Title: Investigating Technologic Advances in Water Sampling

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INVESTIGATING TECHNOLOGIC ADVANCES IN WATER SAMPLING

Brennan.Mair

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Abstract

Water quality monitoring on a regular basis is an important part of managing New Zealand's waterways and gauging changes in the aquatic environment. Traditional methods of taking samples from boats or canoes can be expensive, labour intensive and have health and safety risks.

Advancements in drone technology have made it possible to sample bodies of water via a drone platform in areas where boats or personnel are unable to access. Large expensive boats with a licenced skipper where people lean over the side to take samples will no longer be needed and labour costs with a drone can be reduced to as little as one or two operators who stand on the shore.

Before drones can be used as water sampling devices it is critical to assess their effectiveness in collecting samples without affecting the quality of data collected. This research investigated the production and modification of a novel, low cost, open source Niskin bottle (device that can be attached to a drone), to assess its effectiveness in collecting water samples compared to traditional methods of a Van Dorn.

The water samples were taken from several locations using the created device and traditional method, with samples tested in the lab and graphed to compare for significant differences and similarities. The findings of this research show that the quality of water samples collected using the novel drone device was not significantly different from that of samples collected using traditional sampling techniques. The study also demonstrates that low-cost water sampling devices can be constructed using off the shelf parts and electronics.

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Introduction

Water quality monitoring is an important part of managing our environment. Traditional methods of taking samples from boats or canoes can be expensive, labour intensive and have health and safety risks (Castendyk et al., n.d., p. 1036).

Advancements in drone technology has seen the development of water sampling via a drone platform possible and in areas where boats are unable to access (Castendyk et al., n.d., p. 1036). Large expensive boats with a licenced skipper where people lean over the side to take samples is not needed and labour costs with a drone can be to reduced to as little as one or two operators who stand on the shore. Before drones can be used as water sampling devices it is critical that the method and data collection does not influence the quality of data collected(Lally et al., 2019, p. 571).

This research will investigate the production and modification of a low cost, open source Niskin bottle from a design by Andrew Thaler (2019) distributed under the Creative Common – Attribution license, also to investigate the difference between samples taken with a drone device and traditional methods.

Rationale

Water sampling using traditional methods can be expensive and labour intensive, developments in drone technology coupled with low cost 3D printing and electronics, a device can be made small enough to be delivered to water sampling locations using a drone.

Aim

To use emerging 3D printing and electronic technologies to produce a water sampling device to extract water at depths using a drone as a platform for delivery.

Objectives

1. To implement the production and use of a low cost at depth water sampling device small enough to be carried by a drone.

2. To collect water samples with flask and compare outcome with traditional methodologies and techniques.

Literature Review
Reasons for water sampling

Water testing is done by Environment Southland to create baseline measurements and compare its current state and determine trends over time (Wilson et al., 2012, p. 29). This an important role to make sure our lakes and water ways are not polluted by runoff from land. Water testing is part of the Regional Water Plan standards and the National Policy Statement for Freshwater Management (*About the National Policy Statement for Freshwater Management | Ministry for the Environment*, 2019). Under the National Policy Statement for Freshwater Management, it requires regional councils to:

- consider and recognise Te Mana o te Wai in freshwater management
- safeguard fresh water's life-supporting capacity, ecosystem processes, and Indigenous species
- safeguard the health of people who come into contact with the water
- maintain or improve the overall quality of fresh water within a freshwater management unit
- improve water quality so that it is suitable for primary contact more often
- protect the significant values of wetlands and outstanding freshwater bodies
- follow a specific process (the national objectives framework) for identifying the values that tāngata whenua and communities have for water, and using a specified set of water quality measures (called attributes) to set objectives
- set limits on resource use (e.g., how much water can be taken or how much of a contaminant can be discharged) to meet limits over time and ensure they continue to be met
- determine the appropriate set of methods to meet the objectives and limits
- take an integrated approach to managing land use, fresh water and coastal water
- involve iwi and hapū in decision-making and management of fresh water.

(*About the National Policy Statement for Freshwater Management | Ministry for the Environment*, 2019)

These are all important measures to maintain and protect our fresh water into the future. Frequent and precise sampling enables a reliable baseline of freshwater condition.

Current Methods

Water samples are taken via many different methods, including and not limited to wading, bankside, bridges and boats(*National Environmental Monitoring Standards*, 2019, p. 11). These methods all have their own challenges, for example care must be taken when using a boat to take samples as they need to be taken ahead of the bow to minimise any possible contamination (*National Environmental Monitoring Standards*, n.d., p. 33). Furthermore, motorised boats must be equipped with appropriate safety equipment and comply with Maritime New Zealand rules (*National Environmental Monitoring Standards*, n.d., p. 12).

Onsite risk assessments must be carried out with all methods of sampling, with some being riskier than others (*National Environmental Monitoring Standards*, n.d., p. 12).

Methods of sampling via drone have been used in areas around the world, with some lakes and retired mining zones being too dangerous or not accessible by boat have been successfully tested using drones (Cengiz Koparan et al., 2018, p. 2). Benefits of using drones include reduced labour, reduced costs and increased safety(Cengiz Koparan et al., 2018, p. 2).

What was learnt from literature review

Water testing and getting true base line measurements is important to maintain an accurate overview of the state of the waterways. The traditional methods of taking samples can be time consuming and can have health and safety risks. Within this field there is room on improvements in the methods of taking water samples. Drone delivery of a sampling device could remove the time and safety constraints meaning more testing can be done. With more testing comes more overall understanding of the impacts in the aquatic environment.

Future Scope

As a result of the Niskin bottle[1] being controlled by a small wireless microcontroller, it will be easy to expand the capabilities to take temperature, dissolved oxygen, conductivity and pH readings at the water samples underwater location. Global Positioning System (GPS) logging could also be easily added to provide spatial data on exact sampling location. Depending on payload weight requirements, this may or may not be possible.

[1] A Niskin Bottle is a plastic cylinder with stoppers at each end to capture a water sample, this device is used to take samples at a desired depth (Flanders Marine Institute, 2020)

Methodology

Water sample collection methods

1. Get lab container ready, write sample location, date and time on label and identifier i.e. Normal sample one, remove lid
2. Van Dorn to be used to take water sample
3. Drip 1m below water surface
4. Trigger Van Dorn
5. Remove back to bank
6. Empty Van Dorn into bottles
7. Secure container lid
8. Put in cool chilly bin

Niskin sampling method

1. Get lab container ready, write sample location, date and time on label and identifier i.e. Niskin sample one, remove lid
2. Put Niskin device in water
3. Make connection to devices computer
4. Trigger device with collection program
5. Remove Niskin device from water
6. Remove cap from end
7. Carefully tip water to lab collection container
8. Secure container lid
9. Put in cool chilly bin

Water sample handling and transport

Water samples are to be taken and put in clean plastic containers supplied by the lab. Samples must be kept cold not frozen and transported to the lab as soon as possible after collection. A minimum sample size of 500ml is required (Hills Laboratories, 2020)

Parts list and Costs

Flask

Parts for the flask will need to be sourced overseas as local costs can be up to 3-4 times that of buying overseas. Parts will be brought locally, where parts are available.

