문서번호 APCC-출장-17-0293(2017-03-24)

TRAVEL REPORT FORM
출장보고서

결재	사원	부서장	부서장	원장
	03/21 전인자	03/21 문상원	03/24 김형진	03/24 정홍상
협조	팀장			
	03/23 조재필			

I. **Reporter** 보고자

Department 소속	Position 직위(직급)	Name 성명	Travel Date 날짜	Note 비고
응용사업팀	선임연구원	신용희, 윤선권	2017.3.1.(수).- 3.11(토)	통가 누쿠알로파
대외협력실	사원	전인자	2017.3.1.(수).- 3.11(토)	통가 누쿠알로파

II. **Major Activities** 주요업무 수행내용

1. Main Contents and Activities 주요내용 및 활동

- 2016년도 사업 최종 워크숍 (프로젝트 결과 공유 및 MOU 체결식 등)
- 통가 국토부 수자원관리 직원 대상, Technical Training Workshop (지하수 관리, 데이터로거, 모니터링 서버, 모델링 결과, 웹사이트 활용 등 교육 진행)
- 2017년도 사업 Kick-off 협의 및 프로젝트 진행
  · 수자원분야 프로젝트 내용 세부 협의 (국토부 담당자 협의, 지하수 자동관측장비 추가설치 및 지하수 모델링 관련 사항 논의, 웹기반 지하수 정보 시스템 활용방안 및 서비스 관련 논의 등)
  · 농업분야 프로젝트 내용 세부 협의 (농림부 담당자 협의, 토양수분센서 설치 및 데이터 다운로드 교육, 모니터링, 토성조사 등)
- 통가 정부 고위급 관계자 미팅
  · 기 실시된 수자원 프로젝트 성과물 활용방안 논의 및 신규 프로젝트를 위한 협력방안 논의 등
- (붙임1) 통가 출장보고서, (붙임2, 3) 발표자료 첨부파일 참고

2. Relevance to APEC Climate Center's Activities 결론 및 소감

- (붙임1) 통가 출장보고서, (붙임2, 3) 발표자료 첨부파일 참고

III. References 참고사항

(with attachment of any information or report in case of attendance of conferences, workshops and meetings) 학술대회, 워크숍, 회의 등 참석 시 관련 정보 및 문서 첨부

1. Presented and Collected Materials 주요 수집자료

2. Suggestions and Remarks 건의사항

통가 출장 보고서

[2017. 3. 21.(화) 기후응용팀/대외협력실]

I. 출장 개요

○ 과 업 명 : 통가 물부족 대응을 위한 기후정보 활용 스마트 지하수 관리 시스템 개발(*"Development of smart water management system using climate information in response to shortage of water in the Kingdom of Tonga"*)

○ **출장목적**

- 2016년도 사업 최종 워크숍

· APCC 통가 프로젝트 Joint 최종 워크숍(프로젝트 결과 공유 및 MOU 체결식 등)

· Technical Workshop 진행(지하수 관리, 데이터로거, 모니터링 서버, 모델링 결과분석 등 교육 진행)

- 2017년도 사업 Kick-off 협의 및 프로젝트 진행

· 수자원 프로젝트 내용 세부협의(통가 토지천연자원부 정부관계자 미팅, 지하수 자동관측장비 추가 설치 및 지하수 모델링 관련 사항 논의, 지하수 현장조사 및 세부조사 실시, 웹기반 지하수 정보 시스템의 활용 방안 및 서비스관련 논의 등)

· 농업 프로젝트 내용 세부협의(통가 농림식품수산부 관계자 미팅, 토양수분 센서 및 토양수분포텐셜 센서 설치, 모니터링, 토성조사 및 분석 등)

○ 출장기간 : 2017. 3.1.(수)-11.(토) <10박11일>

○ 출장자(3인) : 응용사업팀 (신용희, 윤선권 선임연구원), 대외협력실 (전인자 사원)

○ 출장관련 주요내용

분야	담당자	방문장소	주요활동
최종 워크숍	기후변화 연구팀/ 윤선권 선임연구원 , 대외협력실 /전인자 사원	• 통가 누쿠알로파 Tanoa Hotel Talanoa Room	- 2017-18년도 프로젝트 MOU 체결식 - 기존 프로젝트(농업 및 수자원) 결과 공유
수자원 (지하수)		• 토지천연자원부 (MLNR) 방문 및 프로젝트 협의 • Final Technical 워크숍 및 사용자 교육 • 지하수 관측정 설치관련 현장답사 및 세부조사	- 현지 담당자 · Mr. Taaniela Kula (Deputy Secretary) - 활동내용 · 기존 프로젝트 결과 공유 및 활용방안 논의 · Technical 워크숍 진행(지하수 관리, 데이터 로거, 모니터링 서버, 모델링 결과분석 등 세부교육 진행) · 신규 프로젝트 제안서 세부 검토, 협의 및 확정 : 연구대상지역 확정, 활용방안 논의, 향후 일정 협의 등 · 자료확보 : 수자원 자료 검토 및 추가 확보(수온, 강수, 염도 등 세부 자료 확보) · 현지조사 : 지하수 취약지역 세부조사 · 향후계획: APCC-통가정부부처 간 상호양해각서 하에서 원활한 사업 추진방안 논의 및 향후계획 논의
농업	기후변화 연구팀/ 신용희 선임연구원 , 대외협력실 /전인자 사원	• 농림식품수산부 (MAFFF) 방문 및 프로젝트 협의 • 토양수분 센서 및 토양수분포텐셜 센서 설치장소 현장답사 및 설치	- 현지 담당자 · Mr. Manaia Halafihi (Head of the Corporate Service Division) - 활동내용 · 신규 프로젝트 제안서 세부 검토, 협의 및 확정 : 연구대상지역 확정, 활용방안 논의, 향후 일정 협의 등 · 자료확보 : 토양성분 자료, 타로 및 얌 관련 통계자료 및 생육정보 등 세부 자료 확보 · 장비설치 : 토양수분 센서 및 토양수분포텐셜 센서 설치 · 현지조사 : 타로 및 얌 재배지역 세부조사 · 향후계획: APCC-통가정부부처 간 상호양해각서 하에서 원활한 사업 추진방안 논의 및 향후계획 논의

II. 주요 활동 및 내용

1. 수자원 분야

- 2016년도 사업 Training Workshop 개최

  : 2016년도에 수행한 「통가 물부족 대응을 위한 기후정보 활용 스마트 물관리 기술개발 사업」의 주요 결과를 공유 하였으며, 통가 국토부(MNSLR) 지하수관련 정부관계자를 대상으로 Technical Training Workshop을 실시하였음

- 2017~2018년(2년) 사업 MOU 문건 및 사업내용 검토

  : 향후 2년 연구사업에 대한 MOU 체결 문건 검토를 실시하였으며, 통가 국토부 장관동의 하에 부총리(Deputy Prime Minister, DPM) 사인을 통한 Agri-Water 사업 MOU체결 진행하기로 함

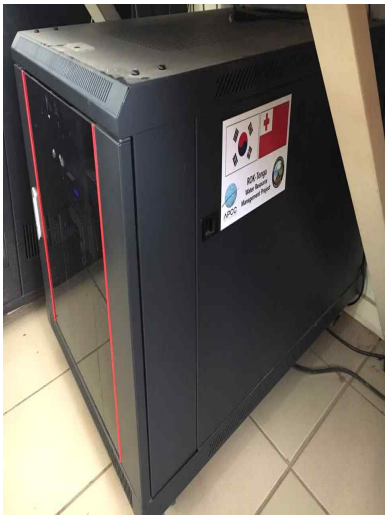
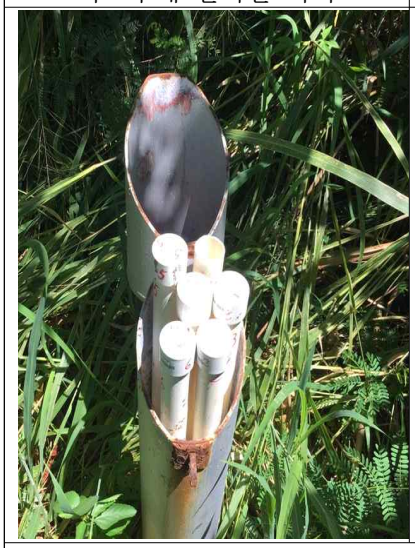
  : 수자원 분야 2년 사업계획에 대한 통가 국토부 정부관계자의 전반적인 동의를 얻어 사업 진행하기로 하였으며, 지하수 자동관측 장비 확장 설치 지역을 선정함

- 기존 설치 장비 점검 및 확장 설치 예정 지역 현장 점검

  : 기존 Salinity Monitoring Borehole (SMB) 3곳에 설치하였던 지하수 자동관측 장비의 현장 실태 점검 및 스티커 부착을 실시하였으며, 통가 국토부 사무실 내에 서버 및 시스템 점검을 실시함

  : 통가 지하수 정보 시스템 구축을 위한 고정 IP를 개설(http://202.134.25.68)하였으며, 5개의 포트 포워딩을 실시하였음

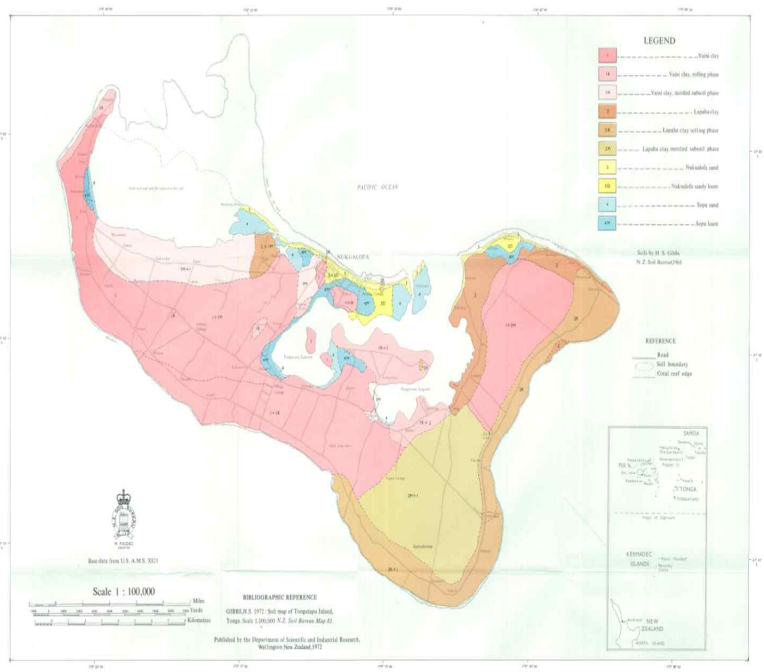
  : 추가 사업을 통하여 확장 설치 예정인 SMB지역 4곳을 방문하였으며, 잠정 설치 지역으로 2곳을 선정하였음

<table>
<tr><td>  </td><td>  </td><td>  </td></tr>
<tr><td>국토부에 설치된 서버</td><td>데이터로거</td><td>데이터로거 센서</td></tr>
<tr><td colspan="3">    </td></tr>
<tr><td colspan="3">설치예정지역 후보군 SMB</td></tr>
</table>

2. 농업 분야

- 통가타푸섬에 대한 지역별 토성의 공간적 분포 조사

  : MAFFF와의 논의 및 현장종사를 통해 통가타푸 내 지역별 토성성분을 조사함

	Vaini Clay (Depth: 13-28cm) Sand: 20.0% Silt : 21.7% Clay : 58.3% Lapaha Clay (Depth: 13-30cm) Sand: 12.0% Silt : 7.4% Clay : 80.6%

- 통가타푸섬 농경지 작물 재배현황 조사

		
Taro	Yam	Cassava
		
Vanilla	Papaya	Sweet potato

- 토양수분 함량 모니터링을 위한 토양수분 센서 설치

MAFF와 협의를 통해 토양수분 함량 관측지점을 선정함

Vaini Farm : MAFF에서 운영하고 있는 시험 포장으로 다양한 작물이 재배되고 있으며 생육정보 수집이 용이함

Fuaamotu Farm : Cash crop인 vanilla를 재배하는 농장으로 통가기상청의 기상 관측 지점과 가까운 거리에 있어 기상정보 수집이 용이함

Nishi Farm : 농작물 수출용 작물을 재배하는 Nishi 팜은 자체 AWS 운용 및 관개 설비 구축을 통해 과학적이고 체계적인 영농을 추구하고 있어 토양수분 함량 관측 자료의 활용성이 클 것으로 판단됨

		
Vaini Farm	Fuaamotu Farm	Nishi Farm

- 통가타푸섬 현지 영농인에 대한 토양수분 함량 관측자료 수집 교육

3. Joint Final Workshop(농업/수자원) 및 MOU (※자세한 내용은 *Joint Final Workshop* 영문보고서 참조)

- APCC AgroMet and Water Projects Joint Final Workshop 개최

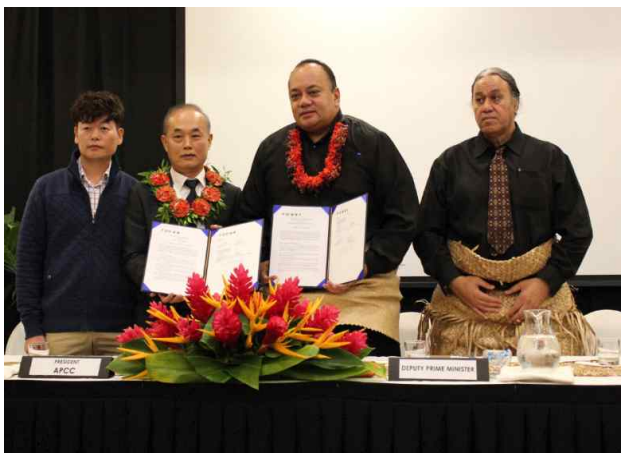
Time	Item	Person
09:50 – 10:00	Arrival and registration	
10:00 – 10:05	Word of Prayer	Mr. Manaia Halafihi *Head of Corporate Service Division, MAFFF*
10:05 – 10:10	Welcome Address from the Ministry of Agriculture and Food, Forests and Fisheries	Dr. Viliami Toalei Manu *CEO, MAFFF*
10:10 – 10:15	Address from the APEC Climate Center	Dr. Hong-Sang Jung *President, APCC*
10:15 – 10:25	Keynote Address from theMinistry of Meteorology, Energy, Information, Disaster Management, Environment, Climate Change and Communications	Hon. Siaosi 'Ofakivahafolau Sovaleni *Deputy Prime Minister and Minister, MEIDECC*
10:25 – 10:35	Signing of MOU for the new Agri-Water Project and photo	APCC-Deputy Prime Minister
10:35 – 10:50	AgroMet Project: Highlights of the August 2014 - December 2016 AgroMet Project	Dr. Kwanghyung Kim *Research Fellow, APCC*
10:50 – 11:00	AgroMet Project: Address from Project Beneficiaries	Ms. Ella Gabriel *Research and Development Officer, Nishi Trading* Mr. Saia Pekipaki *Farmer & Farmer Field School Participant*
11:00 – 11:10	AgroMet Project: Presentation from the Tonga Meteorological Service	Mr. 'Ofa Fa'anunu *Director, TMS*
11:10 – 11:20	AgroMet Project: ToCSA System Handover Ceremony	APCC-MAFFF-TMS
11:30 – 11:50	Water Project: Highlights of the 2016 Water Project	Dr. Sunkwon Yoon *Research Fellow, APCC*
11:50 – 11:55	Water Project: Presentation from the Ministry of Lands, Survey & Natural Resources	Mr. Taaniela Kula *Deputy Secretary, MNSLR*
11:55 – 12:05	Agri-Water Project: Presentation on upcoming APCC Project *development of smart water management system using climate information in response to shortage of water in the Kingdom of Tonga*from	Dr. Yonghee Shin *Research Fellow, APCC*
12:05 – 12:10	Updates on the April 2016 – March 2017 Project *Improved austral winter seasonal forecast*	Ms. Christianne Miko Aikins *Project Manager, APCC*

Time	Item	Person
	and tropical cyclone sub-seasonal to seasonal outlooks in Kingdom of Tonga through APCC MME seasonal prediction	
12:10 – 12:15	Vote of Thanks and Closing Prayer	Mr. Manaia Halafihi *Head of Corporate Service Division, MAFFF*
12:15 – 12:20	Group photo	
12:20 – 13:50	*Lunch at the Tanoa Dateline Hotel*	

: 2014년 8월부터 실시한 통가 농업프로젝트(PI:김광형 박사)의 최종성과보고회, 2016년도 수자원관리 프로젝트(PI:윤선권 박사)의 1차 년도 성과 보고, 2017년도 프로젝트 계획 공유 등을 통해 통가 내 APCC사업의 인지도를 확산시키고 프로젝트 성과물의 활용을 도모하고자 함

- Tonga Agri-Water 사업(2017-2018, 2년) MOU체결

: 통가 국토부 및 농림부 장관 동의 하에 부총리(Deputy Prime Minister, DPM) - APCC 원장의 사인을 통한 Agri-Water 사업 MOU체결을 진행함



III. 세부 일정

<table>
<tr><th rowspan="2">일자</th><th rowspan="2">시간</th><th colspan="2">주요내용</th><th rowspan="2">장소</th><th rowspan="2">비고</th></tr>
<tr><th>농업 분야</th><th>수자원 분야</th></tr>
<tr><td>17.3.1(수)
17.3.2(목)</td><td>13:30
18:40</td><td colspan="2">이동</td><td>한국-통가</td><td></td></tr>
<tr><td rowspan="3">17.3.3(금)</td><td>09:00-12:00</td><td>•Kick-off Meeting
- 통가정부, APCC, 관계자 소개 및 인사
- 프로젝트 진행사항 협의
- 장비설치 논의
- MOU 협의</td><td rowspan="2">•신규프로젝트 Kick-off Meeting
- 프로젝트 진행사항 협의
- 장비추가설치 논의
- MOU 협의 및 확정
- 정부자료수집</td><td>통가 농림부 사무실 /통가 국토부 사무실</td><td rowspan="3">APCC & Tonga MAFFF, MLSNR</td></tr>
<tr><td>13:00-17:00</td><td>•장비설치현장조사
•장비설치</td><td>현장</td></tr>
<tr><td>17.3.4(토)</td><td>09:00-18:00</td><td>•현지조사 및 장비설치</td><td>•내부회의I(APCC)
- 지하수세부 조사방안 논의</td><td>지정장소</td></tr>
<tr><td rowspan="2">17.3.5(일)</td><td>09:00-12:00
13:00-17:00</td><td colspan="2">•내부회의I(APCC)
- 토양수분 세부 조사방안 논의
- 프로젝트 지속가능성 확보방안 논의

•내부회의II(APCC)
- 기존 데이터로거 관리현황 파악
- 통가의 지속가능한 수자원관리 방안 논의</td><td>지정장소</td><td>APCC</td></tr>
<tr><td rowspan="2">17.3.6(월)</td><td>10:00-12:00
13:00-17:00</td><td colspan="2">• 장비설치(계속)
• 통가측담당자교육
- 장비 설치 및 운용방법
- 장비 관리방법
- 작물생육관련 자료수집

•Final Technical Training Workshop
- 지하수관리 강의
- 데이터로거, 모니터링 서버, 모델링관련 교육
- 시스템 유지보수 및 활용방안 교육</td><td>통가 농림부 사무실 /통가 국토부 사무실</td><td>APCC & Tonga MAFFF, MLSNR</td></tr>
<tr><td rowspan="2">17.3.7(화)</td><td>10:00-12:00
13:00-17:00</td><td>• 장비설치(계속)
• 토양수분관련 자료수집

• 현장조사
- 장비 작동 확인
- 관측자료 수집</td><td>•현장조사 및 자료수집
- 장비 추가 설치 지역 현장 방문
- 지하수 관측 관련 자료수집
- 마을 현장 조사</td><td>현장 및 지정장소</td><td>APCC & Tonga MAFFF, MLSNR</td></tr>
<tr><td rowspan="3">17.3.8(수)</td><td>09:00-14:00</td><td colspan="2">•2016년도 프로젝트 최종 워크숍
- 수자원이용현황 및 개선사항
- 신규 프로젝트 MOU 체결식
- 신규 농업 프로젝트 소개</td><td>Tanao 호텔</td><td rowspan="3">APCC & Tonga MAFFF, MLSNR, TMS</td></tr>
<tr><td>15:00-16:00</td><td colspan="2">•통가 농림식품수산부 장관 미팅</td><td>MAFFF 장관실</td></tr>
<tr><td rowspan="2">17.3.9(목)</td><td>09:00-12:00</td><td colspan="2">•통가 토지천연자원부 장관 미팅</td><td>MLSNR 장관실</td></tr>
<tr><td>13:00-18:00</td><td colspan="2">•통가 부총리 미팅</td><td>부총리실</td><td></td></tr>
<tr><td>17.3.10(금)
17.3.11(토)</td><td>14:00
20:40</td><td colspan="2">이동</td><td>통가-한국</td><td></td></tr>
</table>

[첨부1] 통가 정부부처 회의록

1. Ministry of Agriculture and Food, Forests and Fisheries

Date: Wednesday, 8 March 2017

Location: MAFFF Head Office

Participants:

- Dr. Hong-Sang Jung (President, APCC)
- Dr. Viliami Manu (CEO, MAFFF)
- Dr. Kwanghyung Kim, Dr. Yonghee Shin, Dr. Sunkwon Yoon, Ms. Inja Jeon, Ms. Christianne Aikins (APCC)

Highlights:

Dr. Manu shared the story of MAFFF's involvement with APCC and the AgroMet project, noting the many benefits and appreciated outputs. He also explained that gaps remain in the agricultural sector and expressed his interest in expanding ToCSA to include agricultural extension with the Extension Diary. Dr. Jung expressed his appreciation for MAFFF's support and cooperation over the years and his hope for further successful collaborations.

