

GROUNDWATER LEVEL FORECASTING PILOT PROJECT: PHASE 2

June 2025



Prepared for:

**Ministry of Water, Land and Resource
Stewardship**

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Appendix A2	Model User Manual
Appendix A3	Model Performance Statistics
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AMENDMENT RECORD

This report has been issued and amended as follows:

Issue	Description	Date	Approved by	
1	First version of Groundwater Level Forecasting Report Phase2 (Draft)	20250326	Jos Beckers Project Director	Jacob Nunn Project Manager
2	Second version of Groundwater Level Forecasting Report Phase2 (Final)	20250626	 Jos Beckers Project Director	 Jacob Nunn Project Manager

1.0 INTRODUCTION

This report prepared by Hatfield Consultants (Hatfield) for the Water Management Branch of the British Columbia (B.C.) Ministry of Water, Land and Resource Stewardship (WLRS), summarizes the outcomes of Phase 2 of a pilot project aimed at developing and testing statistical and machine learning models to forecast seasonal groundwater levels for observation wells in different parts of the province using hydroclimatic predictor variables. The WLRS goal is for these groundwater level forecasts to subsequently be used to understand the potential for aquifer drought conditions to develop. Currently, WLRS uses real-time daily groundwater level data from select Provincial Groundwater Observation Wells Network (PGOWN) wells and compares these data to historical groundwater level percentile ranges to assess aquifer conditions during the spring-summer core drought season. This comparison aids in shaping drought response strategies. The introduction of early season (e.g., April-June) indicators for potential groundwater drought conditions to occur in summer could offer WLRS an additional early warning system, as used elsewhere in North America (e.g., Dudley et al. 2017). Phase 1 of the project (Hatfield 2024) focused on developing and testing the methodology for a select number of PGOWN wells. Phase 2 refined the forecast methodology based on recommendations from the Phase 1 work and expanded its application and testing to most of the provincial groundwater monitoring network.

1.1 SUMMARY OF PHASE 1

Prior work by Gullacher et al. (2023) pinpointed specific combinations of hydroclimatic variables that could act as early warning indicators for groundwater drought in B.C.'s Lower Mainland and South-Central regions. Phase 1 built upon this prior research by developing models that leverage the identified hydroclimatic variables to forecast groundwater levels and was able to forecast groundwater levels 90 days in advance of current conditions. The project included the development and testing of several different statistical and machine learning modelling approaches to forecast groundwater levels using hydroclimatic predictor variables on a year-round (continuous) basis. Models considered included Generalized Additive Models (GAM), Generalized Linear Models (GLM) and Random Forest (RF). The project spanned 21 PGOWN wells across a diversity of hydroclimatic conditions including rainfall and snowmelt aquifer recharge settings and utilized the statistical and machine learning approaches to forecast potential groundwater conditions.

In snowmelt dominated aquifer recharge settings, key hydroclimatic forecast variables included historic groundwater levels, temperature, precipitation, snow water equivalent (SWE) and snowmelt rate (the change in SWE over a defined period). It was identified that important variable interactions need to be accounted for, including the relationship between temperature, SWE, and snowmelt (e.g., above-average temperatures can lead to higher snowmelt rates, which will have a greater effect on aquifer recharge if there is a large snowpack). Precipitation and temperature also interact, at lower temperatures precipitation falls as snow (impacting future conditions but having no immediate effect on groundwater levels), while at higher temperatures, precipitation falls as rain, impacting groundwater levels more immediately. In rainfall recharge dominated systems the key climate variables used were precipitation and temperature without any need for consideration of interaction terms.

Two approaches were trialed to generate groundwater level forecasts. The first approach only uses data on antecedent conditions (known existing and prior conditions at the time forecasts are made). The use of

prior hydroclimatic data on antecedent conditions accounted for aquifer recharge lag time (i.e. the time between a precipitation or snowmelt event and corresponding groundwater level response). Generally, models using only data on antecedent conditions were found to perform adequately for shorter term prediction intervals (i.e., 14 and 30 days) but struggled predicting further ahead (60 or 90 days). The second approach used seasonal (forward looking) predictor variables in addition to the data on antecedent conditions. In all cases, the forecast model performance was found to improve when using hydroclimatic data for the forecast periods, with larger improvements predicting further ahead (i.e., improvements are greatest for the 60 and 90 days forecast windows). The use of forecast variables was therefore carried forward.

The operational forecast tools developed in Phase 1 allowed for the determination of the percent likelihood of predicted groundwater levels to be above normal, normal or below-normal using results from Monte Carlo simulations, that consider historical hydroclimatic variability over the forecast period. While the groundwater level forecast models were demonstrated to work well, the Phase 1 operational forecast conceptualization inherently treated hydroclimatic conditions over the forecast period as uncertain. The modelling results emphasized that using reliable short to medium- term climate forecasts is key to creating reliable groundwater level forecasts, and this was recommended as a major emphasis point of the Phase 2 work.

1.2 SCOPE OF PHASE 2

Phase 2 of the study considered 238 wells across BC. The scope of Phase 2 project as requested by WLRS was to:

- Narrow down the number of PGOWN wells (i.e., 238) as needed should any prove to be unsuitable for analysis.
- Determine optimal hydroclimatic stations (climate stations, automated snow weather stations, and, if necessary, hydrometric stations) to represent local conditions corresponding to each PGOWN well.
- Refine the existing groundwater level forecast models to improve model performance and for the inclusion of more wells across BC. Defined tasks were to include:
 - Integration of short-term precipitation and temperature forecast data to reduce uncertainty in the groundwater level forecasts.
 - Include the simulation of groundwater level changes (as opposed to simulation of actual groundwater levels) to allow for inclusion of wells with trending water levels and irregular patterns.
 - Further examination of covariance (interaction terms) between hydroclimate variables in snowmelt-dominated aquifer recharge settings.
 - Consideration of net rainfall (precipitation minus evapotranspiration) as an alternative input to precipitation as a possible better predictor of aquifer recharge.
- Provide reporting for forecast uncertainty and ongoing model performance statistics.

In addition to these tasks identified from the Phase 1 project recommendations, the following work was also conducted during Phase 2:

- The incorporation of an Artificial Neural Network (ANN) approach to groundwater simulation was found to improve model performance compared to RF.
- The inclusion of a dynamic weighting approach to using hydroclimatic input variables within the aquifer recharge lag period was found to improve model performance compared to the previously used uniform weighting within the recharge lag period.
- The additional number of wells has led to an increased understanding of the effects on model performance and has identified several model performance indicators to be used when incorporating new wells.

Conversely, the examination of covariance between hydroclimate variables in snowmelt-dominated aquifer recharge settings did not lead to further model refinements and the interactions as determined in Phase 1 remain unchanged for Phase 2.

1.3 REPORT ORGANIZATION

This report is organized as follows:

- Section 2.0 describes the observation well selection and describes the hydroclimatic and aquifer setting for the selected wells.
- Section 3.0 discusses the R script-based model development and model implementation to generate groundwater level forecasts.
- Section 4.0 summarizes the results of the model performance testing (model validation)
- Section 5.0 summarizes the results of the model operational testing.
- Section 6.0 outlines operational forecast model implementation, i.e., how the developed models are used to for groundwater level predictions.
- Section 7.0 summarizes the work conducted and provides recommendations for further work.

2.0 OBSERVATION WELL SELECTION AND SETTING

2.1 WELL SELECTION

WLRS supplied a list of 238 PGOWN wells from across British Columbia. This list was evaluated, and several wells were omitted from the study based on the following criteria:

- Length of data record: wells with less than three years of data were excluded as they do not contain enough data to determine statistical relationships for forecasting purposes.
- Wells with notable pumping effects.
- Wells under tidal influence.

Of the 238 wells, 203 were included in the Phase 2 project while 35 wells were excluded during pre-screening due to above factors. The full list of wells and excluded wells can be found in Appendix A1 as well as wells recommended for groundwater level forecasting.

Following completion of model testing (Section 4.0), additional PGOWN wells were excluded based on poor model performance. Wells that were excluded and not recommended for groundwater level forecasting, as well as those that were recommended to be included in the forecasting, are shown in Figure 1. New PGOWN wells with currently too short a data record for forecasting can be considered for inclusion in the future when a longer data record is available.

Available groundwater level data for each well was used starting in 2004, which aligns with the commencement of consistent, continuous data collection at daily intervals using pressure transducers in the PGOWN network. Prior to 2004, data was often manually collected at larger time intervals. Therefore, data from before 2004 is not used, like the approach taken in Phase 1.

2.2 HYDROGEOLOGICAL SETTING

The province's diverse hydro climatology, small and responsive aquifers, and the intricate interactions between groundwater and surface water result in complex groundwater level responses that show distinct variations between and within hydroclimatic and aquifer settings. These complexities present challenges when trying to understand and predict the potential for groundwater drought conditions to occur. The included well list in Phase 2 encompasses a variety of well types and hydrogeological settings, including unconfined sedimentary aquifers, confined aquifers, and bedrock aquifers, among others. The Phase 2 study therefore captures a broad spectrum of hydrogeological conditions across British Columbia.

2.3 HYDROCLIMATIC SETTINGS

Coastal Regions

In regions such as Vancouver Island and the South Coast, climatic conditions are characterized by precipitation that predominantly occurs as rainfall at lower elevations. The driest months are typically the summer months of July to September, while the wetter months occur from October to January. This rainfall-dominated climate influences the groundwater recharge and seasonal water level fluctuations in the wells located in these areas.

Recent research by Nott et al. (2024) identified two clusters of groundwater trends within the Fraser Valley:

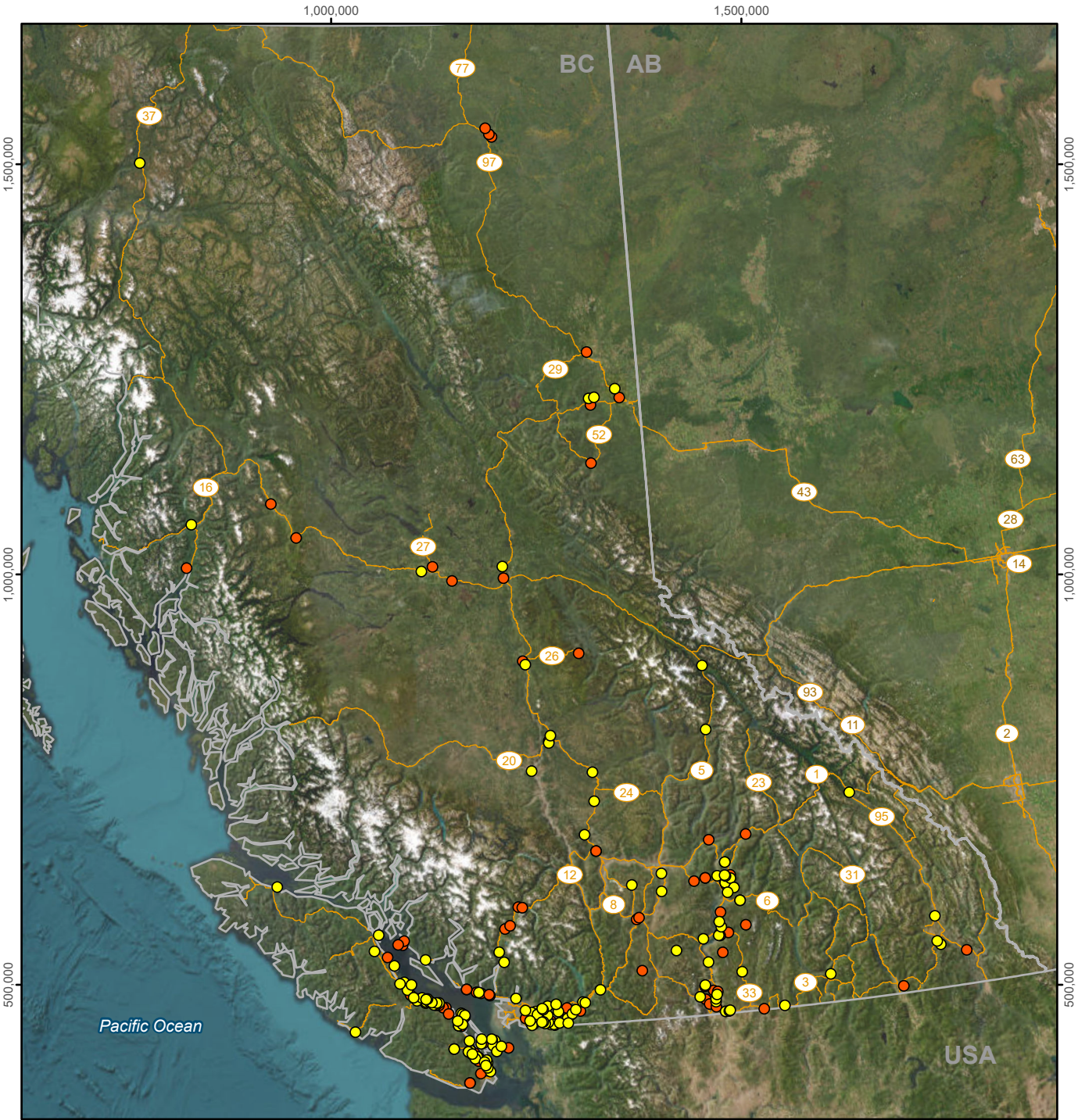
- Cluster 1: Wells in this cluster respond to recharge from local precipitation, primarily rainfall, and react rapidly to both atmospheric rivers during winter recharge and significant rainfall deficits during summer.
- Cluster 2: Wells in this cluster are also driven by precipitation but are additionally influenced by the Fraser River's large summer freshet, which briefly provides a secondary recharge mechanism. Groundwater recessions are offset to later in the summer, contingent on the Fraser River, mediating drought.

While the Phase 1 study only included Cluster 1 type wells based on Gullacher et al. (2023), Cluster 2 wells are additionally considered in Phase 2. These wells are snow-influenced based on their interaction with the Fraser River. Additionally, several other coastal region wells are located adjacent to stream systems whose headwaters are within mountainous regions such as Whistler, Pemberton, and Squamish, as well as some parts of Vancouver Island.

Interior and Northern Regions

The interior and northern regions of BC are marked by snow accumulation during the winter months (November to April), particularly in higher altitude areas, followed by a snowmelt period from April to July. This results in a pronounced freshet signature in the different region's streamflow, which significantly impacts groundwater recharge and seasonal water level variations in the wells. However, these regions also encompass diverse hydroclimatology due to the large area and widespread placement of the wells utilized. This leads to regional variations in climate and precipitation trends. For example, in areas like the Okanagan and South East regions, the driest months typically fall between August and September, while the wetter periods occur from October to January, with a second wetter phase around May. Conversely, the North Coast is characterized by long, mild winters with plenty of rain and snowfall, and cool summers. The Cariboo region is known to have many microclimates but is usually warm and dry in the summer. These complexities and variations in hydroclimatology within the Interior and Northern Regions are addressed by the climate station identification component of the Phase 2 project (Section 3.4).

Figure 1 PGOWN wells considered for groundwater level forecasting.



Legend

- Road
- Provincial Boundary

Well Locations

- Recommended for forecasting
- Not recommended for forecasting

Data Sources:
a) Well locations, BC Government 2025.
b) Roads, CanVec 2021.
c) Provincial boundary, unknown.
d) Background, 30 cm - 50 cm imagery, 2012 - 2024, Esri Online Service.

0 50 100 200 km
Main Map Scale: 1:7,200,000
Projection:
NAD 1983 BC Environment Albers



Groundwater Drought Forecasting

K:\Data\Project\MWLR12378A_MXD\Well_Locations\MWLR12378_Well_Locations_20250526_v01_AH.aprx

MWLR12378_Well_Locations_20250526_v01a_AH

3.0 MODEL DEVELOPMENT AND IMPLEMENTATION

3.1 APPROACH

In Phase 1, statistical and machine learning modeling approaches were developed leveraging hydroclimatic data (predictor variables) to generate groundwater level forecasts for 14 days, 30 days, 60 days, and 90 days in advance. The models can be run at any given time during the year, provided that the latest predictor variables are available. This year-round groundwater level forecasting capability is based on models that establish relationships (correlations) between observed groundwater levels and hydroclimatic predictor variables for the period 2004 to 2024. The implementation of these groundwater level forecasts is carried out using R-based scripts. The overall approach is retained for Phase 2 with refinements as outlined in the sections below.

3.2 MODEL SELECTION

Three different modeling approaches were used in Phase 1 to develop relationships between observed groundwater levels and hydroclimatic predictor variables: GAM, GLM, and RF. GAMs were used in previous work (Gullacher et al. 2023) to identify correlations between groundwater levels and hydroclimatic predictor variables. In the Phase 1 study, a simpler GLM approach was also included, as well as a machine learning (RF) model as a more complex approach relative to GAMs. Phase 2 considers ANN as a fourth modelling approach.

Generalized Additive Model (GAM)

GAMs accommodate non-linear relationships between predictors and the response variable. They achieve this by substituting the assumed linear relationship of groundwater levels and predictor variables in GLMs (discussed below) with a combination of smooth functions that describe these relationships. GAMs can therefore be used to model potential non-linear relationships between groundwater levels and hydroclimatic variables, using the smooth functions to minimize the difference between predicted and actual groundwater levels. GAMs further allow for interaction terms, which means the response of one predictor variable can depend on the value of another. This feature is particularly useful in systems dominated by snowmelt, where the type of precipitation (rainfall or snow accumulation) depends on temperature. Moreover, snowmelt itself depends on both temperature and the availability of snow, or SWE. GAMs were fitted utilizing the “gam” function from the mgcv R Package (Wood 2011; 2017). Through trial-and-error it was observed that GAMs typically overfit results in a snowmelt setting without some restriction to the degrees of freedom allowed. Restricting the GAMs degrees of freedom to 5 typically resulted in the best results. In a GAM, degrees of freedom dictate the number of “knots” in smoothing splines, which are points where piecewise polynomial functions meet, dividing the predictor variable's range into regions. The number of knots influences the model's flexibility and overfitting risk, with more knots increasing complexity and potential overfitting, and fewer knots yielding a simpler, potentially underfit model.

Generalized Linear Model (GLM)

GLMs are based on the premise that relationships between groundwater level changes and hydroclimatic variables follow a linear trend and are therefore simpler than GAMs. These models work by estimating coefficients that minimize the difference between predicted and actual groundwater levels. As a flexible

extension of ordinary linear regression, GLMs can handle response variables that follow error distribution models other than a normal distribution. Like GAMs, GLMs also allow for the inclusion of interaction terms. GLMs were fitted with the `glm()` function which is part of the base R stats package (R Core Team 2020), and it is used for fitting generalized linear models.

Random Forests (RF)

RFs are an ensemble learning method that constructs multiple decision trees during the training phase. Each tree is trained on a random subset of the data and features. Each decision tree in the forest independently learns from its subset of data, and the final prediction is determined by aggregating the predictions of all trees (e.g., majority voting for classification). The output is either the mode of the classes (for classification) or the mean prediction (for regression) of the individual trees. RFs are particularly adept at handling complex datasets as they can model non-linear relationships and interactions between variables. While they do not permit manual input of variable interactions, they have the capability to self-determine these interactions. However, a potential drawback of this approach, as well as other machine learning methods, is that it doesn't provide insight into the interactions and relationships it determines. The RF models were fitted using the “randomForest” function from the randomForest R Package (Breiman 2001, Liaw and Weiner 2002).

Artificial Neural Networks (ANN)

ANNs are a different class of machine learning models from RF inspired by the structure and function of the human brain. They consist of interconnected nodes (neurons) organized in layers: an input layer, one or more hidden layers, and an output layer. Each connection between neurons has an associated weight that is adjusted during the training phase to minimize the error in predictions. ANNs are particularly powerful for capturing complex patterns and non-linear relationships in data.

The `nnet` package in R provides tools for fitting ANNs. The `nnet` function allows users to specify the number of neurons in the hidden layer(s), the learning rate, and other parameters to customize the model. While ANNs can be highly effective for both classification and regression tasks, they require careful tuning of hyperparameters and can be computationally intensive. Additionally, the “black box” nature of ANNs means that they do not easily provide insights into the relationships and interactions they model.

The ANN models were fitted using the `nnet` function from the `nnet` R package (Venables and Ripley 2002, 2025). This function facilitates the training of feed-forward neural networks and supports various options for model customization and optimization. The added complexity of tuning hyperparameters needed to be incorporated through a hyperparameter calibration step, in which hyperparameters were fitted to a grid of possible values (Section 3.6.3). This grid included variations in the number of neurons (size), learning rate (decay), and maximum iterations (`maxit`).

One of the outcomes of including the ANN approach was the scale dependence attribute of ANN models. Unlike GLM, GAM, and RF models, which are not scale-dependent and do not require normalization for variable inputs and predictions, ANN models necessitate an extra step of normalization to ensure accurate representation.

3.3 PREDICTOR VARIABLE SELECTION

Given the hydroclimatic diversity of BC, it's crucial to include specific hydroclimatic variables in the groundwater level forecast models depending on the observation well setting and dominant source of recharge water (i.e., rainfall or snowmelt). Gullacher et al. (2023) identified potential predictor variables for Fraser Valley summertime groundwater levels as temperature, precipitation (dominantly rainfall), and streamflow, while for the South Central region of BC, temperature, SWE, and ENSO 3.4 were identified as predictor variables for summertime groundwater levels.

3.3.1 Adopted Predictor Variables

Adopted predictor variables remain unchanged from Phase 1 but are described below. Relative to the Gullacher et al. (2023) findings, exploratory model testing excluded several predictor variables as discussed in Section 3.3.2. Two different forecast models were developed in Phase 1 based on inferred dominant source of aquifer recharge:

1. In rainfall recharge dominated systems, the key climate variables used are:
 - a. Precipitation: Groundwater is recharged by rainfall infiltration into the subsurface. Where an aquifer is additionally recharged by connection to local streams, that runoff is also generated by local precipitation (i.e., is already captured in using precipitation as a predictor variable).
 - b. Temperature: Affects evapotranspiration, impacting antecedent soil moisture conditions and thereby groundwater recharge. Additionally, while the emphasis of forecasting models is on precipitation, temperature may also impact groundwater usage and thereby the magnitude of seasonal groundwater level fluctuations, as many observations wells are installed in developed aquifers.
2. In snowfall dominated systems, the key climate variables used are:
 - c. Precipitation: Groundwater is recharged by both rainfall and snowmelt infiltration into the subsurface (i.e., groundwater levels are expected to be correlated with total precipitation). Where an aquifer is additionally recharged by connection to local streams, that runoff is also generated by local rainfall and snowmelt (i.e., is already captured in using total precipitation as a predictor variable).
 - d. Temperature: In addition to the considerations provided for rainfall dominated settings, temperature also impacts whether precipitation falls as rain or snow (i.e., rain-snow temperature thresholds), and during the melt season temperature affects snowmelt rates. It's likely that temperature may also impact groundwater usage, which in turn could affect groundwater levels. Therefore, the controlling influence of temperature is more complex than in rainfall dominated settings and may vary seasonally.
 - e. SWE: Provides a measure of the amount of snow (remaining) available for melting.
 - f. Snowmelt: This is calculated as the change in SWE over a defined period of time (explained further in Section 3.3.3).

The work by Gullacher et al. (2023) focused on correlation between springtime hydroclimatic predictor variables and summertime groundwater levels. However, seasonal groundwater level forecasts are also highly influenced by antecedent aquifer conditions (e.g., if springtime groundwater levels in the aquifer are below normal, summertime groundwater levels will likely also be below normal unless offset by above-average recharge during the summer). Existing groundwater levels were therefore identified as the most critical predictor variable to forecast future conditions.

A summary of predictor variables used for rainfall and snowmelt dominated recharge settings is provided in Table 1.

Table 1 **Predictor variables utilized in models.**

Predictor Variable	Used in Rainfall Setting	Use in Snowmelt Setting	Used for Antecedent Conditions	Used as Seasonal Predictor Variable
Precipitation	Yes	Yes	Yes	Yes
Temperature	Yes	Yes	Yes	Yes
SWE	No	Yes	Yes	No
Snowmelt	No	Yes	Yes	Yes
Groundwater Levels	Yes	Yes	Yes	No

3.3.2 Exploratory Testing of Predictor Variables

Streamflow

In Phase 1, streamflow was initially considered as an additional predictor variable based on findings by Gullacher et al. (2023) for the Fraser Valley and the inference that many aquifers considered are connected to streams (Section 2.0). However, the inclusion of streamflow did not materially improve model performance during model validation. It was inferred that this could potentially be due to cross-correlation, as the hydroclimatic variables that affect streamflow also affect groundwater level variations. Furthermore, in a forecast context, when future streamflow conditions are unknown, adding streamflow as a predictor variable was found to add considerable uncertainty to the forecast models, particularly in snowmelt-dominated settings (i.e., freshet streamflow conditions are inherently highly variable). In addition, utilizing streamflow would require additional model conceptualizations and assumptions (i.e., increase model complexity). Therefore, streamflow was not included in Phase 1 or Phase 2.

Nino 3.4 and Canada Seasonal Forecasts

Including the Nino 3.4 index as a predictor variable for ENSO conditions was also considered in Phase 1. Nino 3.4 forecasts and observed Nino 3.4 are readily available, but due to its correlation with temperature, it was not included in Phase 1 or Phase 2. Utilization of Canada Seasonal Climate Forecasts was contemplated in Phase 2 but ultimately not included based on limited skill of the forecast system as

discussed on the ECCC website¹. The short-term forecasts provided by the River Forecast Center (RFC) are used instead (Section 6.0).

Water Surplus

In Phase 2, water surplus was explored as a predictor variable instead of precipitation, which was used in Phase 1. This involved calculating Potential Evapotranspiration (PET) from station temperature data with the Penman-Monteith equation. Water surplus was calculated at a daily time step as:

$$\text{Water surplus} = \text{Precipitation} - \text{PET}$$

It was found that using water surplus instead of precipitation provided limited improvement or a decrease in model performance and therefore was excluded from consideration moving forward in Phase 2.

3.3.3 Correlation/Interaction between Variables

Interactions between predictor variables occur when the effect of one independent variable on the dependent variable (i.e., groundwater levels) depends on the value of another independent variable. In other words, the two independent variables interact to affect the dependent variable. Interaction terms in a GAM or GLM model include the combined effect of two or more independent variables on the dependent variable. Defining interaction terms in the GAM or GLM triggers the models to estimate the degree of interaction between predictor variables and their corresponding effect on the response variable, thus capturing complex relationships between variables. Variations in interaction terms were trialed in Phase 1, with the proposed interactions (detailed below) providing the best results.

For the snowmelt-dominated recharge setting, the following two interaction terms were defined for the GLM and GAM models:

- **Precipitation and Temperature:** This interaction tells the model that the type of precipitation (rain or snow) is dependent on temperature, changing the effect of precipitation on groundwater levels based on temperature conditions. Under higher temperatures, precipitation falls as rain, causing a more immediate effect on groundwater levels. Under lower temperatures, precipitation falls as snow, which does not immediately impact groundwater levels within the recharge lag period.
- **Snowmelt, Temperature, and SWE:** This interaction term changes the effect of snowmelt on groundwater levels based on both temperature and SWE (available snowpack for melt). Through trial and error, it was discovered that without considering SWE, the model could not accurately predict the effects of snowmelt on groundwater levels. For instance, the same amount of melt from a large snowpack in early summer has a different effect on groundwater levels than from a smaller snowpack in late summer. Removing temperature from the interaction terms led to deteriorating model performance, especially for longer forecast periods (60 and 90 days). Temperature acts as a proxy to help the model understand when peak melting might occur during the forecast window.

¹ https://weather.gc.ca/saisons/index_e.html

The above interaction terms were built into the GAM and GLM models, with the adopted interactions providing the best forecasting results. Treating these predictor variables as independent did not allow GAM and GLM models to work well in snowmelt-dominated settings. Other interaction term combinations were trialed but led to poorer model performance.

Machine learning approaches automatically identify interactions between predictor variables without user intervention. The above interaction terms remain unchanged for Phase 2. Limited additional testing was performed in Phase 2 but given that the GAM and GLM model performance (with manually defined interactions) is comparable to the machine learning approaches, it was inferred that the interactions as determined through trial and error must be reasonable.

For rainfall environments there are no interaction terms, thus assuming that temperature and rainfall cause independent effects on groundwater levels.

3.4 FORECASTING GROUNDWATER LEVELS VERSUS GROUNDWATER LEVEL CHANGE

Phase 1 and Phase 2 model testing considered whether forecasting performance differed when using either groundwater levels or groundwater level change as the dependent variable.

Generally, during Phase 2 testing it was found that model performance when forecasting groundwater level change is slightly better when evaluating GLM and GAM models and significantly better when utilizing machine learning approaches. This represents a major change from Phase 1, where groundwater levels were forecasted. The smaller dataset considered in Phase 1 only had PGOWN wells with stable groundwater levels, but with a larger Phase 2 dataset that includes both long-term stable and fluctuating or trending groundwater levels, forecasting groundwater level change appears to offer improvements over the Phase 1 approach.

Forecasting groundwater level change is therefore carried forward in Phase 2 and the analyses used in Sections 4.0 and 5.0 are based on groundwater level change forecasts.

3.5 CLIMATE STATION IDENTIFICATION

Climate and SWE (Snow Water Equivalent) stations were selected to leverage real-time data with robust historical datasets, ensuring they accurately represent the local climatic conditions of the PGOWN wells chosen for the study. During Phase 1 this was done manually given the limited number of PGOWN wells considered but the process was largely automated for Phase 2, as outlined below.

3.5.1 Snow Station Approach

All snow stations within a 500 km radius of each PGOWN well were evaluated to ensure comprehensive coverage and accurate representation of snow conditions. Each PGOWN well was analyzed using Cross-Correlation Function (CCF) analysis to identify the strongest correlation of groundwater levels with a current SWE station within the 500 km radius. This method helped in selecting the most relevant snow stations. On a limited number of occasions, additional manual checking and testing was necessary to ensure that the model results were logical and accurate. This involved verifying the selected stations and making manual adjustments if needed.

3.5.2 Climate Station Approach

Climate stations were selected based on their proximity to the PGOWN wells and their activity status. The primary criterion was to choose stations that are active and cover the most significant portion of the data record without substantial missing data. This ensures that the dataset is as complete and reliable as possible. In cases where data gaps existed, missing data was infilled using information from nearby stations. This infilling process was based on the proximity and similarity of climatic conditions between the stations.

3.6 MODEL PARAMETERS

Three main model parameters need to be included into the models. A factor influencing model performance is how predictor or input variables are integrated and tailored to reflect the unique aquifer and watershed dynamics of each of the wells. This includes accounting for how quickly or slowly an aquifer responds to recharge events, which involves considerations such as Recharge Lag and the Dynamic Weighting Coefficient (discussed below).

Additionally, when using artificial neural networks, hyperparameters must be carefully calibrated. This process is discussed in more detail below.

3.6.1 Recharge Lag

Recharge lag was found to be an important factor in developing the forecast models as it determines how fast groundwater levels respond to hydroclimatic forcings (i.e., changes in predictor variables). In Phase 1, these inferred recharge lags were used to determine the amount of prior data on antecedent conditions which needed to be included in the model for each well. The theory is that including prior data for a significant period less than the recharge lag could result in missing important hydroclimatic conditions that could still impact recorded groundwater levels whereas if the period of prior data used is too long, it may not be relevant to the groundwater levels.

The approach to determine the recharge lag remains unchanged from Phase 1. A CCF evaluation was used in calculating recharge lag; this is the same tool as utilized by Gullacher et al. (2021). This was performed using daily time series data, comparing groundwater levels to a 30-day running average of precipitation in a rainfall-dominated environment and to daily snowmelt (change in SWE from the previous day) in a snowfall-dominated environment. The 30-day running average for rainfall is used because rainfall tends to be sporadic (episodic), with the averaging creating a more consistent (smoothed) signal to compare groundwater levels to, whereas snowmelt tends to happen over prolonged periods, thus not requiring the smoothing approach. The CCF evaluation helped determine the appropriate amount of prior data to be used in the forecast models, based on the observed delay in groundwater level response (i.e., the recharge lag) due to a recharge pulse (i.e., rainfall or snowmelt). For wells that had a lag time of less than 7 days, a minimum lag time of 7 days was applied.

3.6.2 Dynamic Weighting Coefficient

In Phase 1, the included hydroclimatic data was equally weighted within the recharge lag period. In Phase 2, a dynamic weighting approach was introduced to better account for the recharge lag period. Dynamic

weighting is a technique used to assign varying levels of importance to different data points based on their temporal proximity to the event being predicted. In the context of groundwater level forecasting, dynamic weighting involves applying weights to temporal data points such that values are weighted highest when they temporally will have the most impact on predicted groundwater levels. This approach helps in capturing the temporal dynamics of the system more accurately.

The dynamic weights were centered over the recharge lag period, and the weight curves were found to be most effective when shaped like a normal distribution, with the standard deviation approximated as the recharge lag multiplied by a specific coefficient. This coefficient varied for each well, reflecting the unique recharge characteristics of different environments.

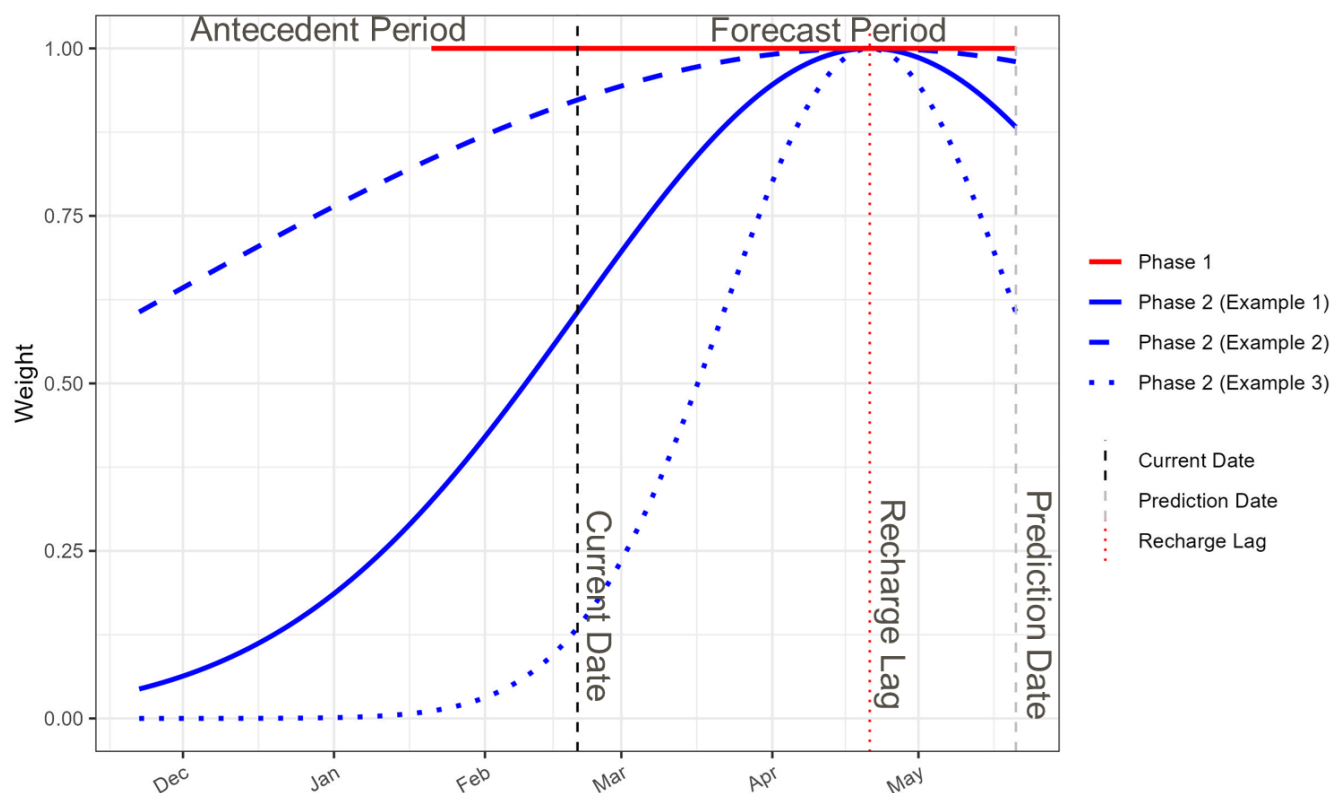
The dynamic weight coefficient was calculated by calibrating the various ANN, GAM, GLM and RF models with a 90-day forecast, iterating different dynamic weighting coefficients for each well. Only one forecast period was deemed necessary for calibration, given that the overall recharge dynamics of the well would be the same regardless of the forecast period (i.e., the same dynamic weight was subsequently applied to other forecast times). This calibration process involved evaluating the performance of the model using various dynamic weighting coefficients, specifically testing values of 0.5, 1, 2, 5, 10, and 100. The goal was to identify the coefficient that provided the best model performance, as measured by the accuracy of the groundwater level forecasts. It was observed that the dynamic weights become relatively uniform by the time coefficients of 10 and 100 are reached, making the results less sensitive to changes in these higher values. Conversely, the model showed high sensitivity at the lower end of the coefficient range.

The calibration process was conducted as follows:

- **Model Setup:** The model was set up to include the dynamic weights as part of the predictor variables. The recharge lag for each well was determined based on historical data and cross-correlation analysis.
- **Iteration of Coefficients:** For each well, the model was run multiple times, each time using a different dynamic weighting coefficient from the set of values (0.5, 1, 2, 5, 10, 100). This involved adjusting the standard deviation of the normal distribution used to shape the dynamic weights.
- **Model Evaluation:** The performance of the model was evaluated for each coefficient value. This was done by comparing the predicted groundwater levels to the observed levels over the 90-day forecast period and using R^2 values as the performance criterion for the four models (ANN, GAM, GLM, and RF). For the ANN model, the added complexity of calibrating hyperparameters (Section 3.6.3) means that the dynamic weighting coefficient was first calibrated utilizing "typical" or initial hyperparameter values.
- **Selection of Optimal Coefficient:** The dynamic weighting coefficient that resulted in the highest R^2 was selected as the optimal coefficient for that well. This coefficient was then used in the final model to ensure the best possible forecast accuracy. A single coefficient was used for all four models (ANN, GAM, GLM, and RF) and across all forecast periods.

Figure 2 presents example dynamic weighting curves, illustrating how the shape of the curve varies with different coefficient values (Example 1 = 2, Example 2 = 5, and Example 3 = 1). These examples demonstrate the influence of the coefficient on the weighting of historical data. Specifically, a lower coefficient produces a steeper, narrower curve, placing greater emphasis on data points closer to the present. In contrast, a higher coefficient results in a broader, flatter curve, distributing weight more evenly across a wider range of past data. Antecedent data (data prior to the current date of prediction) was incorporated into the model and considered for up to three times the recharge lag. For the forecast period (from the date of prediction to the date we want to predict), all data was considered. Figure 2 also shows the singular weighting approach used in Phase 1 which extended over the complete forecast period and utilized antecedent conditions up to the recharge lag. By using this dynamic weighting approach, the models were able to more accurately capture the temporal dynamics of groundwater recharge and improve the overall forecast performance. This method allowed for a more tailored approach to each well, accounting for the unique recharge characteristics and improving the robustness of the groundwater level predictions.

Figure 2 Dynamic weighting approach example for 30 day recharge lag and different Dynamic Weighting Coefficients.



3.6.3 Artificial Neural Network Hyperparameters

As discussed in Section 3.2, ANN models rely on hyperparameters which are set before the learning process begins and control the learning process. The hyperparameters include neurons (size), learning rate (decay), and maximum iterations (maxit). The number of neurons determines the capacity of the network to learn complex patterns, the learning rate controls how much the model adjusts the weights with respect to the loss gradient, and the maximum iterations define the number of times the learning algorithm will work through the entire training dataset.

To calibrate ANN hyper parameters a k-fold cross-validation was employed. This technique involves partitioning the data into a number of subsets (k subsets). In this case, 5 subsets were chosen so that the model is minimally trained on 4 years of data and validated on 1 year, which corresponds to initial testing about the minimal data length needed. The average cross-validation error was calculated to evaluate the model's predictive accuracy. The hyperparameter grid was applied to the cross-validation function, allowing for systematic testing and selection of the optimal combination of hyperparameters. This approach was applied to the entire data record of each well for a 90-day forecast period.

The hyperparameter grid included variations in the number of neurons (size), learning rate (decay), and maximum iterations (maxit). The variations in the number of neurons explored ranged from 5, 10, 15, and 20. The learning rate was explored in the range of 0.001, 0.01, and 0.1, and the maximum iterations ranged from 100, 200, and 500. The process involved increasing the values of the hyperparameters until there was no longer improvement in the model's performance across most of the models. This iterative approach ensured that the optimal combination was chosen. Overall, it was found that the ANN hyperparameters were not overly sensitive.

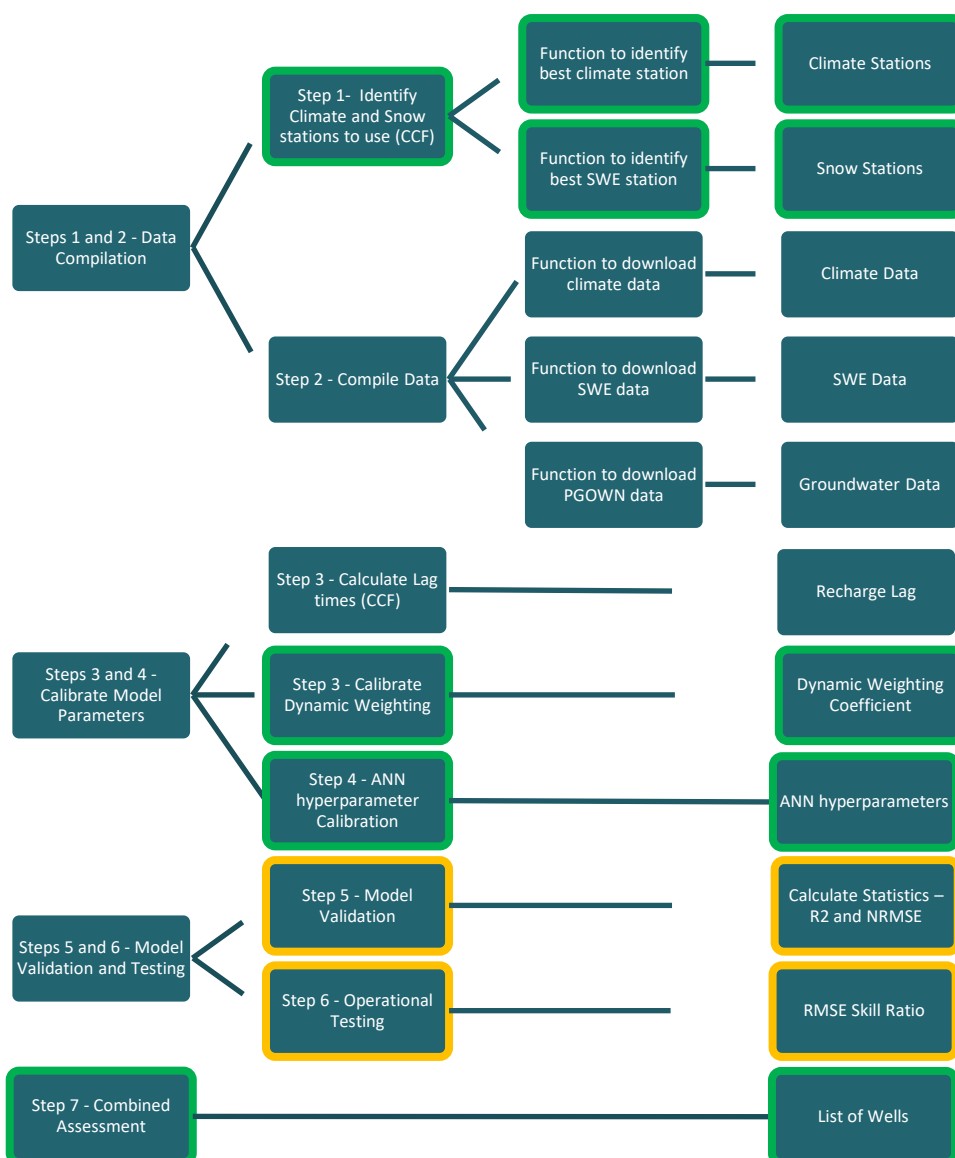
3.7 MODEL TESTING WORKFLOW

The overall model testing builds on the methods used in Phase 1 of the project, with additional aspects introduced through new approaches employed such as the dynamic weighting approach and the inclusion of ANN. Details of the operation and script structure for the overall models can be found in Appendix A2. The overall model testing workflow is shown in Figure 3 and is summarized below:

- Step 1 - Station and Data Identification: Climate and SWE stations were selected to leverage real-time data with robust historical datasets (Section 3.5). The station selection was incorporated in an R script structure. This is a new step in the model testing for Phase 2.
- Step 2 - Data Compilation: Once appropriate climate and SWE stations were identified, the necessary data for validation, testing, and operation was compiled. This includes R scripts for downloading and compiling the real-time data. This step is largely unchanged from Phase 1.
- Step 3 - Recharge Lag and Dynamic Weighting Coefficient:
 - CCF was used to determine the appropriate amount of prior data to use in forecast models based on observed groundwater level response delays (Section 3.6.1). This step is largely unchanged from Phase 1.
 - Dynamic weighting involves applying weights to past data points such that more recent observations are given higher importance compared to older observations to more accurately capture the temporal dynamics of groundwater recharge and improve the overall forecast performance (Section 3.6.3). This is a new approach introduced in Phase 2.
- Step 4 - Calibration of Machine Learning Hyperparameters: Optimal hyperparameters for the ANN model were calibrated by testing a range of values for 90-day forecasts for each well (Section 3.6.3). This is a new approach introduced in Phase 2.

- Step 5 - Model Validation: Similar to Phase 1, a cross-validation approach was used. However, given the much larger number of wells, the focus of the model validation was considerably expanded (Section 4.0).
- Step 6 - Operational Testing: Similar to Phase 1, a cross-validation approach was used.
- Step 7 - Combined Assessment: Based on the results of Step 5 and Step 6, PGOWN wells that showed reasonable results were carried forward and considered in final operational model development. This is discussed Section 5.5 and is a new step introduced in Phase 2.

Figure 3 Model testing workflow.



Boxes highlighted in green represent additional steps from Phase 1 modeling, highlighted in orange indicate approaches based on Phase 1 that have been significantly modified, and non-highlighted boxes indicate steps that remain largely unchanged from Phase 1 modeling.

4.0 MODEL VALIDATION

4.1 APPROACH

Like Phase 1, a cross-validation approach was used to test model performance. This method involves dividing the data into subsets for training and testing. Specifically, model forecasts for each year from 2004 to 2024 were validated individually for the wells included in the study. In each instance, the 2004-2024 training dataset excluded the year being validated. This validation approach closely resembles the intended use of models in operational prediction mode (Section 4.2), where the entire 2004-2024 period is used as a training dataset. Given the large number of wells tested in Phase 2 (203) the wells were grouped by regions when running testing scripts. The groups consist of a maximum of ~25 wells grouping the wells by regions as follows:

- South Coast and Fraser Valley (Coastal) - 3 groups.
- Vancouver Island and Gulf Islands (Vancouver Island) - 3 groups.
- Interior - 3 groups.
- Northern - 1 group.

Well group assignments are listed in Appendix A3.

4.2 PERFORMANCE INDICATORS

Appendix A3 compiles model statistics (Coefficient of Determination - R^2 , Mean Standard Error – MSE, Root Mean Square Error – RMSE, Normalized Root Mean Square Error – NRMSE, Standard Deviation of Residuals – SD) for individual wells, summarizing results for the entire 2004-2024 period (year-round model performance). It was observed that years with incomplete data resulted in less accurate statistics. Therefore, only years with at least 60 percent of the groundwater level data complete were used to calculate performance statistics. Years with less complete datasets are shown as “NA”.

Model performance metric selection tends to be challenging as different metrics are sensitive to different types of bias or error. MSE, RMSE, and SD statistics vary considerably depending on the historical water level range and therefore cannot easily be compared between observation wells. However, these statistics can be used to assess performance differences between different modeling approaches on an individual well basis. It was found that two indicators were generally useful in distinguishing between forecast model results and across the observation wells considered: R^2 and NRMSE. These are the main statistics used in the report.

R^2 measures the proportion of variance in the observed groundwater levels that is explained by the forecast models. R^2 is useful as it typically indicates how well the model matches seasonal variations in groundwater levels (i.e., the ability to simulate groundwater levels under summer drought conditions is an important project objective). However, in wells with significant interannual variability in groundwater levels, R^2 becomes a less sensitive indicator of the model's ability to simulate seasonal water level fluctuations if the model accurately predicts the large historical water level range. Conversely, in cases with a narrow range of interannual variability between water levels, the R^2 value can either reflect the model's ability to simulate

seasonal groundwater level variations (when aquifer recharge lags are relatively long or in snowmelt recharge settings) or can be dominated by the model's ability to simulate short-term water level fluctuations (these can be dominant in aquifers with short recharge lag times in rainfall settings). While there are no universally accepted thresholds for R^2 , values greater than 0.5 are generally considered acceptable, with higher values (e.g., >0.75) indicating excellent performance. However, these are only general ranges. Therefore, project-specific thresholds were determined after analyzing the model performance in all the wells. For model validation, R^2 values above 0.8 are considered good performance, while fair performance is for wells with R^2 values between 0.8 and 0.6. Wells with an R^2 below 0.6 are considered to have poor performance.

R^2 can be misleading if used alone, as it doesn't account for the magnitude of errors or the presence of bias. NRMSE calculates the average magnitude of the differences between simulated and observed values normalized to the historical water level range on the predicted day of the year. NRMSE better captures performance in wells with significant interannual variability in groundwater levels than R^2 because it captures the ability of the model to forecast where groundwater levels fall within the historical range on any given day (i.e., as dominated by the long-term variations). Like R^2 , there also is no single universally accepted threshold for NRMSE, but values below 20% are generally considered good, while values above 30% may indicate a poor fit. Stricter guidelines are typically used for assessing a model's ability to represent spatial variations in groundwater levels where values below 0.1 are considered good, while values up to 0.2 could be acceptable according to groundwater modeling guidelines. However, these are only general ranges and do not directly pertain to time series groundwater levels. Therefore, project-specific thresholds were determined after analyzing the model performance in all the wells. For model validation, NRMSE values below 0.15 are considered good performance, values between 0.15 and 0.25 are considered fair performance, and values above 0.25 are considered poor performance.

The following criteria were chosen to decide overall well performance, leading to three general classifications:

- Good: Both R^2 and NRMSE values are considered good.
- Fair: Either one of R^2 and NRMSE is considered fair, with the other considered good or both R^2 and NRMSE are classified as fair.
- Poor: either one of R^2 and NRMSE is considered poor, with the other considered fair or good, or both R^2 and NRMSE are considered poor.

That is, good model performance is associated with ability to simulate 80% of the groundwater level variations or better over the validation period AND a bias in simulated groundwater levels of 15% or less relative to the historical groundwater level range. Poor model performance is associated with inability to simulate 60% of the groundwater level variations or worse over the validation period AND/OR a bias in simulated groundwater levels of 25% or greater relative to the historical groundwater level range. All other instances are considered fair model performance.

4.3 VALIDATION RESULTS

4.3.1 Phase 2 to Phase 1 Performance Comparison

Model conceptualization improvements for Phase 2 relative to Phase 1 are demonstrated in Figure 4 and Figure 5 for R^2 and NRMSE, respectively, which show overall enhancements for Phase 2 approaches from the Phase 1 model. Mostly, these improvements stem from the dynamic weighting approach, which led to the largest advancement in model performance. Additionally, the approach of simulating changes in groundwater levels (Phase 2), rather than actual groundwater levels (Phase 1), provided some improvement although to a lesser extent while also allowing more wells to be included in the model. In Phase 1, the RF models tended to forecast the smallest amount of groundwater level variability. Changes in Phase 2 have led to RF having better variability of model results, corresponding to RF having the most notable model improvement.

Only the Phase 2 model conceptualization is carried forward in remaining results evaluations.

4.3.2 Statistical versus Machine Learning Models

Figure 6 and Figure 7 (R^2 and NRMSE, respectively) compare 90-day forecast performance for the four different modeling types. For most wells, model performance can be considered fair to good for all four model approaches. However, across the Phase 2 dataset the following trends have become apparent:

- Statistical methods: The non-linear approach of the GAM seems to provide a somewhat better results compared to the linear result of the GLM. This inference agrees with Phase 1 results and the work by Gullacher et al. (2023).
- Machine learning approaches: ANN requires hyperparameters to be calibrated (i.e., is more complex) but generally provides improvements over RF. Random Forests, in addition to their weaker model performance, generally have significantly longer runtimes than ANN.

Overall, between the statistical and machine learning approaches, ANN produces the best results, closely followed by GAM, with GLM and lastly RF providing slightly poorer results. The fact that GAM provides similar overall results to ANN for a snowmelt setting indicates that interaction terms as determined by trial and error for the statistical models are reasonable.

There are specific cases where machine learning approaches, and in particular ANN, outperform the statistical models. Examples are included in Figure 8 and described below for select wells:

- OW320 - ANN and RF demonstrate good results, GAM produces fair results, and GLM shows poor results. This suggests strong non-linear relationships for this well. In this case the GAM model performs better than the GLM but still may be underfitting the data and might improve with less restriction on its degrees of freedom.
- OW354 - ANN, RF, and GAM produce very similar results, with GLM slightly poorer. This indicates that the GAM model can simulate non-linear relationships similarly to machine learning approaches.

- OW463 - ANN and GLM show improved results compared to both RF and GAM, suggesting both the GAM and RF models are overfitting the data. This highlights an instance where RF is performing less consistently than the ANN model.
- OW479 - ANN, GLM, and RF produce very similar results, while GAM does not, possibly due to overfitting the data. The GAM model might improve with more restricted degrees of freedom.

These comparisons highlight limitations of the statistical models, specifically the GLM model's inability to represent non-linear relationships and the risk of overfitting/underfitting of GAM (discussed in Phase 1 report). This GAM limitation is likely related to the approach of using a single value to restrict its degrees of freedom across all wells (degrees of freedom were restricted to 5). These comparisons illustrate that ANN produces good results compared to both GLM and GAM, or either one, suggesting that ANN is better at differentiating between linear and non-linear relationships in the data (i.e., tailored complexity of the model). RF also generally performs well in some of these instances but less consistently than ANN, while also being the worst performer across the larger PGOWN dataset.

4.3.3 Individual Well Model Performance

Individual well statistics from model validation can be found in Appendix A3. Boxplots of well performance for different regions for a 90-day lag period are shown in Figure 9 – Figure 18. These results represent boxplots showing yearly calculated R^2 and NRMSE values from the cross-validation approach. The boxplots represent minimum, maximum, outliers, 75th percentile, 25th percentile, and median values.

In addition to R^2 and NRMSE, the Figure 9 – Figure 18 box plots also show NRMSE values specific to the summertime period reflecting the ability of models to simulate groundwater levels during the core drought period, and a 30-day smoothed R^2 (calculated from a 30-day running average of observed and simulated groundwater levels), which removes model performance effects related to short-term water level fluctuations, which can be strong for aquifers with short recharge lag times, and focuses more on model performance in simulating seasonal and long-term variations in groundwater levels. In practice it was found that these two additional metrics added little information, and they are not carried forward in remaining results.

Individual well model performance varies considerably across the PGOWN dataset and can be subject to a variety of factors, including data record length, rainfall vs. snowmelt environment, and whether the monitored groundwater levels are influenced by other factors than climatic ones not accounted for in the models. These various factors are explored in the sections that follow.

4.4 FACTORS AFFECTING MODEL PERFORMANCE

4.4.1 Rainfall vs Snowmelt Recharge Environment

Similar to what was assessed in Phase 1, model performance for wells in a rainfall recharge environment typically perform better than for wells in a snowfall recharge environment, which becomes most evident at longer forecast periods as lower R^2 values (Figure 4) with a lesser effect on NRMSE (Figure 5). The complex interactions between hydroclimatic predictor variables in snowmelt recharge settings (Section 3.3.3) are important in explaining this result. However, the results persist even for the ANN model, which has

demonstrated the greatest flexibility in handling complex interactions that vary between individual well settings (Section 4.3.2). This suggests that a separate factor that is consistent across the different model approaches is largely responsible for difference in performance between rainfall and snowmelt recharge settings.

SWE stations are generally at high elevations and thus have different timing and melt signatures compared to snowmelt at lower elevations where aquifer recharge occurs (i.e., most PGOWN wells are located in valley aquifers at lower elevations). In addition, given limited spatial resolution of the SWE network in BC, the location and elevation of the stations may not necessarily be within the aquifer's contributing area. Model results could likely be improved by either incorporating a snowmelt model instead of utilizing real SWE inputs or otherwise accounting for the difference in elevation between the SWE stations and the valley aquifers.

4.4.2 Influence of the Fraser River

PGOWN wells in the Fraser Valley can be distinguished in two clusters based on influence by the Fraser River (Section 2.3). Some examples of validation results for Cluster 1 wells are displayed in Figure 19. Generally, the models perform well given that the aquifers are recharged dominantly from local precipitation (rainfall). As discussed in Nott et al. (2024), wells connected to the Fraser are more complicated and are displayed in Figure 20, with the Fraser River acting as a second important source of recharge during snowmelt freshet. An added complication is that the Fraser River freshet reflects conditions in the upstream portions of the watershed covering a large breadth of climatic regions. This highlights a limitation of the current approach of using one local climate and SWE station, which may be insufficient for predicting these Fraser River influences. For groundwater wells installed in aquifers influenced by large river systems, there may be a benefit to including streamflow and a streamflow model for groundwater level forecasting to better incorporate the effects of upstream conditions. However, this was not included in the Phase 2 scope and the current model performance is generally still fair.

4.4.3 Non-Climatic Effects

Non-climatic effects are likely influencing many wells within the PGOWN to varying degrees. When such non-climatic effects are long-term time invariant, they are likely implicitly incorporated in the statistical relationships between groundwater levels and predictor variables, but it is more challenging when these effects vary over the 2004-2024 model validation period. Select examples have been identified to demonstrate situations in which this occurs (Figure 21):

- OW117, OW118, and OW122 are in confined sand and gravel Aquifer 1155 near Armstrong. There has been an increase in seasonal fluctuation in groundwater levels since 2004. This may be related to changes in aquifer usage or potential dam controls on Okanagan Lake water levels, making groundwater levels hard to predict seasonally.
- OW425 is in confined sand and gravel Aquifer 1251 near Qualicum Beach. This well specifically shows an increase in the magnitude of seasonal water level changes since 2018, which corresponds to newer significant water licenses in it and within the adjacent Aquifer 662 (Water Licence 502994 - 25,000 m³/year, completed in 2017, and Water Licence 505335 – 15,000 m³/year, with an unknown completion date).

- OW486 is in unconfined sand and gravel Aquifer #12 near Deroche (the Nicomen Slough Aquifer). It is possible that water levels are affected by controls on slough water levels or agricultural surface water and groundwater use in the area, making it hard to predict groundwater levels based on climatic data.

The goal of these examples was to illustrate potential non-climatic influences on model performance. Regional Hydrogeologists are better able to provide detailed feedback on individual observation wells carried forward for groundwater level forecasting.

4.4.4 Trending or Long-Term Fluctuating Groundwater Levels

In Phase 1, wells that were considered to exhibit long-term trending groundwater levels (year over year increasing or declining groundwater levels) or long-term fluctuating groundwater levels (year over year variations present but not trending) were excluded from consideration, but these wells are included in Phase 2. Some examples of trending or long-term fluctuation wells are presented in Figure 22 for a rainfall recharge setting and Figure 23 for a snowmelt recharge setting. These wells are generally characterized by groundwater level forecast results that are comparable to model performance in wells with stable groundwater levels (i.e. wells with groundwater level trends are no longer a limitation with the refined Phase 2 forecasting methodology). In rainfall recharge settings, most of the long-term trending wells are generally confined (i.e., with longer recharge lag times), while in a snowmelt recharge setting, wells can be confined or unconfined but are typically associated with being disconnected from river systems.

In trending or long-term fluctuations wells large relative long term variations compared to seasonal fluctuations (i.e., compared to wells with long-term stable groundwater levels), results in relatively small NRMSE values and consequently good ability forecasting groundwater levels relative to the large historical range.

4.4.5 Aquifer Subtypes

Model performance results for different aquifer subtypes are shown in Figure 24 and Figure 25 for R^2 and NRMSE, respectively. Aquifer subtypes are described as follows based on deposition type (aquifers derived from stream systems may or may not have a hydraulic connection to a stream system discussed in Section 4.4.9):

- 1a: Unconfined sand and gravel – large river system;
- 1b: Unconfined sand and gravel aquifer - medium stream system;
- 1c: Unconfined sand and gravel aquifer - small stream system;
- 2: Unconfined sand and gravel – deltaic;
- 3: Unconfined sand and gravel - alluvial or colluvial fan;
- 4a: Unconfined sand and gravel - late glacial outwash;
- 4b: Confined sand and gravel – glacial;
- 4c: Confined sand and gravel - glacio-marine;

- 5a: Fractured sedimentary rock;
- 6a: Flat-lying to gently dipping volcanic bedrock; and
- 6b: Fractured crystalline bedrock.

In general, there doesn't seem to be strong or notable correlation between model performance and aquifer subtypes. The sole exception are confined wells which appear to have slightly better model performance. However, overall, it appears that other factors such as recharge type, non-climatic effects and recharge lag may be overwhelming any correlations with aquifer sub-type.

4.4.6 Length of Data Record

Figure 26 and Figure 27 illustrate model performance as a function of the length of the data record for well performance in a rainfall setting, specifically for R^2 and NRMSE respectively. Generally, for all models, there doesn't seem to be a strong or notable correlation between model performance and data period length. This is due to other overriding factors that affect model performance. While the data length of the training set does make a difference to model performance, it does not overshadow model differences.

In practice, there is generally an improvement in model performance with data records of approximately five years. Wells with shorter data records tend to have poorer performance, which seems to be well-dependent, with more complicated responding wells requiring more training time. However, this should be assessed on a case-by-case basis.

It could be surmised that the converse is also true in specific cases. Wells with long data records that have observed a notable change in seasonal response (e.g., possibly related to a change in water use or another non-climatic factor) could potentially improve with a shorter training record that is reflective of current conditions for the forecast period.

4.4.7 Recharge Lag

Model performance results for different aquifer recharge lag times are shown in Figure 28 and Figure 29 for R^2 and NRMSE, respectively. Generally, it is observed that model performance declines when the forecast period is longer than the aquifer recharge lag time. Overall model performance therefore remains better for longer recharge lag times, which tend to be correlated with confined aquifers.

4.4.8 Seasonal Aquifer Usage

Model performance results for different aquifer demands (as defined in provincial aquifer mapping based on well density) are displayed in Figure 32 and Figure 33 for R^2 and NRMSE, respectively. Generally, the models perform well across various aquifers in the province with variable water usage. The models show better performance in a rainfall setting compared to a snowmelt setting, which typically sees worse performance in high-demand aquifers. This is likely due to the more complex variable interactions in a snowmelt setting (see Section 3.3.3), where temperature plays a role in controlling a number of aspects of the seasonal groundwater level response. In a rainfall setting, the relationship between temperature and increased seasonal water usage is more easily defined.

Some aquifers, especially in the Fraser Valley, are highly developed and yield good model performance. It appears that in a rainfall setting, as long as the PGOWN wells are outside the direct drawdown effects of groundwater pumping, the models can largely account for the effects of increased aquifer usage tied to seasonal climatic changes. Model performance declines somewhat in a snowmelt setting. Model performance also declines when there are large changes to water usage in an aquifer, as demonstrated in Section 4.4.3.

4.4.9 Hydraulic Connection to Streamflow

Many of the PGOWN wells included in the study have varying degrees of hydraulic connection to streams and river systems. While the exact degree and nature of these hydraulic connections are likely complicated for each aquifer system, requiring localized detailed analysis, Gullacher et al. (2021) performed a classification analysis of groundwater response mechanisms in PGOWN wells across the province. Their analysis classified PGOWN wells according to the dominant response mechanism:

- Recharge-driven, where the groundwater level response leads the streamflow.
- Streamflow-driven, where the streamflow leads the groundwater level response.

Model performance results for the two classifications are displayed in Figure 32 and Figure 33 for R^2 and NRMSE, respectively. Results that were unclassified in the study or not included are labeled as undetermined. Generally, the models perform similarly well for all classifications. In a rainfall setting, there is some indication that the model may perform better in a streamflow-driven setting. A notable exception to this is for wells connected to large systems such as the Fraser River, which cover a large breadth of climatic regions. This highlights a limitation of the current approach of using one local climate and SWE station (Section 4.4.2).

Figure 4 Changes in model performance from Phase 2 to Phase 1 (R^2).

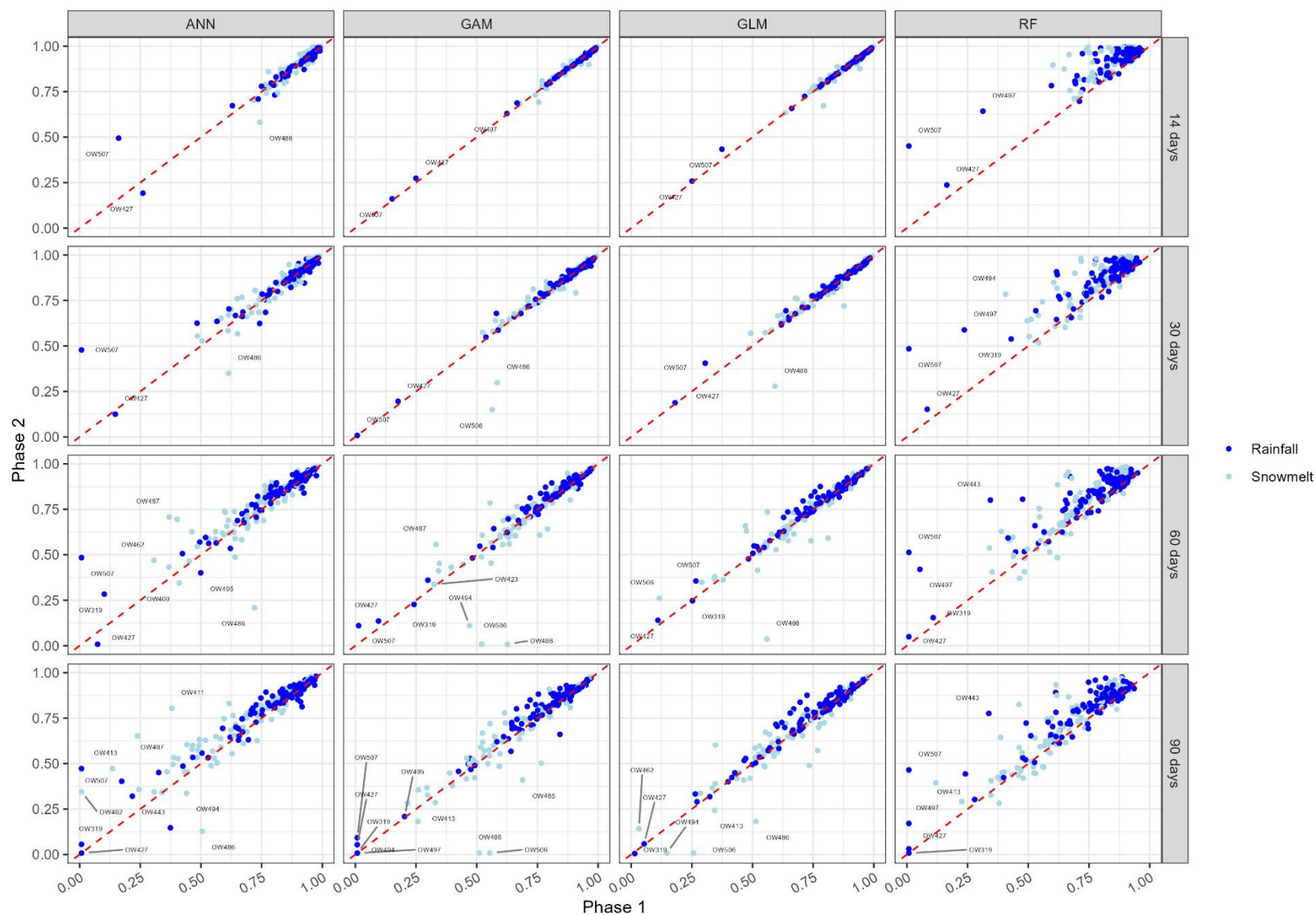


Figure 5 Changes in model performance from Phase 2 to Phase 1 (NRMSE).

