AQUALINC RESEARCH LIMITED

Snow storage estimation

Proposal for professional services.

Prepared for Opuha Water Limited.

Report No C15114-01/1

May 2015

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1 INTRODUCTION

Snow melt is considered to be an important component of Opuha Dam reservoir inflows during spring (OWL Newsletter Nov 2014). At the end of the 2014-2015 irrigation season, one of the ways identified to improve the water resource management was an objective quantification of the snow storage in the reservoir's catchment (OWL Water restrictions update #11 23 Mar. 2015).

This need for knowledge of snow storage is not unique to the Opuha Dam catchment. The former ECNZ identified a similar limitation following the 1992 electricity crisis which led to the development of a daily snow storage estimation system using climate station temperature and rainfall data. The system was applied to historic as well as current data, enabling the current estimate to be presented as a percentage of the long term average. This system is still in use today by Meridian Energy Ltd. and Contact Energy Ltd.

This proposal sets out to prepare a similar snow storage estimation system for the Opuha Dam catchment utilising improvements to the model and computing capability that have occurred since 1992.

1.1 Snow Storage Estimation System

An overview of the Snow Storage Estimation system is provided below.

- The Snow Storage Estimation System uses well-established relationships between:
  - temperature and elevation,
  - snowfall and sub-zero temperatures and
  - snowmelt and temperature.
- A map of the catchment is divided up into a 25 m x 25 m grid.
- Daily temperature measurements are used to estimate the daily temperature at all grid locations in the catchment. This is done by assuming a standard change in temperature with elevation.
- Daily rainfall measurements are used to estimate the daily precipitation at all grid locations in the catchment. This is done by assuming the precipitation falls in a pattern related to the long term average annual rainfall pattern (as derived by the NZ Meteorological Service).
- Precipitation is deemed to fall as snow everywhere that the temperature is less than a threshold temperature (approximately 0^{o} C).
- Snow melt is deemed to occur wherever the temperature is greater than 0^{o} C, at a rate that is proportional to the temperature.
- For each grid location the system keeps track of the accumulated daily snow fall and snow melt to give a daily snow storage estimate. The sum of the snow storage for all grid locations within the catchment provides the total snow storage estimate. This value may be compared to that obtained for the same day for previous years to provide an estimate in terms of a percentage of the long term average.

The system is to be implemented in "R" (a free, open source language and computing environment used extensively throughout the world).

2 SCOPE OF WORK

The proposed work is broken into four components:

1. Preparation of historic snow storage estimates
2. Implementation of an automated operational snow storage estimation system
3. Provision of on-going maintenance of the operational system
4. Guidance for adaptation of rain gauges to function during snowfall conditions.

2.1 Preparation of historic snow storage estimates

The following information will be provided to OWL:

- A chart of the 30 year average daily snow storage with 5, 25, 75, 95 percentiles and the 2014 season's snow storage. An example of this is shown for the Ohau catchment for the April 2007 – Mar 2008 year in Figure 1
- A table of daily snow storage estimates for the last 30 years
- A bar chart of late October snow storage for the last 30 years
- A table of late October snow storage from the last 30 years ordered from lowest to highest.

Note that while Aqualinc document all processes, for efficiency of delivery and budget, a report will only be provided if specifically requested, on a time-and-expenses basis.

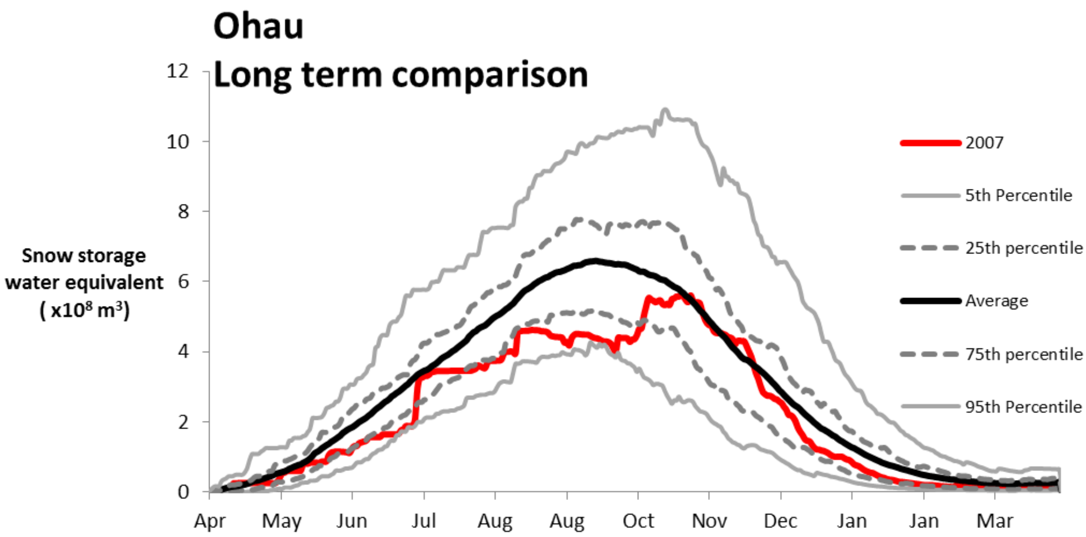

Figure 1. Example graph showing snow storage estimates in the context of the long term estimates