2. Ministry of Lands, Survey, and Natural Resources

Date: Thursday, 9 March 2017

Location: MLSNR Office

Participants:

- Dr. Hong-Sang Jung (President, APCC)
- Lord Ma'afu (Minister for Lands, Survey and Natural Resources)
- Mr. Fetu'u Vea (Acting Chief Executive Officer, MLSNR)
- Mr. Taaniela Kula (Deputy Secretary, MLSNR)
- Dr. Kwanghyung Kim, Dr. Yonghee Shin, Dr. Sunkwon Yoon, Ms. Inja Jeon, Ms. Christianne Aikins (APCC)

Highlights:

The motivation and outputs of the Water project were shared with his Lordship, with a video showing the process and successes. MLSNR expressed their interest in the project and their hope to expand and work together again. Dr. Hong-Sang Jung expressed his appreciation for the support of MLSNR and his hope to have future successful collaborations.

3. Deputy Prime Minister

Date: Thursday, 9 March 2017

Location: MEIDECC Office

Participants:

- Dr. Hong-Sang Jung (President, APCC)
- Hon. Siaosi 'Ofakivahafolau Sovaleni (Deputy Prime Minister and Minister for Meteorology, Energy, Information, Disaster Management, Environment, Climate Change and Communications)
- Mr. Ofa Fa'anunu (Head, TMS)
- Dr. Kwanghyung Kim, Dr. Sunkwon Yoon, Ms. Christianne Aikins (APCC)

Highlights:

His Hon. Sovaleni expressed his appreciation of APCC and the work done through the AgroMet and Water projects, as well as his high hopes for upcoming projects with the Agri-Water project, as well as other new initiatives. The possibility of mimicking the upcoming GCF project implemented by SPREP in Vanuatu for Tonga was discussed, possibly beginning development in late 2018. Dr. Jung explained the importance of Tonga communicating with the Korean Foreign Service to help promote further Korean engagement in Tonga. He also expressed his interest in continuing developing successful projects, such as the GCF project, or other expansions of the agrometeorological work done in Tonga.

Development of smart water management system using climate information in response to shortage of water in the Kingdom of Tonga

Dr. Yonghee Shin, Dr. Sunkwon Yoon, Dr. Kwanghyung Kim

Contents

- Project Design
- Project Contents
  - Water
  - Agriculture
- Expected outcomes
- Timeline

I Project Design

Project Background

- Over the decades, extreme droughts due to El Niño Southern Oscillation (ENSO) events have been both increased and intensified in the Pacific Island Countries (SOPAC and WHO, 2007; and IPCC, 2013).

- The Kingdom of Tonga faces diverse and difficult water challenges. For example, the supply and demand of water resource in Tonga is regionally biased and the quantity and quality of it are at high risk due to the pollution and depletion of surface water as well as seawater intrusion.

- In terms of securing water resources in the island, groundwater is very important.

- Given there is no large catchment area and a lack of fresh water supply system in Tonga, identifying available water resources and storing them are one of the top priorities.

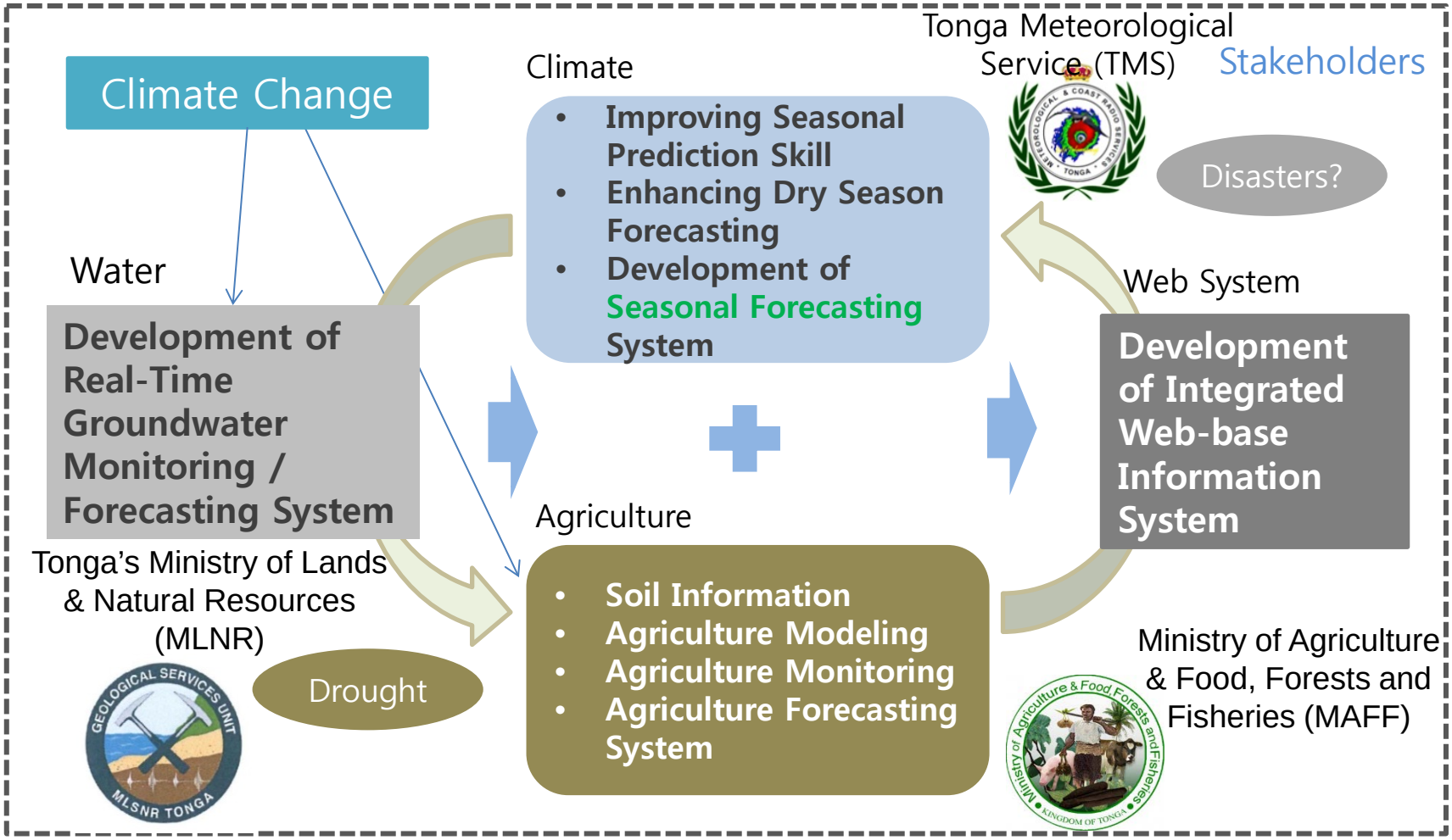
- Therefore, it urgently needs international assistance and cooperation to establish an efficient groundwater management system which allows continuous and sustainable water supply under the threat of climate change.

Project Background

- Agriculture is one of the most important economic sectors in Tonga together with the services and industrial sectors.
- However, the recent climate change and frequent abnormal weather phenomena such as drought have negative impact on agricultural productivity.
- Therefore, the establishment of smart water management system will contribute to Tonga's agricultural economy growth by enabling effective water management.
- Currently, agriculture and water management projects respectively are underway through APCC-Tongan intergovernmental projects, and it is necessary to develop the outcome continuously.
- In addition, this is aligned with the broader development goal of improving the economic productivity and sustainability of crop production in Tonga.
- The importance of securing agricultural water resources and proper water management is of utmost in Tonga's agricultural field.

Tonga Agro-Water Project Design

APCC-Tonga



Background of Tonga Agro-Water Project

Tonga Agro-Water Project Work Sharing

Main Activities (2017 year)

A. Climate

- CMIP5 climate change scenario/APCC MME seasonal prediction data
- Downscaled data using rcmip5/sforecast package
- Climate data processing and analysis for agriculture/water applications

B. Water

- Development of seasonal prediction and evaluation technology for groundwater resource (Prototype)
- Development of climate change impact and climate risk management technology
- Establishment of web-based integrated water management system

C. Agriculture

- Development of soil moisture content monitoring system
- Development of smart water management method in agricultural land linked to prediction of groundwater content (Prototype)
- Agricultural data using ToCSA(Tonga Climate Service for Agriculture)

Success Indicators

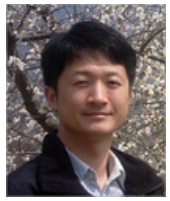
- Climate researcher
- rcmip5/sforecast (@Dr. Jaepil Cho)

\+ Outsource

HNC 하이드로넷 HydroNet Co.,Ltd.

Co-PI: Dr. Sunkwon Yoon

\+



PI: Dr.Yonghee Shin Dr. Kwanghyung Kim

Water

II Water Resources Forecasting and Risk Assessment

Objectives

- This project aims to provide support for better understanding and implementation of water management policies in the Kingdom of Tonga.
- The focus will be to provide guidance to Tongan government a strategic plan for securing water resources in response to seasonal variability and changing climate.
- The various project activities will be implemented within the framework of APEC Climate Center (APCC) and Tonga's Ministry of Lands & Natural Resources (MLNR) partnership.

Component 1 : Installation of the real-time groundwater monitoring system and development of advanced groundwater flow model

Component 2 : Development of climate-smart groundwater information system and decision-making system for sustainable water resources management

APCC/Tonga MLNR Partnership

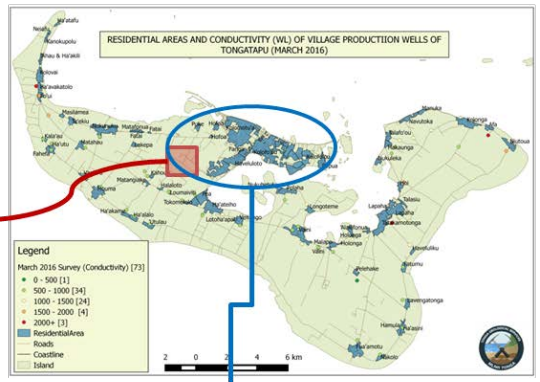
- From 2016, both APCC and MLNR of Tonga have worked together to support water management in Tonga, initiated from Tongatapu, which is the mainland of the country.
- The main mission of the team is to promote strategic planning for sustainable water management in response to climate change and seasonal variability;
- and help improve the quality of livelihood of the local communities through optimal water management.

Component 1 : Installation of the real-time groundwater monitoring system and development of advanced groundwater flow model

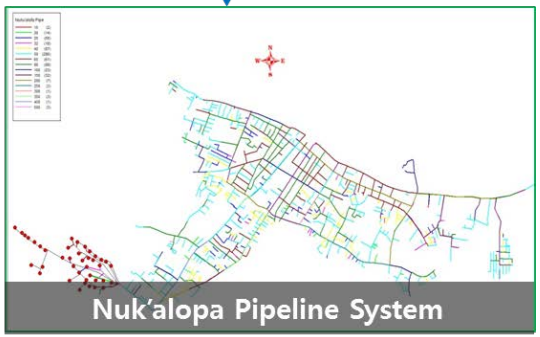
Activity 1.1 : Project planning and data collection
Activity 1.2 : Installation of the real-time groundwater monitoring system

Tonga Urban & Rural Water Distribution System

Urban



Rural



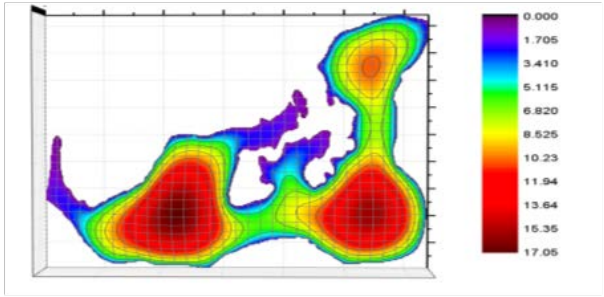
Extending Real-Time Groundwater Monitoring System in Tongatapu

Install the Sensors

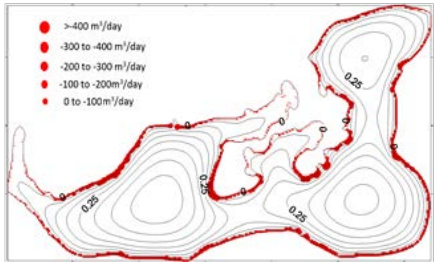
Component 1 : Installation of the real-time groundwater monitoring system and development of advanced groundwater flow model

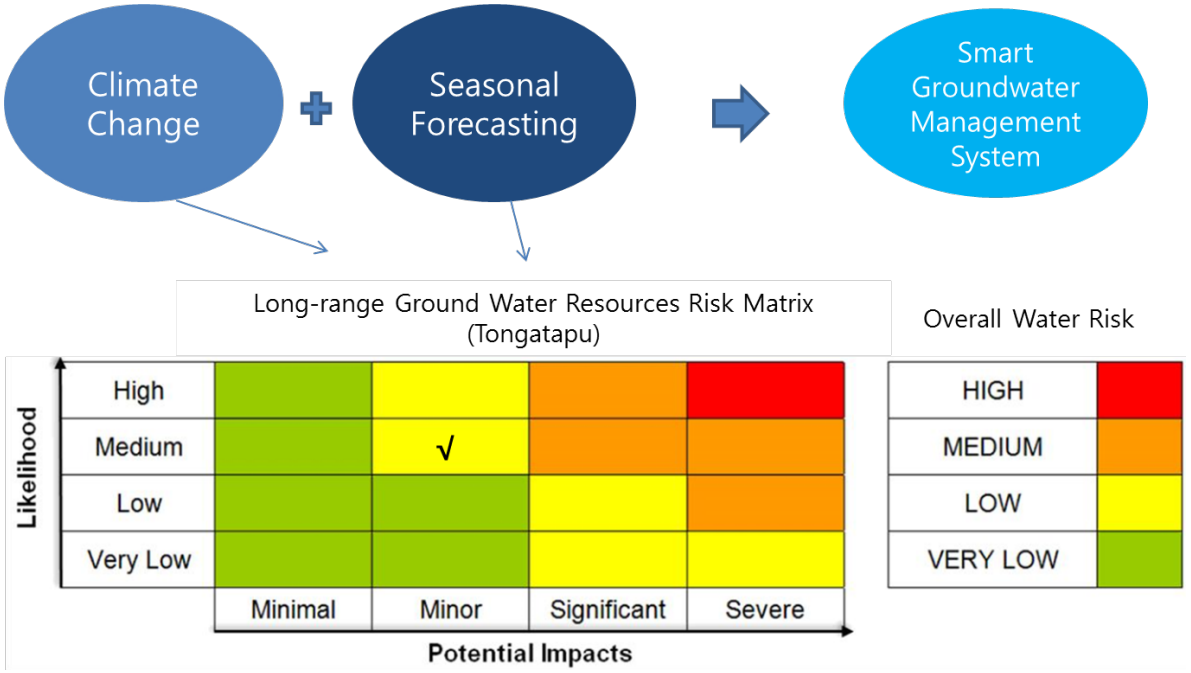
Activity 1.3 : Development of the advanced groundwater flow model
Activity 1.4 : Climate change impact, seasonal prediction, and risk assessment

➢ Freshwater Thickness (m)



➢ Freshwater Influx and Water table



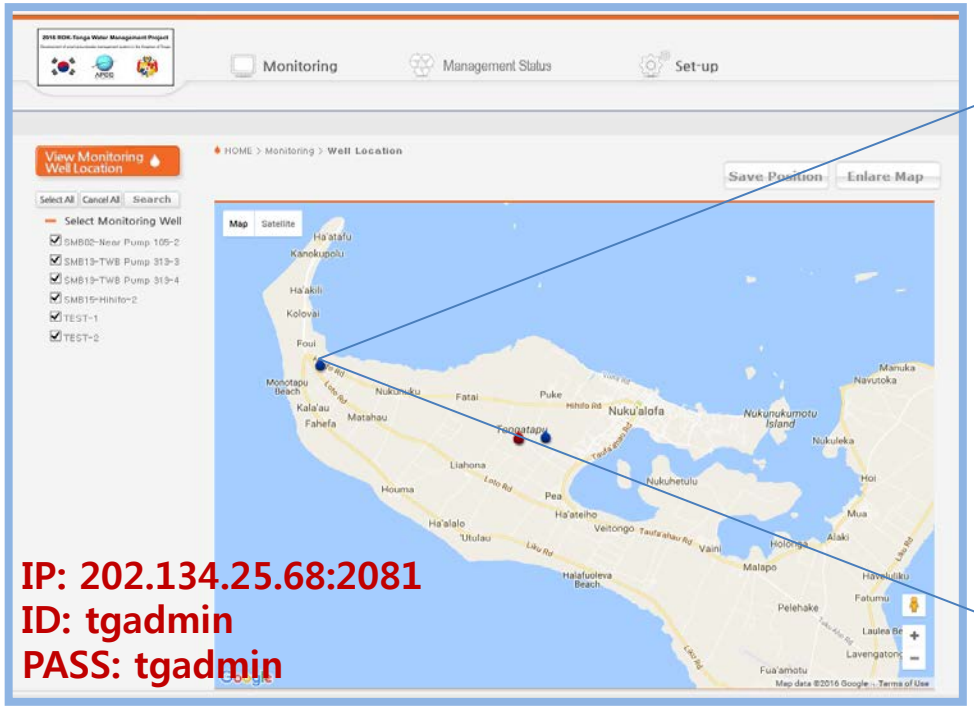


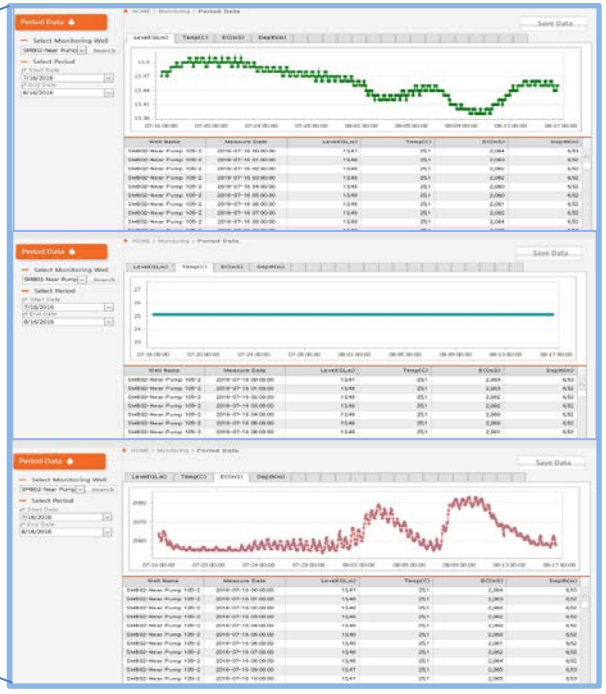
Component 2 : Development of climate-smart groundwater information system and decision-making system for sustainable water resources management

Activity 2.1 : Development of climate-smart groundwater information system (GWIS)
Activity 2.2 : Providing policy-relevant recommendation and long-term plan

- Groundwater Monitoring system
- Locations: Mataki 'Eua (SMB02, SMB13), Hihifo (SMB15)
- Observation Data: Level(GL.m), Temp(C), EC(mS), Depth(m)

PC Version / Smart Phone App.





Agriculture

III Smart Agricultural Water Management

APCC
APEC CLIMATE CENTER

Objectives

- This project aims to increase the capacity of Tongan crop growers and government officials in managing climate risks such as drought in crop fields.
- The focus will be to support the beneficiaries in Tonga's agriculture sector to sustainably secure crop production by providing optimal soil moisture management
- The various project activities will be implemented within the framework of APCC and Tonga's MAFFF (Ministry of Agriculture & Food, Forests and Fisheries) partnership.

Component 1 : Installation of soil moisture sensors and soil water potential sensors and monitoring soil moisture condition

Component 2 : Modeling for soil moisture contents

- This work will contribute towards the establishment of the strategic plan for effective water management in response to abnormal weather such as drought.

APCC/Tonga MAFFF Partnership

- This project will be conducted in partnership between the APEC Climate Center and the Ministry of Agriculture and Food, Forests, and Fisheries (MAFFF) of Tonga as implementing partner.
- From 2014, both APCC and MAFFF of Tonga have worked together to improve agricultural productivity in Tonga through ensuring data availability and enhance agro-meteorological services.
- The main mission of the team is to promote strategic planning for sustainable water management for agriculture in response to climate change and abnormal weather phenomena; and help improve the quality of livelihood of the local farmers in their crop production.

