Managing and Assessing Boat Wake Waves

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Boat Wake Waves

- The Need
- Development Process
- Outcome
- Application

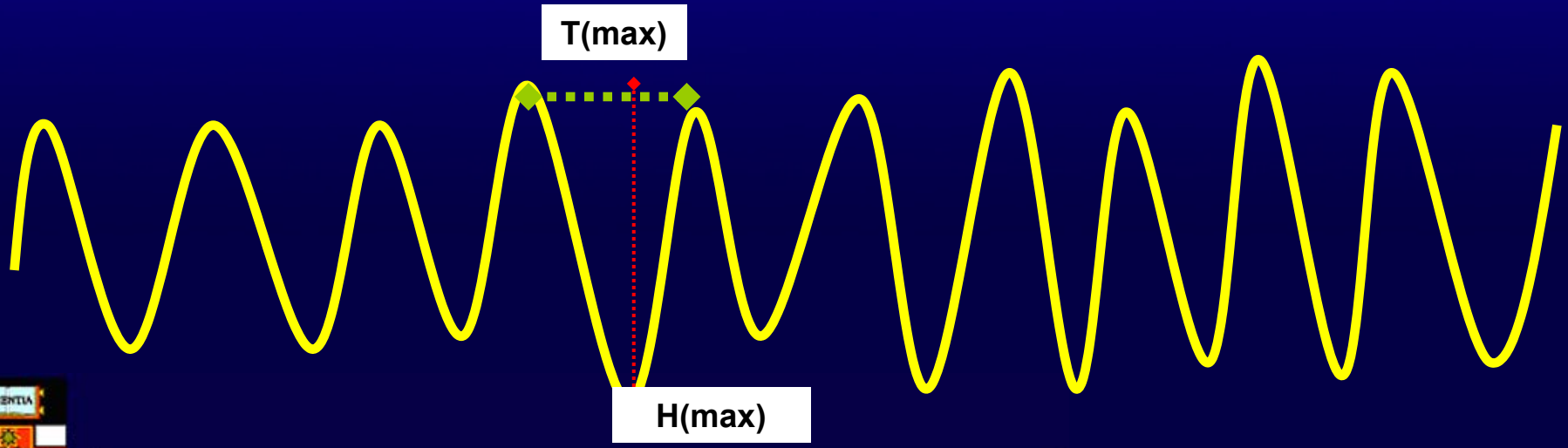
The Need

- Wave theory dates back to Newton (1687).
- Methods are available for managing large waves in dynamic environments.
- Naval engineers designs boats to make certain types of waves.
- YET, few understand the impact of wake waves and none have developed adequate management strategies.

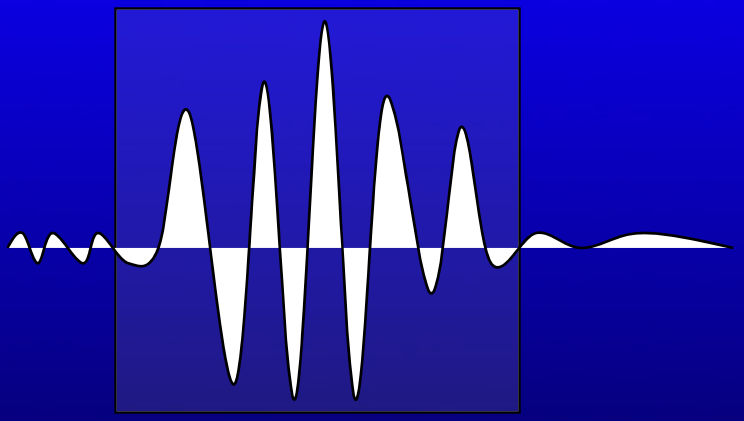
Background

WAVE THEORY

- Waves are typically characterised by period (T) height (H) and energy (E).



Background



WAVE THEORY

- Within a packet of waves, or *wave train*, wave height and wave period are used to describe individual waves and/or a series of waves.

- The energy (Jules/m) within the wave train can be calculated by:

$$E = \frac{\rho g^2 H^2 T^2}{16\pi}$$

where p = water density, g = gravity constant.

Background

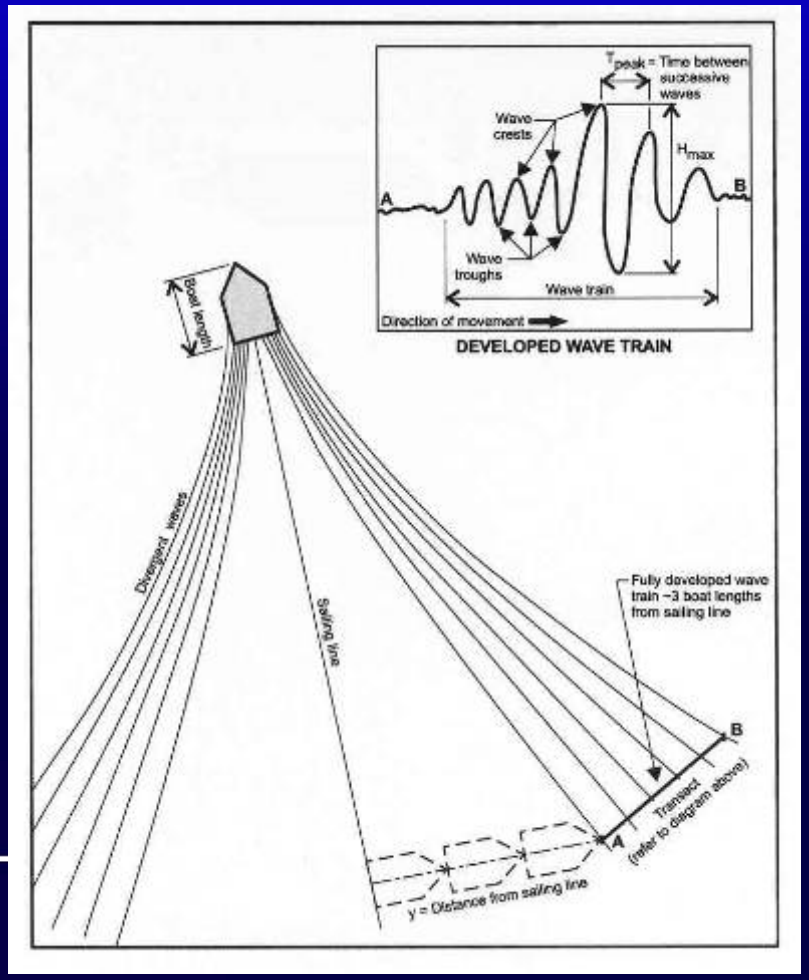
Wash is influenced by:

- Water depth
- Seabed characteristics
- Natural wave environment
- Tidal currents
- Vessel design
- Vessel speed
- Vessel trim
- Loading
- Method of propulsion
- Rate of change in course/speed

Wash typically takes 2-5 boat lengths to fully form.

Main components of divergent waves are:

- Hull form
- Speed
- Speed-length ratio

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The Need

Objective: *Develop a rigorous scientific method to determine whether a vessel will cause erosion on a selected waterway*

Management Guidelines

Previously Established Boat Wash Guidelines

Wave Characteristic	Wave Criteria	Source
Maximum Wave Height (H_{max})	28 cm from peak to trough measured 300 m from sailing line in deep water.	Stumbo *et al.* (1999).
Maximum Wave Height (H_{max})	< 20 cm no action on bank stabilisation required. 20-30 cm requires monitoring. 30-40 cm requires bank engineering assessment and remediation.	Patterson Britton and Partners (2001).
Maximum Wave Height (H_{max})	Based on wave height criteria: $H_h \leq 0.5\sqrt{\frac{4.5}{T_h}}$, where H_h is H_{max} and T_h is mean wave period. (Equates to 0.75m for 2.0 second wave period.)	Parnell and Kofoed-Hansen (2001)
Wave Energy	< 2450 joules/m (150 lb/ft) in the highest significant wave of the wave train as measured 300m from sailing line in deep water.	Stumbo *et al.* (1999).
Wave Energy, Wave Period and Speed	$1962H_m^2T_m^2$ <60 joules/m or <180 joules/m; where H_m is the height of the maximum wave in metres and T_m is the period of the maximum wave in seconds measured at a point 23 m abreast of the sailing line in deep water. (60 J/m vs 180 J/m depends on the river)	Australian Maritime College (2003)

Development

Developing management strategies for boat wake waves has been particularly difficult because of:

