76-53-012

出席「荷蘭海岸地區開發與管理研討會」并考察港埠設施報告

侯和雄

交通部運輸研究所

中華民國七十六年九月

行政院所屬各機關人員出國報告書提要

01 報告書名稱	出席「荷蘭海岸地區開發與管理研討會」并考察港埠設施報告	02 服務機關名稱	交通部運輸研究所		
03 姓名	侯和雄	04 年齡	43歲	05 職(級稱)	簡任 運工組組長
06 出國類別	出席國際會議與考察港埠	07 到達國家及地點	荷蘭海牙及鹿特丹港區等		
08 出國期間	自76年9月5日 迄76年9月25日	09 報告時期	76年9月30日	10	
11 內容提要	1.「荷蘭海岸地區開發與管理研討會」由荷方對其海岸開發與經營情形作一概括性介紹，我方海洋組由台大陳汝勤教授報告，海岸工程組由報告人提出「Development of Coastaland Ocean Engineering in Taiwan,ROC」如附錄一(Appendix I)，會後參觀各項荷蘭新穎之觀測、調查設備。 2.報告人考察鹿特丹港設施如附件一，考察三角洲計畫暨德福特水工試驗設備，摘述如附件二、三所示，海堤設計亦提要如附件四。 3.報告人對荷方與我方之沿岸地區開發與經營管理作一比較，如附件五所示，荷國有海上完善之監測系統并有二十四小時待命之海岸巡防總署建議政府協調有關部、會、署建立類似系統與執行單位。				
12 本機關審核意見	本報告對台灣沿岸地區開發與經營管理甚有助益。				
13 層轉機關審核意見					
14 本院研考會處理意見					
15 備註					

說明：一、表內06「出國類別」欄就「出席國際會議」、「考察」、「視察業務」、「洽辦業務」、「應邀訪問」或「研習」等項擇一填入。

交通部運輸研究所出版品摘要表

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<tr><td colspan="4">關鍵詞：海岸及海洋工程發展</td></tr>
<tr><td colspan="4">摘要：1.中華民國台灣在海岸與海洋工程之發展
2.鹿特丹港、三角洲計畫、德福特水工試驗所等考察記要。</td></tr>
<tr><td>出版日期</td><td>頁數</td><td>工本費</td><td>本出版品取得方式</td></tr>
<tr><td>76年 月</td><td></td><td></td><td>☑洽本所免費贈閱 ☑洽本所訂購 ☐其他（ ）</td></tr>
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<tr><td colspan="4">備註：</td></tr>
</table>

交通部運輸研究所組長侯和雄因公派國外出差人員（考察、開會、訪問）行程表

預計日數	起訖地點	工作項目
9.月5.至6.日	台北—阿姆斯特丹	啓程
9.月7.至18.日	海牙	海岸地區開發與管理研討會
9.月19.至21.日	鹿特丹	參觀鹿特丹港口等設施
9.月22.至23.日	阿姆斯特丹	撰寫該研討會有關政策性問題及港口設施考察報告
9.月24.至25.日	阿姆斯特丹—台北	回程

鹿特丹港之港埠經營與污染防治

鹿特丹港之成長與擴建為近半世紀之歷史，本港之主要運輸除貨櫃外，尚有煤炭、礦砂及穀類等散裝轉運以及石油裝運。其裝卸乃藉由萊茵河中游以浮體或繫船設施經由浮式起重機、升降機以及管線系統而裝卸。1936 年Shell油 公司首先在鹿特丹港區建立煉油廠。二次大戰使本港遭受嚴重之破壞，1950 年本港之重建始告完成一船席水深加深、裝置最近代化設備，港址佈置分配深更有效率。此時一巨大且專業化之貨櫃轉運公司即歐洲貨櫃集散站在此綜合港之南方地區建立後，許多鹿特丹市之裝卸業務乃經由本港進出，由於本港營運量驟增，歐洲港（Europoort Plan）計畫位於萊茵河下游，面臨北海乃於1957 年11月開始執行，第一條油輪始於1960 年11月，持續完成三階段之15 公 里長之歐洲港計畫，同時為嗣應船舶巨型化趨勢乃將港池與航道浚深，1971 年浚至65 呎深，1975 年浚深至68 呎，目前由68 呎加深至72 呎 ，為建造新的礦砂與煤炭轉運用碼頭，已在外港建立容許吃水75 呎之船隻碇泊裝卸。1962 年起遠洋轉運達九千六百萬噸，鹿特丹號稱本港為世界最大之港埠，意謂最高峯之成長時期，紐約港務局亦電賀鹿特丹港，從此紐約港屈居世界第二位，鹿特丹港并於1973 年及 1979 年再創紀錄其營運量超出三億噸 。進港船隻，1959 年第一條超越十萬噸之油輪進港，從此油輪成長快速，最大原油油輪（VLCC）及超級原油油輪（ULCC）均相繼出現，本港于1968 年 32.7萬噸油輪進入，接着 1973 年兩艘 47.7 萬油輪進入本港，1979 年則有56.5 萬噸之油輪進港，礦砂輪、散裝輪則于 1972 年二十萬噸船進入，如同油輪情況礦砂輪無返回之貨，為使它們有返行貨物乃發展油－散裝－礦砂輪（OBO型－Oil－

Bulk - Ore)可供這些不同貨物裝卸。由於巨型散裝輪之進港、碼頭乃藉由巨型卸貨機，長的履帶輸送機及裝貨齒輪供駁船使用。

茲將近兩年(1985 年及 1986 年)鹿特丹港貨物轉運量(總重)統計如次：

總量：1985 年卸量1.94 億噸，裝量0.56 億噸，總計2.51 億噸。
1986 年卸量 2.00 億噸，裝量0.57 億噸，總計2.56 億噸。

總散裝貨：1985 年卸量1.73億噸，裝量0.33 億噸，總計2.06億噸

原油：1985 年卸量0.72 億噸，裝量4.8百萬噸，總計0.77 億噸。
1986 年卸量0.78億噸，裝量4.5百萬噸，總計0.84 億噸。

礦物產油：1985 年卸量0.22億噸，裝量12.3百萬噸，總計0.34億噸
1986年卸量0.22億噸，裝量12.6百萬噸，總計0.35億噸。

礦砂：1985 年卸量0.393 億噸，裝量0.5百萬噸，總計0.40億噸。
1986 年卸量 0.357億噸，裝量0.5百萬噸，總計0.357億噸。

煤質：1985 年卸量9.7百萬噸，裝量4.5百萬噸，總計14.2 百萬噸。
1986 年卸量11.6百萬噸，裝量5.0百萬噸，總計16.6百萬噸。

其他散裝貨：1985 年卸量30.5 百萬噸，裝量10.9百萬噸，總計41.4 百萬噸。
1986 年卸量30.6百萬噸，裝量10.9百萬噸，總計41.7 百萬噸。

總雜貨：1985 年卸量20.9百萬噸，裝量23.4百萬噸，總計44.3 百萬噸。
1986 年卸量22.9百萬噸，裝量23.3百萬噸，總計46.2 百萬噸。

為保持鹿特丹港維持在一定航行水深，需進行維護挖泥以浚深自然之沈積淤沙。由於本港為一河口港，萊茵河上游帶下來之淤泥，與北海侵入港口之沙泥，其土沙堆積量在本港每年需挖除二千三百萬公

方，因此為增加往返船隻之進港，本港之進口航道需特別浚深并保持安全之航行所需水深，因此需大量浚深淤泥與土漿。本港之挖泥主要航道由荷蘭運輸與公共工程部負責，其碼頭、港池、泊渠部份則由鹿特丹市政府負責，因為鹿特丹港務局在鹿市府屬下與工務局平行，此乃荷蘭港市合一之特色。

為使挖泥工作執行更有效率底部鏟平式之自航式吸取型挖泥船（Bottomleveller Training Hopper Dredger）乃發展而為本港經常使用，并由自動資料進行系統量取其挖泥量，經選用港外西南區新生地四個位置作為挖泥之堆置區，對於本港上游面重污染之泥漿，淤泥經特別挖深－28 米四周以沙丘作成高堤之巨大範圍為其堆置區，大約每年需挖泥一千萬公方之污染泥漿堆置于此區（Depot）本區足供本港十五年堆棄污染質之用，其污染流質部份則又於港口左側新生區設置特別之污水處理池分池過濾處理之。因此極端港內污染質另行處理而不倒入北海，為荷蘭對港內污染之一項新設施，但此項設施仍須經西德、英國、丹麥、挪威等北海環繞諸國擧定其安全性。

德福特水工試驗室(德佛斯特分所)特介

德福特水工試驗創立於 1927 年，六十年的經驗主要擅長於水資源管理，環境管制與水力學之整體範圍包括動水力學、水文、地形學等方面，1985 年元月組織編制擴大，包括七個部門，其專長為㈠河口與波浪，㈡水資源與環境，㈢挖泥技術，㈣工業動水力學，㈤水文測量，㈥港灣、海岸及海域技術，㈦河川、航運與結構方面。設備方面包括風浪水槽三座、波浪水槽五座大坐，四座小型，其他水槽十座，波浪與流況試驗池四座，率定設備三座，環流設施六座，航行與船體試驗設施五座，電腦設備計有VAX Ⅱ電腦系統、IBM4361型電腦系統、Cyber 170及175在ENR中心，Cray 1 在ENR中心，Llnivac 1100在DIV中心，HP－1000電腦系統，IBM－PC系統等。截至1985年德福特水工室已進行693個計畫，其中51％屬於荷蘭有關單位委託進行者，20％為國外委託之計畫，另外29％則為水工室本身之研究計畫，總計契約工作量達五千八百萬元荷幣，截至1985年12月31日德福特水工室職員600位，其中科技研究人員350位，助理150位，行政人員65位，計畫管理人員35 位。完成的計畫包括暴潮、港灣、海岸與海洋、河口與海洋動水力學、水質與環境衝擊、水資源管理、水力結構、河川工程與航行、及淤泥濃度研究等方面，該水工室為一健全之顧問與研究機構。

德福特水工試驗量尚包括土壤力學試驗室，土力室又分土結構—護岸、海堤、　等結構，地下結構與擋土結構，工業與都市結構、水工與海上建築，化學與環境大地工程，應用物理與地球物理等。試驗室—標準與非標準試驗室之試驗乃依據國家與國際標準執行，野外試驗包括土壤污染、分類、透水性、密度、海上地質成分、強度與變形

特性、剛度特性等試驗。其設備如標準貫入試驗卡車、輕型卡車、不同鑽筒、平台舉重器、鑽探鈴、壓力梯度量取儀，標準貫入儀整套設備以及室內、野外各項土力試驗基礎研究之儀器俱全。

德福特水工試驗室與德福特土壤力學試驗室均屬於基金水力工程試驗室，此一半屬於政府之研究機構乃由運輸工務部、科學教育部、經濟財政部等指定之董事會來管理，其成員包括政府官員、科學家、施工單位與顧問工程師之代表。本研究機構承擔應用水力研究於成本價值方面以提供為公立與私立委託單位種種不同的顧客，諸如設計師，承包建築工程者、測量師以及管理機構，此外執行基本研究計畫以輔助委託計畫之工作。目前之研究計畫中百分之四十均由荷蘭運輸工務部委託，因此執行過程中經常與該部密切研討，使研究與實際工程進行相互配合。

荷蘭三角洲計畫(Ⅰ)(Delta Project)—哈林里特壩(閘門)

哈林里特壩(Haringvliet dam)為三角洲計畫之一部份，為三角洲網路工作之北部供調整水位之用，共有三十四個閘門，其操作目的主要在控制南部地區複雜地形之水資源，主要着重在安全、水資源管理以及航行等調整其放出之淡水流量。因之，閘門之設計乃在避免水流在狹窄水道過於湍急，因為水道湍急水流容易使河堤遭受破壞、增加河床冲刷幷阻礙船隻航行。

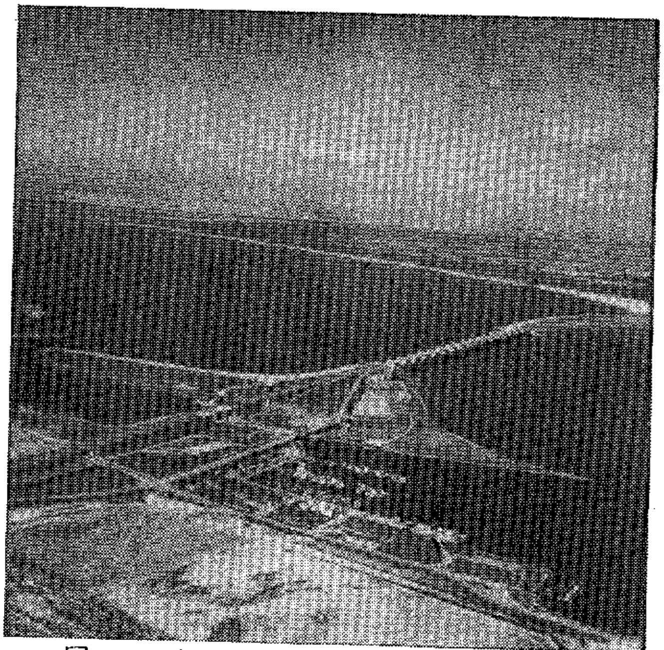
流量調整技術乃在於對閘門之最佳操作開啓放出流量，亦決定於河川上游流量與潮位情況，此流量調整計畫亦按許多因素，如淡水供應家庭用水與工業用水量、農業用水、稻田水之運行與滲流、遊樂區之用水、都市與工業廢水之輸入河川及避免海水之入侵等等。一般而言萊茵(Rhine)河、哇勒(Waal)河與馬斯(Maas)河之水位有定常之變化，而荷蘭地區之水量決定於上述三條河上游之流量，在低流量時卽萊茵河流量低於 1700m^3／sec 時，哈林里特閘門必須封閉，僅容許少量淡水流出閘門以避免河口地區之水滯流。此時僅鹿特丹港之水流出河口輸入北海，以避免海水入侵北部地區，如萊茵河流量在 1700m^3／sec 至 6000m^3／sec 間，則淡水經由哈林里特壩流入北海之量需增加，低潮時其閘門勢必逐漸提高，如萊茵河流量超過6000m^3／sec 時，則閘門需在低潮時全開，俾使過剩之淡水流入北海，以使北部河川不因過度流量加速水道流速對航行構成阻礙，亦可避免洪水氾濫。

哈林里特閘門(Haringvliet Sluice)經建造十四年始告完成，始於 1957 年，完成於 1970 年，主要在於建造矩形圍堰(1400

×600 m）高度高出平均海水位8米，其完成之鳥瞰圖如圖一所示，有6.3至24米長度不等之混凝土樁打入抽乾之海床共達22,000 支。樁上則澆置三米厚之混凝土層作為閘門之底層，一連串16座混凝土基座，每座間相隔60米建造於底層上均高出平均海水位（A.O.D.）18米高，在末端均有閘門300米寬之支牆柱。如圖二所示。

三角洲計畫，事實上乃荷蘭抵抗北海的計畫，為一雄心之計畫為圍堵大部份荷蘭西南海岸河口之計畫，以免海水入侵荷蘭低於海平面地區并防洪水氾濫，本計畫原訂於1978 年完成，後來時程改變，需將橫過東歇爾特之新設計暴潮堤完成即達成目標，因此，該計畫乃延至1986 年始告完成。

三角洲計畫不僅代表抵抗暴潮、洪水之安全牆，在壩後面形成許多自然景觀與新發展區，提供許多娛樂機會，道路鋪築連絡三角洲區至壩頂以及其他鄉間地區、以及壩內之閘門與蓄水庫在壩後形成等等，有助於鄉間大部份水資源經營管理之增進。



圖一　哈林里特壩完成時之鳥瞰圖

(a)

(b)

(c)

圖二　(a)(b)及(c)為哈林里特壩施工過程圖

荷蘭三角洲計畫(Ⅱ)—
暴潮閘門(Storm Surge Barrier)

水對荷蘭而言，是友亦是敵，住民已對它奮鬥抵抗多年，幾世紀，然後征服它并轉害成益。如促進航行、繁榮貿易，使有效應用於農業、工業方面，三角洲計畫旨在封閉主要有潮河口及荷蘭西南海岸之港口，除了鹿特丹港與安特衛普港仍保持進出口航道與北海相通。此計畫不僅減短荷蘭海岸線數百公里，且逼迫鹹水退至北海，對荷蘭整個國家之淡水經營管理有顯著的改進，自從 1953 年大洪水吞食了本區大部份面積，暴潮達十 4.25 米， 1835 人淹死以來，荷政府乃加速此計畫之執行，計按順序完成下列巨大水力工程

