19 Data Analysis

Data recorded in Sap Flow Mode is saved in a Comma Separated Values (*.CSV) file. Data recorded in Needle Temperatures mode is saved in a Binary (*.BIN) file format. Both file formats can be automatically imported into SFT Sap Flow Tool for post processing and detailed analysis. Processed results can be exported to a CSV file for import into your preferred spreadsheet or statistics software. SFT Sap Flow Tool Software can facilitate direct comparison of measured sap flow data with other measured parameters such as Stem Water Potential, Solar Radiation, VPD, Soil Moisture to easily and quickly look at the impact of these environmental interaction's on plant water use.

19.1 Analysis of Raw Heat Pulse Velocity

The Raw Heat Pulse Velocity is a measure of the heat movement through the woody matrix of the plant stem. The velocities measured do not directly relate to sap velocity. This data must first be corrected for wounding, thermal diffusivity, and asymmetry before it can be used for quantification of the sap velocity. Nevertheless, the diurnal trends are still very meaningful and can be interpreted in terms of the timing of events that affected the plants use of water.

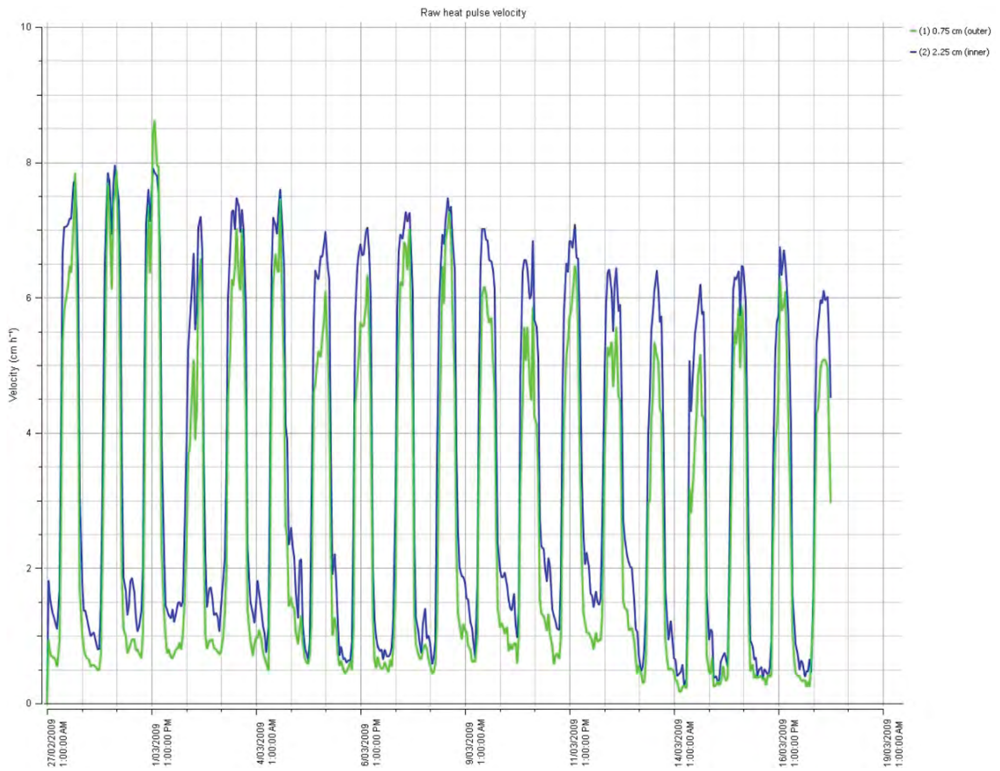

Figure 108: Raw Heat Pulse Velocity data is relative in nature and can be used qualitatively but not quantitatively.

19.2 Corrected Sap Velocity

Corrected Sap Velocity is a quantitative measure of the speed at which water moves through the water conducting xylem of the plant. Using SFT Software it is possible to analyse the velocity and the timing at which velocities of water movement occurred and changed within the tree. In addition to this, a simultaneous sap velocity profile graph can be overlaid on the sap velocity data to characterize the radial gradient of water movement from the outside of the tree in the actively conducting xylem as its water conducting capacity degrades as the xylem ages towards the sap wood - heartwood interface; at which point the heartwood ceases to be functional in conducting water. The diurnal changes can be used to understand changes in access to water. The combined interpretation of the velocity at which water moves through the tree at different times throughout the day and where the water is coming from radially within the tree allows powerful interpretations about plant water stress.

