Static Bay Beach Concept for Coastal Management and Protection

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許榮中

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Presenter

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MEng (**AIT**, 1971), PhD (UWA, 1979)

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* After retirement at 69-year old from 1 August 2013:
Hon. Chair Professor, National Sun Yat-sen Univ. (Kaohsiung): 4 months
Hon. Research Fellow, Univ. of Western Australia (Perth): 8 months

• included in the 261 Highly Cited Researchers in "Engineering" category (Thomson Reuters, April 2013)

First, I would like to thank my former supervisors, for their teaching of practical thoughts in dealing problems related to beach morphology and shore protection.

Prof. Richard Silvester
Univ. Western Australia

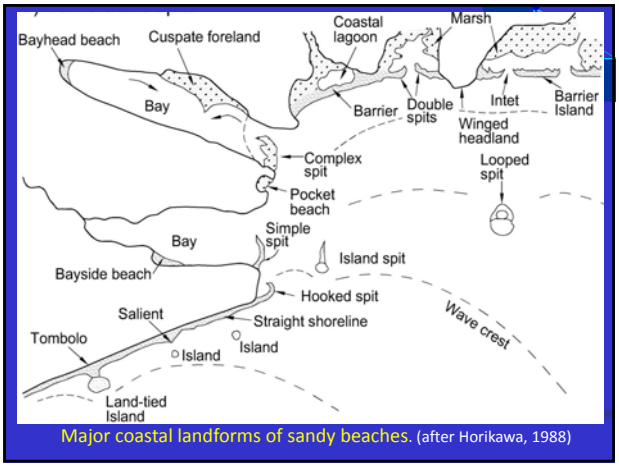
Prof. Yoshito Tsuchiya土屋義人
DPRI, Kyoto University

I can see the harbor, ocean and a new headland-bay beach beyond my office window in NSYSU

Contents

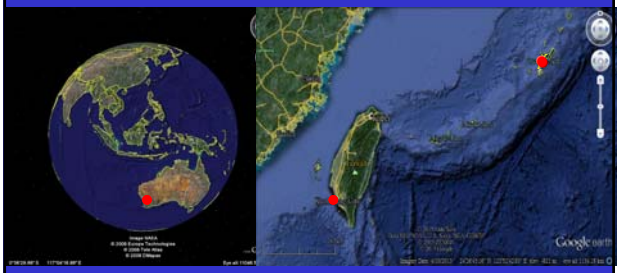
1

Global Aspects of Coastal Environment

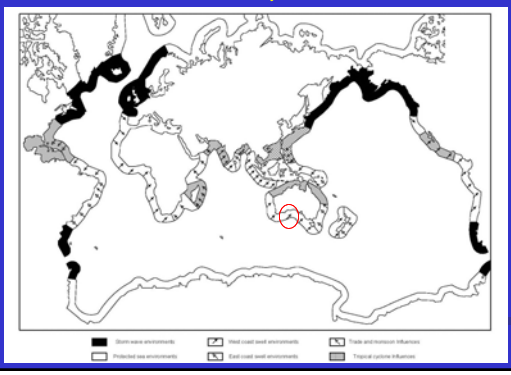


Major coastal landforms of sandy beaches. (after Horikawa, 1988)

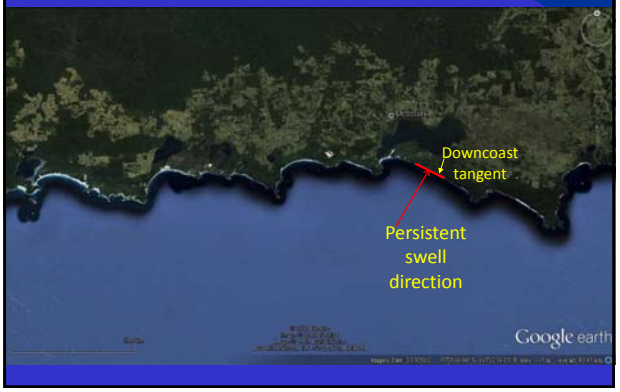
On coastal geomorphology, we are in One World.



1.1 A Global aspects of swell for orientation of stable bay beaches



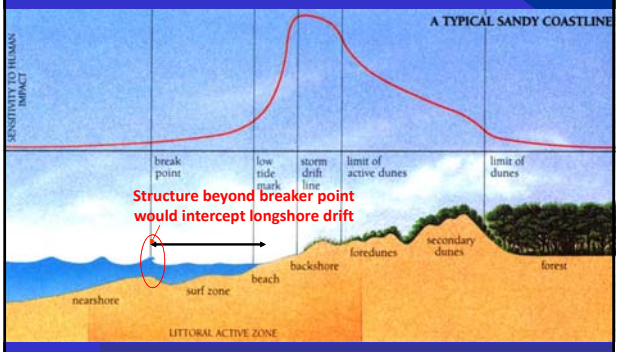
A chain of stable bay shapes near Demark, Western Australia



Wave refraction and diffraction around a headland

(Reader's Digest 1983)

A typical beach profile



Ref: Oceans and Islands (Talbot and Stevenson, eds. 1991)

1.2 Applied Coastal Geomorphology

A branch of earth science

--- Study includes ---

* Geology： Soft and/or hard
* Planform： Shape（straight, curved）& size
* External forcing：Swell, typhoons, tides, currents
*Stability?