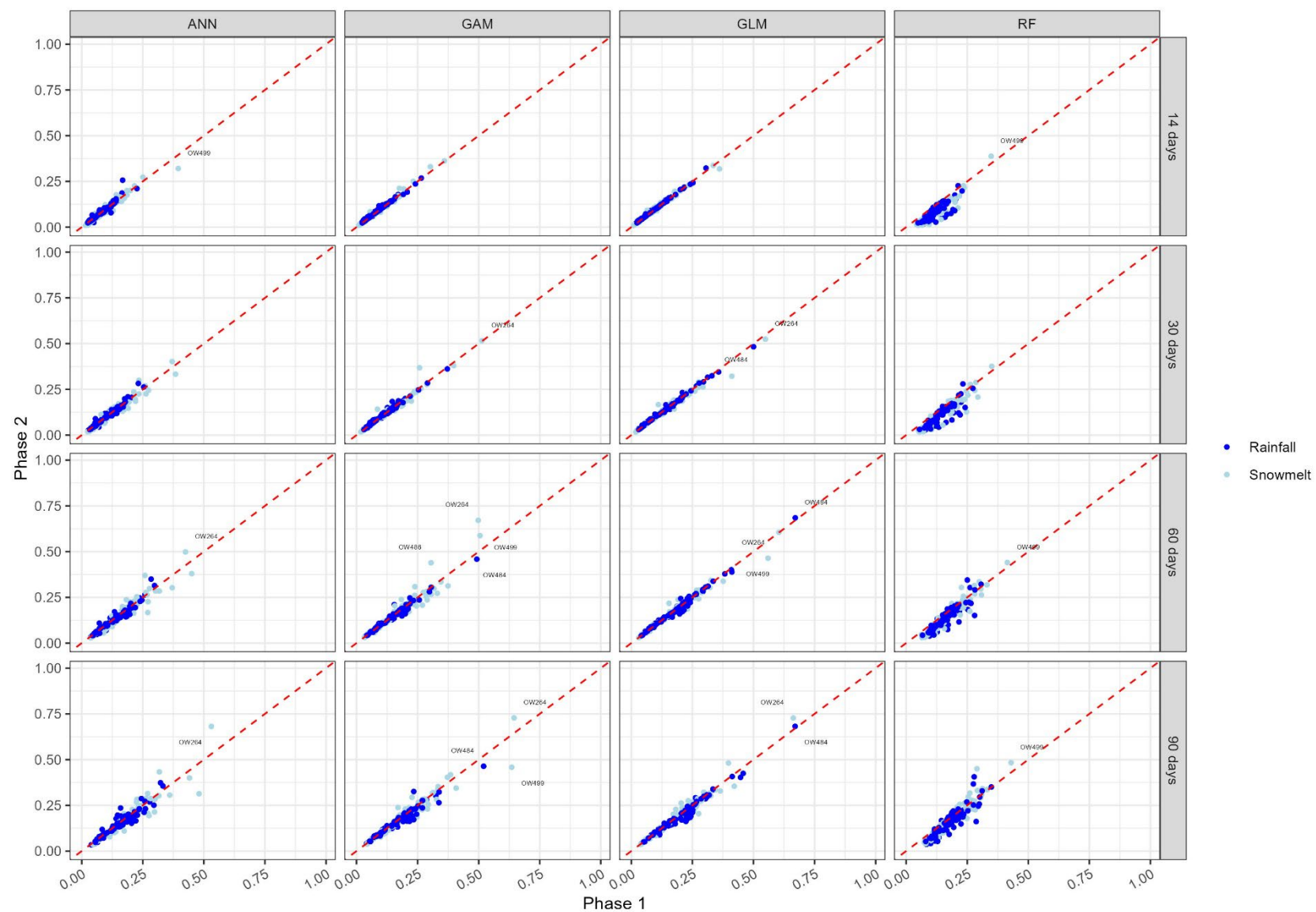


Figure 6 Comparison of other statistical and machine learning models (R^2) to ANN for 90 day forecast period.

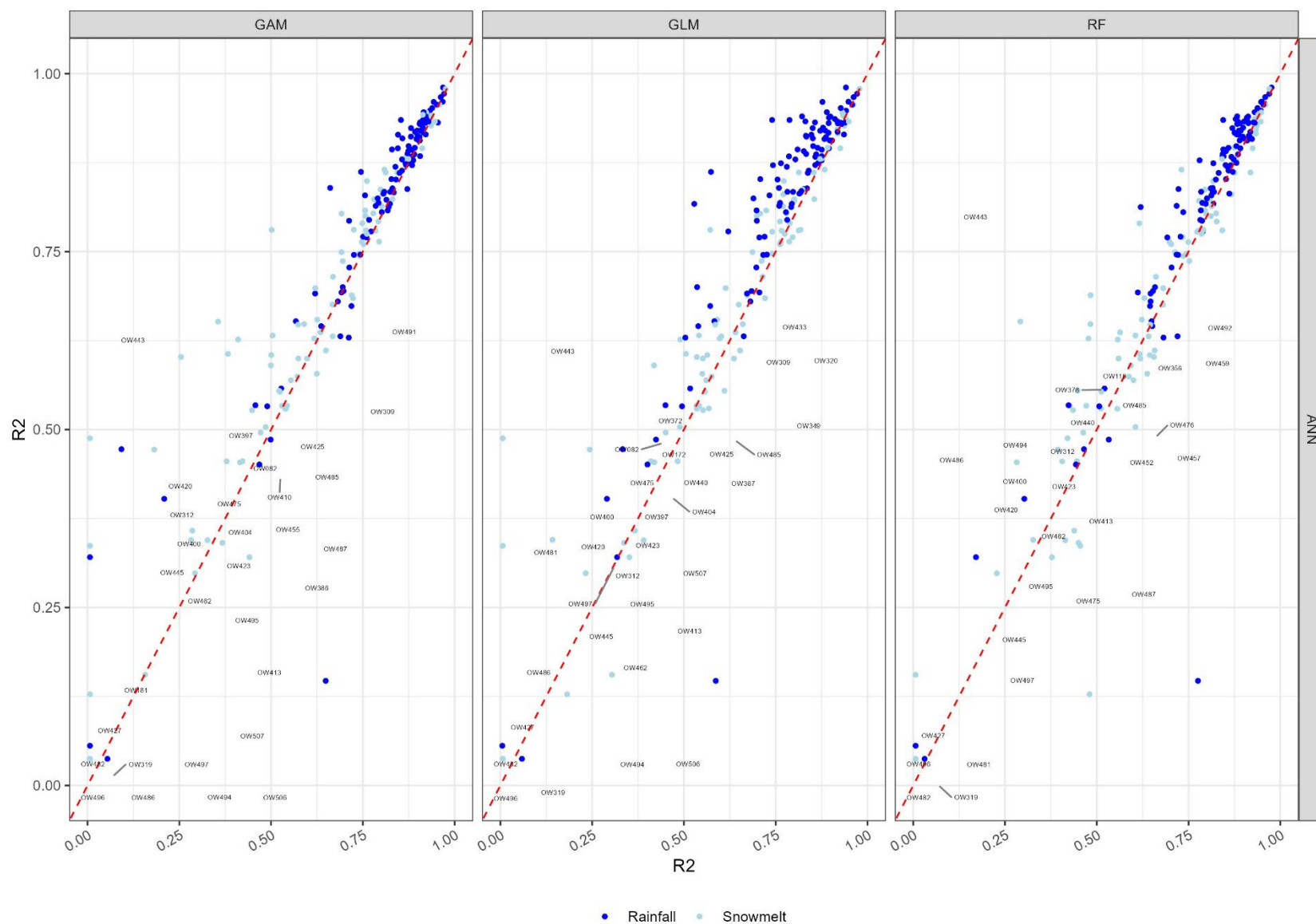


Figure 7 Comparison of other statistical and machine learning models (NRMSE) to ANN for 90 day forecast period.

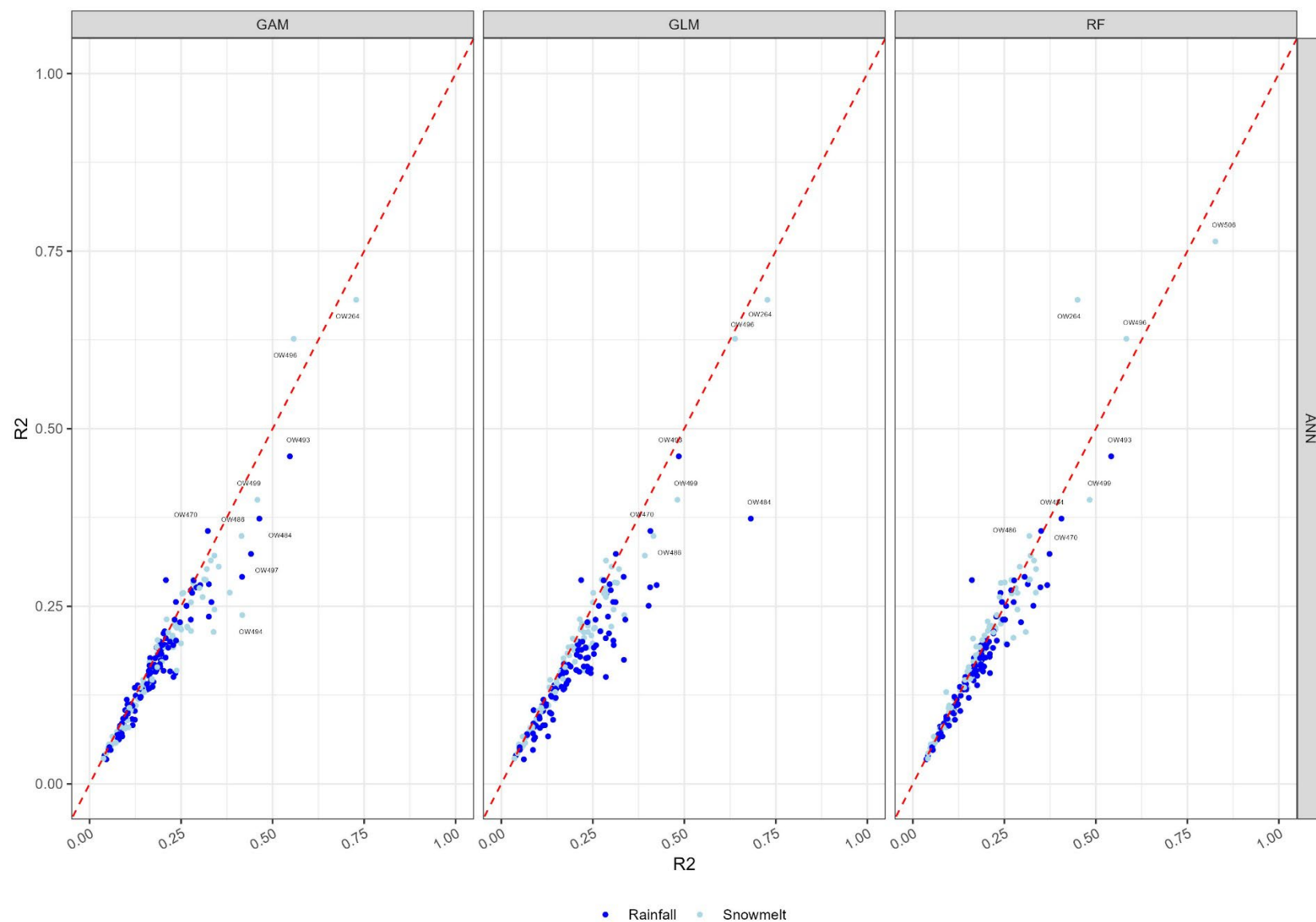


Figure 8 Examples of differences in performance for statistical and machine learning models (90 day forecasts).

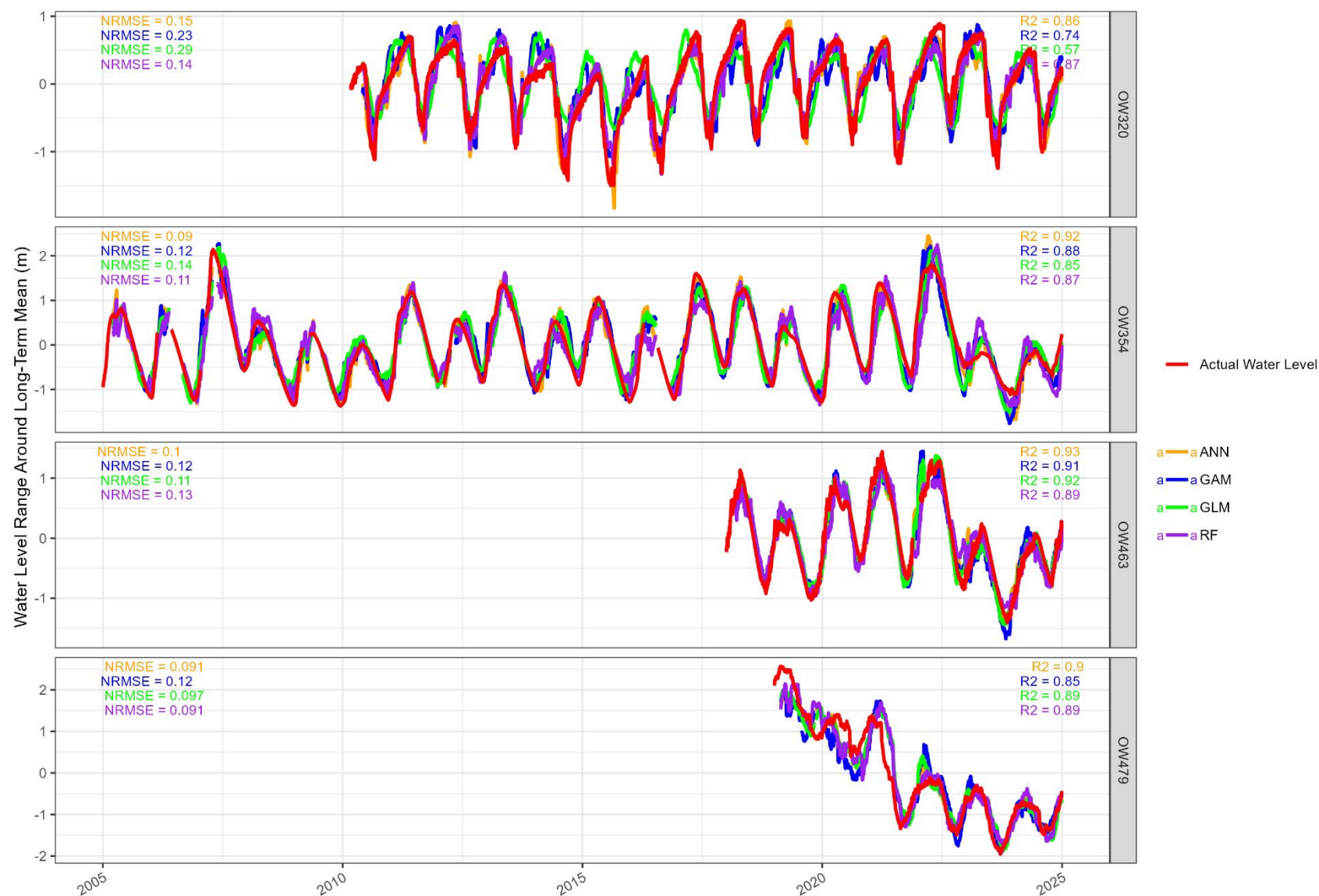


Figure 9 Model validation results for Coastal Group 1.

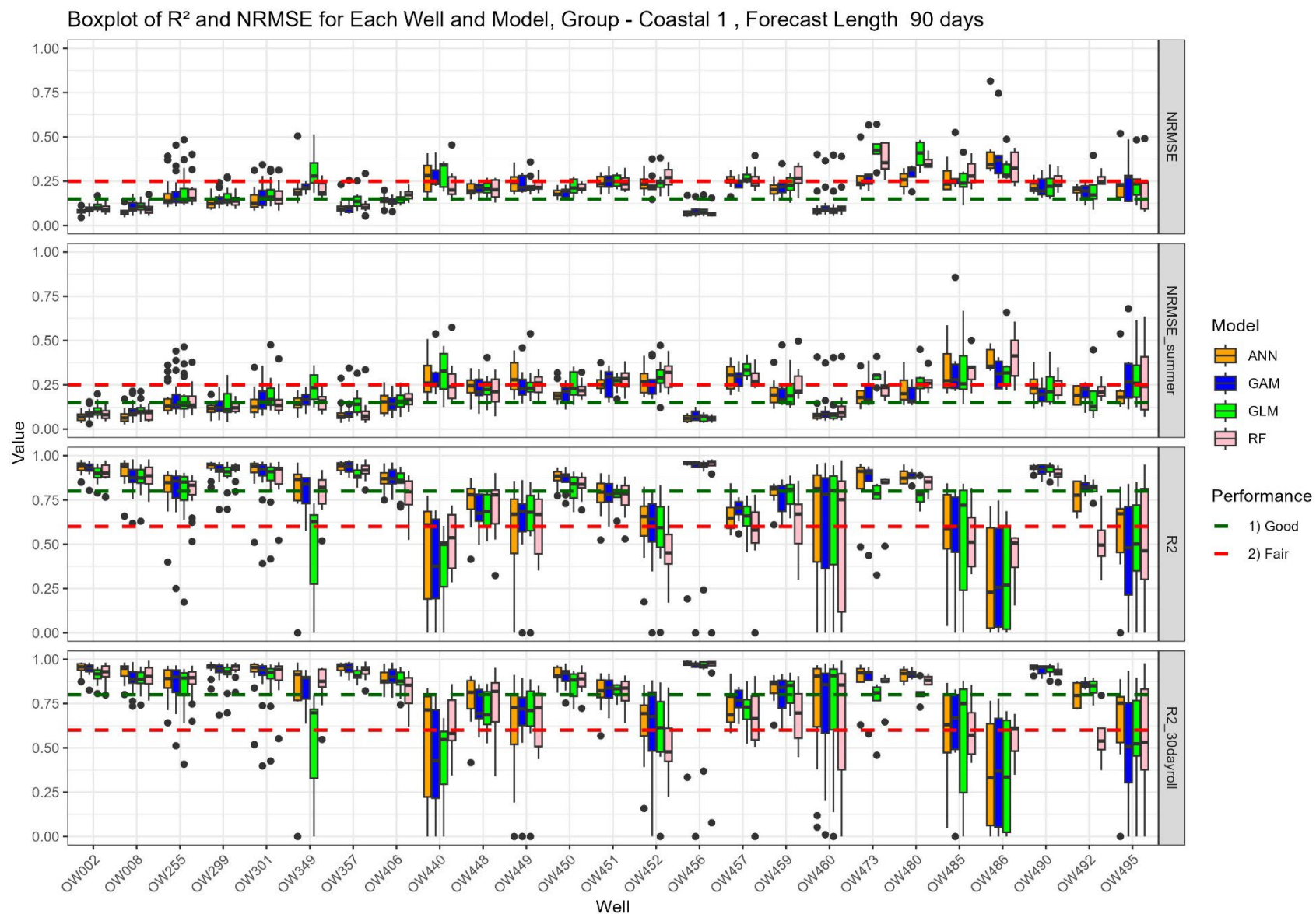


Figure 10 Model validation results for Coastal Group 2.

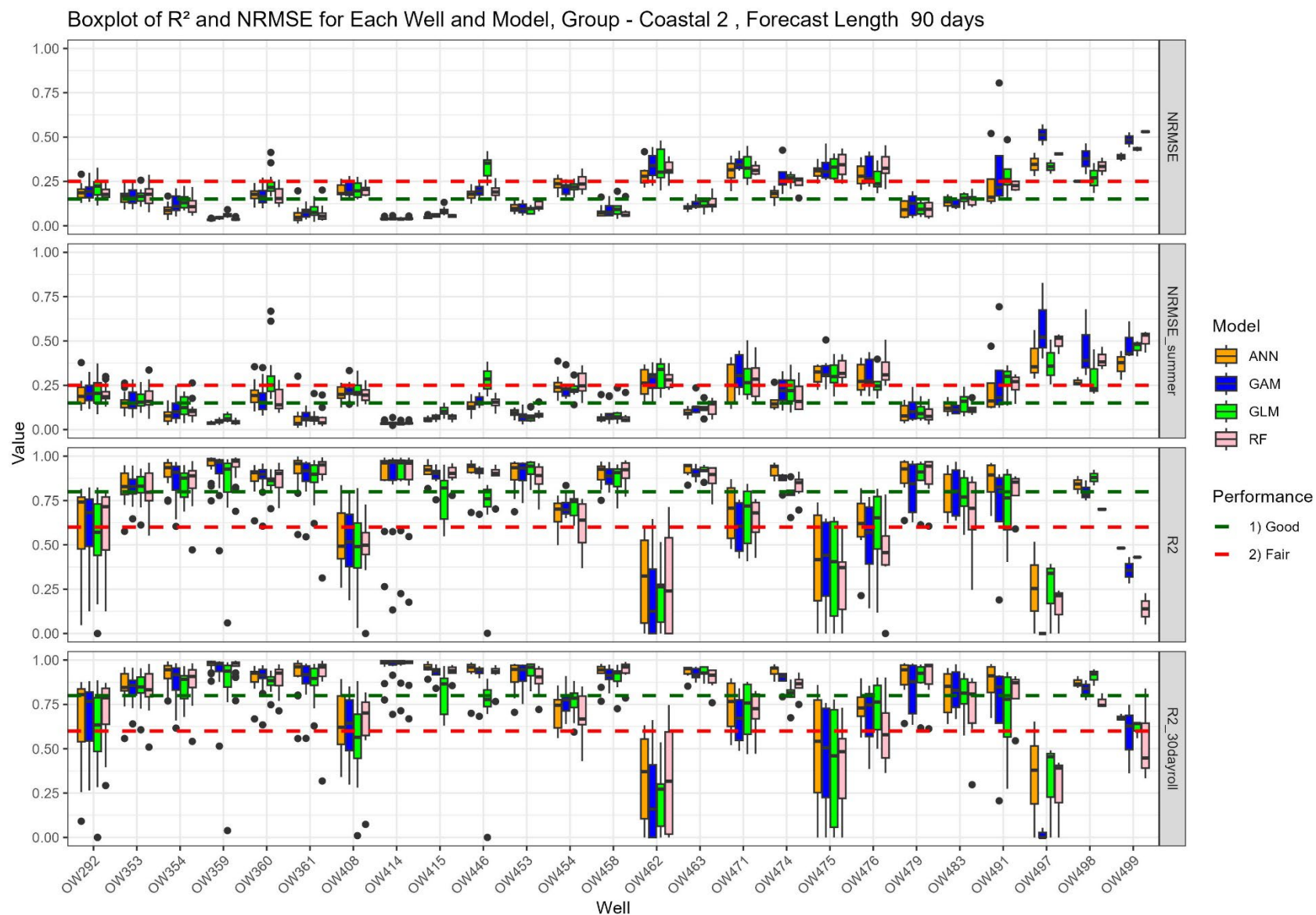


Figure 11 Model validation results for Coastal Group 3.

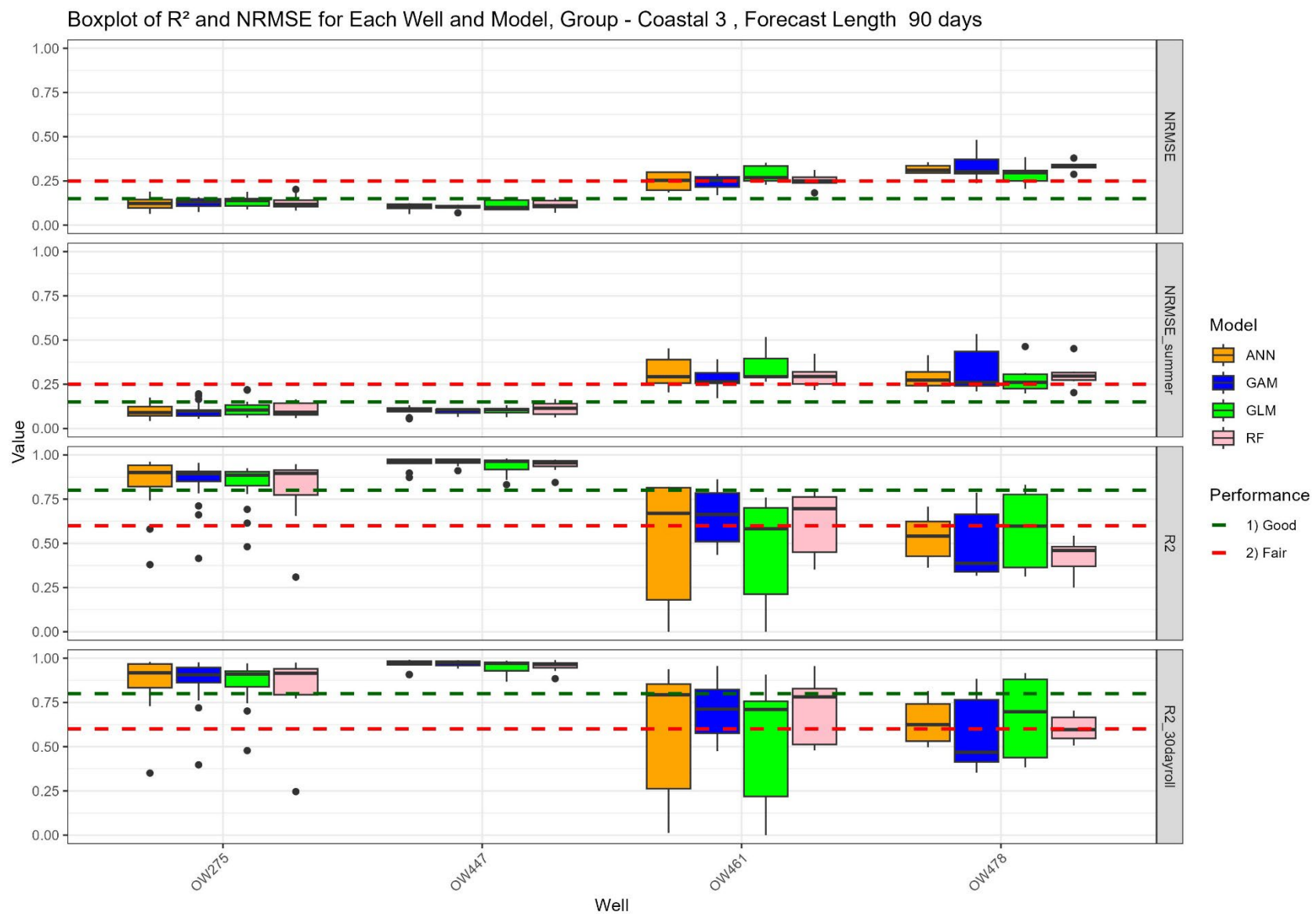


Figure 12 Model validation results for Vancouver Island Group 1.

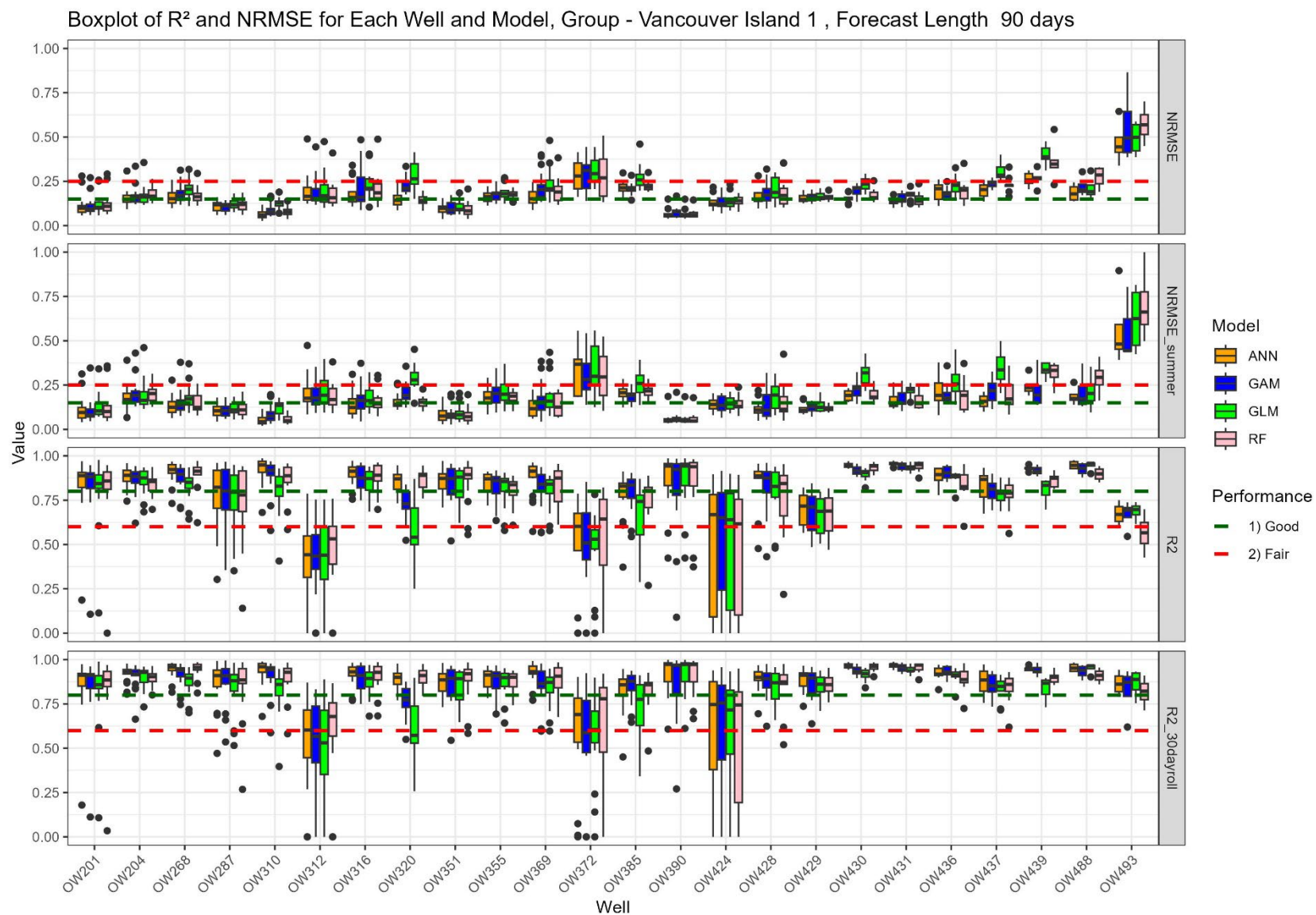


Figure 13 Model validation results for Vancouver Island Group 2.

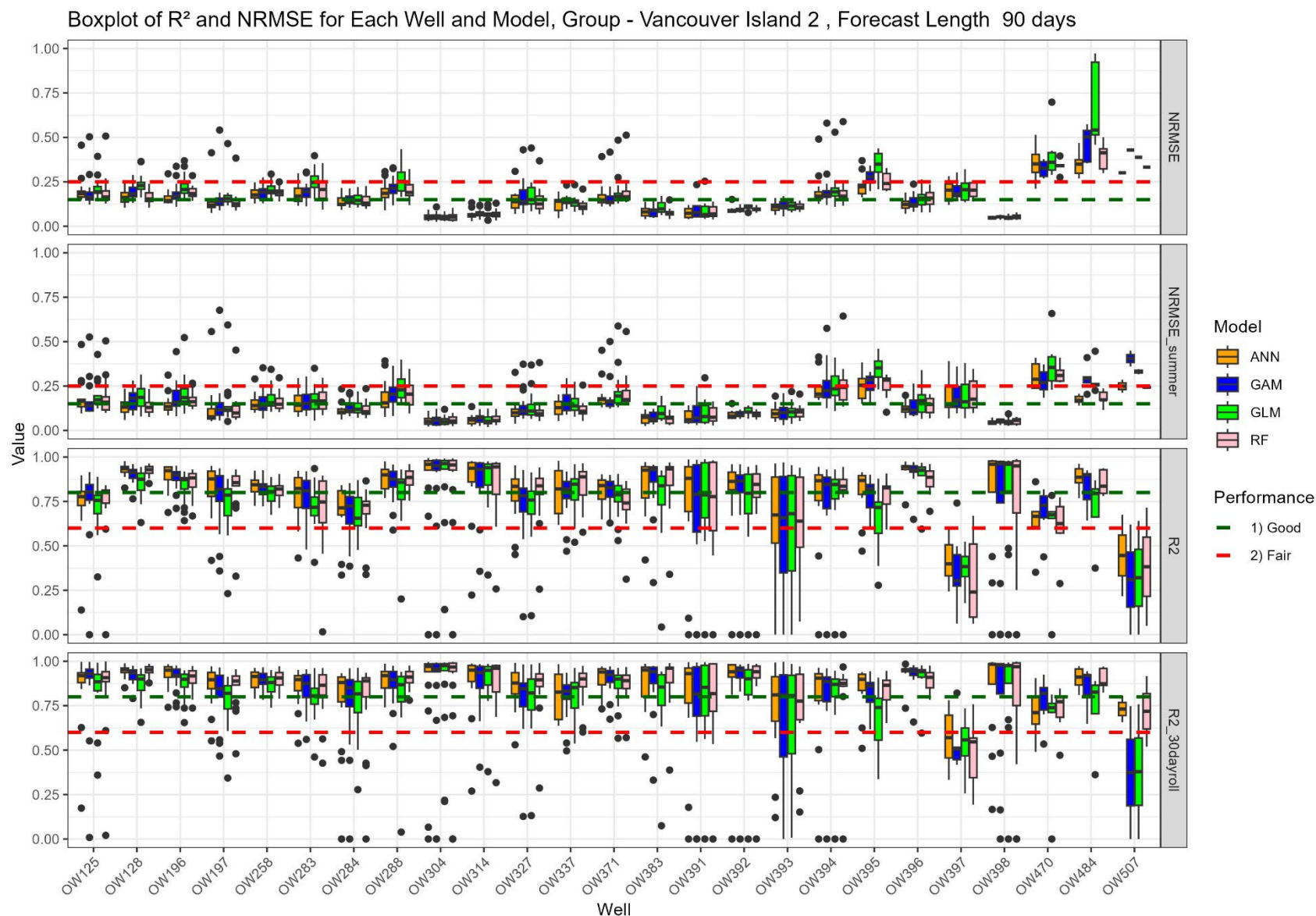


Figure 14 Model validation results for Vancouver Island Group 3.

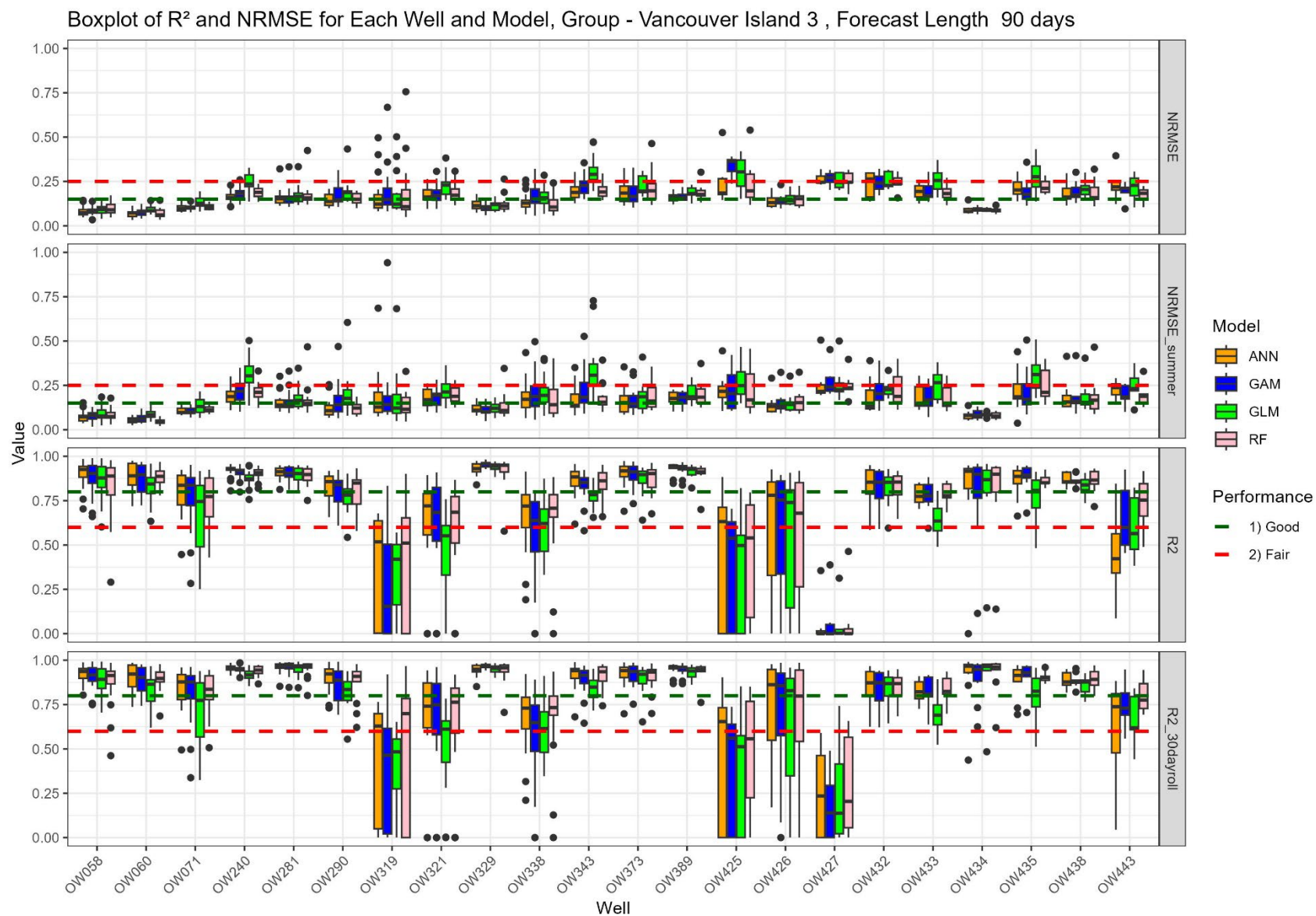


Figure 15 Model validation results for Interior Group 1.

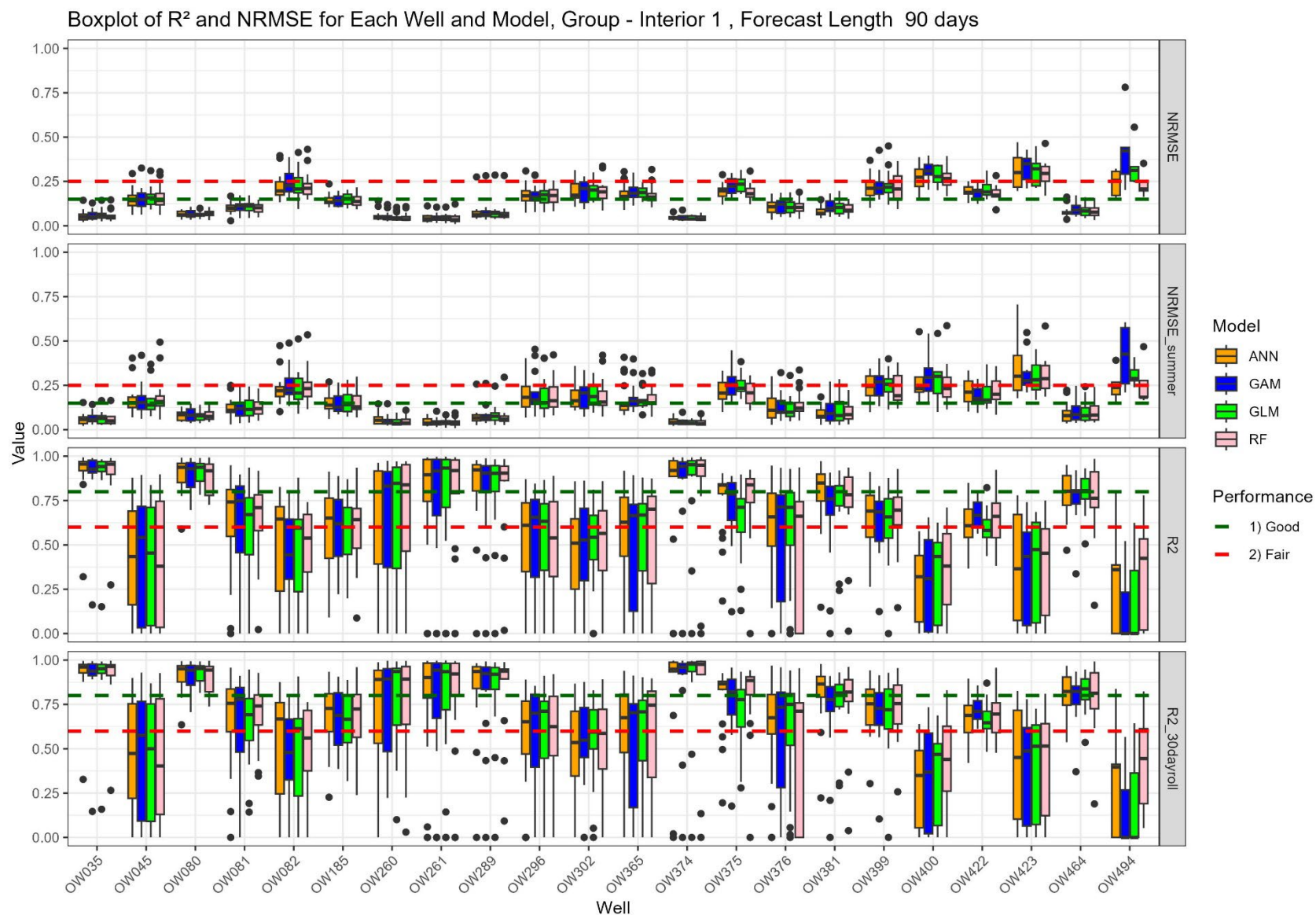


Figure 16 Model validation results for Interior Group 2.

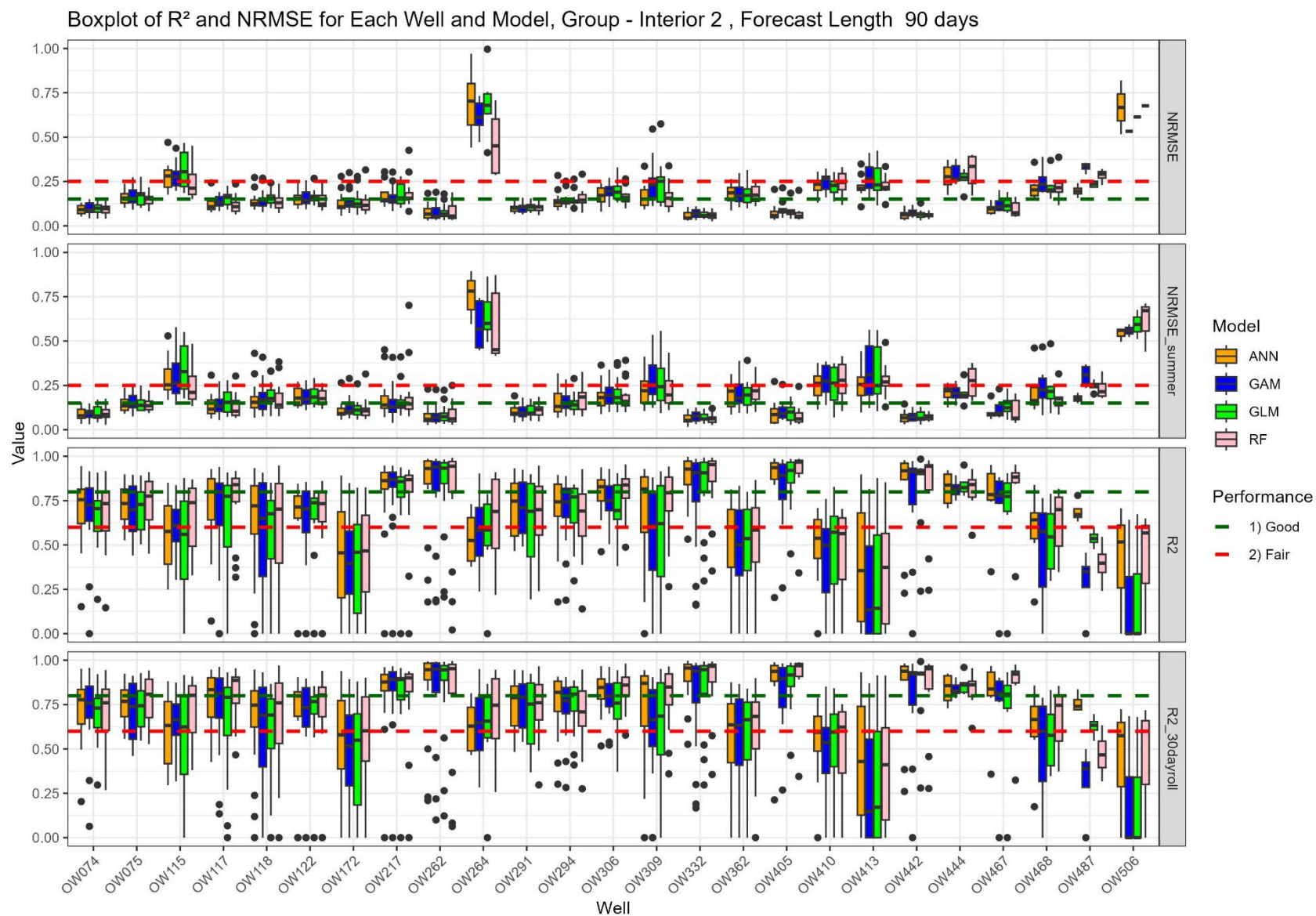


Figure 17 Model validation results for Interior Group 3.

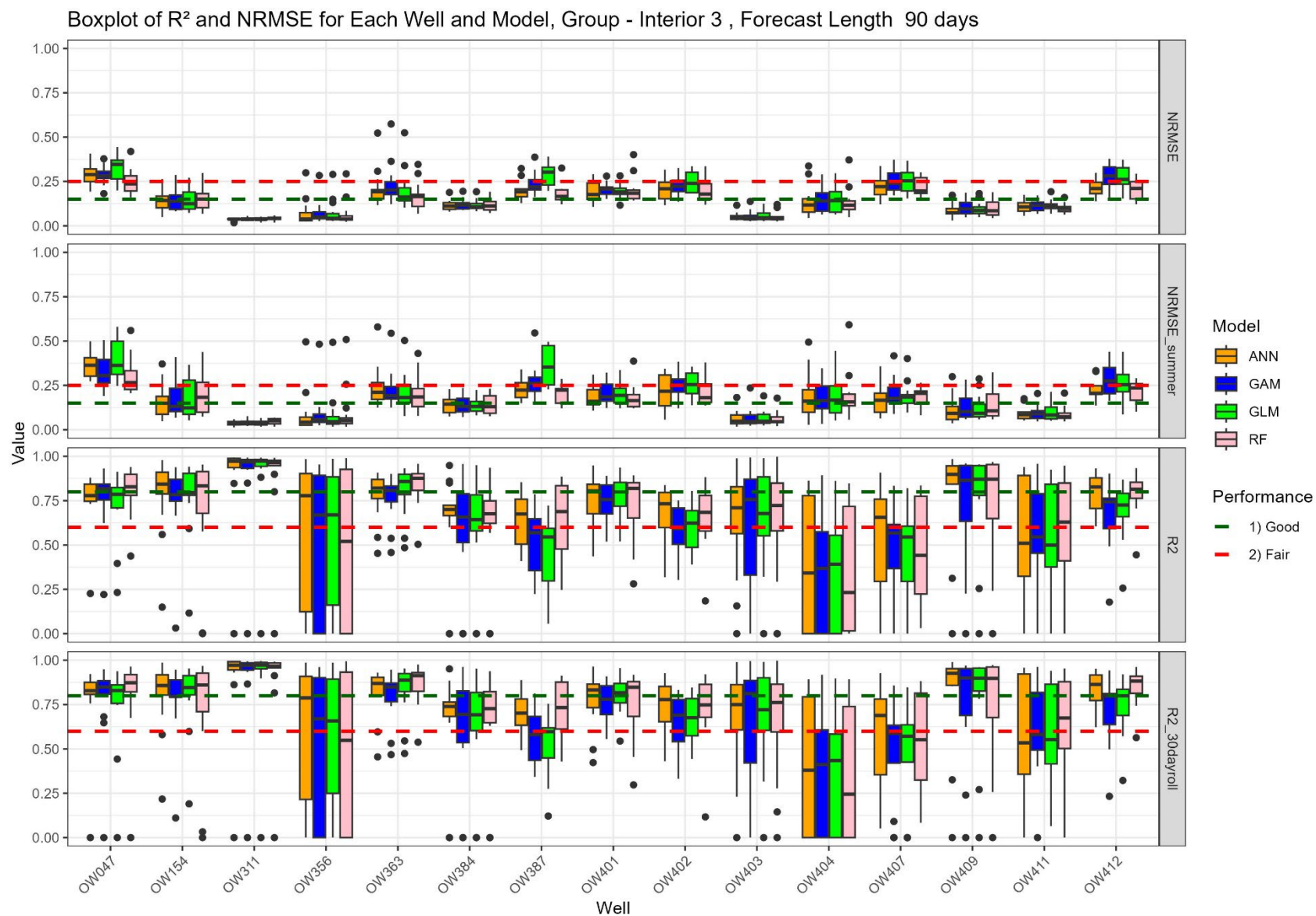


Figure 18 Model validation results for Northern Group 1.

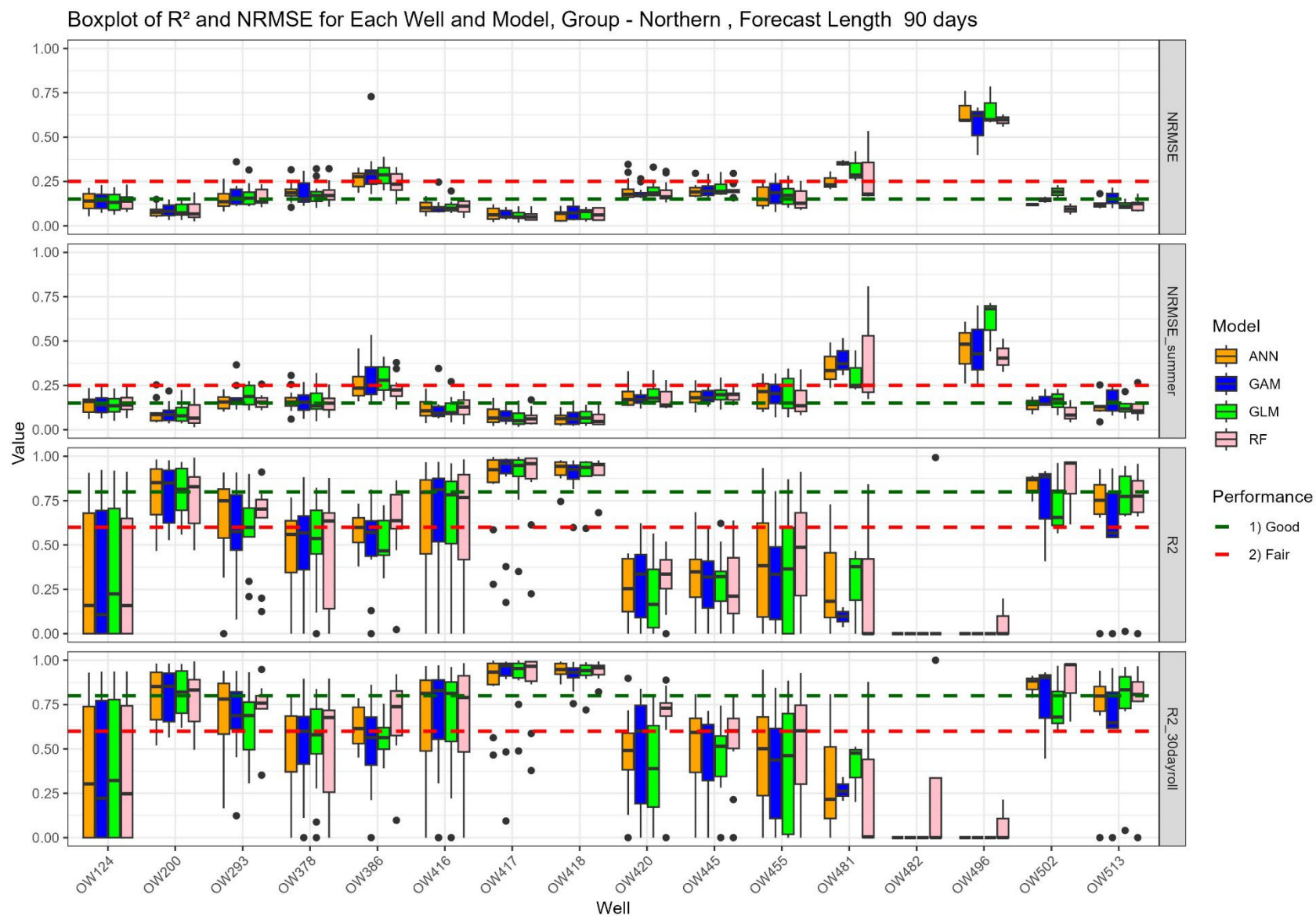


Figure 19 Model performance examples for Fraser Valley Cluster 1 wells not influenced by Fraser River (90 day forecasts).

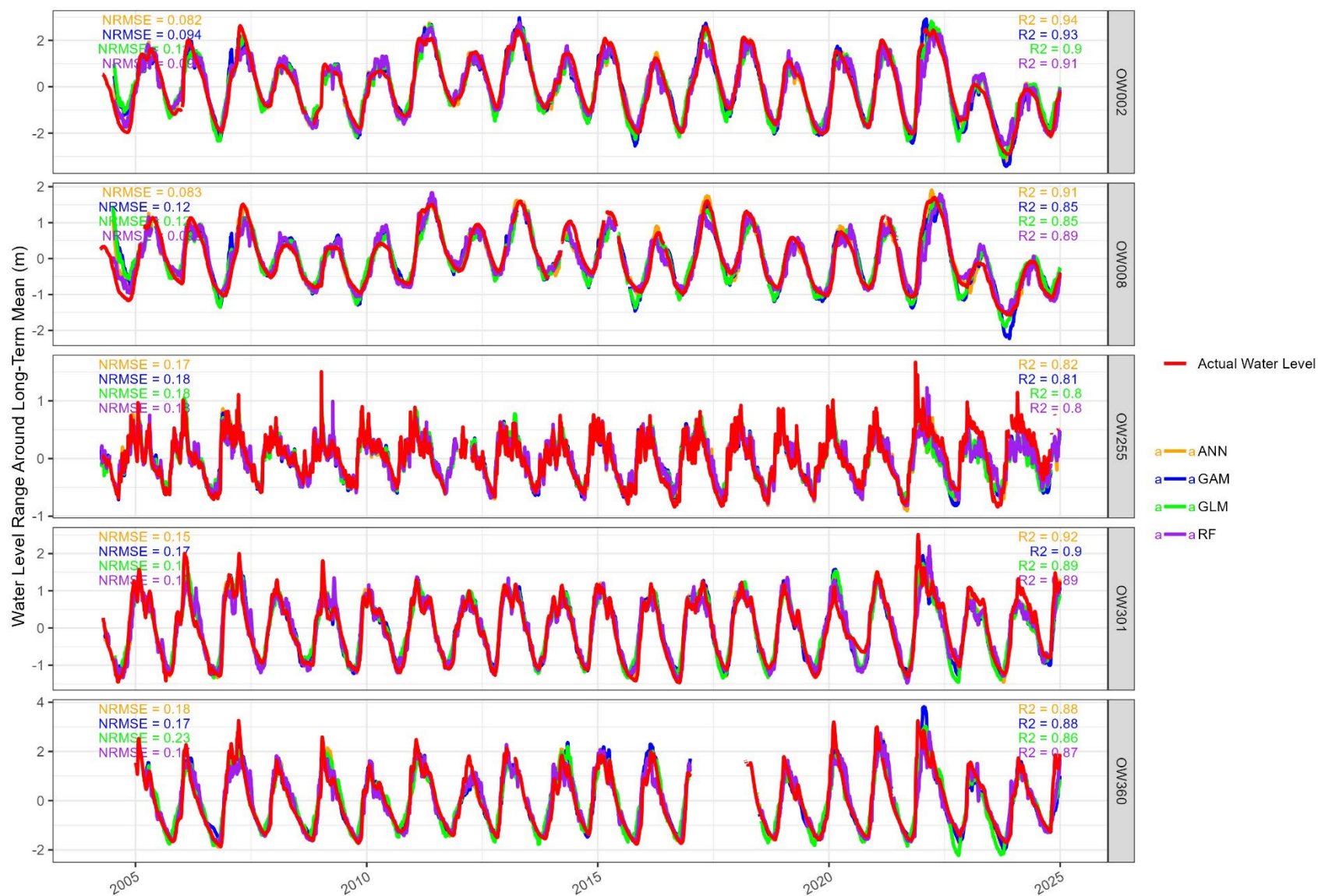


Figure 20 Model performance examples for Fraser Valley Cluster 2 wells influenced by Fraser River (90 day forecasts).

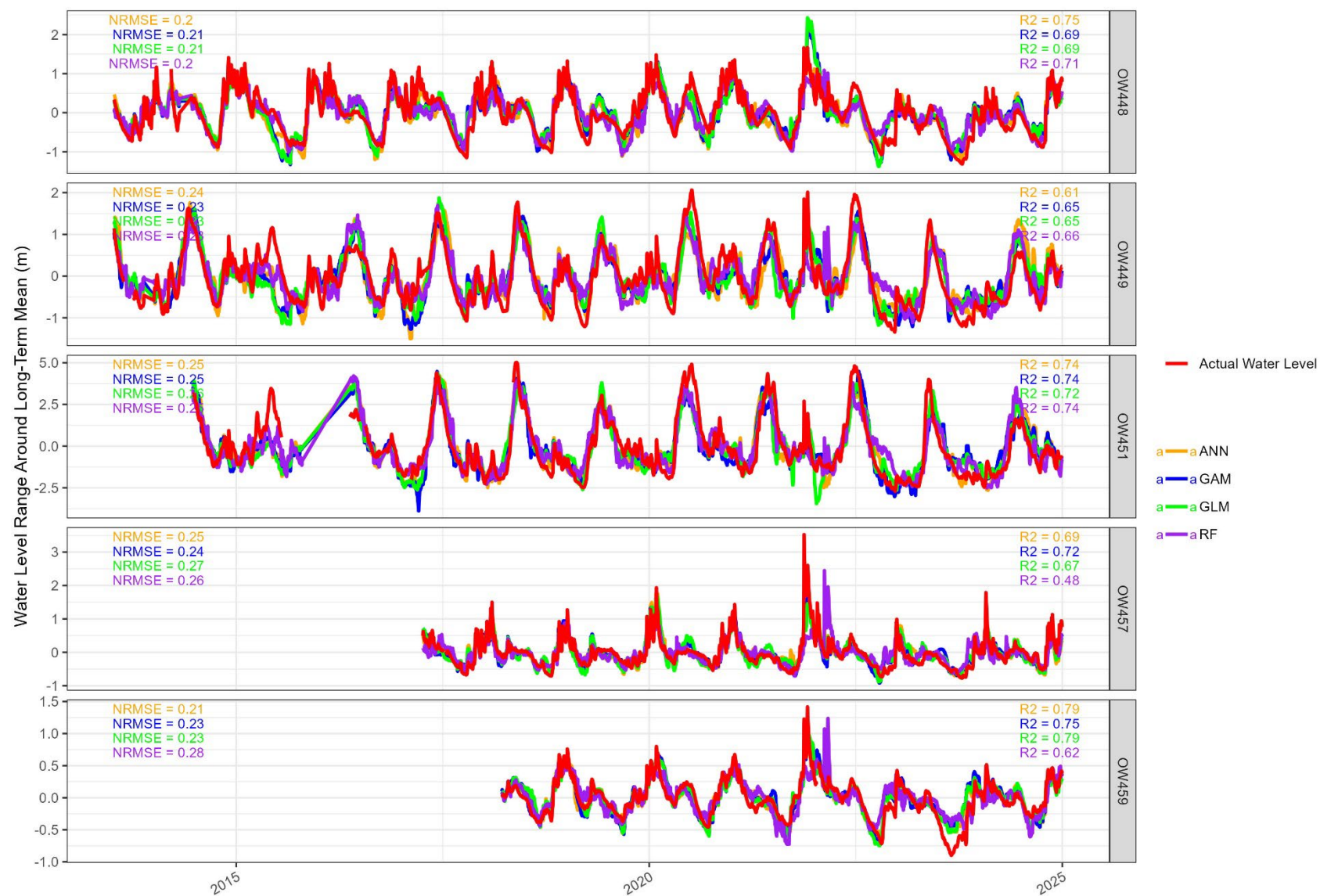


Figure 21 Examples of non-climatic effects affecting model performance (90 day forecasts).

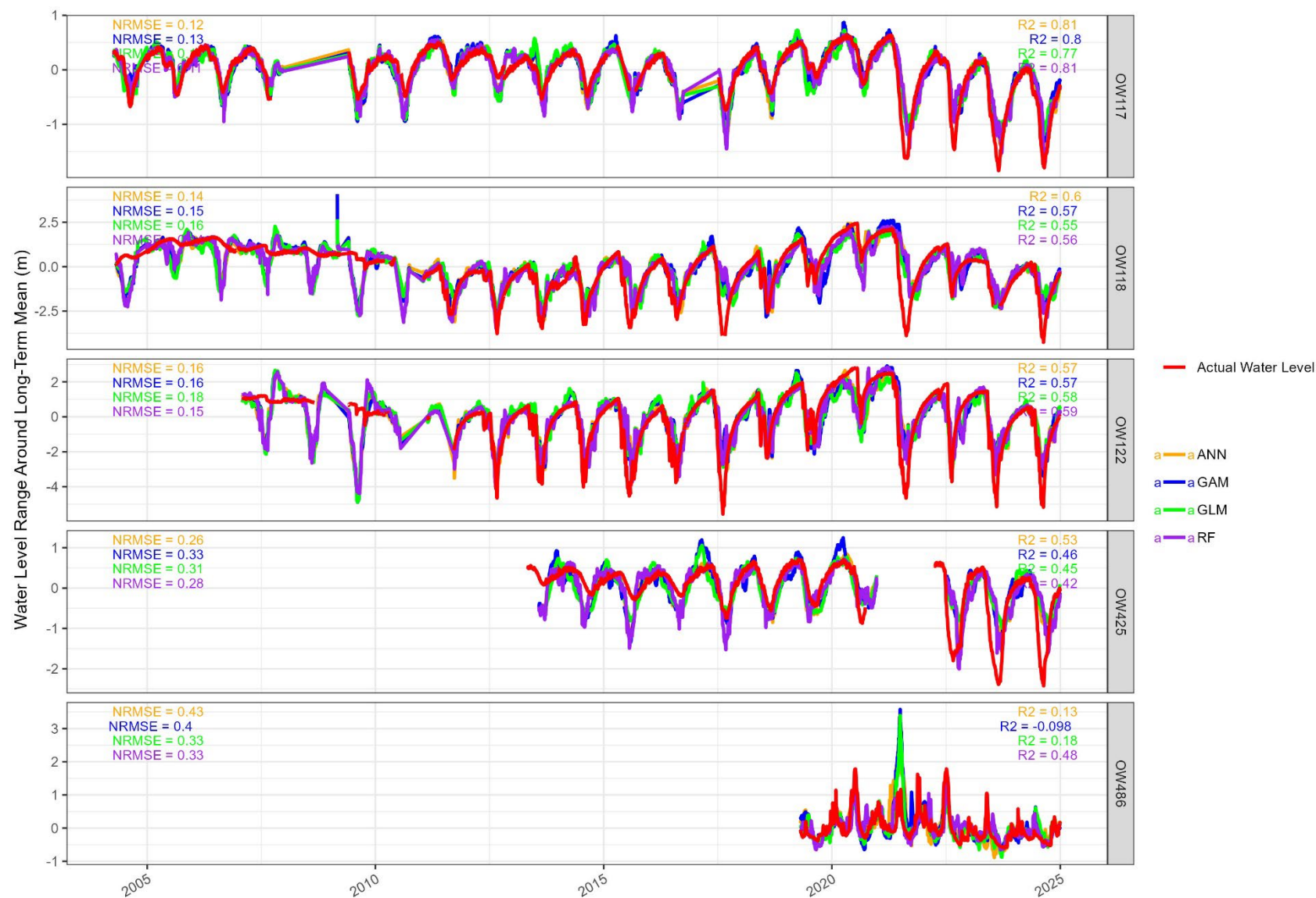


Figure 22 Examples of wells with long-term trending groundwater levels in rainfall recharge setting (90 day forecasts).

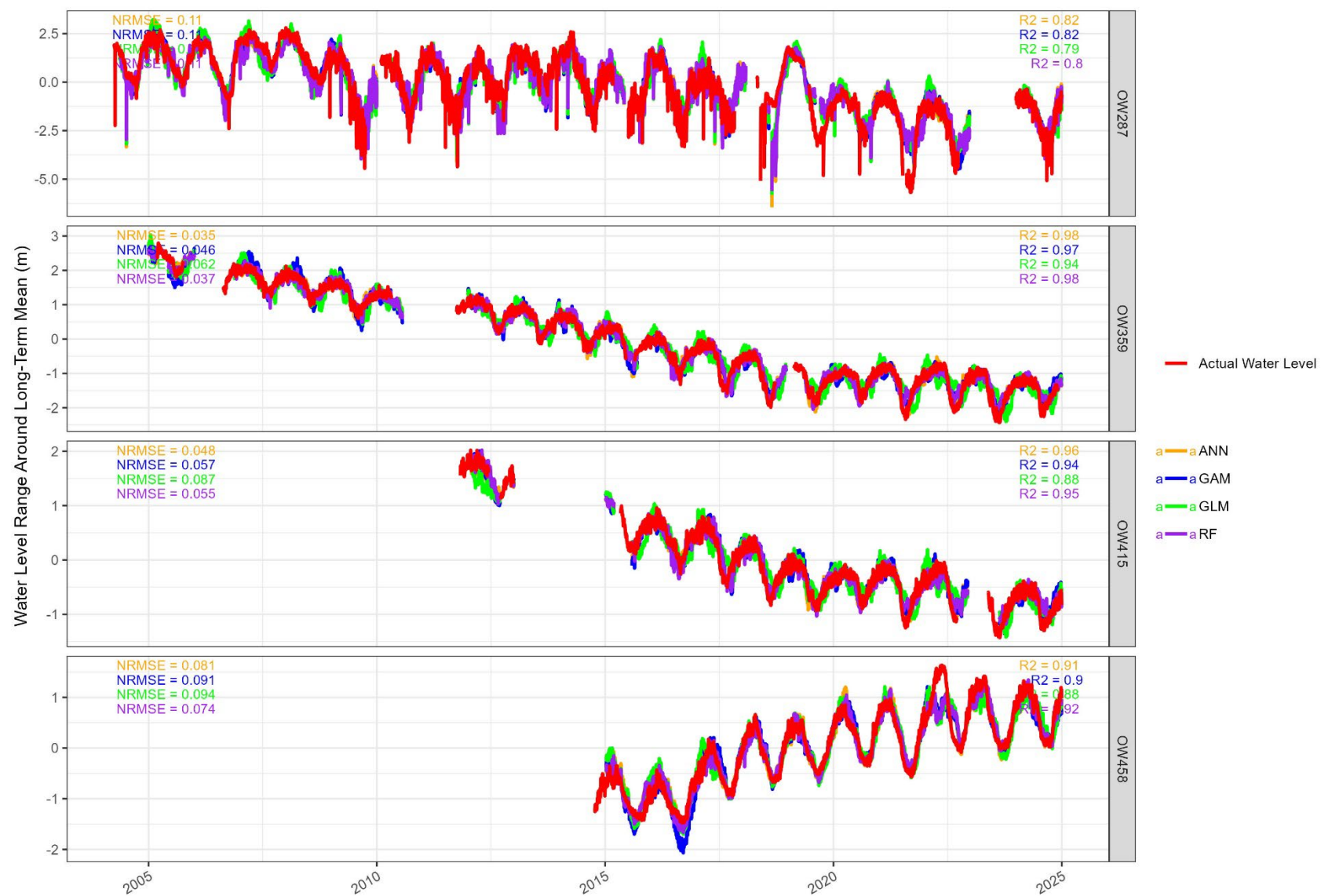


Figure 23 Examples of wells with long-term trending groundwater levels in snowmelt recharge settings (90 day forecasts).

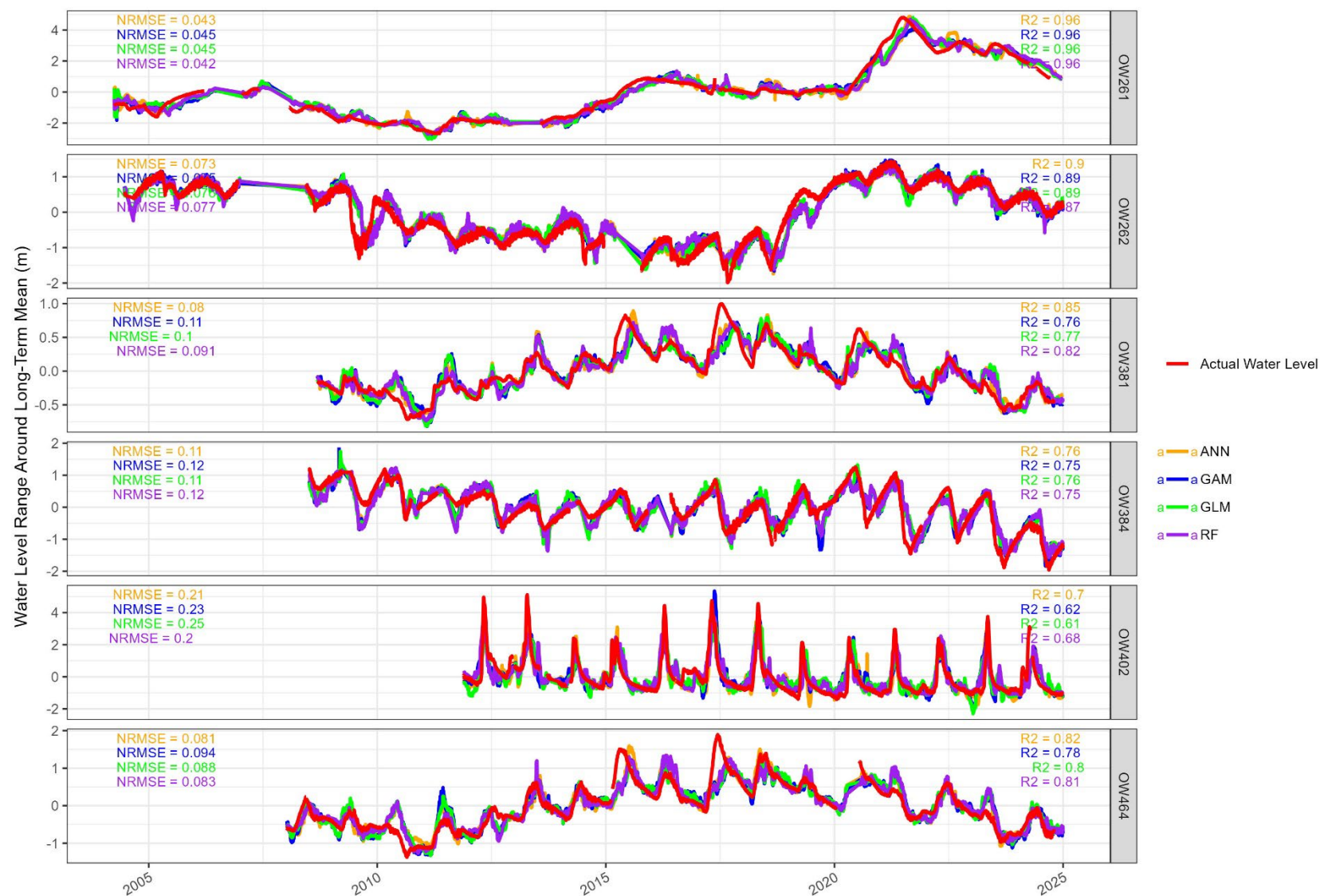


Figure 24 Model performance (R^2) for different aquifer subtypes.

