GLOBAL CONTEXT SERIES- FLUID MECHANICS
Tenganan Water Supply Project

Figure 1. Community residents working to connect a water pipeline

INTRODUCTION

The Tenganan water supply project was undertaken by Engineers Without Borders Australia (EWB) in partnership with the local water management organisation 'Unit Pengelola Sarana Air Bersih' (UPSAB), located in Bali, Indonesia. The partnership's aim was to build the capacity of the Tenganan community to "provide fully for its own water needs".

The partnership successfully achieved that aim by assisting in the design of a water supply system for Tenganan, involving the community in the construction, commissioning and operation of their own water supply system. This will ensure that the resource will be maintained, sustained and used in an optimal way.

This case study will detail the design process of the water supply system, with a focus on the social and environmental issues affecting the choices made in the final design of the piping network and pumping system.

TENGANAN

Tenganan is a rural multi-village community consisting of five villages located in the *Karangasem* region of eastern Bali, Indonesia. It is known as a *Bali Aga* community, as the residents are considered to be the indigenous ethnic group of Bali and conduct their lives according to ancient traditions. Because of this, Tenganan has been the subject of many studies on its land and people, and is especially known for their production of the *geringsing* textile, made using a unique weaving method.

All five villages in Tenganan have problems with water access, quality and supply. The sub-community of Bukit Kauh and its unique water supply problems will be the main focus of attention of this case study.

BUKIT KAUH

Bukit Kauh is a small community located on a hill, with a population of approximately 800 residents. Access to the village is by motorbike (all seasons) or car (dry season) to the base of the hill and from there the journey to Bukit Kauh is best done by foot. Their isolated location makes the acquisition of water difficult for the community, and their elevated location makes the piping of water from water sources problematic without the use of a pumping system.

WATER USAGE AT BUKIT KAUH

Most Tenganan villages have a pipe network connecting them to a water source. However, as Bukit Kauh is located approximately 100 to 150 metres above the rest of the Tenganan community, the pipe network does not supply this region as it would not be possible without a pumping system, which was not available at the time.

The quantity of water required for basic needs such as cooking and bathing is approximately 50 litres per person per day, amounting to 37,000 litres for the whole community (2006 data). To improve the quality of life for the residents, double the amount for basic survival is required and this value will increase as the population increases in the future, as can be seen in table 1.

Table 1. Water usage at Bukit Kauh

		Demand (L/day)	
Year	**Population**	**Minimum water - survival**	**Minimum water - quality of life**
2006	737	37,000	74,000
2016	855 (projected)	42,900	85,900

To obtain this quantity of water, the residents of Bukit Kauh spends several hours each day collecting water in large containers from water sources. Most of these water sources are located at least half a kilometre away and requires a trek through steep terrain whilst carrying the heavy containers filled with water. This time and energy spent obtaining water could otherwise be used for other activities which may create wealth or enable progress in the village.

The community in Bukit Kauh obtain their water from several sources. The major sources of water are:

- Sukun Spring
- Batu Asah Spring
- Buhu River
- Rainwater tanks

These sources and their relationship with the Bukit Kauh village will be discussed further below.

