摘　要

壹、前言

阿公店水庫為一防洪為主要目標之水庫，大壩包含主壩及左、右副壩，其中主壩為中央混凝土心牆滾壓式土壩，副壩為黏土及抱土心牆滾壓式土壩，主要工程設施可分為：大壩、溢洪管、取出水工及越域排洪道等。為解決日趨嚴重之淤積、供水及滯洪空間不足等問題，維持防洪、灌溉、公共給水等多目標功能，特於民國 86 年起進行更新改善計畫，至民國 95 年完工，為臺灣舊水庫再造之最佳案例。

本計畫主要目的在於監測分析及檢查阿公店水庫營運期間之壩體安全性，以提供水庫下游民眾生命財產之安全保證。計畫執行期間配合其相關設施進行安全監測分析及檢查，內容包括監測儀器測讀、資料整理分析與評估、大壩安全檢查等業務，後續依據檢查結果與監測成果評估大壩行為及安全性、檢測及檢討監測儀器設備之堪用性，內容詳下表。

表 摘-1 阿公店水庫大壩安全檢查及監測分析工作項目一覽表

項次	工作項目	項次	工作項目
一	大壩安全監測 1 監測儀器測讀 2.監測儀器資料整理及分析 3.協助彙整上年度與歷年水庫安全小組之意見，列出本年度應持續觀測與回應重點。	三	大壩行為及安定性評估 1.監測資料變化行為研判 2.大壩潛在破壞行為評估 3.異常事件探討及分析 4.辦理必要之數值模型分析以輔助評估 5.壩體安定性及目視檢查綜合研判
二	大壩安全檢查 1.定期月巡檢(巡檢範圍包括：大壩、灌溉管、溢洪管及越域排洪道等結構物) 2.特別(不定期)檢查 3.檢查資料整理評估 4.協助本水庫閘門及吊門機等水工機械汛期前後安全複核	四	安全監測儀器之作業檢討及監測儀器系統維護 1. 於年度全面檢討安全監測儀器是否需要補裝、停用、或另行新裝 2.於年度檢討監測儀器觀測頻率 3.為維監測儀器正常運作及監測數據不中斷，應備大壩壓力式水位傳訊器及自記式水位觀測井水位計至少各 1 組(可採備品)，以作為南水局日後儀器損壞採購期間時可供使用。 4. 於年度內完成十二次各站儀器設備(包含 5 套資料記錄功能之資料蒐集器、壩體水位水壓偵測、8 台自記式地下水位計、自記式滲流量水位計、取水塔水位計)之硬、軟體檢修、校正、維護、測試及技術服務

本計畫執行期間(107 年 1 月 1 日~107 年 12 月 31 日)阿公店水庫水位介於 EL.29.62m~EL.36.60m 間，年累積降雨量約 2252.6mm，單日最大降雨量為 8 月 23 日之 318.30mm，地震儀共蒐錄到 6 次地震，最大 PGA 值 ED02 蒐錄之最大 PGA 值為 10.931gal(南北向-X 軸方向) ，本年度較去年最高水位上升 0.1m，累積雨量增加 1318.1mm，單日最大降雨量增加 192.6mm。

本計畫執行期間共辦理一次特別檢查，說明如下：

(1)24 小時累積降雨量於 8 月 23 日 12:00~8 月 24 日 11:00 期間達 359.4mm(特別檢查標準：24 小時累積雨量超過 350 公厘)。

(2)豎井溢洪管最大放流量於 8 月 24 日 01:00~02:00 達 72.07cms(特別檢查標準：溢洪管排洪量超過每秒 72 立方公尺)。

考慮庫區天候狀況，經與南水局研議，一併於 8 月 27 日針對上述兩起事件辦理 0823 大豪雨後特別檢查。

貳、大壩安全檢查成果

一、壩體結構、上游坡面、下游坡面、附屬結構、水庫周邊區域及水庫周邊邊坡，整體狀況尚屬良好。

二、0823 大豪雨後特別檢查發現 0k+900m 下游壩面有一處淺層滑動，長 13.8 公尺，寬 8.1 公尺，深 0.7 公尺，滑動範圍位於滿水位線以上，管理中心於 107 年 8 月 27 日辦理修復，經檢查發現已無持續滑動跡象，建議持續觀察。

