印刷物第十三號

廣東水患問題

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▲廣東水患問題▼

在本文以內維廉擬將廣東水患問題就水學工程師之觀察畧爲介紹於各界人士至於文內所言力求顯淺以期雖非專門家亦可藉以明瞭本問題之意義因而發生本問題關係重大之觀念也茲特先對於各江之狀況爲簡明之陳述凡所言及多係以就支配河流之種種原因用科學方法攷察所得者爲據此外更對於各項防潦應用方法畧舉其梗概焉

查西江北江珠江及東江皆在六十英里長之海岸線範圍以內貫注入海計每當雨季其流量之數爲每秒鐘二、〇〇〇、〇〇〇立方英尺討論之始先就上述四江之地理及其水流之狀況簡約言之至於貫注本省東北部之韓江（或稱汕頭江）乃自成一系與現在所討論之四江完全隔絕故本文所論暫不及之

西江及其支流

西江及其支流約流灌廣西全省雲南省之東部貴州省之南部及廣東省之一小部（不過爲本省全部面積十分之一耳）其流域之廣足容大不列顛愛你蘭及丹麥國焉就航行之便而論則船隻吃水在六英尺以下者雖在旱季仍可上達梧州過此以往僅能行駛民船及平底電船因有灘數處足爲航行之梗也如用小艇則可安抵貴州之興義約距梧州五百三十英里之遙

夫範圍之大如西江者其所容納支流自必孔多現祇舉其中之最大者如右江及桂江論列如下

桂江又名撫河其上游曾於西歷紀元前二百一十四年以人力挑鑿水道通連湘江湘江屬楊子江統系流入洞庭湖者也此人力所成之水道在遠古時爲廣東與楊子江系河流溝通之點使貢米及其他商品得自廣州經由內地船運以至北京

每當潦漲時期河水增長爲勢極大民國四年大水時梧州水漲之度比諸已往紀錄中之最低水度計增長八二、三英尺假如在廣州西堤大新公司建築物記此高度則水漲之度實達該公司之第六層矣然平常水漲之度不過爲最低水度以上六十一英尺本不足危及沿江之基圍惟沿江各基圍多非堅固故平常大水雖不浸過基面亦常冲潰基身而致氾濫成災也查民國四年梧州地方最大水時經過該處之流量爲每秒鐘二、一〇〇、〇〇〇、〇〇〇立方英尺假使將同量之水置諸從前廣州城垣以內則一小時間可漲至地面以上一百五十七英尺即先施公司三層樓當亦全被淹沒又假使當日或將西江逕行引至順德縣并將順德縣全屬繞以高十三英尺之圍墻者則二十四小時後圍墻以內所容之水亦當高達圍墻之頂矣梧州地方於二十四小時內水漲最高之度爲二十二英尺其時爲民國十三年夏潦洶湧之時也

北江

就本文所述四江之大小而言北江雖爲西江之次然實際言之北江較爲細小其流域

面積不過爲西江流域面積七分之一耳北江支流亦多其較重要者爲武水翁江連州江及綏江或稱竹枝江是也北江起自本省之北其源發自梅嶺南麓梅嶺卽粵贛兩省分界處也

北江與珠江實相通連其通連之水道爲蘆苞涌西南涌佛山滘及佛山滘迄南陳村上下之各汊滘惟祇係潦漲時期內北江之水始由蘆苞涌及西南涌流入珠江而已該兩涌之口因有沙坦數處橫梗其間故旱季期內幷不通流至其餘各汊滘之水則因潮汐之往來而異其流向也

北江與西江亦常通連其通連之點卽爲三水之思賢滘故西北兩江中任何一江水度有變更時皆影響及於別一江之水度計潦期中水多從西江流入北江反之旱期中則水常從北江流入西江也

珠江

珠江較諸本省其他各江不過其小焉者矣至於珠江能否視爲自成一江或僅爲北江之一支流仍屬疑問其實珠江之性質多近於海潮水道而非河流之正宗也試覽地圖便知珠江之水多從北江而來或由西江經三水思賢滘而來凡雨季期內事實上均係如此至於珠江祇於旱季期內具自成一江之性質其時珠江之水灌注介乎北江流域及東江流域間之地方

東江

東江自成一系與本省各江完全分離不生關係灌注廣九鐵路以東一帶其源起自本省與閩贛兩省交界之羣山焉

廣州三角洲

廣州三角洲爲上述四江冲積而成位於廣州之南石龍之西其地爲一廣大之沃壤平原面積約三、一〇〇平方英里居民約八百萬至一千萬之譜

廣州三角洲爲無數水道貫穿此等水道半爲天然所成半爲人工所成且有數處有孤山點綴其間竊以爲此等孤山在遠古時當與環繞亞洲之羣島相聯屬且於未有歷史以前時代其海岸線或且深入以抵羚羊峽而於今日廣利圍所在之處成一海灣幷從此引伸至廣州市北之白雲山止在此海灣中西北兩江之水穿繞島嶼以入海所含泥滓沿途沈澱逐漸積爲平原即現所稱廣州三角洲之地也同時東江之水亦自東來其積成陸地之情形與此無異

凡有冲積性之河流所排泥滓如不爲近岸海流帶至水深之處以減淤積之展拓則冲積地必漸向大海發展計西北兩江經數水道而入海所含泥滓即在沿海一帶沈澱年復一年所沈泥滓足令河底向外伸展河底既如是伸展而河身之斜度必漸較緩而流

勢因之減殺致令上游河底亦漸有淤積之患由是河中水度當必較高其勢復可將泥滓排而入海回復其平均之勢焉

爲基圍所範之河流如本省各江苟基圍無恙者則沿河陸地之面將無淤積之慮但河道日漸向海延長其水面斜度及河底高度亦必相因而至苟欲防禦河身繼長增高莫如任令河水得自由流經陸地上而所含泥滓得在陸上卸去以積高河岸至於祇用挖濬之法以期河底不高實爲最耗費之辦法如本省各江範圍之廣者尤爲難行試舉例言之如將由三水以至紫洞一帶水道祇疏濬河面二分之一挖深三英尺亦須費三百五十萬元惟將兩岸基圍加度三英尺并修築堅固所値僅四十萬元耳

粵人築圍捍護窪地以防水患最少已逾八百年之久其基不獨循繞正幹及各支流之岸而各港汊之通連正幹者亦皆沿岸修築焉

各基建築之初其高度可斷其必能抵障當日洪流不使泛溢惟歷時既久水面高度逐漸增加則基圍之高度遂亦有增加之必要惟其法祇知堆置泥土於基頂而基底之寬必須求同式比例之增加則每不顧及其疏虞之惡果致基身斜度過陡基底寬度不足加以歷來修基所用之土每由本基下半截取獲或於逼近基底之地任意鑿掘凡此均足令本基薄弱或令所立之地脚不牢照此辦理已歷有年所其由下半截移至基頂之土爲數不少故今日各基頂之寬以之與基底之狹相比較恆覺頂寬過度甚爲不合也修築之泥土其曾由逼近基脚掘取者遺留之坑既深且濶而又與基身平行惟基內近底之地既將泥土取去一部分則其抵拒基外水壓之力自必減殺而基脚之抵抗力亦因之而弱此崩決所由來也近年潦至時期此種現象已數見不鮮矣