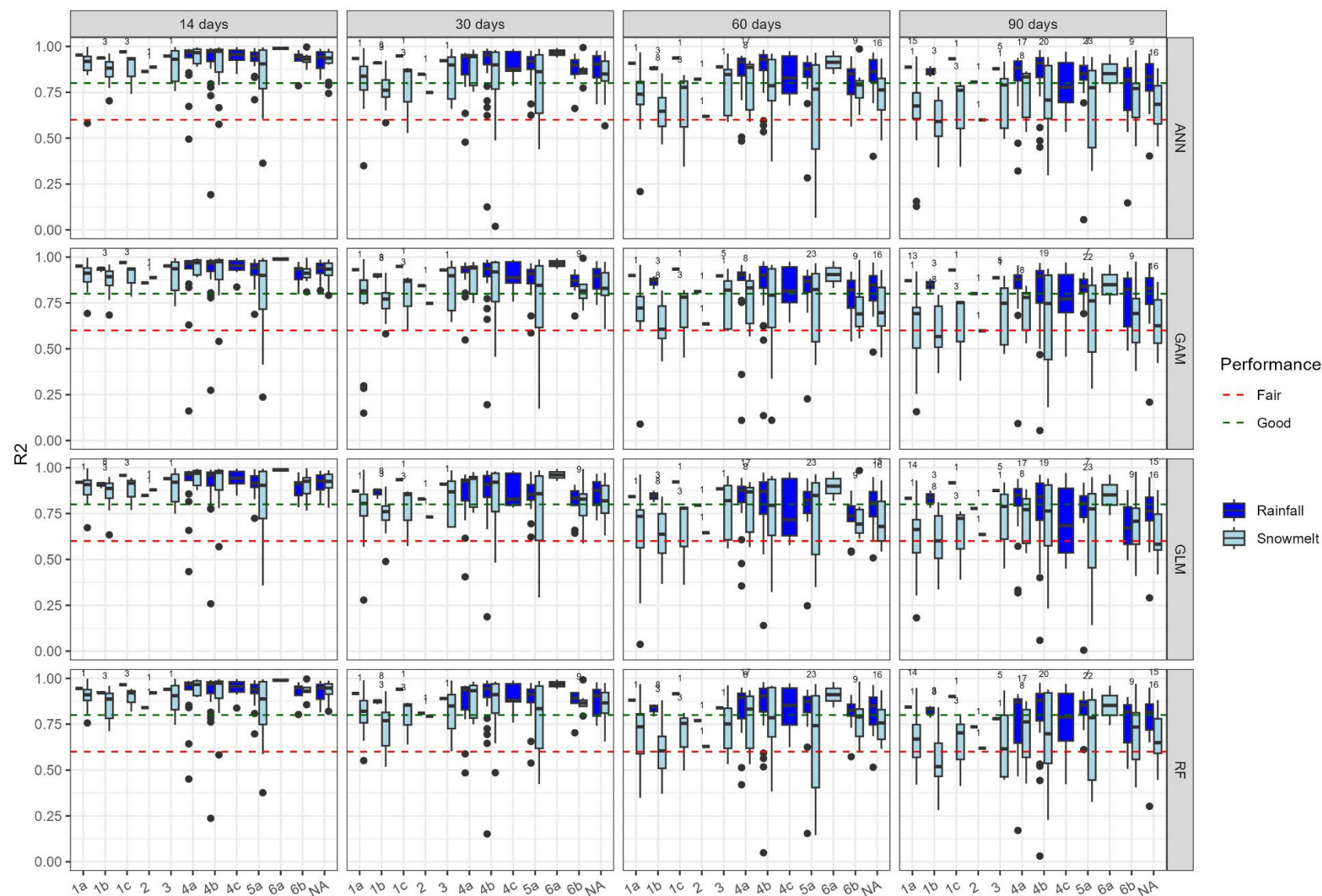


Figure 25 Model performance (NRMSE) for different aquifer subtypes.

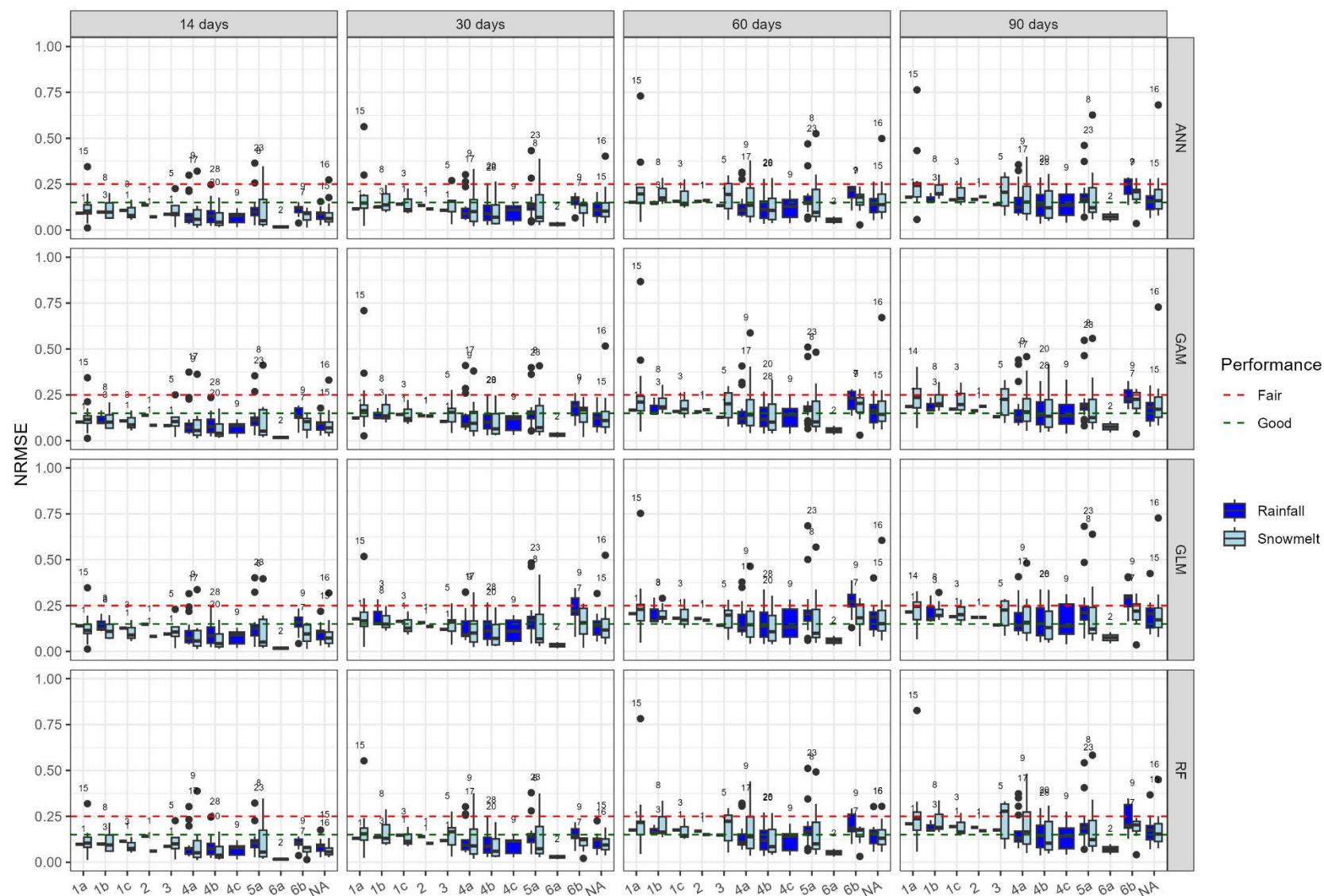


Figure 26 Model performance (R^2) for different data record lengths.



Figure 27 Model performance (NRMSE) for different data record lengths.

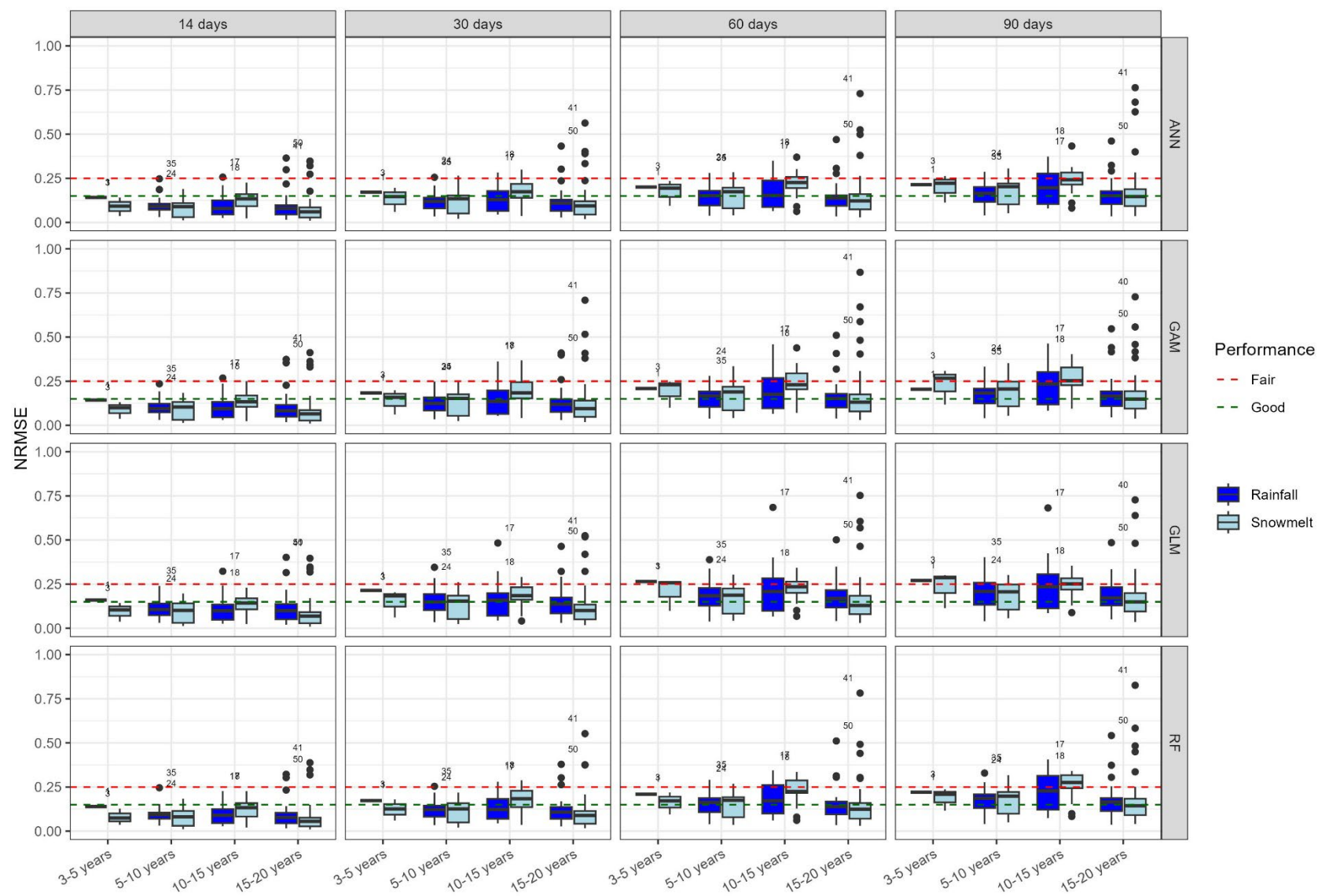


Figure 28 Model performance (R^2) for different aquifer recharge lag times.



Figure 29 Model performance (NRMSE) for different aquifer recharge lag times.

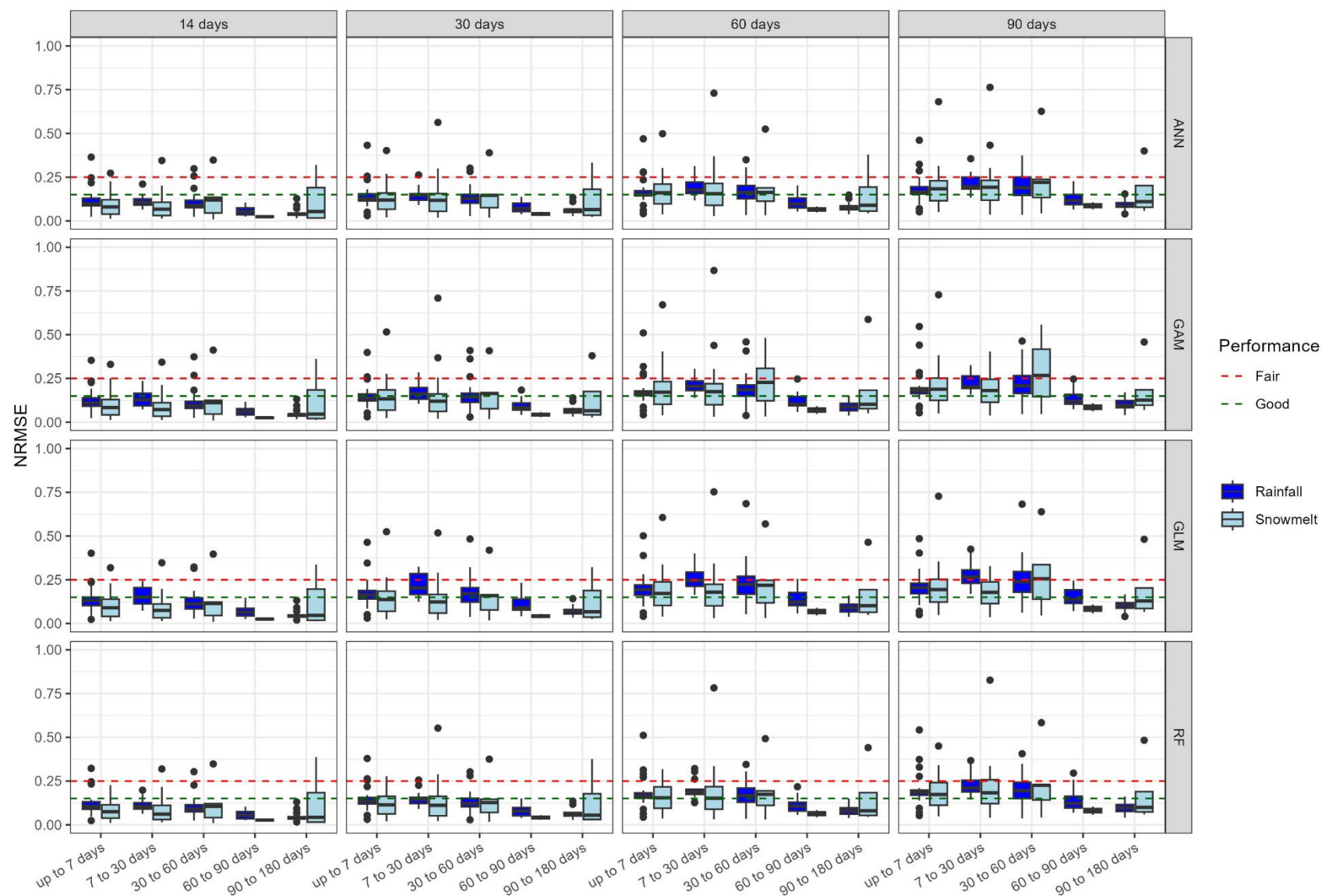


Figure 30 Model performance (R2) for different aquifer demands.

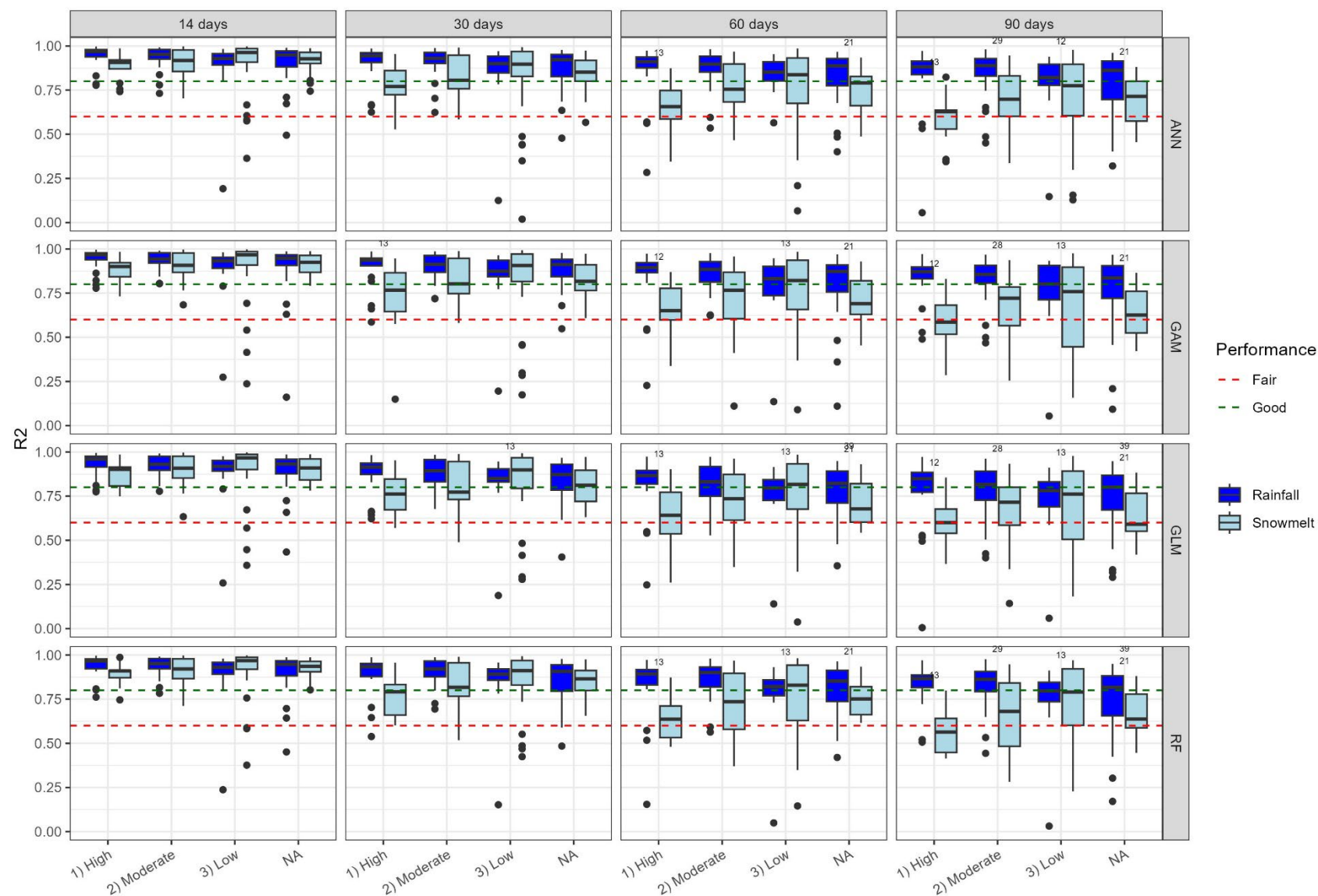


Figure 31 Model performance (NRMSE) for different aquifer demands.

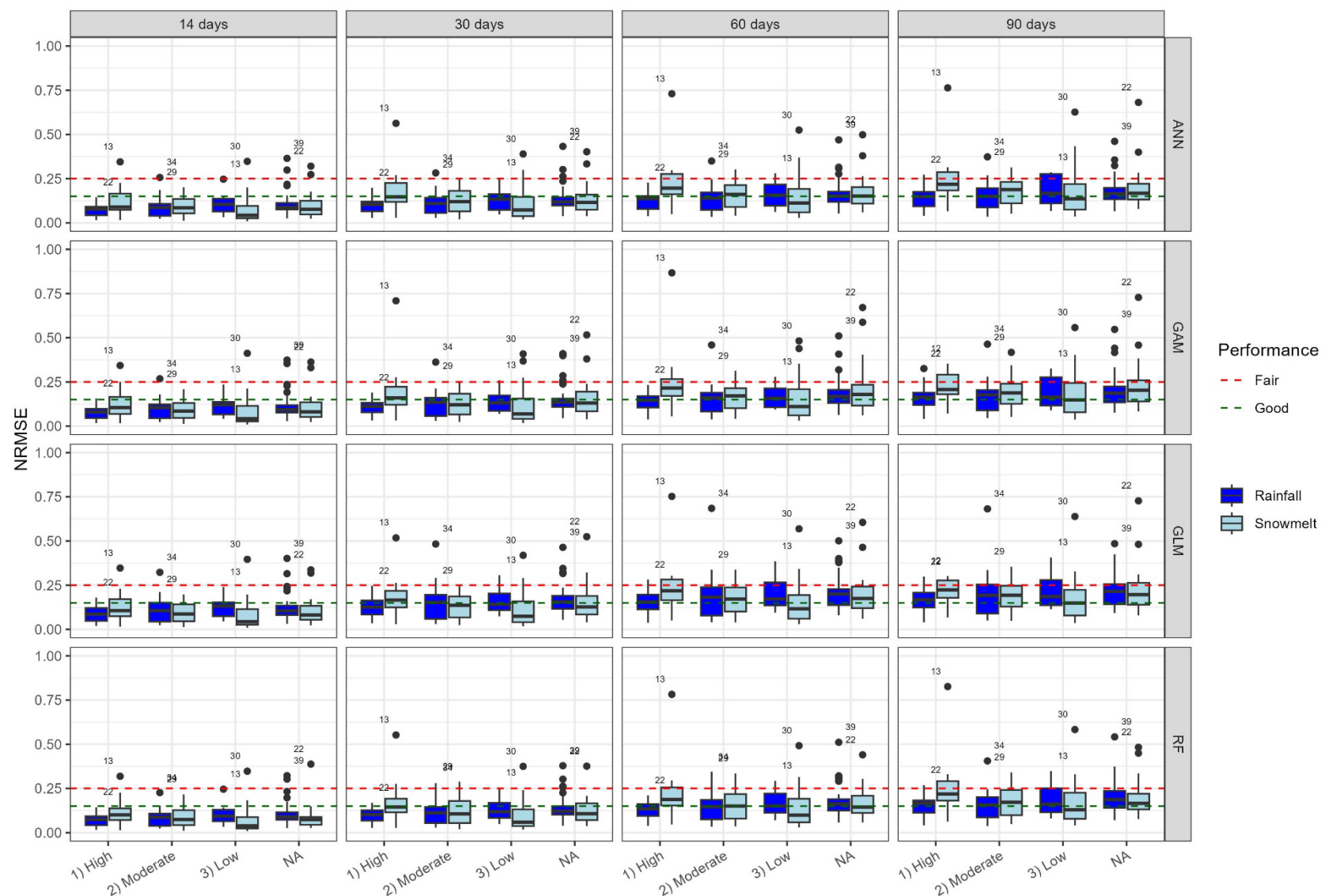


Figure 32 Model Performance (R^2) for dominant response mechanisms from Gullacher et al. (2021).

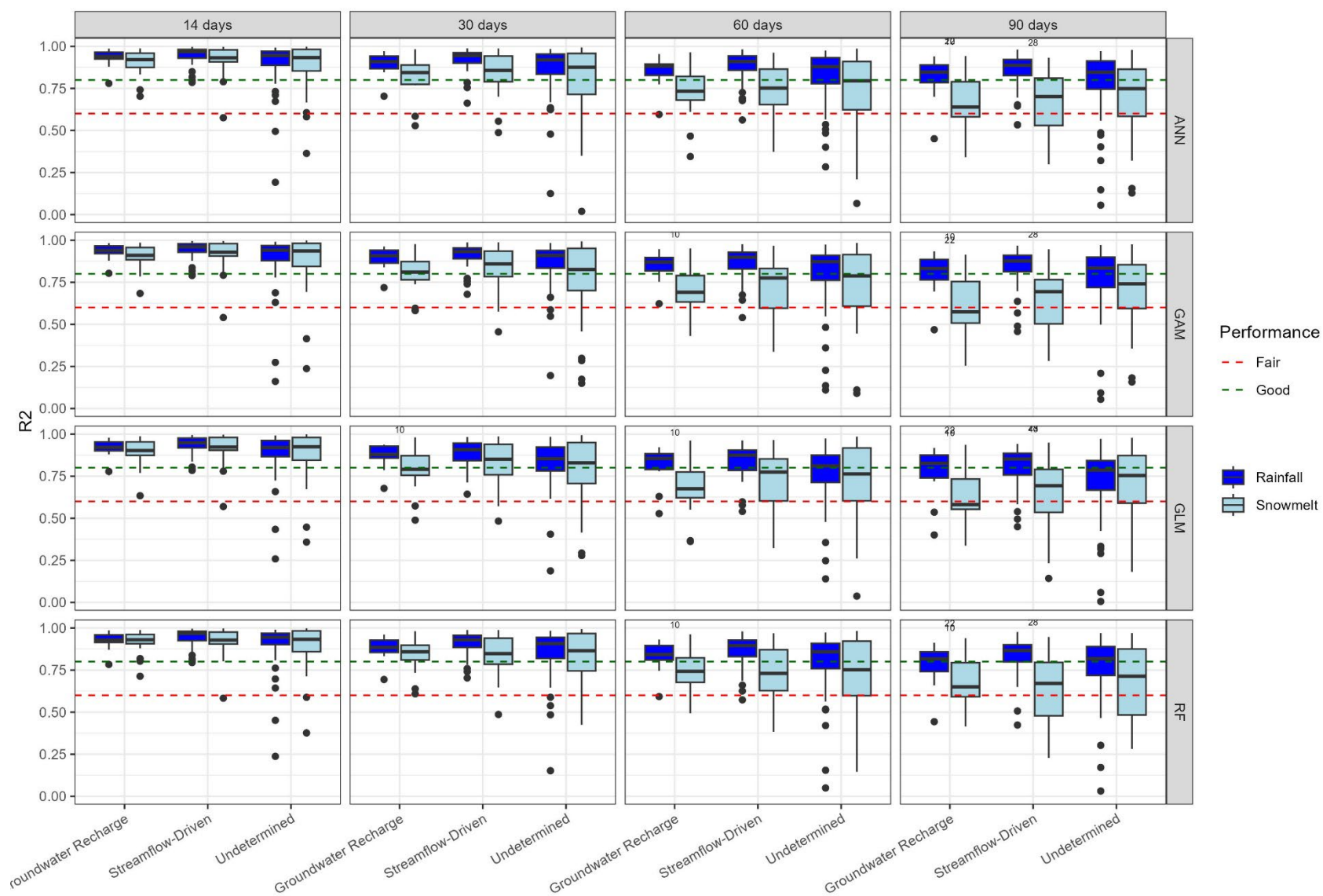
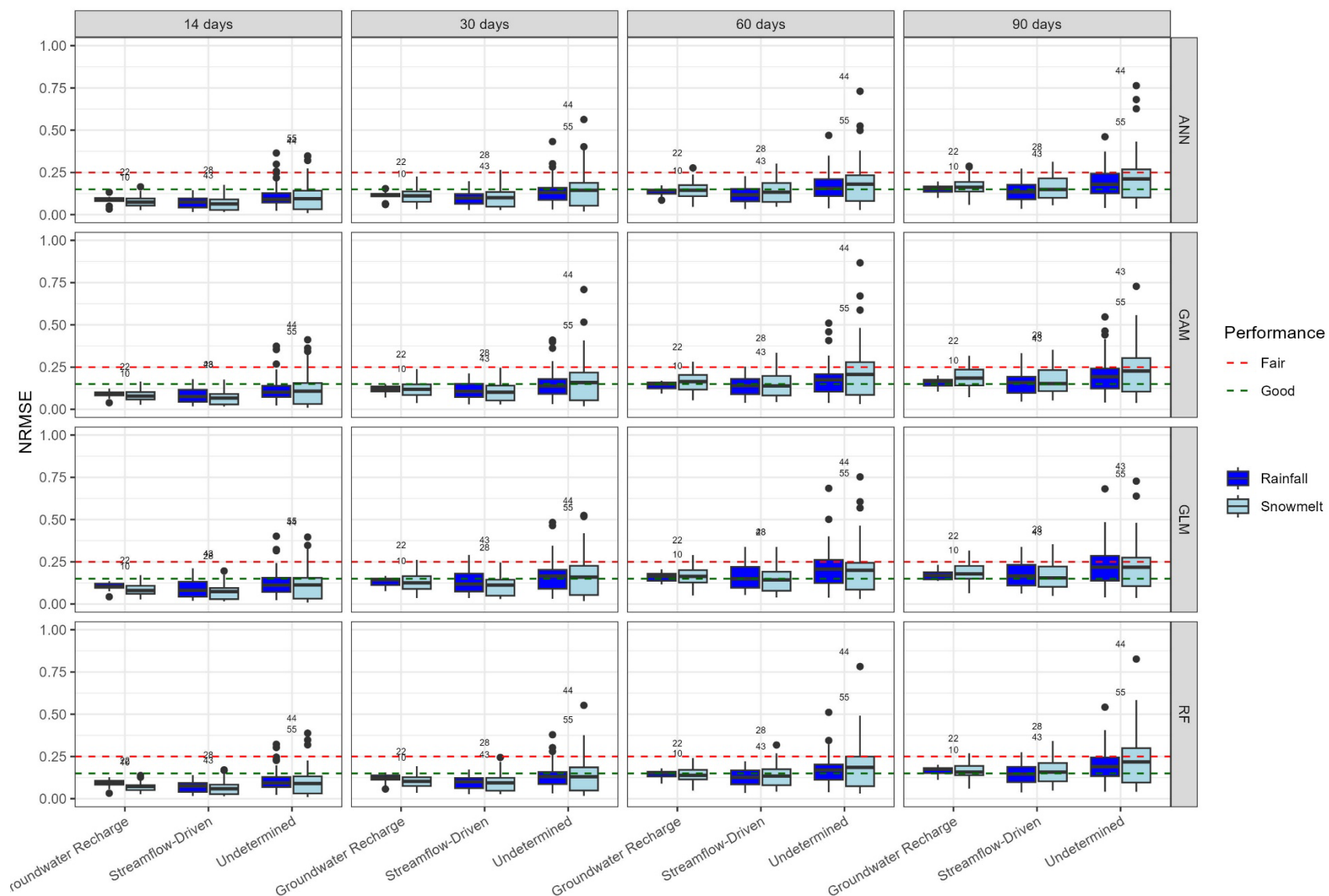


Figure 33 Model Performance (NRMSE) for dominant response mechanisms from Gullacher et al. (2021).



5.0 OPERATIONAL TESTING

5.1 APPROACH

In general, the approach to operational testing remains largely unchanged from Phase 1. For operational forecasting, data on antecedent conditions is used as previously described (Section 3.0), but the approach to using seasonal predictors (i.e., hydroclimatic data for the forward-looking forecast period) is different. This is because for model performance testing, historical data on seasonal predictor variables was available (i.e., historical conditions are known) whereas in an operational forecast mode, future seasonal hydroclimatic conditions are uncertain. For the operational forecasting, historical hydroclimatic variability over the forecast period is therefore used instead. This includes consideration for historical ranges of:

- Precipitation (rainfall and snowmelt settings).
- Temperature (rainfall and snowmelt settings).
- Snowmelt (snowmelt settings only).

The definition and use of these historical hydroclimatic variables is described in Section 3.3.2.

Given the poorer model validation results of RF (Section 4.3) and its much longer model run times, its results were not included in the operational testing, which focuses on ANN, GAM and GLM models.

5.2 HISTORICAL RANGES FOR SEASONAL PREDICTOR VARIABLES

Similar to the approach utilized in Phase 1, the historical ranges for each of the seasonal predictor variables for any given day of the year (temperature, precipitation, and snowmelt), were established using data from the period 2004 to 2024. Using these historical ranges, multiple groundwater level forecasts were generated through a Monte Carlo approach. This method involves varying each predictor variable independently within a normal distribution of historical ranges over the forecast window on a given day of the year. This approach was designed to determine the groundwater level uncertainty associated with climate variability. For forecasting purposes, 500 simulations are conducted using different combinations of the historical percentiles for each of the variables considered (i.e., 0 to 100% of historical precipitation, temperature or snowmelt on a given day). This number of simulations was found to provide a comprehensive coverage of climate variability in both rainfall and snowmelt settings. The results of the Monte Carlo simulations can be presented as likelihoods, demonstrating the probability of various groundwater level ranges occurring.

Historical snowmelt ranges were defined by the changes in SWE over the given forecast interval during the corresponding time of year. These snowmelt ranges were further constrained by the amount of SWE available for melting. This means that the maximum amount of snowmelt is limited to the available SWE, ensuring a realistic representation of potential snowmelt.

The adopted approach to using seasonal predictor variables is subject to the following limitations:

- Future hydroclimatic conditions are to some degree known in the short-term (i.e., from quantitative weather forecasts) but are treated as uncertain. The adopted methodology may therefore overestimate groundwater level forecast uncertainty under typical conditions. The

refinement of using short-term weather forecasts is implemented in Section 6.0 (operational implementation).

- Conversely, the adopted approach does not account for potential hydroclimatic variability outside historical ranges. This could become a concern as extreme weather events are predicted to become more common due to climate change (e.g., the recent heat dome and atmospheric river events).

5.3 OPERATIONAL DEPENDANCE ON CLIMATE FORECASTS

Validation testing was performed in Section 4.0, focusing on pure model performance using recorded data of actual conditions. However, since forecast predictor variables are unknown in an operational setting, operational testing aims to determine how well the range of potential inputs, derived from Monte Carlo simulations of historical conditions, can represent future groundwater level conditions. In this context, groundwater level forecasts are subject to both model uncertainty and hydroclimatic uncertainty for the forecast period. Given that model performance has been evaluated, the goal of operational testing is to determine the value these wells have at forecasting 14, 30, 60, and 90 days in advance or if they are highly dependent on future climate variability (i.e., providing groundwater forecasts that are highly dependent on future climate which is inherently uncertain without reliable forecasts). This is not an indication of overall model performance in a well but more of an indication of how reliant the well is on good climate forecasts.

For longer forecasting periods, results from some wells lead to a wide spectrum of forecasted groundwater levels, often mirroring the historical range. The average of forecast results tends to align with the average of historically observed groundwater levels. This uncertainty is predominantly attributed to the dependence of groundwater level forecasts on future climate forecast and conditions (climate forecasts) over antecedent conditions, with future conditions inherently uncertain.

For each well the forecast period at which this tendency occurs is assessed using the RMSE Skill Ratio (RSR). This value is calculated by comparing the RMSE of forecasted groundwater levels to observed groundwater levels over the entire cross-validation dataset, with the RMSE between long-term daily average water levels (for a given day of the year) and observed levels. The ratio of these two RMSE values indicates how far the model predictions can provide value without certainty in climate forecasts.

The RSR compares:

$$RSR = \frac{\text{RMSE (simulation – observed)}}{\text{RMSE(average water level – observed)}}$$

Results can be interpreted as:

- Results less sensitive to future climate: An RSR below 1 indicates that forecasted groundwater levels provide a better result than just using average historical groundwater levels as an estimate of future conditions (i.e., the simulation results are closer to observed groundwater results than the 2004-2024 historical average groundwater level). This indicates the model can provide valuable forecasts of future groundwater levels even without accurate hydroclimatic forecast data and the groundwater level forecast is less sensitive to future climate variability.

- Results more sensitive to future climate : An RSR around or above 1 indicates that the prediction at a given forecast period becomes reliant on future climate variability, as the forecast results under typical conditions approaches average groundwater level conditions. This does not necessarily mean that the model results are not valuable, but it does indicate that the model is more reliant on future climate conditions than on antecedent climate and groundwater conditions at the time forecast is made. Therefore, the model is limited in its ability to provide firm forecasts of future groundwater levels without accurate forecast hydroclimatic data and the results could therefore likely be improved with better (and/or longer-term) climate forecast inputs.

5.4 EVALUATING FORECAST RESULTS

Figure 34 compares the RSR of the 14, 30, 60, and 90-day forecast performance for the ANN, GAM and GLM recharge types. Individual well RSR values from operational testing can be found in Appendix A3. Generally, for lower RSR values the groundwater level forecast is less dependent on future climate variability (and more dependent on antecedent conditions at time forecast is made), with results above 1 indicating that without reliable climate forecasts, the forecasted groundwater level ranges are likely no more instructive than the historical groundwater level ranges at the forecast date without reliable climate forecasts. The following is noted:

- For shorter forecast periods (14 and 30 days), the groundwater level forecast results for most wells rely mostly on antecedent conditions and are less sensitive to future climate variability providing results that are less reliant on accurate climate forecasts (i.e. RSR values almost exclusively less than 1).
- When forecasting 60 days in advance, the forecasts for a portion of wells become more dependent on future climate variability (some RSR values greater than one particular for snowmelt recharge settings), and by 90 days, forecasts for about half of the wells are sensitive to future climate variability (i.e., groundwater level forecasts are uncertain without accurate climate forecasts).
- Across all forecast periods, model results in rainfall recharge settings are less subject to future climate variability than wells in a snowmelt recharge setting, possibly due to uncertainty regarding climate variability effects on the timing of the snowmelt.

Some specific examples from operational testing that illustrate model performance are provided for context. The figures show observed historical groundwater levels from 2014 to 2024 together with the long-term seasonal average water level, while the forecast results show simulated ranges of groundwater levels utilizing historical climate data from 2004 to 2024 as well as the forecast result under typical climatic conditions over this period. Actual recorded groundwater levels for 2024 are also shown. The examples illustrate the following:

- Figure 35 shows results for confined aquifer well OW002 for 2024 with a long recharge lag in a rainfall recharge setting. The model results indicate a low RSR (less than 1). This suggests that the forecasted groundwater levels rely more on antecedent climate and groundwater conditions (i.e. conditions at time groundwater level forecast is made) and less on future climate

conditions, thereby providing informative groundwater level predictions even if future climate conditions are uncertain.

- Figure 36 shows the results for OW406 for 2024, which is an example of a rainfall recharge setting with more responsive groundwater levels (short recharge lag). Operational testing indicates a high RSR (above 1), suggesting that 90-day simulations are largely dependent on future climate conditions. As a result, forecasted groundwater levels are very similar to the observed groundwater level range. In this case, groundwater forecast results could provide a narrow range of accuracy with better knowledge of future climatic conditions (climate forecasts).
- Figure 37 shows the results for OW185 for 2024 an example for a snowmelt recharge setting. The model results indicate a low RSR (less than 1). This suggests that forecasted groundwater levels rely mostly on antecedent conditions (climate and groundwater) at the time the forecast is made and less on future climate conditions, thereby providing informative groundwater level predictions even if future climate conditions are uncertain..
- Figure 38 shows the results for OW375 for 2020 an example for a snowmelt setting. Operational testing indicates a high RSR (above 1), suggesting 90-day groundwater level forecasts that are highly dependent on future climate conditions. Groundwater forecast results could provide a narrow range of accuracy with better knowledge of future climatic conditions (climate forecasts).
- Figure 39 shows the results for OW035 for 2023, an example of a well with a long-term trend in groundwater levels causing a wide historical range of groundwater levels. Groundwater level forecasts for this well relies heavily on antecedent conditions (climate and groundwater) rather than future climate variability. Deviation in forecasted groundwater levels from observed conditions is more likely to be based on pure model error (i.e., ability to simulate the long-term fluctuation in groundwater levels from year to year) rather than climate forecast variability.

Figure 34 RMSE Skill Ratio (RSR) for various forecast periods, model types and recharge settings.

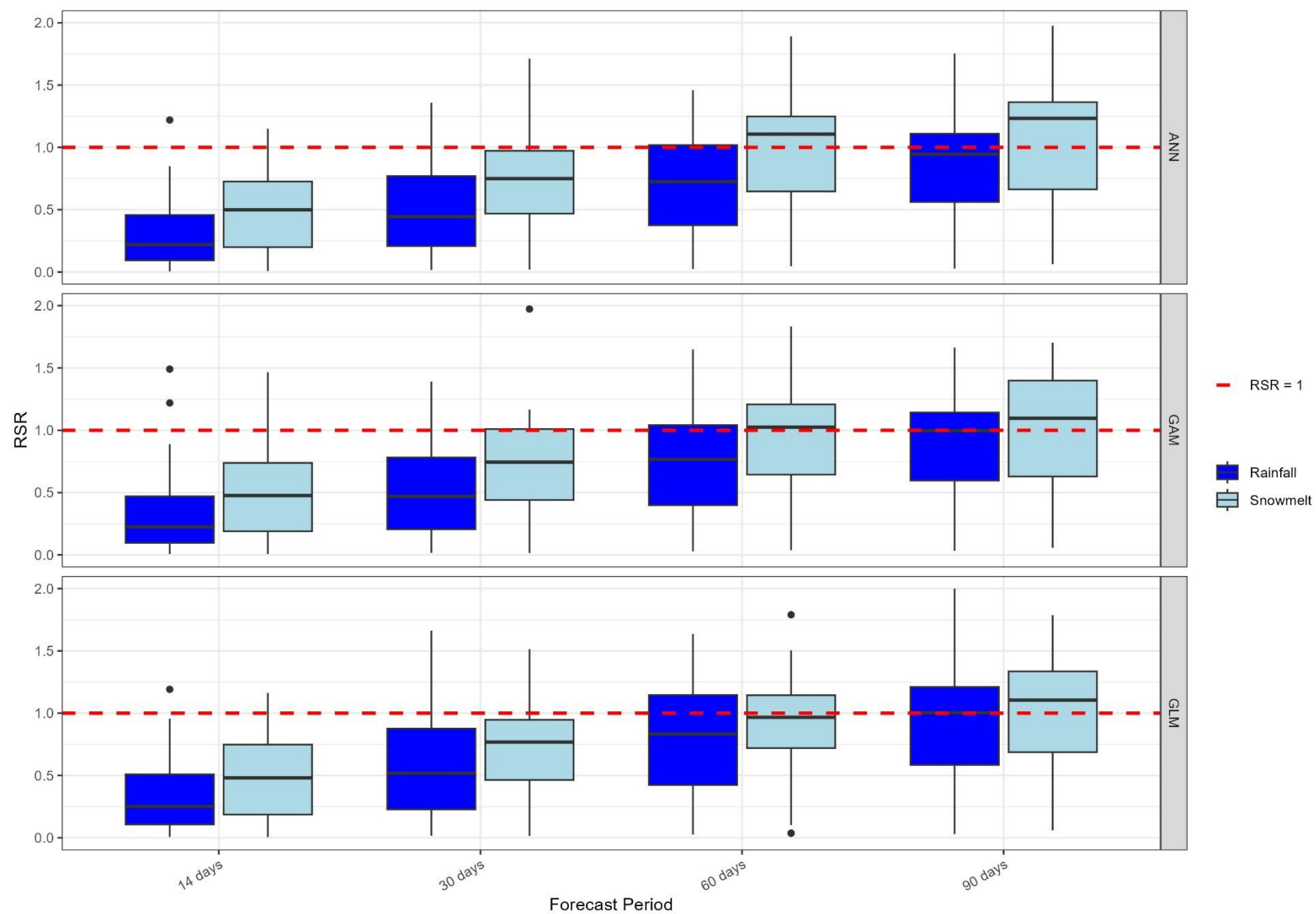


Figure 35 Operational testing for OW002 in 2024 (rainfall setting – results less sensitive to future climate).

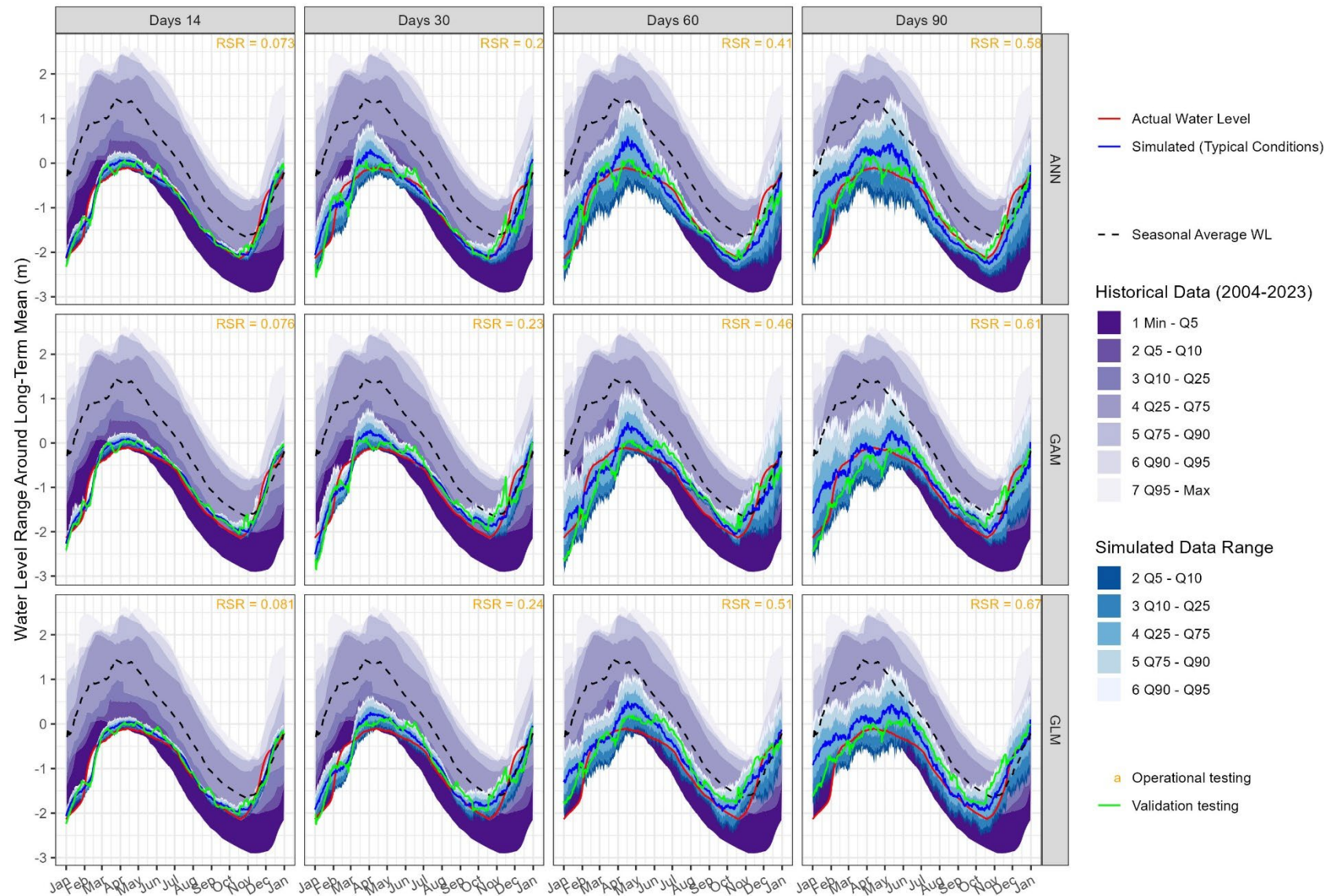


Figure 36 Operational testing for OW406 in 2024 (rainfall setting – results more sensitive to future climate).

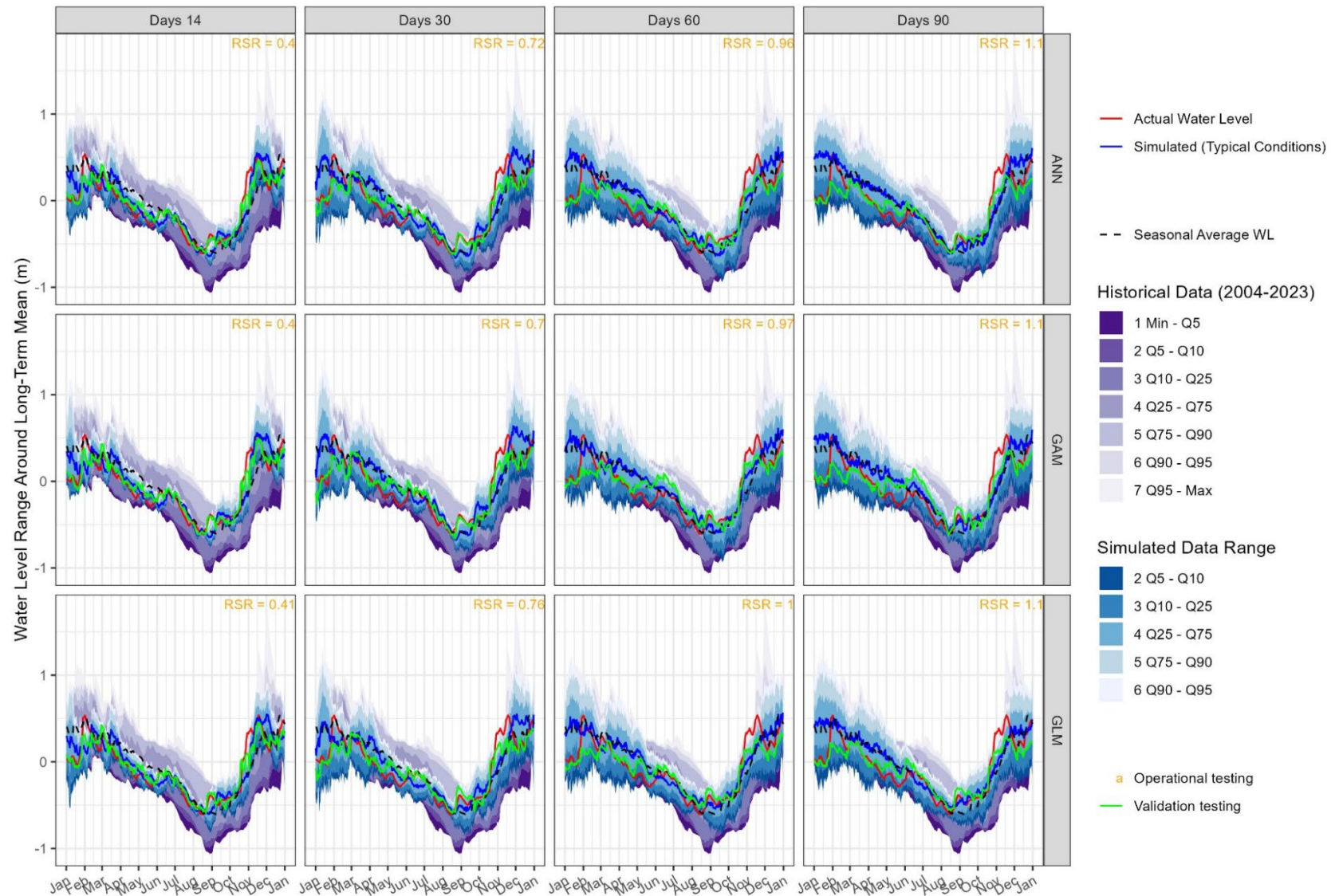


Figure 37 Operational testing for OW185 in 2024 (snowmelt setting - results less sensitive to future climate).

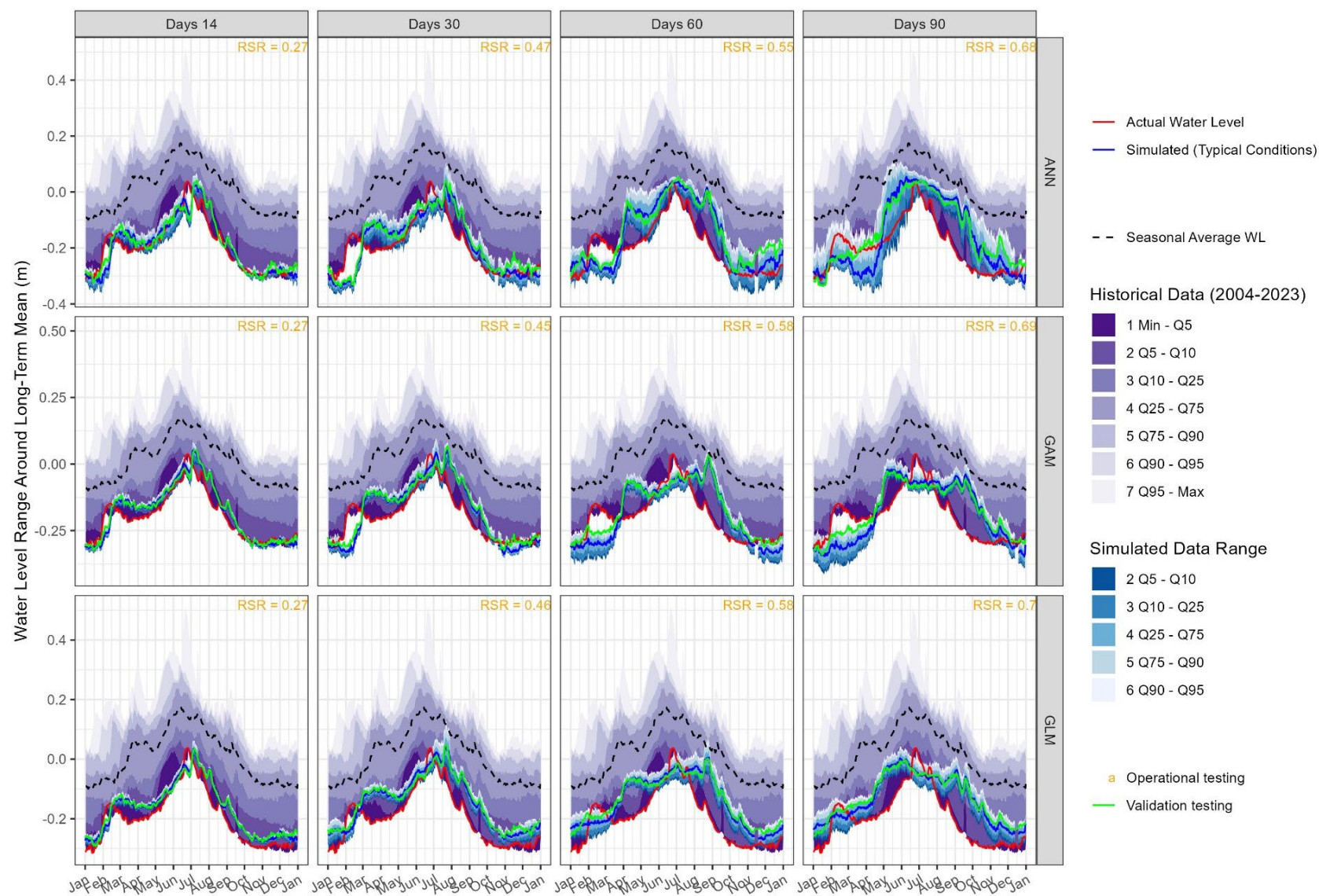


Figure 38 Operational testing for OW375 in 2020 (snowmelt setting - forecast more sensitive to future climate).

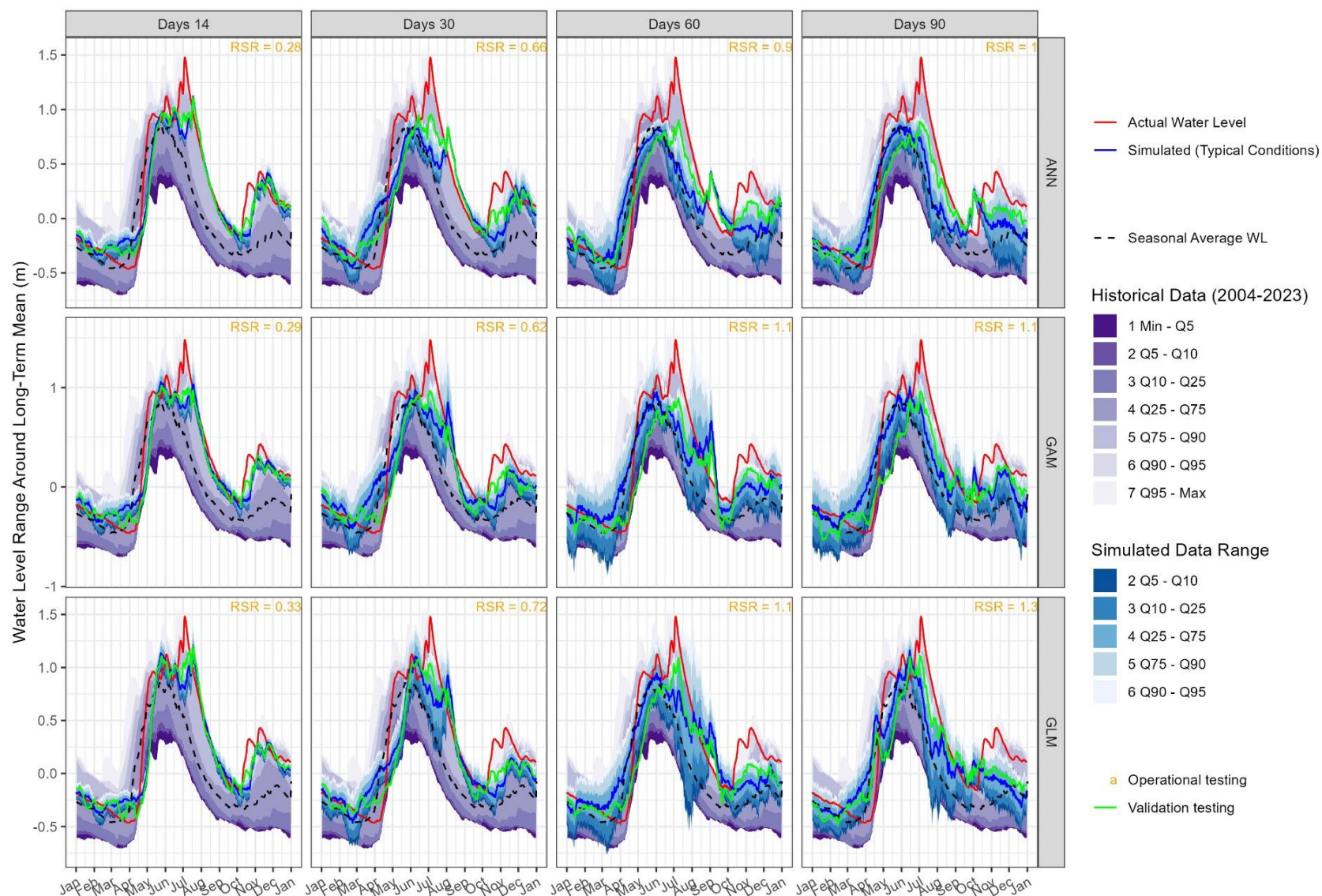
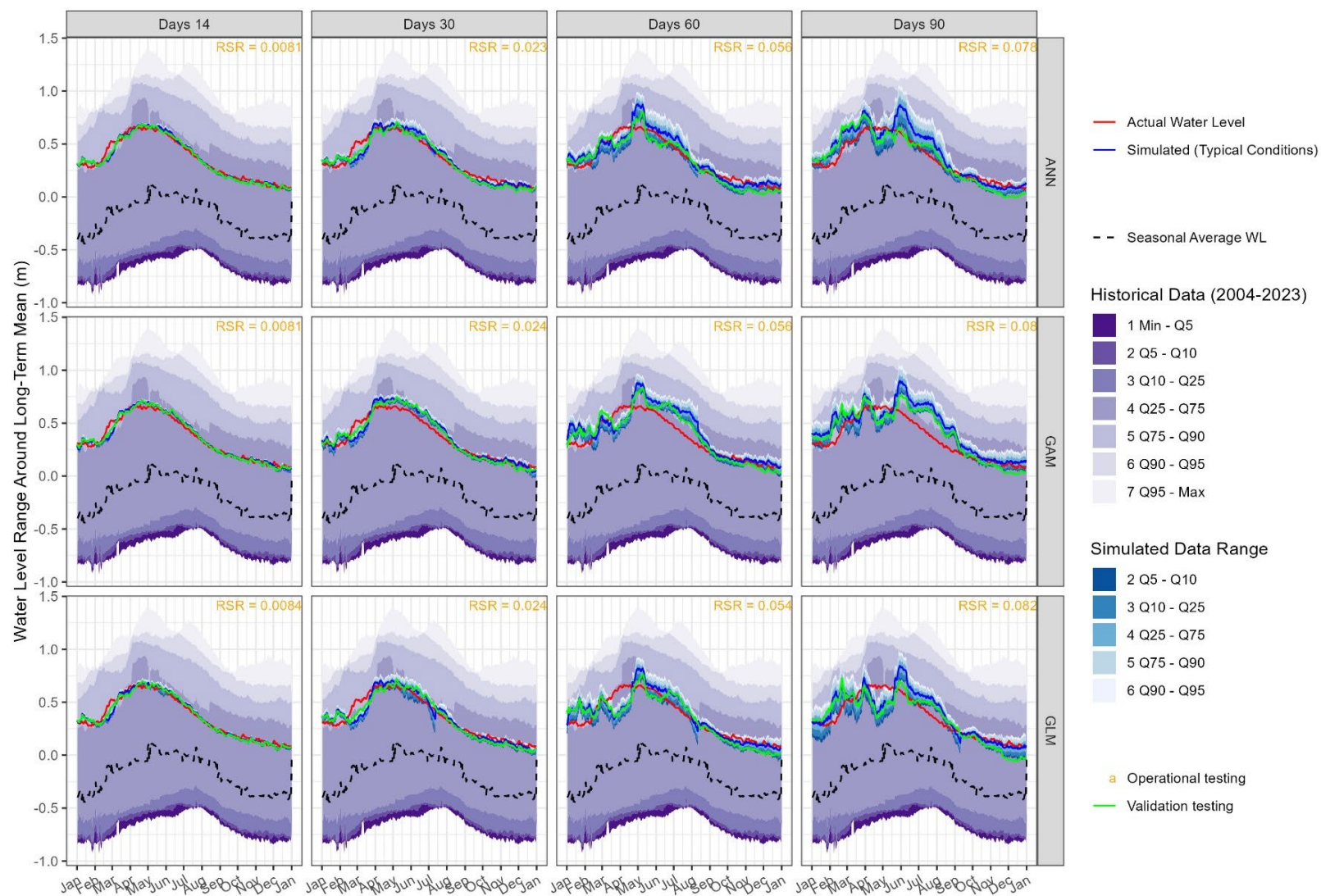


Figure 39 Operational testing for OW035 in 2023 (long-term trends – forecast less sensitive to future climate).



5.5 COMBINED ASSESSMENT

In the combined assessment well recommendations and model performance are finalized based on validation testing and operational testing. The 90-day forecast results were used to filter and categorize model validation performance. Although many wells that perform poorly at 90-day forecasts may exhibit fair or good performance over shorter periods (14, 30, or 60 days), this approach sets an inclusion threshold requiring that wells are characterized by at least a fair or good model validation performance at the 90-day forecasts to be recommended for inclusion into operational implementation. The combined results of the model validation and operational testing have led to a total of five categories of model evaluation:

1. Poor model validation results: Forecast results of no value. This category includes wells that do not meet the R^2 and NRMSE value thresholds outlined in Section 4.2 during validation testing. The forecast results are considered to have no value.

The next four categories reflect fair or good model performance as determined by validation testing with thresholds outlined in Section 4.2 for 90-day forecast periods. This includes two categories dependent on RSR results, indicating whether 90-day forecast results can provide valuable information that outperforms simply relying on average historical groundwater levels to inform future conditions, or whether the results are subject to high rely on climatic forecasting meaning results are highly subject to future climate variability.

2. Good model validation performance, groundwater level forecast less sensitive to future climate.
3. Good model validation performance, groundwater level forecast more sensitive to future climate .
4. Fair model validation performance, groundwater level forecast less sensitive to future climate
5. Fair model validation performance, groundwater level forecast more sensitive to future climate .

Of the 203 wells tested, the classification summary is presented in Table 2, with the following observations:

- ANN model forecasts have the highest number of wells with good validation performance and are less sensitive to future climate forecasts, followed by GAM, and lastly GLM. ANN models also had the fewest wells classified as poor model results, with about 29%, compared to 33% for GAM, 41% for GLM and 30% for RF. This results in 145 wells usable for forecasting with the ANN model, 137 for the GAM, 120 for the GLM, and 144 for the RF. It is therefore recommended that operational forecasting solely be done with the ANN model.
- ANN model forecasts also produce the largest number of wells classified as “Good Performance” with 62 wells compared to 56 - 53 wells for GAM , GLM and RF models.
- The South Coast region had a larger number of wells with poor results compared to Vancouver Island and the Gulf Islands. Several competing factors, discussed in Section 4.2, notably impacted the models' worst performance on wells in aquifers connected to the Fraser River (Cluster 2) in the Lower Mainland.

Of the 145 wells that achieved at least a “Fair” performance rating using the ANN model, a summary of observational performance testing is presented in Table 3. The following key observations were made:

- For all wells, at a 14-day forecast horizon, the RSR values were consistently below 1, indicating that groundwater level forecasts were relatively insensitive to future climate conditions. However, forecast accuracy declined with longer lead times, with performance dropping to 99% at 30 days, 81% at 60 days, and 67% at 90 days.
- Wells located in rainfall-dependent regions, such as the South Coast, Vancouver, and the Gulf Islands exhibit greater sensitivity to future climate conditions with a lower amount of RSR values below 1 at higher forecast periods compared to snowmelt dominated regions. As a result, accurate long-term groundwater level forecasting in these areas requires more reliable climate projections.

Table 2 **Summary of model validation performance assessment for 90 day forecast period.**

Region/Recharge Type	Model	Total Number of Wells	Wells Not Carried Forward (Poor Model Validation)		Wells Carried Forward from Model Validation		Categories of 90 day Forecast Performances for Wells Carried Forward			
			Number Wells	% of Wells	Number Wells	% of Wells	Good Model Validation Performance		Fair Model Validation Performance	
							Number Wells	% of Wells	Number Wells	% of Wells
South Coast	ANN	54	17	31%	37	69%	19	35%	18	33%
	GAM	54	17	31%	37	69%	17	31%	20	37%
	GLM	54	23	43%	31	57%	16	30%	15	28%
	RF	54	20	37%	34	63%	16	30%	18	33%
Vancouver and Gulf Islands	ANN	71	12	17%	59	83%	20	28%	39	55%
	GAM	71	13	18%	58	82%	18	25%	40	56%
	GLM	71	24	34%	47	66%	16	23%	31	44%
	RF	71	13	18%	58	82%	19	27%	39	55%
Interior	ANN	62	21	34%	41	66%	19	31%	22	35%
	GAM	62	26	42%	36	58%	14	23%	22	35%
	GLM	62	26	42%	36	58%	15	24%	21	34%
	RF	62	20	32%	42	68%	17	27%	25	40%
Northern	ANN	16	8	50%	8	50%	4	25%	4	25%
	GAM	16	10	63%	6	38%	4	25%	2	13%
	GLM	16	10	63%	6	38%	5	31%	1	6%
	RF	16	7	44%	9	56%	4	25%	5	31%
Rainfall	ANN	125	29	23%	96	77%	39	31%	57	46%
	GAM	125	30	24%	95	76%	35	28%	60	48%
	GLM	125	47	38%	78	62%	32	26%	46	37%
	RF	125	33	26%	92	74%	35	28%	57	46%
Snowmelt	ANN	78	29	37%	49	63%	23	29%	26	33%
	GAM	78	36	46%	42	54%	18	23%	24	31%
	GLM	78	36	46%	42	54%	20	26%	22	28%
	RF	78	27	35%	51	65%	21	27%	30	38%

Table 2 (Cont'd.)

Region/Recharge Type	Model	Total Number of Wells	Wells Not Carried Forward (Poor Model Validation)		Wells Carried Forward from Model Validation		Categories of 90 day Forecast Performances for Wells Carried Forward			
							Good Model Validation Performance		Fair Model Validation Performance	
			Number Wells	% of Wells	Number Wells	% of Wells	Number Wells	% of Wells	Number Wells	% of Wells
All Wells	ANN	203	58	29%	145	71%	62	31%	83	41%
	GAM	203	66	33%	137	67%	53	26%	84	41%
	GLM	203	83	41%	120	59%	52	26%	68	33%
	RF	203	60	30%	143	70%	56	28%	87	43%

Table 3 **Summary of model operational performance assessment for different forecast periods with ANN model.**

Region/Recharge Type	Forecast Period	Total Wells	Results Less Sensitive to Future Climate (RSR < 1)		Results Sensitive to Future Climate (RSR > 1)	
			Number of Wells	% of Wells	Number of Wells	% of Wells
South Coast	14 days	37	37	100%	0	0%
	30 days	37	37	100%	0	0%
	60 days	37	29	78%	8	22%
	90 days	37	22	59%	15	41%
Interior	14 days	41	41	100%	0	0%
	30 days	41	41	100%	0	0%
	60 days	41	40	98%	1	2%
	90 days	41	34	83%	7	17%
Vancouver and Gulf Islands	14 days	59	59	100%	0	0%
	30 days	59	58	98%	1	2%
	60 days	59	41	69%	18	31%
	90 days	59	33	56%	26	44%
Northern	14 days	8	8	100%	0	0%
	30 days	8	8	100%	0	0%
	60 days	8	8	100%	0	0%
	90 days	8	8	100%	0	0%
Rainfall	14 days	96	96	100%	0	0%
	30 days	96	95	99%	1	1%
	60 days	96	70	73%	26	27%
	90 days	96	55	57%	41	43%
Snowmelt	14 days	49	49	100%	0	0%
	30 days	49	49	100%	0	0%
	60 days	49	48	98%	1	2%
	90 days	49	42	86%	7	14%
All Wells	14 days	145	145	100%	0	0%
	30 days	145	144	99%	1	1%
	60 days	145	118	81%	27	19%
	90 days	145	97	67%	48	33%

6.0 OPERATIONAL IMPLEMENTATION

6.1 MODEL STRUCTURE AND WORKFLOW

The overall forecast model structure builds on the methods used in Phase 1 of the project, with additional aspects introduced through new approaches such as the dynamic weighting over the recharge lag period (Section 3.0). Based on the outcomes of validation testing (Section 4.0), operational testing, and the combined assessment (Section 5.0), the ANN model was recommended for producing outputs due to its best overall performance linked to the ability (flexibility) to distinguish between linear and non-linear relationships between groundwater levels and hydroclimatic predictor variables, which vary across wells in the province.