- Nylon Fishing line 200Lb with Crimps, Hunting and Fishing $22.99
- 6x40mm eyebolts, Mitre10 $8.48
- Spear gun rubber tubing 3x5mm 1m length, Hunting and Fishing $15
- Solid Rubber Stoppers 32mm diameter x2, $18.49
- 2-inch Polycarbonate Tubing $87.87 + $15 freight + GST = $118.30
- HiTec 32646W HS-646WP Waterproof Analog Servo Motor $89.63 + $8 freight = $97.63, www.mindkits.co.nz

Electronics

The operation of the flask will be able to be triggered remotely with Wi-Fi ad-hoc connection to Raspberry Pi and controlled via Virtual Network Computing (VNC) with a laptop or tablet. The waterproof servo is connected to the general-purpose input/output port (GIPO). The batteries installed were two Li-ion 18650 3.7v 4200mAh hour rating, giving 7.4v directly to the servo motor and supplying voltage to the step-down converter for 5v @ 2amps to supply the Raspberry Pi with power. This is more than enough to run the as Raspberry Pi all day even though the raspberry pi zero has excessive computing power and the benefit of Wi-Fi Built in. The distance achieved from the Wi-Fi was trailed, and with the home-built antenna over 150m was observed from a cell phone without any disconnections. This distance could be increased with a laptop, USB Wi-Fi dongle and a home built high gain directional antenna.

- 2 x Battery Li-ion18650 3.7v 6000mAh, www.ebay.com $15
- Rechargeable Li-ion Battery Holder, Jaycar electronics $5.90
- Step Down Voltage Board ebay.com $10
- Raspberry Pi Zero W $20.87, www.mindkits.co.nz
- Homemade antennas
- Copper wire 2mm, Jaycar electronics $15
- RG402 sma male plugs ebay.com $3.30

- 1M Low PIM RF RG402 semi flex coax Cable ebay.com $6.50
- Case 120x70x50mm, Jaycar electronics $15.90
- Waterproof switches x 2, Jaycar electronics $13.80

Electronics Cost Approx. $106.27

Total projected costs, flask $280.89 + $106.27 = $387.16

Environment Southland have covered costs for Flask Construction and water sample laboratory testing.

I will personally covered electronics and 3D printing costs. Total cost including all parts and 3d printing costs/miscellaneous parts, totalled under $500.Flask Construction

Flask Construction

Polycarbonate pipe needs to be cut to size to collect 1L of water

Volume = $\pi r2h$

Options of lengths vs diameter to get 1L sample size:

a) 2.75inch inner diameter = 265 mm long 69mm diameter
b) 1.75inch inner diameter = 650 mm long 45mm diameter
c) 2-inch inner diameter = 500 mm long 51mm diameter
d) 1 7/8inch inner diameter = 570mm long 39mm diameter

The decision was made to go with 2-inch at 525mm long to house 1L of sample water, at this length and diameter stability is maximised. The extra 25mm is to allow room for caps to enter tube.

Flask Construction procedure

1. Print 3d parts
2. Cut tube to length
3. Install rubber between stoppers on inside of tube connected to eyelets
4. Install fishing line to eyelets, trigger and stoppers
5. Install servo in servo holder
6. Connect servo to raspberry pi zero controller

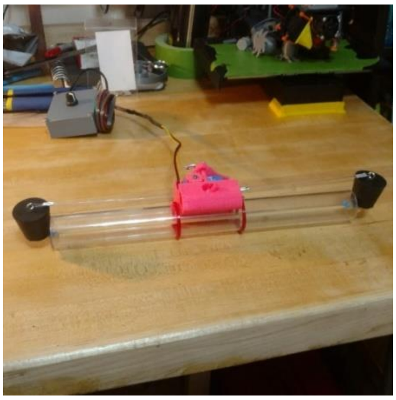

Figure 1. Complete flask. From Niskin3D, by Andrew Thaler, 2019, https://github.com/OceanographyforEveryone/Niskin3D

Electronics Construction and Configuring

1. Download Raspberry Pi software – Raspbian Buster with desktop from https://www.raspberrypi.org/downloads/raspbian/
2. Write operating system image to micro SD card
3. Install completed SD card in Raspberry Pi zero W and turn on
4. Plug in keyboard, mouse and monitor
5. Complete setup on display including wireless network
6. Configure VNC and SSH (Virtual Network Computing, Secure Shell)
7. Solder external antenna port on pi zero
8. Build antenna designed for 2.45Ghz
9. Configure Ad-hoc connection between pi zero and computer
10. Create antenna for Wi-Fi dongle on laptop – Directional 2.4Ghz
11. Wire servo motor on Flask to pi zero, include 1k resistor on data line to stop current overload
12. Install button switch on GIPO 21 and GND for clean shutdown
13. Add batteries and battery management system to pi zero
14. Create and configure app software
15. Test VNC, Wi-Fi ad hoc and servo
16. Test max distance of 2.4ghz Wi-Fi connection
17. Test battery life and measure current consumption of pi zero when servo in operation.
18. Build float system, add connectors and rope. Make sure its waterproof.

Raspberry Pi Zero W

The raspberry pi zero W has a 1Ghz single-core processor with 512MB of RAM. It has built in 802.11n wireless LAN (local area network) and header with GPIO ports (general-purpose input/output) https://www.raspberrypi.org/products/raspberry-pi-zero-w/ . It was chosen for its small size, low power consumption, ease of use and built-in wireless function.

