WATERMAN - Coastal Water Quality Forecast and Management System

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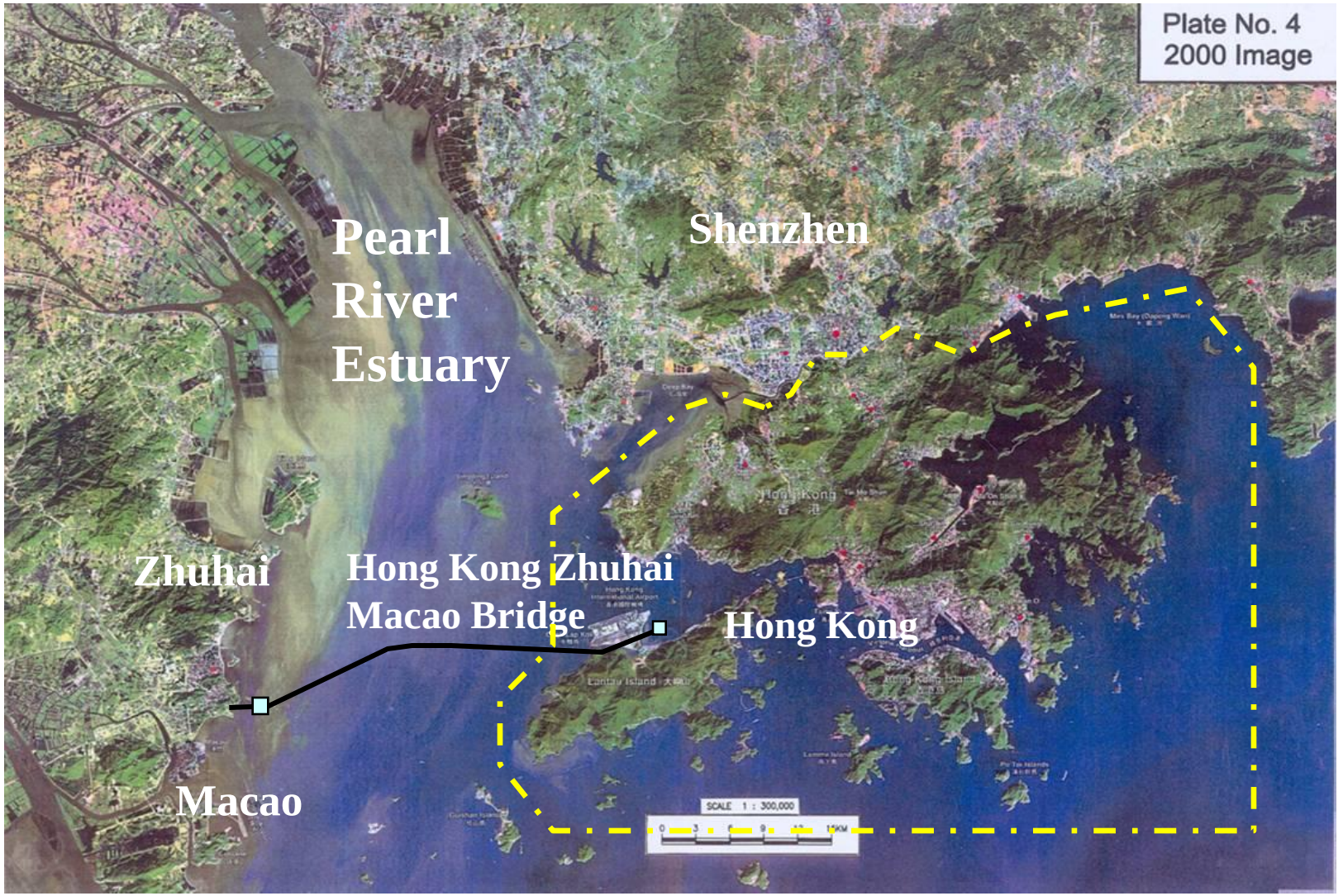
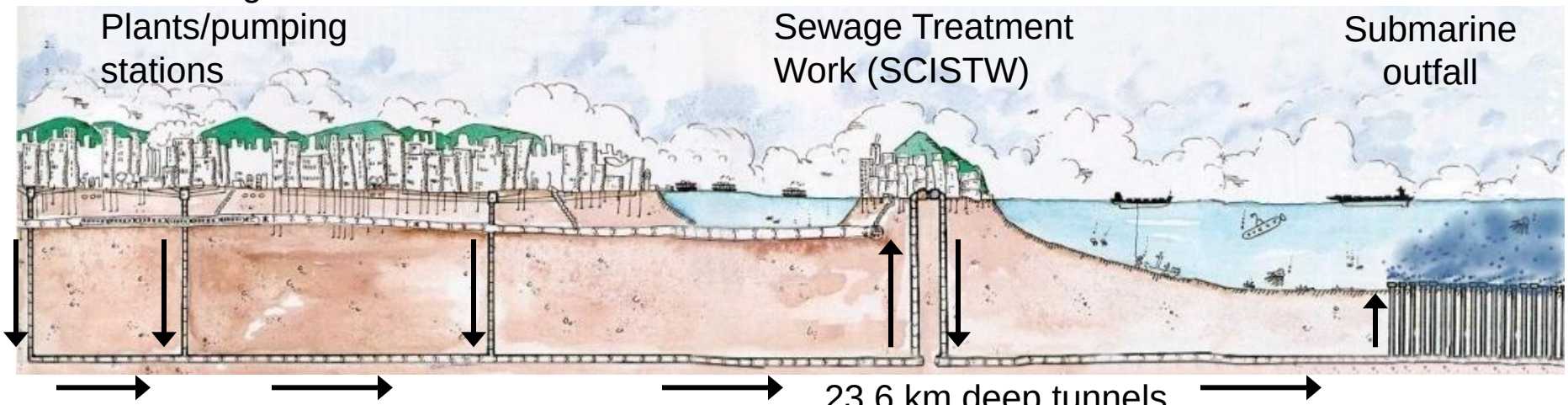
Outline

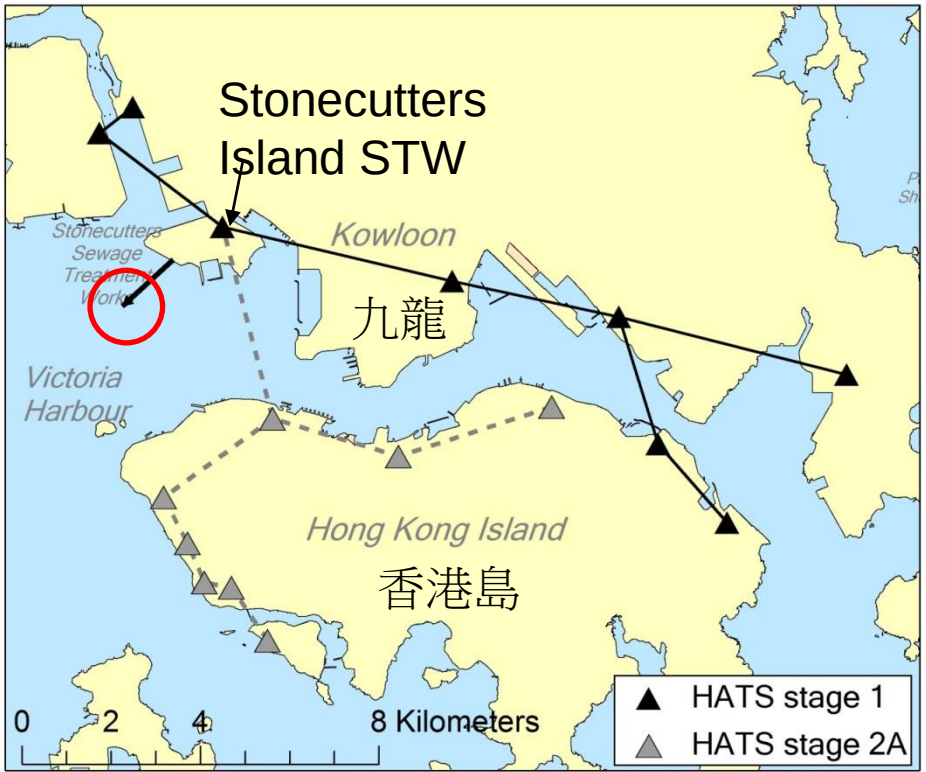
1. **Introduction to WATERMAN system**
2. **Challenges of daily prediction of beach water quality**
3. **Daily forecasting of beach water quality**
4. **WATERMAN operational experience**
5. **Conclusions**