三、大壩下游滲水點對照歷次檢查結果發現部分滲水點因地貌改變，已無滲漏情形，各滲水點並無加劇與惡化之跡象，量水堰之滲流量也無異常變化，尚不致立即影響大壩安全。

四、大壩下游生態池並無氣泡或其他可能滲水之異狀，另汛期前進行

一次水下載具檢查，惟因生態池水質濁度過高導致成效不佳，建議持續觀察。

五、溢洪管(導流墩、下游出口閘門門框、開渠側牆及底版)及取出水工(取水塔、分水工結構與聯絡橋梁)結構大致良好，無重大缺損。

六、越域排洪道溢流堰施工縫有滲水及植物生長，排洪隧道存有混凝土表面剝落及磨損、裂縫、滲水、白華等異狀，多屬小範圍且局部之現象，南水局已於本年度發包辦理阿公店越域排洪道補強工程，並已於 107 年底完工。

七、越域排洪道淨水池側排水系統之填土區與混凝土階梯介面為相對弱面，降雨後無法有效排水，導致下方土層淘空，南水局於今年度汛期前採土石袋修繕，惟民國 107 年 9 月定期檢發現有再度淘刷現象，考量此區域並無重要保全對象，且階梯下方之越域排洪道均可發揮預期功能，因此目前採用的修繕方式屬經濟可行方案。

參、越域引水路汛期前檢查成果

一、襯砌剝落、鋼筋外露、裂縫、滲水及白華等異狀多為既有情形，與「106 年度阿公店水庫 0211 地震後越域引水路隧道特別檢查」成果無明顯差異。

二、里程 7k+475m 處發現之仰拱隆起現象應係受剪裂帶之地質因素影響，建議後續可參考「阿公店水庫越域引水路 9k+830~9k+870 修護工程」採用之底板突起刨除加固工法進行修復。

肆、大壩安全監測成果

一、壩體及壩基水壓計及水位計總水頭變化之規律與趨勢整體而言呈穩定狀態，各斷面監測儀器讀值皆小於警戒值，研判大壩滲流行為尚屬合理。

二、量水堰 WQR-03 監測資料經剔除雨量，並將水庫水位與滲流量關係進行迴歸分析後，其結果顯示庫水位與滲流量呈正相關，藉由

現場調查、監測資料分析與前期辦理水質同位素之成果可知，WQR-03 量測水量主要來源應為壩基礎深處疏鬆砂層滲出之地下水和大壩滲流水。

三、上游側、下游側之歷年累積總沉陷量最大值分別為 2.1cm 及 3.7cm，上游側之最大沉陷量為大壩填土高(10m)之 0.2%，下游側之最大沉陷量為大壩填土高(10.5m)之 0.35%，並未超過國內外文獻建議之沉陷容許值(壩高 1%)。

四、傾斜觀測管 K4 基座旁邊坡處於 8 月 23 日大豪雨後再度出現掏空情形，9 月份傾斜觀測管 K4 總偏移量為 21.79mm，破壞位置距壩軸 125m，已非屬壩體結構，研判暫不致影響大壩安全，惟仍建議辦理修繕；107 年 8 月份 SDE-02 總偏移量為 12.13mm，搭配現場檢查及數值地形成果發現坡面並無明顯滑動之異狀，研判應為儀器之誤差，而非壩體本身之變位。

五、地震儀記錄比對氣象局之地震測報，大都可正常量測大壩與壩基振動反應。

伍、大壩行為及安定性評估

一、大壩里程 0k+280m、0k+425m、0k+550m、0k+700m、0k+738m 及 0k+900m 各斷面下游坡面安定分析成果顯示傾斜觀測管結果皆屬表層變位，無大規模滑動之疑慮，且在滿水位穩態滲流情況下，大壩下游側之安全係數皆大於規範要求，故阿公店水庫壩面尚屬安定。