Another major difference from Phase 1 is the inclusion of a much larger number of PGOWN wells in the groundwater level forecasting (145 wells, after 58 were removed). Model run time and memory became important factors, which were resolved by two changes:

- The models are run for separate regional groups containing up to approximately 25 wells each.
- The model structure is now separated into different components. The first component is model training; this does not need to be done frequently (just seasonally). The second component takes the trained and saved models, downloads updated data and makes predictions.

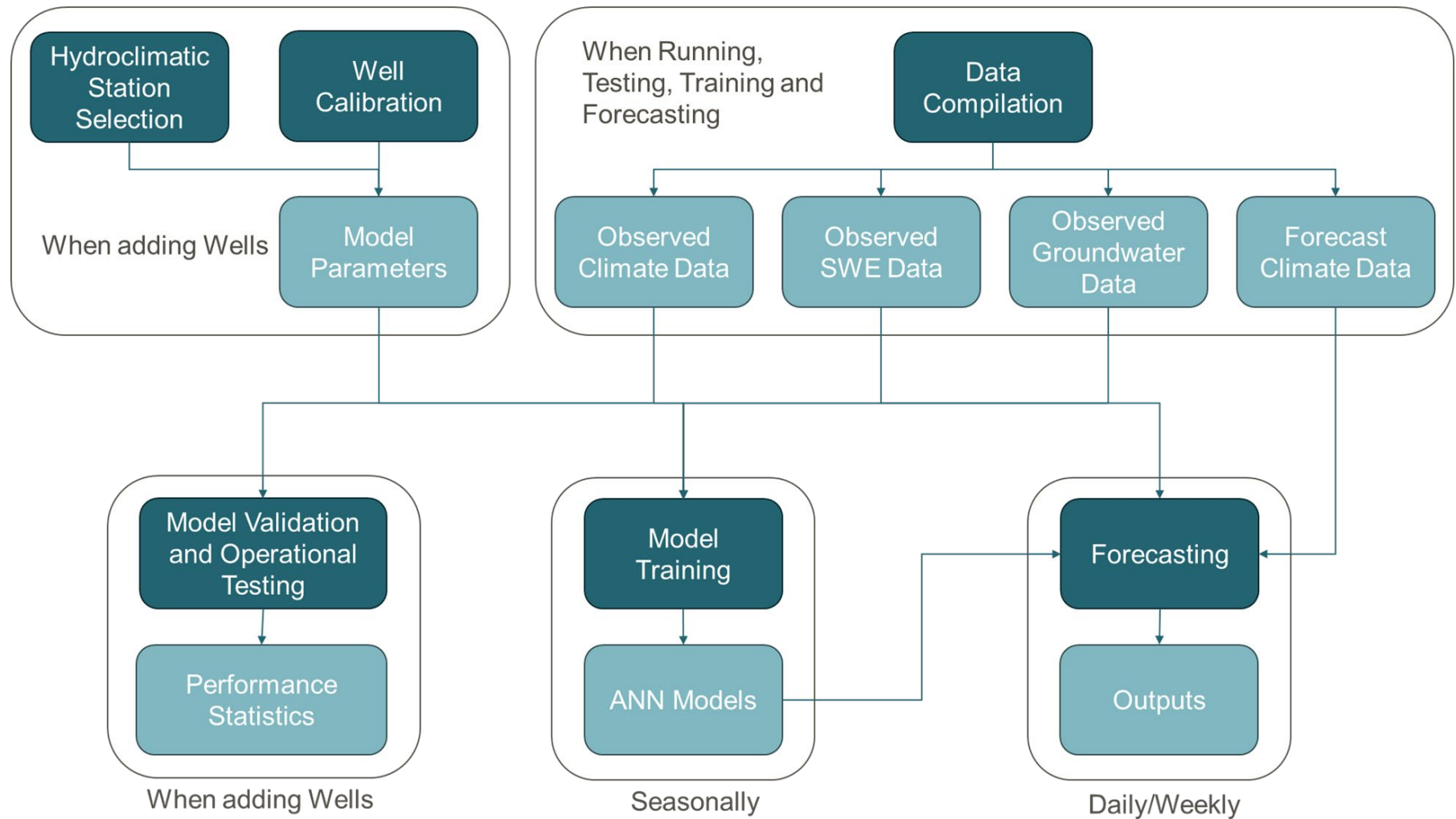
Groundwater level forecasting has also been modified from Phase 1 with the incorporation of deterministic and ensemble climate forecast outputs from RFC (Section 6.2).

Details of the operation and script structure for the overall models can be found in Appendix A2. The overall groundwater forecasting model structure is shown in Figure 40 and summarized below:

- Step 1: Data Compilation - Once appropriate climate and SWE stations are identified, the necessary data for validation, testing, and operation is compiled. This includes R scripts for downloading and compiling the real-time data. This step is largely unchanged from Phase 1 but now includes downloading the outputs from RFC (discussed in Section 6.2).
- Step 2: Training of Models - ANN models are trained separately for each well and groundwater forecast period, saving the models. This needs to be done infrequently (yearly or seasonally).
- Step 3: Forecasting and Generating Outputs - This is done more frequently, generating model predictions.

A summary of wells recommended to be included in groundwater level forecasting, along with necessary inputs (calibration values, climate stations, etc.), can be found in Appendix A4.

Figure 40 **Forecasting model workflow.**



6.2 RFC CLIMATE FORECASTING

The RFC generated climate forecasts includes a deterministic 10-day period and an ensemble climate forecast of 20 scenarios extending up to 16 days in advance. The following approach was utilized in compiling the climate forecast:

- The first 10 days of any climate forecast were deterministic.
- The period from days 10 to 16 was infilled with longer-term ensemble climate forecasts, creating 20 scenarios with the first 10 days determined by the deterministic climate forecast.
- Beyond 16 days, historical variability was determined using the Monte Carlo approach from Phase 1, which is further discussed in Section 5.0.

The RFC generates climate forecasts at various locations around the province. For each PGOWN well, the closest climate forecast station was chosen as the climate forecast station. This selection ensures that the climate forecasts are as relevant and accurate as possible for the specific conditions at each well.

6.3 OUTPUTS

The currently developed operational groundwater forecasting outputs for Phase 2 are illustrated in Figure 41 and Figure 42, which show output examples for rainfall dominated setting wells OW002 and OW310, respectively, and in Figure 43 for an example snowmelt dominated setting well (OW291). The output format overall captures a 1-year (365 day) period with the 90-day maximum forecast period being placed at the end of this period and actual recorded groundwater levels for the 275-day period up to the date the model is run (in this case 2025-06-24) being shown for context. Forecasted groundwater levels 14, 30, 60, and 90 days in advance are shown as box plots for the ANN model, with the center line being the typical or 50th percentile typical conditions for the forecast periods and upper and lower limits of the box representing the 25th and 75th percentile ranges, and the error bars representing the 10th and 90th percentile ranges of the predicted groundwater levels from Monte Carlo simulations. An additional table presents the likelihood of predicted groundwater levels falling into one of three categories:

- above normal, where the groundwater levels exceed the historical 75th percentile,
- normal, where groundwater levels fall within the historic 25th to 75th percentile range, and
- below normal, where groundwater levels are below the historic 25th percentile.

These categories were determined based on the percentage of Monte Carlo simulations that produced groundwater levels within each respective range (i.e., out of the total of 500 model runs). The likelihood percentages are provided for the ANN models. Which of these approaches to determining groundwater level range likelihood is preferred may depend on the model performance as well as the intended use of the groundwater forecast.

Groundwater level forecast (model) performance for associated forecast periods for a given well is represented in the output plots as changing colors. Performance is displayed as categorical model performance categories defined in Section 5.5 as Categories of Acceptable Groundwater Forecast Performances. This is displayed as:

- Green for "Good, Forecast less sensitive to future climate ",

- Yellow for "Good, Forecast more sensitive to future climate ",
- Orange for "Fair, Forecast less sensitive to future climate ", and
- Red for "Fair, Forecast more sensitive to future climate ".

Wells that are classified as " Forecast more sensitive to future climate " reflect when forecast period for a given well relies heavily on future climate conditions, in this case the predicted groundwater range may reflect the historical groundwater range. For some wells this will only happen over very long forecast periods whereas for other wells this may already happen at shorter forecast periods.

Figure 42 represents a well (OW310) whose groundwater forecasted performance for different periods spans three performance categories. The 14-day groundwater forecasts are classified as "Good, Forecast less sensitive to future climate", the 30 and 60-day groundwater forecasts are classified as "Fair, Forecast less sensitive to future climate", and the 90-day groundwater forecasts are classified as "Fair, Forecast more sensitive to future climate".

Additional data on aquifer type and incorporated data is included adjacent to the plot legend above the likelihood of groundwater level data. This includes information such as main climate station and SWE station, and information about the aquifer. Below the groundwater level data, information will be included for the previous 30-day cumulative precipitation, temperature, and, in the case of snowmelt setting wells, SWE. Also included are results of the RFC deterministic and ensemble climate forecasts. In addition, the blue bars in the precipitation information diagram represent the varying aquifer recharge lag periods (indicated by blue dots) and highlight the timeframes (blue bars) when groundwater levels are most sensitive to climate inputs.

While the evaluation of model performance was conducted for the period from 2004 – 2024, all models will be updated to train on and incorporate new and additional data for groundwater forecasting purposes post-2024.

Details and a user-guide to how to perform utilizing the groundwater forecasting tool can be found in Appendix A2.

Figure 41 Example of model groundwater forecast output for OW002 (Abbotsford) on 2025-06-24.

OW002 - Abbotsford, rainfall dominated environment (Prediction Date: 2025-06-24)

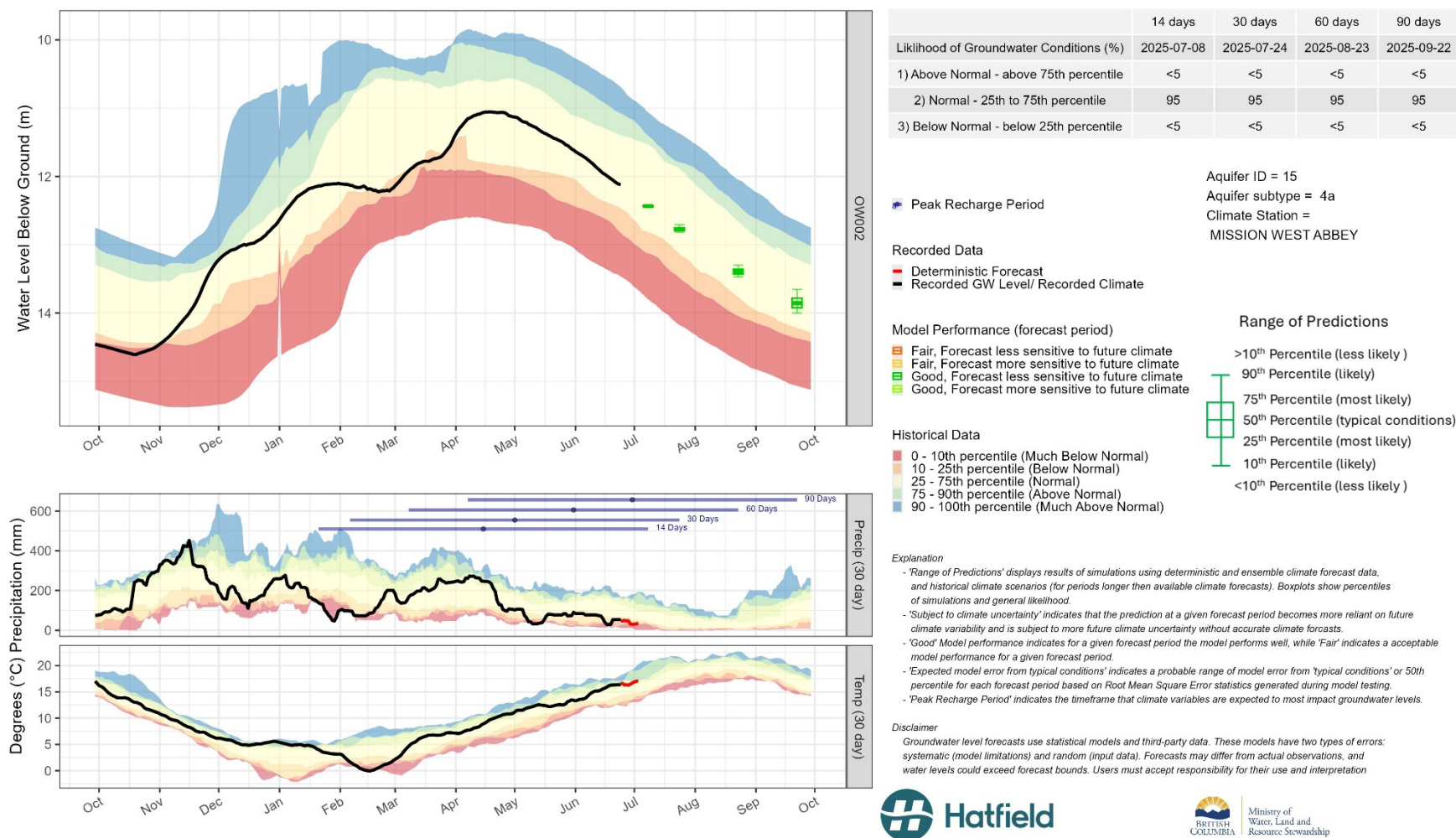


Figure 42 Example of model groundwater forecast output for OW310 (Abbotsford) on 2025-06-24.

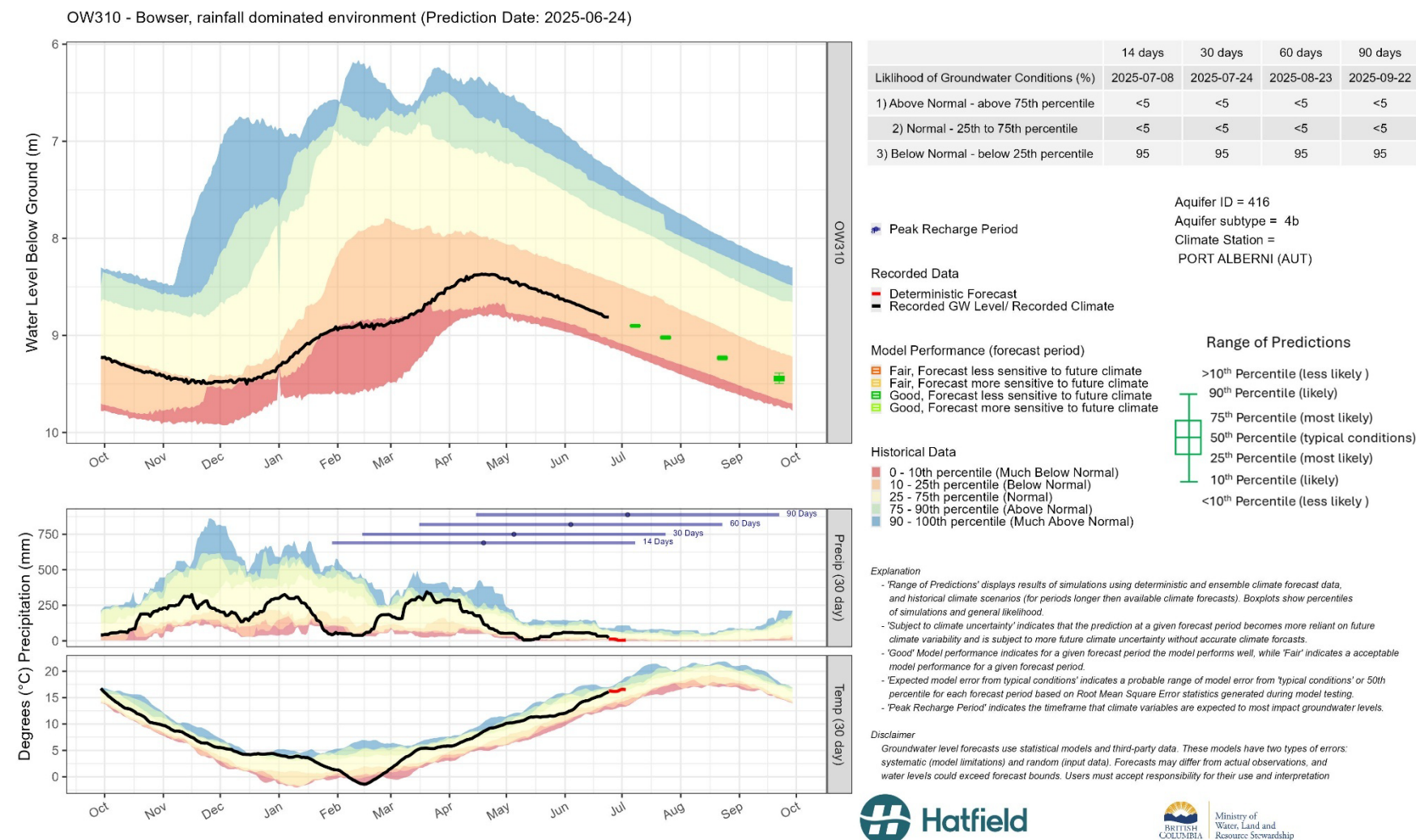
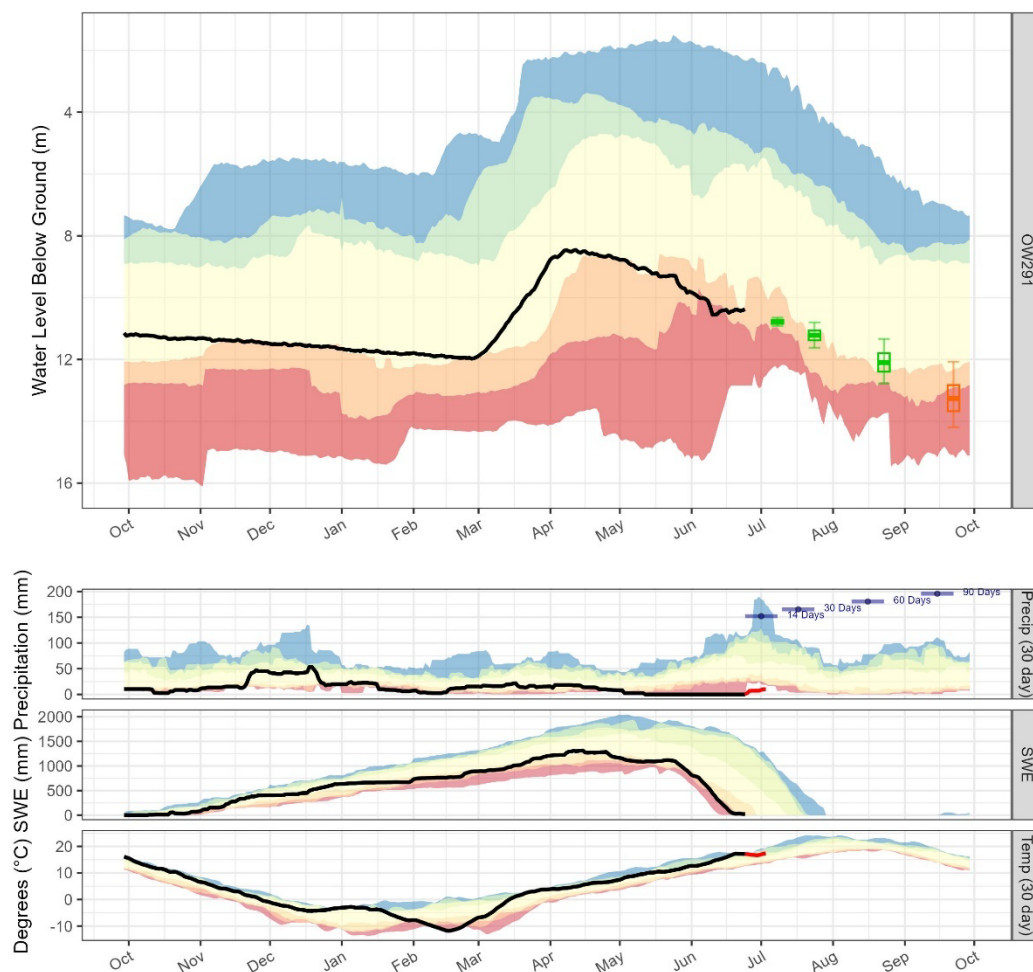


Figure 43 Example of model groundwater forecast output for OW291 (Cranbrook) on 2025-06-24.

OW291 - Cranbrook, snowmelt dominated environment (Prediction Date: 2025-06-24)



	14 days	30 days	60 days	90 days
Likelihood of Groundwater Conditions (%)	2025-07-08	2025-07-24	2025-08-23	2025-09-22
1) Above Normal - above 75th percentile	<5	<5	<5	<5
2) Normal - 25th to 75th percentile	<5	45	60	10
3) Below Normal - below 25th percentile	95	55	40	90

Well = OW291

Location = Cranbrook

Peak Recharge Period

Aquifer ID = 523

Aquifer subtype = NA

Recorded Data

Climate Station = 1174, 50818

■ Deterministic Forecast
— Recorded GW Level/ Recorded Climate

Snow Station = 2D14P

Model Performance (forecast period)

■ Fair, Forecast less sensitive to future climate
■ Fair, Forecast more sensitive to future climate
■ Good, Forecast less sensitive to future climate
■ Good, Forecast more sensitive to future climate

Range of Predictions

■ >10th Percentile (less likely)
■ 90th Percentile (likely)
■ 75th Percentile (most likely)
■ 50th Percentile (typical conditions)
■ 25th Percentile (most likely)
■ 10th Percentile (likely)
■ <10th Percentile (less likely)

Historical Data

■ 0 - 10th percentile (Much Below Normal)
■ 10 - 25th percentile (Below Normal)
■ 25 - 75th percentile (Normal)
■ 75 - 90th percentile (Above Normal)
■ 90 - 100th percentile (Much Above Normal)

Explanation

- 'Range of Predictions' displays results of simulations using deterministic and ensemble climate forecast data, and historical climate scenarios (for periods longer than available climate forecasts). Boxplots show percentiles of simulations and general likelihood.
- 'Subject to climate uncertainty' indicates that the prediction at a given forecast period becomes more reliant on future climate variability and is subject to more future climate uncertainty without accurate climate forecasts.
- 'Good' Model performance indicates for a given forecast period the model performs well, while 'Fair' indicates an acceptable model performance for a given forecast period.
- 'Expected model error from typical conditions' indicates a probable range of model error from 'typical conditions' or 50th percentile for each forecast period based on Root Mean Square Error statistics generated during model testing.
- 'Peak Recharge Period' indicates the timeframe that climate variables are expected to most impact groundwater levels.

Disclaimer

Groundwater level forecasts use statistical models and third-party data. These models have two types of errors: systematic (model limitations) and random (input data). Forecasts may differ from actual observations, and water levels could exceed forecast bounds. Users must accept responsibility for their use and interpretation.



7.0 CLOSURE

The Phase 2 forecast model structure builds on the methods used in Phase 1 of the project, with additional aspects introduced through new approaches such as the dynamic weighting over the recharge lag period. Another major difference from Phase 1 is the inclusion of a much larger number of PGOWN wells in the groundwater level forecasting. Groundwater forecasting has also been modified from Phase 1 with the incorporation of deterministic and ensemble climate forecast outputs from RFC. The main findings and recommendations from the Phase 2 study are outlined below.

7.1 MAIN FINDINGS

- Climate and SWE (Snow Water Equivalent) stations were selected to represent the local climatic conditions for each of the PGOWN wells. This process was manual in Phase 1 but largely automated in Phase 2, ensuring a more efficient and accurate selection process.
- An additional machine learning approach, the artificial neural network (ANN) approach, was included in Phase 2 of the study.
- As in Phase 1, groundwater forecast models included specific hydroclimatic variables based on the observation well setting and source of recharge. This included rainfall and temperature for rainfall settings, and rainfall, temperature, snowmelt, and SWE for snowmelt settings. Interaction terms were built into GLM and GAM models for snowmelt settings, while ANN and RF models automatically identified correlations, making them more adaptable to different recharge environments.
- Phase 2 saw significant model improvements due to dynamic weighting and simulating changes in groundwater levels rather than actual levels. The ANN model produced the best results, followed by GAM, GLM, and RF. ANN was particularly effective in differentiating between linear and non-linear relationships in the data. RF was excluded from operational testing due to its poorer results and significantly longer run times, making it less practical for operational use.
- The groundwater forecast models generally perform well in highly developed aquifers like those in the Fraser Valley. This suggests that the models can implicitly account for effects of seasonal aquifer usage, as long as PGOWN wells are outside the direct drawdown effects of pumping wells. This is likely achieved because seasonal groundwater use is correlated with precipitation and temperature.
- Aquifers with long-term trends were incorporated in Phase 2, with groundwater forecast models showing comparable performance to wells with stable groundwater levels, indicating that the refined forecasting methodology can handle varying groundwater level trends effectively.
- Non-climatic effects influenced groundwater levels in several PGOWN wells, adding factors that the models are largely unable to predict. This may include potential influences such as a large change in groundwater use (e.g., a new license).

- In general, there doesn't seem to be strong or notable correlation between model performance and aquifer subtypes.
- Model performance was not strongly correlated with data period length, with more complicated well settings requiring longer training times. This suggests that while the length of the training set is important, other factors play a more significant role in model performance.
- The model performance was compared to Gullacher et al. (2021) classifications of recharge-driven and streamflow-driven groundwater responses. Generally, models perform well across all classifications, with some indication of better performance in streamflow-driven settings during rainfall dominated recharge settings.
- ANN models showed the highest number of wells with good model performance (determined from validation against historical data) and valuable forecast results (determined as ability to identify when future conditions may deviate from historical averages), followed by GAM and GLM. It is recommended to use the ANN model for operational forecasting, with 152 wells considered usable for forecasting.
- Short-term (up to 16-day) precipitation and temperature forecast data from RFC were integrated to reduce uncertainty in groundwater level forecasts. Additional data on aquifer type and model performance were included in the outputs.

7.2 RECOMMENDATIONS

- The groundwater forecast models continue to perform better for wells in rainfall recharge environments compared to snowfall recharge environments, especially over longer forecast periods. SWE stations at high elevations have different melt signatures compared to lower elevation settings where aquifer recharge occurs with most PGOWN wells situated in valley settings and snow courses at higher elevations. This inherent limitation of the current modelling approach suggests potential for improvement by incorporating a snowmelt model to better account for these differences although trade-offs between increasing model complexity and degree of expected model performance improvement would likely need to be considered.
- PGOWN wells in the Fraser Valley were influenced by the Fraser River, complicating model predictions. Including streamflow as a predictive variable in the forecasts models for these wells could improve performance by better incorporating the effects of regional upstream conditions.
- Wells that have poorer model performance would benefit from Regional Hydrogeologists providing detailed feedback on individual observation wells carried forward for groundwater level forecasting, looking for non-climatic effects or better rationale on model performance.
- Since the required data length for training varies by well and the duration of available data, wells with poor performance may benefit from re-testing when longer or additional datasets become available. Given that training is well-specific, it is recommended not to impose a strict data length cutoff. Instead, the adequacy of the training data should be determined based on testing outcomes and model performance. Wells for which groundwater forecasts performance

was deemed to be of value at 90 days could perhaps support groundwater level forecasts over longer periods if deemed useful for drought assessment purposes.

- Groundwater level forecasts for wells in highly developed aquifers generally performed well, suggesting that the models can implicitly account for the effects of seasonal aquifer usage. However, the current approach cannot account for sudden changes in groundwater use or explicitly quantify the role that groundwater usage plays in affecting the groundwater levels. It is possible that model results could improve for specific situations by explicitly including groundwater usage data (if available or can be reasonably estimated) as an additional variable in these cases, if deemed useful for causal analysis of drought occurrences (e.g., Koksilah watershed where groundwater use likely plays a large role in affecting summertime low flows; Hatfield 2021).
- The forecast models have proven to be adept at predicting climatic influences on groundwater levels. This suggests the possibility of utilizing the models for testing potential future climatic effects across the province using outputs from global climate models. This would help identify which aquifers may be more susceptible to significant changes in groundwater levels under a changing climate.
- The statistical and machine learning forecasting methodologies can likely be successfully extended to forecasting of streamflow. There has been increased interest in the ongoing development of similar (AI) approaches to streamflow prediction across Canada (notably Ontario and the Prairie Provinces). A similar approach for BC, could involve limited further development of the current model focused on testing and comparing the statistical and machine learning methods to current streamflow forecasts used by the province (ELF, COFFEE, and CLEVER) in terms of performance, calibration and maintenance efforts and runtime.

7.3 MODEL UNCERTAINTY AND DISCLAIMER

The groundwater level forecasts were derived using statistical models and using third-party data as inputs. The models have two categories of uncertainty or forecast errors, systematic errors from the model's intrinsic limitations and random errors inherited from the input data. Therefore, it can be expected that the model forecasts are different from the observations. It is also possible that the actual water levels will be higher than the forecast upper bound or lower than the forecast lower bound. Users of this forecast must accept all responsibility for their use and interpretation.

8.0 REFERENCES

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APPENDICES

Appendix A1

RFC Supplied PGOWN List

Table A1.1 RFC Supplied PGOWN List.

Well	Location	Regional Office	Well Tag #	Length of Record	Aquifer #	Aquifer Type OR Well Lithology	Regional Hydrogeo: Should well be included in drought forecasting?	Comments from Regional Hydrogeo	Well in Phase 1	Well included in Phase 2	Reason Excluded	Model Performance	Action	Rationale
OW002	Abbotsford	Surrey	26787	63	15	Unconfined Unconsolidated	Yes	Cluster 1 (well responds to recharge from local precipitation, primarily rainfall, and responds rapidly to both atmospheric rivers during winter reachage and significant rainfall deficits during summer) from Nott et al 2024 - Groundwater Response to Deluge and Drought in the Fraser Valley, Pacific Northwest	Yes	Yes		Good	Recommended forecasting	
OW008	Abbotsford	Surrey	26549	63	15	Unconfined Unconsolidated	Yes	Cluster 1 (well responds to recharge from local precipitation, primarily rainfall, and responds rapidly to both atmospheric rivers during winter reachage and significant rainfall deficits during summer) from Nott et al 2024 - Groundwater Response to Deluge and Drought in the Fraser Valley, Pacific Northwest	No	Yes		Good	Recommended forecasting	
OW035	Stump Lake	Kamloops	20598	57	1174	Confined Unconsolidated	Uncertain	possibly useful for background groundwater conditions in the Stump Lake Creek sub-basin which flows into Nicola Lake	No	Yes		Good	Recommended forecasting	
OW045	Westwold	Kamloops	19522	60	289	Unconfined Unconsolidated	Yes	Obs Well 518 to replace Obs Well 045, need to overlap readings for a while but should be able to use 45 for stats	No	Yes		Poor	Recommend removal	poor, 90 day performance, performance seems fair up until 90 day. Consider re-testing with longer record.
OW047	Silverstar	Penticton	49951	60	351	Bedrock	Yes	High mountain recharge well. Bedrock to surface, shallow WLs (0 - 10 mbgs). Could be used as leading indicator.	No	Yes		Poor	Recommend removal	lots of noise, some seasonal trends, could re-test with longer reord.
OW058	Saanich	Nanaimo	20142	59	610	Confined Unconsolidated	No	Ignored all confined wells not located in a drought prone watershed.	No	Yes		Good	Recommended forecasting	
OW060	Saanich	Nanaimo	20143	59	609	Confined Unconsolidated	No	Ignored all confined wells not located in a drought prone watershed.	No	Yes		Good	Recommended forecasting	
OW071	Saanich	Nanaimo	2133	49	616	Confined Unconsolidated	No	Ignored all confined wells not located in a drought prone watershed.	No	Yes		Good	Recommended forecasting	
OW074	Castlegar	Penticton	20128	59	507	Unconfined Unconsolidated	No	Deep water levels (24 - 32 mbgs) with tight till on top that may cause increased lag time.	No	Yes		Fair	Recommended forecasting	
OW075	Keremeos	Penticton	20533	62	259	Unconfined Unconsolidated	Yes	Shallow water levels (i.e. < 4 mbgs), minimal 'noise' in data	Yes	Yes		Fair	Recommended forecasting	
OW080	Clinton	Kamloops	20593	54	921	Confined Unconsolidated	No	not a high priority area for drought	No	Yes		Good	Recommended forecasting	
OW081	83 Mile	Kamloops	20697	58	124	Bedrock	No	not a high priority area for drought	No	Yes		Fair	Recommended forecasting	
OW082	Barkerville	Kamloops	20904	50	NA	Bedrock	No	not a high priority area for drought	No	Yes		Poor	Recommend removal	poor performance (90 day) - seems to have anomausly high winter levels some years.
OW088	Williams Lake	Kamloops	21023	54	146	Confined Unconsolidated	No	large rate of decline.	No	No	Significant Pumping Effects	Not Tested		
OW115	Mission Creek	Penticton	23980	52	NA	Bedrock	Yes	Shallow bedrock and shallow water levels.	No	Yes		Poor	Recommend re-testing	performance seems good may need re-testing with longer data record (large data gap in record).
OW117	Armstrong	Penticton	24062	54	1155	Confined Unconsolidated	No	Very deep, very confined.	No	Yes		Good	Recommended forecasting	
OW118	Armstrong	Penticton	24080	54	1155	Confined Unconsolidated	No	Very deep, very confined.	No	Yes		Poor	Recommend removal	Appears to be aquifer demand changes (non-seasonal).
OW122	Enderby	Penticton	24093	54	1155	Confined Unconsolidated	No	Very deep, very confined, sometimes artesian.	No	Yes		Poor	Recommend removal	Appears to be aquifer demand changes (non-seasonal).
OW124	Charlie Lake	Fort St. John	25272	54	1271	Bedrock	No		No	Yes		Poor	Recommend re-testing	very noisy, but overall value seems there, may need re-tsting with longer data record.
OW125	Mayne Island	Nanaimo	20721	54	620	Bedrock	No	Ignored all bedrock wells not located in a drought prone watershed.	No	Yes		Fair	Recommended forecasting	
OW128	Mayne Island	Nanaimo	24845	53	447	Bedrock	No	Ignored all bedrock wells not located in a drought prone watershed.	No	Yes		Fair	Recommended forecasting	
OW154	Summerland	Penticton	22792	56	297	Unconfined Unconsolidated	Yes	-	No	Yes		Good	Recommended forecasting	
OW172	Oyama	Penticton	8596	48	1238	Unconfined Unconsolidated	Yes	Potentially too noisy.	No	Yes		Poor	Recommend removal	Anomalous WL level flucations, potentially related to adjacent Quarry.
OW180	Armstrong	Penticton	32340	50	353	Unconfined Unconsolidated	Uncertain	Long term trend = moderate rate of decline; hydrogeologically appropriate	No	No	Significant Pumping Effects	Not Tested		
OW185	Salmon River	Kamloops	30438	51	97	Unconfined Unconsolidated	Yes	drought prone region, very contentious	No	Yes		Fair	Recommended forecasting	
OW196	Gabriola Island	Nanaimo	26709	52	709	Bedrock	No	Ignored all bedrock wells not located in a drought prone watershed.	No	Yes		Fair	Recommended forecasting	
OW197	Gabriola Island	Nanaimo	37811	52	709	Bedrock	No	Ignored all bedrock wells not located in a drought prone watershed.	No	Yes		Good	Recommended forecasting	
OW200	Dease Lake	Smithers	27532	51	828	Confined Unconsolidated		No hydrogeo available.	No	Yes		Good	Recommended forecasting	

Table A1.1 (Cont'd.)

Well	Location	Regional Office	Well Tag #	Length of Record	Aquifer #	Aquifer Type OR Well Lithology	Regional Hydrogeo: Should well be included in drought forecasting?	Comments from Regional Hydrogeo	Well in Phase 1	Well included in Phase 2	Reason Excluded	Model Performance	Action	Rationale
OW201	Alert Bay	Nanaimo	29505	50	858	Confined Unconsolidated	No	Ignored all confined wells not located in a drought prone watershed.	No	Yes		Good	Recommended forecasting	
OW203	Cawston	Penticton	33378	48	259	Unconfined Unconsolidated	No	A lot of interference from summer groundwater users	No	No	Significant Pumping Effects	Not Tested		
OW204	Duncan	Nanaimo	33436	48	186	Unconfined Unconsolidated	Yes	Near Koksilah Watershed. Seasonal fluctuations are roughly 2 metres.	No	Yes		Fair	Recommended forecasting	
OW211	Duncan	Nanaimo	33651	49	186	Unconfined Unconsolidated	Yes	Near Koksilah. Seasonal fluctuations are roughly 2.5 metres.	No	No	Significant Pumping Effects	Not Tested		
OW217	Grand Forks	Penticton	14947	48	158	Unconfined Unconsolidated	Yes	Shallow water levels (i.e. < 4 mbgs)	Yes	Yes		Fair	Recommended forecasting	
OW232	Lantzville	Nanaimo	32217	46	215	Confined Unconsolidated	No	Ignored all confined wells not located in a drought prone watershed.	No	No	Significant Pumping Effects	Not Tested	Recommended forecasting	
OW233	Cowichan Bay	Nanaimo	21169	46	197	Confined Unconsolidated	No	Ignored all confined wells not located in a drought prone watershed.	No	No		Not Tested	Recommended forecasting	
OW236	Rutland	Penticton	41865	46	464	Confined Unconsolidated	No	Thick confining layer, aquifer 464 likely not good for drought forecasting	No	No	Significant Pumping Effects	Not Tested	Recommended forecasting	
OW240	Saanich	Nanaimo	31523	46	608	Bedrock	No	Ignored all bedrock wells not located in a drought prone watershed.	No	Yes		Fair	Recommended forecasting	
OW255	Chilliwack	Surrey	42266	46	1216	Bedrock	Yes	Cluster 1 (well responds to recharge from local precipitation, primarily rainfall, and responds rapidly to both atmospheric rivers during winter recharge and significant rainfall deficits during summer) from Nott et al 2024 - Groundwater Response to Deluge and Drought in the Fraser Valley, Pacific Northwest	No	Yes		Fair	Recommended forecasting	
OW258	Galiano Island	Nanaimo	44593	45	320	Bedrock	No	Ignored all bedrock wells not located in a drought prone watershed.	Yes	Yes		Fair	Recommended forecasting	
OW260	Quesnel	Kamloops	44608	45	115	Confined Unconsolidated	No	not a high priority area for drought, increasing trend	No	Yes		Good	Recommended forecasting	
OW261	Williams Lake	Kamloops	45972	45	148	Bedrock	No	big lag time	No	Yes		Good	Recommended forecasting	
OW262	Kelowna	Penticton	44358	45	464	Confined Unconsolidated	No	Long term trend = large rate of decline; thick confining layer	No	Yes		Good	Recommended forecasting	
OW264	Mt. Kobau	Penticton	62733	45	1113	Bedrock	No	Bedrock to surface but deeper water levels.	No	Yes		Poor	Recommend removal	Surge nearly 9m fluctuation from dramatic snowmelt recharge.
OW265	Saanich	Nanaimo	30098	45	608	Bedrock	No	Ignored all bedrock wells not located in a drought prone watershed.	No	No	Significant Pumping Effects	Not Tested		
OW268	Denman Island	Nanaimo	62734	44	740	Bedrock	No	Ignored all bedrock wells not located in a drought prone watershed.	No	Yes		Fair	Recommended forecasting	
OW272	Abbotsford	Surrey	49293	44	15	Unconfined Unconsolidated	Yes	Cluster 1 (well responds to recharge from local precipitation, primarily rainfall, and responds rapidly to both atmospheric rivers during winter recharge and significant rainfall deficits during summer) from Nott et al 2024 - Groundwater Response to Deluge and Drought in the Fraser Valley, Pacific Northwest	No	No	Significant Pumping Effects	Not Tested	Recommended forecasting	
OW275	Surrey	Surrey	44939	44	41	Unconfined Unconsolidated	Yes	Cluster 1 (well responds to recharge from local precipitation, primarily rainfall, and responds rapidly to both atmospheric rivers during winter recharge and significant rainfall deficits during summer) from Nott et al 2024 - Groundwater Response to Deluge and Drought in the Fraser Valley, Pacific Northwest	Yes	Yes		Good	Recommended forecasting	
OW281	Saltspring Island	Nanaimo	62732	42	721	Bedrock	No	Ignored all bedrock wells not located in a drought prone watershed.	No	Yes		Fair	Recommended forecasting	
OW282	Willow Brook/Meyers Flat	Penticton	51824	42	257	Confined Unconsolidated	No	Pumping interference	No	No	Significant Pumping Effects	Not Tested		
OW283	Pender Island	Nanaimo	51834	42	711	Bedrock	No	Ignored all bedrock wells not located in a drought prone watershed.	No	Yes		Fair	Recommend analysis	Potential pumping effects or data issues.
OW284	Pender Island	Nanaimo	51833	42	720	Bedrock	No	Ignored all bedrock wells not located in a drought prone watershed.	No	Yes		Fair	Recommended forecasting	
OW286	Tumbler Ridge	Fort St. John	52975	42	635	Unconfined Unconsolidated	No		No	No	Significant Pumping Effects	Not Tested		
OW287	Coombs	Nanaimo	53360	41	220	Bedrock	No	Ignored all bedrock wells not located in a drought prone watershed.	No	Yes		Good	Recommended forecasting	
OW288	Hornby Island	Nanaimo	53370	41	438	Bedrock	No	Ignored all bedrock wells not located in a drought prone watershed.	Yes	Yes		Fair	Recommended forecasting	
OW289	Williams Lake	Kamloops	53339	41	139	Confined Unconsolidated	No		No	Yes		Good	Recommended forecasting	

Table A1.1 (Cont'd.)

Well	Location	Regional Office	Well Tag #	Length of Record	Aquifer #	Aquifer Type OR Well Lithology	Regional Hydrogeo: Should well be included in drought forecasting?	Comments from Regional Hydrogeo	Well in Phase 1	Well included in Phase 2	Reason Excluded	Model Performance	Action	Rationale
OW290	Saturna Island	Nanaimo	48780	40	737	Bedrock	No	Ignored all bedrock wells not located in a drought prone watershed.	Yes	Yes		Fair	Recommended forecasting	
OW291	Cranbrook	Penticton	54568	40	523	Bedrock	No	Deep bedrock well	No	Yes		Fair	Recommended forecasting	
OW292	Powell River	Surrey	54586	40	836	Confined Unconsolidated	Uncertain	Not included in Nott et al. 2024	No	Yes		Fair	Recommended forecasting	
OW293	Prince George	Prince George	55786	39	332	Confined Unconsolidated	Uncertain	Completed in confined aquifer. However, water levels fluctuate annually in response to freshet and end of summer/early fall drought. In 2023 when the province experienced prolonged drought the water level in 293 also appeared to the lowest.	No	Yes		Fair	Recommended forecasting	
OW294	Lumby	Penticton	55834	39	316	Unconfined Unconsolidated	Yes	-	No	Yes		Fair	Recommended forecasting	
OW295	Qualicum Beach	Nanaimo	13653	39	217	Confined Unconsolidated	No	Ignored all confined wells not located in a drought prone watershed.	No	No	Significant Pumping Effects	Not Tested		
OW296	Merritt	Kamloops	56918	36	74	Unconfined Unconsolidated	Yes		No	Yes		Poor	Recommend re-testing	performance seems good may need re-testing with longer data record.
OW299	Abbotsford	Surrey	23948	38	15	Unconfined Unconsolidated	Yes	Cluster 1 (well responds to recharge from local precipitation, primarily rainfall, and responds rapidly to both atmospheric rivers during winter recharge and significant rainfall deficits during summer) from Nott et al 2024 - Groundwater Response to Deluge and Drought in the Fraser Valley, Pacific Northwest	No	Yes		Good	Recommended forecasting	
OW301	Abbotsford	Surrey	58399	37	15	Unconfined Unconsolidated	Yes	Cluster 1 (well responds to recharge from local precipitation, primarily rainfall, and responds rapidly to both atmospheric rivers during winter recharge and significant rainfall deficits during summer) from Nott et al 2024 - Groundwater Response to Deluge and Drought in the Fraser Valley, Pacific Northwest	Yes	Yes		Good	Recommended forecasting	
OW302	Malakwa	Kamloops	57976	37	307	Unconfined Unconsolidated	Uncertain	good period of record, quick response, stable historical GW levels, not sure how useful this location would be for drought planning though	No	Yes		Poor	Recommend re-testing	performance seems good may need re-testing with longer data record.
OW303	Qualicum	Nanaimo	43750	37	1250	Confined Unconsolidated	No	Ignored all confined wells not located in a drought prone watershed.	No	No	Significant Pumping Effects	Not Tested		
OW304	Parksville	Nanaimo	58215	37	216	Confined Unconsolidated	No	Ignored all confined wells not located in a drought prone watershed.	No	Yes		Good	Recommended forecasting	
OW306	Beaverdell	Penticton	58685	36	482	Unconfined Unconsolidated	Yes	---	No	Yes		Fair	Recommended forecasting	
OW309	Golden	Penticton	59115	36	450	Confined Unconsolidated	Uncertain	Confining layer is ~4.5 m of clay. 300 m from upper Columbia river, likely connected. Water levels around 23 to 25 mbgs	No	Yes		Fair	Recommended forecasting	
OW310	Bowser	Nanaimo	37367	35	416	Confined Unconsolidated	No	Ignored all confined wells not located in a drought prone watershed.	No	Yes		Good	Recommended forecasting	
OW311	Vernon	Penticton	59305	34	351	Bedrock	No	Bedrock well with 74 ft of clay above. WLs 17 - 19 mbgs	No	Yes		Good	Recommended forecasting	
OW312	Cassidy-Boat Harbour	Nanaimo	59559	34	161	Unconfined Unconsolidated	No	Seasonal fluctuations of roughly 1.5 metres. Not the cleanest response to precipitation observed.	No	Yes		Poor	Recommend removal	Appears to be aquifer demand changes (non-seasonal) possibly pumping effects.
OW314	Parksville	Nanaimo	59923	33	216	Confined Unconsolidated	No	Ignored all confined wells not located in a drought prone watershed.	No	Yes		Good	Recommended forecasting	
OW316	Gabriola Island	Nanaimo	7895	33	709	Bedrock	No	Ignored all bedrock wells not located in a drought prone watershed.	No	Yes		Fair	Recommended forecasting	
OW319	Saturna Island	Nanaimo	59381	33	735	Bedrock	No	Ignored all bedrock wells not located in a drought prone watershed.	No	Yes		Poor	Recommend removal	tidally effected
OW320	Cobble Hill	Nanaimo	41479	33	197	Confined Unconsolidated	No	Ignored all confined wells not located in a drought prone watershed.	No	Yes		Fair	Recommended forecasting	
OW321	Qualicum Beach	Nanaimo	48458	33	1250	Confined Unconsolidated	No	Ignored all confined wells not located in a drought prone watershed.	No	Yes		Fair	Recommended forecasting	
OW327	Galiano Island	Nanaimo	14582	30	320	Bedrock	No	Ignored all bedrock wells not located in a drought prone watershed.	No	Yes		Fair	Recommended forecasting	
OW329	Ucluelet	Nanaimo	62731	30	159	Unconfined Unconsolidated	Yes	Seasonal fluctuations of roughly 4.5 metres.	Yes	Yes		Good	Recommended forecasting	
OW332	Oliver	Penticton	62966	28	254	Unconfined Unconsolidated	Yes	Possible recent downward trend	No	Yes		Good	Recommended forecasting	
OW337	Ladysmith	Nanaimo	74812	27	162	Bedrock	No	Ignored all bedrock wells not located in a drought prone watershed.	No	No		Good	Recommended forecasting	
OW338	Saanich	Nanaimo	34371	27	608	Bedrock	No	Ignored all bedrock wells not located in a drought prone watershed.	No	Yes		Fair	Recommended forecasting	

Table A1.1 (Cont'd.)

Well	Location	Regional Office	Well Tag #	Length of Record	Aquifer #	Aquifer Type OR Well Lithology	Regional Hydrogeo: Should well be included in drought forecasting?	Comments from Regional Hydrogeo	Well in Phase 1	Well included in Phase 2	Reason Excluded	Model Performance	Action	Rationale
OW340	Lantzville	Nanaimo	75044	26	215	Confined Unconsolidated	No	Ignored all confined wells not located in a drought prone watershed.	No	No	Significant Pumping Effects	Not Tested		
OW343	Saanich	Nanaimo	56374	27	608	Bedrock	No	Ignored all bedrock wells not located in a drought prone watershed.	No	Yes		Fair	Recommended forecasting	
OW345	Cobble Hill	Nanaimo	75531	26	197	Confined Unconsolidated	No	Ignored all confined wells not located in a drought prone watershed.	No	No	Significant Pumping Effects	Not Tested		
OW349	Belcarra	Surrey	81565	24	68	Bedrock	No	Cluster 2 (wells are also driven by precipitation, and are additionally influenced by the Fraser River's large summer freshet, briefly providing a secondary recharge mechanism. Groundwater recessions are offset to later in the summer, contingent on the Fraser River, mediating drought) from Nott et al 2024 - Groundwater Response to Deluge and Drought in the Fraser Valley, Pacific Northwest	No	Yes		Fair	Recommended forecasting	
OW351	Comox	Nanaimo	81653	24	408	Unconfined Unconsolidated	No	Near Tsolum watershed. No lithology log. Seasonal fluctuations are only roughly 0.8 metres.	No	Yes		Good	Recommended forecasting	
OW353	Langley	Surrey	84689	21	41	Unconfined Unconsolidated	Yes	Cluster 1 (well responds to recharge from local precipitation, primarily rainfall, and responds rapidly to both atmospheric rivers during winter recharge and significant rainfall deficits during summer) from Nott et al 2024 - Groundwater Response to Deluge and Drought in the Fraser Valley, Pacific Northwest	Yes	Yes		Fair	Recommended forecasting	
OW354	Langley	Surrey	84688	21	35	Unconfined Unconsolidated	Yes	Cluster 1 (well responds to recharge from local precipitation, primarily rainfall, and responds rapidly to both atmospheric rivers during winter recharge and significant rainfall deficits during summer) from Nott et al 2024 - Groundwater Response to Deluge and Drought in the Fraser Valley, Pacific Northwest	No	Yes		Good	Recommended forecasting	
OW355	Chemainus	Nanaimo	81682	21	172	Unconfined Unconsolidated	Yes	Seasonal fluctuations of roughly 2-3 metres.	Yes	Yes		Fair	Recommended forecasting	
OW356	Winfield	Penticton	81678	21	344	Confined Unconsolidated	Uncertain	Log doesn't show confined conditions. However, long term trend = increasing.	No	Yes		Fair	Recommended forecasting	
OW357	Abbotsford	Surrey	84687	21	29	Confined Unconsolidated	Yes	Cluster 1 (well responds to recharge from local precipitation, primarily rainfall, and responds rapidly to both atmospheric rivers during winter recharge and significant rainfall deficits during summer) from Nott et al 2024 - Groundwater Response to Deluge and Drought in the Fraser Valley, Pacific Northwest	No	Yes		Good	Recommended forecasting	
OW359	Langley	Surrey	84686	21	33	Confined Unconsolidated	Uncertain	Not included in Nott et al. 2024	No	Yes		Good	Recommended forecasting	
OW360	Langley	Surrey	84697	21	41	Unconfined Unconsolidated	Yes	Cluster 1 (well responds to recharge from local precipitation, primarily rainfall, and responds rapidly to both atmospheric rivers during winter recharge and significant rainfall deficits during summer) from Nott et al 2024 - Groundwater Response to Deluge and Drought in the Fraser Valley, Pacific Northwest	Yes	Yes		Fair	Recommended forecasting	
OW361	Langley	Surrey	84691	20	27	Confined Unconsolidated	Uncertain	Not included in Nott et al. 2024	No	Yes		Good	Recommended forecasting	
OW362	Jaffray	Penticton	84692	20	521	Unconfined Unconsolidated	Yes	Shallow water levels (i.e. < 3 mbgs)	No	Yes		Poor	Recommend re-testing	performance seems good may need re-testing with longer data record.
OW363	Wasa	Penticton	84693	20	540	Unconfined Unconsolidated	Yes	---	Yes	Yes		Fair	Recommended forecasting	
OW364	Quesnel	Kamloops	84694	19	370	Unconfined Unconsolidated	Uncertain	good period of record, quick response, stable historical GW levels, not sure how useful this location would be for drought planning though	Yes	No	Significant Pumping Effects	Not Tested		
OW365	Shuswap Lake	Kamloops	85623	19	229	Unconfined Unconsolidated	Uncertain	no satellite telemetry	No	Yes		Poor	Recommend re-testing	performance seems good may need re-testing with longer data record.
OW369	Black Creek Gravel Pit	Nanaimo	83157	19	NA	Unconsolidated (Unmapped)	Yes	Near Tsolum watershed. Seasonal fluctuations of roughly 1.5 metres.	No	Yes		Fair	Recommended forecasting	
OW371	Hwy 19A (T'Sable River)	Nanaimo	83159	19	415	Unconfined Unconsolidated	Yes	Seasonal fluctuations of roughly 1.75 metres.	No	Yes		Fair	Recommended forecasting	
OW372	District of Highlands (Gowlland Tod Park)	Nanaimo	83045	18	680	Bedrock	No	Ignored all bedrock wells not located in a drought prone watershed.	No	Yes		Poor	Recommend re-testing	performance seems good may need re-testing with longer data record.
OW373	Saltspring Island	Nanaimo	85621	19	722	Bedrock	Yes	Near Fulford Ck Watershed. Seasonal fluctuations of roughly 7 metres.	Yes	Yes		Fair	Recommended forecasting	
OW374	108 Mile	Kamloops	86843	18	131	Confined Unconsolidated	No		No	Yes		Good	Recommended forecasting	
OW375	Blue River	Kamloops	85622	19	825	Unconfined Unconsolidated	Yes	hydraulic connection to Blue River and North Thompson	No	Yes		Fair	Recommended forecasting	

Table A1.1 (Cont'd.)

Well	Location	Regional Office	Well Tag #	Length of Record	Aquifer #	Aquifer Type OR Well Lithology	Regional Hydrogeo: Should well be included in drought forecasting?	Comments from Regional Hydrogeo	Well in Phase 1	Well included in Phase 2	Reason Excluded	Model Performance	Action	Rationale
OW376	Junction Sheep Range Park	Kamloops	51227	19	NA	Bedrock	No		No	Yes		Fair	Recommended forecasting	
OW377	Smithers	Smithers	94020	17	585	Confined Unconsolidated		No hydrogeo available.	No	No	Significant Pumping Effects	Not Tested		
OW378	Prince George	Prince George	86618	18	92	Unconfined Unconsolidated	Yes	Unconfined well that is connected to both Nechako and Fraser rivers. Clear seasonal variability. Very low water levels in 2023.	No	Yes		Poor	Recommend re-testing	performance seems good may need re-testing with longer data record.
OW381	Canoe Creek	Kamloops	90212	17	108	Unconfined Unconsolidated	Uncertain	no satellite telemetry	Yes	Yes		Good	Recommended forecasting	
OW383	Quadra Island	Nanaimo	93755	17	751	Unconfined Unconsolidated	Yes	Seasonal fluctuations of roughly 0.5 metres. Appears to have a quick response to precip.	No	Yes		Good	Recommended forecasting	
OW384	Spallumcheen	Penticton	93924	17	102	Confined Unconsolidated	No	Long term trend = large rate of decline; thick confining layer	No	Yes		Fair	Recommended forecasting	
OW385	Gabriola Island	Nanaimo	102208	15	709	Bedrock	No	Ignored all bedrock wells not located in a drought prone watershed.	No	Yes		Fair	Recommended forecasting	
OW386	Houston	Smithers	102314	23	659	Unconfined Unconsolidated		No hydrogeo available.	No	Yes		Poor	Recommend re-testing	performance seems good may need re-testing with longer data record.
OW387	Penticton Creek Watershed	Penticton	94930	17	NA	Bedrock	Yes	High mountain recharge well. Bedrock to surface, shallow WLs (0 - 10 mbgs). Could be used as leading indicator.	No	Yes		Poor	Recommend removal	Appears to be aquifer demand changes (non-seasonal).
OW388	Nanaimo	Nanaimo	85327	15	211	Bedrock	No	Ignored all bedrock wells not located in a drought prone watershed.	No	No	Significant Pumping Effects	Not Tested		
OW389	Qualicum Beach	Nanaimo	102925	15	664	Unconfined Unconsolidated	Yes	Seasonal fluctuations of roughly 2 metres. Appears to have a quick response to precip.	Yes	Yes		Fair	Recommended forecasting	
OW390	Cedar	Nanaimo	104541	14	162	Bedrock	No	Ignored all bedrock wells not located in a drought prone watershed.	No	Yes		Good	Recommended forecasting	
OW391	Little Qualicum	Nanaimo	104501	14	662	Confined Unconsolidated	No	Ignored all confined wells not located in a drought prone watershed.	No	Yes		Good	Recommended forecasting	
OW392	Nanoose	Nanaimo	104499	14	1098	Confined Unconsolidated	No	Ignored all confined wells not located in a drought prone watershed.	No	Yes		Good	Recommended forecasting	
OW393	Nanoose	Nanaimo	104500	14	219	Confined Unconsolidated	No	Ignored all confined wells not located in a drought prone watershed.	No	Yes		Fair	Recommended forecasting	
OW394	Nanoose	Nanaimo	75327	13	218	Bedrock	No	Ignored all bedrock wells not located in a drought prone watershed.	Yes	Yes		Fair	Recommended forecasting	
OW395	Nanoose	Nanaimo	94518	13	219	Confined Unconsolidated	No	Ignored all confined wells not located in a drought prone watershed.	No	Yes		Fair	Recommended forecasting	
OW396	Nanoose	Nanaimo	75338	13	219	Confined Unconsolidated	No	Ignored all confined wells not located in a drought prone watershed.	No	Yes		Good	Recommended forecasting	
OW397	Nanoose	Nanaimo	32961	13	1098	Confined Unconsolidated	No	Ignored all confined wells not located in a drought prone watershed.	No	Yes		Poor	Recommend removal	Very noisy data large flucations, perhaps related to pumping or data issues
OW398	Parksville	Nanaimo	107091	12	216	Confined Unconsolidated	No	Ignored all confined wells not located in a drought prone watershed.	No	Yes		Good	Recommended forecasting	
OW399	Knutsford	Kamloops	51604	15	276	Bedrock	Uncertain	no satellite telemetry	No	Yes		Fair	Recommended forecasting	
OW400	Historic Hat Creek Ranch	Kamloops	106329	13	134	Unconfined Unconsolidated	Yes	hydraulic connection to Bonaparte River, good period of record, stable GW level, quick response	No	Yes		Poor	Recommend removal	seems to struggle with melt timing. Potential for improvement with snowmodel.
OW401	Osoyoos	Penticton	102362	14	808	Bedrock	Uncertain	402 is likely more indicative of bedrock water levels predicting drought for this area.	No	Yes		Fair	Recommended forecasting	
OW402	Osoyoos	Penticton	102364	14	936	Bedrock	Yes	Installed to assess higher mountain recharge. Bedrock to surface, screened from 19 ft down. May be helpful as leading-indicator	No	Yes		Fair	Recommended forecasting	
OW403	Twin Lakes	Penticton	104539	14	261	Unconfined Unconsolidated	Uncertain	Deep well with deep WLs (36 - 40 mbgs) - lag time may be too big	No	Yes		Good	Recommended forecasting	
OW404	Twin Lakes	Penticton	104538	14	260	Bedrock	No	Deep bedrock well	No	Yes		Poor	Recommend removal	seems to struggle with melt timing. Potential for improvement with snowmodel.
OW405	Oliver	Penticton	104536	14	256	Unconfined Unconsolidated	Yes	-	No	Yes		Good	Recommended forecasting	
OW406	Chilliwack	Surrey	102462	15	8	Unconfined Unconsolidated	Yes	Cluster 1 (well responds to recharge from local precipitation, primarily rainfall, and responds rapidly to both atmospheric rivers during winter reachege and significant rainfall deficits during summer) from Nott et al 2024 - Groundwater Response to Deluge and Drought in the Fraser Valley, Pacific Northwest	No	Yes		Good	Recommended forecasting	
OW407	Oliver	Penticton	104537	14	255	Unconfined Unconsolidated	Uncertain	May be too 'noisy' due to groundwater diversions.	No	Yes		Fair	Recommended forecasting	
OW408	Savary Island	Surrey	44210	14	834	Confined Unconsolidated	Uncertain	Not included in Nott et al. 2024	No	Yes		Poor	Recommend removal	lots of scatter potential, minimal seasonal waterlevel changes

Table A1.1 (Cont'd.)

Well	Location	Regional Office	Well Tag #	Length of Record	Aquifer #	Aquifer Type OR Well Lithology	Regional Hydrogeo: Should well be included in drought forecasting?	Comments from Regional Hydrogeo	Well in Phase 1	Well included in Phase 2	Reason Excluded	Model Performance	Action	Rationale
OW409	Spallumcheen	Penticton	104830	13	103	Unconfined Unconsolidated	Yes	-	No	Yes		Good	Recommended forecasting	
OW410	Joe Riche	Penticton	106355	13	473	Bedrock	No	Deep bedrock well	No	Yes		Poor	Recommend re-testing	performance seems good may need re-testing with longer data record.
OW411	West Kelowna	Penticton	106351	12	304	Bedrock	Yes	Installed to assess upland recharge. Bedrock begins at 26 ft. Shallow water levels (0 - 13 mbgs)	No	Yes		Good	Recommended forecasting	
OW412	Summerland	Penticton	106501	12	1264	Bedrock	Yes	Installed to assess upland recharge. Bedrock begins at 15 ft with sand above.	No	Yes		Fair	Recommended forecasting	
OW413	Kelowna	Penticton	107713	11	464	Confined Unconsolidated	No	Thick confining layer, aquifer 464 likely not good for drought forecasting	No	Yes		Poor	Recommended forecasting	
OW414	Langley	Surrey	105642	14	1144	Confined Unconsolidated	Uncertain	Not included in Nott et al. 2024	No	Yes		Good	Recommended forecasting	
OW415	Langley	Surrey	105644	14	33	Confined Unconsolidated	Uncertain	Not included in Nott et al. 2024	No	Yes		Good	Recommended forecasting	
OW416	Dawson Creek	Fort St. John	104707	12	595	Bedrock	Yes	Water levels show seasonal response; shallow well in O&G area.	No	Yes		Fair	Recommended forecasting	
OW417	Dawson Creek	Fort St. John	104708	11	595	Bedrock	No		No	Yes		Good	Recommended forecasting	
OW418	Dawson Creek	Fort St. John	104709	13	633	Bedrock	No	Shows a decreasing trend with time.	No	Yes		Good	Recommended forecasting	
OW420	Dawson Creek	Fort St. John	104711	13	593	Bedrock	No		No	Yes		Poor	Recommend removal	very noisy data, limited seasonal response
OW422	Logan Lake	Kamloops	80135	14	822	Confined Unconsolidated	Uncertain	no satellite telemetry	No	Yes		Fair	Recommended forecasting	
OW423	Hat Creek Ranch	Kamloops	106325	13	133	Confined Unconsolidated	Yes	might be interesting to compare with Obs Well 400	No	Yes		Poor	Recommend removal	seems to struggle with melt timing. Potential for improvement with snowmodel.
OW424	Coombs	Nanaimo	107378	12	1250	Confined Unconsolidated	No	Ignored all confined wells not located in a drought prone watershed.	No	Yes		Fair	Recommended forecasting	
OW425	Qualicum	Nanaimo	107878	12	1251	Confined Unconsolidated	No	Ignored all confined wells not located in a drought prone watershed.	No	Yes		Poor	Recommend removal	Appears to be aquifer demand changes (non-seasonal) possibly pumping effects.
OW426	Qualicum	Nanaimo	107879	12	662	Confined Unconsolidated	No	Ignored all confined wells not located in a drought prone watershed.	No	Yes		Fair	Recommended forecasting	
OW427	Qualicum	Nanaimo	107880	12	416	Confined Unconsolidated	No	Ignored all confined wells not located in a drought prone watershed.	No	Yes		Poor	Recommend removal	minimal seasonal flucations
OW428	Cowichan	Nanaimo	107881	12	NA	Bedrock	No	Ignored all bedrock wells not located in a drought prone watershed.	No	Yes		Fair	Recommended forecasting	
OW429	Cowichan	Nanaimo	107882	12	178	Confined Unconsolidated	No	Ignored all confined wells not located in a drought prone watershed.	No	Yes		Fair	Recommended forecasting	
OW430	Cowichan	Nanaimo	107884	12	198	Bedrock	Yes	In Koksilah Watershed. Seasonal fluctuations of roughly 2.25 metres.	No	Yes		Fair	Recommended forecasting	
OW431	Cowichan	Nanaimo	107885	12	199	Confined Unconsolidated	Yes	In Koksilah Watershed. Seasonal fluctuations of roughly 2.25 metres.	No	Yes		Good	Recommended forecasting	
OW432	Yellowpoint	Nanaimo	107886	12	162	Bedrock	No	Ignored all bedrock wells not located in a drought prone watershed.	No	Yes		Fair	Recommended forecasting	
OW433	Qualicum	Nanaimo	108124	12	1250	Confined Unconsolidated	No	Ignored all confined wells not located in a drought prone watershed.	No	Yes		Fair	Recommended forecasting	
OW434	Qualicum	Nanaimo	108125	12	217	Confined Unconsolidated	No	Ignored all confined wells not located in a drought prone watershed.	No	Yes		Good	Recommended forecasting	
OW435	South Wellington	Nanaimo	108187	12	165	Bedrock	No	Ignored all bedrock wells not located in a drought prone watershed.	No	Yes		Fair	Recommended forecasting	
OW436	Cassidy	Nanaimo	110408	10	160	Confined Unconsolidated	No	Ignored all confined wells not located in a drought prone watershed.	No	Yes		Fair	Recommended forecasting	
OW437	Cassidy	Nanaimo	110409	10	161	Unconfined Unconsolidated	Yes	Seasonal fluctuations of roughly 5.5 metres. Appears to have a quick response to precip.	No	Yes		Fair	Recommended forecasting	
OW438	Salt Spring Island	Nanaimo	109115	11	721	Bedrock	No	Ignored all bedrock wells not located in a drought prone watershed.	No	Yes		Fair	Recommended forecasting	
OW439	Cobble Hill	Nanaimo	113013	8	202	Bedrock	No	Ignored all bedrock wells not located in a drought prone watershed.	No	Yes		Poor	Recommend re-testing	performance seems good may need re-testing with longer data record.
OW440	Langley	Surrey	113553	8	50	Confined Unconsolidated	Yes	Cluster 1 (well responds to recharge from local precipitation, primarily rainfall, and responds rapidly to both atmospheric rivers during winter reachage and significant rainfall deficits during summer) from Nott et al 2024 - Groundwater Response to Deluge and Drought in the Fraser Valley, Pacific Northwest	No	Yes		Poor	Recommend removal	lots of scatter potential, potential pumping effects

Table A1.1 (Cont'd.)

Well	Location	Regional Office	Well Tag #	Length of Record	Aquifer #	Aquifer Type OR Well Lithology	Regional Hydrogeo: Should well be included in drought forecasting?	Comments from Regional Hydrogeo	Well in Phase 1	Well included in Phase 2	Reason Excluded	Model Performance	Action	Rationale
OW441	Abbotsford	Surrey	113183	12	28	Confined Unconsolidated	Yes	Cluster 1 (well responds to recharge from local precipitation, primarily rainfall, and responds rapidly to both atmospheric rivers during winter recharge and significant rainfall deficits during summer) from Nott et al 2024 - Groundwater Response to Deluge and Drought in the Fraser Valley, Pacific Northwest	No	No	Significant Pumping Effects			
OW442	Kelowna	Penticton	107712	11	464	Confined Unconsolidated	No	Confining layer not as thick as other wells in AQ464 but aquifer likely not good for forecasting	No	Yes		Good	Recommended forecasting	
OW443	Sooke	Nanaimo	114845	7	606	Bedrock	No	Ignored all bedrock wells not located in a drought prone watershed.	No	Yes		Poor	Recommend re-testing	performance seems good may need re-testing with longer data record.
OW444	Midway	Penticton	116654	7	478	Unconfined Unconsolidated	Yes	---	No	Yes		Poor	Recommend re-testing	performance seems good may need re-testing with longer data record.
OW445	Dawson Creek	Fort St. John	106679	11	590	Confined Unconsolidated	No		No	Yes		Poor	Recommend removal	very noisy data, limited seasonal response
OW446	Langley	Surrey	34654	12	52	Confined Unconsolidated	Yes	Cluster 1 (well responds to recharge from local precipitation, primarily rainfall, and responds rapidly to both atmospheric rivers during winter recharge and significant rainfall deficits during summer) from Nott et al 2024 - Groundwater Response to Deluge and Drought in the Fraser Valley, Pacific Northwest	No	Yes		Fair	Recommended forecasting	
OW447	Surrey	Surrey	74144	12	61	Confined Unconsolidated	Yes	Cluster 1 (well responds to recharge from local precipitation, primarily rainfall, and responds rapidly to both atmospheric rivers during winter recharge and significant rainfall deficits during summer) from Nott et al 2024 - Groundwater Response to Deluge and Drought in the Fraser Valley, Pacific Northwest	No	Yes		Good	Recommended forecasting	
OW448	Agassiz	Surrey	107798	12	4	Unconfined Unconsolidated	No	Cluster 2 (wells are also driven by precipitation, and are additionally influenced by the Fraser River's large summer freshet, briefly providing a secondary recharge mechanism. Groundwater recessions are offset to later in the summer, contingent on the Fraser River, mediating drought) from Nott et al 2024 - Groundwater Response to Deluge and Drought in the Fraser Valley, Pacific Northwest	No	Yes		Fair	Recommended forecasting	
OW449	Agassiz	Surrey	107800	12	4	Unconfined Unconsolidated	No	Cluster 2 (wells are also driven by precipitation, and are additionally influenced by the Fraser River's large summer freshet, briefly providing a secondary recharge mechanism. Groundwater recessions are offset to later in the summer, contingent on the Fraser River, mediating drought) from Nott et al 2024 - Groundwater Response to Deluge and Drought in the Fraser Valley, Pacific Northwest	No	Yes		Fair	Recommended forecasting	
OW450	Chilliwack	Surrey	108905	11	6	Unconfined Unconsolidated	Yes	Cluster 1 (well responds to recharge from local precipitation, primarily rainfall, and responds rapidly to both atmospheric rivers during winter recharge and significant rainfall deficits during summer) from Nott et al 2024 - Groundwater Response to Deluge and Drought in the Fraser Valley, Pacific Northwest	No	Yes		Fair	Recommended forecasting	
OW451	Hope	Surrey	108906	11	1	Unconfined Unconsolidated	No	Cluster 2 (wells are also driven by precipitation, and are additionally influenced by the Fraser River's large summer freshet, briefly providing a secondary recharge mechanism. Groundwater recessions are offset to later in the summer, contingent on the Fraser River, mediating drought) from Nott et al 2024 - Groundwater Response to Deluge and Drought in the Fraser Valley, Pacific Northwest	No	Yes		Fair	Recommended forecasting	
OW452	Langley	Surrey	109140	11	37	Unconfined Unconsolidated	No	Cluster 2 (wells are also driven by precipitation, and are additionally influenced by the Fraser River's large summer freshet, briefly providing a secondary recharge mechanism. Groundwater recessions are offset to later in the summer, contingent on the Fraser River, mediating drought) from Nott et al 2024 - Groundwater Response to Deluge and Drought in the Fraser Valley, Pacific Northwest	No	Yes		Fair	Recommended forecasting	
OW453	Langley	Surrey	109141	11	35	Unconfined Unconsolidated	Yes	Cluster 1 (well responds to recharge from local precipitation, primarily rainfall, and responds rapidly to both atmospheric rivers during winter recharge and significant rainfall deficits during summer) from Nott et al 2024 - Groundwater Response to Deluge and Drought in the Fraser Valley, Pacific Northwest	No	Yes		Good	Recommended forecasting	
OW454	Squamish	Surrey	110090	10	401	Unconfined Unconsolidated	Uncertain	Not included in Nott et al. 2024	Yes	Yes		Fair	Recommended forecasting	
OW455	Vanderhoof	Prince George	112855	8	242	Confined Unconsolidated	No	Completed in deep confined aquifer.	No	Yes		Fair	Recommended forecasting	

Table A1.1 (Cont'd.)