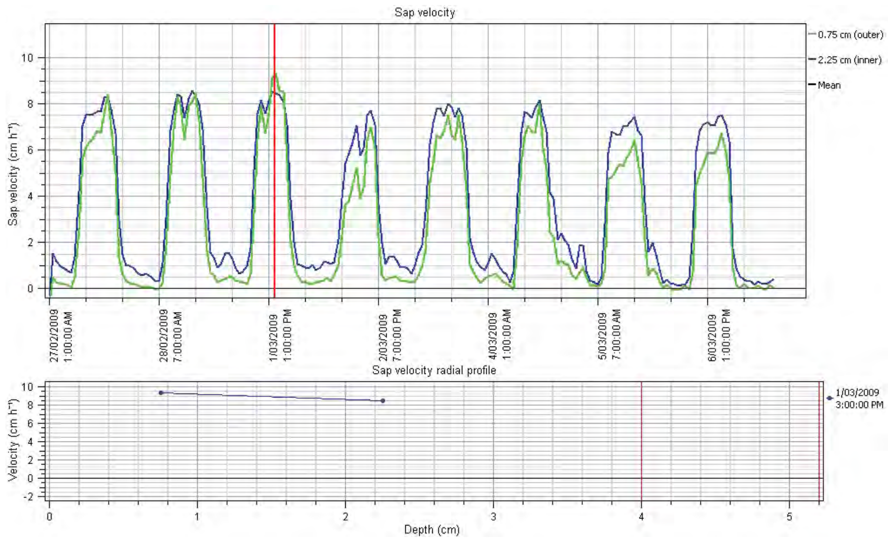

Figure 109: The combined analysis of sap velocity simultaneously overlaid with radial profile of sap velocity.

19.3 Volumetric Sap Flow

The Sap Flow Rate is a corrected, volumetric rate at which water moves through the plant. It displays the volume of water used by the plant at any given time throughout the diurnal pattern. The sap flow rate also enables the accurate determination and quantification of nocturnal sap flow or conversely night time water use.

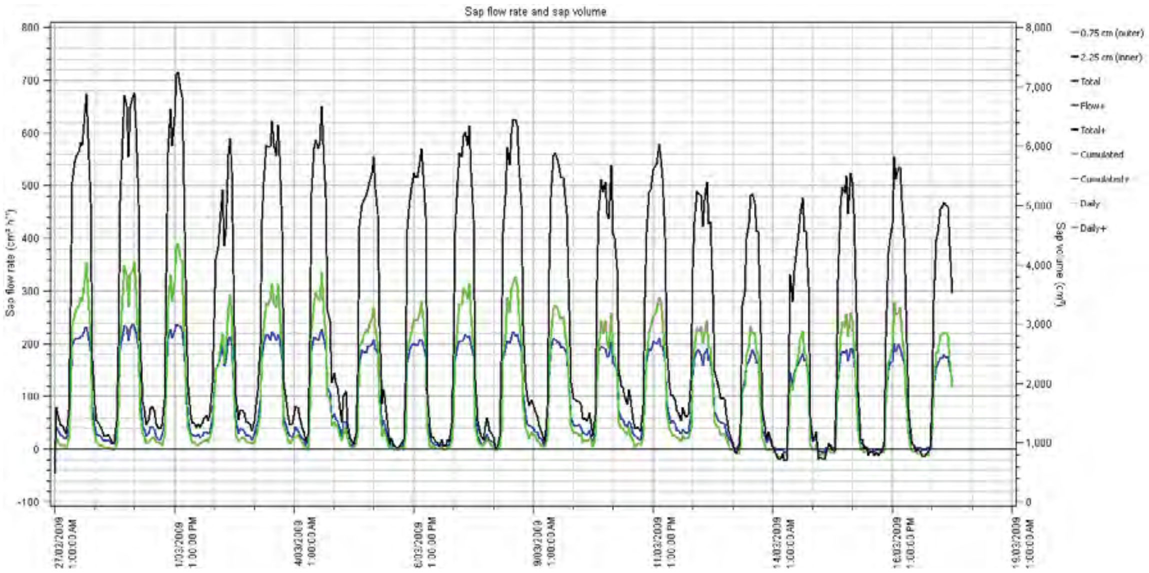

Figure 110: Sap Flow Rate and Sap Volume displayed on the same graph using dual Y axis.

19.4 Cumulative Sap Flow Analysis

Simultaneously, the volume of water used throughout the 24 hour period can be read directly from the 2nd Y axis, instantly providing the total daily water use in litres of water. This figure can then be used to determine water use efficiency and/or schedule irrigation.