二、隨著庫水蓄升、下降，壩基砂層總水頭高程線往砂層出露於地面處坡降，其成果與「106 年度阿公店水庫大壩安全檢查及監測分析，106.12」總水頭分布大致相同，顯示本期間大壩滲流大致維持穩定，並無明顯異常情形。

三、下游滲漏區常態水力坡降最大約 0.0812，管湧潛勢甚低，且自大壩上游面至滲漏點位置距離極長，故應無管湧疑慮。

陸、監測儀器設備檢測及檢討

一、自記水位計及水位觀測井於壩體與水庫下游共設置 19 處，107 年度監測期間曾陸續發現有感測器故障，經改善排除異狀後，目前仍有 C5 及 WLE-10 故障，預計於 108 年 1 月進行改善。

二、水壓計共設置 30 處，107 年度檢測發現 19 組水壓計感測器已失去功能、2 組水壓計測讀值異常，鑑於水壓計抽出更新、確認或鑽孔新設之風險過高，可能擾動壩體填方及造成水力破壞，建議保持現狀，採鄰近水壓計及水位計推估。各水壓計鄰近可供參考儀器詳表 摘-2。

三、監測儀器觀測頻率已符合「蓄水庫構造物管理基準，80.06」之規定及 USBR1987 訂定最小觀測頻率(營運期水庫一般監測頻率約每週一次至每三個月一次不等)，建議維持現狀。

四、大壩下游滲水區共有 6 孔水位井，現採黎明公司自行裝設之水位計進行觀測，惟此滲水區之水位計尚無自動記讀並回傳至管理中心二樓監控室之功能，無法及時監測並反應水庫水位與滲流區地下水位之關聯，為使阿公店水庫監測系統更趨完備，利於南水局日後之監測與維護，本計畫針對滲水區監測儀器智慧管理提出檢討及規劃方案(詳 5-4 節)，做為後續南水局建置之參考。

表 摘-2 水壓計監測異常處理方式

斷面	(1)監測儀器	(2)鄰近可供參考儀器	處理方式
右副壩 0k+280	WPE-01(失去功能)	WPE-02、SDE-01	1.此斷面若(1)之水壓計測讀值發生異常，可由(2)水壓計或水位計驗證其正確性 2.若僅有單一測站之水壓計或水位計讀值發生異常，則可能為人為誤差、儀器誤差或系統故障 3.若左列(1)、(2)之水壓計皆發生異常則需立即進行相關之安全檢查工作。
	WPE-02	SDE-01	
	WPE-03(失去功能)	WLE-01	
	WPE-04(失去功能)	WPE-06、WLE-01	
	WPE-05(失去功能)	SDE-02	
	WPE-06	WLW-01、WPE-07	
	WPE-07	WLW-01、WPE-06	
主壩 0k+425	WPE-08(失去功能)	SDE-03	
	WPE-09(失去功能)	SDE-03	
	WPE-10(失去功能)	WPE-11	
	WPE-11	SDE-04	
	WPE-12(失去功能)	WPE-13、WLE-02	
	WPE-13(異常)	WLW-02、WLE-02	
	WPE-14(失去功能)	WPE-13、WLE-02	
左副壩 0k+700	WPE-15	SDE-05	
	WPE-16(失去功能)	WPE-15	
	WPE-17	WPE-19	
	WPE-18(失去功能)	SDE-06	
	WPE-19	WPE-17	
	WPE-20(失去功能)	WLW-03、K3	
	WPE-21(失去功能)	WPE-17、WPE-19	
左副壩 1k+100	WPE-22(失去功能)		
	WPE-23(失去功能)		
	WPE-24(異常)	WPE-25	
	WPE-25	WPE-24、WLW-04	
	WPE-26(失去功能)	WPE-24、WLW-04	
左副壩 1k+500	WPE-27(失去功能)	WLE-28	
	WPE-28		
	WPE-29	WLE-09	
	WPE-30(失去功能)	WLE-09	