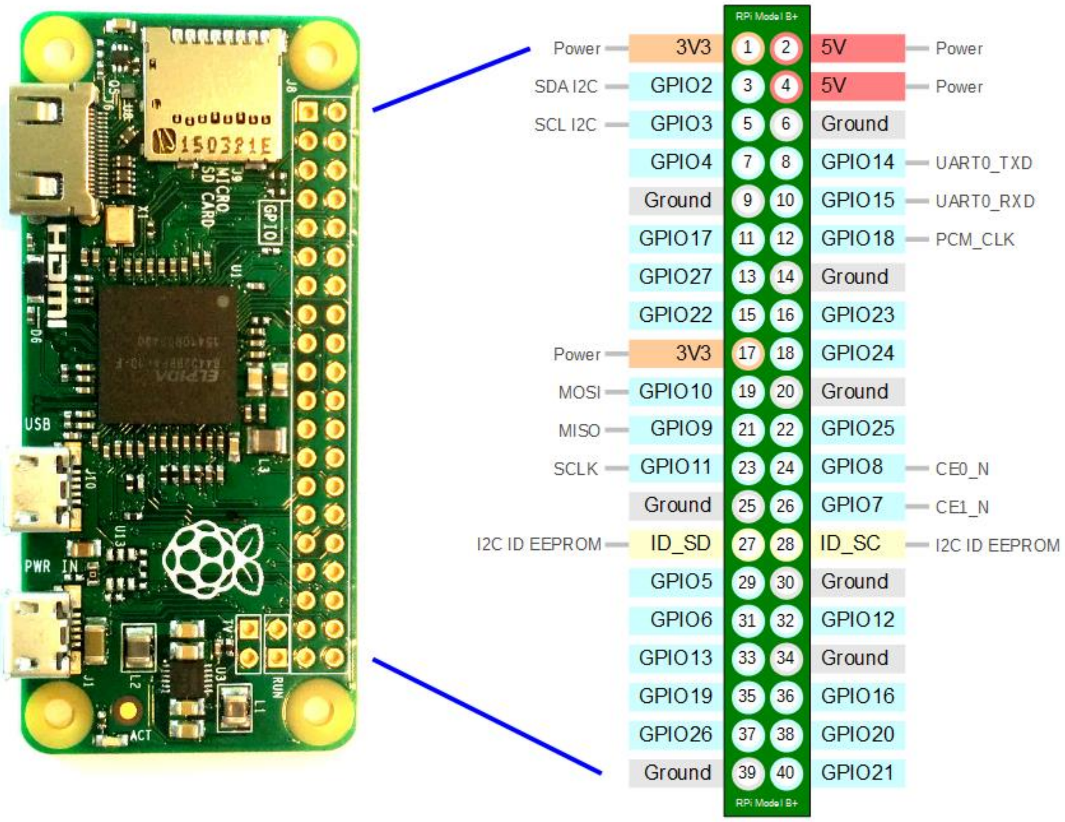

Figure 1. Image of Raspberry Pi Zero W with labelled GIPO port

Figure 2. image of GPIO port on raspberry pi zero W. From Stackexchange, 2019 https://raspberrypi.stackexchange.com/questions/83610/gpio-pinout-orientation-raspberypi-zero-w

- Push button added to GIPO pin 21 and GND, to enable clean shutdown
- Servo is connected to GPIO pin 11 labelled GPIO17, Also to Battery positive in and ground.
- The ds18b20 waterproof digital temperature sensor is connected to GIPO pin 4, with 4.7kokm pull up resistor connected between 3.3v and GIPO 4, this "pulls" GIPO pin 4 to the up state and stops it from floating. Red wire to be connected to 3.3v and black wire connect to ground. (This was not added but can be in future)

Many other sensors can be connected to header i.e. Ph meter, Conductivity meter.

Battery & Power distribution

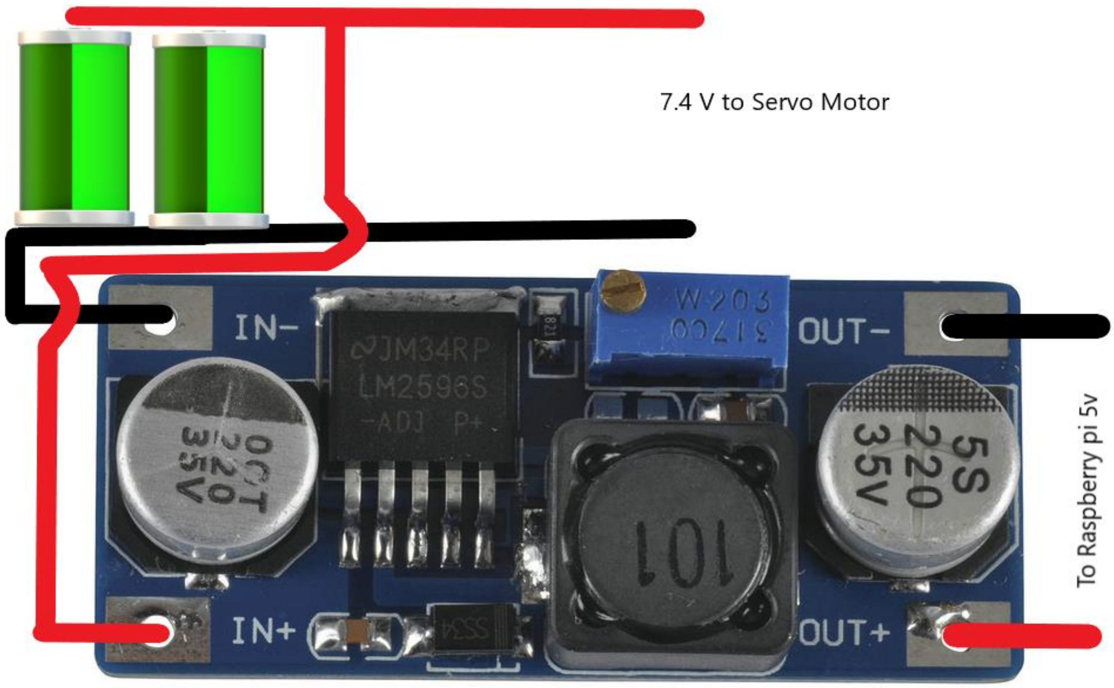

Figure 2. Stepdown Module. From Jaycar electronics 2020, https://www.jaycar.co.nz/arduino-compatible-dc-voltage-regulator/p/XC4514

The battery being used is two 3.7v Lithium LI-ion 18650 Battery giving a total of 7.4volts connected to a stepdown module, this will stepdown the 7.4 volts to 5 volts to supply the raspberry pi zero and the 7.4 volts will be supplied directly to servo motor.

Power consumption is around 120mA (0.7W) for the raspberry pi zero, this is not with servo running. The servo in standby draws 8mA and under normal operation conditions will draw ~1500mA for around two seconds. During testing the power supply held up to the day’s operations without any sign of battery discharge.