Smart Agricultural Water Management

Tongatapu Crops Cultivation Survey

- Crop statistics of Tonga
  (area, production, yield and trade)
- Crop calendar of Tonga
- Cultivation status of taro and yam
- Irrigated and rainfed crop areas

Taro

Yam

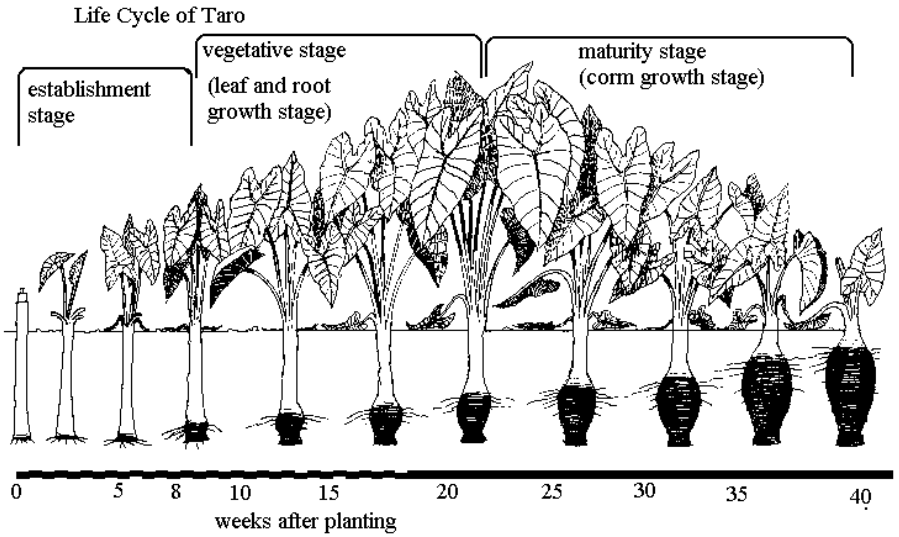
Smart Agricultural Water Management

Crops Growth Information Survey

Production, Yield and Area for Taro in 1998

	Production (1,000 tonnes)	Yield (tonnes/ha)	Area (1,000 ha)
World	**6586**	**6.2**	**1070**
Africa	**4452**	**5.1**	**876**
Asia	**1819**	**12.6**	**144**
China	1387	16.8	82
Japan	255	11.6	22
Philippines	118	3.4	35
Thailand	54	11.0	5
Oceania	**283**	**6.2**	**46**
Papua New Guinea	160	5.2	31
W. Samoa	37	6.2	6
Solomon Islands	28	21.9	1
Tonga	27	6.4	4
Fiji	21	14.7	1

Source: FAO Database, 1999



How to Grow Taro

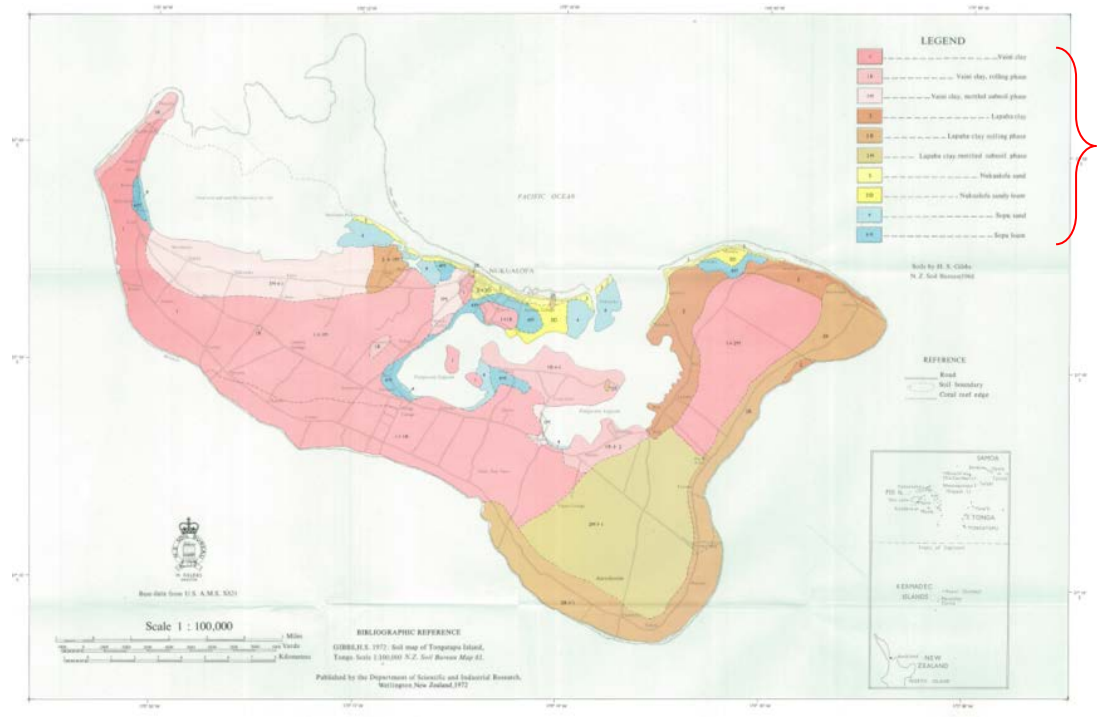
Taro is a perennial herbaceous plant that grows from 90 to 180 cm tall. Taro is a tropical or subtropical plant that requires very warm temperatures (25-35°C) and consistent moisture.

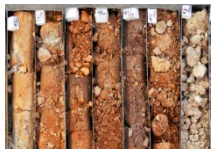
Planting time → Water & Feeding → Care → Pest & Diseases → Harvest

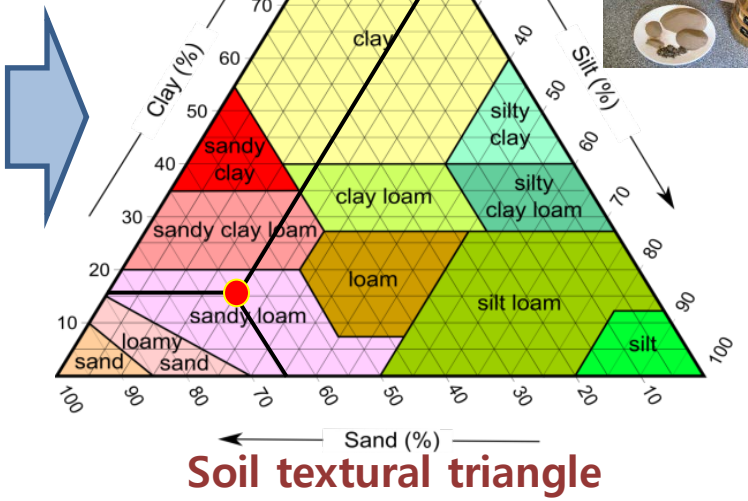
Smart Agricultural Water Management

Tongatapu Soil Information Survey

Soil map of Tongatapu island







Soil textural triangle

- Literature survey about Tongatapu soil
- Soil sampling and experiment of soil texture

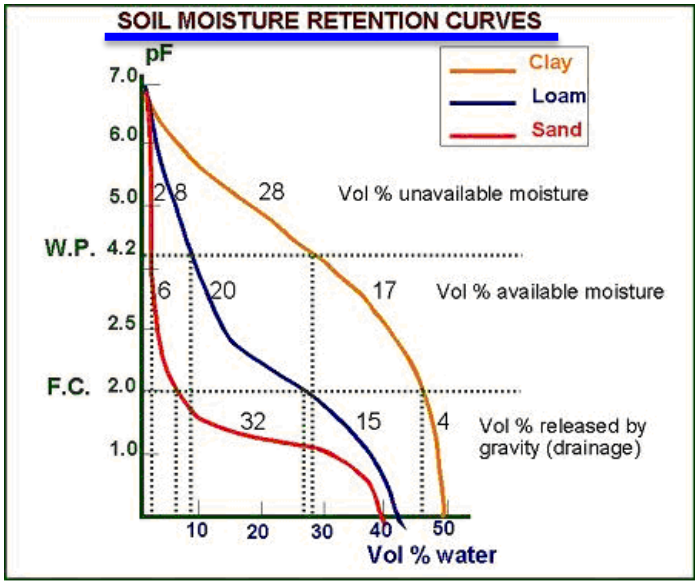
	토양성분 (%)				용적밀도 gr/cm^3	수분함량 (%)	
	Clay	Silt	Sand	토성		33kPa	1500kPa
A	27.5	36.9	35.6	식양토	1.23	25.1	12.9
B	0.8	37.1	62.1	사양토	1.61	11.4	4.6
C	18.7	54.6	26.7	미사질양토	1.3	29.8	12.9
D	17.6	38.1	44.3	양토	1.35	26.2	10.2
E	17.2	68.6	14.2	미사질양토	1.33	30.1	15.9
F	34.8	57.9	7.3	미사질식양토	1.31		
G	17.9	38.8	43.3	양토	1.19	34.9	18.9

Smart Agricultural Water Management

Installation of Soil Water Sensors

Soil Moisture Sensor

Soil Water Potential Sensor



- Installing the soil moisture sensor and soil water potential sensor in study area
- Monitoring the soil water content and soil water potential at the same time
- Making the soil moisture retention curve

Smart Agricultural Water Management

Soil Water Content Observation Points

Cultivation area : 3 sites

Tongatapu island

Nishi farm

Vaini

Fuaamotu

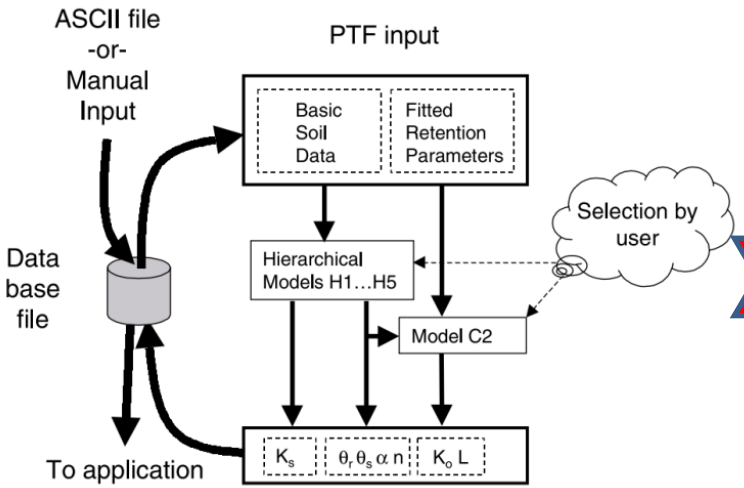
Estimation of Hydraulic Properties

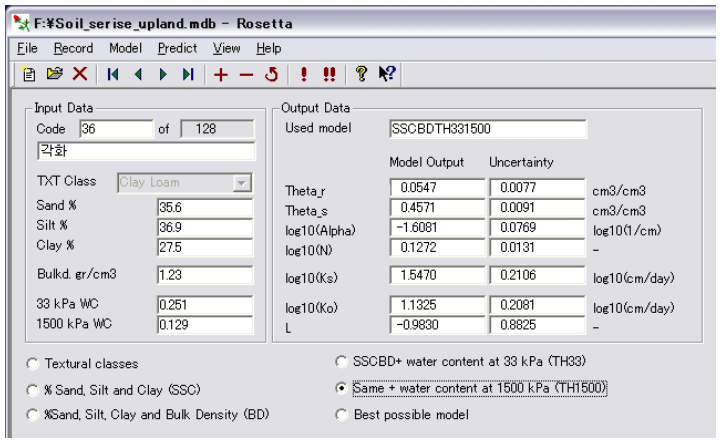
Soil data

- Soil textural class
- Sand, silt and clay percentages
- Bulk density
- θ_{33kPa} , $\theta_{1500kPa}$

Rosetta Model

(Artificial Neural Networks)





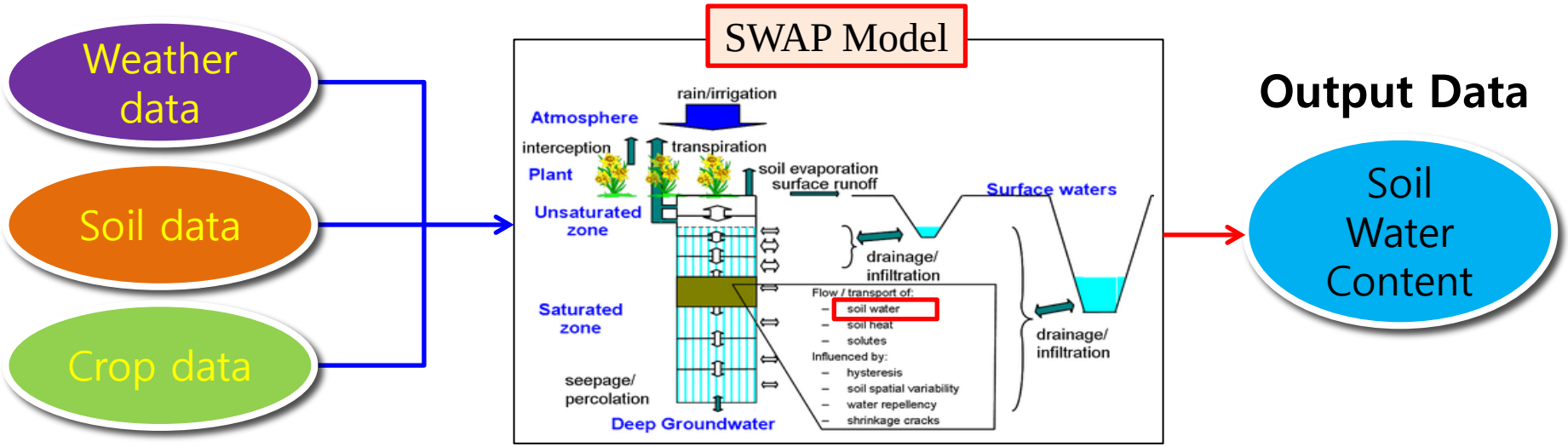
Hydraulic parameter

- **K_s(cm/day)**
  Saturated hydraulic conductivity
- **K_o(cm/day)**
  Unsaturated hydraulic conductivity
- **θ_s(cm^3/cm^3)**
  Saturated water content
- **θ_r(cm^3/cm^3)**
  Residual water content
- **α(1/cm),n(-)**
  Empirical fitting parameter

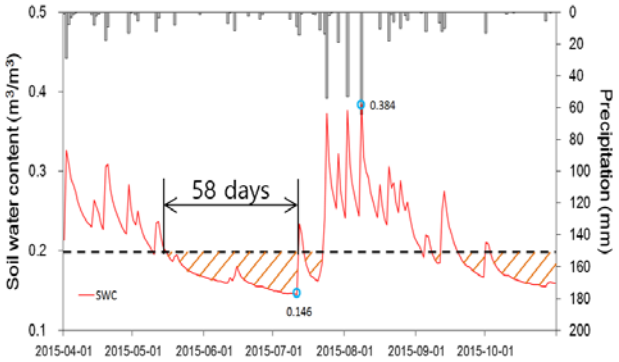
Smart Agricultural Water Management

Simulation of Soil Water Content

Input Data



- Setting of SWAP model's input data (Crops, Soil and Weather data)
- Simulation of soil water content using SWAP model
- Decision of crop wilting point from soil moisture retention curves



Smart Agricultural Water Management

Soil Moisture and Groundwater Monitoring / Forecasting System

Soil Water Content

2017 year: Monitoring

2018 year: Risk Analysis

Notice | Caution | Warning | Danger

2017 year: Seasonal Prediction

2018 year: Outlook (Early warning)

Groundwater Level

2017 year: Monitoring

2018 year: Risk Analysis

Notice | Caution | Warning | Danger

2017 year: Seasonal Prediction

2018 year: Outlook (Early warning)

Management System

Tonga Smart Irrigation System (ToSIS)

Link

ToCSA

IV Expected Outcomes

Expected Outcomes and Implications

- Through this project, the government officials will be able to map out the regional groundwater usage and management in greater detail.
- Groundwater information is expected to help allow the stakeholders to establish a strategic plan for water supply and demand for the public.
- Through this project, it is expected that the period of time and extent of drought will be predicted by the estimation method of soil moisture content at each crop growth stage in cultivation area of Tongatapu.
- As agricultural water management information will be provided for efficient water supply planning, preemptive response to drought and stable crop production will benefit from the provided information.

V Tonga Project Timeline

APCC
APEC CLIMATE CENTER

Tonga Water Project

Project Main Activities and Timeline

Activity (Water)	2017											
	J	F	M	A	M	J	J	A	S	O	N	D
1. Project design												
2. Data collection												
3. Selecting target areas and survey												
4. Installing monitoring system and data collection												
5. Developing climate-smart groundwater information system												
6. Developing seasonal forecasting system and risk assessment												
7. Recommendations of water policy and long-term plan												
8. Workshop and training												
9. Writing and submit a year-end report (1st year)												

Activity (Agriculture)	2017											
	J	F	M	A	M	J	J	A	S	O	N	D
1. Project design												
2. Data collection												
3. Selecting target areas												
4. Installing monitoring system and data collection												
5. Survey of soil properties and Estimating soil hydraulic parameters												
6. Developing soil moisture content estimation technology												
7. Estimating crop water consumption and effective soil moisture content												
8. Workshop and training												
9. Writing and submit a year-end report (1st year)												

Thank you for your attention!

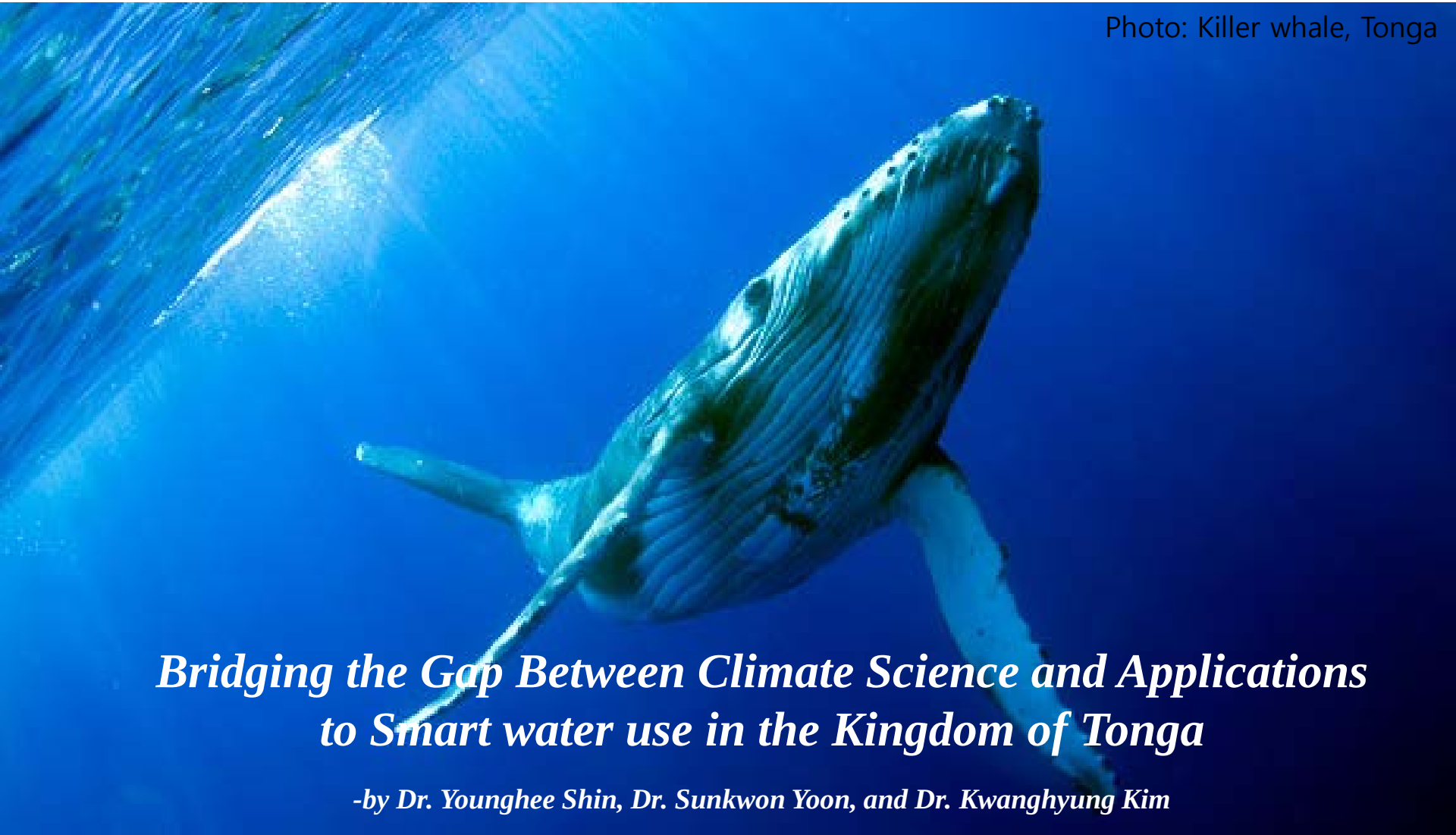


Photo: Killer whale, Tonga

Bridging the Gap Between Climate Science and Applications to Smart water use in the Kingdom of Tonga

-by Dr. Younghee Shin, Dr. Sunkwon Yoon, and Dr. Kwanghyung Kim

Development of smart groundwater management system in the Kingdom of Tonga: utilizing climate information in response to shortage of water

March 8, 2017

Sunkwon Yoon, Ph.D.