Hong Kong Special Administrative Region, China



Harbour Area Treatment Scheme (HATS)



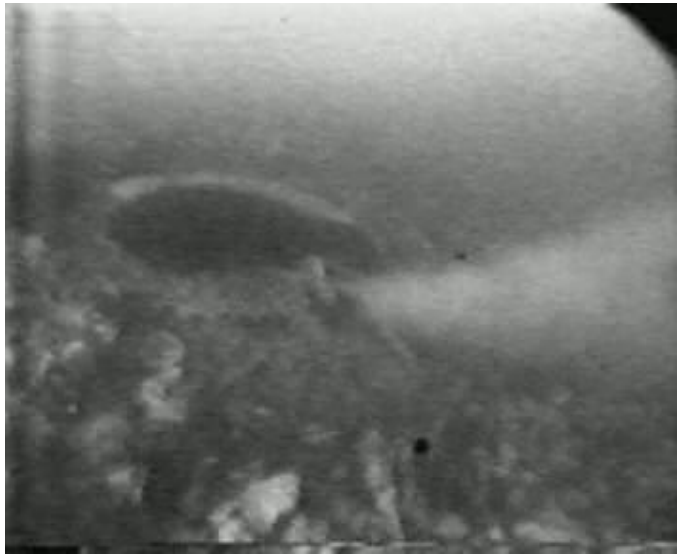


Chemically Enhanced Primary Treatment (CEPT) since 2001; 23.6 km of deep tunnels; disinfection since March 2010

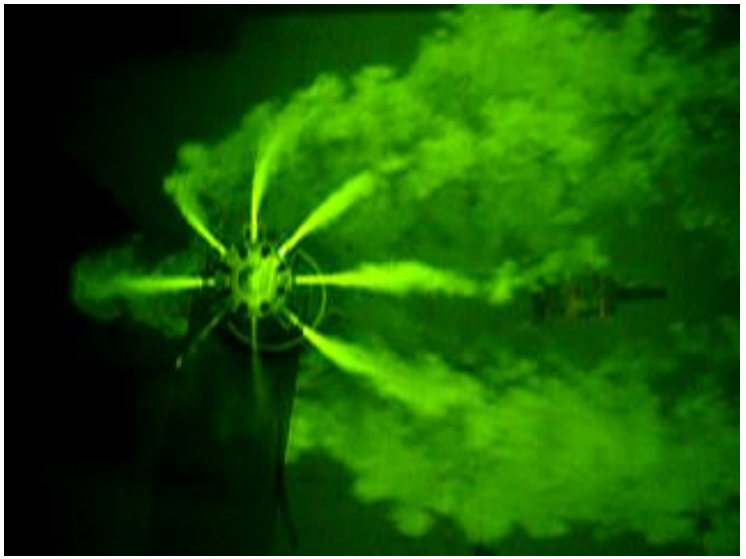
Stage 1: $Q = 1.4 \times 10^6 \ m^3/d$

Stage 2A: $Q = 1.8 \times 10^6 \ m^3/d$

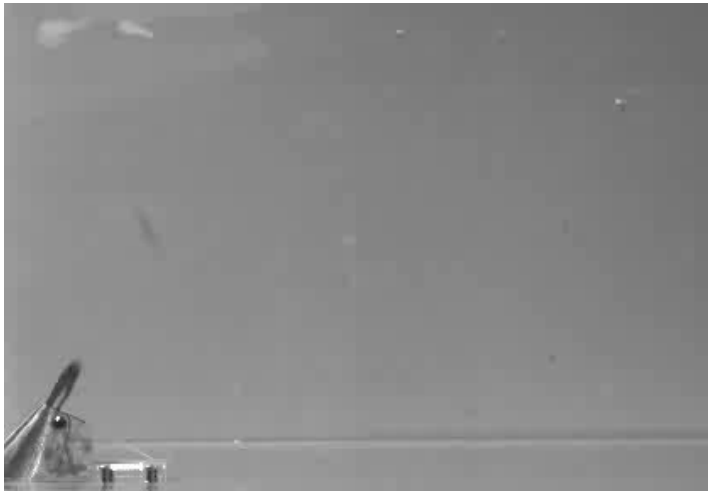
Environmental discharges in the form of buoyant jets



