

Real-Time Groundwater Level Forecasting Using Deep Learning

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February 23, 2026

CWRA Webinar



Outline

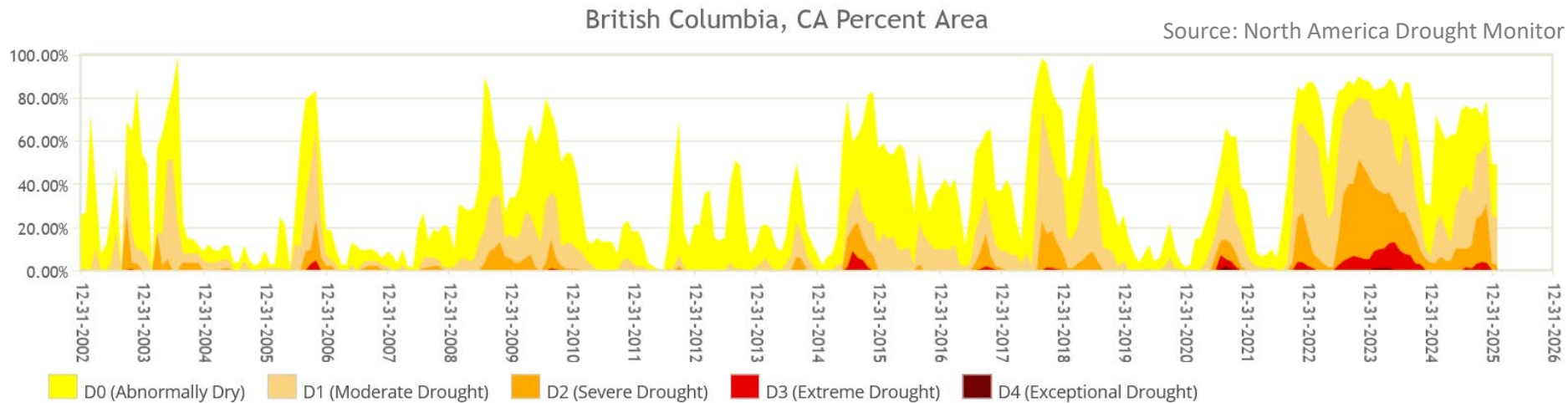
- Introduction
- Model Development
 - Key Challenges
 - Key Considerations
- Model Testing
- Outputs and Visualization
- Next Steps

Introduction

Why Groundwater Matters in British Columbia

- In BC, groundwater supports drinking water, agriculture, aquatic habitat, and drought resilience
- Groundwater is increasingly important as surface water becomes more variable
- Integration of groundwater into resource management is accelerating (e.g., under BC's Water Sustainability Act)
- Drought conditions in recent years have highlighted growing pressure on both surface and groundwater

Drought in British Columbia



British Columbia



Dawson Creek, B.C., has just 150 days of stored water left: CAO

City warns Kiskatinaw River watershed recovery could take years, increases water restrictions



Matt Preprost · CBC News · Posted: Sep 08, 2025 4:28 PM PDT | Last Updated: September 8, 2025

Gulf Islands' water woes an ominous omen for the rest of drought-prone B.C.

Wells run slowly or even go dry as summer droughts become a common feature of islands life

By [Derrick Penner](#)

Published Aug 15, 2023

Last updated Aug 16, 2023

VANCOUVER SUN

Concerns about salmon as Summerland, B.C., continues to face low water levels



Level 4 restrictions have been in place since November in the Okanagan community

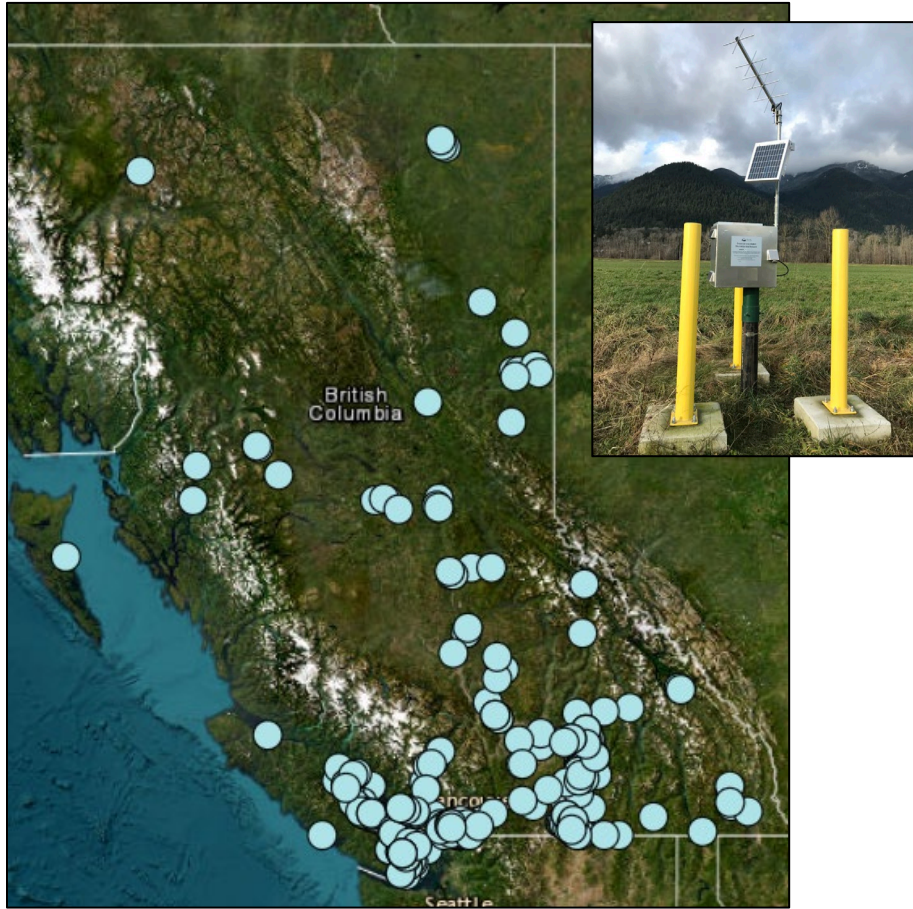
CBC News · Posted: Jan 07, 2026 12:51 PM PST | Last Updated: January 7



Ministry of
Water, Land and
Resource Stewardship



Provincial Groundwater Observation Well Network (PGOWN)



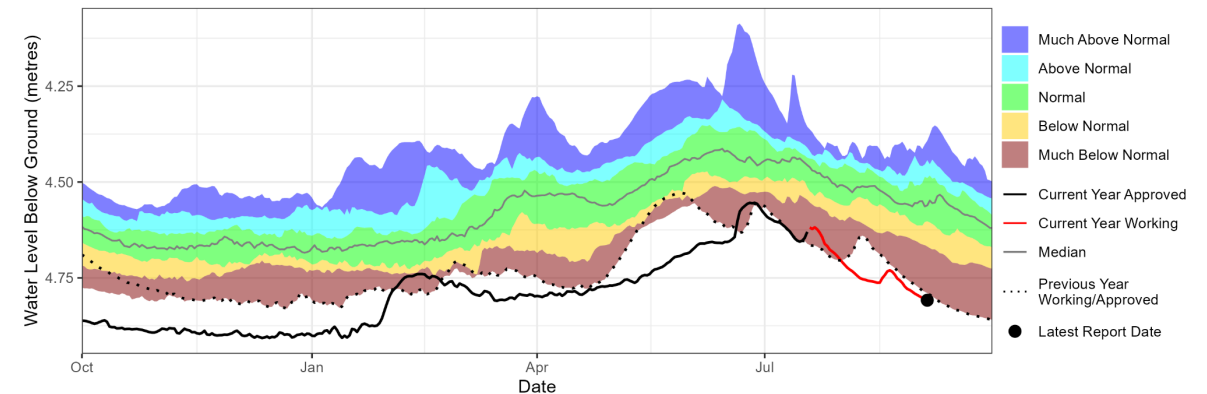
- Collects long-term groundwater level data on BC aquifers to inform resource management decisions
- Has operated for **>60 years**
- Oldest active stations have collected data since **1962**
- **238 active stations** (over 500 in program's history) monitoring ~180 aquifers
- **Two-thirds of stations** are equipped with telemetry for near real-time data

Why groundwater level forecasting?

- Province currently utilizing water levels from PGOWN to track conditions during drought to inform drought response – used as main indicator for determining drought levels
- Developing forecasting tools supports proactive drought and groundwater management, allowing earlier assessment and planning

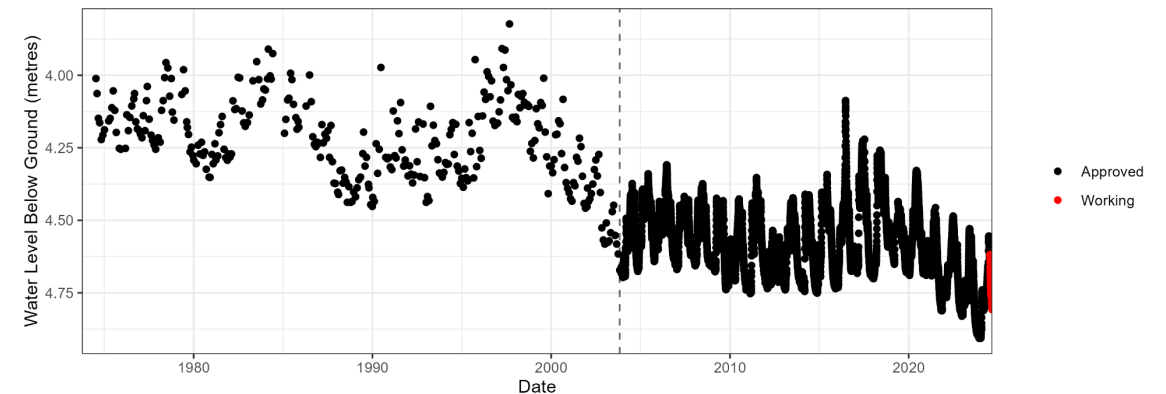
OW185 Daily Water Levels Hydrograph – Water Years: 2004 to 2024

Latest Available Date: 2024-09-04



Note: only continuous daily data from historical records used in percentiles calculations

OW185 Historical Record - 1974-07-15 to 2024-09-03

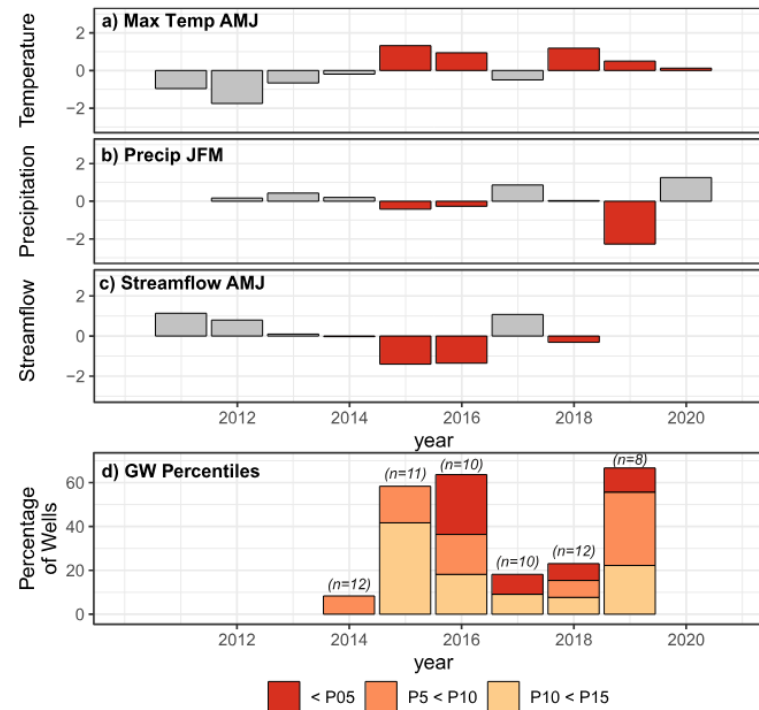


Note: only daily data collected after dashed line used in percentiles calculations

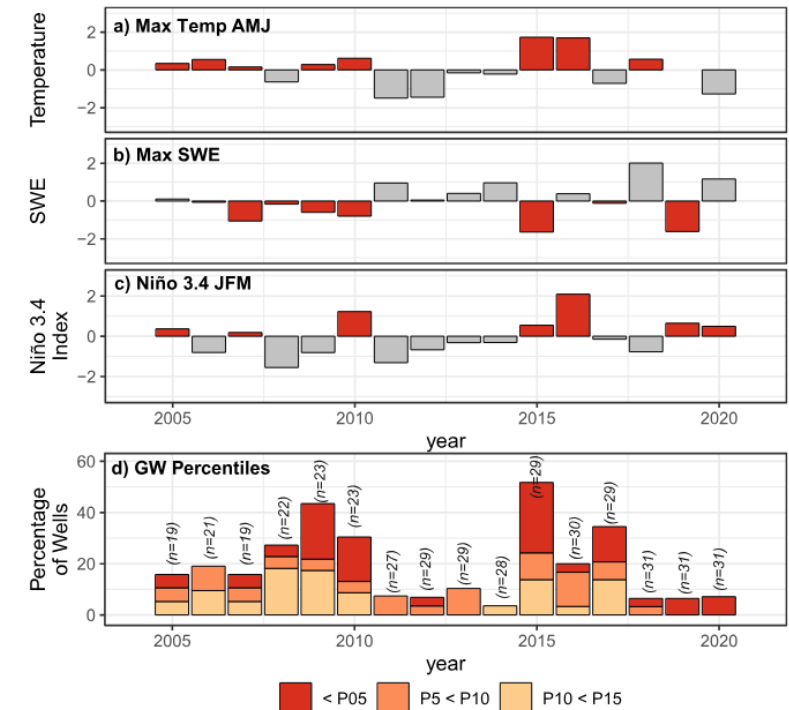
Prior Research – Drought and Groundwater in BC

- Previous SFU and Prov. of BC work investigated groundwater responses to drought and relationships with hydroclimatic variables (streamflow, climate, snowpack, etc.)
- Certain patterns in hydroclimatic variables were associated with summer groundwater levels

Rainfall-dominated Regimes



Snowmelt-dominated Regimes



How could we operationalize these findings?

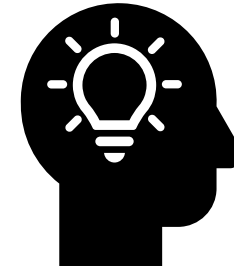
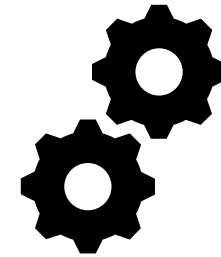
Can we quantify these relationships between hydroclimatic variables and groundwater levels to predict/model summer drought in PGOWN wells?