Well	Location	Regional Office	Well Tag #	Length of Record	Aquifer #	Aquifer Type OR Well Lithology	Regional Hydrogeo: Should well be included in drought forecasting?	Comments from Regional Hydrogeo	Well in Phase 1	Well included in Phase 2	Reason Excluded	Model Performance	Action	Rationale
OW456	Langley	Surrey	111977	8	59	Confined Unconsolidated	Uncertain	Not included in Nott et al. 2024	No	Yes		Good	Recommended forecasting	
OW457	Abbotsford	Surrey	111978	8	21	Unconfined Unconsolidated	No	Cluster 2 (wells are also driven by precipitation, and are additionally influenced by the Fraser River's large summer freshet, briefly providing a secondary recharge mechanism. Groundwater recessions are offset to later in the summer, contingent on the Fraser River, mediating drought) from Nott et al 2024 - Groundwater Response to Deluge and Drought in the Fraser Valley, Pacific Northwest	No	Yes		Poor	Recommend re-testing	Poorer performing, Cluster 2 well. Could re-test with longer data record, incorporation of Fraser River model may need to be incorporated
OW458	Langley	Surrey	111999	11	27	Confined Unconsolidated	Uncertain	Not included in Nott et al. 2024	No	Yes		Good	Recommended forecasting	
OW459	Chilliwack	Surrey	113739	8	8	Unconfined Unconsolidated	No	Cluster 2 (wells are also driven by precipitation, and are additionally influenced by the Fraser River's large summer freshet, briefly providing a secondary recharge mechanism. Groundwater recessions are offset to later in the summer, contingent on the Fraser River, mediating drought) from Nott et al 2024 - Groundwater Response to Deluge and Drought in the Fraser Valley, Pacific Northwest	No	Yes		Fair	Recommended forecasting	
OW460	Gibsons	Surrey	113189	15	560	Unconfined Unconsolidated	Uncertain	Not included in Nott et al. 2024	No	Yes		Fair	recommened anaysis	performance connsidered fair however recent data points to water use changes (pumping) or data issues.
OW461	Surrey	Surrey	113552	8	58	Confined Unconsolidated	Uncertain	Not included in Nott et al. 2024	No	Yes		Poor	Recommend re-testing	performance seems good may need re-testing with longer data record.
OW462	Maple Ridge	Surrey	115015	7	19	Bedrock	Yes	Cluster 1 (well responds to recharge from local precipitation, primarily rainfall, and responds rapidly to both atmospheric rivers during winter recharge and significant rainfall deficits during summer) from Nott et al 2024 - Groundwater Response to Deluge and Drought in the Fraser Valley, Pacific Northwest	No	Yes		Poor	Recommend re-testing	short data range, possible pumping effects,, suggest re-test in a few years.
OW463	Mission	Surrey	113920	8	884	Confined Unconsolidated	Yes	Cluster 1 (well responds to recharge from local precipitation, primarily rainfall, and responds rapidly to both atmospheric rivers during winter recharge and significant rainfall deficits during summer) from Nott et al 2024 - Groundwater Response to Deluge and Drought in the Fraser Valley, Pacific Northwest	No	Yes		Good	Recommended forecasting	
OW464	Canoe Creek	Kamloops	90213	18	109	Confined Unconsolidated	No	increasing trend	No	Yes		Good	Recommended forecasting	
OW467	Osoyoos	Penticton	115691	7	194	Unconfined Unconsolidated	No	Many data artifacts from agricultural surroundings	No	Yes		Good	Recommended forecasting	
OW468	Cranbrook	Penticton	115683	7	525	Confined Unconsolidated	No	Confining layer is ~13 m of dense wet silt. Water levels quite shallow (<2.5 mbgs) vs top of screen (27 m).	No	Yes		Fair	Recommended forecasting	
OW469	Sooke	Nanaimo	114846	7	599	Confined Unconsolidated	No	Ignored all confined wells not located in a drought prone watershed.	No	No	Significant Pumping Effects			
OW470	Mill Bay	Nanaimo	114847	7	206	Unconfined Unconsolidated	Yes	Seasonal fluctuations of roughly 3 metres.	No	Yes		Poor	Recommend re-testing	performance seems good may need re-testing with longer data record.
OW471	Lund	Surrey	113948	7	960	Bedrock	Uncertain	Not included in Nott et al. 2024	No	Yes		Poor	Recommend re-testing	performance seems good may need re-testing with longer data record.
OW473	Bowen Island	Surrey	115134	6	747	Bedrock	Uncertain	Not included in Nott et al. 2024	No	Yes		Poor	Recommend re-testing	performance seems good may need re-testing with longer data record.
OW474	Miracle Valley	Surrey	105719	7	25	Confined Unconsolidated	Yes	Cluster 1 (well responds to recharge from local precipitation, primarily rainfall, and responds rapidly to both atmospheric rivers during winter recharge and significant rainfall deficits during summer) from Nott et al 2024 - Groundwater Response to Deluge and Drought in the Fraser Valley, Pacific Northwest	No	Yes		Fair	Recommended forecasting	
OW475	Pemberton	Surrey	115845	7	326	Unconfined Unconsolidated	Uncertain	Not included in Nott et al. 2024	No	Yes		Poor	Recommend re-testing	Poorer performing, Cluster 2 well. Could re-test with longer data record, incorporation of Fraser River model may need to be incorporated
OW476	Pemberton	Surrey	115847	7	326	Unconfined Unconsolidated	Uncertain	Not included in Nott et al. 2024	No	Yes		Poor	Recommend re-testing	Poorer performing, Cluster 2 well. Could re-test with longer data record, incorporation of Fraser River model may need to be incorporated
OW477	Whistler	Surrey	115761	7	395	Unconfined Unconsolidated	Uncertain	Not included in Nott et al. 2024	No	Yes		Poor	Recommend re-testing	performance seems good may need re-testing with longer data record.
OW478	Whistler	Surrey	115848	7	387	Unconfined Unconsolidated	Uncertain	Not included in Nott et al. 2024	No	Yes		Poor	Recommend re-testing	performance seems good may need re-testing with longer data record.
OW479	Maple Ridge	Surrey	116533	7	19	Bedrock	Uncertain	Not included in Nott et al. 2024	No	Yes		Good		
OW480	Keats Island	Surrey	115317	7	548	Bedrock	Uncertain	Not included in Nott et al. 2024	No	Yes		Poor	Recommend re-testing	performance seems good may need re-testing with longer data record.

Table A1.1 (Cont'd.)

Well	Location	Regional Office	Well Tag #	Length of Record	Aquifer #	Aquifer Type OR Well Lithology	Regional Hydrogeo: Should well be included in drought forecasting?	Comments from Regional Hydrogeo	Well in Phase 1	Well included in Phase 2	Reason Excluded	Model Performance	Action	Rationale
OW481	Fort Nelson First Nation	Fort St. John	118702	7	1041	Unconfined Unconsolidated	No		No	Yes		Poor	Recommend re-testing	performance seems good may need re-testing with longer data record.
OW482	Fort Nelson	Fort St. John	118701	7	1040	Confined Unconsolidated	Yes	Jun suggested adding this one in Fort Nelson.	No	Yes		Poor	Recommend removal	Very minimal seasonal effects on well
OW483	Squamish	Surrey	116124	6	397	Confined Unconsolidated	Uncertain	Not included in Nott et al. 2024	No	Yes		Good		
OW484	Mayne Island	Nanaimo	23162	7	632	Bedrock	No	Ignored all bedrock wells not located in a drought prone watershed.	No	Yes		Poor	Recommend re-testing	performance seems good may need re-testing with longer data record.
OW485	Dewdney	Surrey	116226	6	12	Unconfined Unconsolidated	No	Cluster 2 (wells are also driven by precipitation, and are additionally influenced by the Fraser River's large summer freshet, briefly providing a secondary recharge mechanism. Groundwater recessions are offset to later in the summer, contingent on the Fraser River, mediating drought) from Nott et al 2024 - Groundwater Response to Deluge and Drought in the Fraser Valley, Pacific Northwest	No	Yes		Poor	Recommend re-testing	performance seems good may need re-testing with longer data record.
OW486	Deroche	Surrey	116228	6	12	Unconfined Unconsolidated	No	Cluster 2 (wells are also driven by precipitation, and are additionally influenced by the Fraser River's large summer freshet, briefly providing a secondary recharge mechanism. Groundwater recessions are offset to later in the summer, contingent on the Fraser River, mediating drought) from Nott et al 2024 - Groundwater Response to Deluge and Drought in the Fraser Valley, Pacific Northwest	No	Yes		Poor	Recommend re-testing	performance seems good may need re-testing with longer data record.
OW487	Lumby	Penticton	120396	5	314	Confined Unconsolidated	No	Very deep, very confined.	No	Yes		Fair	Recommended forecasting	
OW488	Cowichan	Nanaimo	117430	6	197	Confined Unconsolidated	Yes	In Koksilah Watershed. Seasonal fluctuations of roughly 3 metres.	No	Yes		Fair	Recommended forecasting	
OW489	Cowichan	Nanaimo	117428	6	197	Confined Unconsolidated	Yes	In Koksilah Watershed. Seasonal fluctuations of roughly 2 metres.	No	No	Significant Pumping Effects		Recommended forecasting	
OW490	Langley	Surrey	117645	9	24	Unconfined Unconsolidated	Yes	Cluster 1 (well responds to recharge from local precipitation, primarily rainfall, and responds rapidly to both atmospheric rivers during winter reachage and significant rainfall deficits during summer) from Nott et al 2024 - Groundwater Response to Deluge and Drought in the Fraser Valley, Pacific Northwest	No	Yes		Fair	Recommended forecasting	
OW491	Maple Ridge	Surrey	120403	5	26	Confined Unconsolidated	Yes	Cluster 1 (well responds to recharge from local precipitation, primarily rainfall, and responds rapidly to both atmospheric rivers during winter reachage and significant rainfall deficits during summer) from Nott et al 2024 - Groundwater Response to Deluge and Drought in the Fraser Valley, Pacific Northwest	No	Yes		Fair	Recommended forecasting	
OW492	Columbia Valley	Surrey	120407	5	20	Unconfined Unconsolidated	Yes	Cluster 1 (well responds to recharge from local precipitation, primarily rainfall, and responds rapidly to both atmospheric rivers during winter reachage and significant rainfall deficits during summer) from Nott et al 2024 - Groundwater Response to Deluge and Drought in the Fraser Valley, Pacific Northwest	No	Yes		Fair	Recommended forecasting	
OW493	Cowichan	Nanaimo	120148	5	198	Bedrock	Yes	In Koksilah Watershed. Scattered WLs during winter months.	No	Yes		Poor	Recommend re-testing	performance seems good may need re-testing with longer data record.
OW494	Merritt	Kamloops	61559	6	1168	Confined Unconsolidated	Yes	period of record = 5 yrs, planning to install telemetry later 2024, possible hydraulic connection with overlying unconfined aquifer	No	Yes		Poor	Recommend removal	very noisy data, no clear seasonal trend
OW495	Bowen Island	Surrey	120711	7	746	Bedrock	Uncertain	Not included in Nott et al. 2024	No	Yes		Poor	Recommend re-testing	performance seems good may need re-testing with longer data record.
OW496	Fort Nelson	Fort St. John	126680	4	1034	Bedrock	No		No	Yes		Poor	Recommend removal	Very minimal seasonal effects on well
OW497	Sunshine Coast Regional District	Surrey	123003	4	560	Unconfined Unconsolidated	Uncertain	Not included in Nott et al. 2024	No	Yes		Poor	Recommend removal	lots of scatter potential, minimal seasonal waterlevel changes
OW498	Sechelt	Surrey	123008	4	566	Unconfined Unconsolidated	Uncertain	Not included in Nott et al. 2024	No	Yes		Poor	Recommend re-testing	performance seems good may need re-testing with longer data record.
OW499	Sechelt	Surrey	123004	4	566	Unconfined Unconsolidated	Uncertain	Not included in Nott et al. 2024	No	Yes		Poor	Recommend re-testing	performance seems good may need re-testing with longer data record.
OW501	Kitimat	Smithers	123333	3	1085	Confined Unconsolidated		No hydrogeo available.	No	No	Data Record less than 3 years	Not Tested		
OW502	Valemount	Prince George	123098	4	800	Confined Unconsolidated	Yes	Completed in a shallow, semi-confined/unconfined aquifer.	No	Yes		Good	Recommended forecasting	
OW503	Chilliwack	Surrey	126214	3	6	Unconfined Unconsolidated	Uncertain	Not included in Nott et al. 2024	No	No	Data Record less than 3 years	Not Tested		
OW504	Langley	Surrey	128157	3	1192	Confined Unconsolidated	Uncertain	Not included in Nott et al. 2024	No	No	Data Record less than 3 years	Not Tested		

Table A1.1 (Cont'd.)

Well	Location	Regional Office	Well Tag #	Length of Record	Aquifer #	Aquifer Type OR Well Lithology	Regional Hydrogeo: Should well be included in drought forecasting?	Comments from Regional Hydrogeo	Well in Phase 1	Well included in Phase 2	Reason Excluded	Model Performance	Action	Rationale
OW506	Vaseux Creek	Penticton	125206	4	255	Unconfined Unconsolidated	No	Limited data (2021 onward)	No	Yes		Poor	Recommend re-testing	performance seems good may need re-testing with longer data record.
OW507	Komoks First Nation	Nanaimo	128047	4	408	Unconfined Unconsolidated	No	Near Tsolum Watershed. Likely confined as 100 ft of "grey silty till tight" material listed in drill log. Minimal seasonal fluctuations. Likely insufficient data for drought forecasting (2021-2024).	No	Yes		Poor	Recommend removal	minimal seasonal flucations
OW508	Tulameen	Penticton	128408	2	1010	Unconfined Unconsolidated	Uncertain	Hydrogeologically appropriate but limited data available (2023 onward); WLs ~4 mbgs	No	No	Significant Pumping Effects	Not Tested		
OW509	Canyon	Penticton	126644	2	489	Unconfined Unconsolidated	Yes	Limited data available (June 2023 onward)	No	No	Data Record less than 3 years	Not Tested		
OW510	Deep Creek	Penticton	128403	2	1153	Confined Unconsolidated	No	Thick confining layer	No	No	Significant Pumping Effects	Not Tested		
OW511	Savary Island	Surrey	128292	3	834	Confined Unconsolidated	Uncertain	Not included in Nott et al. 2024	No	No	Data Record less than 3 years	Not Tested		
OW512	South Okanagan Grasslands Protected Area	Penticton	128380	2	238	Bedrock	No	Limited data available (spring 2023 onward); confined	No	No	Data Record less than 3 years	Not Tested		
OW513	Terrace	Smithers	127610	7	575	Unconfined Unconsolidated		No hydrogeo available.	No	Yes		Fair	Recommended forecasting	
OW514	Falkland	Kamloops	128015	2	97	Unconfined Unconsolidated	Uncertain	high priority area, quick response, but <2 yrs data	No	No	Data Record less than 3 years	Not Tested		
OW515	Falkland	Kamloops	128014	2	98	Confined Unconsolidated	Uncertain	high priority area, quick response, but <2 yrs data	No	No	Data Record less than 3 years	Not Tested		
OW516	Vanderhoof	Prince George	128282	2	242	Confined Unconsolidated	No	Completed in deep confined aquifer	No	No	Data Record less than 3 years	Not Tested		
OW517	Vanderhoof	Prince George	128283	2	246	Unconfined Unconsolidated	No	Completed in deep (relativley) confined aquifer. Seasonal variablity is not clear.	No	No	Data Record less than 3 years	Not Tested		

Appendix A2
Model User Manual



GROUNDWATER LEVEL FORECASTING TOOLKIT USER MANUAL: PHASE 2

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AMENDMENT RECORD

This report has been issued and amended as follows:

Issue	Description	Date	Approved by	
1	First version of Groundwater level forecasting toolkit user manual: Phase 2	20250416	Jos Beckers Project Director	Jacob Nunn Project Manager
2	Second version of Groundwater level forecasting toolkit user manual: Phase 2	20250626	 Jos Beckers Project Director	 Jacob Nunn Project Manager

1.0 INTRODUCTION

The following document prepared by Hatfield Consultants (Hatfield) for the Water Management Branch of the British Columbia (B.C.) Ministry of Water, Land and Resource Stewardship (MWLRS), serves as an updated (Phase 2) user manual for the Provincial Groundwater Observation Well Network (PGOWN) groundwater level forecasting tool. The previous version of the manual (Phase 1) was prepared in 2024. This manual provides a guide for running the forecasting tool in R and assumes the user has a basic understanding of R.

The manual describes the inputs required for the forecasting tool and the scripts needed to run it. It also provides some background on the functions developed to operate the forecasting tool.

For more information on the tool's background and development, please refer to the main document (Hatfield 2025).

Disclaimer

The groundwater level forecasts were derived using statistical models and using third-party data as inputs. The models have two categories of uncertainty or forecast errors, systematic errors from the model's intrinsic limitations and random errors inherited from the input data. Therefore, it can be expected that the model forecasts are different from the observations. It is also possible that the actual water levels will be higher than the forecast upper bound or lower than the forecast lower bound. Users of this forecast must accept all responsibility for their use and interpretation.

2.0 PERFORMING FORECAST SIMULATIONS

2.1 STRUCTURE

The overall forecasting model structure is shown in Figure 1 and summarized below:

- Step 1: Data Compilation - Once appropriate climate and snow water equivalent (SWE) stations are identified for each PGOWN well, the necessary data for validation, testing, and operation are compiled. This includes R scripts for downloading and compiling the real-time data.
- Step 2: Training of Models - ANN models are trained separately for each PGOWN well and forecast period, saving the models. This needs to be done infrequently (yearly or seasonally).
- Step 3: Forecasting and Generating Outputs - This is done more frequently, generating model predictions using RFC climate forecast data.

2.2 RFC CLIMATE FORECASTING

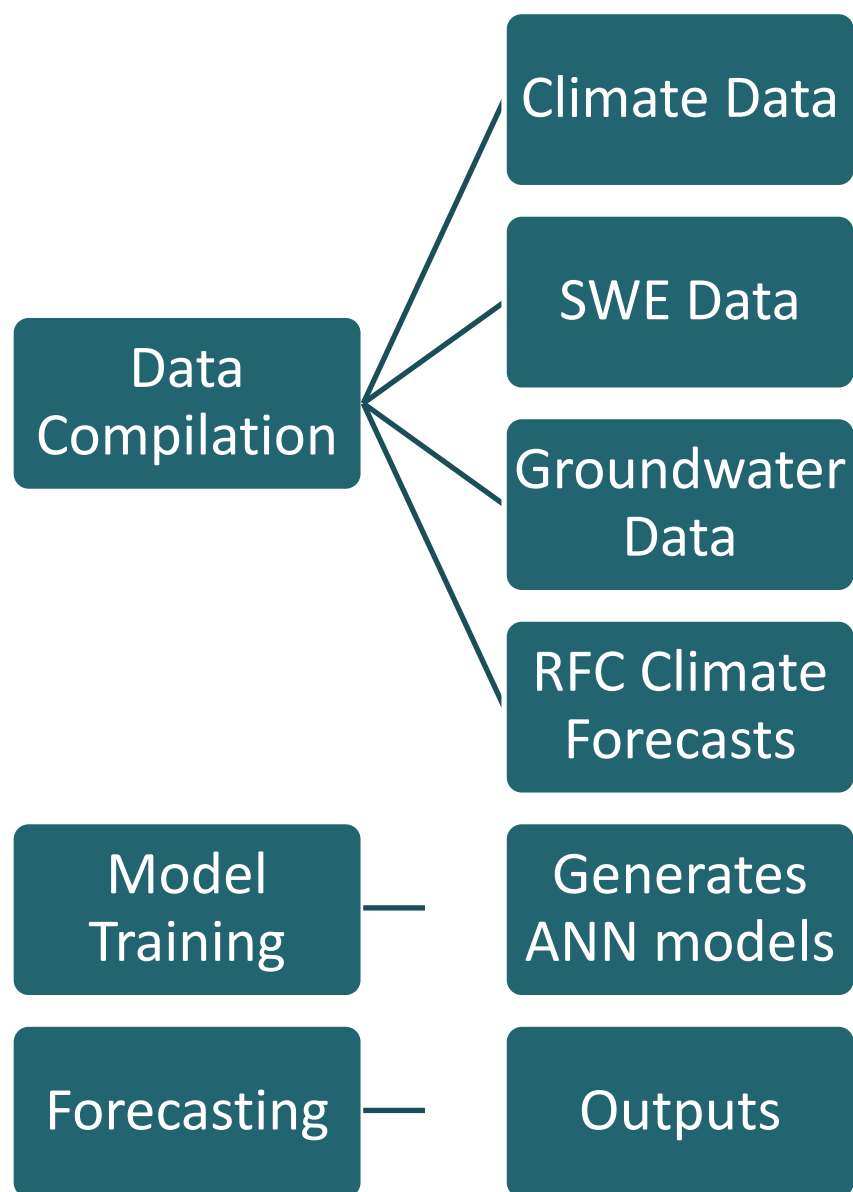
The RFC generated climate forecasts includes a deterministic 10-day period and an ensemble forecast of 20 scenarios extending up to 16 days in advance. The following approach was utilized in compiling the forecast:

- The first 10 days of any forecast were deterministic.

- The period from days 10 to 16 was infilled with longer-term ensemble forecasts, creating 20 scenarios with the first 10 days determined by the deterministic forecast.
- Beyond 16 days, historical climate variability was incorporated using the Monte Carlo approach.

The RFC generated climate forecasts specifically for this project at various locations around the province. For each PGOWN well, the closest forecast station was chosen as the forecast station. This selection ensures that the forecasts are as relevant and accurate as possible for the specific conditions at each well.

Figure 1 **Forecasting model workflow.**



2.3 SIMULATION INPUTS

The *Forecast_Model_Data.csv* spreadsheet where the necessary information required for simulations can be input. The spreadsheet is located in the user input folder. The required information includes:

- Well_id: This is the PGOWN well name.
- Regional_group.
- Region: This is the region where the well is located.
- Location: This is a description of the well's location.
- Aquifer_id: This is the available aquifer number ID.
- Latitude: Well location latitude.
- Longitude: Well location longitude.
- Climate_station_Id: This is the recommended climate station that has available daily data during the historical period required for the well. It should be a representative station (04a_Climate_station_testing.R).
- Climate_Infilled_id: This is the climate station used for infilling missing data. It should be a representative station (04a_Climate_station_testing.R).
- Climate_secondary_Infilled: This is the secondary climate station used for infilling missing data. It should be a representative station (04a_Climate_station_testing.R).
- Climate_tertiary_Infilled: This is the tertiary climate station used for infilling missing data. It should be a representative station (04a_Climate_station_testing.R).
- Climate_quaternary_Infilled: This is the tertiary climate station used for infilling missing data. It should be a representative station (04a_Climate_station_testing.R).
- station_name_RF_forecast: RFC forecast station name to be used to download RFC deterministic and ensemble forecasts (04c_RFC_forecast_assigning.R).
- snow_stn: If the well is inferred to be under the influence of snowmelt, this is a representative snow station (04b_snow_station_testing.R).
- Snow_influenced: This indicates whether the well is inferred to be under the influence of snowmelt.
- Training_start_date: Start date of when to start model training, default should be 2004-01-01.
- Lag_time: This is the recharge lag time. For more information, refer to Hatfield (2025). This can be calculated based on the CCF analysis. For wells with short lag times, it is recommended that the minimum lag time be set to 7 days (05a_CCF_lag_analysis.R)

- **DWC_Precip:** Dynamic Weighing Coefficient for Rainfall (used in Rainfall and snowmelt setting). Calculated based on Dynamic Weighing Coefficient Calibration step. (05b_Dynamic_Weighting_Coeffiecent_Calibration.R).
- **DWC_Snow:** Dynamic Weighing Coefficient for snowmelt (snowmelt setting). Calculated based on Dynamic Weighing Coefficient Calibration step (05b_Dynamic_Weighting_Coeffiecent_Calibration.R).
- **ann_size:** hyperparameter for ANN model, calculated in ANN model calibration (05c_ANN_Parameter_calibration.R).
- **ann_decay:** hyperparameter for ANN model, calculated in ANN model calibration (05c_ANN_Parameter_calibration.R).
- **ann_maxit:** hyperparameter for ANN model, calculated in ANN model calibration (05c_ANN_Parameter_calibration.R).
- **R2_14,R2_30,R2_60 and R2_90:** Model performance statistics for forecast periods. Calculated during Validation testing.
- **NRMSE_14, NRMSE_30, NRMSE_60 and NRMSE_90:** Model performance statistics for forecast periods. Calculated during Validation testing.
- **RSR_14, RSR_30, RSR_60 and RSR_90:** Model performance statistics for forecast periods. Calculated during operational testing.

2.4 SCRIPTS

01_ConfigInputs.R

This script queries and installs necessary R-packages, and loads the required packages. It also sets the location for saving figures, and determines the data location, which is essential for data organization and accessibility. Additionally, it specifies the location of the *Forecast_Model_Data.csv* file. Manual inputs such as forecast day intervals can be adjusted; although the original testing was done on intervals of 14, 30, 60, and 90 days and this is the recommended setting. The number of cores for parallel computing can also be adjusted based on the capabilities of the computer running the script. In addition if a well is missing up to date data and rfc climate forecasts the tolerance to run models and plot results can be set as well, it is recommended to use 3 day tolerances/windows. Modifying these settings can help optimize the script's running time. Here is an example of the code with inputs highlighted:

```
# MANUAL INPUTS -----
---

# Choose location to save files
figure_location <- "Groundwater Level Forecasting R Toolkit version
3/Output/"
data_location <- "Groundwater Level Forecasting R Toolkit version 3/data/"
model_path <- "Groundwater Level Forecasting R Toolkit version 3/models/"
```



```

user_input_location <- "Groundwater Level Forecasting R Toolkit version
3/user_inputs/"

# Fill in well information based on location

pgown_well_info_all <-
read_csv(paste0(user_input_location, "Forecasting Model Data.csv")) %>%
  filter(!is.na(Climate_station_Id) & !is.na(Lag_time)) %>%
  mutate(Climate_Infilled_id = ifelse(is.na(Climate_Infilled_id), 0,
Climate_Infilled_id),
Climate_secondary_Infilled =
ifelse(is.na(Climate_secondary_Infilled), 0, Climate_secondary_Infilled),
Climate_tertiary_Infilled = ifelse(is.na(Climate_tertiary_Infilled),
0, Climate_tertiary_Infilled),
Climate_quaternary_Infilled =
ifelse(is.na(Climate_quaternary_Infilled), 0, Climate_quaternary_Infilled))

Regional_group_list <- pgown_well_info_all %>%
  dplyr::select(Regional_group) %>%
  distinct(Regional_group) %>%
  dplyr::pull(Regional_group)

Regional_group_list <- as.list(Regional_group_list)

# User set number of days to forecast
forecast_days <- c(14, 30, 60, 90)

# Number of cores (for parallel computing)
num_cores <- 4

# Missing data tolerances.
Missing_date_window <- 3

rfc_forecast_date_window <- 3

```

02_Model_Training.R

This script needs to only be operated once a season to generate models. This script loads the necessary inputs and required functions, and downloads climate data, water level data, and snow data from the sources specified in the *Forecast_Model_Data.csv* spreadsheet. The script then trains the models for each well and forecast period, saving the models in the “models” folder.

The script executes the *ConfigInputs.R* script and the developed functions *dl_climate_data.R*, *dl_pgown_wl_data*, *dl_snow_data.R*, and *Model_training_ann.R*. The locations of these functions can be adjusted if needed.

03_Model_Forecasting.R

This script loads the necessary inputs and required functions, and downloads climate data, water level data, snow data and weather forecast data from the sources specified in the *Forecast_Model_Data.csv*

spreadsheet. Downloads the models generated in model training. The script then runs the forecast model for the wells, generating output plots and forecasts.

The script executes the *ConfigInputs.R* script and the developed functions *dl_climate_data.R*, *dl_pgown_wl_data*, *dl_snow_data.R*, *dl_ensemble_forecast.R*, *dl_deterministic.R* and *Forecasting.R*. The locations of these functions can be adjusted if needed.

Outputs from the model forecasting includes:

- Well – Identifier for the well (Well number).
- Date_Predicted – The date for which the forecast is being made.
- Forecast_Day – The length of the forecast period.
- Likelihood of Above Normal Conditions – The percentage of simulations that fall above the 75th percentile of historical normal ranges.
- Likelihood of Normal Conditions – The percentage of simulations that fall within the 25th to 75th percentile range of historical normal conditions.
- Likelihood of Below Normal Conditions – The percentage of simulations that fall below the 25th percentile of historical normal ranges.
- Date – The date the forecast was generated.
- Predicted Value Percentiles – Forecasted values from Monte Carlo simulations, represented by the following percentiles:
 - predicted_value_min
 - predicted_value_max
 - predicted_value_5th
 - predicted_value_10th
 - predicted_value_25th
 - predicted_value_50th
 - predicted_value_75th
 - predicted_value_90th
 - predicted_value_95th

These values represent the distribution of forecasted groundwater levels.

- Groundwater Level Forecast (Model) Performance – Determined based on 90-day model validation. Performance is categorized into four groups:

- Good model validation performance, forecast less sensitive to future climate.
- Good model validation performance, forecast more sensitive to future climate .
- Fair model validation performance, forecast less sensitive to future climate
- Fair model validation performance, forecast more sensitive to future climate
- Missing data – a flag to flag missing data

2.5 DEVELOPED FUNCTIONS

dl_climate_data.R

The function takes in well information and a data location as inputs. It first creates a list of climate stations from the well information. It then downloads the daily climate data from these stations starting from January 1, 2004. The function also sets the order of stations for infilling data and fills in missing climate data from infilling stations.

dl_pgown_wl_data.R

Downloads and processes groundwater level data. The function takes in well information and a data location as inputs. It first creates a list of unique well locations from the well information. The function then downloads the groundwater level data for each well and combines the data into a single dataset. It also calculates the mean and maximum groundwater levels for each well, region, date, and snow influence, excluding any missing values. The processed groundwater data is then saved to a specified location.

dl_snow_data.R

The function downloads and processes snow data from specified stations. The function takes in well information and snow station id on as inputs. It first creates a list of unique snow stations. The function then retrieves daily snow water equivalent (SWE) data for all years from each station and combines the data into a single dataset. Finally, the function saves the raw snow data to a specified location.

dl_deterministic_forecast.R

The function downloads and processes RFC deterministic 10 day forecasts. The function takes in well information and RFC forecast station as inputs. The function then retrieves precipitation and temperature forecasted climate data.

dl_ensemble_forecast.R

The function downloads and processes RFC ensemble 16 day forecasts. The function takes in well information and RFC forecast station as inputs. The function then retrieves precipitation and temperature forecasted climate data for all 20 ensemble forecasts.

Model_training_ann.R

The function creates a forecast model for groundwater levels. The function takes the combined downloaded data, well lag time, forecast days, number of cores, and a figure location as inputs. The function then creates a list of wells from the available data and trains the model for each well in parallel. The function will utilize different variables depending on whether the well is influenced by rain or snow. The function summarizes leading and lagging variables, trains and ANN models and saves them in the “models” folder. This function needs to be run yearly or seasonally to generate forecasts.

Forecasting.R

The function creates a forecast predictions for groundwater levels. The function takes the combined downloaded data, well lag time, forecast days, number of cores, trained models, and a figure location as inputs. The function then creates a list of wells from the available data and runs calculations for each well in parallel. The function will utilize different variables depending on whether the well is influenced by rain or snow. The function summarizes leading and lagging variables fits the ANN models, and generates predictive data utilizing historical percentiles and RFC forecast data. The function also prepares and saves a plot of the forecasted groundwater levels, along with a table summarizing the predicted range of groundwater levels and outputs the results. Wells without missing data defined by tolerances in Config_inputs are not plotted.

2.6 SIMULATION OUTPUTS

The currently developed operational groundwater forecasting outputs for Phase 2 are illustrated in Figure 2 and Figure 3, which show output examples for rainfall dominated setting wells OW002 and OW310, respectively, and in Figure 4 for an example snowmelt dominated setting well (OW291). The output format overall captures a 1-year (365 day) period with the 90-day maximum forecast period being placed at the end of this period and actual recorded groundwater levels for the 275 day period up to the date the model is run (in this case 2025-06-24) being shown for context. Forecasted groundwater levels 14, 30, 60, and 90 days in advance are shown as box plots for the ANN model, with the center line being the typical or 50th percentile typical conditions for the forecast periods and upper and lower limits of the box representing the 25th and 75th percentile ranges, and the error bars representing the 10th and 90th percentile ranges of the predicted groundwater levels from Monte Carlo simulations. An additional table presents the likelihood of predicted groundwater levels falling into one of three categories:

- above normal, where the groundwater levels exceed the historical 75th percentile,
- normal, where groundwater levels fall within the historic 25th to 75th percentile range, and
- below normal, where groundwater levels are below the historic 25th percentile.

These categories were determined based on the percentage of Monte Carlo simulations that produced groundwater levels within each respective range (i.e., out of the total of 500 model runs). The likelihood percentages are provided for the ANN models. Which of these approaches to determining groundwater level range likelihood is preferred may depend on the model performance as well as the intended use of the groundwater forecast.

Groundwater level forecast (model) performance for associated forecast periods for a given well is represented in the output plots as changing colors. Performance is displayed as categorical model performance categories defined in Section 5.5 as Categories of Acceptable Groundwater Forecast Performances. This is displayed as:

- Green for "Good, Forecast less sensitive to future climate",
- Yellow for "Good, Forecast more sensitive to future climate",
- Orange for "Fair, Forecast less sensitive to future climate", and
- Red for "Fair, Forecast more sensitive to future climate".

Wells that are classified as "Forecast more sensitive to future climate" reflect when forecast period for a given well becomes long and relies heavily on future climate conditions, in this case the predicted groundwater range may reflect the historical groundwater range. For some wells this will only happen over very long forecast periods whereas for other wells this may already happen at shorter forecast periods.

Figure 3 represents a well (OW310) whose groundwater forecasted performance for different periods spans three performance categories. The 14-day groundwater forecasts are classified as "Good, Forecast less sensitive to future climate", the 30 and 60-day groundwater forecasts are classified as "Fair, Forecast less sensitive to future climate", and the 90-day groundwater forecasts are classified as "Fair, Forecast more sensitive to future climate".

Additional data on aquifer type and incorporated data is included adjacent to the plot legend above the likelihood of groundwater level data. This includes information such as main climate station and SWE station, and information about the aquifer. Below the groundwater level data, information will be included for the previous 30-day cumulative precipitation, temperature, and, in the case of snowmelt setting wells, SWE. Also included are results of the RFC deterministic and ensemble climate forecasts. In addition, the blue bars in the precipitation information diagram represent the varying aquifer recharge lag periods (indicated by blue dots) and highlight the timeframes (blue bars) when groundwater levels are most sensitive to climate inputs.

While the evaluation of model performance was conducted for the period from 2004 – 2024, all models will be updated to train on and incorporate new and additional data for groundwater forecasting purposes post-2024.

Figure 2 Example of model forecast output for OW002 (Abbotsford) on 2025-06-24.

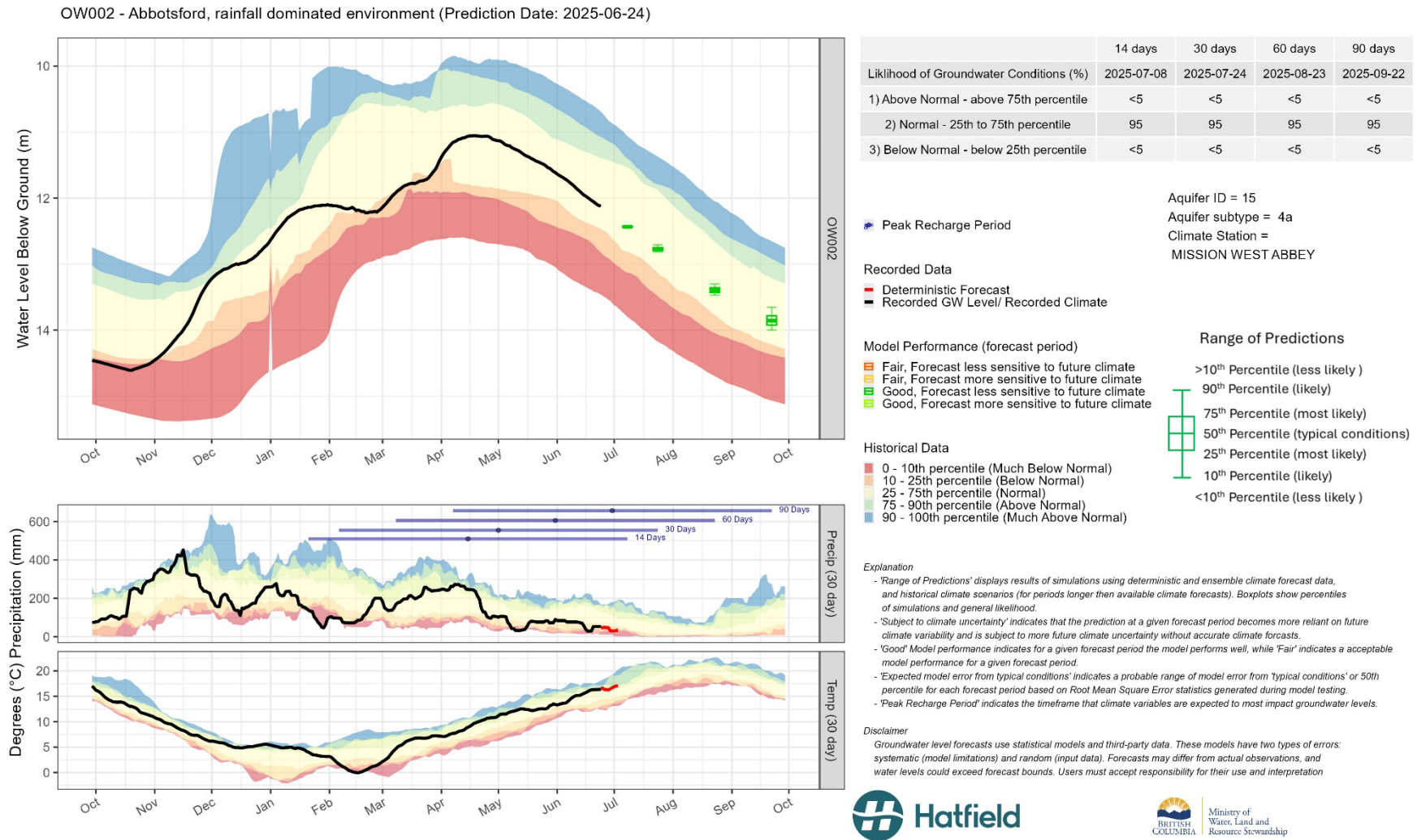


Figure 3 Example of model forecast output for OW310 (Abbotsford) on 2025-06-24.

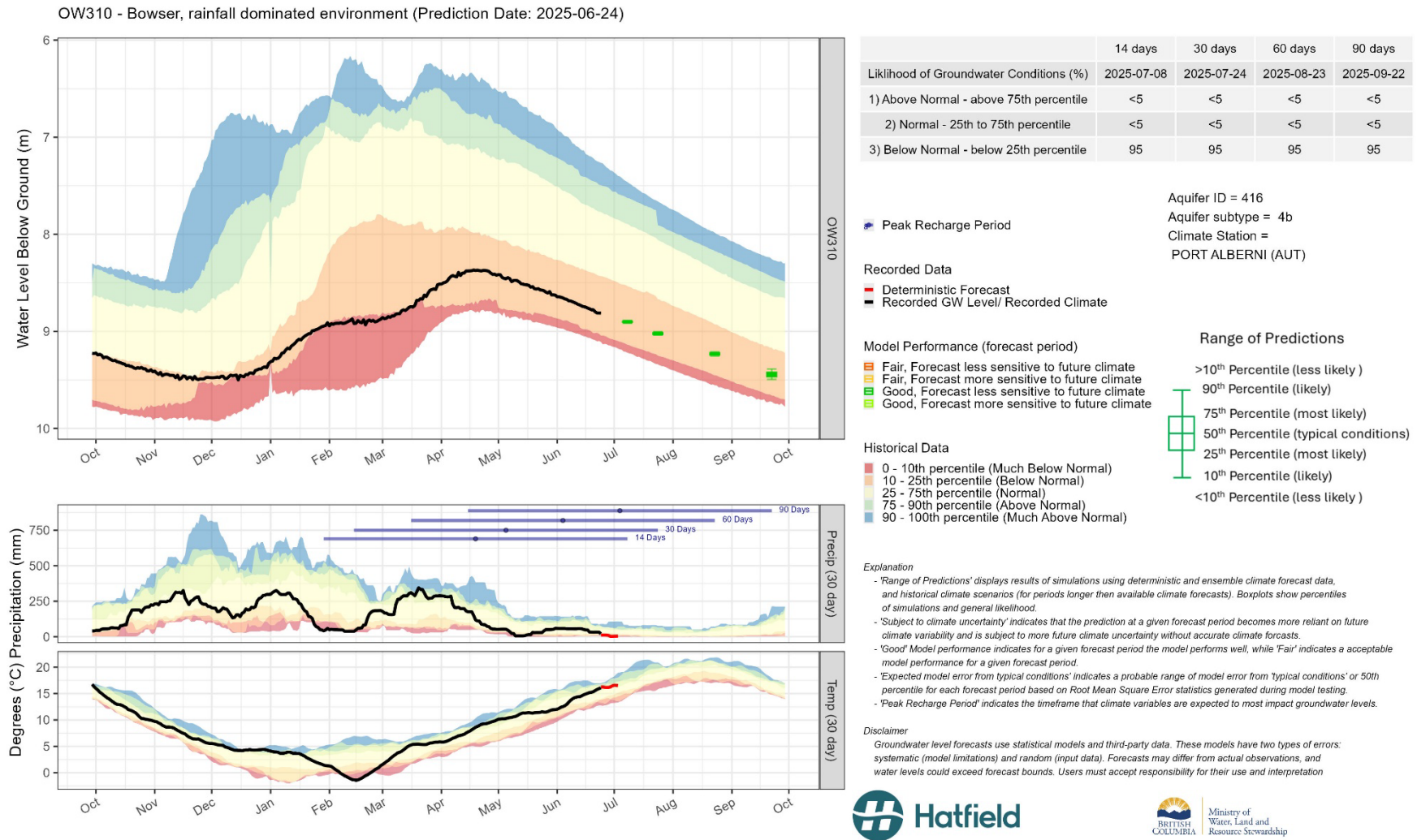
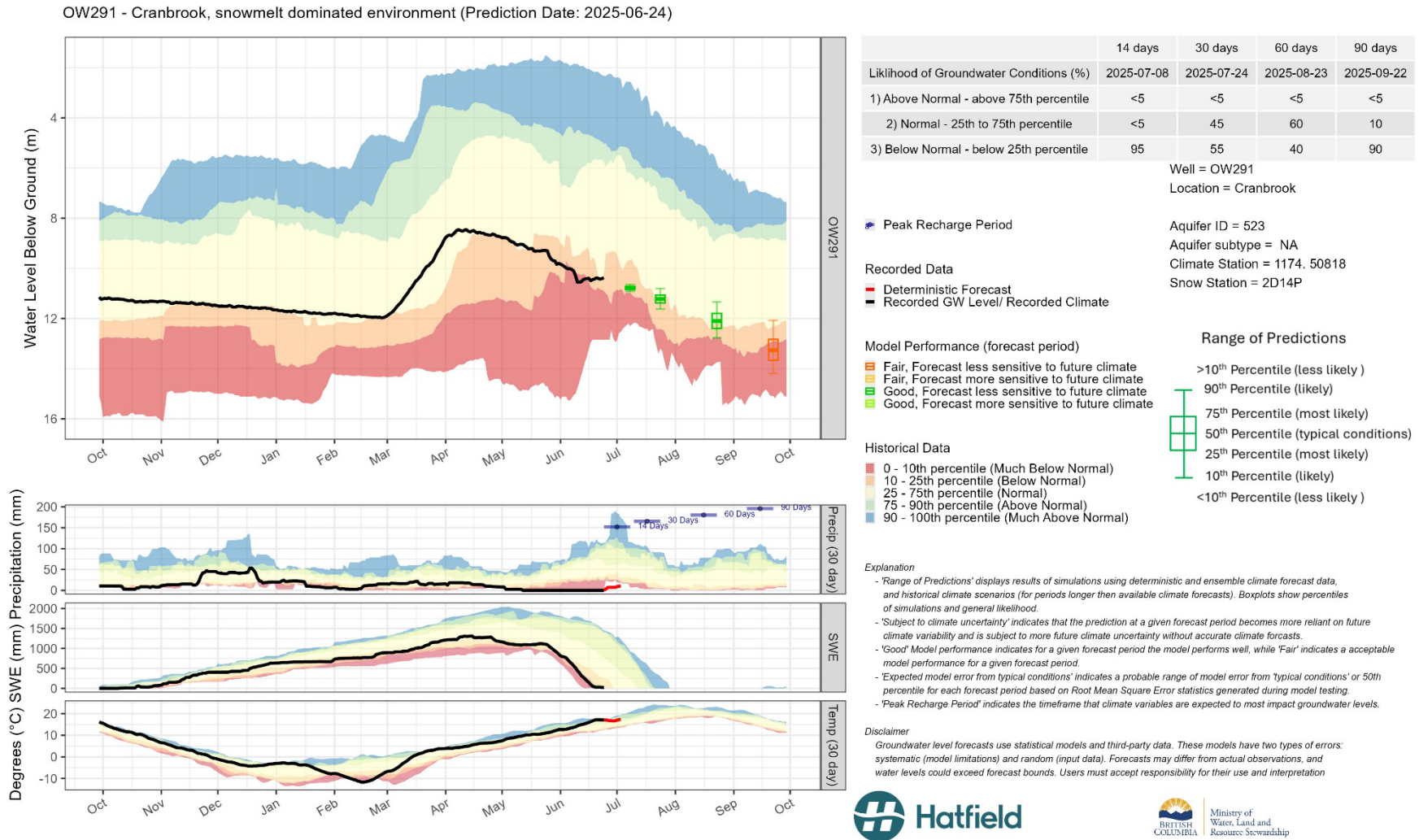


Figure 4 Example of model forecast output for OW291 (Cranbrook) on 2025-06-24.

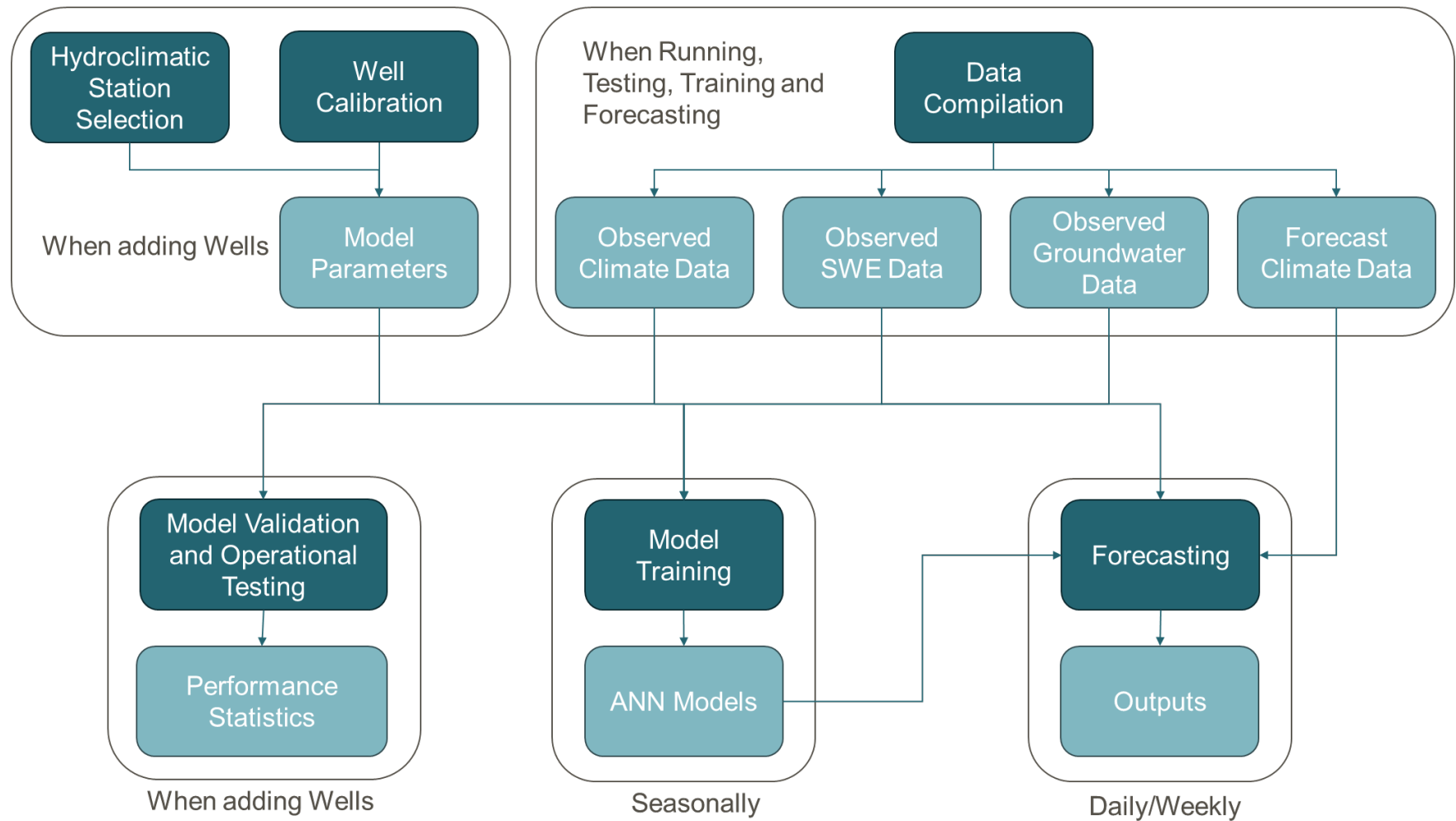


3.0 INCLUDING NEW WELLS OR RE-EVALUATING

The model testing utilizes the methods described in Hatfield (2025). The overall model testing workflow is shown in Figure 5 and is summarized below:

- Station and Data Identification - Climate and SWE stations were selected to leverage real-time data with robust historical datasets.
- Calibration of Model Parameters:
 - Recharge Lag – A Cross-Correlation Function CCF was used to determine the appropriate amount of prior data to use in forecast models based on observed groundwater level response delays this determines the input parameter (Lag_time).
 - Dynamic Weighting Coefficient - In the context of groundwater level forecasting, dynamic weighting involves applying weights to past data points such that more recent observations are given higher importance compared to older observations to more accurately capture the temporal dynamics of groundwater recharge and improve the overall forecast performance. This determines the input parameters DWC_precip and DWC_Snow.
 - Calibration of Machine Learning Hyperparameters - Optimal hyperparameters for the ANN model were calibrated by testing a range of values for 90-day forecasts for each well. This determines the hyperparameters for ANN model and include ann_size, ann_decay and ann_maxit.
- Model Testing:
 - Model Validation – Cross-validation approach to determine raw model performance to determine R2 and NRMSE. This determines input parameters for R2 (R2_14, R2_30, R2_60 and R2_90) and NRMSE (NRMSE_14, NRMSE_30, NRMSE_60 and NRMSE_90).
 - Operational Testing – Cross-validation approach was used. This determines input parameters for RSR (RSR_14, RSR_30, RSR_60 and RSR_90).
- Assessment - Based on the results of model testing, PGOWN wells that showed good model performance for model validation testing at 90 day forecast periods results are carried forward and considered in final operational model development.

Figure 5 **Model testing workflow.**



3.1 DETERMINING DATA INPUTS

3.1.1 Climate Station Testing (04a_Climate_station_testing.R)

Climate stations were selected based on their proximity to the PGOWN wells and their activity status. The primary criterion was to choose stations that are active and cover the most significant portion of the data record without substantial missing data. This ensures that the dataset is as complete and reliable as possible. In cases where data gaps existed, missing data was infilled using information from nearby stations. This infilling process was based on the proximity between the stations.

The script utilized is *04a_Climate_station_testing.R*. This script evaluates and generates a list of potential climate stations that could be utilized for a given well. The general criteria to be included in the list are:

- Stations within 100 km of the PGOWN wells.
- Stations with data gaps of less than 20% for both precipitation and temperature data.
- Stations that are active.
- Stations data record corresponds to 2004 to current.

Over the years, many of the stations have generated new climate station IDs. These stations are grouped, and this grouping determines the primary station. Infilled stations were determined by the following criteria:

- Stations with data gaps of less than 30% for both precipitation and temperature data.

A complete list of stations analyzed is exported and saved as *Complete_climate_station_list.csv*. The recommended infilling stations are saved as *Suggested_climate_station.csv*. These recommendations are largely determined by the distance from the PGOWN well and are saved in the outputs folder. It may be prudent to manually change these if necessary. These stations will need to be manually inputted into other input files.

The necessary input for the *04a_Climate_station_testing.R* script is located in the "Climate_station_testing.csv" file in the inputs folder. The following information needs to be included:

- Well_id: This is the PGOWN well name.
- Regional_group.
- Region: This is the region where the well is located.
- Location: This is a description of the well's location.
- Aquifer_id: This is the available aquifer number ID.
- Latitude: Well location latitude.
- Longitude: Well location longitude.
- Snow_influenced: This indicates whether the well is inferred to be under the influence of snowmelt.

3.1.2 Snow Station Testing (04b_snow_station_testing.R)

All snow stations within a 500 km radius of each PGOWN well were evaluated to ensure comprehensive coverage and accurate representation of snow conditions. Each PGOWN well was analyzed using the Cross-Correlation Function (CCF) analysis to identify the strongest correlation of groundwater levels with a current SWE station within the 500 km radius. This method helped in selecting the most relevant snow stations. The script utilized is *04b_snow_station_testing.R*. This script evaluates and generates a list of potential snow stations that could be utilized for a given well. The general criteria to be included in the list are:

- Stations within 500 km of the PGOWN wells.
- Stations with data gaps of less than 20% for both precipitation and temperature data.
- Stations that are active.
- Contain the data record since 2004.
- Strongest correlation between snow station and PGOWN well.

While climate stations are infilled, this approach was not taken for snow stations as this would involve generating relationships between differing stations that would likely be prone to elevation differences.

A complete list of stations analyzed is exported and saved as *List_Snow_station_test.csv*. Selection of snow stations involves manually checking for distance, data gaps, and a strong correlation between SWE and groundwater levels (CCF_value) relative to each well. On a limited number of occasions, additional manual checking and testing were necessary to ensure that the model results were logical and accurate. This involved verifying the selected stations and making manual adjustments if needed. When the final snow station is selected, put that values in the into the calibration inputs and model input file in the user_input folder.

The necessary input for the *04b_snow_station_testing.R* script is located in the *Climate_station_testing.csv* file in the inputs folder. The following information needs to be included:

- Well_id: This is the PGOWN well name.
- Regional_group.
- Region: This is the region where the well is located.
- Location: This is a description of the well's location.
- Aquifer_id: This is the available aquifer number ID.
- Latitude: Well location latitude.
- Longitude: Well location longitude.
- Snow_influenced: This indicates whether the well is inferred to be under the influence of snowmelt.

3.1.3 Climate Forecast Approach (04c_RFC_forecast_assigning.R)

In Hatfield 2025, the incorporation of short-term weather forecasts from the RFC was implemented to inform outputs. The RFC generated climate forecasts at various locations around the province from ECCC climate models. For each PGOWN well, the closest forecast station was chosen as the forecast station. This selection ensures that the forecasts are as relevant and accurate as possible for the specific conditions at each well.

A list of coordinates for the generated forecasts can be found in the “data” folder, saved as *forecast_station_coords.csv*, and was provided by the RFC. The *04c_RFC_forecast_assigning.R* script is used to match the closest RFC station to each PGOWN well. It saves the matched RFC station in the outputs folder in the spreadsheet *List_RFC_station.csv*. Put this forecast station into the model input file in the user_input folder.

The necessary input for the *04c_RFC_forecast_assigning.R* script is located in the *Climate_station_testing.csv* file in the inputs folder. The following information needs to be included:

- Well_id: This is the PGOWN well name.
- Regional_group.
- Region: This is the region where the well is located.
- Location: This is a description of the well's location.
- Aquifer_id: This is the available aquifer number ID.
- Latitude: Well location latitude.
- Longitude: Well location longitude.
- Snow_influenced: This indicates whether the well is inferred to be under the influence of snowmelt.

3.2 MODEL CALIBRATION

3.2.1 Recharge Lag Analysis (05a_CCF_lag_analysis.R)

A Cross-Correlation Function (CCF) evaluation is used in calculating recharge lag. The CCF evaluation helps determine the appropriate amount of prior data to be used in the forecast models, based on the observed time-to-well response due to major recharge mechanisms. More details on determining recharge lag can be found in Hatfield (2025).

Results can be extracted from the *CCF_lag_analysis_results.csv* in the Outputs folder. For wells with a lag time of less than 7 days, a minimum lag time of 7 days is recommended to be applied.

Before utilizing the CCF lag analysis sheet, the following information needs to be filled in for a well in the *CCF_lag_analysis_inputs.csv* spreadsheet in the user_inputs folder:

- Well_id: This is the PGOWN well name.

- `Regional_group`.
- `Region`: This is the region where the well is located.
- `Location`: This is a description of the well's location.
- `Aquifer_id`: This is the available aquifer number ID.
- `Latitude`: Well location latitude.
- `Longitude`: Well location longitude.
- `Climate_station_Id`: This is the recommended climate station that has available daily data during the historical period required for the well. It should be a representative station.
- `Climate_Infilled_id`: This is the climate station used for infilling missing data. It should be a representative station.
- `Climate_secondary_Infilled`: This is the secondary climate station used for infilling missing data. It should be a representative station.
- `Climate_tertiary_Infilled`: This is the tertiary climate station used for infilling missing data. It should be a representative station.
- `Climate_quaternary_Infilled`: This is the quaternary climate station used for infilling missing data. It should be a representative station.
- `station_name_RF_forecast`: RFC forecast station name to be used to download RFC deterministic and ensemble forecasts.
- `snow_stn`: If the well is inferred to be under the influence of snowmelt, this is a representative snow station.
- `Snow_influenced`: This indicates whether the well is inferred to be under the influence of snowmelt.

3.2.2 Dynamic Weighting Coefficient (05b_Dynamic_Weighting_Coeffiecent_Calibration.R)

Information on the Dynamic Weighting Coefficient (DWC) can be found in Hatfield 2025. The DWC was calculated by calibrating the ANN model with a 90-day forecast, iterating different dynamic weighting coefficients for each well. This calibration process involved evaluating the performance of the model using various values, specifically testing values of 0.5, 1, 2, 5, 10, and 100. The goal was to identify the coefficient that provided the best model performance, as measured by the accuracy of the groundwater level forecasts.

This was done utilizing the *05b_Dynamic_Weighting_Coeffiecent_Calibration.R* script. This script utilizes the function *Dynamic_Weight_calibration.R*.

The calibration process was conducted as follows:

- **Model Setup:** The model was set up to include the dynamic weights as part of the predictor variables. The recharge lag for each well was determined based on historical data and cross-correlation analysis.
- **Iteration of Coefficients:** For each well, the model was run multiple times, each time using a different dynamic weighting coefficient from the set of values (0.5, 1, 2, 5, 10, 100). This involved adjusting the standard deviation of the normal distribution used to shape the dynamic weights.
- **Model Evaluation:** The performance of the model was evaluated for each coefficient value. This was done by comparing the predicted groundwater levels to the observed levels over the 90-day forecast period and using R^2 values as the performance criterion. As calibration of dynamic weighting coefficients occurs before ANN hyperparameter calibration, standard parameters are used (size = 5, decay = 0.01, maxit = 500).
- **Selection of Optimal Coefficient:** The dynamic weighting coefficient that resulted in the lowest R^2 was selected as the optimal coefficient for that well. This coefficient was then used in the final model to ensure the best possible forecast accuracy.

Separate DWC was calculated for rainfall and snowmelt responses (DWC_Precip and DWC_Snow). Outputs are saved in the “outputs” folder.

Before utilizing the Dynamic Weighting Coefficient script, the following information needs to be filled in for a well in the *Calibration_Well_inputs.csv* spreadsheet in the “user_inputs” folder:

- **Well_id:** This is the PGOWN well name.
- **Regional_group.**
- **Region:** This is the region where the well is located.
- **Location:** This is a description of the well's location.
- **Aquifer_id:** This is the available aquifer number ID.
- **Latitude:** Well location latitude.
- **Longitude:** Well location longitude.
- **Climate_station_Id:** This is the recommended climate station that has available daily data during the historical period required for the well. It should be a representative station.
- **Climate_Infilled_id:** This is the climate station used for infilling missing data. It should be a representative station.
- **Climate_secondary_Infilled:** This is the secondary climate station used for infilling missing data. It should be a representative station.

- `Climate_tertiary_Infilled`: This is the tertiary climate station used for infilling missing data. It should be a representative station.
- `Climate_quaternary_Infilled`: This is the quaternary climate station used for infilling missing data. It should be a representative station.
- `station_name_RF_forecast`: RFC forecast station name to be used to download RFC deterministic and ensemble forecasts.
- `snow_stn`: If the well is inferred to be under the influence of snowmelt, this is a representative snow station.
- `Snow_influenced`: This indicates whether the well is inferred to be under the influence of snowmelt.
- `Lag_time`: This is the recharge lag time. For more information, refer to Hatfield (2025). This can be calculated based on the CCF analysis. For wells with short lag times, it is recommended that the minimum lag time be set to 7 days

3.2.3 ANN Hyperparameters (*05c_ANN_Parameter_calibration.R*)

Partitioning the data into a number of subsets (k subsets) was employed, with 5 subsets chosen so that the model is minimally trained on 4 years of data and validated on 1 year. This corresponds to initial testing about the minimal data length needed. The average cross-validation error was calculated to evaluate the model's predictive accuracy. The hyperparameter grid was applied to the cross-validation function, allowing for systematic testing and selection of the optimal combination of hyperparameters. This approach was applied to the entire data record of each well for a 90-day forecast period.

The hyperparameter grid included variations in the number of neurons (size), learning rate (decay), and maximum iterations (maxit). The variations in the number of neurons explored ranged from 5, 10, 15, and 20. The learning rate was explored in the range of 0.001, 0.01, and 0.1, and the maximum iterations ranged from 100, 200, and 500. The process involved increasing the values of the hyperparameters until there was no longer improvement in the model's performance across most of the models. This iterative approach ensured that the optimal combination was chosen. This testing is performed utilizing the *05c_ANN_Parameter_calibration.R* script. This script uses the inputs generated in the *ANN_hyperparameter_inputs.csv* file and utilizes the function *ANN_hyperparameter_calibration.R*. Results generating size, decay, and maxit parameters can be found in the *ANN_hypercalibration_results.csv* file located in the “outputs” folder.

Before utilizing the *05c_ANN_Parameter_calibration.R* script, the following information needs to be filled in for a well in the *ANN_hyperparameter_inputs.csv* spreadsheet in the “user_inputs” folder:

- `Well_id`: This is the PGOWN well name.
- `Regional_group`.
- `Region`: This is the region where the well is located.
- `Location`: This is a description of the well's location.

- `Aquifer_id`: This is the available aquifer number ID.
- `Latitude`: Well location latitude.
- `Longitude`: Well location longitude.
- `Climate_station_Id`: This is the recommended climate station that has available daily data during the historical period required for the well. It should be a representative station.
- `Climate_Infilled_id`: This is the climate station used for infilling missing data. It should be a representative station.
- `Climate_secondary_Infilled`: This is the secondary climate station used for infilling missing data. It should be a representative station.
- `Climate_tertiary_Infilled`: This is the tertiary climate station used for infilling missing data. It should be a representative station.
- `Climate_quaternary_Infilled`: This is the quaternary climate station used for infilling missing data. It should be a representative station.
- `station_name_RF_forecast`: RFC forecast station name to be used to download RFC deterministic and ensemble forecasts.
- `snow_stn`: If the well is inferred to be under the influence of snowmelt, this is a representative snow station.
- `Snow_influenced`: This indicates whether the well is inferred to be under the influence of snowmelt.
- `Lag_time`: This is the recharge lag time. For more information, refer to Hatfield (2025). This can be calculated based on the CCF analysis. For wells with short lag times, it is recommended that the minimum lag time be set to 7 days.
- `DWC_Precip`: Dynamic Weighing Coefficient for Rainfall (used in Rainfall and snowmelt setting). Calculated based on Dynamic Weighting Coefficient Calibration step.
- `DWC_Snow`: Dynamic Weighing Coefficient for snowmelt (snowmelt setting). Calculated based on Dynamic Weighting Coefficient Calibration step.

3.3 MODEL TESTING

3.3.1 Model Testing Script (06_Model_Testing.R)

A cross-validation approach was used to test model performance. This method involves dividing the data into subsets for training and testing. Specifically, model forecasts for each year from 2004 to the last full year are validated individually for the wells being tested. In each instance, the 2004-2024 training dataset excluded the year being validated.

Testing is performed to generate model performance statistics as defined in Hatfield (2025), which includes R^2 , NRMSE, and RSR (RSME Skill Ratio). Which are calculated using the functions *Model_testing.R*

function. R^2 and NRMSE utilizes actual historical data as forecast inputs to determine pure model performance.

RSR is calculated by utilizing historical ranges for forecast inputs of seasonal predictor variables for any given day of the year (temperature, precipitation, and snowmelt), established using data from the period 2004 to the previous year. Using these historical ranges, multiple groundwater level forecasts were generated through a Monte Carlo approach.

Model_testing.R

This function creates a forecast model for groundwater levels for each cross-validation year (from 2004 to the last full year), using both actual historical input data (Validation testing) and historical ranges (Operational testing) for forecast inputs. The function takes the combined downloaded data, well lag time, forecast days, number of cores, and a figure location as inputs. It then creates a list of wells from the available data and runs calculations for each well in parallel. The function will utilize different variables depending on whether the well is influenced by rain or snow. Additionally, it prepares and saves a plot of the forecasted groundwater levels for each validation year comparing each model and saves simulated values for use in determining model performance statistics.

Output figures for the wells tested are generated in the “outputs” folder. This includes visual figures that can be utilized to better assess model performance visually along with statistical outputs generated in the *Model_testing_results.csv*. Before utilizing the model testing script, the following information needs to be filled in for a well in the *Model_testing_inputs.csv* spreadsheet in the “user_inputs” folder:

- Well_id: This is the PGOWN well name.
- Regional_group.
- Region: This is the region where the well is located.
- Location: This is a description of the well's location.
- Aquifer_id: This is the available aquifer number ID.
- Latitude: Well location latitude.
- Longitude: Well location longitude.
- Climate_station_Id: This is the recommended climate station that has available daily data during the historical period required for the well. It should be a representative station.
- Climate_Infilled_id: This is the climate station used for infilling missing data. It should be a representative station.
- Climate_secondary_Infilled: This is the secondary climate station used for infilling missing data. It should be a representative station.
- Climate_tertiary_Infilled: This is the tertiary climate station used for infilling missing data. It should be a representative station.