- If unstable → call coastal scientists or engineers ???

Concept of Equilibrium

"A coastline has an equilibrium form when it maintains its geometrical form." (Bruun, 1951)

Equilibrium both in beach profile (Dean, 1991, 1997) and in planform (Tanner, 1958; Hsu and Evans, 1989)

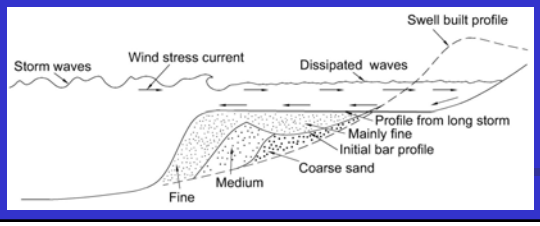
The parabolic bay shape equation is derived for bayed beaches in static equilibrium under null sediment supply, which is a real scenario nowadays.

This macro-scale approach is very useful to coastal engineers, consultants and geographers

Equilibrium Beach Profile (EBP)

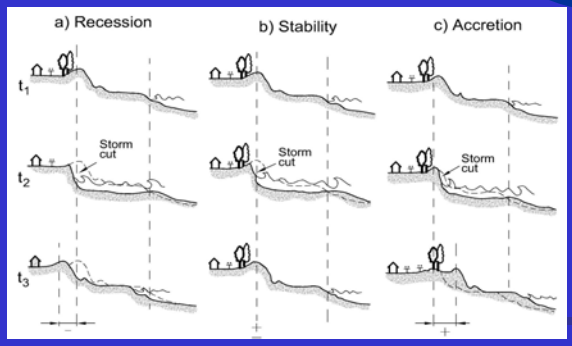
• Swell has almost one single wave period; active T = 6~12" → littoral drift → swell-built beach profile

• Storm waves consist of many wave components with directions changing with time → shift sand from beach and berm in a couple of hours → bar formation → storm-built profile



1.3 Definition of beach erosion

Colin Woodroffe (2003)



A large population of the world lives close to the sea …

Conflict between human and nature has occurred in many countries in recent time

What is the state of erosion on the world coastline?

Natural beaches are diminishing world wide

More than 70% of sandy beaches eroded

over the past few decades

(Eric Bird, 1996)

Melbourne Uni, Australia

Main causes to beach erosion

Natural causes

swell – oblique approach and protruding headlands
storm – beach and berm erosion, bar formation
other natural causes – sea level rise, tectonic movement

Man-made (anthropogenic) causes

(1) disturbance to continuity of littoral drift (coastal structures)
(2) wave sheltering (harbor breakwater, offshore breakwaters)
(3) reduction in sediment supply from rivers (dam, weir)
(4) extraction of sand/gravel from river or navigation channel
(5) land subsidence (groundwater pumping for aquaculture)
(6) deforestation of mangrove forests
(7) improper coastal management etc.

Classification of Causes of Beach Erosion

(Anthropogenic)... (Uda 2010 : Japan's Beach Erosion)

(1) Obstruction of longshore sand transport
(2) Construction of wave sheltering structures
(3) Decrease of fluvial sediment supply
(4) Offshore sand mining/dredging
(5) Construction of detached breakwaters
(6) Excess planting of coastal forest
(7) Construction of gently sloping revetments

1.4 Options for shore protection

- Do-nothing - irresponsible
- Soft engineering
- Hard engineering
- Mixed soft-hard option

Which option do we prefer?

- Being a coastal engineer, I prefer Soft-hard combination, to create a safe embayment with artificial nourishment.

To Combat Beach Erosion

Conventional methods have been used widely, but NOT all have been successful/cost effective.

At present methodology of shoreline protection
. has been gradually changing
. uses soft engineering and coastal management
to replace hard engineering structures

Bird (1996): Beach management will be most effective

" if those concerned understand :
how their beach has taken shape,
what changes are occurring and
Why and what is likely to happen of it in the future."

Shore Protection Methods

Hard Options :

(When safety cannot be compromised)

1. seawalls and revetments
2. groins (straight; L, T, Y-shape; curved, fish-tailed)
3. detached breakwaters

Soft Option :

(Environmentally friendly but may not cost effectively)

4. beach nourishment without protective structure
5. submerged breakwaters, artificial reefs .....