Phase 1 – 2023-2024

- Development of original forecasting models in a pilot project of just 21 PGOWN wells

Phase 2 – 2024-2025

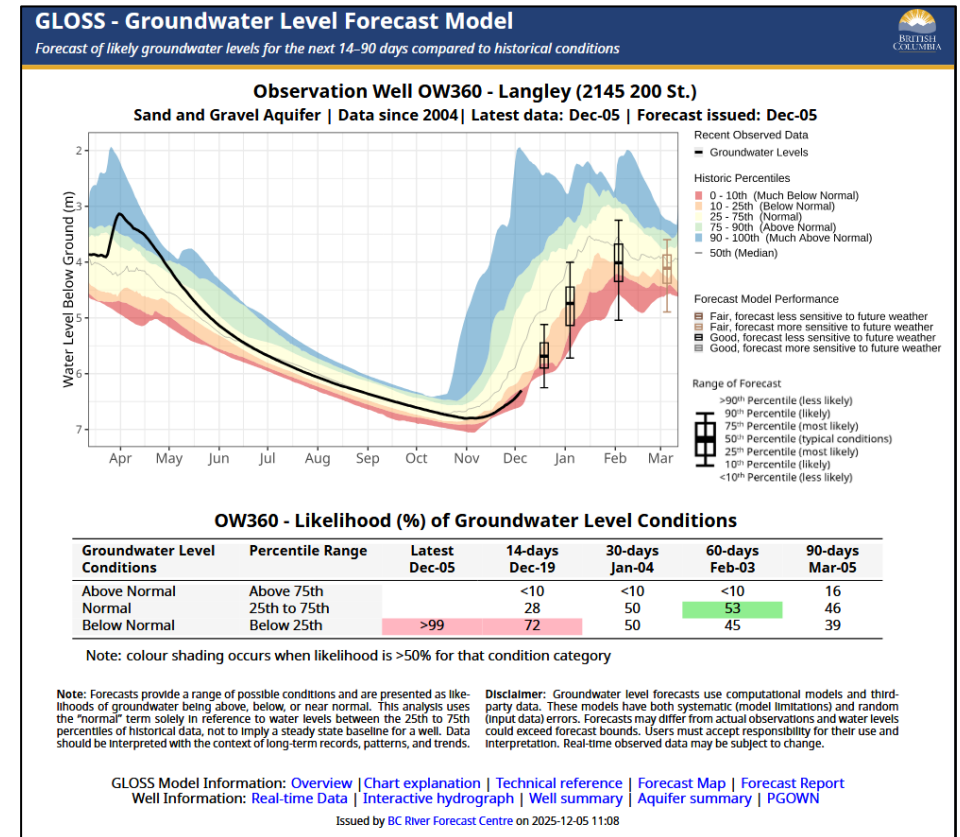
- Further refinement of the model approaches and expansion of testing to full suite of 237 PGOWN wells
- A cross-validation approach was employed and the model comprehensively tested over the 2004-2024 historical period



GLOSS Forecast Model

Groundwater Level Outlook Simulation System

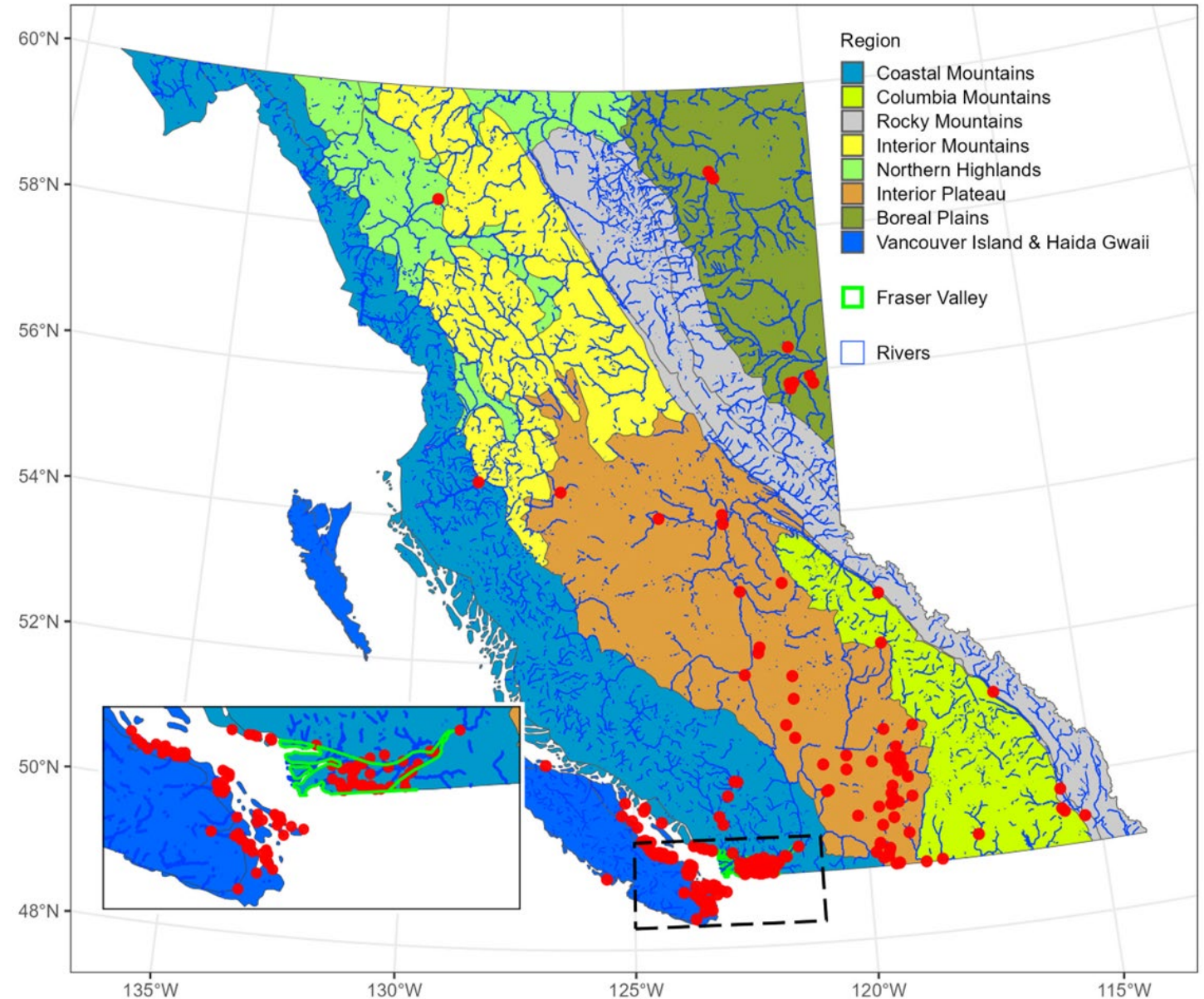
- **Probabilistic forecasting model** using machine learning (Artificial Neural Network) methods
- **Captures climate–groundwater relationships** without the computational demands physically-based aquifer models
- Produces a range of likely groundwater levels **14, 30, 60, 90-days** horizons, compared against historical conditions
- Fully **automated** workflow, **updated daily** to reflect the latest observed and forecast climate data
- Identifies wells and their aquifers at risk of being in “below-normal” conditions



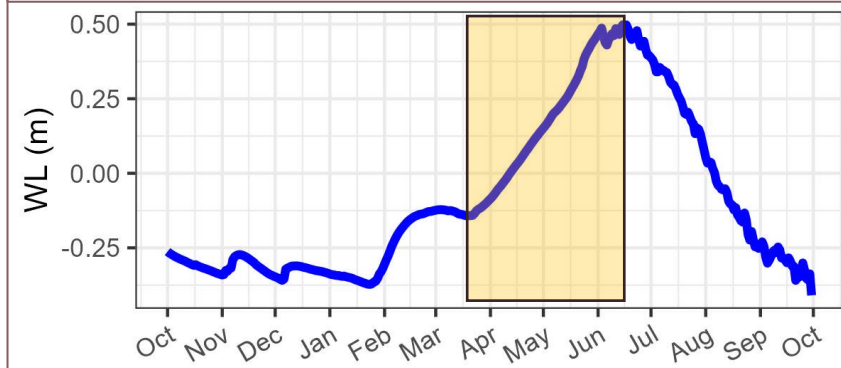
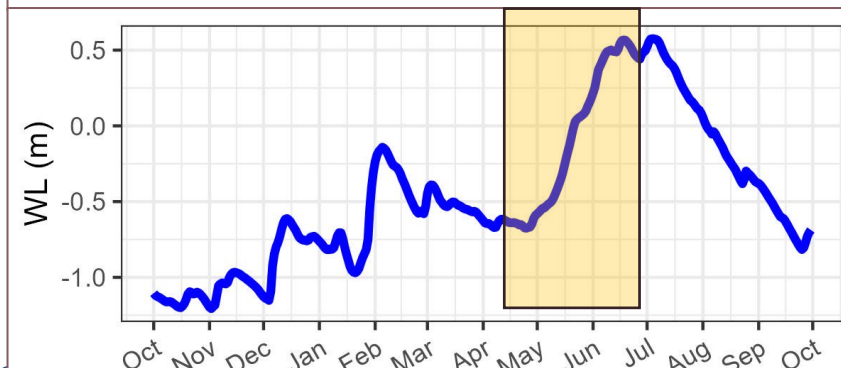
Model Development

Key Challenges

- Large-scale system — forecasting across 200+ PGOWN wells spanning huge and diverse hydroclimatic regions and aquifer conditions.
- Operationalized forecasting — fully automated training, testing, and real-time prediction system



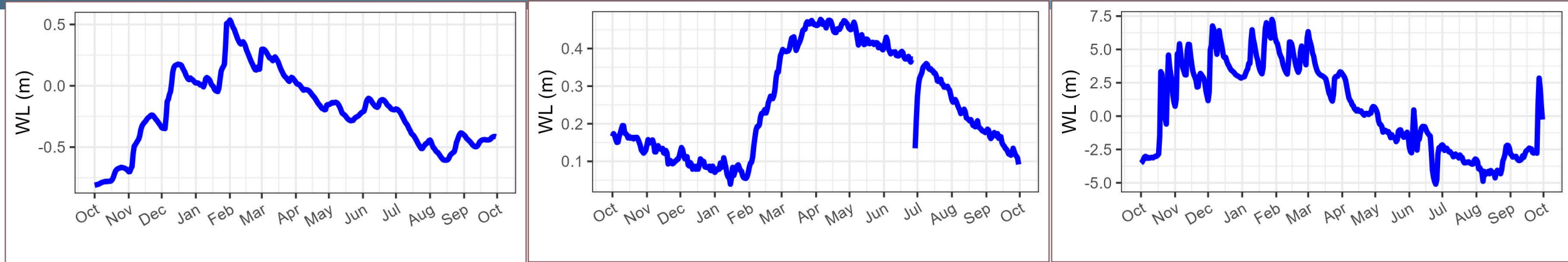
Key Challenges: Hydroclimatic Diversity



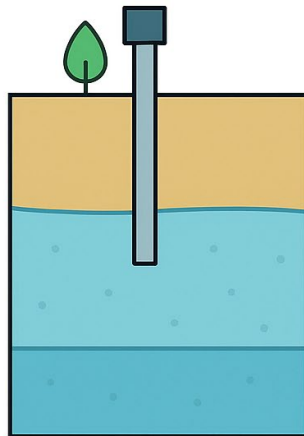
- Rainfall-Dominated: fast, sharp responses to rain
- Snowmelt-Dominated: delayed spring recharge pulse
- Mixed: multiple seasonal pulses
- Stream-Connected: recharge controlled by stream stage



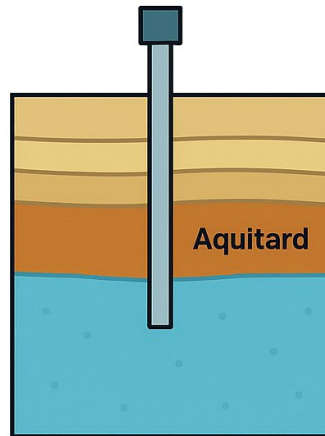
Key Challenges: Aquifer Diversity



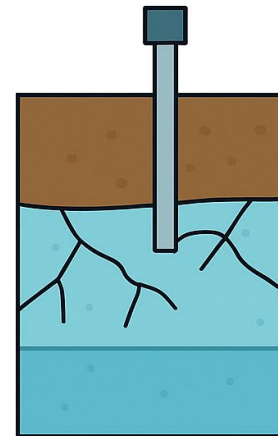
**Unconfined
Aquifer**



**Confined
Aquifer**



**Bedrock
Well**



Key Considerations in Model Development

Modelling Approach

Input Variables

Temporal Dependencies



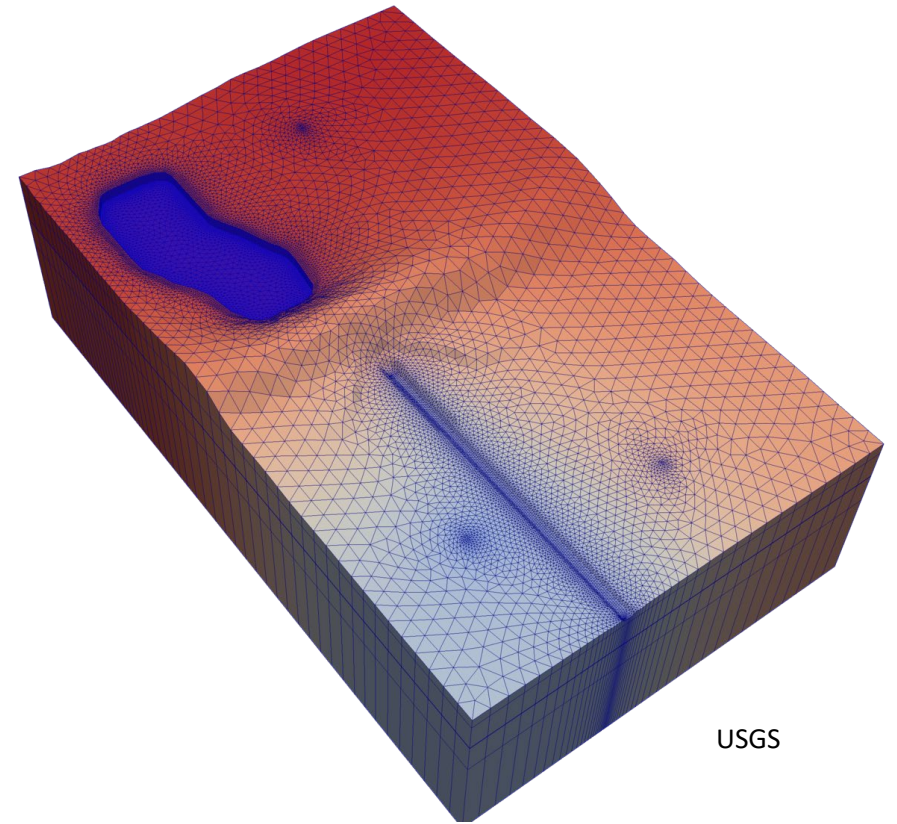
Key Considerations: Modelling Approach

Physically Based Models (Groundwater) (e.g., MODFLOW, FEFLOW)

- Need detailed aquifer properties + recharge data (not available province-wide)
- High-resolution grids → too slow for large-scale or real-time forecasting

Physically Based Models (Watershed) (e.g., SWAT, Raven)

- Very simplified groundwater (“bucket style”) groundwater representation → built for runoff/streamflow, not water levels

