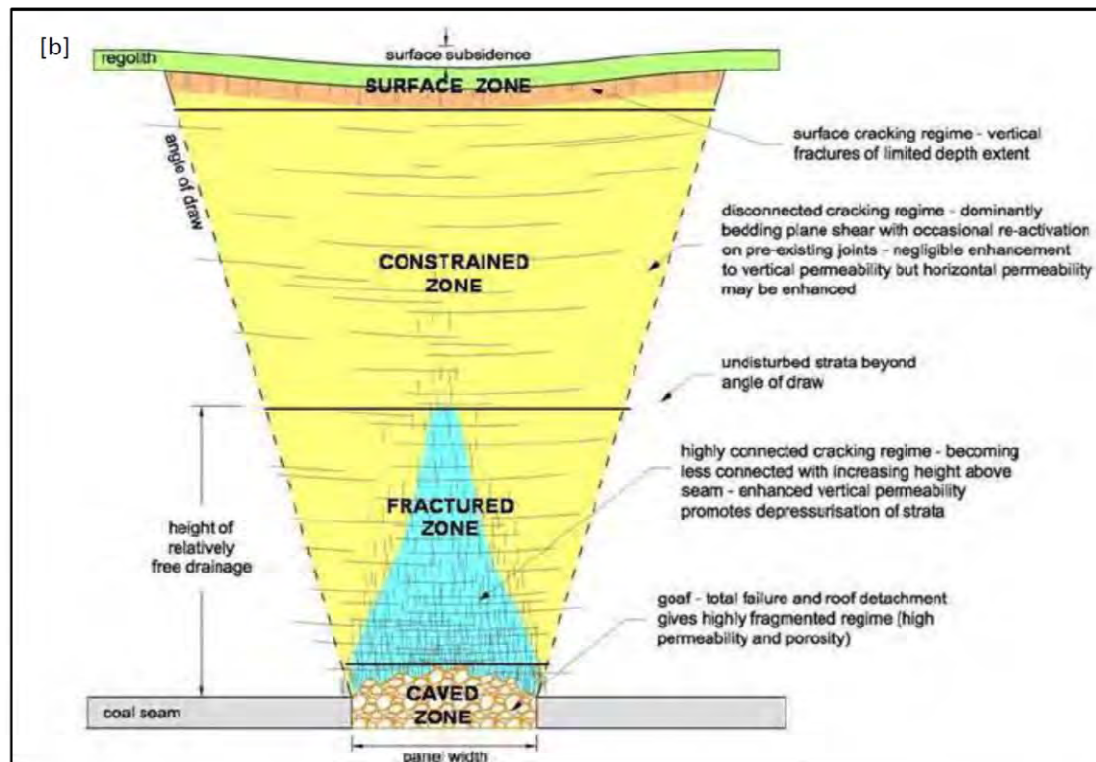
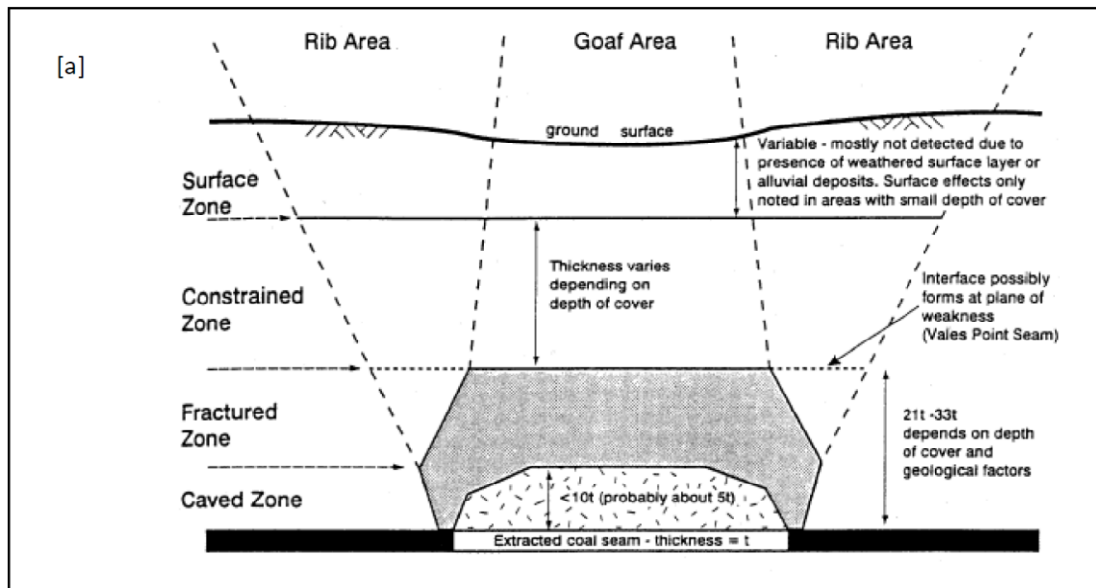




Sources: Forster (1995); New South Wales Government Department of Planning (2008).

Figure 26 Conceptual Model of Longwall Mining-Induced Rock Deformation

3 GROUNDWATER SIMULATION MODEL

3.1 MODEL SOFTWARE AND COMPLEXITY

Groundwater modelling has been conducted in accordance with the Murray-Darling Basin Commission (MDBC) Groundwater Flow Modelling Guideline (MDBC, 2001). New National Guidelines were announced in June 2012, sponsored by the National Water Commission (Barnett et al., 2012). These guidelines build on the 2001 MDBC guide, with broad consistency in the model conceptualisation, design, construction and calibration principles, and the performance and review criteria, although there are differences in details and expansion on particular topics.

The 2012 guide has replaced the model complexity classification of MDBC (2001) by a "model confidence level". The Project model may be classified as Class 2 (effectively "medium confidence"), which is an appropriate level for this project context (i.e. preliminary Groundwater Assessment for a Gateway Application); see Attachment F. Under the 2001 modelling guideline, the model is best categorised as an Impact Assessment Model of medium complexity. The guide (MDBC, 2001) describes this model type as follows:

"Impact Assessment model - a moderate complexity model, requiring more data and a better understanding of the groundwater system dynamics, and suitable for predicting the impacts of proposed developments or management policies."

Numerical modelling has been undertaken using the Groundwater Vistas (Version 6) software interface marketed by Environmental Simulations Inc. and a range of custom utilities, in conjunction with MODFLOW-SURFACT (Version 4) distributed commercially by Hydrogeologic, Inc. (Virginia, USA). MODFLOW-SURFACT is an advanced version of the popular MODFLOW code developed by the United States Geological Survey (Harbaugh and McDonald, 1996). MODFLOW is the most widely used code for groundwater modelling and is accepted as an industry standard.

MODFLOW-SURFACT is a three-dimensional modelling code that is able to simulate variably saturated flow and can handle desaturation and resaturation of multiple model layers without the "dry cell" and related problems of standard MODFLOW. In particular this includes anomalous pressure in and around the extraction voids generated by the standard version.

For this project, MODFLOW-SURFACT's rigorous unsaturated zone flow equations were used (van Genuchten/Brooks-Corey functions for water flow), with unsaturated flow parameters set to constant values throughout the model: van Genuchten alpha and beta of 0.3 and 2, residual saturation of 0.15, and Brooks-Corey exponent of 2.

MODFLOW-SURFACT's Adaptive Time-Stepping and Output package was employed in conjunction with the Preconditioned Conjugate Gradient (PCG5) solver to efficiently solve the flow equations. The PCG5 head criterion for convergence was set to 0.01 m for all simulations, and backtracking was also used.

The most recent releases of MODFLOW-SURFACT also allow the changing of model properties through time using the Time-Varying Material Properties (TMP) package, allowing mine scheduling to be run within a single model.

The model complexity is appropriate for simulating contrasts in hydraulic properties and hydraulic gradients that may be associated with changes to the groundwater system as a result of the proposed development.

3.2 MODEL LAYERS AND GEOMETRY

The model domain was discretised into 384,300 cells comprising 244 rows, 175 columns and 9 layers. Figure 27 shows the extent of the groundwater model domain, which extends 70 km from west to east and 97.6 km from south to north, covering an area of approximately 6,832 km².

Because this preliminary groundwater assessment is for the Gateway Process, which requires a lower resolution modelling approach, a coarser cell size and model layer sub-division was chosen. This reduced both the model build and run times. Based on the width of the longwall panels proposed (400 metres, and 200 metres in the subsidence control zones), a uniform grid size of 400 m was selected.

The 9 model layers used to represent the regional stratigraphic section are outlined in Table 17, and are based on the conceptual hydrogeology described in Section 2.

Table 17 Model Layer Assignment

Layer	Lithology	Median Thickness (m)	Lumped Units
1	Narrabri Fm + Regolith	14.5 + 5.0	
2	Gunnedah Fm + Regolith	21.0 + 3.9	
3	Tertiary Basalts	41.5	Liverpool Range Beds and undifferentiated Tertiary basalts
4	Jurassic Formations	245.6	Glenrowan intrusives, Pilliga Sandstone, Purlawaugh Fm, Garrawilla Volcanics
5	Napperby Fm to Wallala Fm	376.7	Napperby Fm, Digby Fm, Trinkey Fm, Wallala Fm
6	Clare Sandstone	36.7	
7	Benelabri Fm/Interburden	79.1	
8	Hoskissons Seam	10	
9*	Arkarula Fm to Melvilles Seam Floor (Pamboola Fm)	44.8	Arkarula Fm and Melvilles Seam

** This layer defined based on deepest seam proposed for mining by the Watermark Project (i.e. Melvilles Seam).*

Geological surface information from surrounding mines and regional scale projects was extracted from publicly available reports where possible (AGE, 2012; SWS, 2012). Within the EL6505 area, geological surfaces were extracted from BHP Billiton's Project geological resource model. This resource model was also used to extrapolate selected layer thickness out from the lease area.

The 1:100,000 scale geological map of the Gunnedah Coalfield (South) Geological Map (DMR, 1996) was used to guide the subsurface extent of each modelled hydrostratigraphic unit. Modifications to the extent of alluvial deposits were made within the lease based on field mapping conducted for the Project (Umwelt, 2011). This field mapping has been reviewed by McKenzie Soil Management, and it is expected that revised mapping will be available for use in the EIS groundwater model.

BHP Billiton's 2 m resolution Digital Elevation Model (DEM) of EL6505 was used in conjunction with Geoscience Australia's 1 second DEM (Gallant et al., 2011) to define the modelled land surface throughout the model extent.

The geometry of the Upper Namoi Alluvium (Narrabri and Gunnedah Formations; layers 1 and 2) were derived directly from NOW's Upper Namoi numerical groundwater flow model (C. McNeilage, pers. comm. 2013), which is built on a 400 m grid that is perfectly aligned with the Project model used in this study. Minor localised adjustments were made within EL6505 based on BHP Billiton's explorative drilling records.

The depth of regolith (layers 1 and 2) was estimated from exploration data from within EL6505, in conjunction with the mapping of SWS (2012) (i.e. the Namoi Catchment Water Study). The floor of the Tertiary Basalts and of the Melvilles seam were based on the mapping of AGE (2012). The thickness of the modelled Hoskissons coal seam and Clare Sandstone were extrapolated from the BHP Billiton geological model's median thickness data. All other layer elevations were defined based upon the mapping of SWS (2012).

Minimum model layer thickness was set to 1 m for all layers, with the exception of layer 1, which was assigned a minimum thickness of 5 m. It should be noted that all layers are fully present across the active model area. Where a hydrostratigraphic unit becomes inactive, such as up-dip from its subcrop, the layer has been extended across the rest of the model domain as a 1 m thick 'dummy' layer, which has the same properties as the first 'active' underlying layer that exists in that area. This approach allows each layer to represent a single hydrostratigraphic unit, so that impacts on specific units can be readily extracted from the model output files.

The resulting modelled geological surfaces are presented in Attachment B.

Representative east-west and north-south model cross-sections are presented in Figure 28 for northing 6523600 (GDA94 Zone 56) (model row 116) and easting 252800 (model column 82), passing through the Project area.

The model domain has been designed to be large enough to prevent model boundaries significantly influencing predicted drawdowns and associated hydrological effects as a result of mining at the Project site. The model extent lies beyond the subcrop of the deepest coal seam that may be mined by the Project and/or surrounding mines in the future, excluding the western extent of the Hoskissons seam.

3.3 BOUNDARY CONDITIONS

The model domain and boundaries shown in Figure 27 have been selected to incorporate any hydrological features such as streams that could be influenced by mining. Following is detailed description of each of the modelled boundary conditions.

3.3.1 Watercourses

Creeks and rivers throughout the model domain were modelled using MODFLOW's Stream Flow Routing (SFR1) package (Prudic et al., 2004). This boundary condition routes accumulated stream flows down the stream network from headwaters to catchment outlets. It can also simulate extractions from and discharges to watercourses, although this was not employed because total flow (i.e. runoff plus interflow plus baseflow) was not simulated in this case. Only baseflow was simulated and routed down the stream network, and runoff and interflow were not modelled. The SFR1 package is also capable of simulating stream stage dynamics using Manning's equation, which was applied in this case using a wide rectangular channel assumption (Manning's 'n' parameter was set to a constant value of 6.25E-7 days/m, based on rough verification of simulated channel water depths, and previous experience).

Stream bed hydraulic conductivity was conservatively set to 1 m/day and stream bed thicknesses were set to 0.1 m, thereby forcing hydraulic properties of strata to control the degree of connectivity between surface water and groundwater rather than the unknown and often highly variable stream bed properties.

Stream channel base widths were parameterised based on aerial imagery, and are shown in Figure 27. Stream bed elevations were parameterised as the minimum value of the 1 second DEM or LIDAR (preferred) within each 400 m groundwater model grid cell.

Lake Goran (in the model's west) was not explicitly modelled as a lake, because only small areas are regularly waterlogged; much of the lake bed is often used for cropping. Hence, the lake was modelled as a high-evapotranspiration sink (average annual rates of ~870 mm/year – see discussion below on evapotranspiration), with SFR1 cells also draining the lake area in a connected network discharging to the Mooki River to the east (see Figure 27).

3.3.2 Recharge

Spatially and temporally variable groundwater recharge rates to the Namoi Alluvium were directly derived from NOW's Upper Namoi groundwater flow model, which was in turn derived from the Australian Water Availability Project (AWAP; see <http://www.csiro.au/awap/>).

Because the currently available NOW model simulations only extend to June 2012, and the Project model simulation extend to the end of December 2013, the NOW model recharge rates were extrapolated using quarterly averages. The 1980-2012 average recharge to the alluvium from the NOW model (within the Project model extent) is about 18 mm/year, but varying from 9 mm/year around Lake Goran in the west, to 40-60 mm/year around alluvial margins. For the steady state model, NOW's 1958-2012 average recharge rates were applied.

Similarly, because the NOW model does not simulate non-alluvial units, transient recharge rates from the NOW model were extrapolated to non-alluvial (i.e. outcropping basalt and Permian to Jurassic rocks). This was achieved by applying a multiplier on NOW's average recharge rates to the alluvials within the Project model domain, which was adjusted during model calibration. In this way, the temporal variability of recharge to the alluvium was carried through to the non-alluvial units of the Project model, but the rates were reduced. A limitation of this approach is that the bedrock recharge rates in the Project model are not spatially variable.

3.3.3 Evapotranspiration

The MODFLOW Evapotranspiration package was used to simulate evapotranspiration from the groundwater system. Extinction depths were set to 4 m below ground. Maximum potential rates were set directly from the NOW Upper Namoi groundwater flow model (i.e. from AWAP), in the same manner as described above for recharge. Long-term average annual maximum evapotranspiration rates from the NOW model (within the Project model extent) are around 365 mm/year, ranging from around 870 mm/year in the west around Lake Goran to around 290 mm/year in southern elevated catchment areas.

3.3.4 Groundwater Use

Licensed NOW groundwater extraction bores were included in the model using the 'Fracture Well' (FWL4) package³. These are shown in Figure 27, and were directly derived from NOW's Upper Namoi groundwater flow model. Because the currently

³ Fracture Well is an option in MODFLOW-SURFACT that does not mean in fractured rock but includes storage in the bore/well simulated using single fracture hydraulics theory.

available NOW model extends only to June 2012, and the Project model extends to the end of December 2013, the NOW model groundwater extraction rates were extrapolated using quarterly averages.

3.3.5 No Flow Boundaries

All edges of the modelled active area (Figure 27) were designated no flow boundaries. To the east and north, this represents where the 9 modelled hydrostratigraphic units pinch out, and where older units outcrop. To the south, this approach was applied given the lack of information on groundwater pressures within the deeper formations, and given the regional topographic divide and therefore a likely groundwater flow divide. To the west, the mapped regional groundwater flow directions suggest that most flow is along this boundary, not across it (see Figure 13).

3.3.6 Mine Workings

The proposed Project underground mining and groundwater inflow was defined and simulated in the predictive models using Drain (DRN) cells within the mined coal seam. Modelled Drain elevations were set to 0.1 m above the base of the worked seam. These Drain cells were applied wherever workings occur, and were progressively added to simulate removal of the panels over time in the transient model. A Drain conductance value of 1,000 m²/day was applied in order to allow free inflow to occur into the simulated voids without resistance, so that model hydraulic properties rather than Drain conductance control modelled inflows.

Hydraulic parameters were also changed with time in the goaf and overlying fractured zones directly after removal of each longwall panel (see Section 4.1.1 for details), whilst simultaneously activating Drain cells along advancing development headings. The development headings were activated one stress period in advance of the active mining and subsequent subsidence. The horizontal and vertical hydraulic conductivities were raised to 10 m/day per cell to simulate the highly disturbed nature of materials within the caved zone (see Section 2.7).

Surrounding mines were not modelled for this preliminary groundwater assessment for the Gateway process. The principle of superposition was used to conservatively estimate cumulative impacts of all mines, together with the Project predicted impacts.

3.4 HYDRAULIC PROPERTIES

The numerical modelling layers and hydraulic parameters applied are in accordance with the conceptual (and geological) model. The distributions of hydraulic properties in each model layer are shown in Attachment C.

The Permo-Triassic strata were subdivided into a number of layers in order to provide sufficient resolution for representing the vertical hydraulic gradient through the stratigraphic column, the mined coal seam and surrounding hydrostratigraphic units (see Table 18).

Previous studies and investigations within the region, in conjunction with core and packer testing data collected for the Project, provided data for selecting the initial hydraulic parameter values used for the coal seam, interburden and other geological units as shown in Table 18.

The values selected were also based on calibrated parameters used in surrounding mines' models, and earlier modelling for the Project (AGE, 2013).

Table 18 Initial Hydraulic Properties of Hydrostratigraphic Units

Layer	Zone	Hydrostratigraphic Unit (HSU)	Kx (m/day)	Kz (m/day)	Sy	Ss (/m)
1	101	Narrabri Fm	5.86E+00 *	8.00E-03 *	5.21E-02 *	-
2	201	Gunnedah Fm	1.03E+01 *	8.00E-03 *	3.00E-01	3.54E-04 *
2	102	Regolith	2.40E-02	1.20E-03	1.20E-02	1.00E-04
3	3	Tertiary (Liverpool Range) Volcanics	1.50E+00	5.00E-01	2.87E-03	1.80E-05
4	4	Jurassic Formations	1.00E-03	5.00E-04	3.58E-03	1.19E-04
5	5	Napperby Fm to Wallala Fm	1.00E-03	5.00E-04	5.67E-04	8.25E-06
6	6	Clare Sandstone	2.63E-02 #	1.32E-02 #	1.75E-03	7.70E-06
7	7	Benelabri Fm to Hoskissons Seam roof	1.00E-03	5.00E-04	5.72E-04	9.05E-07
8	8	Hoskissons Seam	1.00E-02 #	1.00E-02 #	7.35E-03	7.95E-06
9	9	Arkarula Fm to Melvilles Seam Floor (Pamboola Fm)	1.00E-03	5.00E-04	1.70E-04	9.17E-07

* Average of spatially variable parameter across model domain;

Average of spatially variable parameter across Carroona EL6505 area

Source: D:\HydroSim\CAR001\GWModel\Construction\Properties\CARv2_CalibratedModel_Parameters.xlsx

3.5 MODEL VARIANTS

Both steady-state and transient models were developed for use in this groundwater assessment as summarised below:

- ❑ Steady-state model of pre-mining conditions: Calibration against the observed and estimated pre-mining groundwater levels. This model was used to formulate transient model starting heads.
- ❑ Transient verification model (pre-mining; July 1980 – December 2013). Quarterly stress periods. Verified against the groundwater hydrographs in Attachment D.
- ❑ Transient predictive model extending to the end of mining (30 years), and 280 years post-mining recovery. Primarily annual stress periods, expanding to twenty-year stress periods 20 years after mining cessation.

Transient calibration was not conducted, in accordance with the lower resolution model required by the Gateway process. Transient model calibration will be conducted for the EIS report.

3.6 CALIBRATION

3.6.1 Approach

A combined steady-state calibration and transient verification under pre-mine conditions was conducted for this preliminary groundwater assessment. The steady-state model was calibrated to groundwater levels from a variety of sources including the VWP's installed for the Project (Section 2.6.1; NOW monitoring bores, and NOW time-of-drilling water level records. In the case of the VWP's on EL6505, early data were given a weight of nil in the calibration process because the piezometers were still equilibrating post-installation.

The steady state calibration data set comprised 627 head targets. The transient verification data comprised 60,819 observations from 353 bores (Table 19). The vast majority of observation data (and piezometers) are from the Upper Namoi Alluvium. The model was calibrated using a combination of auto-sensitivity analysis (PEST; Doherty, 2010) and manual modification of model parameters. Greater weight was placed on what were considered reliable VWP data from EL6505, and the NOW monitoring bore data; unreliable VWP data were given a weight of zero in PEST's calibration process. Comparatively low weights were placed on the time-of-drilling water levels. This process of weight assignation within PEST was iterative and manual, and aimed to achieve a broadly equal contribution to PEST's objective function from each of the different reliable data types (i.e. NOW bore data and Project monitoring bore data, as recommended by Doherty (2010)). Less reliable data types (VWP data) were weighted so as to contribute less to PEST's objective function, and the least reliable data types (time-of-drilling records) were weighted to contribute the least to the objective function.

Table 19 Transient Verification Data Summary

Layer	Formation	Count of Observations
1	Narrabri Fm	14,761
2	Gunnedah Fm	45,534
1 + 2	Regolith	149
5	Top of Black Jack Group	16
5	Trinkey Fm	32
5	Intrusive	12
5	Yarraman Seam	2
5	Doona Seam	22
5	Mooki Seam	2
5	Springfield Seam	6
5	Clift Seam	66
6	Clare Sandstone	84
7	Howes Hill Seam	22
7	Benalabri Fm	14
8	Hoskissons Seam	85
9	Arkaroola Fm	6
9	Melville Seam	6
	Total	60,819

Parameters were assigned as single uniform zones in each hydrostratigraphic unit, which were altered during the calibration process. These parameters comprised: horizontal and vertical hydraulic conductivity of all geological units; recharge to Tertiary Basalts and Jurassic to Permian units, and storativity and specific yield of all units. Vertical hydraulic conductivity was calibrated as a factor of horizontal conductivity, (K_z/K_x) with a maximum ratio of 1.

The starting parameters for the calibration process were outlined in Section 3.4 and Table 18. Although automated sensitivity was used in the calibration process, care was taken to ensure that the hydraulic properties reflect the measured and estimated ranges for each of the strata types, as discussed in Section 2.6.5. This was achieved by applying upper and lower limits to model hydraulic parameters based upon available data in the automated (PEST) calibration process. The calibrated values were subsequently checked during transient verification.

Initial parameters for the Namoi Alluvium were obtained directly from NOW's previously-calibrated Upper Namoi groundwater flow model; these are spatially-variable (except S_y of the Gunnedah Fm) and hence a single multiplier was used to up- or down-scale each of these parameter arrays to calibrate the Project model with numerical efficiency.

The Clare Sandstone (layer 6) and Hoskissons Seam (layer 8) were assigned spatially variable depth-dependent horizontal and vertical hydraulic conductivity, based on trends in measured conductivity data (see Section 2.6.5). These arrays were calibrated using a single horizontal conductivity multiplier for each layer. The resulting horizontal conductivity arrays were used to generate vertical conductivity arrays using a single factor for each layer.

As noted in Section 3.3.2, recharge rates to the Tertiary Basalts and Jurassic to Permian formations were calibrated as factors of the model-wide average recharge to the Namoi Alluvium in each stress period (of 3 months duration in the transient model).

3.6.2 Results

Transient verification hydrographs are presented in Attachment D. Both steady-state and transient head verification performance is good (and Figure 31) at 3.0% and 3.4% Scaled Root Mean Square error (SRMS), respectively. These are both below the target 10% and 5% SRMS objectives suggested in the MDBC flow model guideline (MDBC, 2001). The 2012 Australian Groundwater Modelling Guidelines (Barnett *et al.*, 2012) warn against prescriptive performance targets but note that "*Targets such as SRMS < 5% or SRMS < 10% ... may provide useful guides*". The vast majority of calibrated model heads were within 10 m of observed values, and 75% within 5 m and 35% within 2 m (Figure 31). There is no significant bias in the modelled groundwater levels, with the exception of those at the lower (northern) end of the model, where the model boundary is adversely affecting heads and gradients in the alluvials (see the lower left scatter in Figure 31). This is well beyond the probable area of influence of the Project, and hence bears no consequences for model reliability in this regard.

Figure 32 presents the calibrated steady state and transient (end December 2013) modelled water table, and a map of average head calibration error at each piezometer throughout the model domain. In general, the head calibration is better within the alluvials. Head errors increase in the Permo-Triassic units within the EL6505, and in the south of the model in the Tertiary basalts.

3.6.3 Calibrated Model Water Balances

Modelled mass balance error was good at less than 1% for all models in all stress periods, which is within the typically acceptable range.

There are multiple opportunities for groundwater to discharge from and recharge to the groundwater system. Those implemented in the model include:

- ❑ Baseflow to and leakage from streams (represented by the Stream Flow Routing cells in MODFLOW-SURFACT);
- ❑ Evapotranspiration from shallow groundwater (represented by Evapotranspiration cells in MODFLOW-SURFACT); and
- ❑ Groundwater use (represented by Fracture Wells in MODFLOW-SURFACT).

The water balance for the steady state calibration model across the entire model area is summarised in Table 20. The total inflow (recharge) to the groundwater system is approximately 297 ML/day, comprising rainfall recharge (88%), and leakage from streams into groundwater (12%). Groundwater discharge is dominated by baseflow to streams (55%), followed by evapotranspiration (45%).

Table 20 Calibrated Steady State Water Balance

Component	Inflow (ML/day)	Outflow (ML/day)
Recharge (Direct Rainfall)	262.8	0.0
ET (Evapotranspiration)	0.0	134.2
Wells	0.0	0.0
Streams (Leakage/Baseflow)	34.2	162.8
Total	297.0	297.0

Model run CARv2SS012

Source: D:\HydroSim\CAR001\GWModel\CARv2SS\Output\CARv2SS009\CARv2SS009.out

The transient verified model water balance is summarised in Table 21, for the entire modelled time period, and for the last 10 years. The total long term average inflow (recharge) to the total regional groundwater system is approximately 589 ML/day, comprising rainfall recharge (64%), release from groundwater storage (29%), and leakage from streams into groundwater (8%). Groundwater discharge is dominated by baseflow to streams and evapotranspiration (30% each), followed by water entering groundwater storage (24%) and groundwater pumping (16%).

Table 21 Calibrated Transient Water Balance

Component	Average 1980-2013		Average 2003-2013	
	Inflow (ML/day)	Outflow (ML/day)	Inflow (ML/day)	Outflow (ML/day)
Recharge (Direct Rainfall)	375.5	0.0	360.9	0.0
ET (Evapotranspiration)	0.0	176.7	0.0	157.2
Bores/Wells	0.0	92.9	0.0	82.2
Streams (Leakage/Baseflow)	44.6	177.7	48.3	164.9
Storage	168.6	141.3	117.2	122.0
Total	588.7	588.6	526.4	526.3*

* Imbalance due to rounding; run CARv2TR021.

Source:

D:\HydroSim\CAR001\GWModel\CARv2TR\Processing\Calibration\Budget\CARv2TR021zbud_out.xlsx

3.7 CALIBRATED MODEL PARAMETERS

Calibrated model parameters are presented in Table 23 and Table 24. A comparison between the initial and calibrated parameters is presented in Table 22. In terms of horizontal hydraulic conductivities, most are comparable to the starting values presented in Table 18, although the calibrated values are less than the initial values adopted. The exceptions to this are minor increases in the shallow units (Gunnedah Formation, Regolith, Tertiary basalts) and the basal Pamboola Fm. The same pattern is seen for vertical hydraulic conductivities.

The general trend towards lower conductivities is in agreement with the core hydraulic conductivity data (Figure 20, Figure 21, Figure 22), and suggests that the rock matrix hydraulic conductivities form the dominant regional flow controls, rather than fracture conductivities. This could be due to limited regional interconnection between rock fracture networks.

Calibrated recharge rates (average 1980-2013) are approximately 20 mm/year (around 3% of rainfall) to the alluvium, 44 mm/year to the Tertiary basalts (around 5% of rainfall), and 3-4 mm/year (1% of rainfall) to the Jurassic, Triassic and Permian outcrop. These values are in agreement with the observed fluctuations in groundwater levels in the alluvium, the lack of seasonal trends observed in the available record for the Permian units (see Attachment D), and the contrast in relative hydraulic conductivities of each of these units. They are also in agreement with the earlier work of Merrick (2001) and McNeilage (2006).

Table 22 Comparison of Calibrated and Initial Hydraulic Properties of Hydrostratigraphic Units

Layer	Zone	Hydrostratigraphic Unit (HSU)	Kx (m/day)		Kz (m/day)		Sy		Ss (/m)y	
			Initial	Calibrated	Initial	Calibrated	Initial	Calibrated	Initial	Calibrated
1	101	Narrabri Fm	5.86E+00 *	3.50E+00 *	8.00E-03 *	1.20E-03 *	5.21E-02 *	5.21E-02 *	5.21E-02	5.21E-02
2	201	Gunnedah Fm	1.03E+01 *	1.35E+01 *	8.00E-03 *	9.59E-03 *	3.00E-01	3.00E-01	3.54E-04 *	2.60E-04 *
2	102	Regolith	2.40E-02	1.29E-01	1.20E-03	6.73E-02	1.20E-02	1.28E-02	1.00E-04	1.28E-02
3	3	Tertiary (Liverpool Range) Volcanics	1.50E+00	1.70E+00	5.00E-01	4.82E-01	2.87E-03	2.87E-03	1.80E-05	1.80E-05
4	4	Jurassic Formations	1.00E-03	4.62E-04	5.00E-04	1.72E-06	3.58E-03	3.58E-03	1.19E-04	1.19E-05
5	5	Napperby Fm to Wallala Fm	1.00E-03	3.21E-04	5.00E-04	1.39E-06	5.67E-04	5.67E-04	8.25E-06	8.25E-07
6	6	Clare Sandstone	2.63E-02 #	7.60E-04	1.32E-02 #	7.58E-06	1.75E-03	1.75E-03	7.70E-06	7.70E-07
7	7	Benelabri Fm to Hoskissons Seam roof	1.00E-03	6.26E-04	5.00E-04	4.87E-06	5.72E-04	5.72E-04	9.05E-07	9.05E-08
8	8	Hoskissons Seam	1.00E-02 #	1.00E-02	1.00E-02 #	6.96E-05	7.35E-03	7.35E-03	7.95E-06	7.95E-07
9	9	Arkarula Fm to Melvilles Seam Floor (Pamboola Fm)	1.00E-03	2.09E-03	5.00E-04	1.94E-05	1.70E-04	1.70E-04	9.17E-07	9.17E-08

* Average of spatially variable parameter across model domain

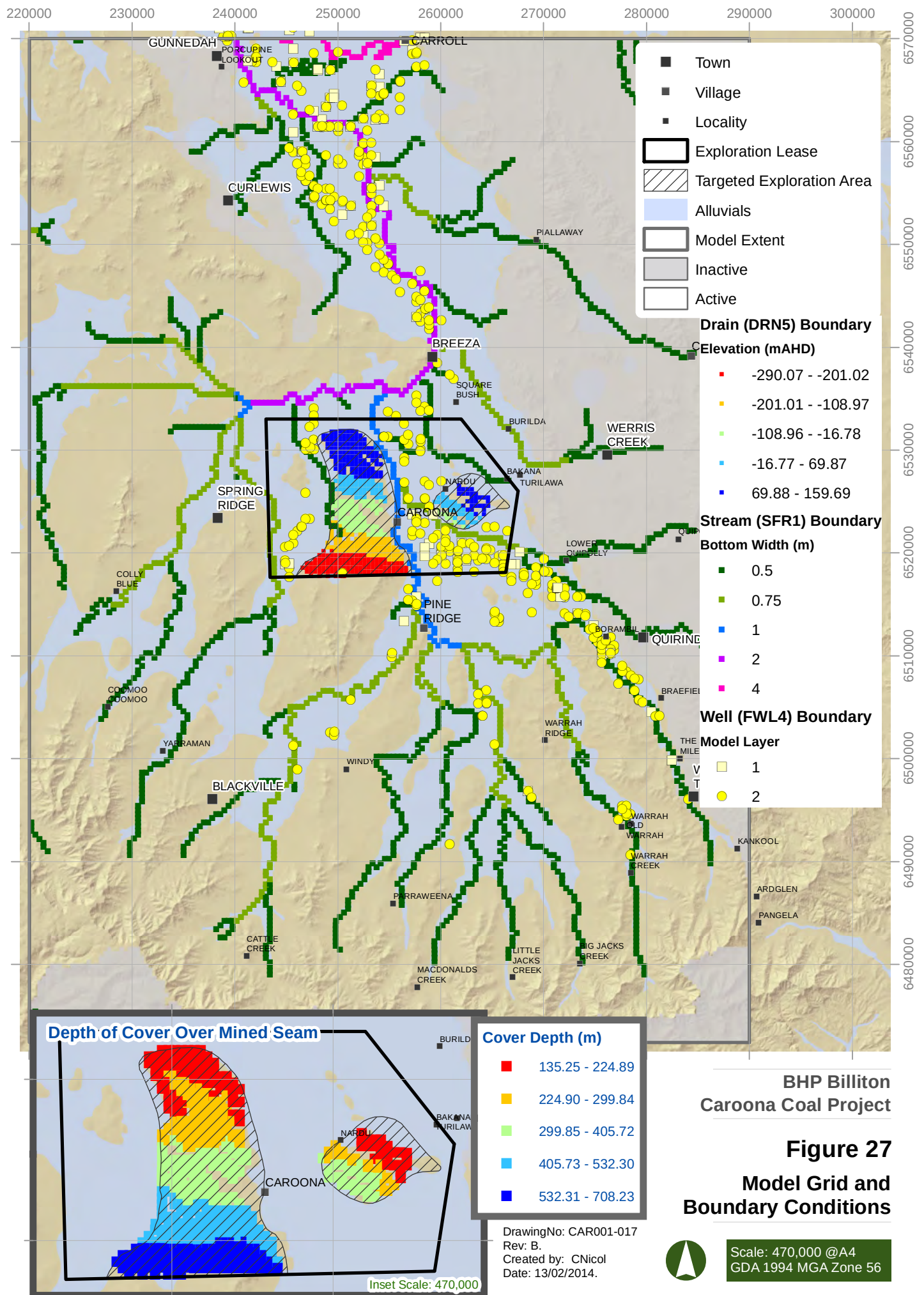
Average of spatially variable parameter across Carroona EL6505 area

Model run 21

Source: D:\HydroSim\CAR001\GWModel\Construction\Properties\CARv2_CalibratedModel_Parameters.xlsx

3.7.1 Calibration Sensitivity Analysis

Figure 33 presents the composite sensitivity of all model parameters used to calibrate the models, as determined by PEST (Doherty, 2010). It is clear that the sensitivity of the calibration to alluvium hydraulic conductivity is greatest, followed by the horizontal and vertical hydraulic conductivities of regolith and Tertiary basalts, in addition to recharge to the Tertiary basalts and Jurassic to Permian units. The model is relatively insensitive to the majority of the hydraulic properties of the Permo-Triassic units. This is despite ensuring that these data, which are far fewer in number than those for the alluvials (see Table 19), were weighted during calibration so as to contribute a similar order of magnitude to PEST's calibration objective function as contributed by the alluvial data (see Section 3.6.1).



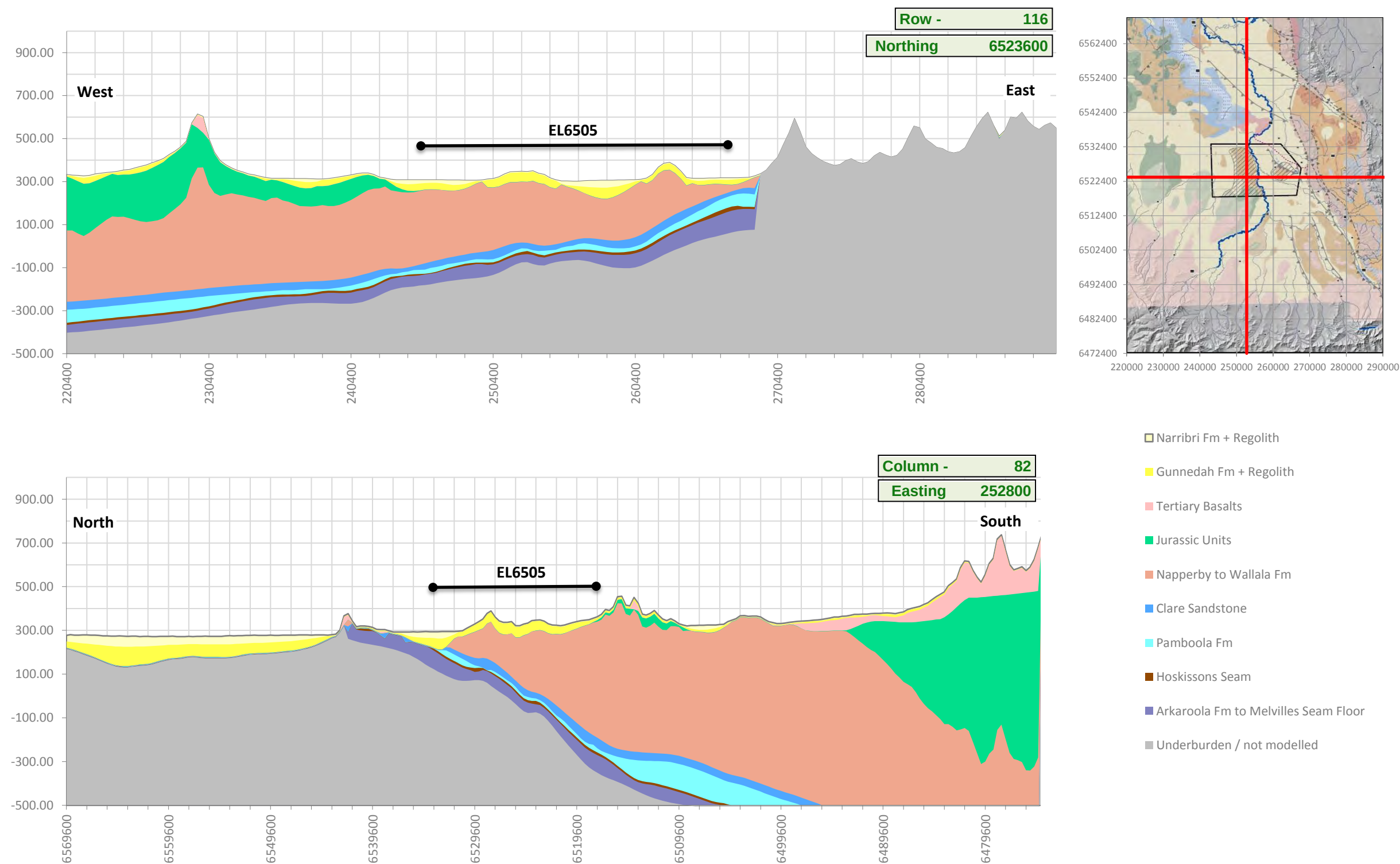


Figure 28 Representative Model Cross-Section

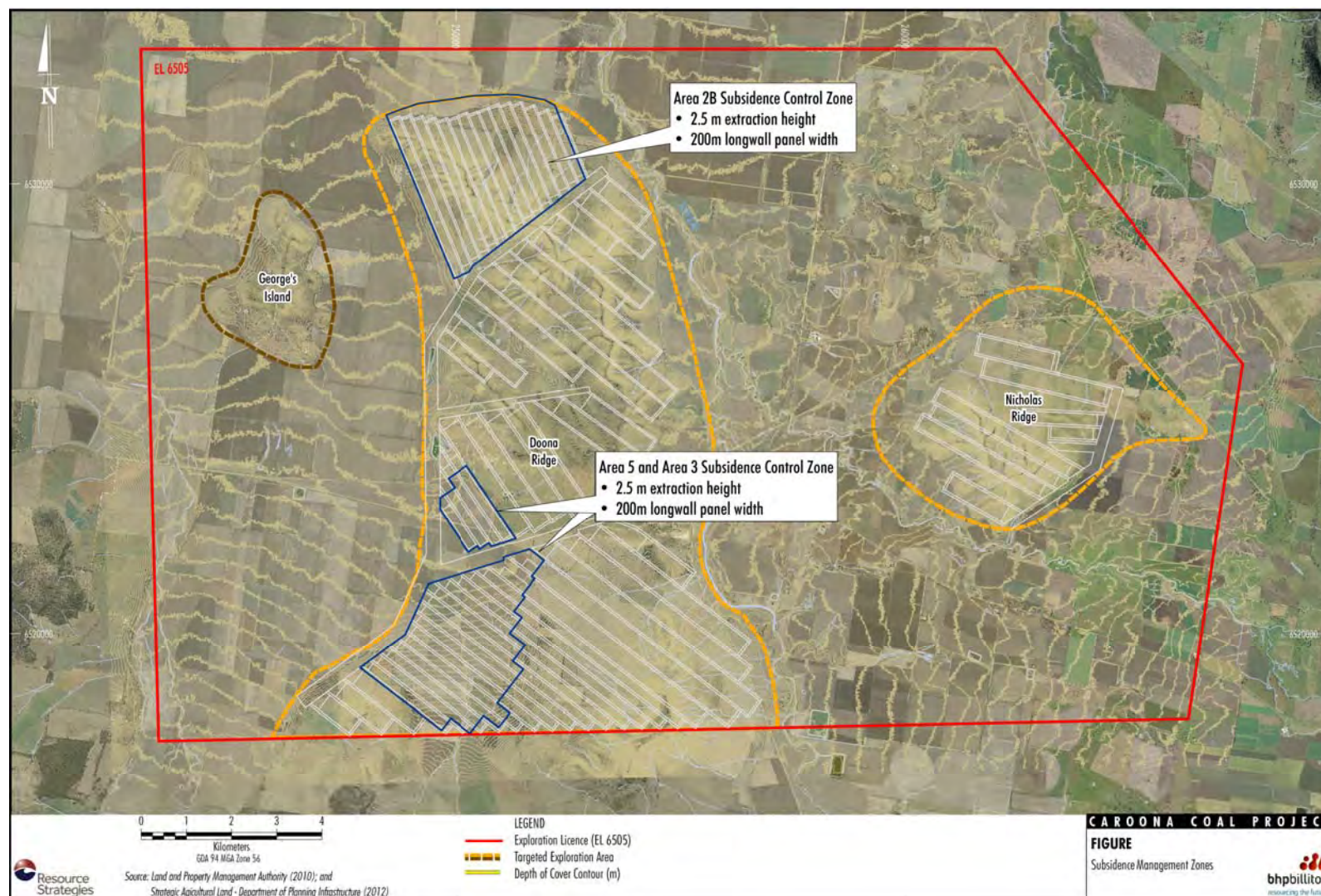


Figure 29 Subsidence Control Zones

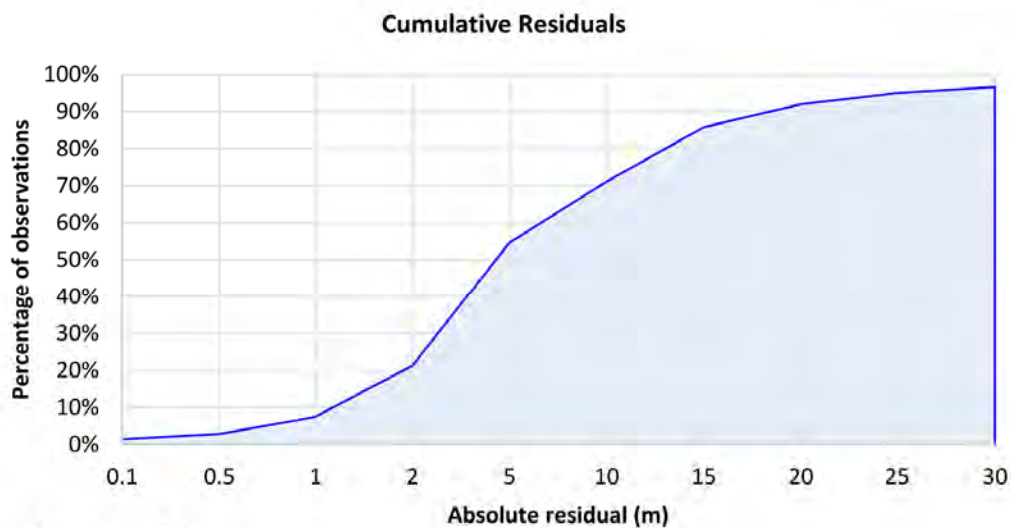
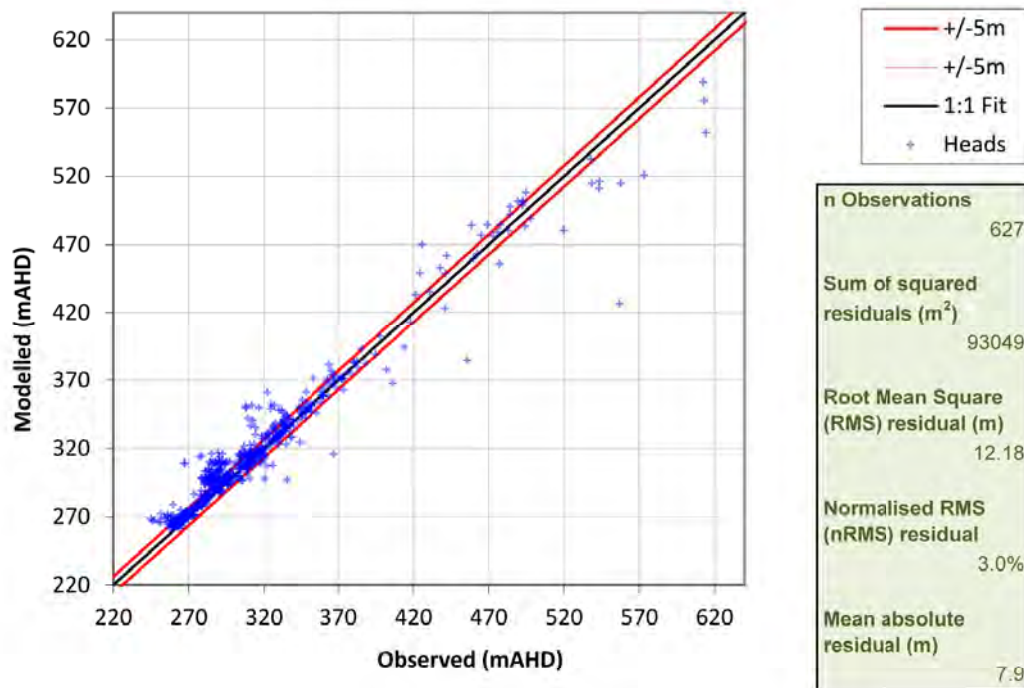


Figure 30 Summary of Steady State Model Calibration

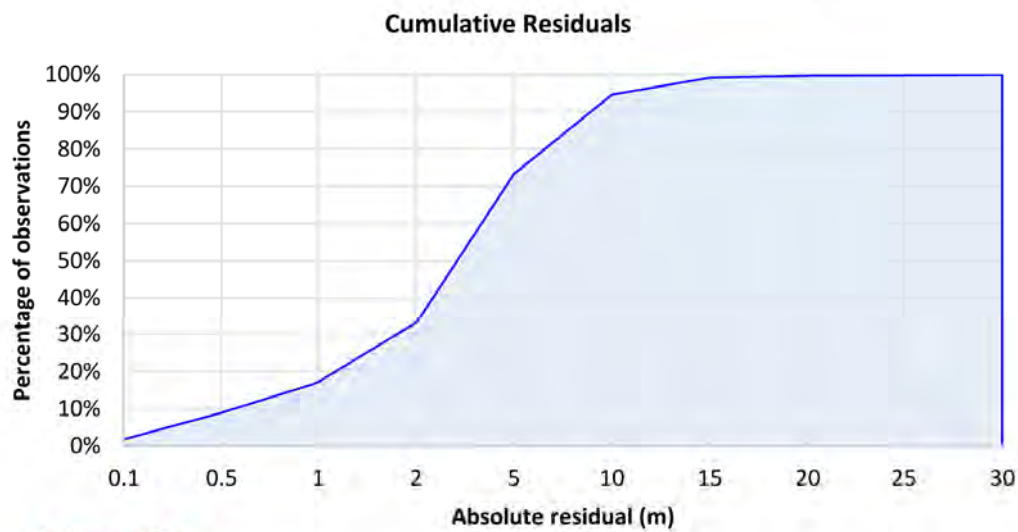
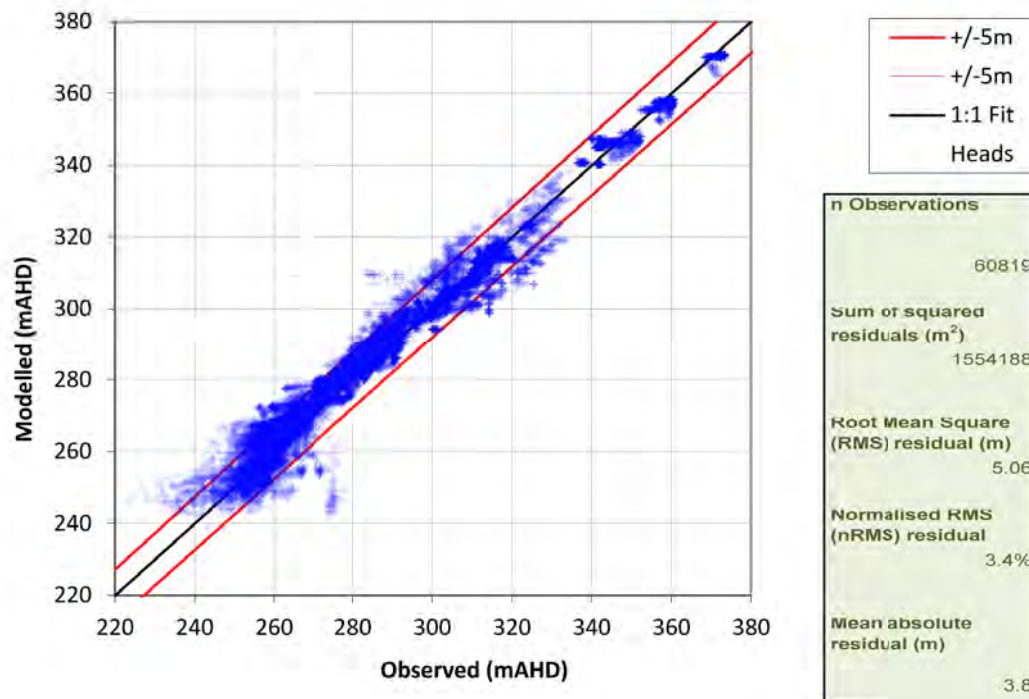
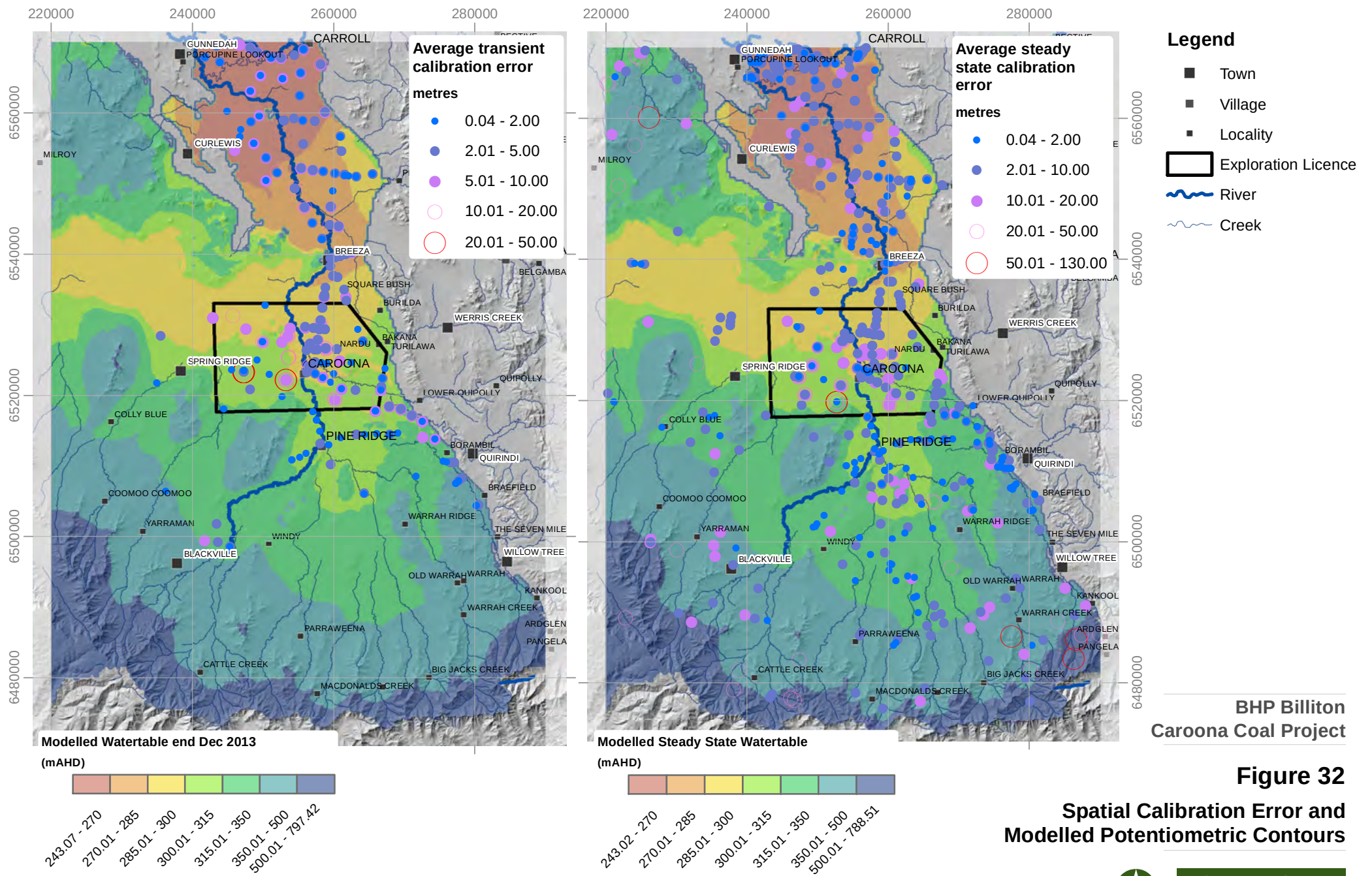


Figure 31 Summary of Transient Model Calibration



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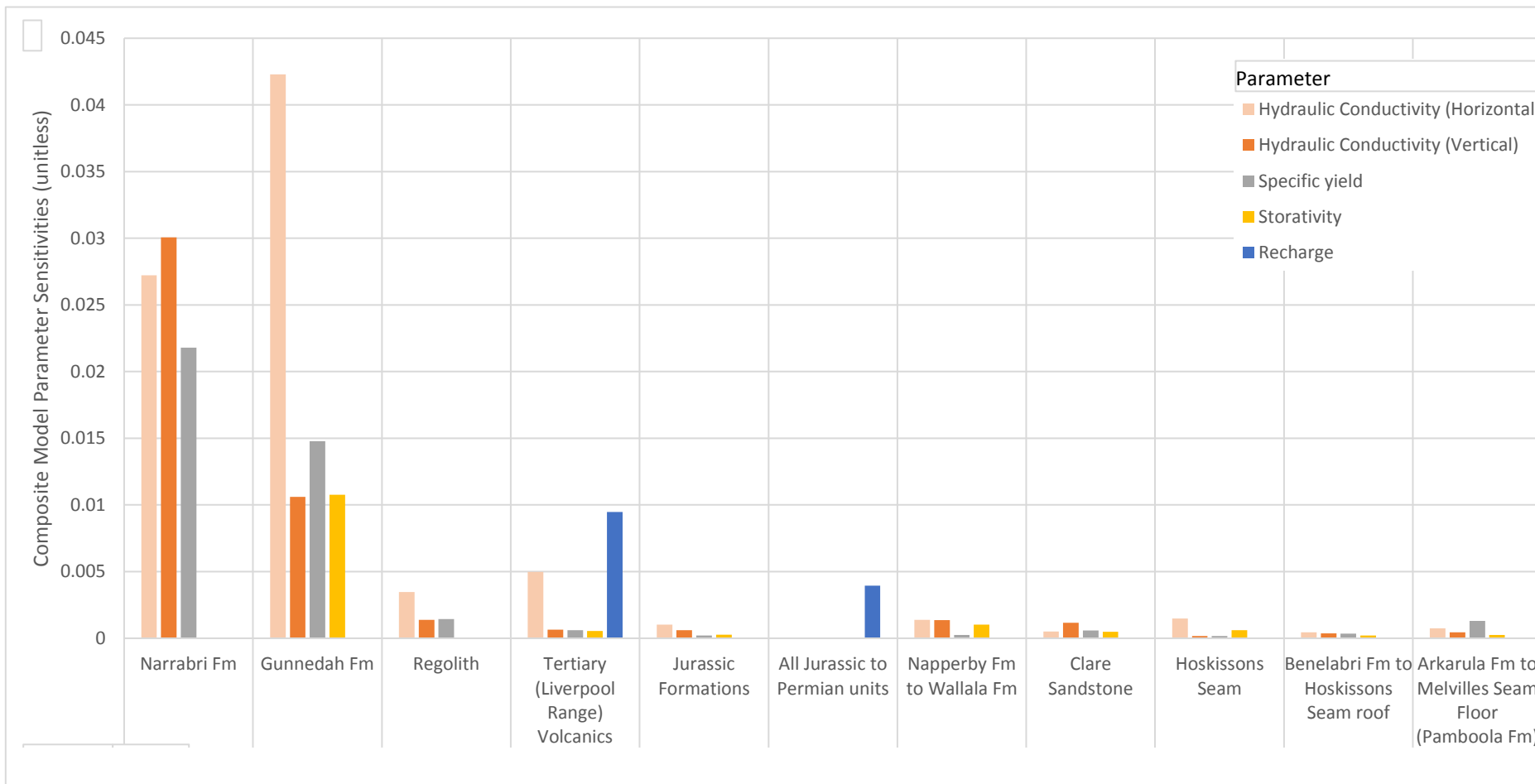


Figure 33 Calibrated Model Parameter Sensitivities

4 PREDICTIVE MODELLING

4.1 MODEL IMPLEMENTATION

The underground mining and inflow and simulated groundwater inflow was simulated using Drain cells within the mined coal seams, with Drain elevations set to 0.1 m above the base of the coal seam. These Drain cells were applied wherever workings occur, and were applied progressively over time increments in accordance with the stress period durations. The model setup involved changing the parameters with time in the goaf and overlying fractured zones directly after mining of each panel (see Section 4.1.1), whilst simultaneously activating Drain cells along development headings. The main roadway headings were activated in advance of the active mining and subsequent subsidence (see Figure 34).

4.1.1 Fractured Zone Implementation

Section 2.7 provides background and conceptual information on the impact of mining on the properties of overburden.

For fractured zones during the prediction period, the hydraulic parameters were changed using the TMP package of MODFLOW-SURFACT which allows varying property values to be applied over time. Fracturing was instigated by altering host rock calibrated hydraulic properties in accordance with mine progression.

The layer resolution within the model allowed the mined coal seam to be represented in model layer 8, with the other layers above it available to simulate the fractured zone to specific heights. This ensured that the impact of progressive caving and fracturing associated with the mining was adequately represented in the model.

The Project longwall panels are primarily 400 m void width, with 200 m widths in the subsidence control zones (Figure 29). Hence the fracture zone height was assumed to be 240 m, with about 120 m fracture heights in the subsidence control zones (assuming 60% of panel width). As the median depth of cover for the Hoskissons seam across the proposed mining area is 360 m, fracturing is unlikely to reach ground surface over significant areas. 240 m and 120 m fracture zone heights have been assumed for this Project's numerical modelling of 400 m width and 200 m width panels, respectively. More detailed investigation of the height of fracturing will be conducted for the EIS.

The fractured zone was simulated with horizontal hydraulic conductivity enhanced by a factor of two (or to 10 m/day within the caved and mined zones). Vertical hydraulic conductivity was enhanced according to a log-linear monotonic (ramp)

function. The function varied the vertical hydraulic conductivity field within the deformation zone overlying coal extraction areas and weighted the hydraulic conductivity changes on layer thickness. Limits for the variability were governed by predicted fracture height and assigned upper and lower bounds on hydraulic conductivity in the fractured zone. Assigned fractured zone properties are presented in Table 23 and Table 24. Note that these were calculated from steady state calibrated model host⁴ (pre-mine calibrated) parameter values.

The hydraulic conductivity of the model layer directly beneath underground mined areas was also increased with a uniform increase in vertical hydraulic conductivity of 3 x host values being applied.

Similarly, horizontal hydraulic conductivity of the underlying layer was increased by a factor of 2 x the host (pre-mine calibrated) values. The assumption was made that this only affects the upper 30 m of underlying rock, and as such the conductivity increase was thickness-weighted accordingly.

Sy was also increased in the coal seam layer to 10% for the longwalls, which represents the void after roof supports have been removed and the rock above has collapsed into the void. For the layers above each mined coal seam Sy was increased according to the extension of the rock mass and increase in porosity due to caving-induced subsidence above each longwall panel. Caving was assumed to occur over a height equal to 10 x the mined seam thickness. Because caved zones often only intersect part of a model layer, caving-induced alteration of the affected model layer's hydraulic properties was weighted by the height of the caved zone within the layer. The caving-induced increase in porosity (and Sy) was assigned to the affected layer by thickness-weighting the deformed (fractured/caved) and host (non-fractured/non-caved) porosities. The assigned fractured zone properties are presented in Table 23 and Table 24. Note that these were calculated from calibrated model host parameter values.

Ss values were also increased in the mined seam and within the overlying caved zone by applying an increase in the rock porosity component of the Ss parameter, in the same manner as defined above for Sy (see Table 23 and Table 24).

⁴ "Host" rock is a term used to describe the strata in its state when unaffected by mining-induced caving. I.e. its state prior to caving and enhanced fracturing due to mine void development. Caving and fracturing resulting from longwall mining alters host rock hydraulic properties (i.e. hydraulic conductivity and porosity).

Table 23 **Modelled Hydraulic Properties within the Fractured Zone**

Layer	Zone	Hydrostratigraphic Unit (HSU)	Host Kx (m/day)	Deformed Kx (m/day)	Host Kz (m/day)	Deformed Kz (m/day)	Host Sy	Deformed Sy	Host Ss (/m)	Deformed Ss (/m)
1	101	Narrabri Fm	3.50E+00 *	N/A	1.20E-03 *	N/A	5.21E-02 *	N/A	5.21E-02	N/A
2	201	Gunnedah Fm	1.35E+01 *	N/A	9.59E-03 *	N/A	3.00E-01	N/A	2.60E-04 *	N/A
2	102	Regolith	1.29E-01	N/A	6.73E-02	N/A	1.28E-02	N/A	1.28E-02	N/A
3	3	Tertiary (Liverpool Range) Volcanics	1.70E+00	N/A	4.82E-01	N/A	2.87E-03	N/A	1.80E-05	N/A
4	4	Jurassic Formations	4.62E-04	N/A	1.72E-06	N/A	3.58E-03	N/A	1.19E-05	N/A
5	5	Napperby Fm to Wallala Fm	3.21E-04	5.02E-04	1.39E-06	7.51E-06	5.67E-04	N/A	8.25E-07	N/A
6	6	Clare Sandstone	7.60E-04 #	1.52E-03	7.58E-06 #	1.30E-04	1.75E-03	4.29E-02	7.70E-07	9.72E-07
7	7	Benelabri Fm to Hoskissons Seam roof	6.26E-04	2.00E-02	4.87E-06	2.02E-04	5.72E-04	4.82E-02	9.05E-08	3.24E-07
8	8	Hoskissons Seam	1.00E-02 #	1.00E+01	6.96E-05 #	1.00E+01	7.35E-03	1.00E-01	7.95E-07	1.25E-06
9	9	Arkarula Fm to Melvilles Seam Floor (Pamboola Fm)	2.09E-03	4.19E-03	1.94E-05	5.81E-05	1.70E-04	N/A	9.17E-08	N/A

* Average of spatially variable parameter across model domain;

Average of spatially variable parameter across Caroon EL6505 area

N/A means that the fractured zone does not reach this layer.

Model run 23

Source: D:\HydroSim\CAR001\GWModel\Construction\Properties\CARv2_CalibratedModel_Parameters_V2.xlsx

Table 24 **Modelled Hydraulic Properties within the Fractured Zone (Subsidence Control Zones)**

Layer	Zone	Hydrostratigraphic Unit (HSU)	Pre-mine Kx (m/day)	Deformed Kx (m/day)	Pre-mine Kz (m/day)	Deformed Kz (m/day)	Pre-mine Sy	Deformed Sy	Pre-mine Ss (/m)	Deformed Ss (/m)
1	101	Narrabri Fm	3.50E+00 *	N/A	1.20E-03 *	N/A	5.21E-02 *	N/A	5.21E-02	N/A
2	201	Gunnedah Fm	1.35E+01 *	N/A	9.59E-03 *	N/A	3.00E-01	N/A	2.60E-04 *	N/A
2	102	Regolith	1.29E-01	N/A	6.73E-02	N/A	1.28E-02	N/A	1.28E-02	N/A
3	3	Tertiary (Liverpool Range) Volcanics	1.70E+00	N/A	4.82E-01	N/A	2.87E-03	N/A	1.80E-05	N/A
4	4	Jurassic Formations	4.62E-04	N/A	1.72E-06	N/A	3.58E-03	N/A	1.19E-05	N/A
5	5	Napperby Fm to Wallala Fm	3.21E-04	3.91E-04	1.39E-06	2.01E-06	5.67E-04	N/A	8.25E-07	N/A
6	6	Clare Sandstone	7.60E-04 #	1.52E-03	7.58E-06 #	7.47E-05	1.75E-03	1.56E-02	7.70E-07	8.38E-07
7	7	Benelabri Fm to Hoskissons Seam roof	6.26E-04	2.00E-02	4.87E-06	1.82E-04	5.72E-04	4.82E-02	9.05E-08	3.24E-07
8	8	Hoskissons Seam	1.00E-02 #	1.00E+01	6.96E-05 #	1.00E+01	7.35E-03	1.00E-01	7.95E-07	1.25E-06
9	9	Arkarula Fm to Melvilles Seam Floor (Pamboola Fm)	2.09E-03	4.19E-03	1.94E-05	5.81E-05	1.70E-04	N/A	9.17E-08	N/A

* Average of spatially variable parameter across model domain;

Average of spatially variable parameter across Caroon EL6505 area

Model run 23

Source: D:\HydroSim\CAR001\GWModel\Construction\Properties\CARv2_CalibratedModel_Parameters.xlsx

4.2 MINE SCHEDULE

A summary of the mining schedule that was used in the Project groundwater model is provided in Figure 34. This figure outlines the stress period setup for the mining period of the transient predictive model run. The prediction period runs for 30 years of the proposed active mine life, followed by 280 years of post-mining recovery modelling (an arbitrary period of 280 years was assigned to simulate the recovery of water levels following the cessation of mining). For this preliminary groundwater assessment, the first 35 years of the simulation comprised annual stress periods to match the scheduled longwall extraction as closely as is reasonably practical given the level of the current assessment. The 280 year recovery period was subdivided into 15 stress periods as outlined in Table 25.

Table 25 Predictive Model Time Discretisation

Stress Period	Period Duration (years)	Cumulative Time (years)	Comment
1-30	Annual	30	Active mining phase
31-35	Annual	35	First 5 years post-mine closure
36	5	40	
37	10	50	
38	20	70	
39	20	90	
40	20	110	
41	20	130	
42	20	150	
43	20	170	
44	20	190	
45	20	210	
46	20	230	
47	20	250	
48	20	270	
49	20	290	
50	20	310	

4.3 IMPACT ASSESSMENT APPROACH

The potential impacts of the development were assessed by making comparisons between baseline predictive runs (with no Project) and impacted predictive runs (with the Project simulated using Drain boundaries and TMP package as per Figure 34 and outlined in Section 4.1.1). This allows the simulated impact of the development on the hydrogeological environment to be isolated from other model processes (such as changes in groundwater levels due to changes in recharge and/or groundwater use).

4.4 SIMULATED MINE INFLOWS

Model predicted inflows are shown in Figure 35 for the Project. The inflow rates are predicted to increase relatively linearly over the first 12 years of operation from about 2-3 ML/day at the start of underground mining activities to a peak of about 6-7 ML/day in years 6, 8, 11 and 12, with rates dropping down to 3-4 ML/day between these years. Inflows then fall suddenly to around 1-3 ML/day in years 13 to 16, after which rates rise back up to around 4 ML/day to year 30. The simulated drop in inflows in years 13-16 is due to a combination of years with relatively small mined areas (upper chart in Figure 35), and the fact that in these years the mining of Area 3 (Figure 34) passes immediately south of Area 2S, which had been dewatered over years 6 to 10. The rise in inflows in years 17-21 appears to be due to a large actively mined area in the south of Doona Ridge, which has not experienced any earlier mining activity.

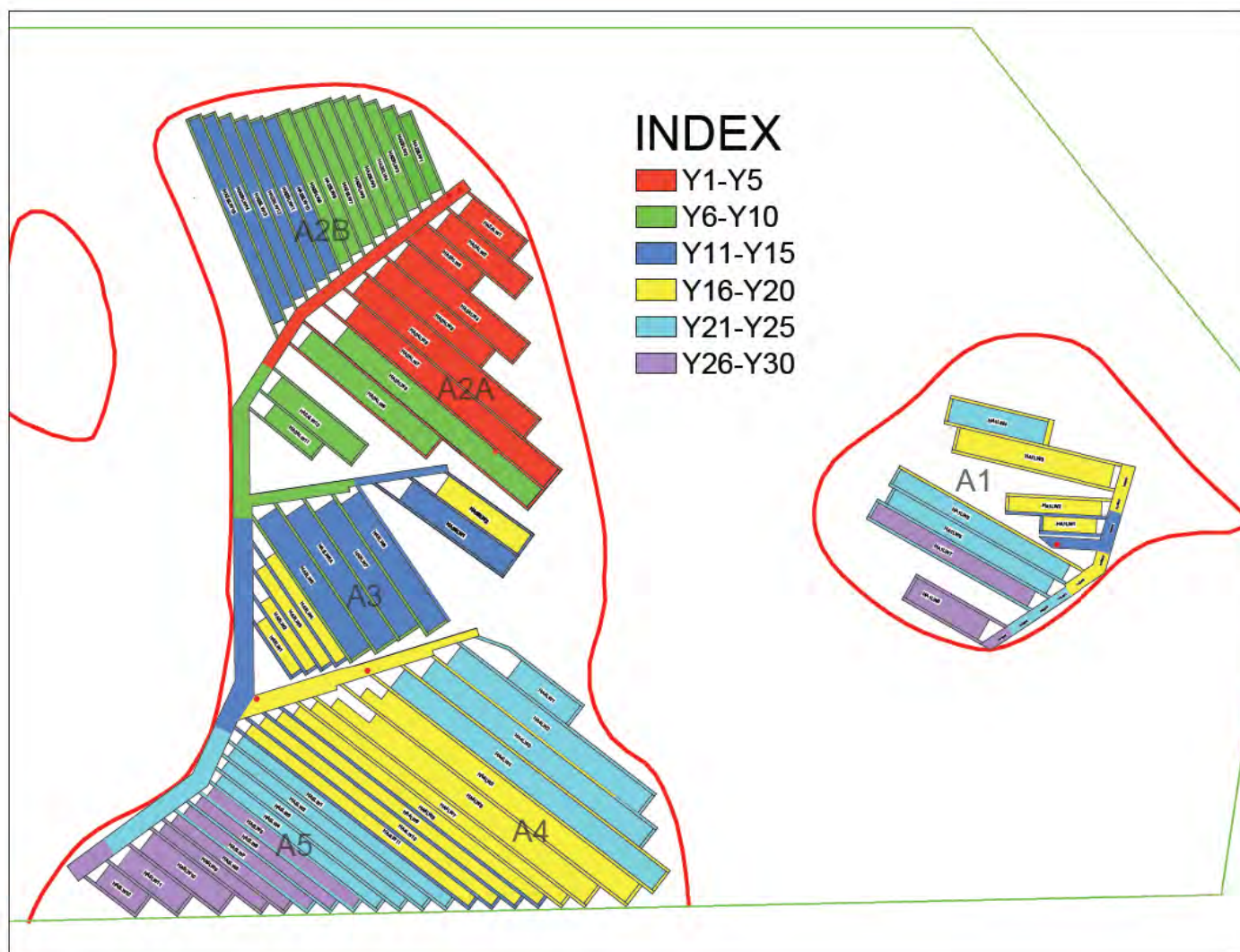


Figure 34 Modelled Mine Schedule

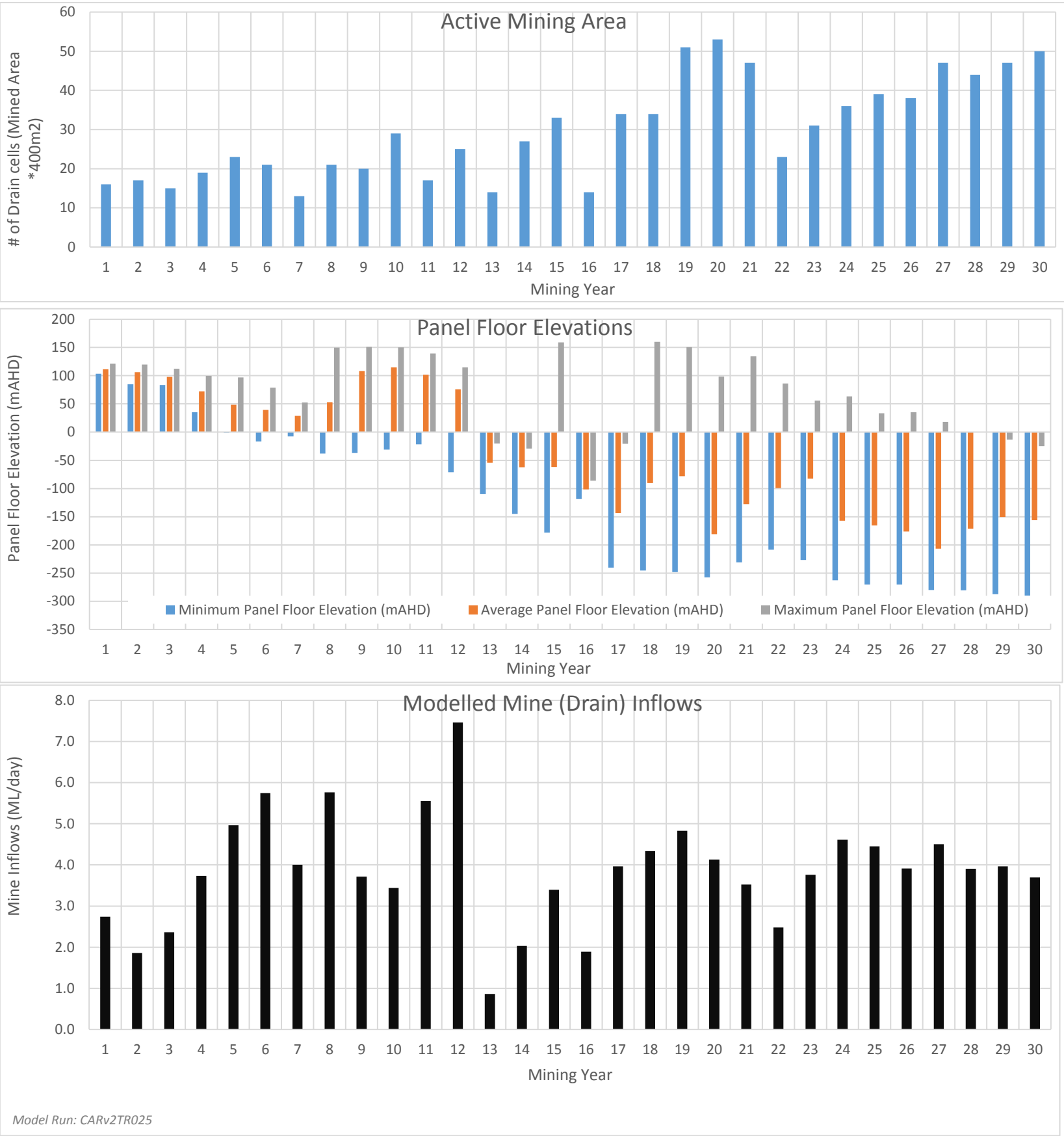


Figure 35 Modelled Mine Groundwater Inflows

5 POTENTIAL IMPACTS

5.1 FRAMEWORK FOR ASSESSMENT

This assessment will focus on the requirements of AI Policy and the Gateway Application (Table 1). The potential changes to the groundwater system as a result of the Project (Section 2.7.6) will contribute to cumulative impacts (i.e. including those of other projects). The potential impacts of the Watermark Project (AGE, 2012), located immediately north of EL6505, are those most likely to form the largest cumulative contribution to those of the Caroona Project. In this Preliminary Groundwater Assessment for the Gateway Application, the approach of addition of impacts from both the Watermark and Caroona Projects has been applied. Further more extensive modelling of cumulative impacts (including consideration of possible coal seam gas extraction) is provided in the Namoi Catchment Water Study (SWS, 2012).

5.2 POTENTIAL CHANGES IN BASEFLOW TO THE MOOKI RIVER

As described in Section 2.6.6, the Mooki River between Caroona and Breeza is referred to as a 'losing system', where water is generally 'lost' from the river during periods of lower flow. Many groundwater level hydrographs in the Namoi Alluvium (Attachment D) indicate that levels in the vicinity of the Mooki River have dropped by 10-15 m since 1980, which is likely in response to the significantly increasing groundwater usage over that time. This effect could have potentially altered the system's status with regard to pre-groundwater development baseflow gains and losses along the Mooki River.

Figure 36 presents the simulated potential reductions in baseflow to the Mooki River at two locations: the Caroona flow gauge (#419034) and downstream at the Breeza flow gauge (#419027). The reductions in baseflow are simulated to primarily occur between the Caroona and Breeza gauges, with potentially significant low flow implications for flows at Breeza and downstream, given that the simulated baseflow reductions form a significant portion of the 70th percentile flow exceedance at Breeza during peak impact, and given that there are no flows at the Breeza gauge around 20% of the time (see Figure 9); these simulated potential impacts could increase the duration of no flow periods, and/or their frequency.

In terms of cumulative baseflow impacts, the Watermark Project (AGE, 2012) simulated Mooki River reductions peaking at 0.15 ML/day. This is significantly lower than those of the Project (0.7 ML/day), because the simulated Watermark Project drawdowns do not reach significant distances into the alluvial aquifer, nor do they reach significant levels in the Mooki alluvial plain, which is where the simulated baseflow reductions of the Caroona Project are primarily manifested. The impacts of Watermark and Caroona are likely to impact upon stream flows cumulatively. Assuming that peak impacts of both projects occur at the same time, cumulative peak baseflow reduction could be as high as 0.9 ML/day.

The Permian coal measures within the mine footprint are simulated to be significantly depressurised during mining of the target coal seam. Outside the mine

footprint, there will be less influence on the potentiometric surface within Permo-Triassic strata and overlying units.

The modelled drawdowns of the proposed mine development are presented in Figure 37 to Figure 41 for all model layers. Each of these figures presents:

- The maximum modelled drawdown in each model layer; and
- Simulated residual drawdown 280 years after the cessation of mining.

In each of these figures, the modelled 2 m drawdown contour is also shown. This is the maximum allowable drawdown interference in accordance with the AI Policy. Following is a description of the simulated drawdowns in each model layer.

Modelled drawdown in layers 1 and 2 (Narrabri Fm and Gunnedah Fm; Namoi Alluvium) is of limited magnitude and spatial extent, particularly in layer 1, with no areas of modelled maximum drawdown greater than 2 m (Figure 37). In layer 2, there is a small area of maximum modelled drawdown of around 2 m within the regolith in the northern end of Doona Ridge.

Most groundwater pumping bores in the area screen the Gunnedah Formation, and as such bore interference greater than the AI criterion of 2 m drawdown is not breached for this formation. At the end of the modelled time period, 280 years post-mining, groundwater levels in layers 1 and 2 have fully recovered (Figure 37).

Modelled maximum drawdown within model layer 3 (Tertiary basalt) is less than 2 m (see Figure 38). Modelled maximum drawdowns do however influence the Jurassic formations (Spring Ridge Management Zone) in layer 4 by more than 2 m (Figure 38), primarily in the south and southwest of Doona Ridge. This affects a number of registered bores in this area in excess of the AI drawdown criterion of 2 m.

In layers 5 through 7 (Permo-Triassic formations overlying the Hoskissons seam), simulated drawdowns extend up to about 15-20 km from the EL6505 boundary, particularly to the south and north-west (see Figure 39 and Figure 40). This results in some vertical leakage down from the Jurassic strata (Spring Ridge Management Zone) into the Permo-Triassic strata (Gunnedah-Oxley Basin MDB (Other) Management Zone).

In model layers 8 and 9 (Hoskissons seam and Permian underburden), modelled maximum drawdowns exceed 2 m over the lease area and extend up to 30 km to the south, and up to 10 km to the north/northwest (Figure 40 and Figure 41). These are the layers in which simulated drawdown reaches its greatest extent. At the end of the model simulation (recovery period), water levels in these layers have almost wholly recovered, with a few small remaining areas of around 2 m drawdown that may affect existing bores in shallow Permian subcrop in the east.

5.3 EXISTING GROUNDWATER USERS

The simulated maximum drawdown effects of the Project, in addition to the potential cumulative effects of surrounding projects on existing groundwater bores

in ‘highly productive’ groundwater in the region are presented in Table 27 (bores indicated to be in-use in NOW’s Pinneena database) and Table 28 (bore census bores). It should be noted that the drawdown values in these tables are the maximum impact attained in the predictive model and would not occur at the same time.

Stage 1 of the Bore Census was undertaken by Groundwater Exploration Services (2014) for BHP Billiton. Stage 1 of the bore census was undertaken with landholders within the Project’s targeted exploration area and included:

- ❑ Meeting with interested landowners who have bores and wish to participate in the bore census (i.e. provide basic details about their bores).
- ❑ Inspecting approximately 100 bores in the vicinity of the Project (with the permission of the relevant landowner) and recording where possible, information such as their location, current groundwater level, water quality and other construction/water usage details and taking a photograph.

Bores visited during Stage 1 of the bore census with a predicted drawdown of greater than 2 m located within ‘highly productive’ groundwater are shown in Table 28. Bores in ‘less productive’ water sources having more than 2 m simulated drawdown and located on BSAL are presented in Tables G-1 and G-2 in Attachment G. Bores licensed for exploration or observation have been removed from the table, and bores where no usage data is available remain included, even though many of these are probably exploration or similar (non-water supply) bores.

It should be noted that bores were assigned to model layers (water bearing strata) based on recorded licensing information, bore location, mapped geological outcrop (i.e. the extent of the alluvial aquifer), and recorded bore depths where possible. For these reasons it is possible that some bores have been incorrectly assigned to strata.

A total of 27 highly productive bores are predicted to experience greater than 2 m of drawdown due to the Project. Table 26 also shows that a number of bores in less productive groundwater on BSAL would also be potentially affected by the Project. Of these, none have Water Access Licences, and none are thought to screen models layers 1 (Narrabri Fm/Regolith), 2 (Gunnedah Fm/Regolith), or 3 (Liverpool Range Basalts). The affected bores are either Basic Rights (stock and domestic) bores, or are not used for water supply. Accounting for cumulative impacts of the adjacent Watermark Project by using the simplifying assumption of the Principle of Superposition, the number of impacted bores remains the same.

Consistent with the Namoi Catchment Water Study (SWS, 2012) and the AI Policy, BHP Billiton has committed to “make good” provisions for any groundwater users adversely affected by mine operations and associated impacts – i.e. provision of alternative water supply or remedial works. Such measures would be documented in a Groundwater Management Plan prior to the commencement of longwall mining operations and would include:

- ❑ A Trigger Action Response Plan for identifying groundwater triggers and appropriate actions that would be invoked.

- Identifying mitigation measures including consideration of deepening of existing wells or bores, relocation of the bore to another aquifer and/or provision of an alternate water supply).

In addition, BHP Billiton will conduct a second stage of the bore census in consultation with relevant landholders to confirm the status, location and details of the bores not yet inspected (in Table 27) in order to inform further impact assessment work planned for the EIS.

Table 26 Summary of Simulated Groundwater Bore Drawdowns

Layer	Hydrostratigraphic Unit	Count of Bores with >2m Simulated Drawdown
1	Narrabri Fm / Regolith	0
2	Gunnedah Fm / Regolith	0
3	Tertiary (Liverpool Range) Volcanics	0
4	Jurassic Formations	27
5*	Napperby Fm to Wallala Fm	32
6*	Clare Sandstone	0
7*	Benelabri Fm to Hoskissons Seam roof	0
8*	Hoskissons Seam	0
9*	Arkarula Fm to Melvilles Seam Floor (Pamboola Fm)	2

* Only less productive bores on BSAL reported for less productive groundwater and excludes Shenhua Watermark Coal Pty Ltd bores.

Table 27 **Modelled Drawdown at Registered Groundwater Bores in ‘Highly Productive’ Water Sources**

Work no	Landholder	Property No.	Easting	Northing	Depth (m)	Model layer	Maximum Drawdown (m)	Watermark Drawdown (m)	Cumulative Drawdown (m)
GW048614	Charters HF	22	247999	6519196	35.00	4	13.77	#N/A	13.77
GW068004	Charters HF	22	247732	6519367	24.30	4	8.24	#N/A	8.24
GW013349	Permaid Pty Ltd	121	250275	6516847	34.40	4	3.81	#N/A	3.81
GW020369	Permaid Pty Ltd	121	250171	6515674	42.70	4	3.36	#N/A	3.36
GW066296	G.S.S.H Pty Ltd	72	249480	6514763	27.00	4	3.06	#N/A	3.06
GW008940	Elsley FE	54	240963	6523740	78.60	4	3.00	#N/A	3.00
GW021809	G.S.S.H Pty Ltd	72	249412	6514268	63.10	4	2.89	#N/A	2.89
GW008941	Elsley FE	54	241624	6522647	93.30	4	2.84	#N/A	2.84
GW020593	Permaid Pty Ltd	121	251333	6515701	30.80	4	2.82	#N/A	2.82
GW900329	Brown GW & SL	17	242618	6520169	36.50	4	2.82	#N/A	2.82
GW003459	G.S.S.H Pty Ltd	72	248478	6513599	24.40	4	2.77	#N/A	2.77
GW014626	Tribella Pty Ltd	152	242559	6519064	55.80	4	2.73	#N/A	2.73
GW022213	Tribella Pty Ltd	152	243090	6517875	24.40	4	2.71	#N/A	2.71
GW022049	G.S.S.H Pty Ltd	72	249629	6512948	41.80	4	2.33	#N/A	2.33
GW008944	Mills RA	107	241820	6521141	107.30	4	2.33	#N/A	2.33
GW005909	McHardy R & D	271	240038	6524765	38.10	4	2.25	#N/A	2.25
GW070839	McHardy R & D	271	240014	6524672	40.00	4	2.25	#N/A	2.25
GW021983	G.S.S.H Pty Ltd	72	248343	6512609	42.70	4	2.20	#N/A	2.20
GW008945	Brown GW & SL	17	241071	6519366	33.50	4	2.04	#N/A	2.04
GW038371	Cudmore KM	224	247645	6512007	91.40	4	2.02	#N/A	2.02
GW024751	Minister for Education and Training	285	238980	6523721	61.00	4	2.02	#N/A	2.02

NB: A list of modelled drawdown for bores in ‘less productive’ water sources is provided within Table G-1 of Attachment G of this report.

SOURCE: D:\HydroSim\CAR001\GWMModel\CARv2TR\Processing\Prediction\MaxDDN\CARv2TR025\CARv2TR025_MaxDDNs_Bores_V3.xlsx

Table 28 **Modelled Drawdown at Groundwater Bores in ‘Highly Productive’ Water Sources Identified in the Project Bore Census**

Work No.	Landholder	Property No.	Description	Easting	Northing	Bore in Use?	Purpose	Year Drilled	Depth (m)	Model Layer	Maximum Drawdown (m)	Watermark Drawdown (m)	Cumulative Drawdown (m)
GW017099	Willis SNB & RNB	161	Bore	249102	6517691	No	Stock & Domestic	1958	48.8	4	12.19	#N/A	12.19
GW015671	Willis SNB & RNB	161	Bore	247249	6519160	Yes	Stock & Domestic	1948	33.5	4	9.91	#N/A	9.91
GW038273	Willis SNB & RNB	161	Bore	247286	6517228	No	Stock & Domestic	1974	47.2	4	7.79	#N/A	7.79
GW020446	Willis SNB & RNB	161	Windmill	249094	6516481	Yes	Stock	1963	24.4	4	4.56	#N/A	4.56
GW022576	Willis SNB & RNB	161	Windmill	249043	6516077	No	Stock	1964	22.6	4	4.01	#N/A	4.01
GW017101*	G.S.S.H. Pty Ltd	72	Bore	247515	6515235	Yes	Stock & Domestic	1958	48.8	4	3.73	#N/A	3.73

NB: A list of modelled drawdown for bores in ‘less productive’ water sources identified in the Project Bore Census on BSAL is provided within Table G-2 of Attachment G of this report.

Source: D:\HydroSim\CAR001\GWMModel\CARv2TR\Processing\Prediction\MaxDDN\CARv2TR023\CARv2TR023_MaxDDNs_Bores_V3.xlsx; Groundwater Exploration Services (2014)

** Bore identified during Stage 1 of bore census on Willis property, however, co-ordinates indicate bore is on G.S.S.H. Pty Ltd land. To be confirmed during Stage 2 of bore census.*

5.4 CULTURALLY SIGNIFICANT SITES

At the time of writing there were no Culturally Significant Sites listed in any of the relevant Water Sharing Plans. Hence there are no known risks of mine development to such sites.

5.5 GROUNDWATER DEPENDENT ECOSYSTEMS

At the time of writing there were no high priority GDEs listed in the 'Upper and Lower Namoi Groundwater Sources' (version current for 20 December 2013 to date (accessed 12 January 2014 at 14:07)). Hence there are no known risks of mine development to such ecosystems relevant to this WSP.

In the case of the Liverpool Ranges Basalt, there were no high priority GDEs identified within the model area in the 'NSW Murray Darling Basin Fractured Rock Groundwater Sources 2011' (Current version for 5 July 2013 to date (accessed 12 January 2014 at 14:16)). This plan does however identify one high priority GDE within the model area (Black Spring, Figure 2), but it is ascribed to the New England Fold Belt MDB water source, despite being located on outcropping 'Gunnedah-Oxley Basin MDB (Other)' water source, as reported in the WSP. Regardless, this GDE is ascribed to rocks which underlie those modelled for this project, and hence is not expected to be impacted by the Project.

In the case of the 'NSW Murray Darling Basin Porous Rock Groundwater Sources', there are two high priority GDEs identified in the WSP (Terdar Spring and Treloar Spring, Figure 2). These are located on the 'Gunnedah-Oxley Basin MDB (Spring Ridge)' water source, near the western model boundary. The modelled drawdown impact at these springs is below the considered model accuracy limits (<0.01 m).

5.6 POTENTIAL IMPACTS ON GROUNDWATER QUALITY

Electrical conductivity data for the coal measures suggests a mean EC of around 1,900 $\mu\text{S}/\text{cm}$, ranging from around 300-11,000 $\mu\text{S}/\text{cm}$ (from 66 measurements from six bores, excluding the regolith). Hence it is considered unlikely that mining-induced mixing of groundwater will result in changes to groundwater quality in the Permo-Triassic rock units in or around the Project area during or following mining. The effect of mixing would also decrease sharply with distance from the active mining area.

Within the Jurassic units, Spring Ridge Management Zone, the simulated impact of the Project is some potential vertical leakage into the underlying Permo-Triassic strata (see Section 0), and therefore would not adversely affect groundwater quality within this geological unit during mining.

There are no significant simulated reduced beneficial uses of the Namoi Alluvium, Mooki River or the Permo-Triassic, Jurassic or Tertiary basalt units as a result of the Project.

5.7 OTHER EFFECTS OF MINING

For the highly productive groundwater source of the Namoi Alluvium, the AI Policy states that:

- ❑ No mining activity to be below the natural ground surface within 200 m laterally from the high bank (understood to apply to open cut mines), **or** 100 m vertically beneath (or the three dimensional extent of the alluvial water source – whichever is the lesser distance) of a highly connected surface water source that is defined as a reliable water supply; and
- ❑ Not more than 10% cumulatively of the three dimensional extent of the alluvial material to be excavated by mining activities beyond 200 m laterally from the high bank (understood to apply to open cut mines), **or** 100 m vertically beneath a highly connected surface water source that is defined as a reliable water supply.

No significant amounts of alluvial material will be excavated. The Mooki River is a 5th order stream in the vicinity of the Project and is therefore a highly connected surface water source that is a reliable water supply under the AI Policy. The minimum modelled vertical separation between the alluvial groundwater source and the mining activity is 108 m. Neither of the above criteria is therefore breached by the proposed mining activity.

5.8 SUMMARY OF ASSESSMENT IN TERMS OF THE AI POLICY

Table 29, Table 30, Table 31 and Table 32 summarise the preceding discussion of potential impacts of the Project in terms of the AI Policy Minimal Impact Considerations.

Given the simulated potential drawdown at existing groundwater users' bores within the Jurassic and Permo-Triassic strata, the Project falls within the AI Policy Level 2 classification of the minimal impact considerations for each of these respective highly productive and less productive groundwater sources. The AI criteria are not simulated to be triggered for the highly productive aquifers of the Namoi Alluvium or the water bearing rocks of Liverpool Range Basalt, for which the Project falls within the Level 1 classification. No minimal impact considerations other than exceeding the 2 m drawdown criteria at existing bores in the Jurassic and Permo-Triassic strata have been identified in this assessment.

Given the Level 2 AI Policy classification described above, the Project will require risk mitigation, prevention or avoidance strategies to be identified in the Project EIS. A Groundwater Management Plan will require development and approval. This will need to define a groundwater monitoring strategy, groundwater level triggers, and a Trigger Response Action Plan.

It is recommended that the Project install a groundwater monitoring network designed to monitor for the potential drawdown influence on existing users' water works.

Furthermore, the Project will require a volumetric take (total mine inflow) metering program. These water takes should be reported on an annual basis to the NOW, and periodically used, in conjunction with the monitoring network data, to verify the numerical modelling and the potential risks of mining activity identified in this assessment. This should include revision of the modelling and identified risks as required.

The means of addressing and managing the identified potential bore drawdown influence greater than 2 m is to 'make good' on the impacted users' water sources. BHP Billiton has committed to this 'make good' process whereby any measured impacts on private groundwater bores as a result of its mining operations will be mitigated by BHP Billiton. This could involve deepening and/or replacing bores and wells, and/or providing an alternative water source to affected users. Before such a process is instigated it is recommended that all water works identified as being potentially adversely affected in this assessment are surveyed for their existence, location, use, depth and construction details, with a pre-mining reading of depth to water. Subsequent to this, remedial action can be planned and undertaken as required (in consultation with the relevant landholders).

Table 29 Summary of AI Policy Assessment – Namoi Alluvium

Aquifer	Upper and Lower Namoi Groundwater Sources	
Category	Highly productive	
Level 1 Minimal Impact Consideration		Assessment
Water Table Less than or equal to a 10 percent (%) cumulative variation in the water table, allowing for typical climatic “post-water sharing plan” variations, 40 m from any: high priority groundwater dependent ecosystem; or high priority culturally significant site; listed in the schedule of the relevant water sharing plan. OR A maximum of a 2 m water table decline cumulatively at any water supply work.		At the time of writing there were no high priority Culturally Significant Sites or high priority groundwater dependent ecosystems (GDEs) in the vicinity of the Project listed in the relevant Water Sharing Plan. Hence there are no known risks of mine development to such sites. No drawdown in excess of the criterion (2 m) within the Namoi Alluvium. Level 1 minimal impact consideration classification.
Water pressure A cumulative pressure head decline of not more than 40% of the “post-water sharing plan” pressure head above the base of the water source to a maximum of a 2m decline, at any water supply work.		No drawdown in excess of the criterion (2 m) within the Namoi Alluvium. Level 1 minimal impact consideration classification.
Water quality Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40 m from the activity. No increase of more than 1% per activity in long-term average salinity in a highly connected surface water source at the nearest point to the activity. No mining activity to be below the natural ground surface within 200m laterally from the top of high bank or 100m vertically beneath (or the three dimensional extent of the alluvial water source - whichever is the lesser distance) of a highly connected surface water source that is defined as a “reliable water supply”. Not more than 10% cumulatively of the three dimensional extent of the alluvial material in this water source to be excavated by mining activities beyond 200m laterally from the top of high bank and 100m vertically beneath a highly connected surface water source that is defined as a “reliable water supply”.		In the long-term, mining is predicted to induce a net reduction in groundwater flow from the Permo-Triassic units into the Namoi Alluvium. This is considered to pose no net observable effect because the reduction in inflow is primarily offset by reduced baseflow to the Mooki River, and reduced evapotranspiration from the alluvials. There are therefore no simulated risks of reduced beneficial uses of the Namoi Alluvium as a result of the Project. Nor is there any predicted increase in the salinity of the Mooki River resulting from groundwater impacts. No proposed mining activity within these specified proximities to the Namoi Alluvium. No significant proposed excavation of alluvial material proposed. Level 1 minimal impact consideration classification.

Table 30 Summary of AI Policy Assessment – Liverpool Range Basalt

Aquifer	NSW Murray Darling Basin Fractured Rock Groundwater Sources (Liverpool Ranges Basalt MDB)	
Category	Highly Productive	
Level 1 Minimal Impact Consideration		Assessment
Water Table Less than or equal to a 10% cumulative variation in the water table, allowing for typical climatic “post-water sharing plan” variations, 40 m from any: - high priority groundwater dependent ecosystem; or - high priority culturally significant site; listed in the schedule of the relevant water sharing plan. OR A maximum of a 2 m water table decline cumulatively at any water supply work.		At the time of writing there were no high priority Culturally Significant Sites known in the vicinity of the Project or listed in Water Sharing Plans for the area. There is one priority GDE identified however this is linked to the New England Fold Belt MDB water source, upon which the Project poses no known risk. Hence there are no known risks of mine development to such sites. Water table drawdown is not in excess of the criterion (2 m) within the Liverpool Ranges Basalt. Level 1 minimal impact consideration classification.
Water pressure A cumulative pressure head decline of not more than a 2m decline, at any water supply work.		No drawdown in excess of the criterion (2 m) within the Liverpool Ranges Basalt at private water supply works. Level 1 minimal impact consideration classification.
Water quality Any change in the groundwater quality should not lower the beneficial use category of the groundwater beyond 40 metres from the activity.		Mining is simulated to induce a net leakage from the Jurassic rock into the underlying Permo-Triassic formations. As such, there are no foreseen risks to water quality in the Liverpool Ranges Basalt, which overlays the Jurassic aged rocks in the area limited to the south of EL6505 (in or near to the Liverpool Ranges). Level 1 minimal impact consideration classification.

Table 31 Summary of AI Policy Assessment – Jurassic Porous Rock

Aquifer	NSW Murray Darling Basin Porous Rock Groundwater Sources (Gunnedah-Oxley Basin MDB (Spring Ridge))	
Category	Highly Productive	
Level 1 Minimal Impact Consideration		Assessment
Water Table Less than or equal to a 10% cumulative variation in the water table, allowing for typical climatic “post-water sharing plan” variations, 40 m from any: high priority groundwater dependent ecosystem; or high priority culturally significant site; listed in the schedule of the relevant water sharing plan. OR A maximum of a 2 m water table decline cumulatively at any water supply work.		At the time of writing there were no high priority Culturally Significant Sites known in the vicinity of the Project or listed in Water Sharing Plans for the area. There are two or high priority GDEs identified; however, they are located on the western margin of the model, and simulated impacts on these GDEs are below model accuracy limits (<0.01m). Hence there are no known risks of mine development to such sites. Drawdown in excess of the water supply work drawdown criterion (2 m) within the Jurassic strata. BHP Billiton would implement ‘make good’ provisions at water supply works impacted by the Project. Level 2 minimal impact consideration classification.
Water pressure A cumulative pressure head decline of not more than a 2m decline, at any water supply work.		Drawdown in excess of the criterion (2 m) within the Jurassic strata at private water supply works. Level 2 minimal impact consideration classification.
Water quality Any change in the groundwater quality should not lower the beneficial use category of the groundwater beyond 40 metres from the activity.		Mining is simulated to induce a net leakage from the Jurassic rock into the underlying Permo-Triassic formations. As such, there are no foreseen risks to water quality in this aquifer. Level 1 minimal impact consideration classification.

Table 32 Summary of AI Policy Assessment – Permo-Triassic Porous Rock

Aquifer	NSW Murray Darling Basin Porous Rock Groundwater Sources (Gunnedah-Oxley Basin MDB (Other))	
Category	Less Productive	
Level 1 Minimal Impact Consideration		Assessment
Water Table Less than or equal to a 10% cumulative variation in the water table, allowing for typical climatic “post-water sharing plan” variations, 40 m from any: high priority groundwater dependent ecosystem; or high priority culturally significant site; listed in the schedule of the relevant water sharing plan. OR A maximum of a 2 m water table decline cumulatively at any water supply work.		At the time of writing there were no high priority Culturally Significant Sites or high priority GDEs known in the vicinity of the Project or listed in Water Sharing Plans for the area, i.e. ‘Hunter Unregulated and Alluvial Water Sources’ (version current for 8 March 2013). Hence there are no known risks of mine development to such sites. Drawdown in excess of the water supply work drawdown criterion (2 m) within the Permian strata. Level 2 minimal impact consideration classification.
Water pressure A cumulative pressure head decline of not more than a 2m decline, at any water supply work.		Drawdown in excess of the criterion (2 m) within the Permian strata at private water supply works. Level 2 minimal impact consideration classification.
Water quality Any change in the groundwater quality should not lower the beneficial use category of the groundwater beyond 40 metres from the activity.		Mining-induced changes to the hydraulic properties and depressurisation of the strata in the mined area will result in mixing of potentially chemically different groundwater between overlying and underlying units. Electrical conductivity data for the coal measures suggests that it is unlikely that mining-induced mixing of groundwater will result in lowering of the beneficial use category of groundwater in the Permo-Triassic rock units in or around the Project area during or following mining. The risk of these impacts decreases with distance from the active mining area and enhanced rock mass fracturing. Level 1 minimal impact consideration classification.

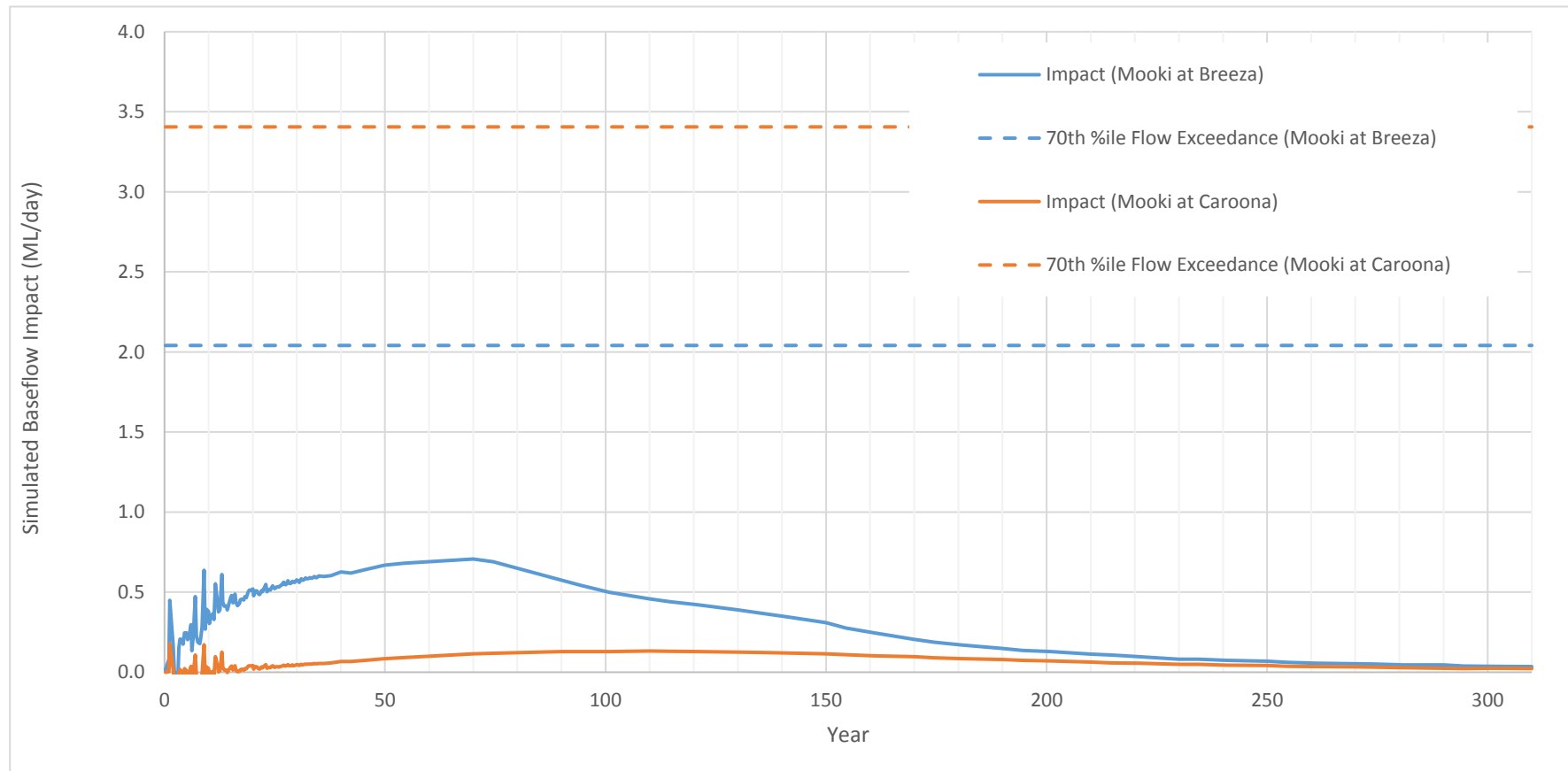
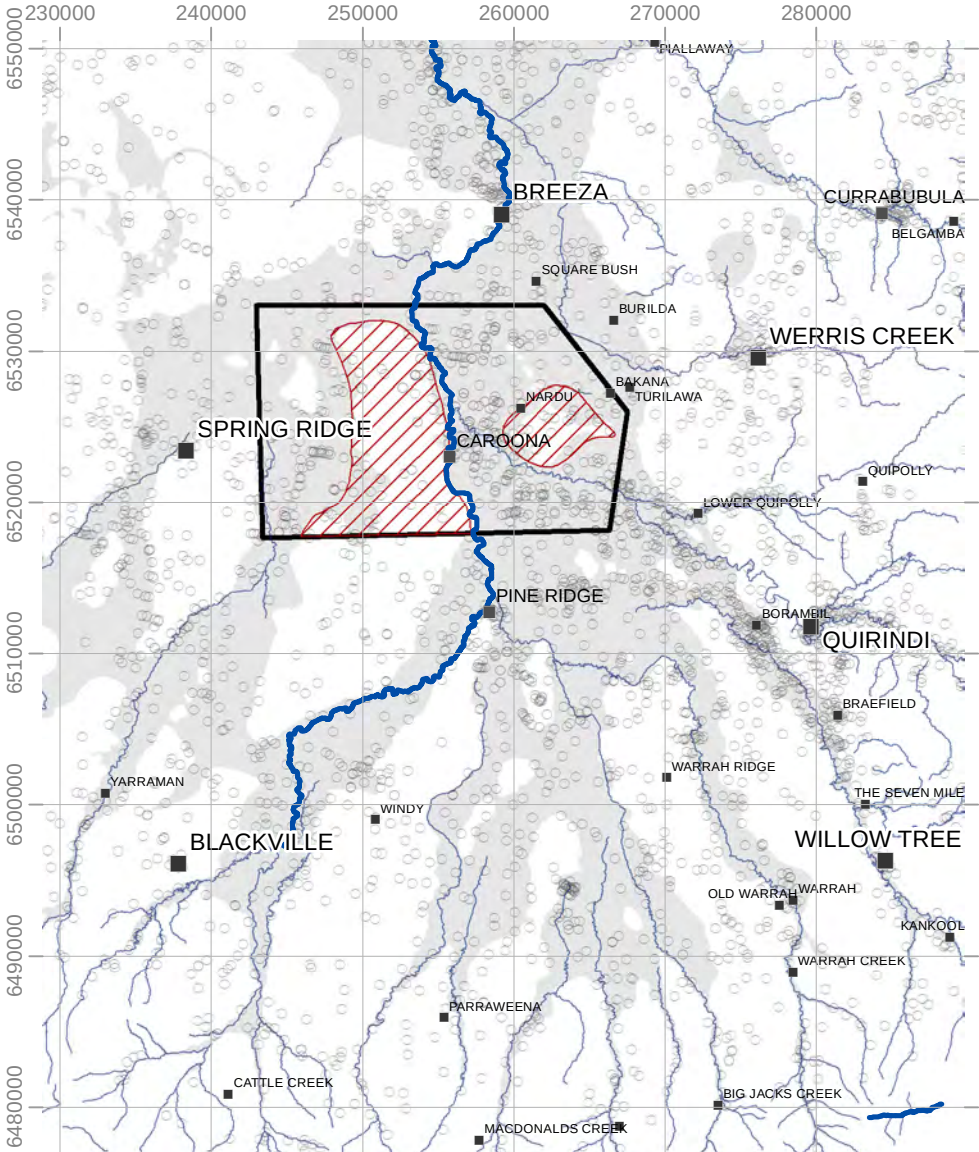
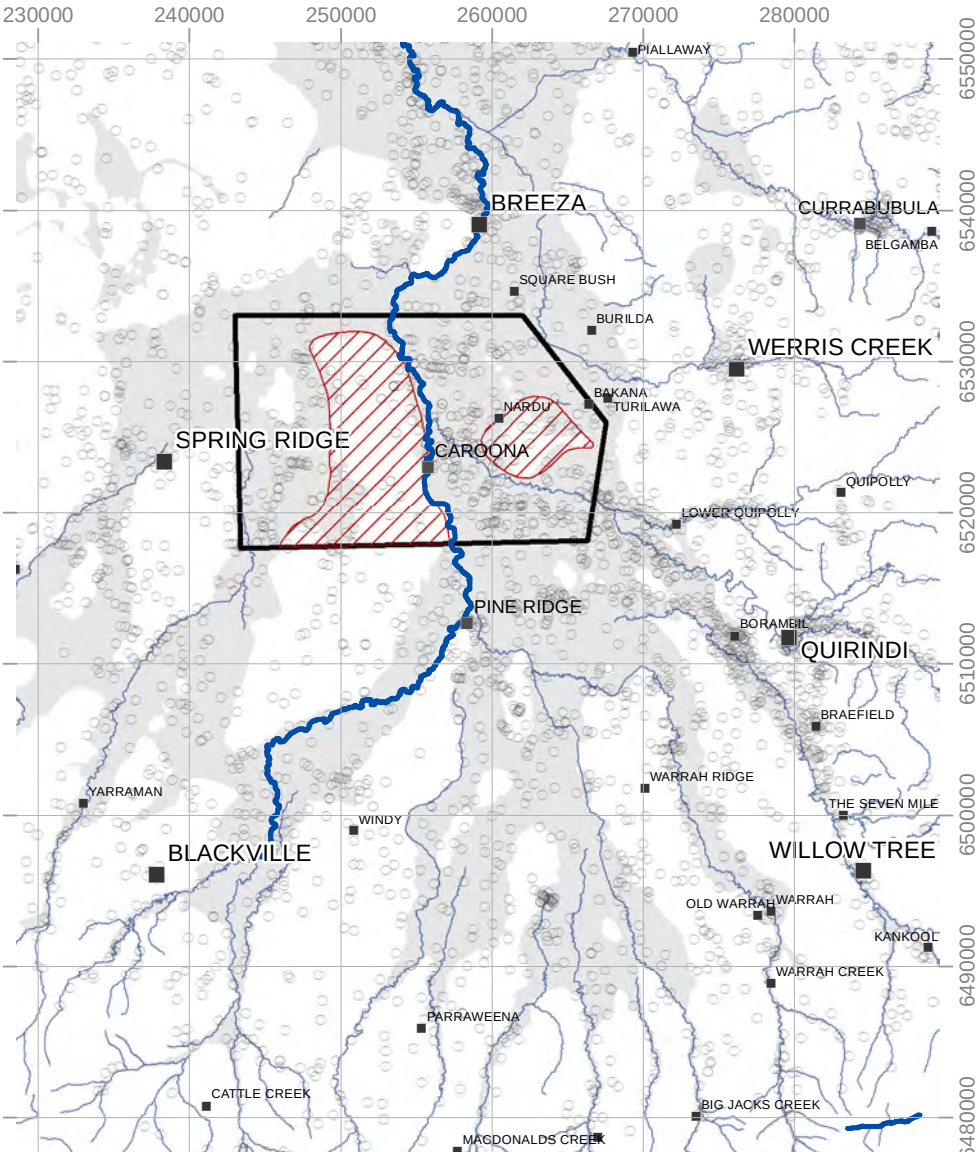


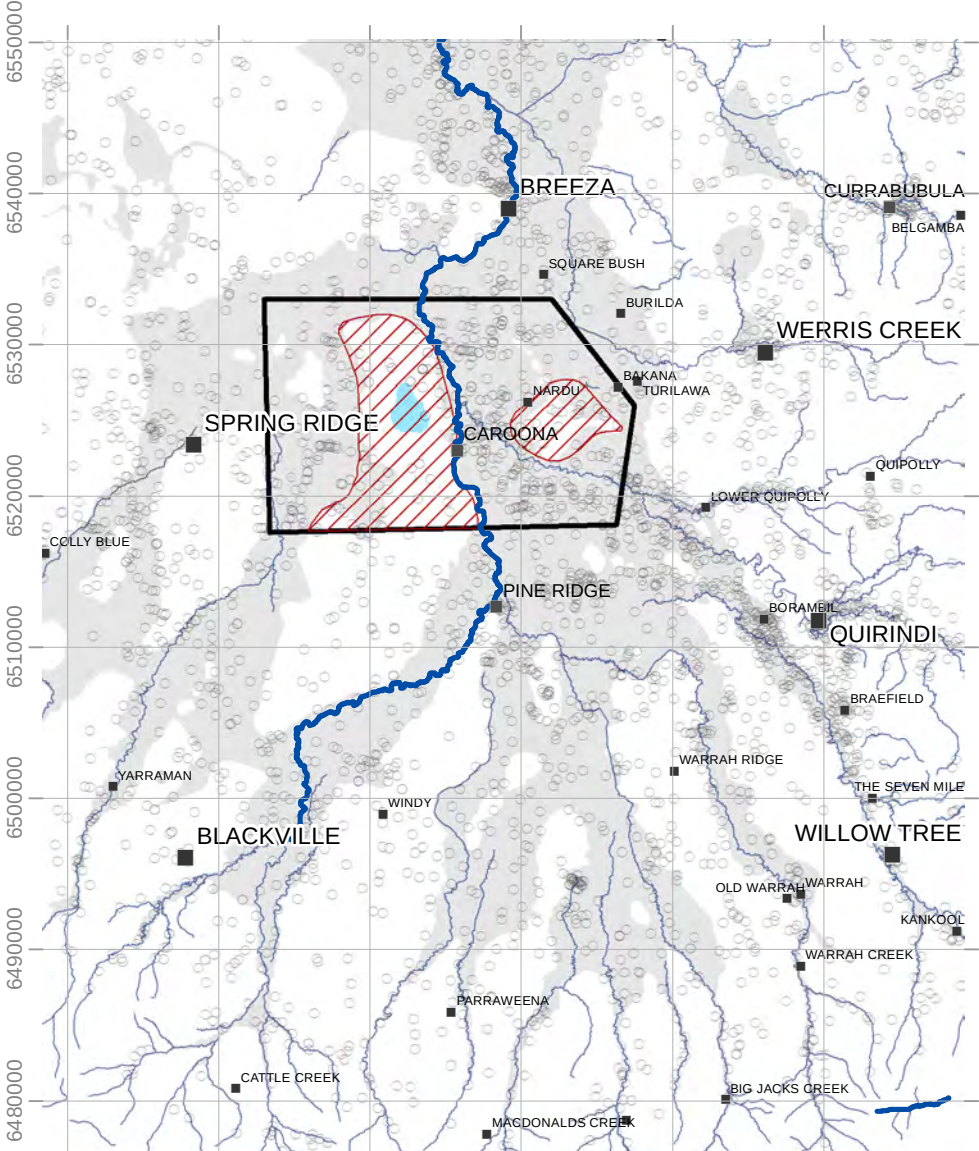
Figure 36 Modelled Mooki River Baseflow Impacts



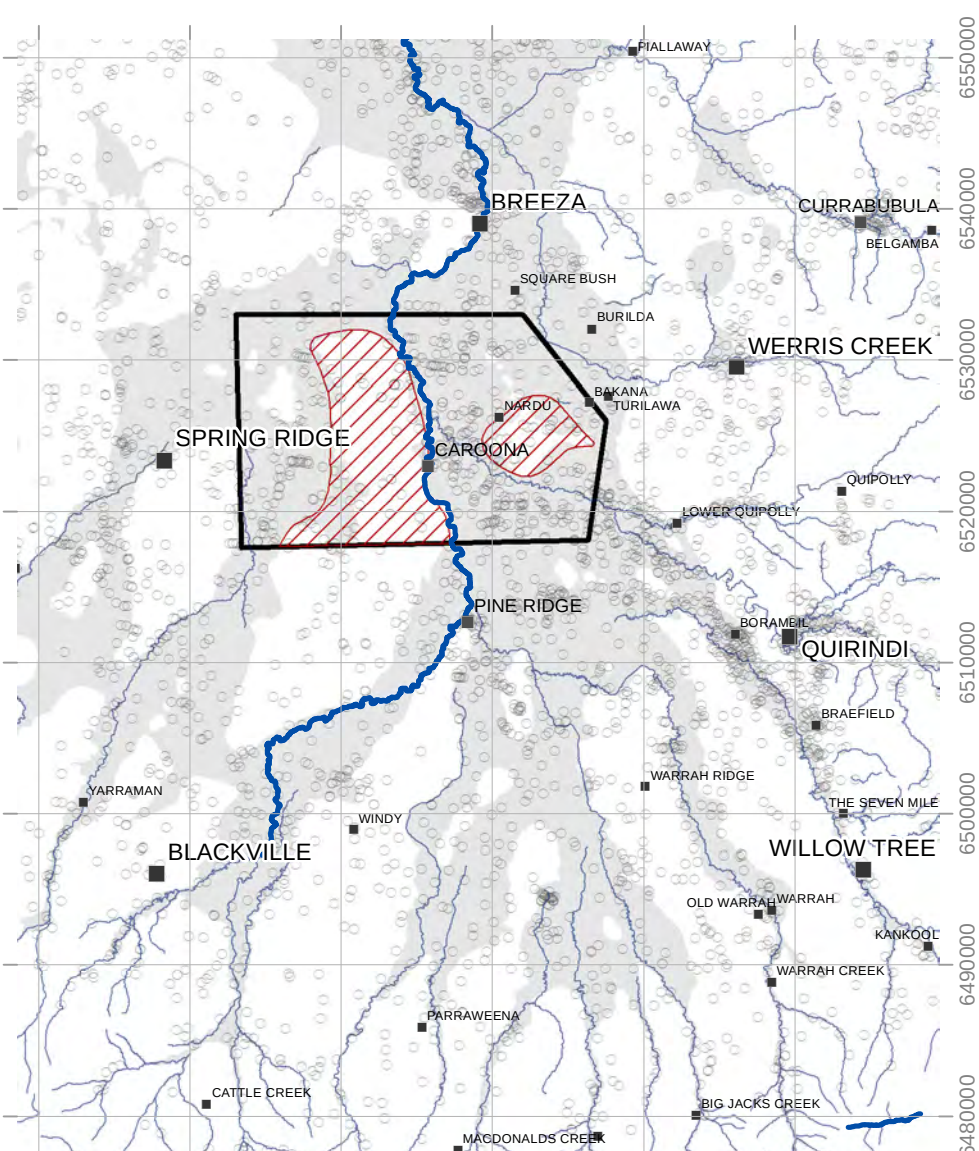
Layer 1 maximum drawdown at any time
Narrabri Fm / Regolith



Layer 1 recovered drawdown (280 years post-mining)
Narrabri Fm / Regolith



Layer 2 maximum drawdown at any time
Gunnedah Fm / Regolith



Layer 2 recovered drawdown (280 years post-mining)
Gunnedah Fm / Regolith

Legend

- NOW Registered Bores

■

Town

■

Village

■

Locality
- River

—

Creek

■

Alluvials

□

Exploration Licence

▨

Targeted Exploration Area

- Maximum Drawdown

(m, at any time)
- <=2
- 2.01 - 10

- 10.01 - 20
- 20.01 - 50
- >50.00

BHP Billiton
Caroonna Coal Project

Figure 37

Simulated Drawdown and Recovery
Model Layers 1 and 2

DrawingNo: CAR001-005
Rev: E.
Created by: CNicol
Date: 04/03/2014.

