8th IWA-ASPIRE Conference
31 Oct – 2 Nov, 2019, Hong Kong
Smart Solutions for Water Resilience

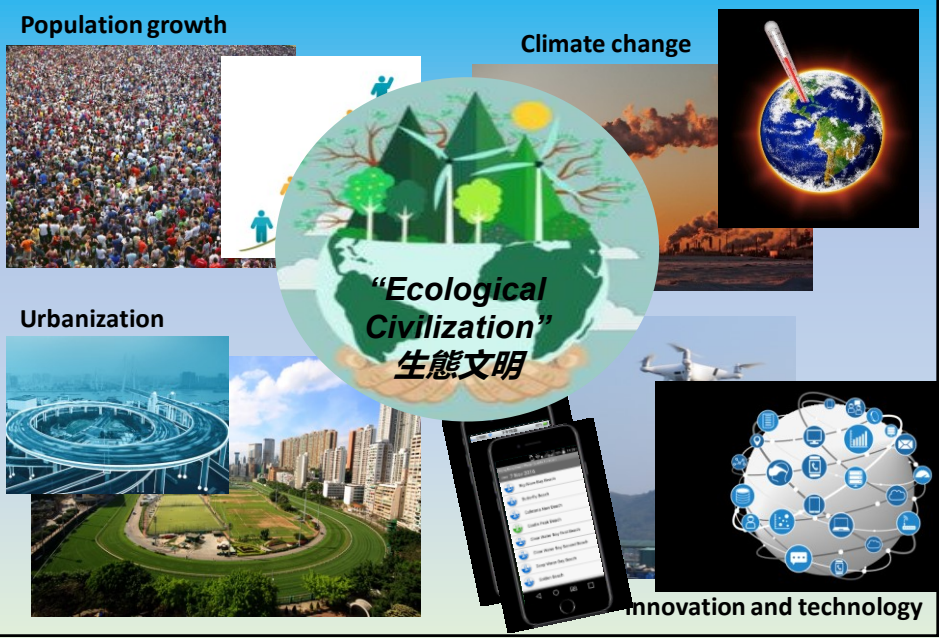
Towards a New International Water Innovation Hub

Joseph Hun-wei Lee
The Hong Kong University of Science and Technology
President, International Association for Hydro-environment Engineering and Research (IAHR)

Outline

1. Landscape for innovation and technology development in Hong Kong
2. Examples of university-government-industry collaboration in water innovation:
   - **WATERMAN real time forecast system for smart environmental management**
   - **SANI** innovative wastewater treatment
   - Smart urban water supply systems **(SUWSS)**
3. A new international water innovation hub
4. Conclusions

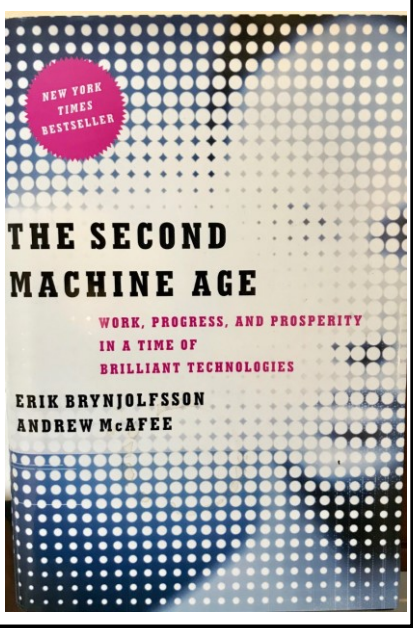
Sustainability Challenges – Drivers of Change



The future: The Second Machine Age

"In the past few years three forces have been yielding breakthroughs that convert science fiction into everyday reality: sustained exponential improvements in computing, Big Data, and recombinant innovation have led to technological innovations like self-driving cars, Jeopardy! supercomputers, humanoid robots, speech recognition software, and 3D printing."

"The Second Machine Age" – by Erik Brynjolfsson and Andrew McAfee, MIT, 2014



Environmental sustainability is critical for the social and economic development of Hong Kong.

- Hong Kong ranks No.1 in the world in infrastructure (2014-15 Global Competitiveness report, World Economic Forum).
- Strict enforcement of environmental regulations
- Coastal marine waters are heavily used, e.g., navigation, recreation, fisheries, waste disposal, water supply, dredging for fill material, large scale reclamation, environmental conservation and scientific work.

An innovative knowledge-based coastal environmental management system is essential to the building of a Smart Hong Kong
開發知識型近岸水環境管理系統，建立智慧香港

A smart city (智慧城市) is a city leveraging people-centric (以人為本) and technology focused (科技為核心) solutions to achieve:

- *Increase efficiency of city operation and management*
  提升城市運作及管理效率
- *Improve quality of life 改善生活質素*
- *Strengthen economic competitiveness 加強經濟競爭力*
- *Through "innovative", "interactive" and "collaborative" approach「創新」、「互動」、「合作」*

中国工程院（CAE）和香港工程科学院（HKAES）

粤港澳大湾区协同科技创新政策研究

Report on
Policy Study on the Integrative Development of Innovation and Technology in the Guangdong-Hong Kong-Macao Greater Bay Area