APEC CLIMATE CENTER

Contents

- Project Overview
- Project Main Outputs
  - Tonga Climate Change Assessment
  - Installation of GW Monitoring System
  - Development of GW Flow Model
  - Web Based GW Information System
- Future Work

I Project Overview

Project Background

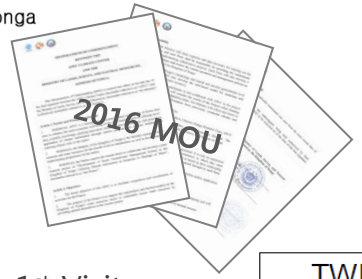
- The Kingdom of Tonga face diverse and difficult water challenges
- For example, the supply and demand of water resource in Tonga is regionally biased and the quantity and quality of it are at high risk due to the pollution and depletion of surface water as well as seawater intrusion
- These facts affect Tonga, putting it in a very vulnerable status in obtaining sustainable water resources
- By developing climate-smart groundwater information system for water resources, Tongan community members and decision makers will be better understanding and implementation for sustainable water use and management

Background of Tonga Water Project

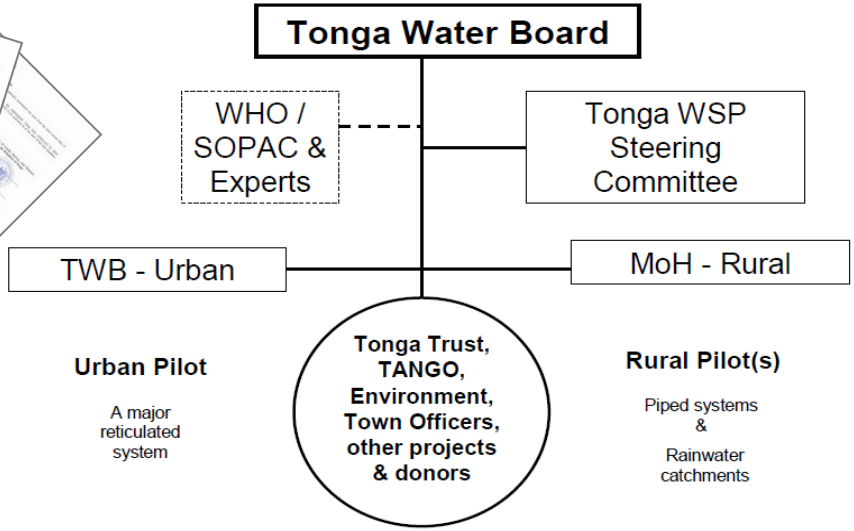
Initiative Tonga Water Project and MOU

2016 ROK-Tonga Water Management Project

Development of smart groundwater management system in the Kingdom of Tonga



- Jun. '15: APCC-Tonga Delegation Meeting
- Dec. '15: MOU Discussion and Field Survey – 1st Visit
- Feb. '16: Project MOU between APCC and Tonga
- Mar. '16: Start the 2016 Tonga Water Project
- Jul. '16: Installation of Sensors and Server – 2nd Visit
- Mar. '17: APCC-Tonga joint Workshop @ TONGA



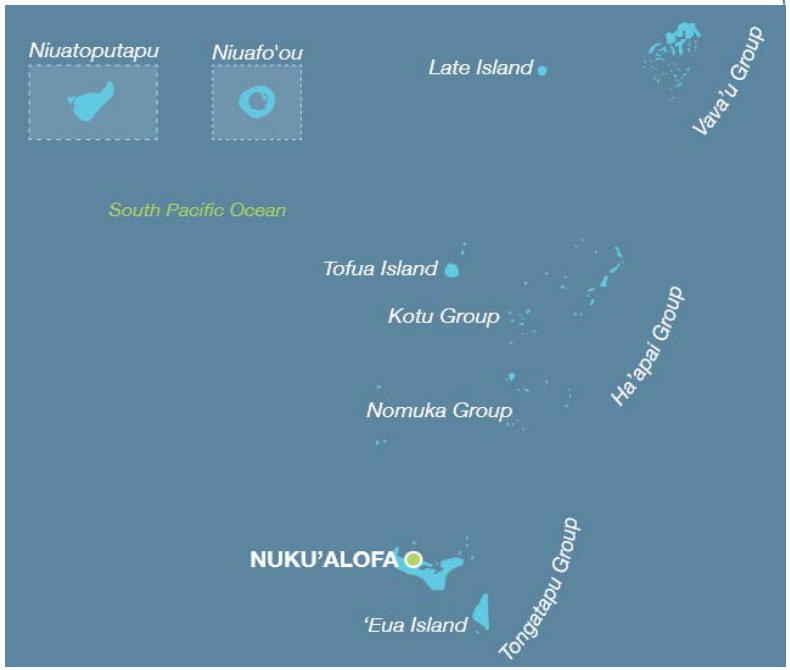
Delegation Meeting @ APCC

Background of Tonga Water Project

Tonga Water Project Overview

❖ Project Outline

- ❍ Partner country : Kingdom of TONGA
- ❍ Period : Mar. 2016 ~ Dec. 2016 (9 months)
- ❍ Tentative Budget : USD 150,000 -1st year
- ❍ Potential Participants : APCC, Dong-a Univ., Hydronet (Univ. of Seoul)



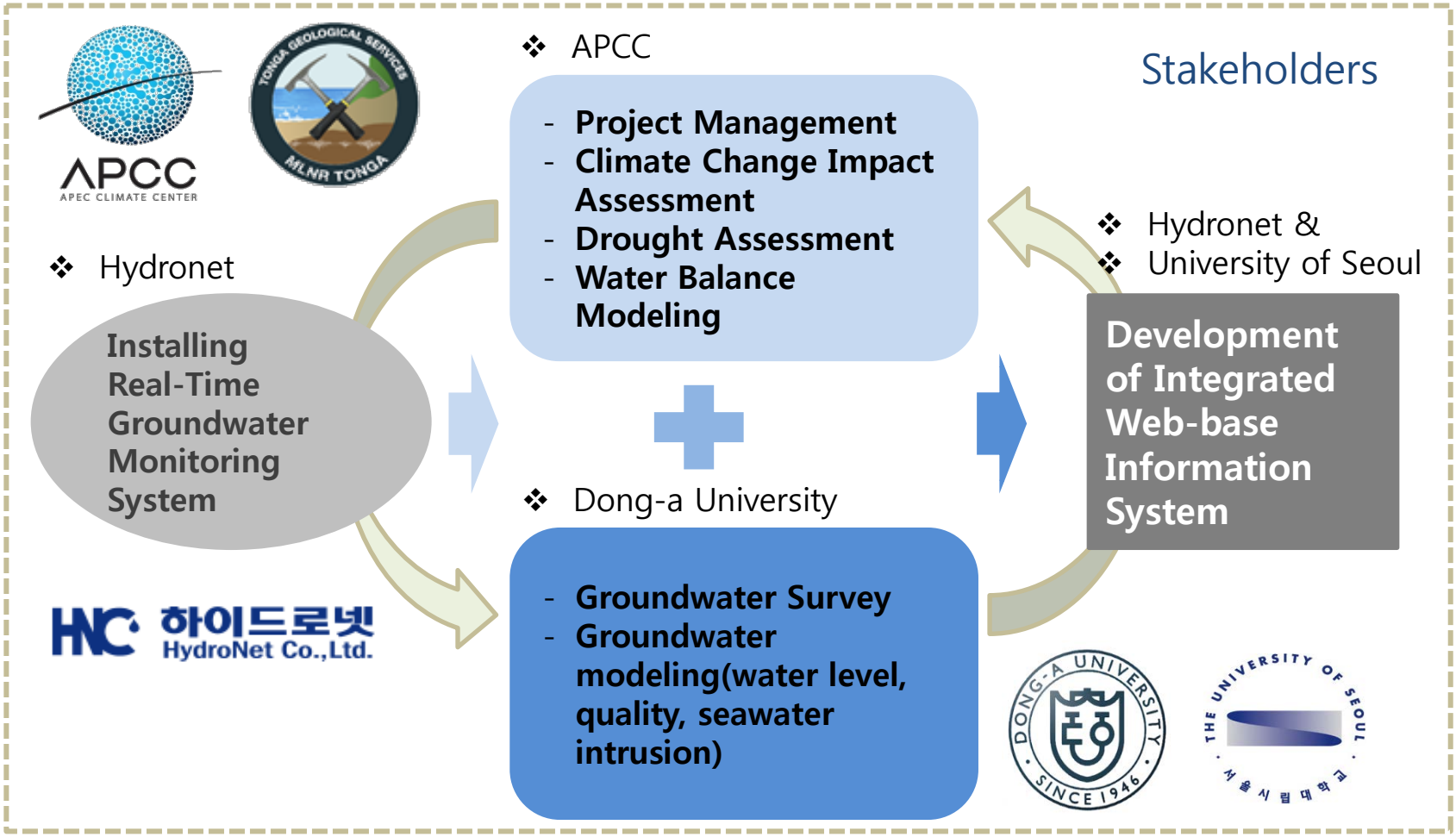
❖ Technical Road Map (TRM)

1st (2016-year)	2nd (2017-year)	3rd (2018-year)
Installation, GW Modeling, and Web GIS-based Monitoring System	Development of Advanced GW Information System and Seasonal Forecasts	Climate-Smart Water Information System for Decision Support and Service

Background of Tonga Water Project

2016 Tonga Water Project Design

APCC+Tonga MLNR(Ministry of Lands, Survey and Natural Resources)



Background of Tonga Water Project

Status of Tonga Water Resources

Source: (http://www.pacificwater.org/pages.cfm/country-information/tonga.html)

Tonga

Home > Country Information > Tonga

Geography

Total Area	748 km^2
Land	718 km^2
Water	30 km^2
Highest Elevation	1,033 m

Land Use

Arable	20%
Perm. Crop	14.67%
Other	65.33% (2005)

People

Population	116,921 (July 2007 est.)
Population Growth Rate	1.847% (July 2007 est.)

Economy

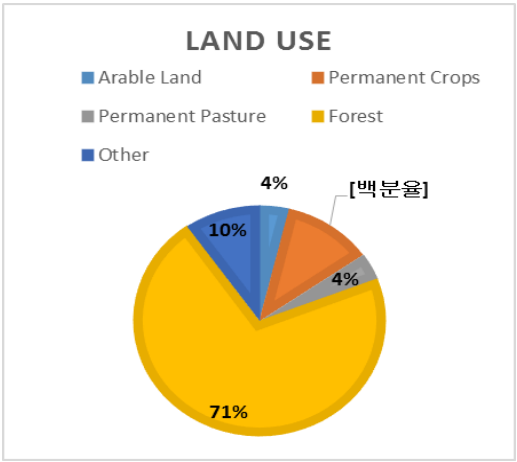
GDP per capita (PPP)	$2,200 (2005 est.)

Water Statistics

Avg Rainfall	Varies from north to south of Tonga with an estimated average of 2500 mm per annum

Problems with Water Resources

- Wastewater management and pollution control
- Information exchanges on water resources



Source of Water	Drinking water coverage estimates					
	Urban (%)		Rural (%)		Total (%)	
	1990	2015	1990	2015	1990	2015
Piped onto premises	--	73	--	80	--	78
Other improved source	97	100	99	100	99	100
Other unimproved	3	0	1	0	1	0
Surface water	--	0	--	0	--	0

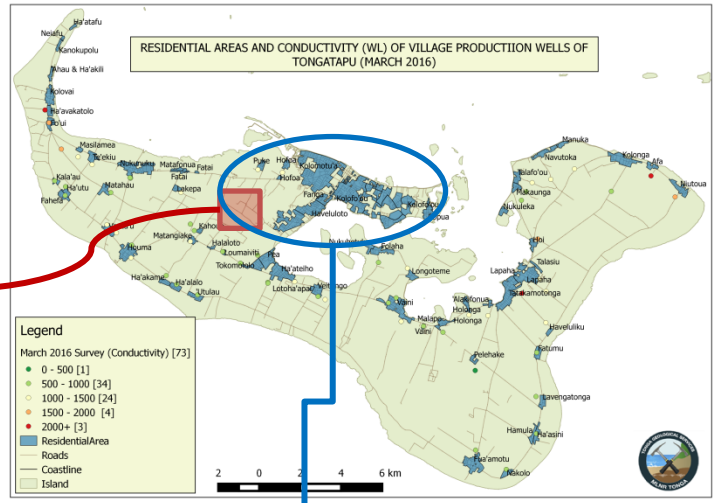
Background of Tonga Water Project

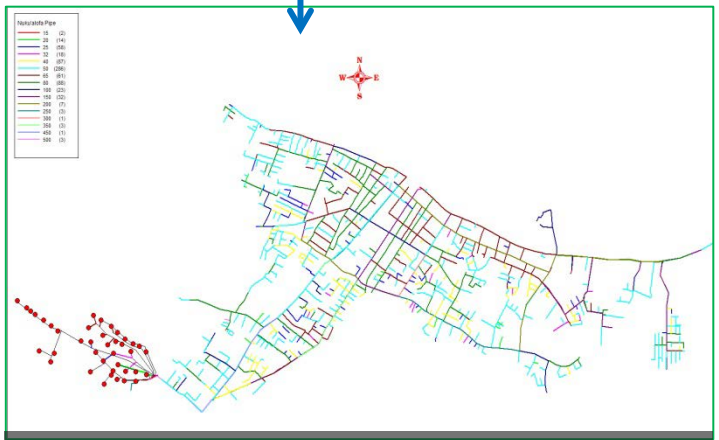
Urban & Rural Water Distribution System

Urban

Concrete Reservoir

Groundwater
Pipe Line System





Nuku'alofa Pipeline System

Rural

Elevation Header Tank

Rainwater
Harvesting

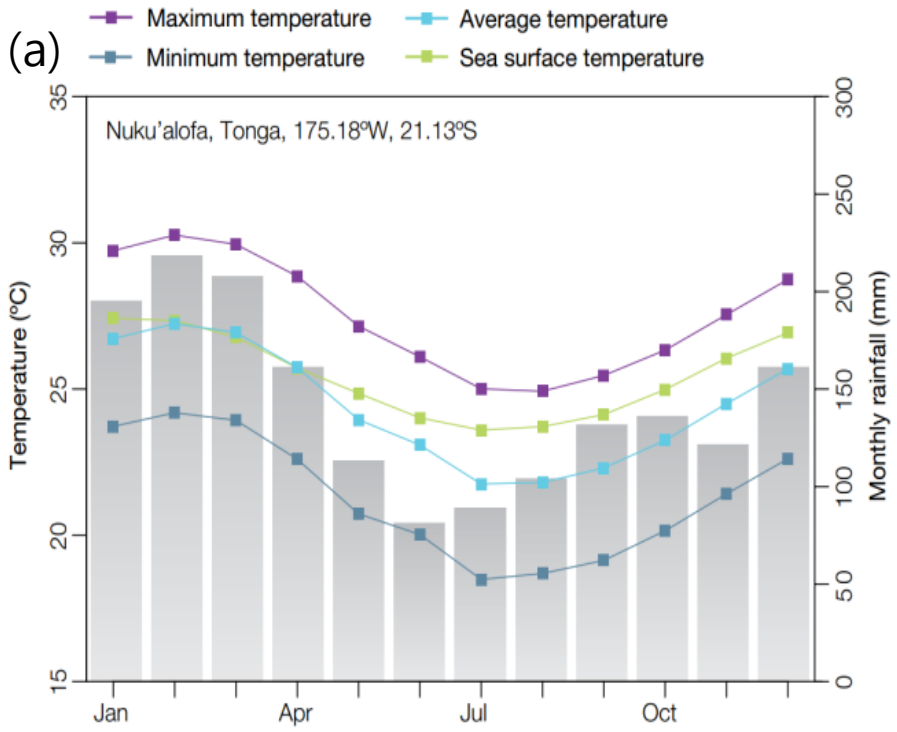
II Project Main Outputs

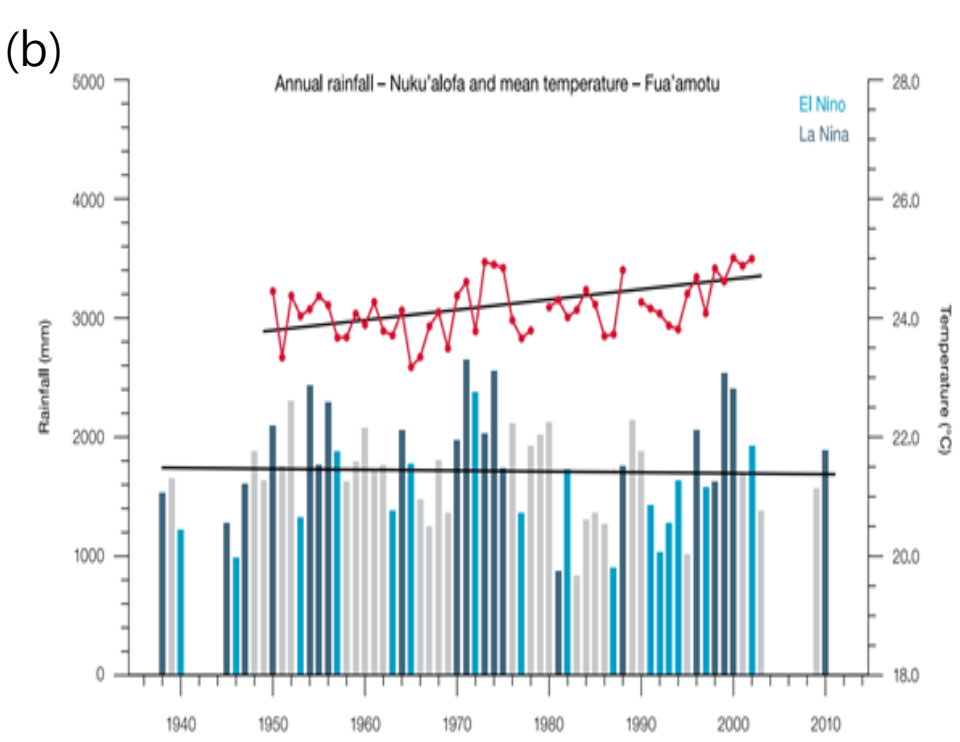
- Tonga Water Status and Changing Climate
- Installation of GW Monitoring System
- Development of Tonga GW Flow Model
- Web Based GW Information System

APCC
APEC CLIMATE CENTER

Climate: Historical Observed Data

(a) Shows seasonal variability of rainfall and temperature, and (b) shows variation of annual rainfall and temperature during El Niño and La Niña in Tongatapu. (PCCSP, 2014)



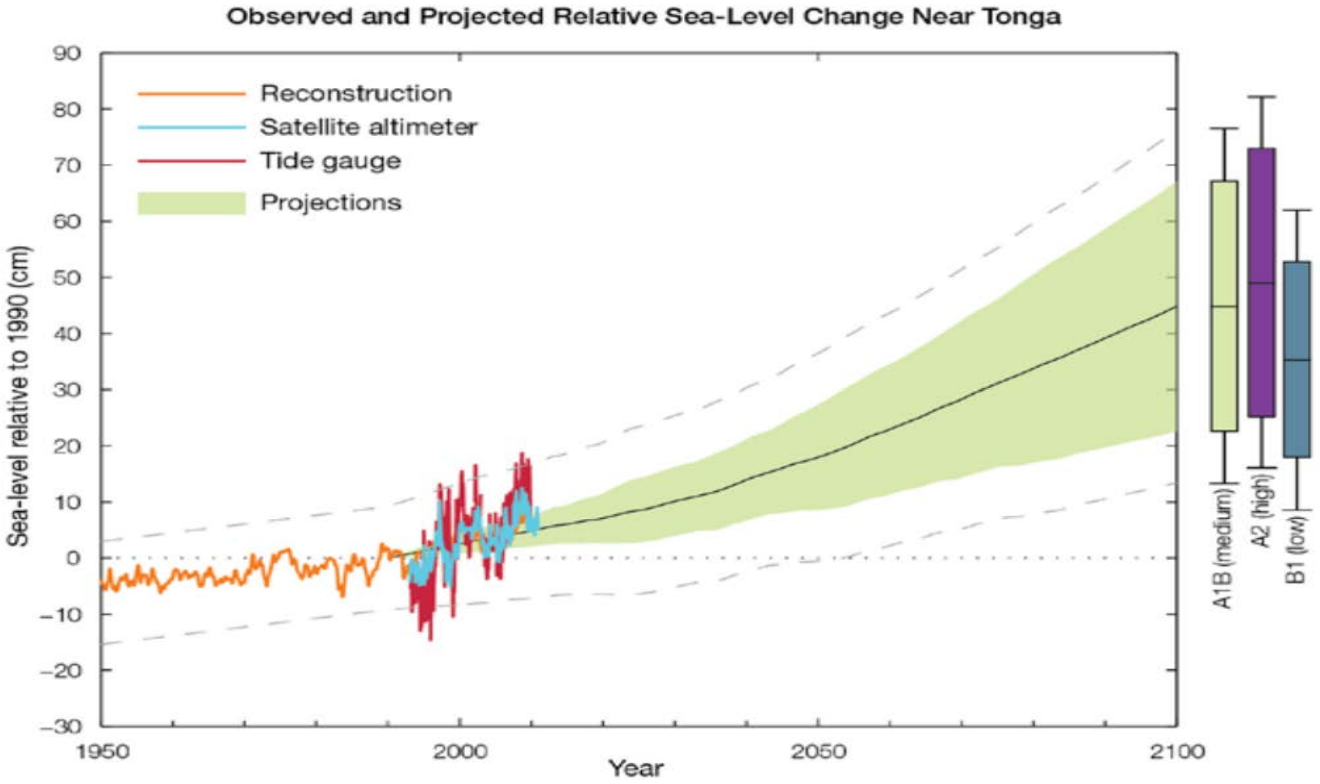


(Source: PCCSP Report, (2014), Current and Future Climate of Tonga, Australian Government)