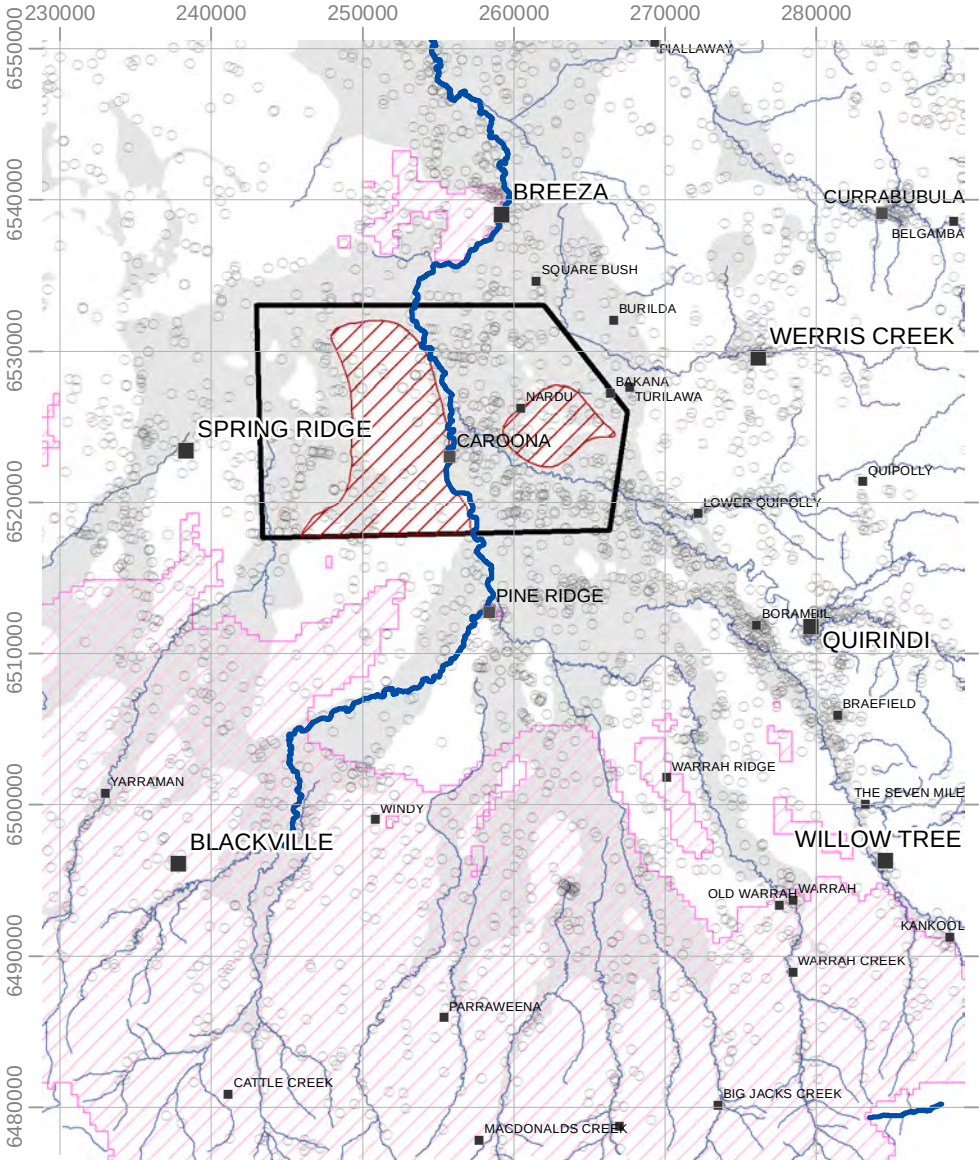


Scale: 500,000 at A3
GDA 1994 MGA Zone 56

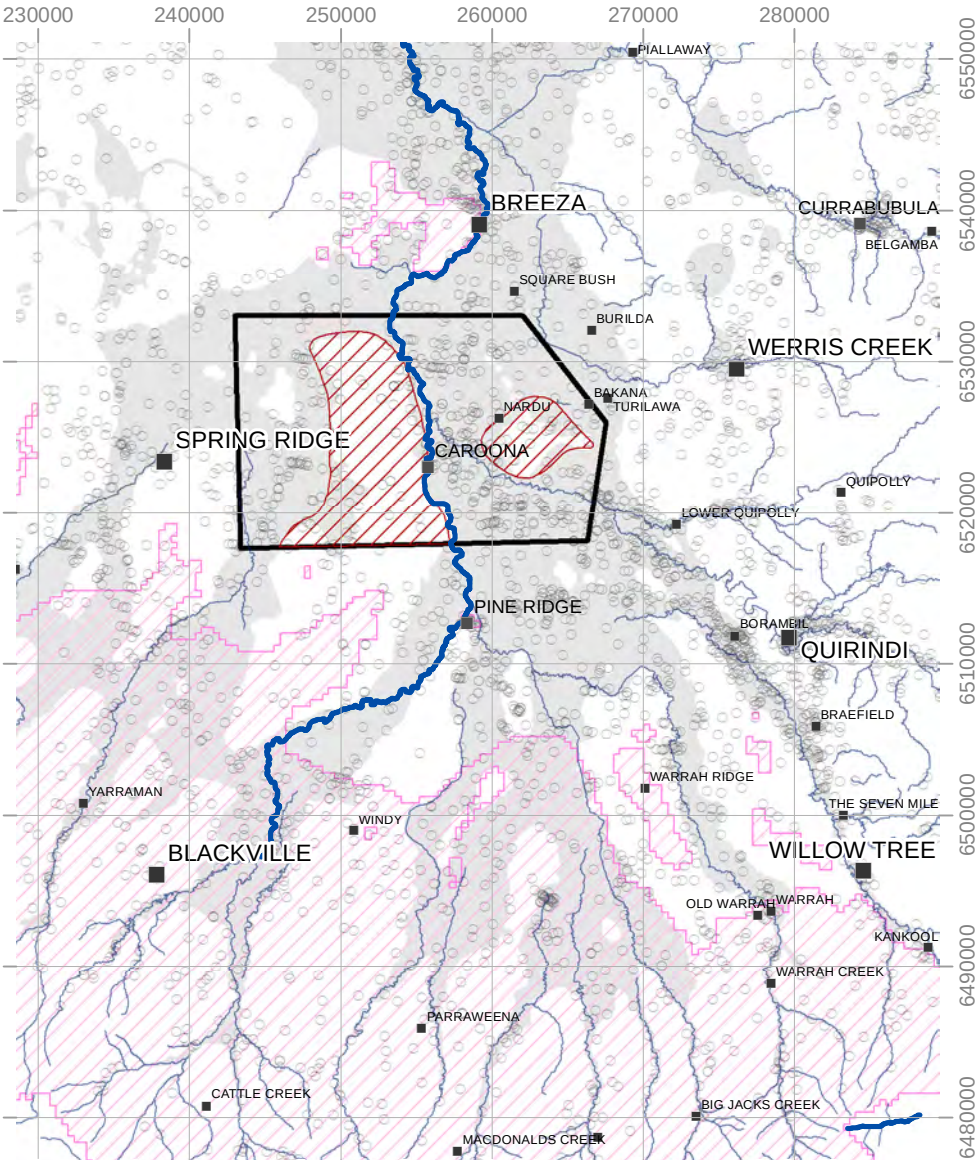


0 2.5 5 10 15 20
Kilometers

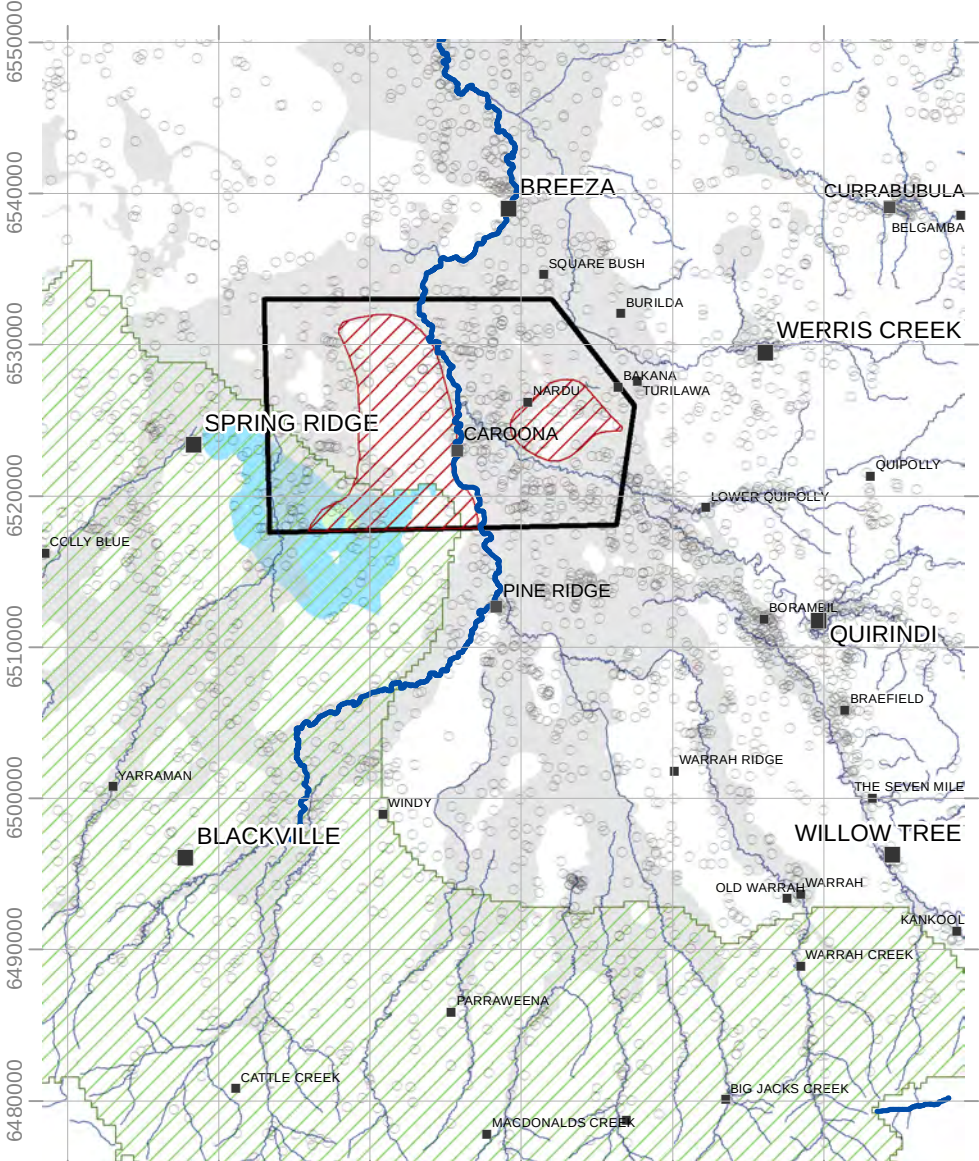
(C) 2013. While Heritage Computing/HydroSimulations has taken care to ensure the accuracy of this product, Heritage/HydroSims and DATA CUSTODIAN(S), make no representations or warranties about its accuracy, completeness or suitability for any particular purpose and cannot accept liability of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred as a result of the product being inaccurate, incomplete or unsuitable in any way and for any reason.



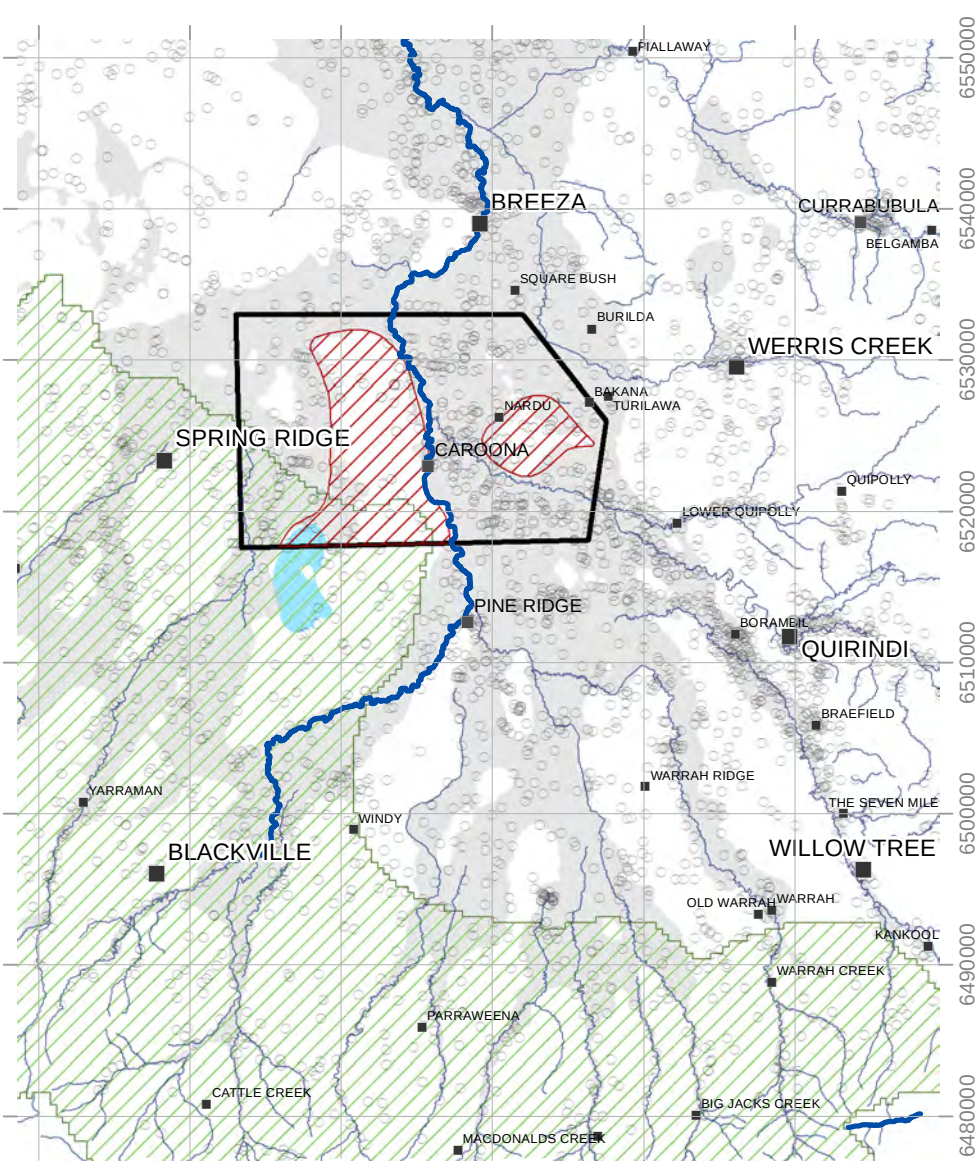
Layer 3 maximum drawdown at any time
Liverpool Ranges Basalt



Layer 3 recovered drawdown (280 years post-mining)
Liverpool Ranges Basalt



Layer 4 maximum drawdown at any time
Jurassic Formations



Layer 4 recovered drawdown (280 years post-mining)
Jurassic Formations

Legend

- NOW Registered Bores
- Town
- Village
- Locality
- Exploration Licence
- River
- Creek
- Alluvials
- ▨ Tertiary Basalts Extent
- ▨ Jurassic Formations Extent
- ▨ Targeted Exploration Area

Maximum Drawdown
(m, at any time)

□	<=2
■	2.01 - 10

■	10.01 - 20
■	20.01 - 50
■	>50.00

BHP Billiton
Caroonna Coal Project

Figure 38

Simulated Drawdown and Recovery
Model Layers 3 and 4

DrawingNo: CAR001-006
Rev: F
Created by: CNicol
Date: 10/03/2014.

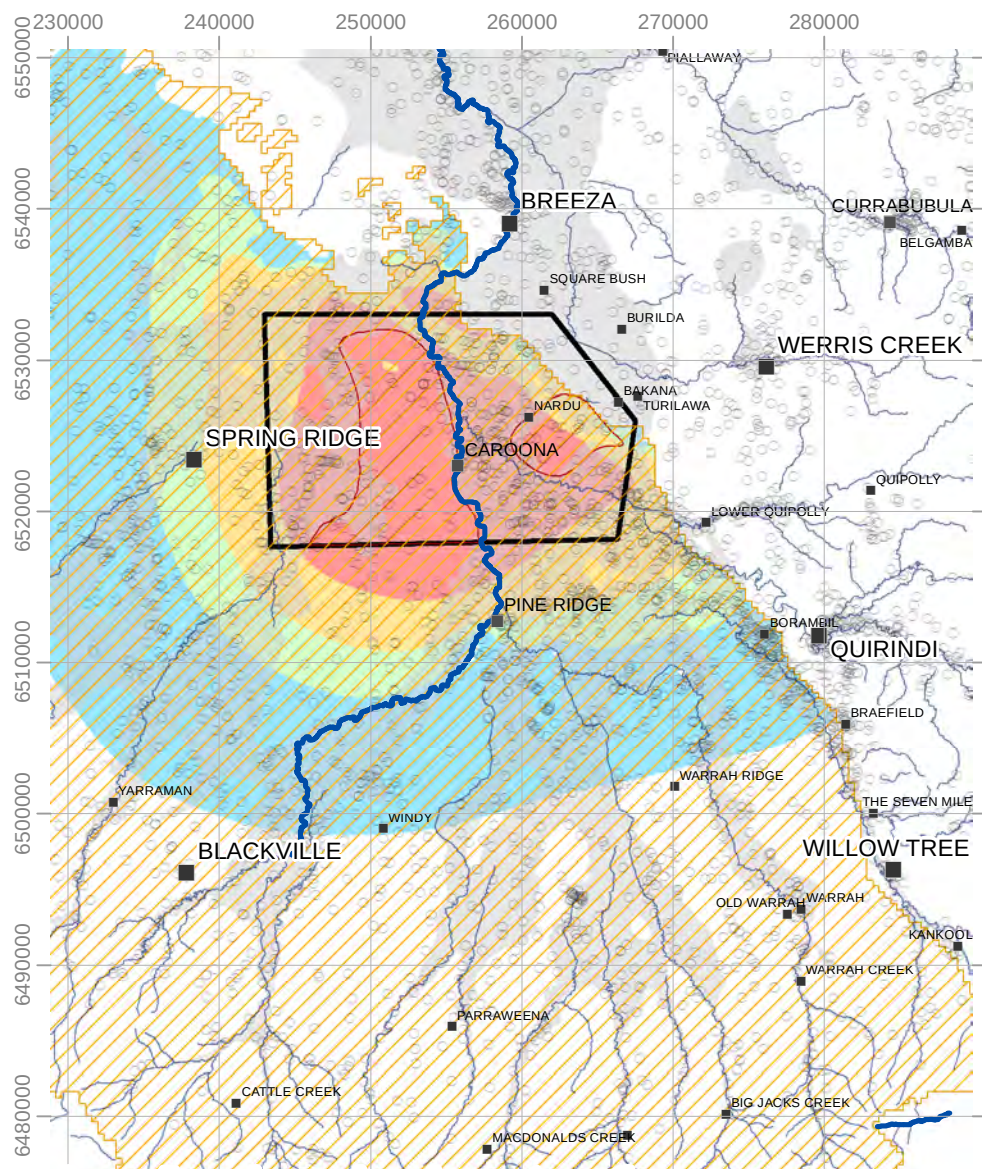


Scale: 500,000 at A3
GDA 1994 MGA Zone 56

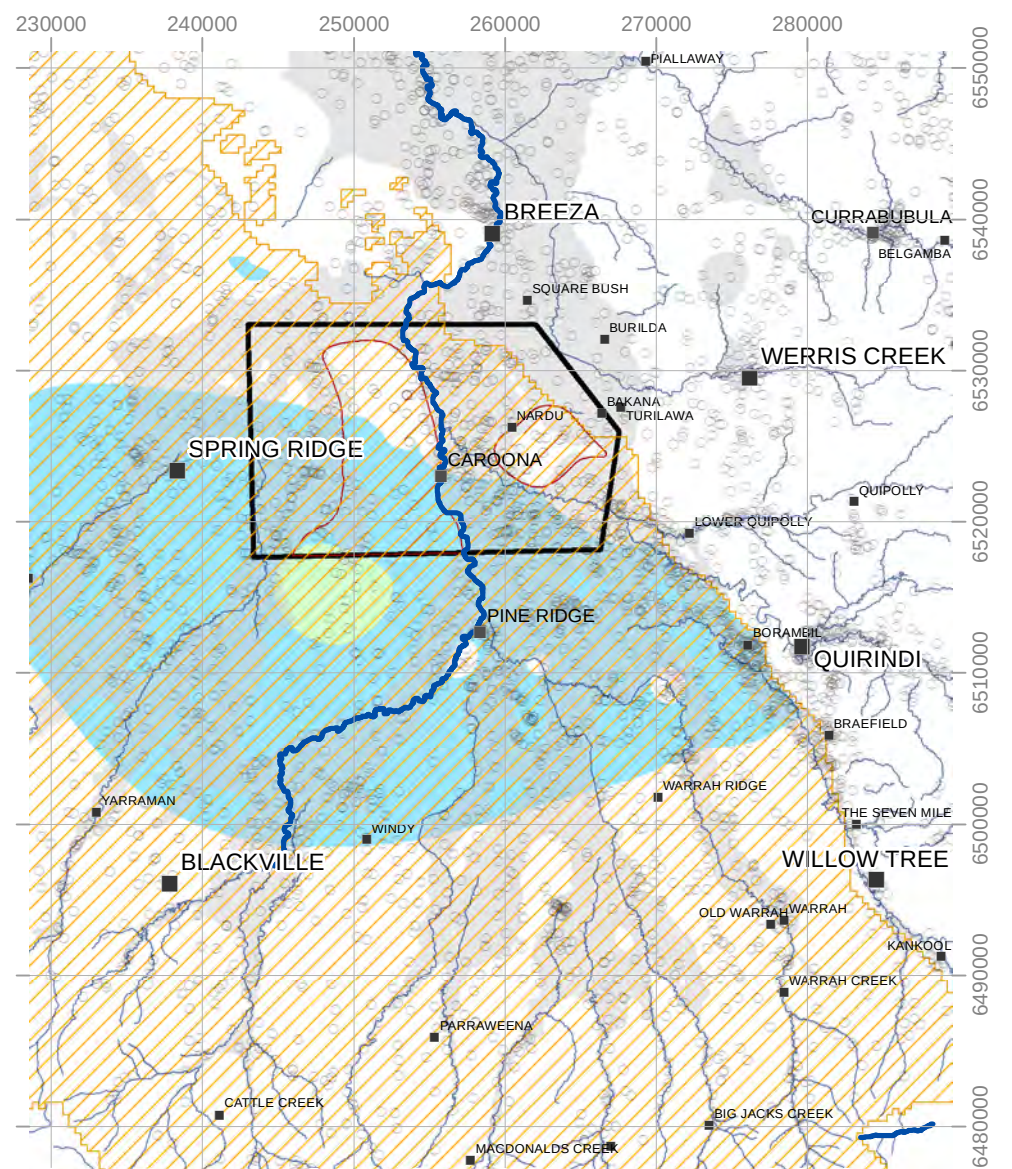


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Kilometers

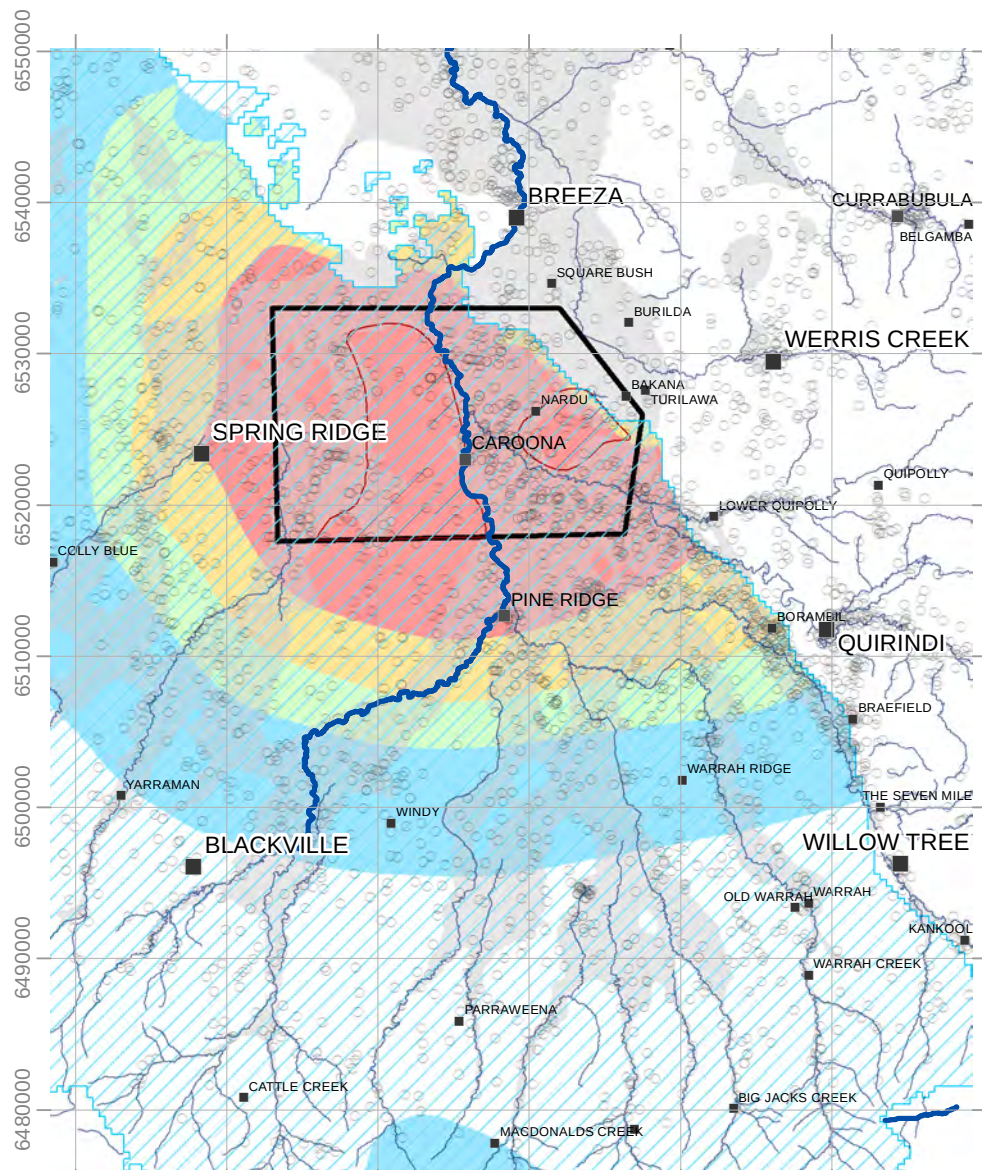
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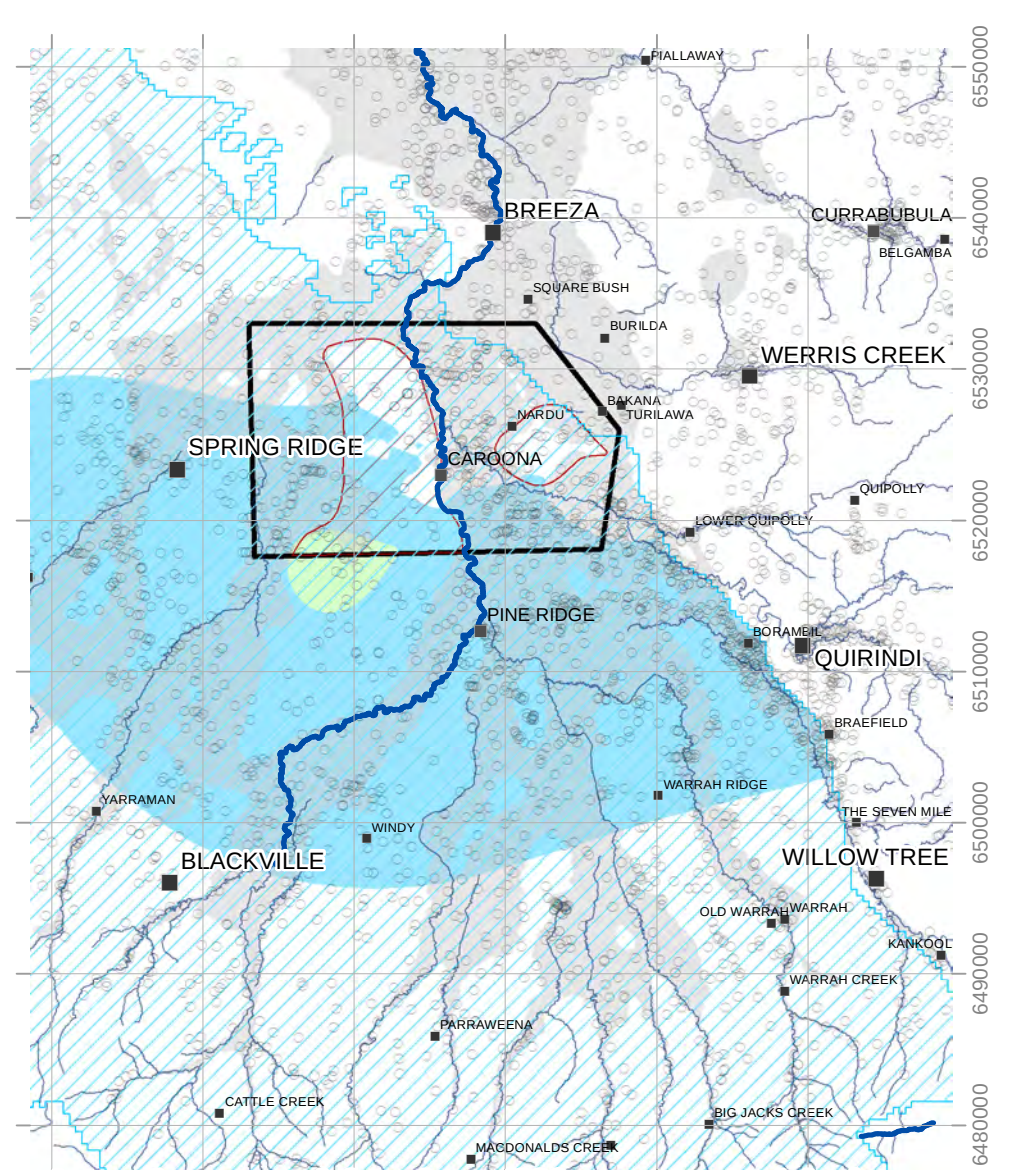
Layer 5 maximum drawdown at any time
Permo-Triassic Units (Napperby Fm to Wallala Fm)



Layer 5 recovered drawdown (280 years post-mining)
Permo-Triassic Units (Napperby Fm to Wallala Fm)



Layer 6 maximum drawdown at any time
Clare Sandstone



Layer 6 recovered drawdown (280 years post-mining)
Clare Sandstone

Legend

- NOW Registered Bores
- Census Bores
- Town
- Village
- Locality
- Exploration Licence
- River
- Creek
- Alluvials
- ▨ Clare Sandstone Extent
- ▨ Napperby to Wallala Fm Extent
- ▨ Targeted Exploration Area

Maximum Drawdown (m, at any time)

- ≤2
- 2.01 - 10

- 10.01 - 20
- 20.01 - 50
- >50.00

BHP Billiton
Caroonna Coal Project

Figure 39

Simulated Drawdown and Recovery Model Layers 5 and 6

DrawingNo: CAR001-007
 Rev: F
 Created by: CNicol
 Date: 10/03/2014.

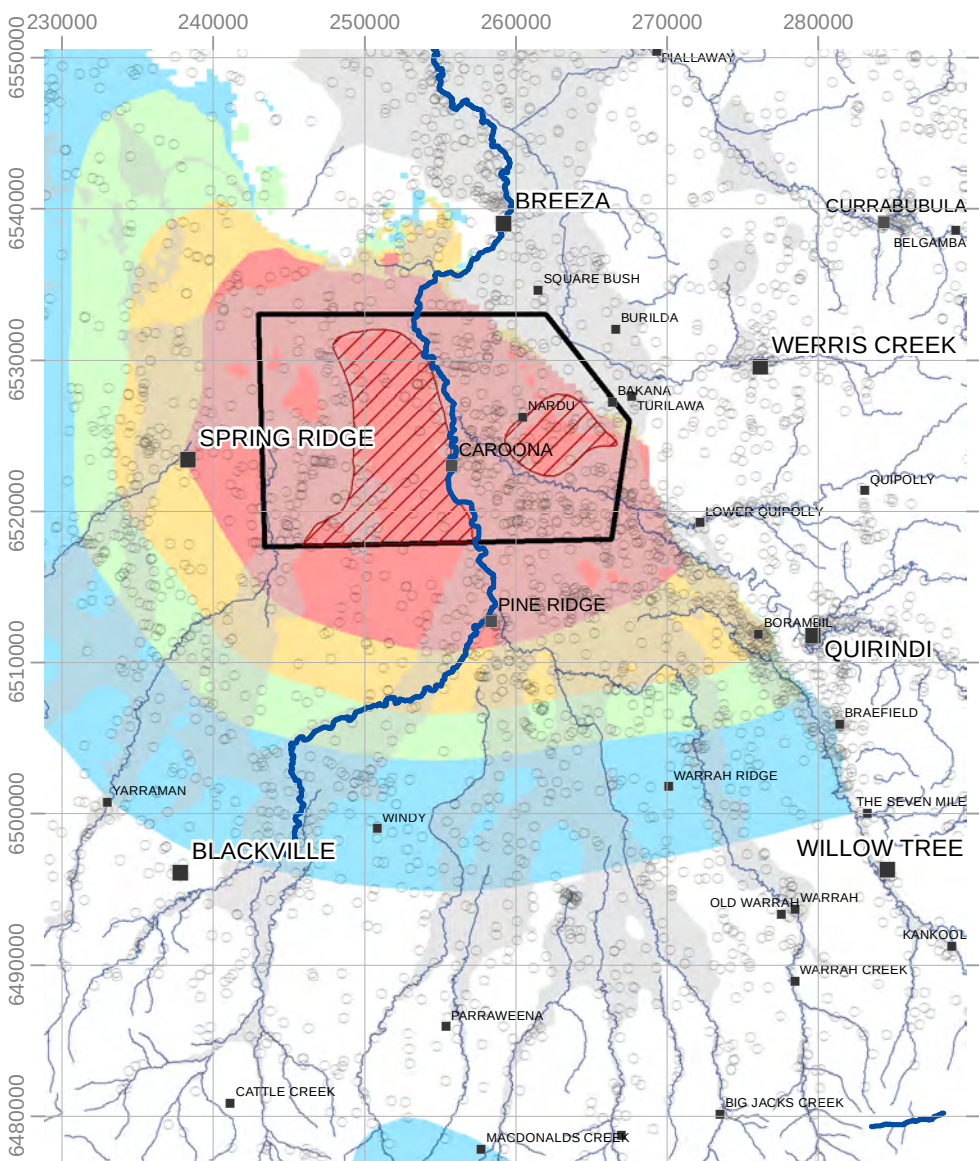


Scale: 500,000 at A3
 GDA 1994 MGA Zone 56

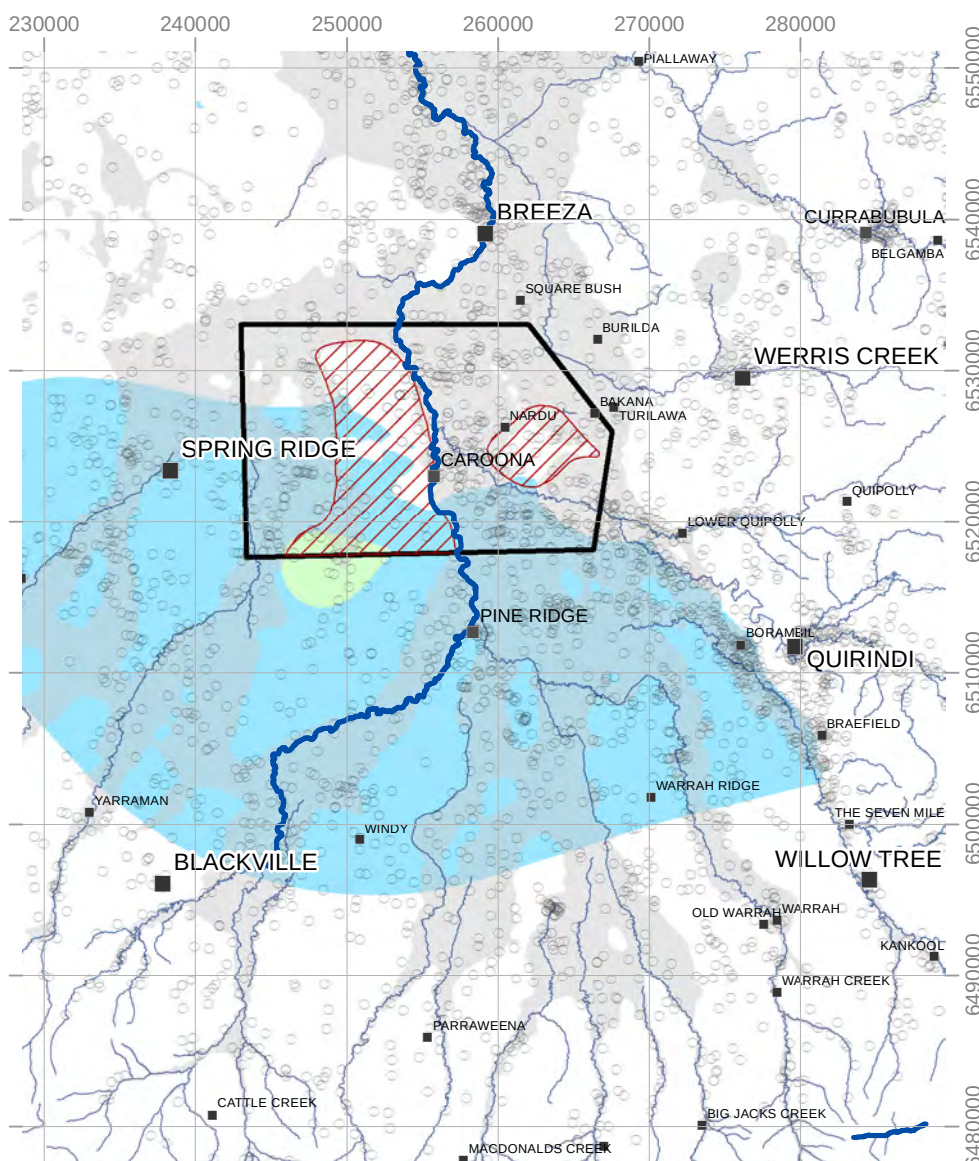


0 2.5 5 10 15 20
 Kilometers

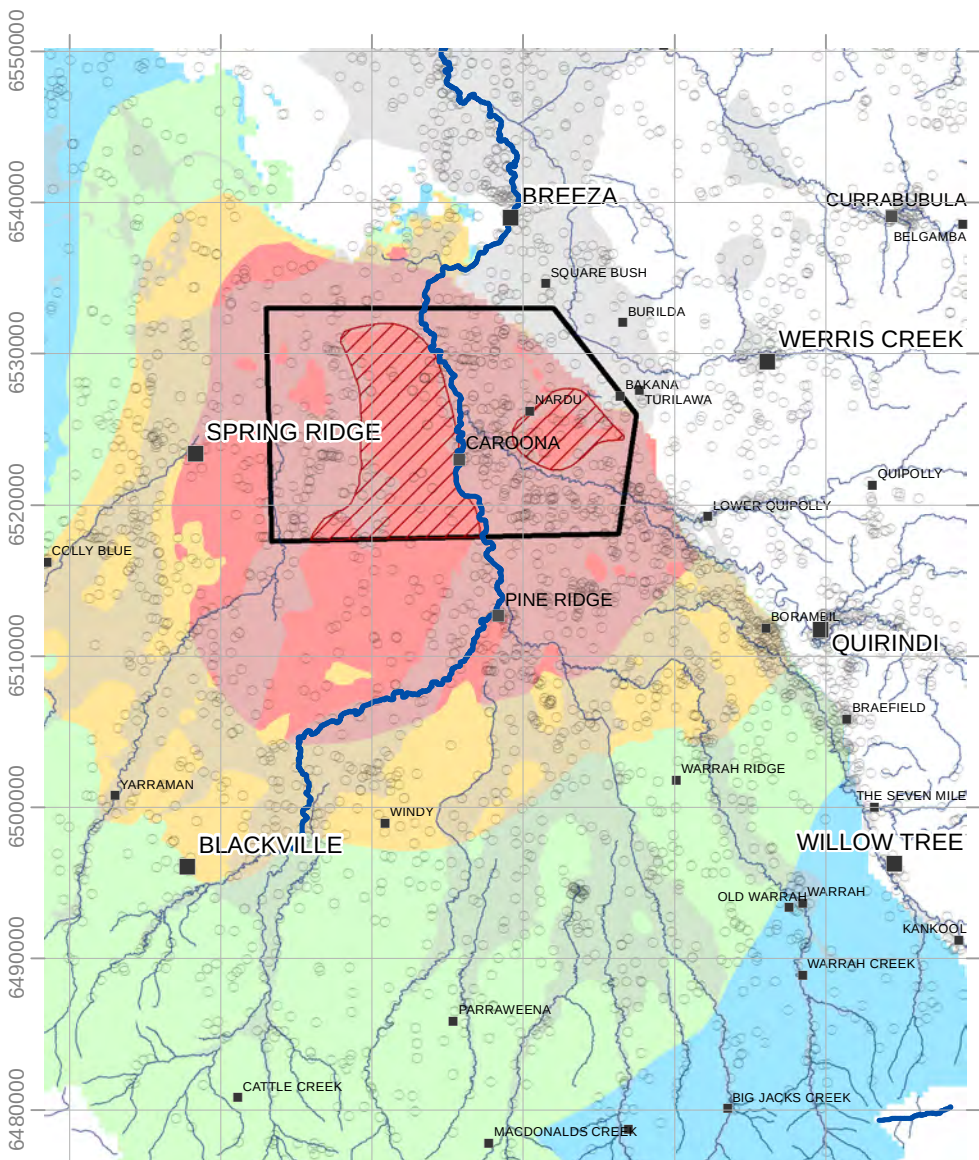
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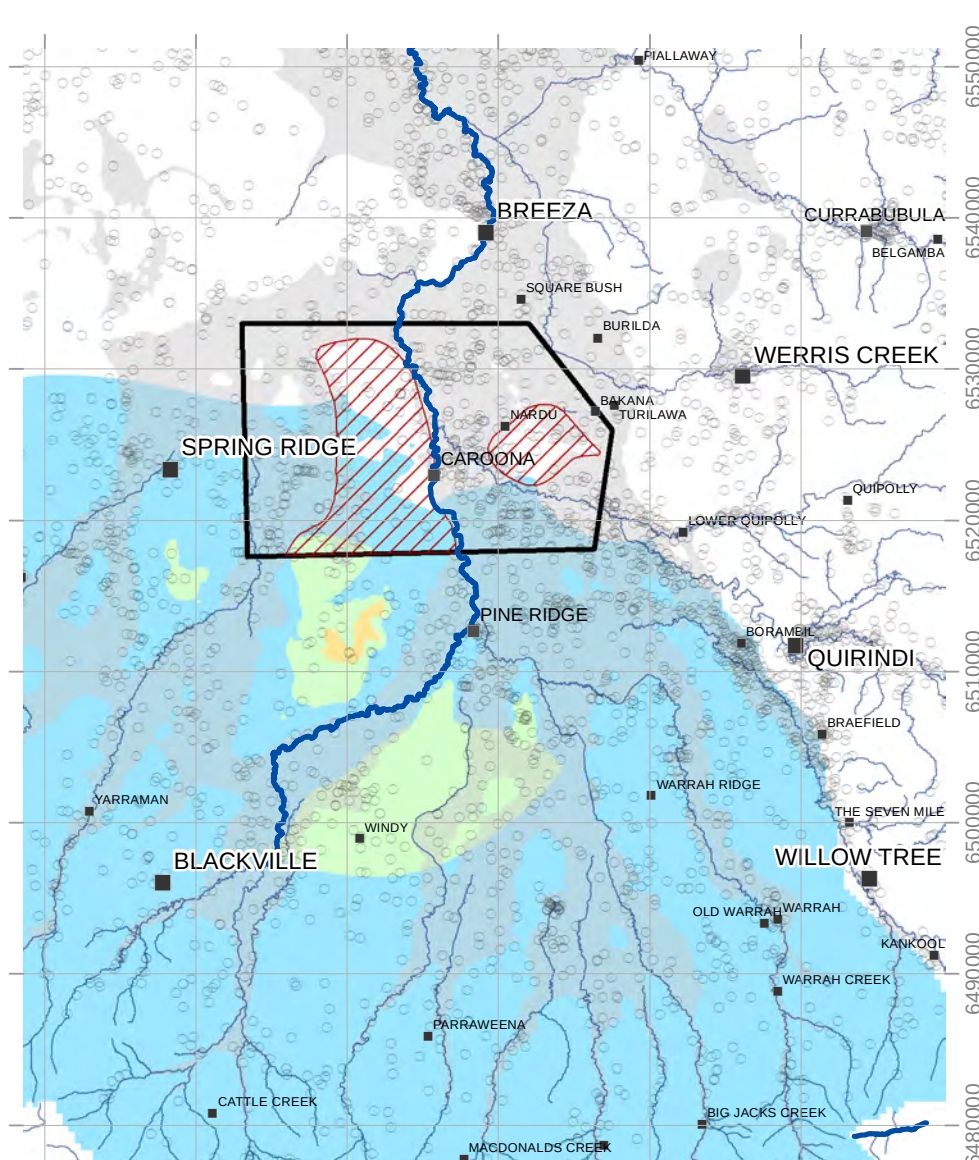
Layer 7 maximum drawdown at any time
Benallabri Fm



Layer 7 recovered drawdown (280 years post-mining)
Benallabri Fm



Layer 8 maximum drawdown at any time
Hoskissons Seam



Layer 8 recovered drawdown (280 years post-mining)
Hoskissons Seam

Legend

- NOW Registered Bores
- Town
- Village
- Locality
- River
- Creek
- Alluvials
- Exploration Licence
- ▨ Targeted Exploration Area

Maximum Drawdown
(m, at any time)

- ≤2
- 2.01 - 10

- 10.01 - 20
- 20.01 - 50
- >50.00

BHP Billiton
Caroonna Coal Project

Figure 40

Simulated Drawdown and Recovery
Model Layers 7 and 8

DrawingNo: CAR001-008
Rev: F
Created by: CNicol
Date: 10/03/2014.

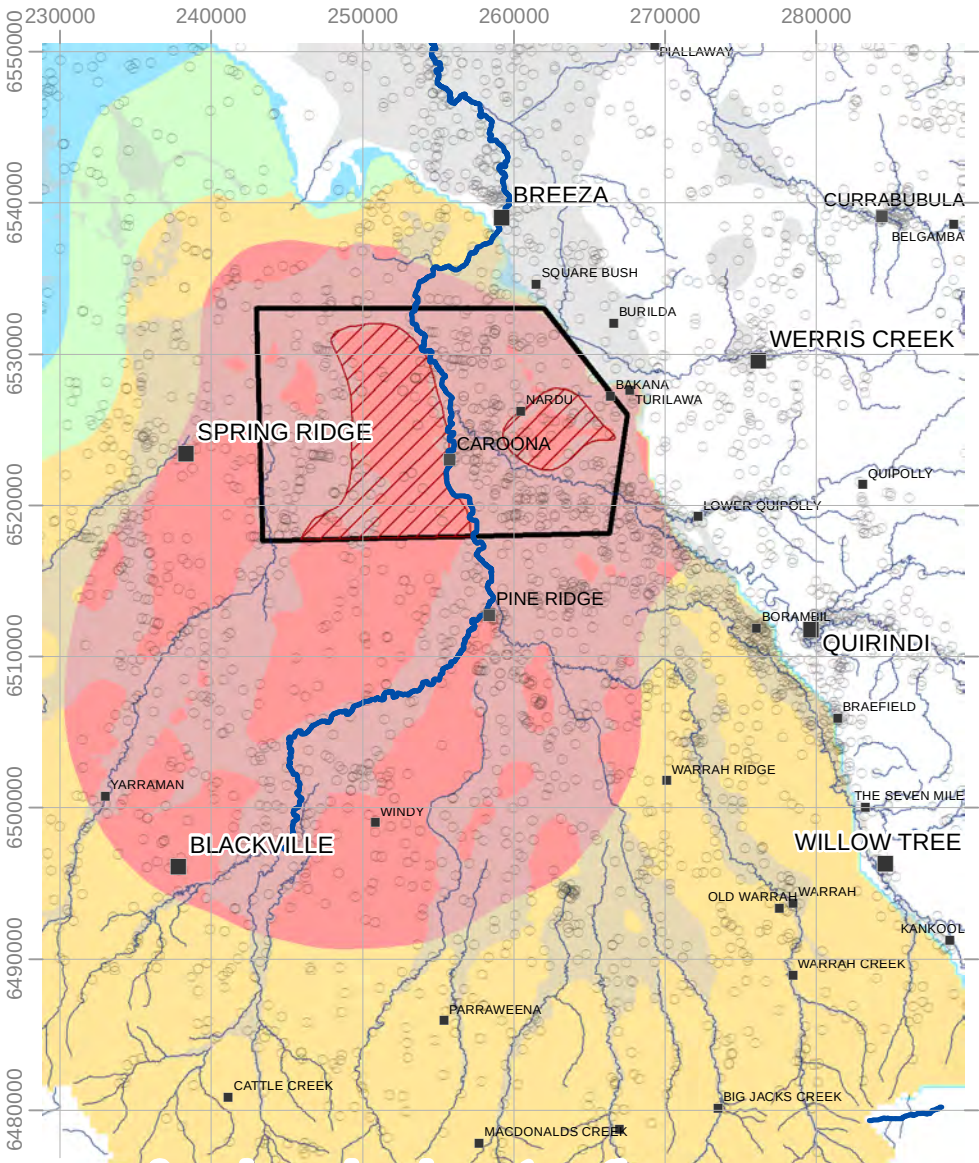


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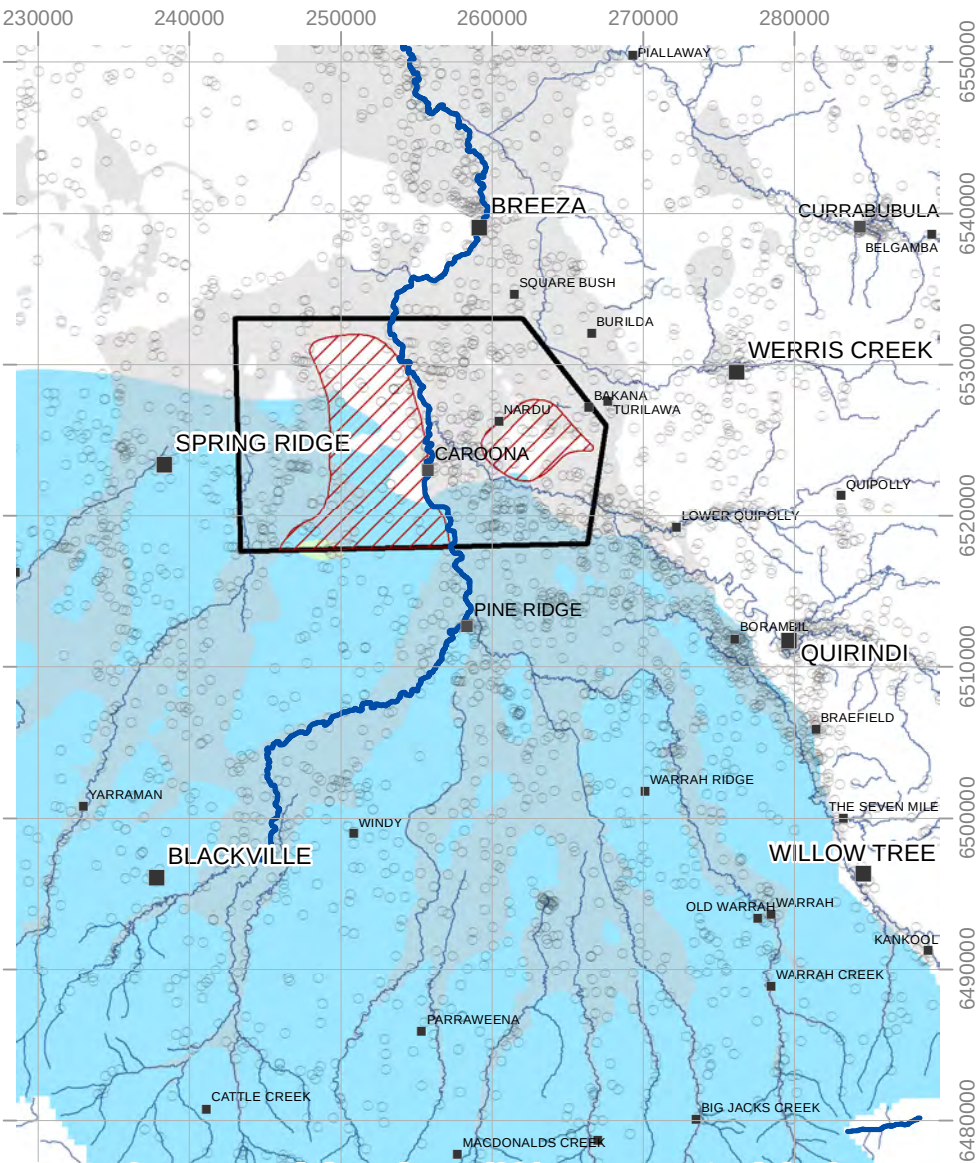


0 2.5 5 10 15 20
Kilometers

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Layer 9 maximum drawdown at any time
Pamboola Fm



Layer 9 recovered drawdown (280 years post-mining)
Pamboola Fm

Legend

- NOW Registered Bores
- Town
- Village
- Locality
- River
- Creek
- Alluvials
- Exploration Licence
- ▨

Targeted Exploration Area

Maximum Drawdown
(m, at any time)

<=2

2.01 - 10

10.01 - 20

20.01 - 50

>50.00

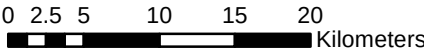
BHP Billiton
Caroona Coal Project

Figure 41
Simulated Drawdown and Recovery
Model Layer 9

DrawingNo: CAR001-009
Rev: E.
Created by: CNicol
Date: 04/03/2014.



Scale: 500,000 at A3
GDA 1994 MGA Zone 56



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6 PREDICTIVE MODEL SENSITIVITY ANALYSIS

In addition to the calibrated 'base case' predictive model, two further models were developed to assess the sensitivity of model predictions to key model parameters, namely:

- ❑ Sensitivity run 1: Vertical hydraulic conductivity one order of magnitude higher than calibrated values in layers 4 through 9 (i.e. Jurassic and Permo-Triassic units). This model is otherwise as per the calibrated 'base case' model. Vertical conductivity of these rock units is the key parameter controlling the timing, location/spatial extent and intensity of impact propagation up from the mined seam to the land surface and shallow water bearing strata; and
- ❑ Sensitivity run 2: No mining-induced fractured zone (no TMP package, but the mine void remains simulated using the Drain package). This serves to define the magnitude of influence of the simulated fractured zone on modelled mining impacts. This is critical given the highly uncertain nature of the fractured zone and its hydraulic effects. This model is otherwise as per the calibrated 'base case' model.

Sensitivity analysis and more rigorous assessment of fractured zone heights and parameters will be conducted as part of the EIS.

6.1 MODELLED MINE INFLOW SENSITIVITY

Sensitivity run #1 shows that vertical hydraulic conductivity in the Jurassic and Permo-Triassic units plays the greatest role in simulated mine inflows, and therefore on the associated groundwater system changes. Peak mine inflows under this sensitivity run reach 11 ML/day (in Year 19 – following the introduction of Nicholas Ridge mining), and average around 7 ML/day, compared with the 'base case' model's simulated peak of around 7 ML/day and average of 4 ML/day. That is, an order of magnitude increase in the vertical hydraulic conductivity of the Jurassic to Permo-Triassic units results in almost double the average and peak simulated mine inflows.

Of particular interest, with the simulated inflows under the higher vertical conductivity scenario is the simulated inflows in mining years 17 through 30, when the mine is simulated to be at its deepest (and Doona Ridge and Nicholas Ridge mining occurs simultaneously). The difference in simulated inflows over this period as compared to the 'base case' model is significantly greater than the difference in the first 16 years of the simulated mine operation.

Sensitivity run #2 highlights the effect of the simulated mining induced fractured zone on modelled mine inflows. Without the simulated fractured zone, peak inflows are less than 2 ML/day, whilst average inflows are about 1 ML/day; on both measures, this is around 25-30% of the simulated inflows in the 'base case' calibrated model.

6.2 MODELLED DRAWDOWN SENSITIVITY

Attachment E presents the simulated alluvial aquifer drawdown (model layers 1 and 2) under sensitivity run #1 (i.e. one order of magnitude lower vertical hydraulic conductivity than in the 'base case' calibrated model). Attachment E also presents these results for all model layers under sensitivity run #1.

This sensitivity run shows that simulated drawdown within the highly productive alluvial aquifer is sensitive to the vertical hydraulic conductivity of the Jurassic to Permo-Triassic rock units. Two small areas of drawdown exceeding the AI Policy's 2 m criteria are simulated to occur within the Gunnedah Formation.

7 LICENSABLE WATER TAKES

Table 33 presents the indicative Project groundwater licensing summary, which is based upon the base model simulated potential water balance changes in response to the Project. For the Upper and Lower Namoi Groundwater Sources, this is further subdivided across each of the NOW management zones in Table 34.

At the Gateway stage, it is understood that the initial estimates of water takes are indications of the order of magnitude relevant to the availability of water licences on hand or on the open market. These licence volumes would be refined as part of the more detailed EIS model predictions.

BHP Billiton holds several Water Access Licences for use for the Project:

- ❑ WAL12931 (422 units - Upper and Lower Namoi Groundwater Sources 2003 Zone 8).
- ❑ WAL14550 (215 units - Upper and Lower Namoi Groundwater Sources 2003 Zone 8)⁵.
- ❑ WAL36496 (1,000 units NSW Murray Darling Basin Porous Rock Groundwater Sources 2011 (Gunnedah-Oxley Basin MDB [Other])).

BHP Billiton will continue to investigate opportunities to obtain additional licences in the NSW Murray Darling Basin Fractured Rock Groundwater Sources 2011 Liverpool Ranges Basalt and NSW Murray Darling Basin Porous Rock Groundwater Sources 2011 Gunnedah-Oxley Basin (Spring Ridge); as well as additional licences in the NSW Murray Darling Basin Porous Rock Groundwater Sources 2011 Gunnedah-Oxley Basin (Other). BHP Billiton would also trade or transfer its existing allocation under WAL12931 to different Upper and Lower Namoi Groundwater Source 2003 Zones, as necessary.

⁵ Supplementary water licence.

Table 33 **Project Groundwater Licensing Summary**

Water Sharing Plan	Management Zone/ Water Source	Predicted Interim Annual Water Takes requiring Licensing (ML/year)	
		During Mine Operation	Post-Mine Operation
Upper and Lower Namoi Groundwater Sources 2003	See Table 34	Avg. 363 Max. 458	Avg. 167 Max. 487
NSW Murray Darling Basin Fractured Rock Groundwater Sources 2011	Liverpool Ranges Basalt MDB	Avg. 9 Max. 10	Avg. 4 Max. 9
NSW Murray Darling Basin Porous Rock Groundwater Sources 2011	Gunnedah-Oxley Basin MDB (Spring Ridge)	Avg. 2 Max. 6	Avg. 6 Max. 11
NSW Murray Darling Basin Porous Rock Groundwater Sources 2011	Gunnedah-Oxley Basin MDB (Other)	Avg. 1033* (Drain (mine) inflow) Max. 2301*	Avg. 88* Max. 254*

* Licence volume adjusted for takes from other water sources (e.g. water take from alluvium subtracted from mine inflows).

Source:

D:\HydroSim\CAR001\GWMModel\CARv2TR\Processing\Prediction\Budget\CARv2TR025zbud_out.xlsx

Table 34 **Modelled Water Takes from each Namoi Alluvium Zone**

Zone	Water Takes During Mining (ML/year)		Water Takes Post-Mining (ML/year)	
	Maximum	Average	Maximum	Average
Alluvium Zone 1	7	1	2	0
Alluvium Zone 3	149	5	21	7
Alluvium Zone 4	0	0	0	0
Alluvium Zone 6	44	4	23	14
Alluvium Zone 7	202	161	217	70
Alluvium Zone 8	181	149	183	47
Alluvium Zone 10	5	0	3	2
Alluvium (no zone)	59	43	67	26
All Alluvium	458*	363	487*	167

* Maximum of all modelled time periods' total water take from the entire modelled alluvium. As such, this does not equal the sum of the maximum rates for each zone, because each zone's maximum take can (and does) occur within different modelled time periods.

Source:

D:\HydroSim\CAR001\GWModel\CARv2TR\Processing\Prediction\Budget\CARv2TR025zbud_Alluvium_out_V3.xlsx

8 CONCLUSIONS

The Project groundwater model developed for this preliminary groundwater assessment for the Gateway process was designed to address the following:

- ❑ Data analysis and conceptualisation of the groundwater system, including assessment of hydrostratigraphic units and their properties, and groundwater recharge and discharge through the flow systems;
- ❑ Development of a lower resolution regional-scale 3-dimensional numerical groundwater flow model. This was based on data analysis and development of a conceptual hydrogeological model;
- ❑ Steady state model calibration to observed groundwater level data, using a single zone of uniform parameters for each hydrostratigraphic unit;
- ❑ Transient model verification against observed groundwater level fluctuation data;
- ❑ Transient prediction for the 30 year mine plan conducted with higher temporal resolution of the extraction schedule, followed by simulation of the post-mining recovery period (280 years post-mining was simulated);
- ❑ Preparation of this Preliminary Groundwater Assessment report for inclusion in the Project Gateway Application documents that includes assessment of potential underground mine groundwater impacts and cumulative impacts with other proposed mines in the area associated with the development. This assessment focussed on the criteria specified by the AI Policy and the Gateway process; and
- ❑ Proposed measures to avoid, mitigate and/or offset (if necessary) potential impacts on groundwater resources and recommendations for future groundwater monitoring to measure actual impacts on groundwater resources associated with the development.

A review of the data, literature and conceptual hydrogeology associated with other studies from the area and surrounds was carried out as a basis for model development. This was supported by a review of currently available information on geology, rock mass hydraulic properties, and strata geometry for the area. Due consideration was given to the setup and creation of model boundaries and surface water/groundwater interaction processes. Justification for all of the modelling approaches that were used has been given within this report. Care was taken to ensure that hydraulic parameters within the model were maintained within realistic ranges that were based on actual measured data or published information for this region. Recharge rates were based largely on estimates (and model calibration), but the zones and values used within the model are consistent with the conceptual hydrogeology for the Project area and surrounds.

Steady-state model calibration and transient model verification were undertaken, yielding good results.

The Project comprises underground coal mine workings in the Hoskissons Coal Seam using the longwall method of extraction. This assessment focussed on the risks of the proposal within the framework of the 'minimal impact considerations' of the AI Policy.

The AI Policy framework identifies two Levels of minimal impact considerations, as described below:

- ❑ Level 1 impact, which is considered acceptable.
- ❑ Level 2 impact, which requires further studies to assess whether a project will prevent the long-term viability of a dependent ecosystem or significant site, or needs other arrangements to mitigate the impacts.

These impacts were assessed for the highly productive Namoi Alluvial aquifer, Liverpool Range Basalt fractured rock groundwater system and Jurassic (Spring Ridge) porous and fractured rock groundwater system, in addition to the less productive Permo-Triassic porous and fractured rock groundwater system.

The key findings of this assessment are:

- ❑ The simulated total annual take of water from the Permo-Triassic rock groundwater system as mine inflow is derived from a range of sources.
- ❑ The post-mining average total water take from the Namoi Alluvium is 167 ML/year. The maximum extraction (water take) rate from this source is 487 ML/year. During simulated mining operations, the average take from this source is 363 ML/year, with a maximum of 458 ML/year.
- ❑ The average total water take from the Liverpool Ranges Basalt (fractured rock) groundwater system during operational mining is 9 ML/year. The maximum water take from this source is 10 ML/year. Post-mining, the simulated take from this source averages 4 ML/year, with a maximum of 9 ML/year.
- ❑ The average total water take from the Jurassic porous and fractured rock groundwater system (Spring Ridge) during operational mining is 2 ML/year. The maximum water take from this source is 11 ML/year. Post-mining, the simulated take from this source averages 6 ML/year, with a maximum of 11 ML/year.
- ❑ The average total water take from the Permo-Triassic porous and fractured rock groundwater system (Other) during operational mining is 1,033 ML/year. The maximum water take at any point in time from this source is 2,301 ML/year. Post-mining, the simulated take from this source averages 88 ML/year, with a maximum of 254 ML/year.
- ❑ The modelling indicates that reduced beneficial uses of any groundwater source or the Mooki River as a result of water quality effects due to the Project would not occur.

- ❑ Neither high value GDEs nor culturally significant sites are identified in the relevant water sharing plans, which could be appreciably influenced by the Project. Hence the proposal is not considered a risk to such features.
- ❑ There is no proposed mining activity within the AI Policy's specified distances to the Namoi Alluvium, nor is there any significant proposed excavation of alluvial material. Hence the proposal poses no risks in this regard.
- ❑ The calibrated model simulates up to 27 privately-owned bores which may experience drawdowns that exceed the 2 m stipulated by the AI policy in the 'highly productive' Jurassic (Spring Ridge) groundwater system. None of these bores have Water Access Licenses (under any Water Sharing Plan), and none are located within the highly productive Namoi Alluvium, or the Liverpool Range Basalts. Accounting for cumulative impacts of surrounding mines by using the simplifying assumption of the Principle of Superposition, the number of impacted bores remains the same.
- ❑ The drawdown created by mining within the Permo-Triassic groundwater system means that the proposal triggers Level 2 of the AI Policy's minimal impact considerations for the highly productive Jurassic (Spring Ridge) groundwater source. In addition, a number of bores within the less productive Permo-Triassic groundwater source would also trigger Level 2 of the AI Policy minimal impact consideration.
- ❑ The Project's influence on the groundwater system as indicated will require monitoring and, where drawdowns exceed 2 m, mitigation measures. Such measures would comprise deepening and/or replacing bores and wells, and/or providing an alternative water source to affected users. BHP Billiton has committed to 'make good' provisions for affected groundwater users.
- ❑ A Groundwater Management Plan will require development and approval prior to longwall mining. This will need to define groundwater level triggers, and a trigger exceedance action plan.
- ❑ BHP Billiton will conduct a second stage of the bore census in consultation with relevant landholders to confirm the status, location and details of the bores not yet inspected (in Table 28) in order to inform further impact assessment work planned for the EIS.

8.1 RECOMMENDATIONS FOR FUTURE WORK

Following determination of the Project's Gateway Application, it is recommended that this preliminary assessment and its supporting numerical model are updated and expanded in greater detail for the purposes of a full EIS, as outlined in Table 35. The scope of the current model used for the Gateway Assessment is included for comparison.

It is recommended that the existing baseline monitoring programme be continued.

In order to augment the existing hydraulic properties dataset, exploration core samples should be taken from a range of rock types within the lease and analysed in a suitably certified laboratory for vertical and horizontal hydraulic conductivity, and porosity.

A second stage bore census should be carried out in order to confirm the status, location and details of the bores not yet inspected, in order to inform further impact assessment to be undertaken for the EIS.

Formal, calibration-constrained predictive model uncertainty analysis is to be conducted as part of the EIS, as per the Australian Groundwater Modelling Guidelines, and the guidelines of the IESC. This is also of value in mine planning and assessing a wide range of Project risks. This analysis could be used to identify data (model parameters) to which critical simulated impacts of the Project are most sensitive, and therefore the data that are of greatest value to the Project and stakeholder interests, in terms of reducing predictive uncertainty.

Table 35 Proposed Scope for a Full Environmental Impact Assessment

	GATEWAY PROCESS	ENVIRONMENTAL IMPACT STATEMENT
Spatial Scale	Coarse	Fine
Temporal Scale	Fine (original intent was coarse)	Fine
Model Extent	70 km x 97.6 km	70 km x 97.6 km
Stratigraphy	9 Layers	>9 Layers
Spatial Parameter Variability	No (unless available from previous models)	Yes
Steady-State Calibration	Yes	Yes
Transient Calibration	No (verification only)	Yes
Prediction	30 years	30 years
Fractured Zone	Yes	Yes
Tracking of Headings	Limited to none	Yes
Sensitivity Analysis	Limited	Extensive
Uncertainty Analysis	No	Limited
Recovery Analysis	Yes	Yes
Cumulative Assessment	Law of Superposition	Simulation
Climate Change	No	Yes
Mitigation Measures	If required	Yes
Monitoring Program	Yes	Yes
Outputs	Focused on AI Policy	Extensive spatial and time-series plots and tables
Licensing Volumes	Indicative	Firm recommendations
Software	MODFLOW-SURFACT	MODFLOW-SURFACT
Report	Condensed	Substantial

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Attachment A

IESC Information Requirements

1. Summary Details

Project Information	Description
Project Title	Caroona Coal Project
Date of Request	Date
Requesting Organisation	Name of the requesting organisation (the Regulator)
EPBC Act Referral	Reference (referral number, type - if EPBC referral)
Advice Stage	Stage of EIS process at which request has been made
Request Details	Background to the referral and advice that is sought from the Committee
Proponent Details	BHP Billiton Ltd
Website Links	Links to web sites, including proponent website and documents
Public Submissions	Summary of public submissions

2. Project Description

Project Information	Description	Report / Section / Answer
	Overview of project location including geographical, geologic, river basin/catchment, hydro-geological basin	Sections 1 and 2
Project Location		
Project Description	Brief project description	Section 1
	Type of project that is being proposed (e.g. new project or extension) and type of operation (CSG, large coal mine)	
Project Type		Large coal mine
Resource	Geologic/ hydro-carbon resource that will be targeted	Hoskissons Coal Seam
Operation Area	Information to define the extent of the operation	Sections 1 and 4.1
		Refer to Gateway
Establishment Activities	Relevant activities required to establish the proposed project	Application/EIS
Operation Details	How the project operations will be undertaken operationally	Sections 1 and 4.1
Lifetime	Lifetime of the project	30 years; Section 1
		Refer to Gateway
Residual Site Condition	Expected site condition after decommissioning and proposed monitoring regime	Application/EIS
		Refer to Gateway
Site Rehabilitation	Outline of planned site rehabilitation works	Application/EIS

3. Regional Water Balance Model

Project Information	Description	Report / Section / Answer
Regional Overview	Proponent's regional and site water balance model	Refer to Gateway Application and Sections 3.7.3 and 4.4
Regional Groundwater	Regional groundwater description	Section 2
Regional Surface Water	Regional surface water description	Section 2
Data Uncertainties / Data Integrity Issues	Level of certainty/uncertainty with respect to the information provided	N/A, out of scope.

4. Local Water Balance Model incorporating the Site

Project Information	Description	Report / Section / Answer
Site Overview	Pre-development baseline water resources	Refer to Gateway
Local and Site Groundwater Overview		Application/EIS
Local and Site Surface Water Overview	Local groundwater description	Refer to Gateway
		Application/EIS
Local and Site Surface Water Overview	Local surface water description	Refer to Gateway
		Application/EIS
Data Uncertainties / Data Integrity Issues	Level of certainty/uncertainty with respect to the information provided	Refer to Gateway
		Application/EIS

5. Impacts of Development

Project Information	Description	Report / Section / Answer
Groundwater Impacts from Project Activities	Impacts to regional, local and site groundwater	Sections 4.4 and 5
Surface Water Impacts from Project Activities	Impacts to surface water	Section 5.3.4
Landform and Land-use Change Impacts from Project Activities	Changes and impacts to landform, geomorphology and land-use	Refer to EIS
Water Related Assets of National Environmental Significance	Relevant impacts to water related Matters of National Environmental Significance for surface and groundwater	Refer to EIS
Impacts on Other Water Related Assets	Assessment of direct and indirect impacts on other water related assets	Section 5.4, 5.5, 5.6, 5.7, 5.8
Data Uncertainties / Data Integrity Issues	Level of certainty/uncertainty with respect to the information provided	N/A, out of scope.

6. Water Related Risk Assessment

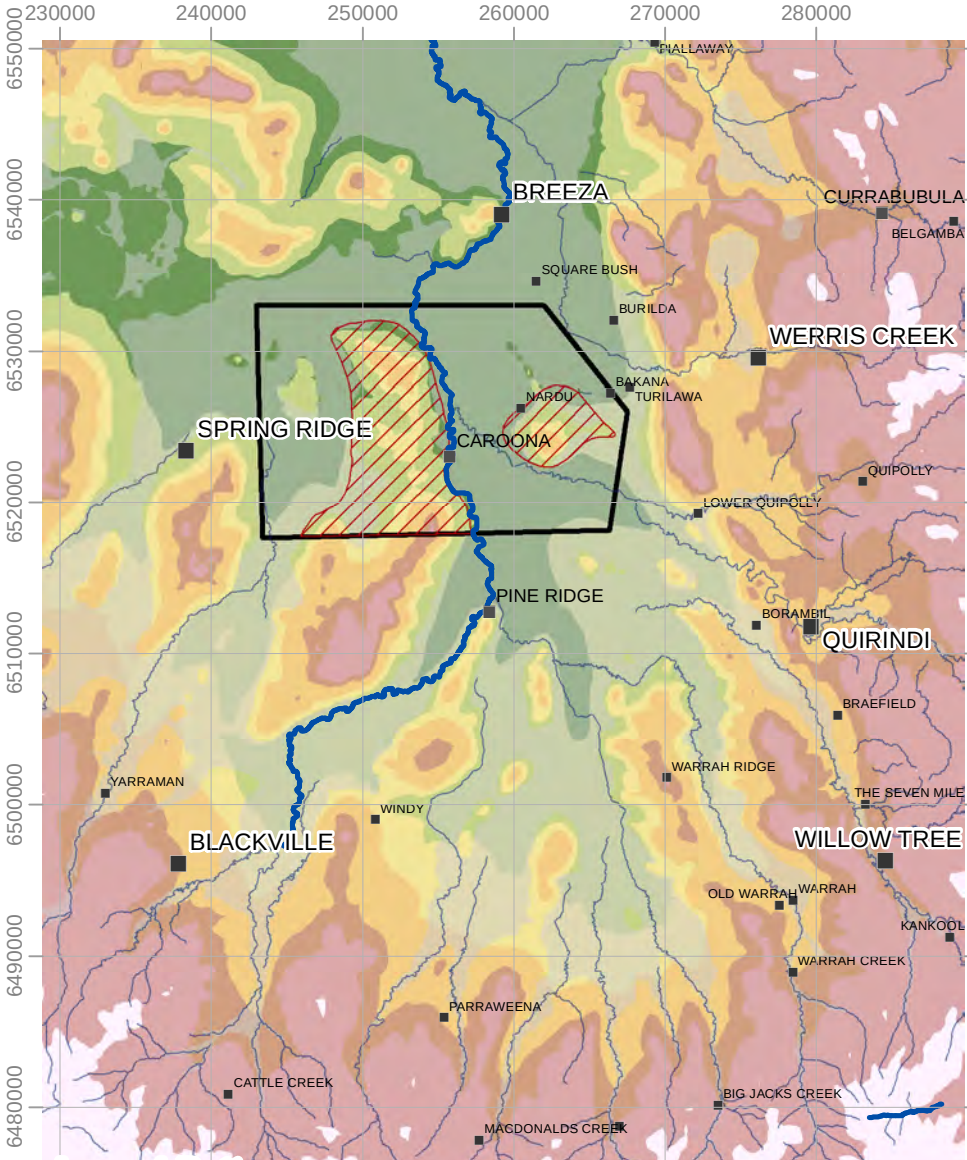
Project Information	Description	Report / Section / Answer
Risk Assessment Overview	Overview of Risk Assessment method that has been used	Refer to EIS
Risk Assessment	Assessment of the overall level of risk to water balance and water related assets	Refer to EIS
Mitigation Measures	Proposed mitigation measures to address potential risks and/or impacts	Refer to EIS
Residual Risks	Mitigation measures that have been provided for residual risk (including monitoring and reporting)	Refer to EIS

7. Cumulative Impacts

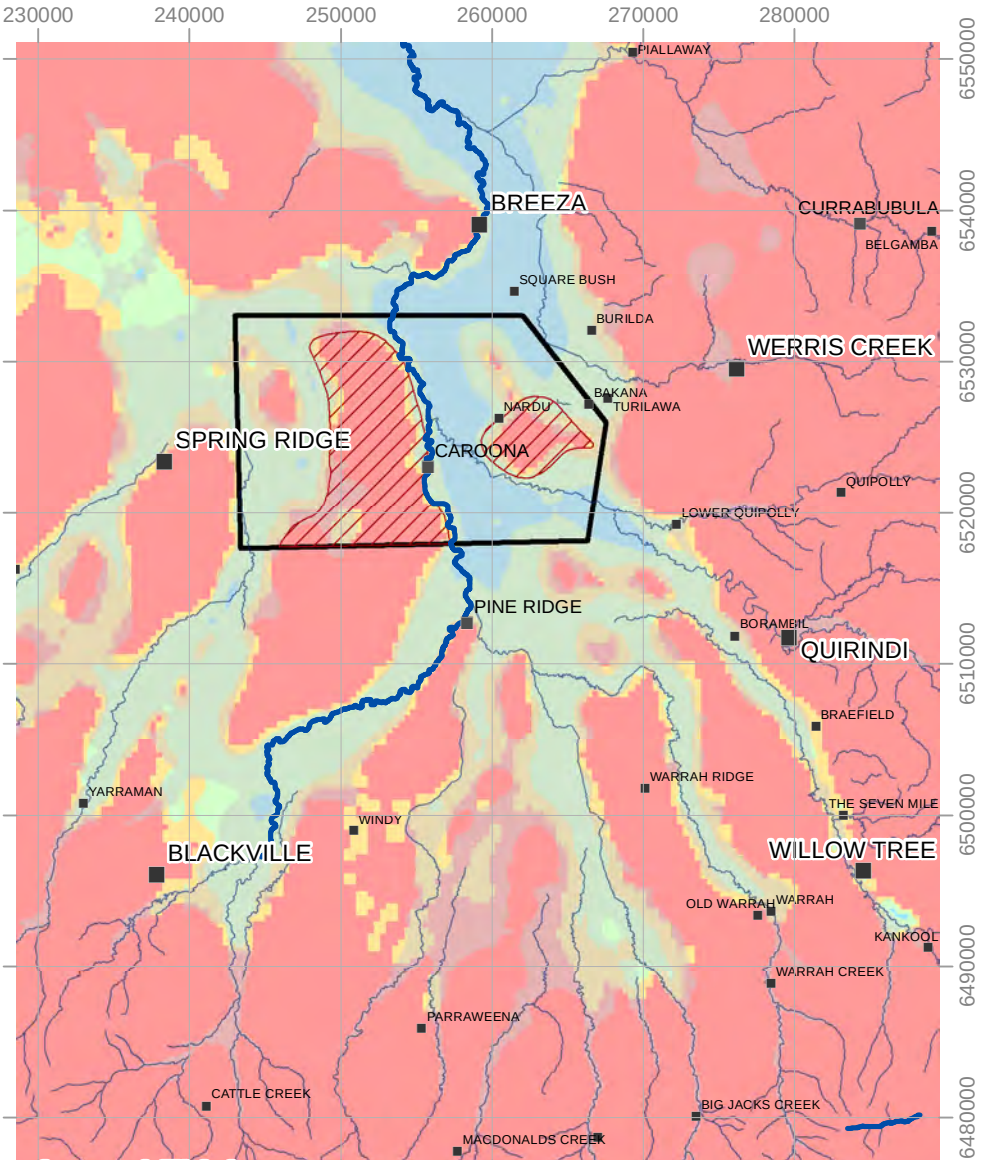
Project Information	Description	Report / Section / Answer
Regional Overview	Summary of CSG and large coal mine developments within the region. Catchment and regional scale information provided through the bioregional assessments or other relevant assessments	Section 5.3
Cumulative Risk Assessment	Cumulative risk assessment of the proposal, considering all relevant developments. Assessment of the overall cumulative level of risk to water related assets	Section 5

ATTACHMENT B

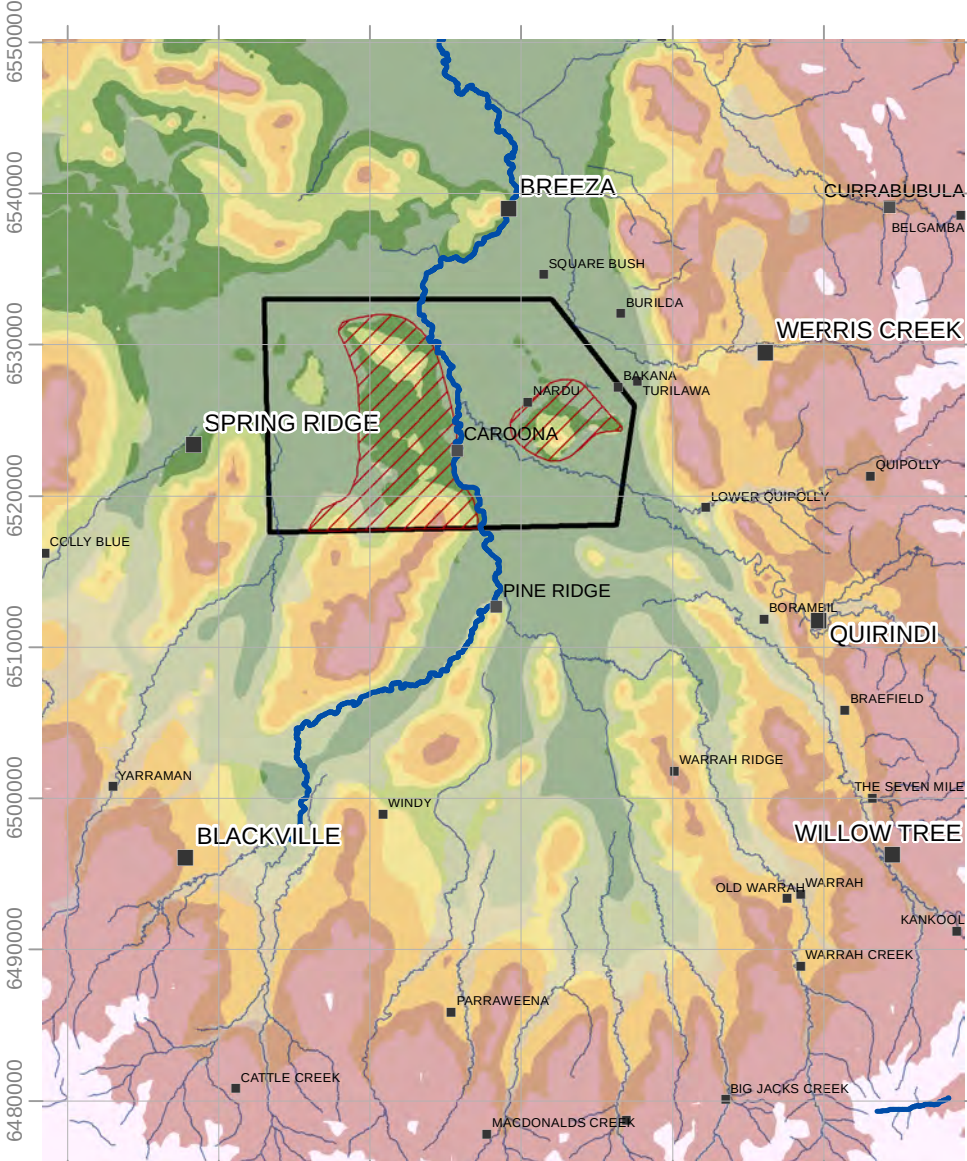
Modelled Geological Surfaces



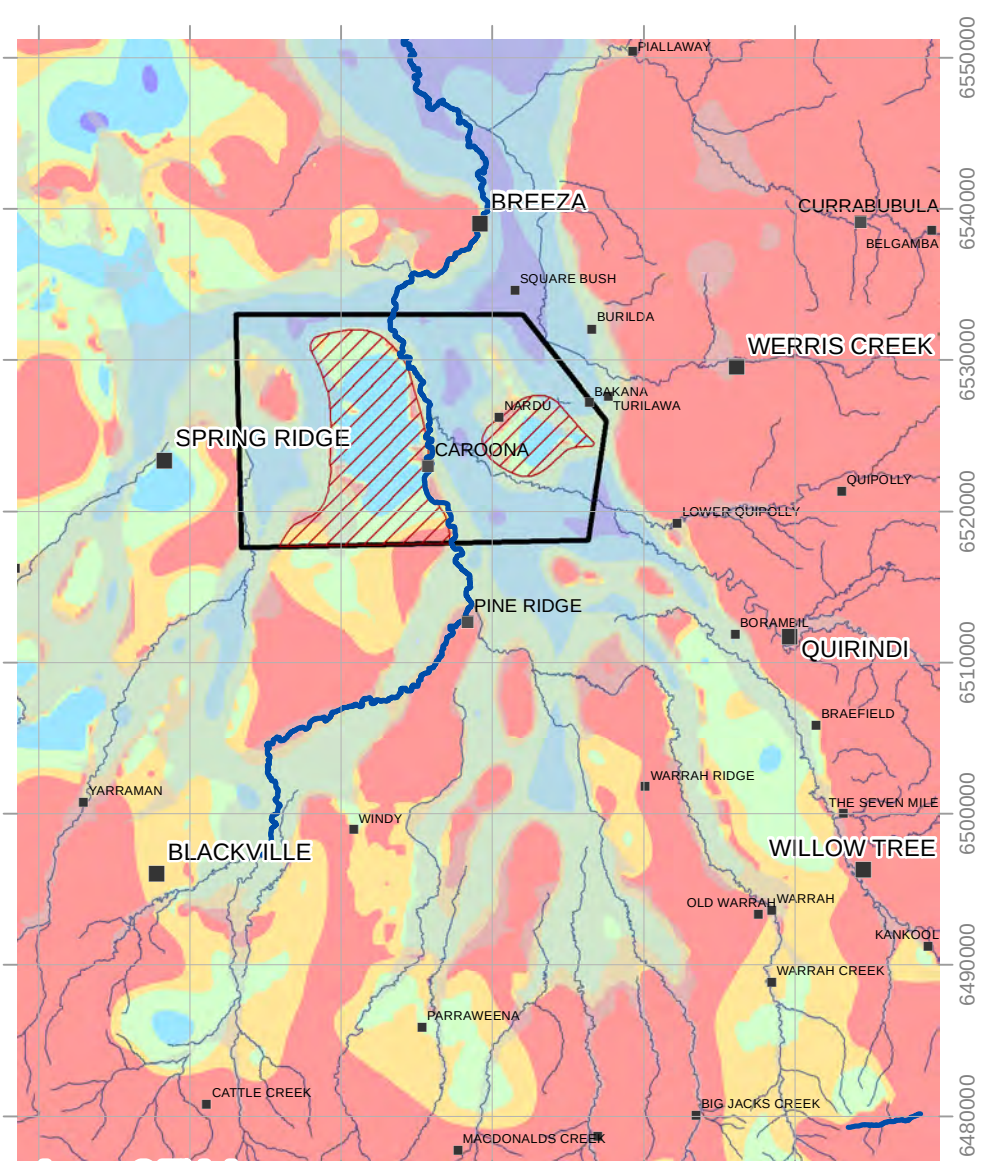
Layer 1 Bottom
Narrabri Fm / Regolith



Layer 1 Thickness
Narrabri Fm / Regolith



Layer 2 Bottom
Gunnedah Fm / Regolith



Layer 2 Thickness
Gunnedah Fm / Regolith

Legend

- Town
- Village
- Locality
- River
- Creek
- Alluvials
- Exploration Licence
- Targeted Exploration Area

Layer Bottom mAHD	
220.01 - 300	350.01 - 400
300.01 - 330	400.01 - 450
330.01 - 350	450.01 - 700
	700.01 - 1,223.05

Thickness metres	
5 - 8.69	16.45 - 25.85
8.7 - 16.44	25.86 - 36.36
	36.37 - 52.04

DrawingNo: CAR001-021
Rev: B.
Created by: CNicol
Date: 13/02/2014.



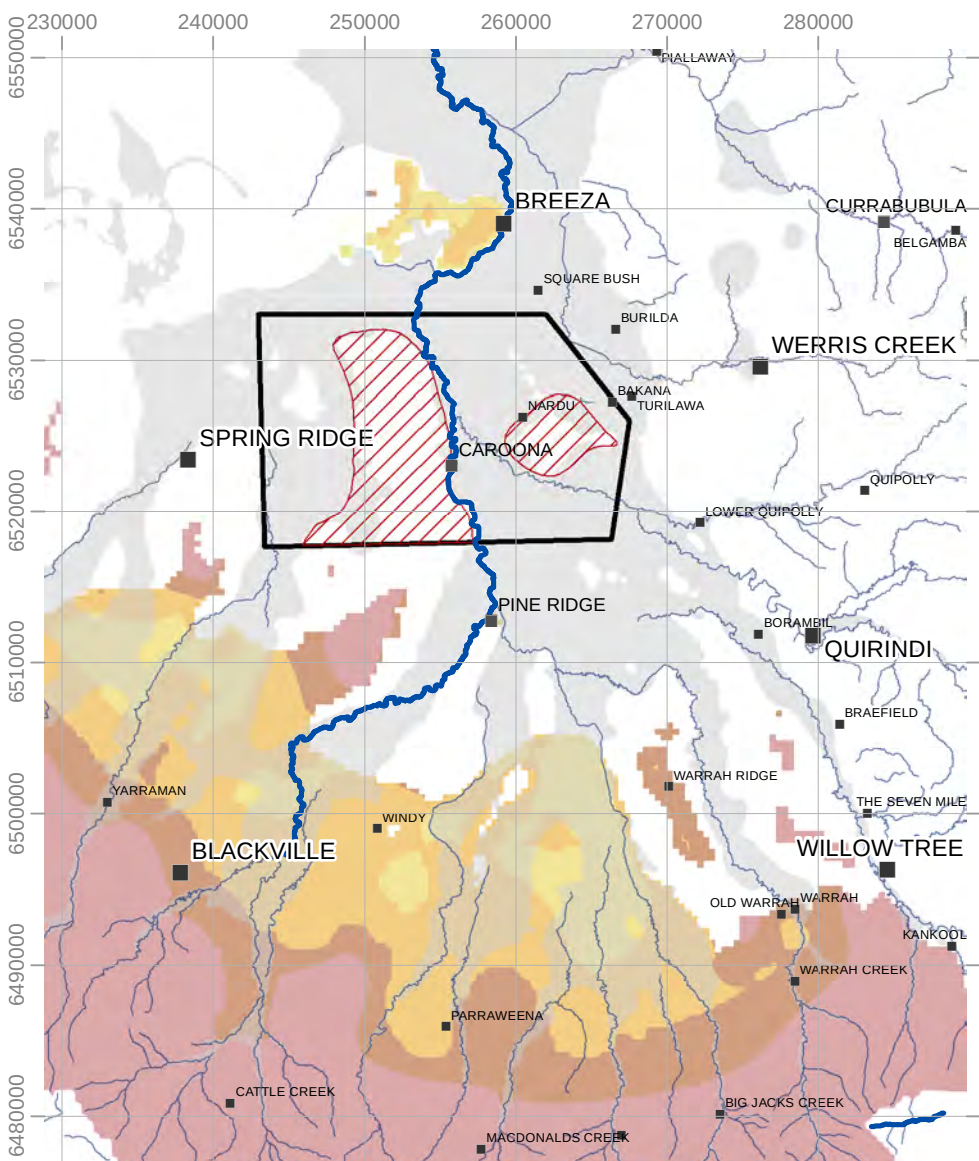
0 2.5 5 10 15 20
Kilometers

BHP Billiton
Caroona Coal Project

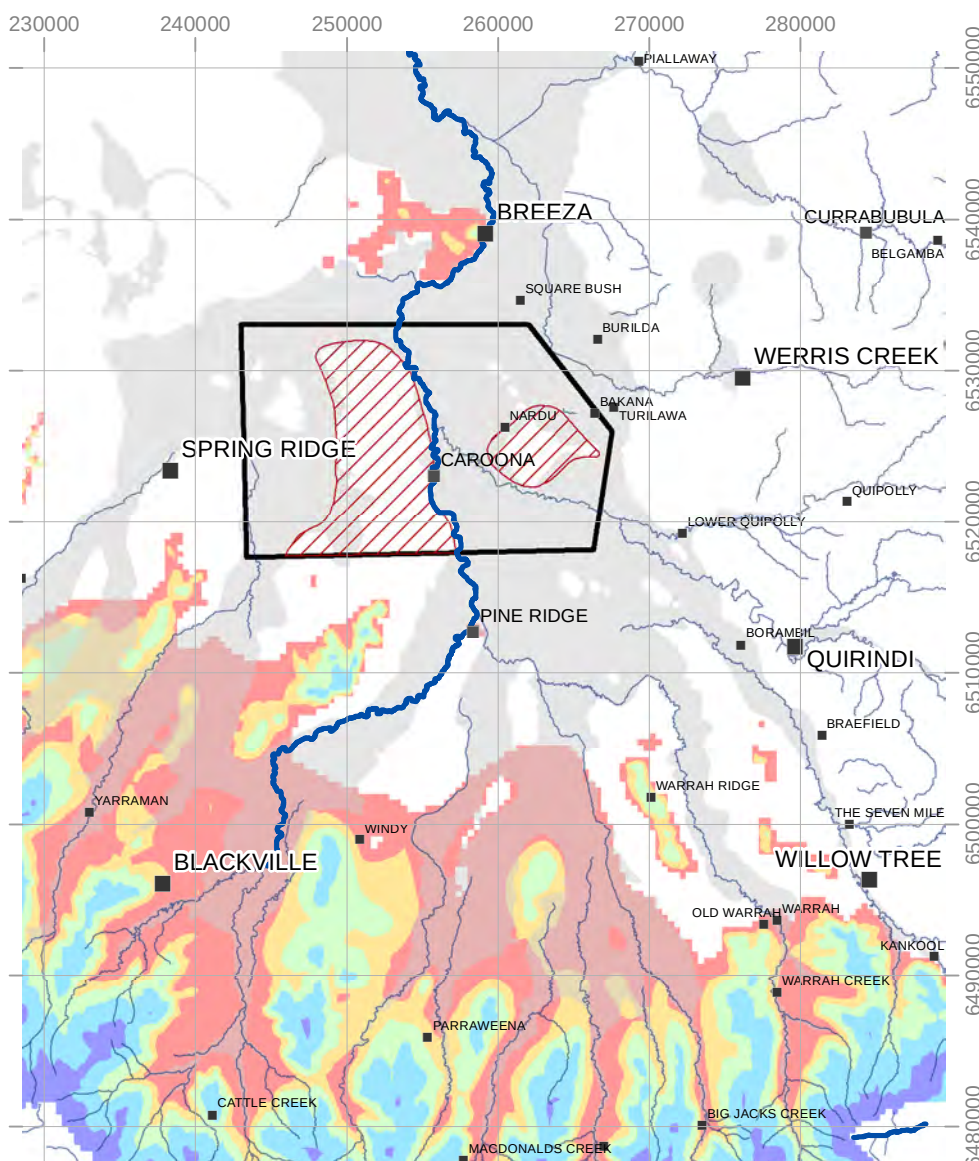
Figure B1
Modelled Surfaces
Layers 1 and 2

Scale: 500,000 at A3
GDA 1994 MGA Zone 56

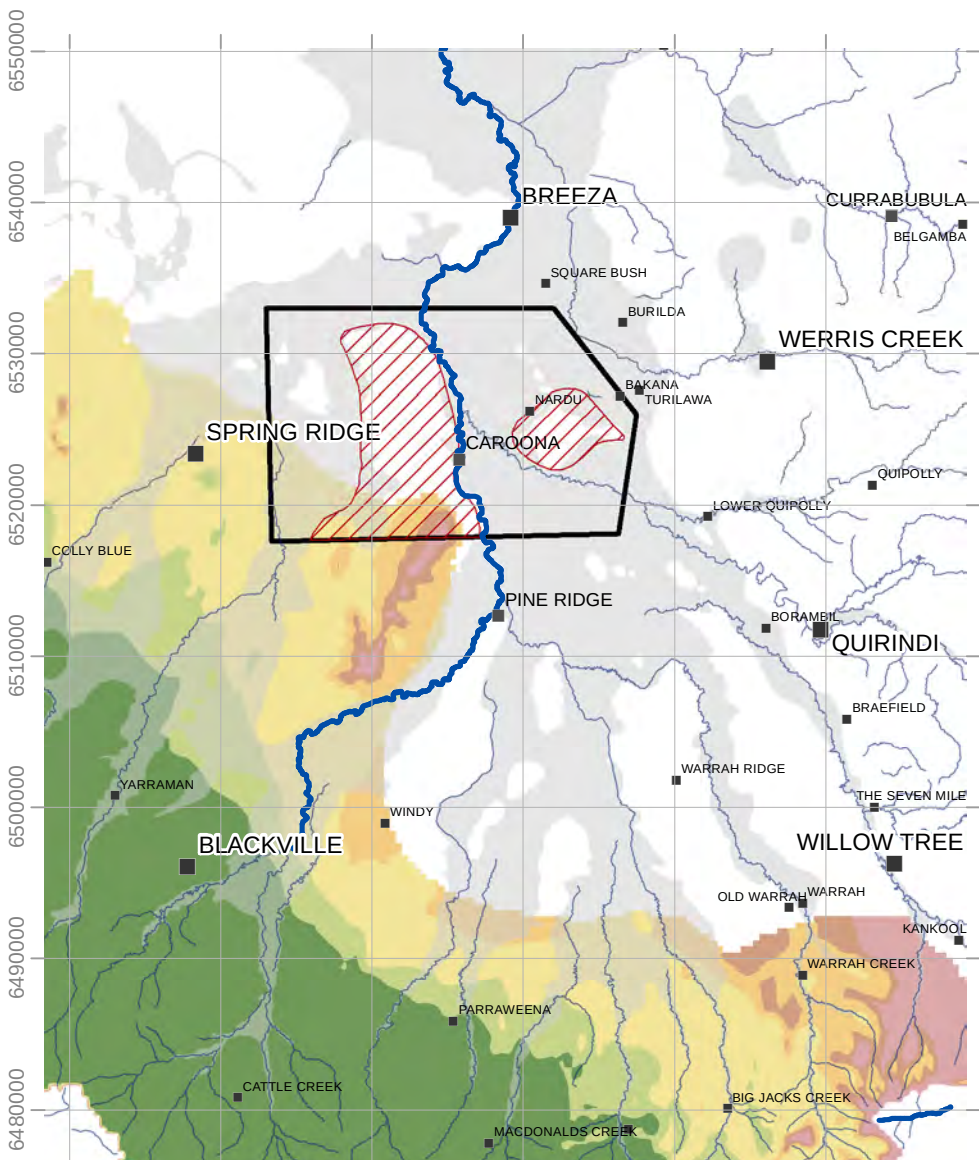
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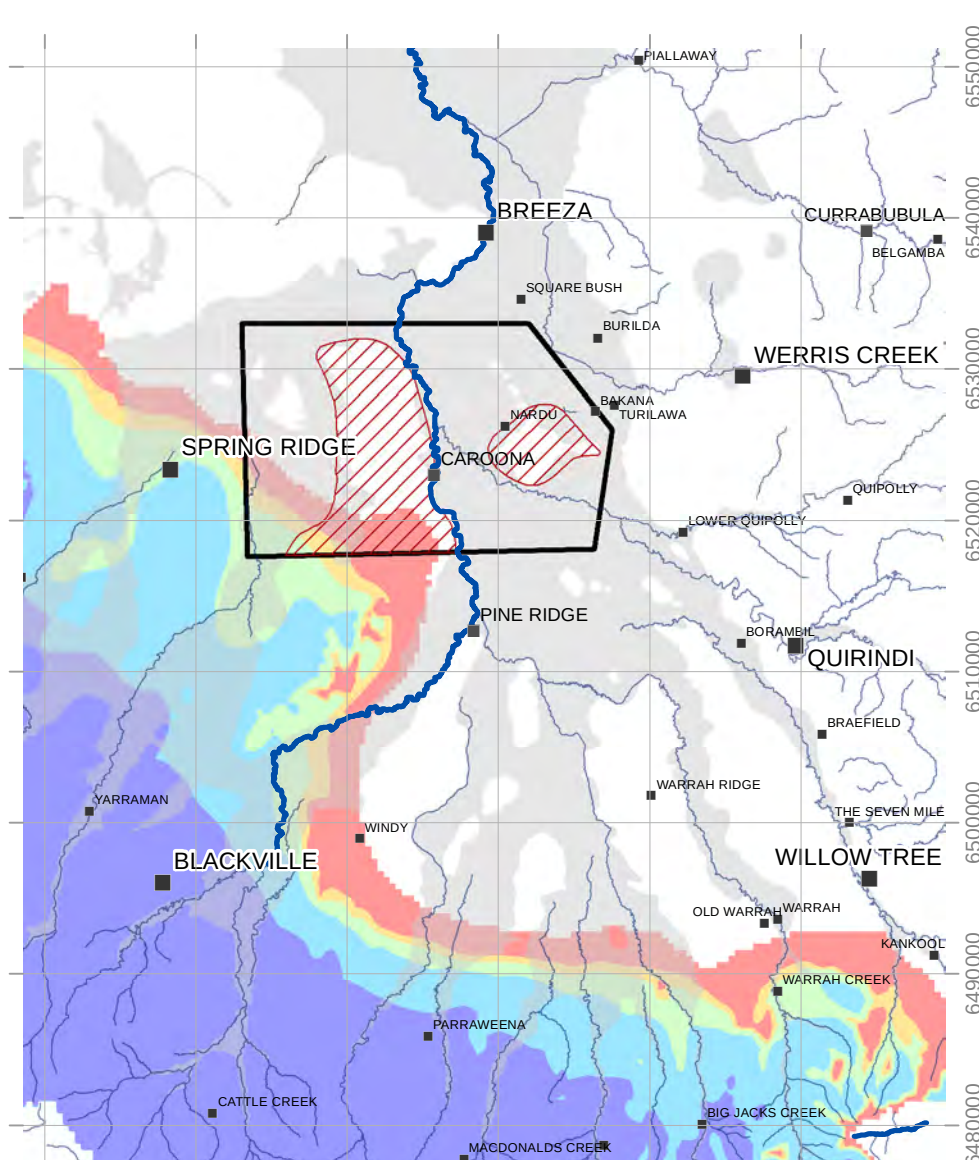
Layer 3 Bottom
Liverpool Ranges Basalt



Layer 3 Thickness
Liverpool Ranges Basalt



Layer 4 Bottom
Jurassic Formations



Layer 4 Thickness
Jurassic Formations

Legend

- Town
- Village
- Locality
- River
- Creek
- Alluvials
- Exploration Licence
- Targeted Exploration Area

Layer Bottom mAHD		Thickness metres
<50	300.01 - 350	< 25
50.01 - 150	350.01 - 400	25.01 - 50
150.01 - 300	400.01 - 600	>250
	>600	

Thickness metres	50.01 - 100
< 25	100.01 - 250
25.01 - 50	>250

BHP Billiton
Caroona Coal Project

Figure B2
Modelled Surfaces
Layers 3 and 4

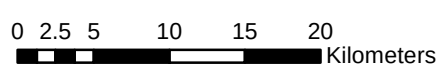
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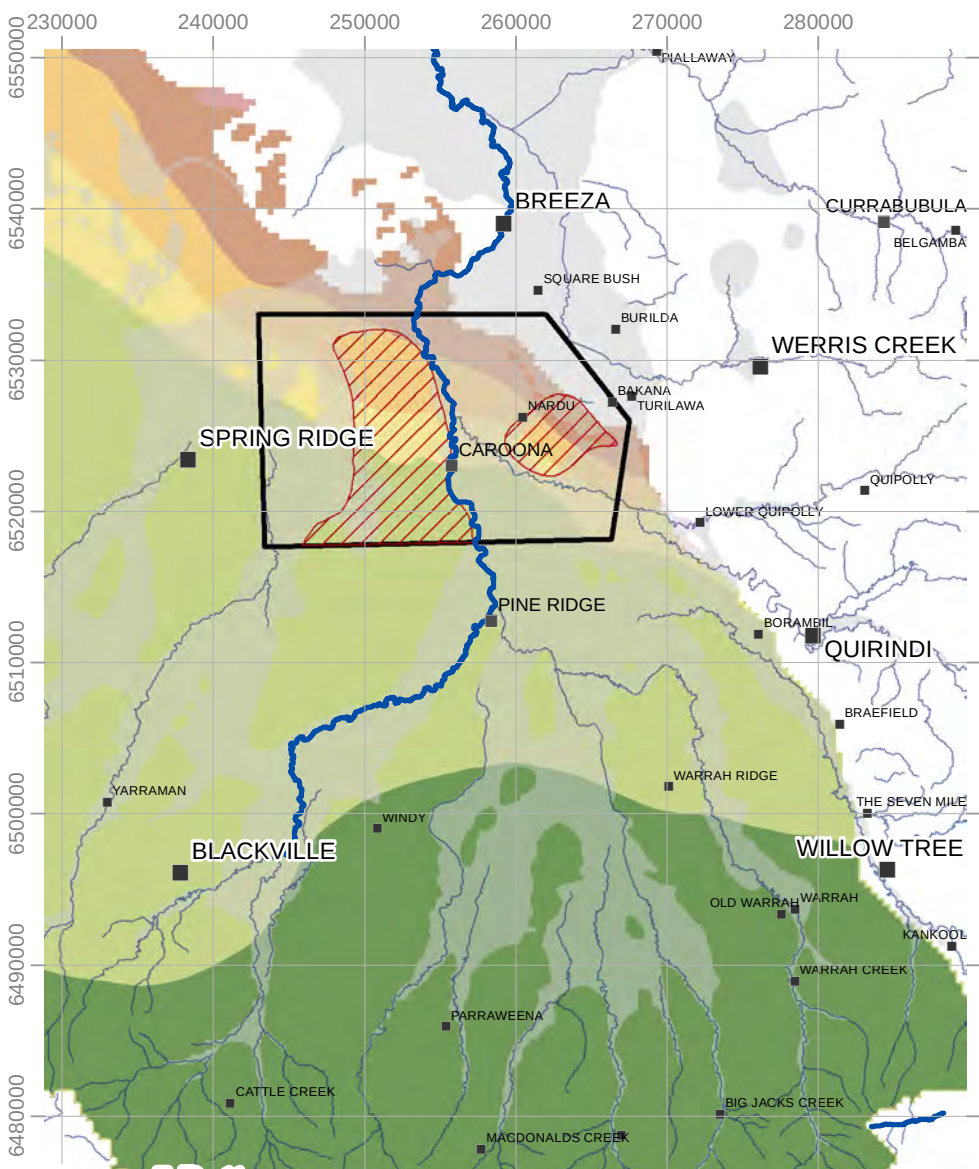


DrawingNo: CAR001-022
Rev: B.
Created by: CNicol
Date: 13/02/2014.

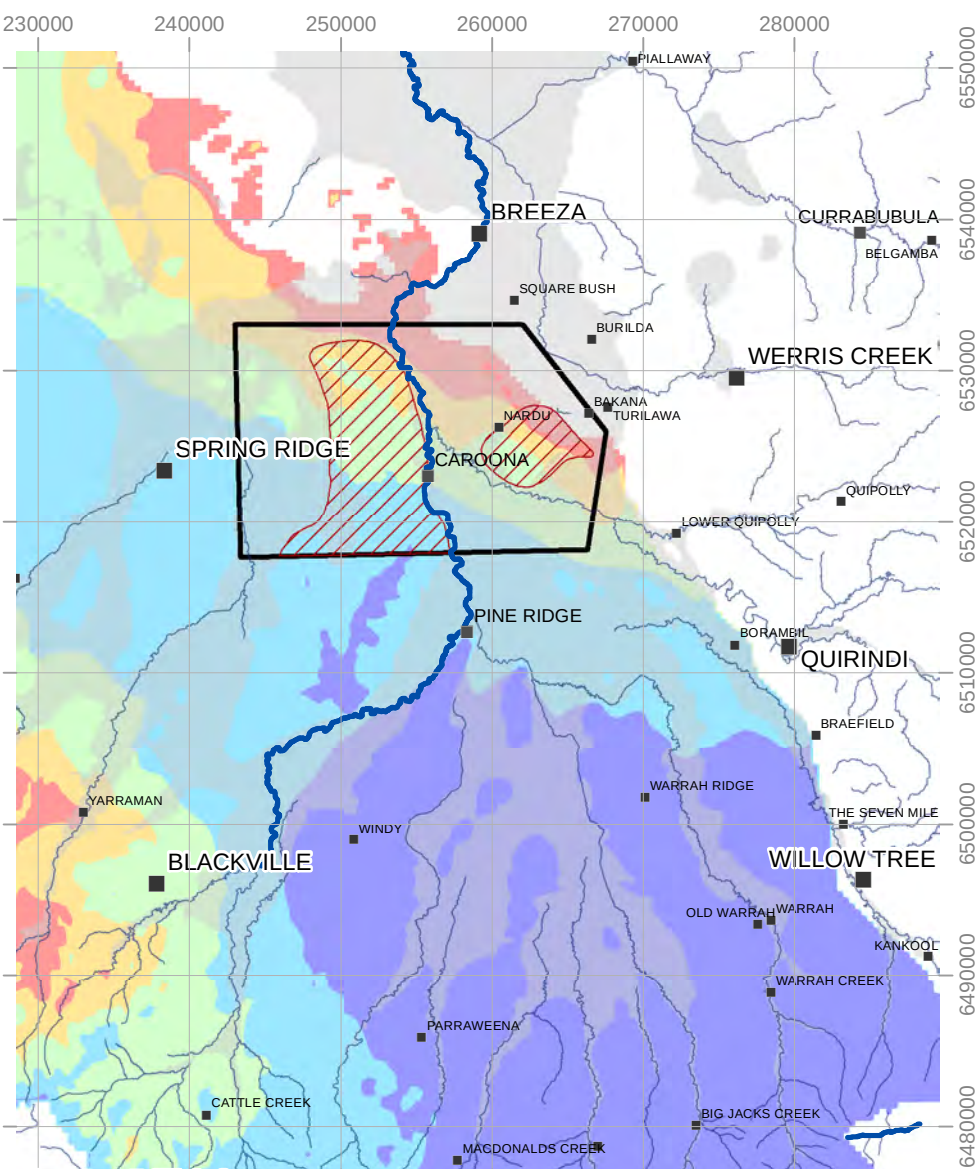


Scale: 500,000 at A3
GDA 1994 MGA Zone 56

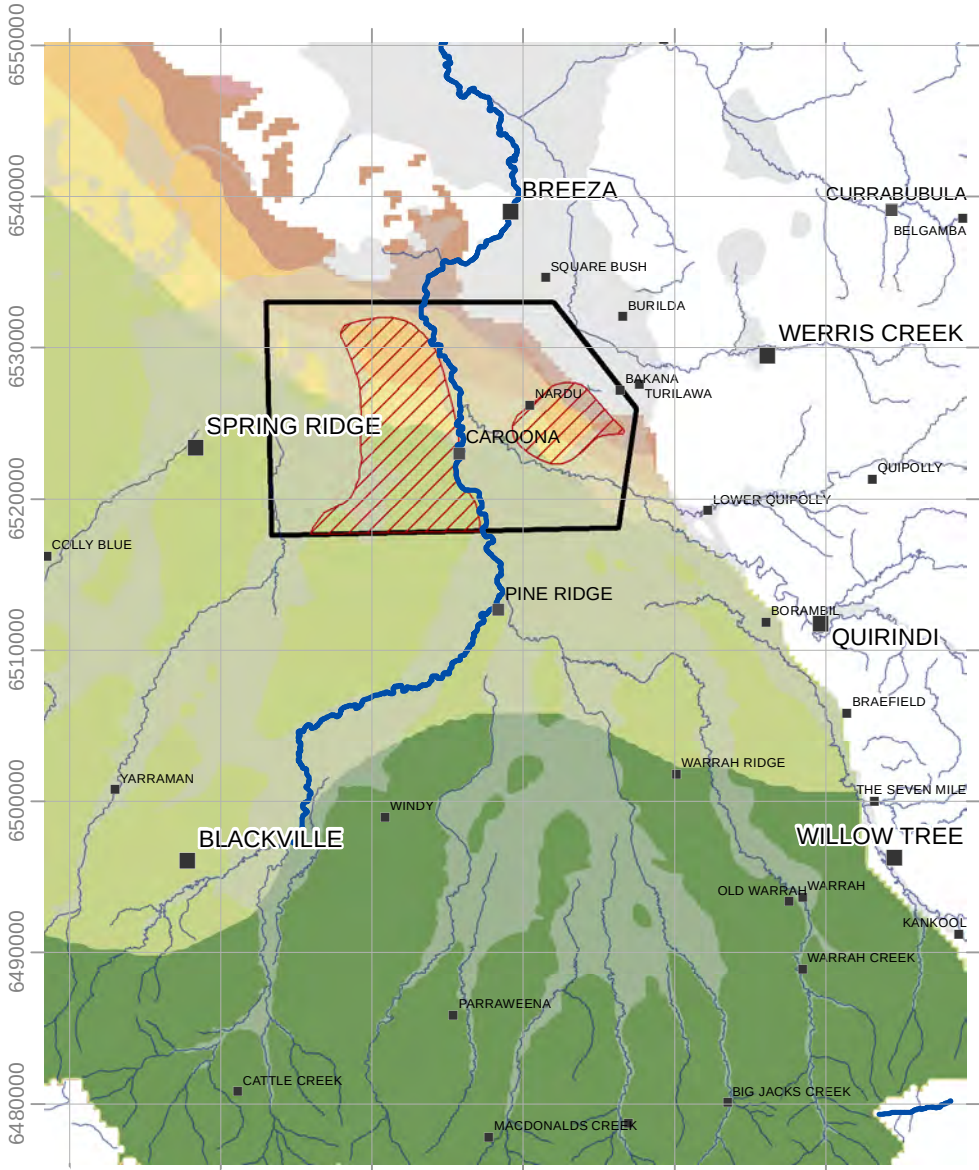




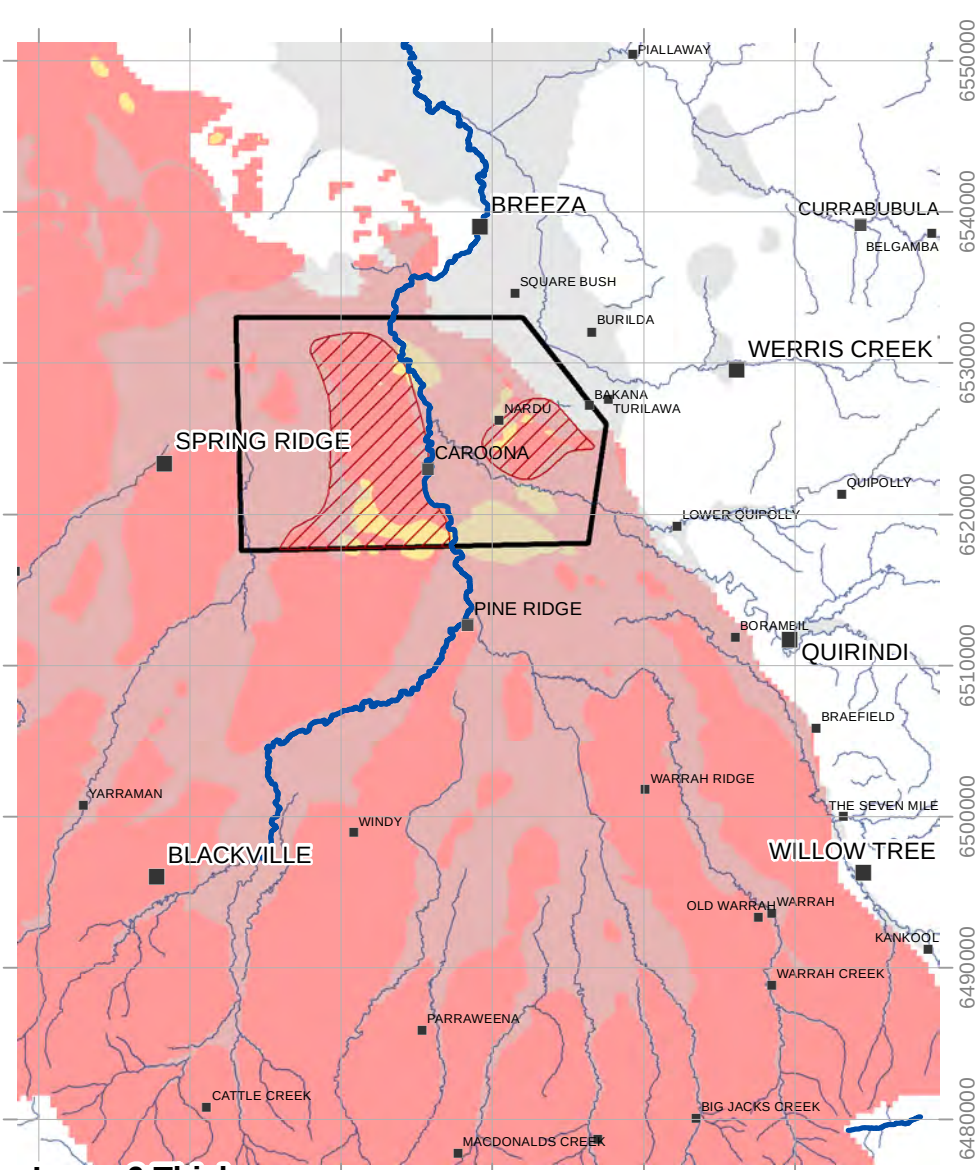
Layer 5 Bottom
Permo-Triassic Units (Napperby Fm to Wallala Fm)



Layer 5 Thickness
Permo-Triassic Units (Napperby Fm to Wallala Fm)



Layer 6 Bottom
Clare Sandstone



Layer 6 Thickness
Clare Sandstone

Legend

- Town
- Village
- Locality
- River
- Creek
- Alluvials
- Exploration Licence
- Targeted Exploration Area

Layer Bottom	
mAHD	
< -400	100.01 - 200
-399.99 - 0	200.01 - 400
0.01 - 100	400.01 - 700
	> 700

Thickness	
metres	
< 50	150.01 - 300
50.01 - 150	300.01 - 600
	> 600

DrawingNo: CAR001-023
Rev: B.
Created by: CNicol
Date: 13/02/2014.



BHP Billiton
Caroona Coal Project

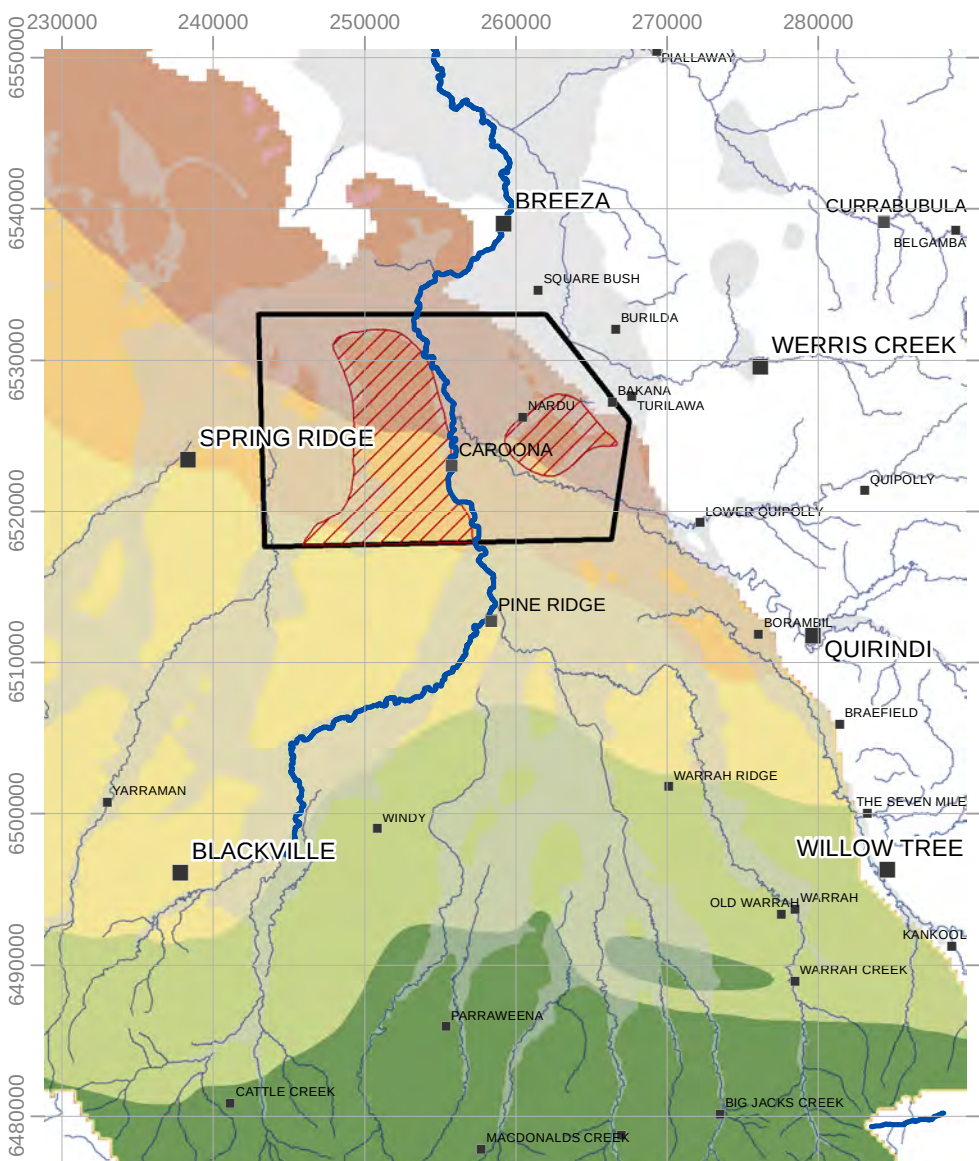
Figure B3
Modelled Surfaces
Layers 5 and 6



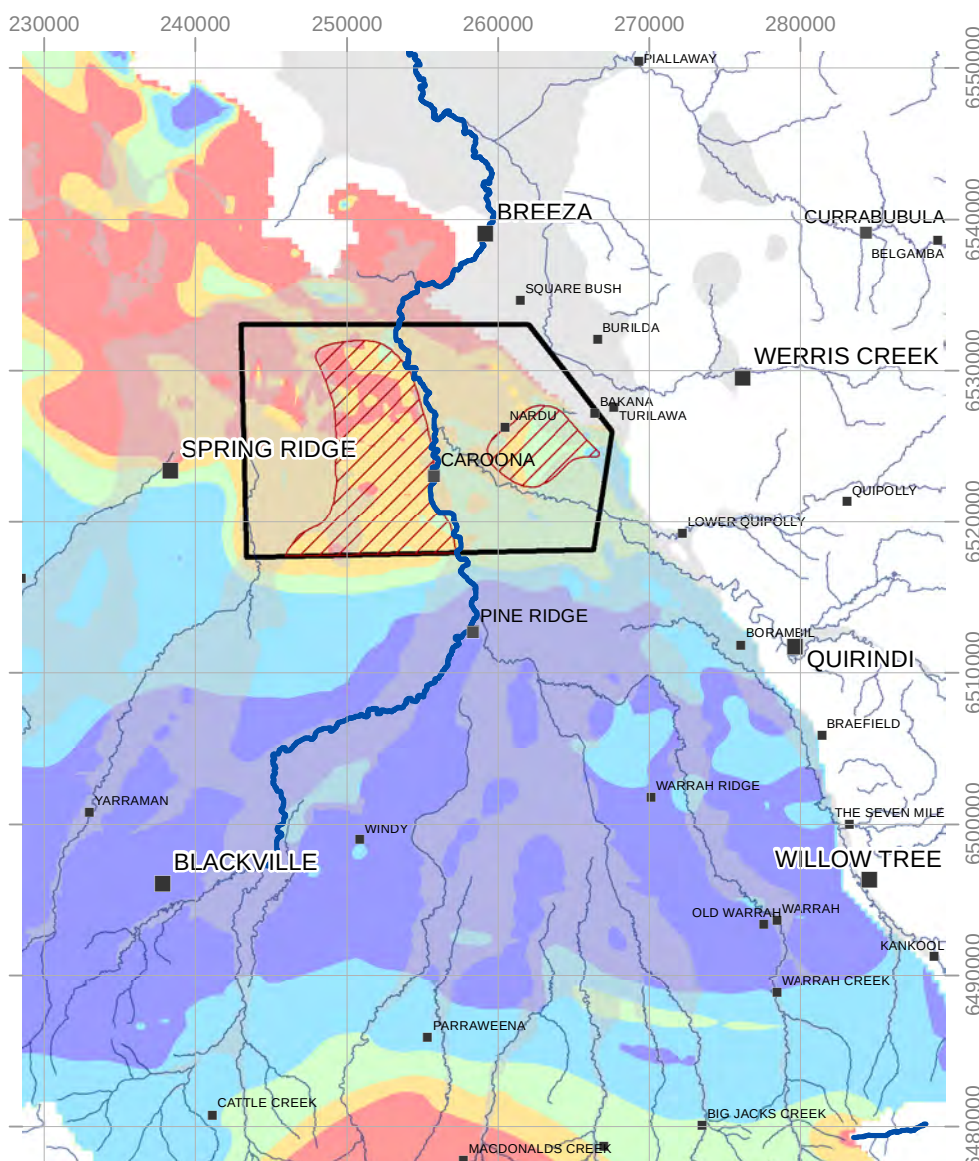
Scale: 500,000 at A3
GDA 1994 MGA Zone 56

0 2.5 5 10 15 20
Kilometers

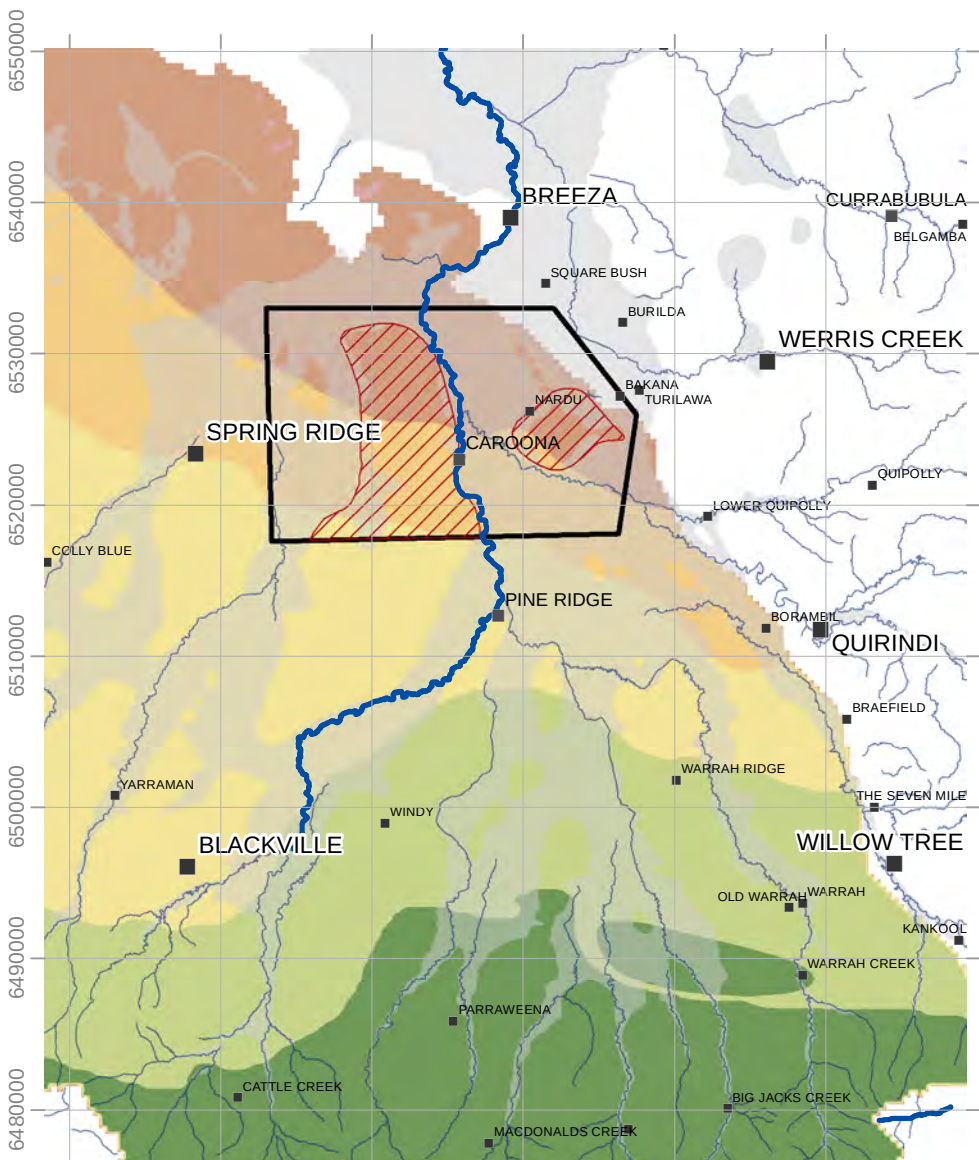
(C) 2013. While Heritage Computing/HydroSimulations has taken care to ensure the accuracy of this product, Heritage/HydroSims and DATA CUSTODIAN(S), make no representations or warranties about its accuracy, completeness or suitability for any particular purpose and cannot accept liability of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred as a result of the product being inaccurate, incomplete or unsuitable in any way and for any reason.



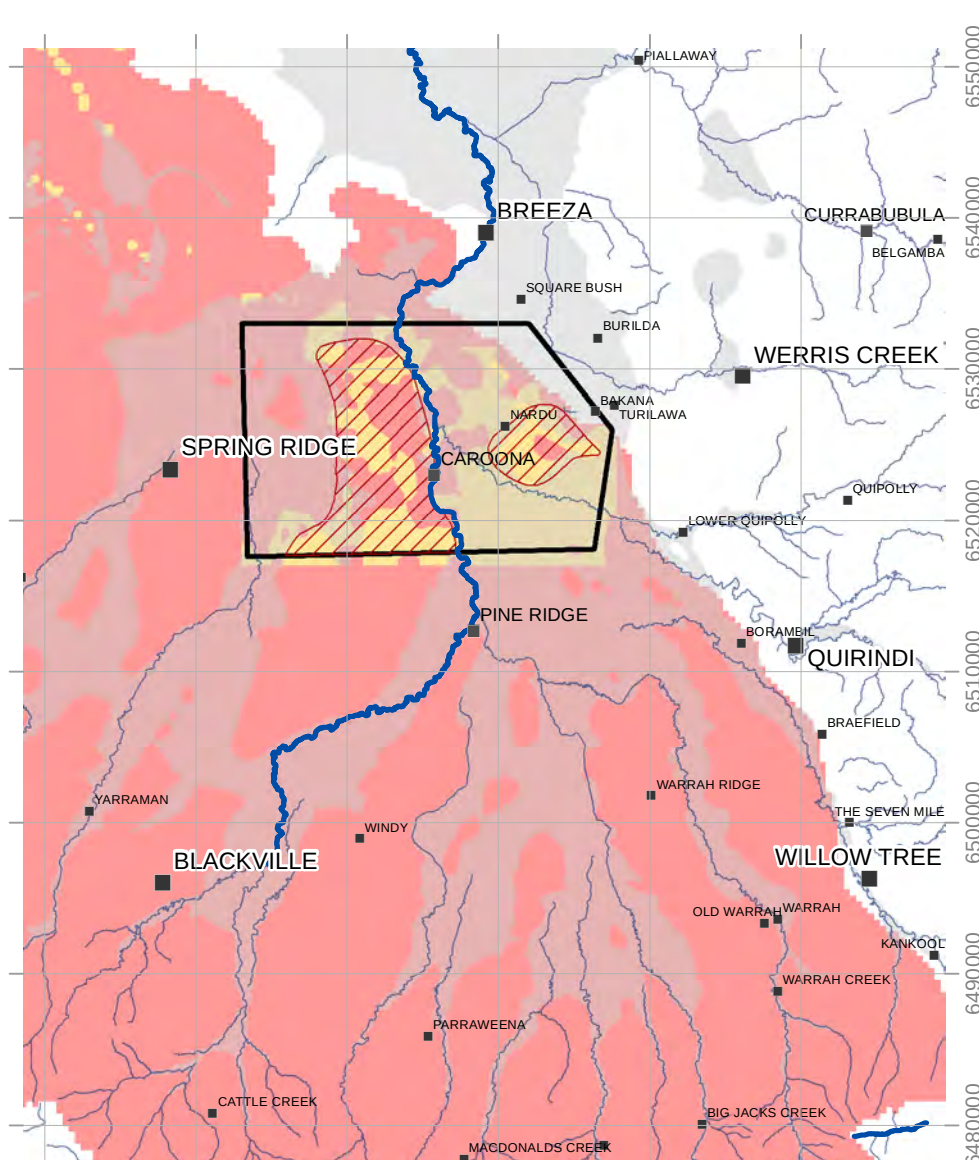
Layer 7 Bottom
Benallabri Fm



Layer 7 Thickness
Benallabri Fm



Layer 8 Bottom
Hoskissons Seam



Layer 8 Thickness
Hoskissons Seam

Legend

- Town
- Village
- Locality
- River
- Creek
- Alluvials
- Exploration Licence
- Targeted Exploration Area

Layer Bottom mAHD	
< -700	-249.99 - 0
-699.99 - -500	0.01 - 350
-499.99 - -250	350.01 - 750
	> 750

Thickness metres	
<10	25.01 - 50
10.01 - 25	50.01 - 100
	> 100

DrawingNo: CAR001-024
Rev: B.
Created by: CNicol
Date: 13/02/2014.



