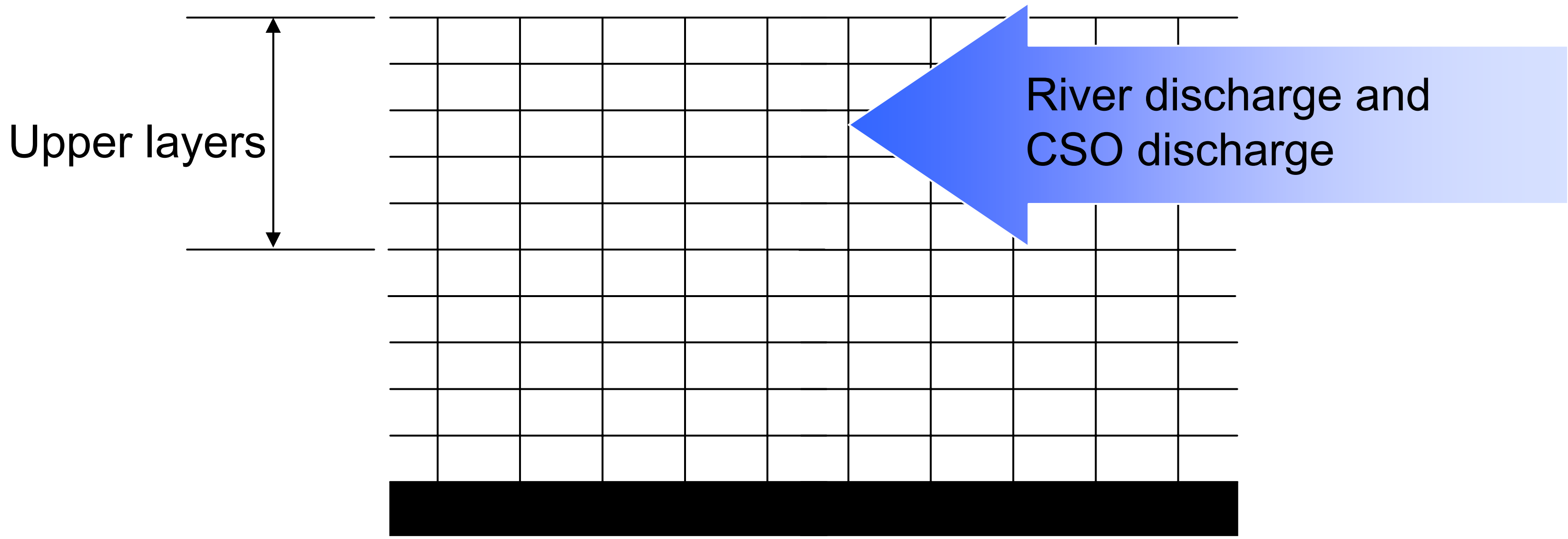
Settling velocity — Decay

$$\frac{\partial C}{\partial t} + u\frac{\partial C}{\partial x} + v\frac{\partial C}{\partial y} + (w + W)\frac{\partial C}{\partial z} = \frac{\partial}{\partial x}(K_X \frac{\partial C}{\partial x}) + \frac{\partial}{\partial y}(K_Y \frac{\partial C}{\partial y}) + \frac{\partial}{\partial z}(K_Z \frac{\partial C}{\partial z}) + R_D + F_{ex}$$

$$R_D = -K_D C$$

$$F_{ex} = (flow_R \times C_R + outflow_P \times C_P + outflow_W \times C_W)/V$$

(***E. coli inflow*** **load to the upper layers**)



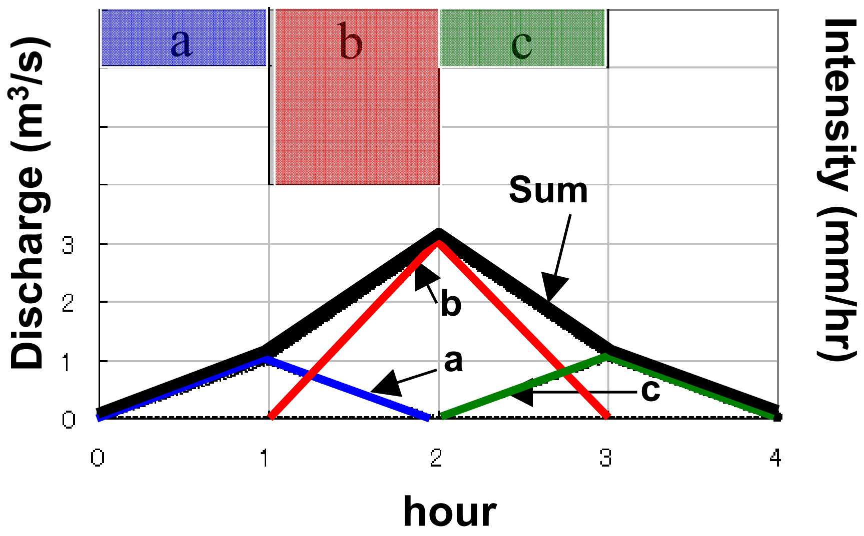
Conditions of river flow and runoff discharge

