美國陸軍工程師團

對臺北地區防洪治本計劃審議報告書

(譯文及影印原文)

臺灣省水利局

中華民國五十四年四月

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總　　目

簽呈

一、謹查本小組之設立，原係臨時性質，前以任務已告完成，曾於五十三年九月廿四日報請結束，並於同年十月間編製「行政院台北地區河川防洪計劃審核小組總報告」一呈請
鑒核在案。嗣奉
鈞院指示：「以本小組之任務，應俟美國陸軍工程師團提出書面報告，經由本小組重加審議提具意見後，始予結束」等因，自當遵辦。

二、茲美方防洪專家郝瑞遜等三人所提出之「美國陸軍工程師團對台北地區防洪治本計劃審議報告書」（以下簡稱報告書），業已由美國陸軍工程師團正式核定，經由經合會於本（五十四）年三月十九日轉送到組。本小組當將報告書複印分發各顧問及水利局公共工程局等有關工作人員，並於三月廿六日召集會議，再就其內容，詳加研討，經獲得綜合意見如下：

(一)報告書內容，經查與郝瑞遜等三人於五十三年九月九日在
鈞院舉行座談會時所作之口頭說明要點，均屬相同。在原則上，仍認定本小組原建議採用之「丙」案，就技術與經濟觀點，係為可行之方案。基此，本小組謹鄭重建議
鈞院明令規定此項方案即本小組所建議之「丙」案，應可作為今後實施台北地區防洪長期之依據。

(二)報告書中，對本計劃之執行，建議分期實施，以蘇財源籌措之困難，同時在實施期間，

按期觀測成效及河況變更情形，隨時考慮計劃之修訂，此種意見，實係辦理長期水利工程應有之態度，至爲允當，殊應加以採納。又報告書中對各期所列之工程項目，經查大致均屬可行，尤以塭子川新河道，不主張立即從事開闢，應請台灣省政府參酌，並就實際需要及財源籌措情形，詳訂分期執行方案。

(三)由於本計劃爲一長期方案，在實施期間，對洪水平原之各項管制法令，依照報告書意見，應即予頒訂，切實執行，同時若干緊急性之臨時措施，如低窪地區居民之遷徙等，亦應及時配合，藉以儘量減少災害損失。以上意見，平易切實，應請台灣省政府參酌，早日辦理。

(四)報告書內建議採用二百年一次之洪水頻率，應予採納，並授權水利主管機關，據以訂定有關本計劃之各項工程設計標準。至於今後本計劃之執行，責在地方，疊床架屋之機構務宜避免，不僅中央爲然，即地方亦宜注意及此，俾事權劃一，責任分明，同時對報告書中所提在每一工程階段對河況水流之觀測分析研究等工作，以及有關模型試驗等配合參證事宜，併應責成水利主管機關，切實辦理。

三、本小組對報告書之意見已如上述，自即日起謹遵
鈞院指示，停止工作。至於本小組撤銷以後，有關本計劃之審議事宜，似應仍循行政體制，分層處理。除報告書原本由台灣省水利局慎加翻譯另行印製備供對照參考外，謹將本小

行政院台北地區河川防洪計劃審核小組

組織報告書內容審議結果及本小組結束日期，報請

鑒核。

謹呈

行政院院長

行政院台北地區河川
防洪計劃審核小組　召集人　沈　怡

五十四年四月十二日

美國陸軍工程師團

對臺北地區防洪治本計劃審議報告書

(譯　　文)

第二次審議小組

克　斯(波 特 蘭 區)

郝瑞遜(米蘇里河區)

黃如福(洛 杉 磯 區)

一九六五年二月一日

美國陸軍工程師團

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一、**引言：** 臺北地區防洪治本計劃第二次審議報告，為美國陸軍工程師團應美國國際開發總署 PIO/T 484-568-2-40079 號計劃辦理者，第一次審議小組由太平洋區之達玲(Wilfred D. Darling)及巴史衞 (J. M. Buswell) 組成，於一九六四年四月至臺北，同年四月二十五日提出備忘錄，報告渠等所獲初步結論。第二次審議小組人員包括：

米蘇里河區之郝瑞遜(Alfred S. Harrison)，兼小組召集人

洛杉磯區之黃如福 (Ralph P. Wang)

波特蘭區之克斯 (Kenneth T. Case)

等三人於一九六四年八月五日至九月十一日間，在臺北從事查勘及審查。達玲先生對本報告中有關地基、堤防及涵洞等部份均曾提供意見。

二、**審議範圍：** 在臺北期間，審議小組曾考察臺北地區之河槽與已有之防洪工程，並曾查勘淡水河上游地區。彼等曾審閱地理資料、工程及經濟研究、暨臺灣省水利局據以擬訂計劃之設計準則等。彼等對該局有關臺北地區防洪方法之探討，與擬訂之甲、乙、丙、丁等比較方案，亦曾作極簡略之研審。由於時間之限制，故彼等僅對水利局建議採用之丙案作詳細之審議。

三、**報告範圍：** 本報告概述第二次審議小組對該計劃之重要結論、意見及建議，並假定閱讀本報告者，對臺北地區與其防洪計劃，已相當熟悉。較詳細之經濟評價與討論，及對今後研究之建議事項，則載於附錄中。

四、防護方法： 改善河槽與興建堤防，均為對臺北地區可獲相當防護程度之最可行方法。其他方法如興建蓄水庫及開闢洩洪道，均以經費過昂，而效益有限，將不予考慮。

五、防護程度： 對此一人口密集之大都市，200年一次之洪水，應為最低之設計流量。所有堤防及防洪牆之出水高，並應可容納500年一次之洪水。

六、丙案： 丙案不僅在技術方面可行，抑且合乎經濟，可作為臺北地區防洪治本計劃之長期方案。方案中各項主要防洪工程可以陸續施工，並於完成後即能分別獲得效益。本方案即使在施工後期，如發覺有實際需要時，仍有調整之可能。由此點而論，其他甲、乙、丁等方案中之河道與堤防計劃，似均可作為丙案需要調整時之參考。

(一)分期實施——如將丙案全部立即付諸實施，實非明智之舉。分期實施除可紓緩財政上之負擔，及可使災害損失最重地區優先獲得保護外，最重要者，即為因治理所導致之河況改變，有分析檢討及設法適應之餘地。茲建議工程實施之分期如下。

第一期：期間二年

(1) 擴寬關渡隘口。

(2) 建築社子區淡水河右岸與基隆河左岸堤防。

(3) 建築士林區基隆河右岸及雙溪外雙溪左岸堤防。

(4) 建築淡水河導流堤。

(5) 淡水河左岸實施洪水平原管理。

第二期：期間四年

(1) 關渡隘口入口段治導工程。

(2) 基隆河左岸松山以下先建環繞臺北機場之堤防。

(3) 開闢基隆河入淡水河之新出口，封閉其在關渡之原有出口。

(4) 建築淡水河右岸關渡至中洲里堤防，及基隆河新出口右岸堤防，使與上游舊北投支流堤防相聯繫。

(5) 加強臺北市週圍及永和堤防防洪牆至新計劃流量所需之高度。

(6) 必要時可從事浚渫，以增加淡水河通水容量，並利用所浚泥沙，填築低地。

第三期：期間四年

(1) 觀測及蒐集淡水河洪水時之各項資料，利用此項資料以檢討所有設計適當至何種程度，並檢討泥沙之運行及維持河道所需之條件，以供本方案後期設計與必要時調整之用。

(2) 建築基隆河左岸松山區堤防。

(3) 建築基隆河支流外雙溪、滷雅溪及磺溪聯繫堤防。

(4) 建築景美溪堤防與新店溪上游右岸堤防。

第四期：期間六年

(1) 建築大嵙崁溪新河槽，及利用挖出之土填地。

(2) 建築淡水河與新店溪左岸各堤防，與中和以西支流之聯繫堤防。

(3) 建築大嵙崁溪新河槽進口上游各堤防，與丙案中其餘各項工程。

(二)可能引致之災害——在第二期末，雖淡水河右岸各堤防均將告完成，敢信並不致使左岸地區之洪水災害，因此有所

增加。就歷史方面而言，臺北市本身使右岸洪泛區受到阻擾，實已歷有年所。此外因關渡改善工程使其進口處減少水頭損失，上游水位於大洪水時可望有所降低。

(三)洪水平原管理　在第一期至末期施工期間，臺北市各堤防之安全，實繫於是否能維持在淡水河左岸三重新莊間，及西北至塭子川一帶，目前天然洩洪道之開敞。因此，建議立即對淡水河左岸洪泛區，實施洪水平原管理，至丙案全部完成時為止。其目標為(1)保留現有天然洩洪道，(2)保留大嵙崁溪新河槽用地，使不再發展，(3)推行建築物防洪措施。

七、計劃流量： 採用二百年一次之流量，為設計之用，估列如下：

大嵙崁溪口	13,200秒立公尺
新店溪口	10,300秒立公尺
基隆河口	2,700秒立公尺
淡水河關渡以下	25,000秒立公尺

上述各流量係由可利用之測站紀錄演算，並依單位歷線法由可利用之雨量紀錄引伸而得。此等採用之二百年一次流量數值，雖非保守，但可認為係代表全計劃平衡設計之合理數字，較諸原建議之計劃流量稍大。

八、技術上分期實施之理由： 因當前尚有若干未盡明瞭之點，故丙案分期實施，至為適當。淡水河水面資料有限，而直接計算之流量，僅限於較河水平岸為低部份。水流溢岸後，繞過臺北橋而奔向左岸之流量，亦祇有估計數字。故現行河槽計劃洪水面之決定，僅賴計算時之假設條件。另一重要問題，為經改善河槽後究能增加淡水河通水容量若干，且今後是否能夠維持不

變？一旦左岸天然洩洪道封堵，則堤後地區之安全，厥繫於設計者對兩岸堤防間河槽容量之估計。故在河槽計劃容量未確知以前，遽將此巨大洪流束範於高堤之間，當非明智之舉；在淡水河問題未解決前，即開始大嵙崁溪改道，亦非審慎之道，蓋淡水河之設計水位與改善其河槽所獲之經驗，均將影響大嵙崁溪之設計。是以建議丙案之實施應行之以漸，並建議從事一周詳之水理與泥沙觀測計劃，庶可獲得洪水期之資料，用以斷定改善河槽所發生之河況變化，作為丙案實施後，任何必需調整之根據。

九、大嵙崁溪新河道： 大嵙崁溪新河槽設計，如能儘量比照西盛附近鐵路橋至河口間長10公里段現在河槽特性，則可能不需大量維護工作。現在河道坡降約 0.0006，在新河道線上亦可以達到。由新河道上端向下游按上述坡降引伸，則下游河床可能較原建議者為高，故新河道全線堤防亦將略高。原擬低水河槽之底寬 200 公尺似頗合理，但仍應經長期河床砂質輸送量之實測，加以平均後確定之。如屬可能，低水槽頂以下，宜以容納一年之洪峯流量而設計之，此或可保證河道之自然而良好之維持，暨使當地人民能有機會在河灘上耕作。估計經費時，應預計低水槽最後可能需興建護岸，以保持其設計寬度。新河道上游堤防間之洪水流路，不可作不必要之束狹，因該區域似為承受大嵙崁溪坡降突然變緩而集積淤澱之所，如將水流集中，可能將此一淤積區域移向下游新河槽之中。

一〇、淡水河： 改善淡水河槽而不需大量維持浚渫，似亦可使關渡計劃水位降低約一公尺。就三十餘年間河槽橫斷面紀錄分析，顯示淡水河實大致平衡，並無顯著之淤澱或冲刷之趨象。鑑

於此點，經選定一改善之斷面，在頻率較大之低水流量下，其流量及流速狀況與現在河道大致相同。此改善河槽所需之寬度，將在現河槽中建築束流之平行導流堤以獲得。如自然冲刷不克發生，則需藉浚渫而加深河槽。與水流正交之丁壩，可能阻滯洪流，增加糙率，與河槽改善以求降低關渡上游水位之目標違背，故不可採用。惟是否應興建此等價格昂貴之導流堤，應與上游堤防及防洪墻因降低高度而可能節省之經費相比較後，再作決定。

一一、基隆河： 現有基隆河槽不需若何增大。

一二、新店溪： 原建議利用現有河槽不作變動實為得計，雖洪水時流速頗高，但此冲積河槽仍相當穩定，如破壞此種「准平衡」河況，似亦非審慎明智之舉。

一三、改善關渡隘口： 現正進行中之擴寬與計劃擬訂之浚深，將可提供足夠之橫斷面；惟上游進口之不利條件，為此隘口產生水頭損失之重大原因，因此建議採用等比水工模型試驗，以研究由治導工程矯正此進口情況之可行性。

一四、基隆河新出口： 基隆河新出口應再行研究，以選擇最經濟之計劃。沿現在基隆河在社子島南端之捷徑(按即番子溝)以出淡水河值得予以研究。蓋可省却為數頗多之基隆河下游堤防。但引導雙溪進入淡水河之堤防，則因而必需延長。

一五、三重市之防護： 丙案實施期中，為臨時保護三重市之堤防，其位置應在事實可能情形下儘量後退，如此則將來臺北大橋延長不致遭受阻碍。

一六、橋樑： 原不擬修改臺北橋及中興大橋之建議應重行考慮。

(一)臺北橋——關渡工程完成後，臺北橋將轉為淡水河之「瓶

頭」，如屬可能，臺北橋應予延長。所有新橋墩之設計，應儘量設法減低水頭損失，及儘可能減少局部冲刷與漂流物之攔集。

(二)中興大橋——淡水河槽現在循右岸中興大橋下行，流路頗劣，應考慮新闢河槽於左岸以改善之。

一七、水位計算： 計算水位時，當斷面收縮及放大時所採用之損失係數，0.10及0.50除突然變化情形外，似均屬過於保守。如糙率係數("n"值)係由實際觀測求得，則不僅代表摩擦損失，同時亦包括其他損失在內。計算橋墩水頭損失時，應考慮漂浮物攔集所增加之阻碍作用。

一八、潮汐對設計水位之影響： 原假定淡水河口水位為+2.40公尺，而用以計算水面線，可認為適當。紀錄最高潮位，約為+2.80公尺。但經比較在設計流量下，河口水位雖相差數公尺，而反映於臺北橋水位者不過數公分而已。

一九、堤防出水高： 建議防洪墻出水高為1.00公尺，堤防為1.50公尺。此最小尺度外，應酌加灣道外側超高，尤以如新店溪景美溪等較狹窄而流速湍急之河槽為然。緊要堤段如上游聯繫堤防及大嵙崁溪新河道右岸堤防等處，堤頂出水高應考慮增加。

二〇、水工模型試驗： 臺北盆地水工模型之設計、佈置、比例尺與操作方法均甚健全。但河槽糙率宜再作調整，俾使臺北橋及中正橋之水位與實體之定量流水位流量率定線一致，並使關渡以下水面線與歐泊、愛美及葛樂禮等次颱洪時實測者相符合。

(一)利用現在模型之研究——建議使用現在之模型，在下述各種洪水流量下，研究臺北盆地之瀦滯作用，對減低流量之效果：(1)盆地內現有堤防與其他條件。(2)全部計劃堤

防。進行此項試驗時，模型中在關渡之下應增添流量排洩及量測裝置。

(二)關渡治導工程——不宜使用不等比模型試驗以研究關渡隘口治導工程設計等局部問題，故宜另建等比模型，其比例尺以較大者為佳，可就水資會模型試驗室場地所能容許者為準。另可試用不固定之河床，以標示相對沖刷情形。

(三)大嵙崁溪及新店溪合流段——另一等比水工模型試驗，可用以研究丙案實施期中大嵙崁溪與新店溪合流段是否需要治導，及其可行性。

二一、支流聯繫堤防： 山溪支流如流量過鉅不能使用涵管穿過堤防排洩時，則應沿支流建聯繫堤防直達高地。玆建議按下述標準設計全部聯繫堤防斷面：

(一)不得低於主流堤防標高。

(二)支流水面，應按支流合理之可能流量與主流設計水位同時發生情形下計算，再加出水高1.00公尺。

(三)或採支流計劃流量為50年一次者，與主流合理之可能流量同時發生情形之水面，再加出水高1.00公尺。

原計劃中基隆河舊北投以南，及新店溪中和以西二支流之聯繫堤防，是否合此標準？似成問題，宜再加研究。

二二、堤內排水： 原計劃中有若干地區堤內集水區之降雨逕流處理，其標準與設施不甚適當。蓋堤內多為市鎮，或可能成為市鎮區域，堤防可提供之保護程度較高，故在經濟可行範圍內，通過堤防之排水容量，應求充裕，庶減少積水次數，縮短時間，及縮小淹水範圍。不推介原計劃中當淡水河水位低時，將堤內排水積存於中洲里。基於上述理由及衛生與觀瞻上之原因，

不宜採用此項辦法，而建議涵洞容量應符下述標準：

(一)淡水河低水位時，涵洞應能排洩頻率10年一次延時1小時之局部暴雨。

(二)當颱風暴雨淡水河水位上昇時，涵洞應能在開始降雨時起30小時內，排洩50年一次24小時內暴雨之積水。

在估計堤內排水涵洞之流量時，應知若干地區目前之污水及雨水溝渠尚在發展之中，當排水系統改善後，流量勢必將較增大。

二三、排水門： 因堤內集水面積之集流時間短促，降雨強度又大，故建議所有在市區及農村之涵洞均在臨河側裝置自動水門。自動水門可增加計劃之效果，不致如人工操縱之閘門因啓閉失時，而發生不必要之積水淹浸。市區所有涵洞，應增設人工操縱門扉，以防萬一自動水門失效時之用。此種緊急閘門，可裝置於堤防臨河側坡之門井內，亦可置於堤內涵洞起端。但以臨河側之位置較佳，因當水門關閉時，河水可緊壓閘門而堤下涵洞不致遭受河水水壓。如使用預鑄混凝土管，或僅設人工閘門，而無自動閘門時，則不應安設於堤內方面。

二四、防潮閘門： 防潮閘門有助於中洲里及蘆州等地之農田排水，因該處地面較高潮時之水面為低。防潮閘門係大型之涵洞，臨河面裝自動門扉，涵洞位置應儘量降低，使在低潮時亦浸於水下。防潮閘門與堤防相輔，自動排洩堤後之水至與低潮位相近。

二五、涵　洞： 於堤防及防洪牆之下，使用波形金屬管，最為適當，因其強度及耐撓性均大。鋼管則應採用鍍鋅者，並應浸塗熱柏油，及酌情加塗煤焦油。臺灣鋁工業發達，波形鋁管亦可

考慮使用。就地澆製之鋼筋混凝土箱型涵洞，亦屬良佳，且較預鑄者為優，蓋後者易生裂痕及接頭不易正直。初步設計箱型涵洞用基樁支承，如詳加檢討或可省除。堤防下之各種涵洞管均須裝設截滲環，以加長滲透線。涵洞進口作成圓滑形狀或可增加水力學效率。

二六、地基情況： 根據現有多數堤防經驗，顯示地基大致適當。惟按諸目前之計劃範圍言，地基鑽探工作仍屬不足，尤其是計劃中之堤防將較現有者為高，而大嵙崁溪新河道在塭子川區域內又可能有深層粘土基礎。

(一)鑽探——堤防與防洪墻基礎下鑽孔隔距應小於 150 公尺。鑽孔深度至少應等於結構物高度，其中另有數孔並應深達結構物高度之1.5 至 2.0倍，如現發軟弱或透水性大之土壤時，應鑽至此類土壤之全深為止。

(二)土壤試驗——全部土樣均經目測鑑定分類，並有充分之試驗結果，以證實此前項分類。堤防及防洪墻基礎下之所有粘性土壤，均應測定其天然含水量，及施作充分之強度及壓實試驗，以確保有適當資料供設計之用。另需酌作三軸壓力試驗數處，用以核對。此項試驗，應為不排水壓縮試驗。前此鑽探所採土壤，不能認為係未擾動者，不適合於作強度試驗之用。直接剪力試驗與無側束壓力試驗之結果並不相符，似不適於使用。故建議遇有粘土時，應用薄殼取樣管採取土樣以供無側束壓力試驗之用。

二七、堤防設計： 所建議之堤防標準斷面，曾歷經多次洪水，而屹立無恙。惟一般而論，其斷面與護坡似極為保守。

(一)堤防斷面——目前所採用之堤頂寬最小者為 5.5 公尺，就

設計觀點言，除堤頂兼充道路者外，在大多數情形下，3.0公尺寬之堤頂已屬適當。此項寬度已可容許為保養堤防單行車路之用。雖通常堤坡臨陸側設置戧道作為堤土飽和時之增強保護，但如遇深層軟弱粘土時，對堤防斷面設計仍應予以特別注意。對每一特殊情況，皆需個別作安定分析。

(二)封堵廢河之堤防——每一處均應鑽探沉滓之成份及深度，堤防究應採用較寬斷面與增加安定之戧道，抑將惡劣土壤挖去而用較小斷面？應視何者經濟而定。

(三)砂礫堤之不透水覆蓋層——堤防標準設計中，砂礫堤臨河側坡採用厚30至50公分之不透水覆蓋層。並考慮此覆層之垂直坡面厚度，至少應增為1.00公尺。

(四)堤下滲漏——以透水性土壤為基礎之堤防或防洪牆，應作流線網分析，以憑設計，而避免堤下滲漏之損害。對堤防言，可憑此分析以決定臨陸側戧道之高度及寬度，與是否需要不透水之截水牆等設計。對防洪牆言，可憑以決定截水牆深度，以減低水流出口坡降至安全範圍。

(五)堤防護坡——初步計劃內若干堤防臨河側及臨陸側堤坡用草皮保護即可者，但均已採用串磚護坡。在多數臨陸堤坡，及附近洪水流速不超過1.5秒公尺之臨河側坡，用草皮保護已屬適當。近堤洪水流速較大之臨河側坡，可憑以往經驗使用串磚、鉛絲蛇籠、漿砌或乾砌塊石護坡。初步計劃中退離河槽之堤防，臨河側護坡基脚，擬用混凝土截水牆。玆建議採用填石之「活動基脚」，填石級配範圍應較大；其防護堤脚被淘刷之功效，或較剛性之混凝土截水牆

更為有效。

二八、浚 渫

(一)維持性浚渫——依賴大量浚渫以維持設計容量之河槽改善方案，不可採用，蓋無法在需要時，均能保證獲得此項容量。

(二)引 河——用浚渫引河方式建築河槽，而冀水流作用可冲刷至設計寬之辦法，不足採用。淡水河流速，尤其是關渡下游，將不致高達能產生所希望冲刷之程度。由大嵙崁溪上游冲刷而下之物質，可能在淡水河沉積，而惡化下游之河槽。

二九、航 運： 建議之淡水河河槽設計，未考慮航運需要。且現在計劃中並無與將來航運改善衝突之處。

三〇、經濟評價： 依照較為保守之成本與效益估計，丙案之總益本比為1.7，分區之益本比則自1.2至2.5。上述益本比係按借款成本年利率6％計算而得。如年利率為9％時，則總益本比將為1.3。故丙案在經濟上為合格者。

三一、水理觀測計劃： 為實施丙案、及研究計劃完成後之效果，一完善之水理觀測計劃，應包括重要洪水時之水面縱坡測量、流量測量、河槽斷面測量、及沉滓測驗等，均屬決定河槽容量與河況變化所必需。吾人雖知在洪水時此等觀測頗為困難，但相信利用在臺北地區現已證明為有效之技術，及其他建議之設備與技術，當可成立一有效之觀測計劃。茲建議派遣一中國工程師至美國考察河流觀測實務(例如在米蘇里河流域)。

三二、計劃之執行及維護： 計劃完成後，倘不密切注意如何維護，及洪水時之操作，將不克產生所計劃之全部效益。有效操作

與維護不可缺少者如下列各點：

(一)擬訂一操作維護手册，包括計劃項目之重要資料，以備隨時參考，擬訂操作及維護之詳細步驟，並明白劃分負責區域等。

(二)建立臺北區洪水警報系統。

(三)指定各地方機構對本計劃應負責之部分，並要求各機構保證將確實履行其職責。

(四)指定一機構負全責指揮洪水警戒期中計劃之操作，視察各處是否按維護步驟辦理，並賦以權力使能督促各機構按照辦理與不斷研究計劃之成效，庶可發現問題而於必要時建議補救措施。

吾人認為上述建議之實施，當有賴於政治及技術方面雙管齊下，始克有濟。

三三、誌　謝： 吾人對美國駐華國際發展公署白慎士署長、農村復興聯合委員會霍夫曼及沈宗瀚委員、交通部沈怡部長及朱登皋先生、國際經濟合作發展委員會李國鼎先生、臺灣省水利局鄧先仁局長等之欵待、建議、及友善協助表示感謝。余等尤感謝太平洋工程區達玲先生之珍貴指教及熱忱支持，徐世大教授對余等工作之關注更足銘感。最後，與余等密切工作之臺灣省水利局劉方燁總工程司、淡水河防洪治本計劃工程處薛觀瀛、胡運鼎先生及該處同仁與農復會張文濤先生等，吾人對渠等之合作、指導、及接待，表示熱誠之感謝。

審議小組召集人

郝瑞遜 (Alfred S. Harrison, P. E.)