BHP Billiton
Caroonna Coal Project

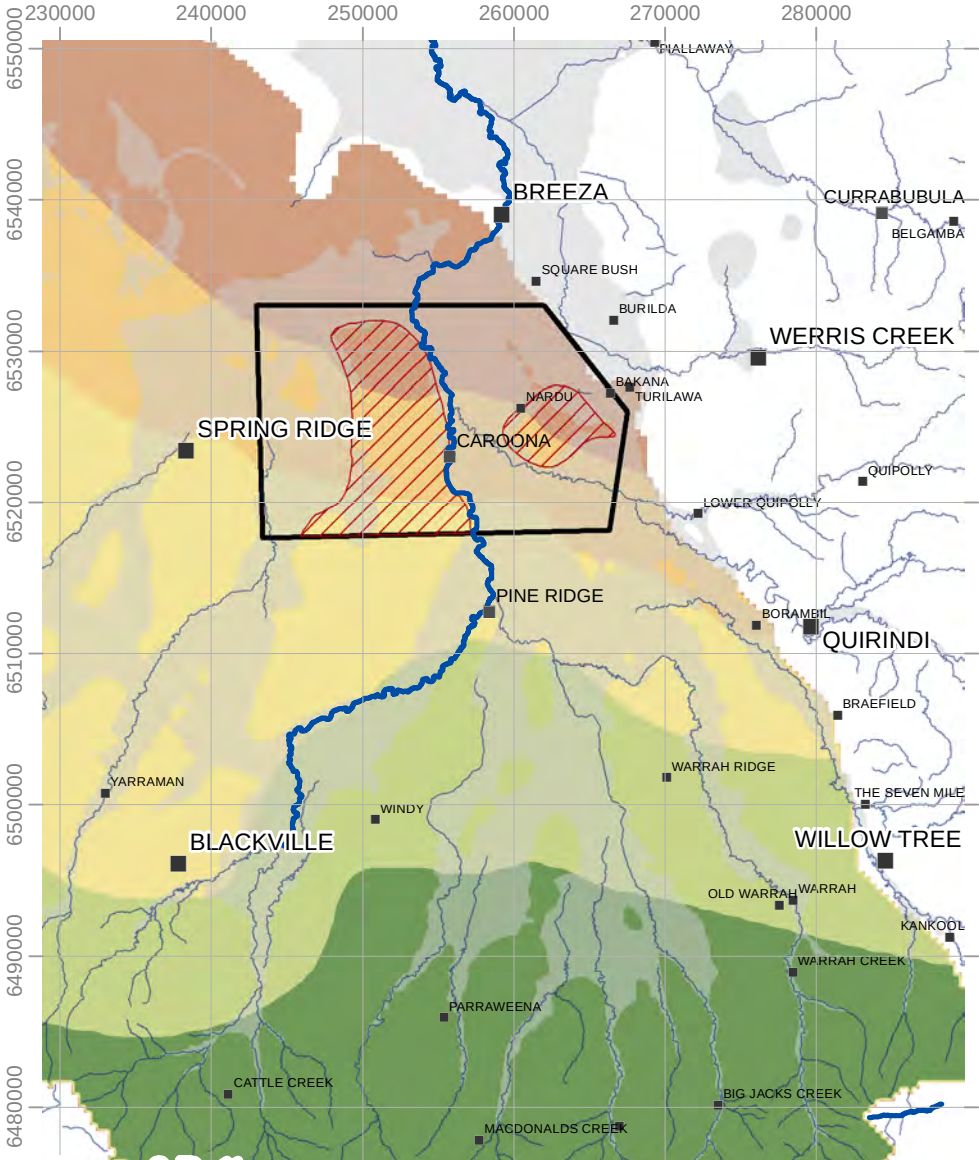
Figure B4
Modelled Surfaces
Layers 7 and 8



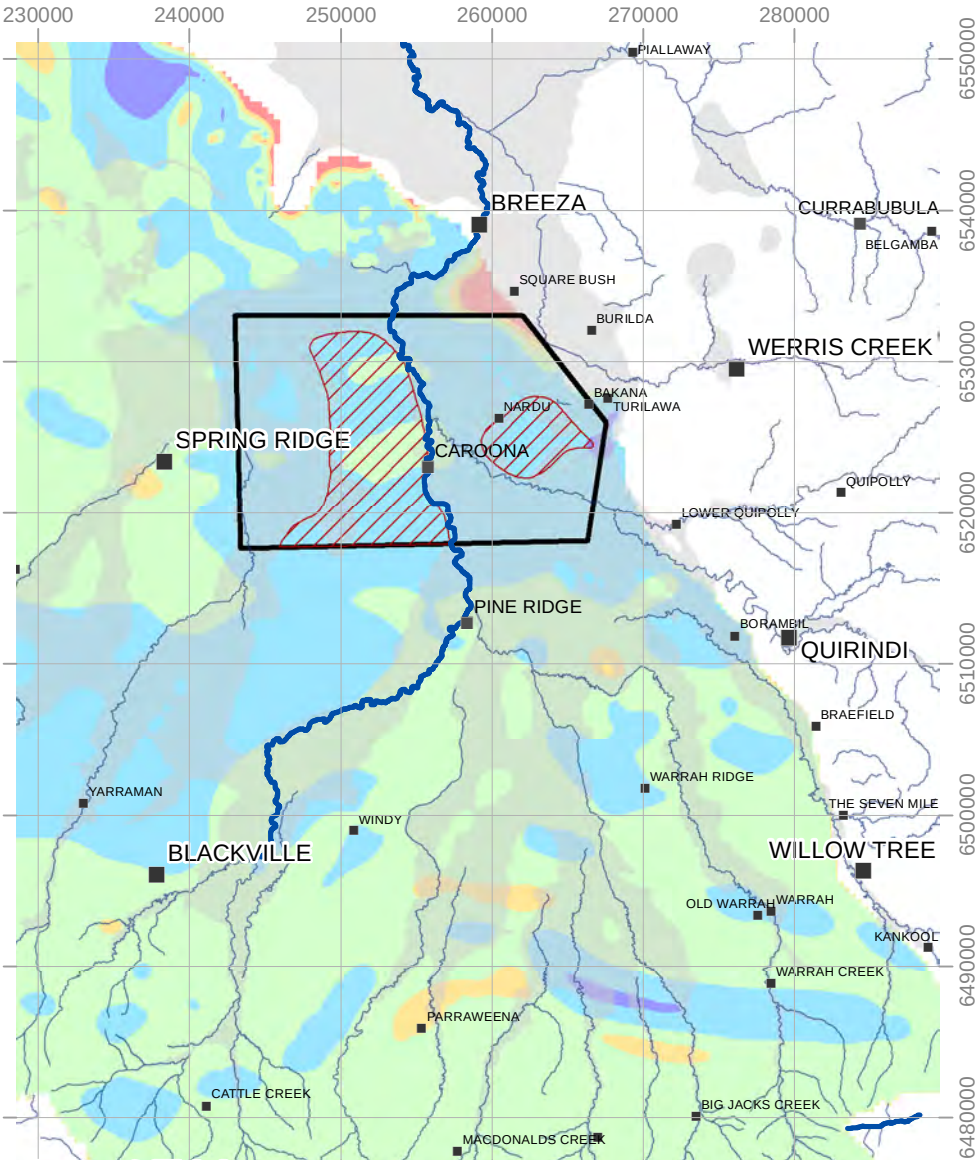
Scale: 500,000 at A3
GDA 1994 MGA Zone 56

0 2.5 5 10 15 20
Kilometers

(C) 2013. While Heritage Computing/HydroSimulations has taken care to ensure the accuracy of this product, Heritage/HydroSims and DATA CUSTODIAN(S), make no representations or warranties about its accuracy, completeness or suitability for any particular purpose and cannot accept liability of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred as a result of the product being inaccurate, incomplete or unsuitable in any way and for any reason.



Layer 9 Bottom
Pamboola Fm



Layer 9 Thickness
Pamboola Fm

Legend

- Town

Village

Locality

River

Creek

Alluvials

Exploration Licence

Targeted Exploration Area

Layer Bottom mAHD	
	< -700
	-699.99 - -500
	-499.99 - -250
	-249.99 - 0
	0.01 - 350
	350.01 - 750
	> 750

Thickness metres	
	<10
	10.01 - 25
	25.01 - 50
	50.01 - 100
	> 100

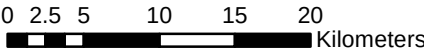
DrawingNo: CAR001-025
Rev: B.
Created by: CNicol
Date: 13/02/2014.

BHP Billiton
Caroonna Coal Project

Figure B5
Modelled Surfaces
Layer 9



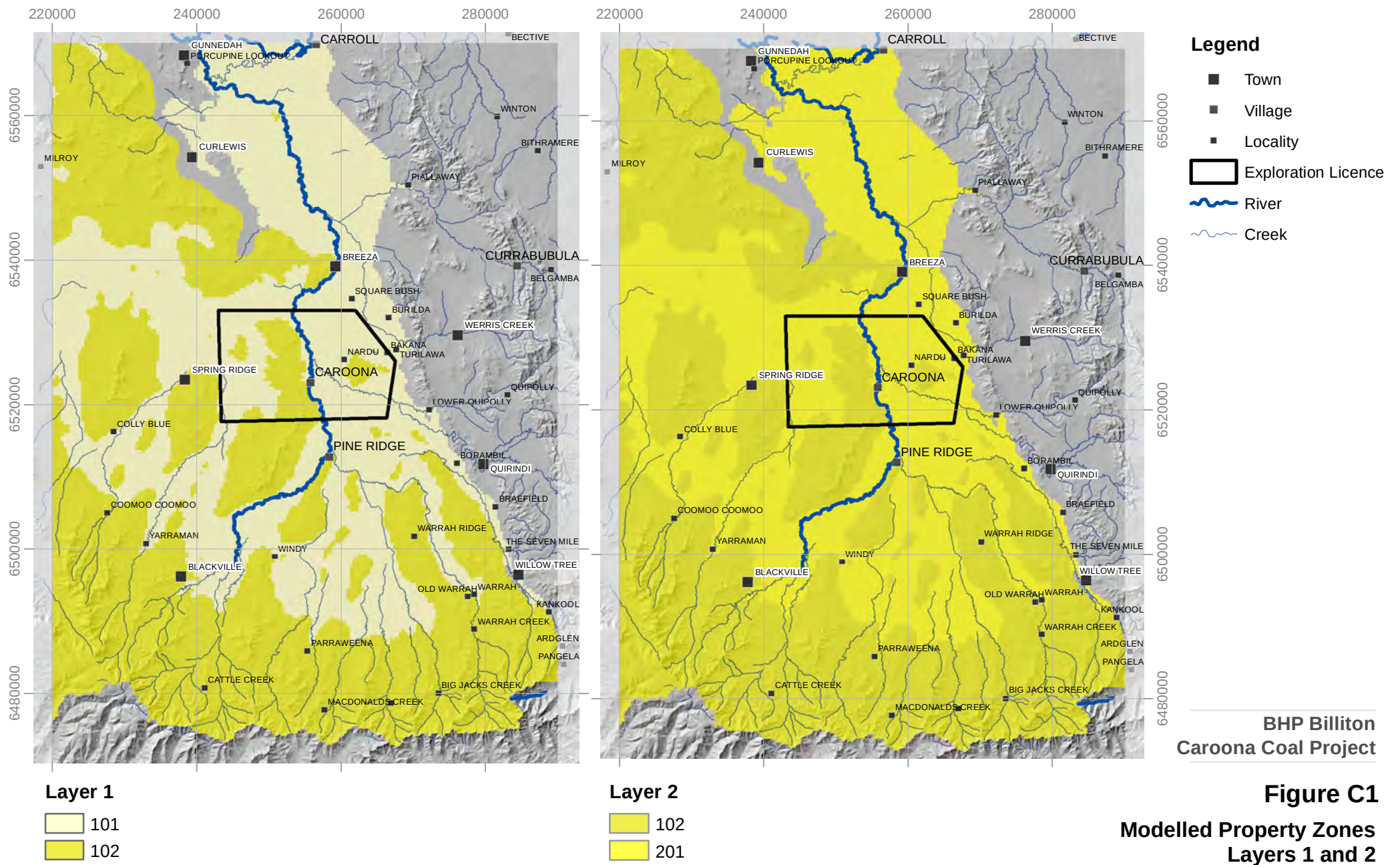
Scale: 500,000 at A3
GDA 1994 MGA Zone 56



(C) 2013. While Heritage Computing/HydroSimulations has taken care to ensure the accuracy of this product, Heritage/HydroSims and DATA CUSTODIAN(S), make no representations or warranties about its accuracy, completeness or suitability for any particular purpose and cannot accept liability of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred as a result of the product being inaccurate, incomplete or unsuitable in any way and for any reason.

ATTACHMENT C

Hydraulic Property Zonation



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D:\HydroSim\CAR001\GISMaps\Deliverable\026_HSUs_Layers_1_2.mxd

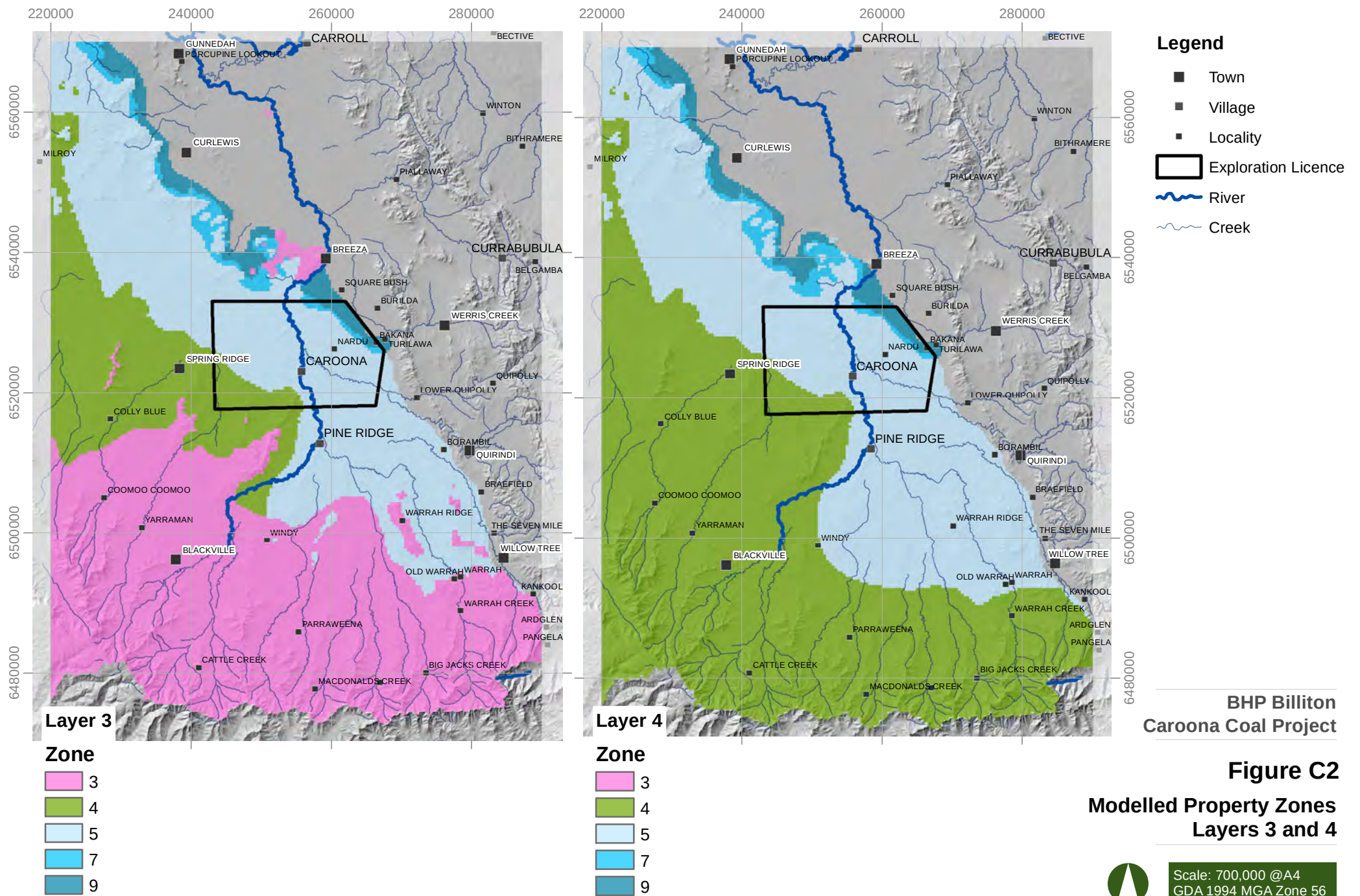
DrawingNo: CAR001-026
Rev: B.
Created by: CNicol
Date: 13/02/2014.

**HYDRO
SIMULATIONS**



Scale: 700,000 @A4
GDA 1994 MGA Zone 56

0 4 8 16 24 32 km



BHP Billiton
Carroona Coal Project

Figure C2

**Modelled Property Zones
Layers 3 and 4**



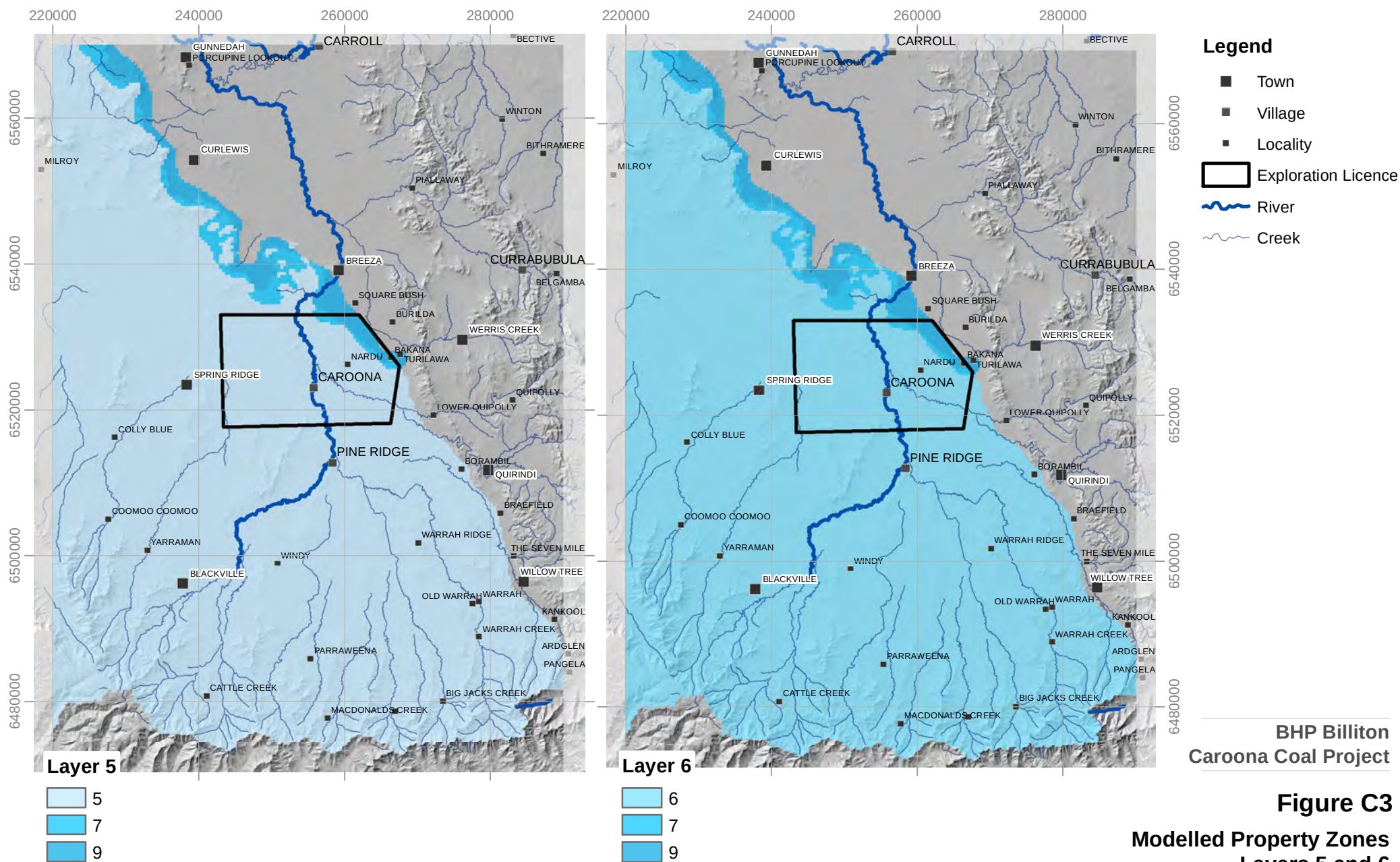
Scale: 700,000 @A4
GDA 1994 MGA Zone 56

**HYDR
SIMULATIONS**

0 4 8 16 24 32 km

(C) 2014. While HydroSimulations has taken care to ensure the accuracy of this product, HydroSimulations, Geoscience Australia and NSW Government make no representations or warranties about its accuracy, completeness or suitability for any particular purpose and cannot accept liability of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred as a result of the product being inaccurate, incomplete or unsuitable in any way and for any reason.

DrawingNo: CAR001-027
Rev: B.
Created by: CNicol
Date: 13/02/2014.

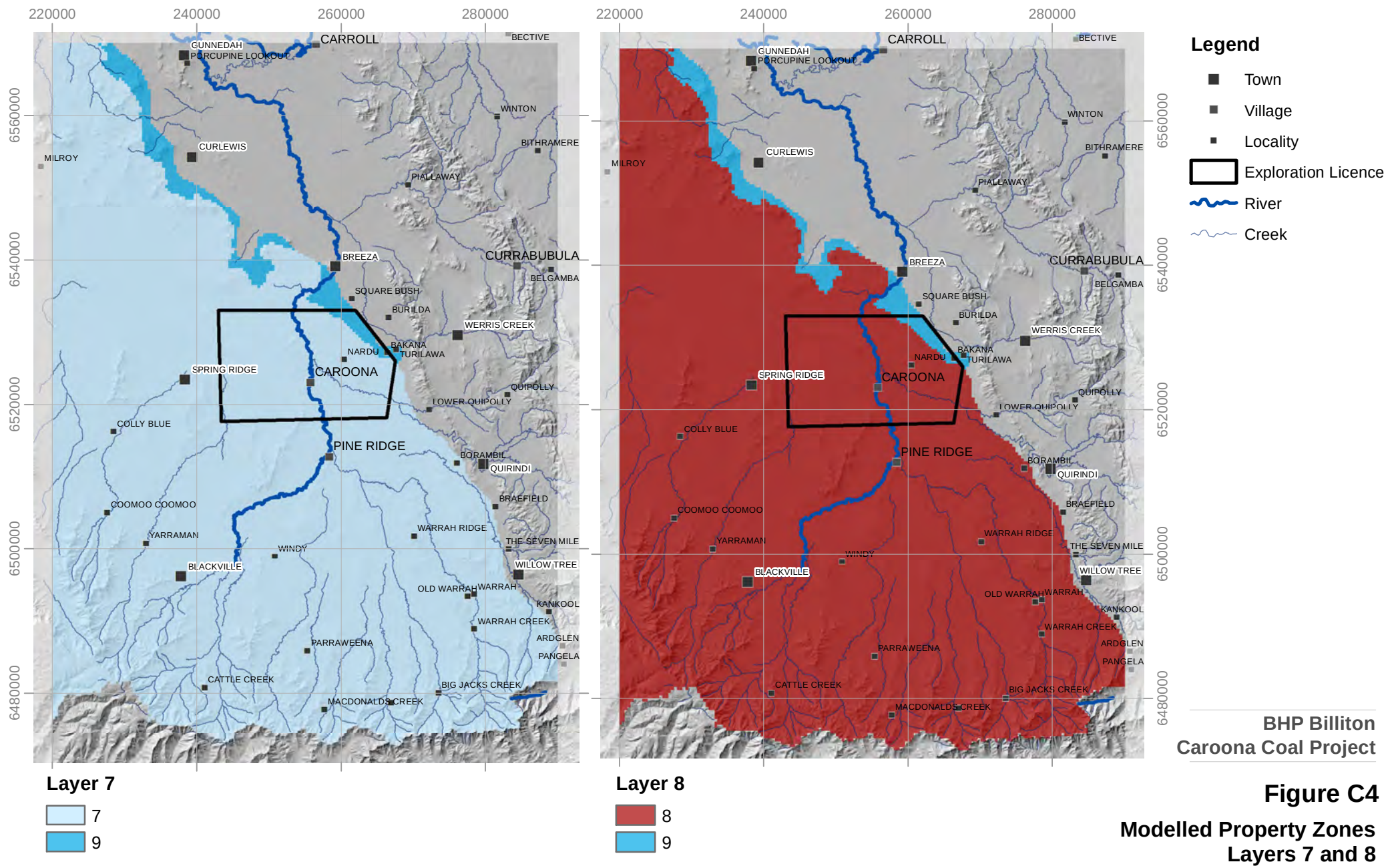


(C) 2014. While HydroSimulations has taken care to ensure the accuracy of this product, HydroSimulations, Geoscience Australia and NSW Government make no representations or warranties about its accuracy, completeness or suitability for any particular purpose and cannot accept liability of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred as a result of the product being inaccurate, incomplete or unsuitable in any way and for any reason.

D:\HydroSim\CAR001\GISMaps\Deliverable\028_HSUs_Layers_5_6.mxd

DrawingNo: CAR001-028
Rev: B.
Created by: CNicol
Date: 13/02/2014.

**HYDRO
SIMULATIONS**



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D:\HydroSim\CAR001\GISMaps\Deliverable\029_HSUs_Layers_7_8.mxd

DrawingNo: CAR001-029
Rev: B.
Created by: CNicol
Date: 13/02/2014.