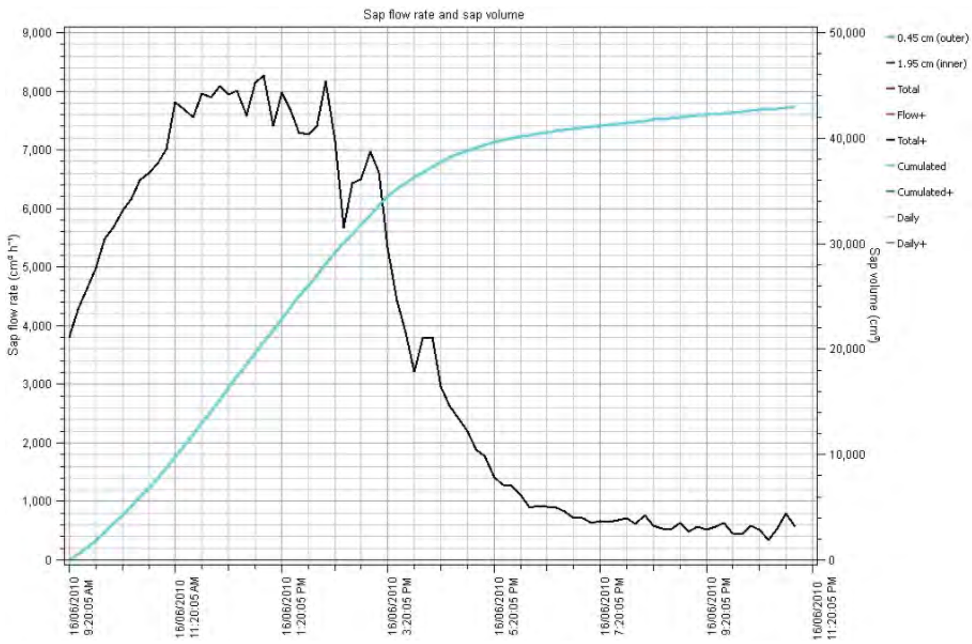

Figure 111: Cumulated sap flow volume provides the plant daily water use as it is an automated integration of the area under the Sap Flow rate curve.

19.5 Environmental Sap Flow Analysis

Sap Flow data is an extremely powerful tool in understanding the complex interrelationship between a plant and the environment. A Tree (or plant) is the ultimate transducer. It synthesizes and integrates all of the abiotic variables of the surrounding environment that are acting upon it and provides a single measurable output that reveals how these inputs have affected its growth.

The continuous, nondestructive, high temporal, diurnal sap flow trace can be considered analogous to the Electrocardiogram (ECG) of a human heart. As external stimuli are imposed on the body, or, in this case, the tree, the sap flow rate will increase or decrease much like an Electro- Xylem-gram (EXG).

As light increases (given all other parameters remain the same and water reserves are adequate to meet supply) so too will the rate of sap flow of the tree. As Light decreases so too will the sap flow. This is because the driving force, or demand, for the exchange of water for CO_2 to perform the process of photosynthesis is decreased.

Because of this intimate interrelationship between the plant and its environment, sap flow must be interpreted not in isolation, but in concert with meteorological and environmental parameters, to be able to isolate and determine both the cause and effect of the changes in the growth of the tree. This detailed analysis can be performed using the SFT1 Sap Flow Tool Software.