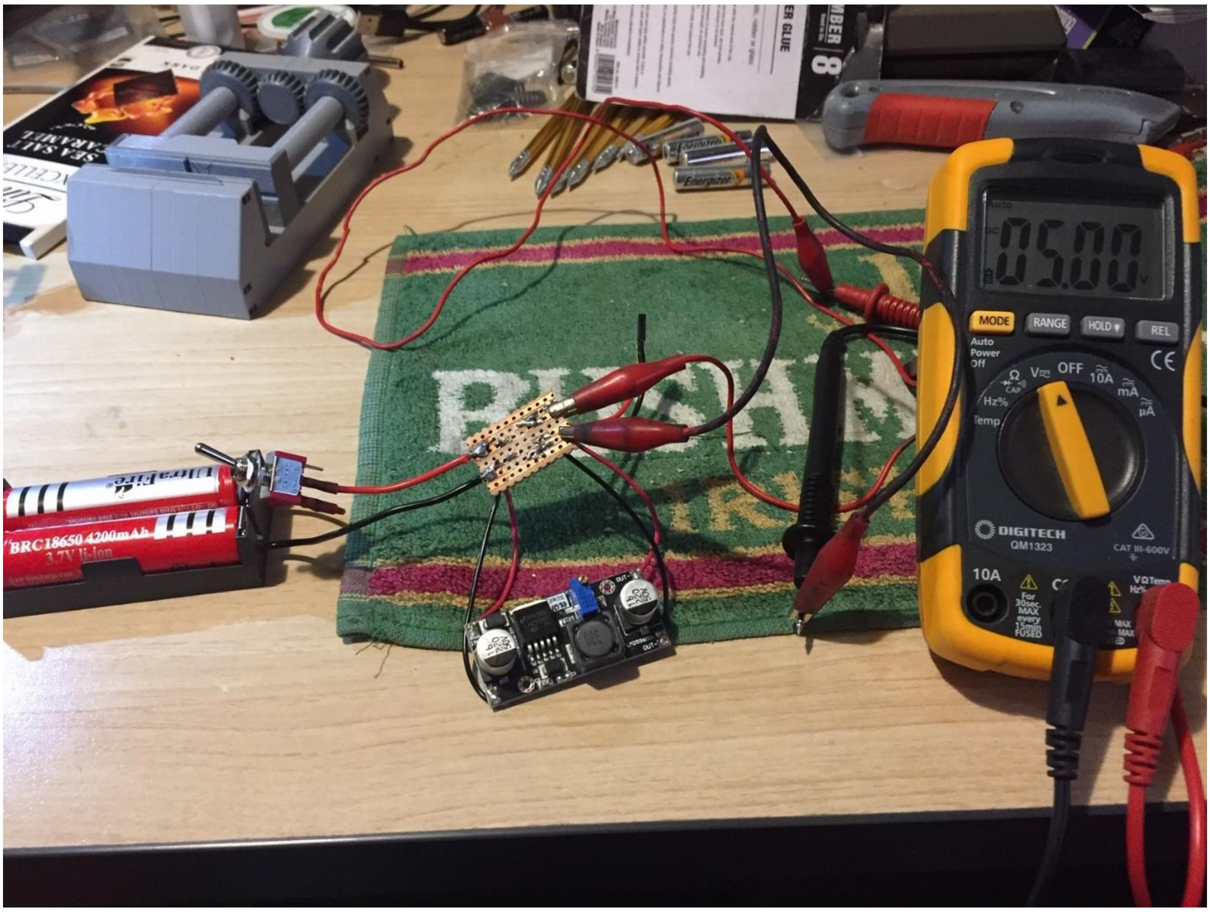

Figure 3. Adjusting stepdown module to 5volts and testing power breakout board. By Brennan Mair

A custom-made power disruption board was constructed to split the power from the batteries and to be sent to the servo motor directly, also for the power to be sent to the stepdown module for regulation to 5v to supply the raspberry pi. A light emitting diode (LED) was installed on the 5v power line to signal that the power was on an operational.

App construction

The app was created using python programming language, on the raspberry pi zero computer. This is a free programming language and can be downloaded at https://www.python.org/downloads/

Python is used because of ease of use and ability to easy access library functions with the GPIOzero (https://gpiozero.readthedocs.io/en/stable/index.html) recipes that can use raspberry pi zeros general purpose input/output (GPIO) port, this coupled with a tutorial on graphical user interfaces at https://core-electronics.com.au/tutorials/raspberry-pi-workshop-for-beginners.html an application can be easily created. Below the application and program will be listed:

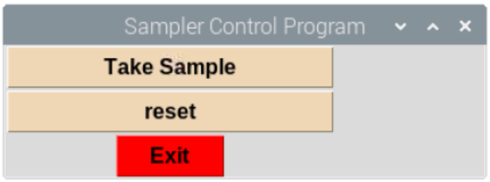

Figure 4. Image of Sampler Control App that runs on remote device. By Brennan Mair, 2020

Because the servo motor is being controlled by a GIPO port pin 4 on the raspberry pi computer, this pin is a Pulse-width modulation (PWM) pin. This is how the servo gets the information from software by how many pulses are sent, giving it the location to stop. But it was found a long way through the project that the servo operated erratically, the motor would move and sit there twitching. After some research it was found that the PWM signal is not stable because of the raspberry pi central processing unit (CPU) has other processes to run at the same time causing the PWM signal to not be perfect(raspberrypi.org, 2020). It is recommended to get a hardware board for controlling the servo to make it work correctly. The objective is to keep costs down so a work around was put in the code to stop the erratic movement. After the servo was called and made its movement for a set time (0.6 sec) a servo.detach command was sent to detach the PWM pin in software from the servo. This seemed to fix the problem with erratic movement without the need for extra hardware.

```
## Servo control when the GUI button is pressed, with hardware shutdown ##

from tkinter import *
import tkinter.font
from tkinter import Button as tkButton
from gpiozero import Servo
from time import sleep
import RPi.GPIO
from gpiozero import Button
from subprocess import check_call
from signal import pause
RPi.GPIO.setmode(RPi.GPIO.BCM)

### HARDWARE DEFINITIONS ###
servo=Servo(17)    #servo GIPO pin number
servo.detach()     #kill GIPO Servo signal, stops servo twitching


### GUI DEFINITIONS ###
win = Tk()
win.title("Sampler")
myFont = tkinter.font.Font(family = 'Helvetica', size = 12, weight = "bold")



### Event Functions ###
def takesample():
    sampleButton["text"]="Take Sample" # Servo to min to take sample
    servo.min()
    sleep(0.6)
    servo.detach()

def reset():
    resetButton["text"]="Reset" # Servo to max to reset trigger
    servo.max()
    sleep(0.6)
    servo.detach()

def close():
    RPi.GPIO.cleanup()      #reset GIPO port
    win.destroy()           #close window

def shutdown():
    check_call(['sudo', 'poweroff'])


shutdown_btn = Button(21, hold_time=2)    #hardware button pressed for 2sec for safe system shutdown
shutdown_btn.when_held = shutdown

### WIDGETS ###

# tkButton, triggers the connected command when it is pressed
sampleButton = tkButton(win, text='Take Sample', font=myFont, command=takesample, bg='green', height=1, width=24)
sampleButton.grid(row=0,column=1)

resetButton = tkButton(win, text='Reset', font=myFont, command=reset, bg='bisque2', height=1, width=24)
resetButton.grid(row=2,column=1)

exitButton = tkButton(win, text='Exit', font=myFont, command=close, bg='red', height=1, width=6)
exitButton.grid(row=3, column=1)

win.protocol("WM_DELETE_WINDOW", close) # cleanup GPIO when user closes window

win.mainloop() # Loops forever
```

Figure 5. Image of python code. By Brennan Mair, 2020

Code for Temperature sensor * this was not added*

The ds18b20 waterproof digital temperature sensor will need below code added to the control application:

```
import os                                                 # import os module
import glob                                               # import glob module
import time                                               # import time module
os.system('modprobe w1-gpio')                             # load one wire communication device kernel modu
os.system('modprobe w1-therm')
base_dir = '/sys/bus/w1/devices/'                         # point to the address
device_folder = glob.glob(base_dir + '28*')[0]            # find device with address starting from 28*
device_file = device_folder + '/w1_slave'                 # store the details
def read_temp_raw():
   f = open(device_file, 'r')
   lines = f.readlines()                                  # read the device details
   f.close()
   return lines

def read_temp():
   lines = read_temp_raw()
   while lines[0].strip()[-3:] != 'YES':                  # ignore first line
      time.sleep(0.2)
      lines = read_temp_raw()
   equals_pos = lines[1].find('t=')                       # find temperature in the details
   if equals_pos != -1:
      temp_string = lines[1][equals_pos+2:]
      temp_c = float(temp_string) / 1000.0                # convert to Celsius
      temp_f = temp_c * 9.0 / 5.0 + 32.0                  # convert to Fahrenheit
      return temp_c, temp_f

while True:
   print(read_temp())                                     # Print temperature
   time.sleep(1)
```

Figure 6. Python code for temperature sensor. From https://electrosome.com/ds18b20-sensor-raspberry-pi-python/

This above code in *figure 7*, will need to be modified to display temperature in the application, also 1-wire communications will need to be enabled for Pi to talk to sensor over digital device communication bus(Vivek Kartha, 2015). This was not completed in the first prototype but can be added in future iterations.

