渠務署
Drainage Services Department

2010 年 7 月 22 日
沙埔仔村水浸事件調查報告
Investigation Report on the Flooding in Sha Po Tsai Village, Tai Po on 22 July 2010

行政摘要
Executive Summary

2010 年 8 月

August 2010

AECOM

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<u>事件概述</u>
2010 年 7 月 22 日下午的特大暴雨引致大埔河中游段洪水氾濫，一名沙埔仔村居民被洪水沖走，不幸喪生，是次事件亦造成沙埔仔村嚴重水浸，並導致多處房屋損毀及財物損失。

沙埔仔村毗鄰渠務署『合約編號 DC/2007/06 – 林村河上游，社山河及大埔河上游河道改善工程』的地盤。圖號 1 顯示了：

(1) 沙埔仔村和上述工程地盤的位置及其周邊環境；
(2) 大埔河 3 段河道的範圍，即大埔河上游段（河道 A、河道 B 及其更上游河道），中游段（西支流、中支流及東支流）和下游段（由達運道橋梯階式河道起，流經大埔新市鎮的河道）；及
(3) 大埔河的各主要水利特徵，例如：匯流點、分流點和交錯分流。

沙埔仔村位於大埔河中游段的中支流及西支流之間。

洪水過後，據現場觀察所得：

(1) 沙埔仔村的水浸情況非常嚴重，洪水從西邊流經該村至東邊，村中水浸深度達 1 米至 2 米多；
(2) 大埔河上游段及中游段出現多處沖刷，並發現有大量殘餘植物、泥沙及大石沉積於大埔河中游段及下游段多處地方，這些沉積物同時堵塞了多處橋下的排水口；
(3) 有些建造工程結構物及物料被沖走或偏離原來位置。

本調查研究了大埔河於上述各種情況下的水力表現，考慮了各種沉積物的來源，評估了建造工程對水浸的影響，並根據研究結果，分析水浸成因。

<u>大埔河流域特性</u>
大埔河全長約 6.7 公里，流域約 7 平方公里，由位於水準基準 752 米的最高點，流至吐露港（如圖號 2 所示）。大埔河河道陡峭，上游地區的坡度約 1 比 5，隨後逐步緩降，於中游段下降至約 1 比 23。根據過往的洪水記錄及當地居民憶述，大埔河中游段，即河道改善工程所在的河段，時有洪水爲患，造成水浸。

<u>擬建河道改善工程</u>
由於大埔河中游段容易出現洪水氾濫，渠務署開展工程合約編號 DC/2007/06，於大埔河中游段的中支流進行河道改善工程，以提高大埔河的排洪能力。承建商昭興建築運輸有限公司自 2008 年 3 月開始負責大埔河改善工程的施工，並由顧問工程師 AECOM Asia Co. Ltd 負責監管。這項工程包括將中支流改造成主河道，於其兩岸修建石籠護岸，在上游興建沉石池及修建行人橋樑。工程完成後，西支流將自 CH_C 180 處與中支流分隔，形成一條只收集附近地面徑流的支流。

洪水事件

在 2010 年 7 月 22 日的前 5 天，大埔河流域內的總降雨量是 70.7 毫米，使土地濕度在暴雨前較飽和，不利於吸收雨水。隨後於 7 月 22 日下午 4:40 至 7:20 出現的特大暴雨，峰值降雨量達每小時 103 毫米，期間的總降雨量達 167 毫米，是近十年來大埔區錄得的最大暴雨量。

從是次調查得悉，當天下午 5:30，沙埔仔村村民發現洪水開始由西支流泛濫，洪水流經沙埔仔村，並湧向中支流。洪水水位於 15 分鐘內迅速升至及膝高度，並於半小時內升至約 1 米高的最高水位，部分房屋更被洪水浸至地下底層的天花頂（約 2 米多高）。水浸持續約一個半小時，至下午約 7:00 爲止。

沙埔仔村水浸後損毀嚴重，當中 2 號屋的一名居民被洪水沖走而罹難，3 號屋倒塌，26 號屋被浸至 2 米多高；此外，多戶家庭因水浸而造成財物損失。

洪水過後，大量泥沙及大石積聚於大埔河的多處樽頸段，並阻塞了位於 7 座橋樑橋下的排水口（分別爲橫跨於中支流 CH_C 230、CH_C 325（橋樑 TB-A）、CH_C 340（橋樑 TB-B）、CH_C 420（橋樑 TB-C）和 CH_C 520（橋樑 TB-D）的 5 座橋樑和橫跨於西支流 CH_W 350 和 CH_W 450 的 2 座橋樑）。

數學模型水力分析

這次調查利用 Danish Hydraulic Institute 的 MIKE 11 （2001b 版）軟件構建了大埔河流域數學模型，以模擬大埔河在這場暴雨下不同條件的各種洪水狀況。數學模型已利用經測量到的最高洪水位及位於 CH_C 620 梯階式河道處的估算流量進行校準，適合對大埔河在各種條件下的洪水狀況進行分析。數學模型共模擬了以下 5 個模擬工況:

- 模擬工況 1 – 原有的河道自然狀況，作爲基綫狀況（施工前）
- 模擬工況 2 – 在基綫狀況下，加上 7 座橋樑橋下排水口淤塞的情況
- 模擬工況 3 – 在基綫狀況下，加上已建工程的情況
- 模擬工況 4 – 在基綫狀況下，加上 7 座橋樑橋下排水口淤塞，再加上已建工程的情況
- 模擬工況 5 – 洪水沖刷沉積後的河岸及河床形態，加上 7 座橋樑橋下排水口淤塞，再加上已建工程的情況

數學模型水力分析的結果，顯示 5 個模擬工況中的水流狀態均十分相似，特別是位於分流 2 處 (CH_C 180 to 240) 的水流狀態，如圖號 3 所顯示。

模擬工況 1 的結果顯示水流於分流 2 處出現分流，約三份一的流量進入西支流， 三份二的流量進入中支流。由於西支流的河床較中支流爲低，水流會首先進入西支流。隨著流量增加，相對較窄的西支流的水位將迅速提升，並流至中支流，中支流的流量亦因此漸漸增加。中支流的河水隨後再分流爲中支流及交錯分流 2。由於交錯分流 2 的河床較位於中支流 CH_C 230 橋樑下的河床低，大量中支流的河水經交錯分流 2 回流至西支流，使匯聚於西支流的流量變得相當高。由於西支流相對狹窄，增加了的流量很快便從右岸泛濫，令大

量河水湧至沙埔仔村 26 號屋附近。此種分流、回流及泛濫的情況是由於地形及河道的幾何形狀所引致的。

根據數學模型的預測，整條西支流的水位均高於右岸的沙埔仔村。同時，西支流的水位亦高於位處 CH_W 350 和 CH_W 450 的兩座橋，令這兩座橋阻礙了水流，造成顯著的能量損失，並明顯地提高上游水位。另一方面，中支流的水位高於左岸的沙埔仔村。與西支流情況相似，中支流的水位亦高於位處 CH_C 230, TB-A, TB-B, TB-C 及 TB-D 的 5 座橋，而這 5 座橋亦阻礙了水流，明顯地提高上游水位。分析結果還顯示，洪水會自西支流經沙埔仔村流至中支流。

模擬工況 1 的結果顯示，西支流的排洪能力不足以應付 2010 年 7 月 22 日的特大暴雨； 即使在施工前的河道原有自然情況，及沒有出現 7 座橋樑橋下排水口淤塞的情況，沙埔仔村同樣會遭受洪水侵襲。

模擬工況 2 的結果顯示，當 7 座橋樑橋下排水口出現淤塞，會引致橋樑上游水位抬高，使更多的河水由西支流泛濫，湧經沙埔仔村進入中支流。根據模擬方案推測，沙埔仔村的水浸程度，在橋下排水口被堵塞的情況下較未被堵塞的情況嚴重。

