Mixing in the nearshore zone

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Dye Tracing Workshop
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warwick Water
Water & Environmental Resources

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DHI

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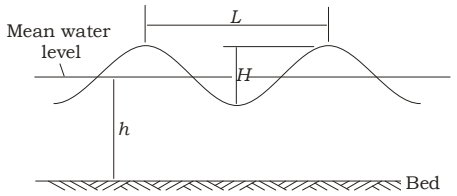
Water



h = distance from bed to mean water level
H = wave height, distance between crest & trough
T = wave Period, the time interval for motion to reoccur at a fixed point
L = Wave length, distance between any two corresponding positions

Definition Sketch of a small amlitude wave

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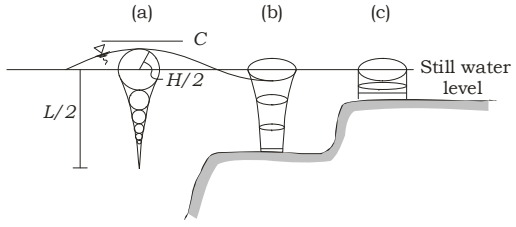

Particle orbits under waves in a) deep water, b) intermediate water & c) shallow water

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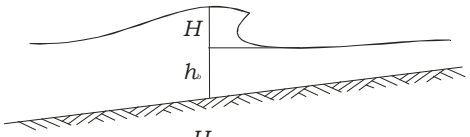

$$\frac{H}{h_b} = 0.78 \text{ average}$$

$$\frac{H}{h_b} = 1.10 \text{ steep beaches}$$

Classification of wave breaking under regular waves

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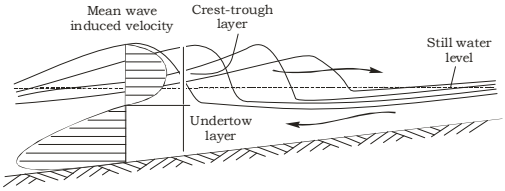
Water



Cross-shore flow in nearshore region

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Mixing in the Near-Shore Zone

Background

Sources of pollution:

Offshore boundary
- Outfalls (but becoming cleaner, but to increased regulation)

Shoreline boundary
- Storm water overflows
  e.g. Pattaya Beach
- Polluted rivers flowing into nearshore region
  e.g. San Diego

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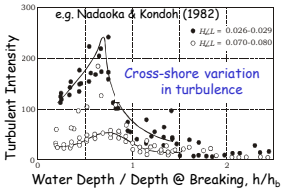
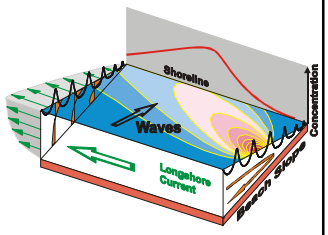
Mixing in the Near-Shore Zone

What are the mixing processes?

- Turbulent diffusion (e_y)
- Shear dispersion (k_y)





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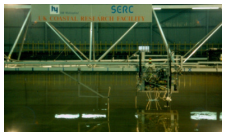
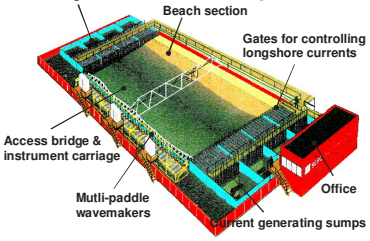
Mixing in the Near-Shore Zone

Coastal Research Facility



UKCRF
(HR Wallingford)



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Mixing in the Near-Shore Zone

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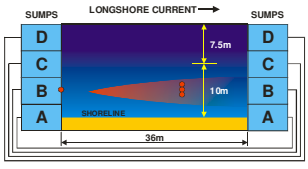
Aim: On-offshore (transverse) mixing under waves & current

Location: seawards of the breaker point

Tests: 4 regular wave conditions (constant period) superimposed on longshore current

Recirculating Flow in the CRF



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Mixing in the Near-Shore Zone