- River flow rate was summation of base river flow and runoff discharge. The runoff discharge was calculated by unit hydrograph method with rational formula depending catchment area and travelling time.

Hydrograph method with rational formula

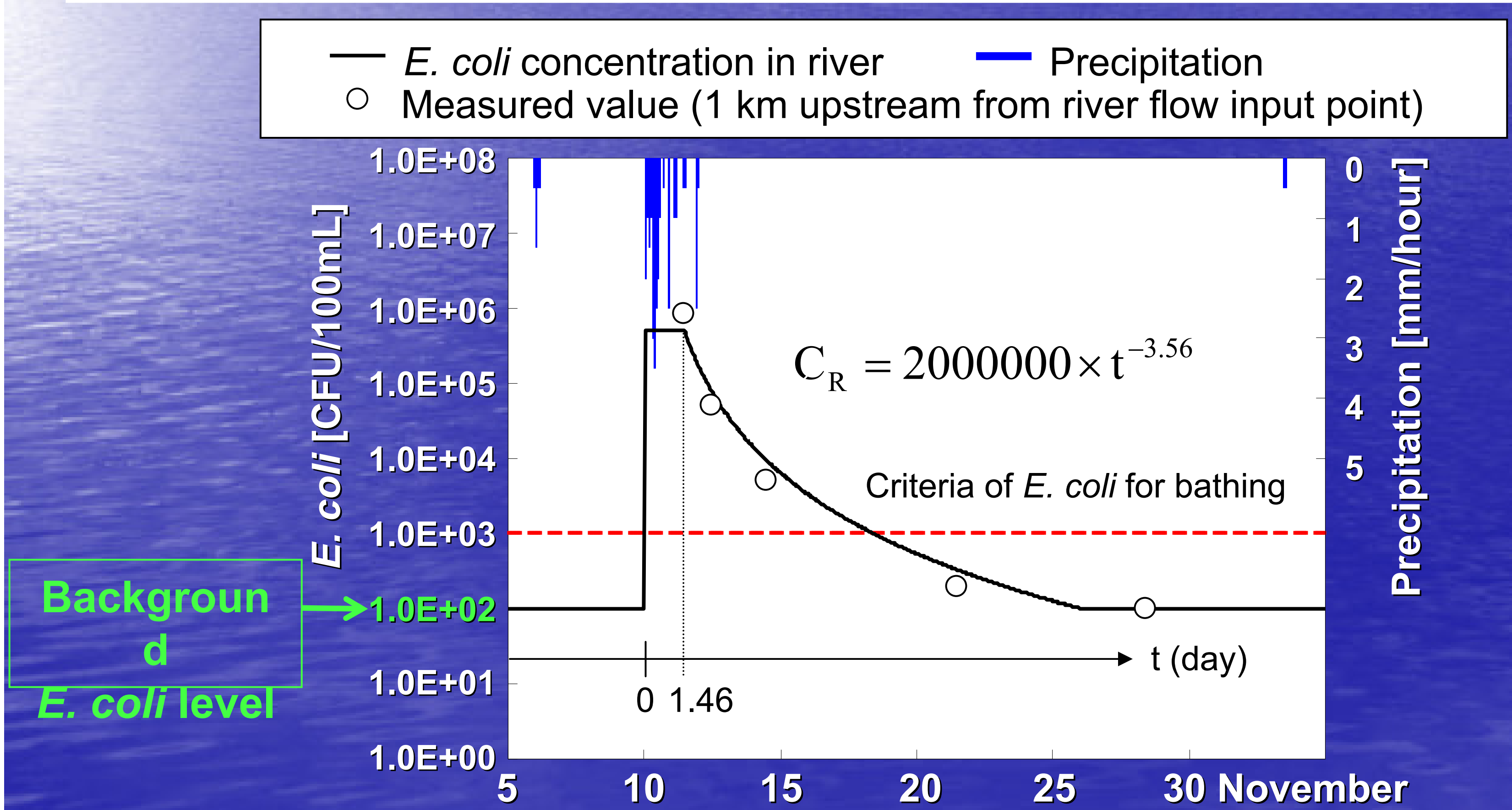
$$Q = \frac{1}{360} \times C \times I \times A$$