October 2017

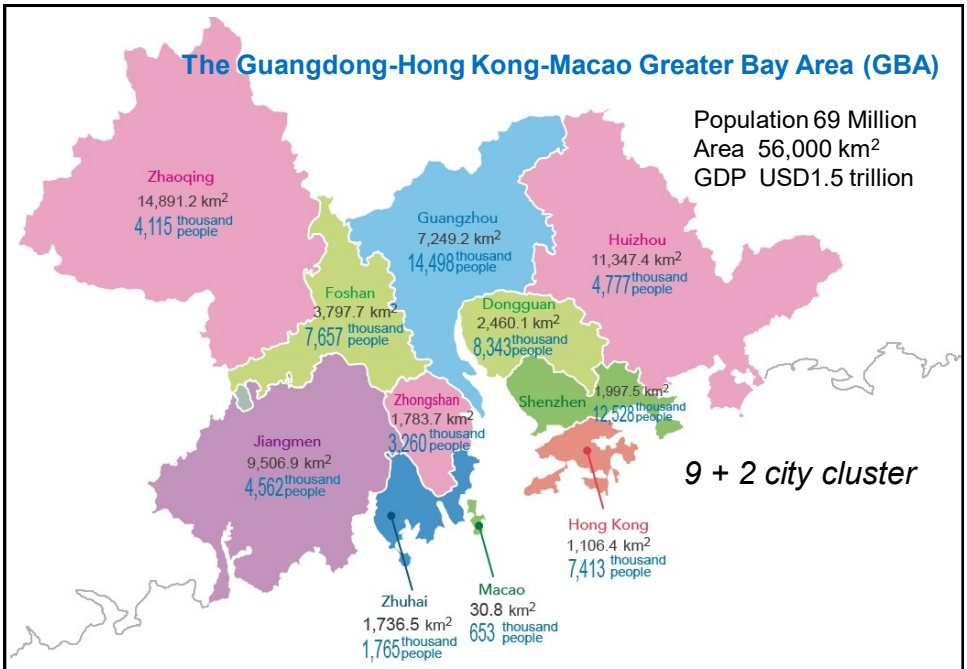
Hong Kong Academy of Engineering Sciences 香港工程科學院
中國工程院 Chinese Academy of Engineering
香港科技大學 THE HONG KONG UNIVERSITY OF SCIENCE AND TECHNOLOGY
IPP INSTITUTE FOR PUBLIC POLICY Innovation for Global Leaders

First cross-border independent study conducted by IPP in collaboration with the Hong Kong Academy of Engineering Sciences (HKAES) and the Chinese Academy of Engineering (CAE) 2017

Recommendations adopted by Greater Bay Area planning

The Guangdong-Hong Kong-Macao Greater Bay Area (GBA)

Population 69 Million
Area 56,000 km²
GDP USD1.5 trillion



9 + 2 city cluster

(Source: www.dsec.gov.mo/BayArea)

主要发现 Major Findings

1) 香港亟需创新

Hong Kong is desperately in need for innovation and technology

- 创新的领域不仅限于ICT,创新驱动经济增长和生活质量的提高.这与1999年MIT提出"香港制造"的情景差异较大.

There is a clear consensus in the community that Innovation and technology cuts across all disciplines (not just ICT) and are the drivers of economic growth and improvement on quality of life. This is a clear change of attitude compared to 1999 around the time of the ITC formation and "Made by HK" study by MIT.

2) 香港应当利用自身优势-世界前列的研究型大学

Hong Kong should build on its strengths – the emergence of top research universities

- 香港的基础研究和创新能力自MIT1997年出版"香港制造"和1998年创新和科技署成立以来受到国际上的关注

The major development since the MIT "Made by Hong Kong" study (1997) and the establishment of the Innovation and Technology Commission (1999) is the rise in international esteem of the Hong Kong universities– in basic research and in **innovation capacity**.

- Collation of 28 success stories in R&D commercialization that have won major international prizes and awards and successfully commercialised with significant impact

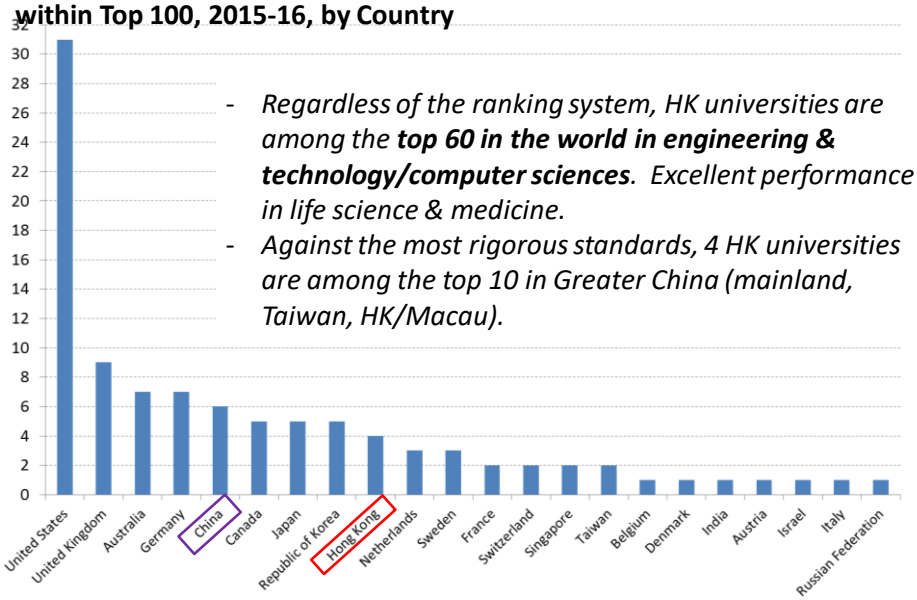
全球高校排名 Globally Recognized Universities

Rankings	HK	London	Boston
City having the greatest no. of World's Top 100 Universities by QS – also higher than San Francisco Bay Area (2), New York (2), Chicago (2), Paris (2), Beijing (2), Tokyo (2), & Melbourne (2)	#1 (4 out of 8)	#1 (4)	#2 (3)

Rankings	HKUST	HKU	CUHK	CityU	PolyU
World's Top 150 Universities in QS World University Rankings 2016	#36	#27	#44	#55	#111
Global Employability University Ranking 2016 (reported by Times Higher Education)	#13 (#1 in China)	#77	#85	#138	-
World's Top 65 Universities in Engineering & Technology • QS World University Ranking 2015	#14	#26	#41	#60	#44
• Times Higher Education Rankings 2016	#19	#33	#74	#58	#74
World's Top 50 Universities in Computer Science & Information Systems • QS World University Rankings 2016	#14 (#1 in China, #2 in Asia)	#19	#22	#49	#49

- *51 % of research output judged by international experts to be "world leading" (4 star) or "internationally excellent" (3 star) in Research Assessment Exercise 2014*

按国别分工程和技术部门排名前100的高校（2015-16）
Number of University Engineering & Technology Departments Ranked within Top 100, 2015-16, by Country

