Asian River Restoration Network（ARRN） 他 主催

河 川 環 境 講 演 会

～ 海外における環境水工学の最新の研究紹介 ～

講師： IAHR 副会長　ピーター グッドウィン 教授
IAHR 副会長　ジョセフ リー 教授

開催にあたって

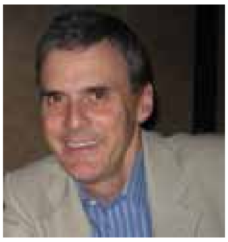
河川管理･河川再生を技術的に支援する分野は、知識情報水工学 (hydroinformatics) 、生態水工学 (ecohydraulics) 、環境水工学 (environmental hydraulics) です。今回こうした分野で世界的に活躍する二人の研究者を招いて最新の知見を講演して頂くとともに、国際的な情報交換の機会として総合討論の時間を予定しております。生態環境工学、環境水工学に関心をお持ちの研究者、実務技術者の来場をお待ちしております。

○ 開催日時： 平成 20 年 9 月 16 日（火） 13：30～17：20 （逐次通訳）
○ 開催場所： 東京大学工学部 1 号館 15 号講堂（東京都文京区本郷 7-3-1）
○ 参 加 費： 3,000 円（参加費は当日受付にてお支払い下さい）
○ 定　　員： 100 名（申し込み順）
○ 主　　催： Asian River Restoration Network（ARRN）
財団法人リバーフロント整備センター
国際水工学会 日本支部
(International Association of Hydraulic Engineering and Research)
○ 後　　援： 社団法人建設コンサルタンツ協会
○ お問合せ： (財)リバーフロント整備センター　技術普及部内　ARRN 事務局
（E-mail： info@a-rr.net　Tel：03-3265-7121）

ARRN
Asian River
Restoration Network

Asian River Restoration Network（ARRN）は国際的に河川再生に関する知識、技術情報の交換を行う公益ネットワークです。日本国内及びアジア諸国を中心とした多くの方々が参加し、情報提供・収集できる組織として河川・流域再生に関するコミュニティーを拡張し、各地域に相応しい河川の再生技術の発展に寄与するものです。
（http://www.a-rr.net/jp/en/arrn/index.html）

【講師紹介】



ピーター グッドウィン教授:
Peter Goodwin
(Vice President International Association for Hydraulic Engineering and Research)
米国アイダホ大学生態環境工学研究所の中心人物で、知識情報工学と生態水工学を融合し、南北アメリカ各地の自然再生で活躍中

ジョセフ リー教授:
Professor Joseph Hun-wei Lee
(University of Hong Kong)
香港島、珠江沿岸域のみでなく、世界各地で淡水化プラントの密度流のコンサルタントとして活躍中
(More about)
He obtained BSc, MSc and PhD degrees from the Massachusetts Institute of Technology, USA (1969-1977). He taught at the University of Delaware as Assistant Professor for three years before he joined the University of Hong Kong in 1980. He has served as Dean of Engineering from 2000 to 2003 and is currently Pro-Vice Chancellor and Vice-President, and Redmond Chair of Civil Engineering. He is also the Director of the Croucher Laboratory of Environmental Hydraulics.
Professor Lee is interested in the use of hydraulics/fluid mechanics to solve environmental problems, in particular the prediction and control of water quality. He is Chief Editor of the Elsevier Journal of Hydro-environment Research (2007-), and an Associate Editor of ASCE Journal of Hydraulic Engineering, Estuarine Coastal and Shelf Science, and Korea Journal of Civil Engineering, He is a recipient of the Alexander von Humboldt Research Fellow award by the German Government in 1991 and 2005, the Croucher Foundation Senior Research Fellow Award in 1998, and the Hong Kong Institution of Engineers Innovation Award for Construction Industry in 2002. Professor Lee is the Vice-President of the International Association of Hydraulic Engineering and Research (IAHR) and the past Chairman of the IAHR-APD Division, and Senior Vice-President of the Hong Kong Academy of Engineering Sciences. He is elected to the Royal Academy of Engineering (UK) in July 2008.
Professor Lee has served as expert advisor to the Hong Kong Government and international consultants on many hydro-environmental projects including the Sydney Ocean Outfall Post-operation Monitoring Study, Hong Kong Harbor Area Treatment Scheme (HATS), Yuen Long Bypass Floodway, Deep Bay Water Quality Regional Control Strategy Study, Red Tide Monitoring and Management Study, Tai Hang Tung Storage Scheme, and the Hong Kong Island West Vortex Intake Study.

Asian River Restoration Network

Seminar

Ecohydraulics and Environmental Hydraulics Incorporated with Advancement in Hydroinformatics

September 16, 2008

New Trends in Hydro-Ecological Engineering Incorporated with Hydroinformatics

By
Peter Goodwin
Vice President
International Association for Hydraulic Engineering and Research

Summary of Further Information

IAHR Sections

IAHR Section on Hydroinformatics http://www.iahr.net/site/index.html
Chair: Professor Vladan Babovic, National University of Singapore [Vladan@nus.edu.sg]

IAHR Section on Ecohydraulics
Chair: Dr. Harm Duel, Delft Hydraulics, the Netherlands [harm.duel@wldelft.nl]

Forthcoming IAHR Meeting

The First Combined meeting of the Ecohydraulics and Hydroinformatics Sections
8th International Conference on Hydroinformatics in collaboration with the
7th International Symposium on Ecohydraulics

http://www.heic2009.org/

Supporting Documents (USA Activities)

Sensors for Environmental Observatories – pdf with Professor Tamai
Cyberinfrastructure – pdf with Professor Tamai
- www.nsf.gov/od/oci/reports/toc.jsp

National River Restoration Science Synthesis – pdf with Professor Tamai
NSF WATERS Network - http://www.watersnet.org/

Further Information: please contact Peter Goodwin pgoodwin@uidaho.edu

IAHR Seminar, Asian River Restoration Network,
Tokyo, September 16, 2008

Recent Research Problems Related to Ocean Outfalls in Hong Kong

By

Professor Joseph Hun-wei Lee
Department of Civil Engineering
The University of Hong Kong

The Faculty of Engineering

Croucher Laboratory of Environmental Hydraulics

環境水力實驗室

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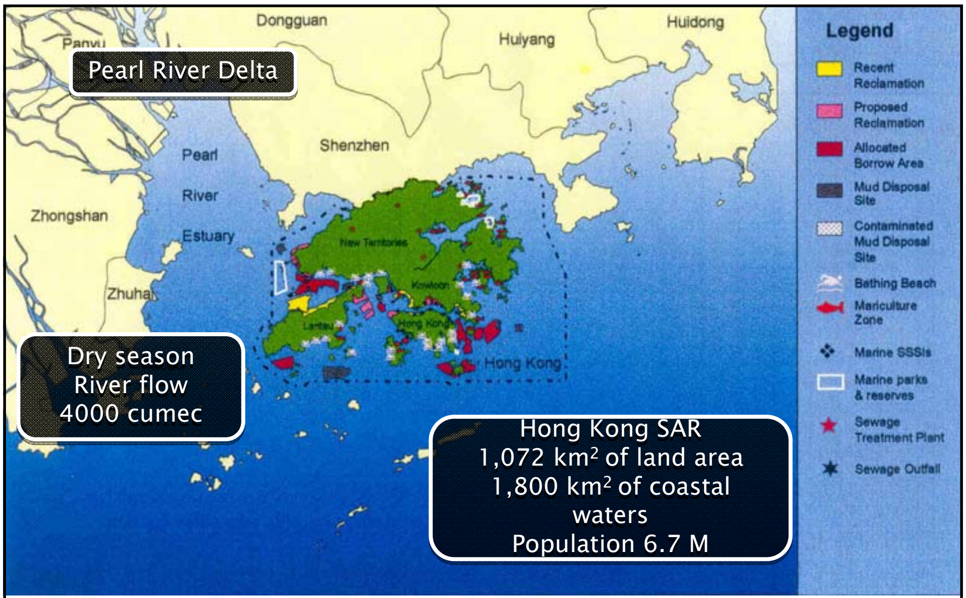
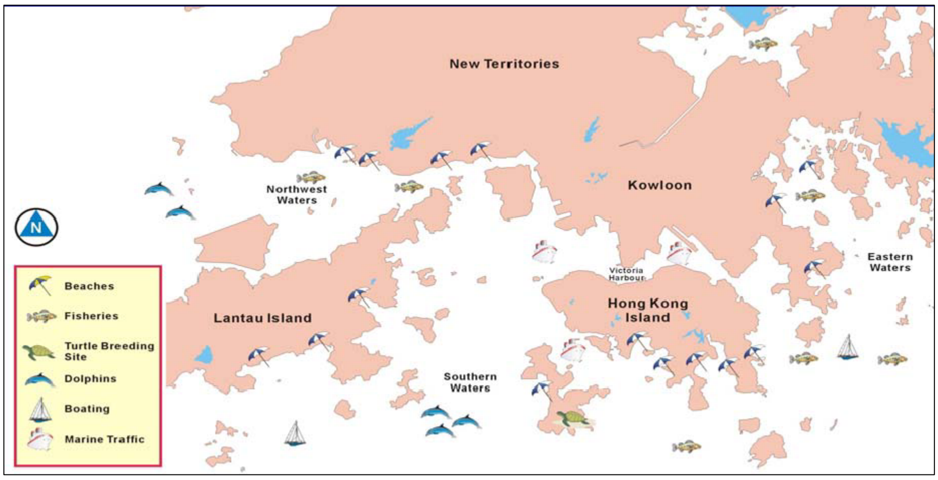
1. Introduction
2. Water quality management in Hong Kong
3. WATERMAN - real-time hydro-environmental modelling and visualization system for public engagement
   - Near field mixing of rosette jet groups from ocean outfalls in a crossflow
   - Modelling of near-far field coupling (Distributed Entrainment Sink Approach)
4. Conclusions