Hybrid Option :

6. Headland Control with nourishment

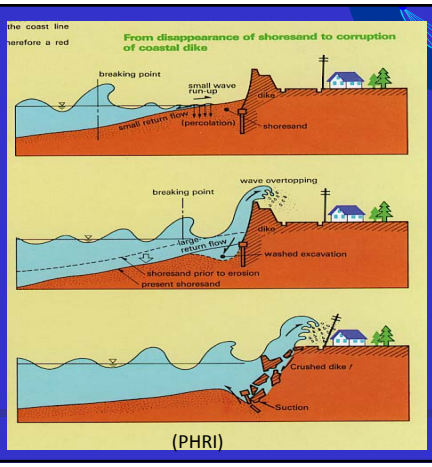
Linear Protection

A seawall without fronting beach

or inadequate storm buffer

... NOW ...

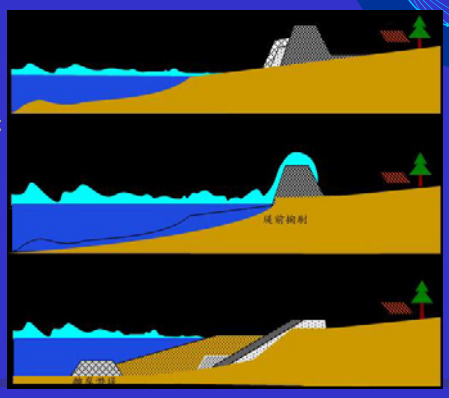
Plan Protection



(PHRI)

Seawalls and wave dissipation work in Taiwan

Detached breakwaters + nourishment



1). Coastal managers and engineers elsewhere have applied various man-made structures to restore/protect eroding beaches, some with artificial beach nourishment;

2). Some schemes at one location, though have achieved the purpose of protection, may be criticized by different people and/or at different time;

3). While managing beach erosion, the problem is not only an issue for engineers, but certain balance among local, governmental, environmental and cost-and-benefit factors.

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Let's observe what have been used elsewhere ...

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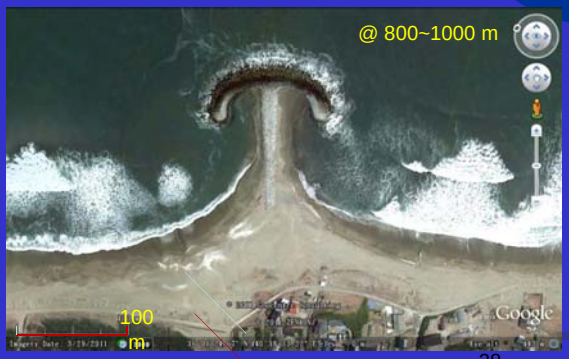
42 curved T-head groins on Kashima coast, Japan



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Pedregalejo, Spain
Google earth
Submerged breakwaters
Mazarron, Spain
Google earth
Irago, Aichi, Japan
Google earth

31


Sentosa & Seringat, Singapore
N
Siloso Beach
Sentosa
Palawan Beach
Tanjong Beach
Pulau Seringat
artificial bay
(Silvester & Hsu
Google earth
1380 m

32


Singapore: Siloso beaches, Sentosa
Google earth
Please compare the main differences between the traditional detached breakwaters and the one installed on Sentosa.

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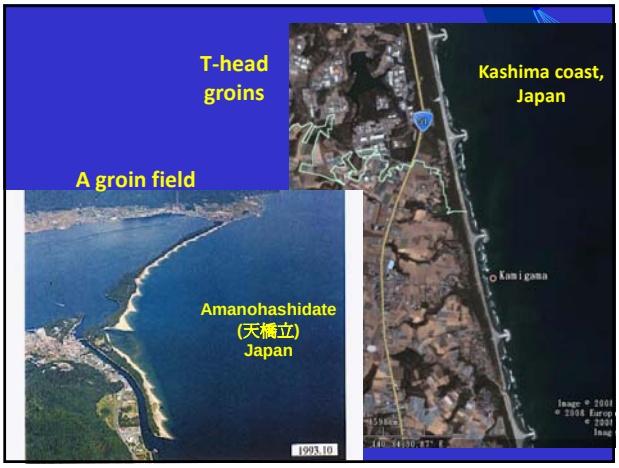

T-head groins
Kashima coast, Japan
A groin field
Amanohashidate (天橋立) Japan
1993.10


Detached Breakwaters
Kaike, Japan
Google


Irago, Aichi, Japan
伊良湖海岸
Submerged offshore breakwaters
Google earth

2

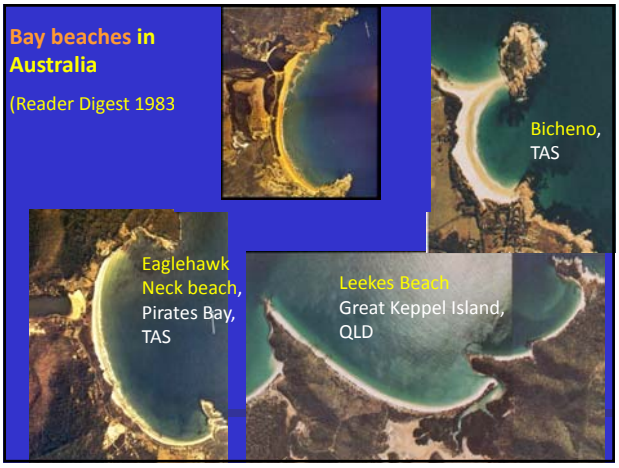
Headland-Bay Beaches in Static Equilibrium