(1) the lack of standardised wave measurement criteria,

(2) the different wave and shoreline monitoring techniques,

(3) the diverse forms of boat wakes generated and

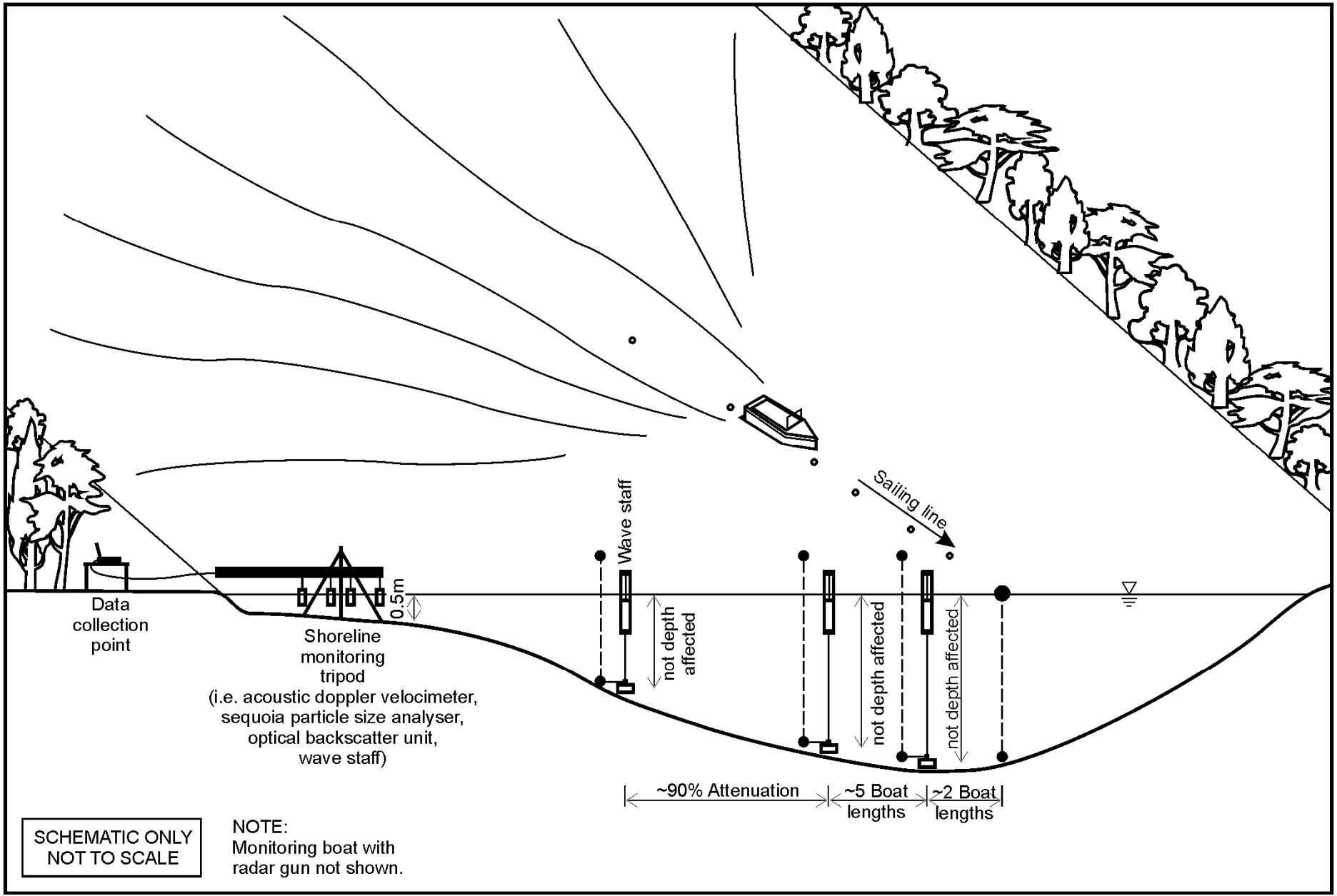
(4) the wide range of shoreline types encountered.

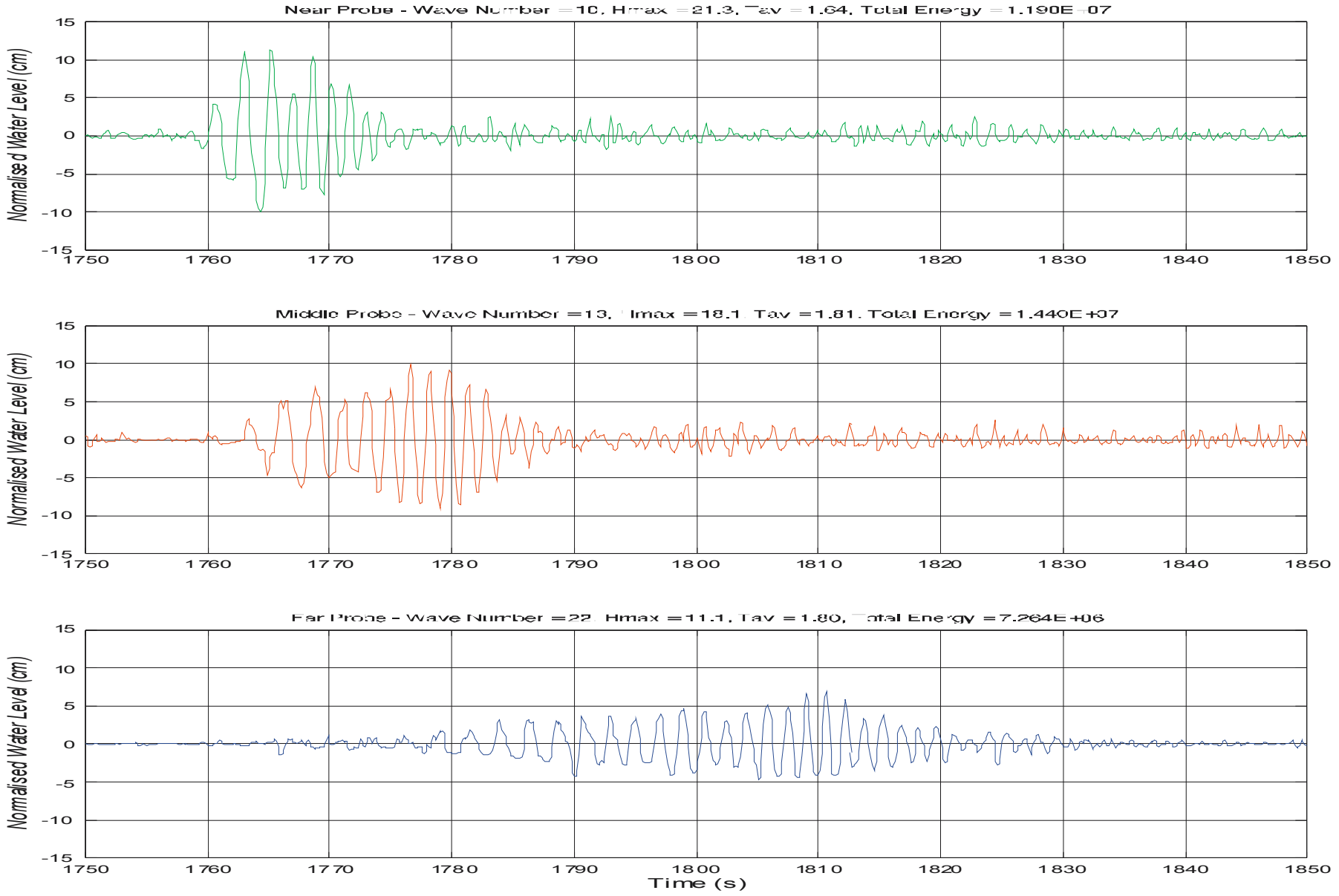
Development: Field Research

Experimental Design

- Criteria include:
  - Number and location of wave staff
  - Deep water, limited current and wind, tidal corrected, no restricted channel effect
  - Limited wave reflection