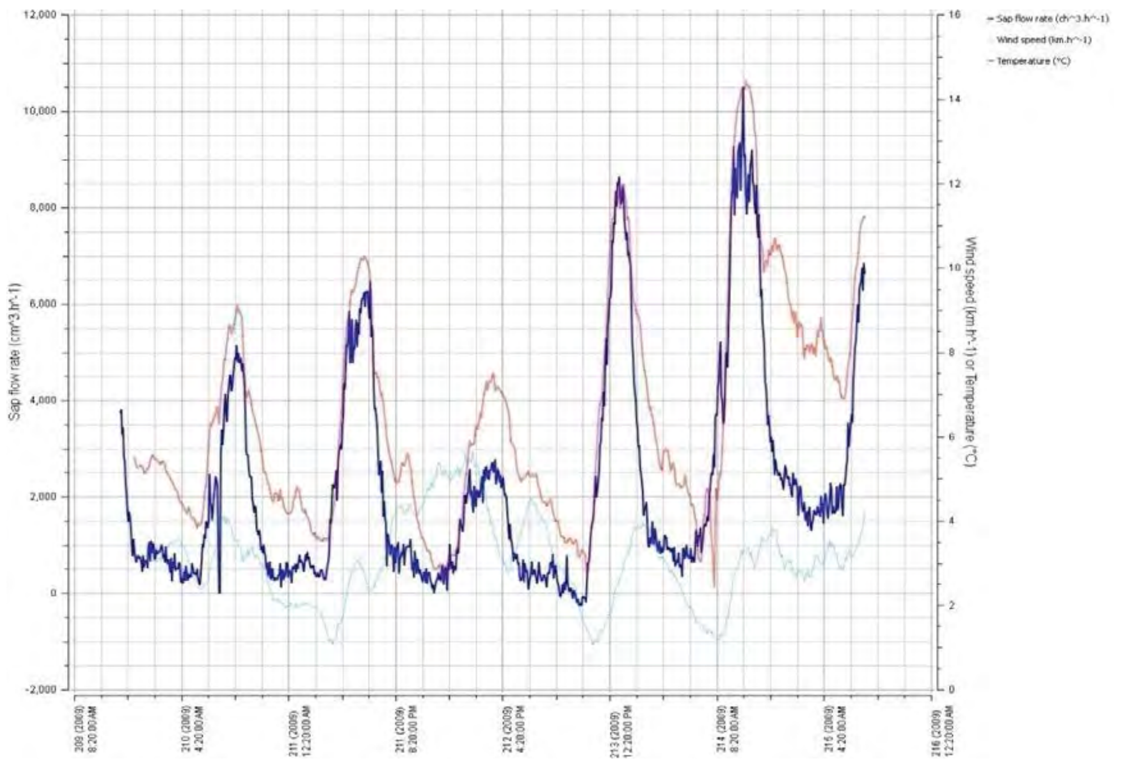

Figure 112: Using SFT1 Sap Flow Tool Software to analyse sap flow data with meteorological data to analyse the intimatacy of the Soil Plant Atmosphere Continuum.

19.6 Measuring Zero Flow

Performing a cut stem experiment is the ultimate measure of zero flow. The stem should be cut during the day and during its maximum sap flow rate. Cut the stem below the measurement needles. The more xylem left between the needles and the cut the longer it takes for the flow to reach zero due to the capacitance of the xylem.
Once the tree exhausts the water reserves stored in the xylem and the flow reaches zero, continue to measure for 30 minutes to 1 hour to ensure a definitive data set of stable zero flow data. If the needles have been installed symmetrically, the flow recorded will indeed zero within a tolerance of +/- 0.5 cm hr^{-1} (the published limits of accuracy for the SFM1). In many cases it will be more accurate than this. If the flow does not reach zero or goes below zero then there is an asymmetrical arrangement of the measurement needles i.e., both needles are not 5mm above and below the heater.

19.6.1 Cut Stem Analysis

For the purpose of comparison this experiment was performed on two different species:

Callitris glaucophylla and Eucalyptus blakelyi with different water use rates and sap wood thicknesses.

19.6.1.1 Callitris glaucophylla

Species: *Callitris glaucophylla*
Sensor installation aspect: West/South West
Diameter: 11.3 cm
Bark thickness: 6 mm
Sapwood thickness: 25 mm
Heartwood Thickness: 20 mm
Wounding: 0 mm radius
Density: ??
Thermal Diffusivity: ??

Approx. Average night time off set:	Inner: 1.88 cm hr^{-1}	Outer: 1.32 cm hr^{-1}
Raw Heat Pulse velocities before Cutting:	Inner: 20.53 cm hr^{-1}	Outer: 24.94 cm hr^{-1}
Raw Heat Pulse Velocity after cutting:	Inner: -0.54 cm hr^{-1}	Outer: 0.49 cm hr^{-1}

Photo 47: Cut Stem *Callitris glaucophylla*.

Sap Flow was measured for 10 days to provide a stable diurnal sap flow data set prior to severing the stem. Subsequent to cutting the stem the zero flow of + 0.49 cm hr^{-1} on outer and -0.54 cm hr^{-1} on inner was reached within 30 minutes of cutting.

These values are within the stated accuracy of the instrument suggesting the installation was symmetrical. Now, with this confirmation, the proceeding 10 days of data can be interpreted.

It shows that the initial days recorded were in fact going to zero at night and, subsequent to this period, when the data was not reaching zero at night that the tree was in fact using water at night.

It cannot be confirmed from this data if that water was transpired through the leaves or used for hydraulic refilling of the vessels. Nevertheless the data can be verified as accurately recording a physiological process.

