Water Quality Monitoring Solution with Community Engagement

30/10/2022

Proposed Development Plan for ILALC

EXECUTIVE SUMMARY

This report analyses the problems and solutions faced by the Illawarra region and proposes future development plans and evaluates them. Currently the Illawarra region creek is facing environmental problems and ILALC needs direct access to water quality data. Our group has proposed three solutions: hardware level (Dataloger), software level (Visualisation System & Community App) and community level (Community tour), and we analyse each solution in more depth in this report. Most importantly, by implementing the solution proposed in this report, the issues mentioned can be alleviated and the ILALC can gain sovereignty over the data relating to the water quality of the creek systems. From this, the ILALC can use the data collected to leverage any negotiations with relevant authorities and South32. If the proposed solution plan is not put into action, further harm may be done to the ecosystem of surrounding areas near Mount Kembla to the point where more drastic and significantly more costly actions are required to restore the ecosystem to a state that is considered acceptable.

PROBLEM AND PROPOSED SOLUTION

There are three main issues in the Illawarra region, firstly the natural habitat of the area is at risk of being permanently defiled by human actions such as coal mining, most notably the creek system around the Kembla Mountains. Secondly, there is a lack of a system that can detect water quality data and thus obtain it directly. The importance of Aboriginal spirituality further adds to the problem of environmental pollution, and we are faced with the question of how to get the community more involved in monitoring water quality.

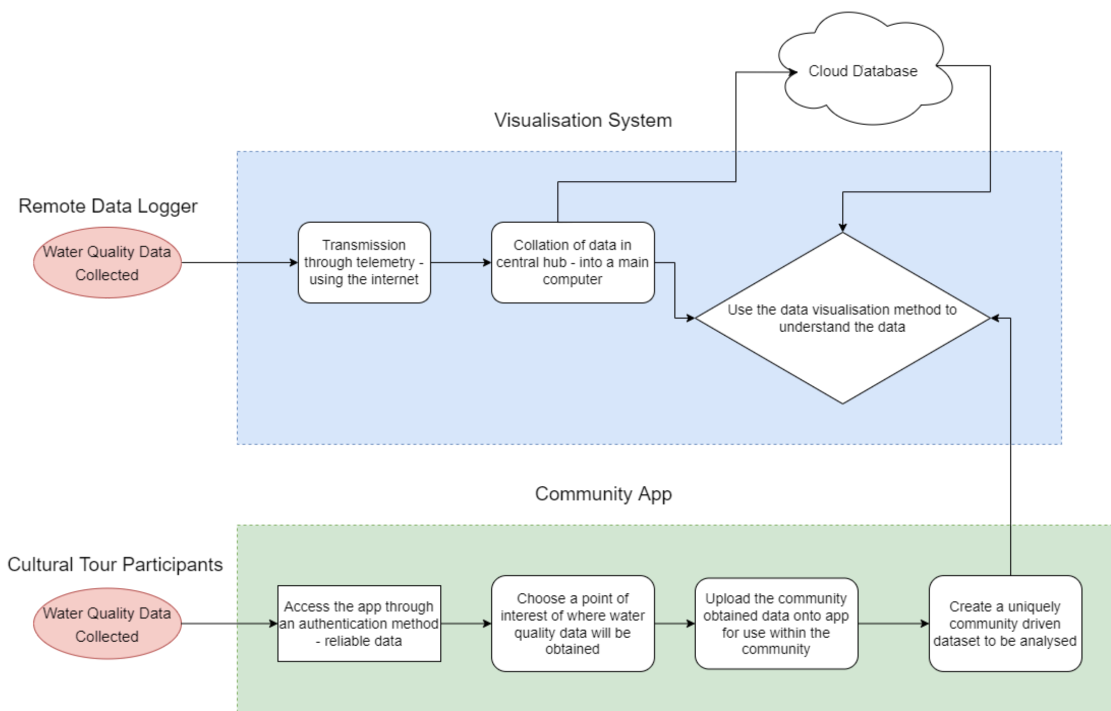


Figure 1: A simplified overall system process diagram which highlights key interactions between the three aspects, hardware, software and tours, of the proposed solution

To address these issues, the proposed solution has a three-tier approach that includes **hardware, software**, and **community** as shown in Figure 1. Hardware in the form of remote data loggers are placed at key locations in the water to provide insightful data on the water quality of the creek system by collecting and transmitting parameters such as temperature, pH and heavy metal concentrations. This hardware will work in an automated manner, greatly reducing the loss of manpower and is an efficient way of lowering cost. The water quality data will be obtained in a very direct manner which means the data is private, secure and easy to access.

For the software component of the solution, a community app and data analysis module was designed to analyse and visualise the raw data. In addition, a community app will be complemented with the cultural tour. Visitors can use the app at any location of the region to carry out simple water quality testing and update the data, others can use the app to monitor water quality. The data will be sent to the back-end data analysis module for a more professional summary. The data analysis software organises the data collected from all sources and then presents it in a graphical format so that patterns can be easily distinguished.

Broader community engagement can be achieved through cultural tours. There are 3 different characteristics of cultural tours, the main cultural one, the science & environmental one and the statistics based one. Among the main cultural tours, the value ILALC sees in the Kembla Mountains area and creek system is explained through exploratory experiences.The science tour is aimed at the younger age groups, and it will explain how water testing is done and its importance by leading a field test of water quality. The statistical tours investigate what the data loggers are capturing, the reasons the devices are placed in specific locations, and how the data can be visualised to form meaningful conclusions. These tours are perfect for supporting educational experiences related to local issues and values. Once the system is fully integrated, we are confident that efforts to restore the natural environment will be facilitated.

SOLUTION DEVELOPMENT

Engineering Requirements

In terms of hardware, there are several engineering requirements for the data logger:

1. Need to be able to record the following variables; water quality such as pH (in the range of at least 7 ± 2 pH level), metal concentrate percentage, phosphorus, water temperature (around 17°C) and water flow, and location data.
2. The following features were needed in the physical structure: it needed to be fixed in position, buoyant, environmentally friendly and waterproof.
3. Need to be able to collect and process the data from the probe hourly and send it to the server after it is stored locally.
4. The internal structure should not be overly complex and needs to be easy to maintain and have a long life span.
5. It must be able to send remote signals in case of hardware damage.

There are also some engineering requirements for data visualisation and community applications, which are the software aspects of the solution:

1. Need to be able to store and display data over a 2-year period
2. The data must be accessible from any device with a portal login key when connected to the Internet.
3. The data should be easy to understand and interpret.
4. The visualisation of the data must show the expected level of the water quality parameter so that deviations from that level can be easily identified .
5. The Community App needs to cater for cross-platform use.

6. The Community App needs to ensure the security of the data transmitted as well as the user information.
7. The operation of the Community App needs to be suitable for all types of people and should be easy to get started.

Community tours also have some engineering requirements.

1. The tour must be able to be modified and applied to all people of different skill levels.
2. Honouring and respecting Aboriginal spirituality
3. Teach people about various aspects such as Aboriginal spirituality and heritage, software skills, and environmental testing and monitoring skills.
4. Have the ability to interpret data to the community.

Hardware

In this section, the hardware operation is broken down to four main parts: implementation demonstration, sensor selection, CDA design, and feasibility analysis. Implementation demonstration outlines the location of implementation to the data loggers as well as the method to implement it. Sensor selection provides the details about the sensors chosen to measure water qualities such as pH, temperature and water level with relevant technical spaces. CAD design shows the sensor-based data logger design for further implementation and analysis after thorough considerations about the features, advantages and disadvantages. Lastly, simplified dynamics analysis illustrates the liability of the supported hardware by constructing critical analysis on physics and mathematical models behind it.

Implementation demonstration

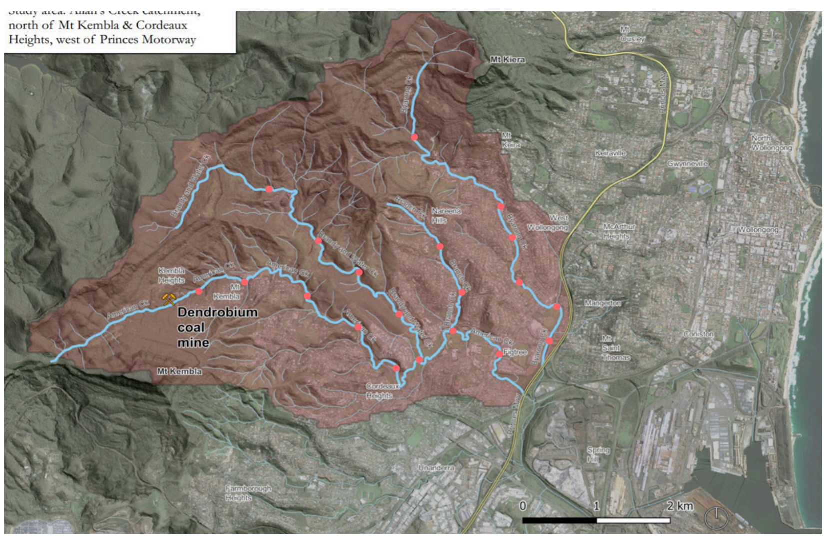


Figure 2: Implementation of location labelled as red dots

Figure 3: Image showing the deployed remote data logger (background image acquired from free source [1])

The complete water quality monitoring system is designed to be implemented near the creek shore after the thorough multiple dimension condensation. As shown in Figure 2, the implementation locations are also labelled as red dots on a given map. Figure 3 illustrates the remote data logger (dark grey) deployed in a creek, where it is fixed by a nylon fishing line (black line) attached to a cement block (blue block). By holding it with a nylon fishing line, the data logger is submerged just below the water surface, allowing for improved the performance of detecting the qualities such as pH, water level etc. since it is not affected by creek bed. The location of the cement block is recorded such that users can easily find and locate the data logger when it needs to be repaired or replaced. A cement block and nylon fishing line were chosen as the materials since they are low cost, non-toxic and chemically inert. In addition, they provide the required properties in this application, which are to be heavy enough to hold the data logger in place and be sufficiently strong (since multiple loops can be used based on the required strength) to withstand the tension that arises from the drag force and buoyancy force acting on the data logger assembly respectively.

