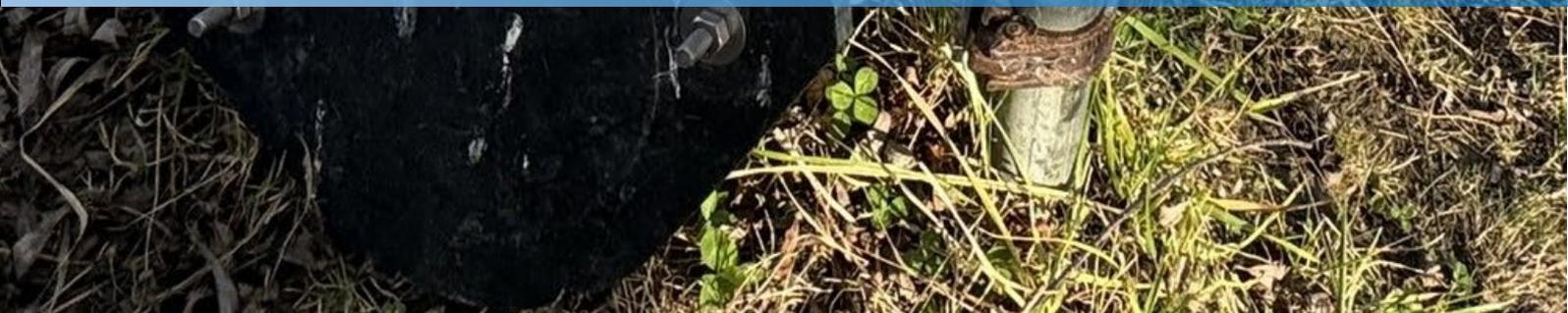




NIWA
Taihoro Nukurangi



WATER TEMPERATURE SENSOR SELECTION



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Front cover: Temperature and dissolved oxygen sensors on the Taieri River at Sutton, Otago [Emily Olson, ORC].

Back cover: Monitoring buoy with a temperature string at Lake Grasmere/Ōpōreaiti, Canterbury [Hamish Carrad, ECan].

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ABSTRACT

Although water temperature sensors appear to be simple to operate, there are challenges, but these can be overcome with good sensor selection and operation. The high frequency water temperature sensors currently available use differing hardware which affects their performance and data quality.

Water temperature sensor use is well established in Aotearoa New Zealand for environmental monitoring, and many sensors are operated at hydrometric sites. Often temperature measurement is included on sensors for indicators that require a temperature correction, such as pressure, electrical conductivity or dissolved oxygen. Care must be taken to check the specifications and suitability of these supporting temperature sensors as a primary water temperature record, because they may use less accurate technology or be positioned in a location less ideal for water temperature sensing.

This chapter describes the basic types of electrical thermometers, compares sensor hardware and software currently in use, summarises key sensor selection questions, and showcases the variety of deployments undertaken across New Zealand. Although this chapter provides detailed guidance on water temperature sensor selection, it does not address field maintenance, data editing or data verification procedures in detail.

BACKGROUND

Obtaining information about water quality dynamics over short time scales (such as daily cycles, or during a storm or rain event lasting a few days) using conventional discrete samples or field measurements may be costly and logistically challenging to undertake frequently. Fortunately, high frequency water quality (HFWQ) monitoring sensors can be deployed on site to measure indicators (e.g., nitrate, dissolved oxygen) and provide detailed insights into water quality dynamics at scales of interest (minutes to hours). However, these HFWQ sensors can create different technical challenges, and unattended deployments can be resource hungry. HFWQ monitoring projects are more likely to succeed if they have (1) clearly defined objectives, (2) robust data collection systems, and (3) well thought-out methods for managing raw data and converting it into knowledge for decision-making.

This chapter provides detailed guidance on water temperature sensor selection. It sits alongside guidance chapters on HFWQ Use Cases, Resourcing, Sensor Selection and Automated Anomaly Detection as part of the *High Frequency Water Quality Monitoring Guidance* project.

PURPOSE AND SCOPE

This chapter provides information on sensor selection for measuring water temperature in-situ, at high frequency in rivers, lakes and estuaries. It will help regional council staff shorten the learning curve for new users, support them to select an appropriate sensor, and help them to accelerate the collection of high-quality water temperature data.

RELATED RESOURCES

Useful reading that expands on the detail in this chapter can be found in the following documents:

- A technical overview of temperature sensors (Reverter 2021).
- National Environmental Monitoring Standards (NEMS) including:
 - NEMS Data Processing (NEMS 2023) outlines procedures for processing various environmental time series.
 - NEMS Water Temperature (NEMS 2025) outlines data standards, data grades and an overview of field and office operating procedures.
- USGS guidance for non-specialists measuring water temperature with low-cost logging temperature sensors (Heck et al. 2018).
- USEPA guidance on how to collect accurate, year-round temperature in wadeable streams and rivers (Stamp et al. 2014).

SENSOR SELECTION STEPS

Sensor selection involves a sequence of steps (Figure 1). Figure 1 also links this chapter to other guidance chapters. Many factors must be considered when selecting a water temperature sensor suitable to meet a user’s monitoring objectives.

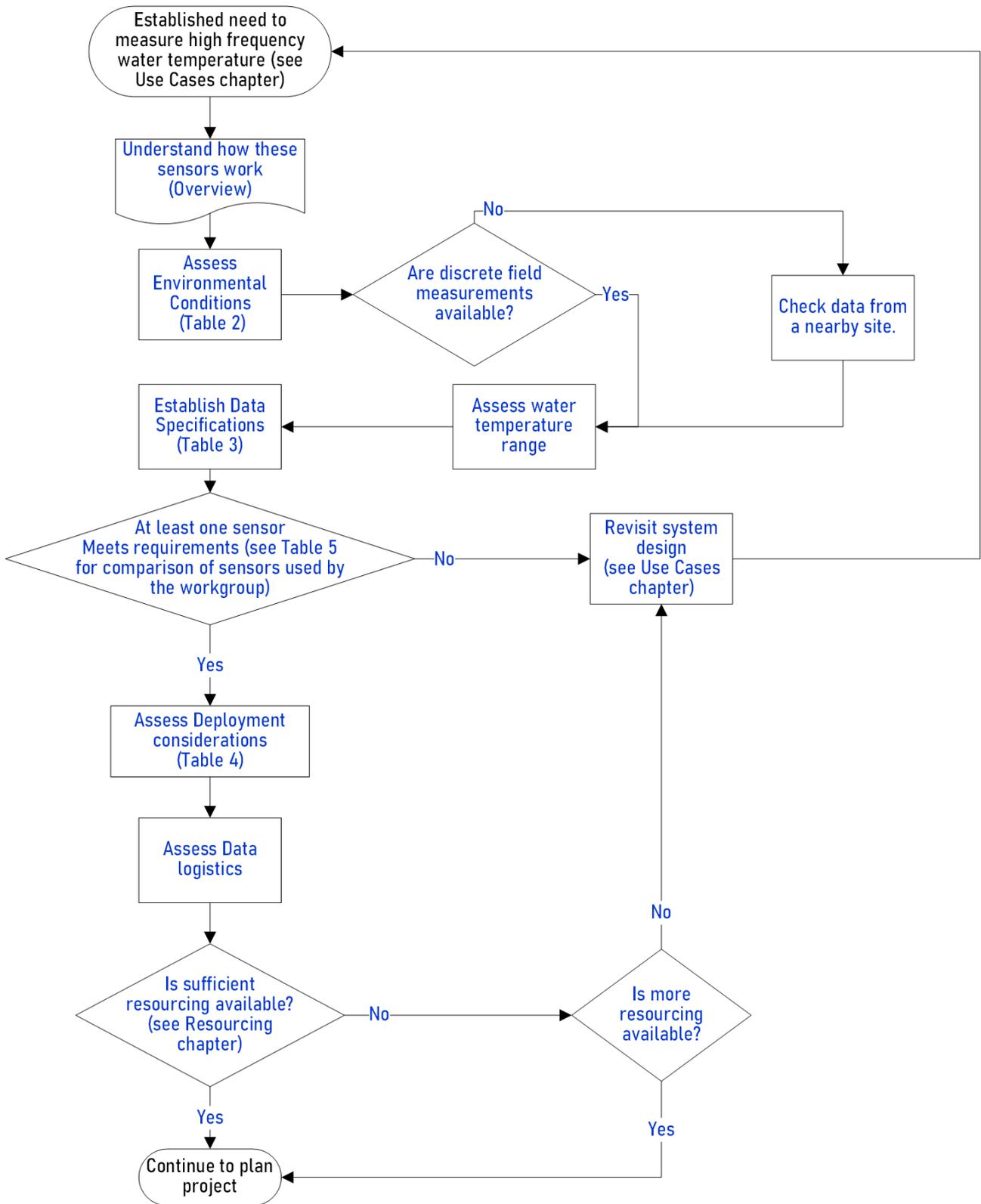


Figure 1. Suggested sequence of steps to guide water temperature sensor selection.

WATER TEMPERATURE SENSOR OVERVIEW

Water temperature measurements are made with a variety of sensors; some are designed to measure only temperature, while others measure temperature as a supporting indicator to other variables (e.g., dissolved oxygen, electrical conductivity or pressure).

A basic water temperature sensor consists of:

- an electrical thermometer,
- a micro-controller to convert the output (current or volts) to a digital value,
- data storage and/or communications capability.

To select a suitable sensor, it's important to understand the technology underlying electrical thermometers that measure water temperature. Thermistors are commonly used, but other thermometer types include thermocouples, resistance detectors and semiconductors. With a basic understanding of the available technologies, a user can then assess other aspects that contribute to the suitability of a sensor, such as accuracy, dynamic response to a change in water temperature, lifespan and durability.

There are several well-established measurement principles which are the basis for temperature sensor technology. This section provides an overview of four key sensor types: thermistors, resistance temperature devices, thermocouples and semiconductors. An in-depth discussion on electrical thermometers, including the background and theory, is available in Reverter (2021).

Thermistors

Thermistors (thermal resistors) are based on the relationships between temperature and the electrical resistance of different semiconductor materials. Thermistors are made from powdered mixtures of metal oxides – recipes are closely guarded secrets – which are formed into a solid mass by applying pressure and heat (sintering).

There is no international standard for thermistor performance, and a wide variety of materials and designs are used in water quality sensors. The semiconductor material is usually chromium, nickel, iron, manganese or copper metal oxide. Thermistors range in size from <1 mm to 2 cm in diameter and can take the form of beads (Figure 2 A), rods, chips or disks. Thermistors are finished by putting on leads and encasing them in epoxy, Teflon or glass to protect the metal oxides from moisture and corrosion. Most commercial thermistors are negative temperature coefficient (NTC) units in which resistivity (how strongly they resist an electric current) decreases non-linearly with increasing temperature (Figure 2 B).