基面或基陂之上建築屋宇爲一般人民之習慣此宜諳誡者也當掘土及下樁以建屋址之時旣足弱及基身而屋宇所在之處又復爲巡視及修理之障碍人民之好建居於此者無非爲圖汲水利便起見然終必爲潦所衝塌轉不若建居於較遠高地上而另求取水之方以免年年有潦淹之患也

此外在基身斜坡種植者爲害亦甚蓋圍基之能持久不壞者全恃斜坡之調護得法斜坡外皮一有損傷其基卽不能持久如斜坡年年鋤挖外皮受傷泥土暴露遂受淋漓夏雨之冲蝕至於在斜坡種植猶以爲未足有等鄉民且鋤掘基身以偷佔數尺之地而展大所毗連之田畝者換言之直以基圍爲無主之物人人得以佔據以便私圖而不顧爲全體人民公共產業純屬保障人民生命財產之設置也凡建築基圍若日後管理無法而損壞處又不立時留心經營則無論建築如何堅固亦不稱爲完備蓋斜坡如有損壞其作始之時雖不甚廣謚然閱時旣久頹毀漸增循至能力漸減不足抵禦洪流而水患必難幸免全圍之能力當以其最弱之處及其最低之橫剖面爲衡若祇顧培補一段令其增加能力而他段則否者仍無濟也

每圍本各有圍董由圍內所屬各界推選學司監察修繕等事然此等圍董每於難題發生時多存因陋就簡之心未克謀澈底之解決且眼光所及又祇限於切己關係之一隅夫基圍原有連帶關係與鐵練情形相若如鐵練之一節偶脫則全練之功能盡失矣試觀綿亘較遠之基圍雖圍內全部之安危爲基之堅固是賴然因分隸多數圍董經管彼此各顧所司不相聯合致令一圍之中此部分修繕完固而彼部分任其殘缺者或此圍董集欵充裕而彼圍董則籌不足數者由此可見設立聯合機關授之以實權不至爲地

方勢力所阻撓且有專門相當知識足以排除技術之障碍始得管理圍基之要領也各江之情形及一向用以防範洪水使循河床而行之辦法皆畧已於前文述及現在再行研究有無別法可為低窪地方防免水患之助查時人所擬防潦辦法約如下述

（甲）就流域中廣植林木

（乙）開鑿新河以洩水入海

（丙）建築蓄水池以貯潦水

（丁）割直河道及濬深河底

茲更就每一方法之效能及如經採用後對於本省水患之影響如何依次討論如下

（甲）就流域中廣植林木

在普通人民心理以為潦漲之原因由於斫伐沿江林木所致故最穩健之防潦方法惟有再植林木而已此種思想非獨一般人民所主張且為水利工程術所贊許然此僅就學理上言之而非從實測而定也近日水利專家根據多年之事實詳細研究大都已變更其主張惟其中意見仍尚未一致有謂斫伐林木足令一帶地方成為不毛之地者有謂林木畧事斫伐反足以增加雨量者惟就歐美兩洲所經事實攷之凡歷來所紀之最大水災在斫伐林木後所發生者較之林木未斫伐之前未嘗有增加也又有為之辯者謂再植林木之後雖潦水仍然高漲惟發生水患之次數較少是說也就各國已往之紀錄攷之亦不盡然

惟林木之落葉腐爛而成一種泥質具有偉大吸收水量之能力此則爲兩派所公認者但吸收之力一經用盡(在時有暴雨之地方誠有此事實)其減殺水勢之能力又往往失却功用耳以一流域而論廣植林木必須數十年始可成林成林之後又須歷半世紀之始能令所落之葉腐爛而成泥質具有吸收水量之能力也

嘗就廣植林木之舉能減殺江河潦漲時流量二分之一之假定而懸擬欲使北江潦漲度減低(其減低之度約比淸遠地方現有圍基之頂下一英尺)所需植林之面積按推算所得苟欲獲此效果者計應行植林之地約爲一二、〇〇〇平方英里殆爲北江流域之面積百分之六十五矣縱有極良之組織及無限之資本第茲事體大政府或人民能否措辦裕如尙屬疑問也

至於森林地方經暴雨冲瀉情形茲設譬以明之如吾人放吸水紙乙張於稍行斜置玻璃方器之上再在吸水紙上徐徐注水於某時間之前水爲吸水紙所收不卽流至器內以迄吸水紙吸收能力告竭不能再行吸收時水始流入器內若無吸水紙者焉凡暴雨經由滿佈植物之山野急流而下之情形與此正同

然就別一方面言之森林對於河流之將來亦不無影響蓋羣山濯濯久經剝蝕泥土日漸鬆浮常遇暴雨則浮泥雜滓卽隨流下卸河中漸釀下游淤積之患故在江河附近山麓植林可藉以捍護山坡泥土此植林有益河道之點也惟植林關係地方經濟利益之大殊堪注意故於各江流域舉辦森林官民合力按科學方法措置亦所贊同惟以植林爲防禦潦災之唯一捷法則未敢以爲可也

（乙）開鑿新河以洩水入海

開鑿新河以通東京灣或南中國海俾西江得以多一出路爲普通人民所主張如欲通東京灣則新河線應於梧州至潯州一帶求之或於潯州至南甯一帶求之俾通右江如欲通南中國海者則選擇通海合宜之地點當於梧州至羚羊峽一帶求之惟由羚羊峽上溯以至右江江口西江流域各地不與海岸相接而爲叢山所間斷山脈方向大都自東而西且有無數支脉或趨於北或趨於南

右江流域各地其與東京灣海岸不相連接之情形正復相同其叢山之支系每有略爲平行之山谷間於其中斜坡向北之山阜與向南者之間大都成一馬鞍形普通人每誤以爲無難於開鑿惟經工程家之實地視察此等地形實爲開鑿新河之莫大障碍

細攷各種地圖幷就各地方詳究其地理及徵諸各方面之所言雖知開鑿此處分水嶺以通中國南部洋海實不可行然亦嘗經實地攷察以期此法幸而可行以收一勞永逸之計

爲欲確知究竟有無開鑿新河之可能俾潦水得由是宣洩若干而現時各圍基頂或免浸沒之虞起見曾在西江之南一帶山脈攷察地點有六處之多不謂六處之中幷無一處地形合開新河之用故由各該處地方鑿河通海以洩潦水之理想應行永遠免除實爲不移之鄙見也