模擬工況 3 模擬了於事發前已建工程（包括沉石池、數段石籠、行人橋橋墩以及其他臨時工程，例如：臨時堤壩、隔音屏障、河岸鞏固設施、臨時石料貯存堆和重新平整的河床，而這些已建工程各自對水浸情況的影響將於稍後章節作更詳細論述）對大埔河的綜合影響。

通過比較模擬工況 3 與模擬工況 1 的結果，修建於交錯分流 2 處的臨時堤壩起到阻擋中支流的河水流向西支流的作用，令更多的河水分流往中支流，減小 26 號屋處的交錯分流和 2 號屋前西支流的洪水流量。雖然中支流的水流將相應增加，但中支流有較好的排洪能力而不會造成洪水氾濫。整體而言，據數學模型分析，在沙埔仔村於事發前已建工程的綜合影響下，其水浸程度將較工程施工前稍為得到紓緩。

模擬工況 4 模擬了 7 座橋樑橋下排水口淤塞，再加上已建工程的狀況。模擬工況 4 與模擬工況 2 的比較，與模擬工況 3 與模擬工況 1 的比較，有類似的關係。根據數學模擬結果推測，沙埔仔村於事發前已建工程的綜合影響下，其水浸程度將較工程施工前及 7 座橋樑橋下排水口被堵塞的情況，稍為得到紓緩。

模擬工況 5 模擬了河床及河岸形狀經洪水期間的沖刷和沉積變化後的情況。模擬工況 5 及模擬工況 4 最接近洪水期間所出現的沖刷及沉積情況。由於大量位於分流 2 及交錯分流 2 處的沉積物減小了進入西支流的流量，就洪水氾濫對沙埔仔村所造成的影響而言，模擬工況 5 較模擬工況 4 略為輕微。

數學模型水力分析的結果表明：

(1) 西支流的排洪能力不足以應付 2010 年 7 月 22 日的特大暴雨。即使大埔河沒有進行河道改善工程，而 7 座橋樑橋下排水口沒有出現堵塞，沙埔仔村也會遭受洪水侵襲；

(2) 7 座橋樑橋下排水口的淤塞加劇了水浸程度；及
(3) 事發前已修建的工程整體上並沒有使水浸情況惡化。

沉積物來源評估

若將 2009 年 11 月與 2010 年 8 月的高空照片作一比對，可以見到沿大埔河上游的河道 A 及河道 B 出現明顯的沖刷現象（如圖號 4 所示），相信是由高速的水流和陡峭的河道所引致的。在施工範圍內之中游段亦發現多處河床及河岸的沖刷；同時，河道內其他地方亦發現有泥沙和大石積聚，主要分佈於西支流與中支流各橋樑的上游處。根據定量分析，這場特大暴雨對河道 A 和河道 B 的河床及河岸造成了嚴重的沖刷，沖走了大量的泥沙和大石（約 5,400 立方米），其中部分沉積於大埔河中游段，餘下部分則被沖至更下游及吐露港。據估算，於大埔河中游段， 約 1,800 立方米的泥石被沖刷，另有約 4,000 立方米的泥石積聚，換言之，從上游段沖來的淨沉積量約爲 2,200 立方米。

已建成工程對洪水的影響

上述數學模型的水力分析結果顯示，整體來說，已建成工程沒有加劇這次水浸的程度。本調查亦對每一項已建成的工程(包括臨時建造工程)的影響，再作進一步的獨立分析研究。水浸發生前的已建成工程有沉石池、數段石籠、行人橋橋墩及一些臨時工程，包括臨時堤壩、隔音屏障、河岸穩固工程、臨時石料貯存堆和河床的平整，如圖號 5 所示。洪水發生後，雖然大部分永久工程均保持原貌，但有一部份臨時工程結構物被沖走或偏離原位；如圖號 6 所示：

- 沉石池 – 攔截了從河道 A 及河道 B 沖刷下來的 580 立方米沉積物，並在修建後使其所在處原來 60 米長的天然河道免受沖刷。而沉石池前面則因沖刷而留下一個坑洞。即使考慮到洪水對這個坑洞的沖刷，沉石池仍然減小了 390 立方米的沉積物沖向下游，產生了正面的效果。
- 數段石籠河堤 - 石籠河堤是沿河修建，大部分位於原河流範圍以外，不應對河流產生負面影響。
- 行人橋橋墩 – 修建於原河岸處，因此不會對河流產生負面影響。
- 臨時堤壩 – 在暴雨過後仍然保持原貌，而且據數學模型推測，可將更多河水帶到中支流，有助減少西支流的流量。
- 隔音屏障 – 這些由鋼框、波狀屏障組件和以大石或灌水鋼油桶固定的隔音屏障，在洪水過後，有 127 個框架，260 塊屏障板和 283 個鋼油桶被沖離原位。其中原本置於分流 2 上游的隔音屏障組件，有 2 個框架和 2 塊屏障板積聚於西支流 CH_W 350 橋前，另有 2 塊屏障板積聚於 CH_C 210。而分流 2 下游的隔音屏障組件，有 5 個框架和 15 塊屏障板積聚於 TB-C 橋前，另 1 個框架和 1 個屏障板則積聚於 TB-D 橋前。其他未被尋獲的，相信已被沖往下游。在橋前積聚的屏障板及框架與其他沉積物混雜，並堵塞了部分橋下排水口。與大量的沉積物相比，這些隔音屏障板及框架並不是造成堵塞的主要成因。
- 臨時石料貯存堆 – 在洪水事件發生前，地盤共有 3 個臨時石堆，兩個於沉石池的東牆外，一個則於其西牆之後，均位於河道範圍之外，洪水過後仍保持原狀。

- 臨時河岸穩固物料 －承建商在中支流河岸擺放了一些大石及混凝土預製磚，作臨時河岸穩固之用。洪水過後，大石仍然保持原位，但如圖號 6 所示，有 17 塊混凝土磚被高速的洪水沖至中支流下游，直至洪水速度減緩方沉積於河道。由於整個過程發生於沙埔仔村下游，這些混凝土磚不應使沙埔仔村的洪水情況惡化。
- 河床的平整區域 – 原有河床有一些不平坦部分，承建商將該部分河床表面修平，以便施工機械操作，但仍然維持該段河道的整體斷面面積，確保不會對水流構成負面影響。洪水過後，重整過的河床部分出現沖刷跡象，主要分佈於交錯分流 2 處下游的中支流處。

環境運輸及工務局技術通告編號 ETWB TC No. 2/2006 及渠務署技術通告編號 DSD TC No. 14/2006 列明於工程項目進行期間的排水風險評估要求。而於施工期間之排水風險管理的原則是『不允許增加排水風險至不能接受的程度』。承建商須提交臨時排水管理計劃，獲審批後方可於河道內進行工程。根據所批核的臨時排水管理計劃，承建商只獲准在特定的旱季時段在河道內進行工程。2010 年 4 月雨季前，承建商須撤離河道，包括移走所有工程物料和機械，以及重新整理河床至原來水準。

建築地盤的施工路受地形所限，主導了本工程的施工次序。施工機械只能通過衛奕信徑與大埔河間的臨時施工路，經由上游的建築地盤，進入地盤的上游部分。位元於此處的沉石池是在工程前期修建，以盡早攔截由上游河道滾落的泥石，減少被沖至下游。兩段石籠是修建於 2008 至 09 及 2009 至 2010 年旱季，而修建於 2008 至 09 年旱季的臨時堤壩，則有助於為西支流提供更好的中期防護。至於餘下工程的施工工序則由 CH_C 230 開始，逐步向上游推進，直至 CH_C 0 為止。