Hardware shutdown button

It was decided to add a hardware shutdown button to complete a clean shutdown of device to stop operating system from corrupt data if shutdown incorrectly, this was added to the GPIO21 and GND pins. Hold 2 seconds for hardware shutdown. Code was added into APP to complete this procedure.

Antennas

The antenna onboard of the raspberry pi zero W will only give a few hundred meters as it's just a small antenna etched onto circuit board (*Raspberry Pi Zero W External Antenna Mod*, n.d.). An external antenna port will need to be soldered onto the board and the track to the etched antenna disconnected. Construction of an external antenna will give much better distance.

Figure 7. Antenna port. From www.ebay.com

Wi-Fi is in the frequency range between 2.4Ghz and 2.5Ghz so antennas will be created to the wavelength of 2.45Ghhz using YouTube video for a guide (*Blade Antenna for 2.4GHz*, n.d.).

Wavelength λ (in meters) = the speed of light (300) / frequency (in Mhz) (*The A.R.R.L Antenna Book*, 1970, p. 25)

Wavelength λ (m) = 300 / 2450

λ = 0.12245 m

λ = 122.45 mm

λ/2 =61.225mm

For omnidirectional reception, a Non-polarized Bi-plain antenna will be created using quad half wavelengths(*The A.R.R.L Antenna Book*, 1970, p. 66).

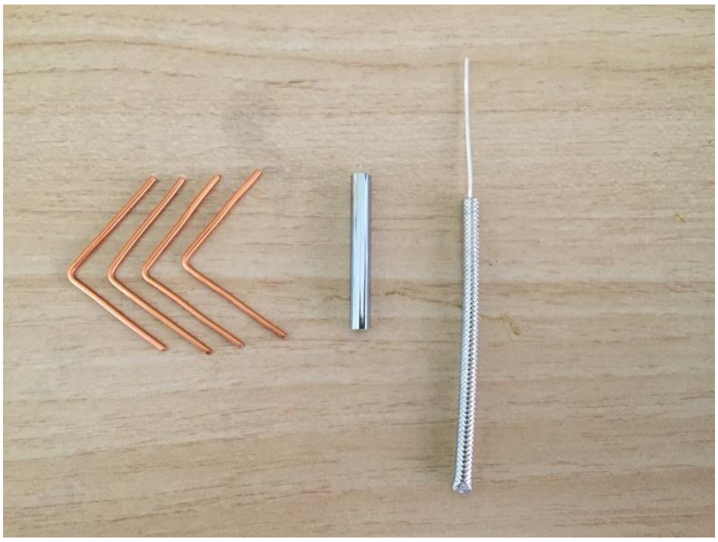

Figure 8. Image of parts required, By Brennan Mair, 2020

Four lengths of 22-gauge copper wire at the length of 61.225mm will be angled at 60 degrees and soldered onto the top of 33mm stripped RG402 (50Ω) rigid coax cable. To create a dipole antenna, 31mm of metal tube is to be soldered with insulation beneath to act as a ground plane (*The A.R.R.L Antenna Book*, 1970, p. 66).

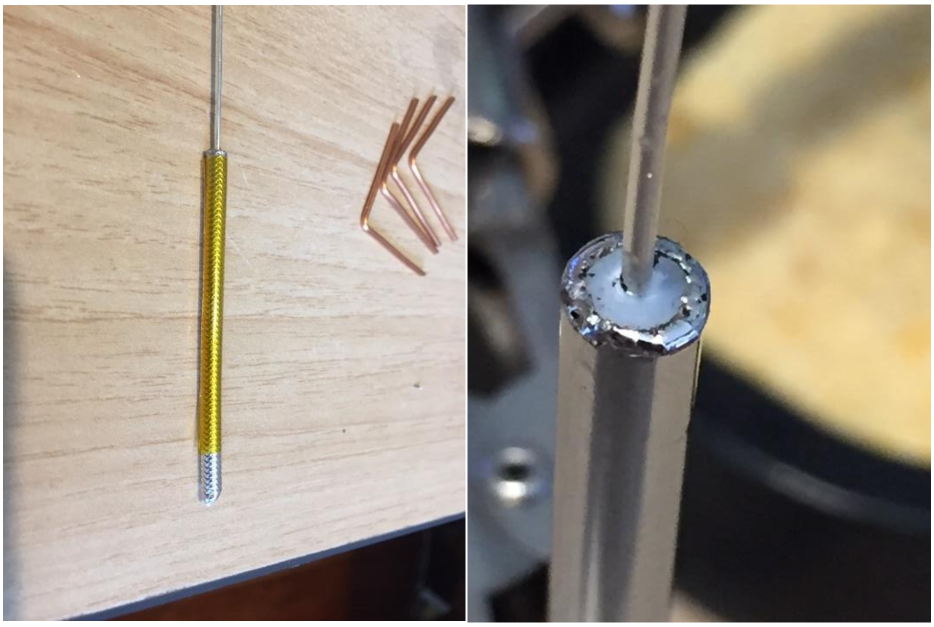

Figure 9. Left image shows RG402 with capton tape for insulation, Right image shows metal tube soldered over insulated RG402. By Brennan Mair, 2020

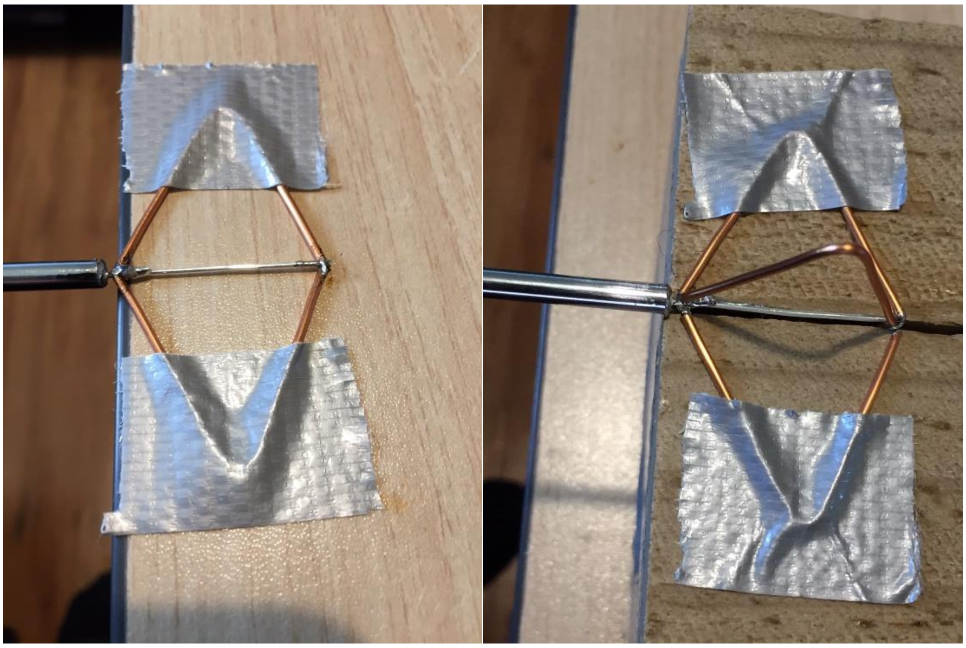

Figure 10. Left image shows elements stuck to table to enable soldering, Right image shows elements taped and vertical elements between two bits of wood, to enable soldering of joints. By Brennan Mair, 2020