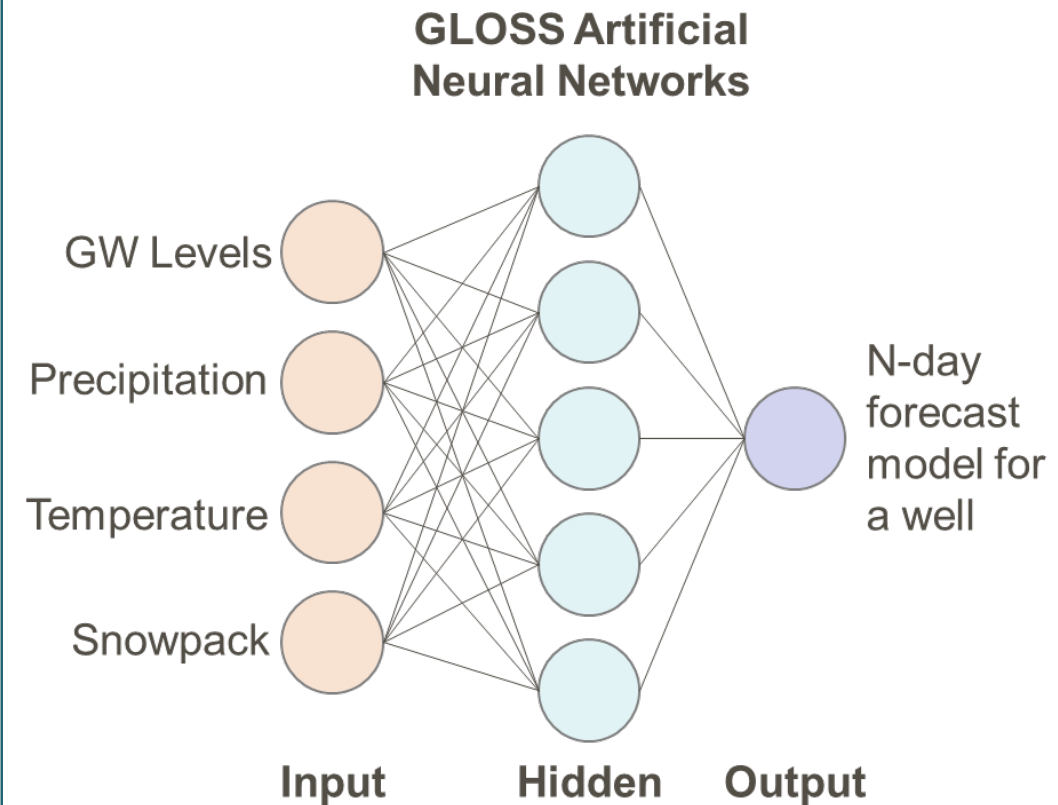


USGS

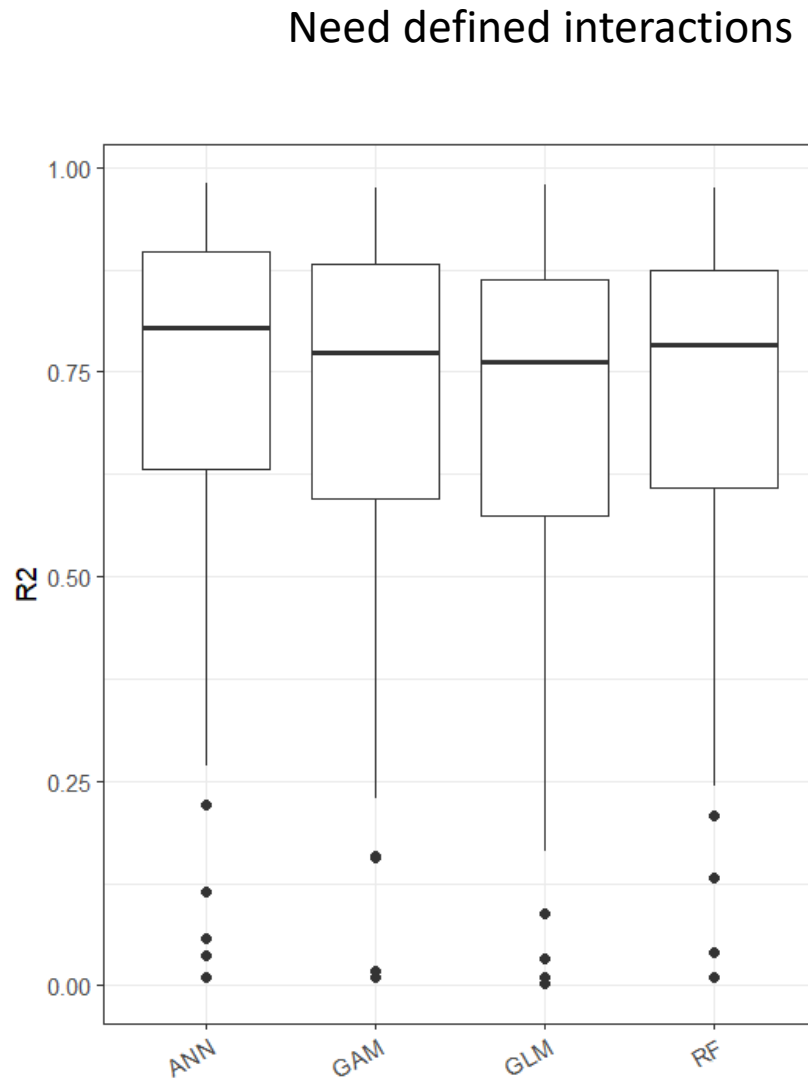
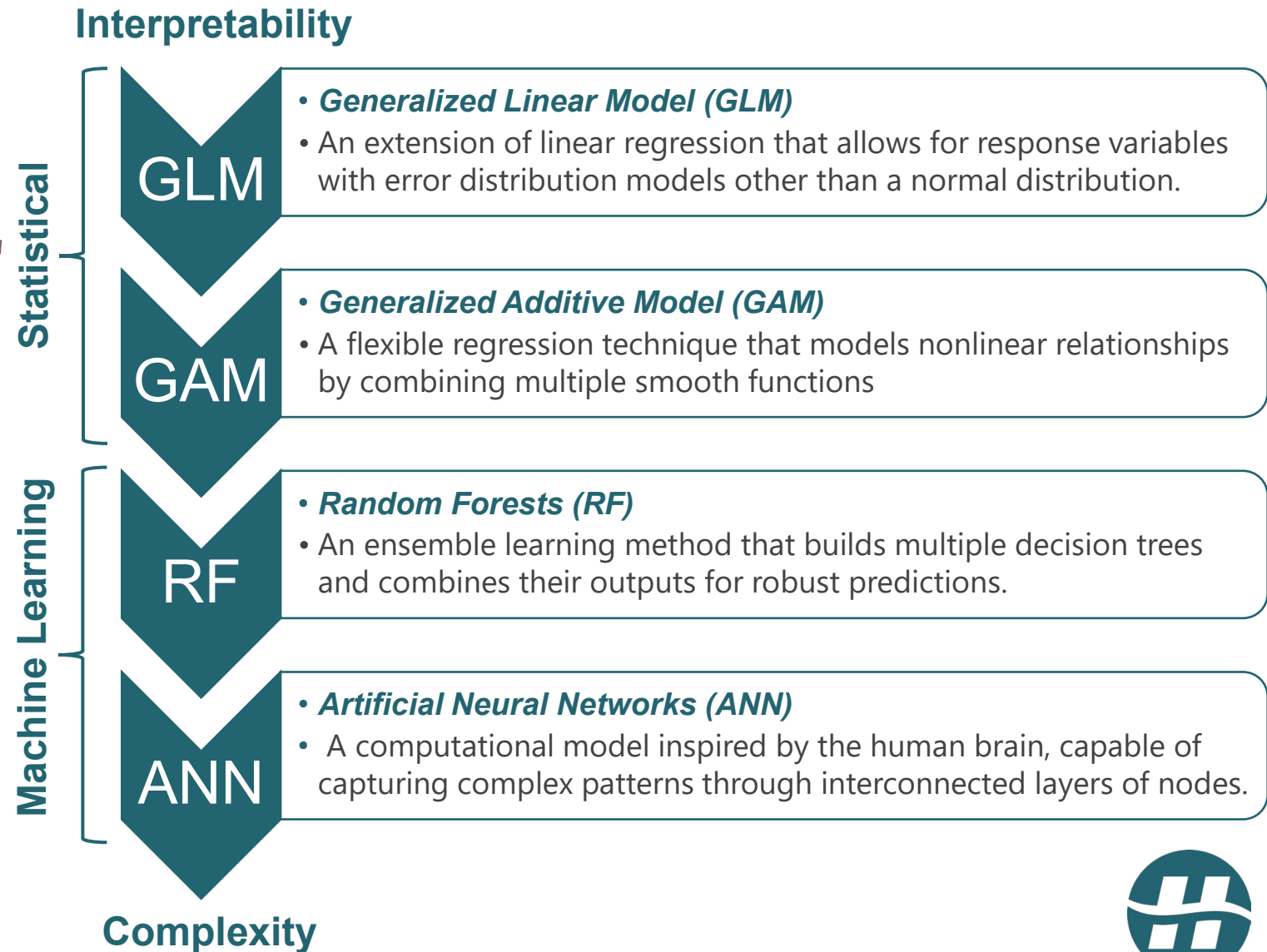
Key Considerations: Modelling Approach

Data Driven Models (Statistical and Machine Learning)

- Learn climate–groundwater relationships directly from historical data, without needing to simulate physical processes.
- Require minimal local expert knowledge and scale easily across many wells and hydroclimatic settings.
- Fast and efficient for real-time, province-wide forecasting, and can generate probabilistic outputs using ensemble climate inputs.
- Limited when conditions shift outside the historical record (e.g., new pumping, land-use change, watershed disturbance).

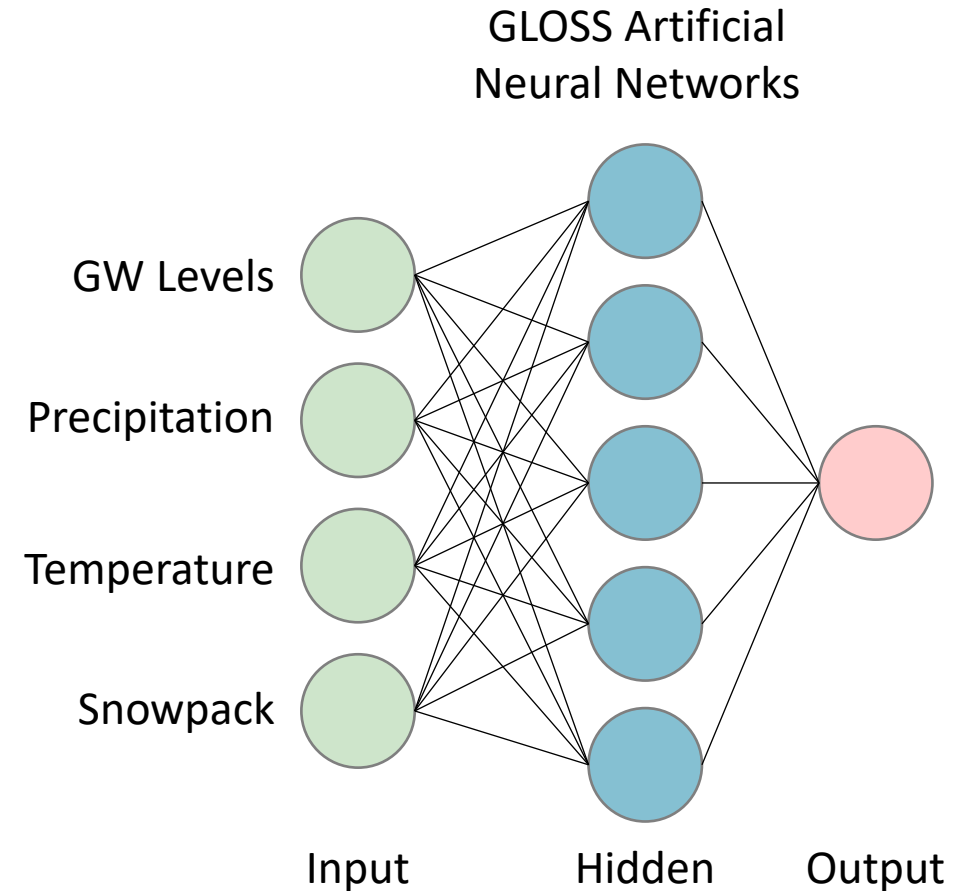


Model Development: Approaches



Model Development: Artificial Neural network

- Takes multiple inputs (e.g., precipitation, temperature, snowpack, past groundwater levels).
- Processes inputs through weighted, nonlinear 'neurons' that learn patterns from historical data.
- Automatically captures variable interactions (e.g., temperature related rainfall/snow fall partitioning).
- Once trained, takes new climate inputs (observed, forecasted, Monte Carlo sequences) and produces future groundwater level predictions..
- Outputs probabilistic forecasts when run with multiple climate sequences, giving a range of likely future groundwater levels.