（丙）建築蓄水池以貯潦水

用蓄水池以調節潦水俾水漲時潦水得暫在水池留貯迄水低時始再由池內放出之辦法似已爲一般人所贊同自水利工程家觀之則此法亦非新異其利益之處及其留貯之力量亦久經他人併求聞之有素矣計蓄水池之效用其留貯潦水也其放水可任意也均足減殺河流自然漲落之助凡此效用與天然之湖沼正同惟自學理言之則人工蓄水池效用更大以其洩放悉置諸管理之中不若天然湖沼之憑任自然也惟實際上建設蓄水池應注意者二事其一卽水池之容量大小若何方爲有效其二則經費問題固無時不須躊躇及之者也惟藉蓄水池以防潦水之計祇在適宜地方行之方見其益又須貼近受益地方以其效用漸遠漸失也

就建築方面言之蓄水池之位置莫善於河之上游惟以位於上游之故祇能調節上游流域一部分之水流其下游流域一帶之水（多比上游較大）仍照常灌注入河之下游故上游蓄水池所生之利益在下游所獲者殆亦微乎其微耳凡洪潦之生多不發於平常情形之時而發於異常水流之變化如暴雨疊來之類查每經大雨一次河潦必行加增使此次所增之潦水爲一蓄水池或數蓄水池所容然不久設遇第二次之大雨則蓄水池如非具兩倍之容量須將前次所容蓄水洩去故欲容納多量之雨水以迄水退時應需鉅量之蓄水池也所以蓄水池一經注滿須設法將水排去以留餘地容納第二次大雨所生之潦水方足減殺河中潦患又蓄水池雖可於某處地方減殺潦水高度惟難免令河水之增長延長暇久此種情形於農業實屬不宜以河之下游一帶低地溝洫地

竇門將因而受阻也各農家寧願忍受高度而爲時較短之潦水耳

至若江河於潦漲時如水中係帶有泥滓者則所屬之蓄水池亦每每受淤積之患而致減却容蓄能力雖淤積係積漸而來爲期頗緩惟於比較蓄水池利害之際亦當一爲注意及之欲於本省各江流域中建蓄水池以爲低地防潦之用殊難望其有效誠以如西江峽下一帶如非將廣大之農作地段佔用將無地供水池之用峽上一帶地段雖比較不甚寶貴惟峽上各江及其支流之流域地類多狹窄而陡斜欲建容量合宜之蓄水池殊不可能吾人爲駁論之便姑假定北江可以建蓄水池又設所欲貯蓄之水量能令清遠水度低於該處圍頂一英尺如此所減之潦水度比民國四年之歷來最高水當低五英尺則所應儲蓄水量最少二三、八〇〇百萬立方英尺具若是容量之蓄水池即使深十六英尺亦據面積五十二平方英里或二三六、〇〇〇華畝再者已蓄如上之量之水後蘆苞地方潦水高度不過可減低二、三英尺至於下游各處則所減又當更少矣

無論採用蓄水池之有效或無效各江下游之圍基仍須倚爲禦潦之具因蓄水之效祇能令極高潦水減低少許之事實吾人所不可忘也

(丁)割直河道與濬深河床

以挖割之工改直河身亦世人所擬減低潦度之一法也蓋無論河身有一處灣曲或數處灣曲苟能挖割之則流量速率必加增而潦漲之度減少此世人所共信也惟學理上

則河身旣因改直而變短水面斜度自必較爲陡峭則水流自必加速照此情形祇係附近施工之處上游減低潦漲之高度而於下游則有增無已因河身一經割潤水來更速其下游趕流不及也故其用挖割之法以求減低潦度雖常經試驗而多無良好效果蓋用此法僅能一處受益而他處則受害徒以鄰爲壑耳如挖割之及下游四週之地尙不致受有潦漲之患者則挖割之法始可以行然所得利益與挖割之費用相較亦祇能得失相償耳惟爲航業計則適得其反改直河身爲利甚溥也

濬深河底之法人多以爲減殺潦水高度之唯一辦法不知祇係已濬之河底能常保暢利始得有效至於帶淤之河有下述之各原因難望其有效也查河底濬深之後河床之剖面自比前增大於是水流之速率因而較緩不能挾泥暢流則泥滓沿途沈澱而所已濬深之河底不久又復積淤故濬深之法非持之有恆河床實無改善之望惟欲使濬深之法能減却潦水高度工程之大常費之多爲節省經費計實非所宜又祇將此處或彼處之淺沙濬深亦不足減全江之潦水高度必須自欲行改善之處以迄江口之全部濬深始稍見效也旣經濬治之河欲令水流速度足以排去泥滓而不致停滯淤積原亦有法其法即設立隄壩及位置圖基於妥合之點以期收束河道是也至於一般人之懸想以爲河底深一尺則水度自減一尺者實爲妄想因江河水面之高下恆視其出口處水度之高下而異廣東各江出口處爲大海其處水度之高下非人力所能變更

欲需費不甚鉅而濬深河底以期減殺潦水高度全世界經驗家皆以爲不能雖濬深之法在帶淤河流中亦常行之以圖航行之利便

綜上列各說觀之可見（一）廣植林木以減殺現時潦患爲不可恃縱使林木能影響水流惟各地湮沒之災得救之日將遙而無期（二）開鑿新河以通大海已不成問題（三）蓄水池縱能設立祗減殺潦水少許因淤積日久且失其容蓄之量（四）挖割河身及濬深河底雖於河之某段可行惟不能專倚之以減低潦水高度使其永遠不超出現時基圍之處也

綜觀以上各項討論可見欲就財力所及以圖改善被潦地方之情形恐不能自減低潦水高度之各種辦法以求有效潦水之高漲爲勢所難免之事而欲防範潦水使不至爲各鄉之患祗有在沿各大江及不能用水閘堵塞之各支流設備牢固之基圍俾潦水爲基圍所範而已查基圍之設遠在前代或亦前人所見殆屬相同也

茲并將治河處所擬舉辦各江及三角洲等地方之防潦工程約畧言其大要

計現時綿亙各江之基圍亟當用有力之泥土培厚其近河之一面尤當加意培保以免有傾卸之虞各圍高度至少應加高至懸想中最高水度之上三英尺至於最高水度之推測應懸想各江最大流量係在兩岸基圍之間通過以爲標準沿江各地如未設之基圍者應補設之各支流及涌滘現時將沿江之大圍間斷者應堵塞之涌滘小者可用尋常水閘堵塞於潦季時期常行關閉其較大之支流 則用活動閘壩以調節支流內之水流焉一經照此 辦法 將水範 於幹河以內則綿亙無數支流兩岸千百里 之子圍自成