1958 年完成荷蘭埃歇爾 (Hollandse Ijssel) 暴潮堤。

1960 年完成詹可利柯 (Zandkreek) 壩。

1961 年完成威爾西 (Veerse) 壩。

1965 年完成格雷弗林根 (Grevelingen) 壩。

1970 年完成弗爾柯拉克 (Volkerak) 壩及綜合閘門。

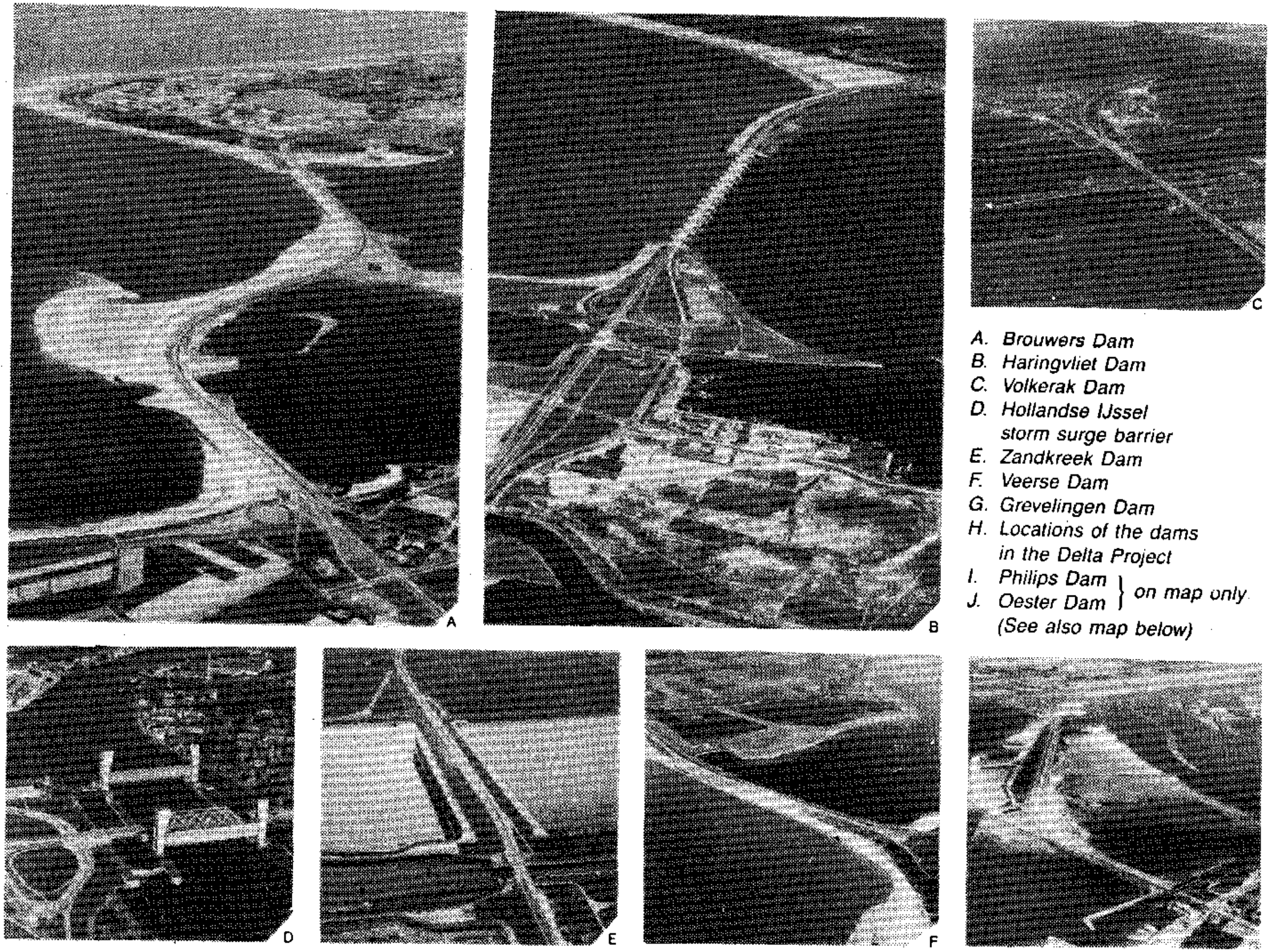
1971 年完成哈林里特 (Haringvliet) 壩及放水閘門。

1972 年完成布拉沃斯 (Brouwers) 壩。

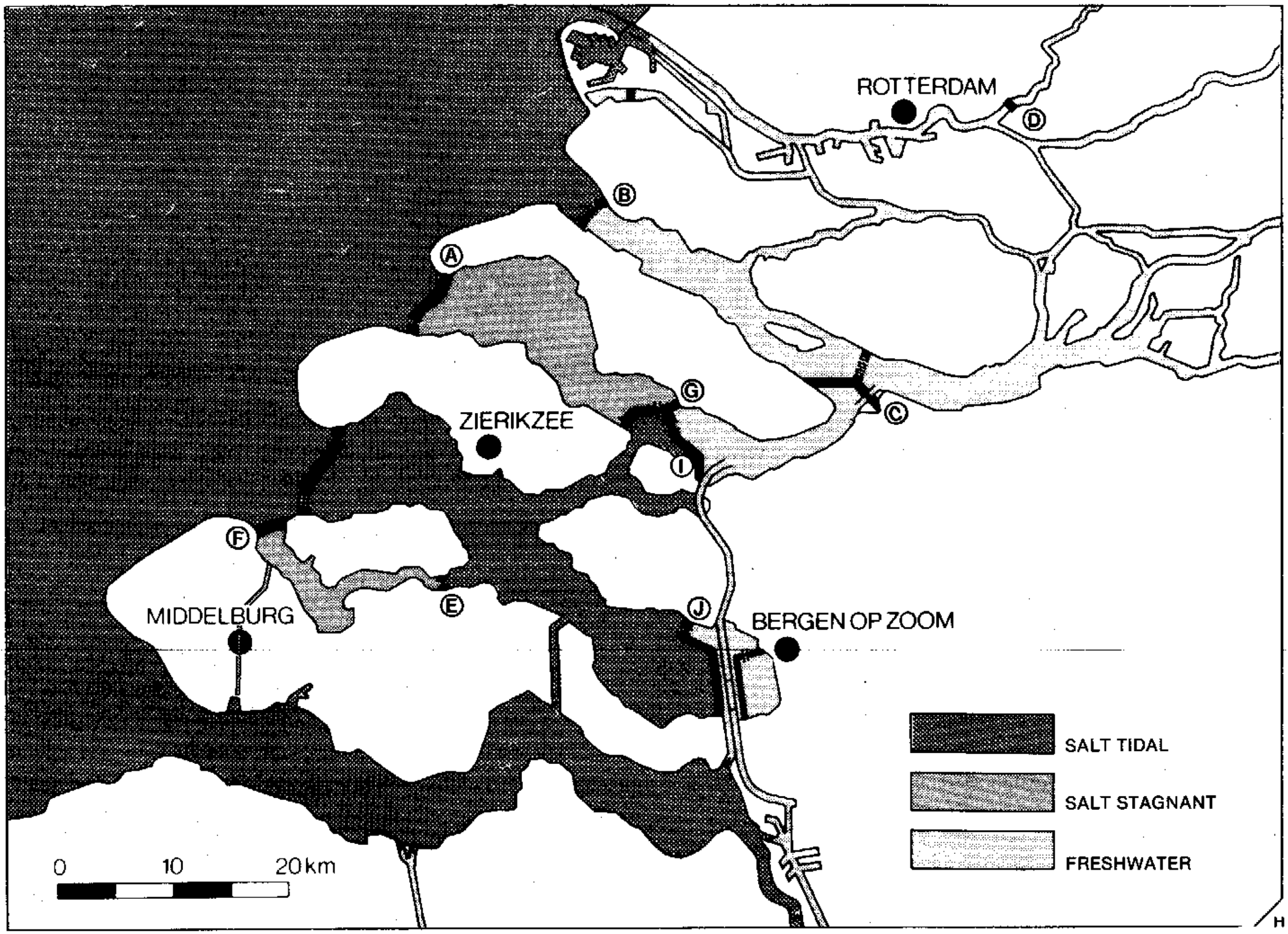
本計畫之最後部份乃在於建壩以封閉東歇凱爾特 (East Scheldt)，此乃為整個三角洲計畫最複雜的部份，即暴潮閘門 (Storm Surge Barrier) 之建造，并應用最新技術與最新工法建造兩座輔助壩，一為飛利浦 (Phillips) 壩，另一為烏斯特 (Oester) 壩，這兩座壩有雙層效用，一來降低暴潮閘門後面感潮水域面積，二來增進安特衛普與萊茵河間不受潮汐影響之航行水路。東歇凱爾特暴潮堤 (Eastern Scheldt Storm Surge Barrier) 必須建造在三條有潮水道 (又稱潮溝) 上為東歇凱爾特河口最深的部份，應用最現代技術預鑄

許多鋼筋混凝土基脚，且應用許多巨型起重船吊放二千噸之結構，其施工法及施工程序尚得抵抗潮流與環境問題遭遇之困難，從細部設計、技術之引進、施工材料之取得，施工計畫之擬定，各項施工機具之配合，品質之管制、整個計畫——暴潮堤與閘門之建造始于 1978 年完成于 1986 年，經歷了八年，完成了位於三條潮溝内 3000 公尺長之暴潮堤，包括了六十五座預鑄之混凝土基座。六十二座滑動之鋼筋閘門則裝設於其間，平常時期開啓著，暴潮來臨則關閉閘門以防止暴潮造成之洪水氾濫於三角洲與荷蘭本土。

暴潮閘門整體操作系統至少每個月需試行操作一次，俾確定閘門開啓自如，并預期一年關閉一次卽當不預期之高水位發生時，關閉與開放閘門每次均需一小時，暴潮堤之設計與建造，荷蘭水利工程技術發展之一項創舉，整體三角洲計畫始于 1958 年，完成于 1986 年，歷經四分之一世紀有餘，完成三角洲計畫後，所有荷蘭海岸之海堤亦因而均行提高堤頂，從此荷蘭一千四百萬人民生命財產，方得以保障。



圖三　三角洲計畫各種壩建造型式與位置



圖三　三角洲計畫各種垻建造型式與位置（續）

荷蘭海堤(dyke)沙堤(dune)等堤防結構之失敗分析「

海堤結構失敗之機率應用設計

摘　要

防浪、防潮與防洪之海堤結構及設計為保持水量在流域內，並使洪水或暴潮不入侵至住宅區域內。

荷蘭現場海場與堤同樣經歷無數次抵抗水災，顯示堤身與堤身完全安全者，絕無僅有。瞭解此點後，海堤、堤等防水結構系統之失敗機率評估之方法，因而引用至設計。

首先需對結構失敗力學可能發生情況與管理上、人為可能發生之錯失加以決定。然後結構失敗力學與所有可能錯失間之關係，以及洪水之最終過程、完整圖形方能，而且必須分析求深。錯失分類(Fault tree)為一很有用的工具來解決此項問題，最後將不同力學失敗之機率必須藉由機率計算(Probabilistic Calculation)法計算求得，其他發生原因則需根據歷史紀錄統計概估求出。

失敗力學與發生原因之機率可結合成錯失分類，以導出防水結構系統之失敗機率。最後，經由社會經濟觀點判斷，此機率若可接受範圍，則問題將會發生。

一、緒言

防水結構機率設計之發展與實際機率方法之應用，在荷蘭乃就東歐凱爾特暴潮閘門之設計加以模擬應用，雖然目前理論方法亦均皆知，但良好經驗配合機率法則可使設計者，對結構設計、機械設備與管理等在一種方法下均一化。目前階段，守法均已充分瞭解，但應用上僅止於困難的個案，因此，新沙堤設計管制流量乃根據機率推理，而

50米高壩之抽水蓄水計畫，目前亦按機率線來估算。

二、系統概述

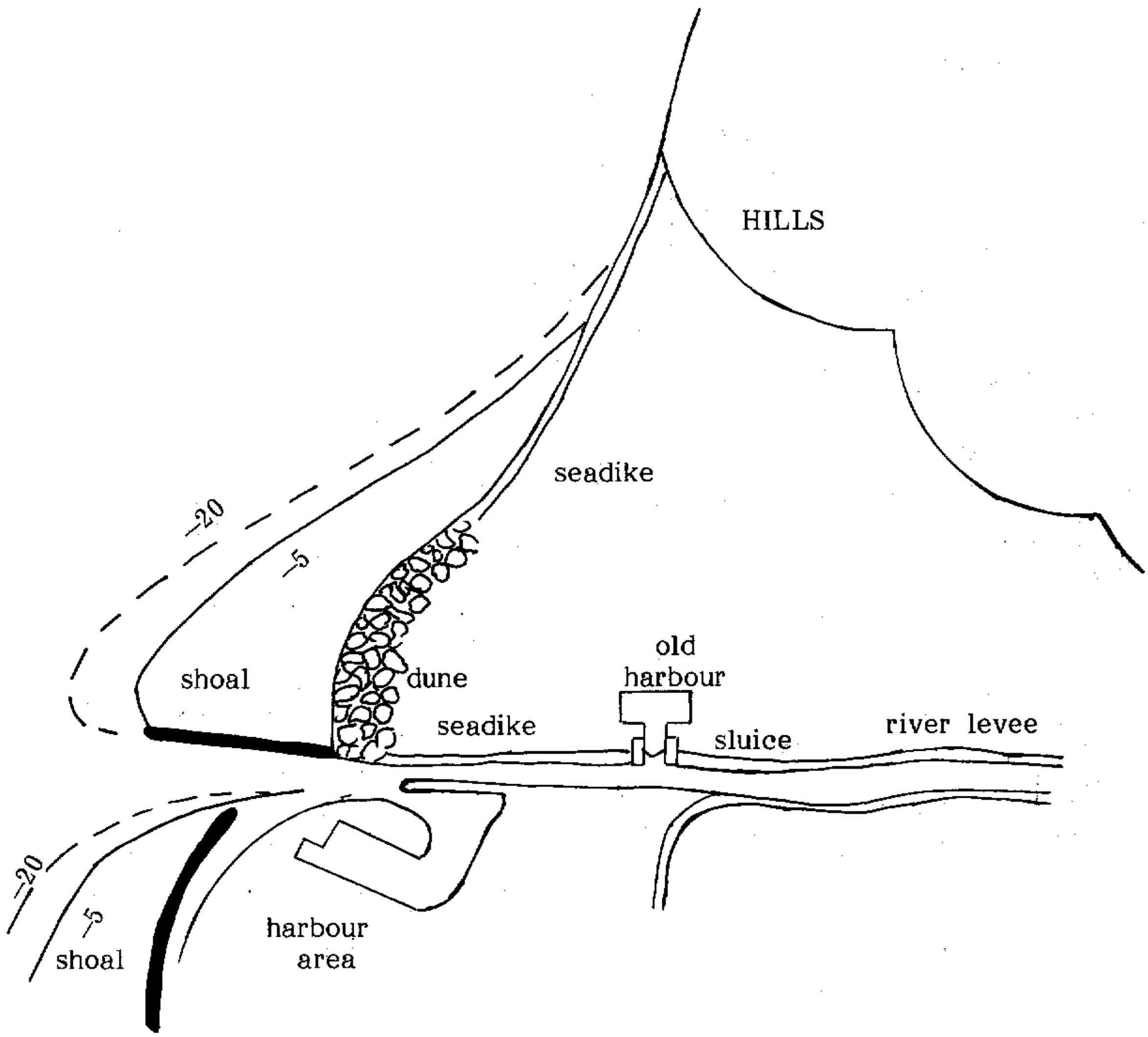
機率分析旨在證實海堤等防水結構系統之失敗可能發生原因，每一情況可能終究導致腹地之氾濫或寶貴水源之損失。一完整分析有賴於對防水詳細之敍述，包括建立檔案與堤址各項量測資料之提供，在設計階段，此項分析應簡化、圖表化。

本文儘量將荷蘭之洪水防制系統以圖表化敍述。荷蘭大都位於北海低潮位，甚或低於低潮位。為抵抗北海來之暴潮、洪水，其防制系統包括海堤與沙堤。海堤部分作用在防止波浪入侵淤淺港口、航道。如圖一所示。

此系統沿着河流繼續延伸。此處海堤逐漸由海堤變成河堤，其延伸部份至潮汐運行達河川上游面位置而告中止。沿着河流之堤防有閘門作為與舊港口之通路。此閘門在水位超過平均高水位時需予以封閉。主要港口則位于海堤之外，因此，當高水位來臨時，港口與本研究無關，不受影響。近代荷蘭海堤之典型斷面包括沙層，以瀝青與不織布墊在海岸區面鋪設，以防波浪與流況之侵蝕，堤頂及背海面之坡度均覆蓋粘土層上面種植草皮，詳如圖二所示。沙堤（dune）則自然堆積沙而形成自然坡度，如圖三所示，已達動力平衡標準河堤斷面則如圖四所示。

三、堤防失敗力學分析

良好工程設計需注意建造時所有可能發生之失敗模式，對于混凝土或鋼結構之設計僅使用一般傳統的設計法卽可。在設計防水結構諸如壩，海堤及沙堤等，其設計法則與機率推理合併使用。此乃在東歐凱爾特暴潮堤之應用機率設計法之實例。



圖一　海堤、沙堤與河堤示意圖

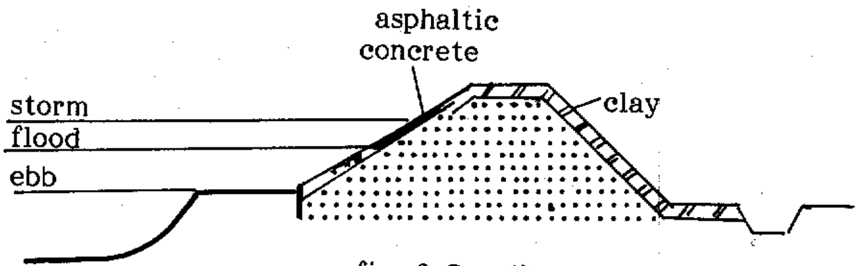


fig. 2 Sea dike

圖二　海堤

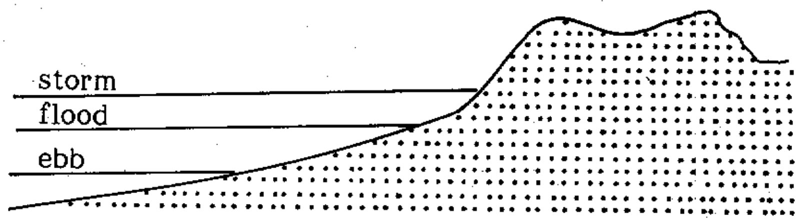


fig. 3 Dune

圖三　沙堤

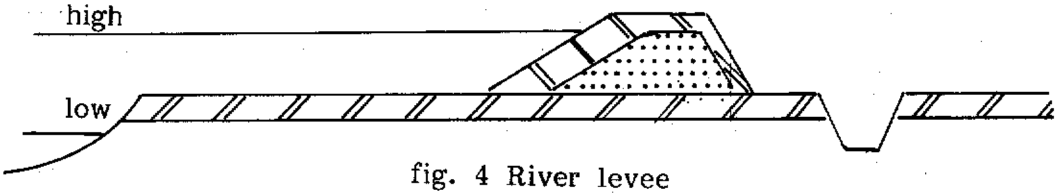


fig. 4 River levee

圖四　河堤

堤或海堤之失敗力學解說如下：

(1)越波（Wave Overtopping）——導致海水侵入農田，並使海堤起泡。堤內側坡度遭受侵蝕。此項越波影響較小者稱為洪水溢頂（Overtopping）

(2)沈陷（Settlement）

(3)外側坡度圓弧滑動（Slip circle outer slope）

(4)內側坡度圓弧滑動（Slip circle inner slope）

(5)液化（liquefaction）

(6)小型不穩定（micro instability）

(7)漂冰（drifting ice）

(8)管湧（piping）

(9)船舶撞上堤頂（ship collision）

(10)滑動（Sliding）。

(11)外側坡度冲刷（erosion outer slope）

(12)傾斜（tilting）

(13)前灘侵蝕（erosion foreshore）

海堤失敗力學之草圖如圖五所示。

沙堤（dune）之失敗力學則如圖六所示。

沙堤之失敗力學與海堤情況極其相似。外側坡度之侵蝕則有顯著不同，沙堤坡度之堤身因均為沙填實，在暴潮侵襲時，則形成特別形狀，即構成「暴潮海灘剖面」（The Storm profile），當此剖面形成的過程中，沙堤的沙則被暴潮回流時帶至前灘區填平此段之剖面，沙堤的沙並無損失。由於堆積與冲蝕之交互作用，沙灘之基腳繼續在改變。沙灘不同運行現象之產生，其運行過程大約有堆積、侵蝕與動力平衡等散亂程序。在設計過程，最着重者乃在於其達到之最終狀態（Ultimate limit State 簡稱 U.L.S.）——即沙堤失敗力學後，