建築地盤的另一出入口位於下游近 CH_C 600，即達運道梯階式河道上游 CH_C 620 處。兩段石籠護岸首先建於 2009 至 2010 年旱季，餘下的工程則計劃由 CH_C 230 開始，往下游方向推進，直至 CH_C 600 達運道出口。若要將建築機械搬運至地盤的其他部分，則需經由河床重整區域進出。雖然在一般情況下，水利工程會由下游至上游方向進行，但受到地盤進出口的限制，此情況並不適用於此河道改善工程。從施工階段的排水風險評估來看，本工程採取以上的施工工序是可以接受的。

<u>洪水成因的分析結果</u>

- 2010 年 7 月 22 日傍晚發生的特大暴雨帶來大量降雨，其峰值降雨量達到每小時 103 毫米；
- 西支流的排洪能力不足以應付 2010 年 7 月 22 日的特大暴雨，即使大埔河未進行任任河道改善工程，7 座橋樑橋下排水口沒有出現堵塞，沙埔仔村都會遭受洪水侵襲；
- 在這場特大暴雨中，大埔河上游段的河道 A 和河道 B 的河床受嚴重沖刷，產生了大量的泥沙及大石（約 5,400 立方米），當中部分沉積於大埔河中游段並導致七座橋樑橋下排水口淤塞，加劇水浸程度；
- 被洪水沖走的臨時工程（隔音屏障框架、屏障板塊、灌水鋼油桶和用以鞏固河岸的混凝土預製磚），與大量的泥沙及大石積聚於河床及橋樑橋下排水口，但由於

其數量相對較小，及考慮到淤積的位置，相信它們並不是造成河道堵塞的主要成因；

- 沉石池攔截了從河道 A 及河道 B 沖刷下來的 580 立方米沉積物，而臨時堤壩則將更多水流帶往中支流而有正面的影響；
- 整體而言，跟據數學模型水力分析的結果，在洪水事發前已興建的工程並沒有加劇水浸的程度；
- 沉石池和臨時堤壩帶來正面的效益；於工程初段興建沉石池和臨時堤壩是合理的做法。從有關施工階段所作的洪水風險評估來看，工程所採用的施工工序是可以接受的。

<u>改善措施</u>

爲減小現有橋樑橋下排水口阻塞的風險並減小分流至西支流的流量，渠務署已推行下列的短期改善措施，並將於 2010 年 9 月中完成:

- 加建臨時網狀巨石護欄；
- 加建沉石池欄柵；
- 加高臨時堤壩高度；
- 於 CH_C 230 處修建臨時行人橋；
- 改善中支流現有橋樑橋下的排水能力。

下列長期改善措施可進一步優化現有設計，建議研究其可行性：

- 增修一個沉石池（以增強攔截石塊能力）；
- 於達運道附近推行更有效的控制架流措施（避免架流所產生的破壞）。

Investigation Report on the Flooding in Sha Po Tsai Village, Tai Po on 22 July 2010

Executive Summary

Introduction

A severe rainstorm in the afternoon of 22 Jul 2010 caused a flash flood at Tai Po River (Middle Reaches). There was one fatal incident involving a resident of Sha Po Tsai Village who was washed away by flood water. There was serious flooding and damage to property in Sha Po Tsai Village.

Sha Po Tsai Village is right next to the Works Site of Drainage Services Department (DSD) Contract No. DC/2007/06 - River Improvement Works in Upper Lam Tsuen River, She Shan River and Upper Tai Po River. A plan (**Fig. 1**) is attached to show:

(4) Location of Sha Po Tsai Village, the Works Site and the adjacent areas;

(5) Three Sections of Tai Po River, namely Tai Po River (Upper Reaches) (Stream A, Stream B and streams in further upland), Tai Po River (Middle Reaches) (West Branch, Central Branch and East Branch) and Tai Po River (Lower Reaches) (Sections downstream of the Stepped Channel and Tat Wan Road Bridge and sections flowing through Tai Po New Town); and

(6) The main features of the river such as confluences, split flow and cross flow. Sha Po Tsai Village is located between the Central Branch and the West Branch.

After the flooding, it was observed that:

(1) The flooding situation at Sha Po Tsai Village was very severe with flood water flowing from west to east across the village at depths from 1m to more than 2m;

(2) There was erosion at many locations along Tai Po River (Upper Reaches and Middle Reaches) and there were large quantities of vegetation, sediments and boulders deposited along other locations of Tai Po River (Middle Reaches and Lower Reaches) and some were found blocking the openings under bridges;

(3) Some construction works and material were washed away and / or displaced.

The investigation considers the hydraulic performance of Tai Po River under scenarios reflecting these observed conditions, the sources of erosion and the effects of the construction works on the flooding situations. The investigation then attempts to determine the causes of the flooding.

The Characteristics of Tai Po River Catchment

The overall length of Tai Po River is about 6.7km with a catchment of 7km^2 descending from 752mPD to sea level at Tolo Harbour (**Fig. 2**). The gradients are steep (about 1 on 5) at Tai Po River (Upper Reaches) and gradually decrease to moderate (about 1 on 23) at Tai Po River (Middle Reaches). Based on previous flood records and verbal accounts

of the residents, Tai Po River (Middle Reaches) at the location of the Works Site is prone to flooding.

Proposed Drainage Improvement Works

In view of the flood-prone nature, DSD is implementing drainage improvement works at the Central Branch of Tai Po River (Middle Reaches) under Contract No. DC/2007/06. The Contractor, Chiu Hing Construction & Transportation Co. Ltd., has been carrying out the construction works since Mar 2008 under the supervision of DSD's engineering consultants, AECOM Asia Co. Ltd. The scope of works includes the improvement of the Central Branch to carry the main river flow between gabion wall banks, a Boulder Trap at the upstream end together with bridge crossings. Upon completion, the West Branch will be cut off from the Central Branch at CH_C 180 and will become a tributary collecting local runoff only.

The Flooding Incident

In the preceding 5 days, there was a total rainfall of 70.7mm which would represent a fairly wet antecedent moisture condition. The major rainstorm on 22 Jul 2010 occurred from 4:40pm to 7:20pm, with a peak hourly rainfall of 103mm. The total rainfall in the period was 167mm. This rainstorm was amongst the heaviest in the recent 10 years according to the available rainfall records in Tai Po.

At around 5:30pm on 22 Jul 2010, Sha Po Tsai Village was reported to see flood water flowing over the bank of the West Branch across the village towards the Central Branch. The flood levels rose rapidly to knee height within 15 minutes and reached its peak within about half an hour. The flood depth was around 1m but some houses were flooded to the ceiling (more than 2m high). The flood lasted for about one and a half hours. All flood water receded at around 7:00pm.

There was significant damage to the Sha Po Tsai Village. A resident of House No. 2 was washed away and later found dead. House No. 3 collapsed and House No. 26 was flooded to over 2m. Many households were inundated with damage to household property.

After the incident, sediments and boulders were found deposited at various constricted sections of the river and in particular caused blockages at 7 bridge crossings (i.e. 5 bridge crossings at the Central Branch at CH_C 230, CH_C 325 (Bridge TB-A), CH_C 340 (Bridge TB-B), CH_C 420 (Bridge TB-C) and CH_C 520 (Bridge TB-D), and 2 bridge crossings at the West Branch at CH_W 350 and CH_W 450).

Hydraulic Analyses by Mathematical Modelling

As part of the investigation, a mathematical model has been constructed for Tai Po River Catchment using Danish Hydraulic Institute river modelling suite MIKE 11 (version 2001b) to simulate various flooding scenarios. The model, having been calibrated with the maximum surveyed flood marks and the estimated flow rate at the Stepped Channel at CH_C 620, is considered fit for the purpose of analyzing different site conditions for flood investigation. 5 Scenarios have been modelled:

- Scenario 1 - Baseline Condition (before commencement of works)

- Scenario 2 - Baseline Condition plus Blockages at 7 Bridges
- Scenario 3 - Baseline Condition plus Interim Drainage Works
- Scenario 4 - Baseline Condition plus Blockages at 7 Bridges plus Interim Drainage Works
- Scenario 5 - Condition of Flooding with Blockages at 7 Bridges, Interim Drainage Works and Final Bank and Bed Levels after the flooding event

Upon analyses of the modelling results, it is noted that the flow pattern for all 5 scenarios are similar, especially at Split Flow 2 location (CH_C 180 to CH_C 240) as shown in **Fig. 3**.