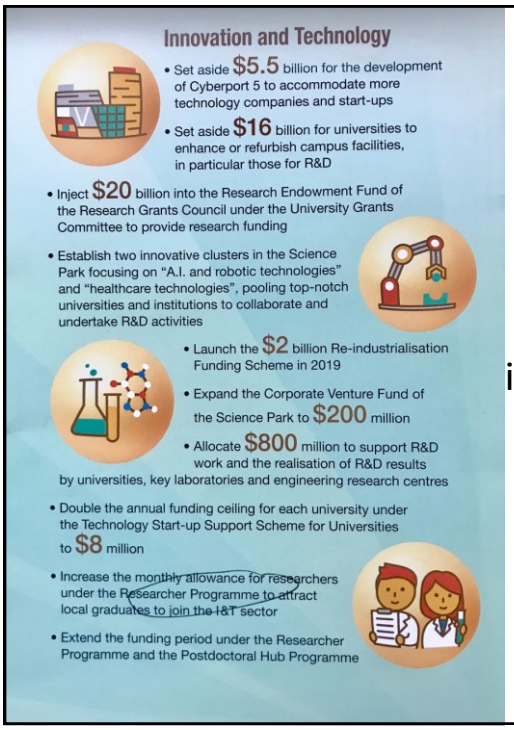


- *Regardless of the ranking system, HK universities are among the **top 60 in the world in engineering & technology/computer sciences**. Excellent performance in life science & medicine.*
- *Against the most rigorous standards, 4 HK universities are among the top 10 in Greater China (mainland, Taiwan, HK/Macau).*

Source: Times Higher Education World University Rankings

Policy Recommendations 政策建议

•Government leadership at the highest level necessary to rejuvenate I&T development
创新及科技发展必需政府最高層的支持
•Professional and technical expertise necessary in government decision making
政府决策部门需要补充专业和技术专家
•Support for local technology innovation
鼓励和支持本地技术创新
•Enhancement of recognition for I&T contribution
加强对科技和创新的认识
•Nurture of human resources and talents in I&T
为创新及科技发展培育人力资源和人才
•The identification of strategic areas for collaboration in Hong Kong and the Greater Bay Area
甄选香港和大湾区合作的战略领域
•Development of integrative collaboration of Hong Kong-Mainland I&T
推进香港-大陆科技和创新协同发展



Hong Kong SAR Government Initiatives

R&D investment increases to 1.5% of GDP (from 0.74%) in 5 years

2018-05-14 習近平對在港兩院院士來信作出重要指示

強調

"促進香港同內地加強科技合作"
"支持香港為建設科技強國貢獻力量"
"有關部門迅速做好貫徹落實工作"
"有序推進內地與香港科技合作"

President Xi Jinping gives major policy directive for HK-mainland collaboration to develop GBA as an international centre of innovation and technology, May 2018

Smart Solutions for Water Resilience

Success stories/examples of university-government-industry collaboration in water research and innovation:

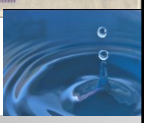
- ***WATERMAN real time forecast system for smart environmental management***
- ***SANI** innovative wastewater treatment*
- *Smart urban water supply systems **(SUWSS)***

Project WATERMAN (2008-2018)

香港近海水質預報及管理系統

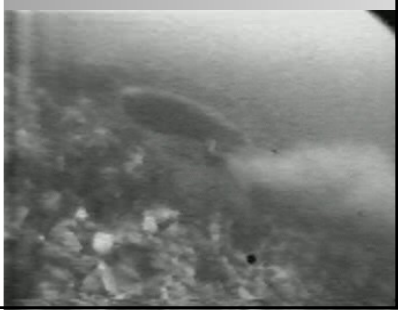
1) Beach water quality forecast system
   - daily/real time forecast 海灘水質預報系統
   - emergency response 應變管理
   - sewage disinfection dosage optimization
     淨化海港計劃消毒劑優化
2) Fisheries management – scientific determination of carrying capacity of fish farming
   海鱼养殖科学管理方法
3) Harmful algal bloom (red tide) forecast and early warning system 近海赤潮預警系統

Every day 1.85 million m^3 of treated sewage is discharged into Victoria Harbour



城市污水排放

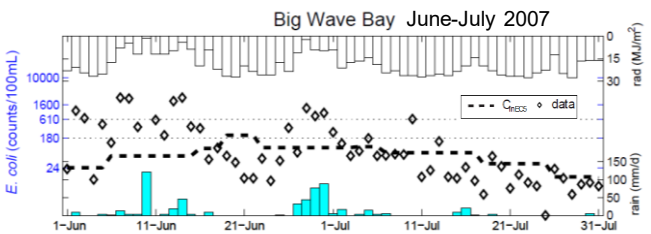
英国苏格兰的一个海洋排污口



Traditional sampling of beach water quality has no forecasting or nowcasting ability

