# SEDIMENT TRANSPORT IN RIVER MOUTH ESTUARY


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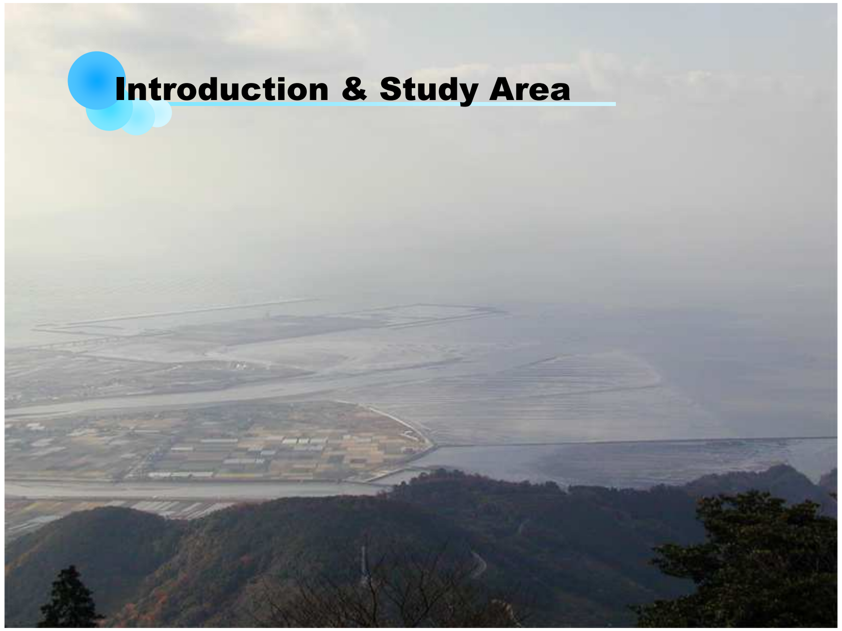
# Introduction & Study Area



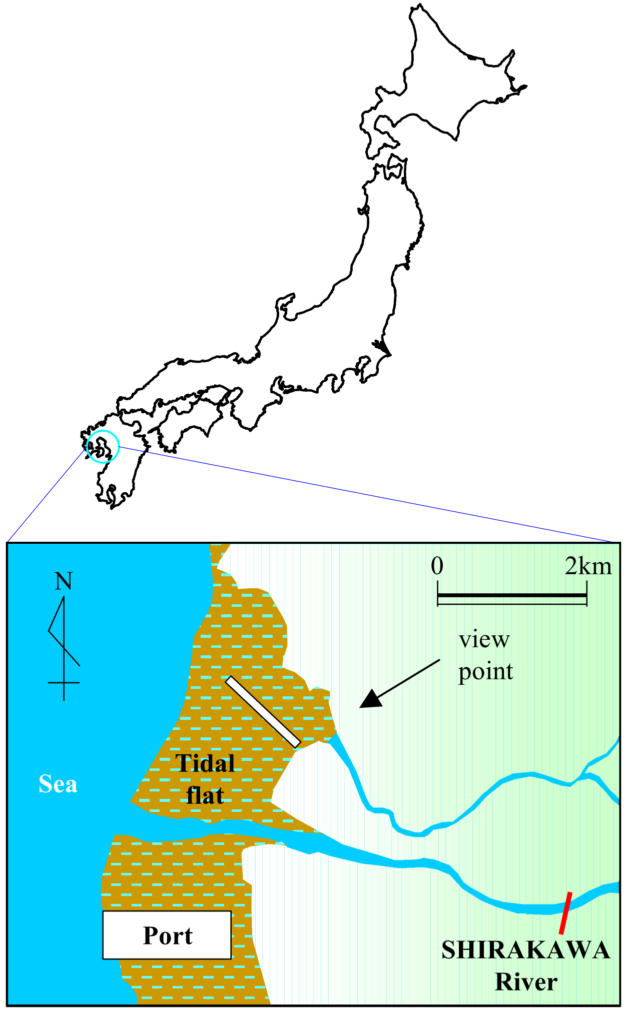
The river mouth estuary and wetland are comprised of variety of natural, morphologically and ecologically complex aquatic environments.