For Scenario 1, at Split Flow 2, the flow from upstream splits one-third to the West Branch and two-thirds to the Central Branch. Because of the lower river bed level, flow enters the West Branch first. When flow increases, the water level in the narrower West Branch rises sharply and flow starts to spread to the Central Branch which gradually takes up more flow. This flow at Central Branch then splits into the Central Branch and Cross Flow 2. Because of the lower river bed level of Cross Flow 2 in relation to the flow along the Central Branch at the bridge openings at CH_C 230, more flow from the Central Branch returns to the West Branch. The combined flow at the West Branch becomes fairly large. This flow soon overtops the right bank of the narrow West Branch and pushes a significant amount of flow across Sha Po Tsai Village near House No. 26. This pattern of split, return and overflow is the natural consequence of the topography and river geometry.

According to the predictions of the model, the water levels along the entire West Branch are higher than the right bank at Sha Po Tsai Village. Also the flow is so large that it overtops the 2 bridges at CH_W 350 and CH_W 450. These 2 bridges pose constriction to the flow with significant energy losses represented by conspicuous backing up of the water levels. The water levels at the Central Branch are higher than the left bank at Sha Po Tsai Village but not the right bank. Similarly the flow is so large that it overtops the 5 bridges at CH_C 230, TB-A, TB-B, TB-C and TB-D. Again these 5 bridges pose constriction to the flow and again back up the water levels. It also indicates that there is flow from the West Branch across Sha Po Tsai Village towards the Central Branch.

This Scenario 1 shows that the West Branch does not have sufficient hydraulic capacity to accommodate the rainstorm of 22 Jul 2010, (a) even in its untouched state before the commencement of the construction works; and (b) even in its untouched state without the blockages of the 7 bridges.

In Scenario 2, the blockages of the 7 bridge crossings raise the water levels at their upstream and cause more severe cross flow across Sha Po Tsai Village. It predicts that the flooding situation at Sha Po Tsai Village with the blockages of the bridge openings would generally be worse than the hypothetical flooding situation before the commencement of the construction works.

Scenario 3 represents the combined effects of the interim drainage works completed before the flooding event (including the Boulder Trap, sections of Gabion Walls, footbridge abutments and miscellaneous temporary works such as the Check Dam, noise barriers, bank protection, temporary rock fill stockpiles and river bed re-profiling, all of which will be described in more details in the following sections). Comparing Scenario 3 with Scenario 1, the Check Dam constructed at Cross Flow 2 blocks the cross flow from the Central Branch to the West Branch and diverts more flow to the Central Branch, reducing the cross flow at House No. 26 and the flow at the West Branch in front of House No. 2. While the flow along the Central Branch increases, it does not cause major flood damage. In summary, the hypothetical flooding situation before the commencement of the construction works is predicted to be alleviated by the combined effects of the interim drainage works completed before the flooding event.

Scenario 4 represents both the blockages of the 7 bridge crossings as well as combined the effects of the construction works completed before the flooding event. Scenario 4 versus Scenario 2 bears a similar relationship to Scenario 3 versus Scenario 1; the hypothetical flooding situation with the blockages of the 7 bridge crossings before the commencement of the construction works is predicted to be alleviated by the combined effects of the interim drainage works completed before the flooding event.

Scenario 5 represents the effects of the river bed and bank shapes being modified by the erosion and deposition during the flooding event. Situations for Scenario 5 and Scenario 4 would be the ones closely resembling the actual situations as erosion and deposition during the flooding event progressed. With respect to the flooding impact on Sha Po Tsai Village, Scenario 5 is slightly less adverse than Scenario 4 owing to reduced flow to the West Branch caused by the extensive deposition of sediment and boulders around Spilt Flow 2 and Cross Flow 2.

Key findings of the model analyses are:

(4) The West Branch does not have sufficient hydraulic capacity to accommodate the rainstorm of 22 Jul 2010. In other words, the Sha Po Tsai Village would have been flooded (a) even if there were no drainage improvement works under construction; and (b) even if there were no blockages of the 7 bridges;

(5) The blockages of the 7 bridge crossings by sediments and boulders exacerbated the flooding situation; and

(6) The overall effects of the interim drainage works completed before the flooding event did not aggravate the flooding situation.

<u>Assessment of the Sources of Sediments</u>

There were clear signs of erosion along Stream A and Stream B of Tai Po River (Upper Reaches) as shown by a comparison of the aerial photos of Nov 2009 and Aug 2010 (**Fig. 4**). The erosion and movement of sizeable boulders and cobbles were caused by the high flow velocities and the steep gradients of these two streams. Within the Tai Po River (Middle Reaches), erosion of sections of river bed and banks was found, whereas there was also deposition of sediments and boulders along other sections of the Tai Po River (Middle Reaches), mainly immediately upstream of the bridges crossing the West Branch and the Central Branch. Based on quantitative analyses of the volume of sediments and boulders transported by erosion and deposition, it is estimated that the erosion of the river bed and banks in Stream A and Stream B during this rainstorm event yielded a significant amount of sediments and boulders (about 5,400m^3), part of which was deposited within the Tai Po River (Middle Reaches), and the remainder washed further downstream to Tai Po River (Lower Reaches) and to Tolo Harbour. Within the Tai Po River (Middle Reaches), an erosion of about 1,800 m^3 was identified, and a deposition of about 4,000 m^3 was found, suggesting that a net deposition of about 2,200m^3 was originated from the Tai Po River (Upper Reaches).

Effects of the Interim Drainage Works on Flooding

While the overall effect of the interim drainage works was assessed in the hydraulic analyses by mathematical modelling to be not adverse, each item of the interim drainage including temporary construction works is studied in more detail. The interim drainage works completed before the flooding event included the Boulder Trap, sections of Gabion Wall and footbridge abutments. The temporary construction works completed before the flooding event included the Check Dam, noise barriers, bank protection, temporary rock fill stockpiles, and river bed re-profiling. Details are shown in **Fig. 5**. All permanent works remained intact after the flooding event. However, some temporary works had been washed away or displaced. Details are shown in **Fig. 6**.

- Boulder Trap – had arrested 580m^3 of sediments and boulders washed down from Stream A and Stream B. Its presence had also avoided the erosion of the original 60m long natural river bed and banks had it not been constructed. Erosion in the form of a scoured pit was found immediately downstream of the Boulder Trap. Taking into account the erosion at this scoured pit, there was a net benefit of trapping 390m^3 of sediments and boulders.
- Sections of Gabion Wall – were constructed in a direction parallel to the river and outside the original river. These should not have major adverse effects on the river flow.
- Footbridge abutments – were constructed at the bank of the original river and should not have major adverse effects on the river flow.
- Check Dam – remained intact and had served a beneficial function in diverting more flow to the Central Branch as predicted by the mathematical modelling.
- Noise Barriers – were comprised of steel frames, panels of corrugated sheet and large boulders or water-filled steel barrels as hold-down weights. 127 frames, 260 panels and 283 steel barrels were displaced due to the flooding. Amongst these, and upstream of Split Flow 2, 2 frames and 2 panels ended up at Bridge at CH_W 350 and 2 panels were trapped at CH_C 210. Also, downstream of Split Flow 2, 5 frames and 15 panels were found at Bridge TB-C; and 1 frame and 1 panel were found at Bridge TB-D. Others were missing and were likely to have been washed away. The trapped frames and panels were found buried with sediments and boulders which blocked some of the bridge openings. In view of the much larger volume of sediments and boulders at the blocked locations, the cause of blockage attributed to the noise barrier frames and panels would not be the dominant one.
- Temporary Stockpiles – there were 3 heaps of temporary stockpiles of rock fill material before the flooding event. 2 heaps were placed outside the east wall and 1heap behind the west wall of the Boulder Trap, all outside the extent of the river. They remained intact after the flooding event.