Pearl River - 2200 km; total catchment area 453,700 sq.km.

Annual precipitation 1470 mm; wet season flow 20,000 m^3/s

Beneficial Uses of Hong Kong Coastal Waters



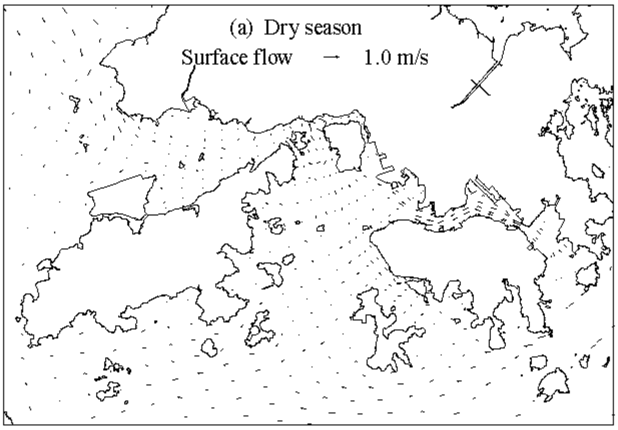
Background

- **Environmental sustainability is critical for the social and economic development of the HKSAR.**
- **Coastal marine waters are heavily used - e.g., navigation, recreation, fisheries, waste disposal, industrial water supply, dredging for fill material, environmental conservation and scientific work.**
- **Water quality management is important for Hong Kong's future development as a world city. This can be achieved with an internet and GIS-based water quality forecast and management system**

Victoria Harbour, Hong Kong SAR, China

1.85 million cubic meters of sewage generated in the harbour area per day

Hong Kong has good flushing by tidal currents



Flow in dry season (November – March)

However, flushing rate in many semi-enclosed tidal inlets (e.g. Tolo Harbour) is very small

- **Effluent discharges located near sensitive areas in many densely populated cities in Asia**
- **Need for robust predictive tool for initial dilution of rosette type ocean outfall**
  - Optimal outfall design
  - Mixing zone analysis
  - Risk assessment
  - Post-operation monitoring

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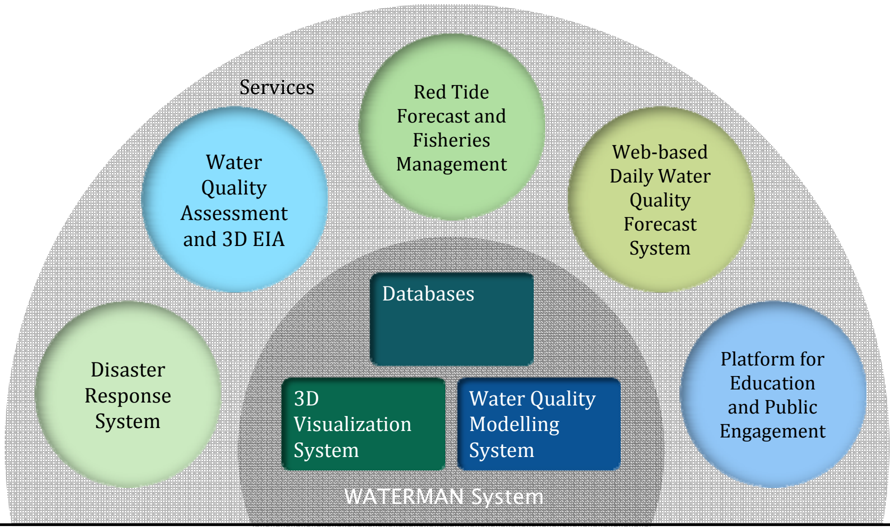
Our Goal

- **To develop an Internet and GIS-based water quality forecast and management system (WATERMAN)**



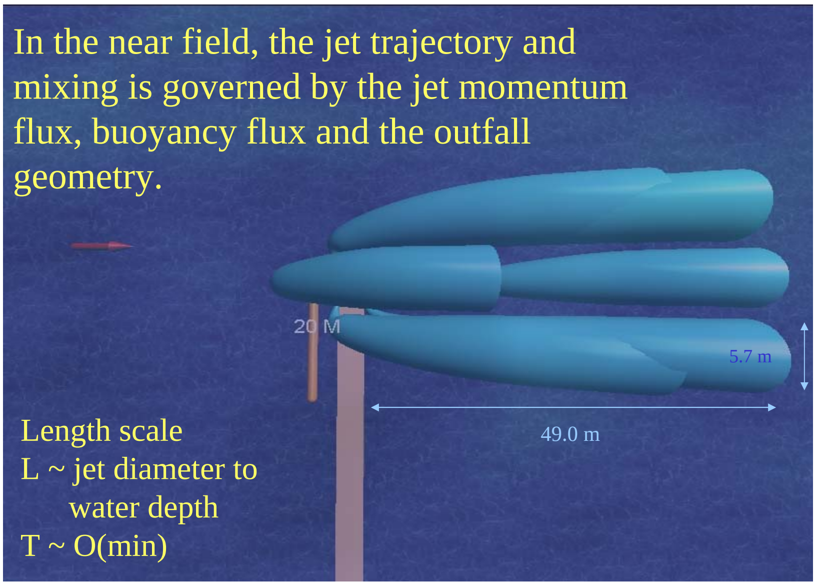
3D Environmental Impact Assessment and Visualization System for Public Engagement

- **risk assessment**
- **seamless prediction**
- **advanced visualization**
- **public engagement**

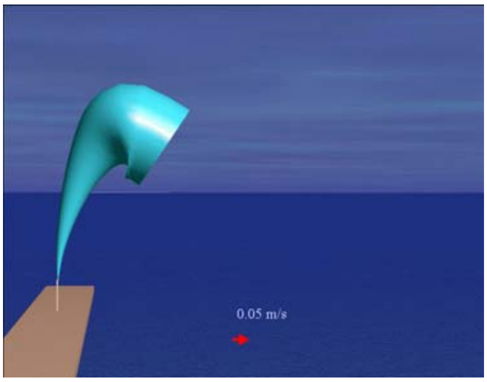
Harbour Area Treatment Scheme (HATS) Stage 1