- Empirical Parabolic Bay Shape Equation derived from 27 mixed (prototype and model) cases of bay beaches believed to be in static equilibrium. (Hsu and Evans, 1989)

Headland-Bay Beaches

- esthetically beautiful
- ubiquitous; have existed over long geological time
- behind or between headlands, natural or man-made
- created by persistent swell from a particular direction
- much more stable compared to straight beaches
- visible from aerial photographs, maps, hydrographic charts, travel magazines

Many geomorphologists and coastal engineers do not realise the potential of bay beaches, nor the difference in the behaviour between a straight coast and a curved beach.



2.1 Bay Beach Stability

1). *static equilibrium* : predominant waves break simultaneously around whole bay periphery, hence littoral drift is almost non-existent, ... Stable if Q↓

2). *dynamic equilibrium* : sediment supply from updrift and/or riverain source within the bay required to maintain its stability, ... Retreat if Q↓

3). *natural reshaping*/*unstable* : associated with wave sheltering effect due to addition or extension of harbor breakwater, detached breakwater etc.

• Only static bay shape can be predicted empirically using wave direction alone (Hsu and Evans, 1989)

2.2 Bay Shape Equations

Geographers and coastal engineers have attempted to derive empirical equations to quantify bay periphery.

Three empirical equations have been proposed:
- logarithmic spiral (Krumbein, 1944; Yasso, 1965),
- parabolic bay shape (Hsu and Evans, 1989; Silvester and Hsu 1993, 1997),
- hyperbolic-tangent (Moreno and Kraus, 1999).

These models have different coordinate systems, origins, and controlling parameters;
Wave heights and periods were not included.

Amongst these, only Hsu and his co-workers consider :
- wave direction
- point of wave diffraction and modification to structure
- beach stability (static equilibrium, with null sediment input).

- With computer program, log-spiral and hyperbolic-tangent models can be applied to fit a bay beach in static equilibrium or non-equilibrium.
- Their shortcomings:

(1) NO recognition of the wave diffraction point.

(2) Their origins of coordinates do not coincide with tip of headland (e.g., point of wave diffraction).

(3) Both models do not address beach stability.

(4) Both models do not give explicit relationship between incoming wave and beach alignment.

(5) Both cannot verify bay beach stability, neither to predict the environmental impact of a new headland nor to evaluate effect of extending an existing structure on a downdrift beach.

2.3 (Empirical) parabolic bay shape equation

(Hsu and Evans, 1989)

$$R_n/R_\beta = C_o + C_1 (\beta/\theta_n) + C_2 (\beta/\theta_n)^2$$

Based on data from bay beaches believed in static equilibrium

Basic parameters:

β Reference wave obliquity

- may be measured or modified by structure installation

R_β Control Line

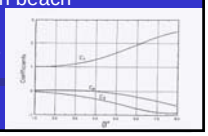
Point on shoreline in static equilibrium:

R_n Radius distance to a point on beach

θ_n Polar angle

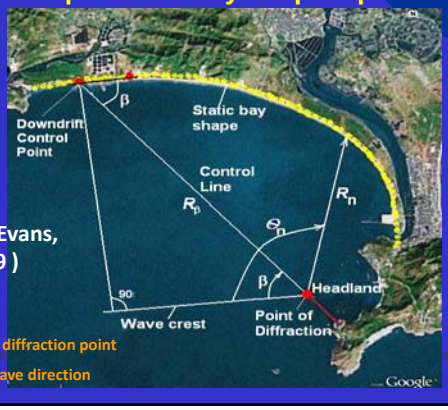
C coef. = f (β), from regression analysis.

(for UPDATE, see Serizawa et al, 1996; Kumada et al, 2002)



Definition for parabolic bay shape equation

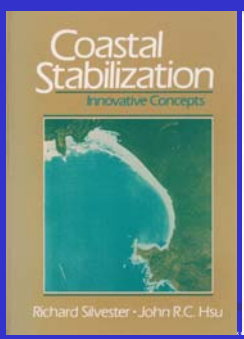
(Hsu & Evans, 1989)

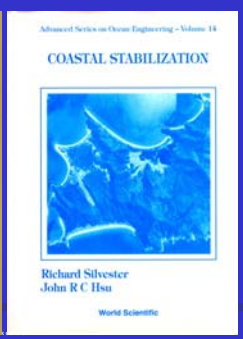


- Wave diffraction point
- Wave direction

Dr Richard Silvester is a man with practical mind and vision.

Silvester (1960) in ***Nature***, promoting bay beach for coastal stabilization.