Sensor Selection

In this section, the selected sensors are discussed in two groups, professional and community based. Sensors labelled as professional are for collecting data and constructing high level data analysis whereas community-based sensors focus on educational purpose use only. The collected data and analysis will be on a different scale. Therefore, the selection also shows the property of high-level technology compared to community one (relative low-level technology). The main differences are features, precisions and costs.

Professional-scale sensor

- HOBO MX2001 Water level sensor [2]

MX2001 is used to measure and monitor the change in water level within various locations including lakes, wetlands, and rivers etc. This wide range of applications also fits most creeks or rivers in Kembla Mountains. The whole device is built by a ceramic pressure sensor, durable housing, an integrated barometric pressure sensor and a Bluetooth communication system. Hence, it supports multiple features – direct access to data via cloud platform, quick finding to deployed location and simple measure to water levels and pressures.

- HOBO MX2501 pH and temperature sensor [3]

MX2501 is used to measure and monitor the changing temperature and pH in aquatic systems. Again, it's suitable for deploying it in our system under most scenarios. This sensor is constructed by a temperature sensor, a pH electrode, an anti-biofouling copper guard and a Bluetooth wireless communication system.

Therefore, it has features – temperature measurement, pH measurement and uploading data to cloud databases. The pH measurement is helpful for experts to analyse the metal concentration in the creeks.

The mentioned sensors are from the HOBO brand, hence they both have access to the HOBO platform where users can collect the data from the platform and configure other extra features [4]. This generalised design leads to reduced complexity of data collection and human errors. Furthermore, the choice of these sensors from the existing market is to ensure its high availability and liability especially when it needs to be replaced or when it's operating. The detailed sensor specifications mentioned above will be provided in Appendix A.

COMMUNITY-BASED KITS

Instead of providing sensors to each group of community participants, API tool kits [5] are better to fit our problem definition which is to increase the community engagements to the monitoring water quality system. Each API tool kit contains several test tubes and testing liquids. It can be used to measure up to 5 instances, pH, high range pH, ammonia, nitrite, and nitrate. The methodology for quality measurements is to collect the water source. Then, drop the dips of testing liquid you want into the tubes. Finally, wait until the colour of liquid inside the tube changes and matches it to the instructions. This simple process allows participants to engage easily by 1. Increasing community's willingness 2. Lowering the entry cost.

CAD Images of The Design

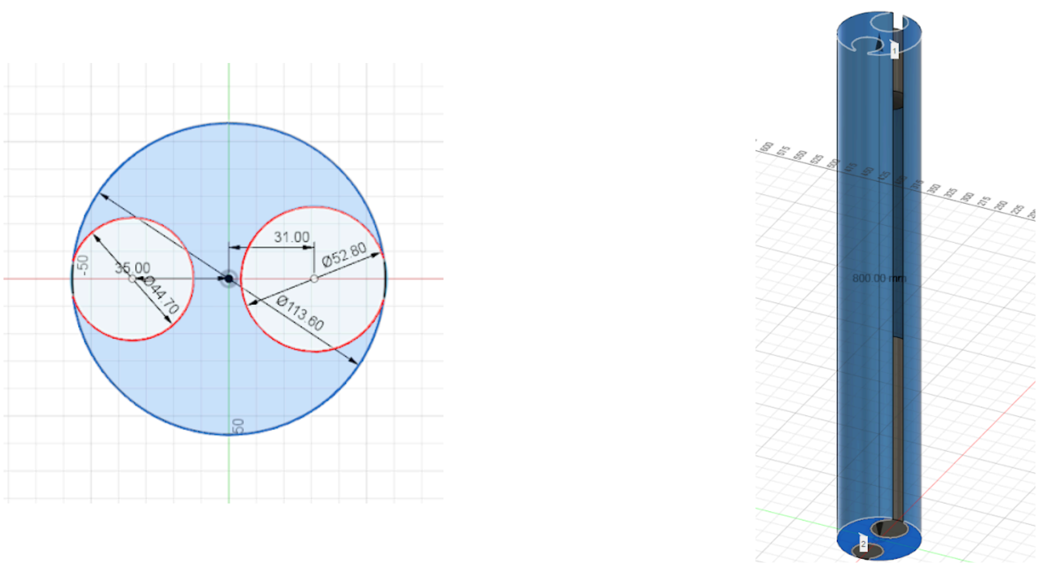
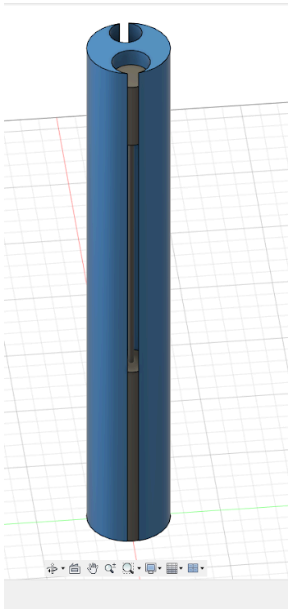
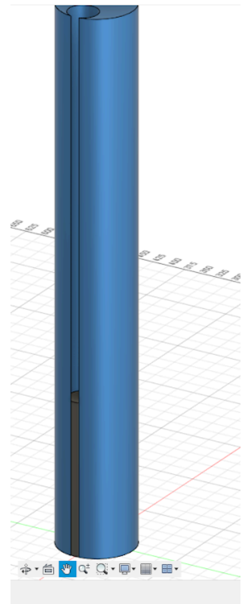


Figure 4: Images showing some of the key dimensions of the remote data logger casing



(a) MX2001 sensor location



(b) MX2501 sensor location

Figure 5: Images showing the placement of sensors (dark grey objects in images) in the remote data logger casing. Note that there is a semi-hemisphere front cap for the cashing which is not shown here.

The blue coloured component is the casing seen in Figures 5 and 6 is used to combine the sensors into the complete remote data logger. It is made of acrylic which has high strength, low weight while being cheap. Note that the casing is hollow on the inside, which significantly reduces the mass of the assembly. Based on the output from the CAD software utilised to create these designs, the volume of the design is 8108.42 cm^3 and the total mass is 2865 g for the overall assembly consisting of the acrylic casing and MX2001 & MX2501 based on user manuals [2,3].

Feasibility Study

The analysis presented in this section serves as a preliminary investigation of the feasibility of the proposed data logger implementation through the application of basic Newtonian mechanics and fundamental fluid mechanics knowledge. This feasibility study assumes the worst case for key parameters and does not make simplifications on the basis of acquiring favourable results. More on the assumptions employed in this study will be detailed in this section.

DEFINING THE SYSTEM

Figures 6 to 8 show the system being considered and the relevant free body diagrams used in analyses to be presented following on from this.

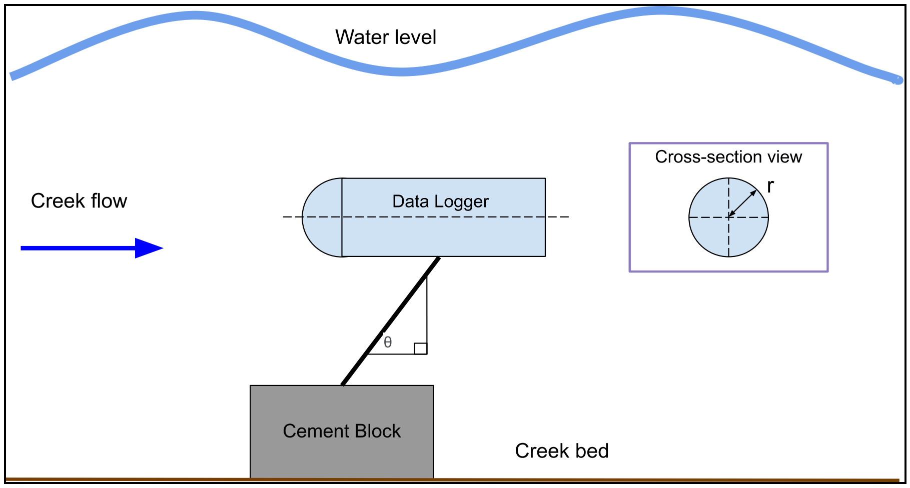


Figure 6: Diagram showing the simplified system when the data logger is submerged

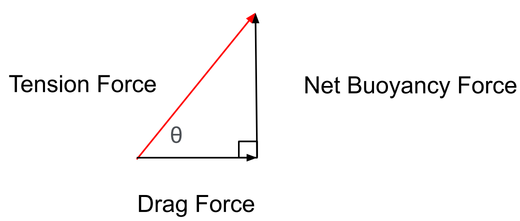


Figure 7: Free body diagram of the forces acting on the data logger which results in the tension force in the tether required to hold the data logger

From Figure 7, using Pythagoras' theorem, the tension force can be expressed as

$$F_{Tension} = \sqrt{F^2_{Buoyancy} + F^2_{Drag,\,logger}}$$

Where

$$F_{Drag,\,logger} = \frac{1}{2}\rho_w u^2 C_{D,\,logger}\left(\pi r^2\right)$$

$$F_{Net\ Buoyancy} = \rho_w V_{logger} g - m_{logger} g$$

In all of the formulas presented above and those that follow, u is the creek flow velocity, C_D is the drag coefficient for a sphere, ρ_w is the fluid volume , V_{logger} is the volume of data logger (obtained from CAD), m_{logger} is the mass of the data logger and g is gravity.