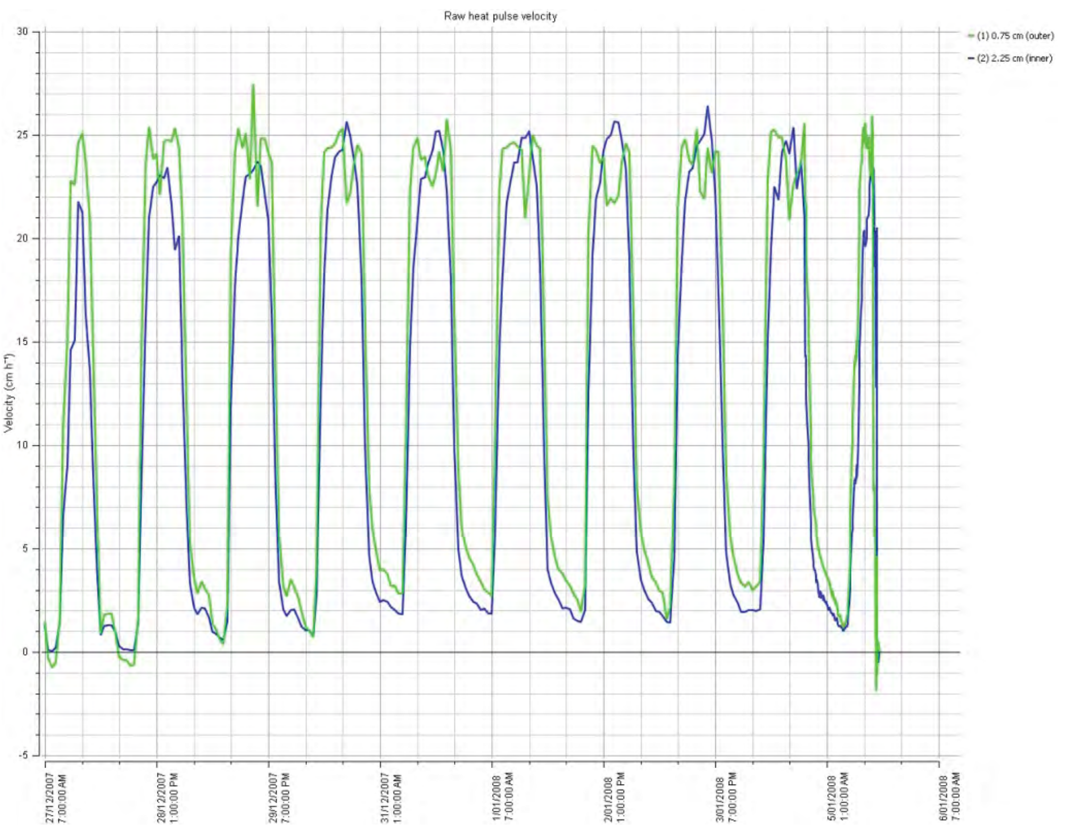

Figure 113: 10 days of stable sap flow data for *Callitris glaucophylla* prior to severing the stem.

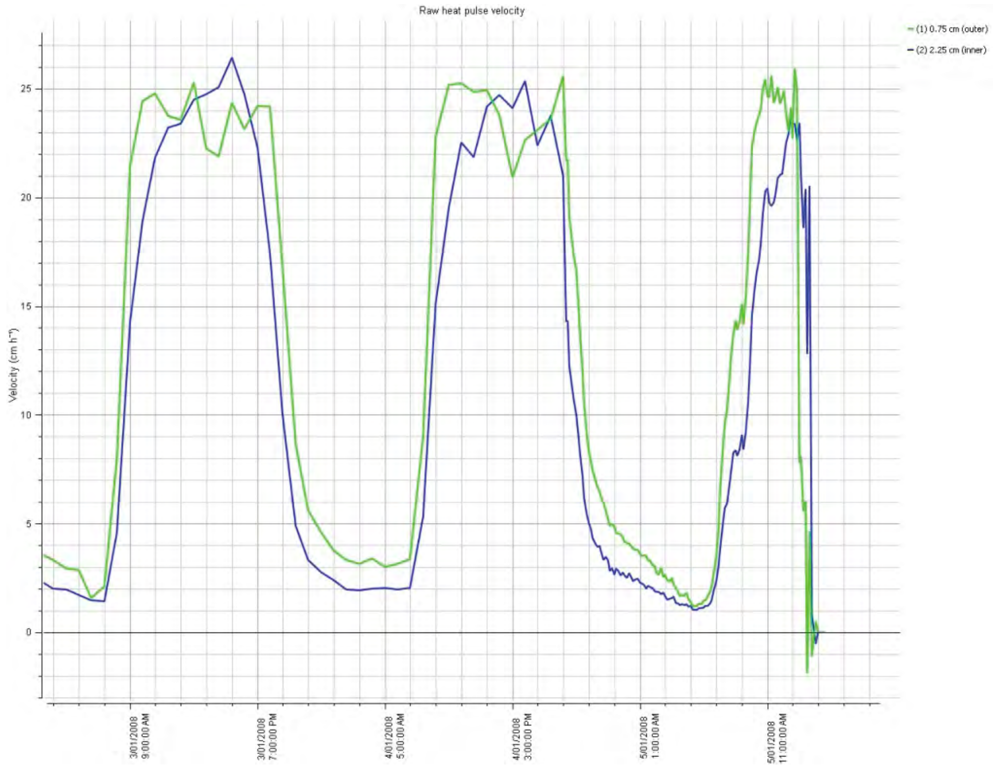

Figure 114: The immediate cessation of sap flow for *Callitris glaucophylla* upon cavitation caused by severing the water column of the tree.