Figure 11. Finished, Constructed antenna without end plug. By Brennan Mair, 2020

Tests of the constructed antenna will need to be conducted to check that resonant frequency is that of required frequency, and to adjust as required. This was not done as I could not get access to the required test equipment.

Floatation device

The electronics will be housed in a polystyrene buoy with a connection point on the top for the drone connection line and below for the flask line and trigger wire. This will need to be sealed enough to not let water into the electronics and batteries. A sealed box from Jaycar Electronics was used with waterproof switches, also the buoy was found to be top heavy so extra floatation was added to help stability.

Drone requirements

The most important attitudes for the drone are reliability and payload lift capacity (Lally et al., 2019, p. 572). With requirements of a sample size of 1L, the drone needs to be capable of lifting between 1-2.5kg payload. Reliability can come from using a hex drone rather than a quad, as if a motor fails a hex done is still able to fly (Agrawal & Shrivastav, 2013, p. 1803).

Testing Location

Setting

Lake Murihiku is a coastal lake 3.7km from Oreti Beach near Invercargill, covering some 5.3ha, with a small catchment area of 31ha. The main land use around the lake is mainly pastoral land and the lake is boarded by rushes and flax, with a variety of fish life. The lake has an average depth of 3meters(Robertson & Stevens, 2013).

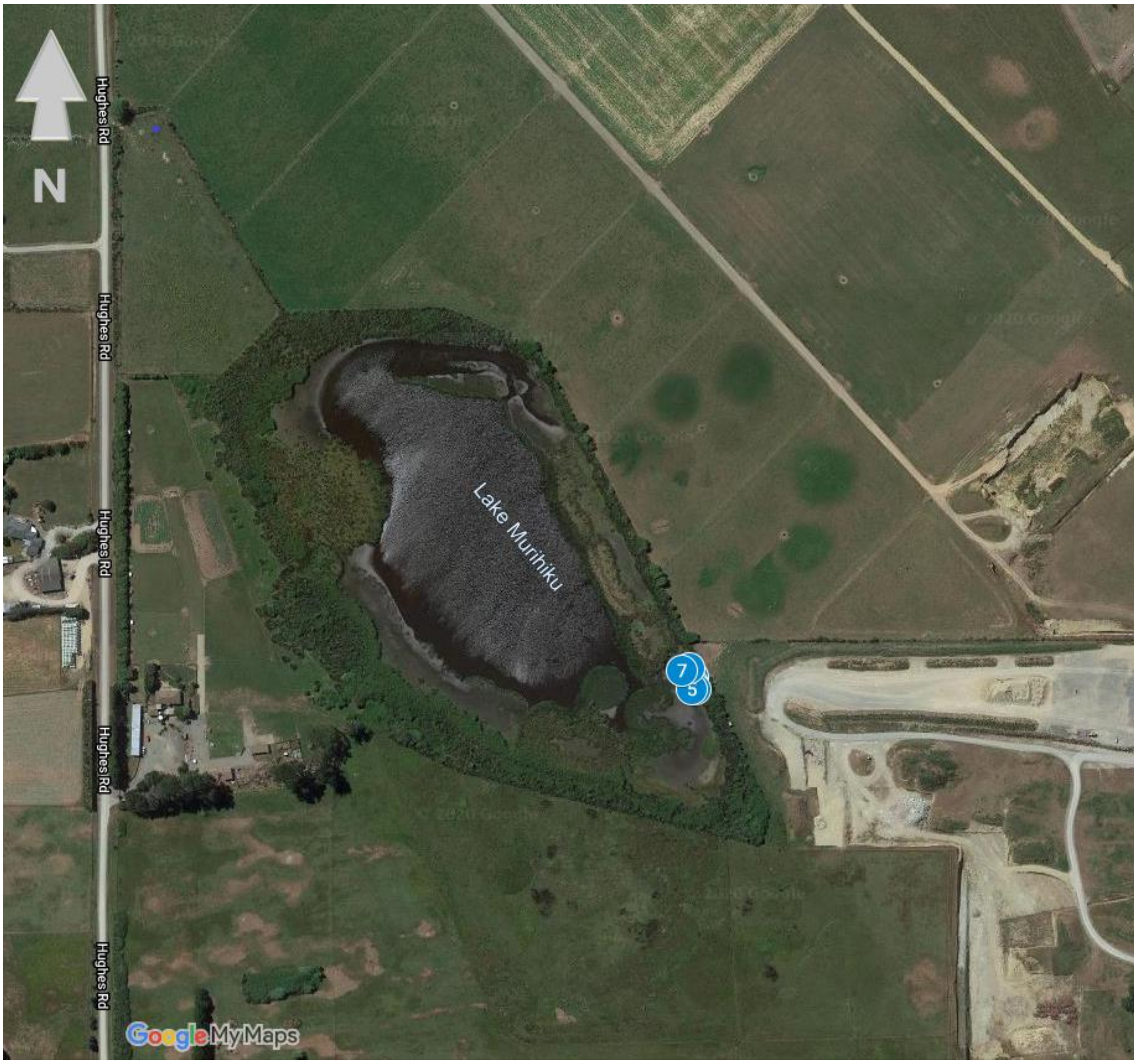

Figure 12.Satellite image from google maps with of test site added. www.maps.google.com

Testing of the flask can take place at above location and compare using lab results using flask method and tradition methods.

Figure 13.Enlarged area showing the 7 test locations. From www.maps.google.com

Laboratory Testing Parameters

The testing laboratory will be testing for the following parameters between samples:

- Total Nitrogen (TN)
- Nitrate-Nitrite Nitrogen (also known as total oxidised nitrogen) (NNN)
- Total Phosphorus (TP)

(*National Environmental Monitoring Standards*, n.d.)

Outliers

Where outliers are deemed accurate as a result of quality assurance checks, these will be included in the data set. Where outliers are deemed erroneous through quality assurance checks, these values will be excluded from data (Wilson et al., 2012)

Data Analysis

Collected laboratory data from water samples of both methods were compared to differentiate inconsistences between methods. Data from lab was converted from g/m^3 to mg/m^3 because the national standards were in mg/m^3.