附 錄 甲

經 濟 分 析

(譯 文)

一九六四年九月

附 錄 甲

經 濟 分 析

目 錄

附 表

附 圖

地 圖

附 錄 甲

經 濟 分 析

一、受 益 區 域

1. 淡水河洪水平原位於臺灣本島之北部，面積約22,000公頃，工農業及市鎮密集發展。

2. 陸軍工程師團代表認為丙案之受益區域，限於流域之下游部份，其中之防洪措施，無可避免的互相關聯。受益區域可分為三區如地圖A—1，簡述如次：

   (一)第一區包括臺北市。東為高地，北為基隆河，西為淡水河，南為新店溪。

   (二)第二區東北以高地為界，西南濱淡水河，南臨基隆河。

   (三)第三區為其餘部份，在淡水河及新店溪下游之西。因審查之計劃內，大嵙崁溪擬由營盤附近改道至獅子頭，故本區包括大嵙崁溪下游之洪水平原，及新店溪左岸，與淡水河左岸之廣大區域在內。

3. 洪水平原區域內土地極為平坦，而幾無突出之高地。最低之致災水位約為海拔3公尺。多數土地在海拔4.5公尺以下，尤以第二區及第三區為甚。

4. 第一區，臺北市人口約一百萬，土地利用狀況由密集之建築至東郊之少數稻田，其中商業區域之法定建築高度限制可達八層。本區亦為交通之樞紐，有鐵道及公路自臺灣兩主要港口之一之基隆港經臺北市南下至島上其餘各地，臺灣唯一之國際航空站亦位於此區。現為自由中國戡亂時期之首都，市區內工業建設甚多。

   第二區多為農業及工業。區內大部面積為稻田及雜作地，

但沿週邊伸至洪水平原內，工業建設亦屬可觀。

第三區按面積論亦以農業為主，但與臺北市隔河相望之三重市，人口約7萬，並已高度工業化，三重至新莊間由於工商發展幾已成一連鎖，但規模較小者佔多數。本區中有若干獨立村莊，多為鄰近耕地之農民與服務供應工業需要者所居住。

5. 全區內電力供應無缺，道路網全年暢通，農業區域大部份均有水灌溉，並與島上其他地點相同，使用大量化學肥料，單位面積之稻米與其他作物產量極高。臺北市內及四週地區均具有適量之公共汽車交通。臺北國際機場為本省唯一之國際航線航空站。觀光事業逐漸發達，最近新旅社相繼落成或建築中，其現代化程度不亞於任何地點。一般經濟呈蓬勃氣象，人民節儉而勤奮。

二、洪災損失資料

6. 淡水河流域以往洪災損失資料係由下述各方面搜集而得：

期　間	來　源
1912—1940	報紙
1929—1942	日據時期土木事業年報
1943—1945	缺
1946—1958	報紙（僅臺北市部份）
1956—1963	由臺灣省水利局根據各區、鄉、鎮公所報告彙編。資料存水利局檔案內。

7. 審查以往資料部份譯本，顯示洪災損失資料不甚完全，且估計偏於保守。以往之洪災損失紀錄均經調整，以反映建設型式之改變、經濟發展、與物價指數等變動因素。早期紀錄中包括簡陋房屋如竹屋茅舍之損失在內，近年幾已均為較堅固之磚房所代替。風災損失已設法扣除，但風災實常與重大洪災同時發生。

8. 由過去遭受之損失，及將來可能之損害觀點，經濟情況可分為四大類型。

(一)農業

(二)建地

(三)公共工程

(四)工業

四次大洪水所遭遇之災害損失估計如下表：

直接洪災損失

按經濟成長率及物價指數調整為1963年情形

洪水日期	1962年8月6日	1962年9月5日	1963年8月25日	1963年9月11日
臺北橋水位(公尺)	5.10	5.50	5.82	6.70
損失(新臺幣1,000元)				
農業	19,372	29,777	38,375	59,931
建地	102,650	281,183	414,400	778,109
公共工程(1)	21,964	55,973	81,500	150,847
工業	321	2,371	12,412	526,040
合計	144,307	369,304	546,687	1,514,927

註：(1) 公共工程損失按農業及建地二者損失和之18%估列。

9. 農業災害中包括作物損失、土地冲蝕損失、肥料損失及家畜損失等。房屋與家財損失，僅佔全數之一極小百分數。所謂「建地」係由成分不一之住宅，商店及工廠等組成，其單位面積之損失額按市區及郊區分別估定。公共工程損失缺乏適當完整資料，故由其與農業及建地損失和之關係估計之。根據部份資料估定公共工程損為前述二者損失失和之18%，其結果似嫌保守。工業損失價值在1963年洪災後，係依據地方政府實際損失報告而彙計者。

三、基本資料檢討

10. 在從事估計淡水河防洪計劃平均年洪災損失及效益之前，最好先考慮其基本洪災資料。如前述，此等資料係由不同來源搜集而得，各機構皆非擬訂計劃之臺灣省水利局所控制者。昔日資料零散不全，惟均已儘量加以分析，並曾就設防與發展現狀及物價指數予以調整。就防洪計劃研究與經濟分析言，幸有1962年至1963年之三次颱風洪水，其資料較為完備可供研究分析之用。1963年9月11日洪水係紀錄中最大而時間亦最近者。該次洪災損失資料可假定與所獲資料同樣優良。

11. 經審查臺灣省水利局所獲最近颱洪災害損失資料譯文，並曾至大部災區查勘後，報告人確信該次洪災資料實偏於保守。在缺乏完整之洪災損失調查下，而欲據之以作量的分析實不可能。而此等調查又非鉅額經費、時間及經過訓練之人員不可。

12. 因無適當之資料可據以估計間接損失，故效益中可避免之災害損失內，亦未包括間接損失在內。

13. 曾與中國工程師試圖估算本計劃對將來土地增值之效益，但因缺乏必需之資料而不果，故土地增值亦未包括於計劃效益之內。惟防洪工程之直接結果，多數地區由農地轉變作住宅、商業及工業之用，地價增值為數必甚龐大。

14. 報告人認為在基本資料大都缺乏情形之下，就數字之推敲與正確性言，在決定計劃之經濟可行性時，實構成一保守之基礎。當地規劃機構曾盡力消除重複與差誤，如仍不能免時，將屬於保守方面者。

四、基 本 準 則

15. 中國工程師在經濟分析時，為估算平均年效益，曾使用下列基本準則，將洪災損失作為將來平均年損失。

(一)僅將現在尚未保護而預期本計劃可提能護區域之損失列入。故平均年效益，卽為平均年洪災損失之可減免部份。

(二)認為今後農業損失維持不變。對於任何無防洪計劃而農業生產之增加不加考慮。

(三)都市計劃機構認為若干地區在1963年後，雖無防洪工程亦將由農地轉變為建地，此項轉變假定於二十年內完成。1963年農業單位面積損失，為每公頃新臺幣4,000至7,500元，而住宅、商店及工廠混雜之建地單位面積損失，則視其位置與河川水位，由每公頃新臺幣100,000至540,000元。將來建地區可避免之災害損失，假定每年按3.5%之複利率增長。

(四)1963年已成建地區域之災害損失假定每年按3.5%複利率增加。

(五)公共工程損失如前述，按相當之農業及建地損失和之18%估列。

(六)1963至1964年間調查已有之「工業損失」，可望將來不致變動，因其已臻若干程序，可能甚少進一步之發展也。在「轉變用途」地區內，因將來農地轉變為建地，故將未來工業發展估列在內。

(七)計劃資金利率假定為每年6%。

16. 對上述基本準則審查意見如下：

(一)被保護之區域既認為與洪災區域相同，而計劃保護程度又大致充足，則用平均年洪災損失之可減部份作為平均年效益，自屬可行。

(二)查閱中國農村復興聯合委員會(農復會)年報，知臺灣農地單位面積生產量在不斷增加中。1964年 8 月31日與農復會農業經濟組農經專家李登輝先生、植物生產組水稻專家黃正華先生，水利工程組張文濤先生、臺灣省水利局淡水河防洪治本計劃工作處副處長薛觀瀛先生及美國陸軍工程師團克斯先生等討論以往稻米與其他作物單位面積生產量及現行增加生產之研究計劃，並考慮改良種籽、肥料、農藥、及耕作方法等可能之效果。此等優越專家之意見以1963年生產量為準，可能之增長率可望為每年百分之二至三，在今後 50 年內，每公頃農業災害損失之增加率，每年約為 1963 年價值之1.5%。

(三)每年經濟成長率 3.5 %為政府各機構採用之數字，在缺乏經濟基本研究下，亦可接受為將來之經濟成長率。由以往成就之許多文件中可證明及支持此一結論。在都市計劃機構認為將由農地轉變為建地之區域，其轉變所需時間估計為20年。前述區域內，農業損失在該期間內逐漸減少。而同期內該新建地區之災害損失則逐漸增加。取今後20年之損失為一坐標，包括年增長率 3.5 %在內，及計算其後30年，即距今 50 年末之損失為另一坐標，亦包括年增長率 3.5 % 在內，再用直線聯接各坐標，以 50除曲線下包圍之面積即得平均年損失。是即為效益之貨幣值。

(四)由目前建地區損失按複利率 3.5 %增加，以求出此等地區

可減免災害之平均年價值。

(五)在缺乏較佳資料情形下，勢需接受中國工程師所採用之公共工程損失為農業及建地損失和之18%估計。

(六)1963年秋葛樂禮颱風後，曾作主要工業損失之實地調查。因將來工業發展，已包含於將由農地轉變為建地之地區内，故表中所列工業損失，不再按任何數量估計增加。

(七)淡水河防洪計劃工程經費按6%年利計息似為合理可行。近年政府公債年利率為12%。農復會李登輝先生研究中顯示公債利率已由1961年1月5日之16%降低至1963年7月1日之12%。李君之結論亦為中央銀行經濟研究處1964年7月1日刊行之「中華民國財政統計月報」所證實，該報告指出公債利率由1959年之18%降減至1964年之12%。1964年9月初中華民國政府公告發行短期公債，其利率僅為10%。依據上述，利率實有降低之趨勢，故本計劃有效年限內採用6%之平均利率當無不合。因有若干人士覺得按9%利率作經濟分析或更較適當，故亦曾依此作概略之分析。

17. 中國工程師決定平均年效益之步驟，係將每一水位各類型損失估計延伸至將來以繪製洪災損失頻率曲線，再由此曲線求得平均年損失。在決定計劃將來效益數值時曾考慮效益延滯因素，最長者達12年。蓋施工期間長，大部份之效益亦因而隨之延滯。但並未將相應之經費延滯考慮在内。對此步驟之修改實為使計劃益本比由小於一而變為遠大於一之基本原因。故決定如在一施工期之後即能發生效益情形下，其經費將不計施工期利息。但計劃之大部份，其收益據估計將延滯至開工後第三年之末，此部份之工程費將加入其施工期利息以憑計算平均年成本，但不考慮任何效益延滯。

五、平均年效益估計

18. 由每區不同大小之洪水以決定，各類災害將來年損失後（參閱表A—1)，製成各區水位災害損失圖，分為農業、建地及工業地區水位損失曲線三種如A—1，A—2及A—3所示。公共工程損失曲線略而未繪，因其為農業與建地損失和之一函數也。

19. 因洪災減免而生之平均年效益，係利用A—4之水位頻率曲線求得之頻率計算而得，如表A—2，A—3及A—4所示。如第12及13兩節所述，此項分析未將減免間接損失與土地增值包括於效益之內。

20. 在第二區及第三區內有關較小效益，將從利用廢棄河槽及以浚渫泥沙填築之地區內取得。此項效益在二三區內可望分別為每年新臺幣6,000,000及17,000,000元。

21. 過去所建若干堤防中，其堤頂寬可兼充雙車道之用，因而增加堤防造價。經與中國工程師討論，知係應地方政府機構之要求，是以因此而生之運輸效益至少應與增添之工費相等。約略估計因兼充道路而增加之經費化成年成本約為新臺幣1,000,000元，故第一區內列入新臺幣1,000,000元之運輸效益。

22. 本計劃經濟分析採用之各區各類效益數字列如下表：

平均年效益

（新臺幣1,000,000元）

區別	土地	運輸	防洪	合計
Ⅰ	—	1	332	333
Ⅱ	6	—	29	35
Ⅲ	17	—	225	242
總計	23	1	586	610

六、經濟分析

23. 經濟分析採用之工程費係1964年9月8日之估計數字。計劃中

之關渡下游淡水河，河槽改善大嵙崁溪新河道及關渡上游淡水河河槽改善等三項施工需期三年，故加計施工期利息。其餘工程之效益可望在其施工季之末即克產生。

24. 經濟分析年限採用50年，其管理維護及換新經費每年估計為總投資之3％。依據1964年9月8日估計，計劃中各項目之工程費及投資連同6％年利列如下表：

項　目	工程費	投　資
	(新臺幣1,000,000元)	
關渡下游淡水河河槽改善	340	371
大嵙崁溪新河道	1,916	2,088
淡水河及新店溪左岸防洪工程	257	257
臺北下游基隆河及淡水河右岸堤防	123	123
臺北市週圍堤防工程	509	509
關渡上游淡水河河槽改善	408	445
總　計	3,553	3,793

三重市環堤經費除臨河部份外，餘未包括於上表之內。茲按前述基準計算平均年成本如下：

利息	新臺幣$3,793\times10^6\times0.06=227\times10^6$
償債基金(按年利率6％以50年計)	$\times0.0034=13\times10^6$
管理維護及換新	$\times\ 0.03=114\times10^6$
	$0.0934=354\times10^6$

平均年效益新臺幣 610,000,000 元，平均年成本為新臺幣354,000,000元，故益本比為1.7比1.0。

25. 按利率9％約略分析如下：

工程費(新臺幣1,000,000元)	3,553
投　資	3,913
平均年成本 3,913×1.213	475
平均年效益	610
益本比	1.3比1.0

26. 地方人士要求分別計算各區之益本比，但需先確定作此研究之

準則。既經考慮丙案，故需就整個系統加以考慮，因有數項工程涉及兩個或以上之區域也。牽涉兩個或多個區域之工程項目，其經費分攤準則如後：

(一)關渡下游河槽改善，按各區總平均年效益比例分攤。

(二)大嵙崁溪新河槽

第一區：估計假定無大嵙崁溪新河槽而需加高堤防代替計劃所需投資。

第二區：無。

第三區：所有其餘經費。

(三)關渡上游淡水河河槽改善，就其兩側之一、三兩區各區總平均年效益比例分攤。

27. 利用上述準則，三區各別分攤經費及益本比如下（此一準則純屬任意擬定者）：

計劃項目	投資（新臺幣1,000,000元）		
	第一區	第二區	第三區
關渡下游淡水河河槽改善	204	22	145
大嵙崁溪新河道	500	—	1,588
淡水河及新店溪左岸防洪工程	—	—	257
臺北以下基隆河及淡水河右岸堤防	—	123	—
臺北市週圍堤防工程	509	—	—
關渡上游淡水河河槽改善工程	258	—	187
總投資	1,471	145	2,177
平均年效益	333	35	242
平均年成本(利率6%)	137	14	203
益本比	2.4比1.0	2.5比1.0	1.2比1.0

28. 如年利率以9%計，由相同之工程費分攤額，第三區之益本比將小於1.0。惟此係丙案整個系統之分析，其總益本比按利率9%計仍為1.3比1.0，故系統中任一主要部份如大嵙崁溪新河道者，不能認為其益本比小於1.0，故亦未曾嘗試重行分攤工程費或其他表面步驟以求獲得9%利率時各區較佳之益本比。

表 A—1

將來年洪災損失

區別	位置	臺北橋水位 公尺	將來平均年洪災損失[1](新臺幣1,000,000元) 農地	建地	工業
I	臺北市	6.70	11.4	2,131.9	49.3 (水位4.50時為0.0)
		5.82	9.4	1,225.5	
		5.50	5.5	840.6	
		5.10	3.6	463.5	
II	北投區	6.70	17.0	94.1	76.7 (水位4.00時為0.0)
		5.82	12.7	69.7	
		5.50	9.4	26.1	
		5.10	6.7	38.6	
III	左岸地區	6.70	84.0	1,037.1	400.0 (水位4.50時為0.0)
		5.82	53.4	543.7	
		5.50	46.4	450.9	
		5.10	33.3	127.8	

註(1) 按1963年物價及考慮未來發展

表 A—2

第一區平均年洪災損失之決定

(參閱圖A—1)

項　　目	各水位時之洪災損失(新臺幣1,000,000元)					
臺北橋水位(公尺)	3.5	4.0	5.0	5.5	7.0	7.75
農　　地	0	0	3	6	13	15
建　　地	0	0	150	900	2,300	2,700
小　　計	0	0	153	906	2,313	2,715
公共工程0.18×小計	0	0	28	163	416	489
工　　業	0	0	1	5	73	150
合　　計	0	0	182	1,074	2,802	3,354

地點：第一區，臺北市　　河流：臺灣省淡水河　　日期：1964年 9 月 6 日

頻率曲線：石門水庫完成後臺北橋，1964年 3 月　　物價基準：1963

貨幣單位：新臺幣1,000,000元　　發展情況：將來

洪　水	水　位(公尺)	流　量	頻　率	損　失	平均損失	頻　率	年損失
	3.5		0.500	0			
	4.0		0.400	0			
					91	0.200	18
	5.0		0.200	182			
					628	0.060	38
	5.5		0.140	1,074			
					1,938	0.122	236
	7.0		0.018	2,802			
					3,078	0.013	40
	7.75		0.005	3,354	總計年損失		332

表 A—3

第二區平均年洪災損失之決定

(參閱圖A—2)

項　　　目	各水位時洪災損失(新臺幣1,000,000元)					
臺北橋水位(公尺)	3.5	4.0	5.0	5.5	7.0	7.75
農　　　地	0	0	5	10	19	23
建　　　地	0	0	8	43	105	130
小　　計	0	0	13	53	124	153
公共工程0.18×小計	0	0	2	10	22	28
工　　　業	0	0	1	7	110	250
合　　計	0	0	16	70	256	431

地點：第二區，北投區　　河流：臺灣省淡水河　　日期：1964年9月6日

頻率曲線：石門水庫完成後臺北橋，1964年3月　　物價基準：1963

貨幣單位：新臺幣1,000,000元　　發展情況：將來

洪　水	水　位 (公尺)	流　量	頻　率	損　失 (1)	平均損失 (1)	頻　　率	年損失 (1)
	3.5		0.500	0			
	4.0		0.400	0			
					8	0.200	2
	5.0		0.200	16			
					43	0.060	3
	5.5		0.140	70			
					163	0.122	20
	7.0		0.018	256			
					344	0.013	4
	7.75		0.005	431	總計年損失		29

表 A—4

第三區平均年洪災損失之決定

(參閱圖A—3)

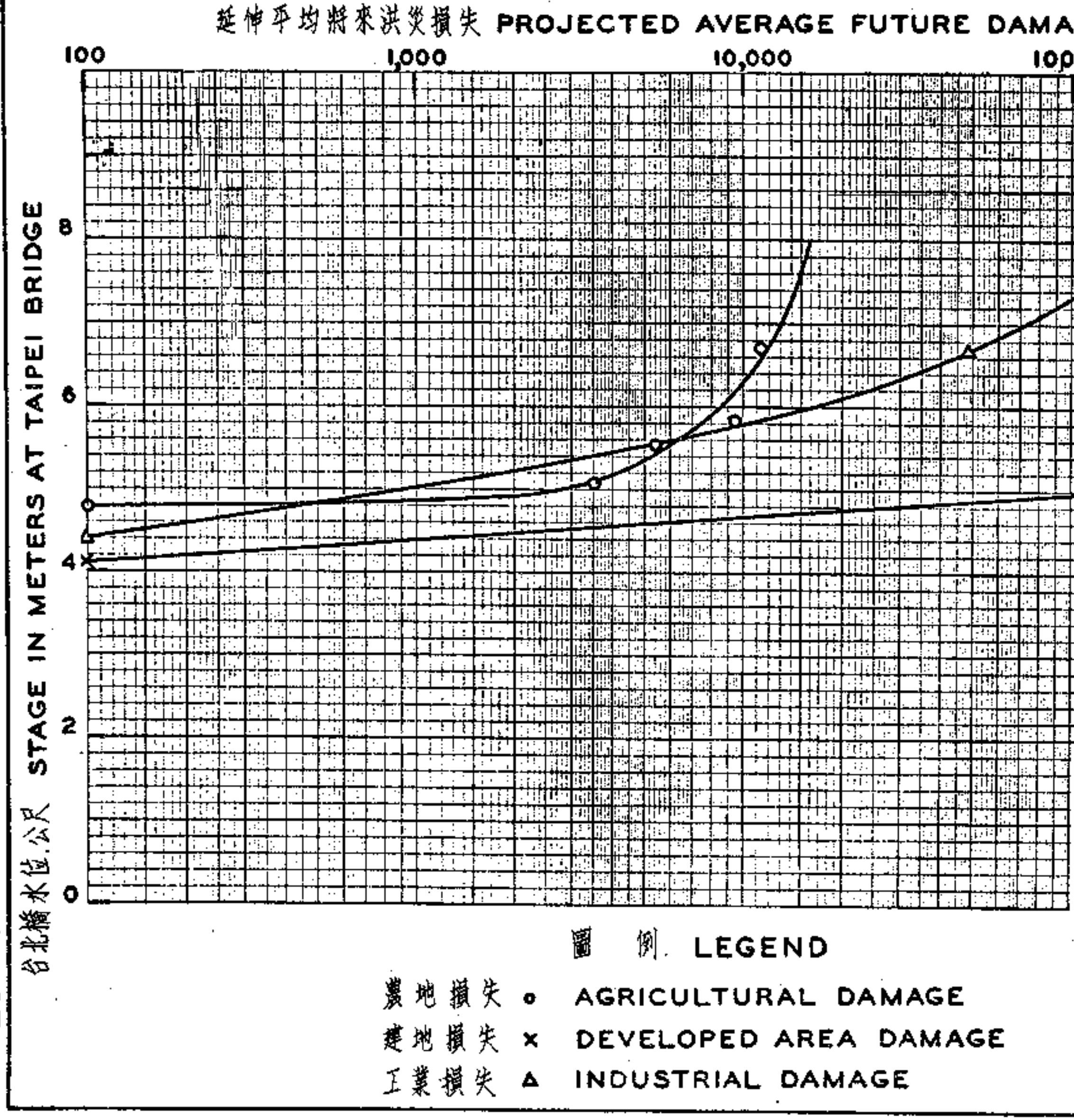
項目	各水位時洪災損失(新臺幣1,000,000元)					
臺北橋水位(公尺)	3.5	4.0	5.0	5.5	7.0	7.75
農地	0	1	20	44	90	101
建地	0	0	70	380	1,200	1,500
小計	0	1	90	424	1,290	1,601
公共工程0.18×小計	0	0	16	76	232	288
工業	0	0	8	38	560	1,200
合計	0	1	114	535	2,082	3,089

地點：第三區，左岸　　河流：臺灣省淡水河　　日期：1964年9月6日

頻率曲線：石門水庫完成後臺北橋，1964年3月　　物價基準：1963

貨幣單位：新臺幣1,000,000元　　發展情況：將來

洪水	水位(公尺)	流量	頻率	損失(1)	平均損失(1)	頻率	年損失(1)
	3.5		0.500	0			
					1	0.100	0
	4.0		0.400	1			
					58	0.200	12
	5.0		0.200	114			
					326	0.060	19
	5.5		0.140	538			
					1,310	0.122	160
	7.0		0.018	2,082			
					2,586	0.013	34
	7.75		0.005	3,089	總計年損失		252



淡水河防洪計劃，丙案

TAN-SHUI RIVER
FLOOD CONTROL PROJECT
PLAN "C"

水位洪災損失曲線

STAGE-DAMAGE CURVES

第一區

ZONE I

8 SEPT. 1964

CHART A-I

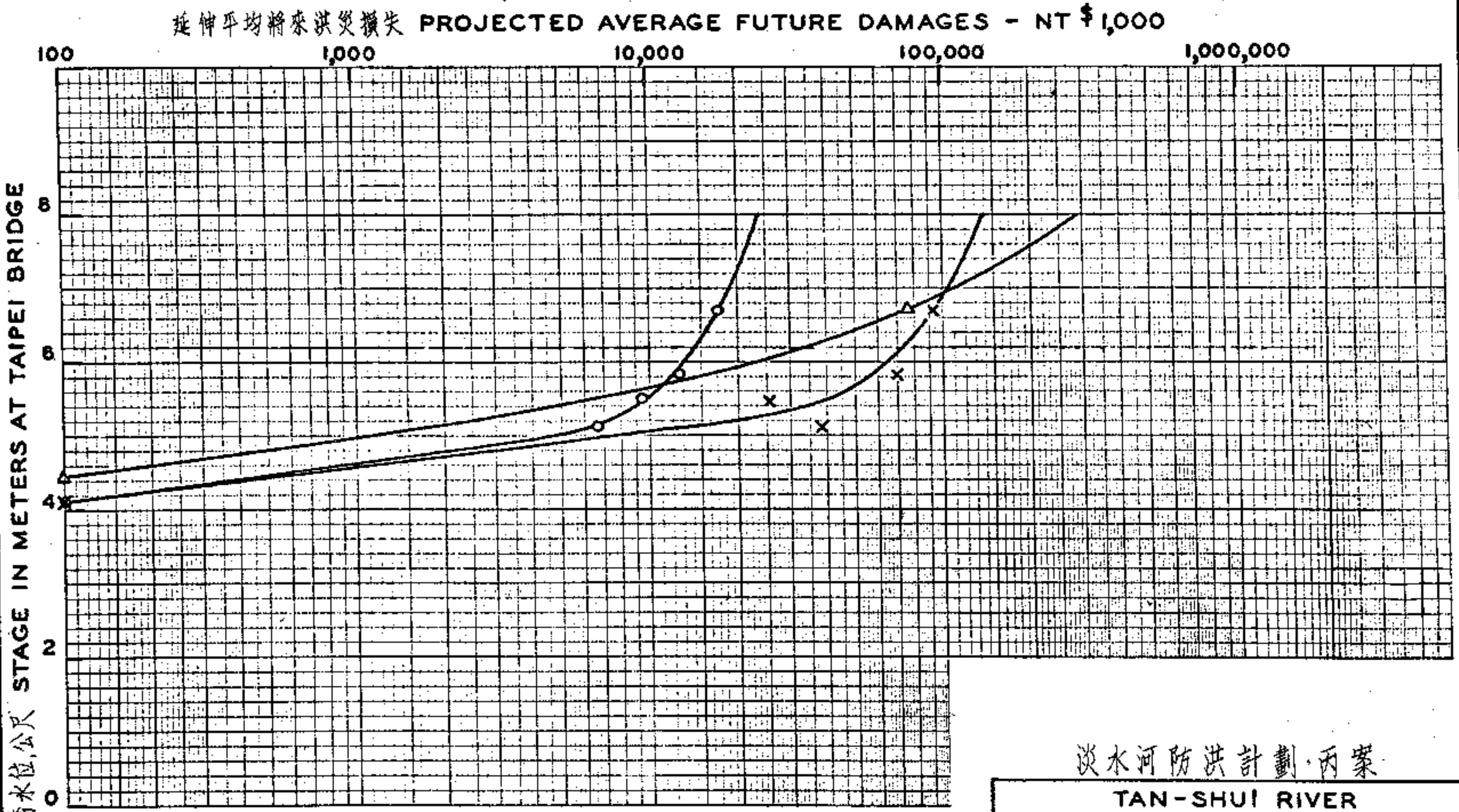


圖 例 LEGEND

農地損失 o AGRICULTURAL DAMAGE
建地損失 x DEVELOPED AREA DAMAGE
工業損失 Δ INDUSTRIAL DAMAGE

淡水河防洪計劃·丙案

TAN-SHUI RIVER
FLOOD CONTROL PROJECT
PLAN "C"
水位洪災損失曲線
STAGE-DAMAGE CURVES
第二區
ZONE II

8 SEPT. 1964

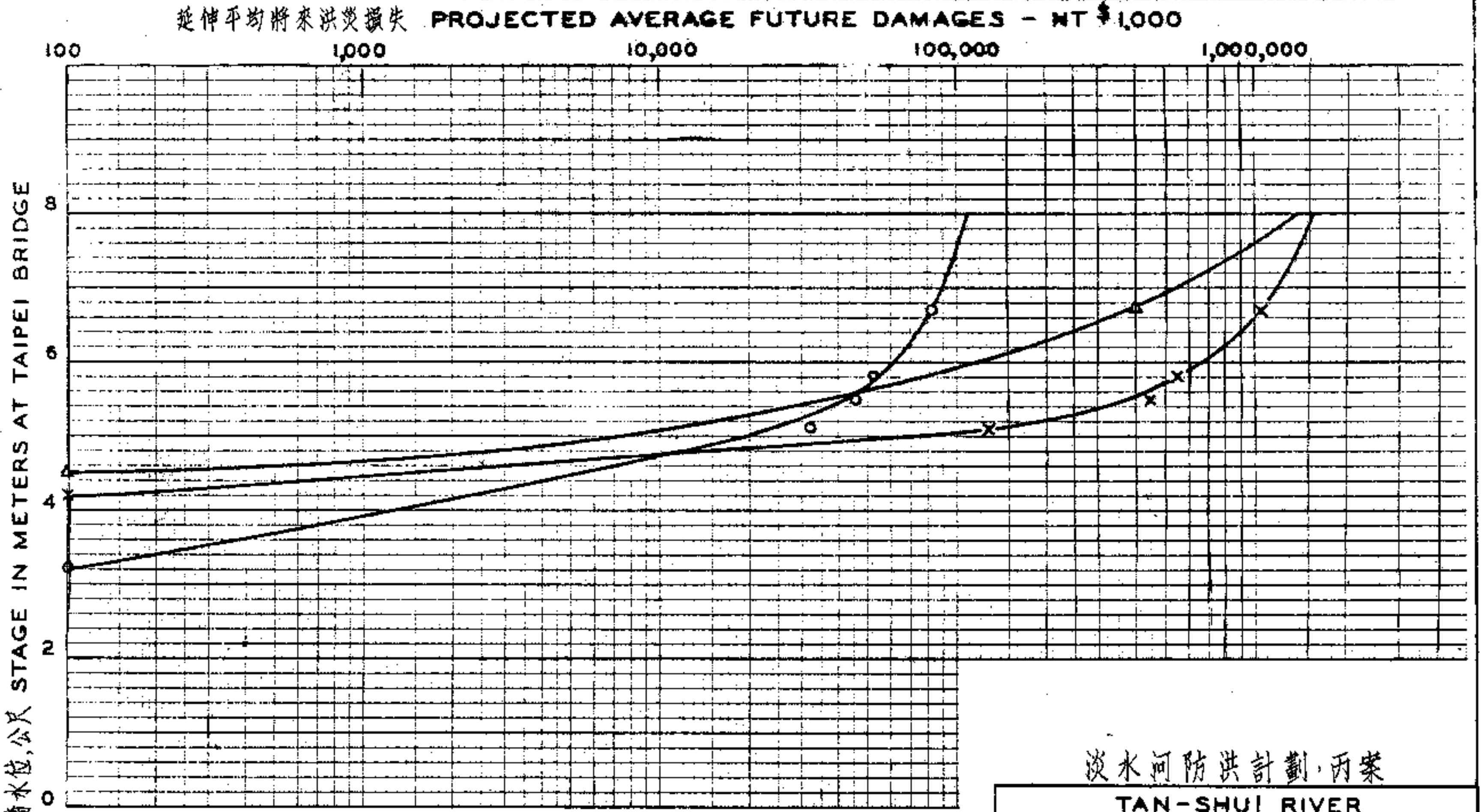


圖 例 LEGEND

農地損失 o AGRICULTURAL DAMAGE

建地損失 × DEVELOPED AREA DAMAGE

工業損失 △ INDUSTRIAL DAMAGE

淡水河防洪計劃,丙案

TAN-SHUI RIVER
FLOOD CONTROL PROJECT
PLAN "C"