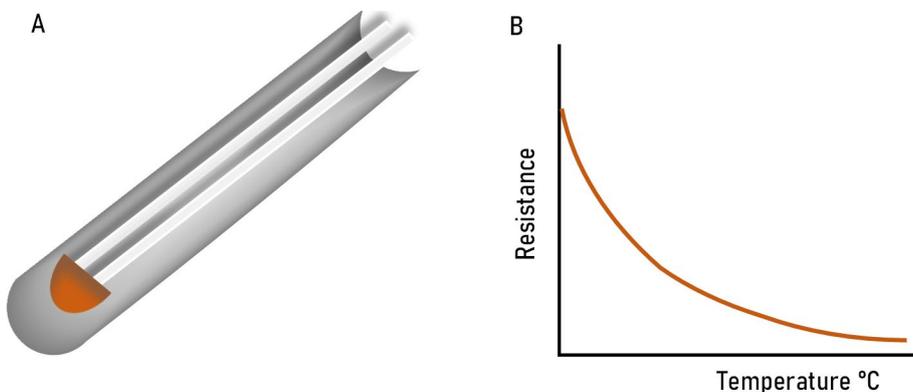


Figure 2. (A) Diagram of a bead thermistor with connecting wires inside a casing (after NIST 2011b). (B) Variation of resistance with temperature for a negative temperature coefficient thermistor (after Bolton 2021).

Thermistors are usually cheap to manufacture, offer good reproducibility and are widely used in water quality sensors. They have a small thermal mass so respond to temperature changes rapidly. Thermistors have high sensitivity (large changes in resistance per degree of temperature change) so can be calibrated over a small range to give high accuracy. Their operating range varies with the materials used and manufacturing process, but they are usually used across the range of -50 °C to around 100 °C and have high stability between 0 and 50 °C. Elevated temperatures excessively age thermistors and cause drift. Their main disadvantage is their non-linearity, which means they lose sensitivity at higher temperatures (Figure 2 B). Ultra-fast response thermistors are available when sub-second response times are required, but they are thinner and generally less durable. NTC thermistors can handle mechanical shock and vibration.

Resistance temperature detectors

Resistance temperature detectors (RTD) also measure resistivity but use a pure metal, such as platinum. RTDs use a sensing element whose resistance varies with temperature, usually with a positive temperature coefficient. Two types of RTD are manufactured: wire coils (Figure 3 A) or a thin film on a non-conductive surface. The film or wire is placed inside a glass or ceramic enclosure to protect the sensor from moisture and corrosion. Wire-coil RTDs are sensitive to mechanical shock, and vibration will cause drift. In contrast, thin-film RTDs are more compact, less expensive, have faster response times and are highly resistant to vibration, but their accuracy is limited to a narrow temperature range.

While RTDs have high accuracy, repeatability and stability, they tend to have slower response times than thermistors. Platinum RTDs have high linearity (Figure 3 B), good repeatability, high long-term stability and can give an accuracy of $\pm 0.5\%$. RTDs are susceptible to parasitic (or unintentional) resistance, so care must be taken to ensure the correct cable is used to avoid introducing error into the temperature measurement. Common platinum RTDs are known as PT100 or PT1000, which have resistances of 100 Ω and 1000 Ω respectively at 0 $^{\circ}\text{C}$.

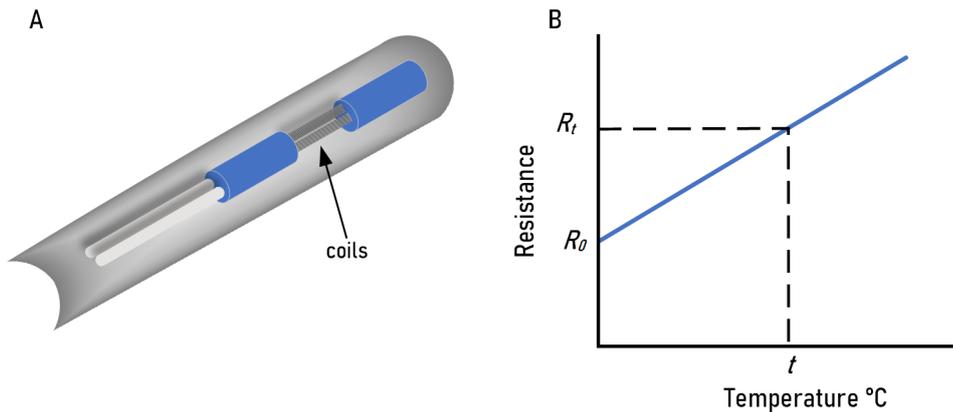


Figure 3. (A) Diagram of a platinum RTD with two coils inside a casing (after NIST 2011a). (B) Resistance variation with temperature for metals (after Bolton 2021).

Thermocouples

A thermocouple is made of two different metals or alloys that are joined together at one end. A thermocouple works based on the movement of the electrons in its metal wires away from the heat source. When the junction of the two metals is heated, electrons in the metals move away from the heat source at different rates, and a voltage is created which is proportional to temperature (Figure 4). Thermocouples can be constructed from a wide range of metals, but usually from two base metals (e.g., copper, iron, nickel or chromium) or two noble metals (e.g., platinum, rhodium). Each pairing of metals will have different electrical characteristics in response to temperature changes; some offer a wide range with a non-linear response, while others measure a smaller range with a more linear response. International standards (e.g., NIST, ASTM, IEC) are available for common metal combinations and define the tolerances (i.e., the maximum difference between the measured and true temperatures). Thermocouples operate without an external power source and can endure very low (~ -200 $^{\circ}\text{C}$) and very high (~ 2000 $^{\circ}\text{C}$) temperatures. Thermocouples are usually mounted in a casing to protect them.

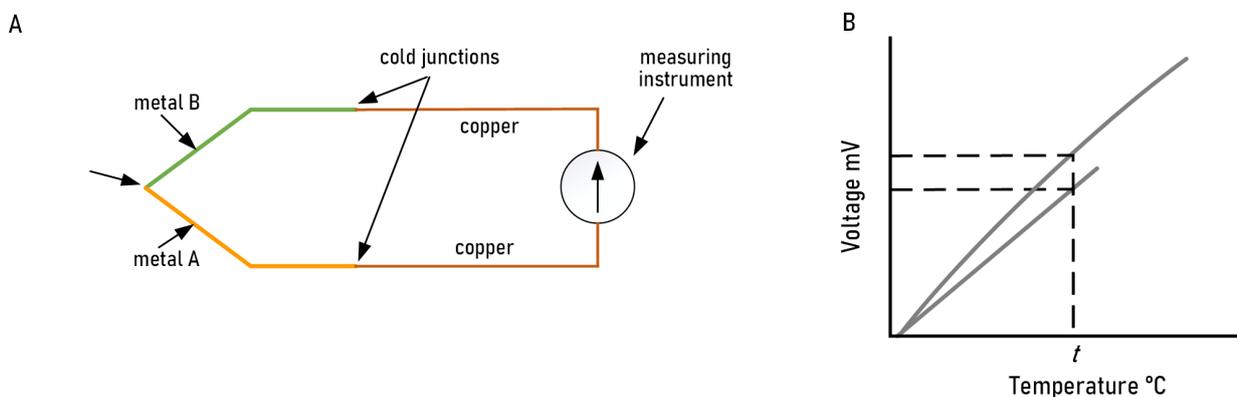


Figure 4. (A) Diagram of a thermocouple (after Bolton, 2021). (B) Resistance variation with temperature for two different thermocouple combinations, one with linear output and one with non-linear output (after Bolton 2021).

Semiconductors

Semiconductors are used as temperature sensors in electronic devices. A *semiconductor* is a substance with characteristics that lie somewhere between those of a *conductor* that conducts electricity (like a metal) and an *insulator* through which electricity hardly flows. These sensing elements have a wide range of designs (Figure 5 A) and names – they may be known as integrated circuits (IC), p-n junction sensors, silicon sensors, monolithic sensors or solid-state sensors. Integrated circuits contain both the sensor and an ADC, and output digital values.

A common semiconductor electrical thermometer design uses bipolar transistors (in simple terms, currents inside a bipolar transistor are conducted by both free negatively charged electrons and the positively charged hole when an electron is mobilised). Temperature is measured as the difference in voltage between the emitter voltage and either two bipolar transistors operating at different current densities or transistors of different dimensions with the same current, or by changing both the transistor dimensions and currents (Figure 5 B). The difference in voltage is linearly related to temperature (Figure 5 C). It is common to amplify the signal to improve the resolution of values. Common models of these sensor types include LM35 (Texas Instruments) and DS18B20 (Maxim Technologies). Note that unless the sensor is made by the original manufacturer, it is likely to be a clone or fake and there is no guarantee it will perform to the Original Equipment Manufacturer (OEM) specifications.

These sensors share several characteristics – linear outputs, relatively small size, limited temperature range (typically -40 to +120 °C), low cost, and good accuracy if calibrated. Their thermal sensitivity depends on the semiconductor selected, the selection of electron donor or acceptor materials, and the chip manufacture process. However, semiconductor sensors tend to be electrically and mechanically more delicate than most other types of electrical thermometer. In addition, the raw sensing element is generally packaged in a standard case for electronic devices and is therefore thermally buffered, resulting in longer response times.

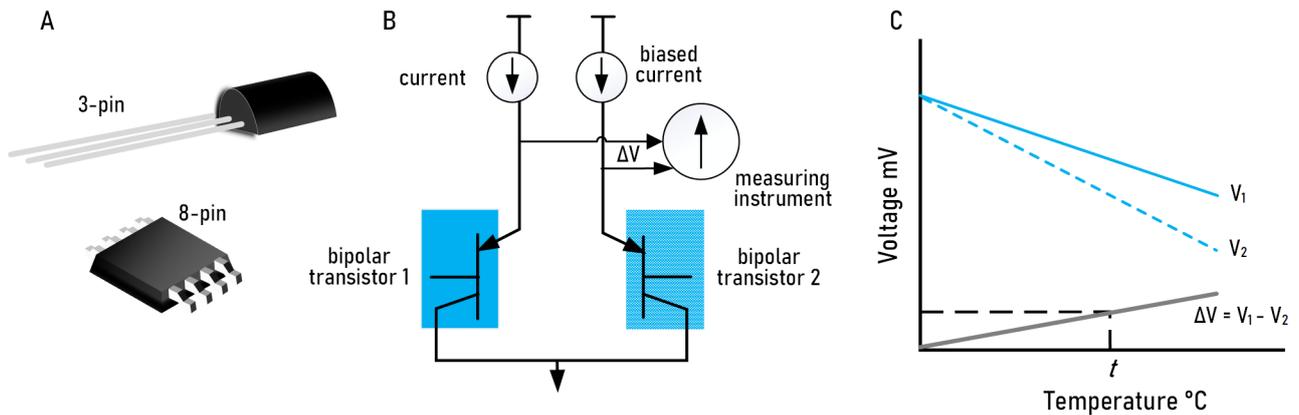


Figure 5. Forms of semiconductors. (A) Simple schematic of typical integrated circuit (IC) forms. (B) Simple schematic of an IC sensor with two bipolar transistors with well-defined biased currents. (C) Voltage variation with temperature for an IC showing the measured voltages (V_1 and V_2) and relationship of the voltage difference to temperature (after Reverter 2021).