23.6 km of deep tunnels; 1.8 M m^3/d Chemically Enhanced Primary Treatment

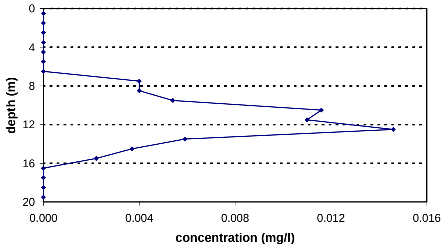
Near field mixing

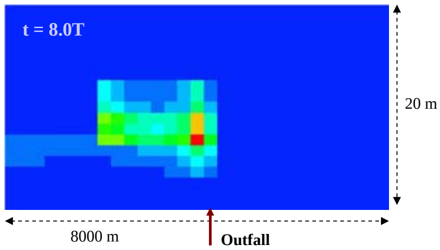


Variation of Trapping Level in Stratified Tidal Flow

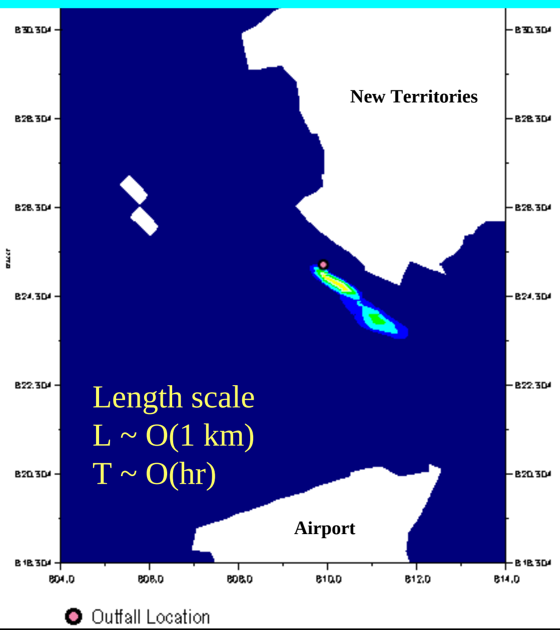


at t = 8.0T and 100 m from the outfall





3D Far-field Shallow Water Circulation Model



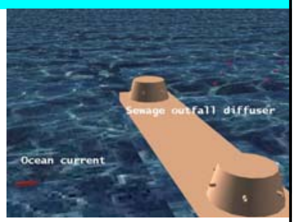
Far field simulation by 3D mass transport model

Advection by currents
Turbulent diffusion
Bacterial decay

Near Field

- **Marine discharge**
  - Discharge of partially treated wastewater to marine environment through a submarine outfall
  - Assimilation by natural processes
  - Economical and environmentally acceptable
- **Multiport diffuser**
  - A number of risers; ports mounted on riser
  - Discharge as rosette jet groups

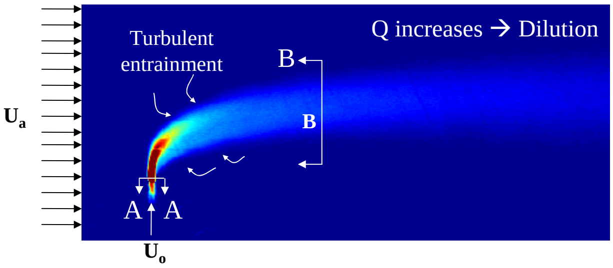
炬播型浮送庭 (8-jets rosette riser in a current)



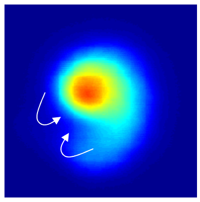
浮送庭從擴散器以不同爰角度排放,產生炬播型爰吐維矩綽

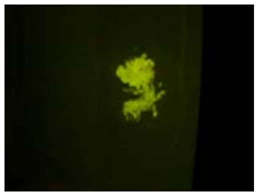
Jet in a coflow (同向), crossflow (橫庭) and counterflow (反向) coexist in this case

Turbulent jet in a crossflow

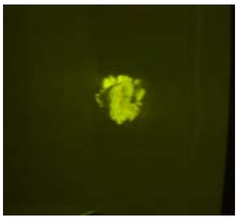


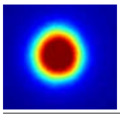
Section B - B





Section A - A

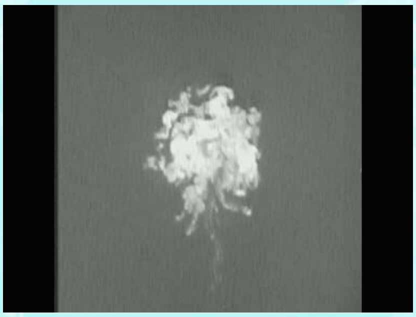




- Gaussian
- Shear entrainment

- Bent-over phase
- Vortex pair
- Vortex entrainment

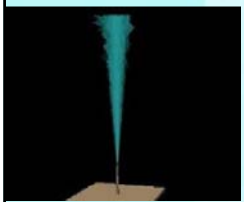
Advected line puff
Cross-sectional view by laser-induced fluorescence technique

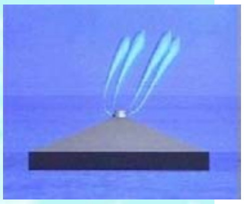


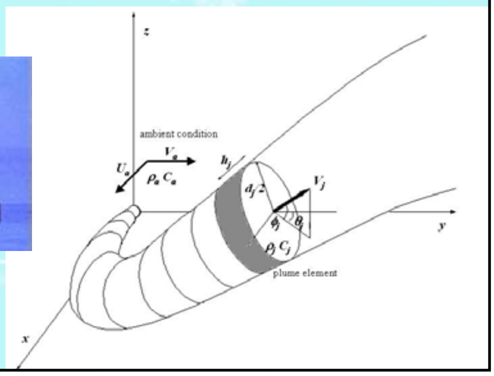
Experimental conditions: jet velocity 5cm/s discharging at 85° to horizontal at 10cm downstream distance

VISJET (www.aoe-water.hku.hk/visjet)

- Windows-based interactive VR software for buoyant jet discharge
- JETLAG model is modeling engine
- Validated Lagrangian model
- Composite dilution calculation







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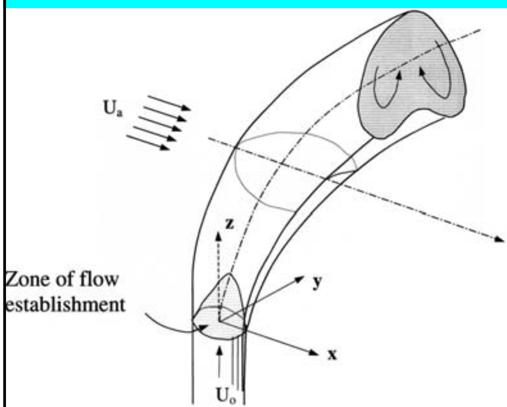
JETLAG – 湍庭卷吸 (Turbulent Entrainment)

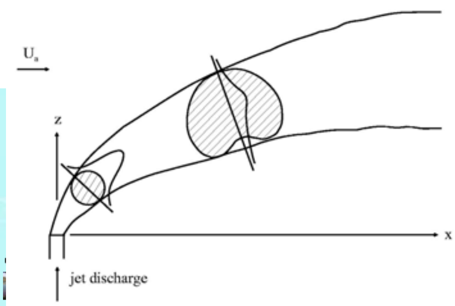


漩渦卷吸 (Vortex entrainment) - 由橫切水流引起的及用「投影面積卷吸」(Projected-area entrainment) 爰假設來計算爰

Bent-over phase
Advected line puff/thermal

速差卷吸 (Shear-entrainment) - 由送庭排放引起爰

Advected jet/plume



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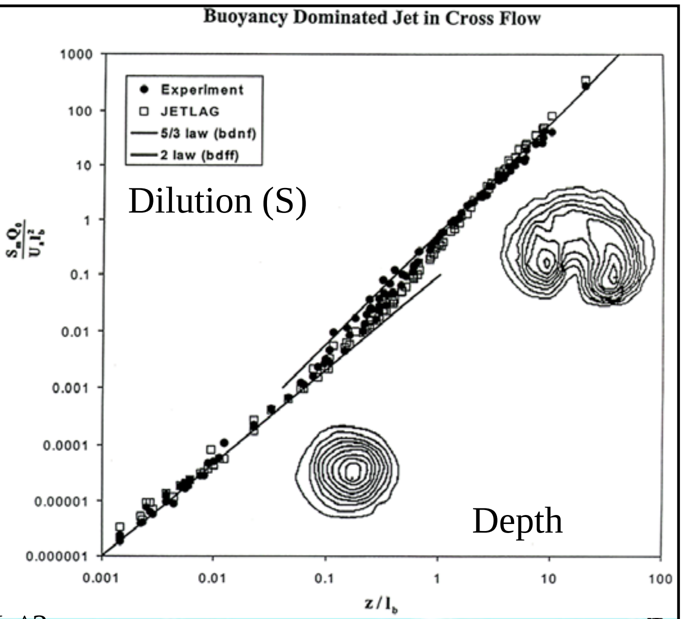
Comparison of JETLAG prediction with laboratory data