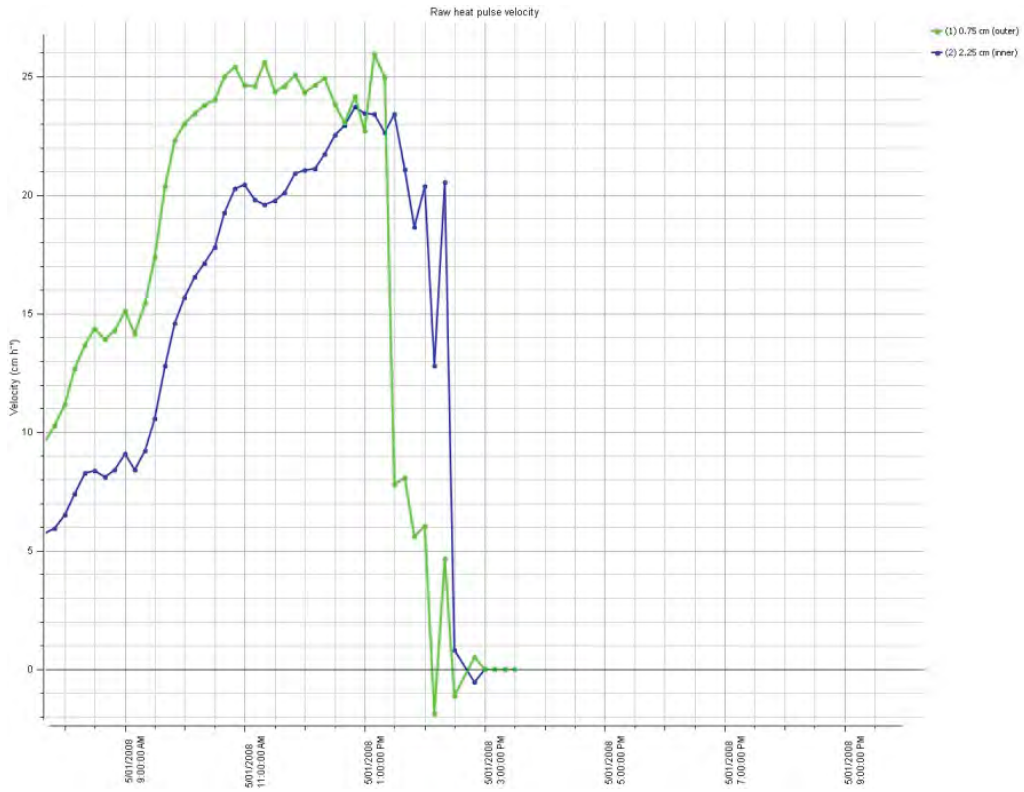

Figure 115: Steady absolute Zero Flow state reached after complete severing of xylem of *Callitris glaucophylla*.

Photo 48: Measuring the Stem Diameter and sapwood depth of *Callitris glaucophylla*.

Photo 49: Measuring the Wound Size of *Callitris glaucophylla* after the cut stem experiment to apply wound size correction coefficients to the data.

19.6.1.2 Eucalyptus blakelyi

Species: *Eucalyptus blakelyi*
Sensor installation aspect: East/South East
Diameter: 12.2 cm
Bark thickness: 6 mm
Sapwood thickness: 6 mm
Heartwood thickness: 30 mm
Wounding: 1 mm radius
Density: ??
Thermal Diffusivity: ??

Approx. Average night time off set:	Inner: - 1.48 cm hr^{-1}	Outer: - 1.49 cm hr^{-1}
Raw Heat Pulse velocities before Cutting:	Inner: - 1.52 cm hr^{-1}	Outer: - 11.78 cm hr^{-1}
Raw Heat Pulse Velocity after cutting:	Inner: - 1.52 cm hr^{-1}	Outer: - 0.53 cm hr^{-1}

Photo 50: Cut stem Eucalyptus *blakelyi*.