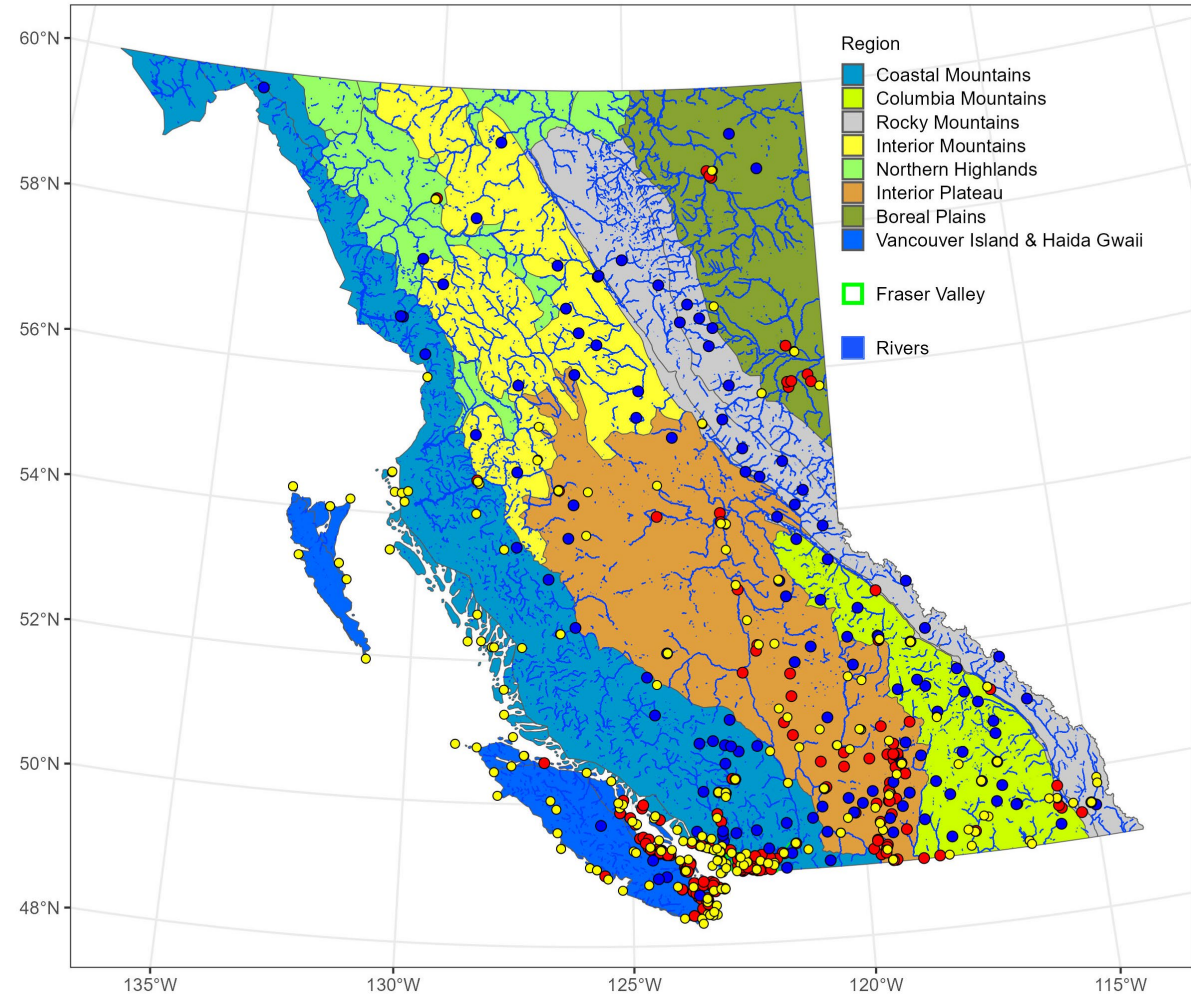
MODEL DEVELOPMENT: INPUT VARIABLES

Rainfall-Dominated Systems

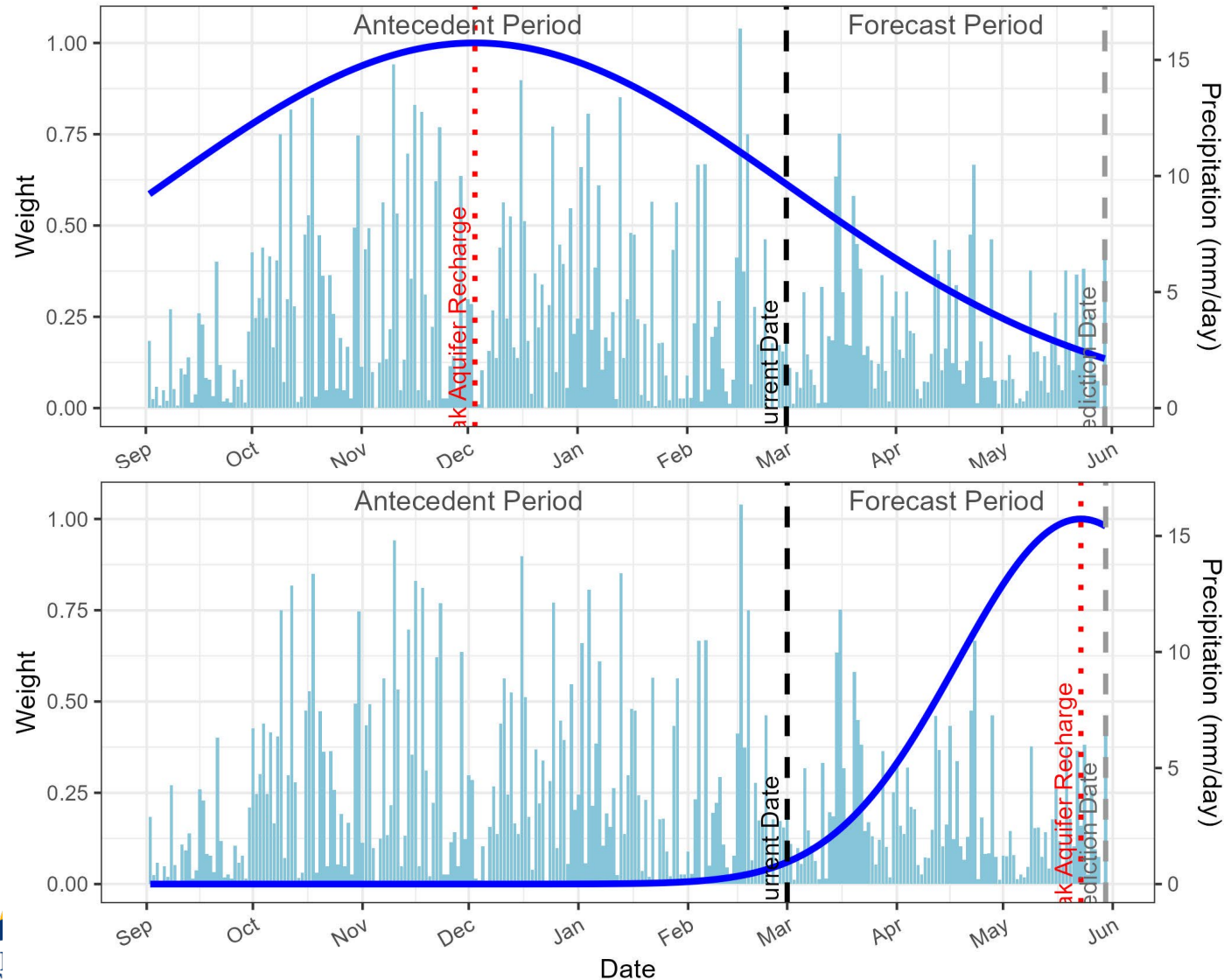
- **Precipitation:** Primary driver of groundwater recharge via infiltration.
- **Temperature:** Influences evapotranspiration and soil moisture (infiltration, recharge); may also affect groundwater use in developed aquifers.

Snowmelt-Dominated Systems

- **Precipitation:** Includes both rainfall and snowmelt; total precipitation correlates with recharge.
- **Temperature:** In addition to roles in rainfall setting, also affects rain/snow partitioning and snowmelt timing.
- **Snow Water Equivalent (SWE):** Indicates snowpack available for melt.
- **Snowmelt:** Derived from changes in SWE over time.



Model Development: Temporal Dependencies



Recharge Lag

- Each well has a different delay between rain/snowmelt and the groundwater response.
- We measure that delay using cross-correlation.

Dynamic Weighting

- We weight the input data, so the model pays more attention to the climate conditions that physically matter most for that well.
- Reflects aquifer response. Reflect the smoothed nature of aquifer response.
- Calibrated for each wells



Model Testing

Validation Testing

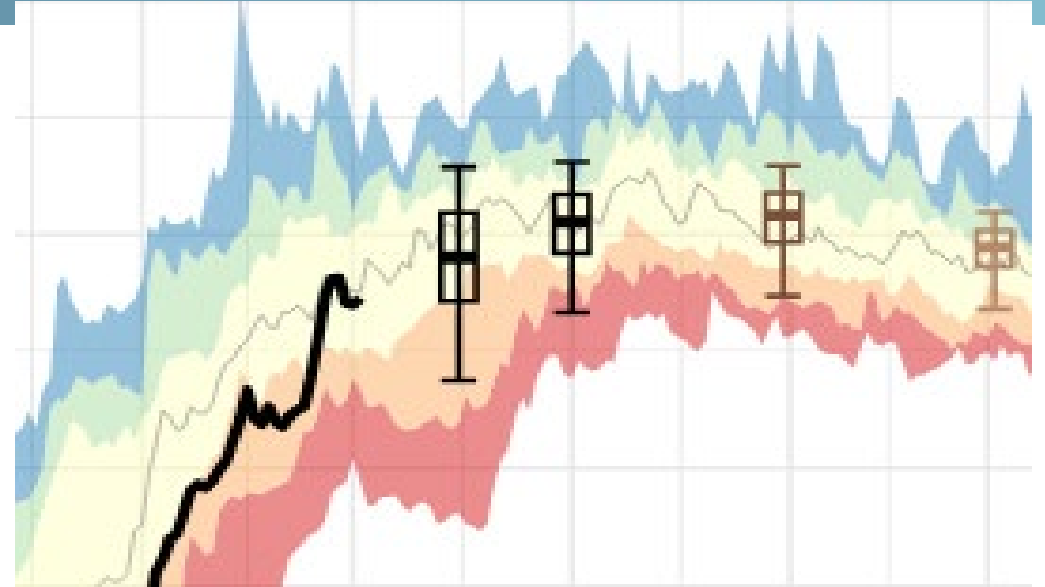
“Can the model reproduce history when we know the real climate?”

- Evaluates the model under ideal conditions (i.e., no climate uncertainty).
- Ensures the model is structurally sound before it is used for forecasting.
- Model Accuracy (R^2 and RMSE): Categorized as “Good” or “Fair” based on how closely the modelled data match observed groundwater levels

Operational Testing

“Can the model still give useful forecasts when future climate is unknown?”

- Real forecasting must rely on forecasted climate, which contains uncertainty.
- Operational testing measures how much predictive skill remains once this uncertainty is included.
- Model Sensitivity (RSR): Indicates how strongly the forecast depends on future weather conditions rather than historical patterns



Forecast Model Performance

- Fair, forecast less sensitive to future weather
- Fair, forecast more sensitive to future weather
- Good, forecast less sensitive to future weather
- Good, forecast more sensitive to future weather

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

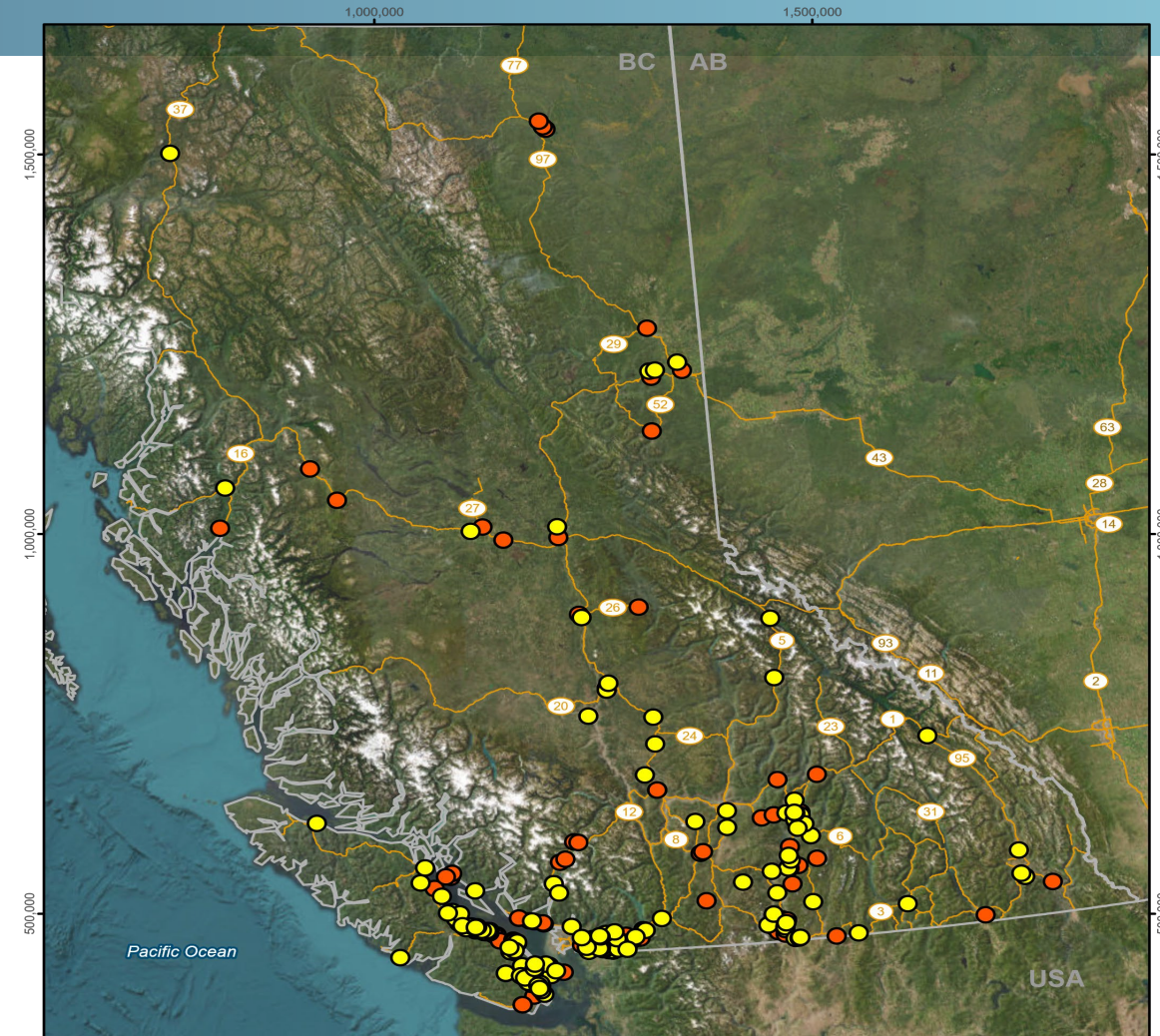
Model Testing: Validation testing

Well Selection & Model Performance

- Good model performance for 145 of 237 PGOWN wells.
- The model successfully generates groundwater forecasts across diverse hydroclimatic settings, aquifer subtypes, aquifers with hydraulic connections to streamflow and with significant seasonal water use.
- Rainfall-recharged wells generally forecast better than snowmelt-dominated wells,

Limitations in Model Performance

- Long-term increases in aquifer use unrelated to seasonal patterns.
- Wells affected by tidal influences or nearby localized pumping.
- Insufficient historical data for model training.
- Connected to large streamflow systems (fraser river)



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



Model Validation Testing: Example #1

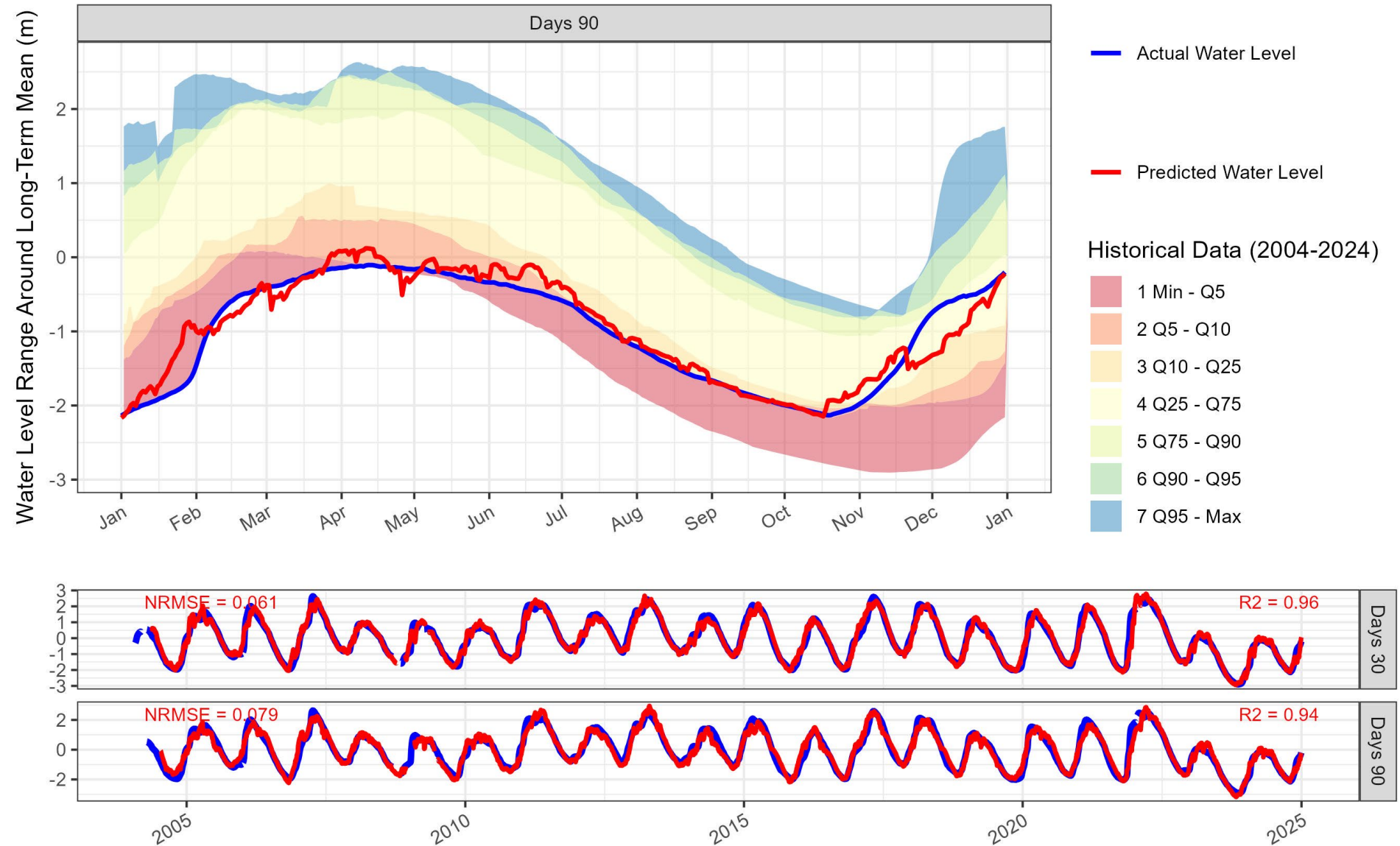
Abbotsford BC,

High aquifer usage area

unconfined sand and
gravel

rainfall dominated
setting.