灼横切佛庭中
爰垂直浮送庭
預測爰稀釋度
與無因次高度
爰關係



Lb=B/Ua^3
Q=discharge flow
B=buoyancy flux

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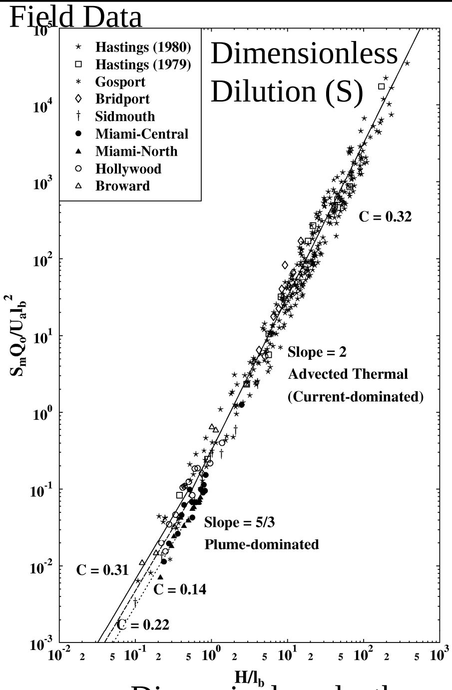
Field Data



Prediction of initial mixing of pollutant discharge in a tidal current

JETLAG/VISJET Model prediction of initial mixing is supported by extensive field data of initial dilution at sea outfalls in the UK, USA and other countries

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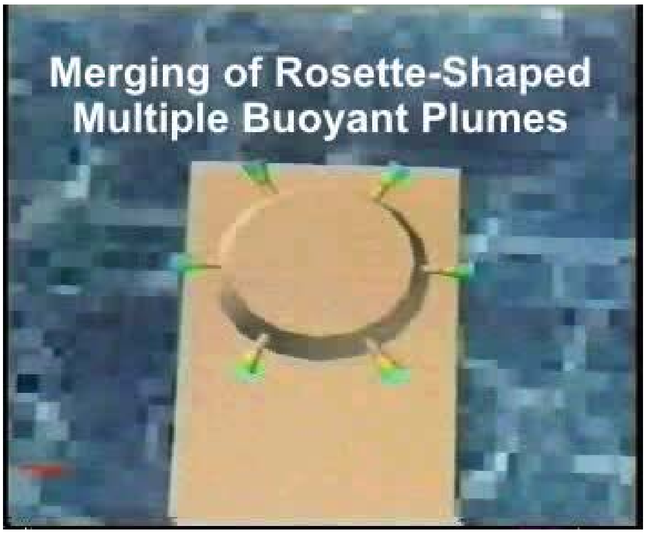
Prediction of plume mixing using <u>near field model</u>



Rosette Diffuser Experiments

San Francisco Outfall model study (Isaacson, Koh and Brooks 1983)
Boston outfall model study (Roberts and Snyder 1993)

" The general subject of buoyant jets and plumes has been studied for several decades. This has yielded an understanding of the physical mixing processes in simple cases. To date, however, no mathematical model is available which can predict the dilution under all combinations of diffuser geometry and ambient ocean conditions."

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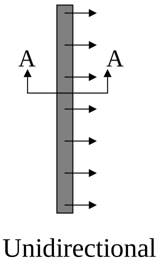
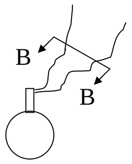
裘槎水力實驗室

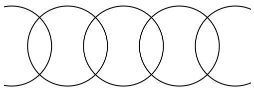
Kinematic interaction of multiple jets



- Merging of jets
- Reduction in jet cross-sectional area
- Reduction in entrainment
- Reduction in effective dilution

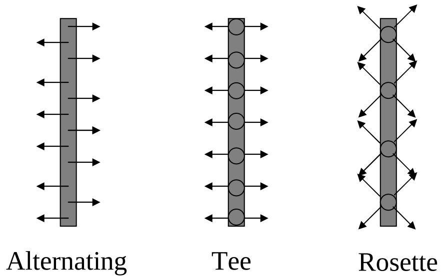


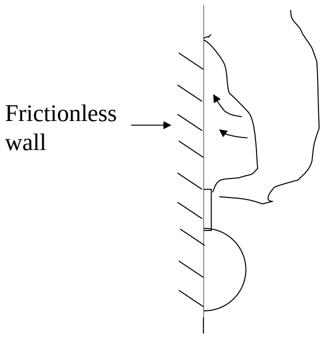
Section A-A



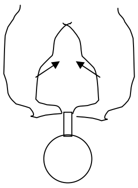
Section B-B

Dynamic interaction of multiple jets (U_a = 0)





$p \propto (\alpha v_j)^2$



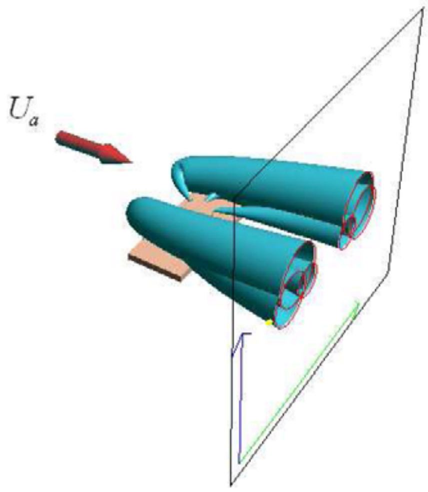
- Entrainment demand for normal spread
- Pressure difference

The composite dilution concept

- **In the Boston Outfall study, Roberts and Snyder (1993) found that a 12-nozzle riser resulted in lower dilutions than 8-nozzle riser, for both stagnant and flowing conditions**
- **Is this due to the dynamic interaction of jets as observed by Liseth (1976) for Ua=0, or the kinematic interaction due to plume overlapping ?**
- **Experimental observations suggest that adjacent jets interact only when very close together or in confinement. For a typical rosette diffuser, the ratio of nozzle/riser diameter ~ 1/10. The rosette type diffuser has a fanned out geometry, and each buoyant jet has a 3D trajectory.**
- **If the ambient flow is sufficient to supply the jet entrainment, it seems reasonable to hypothesize kinematic jet interaction – as the entrainment flow Ve ~ 1/r, and p ~ 1/r**2**

Merging of a rosette jet group in a crossflow

(Cut plane position also shown)

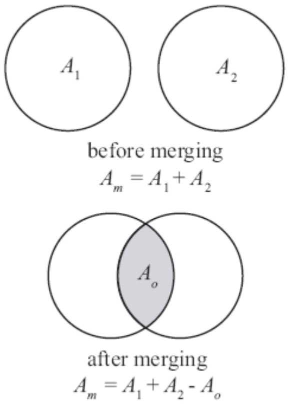


In the bent-over jet

$$u \approx U_a$$

Cross-section of two overlapping plumes
in bent-over phase

(The composite dilution concept)



Composite Dilution

- **Mass flux of rosette buoyant jet group**

$$A_m C_m u_m = \sum_{i=1}^{n} A_i C_i u_i$$

- **After bent-over by crossflow**

$$u \approx U_a$$

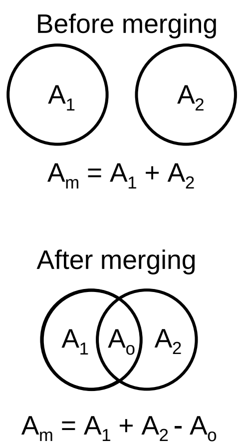
$$C_m = \frac{\sum A_i C_i U_a}{A_m U_a} = \frac{\sum A_i C_i}{A_m}$$

- **Negligible dynamic interaction**

$$A_m = \sum A_i - A_o$$

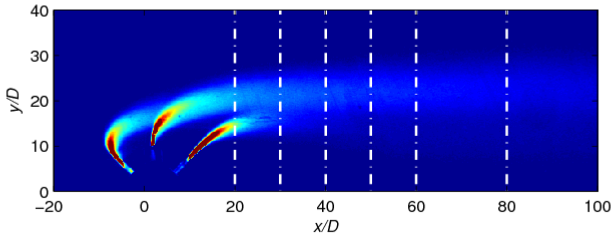
- **Composite dilution**

$$S = C_o / C_m$$



Experiments

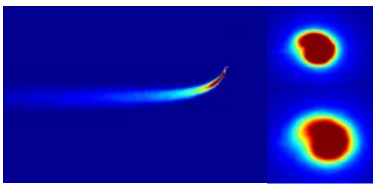
- **Jet Trajectory Measurement**
  - Tracing 3D trajectory of buoyant jet
  - Simultaneous use of overhead and side CCD camera with ordinary dye
- **Cross-sectional Concentration Measurement**
  - LIF technique using underwater CCD camera
  - 400 images (0.1 sec. Interval) taken and averaged
  - Measured at 20*D* – 80*D*



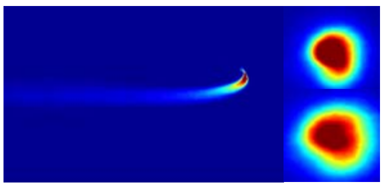
Study of Jet Interaction

1) Individual jet experiment; trajectory & sectional LIF images
2) Multiple jet experiment; trajectory & sectional LIF images