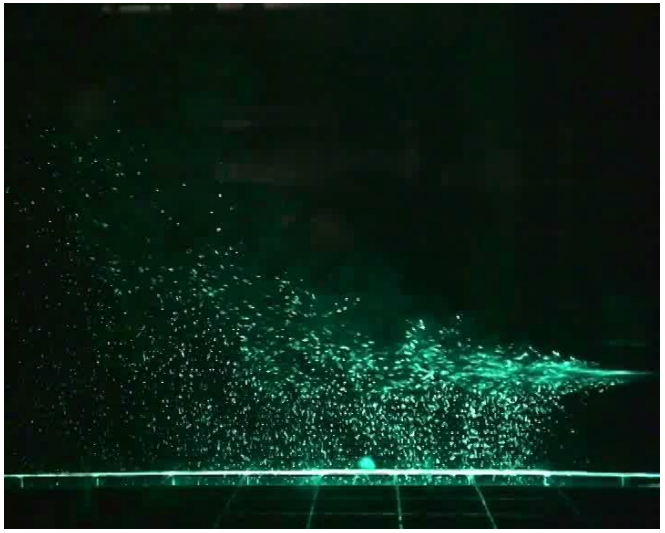
Single buoyant jet



Rosette jet group

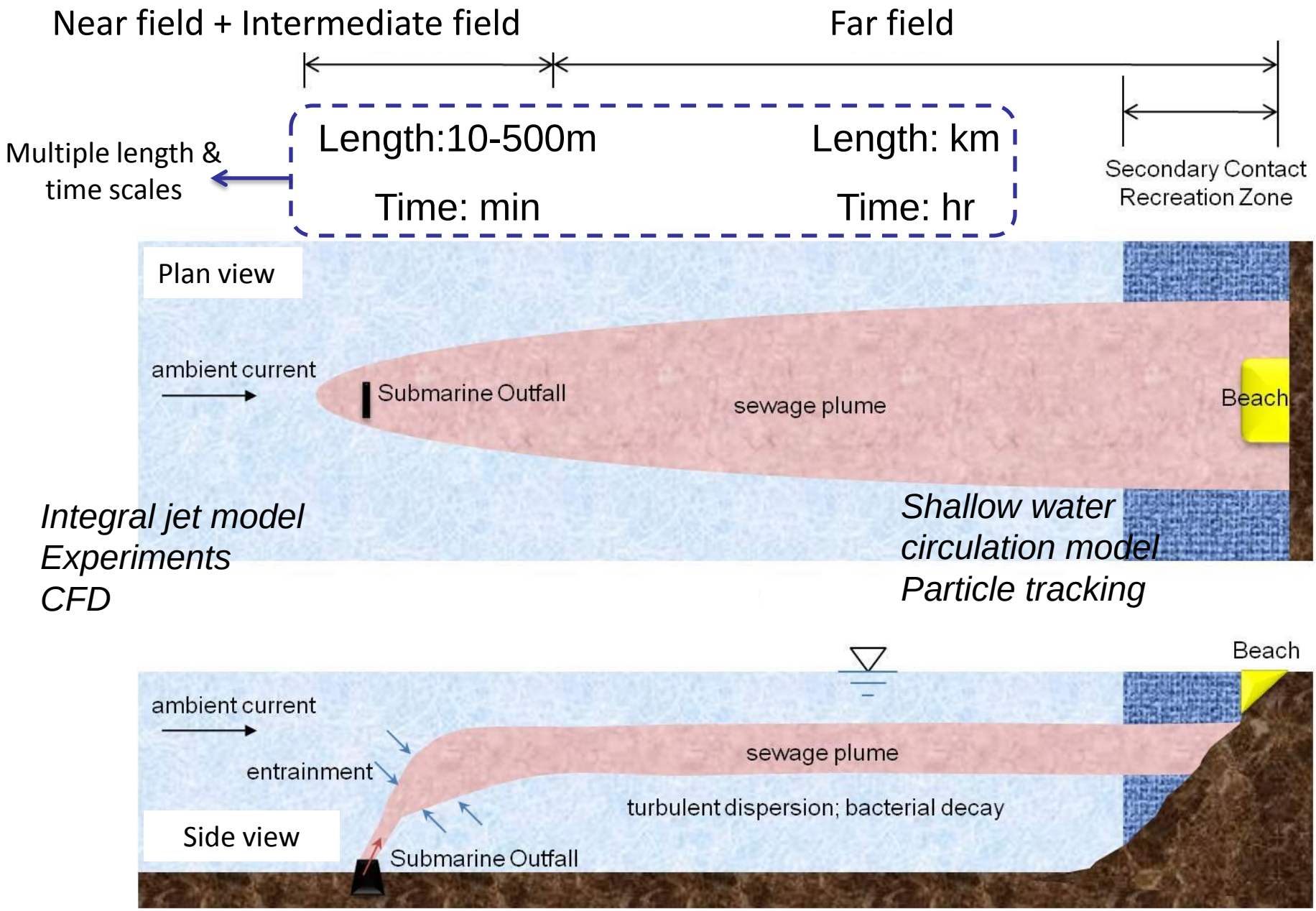


Dense jets



Sediment jets

Mixing and Transport Processes



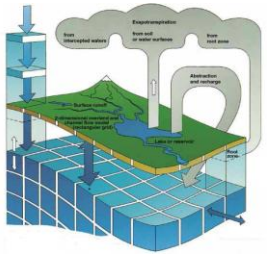
Challenges of Coastal Water Quality Management

- Coastal water quality prediction is a challenging multi-scale and multi-disciplinary problem
- Pollution sources located in close proximity to sensitive receivers
- Dynamic marine environment with complex currents; highly nonlinear biochemical process
- Water quality data are typically sparse and costly
- Uncertainty in rate coefficients, loading and boundary conditions
- Need for public accountability and public engagement

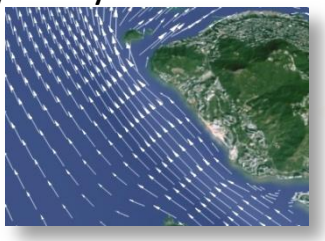
Project WATERMAN

海灘水質預報系統的研發

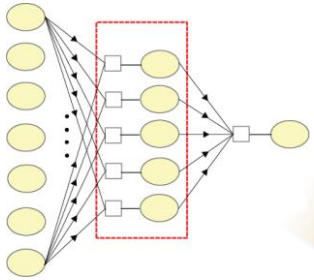
Hydrological model



Hydrodynamic model

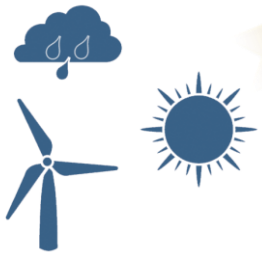


Data-driven models

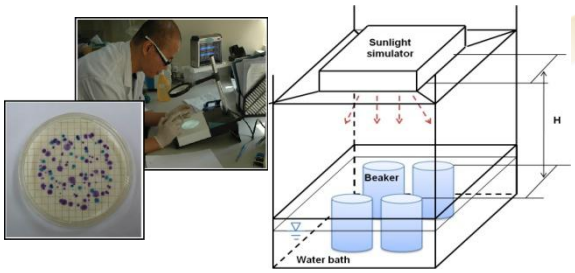


Field studies

Meteorological data

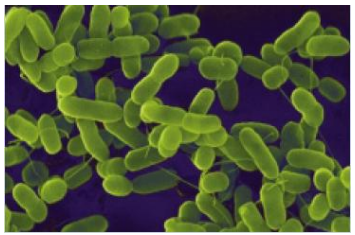


Laboratory studies



Data assimilation

Past data



Beach water quality forecast

Hong Kong's beach grading system
香港海灘水質評級系統

Grading	Beach water quality 泳灘水質	*E. coli* * (counts /100 mL) 大腸桿菌	Minor illnesses rate ** (cases per 1000 swimmers) 發病率	Water Quality Objective Compliance/ Exceedance
1	Good	≤ 24	Undetectable	Compliance
2	Fair	25 - 180	≤ 10	
3	Poor	181 - 610	11 - 15	Exceedance
4	Very poor	> 610	> 15	

***Weekly Beach Grading**: G. Mean *E. coli* level of the 5 most recent data (C_{lnEC5})
Annual Beach Ranking: G. Mean *E. coli* level of all bathing season data (Mar-Oct)

** Skin and Gastrointestinal illnesses (Cheung et al. 1990)

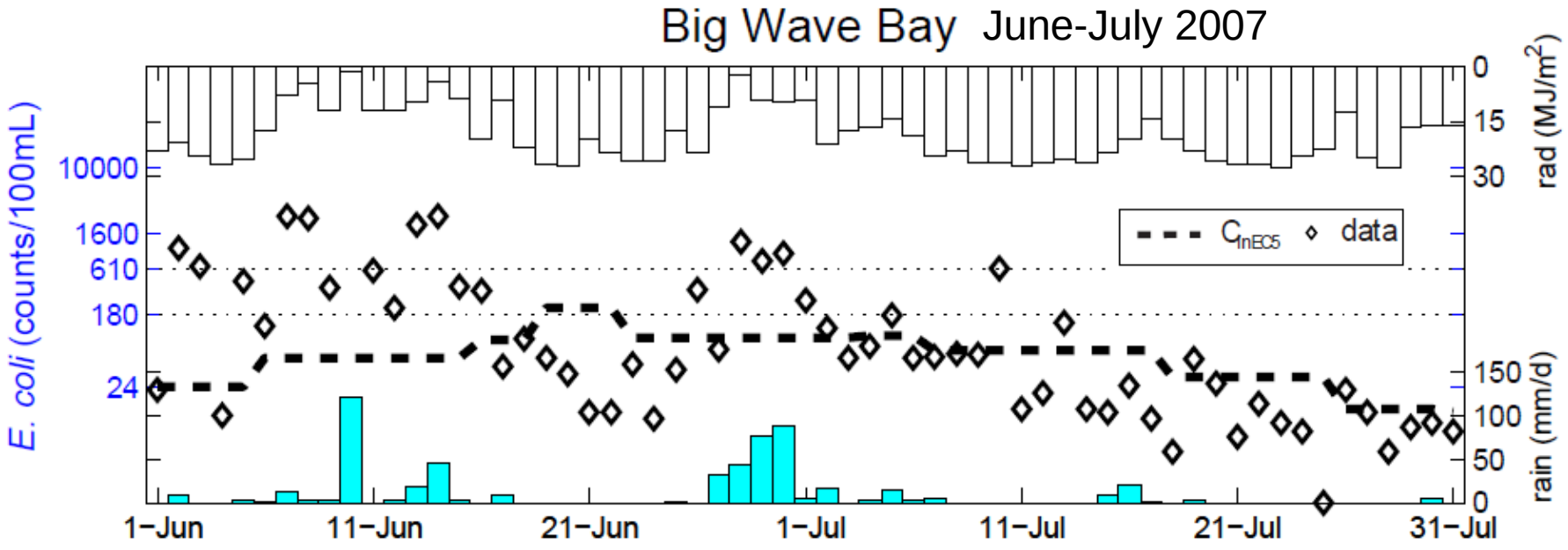
Beach grading based purely on past sparsely sampled data