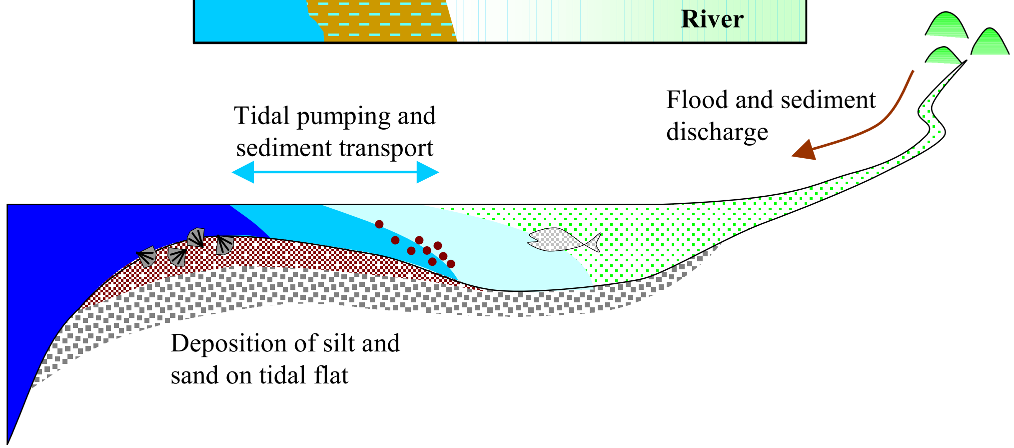
In this region, fresh water mixes with salt water, therefore the river stream runs more slowly, the suspended sediment supplied from the upstream basin deposit and the shallow water area is created.

River mouth estuary is very important area for ecosystem and fishery. On the other hand, it is necessary to dredge and enlarge the river channel in some cases in order to discharge the river flood into sea safely.

The purpose of this study is to develop the rational management practices of river mouth estuarine resource. It is necessary to explain the sediment transport and the topographical process.

A field study was undertaken in the SHIRAKAWA river. The topography change of tidal flat was surveyed and the sediment discharge by floods was measured and the annual sediment transport by tidal current was monitored. Using these results, the amount of sediment load was calculated and the influence of the sediment transport by flood and by tidal current on the topography change was discussed.



# Sediment Load by Flood Discharge

## METHOD

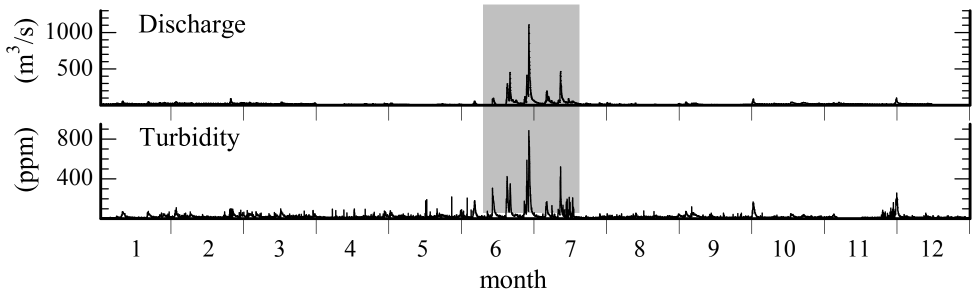
Self-logging Optical Backscatterance Sensor with Wiper

Measurement of Flood Discharge

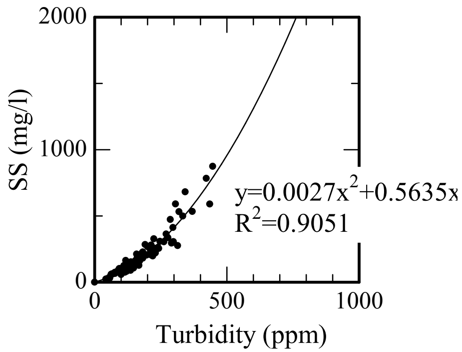
Sediment discharge was measured by combination of two method. Turbidity was monitored continuously by self logging optical backscatterance sensors over one year. Actual suspended sediment concentration (SSC) was determined from flood samples which were collected by lowering the open container to the water surface with a rope. At the same time, turbidity of sampled water was measured. SSC time series will be estimated from turbidity monitoring data by using correlation between SSC and turbidity.

## RESULT

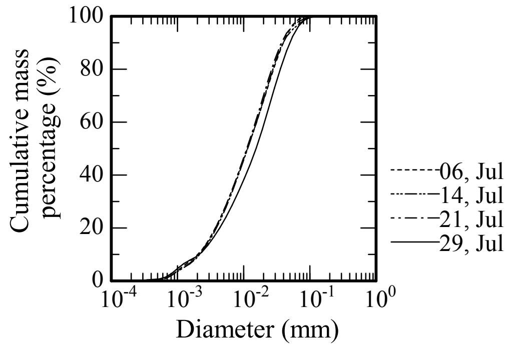
Measurement Result of Turbidity Monitoring during One Year