Single jet $\theta = 60^o$

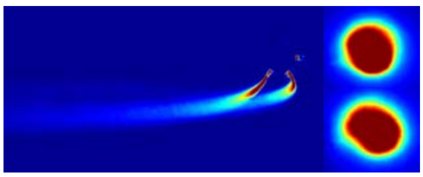


Single jet $\theta = 120^o$



Multiple jet

$\theta = (60^o, 120^o)$



Measured centerline trajectories of various discharge configurations (crosses: multiple jets; circles: individual jet)

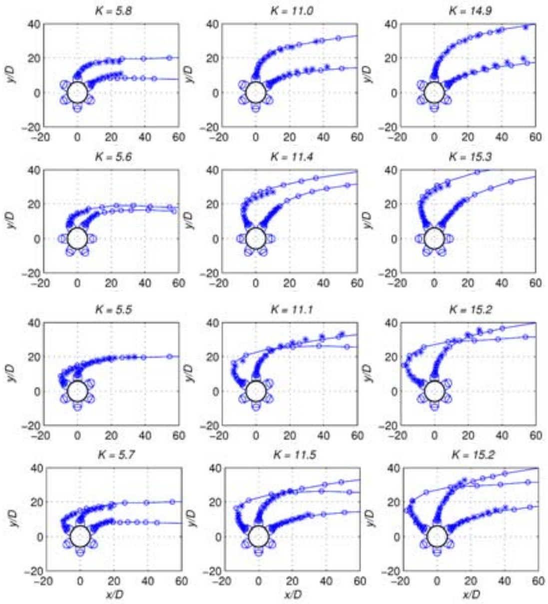
D = 0.30 cm

θ =30°, 90°

θ =60°, 120°

θ =90°, 150°

θ =30°, 90°, 150°



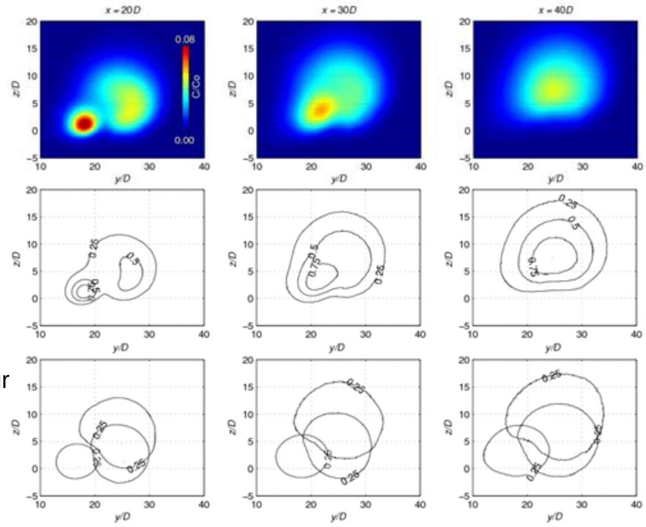
Cross-sectional Concentration Profile

- **Three jet group:** 45, 90, 135°; Fr = 17; U_o / U_a = 8

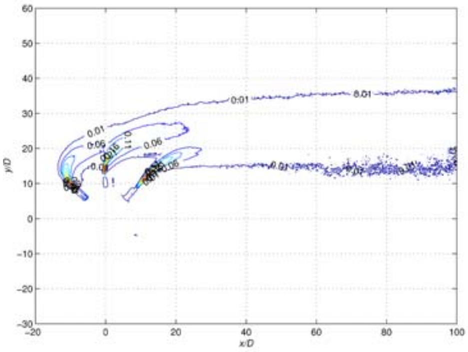
LIF image of multiple jet

Concentration contour from LIF

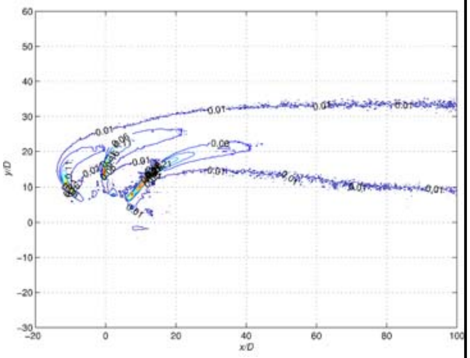
Concentration contour from superposition of individual jets



Measured concentration field of a 3-jet rosette jet group in crossflow (D = 0.30 cm, *Uo* = 78.0 cm/s, *Ua* = 10.9 cm/s)

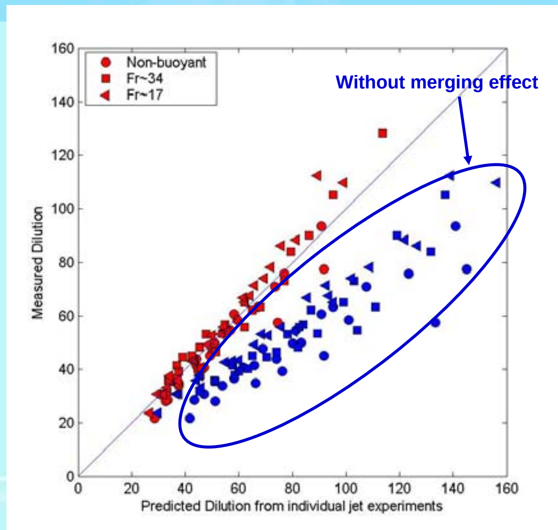


Measured concentration of multiple jets



Concentration field obtained by superposition

Composite Dilution (initial dilution)



- Excellent agreement of (i) Measured dilution of multiple jet and (ii) Dilution obtained by superposition of measured concentration from individual jet experiments - regardless of Jet Froude Number
- Overestimation of dilution without consideration of overlapping area

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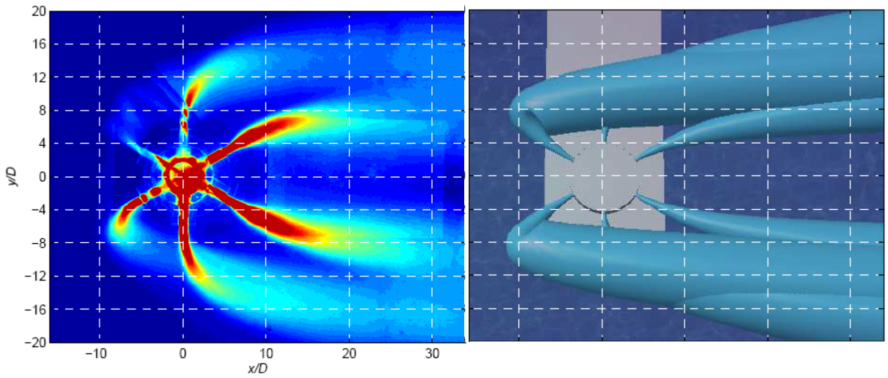
Top view of a rosette jet group in crossflow

(D = 0.49 cm, *Uo* = 34.2 cm/s, *Ua* = 6.5 cm/s)



LIF experiment (cut plane)   VISJET prediction (top view)

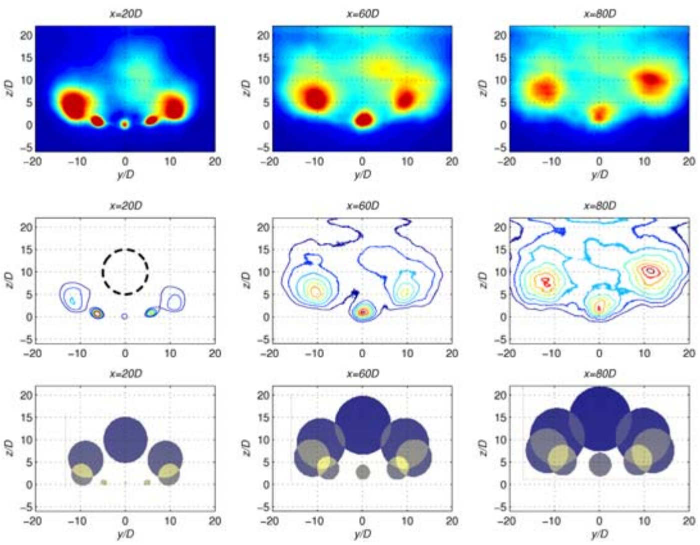
Cross-sectional concentration profile of 8-jet rosette jet group

(D = 0.25 cm, *Uo* = 74.4 cm/s, *Ua* = 4.5 cm/s, Fr = 15.3, H = 30cm)