Experimental Design





WRL Report No. —-/--	Boat 3 - 07.5 kts	Figure 3

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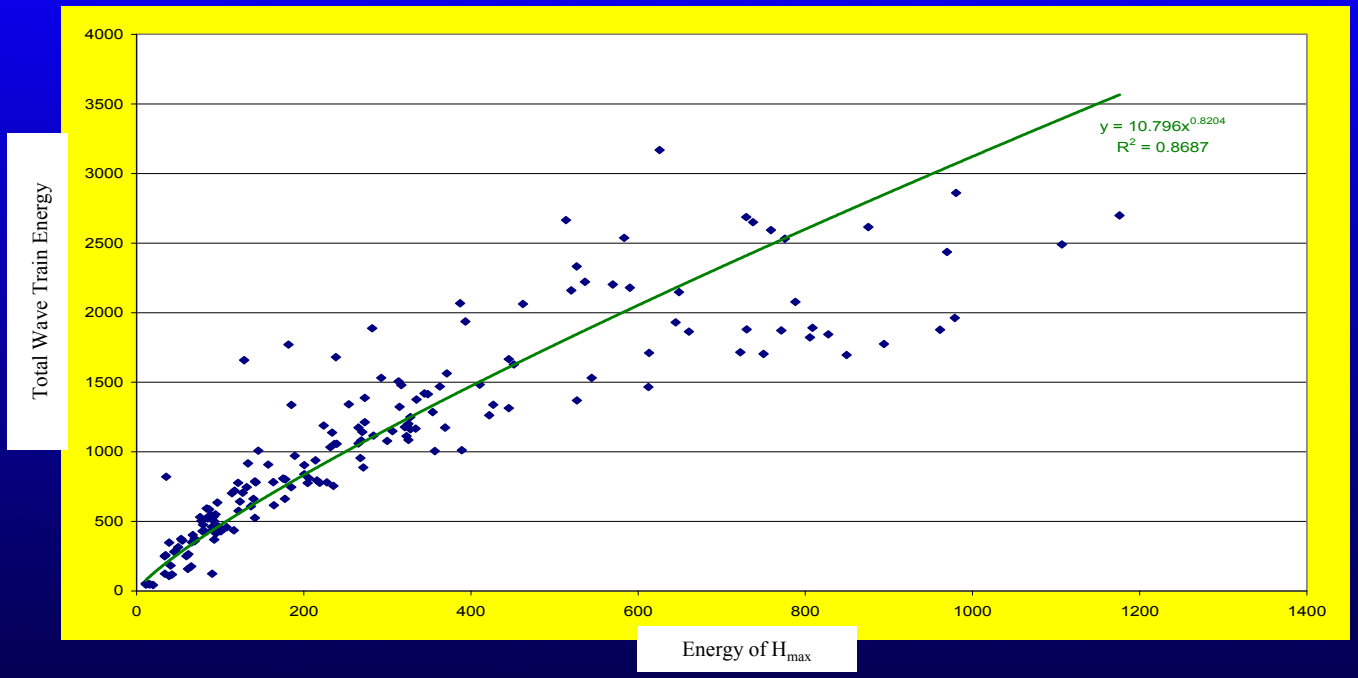
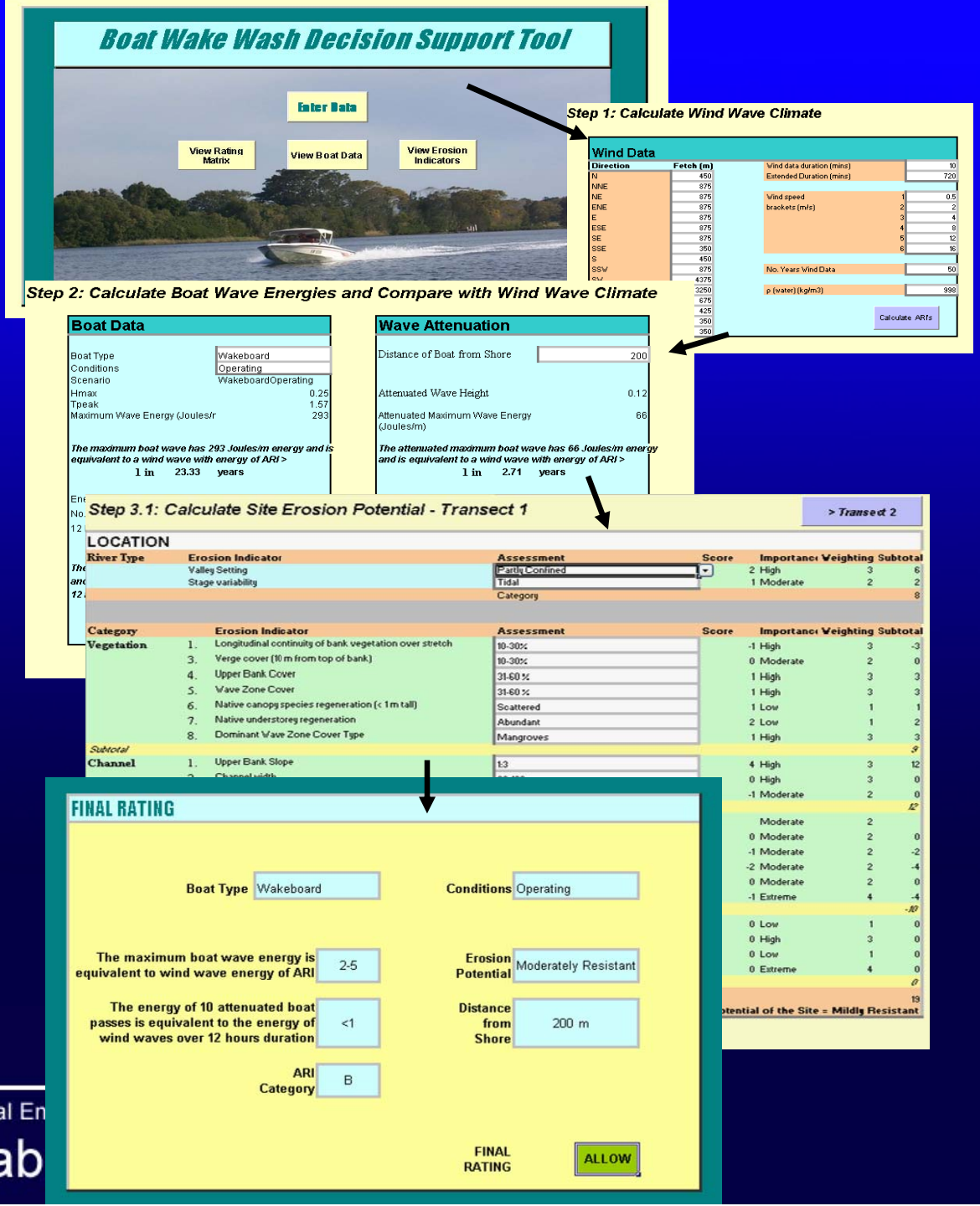
Experimental Design



- Energy of maximum wave can be related to energy of total wave train

$$E_{Tot} = 10.8E_{Hmax}^{0.82}$$

- Field information was useful but did not provide strategy for managing rivers
- Quantitative methods to assess impact of boat wake waves on causing erosion was needed.
- DST was developed based on field data.



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Boat Wake Wash Decision Support Tool