水位洪災損失曲線

STAGE-DAMAGE CURVES

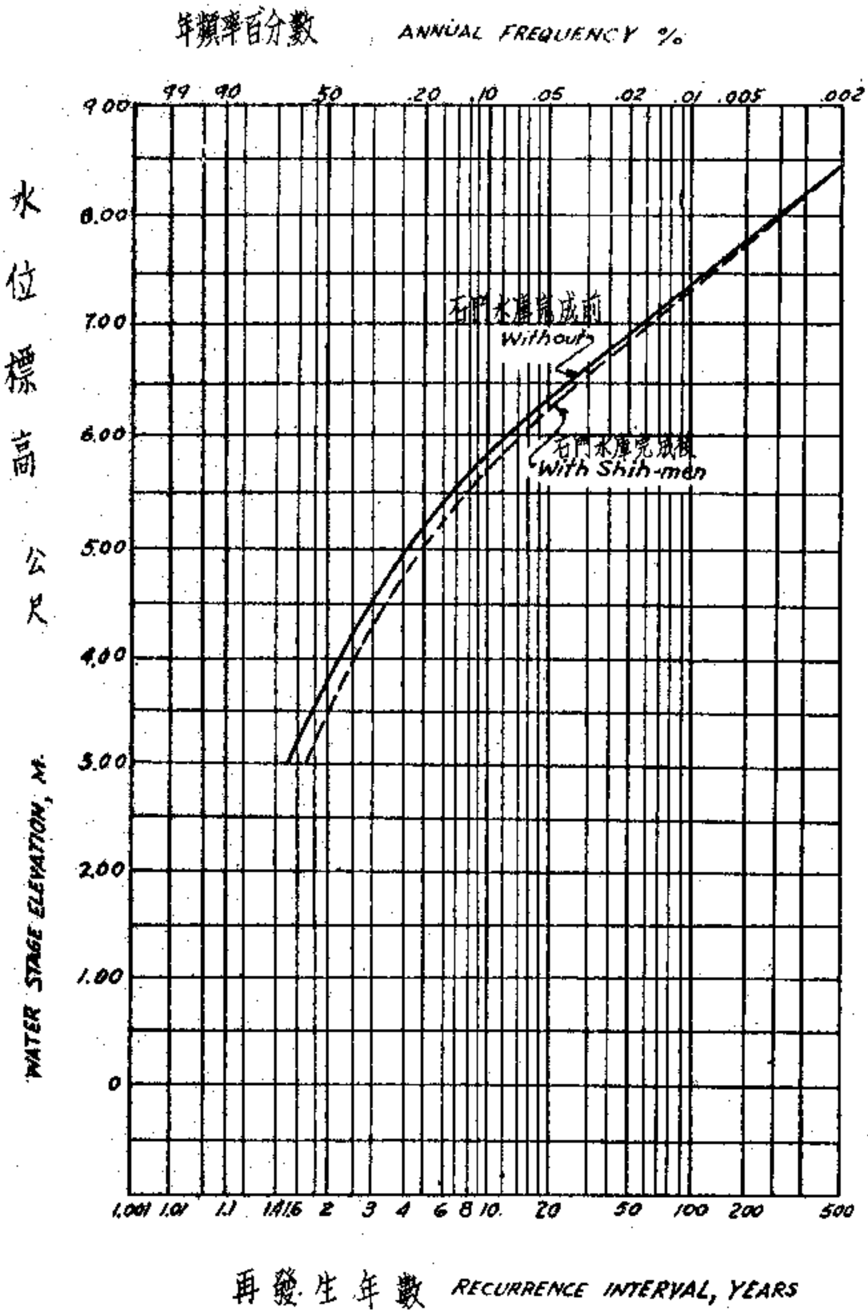
第三圖

ZONE III

8 SEPT. 1964

CHART A-3

CHART A-3



淡水河防洪計劃

TAN-SHUI RIVER
FLOOD CONTROL PROJECT

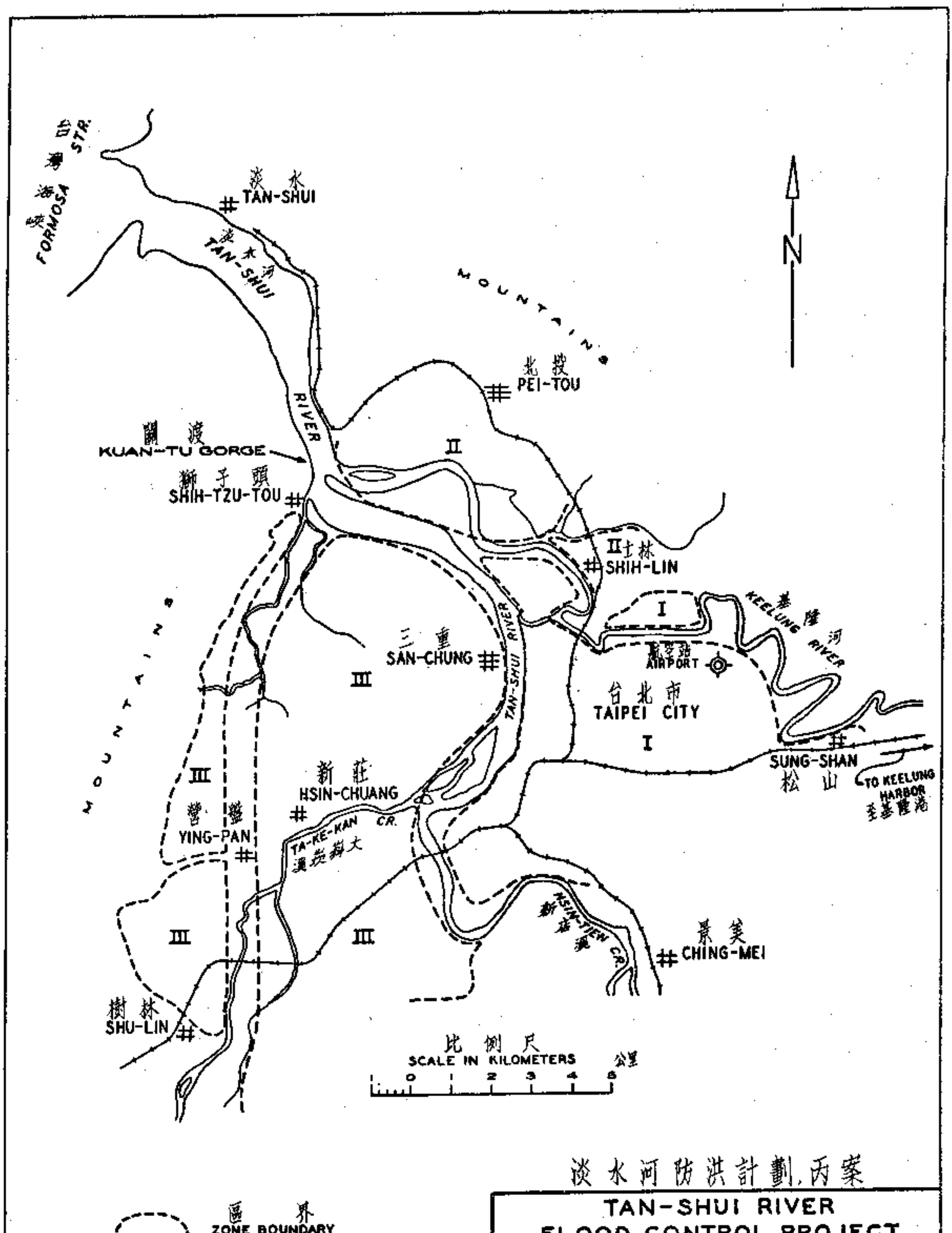
台北橋年洪峰水位頻率曲線

ANNUAL PEAK-STAGE FREQUENCY CURVES

TAIPEI BRIDGE GAGE

8 MAR. 1964

CHART A-4



淡水河防洪計劃,丙案

TAN-SHUI RIVER
FLOOD CONTROL PROJECT
PLAN "C"
洪泛區圖
FLOOD PLAIN ZONES

8 SEPT 1964

PLATE A-I

附 錄 乙

今後研究建議

(譯 文)

一九六五年二月

附　錄　乙

今後研究建議

目　　錄

附錄乙

今後研究建議

一、水理觀測計劃

(一)目　的—報告正文第八段曾強調獲取水理測驗週詳計劃之重要性。此不僅為支證計劃中原來河槽及堤防設計之需要，且可從而探求早期工程對河況之變動，用以制訂後期設計準則，與必要時據以調整計劃方案。颱風洪水時在淡水河及其支流中測驗工作自屬困難，惟相信下列計劃可以達成。

(二)流　量

1. 測　站—計劃區域內重要地點之正確流量估計，為有效計劃之必要條件。流量測驗之目的，在建立水位與流量之關係，通常與長期持續之水位紀錄相輔製成該測站之流量歷線。所冀求之流量歷線可為 (1) 決定通過測站水流總體積所需全年不斷之歷線，或 (2) 僅洪水期中之歷線等二種。茲建議設立下列各流量測驗站：

溪流	地點	紀錄期間
新店溪	中正橋	全年
大嵙崁溪	大溪	全年
大嵙崁溪	新莊	全年
基隆河	五堵	全年
基隆河	中山橋	洪水期
淡水河	臺北橋	全年
淡水河	土地公鼻	洪水期

上列各站除關渡下游土地公鼻以外，其餘均為已有者，土地公鼻之流量測驗雖係困難，但此站洪水流量之正確估定，實為水理觀測計劃內最需要者，因目前當洪水大至漫溢臺北橋左岸後即無直接實測之洪水流量。

2. 水　尺—每一流量測驗站需設水尺二組；一為主尺，一為測坡水尺。各站之主尺應為自記者，因決定流量歷線必需繼續不斷的紀錄。自記水位計應裝置於大洪水不致浸及之高度以免淹沒；如屬可能，最好在洪水時工作人員亦能到達該處，以便校核及調整。不論置於橋樑之上游或下游，均應在橋孔壅高或洩降影響範圍之外。在主要自記水位計附近，應裝設輔尺或垂直水尺，庶萬一自記計失效時，紀錄不致中斷。輔尺應設於極大洪水時可到達之地，或其尺面可由遠處以望遠鏡觀測。

審查1964年9月流量測驗資料，率定曲線中若干點之分散顯係由於水面坡降之變化。低水及中水流量時，基隆河上之測站常受淡水河廻水之影響，而淡水河本身則又受潮汐漲落之影響。因陡峻之洪水波其前坡陡而後坡平緩，故高流量時所有各點之水面坡降均有變化。為顧及坡降變化對水位流量關係之影響，建議每一測驗站均設立測坡水尺。此尺可設於主尺之上游或下游，惟二者之間不可有橋樑，以免二尺間測得之水面降落包括橋樑水頭損失在內。二尺間之距離應較遠，使二尺讀數之差較諸由於水面起伏測讀水尺所生誤差為大。如屬可能，二尺之距離應使中水及洪水時二者水面降落在30至50公分為宜。雖近年在測流量時，多曾同時測量水面坡降，但因二尺間距離太短，所獲坡降數值不顯。測坡水尺能用自記計固佳，惟水標尺或垂直水尺如在洪水時不斷測記能供給一水位歷線者，亦屬滿意可用。

二尺之水位紀錄時間應力求一致，否則漲落迅速之洪水所指示之水面降落，其誤差可能甚大。故建議用人工實際觀

測較依賴二尺紀錄時間完全調整一致為佳。

3. 流量測驗—在此種河流情形下，使用浮標測驗洪水流量，似尚屬切合實際，相信可有滿意之結果。惟建議作若干改進如下：

應增加測量表面流速浮標數目，及增加斷面內測驗處所，土地公鼻站或需由船上施放浮標。

每一測站在洪水時，均應使用流速儀測驗若干次，以資確定表面流速轉化為全深平均流速之係數。流速儀應用重鉛魚由測站附近之橋上以絞車操縱，施測線宜遠離橋墩，以避免局部水流及冲刷影響。建議選擇數施測線測驗多點以確定流速分佈。平均流速與表面流速之比，自易於由此項流速分佈求得。但一迅速而簡單之方法亦可能達到此一目的，即先校核各站確係半對數流速分佈，將測線上各測點之流速繪於普通坐標，而其至河床之距離繪於對數坐標上，如所繪各點能合理的在一直線上，則為具有半對數之分佈。平均流速可由在水面下6/10深處測得。平均流速與表面流速之比可由在水面附近及6/10深度二處測驗而迅速求得，使用此一方法，各施測線之流速比，可由橋上於短時間內測得。此種特殊測驗，在獲得足夠資料可決定每一測站水位變化範圍內改正係數時，即可停止不再舉辦。在土地公鼻，或可用錨將船作短時間之固定，以使用流速儀從事特殊流速測驗。

現在之流量測驗方法中最有疑問者為橫斷面與流速並非同時測量。在新店溪與大嵙崁溪洪水時施測橫斷面或屬不可能，而必需繼續依賴洪水前與洪水後之測量。目前流

量測驗斷面地點應予檢討，務使在橋樑下游，遠距橋樑不受局部冲刷及淤積之處。在基隆河與淡水河測驗流量時，可以同時由船上作斷面測驗。故建議儘可能照此辦理，尤以臺北橋下游及土地公鼻二處為然。

4. 率定曲線——除流量測驗誤差外，多數測站繪成之水位流量關係，顯示頗為「分散」乃由於斷面、糙率及坡降等之變動。玆建議將資料照下述方式繪圖，即將坡降變動考慮在內以求減少此種「分散」現象。

在某一水位下 $Q/\sqrt{S}$ 之數量可解釋為「輸水容量」在該水位下如斷面及糙率係數維持不變，則此一「輸水容量」亦固定不變。Q 為測得之流量，S 為水面坡降。在主尺與測坡水尺間流速水頭變化被忽略時，可假定 S 大致與能量坡降相等。將一測站所有流量測驗之水位與「輸水容量」$Q/\sqrt{S}$ 繪成曲線（其分散之情形可能將較諸通常之流量水位關係曲線為少）。通過此等點，繪一適應最佳曲線，即為輸水容量率定曲線。利用此輸水容量率定曲線，可製成各種 S 值之水位流量曲線羣。利用此曲線羣與該站之水位歷線及量得之水面坡降，雖然斷面及糙率變動之影響將仍存在，但流量歷線仍可得而決定。以往流量測驗水面坡降，未曾適當定出，在分析時 S 可以 $S=S_0+R/W$ 大致表示；其中 S_0 為一定量流，在一定水位時之坡降（水位不隨時間變化）；$\ddot{R}$ 為水位昇高率，以每小時公尺計；W 為洪水波傳播速率，以每小時公尺計。

(三)增添水尺

除第(二)節第1段所列各水尺外，建議將下列各地已有水

尺繼續維持，以求獲得洪水時期之水位歷線：

新店溪	新店
新店溪	水源地
新店溪	光復橋
基隆河	松山
淡水河	獅子頭
淡水河	關渡
淡水河	油車口
臺灣海峽	祥調子

上述各水尺均係現有者。雖最好為自記計，但如在洪水時能繼續測記而能確定水位歷線，則水標尺或垂重水尺亦屬可行。增添水尺之目的在協助決定計劃中重要地點之水位關係、並求所需洪峯時間與洪波移動等資料，以供水文研究與洪水警報系統之用。

(四)河槽橫斷面測量

計劃區域內前設之河槽斷面均適用於本計劃（水理觀測計劃）。每二年重測一次已屬滿意，惟如有大洪水發生，則每年秋季應複測一次。淡水河由河口至萬華間應選擇10個斷面作為特殊研究，其施測次數應較多，藉以瞭解此感潮河段內，每年淤澱及冲刷之情形。此種特殊研究斷面在颱風季之始及末，應各測量一次，冬季再測一次。在洪水時之測量，更有其價值，故颱風季中應視情形盡量辦理加測。第(二)段3節中曾強調流量測驗斷面水深測量之需要，此說對於若干特殊研究斷面言，自亦相同。茲建議儘量善用洪水時有限之時間，選擇少數斷面，隨變化情形測量水深數次。為將水深測驗變為河床標高，測

量時間內自始至終之水位標高必需知曉。故建議水深測量應與下節討論之水面縱剖面測量配合辦理。推移載樣品採集亦應與水深測量配合進行。

(五)水面縱斷面測量

為分析計劃區域內之摩擦係數及局部能量損失，每次洪水不同時間之水面縱剖面應設法取得。為達成此一目標，除(二)段1節及(三)段中所列各水尺外，需要更多地點之水面標高。計劃區域內每隔11.5至2公里處，每一橋樑之上下游及關渡隘口緊接上游右岸等地之水面標高應行獲得。測驗可用水標尺或垂直水尺，由橋樑、防洪牆或其他建築物上之參考點向下量度；或由建立於水濱附近之特殊基準點以水準儀測量。各測點應建立於意料中大洪水時可以通達之處。沿淡水河在關渡下游之道路與右側河岸，洪水時均可通達，而淡水河右岸現有堤防及防洪牆與新店溪右岸由番子溝上游至景美以及基隆河沿岸亦均可通達。淡水河關渡以上6公里間及大嵙崁溪均係重要河段，但在大洪水時甚難接近。在不能接近之地可裝設水尺使能用望遠鏡由遠處測讀為一可能方法。計劃區域中一河段內之每一水面縱剖面，其觀測時距應儘量縮短，以求能獲得代表一近似之「瞬時」水面。可指定流動觀測人員，每人負責數水尺不斷輪流讀記。根據水尺讀數繪成之水位歷線可決定「瞬時」水面縱剖面。

(六)糙率係數

由流量測驗，橫斷面及水面縱剖面可求得計劃區域內各河段之水理糙率係數。

(七)推移載樣品採集

目前所使用之推移載樣品採集技術，與所獲資料均屬優良

，樣品採集應與同一橫斷面測量同時舉行。應試以B-48推移載採樣器於淡水河高水時與水深測量同時採集樣品，亦應由淡水河與基隆河各橋上採集樣品。大嵙崁溪與新店溪河床質顆粒頗大，洪水時能否取得有用之推移載樣品，尚屬疑問；但低水時掘坑採樣似已獲得適當之結果。所有樣品均應作機械分析，每一河段應取一樣品，將其每一部分顆粒作比重分析。

(八)懸移載樣品採集

如能獲知每一支流懸移載量及其相對分佈情形，對估計淡水河可能之維持浚數量與擬訂可能補救方法，必有價值。建議在下列地點維持懸移載樣品採集站：

新店溪中正橋

大嵙崁溪新莊

基隆河五堵

淡水河臺北橋

五堵站及臺北橋站業已設立。所有樣品均應為積深式 (Depth-integrated type) 者，且應作總濃度及沙、淤泥與粘土百分數分析（此三類顆粒分界粒徑約為0.07公厘及0.004公厘）。每一橫斷面在低水時至少應採樣三處，水位較高時採樣處且應逐漸增加至5至10處。應試行在小段水流重心之垂直線上採集樣品；為此以往流測量驗應加分析，以求得測驗斷面在不同水位時流量分佈百分數。（例如：欲分五段採樣，則全斷面應分成10小段，每小段之流量約為總流量之10%；而採樣之垂直線應位於累計流量百分數為10%，30%，50%，70%及90%等處。）採樣垂直線應遠離橋墩以免為局部水流所影響。每一沉滓站在低水時每週至少採樣一次；水位昇高時則按計劃逐漸增加採樣次

數。洪水時應儘量設法以作最多次數之採樣。非颱風季節，在不溢岸之小洪水時，樣品採集亦至重要不可忽略。此等洪峯流量雖不大，但全年逕流之較大部份與年沉滓量之大部份均可能發生於此季中。每站均應繪製沉滓濃度與流量曲線（包括總濃度及沙之濃度）。此種「沉滓量率定線」將用以估計日沉滓量。圖中資料之份布情形將有助於指示何站及何種河流情形之採樣應優先辦理。

(九)優先次序

一般洪水時間不過一至三天，人力與設備之限制將不容許本計劃建議之全部地點均可同時從事觀測。但淡水河應最優先，因最迫切之問題與此段有關也。

(十)設　備

因上述計劃需於相當短促之洪期內，並在數處同時搜集資料，故流速儀、推移載採樣器、積深式採樣器、吊車、捲軸等器材設備或有增添之需要。最迫切需要者為水深測量儀，及於洪水時能在淡水河上安全操作之船隻。在此種河流情形下，回音測深儀為獲得可靠水深資料唯一可行之方法，美陸軍工程師團在美國密蘇里河上曾利用 Bloodworth ES 130 式輕便回音測深自記儀(6或12伏特電力供應)曾有良好之經驗。此項設備可靠、輕便、並易於在船上裝卸。此儀器可插裝於船底之插座中。關於此儀之資料可向 States Electronic Corporation, Blood-worth Marine Division, 96 Gold Street, New York, U. S. A. 詢問。一條長6至8公尺附有船外馬達裝設之小船，可在淡水河上安全操作。美國市場上已有若干新設計之纖維玻璃及鋁質船殼之小船，可在洶湧之水面穩定駕駛。有關資料可向下列各公司索詢。

Crestliner
Division of Bigelow-Sanford. Inc.
Little Falls, Minnesota

Dorsett Marine
1955 Lafayette Street
Santa Clara, California

Grumman Boats
Division of Pearson Corporation
Sausalito, California

Boston Whaler
Fisher-Pierce Company, Incorporated
1149 Hingham Street
Rockland, Massachusetts

Hydro Swift
1750 South Eight West
Salt Lake City, Utah

Lone Star Boat Company
P.O. Box 218
Plano, Texas

Shell Lake Boat Company
Shell Lake, Wisconsin

此等船殼重量輕，可置於小船拖車上，有三四人即易推送下水或拖拉上岸。

為在水中使用順利及安全與在陸上處理方便起見，建議採用船外馬達二具，每具至少動力為40馬力。購船時應同時購一船拖車或就地製造亦可。

(十一)規劃

派遣一中國工程師至美國米蘇里河考察有關採集與分析資料方法，當屬有助於水理觀測計劃之推行。亦可得到選擇回音測深儀、船隻及其他之設備之指導。

二、水工模型試驗

(一)驗證試驗

曾與水工實驗室李德熙及吳建民二先生討論關於模型河槽糙率如能再作驗證試驗自屬得策。每一河槽模型內應施放一組定量流至水位約達平岸狀況。如水位流量關係與所得實際資料不相當時，則模型糙率應加以調整。驗證用之實際資料雖然稀少，但淡水河之臺北橋及新店溪之中正橋已有率定曲線可以利用。淡水河關渡下游當歐珀、愛美及葛樂禮等颱風洪峯時亦有數次水面縱剖面資料可資利用。為進一步之模型驗證，今後應利用每一機會以求獲得實際資料。

(二)減低關渡洪峯

與薛觀瀛先生討論關於臺北盆地模型最有價值之用途，厥為當建議堤防完成而臺北盆地之蓄水作用消失後，估計對關渡洪峯流量之影響。在目前情況下，無疑的，岸上蓄水作用可使洪峯流量減低若干，但建議之堤防完成，則將無降低之可言。估計將來範束之作用，而將流量向上調整，以及根據以往之紀錄，所建議計劃流量為200年者當係必需。惟此預期之洪峯增加，是否適當的反映於報告正文第七段所述之計劃流量，乃一重要之問題。水工模型試驗當可對此問題提供合理之答覆。

洪峯降低之數量或不能與洪峯流量直接相關聯，因洪峯降低數量，尚與洪水體積、洪水歷線坡降、及洪峯流量等有關。（一體積小且洪峯高而陡峻之洪水歷線，其洪峯降低程度自較一體積大而洪峯相同但平緩之洪水歷線所降低者為大。）故需將以往洪水按其歷線性質分成數類，每類各在模型中試放若干

洪水以求出蓄水之作用。在薛君1964年9月5日「計劃流量之選擇」備忘錄中，曾指出由200年暴雨按單位歷線分析所得洪水中，至少應選一次包括在以往洪水內，作模型試驗。每一洪水應按(1)現在堤防及溢岸情形，及(2)全部計劃堤防完成情形，放水試驗及觀測關渡之流量歷線。比較(1)(2)之結果，可求得每類洪水歷線兩岸蓄水對洪峯降低之效果。

為作上述建議之研究，模型內關渡下游需裝置一附有流量測量之水流排洩設備，並於排洩設備上游安置一控制水位之閘門。在排洩設備處應安置一可取下之活動段，庶模型內下游段前水流不受擾動。為求得關渡洪水歷線，每一洪水應放二次：第一次裝置活動段時測驗關渡之水位歷線；第二次操縱排洩裝置，使用閘門以產生前次量得之水位歷線，並測驗流量歷線。

(三)關渡治導工程

由於臺北盆地模型水平比例尺小，及垂直方面之畸形，不適合於報告正文十三段所建議之關渡治導工程局部設計研究。故建議為此目的建一單獨之等比模型，其比例至少應為1：100，其大小應以水資會水工試驗室水源能供應者為度。雖然在模型內無法得到正確冲刷程度。但可裝置可冲刷之河床於研究區域之不同部份，以指示相對之潛在冲刷。

此一模型試驗之目的在求獲得上游治導工程最經濟之佈置。使關渡隘口流入能量損失減至最小。此一研究應預期兩階段之發展。按照報告正文第六段建議之施工計劃，在最初關渡治導工程建造時，大嵙崁溪新河槽尚在未來數年之後。故此項治導工程之設計，應在過渡期間於塭子川附近淡水河左岸原有情況下能有效運用；但此項設計亦應預期第二階段大嵙崁溪新河

道完成時之狀況。為求所希望之水流狀況，第一階段設計中之若干構造物或需於第二階段內拆除。模型研究應針對第一階段之設計使之在第二階段亦能同樣適合及可以實施。兩階段之模型佈置應反映出基隆河現在河口之封堵，並包括新出口於模型之內（如其位於上游不太遠之處）。至於所需考慮之建築物型式，平行之導流堤，較諸突出之丁壩為優，因後者可引致相當之能量消耗也。

三、大嵙崁溪穩定河槽設計

由與胡運鼎君之討論以及報告本文第九段中所述，大嵙崁溪新河道設計一穩定河槽當屬可能。新河槽之平均年推移載運送能量應與現在大嵙崁溪下游10公里段河槽(計劃中將廢棄而以新河道代替)之能量相等為穩定之標準。此下游段河槽斷面，由多年測驗結果研究似屬平衡狀態而無顯著之長期淤澱或冲刷趨勢。苟目前河段係屬平衡狀態，則所設計平均年推移載運送能量與之相同之新河槽自亦可以平衡。