SENSOR PERFORMANCE

The performance of temperature sensors is determined by many factors, including:

- sensor hardware (including the type of electrical thermometer used, location of the electrical thermometer, and analog-to-digital convertor specifications)
- instrument noise (such as fluctuations in voltage in the electrical circuitry)
- sensor deployment (e.g., shielding, heat sources, burial)
- sensor software and firmware
- integration with data loggers.

Dynamic response

An electrical thermometer does not respond instantaneously to a change in temperature; heat must first diffuse through the boundary layer around the sensor and through the sensor's casing, and then the thermometer will respond. The delay between the change in temperature and a measurement response depends on the type of electrical thermometer and where it is located on the sensor. Electrical thermometers that are external (Figure 6 A & B) have short response times (typically seconds or milliseconds). When a faster sub-second response is required, sensors with a thinner casing are appropriate. Thermometers located inside the sensor body (Figure 6 C & D) are thermally buffered by the sensor casing, so there is often a delay in response.

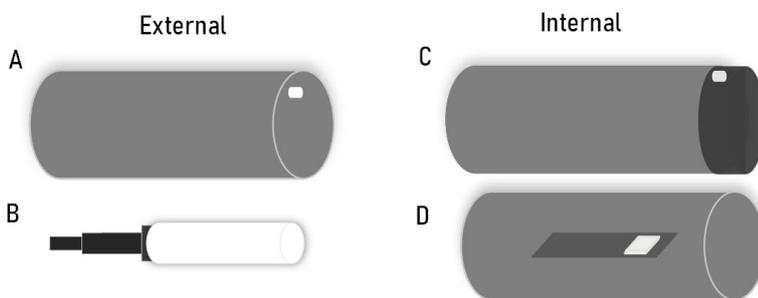


Figure 6. Generalised schematic of electric thermometer (white shape) placement in water temperature sensors. Sensors A and B are external and will respond more rapidly to changes in water temperature than sensors C (inside cap) and D (deep inside sensor), which will be thermally buffered.

A sensor's dynamic characteristics refer to the time taken to respond to an abrupt change in conditions. Two key terms, the time constant (t_{63}) and the response time, are used to describe a sensor's dynamic response (Figure 7). However, care is required when comparing water quality sensor specifications, because details of the test conditions (e.g., $X = 15\text{ }^{\circ}\text{C}$ from $Y\text{ }^{\circ}\text{C}$ to $Y+15\text{ }^{\circ}\text{C}$) are often not disclosed.

Time constant is the time taken for the sensor signal to rise to 63% of its final value after an abrupt change in measuring conditions (X in Figure 7). It may also be called time response, tau (τ) or t_{63} . The time constant is calculated by analysing the response of a sensor immersed in a well-stirred constant temperature bath. For example, by transferring a sensor from room temperature (say $22\text{ }^{\circ}\text{C}$) to a water bath maintained at $2\text{ }^{\circ}\text{C}$.

Response time is the time taken for the sensor signal to rise to a nominated percentage, typically 90%, of its final value after an abrupt change in measuring conditions. Some manufacturers use a different nominated percentage (e.g., 95%), which can make it hard to compare sensor specifications.

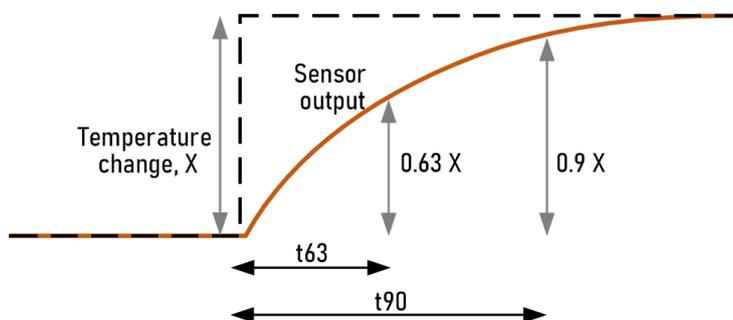


Figure 7. Diagram of time constant and response time for temperature sensors (after Freeman et al. 2004).

Resolution

Resolution refers to the smallest change in input signal that can be detected. Electrical thermometers output analog signals, voltage or current, which are converted to a digital output using an analog-to-digital convertor (ADC). Some sensors have the ADC built into their electronics, while others output an analog signal which is converted to a digital value by an ADC on the data logger. A thermometer's absolute resolution depends on the bit specification of the ADC.

A bit is the most basic unit of information digital communication and refers to a binary value (0 or 1). For example, a normal light switch is binary (on or off is represented by 0 or 1, so there are two possible values). If you are storing a digital 2-bit number, you can store 4 different values: 00, 01, 10, or 11. So a 2-bit device has 4 values (2^2), a 12-bit device has 2^{12} (or 4096) values, and a 16-bit ADC has 2^{16} (65536) values. As the number of bits increases, the absolute resolution also increases. For example, an analog electrical thermometer measures across the range from 0 to 5 volts. With an 8-bit ADC, the values can be digitally interpreted as 2^8 or 256 different values, and the resolution is 5 volts / 256 bits (~ 20 mV per bit). With a 16-bit ADC, 2^{16} or 65536 different values are available, which equates to a resolution of 5 volts / 65536 bits (~ 76 μ V per bit).

User experiences

The workshop participants identified sensor reliability and deployment challenges as key factors impacting performance. Sensor fouling is not a critical problem for temperature sensors, but it is important to keep the sensor clean to ensure it responds to temperature changes. Chemical fouling (e.g., oils) or biological activity (plant roots, algae, snails, etc.) may alter the sensor's measurement by decreasing mixing around the sensor or increasing its response time.

Sensor reliability

Several experienced users have stopped using temperature data output by some water quality sensors; in most cases the electrical thermometer was on a pressure or electrical conductivity sensor. In hindsight, the information provided on thermometer performance and specifications lacked detail. If the available information (typically brochures and manual) lacks detail on basic specifications (e.g., type of electrical thermometer, accuracy, resolution and response times), request more information from the manufacturer.

Operational challenges

The workshop participants identified several operational factors which can affect water temperature sensor performance:

- debris accumulation or mobile bed sediment can bury the sensor, often dampening its response (see Case Study 1)
- adjacent structures can radiate heat (e.g., concrete structures)
- tree roots growing around a sensor (particularly pressure transducers) can reduce the sensor's ability to represent well-mixed flow
- sensor firmware can cause issues with data quality when using data loggers.

More details on these and other operational challenges, and possible solutions to overcome them, are summarised in Table 4.

ADVICE FOR NEW USERS

We asked experienced users to share their experience as advice for new users and to highlight one thing they wish they'd known earlier:

- Read the temperature sensor specifications carefully.
- Understand the sensor (and field reference meter) response times. How long will the temperature sensor take to stabilise after being exposed to a change in temperature?
- Ensure the sensor is deployed in a location and manner so that values always represent stream conditions, i.e., not influenced by roots, gravel, able to be buried or be exposed to the air should water levels drop.
- Make servicing as easy as possible – use durable mountings and ensure the sensor is accessible for retrieval or servicing.
- Make sure the sensor can communicate with your logger (e.g., serial or analog) and check that you have a spare channel on the logger.
- Collect metadata on the performance of each temperature sensor to detect faults early.
- Carry spares or a replacement measuring device. If a sensor fails, it often is possible to install a logging temperature sensor quickly and minimise the data gap while repairs are made or a replacement sensor is purchased.

RANGE OF SENSORS

Many different types of temperature sensors are used by regional councils across rivers, lakes and estuaries. Experienced users typically have a fleet of several temperature sensors and select the appropriate sensor for each application. Fleets commonly include:

- a range of battery-powered logging sensors
- cabled sensors for connection to loggers
- temperature sensors coupled with other indicators
- temperature sensors for moorings if needed.

Coupled sensors

Electrical thermometers are often coupled with other water quality indicators which require a temperature correction to standardise values (e.g., dissolved oxygen, pressure, fluorescence, conductivity, nitrate in marine environments due to bromide interference). It's important to check the thermometer location and specifications carefully to ensure it can meet data requirements and standards.

In estuaries, temperature sensors are often coupled with conductivity and pressure in sensor packages known as CTDs (conductivity-temperature-depth sensors). CTDs often use platinum RTDs and/or thermistors, and thermometers with fast (a few seconds or sub-second) response times are available. CTDs' thermometer specifications are often described in detail, often in manufacturers' white papers rather than manuals or brochures.

Dissolved oxygen sensors all measure water temperature for correcting DO measurements; most will use thermistors, but the location of the thermistor varies widely. Several widely used DO sensors – YSI EXO, In-Situ RDO Pro-X and D-Opto – have external temperature sensors protected by stainless steel casing (Figure 6 A). In other DO sensors – such as the PME miniDOT, WTW IQ700 and HOBO U26 – the thermistor is located inside the cap or casing (Figure 6 C & D).

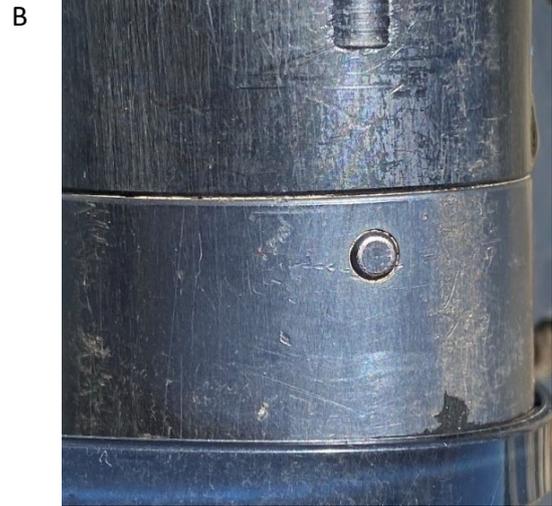
Pressure transducers also measure temperature, but care must be taken to ensure the type of electrical thermometer used is known and its specifications are available, and that the deployment meets standards set for temperature sensors (e.g., solar shielding, well-mixed water, deployed outside the influence of stilling wells). While many pressure transducers will return a temperature value for correcting pressure, the electric thermometer will often be less precise than required and the specifications may not meet standards (such as NEMS). Otago Regional Council have compared a range of temperature sensors (see Case Study 1), including pressure transducers, and use pressure transducer temperature measurement as a backup rather than as the primary sensor.

Similarly, modern fluorescence sensors often measure temperature for the purpose of correcting values, as fluorescence intensity tends to decrease with increasing temperature. Not all fluorescence sensors measure temperature, so users should check for the presence of an electrical thermometer, its location and specifications.