Recent applications

Parabolic bay shape equation (Hsu and Evans, 1989)

Since it first publication in 1989, the parabolic equation did not receive much attention;

until about a decade later

(van Rijn, 1989; Dickmann, 1999; Hardaway and Gunn, 1999; Weesakul, 1999; Gonzalez and Medina, 1999;

Oliveira *et al.*, 2000; Smith *et al.*, 2000; Uda *et al.*, 2002;

Gonzalez and Medina, 2001, 2002; Klein *et al.*, 2002, 2003)

More recently and significantly, it is listed in

USACE (2002) ***Coastal Engineering Manual***

for project evaluation and coastal processes

and Spanish SMC (Coastal Modelling System) software package

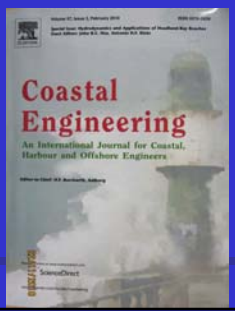
Special Issue in *Coastal Engineering* (2010)

Engineering Applications of Headland-Bay Beaches

Guest-editors: John R-C. Hsu and Antonio H.F. Klein

Contributing authors:

Australia: Andrew Short
Brazil: Antonio Klein, Andre Raabe
Japan: Takaaki Uda
Mexico: Rodolfo Silva
Netherlands: Marcel Stive, R. Lausman
Portugal: Filipa Oliveira, Oscar Ferreira
Spain: Raul Medina, Mauricio Gonzalez
Thailand: Sutat Weesakul
Taiwan: John Hsu
USA: Scott Hardaway , Lindino Benedet



3

Software MEPBAY and SMC

for

Headland-Bay Beaches in Static Equilibrium

MEPBAY

(Model for Equilibrium Planform of BAY beaches)

can be downloaded from

http://siaiacad17.univali.br/MEPBAY

Technical paper: Klein et al. (2003)

Klein, A.H.F., A. Vargas, A.L.A. Raabe, and J.R.C. Hsu

"Visual assessment of bayed beach stability using computer software"

***Computers & Geosciences*, 29: 1249-1257.**

Bay beach in *static equilibrium*, with Q ~0

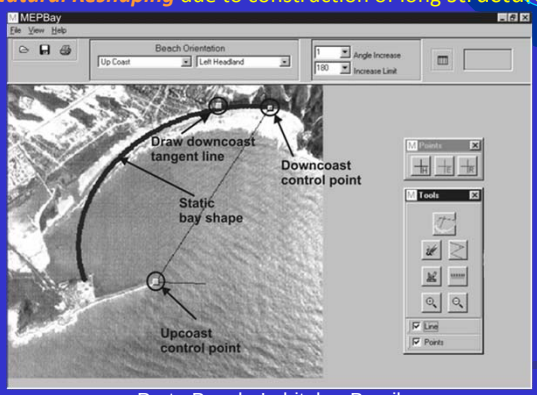
static

Taquaras-Taquarinhas, Brazil

Bay beach in *dynamic equilibrium* or *unstable*

Berneario Camboriu, Brazil

Natural Reshaping due to construction of long structure



Porto Beach, Imbituba, Brazil

Ministerio de Medio Ambiente
(Spanish Ministry of the Environment)

Universidad de Cantabria

SMC

Coastal Modelling System

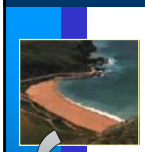
Prof. Raul Medina
Prof. Mauricio Gonzalez

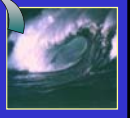
1995 - 2003

G.I.O.C.
Ocean & Coastal Research Group

http://www.smc.ihcantabria.com/es

Coastal Modelling System





Short -Term Models

Wave, currents and beach processes

Long-Middle-Term Models

Equilibrium in beach profile and in planform

SMC

Gijon Harbour (Cantabric Coast, Spain)

G.I.O.C.

Long Term study

EQUILIBRIUM SHORELINE (Hsu model): ACTUAL

4

Geomorphic Approach for Coastal Management

4.1 Stability verification for bay beaches
4.2 Mitigating erosion downdrift of harbors
4.3 Headland Control: shore protection
4.4 Design of recreational beaches
4.5 Coastal management and EIA
4.6 Case studies on beach restoration

4.1 Stability verification for existing bay beach

The only assumptions in sketching the a static bay applying PBSE with MEPBAY :

- The tangent at an appropriate point on the straight downdrift section is assumed in perpendicular direction to the local incident wave propagation at updrift diffraction point for a bay beach in static equilibrium.
- The same principle applies to static, dynamic and unstable condition.
- Based on laboratory results: downdrift tangent remained almost invariant long before the beach approaching static equilibrium.

Bay beach in the lee of offshore island

Bay beach downdrift harbor breakwater

Acapulco, Mexico

Enoshima (江ノ島), Japan

青島第三海浴 1

豐崎 Okinawa (1)

安座間 Okinawa (2)

喜瀨 &Busena, Okinawa (3)

4.2 Mitigating erosion downdrift of harbor

Effect of Harbor Construction

Initial breakwater on a coast
where no natural shelter is available;
hence, interrupting littoral drift → Downdrift erosion

further extension of breakwaters
• diminishing littoral drift
• causing accretion in the lee and erosion downcoast.