非當務之急矣此等子圍照現時情形而論須與沿幹河之幹圍同其高度同其堅固惟各支流倘得活動閘壩爲之調節水流則子圍雖仍不可廢惟毋須與幹圍同其高度而省費不少換言之此等子圍屆時已屬次要之物祇供附近村落之需而已

至於江流集中於三數水道之後速度勢必增加然速度增加祇有益而無損因水流之衝激積淤可以減少而河底可以漸深也

附圖內之黑線爲改建圍基其濃點則爲水閘或活動閘壩

沿西江一帶基圍起自肇慶上約五英里地方幹河兩岸基圍皆全行改建以迄磨刀門止并設立沿途必需之水閘及活動閘壩等至於三角洲一帶各江道多數須用堤壩永久堵塞之除因宣洩潦水或利便航行之必要始在支流涌滘之內兩岸築基

凡此辦法東北兩江亦同一律

至於珠江一帶圍基之維持祇屬附近村落之事因所擬蘆苞西南沙口三處活閘完成之後此處水度減低已屬可能當再無潦患之虞矣

若干支流涌滘之堵塞潦漲期中或不利於航行原爲顯而易見之事惟所謂不利航行者祇發生于每年中之短少期耳人民苟得倖免其魚之慘以較星期間運輸之不便受益多矣倘人民得安然生聚其餘需要自可逐漸設法滿足之也

討論之末更請就完成防潦計劃應需欵項畧陳一二以備研究

計開

		元
西江工程約需	港銀	19,500,000
北江工程約需	同上	10,900,000
東江工程約需	同上	4,600,000
共約需	港銀	35,000,000

由此計劃而得救之地方其面積殊不爲少計西自小湘峽東自博羅北自飛來峽南自中山灣

按上述需欵之數而言爲免除災患起見計可供耕作之地每畝不過費四元六毫耳如每畝每造產禾之代價爲二十五元至三十元則爲防潦之用而費四元六毫亦殊非重負也查全部工程完成之期間預定爲十五年此十五年中農家每年應輸納防潦經費每畝三毫算試思每次水災損失之鉅卽如民國四年粤省水災據見聞所及以最少計之其損失亦達一千萬元以上則人民不能不負責輸納防潦經費矣設使確有保證表示所集之欵祇係備防潦之用而無虛糜之虞者則人民將無不樂事輸將也

深望省內有名團體及各界人士對於省內地方因基圍護養欠善而致歷受潦患之慘苦情形一爲注目了然於水患問題關係之大至於以上所言各江之情形及其保障工程之大客均係事實之談可無置疑之處也此外所擬之補救辦法純係根據健全之技術的設想倘得藉是使各界人士對於防潦辦法之誤點急謀改善之法則言爲不虛矣

廣東治河處正工程師柯維廉述

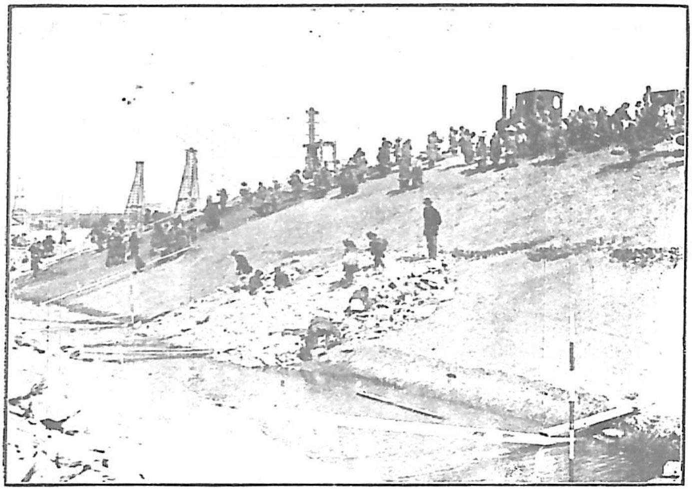

FIG. 3. STONE PITCHING ON DYKE SLOPE. NORTH RIVER.

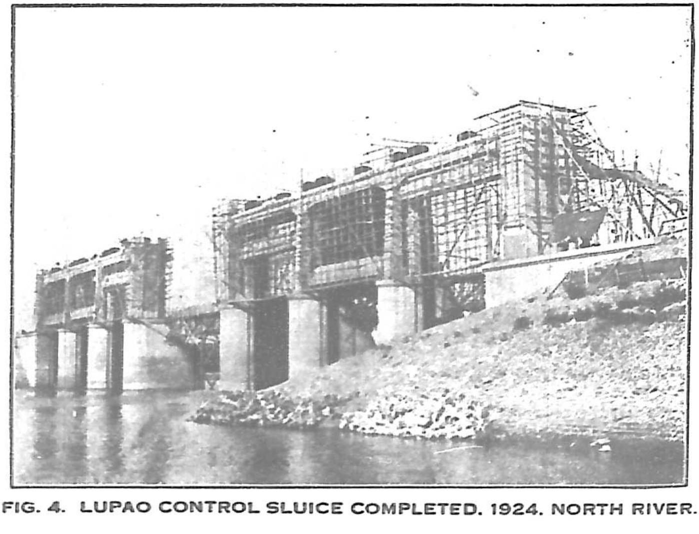

FIG. 4. LUPAO CONTROL SLUICE COMPLETED. 1924. NORTH RIVER.

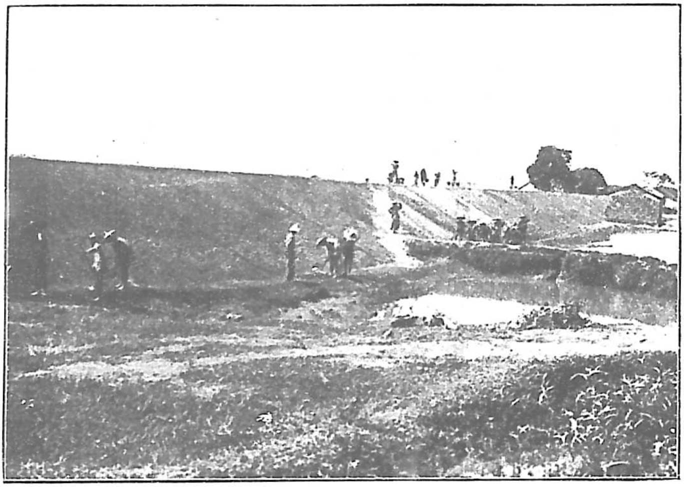

FIG. 1 A RECONSTRUCTED DYKE. EAST RIVER.