Aquatic light sensors may also have an integrated sensor which measures water temperature. However, aquatic light sensors are usually deployed with the sensor facing upwards to measure incoming light. This makes deployment of a solar shield (essential to avoid solar heating) impossible. Using aquatic light sensors for temperature measurement is therefore only practicable if the thermistor is located well away from the light sensor or shielded by the light sensor body.



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[Hamish Carrad, ECan]

Figure 8. Coupled temperature sensors (A) Sea-Bird CTD with internal sensor with pumped flow (thermistor is inside the small pump intake hole) (B) In-Situ RDO Pro-X with external temperature sensor. (C) YSI EXO external temperature sensor on the combined conductivity/temperature sensor (external stainless steel encased thermistor on black C/T sensor at top). (D) PME MiniDOT thermistor is located inside the thick plastic cap (and copper guard if used).

Moorings

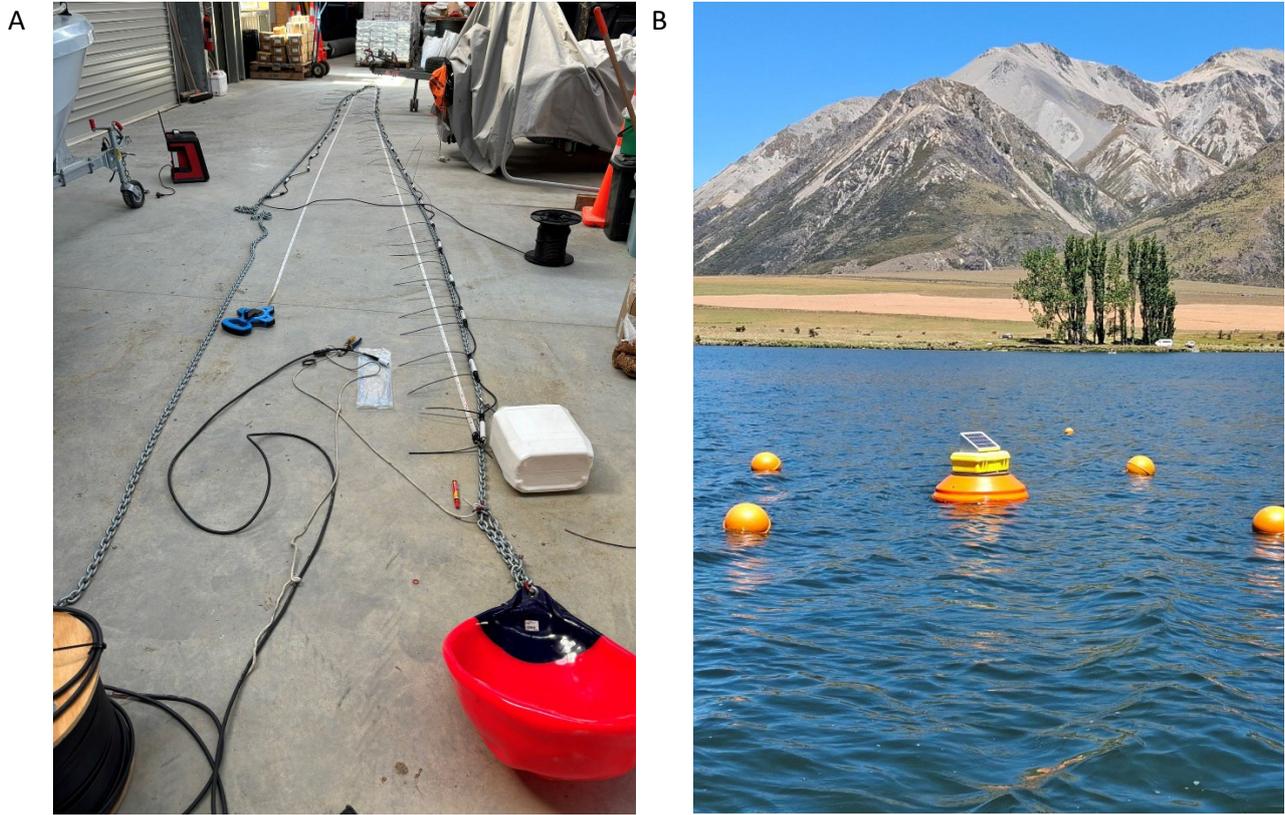
In addition to anchored or fixed temperature sensors, lake and estuary science often requires more information about temperature variation with depth (for example, Figure 9 A). Moorings or buoy systems typically have several components: (1) underwater sensors, (2) mooring array and structure, and (3) above-surface instrumentation. Temperature sensors are important sensors on buoys in lakes as lake ecosystems are tied to lake mixing. More complex moorings, often with several sensors, tend to be used in estuaries. Additional HFWQ indicators can also be measured but increase resourcing requirements, so careful design is required for any lake or estuary mooring.

Instrumented moorings can host a range of water quality sensors, and there are two key approaches: (1) a ‘string’ or ‘chain’ of sensors at fixed depths (see Figure 9) or (2) a ‘profiler’ sensor package which is winched up and down through the water column (see Figure 10). The advantages and disadvantages of these approaches are summarised in Table 1. Fixed depth sensors can output high frequency data (minutes), while profiler systems will return values less frequently (hours, depending on water body depth) as at each depth the sensors need time to adjust to the conditions. Fixed depth sensors are ideal for understanding physical processes, such as thermal stratification. In contrast, profilers can carry a wider range of sensors through the complete water column and are therefore useful for understanding biological and chemical dynamics.

Table 1. Advantages and disadvantages of instrument strings and profilers on monitoring buoys.

Approach	Advantages	Disadvantages
Instrument string	<ul style="list-style-type: none"> - frequent measurements possible (minutes) - can be simple if real-time data is not required - can be used in deep lakes 	<ul style="list-style-type: none"> - differential fouling of sensors on the string (not so important for temperature) - many sensors are required, typically more near the thermocline - user often cannot service a commercial temperature string if one component fails
Profiler	<ul style="list-style-type: none"> - one sensor package is required, so it can include higher-cost sensors - fouling is consistent on one sensor package - more indicators can be measured through the water column 	<ul style="list-style-type: none"> - control equipment (e.g., winch) has more moving parts which can fail - less frequent measurements (hours) due to sensor equilibration at each depth - requires regular maintenance schedule and telemetry - limited to depths <100 m

Most temperature chains will be suspended from a buoy to ensure they are surrounded by representative water. While a simple thermistor chain can be built using a buoy, high quality mooring rope, cable ties and battery-powered temperature sensors, often the data specifications include real-time data delivery. A range of temperature strings for real-time data delivery are commercially available. Strings are made to order to meet the customer’s specifications for length, sensor spacing and additional coupled sensors (e.g., DO). Across New Zealand’s deep and shallow lakes, a range of temperature chains are used, including ENVCO ProString, Scienterra Temp-String (see Figure 9 A) and PME T-Chains. While many strings cannot be serviced by the user, some manufacturers provide component-based systems with connectors (e.g., NexSens T-Node FR) which enables users to swap out faulty or damaged components. If detailed electric thermometer specifications are not available, request them from the manufacturer.



[David Brown, Horizons]

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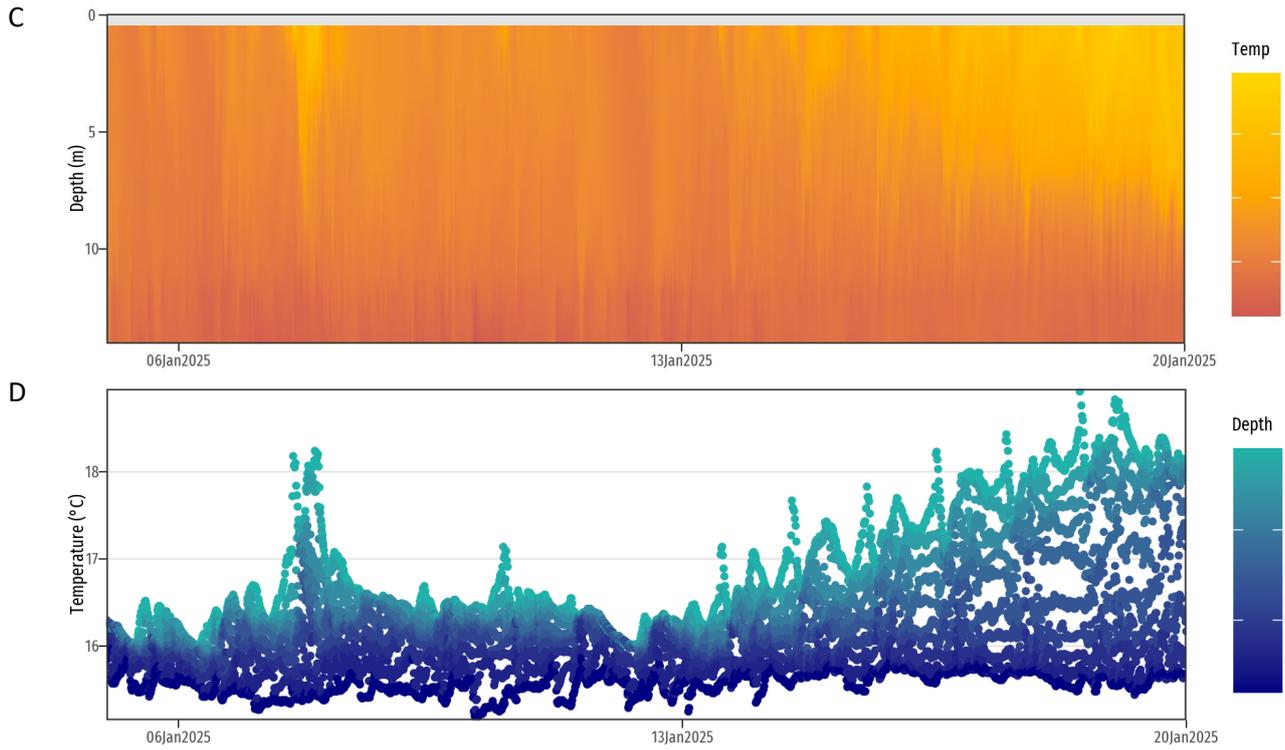
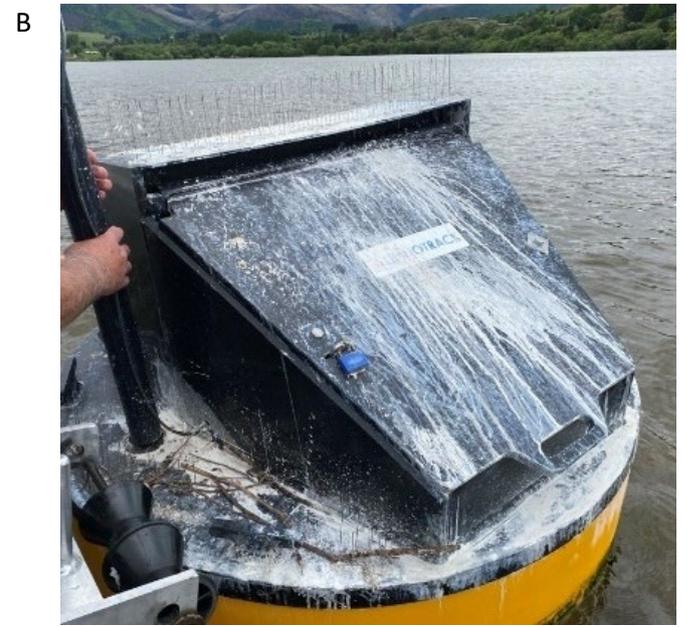