茲建議此項研究宜根據愛因斯坦氏「明渠水流沉滓運送之推移載函數」計算全部推移載運送率，此文刊於美國農業部土壤保持局1950年 9 月1026號技術公報。由此計算所得之數量，容或與實際測得者不符，但相信所獲之相對數值將有相當意義，蓋若計劃河槽中計算之荷載相符，實際者亦可能相符也。

第一步驟為由現在河段中求得平均河槽斷面，此段中計有斷面 8 處。進以決定平均坡降，與利用已有之河床質樣品資料，求得其平均機械分析。研究段之標準流量率定曲線至為需要，最佳莫如在江子翠實測所得者，其次則為利用愛因斯坦分析法求出者。因中水

流量每可能運送平均年荷載之大部分，故需俟有充分之實際流量測量資料，能確定率定曲線至中水流量範圍時或屬可行。第二步驟為依照愛因斯坦方法，分別計算主要河床質中各部份粒徑沉滓運送率與流量之關係，然後利用流量延時曲線，於上述各部份粒徑以求得平均年沉滓量。1964年9月6日「沉滓量估計」備忘錄中雖具有大嵙崁溪在石門水庫完工後之流量延時曲線，但尚欠精確，在時間較裕時，應再作較詳細之分析。

次一研究課題為設計河槽之斷面形式與坡降之假定，及沉積於大嵙崁溪新河槽上物質之成分如何，乃一重要問題。玆建議一途徑如次：假設沉積於新河槽上之粒徑，與現在河槽上所能運送者相同，在實際粒徑分析範圍內，任意選定兩種顆粒成份曲線，計算各組成份曲線範圍內之平均年荷載，以供與計算得之現在河槽相同成份曲線範圍內之荷載相比較，如二者不符過多，則變更河槽寬度，以試求獲得較佳結果。

由上述方法當可提示新河道設計之可能範圍，其平均年沉滓運送能力與現在河槽者相當。能量稍大之新河槽設計或更勝一籌，因其將助於河槽之自然清洗作用。由於受新河道與淡水河滙流段之控制，可望不致發生大量之淘刷。

四、沉滓量與河槽之維持

改善淡水河槽之目的為降低計劃洪水位，庶堤防與防洪牆不致過高。河槽愈大，堤防可愈低，惟河槽愈大，流速愈緩，泥沙淤澱之趨勢愈大，而有賴於維持浚渫以挖除之數量亦愈多。如河槽改善較某一尺度為大時，維持浚渫經費將過鉅，而計劃之安全亦將發生問題，蓋殊難確信能隨時保持所需之河槽容量也。淡水河槽擴大限

度，以能夠維持，而所需維持浚渫數量最小為宜。故有關淡水河沉澤知識，實屬重要，因由此可獲得一維持浚渫所需之最大數量也。其中砂負載之知識尤其重要，其可能為河床變動之主要物質，而淤泥及粘土可為水流運携入海，或雖於低水時期沉澱於河槽，但流量較高時，卽易被冲刷而去。

丙案完成後大嵙崁溪改道，由基隆河口至萬華間現在淡水河槽，將僅為新店溪之水流及沉滓，因之現在大嵙崁溪與新店溪間沉滓量分配情形亟需明瞭。原按二支流水流所設計之改善河槽，是否能大致維持作新店溪一支之延伸？自屬一疑問。

初步分析指示淤澱之可能不高，計劃河槽可在合理浚渫數量下得以維持，惟現在之沉滓量估計僅係根據極有限之採樣資料，且極為粗率。

第一節末段懸移載樣品採集如能行之數年，當可供確估沉滓量所需資料。決定平均年沉滓量時，亦需各站優良之流量延時曲線。1964年 9 月 6 日「沉滓量估計」備忘錄中之延時曲線，僅由約略調整而得，在時間許可下應再作較詳之分析。因洪峯陡峻，延時曲線應使用瞬時流量數值，或時段小於 3 小時之平均數值。

臺北橋已有若干實測沉滓資料，故可在他站之前獲得合理之平均年沉滓量估計。利用李登豪與索浦二氏「沉滓運送研究中之重礦物質」文中建議之方法，估計臺北橋站沙荷載中來自大嵙崁溪與新店溪之比例，亦為一可行之途徑，該文載於1943年美國土壤學協會報告 524 至 530 頁。由大嵙崁溪與新店溪採集之砂樣其粒徑範圍可與淡水河關渡下游砂質河床之粒徑範圍相同，由岩石學試驗，或可覓得不同來源物質間若干相異之性質，如重質礦物或輕質礦物之比例等。如關渡下游河床質中不同物質之比例可以決定，則其中各來

源不同之砂荷載，可得而估計矣。

五、浚渫工費估計

如與胡運鼎君所討論者浚渫工費估計偏高。1964年9月8日計劃經費中估計44,000,000立公尺之浚渫費共計新臺幣990.000.000元，每立公尺單價達新臺幣22.60元，或每立碼美金0.45元。在本計劃情況下，浚渫單價實應較原估半數為廉。（譯者按：上項費用中包括購地、地上物補償、管理費、預備費與包商利潤等在內，實際浚渫單價為每立公尺新臺幣13.60元或每立碼美金0.26元）。

茲建議將船隻、人工、燃料等分項詳加估計以決定單價。以米蘇里河上一工作而擬之詳細估價為例如次，但計算所採用之實際項目及價格，自應與淡水河防洪計劃條件相配合。

審議報告正文第六段所建議之施工計劃中，淡水河與大嵙崁溪浚渫工作需時數年，故浚渫工廠之投資可設法減至最低限度，茲建議主要工廠一項，按十年償債基金期間計算年成本。浚渫專家建議鑑於輸泥管線甚長，臺灣省水利局原假定20吋與24吋攪刀式挖泥船，每小時出泥量400及600立公尺者，宜各減少約15%計算。原假定每年200工作天似屬合理，但每天工作18小時，當較20小時為切實際。

陸上管線既長，為運搬操作便利計，20吋挖泥船或較24吋者更為實用。

如臺灣省水利局尚乏可用之浚渫設備及價格資料，可逕向美國馬利蘭州巴的摩布歇城1611號伊利可特機械公司索取。

標準浚渫價格估計示例

1. 工作數量——供給浚渫3,500,000立碼土砂暨棄土至距浚渫地約

11,000 呎處所需之一切工廠、人工與物料。

2. 土質——含有微量礫石之細砂。

3. 完工期限——一年。

4. 挖泥船

　　$33' \times 100'$，滿載時吃水5.5呎。

　　6 呎攪刀，附 600h.p. 馬達。

　　吸入口徑24吋，出口徑20吋。

　　20吋抽砂泵，附 2,000h.p. 電動馬達。

　　邊纜及速率由 300h.p. 馬達操作。

　　所有馬達均為電動（4,160 伏特）。

　　使用商業供電——13,800 伏特均挖泥船上變壓。距挖泥船 3,000 呎之電線上，加入20吋 2,000h.p. 加壓泵一臺。

　　挖泥時間——每日 3 班各 8 小時，估計實際抽砂時間20小時。

　　估計出泥量每小時 800 立碼。

5. 需要工作時間——3,500,000 立碼÷800＝4,375抽泵小時。全部工作時間$=4,375 \times \frac{24}{20}=$5,250小時或210天。

6. 挖泥船員——挖泥司機、機電工、水手 2、機車長（僅白日班）。

7. 輸泥管線——尺寸——徑20吋

　　總長度——11,000呎（水上管線2,000呎，陸上管線 9,000呎）。

　　每支管長——徑20×40吋呎快速接頭。

　　桶式部份——48吋×20呎，每管長40呎 2 支。

8. 輸泥管線工場——小交通船 1，吊車 1，推土機 1，電銲機 1，

裝配A型架卡車2。

9. 輸泥管人工——交通船司機1，吊車操作手1，曳引司機、工頭、電銲匠、及小工3。

10. 價格

人工

挖泥司機	5250小時	@US$3.00	$15,750
機工	5250	2.75	14,438
水手2	5250	1.85	19,425
機車長	1750	4.00	7,000
交通船司機	5250	2.25	11,813
曳引車司機1	5250	2.75	14,438
吊車司機1	5250	2.75	14,438
工頭	5250	3.50	18,375
電銲工	5250	2.75	14,438
小工3	5250	1.50	23,625
卡車司機2	5250	1.50	15,750
			小計 $169,490
保險、稅金及社會安全等			16,949
			人工費合計 $186,439

11. 材料及什項用品 $5,000

12. 工廠設備

1-20吋挖泥船暨輸泥管線

	5250小時	@$66.18	$347,445
電力費	5250	19.56	102,690
1-加壓泵及動力	5250	17.89	93,923
1-交通船	5250	3.73	19,583
1-起重機	5250	4.00	21,000
1-曳引機	5250	5.61	29,453
1-電銲機	5250	1.00	5,250
2-卡車及A型架	5250	1.50	15,750
1-小貨車	5250	0.75	3,938
小工具			5,000
			工廠合計 $644,032

13.	直接費總計	$866,131
14.	單價(直接費)※	835,471/3,500,000
		=$0.239/立碼

六、土 壤 調 查

對進一步地基調查及土壤試驗之建議如報告正文第二十六段。

七、洪災損失調查應有組織

訓練一批人員，俾於洪災發生後，能立卽展開調查，實屬需要。此種需要並不限於淡水河流域。負責此等調查者，應卽為將來計算防洪計劃效益之人員。茲建議此項人員應卽行訓練，並於臺灣省內任何地點發生洪災時，卽可前往開始工作。為計算興工前後未來之土地增值效益，並建議應尋求饒有經驗之地產估價人員。

※此項單價不包括利潤、機具搬運、共同費、管理費或公司開支等。

影 印 原 文

REPORT ON
REVIEW OF TAIPEI AREA FLOOD CONTROL
PLANNING PHASE II

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CORPS OF ENGINEERS, U.S. ARMY
FEBRUARY 1965

CORPS OF ENGINEERS, U. S. ARMY

REPORT ON

REVIEW OF TAIPEI AREA FLOOD CONTROL PLANNING

PHASE II

Review Team

Kenneth T. Case, Portland District
Alfred S. Harrison, Missouri River Division
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1 February 1965

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PHASE II REVIEW OF TAIPEI
AREA FLOOD CONTROL PLANNING

1. Introduction. - This report on the Phase II review of flood control planning in the Taipei area was conducted by the Corps of Engineers at the request of AID in accordance with PIO/T 484-568-2-40079. The Phase I review team, consisting of Wilfred D. Darling and J. M. Buswell of the Pacific Ocean Division, visited Taipei in April 1964 and reported their preliminary findings in a memorandum dated 25 April 1964. The Phase II review team consisting of:

Alfred S. Harrison, Missouri River Division, Team Leader
Ralph P. Wong, Los Angeles District
Kenneth T. Case, Portland District

was in Taipei from 5 August to 11 September 1964. Mr. Darling contributed portions of this report pertaining to foundations, levees, and culverts.

2. Scope of Review. - While in Taipei the review team inspected the river channels and existing flood control works in the Taipei area and made a reconnaissance of the Tan-Shui River basin upstream from Taipei. They reviewed the physical data, the basic engineering and economic studies, and the design criteria used as a basis for planning by the Provincial Water Conservancy Bureau. They made a very brief review of alternate methods of flood protection for the Taipei area and of alternate channel and levee protection plans A, B, C, and D considered by the PWCB. In the limited time available they were able to review in detail only Plan C which the PWCB has recommended for construction.

3. Scope of This Report. - This report summarizes the principal findings, suggestions, and recommendations of the Phase II review team. It is assumed that the reader has some familiarity with the Taipei area and with the project proposals. More detailed evaluation and discussion, together with some suggestions for further studies, will be found in the appendices.

4. Methods of Protection. - Channel improvements and levees are the most feasible means of obtaining a desirable degree of protection for the Taipei area. Such alternate means as reservoir storage and channel diversion can be eliminated from consideration due to high cost and limited potential benefits.

5. Degree of Protection. - The 200-year flood is the lowest design discharge that should be considered for this densely populated metropolitan area. All levees and floodwalls should contain the 500-year flood well within the freeboard zone.

6. Plan C. - Plan C is technically feasible and economically justified as a long range plan for comprehensive flood protection in the Taipei basin. It lends itself to the successive completion of integral flood control units that will earn benefits as they are constructed. It also lends itself to

revision in the later stages of implementation in case this seems advisable. From this point of view, other channel and levee plans such as A, B, and D might be regarded as possible variations of Plan C.

a. Stage Construction. - It would not be prudent to implement Plan C immediately in its entirety. Construction in stages will ease the financial burden, assure priority of protection to areas with the greatest existing damage potential, and--most important--permit evaluation and accommodation to changes in river regime as they are caused by the improvements. The following construction stages are recommended:

First Stage: 2-year period.

(1) Enlarge the cross section in Kuan-Tu Gorge.
(2) Construct the right levee on Tan-Shui River and the left levee on Kee-Lung River around the She-Tzu area.
(3) Construct the right levee on the Kee-Lung River and the left levee up Shung and Wai-Shuang Creeks in the Shih-Lin area.
(4) Construct training dikes along the Tan-Shui River.
(5) Implement flood plain zoning regulations on left flood plain.

Second Stage: 4-year period.

(1) Construct training works for the entrance to Kuan-Tu Gorge.
(2) Construct levees on the Kee-Lung River upstream to Sung-Shan with the left bank levee around the Taipei City airport as the first unit.
(3) Construct the new Kee-Lung River confluence with the Tan-Shui and close the existing Kee-Lung River outlet at Kuantu Gorge.
(4) Construct the levees in the Kuan-Tu and Chung-Chou-Li areas along the right bank of the Tan-Shui River and the right bank of the Kee-Lung River through the new confluence, together with the tributary tieback levees south of Chiu-Pei-Tou.
(5) Increase the heights of existing levees and flood walls around Taipei City and Yung Ho to the new design heights.
(6) Increase the capacity of the Tan-Shui River by dredging as necessary, and make land fills.

Third Stage: 4-year period.

(1) Observe and collect data on the Tan-Shui River under flood conditions. Use the information to evaluate the adequacy of design, movement of sediment, and maintenance requirements for use in designing the later stages of the project and revising the over-all plan as necessary.

(2) Construct the levee on the left bank of the Kee-Lung River in the Sung-Shan area.

(3) Construct the tieback levees on Wai-Shuang, Nan-Yai, and Huang Creeks.
(4) Construct the levees on Ching-Mei Creek and upstream along the right bank of Hsin-Tien Creek.

Fourth Stage: 6-year period.
(1) Construct the diversion channel for Ta-Ke-Kan Creek, and make land fills.
(2) Construct the levees on the left bank of the Tan-Shui River and Hsin-Tien Creek, together with the tributary tieback levees west of Chung-Ho.
(3) Construct the levees on Ta-Ke-Kan Creek upstream from the diversion channel inlet and the remaining works proposed in Plan C.

b. Induced Damage. - Although by the end of the second stage of construction the levees on the right bank of the Tan-Shui River will be completed, it is not believed they will induce additional flood damages in the left bank area. Historically, Taipei City itself has obstructed the right flood plain for many years. Furthermore, the construction measures to reduce the head loss at the entrance to Kuan-Tu Gorge are expected to lower somewhat the upstream stages for large floods.

c. Flood Plain Zoning. - The integrity of the Taipei City levees during the interim period between the first and last stages of construction depends on maintaining the existing natural floodway across the left bank flood plain, between San-Chung and Hsin Chuang, and northwesterly into the Wen-Tze-Chuan. It is recommended that flood plain zoning, aimed at (1) preserving the existing floodway, (2) preserving the right-of-way for the Ta-Ke-Kan Diversion from higher development, and (3) promoting the flood-proofing of structures, be implemented immediately on the left flood plain and enforced until all construction under Plan C is completed.

7. Design Discharges. - The following estimates of 200-year discharges are accepted for design purposes:

Ta-Ke-Kan Creek at Mouth	13,200 cms.
Hsin-Tien Creek at Mouth	10,300 cms.
Kee-Lung River at Mouth	2,700 cms.
Tan-Shui River below Kuan-Tu	25,000 cms.

These discharges are derived from available stream gaging records, extended by applying unit hydrograph methods to the available rainfall records. Although these adopted values are not considered to be conservative estimates of 200-year discharges, they are considered to be reasonable and to represent a balanced design throughout the project. They are somewhat larger than the design discharges originally proposed.

8. Technical Reasons for Phased Construction. - Several uncertainties point to the advisability of phasing the construction of Plan C over a period of years. Water surface profile data for the Tan-Shui River are limited, and direct determinations of discharge are available only for

flows less than bankfull. For flows above bankfull, when the Taipei Bridge is bypassed on the left bank, only estimates of the discharge are available. Therefore, determination of the design flood profile in the existing river is heavily dependent on computational assumptions. Other important questions are how much additional capacity in the Tan-Shui can be developed by channel improvement and, furthermore, can it be maintained over the years. Once the natural floodway in the left bank is blocked, the integrity of the protected areas behind the levees is dependent on the designer's assessment of the channel capacity between the levees. It would not be prudent to confine these great flood flows between high levees until the design channel capacities are assured; it also would be imprudent to start work on the Ta-Ke-Kan Diversion before the problem on the Tan-Shui is solved, for the design stages on the Tan-Shui and the experience gained in improving that channel will affect the Ta-Ke-Kan design. It is, therefore, recommended that the implementation of Plan C proceed slowly and that a comprehensive program of hydraulic and sedimentation observations be conducted to obtain data during flood flows, to assess changes in river regime as they occur due to the proposed channel improvements, and to provide a basis for any necessary modifications of Plan C in its later stages.

9. Ta-Ke-Kan Diversion. - The design of a reasonably maintenance-free diversion channel for the Ta-Ke-Kan is considered to be feasible, provided the new channel is designed to match, as closely as practicable, the characteristics of the existing river channel in the lower 10 km. reach from the railroad bridge at Hsi-Shung to the mouth. The existing slope of about 0.0006 is available along the diversion alignment. This slope, projected downstream from the upstream point of diversion, will probably result in a higher bed grade than presently proposed at the downstream end and higher levees throughout the length of the diversion. The proposed low flow channel width of 200 meters seems reasonable, but this must be firmed up by a study of its bed material load transporting capacity averaged over a long time period. The low flow channel should be designed, if possible, to carry the one-year peak discharge below berm level. This would probably assure good natural channel maintenance and give local people an opportunity to farm the berms on a chance basis. Cost estimates should anticipate that the low flow channel might eventually require revetting in order to hold the design width. The floodway between levees upstream of the point of diversion should not be narrowed unnecessarily because this area appears to be receiving deposition due to an abrupt flattening of the grade of the Ta-Ke-Kan, and a concentration of flow may shift the zone of deposition downstream into the diversion channel.

10. Tan-Shui River. - It is considered possible to lower the design stage at Kuan-Tu about one meter with a channel improvement on the Tan-Shui that would not require extensive maintenance dredging. Analysis of river cross section records over a 30-year period shows that the Tan-Shui has been more or less in equilibrium with no long term trends of aggradation or degradation. In light of this, an improved cross section has been selected which will have about the same discharge-velocity regime as the existing river in the range of lower, more frequent discharges. The improved channel width will be obtained by contracting the existing channel between parallel training dikes. Deepening will be accomplished by dredging if

natural scour does not occur. Right angle spur dikes should not be used in this reach because they would retard flood flows, creating additional channel roughness and working against the aim of the channel improvement which is to lower stages upstream of Kuan-Tu. It should be determined whether this costly channel improvement is justified by the savings from lower upstream levees and floodwalls.

11. Kee-Lung River. It is agreed that the existing channel should be used with no significant enlargement.

12. Hsin Tien Creek. The proposed use of the existing channel without modification is wise. Despite high velocities during floods, this alluvial channel has remained reasonably stable. It would not seem prudent to upset this "quasi-equilibrium" regime.

13. Kuan-Tu Gorge Improvements. - The widening now underway at Kuan-Tu and the proposed deepening will provide sufficient cross section area; however the very poor upstream approach conditions have been responsible for much of the head loss that has occurred at this constriction. It is recommended that the feasibility of correcting the approach with river training works be studied in an undistorted scale model at the Hydraulic Model Station.

14. New Kee-Lung Confluence. - Further studies should be made to select the most economical plan for relocating the mouth of the Kee-Lung River. It is suggested that an alignment along the existing Kee-Lung cut-off south of She-Tzu has merit. A considerable length of levees along the Kee-Lung would be eliminated; however, it is recognized that additional levees would be needed to bring Shuang Creek into the Tan-Shui.

15. San-Chung Protection. - The floodwall for the interim protection around San-Chung should be located as far landward as practicable in order to permit the possible future widening of the Taipei Bridge constriction.

16. Bridges. - The proposal to use the Taipei and the Chung Hsing bridge section without modification should be reconsidered.

a. With the ~~Taipei Bridge~~ work at Kuan-Tu completed, the Taipei Bridge will become the "bottleneck" in the Tan-Shui River. The Taipei Bridge section should be widened if at all possible, and any new bridge piers should be designed to minimize head losses, local scour, and the accumulation of debris.

b. Chung Hsing Bridge. Consideration should be given to a new channel span on the left which would permit correction of the poor alignment of the Tan-Shui River which now must pass through the channel span at the right end of the bridge.

17. Water Surface Computations. - The contraction and expansion loss coefficients of 0.10 and 0.50 used in water surface calculations are overly conservative except at abrupt changes in section. When roughness coefficients ("n" values) are based on actual river observations, they represent not only the friction loss but also include these other losses. Reasonable allowance should be made for trash and debris on bridge piers when computing bridge loss

18. Tidal Effects on Design Stages. - The assumption of water surface elevation +2.4 meters at the mouth of the Tan-Shui River is considered satisfactory for design water surface profiles. The highest tide level recorded was about +2.8 meters. Furthermore, comparative water surface profile computations show that, for discharges of design magnitude, a stage variation of several meters at the river mouth is reflected by a variation of only a few centimeters at the Taipei Bridge.

19. Freeboard. - Minimum freeboard of one meter is recommended for floodwalls and 1.5 meters for levees. To this minimum should be added on allowance for superelevation in bends, particularly for the relatively narrow, swift channels such as Hsin-Tien and Ching-Mei Creeks. Consideration should be given to additional freeboard at critical locations such as all upstream levee tie-backs and the right levee on the Ta-Ke-Kan Diversion.

20. Hydraulic Model. - The design of the Taipei Basin Model, its layout and scale ratios, and its method of operation are sound. The channel roughness, however, may require further adjustment to match the prototype rating curves for steady flow at the Taipei and the Chung-Cheng Bridges and to match the water surface profiles measured downstream of Kuan-Tu at the peaks of the Opal, Amy, and Gloria floods.

a. Studies With Present Model. - It is recommended that the present model be used to assess the discharge reduction due to the storage effect in the Taipei Basin by running series of floods with (1) existing levees and other conditions in the basin, and (2) all proposed levees in place. In order to do this, a discharge take-out and measuring device must be added to the model just below Kuan-Tu.

b. Kuan-Tu Training Works. - The distorted basin model is not suitable for studying localized problems such as the design of training works into the Kuan-Tu Gorge. An undistorted model with a scale as large as the model station water supply will permit is needed for this purpose. An erodible bed could be included as an indicator of relative scour potential.

c. Ta-Ke-Kan and Hsin-Tien Confluence. - Another undistorted model might be utilized to study the desirability and feasibility of interim training works to improve the confluence of Ta-Ke-Kan and Hsin-Tien Creeks.

21. Tributary Tiebacks. - When the discharge from a hillside tirubtary stream is too large to be handled by a culvert through the levee, tieback levees must be carried along the tributary to high ground. It is recommended that the profile of the tieback levees meet the following criteria throughout their length:

a. No lower than the elevation of the main levee.

b. One meter freeboard above the water surface profile for a tributary discharge that could reasonably be expected to be coincident with the design stage on the main river.

c. One meter freeboard above the water surface for the 50-year discharge on the tributary, coincident with a stage reasonably to be expected on the main river.

There is a question whether the proposed tiebacks for the tributary to the Kee-Lung River south of Chiu-Pei-Tou and the tributary to Hsin-Tien Creek west of Chung-Ho meet these criteria.

22. Interior Drainage. - The criteria and the provisions ppoposed for handling rainfall runoff from interior drainage areas behind the main levee system are considered to be inadequate in some cases. Since most of the interior areas are urban or potentially urban in nature, and since the levees will provide a relatively high degree of protection from river flooding, adequate capacity should be provided through the levees to keep ponding as infrequent, as short in duration, and as limited in extent as economically feasible. Reliance on lagooning of interior runoff at times when the Tan-Shui River is low, as proposed in the Chung-Chou-Li area, is not recommended for the above, as well as for sanitary and aesthetic reasons. It is recommended that culvert capacities meet the following criteria:

a. For local rainfall occurring when the Tan-Shui River is at low stage, culverts should discharge the peak flow from the one hour duration, ten-year storm.

b. For local rainfall from a typhoon storm that produces a rise on the Tan-Shui River, the culverts should drain the 24-hour accumulation from the 50-year storm within 30 hours after the beginning of rainfall.

In estimating the rates at which interior runoff can be delivered to the culverts, it should be recognized that in some areas drainage ditches and storm sewers are in a preliminary stage of development and that delivery rates will increase as the drainage system is improved.

23. Gating of Culverts. - Because of the high rainfall intensities and the relatively short concentration times for the interior drainage areas it is recommended that all culverts in both rural and urban areas be provided with flap gates at the riverward end. The automatic operation of the flap gates will increase the effectiveness of the project by avoiding unnecessary flooding due to either untimely closing or untimely opening of manual slide gates. All culverts in urban areas should also be provided with manual slide gates as a means of emergency closure in case the flap gate malfunctions. The emergency slide gate might be located either in a gate well in the riverward slope of the levee or at the landward end of the culvert. The riverward location is preferred because, in the event of gate closure, a seating pressure would be obtained and the culvert through the levee would not be under pressure from the riverside head. The landward location should not be used if the culvert consists of precast concrete pipe or if a slide gate alone and no flap gate is provided.

24. Tide Gates. - Tide gates will be helpful in alleviating drainage problems in low-lying agricultural lands around Chung-Chou-Li and Lu-Chow that are below river level during high tide periods. Tide gates are large culverts, with flap gates on the river end, set low enough to be submerged at low tide. They will operate automatically in conjunction with levees, to drain the land behind them to a level that approaches low tide.

25. Culvert Structures. - Corrugated metal pipe is the most satisfactory for use under levees and flood walls due to its strength and flexibility. Steel pipe should be galvanized and dipped in hot bituninous compound. Coal tar enamel protection may be necessary. With the growing aluminum industry in Tai-Wan, corrugated aluminum pipe might be considered. Cast in place reinforced concrete boxes will also be satisfactory and are preferred to precast reinforced concrete pipe which is more susceptible to leakage and misalignment of joints. Preliminary designs show concrete box culverts supported on piling; however, further investigation may show the piling are not needed. Seepage rings, or fins, should be included on all culverts under levees to increase the seepage path. Culverts may be given greater hydraulic efficiency by rounding the entrances at concrete headwalls.

26. Foundation Conditions. - Experience with a considerable length of existing levees indicates that the foundation is generally adequate. For a project of the size under consideration, however the foundation explorations conducted thus far are insufficient, especially since the proposed levees will be higher than those existing and there is the possibility of deep clay foundations under the Ta-Ke-Kan Diversion in the Wen-Tze-Chuan area.

a. Borings. - Borings for levees and flood walls should be taken at intervals not to exceed 150 meters. Depth of penetration should be at least equal to the height of the structure with several borings extending 1.5 to 2.0 times the height of the structure. Where weak or very pervious soils are encountered, the full extent of this type soil should be determined.

b. Soil Tests. - All soil samples should be classified visually and sufficient laboratory tests completed to verify visual classifications. Natural moisture content should be determined for all cohesive type soils in the foundations for levees and flood walls. Sufficient strength and consolidation tests should be performed on cohesive soils to insure adequate data for design purposes. Some triaxial compression tests should be made as a check; these should be consolidated-undrained type tests. The samples heretofore obtained by drive sampling methods are not considered "undisturbed" and are not considered suitable for strength tests. The results of direct shear and unconfined compression tests on the samples are not consistent and do not appear to be usable. It is suggested that, where foundation clays are encountered, undisturbed samples be obtained with thin-walled shelby tubes to permit completion of unconfined compression tests.