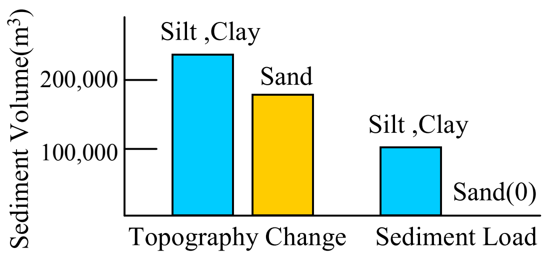

Correlation between Turbidity and SSC




Particle Size Distribution




Comparison of Topography Variation with Sediment Load During Flood Term




Turbidity has high correlation with SSC. SSC time series can be calculated by these results, then sediment load will be estimated by SSC and flow rate. SS component was almost silt and clay.

Topography variation after flood term is lager than sediment load during flood term. The reasons are as follows; Topography variation has error of 100,000m$^3$, because the resolution of sounding survey is few centimeters. Suspended sediment load is accurate in estimation but bed load can not be caught by field measurement.

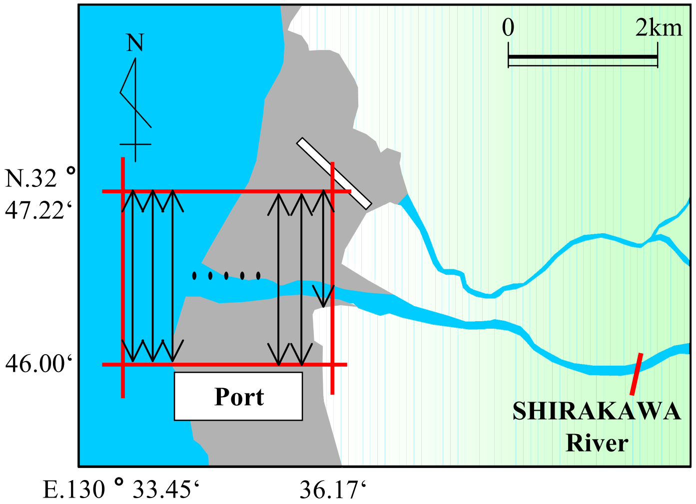
As a result, the quantity of fine sediment transport during flood term (2001) was about 100,000-200,000m3.

# Topography and Deposited Materials Change on Tidal Flat

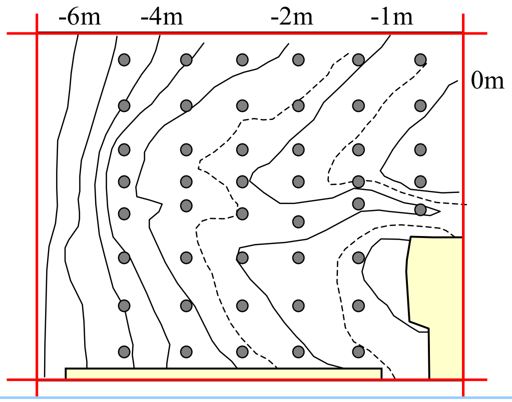
## METHOD

Topography of tidal flat was surveyed by echo sounder and differential GPS. Bed materials was directly sampled by divers. These were undertaken before flood term (June 2001), just after flood term (July 2001).