Sea Level Rise under Climate Change

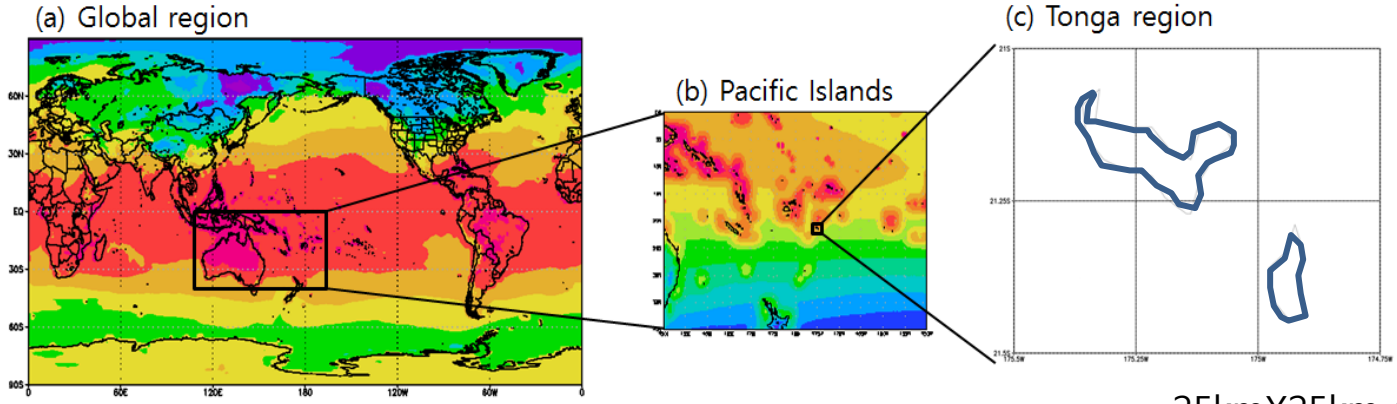
Observed and Projected relative sea level change

(PCCSP, 2014)



(Source: PCCSP Report, (2014), Current and Future Climate of Tonga, Australian Government)

Climate Change in Tongatapu



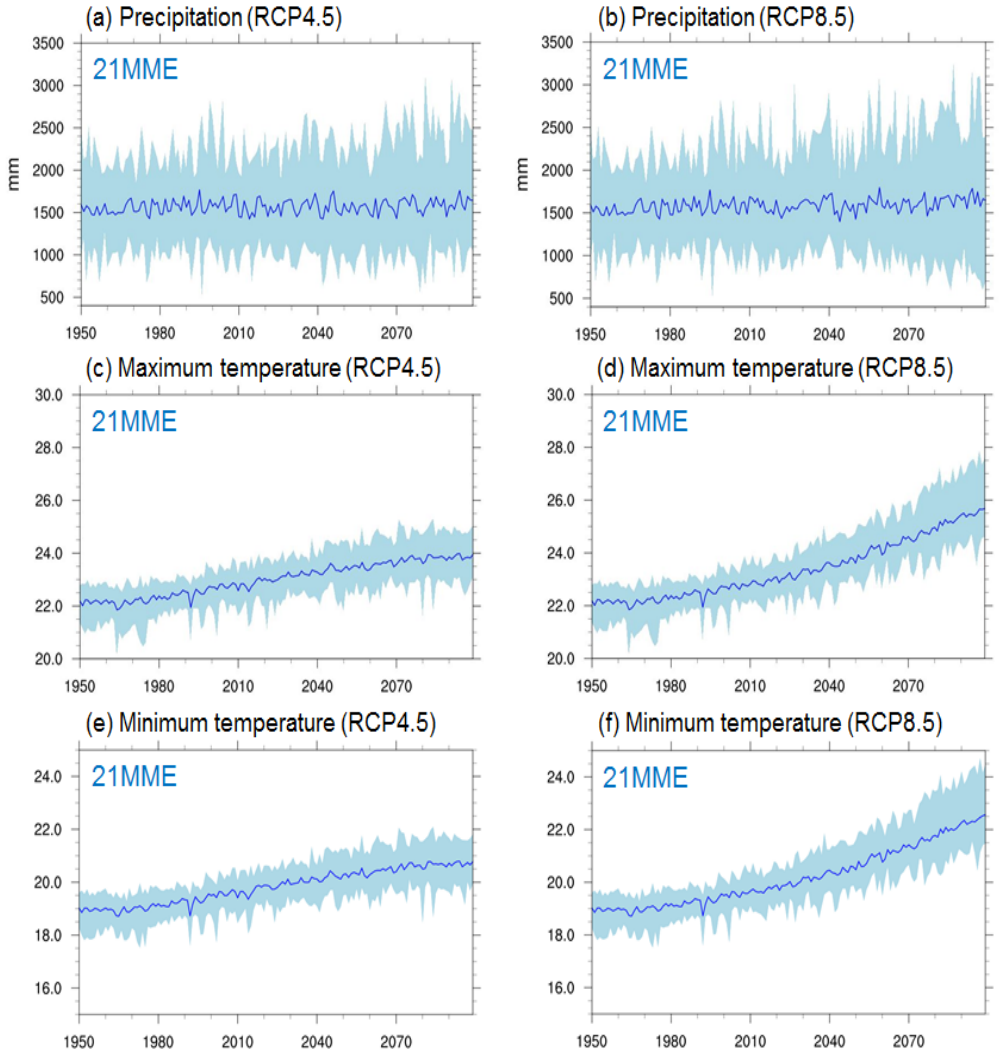
25kmX25km Grid Matrix

No.	Model Name	No.	Model Name
1	ACCESS1-0	12	INMCM4
2	BCC-CSM1-1	13	IPSL-CM5A-LR
3	BNU-ESM	14	IPSL-CM5A-MR
4	CanESM2	15	MIROC-ESM
5	CCSM4	16	MIROC-ESM-CHEM
6	CESM1-BGC	17	MIROC5
7	CNRM-CM5	18	MPI-ESM-LR
8	CSIRO-MK3-6-0	19	MPI-ESM-MR
9	GFDL-CM3	20	MRI-CGCM3
10	GFDL-ESM2G	21	NorESM1-M
11	GFDL-ESM2M		

- NASA NEX-GDDP: https://cds.nccs.nasa.gov/nex-gddp/

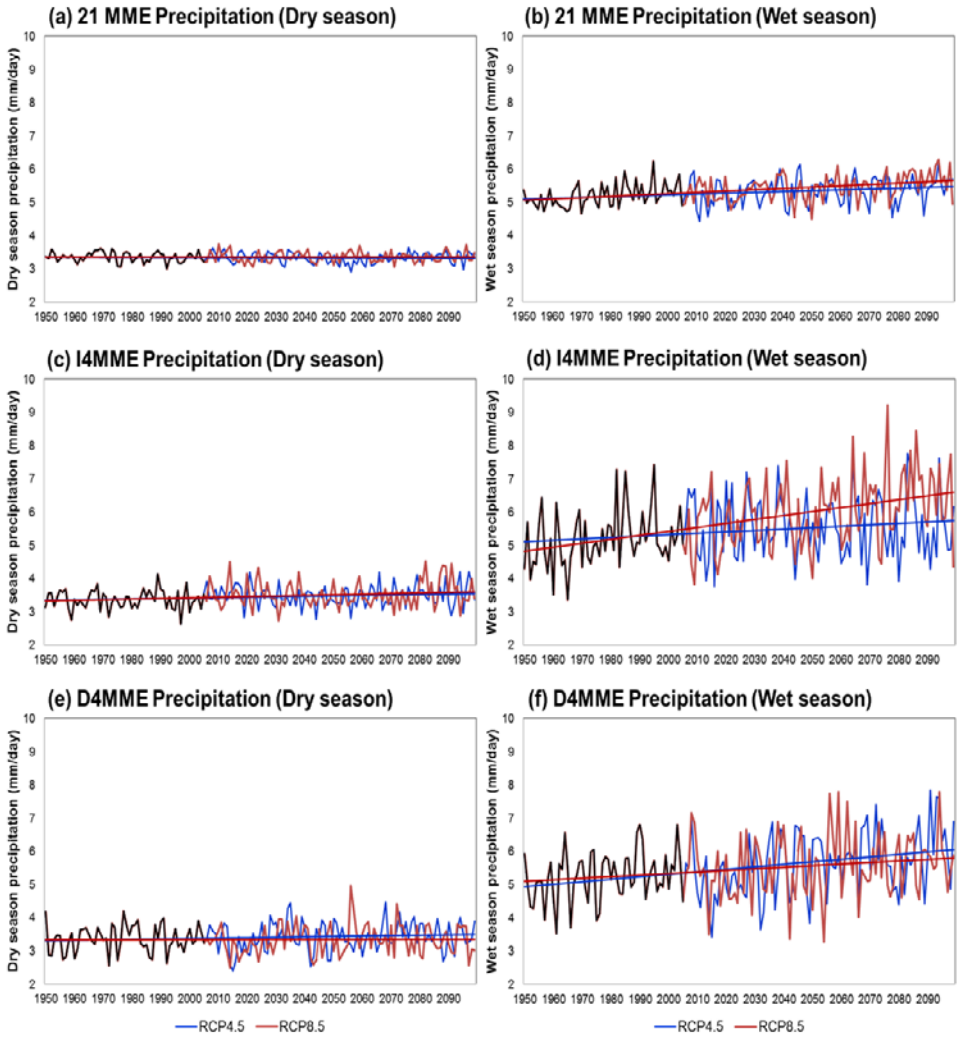
Climate Change in Tongatapu

Time series of (a, b) precipitation, (c, d) maximum and (e, f) minimum temperature during historical and RCP 4.5 (left panels) and RCP 8.5 (right panels). Blue solid line is 21 MME(Multi-Model Ensemble) and shaded sky blue area is range from minimum to maximum among 21 models.



Climate Change in Tongatapu

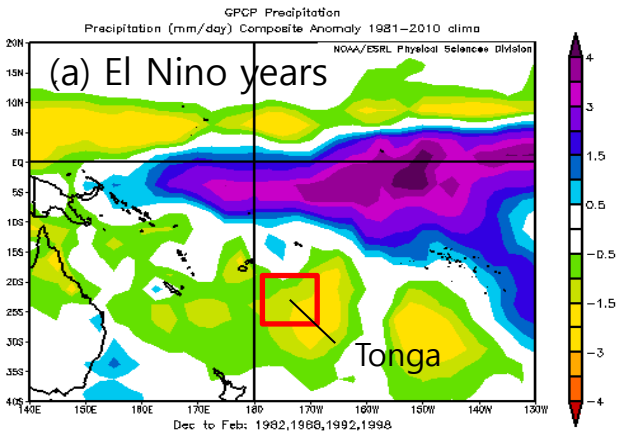
Time series of precipitation of historical and RCP scenarios averaged among (a),(b) 21MME, (c),(d) I4MME and (e),(f) D4MME, respectively. Black solid line is historical variation, blue and red lines are for RCP 4.5 and 8.5 scenario.

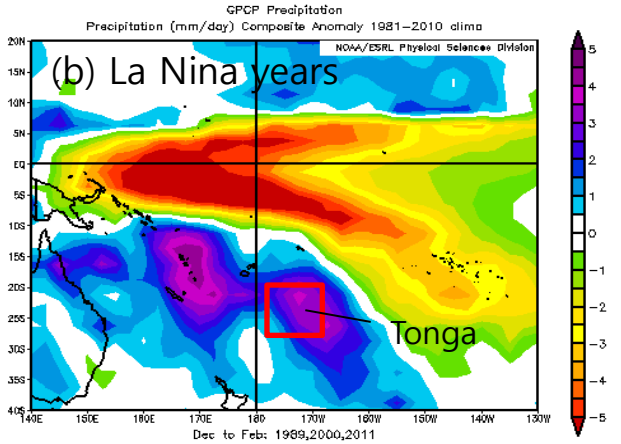


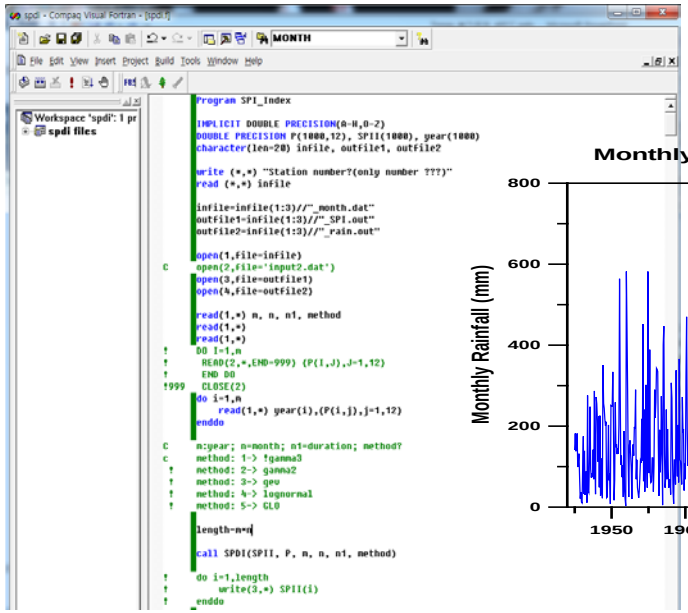
1. Tonga Water Status and Changing Climate

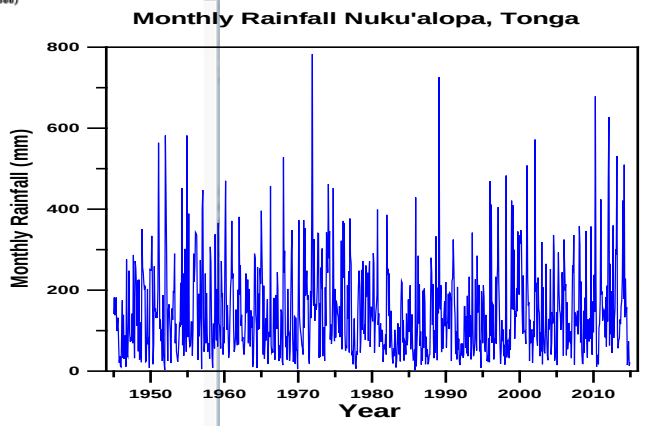
Composite Anomalies and SPI Drought

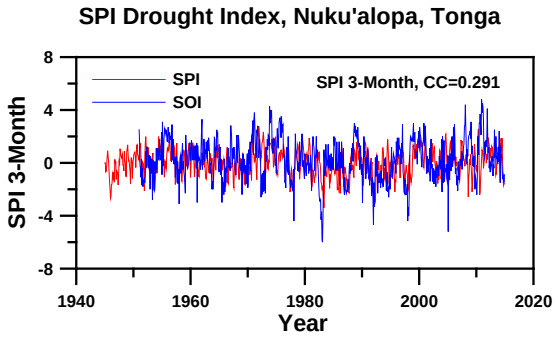
- ENSO/Prcp. teleconnection
- SPI (Standardized Precipitation Index)

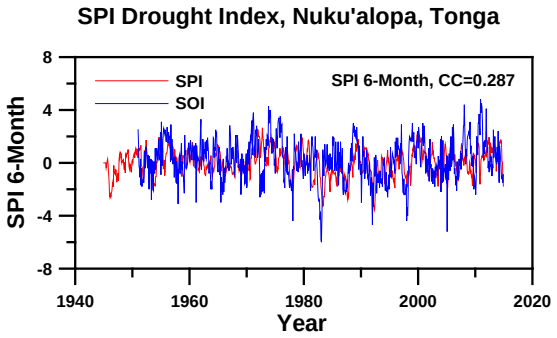






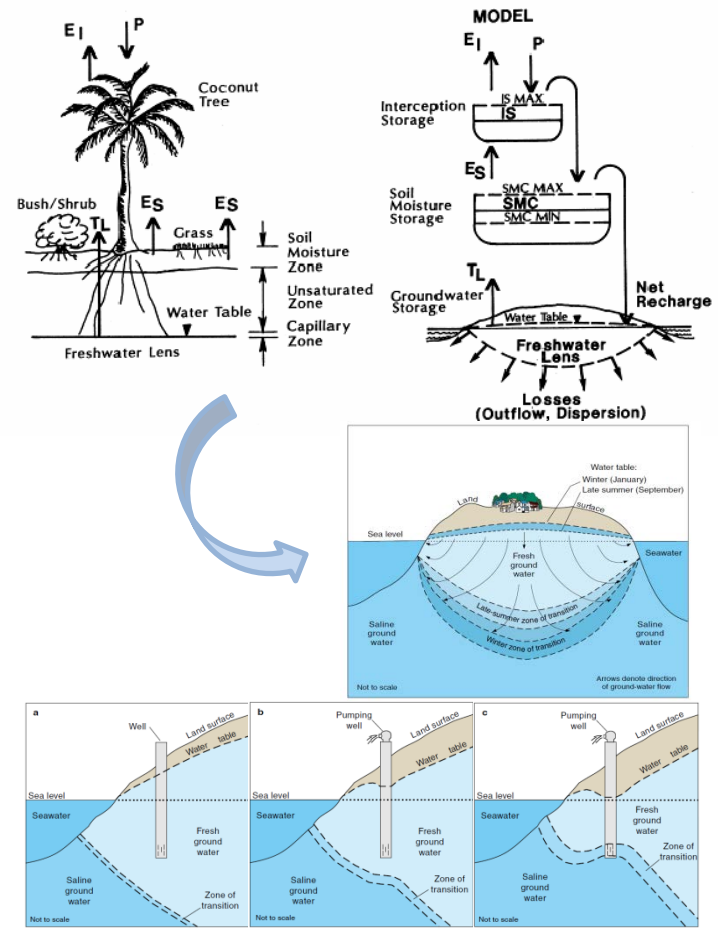






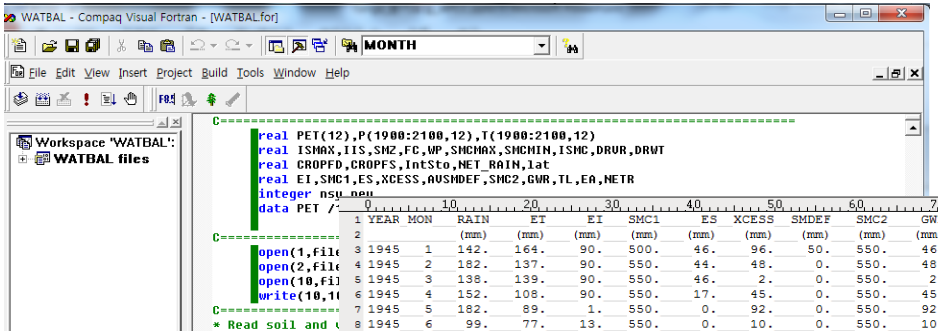
Water Balance Modeling / Recharge Rate

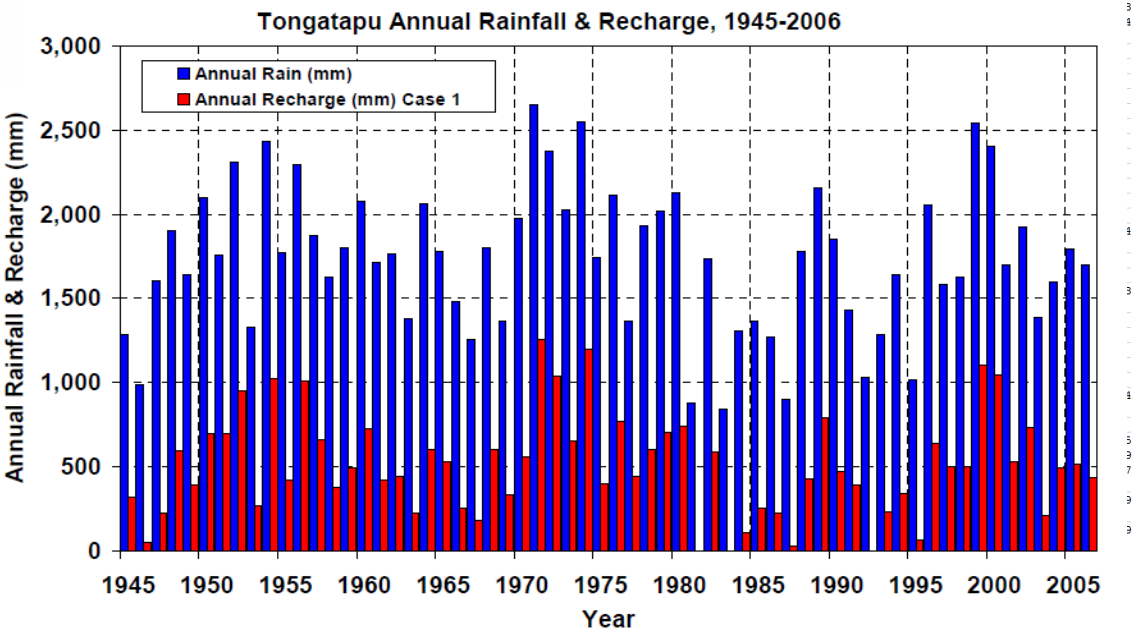
➢ WATBAL modeling



(WATBAL: Falkland & Woodroffe, 1997)