- Temporary Bank Protection – boulders and precast concrete blocks were placed along the bank of the Central Branch as temporary bank protection. The boulders remained in place but 17 precast concrete blocks were displaced and were found deposited at the downstream reaches of the Central Branch as shown in **Fig. 6**. These blocks were moved by the high velocity flow and deposited when the flow subsided. As the process took place on the downstream of the Sha Po Tsai Village, the blocks should not have aggravated the flooding situation there.
- River Bed Re-profiled zones – some parts of the original uneven river bed were re-profiled by the Contractor to facilitate the operation of construction plant. The overall cross sectional area of the river was maintained so that the river flow would not be adversely impacted. Erosion of some sections of the re-profiled zones was found, mainly at the Central Branch downstream of Cross Flow 2.

The requirements for construction stage flood risks assessment were stipulated in ETWB Technical Circular No. 2/2006 and DSD Technical Circular No. 14/2000. The principle of managing the flood risk during construction stage was based on the principle of “no unacceptable increase in flood risk”. The Contractor was required to submit Temporary Drainage Management Plan (TDMP) for any construction works within the river. In accordance with the approved TDMP, the Contractor was only permitted to carry out works within the river during the dry season periods specified. When the wet season began in Apr 2010, the Contractor was required to vacate and had vacated the river, including the removal of all construction plant and material and restoring the re-profiled river bed to below the original bed level.

Limited access to the site dictated the construction sequence. At the upstream end of the Works Site, construction plant could only access Tai Po River (Middle Reaches) from Wilson Trail through a temporary access road. The construction of the Boulder Trap was completed early on in order to provide protection against sediments and boulders from Tai Po River (Upper Reaches). Two sections of Gabion Walls were constructed in the dry seasons of 2008/09 and 2009/10. The Check Dam was constructed in the dry season of 2008/09 to provide better interim protection to the West Branch. The proposed construction sequence of the remaining works was to start working at CH_C 230 and gradually moving upstream and eventually to exit via CH_C 0.

Another access point was at the downstream end of the Works Site near CH_C 600 just upstream of the Stepped Channel at CH_C 620 near Tat Wan Road Bridge. Two sections of Gabion Walls were constructed in the dry season of 2009/10. The proposed construction sequence of the remaining works was to start working at CH_C 230 and gradually moving downstream and eventually to exit via CH_C 600. Plant operation in other parts of the Works Site could only be made by temporarily re-profiling the river bed. While working from downstream end towards the upstream end would be a usual construction sequence, it could not be applied in this Contract due to site access constraints. Instead, the feasibility of the adopted / proposed construction sequence had been demonstrated by appropriate flood risk assessment.

Findings of the Analyses in Determining the Causes of Flooding

- The rainstorm in the evening of 22 Jul 2010 was an intense one with a peak hourly rainfall of 103mm;
- The West Branch does not have sufficient hydraulic capacity to accommodate the rainstorm of 22 Jul 2010. In other words, the Sha Po Tsai Village would have been flooded (a) even if there were no drainage improvement works under construction; and (b) even if there were no blockages of the 7 bridges;
- The erosion of the river bed and banks in Stream A and Stream B of Tai Po River (Upper Reaches) during this rainstorm event yielded a significant amount of sediments and boulders (about 5,400m^3), part of which was deposited within the Tai Po River (Middle Reaches) and contributed to the blockages of 7 bridge crossings. These blockages exacerbated the flooding situation;
- Those temporary works items (noise barrier frames, panels, water-filled steel barrels and precast concrete blocks for bank protection) displaced and deposited among sediment and boulders on the river bed and at bridge crossings should not be the dominant cause of blockage in view of the small quantity and the location where they were deposited;
- The Boulder Trap had arrested 580m^3 of sediments and boulders washed down from the Stream A and Stream B. The Check Dam had served a beneficial function in diverting more flow to the Central Branch;
- Collectively the overall effects of the interim drainage works completed before the flooding event, as illustrated by mathematical modelling, did not aggravate the flooding situation;
- The early construction of the Boulder Trap and Check Dam was reasonable in consideration of their beneficial functions. The feasibility of the adopted / proposed construction sequence had been demonstrated by appropriate flood risk assessment.

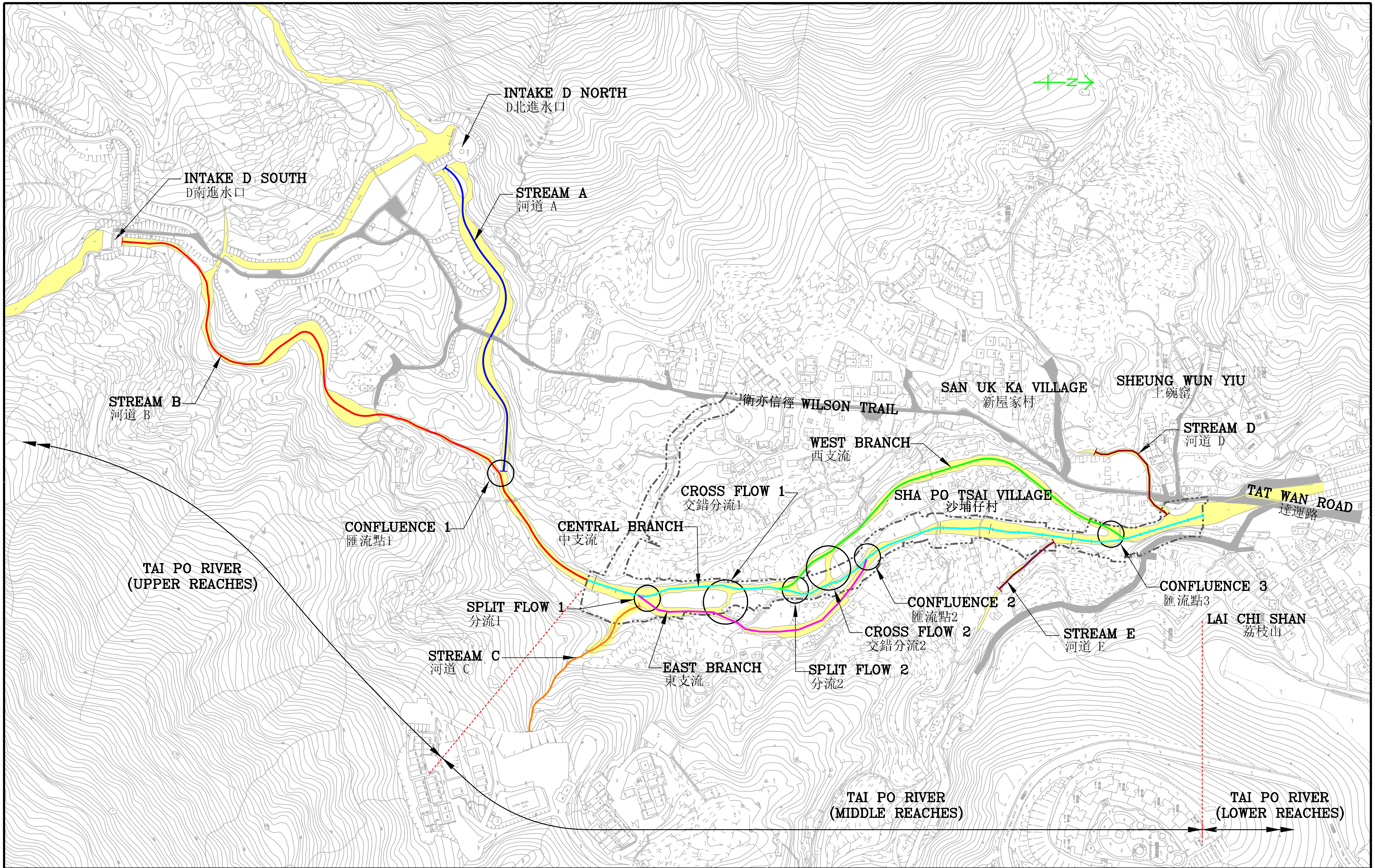
Improvement Measures

In order to enhance the protection against blockages of existing bridge openings and to divert flow away from the West Branch, the following short term improvement measures are being carried out and would be completed in mid Sep 2010:

- Temporary Wire Boulder Fence
- Grille at Boulder Trap
- Raising of Check Dam
- Interim Bridge at CH230
- Improvement at Existing Bridge Crossings at the Central Branch

The following long term improvement measures which will further enhance the current design have been identified and their feasibility will be explored:

- Additional Boulder Trap (to increase the trapping capacity)
- Measures to Better Control the Turbulent Flow Near Tat Wan Road (to prevent the damaging effect of the turbulence)



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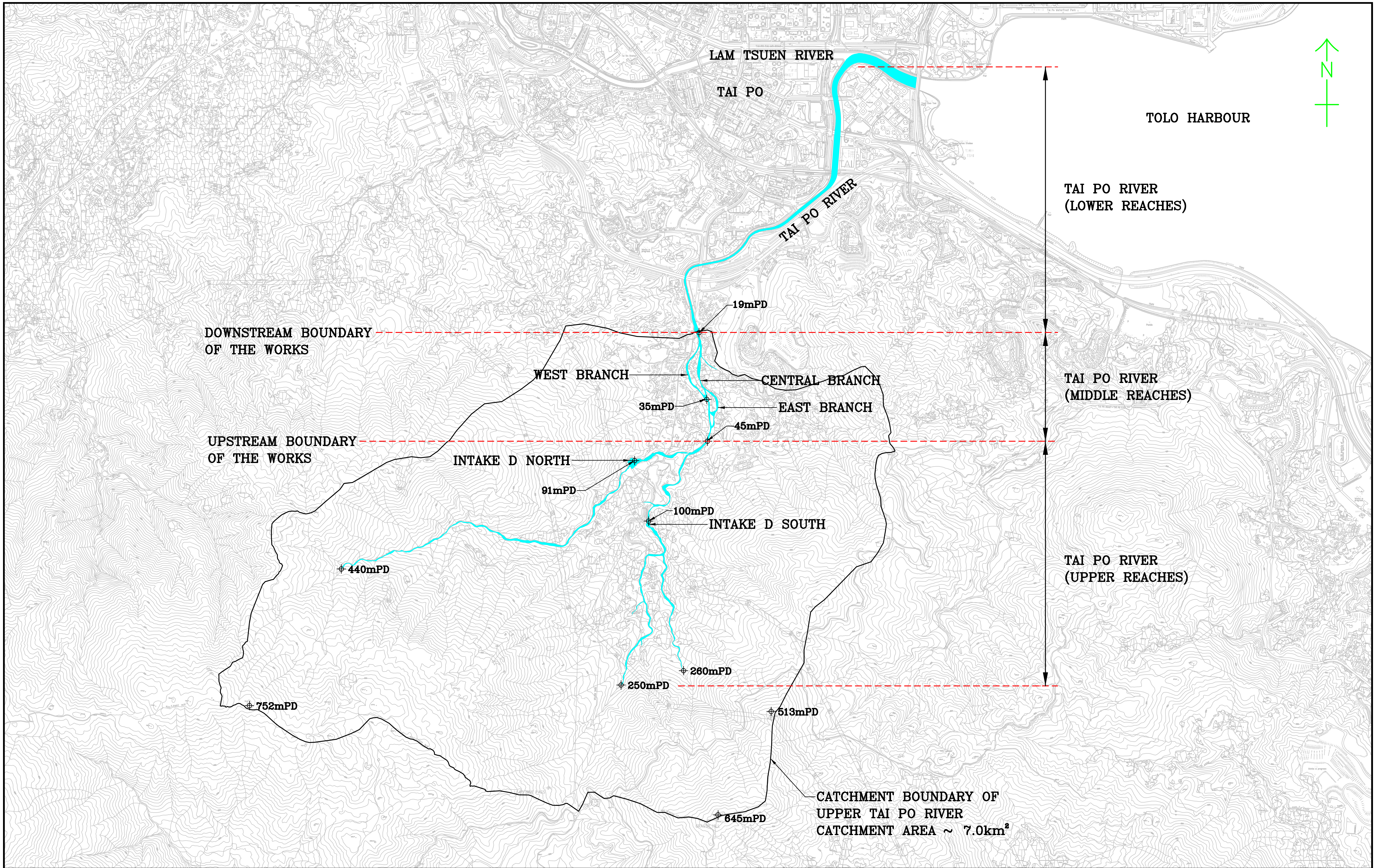
INVESTIGATION REPORT ON THE FLOODING IN
SHA PO TSAI VILLAGE, TAI PO ON 22 JULY 2010

KEY PLAN AND DEFINITION
大綱圖及定義

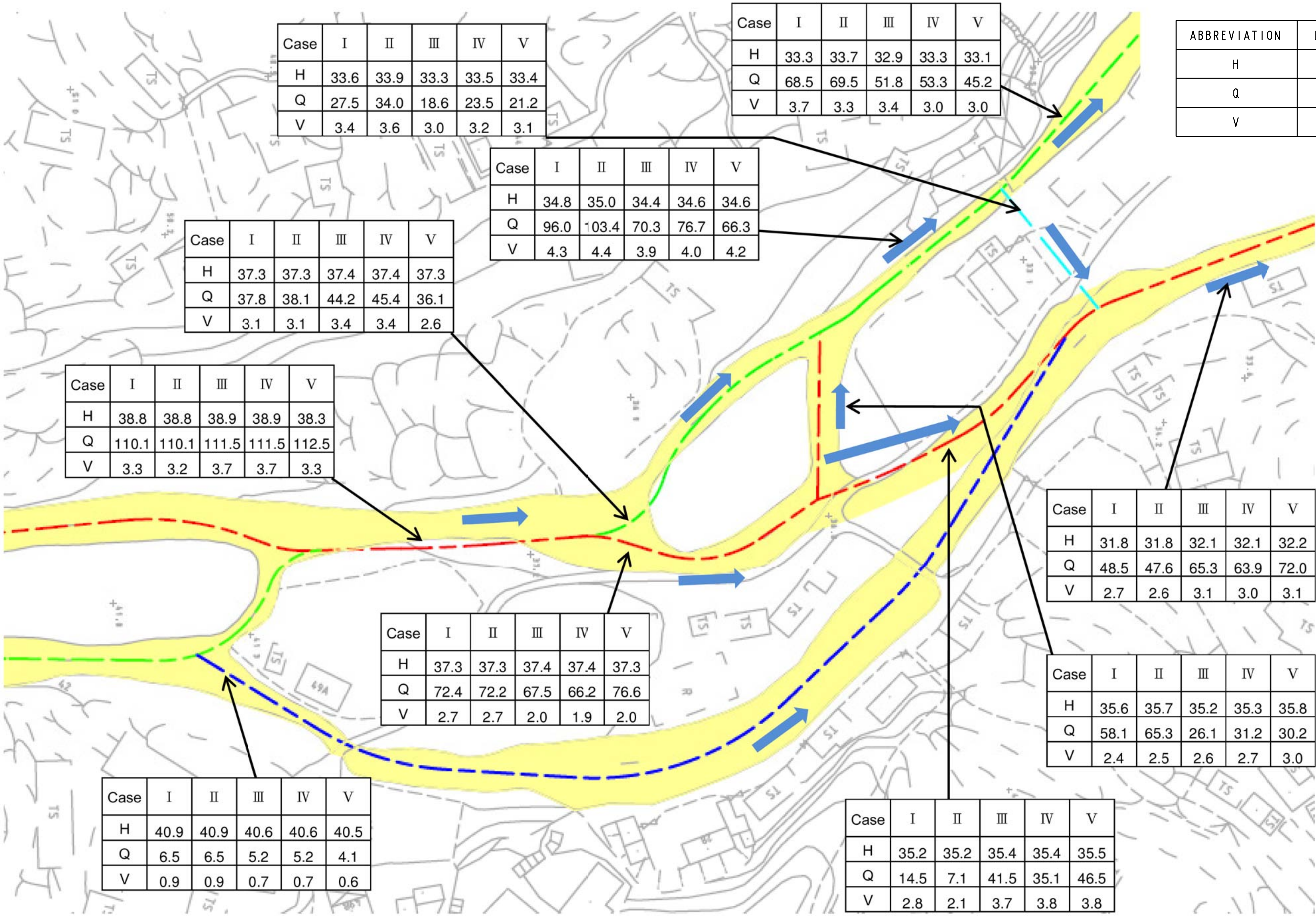
SCALE	1 : 3500 (A3)	DATE	24/08/2010
CHECK	JCHY	APPROVED BY	RCYK
DRAWING No.	FIG 1	REV	A