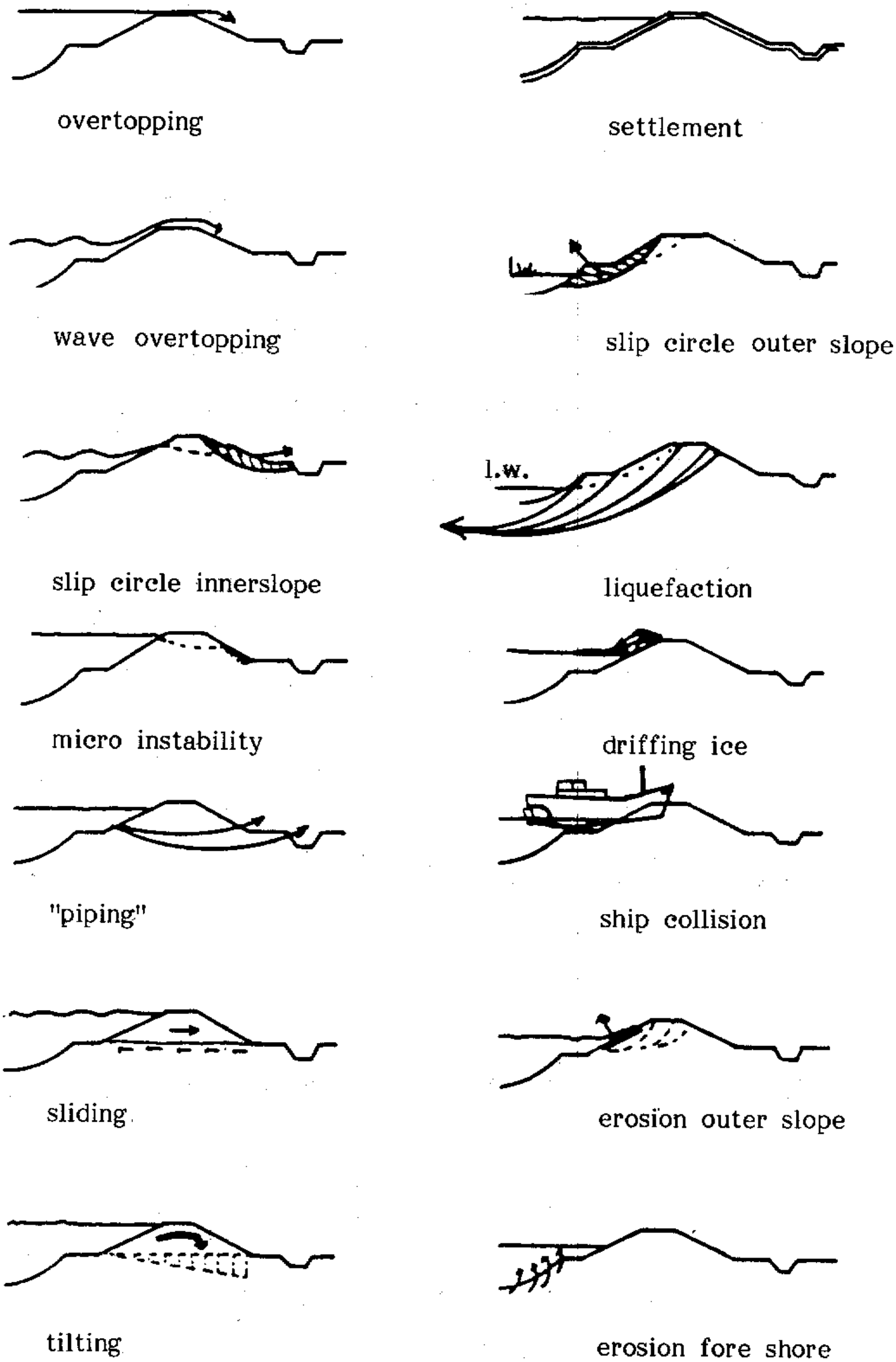


fig. 5 Overview of the falure mechanisms of a dike

圖五 海堤失敗力學示意圖

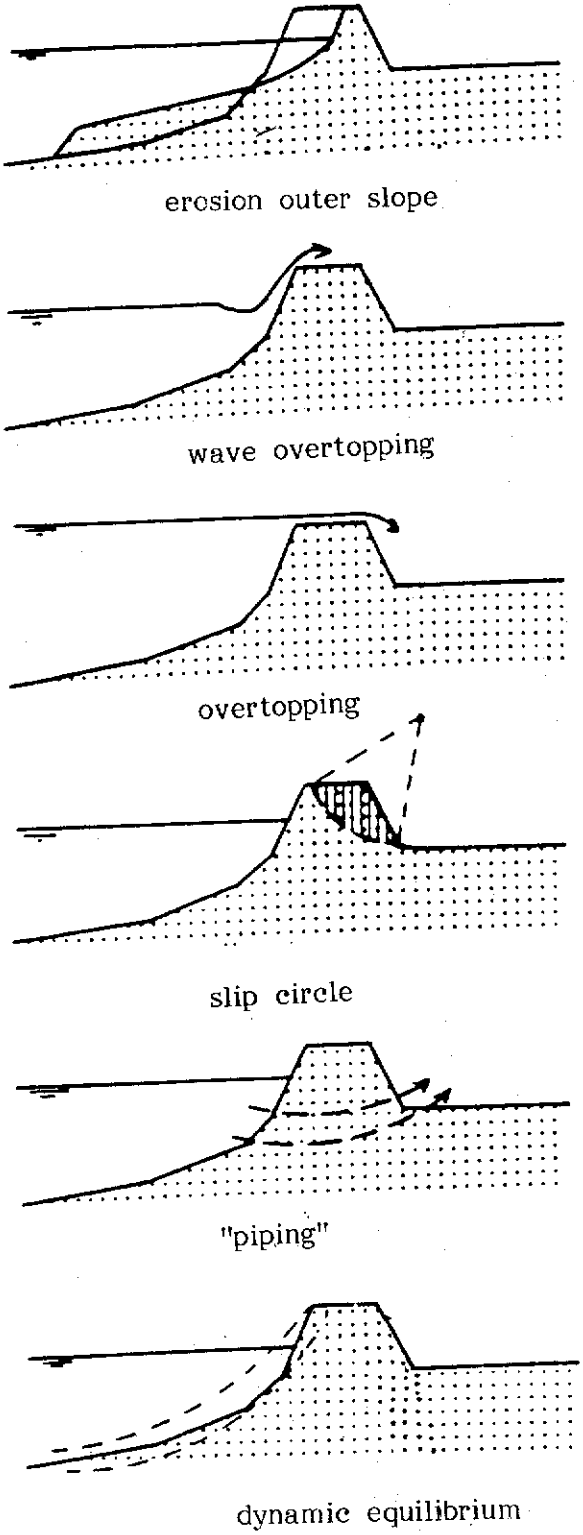


fig. 6 Failure mechanisms of a dune

圖六 沙堤失敗力學示意圖

其沙灘之最終狀態。此狀態為作用之極端負荷S正好與建造之強度R相平衡。假定最終狀態超過建造強度，則沙堤必會崩潰或失敗。最終狀態之觀念則如圖七所示。

最終狀態分析之應用最重要可有下列兩點益處。

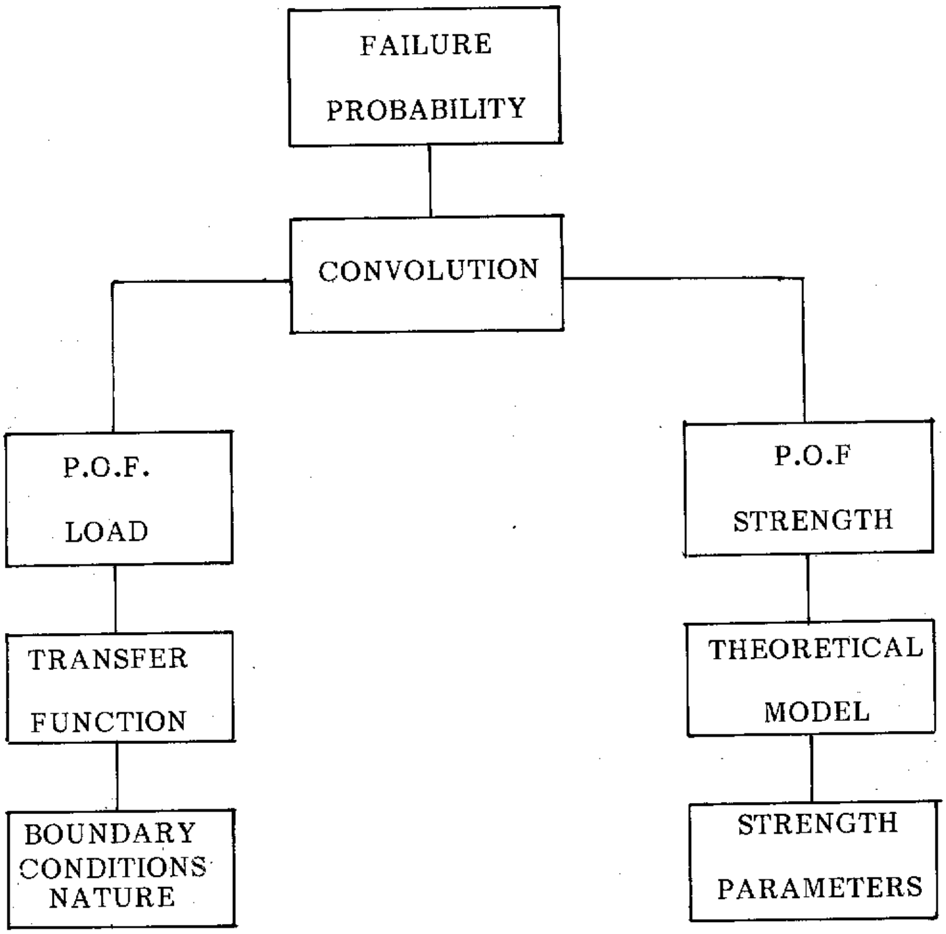
(1)在沙灘之沙堤防護過程中可增進對抗失敗力學之阻力，以保證足夠強度。

(2)阻力之崩潰狀況可藉由檢測與維護過程獲得控制。

海堤斷面之失敗與失敗力學之極限狀態，則可由圖八獲致更詳細分類之分析。

四、結論與建議

荷蘭由於其本身國土一半位於海平面之下，因此海堤（dike）、沙堤（dune）甚至閘門（Sluice）之設計有豐富經驗，因此，經分析海堤與沙堤之堤防結構失敗力學後，可供我國借鏡良多，尤其應用機率分析，亦為我國設計海堤時可考慮之一設計法。



圖七　沙堤最終狀況（U.L.S.）之觀念

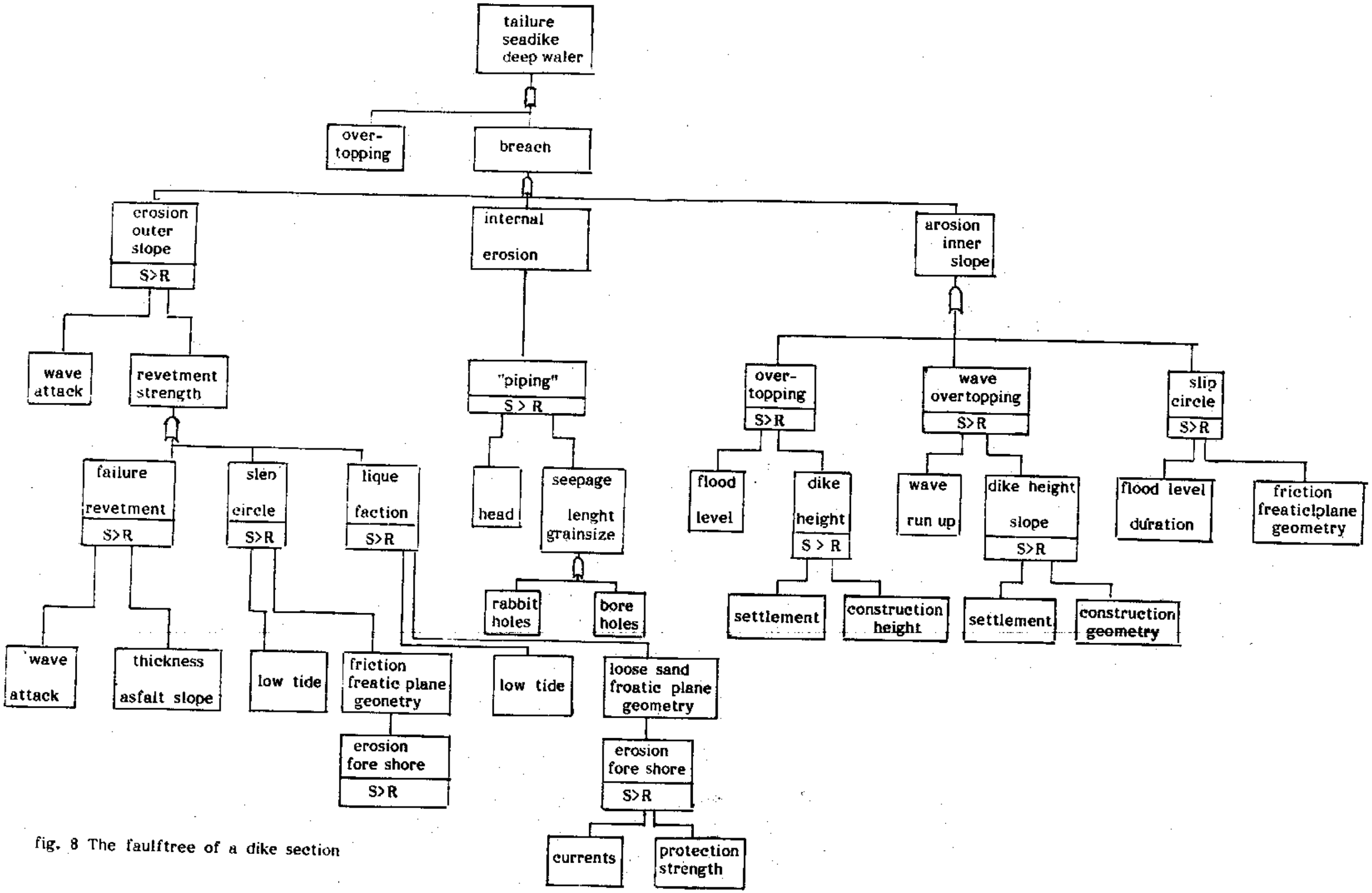


fig. 8 The faulftree of a dike section

圖八　海堤（ dike ）斷面之失敗分類

(ⅠⅤ-2)台灣地區海堤工程之現況發展

壹、台灣海岸概況

台灣全島海域，均屬正規日雙潮地區，一般說來東部海岸潮位較低潮差也小，西海岸則因受海峽地形影響，潮位較高，潮差也大，中部地區潮差甚已高達五公尺以上。

本島冬季有東北季風，夏季則常有颱風吹襲，因此沿海地帶常易受風浪為害，一般說來，東海岸及西南高屏沿海緊鄰深海，深海波浪直襲海岸，受波浪威脅較大，西海岸因海埔地發達，海灘延伸較長，深海距岸尚遠，故受波浪威脅也相形減少。

就全島各沿海地區地形而言，北海岸群山面海直立，岸線曲折參差，且因風浪長年侵襲，海蝕地形柱為發達，海拱、海穴、豆腐岩、燭台石、波切台地等隨處可見，蔚為景觀。西北海岸線平滑，因其走向與東北季風平行，故海岸飛沙常堆積形成沙丘，其上常植有防風林以為保護。中西部海岸平原廣闊，海底坡降平緩，且因多條大河川大量輸送泥砂流下，並沈積於河口且受海岸漂沙及飛沙作用，海岸普遍堆積形成海灘地，西南海岸自曾文溪口起轉北北西走向，其北半段特多沼澤及潟湖為其特點，海灘常因冬、夏季風向不同，形成冬淤夏刷之現象，自高屏溪以南之南半段海岸屬於輕微下降狀態岸線甚為平滑，因緊鄰深淵，河川輸砂直衝入海，無法形成海灘，東部沿海中花蓮、台東海岸皆屬陡峭之斷層海岸，海岸線平直，因受太平洋波浪之侵襲而呈侵襲狀態，但一方面却也呈現上升現象，惟已達早期之成熟狀態，故不易形成平原地區，蘭陽地區海岸線呈平滑而略內凹之曲線，其地勢甚為平緩，且屬全面後降區域，故有排水不良問題。