Location of Sounding Survey

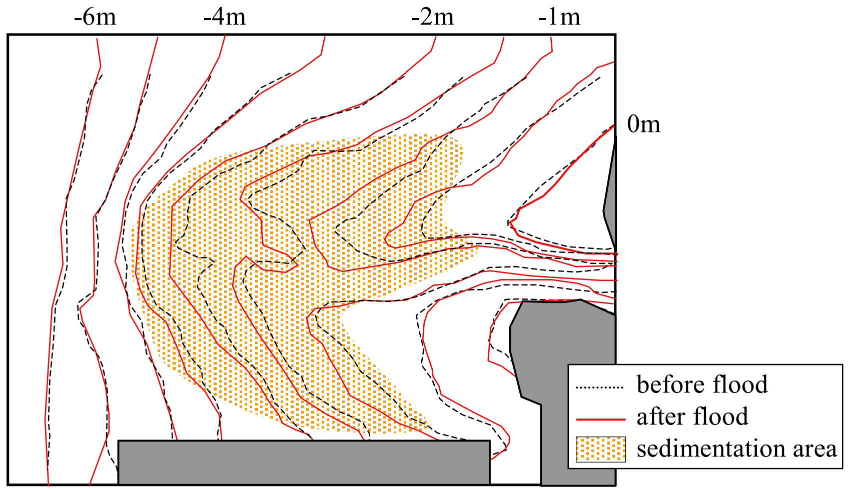



Location of Bed Materials Sampling

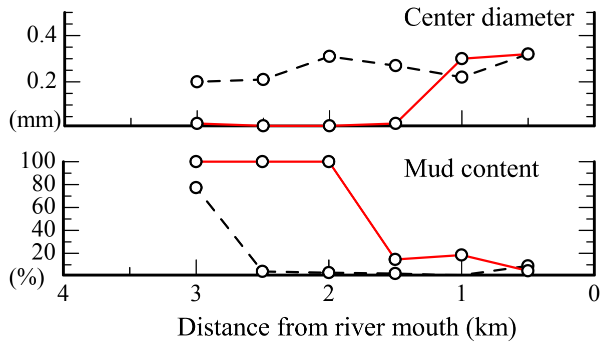



## RESULT

Topography Change




Bed Materials Change




Sedimentation Quantities for Each Particle size

| Type | Variation($m^3$) |
|---|---|
| Silt and Clay | 239,682 |
| Fine Sand | 175,018 |
| Sand | 9,430 |
| Total amount | 424,131 |

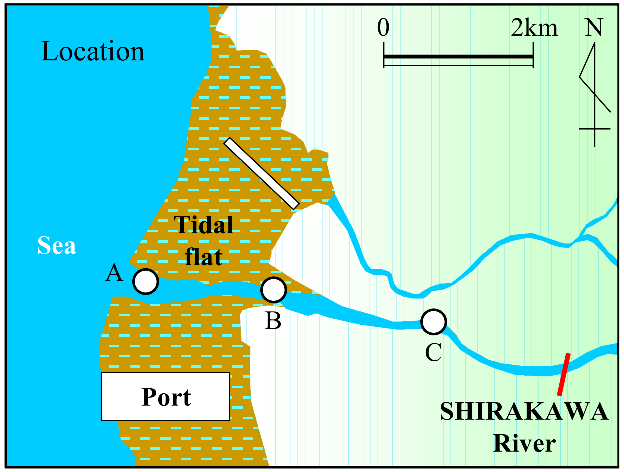
The elevation became high in front of the river mouth after flood term. In the sedimentation area, particle size became small and mud content ratio which is under 0.074mm increased.

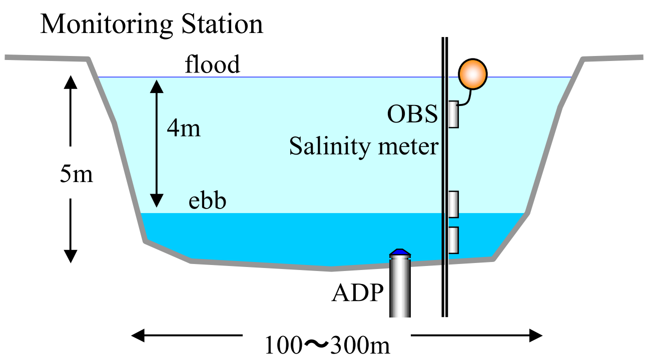
These results shows that a lot of silt and clay were discharged by floods and were deposited on the tidal flat.

The sedimentation quantities are calculated for each particle size, silt and clay were deposited about 240,000$m^3$ during flood term.

# Field Experiments on Sediment Transport by Tidal Current

DEPLOYMENT



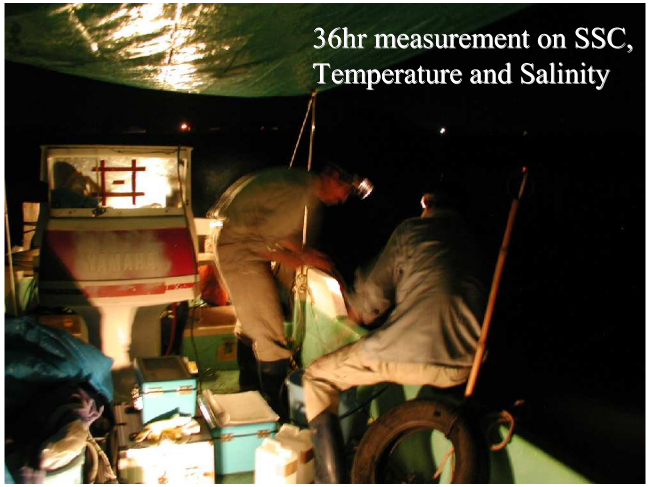

Three field measurements were carried out to investigate sediment transport by tidal current.