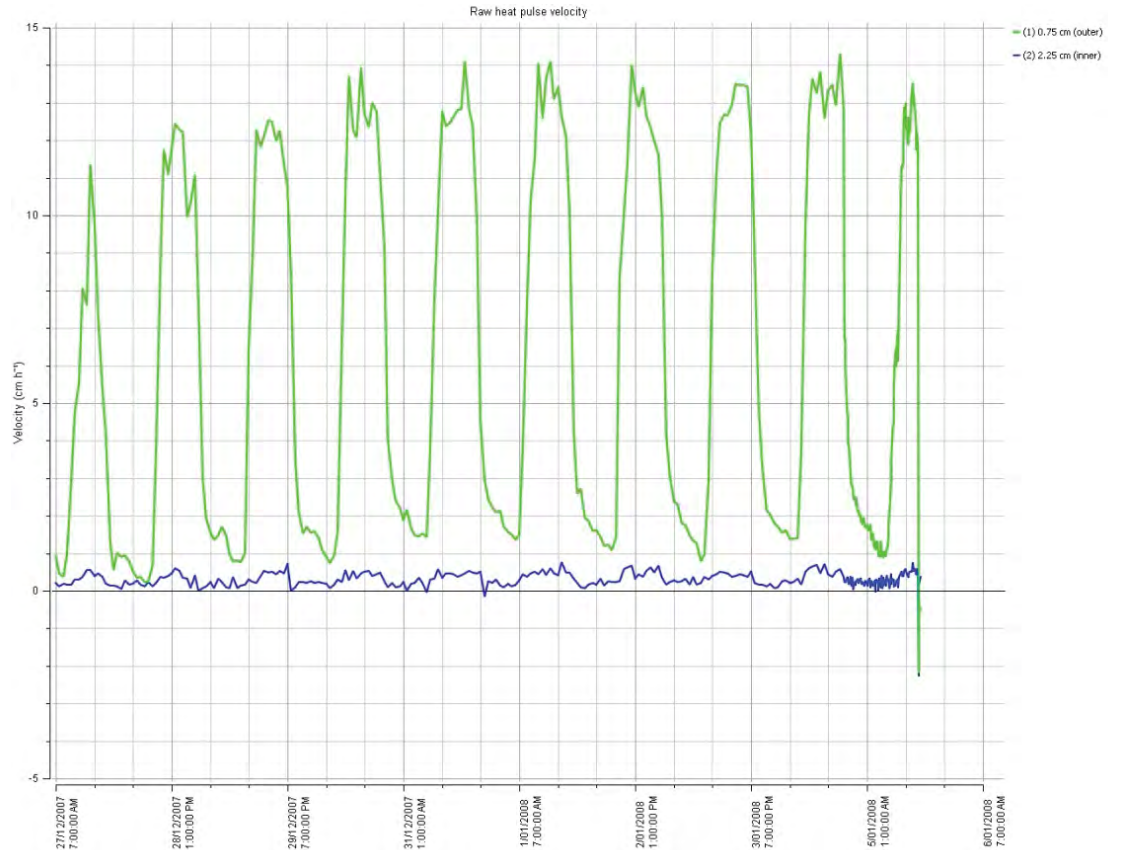

Figure 116: 10 days of stable sap flow data for Eucalyptus blakelyi prior to severing the stem.