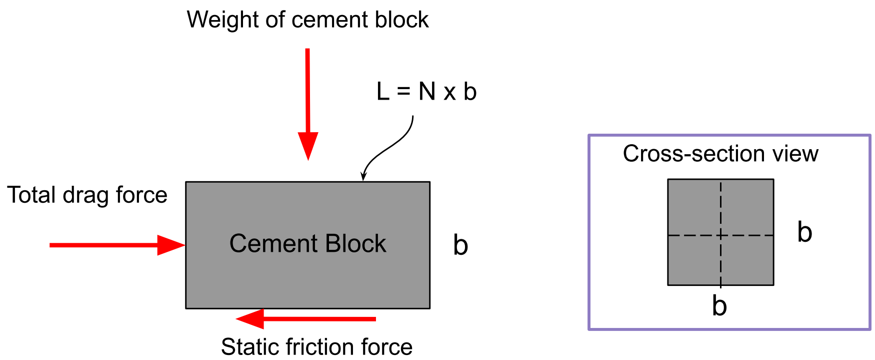


Figure 8: Free body diagram of the forces acting on the cement block where the dimensions of the block are included as variables

Now considering the block seen in Figure 8, to ensure that the cement block is heavy enough to hold the entire assembly in place, which essentially fixes the data logger at the same location in the creek, the following conditions apply:

Condition 1 (based on forces in the y direction) : $F_{Weight\ of\ cement} > F_{Net\ buoyancy}$

Condition 2 (based on forces in the x direction) : $F_{Total\ drag} < F_{Static\ friction}$

Where $F_{Total\ drag} = F_{drag,\ cement} + F_{drag,\ logger} = \frac{1}{2}\rho_{cement} u^2 C_{D,cement}\left(b^2\right) + F_{drag,\ logger}$

ASSUMPTIONS

Below is a list of all the assumptions used in this analysis.

- Data logger assembly cross section is assumed to be cylindrical with a rounded nose (semi-hemisphere) at the front, where the length to diameter ratio is roughly 8. Hence, drag coefficient was able to be estimated as $C_{D,\ logger} = 0.2$ [6]
- The drag coefficient for the cement block is estimated from the value for a rectangular prism where $C_{D,\ cement} = 2.0$ [7]
- Tether (nylon fishing line) mass is negligible
- Worst case scenario of flow rate in the creek is assumed to be $u = 2.5$ m/s, which is roughly twice the flow rate in fast river flows [8]
- Density of water ρ_w is approximated to be 1000 kg/m^3 (higher than water at 25°Celsius)
- Mass of the data logger assembly is estimated from CAD and also specifications for sensors
- The static friction coefficient between the cement block and the creek bed is given by that of cement to sub base soil, $\mu_{cement-soil} = 0.7$ [9]

FULL ANALYSIS

From **condition 1**, the mass of the cement block required can be obtained as follows

$$F_{Weight\ of\ cement} = m_{cement} g > F_{Net\ buoyancy}$$

$$\Rightarrow m_{cement} > \frac{F_{Net\ buoyancy}}{g}$$

This expression for the mass of the cement block needs to be satisfied for condition 1 to hold.

Now considering **condition 2** and assuming that the dimensions of the cement block has dimensions $b \times b \times Nb$, where N is the length to width ratio, the exact dimensions required can be solved using **condition 2** as follows.

$$\frac{1}{2}\rho_w u^2 C_{D,cement}\left(b^2\right) + F_{drag,\,logger} = F_{Total\ drag} < F_{Static\ friction} = m_{cement} g \mu_{cement-soil}$$

Since mass of the cement block is its volume times density,

$$\Rightarrow \frac{1}{2}\rho_w u^2 C_{D,cement}\left(b^2\right) + F_{drag,\,logger} < [\rho_{cement}(Nb^3)] g \mu_{cement-soil}$$

$$\Rightarrow F_{drag,\,logger} < b^2\left(N\rho_{cement} g \mu_{cement-soil} b - \frac{1}{2}\rho_w u^2 C_{D,cement}\right)$$

Since b must be positive and greater than 0, further simplification can be made to yield the following expression

$$\Rightarrow b > \frac{F_{drag,\,logger} + \frac{1}{2}\rho_w u^2 C_{D,cement}}{N\rho_{cement} g \mu_{cement-soil}}$$

For simplicity, the value of b was directly calculated from the above expression multiplied by 1.2 to automatically satisfy **condition 2**, which allowed the value of N to be obtained through trial and error to lower the mass of the cement block while satisfying **condition 1**.

Finally, through calculations completed on a spreadsheet, it was found that a value of N=8 satisfies both conditions. This give the dimensions of the block as $0.095m \times 0.095m \times 0.762m$ with a mass of 9.93 kg. A spreadsheet with the full calculations is provided in Appendix A.

Mass Budget

The final part of this section on the hardware is to establish the mass budget of the entire system as of now which will also help inform the cost of the solution in a later section.

Table 1: Mass budget of the overall remote data logger system, including the remote data logger itself and the cement block

Component	Mass (g)
Data Logger Case	2274.8
MX2001 Sensor	322.0
MX2501 Sensor	268.2
Cement block	9936.8

Software

This section focuses on how the software solutions are implemented into the project. It will look at how the data is transmitted from the sensors to a private cloud database, how that data is visualised and how the community app works to provide a more community focused experience. These solutions are how the ILALC will actually receive and use the data from the sensors to provide evidence towards their concerns about the Mount Kembla creek system health.

Data Transmission

The data transmission concept is how the data obtained from the sensors is transferred from that sensor to a central database or place of storage. This is an essential part of this project as this is what allows the data to be easily accessible for the ILALC especially when there are multiple sensors and they are placed in perhaps harder to reach areas. The data transmission method that this project will implement is an internet transmission of the data by the data sensors to a central cloud database. This data collection will be a constant cycle that will occur several times a day and from this data, the data visualisation can be done using a data visualisation program.

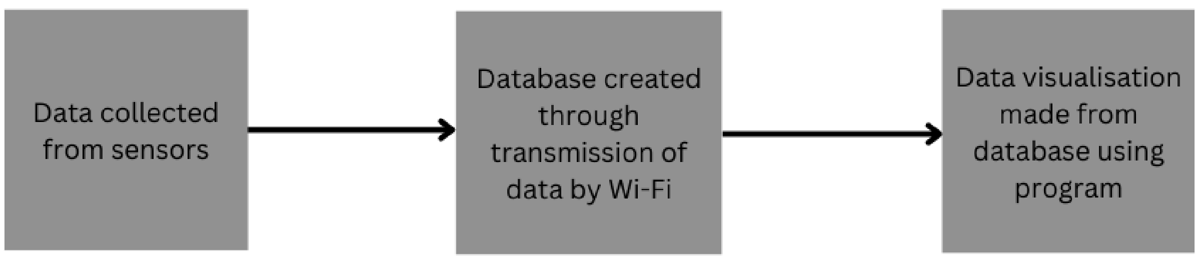


Figure 9: Flowchart of how the data is processed and used

The data transfer to a cloud database has a necessity to be a private cloud system as this project desires the ILALC to have full control over how the data is used. As such the private cloud system will be sourced by Macquarie Cloud Systems with their Launch® Private Cloud product. This highly reputable system was chosen due to its 24/7 technical support, large area coverage (essential for the Mount Kembla area) and most importantly a secure, private system that the ILALC will have full control over. As this system is rather small as it is tracking a very specific set of water quality data (less than 10 TB of data a month), the server costs will approximate to around $2300 per month [10].

It is also important to consider immediate solutions to if the cloud server is down or if the internet connection to the server is not being consistent. A Bluetooth connection to a mobile device such as a phone or tablet can be used to offload the data. This means that in instances where the cloud server may be experiencing some downtime like for maintenance, the community members can integrate themselves with the data collection process by going to the sensors themselves. In these cases they will be trained in how to do so and have their identity be a part of how they authenticate the data. The community app dataset is also obtained and validated in this way, with community members using their identity to provide data on tours.

Data Visualisation

From the cloud database, data visualisation is done so that the ILALC can visualise what the data actually means. This concept revolves around presenting the data in a meaningful way that shows trends that the community members can use in their arguments about the treatment of the creek system. The data visualisation aims to be easy to use for the ILALC, uniquely theirs and a genuine method of providing substance to their concerns about environmental damage being done. This visualisation is in the form of the program, made in Python and uses the pandas package to perform data analytics on the dataset.

The visualisation program works by taking user inputs for what water quality parameter they want to view, asking for what timeframe they want that data from and then outputting a chart that visualises the information that they were asking for. An example of how this program would operate is if the water temperature during a certain time period was desired, the program would take the input of temperature and the specific time period of output a bar chart of that information. Figure 10 and 11 below depicts what the visualisation would look like for that example. The input statements are shown below as this is how the program would ask you what data does the user want to see. This program allows for comparison between two different dates and shows what the expected water temperature would be. The ILALC can use this visualisation to look at the differences for this parameter based on location and gain a deeper understanding of what is happening to the creek. An important note is that Figure 11 depicts data from NSW Estuary Water Quality Data Compilation: 2007 - 2020 project by the NSW government [11] and as a result is not reflective of the Mount Kembla creek system data.

```
Choose one of the parameters to look at: Temp_C
Choose a date to see, in the format of dd/mm/yy: 3/10/2007
['10:50:42', '12:44:12', '13:08:07', '13:20:21', '13:26:24']
[19.45, 19.4, 20.14, 19.2, 15.49]
Would you like to see the parameter for another date? Yes
Choose another date to inspect: 9/10/2007
Program end
```

Figure 10: Input of the data visualisation

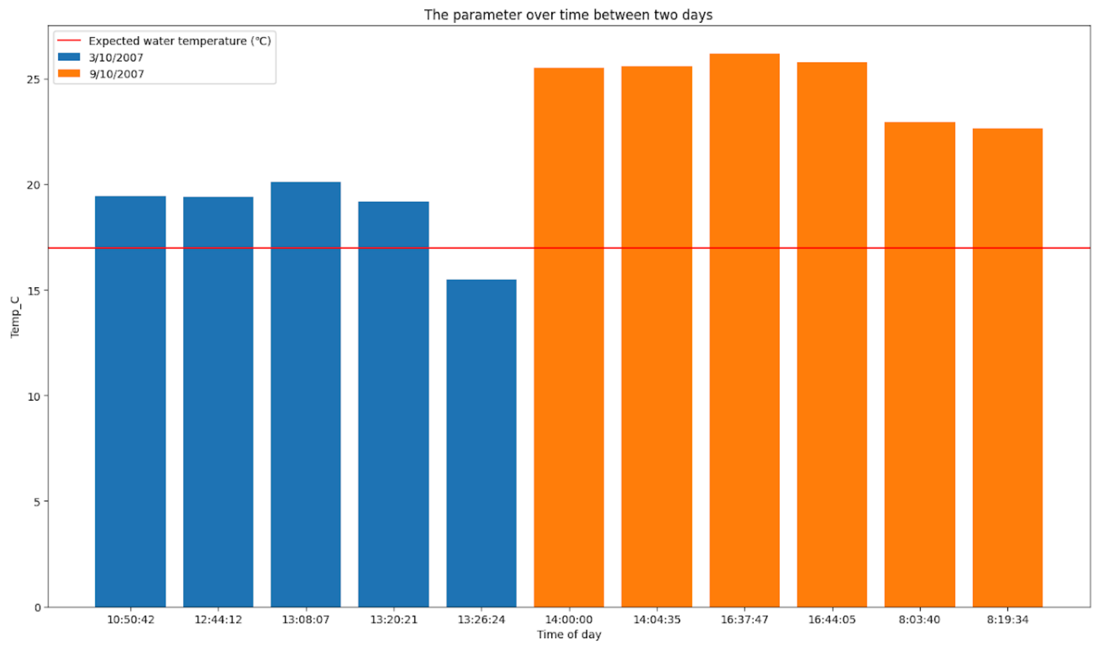


Figure 11: Example of chart output from data visualisation program

A major advantage to using a Python based program is the ease of use and the ability to adapt it based on the user's interests. This means that the ILALC community can adjust the visualisation program to better reflect the parameters they want to see and how they want to view it. The code will be provided in the appendix with explanations as to what each part of the code does. As this program is developed by our team for the exclusive use of the ILALC, this does not have any financial cost towards the project.