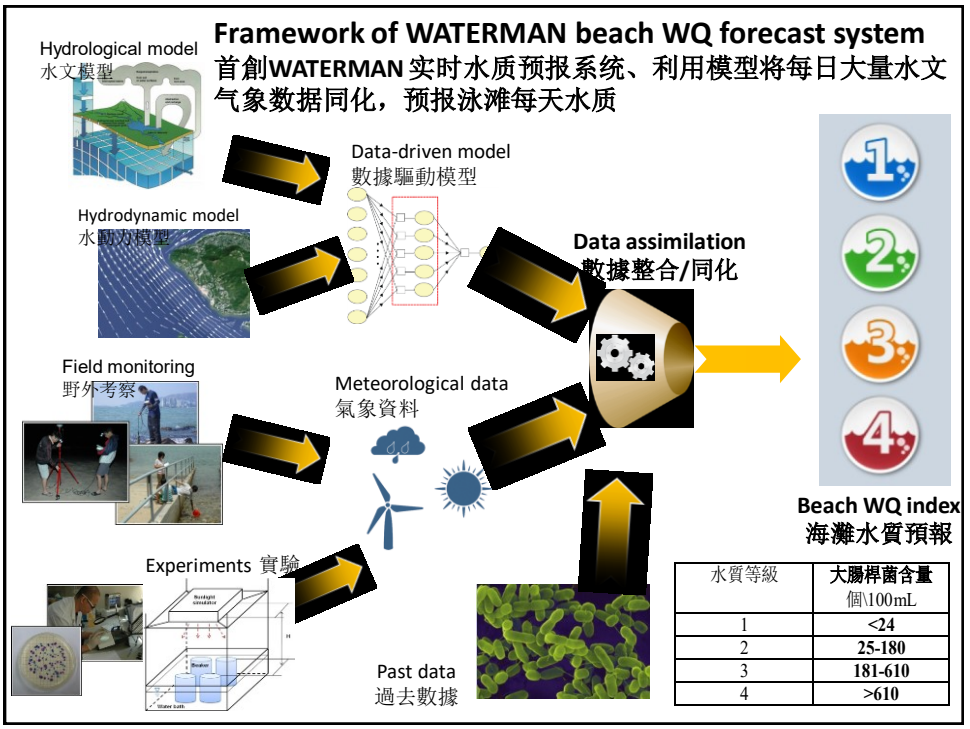
傳統採樣監測沒有預測能力

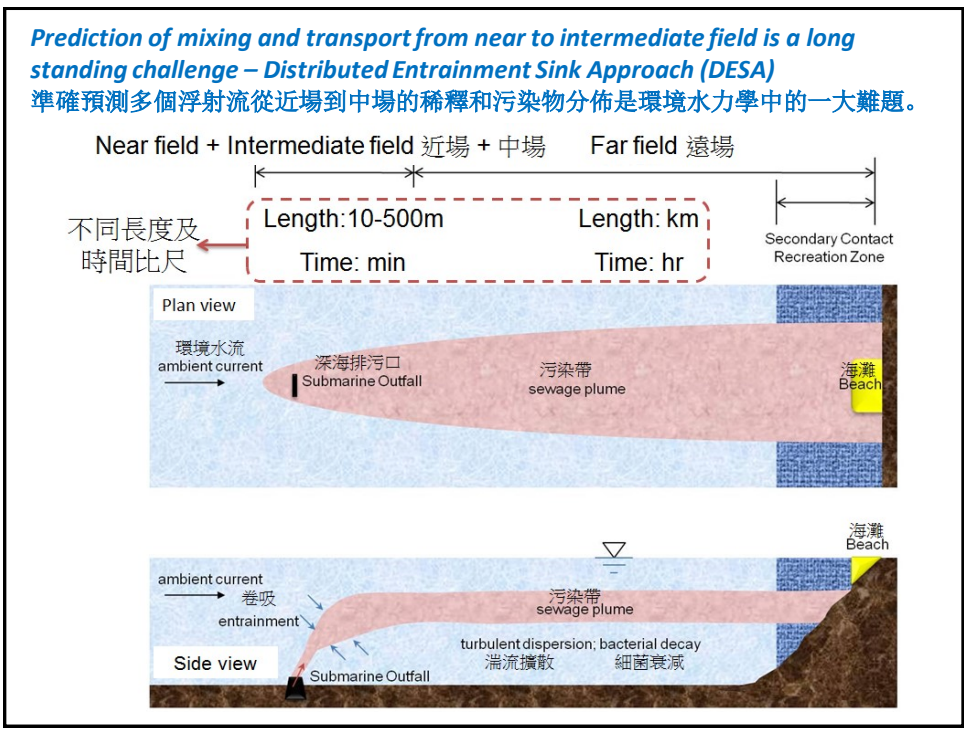
- Sampling frequency ~ typically once per week, few sampling takes place during weekends（每周只得一次採樣，而採樣往往不在周末進行）
- Membrane filtration method takes 18-24 hours before results become available（現行細菌培殖需時18–24小時）
- Even rapid methods like qPCR take several hours to get results; and water quality can vary over time scales shorter than 1 day（快速檢測方法亦需數小時才得出結果，水質可能已出現變化）
- Research proved that water quality today does not necessarily correlate to that yesterday（研究顯示今天的水質和明天的水質沒有必然關聯）



To better protect public health, a predictive modelling tool for beach management is called for

為了加強公眾健康保障，我們需要利用預測模型協助泳灘管理


Framework of WATERMAN beach WQ forecast system
首創WATERMAN 实时水质预报系统、利用模型将每日大量水文气象数据同化，预报泳滩每天水质
Hydrological model
水文模型
Data-driven model
數據驅動模型
Hydrodynamic model
水動力模型
Data assimilation
數據整合/同化
Field monitoring
野外考察
Meteorological data
氣象資料
Experiments 實驗
Past data
過去數據
Beach WQ index
海灘水質預報
水質等級
大腸桿菌含量
個\100mL
1
<24
2
25-180
3
181-610
4
>610


Prediction of mixing and transport from near to intermediate field is a long standing challenge – Distributed Entrainment Sink Approach (DESA)
準確預測多個浮射流從近場到中場的稀釋和污染物分佈是環境水力學中的一大難題。
Near field + Intermediate field 近場 + 中場
Far field 遠場
不同長度及時間比尺
Length:10-500m
Time: min
Length: km
Time: hr
Secondary Contact Recreation Zone
Plan view
環境水流
ambient current
深海排污口
Submarine Outfall
污染帶
sewage plume
海灘
Beach
海灘
Beach
ambient current
卷吸
entrainment
污染帶
sewage plume
Side view
Submarine Outfall
turbulent dispersion; bacterial decay
湍流擴散
細菌衰減

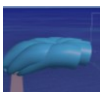
WATERMAN 3D Hydrodynamic Model for HK Beach WQ Forecast

利用「分散汇流DESA」方法，将近场及远场的多尺度模型无缝動態耦合，首次成功预报每日泳滩的水质，大大提升環境管理水平。

Choi and Lee, ASCE Journal of Hydraulic Engineering (2007)