41 beaches ~10 million visitors in 2012

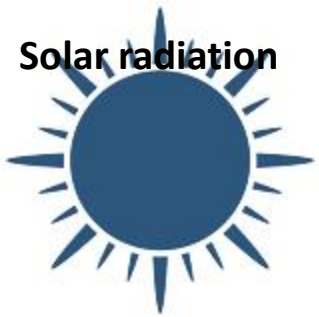
The need for a better beach WQ management system

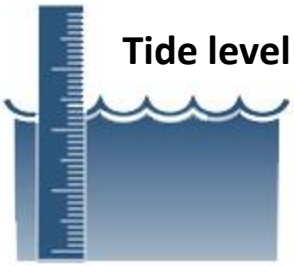
- **Resource-intensive** for sampling and analysis of *E.coli* data

  (41 beaches x 4-5 times/month x 8 months per year)
- At least 24 hr to obtain *E. coli* measurement results – **delayed response** for pollution events
- Represents the average WQ over the past 1 month **- cannot capture the dynamic beach *E. coli* variation**; **no forecast ability!**

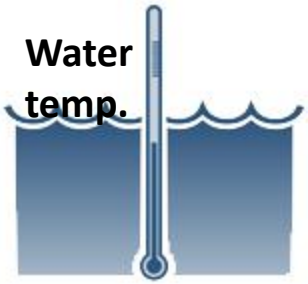


Environmental factors affecting beach water quality
影響水質的環境因素

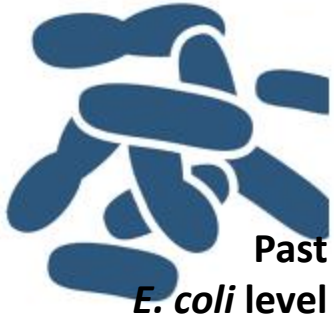




Main factor

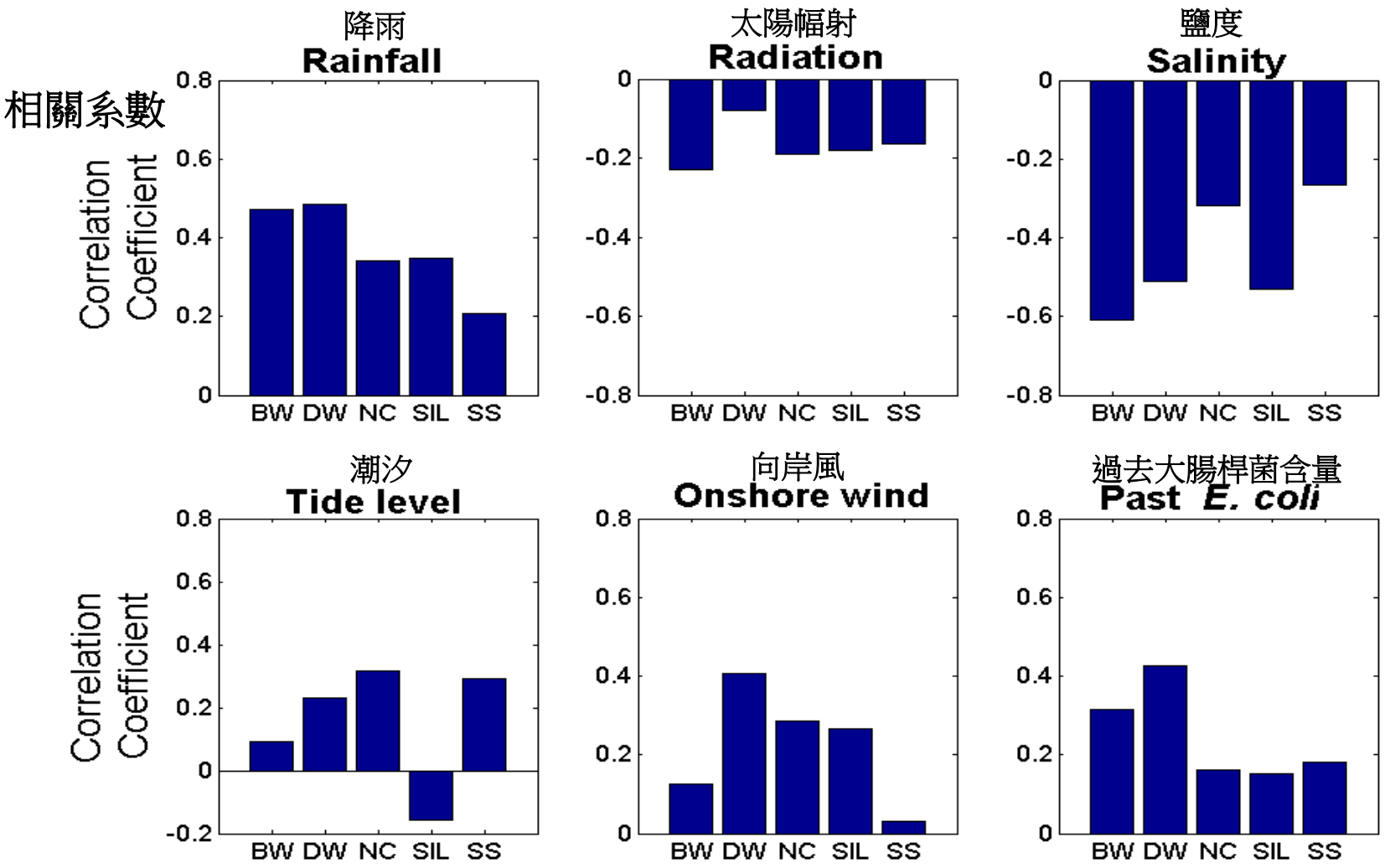


Main factor



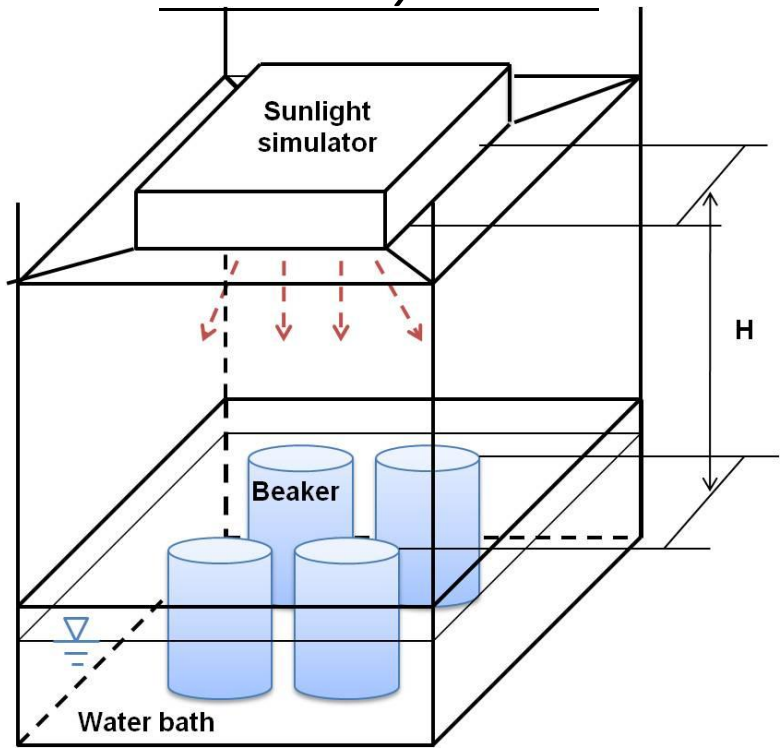
Relationship between *E. coli* level and environmental factors (2002-2006)