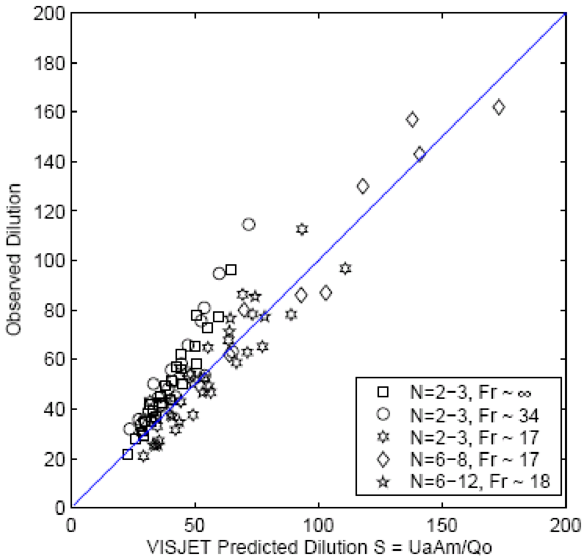
LIF images

Concentration contour (min = $0.25C_m$)

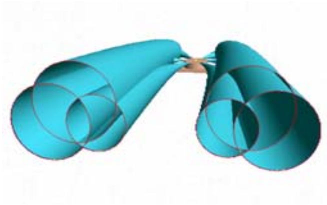
VISJET prediction



Comparison of measured and VISJET predicted cross-sectional averaged dilutions (Composite Dilution)



- **Composite dilution of a jet group can be defined by VISJET by computing the extent of jet merging**



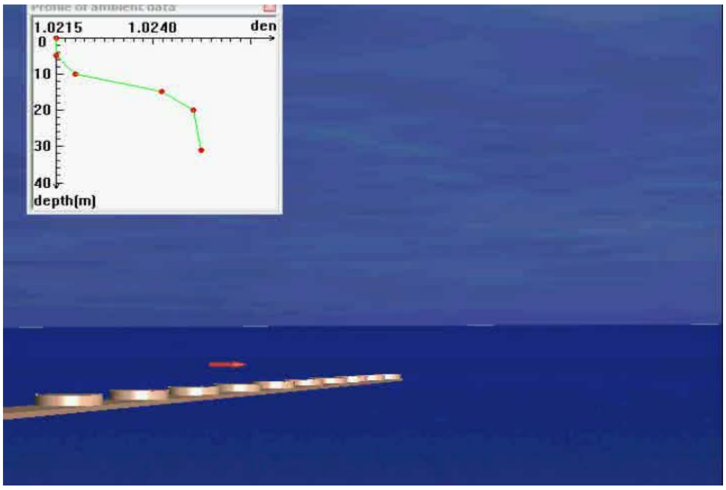
VISJET Simulation of two jet group in non-stratified ambient

Isaacson et al (1983)

- ***q*** **= 0.0198 m^3/s/m**
- ***h*** **= 12.8 m**
- ***D*** **= 0.25 m**
- ***s*** **= 14.6 m**
- **U_a = 0.28 m/s**

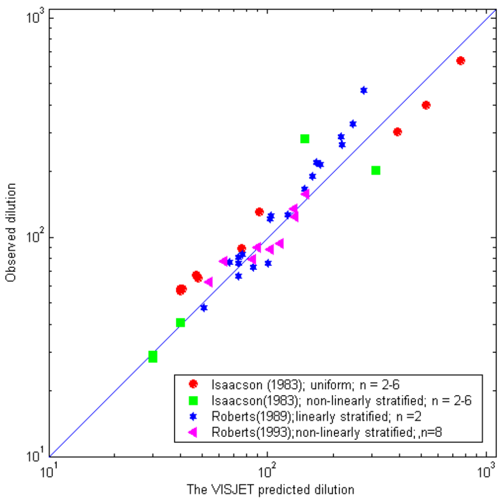
VISJET Simulation of eight jet group in nonlinear-stratification

Roberts & Snyder (1993)



- q = 0.00864 m³/s/m
- D = 0.107 m
- s = 18 m
- U_a = 0.12 m/s

Data of previous experiments of rosette jet group in stratified flow

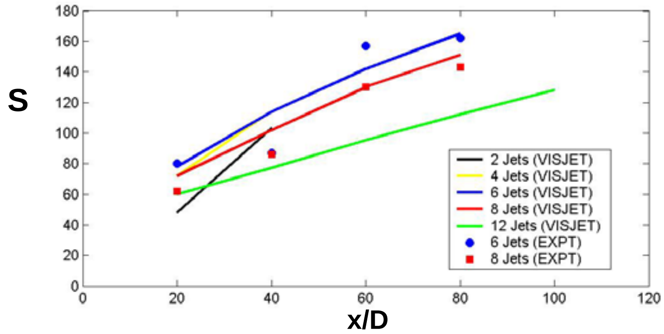


Dilution data of Isaacson et al. (1983), Roberts et al. (1989), Roberts and Snyder (1993)

Unstratified; linearly stratified; Highly non-linear stratified condition

Good agreement supports the application of composite dilution concept

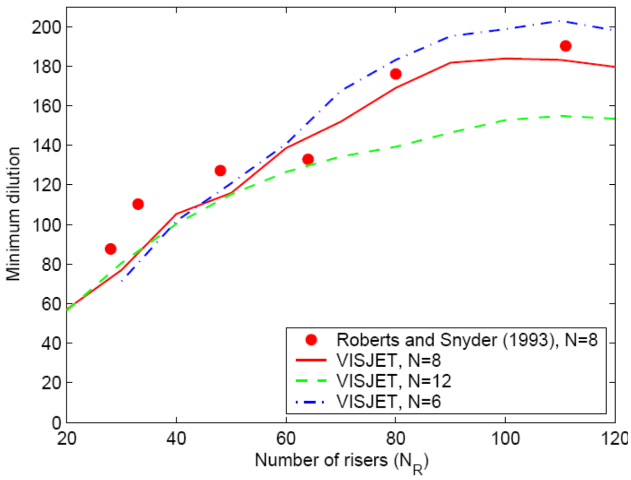
Effect of Number of Jet Nozzles



No. of Jet	Surface dilution
2	103
4	114
6	165
8	151
12	128

- **Total discharge, total nozzle cross-sectional area are kept same**
  - *N* = 2 – 12; *Fr* = 13 – 22; *K* = 17, *h/D* = 60 - 150
- **Simulations are verified experimental data**
  - VISJET shows 8 jets better than 12 jets
  - Experiment and simulation suggest 6 jets give the greatest surface dilution
- **Results from Roberts and Snyder (1993) can be explained by kinematic interaction**

Effect of Number of Risers (Boston Outfall)



Constant discharge and momentum flux/diffuser length

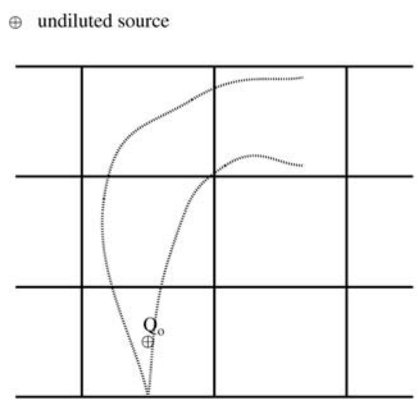
Number of nozzles/riser = N = constant

Remarks

- The initial dilution of a rosette ocean outfall diffuser in a crossflow can be predicted by assuming kinematic interaction and using the composite dilution concept
- As the number of nozzles on a rosette outfall riser increases, the dilution may decrease after a certain point. The optimal number of jet nozzles on a riser or number of outfall risers can be determined using the internet-based virtual reality (VR) model VISJET.