Results

Lab submission number	Field number	Time	Method		Total N	Nitrate-N + Nitrite-N	TKN	TP
20201853	1	0939	BM	Sample 1 N	1.83	0.032	1.8	0.155
20201899	2	0939	Van Dorn	Sample 1 V	1.93	0.02	1.91	0.176
20201900	3	0945	BM	Sample 2 N	1.72	0.021	1.91	0.142
20201901	4	0945	Van Dorn	Sample 2 V	2.8	0.021	2.8	0.46
20201902	5	0950	BM	Sample 3 N	1.7	0.02	1.68	0.121
20201903	6	0950	Van Dorn	Sample 3 V	1.98	0.02	1.96	0.135
20201904	7	0956	BM	Sample 4 N	1.78	0.02	1.76	0.111
20201905	8	0956	Van Dorn	Sample 4 V	4.4	0.021	4.3	0.35
20201906	9	1004	Van Dorn	Sample 5 V	5.5	0.02	5.4	0.5
20201907	10	1004	BM	Sample 5 N	1.67	0.02	1.85	0.143
20201908	11	1009	Van Dorn	Sample 6 V	1.69	0.02	1.67	0.162
20201909	12	1009	BM	Sample 6 N	1.72	0.021	1.7	0.134
20201910	13	1016	Van Dorn	Sample 7 V	2.4	0.021	2.3	0.187
20201911	14	1016	BM	Sample 7 N	1.71	0.021	1.69	0.135

Table 1. Copy of raw data in excel from lab results in Appendix

mg/m3				mg/m3				mg/m3		
(TN) Niskin	(TN) VanDorn	National Bottom Line(TN)		(NNN) Niskin	(NNN) VanDorn	National Bottom Line(NNN)		(TP) Niskin	(TP) VanDorn	National Bottom Line(TP)
1830	1930	800		32.00	20.00	6.90		155	176	500
1720	2800	800		21.00	21.00	6.90		142	460	500
1700	1980	800		20.00	20.00	6.90		121	135	500
1780	4400	800		20.00	21.00	6.90		111	350	500
1670	5500	800		20.00	20.00	6.90		143	500	500
1720	1690	800		21.00	20.00	6.90		134	162	500
1710	2400	800		21.00	21.00	6.90		135	187	500

Table 2. Table of results put into excel

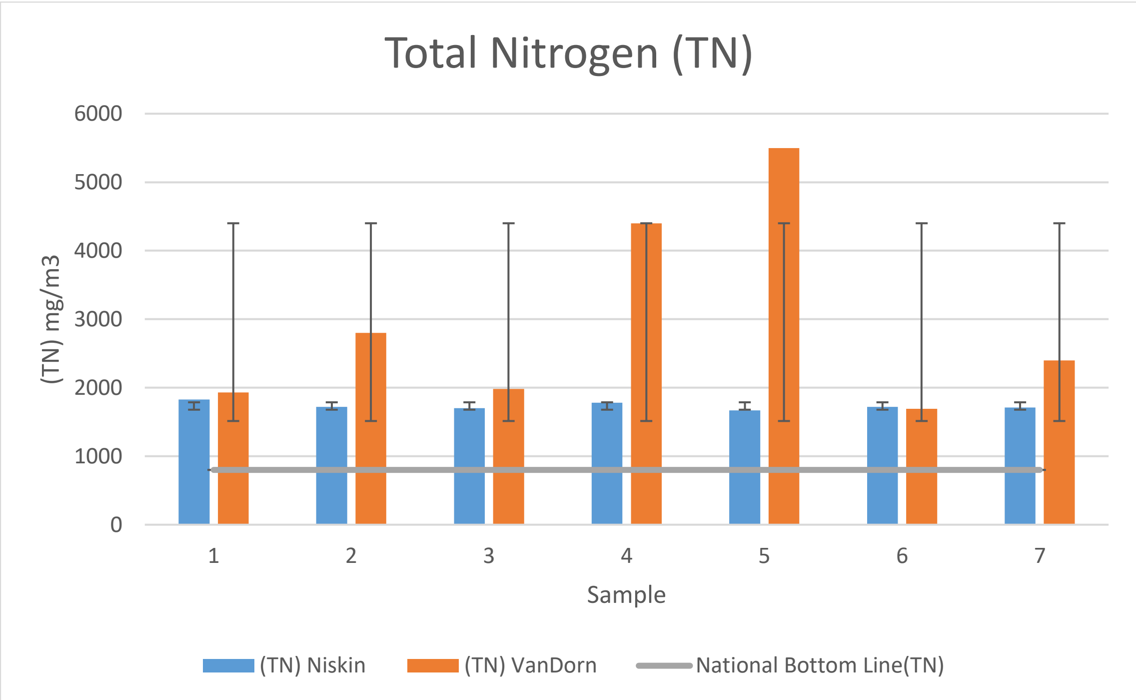

Figure 14. Bar graph of total Nitrogen, with stranded deviation error lines

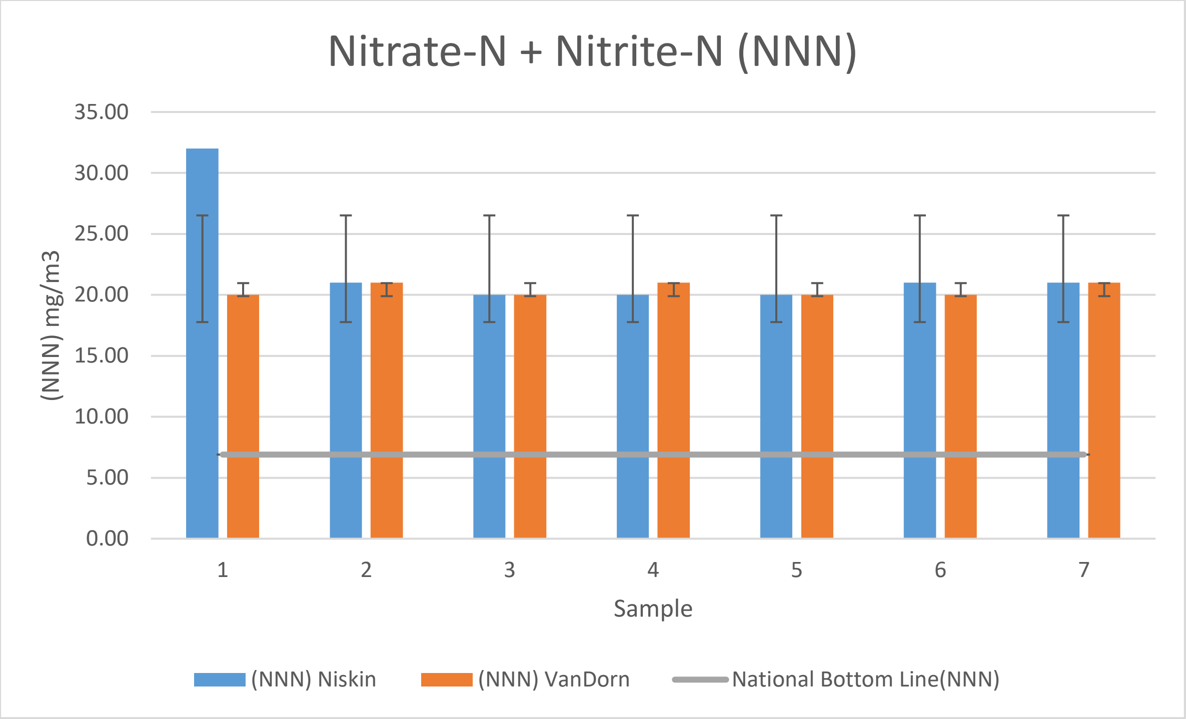

Figure 15. Bar graph of Nitrate-Nitrogen and Nitrite-Nitrogen, with stranded deviation error lines