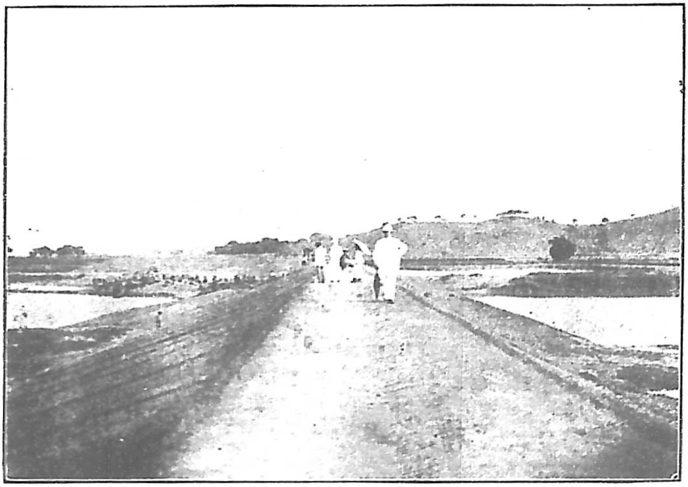

FIG. 2. A RECONSTRUCTED DYKE BEING INSPECTED BY THE ENGINEER-IN-CHIEF.

The West River work would cost	H. K.	$19,500,000
,, North ,, ,, ,, ,,	,,	$10,900,000
,, East ,, ,, ,, ,,	,,	$ 4,600,000
	H. K.	$35,000,000

The total area, including 3,000 sq. miles cultivated land, that would be saved, extends from Siusang Gorge in the West to Poklow in the East, and from Felai Gorge in the North to Heungshan in the South.

The cost for eliminating the danger would amount to, in round figures, $4.60 per mow of cultivated land. Considering that one rice-crop represents a value of $25 to $30 per mow, a cost for necessary protection work of $4.60 is insignificant. I have estimated the time for completion of the scheme at fifteen years, during which time the farmers consequently should have to pay 30 cents per year a mow for flood protection work. Keeping in mind the losses inflicted by one single flood, as for instance the flood of 1915, when according to a very moderate estimation, property up to ten million dollars was destroyed, the population would, no doubt, take upon themselves the responsibility of paying a tax, provided guarantees were given that the tax would be efficiently and well spent for the purposes intended.

It is to be hoped that the leading corporations and men in this Province will have their eyes opened to the deplorable state into which the country has sunk through lack of efficient dyke maintenance, and will be made to understand the true bearing of the flood problem. What I have stated in this paper as to the condition of the rivers and their protection works are facts, and the proposed remedy is based on sound technical suppositions. If I have been able to convince the public of the necessity of immediate steps being taken to straighten what has gone wrong, the purpose of this paper has been attained.

in order to prevent the yearly recurring flooding of the river valleys and delta.

The present dyke systems along the main rivers should be strengthened by substantial earthfill, and protected on the river side against scouring. Their height should be increased to a level reaching at least 3 feet above the expected highest waterlevel. The highest waterlevel shall be determined with the assumption that the river carries its total maximum discharge between the embankments. Where no dykes exist, new ones should be constructed. Creeks and channels now breaking off the continuity in the dyke systems should be closed, the smaller ones by ordinary flood gates, permanently shut during flood time; the large ones by movable dams, which will permit the regulation of flow in these channels. By thus confining the floods to the main rivers, an immense length of dykes, which now border the innumerable branch channels, will be superfluous. It must be borne in mind that these dykes, penetrating far into the interior, must, as conditions are at present, be constructed to the same height and strength as the dykes along the main river. In cases where these dykes should be necessary to maintain, as for instance along a channel in which the flow is restricted by a movable dam, they do not need to have the same height as the main dykes, but could be of a much cheaper structure. In other words, they would become of only secondary importance, and would be needed only for local purposes.

Concentrating the flow in a few channels will naturally increase its velocity, but this would only be an advantage. The silting would decrease, and the river bottom be lowered by scouring.

Following the course of the West River, the first dyke system met with is above Shiuhing. The dykes on both shores should be reconstructed on the whole length down to Motomun, and the necessary flood gates and regulation dams erected. In the Delta a number of channels should be permanently closed by embankments.

The same principle should be applied to the North and East Rivers.

Regarding the Pearl River dykes, their upkeep will become a purely local affair, as the proposed regulation dams at Lupao, Sainam, and Shahow will make possible such reduction of the flow that no danger of flooding is expected.

It is evident that the closing up of several channels during flood time by means of gates and dams is objectionable if looked upon from the interests of the shipping; but this nuisance would only last for a short period every year. The salvation of the people from the frequent inundations must carry more weight than a few weeks' inconvenience in transportation. Secure to the people favourable conditions of life, and means will be found to satisfy other needs !

Finally, a few words regarding the cost that would be involved in the completion of the scheme.

silt-carrying stream for the following reason. By dredging the bottom, the cross section of the bed is made larger than before, which causes a slackening of the current velocity. This being a fact, the current is not strong enough to keep the silt suspended. It settles, and the dredged canal is soon silted again. No improvement can be obtained unless dredging operations are carried on perpetually. Such work would, in order to exercise any effect on the flood heights, reach a magnitude and involve such tremendous yearly outlays, that for economical reasons the method is not justified. It is, furthermore, not sufficient to dredge away a shoal here and there, expecting that such local operations will lower the floods in general. The river bottom, along its whole length, must be lowered from the mouth as far up the river as to where improvement is desired. Now, there are other means to keep the current in a dredged canal at such a speed that the silt is prevented from settling, namely the restriction of the width of the river bed by the help of cribwork and correctly located dyke systems. It is a false supposition that the lowering of the river bottom, say one foot, must effect the same lowering of the water level. The height of the water surface in a river depends, in its lower course, upon the height of the water level at its mouth, which in case of the Kwangtung Rivers is the sea level; and no human being can change that.

Experiences all over the world show that the lowering of flood heights is not obtainable, within reasonable costs, by dredging the bottom, though for navigation purposes it is often resorted to in silt carrying rivers.

Summary

Summing up what has been said, it is obvious that: firstly, reforestation, as a means of lowering the present floods, is not to be relied upon, but would, even if it should have some influence on the flow, postpone the salvation of the country for an indefinite period of time; secondly, that creating new outlets to the sea is out of the question; thirdly, that reservoirs, even if possible to construct, would only given a very slight relief from floods, and would in time lose their storing capacity on account of silting; and fourthly, that cut-offs and dredging of the river bottom, though advisable in some instances, would not alone be effective in lowering the water to a level that would give permanent security against overflow of the present dykes.

The previous investigations show that an improvement of the general flood conditions, falling within limits of available resources, cannot be derived from efforts to reduce the high water level. The remaining means to be taken into consideration agree with the conception of previous generations that an effective system of dykes bordering the main river as well as the tributaries and channels, where adjoined by low-lying land, thus confining the floods within stable limits, would give the protection needed against inundation.

Proposals of the Board of Conservancy Works

I will now give you a short description of the principal feature of the work which has been proposed by the Board of Conservancy Works, In rivers carrying much sediment during floods, reservoirs always run the danger of being silted, and thus losing part of their storing capacity. This is naturally a slow process, but it has to be taken into consideration when the advantages and disadvantages of reservoir systems are compared.