**HYDRO
SIMULATIONS**

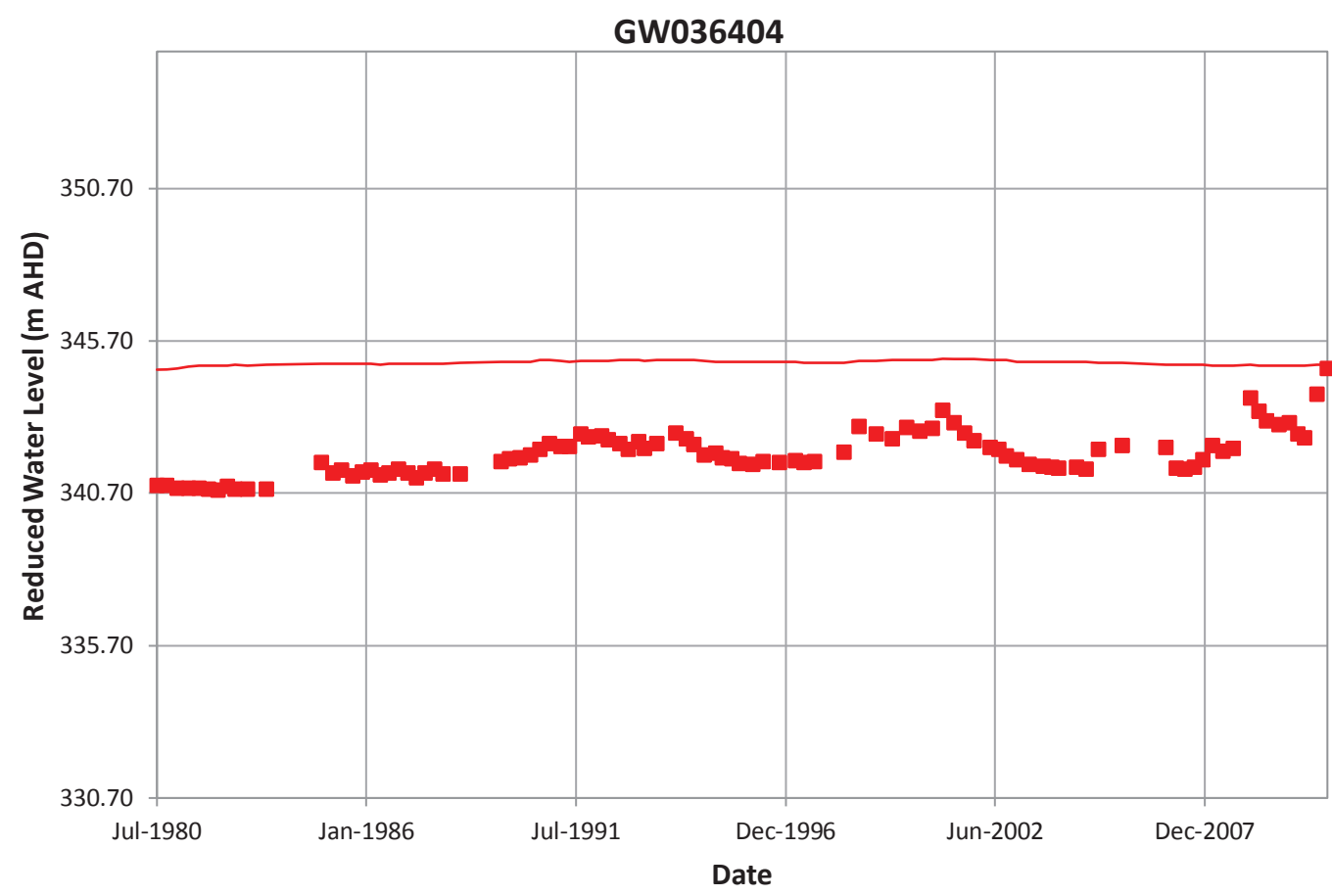


Scale: 700,000 @A4
GDA 1994 MGA Zone 56

0 4 8 16 24 32 km

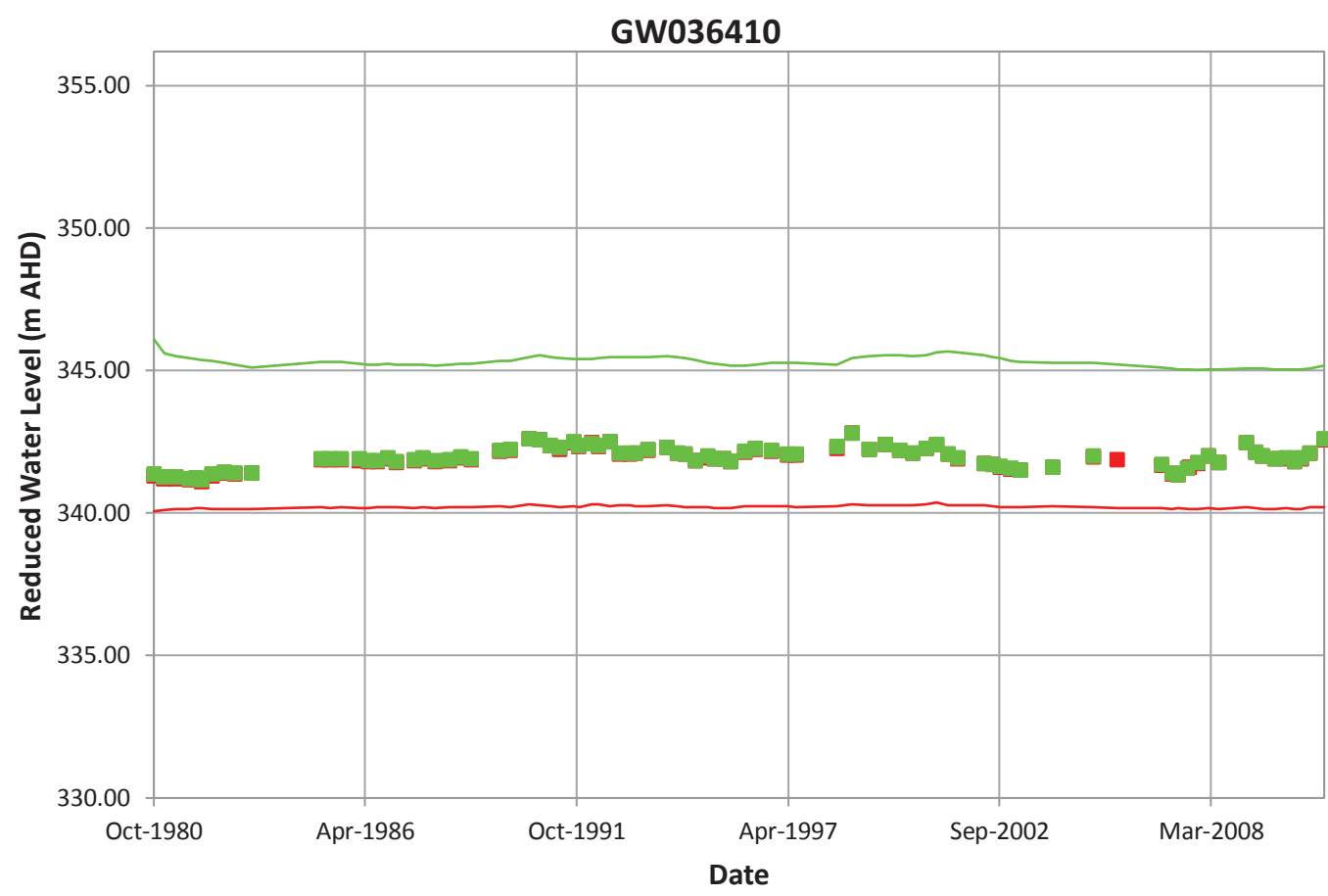
ATTACHMENT D

Verification Hydrographs



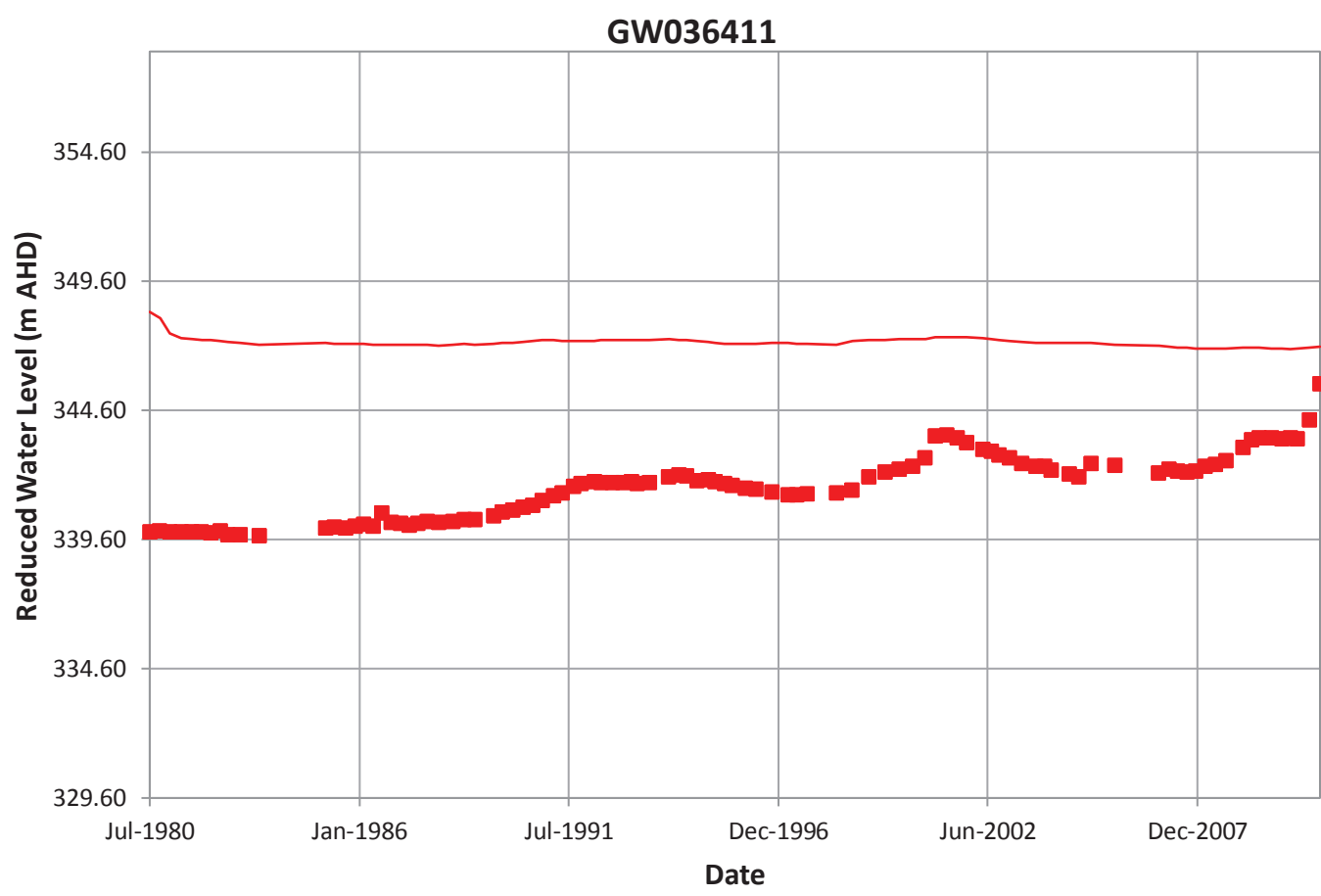
GW036404_1 (Narrabri Fm) - Computed

GW036404_1 (Narrabri Fm) - Observed



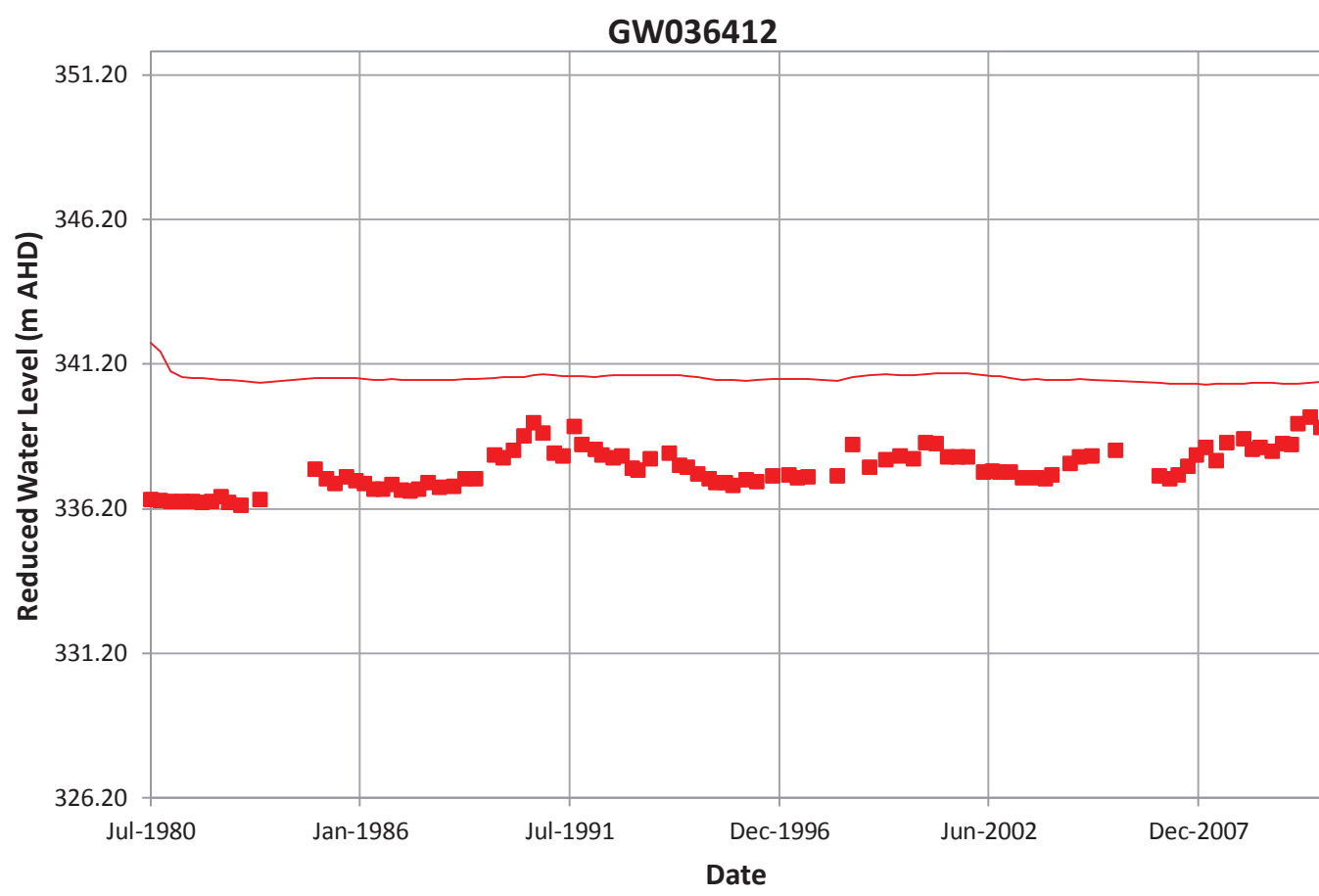
GW036410_1 (Narrabri Fm) - Computed

GW036410_1 (Narrabri Fm) - Observed



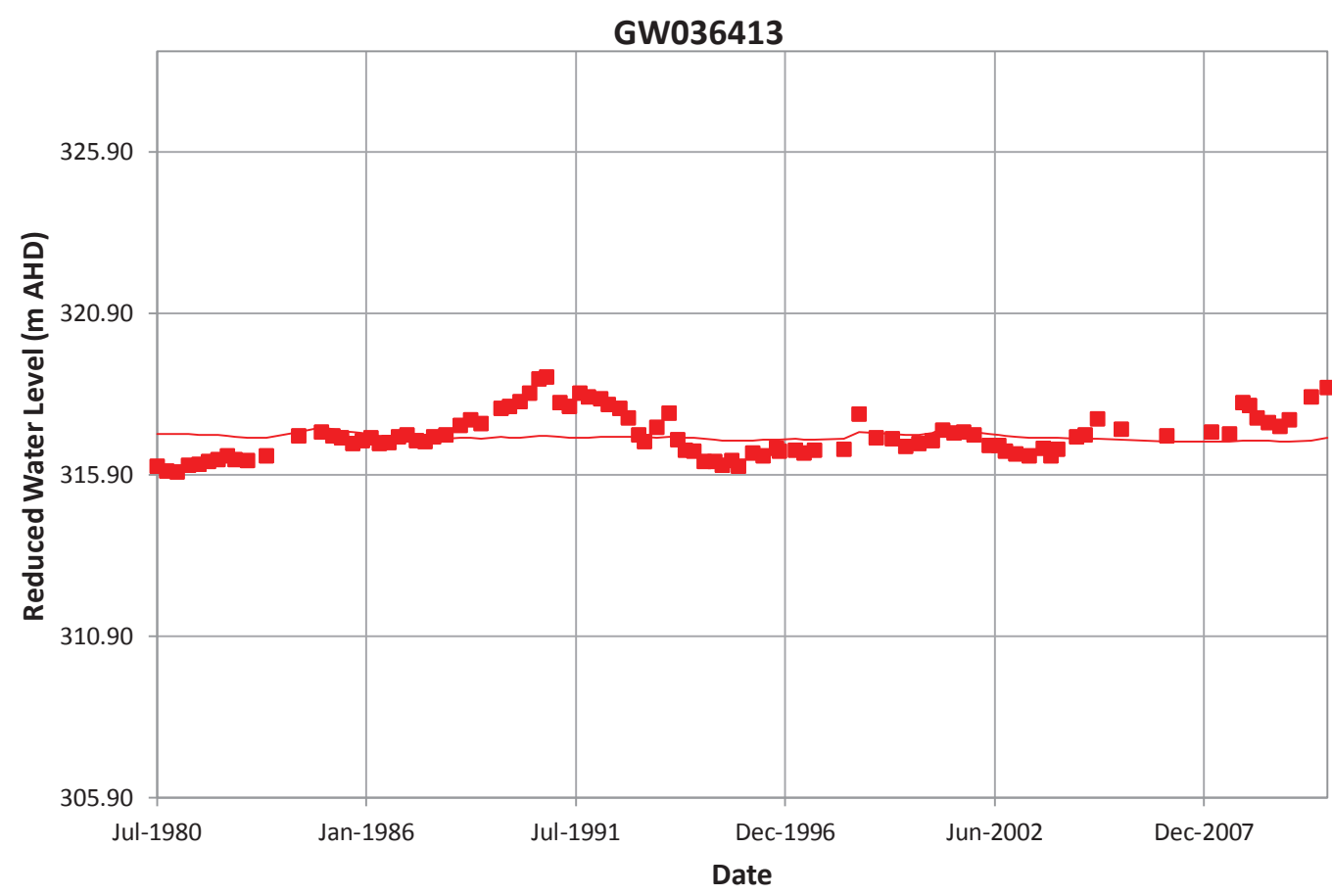
GW036411_1 (Gunnedah Fm) - Computed

GW036411_1 (Gunnedah Fm) - Observed



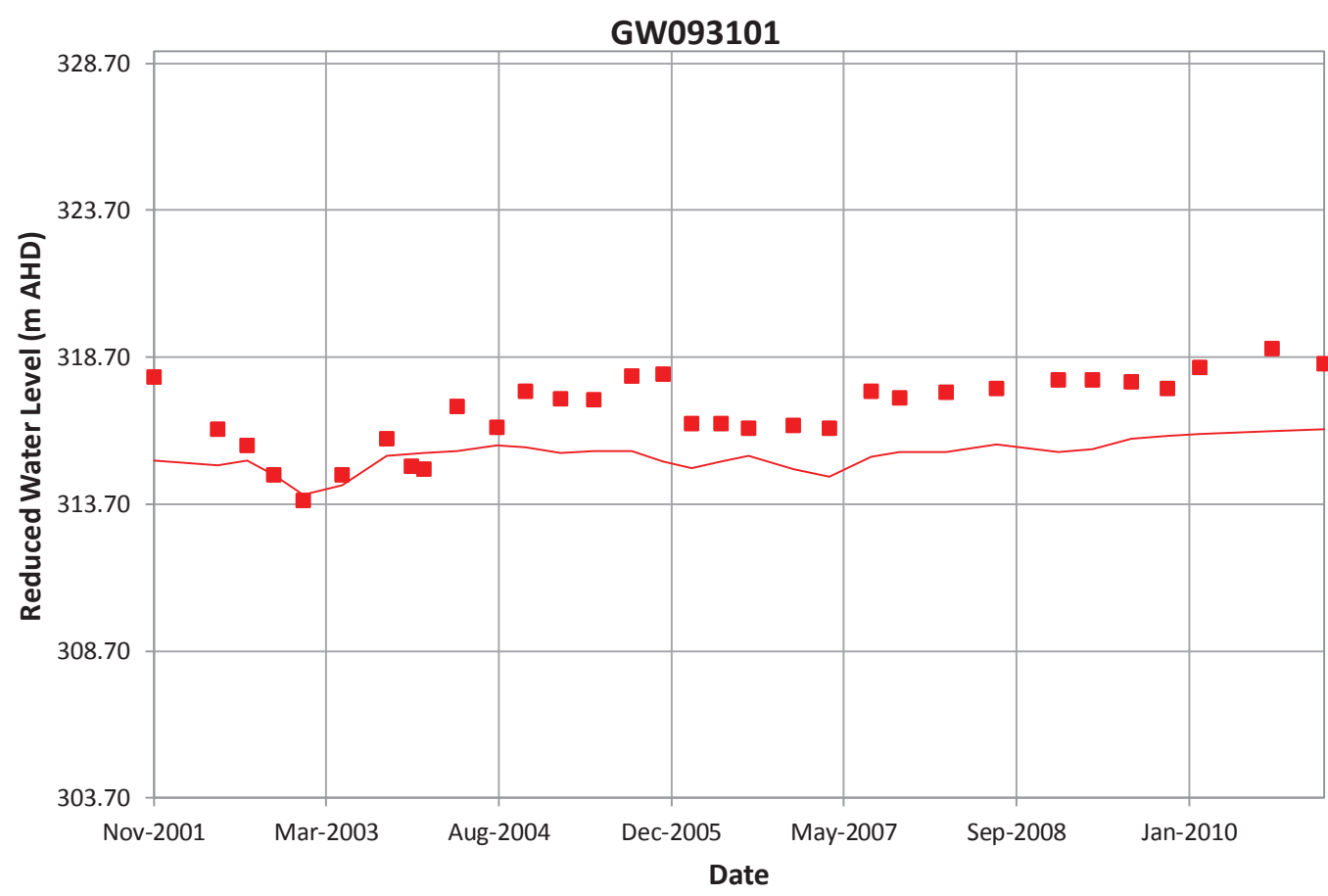
GW036412_1 (Gunnedah Fm) - Computed

GW036412_1 (Gunnedah Fm) - Observed



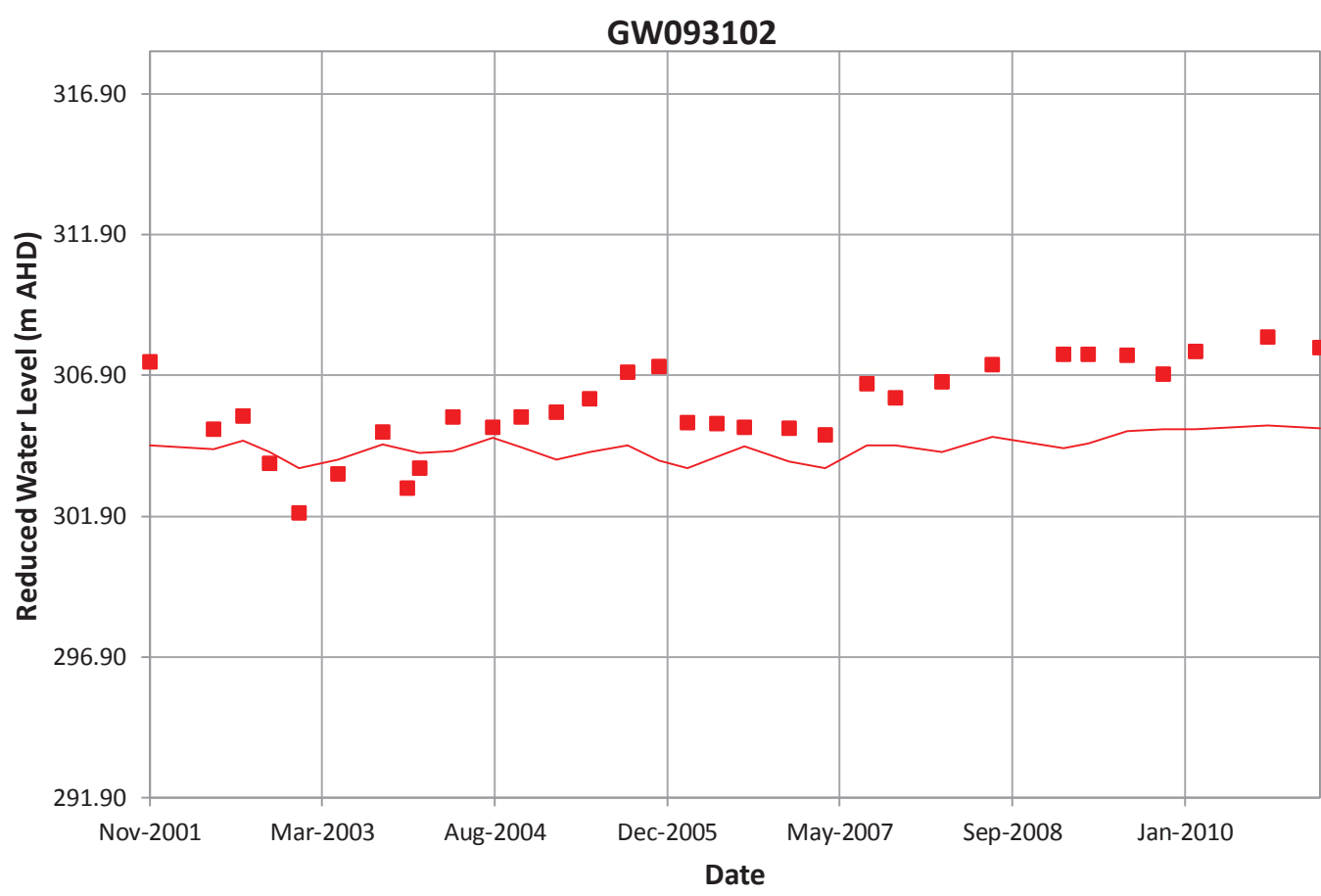
GW036413_1 (Narrabri Fm) - Computed

GW036413_1 (Narrabri Fm) - Observed



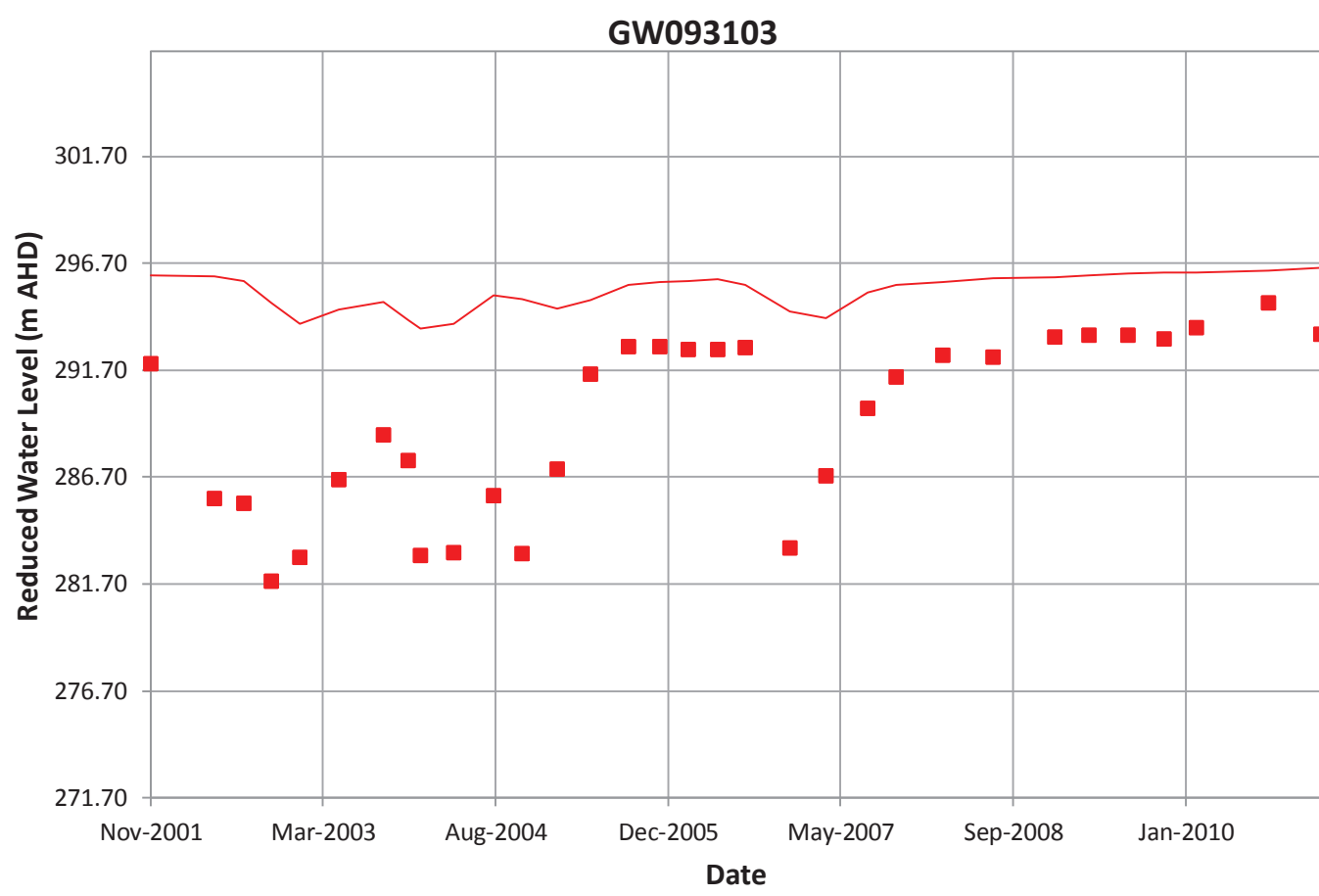
GW093101_1e (Gunnedah Fm) - Computed

GW093101_1e (Gunnedah Fm) - Observed



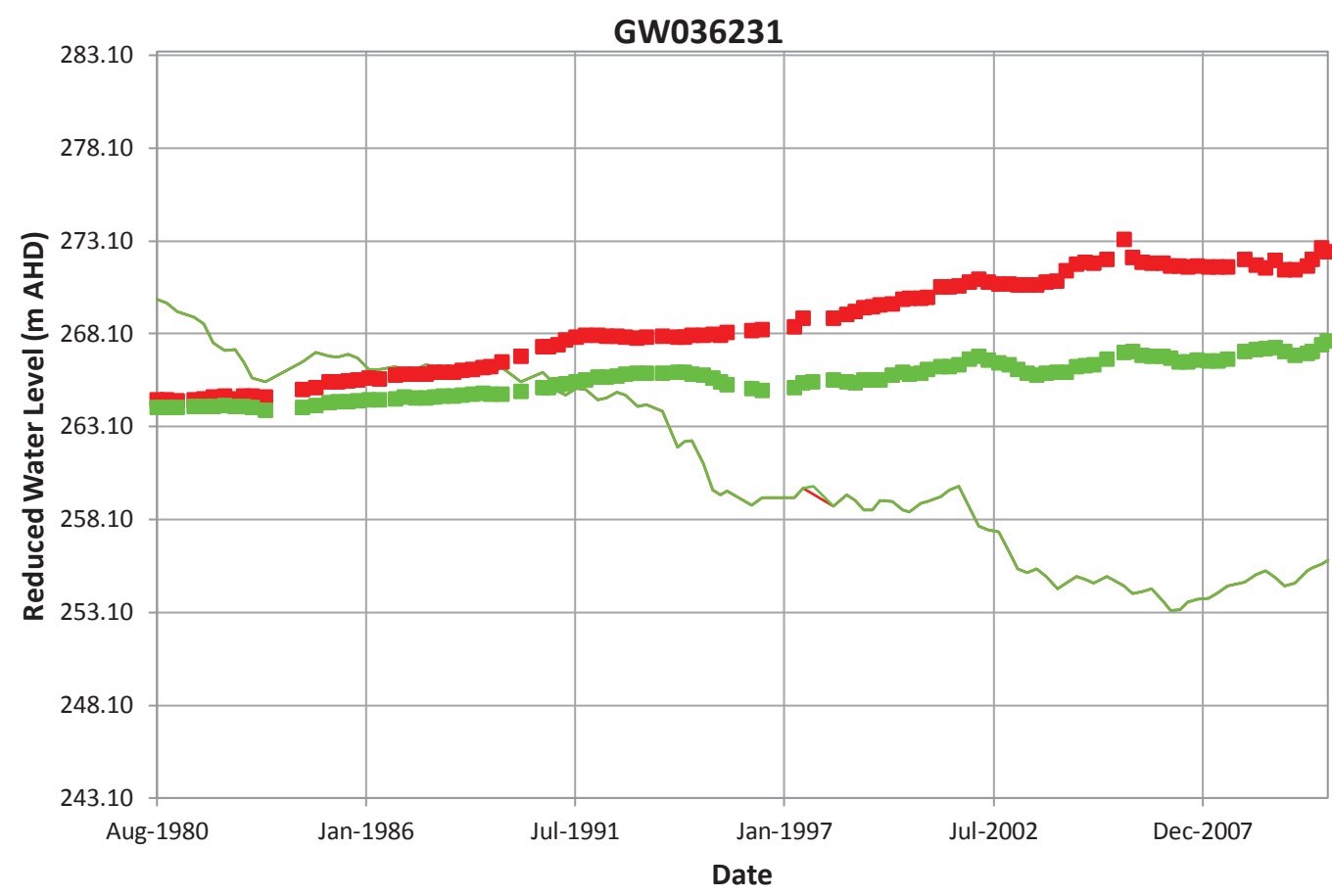
GW093102_1e (Gunnedah Fm) - Computed

GW093102_1e (Gunnedah Fm) - Observed



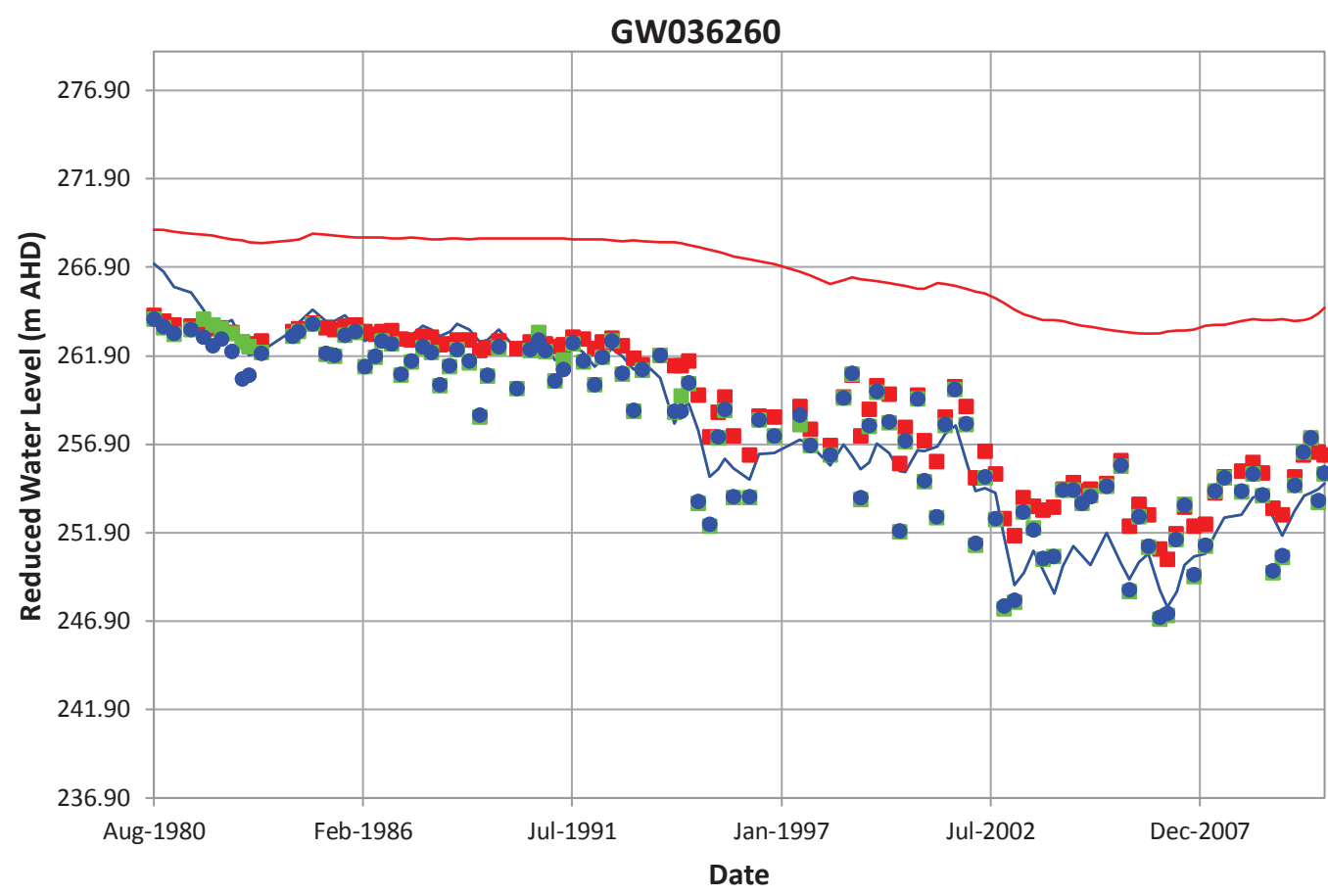
GW093103_1e (Gunnedah Fm) - Computed

GW093103_1e (Gunnedah Fm) - Observed



GW036231_1 (Gunnedah Fm) - Computed

GW036231_1 (Gunnedah Fm) - Observed



GW036260_1 (Narrabri Fm) - Computed

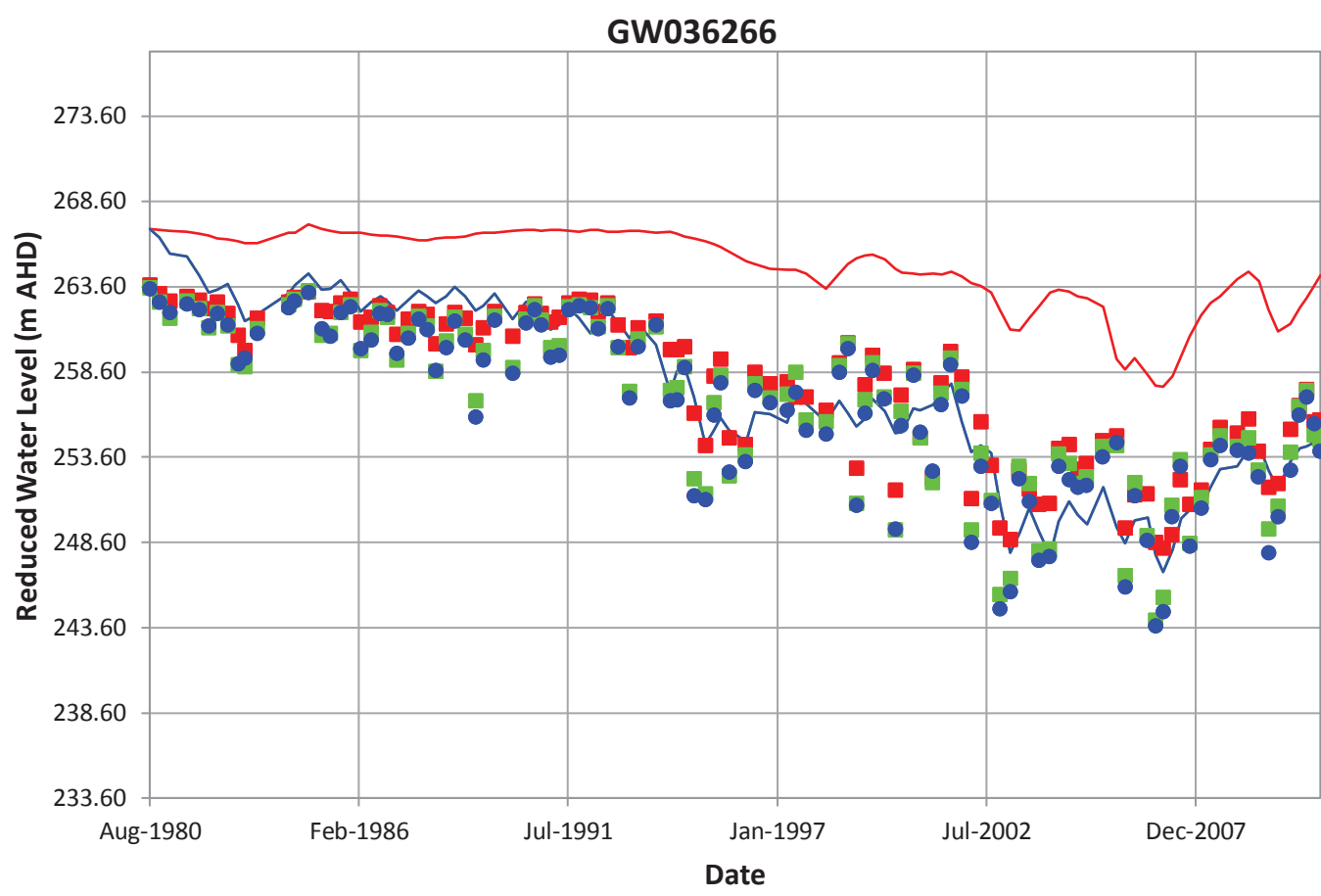
GW036260_1 (Narrabri Fm) - Observed

GW036260_2 (Gunnedah Fm) - Computed

GW036260_2 (Gunnedah Fm) - Observed

GW036260_3 (Gunnedah Fm) - Computed

GW036260_3 (Gunnedah Fm) - Observed



GW036266_1 (Narrabri Fm) - Computed

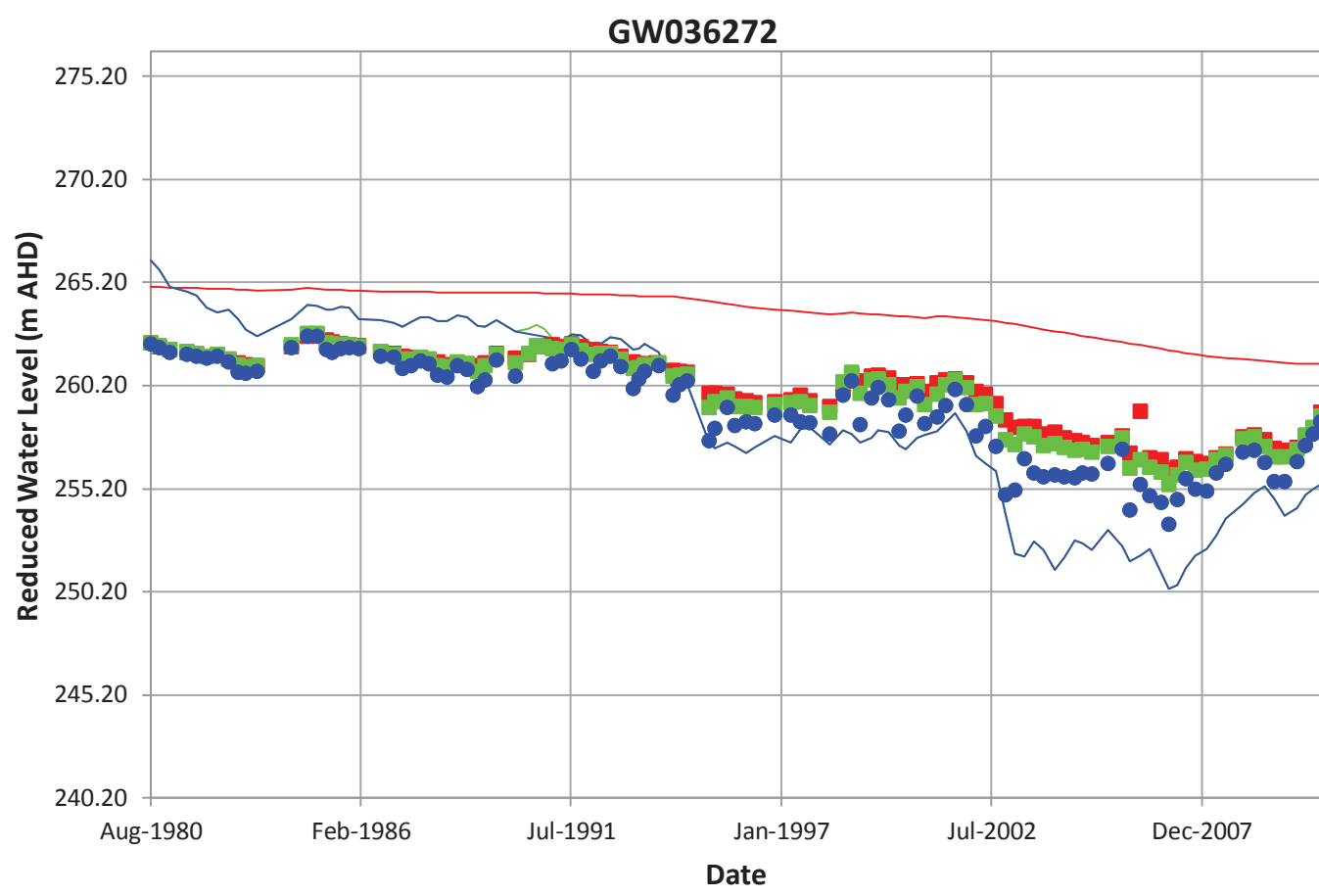
GW036266_1 (Narrabri Fm) - Observed

GW036266_2 (Gunnedah Fm) - Computed

GW036266_2 (Gunnedah Fm) - Observed

GW036266_3 (Gunnedah Fm) - Computed

GW036266_3 (Gunnedah Fm) - Observed



GW036272_1 (Narrabri Fm) - Computed

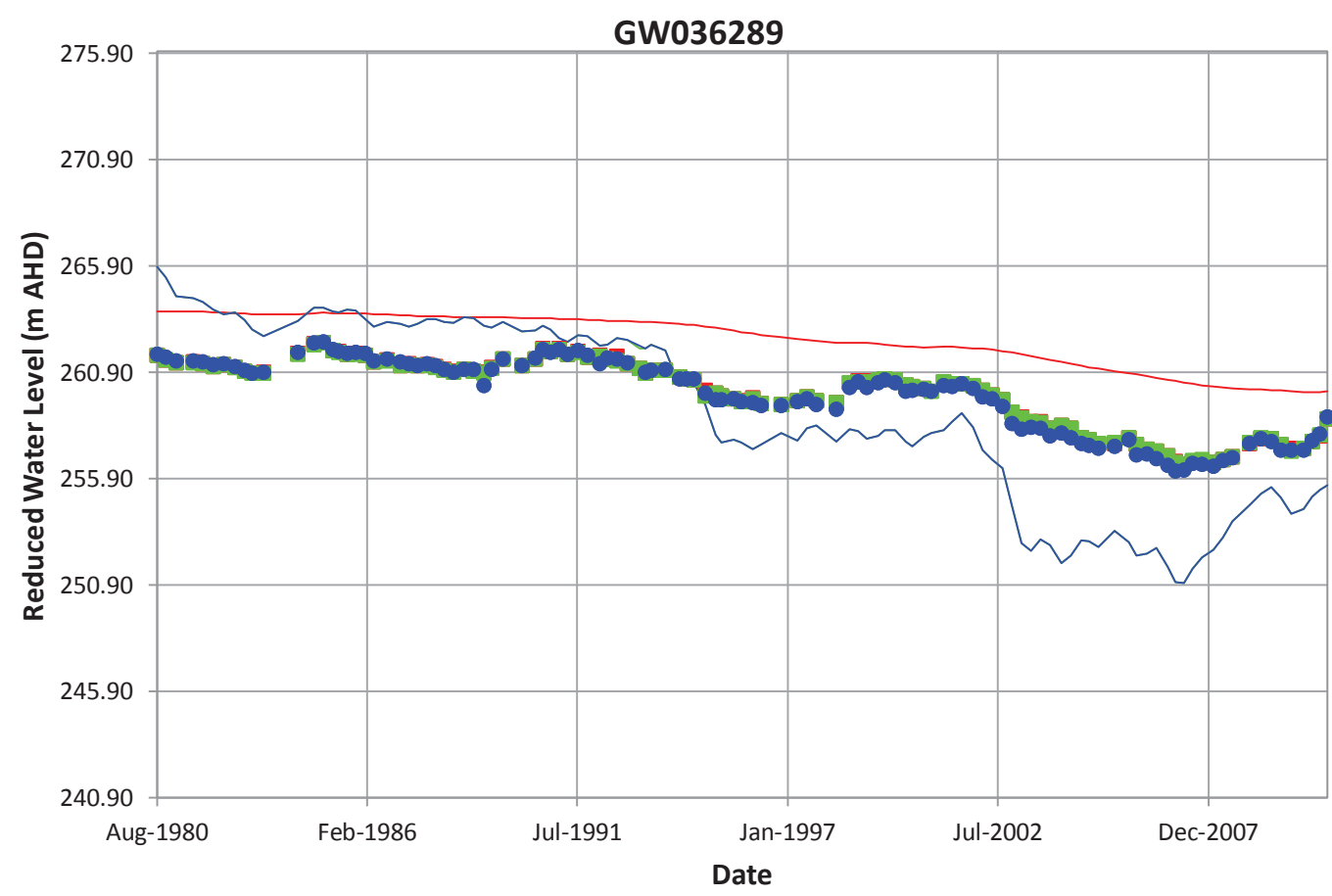
GW036272_1 (Narrabri Fm) - Observed

GW036272_2 (Gunnedah Fm) - Computed

GW036272_2 (Gunnedah Fm) - Observed

GW036272_3 (Gunnedah Fm) - Computed

GW036272_3 (Gunnedah Fm) - Observed



GW036289_1 (Narrabri Fm) - Computed

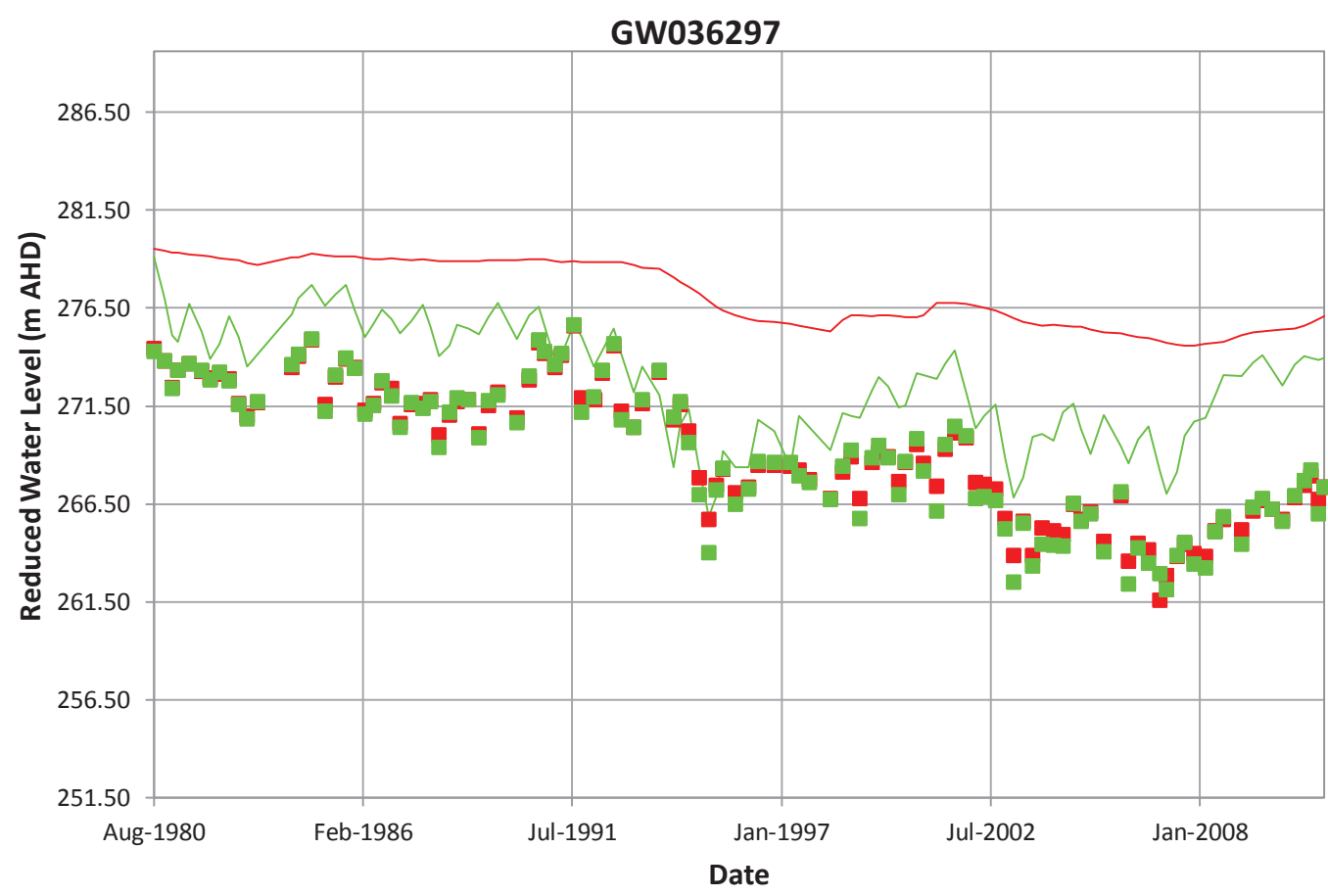
GW036289_1 (Narrabri Fm) - Observed

GW036289_2 (Gunnedah Fm) - Computed

GW036289_2 (Gunnedah Fm) - Observed

GW036289_3 (Gunnedah Fm) - Computed

GW036289_3 (Gunnedah Fm) - Observed



GW036297_1 (Narrabri Fm) - Computed

GW036297_1 (Narrabri Fm) - Observed

GW036297_2 (Gunnedah Fm) - Computed

GW036297_2 (Gunnedah Fm) - Observed

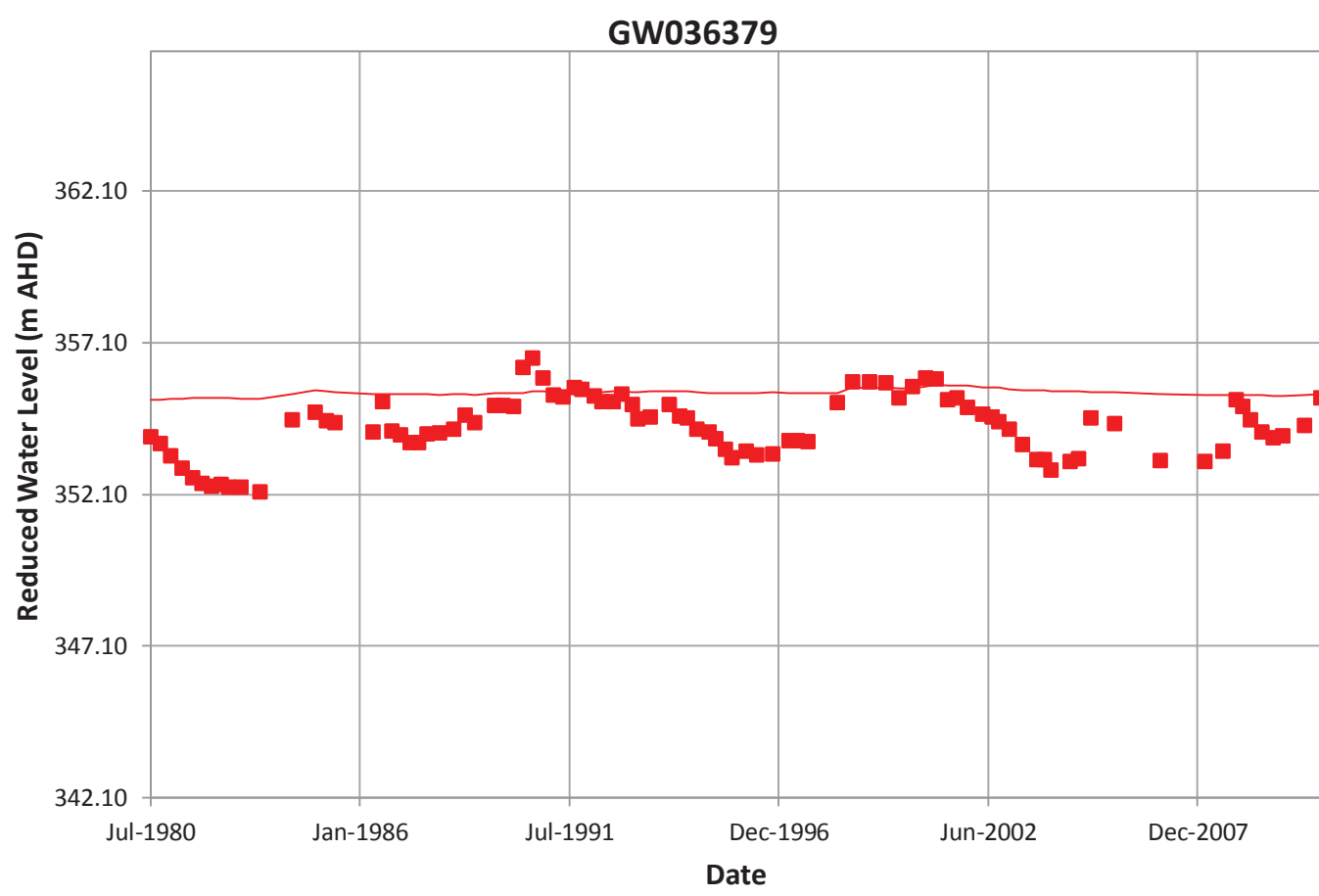


GW036305_1 (Gunnedah Fm) - Computed

GW036305_1 (Gunnedah Fm) - Observed

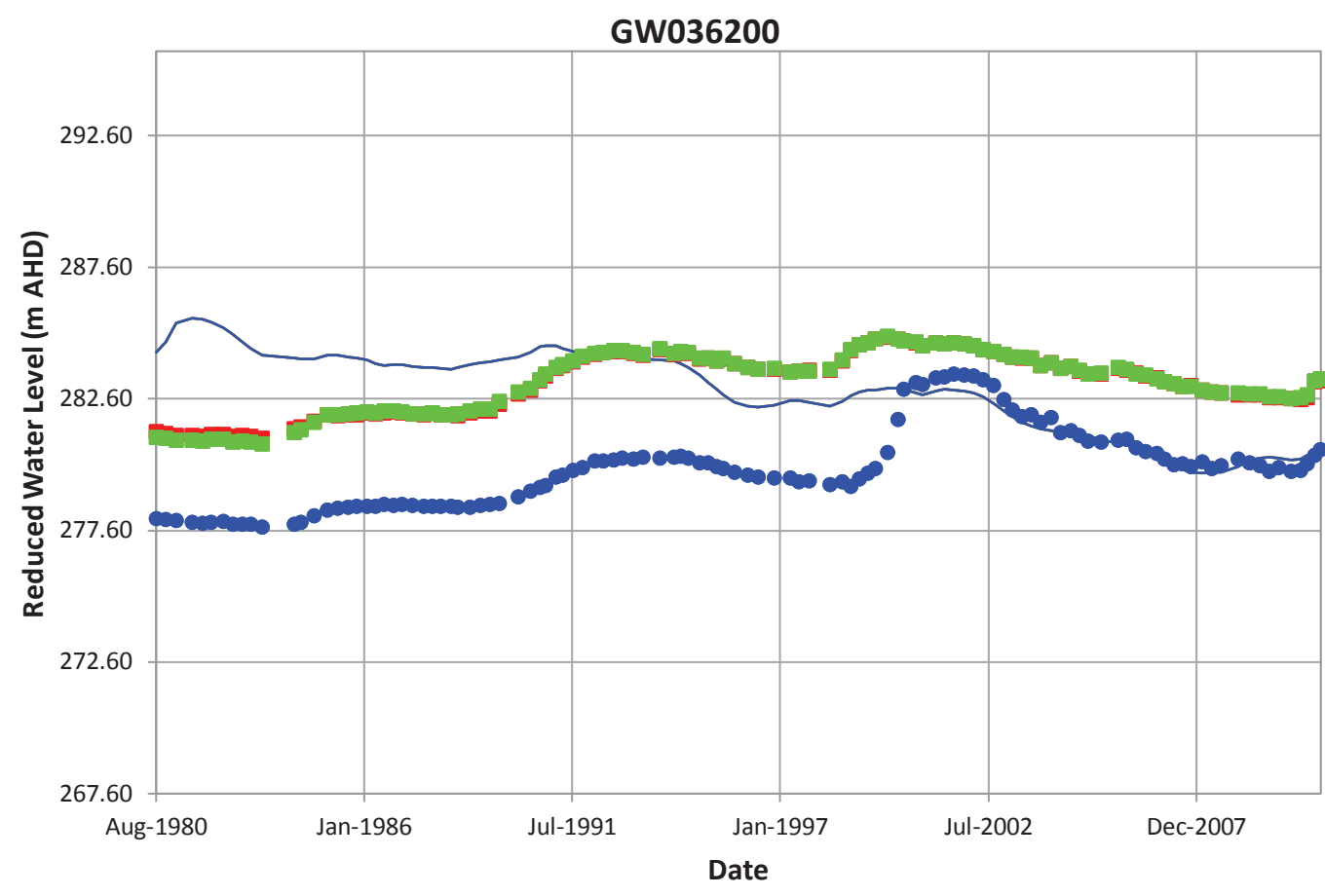
GW036305_2 (Gunnedah Fm) - Computed

GW036305_2 (Gunnedah Fm) - Observed



GW036379_1 (Narrabri Fm) - Computed

GW036379_1 (Narrabri Fm) - Observed



GW036200_1 (Gunnedah Fm) - Computed

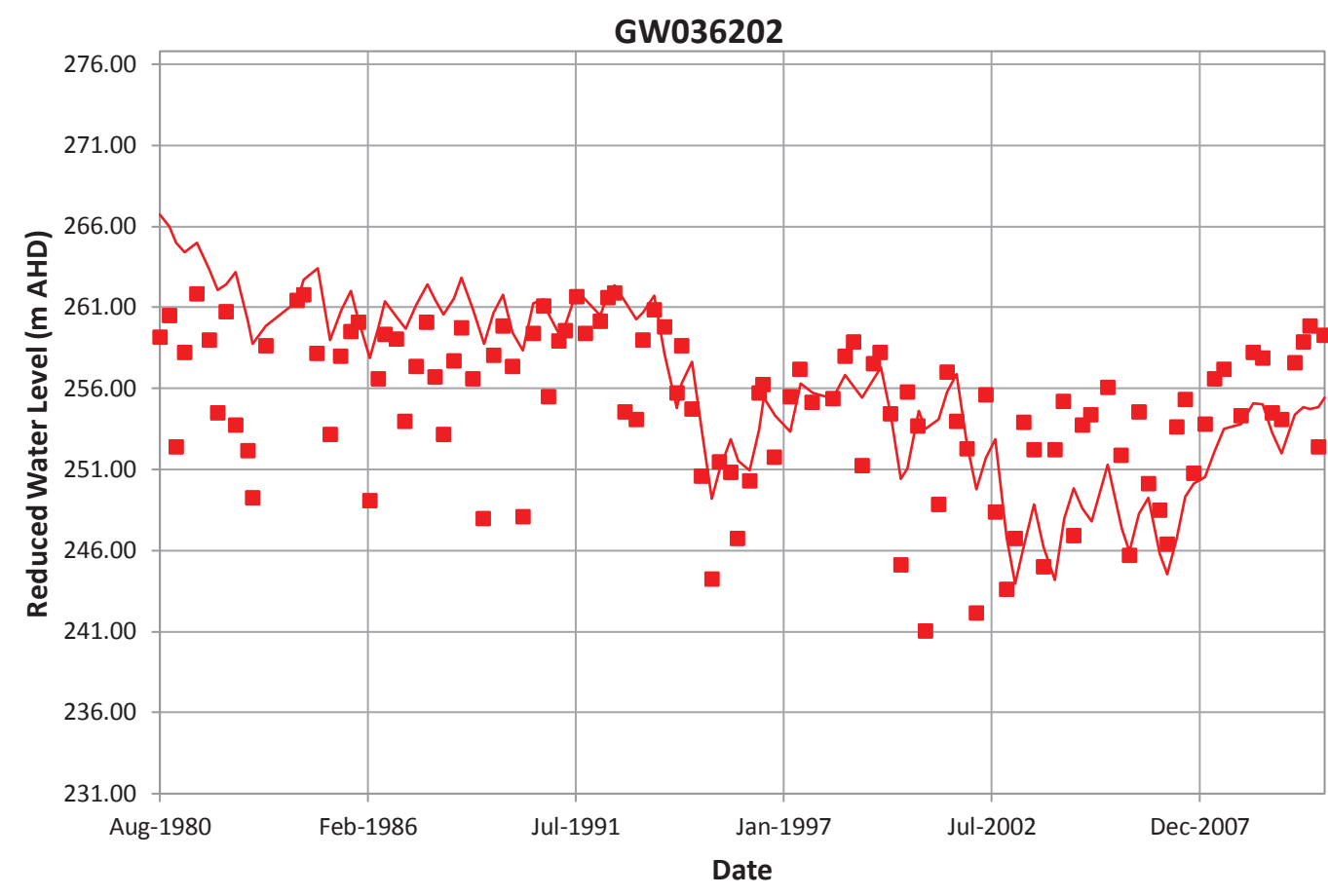
GW036200_1 (Gunnedah Fm) - Observed

GW036200_2 (Gunnedah Fm) - Computed

GW036200_2 (Gunnedah Fm) - Observed

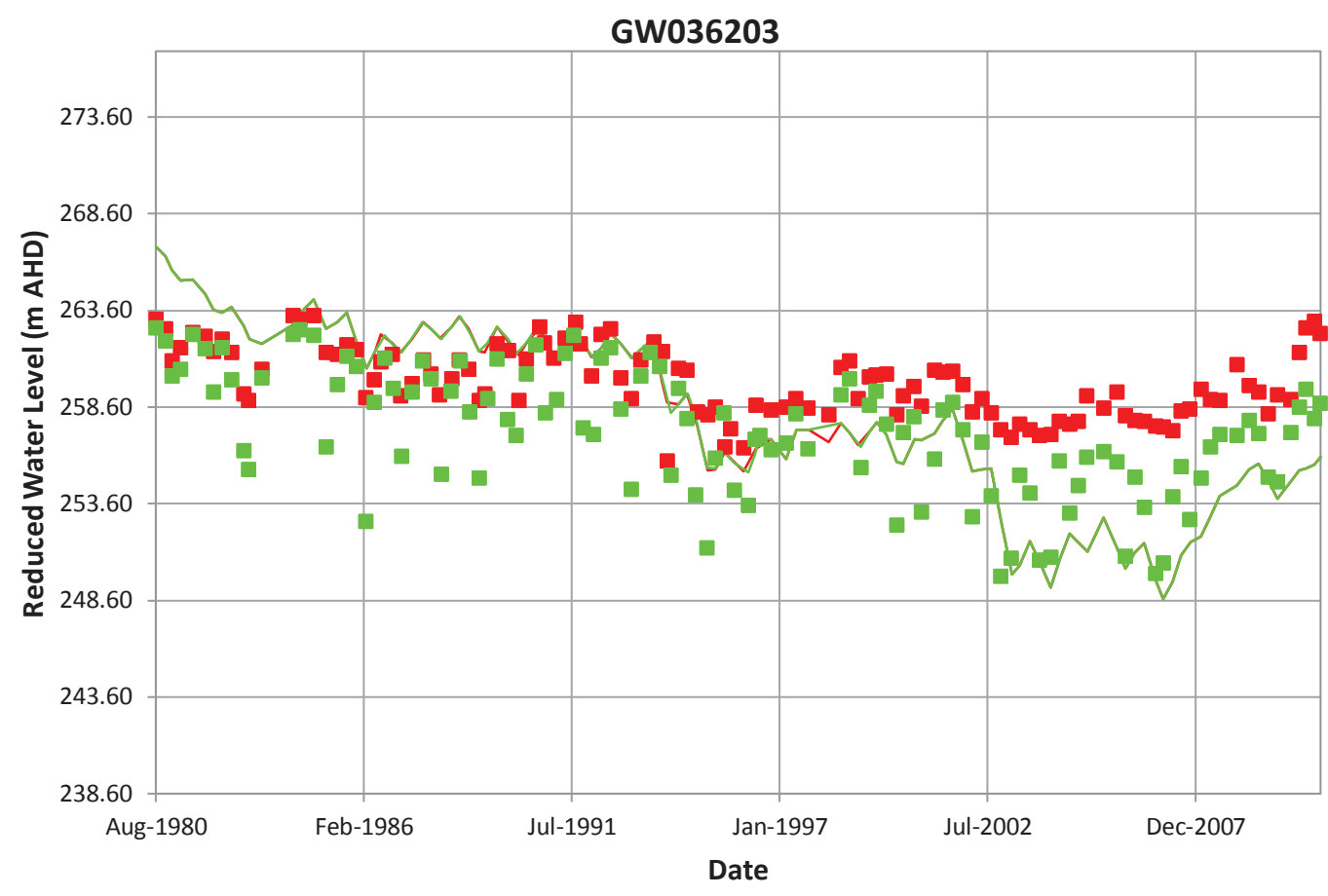
GW036200_3 (Gunnedah Fm) - Computed

GW036200_3 (Gunnedah Fm) - Observed



GW036202_1 (Gunnedah Fm) - Computed

GW036202_1 (Gunnedah Fm) - Observed

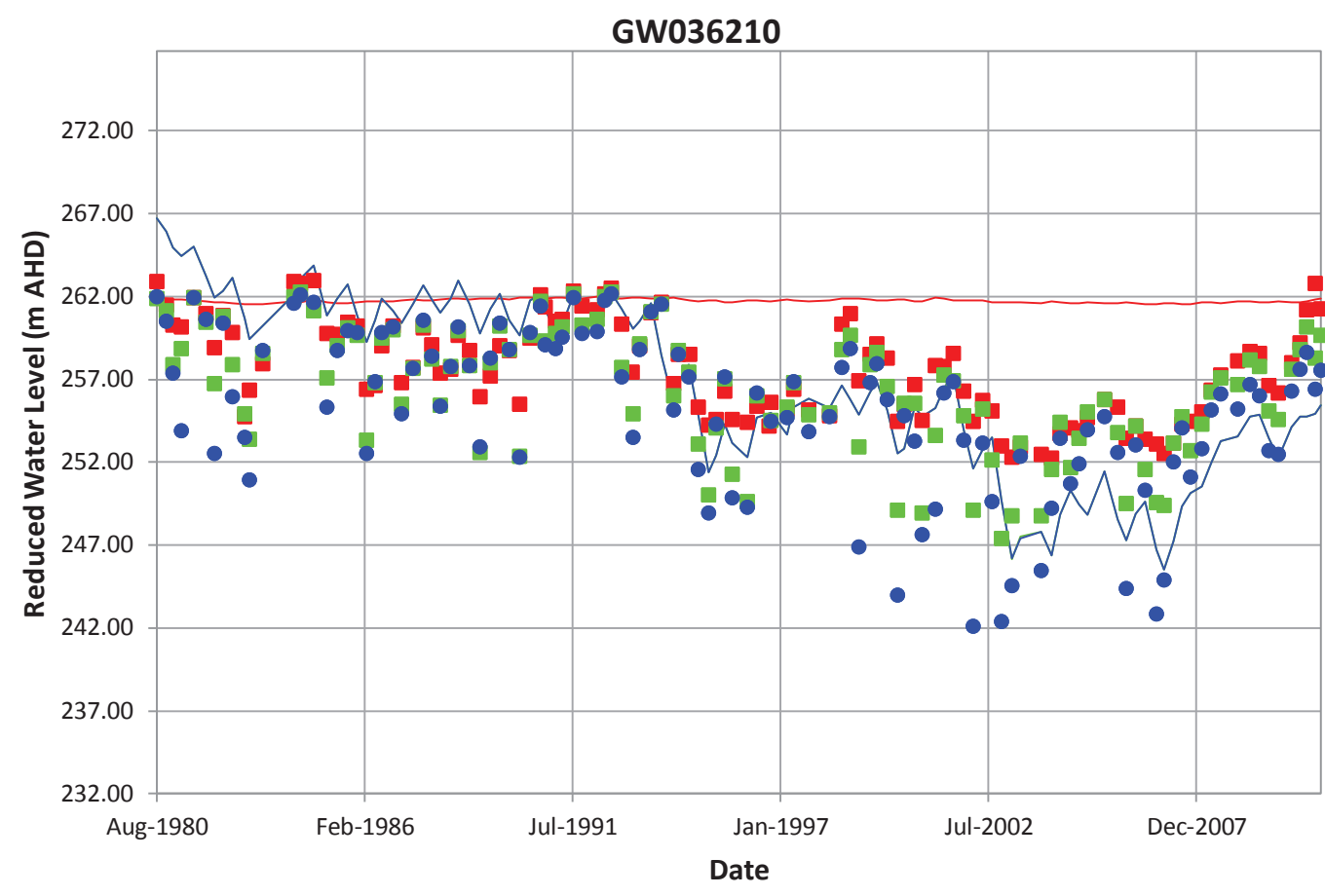


GW036203_1 (Gunnedah Fm) - Computed

GW036203_1 (Gunnedah Fm) - Observed

GW036203_2 (Gunnedah Fm) - Computed

GW036203_2 (Gunnedah Fm) - Observed



GW036210_1 (Narrabri Fm) - Computed

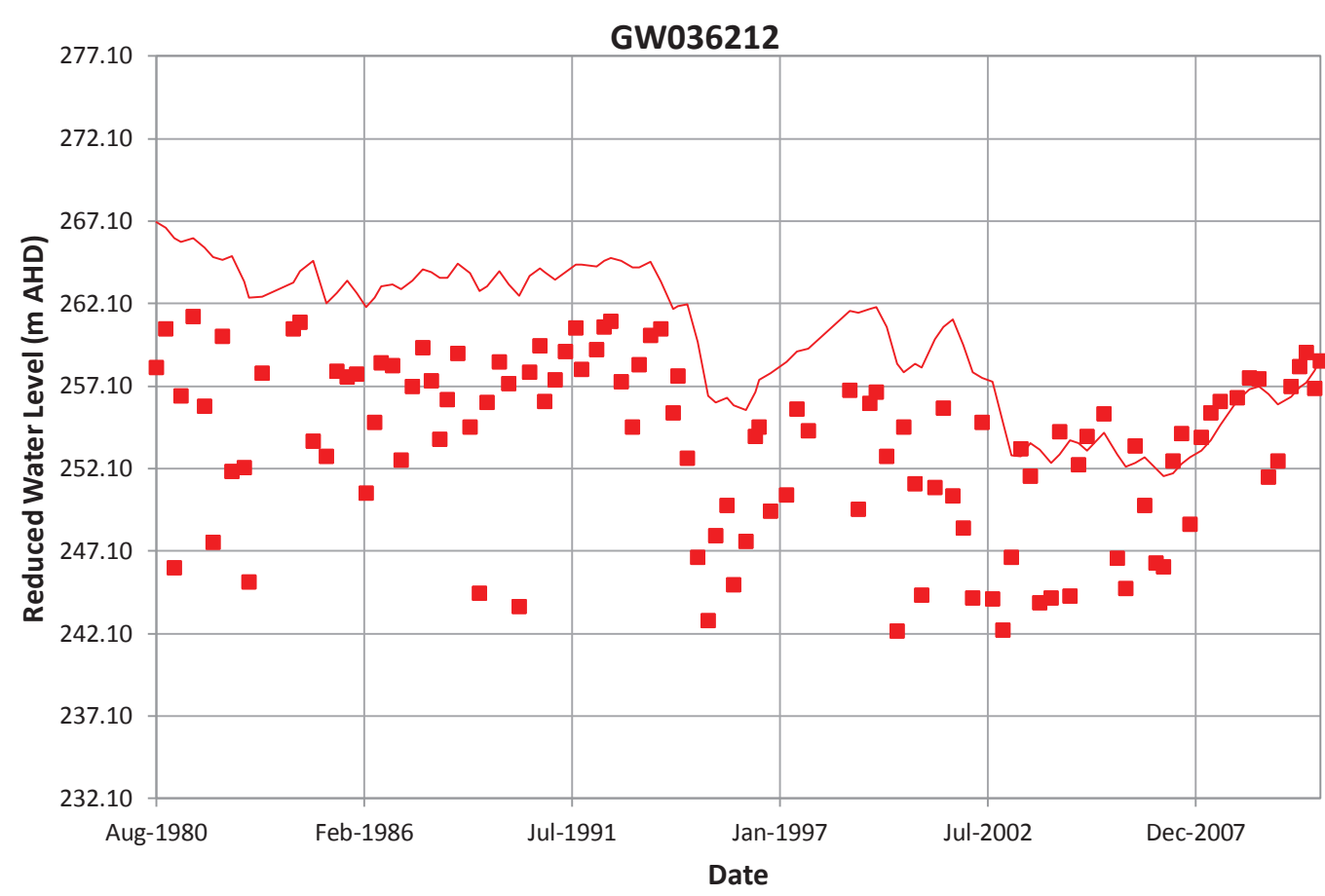
GW036210_1 (Narrabri Fm) - Observed

GW036210_2 (Gunnedah Fm) - Computed

GW036210_2 (Gunnedah Fm) - Observed

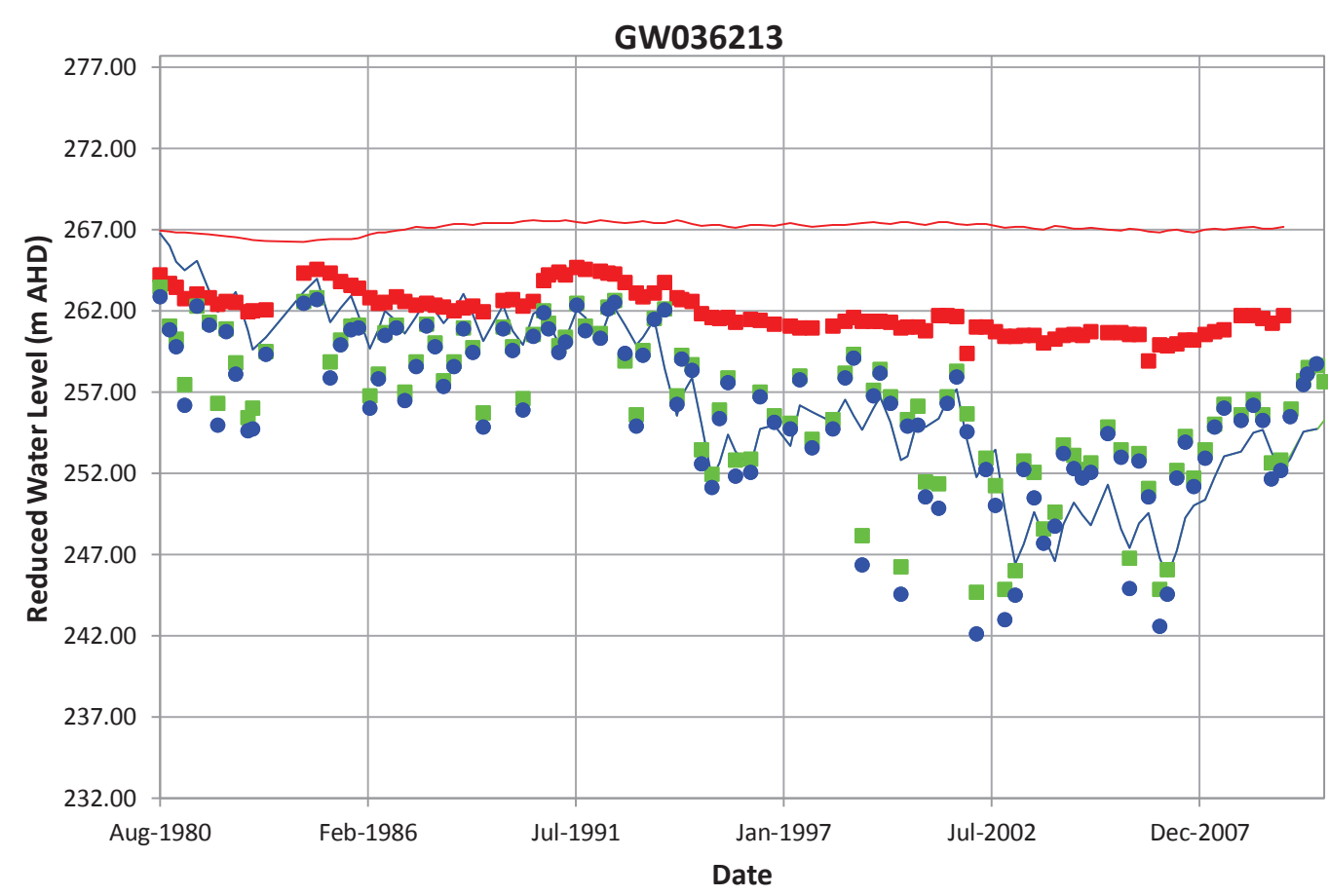
GW036210_3 (Gunnedah Fm) - Computed

GW036210_3 (Gunnedah Fm) - Observed



GW036212_2 (Gunnedah Fm) - Computed

GW036212_2 (Gunnedah Fm) - Observed



GW036213_1 (Narrabri Fm) - Computed

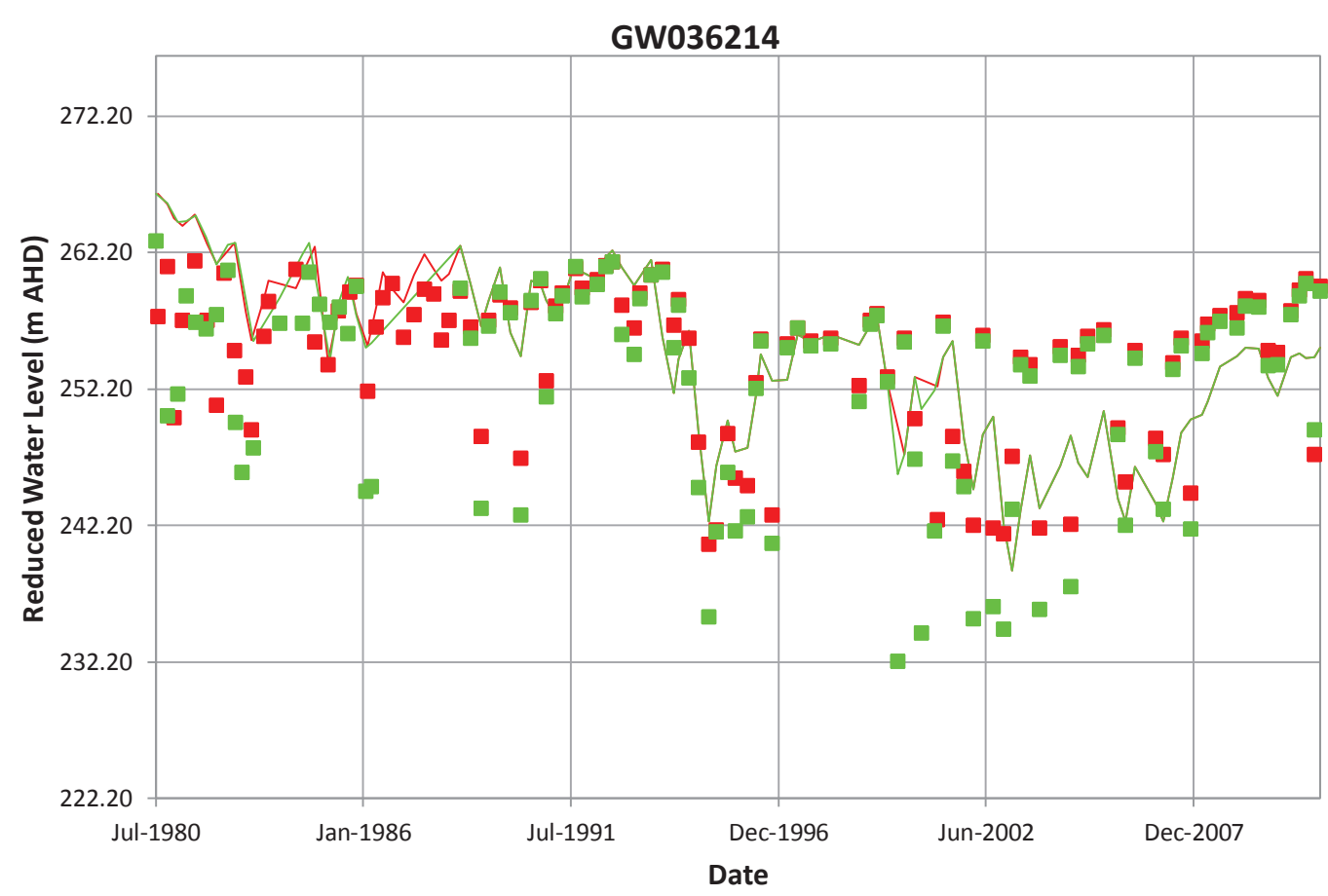
GW036213_1 (Narrabri Fm) - Observed

GW036213_2 (Gunnedah Fm) - Computed

GW036213_2 (Gunnedah Fm) - Observed

GW036213_3 (Gunnedah Fm) - Computed

GW036213_3 (Gunnedah Fm) - Observed

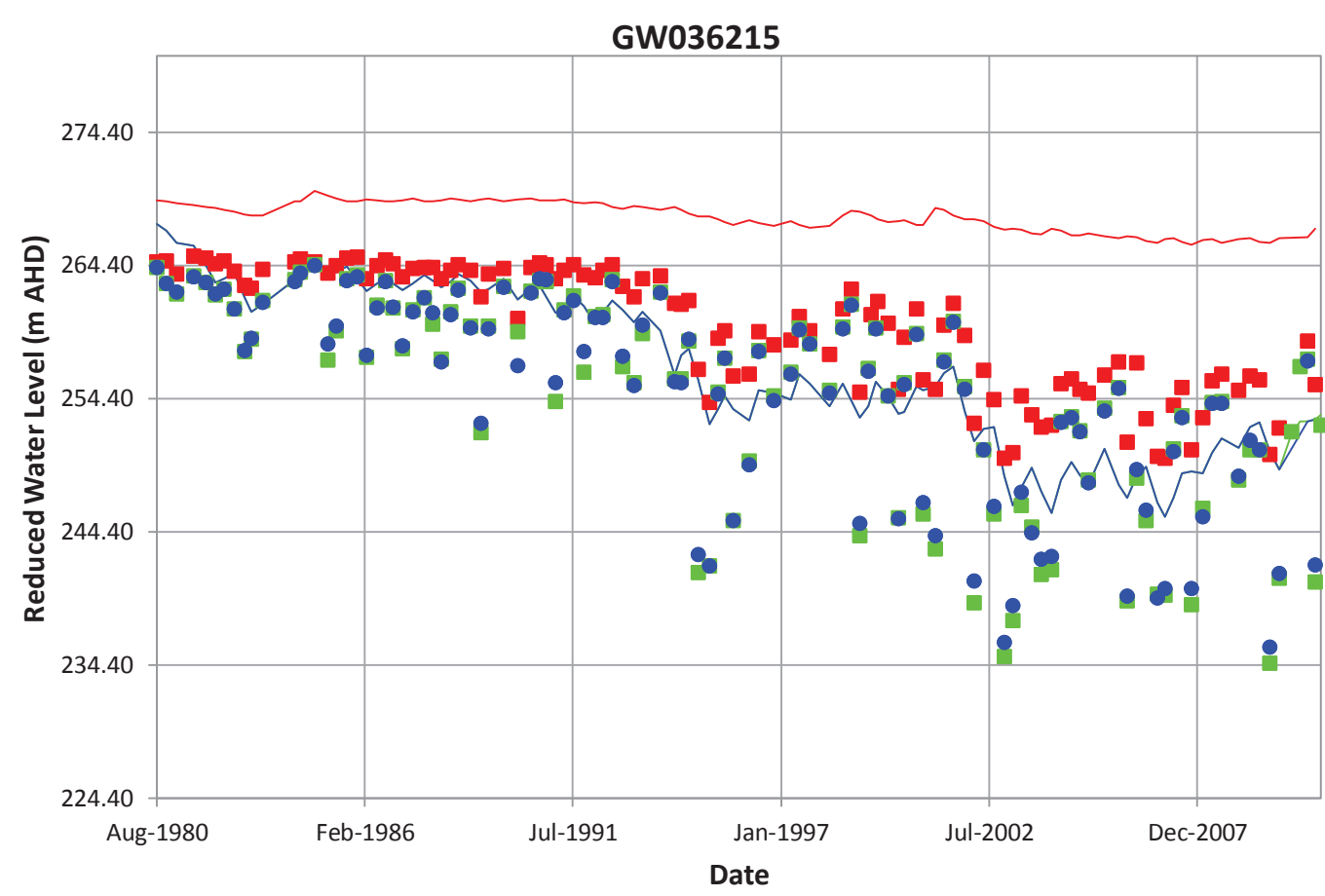


GW036214_1 (Gunnedah Fm) - Computed

GW036214_1 (Gunnedah Fm) - Observed

GW036214_2 (Gunnedah Fm) - Computed

GW036214_2 (Gunnedah Fm) - Observed



GW036215_1 (Narrabri Fm) - Computed

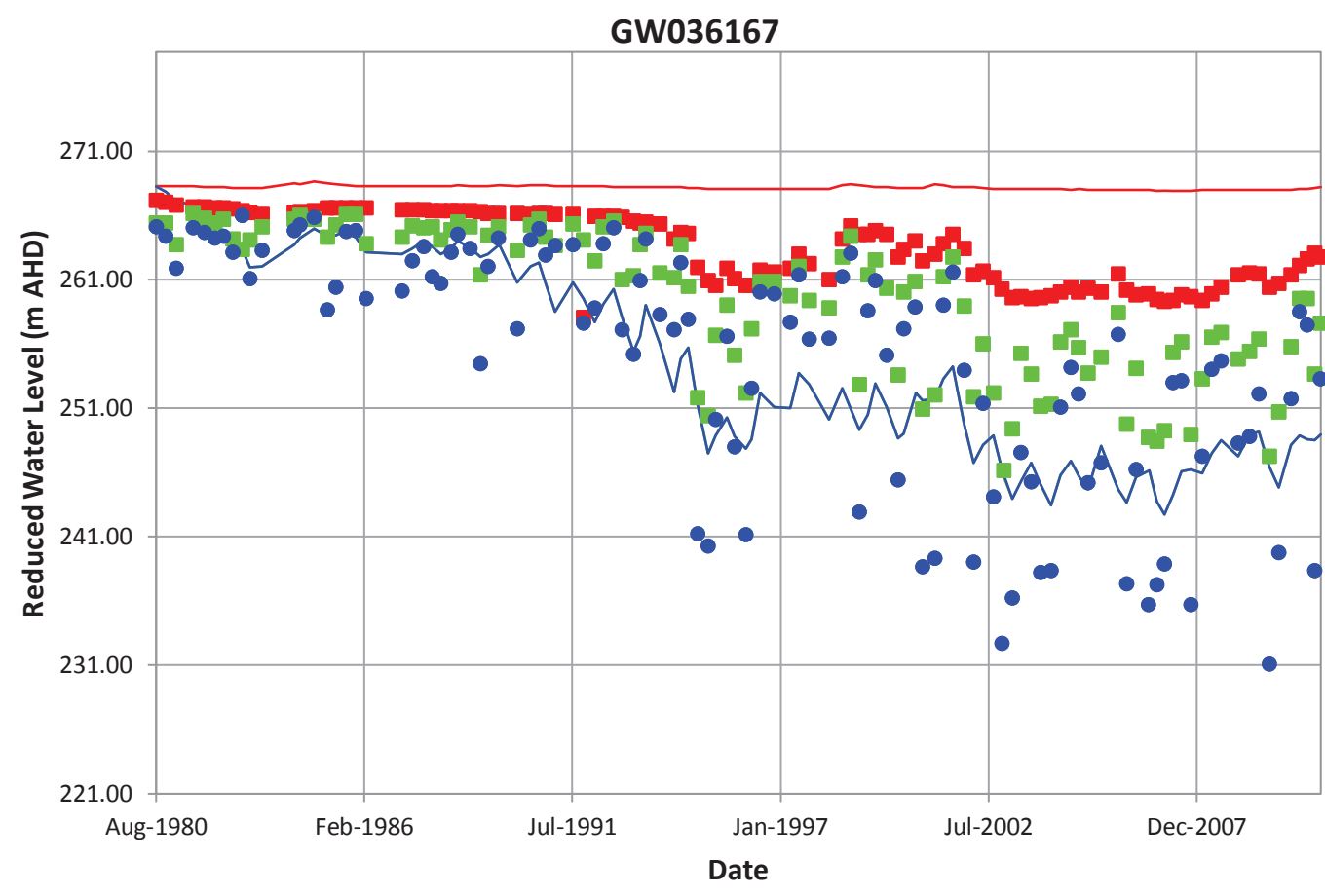
GW036215_1 (Narrabri Fm) - Observed

GW036215_2 (Gunnedah Fm) - Computed

GW036215_2 (Gunnedah Fm) - Observed

GW036215_3 (Gunnedah Fm) - Computed

GW036215_3 (Gunnedah Fm) - Observed



GW036167_1 (Narrabri Fm) - Computed

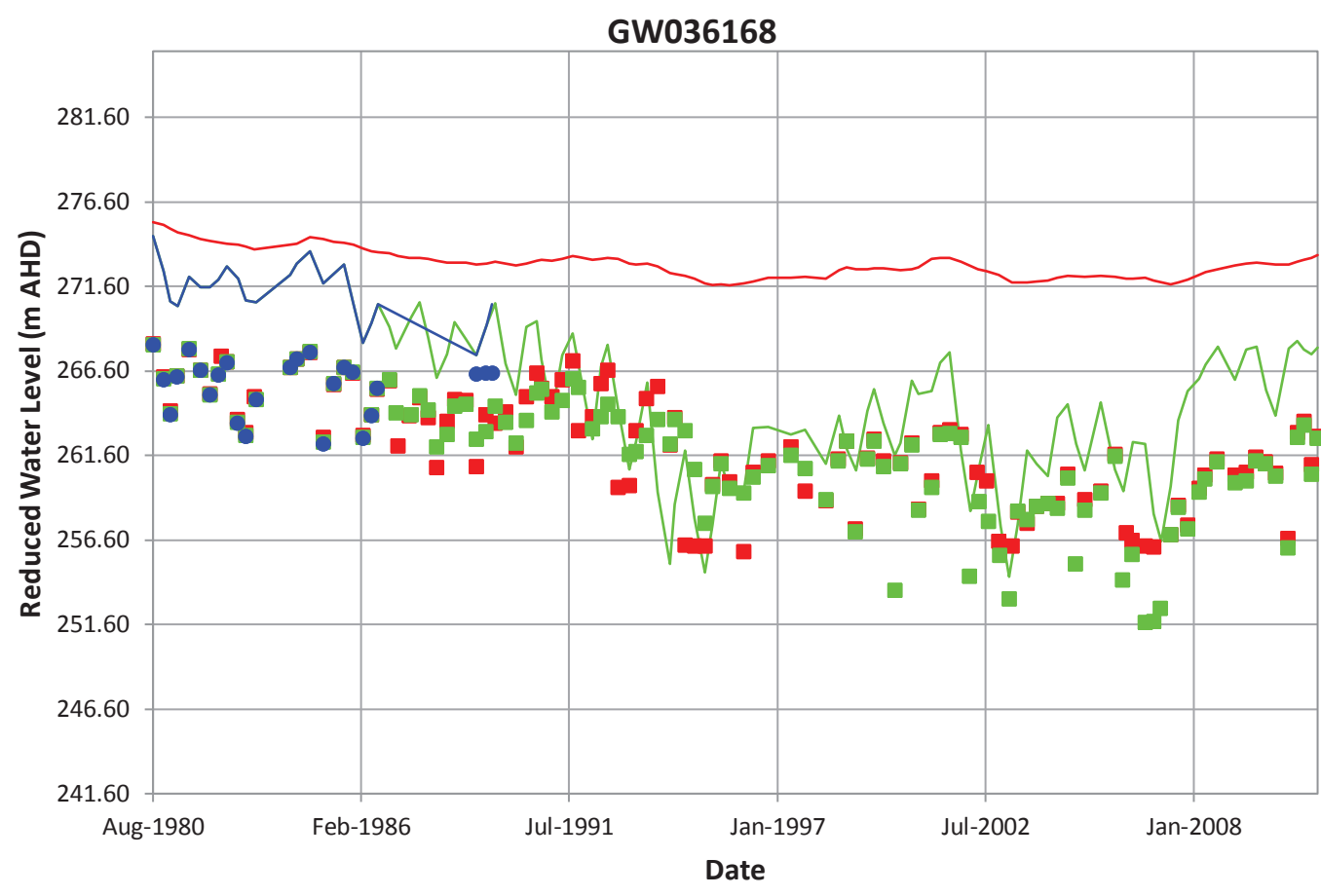
GW036167_1 (Narrabri Fm) - Observed

GW036167_2 (Gunnedah Fm) - Computed

GW036167_2 (Gunnedah Fm) - Observed

GW036167_3 (Gunnedah Fm) - Computed

GW036167_3 (Gunnedah Fm) - Observed



GW036168_1 (Narrabri Fm) - Computed

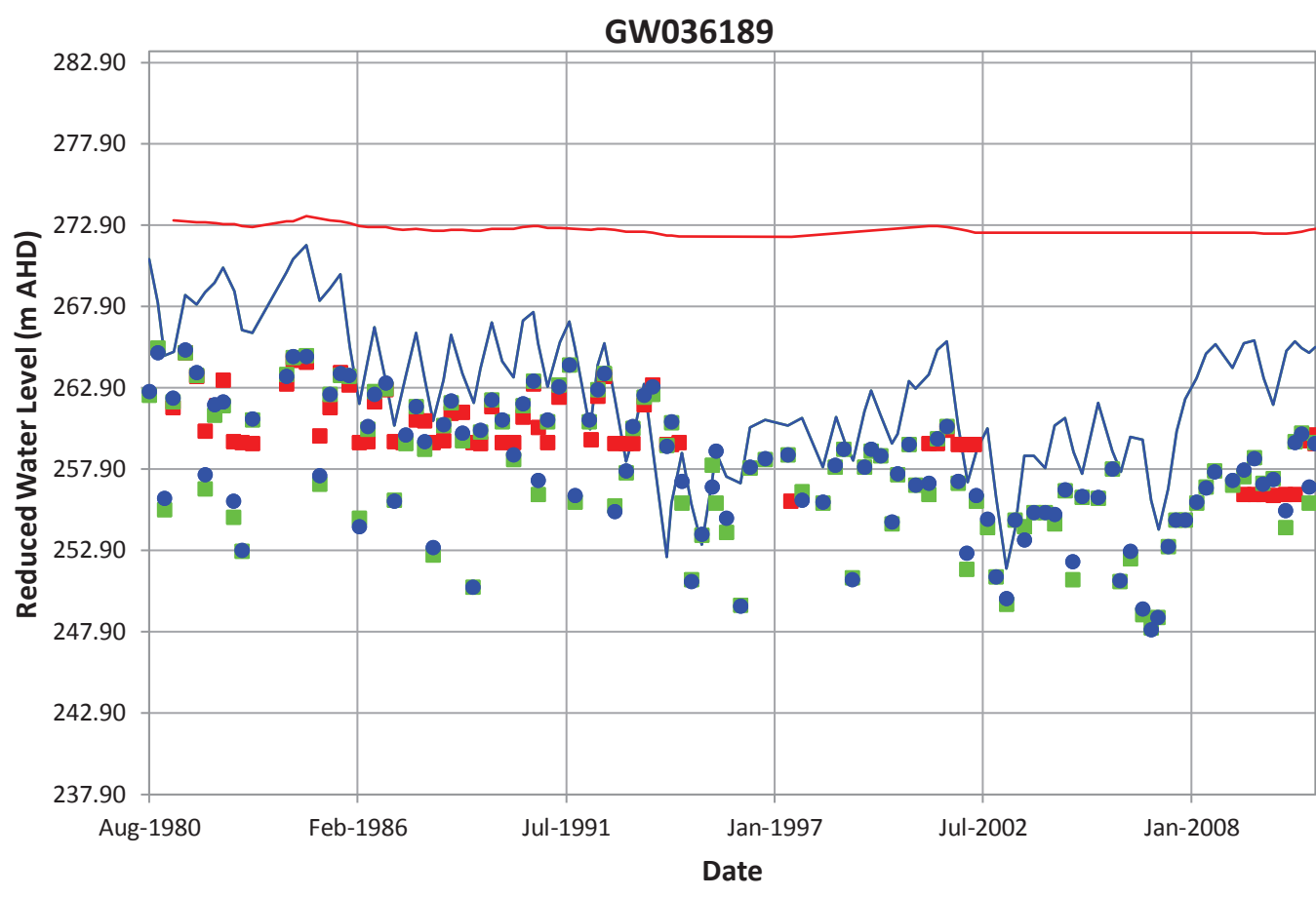
GW036168_1 (Narrabri Fm) - Observed

GW036168_2 (Gunnedah Fm) - Computed

GW036168_2 (Gunnedah Fm) - Observed

GW036168_3 (Gunnedah Fm) - Computed

GW036168_3 (Gunnedah Fm) - Observed



GW036189_1 (Narrabri Fm) - Computed

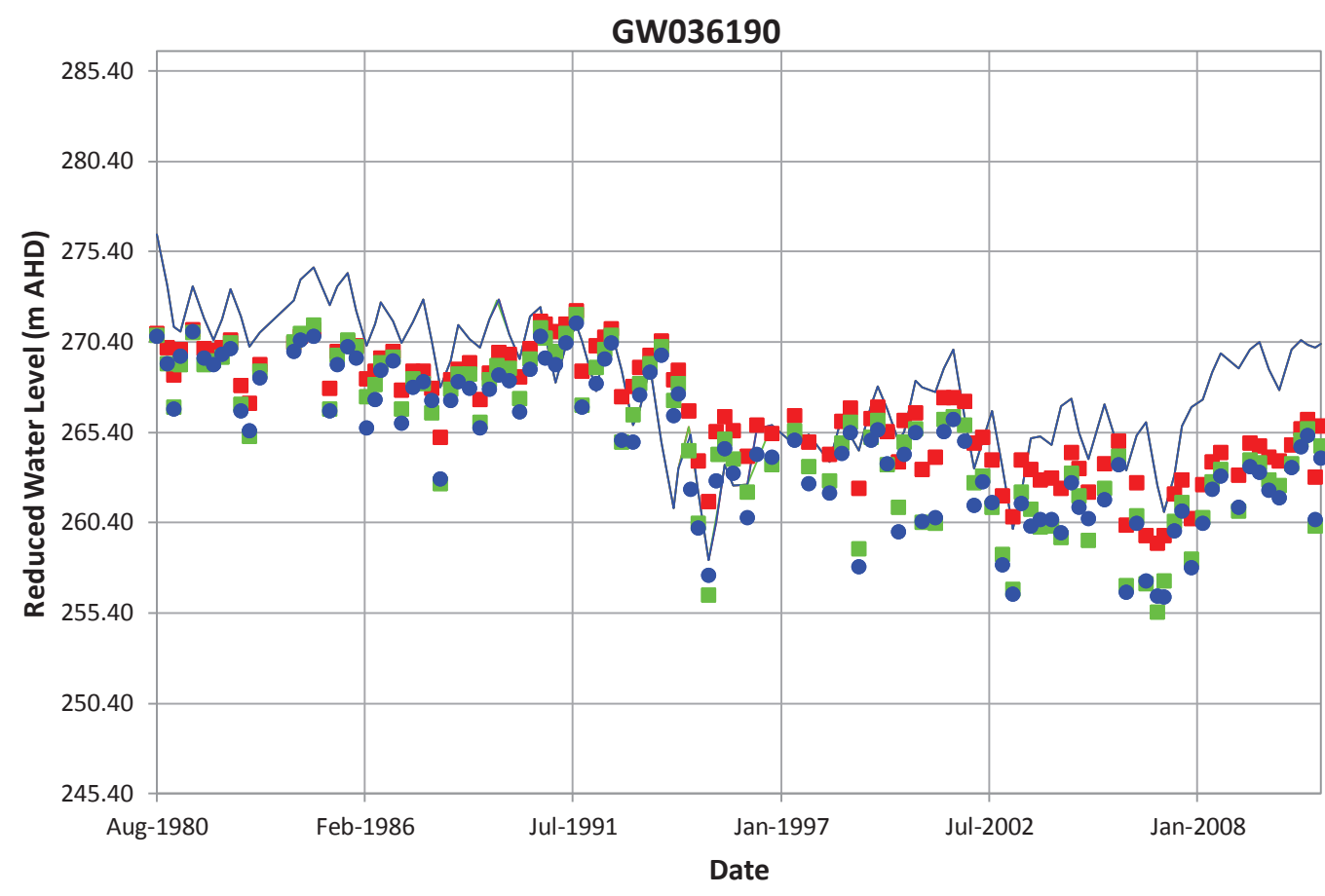
GW036189_1 (Narrabri Fm) - Observed

GW036189_2 (Gunnedah Fm) - Computed

GW036189_2 (Gunnedah Fm) - Observed

GW036189_3 (Gunnedah Fm) - Computed

GW036189_3 (Gunnedah Fm) - Observed



GW036190_1 (Gunnedah Fm) - Computed

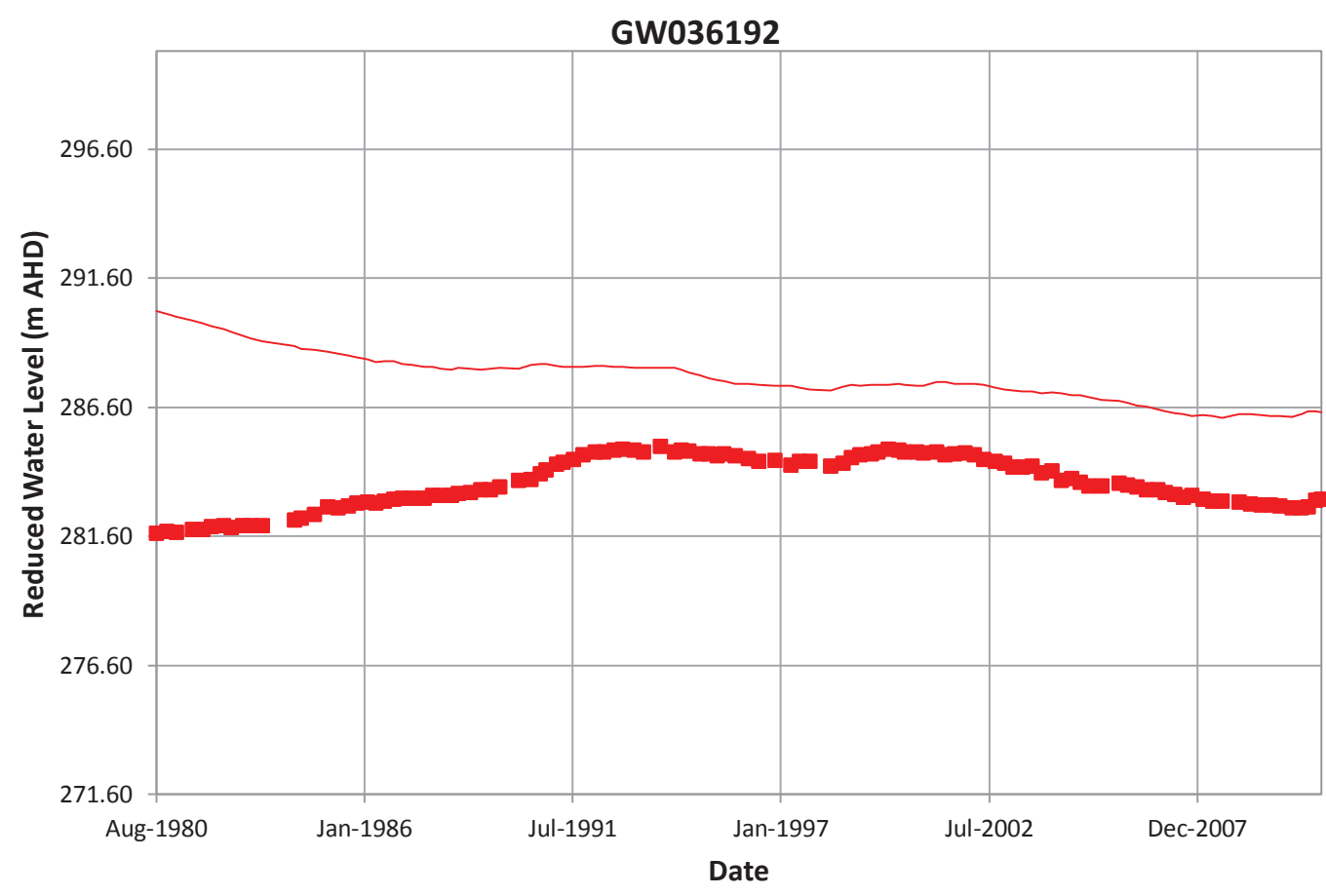
GW036190_1 (Gunnedah Fm) - Observed

GW036190_2 (Gunnedah Fm) - Computed

GW036190_2 (Gunnedah Fm) - Observed

GW036190_3 (Gunnedah Fm) - Computed

GW036190_3 (Gunnedah Fm) - Observed

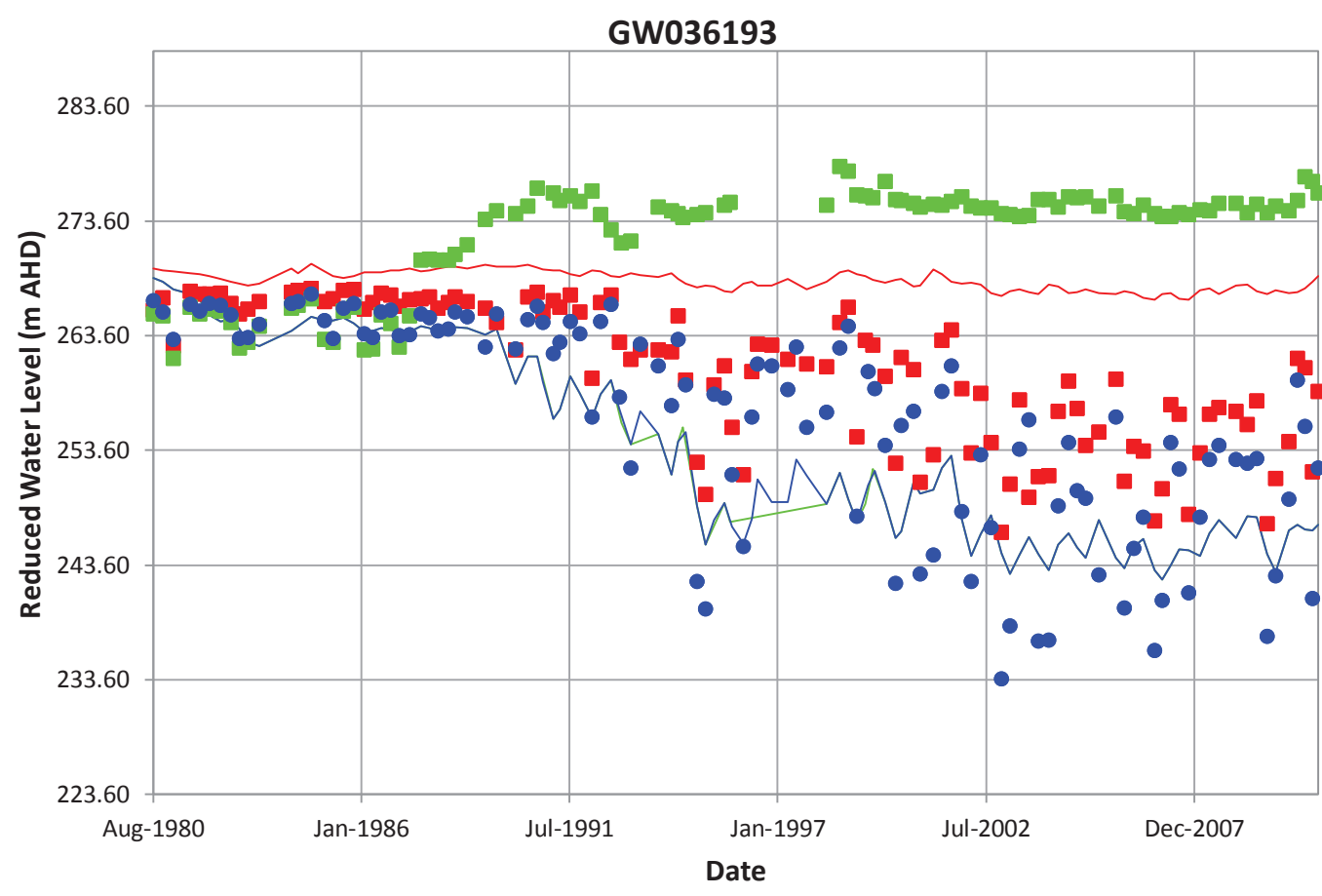


GW036192_1 (Narrabri Fm) - Computed

GW036192_1 (Narrabri Fm) - Observed

GW036192_2 (Narrabri Fm) - Computed

GW036192_2 (Narrabri Fm) - Observed



GW036193_1 (Narrabri Fm) - Computed

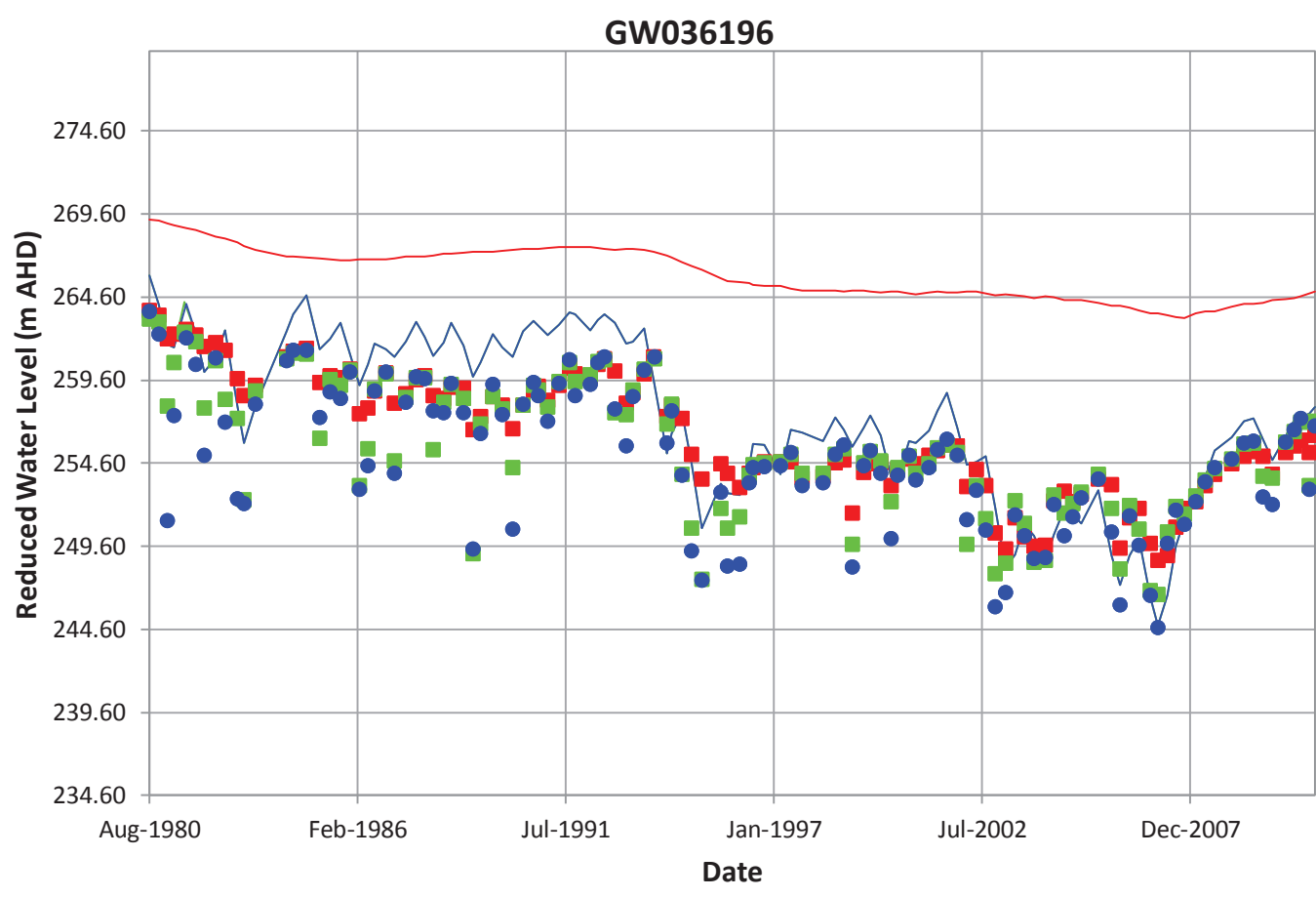
GW036193_1 (Narrabri Fm) - Observed

GW036193_2 (Gunnedah Fm) - Computed

GW036193_2 (Gunnedah Fm) - Observed

GW036193_3 (Gunnedah Fm) - Computed

GW036193_3 (Gunnedah Fm) - Observed



GW036196_1 (Narrabri Fm) - Computed

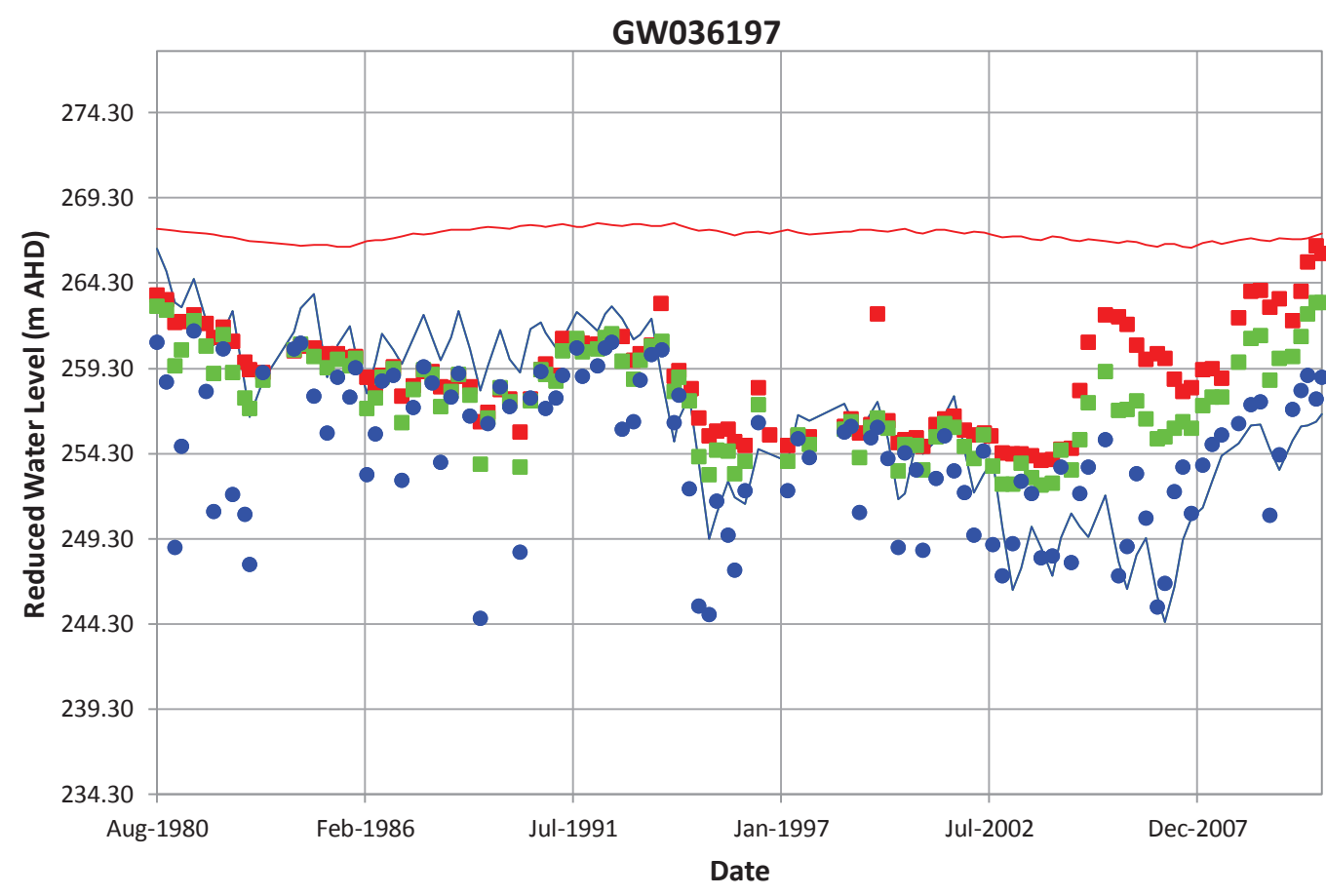
GW036196_1 (Narrabri Fm) - Observed

GW036196_2 (Gunnedah Fm) - Computed

GW036196_2 (Gunnedah Fm) - Observed

GW036196_3 (Gunnedah Fm) - Computed

GW036196_3 (Gunnedah Fm) - Observed



GW036197_1 (Narrabri Fm) - Computed

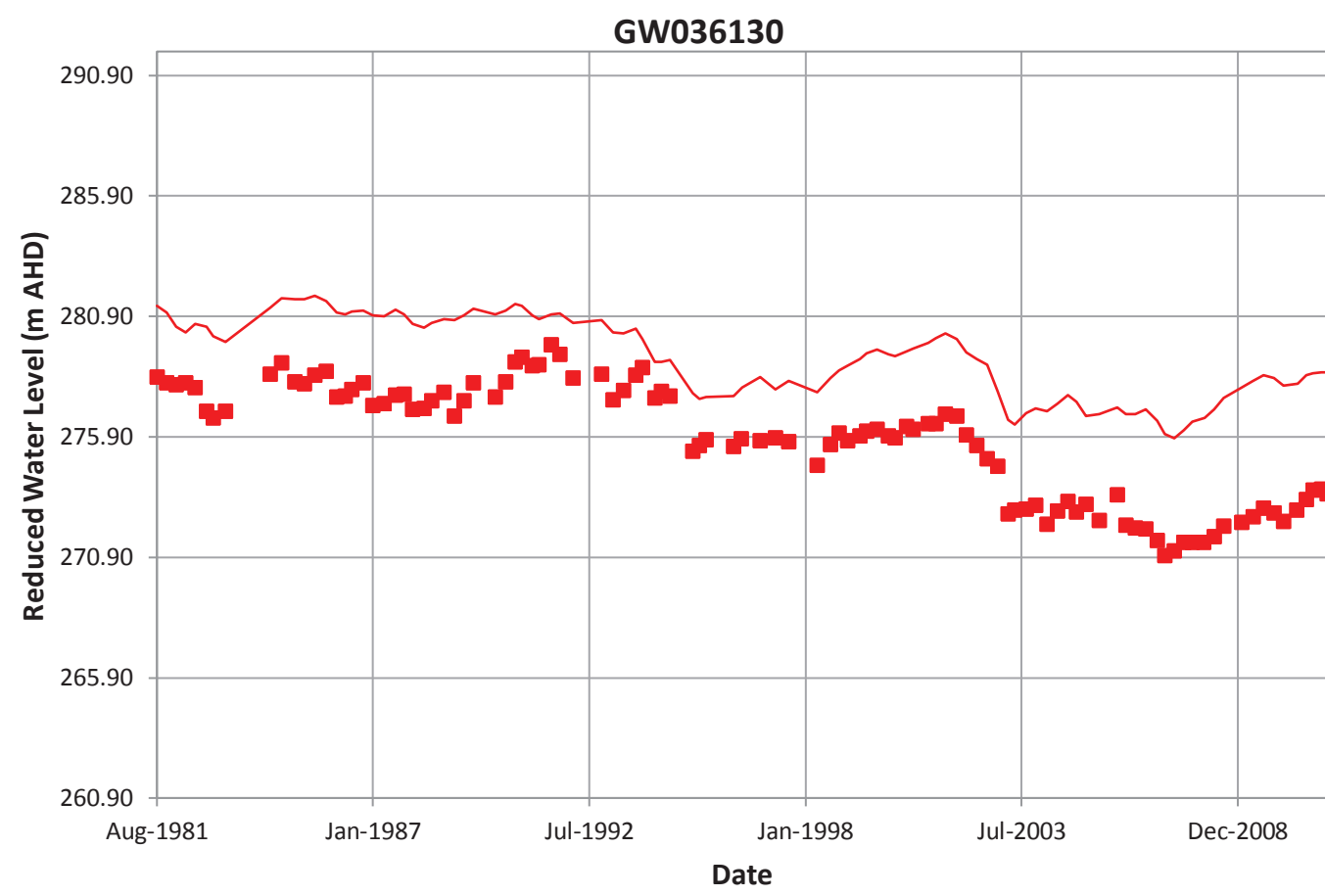
GW036197_1 (Narrabri Fm) - Observed

GW036197_2 (Gunnedah Fm) - Computed

GW036197_2 (Gunnedah Fm) - Observed

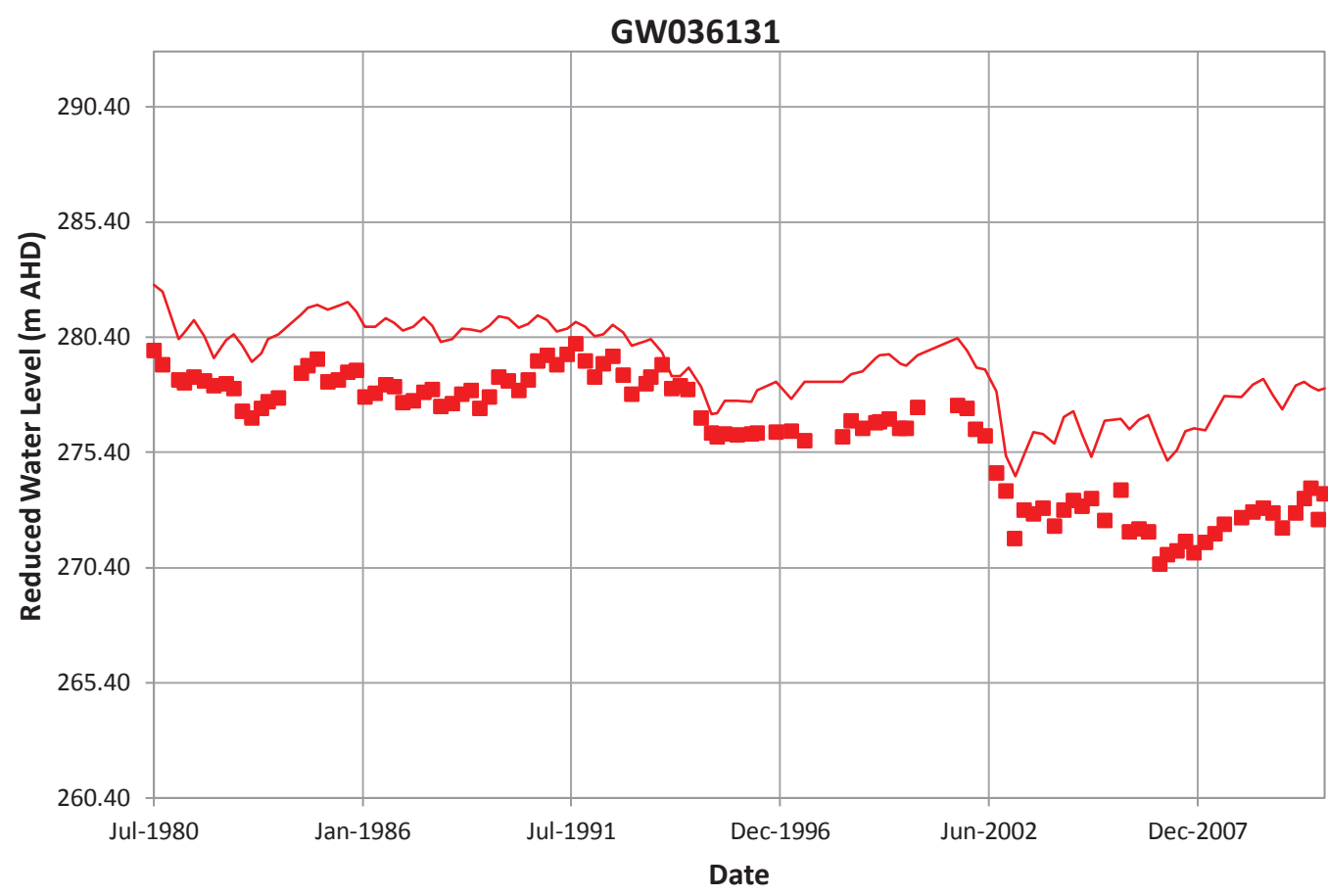
GW036197_3 (Gunnedah Fm) - Computed

GW036197_3 (Gunnedah Fm) - Observed



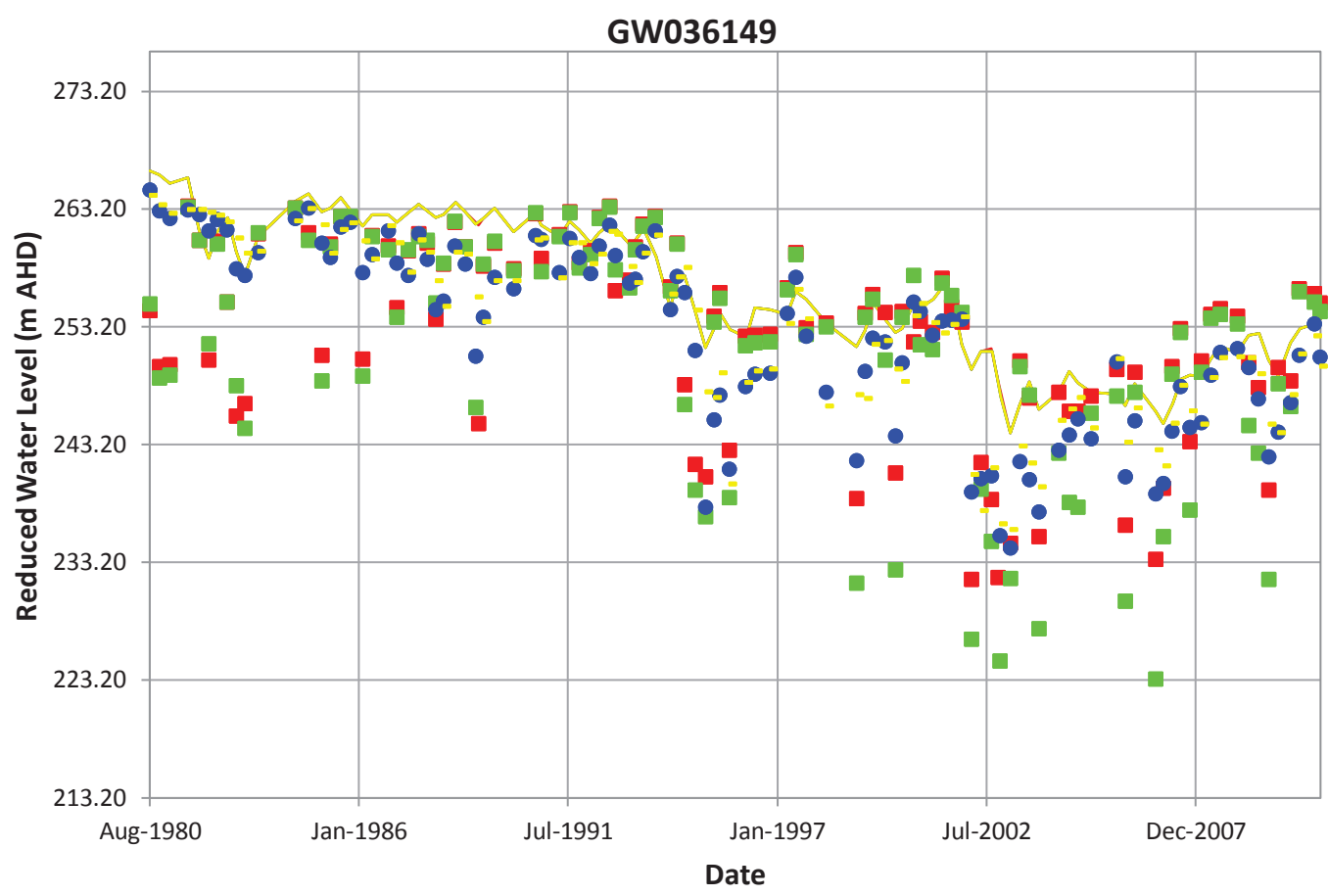
GW036130_1 (Gunnedah Fm) - Computed

GW036130_1 (Gunnedah Fm) - Observed



GW036131_1 (Gunnedah Fm) - Computed

GW036131_1 (Gunnedah Fm) - Observed



GW036149_1 (Gunnedah Fm) - Computed

GW036149_1 (Gunnedah Fm) - Observed

GW036149_2 (Gunnedah Fm) - Computed

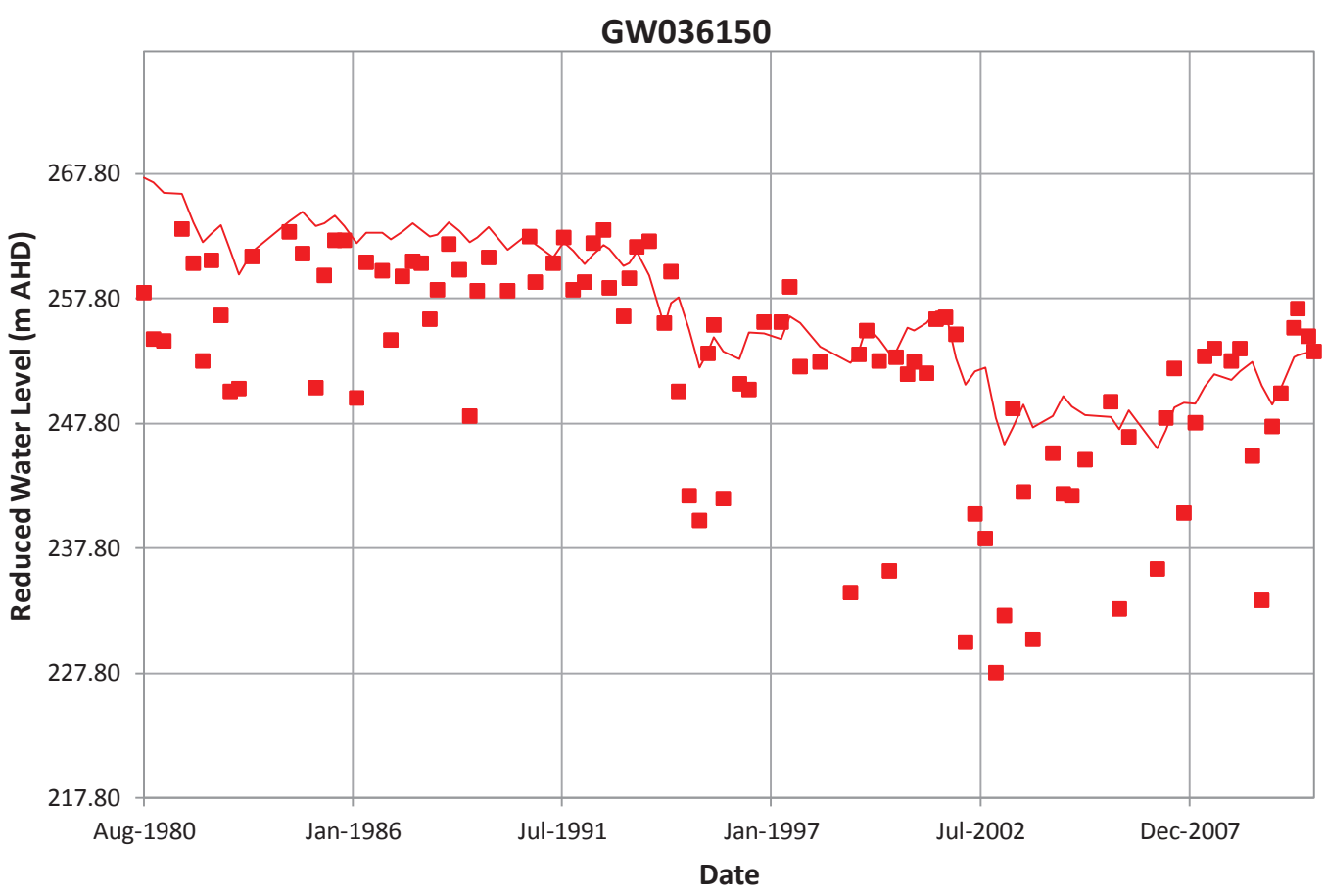
GW036149_2 (Gunnedah Fm) - Observed

GW036149_3 (Gunnedah Fm) - Computed

GW036149_3 (Gunnedah Fm) - Observed

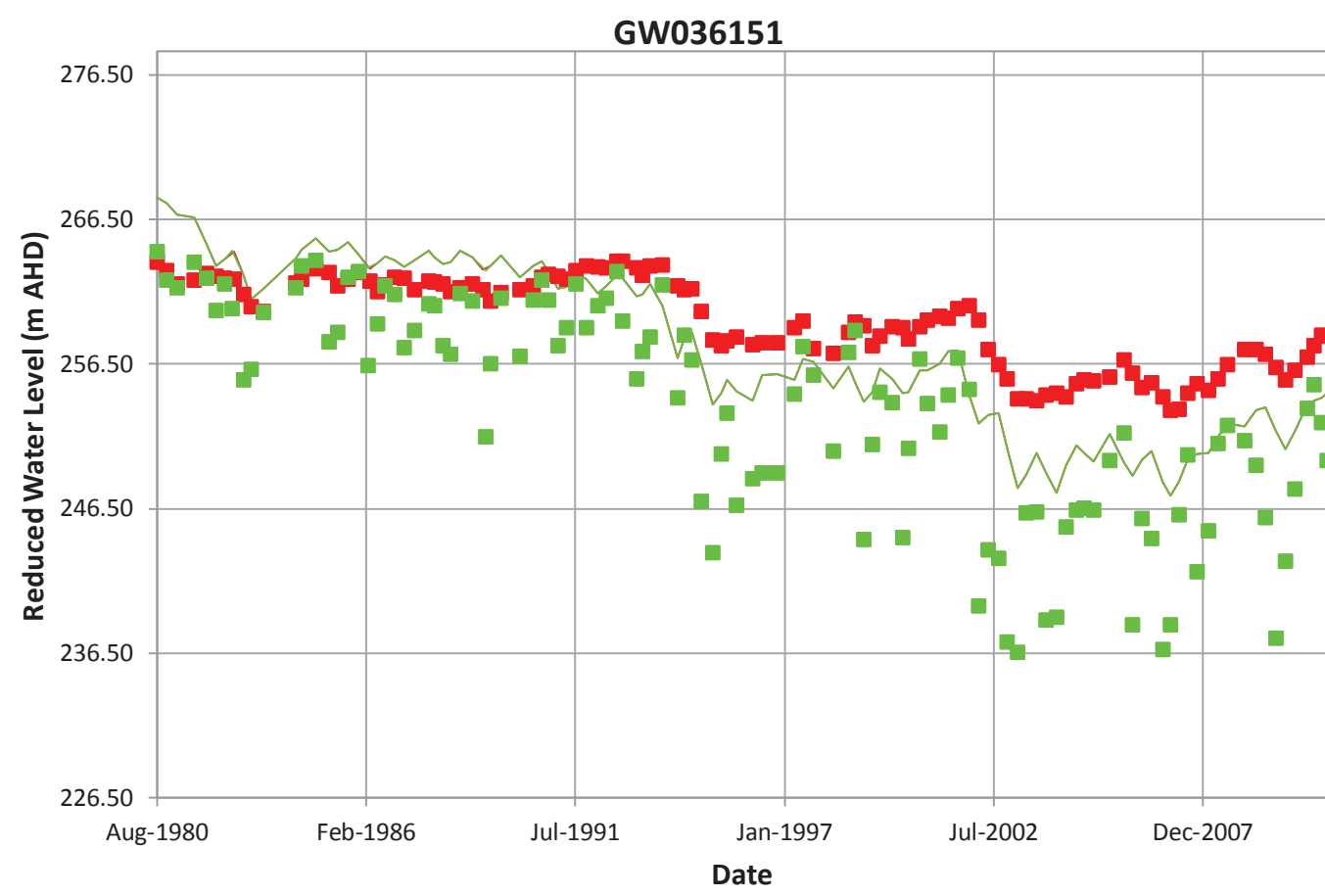
GW036149_4 (Gunnedah Fm) - Computed

GW036149_4 (Gunnedah Fm) - Observed



GW036150_1 (Gunnedah Fm) - Computed

GW036150_1 (Gunnedah Fm) - Observed

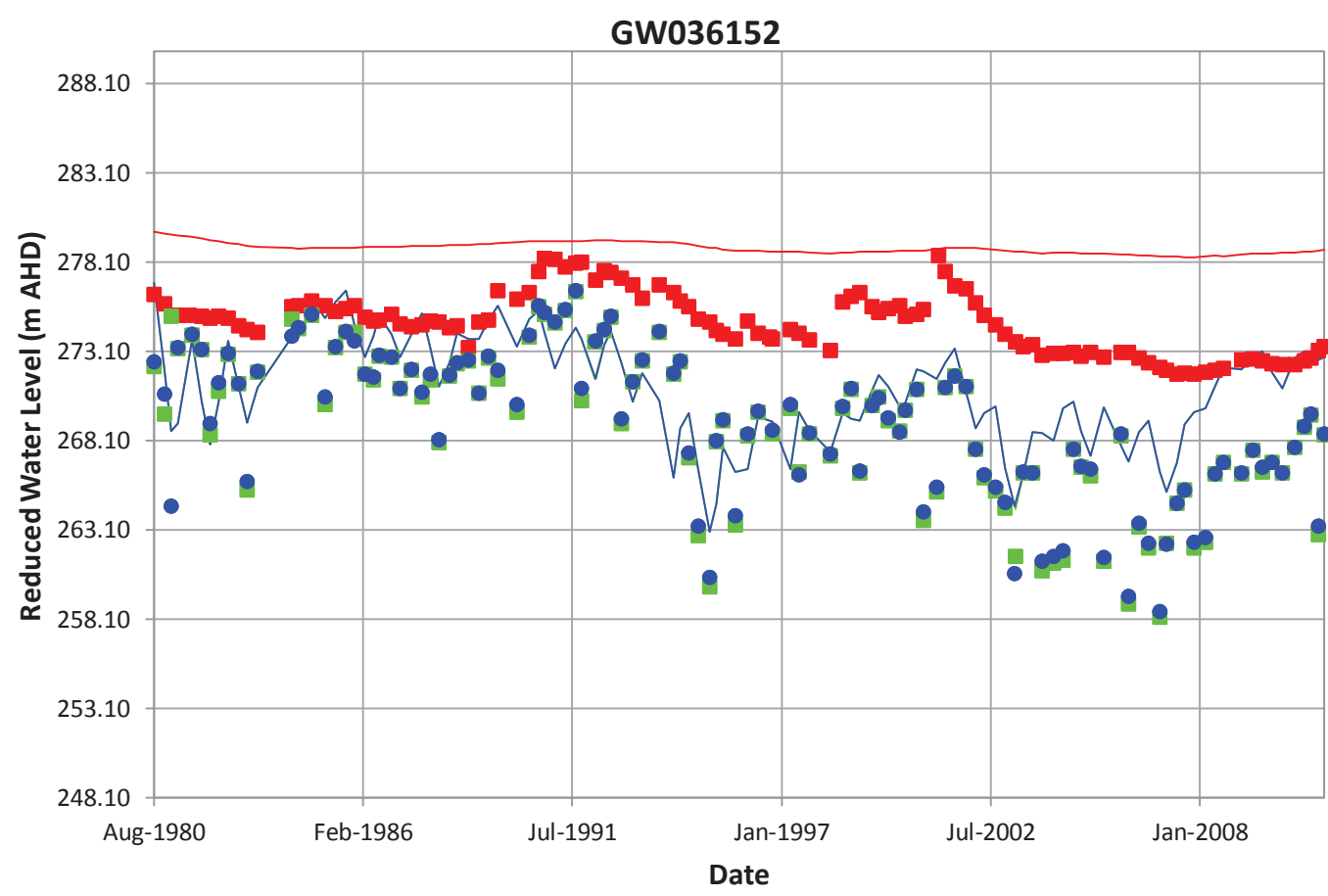


GW036151_1 (Gunnedah Fm) - Computed

GW036151_1 (Gunnedah Fm) - Observed

GW036151_2 (Gunnedah Fm) - Computed

GW036151_2 (Gunnedah Fm) - Observed



GW036152_1 (Narrabri Fm) - Computed

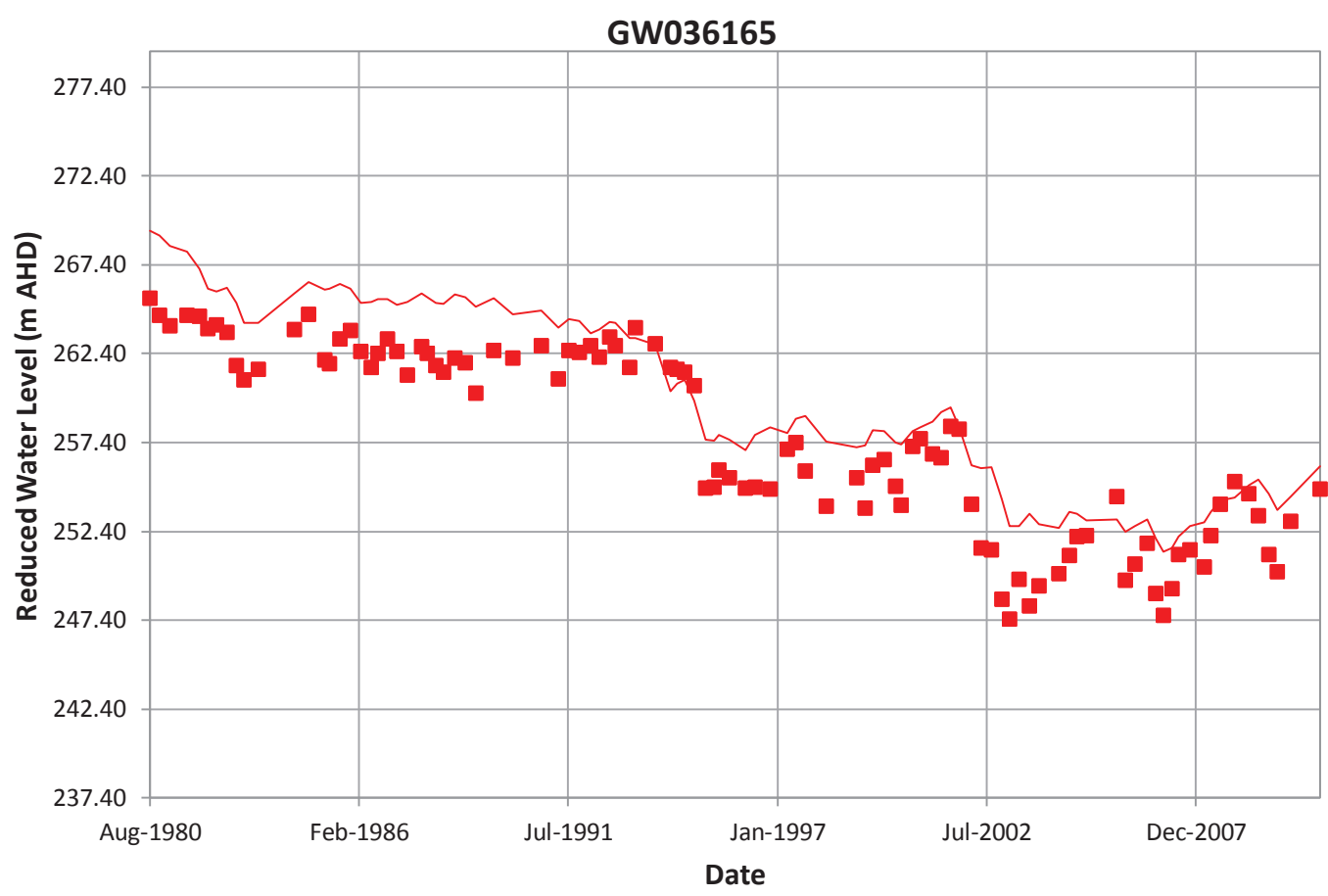
GW036152_1 (Narrabri Fm) - Observed

GW036152_2 (Gunnedah Fm) - Computed

GW036152_2 (Gunnedah Fm) - Observed

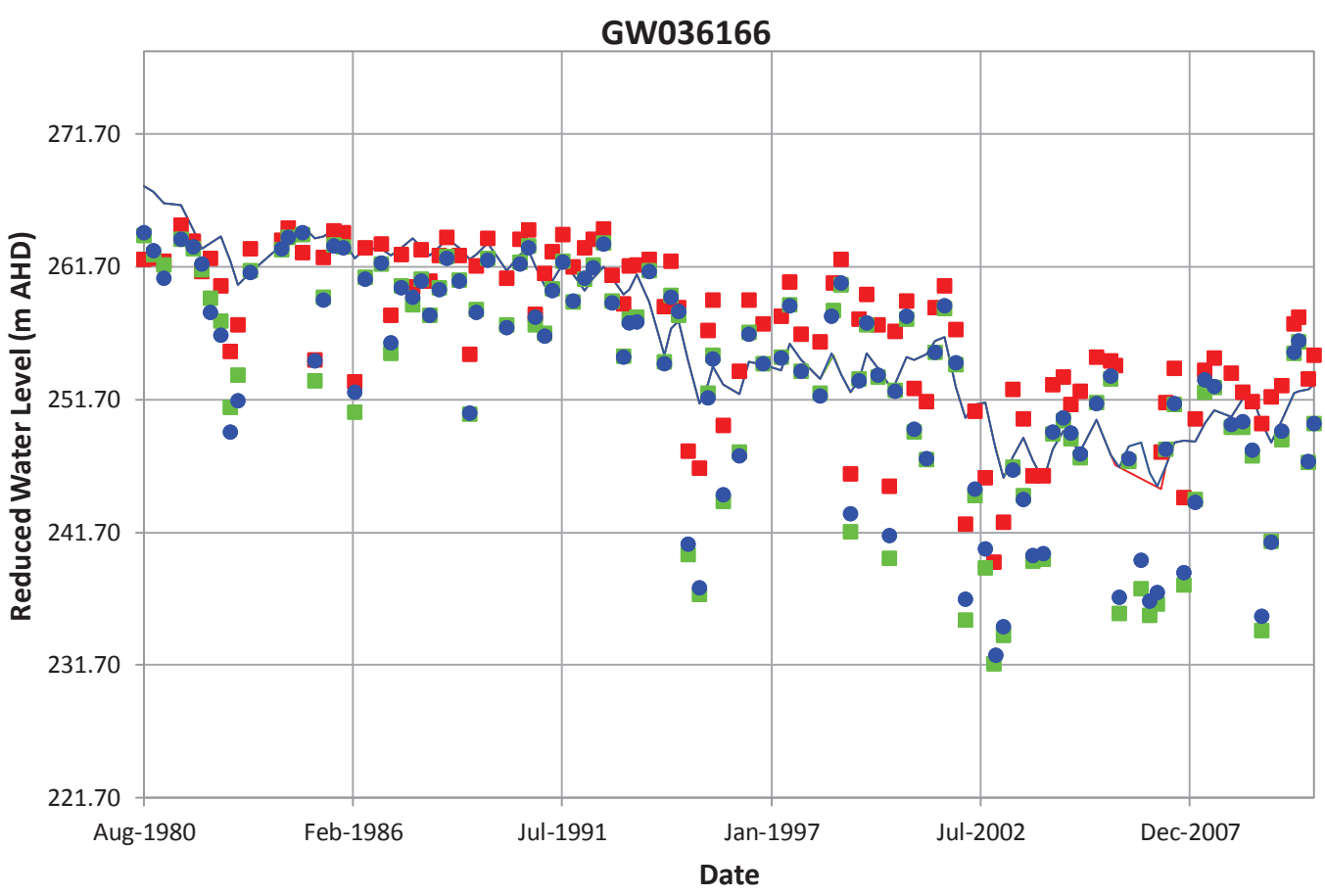
GW036152_3 (Gunnedah Fm) - Computed

GW036152_3 (Gunnedah Fm) - Observed



GW036165_1 (Gunnedah Fm) - Computed

GW036165_1 (Gunnedah Fm) - Observed



GW036166_1 (Gunnedah Fm) - Computed

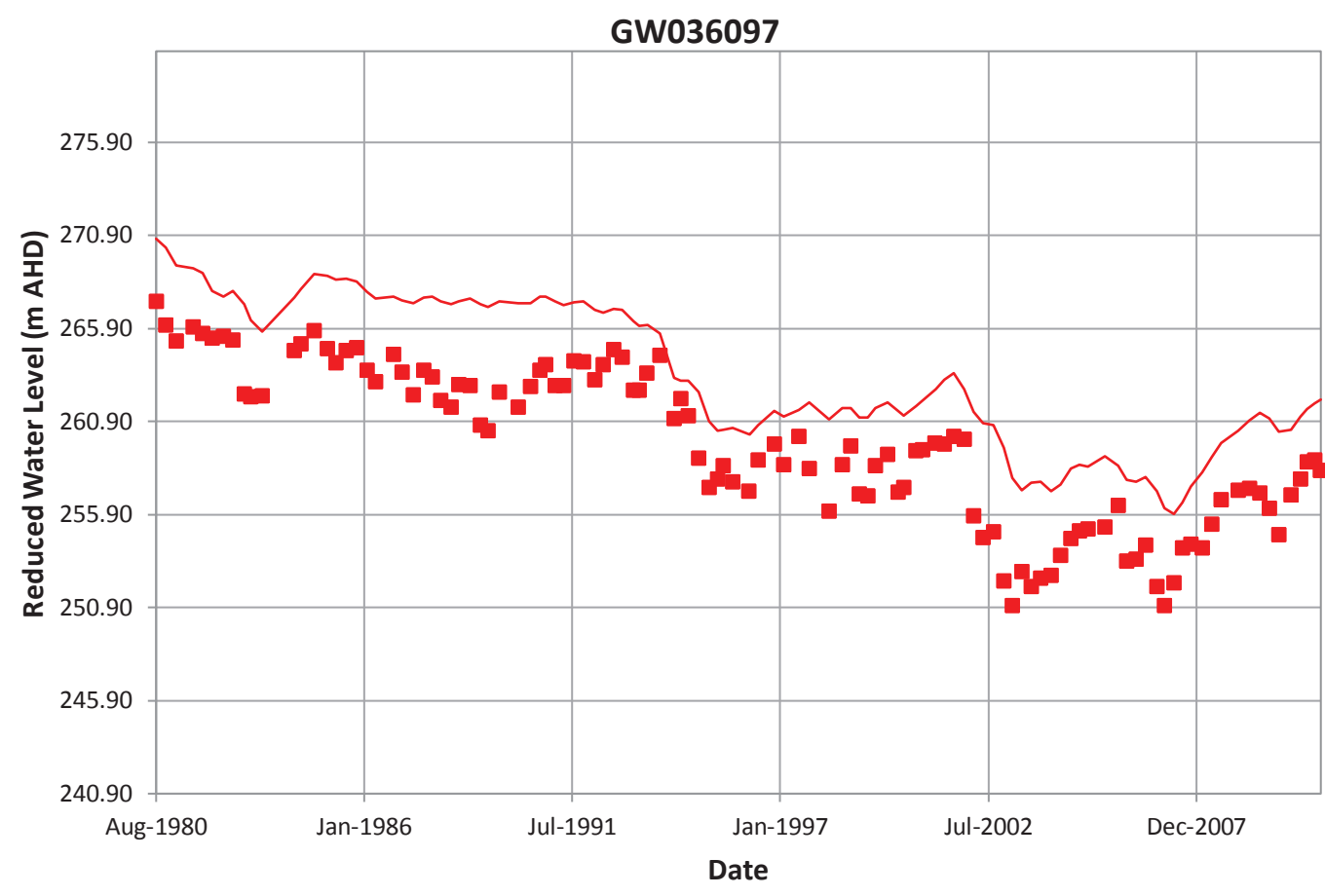
GW036166_1 (Gunnedah Fm) - Observed

GW036166_2 (Gunnedah Fm) - Computed

GW036166_2 (Gunnedah Fm) - Observed

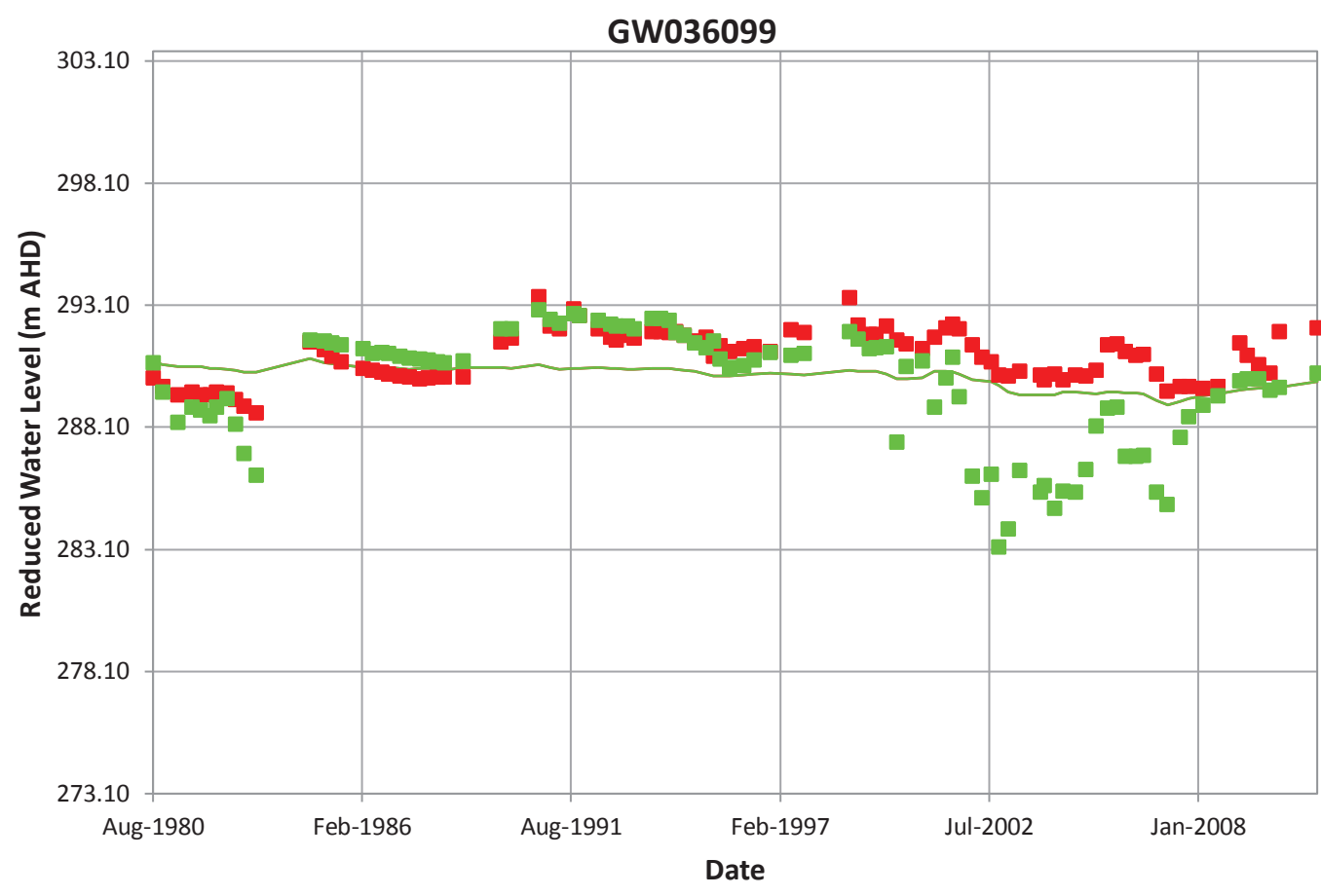
GW036166_3 (Gunnedah Fm) - Computed

GW036166_3 (Gunnedah Fm) - Observed



GW036097_1 (Gunnedah Fm) - Computed

GW036097_1 (Gunnedah Fm) - Observed

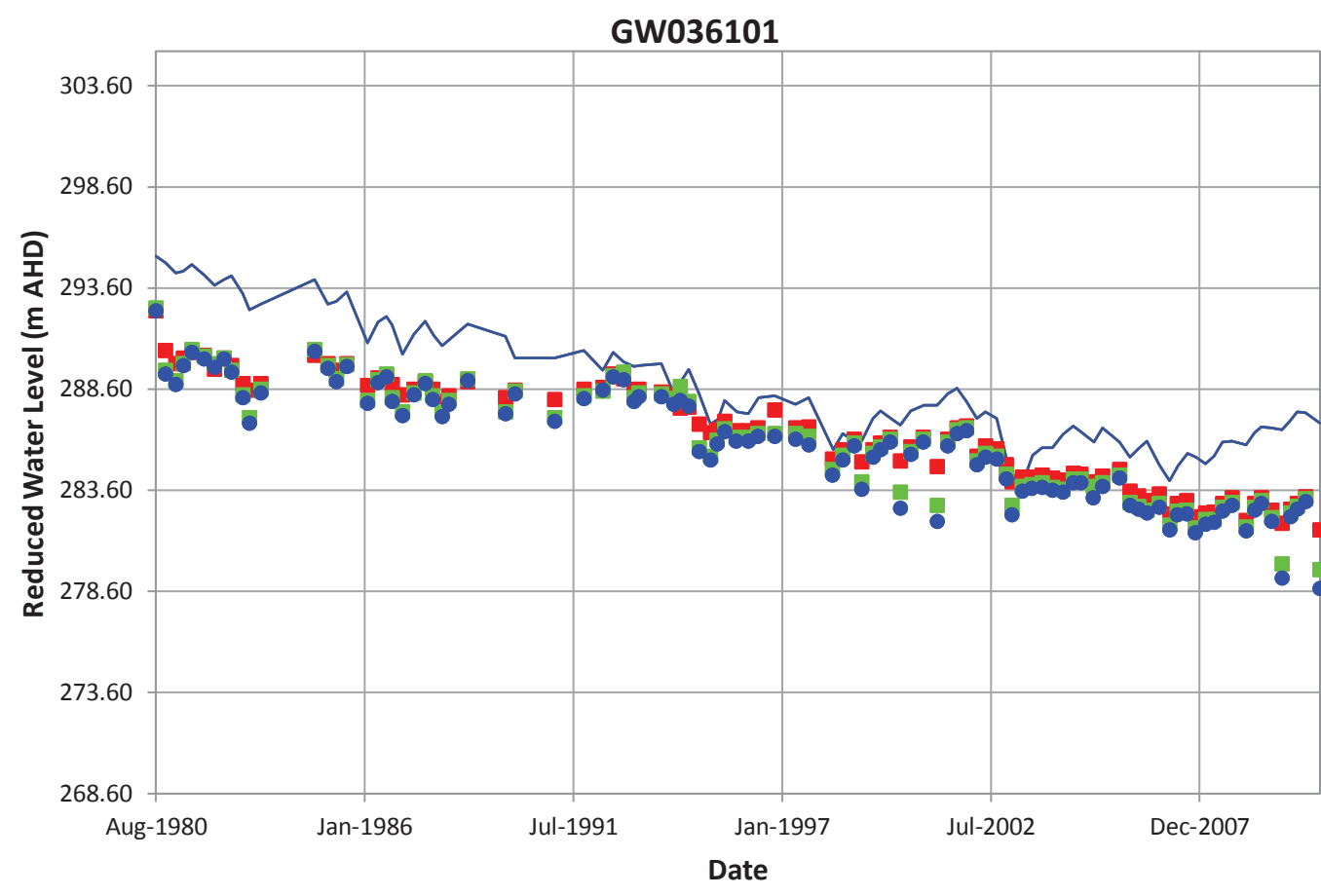


GW036099_1 (Gunnedah Fm) - Computed

GW036099_1 (Gunnedah Fm) - Observed