The methods used to obtain the above estimates are outlined as follows:

- Relevant precipitation and temperature data will be sourced from the NIWA climate database, ECAN and ECS.
- Through correlation of data from different sites a continuous (at least 30 years) rainfall and temperature record will be created for at least one of the currently operating automatic temperature measurement sites, and at least one of the automatic rainfall measurement sites (see Table 1).
- Elevation data and precipitation distribution data will be sourced for the catchment and the immediate surroundings.

- Snow storage estimates for each day for the last thirty years will be generated.

Table 1. Currently operating telemetered climate measurement sites

Site	Parameter	Agency
Opuha Dam	Rainfall	OWL/ECS
Dobson Skifield	Rainfall	OWL/ECS
Fox Peak Skifield	Rainfall	OWL/ECS
Clayton RAWS	Rainfall, temperature	Rural Fire Authority
Fairlie AWS	Rainfall, temperature	NIWA
Kimbell	Rainfall	ECAN
Mt Gerald	Rainfall	ECAN

2.2 Implementation of an automatic operation snow storage system

Aqualinc will set up a system to provide weekly updates to OWL of the daily snow storage estimates in a style (table/chart/summary etc.) to be determined by OWL.
The weekly estimates will be generated automatically using the following methods:

- Automatic download of daily rainfall and temperature data will be setup from NIWA, ECAN, Rural Fire Authority, and ECS as required.
- Procedures to automatically update catchment snow storage using the rainfall and temperature data will be implemented using the “R” program.
- Procedures to automatically generate the client specified output (tables, graphs etc) will be implemented in “R”.
- Procedures to automatically pass the snow storage estimate output to the client will be set up.
- Internal documentation will be generated of the process to ensure seamless operation at all times.

The above systems will be set up on a task scheduler on the computer facilities at Aqualinc

2.3 On-going maintenance

The automated system will be maintained to provide estimates at least once a week. On the occasion that unforeseen circumstances under Aqualinc’s control prevent estimates being provided, the system will be restored, or the estimates will be manually provided within a week. This does not include maintenance of any in-situ measurement equipment. If over the course of the year, the maintenance has used less than a week of time, the left over time will be applied to developing improvements to the system. In this manner, Aqualinc is motivated to keep the system as trouble-free as possible, and the system will incorporate technological and scientific advances as they arise.

2.4 Adaptation of rain gauges to operate correctly during snowfall

Advice will be given to enable the OWL high elevation rain gauges to continue operation throughout winter.
It is understood that OWL has two rain gauges operating at high elevations which stop working during large snowfall events and freezing conditions or return false “melt”

readings on days after snow has stopped falling. This leads to a misleading record of rainfall during winter.
Through the use of a "precipitation adaptor" these rain gauges can measure rain and snow throughout the year. A precipitation adaptor, as available from Campbell Scientific (part number CS705) or fashioned from PVC tubing, may be used. A precipitation adaptor is a container of antifreeze that sits on top of the rain gauge. An overflow pipe runs from the antifreeze reservoir into the rain gauge. Any precipitation (rain or snow) that falls into the antifreeze reservoir results in the equivalent amount of antifreeze overflowing. The overflow is piped into the rain gauge, which records the amount. It is recommended that OWL use ECS to implement these changes for winter. Through previous experience with these systems, Aqualinc can provide advice on the installation of the adaptor.

3 PROGRAMME FOR SERVICE

3.1 Provision of snow storage estimates

Historic snow storage estimates can be provided within one month of placement of order.

Cost	$11200

3.2 Automation of snow storage estimates

Automation of snow storage estimates can be provided within one month of written acceptance of the historic snow storage estimates, or within one month of placement of order for automation, whichever is latest.

Cost	$11200

3.3 On-going maintenance

Maintenance of the automated snow storage system will start from the day that the automated system is accepted or from the placement of order for on-going maintenance, whichever is latest. This is to be re-negotiated each year at the anniversary of the order.

Cost	$7000 for the first year,

3.4 Rain gauge adaption to total precipitation

Advice on conversion of the existing rain gauges can be provided as required on a time–and-expense basis

Cost	$175/hr
Time estimate	less than 8 hours

4 PERSONNEL

The project will be undertaken by Tim Ker from Aqualinc Research Ltd.
Tim is a water scientist with 10 years of snow storage research experience.