MAJOR WATER SOURCES OF BUKIT KAUH

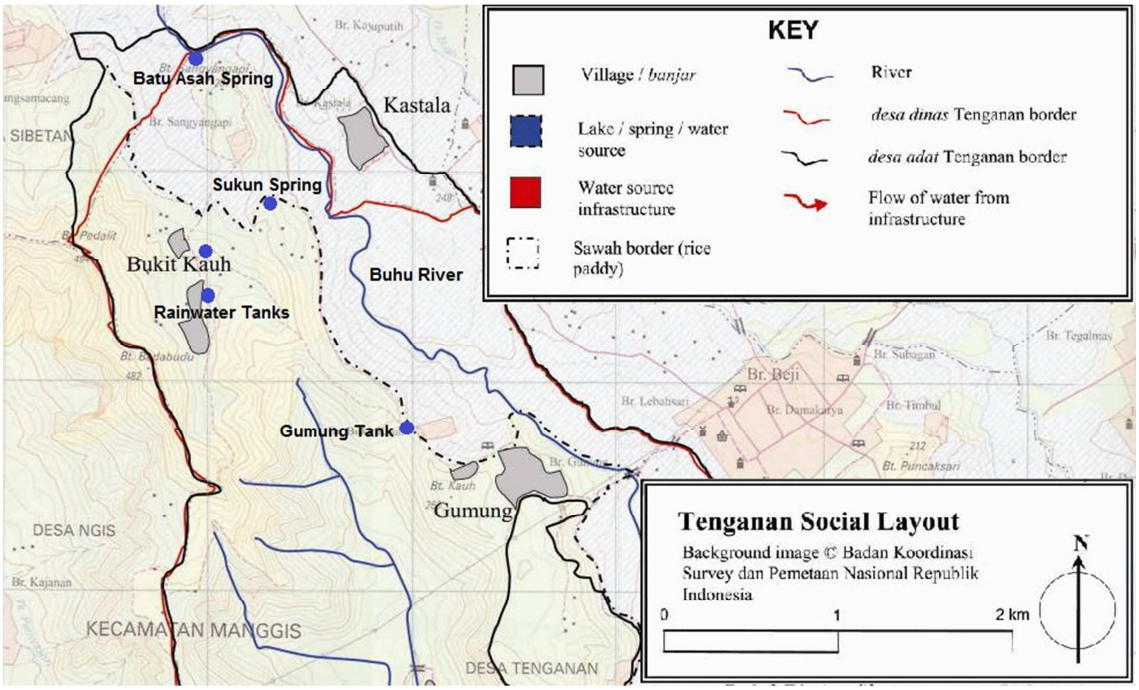

Figure 2. Map of all major water sources for Bukit Kauh

SUKUN SPRING

The Sukun spring is one of the biggest sources of water for the Bukit Kauh village. As the spring is located in a low region, water collection is a daily task for the residents of the village where access requires trekking through more than half a kilometre of steep terrain.

Sukun spring water originates partly from the rice fields situated on the hill and partly from groundwater. The water trickles down from the rice paddies and is collected in stone dams, which is piped into the male and female bathrooms where it can be collected for domestic use. The variation in flow is dependent on crop cycles; during seasons of rain and plantation of rice-crops, Sukun provides enough water for the entire population of Bukit Kauh. In periods of dry-cropping during the dry season, Sukun provides approximately half of the water requirements of the village.

The community attitudes towards Sukun are that the water is considered clean, however they boil it before use because of bacterial contamination. Quality testing conducted on water samples have shown that physical and chemical contamination such as pesticides and fertilizers were below detectable levels, but there was a small microbial issue so the residents have been advised to continue boiling the water before drinking if water is sourced from Sukun.

BATU ASAH SPRING

Batu Asah (*Flat Stone* in Balinese) is another major source of water for the residents of Bukit Kauh, as well as other villages of Tenganan. Acquisition of water by Bukit Kauh residents at Batu Asah is even more tedious than from the Sukun spring, as it is located more than 750 metres away and also requires trekking through steep terrain.

Batu Asah's source of the water is similar to that of the Sukun Spring, where the water seeps through the ground from the rice paddies into two tunnels and is collected in concrete dams. From the dams, one pipe opens to air and is used directly by the local Bukit Kauh women in a

stone bathroom and another pipe feeds water to a pipe network serving the four other villages of Tenganan.

The supply of water from Batu Asah is unreliable, and varies more considerably by season compared to Sukun as the water is sourced entirely from seepage from the rice paddies and not from groundwater. However, another project was currently underway with the intention of improving the reliability of supply at Batu Asah. Water quality in terms of physical and chemical contamination was not a problem; however water is boiled for bacterial disinfection before use.

BUHU RIVER

The Buhu River runs through the northern and eastern portions of the Tenganan islands and is the source of all irrigation water in the Tenganan region. From Bukit Kauh, the journey to Buhu River for the collection of water requires a trek of close to two hours through steep terrain.

Communities along the Buhu River access the water by digging holes in the river bed and collecting the water that seeps into it. Not only is this method of collection time-consuming, but the holes fill with sand and become contaminated with debris during periods of flooding. Because the water in the Buhu River passes in and out of the paddies as it travels towards the coast, the communities have concerns that the water may contain traces of pesticides and fertilisers from upstream. Hence, acquisition of water from the Buhu River is regarded as a 'last resort' source of water.

RAINWATER TANKS

Another source of water for the residents of Bukit Kauh is rainwater tanks. In August 2005, twenty rainwater tanks were built in Bukit Kauh under an Indonesian government project initiative. Each rainwater tank has a capacity of 27,000 litres and each is used by ten families, with a larger capacity tank built at the Bukit Kauh School. The supply relies on enough rainfall to fill the tanks, and if all twenty tanks are full at the end of the wet season, they can provide approximately 1,500 litres of water per day for the rest of the year. Water quality from the rainwater tanks is good, provided that the roof is clean, is excluded away from animals and the first rainwater runoff is diverted away.