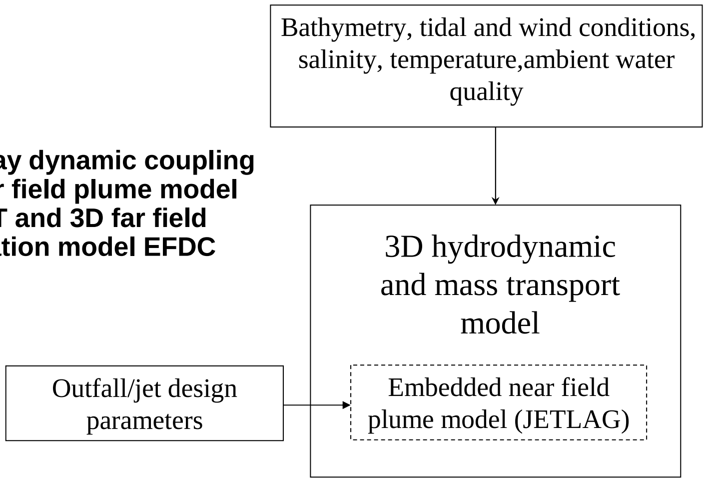
Commonly used "source-only" near- and far-field coupling (Zhang and Adams, JHENG, ASCE 1999)

- Traditional approach – source (flow and pollution mass) terms at discharge point
- Results are strongly grid dependent + only one way coupling



Distributed Entrainment Sink Approach (DESA)

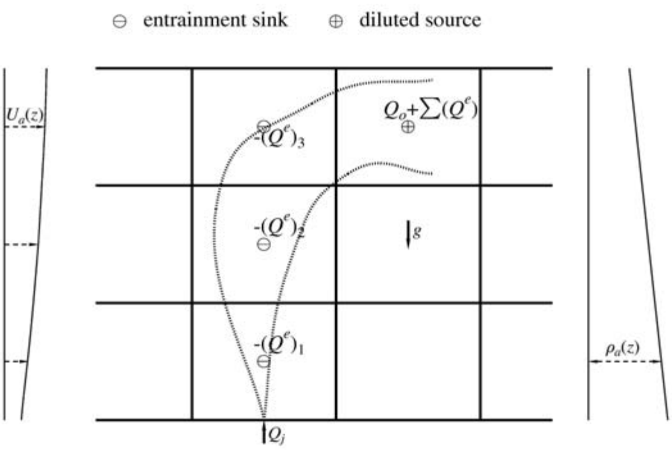
Two-way dynamic coupling of near field plume model VISJET and 3D far field circulation model EFDC



Choi, DKW and Lee, JHW, Journal of Hydraulic Engineering, ASCE 2007

Distributed Entrainment Sink Approach (DESA) 分散滙庭

Plume action on external flow modelled by distributed sink along the jet trajectory and diluted source at terminal level



Entrainment sink/source terms determined by embedded JETLAG model (grid independent)

Source Terms in Far-field Model 遠街模型爱源項

The effluent discharges are modeled as volumetric and tracer mass source in the governing equations for the 3D far field model. The continuity equation(s) are:

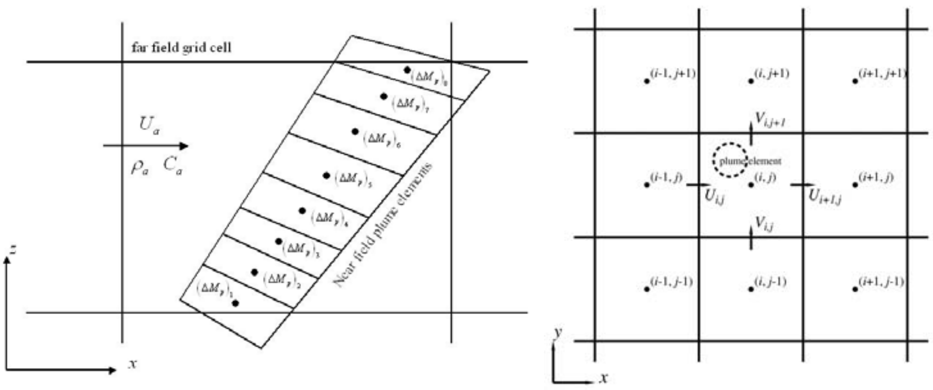
$$\frac{\partial U}{\partial x}+\frac{\partial V}{\partial y}+\frac{\partial W}{\partial z}=Q_S$$

and the mass transport equation (for both salinity and tracer) as

$$\frac{\partial (HC)}{\partial t}+\overline{\nabla}\cdot\nabla(HC)=\frac{\partial}{\partial x}[Hq_x]+\frac{\partial}{\partial y}\left[Hq_y\right]+\frac{\partial}{\partial z}\left[E_v H\frac{\partial C}{\partial z}\right]+Q_C$$

Q_S and Q_c are determined by the near field model

Grid Level Linkage 網格層次爱連結



通過滙庭 (entrainment sink) 連接穿街羽庭單元 (near field plume elements) 便遠街爱網格 (far field grid cell)

Distributed Entrainment Sink Approach (DESA)

- **JETLAG computes the** ***location of the centre*** **(x_k, y_k, z_k) and the** ***total mass entrainment*** **(ΔM_k) of each plume element**
- **Compute the** *distributed entrainment sink* **for** ***each far field model grid cell*** **by summing up the entrainment flows within that cell, i.e.**

$$-Q^e = -\sum \left(\frac{\Delta M_k}{\rho_a \Delta t} \right)$$

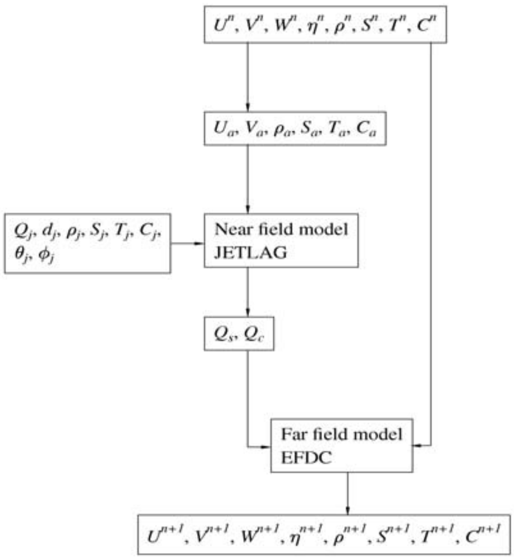
- Compute diluted/mixed flow at terminal level and apply as source term in corresponding grid cell in far field grid model

$$Q^d = Q + \sum Q^e$$

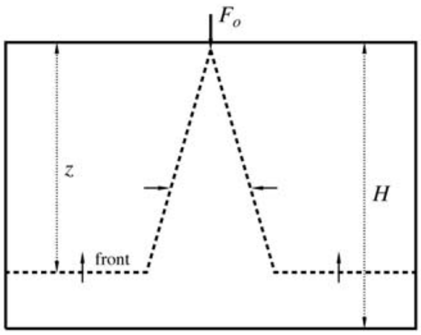
- Solve the 3D equations with the source terms to obtain updated solution of velocity, water level, S, T, C (and turbulence quantities)

餌施穿衔及遠衔
模型動態偶汲爰
庭程圖

Flow chart showing the numerical implementation of the coupling between the near field and far field models

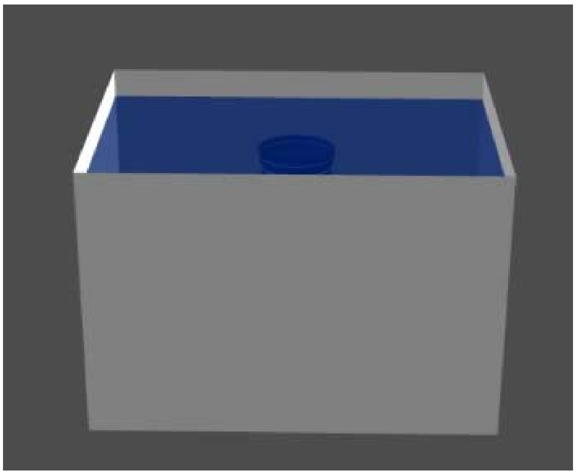


Turbulent Buoyant Convection from a Source in a Confined Region (Baines & Turner 1969) 浮送庭灼局限環境所產生爰垂直密度變化

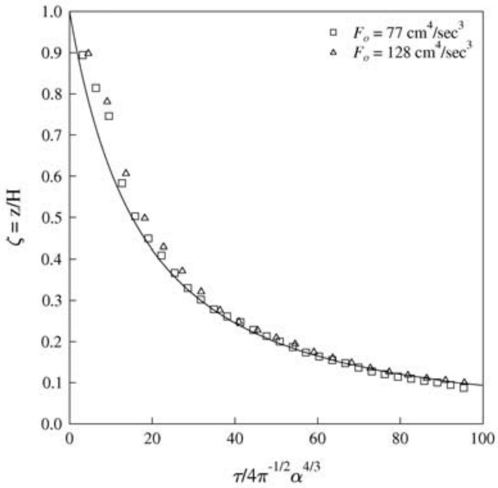


Laboratory experiments to study the effect of continuous convection from small sources of (negative) buoyancy on the properties of the environment when the region of interest is bounded (a tank 57 cm x 45 cm in plane and 45 cm deep). A 19 x 15 x 20 model grid with horizontal grid size 3 cm by 3 cm and 20 uniform vertical layers is used to simulate round plume.