貳、台灣海堤概況

綜觀台灣海岸概況可知淡水河因石門水庫之興建與淡水河床砂石之採取致供給之泥砂來源減少，故淡水河以南至南崁溪河口一帶，屬侵蝕性海岸，而彰雲嘉南沿岸一帶海岸線普遍呈淤積現象。曾文溪以南常成冬淤夏涮現象，又因曾文溪泥砂來源減少，仍屬侵蝕性海岸，故在侵蝕性海岸更迫切需要興建堤防以資保有國土資源。

早期海堤之興建視地方需要或私人投資，興建土堤植草條，其斷面狹小簡陋，且無規則，不勘一擊即潰堤而泛濫成災。嗣後水利局成立海堤規劃總隊，負責全省海堤之規劃，并提出計畫報告書，作為爾後興建海堤之藍本。

近幾年來隨著經濟增長，社會活動頻繁，人民要求提高，以及施工技術等之改進，由簡陋之土堤，改變為混砌塊石或混凝土之堤坡，坡度也由１：１.５轉變後為１：４以下之後坡度，護脚工也由塊石改進為噸級以上之混凝塊，更依各河段侵蝕情況，必要時再以實堤或其他構造物配合保護之。

叁、目前台灣海堤辦理情形

目前台灣省海堤整建新建均列入十二項建設計畫或十四項建設計畫中辦理，按呈報行政院核定有案之重大建設第九項河海堤排水計畫，依擬定之年度計畫逐年執行。

除辦理十四項建設計畫之海堤工程外，亦辦理下列海堤工程。

㈠因養殖漁業超抽地下水引起地盤下陷辦理之海堤工程

屏東、雲林、嘉義等地區近幾年來因養殖面積快速增大，而超抽地下水，致屏東縣林邊、佳冬地區地盤下陷二公尺以上，雲林嘉義等沿海地區亦下陷一公尺以上，致原有堤防高度不夠，海水倒灌，水質污染與排水不良等情形之發生。

1 堤防加高加強工程

屏東縣林邊、佳冬等地區因地盤下陷，水利局由民國67年至75年陸續辦理該地區海堤加高加强，修復及延建等保護工程二億多元。詳如下表：

表 1　塭豐地區歷年海堤建設工程費統計表

項目 / 年度	工程費（萬元）	工程項目 新建（m）	加高加强（m）	搶修（m）	其他
塭子防潮堤（69年）	1,986	720			排水閘內，防潮閘門各乙座
塭子林防潮堤（71年）	259		300		
塭豐海堤（67年）	485	850			
〃（68年）	1,925		修復 750	655	
〃（69年）	566		100		實堤4座
〃（70年）	4,755	2,000	850	30	
〃（71年）	557	266	1,350		
〃（73年）	581		3,066	20.3	
〃（74年）	1,406				
〃（75年）	8,654				離岸堤8座
合計	21,174	3,836	7,266	705.3	

2. 海水溢堤倒灌

雲林地區亦因地盤下陷，由北港溪以北之海堤，也陸續辦理加高加强、修復等工程如下崙海堤由68年至75年間經檢測結果下降的一、二公尺，致韋恩颱風，又遇高潮而潰堤冲毀魚塭。迨76年度下崙海堤已整建完成。

3. 海水倒灌

75年韋恩、艾貝颱風路經雲林地區，因地盤下陷，致牛排灣排水之排水堤高度不足又適逢潮位高漲，乃引起牛排灣排水位高漲而潰堤多處，致海水倒灌，於是除動用民工搶修外，辦理復建工作。另由水利局擬定災害復舊計畫報告書。本案正申

請專案工程，擬予以實施。

二、興建海堤與養灘工程

一般民衆甚至民意代表等，均有嚴重的錯誤觀念，都認為只要興建海堤，該地區就可獲得相當的保護，殊不知在侵蝕性海岸，只有硬體之構造物（海堤）恐難維持其灘地，故必須配合養灘之工程設施，始可防止海岸之侵蝕。

1. 離岸堤工程：

(1)屏東線林邊、佳冬地區由於地下水超抽造成地盤嚴重下陷，村內道路與房屋大半低於海平面，海水與陸地之界限僅為一條狹窄海堤，居民長年飽受海浪威脅。然因本段海堤前灘坡度陡峻，碎波波高變大，底床流速隨之增加。冲涮力量較大，加以整個區域地盤繼續下陷，原設各種防潮保護措施效能減低，已難發揮保護效果。故亟需進一步採取有效之防護對策。水利局乃委請國立成功大學作水工模型試驗，結果建議施設離岸堤工程，不僅能消滅部份波浪能量，以保護現有海堤不為波力所擊毀，且能發揮堤後堆砂作用，產生新海灘，以達到安定海灘及保護海堤之積極效果。

本工程總工程費約五仟七百餘萬元，於民國七十六年三月全部完工。

叁看塭豐離岸堤工程佈置圖及標準斷面圖

(2)地質惡劣之斷崖海岸：

高雄縣赤崁海堤早期興建海堤，因斷崖上層雨水滲透，加上波浪冲擊堤脚及侵蝕，斷崖崩塌而潰堤，嗣後經日本學者上森教授指導改建離岸堤工程，不僅可消滅波浪能量，且在離岸堤後產生新海灘，以安定前灘并防止斷崖海岸繼續崩塌。

2. 突堤群養灘

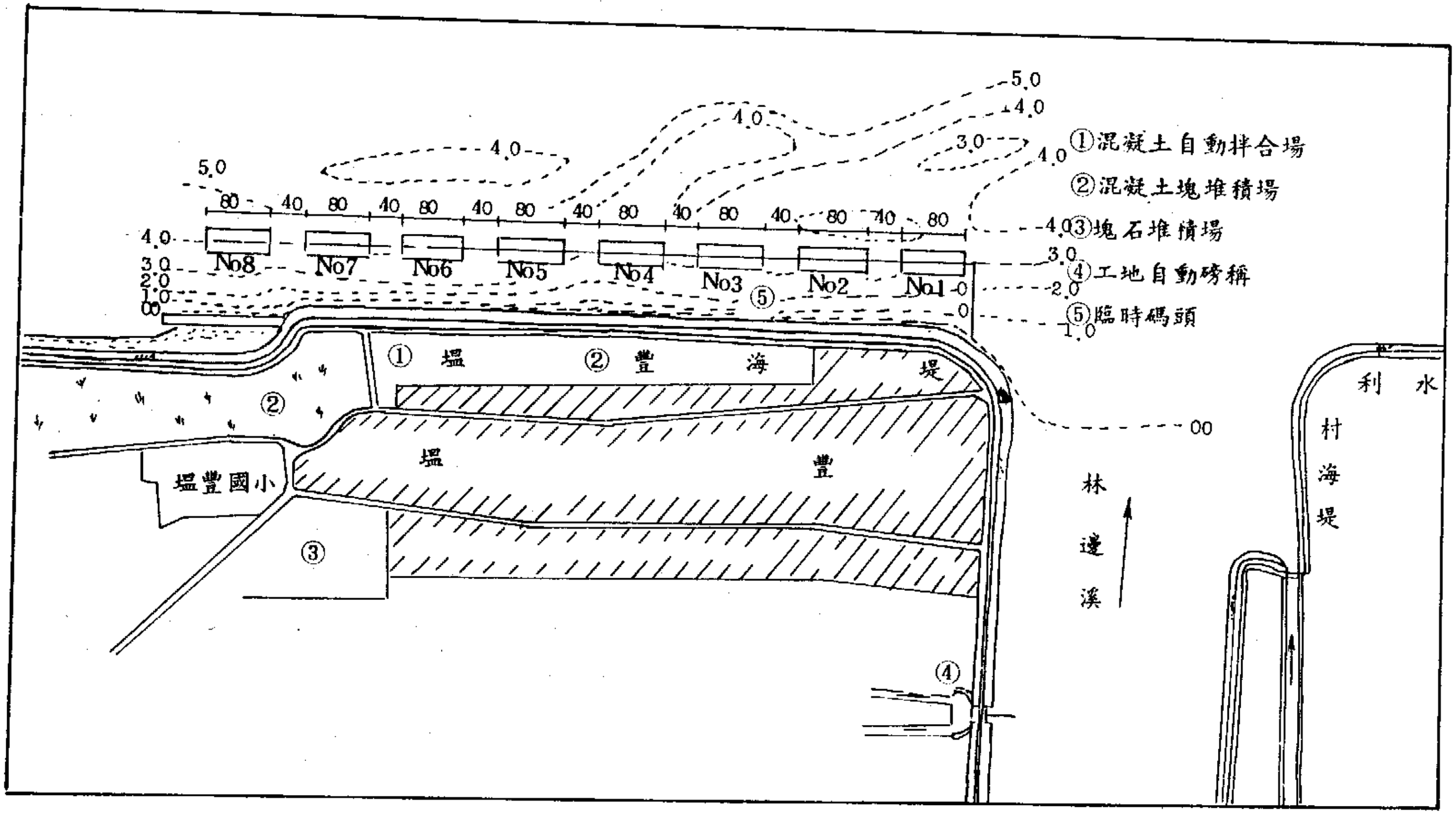


圖 3-1 塭豐海堤及離岸堤之佈置圖

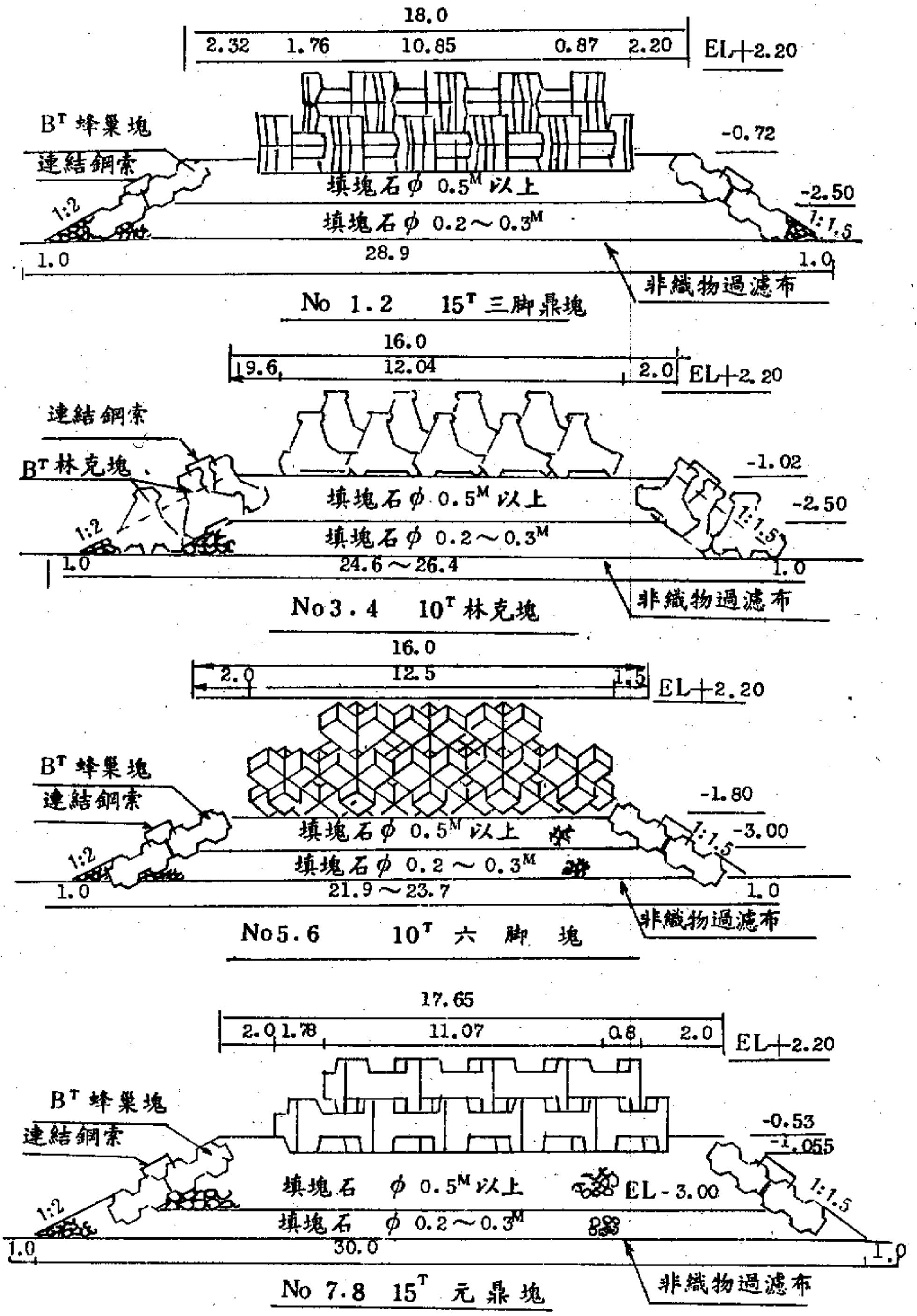
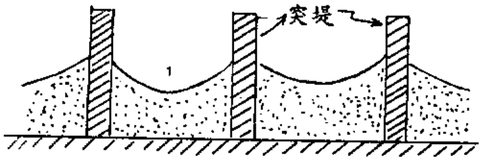


圖 3-2 離岸堤標準斷面圖

海堤前灘之坡度雖平後，惟波浪碎波波高仍大，冲刷力量也較大，加上受漁港防波堤之影響，致原有海堤保護堤脚之塊石或混凝土塊被淘空下降，於是需興建實堤群，以消滅波浪能量以保護原有堤脚工程，并造成新海灘，使其發揮保護海堤之效果。如雲林縣箔仔寮漁港北側之箔仔寮海堤。



3.養灘計畫工程

水利局於民國65年間於高雄縣林園鄉西溪海堤附近之侵蝕性海岸抽砂堆成沙丘，然後將沙丘圍籬笆并覆蓋乾草於沙丘面，再種植馬鞍籐草及林投樹以安定沙丘，結果雖地方居民未能配合保護植生作物，故植物未全部成長，致飛沙彌漫住家，引起居民不滿，惟此沙丘仍相當穩定，迄今該段海岸仍未興建海堤工程。可見已發揮其效果。

荷蘭國家亦曾抽砂堆積砂丘，以安定海灘惟彼國之沙丘仍侵沒於水中，經檢測結果的流失40%，其餘60%仍穩定，可見有其成效，故彼國也列為養灘工法之一。

三海岸地區興建重大工程後對臨近海岸之影響

電力公司於興達港興建核子發電廠，與中油公司天然氣轉運站設置於阿公店溪河口北側後，附近沿海地形地貌完全改變。

1.興達港核子發電廠建立後永安村附近地盤下陷，致原有引水排水兼用之渠道無法暢通必須改善，且全村蒙受淹水之苦。

2.中油公司天然氣轉運站（ＬＮＧ），抽砂填灘地及興建防波堤後影響南側阿公店溪河口之淤塞，又距防波堤二公里多之天然屏障沙丘，也嚴重受侵蝕，又右側之永安村海岸也因防波堤之影響嚴重侵蝕，省水利局乃逐年編列預算辦理海堤之興建，永

安海堤即由中油公司先墊款九千多萬元辦理完成。

四導流堤工程

河川出口常因河川帶來多量泥砂與海岸地區漂沙、潮流、風向等錯綜複雜之關係後形成出口段流路蜿蜒曲折始流入海中或將河口淤塞，影響區內排水等問題，乃於河川出口段興建導流堤將河川流水整流導入海中，以解決區內排水洪泛問題。如宜蘭縣得子口溪河口之導流堤工程。

五防潮閘門工程

宜蘭縣冬山河因潮水流入影響該地區之農田耕作與排水不良，倘遇洪水即泛濫成災，淹沒多日，排水仍無法排成，乃在五結地區興建防潮閘門乙座，控制海水之侵入，并暢洩該地區之排水，以改善農田耕作及解決區內排水問題。

屏東縣林邊、佳冬地區之排水閘門與防潮閘門，因受地盤下陷影響於69年曾改善，迄今尚可發揮其效果。

伍、結論與建議

(一)海堤之設計應予以提高

本省海堤工程設計堤頂高度係採用最高暴潮位加波浪潮上高度，再酌加出水高度，而荷方所採取之出水高度較高相當於約五公尺，本省因採用出水高度不足致地盤下陷後即有溢堤潰堤之危機，如韋恩颱風時雲林縣之下崙海堤因下陷1.2公尺，再加上適逢高潮乃有潰堤現象之發生。故建議地盤下陷地區應加寬堤寬以便海堤將來加高加强時有足夠之用地，以免因工程用地之無法解決，而海堤工程難以執行。

(二)擴大增設氣象等觀測站網（地下水文觀測站網）及資料處理中心

目前全省海岸氣象觀測站不多，其他海岸侵蝕、淤積等觀測網查資料也相當欠缺，致辦理規劃時到處找尋不著基本資料可提

供，以便分析檢討，故將來辦理工程設計，佈置工法時，難以獲得正確判斷資料。

㈢沿岸地區興建重大工程後，對臨近海岸負面影響之檢討

計畫辦理重大工程之前，應加以檢討分析并預測將來興建後對臨近海岸之環境影響，確實評估，以免興建後發生非議、怨言以及無謂之困擾，再有補救設施的情形發生。

㈣養殖用水建議海水集中抽水站

現今所有養殖業者各自由海堤鑿井抽取海水（可防止抽取污染之海水），而抽水管即沿海堤坡橫過水防道路引進輸送至魚塭，經長期抽取後，地層將被淘空而下陷成為海堤危險段，萬一波浪冲擊，而發生潰堤，即水防道路上水管阻碍搶修車輛的行駛，其所發生之災害，更難以想像。為減免這種危機，擬將全部養殖業者現有各自私設之抽水井封閉，計畫興建集中海水抽水站，替代原有私設抽水井，抽取海水供應，消除因在海堤邊抽取大量地下塩水所造成之海岸構造物下陷，侵蝕海岸及國土資源之損害。