A1-01A_FIG-01_FF.dgn 2010-08-29 18:16:25



AECOM	INVESTIGATION REPORT ON THE FLOODING IN SHA PO TSAI VILLAGE, TAI PO ON 22 JULY 2010 CATCHMENT AND TOPOGRAPHICAL PLAN OF TAI PO RIVER (MIDDLE REACHES) 大埔河中游段集水區及地形圖	SCALE 1 : 20000 (A3)	DATE 10/08/2010	
		CHECK JCHY	APPROVED BY RCYK	
		DRAWING No. FIG 2		REV A

ES-02A_FIG-02.dgn 2010-08-29 19:06:06



ABBREVIATION	DESCRIPTION	UNIT
H	WATER LEVEL	(mPD)
Q	FLOW	(m/s^3)
V	VELOCITY	(m/s)

Case	I	II	III	IV	V
H	33.6	33.9	33.3	33.5	33.4
Q	27.5	34.0	18.6	23.5	21.2
V	3.4	3.6	3.0	3.2	3.1

Case	I	II	III	IV	V
H	33.3	33.7	32.9	33.3	33.1
Q	68.5	69.5	51.8	53.3	45.2
V	3.7	3.3	3.4	3.0	3.0

Case	I	II	III	IV	V
H	34.8	35.0	34.4	34.6	34.6
Q	96.0	103.4	70.3	76.7	66.3
V	4.3	4.4	3.9	4.0	4.2

Case	I	II	III	IV	V
H	37.3	37.3	37.4	37.4	37.3
Q	37.8	38.1	44.2	45.4	36.1
V	3.1	3.1	3.4	3.4	2.6

Case	I	II	III	IV	V
H	38.8	38.8	38.9	38.9	38.3
Q	110.1	110.1	111.5	111.5	112.5
V	3.3	3.2	3.7	3.7	3.3

Case	I	II	III	IV	V
H	31.8	31.8	32.1	32.1	32.2
Q	48.5	47.6	65.3	63.9	72.0
V	2.7	2.6	3.1	3.0	3.1

Case	I	II	III	IV	V
H	37.3	37.3	37.4	37.4	37.3
Q	72.4	72.2	67.5	66.2	76.6
V	2.7	2.7	2.0	1.9	2.0

Case	I	II	III	IV	V
H	35.6	35.7	35.2	35.3	35.8
Q	58.1	65.3	26.1	31.2	30.2
V	2.4	2.5	2.6	2.7	3.0

Case	I	II	III	IV	V
H	40.9	40.9	40.6	40.6	40.5
Q	6.5	6.5	5.2	5.2	4.1
V	0.9	0.9	0.7	0.7	0.6

Case	I	II	III	IV	V
H	35.2	35.2	35.4	35.4	35.5
Q	14.5	7.1	41.5	35.1	46.5
V	2.8	2.1	3.7	3.8	3.8

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INVESTIGATION REPORT ON THE FLOODING IN
SHA PO TSAI VILLAGE, TAI PO ON 22 JULY 2010

FLOW PATTERN AT SPLIT FLOW 2 UNDER SCENARIOS 1-5
模擬工況 1至5之下分流2處的水流狀態

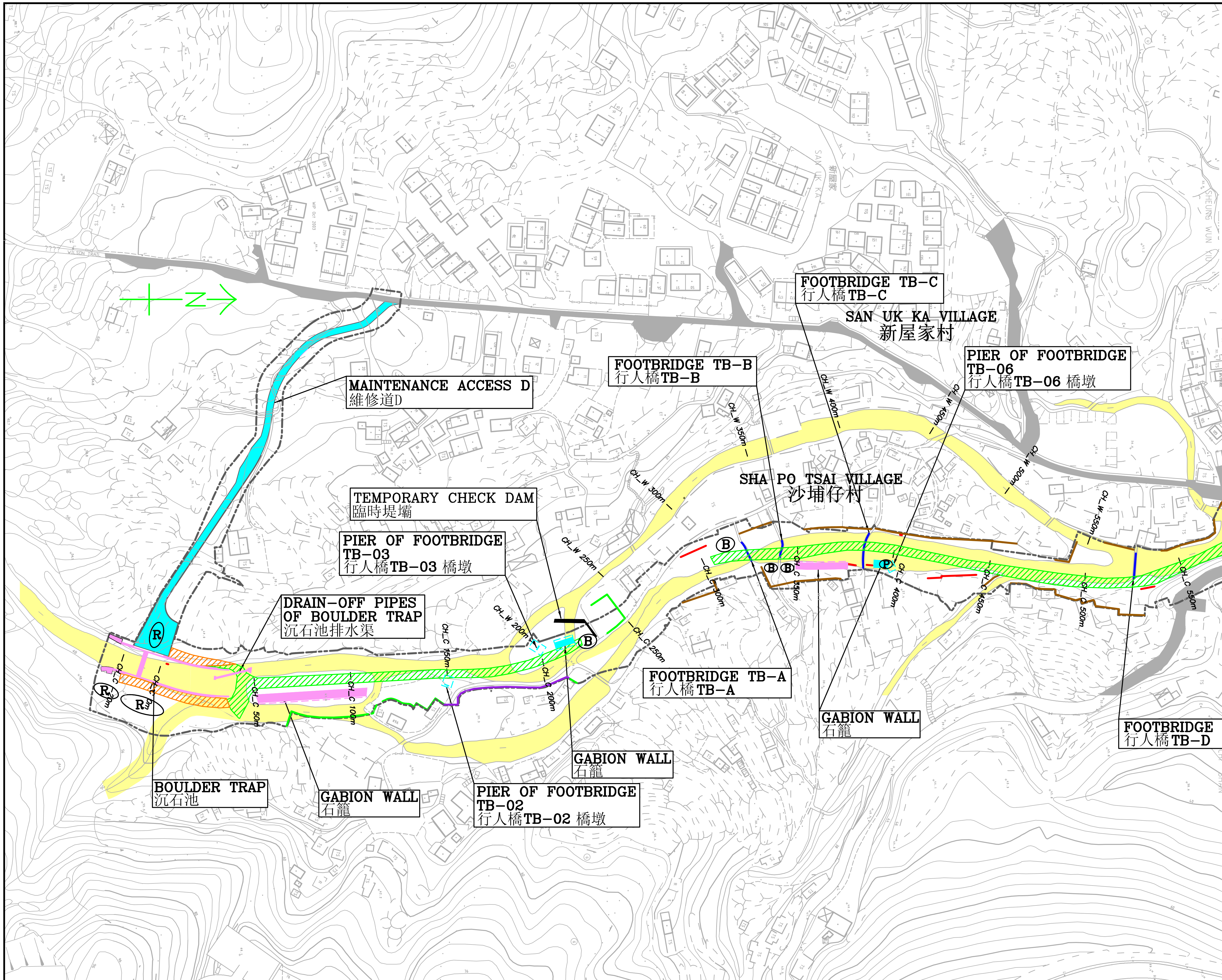
SCALE	N.T.S.	DATE	21-08-2010
CHECK	JCHY	APPROVED BY	RCYK
DRAWING No.	FIG 3	REV	

AERIAL PHOTO OF STREAM A AND STREAM B TAKEN IN NOVEMBER 2009
拍攝於二零零九年十一月之河道A與河道B的航空照片