GW036099_2 (Gunnedah Fm) - Computed

GW036099_2 (Gunnedah Fm) - Observed



GW036101_1 (Gunnedah Fm) - Computed

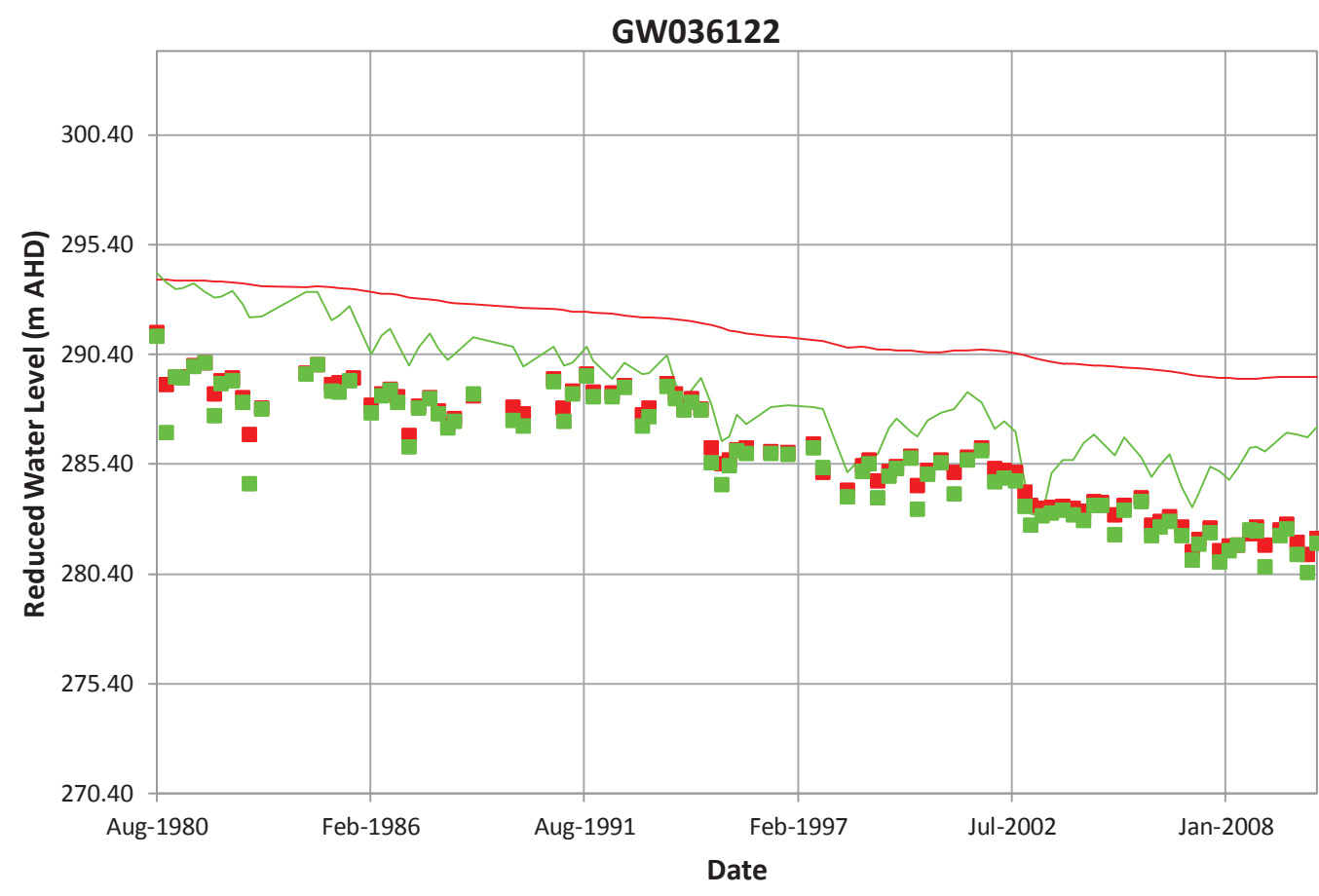
GW036101_1 (Gunnedah Fm) - Observed

GW036101_2 (Gunnedah Fm) - Computed

GW036101_2 (Gunnedah Fm) - Observed

GW036101_3 (Gunnedah Fm) - Computed

GW036101_3 (Gunnedah Fm) - Observed

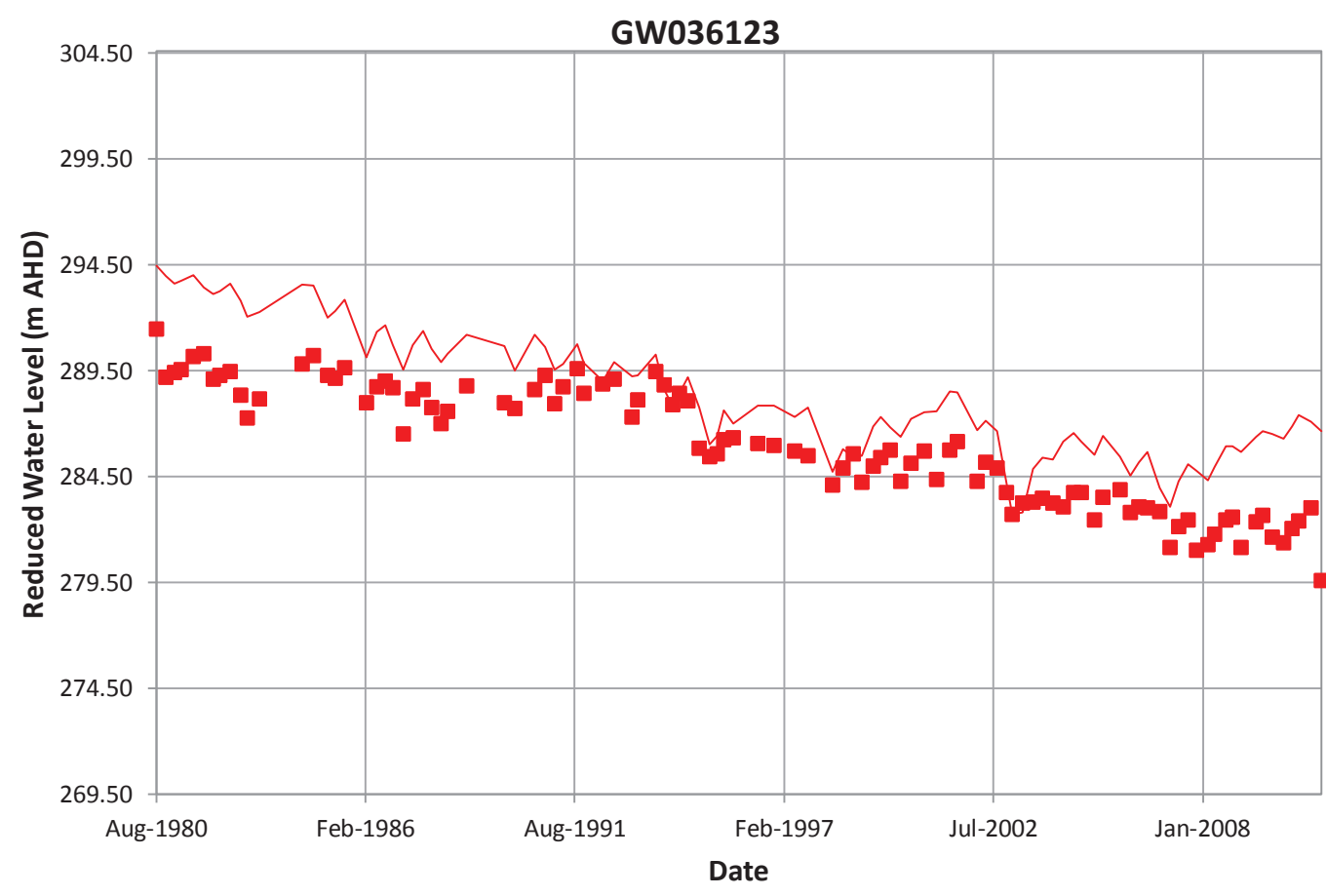


GW036122_1 (Narrabri Fm) - Computed

GW036122_1 (Narrabri Fm) - Observed

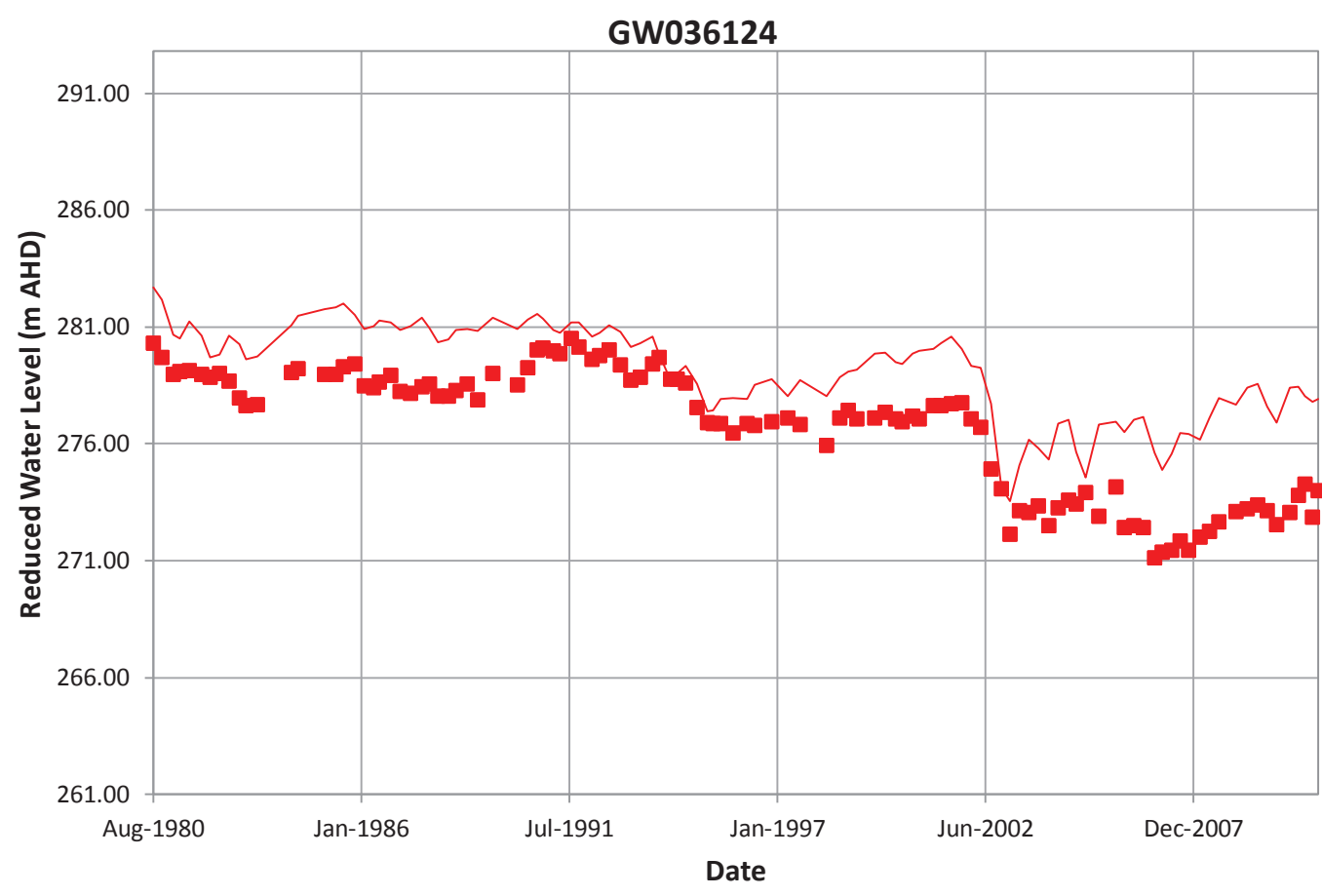
GW036122_2 (Gunnedah Fm) - Computed

GW036122_2 (Gunnedah Fm) - Observed



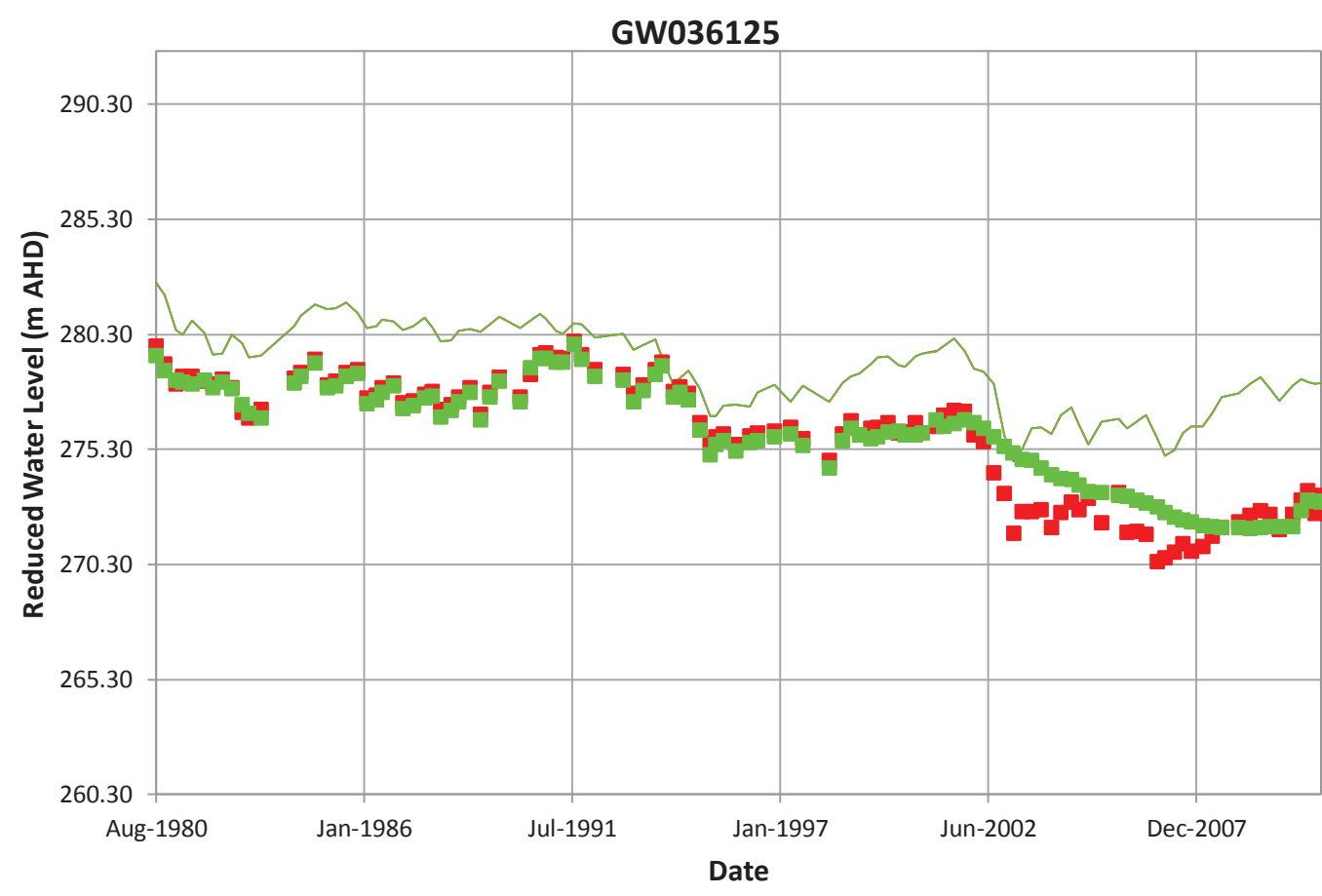
GW036123_1 (Gunnedah Fm) - Computed

GW036123_1 (Gunnedah Fm) - Observed



GW036124_1 (Gunnedah Fm) - Computed

GW036124_1 (Gunnedah Fm) - Observed

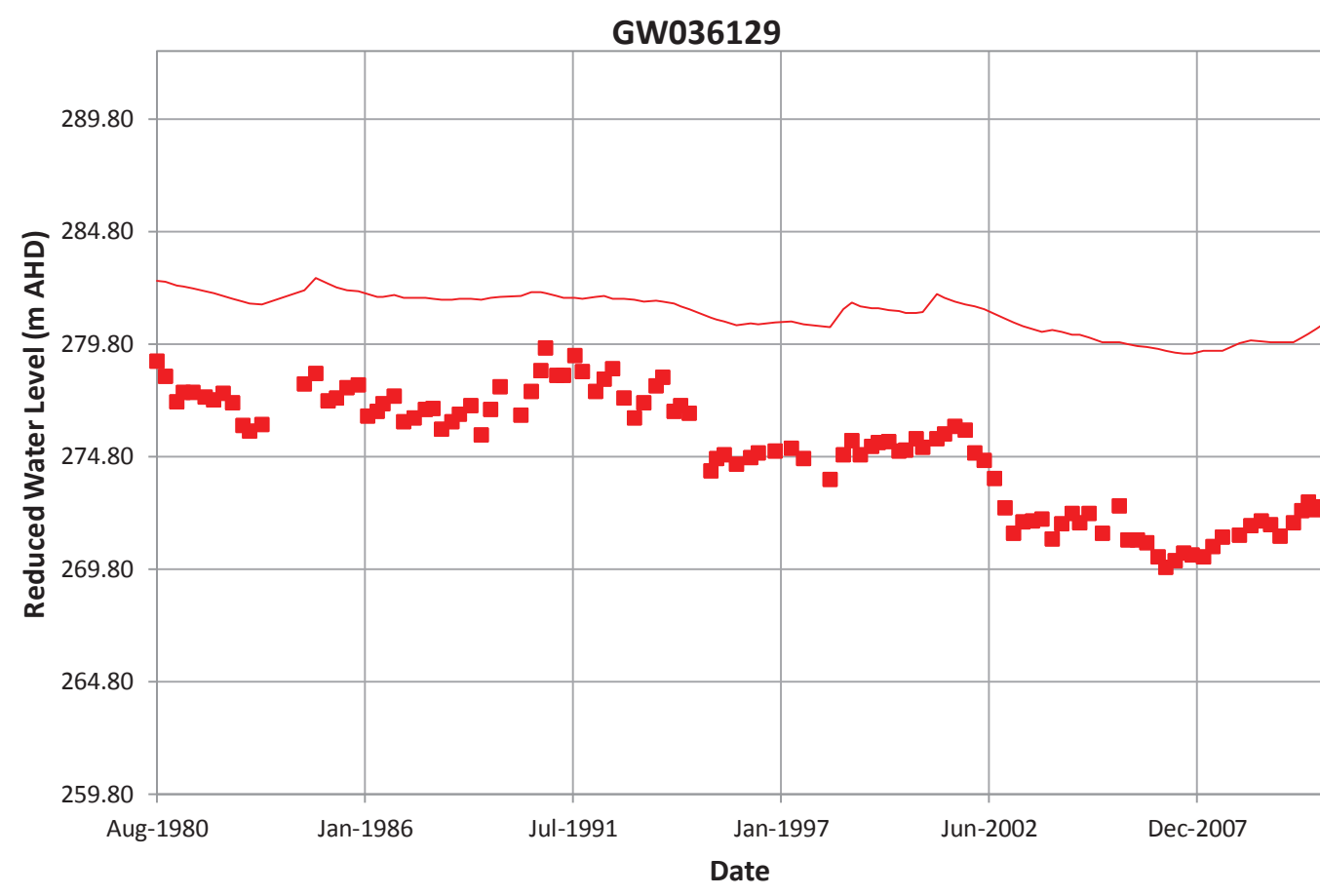


GW036125_1 (Gunnedah Fm) - Computed

GW036125_1 (Gunnedah Fm) - Observed

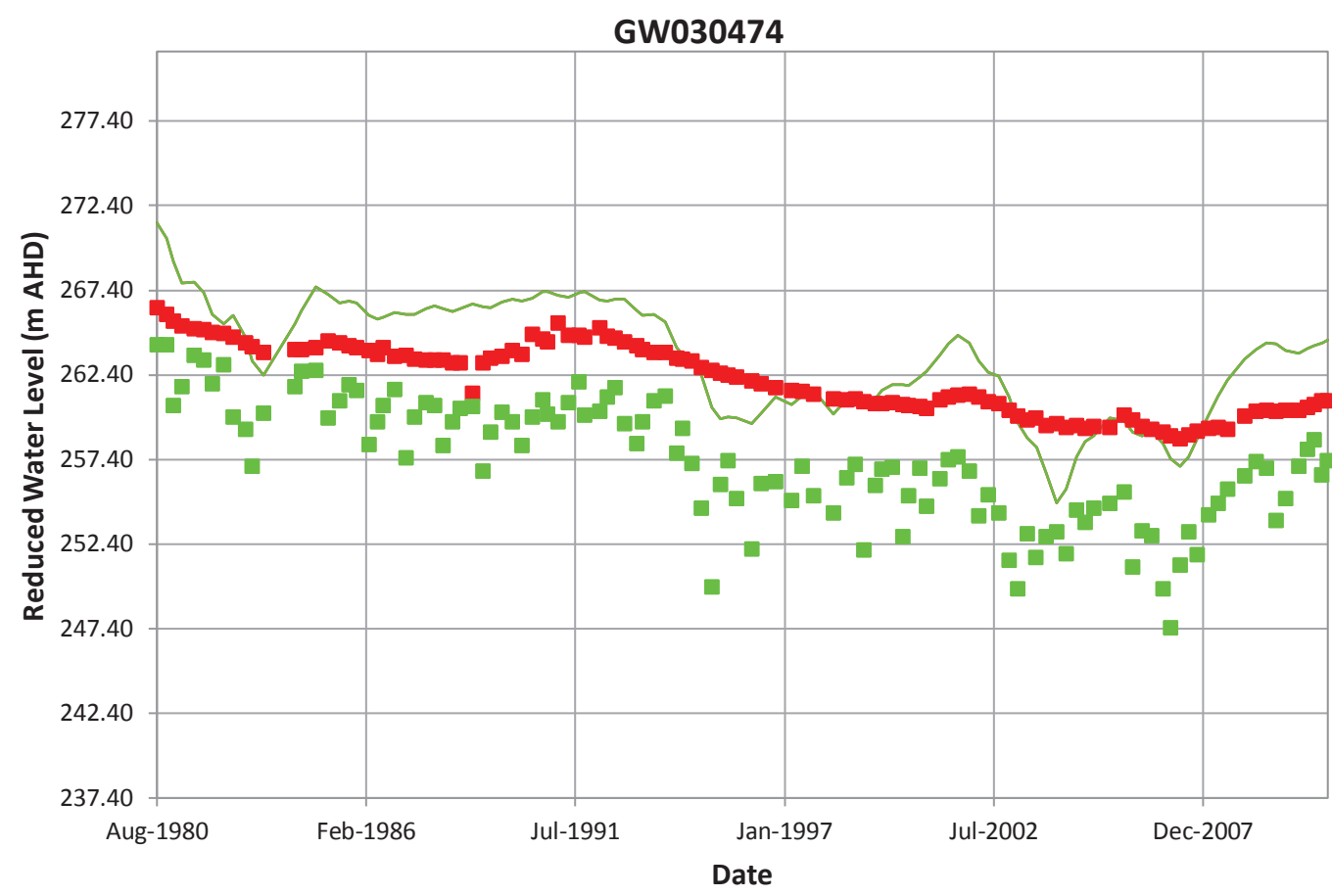
GW036125_2 (Gunnedah Fm) - Computed

GW036125_2 (Gunnedah Fm) - Observed



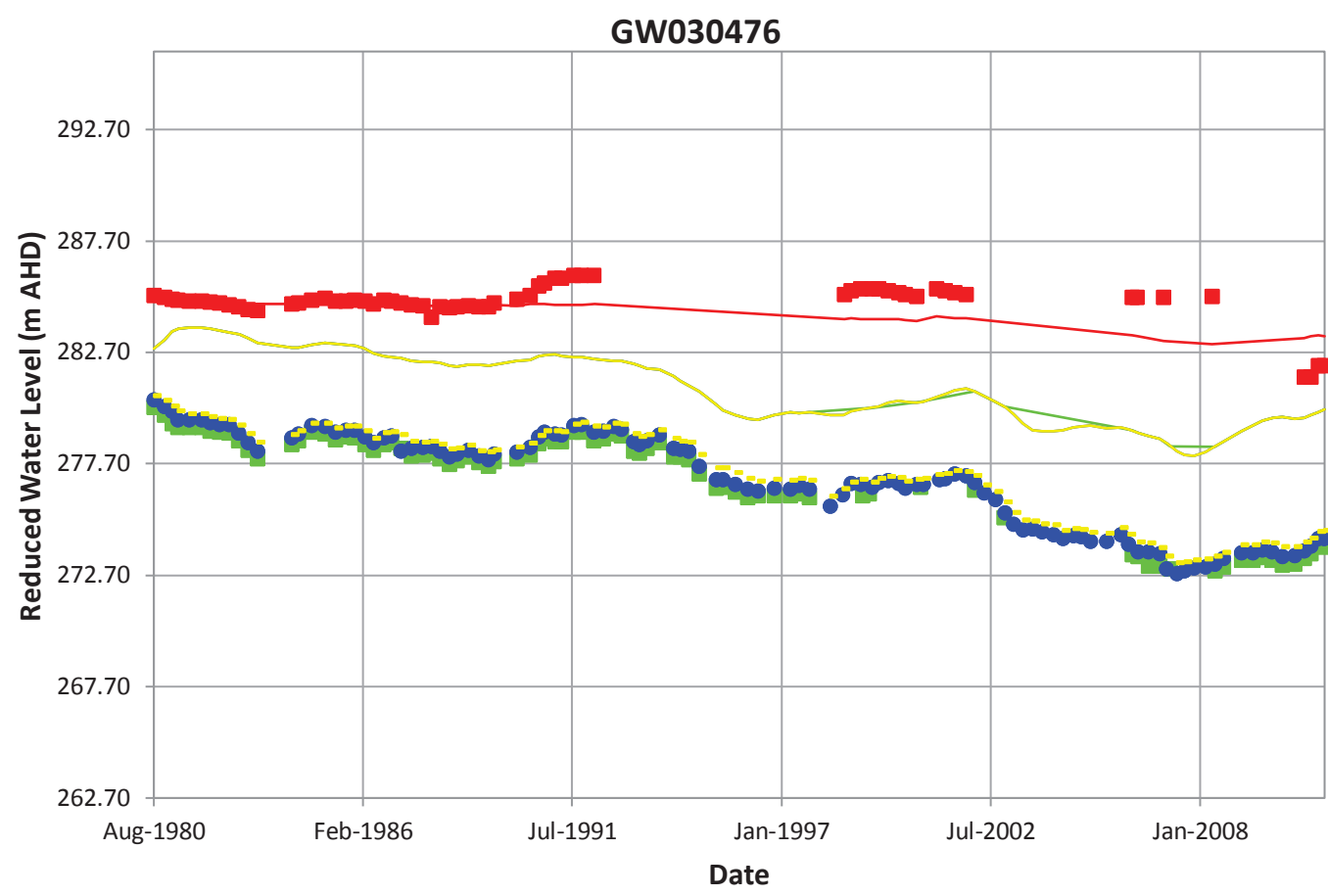
GW036129_1 (Narrabri Fm) - Computed

GW036129_1 (Narrabri Fm) - Observed



GW030474_1 (Gunnedah Fm) - Computed

GW030474_1 (Gunnedah Fm) - Observed



GW030476_1 (Narrabri Fm) - Computed

GW030476_1 (Narrabri Fm) - Observed

GW030476_2 (Gunnedah Fm) - Computed

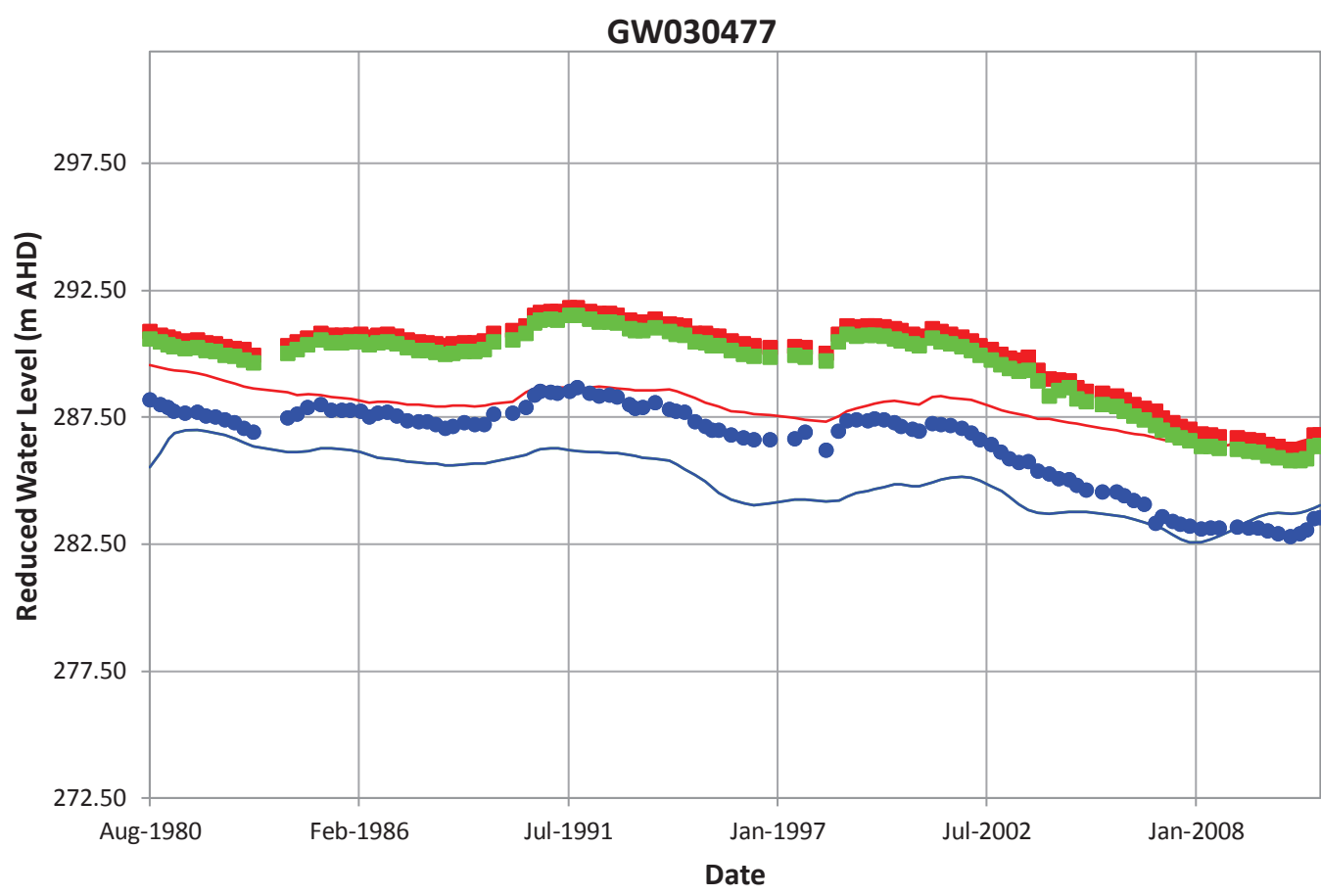
GW030476_2 (Gunnedah Fm) - Observed

GW030476_3 (Gunnedah Fm) - Computed

GW030476_3 (Gunnedah Fm) - Observed

GW030476_4 (Gunnedah Fm) - Computed

GW030476_4 (Gunnedah Fm) - Observed



GW030477_1 (Narrabri Fm) - Computed

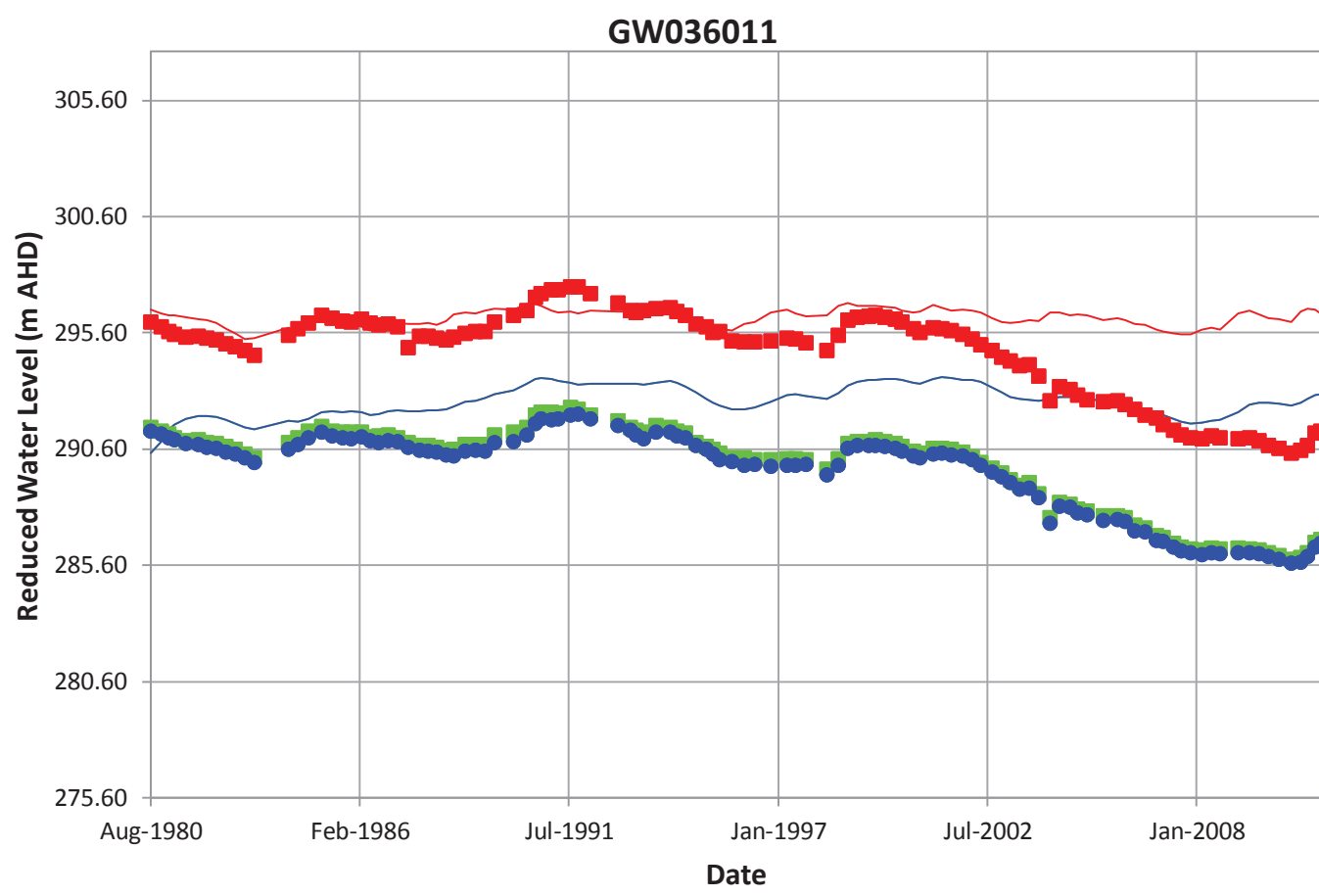
GW030477_1 (Narrabri Fm) - Observed

GW030477_2 (Gunnedah Fm) - Computed

GW030477_2 (Gunnedah Fm) - Observed

GW030477_3 (Gunnedah Fm) - Computed

GW030477_3 (Gunnedah Fm) - Observed



GW036011_1 (Narrabri Fm) - Computed

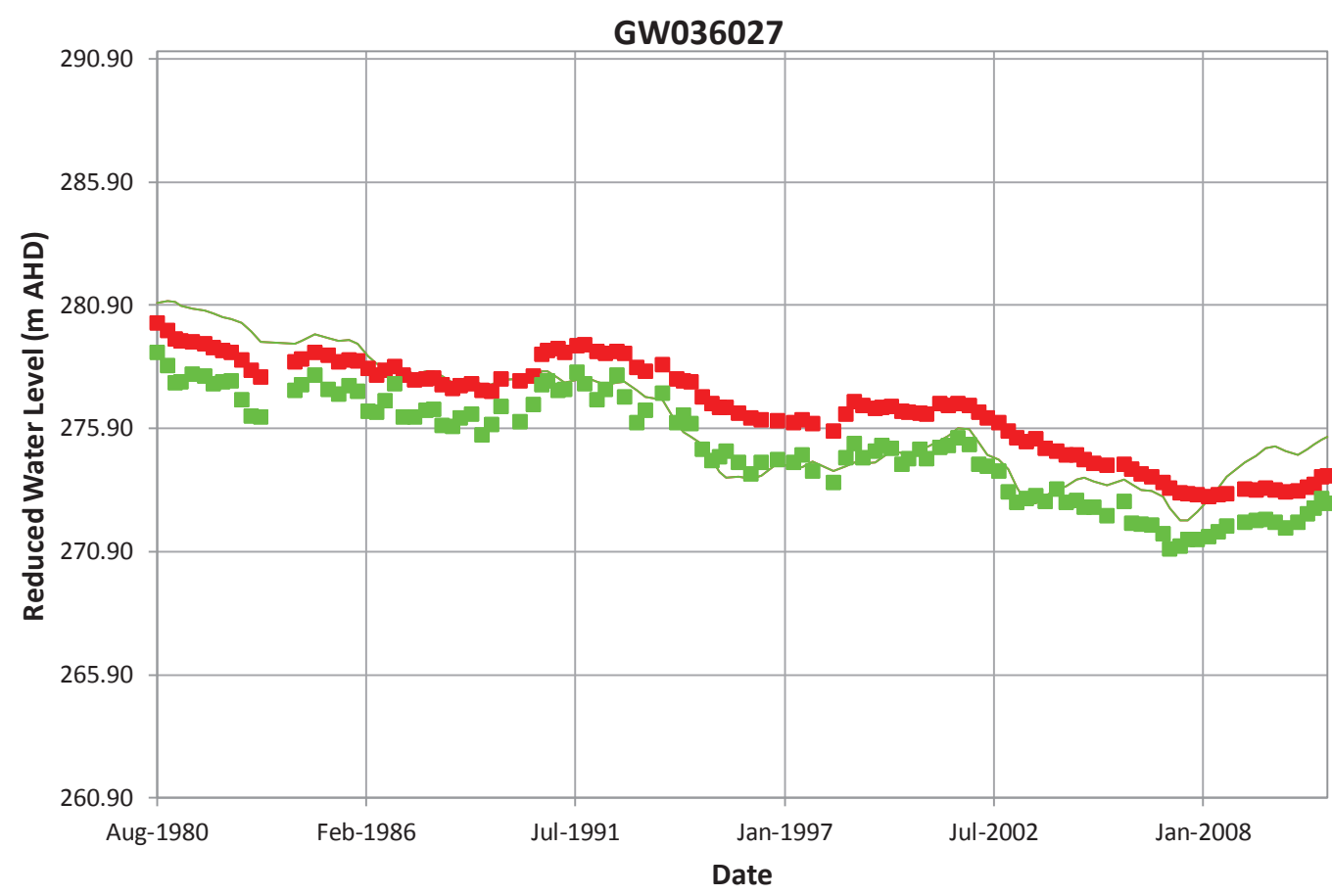
GW036011_1 (Narrabri Fm) - Observed

GW036011_2 (Gunnedah Fm) - Computed

GW036011_2 (Gunnedah Fm) - Observed

GW036011_3 (Gunnedah Fm) - Computed

GW036011_3 (Gunnedah Fm) - Observed

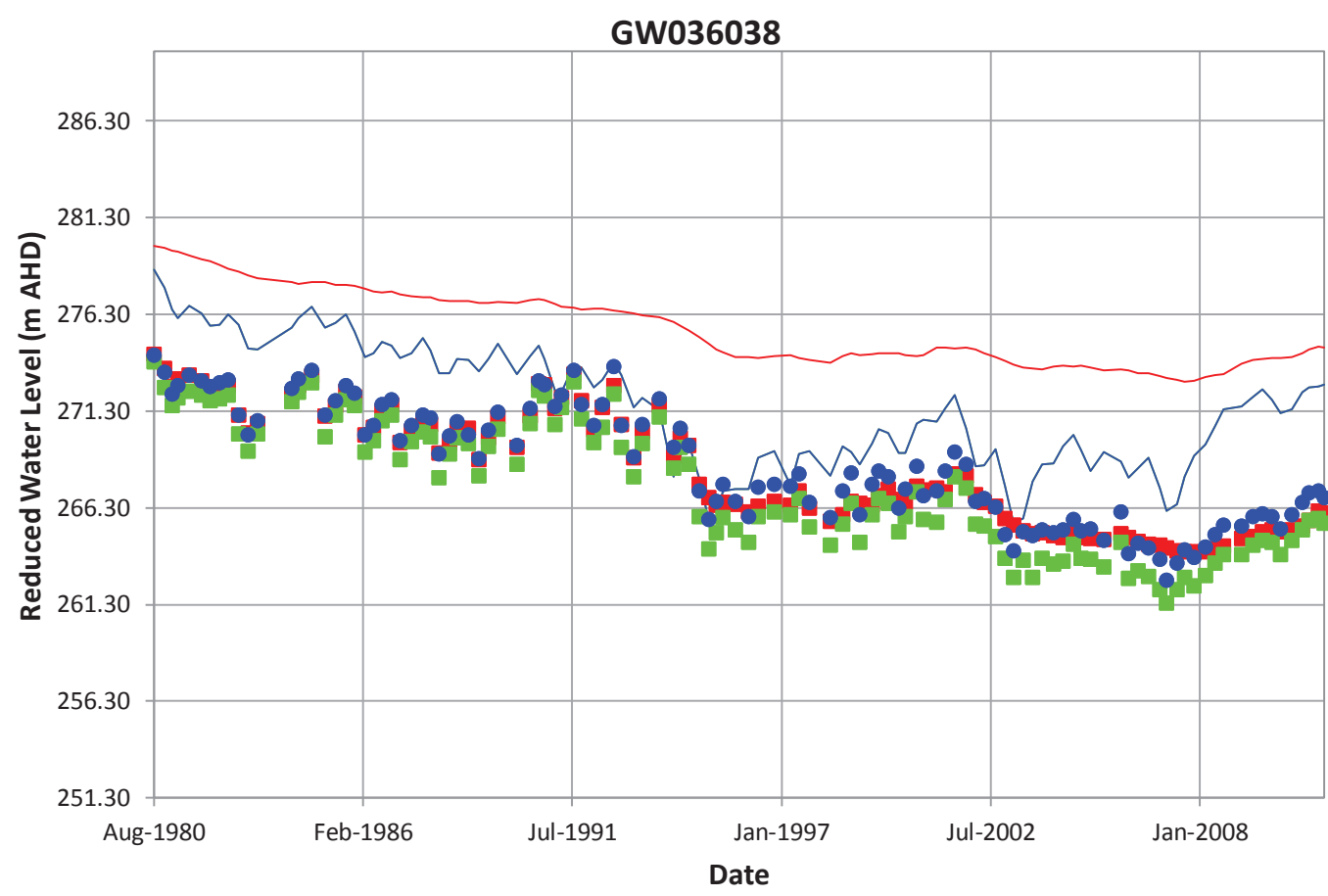


GW036027_1 (Gunnedah Fm) - Computed

GW036027_1 (Gunnedah Fm) - Observed

GW036027_2 (Gunnedah Fm) - Computed

GW036027_2 (Gunnedah Fm) - Observed



GW036038_1 (Narrabri Fm) - Computed

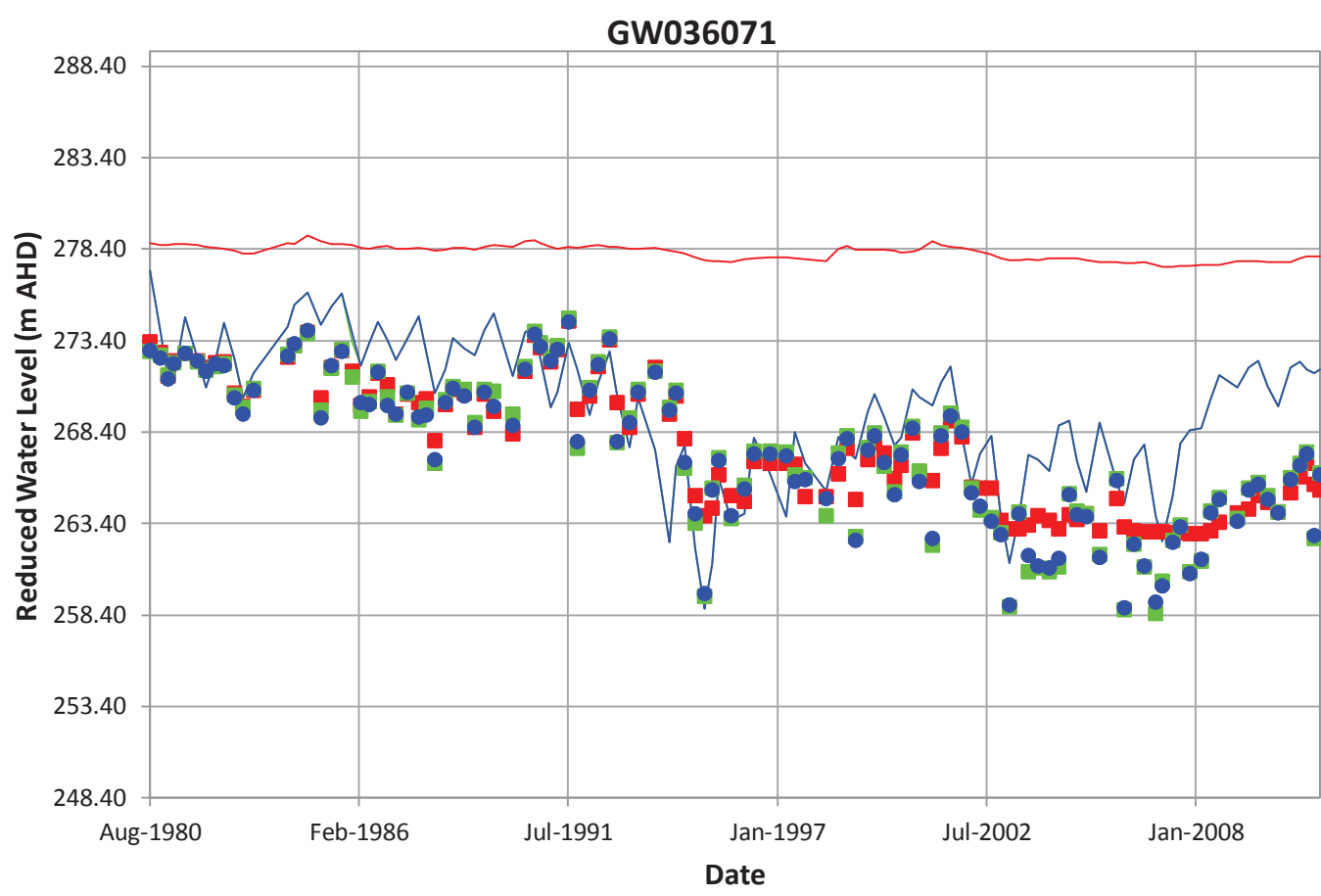
GW036038_1 (Narrabri Fm) - Observed

GW036038_2 (Gunnedah Fm) - Computed

GW036038_2 (Gunnedah Fm) - Observed

GW036038_3 (Gunnedah Fm) - Computed

GW036038_3 (Gunnedah Fm) - Observed



GW036071_1 (Narrabri Fm) - Computed

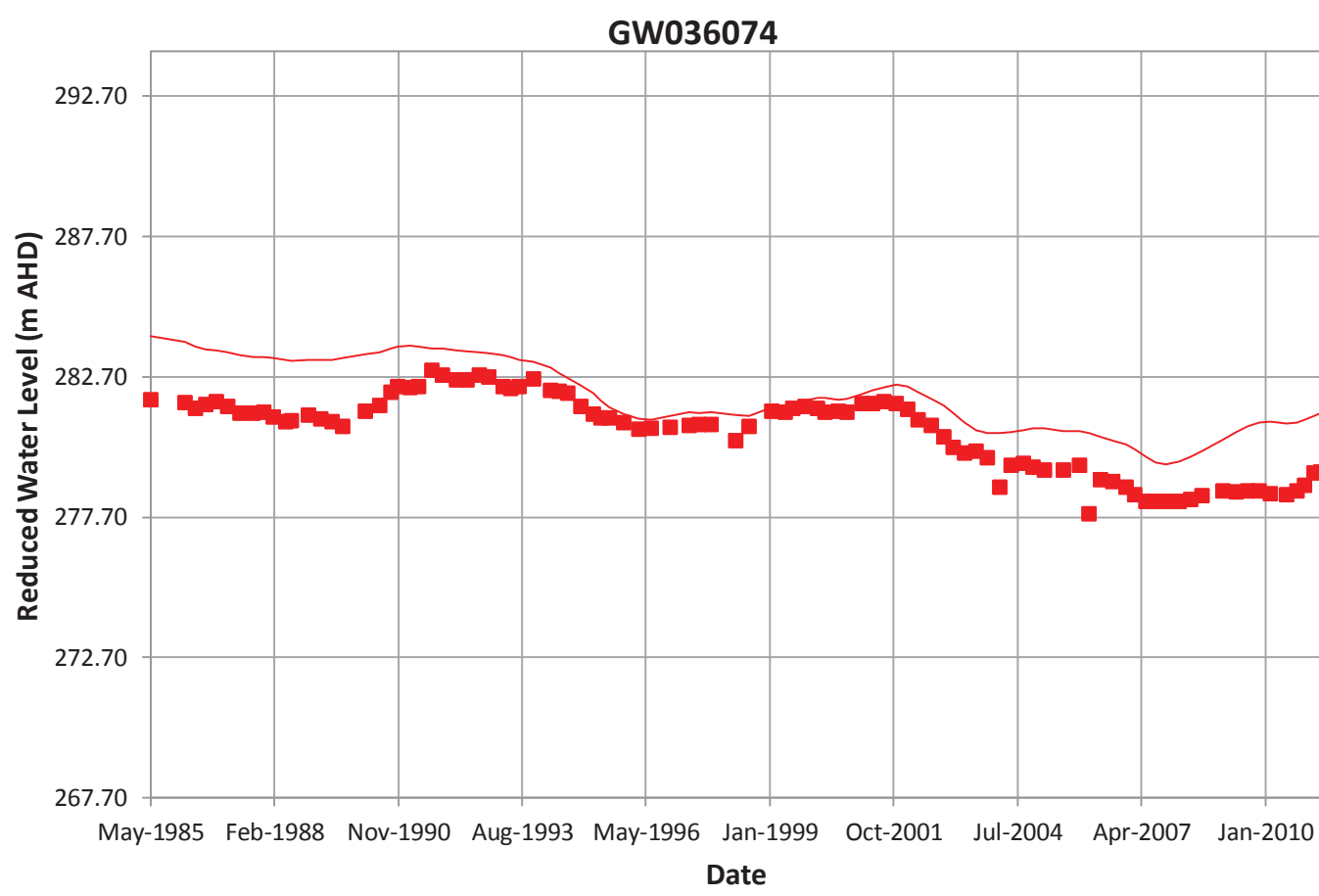
GW036071_1 (Narrabri Fm) - Observed

GW036071_2 (Gunnedah Fm) - Computed

GW036071_2 (Gunnedah Fm) - Observed

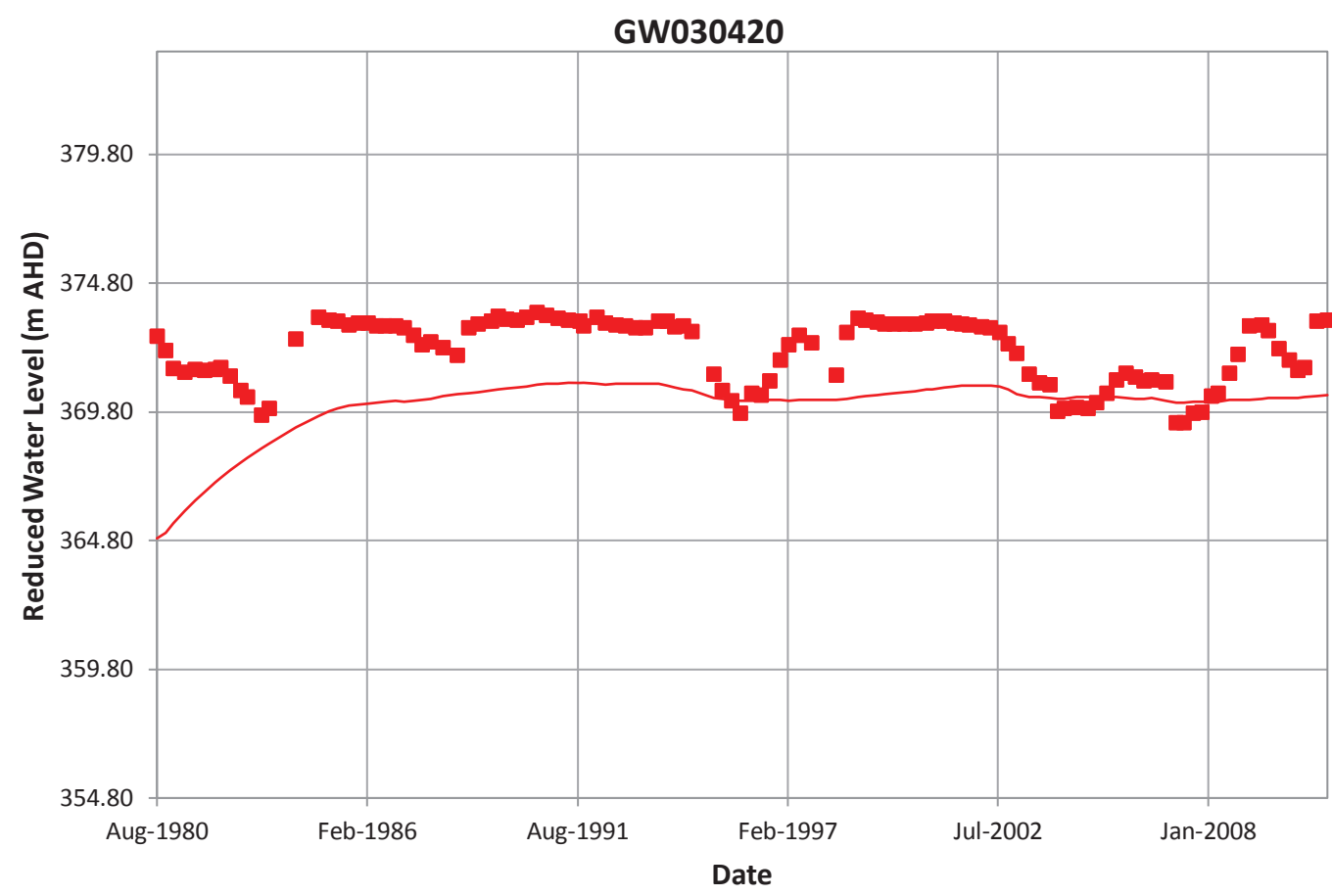
GW036071_3 (Gunnedah Fm) - Computed

GW036071_3 (Gunnedah Fm) - Observed



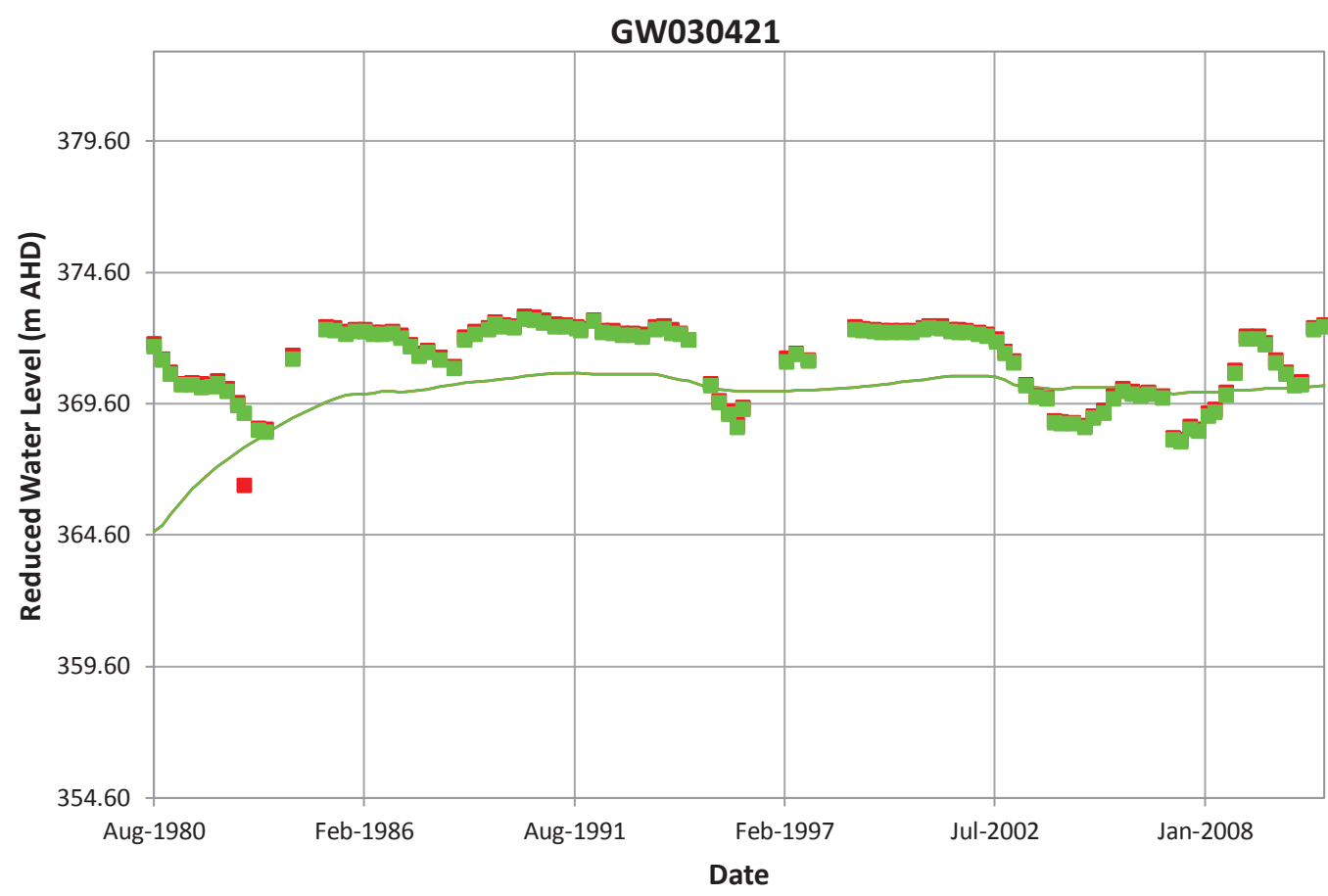
GW036074_1 (Gunnedah Fm) - Computed

GW036074_1 (Gunnedah Fm) - Observed



GW030420_1 (Gunnedah Fm) - Computed

GW030420_1 (Gunnedah Fm) - Observed

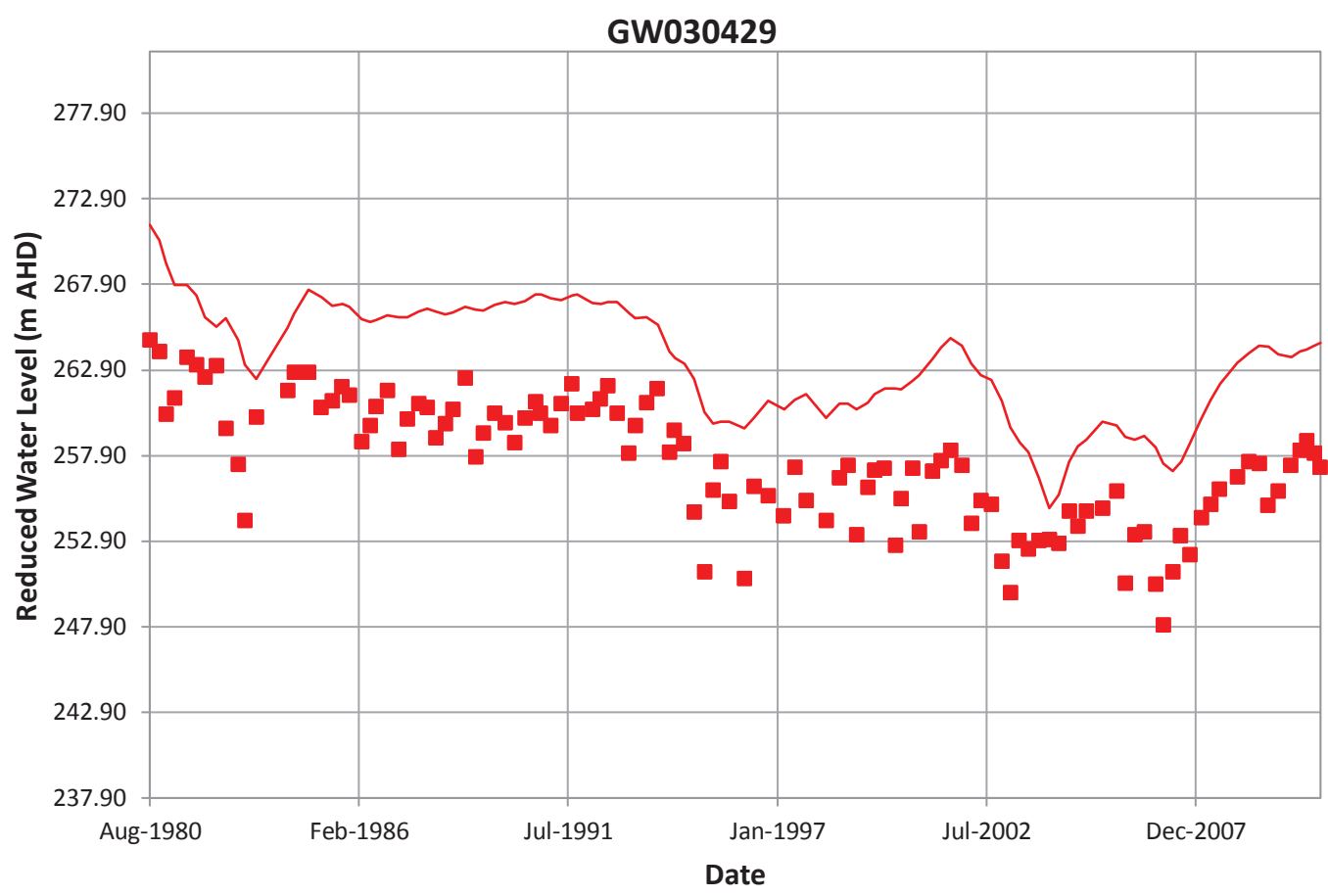


GW030421_1 (Gunnedah Fm) - Computed

GW030421_1 (Gunnedah Fm) - Observed

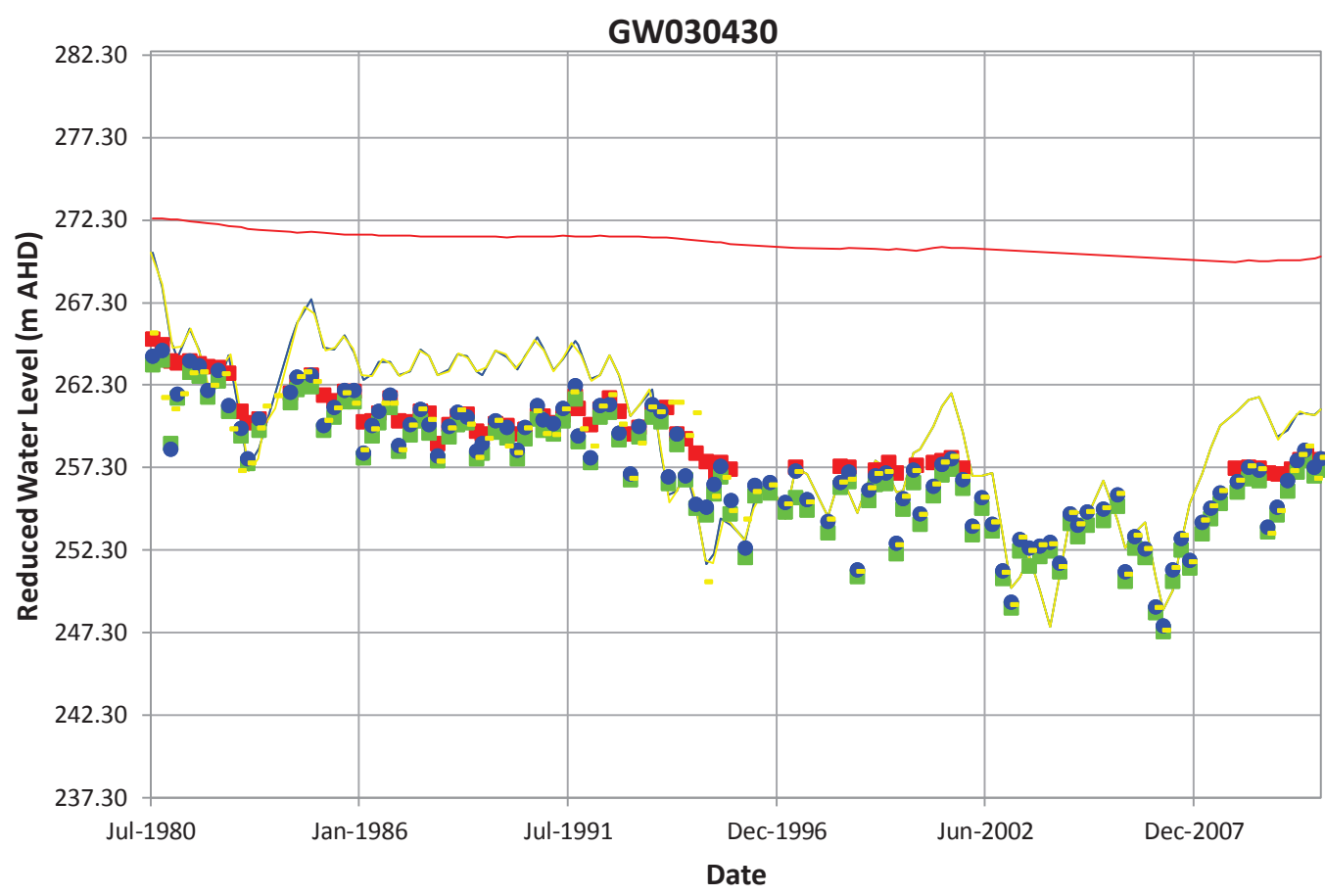
GW030421_2 (Gunnedah Fm) - Computed

GW030421_2 (Gunnedah Fm) - Observed



GW030429_1 (Gunnedah Fm) - Computed

GW030429_1 (Gunnedah Fm) - Observed



GW030430_1 (Narrabri Fm) - Computed

GW030430_1 (Narrabri Fm) - Observed

GW030430_2 (Gunnedah Fm) - Computed

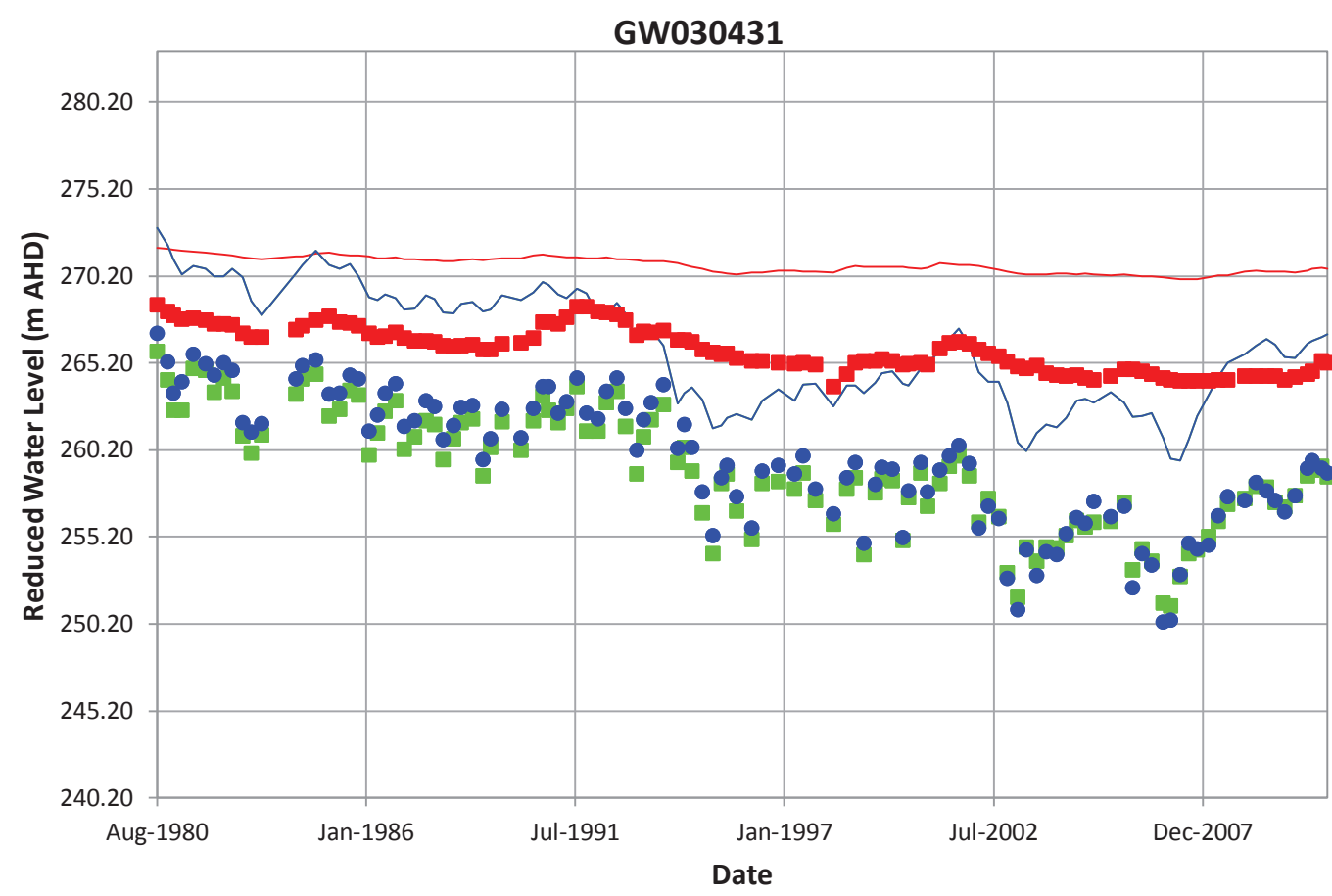
GW030430_2 (Gunnedah Fm) - Observed

GW030430_3 (Gunnedah Fm) - Computed

GW030430_3 (Gunnedah Fm) - Observed

GW030430_4 (Gunnedah Fm) - Computed

GW030430_4 (Gunnedah Fm) - Observed



GW030431_1 (Narrabri Fm) - Computed

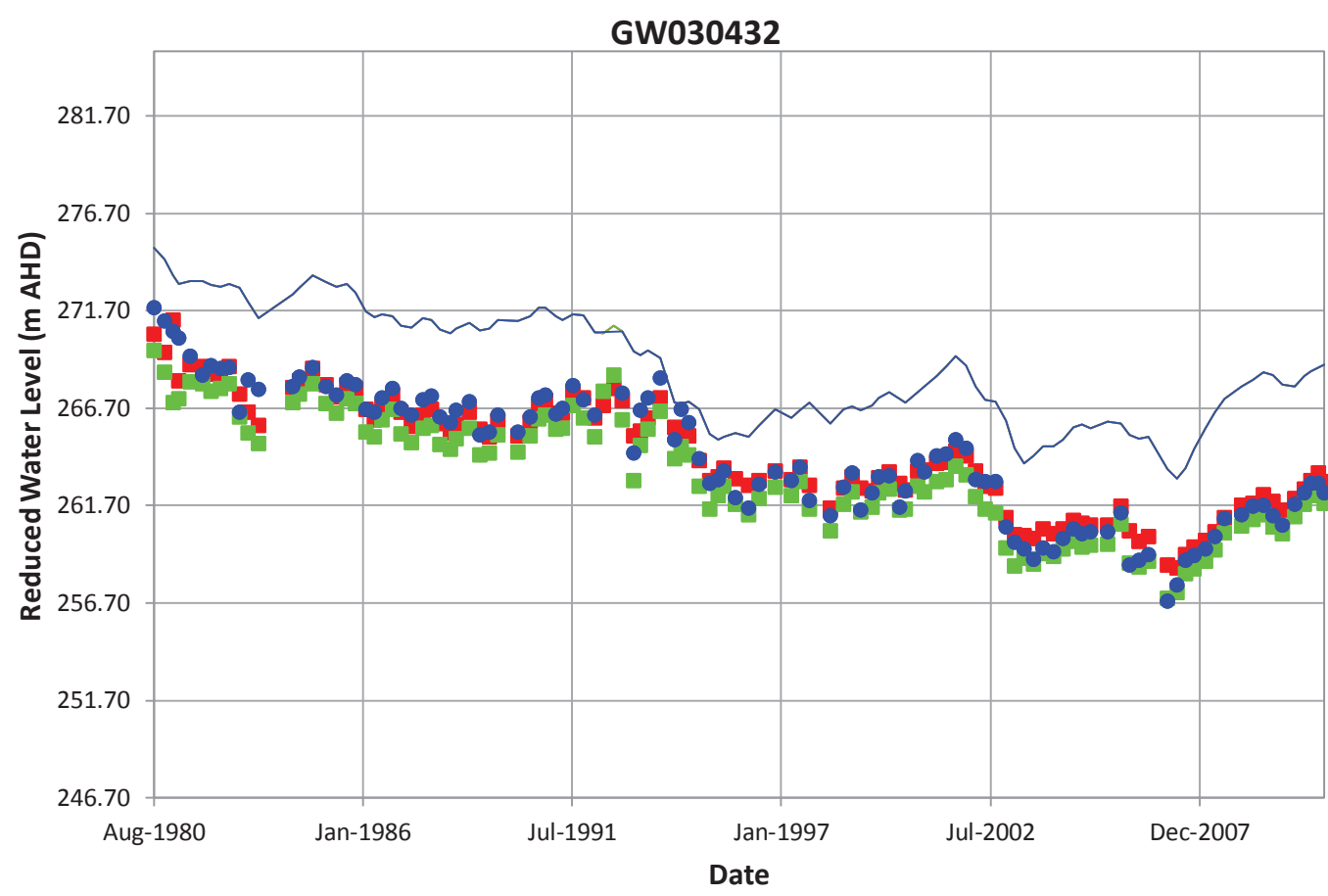
GW030431_1 (Narrabri Fm) - Observed

GW030431_2 (Gunnedah Fm) - Computed

GW030431_2 (Gunnedah Fm) - Observed

GW030431_3 (Gunnedah Fm) - Computed

GW030431_3 (Gunnedah Fm) - Observed



GW030432_1 (Gunnedah Fm) - Computed

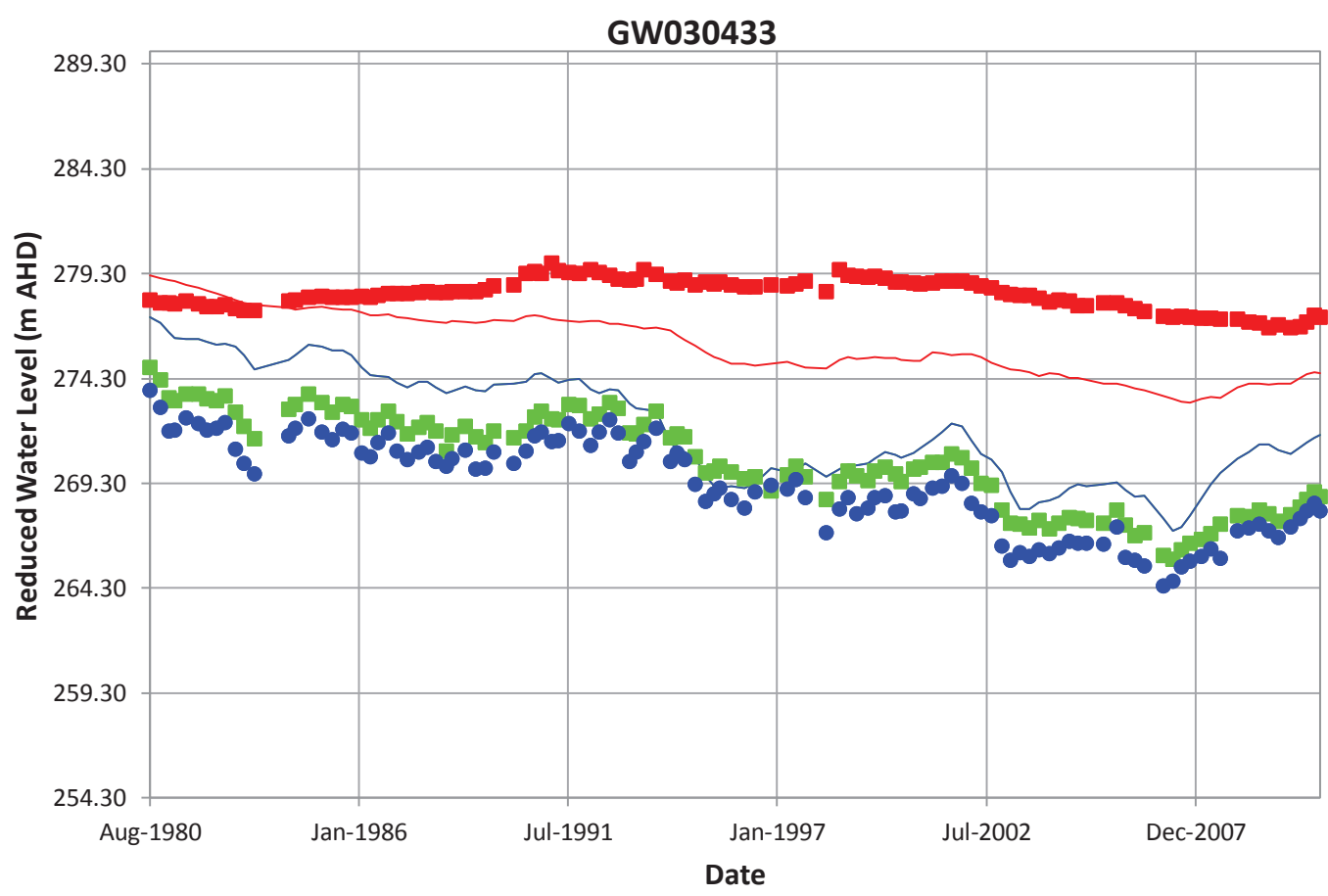
GW030432_1 (Gunnedah Fm) - Observed

GW030432_2 (Gunnedah Fm) - Computed

GW030432_2 (Gunnedah Fm) - Observed

GW030432_3 (Gunnedah Fm) - Computed

GW030432_3 (Gunnedah Fm) - Observed



GW030433_1 (Narrabri Fm) - Computed

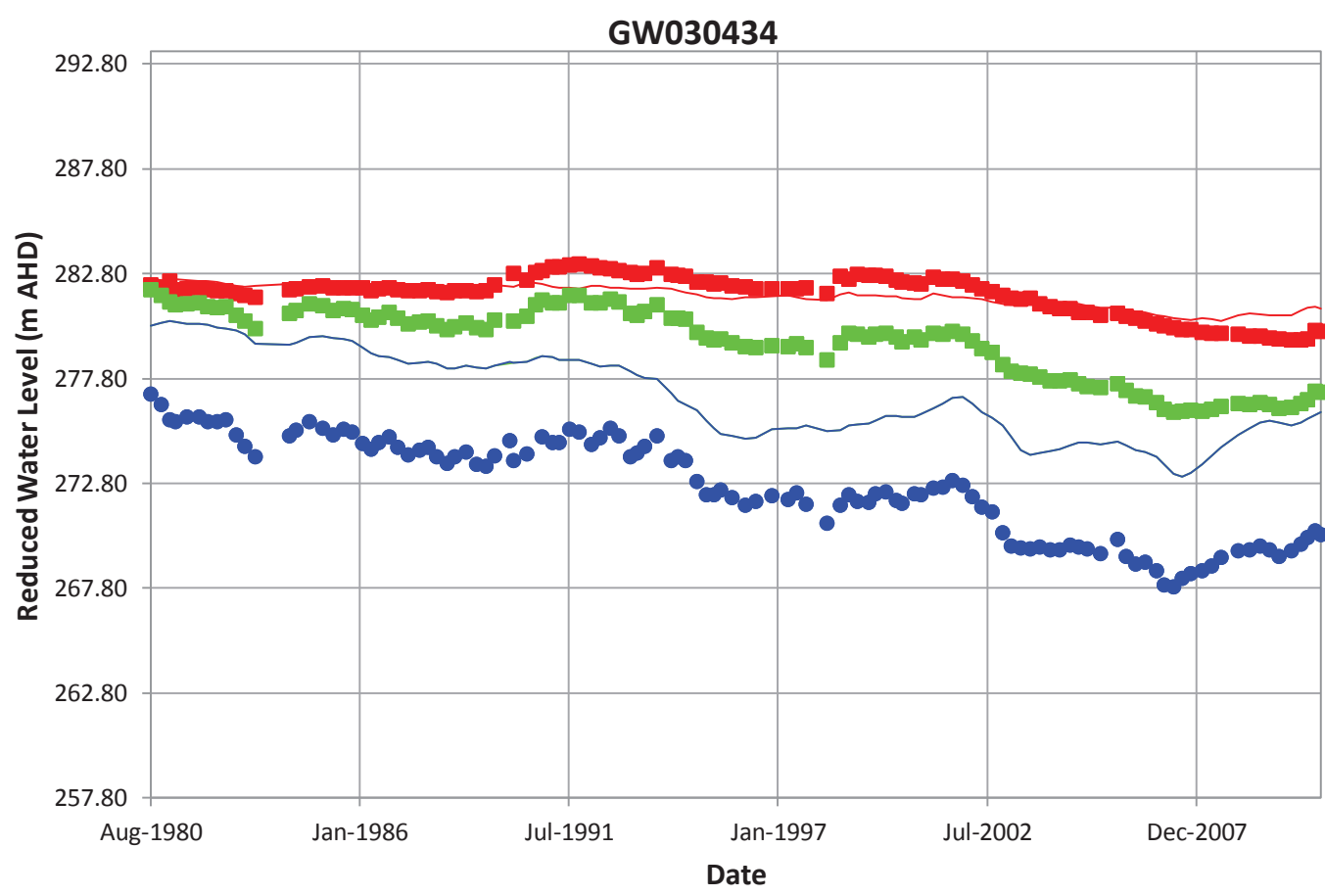
GW030433_1 (Narrabri Fm) - Observed

GW030433_2 (Gunnedah Fm) - Computed

GW030433_2 (Gunnedah Fm) - Observed

GW030433_3 (Gunnedah Fm) - Computed

GW030433_3 (Gunnedah Fm) - Observed



GW030434_1 (Narrabri Fm) - Computed

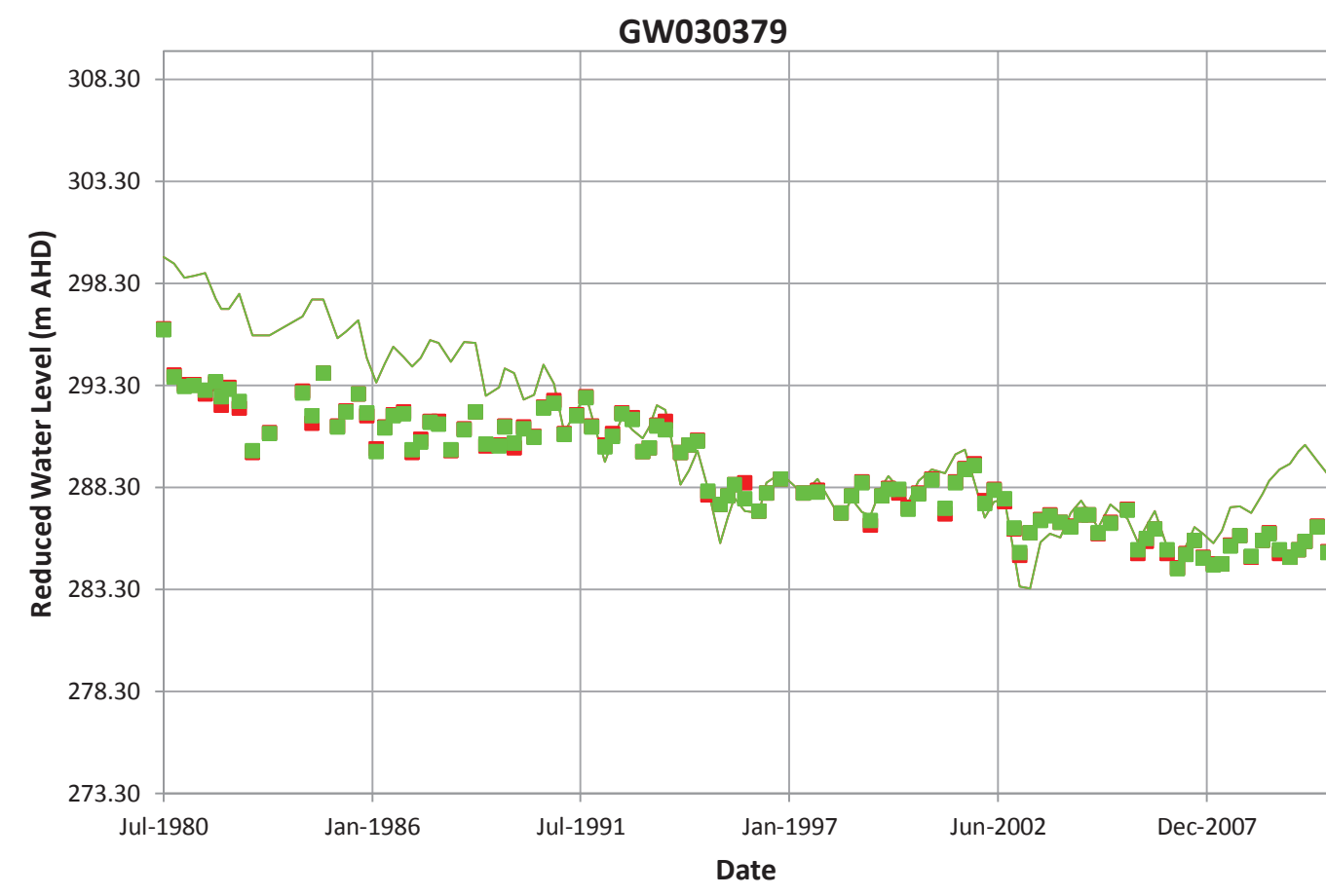
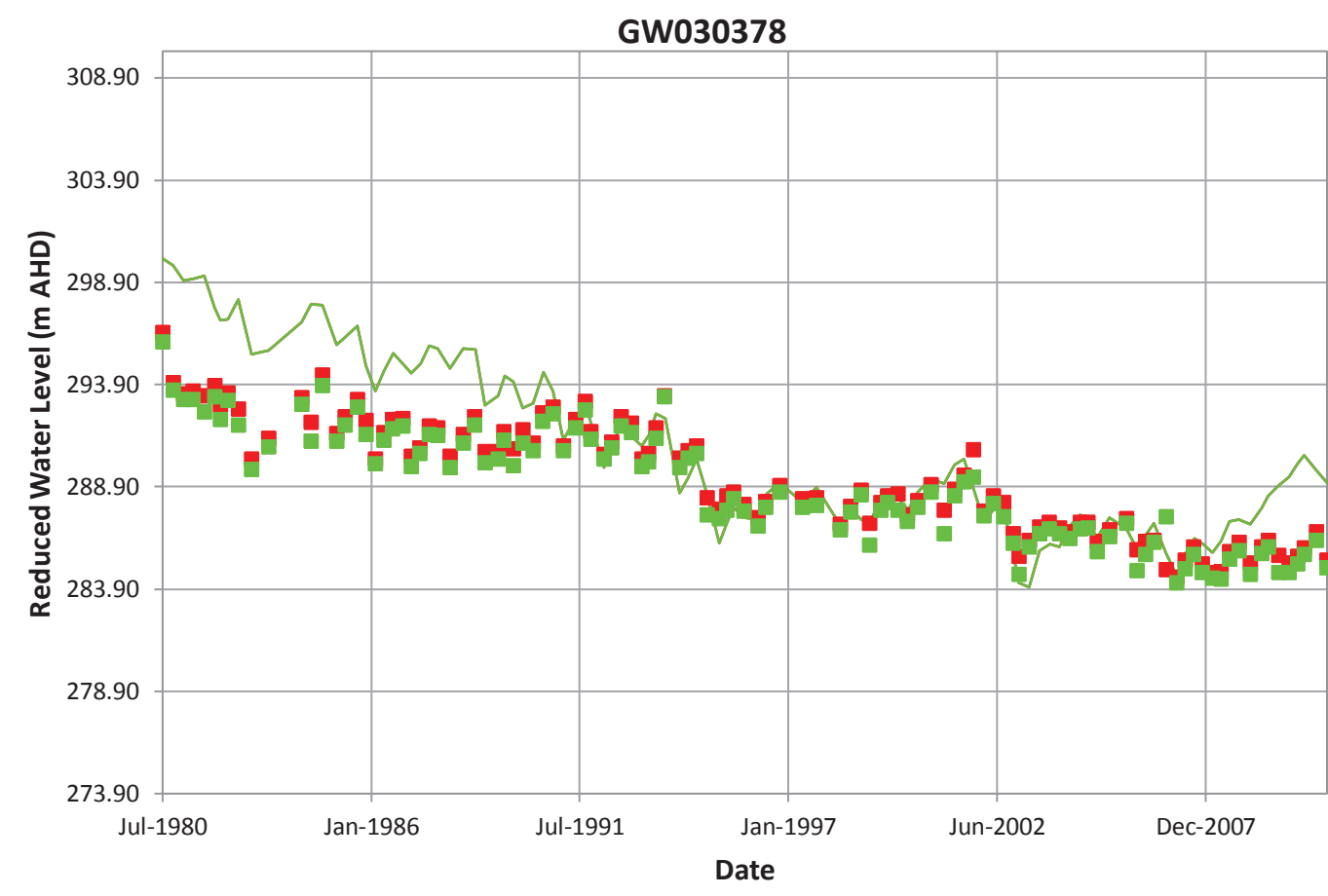
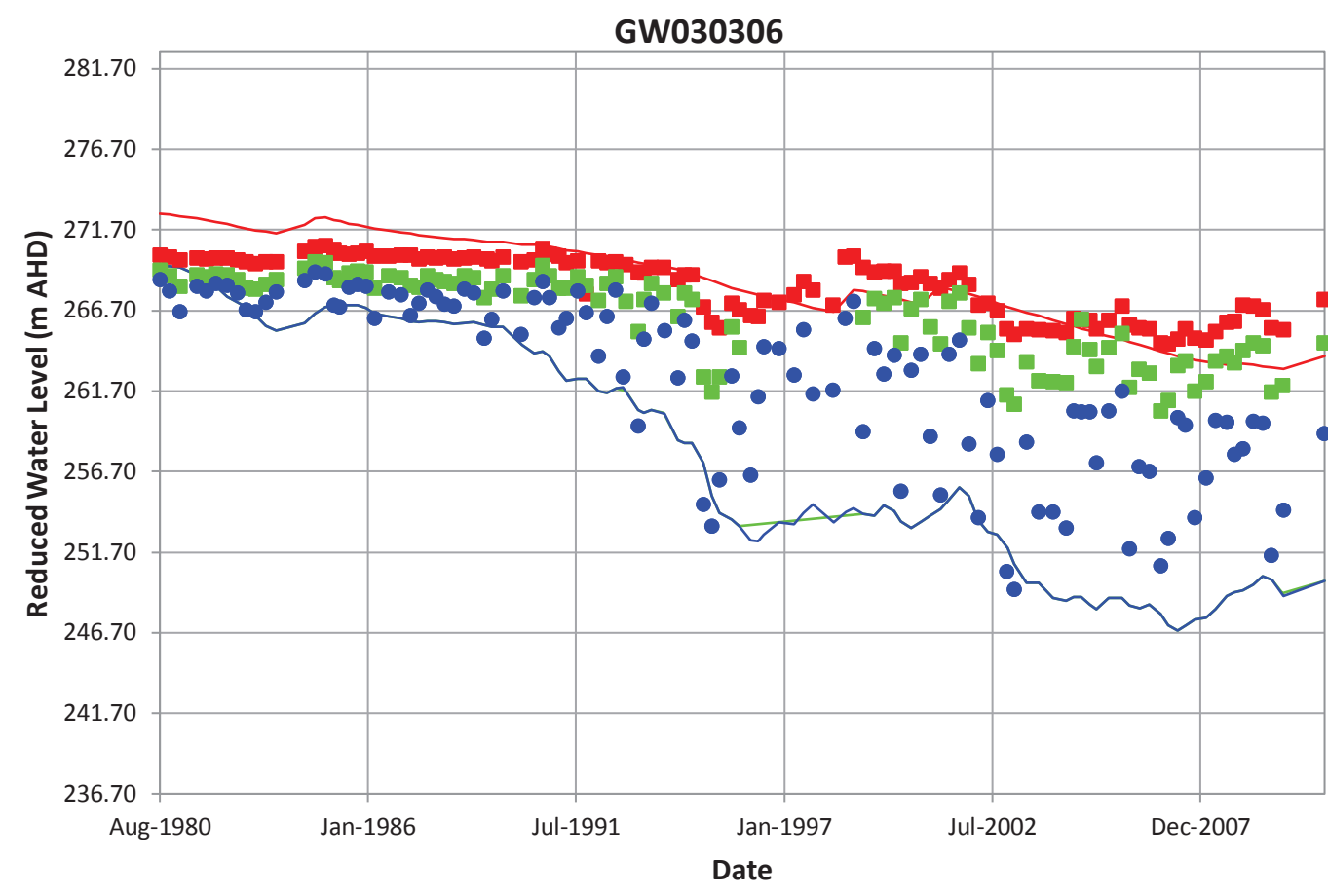
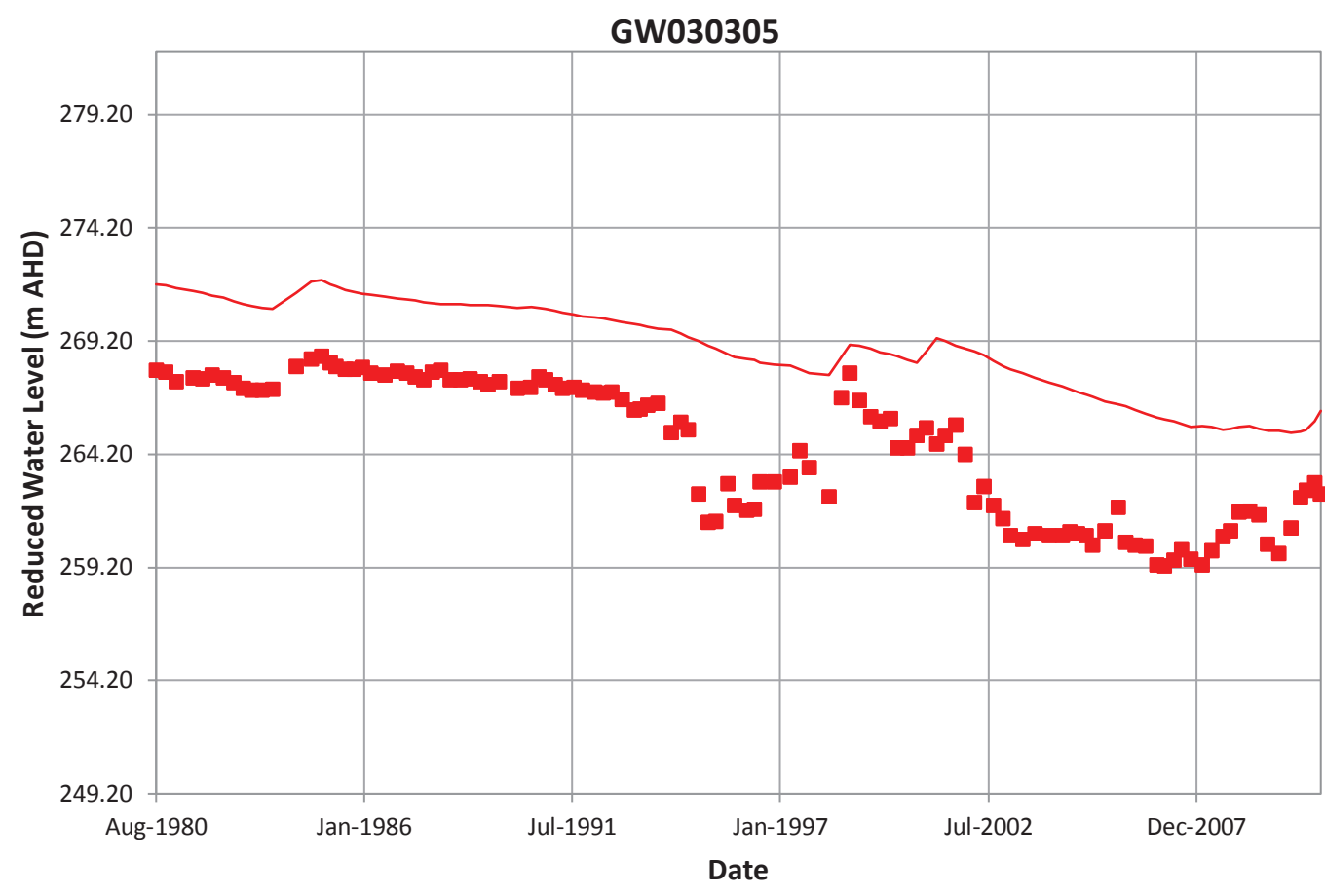
GW030434_1 (Narrabri Fm) - Observed

GW030434_2 (Gunnedah Fm) - Computed

GW030434_2 (Gunnedah Fm) - Observed

GW030434_3 (Gunnedah Fm) - Computed

GW030434_3 (Gunnedah Fm) - Observed



GW030305_1 (Narrabri Fm) - Computed

GW030305_1 (Narrabri Fm) - Observed

GW030306_2 (Gunnedah Fm) - Computed

GW030306_2 (Gunnedah Fm) - Observed

GW030306_3 (Gunnedah Fm) - Computed

GW030306_3 (Gunnedah Fm) - Observed

GW030378_1 (Gunnedah Fm) - Computed

GW030378_1 (Gunnedah Fm) - Observed

GW030378_2 (Gunnedah Fm) - Computed

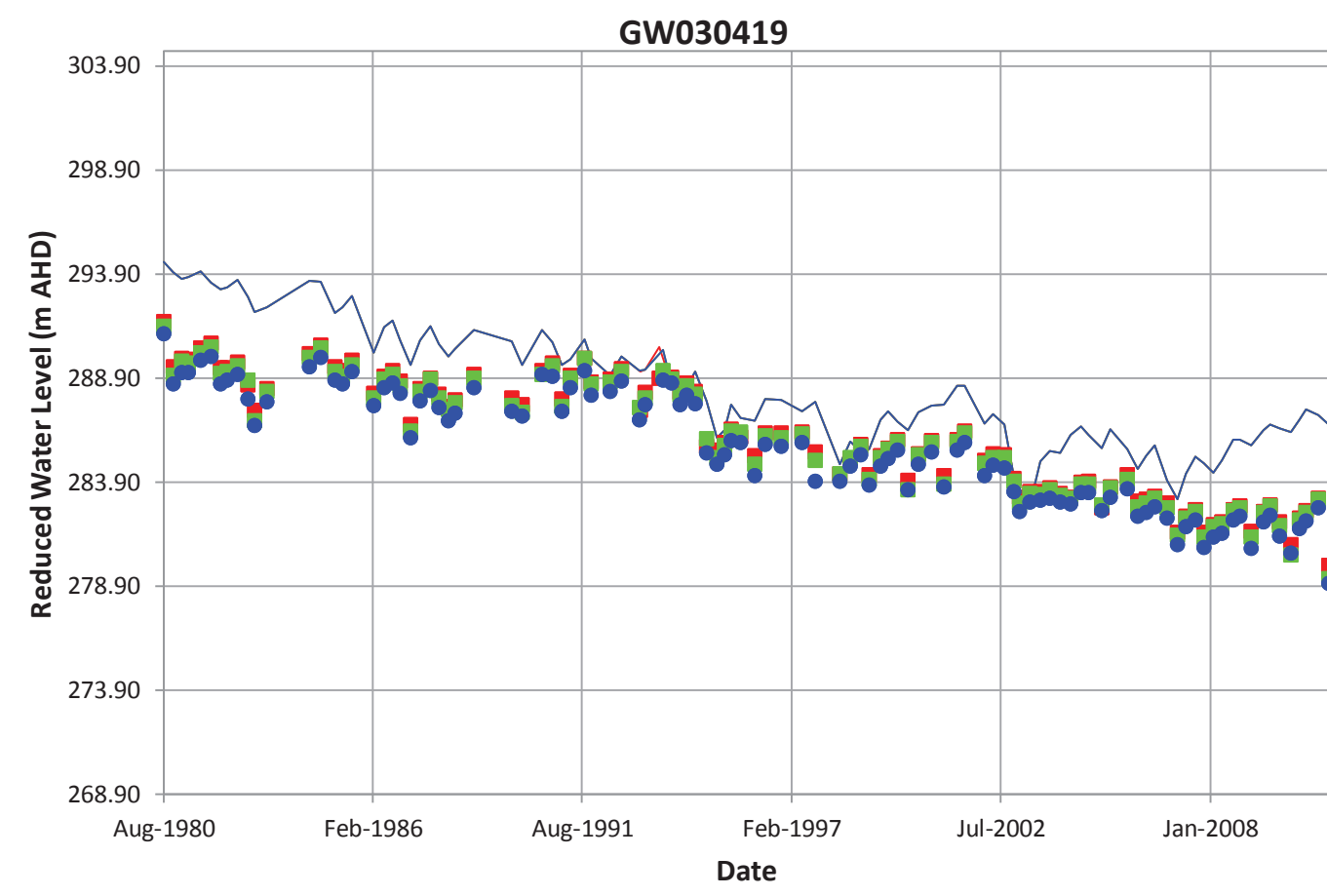
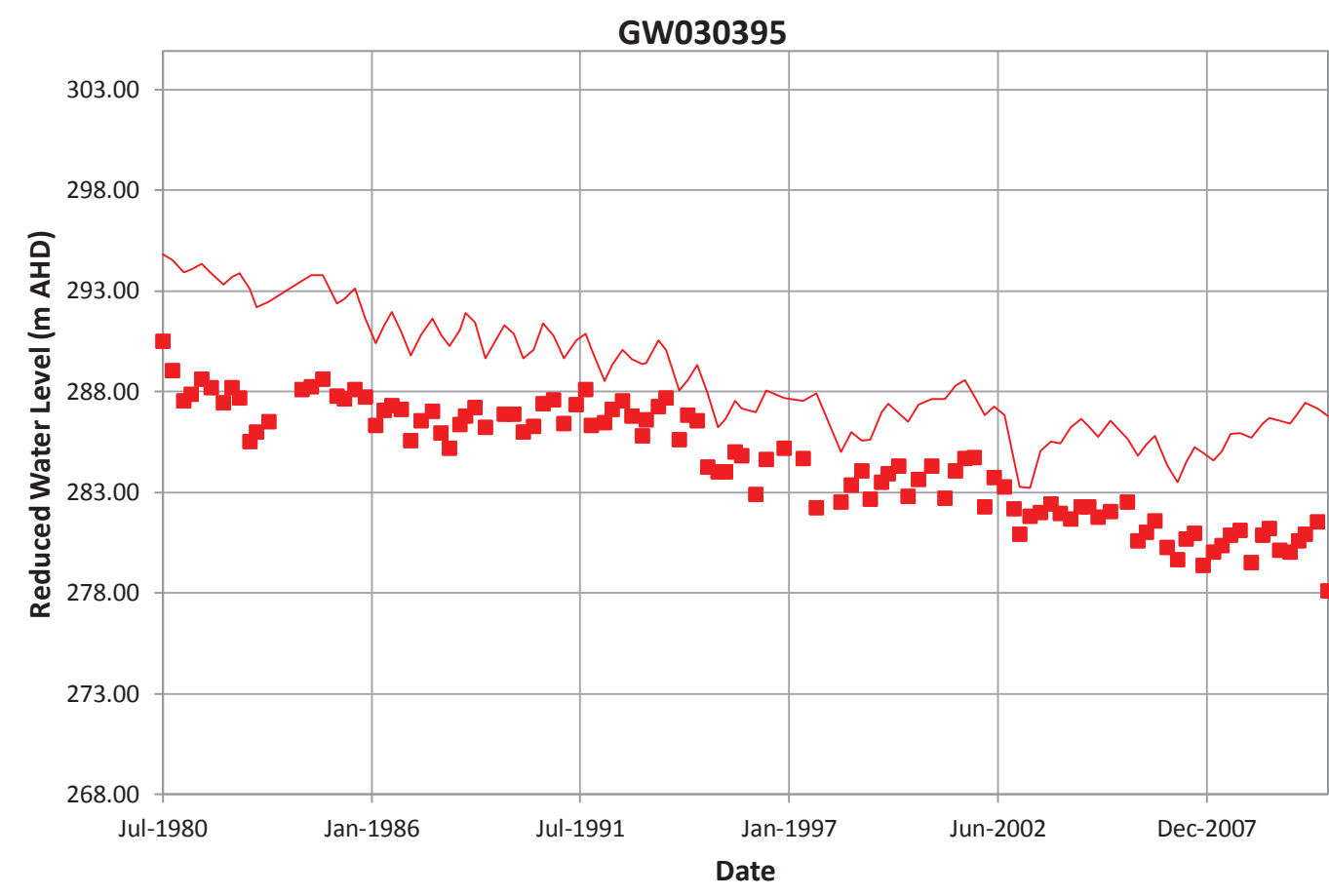
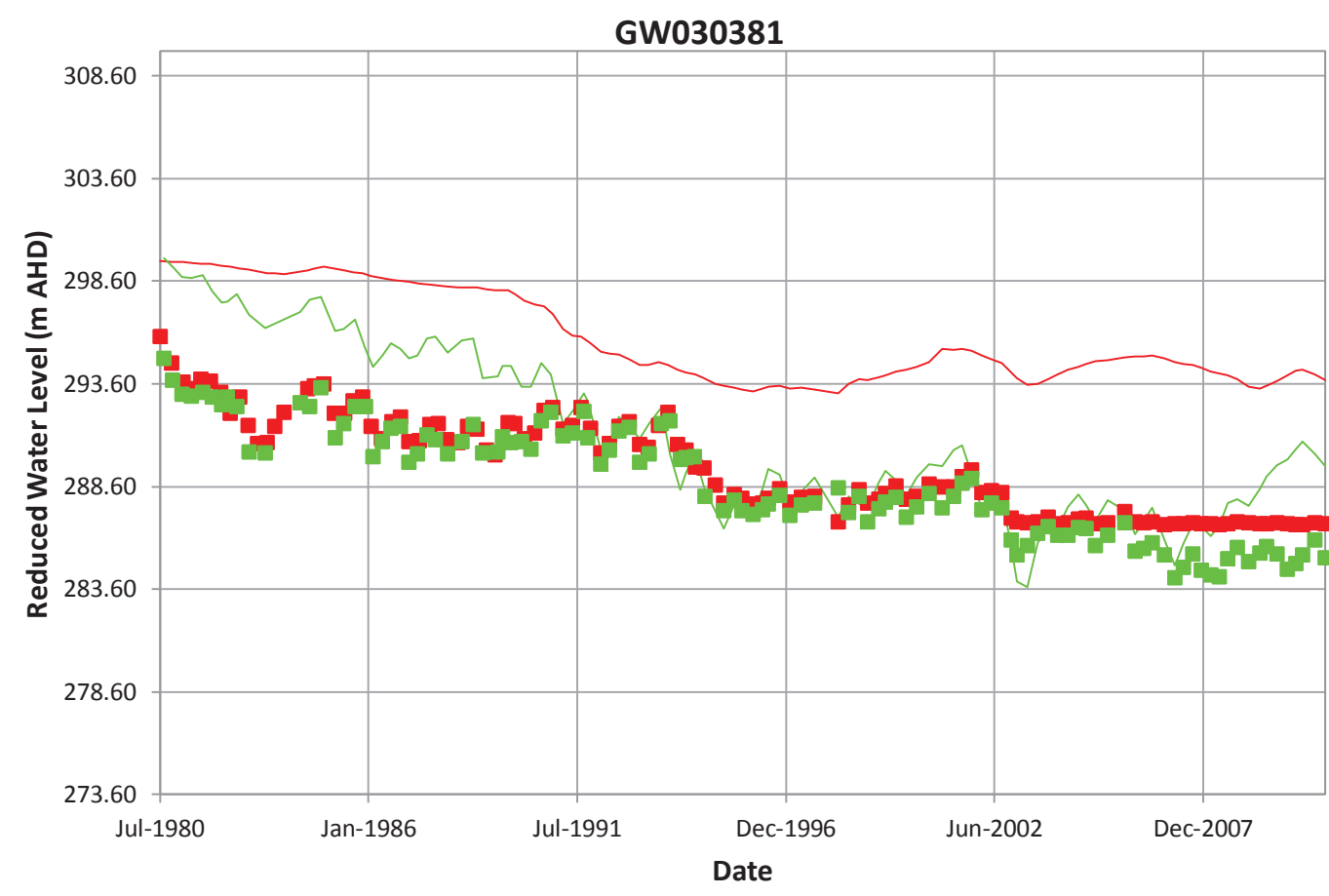
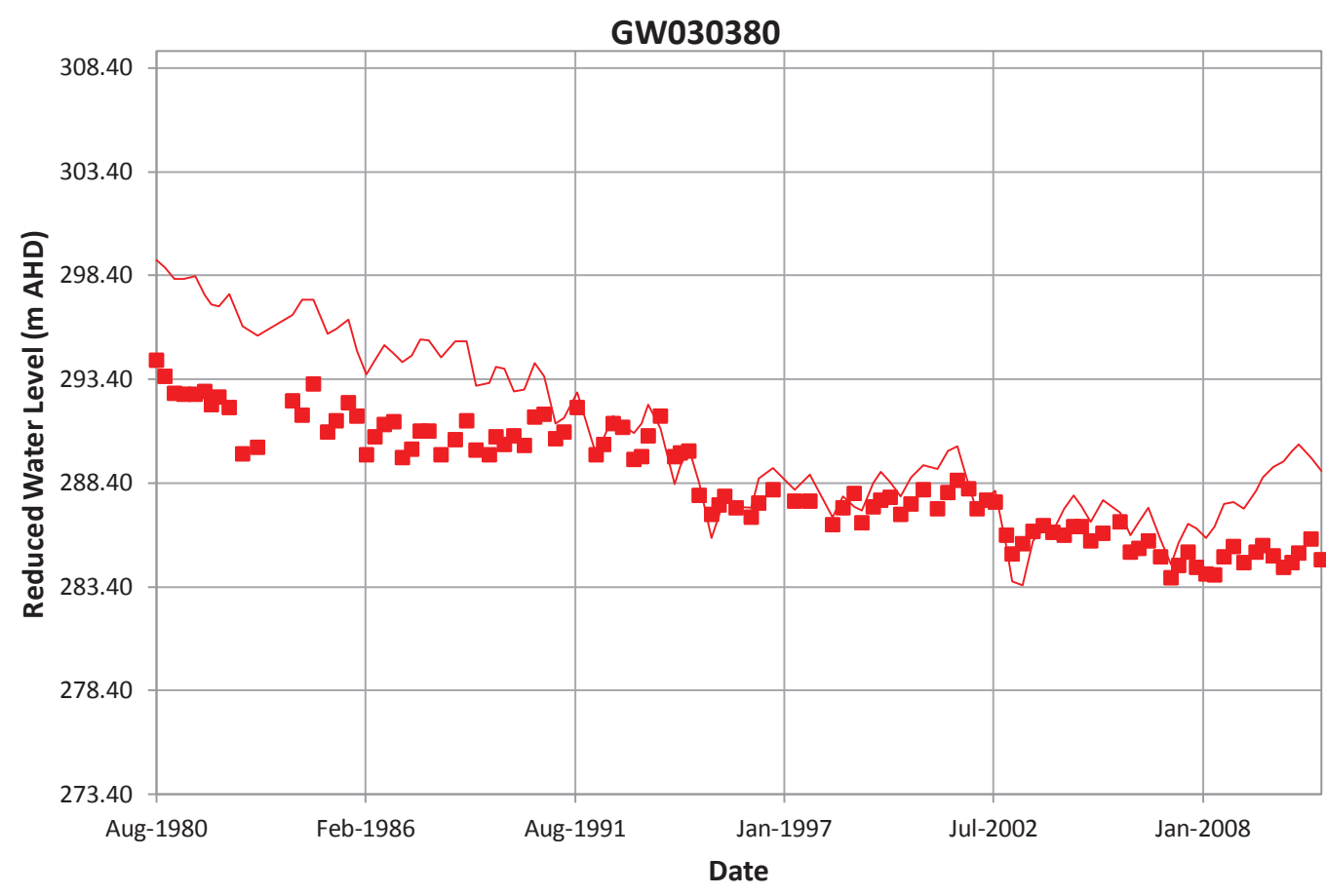
GW030378_2 (Gunnedah Fm) - Observed

GW030379_1 (Gunnedah Fm) - Computed

GW030379_1 (Gunnedah Fm) - Observed

GW030379_2 (Gunnedah Fm) - Computed

GW030379_2 (Gunnedah Fm) - Observed



GW030380_1 (Gunnedah Fm) - Computed

GW030380_1 (Gunnedah Fm) - Observed

GW030381_2 (Gunnedah Fm) - Computed

GW030381_2 (Gunnedah Fm) - Observed

GW030395_1e (Gunnedah Fm) - Computed

GW030395_1e (Gunnedah Fm) - Observed

GW030419_1 (Gunnedah Fm) - Computed

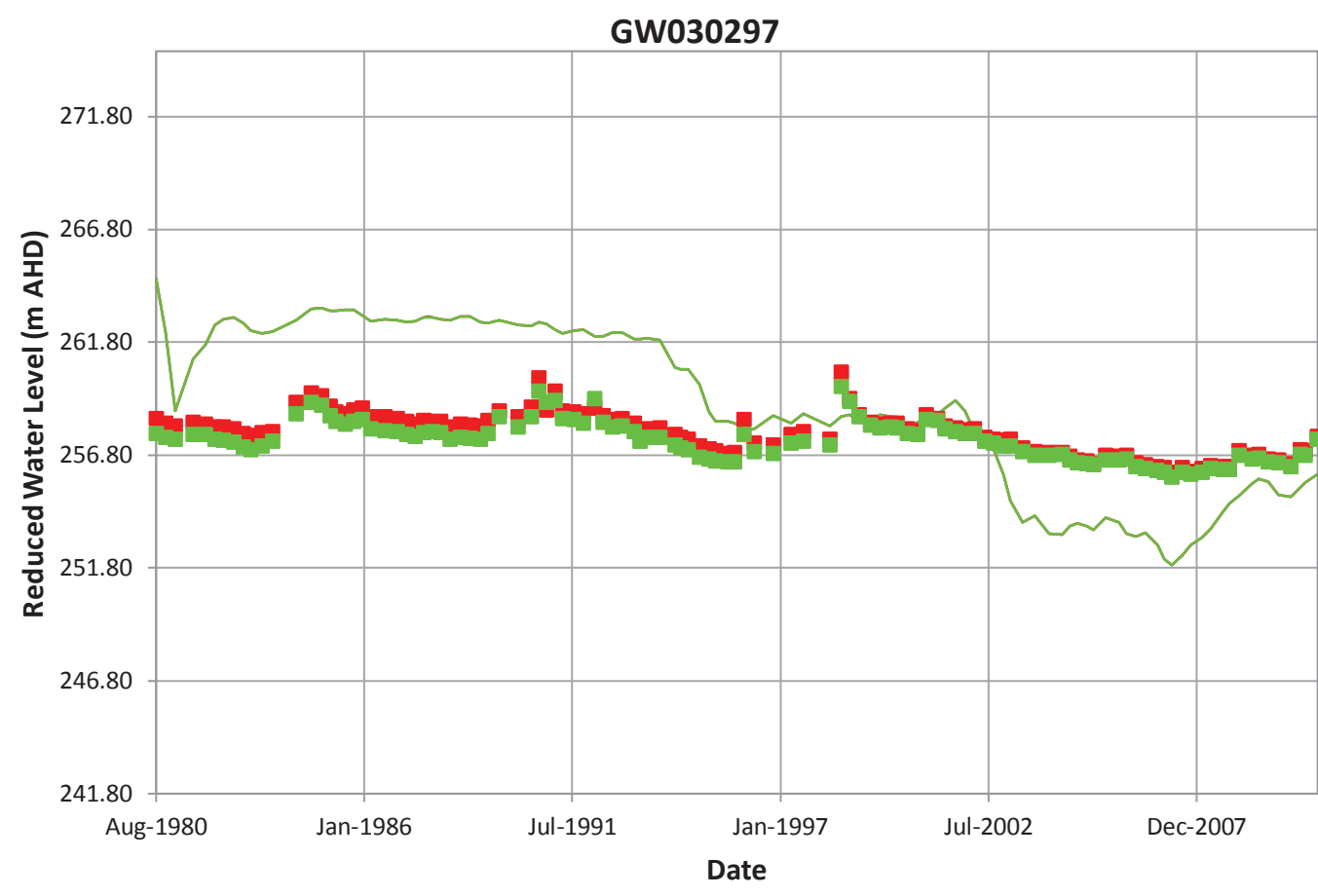
GW030419_1 (Gunnedah Fm) - Observed

GW030419_2 (Gunnedah Fm) - Computed

GW030419_2 (Gunnedah Fm) - Observed

GW030419_3 (Gunnedah Fm) - Computed

GW030419_3 (Gunnedah Fm) - Observed

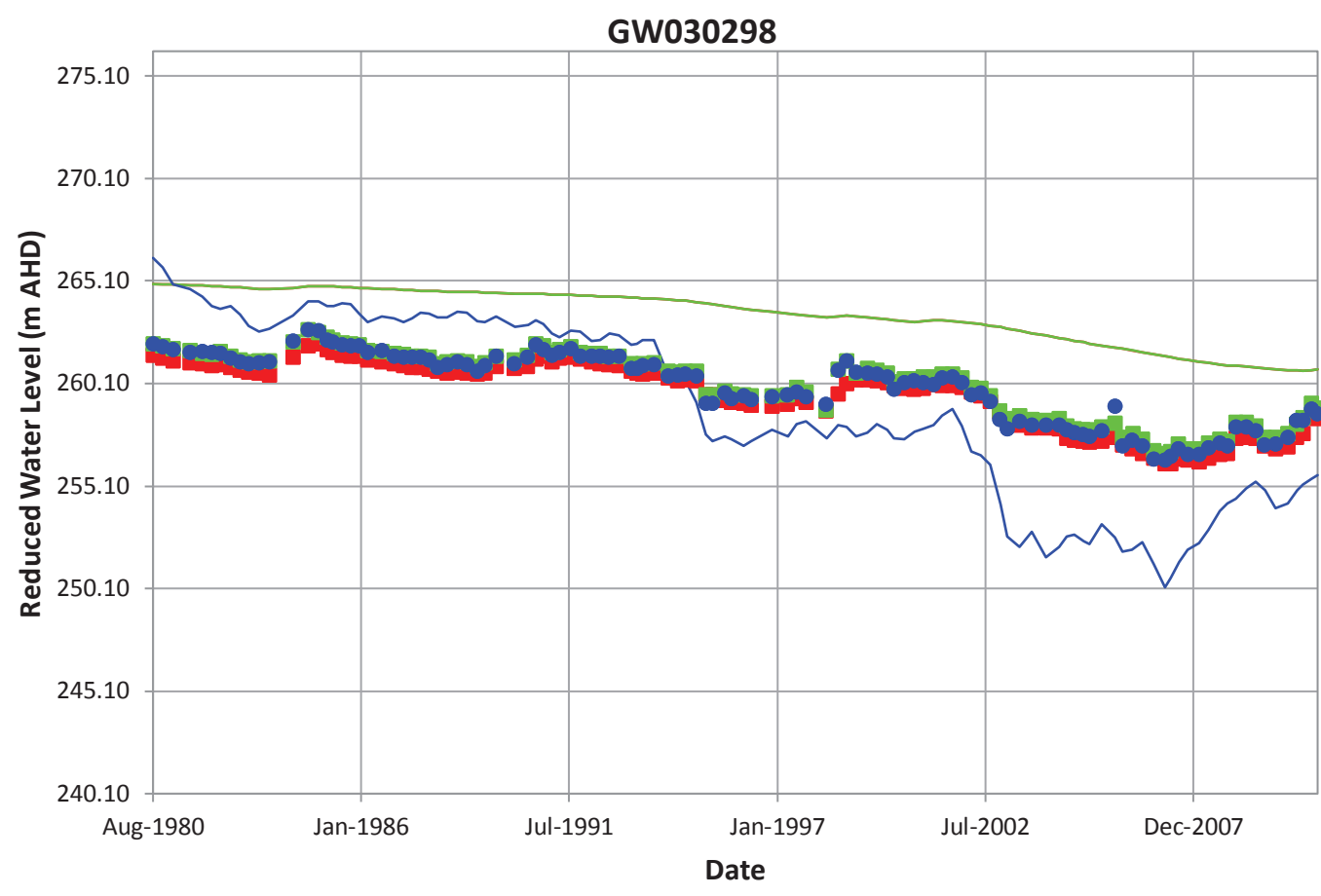


GW030297_1 (Gunnedah Fm) - Computed

GW030297_1 (Gunnedah Fm) - Observed

GW030297_2 (Gunnedah Fm) - Computed

GW030297_2 (Gunnedah Fm) - Observed



GW030298_1 (Narrabri Fm) - Computed

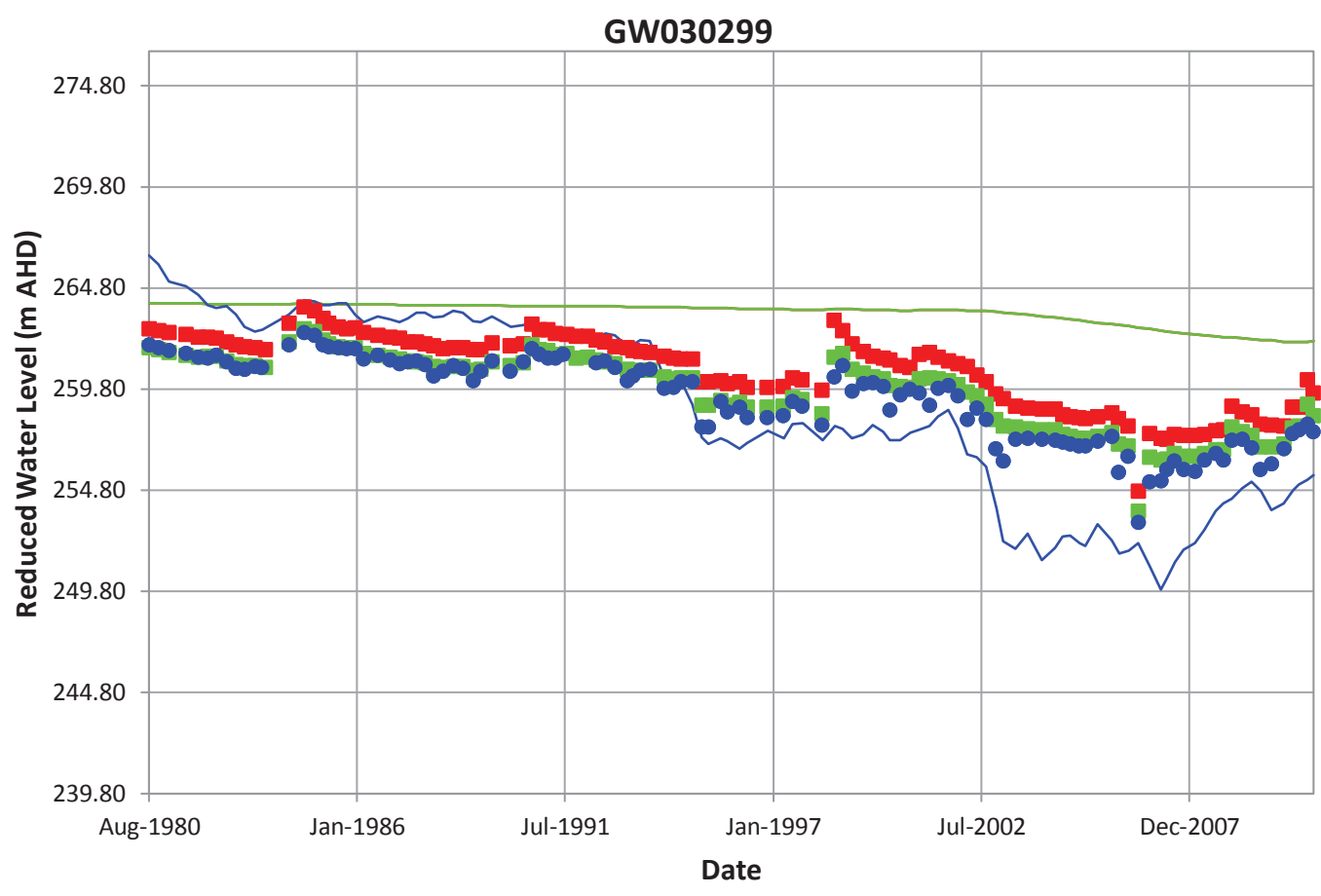
GW030298_1 (Narrabri Fm) - Observed

GW030298_2 (Narrabri Fm) - Computed

GW030298_2 (Narrabri Fm) - Observed

GW030298_3 (Gunnedah Fm) - Computed

GW030298_3 (Gunnedah Fm) - Observed



GW030299_1 (Narrabri Fm) - Computed

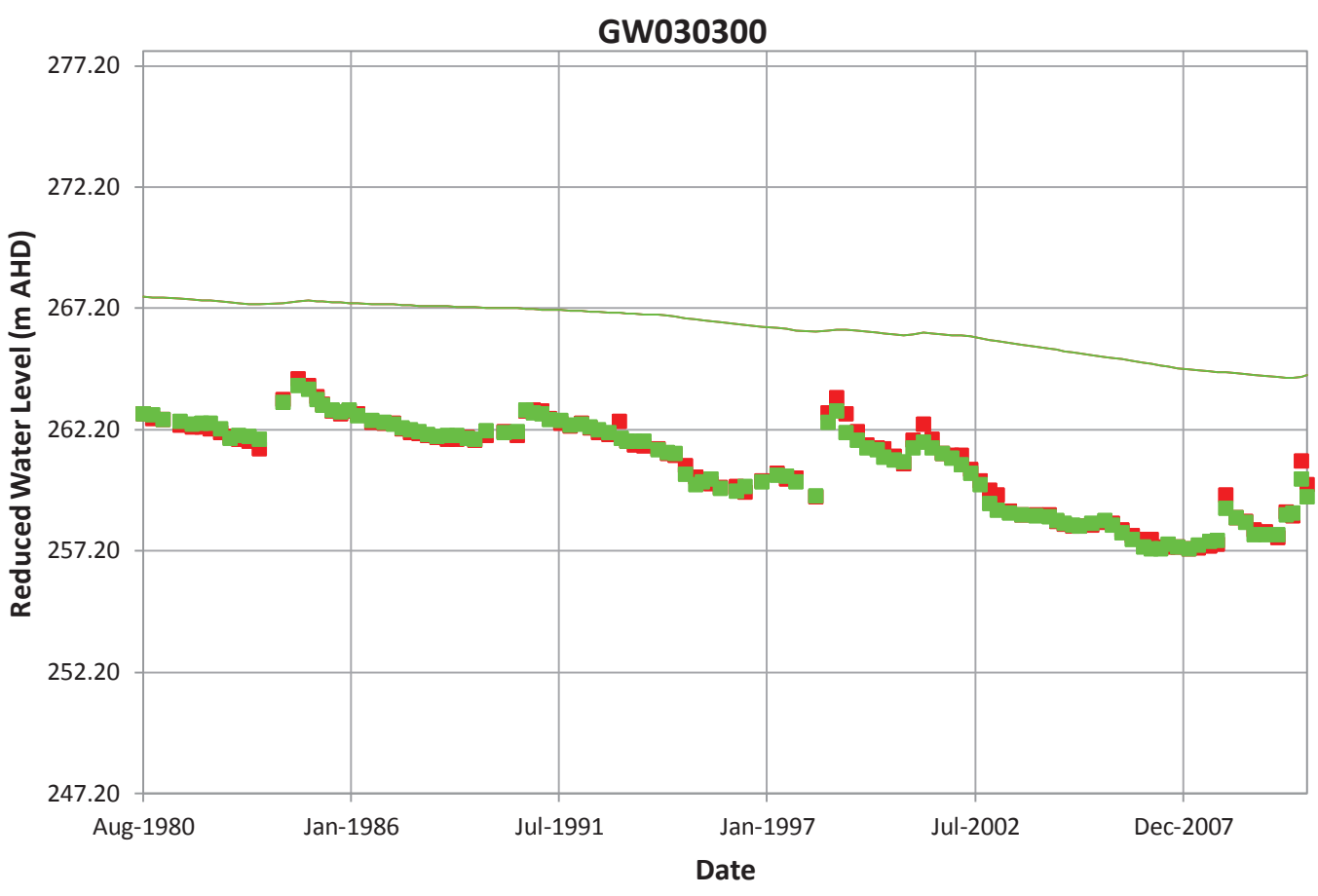
GW030299_1 (Narrabri Fm) - Observed

GW030299_2 (Narrabri Fm) - Computed

GW030299_2 (Narrabri Fm) - Observed

GW030299_3 (Gunnedah Fm) - Computed

GW030299_3 (Gunnedah Fm) - Observed

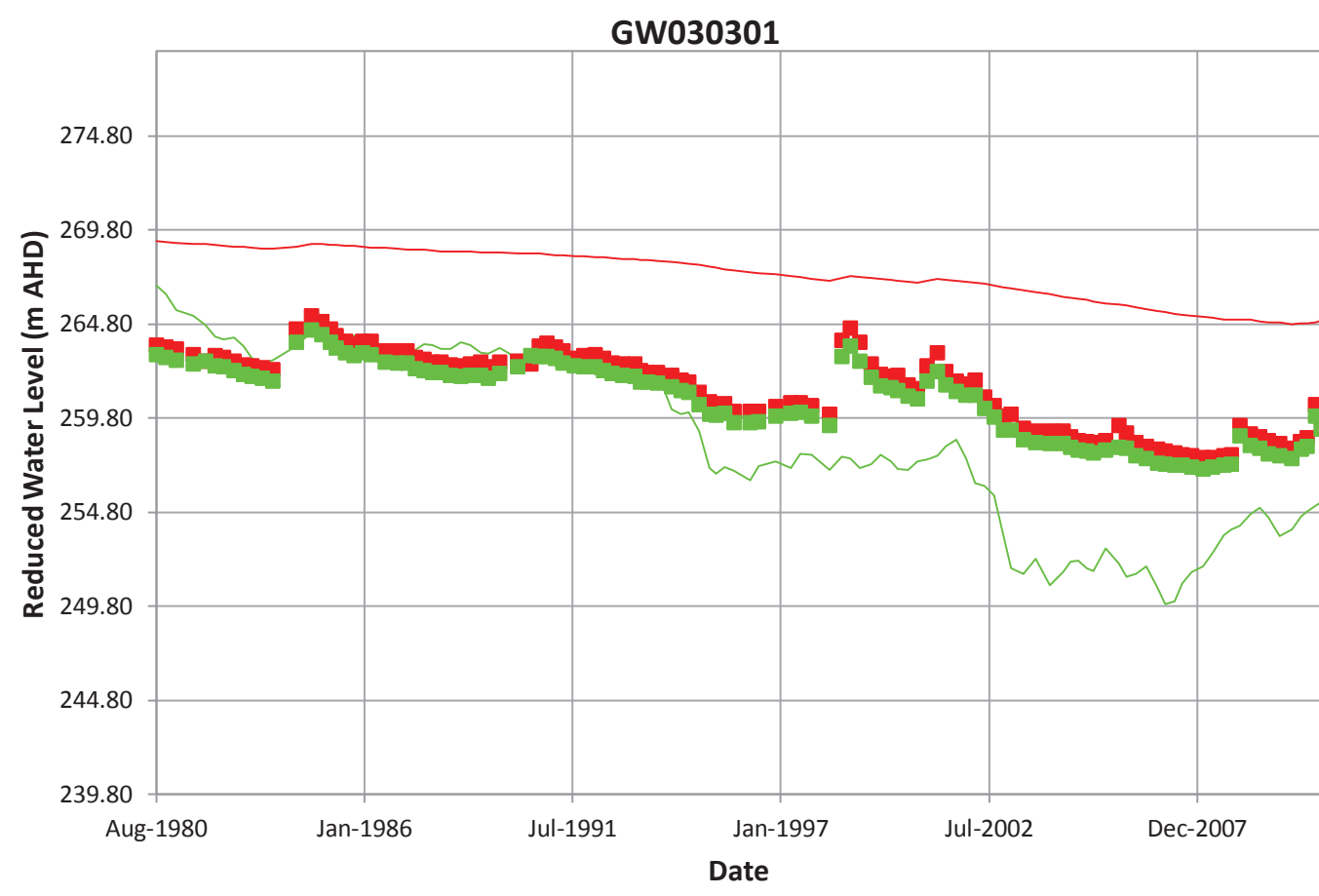


GW030300_1 (Narrabri Fm) - Computed

GW030300_1 (Narrabri Fm) - Observed

GW030300_2 (Narrabri Fm) - Computed

GW030300_2 (Narrabri Fm) - Observed

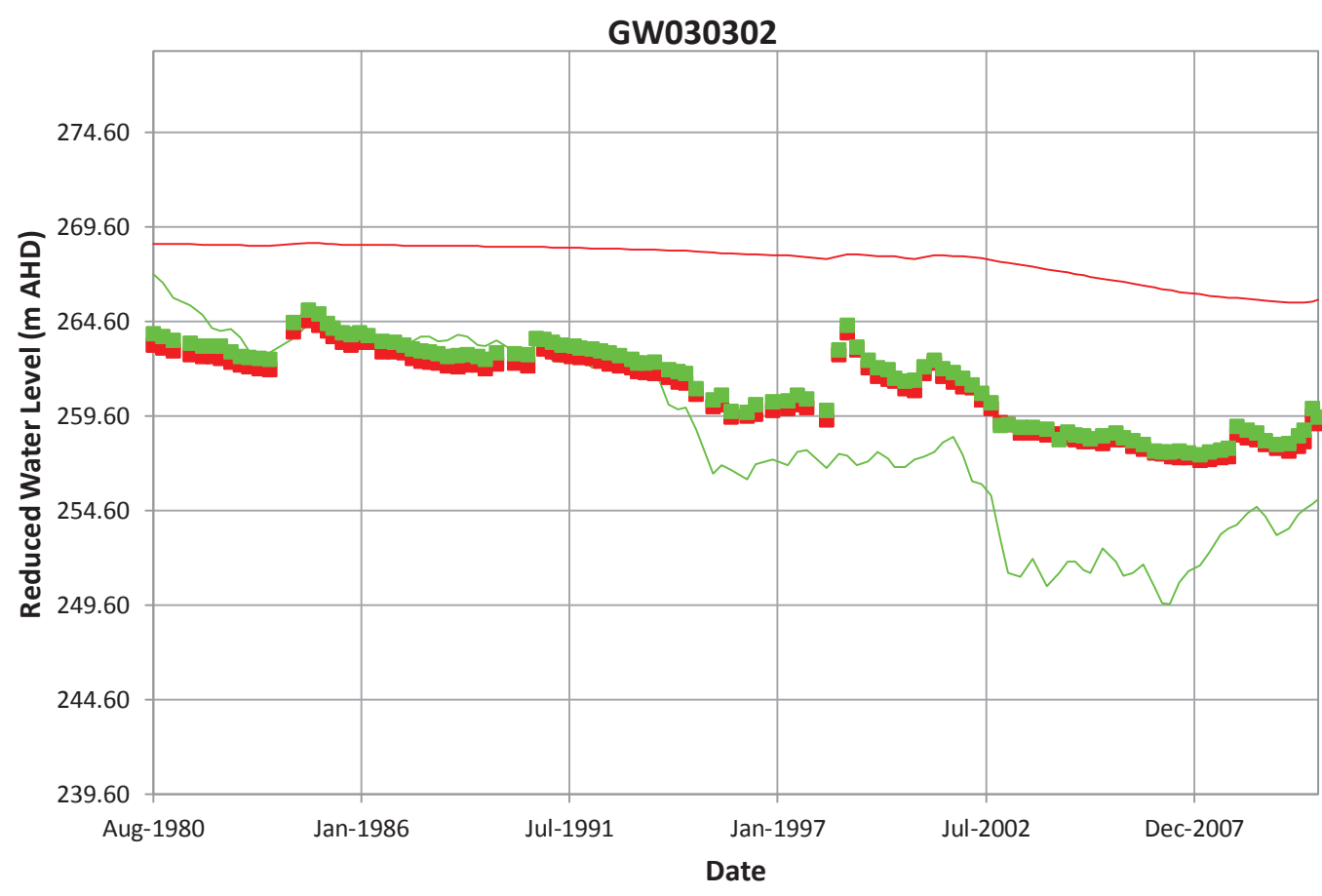


GW030301_1 (Narrabri Fm) - Computed

GW030301_1 (Narrabri Fm) - Observed

GW030301_2 (Gunnedah Fm) - Computed

GW030301_2 (Gunnedah Fm) - Observed

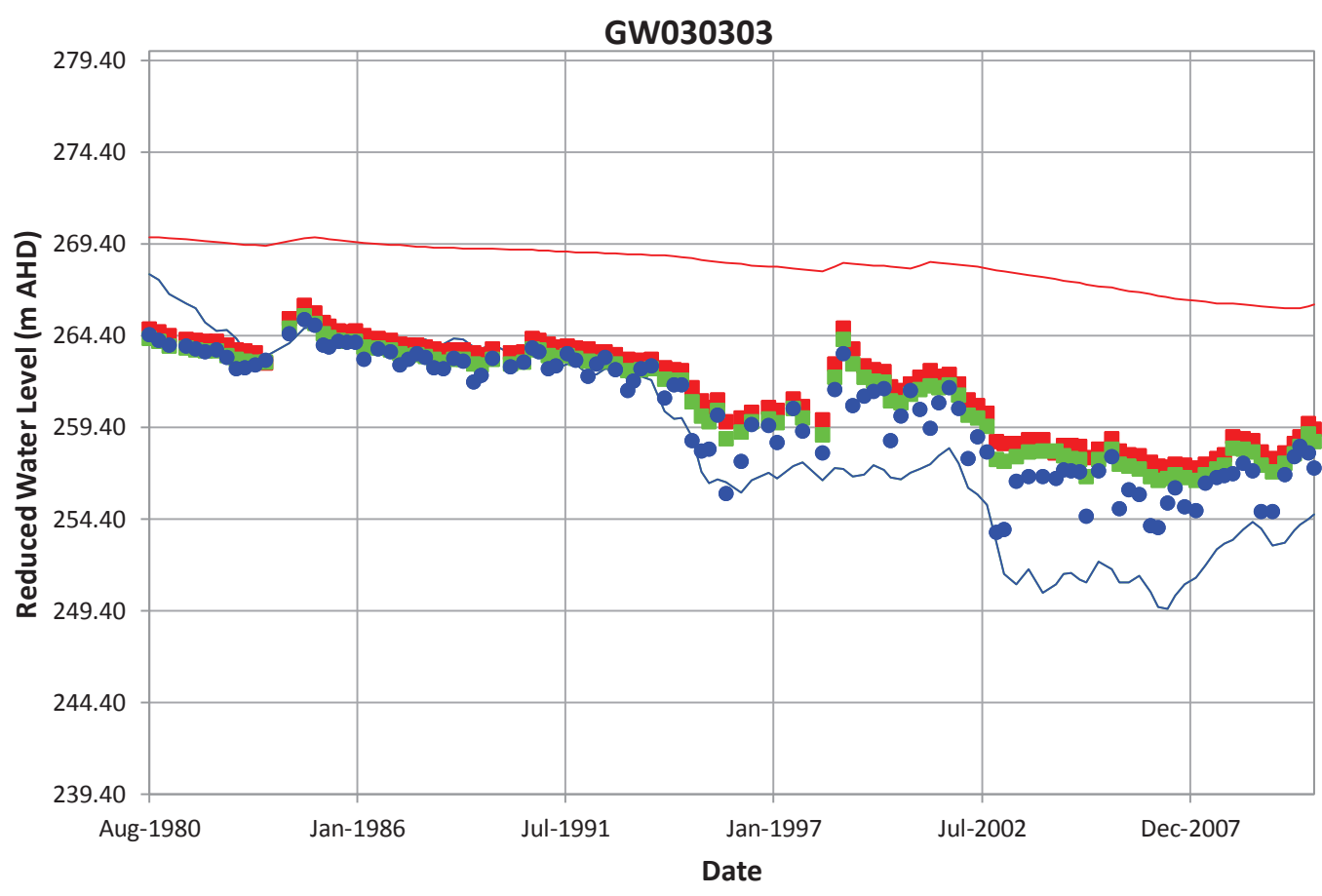


GW030302_1 (Narrabri Fm) - Computed

GW030302_1 (Narrabri Fm) - Observed

GW030302_2 (Gunnedah Fm) - Computed

GW030302_2 (Gunnedah Fm) - Observed



GW030303_1 (Narrabri Fm) - Computed

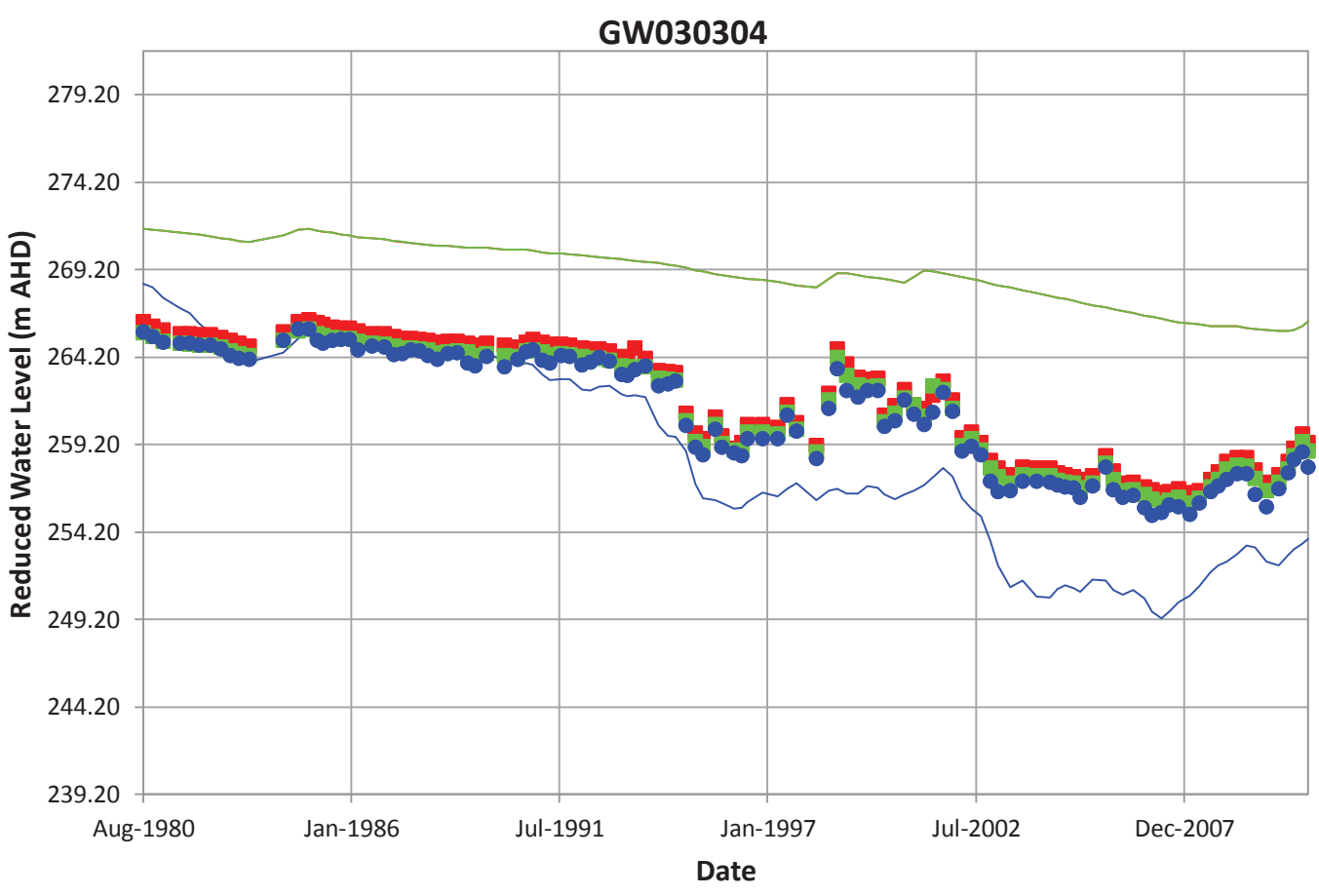
GW030303_1 (Narrabri Fm) - Observed

GW030303_2 (Gunnedah Fm) - Computed

GW030303_2 (Gunnedah Fm) - Observed

GW030303_3 (Gunnedah Fm) - Computed

GW030303_3 (Gunnedah Fm) - Observed



GW030304_1 (Narrabri Fm) - Computed

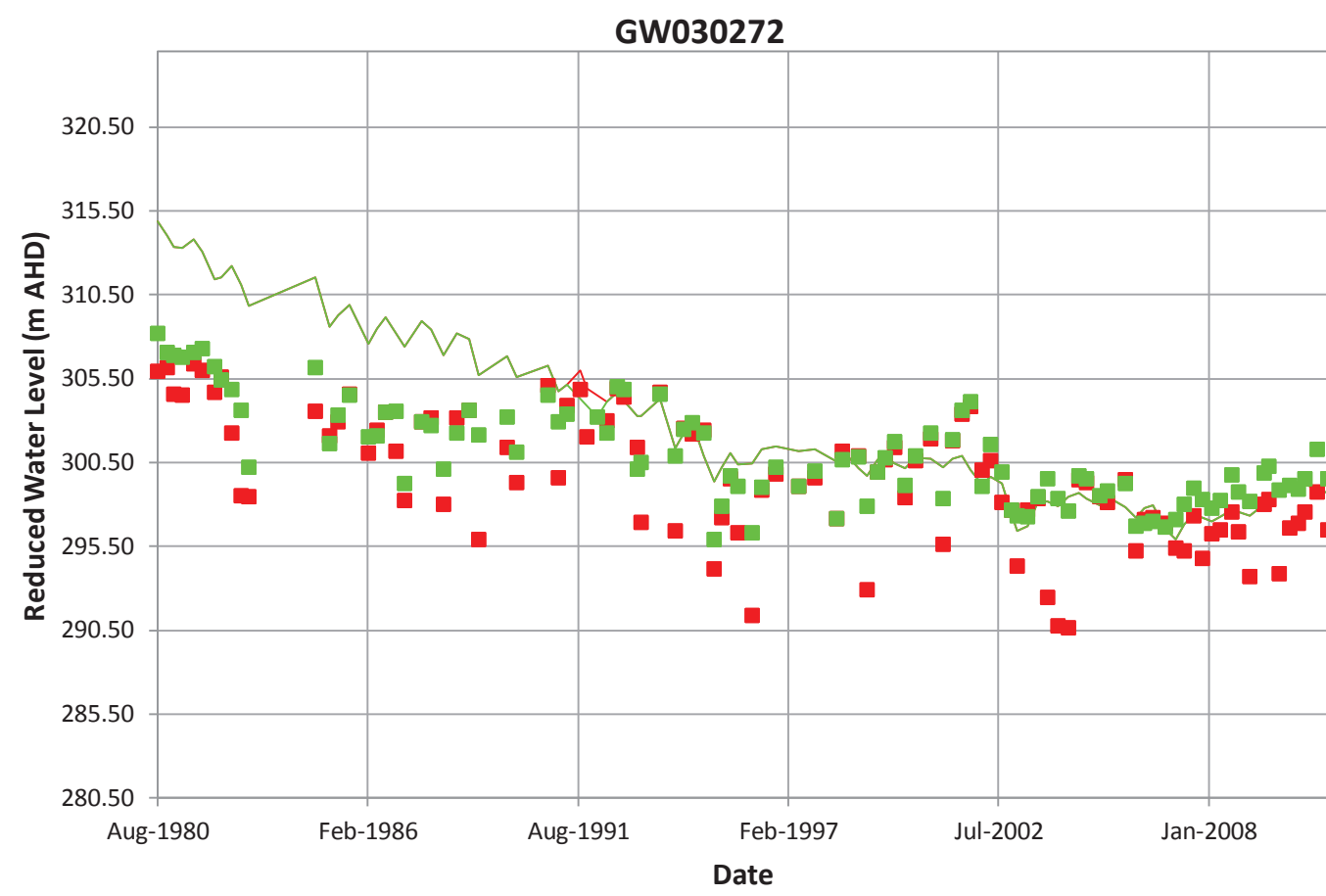
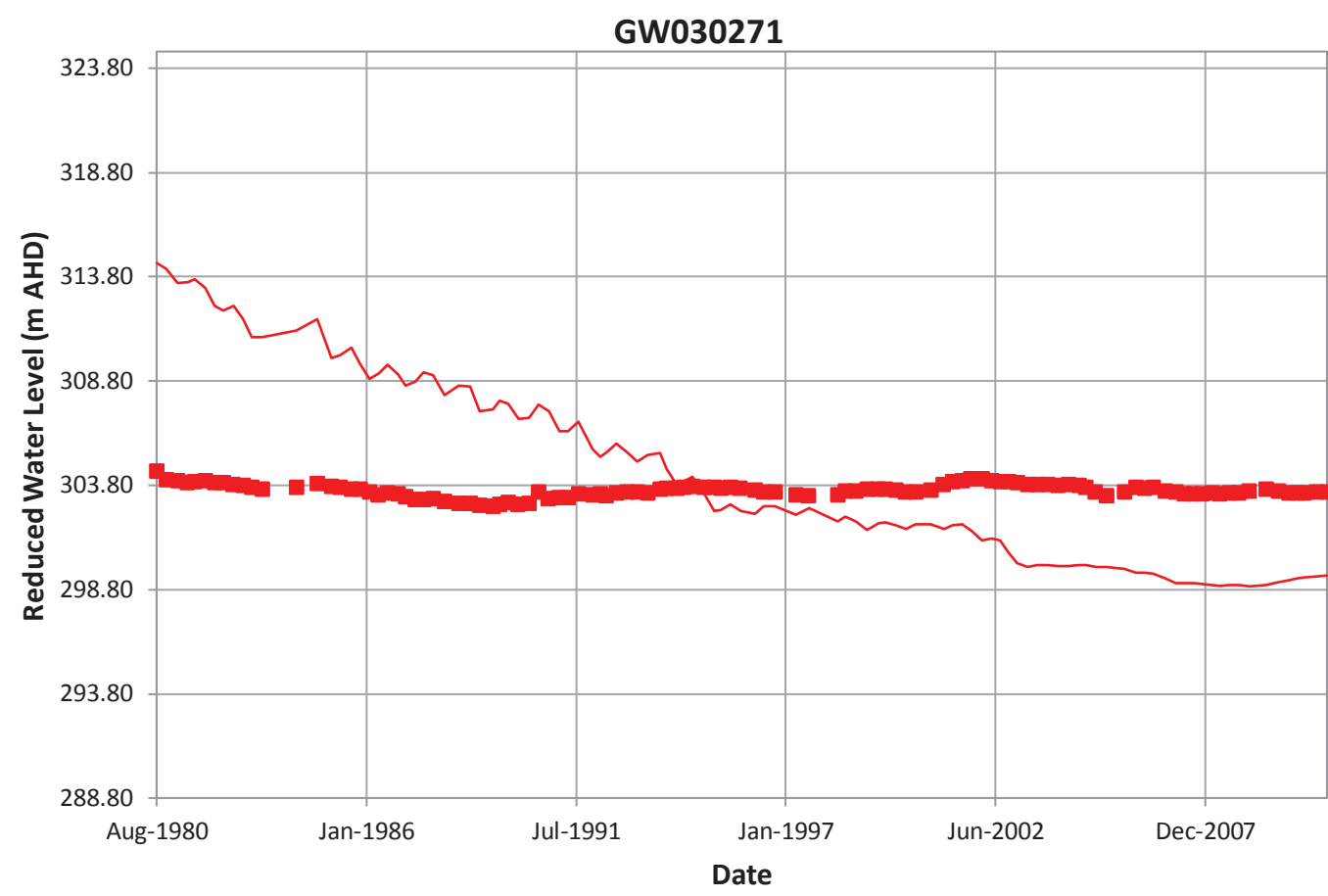
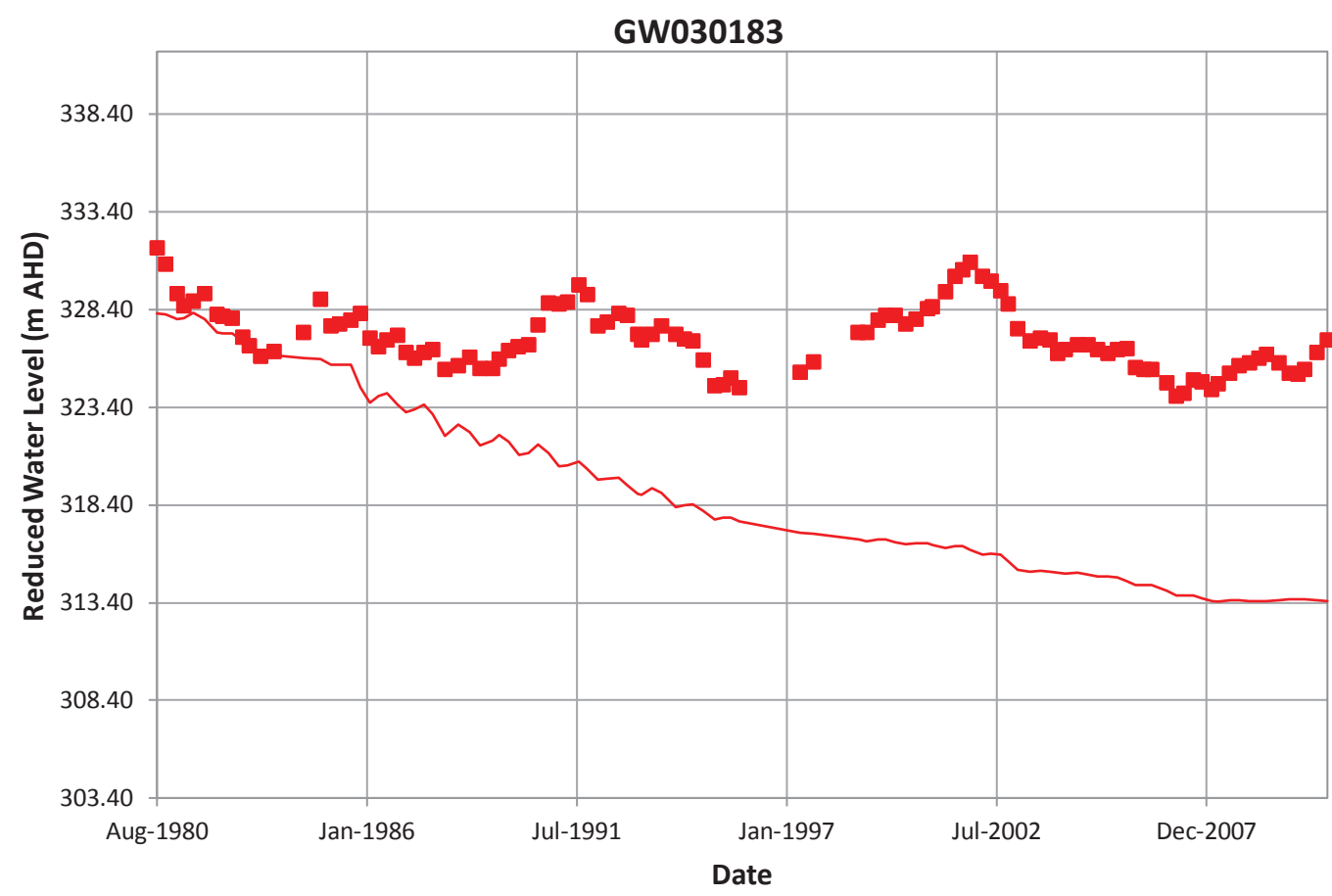
GW030304_1 (Narrabri Fm) - Observed

GW030304_2 (Narrabri Fm) - Computed

GW030304_2 (Narrabri Fm) - Observed

GW030304_3 (Gunnedah Fm) - Computed

GW030304_3 (Gunnedah Fm) - Observed



GW030183_1 (Gunnedah Fm) - Computed

GW030183_1 (Gunnedah Fm) - Observed

GW030184_2 (Gunnedah Fm) - Computed

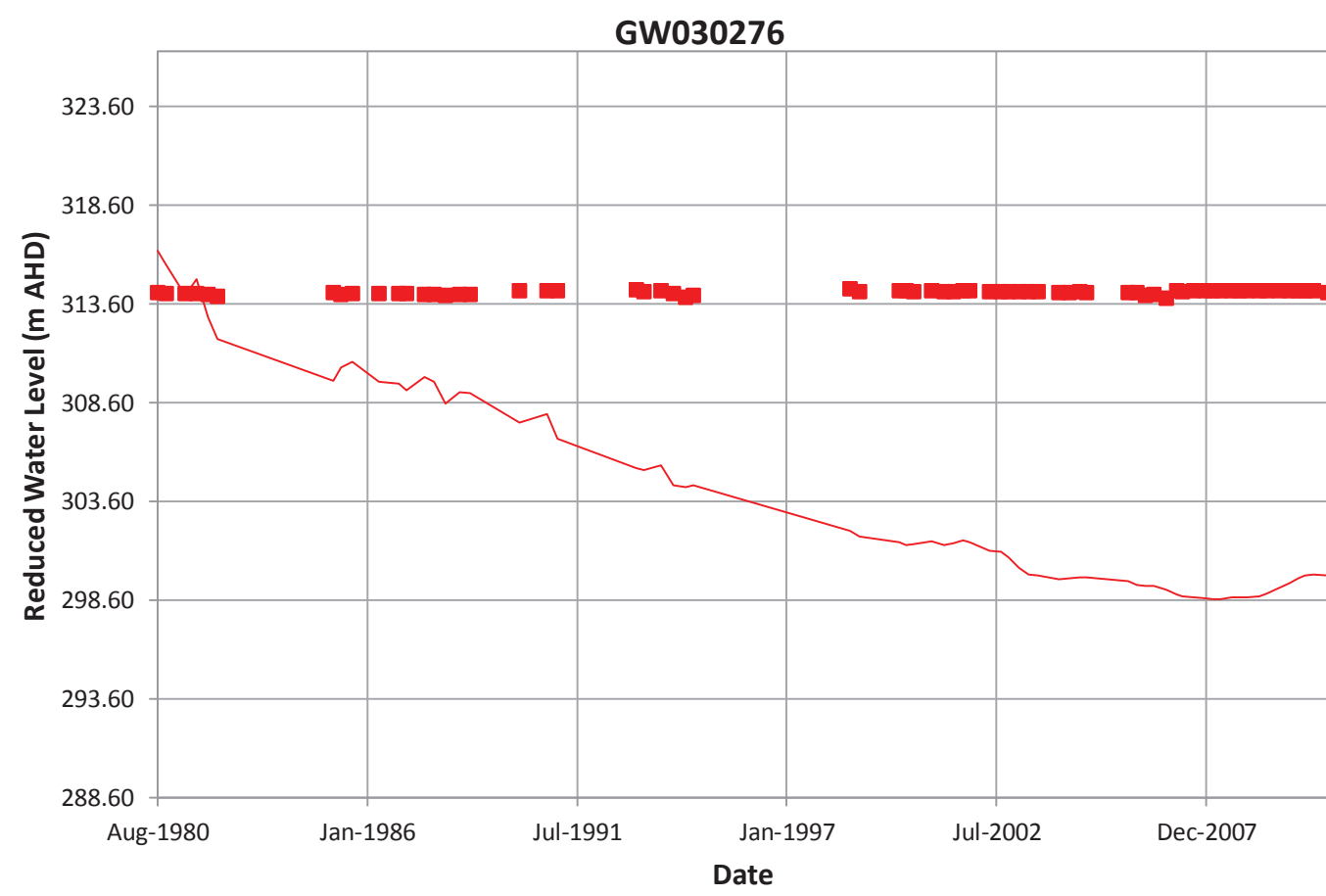
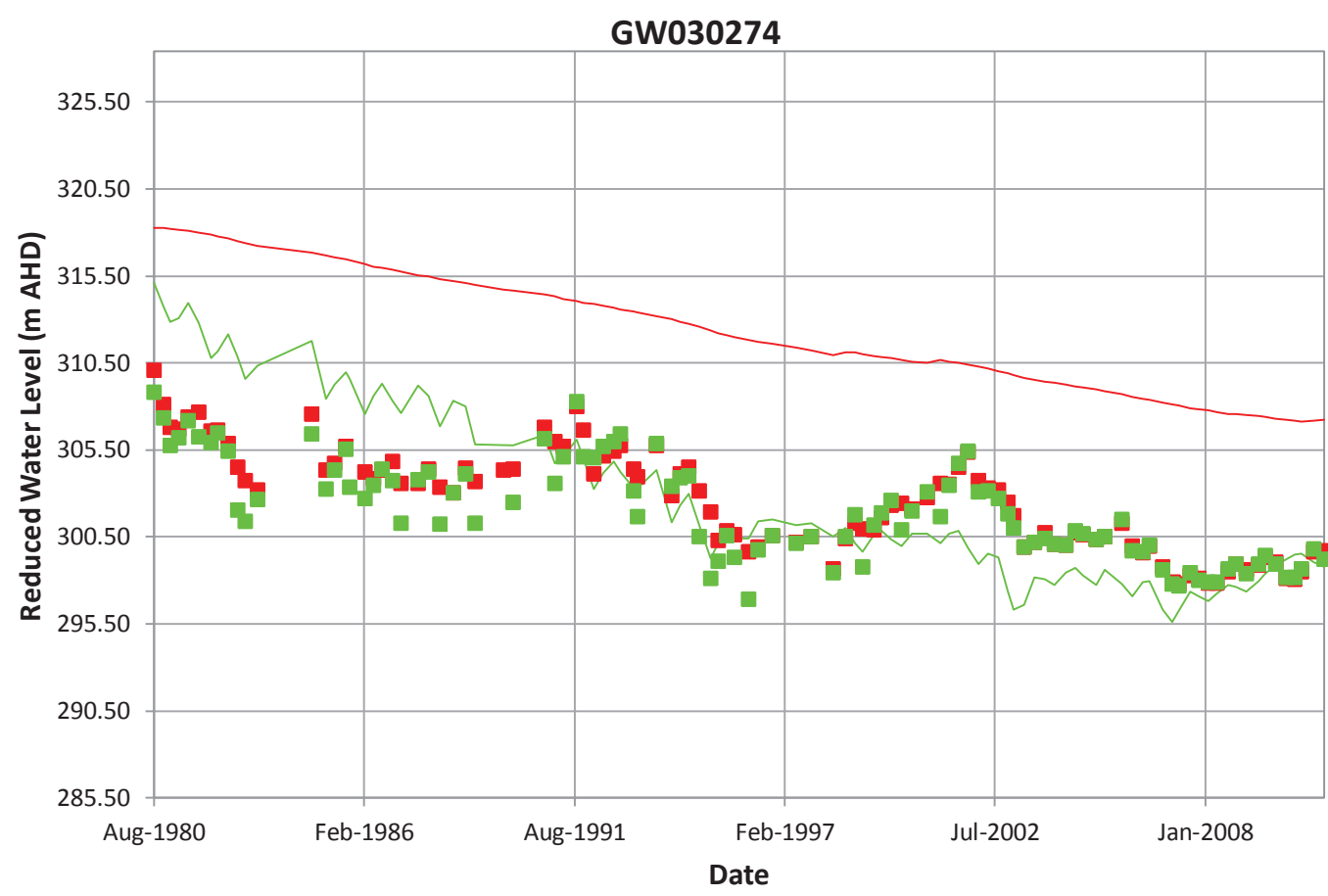
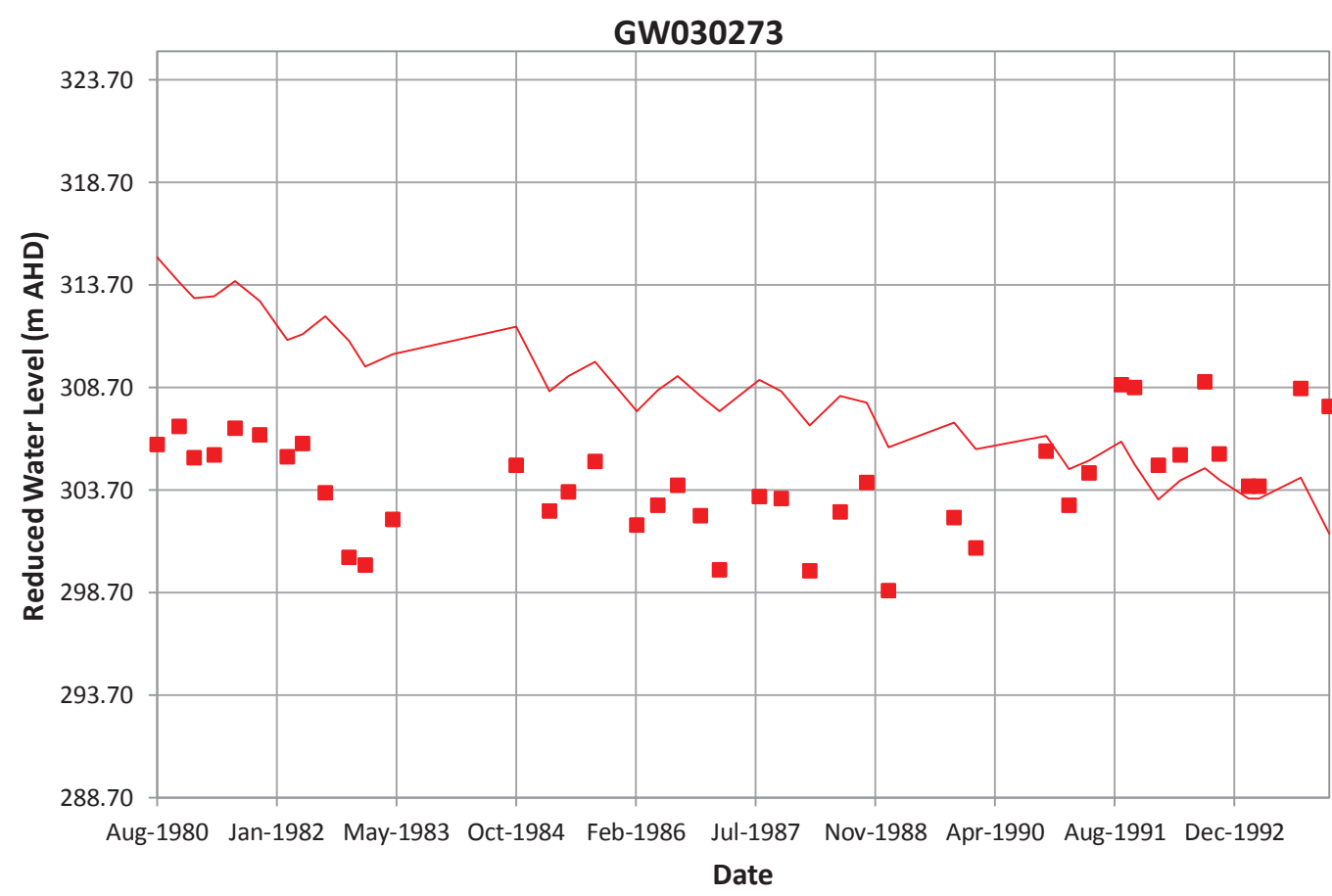
GW030184_2 (Gunnedah Fm) - Observed