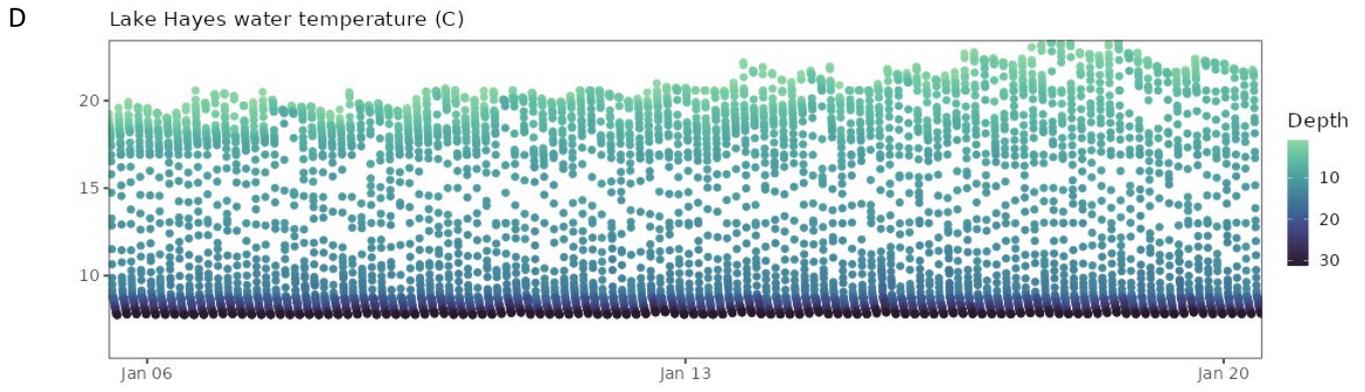
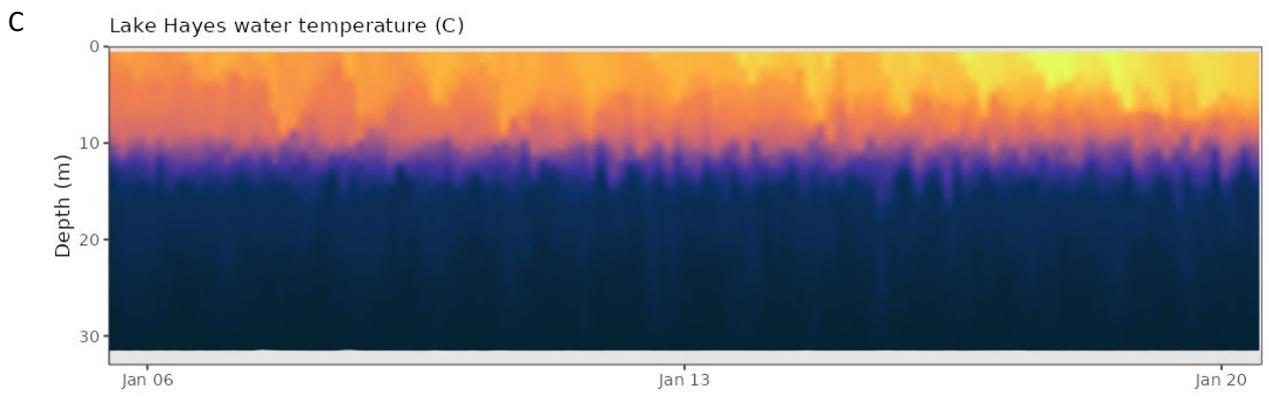
Figure 9. (A) Temperature string (Scienterra) attached to a chain and buoy prior to installation at Lake Wiritoa, a coastal dune lake (max depth ~20 m) near Whanganui. (B) Temperature string (Scienterra) installed on Lake Grasmere/Ōpōreaiti, Canterbury. (C) Heatmap of water temperature during mid-Jan 2025 data for Ōpōreaiti. (D) Time series of water temperature on Ōpōreaiti. The temperature string has 10 sensors between 0.5 and 14 m below the water surface (colour is depth) [ECan data].



[ORC]



[ORC]



[\[Data - ORC Environmental Data Portal\]](#)

Figure 10. (A) The mooring buoy at Lake Hayes, Otago, installed in late 2021. (B) Lake Hayes buoy with protection from roosting birds installed. (C) A heatmap of water temperature during mid-Jan 2025. (D) Data values for each vertical profile collected (8 profiles in 24 hours, each profile takes ~ 2.5 h).

KEY QUESTIONS TO CONSIDER WHEN SELECTING A TEMPERATURE SENSOR

Each temperature sensor should be considered against the monitoring objectives and deployment requirements. Key questions are grouped into Environmental consideration (Table 2), Data specifications (Table 3) and Deployment considerations (Table 4).

Environmental considerations

Table 2. Environmental considerations: Considerations and challenges to help guide sensor selection

Key questions	Consequences	Possible solutions
What is the site's temperature range?	<ul style="list-style-type: none"> - Loss of sensitivity. - Damage to electrical thermometer. 	<ul style="list-style-type: none"> - Select a sensor that operates beyond the range of possible temperatures. Most sensors have an operating range of 0–40 °C, but some can operate below zero.
How rapidly will the temperature change?	<ul style="list-style-type: none"> - Sensors may have an excessive time lag and values may not represent temperature change or transient extremes well. 	<ul style="list-style-type: none"> - Check the sensor response time specifications carefully and identify where the electrical thermometer is located on the sensor. - Also refer to response times of commonly used sensors in Table 5.
What is the maximum depth?	<ul style="list-style-type: none"> - Damage to sensor water tightness. 	<ul style="list-style-type: none"> - Check maximum sensor depths (Table 5) to ensure the sensor housing will withstand the pressure. - Check recommended cable lengths for the sensor type. Some electric thermometers cannot have cable length extensions (for example, calibration in some sensors is linked to cable length, and use of longer cables would require sensor recalibration by the manufacturer).
What's the minimum depth?	<ul style="list-style-type: none"> - Sensor out of water and measuring air temperature. 	<ul style="list-style-type: none"> - Install or identify a local air temperature sensor to check values against. Ensure the air temperature sensor is shielded (and not inside a sealed logger box). - Consider using a sensor which logs both air and water temperature. For example, the new HOBO MX2205 TidbiT also has a cabled thermistor, so at low flow the TidbiT internal thermometer could log air temperature and the cabled thermistor log water temperature.
How will you manage fouling?	<ul style="list-style-type: none"> - Slower response time. 	<ul style="list-style-type: none"> - Fouling is less critical for temperature sensors, but consider: (1) sensor burial, (2) biota (e.g., mud snails, barnacles) or (3) oil and grease creating a film on the sensor.
How robust is the sensor?	<ul style="list-style-type: none"> - Sensor damage from vibrations or knocks. 	<ul style="list-style-type: none"> - Use a sensor which can withstand knocks and vibrations. IC sensors are sensitive to rough handling.
Is the environment corrosive?	<ul style="list-style-type: none"> - Sensor damage. 	<ul style="list-style-type: none"> - Plastic or stainless-steel materials are good for freshwater applications; consider titanium for brackish/ocean water to reduce corrosion.

Data specifications

Table 3. Data specifications: Considerations and challenges to help guide sensor selection

Key questions	Consequences	Possible solutions
What performance is required?	- Data will not meet requirements for decision-making.	- Check sensor performance specifications (particularly range, accuracy & response time) against project requirements. - Check sensor specifications against standards (e.g., NEMS).
Can a combined sensor meet your requirements?	- Temperature data may not meet required specifications. - Longer response times.	- Check temperature sensor specifications of a combined sensor (e.g., DO, pressure or electrical conductivity). Check: (1) the type of electrical thermometer, (2) location of temperature sensor, (3) stated response time, and (4) stated accuracy. Request more information from the manufacturer if required.
What is the required response time?	- Lag in temperature data. - May not detect transient temperature maxima.	- Select a sensor with a suitable response time for your project. - Check response time information carefully. Understand the terminology used (see Dynamic response). Contact the manufacturer if details are not available in the sensor brochure or manual. - If temperature varies rapidly (sub-second), use a sensor capable of a short response time. This might be a version with a thinner thermistor (e.g., RBRsolo T fast) or a software setting (e.g., YSI EXO rapid). - For urban environments where temperature surges are common after rainfall, select a rapid (< 60 s) response sensor.
Are real-time data required?	- No real-time data available for decision-making.	- Choose a sensor which can be connected to a logger with telemetry.
Do you need to measure temperature variation with depth?	- Surface water temperature may not meet data requirements in lakes or coastal waters.	- Consider using a mooring. Mooring design will depend on resourcing and monitoring objectives. Fixed depth temperature sensors are useful for understanding physical processes and can return high frequency data (minutes). For understanding biological or chemical processes, profiling systems might be more suitable as they can carry more complex sensors but return less frequent data (hours).
Does the combined sensor & logging system have the required performance?	- Loss of data resolution. - Inadequate temperature range. - Insufficient accuracy.	- Consider how the temperature sensor will be logged and whether it will be integrated into an existing system. - Check the performance of the combined sensor and logger system prior to deployment. Most new loggers will have 16 or 24-bit ADC on the analog channels, but if you're using an older model, check the ADC convertor specifications.
Are data gaps acceptable?	- Consequences for analysis, particularly if large periods are missing or poor quality.	- If a complete record is required, compare the resourcing required for telemetry and rapid troubleshooting versus operating a backup sensor. A backup sensor would ideally be adjacent to the primary sensor. - Consider the consequences of a data gap for decision making. A one-day gap in a critical period (e.g., during an event in an urban stream) or a 1-hour gap on the warmest day may compromise analysis of temperature maxima.
Is averaging user-controlled?	- Smoothed data may look good but might preclude transient maximum or minimum values.	- Check how on-board averaging works and the ability of the user to fully configure averaging. On some sensors you can turn averaging off, while on others all data is averaged.
Is long-term deployment of the sensor at a site required?	- Sensor may need replacing. - Challenges detecting drift.	- Consider resourcing & availability of replacement sensors. Stationarity of record requires that bias is not introduced with a change in instruments. - Consider telemetry to ensure data loss risk is minimised and troubleshooting is prompt. - Operate a primary and backup temperature sensor to identify drift and other data quality issues. - Select an electric thermometer type which is less susceptible to drift, such as a thermistor.