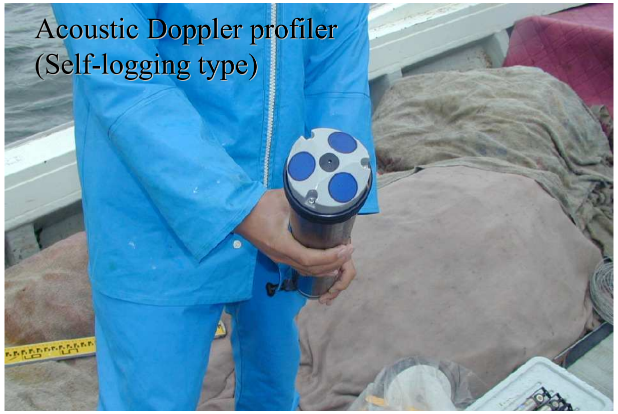
Water current, SSC and salinity were monitored over one year. Acoustic Doppler profiler (ADP) was deployed on the deepest bottom and water current profile was recorded every five minute. Self-logging OBS and salinity-temperature sensors were attached at near bottom, 1m above bottom and surface on the side of H beam and they recorded at 5 minute intervals.

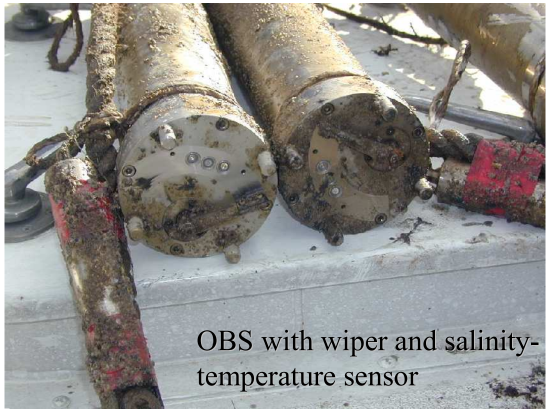
Detailed vertical profile of SSC, salinity and temperature were measured for 36 hours at 10 minute intervals.

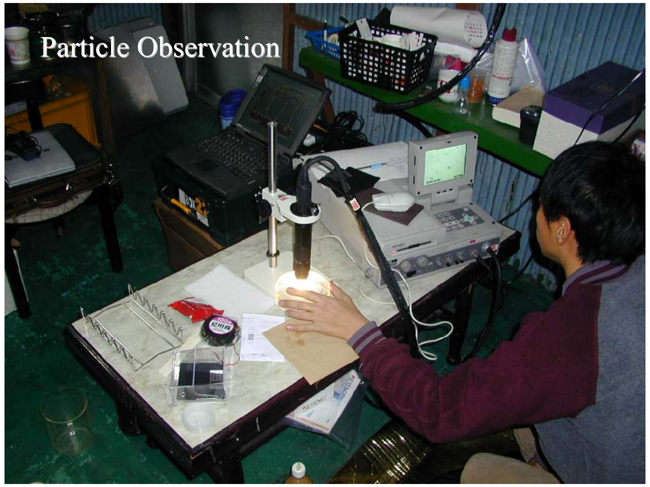
At the same time, turbid water was sampled and suspended particles were soon observed using digital microscope.

Measurement stations were maintained at tidal flat (A), river mouth (B), river cannel (C).


36hr measurement on SSC, Temperature and Salinity

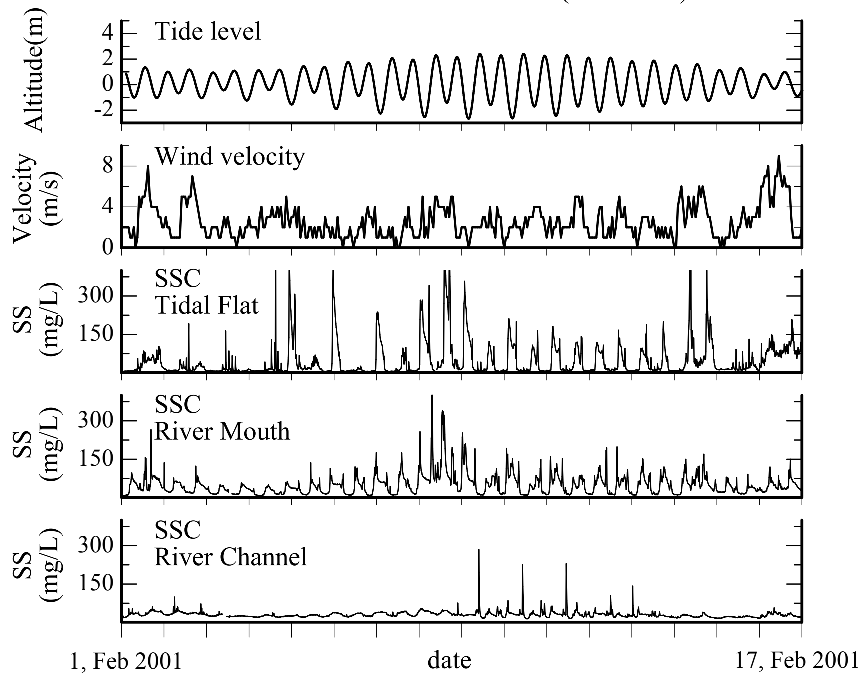

Acoustic Doppler profiler (Self-logging type)