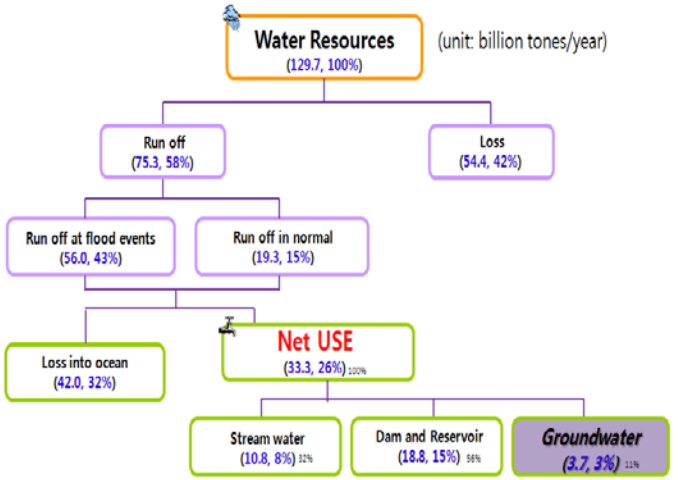
➢ Groundwater Recharge Rate





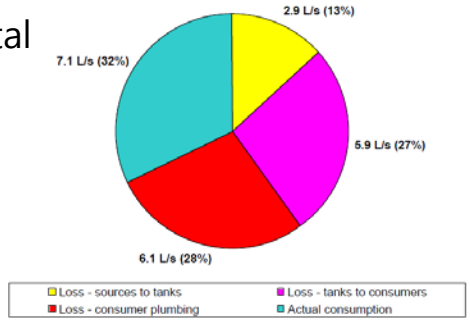
Water Resources and Water Use Survey

- Target Areas: 5-Village (2-Urban/3-Rural)
- Survey: July, 3-13, 2016 (50-Household)
- Interview: Tonga MLSNR Office
- Contents:
  - Total Water Resources(Rainwater, Groundwater)
  - Total Water Use (Agricultural, Domestic, Industrial, Environmental)
  - Pattern of Water usage and Priority Items



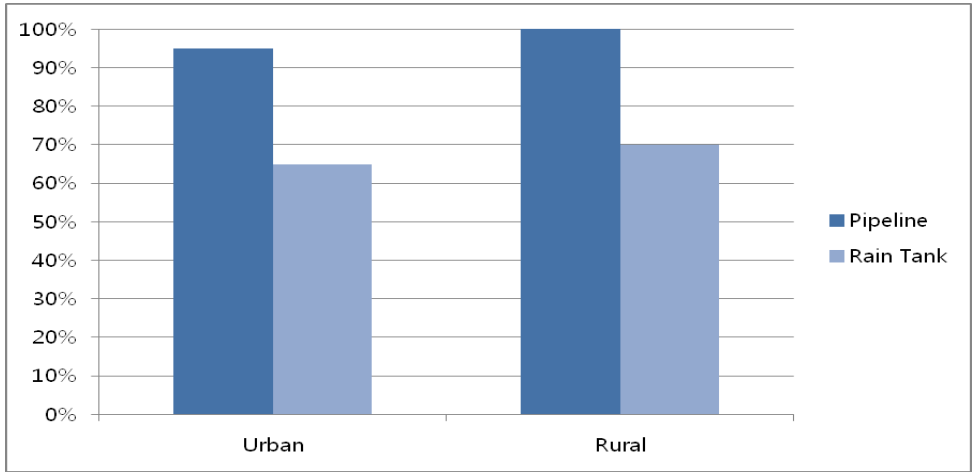
Water Use / Demand Estimation

Distribution of the total supply from sources

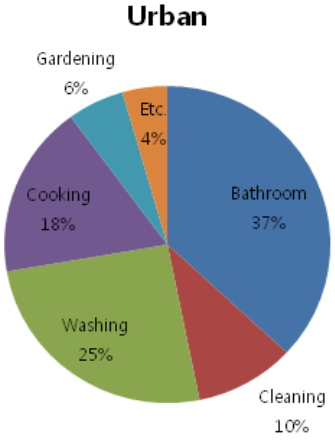


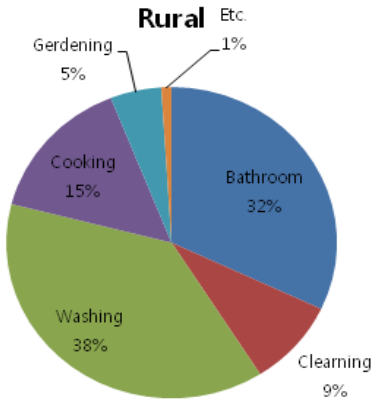
Water Resources and Water Use Survey

- Result of how water is accessed

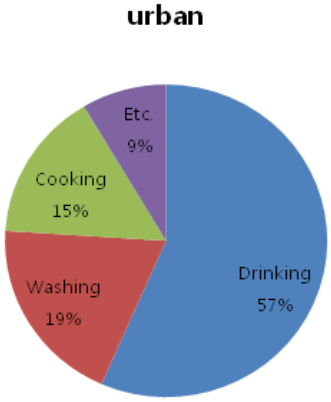


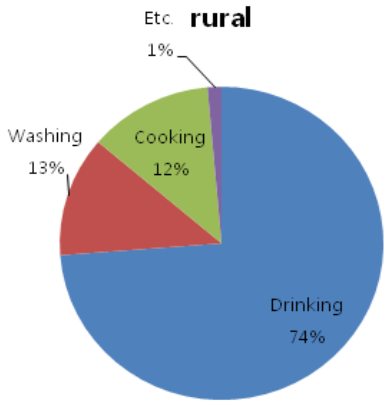
- Result of groundwater usage





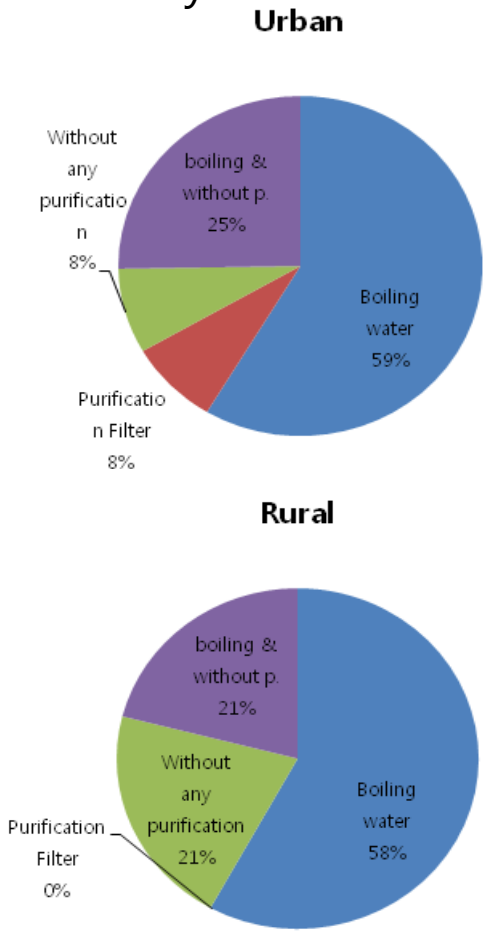
- Result of rain water usage



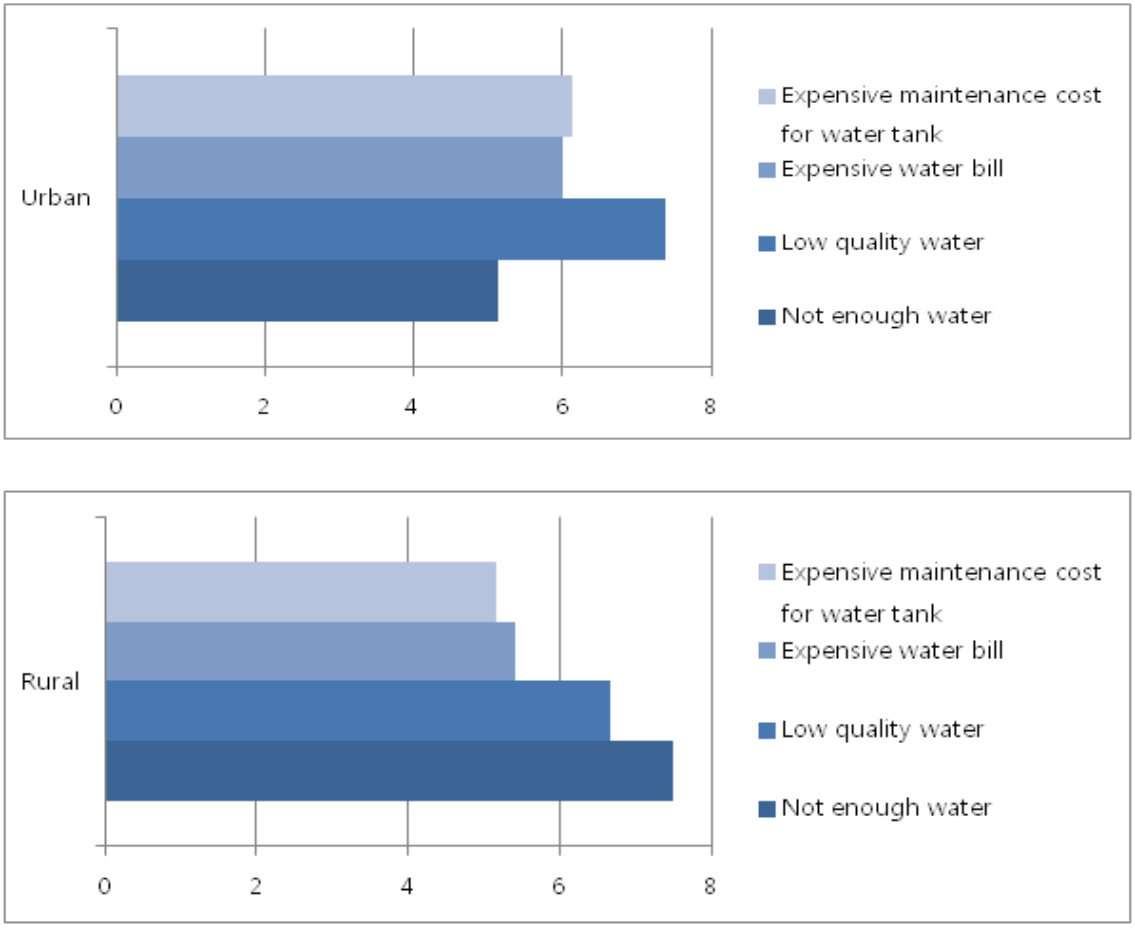


Water Resources and Water Use Survey

➢ Result of how to drink water safely



➢ Result of priority items to be address



Real-Time Groundwater Monitoring System

Sensor

Water Level (depth), Temperature, Electrical Conductivity (EC), Flash Memory (4Mbyte), Internal Lithium Battery

Data Logger

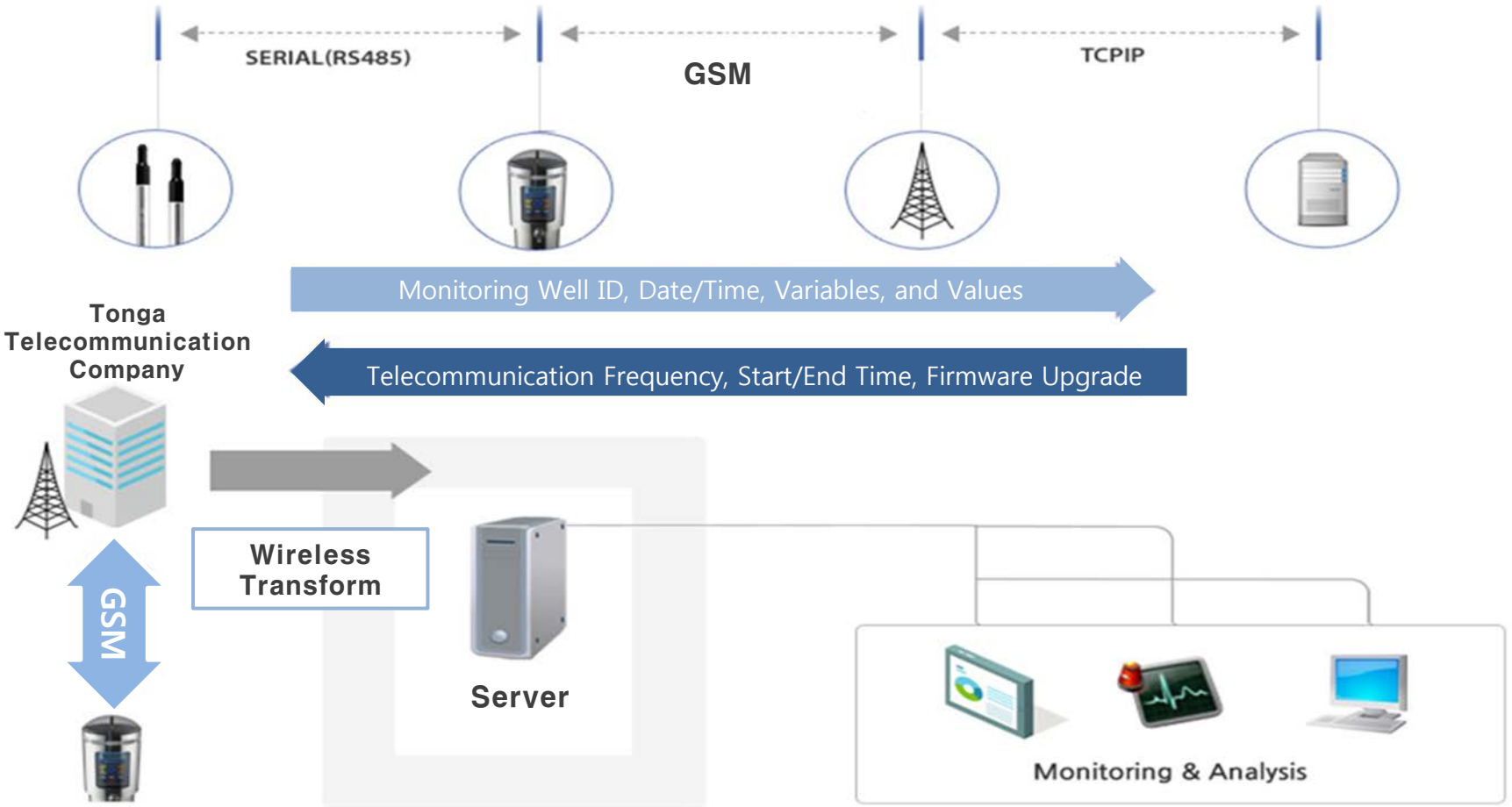
High performance, Low Power Consumption, LCD Monitoring System, and Inner Battery (14.4V Lithium 19Ah)

STU-CAP

Solar Charging Device, Wireless Communication, Saving Space, and Comport Install and Maintain System

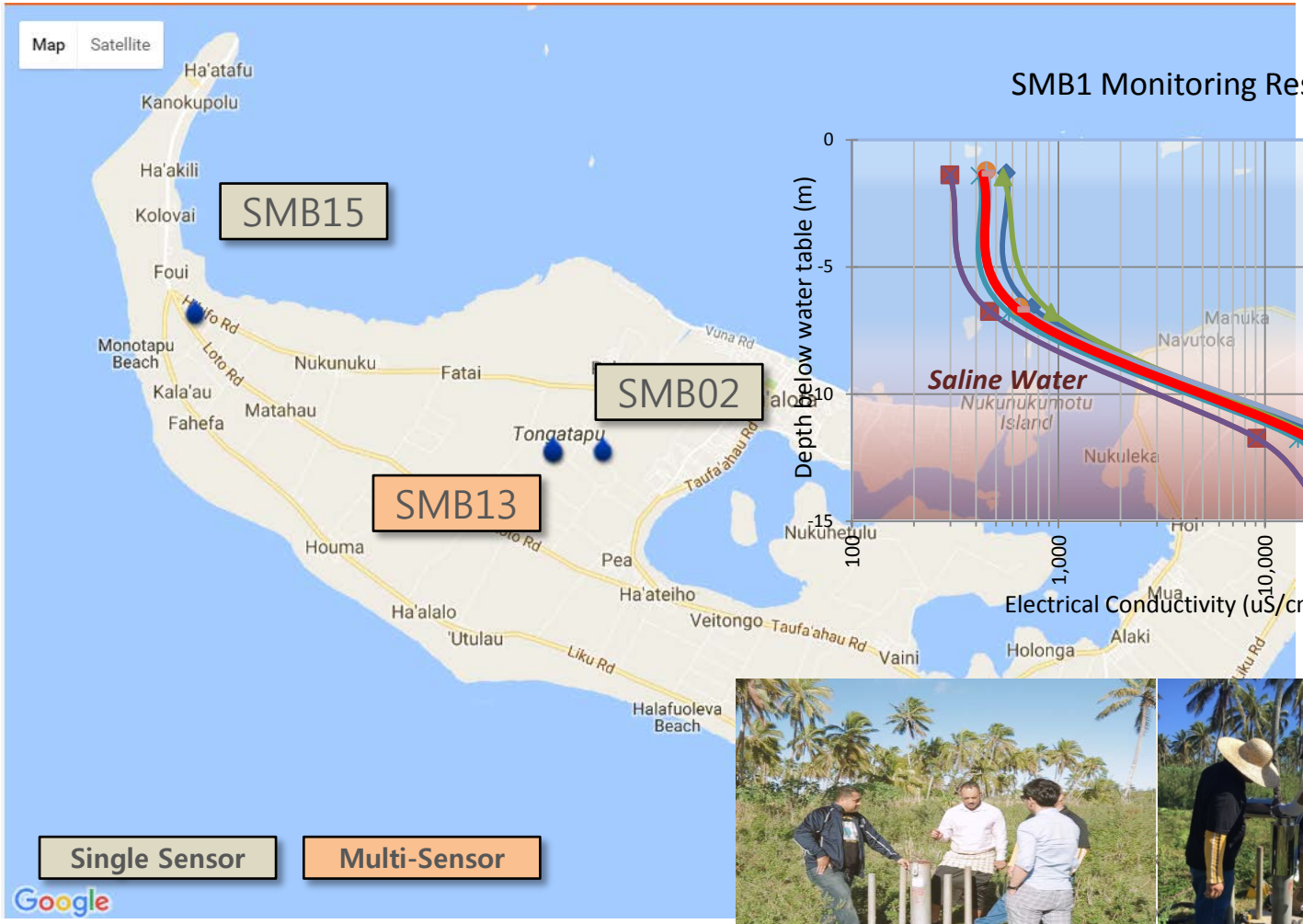
Real-Time Groundwater Monitoring System

Wireless Telecommunication System for Real-Time Groundwater Monitor



2. Installation of GW Monitoring System

Real-Time Groundwater Monitoring System



Installation of the Real-Time Groundwater Monitoring System

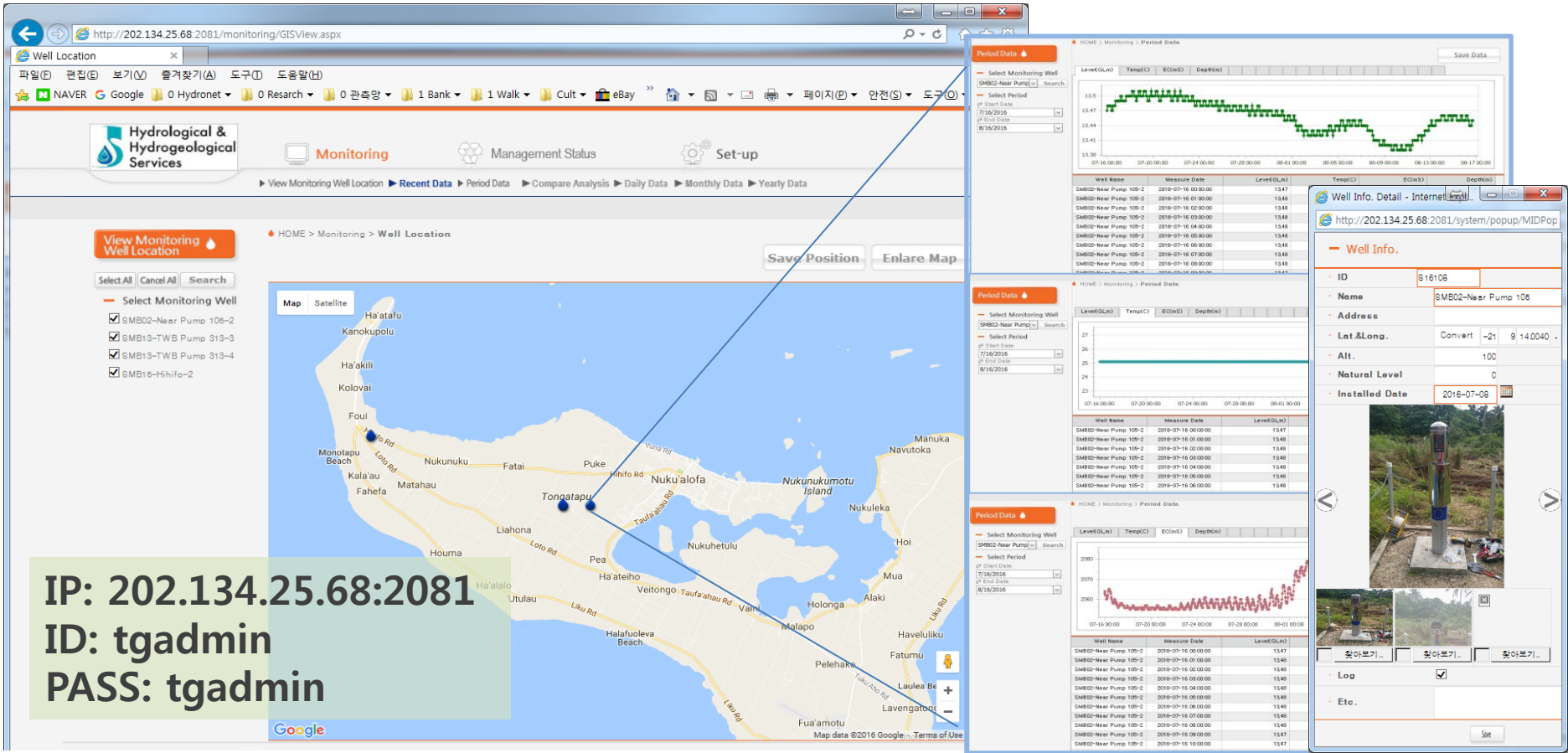
Real-Time Groundwater Monitoring System

The real-time groundwater monitoring systems are installed in the Salinity Monitoring Boreholes (SMBs) in the Island of Tongatapu