Deployment considerations

Table 4. Deployment considerations: Considerations and challenges to help guide sensor selection

Key questions	Consequences	Possible solutions
How will you access the sensor across the range of environmental conditions?	<ul style="list-style-type: none"> - Poor access may make download of data from a sensor with on-board logging difficult. - Unable to check if sensor is still operating during/after extreme events (e.g., floods). 	<ul style="list-style-type: none"> - Consider if access to the sensor is required during high river flows. One option is to select a telemetered sensor so you can frequently check the data continuity and quality. - If you plan to use a sensor with a cable, select a sensor model/option with a waterproof connector so it's simple to disconnect cable from sensor for annual checks, inspections or replacement. - Select a sensor with Bluetooth (e.g., HOBO MX2203) for ease of downloading. Be aware that in high energy environments, vibrations may switch a Bluetooth connection on and off, using additional power. Consider the new HOBO MX2205 with the cabled sensor in the high energy water and comms sensor in a low energy environment.
Will the deployment method ensure representativeness?	<ul style="list-style-type: none"> - Poor representation of local conditions. 	<ul style="list-style-type: none"> - Consider the deployment location carefully and check it is representative of water at the site. Some of the key risks include: (1) stagnant water, (2) solar radiation, (3) exposure to air, (4) burial, (5) secondary thermal radiation from artificial structures (piers, pillars, stilling wells), and (6) water from stilling well outlets in rivers.
How long will it take to deploy the sensor?	<ul style="list-style-type: none"> - Resourcing overspend. 	<ul style="list-style-type: none"> - A temperature sensor with onboard logging can be deployed quickly. In contrast, connecting a sensor to a logger may require more checks and steps.
Will the sensor battery be subject to environmental factors?	<ul style="list-style-type: none"> - Data loss or gaps due to power failure. 	<ul style="list-style-type: none"> - Check the battery specifications. Consider the following: (1) how long will the batteries last? (2) is the battery a specific model (and hard to get)? (3) are lithium batteries recommended? (4) will battery performance be reduced by the operating environment (e.g., low temperatures, vibrations)?
Will cable length affect accuracy?	<ul style="list-style-type: none"> - Long cables can add resistance or increase settling errors in voltage measurement. 	<ul style="list-style-type: none"> - Check maximum cable length. - Purchase sensor with required cable length. - Send sensor back to manufacturer for cable addition.
What are the data download options and additional hardware requirements?	<ul style="list-style-type: none"> - Inability to download if special connector damaged or misplaced. - Inability to recover data. 	<ul style="list-style-type: none"> - Assess if the user can access/swap an internal SD card (if applicable). With access to an internal SD card, it may be possible to recover data without sending the instrument to the manufacturer. - Check data transfer speed from sensor to data offload or mobile device.
How will your sensor integrate into an existing system?	<ul style="list-style-type: none"> - Loss of data resolution. - Overspend resourcing allocation. 	<ul style="list-style-type: none"> - Use a sensor which integrates with existing data collection platforms. - Check the sensor cable length to ensure it can reach the logger. Cables cannot be lengthened on some sensors without returning them to the manufacturer.
Is there existing site infrastructure?	<ul style="list-style-type: none"> - Time and resources required to install a new site. 	<ul style="list-style-type: none"> - If no housing or logger is available, select a sensor with sufficient on-board memory (with redundancy in case the sensor cannot be accessed).
What is your anticipated site visit schedule?	<ul style="list-style-type: none"> - Data loss if the sensor has a fault. 	<ul style="list-style-type: none"> - Check NEMS field verification requirements. - Consider operating a backup sensor or telemeter the data.
Do you have the technical expertise & support to manage the sensor?	<ul style="list-style-type: none"> - Unknown data quality. 	<ul style="list-style-type: none"> - Use a reference thermometer and water bath to undertake annual checks of all sensors pre- and post-deployment (where possible). Follow the NEMS procedures for validating field reference thermometers. - A larger fleet of sensors may be required to ensure there are no data gaps. - Contract out sensor validation as required.
How user-friendly is the software interface?	<ul style="list-style-type: none"> - Discouraged users. - More time spent setting up & downloading sensors. 	<ul style="list-style-type: none"> - Check the software interface (and experienced user comments about software interfaces in Table 5). - What is the format of downloaded data? Text, csv or a proprietary format?
Availability of sensors in stock in New Zealand?	<ul style="list-style-type: none"> - Data gaps. 	<ul style="list-style-type: none"> - Consider if you can source a replacement sensor at short notice.

CASE STUDY 1 – OPERATING TWO SENSORS

Otago Regional Council (ORC) undertook an initial sensor comparison to assess if water temperature data from an aging (>4 years old) pressure transducer was compromised. The data was compromised, so ORC now routinely operate two water temperature sensors at river sites. Their accumulated data from pairs of sensors allow comparisons between sensors and also reveal additional operational challenges. Some pairs of primary and backup sensors they operate include: (1) HOBO Pro V2 and Keller PT 36 XiW, (2) In-Situ RDO and HOBO Pro V2, (3) D-Opto and HOBO MX2203, and (4) HOBO MX2203 and Seametrics PT2X. At each site the two sensors are typically mounted differently:

- HOBO sensors are installed to monitor low flows, so are attached to a chain and sit on the riverbed.
- DO sensors are deployed in a PVC or stainless-steel housing with holes. Where deployed, DO sensors are the primary sensor.
- Pressure transducers are mounted on a stainless-steel pipe or waratah.

This case study includes three examples – a burial event and two sensor comparisons.

Burial event

During a flood event (see Figure 11 A) on the Lindis River at Ardgour, the Seametrics PT12 pressure transducer was buried. From around 18 July until the pressure transducer was extricated, the pressure transducer returned temperature values which were up ± 2.5 °C different from the In-Situ RDO (Figure 11 C).

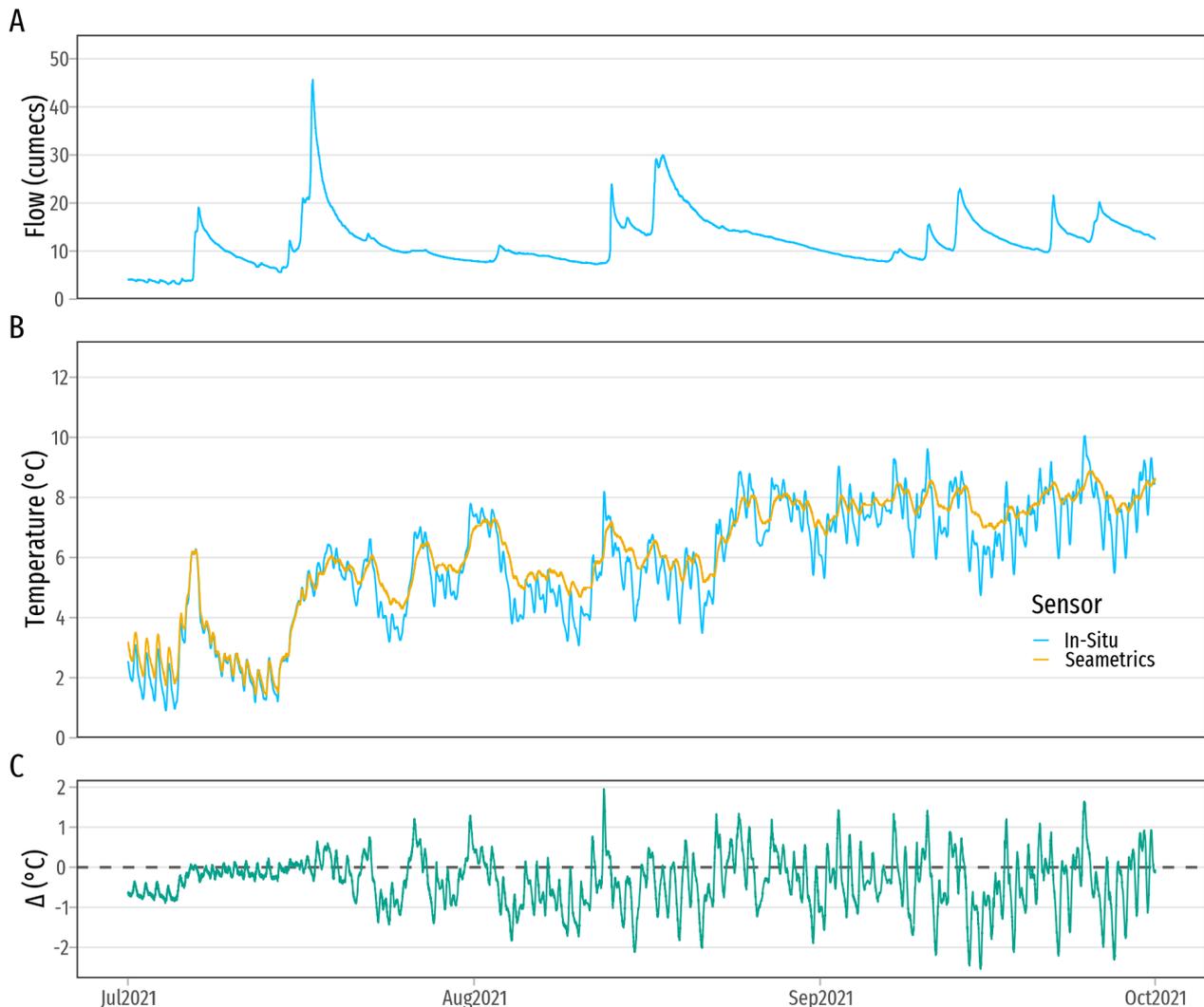


Figure 11. Time series plots for Lindis River at Ardgour Road. (A) Discharge from 1 July 2021 to end Sep 2021. (B) Water temperature measured by an In-Situ RDO and a Seametrics PT12. (C) Difference between In-Situ RDO and Seametrics PT12 water temperature.

This example illustrates the value of operating telemetered temperature sensors in minimising data gaps and detecting sensor issues (such as burial, power failure or sensor loss). It also demonstrates the risk of relying on a

pressure transducer installed for measuring water level to collect water temperature – the sensor will be installed near the stream bed to measure the range of water levels and therefore more susceptible to burial.

Comparison 1

Water temperatures recorded by two sensors operated at the Lauder River at Rail Trail were compared and found to differ by + 0.2 °C. The HOBO Pro V2 consistently – both diel and longer term – measured higher temperatures than the Keller PT 36XiW (Figure 12 C). This offset is consistent across a wide range of water temperatures, from ~ 2.5 °C in winter to ~ 20 °C in early summer (Figure 12 B). A high flow event on 22 Sep 2023 (Figure 12 A) reduced the river water temperature from ~12 °C to 4 °C. Both sensors are operating within acceptable tolerances under NEMS v2.0 (NEMS 2017), which allows an observation tolerance of 0.8 °C between an in-situ sensor and field reference meter.