OBS with wiper and salinity-temperature sensor


Particle Observation

## Movement of Turbidity Maximum

### OVERWIEW OF TIDAL CYCLE (Feb 2001)




High SSC appeared at the spring tide and the latter period on tidal flat and in river mouth. When there were strong wind, it appeared too. On the other hand, it was rare occurrence in river channel and it appeared at after the spring tide.

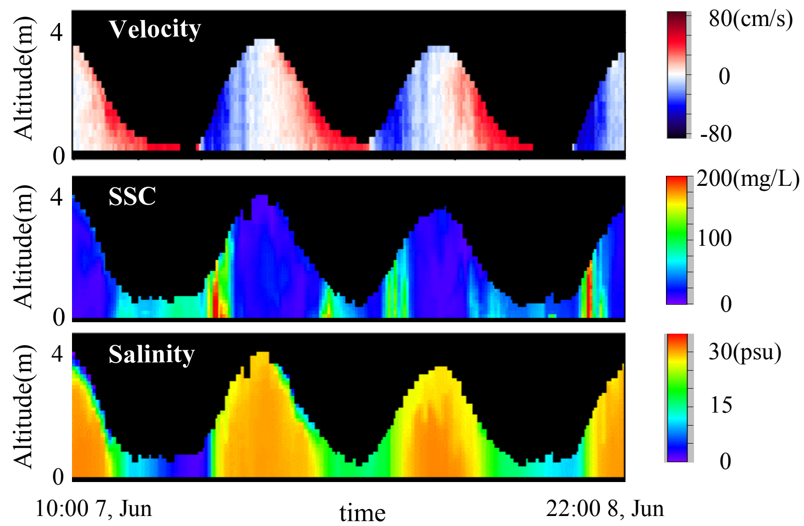
This shows that the surface mud on tidal flat may be eroded and rolled up by the turbulence or shear by tidal current and wind.

In river channel, the current distribution (red color is following current and blue is countercurrent) shows vertically uniform. The water current was fast at both ebb and flood tidal currents, although SSC was asymmetry between ebb and flood, the peak appeared only at flood tidal current, especially at the start of saline water intrusion.

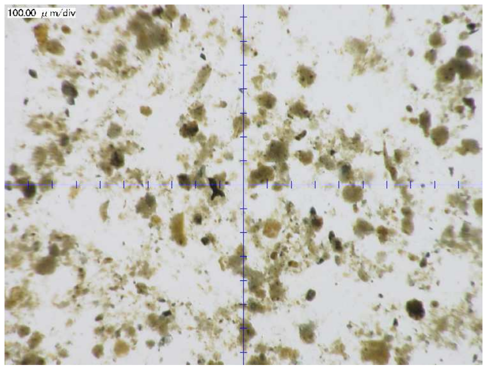
The photograph of suspended particles sampled at SSC peak shows the existence of both floc and mineral particle.

Therefore the suspended particles eroded in tidal flat are transported by the saline water front and they intrude into river channel. On the way to the upstream, they become floc and accumulate on the border of the saline water as sedimentation velocity increase.