Another concept important with using a dataset and with using code to visualise it, is the cleanliness of the data. What this means is when the dataset is transferred to the cloud database, is it in a form where the program can easily read and use it for visualisation purposes. This is essential to do because even though the data sensors being used are of a high quality, errors could still occur and this allows for the ILALC to run the program smoothly without not understanding why it does not work. The cleaning of the dataset will basically remove any null or not applicable values associated with a parameter and replace them with a 0, thus allowing the program to still function. If difficulties arise when using the program, support will be available regarding how to operate and adjust it by the project team.

Community App Demonstration

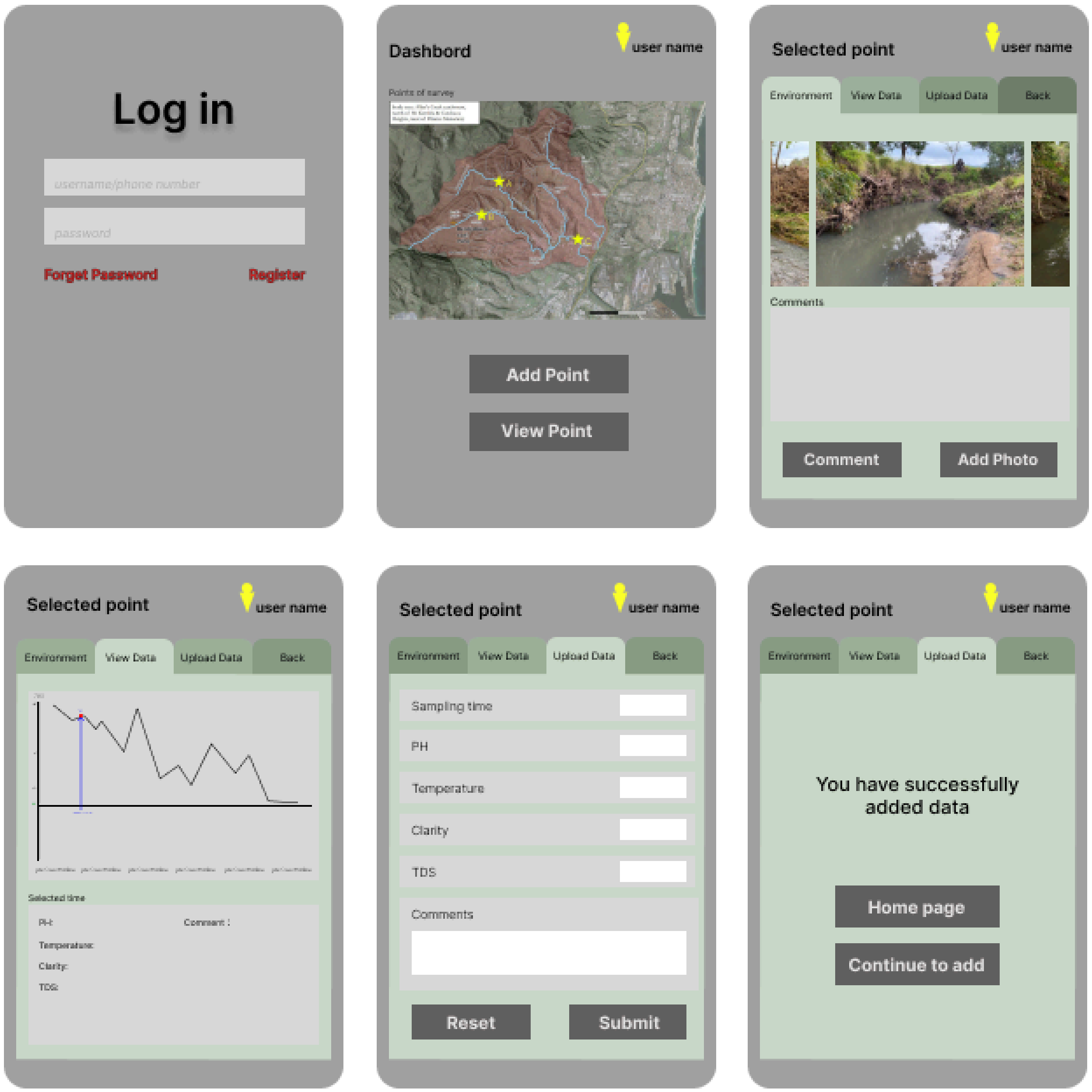


Figure 12: Community App UI step by step usage layout

For the following explanation/walkthrough, observe Figure 6.0, starting with the frame in the top left corner and moving to the right, again with the second row starting from the left. When a user logs in, they are taken directly to the dashboard (home page) where the user has the following interaction points. In the top right corner of the page users can access the profile screen to modify account information; in the center of the screen users can see a map of the stream system in the Kembala Mountains, which shows survey points added by other users; users can add a new survey point by clicking on the "Add Point" button so that other users can use this place later on Supplemental water quality data, users can also click a point, and then click "view points" to jump to the next page.

The new page provides specific information about a particular point. Users can click on "Environment", "View Data", "Upload Data" and "Back" in the navigation bar to switch to different windows. In the "environment" window, the user can edit the basic information of the point, such as site pictures, comments, etc.; in the "view data" window, the user can see the "water quality data" - "time" line graph, the user can drag the pointer on the line to view the specific data of a certain time. In the "upload data" window, the user can add a new set of data, these data will be uploaded to the database at the same time.

App type selection

We need to analyse the different types of apps because the development difficulty and cost are different for each type, and the more expensive and difficult to develop type can get a better user experience. Considering that the functionality of a community app is not too complicated, we need to choose a suitable app type in order to create an app in a short time.

What forms are available for the App

1. WebApp: Web App is a web site optimised for iOS/Android, which users can access without downloading and installing. The general web site uses web technology to display on mobile, including text, video, pictures, etc., while Web App focuses on "function", which is an application developed based on web technology to achieve specific functions and must be run by mobile browser. If the core function of the enterprise is not much, and the demand of the app focuses on the basic functions such as information inquiry and browsing, a Web App can be chosen.

2. Native App: Native App is an App written and operated by native program based on smartphone operating system (now the mainstream is ios and Android). Native App is based on the local operating system when it runs, so it has better compatibility and access ability, the best user experience and the best interactive interface, but it is also the most difficult app to develop and has the highest development and maintenance costs.

3. Hybrid App: It is a half-native and half-web hybrid app, which is developed with web language and program language at the same time and distributed through different application stores, and users need to download and install it. Native App is now the mainstream application, Instagram, Evernote, Uber, Gmail, Twitter are all Hybrid App routes.

What technologies are needed to develop different types of apps

1. Web App: The built-in browser of iOS/Android is based on webkit kernel, so when developing webApp, most of them use html or html5, CSS3, JavaScript technology to do UI layout, realising traditional C/S architecture software function on website page, and java, php, ASP are used for server-side technology.

2. Native App：Developing Native App needs different development language according to the running mobile system, the development language needed for developing Android App is java, and you also need to be familiar with Android environment and mechanism. The main knowledge points are as follows: 1. development environment, Android Studio, eclipse. 2. data structure, some functions of the App involve doing algorithms, so you should have a certain mathematical foundation 3. Android SDK, will API interface development, including the ability to develop APIs on their own and experience in calling third-issue APIs. 4. familiar with tcp, IP, socket and other

network protocols. Net. 6. In addition to these functional bases, App development also involves UI design, framework, performance optimization, debugging adaptation, etc. Objective-C is the mainstream programming language for developing iOS system. Objective-C is the mainstream programming language for developing iOS apps, and developers generally use Apple's iOS SDK to build the development environment. iOS SDK is an indispensable software development kit for developing iOS apps, which provides a variety of tools needed in the development process from creating programs to compiling, debugging, running, testing, etc.

3. Hybrid App: The mainstream of hybrid development is web-based development, that is, the hybrid App development type written in web language, interspersed with Native features, web language mainly html5, CSS3, JavaScript. web-based App user experience is good or bad, depending on the underlying middleware interaction and cross-platform capabilities [13]. Currently there are many excellent development tools on the market, such as AppmAkr, Appmobi. Hybrid App is mostly used for enterprise app development, enterprises can choose different development types and development tools according to their needs, at present, Hybrid App has become a mobile development trend, on the one hand, Hybrid App development does not use or most do not use On the one hand, Hybrid App development does not use or most of the native language, but can have the characteristics of native applications, on the other hand, with the development of web technology, Hybrid App technology has matured.

When developing an Native App we needed to code separate apps for iOS and Android to meet cross-platform services, which meant we needed a longer development time. In addition, the team would need a broader skill base and would require a larger team size. Longer development time and a larger team meant higher costs for development, but this did not meet our requirements.

In order to run Hybrid App properly, hybrid applications require plugins and APIs. These pose security risks. In addition, Hybrid Apps cannot leverage the platform's user interface, which may impact the user experience.