相關大腸桿菌含量和環境因素的相關

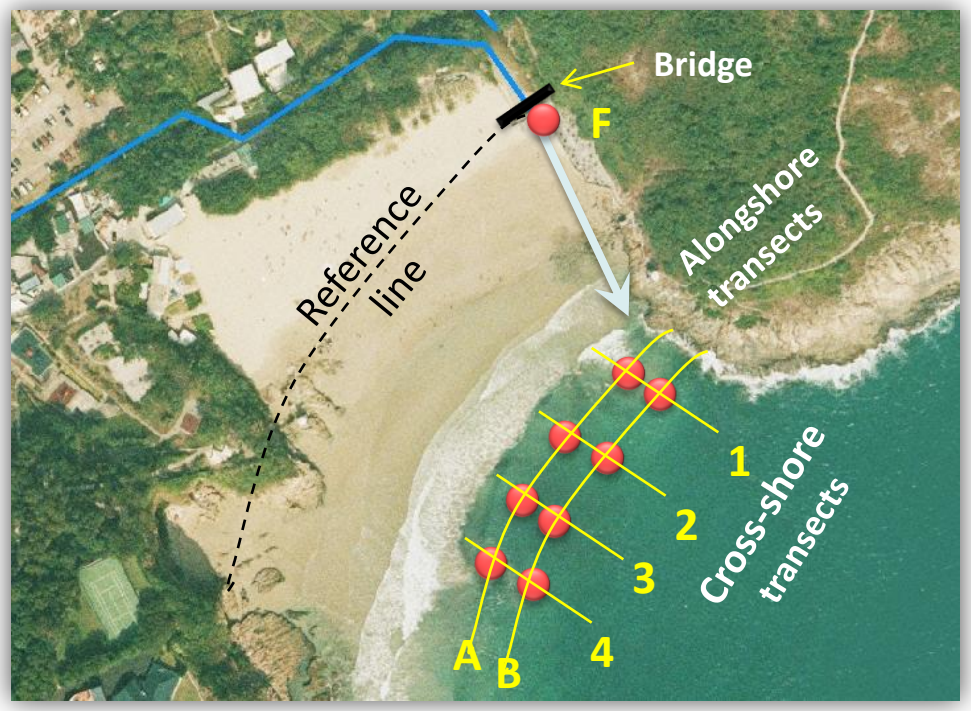


Studies on *E. coli* decay rate
大腸桿菌衰亡率研究 (實驗和野外研究)

Laboratory studies



Field studies (during storms)



$$k(z) = (0.68 + 0.017 \times S) \times 1.07^{(T-20)} + 1.1 \times I_A \times e^{-e_t z}$$

Decay rate

↑鹽度 Salinity

↑水溫 Water temp.

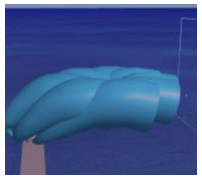
↑光照度 Sunlight intensity

Project WATERMAN

3D Hydrodynamic Model of Hong Kong waters

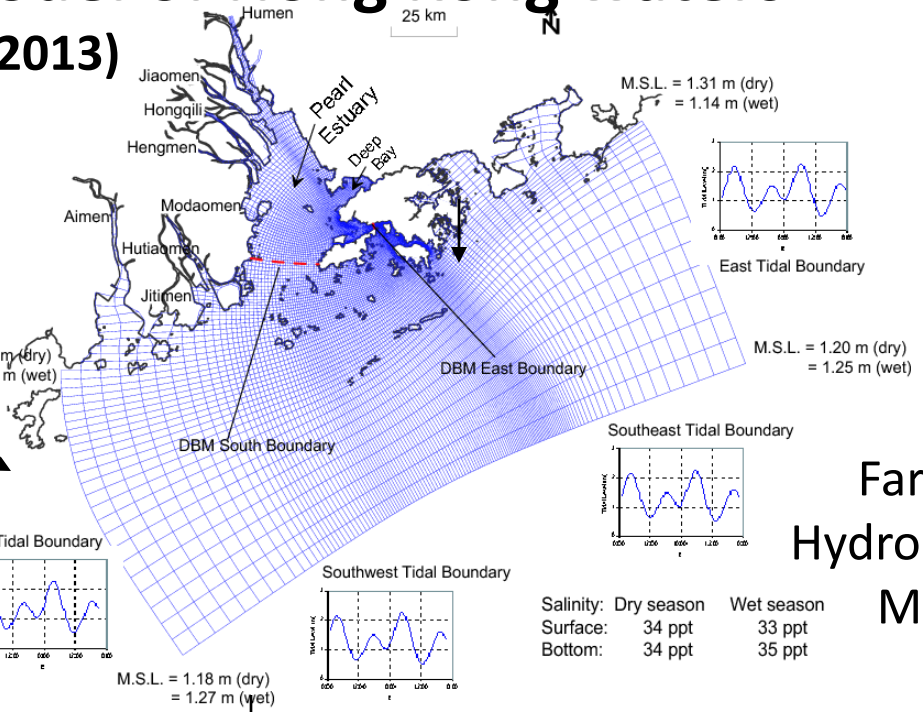
(Water Research, Chan et al. 2013)

Submarine outfalls



Near-field model
JETLAG

Dynamic coupling
(DESA)



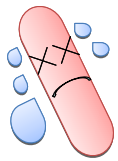
Far-field
Hydrodynamic
Model

Bacterial Loading

Current, Turbulent Mixing

潮汐流、紊流混合

Bacterial decay modeling

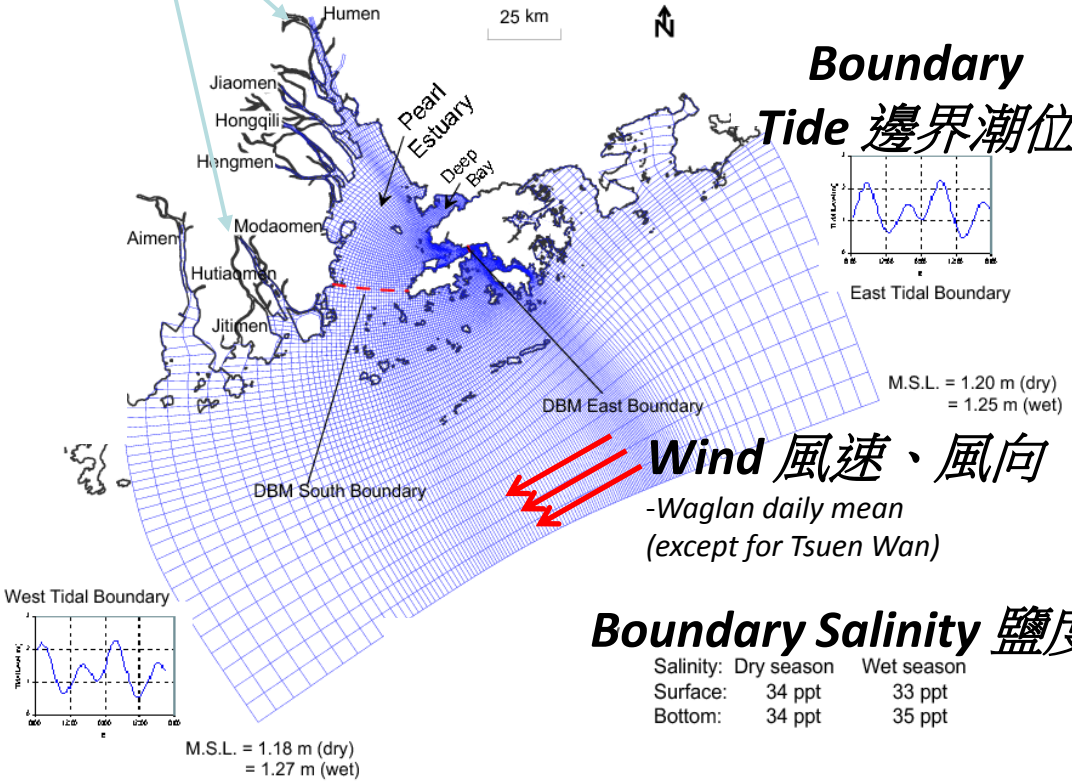


***E. coli* concentration**

(大腸桿菌含量)