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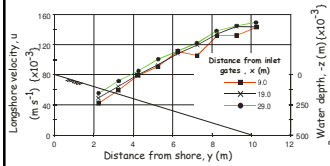
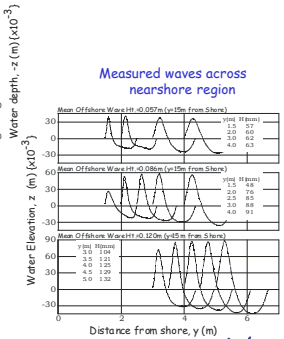


Long-shore velocity under current only conditions

Measured waves across nearshore region



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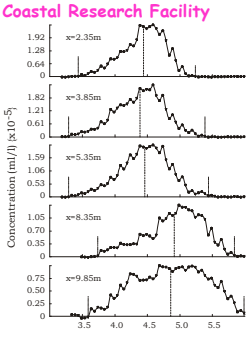
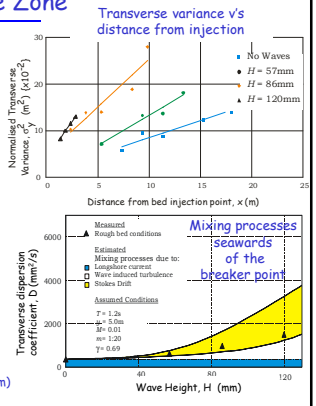
Mixing in the Near-Shore Zone

Coastal Research Facility



Tracer conc. profiles under waves (H = 0.086mm)

Transverse variance v's distance from injection



Summary: Increase in Transverse Mixing due to Waves

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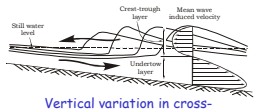
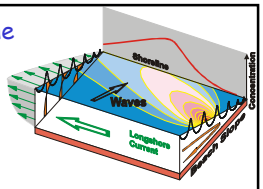
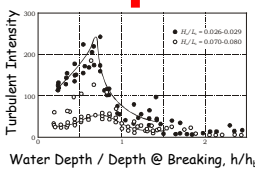
Mixing in the Near-Shore Zone

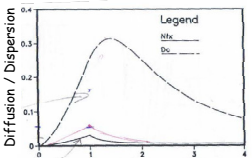
Summary



Vertical variation in cross-shore velocity







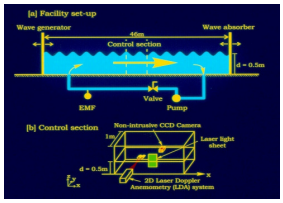
Turbulent diffusion (which exchanges material between the '2' layers)

Shear Dispersion (which varies with distance from shore)

Mixing in the Near-Shore Zone

'Scheldgoot' wave – current facility

Aim: Vertical mixing under waves & combined currents using Laser induced fluorescence



overall length: 56 m
width: 1 m
height: 1.2 m

Facility set-up

Experimental water Depth: 0.5m

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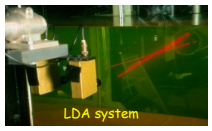
Mixing in the Near-Shore Zone

'Scheldgoot' wave – current facility

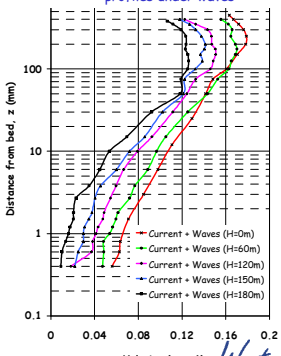


Direct Measurement of Tracer Concentration - 3 dye injection points (bed, +100mm, +200mm)

Detailed Measurement of hydrodynamics - Detailed LDA velocity profiles (+20 points over vertical)

Test conditions - 5 Regular waves (H=0, 60, 120,150 &180mm), T=1.2s tested superimposed on current.