This shows that web applications are less difficult and less expensive to develop. The web app is always up to date because updates are applied centrally and it eliminates any compatibility issues. In addition to this, webapp is highly extensible, any place that has a web browser can actually use webapp, which gives users a richer way to use the app, for example through a computer or tablet [12].

Estimated cost to build a web platform

The main cost of the webapp will be spent on maintenance and servers.

Table 2: Cost of the web app development process

Items	Cost ($) per month
Servers	$70-$320
Push Notifications	$10
Emergency Maintenance	The prices are typically dependent on the size of the app, and the nature of changes in the functionality. $200-$1000
App Stores Developer Fee	$25 at Google Play, $99 at Apple App

Webapp structure

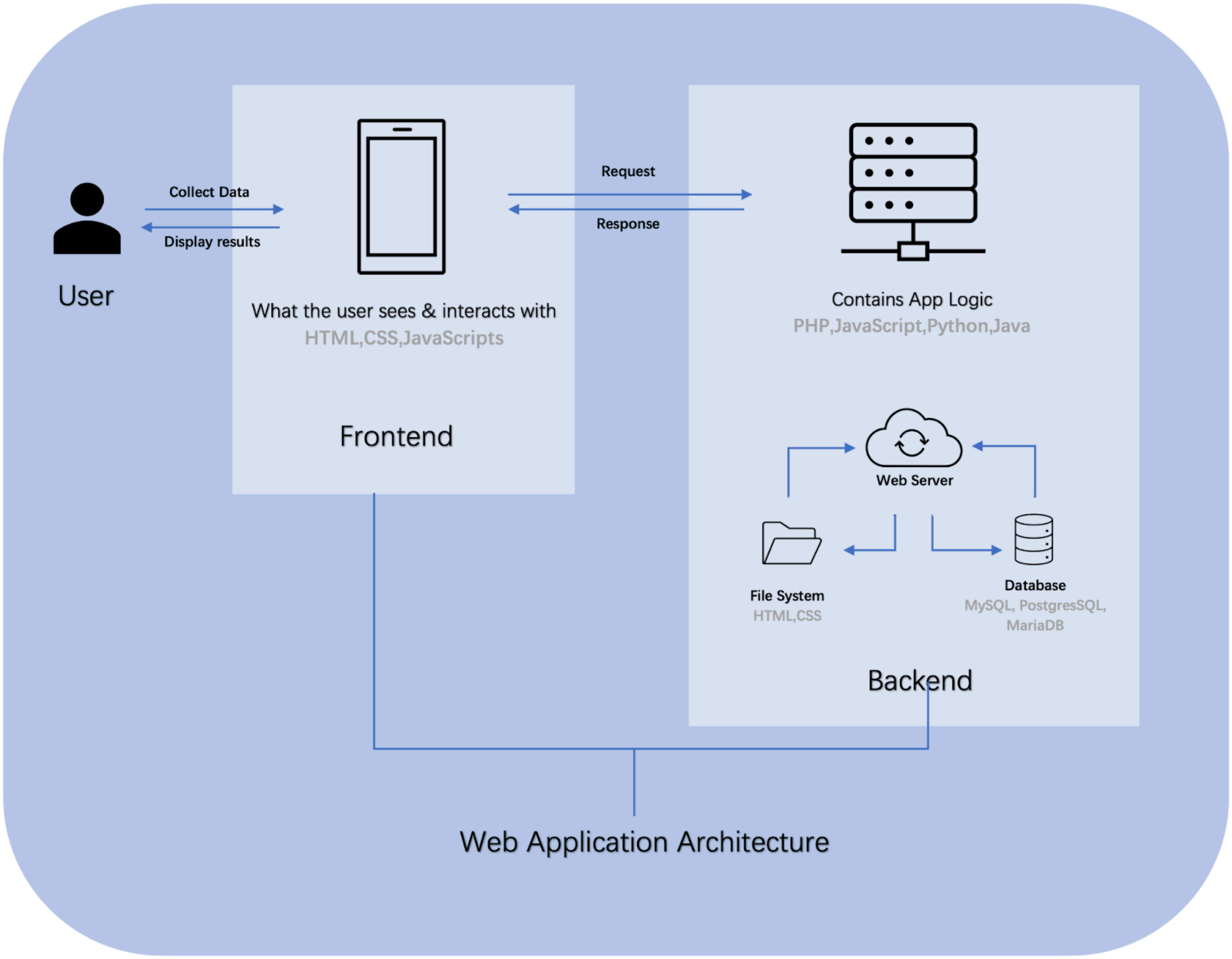


Figure 13: Web Application Architecture

With any typical web application, The code can be divided into two main parts, one is Client-Side and the other is Server-Side, which run side by side.

- Client-side Code - The code that is in the browser and responds to some user input
- Server-side Code - The code that is on the server and responds to the HTTP requests

Web developers developing web applications can write server-side code using C#, Java, JavaScript, Python, Ruby, etc., depending on what the code on the server will do relative to the code in the browser.

The server-side code is responsible for storing different types of data, including user information and user input, as well as creating the pages requested by the user.

Client-side code can be written in CSS, HTML, and JavaScript. Unlike the server-side code, the client-side code can be seen and modified by the user. It reacts to the user's input.

The client-side code communicates only through HTTP requests and cannot read files directly from the server, which explains how the two ends work with each other.

Community Engagement Tours

The ILALC is adamant that they want to have a community driven approach that empowers locals to engage in the water monitoring process. While probes are great for monitoring water quality, the disadvantage is that it is a set-and-forget type of solution, which fails to make any meaningful effort to engage the community in the whole process. By integrating our data loggers solution with tours we are able to provide an accurate water monitoring solution that does not sacrifice community engagement. Our educational tours provide locals, tourists, and educational organisations with the opportunity to understand the significance of the region (cultural tours), how to test the quality of the water (science tours), and how to visualise and interpret the data from the creek system (statistics online learning modules). The community is actively participating in every step from the start to the finish of our solution. There is also the opportunity to raise some revenue with the tours, this money will help to fund the water monitoring solution.

What Tours Will Be Offered?

Table 2: Overview of the tours proposed

Cultural Tours	Scientific Tours	Statistics Online Learning Modules
The cultural tour is designed for anyone interested in learning about the creek system and Aboriginal spirituality. This is the tour that will be marketed the most towards tourists and the community as it has the widest reach in terms of appeal. It could also be used as a way to introduce young children to Aboriginal spirituality or other educational groups.	This tour is geared mainly towards school children as a way to get practical experience with ecology/biology/chemistry. The type of testing conducted will vary depending on age group but it can range from anything as simple as temperature tests to learning about the tests conducted by the data logger for more advanced age groups.	This is more advanced than the tours, it is more appropriate for late highschool students and higher education groups. These modules will rely mainly on partnering with universities and schools as a way to introduce real-world data visualisation to students and grasp some basic programming skills.

Proposed Itineraries

All tours will begin on a van from the ILALC where participants will meet the tour guide who will drive them out to the site, and then bring them back after the tour has ended.

Cultural Tour

This tour will be curated by and ideally led by First Nations persons from the Dharawal region. The exact location and contents of the tour are yet to be finalised as it would not be appropriate for a group of non-First Nations people to dictate which areas are significant spiritual sites and explain the history of the land. The idea is that this tour empowers the local First Nations people by giving them a platform to share their history and culture with willing participants, and thus the contents of this tour is awaiting a Dharawal person's consultation.

Scientific Tour

The tour guide will explain a bit on the drive over about measures of water quality and things that can affect it. The tour guide will drive to a location with a data logger. On site, the tour guide will explain in more detail what tests the group will be doing, this will vary depending on the age group and school teachers would have already been consulted in the booking process to help decide this. Typical tests will include temperature and pH for younger age groups, however older age groups may also learn about all of the things the data logger tests for using a demo one that is not in the creek system. Testing will be supervised and the tour guide will also explain how to log the results into the app. The tour guide will follow this with a quick debrief on what the results they have gathered mean for the quality of the water system while also engaging the group to draw conclusions themselves.

Statistics Online Learning Modules

This differs slightly from the tours because it is not a physical tour but instead a set of online learning modules. The idea is that organisations can purchase a package that will include some recent data collected from the data loggers, and videos and information on how to visualise and interpret the data. The benefits of online learning modules is that after the modules are designed there is little-to-no maintenance cost unlike the tours, the package can simply be sold online to any organisation interested. The modules will run through: reading in the data to a Python script, plotting and visualising data, finding and extracting features of interest, visualising trends, and understanding and interpreting the information they have collected and what it means for the quality of the creek system.

Proposed App Integration

It is proposed that the app that is being developed will be used as an integrated part of the tours that are operated. The app will provide the basis for data to be recorded from members in the tours & will also have information about both the tours & the local area. The app has an inbuilt function to allow for data to be logged and will then additionally allow for participants to use this data to analyse & understand metrics about the water quality. Therefore it will form the foundation for each of the 3 tour types.

Users will be able to view the tours itinerary and additionally see more information about each area that they visit during the tour. It will allow for a more enriched learning experience as people can read information that may not be easy to share verbally in the tour and will allow for further learning experiences.

Estimated Initial Tour Requirements

It is planned that for the first year of implementation the tours would run three days a week with the possibility of expansion with growing demand. The weekly program would run as follows:

- 3x Cultural Tours to be run on a Monday weekly
- 3x Scientific tours to be run on a Tuesday Weekly
- Online Statistics Course All Days of Week

Based on market research it is estimated that in the first year the demand for the courses will be as follows:

Table 3: Summary of the demand of separate tours based on market research

Estimated Initial Tour Demand	
Cultural Tours	3120 People
School Aged	40 People Per Week
Mature Aged	20 People Per Week
Scientific Tours	3120 People
School Aged	40 People Per Week
Mature Aged	20 People Per Week
Statistic Course	50 Classes (School Aged)

To be able to run these tours weekly the ILALC will require to hire and adequately train 2x tour guides that will be able to run these tours. These two full-time staff members will be responsible for running the aforementioned tours and additionally will spend the time that they are not doing the tours, maintaining and running the data logging, processing & maintenance operations required. This will increase the efficiency of the proposed solution as with only two staff members one will be able to run the hardware which is remotely logging the data, the software systems which are helping to develop an understanding of the data & also the income revenue stream which are the tours which are additionally building community engagement and awareness of cultural and environmental areas of concern.