### FLOCCULATION OF SUSPENDED SEDIMENT (Spring tide, Jul 2001)



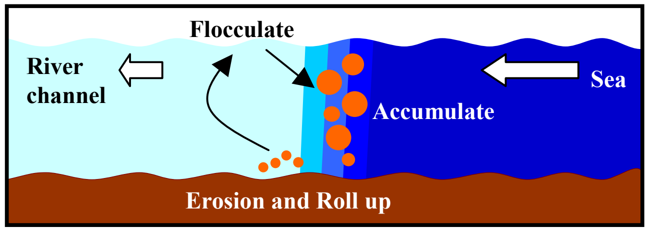

Particle Photograph by Micro-scope



Floc size=0.1mm

Particle size
D10=0.002mm
D50=0.009mm
D90=0.030mm

Sketch of Sediment Transport Processes

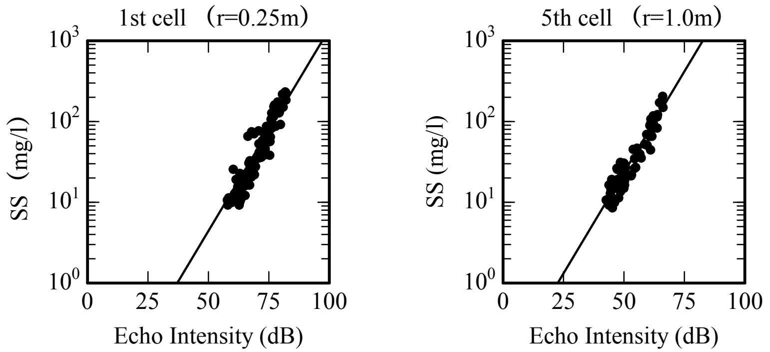


## New Technique for Sediment Transport Monitoring

### ESTIMATION METHOD OF SSC PROFILE USING ECHO INTENSITY

Acoustic Doppler profiler (ADP) measures the water velocity using a physical process known as Doppler shift when the transmitted sound is reflected off particles suspended in the water. The reflected sound intensity (signal amplitude) in itself may be expected to associate with suspended sediment concentration.

When SSC profile is estimated by echo intensity profile, flux of sediment load should be calculated from velocity and estimated SSC profile which are the output of one ADP instrument.




Comparison between SSC and echo intensity at each layers shows that these echo intensity is highly related to SSC and echo magnitude decay as the pulse travel further away from the transducer. Thus, It will possible to estimate detailed SSC distribution from ADP echo intensity. High correlation is exhibited by narrow-band type ADP.

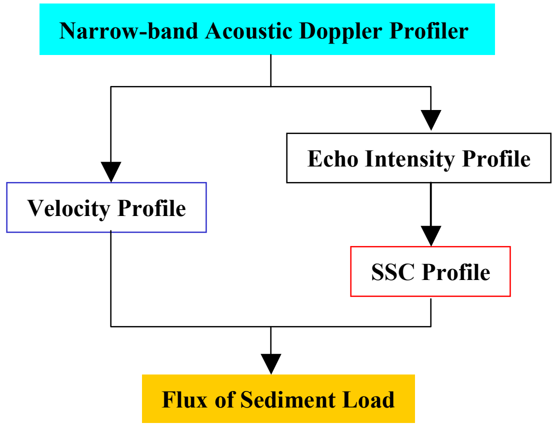
Propagation loss of sound wave is generally expressed by the effect of geometric spreading and the absorption of acoustic energy by the water,

$$T_l = 20\log r + 2\alpha r \qquad (1)$$

where $T_l$ is propagation loss, $r$ is distance from sensor, $\alpha$ is absorption coefficient. The correlation between SSC and echo intensity shown in the figures can be written

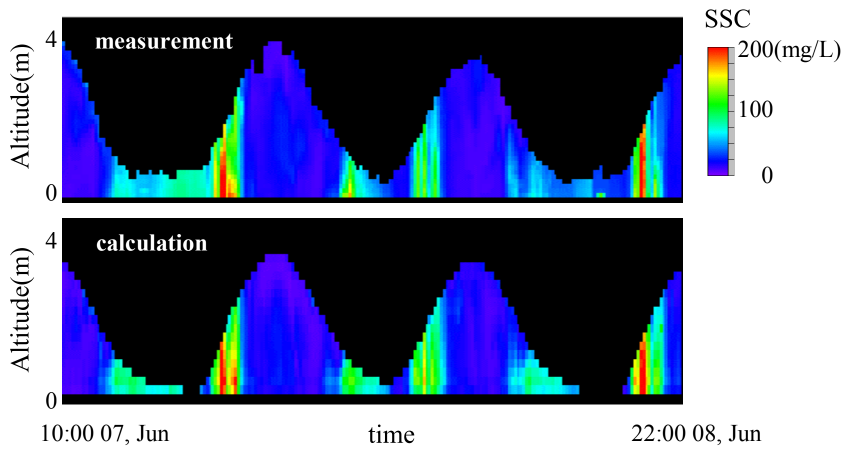
$$20\log SSC = I - B - T_l \qquad (2)$$

where $I$ is echo intensity, B is base sound magnitude.