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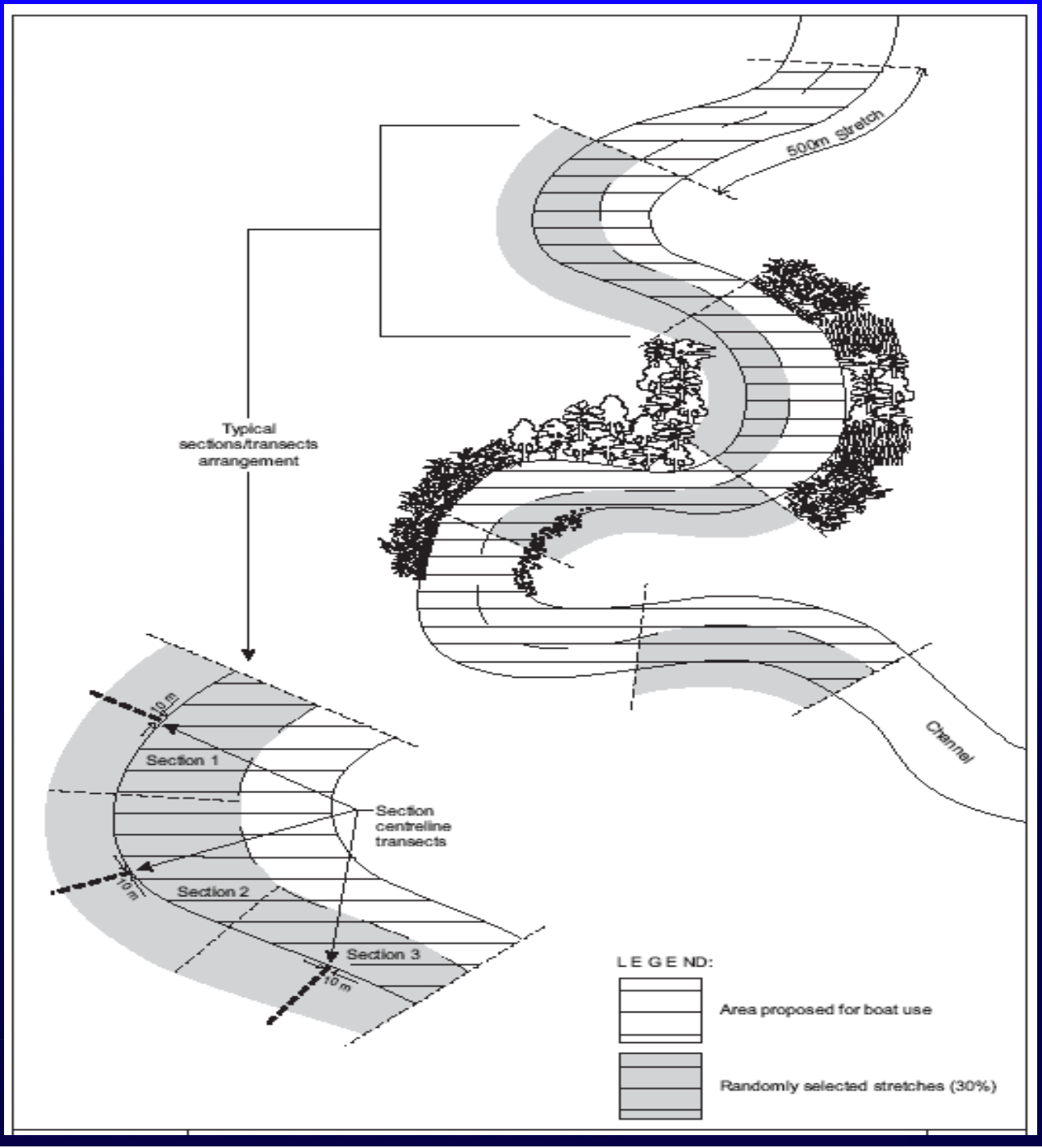
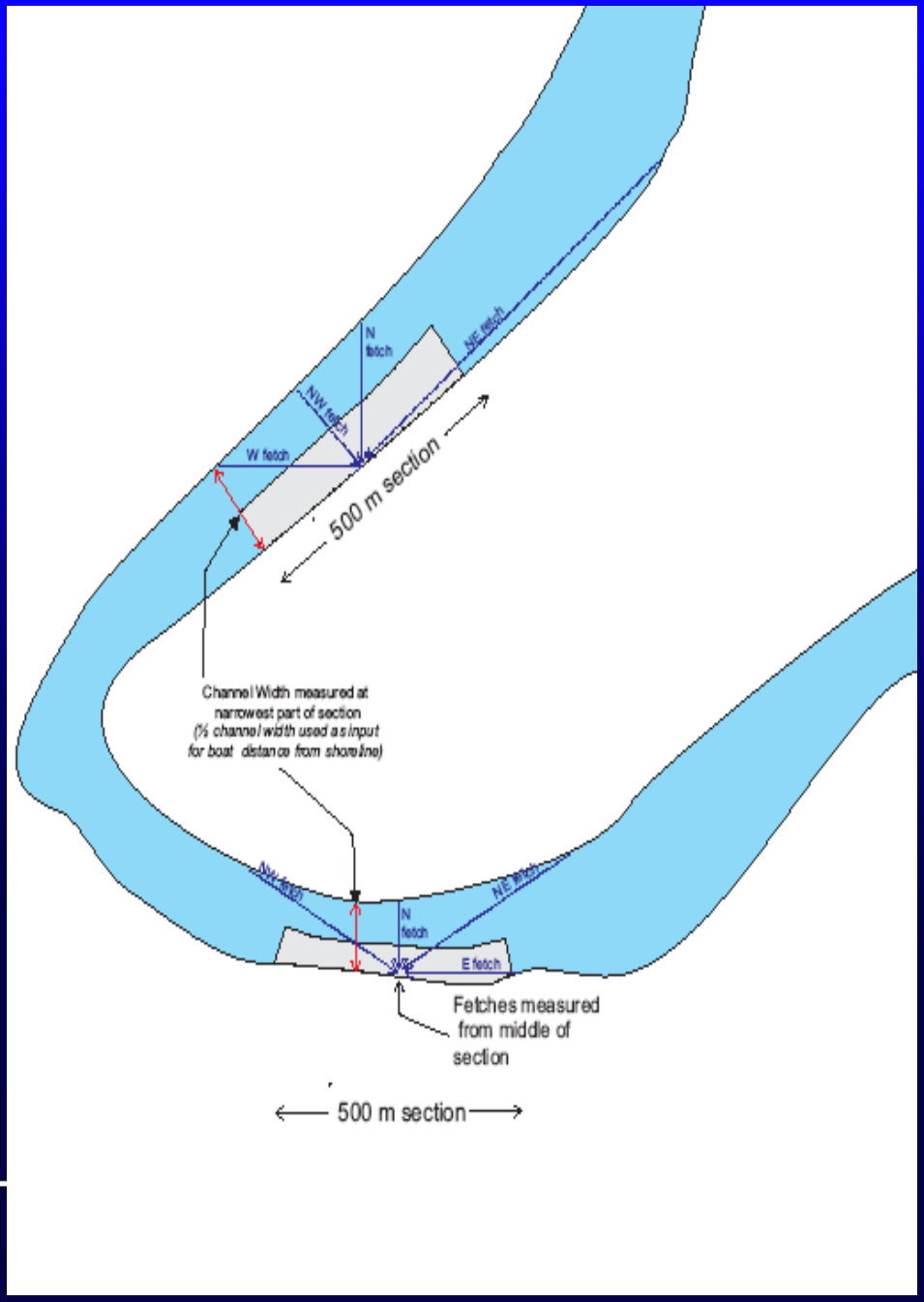
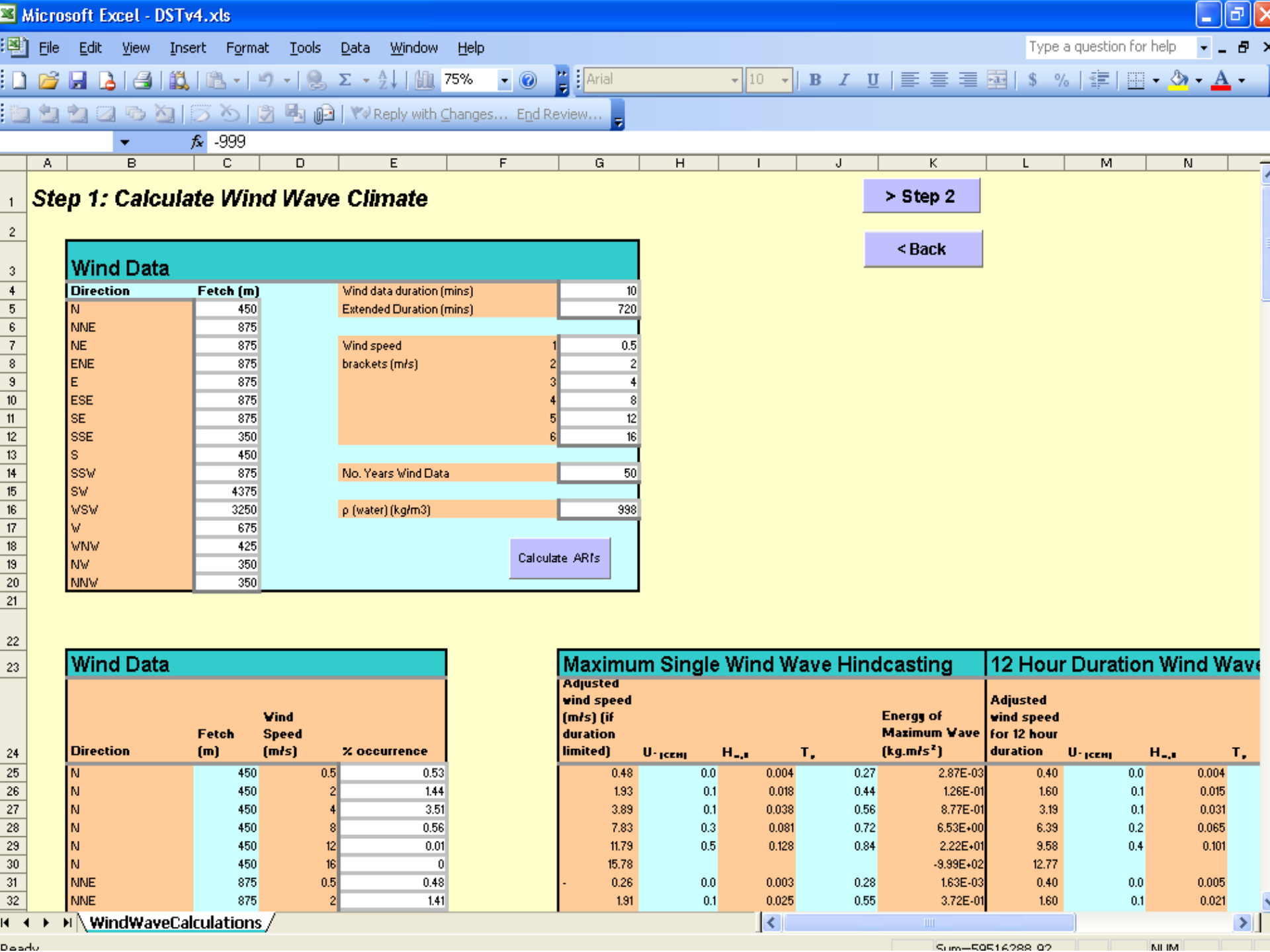
Water Research Laboratory


500m Stretch
Typical sections/transects arrangement
Section 1
Section centreline transects
Section 2
Section 3
10 m
10 m
10 m
Channel
LEGEND:
Area proposed for boat use
Randomly selected stretches (30%)

Wind Energy

- Wind energy at the site is calculated using standard calculations.
- Considerations: ARI, fetch versus duration limited, site data, cumulative energy

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File Edit View Insert Format Tools Data Window Help
Type a question for help
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Arial
10
Reply with Changes... End Review...
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Step 1: Calculate Wind Wave Climate
> Step 2
< Back
Wind Data
Direction
Fetch (m)
N 450
NNE 875
NE 875
ENE 875
E 875
ESE 875
SE 875
SSE 350
S 450
SSW 875
SW 4375
WSW 3250
W 675
WNW 425
NW 350
NNW 350
Wind data duration (mins) 10
Extended Duration (mins) 720
Wind speed brackets (m/s)
1 0.5
2 2
3 4
4 8
5 12
6 16
No. Years Wind Data 50
ρ (water) (kg/m3) 998
Calculate ARIs
Wind Data
Direction
Fetch (m)
Wind Speed (m/s)
% occurrence
N 450 0.5 0.53
N 450 2 1.44
N 450 4 3.51
N 450 8 0.56
N 450 12 0.01
N 450 16 0
NNE 875 0.5 0.48
NNE 875 2 1.41
Maximum Single Wind Wave Hindcasting
Adjusted wind speed (m/s) (if duration limited)
U-(CERC)
H_m0
T_p
Energy of Maximum Wave (kg.m/s²)
0.48 0.0 0.004 0.27 2.87E-03
1.93 0.1 0.018 0.44 1.26E-01
3.89 0.1 0.038 0.56 8.77E-01
7.83 0.3 0.081 0.72 6.53E+00
11.79 0.5 0.128 0.84 2.22E+01
15.78 -9.99E+02
- 0.26 0.0 0.003 0.28 1.63E-03
1.91 0.1 0.025 0.55 3.72E-01
12 Hour Duration Wind Wave
Adjusted wind speed for 12 hour duration
U-(CERC)
H_m0
T_p
0.40 0.0 0.004
1.60 0.1 0.015
3.19 0.1 0.031
6.39 0.2 0.065
9.58 0.4 0.101
12.77
0.40 0.0 0.005
1.60 0.1 0.021
WindWaveCalculations
Ready
Sum=59516288.92
NUM