C: runoff coefficient
I : rainfall intensity
A : catchment area



Condition of *E. coli* concentration from river

- *E. coli* concentration change in river inflow was estimated based on the monitoring data at 1km upstream from the river boundary grid.
- The background *E. coli* concentration was given as 100 CFU /100mL in river flow and coastal water before the rainfall



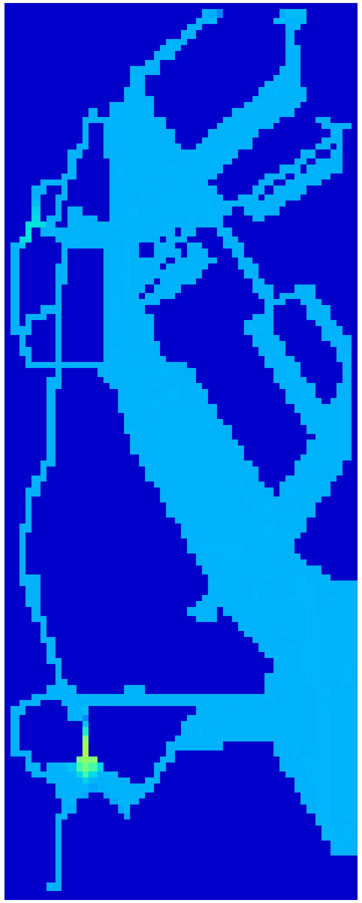
Condition of *E. coli* concentration from Pumping Station (Cp) and WWTP (Cw)

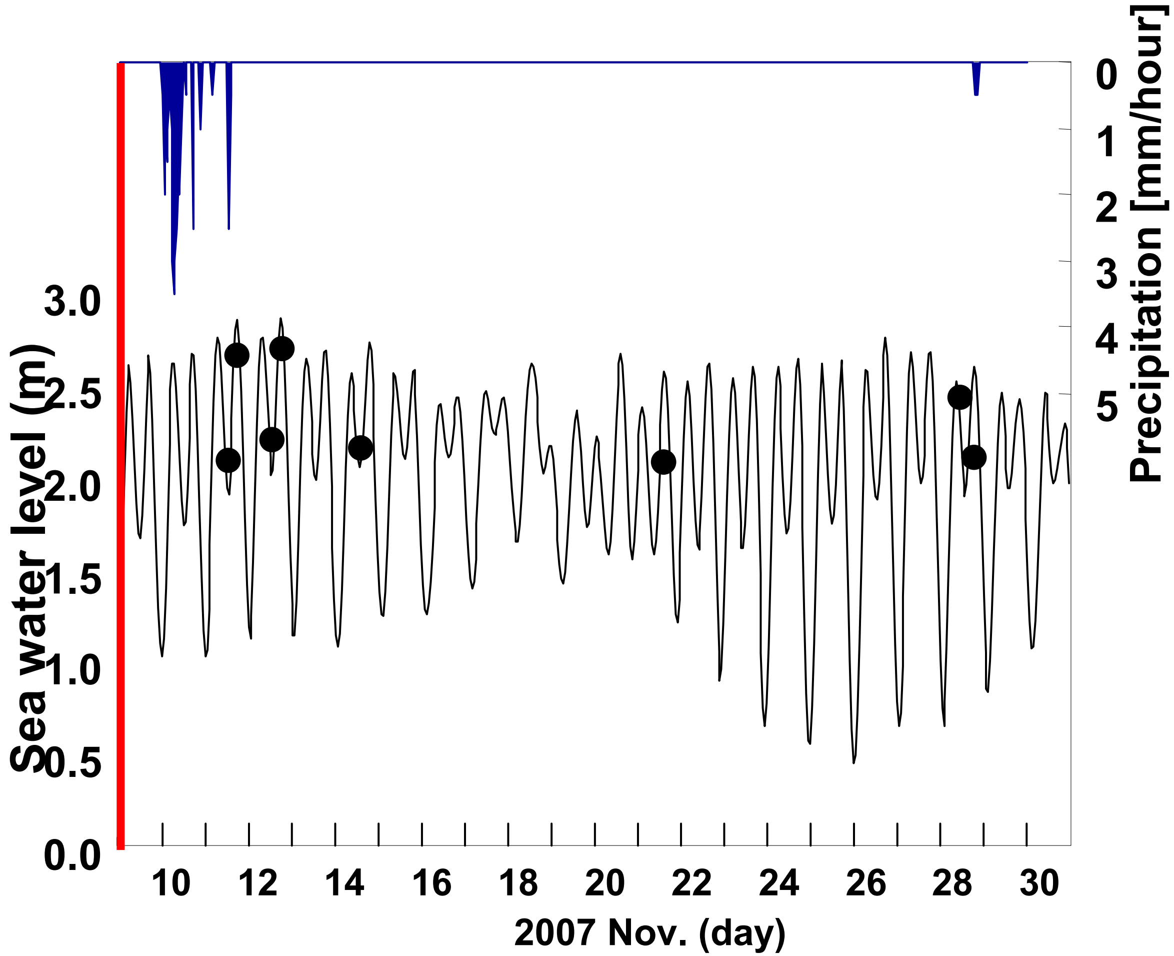
$$C_P = C_S \times \frac{sewage\ flow\ rate}{sewage\ and\ rainwater\ flow\ rate}$$