註 1：WPE 為水壓計。

註 2：WLE 及 WLW 為水位計。

註 3：SDE 為傾斜觀測管

Abstract

I. Preface

The Agongdian Reservoir is a reservoir which is built for preventing flood. The major elements of this reservoir include the main dam, the left and the right auxiliary dam. The main dam is a roller –compacted with core walls consisted of concrete material. The core walls of auxiliary dams consisted of clay and red clay. Main civil structures at Agongdian include the main dam, spillway, intake works, and the interbasin transfer spillway. To solve the issues of sediment accumulation, irrigation, domestic water supply, and inadequate freeboard. In the meantime, to reach the target functions of Flood control, irrigation and public water supply. The updated improvement project started from 1997 and finished in 2006, which is the best case of old reservoirs re-building in Taiwan.

The purpose of this project is to interpret existing monitoring data and evaluate the overall safety of Agongdian Dam during its operation. To ensure the residents living downstream of the dam are safe and secure. During the project progress, doing safety inspection and monitoring analysis with the related equipment. It also includes collecting data from monitoring devices, analysis, evaluation, and dam safety inspection, etc. Afterward, based on the results of inspection and monitoring to evaluate the dam behaviors and safety. And check the usability of the monitoring devices.

Details are as below:

Table 1-1 The list of work items for Agongdian Reservoir dam safety inspection, monitoring and analysis

Item	Work projects	Item	Work projects
I	Dam safety monitoring 1.Monitoring instrument reading 2.Data organizing and analysis 3.Collect past recommendations from dam safety teams as well updating responses and observation this year。	III	Dam behavior and safety evaluation 1.Monitoring data behavior variation determination 2.Protential dam damage behavior evaluation 3.Abnormal event discussion and analysis 4.Conduct necessary numerical model analysis to assist evaluation 5.Comprehensive judgment of dam body safety and visual inspection
II	Dam safety inspection 1.Regular monthly inspection(The scope of inspection include structures of dam, irrigation pipe, spillway pipe and trans basin spillway/Reservoir Trans basin) 2.Spectial inspection(unscheduled) 3.Inspection data compilation and evaluation 4.Conduct safety evaluation of hydraulic gates and hoist and after flood periods	IV	Review of the operation and maintenance of safety monitoring devices 1.Comprehensive review of the monitoring devices which need to be repaired, discontinued or replaced 2.Annual revision of data collection frequency of monitoring devices 3.To make sure the monitoring devices and the data continuously. Should prepare at least one of the piezometer and water level gauges.以 when the monitoring devices was loss capacity, it will be the spares. 4.Finish 12 times monitoring devices detect, correction, test and maintain in this year. The system include 5 sets of data recording devices, piezometers, and self-recording groundwater gauges, seepage weirs, and water level gauges at the intake tower.

During the project progress(January 1,2018 to December 31,2018), the dam water level was between EL. 29.62m ~EL. 36.60m. The annual accumulated rainfall is approximately 2252.6mm. The maximum daily rainfall is 318.30mm on Aug-23rd. The Seismograph has collected 6 earthquakes, the maximum PGA value is 10.931gal, which was collected on ED02(North-south- X-axis direction). The highest water level is 0.1m higher than last year. The annual accumulated rainfall is increased by 1318.1mm compared with last year. The maximum daily rainfall is increased by 192.6mm compared with last year

During the project progress,

(1)24-hour accumulated rainfall reached 359.4mm from 12:00 on August 23 to 11:00 on Aug-24th. (The special inspection standard: 24 hours of accumulated rainfall over 350 mm)

(2)The maximum release flow of the spillway pipe reached 72.07cms on 01:00~02:00 on Aug-24th. (The special inspection standard: The release flow of the spillway pipe over 72cms per seconds.)