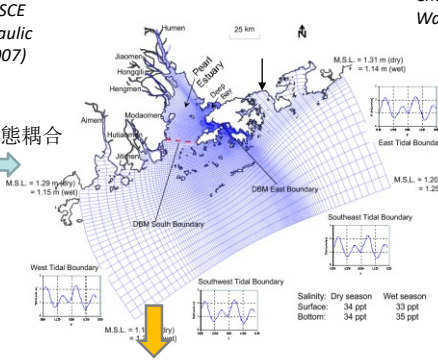
Chan, Thoe and Lee, Water Research (2013)

Outfall



DESA 動態耦合

JETLAG
Near field model



Far-field Hydrodynamic Model
遠場水動力模型

Bacterial Loading
細菌源

Current, Turbulent Mixing
潮汐流、紊流混合

Bacterial decay modeling
細菌衰減

***E. coli* concentration**
(大腸桿菌含量)

2013-2017 Beach Water Quality Forecast Accuracy

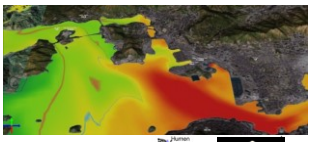
Smart Phone app "HK Beach"

*Overall accuracy: % of correct prediction of WQO (180 cnt/100mL) compliance/exceedance

(N ~ 180 per beach)

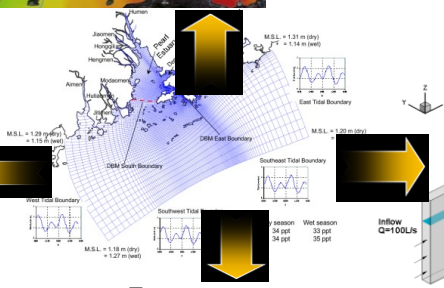
WATERMAN system (2008-2018)

香港近海水質預報及管理系統，開智慧環境管理先河

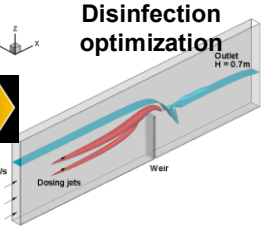


EIA, setting discharge standard

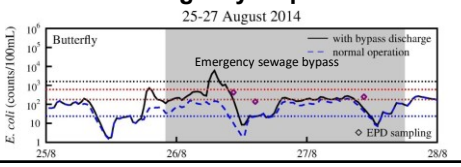
Beach WQ forecast



Disinfection optimization



Emergency response

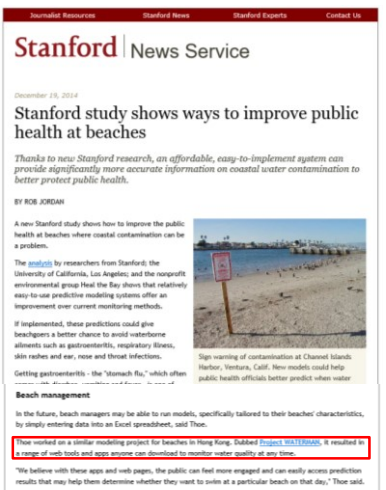


"H.K.Beach"

Protection of Public Health

International Impact (國際影響)

- The WATERMAN System has been heavily referenced by a California beach water quality prediction system, (WATERMAN被美國加州進行的計劃大量引用並作為開發基礎)
- The California nowcast system was jointly developed by Stanford University (史丹福大學) and Heal the Bay, and funded by the California State Water Resources Control Board (加州水資源控制委員會)
- The system has been well-received by the health agencies and the public. It is currently providing daily prediction at 23 coastal beaches along the California coastline in 2019 (為加州沿岸23個泳灘提供每日水質預測) Website: https://beachreportcard.org/
- WATERMAN forecast system also cited by Safeswim system in Oakland, New Zealand



Stanford | News Service

Stanford study shows ways to improve public health at beaches

Thanks to new Stanford research, an affordable, easy-to-implement system can provide significantly more accurate information on coastal water contamination to better protect public health.

BY ROB JORDAN

A new Stanford study shows how to improve the public health at beaches where coastal contamination can be a problem.

The analysis by researchers from Stanford; the University of California, Los Angeles; and the nonprofit environmental group Heal the Bay shows that relatively easy-to-use predictive modeling systems offer an improvement over current monitoring methods.

If implemented, these predictions could give beachgoers a better chance to avoid waterborne ailments such as gastroenteritis, respiratory illness, skin rashes and ear, nose and throat infections.

Getting gastroenteritis - the "stomach flu," which often

Sign warning of contamination at Channel Islands Harbor, Ventura, Calif. New models could help public health officials better predict when water

Beach management

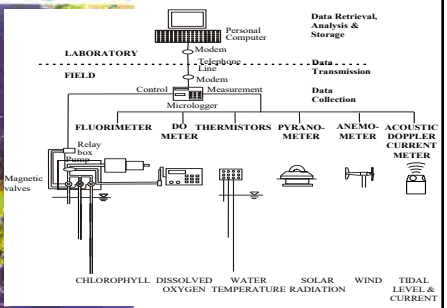
In the future, beach managers may be able to run models, specifically tailored to their beaches' characteristics, by simply entering data into an Excel spreadsheet, said Thoe.

Thoe worked on a similar modeling project for beaches in Hong Kong. Dubbed Project WATERMAN, it resulted in a range of web tools and apps anyone can download to monitor water quality at any time.

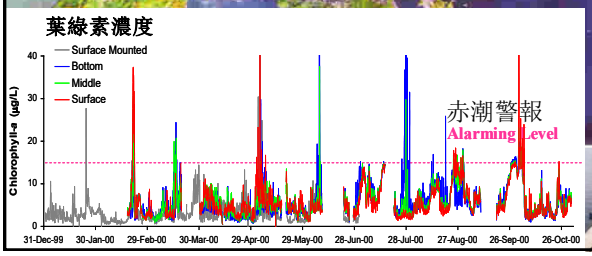
"We believe with these apps and web pages, the public can feel more engaged and can easily access prediction results that may help them determine whether they want to swim at a particular beach on that day," Thoe said.