$$C_W = \frac{C_{WC} \times secndary\ treatment\ flow\ rate + C_{WP} \times primary\ treatment\ flow\ rate}{secndary\ and\ primary\ treatment\ flow\ rate}$$

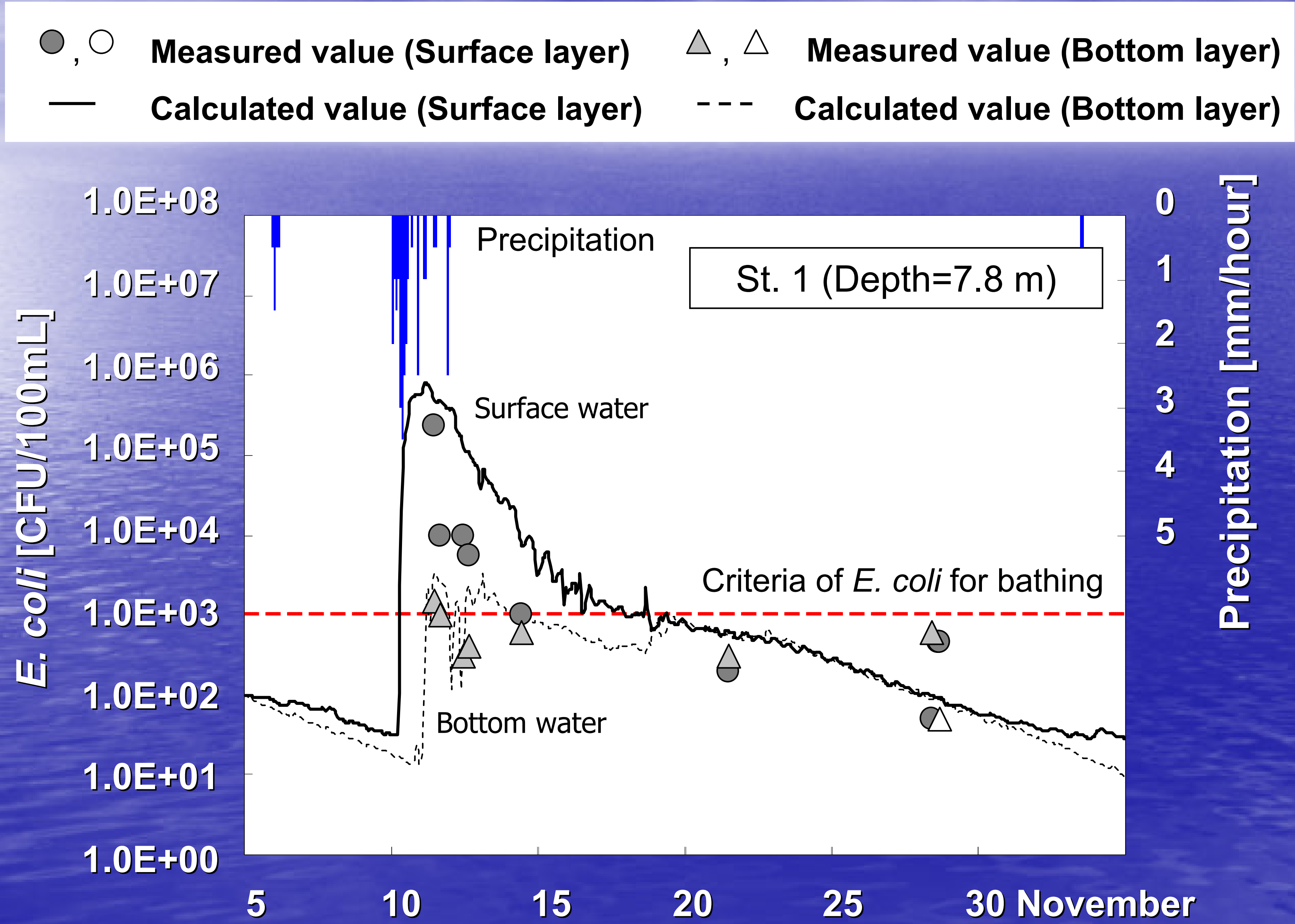
- C_S, C_{WC}, C_{WP} are *E. coli* concentrations in dry weather sewage, secondary effluent and primary treatment discharge.
- Sewage flow rate = dry weather flow rate (Q) changing with time using variation coefficient.
- Runoff (rainwater) flow is estimated by unit hydrograph and rational formula depending on drainage area and travelling time.
- Primary treatment discharge: intercepting flow rate (2-3Q) – secondary treatment flow rate (dry weather flow=Q)