Coastal Geomorphology wasn't invoked
to verify the bay shapes so formed
in the lee of the breakwaters, and to see
whether it was in static or dynamic equilibrium.

Breakwater intercepts littoral drift ...

In Japan,
Harbor construction and maintenance dredging are two of the main causes of beach erosion

Akabane harbor,
赤羽根漁港
Japan (1986)

Causing problem further downdrift...

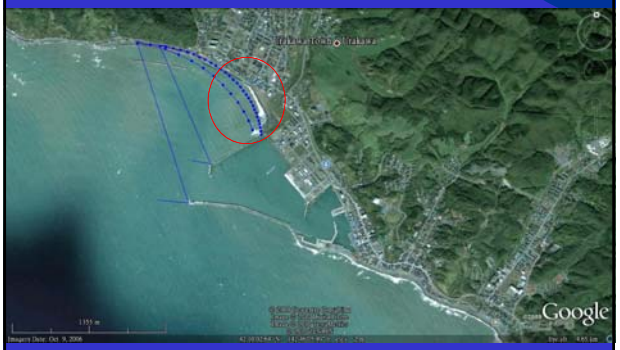
Beach erosion on **Ohno-Kashima coast**, Japan
1980→1986 **Why?** (Kashima Harbor built 1963 ~ 1975)

Kunigami, Ryukyu, Japan

Harbors on Hidaka coast, Hokkaido, Japan

Uda (2010)
p.19-22

Urakawa, Hidaka coast



Monbetsu, Hidaka coast

Uda (2010)
p.22

Bay beach stability determined by
quantity and balance of sediment input and output
- ***dynamic equilibrium***, with balance in sediment supply,
- ***unstable***, if supply reduces, or
- ***static equilibrium***, if supply diminishes or cuts off.

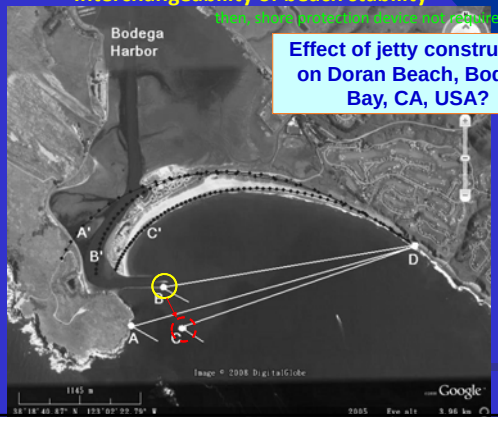
Beach stability can be switched between *static* and *dynamic equilibrium*, due to construction of artificial headland (breakwater, training wall etc)

This concept is extremely useful for practical applications.
- **installing new structures or extension, and**
- **stabilization of bay beach in eroding condition**

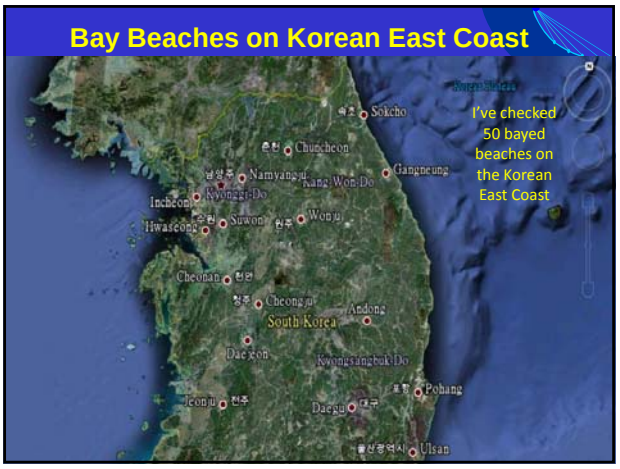
Oarai harbor (Japan) and downdrift beach.
Will beach erosion continue?

Interchangeability of beach stability

then, shore protection device not required



Effect of jetty construction on Doran Beach, Bodega Bay, CA, USA?


Bay Beaches on Korean East Coast
I've checked 50 bayed beaches on the Korean East Coast
Sokcho
Chuncheon
Gangneung
Namyangju
Kyonggi-Do
Kang Won-Do
Incheon
Suwon
Wonju
Hwaseong
Cheonan
Cheongju
Andong
South Korea
Daejeon
Kyongsangbuk-Do
Pohang
Jeonju
Daegu
Ulsan


Close to Static/Dynamic Equilibrium

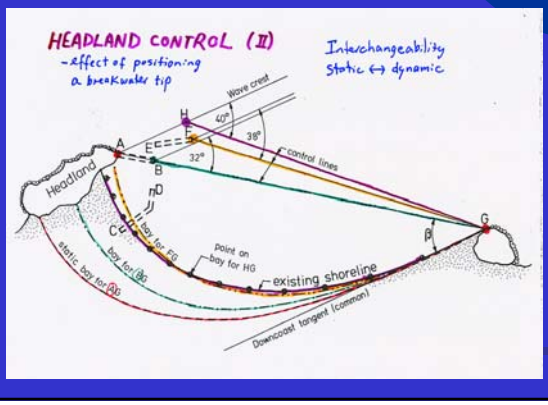

Unstable or Natural Reshaping

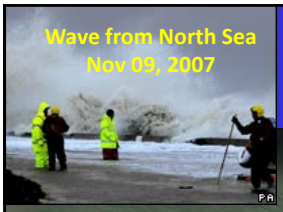

Natural reshaping with short breakwater


Should we extend the breakwater ?