The prospect for introducing reservoirs along the course of the Kwangtung Rivers, as a preventive against inundation of the plains, is not especially encouraging. No site for a reservoir can be found below the gorges, without encroaching upon the rights of the rural population, by putting large and valuable cultivated regions under water. Above the gorges the land is less valuable, but here the valley of the rivers and its tributaries are generally so narrow, and of such steep gradient, that the construction of reservoirs of sufficient capacity is scarcely possible. Let us, however, for argument's sake presume that this is possible for the North River, and that we wish to store so much water as to keep the water level 1 foot below the crest of the dykes in the Tsingyun region. This means at least a reduction in flood height of 5 feet below the high-water level of 1915, which is the highest observed. It would then be necessary to store at least 23,800 million cu. ft. of water to gain the desired reduction at Tsingyun. A reservoir of that capacity would, if filled say to a height of 16 feet, cover an area of 52 sq. miles or 236,000 mao. Storing this volume would not produce a lowering of the flood height at Lupao of more than about 2.3 feet, and still less further down.

Independent of the success or failure of introducing reservoirs, the dykes in the lower course of the river must still remain as a defense against inundation, since we must keep in mind the fact that only a slight lowering of the extreme flood height would be attained by storing.

Cutting off Bends and Dredging of The River Beds

A method suggested for reducing flood height is the straightening of the river by means of cut-offs. It is believed, that by cutting off one or several bends, the discharge of water will increase at such a rate, as to produce a lowering of the flood level in general. Theoretically, an acceleration of the flow will follow, since shortening of the river gives to it a steeper slope. This change of condition, however, will only result in a lower flood level immediately above, and in the upper end of the cutting, while, at the lower end, an increase in flood height will take place, because the water rushes through the improved section much faster than the lower part is able to carry it off. The fact is, that cut offs have been repeatedly tried in rivers as a means of reducing floods, but generally with unsatisfactory result. They afford relief in one locality, but only at the expense of other localities. Cut-offs are justified in case a higher flood level does not cause any inconvenience to the surrounding lands at the lower end, and even then, only when the benefit derived balances the cost of the construction of the canal. For shipping purposes, on the contrary, the straightening of a river may be in many cases advantageous.

Dredging of the river bed has often been held forth as the only means that would lower the flood level. And so it would, if only the once dredged canal remained open. This is, however, not to be expected in a

No less than six different passes in the mountain ranges south of the West River have been examined, between Nanning and the Ling Yang Gorge, in order to ascertain if any possibilities exist to cut a canal big enough to lead off sufficient water, in order to prevent overtopping of the present dyke systems. Not in one single instance did the topographical aspect warrant such a possibility, and I am positive in my opinion that the idea of creating a flood discharge from any point between these places to the open sea, through a canal, must be entirely and finally abandoned.

Storing The Flood In Reservoirs

The plan of controlling the floods by means of reservoirs, in which part of the water is held back during the flood season, again to be released at a lower stage in the river, appears to have met with much popular approval. To the hydraulic engineer, this way of controlling floods is no novelty; its advantages have been thoroughly studied and its limitations are also well known. The very function of reservoirs, that of filling, holding, and emptying their supply of water as required, abstractly renders them particularly adapted to serve to reduce the natural fluctuations in the volume of rivers. This influence is similar in kind to that of natural lakes, but is theoretically even more effective, because the release of the water of a reservoir is wholly under control, while that of lakes is relatively unrestrained. But there are two practical considerations which limit their employment; these are, the storage capacity required for efficiency, and the ever present question of cost. Only where the natural conditions are favourable can the reservoir system for preventing floods be adapted with advantage. As its value rapidly diminishes with distance, it must be close to the locality which is to be benefited.

Generally from a constructive point of view, the best sites for reservoirs are found in the upper courses of the river system, and consequently the run-off in that part of the drainage basin only is regulated by the reservoir. The rest of the basin, in most cases the larger part of it, continues as before to feed the river, and the beneficial influence of the storage in the upper courses is only slight in the lower ones. Great floods do not arise from average conditions, but from exceptional variations, such as are caused by a series of heavy rains rapidly succeeding each other. Each rainstorm produces in the river a flood, the volume of which may be absorbed by a reservoir or a system of them. Should a second storm sweep over the valley, a short time after the first, the reservoirs to be effective must be emptied, or their capacity doubled. To hold all the excess rainfall until low water, would require reservoirs of enormous capacity. Therefore, as soon as a reservoir is filled, and has for the time played its part as a reducer of floods, it should be emptied in order to utilize the same space for a second rainfall. While reducing the flood crest at a given locality, the reservoir necessarily prolongs the period during which the river remains at a high stage. This condition is not desirable from an agricultural point of view, as it prevents the drainage of the lowland in the lower region of the river. A high but short flood may be preferable.

be prevented from flowing down the glass square for a certain period of time ; but, when the paper has exhausted its capacity to absorb more water, the surplus water will begin to flow down the square as freely as if no blotting paper were there at all. This illustrates what happens in nature when heavy precipitations discharge over a mountainous country covered with vegetation.

From another point of view afforestation would play a part in the future regime of the river. Through lack of cover by vegetation, the mountains are now freely exposed to erosion, and, besides, their surfaces are brought to a state of decomposition. Heavy showers, which are frequent in these regions, carry quantities of decomposed matter down into the river valleys, and this accounts for the silt deposits met with in their lower courses. Afforestation on the mountain slopes in the vicinity of the rivers would keep the soil in place and would be justified for that purpose only. A much more important circumstance to be considered is, however, the general economical benefit for the whole country, derived from forest cultivation. This speaks in favour of the adoption of an afforestation scheme throughout the drainage basins, worked in a scientific way and supported by the authorities as well as by the country people themselves.

As the only, immediate, or principal remedy against floods, afforestation is not to be recommended.

Creating New Outlets to the Sea

A scheme which has been much ventilated among laymen is that of creating an additional outlet for the West River, either to the Tongking Gulf or the South China Sea. In the first case, an outlet for the main river should be sought for between Wuchow and Sunchow or, for the Yuh Kiang, between the latter place and Nanning. In the second case, an outlet to the sea from any suitable point between Wuchow and the Ling Yang Gorge would have to be constructed.

The West River valley, above Ling Yang Gorge as far as the junction of Yuh Kiang, is separated from the sea coast by huge mountain ranges, their main direction being from East to West, with a number of branches stretching to the North and to the South.

The Yuh Kiang valley is in a similar way isolated from the coast of Tongking Bay. The branch mountains sometimes form between them gently declining valleys, those sloping to the North being separated from those sloping to the South by an apparently low saddle, which, for the layman seem to be easy enough to overcome, but, when inspected by the engineer, form unsurmountable obstacles for the construction of canals.