Although the use of rainwater tanks is the most convenient option provided there is enough rainfall, there was concern from the community about the quality of workmanship of the tanks. Residents had informed the field volunteers of EWB that the government contractors had constructed the tank with insufficient steel reinforcing in the concrete, which is a common practice in the corrupt government-contracting business.

Table 2 is a summary of all the water sources at Bukit Kauh. Sufficient water for basic requirements can be reliably provided, but access to these water sources is difficult. Quality testing on water samples has shown that chemical and physical contamination is below detectable limits, so it is sufficient for washing and cleaning, but is boiled before consumption. This situation is likely to remain the same in the future.

Table 2. Summary of all water sources for Bukit Kauh

Water Source	Villages serviced	Supply (L/day)		Quality	Access
		High Flow	Low Flow		
Batu Asah	All	> 390,000 More than enough to service all on network	< 30,000 Less than 10% of high flow	No problem with physical and chemical. Problem with microbial.	>750m through steep terrain for Bukit Kauh. Very unreliable supply due to variation with season.
Buhu River	Bukit Kauh, Bukit Kangin, Gumung	> 170,000,000 Streamflow >2,000 L/s*	~52,000,000 Streamflow ~600L/s*	No problem with physical and chemical. Problem with microbial	>750m through very steep terrain. Difficult to collect clean water due to flooding.
Rainwater tanks	Bukit Kauh	1500, If all tanks are full at end of wet season	750, If all tanks are half full at end of wet season	No problems if managed properly.	<100m. Reliable source.
Sukun	Bukit Kauh	>74,000, More than enough to service all in Bukit Kauh	~37,000, Half of requirements	No problem with physical and chemical. Problem with microbial.	>500m through steep terrain

BUKIT KAUH PROJECT

The main issue for the residents of Bukit Kauh is the difficulty in accessing water sources. Consultation with the community led to the definition of the following aims:

1. *Sufficient quantity of good quality water all year round for all people*
   Water quality is important, and the treatment of water to international standards would be the ideal solution. The practicalities of this aim will be discussed further.

2. *Access to the water within 100m of houses*
   Decreasing the amount of time required for acquiring water will free up time for the village residents to focus on other activities. Also, it will eliminate the potential injuries involved with carrying heavy containers filled with water over long distances and steep terrain.

3. *Maximum benefit for the maximum number of people.*

The assistance that EWB provided for the project included:

- *Technical design and assistance*- volunteers in Australia provided assistance with the engineering design for the project
- *Technical volunteers*- volunteers from Australia assisted in the building and commissioning of a project
- *Funding*- Volunteers in Australia helped raise funds for the project.

The village of Bukit Kauh contributed:

- *Labour*- village residents volunteered their time during the construction of the project. During this time, the residents also gain the skills required for maintenance operations as well.
- *Materials*- materials which can be sourced from the environment for free lowered the cost of the project

- *Funds*- the community contributed a small amount towards the project.

Along with the above aims of the project, the following considerations were raised by the community:

- *Government involvement*
  Several community representatives expressed concerns about involving the government in terms of funding for the project, due to several reasons-

  1. If the government assisted in the upgrade of water sources, they may forcibly acquire the resource and then charge the community for water, which they acquired for free before.

  2. If the funds offered by the government for the project is above a certain amount (50,000,000 Rupiah- approximately $5230AUD) then the project can no longer be built by the community and must be completed by contractors

- *Land ownership*
  Land ownership is distributed between the five villages of the Tenganan community, so all communities must be consulted before any project can be undertaken on their land.

- *Community independence*
  The community does not want to be totally dependent on others.

Several limitations were also identified for the project:

- *Limited data*
  The main challenge for this project is the limited data available for ensuring that the appropriate technology is selected. For this project, decisions were made based on data collected by volunteers and on interviews with village representatives.

- *Minimal cost*
  As the available community funds are approximately 2,000,000 Indonesian Rupiah/annum (approximately $220AUD), the design should utilise as much free materials as possible that can be sourced from the local environment such as sand, gravel, stone and clay.