Tim refined the ECNZ snow storage model as part of his Masters research, has published numerous papers about snow storage and mountain precipitation distribution and has developed several snow storage models for different clients and research projects.

A short curriculum vitae for Tim is attached as an appendix to this proposal.

Aqualinc has a track record with OWL through previous contracts and so has an appreciation of the catchment and operational requirements of the Opuha Dam. Aqualinc staff such as Andrew Dark, Peter Brown and Ian McIndoe will be involved in-house for project review.

5 TERMS AND CONDITIONS OF ENGAGEMENT

It is proposed that the terms of engagement be as per the IPENZ/ACENZ *"Short Form Agreement for Consultant Engagement"*. A copy of this document can be made available for viewing upon request.

Aqualinc Research Ltd would enter into a formal agreement with Opuha Water Limited upon acceptance of our proposal.

We thank you for the opportunity to offer the services of Aqualinc Research Ltd. We would look forward to this opportunity of working together with Opuha Water Ltd. staff on this project.

Appendix A: Curriculum vitae

Curriculum Vitae Tim Kerr

Present position

Present employer

Aqualinc Research Ltd.

Present work address

PO Box 20 462, Bishopdale, Christchurch

Specialist Skills

- Surface water hydrology
- Snow and rainfall measurement
- Computer programming
- “bigdata” analysis

Academic qualifications

2009 **Ph.D.** Geography, University of Canterbury, Christchurch, New Zealand **“Precipitation distribution in the Lake Pukaki Catchment, New Zealand”**

2005 **M.Sc.** Geography, University of Canterbury, Christchurch, New Zealand. **“Snow storage modelling in the Lake Pukaki Catchment, New Zealand: An investigation of enhancements to the SnowSim Model”**

1991 **B.Sc. Computer Science,** Massey University, Palmerston North, New Zealand

Years as a practising researcher

10

Society memberships

- New Zealand Hydrological Society
- American Meteorological Society
- Snow and Ice Research Group (NZ)
- International Glaciological Society

Professional positions held

2015- **Water scientist**, Aqualinc Research Ltd.
2013-2014 **Hydro meteorologist, atmospheric modeller and team leader**, Centre of advanced studies in arid zones (CEAZA), La Serena, Chile.
2010-2013 **Post-Doctoral fellow**, investigating alpine precipitation. Funded by the Ministry of Business, Innovation and Employment, hosted at NIWA, Christchurch.
2009-2010 **Hydrologist**, NIWA, Christchurch.
2002-2010 **Mountain Guide**, Alpine Recreation Canterbury, Tekapo.
2005 **Hydrologist**, Meridian Energy Limited, Twizel.
2001-2002 **Science Technician**, Antarctica New Zealand, Scott Base, Antarctica.
1998-2001 **Electronics Engineer**, Hamilton Jet, Christchurch

Professional experience

Experience Summary

Tim undertook a detailed review and improvement of the ECNZ "SnowSim" snow storage estimation system as part of his Masters research. This knowledge, coupled with his in-depth precipitation distribution research (from his Ph.D. and post-doctoral research) enabled him to help improve the snow modelling components of the NIWA TopNet hydrological model. Application of this model provided insight into the importance of snowmelt to catchments in New Zealand which resulted in his peer reviewed publication of estimates of snowmelt contribution to the rivers of the South Island New Zealand (see publications list below).

Number of refereed publications

9

List of major achievements

Some relevant recent publications, reports and presentations

Webster, C., Kingston, D., Kerr, T., 2015: Inter-annual variation in the physiographic controls on catchment-scale snow distribution in a maritime alpine catchment. *Hydrological Processes*, 29(6):1096-1109.

Kerr, T. 2013: The contribution of snowmelt to the rivers of the South Island, New Zealand. *Journal of Hydrology (NZ),* 52(2):61-82.

Kerr, T.; Clark, M.; Hendrikx, J., Anderson, B. 2013: Snow distribution in a steep mid-latitude alpine catchment. *Advances in Water Resources* 55: 17-24.

Clark, M.P.; Hendrikx, J.; Slater, A.G.; Kavetski, D.; Anderson, B.; Cullen, N.J.; Kerr, T.; Hreinsson, E.Ö.; Woods, R.A. 2011: Representing spatial variability of snow water quivalent in hydrologic and land-surface models: A review. *Water Resources Research 47(W07539)*: 23.

Kerr, T., Owens, I., Henderson, R., 2011 The precipitation distribution in the Lake Pukaki Catchment, New Zealand. *Journal of Hydrology (NZ)*, 50(2): 361-382