27. Levee Design. - The proposed standard levee sections have withstood past floods without distress. Generally, however, they appear to be very conservative with respect to the section provided and slope protection.

a. Levee Section. - The narrowest top width now used is 5.5 meters. Except where the levee top will be used as a road, a top width of three meters would be adequate in most cases from the design point of view. This would permit access for one-way traffic for maintenance purposes. Although berms are used generously as added protection against saturation of the landward levee slopes, special attention should be given to design of levee sections where deep, weak clays may be present. Individual stability analyses should be made for each specific case.

b. Levee Crossings of Old Channels. - Borings should be taken in each instance to determine type and depth of sediment. The economics of a wider levee section with stability berms versus removal of undesirable material should be considered.

c. Impervious Blanket for Sand and Gravel Levees. - Standard levee details indicate an impervious blanket from 30 to 50 cms. thick used on the river slopes of levees constructed of sand and gravel. It is considered that the minimum thickness for the impervious blanket measured normal to the slope should be 1.0 meter.

d. Underseepage. - Where levees or flood walls are founded on pervious soils, a flow net study should be made to facilitate design of protection against damaging underseepage. For levees, this would permit determination of height and width of land-side berms, need for impervious cut-off, etc. For floodwalls, this would permit a determination of depth of cut-off wall to reduce the exit hydraulic gradient to a safe value.

e. Slope Protection. - Preliminary plans call for brick revetments on both the landward and riverward slopes of levees where it would appear that grassed slopes would suffice. Grassed slopes would be adequate in most cases on the landward slopes of levees and on the riverward slopes where adjacent velocities during flood flow would not exceed about 1.5 meters per second. For higher velocities adjacent to the riverward slopes, either brick revetments, wire and rock sausages, or wet or dry pitched stone paving should be used in accordance with experience. Where levees are set back from the river channel, preliminary plans call for terminating the slope protection riverward of the levee toe with a concrete cut-off. It is suggested that a flexible "toe" or fillet of loose rock, graded over a wide range of sizes, would provide more effective protection against undercutting than the rigid concrete cut-off.

28. Dredging. -

a. Maintenance Dredging. - A channel improvement scheme designed to depend on any great amount of dredging to maintain the design capacity should not be adopted, since there is no assurance that the channel capacity will be available when needed.

b. Pilot Channel. - Construction of channels by dredging a pilot channel in expectation that the river will scour to design width is not recommended. Velocities in the Tan-Shui, expecially in the reach below Kuan-Tu, will not be high enough to produce the desired scour. Material scoured from upstream on the Ta-Ke-Kan would redeposit in the Tan-Shui and deteriorate that channel.

29. Navigation. - There appears to be no justification for allowing navigation requirements to govern the presently proposed channel design on the Tan-Shui. There is nothing in the proposed plan, however, that would be incompatible with a future navigation improvement.

30. Economic Justification. - Based on what are considered to be conservative evaluations of both costs and benefits, Plan C was found to have an over-all Benefit to Cost Ratio of 1.7, with the ratios in individual zones of the project area ranging from 1.2 to 2.5. The above B/C ratios were obtained using 6 percent per annum as the cost of borrowing money. Using 9 percent per annum, the over-all B/C ratio would be 1.3. Plan C is, therefore, economically justified.

31. Hydraulic Observations Program. - A comprehensive program of hydraulic observations is essential to the implementation of Plan C and to the continuing evaluation of the project after construction. Water surface profile surveys, discharge measurements, cross section soundings, and sediment load measurements obtained under flood conditions are needed for adequate assessement of channel capacities and changes in river regime. It is recognized that such observations under flood conditions will be difficult; however, it is believed that an effective program can be developed utilizing techniques that have proven effective in the Taipei area and other suggested equipment and techniques. It is suggested that a Chinese engineer might visit the United States to observe river observation practices (in the Missouri River Basin, for example).

32. Operation and Maintenance of Project. - The completed project cannot return all the benefits it was designed to create without careful attention to how it will be maintained over the years and operated during floods. The following are considered essential to effective operation and maintenance:

a. Preparation of an Operation and Maintenance Manual containing vital information about project facilities for ready reference, setting forth in detail operation and maintenance procedures, and clearly delineating areas of responsibility.

b. Establishment of a flood warning system for the Taipei area.

c. Assignment of the responsibility for portions of the project to the various local agencies and the requirement of assurances from these agencies that they will meet their responsibilities.

d. Designation of one agency as over-all authority to direct operation of the project during flood alerts, to inspect the project for compliance with maintenance procedures and have the power to enforce compliance, and to evaluate continually the performance of the project in order to detect problems and recommend remedial measures when necessary.

It is recognized that implementation of the above recommendations lies in the political as well as the engineering field.

33. Acknowledgments. - We wish to thank Mr. Howard Parsons of the Agency for International Development; Commissioner G. H. Huffman and Commissioner T. H. Shen of the Joint Commission for Rural Reconstruction; Minister Shen-Yi and Mr. T. K. Chu of the Ministry of Communications; Mr. K. T. Li of the Council for International Economic Cooperation and

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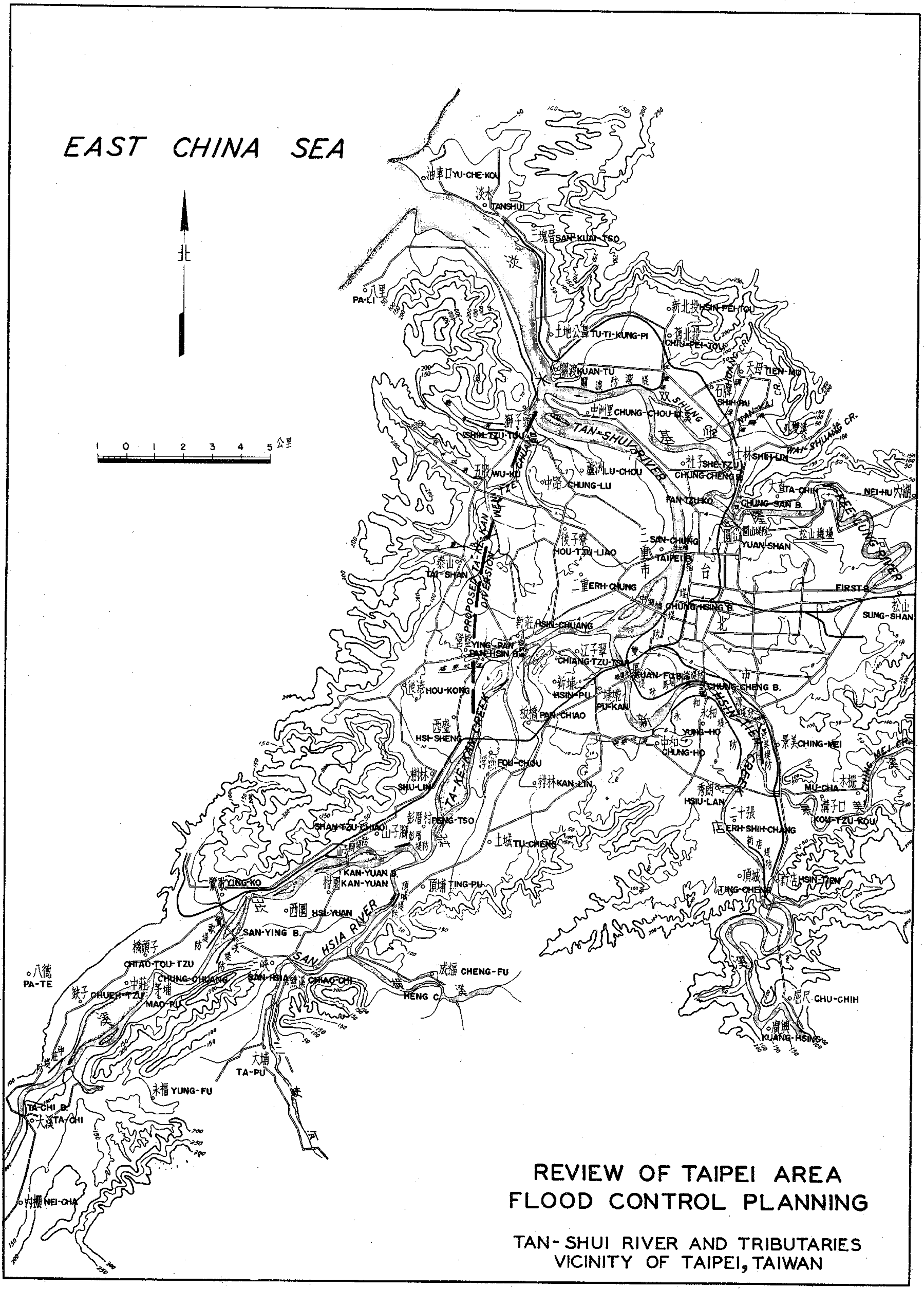

REVIEW OF TAIPEI AREA
FLOOD CONTROL PLANNING

TAN-SHUI RIVER AND TRIBUTARIES
VICINITY OF TAIPEI, TAIWAN

APPENDIX A
ECONOMIC STUDIES

REVIEW OF FLOOD CONTROL PLAN "C"
TAN-SHUI RIVER BASIN
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APPENDIX A
ECONOMIC STUDIES

Prepared by Team of Specialists
from the
Corps of Engineers, U. S. Army
September 1964

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REVIEW OF FLOOD CONTROL PLAN "C"
TAN-SHUI RIVER BASIN
TAIWAN

I Benefited area

1. The flood plain of Tan-shui River lies at the extreme northerly tip of the Island of Taiwan. There are included approximately 22,000 hectares of mixed agricultural, industrial and urban development.

2. The area benefited, as considered in the review of Plan "C" made by the Corps of Engineers representatives in August-September 1964, was limited to the portions of the lower basin for which flood control measures were inescapably inter-related. The benefited area was divided into 3 zones as shown on plate A-1 and briefly described as follows:

a. Zone I consists of Taipei City. It is bounded on the east by high ground, on the north by Keelung River, on the west by Tan-shui River and on the south by Hsin-tien Creek.

b. Zone II is bounded on the east and north by high ground, on the southwest by Tan-shui River and on the south by Keelung River.

c. Zone III includes the remainder of the flood plain lying to the west of Tan-shui River and the lower reaches of Hsin-tien Creek. Since the plan under review contemplates diversion of Ta-ke-kan Creek from the vicinity of Ying-pan to Shih-tzu-tou, the entire lower flood plain of Ta-ke-kan Creek, the left bank of Hsin-tien Creek and the relatively large area on the left bank of Tan-shui River are all included in this zone.

3. The land in the flood plain is very flat, with almost no isolated high ground. Minimum damage stage is approximately 3 meters above sea level and much of the land, particularly in Zones II and III, lies below elevation 4.5 meters.

4. Zone I, Taipei City, has a population of approximately 1,000,000 people. Land use varies from concentrated buildings with a legal maximum height of 8 stories in the business district to relatively small amounts of rice paddy in the extreme eastern suburbs. It is a major hub for transportation since the rail line and highways to Keelung Harbor, one of two major seaports for Taiwan, pass thru Taipei before going southward to the rest of the island. It contains the only international airport in Taiwan and is the seat of the National Government of Free China. There are numerous industrial establishments in the city proper. Zone II is primarily agricultural and industrial. The major portion of the area is devoted to rice

paddies and other crops but there are around the rim, extending into the flood plain, a considerable number of industries. Zone III is also primarily agricultural as far as area is concerned; however, the town of San-chung directly across the river from Taipei has a population of approximately 70,000 persons and is highly industrialized. There is an almost continuous chain of development either commercial or industrial, most of which are small industries, reaching from San-chung to Hsin-chuang. There are isolated residential communities, most of which are occupied by the farmers tilling the adjacent areas and by the service industries required to supply their needs.

5. The entire area is well supplied with electric energy and has an adequate net of all-year roads. The agricultural areas have, to a major degree, irrigation water available most years. As on the rest of the island of Taiwan, large amounts of commercial fertilizer are used and production of rice and other crops is very high per unit of area. There appears to be an adequate bus transportation system, both within the city of Taipei and the surrounding area. Taipei International Airport is the only air terminal for international flights. Tourism is becoming important and a number of new hotels have recently been constructed or are under construction, as modern as any that may be found anywhere. The general economy appears to be vigorous and the people thrifty and industrious.

II Flood damage data

6. The data available on damages caused by past floods in the Tan-shui River Basin have been obtained from several sources as shown below:

Period	Source
1912-1940	Newspapers
1929-1942	Annual report on civil engineering works prepared by the Japanese
1943-1945	No data
1946-1958	Newspapers (Taipei City only)
1956-1963	Compiled by Provincial Water Conservancy Bureau from reports by local political subdivisions. On file in PWCB office.

7. Examination of translations of samples of past records indicated that flood damage data are incomplete and produce conservative values. Flood damages shown in the older records have been adjusted to reflect the changes in type of construction as well as economic development and changes in price indexes. Earlier records include damages to, and, in many cases, destruction of lightly constructed small buildings, often made of bamboo. This type of construction has been almost completely replaced by more substantial construction, usually brick. Every effort has been made to exclude wind damage, which is always present at the time of major floods.

8. From the standpoint of damages suffered and future damages expected, the economy has been divided into four major subdivisions:

a. Agriculture
b. Developed area
c. Public facilities
d. Industry

Estimated losses resulting from four major floods are shown in the following tabulation:

Estimated direct flood damages
adjusted to 1963 prices and developments

Date of flood	6 Aug 62	5 Sept 62	25 Aug 32	11 Sept 63
Stage at Taipei Br. in meters	5.10	5.50	5.82	6.70
	Damages in NT$1,000 (U.S. $1.00 = NT$40.00)			
Agricultural	19,372	29,777	38,375	59,931
Developed area	102,650	281,183	414,400	778,109
Public facilities 1/	21,964	55,973	81,500	150,847
Industrial	321	2,371	12,412	526,040
Total	144,307	369,304	546,687	1,514,927

1/ Public facilities damage estimated to be 18 percent of the total of damage to agricultural and developed land.

9. The elements included in agricultural damage are primarily crop losses, land loss by erosion, loss of fertilizer and loss of livestock. Damage to buildings and loss of personal property, while included, represent a very small part of the total. So called "developed area" is made up of an undefined mixture of residential, commercial and industrial development for which unit values of damage have been derived for urban and suburban areas. Lack of adequate overall data on damage to public facilities has made it necessary to derive a relationship to the total damage in agricultural and developed areas. Fragmentary data have been used to arrive at such an overall relationship of flood damage to public facilities as 18 percent of the total flood damage in the corresponding agricultural and developed areas. The result appears to be on the conservative side. The values for industrial damages were derived from actual damage reports received through the local Governmental units following the flood of 1963.

III Observations on the basic data

10. Before proceeding further into the derivation of the average annual damages and benefits for the Tan-shui River Flood Control Project, it may be well to consider the basic flood damage data. As noted previously, it has been obtained from a number of different sources, none of which are under the control of the organization, the Provincial Water Conservancy Bureau (PWCB), which is making the flood control study. The old records are fragmentary at best, but every effort has been made to analyze them and to convert them to present conditions of protection and development as well as prices. From the flood control study and economic analysis standpoint it is fortunate that there were three floods caused by typhoons during the years 1962-1963. One of these floods, that of 11 September 1963, was the flood of record, as well as being the most recent. The flood damage data received following that flood may be presumed to be as good as any that is available.

11. Translations of samples of flood damage data as received by the PWCB following the most recent typhoon were examined. The net result of the examination of these samples of flood damage reports and a series of field trips covering almost the entire flood area has convinced the writer that the flood damage data are definitely on the conservative side. Without a complete flood damage survey which would require extensive cost and time and trained personnel an actual quantitative analysis of these values is not feasible.

12. No adequate data were available by which to estimate indirect damages. Indirect damages therefore are not included in the damages prevented that are taken as benefits.

13. An attempt was made by local engineers working with the writer to evaluate the future land enhancement benefits which might be credited to the proposed project. The necessary data were not available, and land enhancement benefits have not been included in the benefits credited to the project. They would, however, be quite substantial since a large portion of the area may be expected to be converted from agricultural to residential, commercial and/or industrial purposes as a direct result of flood control.

14. It is the opinion of the writer that while the basic data leave a great deal to be desired from the standpoint of refinement and perhaps accuracy, they do constitute a conservative basis for determining the economic feasibility of the project. Every effort has been made by the local planning agencies to eliminate duplication and to err, if at all, on the conservative side wherever a question has arisen.

IV Basic criteria

15. In converting the estimated flood damage by floods to future average yearly damages for use in deriving the average annual benefits in an economic analysis, certain basic criteria have been in use by the local engineers.

a. Damages were tabulated only in those areas, not now protected, where it was anticipated that substantially complete protection was to be provided. Average annual damages then become average annual benefits from the reduction of flood damages.

b. Future unit agricultural damages were considered to remain constant. Any possible increase in agricultural productivity without flood control was ignored.

c. Certain areas, designated by the City Planning Authority, were considered as "change use" areas and would convert, without flood control, from agriculture to, so called, developed areas after 1963. The change was assumed to take place in twenty years. The estimated 1963 unit values of agricultural damages ranged from about NT$4,000 to 7,500 per hectare; whereas, unit values of damage for developed areas, made up of an undefined combination of residential, commercial and industrial land use, amounts to from NT$100,000 to 540,000 per hectare, depending on location and river stage. The preventable damages in future developed areas were assumed to increase at a rate of 3.5 percent per annum compounded annually.

d. Damages estimated to occur on existing developed land as of 1963 were assumed to increase at 3.5 percent per annum compounded annually.

e. As previously mentioned, damage to public facilities was taken as 18 percent of the total corresponding agricultural and developed area damage.

f. Existing "industrial damage" estimated from a survey in 1963-64 was not expected to change in the future as it was tied to specific industrial development. Future development in industry is included in the "change use" areas which will convert from agricultural to developed areas.

g. The cost of money for project construction was assumed to be 6 percent per annum.

16. A review of the above criteria indicated the following:

a. Since the damaged area considered coincides exactly with the area to be protected, and the degree of protection proposed is substantially complete, the use of average annual damages as average annual benefits for the reduction of flood damages is an acceptable practice.

b. Examination of annual reports published by the Joint Commission for Rural Reconstruction (JCRR) indicated that the unit productivity of farm land on the island of Taiwan has been increasing. On 31 August 1964 discussions were held with Mr. T. H. Lee, Agricultural Economic Specialist, Rural Economic Division, JCRR, and Mr. Y. C. Huang, Specialist on rice production in the Plant Industrial Division, JCRR. Others present were Mr. W. T. Chang, Irrigation and Engineering Division, JCRR, Mr. K. Y. Hsueh, Deputy Chief Engineer, Tan-shui River Flood Control Working Office, PWCB and Mr. Kenneth T. Case, Corps of Engineers, U. S. Army. The past increase in yield of rice and other crops per hectare and the present research program directed toward improved production were discussed. The probable effects of improved strains of seed, improvements in the use of fertilizers and pesticides, and improved farming practices were considered. It was the opinion of those best qualified to judge that while a growth of possibly 2 to 3 percent of the 1963 production may be expected annually, a conservative value for the increase in agricultural damages per hectare would be 1.5 percent per year of the 1963 value for the next 50 years.

c. The growth rate of 3.5 percent per annum of the economy is used by all echelons of government and in the absence of an economic base study was accepted as the future economic growth rate. There is a considerable amount of documentary evidence, based on past performance, to support this conclusion. In those areas where City Planning Authority considered that certain lands would change from agriculture use to developed area, the change was estimated to take place in 20 years. The agricultural damage in these designated areas therefore reduced from the 1963 value to zero in that length of time. The physical damages on the newly developed area land increased from zero to the amount included in the full area 20 years hence. The monetary benefit was obtained by determining the damage ordinate 20 years hence, including the effect of the 3.5 percent per annum development factor, and again by calculating the ordinate 30 years later or at the end of 50 years, taking into account the 3.5 percent per annum growth factor. These points were connected by straight lines and the area under the curve divided by 50 to get the average yearly damage.

d. The currently developed area damage was increased by the 3.5% compound interest development factor in order to get an average yearly value for the damage prevented on this type of land.

e. In the absence of any better data it was necessary to accept the local practice of using 18% of the total of the agricultural and development area damage in any locality as the damage to public facilities.

f. An actual survey was made of major industrial damage following typhoon Gloria in the fall of 1963. Since future industrial development is included in the "change use" land to be converted from agricultural use to developed area, damages to industry as shown in the table were not projected into the future at any increased amount.

g. The use of the rate of interest of 6 percent for the cost of money required for the construction of the Tan-shui River Flood Control Project appears to be reasonably valid. The present cost of money to the government, based on the rate of interest paid on public bonds, is currently 12 percent. A study prepared by Mr. T. H. Lee, JCRR, shows that the interest rate paid on public bonds has decreased from 16 percent per annum on 5 January 1961 to 12 percent on 1 July 1963. Mr. Lee's findings are supported by the report entitled "The Republic of China, Financial Statistics Monthly" published by the Economic Research Department, Central Bank of China, dated 1 July 1964. That report indicates that the rate on public bonds was as high as 18 percent in 1959 and has been reduced to 12 percent in 1964. Shortly after 1 September 1964 the Chinese Nationalist Government advertised an offering of short-term bonds with an interest rate of 10 percent. On the basis of the above it appears that there is a definite trend toward lower interest rates which may well make the average cost of money for the project during its life on the order of 6 percent. Since there were some individuals who felt that it would be desirable to make an economic analysis on the basis of 9 percent such an analysis was made in an approximate manner.

17. Review of the local procedure for the determination average annual benefits showed that the estimated damage in each category at each stage, projected into the future was used to construct damage frequency curves. From these the average annual damages were prepared. It was also found that combined mathematically with the determination of the projected future values there was included a discount for delay in receipt of benefits which amounted to as much as 12 years for a major portion of the benefits because of delay in the receipt of benefits due to extended construction time. There was, however, no corresponding discount taken for the delayed costs. The correction of this procedure was actually the basis for converting the project benefit-to-cost ratio from less than 1 to a figure substantially greater than 1. It was decided that in those cases where the benefits

from the expenditure of funds would be immediately available following the end of each construction season, there would be no interest during construction charged against those costs. However, there was a considerable portion of the project where it was estimated that the accrual of benefits would be delayed until the end of the third year after the start of construction. Interest during construction was added to the construction cost for this portion of the project in determining the average annual cost, but in no case were benefits discounted because of delay of receipt.

V Derivation of average annual benefits

18. Having determined the future yearly damage from floods of various sizes for each category of damages experienced in each zone (see table A-1), stage damage curves for each of the three zones were prepared as shown on charts A-1, A-2 and A-3. They include stage damage curves for agricultural, developed, and industrial areas. Curves for damage to public facilities were omitted since they are a function of the total of damage in agricultural and developed areas.

19. Average annual benefits from the reduction of flood damage were calculated by the use of frequencies, obtained from the stage-frequency curve on chart A-4, as shown in tables A-2, A-3, and A-4. As noted in paragraphs 12 and 13, benefits from the prevention of indirect damages and land enhancement have not been included in this analysis.

20. Relatively minor benefits in Zones II and III will be received from the reclamation of land in abandoned river channels and from areas filled by dredge spoil. These benefits are expected to amount to NT$6,000,000 and 17,000,000 per annum in Zones II and III, respectively.

21. Certain levees that have been built in the past were constructed with top widths adequate to carry two-lane surfaced roads. This additional width has naturally resulted in excessive levee costs. Discussion with local engineers indicated that the additional width of levee to accommodate the improved road was provided at the request of local governmental organizations and that the transportation benefit to be derived was expected to at least equal the additional cost of the levee construction involved. A rough estimate was made of the additional costs of levees due to their use as roads, which, when converted to annual costs, amounted to NT$1,000,000. A transportation benefit of NT$1,000,000 was taken in Zone I.

22. The breakdown by zones and sources of the benefits used in the economic analysis of this project are shown in the following tabulation:

Average annual benefits

Zone	Reclamation	Transportation NT$1,000,000	Flood control	Total
I	-	1	332	333
II	6	-	29	35
III	17	-	225	242
Total	23	1	586	610

VI Economic analysis

23. Construction costs for economic analysis are based on the cost estimate breakdown prepared 8 September 1964. Three elements of the project; improvement of Tan-shui River below Kuan-tu Gorge, diversion of Ta-ke-kan Creek, and improvement of Tan-shui River above Kuan-tu Gorge; were considered to have a 3-year construction period. For these, interest during construction was calculated. The remaining expenditures were expected to generate benefits commensurate with the cost at the end of each construction season.

24. A period of economic analysis of 50 years was used and operation, maintenance and replacement were estimated to total 3 percent of the investment per annum. Construction and investment costs of the various elements of the project, based on the 8 September 1964 estimate and an interest rate of 6 percent per annum, are shown in the following tabulation:

Element	Cost NT$1,000,000 Construction	Investment
Improvement of Tan-shui River below Kuan-tu Gorge	340	371
Diversion of Ta-ke-kan Creek	1,916	2,088
Protection along left bank of Tan-shui River and Hsin-tien Creek	257	257
Levees on right bank of Keelung and Tan-shui Rivers below Taipei	123	123
Completion of Taipei levee system	509	509
Improvement of Tan-shui River above Kuan-tu Gorge	408	445
Total	3,553	3,793

The costs of the ring levee around San-chung, except for the river side, are not included in the above. The average annual cost, calculated on the previously mentioned basis, is shown below:

Interest	NT$3,793 x 10^6	x .06	= NT$227 x 10^6
Amortization (50 years at 6%)		x .0034	= 13 "
Operation & maintenance and replacement		x .03	= 114 "
		.0934	NT$354 x 10^6

With average annual benefits of NT$610,000,000 and average annual costs of NT$354,000,000 the benefit-to-cost ratio is 1.7 to 1.0.

25. On the basis of 9 percent interest the analysis would work out approximately as follows:

	NT$ x 10^6
Construction Cost	3,553
Investment	3,913
Average annual cost	
3,913 x .1213	475
Average annual benefits	610
B/C ratio	1.3:1.0

26. In order to prepare approximate benefit-to-cost ratios for each of the three zones, as requested by local interests, it was first necessary to establish the criteria upon which such a study was to be based. Since the only plan under consideration was Plan "C" it was necessary to consider a system analysis, inasmuch as several elements of the project affected two or more zones. The criteria for distributing the costs of elements of the project affecting two or more zones are shown below:

a. Improvements to channel below Kuan-tu Gorge - distributed to zones in proportion to total average annual benefits in each zone.

b. Channel for the diversion of Ta-ke-kan Creek -

Zone I - Estimated alternate investment cost of raising levees required without the diversion channel

Zone II - None

Zone III - Remaining cost

c. Improvement of Tan-shui River channel above Kuan-tu Gorge-Divided between Zones I and III in proportion to the total average annual benefits in each zone.

27. Using the above criteria, which are purely arbitrary, the costs chargeable to each of the three zones and the applicable benefit-to-cost ratios are as follows:

Project feature	Financial elements in NT$1,000,000		
	Zone I	Zone II	Zone III
		Investment	
Channel improvement, Tan-shui River below Kuan-tu Gorge	204	22	145
Diversion of Ta-ke-kan Creek	500	-	1,588
Protection along left bank of Tan-shui River and Hsin-tien Creek	-	-	257
Levees on right bank of Keelung and Tan-shui Rivers below Taipei	-	123	-
Completion of Taipei levee system	509	-	-
Channel improvement, Tan-shui River above Kuan-tu Gorge	258	-	187
Total investment	1,471	145	2,177
Average annual benefits	333	35	242
Average annual costs (using 6%)	137	14	203
Benefit-to-cost ratio	2.4:1.0	2.5:1.0	1.2:1.0

28. Using an interest rate of 9 percent per annum, a purely mathematical solution, using the same construction cost distribution, would produce a benefit-to-cost ratio of less than 1.0 for Zone III. However, since this is a system analysis of Plan "C," which at 9 percent still has a favorable benefit-to-cost ratio of 1.3 to 1.0, no essential part of the system, such as the Ta-ke-kan Creek diversion channel, can be considered to have a benefit-to-cost ratio of less than 1.0. No attempt has been made to develop a cost distribution or other superficial procedure to provide favorable benefit-to-cost ratios for all zones using an interest rate of 9 percent per annum.