- **Climate_quaternary_Infilled:** This is the tertiary climate station used for infilling missing data. It should be a representative station.
- **station_name_RF_forecast:** RFC forecast station name to be used to download RFC deterministic and ensemble forecasts.
- **snow_stn:** If the well is inferred to be under the influence of snowmelt, this is a representative snow station.
- **Snow_influenced:** This indicates whether the well is inferred to be under the influence of snowmelt.
- **Lag_time:** This is the recharge lag time. For more information, refer to Hatfield (2025). This can be calculated based on the CCF analysis. For wells with short lag times, it is recommended that the minimum lag time be set to 7 days.
- **DWC_Precip:** Dynamic Weighing Coefficient for Rainfall (used in Rainfall and snowmelt setting). Calculated based on Dynamic Weighing Coefficient Calibration step.
- **DWC_Snow:** Dynamic Weighing Coefficient for snowmelt (snowmelt setting). Calculated based on Dynamic Weighing Coefficient Calibration step.
- **ann_size:** hyperparameter for ANN model, calculated in ANN model calibration.
- **ann_decay:** hyperparameter for ANN model, calculated in ANN model calibration.
- **ann_maxit:** hyperparameter for ANN model, calculated in ANN model calibration.

3.3.2 Model Testing Assessment

Once model testing statistics have been generated, the overall model performance for different wells and forecast periods can be assessed. These performance categories are derived from Hatfield (2025), which tested a large number of wells to define performance indicators. Good model performance is associated with the ability to simulate 80% or more of the groundwater level variations over the validation period and a bias in simulated groundwater levels of 15% or less relative to the historical groundwater level range. Poor model performance is associated with the inability to simulate 60% or more of the groundwater level variations over the validation period and/or a bias in simulated groundwater levels of 25% or greater relative to the historical groundwater level range. All other instances are considered fair model performance.

For longer forecasting periods, results from some wells lead to a wide spectrum of forecasted groundwater levels, often mirroring the historical range. The average of forecast results tends to align with the average of historically observed groundwater levels. This uncertainty is predominantly attributed to the dependence of groundwater level forecasts on climate forecasts or antecedent conditions, with forecasts inherently uncertain. For each well, the forecast period at which this tendency occurs is assessed using the RSR. This value is calculated by comparing the RMSE of forecasted groundwater levels to observed groundwater levels over the entire cross-validation dataset, with the RMSE between long-term daily average water levels (for a given day of the year) and observed levels. The ratio of these two RMSE values indicates how far the model predictions can provide value without certainty in climate forecasts. An RSR below 1 indicates that the model's forecasts are more accurate than using the historical average groundwater levels, suggesting

that the model can provide valuable predictions even without precise hydroclimatic data. Conversely, an RSR around or above 1 implies that the model's forecasts are less useful, as they tend to align with average groundwater levels under typical conditions. This indicates that the model relies more on forecasted conditions than historical data, and its predictive value could be enhanced with better forecast inputs.

The combined results of Hatfield (2025) and the above performance indicator thresholds have led to a total of five categories of model evaluation. It is recommended that model performance be assessed for 90-day forecasts, providing the strictest performance thresholds:

- Poor model validation results: Forecast results of no value. This category includes wells that do not meet the R^2 and NRMSE value thresholds and cannot be recommended for use in forecasting.
- Good model validation performance, forecast results of value.
- Good model validation performance, forecast results of limited value.
- Fair model validation performance, forecast results of value.
- Fair model validation performance, forecast results of limited value.

Wells that are considered to have poor performance are not recommended for inclusion in the forecast network. It is possible that these wells may need further data to assist in training, and re-testing could be recommended.

4.0 REFERENCES

Hatfield Consultants. 2025. Groundwater Level Forecasting Pilot Project: Phase 2. Prepared for Ministry of Water, Land and Resource Stewardship. June 2025.

Appendix A3

Model Performance Statistics

Table A3.1 Model Performance Statistics.

Well	Regional Group	Snow Influenced	Model	R2				NRMSE				RMSE Ratio Skill				Operational Testing	Model Validation
				14 days	30 day	60 days	90 days	14 days	30 day	60 days	90 days	14 days	30 day	60 days	90 days		
OW002	Coastal 1	0	ANN	0.98	0.95	0.95	0.94	0.04	0.06	0.07	0.08	0.07	0.20	0.41	0.58	Forecast less sensitive to future climate	Good
OW002	Coastal 1	0	GAM	0.98	0.95	0.93	0.93	0.05	0.08	0.09	0.09	0.08	0.23	0.46	0.61	Forecast less sensitive to future climate	Good
OW002	Coastal 1	0	GLM	0.97	0.94	0.90	0.90	0.05	0.08	0.11	0.11	0.08	0.24	0.51	0.67	Forecast less sensitive to future climate	Good
OW002	Coastal 1	0	RF	0.98	0.95	0.94	0.91	0.04	0.06	0.08	0.10	0.07	0.21	0.44	0.65	Forecast less sensitive to future climate	Good
OW008	Coastal 1	0	ANN	0.99	0.96	0.93	0.91	0.03	0.05	0.07	0.08	0.04	0.12	0.35	0.53	Forecast less sensitive to future climate	Good
OW008	Coastal 1	0	GAM	0.98	0.94	0.88	0.85	0.04	0.07	0.11	0.12	0.04	0.15	0.41	0.61	Forecast less sensitive to future climate	Good
OW008	Coastal 1	0	GLM	0.98	0.94	0.88	0.85	0.04	0.07	0.11	0.12	0.05	0.17	0.43	0.62	Forecast less sensitive to future climate	Good
OW008	Coastal 1	0	RF	0.99	0.96	0.92	0.89	0.03	0.05	0.08	0.10	0.04	0.13	0.36	0.55	Forecast less sensitive to future climate	Good
OW255	Coastal 1	0	ANN	0.94	0.90	0.86	0.82	0.09	0.12	0.15	0.17	0.62	0.80	0.96	1.04	Forecast more sensitive to future climate	Fair
OW255	Coastal 1	0	GAM	0.93	0.88	0.84	0.81	0.10	0.14	0.17	0.18	0.65	0.86	1.04	1.09	Forecast more sensitive to future climate	Fair
OW255	Coastal 1	0	GLM	0.93	0.88	0.82	0.80	0.11	0.14	0.17	0.18	0.67	0.88	1.07	1.13	Forecast more sensitive to future climate	Fair
OW255	Coastal 1	0	RF	0.93	0.89	0.84	0.80	0.10	0.13	0.16	0.18	0.64	0.84	1.02	1.10	Forecast more sensitive to future climate	Fair
OW299	Coastal 1	0	ANN	0.98	0.96	0.94	0.93	0.07	0.09	0.12	0.13	0.40	0.64	0.86	0.95	Forecast less sensitive to future climate	Good
OW299	Coastal 1	0	GAM	0.98	0.95	0.92	0.91	0.07	0.11	0.14	0.16	0.41	0.66	0.90	1.02	Forecast more sensitive to future climate	Fair
OW299	Coastal 1	0	GLM	0.96	0.93	0.90	0.89	0.09	0.13	0.17	0.17	0.45	0.77	0.99	1.08	Forecast more sensitive to future climate	Fair
OW299	Coastal 1	0	RF	0.97	0.95	0.93	0.91	0.07	0.10	0.13	0.15	0.42	0.70	0.92	1.05	Forecast more sensitive to future climate	Good
OW301	Coastal 1	0	ANN	0.96	0.95	0.93	0.92	0.09	0.11	0.14	0.15	0.35	0.68	0.94	1.04	Forecast more sensitive to future climate	Good
OW301	Coastal 1	0	GAM	0.96	0.94	0.91	0.90	0.09	0.12	0.15	0.17	0.35	0.70	0.99	1.06	Forecast more sensitive to future climate	Fair
OW301	Coastal 1	0	GLM	0.95	0.91	0.89	0.89	0.11	0.16	0.18	0.18	0.40	0.85	1.07	1.12	Forecast more sensitive to future climate	Fair
OW301	Coastal 1	0	RF	0.96	0.93	0.90	0.89	0.09	0.12	0.15	0.17	0.35	0.75	1.07	1.19	Forecast more sensitive to future climate	Fair
OW349	Coastal 1	0	ANN	0.92	0.86	0.85	0.82	0.12	0.17	0.18	0.20	0.49	0.87	1.04	1.16	Forecast more sensitive to future climate	Fair
OW349	Coastal 1	0	GAM	0.86	0.82	0.82	0.82	0.16	0.19	0.19	0.21	0.59	0.85	1.05	1.12	Forecast more sensitive to future climate	Fair
OW349	Coastal 1	0	GLM	0.81	0.66	0.55	0.53	0.18	0.25	0.28	0.29	0.61	0.97	1.21	1.27	Forecast more sensitive to future climate	Poor
OW349	Coastal 1	0	RF	0.91	0.86	0.83	0.82	0.12	0.15	0.18	0.20	0.51	0.79	1.06	1.16	Forecast more sensitive to future climate	Fair
OW357	Coastal 1	0	ANN	0.98	0.97	0.95	0.94	0.05	0.07	0.09	0.10	0.22	0.45	0.71	0.82	Forecast less sensitive to future climate	Good
OW357	Coastal 1	0	GAM	0.98	0.96	0.95	0.93	0.06	0.08	0.09	0.10	0.22	0.47	0.73	0.83	Forecast less sensitive to future climate	Good
OW357	Coastal 1	0	GLM	0.97	0.94	0.90	0.90	0.08	0.11	0.14	0.14	0.24	0.52	0.82	0.91	Forecast less sensitive to future climate	Good
OW357	Coastal 1	0	RF	0.98	0.96	0.93	0.91	0.06	0.08	0.10	0.11	0.23	0.48	0.76	0.93	Forecast less sensitive to future climate	Good
OW406	Coastal 1	0	ANN	0.95	0.92	0.89	0.88	0.09	0.11	0.13	0.14	0.40	0.72	1.00	1.08	Forecast more sensitive to future climate	Good
OW406	Coastal 1	0	GAM	0.95	0.93	0.90	0.89	0.08	0.11	0.13	0.13	0.40	0.71	0.98	1.10	Forecast more sensitive to future climate	Good
OW406	Coastal 1	0	GLM	0.94	0.91	0.89	0.88	0.10	0.12	0.14	0.15	0.42	0.76	1.01	1.09	Forecast more sensitive to future climate	Good
OW406	Coastal 1	0	RF	0.94	0.89	0.84	0.78	0.09	0.12	0.15	0.18	0.42	0.73	1.02	1.18	Forecast more sensitive to future climate	Fair
OW440	Coastal 1	0	ANN	0.73	0.62	0.54	0.49	0.19	0.21	0.25	0.27	0.64	0.82	1.07	1.32	Forecast more sensitive to future climate	Poor
OW440	Coastal 1	0	GAM	0.81	0.72	0.63	0.50	0.17	0.20	0.23	0.28	0.46	0.69	1.01	1.35	Forecast more sensitive to future climate	Poor
OW440	Coastal 1	0	GLM	0.81	0.71	0.55	0.42	0.17	0.21	0.26	0.29	0.42	0.66	1.04	1.31	Forecast more sensitive to future climate	Poor
OW440	Coastal 1	0	RF	0.82	0.73	0.56	0.53	0.15	0.18	0.22	0.24	0.43	0.69	1.09	1.43	Forecast more sensitive to future climate	Poor
OW448	Coastal 1	1	ANN	0.93	0.90	0.83	0.75	0.09	0.12	0.15	0.20	0.55	0.80	1.05	1.22	Forecast more sensitive to future climate	Fair
OW448	Coastal 1	1	GAM	0.91	0.82	0.72	0.69	0.10	0.15	0.18	0.21	0.51	0.76	1.02	1.13	Forecast more sensitive to future climate	Fair
OW448	Coastal 1	1	GLM	0.89	0.78	0.74	0.69	0.11	0.16	0.19	0.21	0.53	0.80	0.99	1.14	Forecast more sensitive to future climate	Fair
OW448	Coastal 1	1	RF	0.93	0.88	0.79	0.71	0.09	0.13	0.17	0.20	0.54	0.79	1.04	1.20	Forecast more sensitive to future climate	Fair
OW449	Coastal 1	1	ANN	0.92	0.83	0.75	0.61	0.11	0.15	0.18	0.24	0.44	0.75	1.01	1.25	Forecast more sensitive to future climate	Fair
OW449	Coastal 1	1	GAM	0.91	0.83	0.71	0.65	0.12	0.16	0.21	0.23	0.43	0.75	1.03	1.13	Forecast more sensitive to future climate	Fair
OW449	Coastal 1	1	GLM	0.91	0.83	0.74	0.65	0.12	0.15	0.20	0.23	0.44	0.73	0.94	1.14	Forecast more sensitive to future climate	Fair
OW449	Coastal 1	1	RF	0.91	0.82	0.75	0.66	0.11	0.16	0.19	0.23	0.42	0.73	1.02	1.19	Forecast more sensitive to future climate	Fair
OW450	Coastal 1	0	ANN	0.95	0.93	0.91	0.89	0.09	0.12	0.15	0.18	0.61	0.77	0.98	1.15	Forecast more sensitive to future climate	Fair
OW450	Coastal 1	0	GAM	0.95	0.93	0.90	0.87	0.10	0.12	0.17	0.19	0.61	0.76	0.97	1.15	Forecast more sensitive to future climate	Fair
OW450	Coastal 1	0	GLM	0.92	0.87	0.84	0.83	0.14	0.18	0.21	0.22	0.68	0.95	1.16	1.23	Forecast more sensitive to future climate	Fair
OW450	Coastal 1	0	RF	0.94	0.92	0.88	0.84	0.10	0.13	0.18	0.21	0.61	0.77	1.01	1.29	Forecast more sensitive to future climate	Fair
OW451	Coastal 1	1	ANN	0.92	0.85	0.75	0.74	0.13	0.18	0.24	0.25	0.55	0.98	1.45	1.41	Forecast more sensitive to future climate	Fair
OW451	Coastal 1	1	GAM	0.92	0.85	0.77	0.74	0.14	0.19	0.24	0.25	0.55	0.95	1.39	1.54	Forecast more sensitive to future climate	Poor
OW451	Coastal 1	1	GLM	0.91	0.84	0.78	0.72	0.14	0.19	0.23	0.26	0.57	0.92	1.24	1.38	Forecast more sensitive to future climate	Poor
OW451	Coastal 1	1	RF	0.90	0.84	0.80	0.74	0.14	0.19	0.23	0.25	0.49	0.85	1.27	1.39	Forecast more sensitive to future climate	Fair
OW452	Coastal 1	1	ANN	0.91	0.79	0.65	0.63	0.11	0.17	0.23	0.24	0.32	0.76	1.19	1.18	Forecast more sensitive to future climate	Fair
OW452	Coastal 1	1	GAM	0.90	0.81	0.65	0.62	0.11	0.16	0.22	0.23	0.32	0.71	1.09	1.17	Forecast more sensitive to future climate	Fair
OW452	Coastal 1	1	GLM	0.90	0.79	0.66	0.60	0.11	0.17	0.22	0.24	0.31	0.75	1.12	1.20	Forecast more sensitive to future climate	Poor
OW452	Coastal 1	1	RF	0.90	0.75	0.56	0.48	0.12	0.18	0.25	0.27	0.31	0.77	1.27	1.38	Forecast more sensitive to future climate	Poor
OW456	Coastal 1	0	ANN	0.98	0.98	0.96	0.95	0.04	0.05	0.06	0.08	0.02	0.03	0.04	0.07	Forecast less sensitive to future climate	Good
OW456	Coastal 1	0	GAM	0.98	0.97	0.96	0.93	0.05	0.05	0.07	0.08	0.02	0.03	0.05	0.09	Forecast less sensitive to future climate	Good
OW456	Coastal 1	0	GLM	0.98	0.98	0.96	0.94	0.04	0.05	0.07	0.09	0.02	0.03	0.04	0.07	Forecast less sensitive to future climate	Good
OW456	Coastal 1	0	RF	0.98	0.98	0.97	0.95	0.04	0.05	0.06	0.07	0.02	0.02	0.04	0.06	Forecast less sensitive to future climate	Good
OW457	Coastal 1	1	ANN	0.84	0.81	0.74	0.69	0.16	0.19	0.23	0.25	0.75	0.97	1.11	1.16	Forecast more sensitive to future climate	Poor

Table A3 .1 (Cont'd.)

Well	Regional Group	Snow Influenced	Model	R2				NRMSE				RMSE Ratio Skill				Operational Testing	Model Validation
				14 days	30 day	60 days	90 days	14 days	30 day	60 days	90 days	14 days	30 day	60 days	90 days		
OW457	Coastal 1	1	GAM	0.81	0.81	0.78	0.72	0.18	0.19	0.21	0.24	0.83	0.91	1.07	1.13	Forecast more sensitive to future climate	Fair
OW457	Coastal 1	1	GLM	0.80	0.76	0.74	0.67	0.20	0.22	0.25	0.27	0.77	1.01	1.10	1.15	Forecast more sensitive to future climate	Poor
OW457	Coastal 1	1	RF	0.81	0.72	0.56	0.48	0.16	0.19	0.22	0.26	0.71	0.93	1.35	1.47	Forecast more sensitive to future climate	Poor
OW459	Coastal 1	1	ANN	0.93	0.90	0.85	0.79	0.13	0.16	0.19	0.21	0.51	0.77	1.13	1.43	Forecast more sensitive to future climate	Fair
OW459	Coastal 1	1	GAM	0.94	0.90	0.82	0.75	0.13	0.16	0.20	0.23	0.48	0.77	1.06	1.43	Forecast more sensitive to future climate	Fair
OW459	Coastal 1	1	GLM	0.92	0.87	0.82	0.79	0.13	0.16	0.20	0.23	0.50	0.83	1.14	1.42	Forecast more sensitive to future climate	Fair
OW459	Coastal 1	1	RF	0.90	0.85	0.75	0.62	0.13	0.19	0.22	0.28	0.49	0.76	1.03	1.38	Forecast more sensitive to future climate	Poor
OW460	Coastal 1	0	ANN	0.86	0.81	0.75	0.68	0.07	0.09	0.10	0.11	0.15	0.20	0.26	0.34	Forecast less sensitive to future climate	Fair
OW460	Coastal 1	0	GAM	0.85	0.80	0.75	0.68	0.07	0.09	0.10	0.12	0.16	0.21	0.26	0.34	Forecast less sensitive to future climate	Fair
OW460	Coastal 1	0	GLM	0.86	0.81	0.75	0.68	0.07	0.09	0.10	0.11	0.15	0.20	0.26	0.34	Forecast less sensitive to future climate	Fair
OW460	Coastal 1	0	RF	0.84	0.79	0.72	0.65	0.08	0.09	0.11	0.12	0.16	0.22	0.28	0.35	Forecast less sensitive to future climate	Fair
OW473	Coastal 1	0	ANN	0.96	0.93	0.89	0.87	0.16	0.21	0.26	0.28	0.22	0.72	1.23	1.36	Forecast more sensitive to future climate	Poor
OW473	Coastal 1	0	GAM	0.95	0.91	0.88	0.87	0.18	0.24	0.27	0.30	0.26	0.72	1.20	1.38	Forecast more sensitive to future climate	Poor
OW473	Coastal 1	0	GLM	0.93	0.85	0.79	0.76	0.22	0.32	0.40	0.42	0.35	0.85	1.34	1.47	Forecast more sensitive to future climate	Poor
OW473	Coastal 1	0	RF	0.95	0.90	0.85	0.82	0.18	0.23	0.30	0.37	0.27	0.73	1.35	1.57	Forecast more sensitive to future climate	Poor
OW480	Coastal 1	0	ANN	0.94	0.91	0.87	0.88	0.15	0.20	0.24	0.28	0.42	0.75	1.32	1.24	Forecast more sensitive to future climate	Poor
OW480	Coastal 1	0	GAM	0.94	0.87	0.87	0.88	0.18	0.26	0.28	0.29	0.38	0.80	0.98	1.18	Forecast more sensitive to future climate	Poor
OW480	Coastal 1	0	GLM	0.91	0.83	0.79	0.79	0.19	0.31	0.38	0.41	0.48	1.02	1.35	1.43	Forecast more sensitive to future climate	Poor
OW480	Coastal 1	0	RF	0.96	0.90	0.86	0.85	0.13	0.19	0.29	0.35	0.33	0.73	1.10	1.33	Forecast more sensitive to future climate	Poor
OW485	Coastal 1	1	ANN	0.95	0.89	0.69	0.63	0.09	0.15	0.23	0.27	0.16	0.44	0.96	1.19	Forecast more sensitive to future climate	Poor
OW485	Coastal 1	1	GAM	0.94	0.88	0.61	0.41	0.10	0.15	0.24	0.29	0.17	0.42	0.97	1.43	Forecast more sensitive to future climate	Poor
OW485	Coastal 1	1	GLM	0.92	0.83	0.58	0.49	0.10	0.17	0.24	0.26	0.19	0.52	0.99	1.21	Forecast more sensitive to future climate	Poor
OW485	Coastal 1	1	RF	0.93	0.82	0.62	0.56	0.09	0.15	0.24	0.30	0.17	0.47	0.88	1.06	Forecast more sensitive to future climate	Poor
OW486	Coastal 1	1	ANN	0.58	0.35	0.21	0.13	0.20	0.30	0.37	0.43	0.71	1.28	1.87	2.01	Forecast more sensitive to future climate	Poor
OW486	Coastal 1	1	GAM	0.69	0.30	-0.40	-0.10	0.21	0.37	0.44	0.40	0.61	1.31	2.67	2.40	Forecast more sensitive to future climate	Poor
OW486	Coastal 1	1	GLM	0.67	0.28	0.04	0.18	0.19	0.29	0.34	0.33	0.60	1.16	1.78	1.79	Forecast more sensitive to future climate	Poor
OW486	Coastal 1	1	RF	0.76	0.55	0.41	0.48	0.16	0.24	0.31	0.33	0.48	0.87	1.23	1.18	Forecast more sensitive to future climate	Poor
OW490	Coastal 1	1	ANN	0.98	0.97	0.95	0.93	0.11	0.14	0.18	0.23	0.41	0.59	1.01	1.20	Forecast more sensitive to future climate	Fair
OW490	Coastal 1	1	GAM	0.98	0.95	0.93	0.92	0.12	0.17	0.20	0.23	0.40	0.67	0.94	1.11	Forecast more sensitive to future climate	Fair
OW490	Coastal 1	1	GLM	0.97	0.95	0.93	0.92	0.13	0.18	0.22	0.24	0.41	0.67	0.98	1.27	Forecast more sensitive to future climate	Fair
OW490	Coastal 1	1	RF	0.98	0.96	0.92	0.90	0.11	0.16	0.22	0.26	0.40	0.63	1.01	1.24	Forecast more sensitive to future climate	Poor
OW492	Coastal 1	0	ANN	0.94	0.85	0.84	0.81	0.08	0.13	0.17	0.20	0.13	0.44	0.85	1.19	Forecast more sensitive to future climate	Fair
OW492	Coastal 1	0	GAM	0.94	0.88	0.89	0.82	0.09	0.14	0.18	0.20	0.13	0.33	0.59	0.88	Forecast less sensitive to future climate	Fair
OW492	Coastal 1	0	GLM	0.93	0.82	0.81	0.79	0.09	0.17	0.20	0.21	0.14	0.49	0.85	1.18	Forecast more sensitive to future climate	Fair
OW492	Coastal 1	0	RF	0.94	0.83	0.78	0.62	0.07	0.12	0.18	0.26	0.13	0.36	0.84	1.23	Forecast more sensitive to future climate	Poor
OW495	Coastal 1	0	ANN	0.87	0.68	0.40	0.40	0.09	0.15	0.22	0.25	0.20	0.49	0.87	0.92	Forecast less sensitive to future climate	Poor
OW495	Coastal 1	0	GAM	0.92	0.78	0.48	0.21	0.07	0.12	0.21	0.26	0.14	0.34	0.72	0.92	Forecast less sensitive to future climate	Poor
OW495	Coastal 1	0	GLM	0.92	0.77	0.51	0.29	0.07	0.13	0.22	0.27	0.14	0.37	0.74	0.98	Forecast less sensitive to future climate	Poor
OW495	Coastal 1	0	RF	0.93	0.80	0.58	0.42	0.06	0.10	0.17	0.21	0.14	0.37	0.73	0.89	Forecast less sensitive to future climate	Poor
OW292	Coastal 2	0	ANN	0.82	0.75	0.69	0.65	0.13	0.15	0.17	0.19	0.45	0.61	0.79	0.91	Forecast less sensitive to future climate	Fair
OW292	Coastal 2	0	GAM	0.82	0.74	0.67	0.64	0.13	0.16	0.18	0.20	0.46	0.66	0.83	0.92	Forecast less sensitive to future climate	Fair
OW292	Coastal 2	0	GLM	0.80	0.71	0.60	0.54	0.13	0.17	0.20	0.22	0.47	0.69	0.97	1.13	Forecast more sensitive to future climate	Poor
OW292	Coastal 2	0	RF	0.81	0.74	0.69	0.65	0.13	0.16	0.17	0.19	0.46	0.63	0.78	0.91	Forecast less sensitive to future climate	Fair
OW353	Coastal 2	0	ANN	0.96	0.93	0.88	0.84	0.08	0.10	0.14	0.16	0.24	0.48	0.77	0.94	Forecast less sensitive to future climate	Fair
OW353	Coastal 2	0	GAM	0.96	0.93	0.87	0.83	0.08	0.11	0.14	0.16	0.24	0.49	0.82	1.01	Forecast more sensitive to future climate	Fair
OW353	Coastal 2	0	GLM	0.96	0.92	0.86	0.84	0.08	0.12	0.15	0.17	0.25	0.52	0.82	0.95	Forecast less sensitive to future climate	Fair
OW353	Coastal 2	0	RF	0.96	0.93	0.87	0.81	0.07	0.10	0.14	0.17	0.23	0.48	0.79	1.02	Forecast more sensitive to future climate	Fair
OW354	Coastal 2	0	ANN	0.98	0.95	0.94	0.92	0.04	0.07	0.08	0.09	0.04	0.13	0.28	0.46	Forecast less sensitive to future climate	Good
OW354	Coastal 2	0	GAM	0.98	0.94	0.89	0.88	0.04	0.08	0.12	0.12	0.05	0.15	0.36	0.56	Forecast less sensitive to future climate	Good
OW354	Coastal 2	0	GLM	0.98	0.93	0.87	0.85	0.05	0.09	0.13	0.14	0.05	0.17	0.39	0.56	Forecast less sensitive to future climate	Good
OW354	Coastal 2	0	RF	0.98	0.94	0.90	0.87	0.04	0.07	0.10	0.11	0.04	0.14	0.33	0.52	Forecast less sensitive to future climate	Good
OW359	Coastal 2	0	ANN	0.99	0.99	0.98	0.98	0.02	0.03	0.03	0.03	0.01	0.02	0.02	0.03	Forecast less sensitive to future climate	Good
OW359	Coastal 2	0	GAM	0.99	0.99	0.98	0.97	0.02	0.03	0.04	0.05	0.01	0.02	0.03	0.04	Forecast less sensitive to future climate	Good
OW359	Coastal 2	0	GLM	0.99	0.98	0.95	0.94	0.03	0.04	0.05	0.06	0.01	0.03	0.05	0.07	Forecast less sensitive to future climate	Good
OW359	Coastal 2	0	RF	0.99	0.99	0.98	0.98	0.02	0.03	0.03	0.04	0.01	0.02	0.03	0.03	Forecast less sensitive to future climate	Good
OW360	Coastal 2	0	ANN	0.95	0.93	0.92	0.88	0.09	0.12	0.14	0.18	0.34	0.67	0.92	1.05	Forecast more sensitive to future climate	Fair
OW360	Coastal 2	0	GAM	0.95	0.93	0.91	0.88	0.12	0.15	0.16	0.17	0.36	0.70	0.95	1.07	Forecast more sensitive to future climate	Fair
OW360	Coastal 2	0	GLM	0.93	0.87	0.85	0.86	0.15	0.23	0.26	0.23	0.43	0.95	1.19	1.15	Forecast more sensitive to future climate	Fair
OW360	Coastal 2	0	RF	0.95	0.92	0.90	0.87	0.07	0.10	0.13	0.17	0.33	0.68	1.01	1.20	Forecast more sensitive to future climate	Fair
OW361	Coastal 2	0	ANN	1.00	0.99	0.95	0.91	0.02	0.03	0.05	0.06	0.00	0.02	0.08	0.17	Forecast less sensitive to future climate	Good
OW361	Coastal 2	0	GAM	1.00	0.99	0.95	0.90	0.02	0.03	0.06	0.08	0.01	0.02	0.08	0.16	Forecast less sensitive to future climate	Good

Table A3.1 (Cont'd.)

Well	Regional Group	Snow Influenced	Model	R2				NRMSE				RMSE Ratio Skill				Operational Testing	Model Validation
				14 days	30 day	60 days	90 days	14 days	30 day	60 days	90 days	14 days	30 day	60 days	90 days		
OW361	Coastal 2	0	GLM	0.99	0.98	0.94	0.89	0.02	0.04	0.06	0.09	0.01	0.03	0.10	0.20	Forecast less sensitive to future climate	Good
OW361	Coastal 2	0	RF	1.00	0.99	0.96	0.92	0.02	0.03	0.05	0.07	0.01	0.02	0.07	0.15	Forecast less sensitive to future climate	Good
OW408	Coastal 2	0	ANN	0.78	0.67	0.57	0.56	0.14	0.16	0.19	0.20	0.49	0.67	0.86	0.92	Forecast less sensitive to future climate	Poor
OW408	Coastal 2	0	GAM	0.78	0.66	0.55	0.53	0.14	0.17	0.19	0.21	0.49	0.66	0.90	0.98	Forecast less sensitive to future climate	Poor
OW408	Coastal 2	0	GLM	0.77	0.66	0.55	0.52	0.14	0.17	0.19	0.21	0.49	0.68	0.88	0.97	Forecast less sensitive to future climate	Poor
OW408	Coastal 2	0	RF	0.76	0.65	0.52	0.52	0.14	0.17	0.20	0.20	0.50	0.67	0.91	0.98	Forecast less sensitive to future climate	Poor
OW414	Coastal 2	0	ANN	0.98	0.98	0.97	0.97	0.03	0.03	0.04	0.04	0.02	0.02	0.03	0.03	Forecast less sensitive to future climate	Good
OW414	Coastal 2	0	GAM	0.98	0.98	0.97	0.97	0.03	0.03	0.04	0.04	0.02	0.02	0.03	0.03	Forecast less sensitive to future climate	Good
OW414	Coastal 2	0	GLM	0.98	0.98	0.97	0.97	0.03	0.03	0.04	0.04	0.02	0.02	0.03	0.03	Forecast less sensitive to future climate	Good
OW414	Coastal 2	0	RF	0.98	0.98	0.97	0.97	0.03	0.04	0.04	0.04	0.02	0.02	0.03	0.03	Forecast less sensitive to future climate	Good
OW415	Coastal 2	0	ANN	0.98	0.97	0.96	0.96	0.04	0.04	0.05	0.05	0.03	0.04	0.06	0.06	Forecast less sensitive to future climate	Good
OW415	Coastal 2	0	GAM	0.98	0.97	0.96	0.94	0.04	0.04	0.05	0.06	0.03	0.04	0.07	0.08	Forecast less sensitive to future climate	Good
OW415	Coastal 2	0	GLM	0.98	0.95	0.91	0.88	0.04	0.06	0.08	0.09	0.04	0.07	0.14	0.19	Forecast less sensitive to future climate	Good
OW415	Coastal 2	0	RF	0.98	0.97	0.96	0.95	0.04	0.04	0.05	0.05	0.03	0.05	0.06	0.08	Forecast less sensitive to future climate	Good
OW446	Coastal 2	0	ANN	0.97	0.96	0.94	0.93	0.10	0.13	0.16	0.17	0.36	0.59	0.87	1.04	Forecast more sensitive to future climate	Fair
OW446	Coastal 2	0	GAM	0.96	0.92	0.90	0.91	0.12	0.17	0.19	0.19	0.40	0.68	0.92	0.99	Forecast less sensitive to future climate	Fair
OW446	Coastal 2	0	GLM	0.93	0.84	0.75	0.74	0.16	0.27	0.34	0.34	0.51	1.04	1.56	1.65	Forecast more sensitive to future climate	Poor
OW446	Coastal 2	0	RF	0.97	0.95	0.93	0.91	0.10	0.14	0.17	0.19	0.38	0.62	0.85	1.05	Forecast more sensitive to future climate	Fair
OW453	Coastal 2	0	ANN	0.98	0.96	0.94	0.91	0.04	0.07	0.09	0.10	0.05	0.15	0.36	0.57	Forecast less sensitive to future climate	Good
OW453	Coastal 2	0	GAM	0.98	0.97	0.94	0.92	0.04	0.06	0.09	0.10	0.05	0.16	0.38	0.57	Forecast less sensitive to future climate	Good
OW453	Coastal 2	0	GLM	0.98	0.96	0.94	0.94	0.04	0.07	0.09	0.09	0.05	0.15	0.35	0.54	Forecast less sensitive to future climate	Good
OW453	Coastal 2	0	RF	0.98	0.96	0.92	0.88	0.04	0.07	0.09	0.11	0.05	0.16	0.40	0.61	Forecast less sensitive to future climate	Good
OW454	Coastal 2	1	ANN	0.85	0.76	0.70	0.68	0.14	0.18	0.21	0.23	0.63	0.92	1.17	1.17	Forecast more sensitive to future climate	Fair
OW454	Coastal 2	1	GAM	0.87	0.78	0.71	0.72	0.13	0.18	0.21	0.21	0.61	0.90	1.16	1.15	Forecast more sensitive to future climate	Fair
OW454	Coastal 2	1	GLM	0.86	0.77	0.73	0.72	0.14	0.18	0.21	0.21	0.62	0.89	1.10	1.13	Forecast more sensitive to future climate	Fair
OW454	Coastal 2	1	RF	0.86	0.77	0.68	0.63	0.13	0.18	0.22	0.24	0.62	0.96	1.26	1.28	Forecast more sensitive to future climate	Fair
OW458	Coastal 2	0	ANN	0.98	0.97	0.94	0.91	0.04	0.05	0.07	0.08	0.03	0.06	0.11	0.17	Forecast less sensitive to future climate	Good
OW458	Coastal 2	0	GAM	0.98	0.96	0.93	0.90	0.04	0.06	0.08	0.09	0.03	0.06	0.12	0.17	Forecast less sensitive to future climate	Good
OW458	Coastal 2	0	GLM	0.98	0.96	0.92	0.88	0.04	0.06	0.08	0.09	0.03	0.06	0.13	0.20	Forecast less sensitive to future climate	Good
OW458	Coastal 2	0	RF	0.98	0.97	0.95	0.92	0.04	0.05	0.06	0.07	0.03	0.05	0.10	0.15	Forecast less sensitive to future climate	Good
OW462	Coastal 2	1	ANN	0.82	0.70	0.47	0.35	0.16	0.23	0.30	0.31	0.33	0.55	1.01	1.31	Forecast more sensitive to future climate	Poor
OW462	Coastal 2	1	GAM	0.82	0.67	0.41	0.28	0.16	0.24	0.31	0.34	0.34	0.62	1.27	1.45	Forecast more sensitive to future climate	Poor
OW462	Coastal 2	1	GLM	0.82	0.67	0.35	0.14	0.17	0.25	0.34	0.35	0.35	0.62	1.28	1.70	Forecast more sensitive to future climate	Poor
OW462	Coastal 2	1	RF	0.80	0.67	0.41	0.33	0.17	0.24	0.32	0.34	0.35	0.58	1.02	1.20	Forecast more sensitive to future climate	Poor
OW463	Coastal 2	0	ANN	0.98	0.97	0.95	0.93	0.05	0.06	0.08	0.10	0.05	0.12	0.29	0.48	Forecast less sensitive to future climate	Good
OW463	Coastal 2	0	GAM	0.99	0.97	0.95	0.91	0.05	0.06	0.10	0.12	0.05	0.12	0.30	0.44	Forecast less sensitive to future climate	Good
OW463	Coastal 2	0	GLM	0.98	0.97	0.94	0.92	0.05	0.07	0.10	0.11	0.05	0.12	0.28	0.43	Forecast less sensitive to future climate	Good
OW463	Coastal 2	0	RF	0.98	0.97	0.93	0.89	0.05	0.07	0.10	0.13	0.05	0.13	0.33	0.50	Forecast less sensitive to future climate	Good
OW471	Coastal 2	0	ANN	0.93	0.85	0.74	0.69	0.13	0.18	0.24	0.28	0.31	0.67	1.12	1.33	Forecast more sensitive to future climate	Poor
OW471	Coastal 2	0	GAM	0.92	0.84	0.71	0.62	0.13	0.20	0.27	0.33	0.34	0.73	1.26	1.62	Forecast more sensitive to future climate	Poor
OW471	Coastal 2	0	GLM	0.92	0.83	0.71	0.67	0.13	0.20	0.27	0.30	0.33	0.71	1.22	1.38	Forecast more sensitive to future climate	Poor
OW471	Coastal 2	0	RF	0.93	0.86	0.73	0.65	0.13	0.18	0.26	0.31	0.32	0.64	1.21	1.64	Forecast more sensitive to future climate	Poor
OW474	Coastal 2	0	ANN	0.97	0.94	0.92	0.93	0.10	0.13	0.15	0.16	0.11	0.32	0.60	0.87	Forecast less sensitive to future climate	Fair
OW474	Coastal 2	0	GAM	0.97	0.95	0.93	0.85	0.11	0.14	0.17	0.23	0.10	0.27	0.60	0.94	Forecast less sensitive to future climate	Fair
OW474	Coastal 2	0	GLM	0.96	0.90	0.83	0.79	0.12	0.16	0.21	0.24	0.15	0.47	0.97	1.15	Forecast more sensitive to future climate	Fair
OW474	Coastal 2	0	RF	0.97	0.95	0.90	0.84	0.10	0.14	0.17	0.21	0.10	0.27	0.56	0.99	Forecast less sensitive to future climate	Fair
OW475	Coastal 2	1	ANN	0.77	0.65	0.55	0.45	0.20	0.25	0.29	0.30	0.83	1.09	1.44	1.56	Forecast more sensitive to future climate	Poor
OW475	Coastal 2	1	GAM	0.77	0.63	0.49	0.42	0.21	0.26	0.30	0.32	0.75	1.01	1.51	1.65	Forecast more sensitive to future climate	Poor
OW475	Coastal 2	1	GLM	0.77	0.64	0.53	0.42	0.20	0.25	0.29	0.32	0.80	1.00	1.27	1.49	Forecast more sensitive to future climate	Poor
OW475	Coastal 2	1	RF	0.71	0.52	0.37	0.28	0.22	0.29	0.34	0.34	0.79	1.11	1.45	1.68	Forecast more sensitive to future climate	Poor
OW476	Coastal 2	1	ANN	0.85	0.76	0.68	0.65	0.18	0.23	0.26	0.29	0.73	1.04	1.30	1.28	Forecast more sensitive to future climate	Poor
OW476	Coastal 2	1	GAM	0.87	0.75	0.60	0.59	0.17	0.24	0.29	0.31	0.73	1.06	1.50	1.61	Forecast more sensitive to future climate	Poor
OW476	Coastal 2	1	GLM	0.87	0.76	0.68	0.66	0.17	0.23	0.26	0.27	0.75	1.07	1.23	1.32	Forecast more sensitive to future climate	Poor
OW476	Coastal 2	1	RF	0.81	0.64	0.52	0.48	0.20	0.28	0.32	0.32	0.73	1.10	1.47	1.60	Forecast more sensitive to future climate	Poor
OW479	Coastal 2	0	ANN	0.99	0.98	0.94	0.90	0.03	0.04	0.07	0.09	0.01	0.03	0.09	0.15	Forecast less sensitive to future climate	Good
OW479	Coastal 2	0	GAM	0.99	0.97	0.91	0.85	0.03	0.06	0.09	0.12	0.02	0.05	0.12	0.20	Forecast less sensitive to future climate	Good
OW479	Coastal 2	0	GLM	0.99	0.98	0.94	0.89	0.03	0.04	0.07	0.10	0.01	0.03	0.08	0.14	Forecast less sensitive to future climate	Good
OW479	Coastal 2	0	RF	0.99	0.98	0.93	0.89	0.03	0.04	0.07	0.09	0.01	0.04	0.10	0.16	Forecast less sensitive to future climate	Good
OW483	Coastal 2	0	ANN	0.97	0.95	0.88	0.84	0.05	0.07	0.11	0.14	0.11	0.22	0.44	0.72	Forecast less sensitive to future climate	Good
OW483	Coastal 2	0	GAM	0.96	0.92	0.90	0.87	0.06	0.09	0.10	0.12	0.11	0.25	0.41	0.61	Forecast less sensitive to future climate	Good
OW483	Coastal 2	0	GLM	0.96	0.94	0.86	0.83	0.06	0.08	0.13	0.15	0.11	0.23	0.51	0.69	Forecast less sensitive to future climate	Fair

Table A3.1 (Cont'd.)

Well	Regional Group	Snow Influenced	Model	R2				NRMSE				RMSE Ratio Skill				Operational Testing	Model Validation
				14 days	30 day	60 days	90 days	14 days	30 day	60 days	90 days	14 days	30 day	60 days	90 days		
OW483	Coastal 2	0	RF	0.96	0.91	0.81	0.72	0.05	0.08	0.12	0.15	0.12	0.23	0.43	0.64	Forecast less sensitive to future climate	Fair
OW491	Coastal 2	0	ANN	0.98	0.96	0.93	0.84	0.09	0.11	0.15	0.24	0.12	0.27	0.56	0.94	Forecast less sensitive to future climate	Fair
OW491	Coastal 2	0	GAM	0.97	0.95	0.86	0.66	0.09	0.12	0.21	0.33	0.14	0.32	0.72	1.28	Forecast more sensitive to future climate	Poor
OW491	Coastal 2	0	GLM	0.96	0.91	0.82	0.76	0.11	0.16	0.24	0.29	0.13	0.32	0.69	0.97	Forecast less sensitive to future climate	Poor
OW491	Coastal 2	0	RF	0.97	0.95	0.89	0.82	0.10	0.12	0.17	0.23	0.13	0.28	0.63	1.03	Forecast more sensitive to future climate	Fair
OW497	Coastal 2	0	ANN	0.67	0.64	0.51	0.32	0.22	0.24	0.28	0.32	0.36	0.41	0.56	0.78	Forecast less sensitive to future climate	Poor
OW497	Coastal 2	0	GAM	0.63	0.55	0.36	-0.10	0.23	0.26	0.32	0.44	0.42	0.49	0.67	1.01	Forecast more sensitive to future climate	Poor
OW497	Coastal 2	0	GLM	0.66	0.62	0.48	0.32	0.22	0.24	0.28	0.31	0.39	0.43	0.61	0.84	Forecast less sensitive to future climate	Poor
OW497	Coastal 2	0	RF	0.64	0.59	0.42	0.17	0.23	0.26	0.31	0.37	0.41	0.46	0.63	0.91	Forecast less sensitive to future climate	Poor
OW498	Coastal 2	1	ANN	0.96	0.94	0.89	0.87	0.13	0.19	0.25	0.27	0.29	0.53	0.94	1.30	Forecast more sensitive to future climate	Poor
OW498	Coastal 2	1	GAM	0.96	0.93	0.80	0.81	0.14	0.21	0.40	0.38	0.31	0.68	1.52	1.79	Forecast more sensitive to future climate	Poor
OW498	Coastal 2	1	GLM	0.96	0.94	0.91	0.88	0.13	0.19	0.24	0.29	0.30	0.56	1.03	1.44	Forecast more sensitive to future climate	Poor
OW498	Coastal 2	1	RF	0.95	0.91	0.79	0.73	0.15	0.21	0.30	0.34	0.32	0.61	1.15	1.67	Forecast more sensitive to future climate	Poor
OW499	Coastal 2	1	ANN	0.67	0.63	0.57	0.54	0.33	0.34	0.40	0.41	1.14	1.20	1.39	1.52	Forecast more sensitive to future climate	Poor
OW499	Coastal 2	1	GAM	0.56	0.47	0.22	0.47	0.40	0.45	0.54	0.51	1.28	1.67	3.37	1.83	Forecast more sensitive to future climate	Poor
OW499	Coastal 2	1	GLM	0.64	0.61	0.48	0.49	0.37	0.36	0.42	0.44	1.21	1.36	2.48	1.87	Forecast more sensitive to future climate	Poor
OW499	Coastal 2	1	RF	0.61	0.56	0.49	0.39	0.38	0.38	0.43	0.47	1.26	1.26	1.51	1.86	Forecast more sensitive to future climate	Poor
OW275	Coastal 3	0	ANN	0.97	0.94	0.91	0.87	0.05	0.08	0.10	0.12	0.13	0.34	0.65	0.87	Forecast less sensitive to future climate	Good
OW275	Coastal 3	0	GAM	0.97	0.95	0.90	0.87	0.06	0.08	0.11	0.13	0.14	0.36	0.74	0.95	Forecast less sensitive to future climate	Good
OW275	Coastal 3	0	GLM	0.97	0.93	0.88	0.86	0.06	0.09	0.12	0.14	0.14	0.39	0.74	0.91	Forecast less sensitive to future climate	Good
OW275	Coastal 3	0	RF	0.97	0.94	0.89	0.85	0.05	0.08	0.11	0.13	0.13	0.34	0.70	0.96	Forecast less sensitive to future climate	Good
OW447	Coastal 3	0	ANN	0.99	0.98	0.97	0.96	0.06	0.08	0.10	0.11	0.10	0.23	0.46	0.67	Forecast less sensitive to future climate	Good
OW447	Coastal 3	0	GAM	0.99	0.98	0.97	0.97	0.06	0.08	0.10	0.10	0.10	0.23	0.45	0.65	Forecast less sensitive to future climate	Good
OW447	Coastal 3	0	GLM	0.98	0.97	0.95	0.95	0.07	0.09	0.12	0.13	0.12	0.26	0.51	0.69	Forecast less sensitive to future climate	Good
OW447	Coastal 3	0	RF	0.99	0.98	0.96	0.95	0.06	0.08	0.10	0.12	0.10	0.23	0.49	0.73	Forecast less sensitive to future climate	Good
OW461	Coastal 3	0	ANN	0.93	0.87	0.74	0.63	0.12	0.15	0.22	0.26	0.26	0.52	0.98	1.31	Forecast more sensitive to future climate	Poor
OW461	Coastal 3	0	GAM	0.93	0.89	0.81	0.71	0.12	0.14	0.19	0.24	0.25	0.51	0.92	1.26	Forecast more sensitive to future climate	Fair
OW461	Coastal 3	0	GLM	0.91	0.79	0.60	0.50	0.13	0.20	0.28	0.31	0.28	0.64	1.27	1.58	Forecast more sensitive to future climate	Poor
OW461	Coastal 3	0	RF	0.93	0.88	0.76	0.68	0.12	0.15	0.21	0.24	0.26	0.51	1.01	1.43	Forecast more sensitive to future climate	Fair
OW477	Coastal 3	1	ANN	0.82	0.74	0.61	0.64	0.20	0.24	0.28	0.26	0.77	0.94	1.25	1.36	Forecast more sensitive to future climate	Poor
OW477	Coastal 3	1	GAM	0.84	0.73	0.70	0.64	0.19	0.25	0.28	0.28	0.74	1.01	1.25	1.40	Forecast more sensitive to future climate	Poor
OW477	Coastal 3	1	GLM	0.81	0.73	0.67	0.67	0.21	0.24	0.27	0.25	0.79	1.06	1.20	1.33	Forecast more sensitive to future climate	Poor
OW477	Coastal 3	1	RF	0.80	0.71	0.67	0.57	0.21	0.26	0.27	0.29	NA	NA	NA	NA	Forecast more sensitive to future climate	Poor
OW478	Coastal 3	1	ANN	0.76	0.66	0.59	0.55	0.23	0.27	0.30	0.31	0.73	0.97	1.20	1.30	Forecast more sensitive to future climate	Poor
OW478	Coastal 3	1	GAM	0.73	0.65	0.61	0.52	0.25	0.28	0.30	0.33	0.79	1.05	1.23	1.43	Forecast more sensitive to future climate	Poor
OW478	Coastal 3	1	GLM	0.75	0.67	0.61	0.61	0.23	0.26	0.28	0.29	0.75	0.94	1.14	1.31	Forecast more sensitive to future climate	Poor
OW478	Coastal 3	1	RF	0.75	0.60	0.53	0.45	0.23	0.28	0.30	0.33	0.74	0.99	1.17	1.38	Forecast more sensitive to future climate	Poor
OW035	Interior 1	1	ANN	0.99	0.98	0.96	0.94	0.02	0.03	0.05	0.05	0.01	0.02	0.06	0.08	Forecast less sensitive to future climate	Good
OW035	Interior 1	1	GAM	0.99	0.98	0.95	0.94	0.02	0.03	0.05	0.06	0.01	0.02	0.06	0.08	Forecast less sensitive to future climate	Good
OW035	Interior 1	1	GLM	0.99	0.98	0.95	0.93	0.02	0.03	0.05	0.06	0.01	0.02	0.05	0.08	Forecast less sensitive to future climate	Good
OW035	Interior 1	1	RF	0.99	0.98	0.96	0.94	0.02	0.03	0.04	0.06	0.01	0.02	0.05	0.08	Forecast less sensitive to future climate	Good
OW045	Interior 1	1	ANN	0.90	0.75	0.59	0.53	0.06	0.10	0.14	0.15	0.12	0.30	0.57	0.70	Forecast less sensitive to future climate	Poor
OW045	Interior 1	1	GAM	0.90	0.75	0.57	0.53	0.06	0.10	0.14	0.16	0.12	0.31	0.62	0.70	Forecast less sensitive to future climate	Poor
OW045	Interior 1	1	GLM	0.90	0.76	0.57	0.53	0.06	0.10	0.15	0.16	0.11	0.30	0.61	0.71	Forecast less sensitive to future climate	Poor
OW045	Interior 1	1	RF	0.90	0.76	0.53	0.43	0.05	0.09	0.14	0.16	0.12	0.31	0.62	0.79	Forecast less sensitive to future climate	Poor
OW080	Interior 1	1	ANN	0.98	0.97	0.95	0.94	0.03	0.04	0.06	0.07	0.02	0.05	0.10	0.13	Forecast less sensitive to future climate	Good
OW080	Interior 1	1	GAM	0.99	0.97	0.95	0.93	0.03	0.04	0.06	0.07	0.02	0.05	0.11	0.18	Forecast less sensitive to future climate	Good
OW080	Interior 1	1	GLM	0.98	0.97	0.95	0.94	0.03	0.04	0.06	0.06	0.02	0.06	0.14	0.19	Forecast less sensitive to future climate	Good
OW080	Interior 1	1	RF	0.99	0.97	0.95	0.93	0.03	0.04	0.06	0.07	0.02	0.05	0.09	0.13	Forecast less sensitive to future climate	Good
OW081	Interior 1	1	ANN	0.98	0.94	0.85	0.75	0.03	0.04	0.07	0.10	0.03	0.08	0.19	0.32	Forecast less sensitive to future climate	Fair
OW081	Interior 1	1	GAM	0.98	0.94	0.83	0.74	0.03	0.05	0.08	0.11	0.03	0.09	0.23	0.36	Forecast less sensitive to future climate	Fair
OW081	Interior 1	1	GLM	0.98	0.93	0.82	0.74	0.03	0.05	0.09	0.10	0.03	0.09	0.24	0.34	Forecast less sensitive to future climate	Fair
OW081	Interior 1	1	RF	0.98	0.94	0.84	0.74	0.02	0.04	0.07	0.10	0.02	0.07	0.20	0.35	Forecast less sensitive to future climate	Fair
OW082	Interior 1	1	ANN	0.96	0.85	0.58	0.46	0.06	0.13	0.20	0.22	0.06	0.24	0.69	1.02	Forecast more sensitive to future climate	Poor
OW082	Interior 1	1	GAM	0.95	0.82	0.56	0.42	0.07	0.14	0.21	0.24	0.08	0.28	0.76	1.07	Forecast more sensitive to future climate	Poor
OW082	Interior 1	1	GLM	0.95	0.83	0.58	0.48	0.07	0.13	0.20	0.22	0.08	0.27	0.67	0.95	Forecast less sensitive to future climate	Poor
OW082	Interior 1	1	RF	0.96	0.86	0.62	0.45	0.06	0.11	0.19	0.22	0.06	0.22	0.66	1.01	Forecast more sensitive to future climate	Poor
OW185	Interior 1	1	ANN	0.86	0.76	0.74	0.68	0.09	0.12	0.13	0.15	0.27	0.47	0.55	0.68	Forecast less sensitive to future climate	Fair
OW185	Interior 1	1	GAM	0.85	0.76	0.71	0.67	0.09	0.12	0.14	0.15	0.27	0.45	0.58	0.69	Forecast less sensitive to future climate	Fair
OW185	Interior 1	1	GLM	0.85	0.75	0.70	0.65	0.09	0.12	0.14	0.15	0.27	0.46	0.58	0.70	Forecast less sensitive to future climate	Fair
OW185	Interior 1	1	RF	0.87	0.79	0.74	0.68	0.08	0.11	0.13	0.14	0.25	0.41	0.52	0.65	Forecast less sensitive to future climate	Fair

Table A3.1 (Cont'd.)

Well	Regional Group	Snow Influenced	Model	R2				NRMSE				RMSE Ratio Skill				Operational Testing	Model Validation
				14 days	30 day	60 days	90 days	14 days	30 day	60 days	90 days	14 days	30 day	60 days	90 days		
OW260	Interior 1	1	ANN	0.98	0.96	0.93	0.90	0.03	0.03	0.05	0.06	0.02	0.04	0.07	0.10	Forecast less sensitive to future climate	Good
OW260	Interior 1	1	GAM	0.98	0.97	0.94	0.91	0.03	0.03	0.04	0.05	0.02	0.03	0.05	0.09	Forecast less sensitive to future climate	Good
OW260	Interior 1	1	GLM	0.98	0.97	0.95	0.93	0.03	0.03	0.04	0.05	0.02	0.03	0.05	0.07	Forecast less sensitive to future climate	Good
OW260	Interior 1	1	RF	0.98	0.97	0.95	0.92	0.03	0.03	0.04	0.05	0.02	0.03	0.05	0.08	Forecast less sensitive to future climate	Good
OW261	Interior 1	1	ANN	1.00	0.99	0.98	0.96	0.01	0.02	0.03	0.04	0.00	0.01	0.02	0.05	Forecast less sensitive to future climate	Good
OW261	Interior 1	1	GAM	1.00	0.99	0.98	0.96	0.01	0.02	0.03	0.05	0.00	0.01	0.02	0.05	Forecast less sensitive to future climate	Good
OW261	Interior 1	1	GLM	1.00	0.99	0.98	0.96	0.01	0.02	0.03	0.04	0.00	0.01	0.02	0.04	Forecast less sensitive to future climate	Good
OW261	Interior 1	1	RF	1.00	0.99	0.98	0.96	0.01	0.02	0.03	0.04	0.00	0.01	0.02	0.04	Forecast less sensitive to future climate	Good
OW289	Interior 1	1	ANN	0.99	0.97	0.93	0.88	0.03	0.04	0.06	0.08	0.02	0.03	0.08	0.14	Forecast less sensitive to future climate	Good
OW289	Interior 1	1	GAM	0.99	0.97	0.93	0.86	0.03	0.04	0.06	0.08	0.02	0.03	0.08	0.15	Forecast less sensitive to future climate	Good
OW289	Interior 1	1	GLM	0.99	0.97	0.93	0.88	0.03	0.04	0.06	0.08	0.02	0.04	0.09	0.14	Forecast less sensitive to future climate	Good
OW289	Interior 1	1	RF	0.99	0.97	0.93	0.88	0.03	0.04	0.06	0.08	0.02	0.03	0.08	0.13	Forecast less sensitive to future climate	Good
OW296	Interior 1	1	ANN	0.91	0.80	0.66	0.53	0.08	0.12	0.15	0.18	0.15	0.36	0.63	0.90	Forecast less sensitive to future climate	Poor
OW296	Interior 1	1	GAM	0.91	0.80	0.66	0.54	0.08	0.12	0.16	0.18	0.16	0.38	0.68	0.94	Forecast less sensitive to future climate	Poor
OW296	Interior 1	1	GLM	0.91	0.80	0.68	0.57	0.08	0.12	0.15	0.17	0.17	0.38	0.65	0.85	Forecast less sensitive to future climate	Poor
OW296	Interior 1	1	RF	0.91	0.80	0.67	0.51	0.08	0.12	0.15	0.17	0.15	0.37	0.65	0.96	Forecast less sensitive to future climate	Poor
OW302	Interior 1	1	ANN	0.93	0.80	0.61	0.53	0.06	0.11	0.16	0.19	0.14	0.41	0.86	1.01	Forecast more sensitive to future climate	Poor
OW302	Interior 1	1	GAM	0.93	0.78	0.61	0.54	0.07	0.12	0.17	0.19	0.15	0.46	0.93	1.06	Forecast more sensitive to future climate	Poor
OW302	Interior 1	1	GLM	0.92	0.76	0.59	0.54	0.07	0.13	0.17	0.20	0.16	0.53	0.99	1.02	Forecast more sensitive to future climate	Poor
OW302	Interior 1	1	RF	0.94	0.81	0.58	0.47	0.06	0.11	0.16	0.20	0.13	0.41	0.90	1.11	Forecast more sensitive to future climate	Poor
OW365	Interior 1	1	ANN	0.89	0.75	0.62	0.60	0.07	0.11	0.16	0.18	0.26	0.59	0.88	1.00	Forecast more sensitive to future climate	Poor
OW365	Interior 1	1	GAM	0.89	0.75	0.64	0.60	0.08	0.13	0.17	0.19	0.26	0.60	0.98	1.05	Forecast more sensitive to future climate	Poor
OW365	Interior 1	1	GLM	0.88	0.73	0.65	0.64	0.08	0.14	0.17	0.19	0.28	0.63	0.86	0.96	Forecast less sensitive to future climate	Fair
OW365	Interior 1	1	RF	0.92	0.79	0.63	0.62	0.06	0.10	0.15	0.17	0.20	0.54	0.92	1.00	Forecast less sensitive to future climate	Fair
OW374	Interior 1	1	ANN	0.98	0.97	0.96	0.93	0.03	0.03	0.04	0.05	0.02	0.03	0.04	0.07	Forecast less sensitive to future climate	Good
OW374	Interior 1	1	GAM	0.98	0.97	0.96	0.94	0.03	0.03	0.04	0.05	0.02	0.03	0.04	0.07	Forecast less sensitive to future climate	Good
OW374	Interior 1	1	GLM	0.98	0.97	0.95	0.94	0.03	0.03	0.04	0.05	0.02	0.03	0.05	0.06	Forecast less sensitive to future climate	Good
OW374	Interior 1	1	RF	0.98	0.97	0.96	0.94	0.03	0.03	0.04	0.05	0.02	0.03	0.04	0.06	Forecast less sensitive to future climate	Good
OW375	Interior 1	1	ANN	0.92	0.84	0.81	0.80	0.10	0.15	0.18	0.19	0.28	0.66	0.90	1.02	Forecast more sensitive to future climate	Fair
OW375	Interior 1	1	GAM	0.92	0.84	0.79	0.76	0.11	0.16	0.20	0.23	0.29	0.62	1.10	1.14	Forecast more sensitive to future climate	Fair
OW375	Interior 1	1	GLM	0.91	0.81	0.78	0.70	0.11	0.18	0.20	0.24	0.33	0.72	1.12	1.32	Forecast more sensitive to future climate	Fair
OW375	Interior 1	1	RF	0.94	0.88	0.82	0.81	0.08	0.13	0.17	0.19	0.24	0.48	0.81	0.99	Forecast less sensitive to future climate	Fair
OW376	Interior 1	1	ANN	0.98	0.94	0.83	0.71	0.02	0.04	0.08	0.10	0.02	0.07	0.18	0.29	Forecast less sensitive to future climate	Fair
OW376	Interior 1	1	GAM	0.98	0.93	0.81	0.67	0.02	0.04	0.08	0.11	0.02	0.07	0.20	0.33	Forecast less sensitive to future climate	Fair
OW376	Interior 1	1	GLM	0.98	0.94	0.82	0.71	0.02	0.04	0.08	0.10	0.02	0.07	0.19	0.33	Forecast less sensitive to future climate	Fair
OW376	Interior 1	1	RF	0.97	0.92	0.80	0.66	0.03	0.05	0.08	0.11	0.03	0.08	0.20	0.34	Forecast less sensitive to future climate	Fair
OW381	Interior 1	1	ANN	0.98	0.96	0.91	0.85	0.03	0.05	0.07	0.08	0.02	0.05	0.11	0.20	Forecast less sensitive to future climate	Good
OW381	Interior 1	1	GAM	0.98	0.95	0.86	0.76	0.03	0.05	0.08	0.11	0.02	0.06	0.16	0.27	Forecast less sensitive to future climate	Fair
OW381	Interior 1	1	GLM	0.98	0.95	0.87	0.77	0.03	0.05	0.08	0.10	0.02	0.06	0.15	0.25	Forecast less sensitive to future climate	Fair
OW381	Interior 1	1	RF	0.99	0.96	0.90	0.82	0.03	0.04	0.07	0.09	0.02	0.05	0.13	0.22	Forecast less sensitive to future climate	Good
OW399	Interior 1	1	ANN	0.79	0.69	0.63	0.65	0.14	0.20	0.23	0.22	0.54	0.85	1.08	1.07	Forecast more sensitive to future climate	Fair
OW399	Interior 1	1	GAM	0.79	0.68	0.61	0.63	0.15	0.21	0.23	0.23	0.55	0.91	1.15	1.19	Forecast more sensitive to future climate	Fair
OW399	Interior 1	1	GLM	0.78	0.63	0.55	0.59	0.16	0.22	0.24	0.24	0.58	1.02	1.22	1.18	Forecast more sensitive to future climate	Poor
OW399	Interior 1	1	RF	0.82	0.70	0.63	0.62	0.13	0.19	0.22	0.21	0.50	0.83	1.13	1.18	Forecast more sensitive to future climate	Fair
OW400	Interior 1	1	ANN	0.74	0.53	0.34	0.34	0.17	0.23	0.28	0.29	0.63	1.07	1.42	1.53	Forecast more sensitive to future climate	Poor
OW400	Interior 1	1	GAM	0.78	0.60	0.45	0.33	0.17	0.22	0.27	0.32	0.57	0.95	1.31	1.52	Forecast more sensitive to future climate	Poor
OW400	Interior 1	1	GLM	0.77	0.57	0.36	0.39	0.17	0.22	0.29	0.28	0.59	0.97	1.36	1.52	Forecast more sensitive to future climate	Poor
OW400	Interior 1	1	RF	0.82	0.64	0.50	0.41	0.14	0.19	0.24	0.27	0.53	0.85	1.08	1.31	Forecast more sensitive to future climate	Poor
OW422	Interior 1	1	ANN	0.87	0.77	0.70	0.63	0.08	0.13	0.17	0.19	0.29	0.54	0.67	0.86	Forecast less sensitive to future climate	Fair
OW422	Interior 1	1	GAM	0.89	0.77	0.69	0.67	0.08	0.13	0.17	0.19	0.24	0.53	0.69	0.81	Forecast less sensitive to future climate	Fair
OW422	Interior 1	1	GLM	0.89	0.76	0.66	0.60	0.09	0.14	0.19	0.20	0.25	0.53	0.73	0.86	Forecast less sensitive to future climate	Fair
OW422	Interior 1	1	RF	0.91	0.82	0.71	0.64	0.07	0.11	0.15	0.18	0.21	0.44	0.69	0.91	Forecast less sensitive to future climate	Fair
OW423	Interior 1	1	ANN	0.79	0.55	0.43	0.36	0.18	0.26	0.28	0.31	0.54	0.95	1.19	1.44	Forecast more sensitive to future climate	Poor
OW423	Interior 1	1	GAM	0.79	0.57	0.34	0.29	0.17	0.25	0.33	0.35	0.51	0.92	1.49	1.64	Forecast more sensitive to future climate	Poor
OW423	Interior 1	1	GLM	0.78	0.57	0.38	0.37	0.17	0.24	0.30	0.30	0.57	1.15	1.41	1.44	Forecast more sensitive to future climate	Poor
OW423	Interior 1	1	RF	0.81	0.65	0.48	0.44	0.15	0.22	0.27	0.29	0.48	0.87	1.13	1.29	Forecast more sensitive to future climate	Poor
OW464	Interior 1	1	ANN	0.99	0.97	0.90	0.82	0.02	0.04	0.06	0.08	0.02	0.05	0.14	0.25	Forecast less sensitive to future climate	Good
OW464	Interior 1	1	GAM	0.99	0.96	0.88	0.78	0.02	0.04	0.07	0.09	0.02	0.06	0.16	0.28	Forecast less sensitive to future climate	Fair
OW464	Interior 1	1	GLM	0.99	0.96	0.89	0.80	0.02	0.04	0.07	0.09	0.02	0.06	0.17	0.26	Forecast less sensitive to future climate	Good
OW464	Interior 1	1	RF	0.99	0.97	0.89	0.81	0.02	0.04	0.06	0.08	0.02	0.05	0.14	0.24	Forecast less sensitive to future climate	Good
OW494	Interior 1	1	ANN	0.80	0.67	0.73	0.34	0.13	0.15	0.16	0.24	0.26	0.48	0.61	1.22	Forecast more sensitive to future climate	Poor

Table A3.1 (Cont'd.)