Well = OW002 ; year = 2024



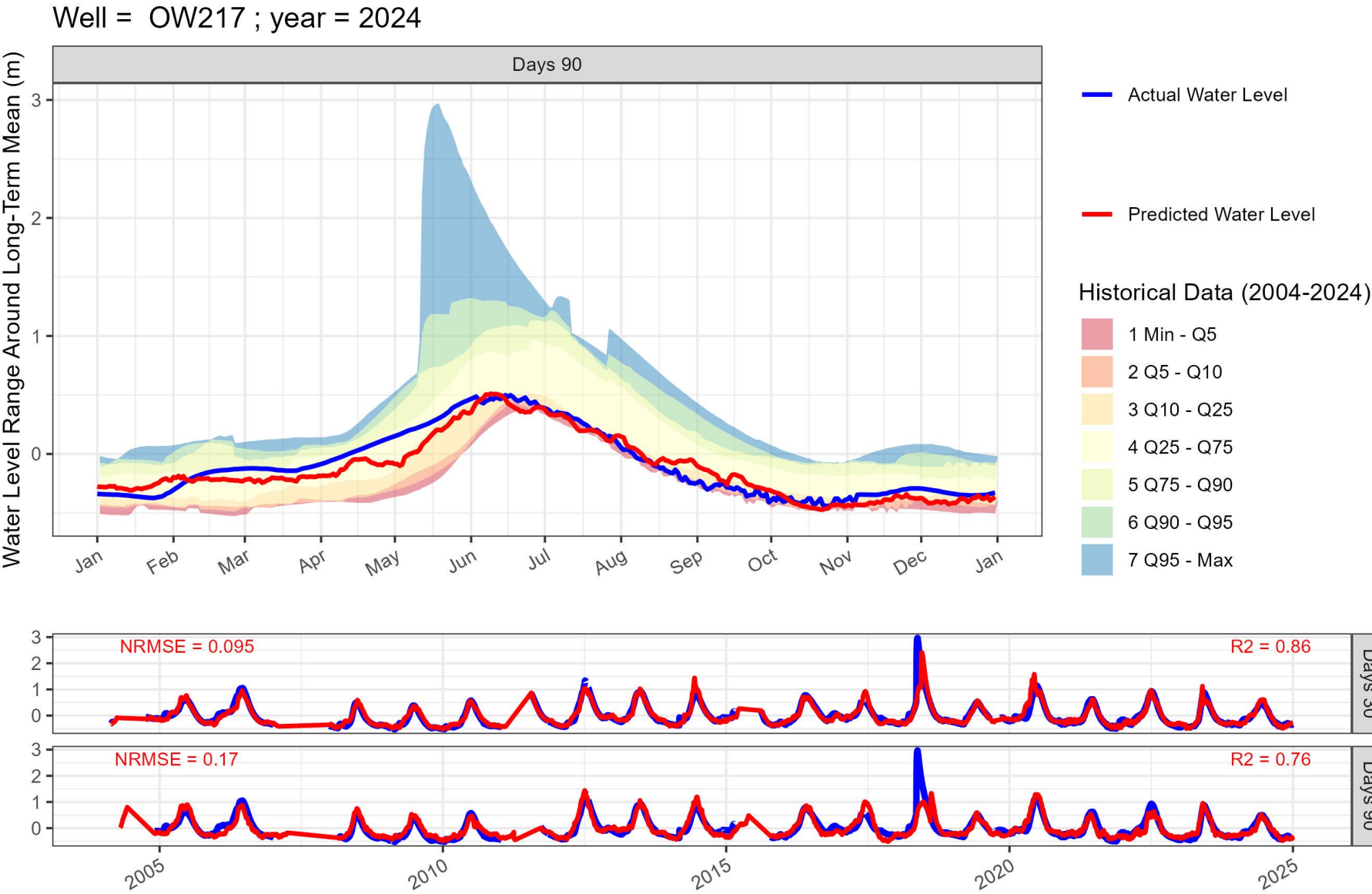
Model Validation Testing: Example #2

Grand forks,BC

Unconfined sand and gravel

Snowmelt setting

Hydraulic connected aquifer



Model Validation Testing: Example #3

Qualicum ,BC

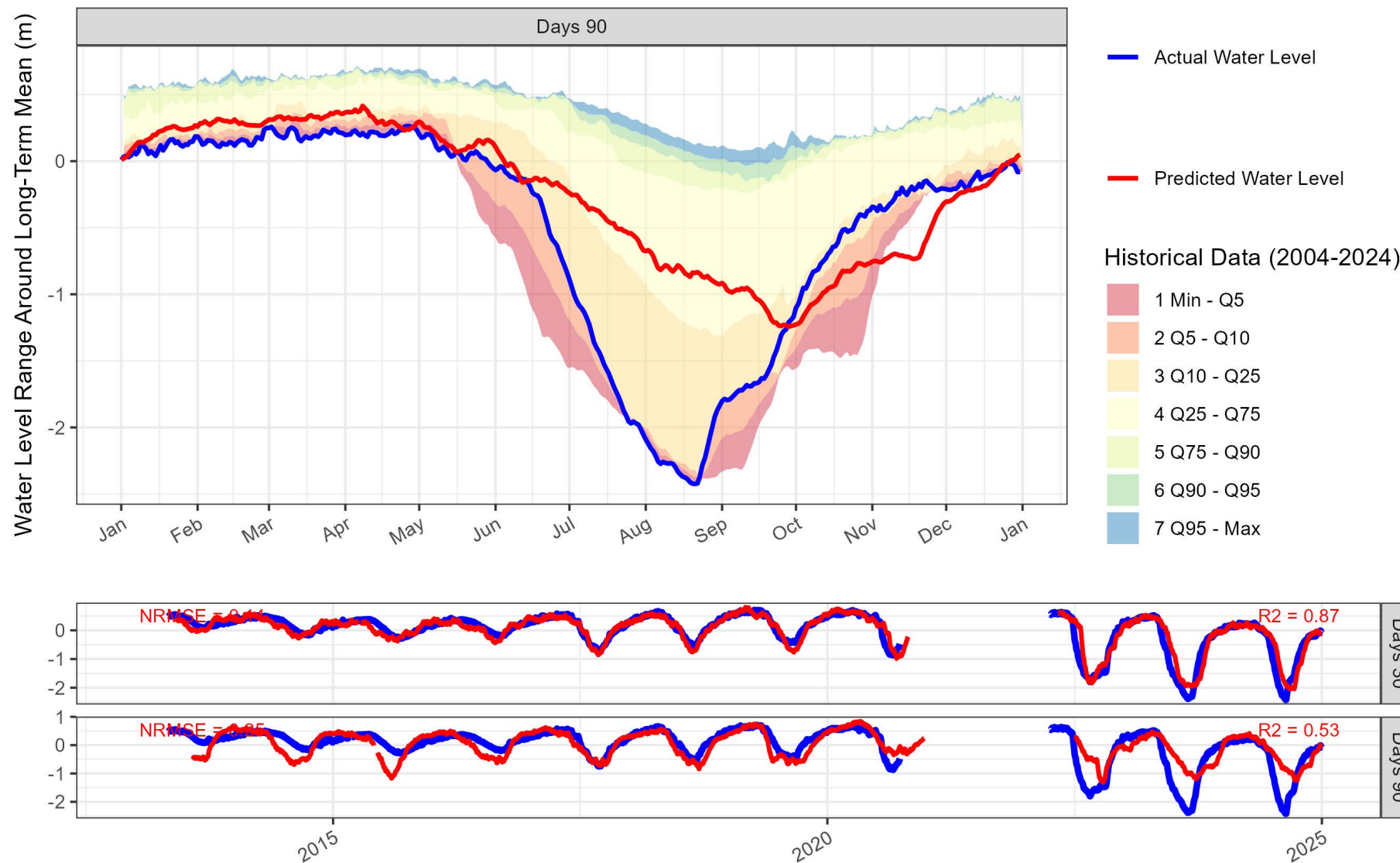
Unconfined sand and gravel

Rainfall setting

Well completed in 2017 with large water license.

Changing allocations.

Well = OW425 ; year = 2024



Model Validation Testing: Example #4

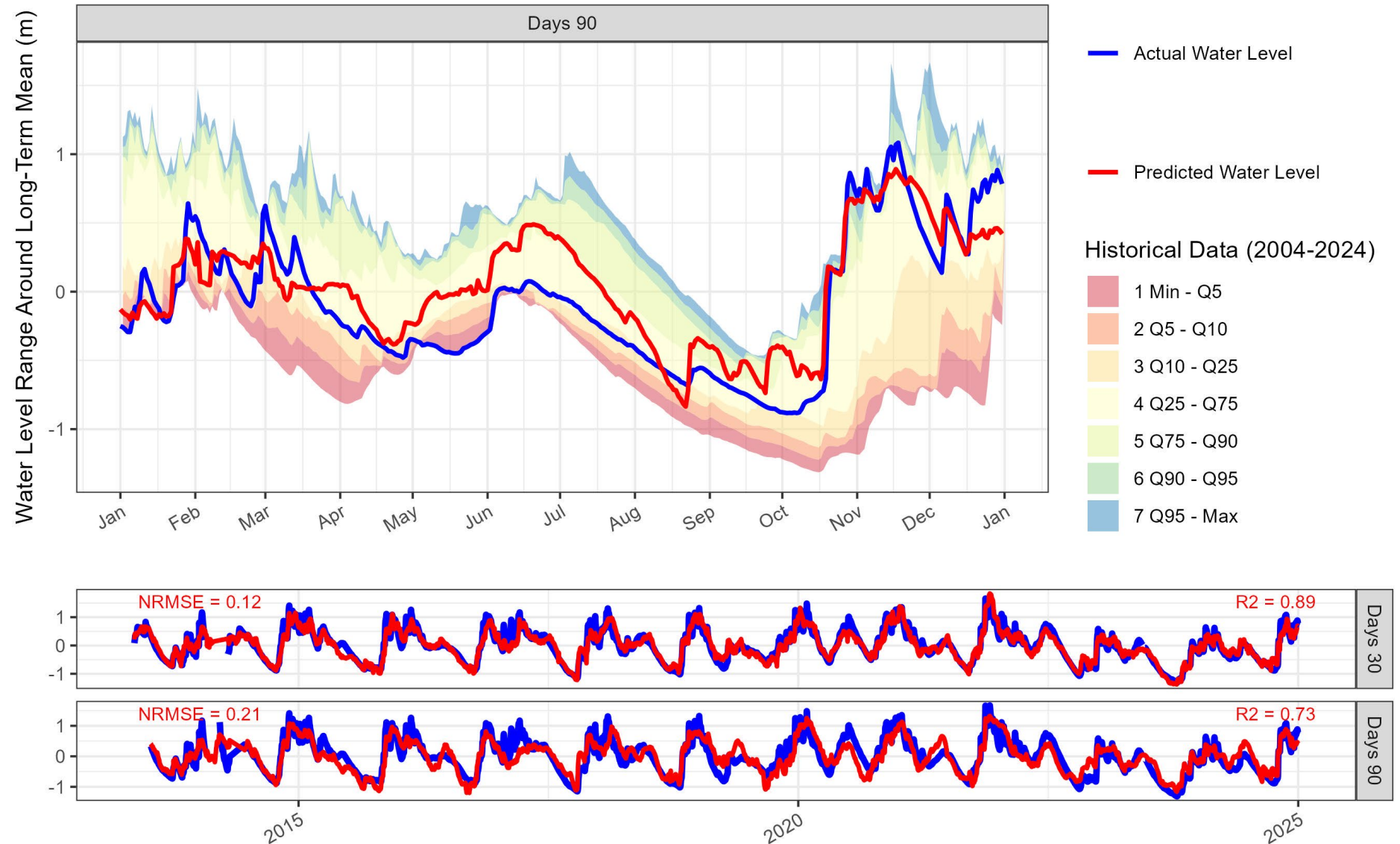
Agassiz ,BC

Unconfined sand and gravel

Rainfall setting

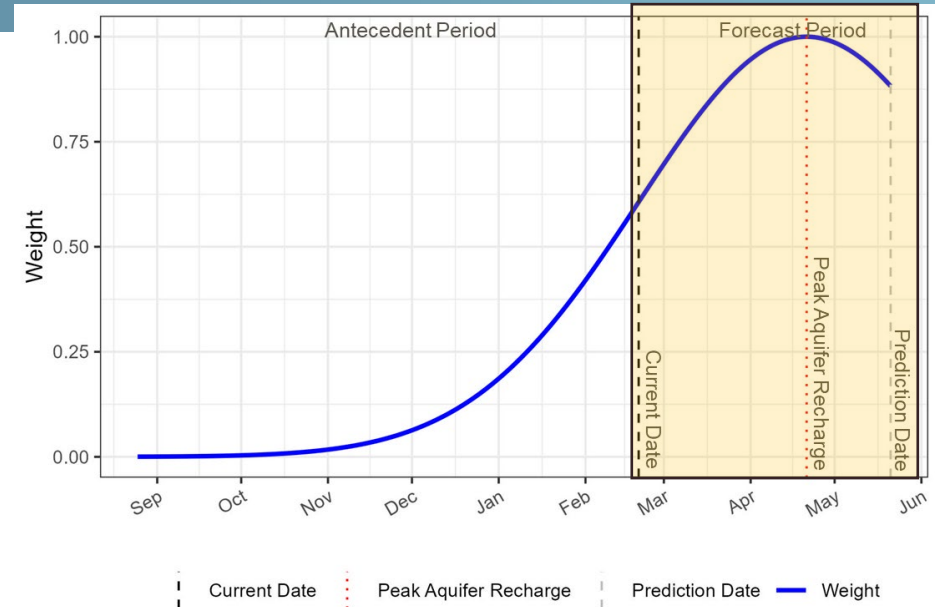
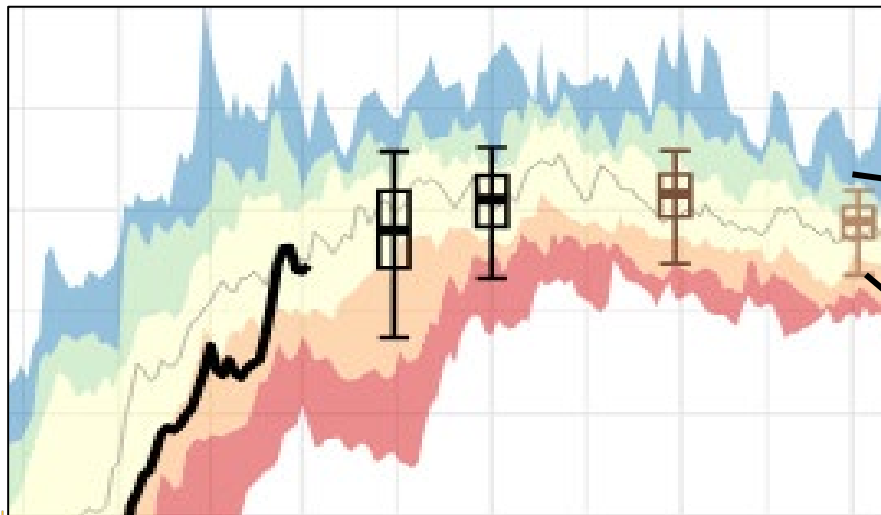
Aquifer in Connection with Fraser River

Well = OW448 ; year = 2024



Operational testing

- Use real antecedent conditions, and replace known future climate with historical climate variability (2004–2024).
- Use Monte Carlo sampling of historical climate to create many possible future climate sequences and produce probabilistic groundwater forecasts.