- ***Croucher Laboratory of Environmental Hydraulics 2004-***
- ***Hong Kong UGC Area of Excellence (AoE) in Marine Environmental Research and Innovative Technology (MERIT) 2005***
- ***ASCE Hunter Rouse Hydraulic Engineering Award 2009***
- ***China State Scientific and Technological Progress Award (Second Class) 2010***
- ***ASCE Emil Hilgard Hydraulic Prize 2013***

Real time red tide early warning system successfully tracked 19 algal bloom events (2000-2003) 成功跟踪19次赤潮

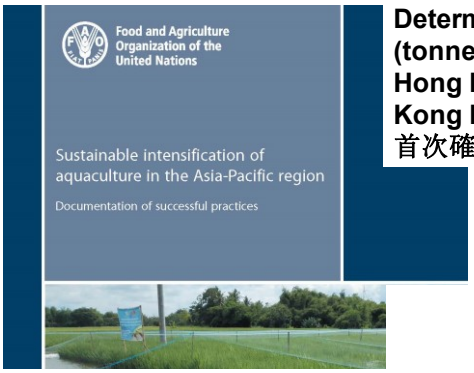


赤潮遙測系統



Determination of carrying capacity (tonnes) of all marine fish culture zones in Hong Kong – Endorsed by FAO and Hong Kong Legislative Council
首次確定香港每個海魚養殖區的環境承載力