Well	Regional Group	Snow Influenced	Model	R2				NRMSE				RMSE Ratio Skill				Operational Testing	Model Validation
				14 days	30 day	60 days	90 days	14 days	30 day	60 days	90 days	14 days	30 day	60 days	90 days		
OW494	Interior 1	1	GAM	0.88	0.69	0.11	-0.58	0.11	0.16	0.31	0.42	0.15	0.39	1.23	2.19	Forecast more sensitive to future climate	Poor
OW494	Interior 1	1	GLM	0.88	0.72	0.41	-0.15	0.11	0.16	0.25	0.34	0.14	0.37	0.83	1.63	Forecast more sensitive to future climate	Poor
OW494	Interior 1	1	RF	0.90	0.79	0.63	0.46	0.11	0.13	0.17	0.23	0.13	0.29	0.61	0.92	Forecast less sensitive to future climate	Poor
OW074	Interior 2	1	ANN	0.97	0.92	0.83	0.78	0.03	0.05	0.08	0.09	0.03	0.09	0.25	0.34	Forecast less sensitive to future climate	Fair
OW074	Interior 2	1	GAM	0.97	0.93	0.84	0.76	0.03	0.05	0.08	0.10	0.03	0.10	0.29	0.39	Forecast less sensitive to future climate	Fair
OW074	Interior 2	1	GLM	0.97	0.92	0.82	0.74	0.03	0.05	0.08	0.10	0.03	0.10	0.27	0.38	Forecast less sensitive to future climate	Fair
OW074	Interior 2	1	RF	0.97	0.92	0.84	0.77	0.03	0.05	0.07	0.09	0.03	0.09	0.22	0.35	Forecast less sensitive to future climate	Fair
OW075	Interior 2	1	ANN	0.94	0.87	0.79	0.74	0.07	0.11	0.14	0.16	0.16	0.30	0.50	0.65	Forecast less sensitive to future climate	Fair
OW075	Interior 2	1	GAM	0.94	0.87	0.77	0.70	0.07	0.11	0.14	0.16	0.16	0.32	0.51	0.66	Forecast less sensitive to future climate	Fair
OW075	Interior 2	1	GLM	0.94	0.87	0.76	0.71	0.07	0.11	0.15	0.16	0.16	0.32	0.52	0.65	Forecast less sensitive to future climate	Fair
OW075	Interior 2	1	RF	0.94	0.88	0.81	0.75	0.07	0.10	0.13	0.15	0.15	0.29	0.46	0.61	Forecast less sensitive to future climate	Fair
OW115	Interior 2	1	ANN	0.80	0.68	0.62	0.58	0.18	0.24	0.26	0.28	0.70	1.15	1.33	1.46	Forecast more sensitive to future climate	Poor
OW115	Interior 2	1	GAM	0.82	0.71	0.63	0.62	0.17	0.23	0.28	0.28	0.67	1.02	1.34	1.30	Forecast more sensitive to future climate	Poor
OW115	Interior 2	1	GLM	0.82	0.69	0.61	0.55	0.17	0.24	0.28	0.31	0.68	1.06	1.45	1.53	Forecast more sensitive to future climate	Poor
OW115	Interior 2	1	RF	0.85	0.75	0.66	0.64	0.13	0.19	0.24	0.25	0.57	0.91	1.21	1.29	Forecast more sensitive to future climate	Poor
OW117	Interior 2	1	ANN	0.97	0.92	0.86	0.81	0.05	0.07	0.10	0.12	0.08	0.22	0.46	0.65	Forecast less sensitive to future climate	Good
OW117	Interior 2	1	GAM	0.96	0.91	0.85	0.80	0.06	0.08	0.11	0.13	0.09	0.26	0.51	0.73	Forecast less sensitive to future climate	Good
OW117	Interior 2	1	GLM	0.96	0.90	0.81	0.77	0.06	0.09	0.13	0.15	0.08	0.24	0.52	0.73	Forecast less sensitive to future climate	Fair
OW117	Interior 2	1	RF	0.97	0.93	0.85	0.81	0.05	0.07	0.10	0.11	0.07	0.19	0.47	0.68	Forecast less sensitive to future climate	Good
OW118	Interior 2	1	ANN	0.95	0.87	0.73	0.60	0.05	0.07	0.11	0.14	0.08	0.20	0.42	0.61	Forecast less sensitive to future climate	Poor
OW118	Interior 2	1	GAM	0.94	0.86	0.70	0.57	0.05	0.08	0.13	0.15	0.08	0.21	0.45	0.67	Forecast less sensitive to future climate	Poor
OW118	Interior 2	1	GLM	0.94	0.85	0.68	0.55	0.05	0.09	0.13	0.16	0.08	0.22	0.47	0.67	Forecast less sensitive to future climate	Poor
OW118	Interior 2	1	RF	0.95	0.87	0.70	0.56	0.04	0.07	0.11	0.14	0.07	0.18	0.41	0.63	Forecast less sensitive to future climate	Poor
OW122	Interior 2	1	ANN	0.90	0.82	0.69	0.57	0.06	0.09	0.13	0.16	0.21	0.43	0.72	0.98	Forecast less sensitive to future climate	Poor
OW122	Interior 2	1	GAM	0.90	0.81	0.69	0.57	0.07	0.10	0.13	0.16	0.21	0.42	0.73	0.98	Forecast less sensitive to future climate	Poor
OW122	Interior 2	1	GLM	0.89	0.79	0.66	0.58	0.08	0.11	0.15	0.18	0.21	0.44	0.75	0.95	Forecast less sensitive to future climate	Poor
OW122	Interior 2	1	RF	0.91	0.81	0.67	0.59	0.06	0.09	0.12	0.15	0.19	0.42	0.73	0.97	Forecast less sensitive to future climate	Poor
OW172	Interior 2	1	ANN	0.81	0.71	0.62	0.50	0.08	0.10	0.12	0.13	0.22	0.33	0.44	0.57	Forecast less sensitive to future climate	Poor
OW172	Interior 2	1	GAM	0.82	0.71	0.60	0.47	0.08	0.10	0.13	0.14	0.21	0.33	0.46	0.60	Forecast less sensitive to future climate	Poor
OW172	Interior 2	1	GLM	0.81	0.68	0.56	0.45	0.08	0.11	0.13	0.14	0.21	0.35	0.48	0.59	Forecast less sensitive to future climate	Poor
OW172	Interior 2	1	RF	0.83	0.73	0.62	0.46	0.07	0.09	0.12	0.13	0.20	0.31	0.42	0.58	Forecast less sensitive to future climate	Poor
OW217	Interior 2	1	ANN	0.91	0.86	0.79	0.76	0.06	0.10	0.14	0.17	0.27	0.50	0.79	0.91	Forecast less sensitive to future climate	Fair
OW217	Interior 2	1	GAM	0.92	0.87	0.80	0.79	0.07	0.10	0.15	0.16	0.25	0.48	0.73	0.79	Forecast less sensitive to future climate	Fair
OW217	Interior 2	1	GLM	0.91	0.85	0.80	0.79	0.07	0.11	0.15	0.17	0.27	0.51	0.71	0.83	Forecast less sensitive to future climate	Fair
OW217	Interior 2	1	RF	0.91	0.83	0.71	0.70	0.06	0.10	0.15	0.18	0.28	0.56	1.02	1.15	Forecast more sensitive to future climate	Fair
OW262	Interior 2	1	ANN	0.98	0.97	0.93	0.90	0.03	0.04	0.06	0.07	0.02	0.04	0.08	0.12	Forecast less sensitive to future climate	Good
OW262	Interior 2	1	GAM	0.98	0.97	0.93	0.89	0.03	0.04	0.06	0.07	0.02	0.04	0.08	0.13	Forecast less sensitive to future climate	Good
OW262	Interior 2	1	GLM	0.98	0.97	0.93	0.89	0.03	0.04	0.06	0.08	0.02	0.04	0.08	0.12	Forecast less sensitive to future climate	Good
OW262	Interior 2	1	RF	0.98	0.96	0.92	0.87	0.03	0.04	0.06	0.08	0.02	0.04	0.08	0.13	Forecast less sensitive to future climate	Good
OW264	Interior 2	1	ANN	0.74	0.57	0.49	0.50	0.27	0.40	0.50	0.68	1.06	1.62	2.14	2.19	Forecast more sensitive to future climate	Poor
OW264	Interior 2	1	GAM	0.81	0.61	0.45	0.49	0.33	0.52	0.67	0.73	0.95	1.76	2.03	2.17	Forecast more sensitive to future climate	Poor
OW264	Interior 2	1	GLM	0.82	0.68	0.60	0.49	0.32	0.52	0.61	0.73	0.89	1.33	1.62	2.12	Forecast more sensitive to future climate	Poor
OW264	Interior 2	1	RF	0.83	0.66	0.62	0.61	0.09	0.18	0.30	0.45	0.74	1.47	1.63	1.83	Forecast more sensitive to future climate	Poor
OW291	Interior 2	1	ANN	0.96	0.90	0.82	0.78	0.04	0.07	0.09	0.10	0.06	0.15	0.27	0.32	Forecast less sensitive to future climate	Fair
OW291	Interior 2	1	GAM	0.96	0.90	0.83	0.78	0.04	0.07	0.09	0.10	0.06	0.15	0.28	0.35	Forecast less sensitive to future climate	Fair
OW291	Interior 2	1	GLM	0.96	0.89	0.82	0.77	0.04	0.07	0.09	0.11	0.06	0.17	0.31	0.36	Forecast less sensitive to future climate	Fair
OW291	Interior 2	1	RF	0.96	0.91	0.82	0.78	0.04	0.06	0.09	0.10	0.05	0.13	0.25	0.33	Forecast less sensitive to future climate	Fair
OW294	Interior 2	1	ANN	0.94	0.87	0.78	0.76	0.06	0.09	0.12	0.14	0.12	0.28	0.51	0.63	Forecast less sensitive to future climate	Fair
OW294	Interior 2	1	GAM	0.94	0.87	0.78	0.75	0.06	0.09	0.12	0.14	0.12	0.30	0.50	0.66	Forecast less sensitive to future climate	Fair
OW294	Interior 2	1	GLM	0.94	0.87	0.78	0.76	0.06	0.09	0.13	0.14	0.11	0.28	0.51	0.62	Forecast less sensitive to future climate	Fair
OW294	Interior 2	1	RF	0.94	0.87	0.75	0.70	0.05	0.09	0.13	0.15	0.11	0.28	0.54	0.73	Forecast less sensitive to future climate	Fair
OW306	Interior 2	1	ANN	0.93	0.88	0.84	0.81	0.08	0.11	0.15	0.17	0.27	0.50	0.74	0.85	Forecast less sensitive to future climate	Fair
OW306	Interior 2	1	GAM	0.93	0.89	0.82	0.76	0.09	0.12	0.17	0.20	0.26	0.52	0.97	0.98	Forecast less sensitive to future climate	Fair
OW306	Interior 2	1	GLM	0.92	0.85	0.79	0.72	0.09	0.13	0.17	0.20	0.31	0.67	1.10	1.08	Forecast more sensitive to future climate	Fair
OW306	Interior 2	1	RF	0.92	0.85	0.81	0.80	0.08	0.11	0.15	0.16	0.29	0.56	0.83	0.90	Forecast less sensitive to future climate	Fair
OW309	Interior 2	1	ANN	0.91	0.85	0.80	0.78	0.07	0.11	0.15	0.16	0.33	0.64	0.86	0.94	Forecast less sensitive to future climate	Fair
OW309	Interior 2	1	GAM	0.90	0.79	0.64	0.50	0.08	0.14	0.20	0.24	0.39	0.84	1.37	2.07	Forecast more sensitive to future climate	Poor
OW309	Interior 2	1	GLM	0.88	0.72	0.59	0.57	0.09	0.17	0.22	0.23	0.46	1.15	1.74	1.82	Forecast more sensitive to future climate	Poor
OW309	Interior 2	1	RF	0.91	0.83	0.80	0.78	0.06	0.10	0.14	0.16	0.33	0.69	0.89	0.99	Forecast less sensitive to future climate	Fair
OW332	Interior 2	1	ANN	1.00	0.99	0.97	0.95	0.01	0.02	0.04	0.06	0.00	0.01	0.04	0.06	Forecast less sensitive to future climate	Good
OW332	Interior 2	1	GAM	1.00	0.99	0.96	0.92	0.01	0.03	0.05	0.07	0.00	0.01	0.05	0.09	Forecast less sensitive to future climate	Good

Table A3.1 (Cont'd.)

Well	Regional Group	Snow Influenced	Model	R2				NRMSE				RMSE Ratio Skill				Operational Testing	Model Validation
				14 days	30 day	60 days	90 days	14 days	30 day	60 days	90 days	14 days	30 day	60 days	90 days		
OW332	Interior 2	1	GLM	1.00	0.99	0.96	0.93	0.01	0.03	0.05	0.07	0.00	0.01	0.04	0.08	Forecast less sensitive to future climate	Good
OW332	Interior 2	1	RF	1.00	0.99	0.97	0.95	0.01	0.02	0.04	0.06	0.00	0.01	0.03	0.06	Forecast less sensitive to future climate	Good
OW362	Interior 2	1	ANN	0.89	0.77	0.66	0.57	0.08	0.12	0.16	0.18	0.23	0.48	0.70	0.88	Forecast less sensitive to future climate	Poor
OW362	Interior 2	1	GAM	0.89	0.76	0.60	0.55	0.08	0.12	0.17	0.19	0.25	0.54	0.74	0.89	Forecast less sensitive to future climate	Poor
OW362	Interior 2	1	GLM	0.88	0.75	0.62	0.56	0.08	0.12	0.17	0.18	0.24	0.48	0.74	0.91	Forecast less sensitive to future climate	Poor
OW362	Interior 2	1	RF	0.91	0.79	0.64	0.60	0.07	0.12	0.16	0.18	0.21	0.43	0.69	0.81	Forecast less sensitive to future climate	Fair
OW405	Interior 2	1	ANN	1.00	0.99	0.96	0.92	0.02	0.03	0.06	0.08	0.00	0.02	0.05	0.12	Forecast less sensitive to future climate	Good
OW405	Interior 2	1	GAM	1.00	0.98	0.94	0.90	0.02	0.04	0.08	0.10	0.01	0.02	0.08	0.15	Forecast less sensitive to future climate	Good
OW405	Interior 2	1	GLM	1.00	0.99	0.96	0.92	0.02	0.04	0.06	0.09	0.00	0.02	0.06	0.12	Forecast less sensitive to future climate	Good
OW405	Interior 2	1	RF	1.00	0.99	0.96	0.93	0.02	0.03	0.05	0.07	0.00	0.02	0.05	0.10	Forecast less sensitive to future climate	Good
OW410	Interior 2	1	ANN	0.93	0.85	0.67	0.53	0.08	0.12	0.19	0.23	0.12	0.27	0.59	0.87	Forecast less sensitive to future climate	Poor
OW410	Interior 2	1	GAM	0.92	0.82	0.60	0.45	0.08	0.13	0.20	0.25	0.14	0.32	0.71	0.97	Forecast less sensitive to future climate	Poor
OW410	Interior 2	1	GLM	0.93	0.85	0.69	0.55	0.08	0.12	0.18	0.22	0.12	0.28	0.57	0.81	Forecast less sensitive to future climate	Poor
OW410	Interior 2	1	RF	0.92	0.85	0.66	0.44	0.08	0.12	0.18	0.24	0.14	0.30	0.62	0.96	Forecast less sensitive to future climate	Poor
OW413	Interior 2	1	ANN	0.85	0.79	0.63	0.47	0.12	0.15	0.19	0.22	0.20	0.29	0.49	0.69	Forecast less sensitive to future climate	Poor
OW413	Interior 2	1	GAM	0.85	0.73	0.45	0.18	0.13	0.17	0.23	0.27	0.21	0.36	0.74	1.05	Forecast more sensitive to future climate	Poor
OW413	Interior 2	1	GLM	0.85	0.76	0.51	0.24	0.12	0.16	0.22	0.26	0.20	0.31	0.59	0.87	Forecast less sensitive to future climate	Poor
OW413	Interior 2	1	RF	0.86	0.79	0.58	0.39	0.12	0.15	0.19	0.23	0.19	0.27	0.54	0.77	Forecast less sensitive to future climate	Poor
OW442	Interior 2	1	ANN	0.99	0.98	0.95	0.92	0.02	0.03	0.05	0.07	0.01	0.02	0.06	0.08	Forecast less sensitive to future climate	Good
OW442	Interior 2	1	GAM	0.99	0.98	0.95	0.91	0.02	0.04	0.06	0.08	0.01	0.03	0.06	0.09	Forecast less sensitive to future climate	Good
OW442	Interior 2	1	GLM	0.99	0.98	0.95	0.92	0.02	0.04	0.06	0.07	0.01	0.03	0.06	0.08	Forecast less sensitive to future climate	Good
OW442	Interior 2	1	RF	0.99	0.98	0.95	0.93	0.02	0.03	0.05	0.06	0.01	0.02	0.05	0.07	Forecast less sensitive to future climate	Good
OW444	Interior 2	1	ANN	0.98	0.94	0.87	0.82	0.09	0.16	0.25	0.29	0.15	0.38	0.70	1.04	Forecast more sensitive to future climate	Poor
OW444	Interior 2	1	GAM	0.97	0.94	0.87	0.83	0.10	0.18	0.26	0.28	0.18	0.37	0.68	1.00	Forecast less sensitive to future climate	Poor
OW444	Interior 2	1	GLM	0.96	0.93	0.90	0.86	0.11	0.17	0.22	0.27	0.24	0.46	0.64	0.92	Forecast less sensitive to future climate	Poor
OW444	Interior 2	1	RF	0.96	0.91	0.84	0.80	0.10	0.17	0.26	0.32	0.24	0.55	0.94	1.18	Forecast more sensitive to future climate	Poor
OW467	Interior 2	1	ANN	0.97	0.95	0.90	0.83	0.05	0.07	0.09	0.11	0.04	0.06	0.10	0.17	Forecast less sensitive to future climate	Good
OW467	Interior 2	1	GAM	0.98	0.95	0.87	0.80	0.05	0.07	0.10	0.13	0.03	0.06	0.14	0.24	Forecast less sensitive to future climate	Good
OW467	Interior 2	1	GLM	0.98	0.94	0.86	0.77	0.05	0.07	0.10	0.13	0.03	0.06	0.15	0.25	Forecast less sensitive to future climate	Fair
OW467	Interior 2	1	RF	0.98	0.97	0.92	0.87	0.04	0.05	0.08	0.10	0.02	0.04	0.08	0.14	Forecast less sensitive to future climate	Good
OW468	Interior 2	1	ANN	0.96	0.89	0.74	0.60	0.08	0.13	0.20	0.22	0.08	0.22	0.46	0.69	Forecast less sensitive to future climate	Fair
OW468	Interior 2	1	GAM	0.96	0.87	0.67	0.50	0.08	0.14	0.21	0.25	0.10	0.26	0.56	0.84	Forecast less sensitive to future climate	Poor
OW468	Interior 2	1	GLM	0.96	0.87	0.71	0.56	0.08	0.14	0.19	0.22	0.09	0.24	0.50	0.77	Forecast less sensitive to future climate	Poor
OW468	Interior 2	1	RF	0.96	0.90	0.75	0.64	0.08	0.13	0.19	0.23	0.09	0.20	0.43	0.62	Forecast less sensitive to future climate	Fair
OW487	Interior 2	1	ANN	0.86	0.76	0.71	0.65	0.14	0.20	0.23	0.21	0.22	0.45	0.92	1.37	Forecast more sensitive to future climate	Fair
OW487	Interior 2	1	GAM	0.83	0.64	0.56	0.36	0.16	0.25	0.27	0.34	0.26	0.70	1.57	2.26	Forecast more sensitive to future climate	Poor
OW487	Interior 2	1	GLM	0.84	0.67	0.63	0.59	0.16	0.23	0.24	0.24	0.23	0.49	0.96	1.44	Forecast more sensitive to future climate	Poor
OW487	Interior 2	1	RF	0.87	0.74	0.54	0.29	0.14	0.20	0.26	0.31	0.19	0.41	0.84	1.24	Forecast more sensitive to future climate	Poor
OW506	Interior 2	1	ANN	0.88	0.72	0.59	0.49	0.35	0.56	0.73	0.76	0.58	1.36	1.98	2.54	Forecast more sensitive to future climate	Poor
OW506	Interior 2	1	GAM	0.84	0.15	-0.36	-0.27	0.34	0.71	0.87	1.02	0.79	4.88	6.33	7.34	Forecast more sensitive to future climate	Poor
OW506	Interior 2	1	GLM	0.81	0.57	0.26	-0.02	0.35	0.52	0.75	1.01	0.95	1.81	3.22	5.04	Forecast more sensitive to future climate	Poor
OW506	Interior 2	1	RF	0.87	0.66	0.48	0.42	0.32	0.55	0.78	0.83	0.65	1.69	2.52	3.02	Forecast more sensitive to future climate	Poor
OW047	Interior 3	1	ANN	0.90	0.87	0.83	0.79	0.12	0.17	0.24	0.28	0.48	0.71	1.02	1.24	Forecast more sensitive to future climate	Poor
OW047	Interior 3	1	GAM	0.91	0.86	0.79	0.79	0.13	0.19	0.25	0.28	0.45	0.85	2.06	2.62	Forecast more sensitive to future climate	Poor
OW047	Interior 3	1	GLM	0.88	0.79	0.76	0.76	0.15	0.23	0.29	0.32	0.58	0.97	1.34	2.10	Forecast more sensitive to future climate	Poor
OW047	Interior 3	1	RF	0.93	0.89	0.85	0.83	0.09	0.13	0.19	0.24	0.37	0.60	0.85	1.02	Forecast more sensitive to future climate	Fair
OW154	Interior 3	1	ANN	0.98	0.94	0.88	0.82	0.05	0.08	0.11	0.13	0.05	0.14	0.32	0.51	Forecast less sensitive to future climate	Good
OW154	Interior 3	1	GAM	0.98	0.94	0.86	0.79	0.05	0.08	0.12	0.15	0.04	0.13	0.36	0.63	Forecast less sensitive to future climate	Fair
OW154	Interior 3	1	GLM	0.98	0.94	0.86	0.80	0.05	0.08	0.12	0.14	0.04	0.13	0.34	0.57	Forecast less sensitive to future climate	Good
OW154	Interior 3	1	RF	0.98	0.95	0.87	0.78	0.04	0.07	0.11	0.14	0.04	0.12	0.34	0.58	Forecast less sensitive to future climate	Fair
OW311	Interior 3	1	ANN	1.00	0.99	0.99	0.98	0.01	0.02	0.03	0.04	0.00	0.01	0.01	0.02	Forecast less sensitive to future climate	Good
OW311	Interior 3	1	GAM	1.00	0.99	0.98	0.98	0.01	0.02	0.03	0.04	0.00	0.01	0.02	0.03	Forecast less sensitive to future climate	Good
OW311	Interior 3	1	GLM	1.00	0.99	0.98	0.98	0.01	0.02	0.03	0.04	0.00	0.01	0.02	0.02	Forecast less sensitive to future climate	Good
OW311	Interior 3	1	RF	1.00	0.99	0.98	0.97	0.01	0.02	0.03	0.04	0.00	0.01	0.02	0.03	Forecast less sensitive to future climate	Good
OW356	Interior 3	1	ANN	0.97	0.90	0.75	0.64	0.02	0.03	0.05	0.07	0.03	0.10	0.24	0.36	Forecast less sensitive to future climate	Fair
OW356	Interior 3	1	GAM	0.98	0.91	0.77	0.63	0.02	0.03	0.05	0.07	0.02	0.08	0.23	0.37	Forecast less sensitive to future climate	Fair
OW356	Interior 3	1	GLM	0.98	0.92	0.77	0.64	0.02	0.03	0.05	0.07	0.02	0.08	0.23	0.36	Forecast less sensitive to future climate	Fair
OW356	Interior 3	1	RF	0.97	0.89	0.72	0.56	0.01	0.03	0.05	0.06	0.03	0.10	0.25	0.40	Forecast less sensitive to future climate	Poor
OW363	Interior 3	1	ANN	0.96	0.92	0.85	0.78	0.07	0.10	0.16	0.20	0.22	0.48	0.88	1.26	Forecast more sensitive to future climate	Fair
OW363	Interior 3	1	GAM	0.96	0.91	0.82	0.76	0.08	0.12	0.19	0.23	0.23	0.48	0.99	1.28	Forecast more sensitive to future climate	Fair
OW363	Interior 3	1	GLM	0.95	0.90	0.84	0.81	0.09	0.14	0.18	0.20	0.25	0.49	0.85	1.17	Forecast more sensitive to future climate	Fair

Table A3.1 (Cont'd.)

Well	Regional Group	Snow Influenced	Model	R2				NRMSE				RMSE Ratio Skill				Operational Testing	Model Validation
				14 days	30 day	60 days	90 days	14 days	30 day	60 days	90 days	14 days	30 day	60 days	90 days		
OW363	Interior 3	1	RF	0.96	0.93	0.88	0.84	0.06	0.09	0.14	0.16	0.22	0.40	0.68	0.93	Forecast less sensitive to future climate	Fair
OW384	Interior 3	1	ANN	0.97	0.93	0.82	0.76	0.04	0.06	0.09	0.11	0.04	0.12	0.31	0.45	Forecast less sensitive to future climate	Fair
OW384	Interior 3	1	GAM	0.97	0.92	0.82	0.75	0.04	0.06	0.10	0.12	0.04	0.13	0.33	0.47	Forecast less sensitive to future climate	Fair
OW384	Interior 3	1	GLM	0.97	0.93	0.82	0.76	0.04	0.06	0.10	0.11	0.04	0.12	0.31	0.44	Forecast less sensitive to future climate	Fair
OW384	Interior 3	1	RF	0.97	0.92	0.82	0.75	0.04	0.06	0.10	0.12	0.04	0.12	0.31	0.46	Forecast less sensitive to future climate	Fair
OW387	Interior 3	1	ANN	0.92	0.83	0.68	0.59	0.09	0.15	0.19	0.22	0.15	0.37	0.74	0.96	Forecast less sensitive to future climate	Poor
OW387	Interior 3	1	GAM	0.92	0.79	0.60	0.50	0.10	0.16	0.23	0.27	0.15	0.40	0.80	0.97	Forecast less sensitive to future climate	Poor
OW387	Interior 3	1	GLM	0.91	0.76	0.54	0.42	0.10	0.18	0.26	0.30	0.16	0.47	1.03	1.54	Forecast more sensitive to future climate	Poor
OW387	Interior 3	1	RF	0.94	0.84	0.72	0.59	0.07	0.13	0.17	0.21	0.12	0.35	0.76	1.00	Forecast less sensitive to future climate	Poor
OW401	Interior 3	1	ANN	0.93	0.87	0.80	0.77	0.09	0.14	0.18	0.19	0.24	0.54	0.91	1.13	Forecast more sensitive to future climate	Fair
OW401	Interior 3	1	GAM	0.91	0.80	0.77	0.76	0.10	0.17	0.19	0.20	0.33	0.74	1.11	1.26	Forecast more sensitive to future climate	Fair
OW401	Interior 3	1	GLM	0.93	0.83	0.79	0.80	0.10	0.16	0.18	0.19	0.26	0.66	1.05	1.18	Forecast more sensitive to future climate	Fair
OW401	Interior 3	1	RF	0.95	0.87	0.79	0.73	0.08	0.13	0.18	0.20	0.21	0.52	0.96	1.27	Forecast more sensitive to future climate	Fair
OW402	Interior 3	1	ANN	0.87	0.77	0.77	0.70	0.10	0.14	0.17	0.21	0.34	0.64	0.82	1.08	Forecast more sensitive to future climate	Fair
OW402	Interior 3	1	GAM	0.81	0.71	0.64	0.62	0.12	0.18	0.21	0.23	0.48	0.87	1.14	1.42	Forecast more sensitive to future climate	Fair
OW402	Interior 3	1	GLM	0.76	0.59	0.61	0.61	0.14	0.24	0.24	0.25	0.60	1.19	1.38	1.45	Forecast more sensitive to future climate	Fair
OW402	Interior 3	1	RF	0.86	0.79	0.70	0.68	0.09	0.12	0.18	0.20	0.36	0.61	0.90	1.04	Forecast more sensitive to future climate	Fair
OW403	Interior 3	1	ANN	0.99	0.98	0.92	0.86	0.01	0.02	0.04	0.05	0.01	0.02	0.08	0.13	Forecast less sensitive to future climate	Good
OW403	Interior 3	1	GAM	0.99	0.97	0.91	0.84	0.01	0.02	0.04	0.05	0.01	0.03	0.09	0.15	Forecast less sensitive to future climate	Good
OW403	Interior 3	1	GLM	0.99	0.98	0.92	0.85	0.01	0.02	0.04	0.06	0.01	0.02	0.07	0.13	Forecast less sensitive to future climate	Good
OW403	Interior 3	1	RF	1.00	0.98	0.94	0.88	0.01	0.02	0.04	0.05	0.01	0.02	0.06	0.13	Forecast less sensitive to future climate	Good
OW404	Interior 3	1	ANN	0.96	0.85	0.63	0.46	0.03	0.06	0.10	0.14	0.05	0.16	0.39	0.54	Forecast less sensitive to future climate	Poor
OW404	Interior 3	1	GAM	0.95	0.85	0.56	0.38	0.04	0.07	0.12	0.15	0.06	0.18	0.44	0.60	Forecast less sensitive to future climate	Poor
OW404	Interior 3	1	GLM	0.96	0.87	0.61	0.41	0.04	0.07	0.12	0.15	0.05	0.16	0.42	0.60	Forecast less sensitive to future climate	Poor
OW404	Interior 3	1	RF	0.95	0.85	0.60	0.41	0.03	0.06	0.10	0.14	0.05	0.17	0.43	0.59	Forecast less sensitive to future climate	Poor
OW407	Interior 3	1	ANN	0.92	0.84	0.72	0.63	0.10	0.15	0.20	0.22	0.13	0.29	0.59	0.90	Forecast less sensitive to future climate	Fair
OW407	Interior 3	1	GAM	0.91	0.80	0.65	0.50	0.11	0.16	0.22	0.25	0.15	0.36	0.62	1.03	Forecast more sensitive to future climate	Poor
OW407	Interior 3	1	GLM	0.91	0.81	0.64	0.54	0.11	0.17	0.23	0.25	0.15	0.36	0.66	0.93	Forecast less sensitive to future climate	Poor
OW407	Interior 3	1	RF	0.91	0.82	0.71	0.61	0.10	0.15	0.19	0.22	0.14	0.33	0.59	0.96	Forecast less sensitive to future climate	Fair
OW409	Interior 3	1	ANN	0.99	0.95	0.88	0.84	0.03	0.05	0.07	0.09	0.02	0.05	0.14	0.22	Forecast less sensitive to future climate	Good
OW409	Interior 3	1	GAM	0.99	0.96	0.87	0.80	0.03	0.05	0.08	0.10	0.01	0.05	0.16	0.25	Forecast less sensitive to future climate	Fair
OW409	Interior 3	1	GLM	0.99	0.96	0.89	0.82	0.02	0.05	0.08	0.10	0.01	0.05	0.15	0.23	Forecast less sensitive to future climate	Good
OW409	Interior 3	1	RF	0.99	0.96	0.87	0.79	0.02	0.04	0.07	0.10	0.01	0.05	0.15	0.25	Forecast less sensitive to future climate	Fair
OW411	Interior 3	1	ANN	0.98	0.94	0.88	0.80	0.03	0.06	0.08	0.11	0.03	0.06	0.14	0.22	Forecast less sensitive to future climate	Good
OW411	Interior 3	1	GAM	0.98	0.94	0.87	0.78	0.03	0.06	0.09	0.11	0.03	0.06	0.14	0.23	Forecast less sensitive to future climate	Fair
OW411	Interior 3	1	GLM	0.98	0.95	0.87	0.78	0.03	0.05	0.08	0.11	0.03	0.07	0.16	0.29	Forecast less sensitive to future climate	Fair
OW411	Interior 3	1	RF	0.98	0.95	0.89	0.83	0.03	0.05	0.08	0.10	0.02	0.06	0.12	0.18	Forecast less sensitive to future climate	Good
OW412	Interior 3	1	ANN	0.93	0.89	0.79	0.80	0.10	0.14	0.20	0.22	0.35	0.64	0.92	1.15	Forecast more sensitive to future climate	Fair
OW412	Interior 3	1	GAM	0.87	0.75	0.69	0.69	0.15	0.24	0.28	0.28	0.53	1.06	1.71	1.69	Forecast more sensitive to future climate	Poor
OW412	Interior 3	1	GLM	0.84	0.69	0.67	0.71	0.16	0.26	0.28	0.27	0.64	1.22	1.66	1.83	Forecast more sensitive to future climate	Poor
OW412	Interior 3	1	RF	0.93	0.86	0.81	0.80	0.08	0.13	0.18	0.20	0.37	0.67	0.83	0.96	Forecast less sensitive to future climate	Fair
OW124	Northern	1	ANN	0.83	0.78	0.67	0.55	0.07	0.08	0.11	0.14	0.18	0.24	0.36	0.50	Forecast less sensitive to future climate	Poor
OW124	Northern	1	GAM	0.82	0.76	0.63	0.52	0.07	0.09	0.11	0.14	0.19	0.26	0.41	0.54	Forecast less sensitive to future climate	Poor
OW124	Northern	1	GLM	0.83	0.78	0.67	0.56	0.07	0.08	0.11	0.13	0.18	0.25	0.37	0.50	Forecast less sensitive to future climate	Poor
OW124	Northern	1	RF	0.80	0.73	0.63	0.51	0.08	0.09	0.12	0.14	0.20	0.28	0.40	0.55	Forecast less sensitive to future climate	Poor
OW200	Northern	1	ANN	0.99	0.98	0.92	0.88	0.02	0.03	0.06	0.08	0.01	0.02	0.08	0.13	Forecast less sensitive to future climate	Good
OW200	Northern	1	GAM	0.99	0.97	0.93	0.87	0.02	0.04	0.06	0.09	0.01	0.03	0.08	0.14	Forecast less sensitive to future climate	Good
OW200	Northern	1	GLM	0.99	0.97	0.92	0.87	0.02	0.04	0.06	0.09	0.01	0.03	0.09	0.18	Forecast less sensitive to future climate	Good
OW200	Northern	1	RF	1.00	0.98	0.92	0.84	0.01	0.03	0.06	0.08	0.01	0.02	0.08	0.16	Forecast less sensitive to future climate	Good
OW293	Northern	1	ANN	0.86	0.77	0.70	0.65	0.09	0.12	0.14	0.15	0.23	0.43	0.61	0.70	Forecast less sensitive to future climate	Fair
OW293	Northern	1	GAM	0.87	0.79	0.64	0.57	0.08	0.12	0.16	0.17	0.26	0.46	0.70	0.78	Forecast less sensitive to future climate	Poor
OW293	Northern	1	GLM	0.87	0.76	0.63	0.59	0.09	0.13	0.16	0.17	0.23	0.46	0.70	0.76	Forecast less sensitive to future climate	Poor
OW293	Northern	1	RF	0.88	0.82	0.70	0.65	0.07	0.10	0.14	0.16	0.24	0.42	0.62	0.70	Forecast less sensitive to future climate	Fair
OW378	Northern	1	ANN	0.91	0.75	0.57	0.53	0.07	0.13	0.18	0.19	0.15	0.43	0.70	0.75	Forecast less sensitive to future climate	Poor
OW378	Northern	1	GAM	0.91	0.76	0.58	0.54	0.07	0.12	0.17	0.18	0.15	0.39	0.65	0.75	Forecast less sensitive to future climate	Poor
OW378	Northern	1	GLM	0.90	0.74	0.54	0.54	0.07	0.13	0.19	0.18	0.16	0.46	0.78	0.77	Forecast less sensitive to future climate	Poor
OW378	Northern	1	RF	0.91	0.77	0.63	0.56	0.07	0.12	0.17	0.18	0.15	0.41	0.61	0.73	Forecast less sensitive to future climate	Poor
OW386	Northern	1	ANN	0.86	0.77	0.68	0.60	0.14	0.20	0.24	0.26	0.51	0.85	1.15	1.37	Forecast more sensitive to future climate	Poor
OW386	Northern	1	GAM	0.88	0.74	0.60	0.25	0.13	0.20	0.25	0.31	0.45	1.16	1.97	2.77	Forecast more sensitive to future climate	Poor
OW386	Northern	1	GLM	0.85	0.72	0.55	0.53	0.14	0.20	0.27	0.29	0.49	1.20	1.90	1.55	Forecast more sensitive to future climate	Poor
OW386	Northern	1	RF	0.89	0.78	0.69	0.66	0.13	0.18	0.22	0.24	0.42	0.76	1.09	1.29	Forecast more sensitive to future climate	Fair

Table A3.1 (Cont'd.)

Well	Regional Group	Snow Influenced	Model	R2				NRMSE				RMSE Ratio Skill				Operational Testing	Model Validation
				14 days	30 day	60 days	90 days	14 days	30 day	60 days	90 days	14 days	30 day	60 days	90 days		
OW416	Northern	1	ANN	0.98	0.94	0.86	0.77	0.03	0.05	0.08	0.11	0.02	0.06	0.16	0.27	Forecast less sensitive to future climate	Fair
OW416	Northern	1	GAM	0.98	0.93	0.82	0.76	0.03	0.06	0.09	0.11	0.03	0.08	0.19	0.28	Forecast less sensitive to future climate	Fair
OW416	Northern	1	GLM	0.98	0.94	0.85	0.77	0.03	0.05	0.09	0.11	0.03	0.07	0.18	0.26	Forecast less sensitive to future climate	Fair
OW416	Northern	1	RF	0.97	0.94	0.86	0.79	0.03	0.05	0.08	0.10	0.03	0.07	0.16	0.23	Forecast less sensitive to future climate	Fair
OW417	Northern	1	ANN	0.99	0.99	0.96	0.93	0.02	0.03	0.05	0.07	0.01	0.01	0.04	0.07	Forecast less sensitive to future climate	Good
OW417	Northern	1	GAM	0.99	0.99	0.97	0.95	0.02	0.03	0.05	0.06	0.01	0.01	0.03	0.06	Forecast less sensitive to future climate	Good
OW417	Northern	1	GLM	0.99	0.99	0.96	0.95	0.02	0.03	0.05	0.06	0.01	0.01	0.04	0.06	Forecast less sensitive to future climate	Good
OW417	Northern	1	RF	0.99	0.99	0.97	0.95	0.02	0.03	0.04	0.06	0.01	0.01	0.03	0.06	Forecast less sensitive to future climate	Good
OW418	Northern	1	ANN	0.99	0.98	0.96	0.94	0.03	0.03	0.05	0.06	0.01	0.02	0.03	0.05	Forecast less sensitive to future climate	Good
OW418	Northern	1	GAM	0.99	0.98	0.95	0.91	0.03	0.04	0.05	0.07	0.01	0.02	0.05	0.08	Forecast less sensitive to future climate	Good
OW418	Northern	1	GLM	0.99	0.98	0.96	0.94	0.03	0.04	0.05	0.06	0.01	0.02	0.04	0.06	Forecast less sensitive to future climate	Good
OW418	Northern	1	RF	0.99	0.98	0.96	0.94	0.03	0.03	0.05	0.06	0.01	0.02	0.04	0.05	Forecast less sensitive to future climate	Good
OW420	Northern	1	ANN	0.36	0.44	0.35	0.32	0.19	0.18	0.19	0.20	0.67	0.59	0.69	0.72	Forecast less sensitive to future climate	Poor
OW420	Northern	1	GAM	0.41	0.46	0.44	0.44	0.18	0.18	0.18	0.19	0.63	0.58	0.61	0.61	Forecast less sensitive to future climate	Poor
OW420	Northern	1	GLM	0.36	0.41	0.39	0.35	0.20	0.19	0.19	0.20	0.69	0.62	0.65	0.68	Forecast less sensitive to future climate	Poor
OW420	Northern	1	RF	0.38	0.42	0.40	0.38	0.18	0.18	0.18	0.19	0.65	0.60	0.65	0.67	Forecast less sensitive to future climate	Poor
OW445	Northern	1	ANN	0.58	0.49	0.37	0.30	0.17	0.18	0.20	0.21	0.46	0.56	0.67	0.71	Forecast less sensitive to future climate	Poor
OW445	Northern	1	GAM	0.54	0.46	0.37	0.29	0.18	0.19	0.20	0.21	0.49	0.58	0.68	0.71	Forecast less sensitive to future climate	Poor
OW445	Northern	1	GLM	0.57	0.48	0.32	0.23	0.17	0.18	0.21	0.23	0.47	0.57	0.71	0.80	Forecast less sensitive to future climate	Poor
OW445	Northern	1	RF	0.58	0.49	0.38	0.23	0.17	0.19	0.20	0.22	0.46	0.55	0.65	0.75	Forecast less sensitive to future climate	Poor
OW455	Northern	1	ANN	0.92	0.82	0.71	0.61	0.07	0.11	0.14	0.16	0.09	0.18	0.29	0.39	Forecast less sensitive to future climate	Fair
OW455	Northern	1	GAM	0.91	0.81	0.71	0.38	0.08	0.11	0.13	0.18	0.10	0.18	0.28	0.58	Forecast less sensitive to future climate	Poor
OW455	Northern	1	GLM	0.91	0.81	0.68	0.51	0.07	0.11	0.14	0.17	0.10	0.19	0.30	0.46	Forecast less sensitive to future climate	Poor
OW455	Northern	1	RF	0.92	0.85	0.73	0.62	0.07	0.10	0.13	0.15	0.09	0.15	0.25	0.36	Forecast less sensitive to future climate	Fair
OW481	Northern	1	ANN	0.89	0.66	0.55	0.16	0.10	0.16	0.21	0.25	0.13	0.53	0.72	1.08	Forecast more sensitive to future climate	Poor
OW481	Northern	1	GAM	0.88	0.28	0.09	0.16	0.13	0.27	0.35	0.34	0.15	0.58	1.16	1.27	Forecast more sensitive to future climate	Poor
OW481	Northern	1	GLM	0.90	0.72	0.53	0.30	0.15	0.23	0.27	0.31	0.16	0.45	1.10	1.64	Forecast more sensitive to future climate	Poor
OW481	Northern	1	RF	0.92	0.73	0.35	-0.01	0.08	0.13	0.22	0.29	0.14	0.44	1.02	1.47	Forecast more sensitive to future climate	Poor
OW482	Northern	1	ANN	0.67	0.02	-2.29	-14.45	444.34	802.72	1566.90	3217.08	1913161.14	5679362.86	19052094.60	89214307.98	Forecast more sensitive to future climate	Poor
OW482	Northern	1	GAM	-7.25	-19.31	-23.93	-35.55	2109.96	3300.91	3109.58	3968.61	46117954.91	111599053.84	144529813.32	206017708.10	Forecast more sensitive to future climate	Poor
OW482	Northern	1	GLM	-31.10	-35.49	-23.94	-62.36	4206.64	4855.68	3971.45	5672.98	152571141.50	193657172.02	158746472.10	391822620.71	Forecast more sensitive to future climate	Poor
OW482	Northern	1	RF	-53.29	-119.55	-412.68	-152.30	1846.90	4240.41	7927.11	4338.16	56030123.65	397909200.82	2644225202.61	1336474744.92	Forecast more sensitive to future climate	Poor
OW496	Northern	1	ANN	0.61	0.44	0.07	-0.50	0.35	0.39	0.52	0.63	0.44	0.67	1.13	1.72	Forecast more sensitive to future climate	Poor
OW496	Northern	1	GAM	0.24	0.17	-0.17	-0.91	0.41	0.41	0.48	0.56	0.88	0.95	1.38	2.62	Forecast more sensitive to future climate	Poor
OW496	Northern	1	GLM	0.45	0.29	-0.26	-1.11	0.40	0.42	0.57	0.64	0.66	1.01	2.16	3.32	Forecast more sensitive to future climate	Poor
OW496	Northern	1	RF	0.59	0.47	0.15	-0.32	0.35	0.37	0.49	0.58	0.47	0.60	0.98	1.44	Forecast more sensitive to future climate	Poor
OW502	Northern	1	ANN	0.98	0.94	0.88	0.86	0.05	0.08	0.12	0.13	0.03	0.07	0.14	0.24	Forecast less sensitive to future climate	Good
OW502	Northern	1	GAM	0.98	0.95	0.90	0.81	0.04	0.07	0.10	0.15	0.03	0.06	0.15	0.26	Forecast less sensitive to future climate	Good
OW502	Northern	1	GLM	0.98	0.94	0.89	0.81	0.05	0.08	0.12	0.15	0.03	0.08	0.15	0.24	Forecast less sensitive to future climate	Good
OW502	Northern	1	RF	0.98	0.97	0.95	0.92	0.04	0.06	0.07	0.09	0.03	0.05	0.10	0.19	Forecast less sensitive to future climate	Good
OW513	Northern	1	ANN	0.99	0.96	0.87	0.78	0.04	0.07	0.11	0.15	0.02	0.06	0.19	0.32	Forecast less sensitive to future climate	Fair
OW513	Northern	1	GAM	0.98	0.95	0.82	0.73	0.04	0.08	0.13	0.17	0.02	0.08	0.27	0.44	Forecast less sensitive to future climate	Fair
OW513	Northern	1	GLM	0.99	0.95	0.88	0.82	0.04	0.07	0.11	0.13	0.02	0.06	0.19	0.33	Forecast less sensitive to future climate	Good
OW513	Northern	1	RF	0.99	0.96	0.87	0.79	0.04	0.07	0.11	0.14	0.02	0.06	0.18	0.31	Forecast less sensitive to future climate	Fair
OW201	Vancouver Island 1	0	ANN	0.96	0.94	0.88	0.84	0.05	0.07	0.10	0.11	0.13	0.25	0.43	0.59	Forecast less sensitive to future climate	Good
OW201	Vancouver Island 1	0	GAM	0.96	0.93	0.87	0.83	0.05	0.07	0.10	0.11	0.13	0.25	0.43	0.58	Forecast less sensitive to future climate	Good
OW201	Vancouver Island 1	0	GLM	0.96	0.93	0.86	0.82	0.06	0.08	0.11	0.12	0.13	0.27	0.48	0.63	Forecast less sensitive to future climate	Good
OW201	Vancouver Island 1	0	RF	0.96	0.92	0.86	0.82	0.05	0.08	0.10	0.12	0.13	0.26	0.46	0.65	Forecast less sensitive to future climate	Good
OW204	Vancouver Island 1	0	ANN	0.94	0.91	0.90	0.89	0.10	0.13	0.14	0.15	0.69	0.95	1.04	1.06	Forecast more sensitive to future climate	Fair
OW204	Vancouver Island 1	0	GAM	0.94	0.91	0.89	0.88	0.10	0.13	0.15	0.16	0.69	0.96	1.06	1.07	Forecast more sensitive to future climate	Fair
OW204	Vancouver Island 1	0	GLM	0.91	0.88	0.88	0.88	0.12	0.15	0.16	0.16	0.72	1.01	1.07	1.08	Forecast more sensitive to future climate	Fair
OW204	Vancouver Island 1	0	RF	0.92	0.88	0.86	0.85	0.11	0.14	0.16	0.18	0.72	1.00	1.12	1.16	Forecast more sensitive to future climate	Fair
OW268	Vancouver Island 1	0	ANN	0.94	0.93	0.92	0.91	0.11	0.13	0.15	0.16	0.68	0.89	1.04	1.08	Forecast more sensitive to future climate	Fair
OW268	Vancouver Island 1	0	GAM	0.93	0.90	0.88	0.88	0.12	0.16	0.17	0.18	0.68	0.93	1.06	1.12	Forecast more sensitive to future climate	Fair
OW268	Vancouver Island 1	0	GLM	0.91	0.85	0.83	0.83	0.14	0.19	0.21	0.21	0.75	1.08	1.21	1.26	Forecast more sensitive to future climate	Fair
OW268	Vancouver Island 1	0	RF	0.94	0.92	0.90	0.90	0.11	0.14	0.16	0.17	0.68	0.92	1.09	1.21	Forecast more sensitive to future climate	Fair
OW287	Vancouver Island 1	0	ANN	0.89	0.86	0.83	0.82	0.08	0.10	0.11	0.11	0.17	0.23	0.30	0.33	Forecast less sensitive to future climate	Good
OW287	Vancouver Island 1	0	GAM	0.89	0.86	0.83	0.82	0.08	0.10	0.11	0.11	0.17	0.23	0.30	0.34	Forecast less sensitive to future climate	Good
OW287	Vancouver Island 1	0	GLM	0.89	0.85	0.80	0.79	0.08	0.10	0.12	0.12	0.17	0.24	0.35	0.38	Forecast less sensitive to future climate	Fair
OW287	Vancouver Island 1	0	RF	0.89	0.86	0.80	0.80	0.08	0.10	0.11	0.11	0.17	0.22	0.32	0.35	Forecast less sensitive to future climate	Fair
OW310	Vancouver Island 1	0	ANN	0.98	0.95	0.93	0.93	0.03	0.05	0.06	0.07	0.05	0.15	0.35	0.51	Forecast less sensitive to future climate	Good

Table A3.1 (Cont'd.)

Well	Regional Group	Snow Influenced	Model	R2				NRMSE				RMSE Ratio Skill				Operational Testing	Model Validation
				14 days	30 day	60 days	90 days	14 days	30 day	60 days	90 days	14 days	30 day	60 days	90 days		
OW310	Vancouver Island 1	0	GAM	0.97	0.94	0.90	0.91	0.04	0.07	0.10	0.09	0.06	0.18	0.41	0.55	Forecast less sensitive to future climate	Good
OW310	Vancouver Island 1	0	GLM	0.96	0.91	0.84	0.83	0.05	0.08	0.12	0.13	0.08	0.24	0.50	0.64	Forecast less sensitive to future climate	Good
OW310	Vancouver Island 1	0	RF	0.97	0.94	0.91	0.88	0.03	0.05	0.07	0.08	0.05	0.16	0.39	0.60	Forecast less sensitive to future climate	Good
OW312	Vancouver Island 1	1	ANN	0.70	0.58	0.47	0.34	0.12	0.14	0.17	0.19	0.59	0.72	0.90	1.03	Forecast more sensitive to future climate	Poor
OW312	Vancouver Island 1	1	GAM	0.68	0.58	0.43	0.37	0.13	0.15	0.18	0.19	0.56	0.70	0.94	1.02	Forecast more sensitive to future climate	Poor
OW312	Vancouver Island 1	1	GLM	0.63	0.49	0.37	0.34	0.13	0.16	0.18	0.19	0.63	0.81	0.98	1.03	Forecast more sensitive to future climate	Poor
OW312	Vancouver Island 1	1	RF	0.71	0.61	0.49	0.45	0.12	0.14	0.16	0.17	0.57	0.71	0.86	0.93	Forecast less sensitive to future climate	Poor
OW316	Vancouver Island 1	0	ANN	0.97	0.95	0.92	0.90	0.08	0.11	0.15	0.18	0.47	0.75	1.07	1.14	Forecast more sensitive to future climate	Fair
OW316	Vancouver Island 1	0	GAM	0.96	0.93	0.89	0.87	0.11	0.15	0.19	0.21	0.47	0.75	1.08	1.16	Forecast more sensitive to future climate	Fair
OW316	Vancouver Island 1	0	GLM	0.95	0.91	0.86	0.85	0.12	0.17	0.22	0.24	0.46	0.76	1.03	1.07	Forecast more sensitive to future climate	Fair
OW316	Vancouver Island 1	0	RF	0.97	0.95	0.91	0.88	0.08	0.10	0.15	0.20	0.46	0.70	1.06	1.20	Forecast more sensitive to future climate	Fair
OW320	Vancouver Island 1	0	ANN	0.94	0.92	0.89	0.86	0.08	0.09	0.12	0.15	0.24	0.43	0.64	0.78	Forecast less sensitive to future climate	Fair
OW320	Vancouver Island 1	0	GAM	0.94	0.91	0.83	0.74	0.08	0.11	0.18	0.23	0.24	0.40	0.67	0.94	Forecast less sensitive to future climate	Fair
OW320	Vancouver Island 1	0	GLM	0.90	0.78	0.62	0.57	0.12	0.19	0.27	0.29	0.34	0.77	1.35	1.58	Forecast more sensitive to future climate	Poor
OW320	Vancouver Island 1	0	RF	0.95	0.93	0.89	0.87	0.07	0.09	0.12	0.14	0.23	0.38	0.54	0.70	Forecast less sensitive to future climate	Good
OW351	Vancouver Island 1	0	ANN	0.98	0.96	0.91	0.87	0.04	0.05	0.08	0.09	0.04	0.12	0.28	0.46	Forecast less sensitive to future climate	Good
OW351	Vancouver Island 1	0	GAM	0.98	0.95	0.90	0.88	0.04	0.06	0.09	0.10	0.04	0.12	0.31	0.47	Forecast less sensitive to future climate	Good
OW351	Vancouver Island 1	0	GLM	0.98	0.95	0.90	0.87	0.04	0.06	0.09	0.10	0.04	0.13	0.31	0.47	Forecast less sensitive to future climate	Good
OW351	Vancouver Island 1	0	RF	0.98	0.95	0.91	0.88	0.04	0.06	0.08	0.09	0.04	0.11	0.27	0.43	Forecast less sensitive to future climate	Good
OW355	Vancouver Island 1	0	ANN	0.94	0.90	0.87	0.86	0.09	0.12	0.14	0.16	0.59	0.78	0.89	0.96	Forecast less sensitive to future climate	Fair
OW355	Vancouver Island 1	0	GAM	0.94	0.90	0.87	0.85	0.09	0.12	0.15	0.17	0.59	0.78	0.95	1.01	Forecast more sensitive to future climate	Fair
OW355	Vancouver Island 1	0	GLM	0.92	0.88	0.85	0.84	0.11	0.14	0.17	0.18	0.65	0.87	1.02	1.06	Forecast more sensitive to future climate	Fair
OW355	Vancouver Island 1	0	RF	0.93	0.88	0.85	0.83	0.09	0.13	0.15	0.17	0.60	0.82	0.98	1.01	Forecast more sensitive to future climate	Fair
OW369	Vancouver Island 1	0	ANN	0.96	0.94	0.91	0.89	0.08	0.10	0.13	0.16	0.36	0.70	0.95	1.14	Forecast more sensitive to future climate	Fair
OW369	Vancouver Island 1	0	GAM	0.95	0.90	0.85	0.83	0.10	0.16	0.21	0.22	0.37	0.73	1.02	1.19	Forecast more sensitive to future climate	Fair
OW369	Vancouver Island 1	0	GLM	0.95	0.88	0.83	0.81	0.11	0.17	0.23	0.24	0.40	0.78	1.07	1.16	Forecast more sensitive to future climate	Fair
OW369	Vancouver Island 1	0	RF	0.96	0.92	0.88	0.84	0.08	0.11	0.16	0.19	0.37	0.72	1.03	1.24	Forecast more sensitive to future climate	Fair
OW372	Vancouver Island 1	0	ANN	0.79	0.66	0.56	0.53	0.14	0.20	0.23	0.27	0.57	0.87	1.12	1.18	Forecast more sensitive to future climate	Poor
OW372	Vancouver Island 1	0	GAM	0.80	0.68	0.54	0.49	0.13	0.19	0.23	0.28	0.54	0.82	1.17	1.24	Forecast more sensitive to future climate	Poor
OW372	Vancouver Island 1	0	GLM	0.78	0.64	0.54	0.49	0.15	0.22	0.27	0.30	0.57	0.93	1.18	1.26	Forecast more sensitive to future climate	Poor
OW372	Vancouver Island 1	0	RF	0.80	0.70	0.57	0.51	0.10	0.14	0.21	0.27	0.53	0.84	1.21	1.37	Forecast more sensitive to future climate	Poor
OW385	Vancouver Island 1	0	ANN	0.92	0.88	0.84	0.81	0.14	0.17	0.20	0.21	0.48	0.75	1.04	1.17	Forecast more sensitive to future climate	Fair
OW385	Vancouver Island 1	0	GAM	0.92	0.86	0.82	0.82	0.14	0.18	0.21	0.20	0.49	0.80	1.07	1.09	Forecast more sensitive to future climate	Fair
OW385	Vancouver Island 1	0	GLM	0.89	0.81	0.72	0.70	0.16	0.21	0.26	0.27	0.54	0.93	1.30	1.44	Forecast more sensitive to future climate	Poor
OW385	Vancouver Island 1	0	RF	0.92	0.88	0.82	0.78	0.14	0.17	0.21	0.22	0.49	0.78	1.11	1.22	Forecast more sensitive to future climate	Fair
OW390	Vancouver Island 1	0	ANN	0.97	0.96	0.94	0.92	0.04	0.05	0.06	0.07	0.03	0.04	0.06	0.08	Forecast less sensitive to future climate	Good
OW390	Vancouver Island 1	0	GAM	0.97	0.95	0.93	0.89	0.05	0.05	0.07	0.08	0.03	0.05	0.07	0.10	Forecast less sensitive to future climate	Good
OW390	Vancouver Island 1	0	GLM	0.97	0.96	0.94	0.92	0.04	0.05	0.06	0.07	0.03	0.04	0.06	0.08	Forecast less sensitive to future climate	Good
OW390	Vancouver Island 1	0	RF	0.97	0.95	0.93	0.92	0.05	0.05	0.06	0.07	0.03	0.05	0.07	0.09	Forecast less sensitive to future climate	Good
OW424	Vancouver Island 1	0	ANN	0.85	0.79	0.73	0.69	0.09	0.11	0.13	0.13	0.17	0.24	0.32	0.36	Forecast less sensitive to future climate	Fair
OW424	Vancouver Island 1	0	GAM	0.84	0.76	0.69	0.70	0.09	0.12	0.14	0.14	0.18	0.27	0.35	0.37	Forecast less sensitive to future climate	Fair
OW424	Vancouver Island 1	0	GLM	0.85	0.78	0.72	0.68	0.09	0.11	0.13	0.14	0.17	0.24	0.33	0.38	Forecast less sensitive to future climate	Fair
OW424	Vancouver Island 1	0	RF	0.84	0.76	0.66	0.65	0.09	0.12	0.14	0.14	0.17	0.26	0.37	0.39	Forecast less sensitive to future climate	Fair
OW428	Vancouver Island 1	0	ANN	0.89	0.85	0.84	0.81	0.08	0.11	0.14	0.16	0.52	0.76	0.95	1.08	Forecast more sensitive to future climate	Fair
OW428	Vancouver Island 1	0	GAM	0.90	0.86	0.82	0.78	0.08	0.12	0.16	0.18	0.49	0.72	0.97	1.12	Forecast more sensitive to future climate	Fair
OW428	Vancouver Island 1	0	GLM	0.84	0.81	0.79	0.76	0.12	0.15	0.19	0.21	0.70	0.88	1.06	1.19	Forecast more sensitive to future climate	Fair
OW428	Vancouver Island 1	0	RF	0.85	0.80	0.73	0.72	0.09	0.12	0.18	0.19	0.65	0.95	1.28	1.45	Forecast more sensitive to future climate	Fair
OW429	Vancouver Island 1	0	ANN	0.80	0.78	0.75	0.73	0.13	0.13	0.15	0.15	0.33	0.37	0.48	0.54	Forecast less sensitive to future climate	Fair
OW429	Vancouver Island 1	0	GAM	0.79	0.77	0.74	0.71	0.13	0.14	0.15	0.16	0.34	0.39	0.51	0.59	Forecast less sensitive to future climate	Fair
OW429	Vancouver Island 1	0	GLM	0.79	0.77	0.72	0.70	0.13	0.14	0.16	0.17	0.34	0.39	0.51	0.58	Forecast less sensitive to future climate	Fair
OW429	Vancouver Island 1	0	RF	0.79	0.78	0.74	0.70	0.13	0.14	0.15	0.16	0.34	0.38	0.50	0.60	Forecast less sensitive to future climate	Fair
OW430	Vancouver Island 1	0	ANN	0.97	0.95	0.95	0.95	0.11	0.14	0.15	0.16	0.33	0.61	0.90	1.12	Forecast more sensitive to future climate	Fair
OW430	Vancouver Island 1	0	GAM	0.96	0.94	0.93	0.92	0.12	0.15	0.18	0.20	0.37	0.70	1.08	1.37	Forecast more sensitive to future climate	Fair
OW430	Vancouver Island 1	0	GLM	0.95	0.92	0.90	0.89	0.14	0.19	0.22	0.24	0.42	0.88	1.33	1.50	Forecast more sensitive to future climate	Fair
OW430	Vancouver Island 1	0	RF	0.97	0.95	0.94	0.93	0.11	0.14	0.16	0.17	0.32	0.60	0.95	1.26	Forecast more sensitive to future climate	Fair
OW431	Vancouver Island 1	0	ANN	0.98	0.97	0.97	0.95	0.08	0.11	0.11	0.14	0.20	0.49	0.82	1.06	Forecast more sensitive to future climate	Good
OW431	Vancouver Island 1	0	GAM	0.98	0.96	0.95	0.94	0.09	0.12	0.15	0.16	0.22	0.54	0.92	1.18	Forecast more sensitive to future climate	Fair
OW431	Vancouver Island 1	0	GLM	0.98	0.95	0.93	0.93	0.10	0.14	0.17	0.18	0.24	0.61	1.02	1.21	Forecast more sensitive to future climate	Fair
OW431	Vancouver Island 1	0	RF	0.98	0.97	0.95	0.94	0.08	0.11	0.13	0.15	0.21	0.50	0.84	1.07	Forecast more sensitive to future climate	Good
OW436	Vancouver Island 1	0	ANN	0.95	0.94	0.90	0.88	0.11	0.12	0.16	0.19	0.43	0.79	1.10	1.19	Forecast more sensitive to future climate	Fair
OW436	Vancouver Island 1	0	GAM	0.94	0.94	0.90	0.91	0.12	0.13	0.18	0.18	0.43	0.75	1.16	1.23	Forecast more sensitive to future climate	Fair

Table A3.1 (Cont'd.)

Well	Regional Group	Snow Influenced	Model	R2				NRMSE				RMSE Ratio Skill				Operational Testing	Model Validation
				14 days	30 day	60 days	90 days	14 days	30 day	60 days	90 days	14 days	30 day	60 days	90 days		
OW436	Vancouver Island 1	0	GLM	0.93	0.90	0.89	0.88	0.15	0.20	0.21	0.23	0.50	0.96	1.15	1.21	Forecast more sensitive to future climate	Fair
OW436	Vancouver Island 1	0	RF	0.95	0.92	0.84	0.84	0.09	0.12	0.18	0.19	0.46	0.87	1.37	1.46	Forecast more sensitive to future climate	Fair
OW437	Vancouver Island 1	0	ANN	0.93	0.91	0.88	0.83	0.11	0.13	0.16	0.20	0.45	0.75	1.19	1.24	Forecast more sensitive to future climate	Fair
OW437	Vancouver Island 1	0	GAM	0.92	0.88	0.83	0.81	0.17	0.18	0.24	0.24	0.52	0.87	1.16	1.19	Forecast more sensitive to future climate	Fair
OW437	Vancouver Island 1	0	GLM	0.89	0.83	0.81	0.78	0.21	0.28	0.29	0.31	0.63	1.13	1.21	1.24	Forecast more sensitive to future climate	Poor
OW437	Vancouver Island 1	0	RF	0.92	0.86	0.79	0.78	0.10	0.14	0.20	0.23	0.49	0.91	1.27	1.36	Forecast more sensitive to future climate	Fair
OW439	Vancouver Island 1	0	ANN	0.97	0.96	0.95	0.94	0.13	0.18	0.24	0.25	0.72	1.08	1.28	1.36	Forecast more sensitive to future climate	Poor
OW439	Vancouver Island 1	0	GAM	0.93	0.91	0.91	0.92	0.19	0.25	0.28	0.26	0.88	1.20	1.45	1.46	Forecast more sensitive to future climate	Poor
OW439	Vancouver Island 1	0	GLM	0.91	0.85	0.83	0.82	0.23	0.35	0.39	0.40	0.96	1.50	1.68	1.84	Forecast more sensitive to future climate	Poor
OW439	Vancouver Island 1	0	RF	0.95	0.92	0.91	0.88	0.14	0.22	0.29	0.33	0.84	1.26	1.50	1.69	Forecast more sensitive to future climate	Poor
OW488	Vancouver Island 1	0	ANN	0.99	0.97	0.94	0.93	0.08	0.14	0.20	0.23	0.12	0.35	0.75	1.03	Forecast more sensitive to future climate	Fair
OW488	Vancouver Island 1	0	GAM	0.98	0.94	0.89	0.90	0.10	0.18	0.25	0.25	0.18	0.64	1.21	1.15	Forecast more sensitive to future climate	Fair
OW488	Vancouver Island 1	0	GLM	0.99	0.96	0.93	0.93	0.10	0.16	0.22	0.24	0.15	0.43	0.83	0.93	Forecast less sensitive to future climate	Fair
OW488	Vancouver Island 1	0	RF	0.99	0.96	0.93	0.88	0.09	0.15	0.22	0.30	0.14	0.38	0.86	1.34	Forecast more sensitive to future climate	Poor
OW493	Vancouver Island 1	0	ANN	0.71	0.69	0.69	0.69	0.36	0.43	0.47	0.46	1.26	1.35	1.42	1.39	Forecast more sensitive to future climate	Poor
OW493	Vancouver Island 1	0	GAM	0.69	0.68	0.70	0.69	0.35	0.40	0.51	0.55	1.26	1.35	1.46	1.35	Forecast more sensitive to future climate	Poor
OW493	Vancouver Island 1	0	GLM	0.72	0.69	0.71	0.71	0.40	0.46	0.50	0.48	1.20	1.31	1.37	1.35	Forecast more sensitive to future climate	Poor
OW493	Vancouver Island 1	0	RF	0.70	0.66	0.62	0.61	0.32	0.38	0.51	0.54	1.32	1.49	1.54	1.62	Forecast more sensitive to future climate	Poor
OW125	Vancouver Island 2	0	ANN	0.84	0.79	0.77	0.75	0.15	0.18	0.19	0.20	0.88	1.04	1.10	1.15	Forecast more sensitive to future climate	Fair
OW125	Vancouver Island 2	0	GAM	0.84	0.79	0.76	0.74	0.15	0.18	0.19	0.19	0.88	1.03	1.09	1.12	Forecast more sensitive to future climate	Fair
OW125	Vancouver Island 2	0	GLM	0.83	0.77	0.75	0.73	0.16	0.19	0.20	0.21	0.89	1.06	1.16	1.20	Forecast more sensitive to future climate	Fair
OW125	Vancouver Island 2	0	RF	0.85	0.80	0.74	0.72	0.14	0.17	0.19	0.20	0.87	1.01	1.12	1.15	Forecast more sensitive to future climate	Fair
OW128	Vancouver Island 2	0	ANN	0.97	0.96	0.94	0.93	0.09	0.12	0.15	0.17	0.46	0.72	0.99	1.09	Forecast more sensitive to future climate	Fair
OW128	Vancouver Island 2	0	GAM	0.97	0.94	0.91	0.91	0.09	0.14	0.19	0.19	0.46	0.76	1.02	1.07	Forecast more sensitive to future climate	Fair
OW128	Vancouver Island 2	0	GLM	0.96	0.92	0.88	0.86	0.11	0.17	0.21	0.23	0.52	0.87	1.18	1.34	Forecast more sensitive to future climate	Fair
OW128	Vancouver Island 2	0	RF	0.97	0.95	0.94	0.93	0.09	0.12	0.16	0.17	0.46	0.75	1.01	1.09	Forecast more sensitive to future climate	Fair
OW196	Vancouver Island 2	0	ANN	0.95	0.92	0.90	0.89	0.10	0.13	0.15	0.17	0.68	0.90	1.05	1.08	Forecast more sensitive to future climate	Fair
OW196	Vancouver Island 2	0	GAM	0.94	0.91	0.88	0.87	0.12	0.15	0.17	0.19	0.67	0.94	1.12	1.17	Forecast more sensitive to future climate	Fair
OW196	Vancouver Island 2	0	GLM	0.91	0.86	0.82	0.83	0.14	0.19	0.22	0.23	0.73	1.01	1.17	1.19	Forecast more sensitive to future climate	Fair
OW196	Vancouver Island 2	0	RF	0.94	0.91	0.87	0.85	0.11	0.14	0.17	0.19	0.70	0.89	1.10	1.20	Forecast more sensitive to future climate	Fair
OW197	Vancouver Island 2	0	ANN	0.95	0.91	0.87	0.83	0.07	0.09	0.12	0.13	0.24	0.46	0.71	0.90	Forecast less sensitive to future climate	Good
OW197	Vancouver Island 2	0	GAM	0.94	0.89	0.81	0.76	0.07	0.11	0.14	0.16	0.26	0.55	0.88	1.05	Forecast more sensitive to future climate	Fair
OW197	Vancouver Island 2	0	GLM	0.93	0.84	0.76	0.73	0.08	0.12	0.16	0.17	0.28	0.58	0.89	1.02	Forecast more sensitive to future climate	Fair
OW197	Vancouver Island 2	0	RF	0.95	0.92	0.85	0.81	0.06	0.09	0.13	0.14	0.24	0.48	0.75	0.90	Forecast less sensitive to future climate	Good
OW258	Vancouver Island 2	0	ANN	0.90	0.87	0.85	0.83	0.13	0.15	0.17	0.18	0.78	0.91	1.05	1.08	Forecast more sensitive to future climate	Fair
OW258	Vancouver Island 2	0	GAM	0.89	0.86	0.84	0.82	0.14	0.16	0.18	0.19	0.76	0.91	1.05	1.06	Forecast more sensitive to future climate	Fair
OW258	Vancouver Island 2	0	GLM	0.88	0.84	0.81	0.80	0.15	0.18	0.19	0.21	0.80	0.93	1.04	1.09	Forecast more sensitive to future climate	Fair
OW258	Vancouver Island 2	0	RF	0.90	0.86	0.83	0.82	0.13	0.16	0.18	0.19	0.79	0.95	1.12	1.12	Forecast more sensitive to future climate	Fair
OW283	Vancouver Island 2	0	ANN	0.83	0.80	0.78	0.77	0.13	0.15	0.18	0.18	0.73	0.90	1.03	1.07	Forecast more sensitive to future climate	Fair
OW283	Vancouver Island 2	0	GAM	0.83	0.79	0.77	0.76	0.14	0.18	0.21	0.20	0.71	0.90	1.06	1.07	Forecast more sensitive to future climate	Fair
OW283	Vancouver Island 2	0	GLM	0.81	0.76	0.72	0.71	0.16	0.21	0.25	0.25	0.78	0.99	1.15	1.21	Forecast more sensitive to future climate	Poor
OW283	Vancouver Island 2	0	RF	0.83	0.77	0.74	0.69	0.12	0.16	0.19	0.21	0.76	1.00	1.19	1.30	Forecast more sensitive to future climate	Fair
OW284	Vancouver Island 2	0	ANN	0.86	0.81	0.78	0.75	0.09	0.11	0.12	0.13	0.45	0.52	0.61	0.65	Forecast less sensitive to future climate	Fair
OW284	Vancouver Island 2	0	GAM	0.86	0.79	0.75	0.73	0.09	0.12	0.13	0.14	0.47	0.54	0.63	0.67	Forecast less sensitive to future climate	Fair
OW284	Vancouver Island 2	0	GLM	0.84	0.78	0.74	0.72	0.10	0.12	0.14	0.15	0.49	0.58	0.67	0.69	Forecast less sensitive to future climate	Fair
OW284	Vancouver Island 2	0	RF	0.85	0.79	0.75	0.72	0.09	0.11	0.13	0.14	0.46	0.56	0.64	0.65	Forecast less sensitive to future climate	Fair
OW288	Vancouver Island 2	0	ANN	0.97	0.94	0.90	0.88	0.09	0.13	0.17	0.19	0.20	0.44	0.78	0.95	Forecast less sensitive to future climate	Fair
OW288	Vancouver Island 2	0	GAM	0.97	0.94	0.89	0.86	0.09	0.13	0.18	0.21	0.21	0.46	0.81	1.01	Forecast more sensitive to future climate	Fair
OW288	Vancouver Island 2	0	GLM	0.96	0.90	0.82	0.80	0.11	0.17	0.24	0.25	0.28	0.67	1.16	1.31	Forecast more sensitive to future climate	Poor
OW288	Vancouver Island 2	0	RF	0.97	0.94	0.89	0.87	0.09	0.13	0.17	0.20	0.20	0.45	0.83	0.98	Forecast less sensitive to future climate	Fair
OW304	Vancouver Island 2	0	ANN	0.99	0.98	0.97	0.96	0.02	0.03	0.04	0.05	0.01	0.02	0.03	0.04	Forecast less sensitive to future climate	Good
OW304	Vancouver Island 2	0	GAM	0.99	0.98	0.97	0.95	0.02	0.03	0.04	0.05	0.01	0.02	0.03	0.05	Forecast less sensitive to future climate	Good
OW304	Vancouver Island 2	0	GLM	0.99	0.98	0.97	0.96	0.02	0.03	0.04	0.05	0.01	0.02	0.03	0.04	Forecast less sensitive to future climate	Good
OW304	Vancouver Island 2	0	RF	0.99	0.98	0.97	0.95	0.02	0.03	0.04	0.05	0.01	0.02	0.03	0.04	Forecast less sensitive to future climate	Good
OW314	Vancouver Island 2	0	ANN	0.99	0.98	0.95	0.93	0.03	0.04	0.06	0.07	0.02	0.04	0.08	0.12	Forecast less sensitive to future climate	Good
OW314	Vancouver Island 2	0	GAM	0.99	0.98	0.95	0.92	0.03	0.04	0.06	0.07	0.02	0.04	0.08	0.13	Forecast less sensitive to future climate	Good
OW314	Vancouver Island 2	0	GLM	0.99	0.97	0.95	0.93	0.03	0.04	0.06	0.07	0.02	0.04	0.08	0.12	Forecast less sensitive to future climate	Good
OW314	Vancouver Island 2	0	RF	0.99	0.98	0.95	0.93	0.03	0.04	0.06	0.07	0.02	0.04	0.08	0.12	Forecast less sensitive to future climate	Good
OW327	Vancouver Island 2	0	ANN	0.93	0.87	0.81	0.79	0.08	0.11	0.14	0.14	0.27	0.42	0.52	0.55	Forecast less sensitive to future climate	Fair
OW327	Vancouver Island 2	0	GAM	0.90	0.83	0.75	0.71	0.10	0.13	0.16	0.17	0.29	0.46	0.62	0.67	Forecast less sensitive to future climate	Fair
OW327	Vancouver Island 2	0	GLM	0.90	0.82	0.73	0.70	0.10	0.14	0.17	0.18	0.30	0.47	0.63	0.67		

Table A3.1 (Cont'd.)