屏東縣林邊、佳冬地區經水利局規劃結果，擬將該地區分為四大區設立抽水站17處，加壓站44處，全部工程費需426,747,000元。詳如右表。

各區工程費

第一大區工程費	75,372,000 元
第二大區工程費	171,398,000 元
第三大區工程費	110,893,000 元
第四大區工程費	69,384.000 元

附件五：

台灣地區海岸之經營管理與荷蘭沿岸情形之比較

侯和雄

交通部運輸研究所運輸工程組組長

I、台灣地區沿岸工程開發現況

台灣為中華民國海島一省，其經濟發展與海岸、海洋工程有著密切之關係，台灣地區海岸、海洋工程貢獻於經濟發展上可包括（一）有用陸地面積之擴張，（二）外貿輸入、輸出之港口建造以及漁港之漁業發展，（三）外海平台鑽油與海洋資源發展，（四）海岸地區防制海灘地區之侵蝕等保護工程、其他諸如暴潮與海灘巨浪侵襲之防制等。台灣沿岸在過去卅年來所獲致之主要成就可概述如下：

(1)潮間帶與新生地圍墾

總計有 5,121 英畝之潮間帶新生地圍墾為農業用地，養魚、蝦池、鹽田以及住宅，此外，有 1,277 英畝圍墾為養殖用途。另一方面，政府亦於 1978 年開始進行彰化濱海工業區開發計畫圍墾 6,292 英畝之潮間帶新生地供工業用途。此計畫由於經濟不景氣與環境衝擊問題於 1984 年停頓下來，希望此計畫在不久將來即又復蘇。

(2)港口碼頭與外海卸油站之建造

為紓緩貨運航行之擁擠，對於現有之基隆港與高雄港，除幫助其本身之營運發展外，政府並於 1971 年開始執行其長程計畫，包括現有國際商港－基隆港、高雄港與花蓮港之擴建以

及新國際商港一台中港與蘇澳港之關鍵、國內港安平港之興建以及漁港、漁澳之擴充發展。在這些新港中，台中港的規模最大，它是一人工港，位於台灣中西部海岸上，總面積為卅平方公里，大約十公里長，三公里寬，佔據在原海岸線西側防波堤之間。第一階段工程於 1976 年完成，後續工程繼續進行時，本港即開始通航營運。

至於漁業發展方面，台灣地區大約有 1,5000 艘漁船、153 個漁港漁澳。近幾十年來漁船有變大型化趨勢，大部份漁港與漁澳均有水深不夠與船渠空間不足之問題發生，為改進此一情況，省漁業局在最近完成九年計畫。第一階段為現有漁港之擴建與新漁港之興建，第二階段正進行中。

我國每年進口巨量石油，因此而有輸油站之建立。該輸油站乃提供油輪卸油之用。一卸油浮筒建於台灣北部深澳灣內。另兩座單點碇泊卸油站，一安裝於桃園沙崙外海，一則安裝於高雄大林外海。經這些年的經驗，單點碇泊似較多點浮筒碇泊適於大型油輪之卸油作業。

(3)外海石油探勘與發展

我國對於海洋資源深測與發展不遺餘力，尤其對於石油或油氣之鑽取與挖掘，從 1973 年開始發展至目前新竹外海長康計畫、鑽油甚為成功。有些油井已開始生產供應至市場。計有三種不同之鑽油海域平台結構、主要為(一)混凝土重力型，(二)張力基脚型(Tension-Leg type)，及(三)基樁支柱之鋼架型(Pile-Supported Steel Jacket Type)等曾被考慮在台灣沿岸外海建造成海域鑽油平台；經審慎研究後，基樁支柱鋼架乃被選定並建造於鑽油域區域。

(4)電廠熱排水環境衝擊之降低與冷卻水效果之增進

我國許多電廠—火力電廠與核能電廠均建造於台灣沿岸地區。俾方便使用海水作為冷卻水。其結果，它們的溫排水將增加海水的溫度，影響海洋生態環境，因此電廠之進出水口均經過審慎研究、規劃與佈置，俾減少熱排水對附近海域環境之衝擊；並因而增進電廠冷卻水之冷卻效果，截至目前，許多計畫均完成其環境影響評估，俾瞭解電廠熱排水之環境衝擊，加以改善消除。

(5)海岸對於海灘侵蝕、暴潮與波浪侵襲之保護

台灣地區海岸線總長 1,100 公里，台灣陸地週圍受太平洋、台灣海峽與巴士海峽環繞著，其中有 481 公里之海岸屬于侵蝕範圍受海堤保護著。台灣西北與西南海岸因河川輸沙不足，與平均海平面上昇，或地盤下陷導致海灘侵蝕。台灣南部海岸在過去廿年平均海平面上昇廿公分。同時，南部海岸最嚴重之地盤下陷量達 2.3 米之多。平均海面上升與地盤下陷造成海灘侵蝕量其垂直與水平比值，由 1 ：15至1 ：25不等。

(6)我國海岸與海洋工程之研究發展

大學研究所、專業研究機構—交通部運研所、氣象科技中心、電信所及省港研所等對于海岸與海洋工程之研究已卅餘年，其研究成果並已發表在國際海岸、港灣與海洋有關之學術研討會，刊登在各項會議之論文集內。國內土木水利學會海洋工程委員會，則每年舉辦海洋工程研討會，俾交換研究新知與數值、試驗之成果、大抵可分列如次：

(a)水工模型試驗—台中港固定床波浪遮蔽試驗與漂沙活動床水工試驗已在十六年前成功地在台中港水工模型試驗室完成大比例尺之試驗，其室內大型試驗池（ 60 米 x 43 米 x 1 米 ）提供各項試驗之設備、港池盪漾、進出水口熱擴散試驗

亦在該試驗池內完成。

(b)固定型突堤、多種浮體碇泊與單點浮體碇泊系統均作分析及試驗研究，最後結論認為單點浮體碇泊系統較為適合為實際裝設用。

(c)海域平台三種型式，經研究分析後，認為基樁支柱鋼架型最適用乃選為台灣地區鑽油之海域平台建造用。

(d)台灣海峽淺海波特性與預測方法，不斷研究創新，波浪計算法並應用實際氣象資料加以修正印證並改進。

(e)平均海平面變化之研究，結果顯示台灣南部沿岸平均海面在過去廿年當中上升廿公分之多。

(f)國際商港、重要漁港港與海岸保護系統之佈置與規劃，均經水工模型試驗加以研究修正。

(g)港域污染不僅作現場調查分析，尚且經由數值擴散模式與擴散模型進行研究。

II、荷蘭沿岸工程開發與技術發展

此次「參與荷蘭沿岸開發與管理研討會」，工程方面值得一提為三角洲計畫、海堤(dike)、沙堤(dune)與閘門(sluice gate)之建造，鹿特丹港外港擴建與污染防治，另外如德福特水工、土力試驗室等之研究發展均值得我國借鏡。茲將其沿岸工程開發與技術發展摘述如次。

(1)三角洲計畫

此項計畫始於 1957 年，完成於 1986 年，歷時卅年之久為荷蘭水資源之開發，經營與管理技術上發揮極致。其防災計畫一抵抗暴潮，洪水等建造海堤、暴潮堤、河堤與閘門等保護與圍堵設施，並應用機率設計法亦為一項新創，深深感佩荷蘭

在水利工程，尤其防水結構物之設計與建造技術之研究發展。

(2)鹿特丹港污染防治與北海油污染控制

海洋環境保護與港灣污染防治為我國海岸開發管理刻不容緩須解決之問題—高雄港重金屬與污水，廢水之污染極需整治，目前鹿特丹港對于萊茵河排下之廢水、淤沙污染防制之作法值得我國借鏡參考。鹿特丹港當局每年浚渫泥量約二千三百萬公方，為萊茵河，北海，該港港池與河口帶來之污染，研究結果認為污染性浚渫物質之處置以堆置於陸地或湖泊中處理儲存應用，較諸傾倒海洋為佳。因為控制海洋之污染擴散幾為不可能，且影響海域生態環境。故荷蘭港務當局一再研究其處置方式之長期規劃，並圍堰作中期之填放拋棄地點，以解決未來十五、廿年間大量污染性淤泥處置。且荷蘭鹿特丹港、市當局對各污染情況作長期性監測，以保護海岸環境之生態不受危害等之研究，為目前港灣污染防治之一最佳實例。

荷蘭使用飛機及遙測技術監測海洋油污染，執行單位為荷蘭海岸巡防隊與運輸、工務部所屬北海總署，該單位並發展一種掃油臂的機具以回收海上洩油。於惡劣天候或油污殘留於淺海處時用化學藥劑處理，有時以飛機噴射油處理劑，其他尚有各種回收油之機具。對于北海及各港與沿岸地區之海洋水文資料與污染情形，荷蘭當局有完善之監測系統並有 24 小時待命之海岸巡防隊監管，此為我國所欠缺，應協調有關部、會、署建立類似系統與執行單位。

(3)海埔地開發

荷國地勢低低窪，一半以上土地低於海水面，需有海堤、沙堤與暴潮堤保護，否則即為海淹沒，歷世紀來荷國人民與海搏鬥乃為保持土地乾涸加以利用。據荷政府統計，自 1200 年

至今，海灘開發之海埔地達 380,000 公頃，以內海開發之海埔地達 140,000 公頃，合計 520,000 公頃。同期間因洪水侵襲而流失之土地則達 570,000 公頃。縱然荷國對海埔地開發不遺餘力，仍損失 50,000 公頃。台灣沿岸地區海埔地開發條件比荷蘭良好甚多，但荷國之開墾、經營技術，值得借鏡。荷國瑞達海（Zuyder Sea）之封閉計畫于 1920 年執行以來，其開發計畫為荷蘭海埔地規模最大者。其計畫目標為①防止洪水（包括海岸災害）②增加水資源（以淡水湖蓄水）③增加農地面積。主要工程為切斷北海與瑞達海，因此需建卅公里之海堤以隔開海水與淡水。計畫完成後農民每人分配之土地約為廿至六十公頃不等。荷國對海埔地開發甚重視其對生態環境之影響，我國海埔地不論作為農耕或養殖之用，應注意環境衝擊，為地下水位變化、海岸地形變遷與海岸生態影響等。

(4)鹿特丹濱海工業區開發

荷國自然資源缺乏全仰賴外貿發展，幸有鹿特丹港為世界第一散裝貨與貨櫃港，該港之成長，由於工業發達而急速擴長。外港即歐洲港（Europe Port）全部為應工業發達而闢為工業區用地，主要為石化工業，也因而歐洲港乃成為巨大油輪及礦砂輪之專用港。當然亦發展新貨櫃中心。

歐洲港工業區計畫全長共十五公里，分三階段執行完成。該計畫使港域面積增至 10,000 公頃區內進行石油化學，火力電廠及煤運等工業。工業區開發方式以浸挖航道而圍築新生地之土方平衡方法執行。工業區之海堤除面海部份以拋石海堤保護外，其他部份均以砂丘種植草皮及自然海灘型式之沙堤構成，造價低廉，對景觀環境之衝擊亦小。荷蘭重要工業區均位于港埠濱海地區，鹿特丹及其外港（Europe port）之工業區僅

其一例，但足可供我國高雄港及台中港發展工業區之參考。

(5)荷蘭海堤建造與災害防制

荷蘭在海岸災害防制上，層出不窮，早期圍築新生地，有效利用沙灘構築沙堤（ dune ）防止海浪入侵，同時為免除所圍低於海平面之新生地受災害，採用運河排水或風車排水（目前已用電動抽水機抽水以利排水）等，為防制海洋侵蝕，更在沿岸地區大量構築突堤群 （ jetty goins ） ，更近期則進行人工養灘使達沙灘之動力平衡。以上種種工法均為防制災害之作法，主要即為(a)保護低窪地使免受災害(b)制止沙灘之侵蝕情況(c)隨時保持警覺（廣設監測站）(d)喚起民衆注意。

1953 年文暴潮又暴風侵襲荷蘭海岸堤防潰決流失一千八百餘名人民、財產作物損失無數政府乃集中各階段人力、智慧，應用最近代技術，透過國會支持執行歷時卅年之三角洲計畫（ Delta Project ），其計畫目標(a)絶不允許再度發生一即完全防災(b)水資源充份利用一保持暴潮堤內面為淡水。(c)維持內河航運一調整閘門放水。(d)環境景觀維護一東歇凱爾特巨型暴潮閘門將原計畫封閉改為開放即在保護該湖之環境生態，由於設計變更，工程艱鉅，乃引用機率設計法新技術新施工機具與新施工法，耗資六、七百億元完成。由於堤身應用最新機率之設計觀念，促使防災工程技術之增進，頗值得我國人效仿。

(6)荷蘭之海岸、海洋工程研究發展

荷國對于海岸、海岸工程已研究達七至八千公尺深之海域，配合德福特水工試驗室與北海總部，其在外海之觀測與海岸漂沙、海洋結構之研究發展，亦值得我國此方面研究之借鏡。

Ⅲ、結論與建議

近年來台灣海岸地區主要之土地利用與活動大致有(1)農業用地(2)林業用地(3)海岸陸地養殖及淺海養殖(4)海埔地開發(5)港灣（含漁港）建設(6)工業區設置(7)大型能源設施（電廠）之設置(8)住宅社區興建(9)風景、遊憩設施(10)機場闢建(11)海堤建造(12)採砂、礦石(13)垃圾掩埋廠(14)廢水處理場(15)海洋放流管設置。

由於海岸資源利用強度迅增，土地利用性質不相容形態出現，河川及近岸水域污染無法有效處理與控制，以及管理專責機構與專法之欠缺，乃使台灣海岸地區快速發展利用，而無有效經營管理下，環境品質迅速惡化，產生各種環境問題。列述如下：

(a)草蝦養殖，超量抽用地下水，造成濱海地區地層嚴重下陷。

(b)河川、近岸淺水域污染嚴重，導致河口與淺海養殖魚，且屢生暴斃。

(c)火力電廠，核能電廠冷卻進水口大量進水產生強大水流及排放熱水對海洋生態造成影響。

(d)傾倒海邊及河水挾帶出海之垃圾，受風、浪、流綜合作用，遍佈海岸，造成環境公害，降低海灘遊憩品質。

台灣海岸地區因乏專責機構與專法經營管理，而形成土地利用在管制上重疊或呈真空狀態。

為促使台灣海岸地區有效利用，便於整體規劃與經營管理，因此作如下之建議：

①國內海洋資料的蒐集均由台電、中油、運研所、各港務局、港研所以及各大學各自作業，花費大批人力與經費，資料取得時間與設備機型均不一致，較難分析比較，希望能統籌各

單位作成一種「海洋蒐集網路」、聯線作業，取得同步資料，其資料之意義必大幅提昇，且具價值。

②國內海岸工程實際執行亦各自為政，農發會發展漁業作人工漁礁、水利局建海堤、台電造電廠、港務局闢建海港、觀光局作海岸規劃、台灣四面環海，花費在近海工程施工上極為龐大，是否可跨部會成立一「海岸工程評估小組」審查：

㈠經費運用是否適當？（譬如農發會配合漁業局漁港台灣的近海漁業還有多少市場？）

㈡工程建造後，其實際效益如何？

㈢工程技術有無困難？(1)對國內海岸工程技術有否提昇？(2)國外海洋工程公司至台灣承包工程曾否作技術轉移？

㈣是否可能國內已有的工程技術，因主管單位缺乏專業知識或負責精神不夠，導致外國公司獲利，因而無法培養國內技術，且損失外滙。

㈤國內海岸工程機具、船舶、設備仍嫌落伍，效率應如何提高？

㈥基於上述理由成立跨部會之「近海工程評估小組」似有其必要性，成員可包括「土木、海洋、港灣、地質、管理、船舶與航海等方面之專業人才」。

此一小組應有一些核心工作人員常年作會務及行政、資料的蒐集、聯絡與整理，以便使繁忙的評估小組委員成員不必操心資料整理及行政工作。同時評估小組委員可隨時透過此一群核心工作人員去針對某一有問題之疑難之點作調查，以瞭解現況真象，目前交通部電信研究所有一海纜組似可擔任此一任務。

海洋工程的驗收非常麻煩，水上猶可運用土木工法，

水下則極為困難，而問題之發生大都在水下，因此應建造商用潛艇以作檢修、埋設、驗收、勘測、研究、資料蒐集之用。

另外，萬一有海事糾紛時究應由何種機關仲裁？因海洋工程之費用龐大，耗時日久，廠商受損極大，而委託單位無法使用亦造成損失。因而上述所提評估小組可兼任此項仲裁之任務，以使海事工程損失減至最低。

③建議對深海水洋、港灣結構物應作短期講習。邀請國內外有專精之學者專家主講，俾瞭解深水結構之機能、安定性及施工可行性，對其規劃與設計方能考慮週詳。目前我國近岸工程已逐漸發展至深海工程，此方面之資訊似有未雨綢繆之必要。

③整合台灣海岸地區現行相關法令一區域計畫法、都市計畫法、國家公園法、土地法、森林法、水利法、漁業法、礦業法水污染防治法、廢棄物清理法、海埔地開發管理辦法及其他，研討「台灣地區沿岸發展與經營管理計畫」，以指導台灣海岸資源之發展利用與經營管理。

Development of Coastal and Ocean Engineering in Taiwan, R.O.C.

Ho-shong Hou

SUMMARY

The economic development of Taiwan, an island province of the Republic of China, is highly related to coastal and ocean engineering. The activities of coastal and ocean engineering contributing to the economic development in Taiwan encompass: (1) expansion of useful land area, (2) construction of harbors for import, export and fishery development, (3) offshore exploration and development of petroleum and marine resources, and (4) protection of coastal land against beach erosion, storm surge, and waves. In the past three decades, the achievements of these activities may be summarized as follows:

A. Tideland and nourished beach reclamation

In total, 5,121 hectares (ha) of tideland have been reclaimed as for farmland, fish ponds, salt fields and housing areas. In adddition, 1,277 ha of tideland are being reclaimed for the aquaculture purpose.