Tan-shui River
Flood Control Project

Table A-1

Future Yearly Damages

Zone	Location	River Stage (Meters at Taipei Br.)	Average future yearly damage[1] (NT$1,000,000)		
			Agricultural	Developed Area	Industrial
I	Taipei City	6.70	11.4	2,131.9	49.3 (0.0 at stage 4.50)
		5.82	9.4	1,225.5	
		5.50	5.5	840.6	
		5.10	3.6	463.5	
II	Pei-tou area	6.70	17.0	94.1	76.7 (0.0 at stage 4.00)
		5.82	12.7	69.7	
		5.50	9.4	26.1	
		5.10	6.7	38.6	
III	Left bank area	6.70	84.0	1,037.1	400.0 (0.0 at stage 4.50)
		5.82	53.4	543.7	
		5.50	46.4	450.9	
		5.10	33.3	127.8	

1 Based on 1963 prices and projected future development.

Tan-shui River
Flood Control Project
Table A-2

Zone I - Determination of Average Annual Damages

Reference - Chart A-1

Sheet 1 of 2

Item	Damage at Stage (NT$1,000,000)		
Stage (m)[1]	3.5	4.0	5.0
Agricultural	0	0	3
Developed Area	0	0	150
Subtotal	0	0	153
0.18 Subtotal[2]	0	0	28
Industrial	0	0	1
Total	0	0	182
Stage (m)[1]	5.5	7.0	7.75
Agricultural	6	13	15
Developed Area	900	2,300	2,700
Subtotal	906	2,313	2,715
0.18 Subtotal[2]	163	416	489
Industrial	5	73	150
Total	1,074	2,802	3,354

1 River stage as measured at the Taipei Bridge
2 Public facilities

DETERMINATION OF AVERAGE ANNUAL DAMAGES

Location: Zone I, Taipei City Stream: Tan-shui River, Taiwan Date: 6 September 1964

Frequency Curve: Taipei Bridge-w/Shih-men Dam-March 1964 Price Level: 1963 Development: Future

FLOOD	STAGE m	DISCHARGE C. F. S.	FREQUENCY	DAMAGE $ 1	AVERAGE DAMAGE IN INTERVAL $ 1	FREQUENCY OF INTERVAL	ANNUAL DAMAGE $ 1	$ 1
	3.5		0.500	0				
	4.0		0.400	0				
					91	0.200	18	
	5.0		0.200	182				
					628	0.060	38	
	5.5		0.140	1,074				
					1,938	0.122	236	
	7.0		0.018	2,802				
					3,078	0.013	40	
	7.75		0.005	3,354				
					TOTAL ANNUAL DAMAGE		$ 1 332	$ 1

Table A-2

1 All monetary values in NT$1,000,000

NPP Form 285
Sept. 1961

TABLE A-2

Tan-shui River
Flood Control Project
Table A-3

Zone II-Determination of Average Annual Damages

Reference - Chart A-2

Sheet 1 of 2

Item	Damage at Stage (NT$1,000,000)		
Stage (m)[1]	3.5	4.0	5.0
Agricultural	0	0	5
Developed Area	0	0	8
Subtotal	0	0	13
0.18 Subtotal[2]	0	0	2
Industrial	0	0	1
Total	0	0	16
Stage (m)[1]	5.5	7.0	7.75
Agricultural	10	19	23
Developed Area	43	105	130
Subtotal	53	124	153
0.18 Subtotal[2]	10	22	28
Industrial	7	110	250
Total	70	256	431

1 River stage as measured at Taipei Bridge
2 Public facilities

DETERMINATION OF AVERAGE ANNUAL DAMAGES

Location: Zone II, Pei-tou Area **Stream:** Tan-shui River, Taiwan **Date:** 6 September 1964

Frequency Curve: Taipei Bridge-w/Shih-men Dam-March 1964 **Price Level:** 1963 **Development:** Future

FLOOD	STAGE m	DISCHARGE C. F. S.	FREQUENCY	DAMAGE $ 1
	3.5		0.500	0
	4.0		0.400	0
	5.0		0.200	16
	5.5		0.140	70
	7.0		0.018	256
	7.75		0.005	431

AVERAGE DAMAGE IN INTERVAL $ 1	FREQUENCY OF INTERVAL	ANNUAL DAMAGE $ 1	$ 1
8	0.200	2	
43	0.060	3	
163	0.122	20	
344	0.013	4	
TOTAL ANNUAL DAMAGE		$ 1 29	$ 1

Table A-3

1 All monetary values in NT$1,000,000

NPP Form 285
Sept. 1961

TABLE A-3

Tan-shui River
Flood Control Project
Table A-4

Zone III - Determination of Average Annual Damages

Reference - Chart A-3

Sheet 1 of 2

Item	Damage at Stage (NT$1,000,000)		
Stage (m)[1]	3.5	4.0	5.0
Agricultural	0	1	20
Developed Area	0	0	70
Subtotal	0	1	90
0.18 Subtotal[2]	0	0	16
Industrial	0	0	8
Total	0	1	114
Stage (m)[1]	5.5	7.0	7.75
Agricultural	44	90	101
Developed Area	380	1,200	1,500
Subtotal	424	1,290	1,601
0.18 Subtotal[2]	76	232	288
Industrial	38	560	1,200
Total	538	2,082	3,089

1 River stage as measured at Taipei Bridge
2 Public facilities

DETERMINATION OF AVERAGE ANNUAL DAMAGES

Location: Zone III, Left Bank **Stream:** Tan-shui River, Taiwan **Date:** 6 September 1964

Frequency Curve: Taipei Bridge-w/Shih-men Dam-March 1964 **Price Level:** 1963 **Development:** Future

FLOOD	STAGE	DISCHARGE C. F. S.	FREQUENCY	DAMAGE
				$1
	3.5		0.500	0
	4.0		0.400	1
	5.0		0.200	114
	5.5		0.140	538
	7.0		0.018	2,082
	7.75		0.005	3,089

AVERAGE DAMAGE IN INTERVAL	FREQUENCY OF INTERVAL	ANNUAL DAMAGE	
$ 1		$ 1	$
1	0.100	0	
58	0.200	12	
326	0.060	19	
1,310	0.122	160	
2,586	0.013	34	
TOTAL ANNUAL DAMAGE		$ 1 225	$

Table A-4

1 All monetary values in NT$1,000,000

NPP Form 285
Sept. 1961

TABLE A-4

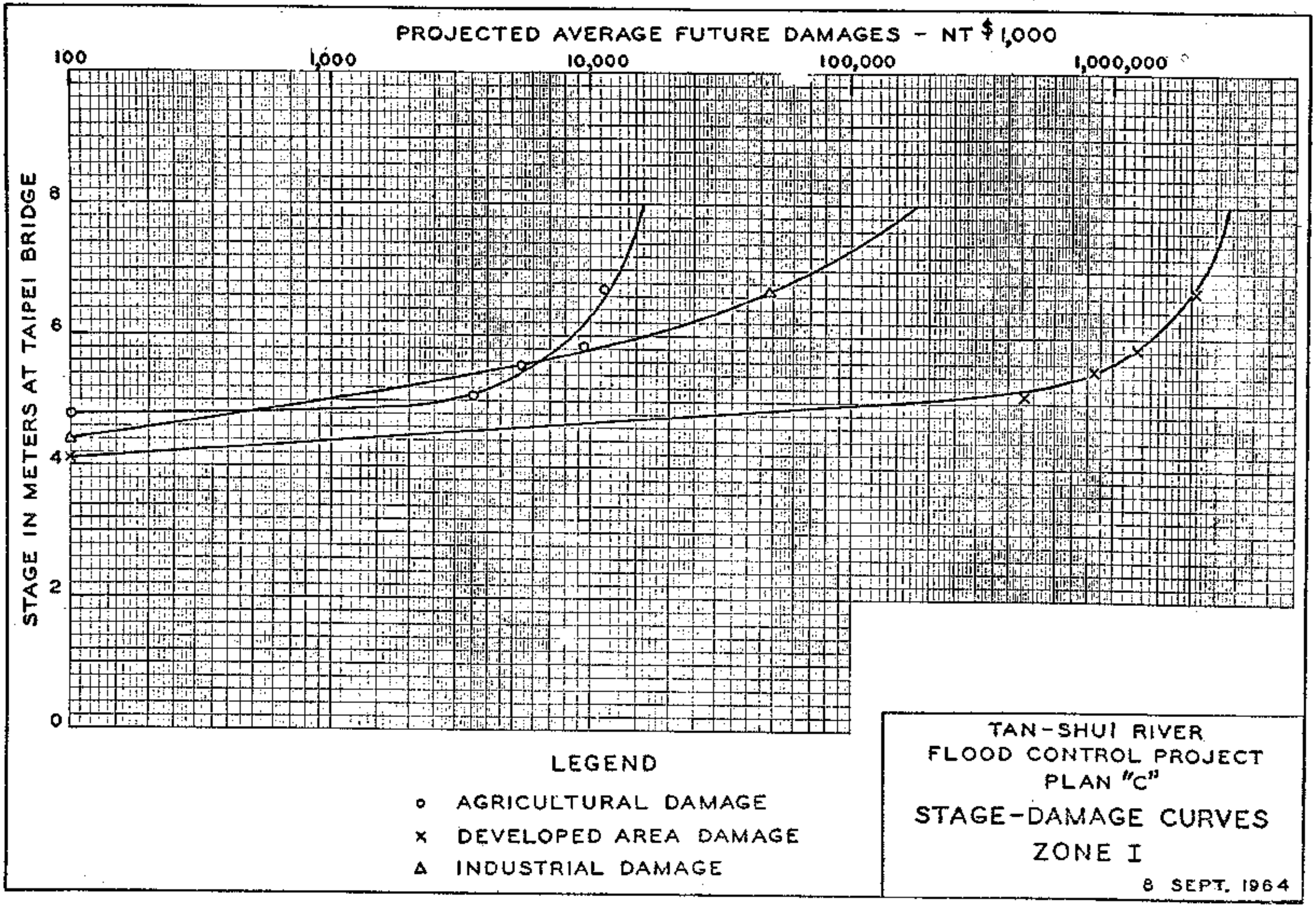
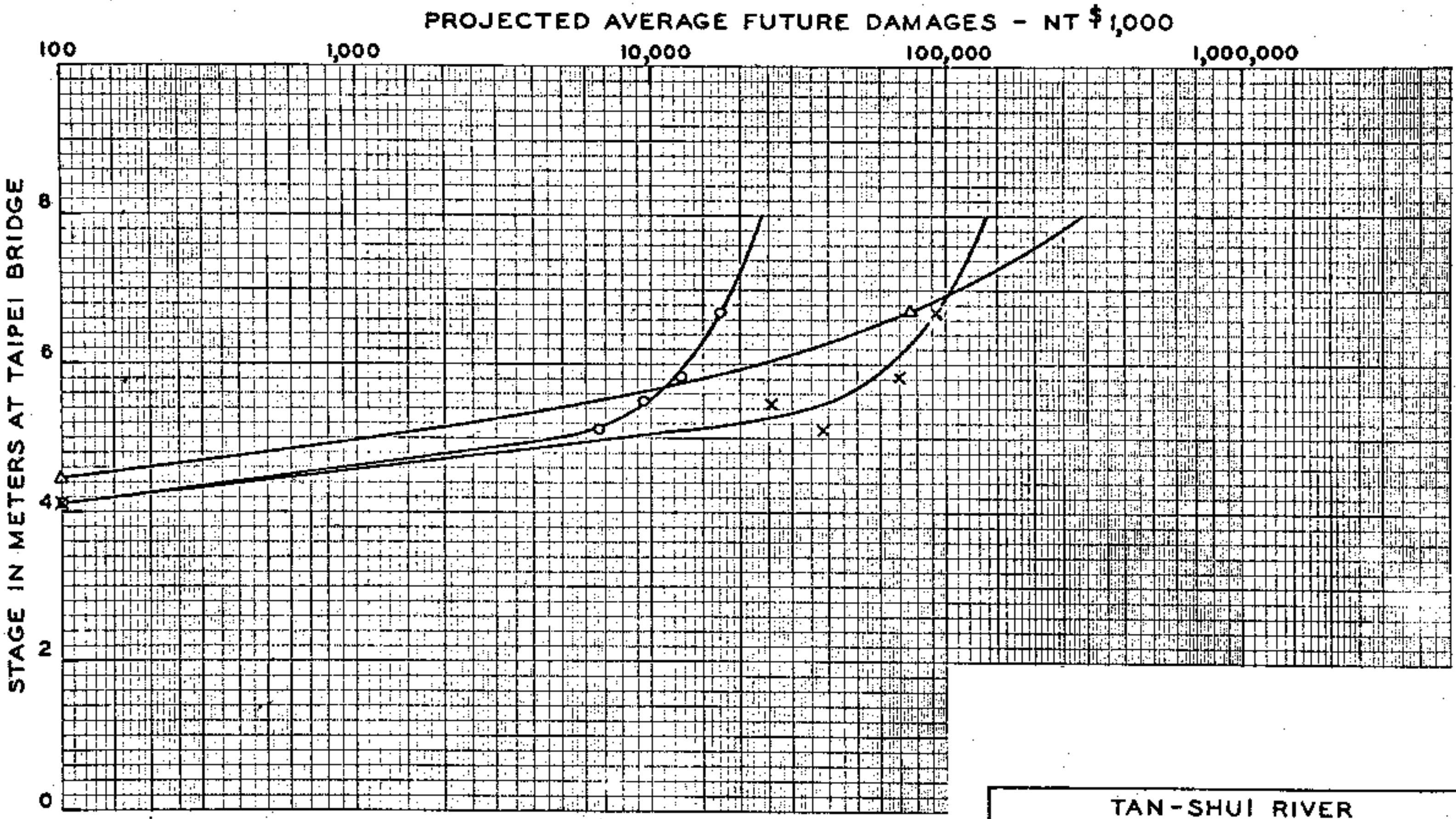


CHART A-1

CHART A-1



LEGEND

o AGRICULTURAL DAMAGE
x DEVELOPED AREA DAMAGE
Δ INDUSTRIAL DAMAGE

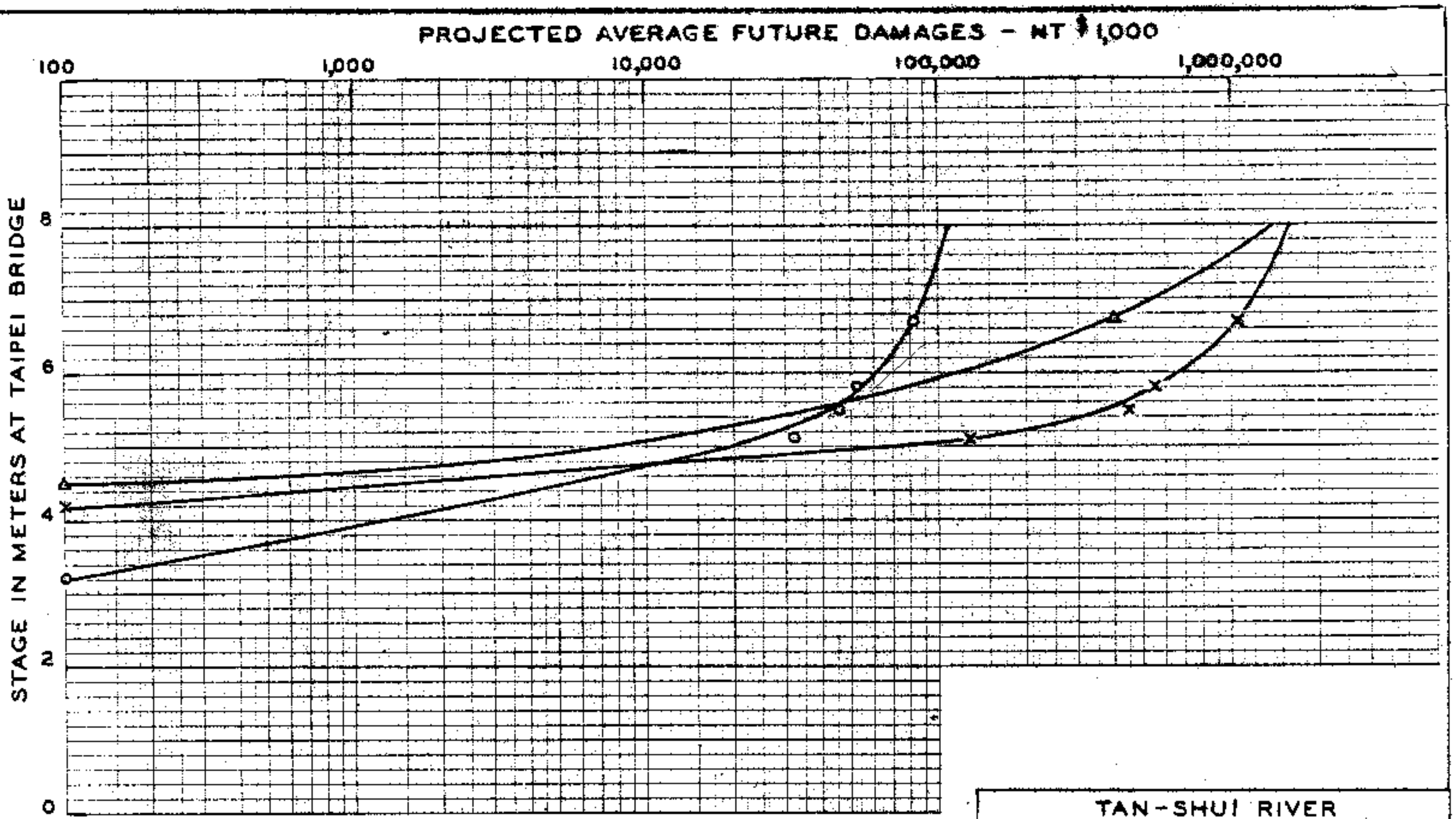
TAN-SHUI RIVER
FLOOD CONTROL PROJECT
PLAN "C"

STAGE-DAMAGE CURVES
ZONE II

8 SEPT. 1964

CHART A-2

CHART A-2



LEGEND

- o AGRICULTURAL DAMAGE
- x DEVELOPED AREA DAMAGE
- △ INDUSTRIAL DAMAGE

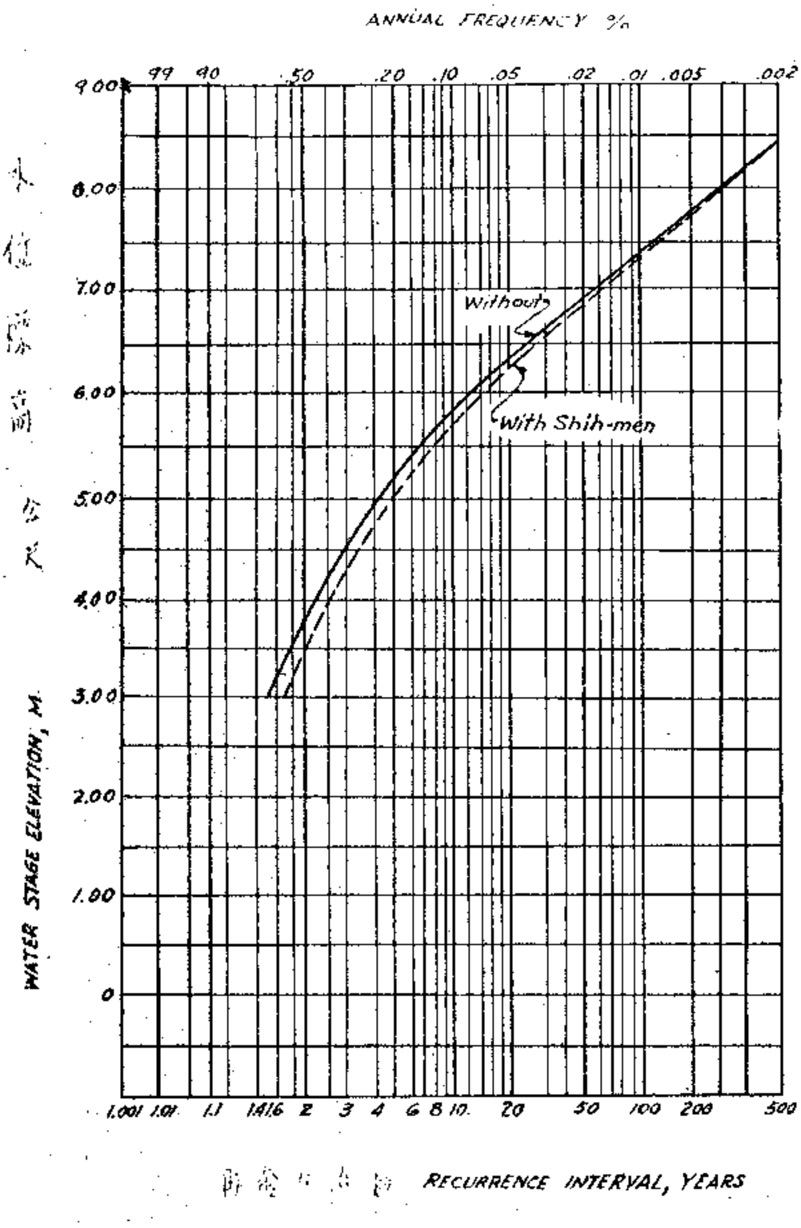
TAN-SHUI RIVER
FLOOD CONTROL PROJECT
PLAN "C"

STAGE-DAMAGE CURVES
ZONE III

8 SEPT. 1964

CHART A-3

CHART A-3



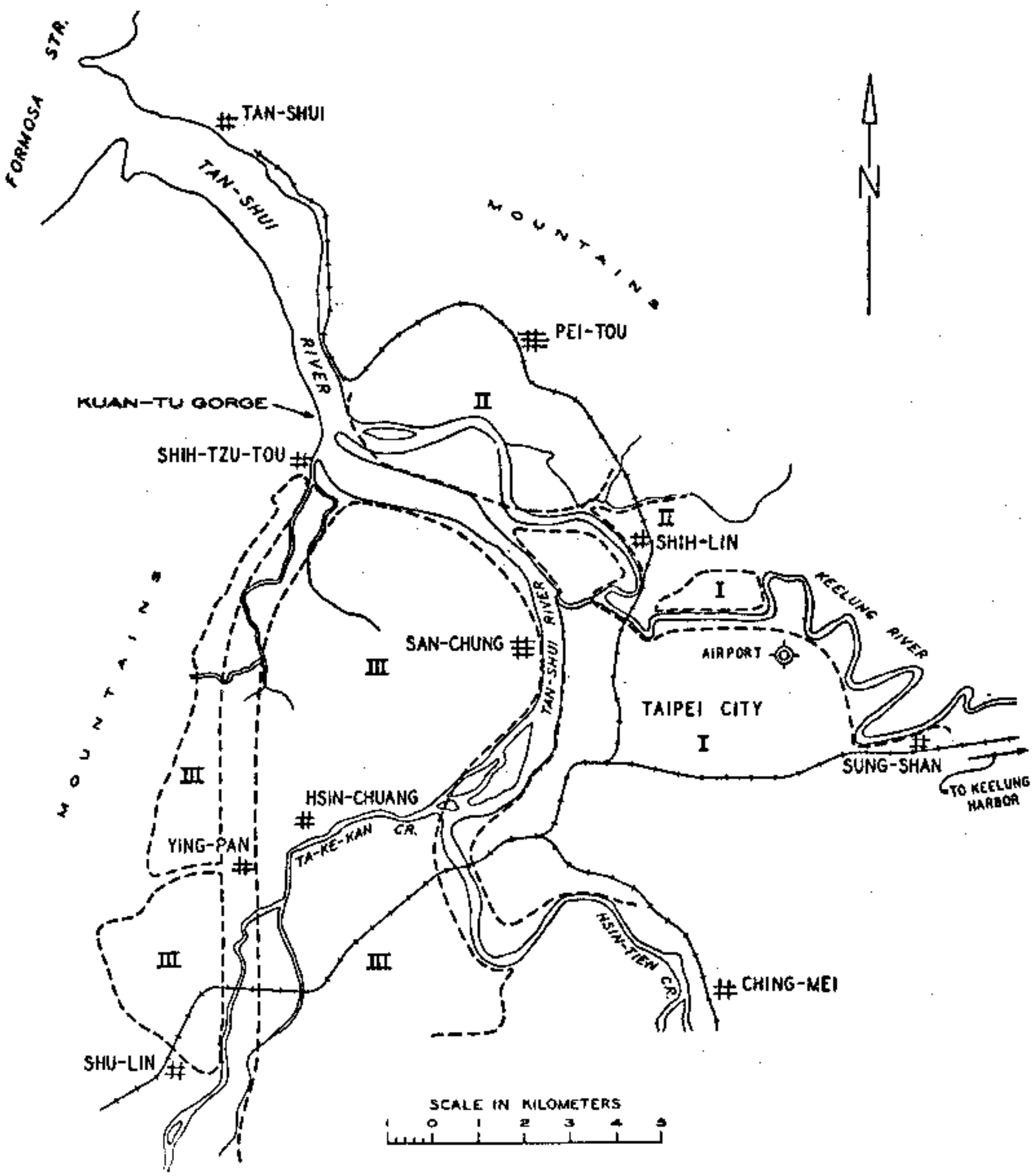
TAN-SHUI RIVER
FLOOD CONTROL PROJECT

ANNUAL PEAK-STAGE FREQUENCY CURVES

TAIPEI BRIDGE GAGE

8 MAR. 1964

CHART A-4



ZONE BOUNDARY

TAN-SHUI RIVER
FLOOD CONTROL PROJECT
PLAN "C"

FLOOD PLAIN ZONES

8 SEPT 1964

PLATE A-1

APPENDIX B

SUGGESTIONS FOR FUTURE STUDIES

Report on

Review of Taipei Area Flood Control Planning

Phase II

Appendix B

Suggestions for Future Studies

Corps of Engineers, U. S. Army

February 1965

TABLE OF CONTENTS

I. HYDRAULIC OBSERVATION PROGRAM. -

A. Purpose. -

The importance of a comprehensive program for obtaining hydraulic measurements is emphasized in paragraph 8 of the Report. These data are needed not only to support criteria used in the initial channel and levee designs for the project, but also to permit a continuing evaluation of changes in river regime caused by the early construction stages in order to develop design criteria for the later stages and to modify the project scheme if necessary. Measurements on the Tan-Shui and its tributaries will be difficult during a typhoon flood, but is believed that the program outlined below can be accomplished.

B. Discharges.

1. Stations. Good estimates of discharge at key locations within the project are essential for an effective program. The purpose of discharge measurements is to establish a stage-discharge relationship which is normally used in conjunction with a continuous record of stage to produce a discharge hydrograph at the measuring station. A discharge hydrograph may be desired either, (a) continuously on a 12-month basis for a determination of the total water volume past the station, or (b) only during flood periods. The following discharge measuring stations are recommended:

Stream	Location	Record Required
Hsin Tien Creek	Chung-Cheng Bridge	12 months
Ta-Ke-Kan Creek	Ta-Chi	12 months
Ta-Ke-Kan Creek	Hsin-Chuang	12 months
Kee-Lung River	Wu-Tu	12 months
Kee-Lung River	Chung-Shan Bridge	During floods
Tan-Shui River	Taipei Bridge	12 months
Tan-Shui River	Tu-Ti-Kung-Pi	During floods

With the exception of the station at Tu-Ti-Kung-Pi (below Kuan-Tu), all the above are existing stations. It is recognized that discharge measurements at Tu-Ti-Kung-Pi will be difficult to obtain, but a good determination of flood discharges at this point is considered to be a most essential element in the Hydraulic Observations Program since at present there are no direct discharge determinations for floods large enough to by-pass the Taipei Bridge on the left overbank.