Well	Regional Group	Snow Influenced	Model	R2				NRMSE				RMSE Ratio Skill				Operational Testing	Model Validation
				14 days	30 day	60 days	90 days	14 days	30 day	60 days	90 days	14 days	30 day	60 days	90 days		
OW327	Vancouver Island 2	0	RF	0.92	0.86	0.79	0.79	0.08	0.11	0.14	0.14	0.27	0.42	0.54	0.54	Forecast less sensitive to future climate	Fair
OW337	Vancouver Island 2	0	ANN	0.99	0.96	0.89	0.83	0.03	0.06	0.10	0.12	0.03	0.11	0.31	0.53	Forecast less sensitive to future climate	Good
OW337	Vancouver Island 2	0	GAM	0.98	0.94	0.87	0.81	0.04	0.07	0.11	0.14	0.04	0.14	0.37	0.54		
OW337	Vancouver Island 2	0	GLM	0.98	0.94	0.86	0.81	0.04	0.08	0.12	0.14	0.05	0.16	0.39	0.56	Forecast less sensitive to future climate	Good
OW337	Vancouver Island 2	0	RF	0.99	0.96	0.91	0.86	0.03	0.06	0.09	0.11	0.03	0.11	0.29	0.45	Forecast less sensitive to future climate	Good
OW371	Vancouver Island 2	0	ANN	0.86	0.85	0.82	0.81	0.14	0.13	0.16	0.17	0.83	0.96	1.04	1.08	Forecast more sensitive to future climate	Fair
OW371	Vancouver Island 2	0	GAM	0.86	0.84	0.81	0.80	0.14	0.14	0.16	0.16	0.83	0.95	1.05	1.08	Forecast more sensitive to future climate	Fair
OW371	Vancouver Island 2	0	GLM	0.85	0.83	0.80	0.78	0.15	0.16	0.18	0.19	0.86	0.99	1.07	1.09	Forecast more sensitive to future climate	Fair
OW371	Vancouver Island 2	0	RF	0.84	0.81	0.77	0.74	0.14	0.14	0.17	0.19	0.84	0.99	1.09	1.18	Forecast more sensitive to future climate	Fair
OW383	Vancouver Island 2	0	ANN	0.97	0.95	0.92	0.91	0.05	0.06	0.07	0.08	0.04	0.06	0.10	0.11	Forecast less sensitive to future climate	Good
OW383	Vancouver Island 2	0	GAM	0.96	0.94	0.92	0.90	0.05	0.06	0.07	0.08	0.04	0.07	0.11	0.15	Forecast less sensitive to future climate	Good
OW383	Vancouver Island 2	0	GLM	0.96	0.94	0.88	0.83	0.05	0.07	0.09	0.11	0.04	0.08	0.15	0.22	Forecast less sensitive to future climate	Good
OW383	Vancouver Island 2	0	RF	0.97	0.95	0.93	0.91	0.05	0.06	0.07	0.08	0.04	0.06	0.08	0.11	Forecast less sensitive to future climate	Good
OW391	Vancouver Island 2	0	ANN	0.98	0.97	0.95	0.91	0.04	0.04	0.05	0.07	0.02	0.03	0.05	0.08	Forecast less sensitive to future climate	Good
OW391	Vancouver Island 2	0	GAM	0.98	0.97	0.94	0.86	0.03	0.04	0.06	0.09	0.02	0.03	0.06	0.13	Forecast less sensitive to future climate	Good
OW391	Vancouver Island 2	0	GLM	0.98	0.96	0.92	0.85	0.04	0.05	0.07	0.09	0.02	0.04	0.08	0.15	Forecast less sensitive to future climate	Good
OW391	Vancouver Island 2	0	RF	0.98	0.97	0.94	0.90	0.04	0.04	0.06	0.08	0.02	0.03	0.05	0.09	Forecast less sensitive to future climate	Good
OW392	Vancouver Island 2	0	ANN	0.92	0.91	0.90	0.89	0.08	0.08	0.09	0.09	0.08	0.09	0.11	0.11	Forecast less sensitive to future climate	Good
OW392	Vancouver Island 2	0	GAM	0.92	0.91	0.90	0.89	0.07	0.08	0.09	0.09	0.08	0.09	0.10	0.11	Forecast less sensitive to future climate	Good
OW392	Vancouver Island 2	0	GLM	0.92	0.90	0.88	0.86	0.08	0.08	0.10	0.10	0.09	0.10	0.13	0.15	Forecast less sensitive to future climate	Good
OW392	Vancouver Island 2	0	RF	0.92	0.91	0.90	0.88	0.08	0.08	0.09	0.09	0.08	0.09	0.10	0.11	Forecast less sensitive to future climate	Good
OW393	Vancouver Island 2	0	ANN	0.92	0.90	0.85	0.79	0.06	0.07	0.09	0.11	0.10	0.12	0.19	0.28	Forecast less sensitive to future climate	Fair
OW393	Vancouver Island 2	0	GAM	0.92	0.89	0.83	0.77	0.07	0.08	0.10	0.12	0.10	0.13	0.21	0.32	Forecast less sensitive to future climate	Fair
OW393	Vancouver Island 2	0	GLM	0.92	0.90	0.84	0.78	0.06	0.07	0.09	0.11	0.10	0.12	0.19	0.28	Forecast less sensitive to future climate	Fair
OW393	Vancouver Island 2	0	RF	0.92	0.90	0.84	0.78	0.06	0.07	0.10	0.12	0.10	0.12	0.19	0.28	Forecast less sensitive to future climate	Fair
OW394	Vancouver Island 2	0	ANN	0.94	0.89	0.84	0.63	0.10	0.14	0.17	0.20	0.21	0.47	0.78	1.42	Forecast more sensitive to future climate	Fair
OW394	Vancouver Island 2	0	GAM	0.94	0.87	0.76	0.69	0.10	0.14	0.19	0.22	0.21	0.50	1.00	1.28	Forecast more sensitive to future climate	Fair
OW394	Vancouver Island 2	0	GLM	0.94	0.86	0.73	0.66	0.10	0.15	0.20	0.22	0.22	0.52	0.99	1.20	Forecast more sensitive to future climate	Fair
OW394	Vancouver Island 2	0	RF	0.95	0.91	0.82	0.72	0.10	0.13	0.17	0.21	0.19	0.40	0.87	1.20	Forecast more sensitive to future climate	Fair
OW395	Vancouver Island 2	0	ANN	0.93	0.90	0.86	0.82	0.14	0.16	0.20	0.23	0.47	0.64	0.88	1.04	Forecast more sensitive to future climate	Fair
OW395	Vancouver Island 2	0	GAM	0.93	0.89	0.85	0.79	0.14	0.17	0.21	0.28	0.48	0.66	0.90	1.15	Forecast more sensitive to future climate	Poor
OW395	Vancouver Island 2	0	GLM	0.90	0.84	0.75	0.69	0.18	0.24	0.31	0.34	0.55	0.90	1.43	1.85	Forecast more sensitive to future climate	Poor
OW395	Vancouver Island 2	0	RF	0.93	0.88	0.82	0.80	0.13	0.17	0.22	0.25	0.51	0.71	1.06	1.14	Forecast more sensitive to future climate	Poor
OW396	Vancouver Island 2	0	ANN	0.98	0.97	0.95	0.94	0.05	0.07	0.10	0.12	0.09	0.25	0.58	0.84	Forecast less sensitive to future climate	Good
OW396	Vancouver Island 2	0	GAM	0.98	0.96	0.94	0.92	0.06	0.09	0.11	0.14	0.10	0.28	0.62	0.86	Forecast less sensitive to future climate	Good
OW396	Vancouver Island 2	0	GLM	0.98	0.95	0.92	0.91	0.07	0.11	0.14	0.15	0.11	0.32	0.68	0.87	Forecast less sensitive to future climate	Good
OW396	Vancouver Island 2	0	RF	0.98	0.96	0.92	0.88	0.06	0.08	0.11	0.15	0.09	0.27	0.66	1.01	Forecast more sensitive to future climate	Fair
OW397	Vancouver Island 2	0	ANN	0.78	0.70	0.60	0.45	0.13	0.15	0.17	0.20	0.38	0.54	0.72	0.90	Forecast less sensitive to future climate	Poor
OW397	Vancouver Island 2	0	GAM	0.80	0.72	0.62	0.47	0.12	0.15	0.17	0.20	0.37	0.53	0.67	0.84	Forecast less sensitive to future climate	Poor
OW397	Vancouver Island 2	0	GLM	0.78	0.68	0.53	0.40	0.14	0.17	0.19	0.21	0.38	0.57	0.83	0.97	Forecast less sensitive to future climate	Poor
OW397	Vancouver Island 2	0	RF	0.78	0.69	0.59	0.44	0.13	0.16	0.18	0.20	0.38	0.55	0.69	0.92	Forecast less sensitive to future climate	Poor
OW398	Vancouver Island 2	0	ANN	0.98	0.98	0.97	0.97	0.03	0.03	0.04	0.05	0.02	0.02	0.03	0.04	Forecast less sensitive to future climate	Good
OW398	Vancouver Island 2	0	GAM	0.98	0.98	0.97	0.96	0.03	0.03	0.04	0.05	0.02	0.02	0.03	0.04	Forecast less sensitive to future climate	Good
OW398	Vancouver Island 2	0	GLM	0.98	0.98	0.97	0.96	0.03	0.03	0.04	0.05	0.02	0.02	0.03	0.04	Forecast less sensitive to future climate	Good
OW398	Vancouver Island 2	0	RF	0.98	0.98	0.97	0.96	0.03	0.03	0.04	0.05	0.02	0.02	0.03	0.04	Forecast less sensitive to future climate	Good
OW470	Vancouver Island 2	0	ANN	0.84	0.78	0.71	0.67	0.21	0.26	0.31	0.36	0.63	0.92	1.24	1.75	Forecast more sensitive to future climate	Poor
OW470	Vancouver Island 2	0	GAM	0.83	0.78	0.76	0.72	0.24	0.29	0.31	0.32	0.64	0.90	1.10	1.46	Forecast more sensitive to future climate	Poor
OW470	Vancouver Island 2	0	GLM	0.82	0.71	0.61	0.57	0.24	0.32	0.38	0.41	0.67	1.14	1.64	1.78	Forecast more sensitive to future climate	Poor
OW470	Vancouver Island 2	0	RF	0.85	0.78	0.70	0.65	0.20	0.26	0.32	0.35	0.59	0.87	1.23	1.59	Forecast more sensitive to future climate	Poor
OW484	Vancouver Island 2	0	ANN	0.93	0.91	0.87	0.85	0.26	0.28	0.35	0.37	0.60	0.80	1.21	1.40	Forecast more sensitive to future climate	Poor
OW484	Vancouver Island 2	0	GAM	0.93	0.85	0.80	0.83	0.27	0.36	0.46	0.46	0.58	1.17	1.49	1.33	Forecast more sensitive to future climate	Poor
OW484	Vancouver Island 2	0	GLM	0.90	0.78	0.72	0.71	0.32	0.48	0.68	0.68	0.82	1.64	2.13	2.17	Forecast more sensitive to future climate	Poor
OW484	Vancouver Island 2	0	RF	0.93	0.90	0.88	0.85	0.23	0.28	0.34	0.41	0.52	0.90	1.10	1.30	Forecast more sensitive to future climate	Poor
OW507	Vancouver Island 2	0	ANN	0.49	0.48	0.48	0.47	0.30	0.30	0.31	0.29	0.65	0.66	0.66	0.73	Forecast less sensitive to future climate	Poor
OW507	Vancouver Island 2	0	GAM	0.16	-0.05	0.11	0.09	0.37	0.41	0.41	0.42	1.11	1.37	1.15	1.16	Forecast more sensitive to future climate	Poor
OW507	Vancouver Island 2	0	GLM	0.43	0.41	0.36	0.33	0.32	0.32	0.35	0.33	0.73	0.74	0.81	0.90	Forecast less sensitive to future climate	Poor
OW507	Vancouver Island 2	0	RF	0.45	0.48	0.51	0.47	0.30	0.30	0.31	0.31	0.69	0.65	0.65	0.74	Forecast less sensitive to future climate	Poor
OW058	Vancouver Island 3	0	ANN	0.98	0.96	0.94	0.92	0.03	0.05	0.06	0.08	0.03	0.10	0.25	0.41	Forecast less sensitive to future climate	Good
OW058	Vancouver Island 3	0	GAM	0.98	0.95	0.93	0.92	0.03	0.06	0.07	0.08	0.04	0.11	0.26	0.40	Forecast less sensitive to future climate	Good
OW058	Vancouver Island 3	0	GLM	0.98	0.95	0.91	0.89	0.04	0.06	0.09	0.09	0.04	0.13	0.30	0.44	Forecast less sensitive to future climate	Good
OW058	Vancouver Island 3	0	RF	0.98	0.96	0.92	0.88	0.03	0.05	0.08	0.10	0.03	0.10	0.24	0.42	Forecast less sensitive to future climate	Good

Table A3.1 (Cont'd.)

Well	Regional Group	Snow Influenced	Model	R2				NRMSE				RMSE Ratio Skill				Operational Testing	Model Validation
				14 days	30 day	60 days	90 days	14 days	30 day	60 days	90 days	14 days	30 day	60 days	90 days		
OW060	Vancouver Island 3	0	ANN	0.99	0.97	0.95	0.92	0.03	0.04	0.05	0.07	0.03	0.09	0.21	0.33	Forecast less sensitive to future climate	Good
OW060	Vancouver Island 3	0	GAM	0.99	0.97	0.93	0.91	0.03	0.05	0.06	0.08	0.03	0.10	0.24	0.37	Forecast less sensitive to future climate	Good
OW060	Vancouver Island 3	0	GLM	0.98	0.96	0.90	0.87	0.03	0.05	0.08	0.09	0.04	0.11	0.28	0.41	Forecast less sensitive to future climate	Good
OW060	Vancouver Island 3	0	RF	0.99	0.97	0.93	0.89	0.03	0.04	0.06	0.07	0.03	0.09	0.23	0.34	Forecast less sensitive to future climate	Good
OW071	Vancouver Island 3	0	ANN	0.93	0.90	0.86	0.85	0.06	0.08	0.09	0.10	0.13	0.21	0.30	0.34	Forecast less sensitive to future climate	Good
OW071	Vancouver Island 3	0	GAM	0.94	0.90	0.87	0.84	0.06	0.08	0.09	0.10	0.13	0.21	0.30	0.35	Forecast less sensitive to future climate	Good
OW071	Vancouver Island 3	0	GLM	0.93	0.88	0.81	0.75	0.06	0.09	0.12	0.13	0.15	0.25	0.39	0.52	Forecast less sensitive to future climate	Fair
OW071	Vancouver Island 3	0	RF	0.93	0.89	0.85	0.82	0.06	0.08	0.10	0.11	0.14	0.22	0.30	0.35	Forecast less sensitive to future climate	Good
OW240	Vancouver Island 3	0	ANN	0.95	0.95	0.93	0.92	0.10	0.11	0.14	0.16	0.65	0.92	1.07	1.05	Forecast more sensitive to future climate	Fair
OW240	Vancouver Island 3	0	GAM	0.94	0.93	0.92	0.91	0.12	0.14	0.16	0.18	0.66	0.94	1.09	1.10	Forecast more sensitive to future climate	Fair
OW240	Vancouver Island 3	0	GLM	0.92	0.89	0.87	0.88	0.16	0.21	0.24	0.24	0.74	1.12	1.24	1.19	Forecast more sensitive to future climate	Fair
OW240	Vancouver Island 3	0	RF	0.95	0.92	0.90	0.90	0.09	0.13	0.17	0.19	0.65	0.98	1.17	1.09	Forecast more sensitive to future climate	Fair
OW281	Vancouver Island 3	0	ANN	0.93	0.92	0.91	0.91	0.13	0.14	0.15	0.16	0.86	0.96	1.05	1.09	Forecast more sensitive to future climate	Fair
OW281	Vancouver Island 3	0	GAM	0.93	0.92	0.91	0.91	0.13	0.15	0.16	0.16	0.88	0.98	1.07	1.09	Forecast more sensitive to future climate	Fair
OW281	Vancouver Island 3	0	GLM	0.92	0.91	0.90	0.90	0.14	0.16	0.17	0.17	0.88	0.97	1.06	1.09	Forecast more sensitive to future climate	Fair
OW281	Vancouver Island 3	0	RF	0.93	0.91	0.90	0.89	0.13	0.15	0.17	0.17	0.86	0.98	1.13	1.21	Forecast more sensitive to future climate	Fair
OW290	Vancouver Island 3	0	ANN	0.92	0.88	0.83	0.82	0.09	0.12	0.16	0.16	0.55	0.73	0.94	0.96	Forecast less sensitive to future climate	Fair
OW290	Vancouver Island 3	0	GAM	0.90	0.84	0.81	0.79	0.11	0.15	0.17	0.18	0.58	0.82	0.98	1.00	Forecast less sensitive to future climate	Fair
OW290	Vancouver Island 3	0	GLM	0.89	0.83	0.78	0.76	0.13	0.17	0.20	0.20	0.60	0.86	1.06	1.11	Forecast more sensitive to future climate	Fair
OW290	Vancouver Island 3	0	RF	0.91	0.87	0.81	0.79	0.09	0.12	0.16	0.17	0.56	0.74	0.94	1.02	Forecast more sensitive to future climate	Fair
OW319	Vancouver Island 3	0	ANN	0.83	0.63	0.28	0.06	0.08	0.11	0.15	0.17	0.19	0.40	0.75	0.96	Forecast less sensitive to future climate	Poor
OW319	Vancouver Island 3	0	GAM	0.82	0.59	0.23	-0.01	0.08	0.12	0.16	0.19	0.19	0.44	0.82	1.00	Forecast less sensitive to future climate	Poor
OW319	Vancouver Island 3	0	GLM	0.83	0.62	0.25	0.01	0.08	0.11	0.15	0.17	0.19	0.40	0.78	1.01	Forecast more sensitive to future climate	Poor
OW319	Vancouver Island 3	0	RF	0.81	0.54	0.15	-0.21	0.08	0.12	0.15	0.19	0.21	0.47	0.88	1.11	Forecast more sensitive to future climate	Poor
OW321	Vancouver Island 3	0	ANN	0.92	0.85	0.77	0.70	0.08	0.11	0.15	0.18	0.21	0.38	0.56	0.68	Forecast less sensitive to future climate	Fair
OW321	Vancouver Island 3	0	GAM	0.92	0.84	0.75	0.70	0.08	0.12	0.16	0.18	0.21	0.39	0.58	0.67	Forecast less sensitive to future climate	Fair
OW321	Vancouver Island 3	0	GLM	0.90	0.79	0.63	0.54	0.10	0.15	0.21	0.23	0.23	0.46	0.79	0.96	Forecast less sensitive to future climate	Poor
OW321	Vancouver Island 3	0	RF	0.91	0.83	0.75	0.66	0.08	0.12	0.15	0.18	0.21	0.39	0.57	0.70	Forecast less sensitive to future climate	Fair
OW329	Vancouver Island 3	0	ANN	0.97	0.96	0.93	0.93	0.07	0.09	0.11	0.12	0.23	0.52	0.84	0.99	Forecast less sensitive to future climate	Good
OW329	Vancouver Island 3	0	GAM	0.98	0.97	0.96	0.95	0.06	0.08	0.09	0.10	0.21	0.45	0.73	0.90	Forecast less sensitive to future climate	Good
OW329	Vancouver Island 3	0	GLM	0.98	0.96	0.94	0.94	0.06	0.09	0.11	0.12	0.22	0.48	0.77	0.92	Forecast less sensitive to future climate	Good
OW329	Vancouver Island 3	0	RF	0.98	0.96	0.95	0.91	0.06	0.08	0.10	0.12	0.21	0.48	0.73	0.98	Forecast less sensitive to future climate	Good
OW338	Vancouver Island 3	0	ANN	0.98	0.93	0.79	0.65	0.04	0.07	0.11	0.14	0.03	0.10	0.30	0.47	Forecast less sensitive to future climate	Fair
OW338	Vancouver Island 3	0	GAM	0.97	0.90	0.72	0.57	0.04	0.08	0.14	0.17	0.04	0.14	0.38	0.61	Forecast less sensitive to future climate	Poor
OW338	Vancouver Island 3	0	GLM	0.97	0.91	0.74	0.58	0.04	0.08	0.13	0.16	0.04	0.13	0.37	0.57	Forecast less sensitive to future climate	Poor
OW338	Vancouver Island 3	0	RF	0.98	0.93	0.79	0.65	0.04	0.06	0.10	0.13	0.03	0.10	0.29	0.48	Forecast less sensitive to future climate	Fair
OW343	Vancouver Island 3	0	ANN	0.92	0.90	0.88	0.87	0.12	0.15	0.18	0.20	0.65	0.88	1.09	1.14	Forecast more sensitive to future climate	Fair
OW343	Vancouver Island 3	0	GAM	0.88	0.84	0.83	0.84	0.18	0.21	0.23	0.23	0.70	0.95	1.13	1.12	Forecast more sensitive to future climate	Fair
OW343	Vancouver Island 3	0	GLM	0.85	0.79	0.78	0.78	0.21	0.29	0.31	0.31	0.81	1.16	1.24	1.22	Forecast more sensitive to future climate	Poor
OW343	Vancouver Island 3	0	RF	0.91	0.87	0.86	0.86	0.11	0.15	0.19	0.20	0.63	0.96	1.21	1.19	Forecast more sensitive to future climate	Fair
OW373	Vancouver Island 3	0	ANN	0.95	0.93	0.91	0.90	0.12	0.15	0.17	0.19	0.39	0.75	1.06	1.16	Forecast more sensitive to future climate	Fair
OW373	Vancouver Island 3	0	GAM	0.95	0.92	0.90	0.89	0.12	0.15	0.18	0.19	0.40	0.80	1.10	1.11	Forecast more sensitive to future climate	Fair
OW373	Vancouver Island 3	0	GLM	0.94	0.90	0.87	0.86	0.13	0.19	0.22	0.23	0.46	0.91	1.21	1.29	Forecast more sensitive to future climate	Fair
OW373	Vancouver Island 3	0	RF	0.95	0.92	0.88	0.86	0.12	0.15	0.19	0.22	0.41	0.87	1.31	1.46	Forecast more sensitive to future climate	Fair
OW389	Vancouver Island 3	0	ANN	0.97	0.95	0.94	0.93	0.11	0.14	0.16	0.17	0.59	0.90	1.08	1.11	Forecast more sensitive to future climate	Fair
OW389	Vancouver Island 3	0	GAM	0.97	0.95	0.93	0.93	0.11	0.14	0.16	0.17	0.59	0.92	1.13	1.15	Forecast more sensitive to future climate	Fair
OW389	Vancouver Island 3	0	GLM	0.96	0.93	0.92	0.92	0.13	0.16	0.18	0.19	0.60	0.97	1.17	1.23	Forecast more sensitive to future climate	Fair
OW389	Vancouver Island 3	0	RF	0.97	0.94	0.92	0.90	0.11	0.15	0.18	0.19	0.60	0.91	1.23	1.30	Forecast more sensitive to future climate	Fair
OW425	Vancouver Island 3	0	ANN	0.95	0.87	0.68	0.53	0.09	0.14	0.20	0.26	0.09	0.27	0.63	0.90	Forecast less sensitive to future climate	Poor
OW425	Vancouver Island 3	0	GAM	0.95	0.86	0.64	0.46	0.09	0.16	0.25	0.33	0.10	0.28	0.66	0.97	Forecast less sensitive to future climate	Poor
OW425	Vancouver Island 3	0	GLM	0.94	0.82	0.58	0.45	0.11	0.20	0.28	0.31	0.11	0.36	0.82	1.09	Forecast more sensitive to future climate	Poor
OW425	Vancouver Island 3	0	RF	0.96	0.87	0.63	0.42	0.08	0.12	0.20	0.28	0.09	0.26	0.64	1.02	Forecast more sensitive to future climate	Poor
OW426	Vancouver Island 3	0	ANN	0.88	0.85	0.82	0.77	0.10	0.11	0.12	0.13	0.14	0.17	0.21	0.26	Forecast less sensitive to future climate	Fair
OW426	Vancouver Island 3	0	GAM	0.88	0.86	0.81	0.75	0.10	0.11	0.12	0.14	0.14	0.16	0.21	0.28	Forecast less sensitive to future climate	Fair
OW426	Vancouver Island 3	0	GLM	0.88	0.85	0.78	0.72	0.10	0.11	0.13	0.15	0.14	0.17	0.26	0.32	Forecast less sensitive to future climate	Fair
OW426	Vancouver Island 3	0	RF	0.87	0.85	0.80	0.73	0.10	0.11	0.13	0.15	0.14	0.17	0.22	0.29	Forecast less sensitive to future climate	Fair
OW427	Vancouver Island 3	0	ANN	0.19	0.12	-0.01	-0.01	0.25	0.26	0.28	0.29	0.81	0.87	0.95	1.01	Forecast more sensitive to future climate	Poor
OW427	Vancouver Island 3	0	GAM	0.27	0.20	0.14	0.05	0.24	0.25	0.27	0.28	0.77	0.85	0.92	1.02	Forecast more sensitive to future climate	Poor
OW427	Vancouver Island 3	0	GLM	0.26	0.19	0.14	0.06	0.24	0.25	0.27	0.28	0.78	0.87	0.93	1.01	Forecast more sensitive to future climate	Poor
OW427	Vancouver Island 3	0	RF	0.24	0.15	0.05	0.03	0.25	0.25	0.27	0.28	0.79	0.86	0.93	0.99	Forecast less sensitive to future climate	Poor
OW432	Vancouver Island 3	0	ANN	0.97	0.93	0.87	0.83	0.10	0.14	0.19	0.23	0.27	0.63	1.09	1.22	Forecast more sensitive to future climate	Fair

Table A3.1 (Cont'd.)

Well	Regional Group	Snow Influenced	Model	R2				NRMSE				RMSE Ratio Skill				Operational Testing	Model Validation
				14 days	30 day	60 days	90 days	14 days	30 day	60 days	90 days	14 days	30 day	60 days	90 days		
OW432	Vancouver Island 3	0	GAM	0.96	0.91	0.84	0.83	0.11	0.16	0.22	0.23	0.27	0.65	1.10	1.15	Forecast more sensitive to future climate	Fair
OW432	Vancouver Island 3	0	GLM	0.96	0.91	0.83	0.82	0.11	0.17	0.22	0.26	0.28	0.66	1.12	1.18	Forecast more sensitive to future climate	Poor
OW432	Vancouver Island 3	0	RF	0.96	0.91	0.84	0.82	0.10	0.16	0.22	0.25	0.30	0.74	1.35	1.41	Forecast more sensitive to future climate	Fair
OW433	Vancouver Island 3	0	ANN	0.95	0.88	0.83	0.78	0.08	0.13	0.17	0.20	0.18	0.40	0.53	0.61	Forecast less sensitive to future climate	Fair
OW433	Vancouver Island 3	0	GAM	0.95	0.88	0.81	0.77	0.09	0.14	0.18	0.20	0.20	0.42	0.56	0.65	Forecast less sensitive to future climate	Fair
OW433	Vancouver Island 3	0	GLM	0.93	0.83	0.70	0.62	0.11	0.17	0.23	0.26	0.21	0.51	0.88	1.06	Forecast more sensitive to future climate	Poor
OW433	Vancouver Island 3	0	RF	0.94	0.88	0.85	0.79	0.09	0.13	0.15	0.19	0.18	0.39	0.46	0.59	Forecast less sensitive to future climate	Fair
OW434	Vancouver Island 3	0	ANN	0.93	0.93	0.92	0.91	0.07	0.07	0.08	0.08	0.07	0.07	0.09	0.10	Forecast less sensitive to future climate	Good
OW434	Vancouver Island 3	0	GAM	0.93	0.93	0.92	0.90	0.07	0.07	0.08	0.09	0.07	0.07	0.08	0.10	Forecast less sensitive to future climate	Good
OW434	Vancouver Island 3	0	GLM	0.93	0.93	0.92	0.90	0.07	0.07	0.08	0.09	0.07	0.07	0.08	0.10	Forecast less sensitive to future climate	Good
OW434	Vancouver Island 3	0	RF	0.93	0.93	0.92	0.91	0.07	0.07	0.08	0.08	0.07	0.07	0.08	0.09	Forecast less sensitive to future climate	Good
OW435	Vancouver Island 3	0	ANN	0.95	0.93	0.88	0.87	0.10	0.14	0.19	0.21	0.46	0.84	1.17	1.17	Forecast more sensitive to future climate	Fair
OW435	Vancouver Island 3	0	GAM	0.94	0.91	0.89	0.88	0.12	0.16	0.19	0.20	0.45	0.80	1.14	1.12	Forecast more sensitive to future climate	Fair
OW435	Vancouver Island 3	0	GLM	0.91	0.83	0.75	0.74	0.15	0.22	0.28	0.29	0.49	0.84	1.14	1.19	Forecast more sensitive to future climate	Poor
OW435	Vancouver Island 3	0	RF	0.94	0.91	0.87	0.86	0.10	0.15	0.19	0.22	0.43	0.79	1.16	1.24	Forecast more sensitive to future climate	Fair
OW438	Vancouver Island 3	0	ANN	0.97	0.94	0.89	0.86	0.09	0.12	0.17	0.19	0.18	0.35	0.64	0.85	Forecast less sensitive to future climate	Fair
OW438	Vancouver Island 3	0	GAM	0.97	0.94	0.89	0.86	0.09	0.12	0.17	0.19	0.18	0.37	0.66	0.86	Forecast less sensitive to future climate	Fair
OW438	Vancouver Island 3	0	GLM	0.97	0.94	0.87	0.84	0.09	0.13	0.18	0.21	0.18	0.37	0.69	0.88	Forecast less sensitive to future climate	Fair
OW438	Vancouver Island 3	0	RF	0.97	0.94	0.89	0.86	0.09	0.12	0.17	0.19	0.18	0.37	0.65	0.85	Forecast less sensitive to future climate	Fair
OW443	Vancouver Island 3	0	ANN	0.96	0.82	0.56	0.15	0.07	0.14	0.22	0.29	0.06	0.25	0.57	1.19	Forecast more sensitive to future climate	Poor
OW443	Vancouver Island 3	0	GAM	0.95	0.87	0.73	0.65	0.07	0.12	0.17	0.21	0.07	0.18	0.36	0.47	Forecast less sensitive to future climate	Fair
OW443	Vancouver Island 3	0	GLM	0.95	0.87	0.73	0.59	0.07	0.12	0.17	0.22	0.07	0.16	0.35	0.54	Forecast less sensitive to future climate	Poor
OW443	Vancouver Island 3	0	RF	0.96	0.89	0.80	0.78	0.07	0.11	0.15	0.16	0.06	0.17	0.29	0.36	Forecast less sensitive to future climate	Fair

Appendix A4

Forecasting Model Data

Table A4.1 Forecasting Model Data.

Well	Regional Group	Region	Location	Latitude	Longitude	Aquifer ID	Subtype Sym	Snow Influenced	Training Start Date	Climate Station ID	Climate Station ME	Climate Infilled ID	Climate Secondary Infilled	Climate Tertiary Infilled	Climate Quaternary Infilled	Snow Station	Lag Time	DWC Precipitation	DWC Snow	Station Name RF Forecast	Ann Size	Ann Decay	Ann Maxit	R2 14	R2 30	R2 60	R2 90	NRMSE 14	NRMSE 30	NRMSE 60	NRMSE 90	RSR 14	RSR 30	RSR 60	RSR 90
OW002	Coastal 1	Surrey	Abbotsford	49.0171	-122.34165	15	4a	0	2004-01-01	810	MISSION WEST ABBEY	702. 50308. 54238	43723	50368	0	1D17P	84	1		YXX	5	0.1	500	0.98	0.95	0.95	0.94	0.04	0.06	0.07	0.08	0.07	0.20	0.41	0.58
OW008	Coastal 1	Surrey	Abbotsford	49.01696	-122.2894	15	4a	0	2004-01-01	810	MISSION WEST	702. 50308.	43723	50368	0	1D17P	99	1		YXX	15	0.01	100	0.99	0.96	0.93	0.91	0.03	0.05	0.07	0.08	0.04	0.12	0.35	0.53
OW255	Coastal 1	Surrey	Chilliwack	49.07409	-122.05764	1216	NA	0	2004-01-01	50368	CULTUS LAKE	810	702. 50308. 54238	707	0	1D17P	7	2		YXX	10	0.001	200	0.94	0.90	0.86	0.82	0.09	0.12	0.15	0.17	0.62	0.80	0.96	1.04
OW299	Coastal 1	Surrey	Abbotsford	49.04214	-122.38148	15	4a	0	2004-01-01	810	MISSION WEST ABBEY	702. 50308. 54238	43723	747	0	1D17P	17	1		YXX	20	0.01	100	0.98	0.96	0.94	0.93	0.07	0.09	0.12	0.13	0.40	0.64	0.86	0.95
OW301	Coastal 1	Surrey	Abbotsford	49.03127	-122.43471	15	4a	0	2004-01-01	43723	FORT LANGLEY TELEGRAPH TRAIL	702. 50308. 54238	810	747	925	1D17P	25	1		YXX	10	0.01	100	0.96	0.95	0.93	0.92	0.09	0.11	0.14	0.15	0.35	0.68	0.94	1.04
OW349	Coastal 1	Surrey	Belcarra	49.32042	-122.90234	68	6b	0	2004-01-01	888	VANCOUVER HARBOUR CS	823	6830	0	0	1D17P	7	5		COQ	20	0.001	200	0.92	0.86	0.85	0.82	0.12	0.17	0.18	0.20	0.49	0.87	1.04	1.16
OW357	Coastal 1	Surrey	Abbotsford	49.11834	-122.38712	29	4b	0	2004-01-01	810	MISSION WEST ABBEY	702. 50308. 54238	43723	747	0	1D17P	54	3		YXX	10	0.01	100	0.98	0.97	0.95	0.94	0.05	0.07	0.09	0.10	0.22	0.45	0.71	0.82
OW406	Coastal 1	Surrey	Chilliwack	49.12231	-121.97352	8	3	0	2004-01-01	50368	CULTUS LAKE	707	706	810	0	1D17P	7	5		WZA	15	0.1	100	0.95	0.92	0.89	0.88	0.09	0.11	0.13	0.14	0.40	0.72	1.00	1.08
OW448	Coastal 1	Surrey	Agassiz	49.244304	-121.785054	4	1a	1	2004-01-01	706	AGASSIZ RCS	707	50368	49588	50517	1D19P	7	5	100	WZA	5	0.01	500	0.93	0.90	0.83	0.75	0.09	0.12	0.15	0.20	0.55	0.80	1.05	1.22
OW449	Coastal 1	Surrey	Agassiz	49.235153	-121.747747	4	1a	1	2004-01-01	706	AGASSIZ RCS	707	49588	50517	50368	1D19P	7	10	5	WZA	5	0.001	500	0.92	0.83	0.75	0.61	0.11	0.15	0.18	0.24	0.44	0.75	1.01	1.25
OW450	Coastal 1	Surrey	Chilliwack	49.16495	-121.91194	6	1a	0	2004-01-01	50368	CULTUS LAKE	707	706	810	0	1D17P	7	3		WZA	15	0.01	100	0.95	0.93	0.91	0.89	0.09	0.12	0.15	0.18	0.61	0.77	0.98	1.15
OW451	Coastal 1	Surrey	Hope	49.36575	-121.48121	1	1a	1	2004-01-01	50517	HOPE AIRPORT	49588	951	707	706	1D19P	7	100	3	VPE	10	0.01	200	0.92	0.85	0.75	0.74	0.13	0.18	0.24	0.25	0.55	0.98	1.45	1.41
OW452	Coastal 1	Surrey	Langley	49.167753	-122.584482	37	4a	1	2004-01-01	43723	FORT LANGLEY TELEGRAPH TRAIL	6830	747	925	702. 50308. 54238	1D19P	11	5	3	WMM	5	0.1	200	0.91	0.79	0.65	0.63	0.11	0.17	0.23	0.24	0.32	0.76	1.19	1.18
OW456	Coastal 1	Surrey	Langley	49.158707	-122.651309	59	4b	0	2004-01-01	6830	PITT MEADOWS CS	747	43723	925	0	1D09P	70	100		WMM	5	0.1	100	0.98	0.98	0.96	0.95	0.04	0.05	0.06	0.08	0.02	0.03	0.04	0.07
OW459	Coastal 1	Surrey	Chilliwack	49.110477	-121.998289	8	3	1	2004-01-01	50368	CULTUS LAKE	810	707	706	0	1D19P	7	5	2	YXX	5	0.01	200	0.93	0.90	0.85	0.79	0.13	0.16	0.19	0.21	0.51	0.77	1.13	1.43
OW460	Coastal 1	Surrey	Gibsons	49.401641	-123.520065	560	4a	0	2004-01-01	309	GIBSONS GOWER	45267	45788	6817	0	3A25P	89	0.5		TSE	10	0.1	100	0.86	0.81	0.75	0.68	0.07	0.09	0.10	0.11	0.15	0.20	0.26	0.34
OW490	Coastal 1	Surrey	Langley	49.14763	-122.53144	24	1a	1	2004-01-01	43723	FORT LANGLEY TELEGRAPH TRAIL	747	6830	702. 50308. 54238	810	1D19P	7	100	5	UBC	10	0.001	200	0.98	0.97	0.95	0.93	0.11	0.14	0.18	0.23	0.41	0.59	1.01	1.20
OW492	Coastal 1	Surrey	Columbia Valley	49.02244	-122.05063	20	4a	0	2004-01-01	50368	CULTUS LAKE	810	702. 50308. 54238	707	0	1D09P	73	1		YXX	5	0.1	500	0.94	0.85	0.84	0.81	0.08	0.13	0.17	0.20	0.13	0.44	0.85	1.19
OW292	Coastal 2	Surrey	Powell River	49.77559	-124.40106	836	NA	0	2004-01-01	45807	POWELL RIVER	327. 52018	0	0	0	3B17P	21	100		PRW	15	0.1	200	0.82	0.75	0.69	0.65	0.13	0.15	0.17	0.19	0.45	0.61	0.79	0.91
OW353	Coastal 2	Surrey	Langley	49.06717	-122.67997	41	4a	0	2004-01-01	925	WHITE ROCK CAMPBELL SCIENTIFIC	747	43723	6830	702. 50308. 54238	1D17P	45	10		WWK	15	0.1	500	0.96	0.93	0.88	0.84	0.08	0.10	0.14	0.16	0.24	0.48	0.77	0.94
OW354	Coastal 2	Surrey	Langley	49.09392	-122.56474	35	4a	0	2004-01-01	43723	FORT LANGLEY TELEGRAPH TRAIL	747	6830	702. 50308. 54238	925	1D17P	116	0.5		WMM	5	0.01	500	0.98	0.95	0.94	0.92	0.04	0.07	0.08	0.09	0.04	0.13	0.28	0.46
OW359	Coastal 2	Surrey	Langley	49.06252	-122.55919	33	4b	0	2004-01-01	43723	FORT LANGLEY TELEGRAPH TRAIL	747	702. 50308. 54238	925	6830	1D09P	25	2		YXX	10	0.001	100	0.99	0.99	0.98	0.98	0.02	0.03	0.03	0.03	0.01	0.02	0.02	0.03
OW360	Coastal 2	Surrey	Langley	49.04074	-122.67138	41	4a	0	2004-01-01	925	WHITE ROCK CAMPBELL SCIENTIFIC	747	43723	6830	702. 50308. 54238	1D17P	50	2		WWK	10	0.1	100	0.95	0.93	0.92	0.88	0.09	0.12	0.14	0.18	0.34	0.67	0.92	1.05
OW361	Coastal 2	Surrey	Langley	49.05044	-122.46313	27	4c	0	2004-01-01	43723	FORT LANGLEY TELEGRAPH TRAIL	702. 50308. 54238	810	747	925	1D17P	116	1		YXX	5	0.001	500	1.00	0.99	0.95	0.91	0.02	0.03	0.05	0.06	0.00	0.02	0.08	0.17
OW414	Coastal 2	Surrey	Langley	49.06537	-122.54718	1144	4c	0	2004-01-01	43723	FORT LANGLEY TELEGRAPH TRAIL	747	702. 50308. 54238	925	6830	1D18P	180	1		YXX	5	0.1	100	0.98	0.98	0.97	0.97	0.03	0.03	0.04	0.04	0.02	0.02	0.03	0.03
OW415	Coastal 2	Surrey	Langley	49.06537	-122.54718	33	4b	0	2004-01-01	43723	FORT LANGLEY TELEGRAPH TRAIL	747	702. 50308. 54238	925	6830	1D17P	25	5		YXX	5	0.01	500	0.98	0.97	0.96	0.96	0.04	0.04	0.05	0.05	0.03	0.04	0.06	0.06
OW446	Coastal 2	Surrey	Langley	49.0188	-122.65452	52	4b	0	2004-01-01	925	WHITE ROCK CAMPBELL SCIENTIFIC	747	43723	6830	702. 50308. 54238	1D17P	35	1		WWK	15	0.01	100	0.97	0.96	0.94	0.93	0.10	0.13	0.16	0.17	0.36	0.59	0.87	1.04
OW453	Coastal 2	Surrey	Langley	49.13393	-122.55637	35	4a	0	2004-01-01	43723	FORT LANGLEY TELEGRAPH TRAIL	747	6830	702. 50308. 54238	925	1D17P	89	0.5		WMM	15	0.1	100	0.98	0.96	0.94	0.91	0.04	0.07	0.09	0.10	0.05	0.15	0.36	0.57
OW454	Coastal 2	Surrey	Squamish	49.83479	-123.15197	401	1b	1	2004-01-01	336. 10816	SQUAMISH AIRPORT	43500	43443	348	0	3A25P	7	10	1	WSK	5	0.1	200	0.85	0.76	0.70	0.68	0.14	0.18	0.21	0.23	0.63	0.92	1.17	1.17
OW458	Coastal 2	Surrey	Langley	49.046826	-122.487051	27	4c	0	2004-01-01	43723	FORT LANGLEY TELEGRAPH TRAIL	702. 50308. 54238	747	810	925	1D17P	57	2		YXX	15	0.1	100	0.98	0.97	0.94	0.91	0.04	0.05	0.07	0.08	0.03	0.06	0.11	0.17
OW463	Coastal 2	Surrey	Mission	49.220192	-122.379292	884	4c	0	2004-01-01	810	MISSION WEST ABBEY	43723	702. 50308. 54238	6830	0	1D17P	86	1		UBC	10	0.1	100	0.98	0.97	0.95	0.93	0.05	0.06	0.08	0.10	0.05	0.12	0.29	0.48
OW474	Coastal 2	Surrey	Miracle Valley	49.23549	-122.23649	25	4b	0	2004-01-01	810	MISSION WEST ABBEY	702. 50308. 54238	43723	50368	0	1D18P	48	1		UBC	10	0.001	100	0.97	0.94	0.92	0.93	0.10	0.13	0.15	0.16	0.11	0.32	0.60	0.87
OW479	Coastal 2	Surrey	Maple Ridge	49.18354	-122.45753	19	5a	0	2004-01-01	43723	FORT LANGLEY TELEGRAPH TRAIL	810	6830	702. 50308. 54238	747	1D18P	70	0.5		UBC	15	0.1	100	0.99	0.98	0.94	0.90	0.03	0.04	0.07	0.09	0.01	0.03	0.09	0.15
OW483	Coastal 2	Surrey	Squamish	49.72254	-123.07491	397	4b	0	2004-01-01	336. 10816	SQUAMISH AIRPORT	6817	45267	823	0	1D18P	63	10		WSK	5	0.01	200	0.97	0.95	0.88	0.84	0.05	0.07	0.11	0.14	0.11	0.22	0.44	0.72
OW491	Coastal 2	Surrey	Maple Ridge	49.19573	-122.47144	26	4b	0	2004-01-01	43723	FORT LANGLEY TELEGRAPH TRAIL	810	6830	747	702. 50308. 54238	1D18P	57	3		UBC	10	0.01	100	0.98	0.96	0.93	0.84	0.09	0.11	0.15	0.24	0.12	0.27	0.56	0.94
OW275	Coastal 3	Surrey	Surrey	49.06754	-122.68439	41	4a	0	2004-01-01	925	WHITE ROCK CAMPBELL SCIENTIFIC	747	43723	6830	702. 50308. 54238	1D17P	61	10		WWK	10	0.1	100	0.97	0.94	0.91	0.87	0.05	0.08	0.10	0.12	0.13	0.34	0.65	0.87
OW447	Coastal 3	Surrey	Surrey	49.18456	-122.75323	61	NA	0	2004-01-01	6830	PITT MEADOWS CS	747	43723	925	0	1D17P	63	1																	

Table A4.1 (Cont'd.)

Well	Regional Group	Region	Location	Latitude	Longitude	Aquifer ID	Subtype Sym	Snow Influenced	Training Start Date	Climate Station ID	Climate Station ME	Climate Infilled ID	Climate Secondary Infilled	Climate Tertiary Infilled	Climate Quaternary Infilled	Snow Station	Lag Time	DWC Precipitation	DWC Snow	Station Name RF Forecast	Ann Size	Ann Decay	Ann Maxit	R2 14	R2 30	R2 60	R2 90	NRMSE 14	NRMSE 30	NRMSE 60	NRMSE 90	RSR 14	RSR 30	RSR 60	RSR 90
OW217	Interior 2	Pentiction	Grand Forks	49.023016	-118.434061	158	1b	1	2004-01-01	1100	BILLINGS	1091	31067	1106	1105. 52938	2F05P	14	10	2	GDF	10	0.01	200	0.91	0.86	0.79	0.76	0.06	0.10	0.14	0.17	0.27	0.50	0.79	0.91
OW262	Interior 2	Pentiction	Kelow	49.860097	-119.421006	464	4b	1	2004-01-01	51117	KELOWNA UBCO	48369	1046	979	46987	2E07P	7	100	100	VKU	15	0.1	200	0.98	0.97	0.93	0.90	0.03	0.04	0.06	0.07	0.02	0.04	0.08	0.12
OW291	Interior 2	Pentiction	Cranbrook	49.473055	-115.718887	523	NA	1	2004-01-01	1174. 50818	CRANBROOK A	51818	1180	0	0	2D14P	7	100	5	YXC	15	0.1	200	0.96	0.90	0.82	0.78	0.04	0.07	0.09	0.10	0.06	0.15	0.27	0.32
OW294	Interior 2	Pentiction	Lumby	50.219595	-119.003824	316	1c	1	2004-01-01	46987	VERNON AUTO	48369	51117	6843	0	1F03P	8	100	2	WJV	5	0.1	200	0.94	0.87	0.78	0.76	0.06	0.09	0.12	0.14	0.12	0.28	0.51	0.63
OW306	Interior 2	Pentiction	Beaverdell	49.438271	-119.086497	482	1c	1	2004-01-01	1053. 50269	PENTICTON A	979	1041	1091	1046	2E07P	7	10	5	BVD	15	0.01	200	0.93	0.88	0.84	0.81	0.08	0.11	0.15	0.17	0.27	0.50	0.74	0.85
OW309	Interior 2	Pentiction	Golden	51.25933	-116.91873	450	NA	1	2004-01-01	54318	GOLDEN AIRPORT	1364. 52980	49492	49548	0	2A30P	10	100	3	VGE	15	0.01	500	0.91	0.85	0.80	0.78	0.07	0.11	0.15	0.16	0.33	0.64	0.86	0.94
OW332	Interior 2	Pentiction	Oliver	49.137819	-119.569162	254	1a	1	2004-01-01	1053. 50269	PENTICTON A	1041	979	1091	1046	2G03P	155	10	0.5	MCC	5	0.1	500	1.00	0.99	0.97	0.95	0.01	0.02	0.04	0.06	0.00	0.01	0.04	0.06
OW405	Interior 2	Pentiction	Oliver	49.16931	-119.5639	256	3	1	2004-01-01	1053. 50269	PENTICTON A	1041	979	1091	1046	2G03P	124	2	1	MCC	5	0.01	500	1.00	0.99	0.96	0.92	0.02	0.03	0.06	0.08	0.00	0.02	0.05	0.12
OW442	Interior 2	Pentiction	Kelow	49.950925	-119.365802	464	4b	1	2004-01-01	48369	KELOWNA	51117	1046	46987	979	2F18P	7	10	5	YLW	10	0.1	200	0.99	0.98	0.95	0.92	0.02	0.03	0.05	0.07	0.01	0.02	0.06	0.08
OW467	Interior 2	Pentiction	Osoyoos	49.02232	-119.42551	194	4a	1	2004-01-01	1053. 50269	PENTICTON A	1041	1091	979	1100	2E07P	170	3	0.5	WYY	5	0.001	200	0.97	0.95	0.90	0.83	0.05	0.07	0.09	0.11	0.04	0.06	0.10	0.17
OW468	Interior 2	Pentiction	Cranbrook	49.51528	-115.770422	525	4b	1	2004-01-01	1174. 50818	CRANBROOK A	51818	1180	0	0	2D14P	7	10	100	YXC	5	0.1	200	0.96	0.89	0.74	0.60	0.08	0.13	0.20	0.22	0.08	0.22	0.46	0.69
OW487	Interior 2	Pentiction	Lumby	50.219445	-119.003821	314	4b	1	2004-01-01	46987	VERNON AUTO	48369	51117	6843	0	2F10P	7	100	100	WJV	15	0.01	200	0.86	0.76	0.71	0.65	0.14	0.20	0.23	0.21	0.22	0.45	0.92	1.37
OW154	Interior 3	Pentiction	Summerland	49.57765	-119.63526	297	NA	1	2004-01-01	979	SUMMERLAND CS	1053. 50269	1046	51117	48369	2E07P	52	100	5	WUS	5	0.1	200	0.98	0.94	0.88	0.82	0.05	0.08	0.11	0.13	0.05	0.14	0.32	0.51
OW311	Interior 3	Pentiction	Vernon	50.320322	-119.202478	351	6b	1	2004-01-01	46987	VERNON AUTO	48369	6843	51117	0	1F03P	19	10	100	WJV	10	0.1	200	1.00	0.99	0.99	0.98	0.01	0.02	0.03	0.04	0.00	0.01	0.01	0.02
OW356	Interior 3	Pentiction	Winfield	50.008442	-119.3918	344	4b	1	2004-01-01	48369	KELOWNA	51117	46987	1046	0	2E07P	27	3	5	YLW	10	0.1	200	0.97	0.90	0.75	0.64	0.02	0.03	0.05	0.07	0.03	0.10	0.24	0.36
OW363	Interior 3	Pentiction	Wasa	49.79076	-115.74855	540	1b	1	2004-01-01	51818	CRANBROOK AIRPORT AUTO	1174. 50818	1180	0	0	2D14P	9	10	10	JSL	10	0.1	500	0.96	0.92	0.85	0.78	0.07	0.10	0.16	0.20	0.22	0.48	0.88	1.26
OW384	Interior 3	Pentiction	Spallumcheen	50.499953	-119.211984	102	4b	1	2004-01-01	6843	SALMON ARM CS	46987	48369	51117	0	1F03P	7	10	3	SSM	15	0.1	200	0.97	0.93	0.82	0.76	0.04	0.06	0.09	0.11	0.04	0.12	0.31	0.45
OW401	Interior 3	Pentiction	Osoyoos	49.023341	-119.363599	808	6b	1	2004-01-01	1053. 50269	PENTICTON A	1041	1091	979	1100	2G03P	7	100	100	WYY	5	0.1	500	0.93	0.87	0.80	0.77	0.09	0.14	0.18	0.19	0.24	0.54	0.91	1.13
OW402	Interior 3	Pentiction	Osoyoos	49.030404	-119.347269	936	6b	1	2004-01-01	1053. 50269	PENTICTON A	1041	1091	979	1100	2E07P	7	100	10	WYY	10	0.01	500	0.87	0.77	0.77	0.70	0.10	0.14	0.17	0.21	0.34	0.64	0.82	1.08
OW403	Interior 3	Pentiction	Twin Lakes	49.33003	-119.72338	261	4a	1	2004-01-01	1053. 50269	PENTICTON A	979	1041	1046	27122	2G03P	7	10	5	YYF	5	0.001	500	0.99	0.98	0.92	0.86	0.01	0.02	0.04	0.05	0.01	0.02	0.08	0.13
OW407	Interior 3	Pentiction	Oliver	49.21599	-119.54109	255	1a	1	2004-01-01	1053. 50269	PENTICTON A	1041	979	1091	1046	2G03P	14	5	3	MCC	10	0.1	200	0.92	0.84	0.72	0.63	0.10	0.15	0.20	0.22	0.13	0.29	0.59	0.90
OW409	Interior 3	Pentiction	Spallumcheen	50.510481	-119.225923	103	4a	1	2004-01-01	6843	SALMON ARM CS	46987	48369	51117	0	1F03P	7	100	10	SSM	15	0.1	200	0.99	0.95	0.88	0.84	0.03	0.05	0.07	0.09	0.02	0.05	0.14	0.22
OW411	Interior 3	Pentiction	West Kelow	49.83667	-119.68638	304	5a	1	2004-01-01	1046	PEACHLAND	51117	48369	979	1053. 50269	2F18P	7	100	100	WKE	5	0.1	500	0.98	0.94	0.88	0.80	0.03	0.06	0.08	0.11	0.03	0.06	0.14	0.22
OW412	Interior 3	Pentiction	Summerland	49.734442	-120.156664	1264	6b	1	2004-01-01	27122	JELLCOE	1046	1056. 52958	6834	979	2G03P	7	100	10	TCW	5	0.01	500	0.93	0.89	0.79	0.80	0.10	0.14	0.20	0.22	0.35	0.64	0.92	1.15
OW200	Northern	Smithers	Dease Lake	58.43794	-129.9923	828	4b	1	2004-01-01	6845	DEASE LAKE (AUT)	49628	0	0	0	4D11P	7	5	5	DVS	5	0.1	200	0.99	0.98	0.92	0.88	0.02	0.03	0.06	0.08	0.01	0.02	0.08	0.13
OW293	Northern	Prince George	Prince George	54.0472	-122.8038	332	4b	1	2004-01-01	50169	PRINCE GEORGE MASSEY AUTO	48248	48370	55363	51538	1A14P	7	3	10	VXS	5	0.1	500	0.86	0.77	0.70	0.65	0.09	0.12	0.14	0.15	0.23	0.43	0.61	0.70
OW416	Northern	Fort St. John	Dawson Creek	55.82529	-120.97583	595	5a	1	2004-01-01	50837	FORT ST. JOHN A	1400. 52939	55198	1404. 48208	32255	1A14P	61	3	2	VSJ	15	0.1	200	0.98	0.94	0.86	0.77	0.03	0.05	0.08	0.11	0.02	0.06	0.16	0.27
OW417	Northern	Fort St. John	Dawson Creek	55.83334	-120.871105	595	5a	1	2004-01-01	50837	FORT ST. JOHN A	1404. 48208	55198	1400. 52939	32255	1A14P	84	1	3	YDQ	5	0.1	200	0.99	0.99	0.96	0.93	0.02	0.03	0.05	0.07	0.01	0.01	0.04	0.07
OW418	Northern	Fort St. John	Dawson Creek	55.909962	-120.453375	633	5a	1	2004-01-01	50837	FORT ST. JOHN A	1404. 48208	55198	32255	47107	1A14P	7	10	3	YDQ	5	0.1	200	0.99	0.98	0.96	0.94	0.03	0.03	0.05	0.06	0.01	0.02	0.03	0.05
OW455	Northern	Prince George	Vanderhoof	54.02345	-124.31642	242	4b	1	2004-01-01	55363	FORT ST JAMES GOLF CLUB	51538	50169	48370	48248	4A02P	7	100	100	VAN	10	0.1	200	0.92	0.82	0.71	0.61	0.07	0.11	0.14	0.16	0.09	0.18	0.29	0.39
OW502	Northern	Prince George	Valemount	52.81655	-119.27067	800	4b	1	2004-01-01	1237	BLUE RIVER A	8214	10223	10930	0	1E02P	7	100	5	VAL	5	0.01	200	0.98	0.94	0.88	0.86	0.05	0.08	0.12	0.13	0.03	0.07	0.14	0.24
OW513	Northern	Smithers	Terrace	54.5177	-128.63653	575	1a	1	2004-01-01	442	TERRACE PCC	441. 51037	54978	51658	48628	4B17P	7	5	100	YXT	10	0.1	500	0.99	0.96	0.87	0.78	0.04	0.07	0.11	0.15	0.02	0.06	0.19	0.32
OW201	Vancouver Island 1	Nanaimo	Alert Bay	50.58197	-126.92605	858	NA	0	2004-01-01	202. 51319	PORT HARDY A	271	48888	29733	0	3A24P	61	3		VHD	5	0.1	200	0.96	0.94	0.88	0.84	0.05	0.07	0.10	0.11	0.13	0.25	0.43	0.59
OW204	Vancouver Island 1	Nanaimo	Duncan	48.77047	-123.69335	186	1b	0	2004-01-01	26	CHEMAINUS	97	51337	0	0	1D17P	7	2		VOO	20	0.001	100	0.94	0.91	0.90	0.89	0.10	0.13	0.14	0.15	0.69	0.95	1.04	1.06
OW268	Vancouver Island 1	Nanaimo	Denman Island	49.53466	-124.76883	740	5a	0	2004-01-01	155	COMOX A	225	8045	181	0	3A25P	7	5		BOW	5	0.01	200	0.94	0.93	0.92	0.91	0.11	0.13	0.15	0.16	0.68	0.89	1.04	1.08
OW287	Vancouver Island 1	Nanaimo	Coombs	49.301596	-124.415168	220	5a	0	2004-01-01	45627	QUALICUM BEACH AIRPORT	181	138	0	0	3A25P	34	100		VOQ	15	0.1	100	0.89	0.86	0.83	0.82	0.08	0.10	0.11	0.11	0.17	0.23	0.30	0.33
OW310	Vancouver Island 1	Nanaimo	Bowser	49.448724	-124.716175	416	4b	0	2004-01-01	8045	PORT ALBERNI (AUT)	181	225	45627	0	3A25P	80	1		BOW	5	0.01	200	0.98	0.95	0.93	0.93	0.03	0.05	0.06	0.07	0.05	0.15	0.35	0.51

Table A4.1 (Cont'd.)

Well	Regional Group	Region	Location	Latitude	Longitude	Aquifer ID	Subtype Sym	Snow Influenced	Training Start Date	Climate Station ID	Climate Station ME	Climate Infilled ID	Climate Secondary Infilled	Climate Tertiary Infilled	Climate Quaternary Infilled	Snow Station	Lag Time	DWC Precipitation	DWC Snow	Station Name RF Forecast	Ann Size	Ann Decay	Ann Maxit	R2 14	R2 30	R2 60	R2 90	NRMSE 14	NRMSE 30	NRMSE 60	NRMSE 90	RSR 14	RSR 30	RSR 60	RSR 90
OW284	Vancouver Island 2	Nanaimo	Pender Island	48.74882	-123.25686	720	NA	0	2004-01-01	77	NORTH PENDER ISLAND	6810	96	51337	87	1D17P	7	3		VTS	10	0.01	100	0.86	0.81	0.78	0.75	0.09	0.11	0.12	0.13	0.45	0.52	0.61	0.65
OW288	Vancouver Island 2	Nanaimo	Hornby Island	49.506	-124.64873	438	5a	0	2004-01-01	45627	QUALICUM BEACH AIRPORT	181	8045	155	0	3A25P	30	1		BOW	10	0.01	100	0.97	0.94	0.90	0.88	0.09	0.13	0.17	0.19	0.20	0.44	0.78	0.95
OW304	Vancouver Island 2	Nanaimo	Parksville	49.310444	-124.330671	216	4b	0	2004-01-01	45627	QUALICUM BEACH AIRPORT	138	181	0	0	3B23P	12	100		VOQ	20	0.1	100	0.99	0.98	0.97	0.96	0.02	0.03	0.04	0.05	0.01	0.02	0.03	0.04
OW314	Vancouver Island 2	Nanaimo	Parksville	49.31149	-124.34853	216	4b	0	2004-01-01	45627	QUALICUM BEACH AIRPORT	181	138	0	0	3A25P	69	10		VOQ	5	0.1	100	0.99	0.98	0.95	0.93	0.03	0.04	0.06	0.07	0.02	0.04	0.08	0.12
OW327	Vancouver Island 2	Nanaimo	Galiano Island	48.885558	-123.334866	320	5a	0	2004-01-01	77	NORTH PENDER ISLAND	6810	766	96	0	1D17P	7	5		SLT	20	0.01	100	0.93	0.87	0.81	0.79	0.08	0.11	0.14	0.14	0.27	0.42	0.52	0.55
OW337	Vancouver Island 2	imo	Ladysmith	49.036948	-123.828877	162	5a	0	2004-01-01	26	CHEMAINUS	192. 51318. 52941	132. 29411	0	0	3A25P	82	0.5		CED	15	0.01	200	0.99	0.96	0.89	0.83	0.03	0.06	0.10	0.12	0.03	0.11	0.31	0.53
OW371	Vancouver Island 2	Nanaimo	Hwy 19A (T'Sable River)	49.51874	-124.83962	415	2	0	2004-01-01	225	ALBERNI ROBERTSON CREEK	155	8045	181	0	3A25P	7	2		BOW	20	0.01	500	0.86	0.85	0.82	0.81	0.14	0.13	0.16	0.17	0.83	0.96	1.04	1.08
OW383	Vancouver Island 2	Nanaimo	Quadra Island	50.055599	-125.189118	751	4a	0	2004-01-01	152	CAPE MUDGE	145. 52979	155	0	0	3A25P	40	10		QUI	5	0.001	100	0.97	0.95	0.92	0.91	0.05	0.06	0.07	0.08	0.04	0.06	0.10	0.11
OW391	Vancouver Island 2	Nanaimo	Little Qualicum	49.32983	-124.56006	662	4b	0	2004-01-01	45627	QUALICUM BEACH AIRPORT	181	8045	138	0	3B17P	7	1		VOQ	5	0.001	100	0.98	0.97	0.95	0.91	0.04	0.04	0.05	0.07	0.02	0.03	0.05	0.08
OW392	Vancouver Island 2	Nanaimo	noose	49.27794	-124.24362	1098	4b	0	2004-01-01	138	BALLENAS ISLAND	45627	181	0	0	3A25P	56	3		WGB	5	0.001	100	0.92	0.91	0.90	0.89	0.08	0.08	0.09	0.09	0.08	0.09	0.11	0.11
OW393	Vancouver Island 2	Nanaimo	noose	49.27794	-124.24362	219	4b	0	2004-01-01	138	BALLENAS ISLAND	45627	181	0	0	3A25P	148	1		WGB	10	0.1	100	0.92	0.90	0.85	0.79	0.06	0.07	0.09	0.11	0.10	0.12	0.19	0.28
OW394	Vancouver Island 2	Nanaimo	noose	49.30096	-124.19139	218	NA	0	2004-01-01	138	BALLENAS ISLAND	45627	181	0	0	3A25P	29	2		WGB	10	0.001	100	0.94	0.89	0.84	0.63	0.10	0.14	0.17	0.20	0.21	0.47	0.78	1.42
OW395	Vancouver Island 2	Nanaimo	noose	49.28029	-124.28061	219	4b	0	2004-01-01	45627	QUALICUM BEACH AIRPORT	138	181	0	0	3B17P	25	3		VOQ	20	0.1	200	0.93	0.90	0.86	0.82	0.14	0.16	0.20	0.23	0.47	0.64	0.88	1.04
OW396	Vancouver Island 2	Nanaimo	noose	49.30131	-124.22964	219	4b	0	2004-01-01	138	BALLENAS ISLAND	45627	181	0	0	3A25P	57	1		WGB	5	0.01	500	0.98	0.97	0.95	0.94	0.05	0.07	0.10	0.12	0.09	0.25	0.58	0.84
OW398	Vancouver Island 2	Nanaimo	Parksville	49.307161	-124.311776	216	4b	0	2004-01-01	45627	QUALICUM BEACH AIRPORT	138	181	0	0	3A25P	91	1		VOQ	20	0.1	100	0.98	0.98	0.97	0.97	0.03	0.03	0.04	0.05	0.02	0.02	0.03	0.04
OW058	Vancouver Island 3	Nanaimo	Saanich	48.63119	-123.41753	610	NA	0	2004-01-01	54641	SAANICHTON CFIA	87	51337	0	0	1D17P	89	0.5		VSA	20	0.1	100	0.98	0.96	0.94	0.92	0.03	0.05	0.06	0.08	0.03	0.10	0.25	0.41
OW060	Vancouver Island 3	Nanaimo	Saanich	48.65863	-123.4304	609	NA	0	2004-01-01	51337	VICTORIA INTL A	54641	87	0	0	1D17P	81	1		YYJ	20	0.1	200	0.99	0.97	0.95	0.92	0.03	0.04	0.05	0.07	0.03	0.09	0.21	0.33
OW071	Vancouver Island 3	Nanaimo	Saanich	48.5304	-123.37483	616	NA	0	2004-01-01	6812	VICTORIA UNIVERSITY CS	54641	87	0	0	1D17P	35	1		WYJ	15	0.01	100	0.93	0.90	0.86	0.85	0.06	0.08	0.09	0.10	0.13	0.21	0.30	0.34
OW240	Vancouver Island 3	Nanaimo	Saanich	48.63667	-123.46583	608	6b	0	2004-01-01	51337	VICTORIA INTL A	54641	87	0	0	1D17P	7	3		YYJ	15	0.01	100	0.95	0.95	0.93	0.92	0.10	0.11	0.14	0.16	0.65	0.92	1.07	1.05
OW281	Vancouver Island 3	imo	Saltspring Island	48.85179	-123.45708	721	5a	0	2004-01-01	77	NORTH PENDER ISLAND	51337	26	6810	0	1D17P	7	1		SLT	20	0.01	100	0.93	0.92	0.91	0.91	0.13	0.14	0.15	0.16	0.86	0.96	1.05	1.09
OW290	Vancouver Island 3	Nanaimo	Satur Island	48.80294	-123.17863	737	5a	0	2004-01-01	6810	SATURNA CAPMON CS	77	96	766	0	1D17P	7	5		VTS	5	0.01	100	0.92	0.88	0.83	0.82	0.09	0.12	0.16	0.16	0.55	0.73	0.94	0.96
OW321	Vancouver Island 3	Nanaimo	Qualicum Beach	49.34769	-124.38281	1250	4c	0	2004-01-01	45627	QUALICUM BEACH AIRPORT	181	138	0	0	3A25P	7	5		VOQ	20	0.01	100	0.92	0.85	0.77	0.70	0.08	0.11	0.15	0.18	0.21	0.38	0.56	0.68
OW329	Vancouver Island 3	Nanaimo	Ucluelet	48.994962	-125.59433	159	4a	0	2004-01-01	283	UCLUELET KENNEDY CAMP	277. 52960	235	262	0	3A25P	41	5		TEF	5	0.01	100	0.97	0.96	0.93	0.93	0.07	0.09	0.11	0.12	0.23	0.52	0.84	0.99
OW338	Vancouver Island 3	Nanaimo	Saanich	48.57242	-123.41726	608	6b	0	2004-01-01	54641	SAANICHTON CFIA	87	51337	0	0	1D17P	102	100		VSA	20	0.1	100	0.98	0.93	0.79	0.65	0.04	0.07	0.11	0.14	0.03	0.10	0.30	0.47
OW343	Vancouver Island 3	Nanaimo	Saanich	48.599	-123.445816	608	6b	0	2004-01-01	54641	SAANICHTON CFIA	87	51337	0	0	1D17P	17	3		VSA	5	0.01	200	0.92	0.90	0.88	0.87	0.12	0.15	0.18	0.20	0.65	0.88	1.09	1.14
OW373	Vancouver Island 3	Nanaimo	Saltspring Island	48.83867	-123.51075	722	5a	0	2004-01-01	77	NORTH PENDER ISLAND	26	51337	97	0	1D17P	34	1		SLT	10	0.1	200	0.95	0.93	0.91	0.90	0.12	0.15	0.17	0.19	0.39	0.75	1.06	1.16
OW389	Vancouver Island 3	Nanaimo	Qualicum Beach	49.35992	-124.47597	664	1c	0	2004-01-01	45627	QUALICUM BEACH AIRPORT	181	138	8045	0	3A25P	7	3		VOQ	20	0.001	100	0.97	0.95	0.94	0.93	0.11	0.14	0.16	0.17	0.59	0.90	1.08	1.11
OW426	Vancouver Island 3	Nanaimo	Qualicum	49.36456	-124.61434	662	4b	0	2004-01-01	45627	QUALICUM BEACH AIRPORT	181	8045	225	0	3A25P	7	1		BOW	15	0.1	200	0.88	0.85	0.82	0.77	0.10	0.11	0.12	0.13	0.14	0.17	0.21	0.26
OW432	Vancouver Island 3	Nanaimo	Yellowpoint	49.05833	-123.80978	162	5a	0	2004-01-01	26	CHEMAINUS	192. 51318. 52941	132. 29411	0	0	3A25P	30	1		CED	15	0.1	100	0.97	0.93	0.87	0.83	0.10	0.14	0.19	0.23	0.27	0.63	1.09	1.22
OW433	Vancouver Island 3	Nanaimo	Qualicum	49.34244	-124.40625	1250	4c	0	2004-01-01	45627	QUALICUM BEACH AIRPORT	181	138	0	0	3A25P	7	3		VOQ	5	0.001	100	0.95	0.88	0.83	0.78	0.08	0.13	0.17	0.20	0.18	0.40	0.53	0.61
OW434	Vancouver Island 3	Nanaimo	Qualicum	49.34232	-124.40714	217	4b	0	2004-01-01	45627	QUALICUM BEACH AIRPORT	181	138	0	0	3B23P	94	100		VOQ	15	0.01	200	0.93	0.93	0.92	0.91	0.07	0.07	0.08	0.08	0.07	0.07	0.09	0.10
OW435	Vancouver Island 3	Nanaimo	South Wellington	49.096728	-123.888749	165	5a	0	2004-01-01	132. 29411	ENTRANCE ISLAND	192. 51318. 52941	26	0	0	3A25P	7	2		CED	20	0.001	100	0.95	0.93	0.88	0.87	0.10	0.14	0.19	0.21	0.46	0.84	1.17	1.17
OW438	Vancouver Island 3	Nanaimo	Salt Spring Island	48.89015	-123.50125	721	5a	0	2004-01-01	26	CHEMAINUS	77	51337	97	0	1D17P	37	1		SLT	20	0.1	100	0.97	0.94	0.89	0.86	0.09	0.12	0.17	0.19	0.18	0.35	0.64	0.85