Step 2: Calculate Boat Wave Energies and Compare with Wind Wave Climate

Boat Data

Boat Type	Wakeboard
Conditions	Operating
Scenario	WakeboardOperating
Hmax	0.25
Tpeak	1.57
Maximum Wave Energy (Joules/r	293

The maximum boat wave has 293 Joules/m energy and is equivalent to a wind wave with energy of ARI >

1 in 23.33 years

Energy of Wave Train (Joules/m)	1138
No. Boat Passes/12 hours	10
12 HOUR ENERGY (Joules/m)	11383

The energy of 10 boat passes = 11383 Joules/m and is equivalent to the energy of wind waves over 12 hours duration with ARI >

1 in 0.05 years

Wave Attenuation

Distance of Boat from Shore	200
Attenuated Wave Height	0.12
Attenuated Maximum Wave Energy (Joules/m)	66

The attenuated maximum boat wave has 66 Joules/m energy and is equivalent to a wind wave with energy of ARI >

1 in 2.71 years

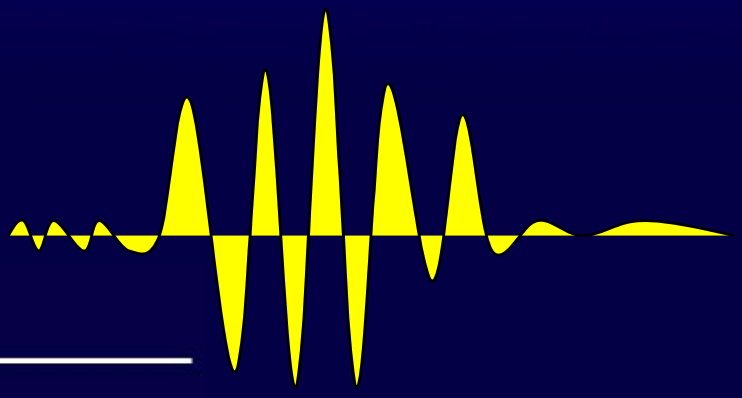
Energy of Wave Train (Joules/m)	335
No. Boat Passes/12 hours	10
12 HOUR ENERGY (Joules/m)	3353

The energy of 10 attenuated boat passes = 3353 Joules/m and is equivalent to the energy of wind waves over 12 hours duration with ARI >

1 in 0.04 years

DST- Boat Waves

- Includes:
  - Individual maximum waves
  - Wave train
  - Energy of wave train over time
    (Energy of Hmax vs Energy of total wave train).
  - Wave attenuation
  - Number of boat passes

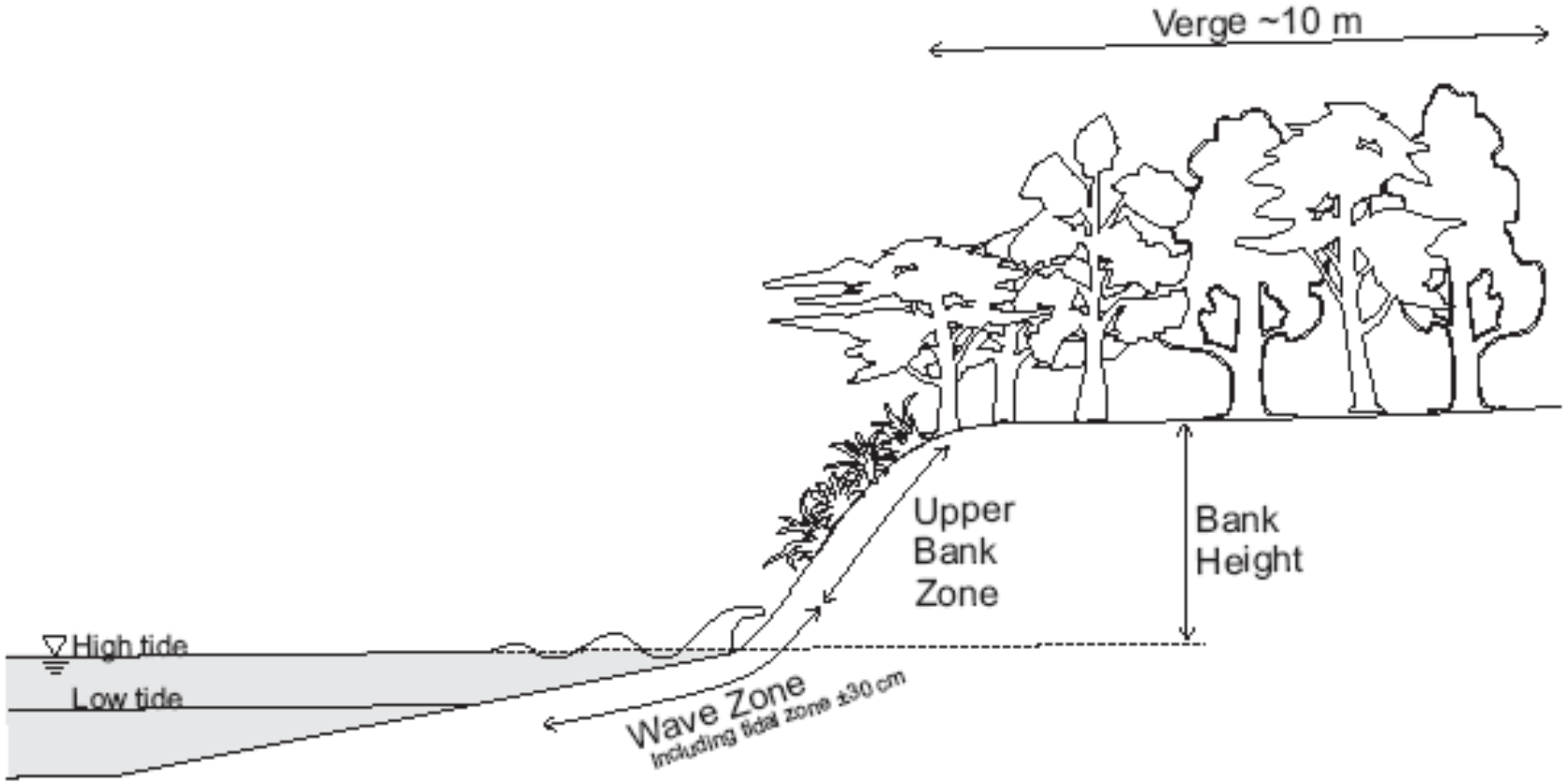


Management Outcomes

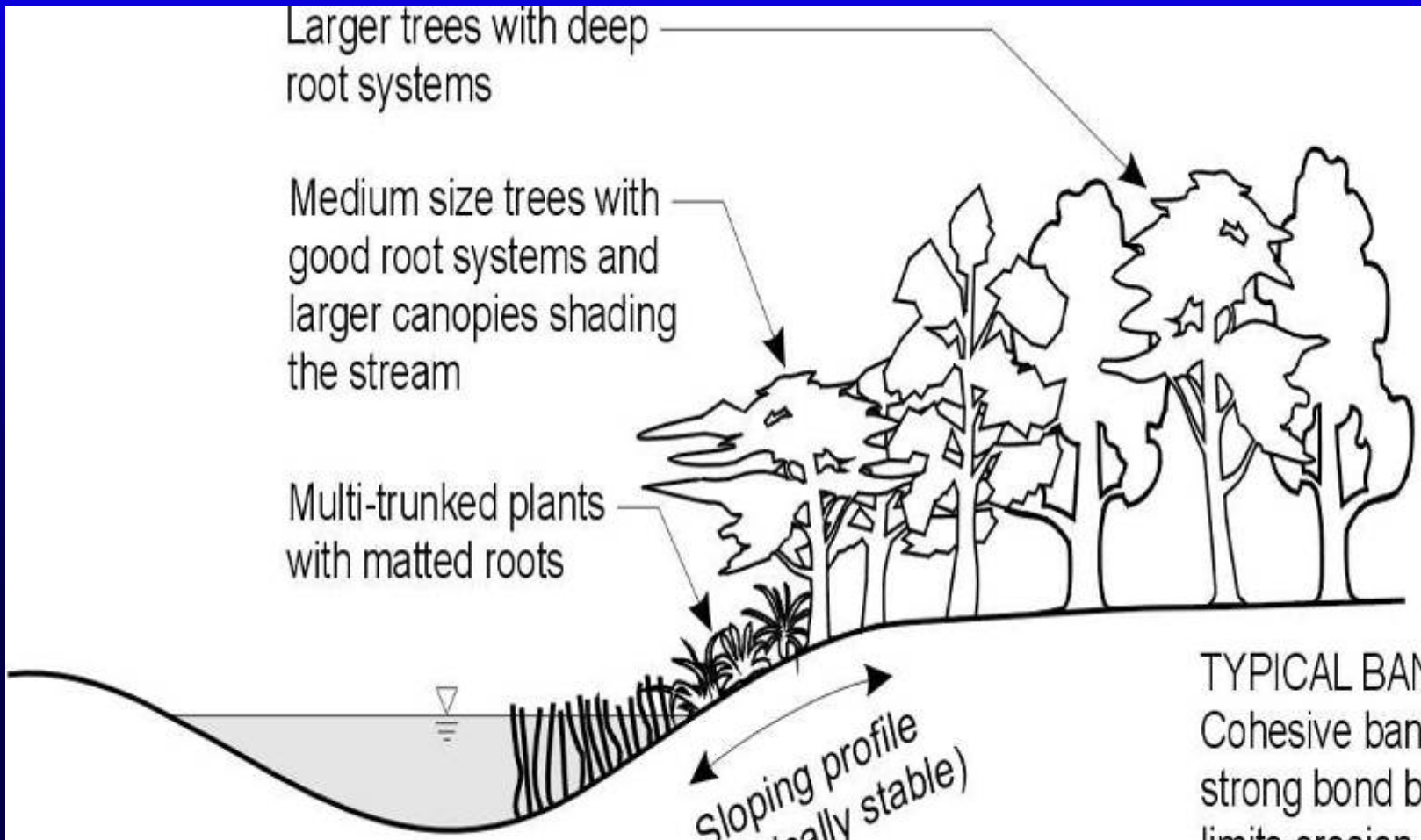
- Based on the comparison of wind waves versus boat waves a rating is given (A-E)