Consider the weather conditions in the reservoir area and after the discussion with WRASB, we decided to launch special inspection on Aug-27th for above-mentioned two cases after Aug-23rd heavy rain.

II. Safety Inspection Results

a.The overall conditions of the dam structure、upstream hillside、downstream hillside、Subsidiary structures、and the surrounding area are fine.

b.After the special inspection of Aug-23rd heavy rain, we found a shallow slide which is 13.8m(L)*8.1m(W)*0.7m(depth) on 0k+900m surface of the downstream dam. The slide area is located above the EL. 37.0m. The WRASB already made repair on Aug-27th 2018. There is no continuously slide sign after inspection. Suggest to keep observing.

c. After comparing several times the inspection results, we found that some of the seepage of downstream on the dam have no leak situation because of the change of landform. Every seepage has no intensifying or worsen situation. The seepage flow of the measuring weir have not abnormal changes, either. So, there's no immediate impact on the safety of the dam.

d.The ecological pool of downstream dam have no abnormal conditions which are having bubbles or possibility of seepage. The result of the submarine inspection before flood season is not good enough because the turbidity is too high in the ecological pool. Suggest to keep observing.

e.Spillway pipe components (e.g. diversion piers, gate from at the downstream outlet, channel sidewalls and floor slabs) and the intake works (e.g. intake tower, diversion structures, connecting bridge) are all

in good conditions. No major damages.

f. There are seepage and plants grown in the construction joint of the trans basin floodway's overflow weir. The concrete surface have peeled off, and abnormal conditions of abrasion、cracking、seepage and efflorescence. They are all small areas and partial situation. The trans basin floodway reinforce engineering is finished at the end of 2018.

g. These have a plane of weakness between the drainage system which nearby the stilling pond's backfilling area and concrete ladder. It cannot effectively drain after rains and it lead to hollow out the lower soil layer. Already repair with cage debris bag before flood season this year. Consider there's no important equipment in the area and the trans basin floodway below the stairs still have expected conditions, so the current repair method is more economical and workable.

III. Trans basin Waterway Safety Inspection Results

a. The abnormal conditions of spalling tunnel lining、 exposed deformed bar、crack、seepage and efflorescence already exist form the past. There is no significant difference from last year's results.

b. The heaving inverted lining at sta.7k+475m is affected by the shear zone. We recommend repairing with reference to the previous work methods.

IV. Monitors Results

a. The change in the total head which in the dam body and dam foundation is regular and stable. All of the monitors at the dam sections are both below the warning value. So, we judge that dam seepage is reasonable.

b. By eliminating the effects of rainfall form measuring weir's(WQR-03) monitoring data, and regression analysis between the dam water level and seepage. The result illustrate that dam water level and seepage are positive

correlation.

c. The maximum settlement at upstream is 2.1cm, which is 0.2% of the dam elevation(10m). The maximum settlement at downstream is 3.7cm, which is 0.35% of the dam elevation(10.5m).

d. The slope nearby the tilemeter-K4 was hollowed out once again on Aug-23rd, and the offset in September is 21.79mm. The destruction position is 125m from dam axis, which is not belong to dam structure. So, it will temporarily not affect the safety of the dam; The offset of tilemeter-SDE02 in August is 12.13mm. According to the inspection and the digital topographic survey result, it is not the dam deformation but the instrumental error.

e. Both the onsite and the free-field seismometers reflected the vibrational behavior of the dam and the foundation accurately when compared to the records from the Central Weather Bureau.

V. Behavior And Stability Evaluation

a. The result of stable analysis with every section on downstream slide which are dam sta. 0k+280m、0k+425m、0k+550m、0k+700m、0k+738mand0k+900m shows the result of tiltmeter is surface displacement and no concern on big scale of sliding. Also, when in the situation of steady state seepage(EL. 37.0m), the safety factor is over the regulation. As a result, the dam surface of Agongdian reservoir is considered as stable.

b. When the reservoir level goes up or down, the total head contour line, which in sand layer of dam foundation will grade to the area, where is the emergent sand layer area. The total head result is mostly same as 「Safety Inspection and Monitoring of Agongdian Reservoir in Year 2017」. It represents the seepage keeps stable during these time period and no

abnormal conditions.

c. The maximum normal hydraulic slope on downstream seepage area is 0.0812. The piping potential is quite low and the distance from dam upstream surface to seepage is quite long. As a result, there is no concern of piping.