Lee et al; FAO 2016



立法會 CB(2)2520/11-12(01)號文件

二零一二年七月十一日
討論文件

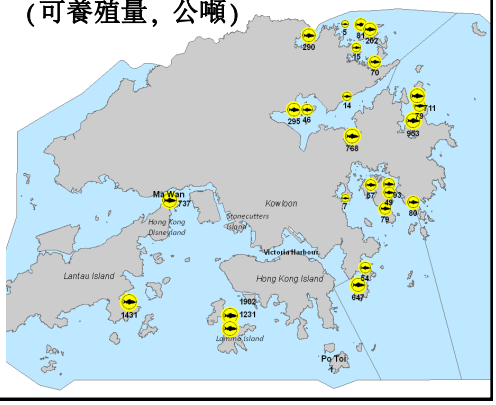
立法會食物安全及環境衞生事務委員會

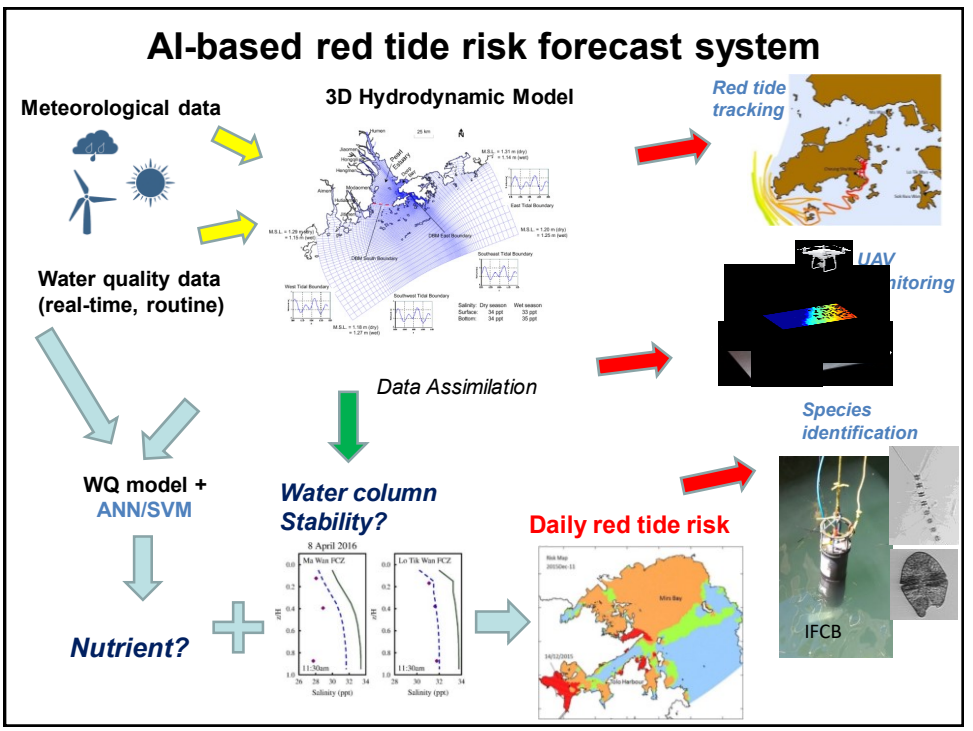
香港的海魚養殖

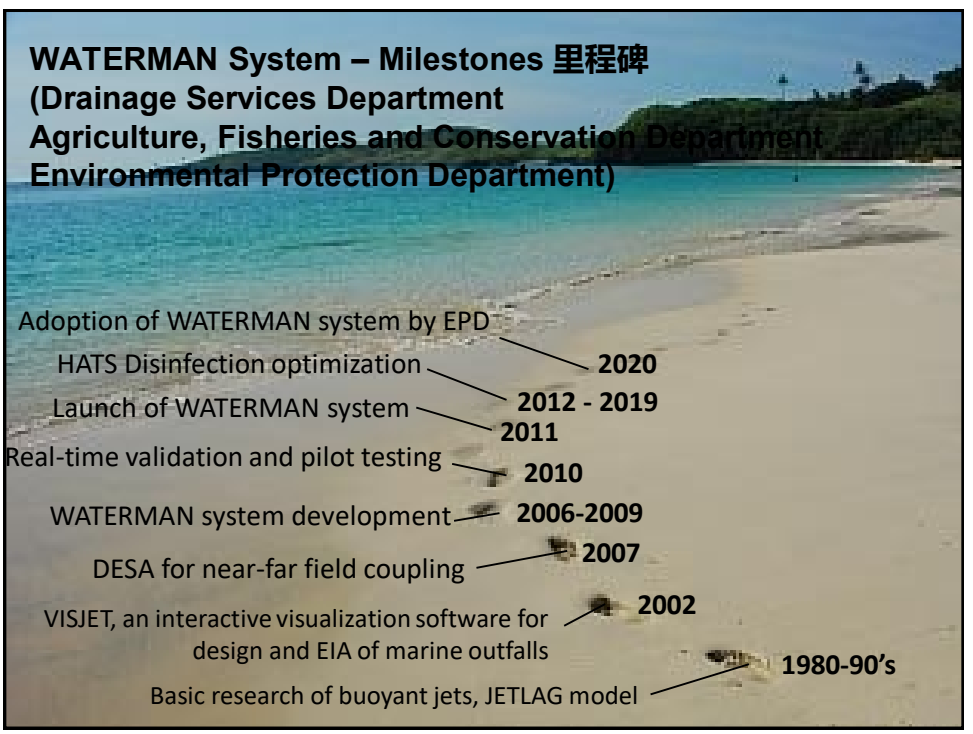
WATERMAN 系統

15. 在漁護署協助下，香港大學最近研發了一套的有關香港水環境的電腦資料庫／模擬系統，名為 WATERMAN。該系統有四個主要部分，其中的漁業管理系統可就現有和可能關設的魚類養殖區對環境的影響能否維持在可接受的程度，作出客觀和科學的評估，從而讓我們得以確定這些養殖區的環境承載

Carrying capacity of 26 FCZs in HK(
香港26个海漁養殖區的環境承載力
(可養殖量，公噸)




AI-based red tide risk forecast system
Meteorological data
3D Hydrodynamic Model
Red tide tracking
Water quality data (real-time, routine)
UAV
itoring
Data Assimilation
Species identification
WQ model + ANN/SVM
Water column Stability?
Daily red tide risk
Nutrient?
IFCB


WATERMAN System – Milestones 里程碑
(Drainage Services Department
Agriculture, Fisheries and Conservation Department
Environmental Protection Department)
Adoption of WATERMAN system by EPD
HATS Disinfection optimization
2020
Launch of WATERMAN system
2012 - 2019
2011
Real-time validation and pilot testing
2010
WATERMAN system development
2006-2009
DESA for near-far field coupling
2007
VISJET, an interactive visualization software for design and EIA of marine outfalls
2002
Basic research of buoyant jets, JETLAG model
1980-90's

HONG KONG INNOVATION IN WASTEWATER TREATMENT
Professor Guanghao Chen, HKUST

Home-grown new sewage treatment technology-SANI Process

1200 tonnes sewage sludge waste produced daily for disposal.

T-Park for sludge incineration, Tuen Mun
(Source: Civil Service Newsletter, HK)

1.5- 3M kWh electricity consumed daily

Aeration: major energy consumption source
(Source: HKDSD Annual Report, 2011-2012)

Space of Sha Tin Sewage Treatment Works (STSTWs) 280,000 m² (HKCEDD, 2011) = 40 football fields.

(Source: HKDSD Annual Report, 2011-2012)

SANI process can reduce 60-70% secondary sludge, 10-20% energy consumption, and 30-40% space in comparison with STSTWs (1000 tonne/d) (Wu et al., Wat. Res., 2016).

China National Engineering Research Center on Heavy Metal Pollution, Professor Guanghao CHEN, HKUST

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HONG KONG INNOVATION IN WASTEWATER TREATMENT
(Collaboration with Drainage Services Department)

Development History

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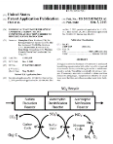
INTERNATIONAL IMPACT

Professional Recognition

- **Patents**

First granted patent in 2011


Core patents in USA, Japan, mainland, Hong Kong, etc.

- **Awards**

IWA Project Innovation Awards-Global Honor Award (Pusan, 2012)

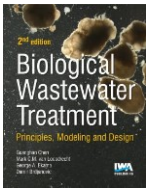
The World Smart Cities Awards - Finalist in the Group Category (Barcelona, 2012)

The International Huber Technology Prize - Second Prize (Frankfurt, 2012)


Bronze medal winner of 2018 IWA Project Innovation Award in the category 'Breakthroughs in Research and Development' (*Tokyo, 2018)*


Hong Kong Green Innovation Awards 2018-Gold Award (*Hong Kong, 2019)*

- **Knowledge**



(London, late 2020)

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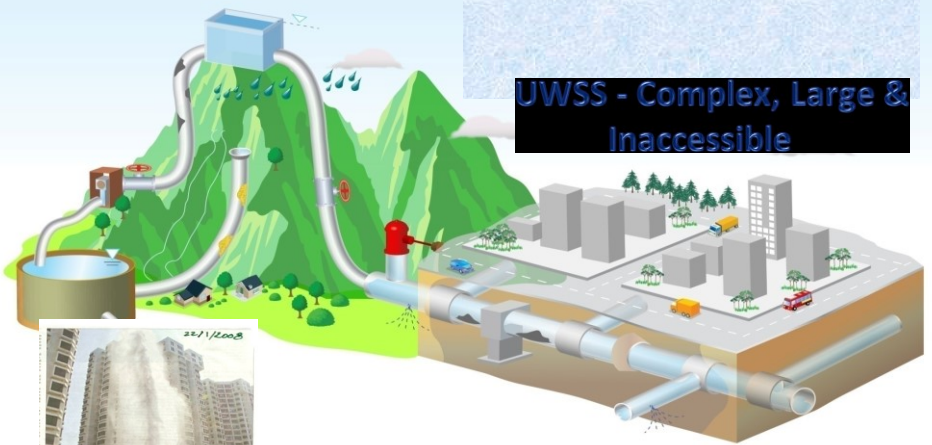
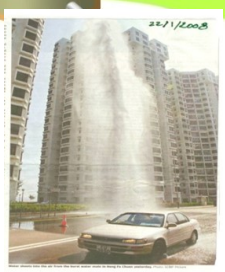
HONG KONG Smart Urban Water Supply Systems – Prof MH Ghidaoui (Theme-based Research Project)