Equivalent ARI for maximum boat wake wave energy	Equivalent ARI of boat wake wave energy over an extended period (typically 8 - 12 hours)					
	<1	1-2	2-5	5-10	10-20	>20
<1	A	A	B	C	C	C
1-2	A	B	B	C	C	D
2-5	A	B	C	C	D	D
5-10	B	B	C	C	D	D
10-20	B	C	C	D	D	E
>20	B	C	C	D	E	E

Bank Erosion Issues

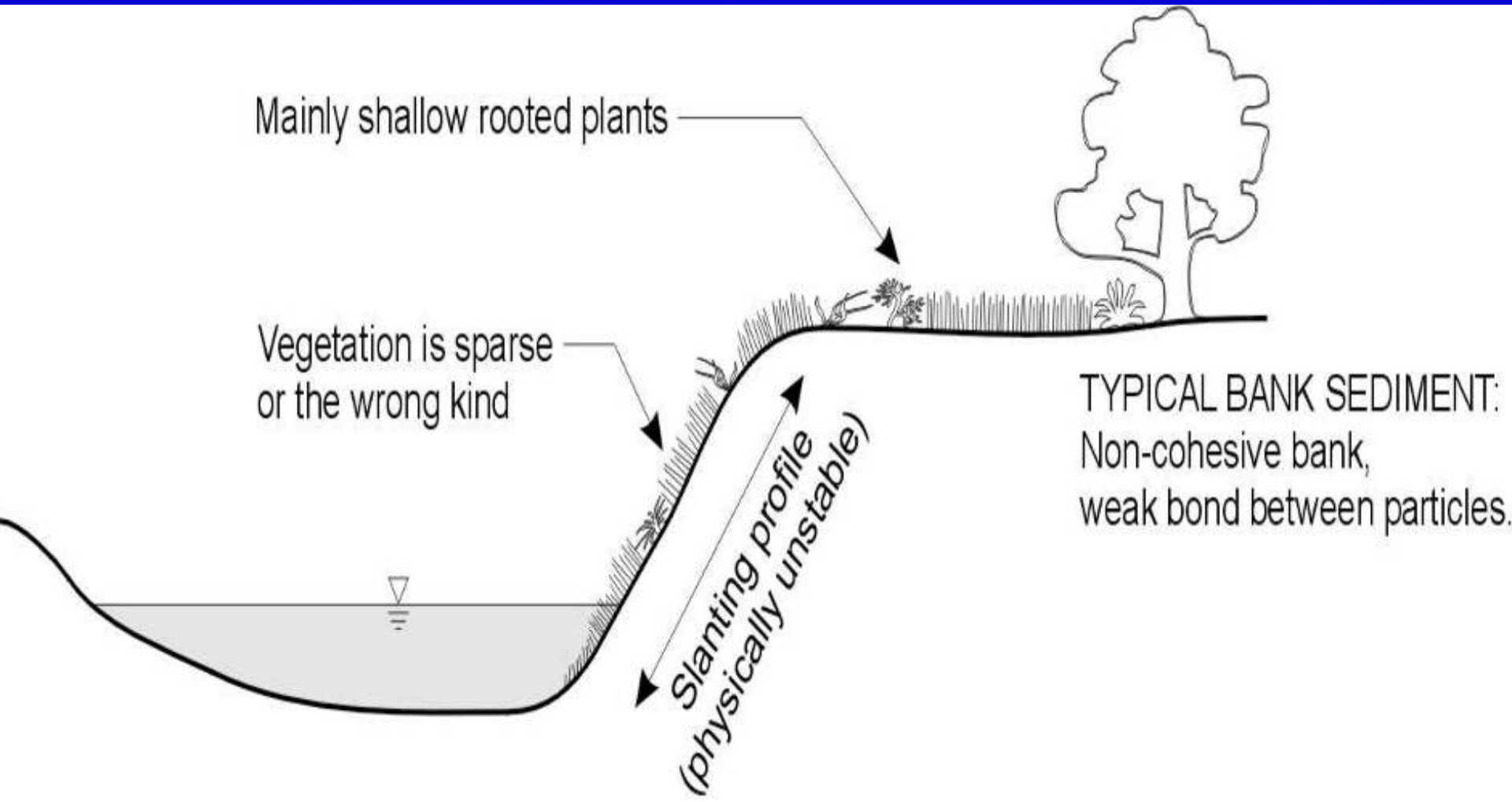


Low Erosion Potential



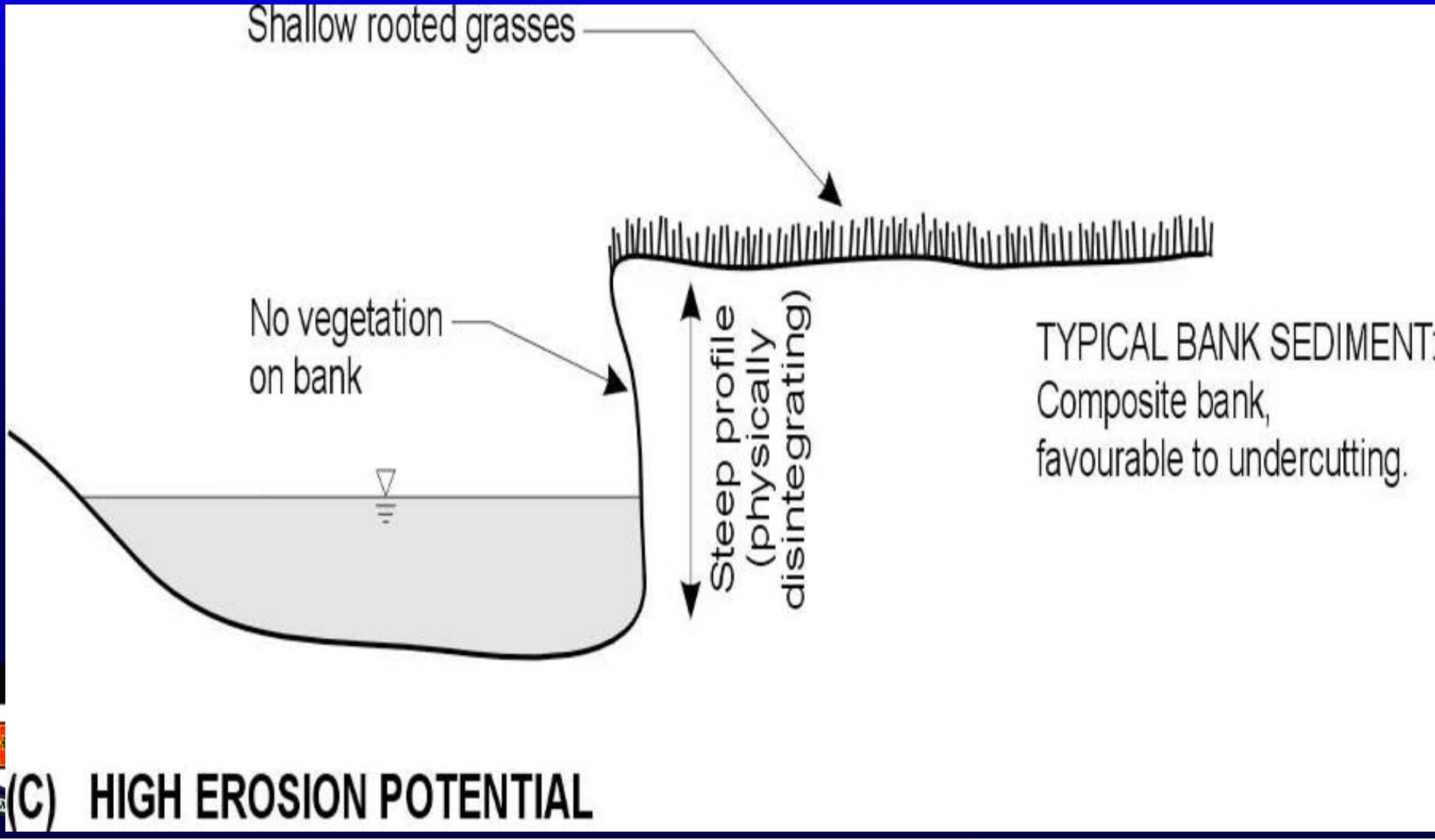
* Includes armoured sites

Moderate Erosion Potential



(B) MODERATE EROSION POTENTIAL

High Erosion Potential



Category	Indicator	Weighting	Indicator Options
River Type	– Valley Setting	High	Confined, Partially Confined, Laterally Unconfined, Completely Armoured, Partially Armoured
	– Stage variability	Moderate	Tidal, Natural, Regulated
Vegetation	– Longitudinal continuity of bank vegetation over stretch	High	<10%, 10-30%, 30-60%, >60%
	– Verge cover (10 m from top of bank)	Moderate	<10%, 10-30%, 30-60%, >60%
	– Upper Bank Cover	High	<10%, 10-30%, 30-60%, >60%
	– Wave Zone Cover	High	<10%, 10-30%, 30-60%, >60%
	– Native canopy species regeneration (< 1 m tall)	Low	None, Scattered, Abundant
	– Native understorey regeneration	Low	None, Scattered, Abundant
	– Dominant Wave Zone Cover	High	Bare (vertical slope), Bare (1:3 slope), Bare (<1:7 slope), Rocks, Tree Roots, Mangroves, Grasses, Reeds
Channel Features	– Bank Slope*	High	Near-Vertical, 1:3, 1:5, 1:7
	– Bank Height	Moderate	<1 m, 1-3 m, >3 m
	– Channel width	High	<36 m, 36 -120 m, >120 m
Erosion	– Bank Sediment Type	Moderate	Bedrock/Boulders/Armour, Cohesive, Non-Cohesive, Complex
	– Lateral Stability	Moderate	High, Moderate, Low (based on evidence of channel migration)
	– Sinuosity	Moderate	<1:3, >1:3
	– Erosion above the wave zone	Moderate	Absent, <10%, 10-30%, >30%
	– Slumping	Moderate	Absent, <10%, 10-30%, >30%
	– Undercutting in the wave zone	Extreme	Absent, <10%, 10-30%, >30%
Land use	– Desnagging	Low	None, Conducted in Last Year
	– Excavation	High	Present, Absent
	– Extraction	Low	None, Water, Sediment
	– Stock access	Extreme	Present, Absent

DST FIELD SHEET

Date:	Stretch:
Time:	Section (1,2 or 3):
Assessing Personnel:	GPS Waypoint: or E: N: AMG/MGA (circle correct one)
Photo Numbers:	

River Type

Valley Setting:	❑ Confined	❑ Completely Armoured
	❑ Partly Confined	❑ Partially armoured
	❑ Laterally Unconfined	

Vegetation (Not required if completely Confined or Armoured)

Longitudinal continuity of bank vegetation over WHOLE STRETCH:	❑ < 10 %	❑ 31-60 %
	❑ 10-30 %	❑ > 60 %
Verge cover (10 m from top of bank):	❑ < 10 %	❑ 31-60 %
	❑ 10-30 %	❑ > 60 %
Upper Bank Cover:	❑ < 10 %	❑ 31-60 %
	❑ 10-30 %	❑ > 60 %
Wave Zone Cover:	❑ < 10 %	❑ 31-60 %
	❑ 10-30 %	❑ > 60 %