The staff members will need to be adequately trained in the following areas:

- The rich history of the land and important cultural aspects for the Cultural tours
- A developed understanding of statistics & science that will allow for them to teach the pre-made lesson plans
- Ability to use and maintain the data loggers
- A knowledge of the local area and the itinerary that the kids will be doing in order to allow for them to successfully lead a group of participants on the tour
- Required First aid qualifications

RISK MANAGEMENT

Risks for this project have been split into 4 categories:

1. Data & Software: Because we are reliant on data loggers being able to wirelessly transmit data and also a community app, we need to account for the risks that could be encountered if these were to malfunction
2. Hardware: The data loggers themselves are not foolproof, there are many risks in regards to how they collect data and if they were to be damaged or lost
3. Tourism: A huge aspect of our solution is reliant on community engagement and tours, the logistics of moving lots of people around and risks to health and safety must be accounted for
4. Planning: This section relates to risks that may occur prior to the deployment of the solution, these risks typically are the highest because if there are any major issues here then the entire proposal will not be able to go ahead

The risk level is displayed for each of the risks, these were decided using the Risk Level table in Appendix E. After the mitigation strategy is employed, the risks have been shown to be greatly reduced, and there are no longer any "Very High" risks.

Risk Register

Risk source/hazard	*Likelihood*	*Potential Impact*	*Risk level*	*Risk Liability*	*Risk control/mitigation plan*	*Responsible party for risk control/mitigation*	*Altered Risk*
DATA & SOFTWARE							
Hacking	Possible	Moderate	**High**	Data scientists and ILALC, legal action may be pursued	Employ a software engineer to implement safety measures	Software engineer	Unlikely/Moderate = **Medium**
Incorrect data collected from probes	Possible	Moderate	**High**	Incorrect conclusions will be made from the data - could lead to inability to challenge for necessary change	Revise the design and functionality of the probes, do lots of testing and monitoring	Our team	Unlikely/Moderate = **Medium**
Incorrect data collected from tour members	Possible	Minor	**Medium**	Community will see incorrect or meaningless conclusions - discourage them from engaging with project	Improve our explanation on how to take the measurements and make the kits easy to use. Discard the measurements	Tour guide	Unlikely/Not significant = **Low**

Cloud server being destroyed	Rare	Major	**Low**	Software engineers will be liable, potential to lose all data collected, very disastrous for ILALC	Employ a software engineer to implement safety measures, backup to a harddrive regularly	Software engineer	Rare/Moderate = **Low**
Bugs in community app and software	Unlikely	Minor	**Low**	Hard for the community to engage with the app if it crashes and is buggy	Employ a software engineer to eliminate the bugs, do lots of beta testing before deployment	Software engineer	Unlikely/Minor = **Low**
Privacy concerns on community app	Unlikely	Moderate	**Medium**	Depending on what type of data is stored on the app, users could risk sensitive information being breached	Employ a software engineer to implement safety measures. Reduce need to have user info, keep everything deidentified	Software engineer	Rare/Minor = **Low**
HARDWARE							
Data logger malfunctions	Likely	Minor	**High**	Loss of data acquisition, money and environmental damage could be caused	Employ a technician to repair if it is significant otherwise train the tour guide on basic maintenance, do lots of stress testing	Technician or tour guide	Possible/Minor = **Medium**
Damage due to flora/fauna	Possible	Moderate	**High**	Loss of data acquisition, money and environmental damage could be caused	Employ a technician to repair if it is significant, or replace it, otherwise train the tour guide on basic maintenance, do lots of stress testing	Technician or tour guide	Unlikely/Minor = **Low**
Natural disasters	Unlikely	Severe	**High**	Loss of data acquisition, money and environmental damage could be caused	Employ a technician to repair if it is significant, or replace it, otherwise train the tour guide on basic maintenance, do lots of stress testing	Technician or tour guide	Unlikely/Moderate = **Medium**
Sabotage	Rare	Minor	**Low**	Loss of data acquisition, money and environmental damage could be caused	Employ a technician to repair if it is significant, or replace it, otherwise train the tour guide on basic maintenance	Technician or tour guide	Rare/Minor = **Low**
Probe becomes dislodged and drifts downstream	Unlikely	Moderate	**Medium**	Loss of data acquisition, money and environmental damage could be caused	Get tour guide to relocate if close, otherwise get a technician, ensure that it is properly and securely anchored, GPS tracking	Technician or tour guide	Unlikely/Minor = **Low**
TOURISM							

Not enough bookings	Possible	Moderate	**High**	ILALC will lose money from fewer bookings, solution will not seem as attractive to the community. Tour guides will be out of work	Lots of advertisements and outreach to universities and schools	Our team and ILALC	Unlikely/Minor = **Medium**
Injuries on tour	Unlikely	Moderate	**Medium**	ILALC and our team. Reflects a bad image onto the tour - less people want to go	Sign a waiver. Safety talk/guidelines. Tour guide be trained in First Aid and carry a First Aid kit.	Tour guide and people supervising the program	Unlikely/Minor = **Low**
Getting lost on tour	Unlikely	Moderate	**Medium**	Emergency services will likely have to be called, likely to be traumatic for the person(s) lost. Bad image for the tours	Safety talk/guidelines. Give participants a map and ways to contact the tour guide. Make everyone buddy up	Tour guide	Rare/Moderate = **Low**
Not enough qualified tour guides	Possible	Major	**High**	Tours may be hard to organise, organisations and people may lose interest in booking	Ample advertising and community outreach programs to find qualified people. Competitive remuneration	ILALC and tour team	Unlikely/Major = **Medium**
Bad weather on a day the tour is scheduled	Likely	Major	**Very High**	The tour may have to be cancelled, rain could interfere with testing. Very inconvenient to those who have booked	Provide apparel suitable for wet weather conditions. Reschedule or provide refunds if it needs to be called off	ILALC and tour team	Likely/Moderate = **High**
PLANNING							
ILALC do not like the idea	Possible	Severe	**Very High**	Our team will have to revise the idea to make it suitable with ILALC's needs. Potential to waste their time	Consult them regularly throughout the planning stage to make a proposal suited to their needs. Alter our vision to meet their desires	Tour team	Possible/Major = **High**
South32 objecting the data acquisition	Likely	Major	**Very High**	Depending on the legitimacy of their claim, legal actions may be pursued. ILALC, tour team and lawyers will	Consult them regularly throughout the planning stage. Understand what we can legally do. Market it in a way that appears to help them.	ILALC and tour team	Likely/Moderate = **High**

				have to negotiate with South32			
Unable to acquire data probes in a timely manner	Possible	Minor	**Medium**	Delay on project starting will mean the tours may not be able to be booked and supply chain may need to be reconsidered. May cost more money for ILALC	Do significant planning and stay in communication with suppliers	Tour team	Unlikely/Minor = **Low**
People do not understand or engage with the community app	Likely	Minor	**High**	Tour team will have to investigate the marketing and UI of the app. Will disincentive the tours	Promote community engagement through social media, and outreach programs	Tour team	Likely/Minor = **High**

STAKEHOLDER MANAGEMENT

This plan aims to show how this project will interact and work with each of the stakeholders that hold any level of interest.

Stakeholder	Nature of interest	Level of interest	Level of influence	Engagement level (see matrix)	Engagement method(s)	Engagement timeframe	Anticipated outcomes
ILALC	Direct - asked for this project to be done	High	High	Full engagement	Face-to-face, zoom meetings, email, phone calls, all available options for both parties. Will directly interact with the ILALC	As long as necessary and however often as each party wants to. This team will work with the ILALC's schedule.	Their input and opinions are of utmost importance so the direction of the project will be dependent on them. All decisions will be run by them before implementation.
Local Government	Secondary - they need to be shown reasons to be interested	Low	High	Keep satisfied	Emails and phone calls. Will mainly on their request if plans are not regulation but that should not happen. Will directly interact with the local government	Will mainly contact them during the implementation phase of the project to make sure everything is within regulation. After that period less contact	They are important as they can affect the go ahead to actually implement the project but since policies have been checked and abided by, this project should be okay
South32	Direct - helping facilitate the project	High	Low	Keep informed	Face-to-face, zoom meetings, email, phone calls, all available options for both parties. Will directly interact with South32	They will be contacted by us whenever data or information is required that encroaches on their area. Also when probes are placed in areas that they own, it is important to get their permission.	As our project is within regulations and is aiming to provide context towards the ILALC's concerns, South32 should support this project. It is also within the scope for this project to allow South32 to gain a deeper

							connection to the local community.
Schools/Institutions	Educational	Low	High	Keep satisfied	Face-to-face, zoom meetings, email, phone calls, all available options for both parties. Will be in touch with educational institutions	They will be contacted in the planning for tours phase of the project to get their involvement. Afterwards it will be a constant communication on how the tours are going in terms of patron satisfaction.	The tours will gain a genuine source of interest and community engagement. The educational aspect of the project will help foster a greater connection towards the creek health by the local community
Local indigenous people	Cultural	High	Low	Keep informed	Face-to-face, zoom meetings, email, phone calls, all available options for both parties and social media posts. Will mainly interact through community forums/gatherings	They will get updates all throughout the project. Mainly in terms of the tours content and how to better facilitate this project towards community wants	The project will be more well-rounded in the cultural aspect as the local indigenous people would understand that the best. By integrating their opinions this project will create a more culturally sensitive work.
Local residents		Low	Low	Little effort required	Face-to-face, zoom meetings, email, phone calls, all available options for both parties and social media posts. Will mainly interact through community forums/gatherings	Provide updates through social media or community gatherings throughout the project. Mainly for interested people.	This provides a tertiary perspective to how people will use this project. Will see how people feel the project will affect a wider audience.

Refer to Appendix C for the engagement level matrix

ECONOMIC VIABILITY ASSESSMENT

This assessment is broken down into initial startup costs, yearly costs and revenue. The costs are further broken down into hardware, software and tours aspects of the proposed solution.