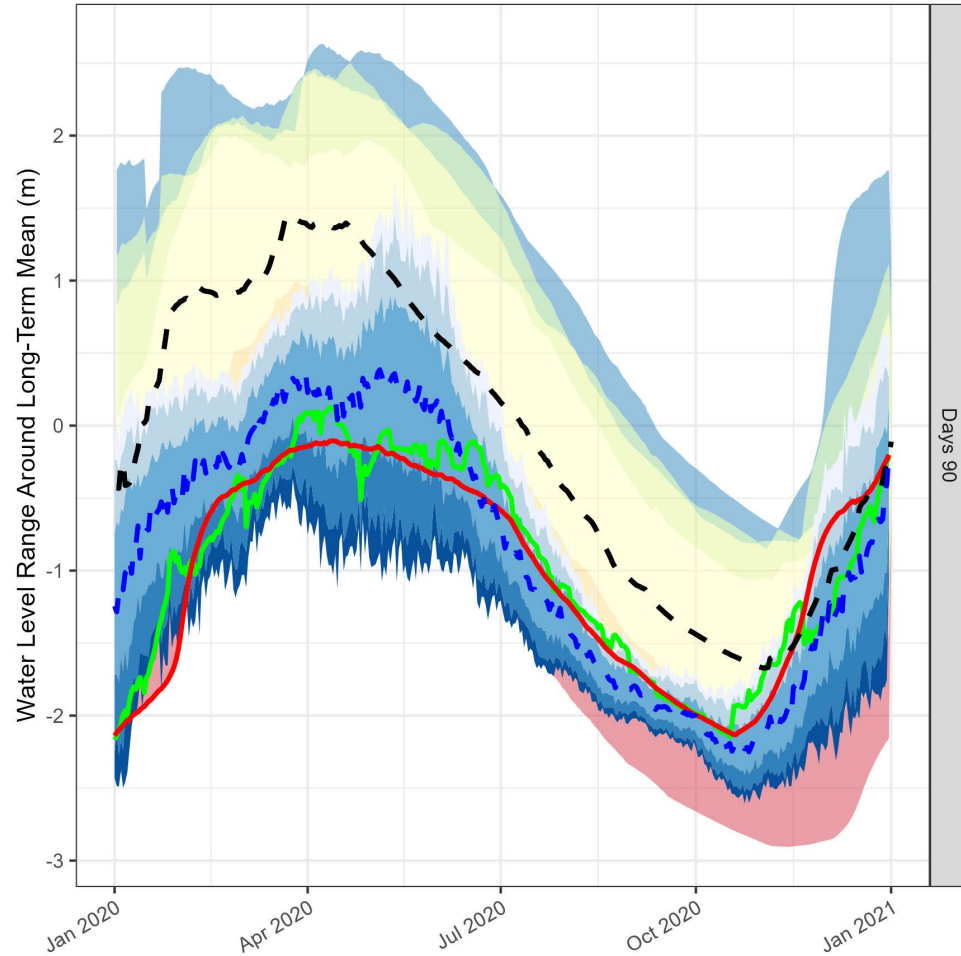


Range of Forecast

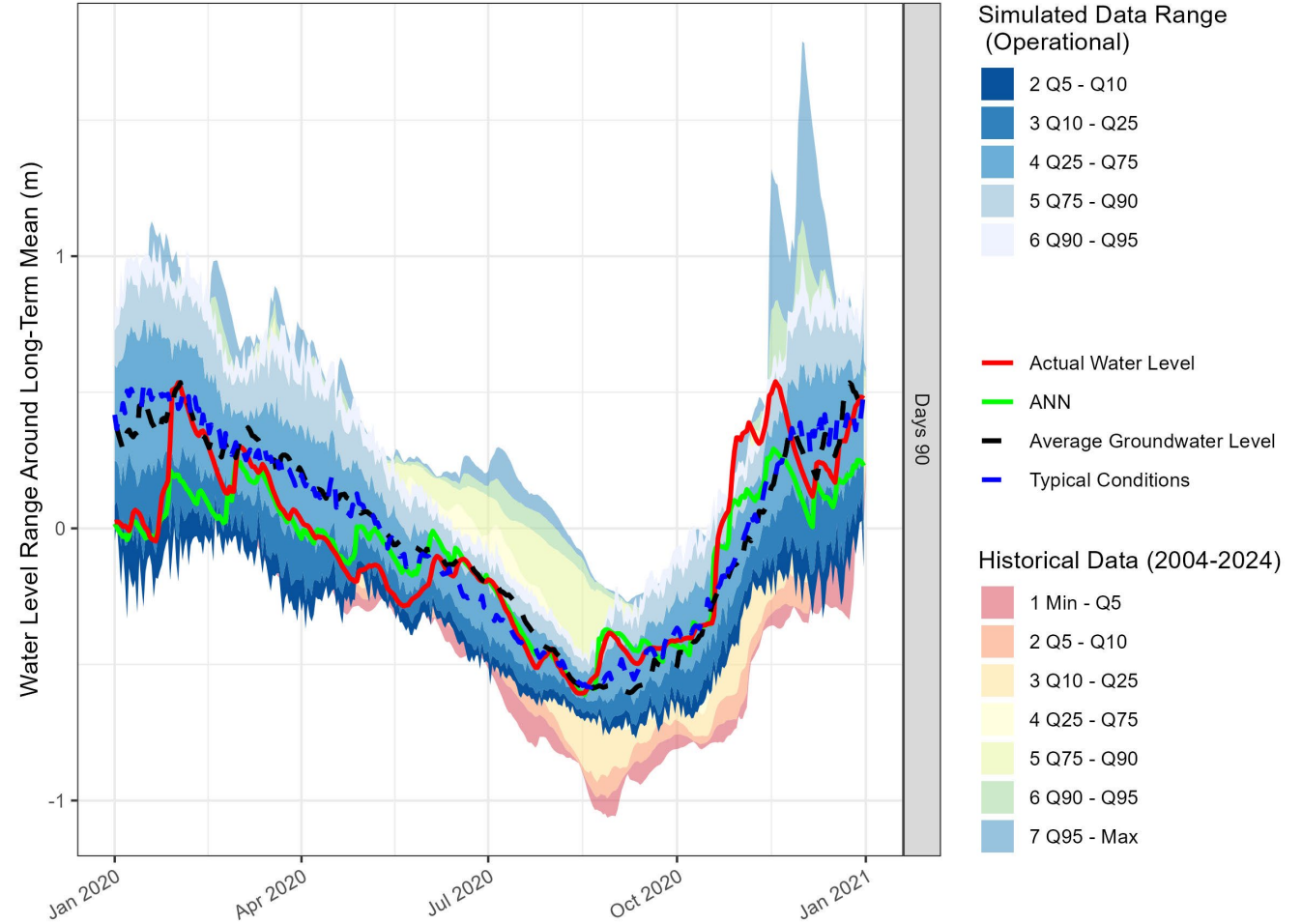
- >90th Percentile (less likely)
- 90th Percentile (likely)
- 75th Percentile (most likely)
- 50th Percentile (typical conditions)
- 25th Percentile (most likely)
- 10th Percentile (likely)
- <10th Percentile (less likely)

Operational testing

OW002 – Results less sensitive to future climate



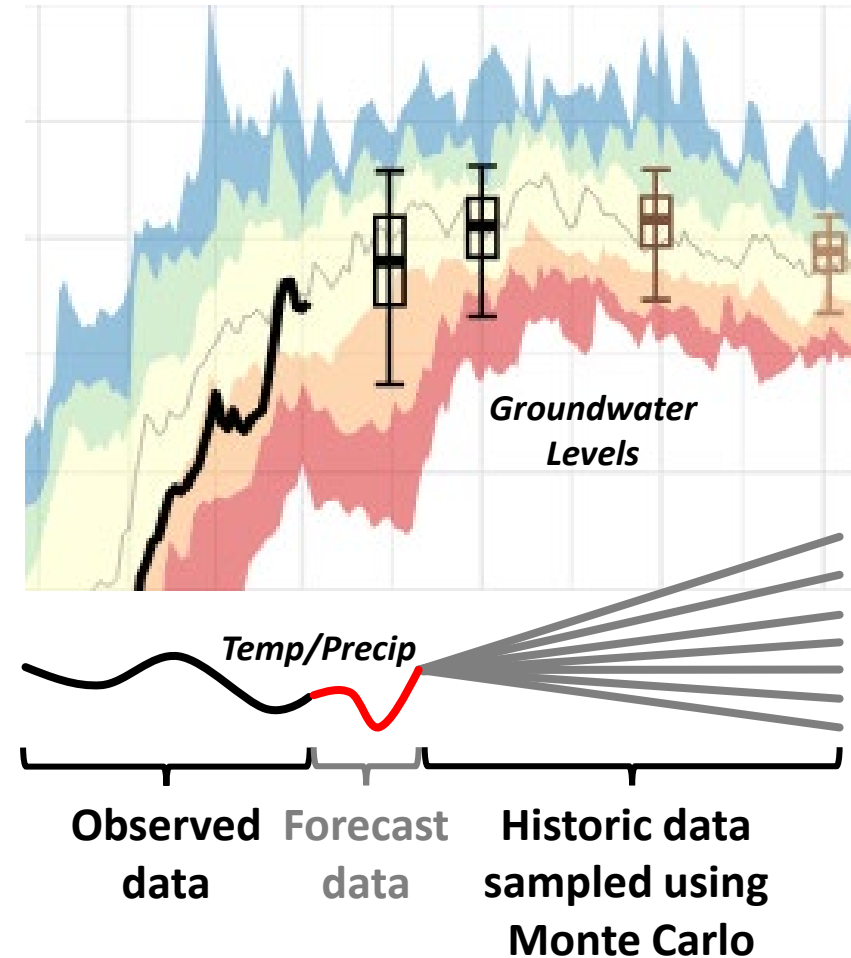
OW406 – Results more sensitive to future climate



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

Incorporating Climate Forecasts

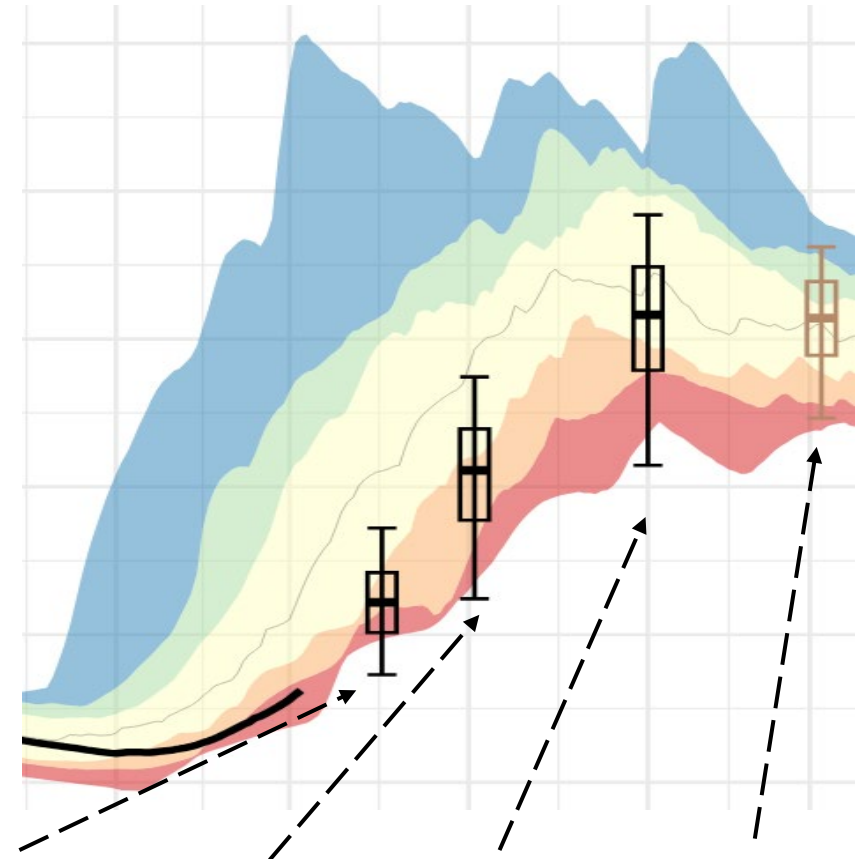
- Observed climate data – up to the most recent day
- Short-term forecast data – precipitation and temperature for the next ~10 days
- Monte Carlo samples of historical climate – to represent many possible weather patterns beyond the forecast horizon