On the other hand, the government also initiated in 1978 the Changhua Industrial Estate project to reclaim 6,292 ha of tideland for industrial use. This project was halted in 1984 due to economic

depression and environment impact problems. It is hoped that the project will be continued in the near future.

B. Harbor and terminal construction

In order to relieve the shipping congestion in the existing Keelung and Kaohsiung harbors, the government started in 1971 a long term project which included the expansion of Keelung, Kaohsiung and Hualien harbors, and construction of new ones such as Taichung, Suao and Anping harbors. Among the new harbors, Taichung harbor has the largest scale. It is an artificial harbor located on the mid-ewestern coast of Taiwan. Its total area is about 30 square kilometers, about 10 km long along the coast and 3 km wide between the original shoreline and the western breakwater. The first stage construction of engineering works was completed in 1976. During the construction, the harbor started shipping operation.

As far as the fishery industry is concerned, Taiwan has about 15,000 fishing boats and 153 fishery harbors and docks. Because the fishing boats became larger in recent decades, most fishery harbors and docks have problems with insufficient water depths and basin spaces. In order to improve this situation, the Taiwan Fisheries Bureau completed a nine-year project in 1987 as the first stage for enlargement of existing fishery harbors and building new ones. The second stage project is now underway.

This country imports a large amount of petroleum annually. Many terminals are required for discharging petroleum from tankers. One discharge dolphin was constructed inside the Shen-Ao bay in northern Taiwan, and two single-point mooring terminals were installed in the nearshore of Taoyuan and Kaohsiung in recent years. From those years' experience, a single-point mooring appears to be better suited to exposed locations than a multibuoy mooring for a large tanker.

C. Offshore petroleum exploration and development

This country has engaged in the marine resources exploration and development especially for oil drilling and excavating since 1973. Some wells in the nearshore of Hsinchu in northern Taiwan have started their production for supplies to the market. Three different types of marine structures, mainly: (1) concrete gravity type, (2) tension leg type, and (3) pile-supported steel jacket type, were previously chosen for consideration in construction of the offshore drilling platform in the area. After careful consideration, the pile-supported steel jacket type platform was selected and installed.

D. Reducing environment impact of thermal discharge and increasing cooling efficiency of power plants

Many power plants were built along the coast to take the advantage of using seawater for cooling. As a result, their thermal discharges will increase the temperature of seawater. The locations of intakes and outlets must be carefully studied in order to reduce environment impact of thermal discharges and to increase cooling efficiency of power plants. So far, many projects have been carried out to evaluate the environment impacts caused by thermal discharges of power plants.

E. Shore protection against beach erosion, storm surge, and waves

The total length of the coastline in Taiwan is about 1,100 km, of which, a length of 481 km especially in the beach erosion areas is protected by sea-dikes. The north-western and south-western coasts suffer from beach erosion problems which are due to reducing sand drifts from rivers or mean sea level rising, or land subsidence. The mean sea level in the southern coast rised about twenty centimeters in the past twenty years. In the meantime, the land subsidence reached 2.3 meters in the most severe area of the southern coast. Both mean sea level rising and land subsidence cause beach erosion at rate of 1:15 to 1:25 (vertical: horizontal).

F. Research developments on coastal and ocean engineering

The universities, Harbor Engineering Research Institute, and related authorities have engaged in investigation and research on coastal and ocean engineering for more than three decades. Their achievements have been presented and published in various international conferences or symposiums. At least, a conference on coastal and ocean engineering is held in Taiwan every year for exchanging knowledge and the results of studies and experiments are listed as follows:

(1) The fixed-bed and the moveable-bed hydraulic experiments for Taichung harbor were successfully accomplished in the Taichung harbor laboratory which has an inside huge test basin (60 m × 43 m × 1 m). Both harbor oscillation, sedimentation and other factors have been investigated from the model experiments.

(2) Fixed jetty, multibuoy mooring and single buoy mooring systems for offshore terminals were studied and tested for selection. Finally the single buoy mooring system was found suitable and selected for the actual installation.

(3) After having studied three different types of possible offshore drilling platforms, the pile-supported steel jacket type platform was selected as the most suitable one for the condition's in Taiwan.

(4) Wave characteristics and forecasting methods in the Taiwan Strait have been studied. The method of calculating wave height according to meteorological data has also been improved.

(5) The study of sea level changing revealed that the mean sea

level of southern Taiwan has rised twenty centimeters in the past twenty years.

(6) The layout of commercial ports, important fishery harbors, and shore protection systems have been studied and modified according to the results of hydraulic model experiments.

1. DEVELOPMENT OF THE NOURISHED BEACH

The central and south part of the west coast in Taiwan is an emerge coast, thus the sand sources is richful. Taiwan Provincial Water Conservancy Bureau has done many works about the development of the nourished beach and this development could also reduce the littoral transport along the central west and south-western coasts in Taiwan. There are about 4 main regions in these areas where are considered to be nourished and to be constructed natural beach protection.

The first region is located from the south bank of Ta-Chia river estuary up to the north breakwater of Taichung harbor, the wind break area is already designed for future development before the construction of Taichung harbor. But later on, may be we could plant the palm tree like Wakiki beach of Honolulu in Hawaii. It's good idea to exeavate as a Swimming beach and National park.

The second region is Wang-Kung coastal beach at Chang-Hua county. There' are many rivers, and they distributed and scattered down to these area, such as Ta-Tu river discharges a large quantity of silt and sand which deposit these area and form the nature beach so it is very suitable condition for developing. At present, the Ministry of Economics has a policy to develop the nourished beach of Wang-Kung as the water front industrical area in the mid-west coast of Taiwan, in order to excavate and expedite the industrial development of the mid-west part of Taiwan.

The third region is the Tung-Shih and Pu-Tai coast of Chia-Yi county, the wind-break plantation and shallow water sea wall protection will be planted and constructed to stabilize the large area of the deposited natural beach. The development of the salt producting field along the protected coast and harbor construction of Pu-Tai as a middle size commercial harbor will accelerate the exploitation of these area.

The fourth region will be Tseng-Wen coastal beach deposited by Tseng Wen river. It will be nourished by planting casuarina along the sand bar island to form as a natural breakwater. The construction of sea wall for the coastal protection from attacking of waves, tides and storm surge etc., need to be carefully researched and planned. After the planning and design of the seawall is completed, the structural section strength is requirod to be checked by the physical model test.

2. HARBOR CONSTRUCTION

2.1 Taichung Harbor Construction--An Artificial Harabor Built on the Sandy Coast.

Taichung Harbor is an artificial harbor located on the mid-western coast of Taiwan, between the mouths of Ta-Chia and Ta-Tu rivers, the total area of the harbor is about 30 km^2, 10 km long along the coast and 3 km wide between the shore and the offshore breakwaters.

The Taichung Harbor Construction Bureau has been charged with the mission of planning the construction of the harbor since 1971, but the construction work was formally started on October 31, 1973. It will take ten years to complete the whole projection with construction organized in three stages. The present master plan of Taichung Harbor is based on the model investigation which calls for extending the head of north breakwater to 20 m depth and that of the south breakwater to 15 m depth. The main channel and harbor basin are to be dredged to the depths between 13 and 15 m to meet the requirement of a modern international trade port. The full competion of the three stages, Taichung Harbor will handle a capacity of 12 million RT.

Upon completioı of the master plan, it will not only relieve the shipping congestion presently existing in the ports of Keelung and Kaohsiung and reduce the land traffic burden of the down island transportation as well, but also further expedite the economic development of this island by providing a gate way to central part of Taiwan.

Form the author's memory, especially during the year 1976, it was the third year from the start of Taichung Harabor construction. According to the predecided schedule, the first stage of Taichung Harbor construction work had to be accomplished by the October of that year. Therefore in that year all working personnel has to strain every nerve to perform the most difficult work. All the working personnel of Taichung Harabor Construction Bureau and Ret-ser Engineering Agency, suffering with sever cold, and considerably hot days, and the even worse weather of monsoon season, encountered all kinds of tough obstacles. WOrking personnel, wearing mask and putting on protective eye-glasses, worked hard from day to night in order to accomplish the engineering work of the first stage and open the harbor to shipping on schedule.

The engineering work of the first stage followed a predetermined schedule and was accomplished one month before hand. The inauguration was given on Oct. 31, 1976. In observance of the 90th birth anniversary of the late President Chiang Kai-shek.

To match the shipping operation inauguration on Oct. 31, 1976 the completion of the first stage engineering. " Taichung Harbor Construction Bureau. " has therefore changed its organization to " Taichung Harbor Bureau. " The director of Taichung Harbor

Construction Bureau--Admiral Chen, Ming-Cheng has accordingly become the first director of Taichung Harbor Bureau. He conducts the engineering work of the first stage on the one hand, and directs the business shipping operation on the other.

The great success of the Taichung Harbor construction was the result of the hard labor of all working personnel. The honor of Taichung Harbor belongs to Chinese.

2.2 Su-Ao Harbor Construction

To relieve the shipping congestion in Keelung Harbor and promots the economic development of the north-eastern port of this island, Su-Ao harbor is planned to construct as an international seaport within 10 years. The project is scheduled to be performed in two states, the first stage had been started in 1974 and was completed in Dec., 1978, the second stage will be started in Jan, 1979 to 1981 in three years. Upon the completion of the plan, the handling capacity of general cargo of this harbor will be 6.6 million RT.

2.3 Extension Project of th Outer Harbor at the Port of Hualien

The port of Hualien is located on the east coast of Taiwan, due to the existing topography, the port is limited by narrow width of its fairway. It is difficult to allow ships over 15,000 tons getting into the inner harbor. To meet the economic development demand, planning of the outer harbor extension has been studied to accommodate 19 ships of 10,000-100,000 tons for the long term development of Hualien. The port will be capable of handling cargo up to 10,000,000 tons annually as the project completed.

3. INSTALLATION AND OPERATION OF THE OFFSHORE TERMINAL

China except one oil discharge dolphin constructed inside the Sheng-Ao Harbor, the other oil terminals are mostly installed in the offshore aone. When considering an offshore tanker berth, a choice can be made between a fixed jetty, a multibuoy mooring (or conventional buoy mooring), or a single-point mooring. For large tankers the single-point mooring (SPM) appears to be better suited to exposed locations because it has the advantage that the moored vessel can swing freely around it, thus taking the most advantageous position under the combined influences of winds, currents and waves. Over 100 units of SPM are now in use in all parts of the world. In our country, two units of SPM are under operation, one is located in the offshore zone near Taoyuan coast, it is operated and connected to the Sah-Run oil supplying station the other is also installed in the offshore zone along Nan-Tsu coast nuar Kao-Hsiung coast. It is operated and connected to the Kao-Hsiung oil refinery plant, Therefore SPM terminals are installed and operated well in Taiwan.

4. EXLARGEMENT OF FISHERY HARBOR CONSTRUCTION

Now Taiwan Fisheries Bureau has been engaged the 9 year planning of enlargement of fishery harbor construction for exploiting the coast and the ocean fishery field. For the enlargement and development of fishery harbor, it divides into 6 regions in Taiwan within 9 years. It is expected to complete 80 fishery harbors and 73 docks, total budget of the engineering expenditure will be NT$ 5.9 billion. Upon the completion of enlargement and reconstruction for the above fishery harbors and docks, our country will enter a brand new stage of the ocean fishery investigation and exploitation.

5. OFFSHORE PETROLEUM EXPLORATION AND DEVELOPMENT

Offshore Petroleum Exploration Divihion, Chinese Petroleum company has been engaged in the marine resources for oil drilling and excavating from the beginning of the year 1973.

Since the investment of the offshore drilling platform is huge and need take considerable risk, therefore before the geginning of operation, full preparation works are necessary for the selection of the type predetermination of design eriteria, determination of the material and operation type of installations. For the type of the offshore drilling platform, at present, there are 3 different kinds, such as (1) Concrete gravity (2) Tension leg platform and (3) Pile-supported steel jacket type platform.

Based on the experience and technology from the further development country and cosidered the objective natural condition of the offshore zone, Offshore Petroleum Division of Chinese Petroleum COmpany think the Pile-supported steel jacket type platform is the best one for adjusting conditions in these areas. Now, this division has been engaging the researches about the design, construction, installation and planning of the pile-supported steel jacket type platform and has obtained the preliminary achievement.

6. THE DEVELOPMENT OF CHANGHUA INDUSTRIAL ESTATE

6.1 Location of Changhua Industrial Estate

The Changhua Industrial Estate is located on the West Coast of Central Taiwan, It streches from the south estuary of the Wuchi river down south to the Meiji drainage channel. The length is 26 km and the width varies from 2.5 km to 4.5 km, It was divided into six districts, shinkang, Yupu, Lunwei, Lukang, Fushin and Hanpao. With a total area of 6292 hectares.

6.2 Kinds of Industry and Areas to be Developed

Shingkang	General Industry	804ha
Yupu	Metalic and machinery	1072ha
Lunwei	'Basic metal and power generation	1258ha
lukang	oil refining and petrochemical	1247ha
fushin	chemical	1911ha
hangpao		

6.3 Layout of the Estate

For the drainage of the CIE and inland area, a waterway of about 200 m width was planned, and a water basin of 1300 m width between Lunwei and Lukang was planned to serve as borrow pit and to form the basin of navigation and berthing area.

The roadway system be parallel to the seawall and district boundaries, a belat of width from 50 m to 120 m along the seawall, north boundary and inner dike was planned for windbreak plantation.

Other public facilities such as drainage, waste-water treatment, power and communication lines have also been planned.

6.4 Reclamation

Elevation of Original seabed is about −1.0 m, design elevation is −4.2 m, total volume of hydraulic fill is about $200\times10^6\,m^3$ 50% of the fill is borrowed from the water basin between Lunwer and Lukang, the remainder from waterways.

Th reclaimed land was covered with 15 cm thick soil-aggregate borrowed from the Tatu hill.

The dredgers' Capacity is from 4,000 ~ 8,000 Hp.

6.5 Seawall, Inner dike and revetments

Seawall: 32 km, Rubble-mound type covered with 5^T arm block.

Inner Dike: 33 km, Riprap type.

Revetment: 23 km, Rubble-mound type.

6.6 Completed works

This profect started in 1978, slowdown in 1983 and stopped in 1984 due to economic depression, Completed works are:

Land reclamation: 400 ha

seawall : 7.8 km

Revetment : 3.0 km

Inner Dike : 3.5 km

6.7 Problems Encountered

a. A tidal channel occoured during the contruction of seawall and land fill.

b. Scouring of the seabed infront of seawall was happened and the works to elongate the seawall too and constructed groin sets were started from 1985.

6.8 Owner

Bureau of Industrial Development Bureau, Ministry of Economic Affairs, R.O.C.

6.9 Constructor

RSEA and BES.

7. INFORMATION ON LAND SUBSIDENCE DUE TO FISH CULTURE IN PINGTUNG COASTAL AREAS OF TAIWAN

7.1 Introduction

The western and southern coastal plains are formed mostly from alluvial soils. Before 1960, most of them were cultivated for the production of paddy rice and various crops. However, the coastal lands are generally subject to damage due to unfavorable drainage conditions and the farmers' income can not be compared with that of other cultivated lands.

Since 1969, some farmers in the coastal areas have tried to change their land use from crop production to raising eels in order to make higher profit. In about the same time, the Tungkang Fishery Research Institute succeeded in its experiments in artificially propagating a kind of edible shrimp. Besides, aquacultural farming was proved to be more profitable than other methods of crop cultivation, and the government could not effectively restrict the expansion of acquacultural farms until land subsidence happened seriously in some of the coastal areas in recent years. Consequently, a considerable acreage of agricultural farms have been switched to raise eels, shrimps, etc., and the situation of land subsidence has going worse.

Table 1 shows the acreage of fishery farms in 1983.

7.2 Water consumption of fishery farms

According to survey made by the Agricultural Engineering Center in 1983, among the aquacultural farms, a eel farm consumes the highest fresh water annually at more than 300,000 m^3 per ha., which is about ten times of the water consumption by paddy fields. A shrimp farm requires brackish water which is mixed up with fresh water and sea water. It meeds less amount of fresh water approxim-

Table 1 Acreage of fishery farms in Taiwan in 1983

unit: ha.

major spocies	Brackish farm		Fresh water farm		Total
	single species	multi-species	single species	multi-species	
milk fish	11,447	3,293	437	288	15,465
tilapia	10	389	645	7,705	8,749
shrimp	2,051	1,600	321	80	4,052
eel	0	0	2,034	86	2,120
others	814	1,911	767	6,652	10,144
total	14,322	7,193	4.204	14,811	40,530

Data Source : From " The Annual Report of Taiwn Fishery Bureau in 1983 " by Taiwan Fishery Bureau. (in Chinese) ately 60% of the water consumption by a eel farm. However, the water consumption of aquacultural farms depends largely on the species and density of fish in the ponds. The result of the survey is shown in Table 2.

Table 2 Average water consumption of fishery farms

species / water consumption	shrimp	eel	tilapia	fresh water milk fish
Per hectare (m^3/ha)	172,403	476,419	25,818	28,091
Per unit product (m^3/kg)	17.70	22.76	3.56	23.54

Data Source: From the report of " Investigation and Study on the Water Consumption of Aquaculture " by Agricultural Engineering Research Conter in 1984. (in chinese)

7.3 Water supply problems

Generally, rainfall in Taiwan is not evenly distributed, and sometimes water shortage happens during dry seasons, because about 80% of annual rainfall concentrates in a short period resulting in a large amount of run-off flowing into the sea. Therefore, fresh water from rivers or rainfall is naturally insufficient for the purpose of aquaculture. Furthermore, some rivers are polluted and inappropriate to supply large amount of surface water for fish farming. The only way for the fishery farmers to get enough water is to take underground water locally by drilling wells. Following the expansion of fishery farms, wells have been increased rapidly. In 1983, over withrawal of ground water was found along the coastal areas in Chang-hua, Yunlin and Pingtung counties as shown in Fig. 1.