- *Community level of skill and labour*
  The design must take into account the community level of skill and labour, so minimal mechanical equipment must be a factor in the design. Also, if water is to be treated for quality reasons, then no chemical dosing such as chlorine should be required as this will require specialist knowledge, which may not be readily available or accessible to the village. However, if the above comments are taken into account in the design process, this will minimise the costs involved in the project as unskilled labour will be provided by the community, and no funds will be required for the purchase of chemicals. Also, a simple mechanical system will have low maintenance costs, which will also minimise the ongoing costs of the project.

PROJECT DESIGN

Using the data gathered by the field volunteers at Bukit Kauh, the design of the system was carried out by a project team based in Australia, consisting of approximately twenty engineers who provided technical expertise on a voluntary basis.

One request from the Bukit Kauh village is the preference for a non-mechanical solution such as a gravity-fed pipe distribution network. However, due to the elevated location of Bukit Kauh

from all other water sources, a design of that nature was deemed impossible. Since a pump system was required in the design, confirmation from the residents of Bukit Kauh was obtained before proceeding, as the installation of a pump was not agreed on beforehand.

It was decided that a pipe network would be developed from a water source, which would be connected to a water holding tank at Bukit Kauh for use by the residents.

From the analysis of all possible water sources at Bukit Kauh, three potential water sources were chosen- Sukun Spring, Batu Asah Spring and a water holding tank downstream of a water treatment system located at the nearby village, Gumung. All three will be discussed further.

OPTION SUKUN SPRING

Sukun Spring is currently used as a major source of water by northern Bukit Kauh residents. However, there is no existing water conveyance infrastructure between Sukun Spring and Bukit Kauh.

A new, 50mm steel above ground pipeline was considered as the best connection between the two points, with a pipe length of 351m. A pump system will also be required as the difference in elevation between Sukun Spring and Bukit Kauh is 50m.

OPTION BATU ASAH

Batu Asah is another source used by Bukit Kauh residents, as well as the greater Tenganan community. Although the supply of water from Batu Asah varies according to season, further project work completed by EWB on the water source of Batu Asah will ensure the security of the supply.

There is an existing pipeline from Batu Asah to an unused tank at Bukit Kauh, which was part of a failed water supply scheme completed some time ago.

Assuming that the existing pipeline is unfit for use, a 50mm steel above-ground pipeline was considered, with a total pipe length of 641m. A pump system will also be required as the difference in elevation between Batu Asah and Bukit Kauh is 30m.

OPTION GUMUNG

Gumung is a village close to Bukit Kauh. The reason why it has been considered as a water source is because of a water treatment plant located in Gumung, with the possibility of being able to supply Bukit Kauh with treated water. However, there is no existing water conveyance infrastructure between the two villages.

A new, 50mm steel above ground pipeline was considered as the connection between the treated water holding tank at Gumung and a tank at Bukit Kauh, with a pipe length of 1,157m. A pump system will also be required as the difference in elevation between Gumung and Bukit Kauh is 130m.

A schematic diagram of all options is given below.