Outputs and Visualization

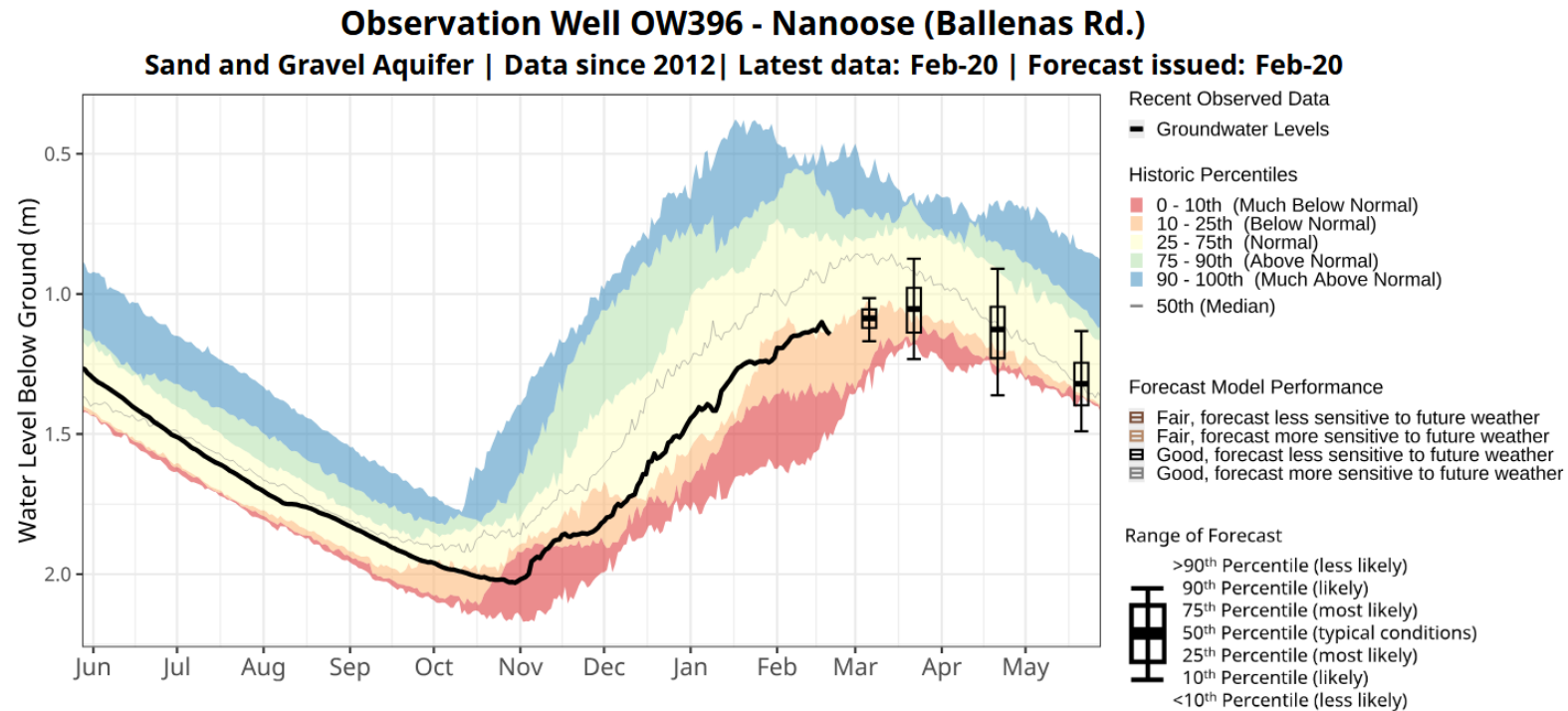
Forecast likely conditions

- Use the likelihood range to determine most probably condition category, based on percentile thresholds
 - Normal, Above Normal, Below Normal
- “Normal” refers strictly to groundwater levels between the 25th–75th percentiles of historical data, does not imply ideal, expected, or healthy conditions, just how current levels compare to past patterns



Groundwater Level Conditions	Percentile Range	Latest Dec-03	14-days Dec-17	30-days Jan-02	60-days Feb-01	90-days Mar-03
Above Normal	Above 75th		<10	<10	<10	39
Normal	25th to 75th		31	43	64	44
Below Normal	Below 25th	>99	69	56	34	17

Output Example: Vancouver Island



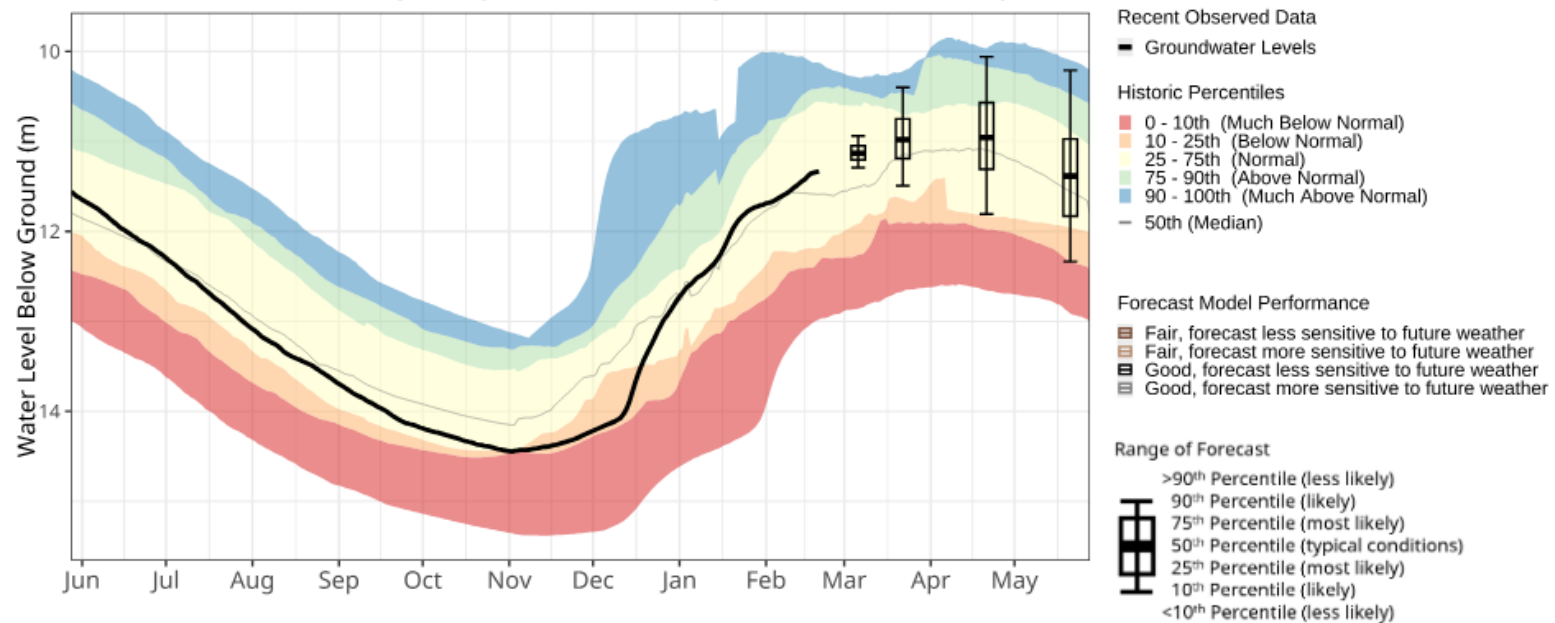
OW396 - Likelihood (%) of Groundwater Level Conditions

Groundwater Level Conditions	Percentile Range	Latest Feb-20	14-days Mar-06	30-days Mar-22	60-days Apr-21	90-days May-21
Above Normal	Above 75th		<10	<10	<10	<10
Normal	25th to 75th		<10	63	63	59
Below Normal	Below 25th	>99	>90	36	32	39

Note: colour shading occurs when likelihood is >50% for that condition category

Output Example: Lower Mainland

Observation Well OW002 - Abbotsford (Airport, Huntingdon Rd W Of Clearbrook Rd)
Sand and Gravel Aquifer | Data since 2004 | Latest data: Feb-20 | Forecast issued: Feb-20

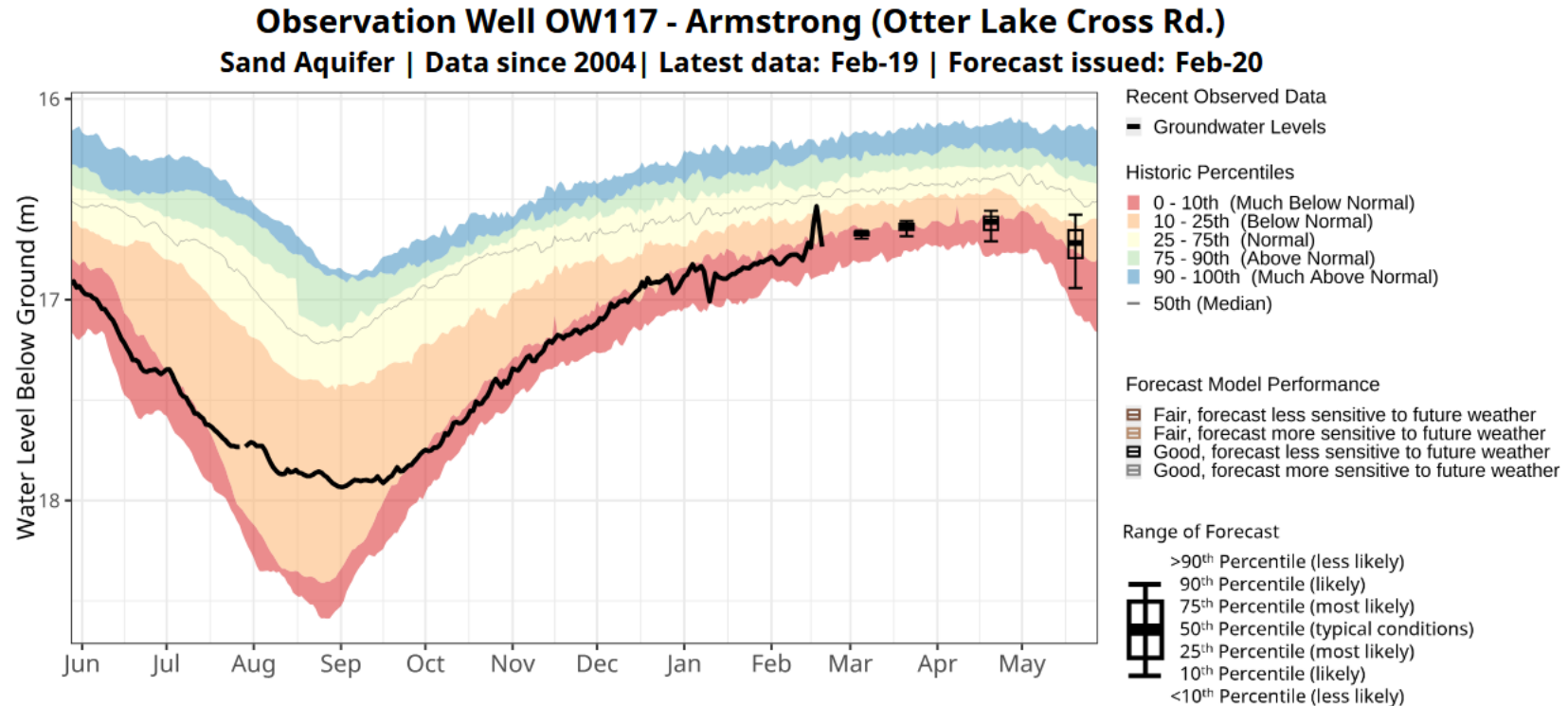


OW002 - Likelihood (%) of Groundwater Level Conditions

Groundwater Level Conditions	Percentile Range	Latest Feb-20	14-days Mar-06	30-days Mar-22	60-days Apr-21	90-days May-21
Above Normal	Above 75th		<10	18	28	23
Normal	25th to 75th	>99	>90	81	68	59
Below Normal	Below 25th		<10	<10	<10	18

Note: colour shading occurs when likelihood is >50% for that condition category

Output Example: Southern Interior

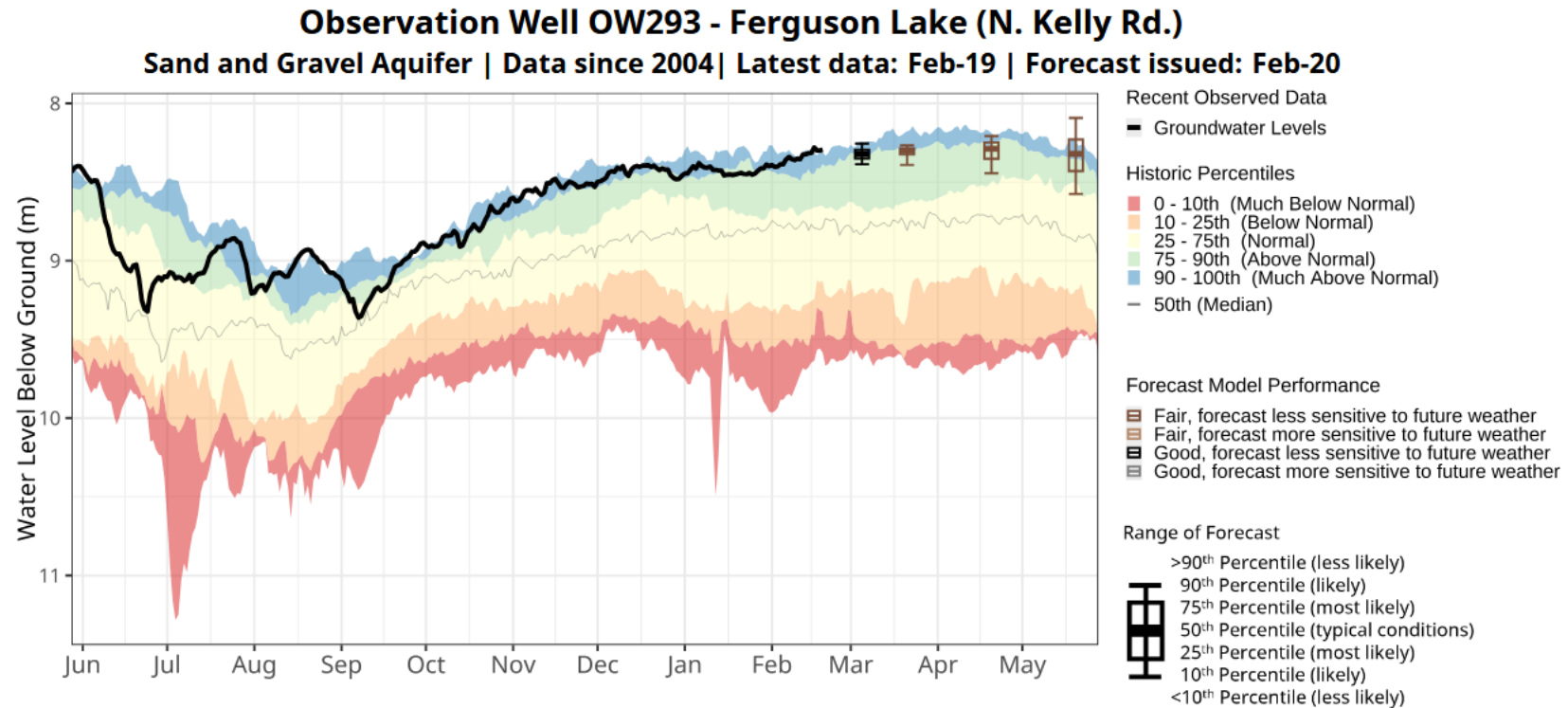


OW117 - Likelihood (%) of Groundwater Level Conditions

Groundwater Level Conditions	Percentile Range	Latest Feb-19	14-days Mar-05	30-days Mar-21	60-days Apr-20	90-days May-20
Above Normal	Above 75th		<10	<10	<10	<10
Normal	25th to 75th		<10	<10	<10	12
Below Normal	Below 25th	>99	>90	>90	>90	88