2. Gages. Two gages will be required at each discharge measuring station. These will be designated as main gages and water surface slope gages. The main gage at each station should be a recorder since a continuous record is needed for the determination of discharge hydrographs. The recorder should be set high enough that it will not be drowned out by large floods and should, if possible, be accessible during floods for checking and adjustments. It should be located far enough upstream or downstream of a bridge that it is not affected by "drawdown" of the water surface into the bridge opening. Auxiliary staff or wire weight gages

should be established near the main recorder to provide a means of continuing the record in case the recorder fails. The auxiliary gages should be located to be accessible during very large floods--or should be oriented so that they can be read from a distance with a telescope.

From the discharge measurement data reviewed in September 1964 it was apparent that variations in water surface slope accounted for some of the "scatter" in plotted rating curves. At low and medium discharges the stations on the Kee-Lung River are usually subject to backwater from the Tan-Shui and the Tan-Shui itself is affected by tidal fluctuations. At high discharges the water surface slope is variable at all stations due to steep slopes on the fronts and flat slopes on the backs of sharply peaking flood waves. In order to account for the effect of slope variations in stage-discharge relationships, it is recommended that <u>water surface slope gages</u> be established for each measuring station. The <u>water surface slope gage</u> may be either upstream or downstream of the <u>main gage</u>, provided a bridge does not fall in between to augment with bridge losses the measured fall in the water surface. The distance between the two gages should be long enough that the difference between the two readings will be large compared with the probable error in either reading due to water level fluctuations. A spacing, if practicable, at which the fall in water surface would be 30 to 50 cm at medium and high discharges is recommended. Water surface slopes have been measured in conjunction with many of the discharge measurements made in recent years; however, the reach lengths used have usually been too short to obtain significant slope values. Recorders would be desirable for the <u>water surface slope gages</u> but staff or wire weight gages will be satisfactory provided they are read continually during floods to provide a stage hydrograph.

The stage records from the two gages should be carefully synchronized during floods or the indicated fall may be considerably in error for fast-rising and fast-falling flood waves. During a discharge measurement, it is recommended that both gages actually be read by observers, rather than depending on gage records being perfectly synchronized.

3. <u>Discharge Measurements</u>. The present technique for measuring flood discharges with floats appears to be practicable for these stream conditions and is believed to yield satisfactory results. Certain refinements are suggested, however.

More floats should be used to measure surface velocities in more locations in the cross sections. At Tu-Ti-Kung-Pi the floats probably must be placed in the water from a boat.

Some special measurements should be made with a current meter at each station during flood flows to firm up the coefficient used to convert surface velocities to average velocities over the stream depth. A current meter with a heavy weight should be operated with a winch from a bridge near each measuring station. Measuring verticals should be located well away from bridge piers to avoid local flow and scour patterns.

First, it is suggested that enough points be measured in a few verticals to define the velocity distribution. The ratio of average velocities to surface velocity can be obtained easily from these distributions, but a quicker and simpler procedure will be possible after a check to assure that the usual semi-logarithmic velocity distribution exists at these stations. Plot the velocity at each point in the vertical against the logarithm of the distance from the streambed. If the plotted points define a straight line reasonably well, the semi-logarithmic distribution holds; and the average velocity can be found by measuring about 6/10 of the depth below the water surface. The ratio of average velocity to surface velocity can, therefore, be found quickly by measuring near the surface and at 6/10 depth. With this procedure the ratios for a number of verticals can be measured from a bridge in a short time. These special measurements should be discontinued when it is decided that enough data are available to define correction coefficients over a range of stages at each station. At Tu-Ti-Kung-Pi it may be possible to anchor a boat for a short time while obtaining special current meter measurements.

The most questionable feature of the present discharge measuring technique is that cross sections are not measured concurrently with the velocity measurements. On the Hsin-Tien and the Ta-Ke-Kan, cross section surveys under flood conditions are probably not feasible and reliance must continue to be placed on surveys made just before and just after flood events. The present pair of discharge measuring cross sections should be evaluated to assure that they are far enough downstream from bridges to assure that they are not affected by local scour in the opening or by the deposition of the scoured material. On the Kee-Lung and the Tan-Shui, it should be possible to sound the cross sections by boat concurrently with discharge measurements; and it is recommended that this be done whenever possible, particularly below the Taipei Bridge and at Tu-Ti-Kung-Pi.

4. Rating Curves. Aside from errors in the discharge measurement itself, plotted stage-discharge relationships for most stations show considerable "scatter" due to changes in cross section, changes in hydraulic roughness, and changes in slope. It is suggested that the "scatter" can be reduced by plotting the data in the following way that takes slope changes into account.

The quantity $Q/\sqrt{S}$ at a given stage is defined as the "conveyance" which remains constant at the given stage as long as the cross section and the roughness coefficient do not change. Q is the measured discharge; and S is the water surface slope, assumed to be about equal to the energy gradient as long as velocity head changes between the main gage and the water surface slope gage can be neglected. Plot the "conveyance", $Q/\sqrt{S}$, against stage for all discharge measurements at a station. (The scatter will probably be less than for the usual Q versus stage relationship.) Draw a curve of best fit through the points; this will be a "conveyance" rating curve. Using the conveyance rating curve it will be possible to prepare a family of stage versus Q curves with curves for various values of S. Using this family of rating curves and the hydrographs of stage and water surface slope measured at a station, the discharge hydrograph can be determined, although uncertainities as to the effects of cross section and roughness changes will still remain. In analyzing past discharge measurements in which the water surface slope has not been adequately determined, S can be approximated by the expression, $S = S_o + R/W$, in which S_o is the slope at that stage for a steady discharge (stage not changing with time), R is the rate of rise in stage in meters per hour, and W is the speed of travel of the flood wave in meters per hour.

C. ADDITIONAL GAGES.

In addition to the gages listed in paragraph B1, it is recommended that gages be maintained at the following locations to obtain stage hydrographs during floods:

Hsin Tein Creek at Hsin Tein
Hsin Tein Creek at the new Taipei Waterworks
Hsin Tein Creek at the Kuan-Fu Bridge
Kee-Lung River at Sung-Shan
Tan-Shui River at Shih-Tzu-Tou
Tan-Shui River at Kuan-Tu
Tan-Shui River at You-Che-Kou
East China Sea at Hsiang-Diao-Tzu

These gages are now in existance. Although recorders are preferable, staff or wire weight gages will be satisfactory provided they are read continually to define stage hydrographs during flood periods. The purpose of the additional gages is to help define stage relationships between key locations in the project and to provide information on the timing of flood peaks and rates of flood wave travel for use in hydrologic studies and in a flood warning system.

D. CROSS SECTION SURVEYS.

The channel cross sections already established throughout the project area will be entirely adequate for this program. Resurveys about every two years should be satisfactory, although resurveys should be made in the Fall of each year that a very large flood occurs. On the Tan-Shui River about ten cross sections, spaced from the mouth to Wan-Hua, should be selected for special study purposes and resurveyed more frequently in order to understand the annual pattern of deposition and scour in this tide-affected reach. The special study cross sections should be surveyed at the beginning and end of the typhoon season, once during the winter, and as often as indicated during the typhoon season. It will be especially valuable to survey these sections during floods. Paragraph B3 emphasizes the need for sounding the discharge measurement sections. These, of course, may correspond to some of the special study sections. It is suggested that the best use can be made of the limited time during flood flows by selecting a few special sections and sounding them several times to follow the changes. In order to convert soundings to bed elevations, the water surface elevations should be known throughout the survey period.

It is, therefore, suggested that the sounding surveys be coordinated with the water surface profile measurements to be discussed below. Bed sampling should also be coordinated with the soundings.

E. WATER SURFACE PROFILES. -

For analysis of friction coefficients and localized energy losses throughout the project area, provision should be made for obtaining water surface profiles at various times during each flood. For this purpose water surface elevations are needed at many locations in addition to the gages listed in Sections B1 and C. Elevations should be obtained about every 1-1/2 to 2 kilometers throughout the project with additional measuring points above and below each bridge and on the right bank just upstream from the Kuan-Tu Gorge. Measurements can be made with staff or wire weight gages; by measuring down from reference points on bridges, floodwalls or other structures; or by leveling from special bench marks established near the water's edge. The measuring points should be established with accessibility during floods in mind. Along the Tan-Shui below Kuan-Tu the road along the right bank provides good access, as do existing levees and floodwalls along the right bank of the Tan-Shui and the Hsin-Tien from Fan-Tzu-Ko upstream to Ching-Mei. Access is also probably available along the Kee-Lung. The Tan-Shui in the first 6 kilometers above Kuan-Tu and the Ta-Ka-Kan are important reaches where access will be difficult during large floods. Staff gages oriented so they can be read from a distance by telescope would be one possibility where access would otherwise be impossible. Each water surface profile in a reach of the project should be obtained over as short a time as possible in order to represent a nearly instantaneous picture of the water surface. This might be accomplished by assigning mobile observers to read a number of gages in turn on a continual schedule. Stage hydrographs plotted from the readings would permit determination of "instantaneous" profiles.

F. ROUGHNESS COEFFICIENTS. -

The discharge measurements, cross sections, and water surface profiles will permit evaluation of hydraulic roughness coefficients for stream reaches throughout the project.

G. BED SAMPLING. -

The techniques used in bed sampling and the data obtained thus far have been excellent. Sampling should be repeated at the same locations concurrently with all cross section resurveys. Attempts should be made to obtain samples with a B-48 Bed Sampler in conjunction with soundings during high water in the Tan-Shui River when samples should also be obtained from bridges over the Tan-Shui and Kee-Lung. Due to the large size of the material, it is questionable that valid bed samples can be obtained during high water on the Ta-Ke-Kan and the Hsin-Tien; however, the pit sampling during low water seems to have produced consistent results. A mechanical analysis should be run on all samples. For an occassional sample in each stream channel reach, specific gravities should be run for each sieve fraction of the material.

H. SUSPENDED SEDIMENT SAMPLING. -

It will be of value to know the total magnitude of the suspended sediment load and the relative contribution from each tributary in assessing the potential for dredging maintenance in the Tan-Shui River and planning possible remedial measures. It is recommended that suspended sediment sampling stations be maintained at the following locations:

Chung-Cheng Bridge on the Hsin-Tien
Hsin-Chuang on the Ta-Ke-Kan
Wu-Tu on the Kee-Lung
Taipei Bridge on the Tan-Shui

The stations at Wu-Tu and the Taipei Bridge have been established. All samples should be of the depth-integrated type and should be analyzed for total concentration and the percents of sand, silt, and clay. (The grain sizes separating these three catagories are about 0.07 mm and 0.004 mm.) A minimum of three verticals should be sampled at low flows, and the number of verticals should be increased with higher stages to a maximum of 5 to 10. An attempt should be made to locate all sampling verticals in centroids of flow; for this purpose past discharge measurements should be analyzed to obtain the percent distribution of discharge across the measuring section at various stages. (If five sampling verticals are to be used, for example, the cross section should be divided into ten segments with about 10% of the flow in each segment; and the sampling verticals should be located at the points where the cumulative percent of flow across the section is 10%, 30%, 50%, 70%, and 90%.) Verticals should be located far enough from bridge piers that they will not be unduly affected by local flow patterns. Each sediment station should be sampled at least once each week during low flows and more often during rises in stage in accordance with a planned schedule. Efforts should be made to obtain a maximum number of sampling measurements during flood flows. It is considered important not to neglect the sampling of within-the-channel rises during the non-typhoon season. Although these discharge peaks usually are not high, a relatively large portion of the annual run-off--and presumably a large portion of the annual sediment load--occurs during this season. Plots of sediment concentration versus water discharge, for both total concentration and sand concentration, should be maintained for each station. These "sediment rating curves" will be used in estimating daily sediment loads. The distribution of data on the plots will help indicate which stations and which river conditions should have priority in sampling.

I. PRIORITY. -

It is recognized that in the one to three days available during a typical flood event man power and equipment limitations will not permit all the observations in all the locations proposed for this program. The Tan-Shui River should be given priority since the most immediate problems are concerned with this reach.

J. EQUIPMENT. -

Since the above program requires the collection of data at several locations during relatively short flood periods, additional equipment such as current meters, bed samplers, depth-integrating samplers, and cranes and reels for handling them, will probably be required. The most critical need, however, is for sounding gear and for a boat that can be operated safely on the Tan-Shui River during floods. An echo sounder is the only feasible means of obtaining reliable sounding data under these river conditions. The Corps of Engineers on the Missouri River in the United States has had good experience with the Bloodworth Portable Echo Depth Recorder ES 130 for 6 or 12 volt power supply. This equipment is reliable, light in weight, and easily transferred into and out of a boat. The sounder can be plugged into transducers mounted permanently in the bottom of the boat. Information can be obtained from States Electronic Corporation, Bloodworth Marine Division, 96 Gold Street, New York, New York, U.S.A. A 6 to 8 meter boat with outboard motors would be needed to operate safely on the Tan-Shui. A number of newly designed fiber-glass and aluminum hulks which are stable and maneuverable in rough water are now on the market in the United States. Information can be obtained from the following companies:

Crestliner
Division of Bigelow-Sanford, Inc.
Little Falls, Minnesota

Dorsett Marine
1955 Lafayette Street
Santa Clara, California

Grumman Boats
Division of Pearson Corporation
Sausalito, California

Boston Whaler
Fisher-Pierce Company, Incorporated
1149 Hingham Street
Rockland, Massachusetts

Hydro Swift
1750 South Eight West
Salt Lake City, Utah

Lone Star Boat Company
P. O. Box 218
Plano, Texas

Shell Lake Boat Company
Shell Lake, Wisconsin

These hulls are light in weight, can be transported on a small boat trailer, and can be easily launched and retrieved by 3 or 4 men.

It is recommended that the best performance and safety in the water and the most convenient handling on land can be obtained by powering the boat with two outboard motors, each with a minimum of 40 horsepower. A boat trailer should be purchased with the boat or manufactured locally.

K. PLANNING. -

It might be helpful in planning a Hydraulic Observations Program for a Chinese engineer to visit the United States to observe the techniques employed for obtaining and analyzing data on the Missouri River and to receive guidance, if desired, in the selection of a sounder, a boat, and other equipment.

II. HYDRAULIC MODEL STUDIES. -

A. Verification Studies. -

As discussed with Mr. T. S. Lee and Mr. R. C. Wu, it would be advisable to make further verification of the model channel roughness. Series of steady flows should be run in each model channel for stages up to about bank full. Where the stage-discharge relationships do not correspond to available prototype data, the model roughness should be adjusted. There is a scarcity of prototype data for verification purposes, but rating curves do exist for the Taipei Bridge on the Tan-Shui and the Chung-Cheng Bridge on the Hsin Tien. Some water surface profile data are also available for peak flows during the Opal, Amy, and Gloria floods in the Tan-Shui downstream of Kuan-Tu. Every opportunity should be taken in the future to obtain prototype data for further model verification.

B. Peak Reduction at Kuan-Tu. -

As discussed with Mr. K. Y. Hsueh, the most valuable use of the Taipei Basin Model will be in estimating the effect on peak discharges at Kuan-Tu after overbank storage in the Taipei Basin is eliminated by confining floods between the proposed levees. Under present conditions the overbank storage effect undoubtedly produces some peak reduction which would not occur with the proposed levees. The proposed 200-year design discharges are necessarily based on analyses of historic records with upward adjustments for the estimated effect of future confinement. An important question is whether the expected increase in flood peaks is adequately reflected in the design discharges presented in paragraph 7 of the Report. The model should provide a reasonable answer to this question.

The amount of peak reduction probably cannot be correlated directly with peak discharges because the reduction is a function of flood volume and the slope of the hydrograph, as well as peak flow. (A flood hydrograph with a small volume but a high, sharp peak will have more reduction than a hydrograph with a large volume and a long, flat peak of the same magnitude.) It will be necessary, therefore, to evaluate the storage effect by categorizing historic floods on the basis of their hydrograph characteristics and running through the model a series of floods in each category. At least one of the floods derived from unit hydrograph analysis of 200-year storm rainfalls, described in Mr. Hsueh's memorandum, "Selection of Design Discharge", dated 5 September 1964, should be included with the historic floods to be run through the model. Each flood should be run (1) with existing levees and overbank conditions and (2) with all proposed levees in place, and the discharge hydrographs at Kuan-Tu should be measured. By comparing the results from (1) and (2), the effect of overbank storage on peak reduction can then be evaluated for each category of flood hydrograph.

In order to make the study recommended above it will be necessary to construct in the model just downstream from Kuan-Tu a discharge take-out equipped with a device for measuring discharge hydrographs and a gate for controlling stages in the model upstream of the take-out. At the take-out a removable section should be provided which can be replaced, allowing flow in the model to precede downstream undisturbed. In obtaining flood hydrographs at Kuan-Tu, it will be necessary to run each flood twice: first, with the removable section in place, measure the stage hydrograph at Kuan-Tu; second, with the take-out in operation, use the control gate to produce the previously measured stage hydrograph and measure the discharge hydrograph.

C. Kuan-Tu Training Works. -

Due to the small horizontal scale and the vertical distortion of the Taipei Basin Model, it is not suitable for localized design problems such as the Kuan-Tu Gorge training works recommended in paragraph 13 of the Report. It is recommended that a separate undistorted model be constructed for this purpose. The scale should be at least 1:100 and as large as the water supply at the Hydraulic Model Station will permit. An erodible bed might be provided to give an indication of the relative potential for scour in various parts of the study area, although a quantitative reproduction of scour should not be expected.

The purpose of the model study will be to develop the most economical arrangement of upstream training works to minimize the energy loss at the entrance to Kuan-Tu Gorge. The study should anticipate two stages of development. According to the construction schedule recommended in paragraph 6a of the Report, when the Kuan-Tu training works are initially constructed, the Ta-Ke-Kan Diversion will be several years in the future. The training works, therefore, must be designed to operate efficiently in the interim period with existing conditions on the left bank of the Tan-Shui in the vicinity of the Wen-Tze-Chuan. But the design should anticipate a second construction stage at the time the Ta-Ke-Kan Diversion is accomplished. In order to provide desirable flow conditions, the first stage design may require some construction that must be removed in the second stage. The model study should aim at a first stage design which is as compatible as practicable with the second stage. The model layout for both stages should reflect the proposed closure of the existing mouth of the Kee-Lung River on the right bank of the Tan-Shui and should include the new confluence if this is not too far upstream to be in the model. With reference to the type of structures to be considered, parallel training dikes are preferable to straight-out spur dikes since the latter induce considerable energy dissipation.

III. TA-KE-KAN STABLE CHANNEL DESIGN. -

As discussed with Mr. Hu, and as stated in paragraph 9 of the Report, it is believed feasible to design a stable diversion channel for the Ta-Ke-Kan. The criterion for stability is that the new channel should have the same average annual capacity for transporting bed material load as the lower 10 Km reach of the existing Ta-Ke-Kan channel which will be replaced by the diversion channel. A study of cross sections of the Ta-Ke-Kan obtained over a period of years revealed that the lower reach seems to be in equilibrium with no marked long-term trends of aggradation or degradation. If the existing reach is in equilibrium, a diversion channel designed for the same average annual bed material load transporting capacity should also be in equilibrium.

It is suggested that the study be based on total bed material load transport rates computed by the method presented by H. A. Einstein in, "The Bed Load Function for Sediment Transportation in Open Channel Flows," U. S. Department of Agriculture, Soil Conservation Service, Technical Bulletin No. 1026, September 1950. While these calculated loads will probably not agree with the magnitude of loads in the prototype, provided they could be measured, it is believed that the relative values obtained will be significant. That is, if the calculated loads in the and the proposed channels agree, the actual loads probably will also agree.

The first step is to obtain an average channel cross section in the existing reach. Some eight cross sections are now available for averaging purposes. Next an average slope is determined and an average mechanical analysis of the bed material is adopted from available bed sampling data. A discharge rating curve, typical of the study reach, is now needed. It would be best to develop an actual rating curve from measurements at Chang-Tsu-Tsui; but as a second alternative a rating curve can be developed analytically by the method presented by Einstein. Since medium discharges will probably be found to transport a large portion of the average annual load, it may be feasible to await flow measurements that will define an actual rating curve up to the medium range of discharge. The next step is to compute by the Einstein method a sediment transport rate versus water discharge relationship for each sieve fraction of grain sizes found in significant proportion in the bed material. A discharge-duration curve is now applied to these sediment transport relationships to obtain average annual loads for each sieve fraction. Although a discharge-duration curve for the Ta-Ke-Kan with Shi-Men Dam in operation is presented in the Memorandum, "Sediment Discharge Estimation," dated September 6, 1964, it was derived very approximately and should be refined when there is time for a more detailed analysis.

The next phase of the study is to assume the cross section and slope of a design channel. The composition of the bed which the Ta-Ke-Kan will deposit in the new channel is an important question. The suggested approach is to assume that the bed will consist of the same grain sizes which th existing channel can transport and to arbitrarily assign two mechanical analysis curves which define the limits of a range in which the actual mechanical analysis can be expected to fall. Now compute average annual loads for each limiting mechanical analysis. This will define a range in possible transport rate for each sieve fraction for comparison with the computed loads in the existing channel. If they do not compare reasonably well,vary the design width over practical limits to see if better results can be obtained.

It is believed that by this method it can be demonstrated that a range of possible diversion channel designs exists in which the average annual transport capacity compares with that of the existing channel. A design to produce a moderate excess of capacity would probably be preferable in order to facilitate natural channel clean-out. No excessive degradation would be expected, due to the controlled water surface at the confluence of the diversion channel and the Tan-Shui River.

IV. SEDIMENT LOADS AND CHANNEL MAINTENANCE. -

The aim of channel improvement on the Tan-Shui River is to lower the design water surface profiles to permit reasonable heights of levees and flood walls. The larger the improved channel, the lower the levees and flood walls. But at the same time, the larger the improved channel, the lower will be its velocities and the greater will be the tendency for sediment deposition which must be removed by maintenance dredging. There is an improved channel size beyond which maintenance dredging costs become too high and the safety of the project is in question because there is no assurance the channel capacity will be available when needed. One goal of the design studies for the Tan-Shui channel improvement is to determine a practical limit of channel enlargement that can be maintained with a minimum of maintenance dredging. Knowledge of the sediment load of the Tan-Shui is, therefore, important because from the magnitude of the load can be deduced an upper limit of the maintenance dredging that might be required. Knowledge of the sand load is particularly important since the sand is probably the material principally involved in bed changes, while the silts and clays are carried through to the sea or are deposited at low flows but readily scoured at higher flows.

The distribution of the existing sediment load between Hsin-Tien Creek and Ta-Ke-Kan Creek is also important to know because Plan C calls for eventual diversion of the Ta-Ke-Kan which would make Hsin-Tien Creek the only contributor of water and sediment to the existing reach of the Tan-Shui from Wan-Hua to the confluence of the Kee-Lung. There is a question whether the Tan-Shui channel in this reach, initially improved to carry the combined flows, can be maintained essentially as an extension of Hsin-Tien Creek.

Preliminary indications are that the potential for deposition is not high and that the proposed channels can be maintained with a reasonable amount of dredging. However, present estimates of sediment loads are based on very limited sampling data and are only very approximate.

The program proposed in Section I, paragraph H, if it is implemented consistently for several years, will provide the data needed for firm estimates of sediment loads. Good discharge-duration curves are also needed at each station for determination of average annual loads. Some of the duration curves presented in the memorandum, "Sediment Discharge Estimation", dated 6 September 1964, are the result of approximate adjustments and should be firmed up with a more complete analysis when time permits. Due to the sharp peaks of flood hydrographs, duration curves should be based on instantaneous discharge values or on discharges averaged for a period no longer than 3 hours.

Since some good sampling data are already available at the Taipei Bridge, a reasonably good estimate of average annual load will probably be available at this station before it is available at the others. One approach to estimating the proportions of the sand load at the Taipei Bridge originating from Ta-Ke-Kan Creek and Hsin-Tien Creek is suggested by Rittenhouse and Thorp in "Heavy Minerals in Sediment-Transportation Studies", Transactions, American Geophysical Union, 1943, p.p. 524-530. Samples of sand might be collected from the Hsin-Tien and the Ta-Ke-Kan in the same size range as the sand bed downstream of Kuan-Tu in the Tan-Shui. Through petrographic examinations it might be possible to find some distinctive quality, such as proportion of heavy minerals or light minerals, that "labels" the material from each source. By determining the proportions in which the "labeled" material is mixed in the bed material below Kuan-Tu, it may be possible to estimate the portion of the sand load from each source.

V. DREDGING COST ESTIMATE. -

As discussed with Mr. Y. T. Hu, the cost estimate for dredging is high. The project estimate dated 8 September 1965 shows a total of 44,000,000 cubic meters of dredged material at a cost of NT$990,000,000, giving a unit cost of NT$22.60 per cubic meter or US$0.45 per cubic yard. Under these project conditions the unit cost should run well under half this amount.

It is suggested that a more firm estimate can be based on a breakdown of the individual items, such as plant, labor, and fuel, which make up the total cost of dredging. An example of such a detailed estimate prepared for a job on the Missouri River is shown below. The actual items and costs to be used in the computations must, of course, fit the conditions of the Taipei flood control project.

The construction schedule recommended in paragraph 6a of the report allows several years for dredging the Tan-Shui and the Ta-Ke-Kan and, therefore, permits a minimum capital investment in dredging plant. It is suggested that the annual cost of major plant items be based on a ten-year amortization period. Dredging experts suggest that with the long pipe lines required it might be advisable to reduce by 15% the capacities of 400 M^3/hr and 600 M^3/hr for 20-inch and 24-inch cutter-head dredges, assumed by the PWCB for planning purposes. The assumption of 200 work days per year seems reasonable, but an 18 hour work day would be more realistic than 20 hours.

Due to problems in handling long and unweildy land-lines, it has been suggested that 20-inch dredges might be more practicable than 24-inch.

Useful information on dredging equipment and costs may be obtained, if not already available in the PWCB office, from the Ellicott Machine Corporation, 1611 Bush Street, Baltimore 30, Maryland, U.S.A.

Typical Dredging Cost Estimate

1. Work to be done. - Furnish all plant, labor and materials necessary to dredge 3,500,000 c.y. of material and waste it approximately 11,000 feet from the dredging source. Waste area is 30 feet higher than the water surface. Maximum pumping depth 32 feet from water surface.

2. Material. - Fine sand with low percent gravel.

3. Completion time. - One year.

4. Dredge. - 33' x 100' with 5.5 feet draft (loaded)
   6 foot cutter head with 600 h.p. motor
   24 inch intake (suction) - 20 inch discharge
   20 inch dredge pump with 2000 h.p. elec motor
   Side lines and speeds operate from 1-300 h.p. motor
   All motors are electric (4160 volt)
   Commercial power to be used - 13,800 volts transformed at the dredge. A 20-inch booster pump with 2000 h.p. required will be inserted in the pipe line 3000 ft. from dredge.
   Dredge operation - three 8-hour shifts with 20 hours estimated actual pumping time.
   Estimated output 800 cubic yard/hour of actual pumping time.

5. Time. - 3,500,000 cubic yard ÷ 800 = 4375 hours pumping time.
   Total operation time required - $4375 \times \frac{24}{20} = 5250$ hours or 210 days.