Initial Startup Costs

Table 4: Summary of categorised initial startup cost estimates

Component	Estimated Unit Cost	Quantity	Estimated Cost
Remote Data Logger			**$75,354**
Cement blocks	$5	20	$100
Data logger case	$50	20	$1,000
MX2001 sensor	$1690	20	$33,800
MX2501 sensor	$1853	20	$37,000
Exhibited demo set of data logger to clients	$3594	1	$3594
Software			**$4.500**
App development	$4,500	1	$4,500
Tours			**$80.000**
Van	$75,000	1	$75,000
Video Production for Statistics Course	$500	10	$5,000
Total	**NA**	**NA**	**$159,854**

Yearly Costs

Table 6: Summary of categorised yearly cost estimates

Component	Unit Cost	Quantity	Estimated Cost
Remote Data Logger			**$10,000**
Maintenance	$500	20	$10,000
API tool kits	$67	20	$1,340
Software			**$30,590**
Private cloud server	$27,600	1	$27,600

App hosting server	$2,340	1	$2,340
Emergency Maintenance	$650	1	$650
Tours			**$135,000**
Wages of Staff (Per Year)	$60,000	2	$120,000
Yearly Van Costs	$5,000	LS	$5,000
Equipment for Cultural & Scientific Tours (Per Year)	$10,000	LS	$10,000
Total	**NA**	**NA**	**$175,590**

Revenue

Table 7: Summary of estimated revenue generated from tours

Component	Ticket Price	Tours Per Year	Estimated Income
Cultural Tours (Per Student	$30	3120	$93,600
Scientific Tours (Per Student)	$30	3120	$93,600
Statistics Course Subscription (Per Class)	$200	3120	$10,000
Total			**$197,200**

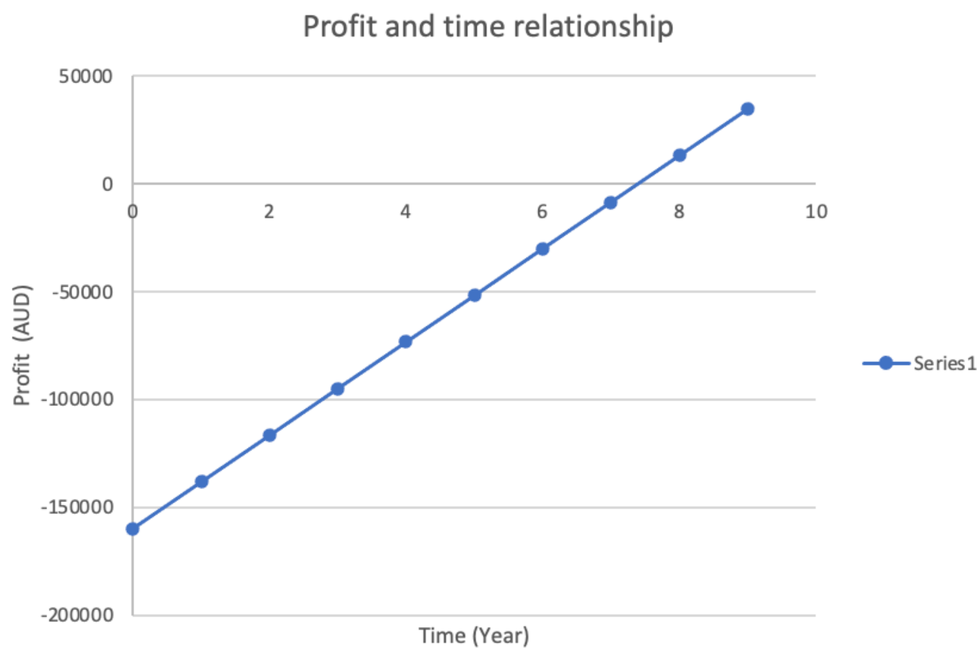


Figure 8: Graph of profit and time relationship

This mathematical model shows that our proposal starts making profit at around 7.5 years after we launch it. (Figure 8)

Conclusion

Our solution is a three-pronged approach to solving the ILALC's need for a community-driven water monitoring system for the Mount Kembla Creek system. We combine hardware in the form of data loggers, software in the form of a community water quality logging app, and tours as a way to engage the community from the start to the end of the solution. We plan to empower the Land's Council with a way to engage the community in the testing and data visualisation processes, whilst also spreading awareness and educating locals and tourists about the significance of the region and giving them the opportunity to learn more about Aboriginal spirituality.

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APPENDIX A

MX2001 specifications [2]

HOBO MX Water Level Logger

Specifications

Pressure (Absolute) and Water Level Measurements MX2001-01-S and MX2001-01-Ti-S

Operation Range	0 to 207 kPa (0 to 30 psia); approximately 0 to 9 m (0 to 30 ft) of water depth at sea level, or 0 to 12 m (0 to 40 ft) of water at 3,000 m (10,000 ft) of altitude
Factory Calibrated Range	69 to 207 kPa (10 to 30 psia), 0° to 40°C (32° to 104°F)
Burst Pressure	310 kPa (45 psia) or 18 m (60 ft) depth
Water Level Accuracy*	Typical error: ±0.05% FS, 0.5 cm (0.015 ft) water Maximum error: ±0.1% FS, 1.0 cm (0.03 ft) water
Raw Pressure Accuracy**	±0.3% FS, 0.62 kPa (0.09 psi) maximum error
Resolution	<0.02 kPa (0.003 psi), 0.21 cm (0.007 ft) water
Pressure Response Time (90%)***	<1 second at a stable temperature

Pressure (Absolute) and Water Level Measurements MX2001-02-S

Operation Range	0 to 400 kPa (0 to 58 psia); approximately 0 to 30.6 m (0 to 100 ft) of water depth at sea level, or 0 to 33.6 m (0 to 111 ft) of water at 3,000 m (10,000 ft) of altitude
Factory Calibrated Range	69 to 400 kPa (10 to 58 psia), 0° to 40°C (32° to 104°F)
Burst Pressure	500 kPa (72.5 psia) or 40.8 m (134 ft) depth
Water Level Accuracy*	Typical error: ±0.05% FS, 1.5 cm (0.05 ft) water Maximum error: ±0.1% FS, 3.0 cm (0.1 ft) water
Raw Pressure Accuracy**	±0.3% FS, 1.20 kPa (0.17 psi) maximum error
Resolution	<0.04 kPa (0.006 psi), 0.41 cm (0.013 ft) water
Pressure Response Time (90%)***	<1 second at a stable temperature

Pressure (Absolute) and Water Level Measurements MX2001-03-S

Operation Range	0 to 850 kPa (0 to 123.3 psia); approximately 0 to 76.5 m (0 to 251 ft) of water depth at sea level, or 0 to 79.5 m (0 to 262 ft) of water at 3,000 m (10,000 ft) of altitude
Factory Calibrated Range	69 to 850 kPa (10 to 123.3 psia), 0° to 40°C (32° to 104°F)
Burst Pressure	1,200 kPa (174 psia) or 112 m (368 ft) depth
Water Level Accuracy*	Typical error: ±0.05% FS, 3.8 cm (0.125 ft) water Maximum error: ±0.1% FS, 7.6 cm (0.25 ft) water
Raw Pressure Accuracy**	±0.3% FS, 2.55 kPa (0.37 psi) maximum error
Resolution	<0.085 kPa (0.012 psi), 0.87 cm (0.028 ft) water
Pressure Response Time (90%)***	<1 second at a stable temperature

Specifications (continued)

Pressure (Absolute) and Water Level Measurements MX2001-04-S and MX2001-04-Ti-S

Operation Range	0 to 145 kPa (0 to 21 psia); approximately 0 to 4 m (0 to 13 ft) of water depth at sea level, or 0 to 7 m (0 to 23 ft) of water at 3,000 m (10,000 ft) of altitude
Factory Calibrated Range	69 to 145 kPa (10 to 21 psia), 0° to 40°C (32° to 104°F)
Burst Pressure	310 kPa (45 psia) or 18 m (60 ft) depth
Water Level Accuracy*	Typical error: ±0.075% FS, 0.3 cm (0.01 ft) water Maximum error: ±0.15% FS, 0.6 cm (0.02 ft) water
Raw Pressure Accuracy**	±0.3% FS, 0.43 kPa (0.063 psi) maximum error
Resolution	<0.014 kPa (0.002 psi), 0.14 cm (0.005 ft) water
Pressure Response Time (90%)***	<1 second at a stable temperature

Barometric Pressure (MX2001-TOP)

Operation Range	66 to 107 kPa (9.57 to 15.52 psia)
Temperature Calibrated Range	-20 to 50°C (-4 to 122°C)
Accuracy	±0.2 kPa (±0.029 psi) over full temperature range at fixed pressure; maximum error ±0.5% FS
Water Level Accuracy*	Typical error: ±0.075% FS, 0.3 cm (0.01 ft) water Maximum error: ±0.15% FS, 0.6 cm (0.02 ft) water
Resolution	<0.01 kPa (0.0015 psi)
Response Time	<1 second at stable temperature
Stability (Drift)	<0.01 kPa (0.0015 psi) per year

Temperature Measurements (All Sensor End Models MX2001-0x-S and MX2001-0x-Ti-S)

Operation Range	-20° to 50°C (-4° to 122°F)
Accuracy	±0.44°C from 0° to 50°C (±0.79°F from 32° to 122°F), see Plot A
Resolution	0.1°C at 25°C (0.18°F at 77°F), see Plot A
Response Time (90%)	5 minutes in water (typical)
Stability (Drift)	0.1°C (0.18°F) per year

Logger

Operating Range	-20° to 50°C (-4° to 122°F)
Radio Power	1 mW (0 dBm)
Transmission Range	Approximately 30.5 m (100 ft) line-of-sight
Wireless Data Standard	Bluetooth Low Energy (Bluetooth Smart®)
Logging Rate	1 second to 18 hours
Logging Modes	Fixed interval, multiple intervals with up to 8 user-defined logging intervals and durations, or burst
Memory Modes	Wrap when full or stop when full
Start Modes	Immediate, date & time, or next interval
Stop Modes	When memory full, stop with HOBOmobile, date & time, or after a set logging period
Time Accuracy	±1 minute per month 0° to 50°C (32° to 122°F)
Battery	Two AA, 1.5 V alkaline batteries, user replaceable
Battery Life	1 year, typical with logging interval of 1 minute. Faster logging and/or statistics sampling intervals, entering burst logging mode, excessive readouts, checking of Full Status Details, and remaining connected with HOBOmobile will impact battery life.
Memory	256 KB memory (30,000 sets of measurements)
Full Memory Download Time	Approximately 2 minutes; may take longer the further the device is from the top end of the logger
Dimensions	Top end (MX2001-TOP): 2.54 cm (1.0 inches) diameter, 28.9 cm (11.4 inches) length; mounting hole 7.6 mm (0.3 inches) diameter Sensor end (MX2001-0x-S and MX2001-0x-Ti-S: 2.54 cm (1.0 inches) diameter, 9.91 cm (3.9 inches) length **Note:** The length of the water level logger cable (CABLE-DR-xxx) can vary ±3% from the length ordered. The logger adds 38.8 cm (15.3) inches to the length of the cable ordered.