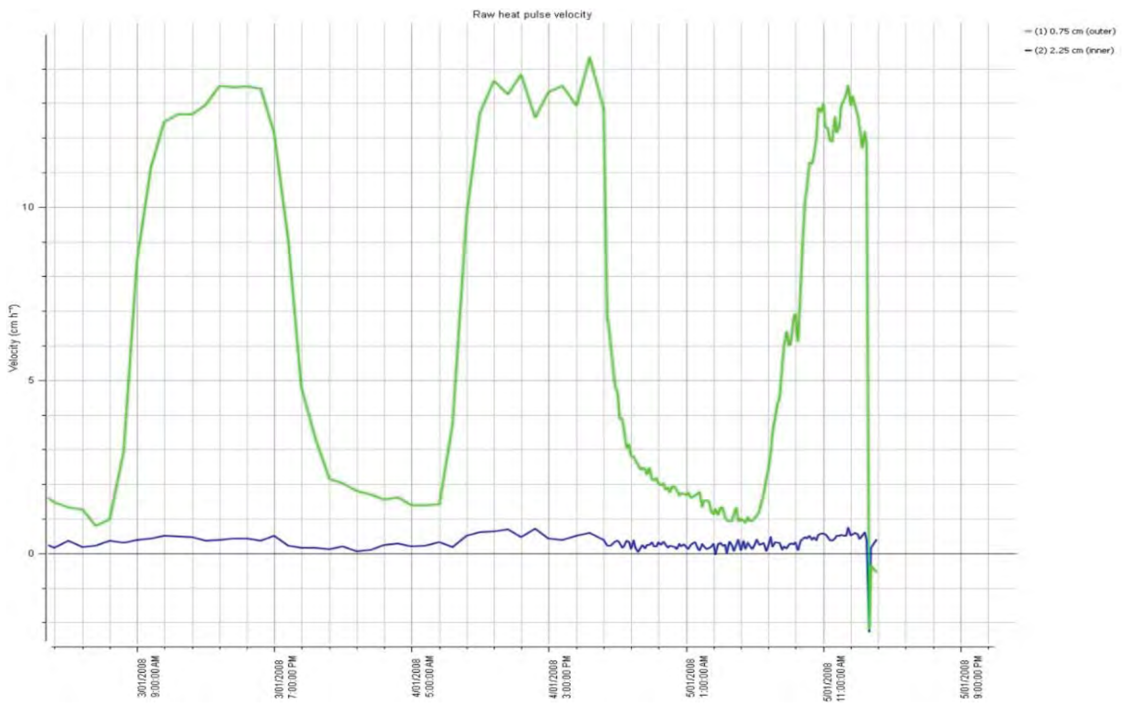

Figure 117: The immediate cessation of sap flow for Eucalyptus blakelyi upon cavitation caused by severing the water column of the tree.

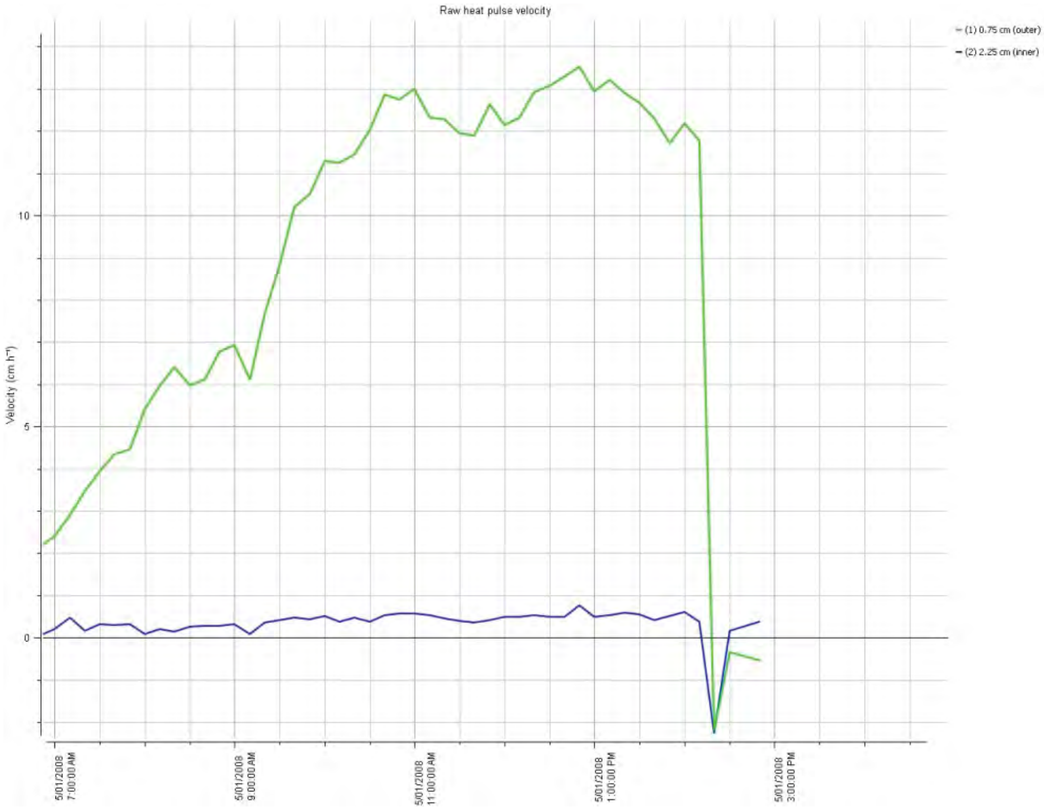

Figure 118: Absolute Zero Flow state reached after complete severing of xylem of *Eucalyptus blakelyi*. Note the negative spike immediately after severing as the values come to equilirium following the next measurement.

E. blakelyi had a much higher heartwood percentage than sapwood with a hollow pipe in the middle of the tree. The narrow sapwood explains the noisy flat line data that shows no diurnal pattern recorded for the inner thermistor located in heartwood. The heartwood also consisted of very dense non conducting xylem with fissures of open air voids or cracks emanating from the hollow pipe at the centre of the tree.

Photo 51: Stem diameter, *Eucalyptus blakelyi*.

Photo 52: Sap Wood thickness, *Eucalyptus blakelyi*.

Photo 53: Wound size, *Eucalyptus blakelyi*.