In HK: ~ 7,000 km of pipes; ~200 pump stations; ~1000s of valves and controls

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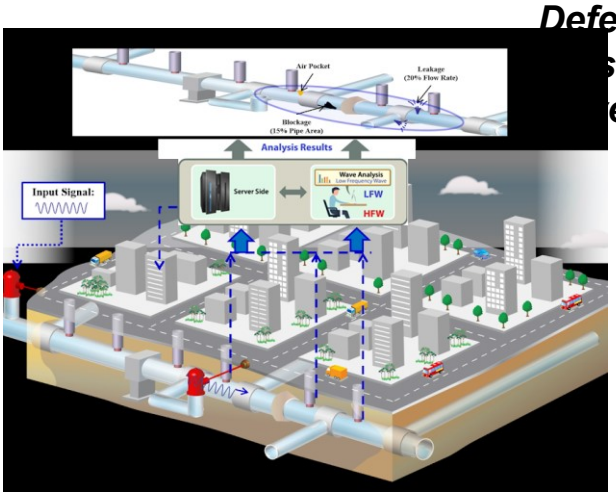
Smart Urban Water Supply Systems –

Hong Kong Research Grants Council Theme-based Research Project
Collaboration with Water Supplies Department

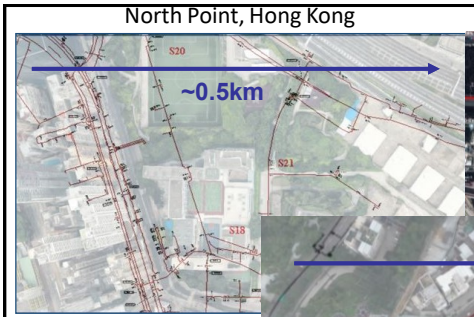


Defect detection by ssure/acoustic es

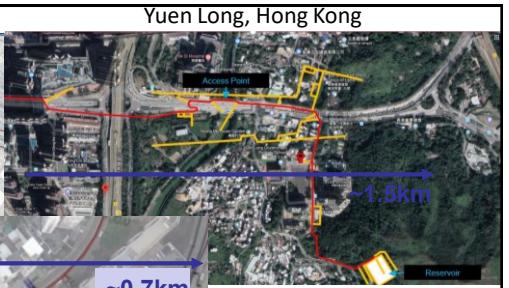
Data frequency of pressure measurement by traditional SCADA systems: 1 sample/15 minutes

High frequency pressure data measurement and acquisition system: 200 – 1000 samples/second

North Point, Hong Kong



Yuen Long, Hong Kong



Ngau Tau Kok, Hong Kong

Trento, Italy

Milan, Italy

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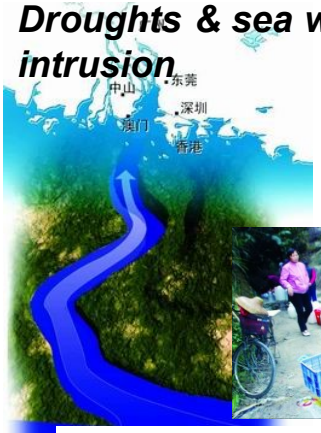
The Future

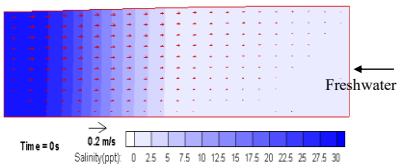
1) Science and technology are engines of economic growth.
2) Fundamental research is the basis of all innovations – long term sustained research is the key; research ideas only come from research
3) Innovation and technology entrepreneurship is important for Hong Kong's future social and economic development. Hong Kong can play an important role in the fervent national drive towards an innovation economy with self-determined technology.

Hong Kong's Urgent Water Research Needs

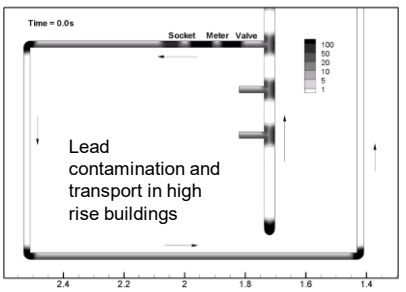
1) Maintenance and further development of Hong Kong's world class infrastructure depends on strong water and environmental engineering capabilities
2) Water resources, flood management, eco-hydrology & hydraulics, wastewater engineering, coastal engineering
3) Need for local/regional training, capacity building, and professional development across government departments (WSD, DSD, CEDD, EPD, AFCD)
4) **An international hub for water research and training like HR Wallingford, Delft IHE, IWHR based in HK?**

Drinking water security Droughts & sea water intrusion





Excess lead found in drinking water of public rental housing estates



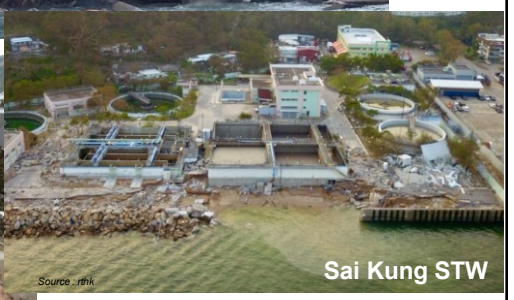
Lead contamination and transport in high rise buildings

Debris flood and boulder current in Tai Po River

Rainfall on 22/7/2010 (225 mm/d) ; 114.5 mm/hr

1 human casualty; severe property damages

Resilience to extreme weather (Typhoon Mangkhut, 2018)



Courtesy of Ir PK Chan

Towards a New International Water Innovation Hub: Ingredient of Success

1. Unprecedented policy, $$ and society support for innovation and technology development in GBA
2. Emergence of world class research universities
3. Demonstrated success of university-government-industry collaboration
4. Need for focused and coordinated synergistic development of I&T, capacity building, and training.
5. Hong Kong as a “super-connector”

Concluding Remarks

1) University-Government-Industry collaboration is essential for the sustainable development of Hong Kong's world class water infrastructure
2) An International Water Innovation Hub to serve Hong Kong and the Greater Bay Area (GBA)
3) A Water Research Institute in the Science Park/River Loop
   - Capture wave of policy and $$ support for innovation and technology in the Greater Bay Area (GBA)
   - Develop world class research and innovative technology in water environment engineering
   - Create new water industries
   - Synergize international and local collaboration across disciplinary boundaries
   - Provide world class training and professional development
   - Provide training in evidence-based water policy