AERIAL PHOTO OF STREAM A AND STREAM B TAKEN ON 1 AUGUST 2010
拍攝於二零一零年八月一日之河道A與河道B的航空照片

AECOM	INVESTIGATION REPORT ON THE FLOODING IN SHA PO TSAI VILLAGE, TAI PO ON 22 JULY 2010 COMPARISON OF RIVER CONDITION AT STREAM A AND STREAM B BEFORE AND AFTER THE RAINSTORM ON 22 JULY 2010 河道A與河道B於二零一零年七月二十二日暴雨前及暴雨後的狀況比較圖	SCALE	N.T.S (A3)	DATE	27/08/2010
		CHECK	JCHY	APPROVED BY	RCYK
		DRAWING No.	FIG 4	REV	

ES-04_FIG-04.dgn 2010-08-29 13:10:23



LEGEND :

- CARRIAGEWAY 行車路
- RIVER/STREAM 河流/河道
- WORKS COMPLETED 已完成工程
- WORKS PARTIALLY COMPLETED 部分完成工程
- CH_C 00 CHAINAGE MARK 鏈距
- SITE BOUNDARY 工地界線
- TEMPORARY NOISE BARRIER (WITH FRAME ONLY) 臨時隔音屏支架
- TEMPORARY NOISE BARRIER (WITH FRAME AND LOWER PORTION OF PANEL) 臨時隔音屏(下半部)及支架
- TEMPORARY NOISE BARRIER (WITH FRAME AND FULL PANEL) 臨時隔音屏及支架
- TEMPORARY CONCRETE BLOCK 臨時混凝土磚
- RAILING 欄杆
- B TEMPORARY BANK PROTECTION BY BOULDERS 臨時石建河岸保護
- R TEMPORARY STOCKPILED ROCK FILL MATERIALS 臨時存放石料
- P TEMPORARY STOCKPILED PRECAST CONCRETE PLANTER 臨時存放混凝土花槽
- RE-PROFILED ZONE FOR THE OPERATION OF CONSTRUCTION PLANT 建築機械運作的平整區域
- HAUL ROAD 施工臨時路

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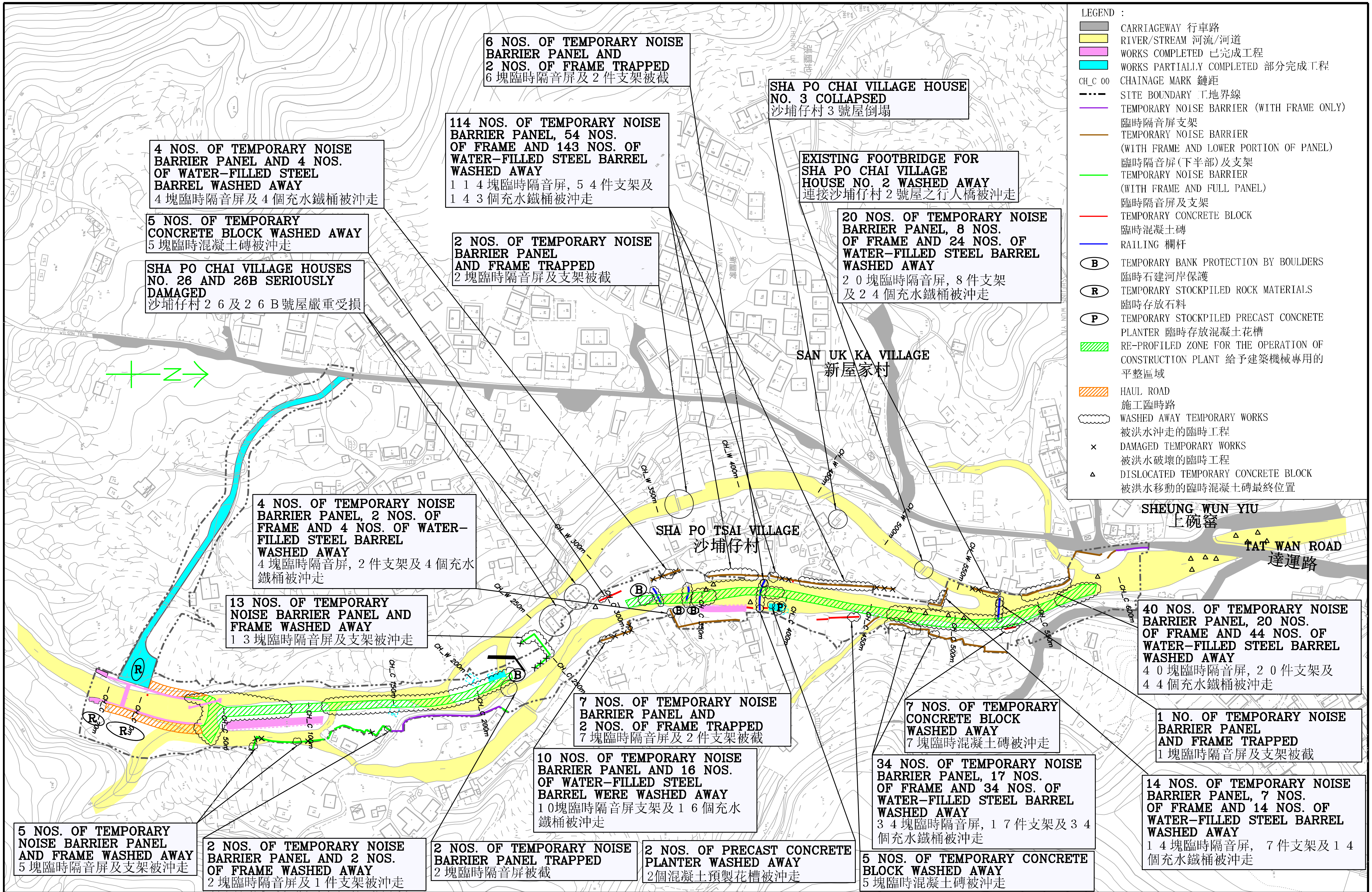
INVESTIGATION REPORT ON THE FLOODING IN
SHA PO TSAI VILLAGE, TAI PO ON 22 JULY 2010

STATUS OF SITE IN TAI PO RIVER (MIDDLE REACHES) ON 22 JULY 2010 BEFORE RAINSTORM
二零一零年七月二十二日下雨前大埔河中游段工地狀況

SCALE	1 : 1000 (A1) 1 : 2000 (A3)	DATE	14/08/2010
CHECK	JCHY	APPROVED BY	RCYK
DRAWING No.	FIG 5	REV	-

FIGURE 5.dgn 2010-08-29 17:39:33



AECOM

INVESTIGATION REPORT ON THE FLOODING IN SHA PO TSAI VILLAGE, TAI PO ON 22 JULY 2010

STATUS OF SITE IN TAI PO RIVER (MIDDLE REACHES) ON 23 JULY 2010 (AFTER FLOODING)
二零一零年七月二十三日(水浸後)大埔河中游段工地狀況

SCALE	1 : 1000 (A1) 1 : 2000 (A3)	DATE	10/08/2010
CHECK	JCHY	APPROVED BY	RCYK
DRAWING No.	FIG 6	REV	A

A8.3-02A_FIG-06_FF.dgn 2010-08-29 18:03:23