Simulation results of *E. coli* concentration (Surface water)

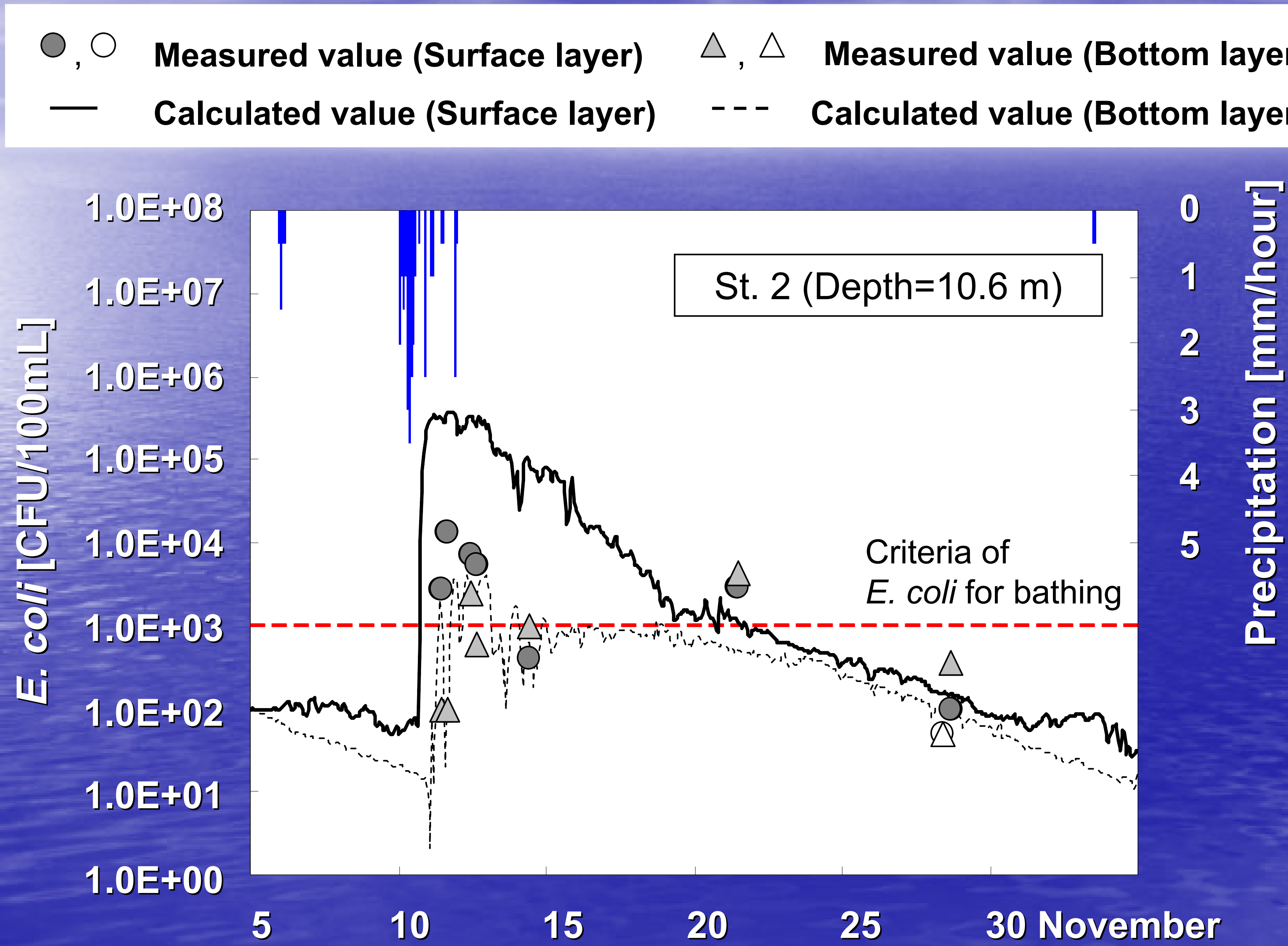




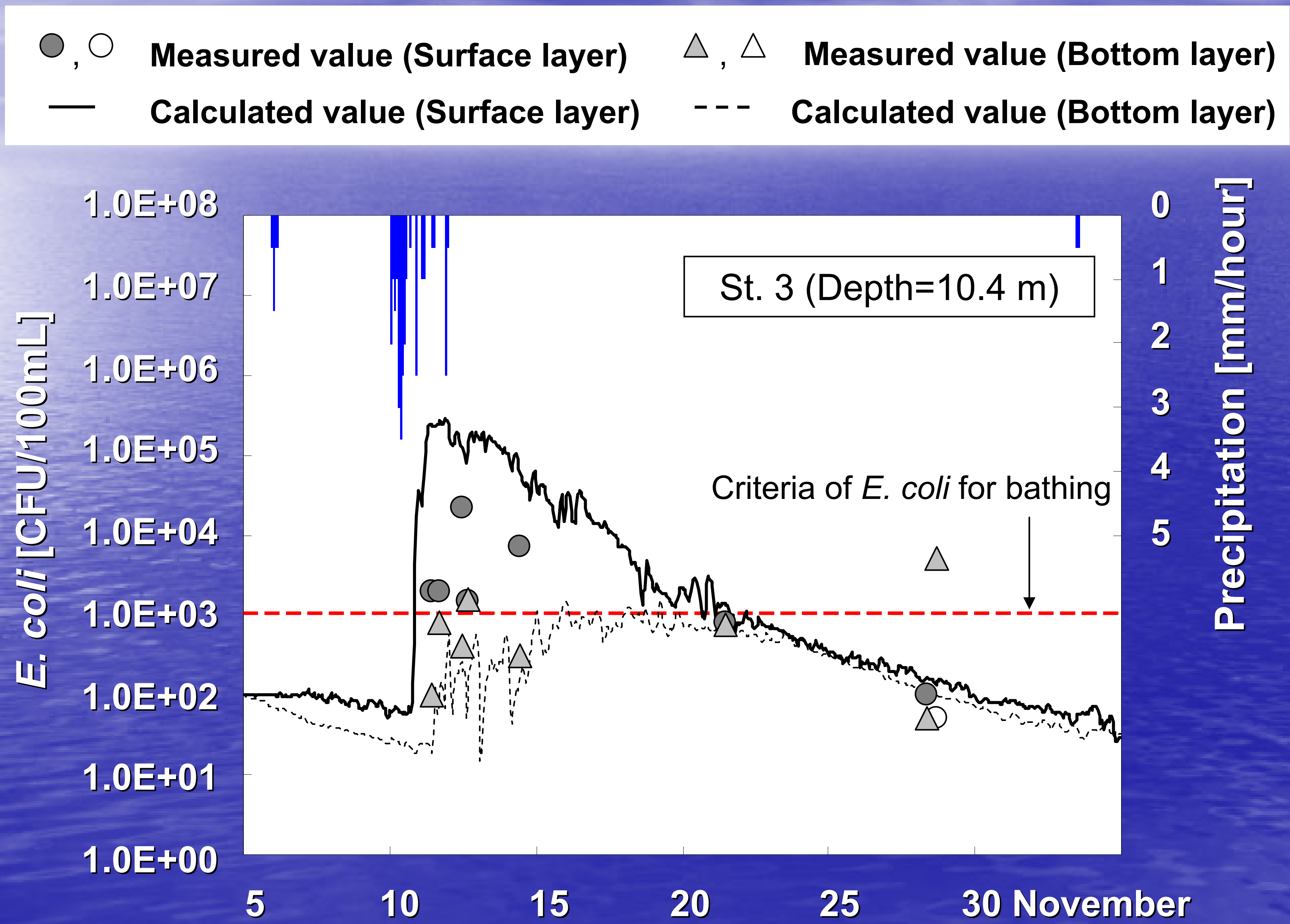