GW030271_1 (Gunnedah Fm) - Computed

GW030271_1 (Gunnedah Fm) - Observed

GW030272_1 (Gunnedah Fm) - Computed

GW030272_1 (Gunnedah Fm) - Observed



GW030273_1 (Gunnedah Fm) - Computed

GW030273_1 (Gunnedah Fm) - Observed

GW030274_2 (Gunnedah Fm) - Computed

GW030274_2 (Gunnedah Fm) - Observed

GW030275_2 (Gunnedah Fm) - Computed

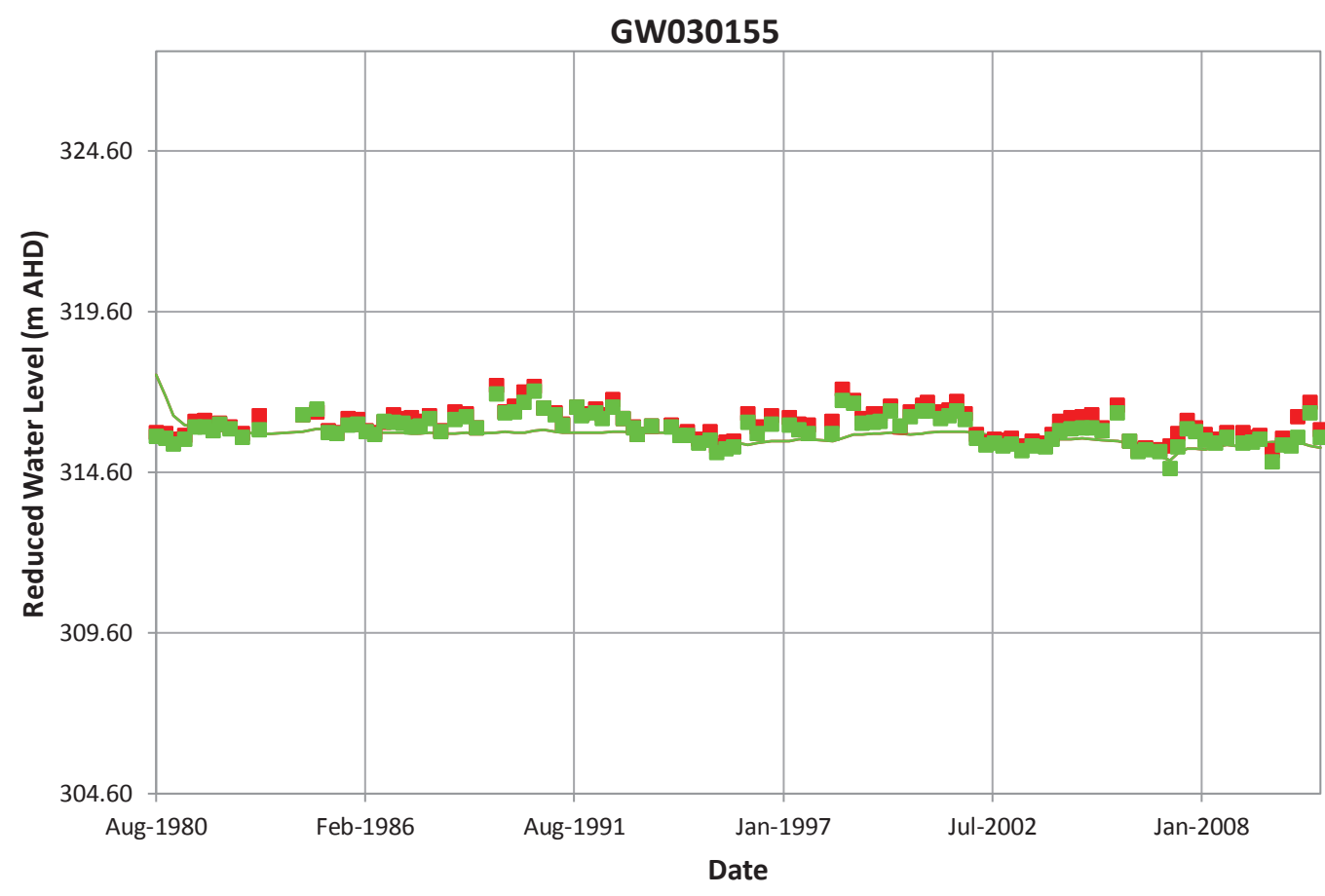
GW030275_2 (Gunnedah Fm) - Observed

GW030276_1 (Gunnedah Fm) - Computed

GW030276_1 (Gunnedah Fm) - Observed

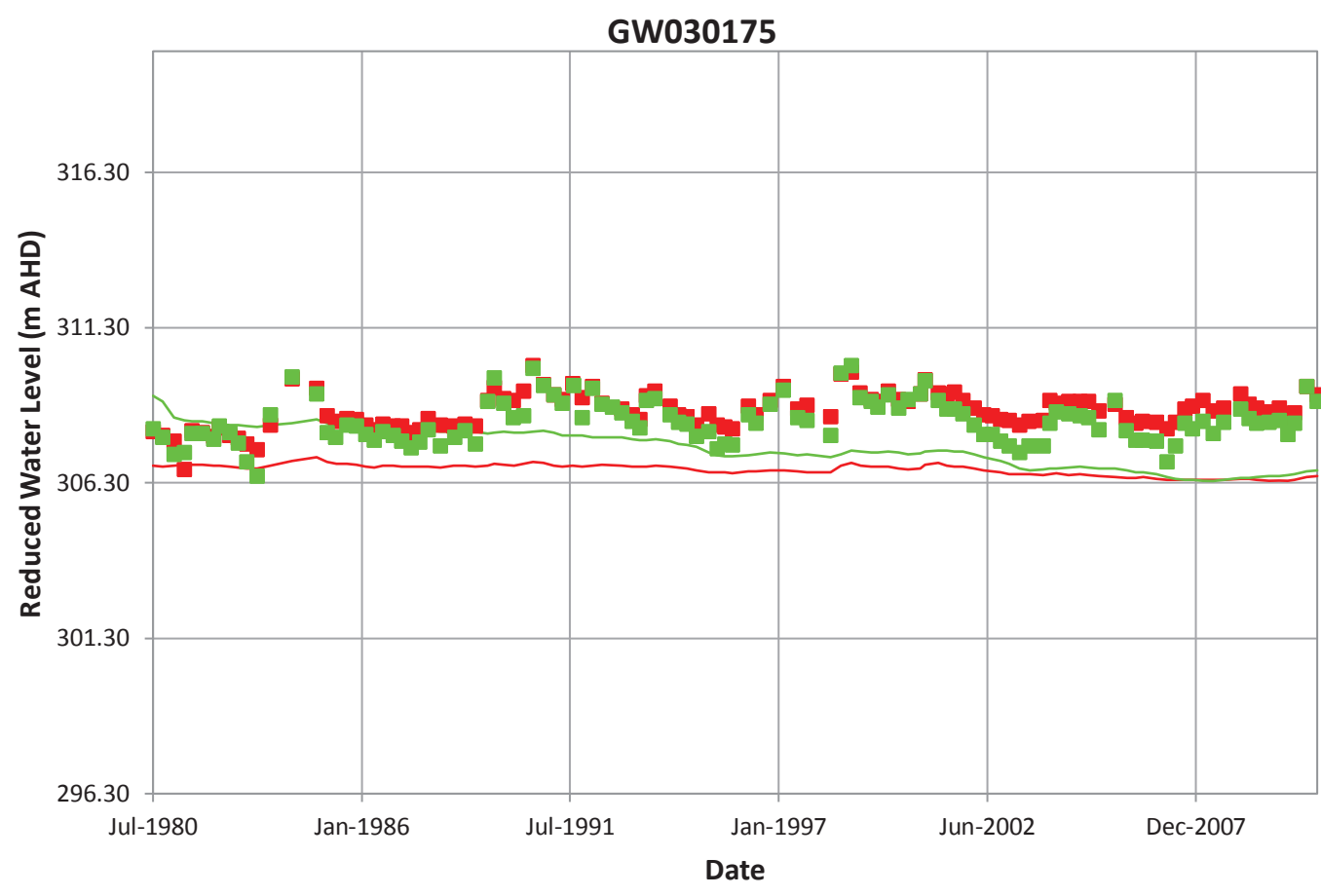
GW030275_3 (Gunnedah Fm) - Computed

GW030275_3 (Gunnedah Fm) - Observed



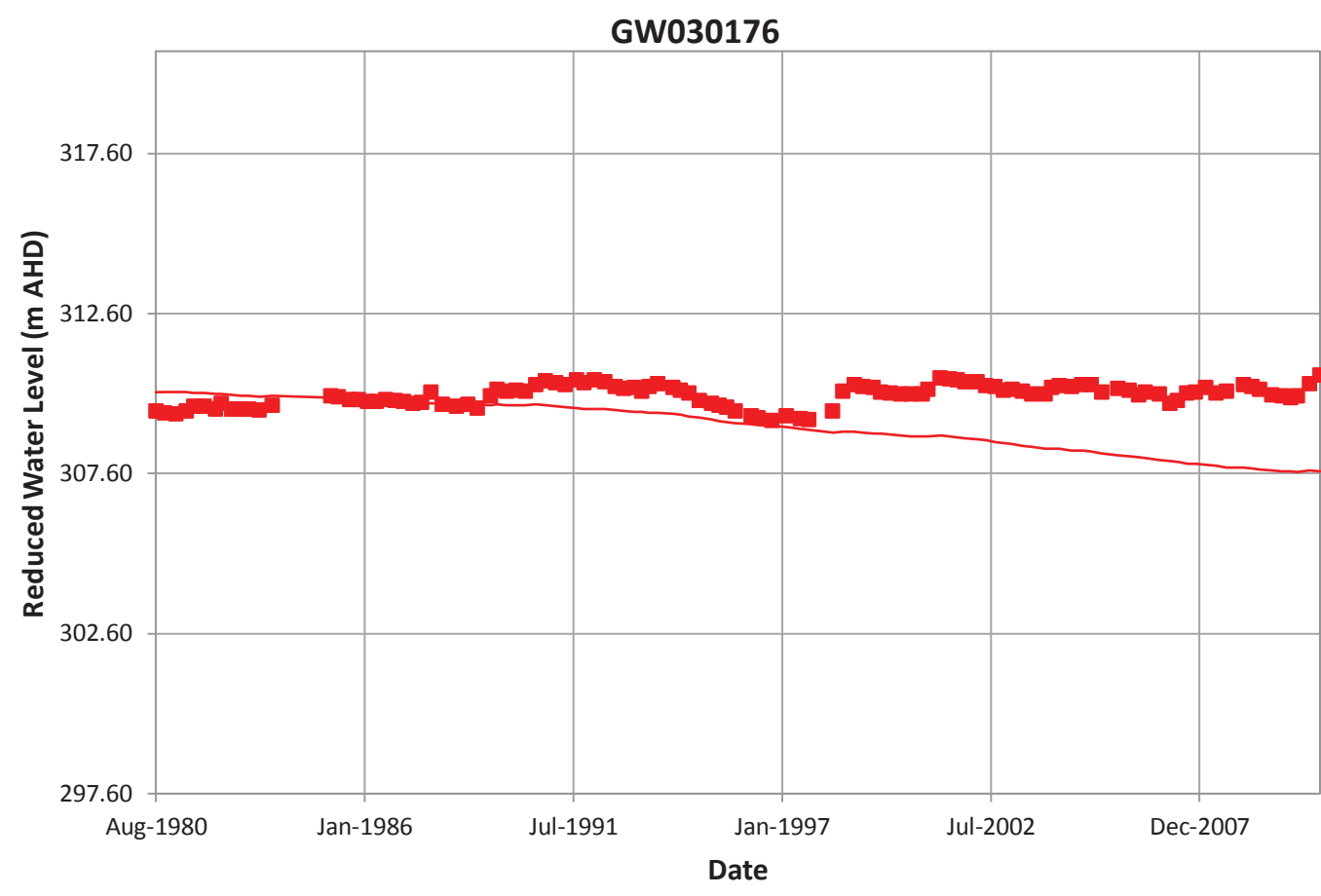
GW030155_1 (Gunnedah Fm) - Computed

GW030155_1 (Gunnedah Fm) - Observed



GW030175_1 (Narrabri Fm) - Computed

GW030175_1 (Narrabri Fm) - Observed



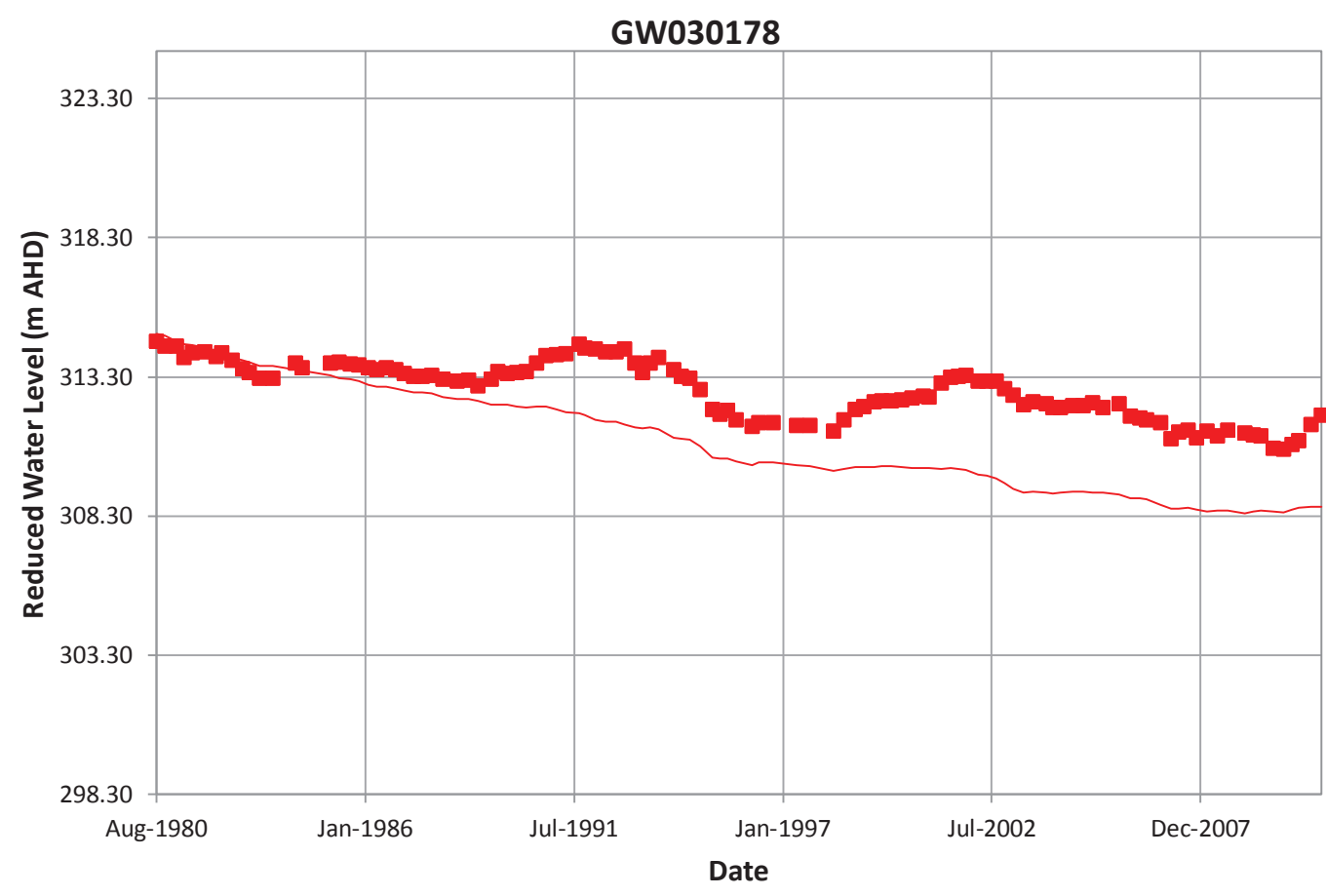
GW030176_1 (Narrabri Fm) - Computed

GW030176_1 (Narrabri Fm) - Observed



GW030177_1 (Gunnedah Fm) - Computed

GW030177_1 (Gunnedah Fm) - Observed



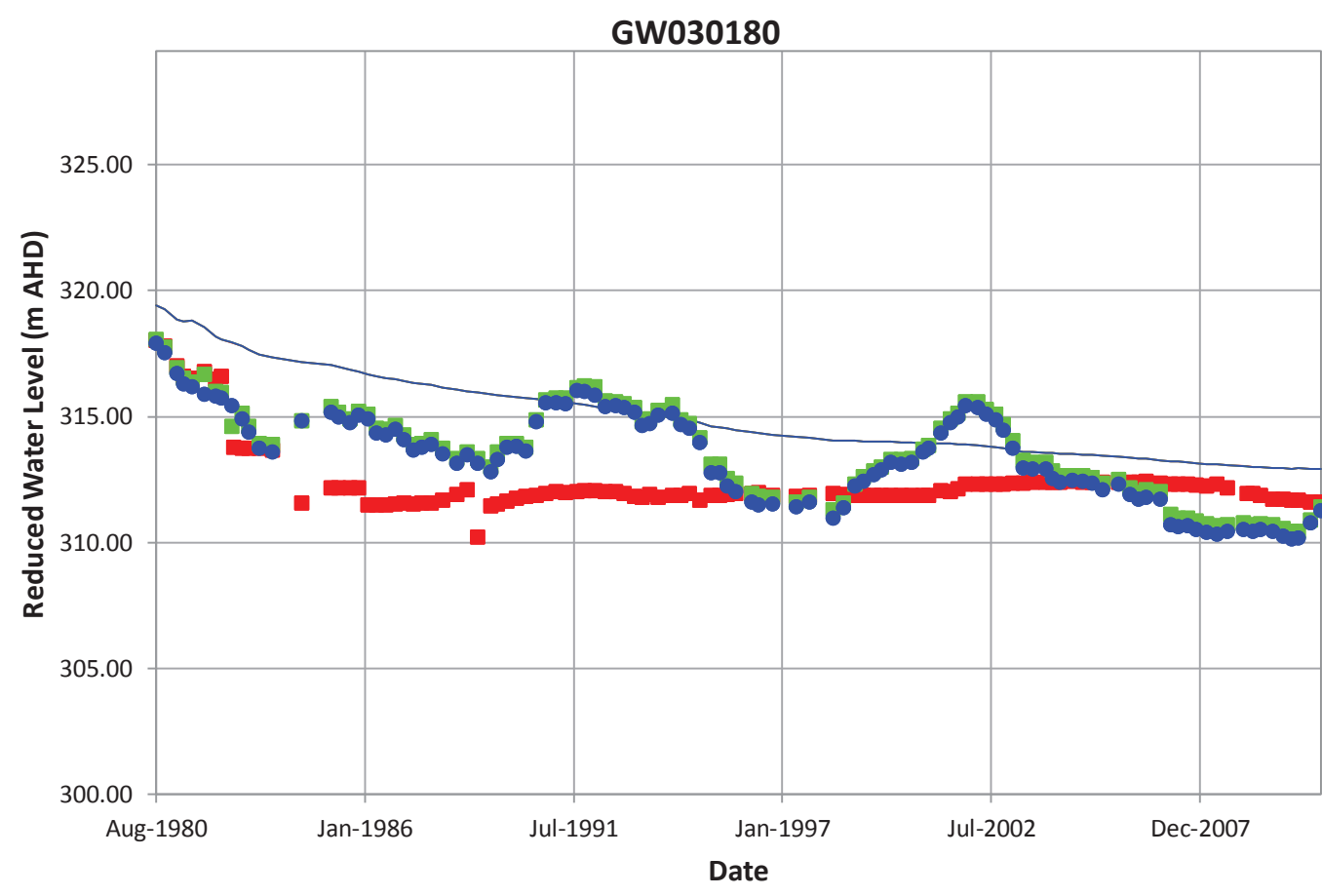
GW030178_1 (Gunnedah Fm) - Computed

GW030178_1 (Gunnedah Fm) - Observed



GW030179_1 (Gunnedah Fm) - Computed

GW030179_1 (Gunnedah Fm) - Observed



GW030180_1 (Gunnedah Fm) - Computed

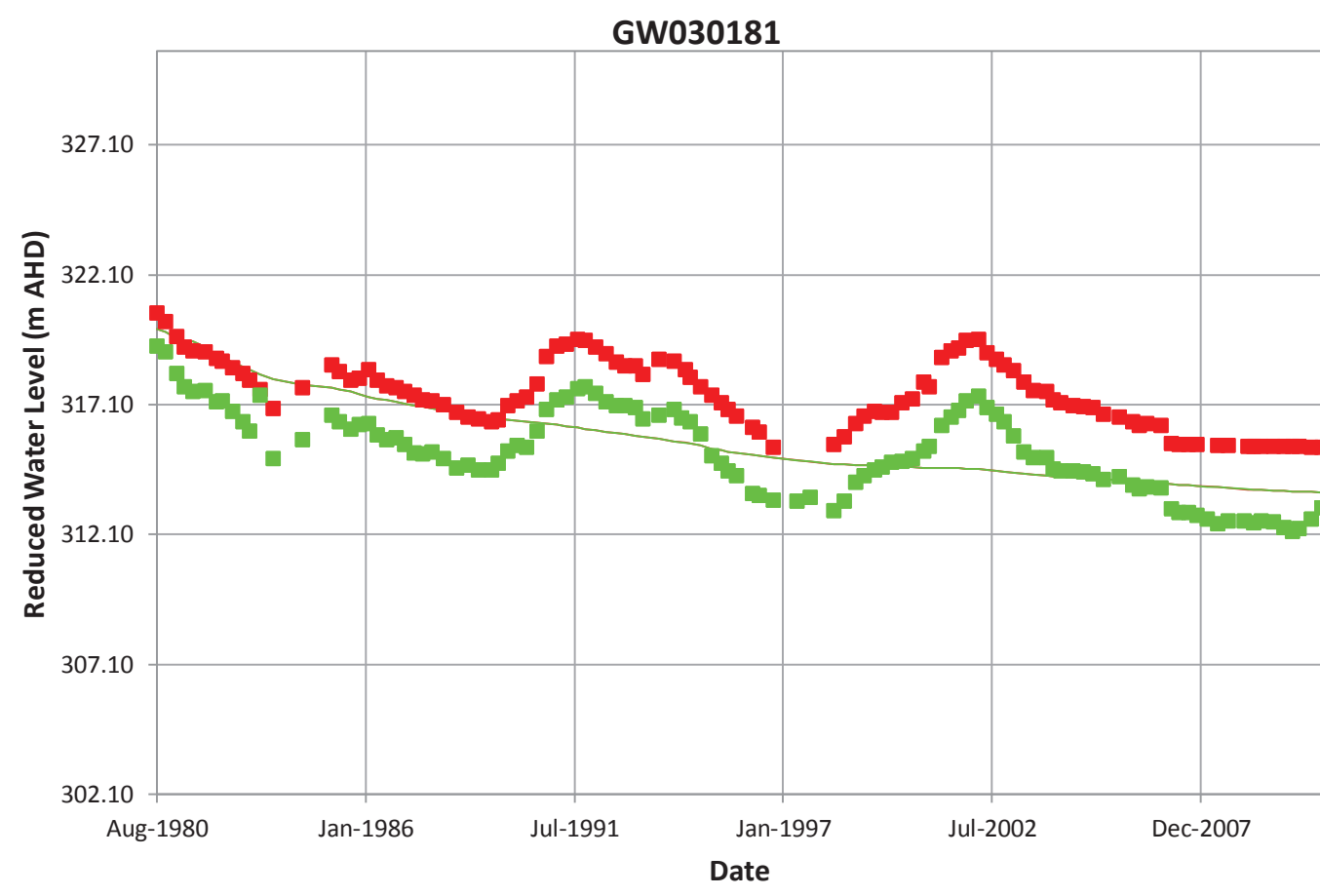
GW030180_1 (Gunnedah Fm) - Observed

GW030180_2 (Gunnedah Fm) - Computed

GW030180_2 (Gunnedah Fm) - Observed

GW030180_3 (Gunnedah Fm) - Computed

GW030180_3 (Gunnedah Fm) - Observed

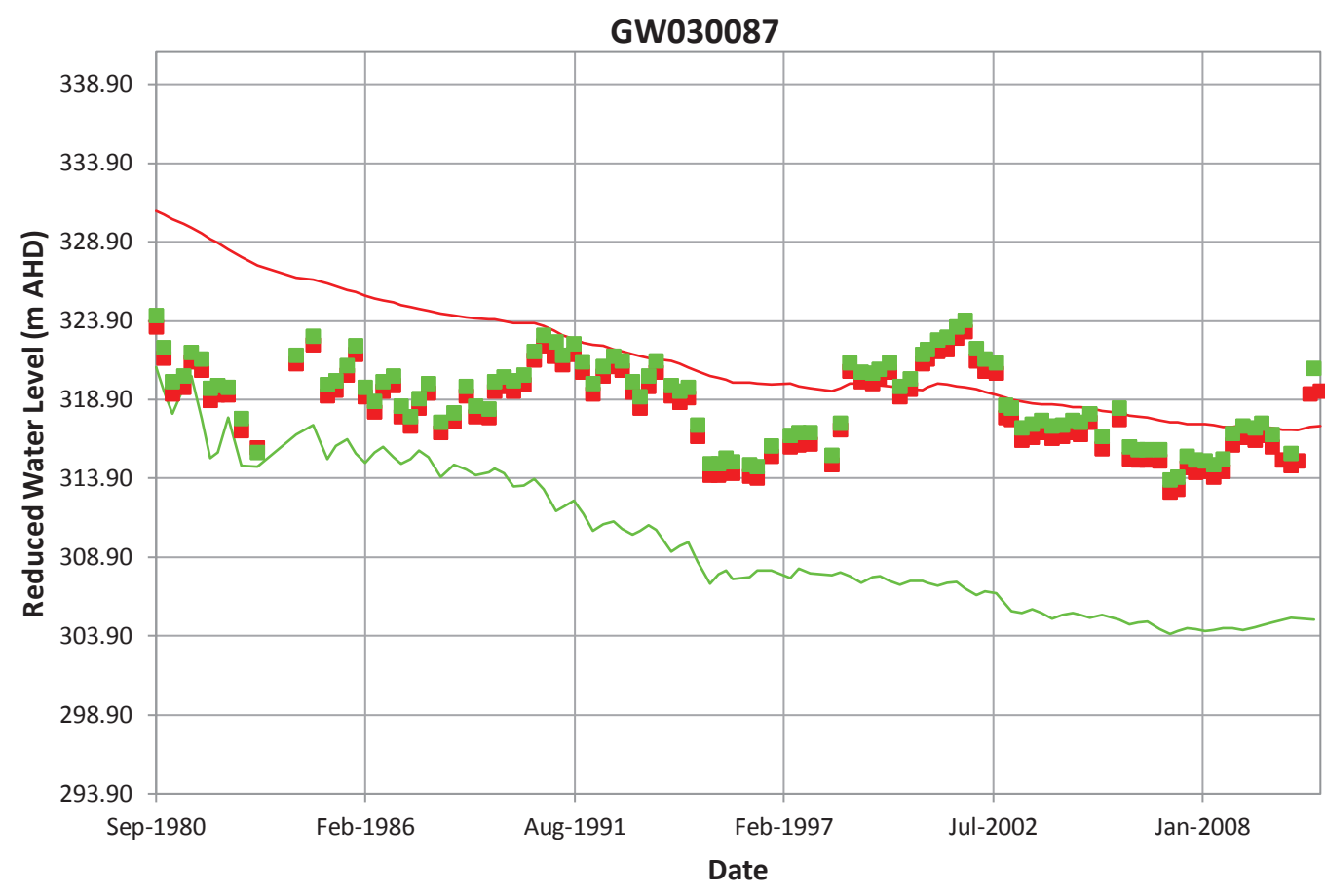


GW030181_1 (Gunnedah Fm) - Computed

GW030181_1 (Gunnedah Fm) - Observed

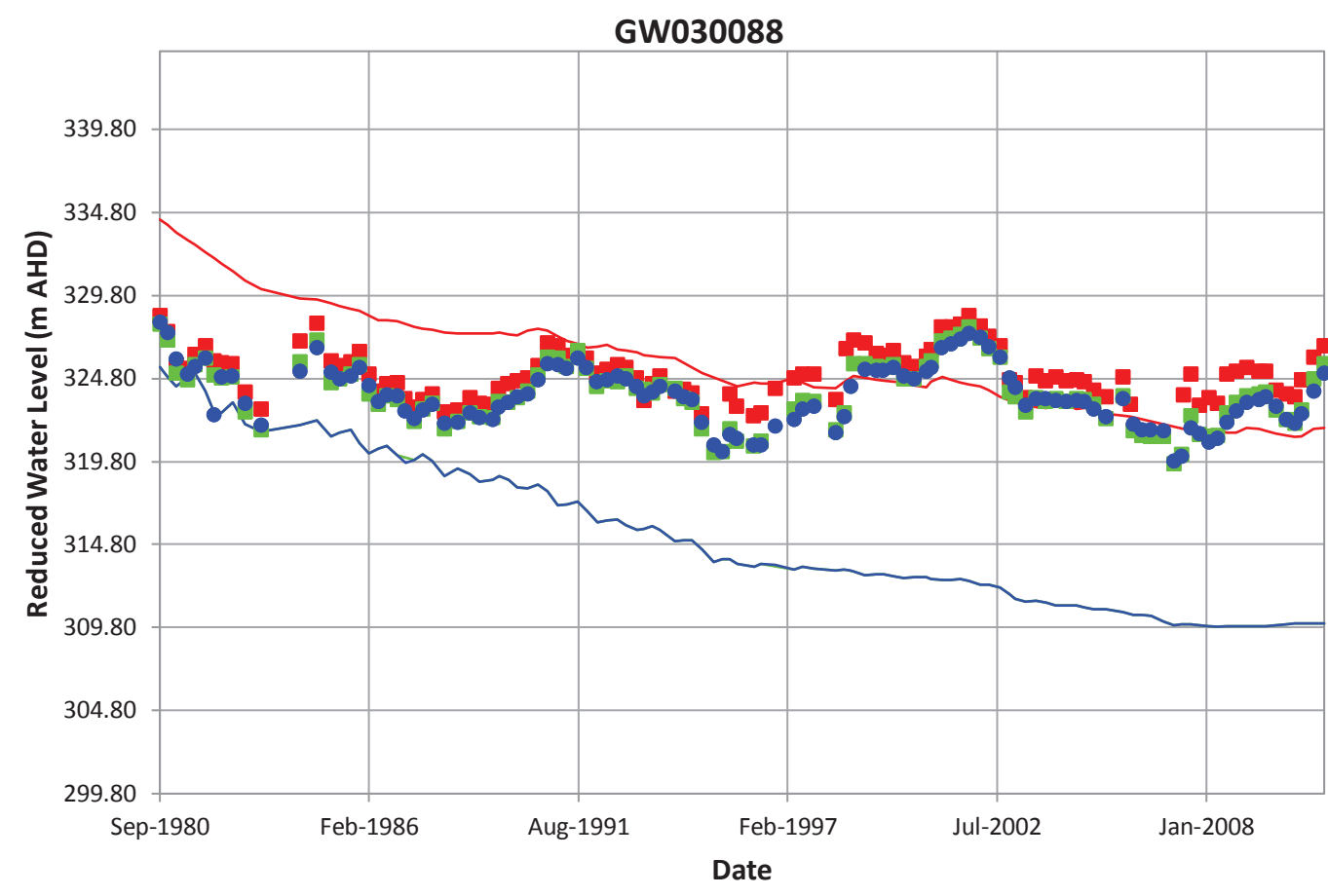
GW030181_2 (Gunnedah Fm) - Computed

GW030181_2 (Gunnedah Fm) - Observed



GW030087_1 (Narrabri Fm) - Computed

GW030087_1 (Narrabri Fm) - Observed



GW030088_1 (Narrabri Fm) - Computed

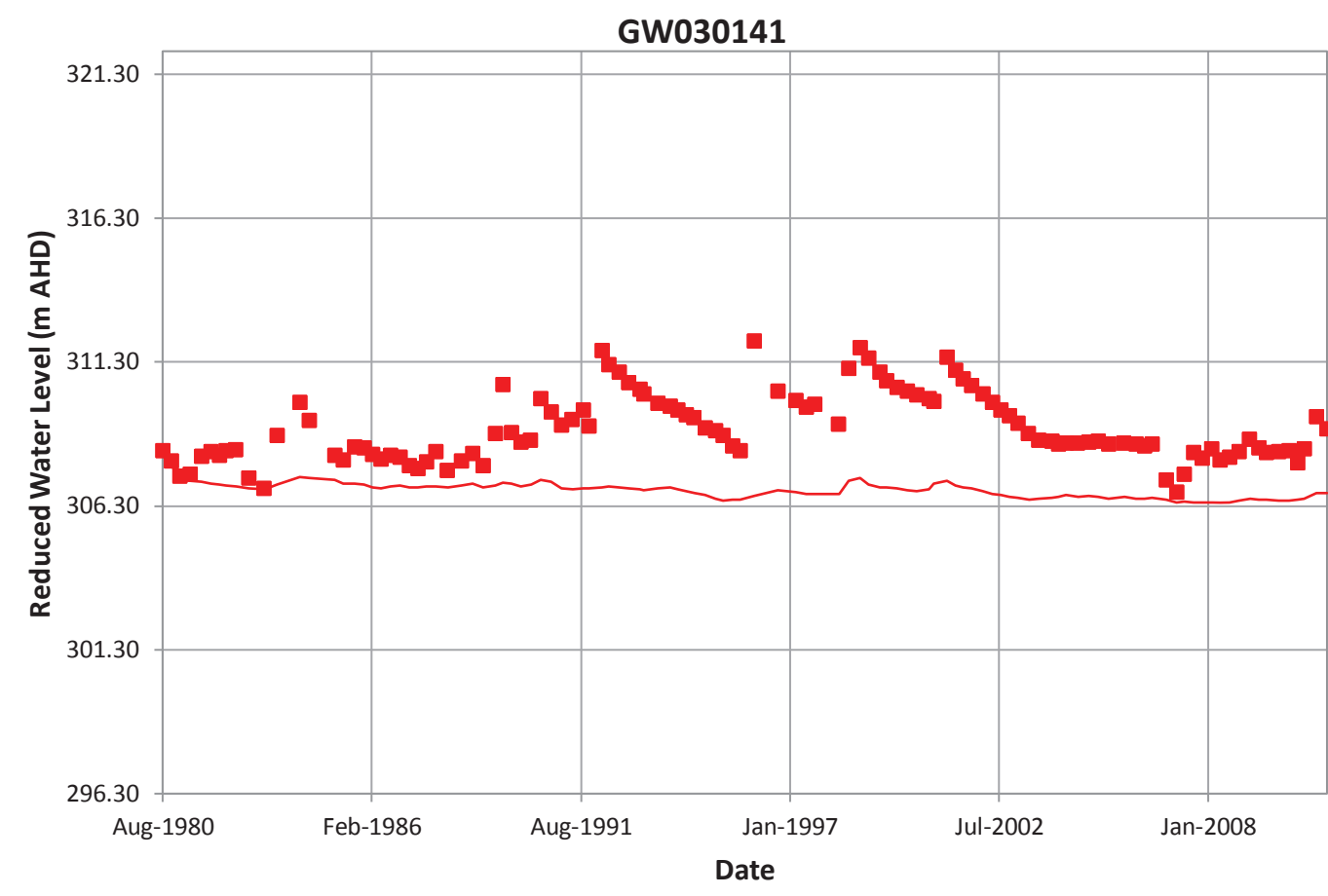
GW030088_1 (Narrabri Fm) - Observed

GW030088_2 (Gunnedah Fm) - Computed

GW030088_2 (Gunnedah Fm) - Observed

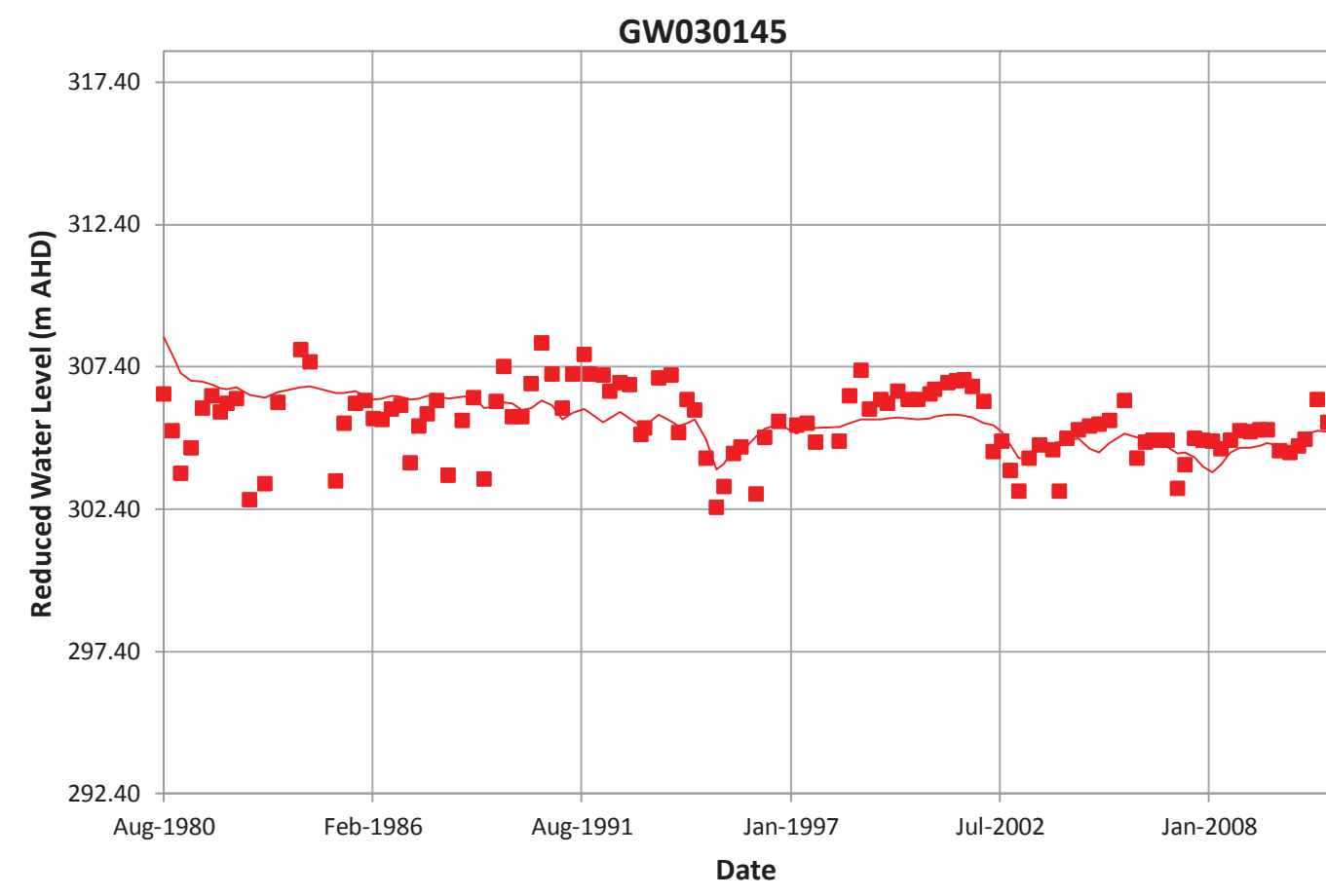
GW030088_3 (Gunnedah Fm) - Computed

GW030088_3 (Gunnedah Fm) - Observed



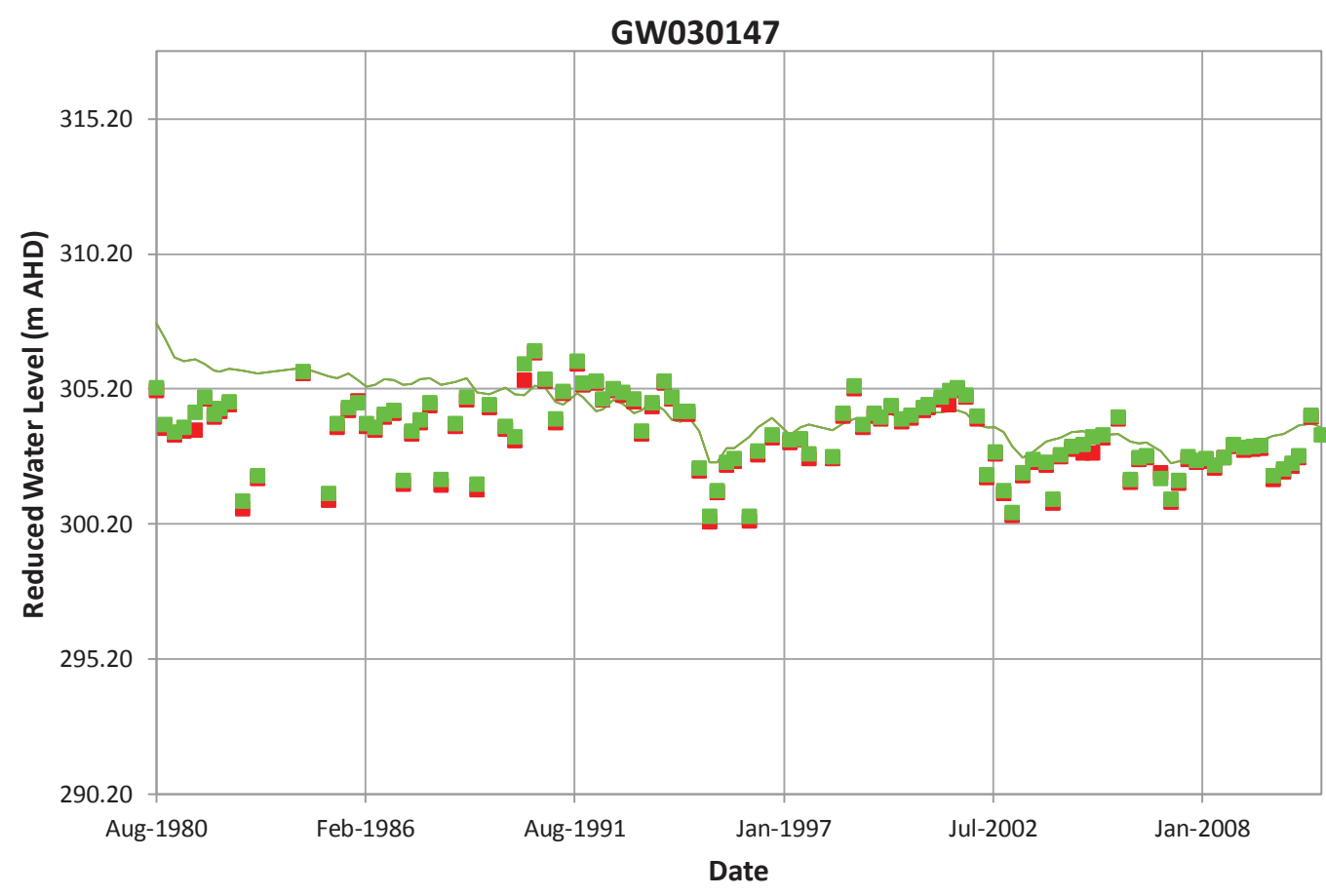
GW030141_1 (Gunnedah Fm) - Computed

GW030141_1 (Gunnedah Fm) - Observed



GW030145_1 (Gunnedah Fm) - Computed

GW030145_1 (Gunnedah Fm) - Observed



GW030147_1 (Gunnedah Fm) - Computed

GW030147_1 (Gunnedah Fm) - Observed

GW030147_2 (Gunnedah Fm) - Computed

GW030147_2 (Gunnedah Fm) - Observed

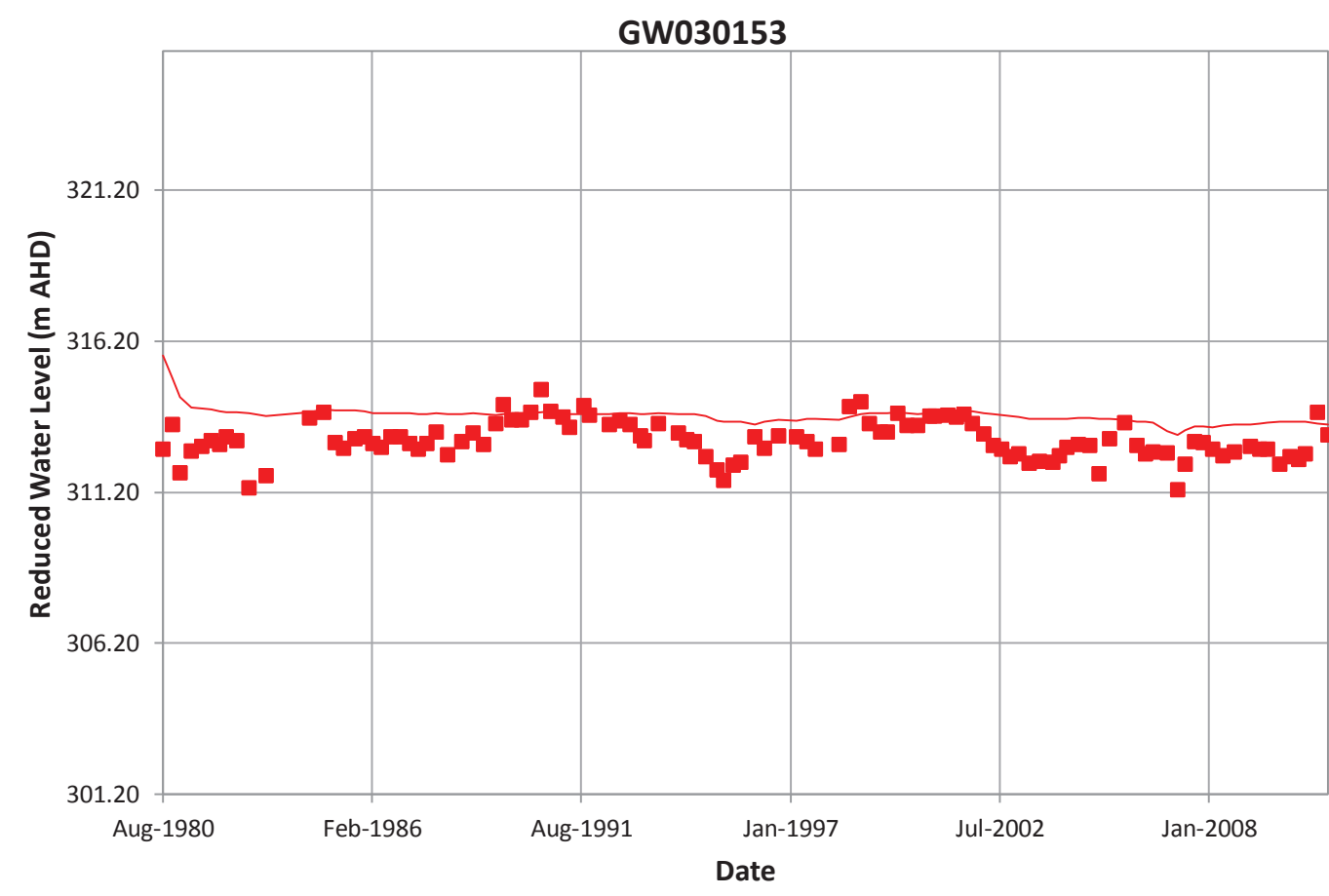


GW030152_1 (Gunnedah Fm) - Computed

GW030152_1 (Gunnedah Fm) - Observed

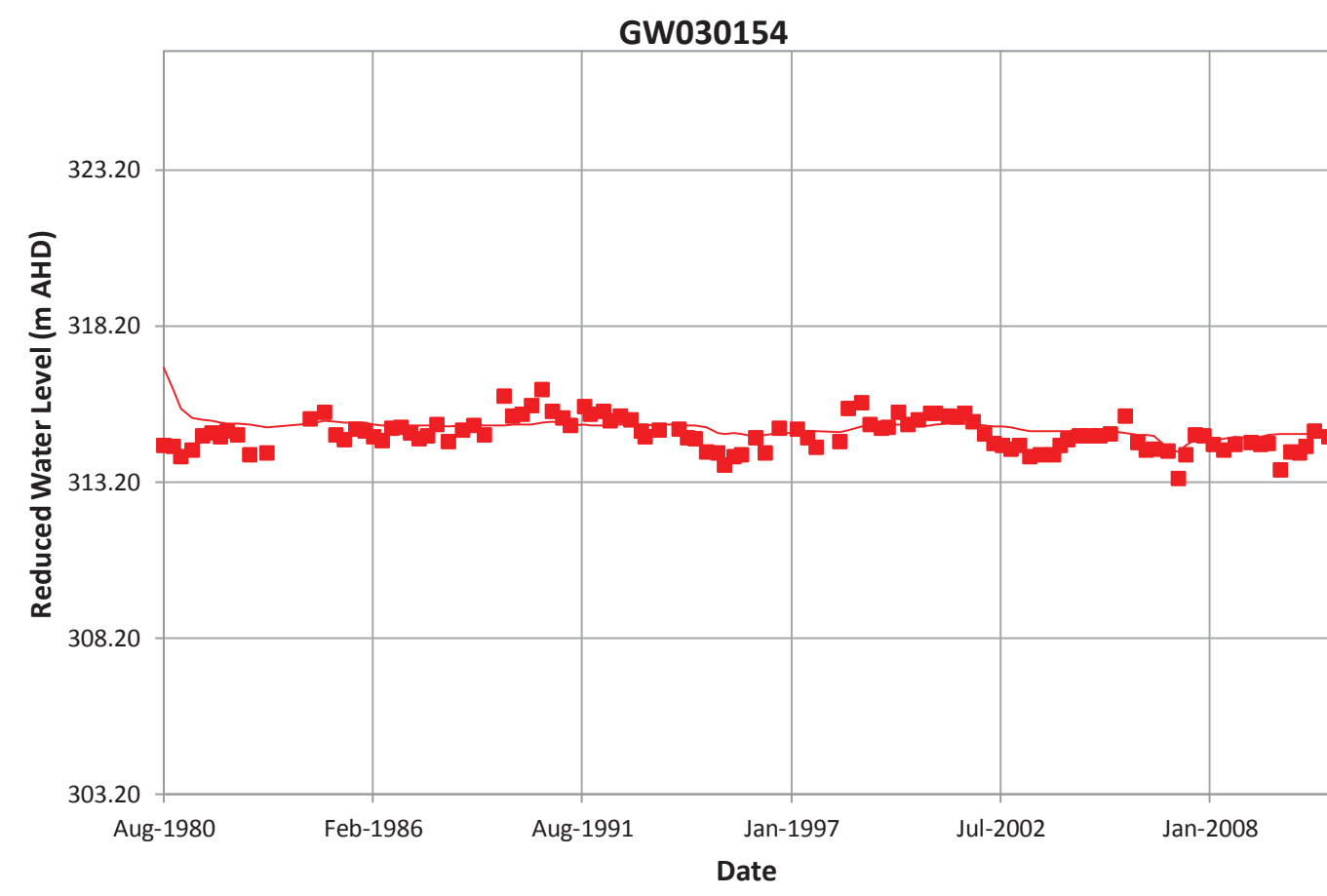
GW030152_2 (Gunnedah Fm) - Computed

GW030152_2 (Gunnedah Fm) - Observed



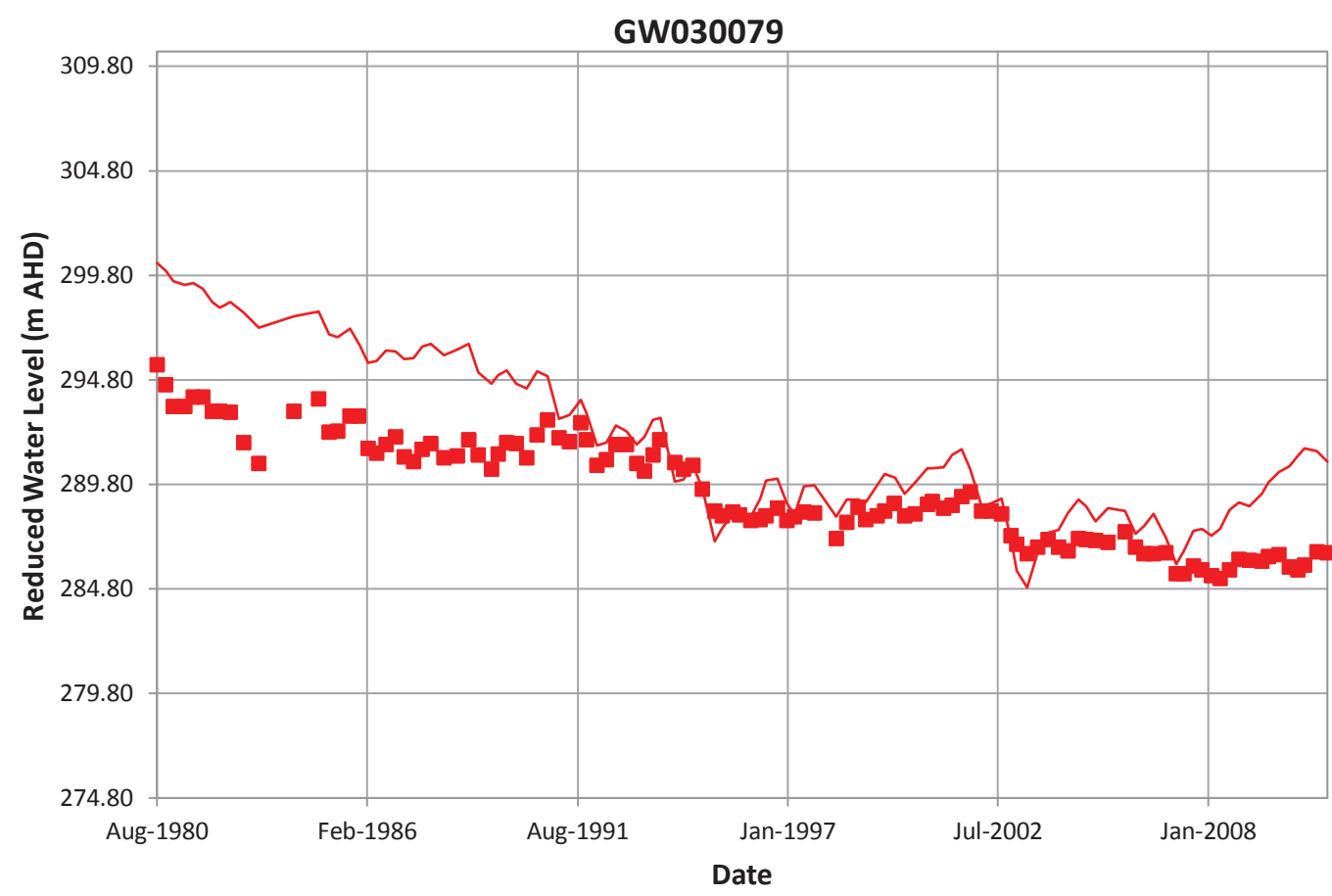
GW030153_1 (Gunnedah Fm) - Computed

GW030153_1 (Gunnedah Fm) - Observed



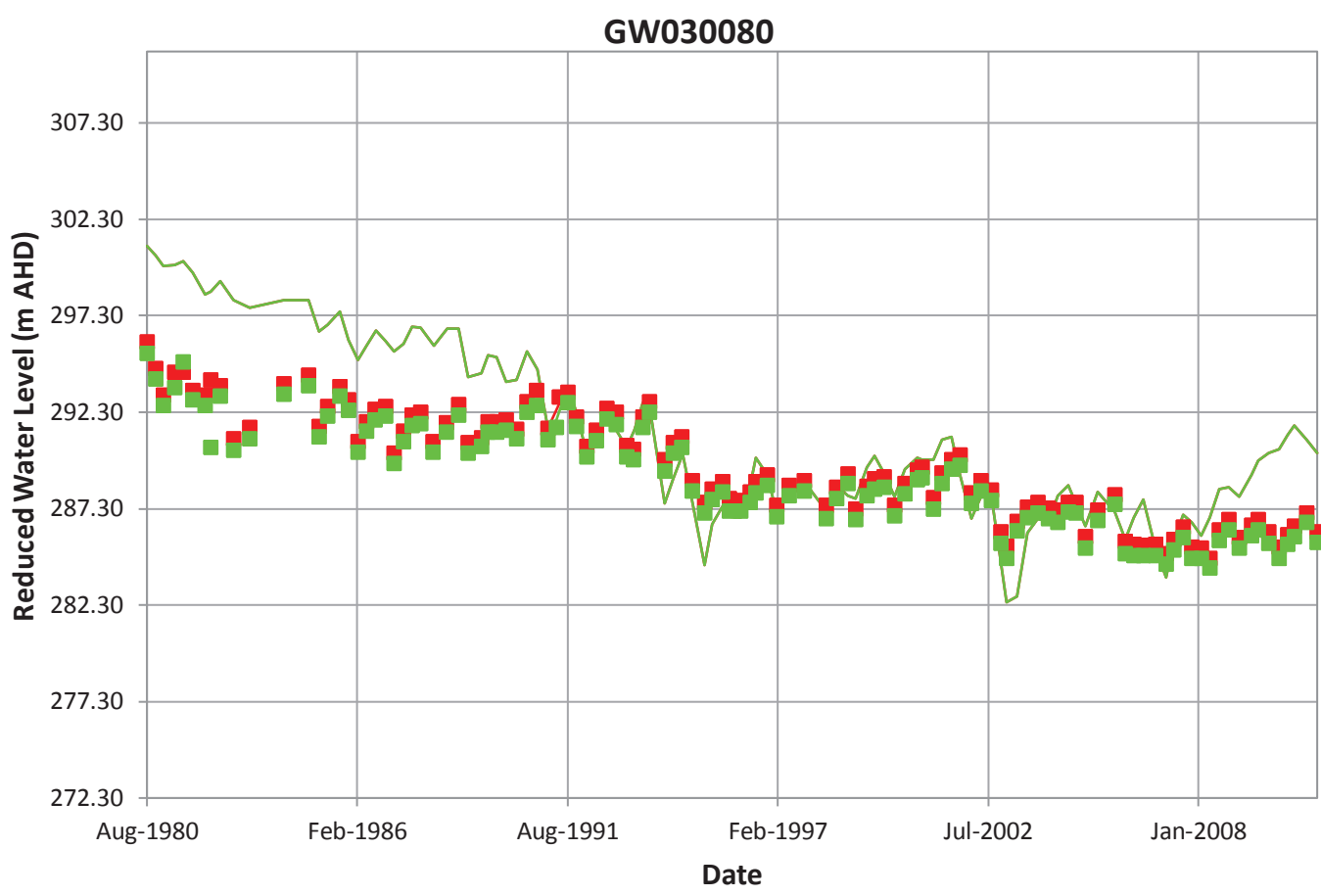
GW030154_1 (Gunnedah Fm) - Computed

GW030154_1 (Gunnedah Fm) - Observed



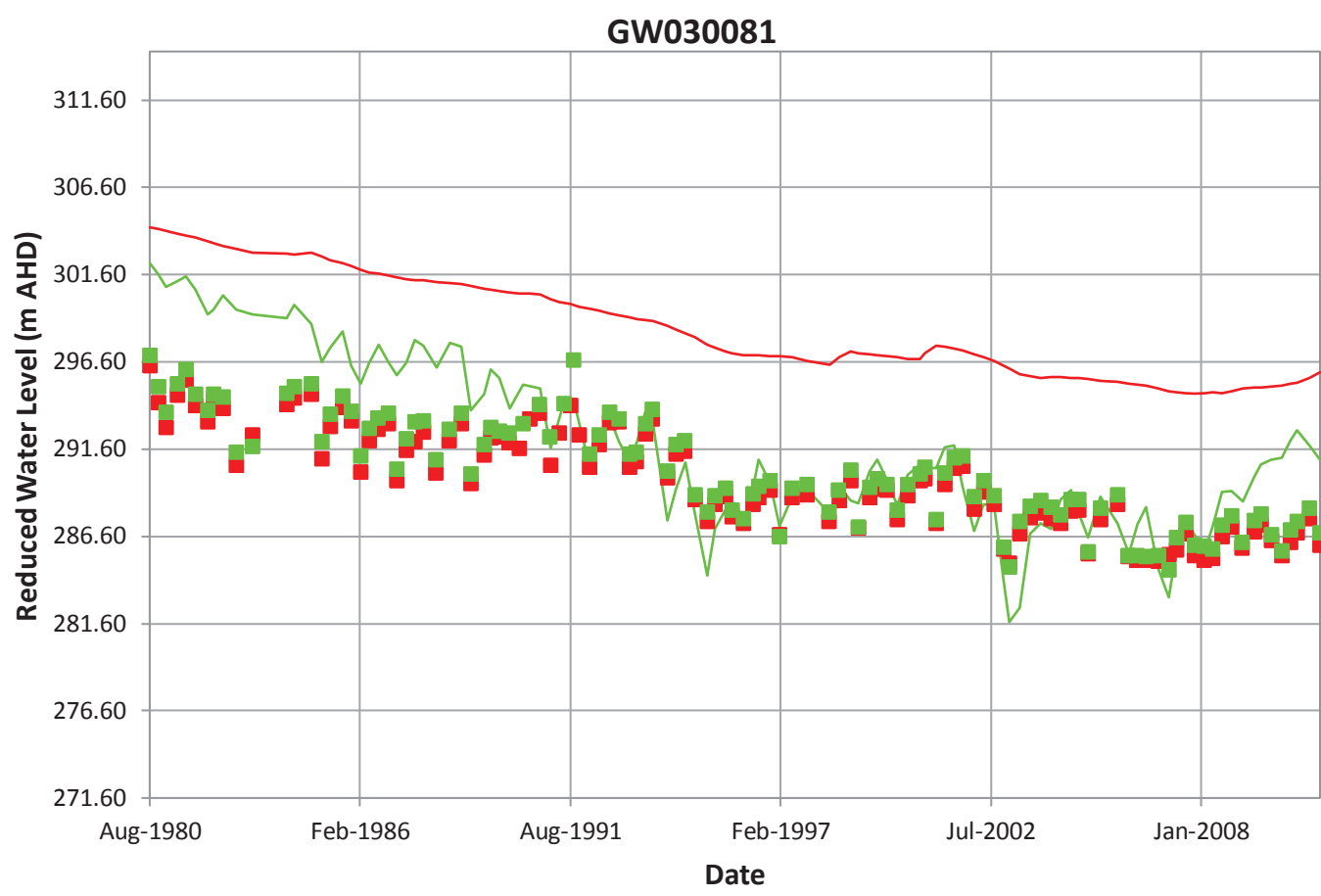
GW030079_1 (Gunnedah Fm) - Computed

GW030079_1 (Gunnedah Fm) - Observed



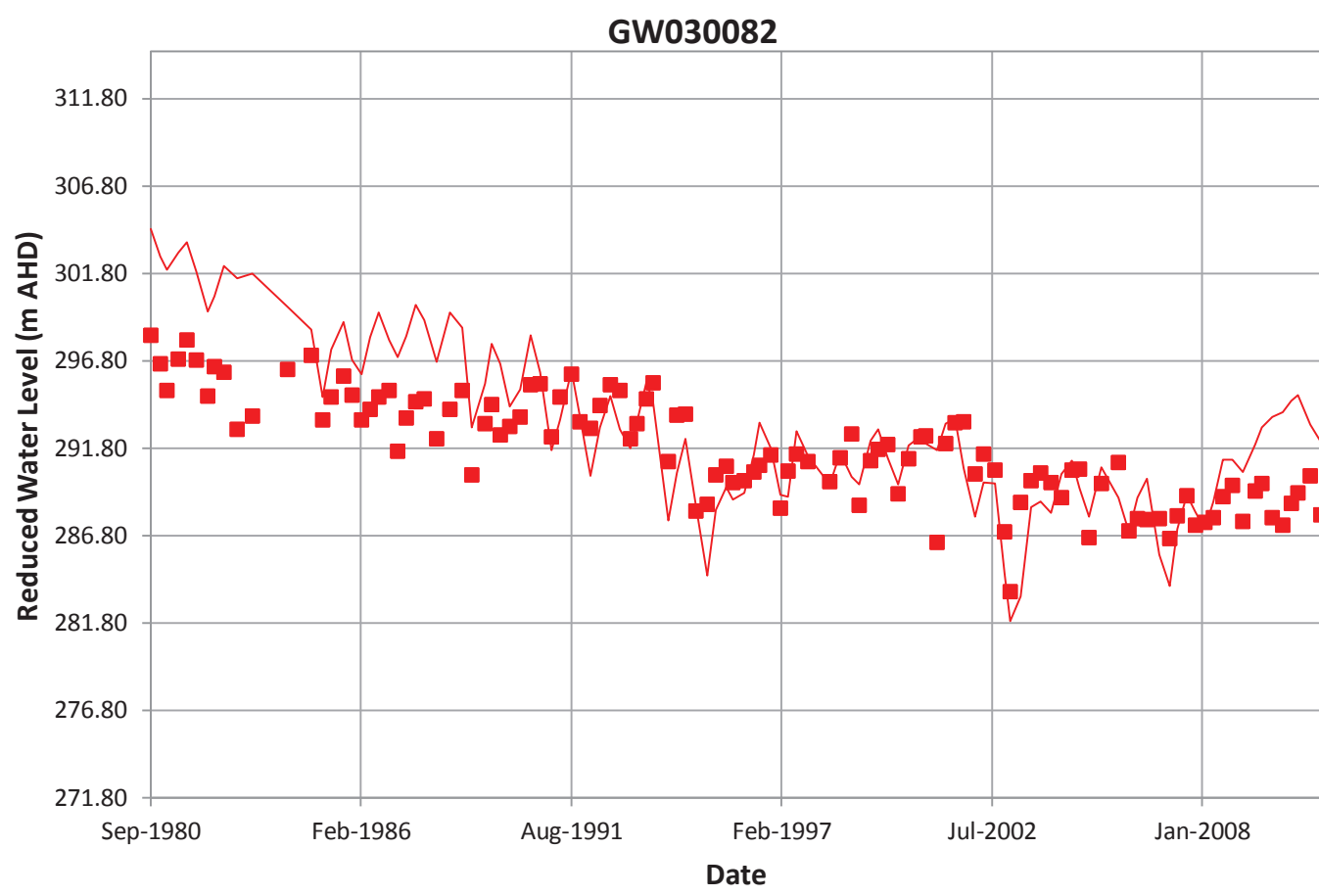
GW030080_1 (Gunnedah Fm) - Computed

GW030080_1 (Gunnedah Fm) - Observed



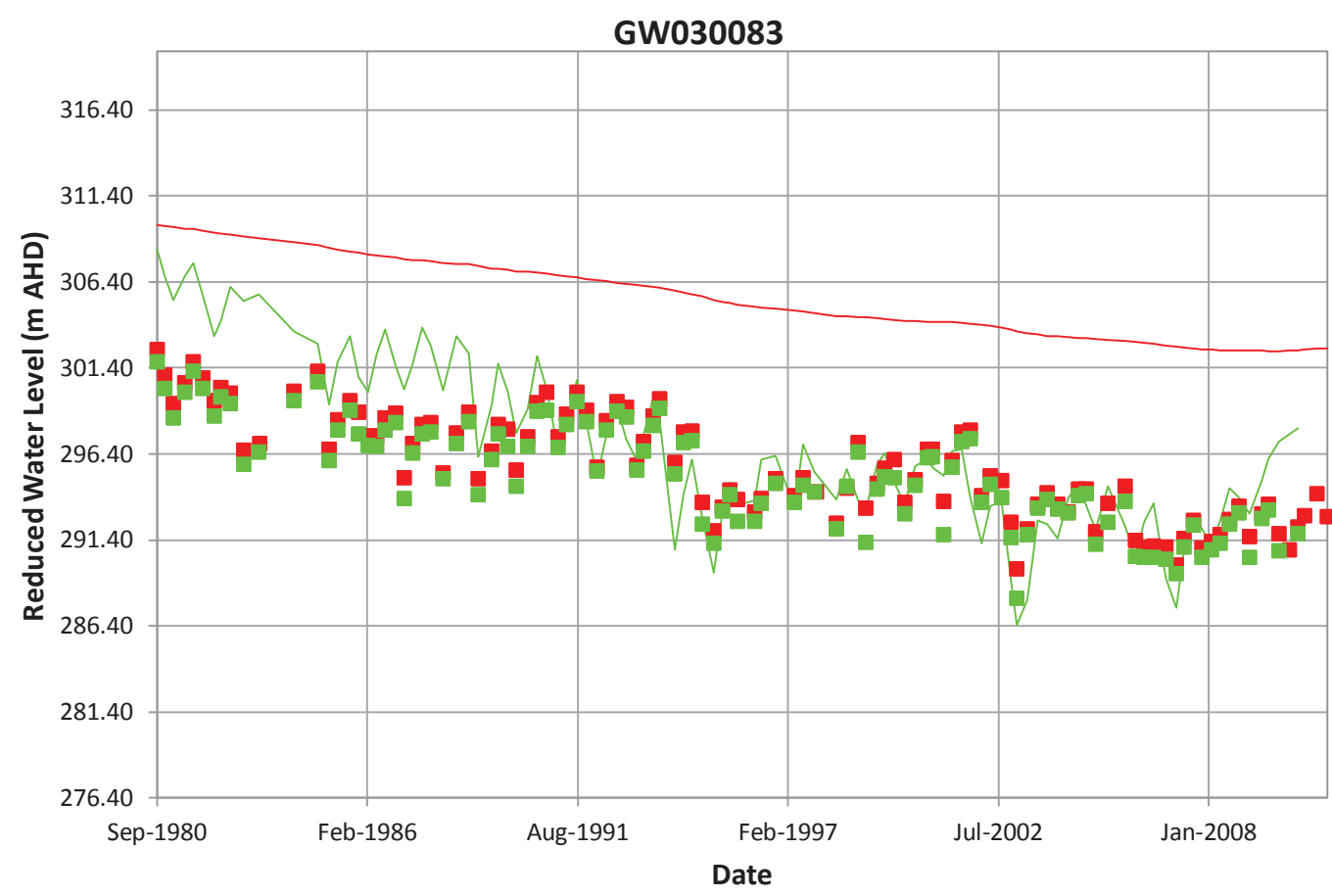
GW030081_1 (Narrabri Fm) - Computed

GW030081_1 (Narrabri Fm) - Observed



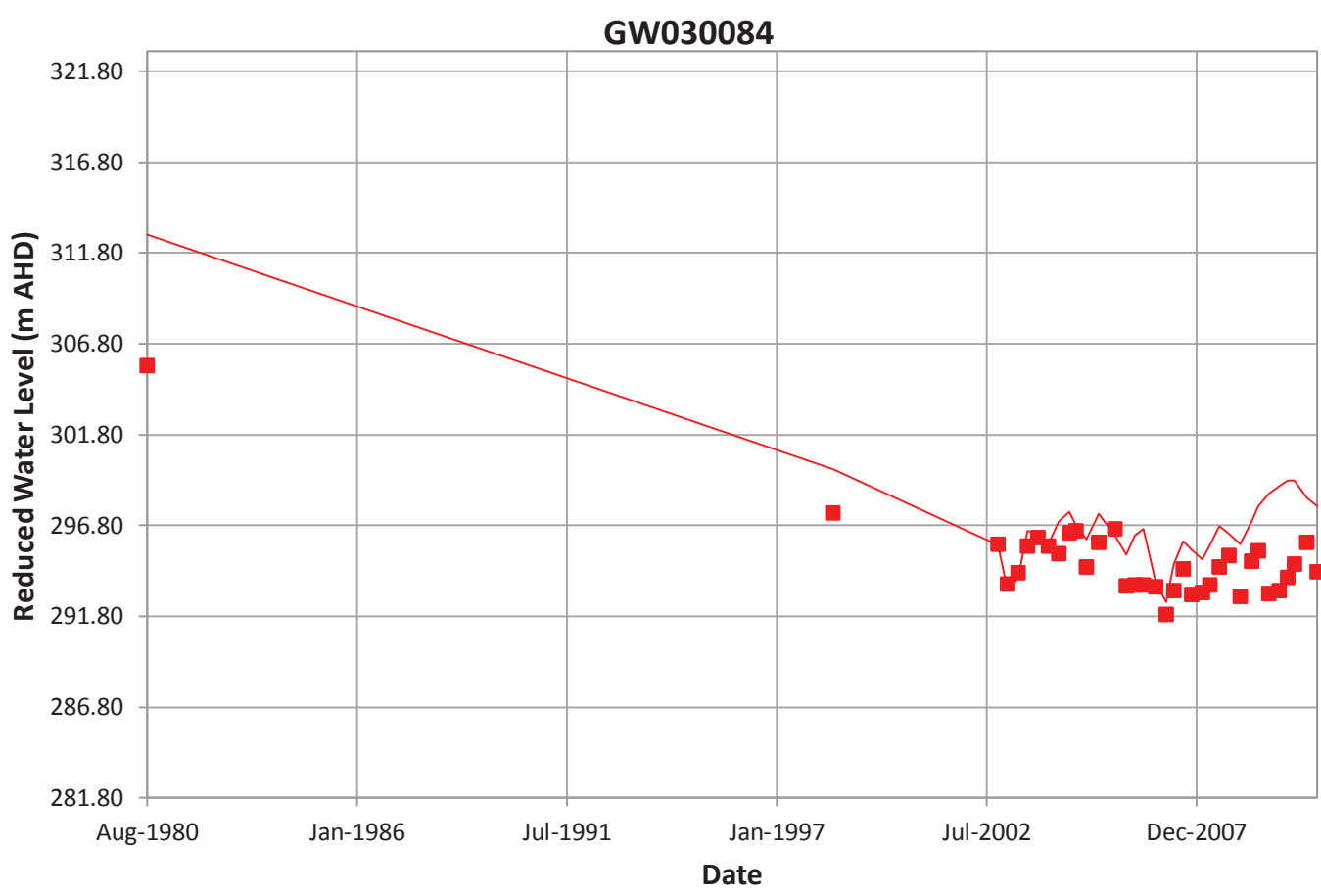
GW030082_1 (Gunnedah Fm) - Computed

GW030082_1 (Gunnedah Fm) - Observed



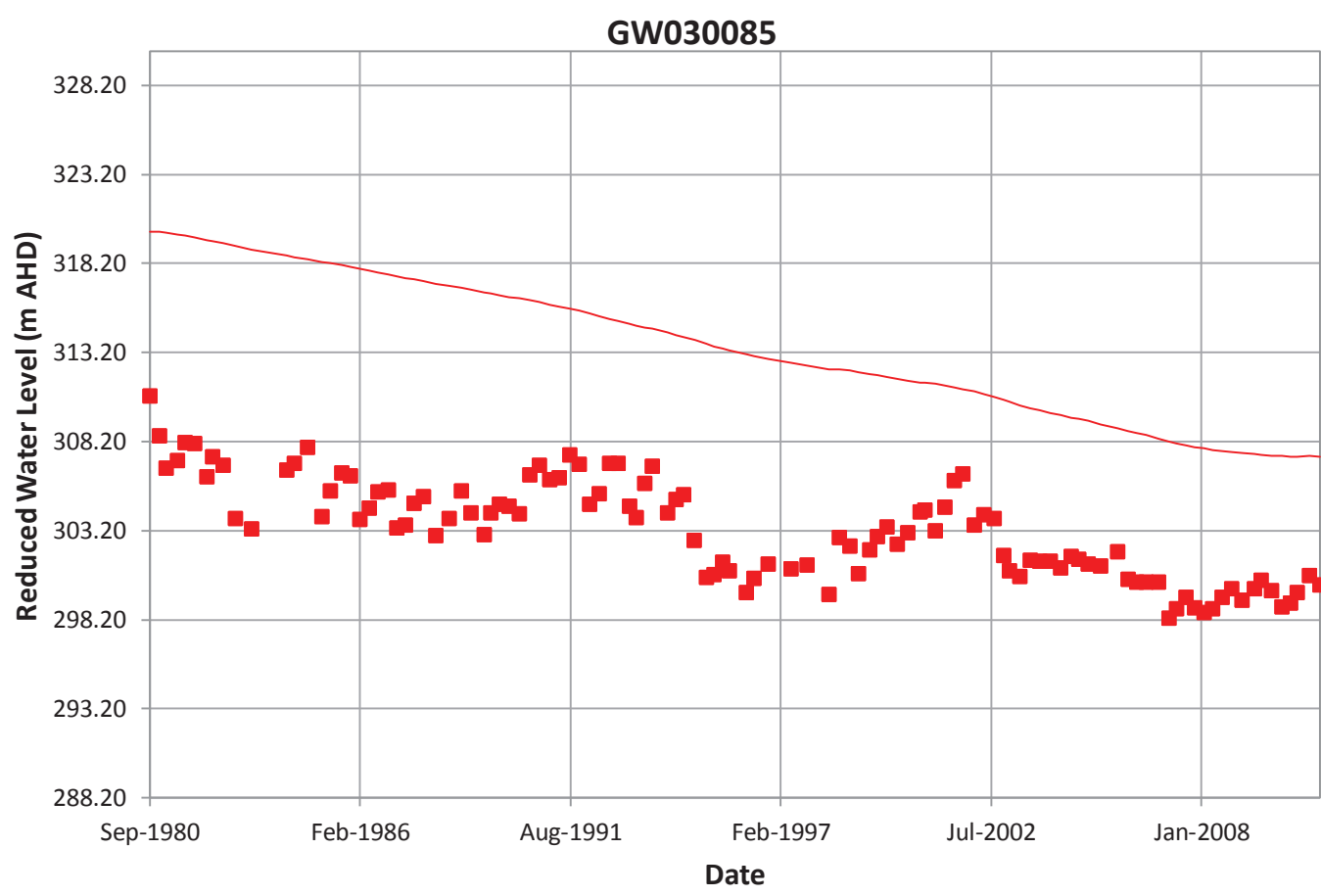
GW030083_1 (Narrabri Fm) - Computed

GW030083_1 (Narrabri Fm) - Observed



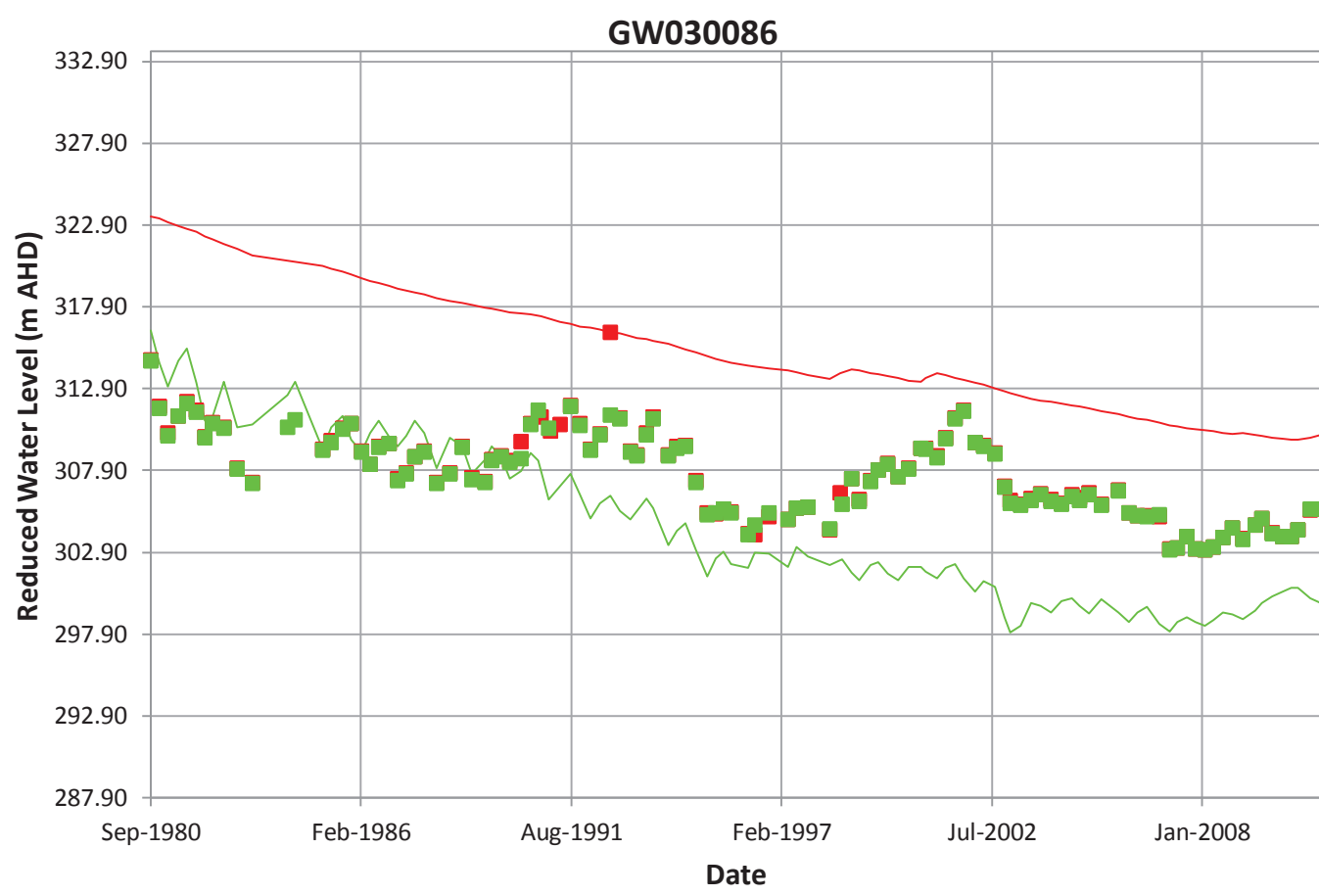
GW030084_1 (Gunnedah Fm) - Computed

GW030084_1 (Gunnedah Fm) - Observed



GW030085_1 (Narrabri Fm) - Computed

GW030085_1 (Narrabri Fm) - Observed



GW030086_1 (Narrabri Fm) - Computed

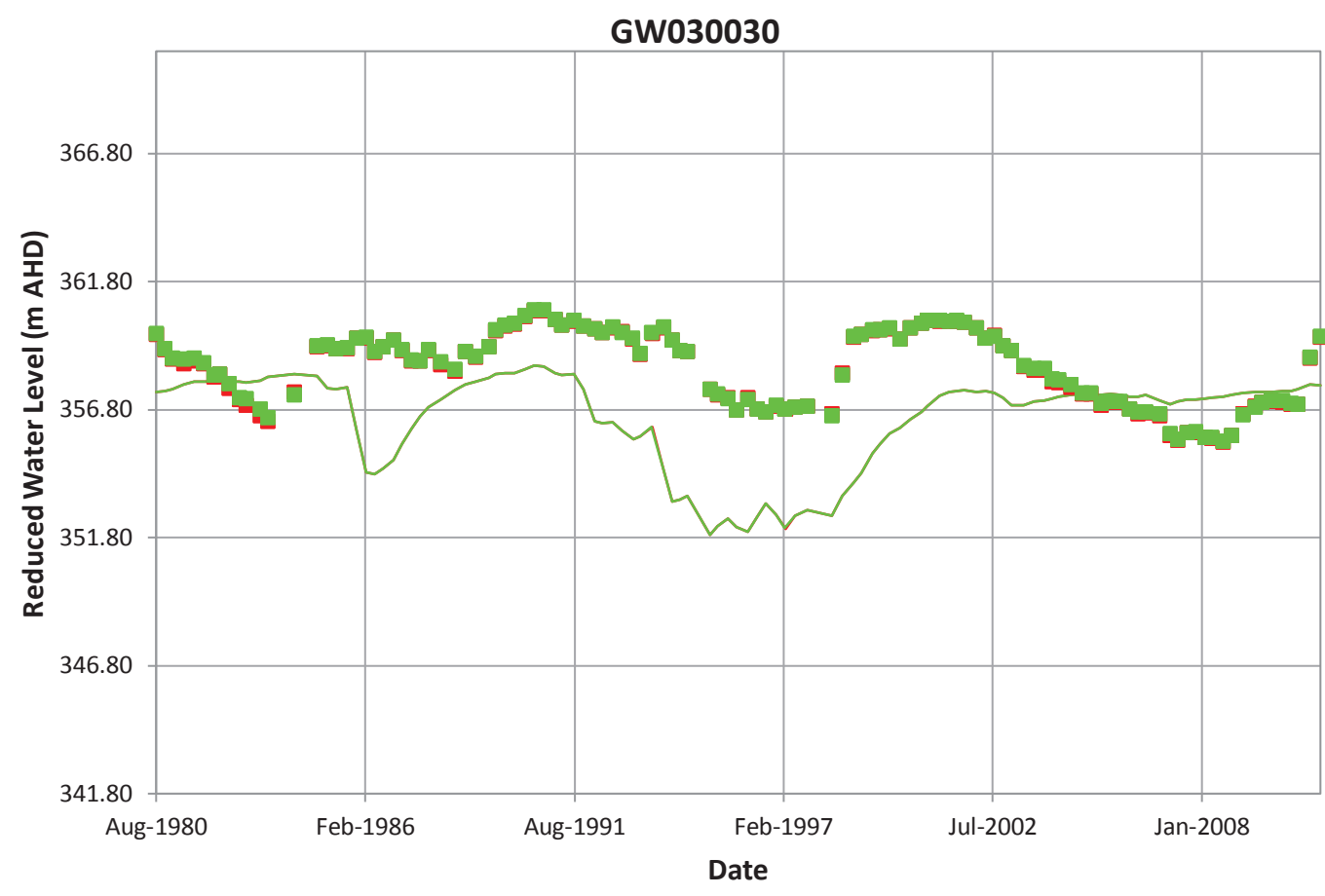
GW030086_1 (Narrabri Fm) - Observed

GW030083_2 (Gunnedah Fm) - Computed

GW030083_2 (Gunnedah Fm) - Observed

GW030086_2 (Gunnedah Fm) - Computed

GW030086_2 (Gunnedah Fm) - Observed

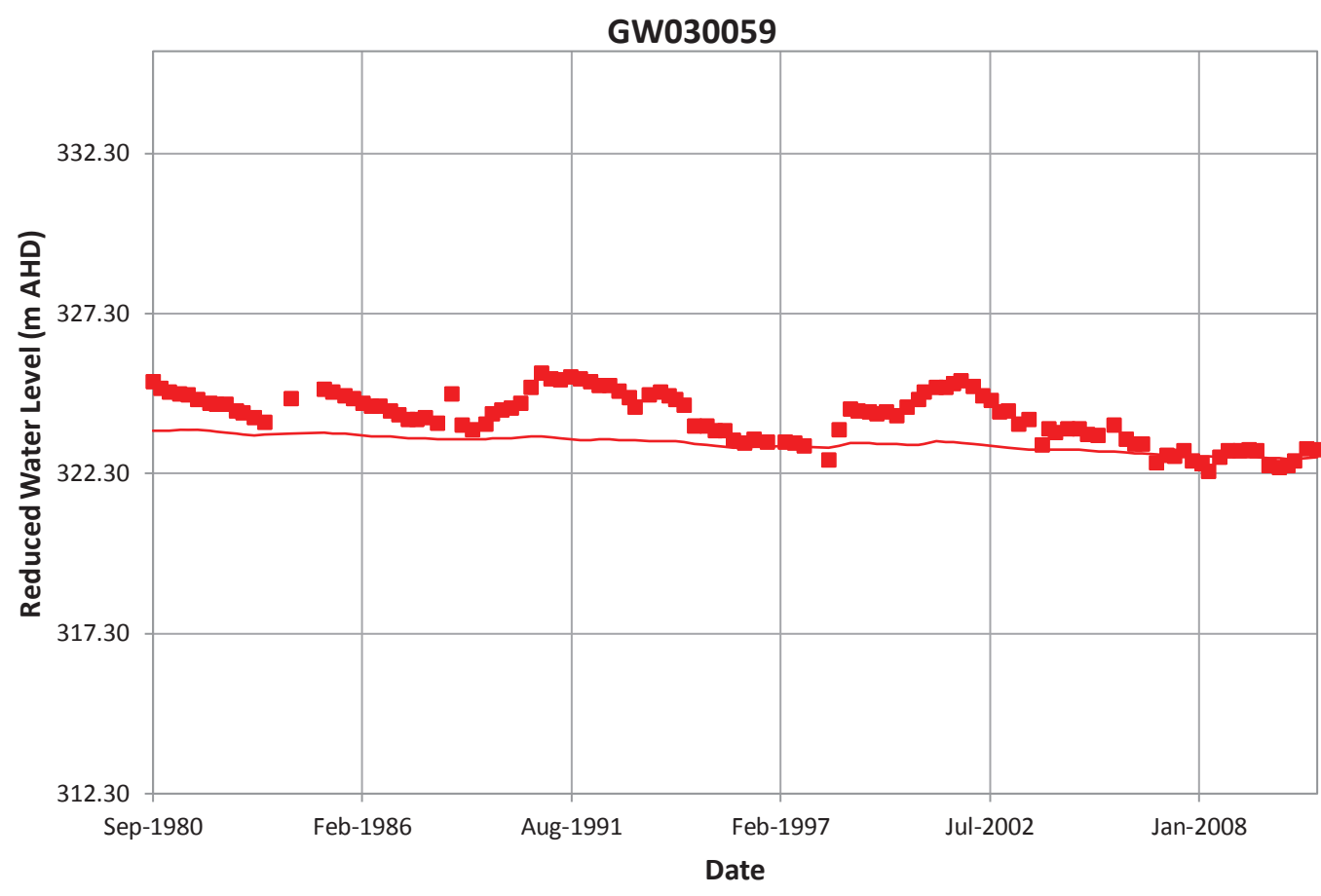


GW030030_1 (Gunnedah Fm) - Computed

GW030030_1 (Gunnedah Fm) - Observed

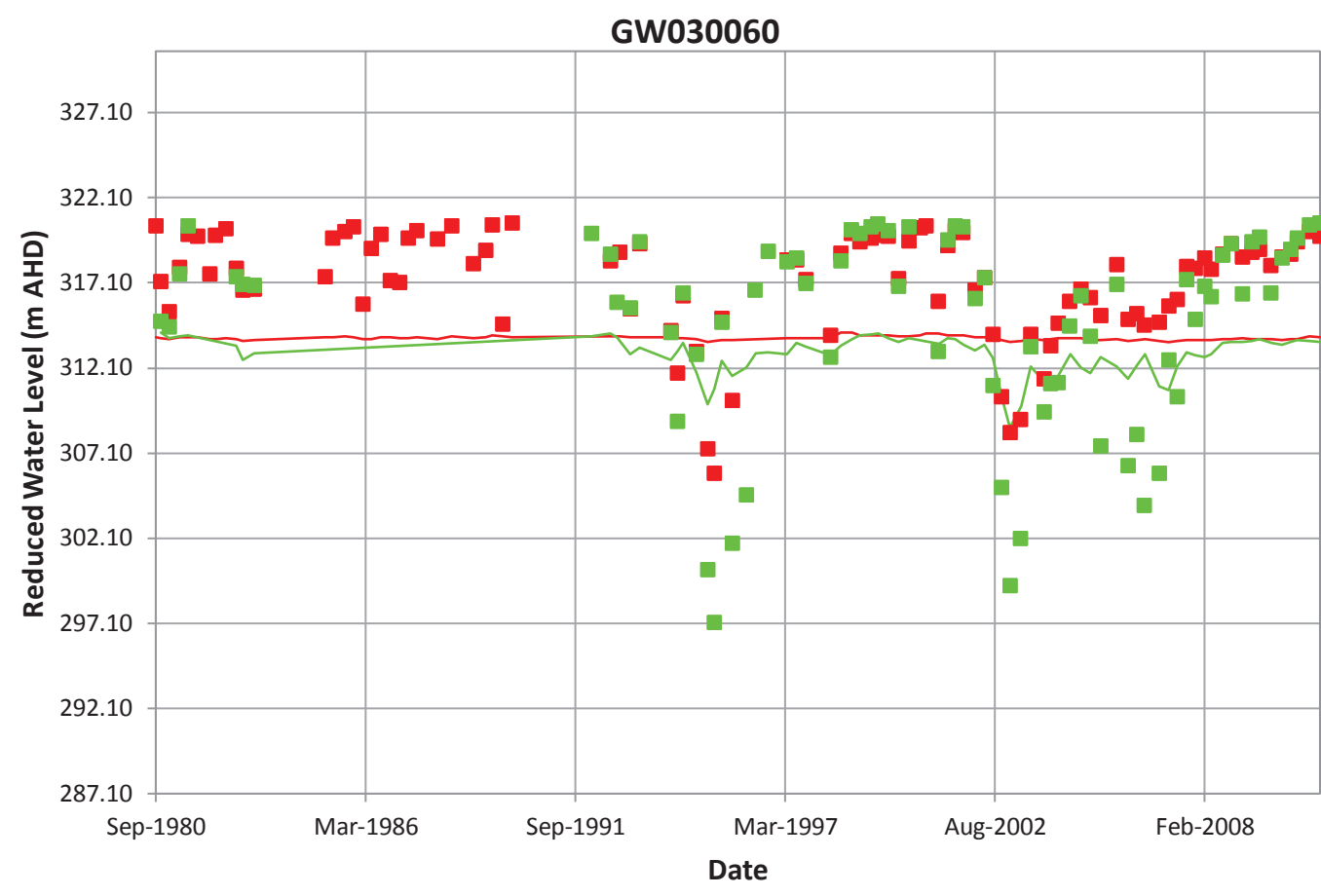
GW030030_2 (Gunnedah Fm) - Computed

GW030030_2 (Gunnedah Fm) - Observed



GW030059_1 (Gunnedah Fm) - Computed

GW030059_1 (Gunnedah Fm) - Observed

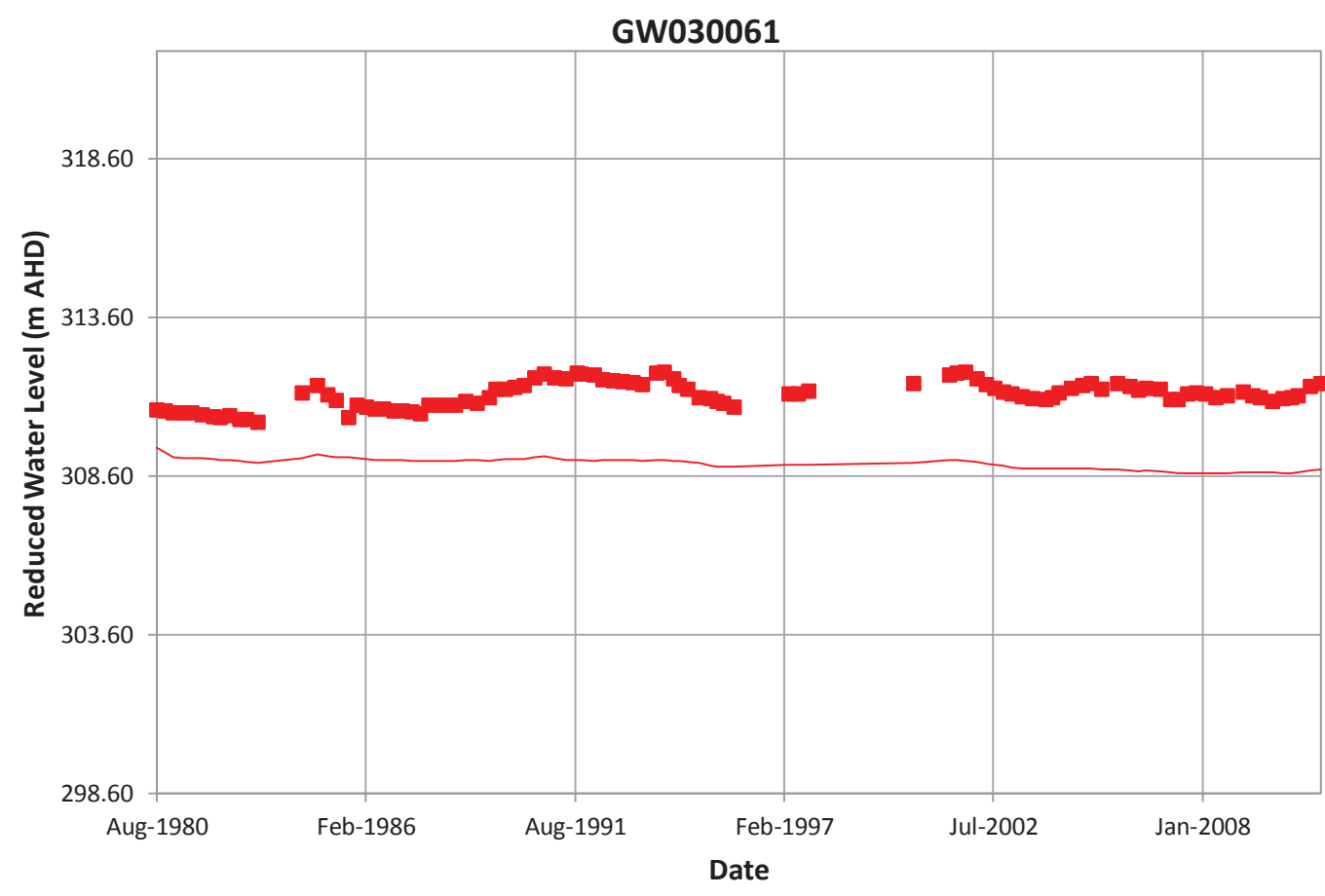


GW030060_1 (Narrabri Fm) - Computed

GW030060_1 (Narrabri Fm) - Observed

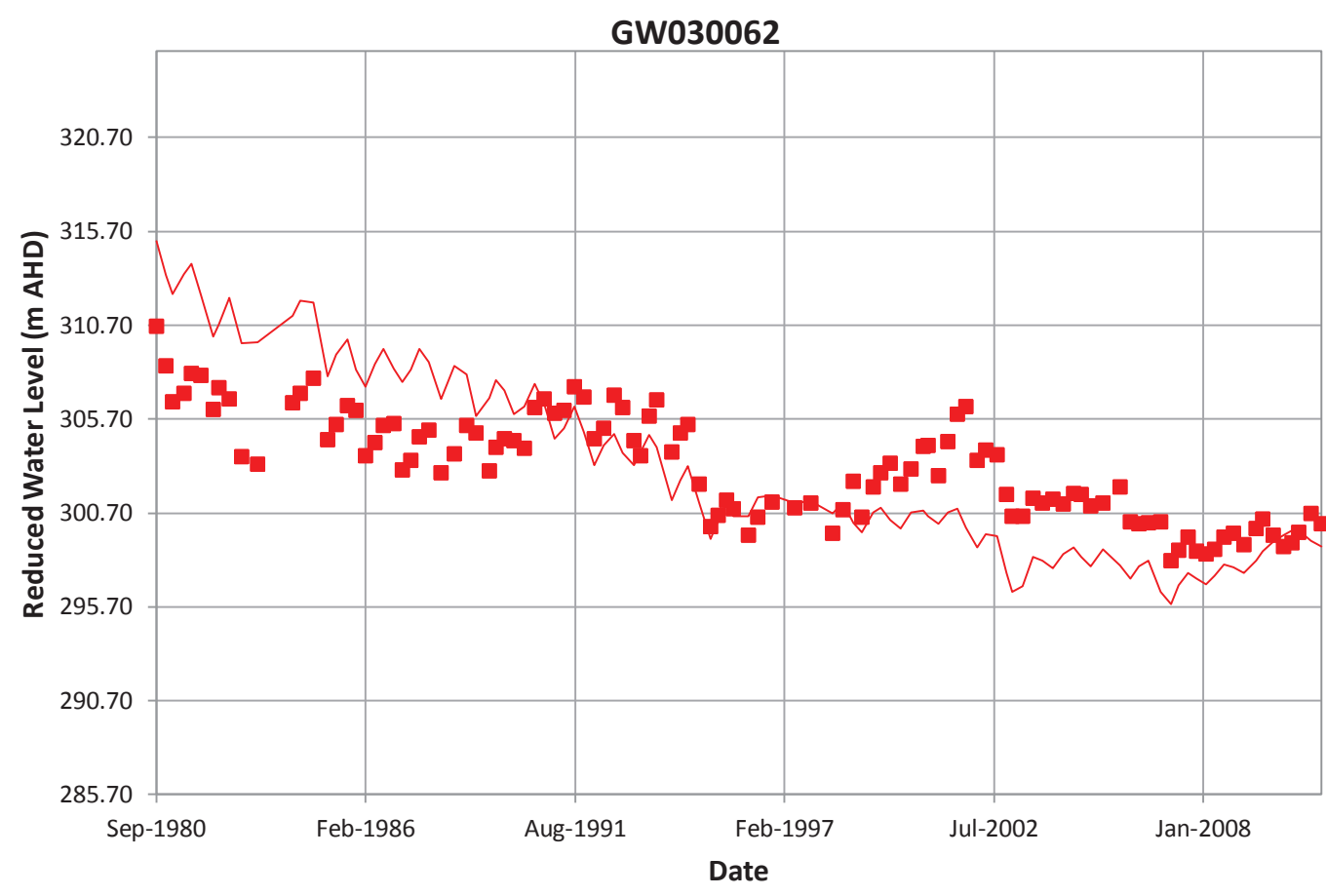
GW030060_2 (Gunnedah Fm) - Computed

GW030060_2 (Gunnedah Fm) - Observed



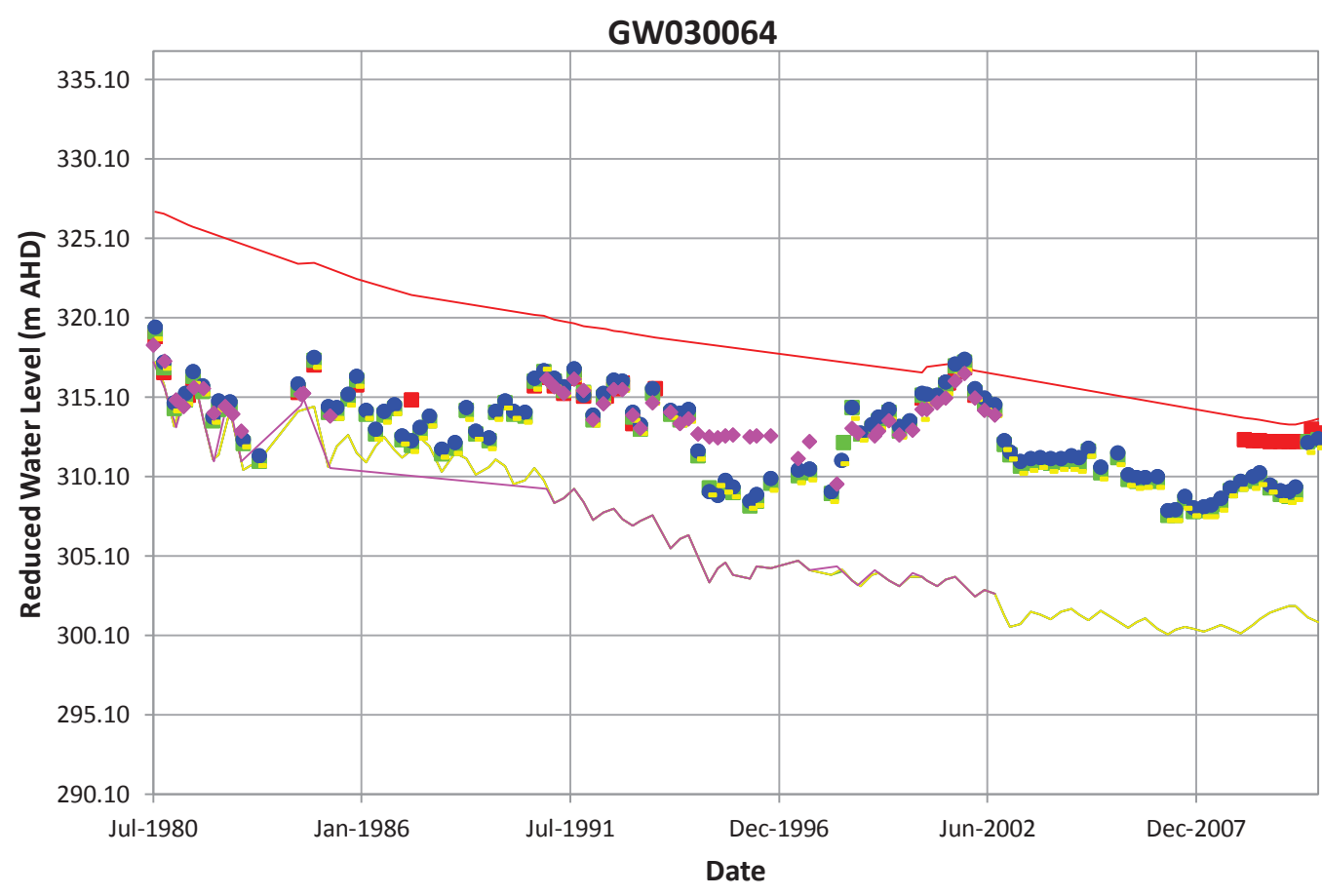
GW030061_1 (Gunnedah Fm) - Computed

GW030061_1 (Gunnedah Fm) - Observed



GW030062_1 (Gunnedah Fm) - Computed

GW030062_1 (Gunnedah Fm) - Observed



GW030064_1 (Narrabri Fm) - Computed

GW030064_1 (Narrabri Fm) - Observed

GW030064_2 (Gunnedah Fm) - Computed

GW030064_2 (Gunnedah Fm) - Observed

GW030064_3 (Gunnedah Fm) - Computed

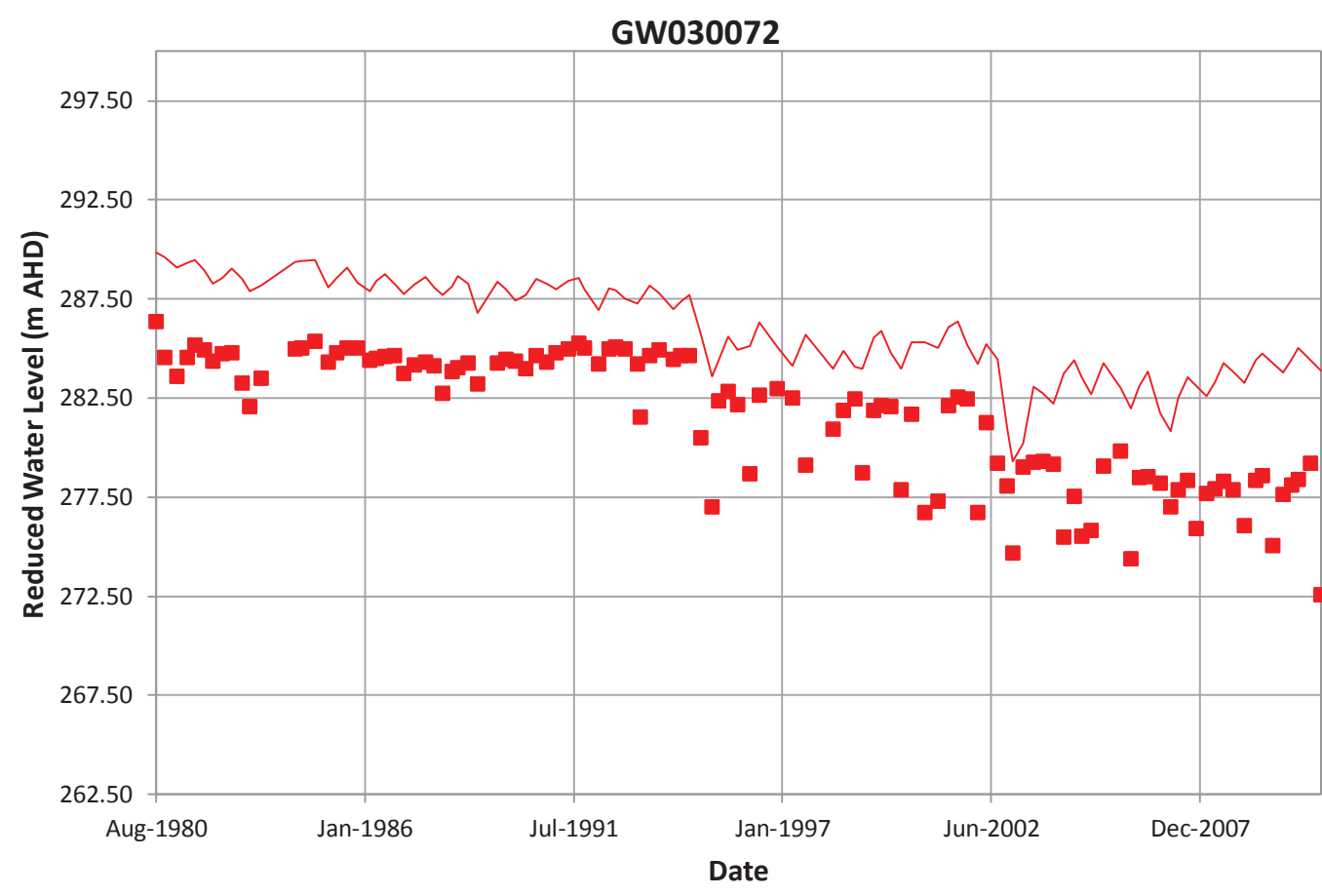
GW030064_3 (Gunnedah Fm) - Observed

GW030064_4 (Gunnedah Fm) - Computed

GW030064_4 (Gunnedah Fm) - Observed

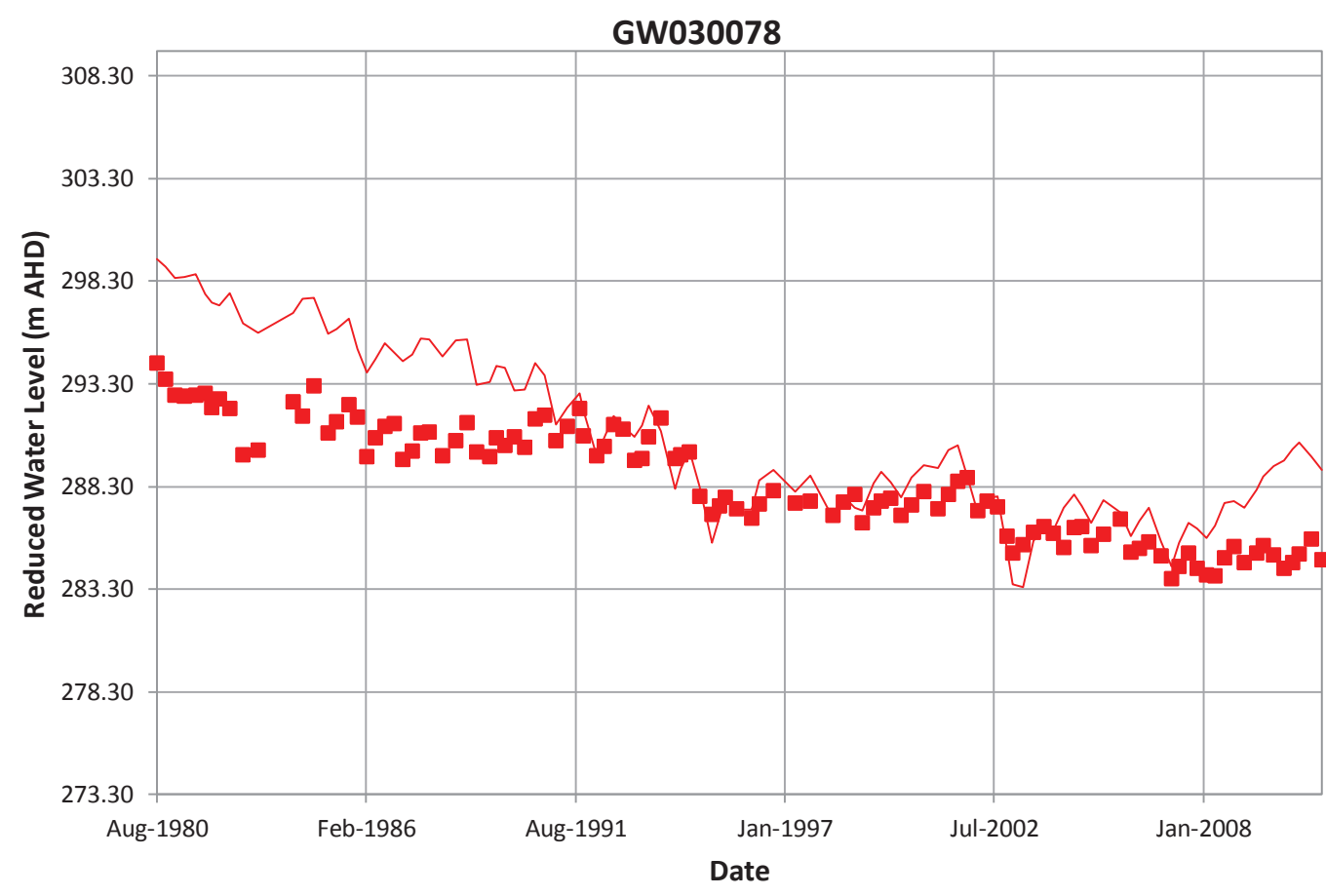
GW030064_5 (Gunnedah Fm) - Computed

GW030064_5 (Gunnedah Fm) - Observed



GW030072_1 (Gunnedah Fm) - Computed

GW030072_1 (Gunnedah Fm) - Observed



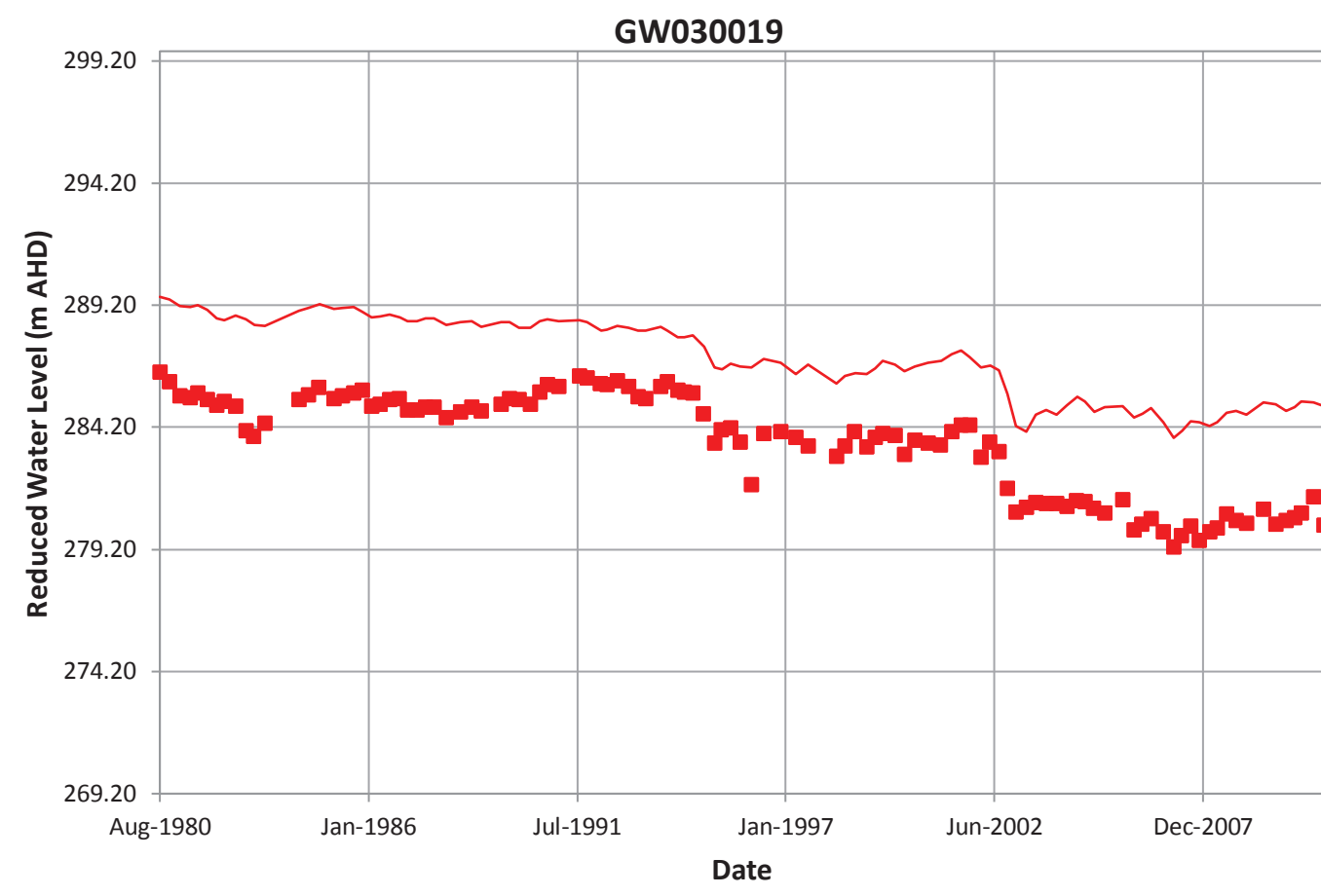
GW030078_1 (Gunnedah Fm) - Computed

GW030078_1 (Gunnedah Fm) - Observed



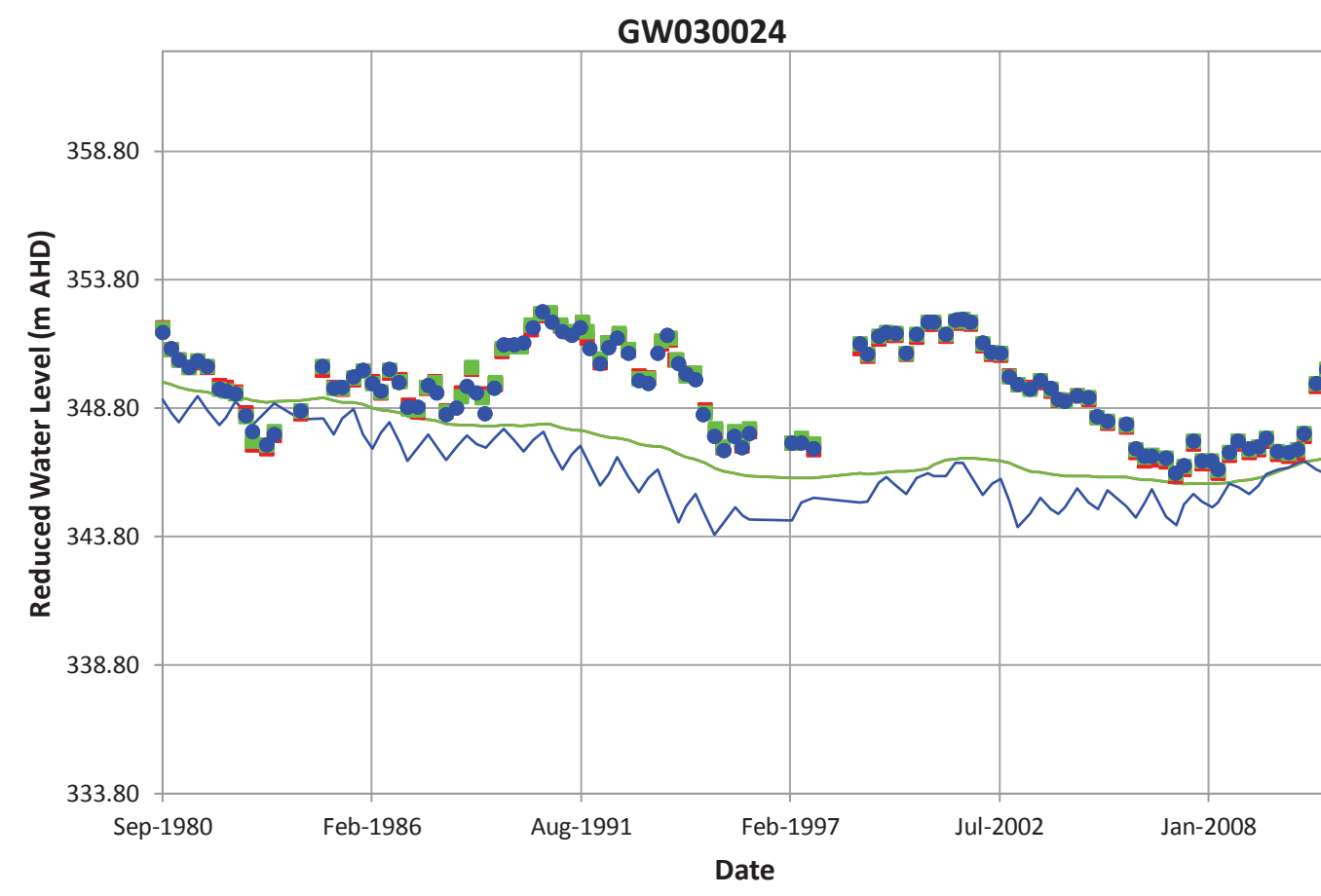
GW030018_1 (Narrabri Fm) - Computed

GW030018_1 (Narrabri Fm) - Observed



GW030019_1 (Gunnedah Fm) - Computed

GW030019_1 (Gunnedah Fm) - Observed



GW030024_1 (Narrabri Fm) - Computed

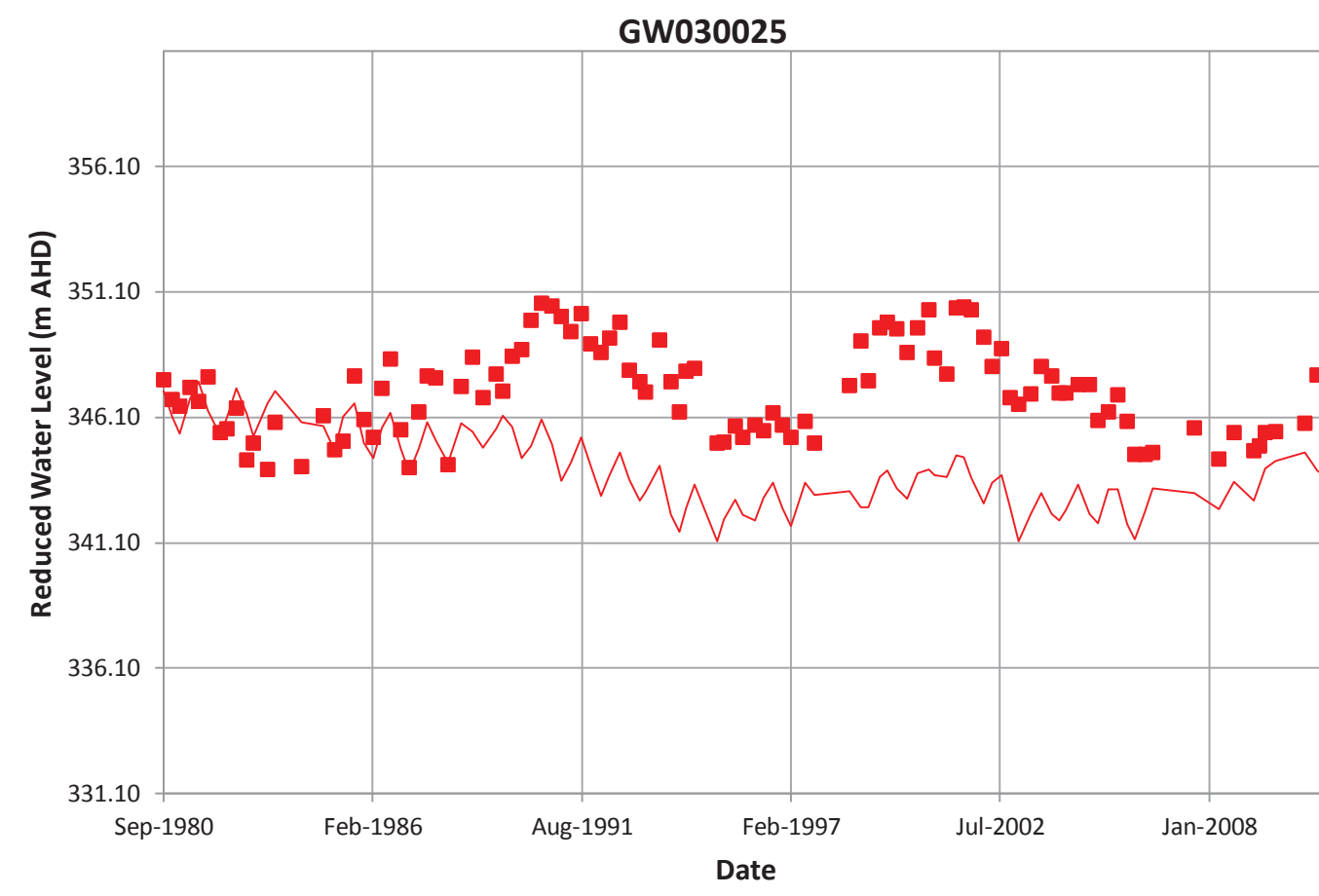
GW030024_1 (Narrabri Fm) - Observed

GW030024_2 (Narrabri Fm) - Computed

GW030024_2 (Narrabri Fm) - Observed

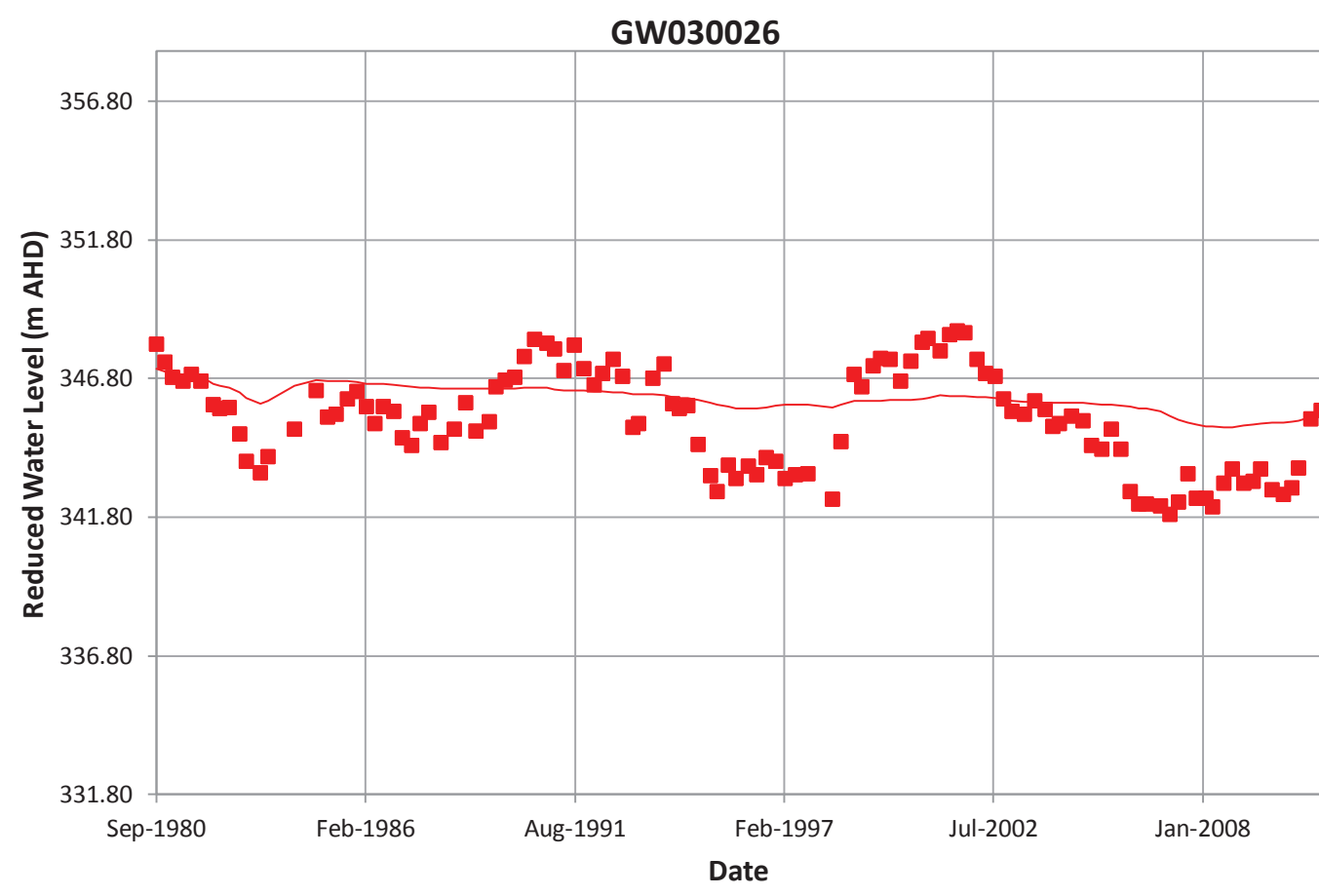
GW030024_3 (Gunnedah Fm) - Computed

GW030024_3 (Gunnedah Fm) - Observed



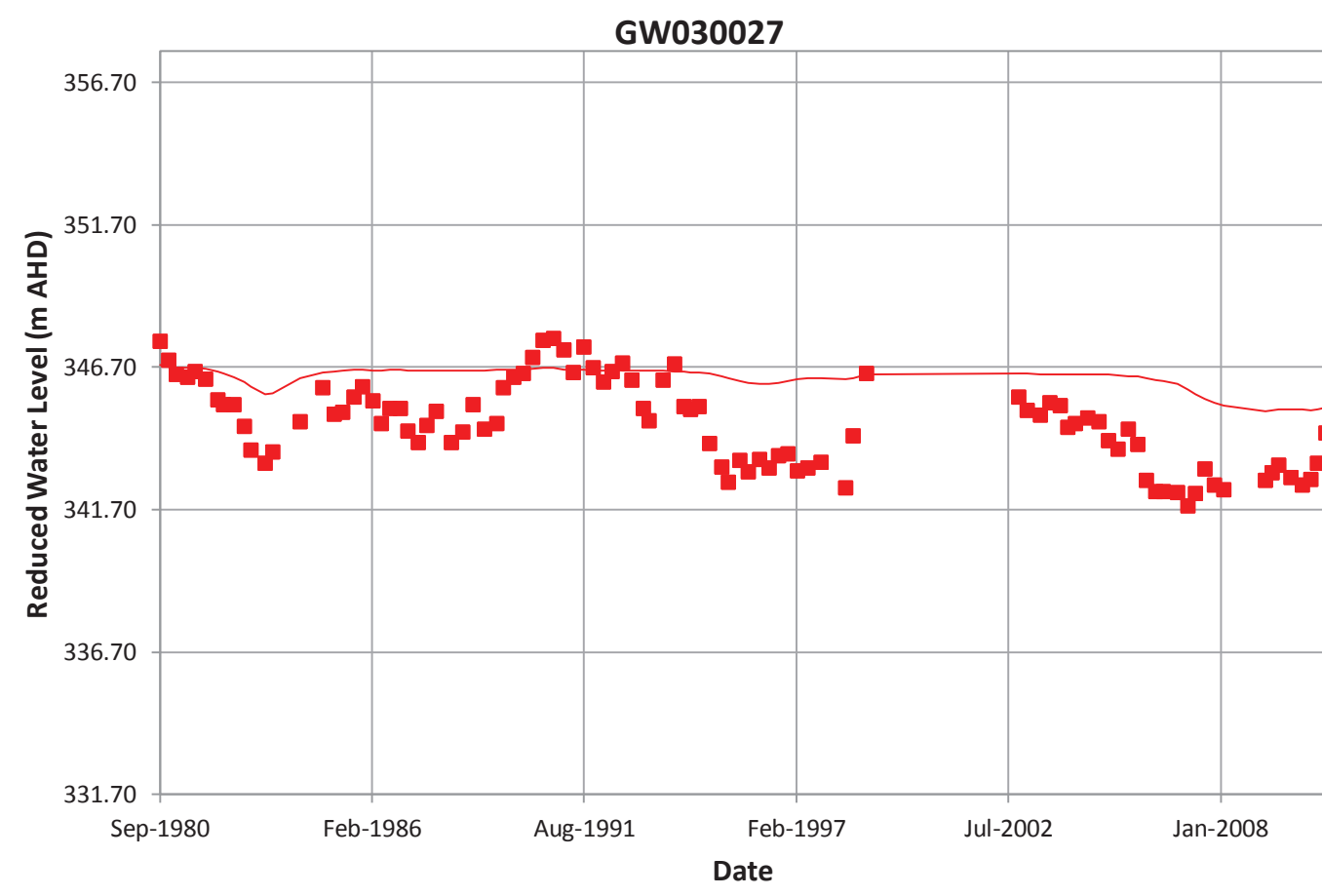
GW030025_1 (Gunnedah Fm) - Computed

GW030025_1 (Gunnedah Fm) - Observed



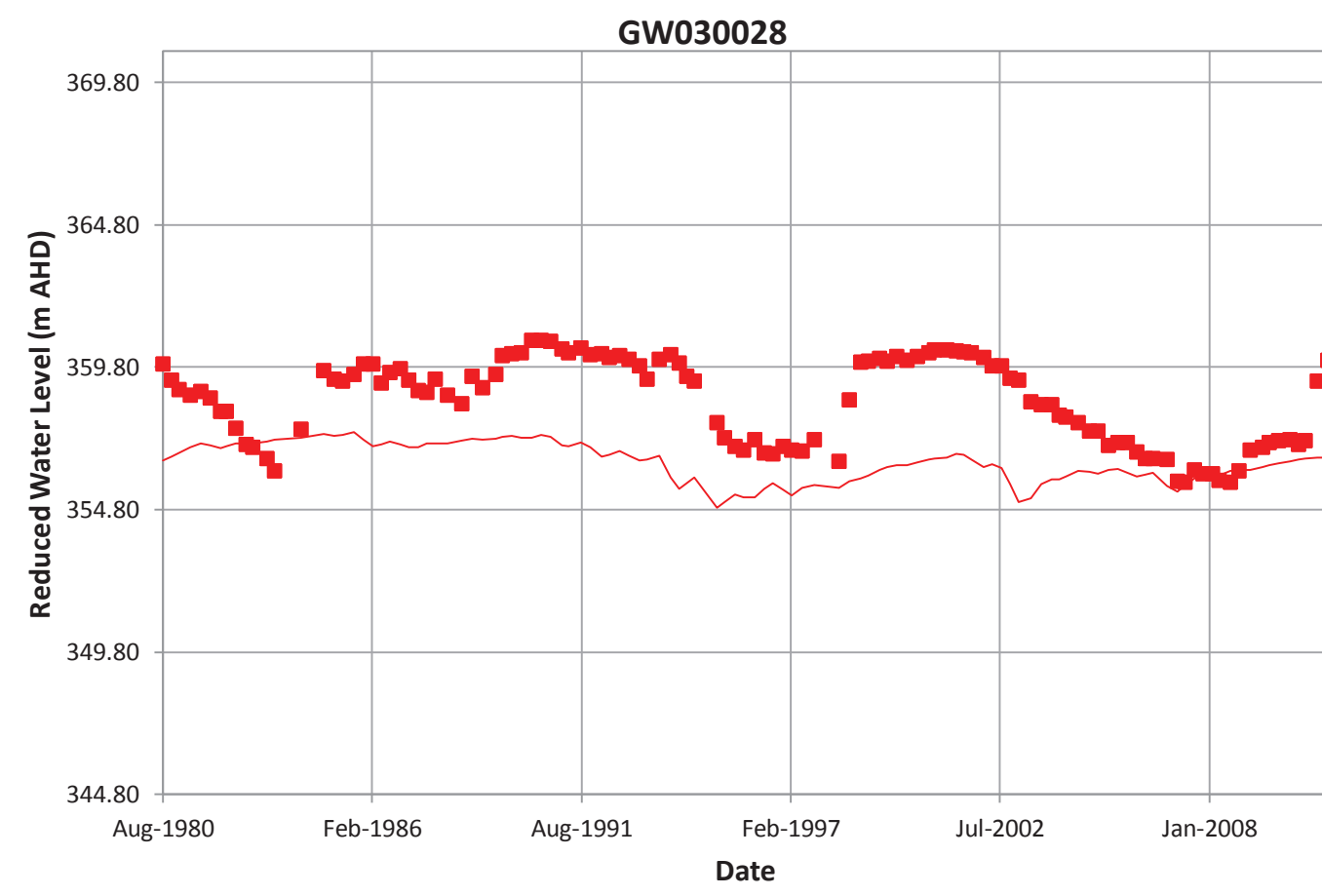