VI. Review and Revision of Monitoring Devices

a. There are 19 automatic water gauge set up on dam and reservoir downstream. Starting from 2018, continuously found the sensor is broken. After eliminating the abnormal status, the C5 and WLE-10 is still broken. We planned to do the improvement from 2019 January.

b. There are 30 piezometers set on the dam. After annual inspection, there are 19 piezometers are failure and 2 piezometers have abnormal reading in 2018. In view of the high risk of pumping out the piezometer, it might lead to the hydraulic fracturing because of disturbance the filling material in the dam. Recommended to keep the current status and consult the nearby piezometers and level gauges to estimate the total head. Table 1-2 shows the methods of handing piezometer anomalies.

c. The frequency of collecting data at Agongdian Reservoir was found to satisfy the "Structure Management Guidelines of Reservoirs, June 1997" and the minimum required frequency established by USBR 1987, whereby the stated monitoring frequency is between once a week and once every three months. The current regime is adequate.

d. There are 6 gauging wells at the downstream seepage area. In order to make the monitor system be more complete and convenient to maintain, this plan list out the review and details plans regarding the intellectual management of the monitors in seepage area for WRASB's future construction reference.

Table 1-2 Methods of handing piezometer anomalies

Cross-section	(1)Monitoring Device	(2)Substitute Devices	Handing methods
Right auxiliary dam 0k+280	WPE-01(lose capacity)*	WPE-02、SDE-01	a. If (1) piezometer readings appear erroneous in this section, the correctness of the readings could be verified through (2) piezometers or water level gauges. b. If errors occurred in only at a single piezometer or water level gauges, then it probably caused by human error, or system malfunction. c. If anomalies occurred in piezometer of (1) and (2) on the left, then immediate safety checks should be conducted.
	WPE-02	SDE-01	
	WPE-03(lose capacity)	SDE-02	
	WPE-04(lose capacity)	SDE-02	
	WPE-05(lose capacity)	SDE-02	
	WPE-06	WLW-01	
	WPE-07(lose capacity)	WLW-01	
Main dam 0k+425	WPE-08(lose capacity)	SDE-03	
	WPE-09(lose capacity)	SDE-03	
	WPE-10(lose capacity)	WPE-11、SDE-04	
	WPE-11	SDE-04	
	WPE-12(lose capacity)	WPE-13	
	WPE-13(anomalies)	WLW-02	
	WPE-14(lose capacity)	WLW-02	
Left auxiliary dam 0k+700	WPE-15	SDE-05	
	WPE-16(lose capacity)	WPE-15、SDE-05	
	WPE-17	WPE-19、WLW-03	
	WPE-18(lose capacity)	WLE-04	
	WPE-19	WPE-17、WLW-03	
	WPE-20(lose capacity)	WPE-17、WPE-19	
	WPE-21(lose capacity)	WPE-17、WPE-19	
Left auxiliary dam 1k+100	WPE-22(lose capacity)	WPE-25	
	WPE-23(lose capacity)	WPE-24	
	WPE-24	WPE-25	
	WPE-25	WPE-24、WLW-04	
	WPE-26(lose capacity)	WPE-24	
Left auxiliary dam 1k+500	WPE-27(anomalies)	WLE-09	
	WPE-28	WPE-27	
	WPE-29(lose capacity)	WLE-09	
	WPE-30(lose capacity)	WLE-09	

Note 1：WPE stands for piezometer.

Note 2：WLE and WLW are water level gauges.

Note 3：SDE is inclinometers.