Simulation results at St. 1



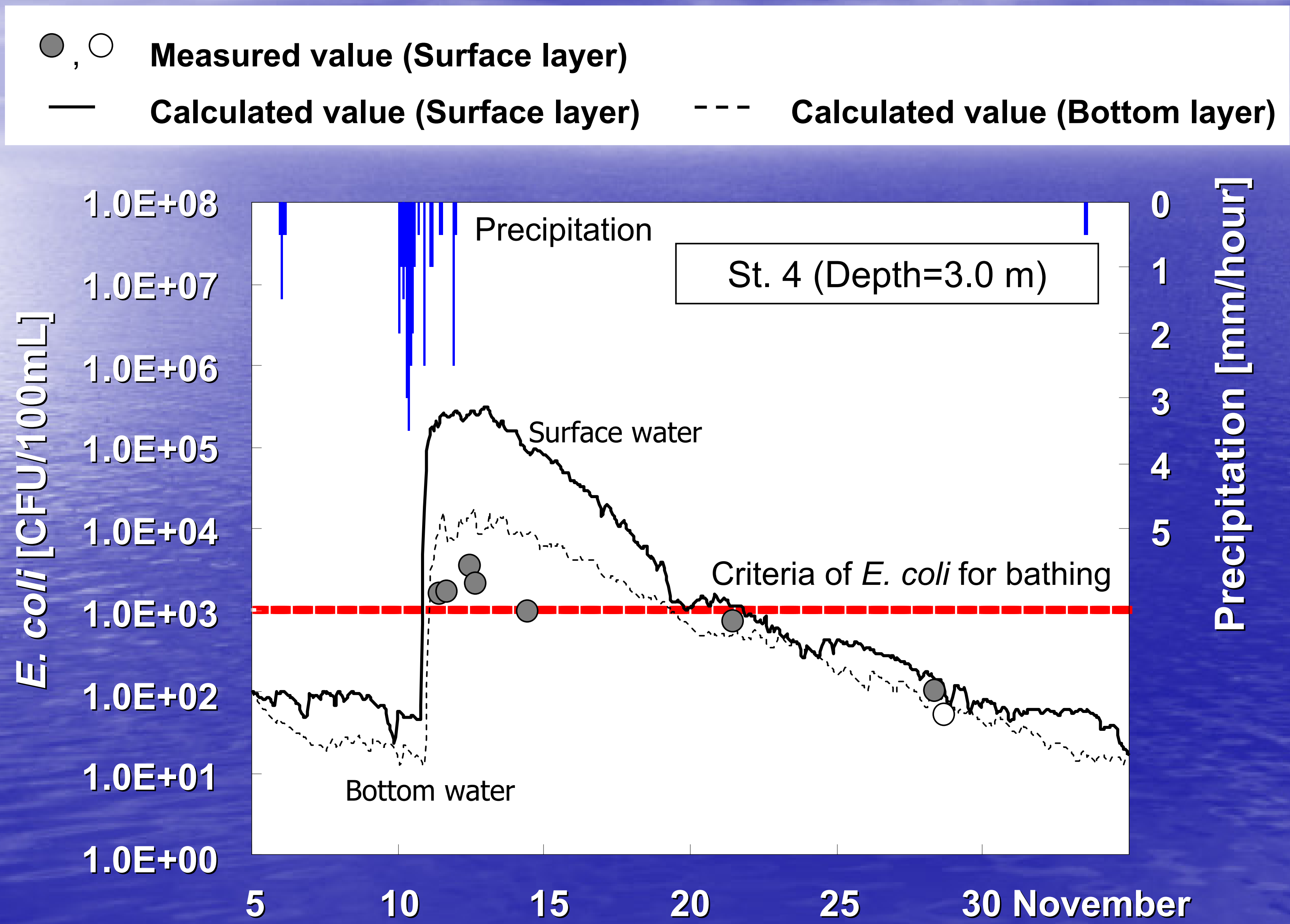
Simulation results at St. 2



Simulation results at St. 3



Simulation results at St. 4 (Odaiba seaside park)

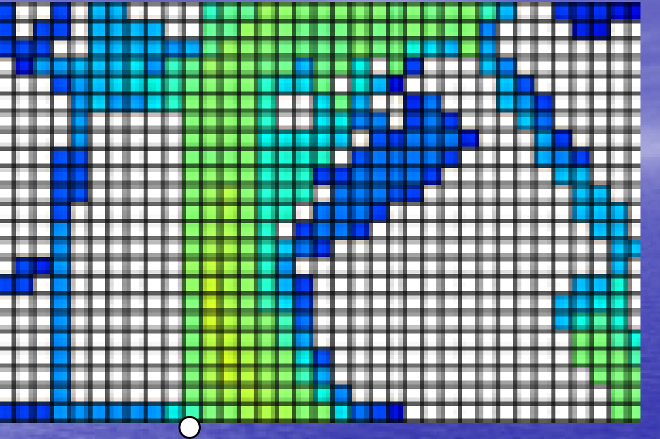


Summary (3-dimensional simulation model)