Specifications (continued)

Weight	Top end (MX2001-TOP): Approximately 136 g (4.78 oz) in air Stainless sensor end (MX2001-0x-S): Approximately 106 g (3.74 oz) in air; approximately 53.9 g (1.9 oz) in fresh water Titanium sensor end (MX2001-0x-Ti-S): Approximately 80 g (2.83 oz) in air; approximately 37 g (1.3 oz) in fresh water
Wetted Materials	Top end (MX2001-TOP): PVC housing, Polycarbonate end cap, Viton O-ring Stainless sensor end (MX2001-0x-S): Acetal housing, Viton and Buna-N O-rings, ceramic sensor in stainless steel end cap Titanium sensor end (MX2001-0x-Ti-S): Acetal housing, Viton and Buna-N O-rings, ceramic sensor in Titanium end cap Cable (CABLE-DR-XXX): Polycarbonate end cap, PVC end cap, polycarbonate collar nut, Viton O-rings, polyurethane jacket
Environmental Rating	NEMA 6, IP67 (top end)
CE	The CE Marking identifies this product as complying with all relevant directives in the European Union (EU).
FC	See last page

MX2501 specifications [3]

HOBO MX pH and Temperature Logger

MX2501

Specifications

pH Sensor

	in pH	in mV
Range	2.00 to 12.00 pH	-512 to 512 mV
Accuracy	±0.10 pH units within ±10°C of temperature at calibration	±0.20 mV
Resolution	0.01 pH	0.02 mV
Response Time	1 minute typical to 90% at constant temperature in stirred water	

Temperature Sensor

Range	-2° to 50°C (28.4° to 122°F)
Accuracy	±0.2°C (±0.36°F)
Resolution	0.024°C at 25°C (0.04°F at 77°F)
Response Time	7 minutes typical to 90% in stirred water

Logger

Operating Range	-2° to 50°C (28.4° to 122°F) — non-freezing
Buoyancy	Fresh water: 13.6 g (0.48 oz) negative Salt water: 19.6 g (0.69 oz) negative
Waterproof	To 40 m (131.2 ft)
Water Detection	Water conductivity level of 100 µS/cm or greater is necessary for reliable detection of water. Deionized water or water below 100 µS/cm may not be detected. The water conductivity circuit may not reliably detect water that has frozen around the electrodes, i.e. below 0°C (32°F).
Radio Power	1 mW (0 dBm)
Transmission Range	Approximately 30.5 m (100 ft) line-of-sight in air
Wireless Data Standard	Bluetooth Low Energy (Bluetooth Smart)
Logging Rate	1 second to 18 hours
Logging Modes	Fixed interval (normal, statistics) or burst
Memory Modes	Wrap when full or stop when full
Start Modes	Immediate, push button, date & time, or next interval
Stop Modes	When memory is full, push button, date & time, or after a set logging period
Time Accuracy	±1 minute per month 0° to 50°C (32° to 122°F)
Battery Type	One AA 1.5 Volt, user-replaceable
Battery Life	1 year typical at 25°C (77°F) with logging interval of 1 minute and Bluetooth Always On selected in software. 2 years typical at 25°C (77°F) with logging interval of 1 minute and Bluetooth Off Water Detect enabled in software. 3 years typical at 25°C (77°F) with logging interval of 1 minute and Bluetooth Always Off selected in software. Faster logging intervals and statistics sampling intervals, burst logging, remaining connected with the app, excessive downloads, and paging may impact battery life.
pH Electrode Life	6 months
Memory	152 KB (43,300 measurements, maximum)
Full Memory Download Time	Approximately 60 seconds; may take longer the further the mobile device is from the logger
Dimensions	22.86 x 4.27 cm (9.0 x 1.68 inches)
Weight	268.2 g (9.46 oz)
Wetted Materials	Logger: PVC housing and sensor end cap, polycarbonate closure caps and mounting end cap with a TPE switch pH electrode: plastic-bodied with Pellon® junctions and gel electrolyte, glass pH sensor bulb
Environmental Rating	IP68
CE	The CE Marking identifies this product as complying with all relevant directives in the European Union (EU).
FC	See last page

Spreadsheet calculations for feasibility study

Parameters			Calculated Forces		
Mass of data logger (kg)	2.865		Drag force (N)	25.33882971	
Volume of data logger (m^3)	0.00810842		Net buoyancy force (N)	51.4379502	
Drag coefficient of data logger	0.2		Tension force (N)	57.34037855	
Cross-section radius (m)	0.1136		Buotancy force/g (kg)	5.24342	
Drag coefficient of cement block	2				
Gravity (m^2/s)	9.81		**Calculated values for the cement block**		
Water density (kg/m^3)	1000		Mass (kg)	9.936860154	condition 1&2 satisfied
Flow velocity (m^2/s)	2.5		Width and height,b (m)	0.09519165984	
Static friction coefficient	0.7		Length, L (m)	0.7615332787	
Density of cement (kg/m^3)	1440		Width to length ratio, N	8	

Appendix B

Data Visualisation python script code

```
import pandas as pd # Import necessary packages

import matplotlib.pyplot as plt


# Read the cleaned dataset and create pandas DataFrame

data = pd.read_csv('waterdata_cleaned.csv')

df = pd.DataFrame(data)


# Show available parameters

for col in df.columns:

    print(col)


# Create inputs for parameters and date

parameter = input('Choose one of the parameters to look at: ')


date = input('Choose a date to see, in the format of dd/mm/yy: ')


# Find the data corresponding to the inputs

rows = df[df['Date'] == date]

time = sorted(rows['Time'].tolist())

print(time)

value = df[df['Date'] == date][parameter].tolist()

print(value)


# If a comparision is wanted between two dates, get another one, otherwise end the program

q = input('Would you like to see the parameter for another date? ')
```

```
if q.lower() == 'yes':

    date2 = input('Choose another date to inspect: ')

    print('Program end')

else:

    print('Program end')


rows2 = df[df['Date'] == date2]

time2 = sorted(rows2['Time'].tolist())

value2 = df[df['Date'] == date2][parameter].tolist()


# Function to get the expected value for chosen parameter, ILALC can add the
other values after doing some testing

def expected_var(parameter):

    y ={'Temp_C':17}

    return y[parameter]


# Display the chart

plt.bar(time,value,label = date )

plt.bar(time2,value2,label = date2)

plt.xlabel('Time of day')

plt.ylabel(parameter)

plt.axhline(expected_var(parameter),color = 'red', label = 'Expected water
temperature (℃)')

plt.legend()

plt.title('The parameter over time between two days')

plt.show()
```

Appendix C

Engagement level matrix

		Power/Influence	
		Low	High
Interest	High	Keep Informed (e.g. email update lists, town hall information events)	Full engagement (E.g. one-on-one consultation, small group meetings, regular 2-way communication)
	Low	Little effort required (e.g. information on request or access to public announcements)	Keep satisfied (E.g. address interests, keep well informed, incorporate views where offered)

Appendix D

Project Implementation Plan (Gantt Chart)

		Jan 2023	Feb 2023	Mar 2023	Apr 2023	May 2023	Jun 2023	July 2023	Aug 2023	Sep 2023	Oct 2023	Nov 2023	Dec 2023	Jan 2024
	REMOTE DATA LOGGER HARDWARE													
1.1	Development of the Design	■	■	■										
1.2	Prototyping of Design Phase				■	■	■							
1.3	Functionality Testing & Modifications							■	■	■				
1.4	Integration Testing within System										■	■	■	
1.5	Implementation													■
	SOFTWARE													
2.1	Project Specific & Planning Stage	■	■	■										
2.2	Development of the Cloud Data Base				■	■	■	■	■					
2.3	Development of the Data Visualisation Script				■	■	■	■	■					
2.4	Integration of Systems									■	■			
2.5	Testing of Systems											■	■	
2.6	Implementation													■
2.7	Initial System Scope Definitions for App	■	■	■										
2.8	Design of UI & Backend of App				■	■	■	■	■					
2.9	Refinements of App									■	■	■		
2.10	Implementation Deployment												■	■
	IMPLEMENTATION OF TOURS													
3.1	Develop Programs	■	■	■										
3.2	Consultation with Area Specific Experts about Programs				■	■								
3.3	Integration of Tour Requirements into App						■	■	■					
3.4	Hiring & Training Relevant Staff									■	■	■	■	
3.5	Tours Begin													■

Appendix E

Risk level

			Potential consequences				
			Minimal consequences. (E.g. Will not significantly delay project, cost implications easy to manage)	Temporary impacts requiring some effort to rectify (E.g. Project delays, deferral of work, require design revisions)	Temporary impact requiring significant effort to rectify	Permanent impact (E.g. requires significant redesign, revision of project scope, requirement to source more funding)	Total loss (E.g. project cancellation)
			Not significant	**Minor**	**Moderate**	**Major**	**Severe**
Likelihood	Expected to occur regularly under normal circumstances	**Almost certain**	**Medium**	**High**	**Very high**	**Very high**	**Very high**
	Expected to occur at some time	**Likely**	**Medium**	**High**	**High**	**Very high**	**Very high**
	May occur at some time	**Possible**	**Low**	**Medium**	**High**	**High**	**Very high**
	Not likely to occur in normal circumstances	**Unlikely**	**Low**	**Low**	**Medium**	**Medium**	**High**
	Could happen but probably never will	**Rare**	**Low**	**Low**	**Low**	**Low**	**Medium**