Ground-water levels in some areas have fallen down much below the sea level. The contour lines of ground-water levels in Changhua, Yun-lin and Chiayi, Pingtung counties are shown in Fig. 2. The lowest ground-water level of − 20 m was found in Yunlin and Chiayi counties.

7.4 Status of land subsidence

The over use of ground-water as mentioned above has resulted in land subsidence in the coastal areas. Among others, the problem in Pingtung county is found the worst. The historical data of elevations of various bench markes in the Pingtung coastal area are shown in Fig. 3. Up to 1985, its maximum land subsidence accumulated to 2.24 m. Fig. 4. shows contour lines of land subsidence in the coastal area of Pingtung county.

The west of Yunlin county is also identified as a land subsidence area. The main reason is also attributed to over withdrawal of groundwater by aquacultural farmers. The historical data of elevations of various bence marks are shown in Fig. 5. Up to 1985, its maximum land subsidence accumulated to 1.45 m. The contour lines of its land subsidence in 5 months from June to November 1984 are shown in Fig. 6. The deepest line of −8.2 cm is near the sea coast.

The coastal areas of Changhua and Chiayi counties are suspicious of land subsidence, where an overall tracing survey has not been done, except a survey on the number of wells.

7.5 Monitoring systems

It is known that the land subsidence in the coastal areas is mainly caused by over withdrawal of ground-water. Two monitoring systems were set up by the Provincial Water Conservancy Bureau (PWCB) for observing both gorund-water levels and land subsidence at various locations. The monitoring system of observing ground-water levels covers 332 wells. Among them, 25 wells are recorded automatically, and already have long term data. The distribution of the monitoring wells are shown in Fig. 7. The monitoring system of land subsidence is set up with 7 recorders, of which five are installed respectively in Ilan, Changhua, Yunlin, Chiayi and Kaohsuing counties, and two in Pingtung county. However, the data from land subsidence recorders show a little difference as compared with the conventionally measured data, and accordingly correction work for the recorders is under way.

7.6 Ground water supervision

In order to control the withdrawal of ground-water, the government promulgated " Measures for Supervising Withdrawal of Ground-water " in 1971. According to the measures, each well should get a permission from the county government before its operation. The competent authority at the national level referred to in the Measures is the Ministry of Economic Afairs. At present, it is roughly estimated that only less than 20% of the wells used have registered to have the government permission. In order to prohibit the illegal wells from over withdrawal of ground-water to aviod continuoued land subsidence, the Provincial Government organized a team in 1985 to assume the responsibility of improving the situation. However, the illegal wells are too many to be handled by the team. According to the data collected by the team, the number of the illegal wells in the restricted districts under the jurisdiction of the Measures are about 25,000 in total as listed in Table 3.

Table 3 Number of illegal wells in ground-water restricted areas

county/city	number of illegal wells
Pingtung county	3,871
Yunlin county	9,136
Changhua county	9,852*
Keelung city	8
Tainan city	463
Taichung city	1,000

Taichung county	523
Penghu county	10
Taipei county	52
Total	24,915

* Surveyed by the Chiayi Agricultural Junior College under the projcet of " Investigation and study on the safety yield of ground-water in Changhua area. "

Actually, there are more illegal wells in Changhua county including those listed in the above table, which are located in the restricted district.

7.7 Engineeing protection

It is known that inundation in the coastal areas gets worse as the degree of land subsidence increases. After serious subsidence like the coastal area of Pingtung county, the goverment had to provide seadikes and tidal gates, for reducing sea water intrusion. As the subsided area expands, the area of fishery farm also increases, because of the land becoming inappropriate for agriculture and the higher profit of aquaculture. Another reason of increasing fishery farms is the effectiveness of the protection works constructed by the government to keep out sea water intrusion.

7.8 Study on improvement

In order to solve the problems caused by land subsidence due to over withdrawal of ground-water, the Council of Agriculture has granted the Provincial Water Conservancy Bureau (PWCB) in carrying out the following projects:

(1) Water diversion and delivery planning for fish culturing in Ping-tung coastal area.

(2) Improvement of Niao-song and Chien-shan drainage systems in Yun-lin county.

(3) Investigation and study on the safety yield of ground-water in the changhua area.

Among the three projects, the first one recommended some improvement measures to be undertaken by the fishery agencies concerned.

8. RESEARCH OF THE MODEL STUDY

8.1 Model Sheltering Experiment

The Model Sheltering Experiment deals with the planning arrangement of the proposed harbor and is done by the worst wave condition (with respect to wave direction, wave height, and wave period) which probably occurred on the proposed harbor. The objectives of this experiment are to get the wave pattern of the harbor basin and to understand the various phenomena of the wave refraction, diffraction, and reflection caused by model test due to different harbor arrangement, and to comprehend the sheltering effect of the outer breakwaters. From the analysis of theses test results, harbor planning of the most effective arrangement-the most economic length of breakwaters and the most ideal width of harbor entrance could be selected. For the purpose of analyzing results of model tests; comparison of theoretical wave diffraction calculation is proposed. The model experiments are conducted in the large test basin (60 m×43 m ×1 m) of Taichung Harbor hydraulic laboratory.

8.2 Movable-Bed Model Investigation

The author studies the establishment and operation of a distorted movable-bed model of Taichung Harbor located on the west coast of Taiwan where sand migration from the littoral drift, partially nourished by the Ta-Chia River, makes extensive dredging necessary to keep the harbor inlet channel open.

The model employed is a three-dimensional movable-bed Froude model for all prototype depths less than 50 m (164 ft). At depths in excess of this value the influence of sediment transport is considered negligible and a fixed-bed is used.

The objective of the model study is to investigate the performance of various outer breakwater configurations and to select the optimum configuration which will stabilize the harbor inlet channel, i.e., protect it from excessive shoaling caused by the seasonal wave action and the littoral drift. The wave used in the model corresponds to a wave of 5 m (16.ft) in height and 12 seconds in period from a northerly direction. The optimum breakwate configuration is determined such that dredging of the harbor inlet will not be necessary during the first 15 years of the structures lifetime. After this period of time has elapsed minor yearly dredgings are expected to be needed.

The results of the investigation are brought on a general form and it is hoped that these results may serve as a guidance to designers of harbor inlets under similar but not necessary the same conditions.

Taichung Harbor is an artificial harbor located on the mid-western coast of Taiwan, between the mouths of Ta-Chia and Ta-Thu Rivers, as shown in Fig. 1 and Fig. 3. The total area of the harbor is about 30 km ^{2}, 10 km long along the coast and 3 km wide between the shore and the offshore breakwaters (Fig. 4).

The construction of Taichung Harbor was initiated in 1939, but the work was suspended in 1944 due to World War II. The construction at that time included the 3,300 m long north breakwater and the 2,100 m long south breakwater as shown if Fig. 4. Dredging was continued to prevent the harbor from shoaling. In July, 1944, the main channel was dredged to an elevation of -7 m, but during the winter of 1944/45, the harbor entrance and the main channel had shoaled substantially.

Due to the excessive shoaling of the harbor experienced during the period of suspended construction, it became apparent, the field observation and movable-bed model investigations were urgently needed before the resumption of the construction work. Since its establishment in 1970, the Taichung Harbor Construction Bureau has been charged with the mission of planning the construction of the harbor. The present master plan of Taichung Harbor is based on the model investigation which calls for extending the head of the north breakwater to 20 m depth and that of the south breakwater to 15 m depth. The main channel and harbor basin are to be dredged to the depths between 13 and 15 m to meet the requirement of a modern international trade port.

The west coast of Taiwan is a sandy coast whose net littoral drift is from north to south at a rate of about 1.2 million cubic meters per year. Because of the heavy activity of littoral transport, any harbor project on this coast must address itself to the important problem of shoaling and maintenance of the harbor entrance and its main channel and basin. This study presents the main points of the movable-bed model investigation and conclusions.

8.3 Model Study of Wave/Wind Induced Harbor Oscillation

The methods used in an investigation of the response characteristics of large manmade harbor underconstruction. In the investigation a three-dimensional finite difference model is applied in conjunction with physical models and field observations to assist in determining criteria for design and operation. In the modeling investigation, the dynamic response of the harbor system induced by tied, incoming short/long waves, wind stress and bottom dissipation are considered simultaneously. Particular emphasis of the study has been on the wave-and strong monsoon-induced oscillations that match the range of the resonant period of ships and mooring systems expected to operate in the harbor. The resolution required to handle short-period oscillation and wind stress precludes the possibility of using methods involving the inversion of extremely large materices.

The results of the numerical simulation at important localities within the harbor system are later analyzed by spectral and cross-spectral methods. The same methods can then be used to study ships' responses at these localities with the predicted water level and three-dimensional current components.

Fig. 1 The Utilization of ground-water in Taiwan

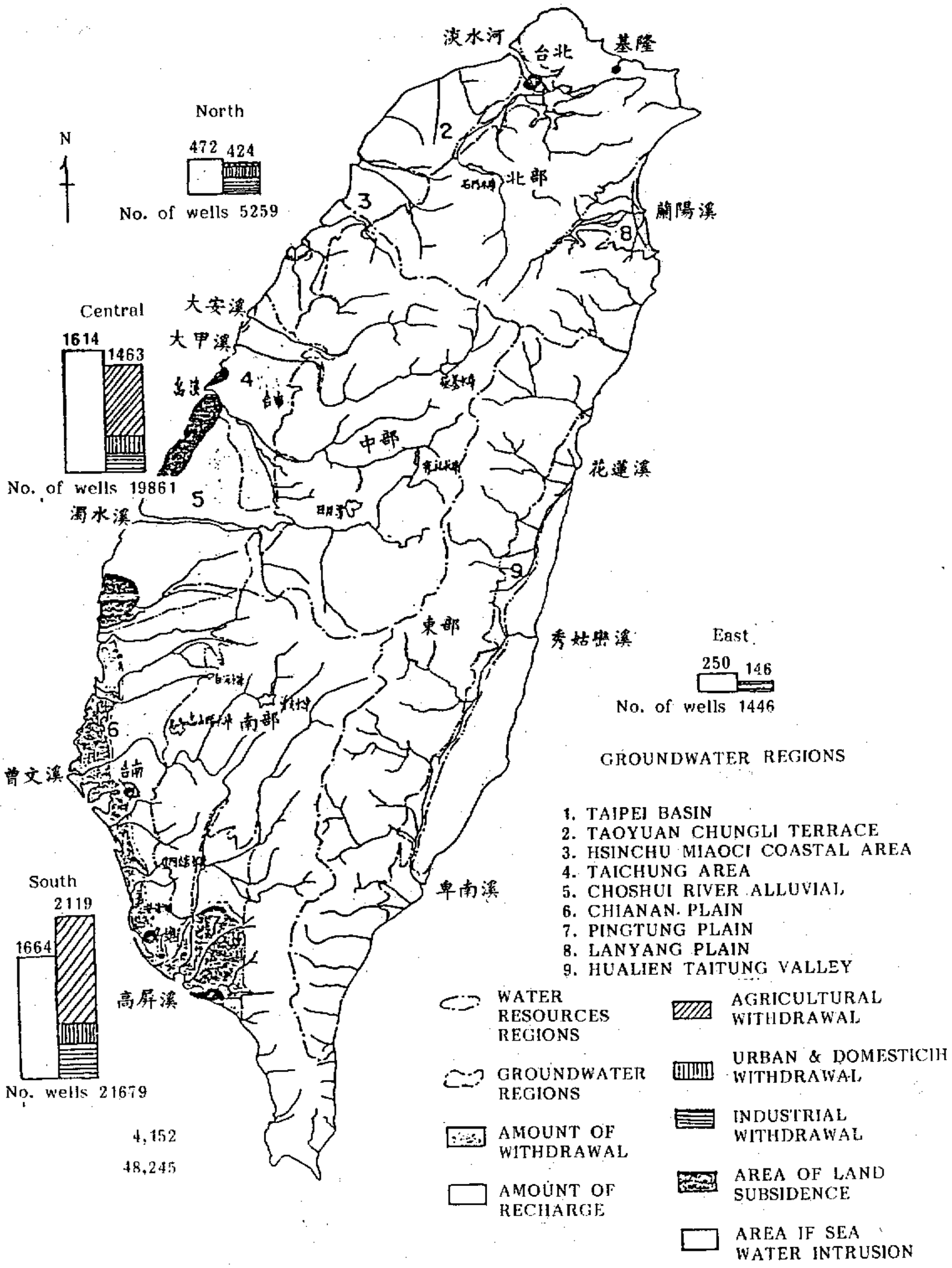


Fig. 2 The contour lines of groud-water level in Taiwan (Apr. 1982)

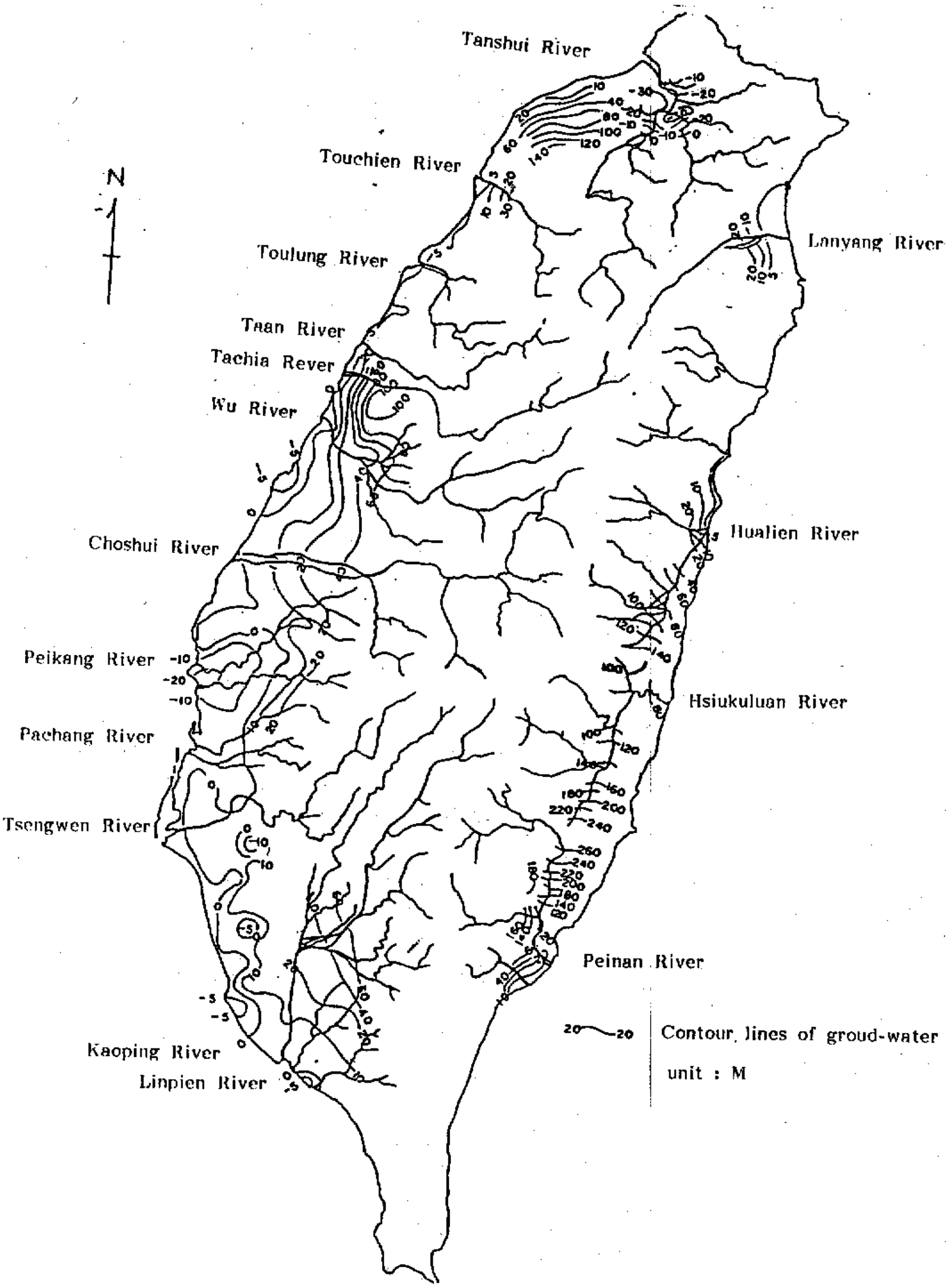


Fig. 3 The historical data of elevations of various bench marks in the coast of Ping-tung County