### RESULT OF SSC ESTIMATION

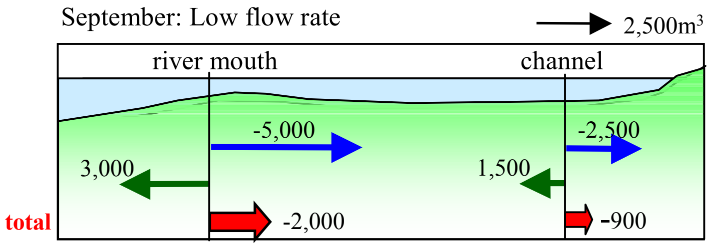
Time Series of SSC Distribution



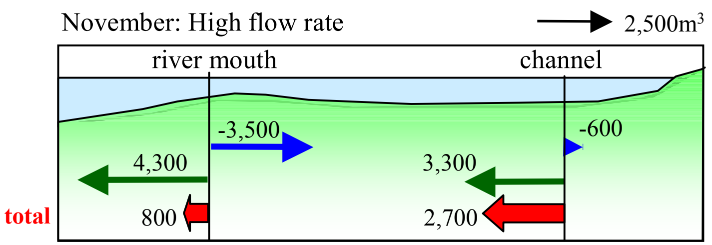

Predicted time series of SSC distribution agree well with measured SSC. This new technique is useful monitoring equipment for sediment transport, since time-spacial distribution of suspended sediment concentration can be obtained only one equipment deployed either on the bottom or near the surface.

## Sediment Transport by Tidal Current and Flood Discharge

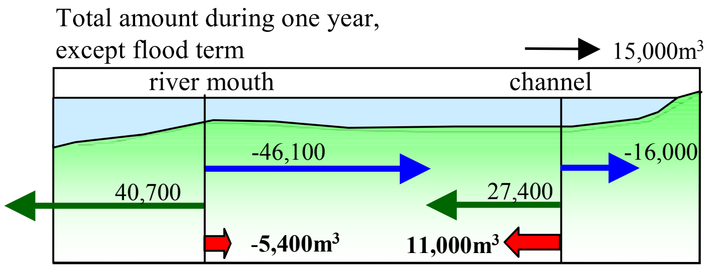
### SEDIMENT LOAD BY TIDAL CYCLE




**sedimentation: 1,100**




**sedimentation: 1,900**



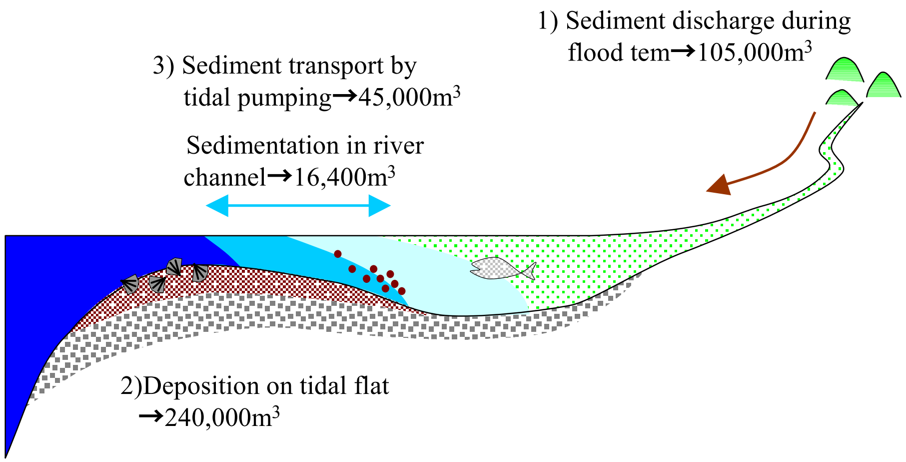

**sedimentation: 16,400**

Suspended sediment flux through the channel and river mouth are estimated from velocity and SSC profile which are both obtained by ADP measurement. Horizontal velocity profile is assumed to be uniform and corrected by several approach so that the water flux at each stations are coordinate.

Two calculation for one month shows that suspended sediment were deposited in river channel in any condition. Total accumulation of net flux during one year was 16,400m$^3$.

### CONCLUSION

Annual Balance on Suspended Sediment Transport, 2001




In this study, suspended sediment transport in river mouth estuary was investigated being divided into three processes. One is flood discharge from river basin, one is sediment deposition on tidal flat after flood term and one is suspended sediment transport by daily tidal pumping.

During flood term, discharged and deposited fine sediment were 100,000m$^3$ to 200,000m$^3$. The flood of this year occurs in a frequency of once in three years.

Annual sediment load by tidal pumping was about 45,000m and sedimentation volume in river channel was about 16,000m. These volume correspond to middle crass flood which occur a frequency of 2 to 3 times in one year.

In Japan, the river water is very clear usually, but daily sediment transport by tidal current would have a influence on the estuary ecosystem and topography.