A study of available maps, and the general geographical conditions of the country, together with information collected from different sources, led to the conclusion that an attempt to cut through the water-shed to the south would prove impossible. Nevertheless, investigations have been undertaken with the principal object of climinating this scheme once for all.

1. Afforestation of the drainage basin.
2. Creating new outlets to the sea.
3. Storing the floods in reservoirs.
4. Cutting off bends and dredging of the river-bed.

I will examine the effectiveness of each of these means in their proper turn, and also state their influence upon the floods, if applied on the Kwangtung Rivers.

Afforestation of the Drainage Basin

There exists in the public mind an impression that the prime cause of the floods has been the destruction of forests in the river valleys, and that the surest way to prevent them is by reforestation. This conception is held not only by laymen, but also has been advocated by hydraulic engineers, though more as a matter of theory than founded on actual observations. Recent investigations, based on facts collected during a long sequence of years, have so far, in a measure, changed this conception amongst the experts on hydraulics. Still there is a great diversity of opinion on the subject, some maintaining that the cutting down of forests will ultimately convert a country into a desert, while others claim that a moderate cutting down of the forest even increases the rainfall.

The fact remains that in Europe as well as in America remarkable series of great floods, in land covered with woods, have not occurred more frequently *after* the forests were cut down. It is also argued by some, that with reforestation, if the floods occasionally were high, they would not be as frequent. However, where long periods of records are available, they do not always verify this apprehension.

It is generally accepted by both sides that the leaves falling from forest trees, as they decay, form a humus which has a capacity to absorb water. However, after this capacity is utilized, a condition which soon will arrive in countries subject to heavy rainfalls at short intervals, the retarding influence of humus on the run-off is more or less lost. It will require tens of years to produce a good forest growth within the drainage basin of a river. After that half a century will probably be required for the leaves to decay in sufficient quantities to produce a layer of humus thick enough to absorb the rainfall.

Under the assumption that reforestation would reduce the flood discharge of a stream to one-half, I have made an estimation of the forested area that would be required to lower the flood heights in the North River to an elevation of 1 foot below the present dyke crests at Tsingyun. I have found that at least 65 per cent of the total drainage basin, amounting to about 12,000 sq. miles, would have to be covered with forest to bring about such effect. Even with the best organization, and unlimited resources, it is doubtful if the government or the communities would be able to inaugurate such a scheme.

The following illustrates what happens when a heavy downpour drenches a wood land. If we take a piece of blotting paper and place it on a glass square, and give to that square an inclination, and then pour water over the blotting paper, the water will be absorbed by the paper and higher ground, and construct an artificial water supply, rather than to run the risk of having them spoiled by floods year after year.

Another circumstance which causes serious damage to the dyke is the custom of laying the slopes under cultivation. As the durability of an earth-embankment depends on the protection given to its slopes, this durability is imperiled as soon as the cover is injured or taken away. The yearly ploughing of the slopes spoils the cover and exposes the soil to the erosion of the heavy summer rains.

But not content with the use of the dyke-slopes for agricultural purposes, the country people do not hesitate to carry on excavations in the dyke body itself in order to gain a few additional square feet of land for their adjacent rice-fields.

In other words, the dykes seem to be considered as "no man's land", which every one has the right to use for his own selfish purposes, instead of being looked upon as the common property of the whole population, for the safety of whose life they are provided.

It is not sufficient to construct a dyke, however strong, if the future upkeep is neglected and damage left without immediate attention. A cut out of the slope, which at the beginning may be of inconsiderable dimension, increases in the course of time, until the strength of the construction is so diminished that, when the floods occur, a catastrophe is certain to happen. The strength of a dyke system is determined by its weakest and lowest section, and it is useless to give to one part of it a strength which is not shared by the rest.

There are, it is true, committees for every dyke district, formed by delegates from the different communities within the protected area, whose function it is to supervise and carry out necessary repairs. In most cases these committees have no aptitude for dealing in a thorough way with the problems which arise, and their oversight is limited to only their part of the dyke-system. A district surrounded by a continuous embankment on whose solidity and maintenance the safety of the whole enclosed area depends, is often kept under supervision by several committees, each working in its own interests, without any cooperation whatever. The result is, that one part of the embankment may be well kept up, while another is left to its fate, one committee being well supplied and the other ill supplied with funds. The dyke is like a chain ; if one link breaks the chain fails to do its duty.

It seems, therefore that one homogeneous organization, with sufficient power, independent of local influence, and possessing the requisite qualifications to overcome technical obstacles, is the only suitable corporation to conduct the dyke supervision.

I have now given you a general conception of the condition of the rivers, and of the means which have hitherto been applied in trying to confine the floods to the river-bed. We will now investigate if there are any any other ways to prevent the flooding of the low lying country. The principal means suggested as remedies against the violating floods may be classified as follows :—

If a river is confined within dykes, as is the case with the Kwangtung Rivers, no rise of the land surface by silting is to be counted on, as long as the dykes are intact. Following the growth of the river, towards the sea, the gradient must be maintained, and a rise of the bottom follows. The most effective means to stop the growing divergence in level, between the river bottom and the land, would be to give free access to the water to spread out over, the land, there to unload its silt, and raise the river banks. To keep the bottom low by permanent dredging only is a very expensive operation, which can scarcely be resorted to in rivers of such magnitude as those of Kwangtung. As an example it may be stated, that deepening the river bed only 3 ft. on half its width, between Samshui and Tzetung, would cost at least 3.5 million dollars, whereas raising the dykes on both sides 3 ft., and giving them sufficient strength, would cost only about 400,000 dollars.

During a period, covering probably at least 800 years, the population in the south of Kwangtung has protected their low lying land against inundation by means of extensive embankments, running along the bank of the rivers, and their tributaries, also following the innumerable creeks, which are in communication with the main rivers.

At the time of their construction, the dykes were undoubtedly raised to a sufficient elevation, to prevent over-flow from the then prevailing high water. But in time the flood level has become higher, necessitating an increase of the height of the dykes. Where this has been done, successive additions of earth to the top have been laid, without regard to the necessity of proportionately increasing the width of the base. The consequence of this inadvertence is too steep gradients, and insufficient width of the base of the dyke section. The earth required for the work has often been procured from the lower part of the dyke itself, or dug out from the natural ground in the immediate vicinity of the base, thus weakening either the embankment itself or the foundation upon which it rests. For years this procedure has been carried on, and considerable quantities of earth have been removed from the lower part of the dyke to its top. The result is that the top width, as a general rule, has now become unnecessarily large as compared with that of the base.

Where the material for repairs has been taken from the ground near the dyke on the landside, more or less deep excavations now remain, being of considerable width and running paralled to the dyke. It is evident that if a part of the soil on the landside, close to the base, is taken away, the load which has to counterbalance the water pressure on the riverside is decreased. In this case the resistance of the foundation is weakened, and the danger of undermining arises. This phenomenon has been of common occurrence during recent floods.