GW030026_1 (Narrabri Fm) - Computed

GW030026_1 (Narrabri Fm) - Observed



GW030027_1 (Narrabri Fm) - Computed

GW030027_1 (Narrabri Fm) - Observed



GW030028_1 (Gunnedah Fm) - Computed

GW030028_1 (Gunnedah Fm) - Observed

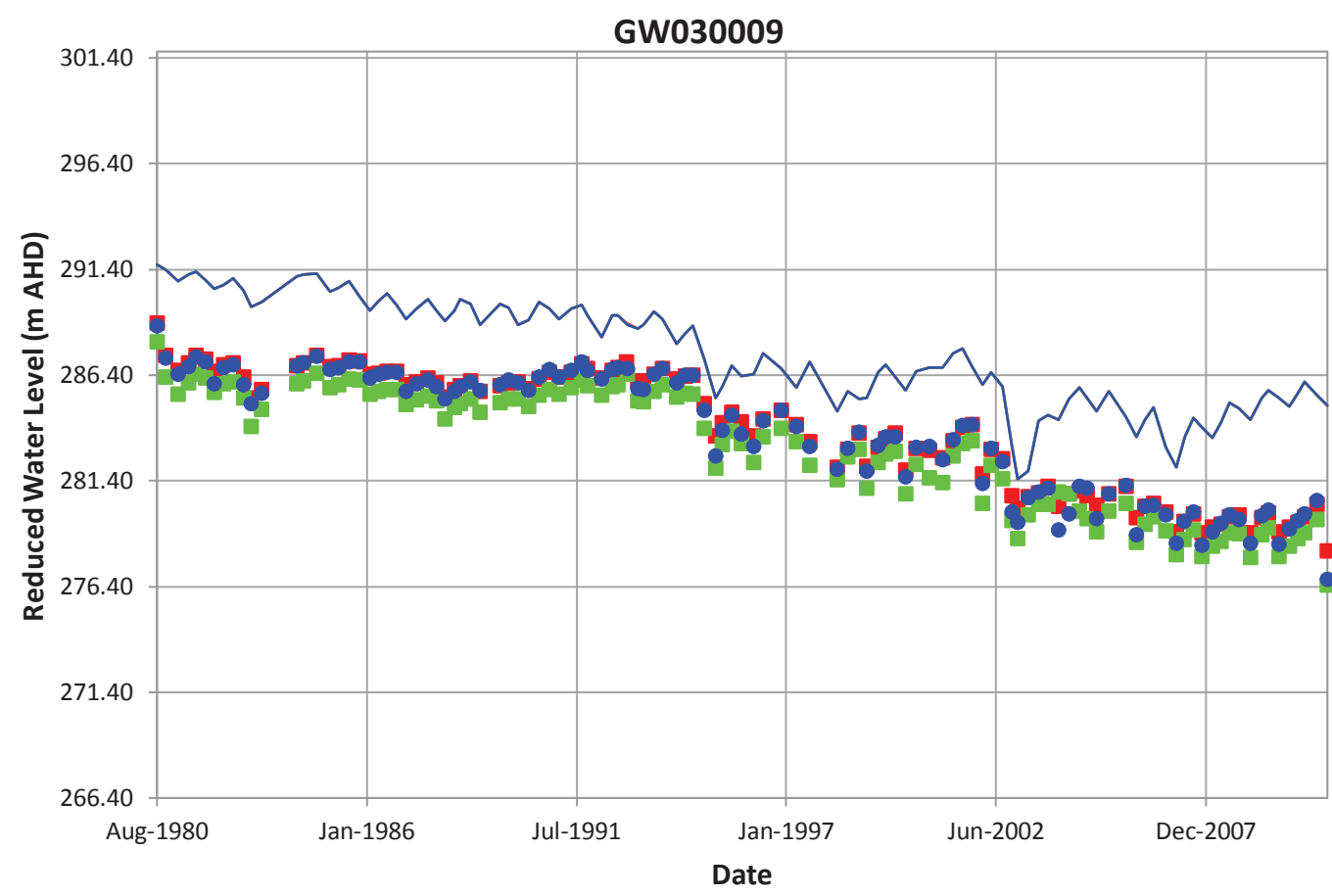


GW030029_1 (Narrabri Fm) - Computed

GW030029_1 (Narrabri Fm) - Observed

GW030029_2 (Gunnedah Fm) - Computed

GW030029_2 (Gunnedah Fm) - Observed



GW030009_1 (Gunnedah Fm) - Computed

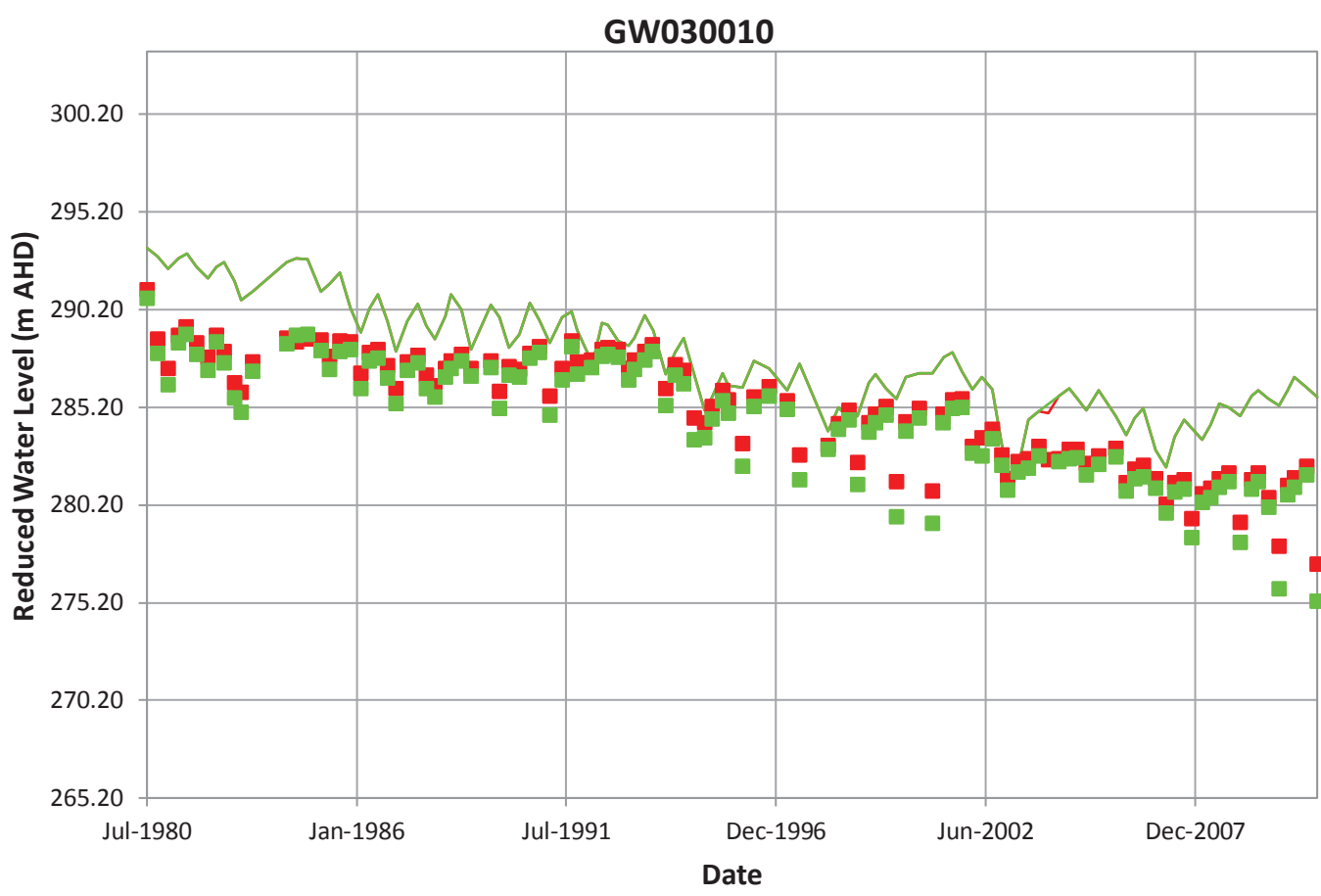
GW030009_1 (Gunnedah Fm) - Observed

GW030009_2 (Gunnedah Fm) - Computed

GW030009_2 (Gunnedah Fm) - Observed

GW030009_3 (Gunnedah Fm) - Computed

GW030009_3 (Gunnedah Fm) - Observed

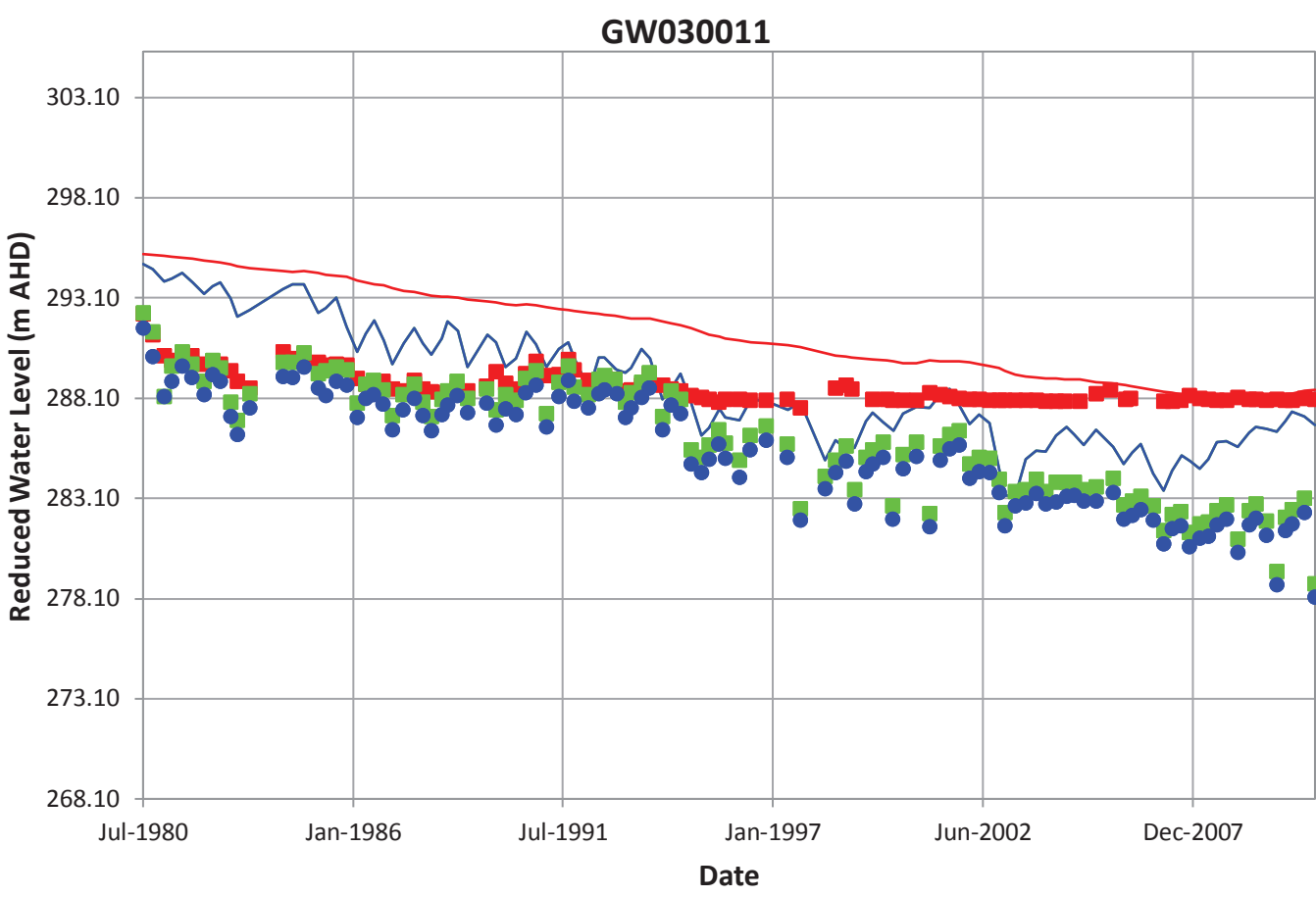


GW030010_1 (Gunnedah Fm) - Computed

GW030010_1 (Gunnedah Fm) - Observed

GW030010_2 (Gunnedah Fm) - Computed

GW030010_2 (Gunnedah Fm) - Observed



GW030011_1 (Narrabri Fm) - Computed

GW030011_1 (Narrabri Fm) - Observed

GW030011_2 (Gunnedah Fm) - Computed

GW030011_2 (Gunnedah Fm) - Observed

GW030011_3 (Gunnedah Fm) - Computed

GW030011_3 (Gunnedah Fm) - Observed

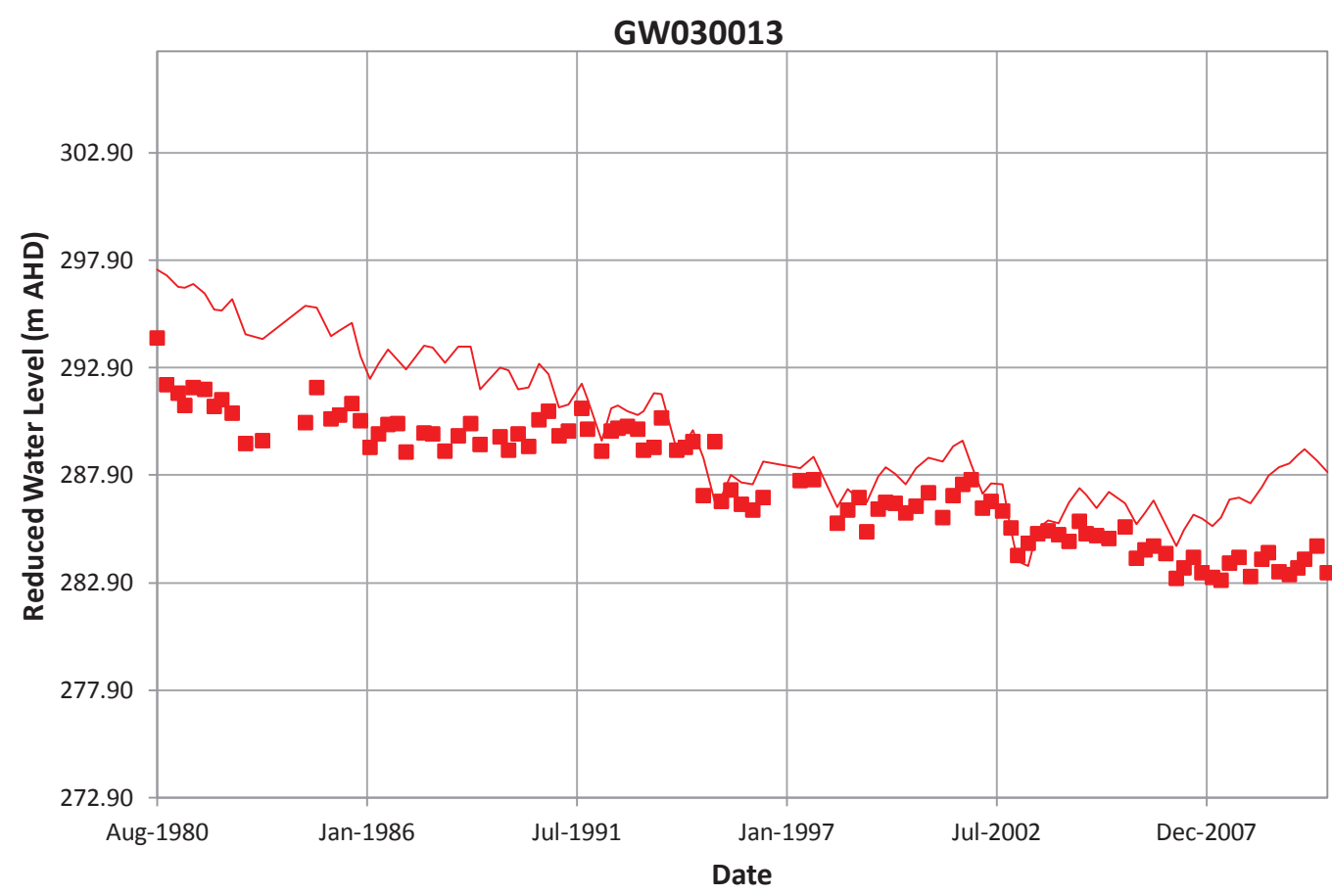


GW030012_1 (Narrabri Fm) - Computed

GW030012_1 (Narrabri Fm) - Observed

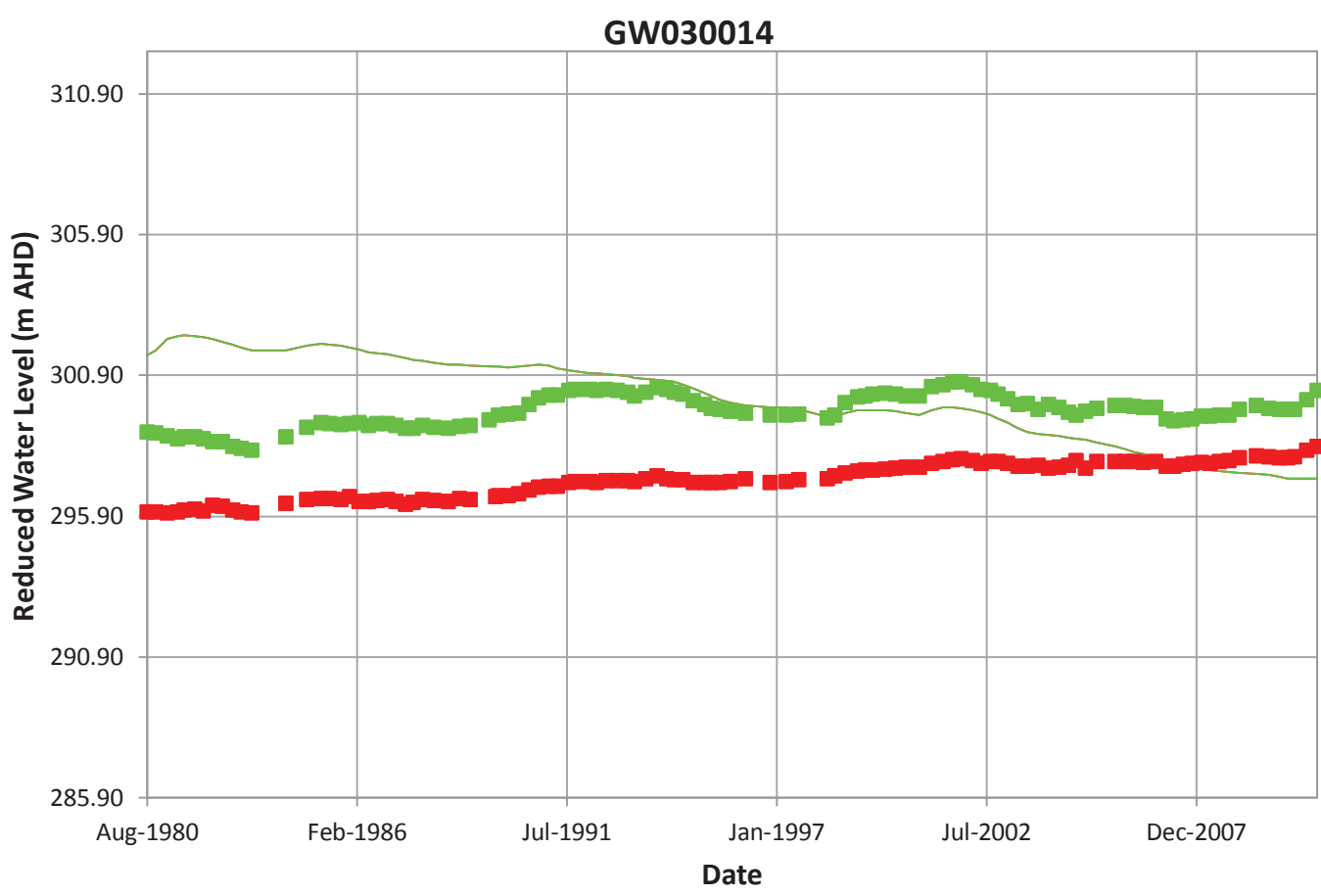
GW030012_2 (Gunnedah Fm) - Computed

GW030012_2 (Gunnedah Fm) - Observed



GW030013_1 (Gunnedah Fm) - Computed

GW030013_1 (Gunnedah Fm) - Observed

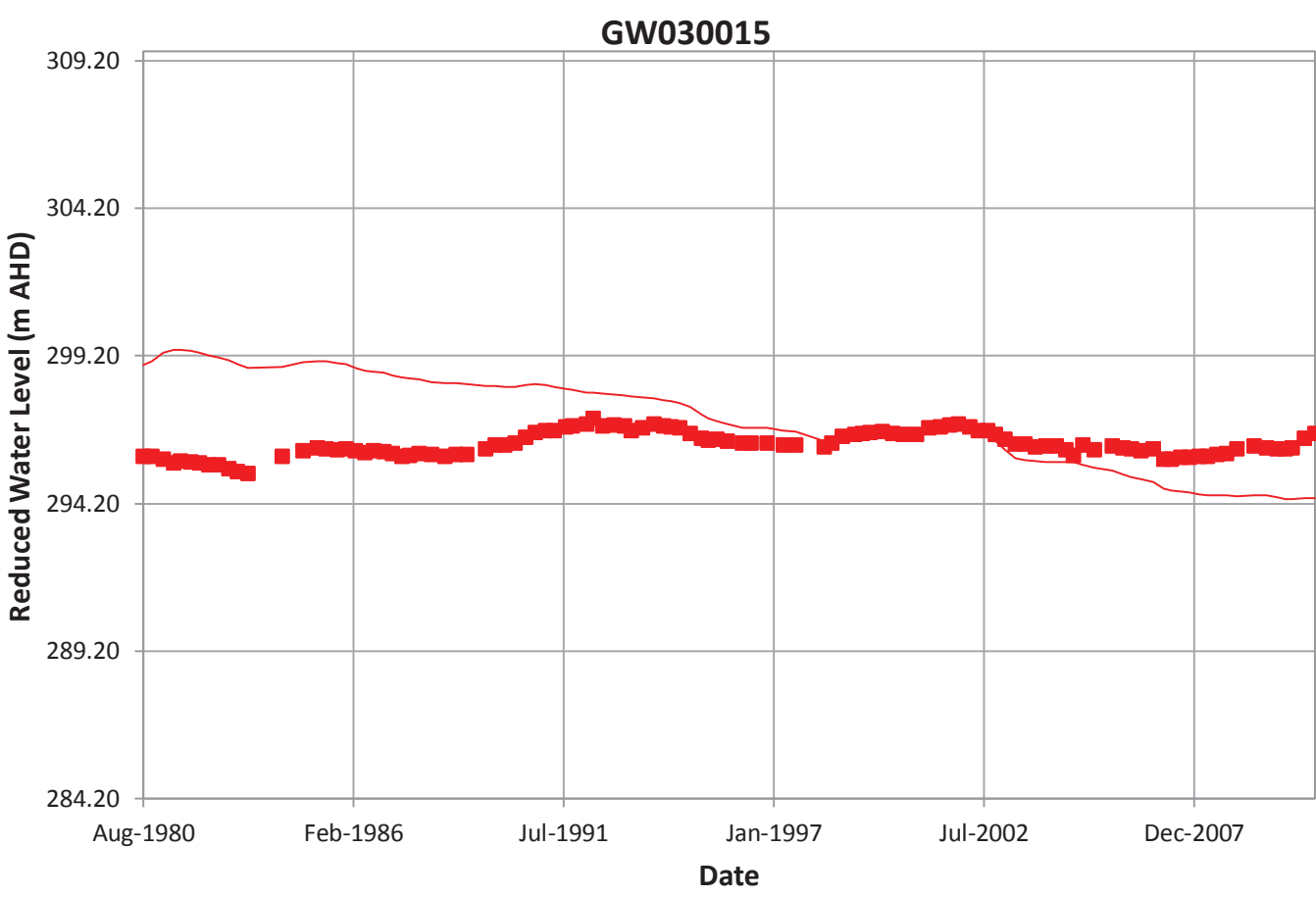


GW030014_1 (Gunnedah Fm) - Computed

GW030014_1 (Gunnedah Fm) - Observed

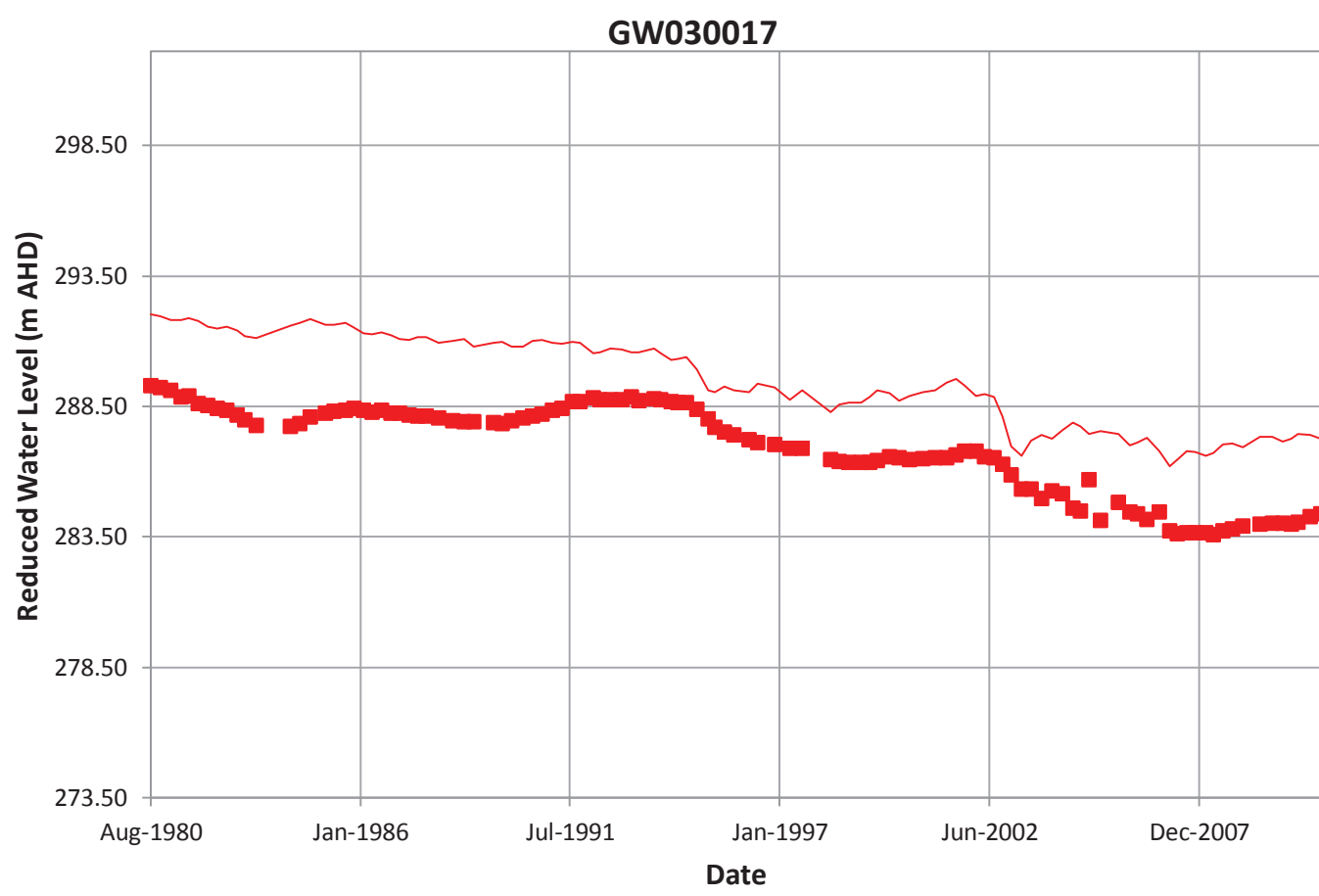
GW030014_2 (Gunnedah Fm) - Computed

GW030014_2 (Gunnedah Fm) - Observed



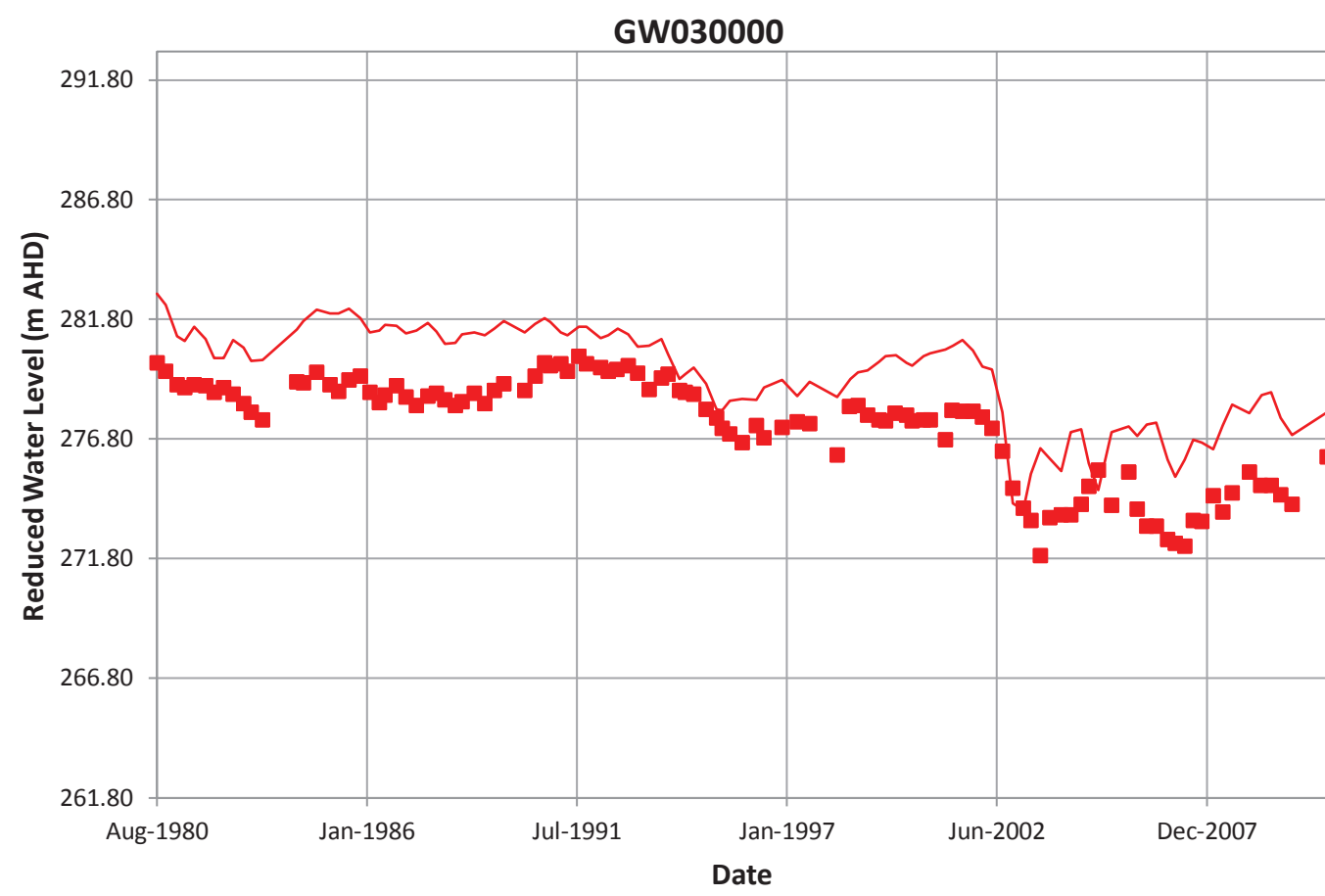
GW030015_1 (Gunnedah Fm) - Computed

GW030015_1 (Gunnedah Fm) - Observed



GW030017_1 (Gunnedah Fm) - Computed

GW030017_1 (Gunnedah Fm) - Observed



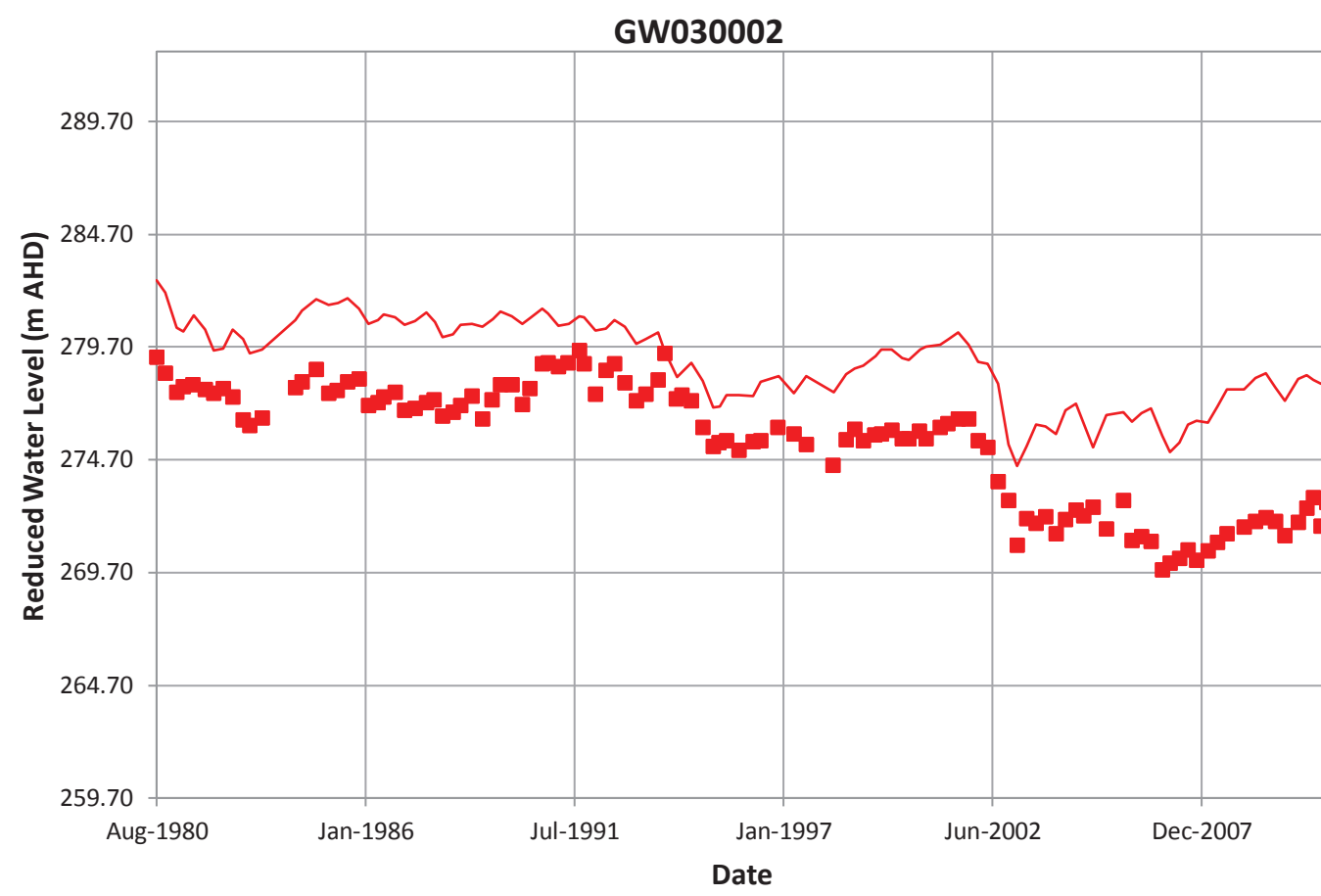
— GW030000_1 (Gunnedah Fm) - Computed

■ GW030000_1 (Gunnedah Fm) - Observed



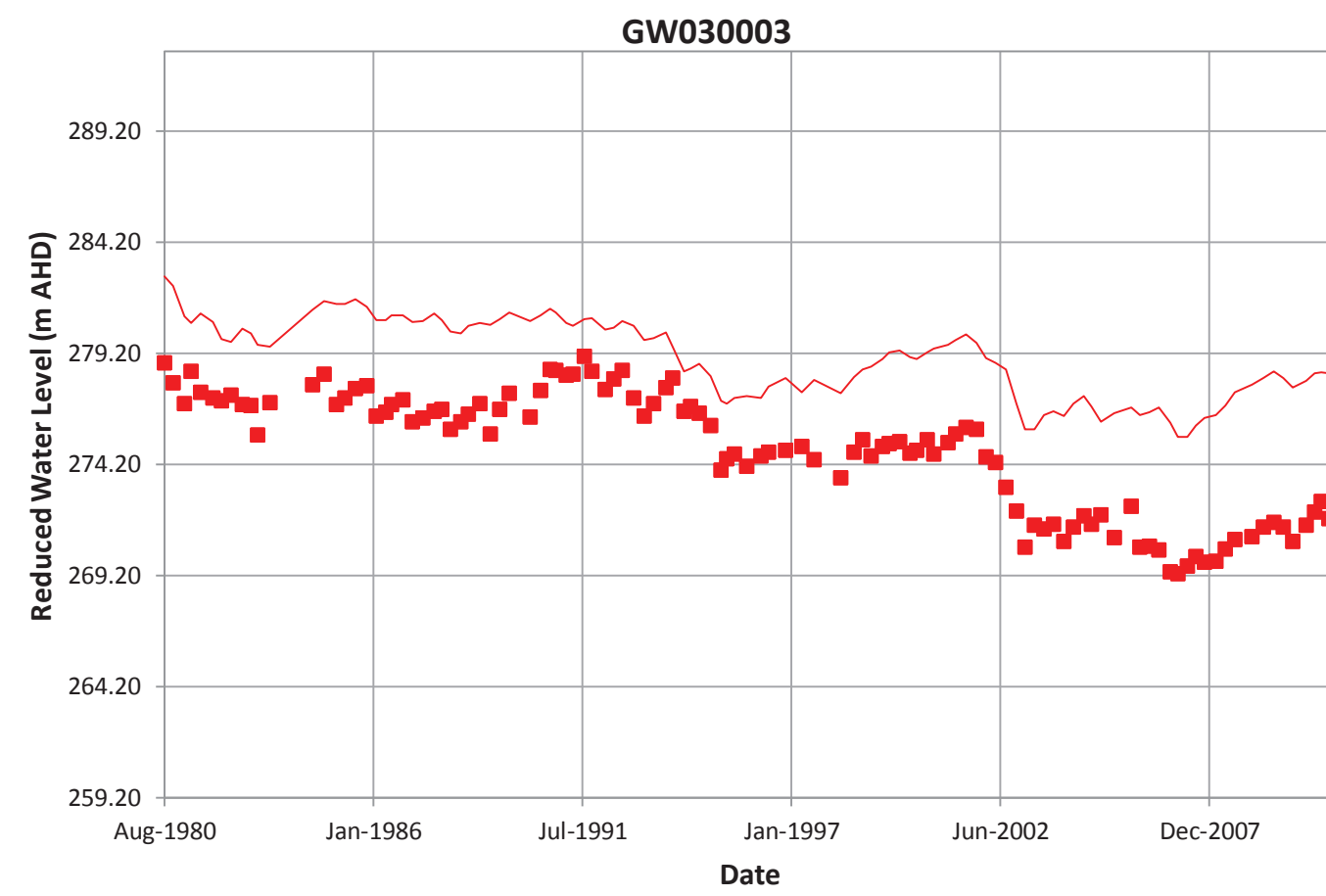
— GW030001_1 (Narrabri Fm) - Computed

■ GW030001_1 (Narrabri Fm) - Observed



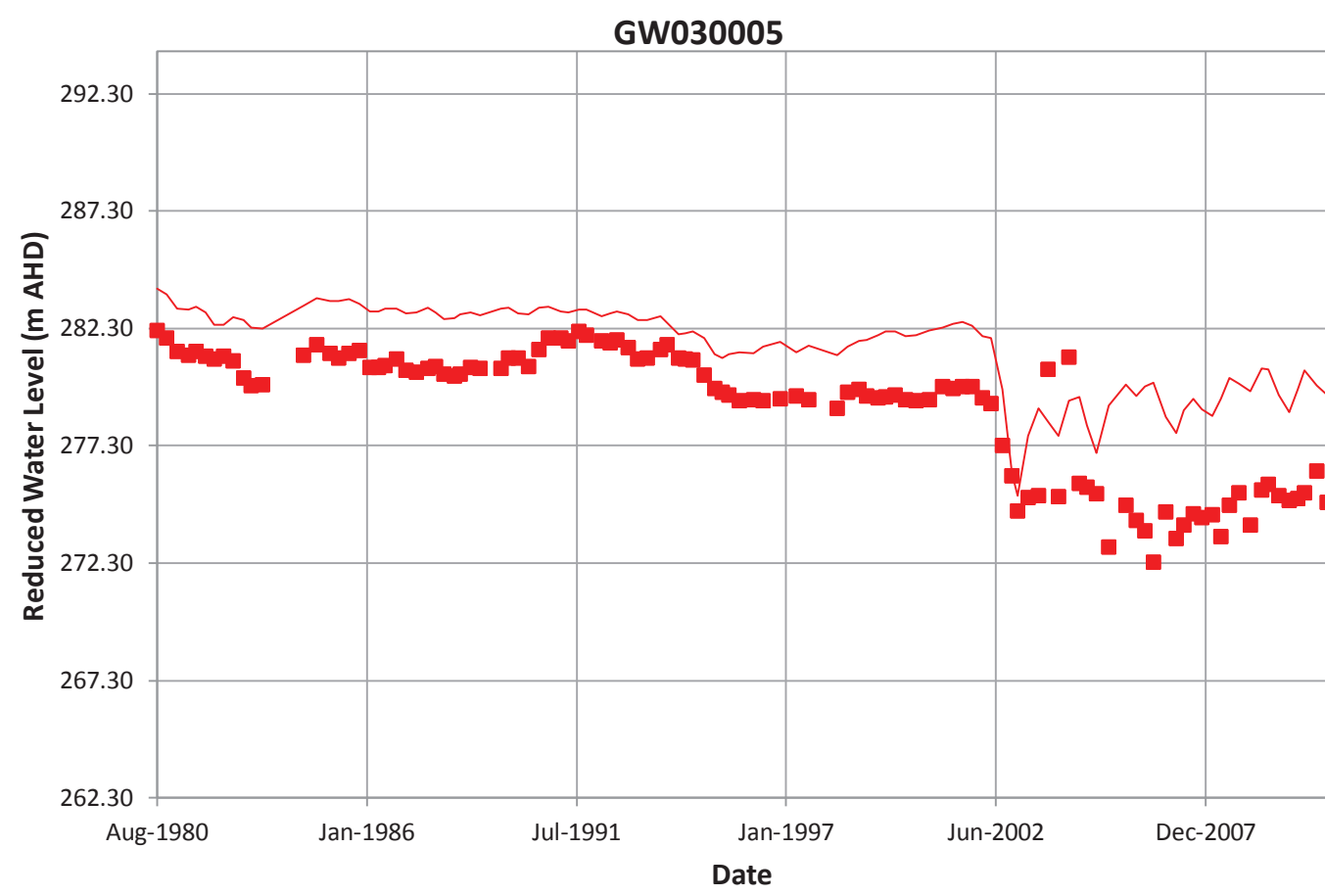
— GW030002_1 (Gunnedah Fm) - Computed

■ GW030002_1 (Gunnedah Fm) - Observed



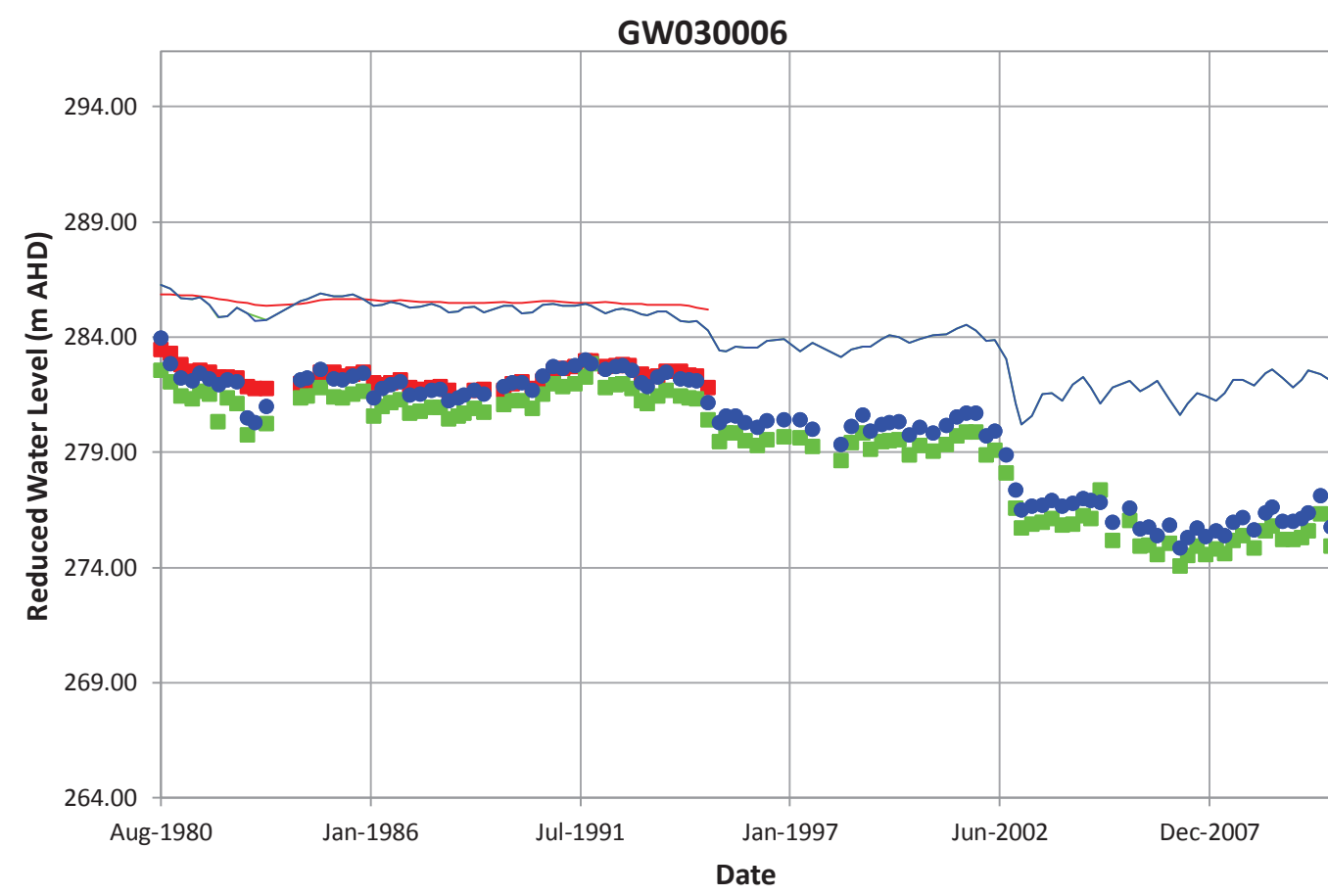
— GW030003_1 (Gunnedah Fm) - Computed

■ GW030003_1 (Gunnedah Fm) - Observed



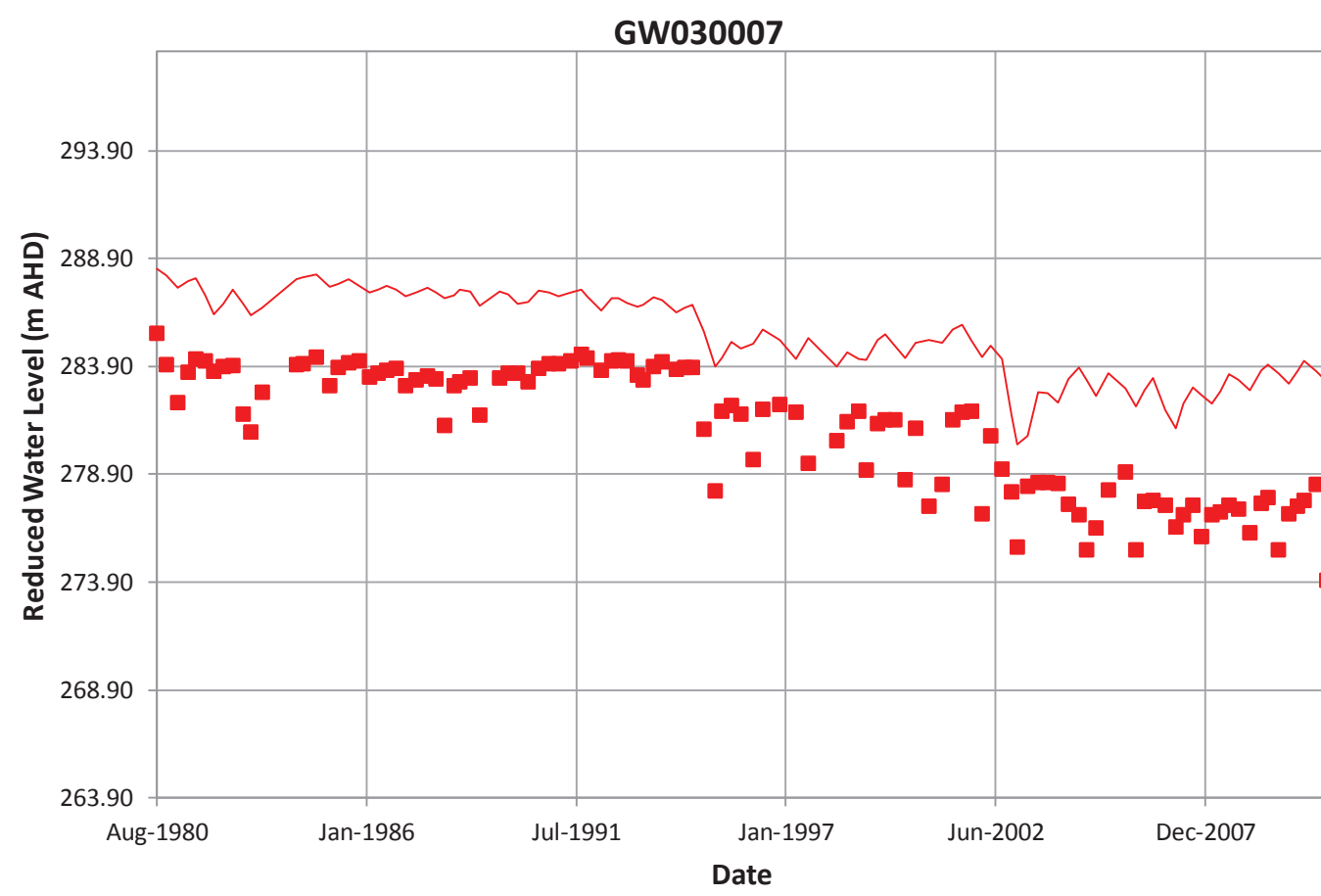
— GW030005_1 (Gunnedah Fm) - Computed

■ GW030005_1 (Gunnedah Fm) - Observed



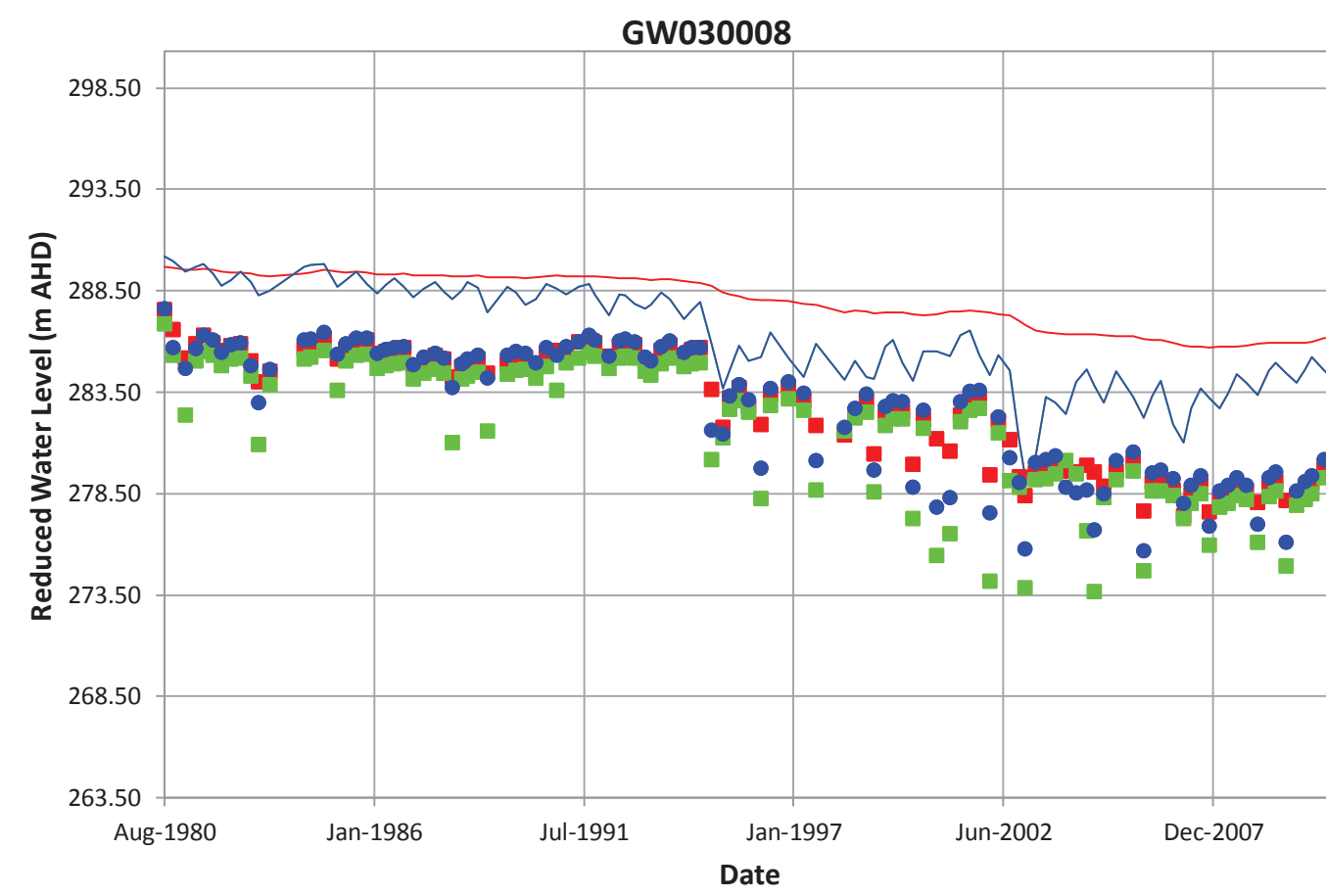
— GW030006_1 (Narrabri Fm) - Computed

■ GW030006_1 (Narrabri Fm) - Observed



— GW030007_2 (Gunnedah Fm) - Computed

■ GW030007_2 (Gunnedah Fm) - Observed



— GW030008_1 (Narrabri Fm) - Computed

■ GW030008_1 (Narrabri Fm) - Observed

— GW030006_2 (Gunnedah Fm) - Computed

■ GW030006_2 (Gunnedah Fm) - Observed

— GW030006_3 (Gunnedah Fm) - Computed

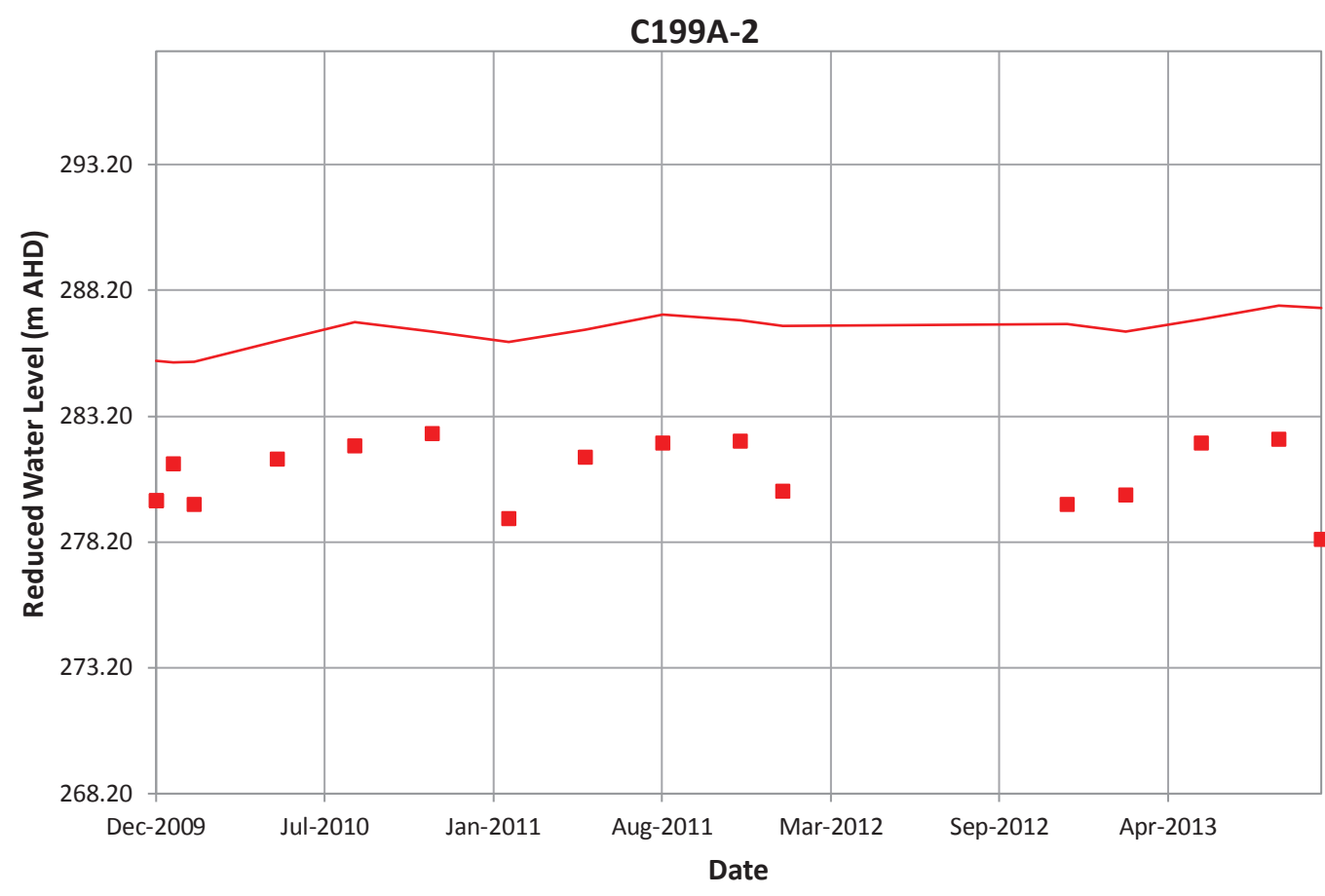
■ GW030006_3 (Gunnedah Fm) - Observed

— GW030008_2 (Gunnedah Fm) - Computed

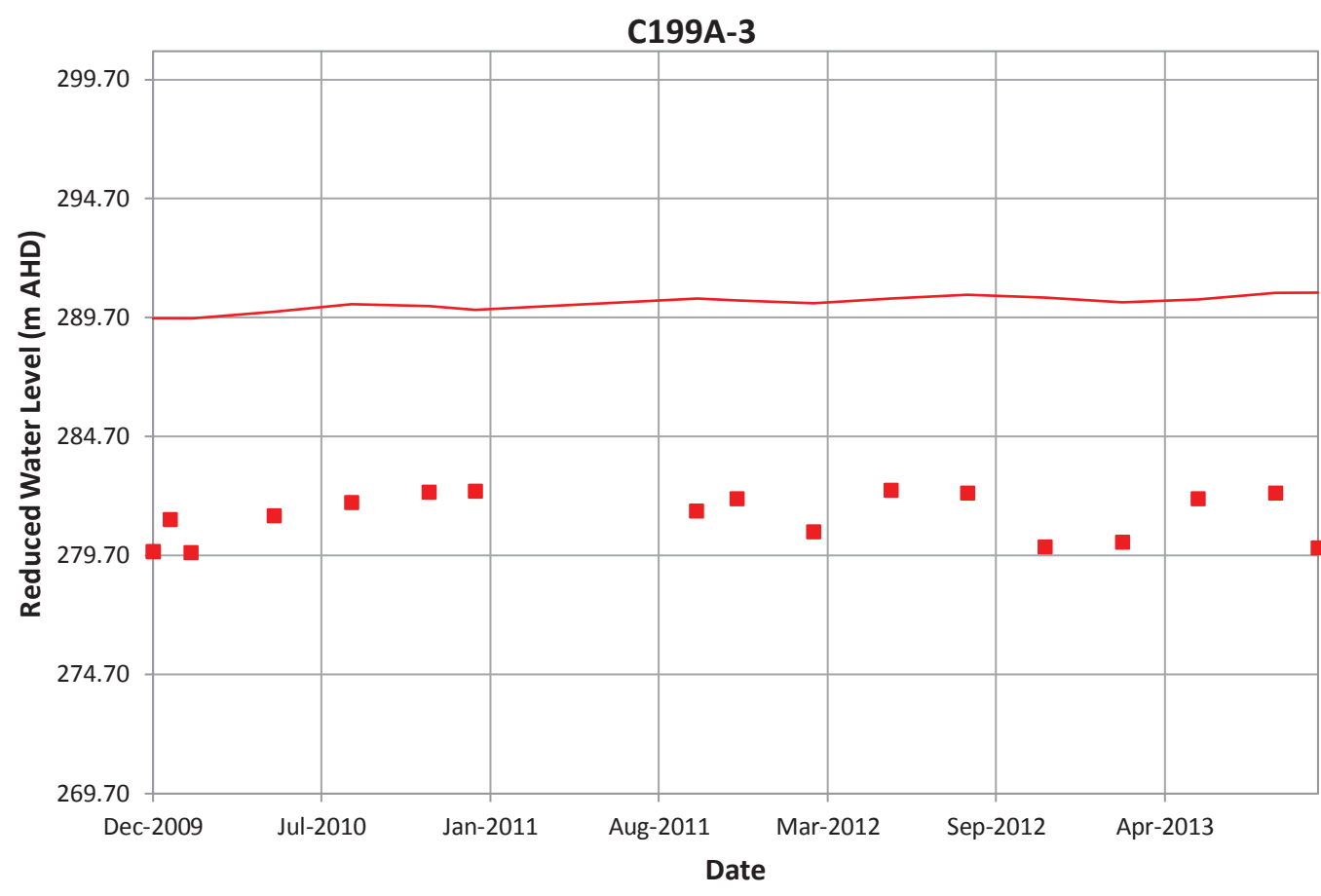
■ GW030008_2 (Gunnedah Fm) - Observed

— GW030008_3 (Gunnedah Fm) - Computed

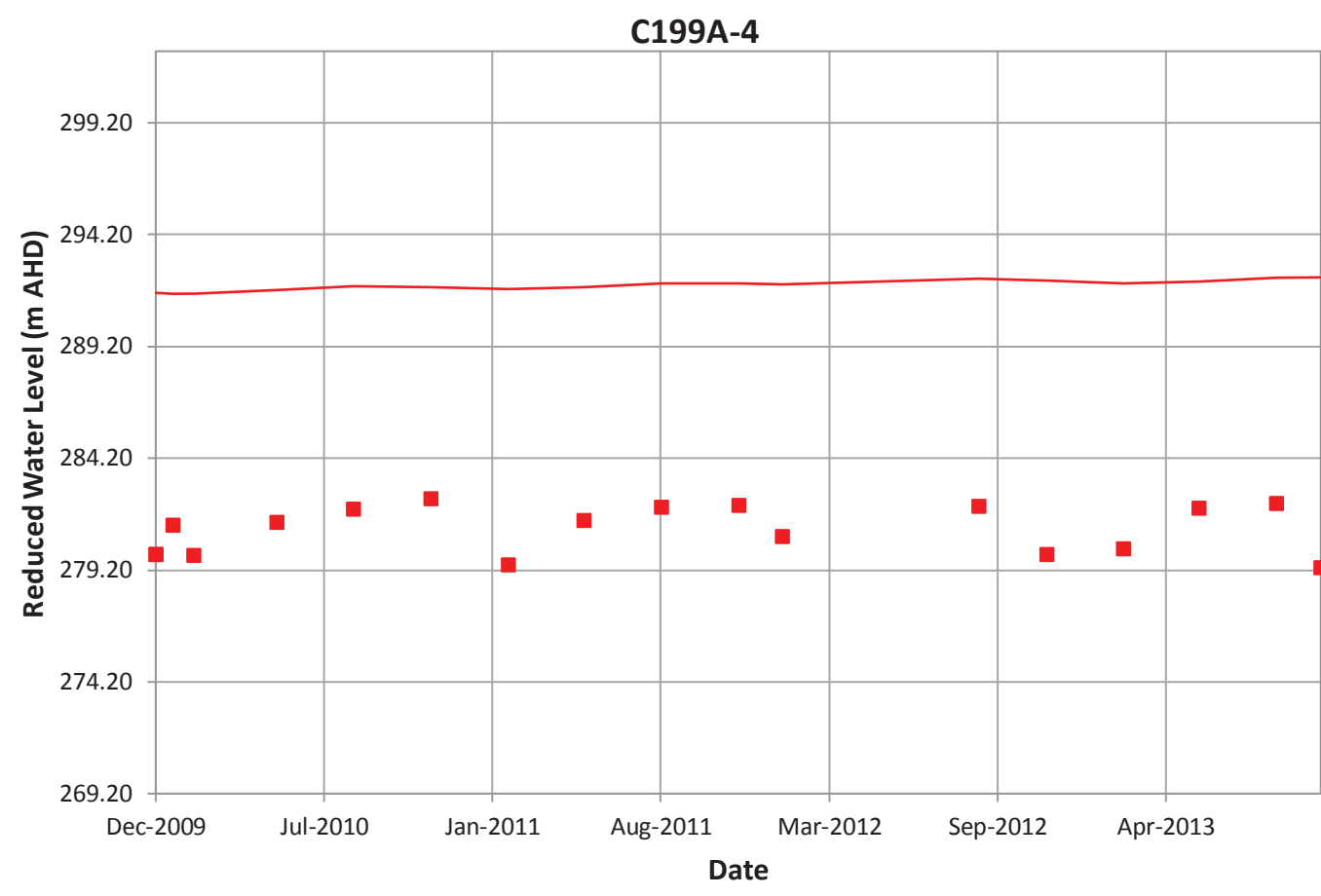
■ GW030008_3 (Gunnedah Fm) - Observed



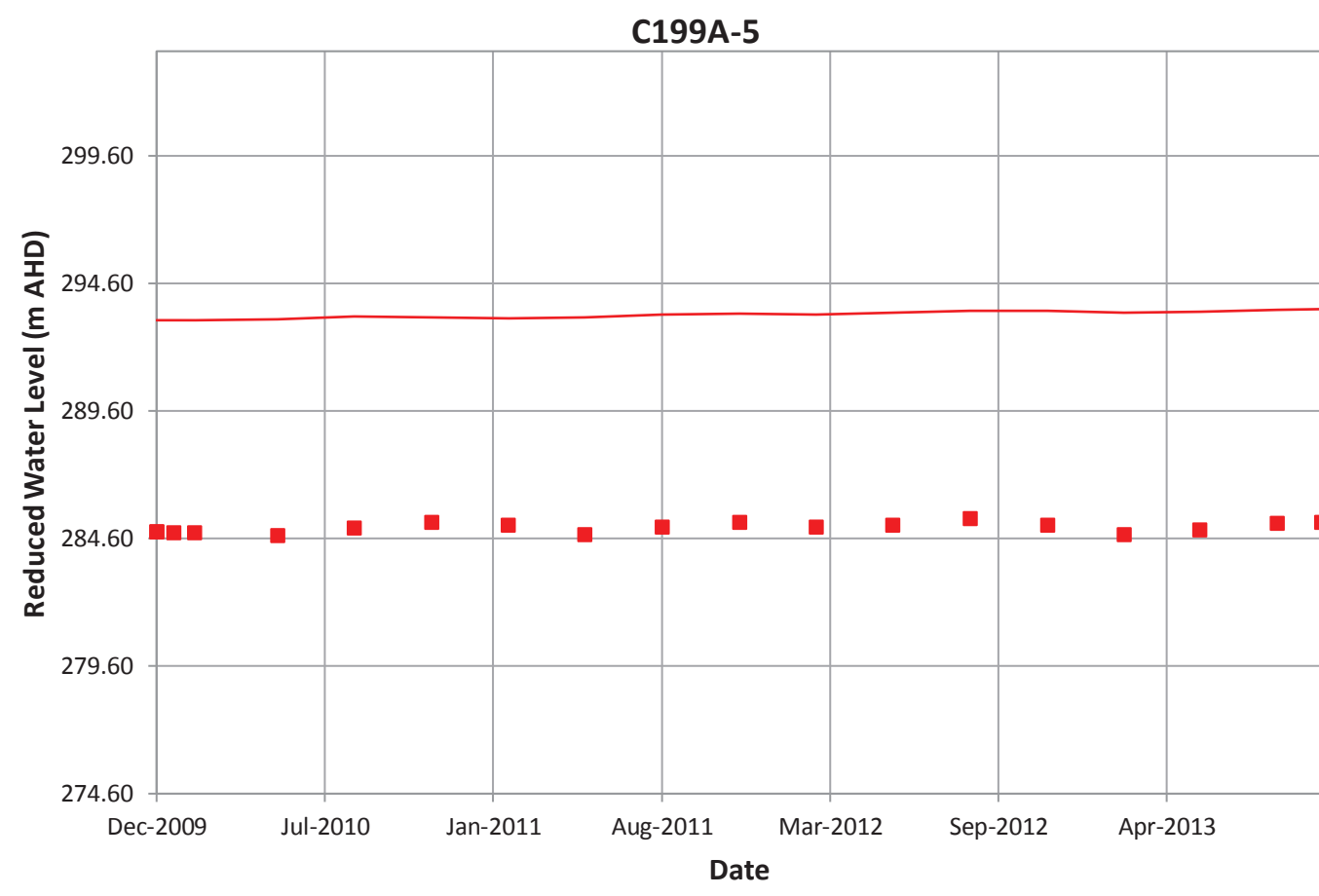
— C199A-2 (Alluvium - Gunnedah Formation) - Computed ■ C199A-2 (Alluvium - Gunnedah Formation) - Observed



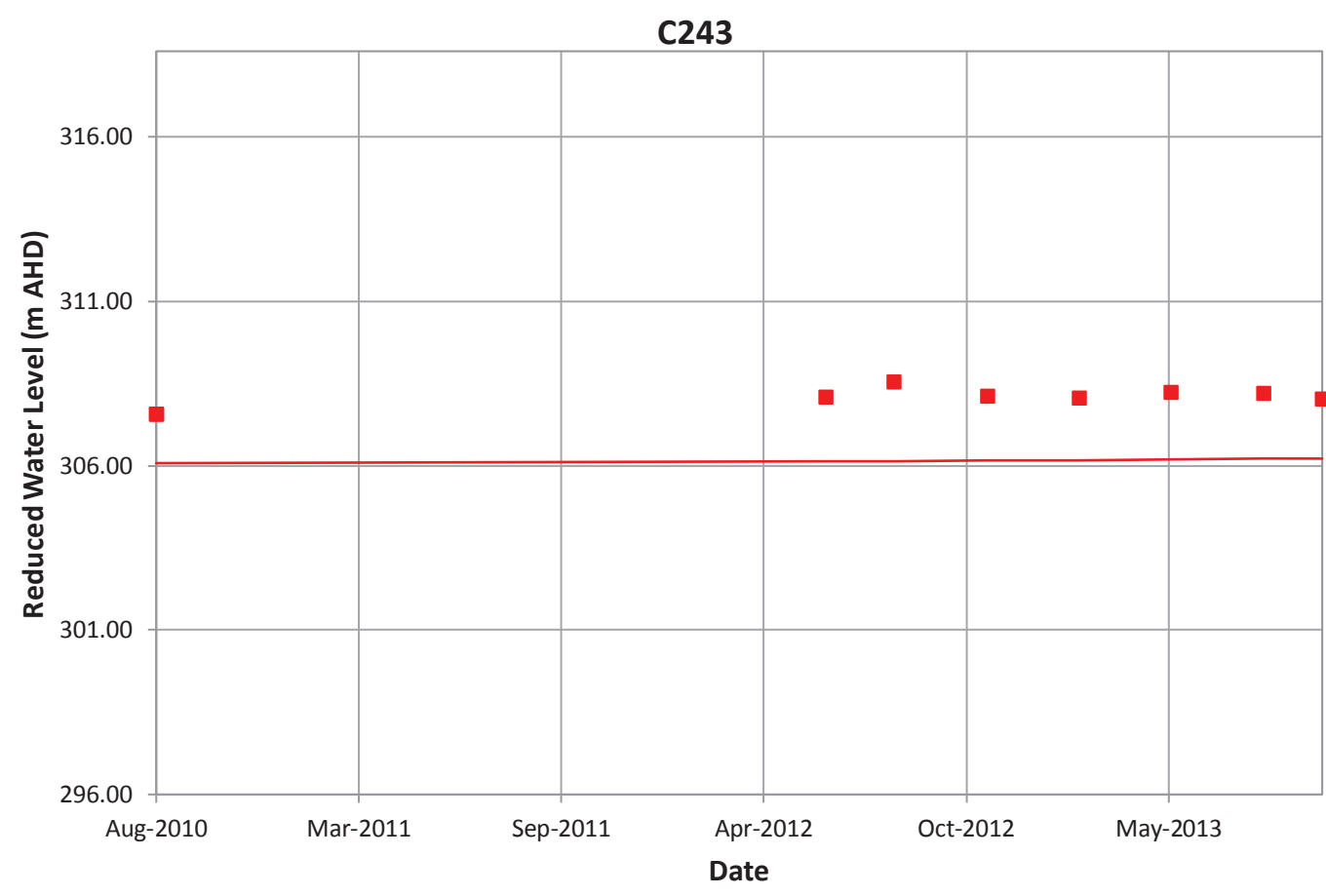
— C199A-3 (Clare Sandstone) - Computed ■ C199A-3 (Clare Sandstone) - Observed



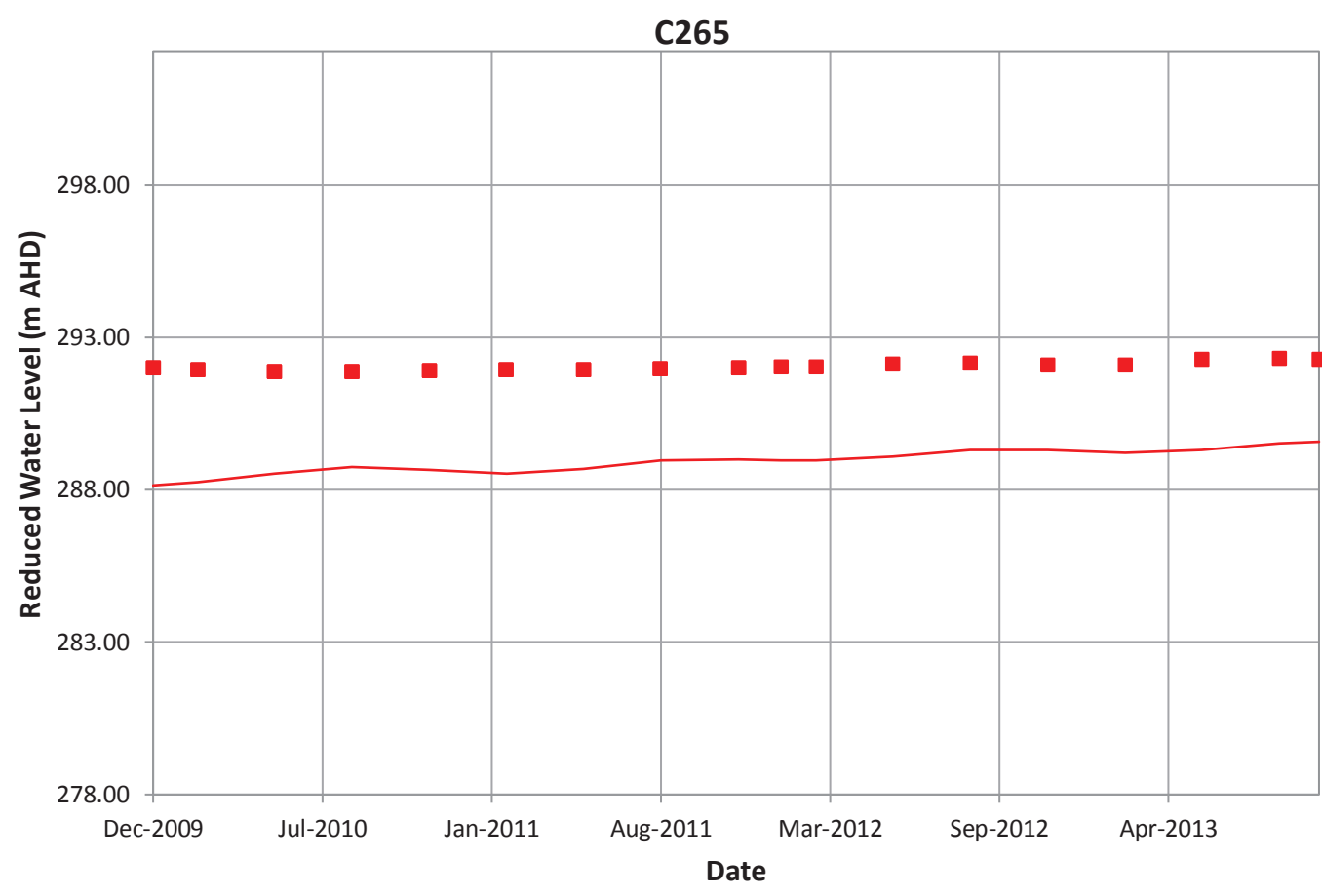
— C199A-4 (Howes Hill Seam) - Computed ■ C199A-4 (Howes Hill Seam) - Observed



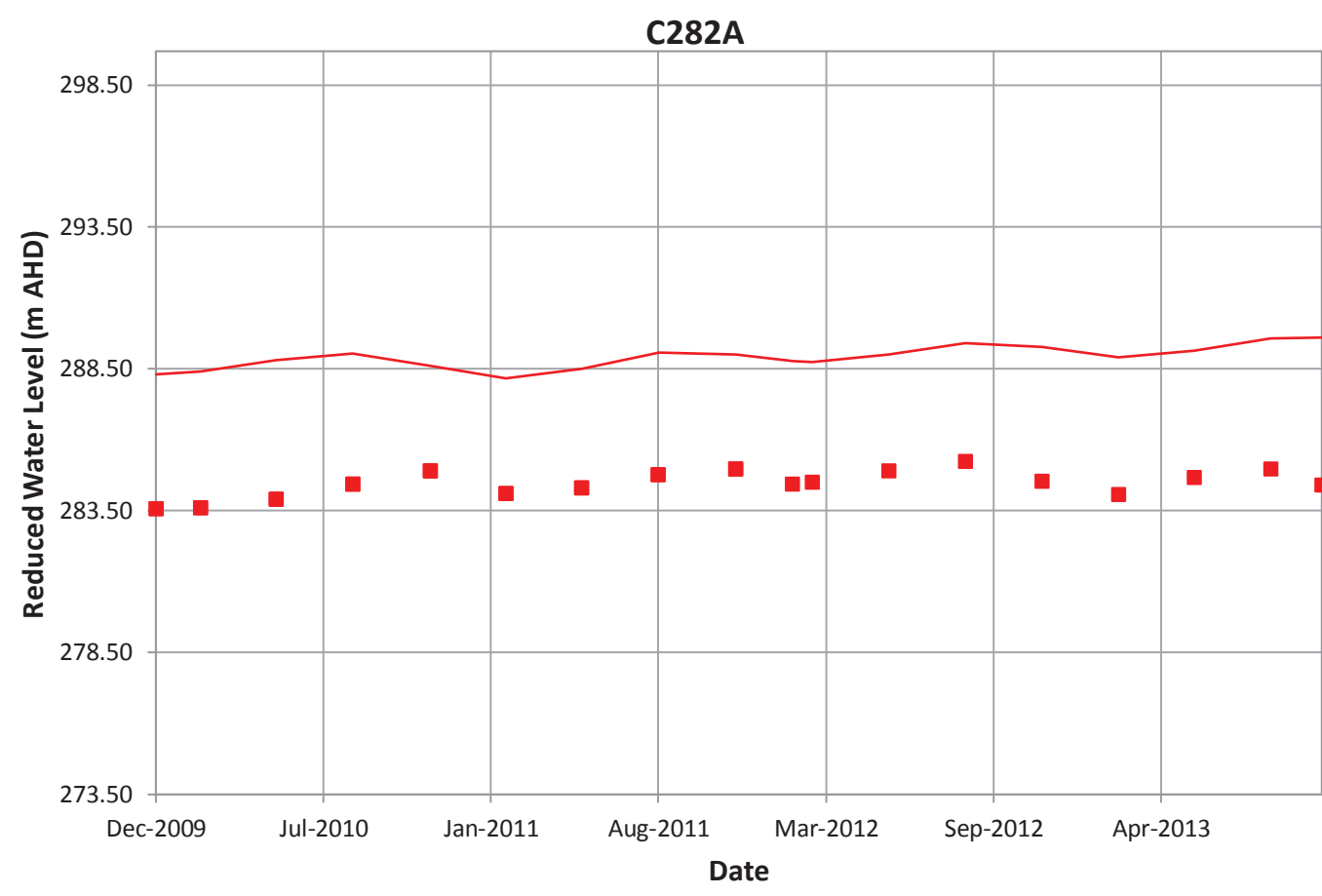
— C199A-5 (Hoskisson Seam) - Computed ■ C199A-5 (Hoskisson Seam) - Observed



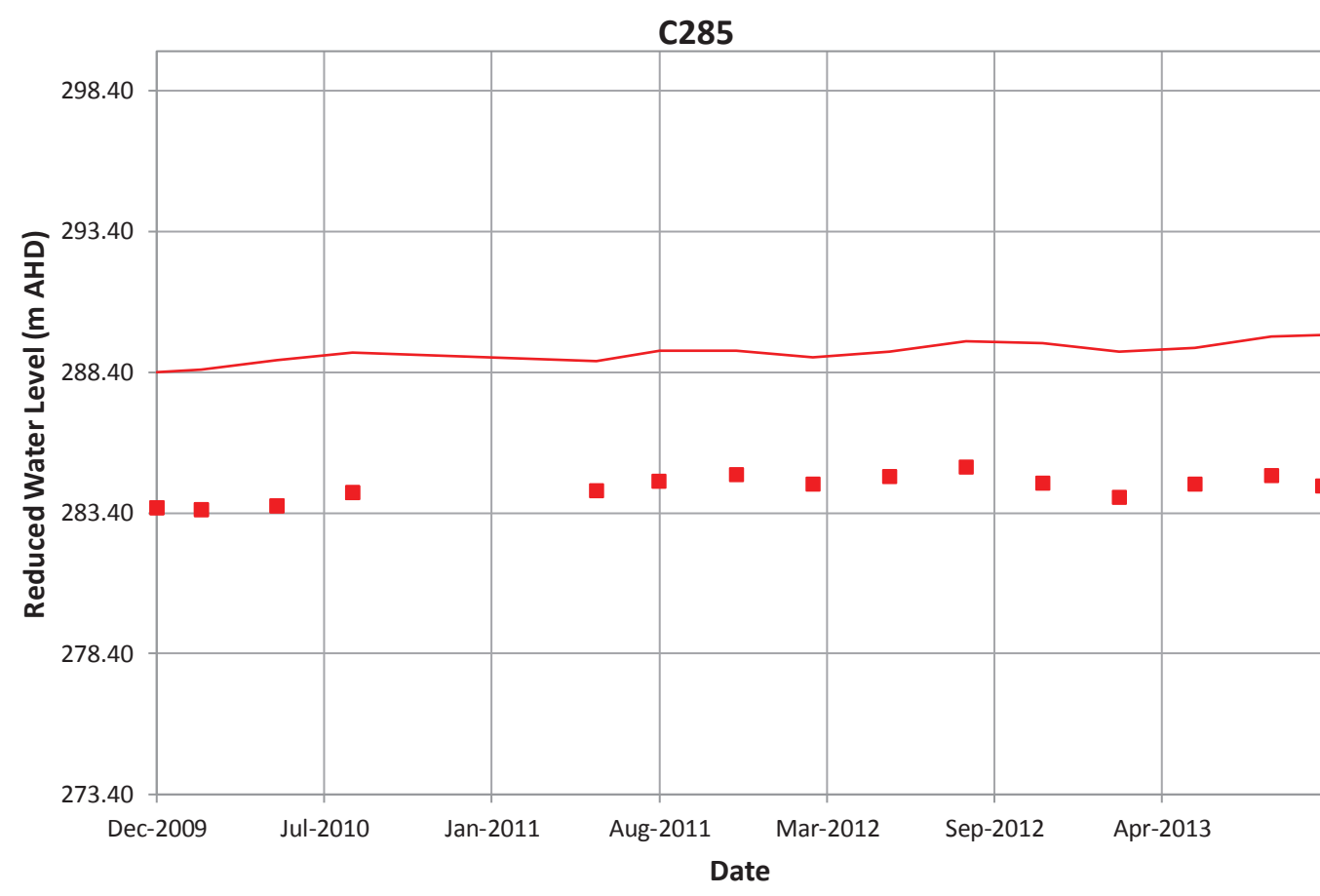
— C243 (Regolith) - Computed ■ C243 (Regolith) - Observed



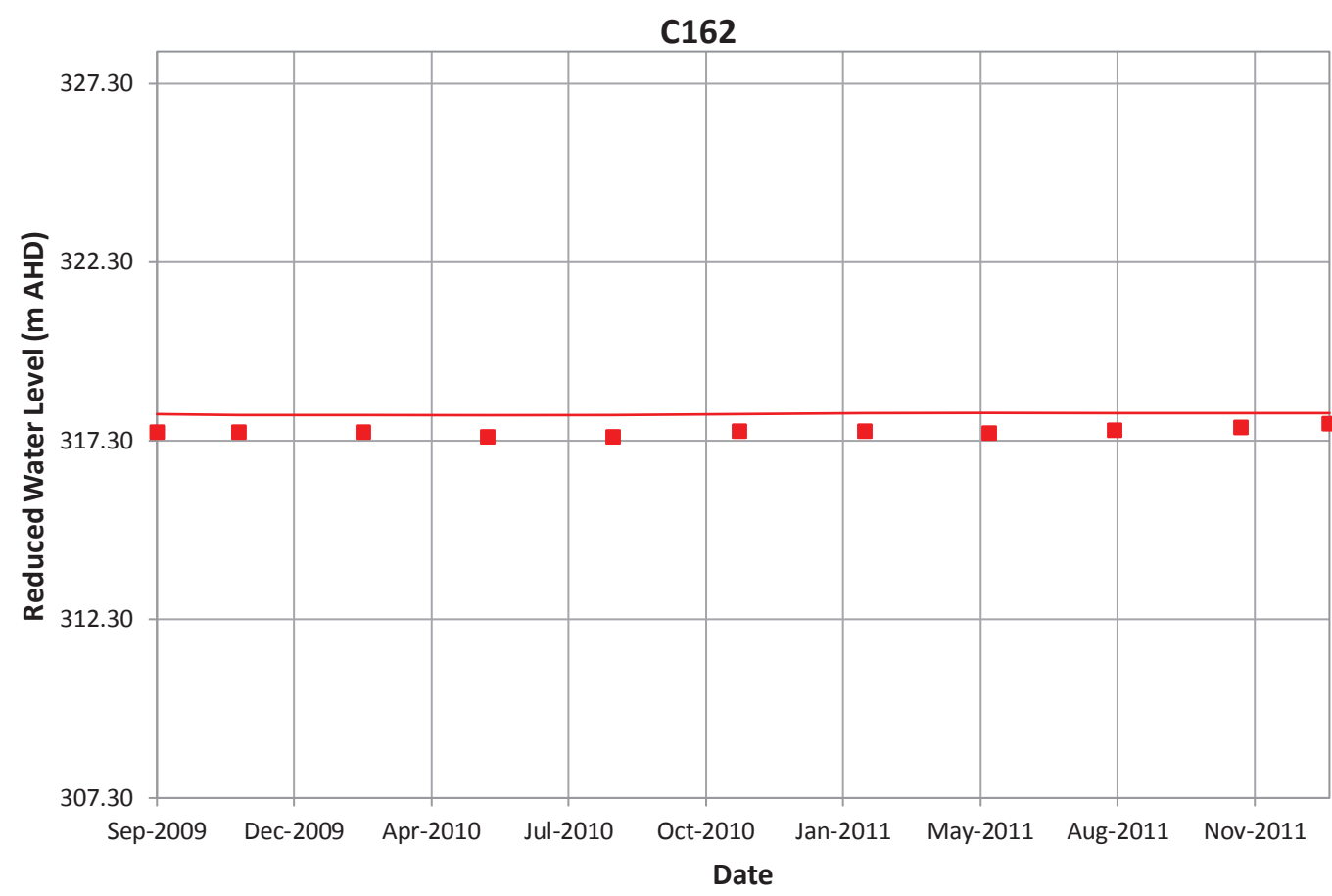
— C265 (Alluvium - Gunnedah Formation) - Computed ■ C265 (Alluvium - Gunnedah Formation) - Observed



— C282A (Alluvium - Gunnedah Formation) - Computed ■ C282A (Alluvium - Gunnedah Formation) - Observed



— C285 (Alluvium - Gunnedah Formation) - Computed ■ C285 (Alluvium - Gunnedah Formation) - Observed



C162 (Regolith) - Computed

C162 (Regolith) - Observed



C168A_181.5 (Doona Seam) - Computed

C168A_181.5 (Doona Seam) - Observed

C168A_275 (Clift Seam) - Computed

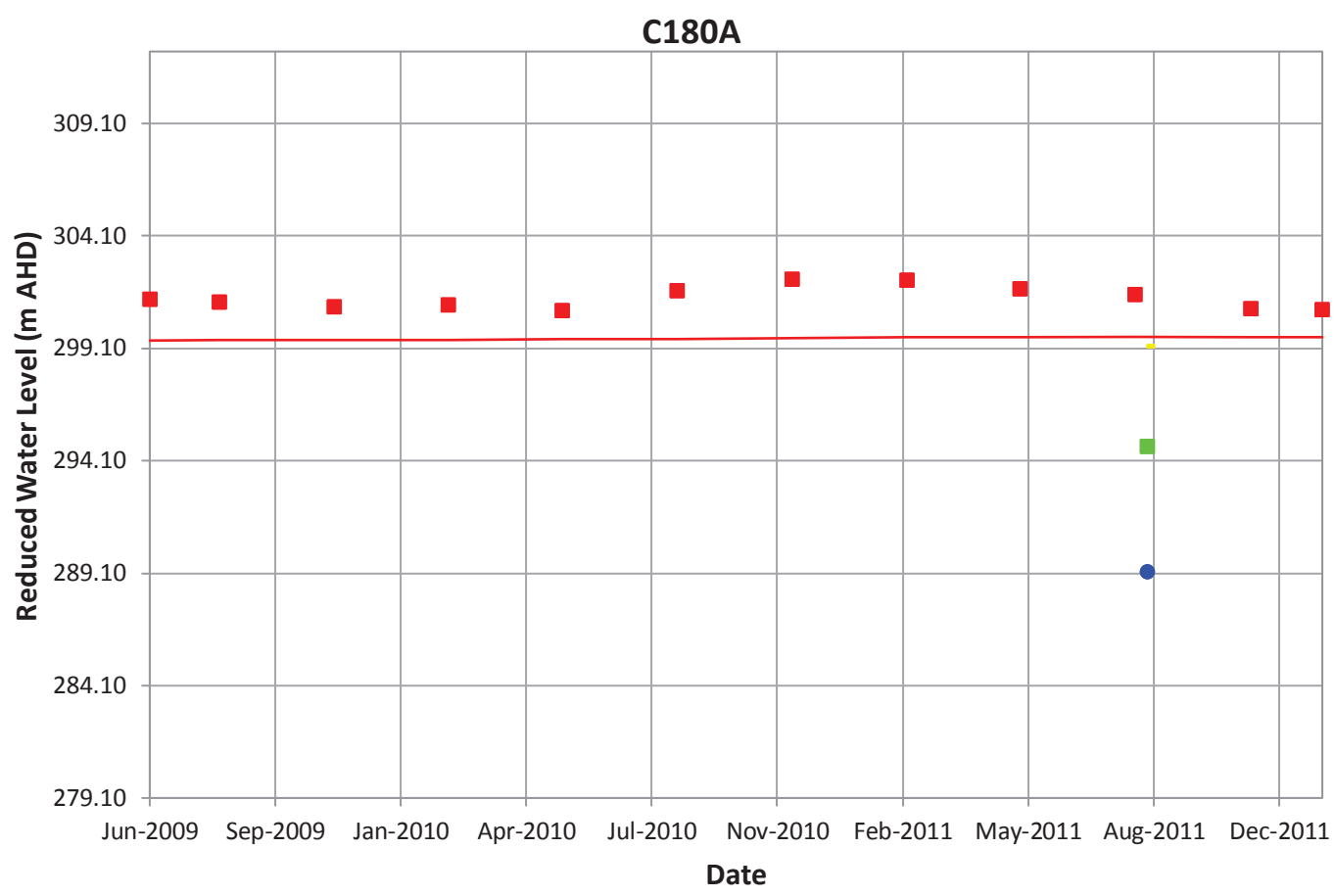
C168A_275 (Clift Seam) - Observed

C168A_311 (Clare Sandstone B) - Computed

C168A_311 (Clare Sandstone B) - Observed

C168A_363 (Hoskisson Seam) - Computed

C168A_363 (Hoskisson Seam) - Observed



C180A (Alluvium - Gunnedah Formation) - Computed

C180A (Alluvium - Gunnedah Formation) - Observed

C180A_114 (Mooki Seam) - Computed

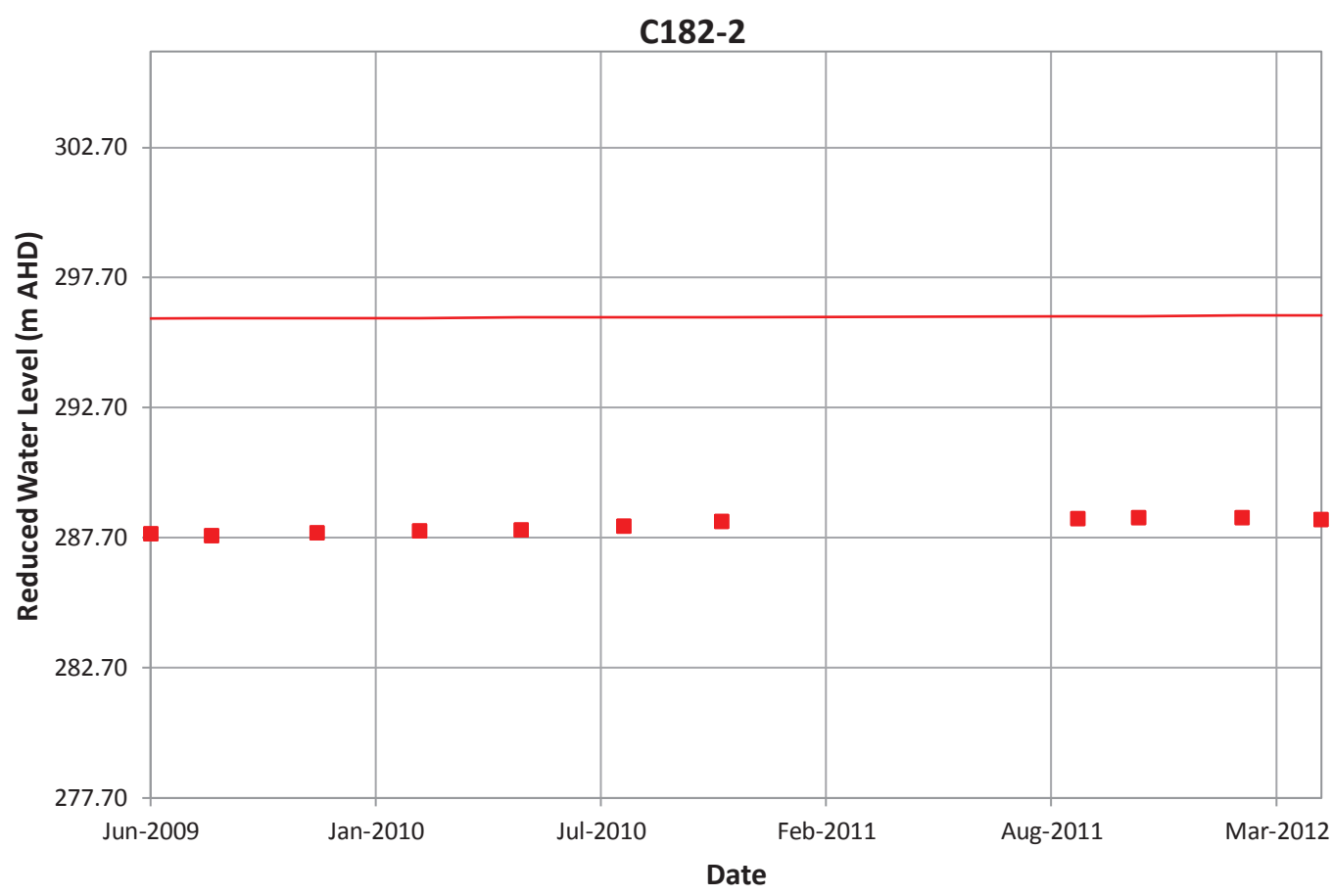
C180A_114 (Mooki Seam) - Observed

C180A_127 (Springfield Seam) - Computed

C180A_127 (Springfield Seam) - Observed

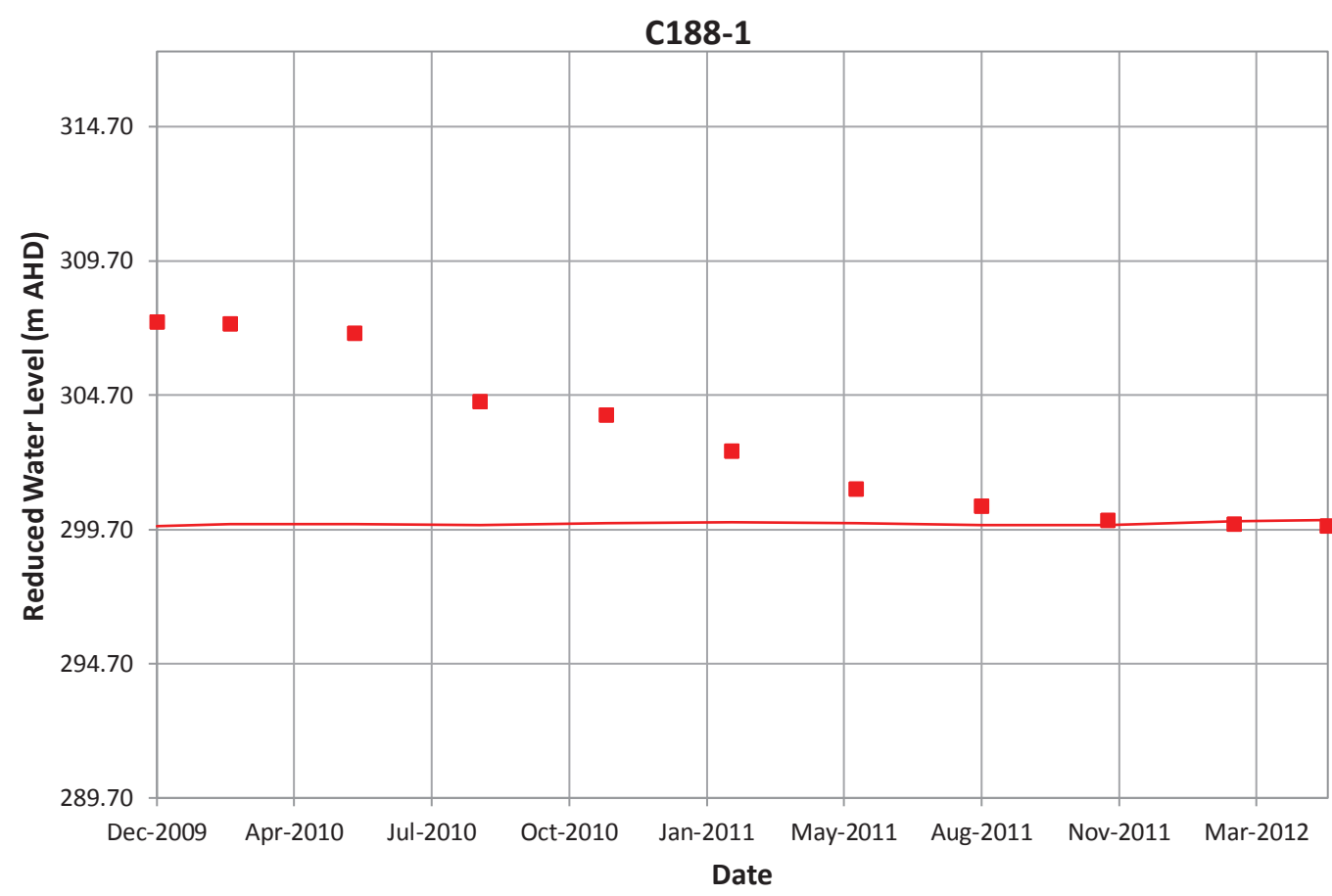
C180A_68.8 (Yarraman Seam) - Computed

C180A_68.8 (Yarraman Seam) - Observed



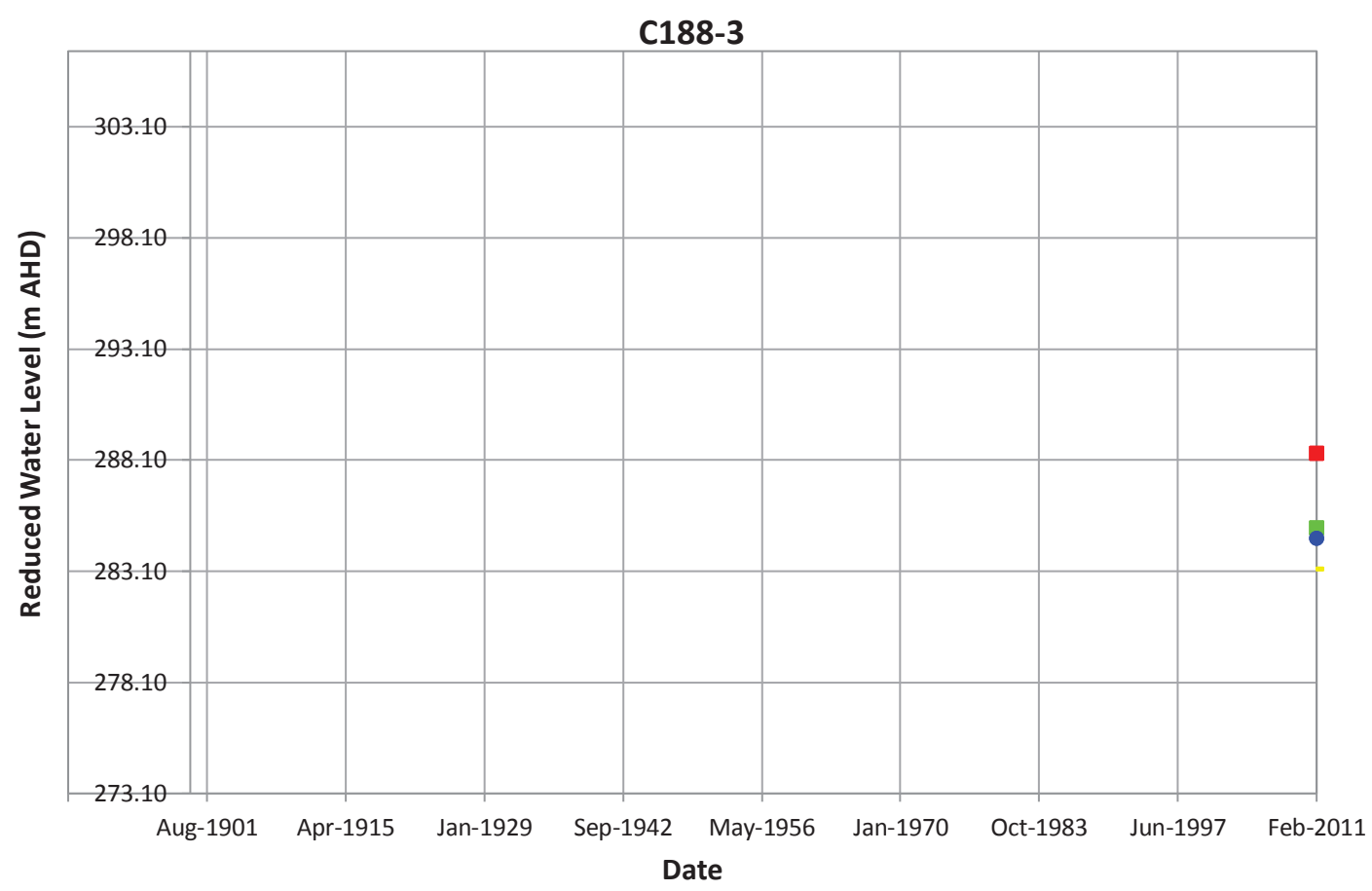
C182-2 (Clare Sandstone) - Computed

C182-2 (Clare Sandstone) - Observed



C188-1 (Regolith) - Computed

C188-1 (Regolith) - Observed



C188-3_120 (Clift Seam Roof2) - Computed

C188-3_120 (Clift Seam Roof2) - Observed

C188-3_132.5 (Clift Seam Roof1) - Computed

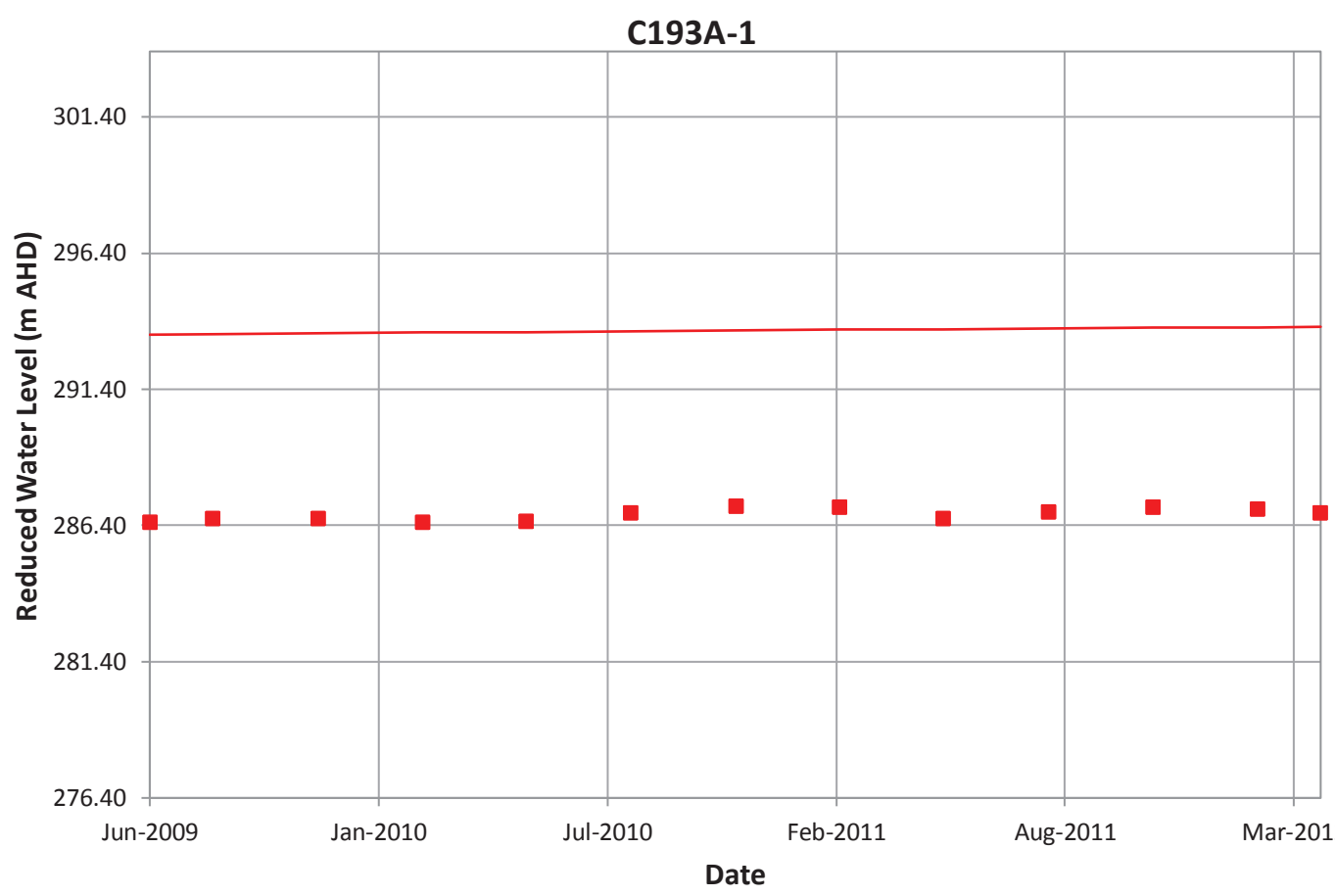
C188-3_132.5 (Clift Seam Roof1) - Observed

C188-3_73 (Doona Seam Roof) - Computed

C188-3_73 (Doona Seam Roof) - Observed

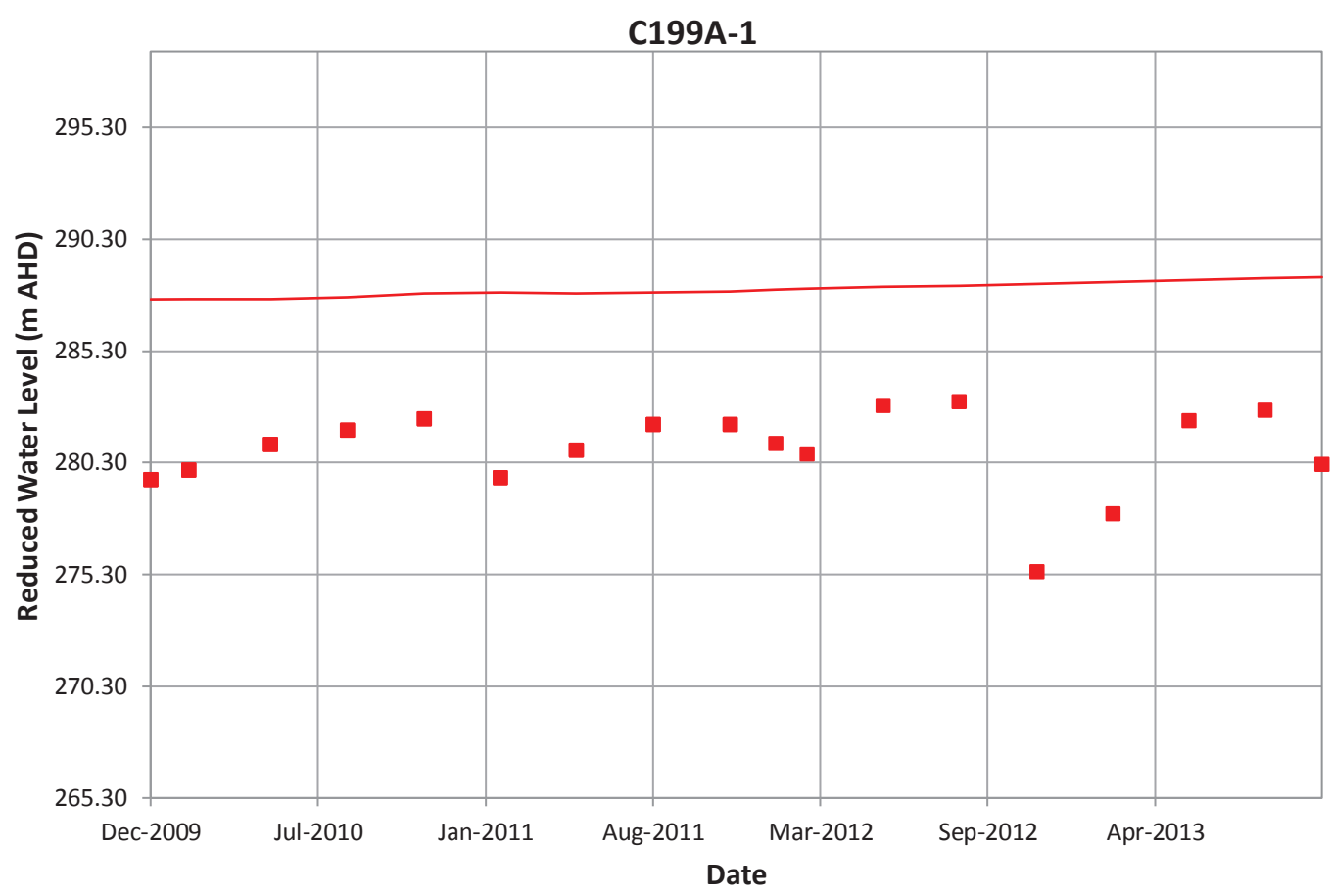
C188-3_87 (Doona Seam) - Computed

C188-3_87 (Doona Seam) - Observed



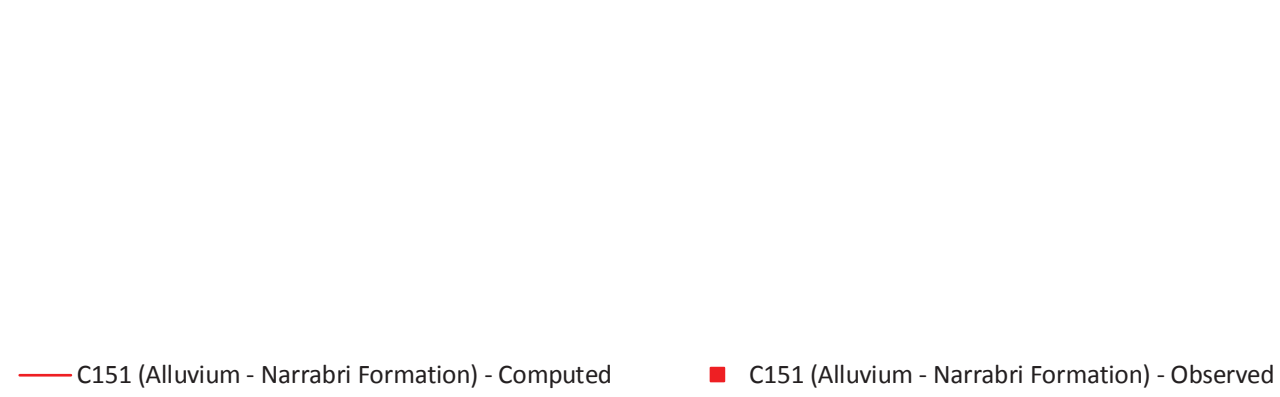
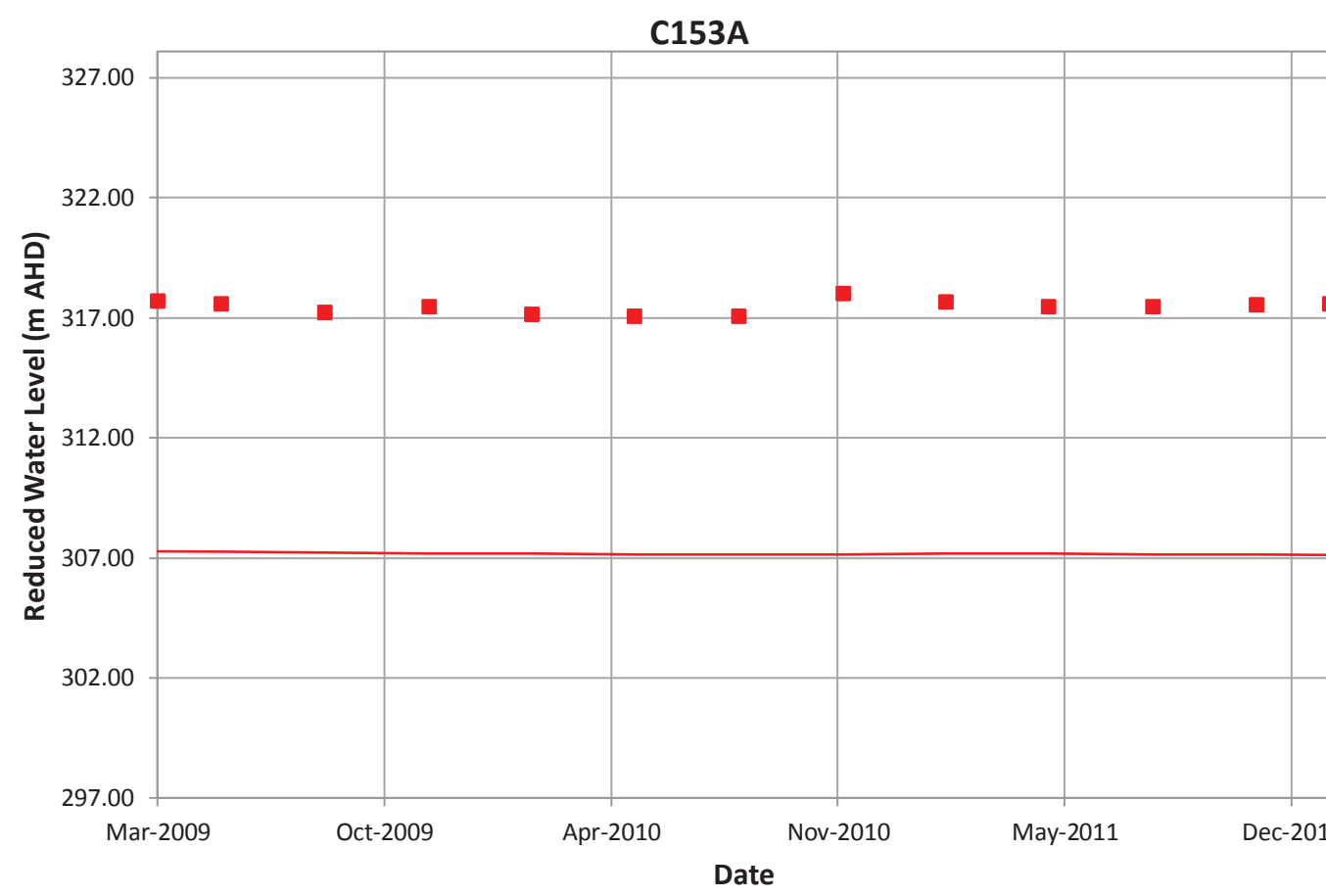
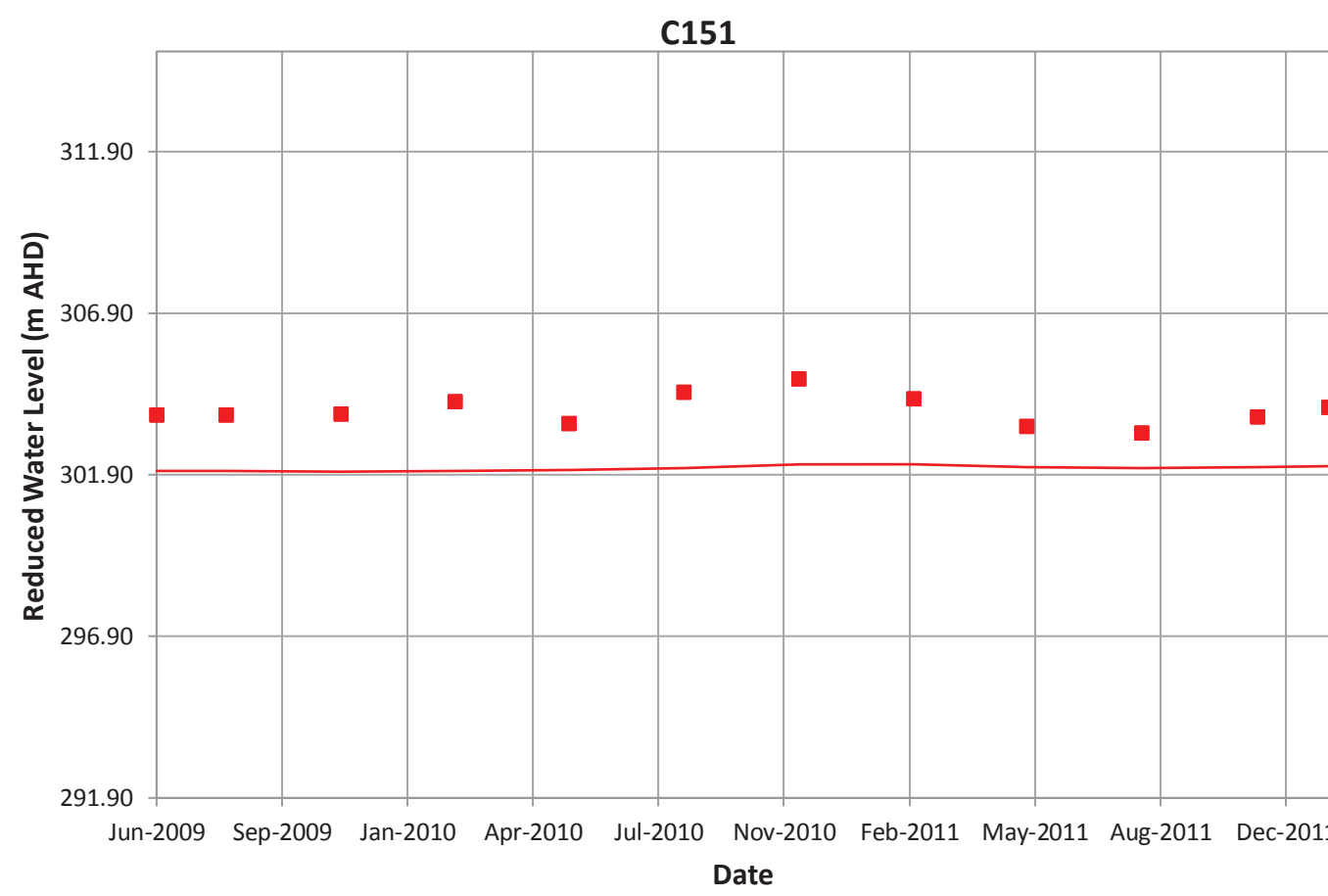
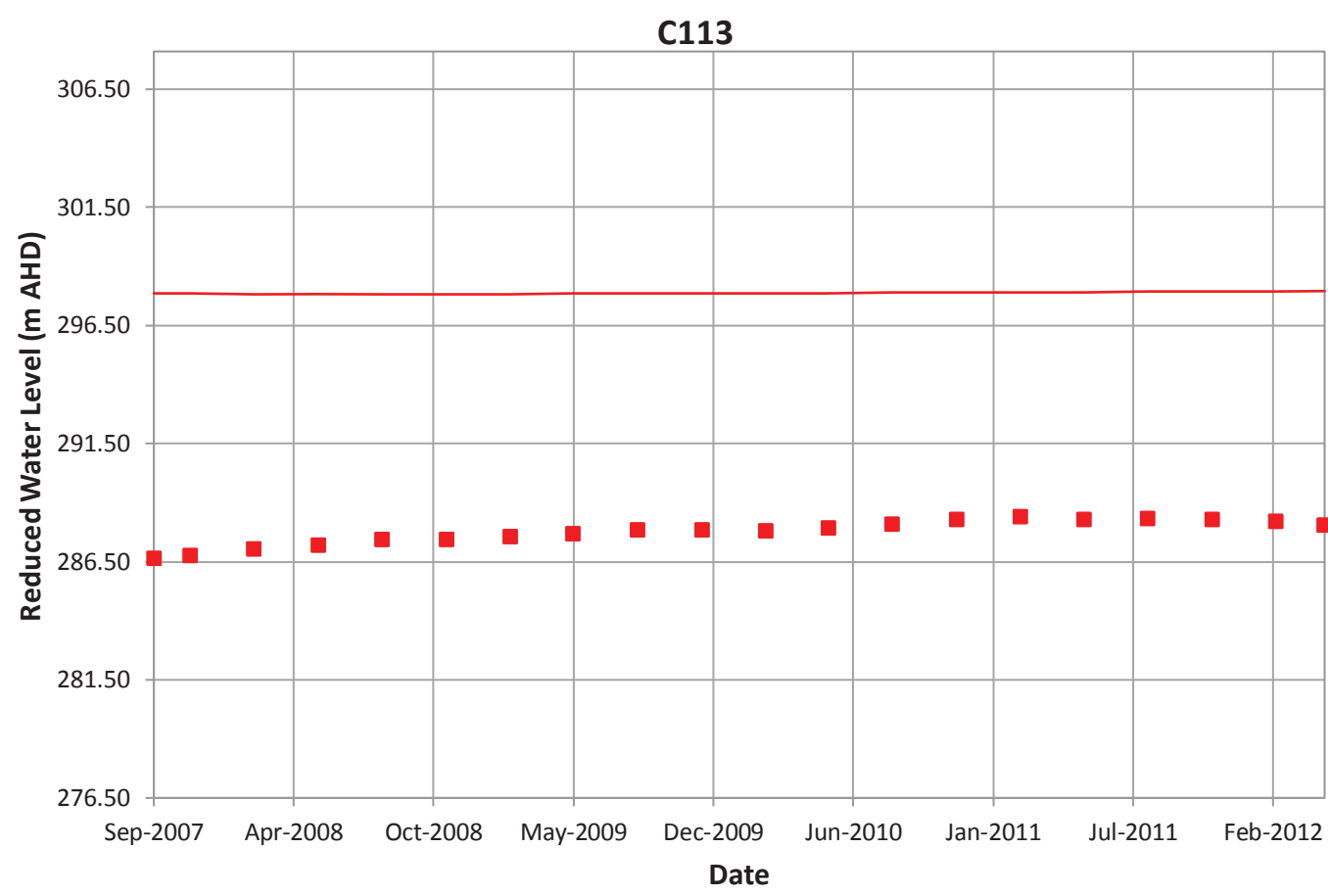
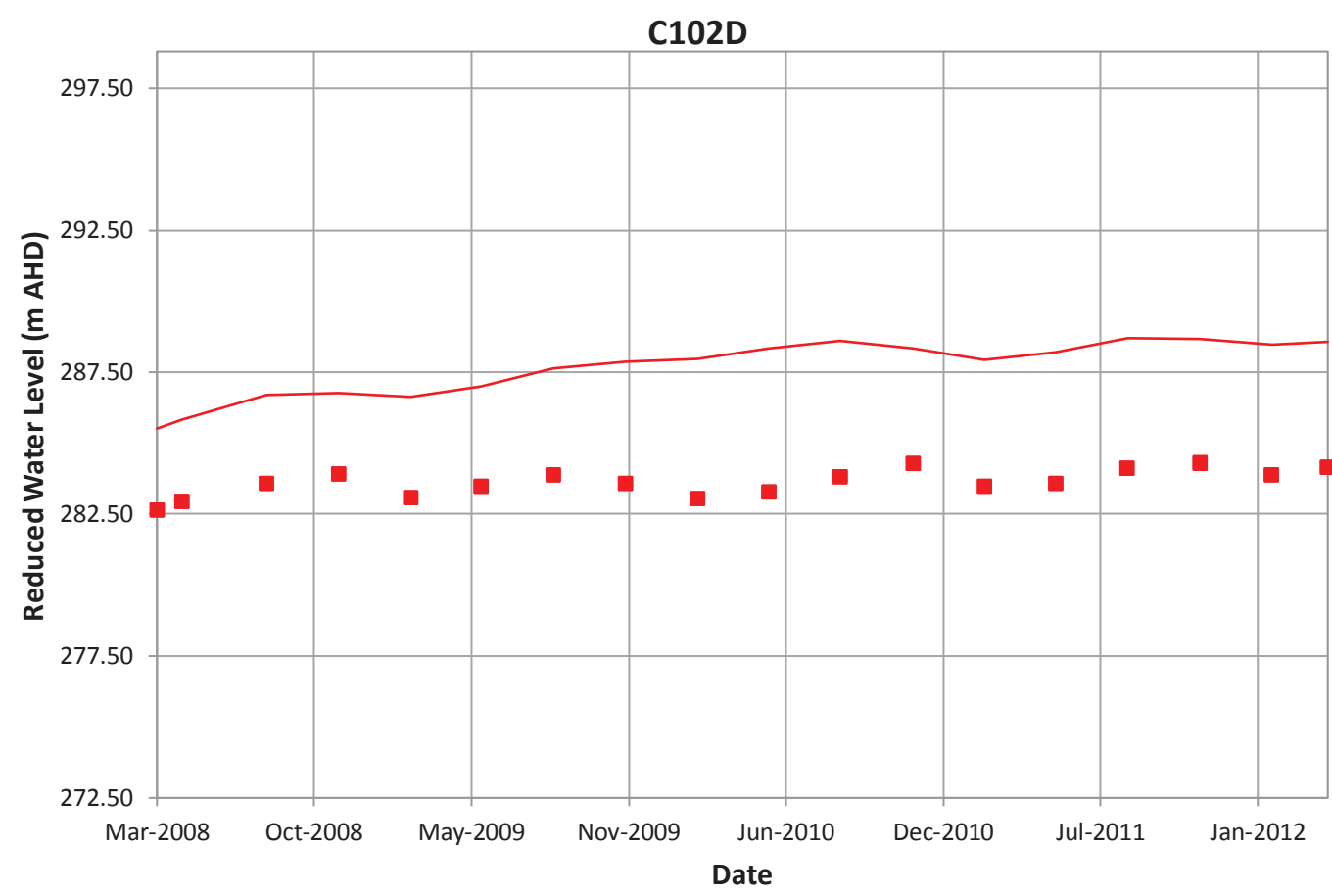
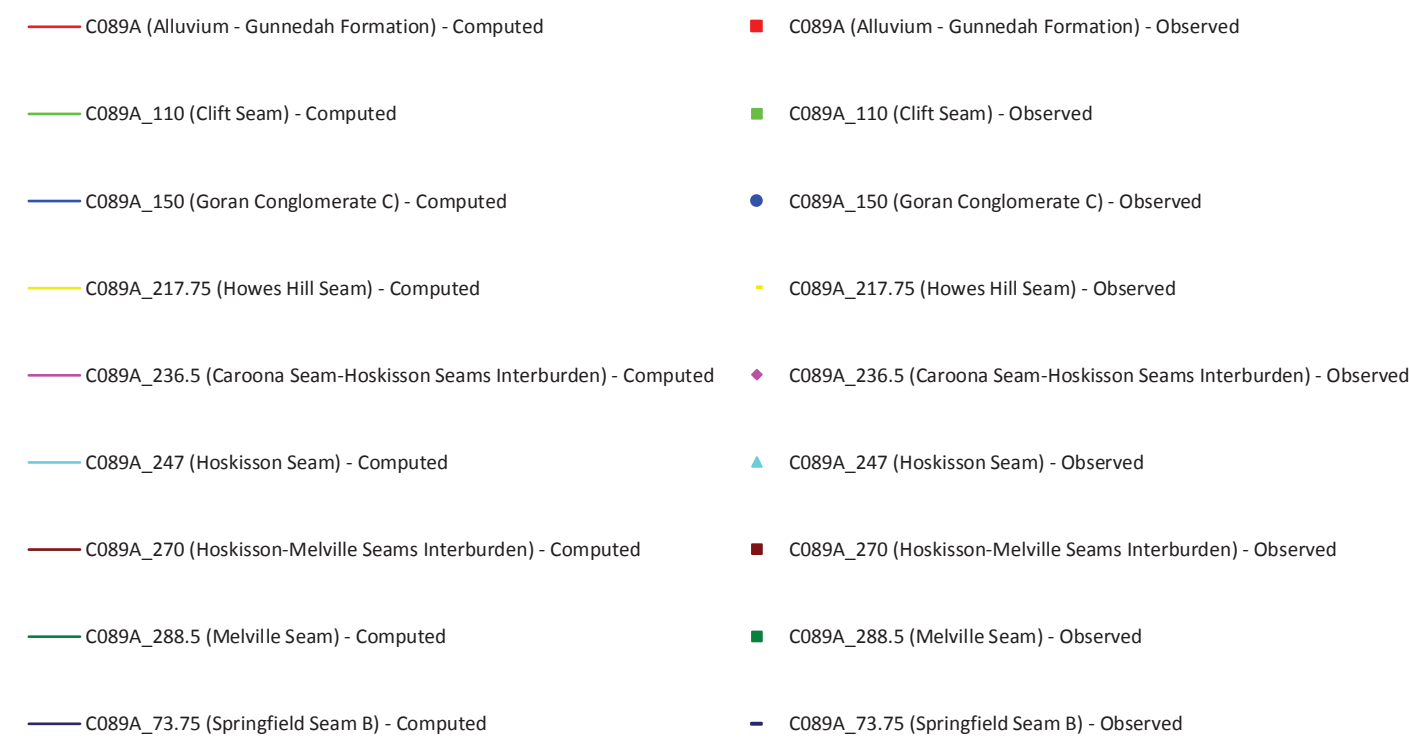
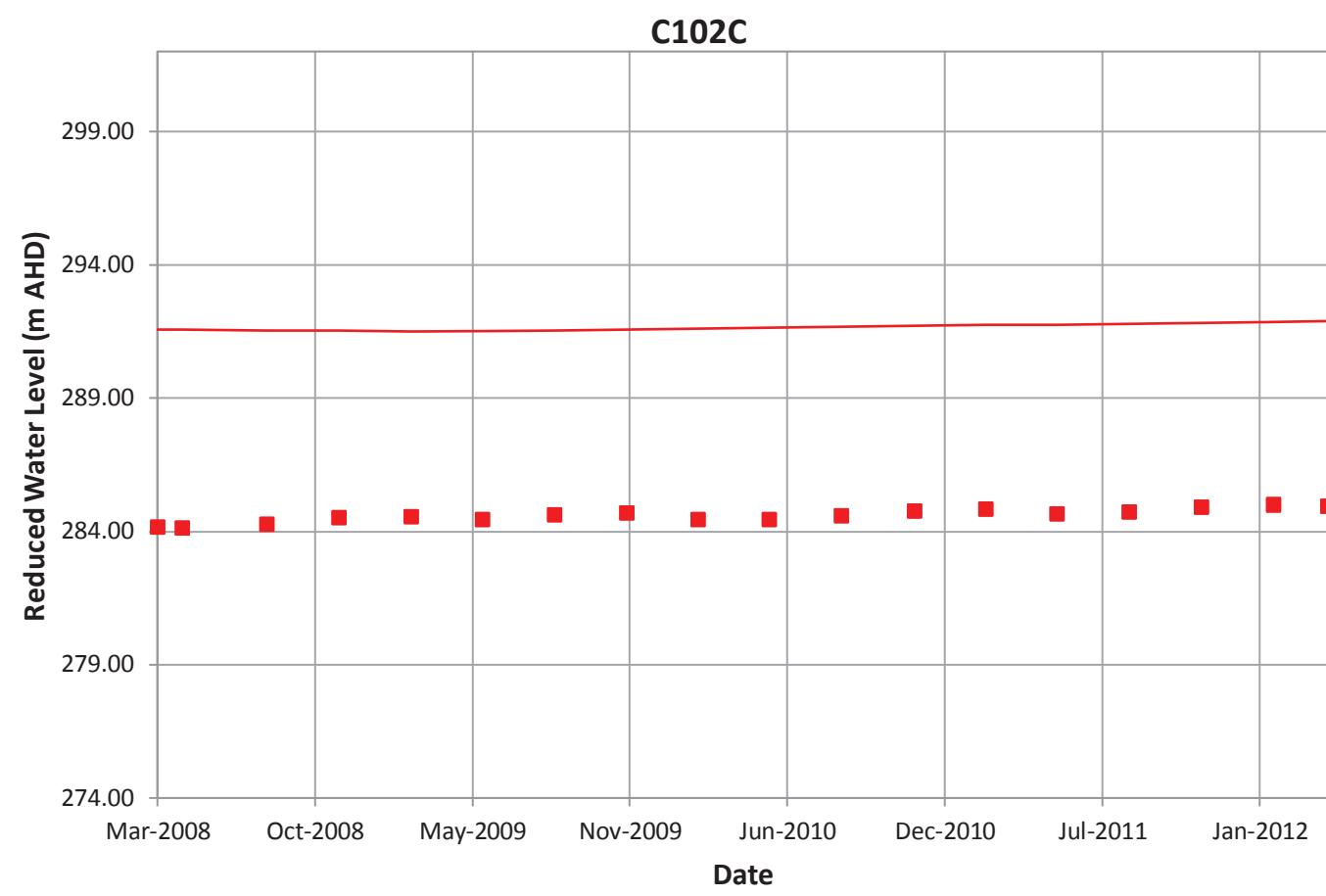
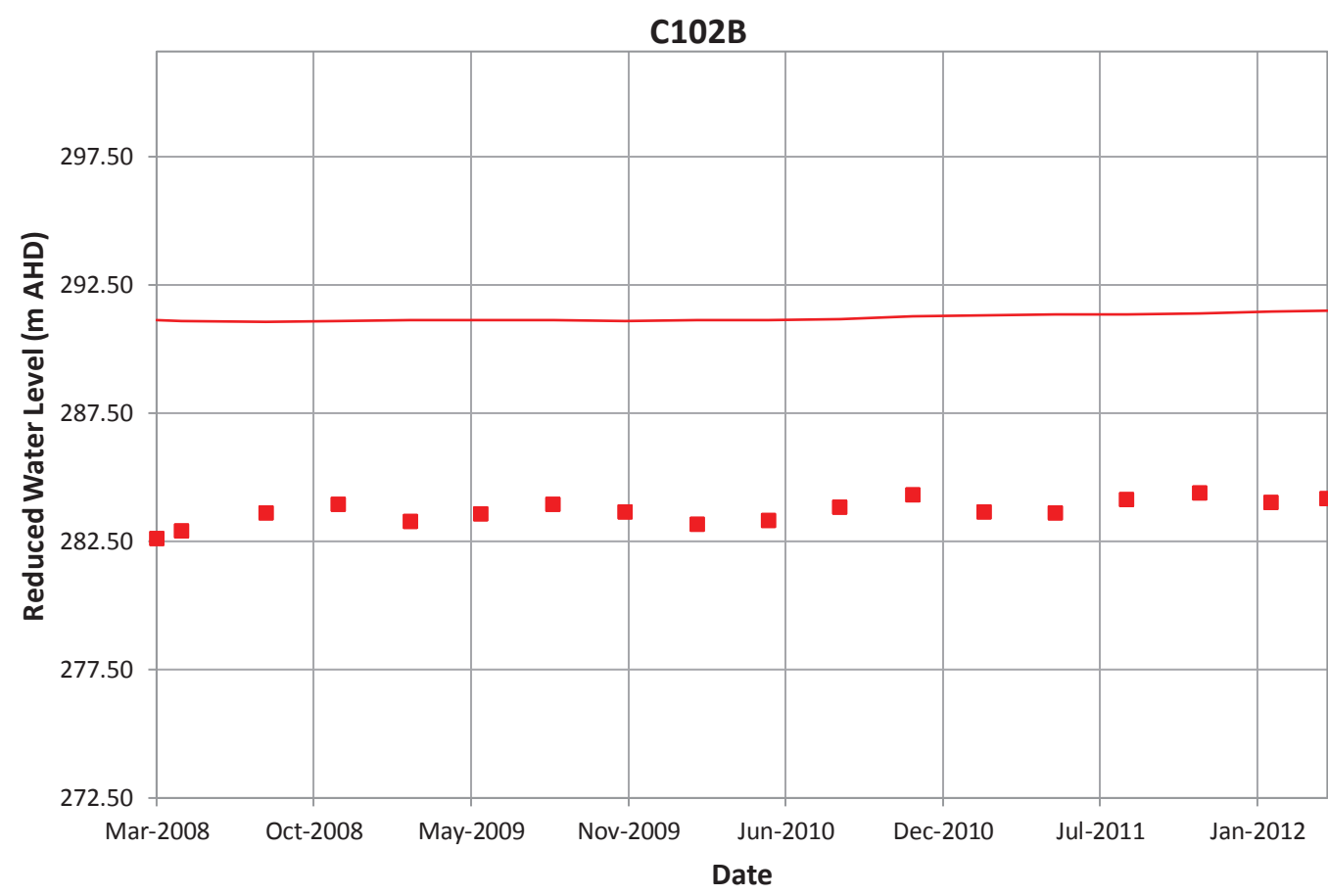
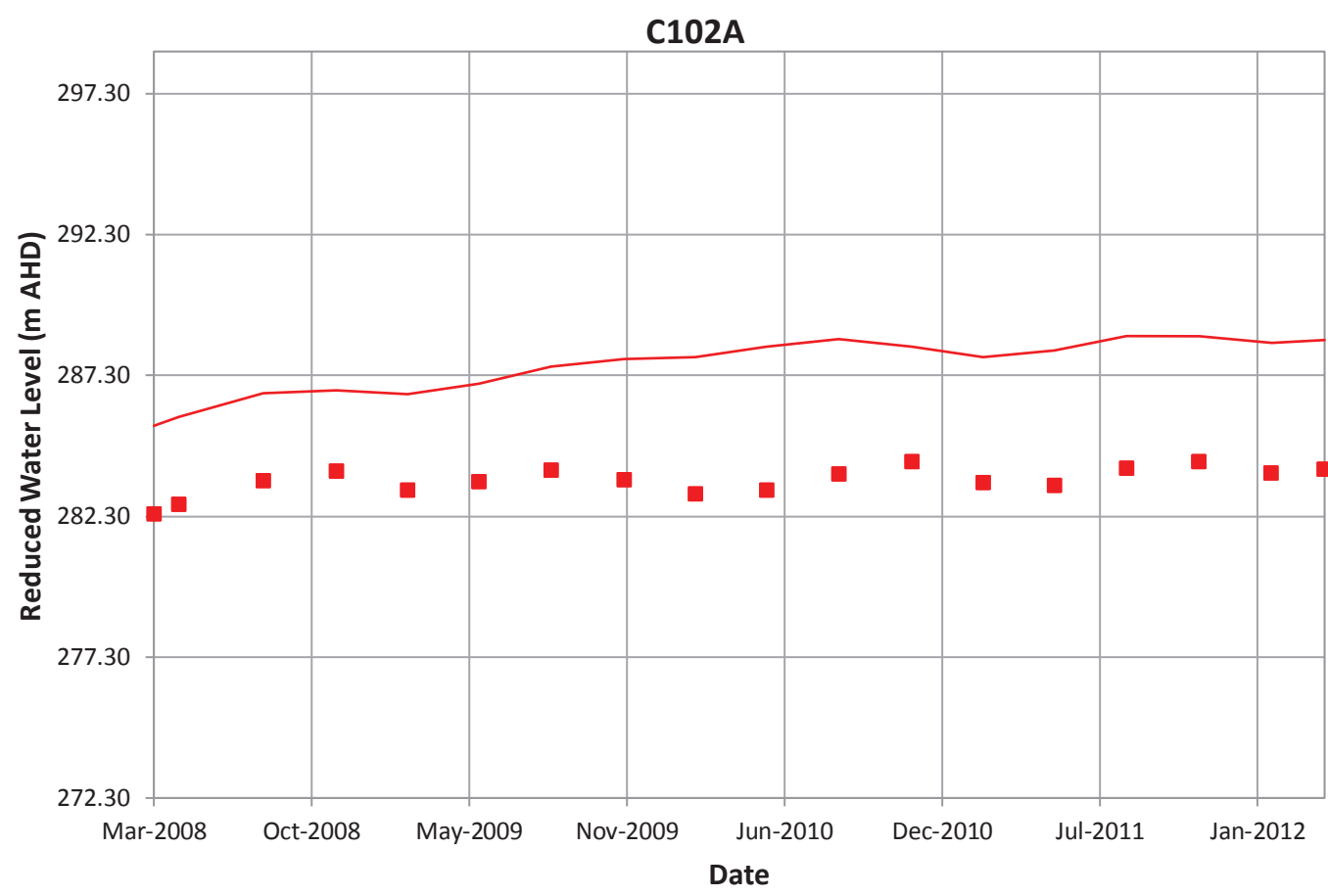
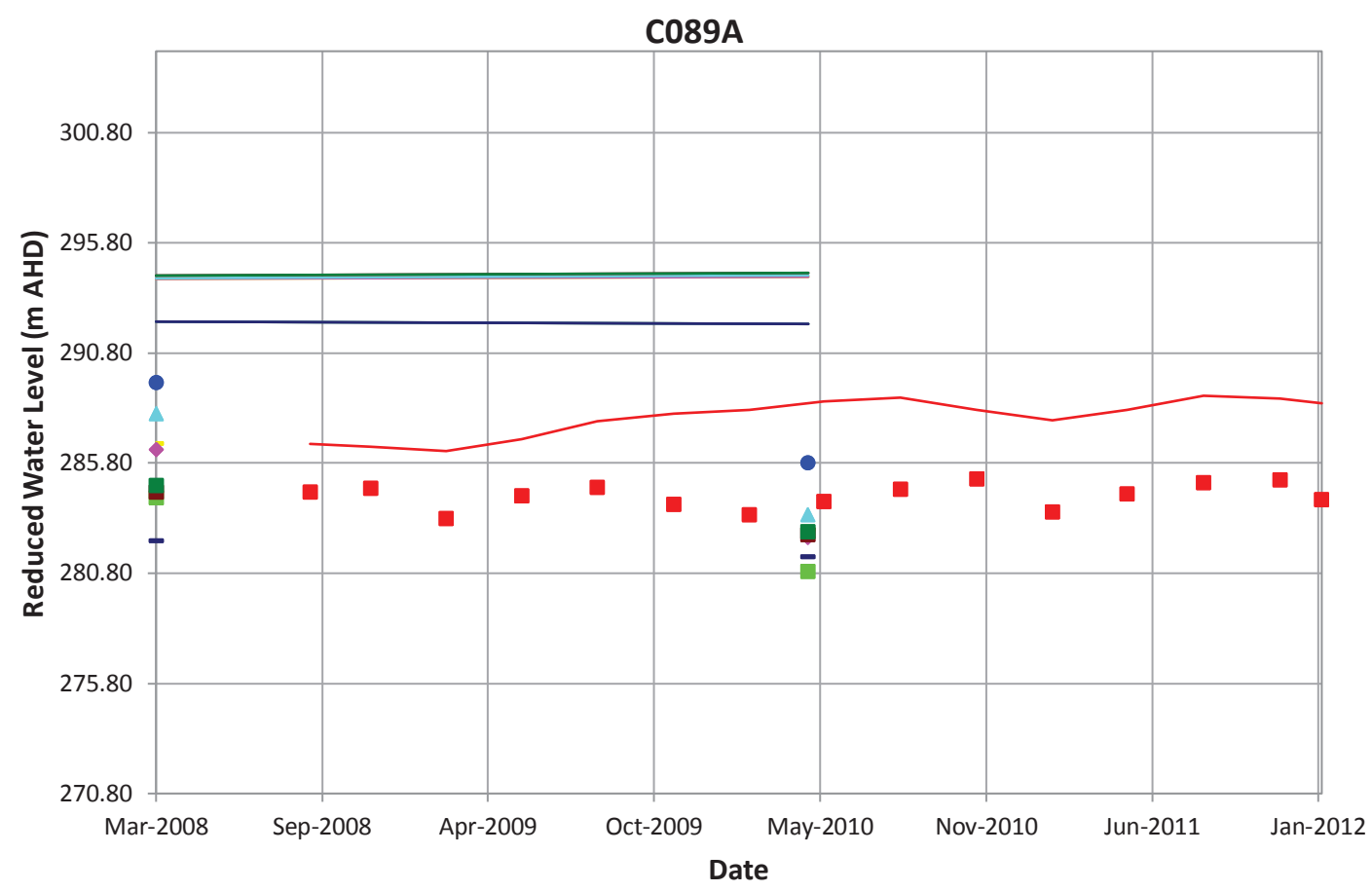
C193A-1 (Clare Sandstone) - Computed