Input for deterministic forecast

Pearl River flow
珠江流量(ANN模型)
- Estimated using rainfall with ANN model



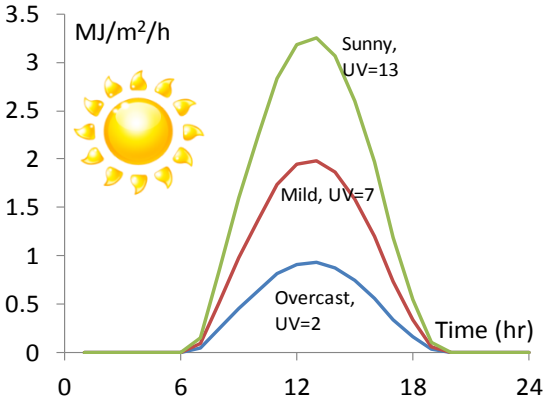
Boundary Tide 邊界潮位
East Tidal Boundary

Wind 風速、風向
-Waglan daily mean
(except for Tsuen Wan)

Boundary Salinity 鹽度

Salinity:	Dry season	Wet season
Surface:	34 ppt	33 ppt
Bottom:	34 ppt	35 ppt

Solar radiation
太陽輻射



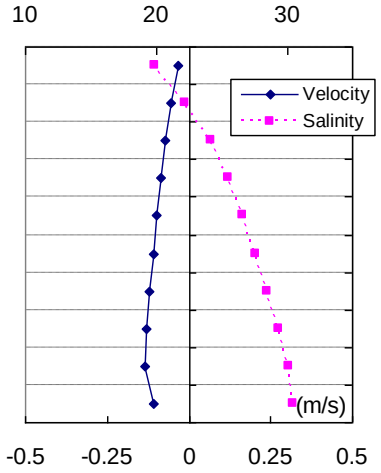
Water Temp.
水溫
- Meas. North Point

Bacterial decay rate
細菌衰亡率

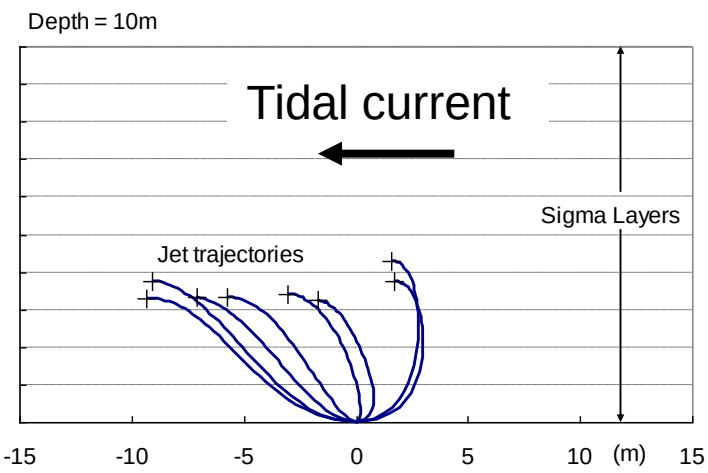
Rainfall induced E.coli loading
降雨引發的細菌污染
- Empirical correction using previous 3-day rainfall

Near-far field coupling

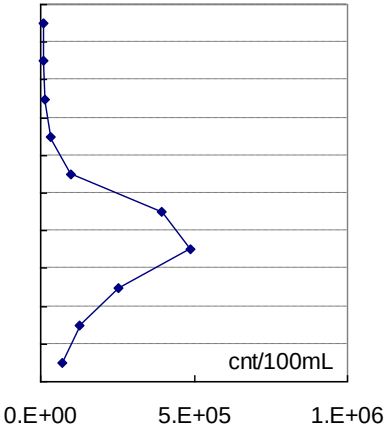
Velocity/salinity



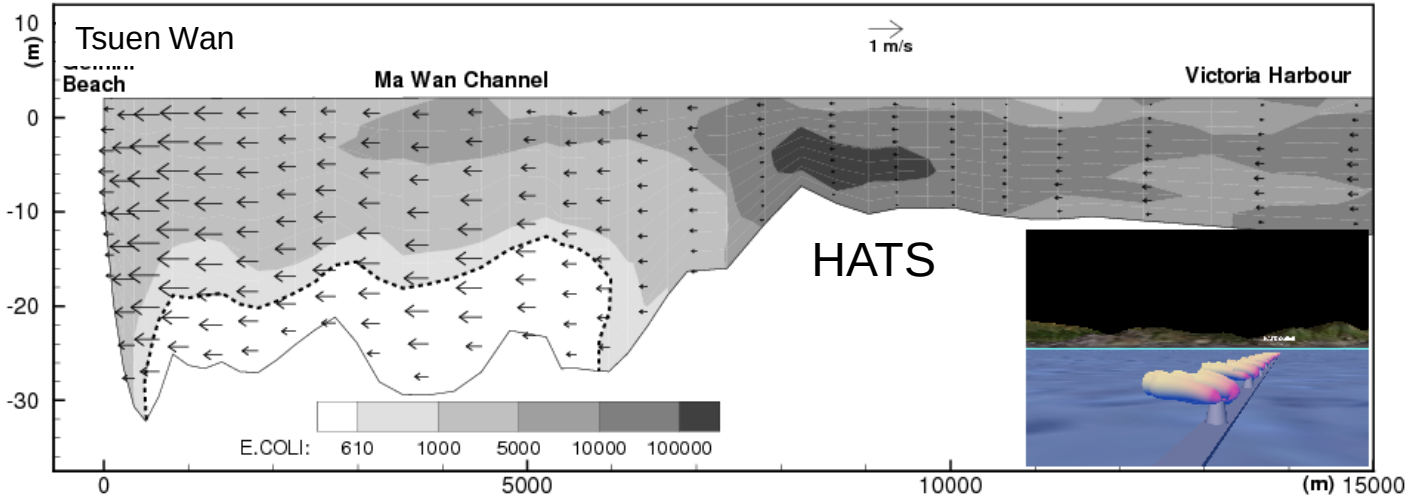
3D jet trajectories



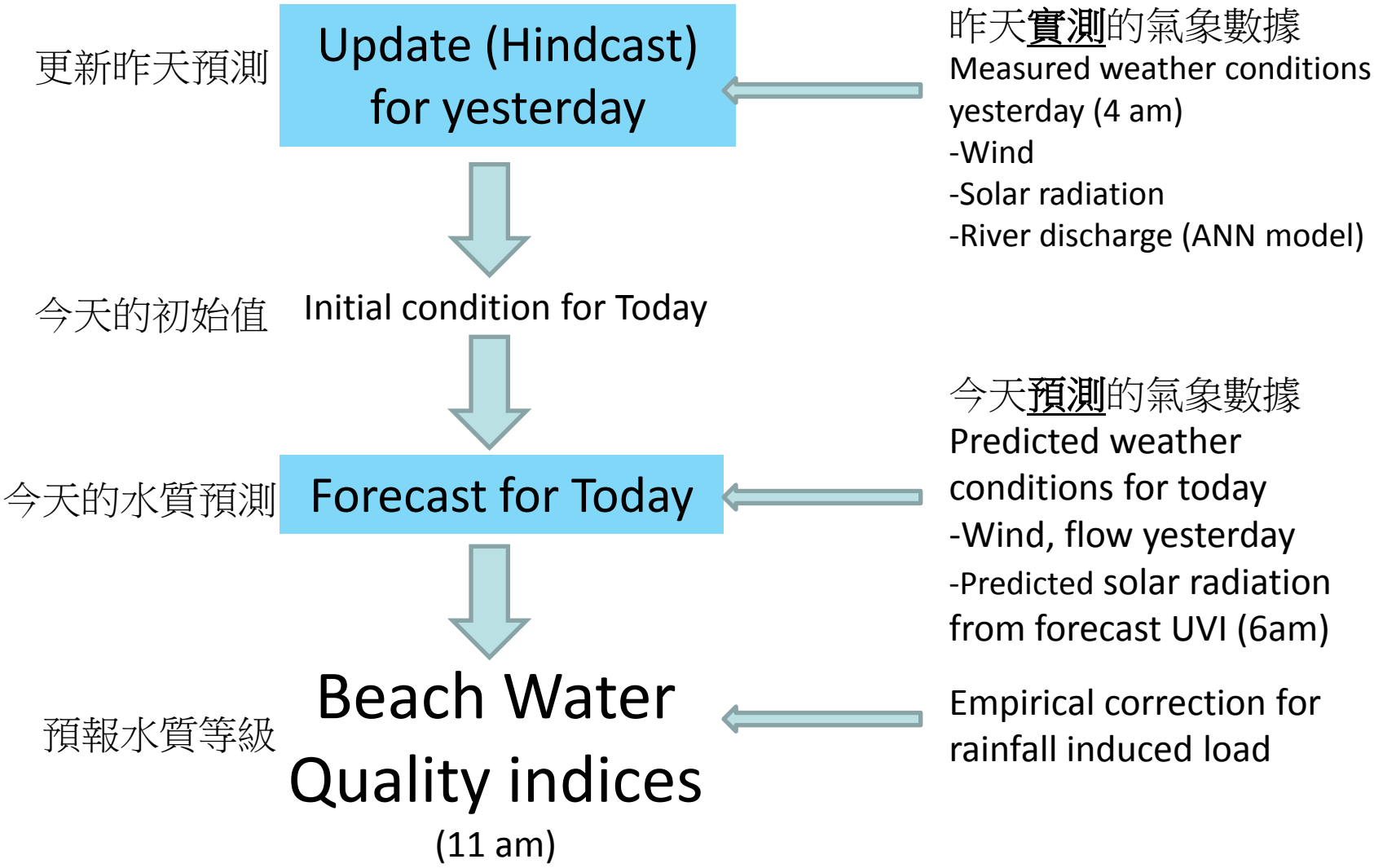
Computed *E.coli* profile by far field model