Mean longitudinal velocity profiles under waves



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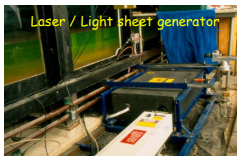
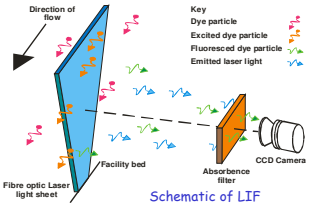
Mixing in the Near-Shore Zone

'Scheldgoot' wave – current facility





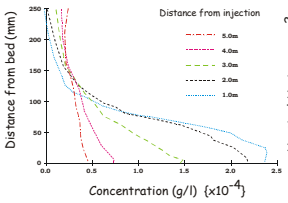
Schematic of LIF

Fluoresced 6G dye passing thro' lightsheet (~1m up stream)

Mixing in the Near-Shore Zone

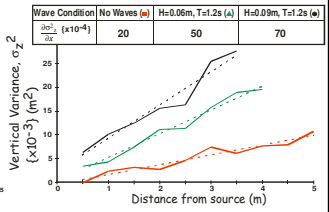
'Scheldgoot' wave – current facility

Vertical concentration distribution from bed injection



Vertical variance v's distance from injection

Wave Condition	No Waves (■)	H=0.06m, T=1.2s (▲)	H=0.09m, T=1.2s (●)
$\frac{\partial \sigma_z^2}{\partial x}$ {x10^{-4}}	20	50	70



Summary: Increase in Vertical Mixing due to Waves

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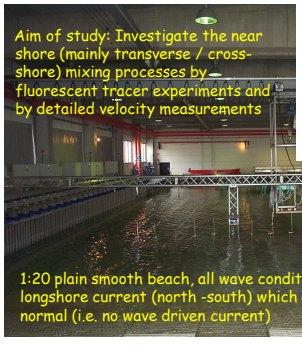
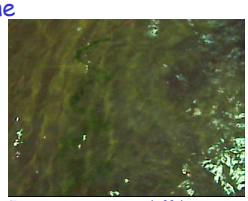
Mixing in the Near-Shore Zone

Wave Current facility at DHI

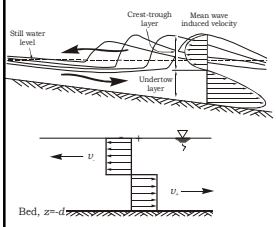




Tracer near injection (offshore region)

Mixing in the Near-Shore Zone

Wave Current facility at DHI



assuming the idealized case, that mean velocities can be estimated from the mass flux of the breaking wave

… we can get a basic estimate of the overall transverse mixing coefficient in the surfzone:

$$D_y = \frac{gH^4}{768 d e_z} + e_y$$

The turbulent diffusion (e_z, e_y) can be estimated from Svendsen's work [e.g. Svendsen (1987), Svendsen & Putrevu (1994)]

$$D_y = k_y + e_y = \frac{(v_+ - v_-)^2 d^2}{48 e_z} + e_y$$

… standard solution

$\nu_t = Md\sqrt{gd}$ Inside surfzone

$\nu_t = (0.8(d/d_b)^{-4} + 0.2)\nu_{tb}$ Outside surfzone

how does the simple model compare to measured data?

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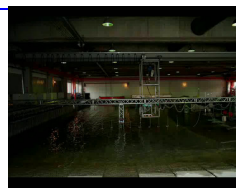
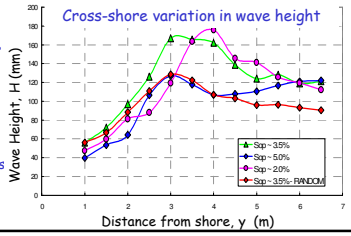
Mixing in the Near-Shore Zone



Direct Measurement of Tracer Concentration - 3 dye injection points (offshore, around breaker point & in surfzone)

Detailed Measurement of hydrodynamics - Detailed velocity profiles at y=1,2,3,4,5,6m from shoreline