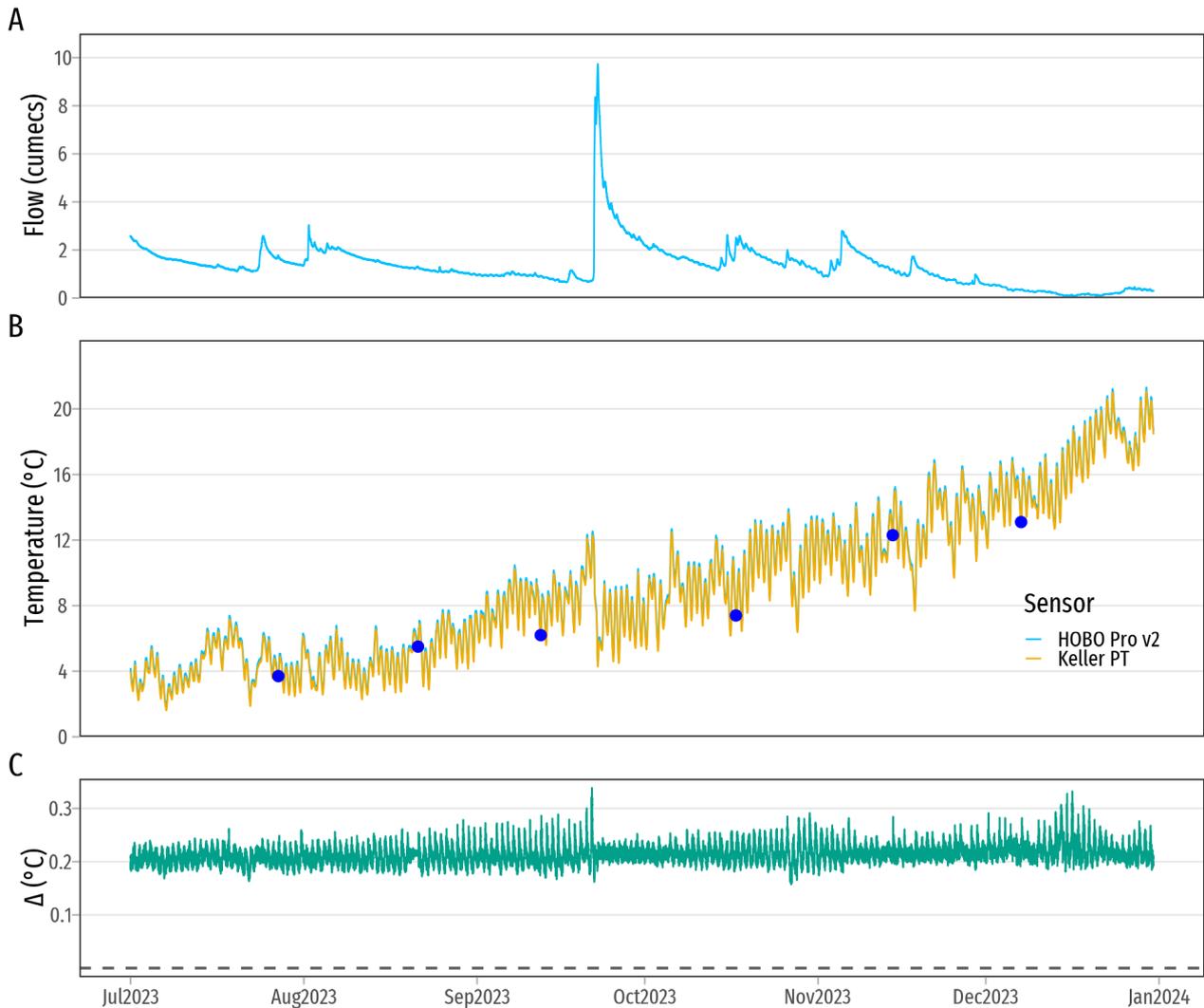


Figure 12. Time series plots for Lauder River at Rail Trail (A) Discharge from July to Dec 2023. (B) Water temperature measured by a HOBO Pro v2, a Keller PT12, and a YSI ProDSS as a reference sensor (blue dots). (C) Difference between HOBO Pro v2 and Keller PT water temperature values at each 5-min time step.

Comparison 2

Comparison of water temperature data from two sensors operated on the Cardrona River at Mt Barker during the summer of 2023/4 shows their values correspond closely (Figure 13). The HOBO TidbiT was deployed on a chain on the bottom of the riverbed and the D-Opto sensor was deployed in a housing tube.

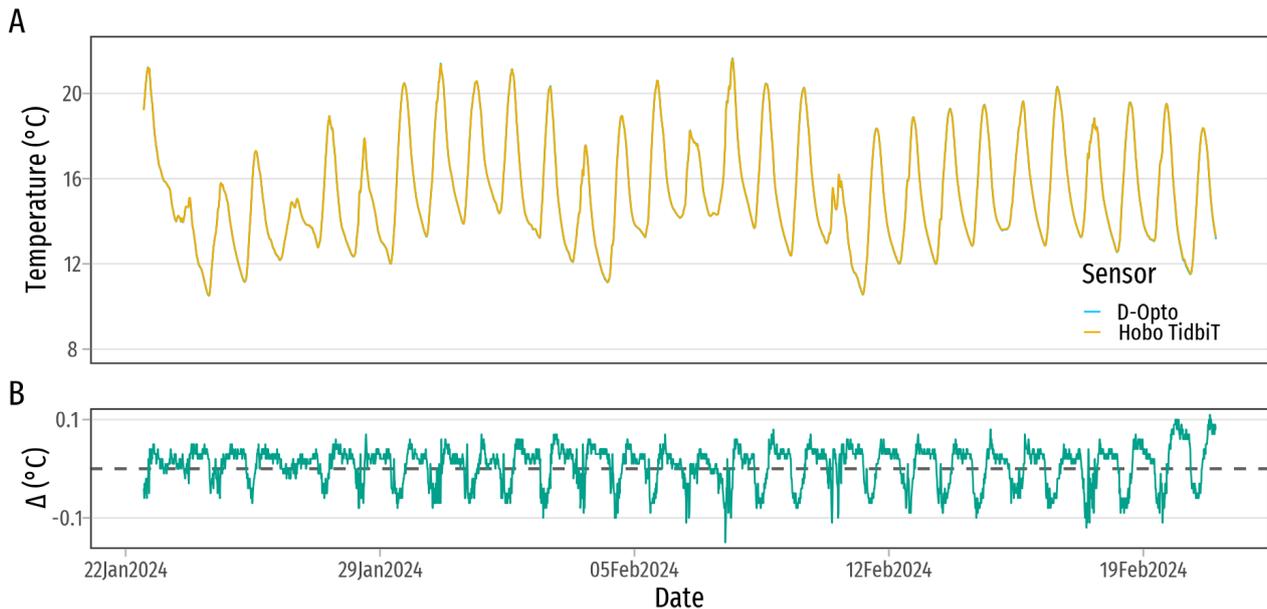


Figure 13. (A) Time series plot of water temperature at Cardrona at Mt Barker (the blue line is obscured by the orange line). (B) Difference between HOBO TidbiT (master) and D-Opto (backup) water temperature values at each 15-min time step.

Operating sensors in pairs has improved the quality of ORC's water temperature records. When processing the data it is possible to: (1) confirm when one sensor is not collecting representative data, and (2) fill gaps with the secondary sensor, creating a more complete temperature record.

Water temperature data quality can be reduced by a change in conditions around sensors such that they are no longer representative (e.g., debris dams, burial, channel change, low water level), sensor failure, or sensor loss during high flow events. Some additional recommendations to overcome changing conditions include:

- For rivers with fluctuating flows, one sensor might be out of the water at times. Setting up one sensor on a chain in the riverbed provides water temperature measurements when the water level is low.
- If the secondary (backup) temperature values are provided by a thermometer on a pressure transducer, ensure the sensor remains in well-mixed water and check the sensor specifications carefully, noting that lower temperature sensor performance is acceptable for pressure correction.

SENSOR COMPARISON TABLE

Table 5. Comparison of temperature sensors used by the workgroup in 2023. At least one sensor user contributed to each column. All costs in NZD. See notes below table for detailed additional comments on each sensor. To evaluate a different sensor, gather equivalent information from brochures, manuals, manufacturer and other users.

	Temperature-only sensors				Sondes and CTDs			DO sensors				Pressure transducers	
Feature	Campbell 107/109	HOBO Pro V2 or TidbiT V2	HOBO TidbiT	RBRsolo T std	YSI EXO	In-Situ Aqua TROLL 600	Sea-Bird HydroCAT CTD	In-Situ RDO Pro-X	HOBO U26 DO	WTW FDO 700	ZebraTech D-Opto	Seametrics PT12	Keller PT 36XiW
Basic information													
Cost (\$ <400, \$\$ 400-1000, \$\$\$ 1000-2500, \$\$\$\$ > 2500)	\$	\$\$	\$	\$\$	\$\$ (+ sonde \$\$\$\$)	\$\$ (+sonde \$\$\$\$)	\$\$\$\$ with antifouling pump	\$\$\$\$	\$\$\$\$	\$\$\$\$	\$\$\$\$	\$\$\$	\$\$\$
Sensor type	Thermistor ^c	Thermistor	Thermistor	Thermistor	Thermistor	Thermistor	Thermistor ^{sb}	Thermistor	Thermistor	Thermistor	Thermistor	Digital IC	Chip ^k
Sensor location	External ^c	Internal	Internal	External	External	External	External	External	Internal	Internal	External	Internal	Internal
Sensor combos	Temp	Temp ^{hv2}	Temp	Temp	EC	EC	EC, depth, etc.	DO	DO	DO	DO	Water level	Water level
Sensor models		Pro V2 or TidbiTV2	Various	Various ^r	Wiped and non-wiped							Logger or sensor	
Suited environments	Any	Any	Any	Any	Any ^e	Any	Any	Any	Any	Any	Any	Any	Any
Casing materials	Aluminium casing	Plastic	Plastic (MX2204/5: epoxy)	Plastic or titanium	Stainless steel or titanium	Combo - sensor plastic	Plastic	Plastic & stainless steel	Plastic	Plastic & stainless steel	Plastic & stainless steel	Stainless steel	Stainless steel
Sensor dimensions (cm)	10.4 x 0.76	Pro: 3 x 11.5	~4 x 7 x 3.5	24 x 2.5	EXO2: 7.6 x 71.1	500: 4.7 x 46 600: 4.7 x 60	CTD: 72.2 x 14	20.3 x 4.7	26.7 x 4	4 x 40	4.8 x 15/20	21.4 x 1.9	10.7 x 2.2
Depth rating (m)	15	Pro: 120 TidbiT: 305	MX2201: 30 MX2203: 120 MX2204: 1500	1700	250 ^e	250 ^{at}	350	100	100	100	30	600	3, 10, 30 and 100 m ranges
Detachable sensors	No	No	No	No	Yes	Yes	Yes	Yes	No	Yes ^w	No	No	No
Power source	External	Internal	Internal	Internal	Both ^f or External	600: Both 500: 8–36 VDC	Either (9–24 VDC or battery)	External - 12 VDC	Internal	External - 24 VDC	Either (8–24 VDC or battery)	External	External
Battery type, lifespan and replacement	–	3.6 V Li; ~ 5–6 y; factory	3V Li; ~1 y; user	AA; user	D Cell ~ 1–3 mo; user	D cell; ~ 6 mo; user	12 AA Li (3 brands); user	–	3.6 V Li; ~ 3 y; factory	–	9 V alkaline; user ~ 3–4 mo	–	–
Data logging	External	Internal	Internal	Internal	Both	Both	Both	External	Internal	External	Either	External	External
Output to logger	Analog 0–20 mA	–	–	–	SDI-12 via DCP, RS-232, RS-485; EXO3 also SDI-12 ^e	SDI-12, RS-485 Modbus	SDI-12 or RS-232	Modbus/RS-485, SDI-12, 4–20 mA	–	Analog 4–20 mA or RS-485 Modbus	Sensor: Any 4–20 mA, Logger: 4–20 mA, requires interface panel (2024: SDI-12)	RS-485 Modbus, SDI-12	SDI-12
Data transfer & cable options	Cable max 305 m; cable end options	Data offload device (Optic base station or Shuttle)	Bluetooth data transfer	USB-C data transfer	Cable (many options), Bluetooth	Bluetooth, WiFi, Cable	Cable (many options)	Cable, 10 m, fixed or connector	Data offload device (Optic base station or Shuttle)	Requires controller between sensor & logger	Logger: jack Sensor: 4–20 mA, requires interface panel (2024: SDI-12)	Cable (up to 600 m)	Cable (up to 250 m)
Stated specifications													