4.3 Headland Control: shore protection
San Diego
Zuniga jetty
Silver Strand Blvd
Coronado Bay
Rock revetment
Imperial Beach
Google

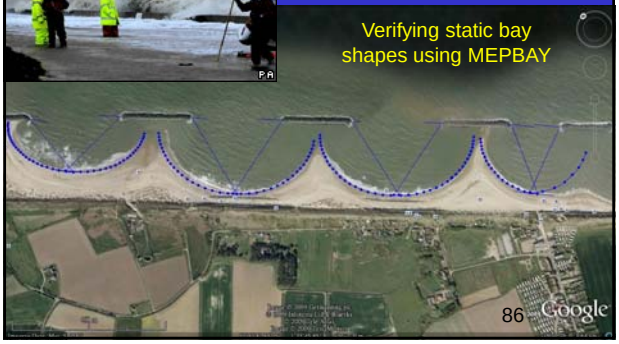
Relocation of breakwater tip to convert dynamic into static





Sea Palling, Norwich, UK

Verifying static bay shapes using MEPBAY



Verifying static bay shape using MEPBAY for bay beaches on **Rayong coast, Thailand**

4.4 Design of Recreational Beaches

Brazilian beach scene

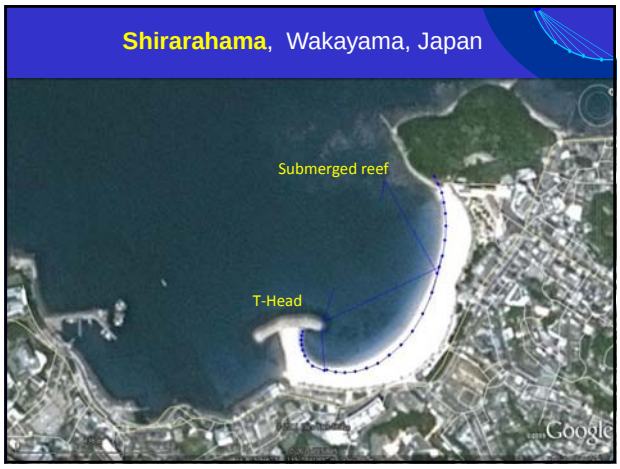
Australian humour; The beautiful and the ugly on a beach