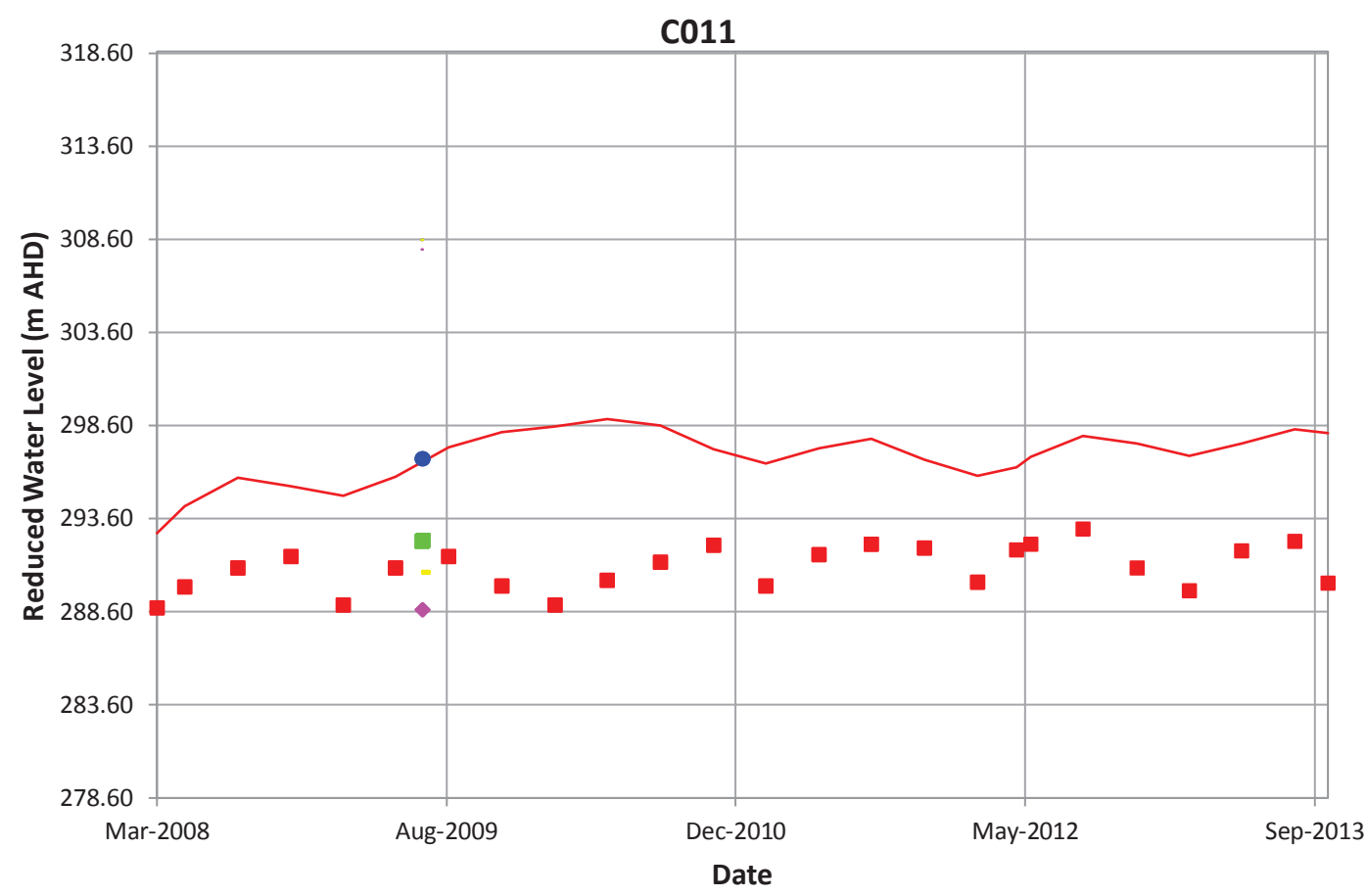
C193A-1 (Clare Sandstone) - Observed



C199A-1 (Alluvium - Narrabri Formation) - Computed

C199A-1 (Alluvium - Narrabri Formation) - Observed





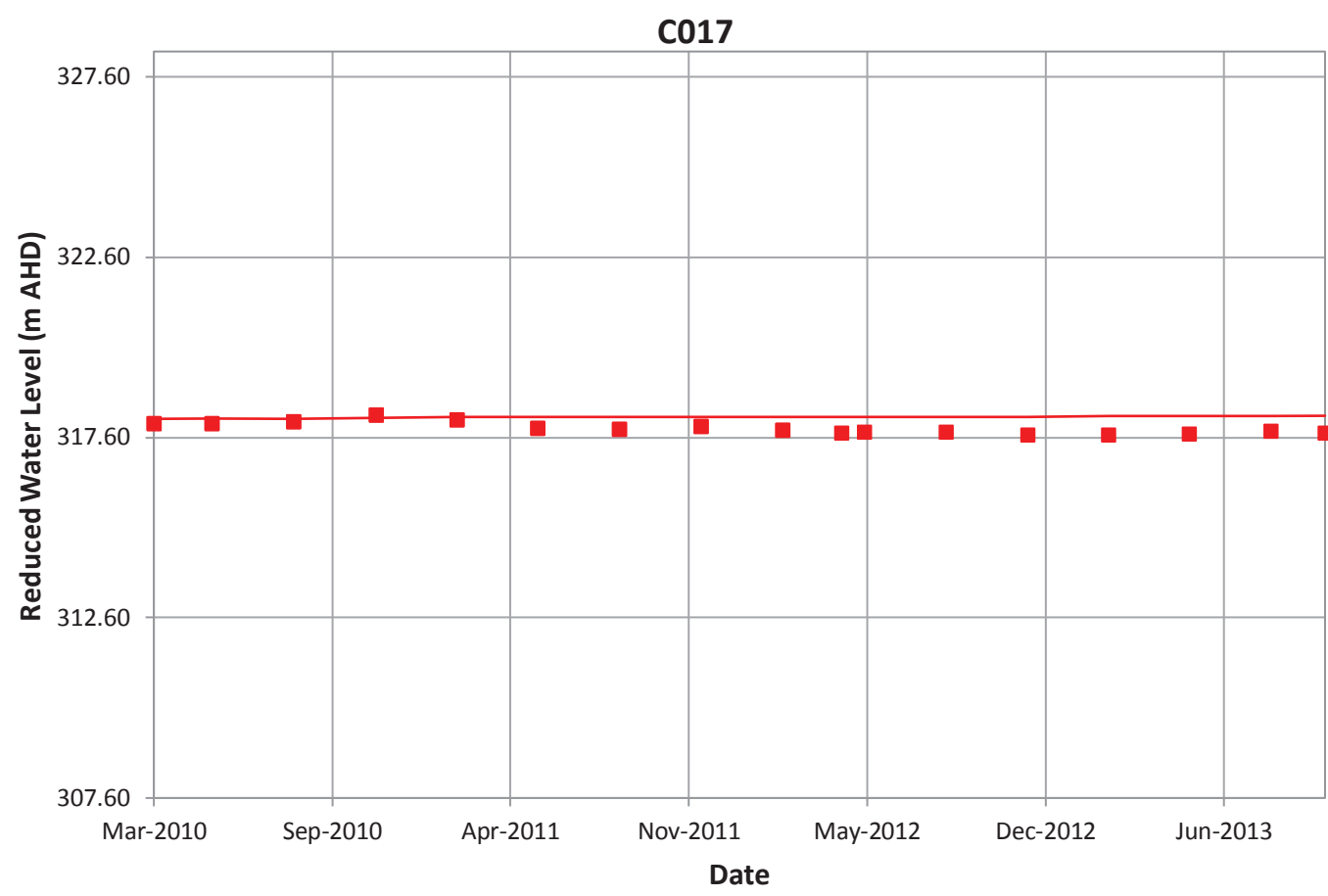
— C011 (Alluvium - Gunnedah Formation) - Computed ■ C011 (Alluvium - Gunnedah Formation) - Observed

— C011_105 (Below Base of Alluvials) - Computed ■ C011_105 (Below Base of Alluvials) - Observed

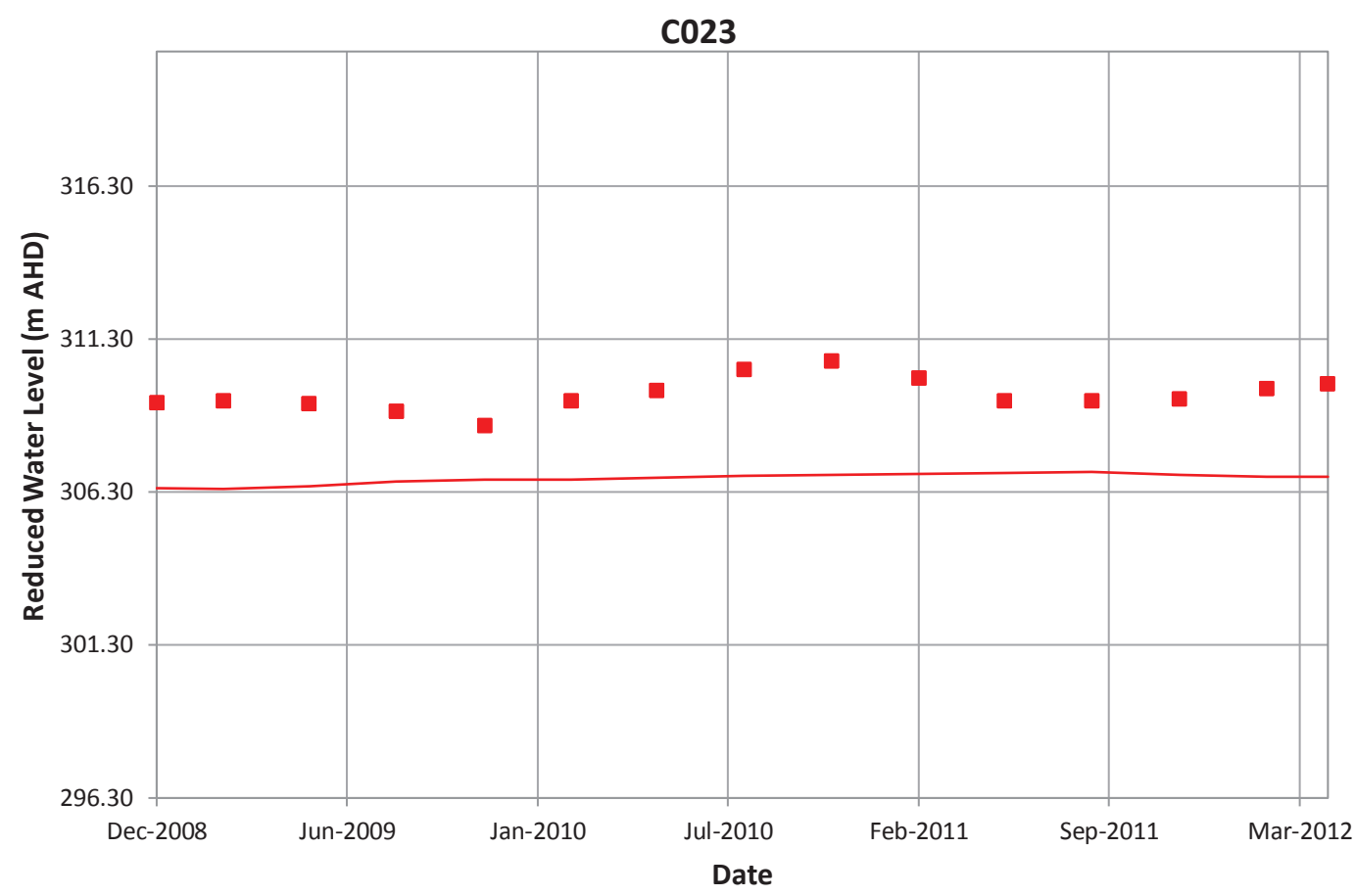
— C011_195 (Sandstone-Conglomerate) - Computed ● C011_195 (Sandstone-Conglomerate) - Observed

— C011_424 (Clift Seam) - Computed - C011_424 (Clift Seam) - Observed

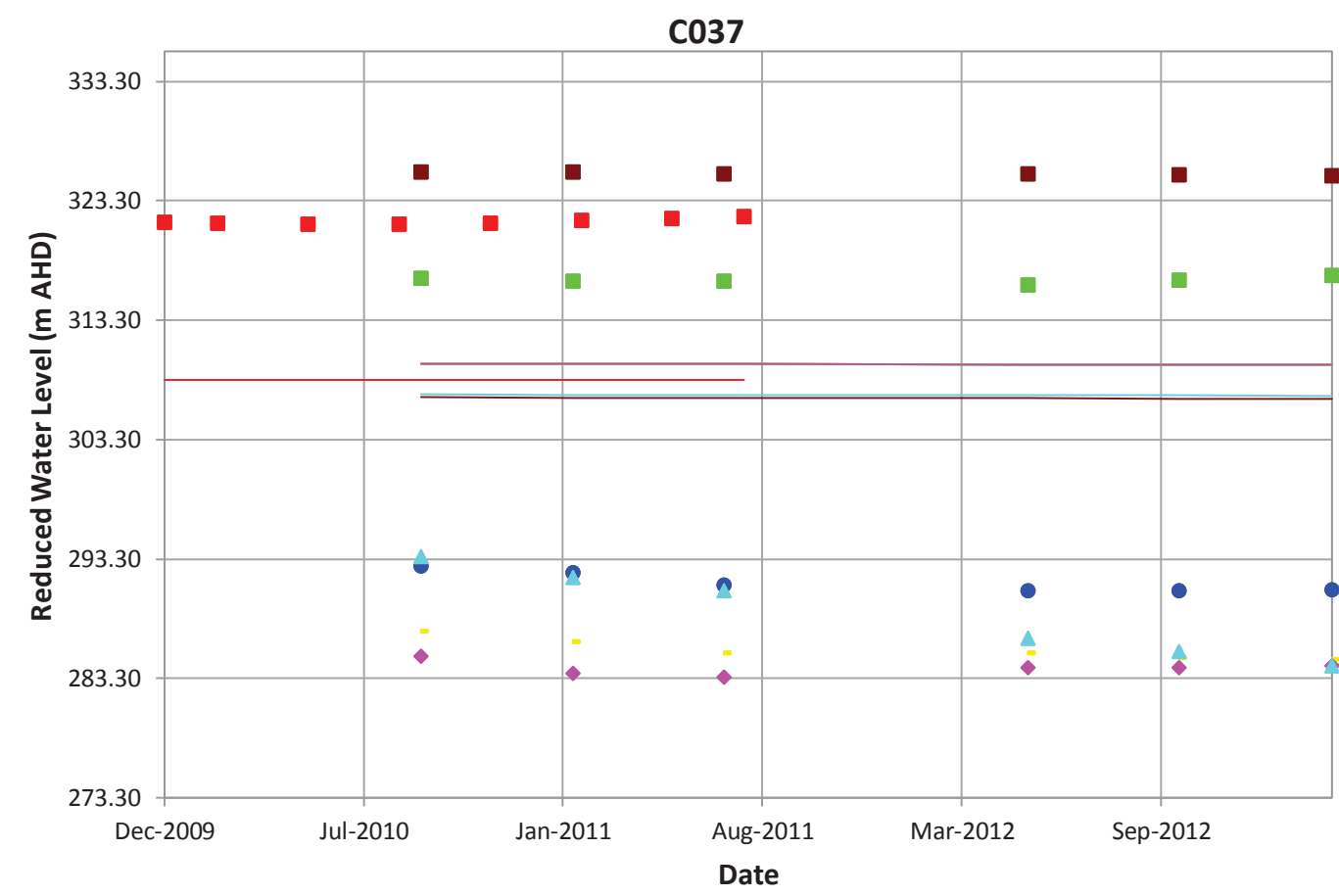
— C011_530 (Hoskisson Seam) - Computed ◆ C011_530 (Hoskisson Seam) - Observed



— C017 (Regolith) - Computed ■ C017 (Regolith) - Observed



— C023 (Alluvium - Gunnedah Formation) - Computed ■ C023 (Alluvium - Gunnedah Formation) - Observed



— C037 (Regolith) - Computed ■ C037 (Regolith) - Observed

— C037_100 (Conglomerate) - Computed ■ C037_100 (Conglomerate) - Observed

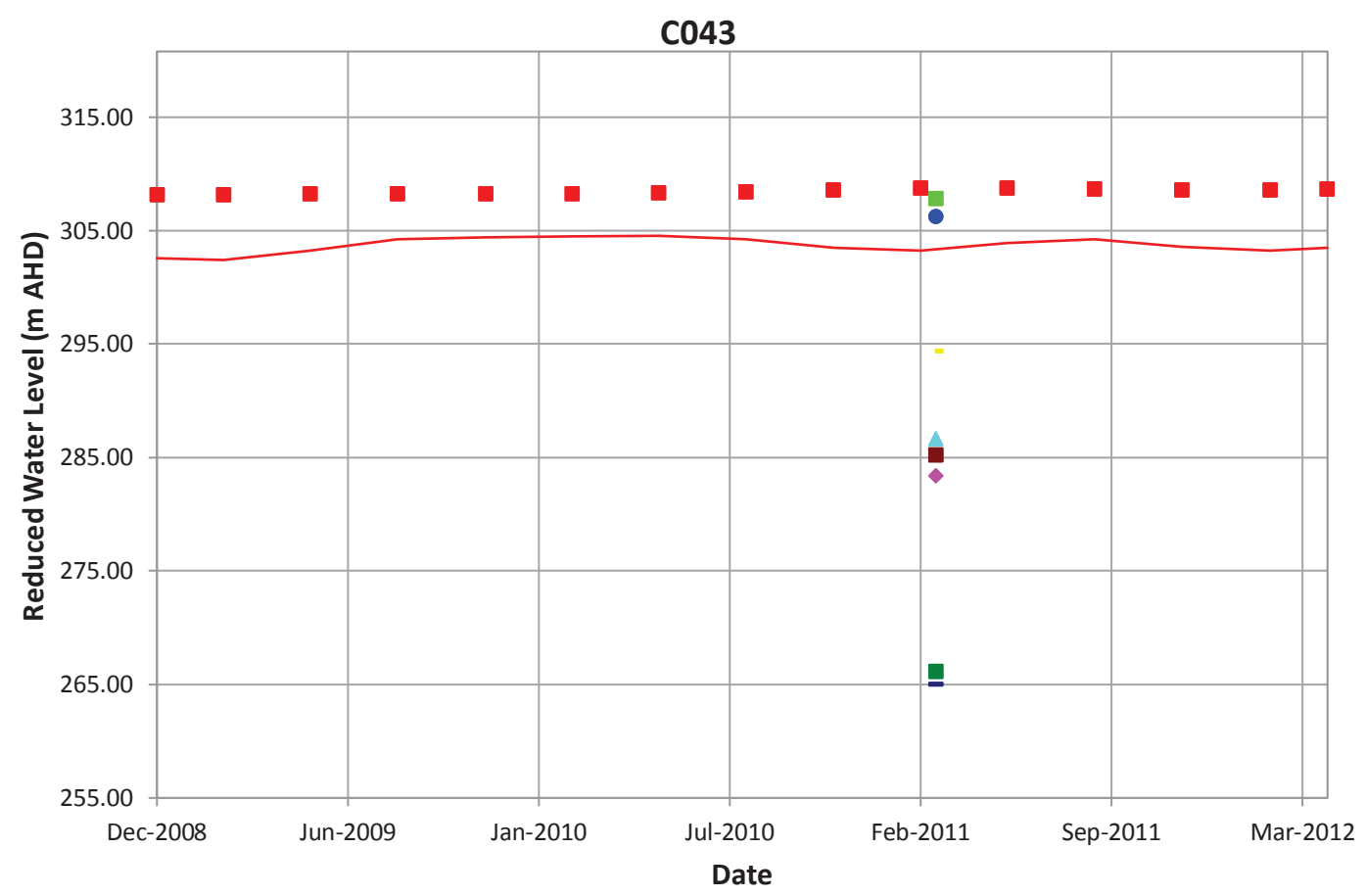
— C037_226 (Doona Seam) - Computed ● C037_226 (Doona Seam) - Observed

— C037_285 (Intrusive) - Computed - C037_285 (Intrusive) - Observed

— C037_338 (Clift Seam) - Computed ◆ C037_338 (Clift Seam) - Observed

— C037_370 (Clare Sandstone B) - Computed ▲ C037_370 (Clare Sandstone B) - Observed

— C037_413 (Hoskisson Seam) - Computed ■ C037_413 (Hoskisson Seam) - Observed



— C043 (Alluvium - Base of) - Computed ■ C043 (Alluvium - Base of) - Observed

— C043_110 (Below Base Alluvials) - Computed ■ C043_110 (Below Base Alluvials) - Observed

— C043_193 (BHAL-Doona Seam Interburden) - Computed ● C043_193 (BHAL-Doona Seam Interburden) - Observed

— C043_271 (Doona Seam) - Computed - C043_271 (Doona Seam) - Observed

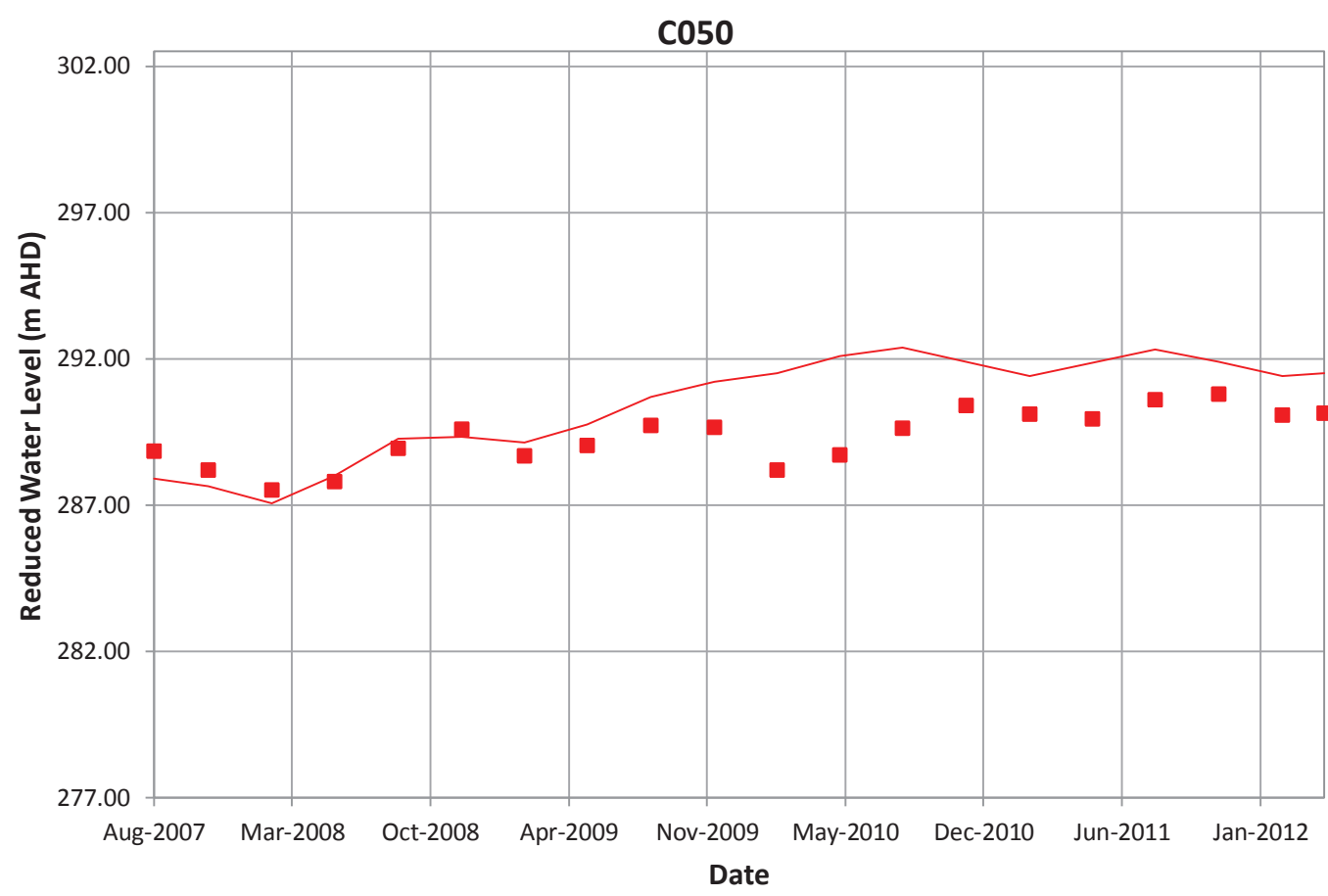
— C043_358 (Clift Seam) - Computed ◆ C043_358 (Clift Seam) - Observed

— C043_396 (Clare Sandstone C) - Computed ▲ C043_396 (Clare Sandstone C) - Observed

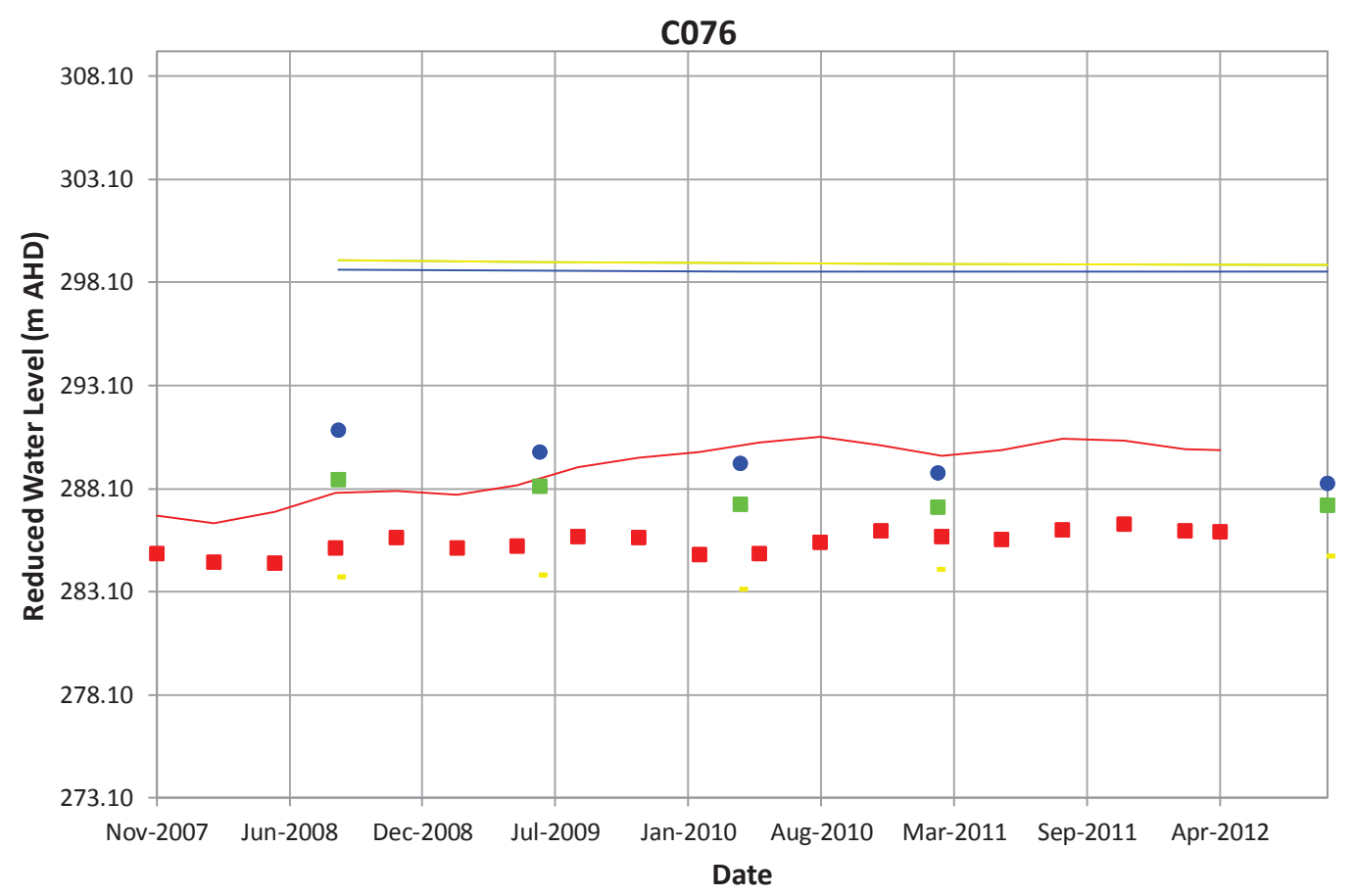
— C043_424.4 (Hoskisson Seam) - Computed ■ C043_424.4 (Hoskisson Seam) - Observed

— C043_444 (Hoskisson-Melville Seams Interburden) - Computed ■ C043_444 (Hoskisson-Melville Seams Interburden) - Observed

— C043_461 (Melville Seam) - Computed - C043_461 (Melville Seam) - Observed



— C050 (Alluvium - Gunnedah Formation) - Computed ■ C050 (Alluvium - Gunnedah Formation) - Observed

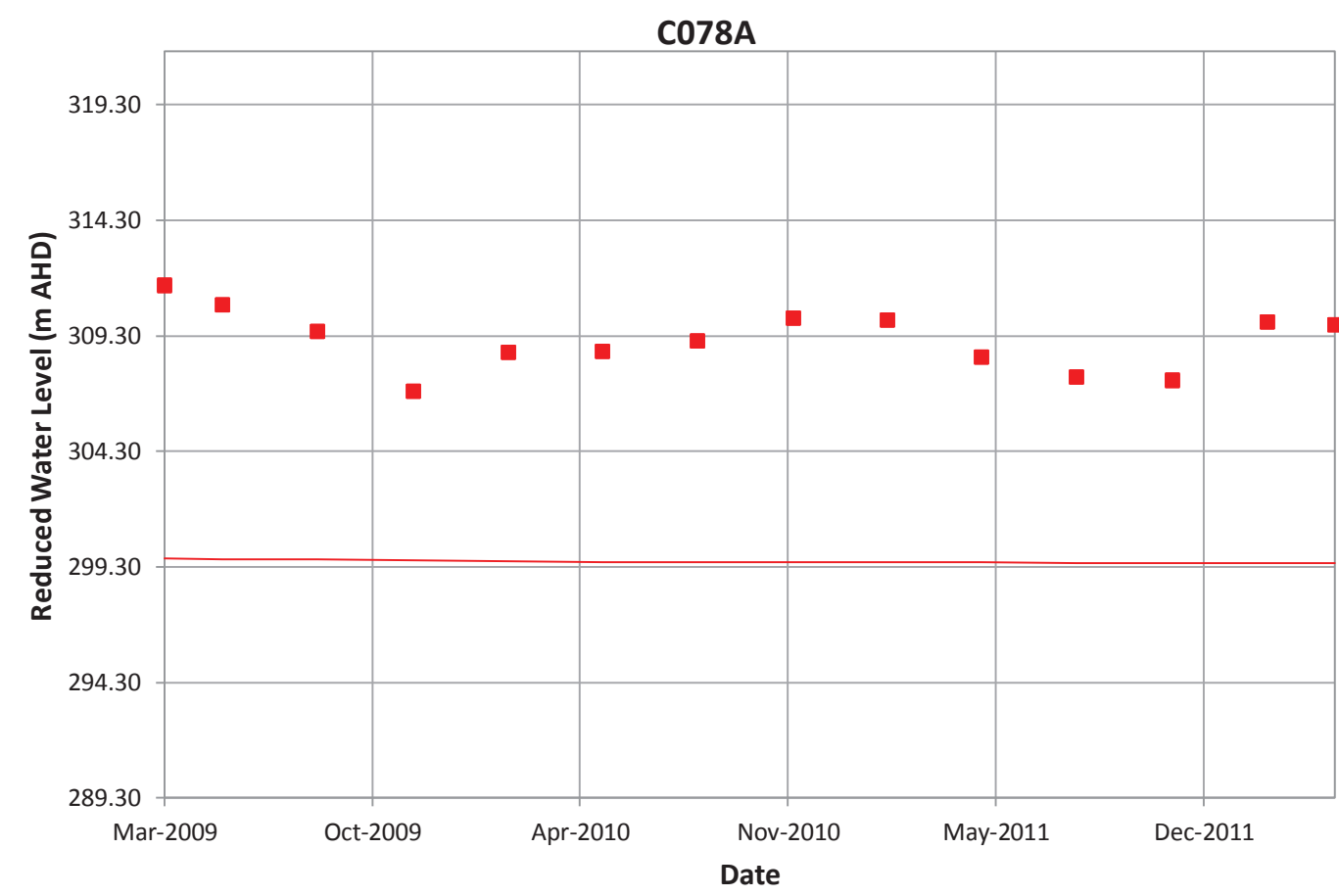


— C076 (Alluvium - Gunnedah Formation) - Computed ■ C076 (Alluvium - Gunnedah Formation) - Observed

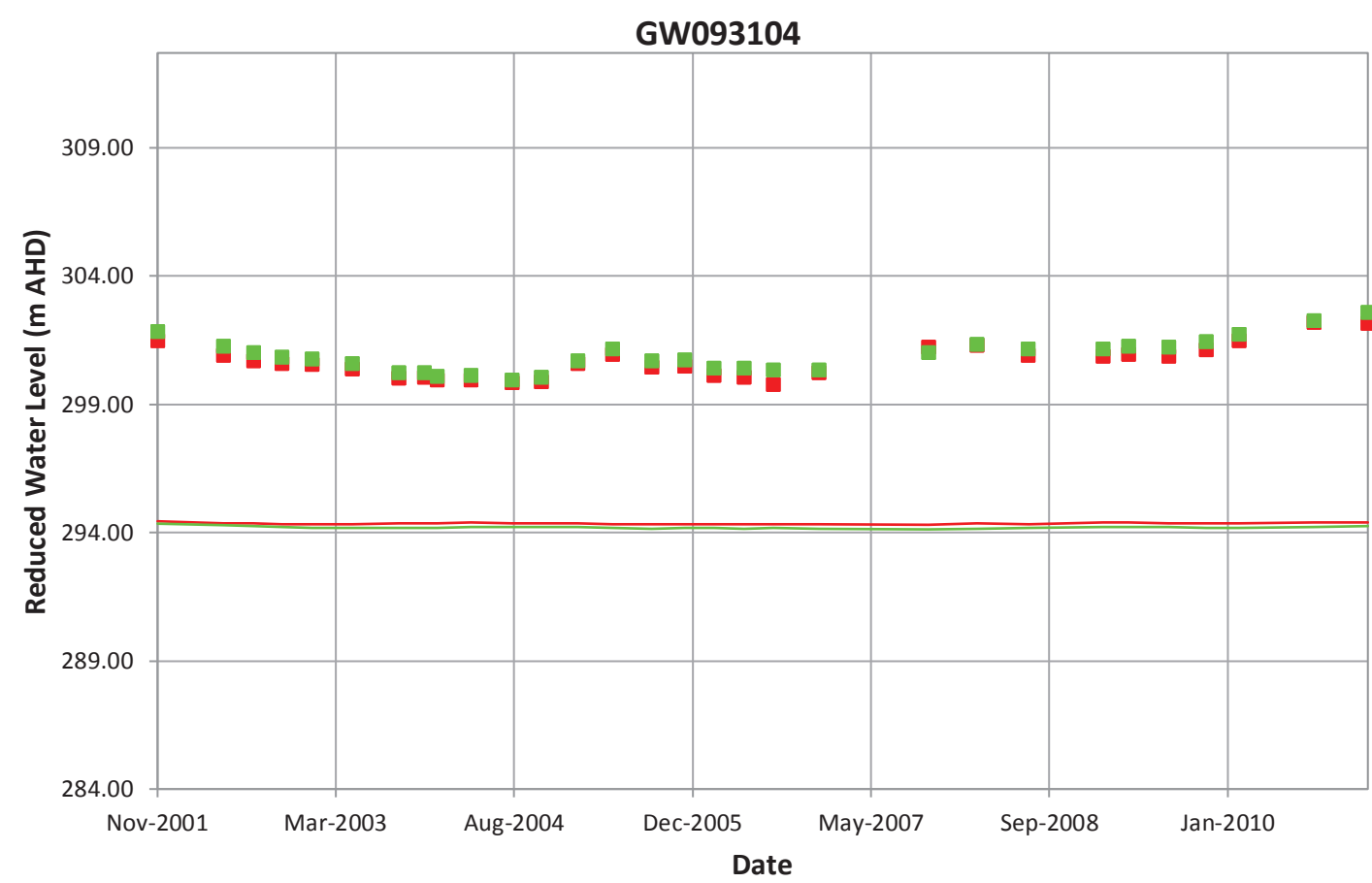
— C076_207 (Springfield-Clift Seams Interburden) - Computed ■ C076_207 (Springfield-Clift Seams Interburden) - Observed

— C076_299 (Caroonia Seam-Hoskisson Seams Interburden) - Computed ● C076_299 (Caroonia Seam-Hoskisson Seams Interburden) - Observed

— C076_80 (Below Base of Alluvials) - Computed - C076_80 (Below Base of Alluvials) - Observed



— C078A (Regolith) - Computed ■ C078A (Regolith) - Observed

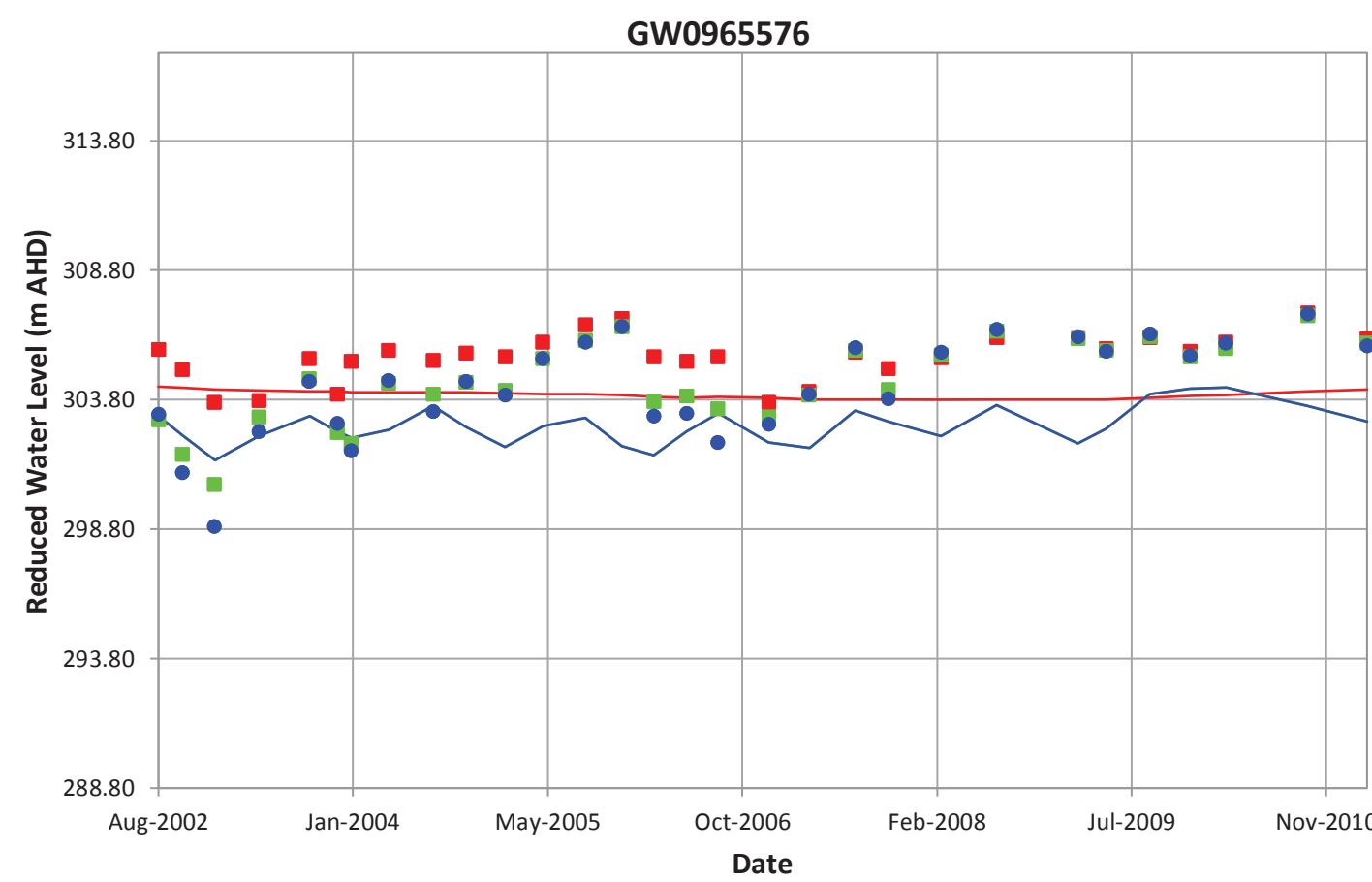


GW093104_1e (Narrabri Fm) - Computed

GW093104_1e (Narrabri Fm) - Observed

GW093104_2e (Gunnedah Fm) - Computed

GW093104_2e (Gunnedah Fm) - Observed



GW0965576_1e (Narrabri Fm) - Computed

GW0965576_1e (Narrabri Fm) - Observed

GW0965576_2e (Gunnedah Fm) - Computed

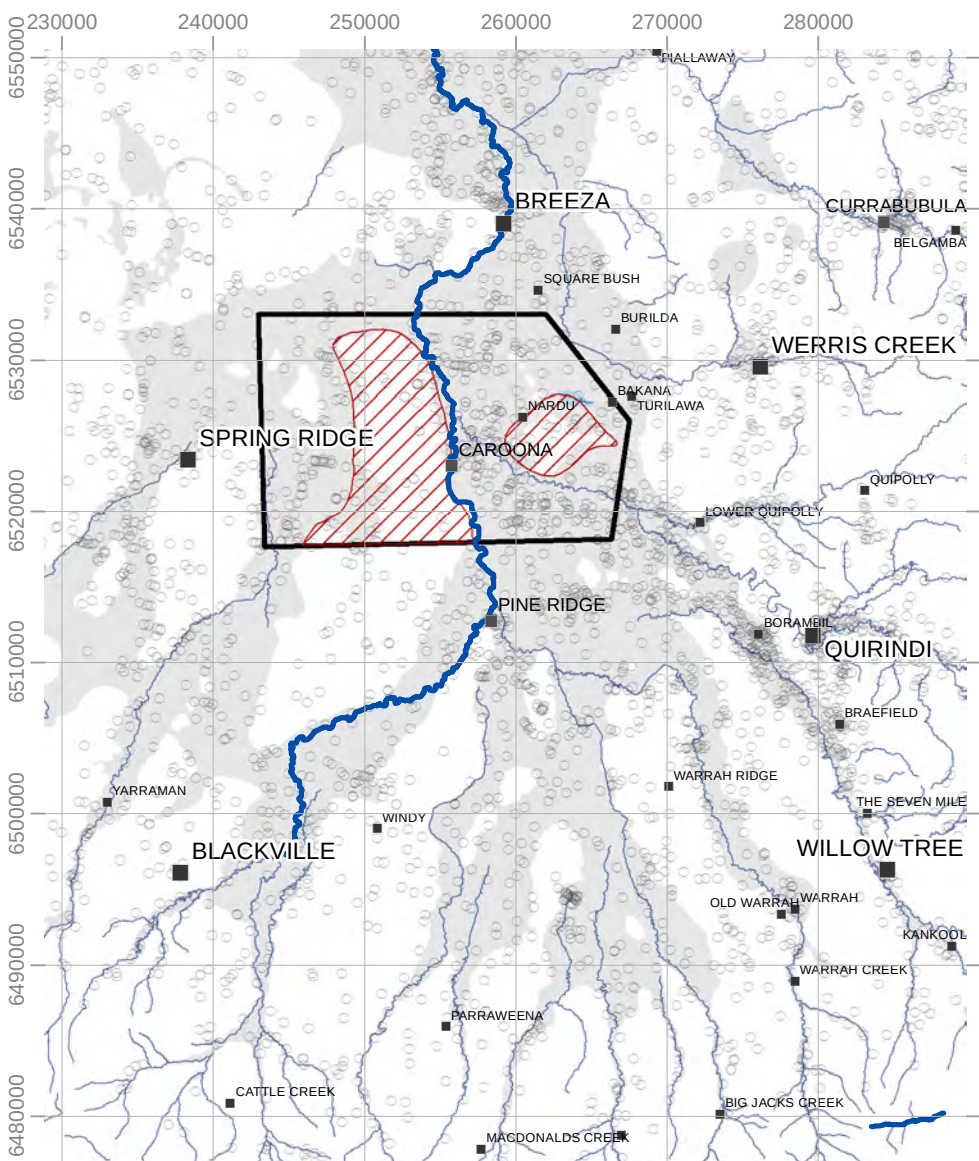
GW0965576_2e (Gunnedah Fm) - Observed

GW0965576_3e (Gunnedah Fm) - Computed

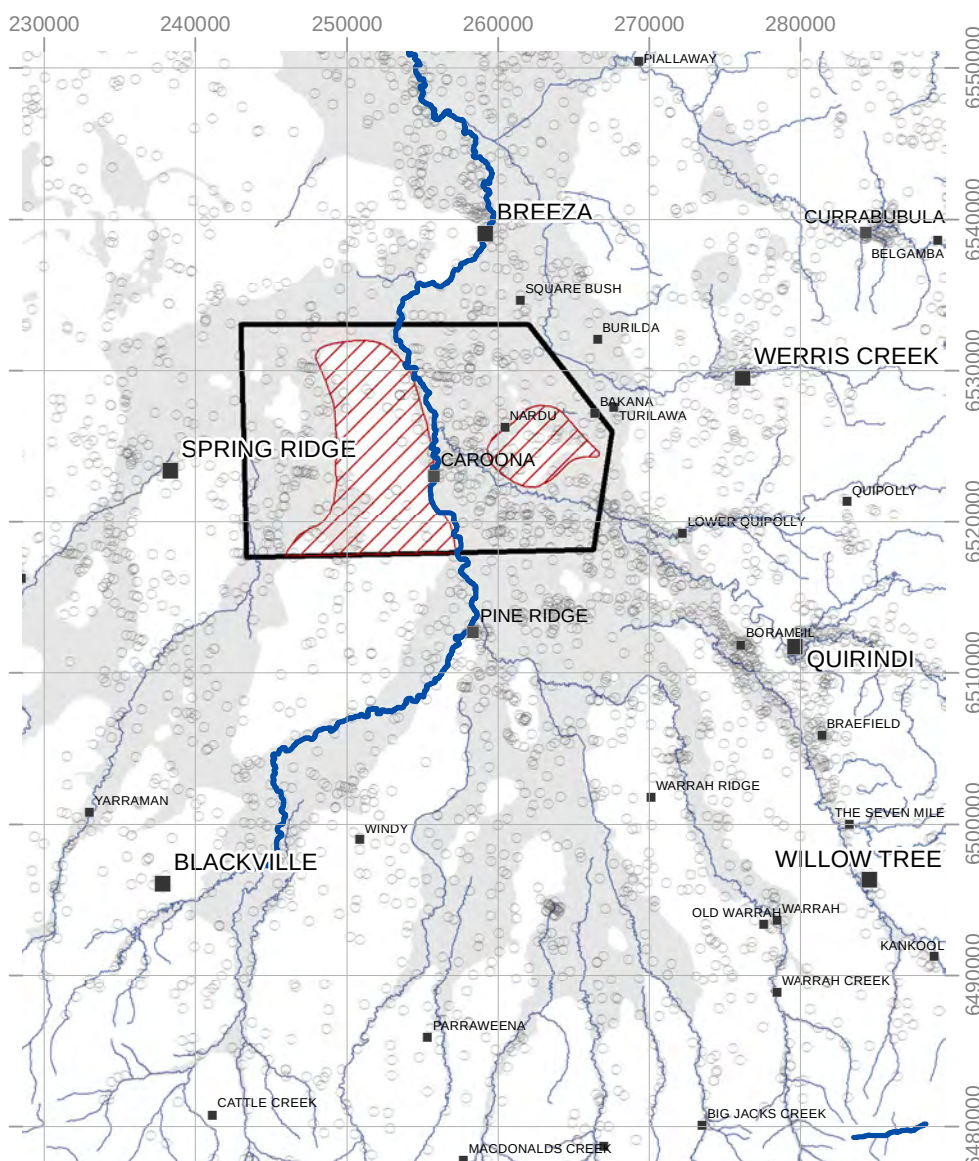
GW0965576_3e (Gunnedah Fm) - Observed

ATTACHMENT E

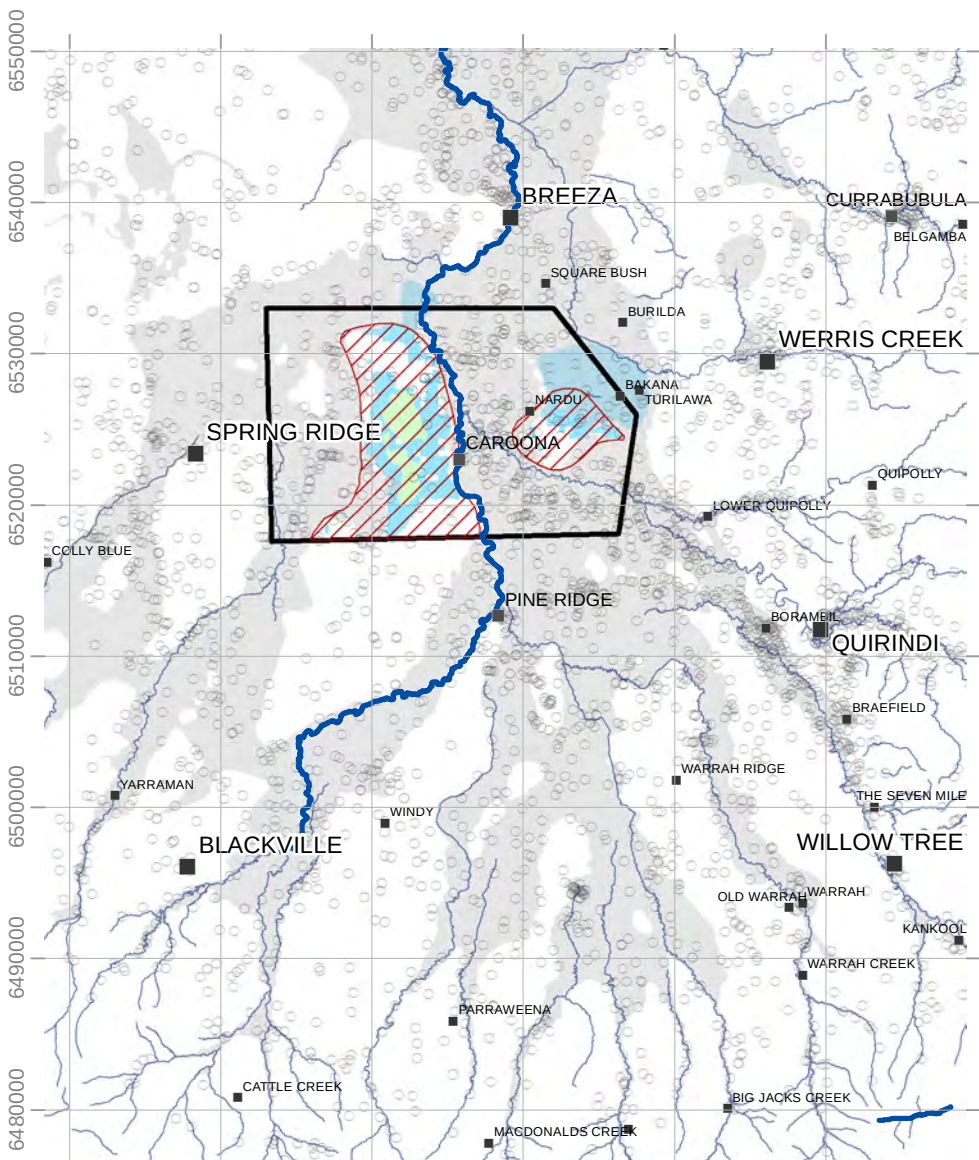
Modelled Drawdowns – Sensitivity Run #1



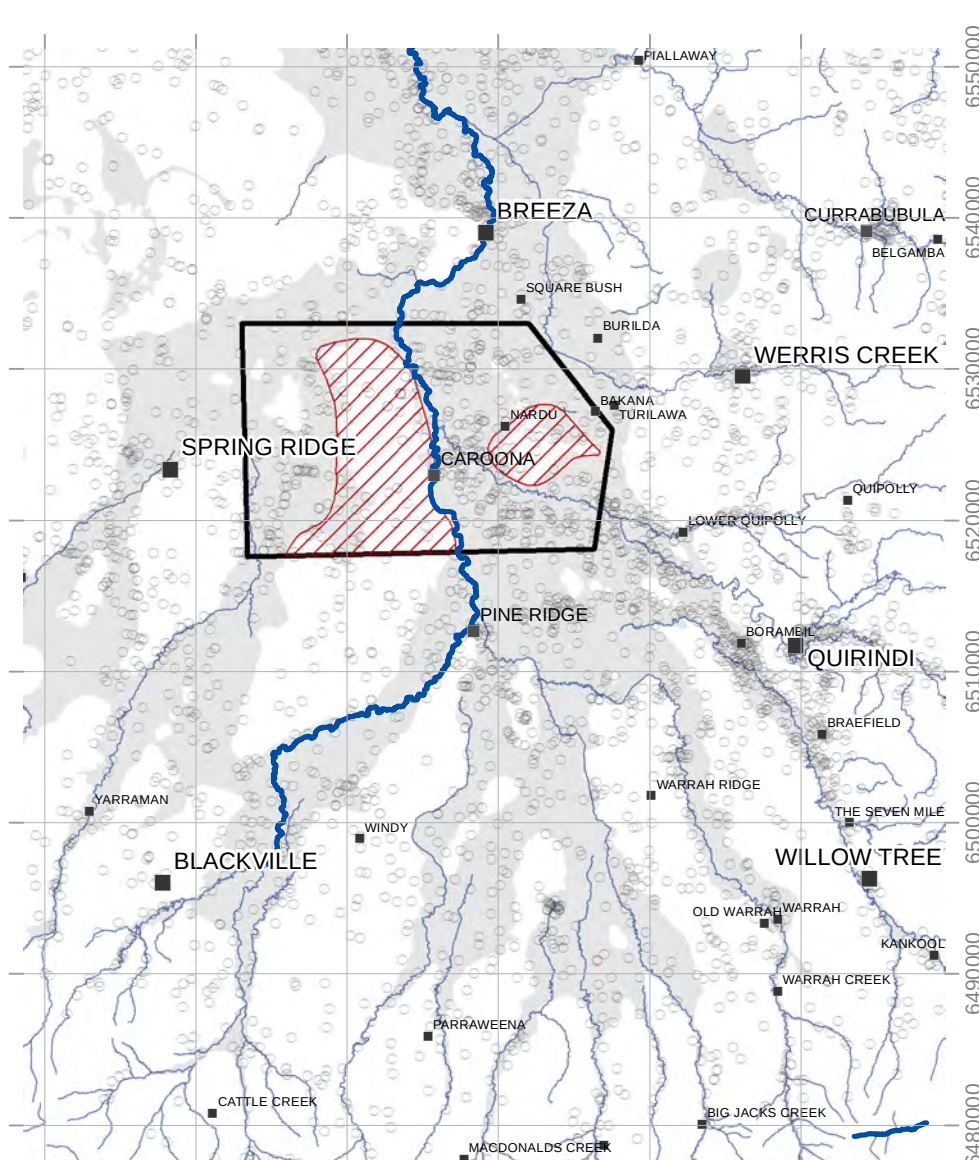
Layer 1 maximum drawdown at any time
Narrabri Fm / Regolith



Layer 1 recovered drawdown (280 years post-mining)
Narrabri Fm / Regolith



Layer 2 maximum drawdown at any time
Gunnedah Fm / Regolith



Layer 2 recovered drawdown (280 years post-mining)
Gunnedah Fm / Regolith

Legend

- NOW Registered Bores
- Town
- Village
- Locality
- River
- Creek
- Alluvials
- Exploration Licence
- ▨ Targeted Exploration Area

Maximum Drawdown
(m, at any time)

□	<=2
■	2.01 - 10

■	10.01 - 20
■	20.01 - 50
■	>50.00

BHP Billiton
Caroonna Coal Project

Figure E1

Simulated Drawdown and Recovery
Model Layers 1 and 2 - Sensivity Run #1

DrawingNo: CAR001-005
Rev: D.
Created by: CNicol
Date: 04/03/2014.

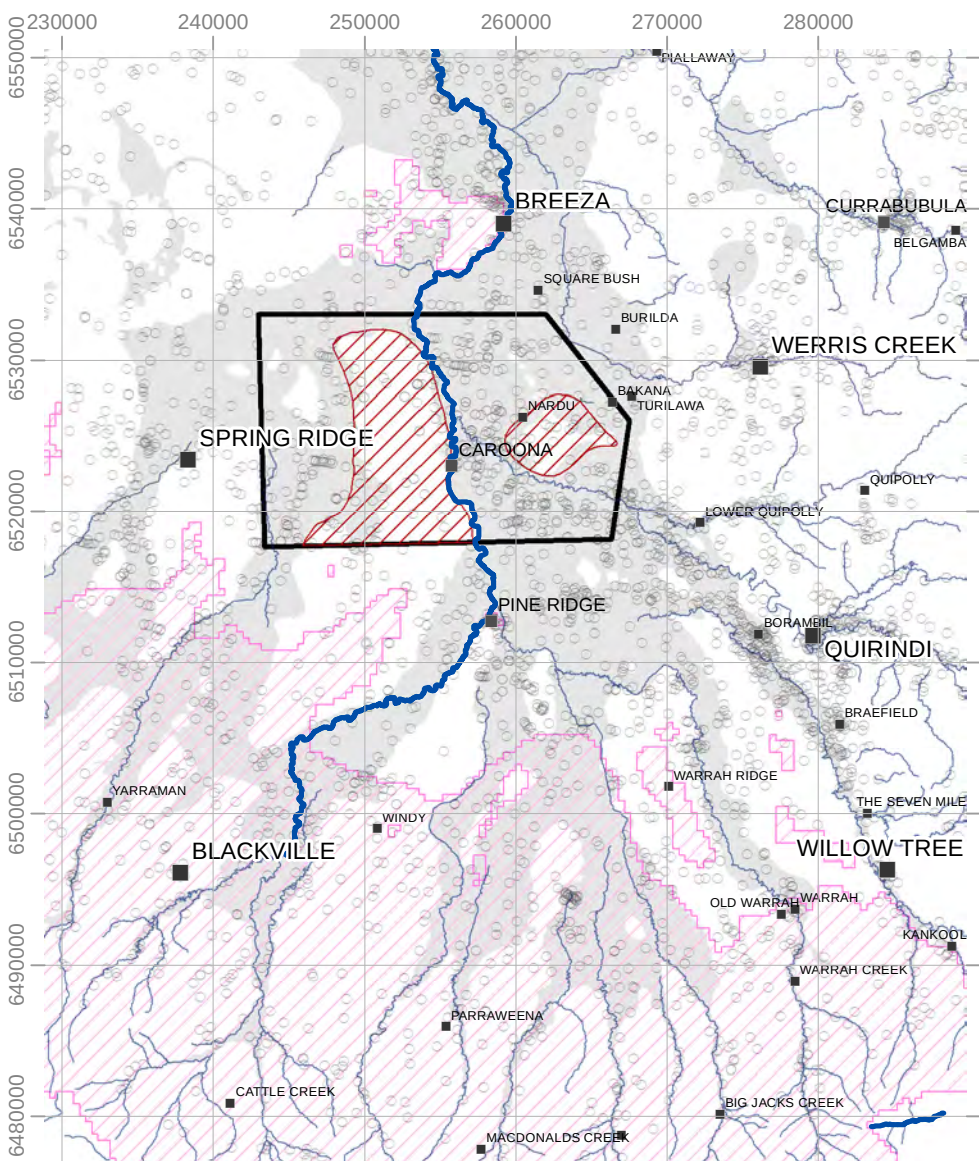


Scale: 500,000 at A3
GDA 1994 MGA Zone 56

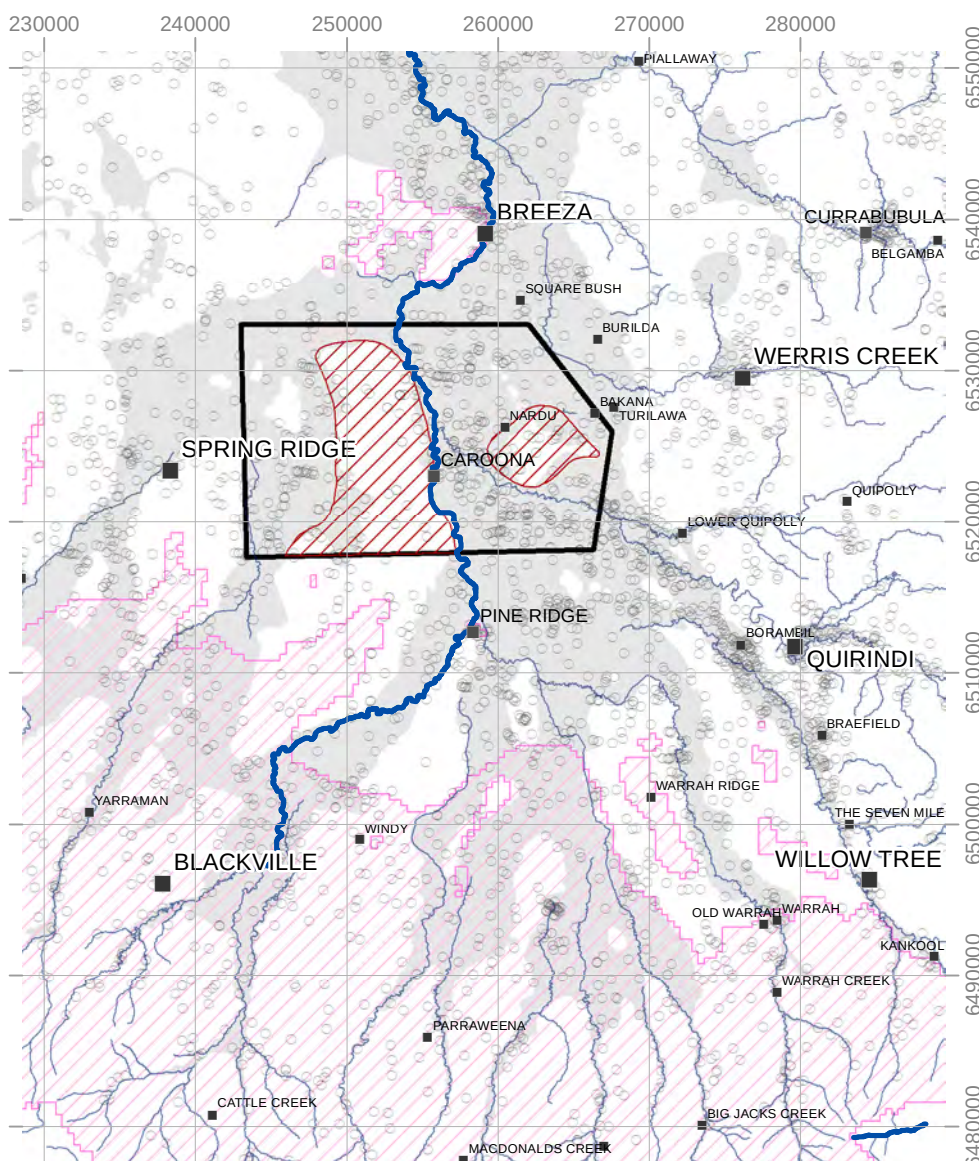


0 2.5 5 10 15 20
Kilometers

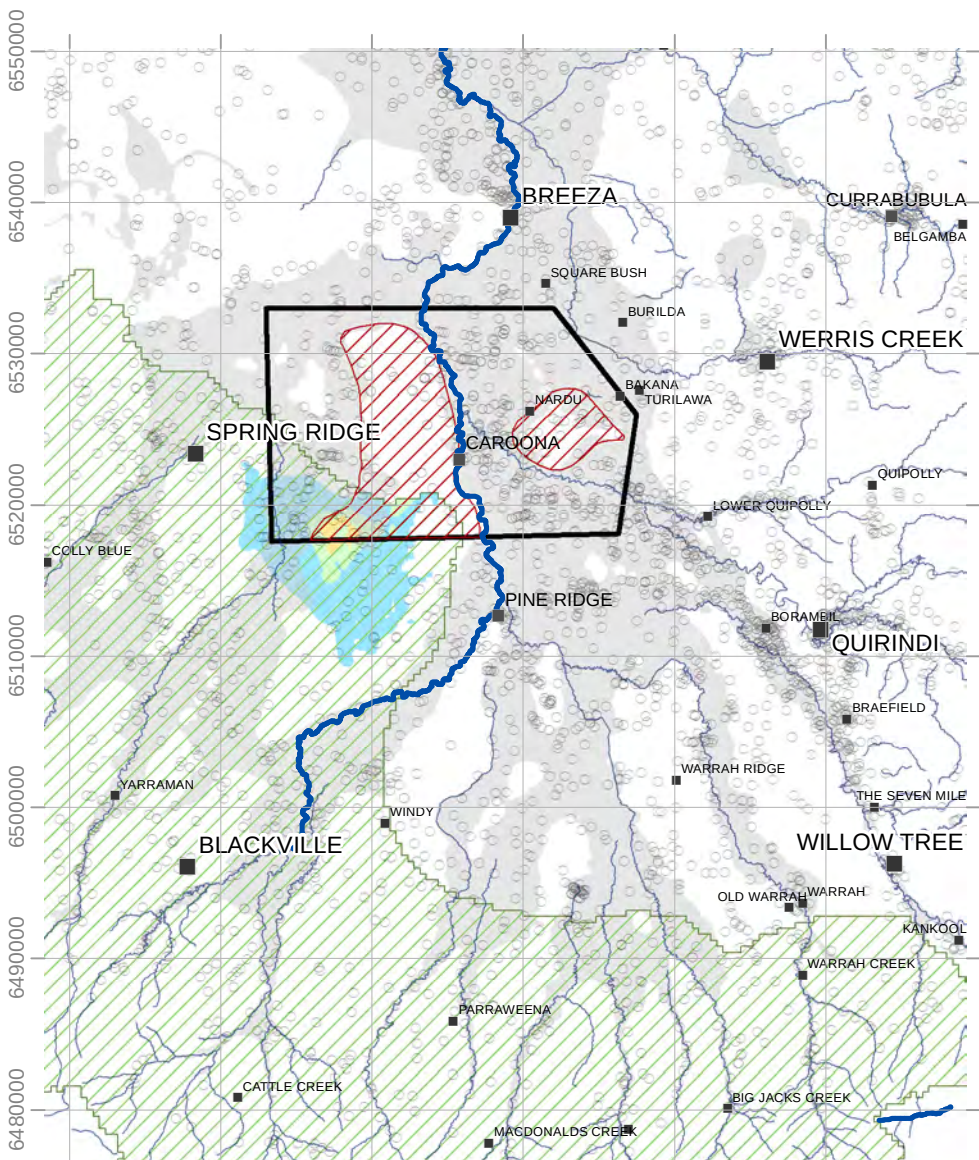
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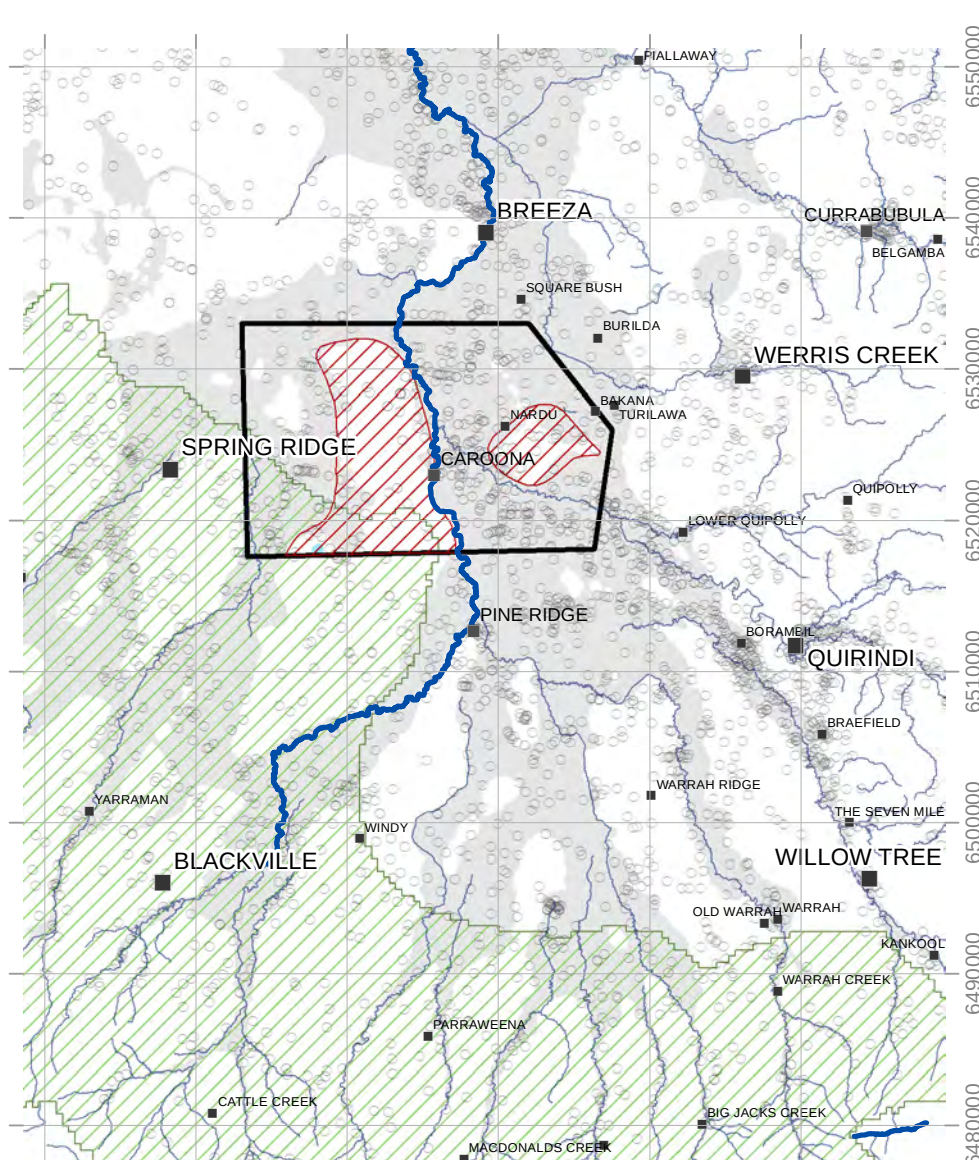
Layer 3 maximum drawdown at any time
Liverpool Ranges Basalt



Layer 3 recovered drawdown (280 years post-mining)
Liverpool Ranges Basalt



Layer 4 maximum drawdown at any time
Jurassic Formations



Layer 4 recovered drawdown (280 years post-mining)
Jurassic Formations

- Legend**
- NOW Registered Bores
 - Town
 - Village
 - Locality
 - Exploration Licence
 - River
 - Creek
 - Alluvials
 - Tertiary Basalts Extent
 - Jurassic Formations Extent
 - Targeted Exploration Area

Maximum Drawdown
(m, at any time)

- ≤2
- 2.01 - 10

- 10.01 - 20
- 20.01 - 50
- >50.00

**BHP Billiton
Caroonna Coal Project**

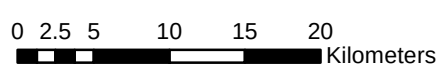
Figure E2

**Simulated Drawdown and Recovery
Model Layers 3 and 4 - Sensivity Run #1**

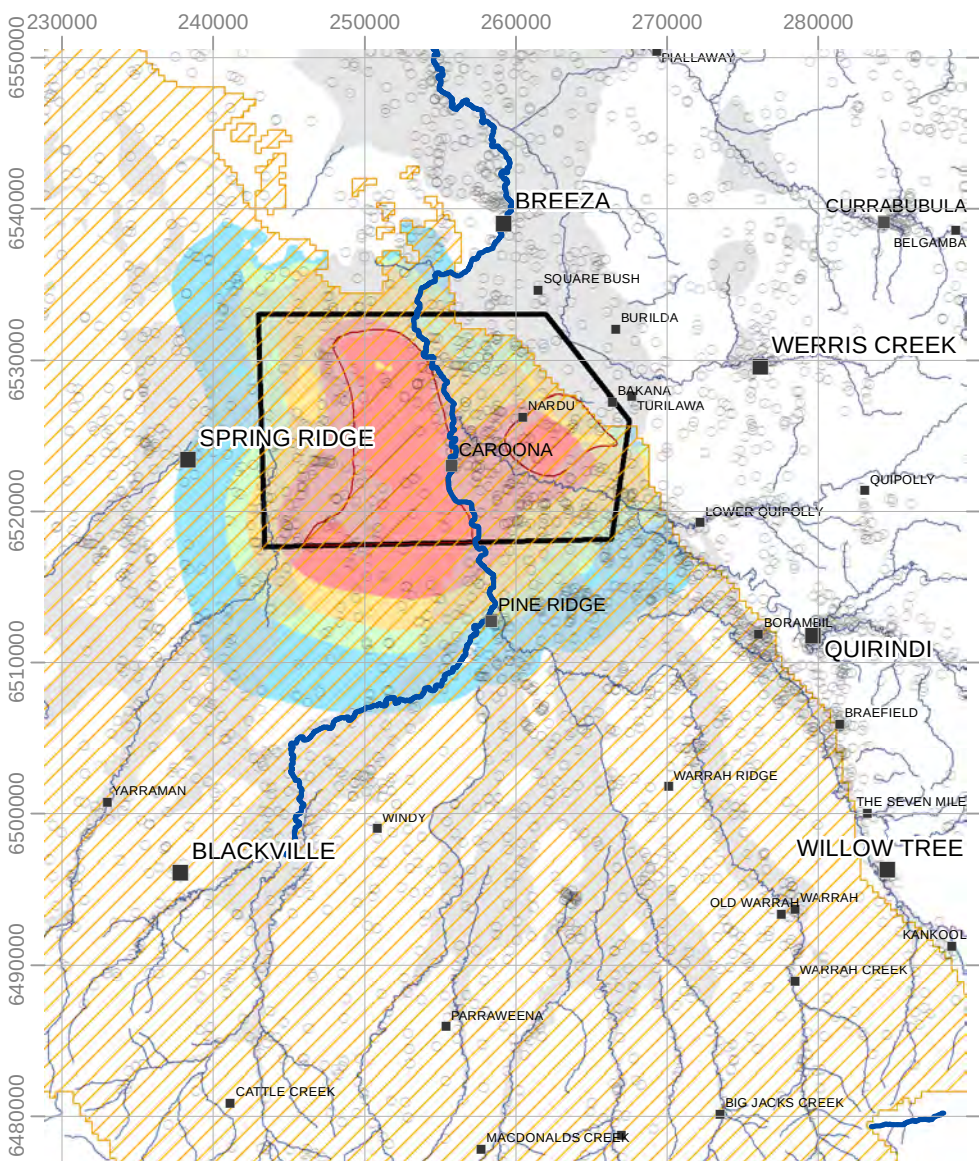
DrawingNo: CAR001-006
Rev: D.
Created by: CNicol
Date: 04/03/2014.



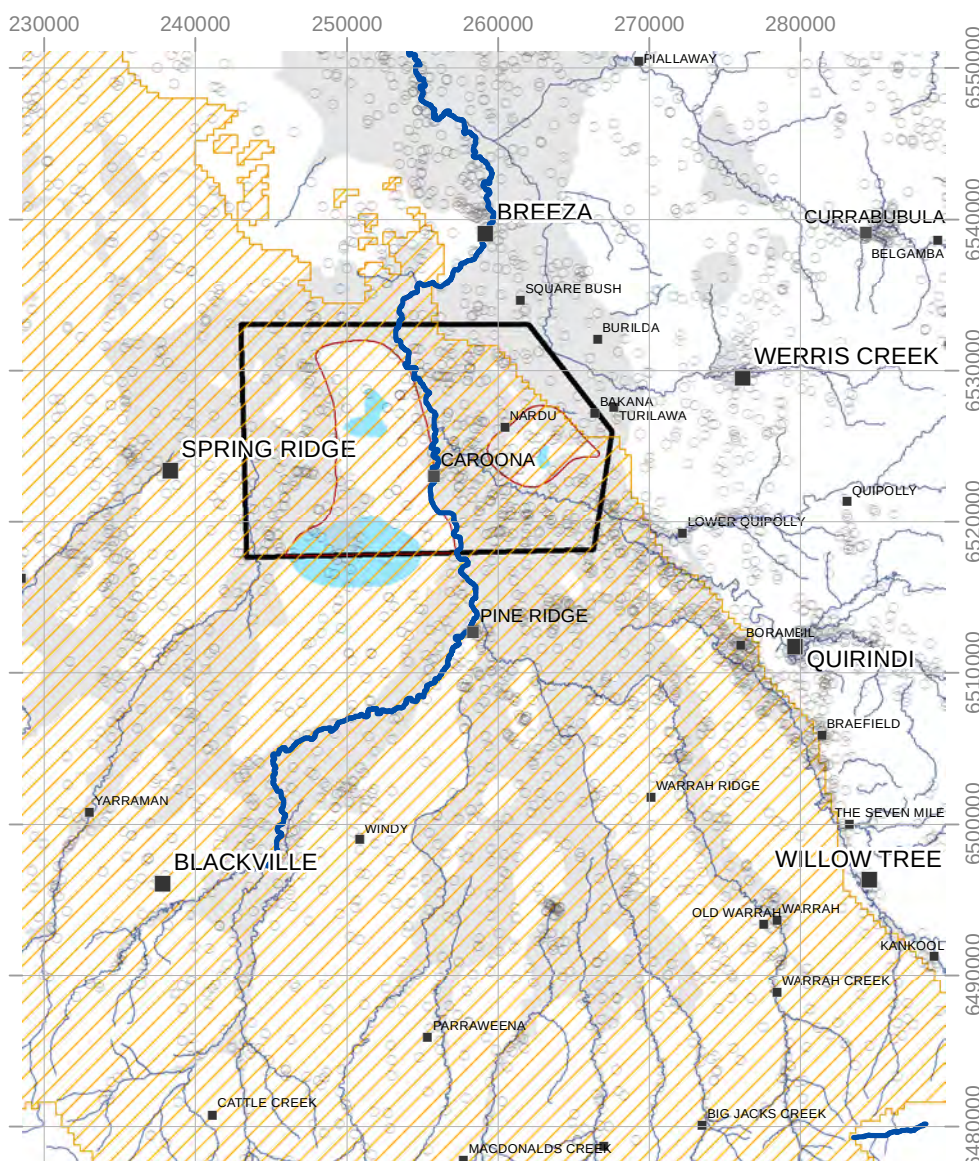
Scale: 500,000 at A3
GDA 1994 MGA Zone 56



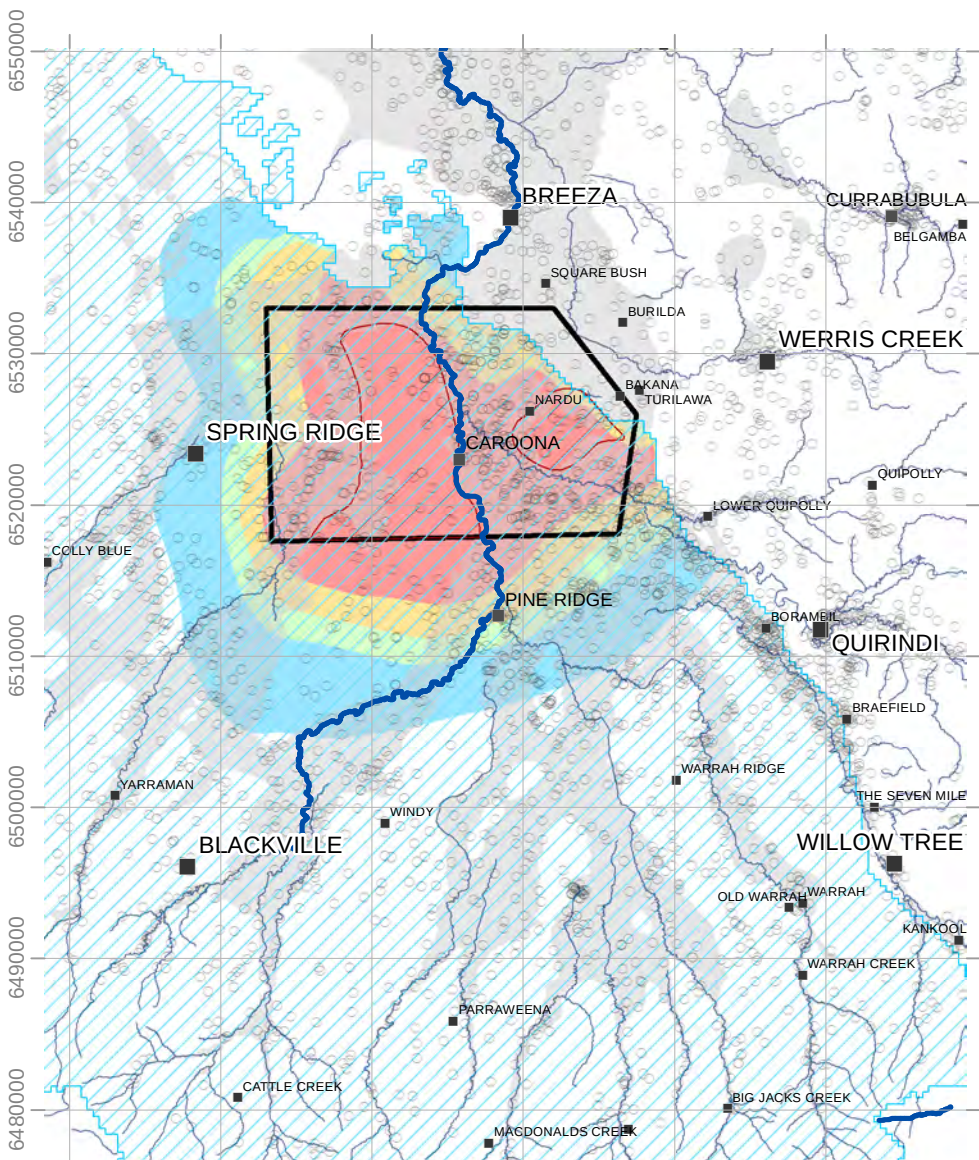
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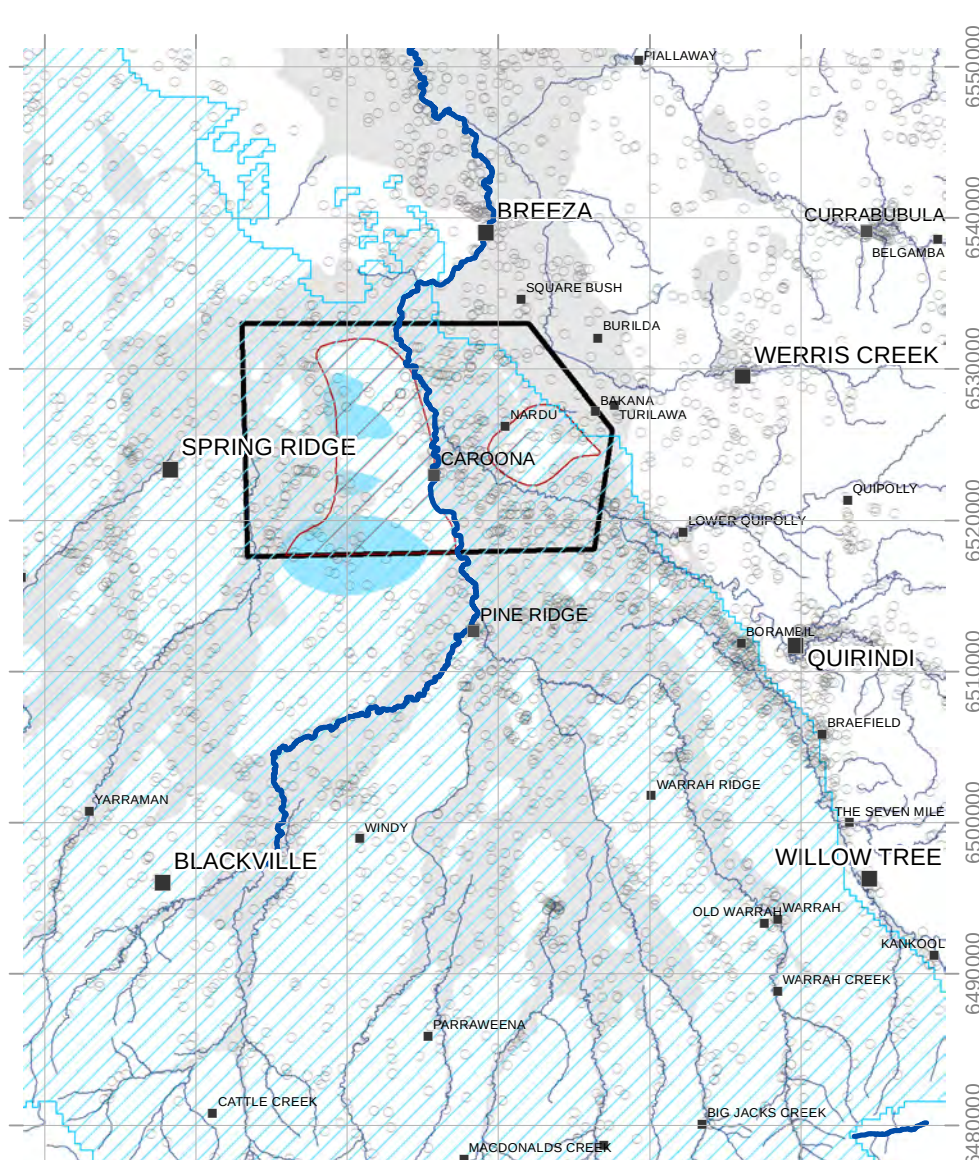
Layer 5 maximum drawdown at any time
Permo-Triassic Units (Napperby Fm to Wallala Fm)



Layer 5 recovered drawdown (280 years post-mining)
Permo-Triassic Units (Napperby Fm to Wallala Fm)



Layer 6 maximum drawdown at any time
Clare Sandstone



Layer 6 recovered drawdown (280 years post-mining)
Clare Sandstone

Legend

- NOW Registered Bores
- Census Bores
- Town
- Village
- Locality
- Exploration Licence
- River
- Creek
- Alluvials
- ▨ Clare Sandstone Extent
- ▨ Napperby to Wallala Fm Extent
- ▨ Targeted Exploration Area

Maximum Drawdown
(m, at any time)

- ≤2
- 2.01 - 10

- 10.01 - 20
- 20.01 - 50
- >50.00

BHP Billiton
Caroonna Coal Project

Figure E3

Simulated Drawdown and Recovery
Model Layers 5 and 6 - Sensivity Run #1

DrawingNo: CAR001-007
Rev: D.
Created by: CNicol
Date: 04/03/2014.

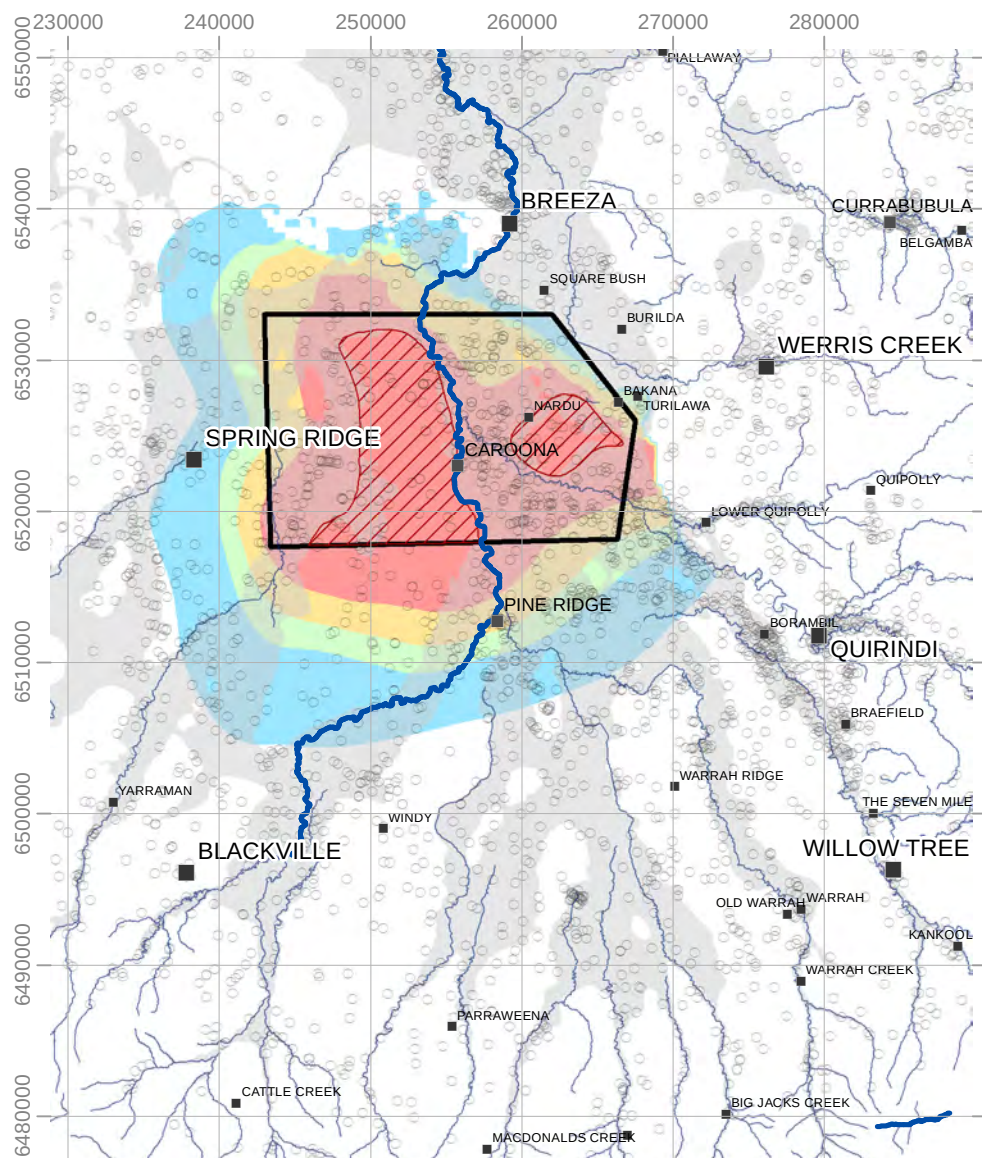


Scale: 500,000 at A3
GDA 1994 MGA Zone 56

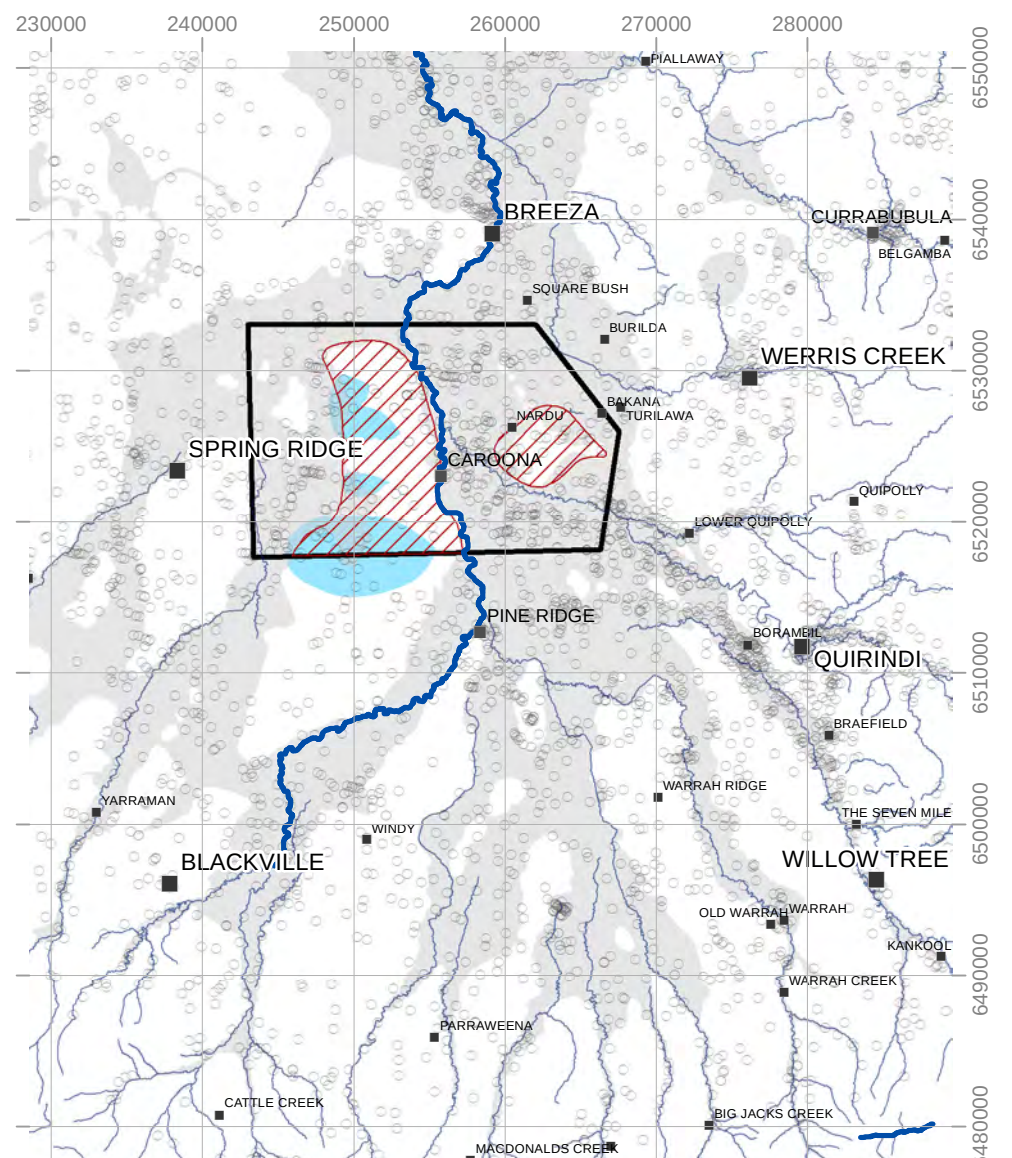


0 2.5 5 10 15 20
Kilometers

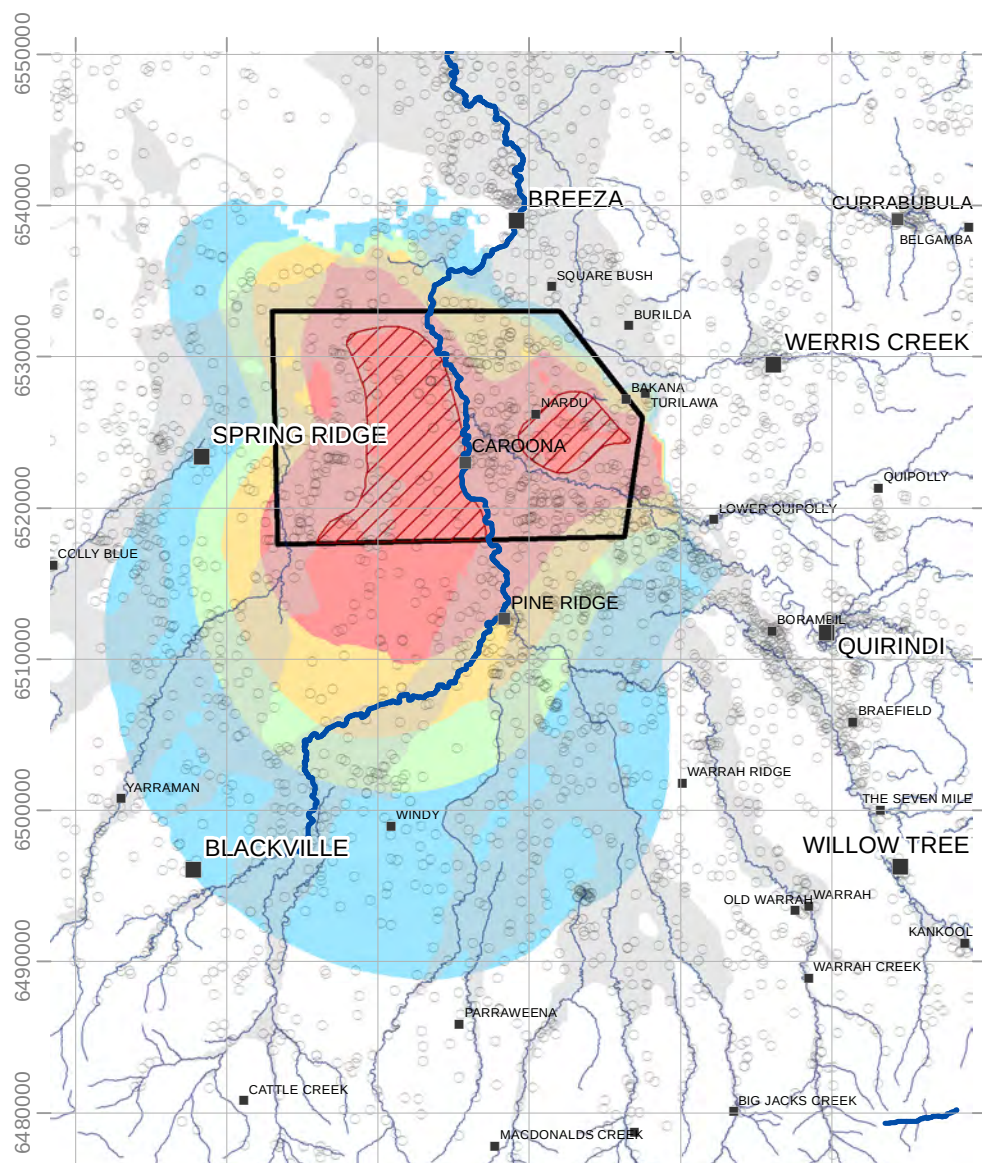
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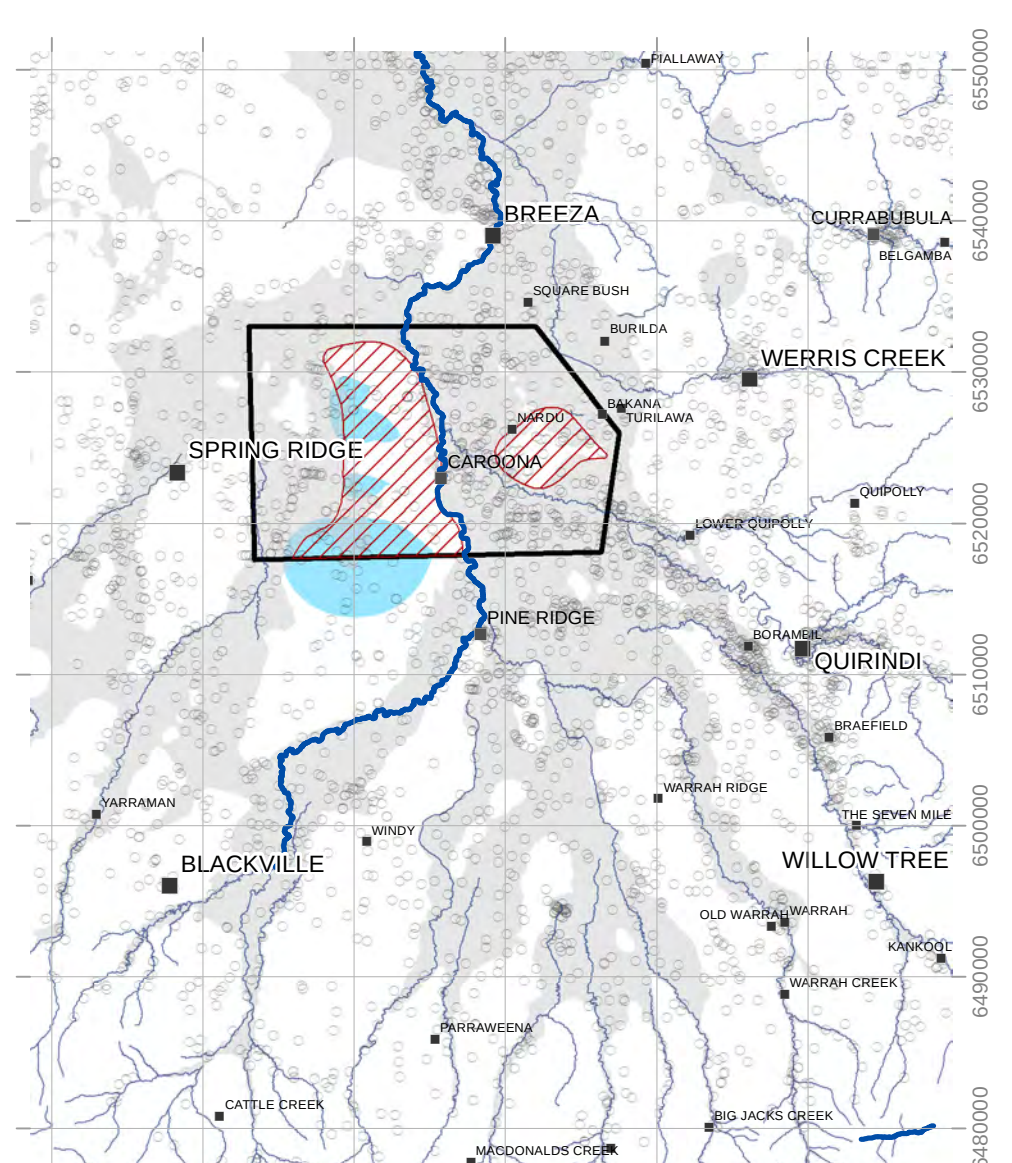
**Layer 7 maximum drawdown at any time
Benallabri Fm**



**Layer 7 recovered drawdown (280 years post-mining)
Benallabri Fm**



**Layer 8 maximum drawdown at any time
Hoskissons Seam**



**Layer 8 recovered drawdown (280 years post-mining)
Hoskissons Seam**

Legend

- NOW Registered Bores
- Town
- Village
- Locality
- River
- Creek
- Alluvials
- Exploration Licence
- ▨ Targeted Exploration Area

**Maximum Drawdown
(m, at any time)**

- ≤2
- 2.01 - 10

- 10.01 - 20
- 20.01 - 50
- >50.00

**BHP Billiton
Caroonna Coal Project**

Figure E4

**Simulated Drawdown and Recovery
Model Layers 7 and 8 - Sensitivity Run #1**

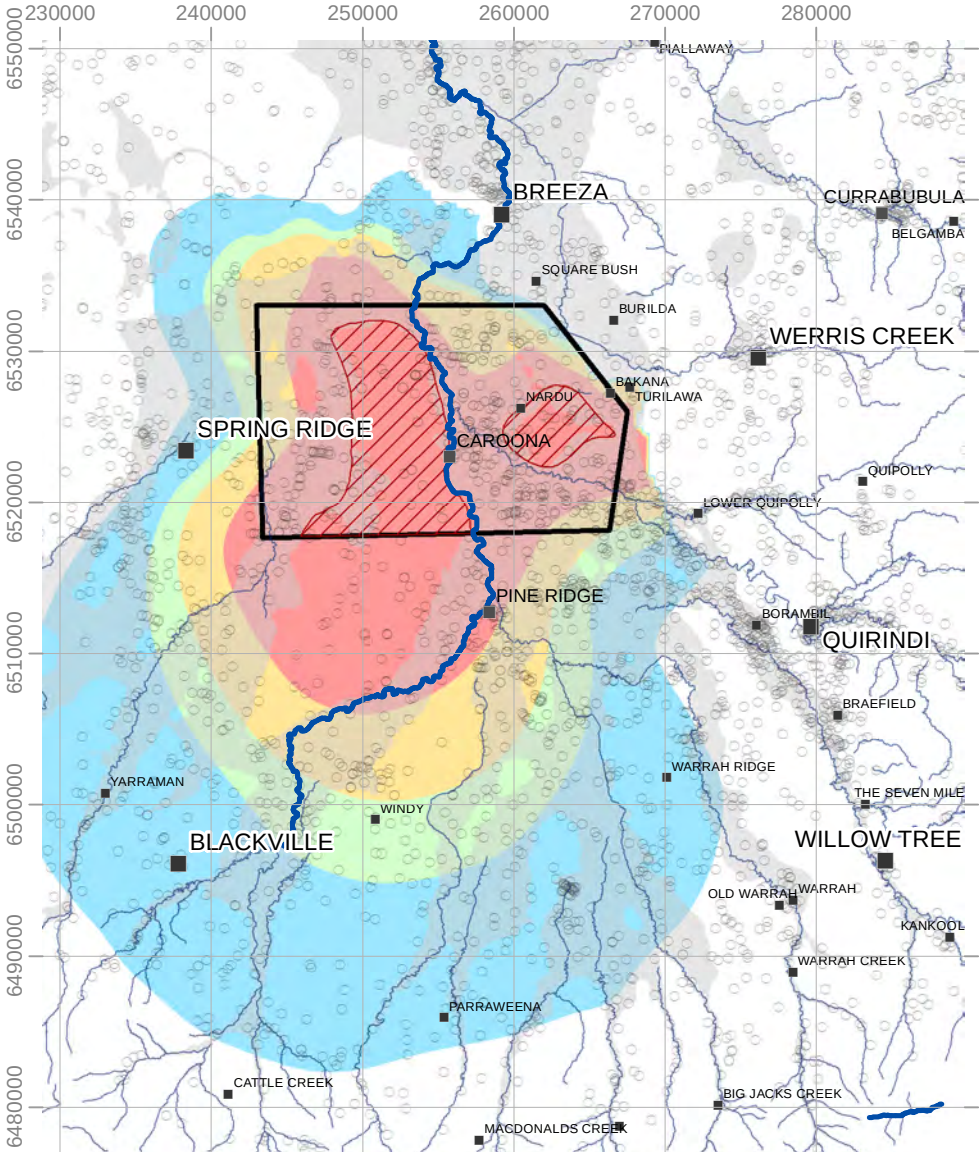
DrawingNo: CAR001-008
Rev: D.
Created by: CNicol
Date: 04/03/2014.



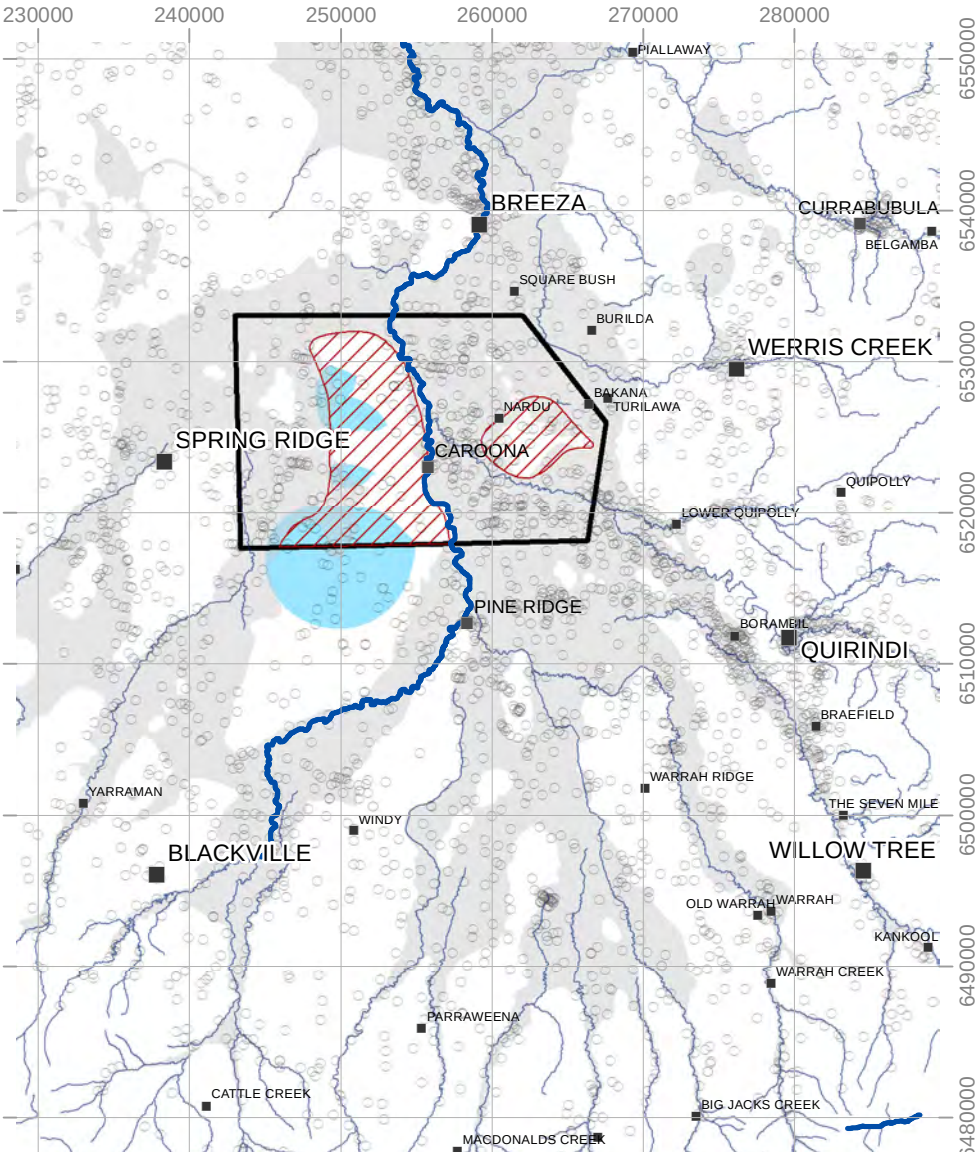
Scale: 500,000 at A3
GDA 1994 MGA Zone 56



0 2.5 5 10 15 20
Kilometers



Layer 9 maximum drawdown at any time
Pamboola Fm



Layer 9 recovered drawdown (280 years post-mining)
Pamboola Fm

Legend

- NOW Registered Bores

■

Town

■

Village

■

Locality
- River

—

Creek

■

Alluvials

□

Exploration Licence

▨

Targeted Exploration Area

Maximum Drawdown (m, at any time)	
<=2	10.01 - 20
2.01 - 10	20.01 - 50
	>50.00

BHP Billiton
Caroona Coal Project

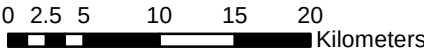
Figure E5

Simulated Drawdown and Recovery
Model Layer 9 - Sensivity Run #1

DrawingNo: CAR001-009
Rev: D.
Created by: CNicol
Date: 04/03/2014.



Scale: 500,000 at A3
GDA 1994 MGA Zone 56



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ATTACHMENT F

Australian Groundwater Modelling Guidelines - Model confidence level classification

Table 2-1: Model confidence level classification—characteristics and indicators

Confidence level classification	Data	Calibration	Prediction	Key indicator	Examples of specific uses
Class 3 Key indicators met: 3	- Spatial and temporal distribution of groundwater head observations adequately define groundwater behaviour, especially in areas of greatest interest and where outcomes are to be reported. - Spatial distribution of bore logs and associated stratigraphic interpretations clearly define aquifer geometry. - Reliable metered groundwater extraction and injection data is available. * Rainfall and evaporation data is available. * Aquifer-testing data to define key parameters. - Streamflow and stage measurements are available with reliable baseflow estimates at a number of points. * Reliable land-use and soil-mapping data available. - Reliable irrigation application data (where relevant) is available. - Good quality and adequate spatial coverage of digital elevation model to define ground surface elevation.	* Adequate validation* is demonstrated. * Scaled RMS error (refer Chapter 5) or other calibration statistics are acceptable. * Long-term trends are adequately replicated where these are important. * Seasonal fluctuations are adequately replicated where these are important. * Transient calibration is current, i.e. uses recent data. - Model is calibrated to heads and fluxes. - Observations of the key modelling outcomes dataset is used in calibration.	- Length of predictive model is not excessive compared to length of calibration period. - Temporal discretisation used in the predictive model is consistent with the transient calibration. - Level and type of stresses included in the predictive model are within the range of those used in the transient calibration. - Model validation* suggests calibration is appropriate for locations and/or times outside the calibration model. * Steady-state predictions used when the model is calibrated in steady-state only.	* Key calibration statistics are acceptable and meet agreed targets. - Model predictive time frame is less than 3 times the duration of transient calibration. - Stresses are not more than 2 times greater than those included in calibration. - Temporal discretisation in predictive model is the same as that used in calibration. * Mass balance closure error is less than 0.5% of total. - Model parameters consistent with conceptualisation. * Appropriate computational methods used with appropriate spatial discretisation to model the problem. - The model has been reviewed and deemed fit for purpose by an experienced, independent hydrogeologist with modelling experience.	- Suitable for predicting groundwater responses to arbitrary changes in applied stress or hydrological conditions anywhere within the model domain. - Provide information for sustainable yield assessments for high-value regional aquifer systems. - Evaluation and management of potentially high-risk impacts. - Can be used to design complex mine-dewatering schemes, salt-interception schemes or water-allocation plans. - Simulating the interaction between groundwater and surface water bodies to a level of reliability required for dynamic linkage to surface water models. - Assessment of complex, large-scale solute transport processes.
Class 2 Key indicators met: 3 Cont'd overleaf	* Groundwater head observations and bore logs are available but may not provide adequate coverage throughout the model domain.	- Validation* is either not undertaken or is not demonstrated for the full model domain. - Calibration statistics are generally reasonable but may suggest significant errors in parts of the	* Transient calibration over a short time frame compared to that of prediction. * Temporal discretisation used in the predictive model is different from that used in transient	- Key calibration statistics suggest poor calibration in parts of the model domain. - Model predictive time frame is * between 3 and 10 times the duration of transient calibration. - Stresses are between 2 and 5 times greater than those	- Prediction of impacts of proposed developments in medium value aquifers. - Evaluation and management of medium risk impacts.

Confidence level classification	Data	Calibration	Prediction	Key indicator	Examples of specific uses
Class 2 Cont'd	* Metered groundwater-extraction data may be available but spatial and temporal coverage may not be extensive. * Streamflow data and baseflow estimates available at a few points. * Reliable irrigation-application data available in part of the area or for part of the model duration.	- model domain(s). - Long-term trends not replicated in all parts of the model domain. - Transient calibration to historic data but not extending to the present day. - Seasonal fluctuations not adequately replicated in all parts of the model domain. * Observations of the key modelling outcome data set are not used in calibration.	- calibration. * Level and type of stresses included in the predictive model are outside the range of those used in the transient calibration. - Validation* suggests relatively poor match to observations when calibration data is extended in time and/or space.	- included in calibration. * Temporal discretisation in predictive model is not the same as that used in calibration. * Mass balance closure error is less than 1% of total. - Not all model parameters consistent with conceptualisation. * Spatial refinement too coarse in key parts of the model domain. - The model has been reviewed and deemed fit for purpose by an independent hydrogeologist.	- Providing estimates of dewatering requirements for mines and excavations and the associated impacts. - Designing groundwater management schemes such as managed aquifer recharge, salinity management schemes and infiltration basins. - Estimating distance of travel of contamination through particle-tracking methods. Defining water source protection zones.
Class 1 Key indicators met: 2	- Few or poorly distributed existing wells from which to obtain reliable groundwater and geological information. - Observations and measurements unavailable or sparsely distributed in areas of greatest interest. - No available records of metered groundwater extraction or injection. - Climate data only available from relatively remote locations. - Little or no useful data on land-use, soils or river flows and stage elevations.	- No calibration is possible. - Calibration illustrates unacceptable levels of error especially in key areas. - Calibration is based on an inadequate distribution of data. * Calibration only to datasets other than that required for prediction.	* Predictive model time frame far exceeds that of calibration. * Temporal discretisation is different to that of calibration. - Transient predictions are made when calibration is in steady state only. - Model validation* suggests unacceptable errors when calibration dataset is extended in time and/or space.	- Model is uncalibrated or key calibration statistics do not meet agreed targets. - Model predictive time frame is more than 10 times longer than transient calibration period. * Stresses in predictions are more than 5 times higher than those in calibration. * Stress period or calculation interval is different from that used in calibration. - Transient predictions made but calibration in steady state only. - Cumulative mass-balance closure error exceeds 1% or exceeds 5% at any given calculation time. - Model parameters outside the range expected by the conceptualisation with no further justification. - Unsuitable spatial or temporal discretisation. - The model has not been reviewed.	- Design observation bore array for pumping tests. - Predicting long-term impacts of proposed developments in low-value aquifers. - Estimating impacts of low-risk developments. - Understanding groundwater flow processes under various hypothetical conditions. - Provide first-pass estimates of extraction volumes and rates required for mine dewatering. - Developing coarse relationships between groundwater extraction locations and rates and associated impacts. - As a starting point on which to develop higher class models as more data is collected and used.

(*Refer Chapter 5 for discussion around validation as part of the calibration process.)

ATTACHMENT G

Modelled Drawdowns at Registered Bores in 'Less Productive' Water Sources within BSAL

Table G-1 Modelled Drawdown at Registered Groundwater Bores in ‘Less Productive’ Water Sources located on BSAL

Work no	Landholder	Property No.	Easting	Northing	Depth (m)	Model layer	Maximum Drawdown (m)	Watermark Drawdown (m)	Cumulative Drawdown (m)
GW048250	Hanuta Pty Ltd	83	254005	6521127	36.4	5	185.84	#N/A	185.84
GW004845	Wallalla Holdings Pty Limited	158	253217	6519814	42.90	5	184.58	#N/A	184.58
GW038808	Wallalla Holdings Pty Limited	158	251220	6520445	34.10	5	165.79	#N/A	165.79
GW015673	Charters HF	22	248844	6518138	61	5	108.18	#N/A	108.18
GW015406	Permaid Pty Ltd	121	254438	6515097	39.10	5	63.74	#N/A	63.74
GW015404	James Hockey Holdings Pty Ltd	278	254168	6513087	27.40	5	35.65	#N/A	35.65
GW003450	James Hockey Holdings Pty Ltd	278	253623	6512674	40.80	5	32.18	#N/A	32.18
GW022209	James Hockey Holdings Pty Ltd	278	254104	6512439	64.60	5	31.41	#N/A	31.41
GW029287	Shenhua Watermark Coal Pty Ltd	105	257281	6537106	25.30	9	31.11	#N/A	31.11
GW030141	Local	2008	258128	6513149	49.40	5	22.42	#N/A	22.42

Work no	Landholder	Property No.	Easting	Northing	Depth (m)	Model layer	Maximum Drawdown (m)	Watermark Drawdown (m)	Cumulative Drawdown (m)
	Government Authority								
GW054961	Fuller JW & RM	70	258448	6513003	23.70	5	22.22	#N/A	22.22
GW028952	Shenhua Watermark Coal Pty Ltd	9	253126	6541601	24.70	9	19.57	#N/A	19.57
GW026576	Webster & Sons Pty Ltd	230	251292	6509660	76.20	5	15.91	#N/A	15.91
GW033079	Webster & Sons Pty Ltd	230	252525	6509997	45.70	5	15.24	#N/A	15.24
GW015662	Morrice JW & JH	240	251592	6508157	12.80	5	10.92	#N/A	10.92
GW045923	Morrice JW & JH	240	251567	6508125	30.00	5	10.92	#N/A	10.92
GW022369	Kickerbell Pty Ltd	231	247028	6508047	154.80	5	10.24	#N/A	10.24
GW015192	Gunning IR	276	268335	6511286	19.40	5	10.09	#N/A	10.09
GW045989	Rannoch Pastoral Pty Ltd	242	250317	6507417	47.00	5	9.43	#N/A	9.43
GW901053	Grein Pty Ltd	253	234410	6527736	67.00	5	8.61	#N/A	8.61
GW022535	Shenhua Watermark Coal Pty Ltd	9	255139	6539306	11.00	5	7.02	#N/A	7.02
GW011452	ACN 060 661	238	233200	6525394	121.90	5	6.68	#N/A	6.68

Work no	Landholder	Property No.	Easting	Northing	Depth (m)	Model layer	Maximum Drawdown (m)	Watermark Drawdown (m)	Cumulative Drawdown (m)
	565 Pty Ltd								
GW051719	Hallman JJ & Kerrison KE	223	275053	6510725	73.10	5	6.53	#N/A	6.53
GW011766	ACN 060 661 565 Pty Ltd	238	232631	6525934	121.90	5	6.23	#N/A	6.23
GW011982	Archer TK & RE	232	232197	6525337	122.50	5	5.84	#N/A	5.84
GW012489	Bentone Pty Ltd	283	232004	6525610	150.30	5	5.83	#N/A	5.83
GW007956	Lynch SH & LC	258	232470	6532218	27.40	5	5.73	#N/A	5.73
GW017271	Barrie JA	279	266636	6508197	12.20	5	5.45	#N/A	5.45
GW011171	Curlewis Coal & Coke Pty Ltd	284	235723	6554431	92.00	9	5.23	#N/A	5.23
GW017261	Shenhua Watermark Coal Pty Ltd	9	257960	6504486	21.00	5	3.61	#N/A	3.61
GW035187	Winterthur Pty Ltd	249	270568	6508193	34.10	5	3.43	#N/A	3.43
GW965639	The Glen Rural Pty Ltd	234	266624	6505475	28.60	5	3.31	#N/A	3.31
GW030030	Bolwarra Estates Pty Ltd	228	277338	6507539	43.30	5	3.07	#N/A	3.07

Work no	Landholder	Property No.	Easting	Northing	Depth (m)	Model layer	Maximum Drawdown (m)	Watermark Drawdown (m)	Cumulative Drawdown (m)
GW008510	Borethistle WJ & JG (est)	266	234464	6557081	22.8	9	2.4	#N/A	2.4
GW033768	Romani Pastoral Company Pty Ltd	274	258885	6500994	30.50	5	2.21	#N/A	2.21
GW043595	The Glen Rural Pty Ltd	234	266417	6502676	43.80	5	2.16	#N/A	2.16
GW030581	The Glen Rural Pty Ltd	234	267009	6502166	28.70	5	2.02	#N/A	2.02

Table G-2 Modelled Drawdown at Groundwater Bores in ‘Less Productive’ Water Sources Identified in the Project Bore Census on BSAL

Work No.	Landholder	Property No.	Description	Easting	Northin g	Bore in Use?	Purpose	Year Drilled	Depth (m)	Model Layer	Maximum Drawdown (m)	Watermark Drawdown (m)	Cumulative Drawdown (m)
GW044769	Williewarina Pty Ltd	160	Bore	255316	6518948	Not Recorded	Stock	1975	137.2	5	163.19	#N/A	163.19