6. Dredge crew. - Dredge operator, mechanic-electrician, 2 deck hands, master engineer (day shift only).

7. Discharge line. - Size - 20 inch diameter
   Length - 11,000 feet (2000 feet floating type, 9000 feet land type)
   Pipe Section - 200 inch diameter x 40 feet quick connected
   Portions Barrel-type - 48" x 20' long, 2 per 40 feet of pipe

8. Plant for discharge line. - 1 small motor launch, 1 crane, 1 bull-dozer, welding machine and 2 trucks with A-frames.

9. Labor for discharge line. - Launch operator, 1 crane operator, tractor operator, foreman, welder, and 3 laborers.

10. <u>Costs.</u> -

Labor:

Dredge operator	5250 hours @ $3.00	$15,750
Mechanic	5250 hours @ 2.75	14,438
2 Deckhands	5250 hours @ 1.85	19,425
Master Engineer	1750 hours @ 4.00	7,000
Launch Operator	5250 hours @ 2.25	11,813
1 Tractor Operator	5250 hours @ 2.75	14,438
1 Crance Operator	5250 hours @ 2.75	14,438
Foreman	5250 hours @ 3.50	18,375
Welder	5250 hours @ 2.75	14,438
3 Laborers	5250 Hours @ 1.50	23,625
2 Truck Dirvers	5250 hours @ 1.50	15,750
	Sub-total	$169,490
Insurance, Taxes & Social Security		16,949
	Total Labor	186,439

11. <u>Materials & Miscellaneous Supplies</u> $ 5,000

12. <u>Plant.</u> -

1-20" Dredge w/Discharge Line	5250 hours @ $66.18	$347,445
Electric Power	5250 hours @ $19.56	102,690
1-Booster Pump w/Power	5250 hours @ $17.89	93,923
1-Launch	5250 hours @ $ 3.73	19,583
1-Crane	5250 hours @ $ 4.00	21,000
1-Tractor	5250 hours @ $ 5.61	29,453
1-Welder	5250 hours @ $ 1.00	5,250
2-Trucks w/A-Frame	5250 hours @ $ 1.50	15,750
1-Pickup	5250 hours @ $ 0.75	3,938
Small Tools	L.S.	5,000
	Total Plant	$644,032

13. <u>Total direct cost.</u> - $866,131

14. <u>Direct unit cost*</u> - 835,471/3,500,000 = $0.239 per cubic yard

* This cost does not include profit, mobilization, demobilization, job overhead, and supervision or home office expenses.

VI. SOILS INVESTIGATIONS. -

Recommendations for further foundations investigations and soils tests are presented in paragraph 26 of the Report.

VII. ORGANIZATION FOR FLOOD DAMAGE SURVEYS. -

There is need to develop a trained staff to survey flood damages immediately after their occurrence. This need is not limited to the Tan-Shui River Basin. The control of such surveys should be in the hands of those who are charged with the responsibility for calculating future benefits for flood-control projects. It is suggested that such a staff be developed as rapidly as possible and be available for damage surveys upon the occurrence of flooding at any point in the Province. It is further suggested that the services of trained real estate appraisers be obtained for use in estimating property values with and without proposed projects for use in calculating benefits from future land enhancement.

PRELIMINARY REVIEW OF FLOOD PROTECTION PLAN FOR TAN-SHUI RIVER, TAIPEI PLAIN, TAIWAN

WILFRED D. DARLING
JOSEPH M. BUSWELL

PACIFIC OCEAN DIVISION
CORPS OF ENGINEERS, U. S. ARMY
APRIL 1964

24 April 1964

MEMORANDUM FOR THE RECORD:

SUBJECT: Preliminary Review of Flood Protection Plan for Tan-Shui River, Taipei Plain, Taiwan

1. The undersigned arrived in Taipei, Taiwan on the evening of 6 April 1964, in response to a request from AID, Taiwan, to the District Engineer, USA Engineer District, Okinawa. Assistance was requested from the Corps of Engineers, U.S. Army in reviewing a Flood Control Protection Plan for Taipei and surrounding areas which are in the Tan-Shui River flood plain. Col. S. E. Smith, Division Engineer, Pacific Ocean Division, Corps of Engineers and Col. H. C. Schrader, District Engineer, Okinawa District, Corps of Engineers, arrived at the same time for inspection of projects under construction in the Taipei area under the jurisdiction of the Taiwan Area Office of the Okinawa Engineer District, as well as to attend initial meetings relative to the flood control study. Mr. H. L. Parsons, Mission Director, AID, Taiwan was called on during the morning of 7 April 1964 at which time Mr. Parsons gave a short briefing of the proposed work to be accomplished. Flood protection studies have been carried out by the Chinese under a grant of NT$ 4,000,000 from AID. See Incl #1 for list of individuals present at this briefing. In accordance with an agreement between Col. Schrader and Mr. Parsons, the review of the Tan-Shui River Flood Control Protection Plan would be accomplished in two phases. The initial phase would be preliminary in nature but would be sufficient to permit an evaluation of the composition of a team of engineers who would make a detailed review of the plan. This would include the estimated time and costs required for a detailed review. Mr. Parsons mentioned that the report on phase 1 study should be completed prior to 1 May 1964. He also mentioned that the Chinese Government desires a workable solution for flood protection by 30 September 1964.

2. During the afternoon of 7 April 1964 a meeting was attended at the Project Office of the Tan-Shui River Flood Control Planning Committee, Provincial Water Conservancy Bureau (PWCB). See Incl #2 for a list of individuals present at the meeting. Mr. E. Y. Liu, Chief Engineer, PWCB, gave a briefing of the project with the aid of maps showing the Tan-Shui River drainage basin, and the various

schemes for alleviating the flooding of Taipei and adjacent area which have been considered. Mr. Liu pointed out that studies have been under way for several years and every possible means of providing protection has been included in the studies. Taipei and the surrounding areas has been subjected to damaging floods during typhoons on many occasion, the latest and most damaging flood occurred during typhoon "Gloria" on 10 and 11 September 1963. During that flood a large area of Taipei and adjacent areas were covered with from 1 to over 3 meters of water. There were 31 lives lost in the Taipei area and damages to properties estimated between NT$700,000,000 and NT$1,000,000,000.

a. The Tan-Shui River basin drains an area of 2,726 sq. km. along a length of 195 km, (see Incl 3). There are three main tributaries of the Tan-Shui River, namely: Take-Kan Creek, Hsin Tien Creek, and Kee-lung River, all of which meet in the Taipei basin and empty to the sea through the Kuan-tu gorge. The latter is a constriction of the Tan-Shui River which causes back water in the Taipei basin and aggravates the flooding problem. The project under study is limited to the basin area, bordered by Hseu-ling on Take-Kan Creek, Hsin-tien on Hsin-tien Creek and Song-san on Kee-lung River. See Incl 4 for plan of area and Incl 5 for location of range lines and profiles along the streams. The total length along the river amounts to 35 km. There are existing dikes with a total length of 30 km, 9.8 km of bank protection and 127 sets of groins. The oldest part of the existing flood protection system consists of the Taipei City flood wall which was started during 1913.

b. Mr. Liu stated that the various schemes considered included the use of upstream flood control reservoirs, diversion through tunnels to other areas, diversion of the Take-Kan Creek and Hsin-Tien Creek within the Taipei basin, dredging of the Tan-Shui River, and diking as the major protection feature. The operation of Shih-Men dam on the upper reaches of Take-Kan Creek for flood control was also considered. This dam is a multiple purpose project which is operated mainly for power and irrigation, the flood control storage reserved in the reservoir amounts to only 64,000,000 cubic meters which would delay the peak flow 5 to 7 hours but would not reduce the peak. It was decided to concentrate on the most feasible means of local flood protection within the areas subject to flooding. Four different schemes were investigated in detail and a fifth scheme was included later. The scheme adopted is a comprehensive one. It includes complete diversion of Take-Kan creek from Hsin-Chuan into new channel through Wen-tze-chuen area and joining Tan-Shui River at Kuan-tu (see Incl 6). The abandoned river bed of 300 hectares could be reclaimed and town area of Hsin-Chuan could be joined to Pan-Chiao to provide an uninterrupted area for development. Under this plan, bridges over Tan-Shui River and Hsin-tien creek as well as existing levees along Hsin-tien creek would not require raising. The adopted plan provides more benefits than any other scheme based on PWCB computations although the B/C ratio they show is less than 1. It was pointed out that there are many intangible benefits connected with this project, such as prevention of loss of human life and the fact that Taipei is the capital city.

c. To assist in the design of the flood protection project, a hydraulic model will be used. The model was just recently completed and verification tests will be carried out within the next 6 weeks or two months. See Incl #7 for details of the model.

3. After the briefing by Mr. Liu, a discussion was held to determine the best way on how to carry on the phase 1 review study of the Tan-Shui flood protection project. It was agreed that a visit to the model and the existing flood protection works, as well as the areas subject to flooding, would be highly desirable before begining a review of the reports.

4. On 8 and 9 April 1964, an inspection was made to the hydraulic model located adjacent to the water resourses planning commission hydraulic laboratory (see Incl #8 for those present); Shih-Men Dam; the site of the Ta Chi Dam that was considered during the studies; existing flood protection levees and flood walls along Take-Kan and Hsin-Tien Creeks; as well as to view the Taipei plain area subjected to flooding. The Kuan-tu gorge and the Tan-Shui river between the gorge and the mouth were also visited. On 15 April 1964, the 3 existing pumping stations in Taipei were visited as well as the pumping station at Yung-ho. During the inspection of Shih-Men dam mentioned above, Mr. F. T. Y. Ting, Director, Dam Construction Department, Shih-Men Development Commission, gave a briefing at the model building at the Shih-Men dam, and conducted the tour of the dam. Those present were Mr. T. K. Chu, Mr. Y. T. Hu, Mr. K. Y. Hsueh, Mr. W. T. Chang, Mr. J. D. McCoy, Professor S. T. Hsu and Mr. W. D. Darling. Professor Hsu is a consultant to the PWCB.

5. Between 10* and 24 April 1964 a review was made of the studies which have been made to date. This was accomplished mainly at the project office of the Tan-Shui River Flood Control Planning Committee, PWCB. Messrs K. Y. Hsueh and Y. T. Hu, Senior Engineers, PWCB, were very helpful in making data available and explaining details. Mr. W. T. Chang, JCRR, was also present most of the time and assisted very much in translating several of the reports. The responsibility for design of the project is divided between three different agencies; PWCB is responsible for protection works including outlet works for the entire area; interior drainage within Taipei city is the responsibility of the Taipei drainage & Sewerage Corps; while interior drainage in the villages outside Taipeicity limits is the responsibility of the Public Works Bureau. A total of 46 reports have been prepared during 1963 and 1964 by the PWCB Flood Control Planning Committee (see Incl #9 for list); in addition several Memoranda were prepared by Dr. Hans R. Kivisild, Flood Control Expert for United Nations; a report on Typhoon Gloria and its effect on Taipei and surrounding areas by A. D. Smythe, Sanitary Engineer, World Health Organization,

* Mr. Buswell participitated between 18 and 24 April 1964.

was made available and the Report on Storm Drainage Facilities for the Municipality of Taipei prepared by the Taipei Drainage and Sewerage Corps was furnished. A large number of the reports were read, some were studied while others were scanned.

6. Based on review of available data the following phases of the study program and project features are discussed:

a. Hydrology (see Incl #10 for location of rain fall stations within the basin and Incl #11 for a record of rainfall during typhoons between 1912 and 1963): The storm design adapted by PWCB has been a controversial question between the PWCB engineers and Dr. H. R. Kivisild, UN Flood Control Expert, who reviewed the Flood Control Planning Committee work between March 1961 and January 1964. PWCB engineers have used what they consider the maximum flood of record for each drainage area in the basin for design of flood barriers. These data are based on gage readings, float tests for velocity and cross sections obtained after the flood, plus attempts to correlate rainfall readings with estimated discharges. The difference of opinion is in connection with the estimated discharge of the Tan-Shui River at the Taipei Bridge. When the gage reading at the Taipei Bridge exceeds 5.5 M, the river overflows into the Wen-tse-chuang area, thus an estimate of the amount of overflow is required. Also since the river cross-section at the Taipei Bridge is based on soundings after the flood, it is possible, and quite likely, that the cross-section is much deeper during peak discharges due to erosion by high velocity flow during the flood; the eroded areas later filled as the current velocity drops.

b. Hydraulic Design: The effect of the diversion channel on the regime of the river is unknown. There is a considerable variation of current velocities with discharge, this will effect sediment load. The bed material in the upper reaches of Take-Kan and Hsin-Tien creeks is composed of gravel and cobbles. In Take-Kan creek, the mean diameter of bed materials at a point about 18 Km above the confluence with Hsin-Tien creek is about 117 mm. There is a gradual reduction in size between that point and the mouth where the mean diameter is about 0.3 mm. The mean diameter of bed materials in Hsin-Tien creek 14 km above the mouth is 62 mm. This is reduced to about 37 mm at a point 6 km from the mouth; from that point there is an abrupt drop to slightly over 1.0 mm. At the mouth the mean diameter is about 0.4 mm. The mean diameter of bed materials in the Kee-lung River varies between 0.10 mm and 0.35 mm in the reach studied. Design of the optimum channel widening required at the upper end of the Kuan-tu gorge is proposed by Hydraulic model study. Design of the diversion channel is based on a simple trapezoidal section in cut to take normal flows. Flood flows will be by overbank flow between confining levees. Except for the upstream end of the diversion channel which will be in sand, the major portion of the excavation will be in clay which is generally present in the upper stratum of soil in the entire Taipei Flood plain. Dredging of the Tan-Shui river from Kuan-tu to the present mouth of Take-Kan creek will be mainly in fine sand will vary from 2 meters to 5 meters in depth. Maintenance dredging in this reach may be a considerable problem. The estimated annual maintenance dredging in the reach between the sea and the upstream end of Tan-Shui river is 200,000 cubic meters, this could be higher.

c. Geology and Soils: For bed materials in the three tributaries of the Tan-Shui River, see above paragraph. The bed material in the Tan-Shui River is predominantly fine sand with some sandy silt and silt present. Between Kuan-tu gorge and the mouth, the bed material is mainly sand; there are large sand bars at the mouth. Boring locations are shown on Incl #12, while logs of borings are shown on Incl Nos 13- 16, inclusive. A large number of direct shear, unconfined compression and consolidation tests have been completed on materials obtained by standard drive samplers along the proposed diversion channel. The soil is classified mainly as a CL clay. Results of direct shear and unconfined compression tests do not appear usable. A high percentage of the direct shear tests indicate angle of internal friction in the high 30°s and up to 53° with cohession varying from 0.05 to 0.3 kg lcm². Results of unconfined compression tests show very low strengths; many only 30 to 40 pounds per sq foot. The samples obtained by drive sampling methods are not considered "undisturbed" and are not considered suitable for strength tests. Because of the small size samples obtained it appears that remolded soil may have been used for preparation of test specimens. Soils report forms could be improved considerably since there is no single form on which all of the basic test data is tabulated to permit overall evaluation of test data. Boring logs, like wise, include only symbols indicating soil type, thus it is not possible to evaluate conditions by glancing at boring logs along the soil profiles shown. A standard set of Corps of Engineer soils forms was furnished PWCB engineers for consideration for future use. Undisturbed sample of the foundation clay along the levee alignment on either side of the diversion channel should be obtained by using thin walled shelby tubes to permit completion of unconfined compression tests. Direct shear tests are not considered necessary for the low levees involved. Guidance in the location of borings could be obtained from classification and moisture tests on drive samples already obtained. Depth of boring under these levees should be a minimum of 7 meters with a percentage of the boring drilled to 10 and 15 meters below ground surface.

27 April 1964

SUBJECT: Preliminary Review of Flood Protection Plan for Tan-Shui River, Taipei, Plain, Taiwan

d. Flood Barrier Design: Earth levees and gravity type flood walls are used as flood barriers. Sections used appear quite conservative, flood walls over 50 years old are still in use and appear in good condition. The narrowest top width used for levees is 5.5 meters with the majority of them being 8 or 10 meters wide since the top of most levees are used as roads. Sideslopes of 1 or 2 are quite common. Where earth levee heights exceed 4 meter in height a 4 meter landside berm is added 3 meters below the top. When sandy or silty fill materials are used for levee construction a clay blanket is used 30-50 cm thick. In some areas cobble levees are used, grouted stone facing is used on these levees. A 1 to 2 meter deep toe trench is used with the cobble levees. Flood walls are gravity type with sheet pile cut off at the river toe and drainage at the heel. Most are pile supported. PWCB engineers indicated that these are considered more economical in Taiwan than the inverted T-type flood walls used in the United States. Several different types of slope protection are used on the levees, including turfing, brick paving, concrete paving, concrete block paving, and grouted stone. Several areas were noted where levees are subjected to only back water on which slope protection was concrete pavement or another expensive type, which would be adequately protected by turfing. Toe protection is provided in may areas by "wire sausages". These are long oval shaped bundles of cobble stone held together by wire mesh made with No. 8 galvanized wire. Two sizes of these wire sausages are used the larger size being 60 cm by 1 meter and the smaller size being 40 cm by 67 cm. Lengths of wire sausages vary; they usually extend 8 meters riverward of levee toe and extend up the slope 14.5 meters. The life of the sausages is dependent on the wire mesh remaining intact; in fresh water where there is no abrasion by cobbles or boulders moving along the channel, a life of 5 to 12 years may be expected. The wires last only 1 to 2 years where exposed to sea water and abrasion by stones, thus these are not generally used in the upper or lower reaches of the streams for new work. Except for turf, brick paving is the most economical type of slope protection. Bricks 5" x 10" x 2" thick are used set on edge. Each brick has 4 holes through which No. 8 wire is used to hold the mass together. Adjacent rows of bricks are staggered. The wires are secured to a concrete beam at the toe and at the top of slope. For levee heights over 5.5M., an intermediate berm is added. Concrete paving is used in ares of highest velocities, with concrete placed in alternate blocks on a filter layer. Thickness of concrete used isabout 6 inches. One project under construction along the Yung-ho levee was viewed which did not have an adequate filter. About 1½ inches of gravel of uniform 1½ inches size was used, the gravel was being pounded into the clay embankment slope by wooden tampers. See paragraph 6h, below, for comment on levee sections along the diversion channel.

e. Interior Drainage. As mentioned above interior drainage including pumping stations is the responsibility of the Taipei Drainage and Sewerage Corps within Taipei city while the Public Works Bureau has the responsibility for the villages outside of Taipei city. The PWCB are responsible for design of drainage gates through the flood barriers. See inclosure #17 for drainage plan prepared by PWCB, this includes drainage and check gates only. Existing pumping station have been indicated in red pencil. There are three existing pumping stations within Taipei city plus one in the village of Yung-ho. The Taipei Drainage on Sewerage Corps have proposed 16 drainage districts within Taipei city with a total of 5 pumping stations. Present sewers are combined sanitary and storm sewers, mainly of the open ditch type, although probably less than 20 percent of the population use modern plumbing, the majority of the population are served by the night-soil collection system. It is proposed to have seperate sanitary and storm sewers eventually. The Japanese at one time prepared plans for a seperate sanitary sewage system with 4 treatment plants for the city of Taipei. Storm sewers and pumping plants for the city of Taipei are disigned for 5 year rainfall intensity duration. A run-off coefficient of 0.7 is used initially. Five hours after flood gates are closed a run off coefficient of 0.8 is used for all subsequent run off quantity computations. Drainage structures designed by PWCB are designed for a 10-year rainfall intensity duration. Initially it is proposed to furnish pumping capacity less than the above by taking advantage of ponding in areas which presently are not bult up. As the areas are utilized and ponding areas are reduced additional pumping capacity will be added. The public works Bureau proposes 2 pumping stations each for San-Chung and Shi-Lin. Equipment provided at the existing pumping stations is as follows:

Taipei City

Station	Power Units	Pump Size
Shuang-Yang	3-Allis Chalmers Diesel, 250 HP Each	3-48"
Min-Sheng	3-Waukesha Gasoline, 125 HP Each	3-48"
Yuan-Shan	3-Waukesha Gasoline, 125 HP Each	3-48"
Yung-Ho Village		
Yung-Ho	2-Waukesha Gasoline, 125 HP Each	2-48"

Costs for interior drainage, including pumping station are not included in project costs. The estimated cost for interior drainage for Taipei city is NT$1,320,000,000.

f. Bridges: See Incl #18 for bridge alterations and additions. A total of 38 bridges are involved although many of these are obsolete and are to be replaced under a regular program, these are not changed to the project. Three new bridges will be required across the diversion channel. These plus 13 others to be altered are included in project costs. The total estimated cost of bridge work is NT$256,350,000.

g. Jetties at mouth of Tan-Shui River: The need for jetties for the flood control project is questioned. It is considered that these should be included in the navigation project being considered including a harbor for coastal vessels along the right bank of the Tan-Shui river upstream from the mouth and the cost of the jetties deleted from the flood control project.

h. Diversion channel construction: It is contemplated that 2-18" and 2-24" hydraulic dredges and 2-24" booster pumping station will be used on the project. Estimated production is 200-300 M^3/hour for the 18" dredges and 600 M^3/hour for the 24" dredges, based on a 20 hour operational day. A unit cost of NT$13.6/$M^3$ plus 10% indirect costs has been used. Contingencies of 15% have been added. Since the majority of the material to be dredged in the diversion channel is clay the above figures appear reasonable. However only about 50 percent of the total dredging for the project is included in the diversion channel, the costs may be too conservative for dreging fine sand in the Tan-Shui river since production per hour should be much higher for this material. It has been proposed to build the levees on either side of the diversion channel by discharge from the hydraulic dredges. Since the material is mainly clay this method of construction is questioned. The levee section proposed is 10 meters top width with 1 on 3 side slopes, however, this has not been designed. Height of the levees above existing ground will be about 5 meters. The levee section proposed would appear to be stable for the 5 meter height on the clay foundation, although this should be verified after undisturbed samples are taken and shear tests completed as mentioned in paragraph 6e, above. Special attention should be given to the upstream end of the diversion channel where sand foundation is shown by borings. The possibility of piping and boils at landward toe should be investigated, a special cut-off trench may be required in this area. The need for a top width of 10 meters where clay dike will rest on clay foundation is questioned. A top width of 3 meters would be adequate. A saving of approximately 28 o% fill quantities, or 700,000 M^3 less fill would be required if a 3 meter top width was adopted. This is based on the estimated quantity of 2,500,000 M^3 of fill required for the levees with 10 meter top width.

24 April 1964

SUBJECT: Preminary Review of Flood Protection Plan for Tan-Shui River, Taipei Plain, Taiwan

1. Economic Evaluation - All economic evaluations made to date have compared comprehensive plans of improvement on a total basis. Some of the costs are not properly chargeable to the flood control improvements. For example, costs of acquiring land between the low water line and the river banks are included; also costs of relocating villages in the flood plain in areas that will not be affected by the flood control works are included.

A reanalysis of the plans of improvement is necessary to determine whether separable elements of the plans are justified.

Some items of cost properly chargeable to the plan of improvement have been omitted such as costs of pumping plants or ponding areas required to handle interior drainage at the levees during floods.

Damages are not based on data comparable to Corps standards. Except in Taipei City where damages from inundation will be prevented as soon as the levee now under construction is completed, all damage data are based on estimates by the individuals damaged. Where unit damages using such data were obviously incorrect, assumed reasonable unit damages were used. The unit flood damages do not appear reasonable and should be reevaluated by a competent flood damage appraiser.

These should be a significant benefit from charge in land use applicable to protecting the Wen-Tze-Chuan area from floods. Some of this benefit has been included in current economic evaluations by estimating damages to land that will change use in the future flood plain and including that damages as part of the flood damage prevented. Land enhancement benefits should be distinguished from flood damages prevented and computed separately. There is need for determining the change in value of land from change to higher type use.

Flood damages from inadequate interior drainage should be separated from damage from inundation as different protective measures are required to eliminate these damages than to eliminate overflow damage.

There is a need for determining the reasonableness of the frequency curves used in determining flood benefits, as pointed out previously, determining of flood discharges and stages is difficult and subject to much error. Relating all flood damages in the Tanshui flood plain to the stage at Taipei bridge is questioned. When separable elements of the plan are evaluated stage frequencies at other points in the flood plain should be more applicable for many areas than using the stage at Taipei bridge as a reference.

7. Dr. Hans R. Kivisild, UN Flood Control Consultant - who was a member of the UN review team of 1961 for the Tanshui Flood Control plan, has prepared eight memoranda and reports concerning the proposed plans during the period June 1963 thru June 1964. These reports are listed in Incl. #9. It is suggested that these reports be carefully considered by personnel of any subsequent review team, especially his final report of 15 January 1964. The modified scheme D proposed in that report deserves serious consideration as an optimum plan of development.

8. Conclusions - Plan C should not be considered as a single plan of development whose justification can be expressed solely by a single benefit - cost ratio. It is a collection of separable items of work relating primarily to flood control. If each of the separable parts of the flow were evaluated, most of the items included in stage 1 would be justified by tangible benefits; full protection from flooding of most of the Wen-tse-chuang flood plain would be found not justified, however, some items would be found justified by intangible benefits such as (a) Prevention of loss of human life, (b) enhancement of the general welfare and security of the people, (c) improvement of sanitation, (d) protection against epidemics, and (e) maintaining uninterrupted functioning of the national government located in the flood plain.

9. The following studies would be required to substantiate the preceding conclusion and determine the best alternative to the plan C treatment of the Wentsechuang flood plain.

a. Review and revision, if found necessary, of the hydrologic computations used to establish the stage and discharge frequency curves and design floods.

b. Review and revision, as found necessary, of the hydraulic design of the proposed plans of improvement. We have serious doubts as to the dependability of the hydraulic capacity obtained in plan C by dredging the sandy bottom of the Tan-Shui river bed as well as that of the proposed diversion channel which will be subjected to the entire bed load of Take-kan Creek. The design of interior drainage storm sewers and pumping stations on a 5-year intensity duration is obviously too low as much damage resulted from interior flooding during the flood of September 1963.

c. Revision of damage-frequency curves into individual ones applicable to each separate unit of the plan.

d. Determination of justification or lack of justification for each unit of the plan based on flood damages prevented or intangible benefits.

e. Determination of best plan of improvement for Wen-tse-chuang flood plain. This would require evaluation of land enhancement benefits.

10. A Corps of Engineers Review Team consisting of the following members would be required to accomplish the preceeding studies.

One Hydrologist	GS-12 or 13
One Hydraulic Engineer	GS-13 or 14
One Ecomomist	FS-12 or 13

Assuming local engineer would be able to determine the justification of each of the elements of the plan under the guidance of team members, it is estimated that the review would require approximately 2 months exclusive of travel time.

The cost of the review is estimated to be $18,000.00

11. Inclosure #19 contains the names of individuals of AID, JCRR and the Chinese Government with whom discussion were held during the review period.

Wilfred D. Darling
WILFRED D. DARLING

Joseph M. Buswell
JOSEPH M. BUSWELL

19 Inclosures.

1. List of individuals present at AID office, Taipei during morning of 7 Apr 1964
2. List of individuals present at project office of Tanshui River Flood Control Planning Committee, Provincial Water Conservancy Bureau, afternoon 7 Apr 1964.
3. Map of Tan-Shui River Basin
4. Map showing first stage work for adopted flood protection plans
5. Location of range lines and river profiles along streams
6. Plan showing Proposed Scheme "C" for Flood Control of Tan-Shui River
7. Tan Shui River Hydraulic Model test plan
8. List of individuals who inspected Hydraulic Model during AM, 8 April 1964
9. Tabulation of Reports and Memoranda on Tan Shui River Flood Control
10. Location of rainfall stations, Tan Shui River basin
11. Tan Shui Basin average depth at 3-day storm rainfall during typhoon 1912-1963
12. Map showing boring locations
13. Boring logs along Tan Shui River bed
14. Boring logs in Wen-Tzu-Chuan Area
15. Boring logs in Fan-Tzu-Kou
16. Boring logs along left bank of Tan Shui River at San Chung
17. Lay out of drainage system
18. Location of bridge revisions and additions of Tan Shui River Flood Control Project
19. Names of individuals of AID, JCRR, and the Chinese Government with whom discussion were made during the review period