Note: colour shading occurs when likelihood is >50% for that condition category

Output Example: Northern BC

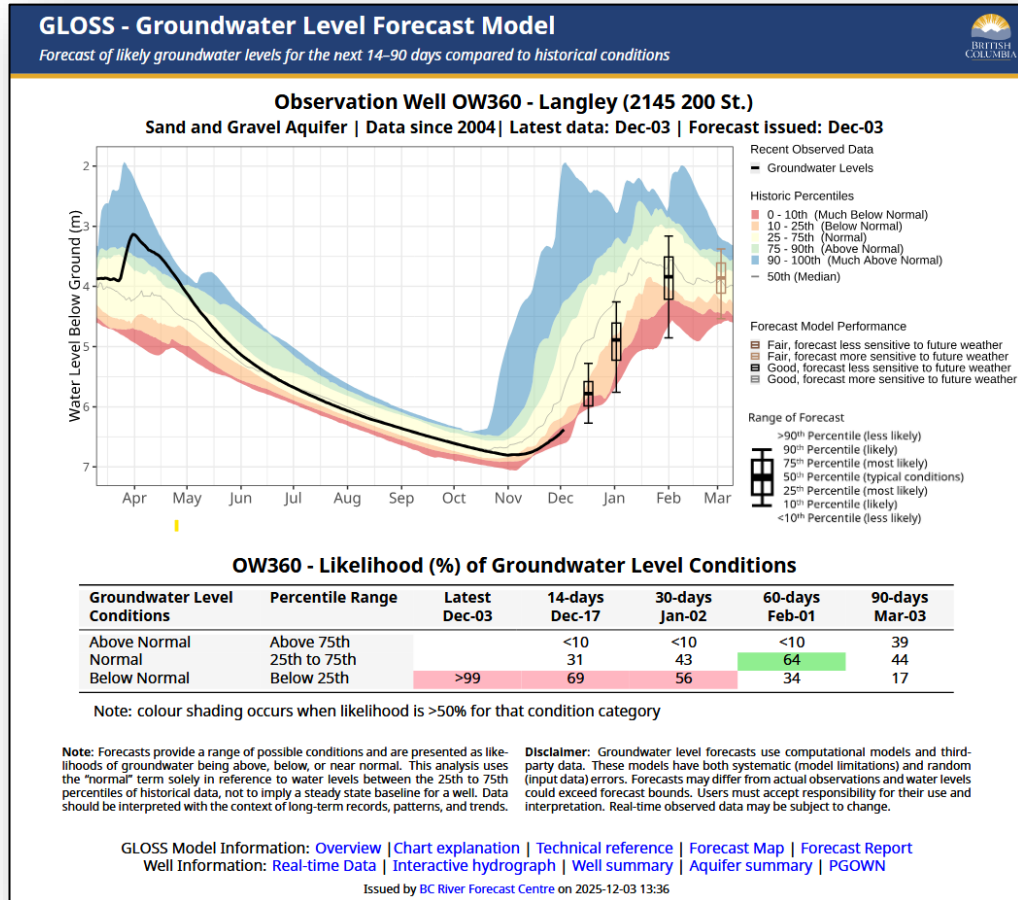
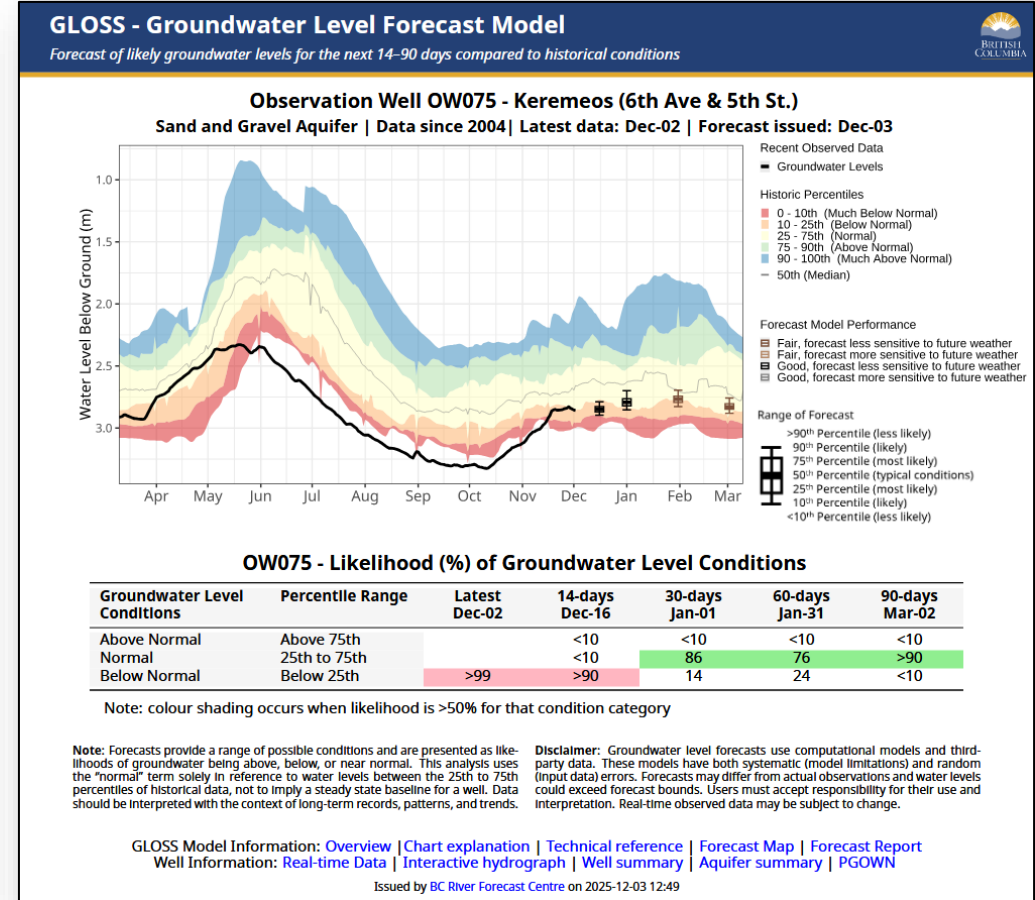


OW293 - Likelihood (%) of Groundwater Level Conditions

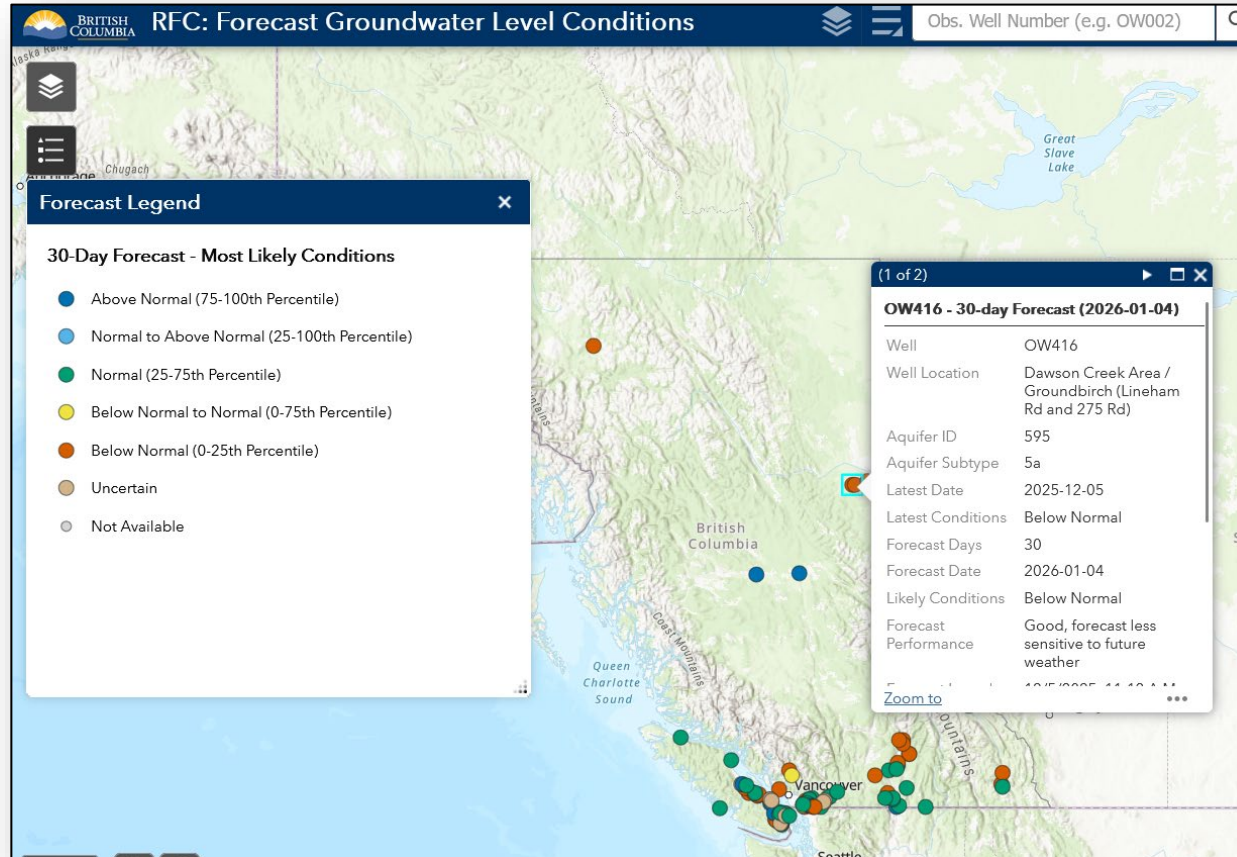
Groundwater Level Conditions	Percentile Range	Latest Feb-19	14-days Mar-05	30-days Mar-21	60-days Apr-20	90-days May-20
Above Normal	Above 75th	>99	>90	>90	>90	87
Normal	25th to 75th		<10	<10	<10	13
Below Normal	Below 25th		<10	<10	<10	<10

Note: colour shading occurs when likelihood is >50% for that condition category

Products: Well Reports

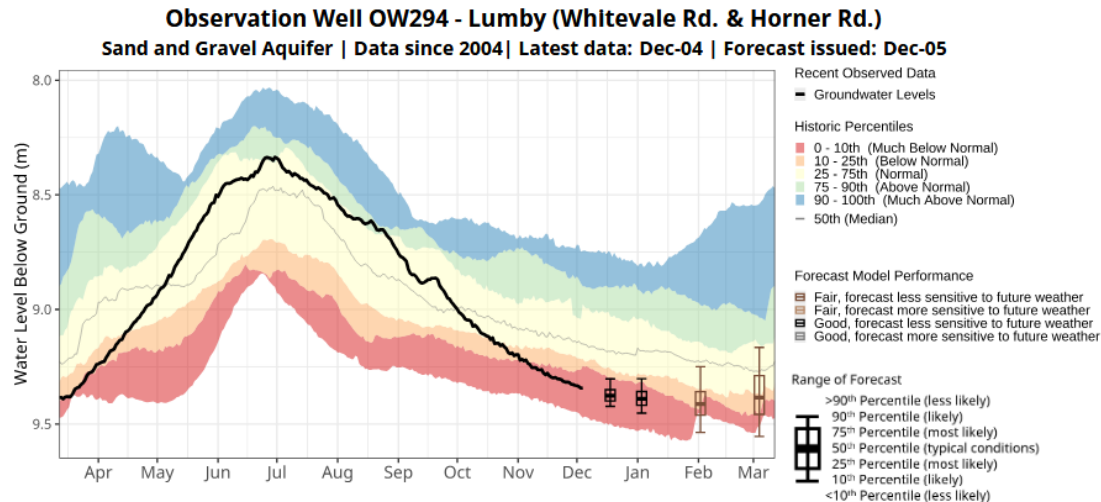


Products: Provincial Maps and Reports



Well	Location	Latest (Sep-17)	14 days (Oct-01)	30 days (Oct-17)	60 days (Nov-16)	90 days (Dec-16)
South Coast Region						
OW002	Abbotsford (Airport, Huntingdon Rd W Of Clearbrook Rd)	Normal	<10% - Very Unlikely	<10% - Very Unlikely	25-50% - Somewhat Likely	25-50% - Somewhat Likely
OW008	Abbotsford (Vye Rd E Of McCallum Rd)	Below Normal	>90% - Extremely Likely	50-75% - Likely	75-90% - Very Likely	50-75% - Likely
OW299	Abbotsford (Mt Lehman Rd N Of Marshall Rd Extension)	Above Normal	<10% - Very Unlikely	<10% - Very Unlikely	10-25% - Unlikely	25-50% - Somewhat Likely
OW301	Abbotsford (King Rd W Of Bradner Rd)	Above Normal	<10% - Very Unlikely	<10% - Very Unlikely	25-50% - Somewhat Likely	25-50% - Somewhat Likely
OW406	Chilliwack	Normal	10-25% - Unlikely	<10% - Very Unlikely	10-25% - Unlikely	25-50% - Somewhat Likely
OW448	Agassiz (Wilson Road)	Below Normal	75-90% - Very Likely	25-50% - Somewhat Likely	10-25% - Unlikely	<10% - Very Unlikely
OW449	Agassiz (Morrow Road)	Normal	50-75% - Likely	50-75% - Likely	10-25% - Unlikely	10-25% - Unlikely
OW450	Chilliwack (Sweet Briar Ave)	Normal	25-50% - Somewhat Likely	10-25% - Unlikely	25-50% - Somewhat Likely	10-25% - Unlikely
OW451	Hope (Tobena Road At Flood Hope Road)	Below Normal	75-90% - Very Likely	75-90% - Very Likely	75-90% - Very Likely	50-75% - Likely
OW452	Langley (Fort Langley Park)	Above Normal	<10% - Very Unlikely	<10% - Very Unlikely	25-50% - Somewhat Likely	<10% - Very Unlikely
OW459	Chilliwack (Unsworth Rd)	Normal	10-25% - Unlikely	<10% - Very Unlikely	<10% - Very Unlikely	<10% - Very Unlikely
OW460	Chilliwack (Greenmount Blvd & Shaw St)	Below Normal	>90% - Extremely Likely	>90% - Extremely Likely	>90% - Extremely Likely	>90% - Extremely Likely

Application for drought management



OW294 - Likelihood (%) of Groundwater Level Conditions

Groundwater Level Conditions	Percentile Range	Latest Dec-04	14-days Dec-18	30-days Jan-03	60-days Feb-02	90-days Mar-04
Above Normal	Above 75th		<10	<10	<10	<10
Normal	25th to 75th		<10	<10	21	41
Below Normal	Below 25th	>99	>90	>90	79	55

Note: colour shading occurs when likelihood is >50% for that condition category

- Shows wells at risk of below-normal conditions 14–90 days ahead
- Provides early indication of declining groundwater levels before impacts may appear
- Helps identify priority areas where drought may intensify, support priority wells for monitoring
- Supports resource planning, such as monitoring needs, outreach, and water-use coordination
- Can also be used outside of drought to forecast potential conditions during rainy and freshet seasons

Model Considerations

- “Normal” refers strictly to groundwater levels between the 25th–75th percentiles of historical data, does not imply ideal, expected, or healthy conditions, just how current levels compare to past patterns
- “All models are wrong, but some are useful” – just a model that provides potential scenarios of outcomes – will not be perfect
 - Probabilistic model based on inputs and confined within statistical methods
 - Forecast range uses historic conditions, extreme conditions outside of bounds
 - Non-climatic effects can influence water level (new pumping etc.)
 - Data gaps or errors in climate or groundwater data influence model performance.
- Informational tool, not a guarantee — forecasts support decision-making but should be used with other indicators and local expertise

Ongoing and next steps

- Review wells for inclusion in final public product
- Finalize reporting and visualization tools
- Gathering feedback from internal users
- Publications – scientific journal, Water Science Series and supporting documentation
- Potential implementation/public reporting next summer

Contact Information

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