Native canopy species regeneration (< 1 m tall):	❑ None	❑ Scattered
		❑ Abundant
Native understorey regeneration:	❑ None	❑ Scattered
		❑ Abundant
Dominant Wave Zone Cover Type:	❑ Bare (vertical slope)	❑ Grasses
	❑ Bare (1:3 – 1:6 slope)	❑ Reeds
	❑ Bare (≤1:7 slope)	❑ Trees/Tree roots
	❑ Rocks	❑ Mangroves

Channel Features

Upper Bank Slope:	❑ Near Vertical	❑ ~1:5
	❑ ~1:3	❑ <1:7
Channel width:	❑ <36	❑ >120
	❑ 36-120	
Bank Height	❑ > 3 m	❑ < 1 m
	❑ 1-3 m	

Erosion

Bank Sediment Type:	❑ Bedrock/Boulders/Cobbles/ Armouring	❑ Complex (sand & clay)
	❑ Cohesive	❑ Non-Cohesive
Erosion above the Wave Zone:	❑ Absent	❑ 10-30 % banks
	❑ < 10 % banks	❑ > 30 % banks
Slumping:	❑ Absent	❑ 10-30 % banks
	❑ < 10 % banks	❑ > 30 % banks
Undercutting in the Wave Zone:	❑ Absent	❑ 10-30 % banks
	❑ < 10 % banks	❑ > 30 % banks

Land use

Desnagging:	❑ None	❑ Conducted in last previous year
Excavation:	❑ Present	❑ Absent
Extraction:	❑ None	❑ Water
		❑ Sediment
Stock access:	❑ Absent	❑ Present

Brief Description of Site

Step 3.1: Calculate Site Erosion Potential - Transect 1

> Transect 2

LOCATION

River Type	Erosion Indicator	Assessment	Score	Importance	Weighting	Subtotal
	Valley Setting	Partly Confined	2	High	3	6
	Stage variability	Tidal	1	Moderate	2	2
		Category				8

Category		Erosion Indicator	Assessment	Score	Importance	Weighting	Subtotal
Vegetation	1.	Longitudinal continuity of bank vegetation over stretch	10-30%	-1	High	3	-3
	3.	Verge cover (10 m from top of bank)	10-30%	0	Moderate	2	0
	4.	Upper Bank Cover	31-60 %	1	High	3	3
	5.	Wave Zone Cover	31-60 %	1	High	3	3
	6.	Native canopy species regeneration (< 1 m tall)	Scattered	1	Low	1	1
	7.	Native understorey regeneration	Abundant	2	Low	1	2
	8.	Dominant Wave Zone Cover Type	Mangroves	1	High	3	3
Subtotal							*9*
Channel	1.	Upper Bank Slope	1:3	4	High	3	12
	2.	Channel width	36-120	0	High	3	0
	3	Bank Height	1-3 m	-1	Moderate	2	0
Subtotal							*12*
Erosion	1.	Bank Sediment Type	Bedrock/Boulders/Cobbles/Armouring		Moderate	2	
	2.	Lateral Stability	High (no evidence of channel migration)	0	Moderate	2	0
	3.	Sinuosity	>1.3	-1	Moderate	2	-2
	4.	Erosion above wave zone	10-30 % banks	-2	Moderate	2	-4
	5.	Slumping	Absent	0	Moderate	2	0
	6.	Undercutting within the wave zone	< 10 % banks	-1	Extreme	4	-4
Subtotal							*-10*
Land use	1.	Desnagging	None	0	Low	1	0
	2.	Excavation	Absent	0	High	3	0
	3.	Extraction	None	0	Low	1	0
	4.	Stock access	Absent	0	Extreme	4	0
Subtotal							*0*
TOTAL SCORE							19

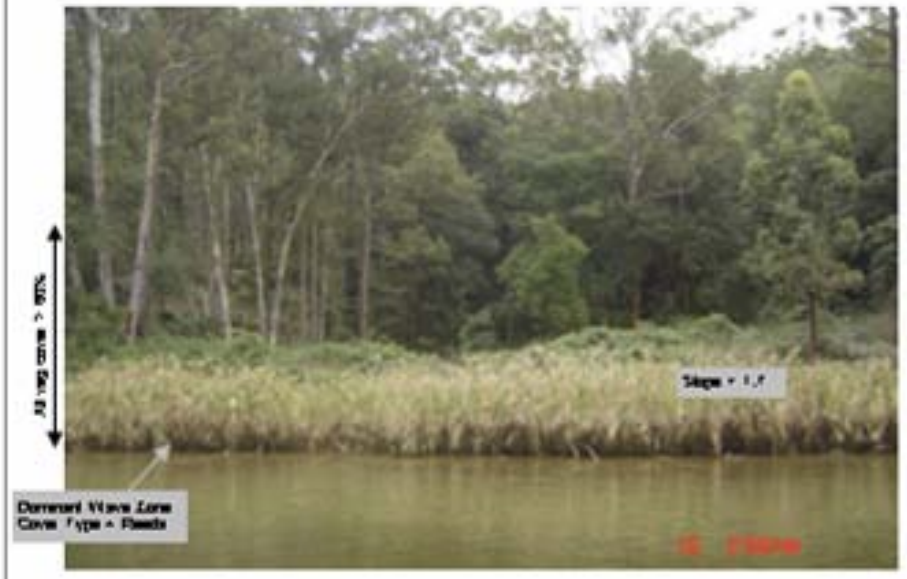
Erosion Potential of the Site = Mildly Resistant

*Bank sediment and bank slope only become important if vegetation quality is not excellent