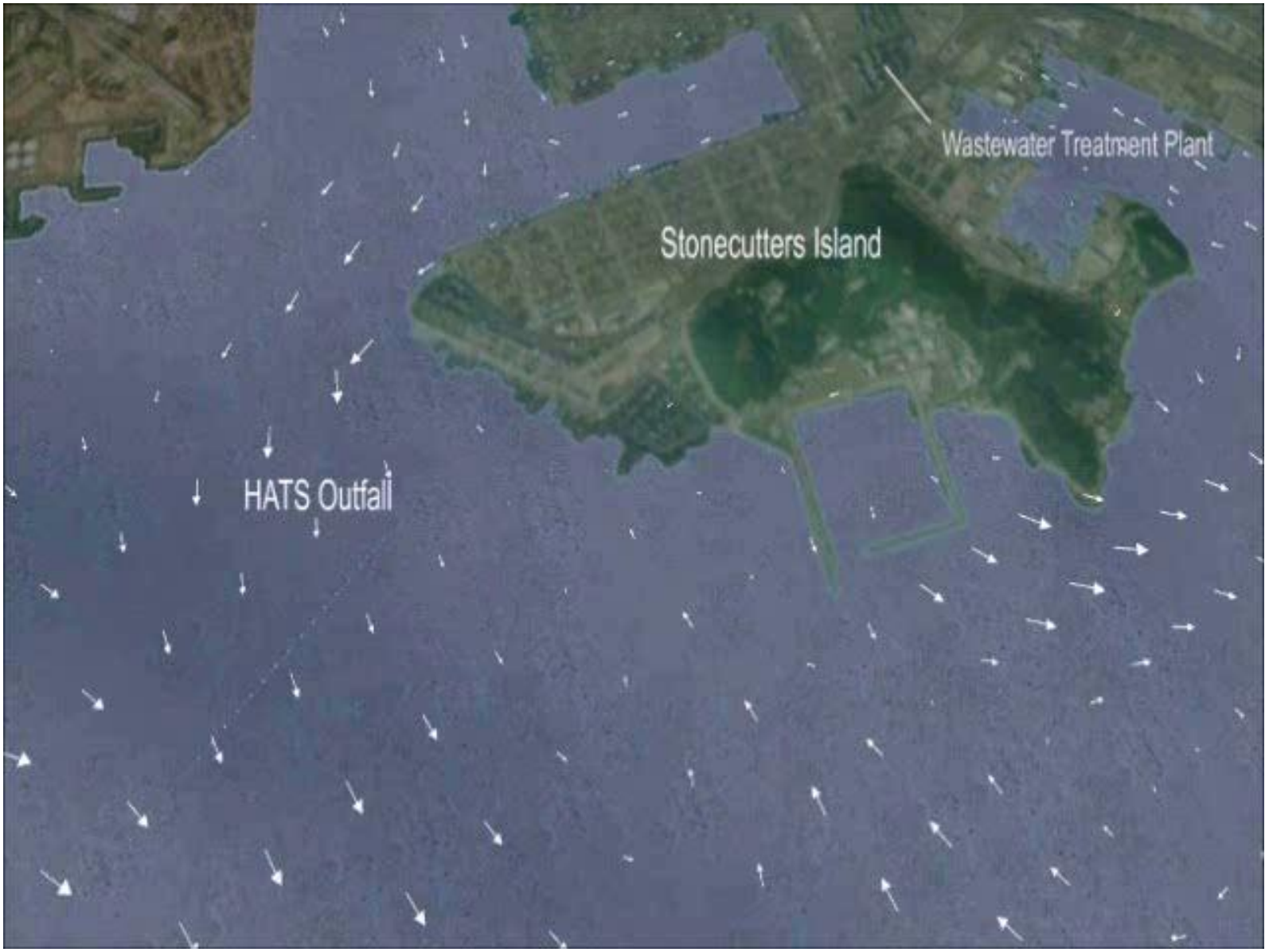
Longitudinal transect of computed *E.coli* concentration field



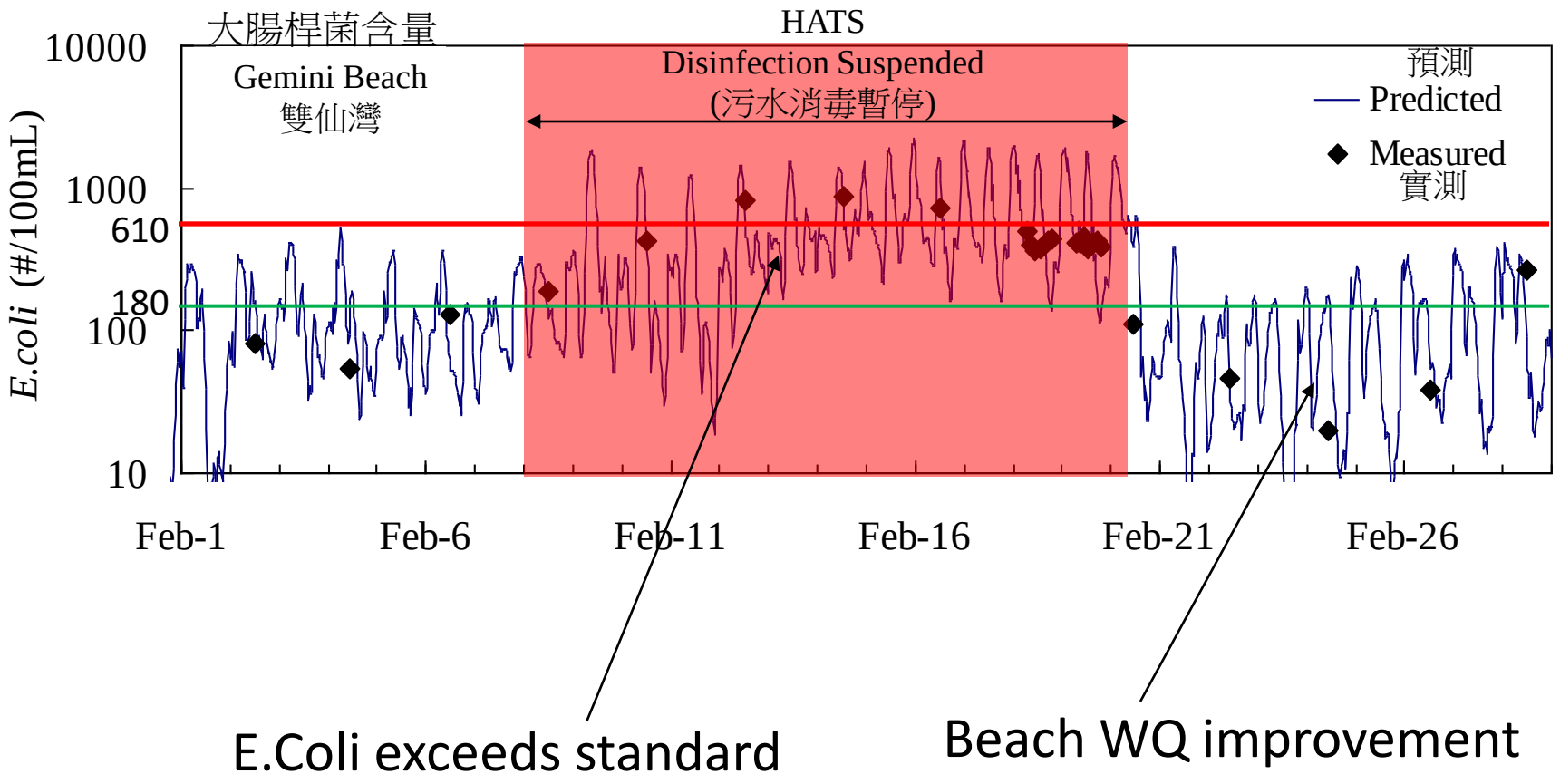
Daily Deterministic Beach Water Quality Forecast
3D模型水質預報流程