SMB 02	SMB 13	SMB 15
Mataki 'Eua well field	Mataki 'Eua well field	Hihifo well field
		
Tube No. 2 Depth (m) : 20 Water Level (GL.m) : 13.47	Tube No. 3 and No.4 Depth (m) : 26, 30 Water Level (GL.m) : 13.32	Tube No. 2 Depth (m) : 16 Water Level (GL.m) : 7.53

Real-Time Groundwater Monitoring System

- Demonstration: Real-Time Groundwater Management System
- Observation Data: Level(GL.m), Temp(C), EC(mS), Depth(m)



Tonga Groundwater Flow Model (ToGFlow)

Model Characteristics

- Objective:
  Simulation of Groundwater Flow
- DUSWIM
- Two Phase
- Quasi Three dimensional
- Sharp Interface FEM
- Steady State

Model Geometry

- Original Geometry
- Coordinate Rotation and Translation are needed
- Non uniform mesh 100 m X 100 m;
  25 m X 25 m in well field
- Elements: 89200 and Nodes:89824
- Coastal Boundary

Governing Equations

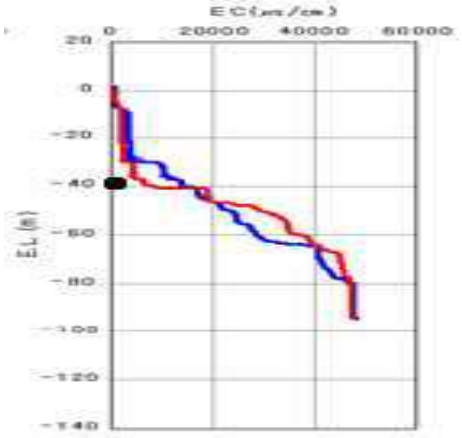
$$\frac{\partial}{\partial x_i}\left[K_{ij}^f \; b^f \; \frac{\partial h^f}{\partial x_j}\right] + \alpha_T^f \lambda'^f h^f + \alpha_B^f \lambda'^f h^f$$

$$= b^f S_s^f \frac{\partial h^f}{\partial t} - \theta \frac{\partial \xi}{\partial t} - Q^f \qquad (i,j=1,2) \qquad (1)$$

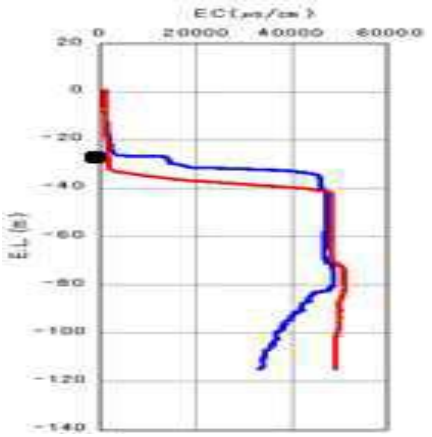
$$\frac{\partial}{\partial x_i}\left[K_{ij}^s \; b^s \; \frac{\partial h^s}{\partial x_j}\right] + \alpha_T^s \lambda'^s h^s + \alpha_B^s \lambda'^s h^s$$

$$= b^s S_s^s \frac{\partial h^s}{\partial t} + \theta \frac{\partial \xi}{\partial t} - Q^s \qquad (i,j=1,2) \qquad (2)$$

Dispersion



Advection



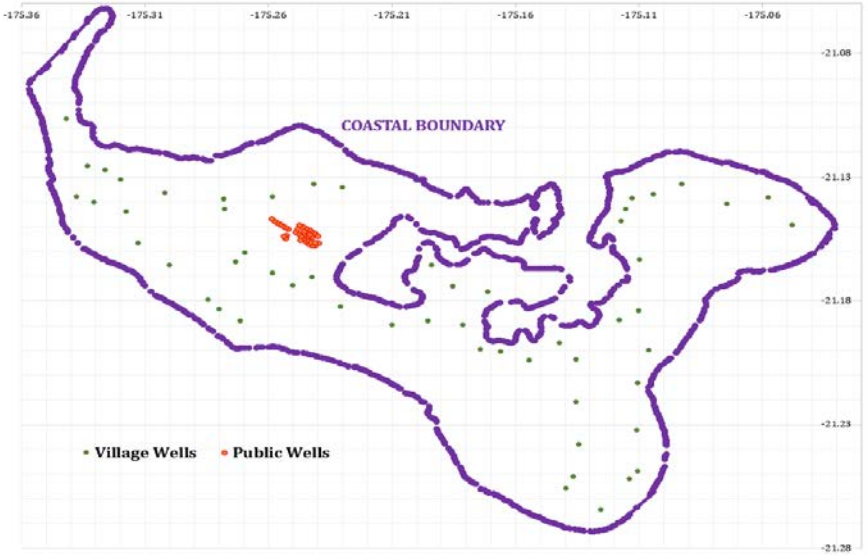
Tonga Groundwater Flow Model (ToGFlow)

Assumptions

- Darcy's law
- Constant densities & dynamic viscosities
- Flow in areal plane
- Single porous continuum.
- Unconfined Homogeneous and Isotropic Aquifer
- Porosity 0.3; Thickness 40 m
- Steady & uniform recharge rates
- Steady pumping
- No Tidal Effects
- Fangauta Lagoon : coastal boundary
- Annual average recharge : 570 mm

Groundwater Withdrawal

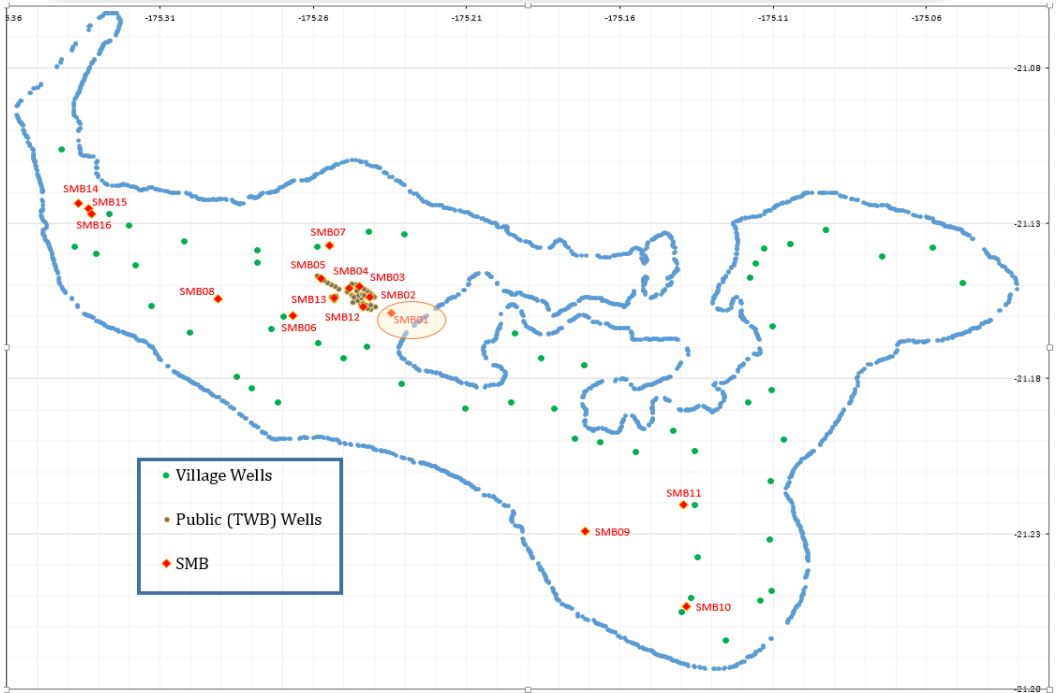
- Estimated steady pumping
- 39 Public wells 250 m^3/day
- 56 Village wells 125 m^3/day

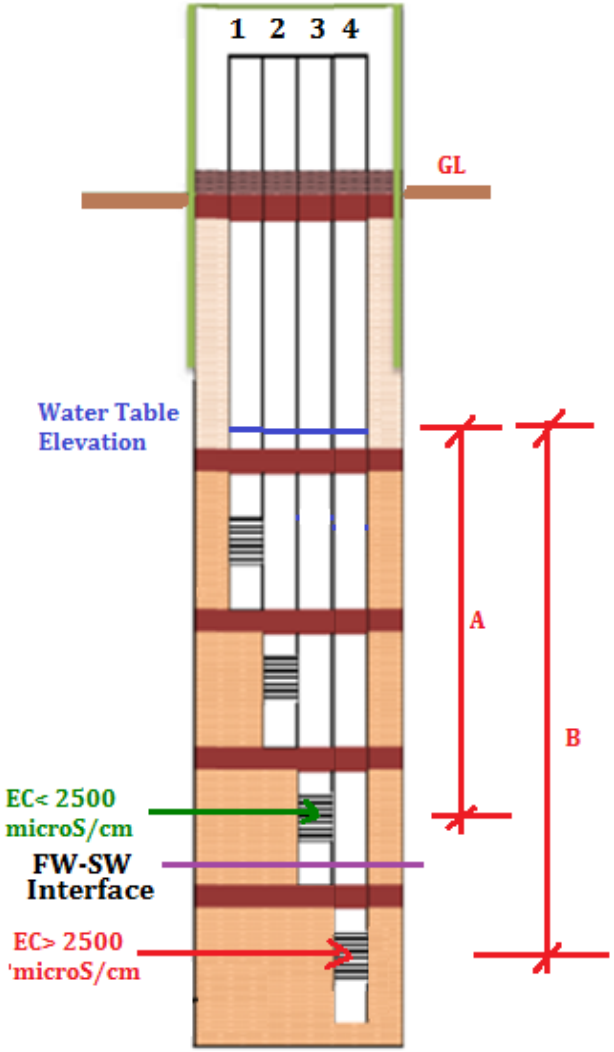


Tonga Groundwater Flow Model (ToGFlow)

Calibration and Validation

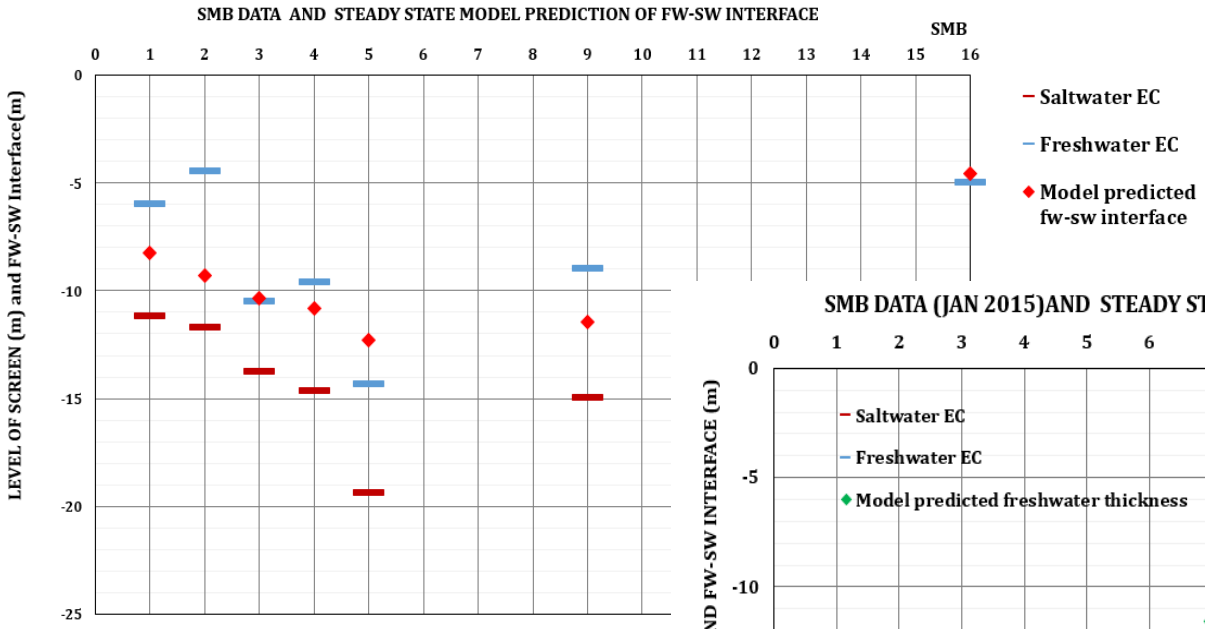
- ❑ Freshwater-Saltwater interface
- ❑ SMBs with constant FW-SW interface
- ❑ K value 3600 m/day
- ❑ Validation - January 2015 data



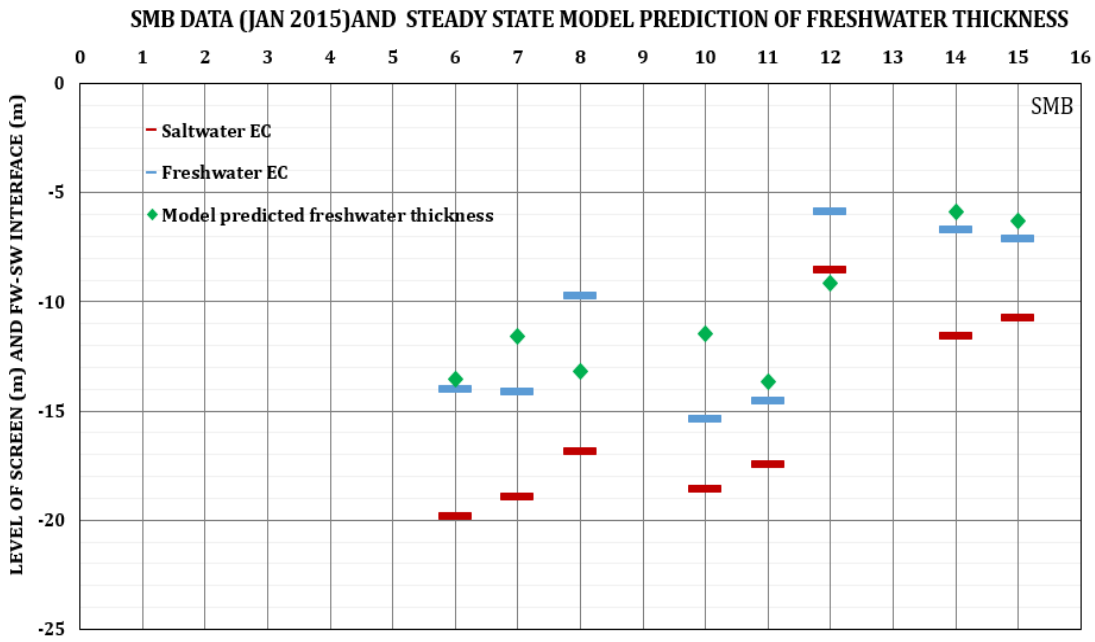


Tonga Groundwater Flow Model (ToGFlow)

➢ Calibration of model with 16-SMB observed data



➢ Validation of Model



Tonga Groundwater Flow Model (ToGFlow)

Limitations

- ❑ Assumptions – lack of data
- ❑ Seasonal effects - not considered
- ❑ Tidal effects - not considered

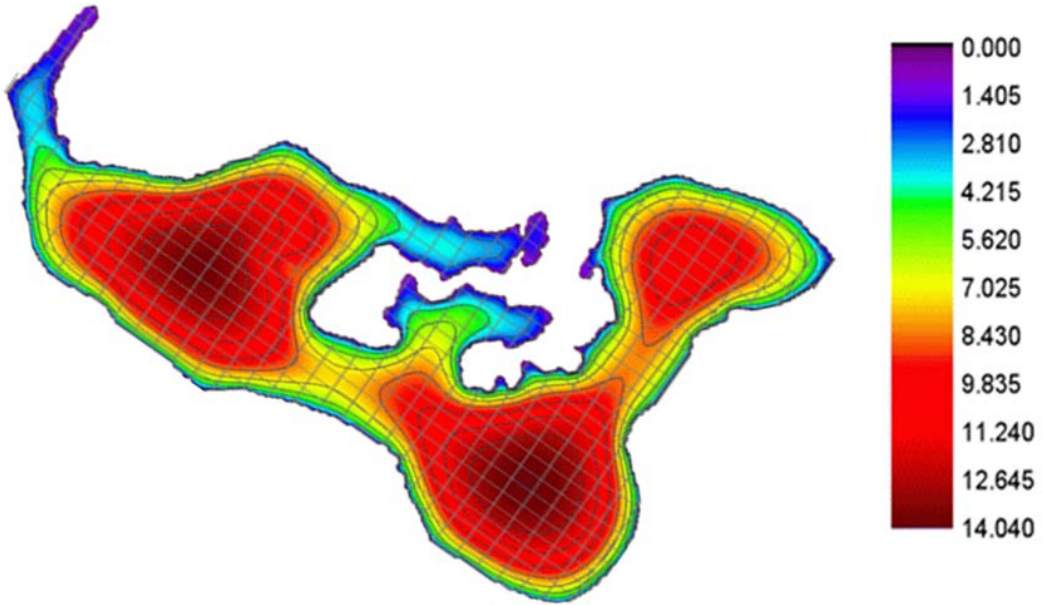
Range Input values

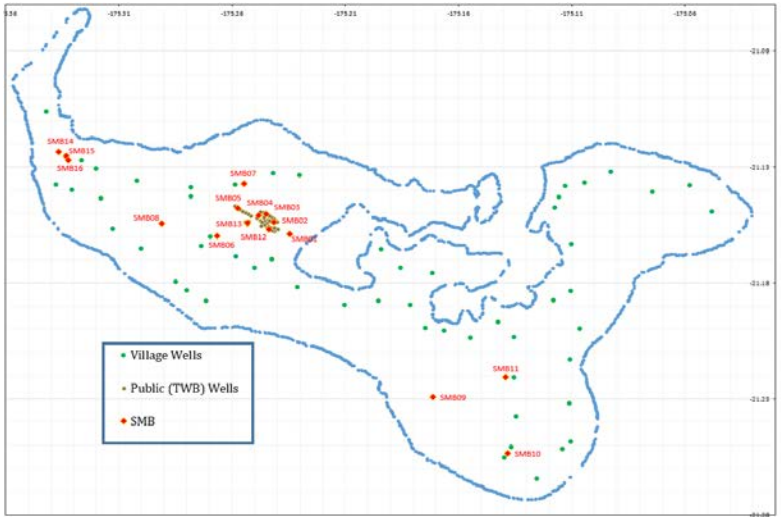
Item	Description	Range of Values	Default Value
1	Hydraulic Conductivity	1500-5000 m/day	3600 m/day
2	Recharge Rate	100-1000 mm/year	570 mm/year
3	Sea Level Rise	0-1 m	0 m
4	Number of wells	upto 450	95
5	Well Screen bottom elevation	upto –10 m	-5.0 m
6	Well screen length	upto 10 m	3.0 m
7	Pumping Rates-Public Wells	50-450 m^3/day	250 m^3/day
8	Pumping Rates-Village Wells	50-450 m^3/day	125 m^3/day
9	Monitoring Wells		16

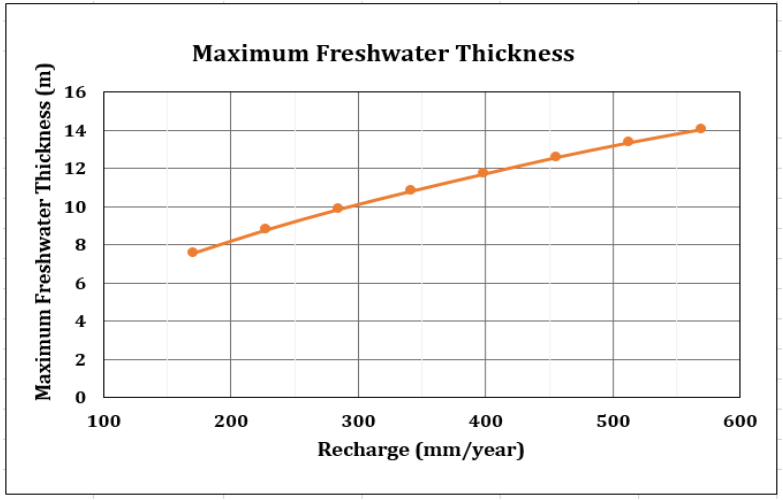
Tonga Groundwater Flow Model (ToGFlow)

Steady state analysis results

➢ Freshwater Thickness (m)