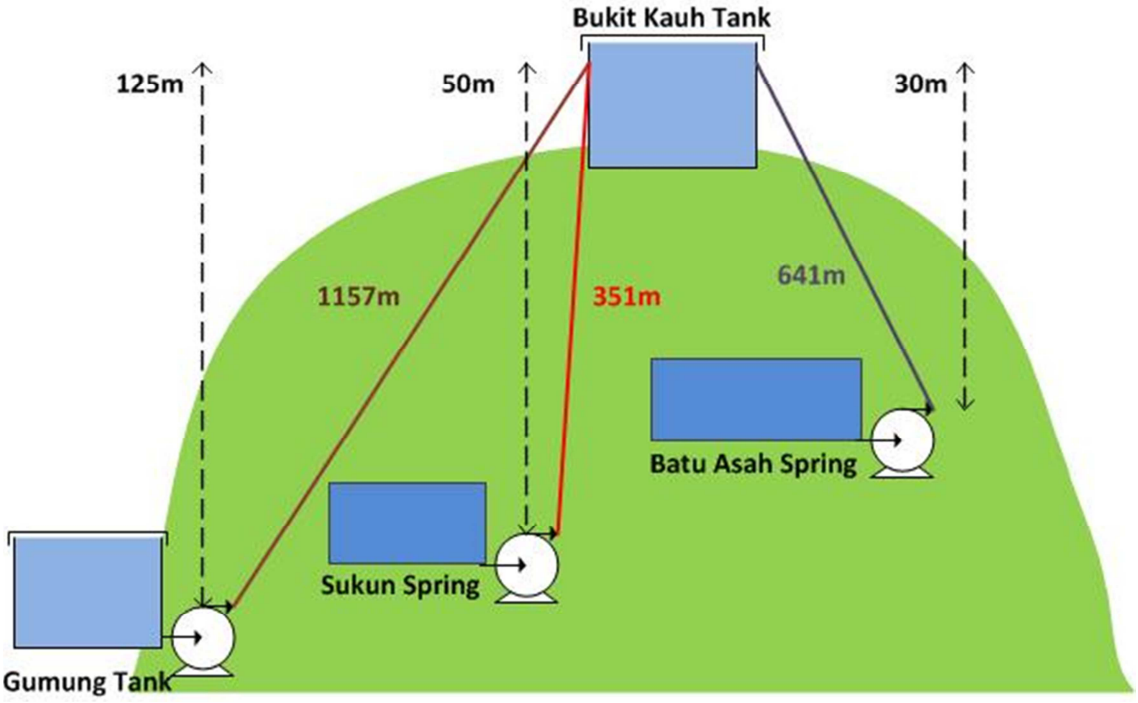

Figure 3. Diagram of all water source options for Bukit Kauh

DECISION

Calculations were completed on all three options and are tabulated below. Based on the analysis, the recommendation given was to use the existing Batu Asah source and provide the water conveyance and pumping infrastructure to pump water to Bukit Kauh.

Table 3. Summary of water system specifications

		Source		
		Batu Asah	**Sukun Spring**	**Gumung Tank**
Pipe Specifications	**Type**	Steel	Steel	Steel
	Diameter (mm)	50mm	50mm	50mm
	Length (m)	641	351	1157
Specifications	**Flow (L/s pumping 8 hours/day)**	1.4	1.4	1.4
	Daily flow required (kL/day)	40	40	40
	Elevation (m)	30	50	125

PUMP SYSTEM OPTIONS

To be able to sustain the water supply at Bukit Kauh, it was determined that the daily flow required from the network is 40kL/day. Considering how peak water usage occurs during the day, it is assumed that the water would be pumped eight hours a day at 1.4L/s on a daily basis, rather than have it pumped continuously.

Several pumps were considered for the pumping of water from the three sources to Bukit Kauh. A non-mechanical solution, as requested by the community, was considered ideal; however the elevated location of Bukit Kauh made such options unfeasible.

The two most viable options based upon capability were petrol/diesel powered pumps and solar powered pumps. One factor which sets the two apart is the capital cost of the pump- a solar pump system can cost around $20,000 AUD, while the petrol/diesel pumps with the same capacity range in the $300-$1,000AUD. Although the solar pump would be ideal solution as it requires no ongoing fuel costs, the petrol/diesel pump was the recommended pumping system for the community as the amount of funds required was more achievable. Community approval and comment was sought by the project team because this solution did not align with the project scope requested by the community.

Water quality was also taken into consideration when choosing Batu Asah as a water source compared to the other two options. Although there was the option of obtaining treated water from the water treatment plant in Gumung, the length of the pipe connection (1157m) as well as the pump head required to pump the water to the elevated position of Bukit Kauh will dramatically increase the ongoing operating costs of the system. As the Bukit Kauh village is trying to minimise the costs involved in obtaining water, water sourced from Batu Asah is the most appropriate option as the required pumping head is the lowest amongst the other sources. Even though the water sourced from Batu Asah will be untreated, the water quality at Batu Asah is considered acceptable for the village's uses. Moreover, the water supply at Batu Asah is expected to become more reliable after upgrades to the greater supply system are complete.

CONCLUSION

A summary of the project is given below:

- Batu Asah (which also supplies water to the other four communities through a pipe network) will now also service the Bukit Kauh village via a pipe network and pumping system
- A petrol/diesel pump was chosen with the consent of the community
- The residents of Bukit Kauh volunteered their time to complete the project, under the guidance of technical volunteers
- The residents of Bukit Kauh no longer have to make the arduous trek to collect water and can now utilise that time for other activities

Youtube links:

Bukit Kauh water collection-
http://www.youtube.com/watch?v=TG4jWFnklwA

Tenganan water supply project-
http://www.youtube.com/watch?v=4XHI2dp3ZS4

EWB volunteer experiences-
http://www.youtube.com/watch?v=D1QoqeXmcps&context=C32bc226ADOEgsToPDskJIprrhCSqmzI94J0reRU7M