The erection of houses on the tops and slopes of dykes is a common practice among the people and should be condemned. The excavation or driving of piles for foundations weakens the dykes, and the presence of the buildings interferes with proper inspection and repairs. The probable reason for building on the dykes is the desire to be near the river as a water supply. But it would pay in the end to move the houses further inland to

The Pearl River

The Pearl River, or Chu Kiang, is only a small river, compared with other rivers of Kwangtung province. It may even be open to question whether the Pearl River, should be considered as an independent river at all, or only as a branch of the North River. Furthermore, it has more the character of a tidal channel than that of a river proper. A study of the map gives the impression, that the river is principally fed from the North River, and also, via the Samshui junction, from the West River. This is, indeed, the fact during the wet season. In the dry season the Canton River drains the country situated between the basins of the North and East Rivers, and has the character of an independent river.

The East River

The East River, or Tung Kiang, forms a water system of its own, entirely separated from, and independent of, the other systems. It drains the land to the East of the Canton-Kowloon railway and comes from the mountains on the boundaries of Kwangtung, Kiangsi, and Fukien.

All these four rivers have together built up the Canton Delta, a vast plain of alluvial soil which covers an area of about 3,100 sq. miles, situated to the South of Canton and to the West of Sheklung. This area has a population of 8,000,000 to 10,000,000 people.

The Delta

The Delta is penetrated by an immense number of channels, formed partly by nature, and partly by man, and in places dotted with isolated mountains. In ancient times, these mountains evidently formed parts of the archipelago, which surrounded the continent. In prehistoric times the seashore seems to have reached as far as the Ling Yang Gorge, forming a large bay where now the Kwangli enclosure lies, and extending to the White Cloud Mountains north of Canton. In this bay the West and North Rivers meandered between the islands out to the open sea, depositing their silt, and successively building up the plains now known as the Canton Delta. Simultaneously the East River approached from the East, building up land in the same way.

Every alluvial river is bound to extend its delta further out into the sea, as long as the littoral currents do not prevent its extension, by carrying the silt laden river-waters out to the deep sea. The West and North Rivers debouch through several channels into the sea, where the silt settles along the coast. Year after year the settling continues, resulting in an extension of the river bottom outwards. As the river-bed is thus extended, the slope of the river becomes more gentle, causing a slacking of the current, and silting of the bed further up the river. A rise in water level is then bound to follow, giving to the flow a velocity sufficient to carry the silt out to the sea.

In old days this canal was the connecting link between the Kwangtung and the Yangtze River systems, and made it possible to ship tribute rice and merchandise, inland, from Canton to Peking.

At flood time the rivers rise tremendously. During the big floods of 1915 the water at Wuchow rose 82.3 ft. above the lowest water level on record. That is to say, if we should mark this height on the Sun Company's Building on the Bund, the water would reach to the fifth floor. The average rise is about 61 ft. above the lowest low-water mark, and such floods are generally not dangerous to the dykes along the river. Still, even moderate floods may cause inundation, not by over-topping the dykes, but by washing out those dykes which are not of a sufficiently strong construction. During the year 1915, the quantity of water passing Wuchow at the highest stage was 2,100,000,000 cu. ft. per second. That means, that if this quantity had been confined within the old city walls of Canton, the water would have risen, in one hour, to a height of 157 ft. above the ground, and would have entirely covered the Sincere Building. I will give another example. If the river had, at that time, been led into the Shuntak district, and that district had been surrounded by a wall, 13 ft. in height, this basin would have been filled up to the top of the wall in 24 hours. The highest rise in 24 hours at Wuchow was 22 ft. during the summer flood of 1924.

The North River

The North River, or Pei Kiang, is next in size to the West River, but comparatively a small one, having a drainage area of only 1/7 of that for the West River. The North River also has a great number of tributaries. The most important of them are the Wushui, the Yungkiang, the Linchowkiang, and the Sui Kong or Bamboo River. This river rises in the northern part of the province, having its sources on the southern slopes of the Meiling range, which latter separates the Kwangtung and Kwangsi provinces.

The North River is in communication with the Canton River through the Lupao Channel, the Sainam Channel, the Fatshan Channel, and, south of the latter, through several channels above and below Chanchuen. It is only during the flood season that water flows from the Lupao and Sainam channels to the Canton River. Sandbanks formed in their openings cut off water communications during the dry season. In the other channels the water flows both ways, according to the ebb and flood in the sea.

The North and the West Rivers are in permanent communication through the Junction Channel at Samshui. Any variation of flow in the one river, therefore, exercises a certain influence upon the flow in the other. During the wet season the West River is the dominating one, and the water flows from that river into the other; but in the dry season the reverse frequently occurs so that the water in the North River goes into the West River.

THE FLOOD PROBLEM OF KWANGTUNG

by

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[A lecture given at Canton Christian College]

In the following paper I wish to put before the public the Flood Problem of Kwangtung, such as it appears to the hydraulic engineer, but in such a way that the layman will also be able to grasp the purport of the problem and to form, for himself, an idea of its magnitude. Here I will give, in a concise form, a brief statement of the condition of the rivers. This statement is based upon comprehensive investigations of the causes that rule the flow. I will also outline the methods that must be applied in order to control the floods.

On a stretch of coast, 60 miles in length, no less than four rivers debouch into the sea, viz, the West, the North, the Pearl, and the East Rivers, discharging during the rainy season about 2,800,000 cu. ft. of water per second.

I will begin by giving you a general brief description of the geographical and the hydrographical features of these four rivers. The Han or Swatow river, draining the extreme north-eastern part of the Kwangtung province, will not be dealt with in this context, as it forms a river system of its own, entirely separated from the four rivers under discussion.

The West River

The West River or Sikiang, *with its tributaries,* drains, broadly speaking, the whole province of Kwangsi, the eastern part of Yunnan, the southern part of Kweichow, but only a small part of Kwangtung, or about 1/10 of the whole province. Its drainage basin covers an area, within which could be placed the whole of Great Britain and Ireland, together with the Kingdom of Denmark.

The river is navigable, even during the dry season, as far as Wuchow, for craft having a draft not more than 6 ft.; but beyond this place only for native boats and flat-bottomed motor-boats, as several rapids form obstructions difficult to overcome. Small boats may proceed with certainty up to Hingi in Kweichow, a distance of about 530 miles from Wuchow.

A river of this magnitude naturally receives a great number of tributaries, but I will restrict myself to mention only the two largest of them, the Yuh Kiang and the Kwei Kiang. The latter, which also is called Fu Ho, has in its upper course a canal built in 214 B.C. This canal is connected with the river Siang Kiang, belonging to the Yangtze River system. Siang Kiang debouches into the Tung Ting Lake.

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