	Temperature-only sensors				Sondes and CTDs			DO sensors				Pressure transducers	
Feature	Campbell 107/109	HOBO Pro V2 or TidbiT V2	HOBO TidbiT	RBRsolo T std	YSI EXO	In-Situ Aqua TROLL 600	Sea-Bird HydroCAT CTD	In-Situ RDO Pro-X	HOBO U26 DO	WTW FDO 700	ZebraTech D-Opto	Seametrics PT12	Keller PT 36XiW
Operating range (°C)	-50 to 70	max 50	-20 to 50	-5 to 35	-5 to 50	-5 to 50	-5 to 45	0 to 50	-5 to 40	-5 to 50	0 to 60	-15 to 55	
Accuracy (°C)	± 0.25 (-10 to 70 °C)	± 0.21 from 0 to 50 °C	MX2201: ± 0.5 MX2203/4: ± 0.2 0-50°	± 0.002	CT: ± 0.01 (-5 to 35 °C); wiped CT ± 0.2	± 0.01	± 0.002 (-5 to 35)	± 0.01	0.2	± 0.5	± 0.1	± 0.5	chip ± 1.5 PT1000 ± 0.1 ^k
Response		T90: 5 min	4-7 min ^h	T63: < 1 s	C/T T63: < 1 s Wiped: T95: < 30 s	T63: < 2 s, T90: < 15 s, T95: < 30 s ^{at}			T90: < 30 min				
Resolution (°C)		0.02 at 25 °C	MX2203/4: 0.01 MX2201: 0.04	< 0.00005	0.001	0.01	0.0001	0.01	0.02	0.1	0.01	0.06	0.01
User experience													
Specs level of detail	Good	Excellent	Good	Excellent	Good	Excellent	Good	Good	Good	OK	OK	OK	Good
Performance	Consistent with specs	Consistent with specs	Consistent with specs	Consistent with specs	Consistent with specs	Consistent with specs	Consistent with specs	Consistent with specs	Consistent with specs	Consistent with specs	Consistent with specs	Consistent with specs	Consistent with specs
Software interface	Short Cut	HOBOWare	HOBOWare	Ruskin	KOR, KOR2	VuSitu for mobiles, WinSitu 5	SeaTerm and SeaSoft	VuSitu for mobiles, WinSitu 5	HOBOWare	IQ SensorNet	Sensor: D-OptoCom Logger: D-OptoLog	Aqua4Plus	-
Software user friendliness	Easy to use	Easy to use	Easy to use	Easy to use	Easy to use	VuSitu very easy to use	Advanced software -takes a bit of learning	VuSitu very easy to use	Easy to use	Takes a bit of learning	Old but easy to use		-
Metadata		Battery voltage											
Manual usefulness	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good
Averaging	User control via logger	User control	User control	User control	Inbuilt; some user control		User control	Logger control	User control		Sensor: User control Logger: No	User control via logger	User control via logger

^{at} In-Situ Aqua TROLL notes: (1) Response time for 15 °C change. (2) Analog signal must be enabled in Win-Situ 5 prior to use. Modbus RS-232 also available but requires third-party convertor. Std 10 m cable; max cable length 1219 m Analog & Modbus RS485; 60 m SDI-12 and Modbus RS-232. (3) Check depth sensor rating.

^c Campbell notes: (1) 100K6A1iA/ 10K3A1iA located 3 mm back from probe tip. (2) 107 had historic issues with calibration equation; stock cable lengths will be available 2-3 days, custom cable lengths 3-4 weeks.

^e YSI EXO notes: (1) both can operate concurrently. (2) Check depth sensor rating. (3) EXO2 requires DCP adaptor to convert to SDI-12, EXO3 SDI-12 native. (4) Use C/T (not wiped C/T) for profiling. (5) Width may be an issue for groundwater.

^h HOBO TidbiT notes: (1) various models MX2201-4 various depths, MX2202 with light, MX2205 Ext probe; MX2203 and 2204 water detection feature. (2) Depends on model (T90; stirred, unmounted).

^{hv2} HOBO V2 notes: (1) Lower battery life with operation >35 °C. Requires dongle/shuttle.

^k Keller notes: (1) PT1000 option available. (2) Specs for 0-50 °C.

^r RBR notes: (1) Various versions available - |fast, |slow, |deep, and cabled version RBR coda³ T.

^{sb} Sea-Bird notes: (1) Located just inside intake.

^w WTW notes: (1) Cable can be removed from sensor but recommended to only disconnect when sensor body is clean.

LOGISTICS – GETTING THE DATA

Most water temperature sensors will output a temperature value using the manufacturer’s calibration. While some oceanographic temperature sensors do allow the user to output raw engineering data, most sensors do not have this capability.

Internal logging is possible for most water temperature sensors, and for some it is the only option. The use of internal logging requires robust consideration of the consequences of data loss, while the adoption of telemetry may require additional resourcing. The key advantages and disadvantages of using sensors with internal logging or telemetry are summarised in Table 6.

Table 6. Advantages and disadvantages of data communication systems (after Wagner et al., 2006).

Data capture system	Advantages	Disadvantages
Telemetry	<ul style="list-style-type: none"> - Data secure once transmitted. - Data can be viewed at any time, including on public-facing portals. - Real-time decision-making is possible. - Systems can be monitored remotely and additional services carried out in a timely manner. 	<ul style="list-style-type: none"> - Requires additional resourcing (if a logger is not already on site). - More complex system and more faults are possible. - Telecommunications protocol may need to be updated (satellite/mobile system switch off). - Site may attract vandals – particularly solar panels.
Internal logging	<ul style="list-style-type: none"> - Deployment & location options are flexible, including lake bottoms (depending on sensor maximum depth rating). - Vandalism may be reduced due to absence of visible infrastructure, particularly solar panels. - Sensor theft may be reduced if the sensor can be well-hidden. - Sensors can be installed and replaced rapidly (reducing resourcing). - Small, battery-powered sensors may be less likely catch flood debris. - Bluetooth receivers can collect data from shallow submerged sensors in hard-to-service locations. 	<ul style="list-style-type: none"> - Real-time decision-making not possible. - Data are only available during site visits. - Migrating channels or bank erosion may require adjustment to sensor placement. - Status of equipment can only be checked during servicing. - Data cannot be viewed without a site visit. - Loss of data is unknown until site visit. - Battery may lose power.

DEPLOYMENT OVERVIEW

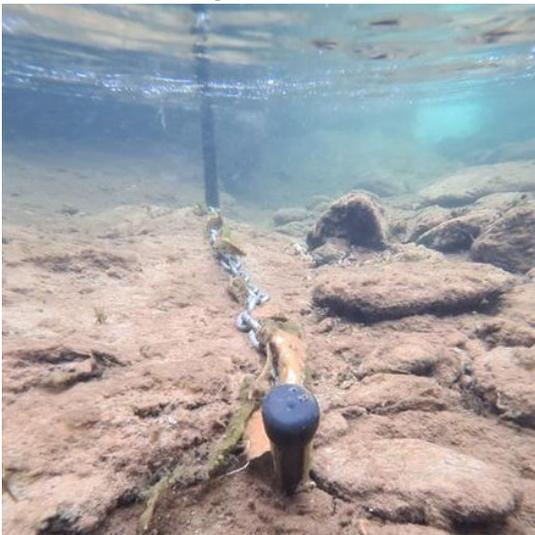
This project does not cover deployment in detail; however, good-quality data depends on good deployment design. The photos on this page demonstrate a range of deployments undertaken in New Zealand.



Field verification sensor (pink) beside a field sonde (PVC housing) in an urban stream [Gareth van Assema, NIWA]



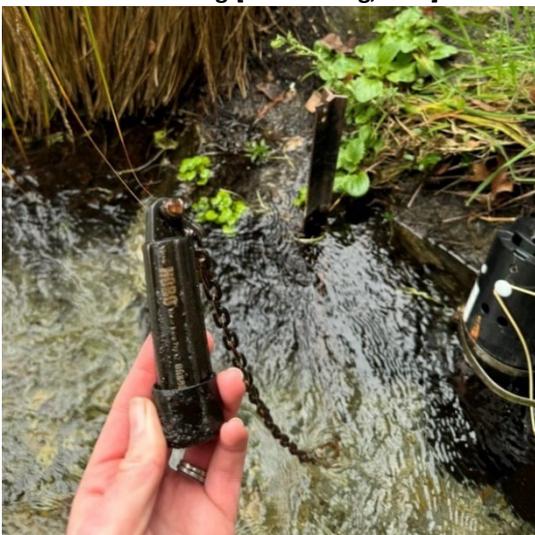
HOBO TidbiT (on black paddle) installed on a paddle attached to scaffold pipe [Emily Olson, ORC]



HOBO Pro V2 waratah and chain setup for river low flow monitoring [Jono Young, ORC]



WRIBO monitoring buoy, Wellington [Mark Gall, NIWA]



HOBO ProV2 chain installation on Bullock Creek, Otago [Emily Olson, ORC]



Cable mounted YSI EXO sonde and Sea-Bird C-Star at Waikoropupū Springs, Tasman [Patrick Butler, NIWA]

SUPPORT FOR NEW USERS

All NZ sensor reps are helpful and approachable; some will be able to give detailed operational guidance, while others will need to defer to colleagues.

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