Mamzar Beach Park, Dubai, UAE

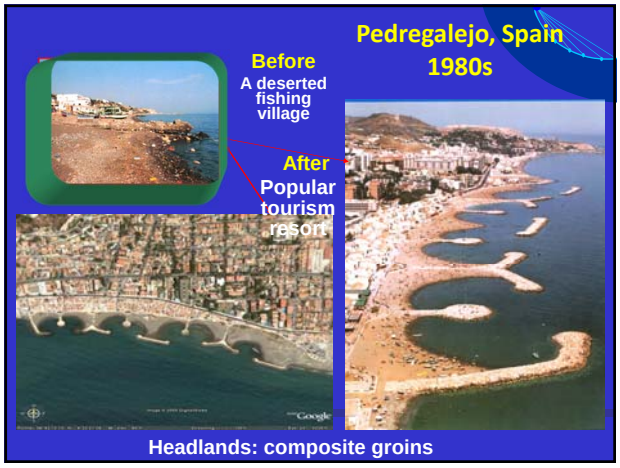
Bay beaches at Sanur, Bali, Indonesia

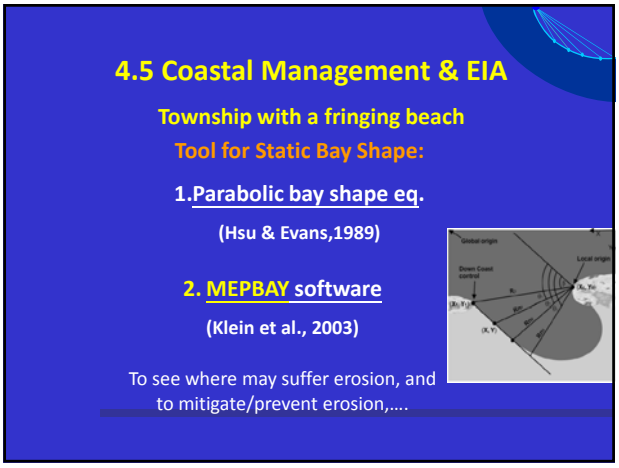
90

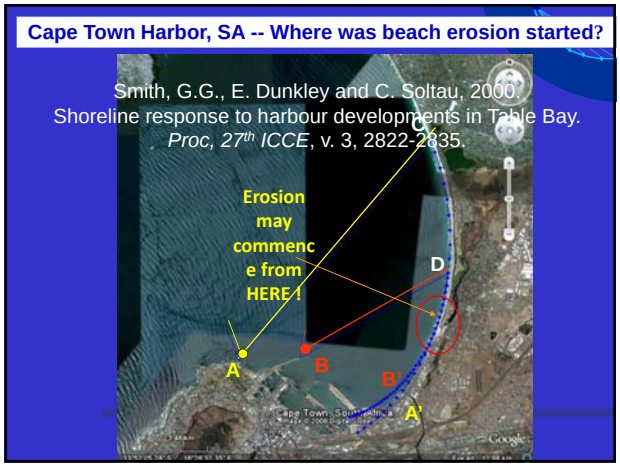

Bay beach between T-head & submerged obwtr.
Shirarahama,
和歌山縣白良浜
JAPAN
1980-90s
T-head +
Nourishment
5/6


Shirarahama, Wakayama, Japan
Submerged reef
T-Head
Google


Pulau Seringat
Singapore
Hand-drawn by
Silvester and Hsu
in early 1990s
2001
2007
Verification
using
MEPBAY


Pedregalejo, Spain
1980s
Before
A deserted
fishing
village
After
Popular
tourism
resort
Headlands: composite groins


4.5 Coastal Management & EIA
Township with a fringing beach
Tool for Static Bay Shape:
1.Parabolic bay shape eq.
(Hsu & Evans,1989)
2. MEPBAY software
(Klein et al., 2003)
To see where may suffer erosion, and
to mitigate/prevent erosion,….


Cape Town Harbor, SA -- Where was beach erosion started?
Smith, G.G., E. Dunkley and C. Soltau, 2000.
Shoreline response to harbour developments in Table Bay.
Proc, 27th ICCE, v. 3, 2822-2835.
Erosion
may
commenc
e from
HERE !
A
B
B'
A'
C
D
Google

4.6 Case Studies on Beach Restoration

to meet the condition of diminishing littoral drift

- Properly position the tip of an artificial headland*
  *(a T- or Y-groyne, offshore breakwater etc.)
- Use headlands in large spacing @300m~400 m
  (allow nature beach to dissipate wave energy)
- Aided by initial beach nourishment as storm buffer
  - Re-orient the new each, thus allowing normal wave approach around the entire bay periphery.
- Self-defensive and minimum on-going maintenance

Planning issues for beach protection & restoration:

- Budget restraint?
- On straight or bay beach?
- With artificial nourishment?
- Type and layout of artificial headland?
- Examples of stable man-made bay beaches?
- What planning tools (formulae, software) available?

Beach Restoration: Anping

Beach Restoration at Sizihwan

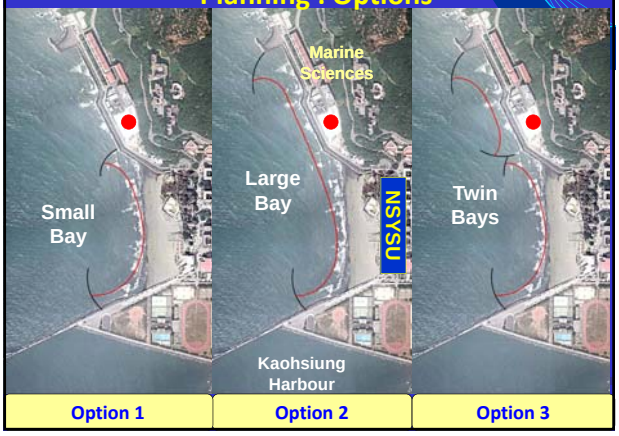
NSYSU re-established at Sizihwan in 1980

Verification of bay beach stability

Software: MEPBAY, GENESIS, SMC

2005

Planning : Options



Sizihwan beach restoration, 2006~2008

John Hsu & China Eng. Consultant Inc. have worked together since 2003

Concluding Remarks

5
Concluding Remarks

5.1 Concept of equilibrium bay shape

is simple to use.

- to verify stability of bay beaches
- for protection of eroding beaches
- design of recreational beaches and
- for coastal planning.

5.2 Verification of beach stability

prior to and after a proposed construction of breakwater or structure

- to determine the optimum dimensions and the location of its tip,
- to minimize likely erosion downdrift.

5.3 If a bay beach is in *dynamic equilibrium*

- to determine optimum dimensions of a new structure, thus converting a potentially unstable beach into static equilibrium.
- save the need for costly protective measures to be built later.

5.4 Should a bay beach in *static equilibrium*

- the beach should be spared from any proposal of large-scale development, or facing an everlasting consequence of threat in beach erosion.

Thank YOU

for
Allowing me to introduce the
Static Bay Beach Concept for headland-bay beaches
for coastal management and protection, and design of recreational bay beaches.

Let's produce stable bay beaches
for the community

See you again somewhere