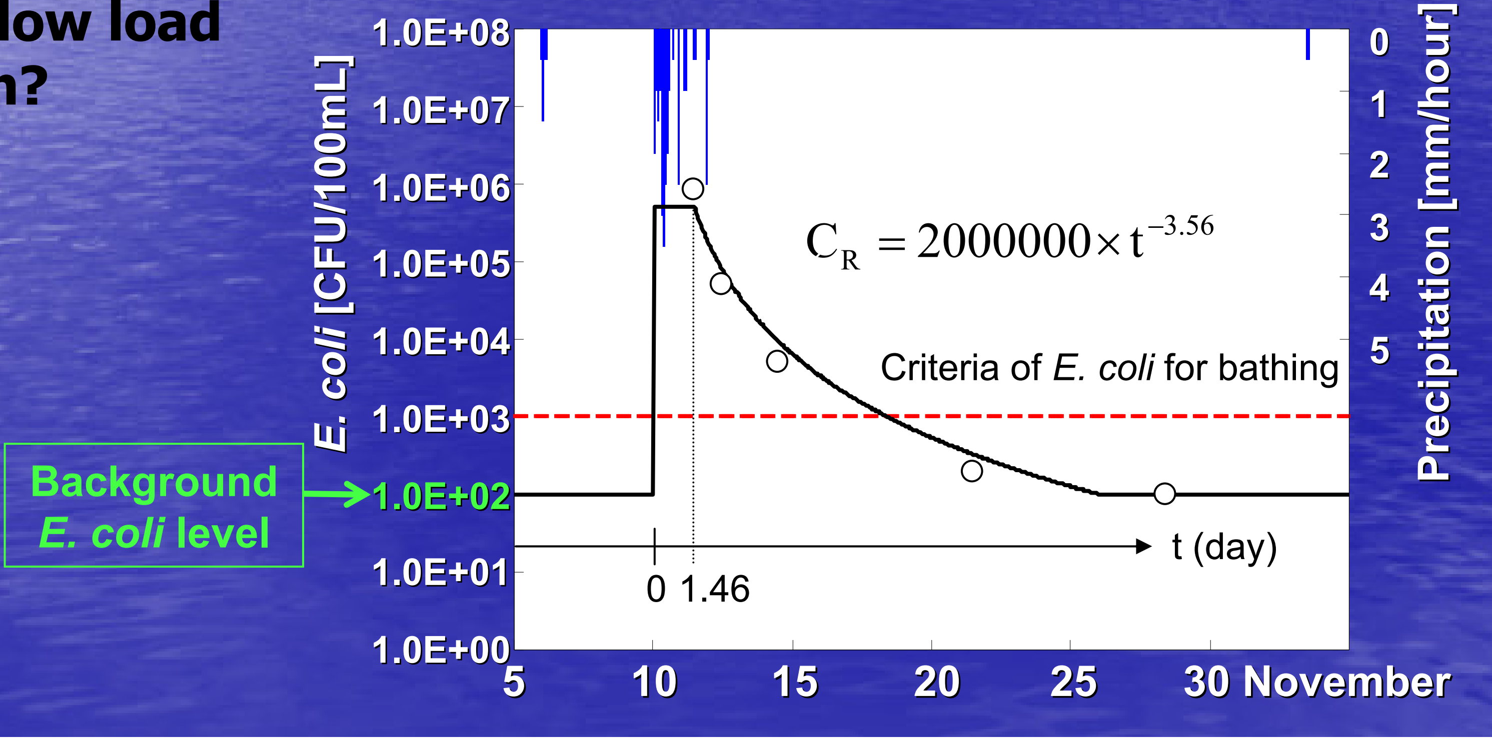
- Spatial distribution and temporal changes of *E. coli* concentration were simulated using 3-dimensional water quality model.
- This simulation suggested that *E. coli* loading from the river inflow can have a greater impact on increasing trend in *E. coli* concentration in coastal area including the Odaiba seaside park.
- However, the simulation results overestimated the *E. coli* concentration in surface water during several days, while the concentration was relatively well-expressed in the bottom water.
- It is necessary to elaborate the input condition of pollutant load from river inflow so that model calibration could be sufficiently achieved for *E. coli* behavior prediction in the coastal area.

Points to be improved

Grid resolution?



River inflow load condition?



Thank you for your kind attention