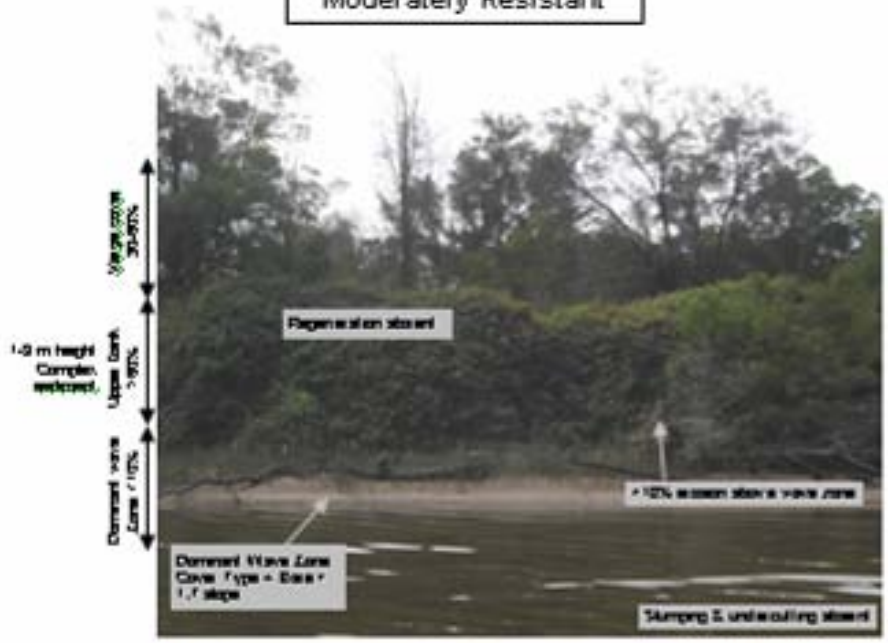
*If valley setting is Confined or Completely armoured, and bank sediment type is bedrock, automatically score full points for vegetation

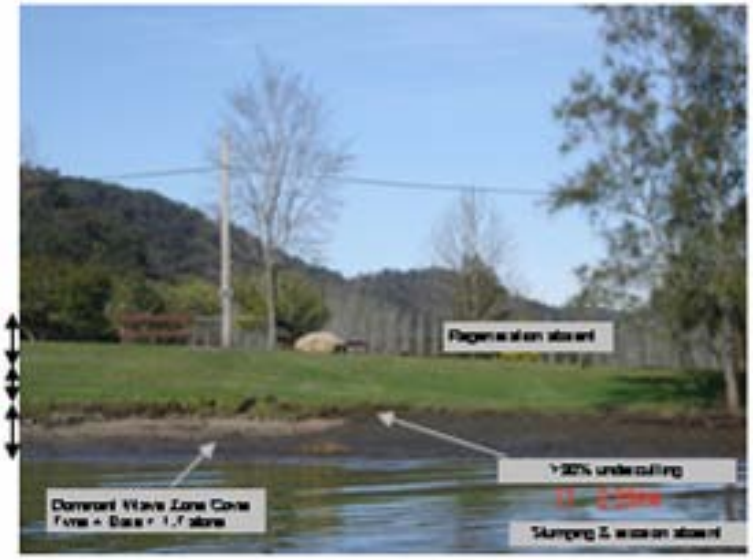
Highly Resistant – Completely Armoured

Highly Resistant – Excellent Vegetation



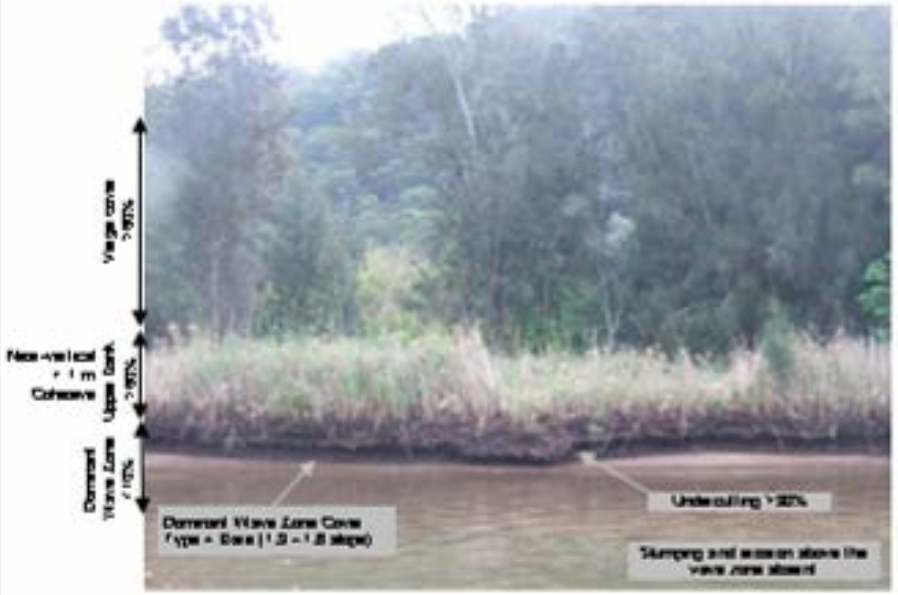
Moderately Resistant





Mildly Resistant

Moderately Erosive



Highly Erosive

Management Outcome

- Based on the ARI rating and the Erosion Index Rating a **management outcome** is determined

	Erosion Potential				
ARI Rating	**Highly Resistant**	**Moderately Resistant**	**Mildly Resistant**	**Moderately Erosive**	**Highly Erosive**
A	ALLOW	ALLOW	ALLOW	MANAGE/ MONITOR	MANAGE/ RESTRICT
B	ALLOW	ALLOW	MANAGE/ MONITOR	MANAGE/ MONITOR	MANAGE/ RESTRICT
C	ALLOW	MANAGE/ MONITOR	MANAGE/ MONITOR	MANAGE/ RESTRICT	MANAGE/ RESTRICT
D	MANAGE/ MONITOR	MANAGE/ MONITOR	MANAGE/ MONITOR	MANAGE/ RESTRICT	MANAGE/ RESTRICT
E	MANAGE/ MONITOR	MANAGE/ RESTRICT	MANAGE/ RESTRICT	MANAGE/ RESTRICT	MANAGE/ RESTRICT

FINAL RATING

Boat Type	Wakeboard	**Conditions**	Operating
The maximum boat wave energy is equivalent to wind wave energy of ARI	2-5	**Erosion Potential**	Moderately Resistant
The energy of 10 attenuated boat passes is equivalent to the energy of wind waves over 12 hours duration	<1	**Distance from Shore**	200 m
ARI Category	B		

FINAL RATING ALLOW

DST-Management Outcomes

Management Criteria

Restricted Boat Movements	Monitored Boat Movements	Unrestricted Boat Movements

Reassessed every:	2 years	5 years

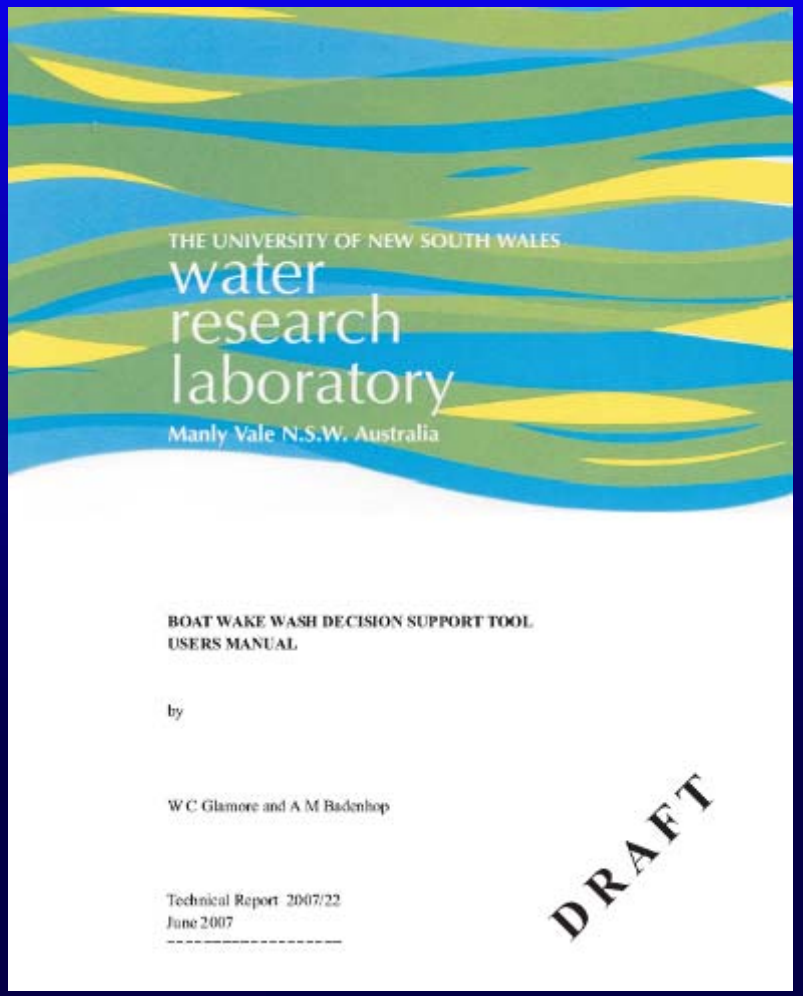
DST includes:

- Max and Duration Waves
- Energy of waves
- Attenuation of waves
- Wave train (not just one)
- Different boat types
- Different operating type
- Wind conditions at site
- ARI of waves
- Comprehensive Erosion Indicators
- Desktop and Field tested

- River setting and site specific
- Weighted Indicators
- Site selection method
- Multiple transects
- Repeat timeframes
- Not overly conservative
- Easily modified
- Based on previous work
- Rapid Assessment
- Expert reviewed
- User Manuals and Tutorials

Application Information

- Users Manual
- Interactive Spreadsheet
- Theoretical Manual
- Field Sheets
- Descriptive Photos
- Presentations and Papers



Future Work

- Onsite Application
- Peer Review
- Widespread Distribution
- Other boat wake types
- Flume Testing of Erosion Potential