Test conditions - 3 Regular waves (sop 2, 3.5, 5%) & 1 Random Ho ~120mm

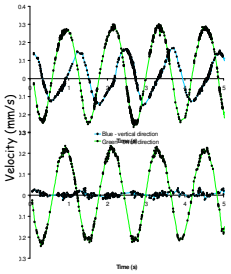


Mixing in the Near-Shore Zone

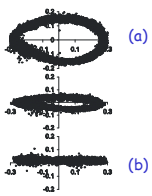
LDA velocity measurements

Mixing in the Near-Shore Zone

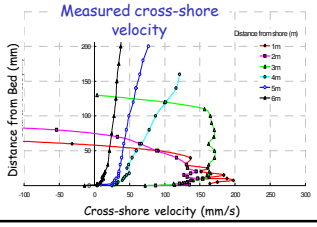
LDA velocity observations



Time series
a) near surface,
b) near bed



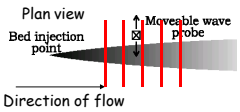
Z Y velocity
a) near surface,
b) near bed



Mixing in the Near-Shore Zone

Tracer measurements

Constant head of fluorescent dye injected into facility



resultant dye concentration measured at a number of locations down stream to determine the mixing coefficient / processes

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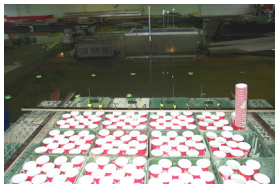
Mixing in the Near-Shore Zone

Tracer measurements

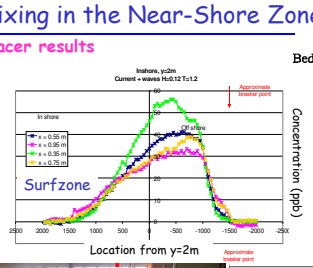
Dye collected by pumping samples from flow (for 180 seconds)

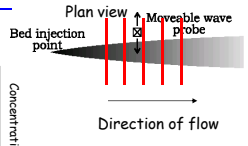
… into suitable containers and analysed by fluorometer to determine dye concentration

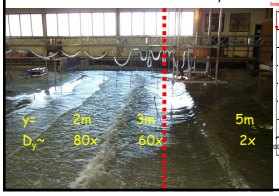


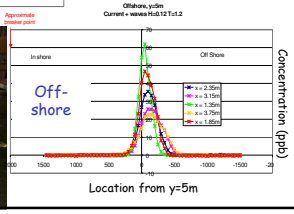
Mixing in the Near-Shore Zone

Tracer results



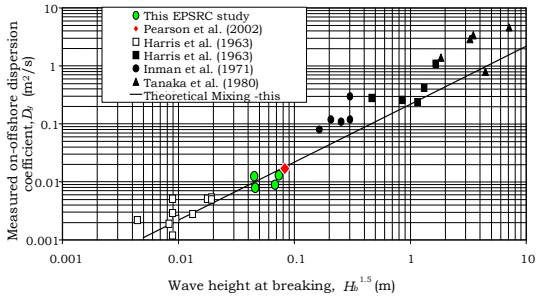






Mixing in the Near-Shore Zone

...comparisons in the surf zone for all measured conditions



Summary: Transverse mixing increases in surfzone & coefficient varies by orders of magnitude

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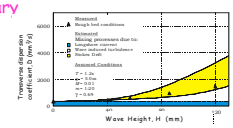
Mixing in the Near-Shore Zone

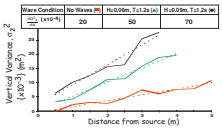
Summary

OutSide - SurfZone



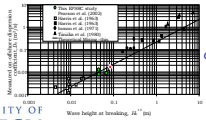
Increase in Transverse Mixing due to Waves

Vertical Mixing (Non-Breaking)



Increase in Vertical Mixing due to Waves

Inside Surfzone



Transverse mixing increases in surfzone & coefficient varies by orders of magnitude

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