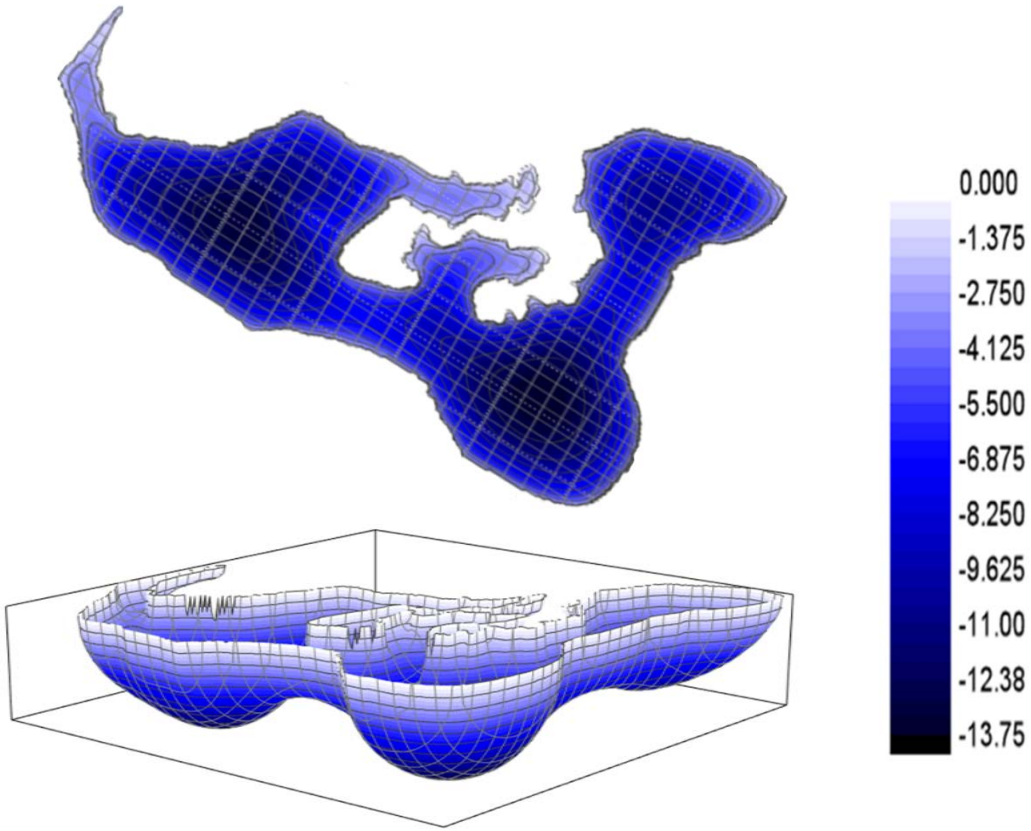






Tonga Groundwater Flow Model (ToGFlow)

Freshwater –Saltwater Interface Elevations



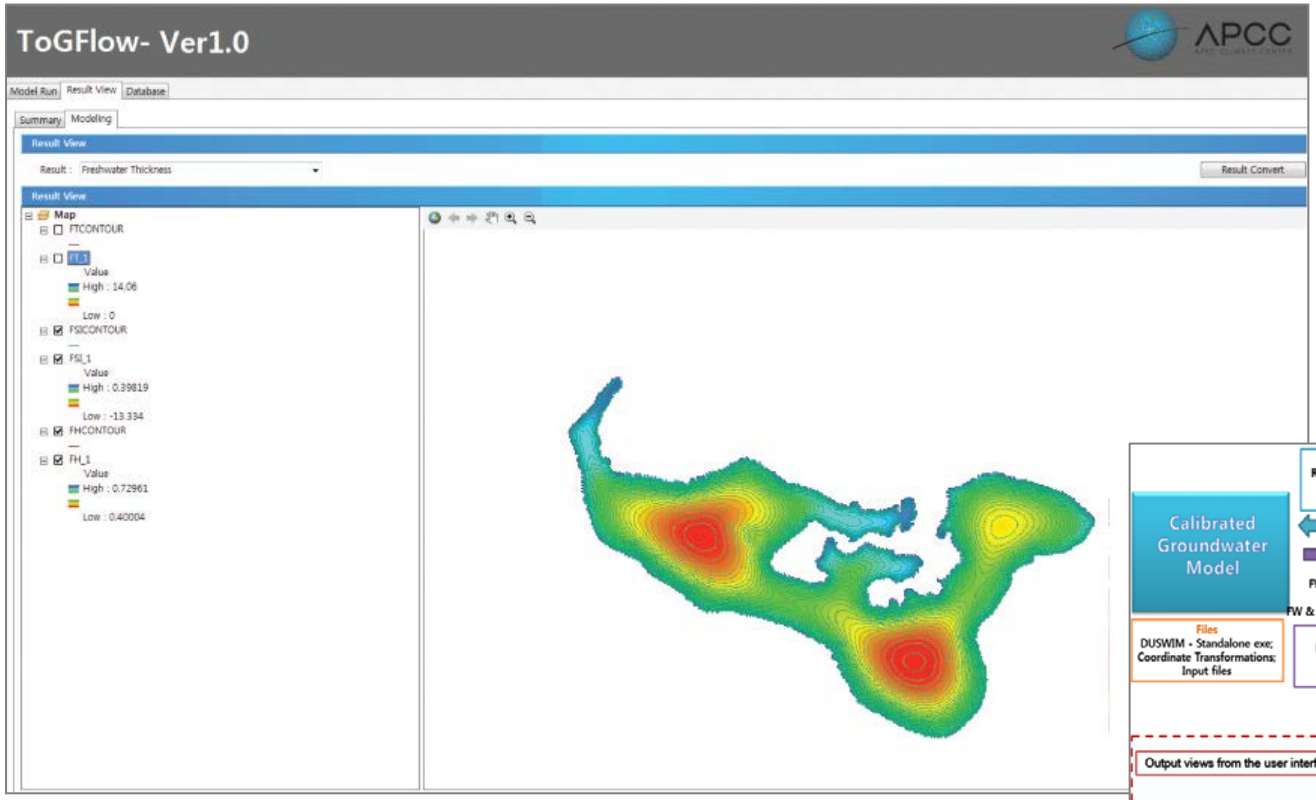
Present Freshwater Resources in Tongatapu Island

Average FW Thickness (m)	Maximum FW Thickness (m)
8.42	14.04

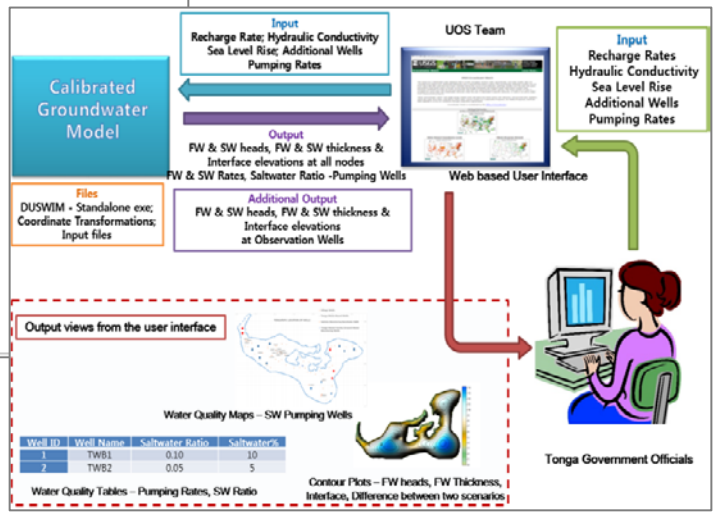
Total Volume of Usable FW (m^3)	Total Volume of FW (m^3)
1,938,000	2,123,000

Tonga Groundwater Flow Model (ToGFlow)

ToGFlow allows 'easy to run' by adjusting parameters and model simulation

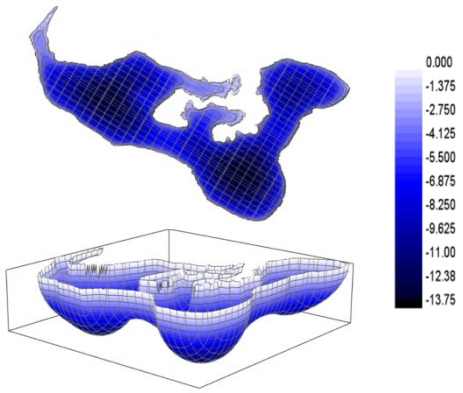


Integrated system for web based groundwater modeling

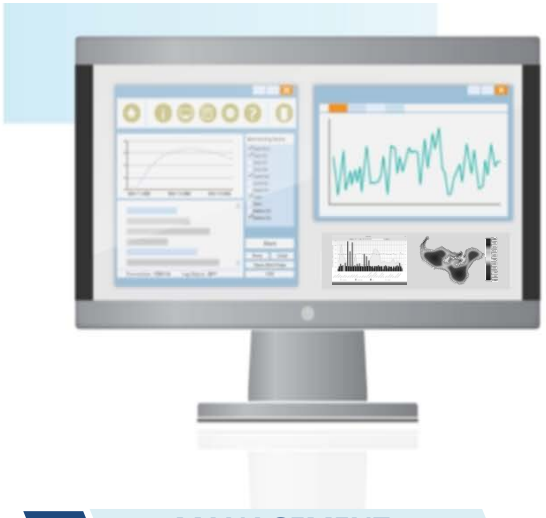


Groundwater Information System (ToGWIS)

01 MONITORING



02 MODELING

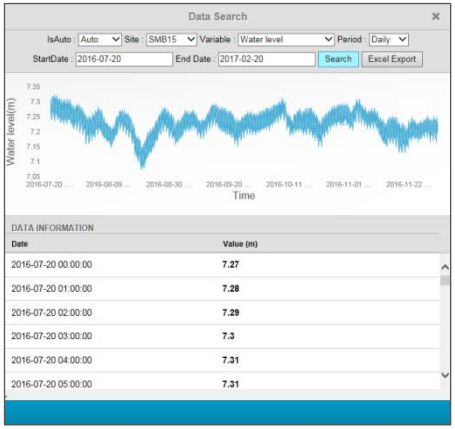


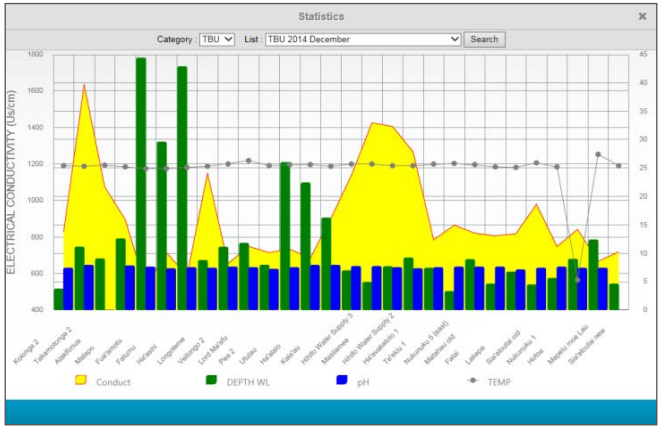
03 MANAGEMENT

ONE STOP SOLUTION FOR GROUNDWATER MANAGEMENT

4. Web Based Groundwater Information System

Groundwater Information System (ToGWIS)





ToGWIS: http://210.125.181.22/login

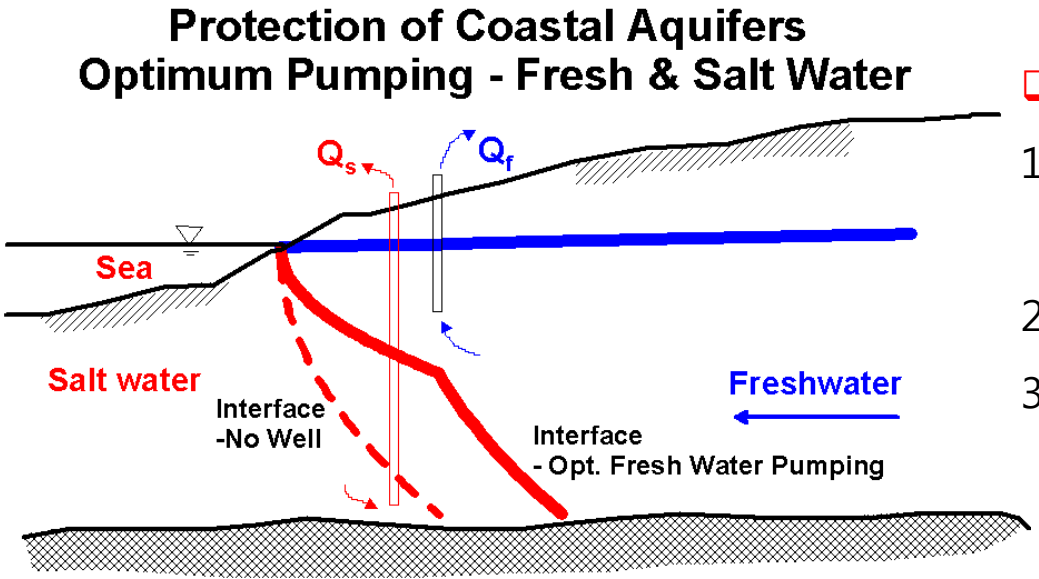
Future Water Management Measures

❑ Short-Term Measures

1. Optimal allocation of pumping rates
2. Proactive adjustment of groundwater
3. Mitigation of seawater upconing
4. Artificial recharge

❑ Long-Term Measures

1. Extend Monitoring wells
2. Management of the Fangaua Lagoon
3. Leak detection and reduction of water distribution pipe network
4. Water quality



❑ Policy Recommendations

1. Inventory for and meter installations of pumping wells and water users
2. QA/QC - field observed data
3. Groundwater governance

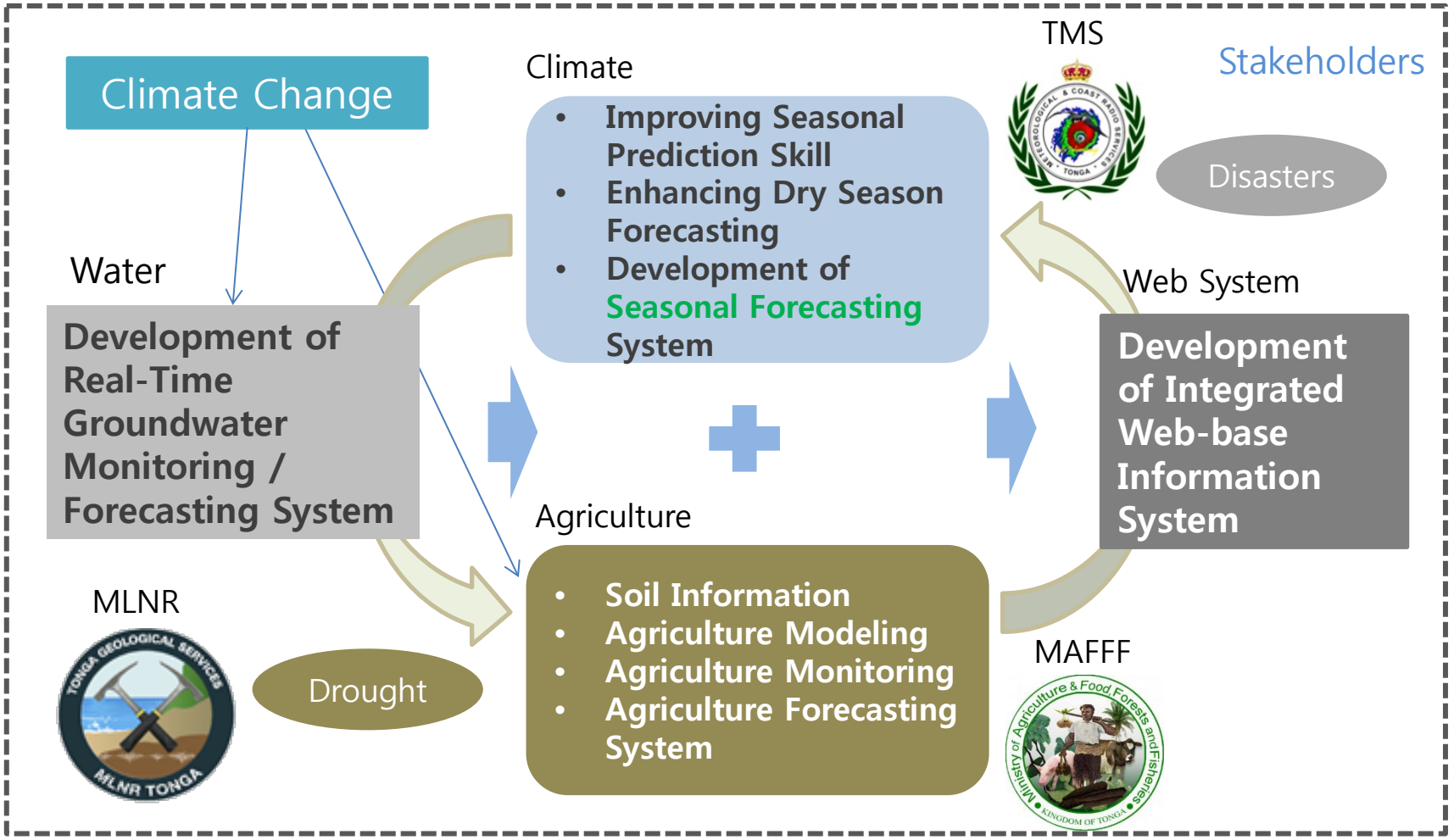
III Future Work

APCC
APEC CLIMATE CENTER

Frame Work for Next 2-year Project

Tonga Agro-Water Project Design

APCC-Tonga Water Project



Tonga Water Resources Risk Assessment

Climate Change + Seasonal Forecasting → Climate-Smart Groundwater Management System

Long-Range Groundwater Resources Risk Matrix (Tongatapu)

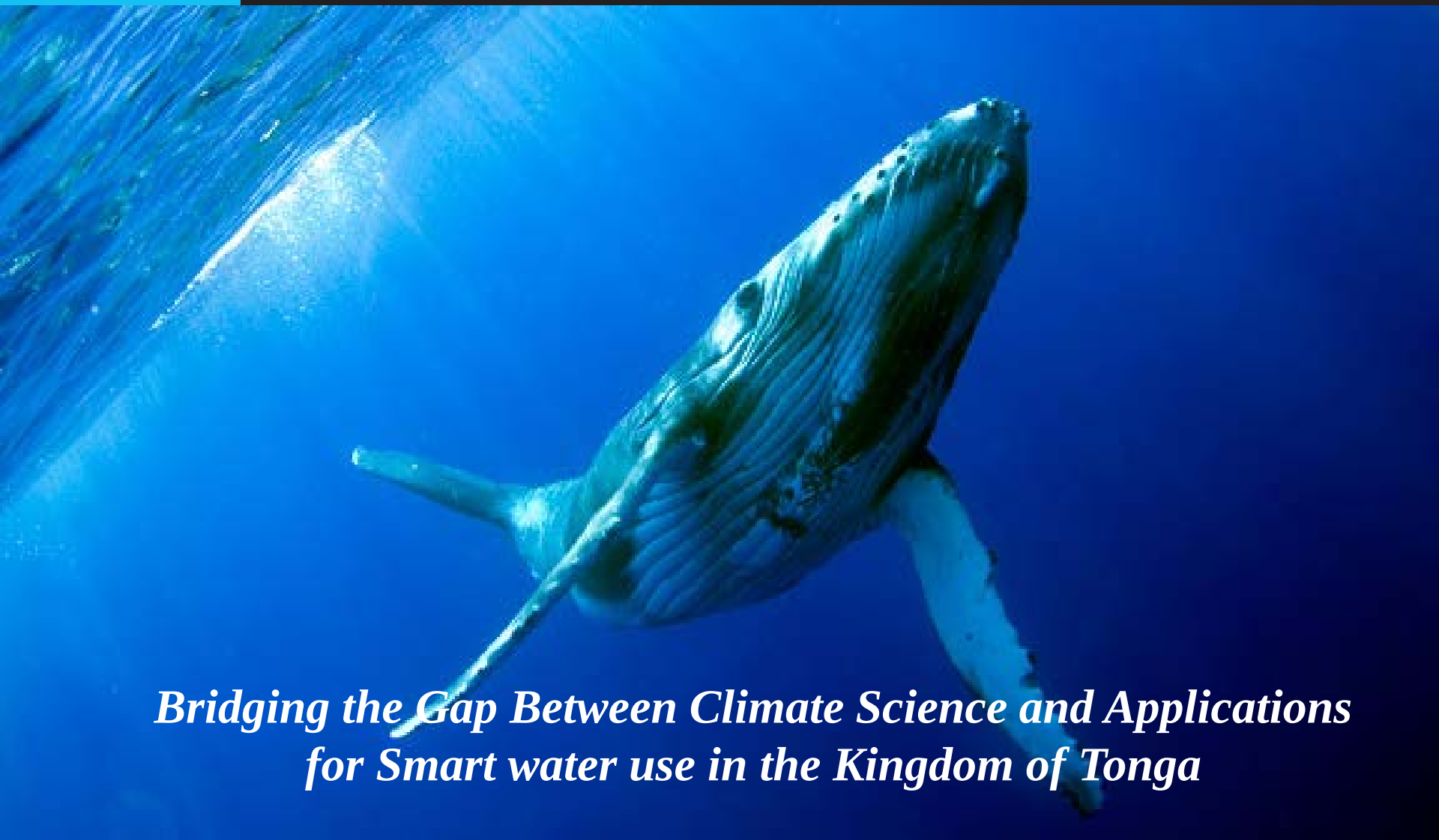
Likelihood	Minimal	Minor	Significant	Severe
High				
Medium		√		
Low				
Very Low				

Potential Impacts

Overall Water Risk

HIGH
MEDIUM
LOW
VERY LOW

Thank you for your attention! Malo!!



Bridging the Gap Between Climate Science and Applications for Smart water use in the Kingdom of Tonga