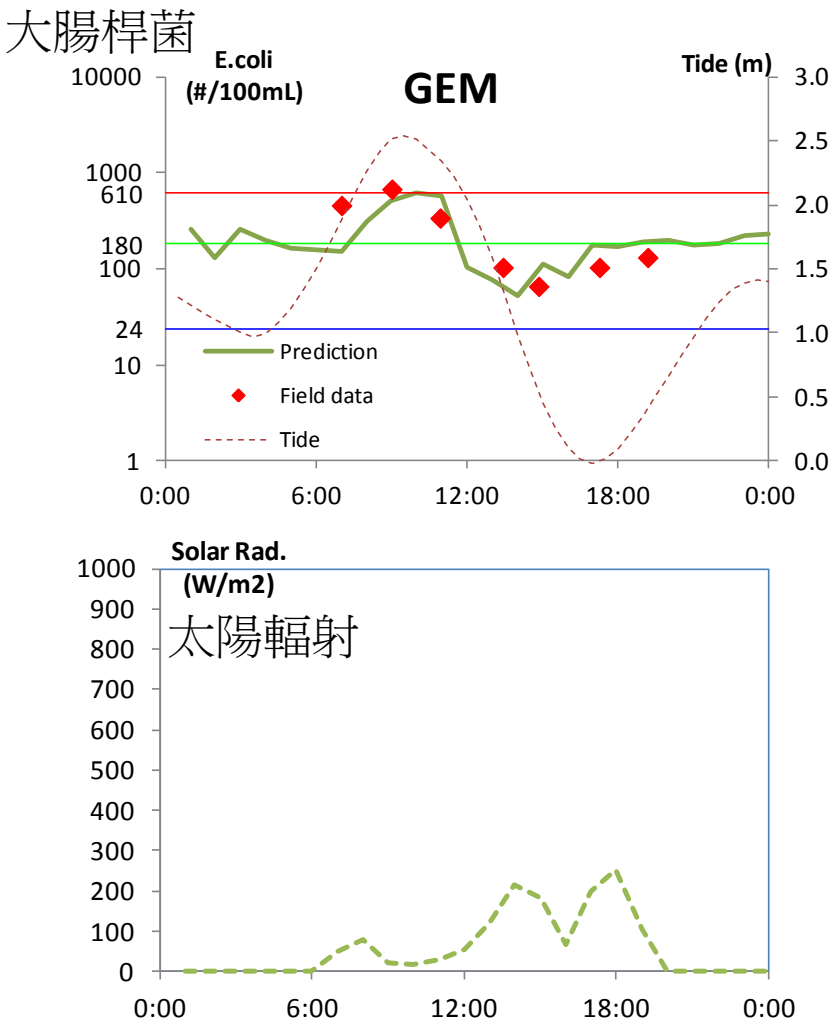
GIS-based 3D Visualization System



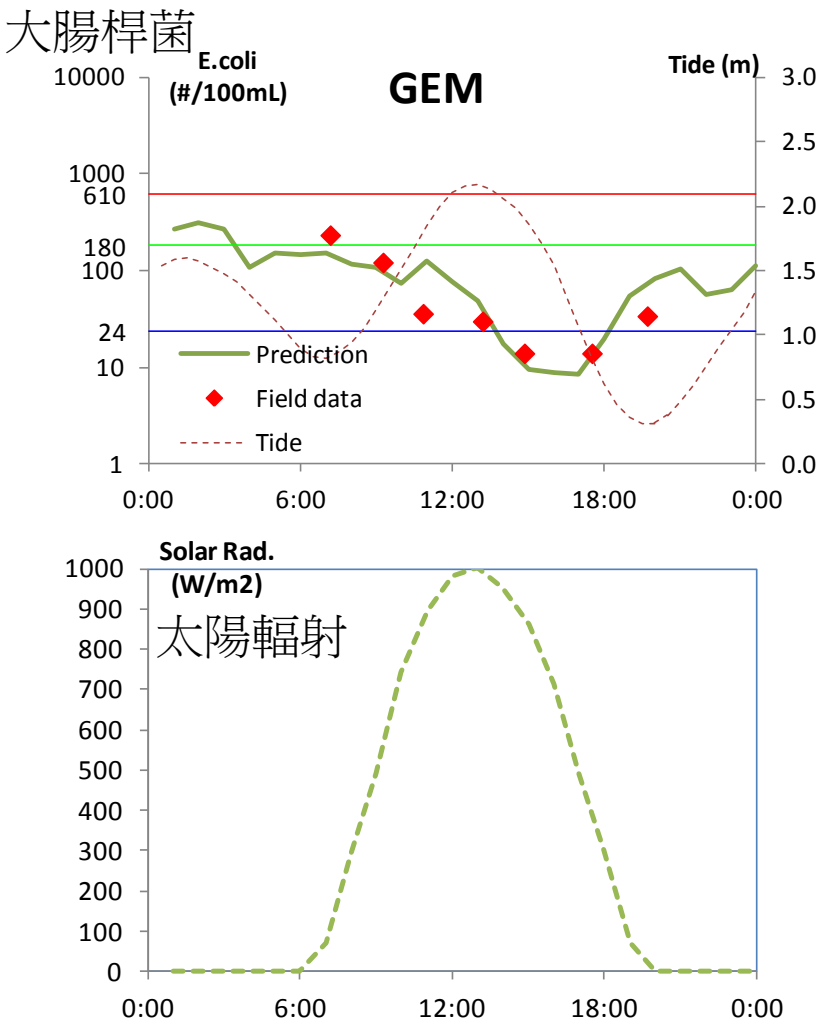
Dynamic variation of E.coli, Gemini Beach, Feb 2010
雙仙灣海灘的大腸桿菌含量的變化



Model – data comparison, Gemini Beach



16 Jun, 2011
Overcast with rain 密雲有雨
Solar Rad. = 5.0 MJ/m²/d
High water to ebb tide 高潮



6 Jul, 2011
Sunny day 晴天
Solar Rad. = 28.3 MJ/m²/d
Flood tide 漲潮

Forecast Accuracy* in 2010-2012

20 Key Beaches

* Accuracy for forecasting the compliance/exceedance of beach water quality objective (180 cnt/100mL)

(N ~ 100 per beach)

總結

- **WATERMAN**海灘水質預報系統應用到水文、水動力及水質等先進數學模型，和每天的大量水文氣象數據同化，利用考察和實驗數據對模型預測進行大量科學驗証。
- **2011-2013**年，**WATERMAN**系統在預報泳灘水質達標／超標的整體準確率高達**74-98%**。
- **WATERMAN**系統已被用於研究優化**HATS**消毒劑的用量，和應變突發性的海灘污染事件（如污水管破裂）。
- **WATERMAN**海灘水質預報系統是國際上最先進的同類系統之一，將是未來香港邁向智慧城市不可或缺的一部分。