Turbulent Buoyant Convection from a Source in a Confined Region (Baines and Turner 1969)



Time Variation of the Interface Position



$$\tau = 5\left(\frac{5}{18}\right)^{1/3}\left[\varsigma^{-2/3} - 1\right]$$

with

$$\varsigma = \frac{z}{H}$$

$$\tau = \frac{4}{\pi^{1/3}}\alpha^{4/3}\left(\frac{H}{R}\right)^2 \frac{F_o^{1/3}}{H^{4/3}} t$$

Dimensionless position of the interface (defined by 0.1 $\Delta\rho_{max}$ contour, where $\Delta\rho_{max} = \rho_o - \rho$). Solid line is equation (6a) in Baines and Turner (1969) with $\alpha = 0.10$ – excellent agreement with data.

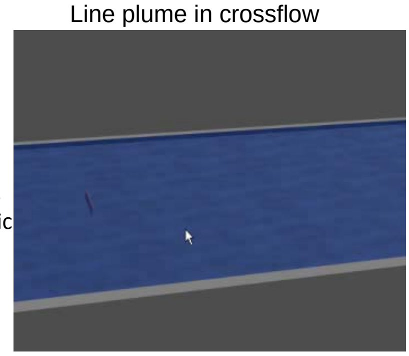
WATERMAN Services – Environmental Impact Assessment and Public Engagement

Victoria Harbour

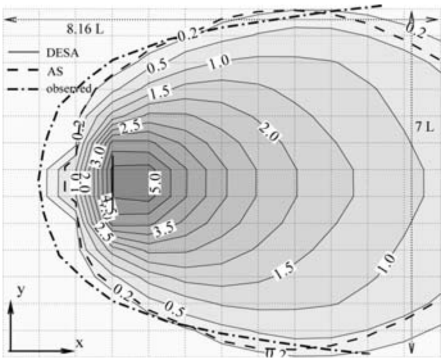
Environmental discharges: sewage outfalls, thermal effluents from power stations, toxic spills, stormwater overflows

Gravitational spreading of buoyant surface sewage field

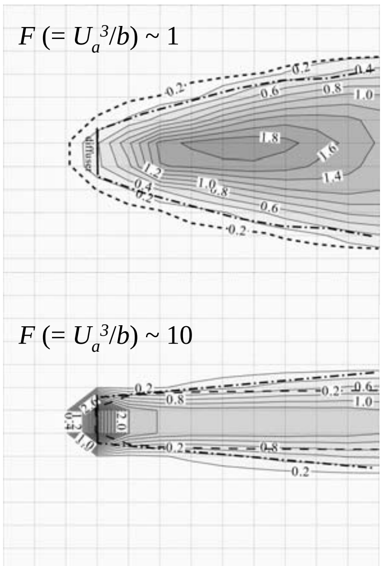
Line plume in crossflow



Line Plume in Crossflow (Roberts 1979)



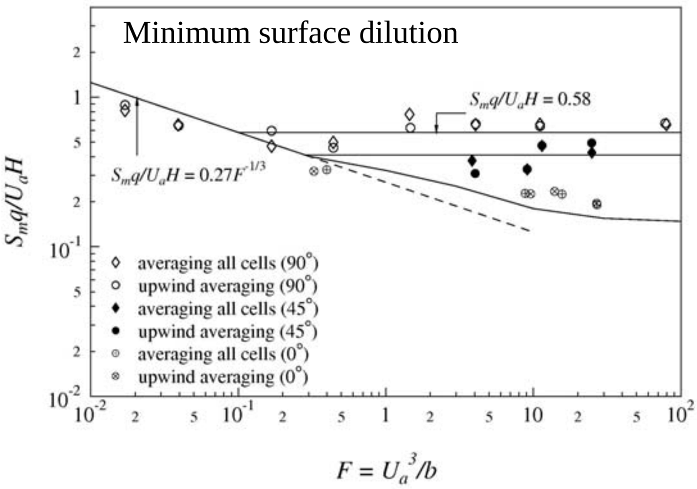
$F\ (= U_a^3/b) \sim 0.1$



$F\ (= U_a^3/b) \sim 1$

$F\ (= U_a^3/b) \sim 10$

Line Plume in Crossflow

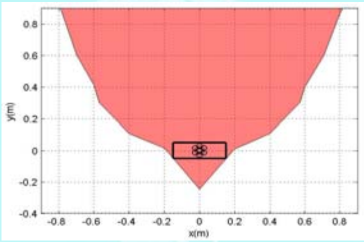


Minimum surface dilution with different *F*
(prediction vs experiment)

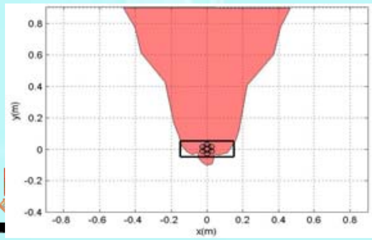
Top-view comparison

DESA predictions **Observed**

6 jets; D = 0.3 cm; H = 0.3 m; Uo = 75 cm/s; Ua = 3 cm/s; Fr = 15; Re = 2260;



6 jets; D = 0.3 cm; H = 0.3 m; Uo = 75 cm/s; Ua = 4 cm/s; Fr = 15; Re = 2260;

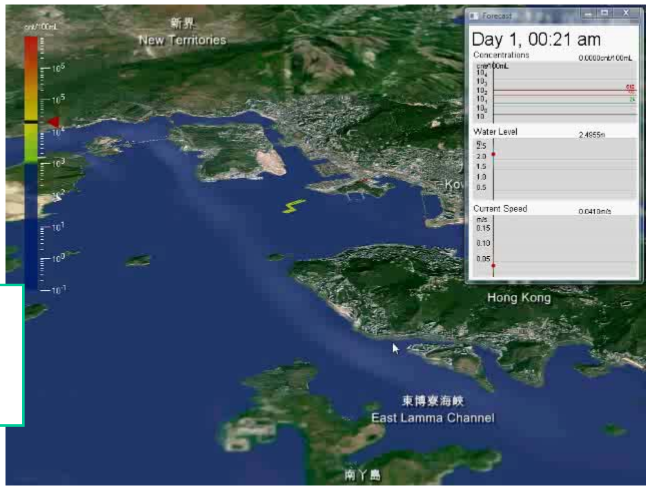


WATERMAN Services – Environmental Impact Assessment and Public Engagement

Example of 3D Virtual Reality EIA system

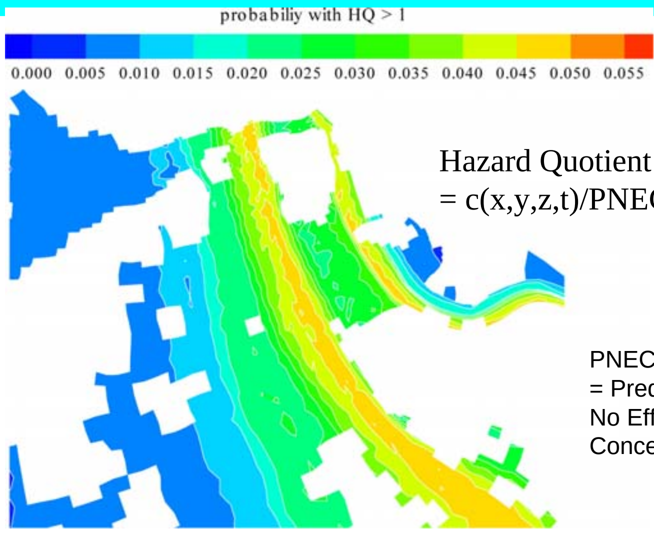
Impact of Harbour Area Treatment Scheme (HATS) on beach water quality

3D EIA enables risk assessment, effective communication of impact



The 3D modeling engine is fully integrated with the GIS information and the 3D visualization.

Environmental Risk Assessment



Hazard Quotient (HQ) = c(x,y,z,t)/PNEC

PNEC = Predicted No Effect Concentration

Monte-carlo type simulation for both "exposure concentration" and "benchmark concentration", resulting in probabilistic description of Hazard Quotient (HQ) at every grid point in Hong Kong

Conclusions

- **The initial dilution of complex rosette jet groups from ocean outfalls can be predicted using the composite dilution concept.**
- **Mixing zones can be defined by modelling wastewater mixing from the near to intermediate field using a Distributed Entrainment Sink Approach (DESA).**
- **A real time hydro-environmental modelling and visualization system can be developed for effective impact and risk assessment, and to enhance public awareness and appreciation of public projects.**