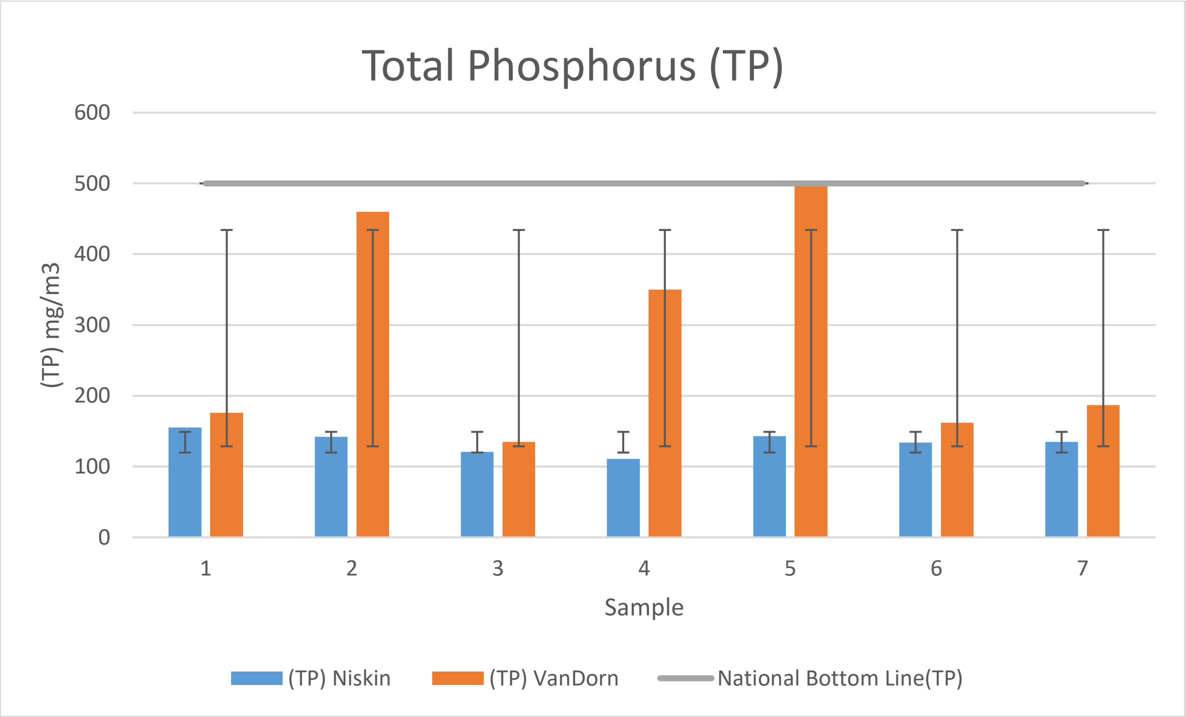

Figure 16. Bar graph of total Phosphorus, with stranded deviation error lines

Discussion

The amount of total nitrogen in figure 15 shows a large variance in values between samples, this is the same for Total Phosphorus in figure 17. This could have been contamination of the samples 2,4 and 5 due to a mixing up of bottom sediment during sample retrieval by wading, or differences in the water take between devices as the Van Dorm takes 3-4 times the volume of water giving the chance for it to suck in more surrounding water disturbing fine bottom sediments. These samples show high levels of Nitrogen, Nitrates and Nitrites in the water showing the lake water to be Hypertrophic (*Table 3*) with Total nitrogen well in excess of 800mg/m^3 max guidelines(NZ Government, 2017, p. 32) and phosphorus ranging between 100-500mg/m^3. The National policy statement for freshwater management 2014 states the levels for Total Phosphorus to be less that 500mg/m^3 shown as grey bar on figure 17 (NZ Government, 2017, p. 32).

Lake class	Chlorophyll *a* (mg m^{-3})	Secchi depth (m)	Total phosphorus (mg m^{-3})	Total nitrogen (mg m^{-3})
Oligotrophic	<2.0	>10	<10	<200
Mesotrophic	2–5	5–10	10Ğ20	200Ğ300
Eutrophic	5–30	1.5–5.0	20Ğ50	300Ğ500
Hypertrophic	>30	<1.5	>50	>500

Table 3. Values of variables defining boundaries of different trophic levels for NZ lakes (Robertson & Stevens, 2013).

These high Nitrogen and phosphorus levels are consistent to the surrounding land type use of farmland and could be contributed to nutrient water runoff from this land (The Parliamentary Commissioner for the Environment, 2012, p. 31).

Overall, the above graphs show consistent readings for the novel niskin device, the samples vary little from sample to sample throughout all the different nutrients. This could be down to the small sample size of 1L of water and its ability to not disturb the surrounding fine sediments. Further investigating is needed to assess the reliability of the data.

Conclusion

The aim of this research was to investigate if a low-cost sampling device could be created and take samples from a drone. The device was built using 3d printing technology and low-cost electronics with a custom-made antenna system. An application was created to perform the water sample triggering using a remote device like a cell phone, laptop or tablet. Using this created device, the samples were taken at the same time as using the traditional technique using a Van Dorn, with both water samples being tested in a lab. Lab results were graphed and compared between both methods to see differences and consistency within results. With the aims of the research being the creation of a low cost device and investigating if it could take consistent samples, these aims have been met and other than the use of a drone for delivery the device performed as expected and collected a stable group of samples. Further research needs to be conducted to confirm that this device can consistently take true samples in a reliable manner.

Health and Safety

All health and safety rules and regulations were followed during this study. Completed health and safety forms can be found in appendix.

Ethics

Ethics are not needed for the extent of this project and are covered under the Southern Institute of technology's blanket approval.

Delimitations & Limitations of Study

Limitations in the access to materials within New Zealand is a challenging factor or ordering overseas takes a long time for deliveries. Keeping weight down is a problem and all materials need to be as light as possible.

Time to complete, with time constraints it may be difficult to complete research and development.

With the COVID-19 pandemic and lockdowns because of this made doing field work during this time impossible. Also, worldwide shipping was disrupted.

Specialized equipment and test equipment were also a problem during this research, the created antenna was never tested for its Standing Wave Ratio (SWR). The SWR is important because it shows how much radio waves are being radiated through the antenna and how much energy is going back down into the transmitter.

Also, the antenna port was a challenge to install on the board without the required surface mount (SMD) equipment.

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