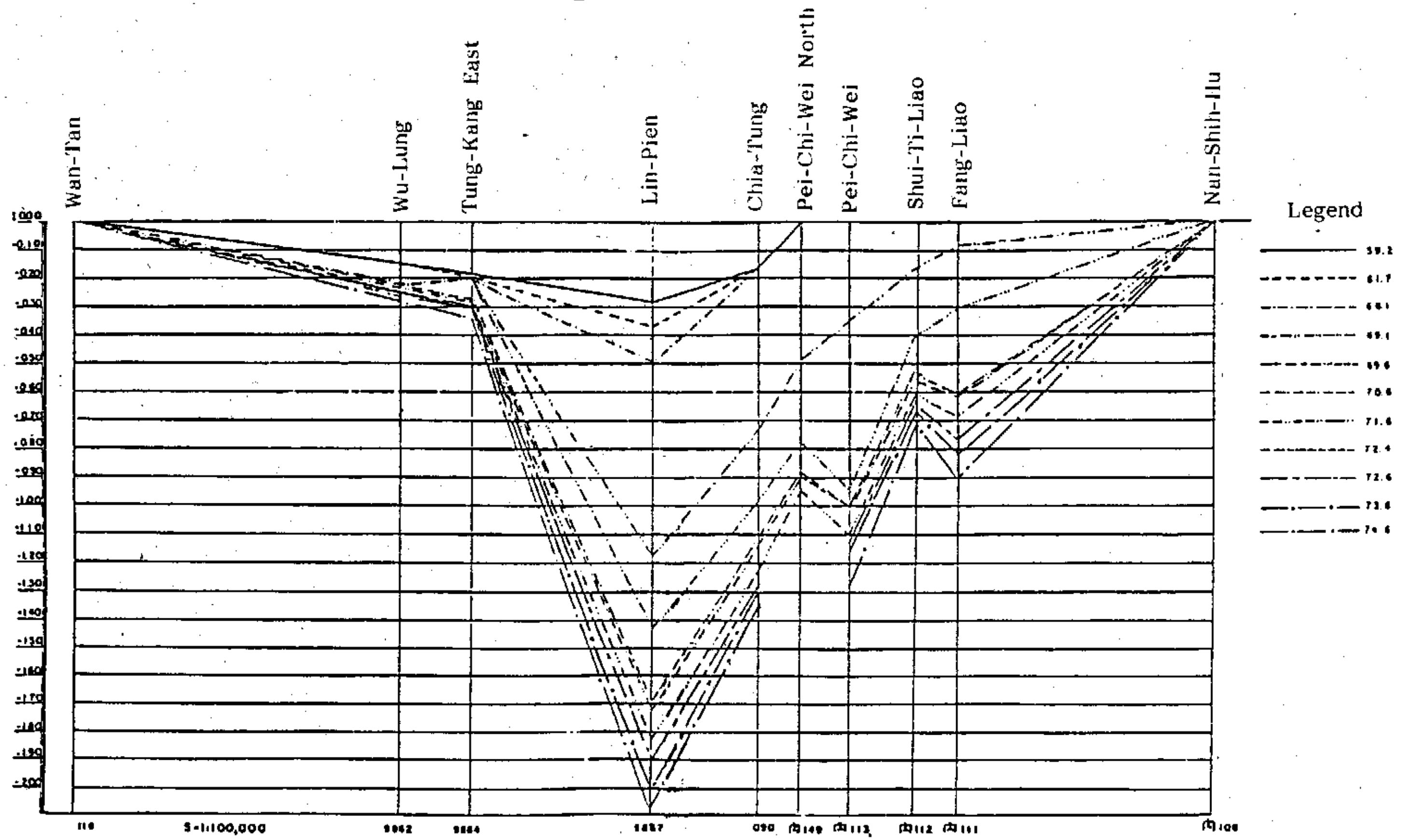
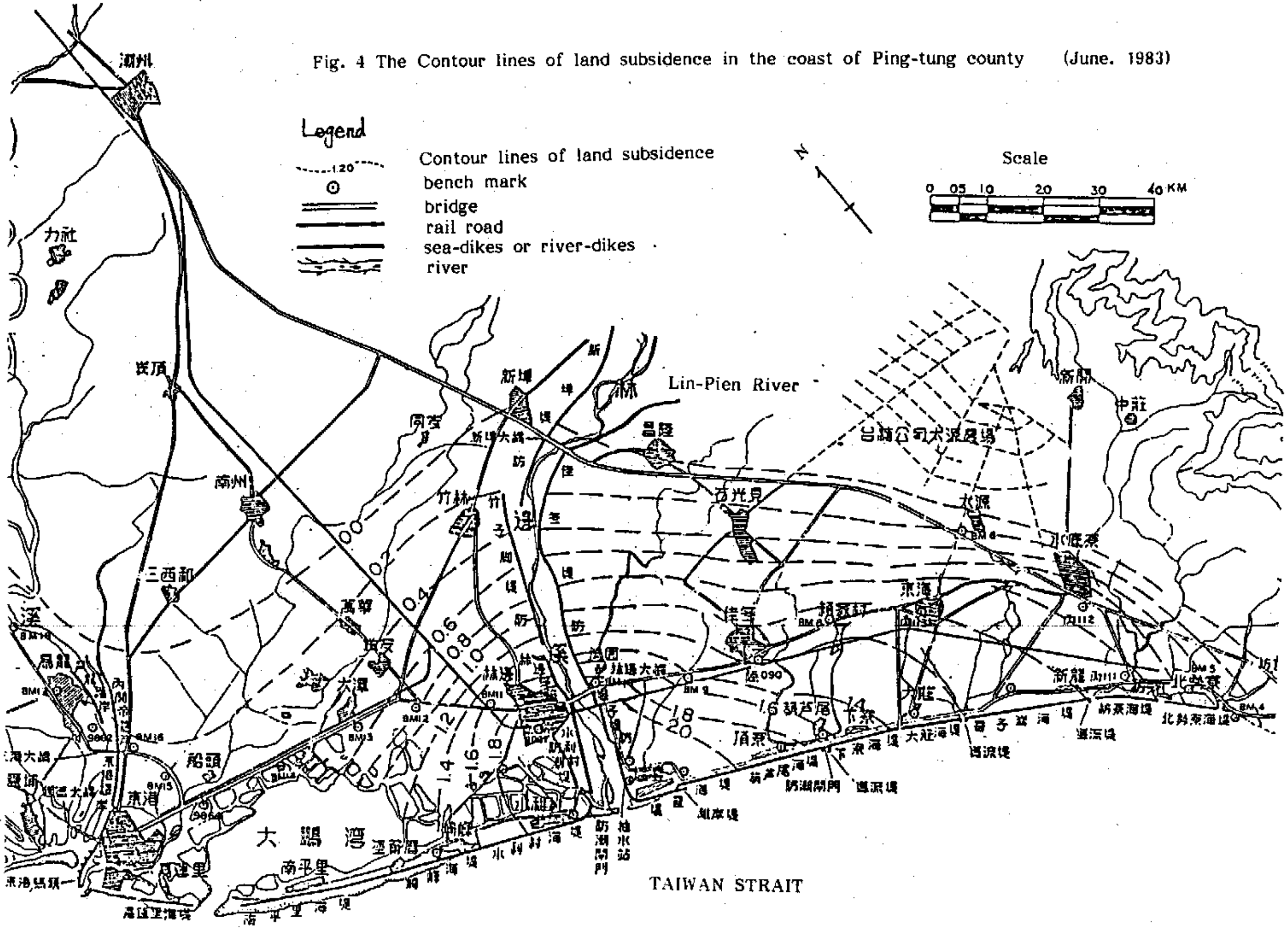


Fig. 4 The Contour lines of land subsidence in the coast of Ping-tung county (June. 1983)



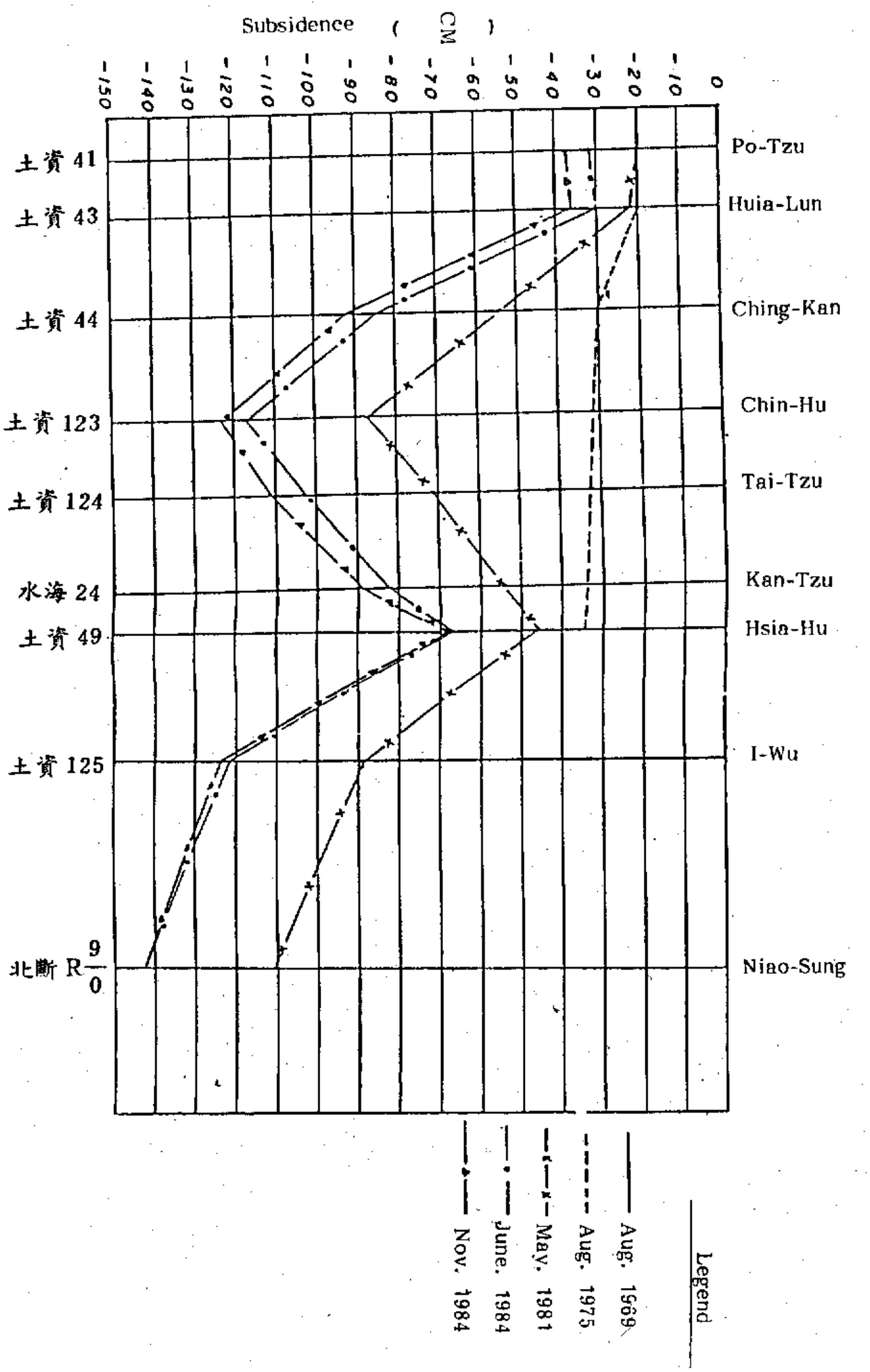


Fig. 5 The historical data of elevations of various bench marks in the coast of Kou-Hu county

Fig. 6 The contour line of land subsidence in the coast of Yun-Lin county (June.-Nov. 1984)

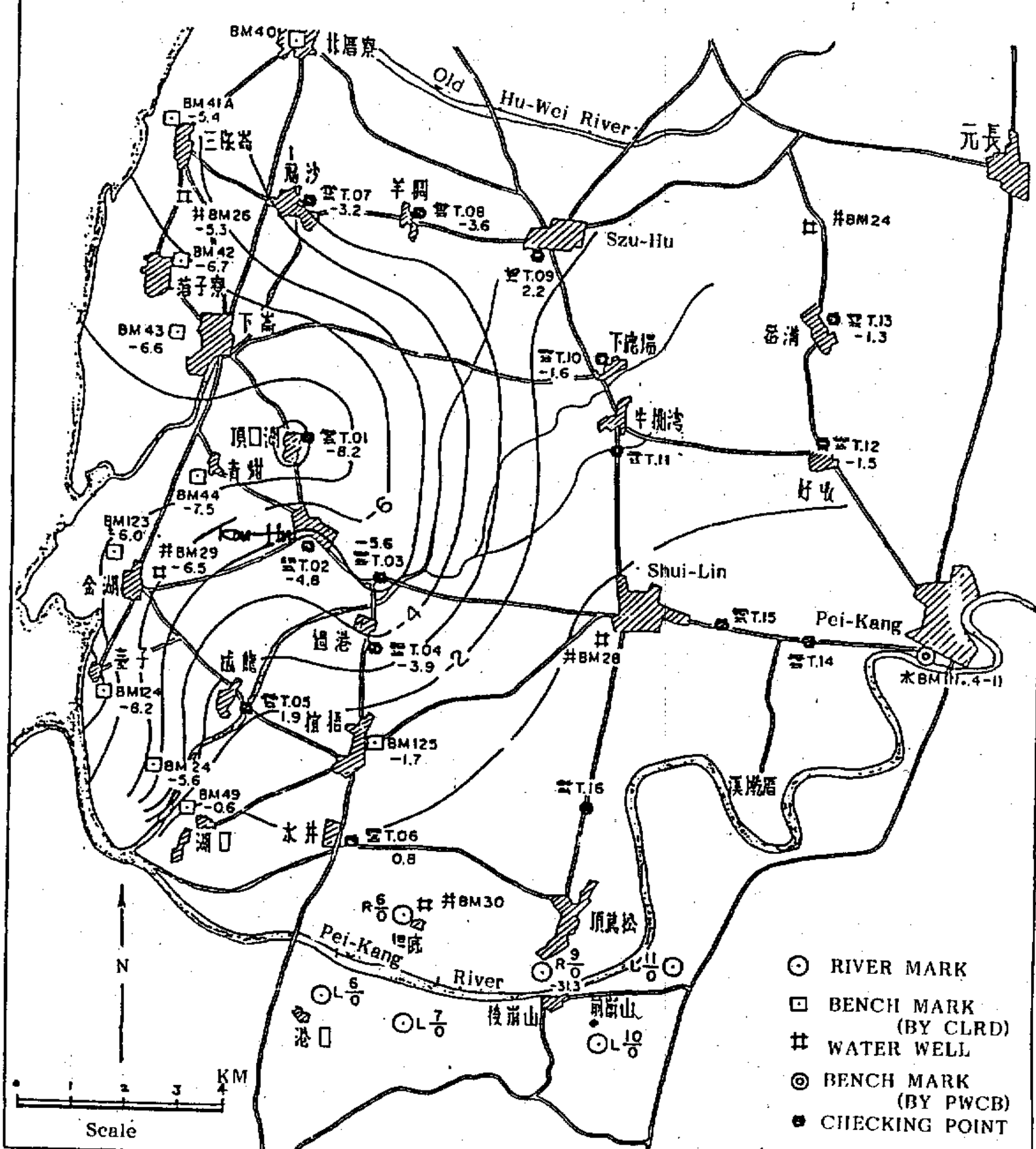
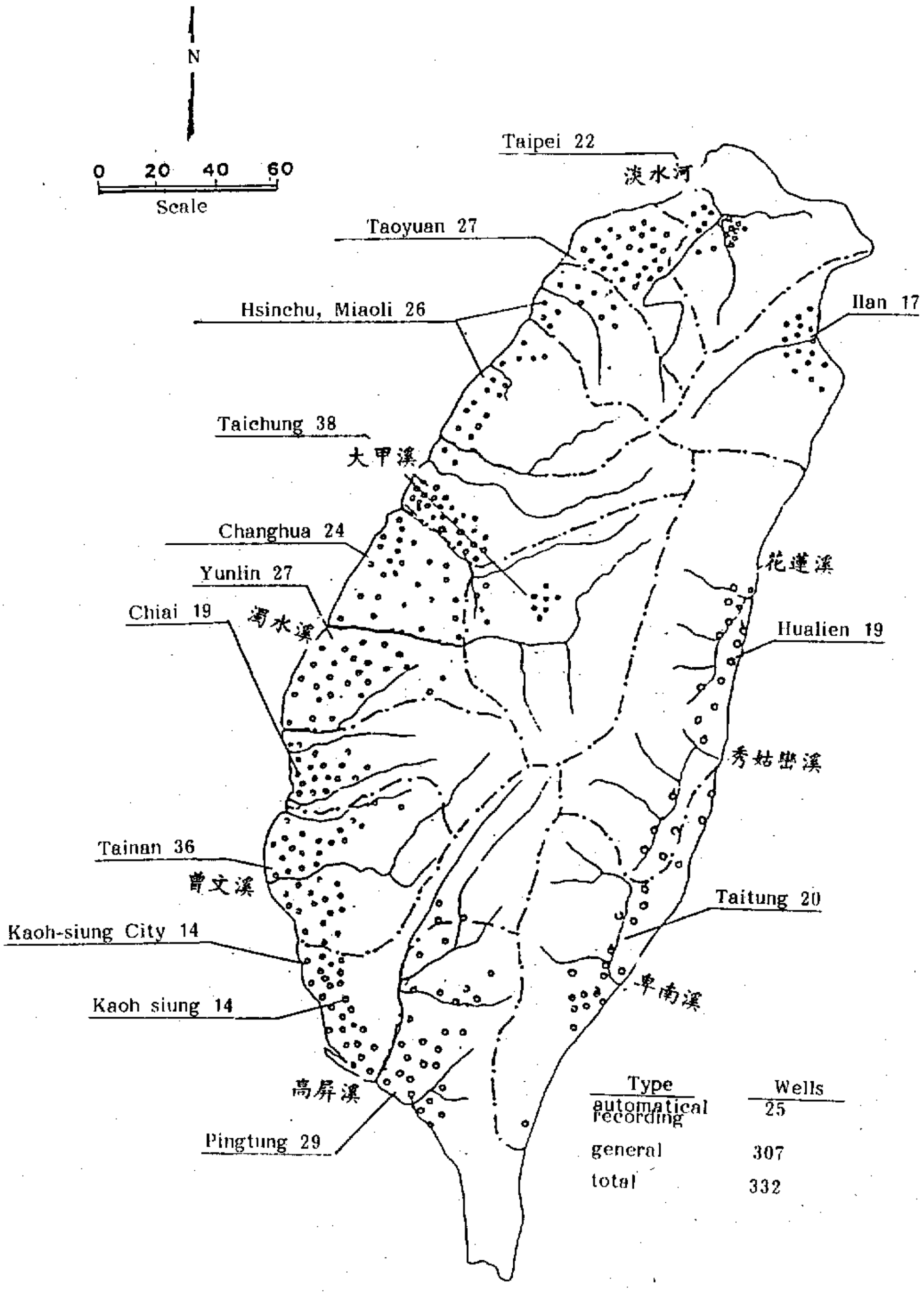


Fig. 7. The distribution of monitoring wells in Taiwan



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