# MEMORANDUM

BBA water consultants

BISHOP-BROGDEN ASSOCIATES, INC.

To: Joe Lamanna

From: Timothy A. Crawford

Subject: Ready Mixed Concrete Company – Holton-Morton Lakes Site – A&W Well Impact Review

Job: 0430.08

Date: January 11, 2018

This memorandum presents a review of potential water level changes and possible affects to the permitted yield of an A&W Water Service, Inc. (A&W) well (Permit No. 61793-F) located north of the Ready Mixed Concrete Company (RMCC) Holton-Morton Lakes Site Stage 6A and 6B gravel pits. The A&W well and Stages 6A and 6B are generally located in Section 1, Township 1 North, Range 67 West of the 6th P.M., as presented in Figure 1. A&W and RMCC met onsite on May 4, 2017 to discuss possible effects of mine dewatering and mine pit lining activities on the A&W well. The understandings between the parties reached at the meeting are reflected in a memorandum that counsel for RMCC and A&W developed between them, dated May 17, 2017. Consistent with Section 2 of the memo, the purpose of this review is to provide an "Impact Report" addressing potential impacts to the permitted yield of the A&W well that could result from the development of Stages 6A and 6B (and subsequent reclamation of these mine stages), as well as to provide potential monitoring well benchmarks, termed "trigger" levels in this report, that could indicate when mitigation of impacts to the well might be warranted to maintain the permitted pumping rate of the A&W well.

**Executive Summary**

- There is limited physical and operational data available for the A&W well; BBA currently lacks water level and pump setting depth information, both of which are needed to establish trigger levels. There are also unanswered questions regarding the completion of the A&W well, specifically the total depth of the well. BBA recommends that a pump contractor be engaged to confirm static and pumping water levels, the pump setting depth and the total depth of the well to better inform the analysis presented in this report.

- Since this investigation is significantly limited by the lack of physical and operational information and data regarding the A&W well, conservative estimates were made regarding its operation and pumping and static water levels. These estimates were used to develop trigger levels that could indicate when mitigation measures may be needed to ensure the continued permitted use of the well.

- Based on the limited available well completion data and monitoring well water level information, we estimate a saturated thickness of approximately 28.5 feet in the A&W well under static (non-pumping) conditions.

- Alluvial aquifer characteristics were identified for a MODFLOW modeling effort investigating the effects of the dewatering of Stages 6A and 6B. Based on those aquifer

characteristics and permitted well operations, the A&W well may experience operational drawdowns ranging from 2.5 to 10.5 feet.

- Based on the modeling, the dewatering of Stages 6A and 6B may result in additional water level changes as high as 11.6 feet at the location of the A&W well.

- Our analysis estimates a projected pumping water level, including the impact of the mine dewatering and A&W pump operation, of 28.1 feet below the ground surface. We project that the A&W well should still be able to achieve its permitted pumping rate under this water level condition.

- Based on this analysis, we estimate that the A&W well operation would not be affected unless the static (non-pumping) water level in the well reaches approximately 21.4 feet below the surface. Given this estimation, a static water level trigger level of 20.0 feet in the pumping well would likely provide a conservative benchmark for when mitigation efforts might be needed.

- Gravel pit lining after mining is completed (i.e. final reclamation of Stages 6A and 6B) is not expected to cause water level changes (less than 0.2 feet) that would affect the permitted yield of the A&W well.

- This analysis includes a number of key assumptions about the A&W well, which were necessary given that A&W did not provide pumping and static water level measurements from the well or access to the well. For example, the well may not be constructed to the base of the aquifer, the pump equipment may not be installed in the bottom of the well and/or the well may not operate efficiently due to age or other considerations. These uncertainties impact the conclusions regarding the water level conditions that may affect pumping operations and expected yield from the well. Additional information regarding the operation of the well including static and pumping water levels, well completion information, pump setting depths and/or pumping test data would allow refinement of this investigation and a more complete and accurate assessment of potential impacts of dewatering in Stages 6A and 6B and the more accurate establishment of applicable triggers levels designed to be protective of the A&W well.

**Background**

Gravel Pit Mining

Sand and gravel are mined from the South Platte River alluvium found within the Holton-Morton Lakes Site Stages 6A and 6B. Dewatering of the mine stages during mining is required due to saturated conditions. Dewatering will also lower water levels in the alluvium near the mine stages and in wells completed in the alluvium near the pits. After mining is completed, the stages will be lined with a slurry wall. The lining of the pits has the potential to slightly raise water levels in the alluvium (mound) upstream from the liner and slightly reduce water levels in the alluvium (shadow) downstream from the liner.

Mining of Stage 6A commenced in November of 2016 and mining of Stage 6B commenced in July of 2017. Current dewatering pumping rates for the stages average approximately 2,250 gallons per minute (gpm). Dewatering pumping rates are expected to increase as more of each stage is opened for mining. We are not aware of any complaints regarding well performance at this level of dewatering.

A&W Well

A&W operates an active water supply well that is located proximate to the RMCC Stages 6A and 6B at the Holton-Morton Lakes Site. The A&W well was completed on July 3, 1961 (approximately 56 years old) under Permit No. 3250-F with a 36-inch diameter borehole drilled to a total depth of 39.5 feet. Solid 18-inch diameter casing was reportedly installed from the ground surface to a depth of 15 feet and 18-inch diameter louvered perforated casing was reportedly installed between depths of 15 and 30 feet. The total depth of the well is reported to be 39.5 feet. The borehole for the well encountered top soil, gravel, clay and shale. The shale bedrock was encountered at approximately 39 feet. No water level information was reported on the original "Log and History of Well" and no pump installation information is available for the well from the State's well permit file. The well was originally permitted for irrigation uses at a pumping rate of 100 gpm. In 2004, the well was repermitted under Permit No. 61793-F to allow for industrial and commercial uses at a pumping rate of 500 gpm with an annual amount of 252 acre-feet per year. The well pumping is limited to 8.5 acre-feet per week pursuant to a stipulation with objectors entered in Water Court Case No. 03CW416 as a condition of obtaining the well permit.

Water level data from a monitoring well located approximately 150 feet to the northeast of the A&W well indicates water levels ranging from 10.5 to 13.7 feet below the ground surface, as presented in Table 1. Based on this water level data and a depth to bedrock of approximately 39 feet at the location of the A&W well, there is projected to be approximately 28.5 to 25.3 feet of saturated thickness at the location of the A&W well. It should be noted that the available water level data was collected starting in May of 2017 after the start of mining of Stages 6A and 6B and it is affected by the dewatering of the gravel pits. The monitoring well levels are also impacted by pumping from the A&W well. Historic static and pumping water level information for the A&W well has been requested from A&W, but no such information has been supplied in response as needed to inform this review.

**Ground Water Modelling**

A MODFLOW model was prepared to analyze the potential change in water level in the alluvial aquifer as a result of the dewatering of Stages 6A and 6B and the mounding and shadowing effects of lining the mine stages when complete (i.e., upon final reclamation). A single layer MODFLOW model including a model domain of 32 square miles, discretized into 100-foot square cells, was utilized to represent the alluvial aquifer bounded by lower permeability bedrock.

Top and bottom elevations of modeled cells were based on South Platte Decision Support System (SPDSS) ground surface elevation mapping, SPDSS bedrock elevation mapping, SPDSS alluvial boundary mapping and test drilling data provided by RMCC. SPDSS water level elevation information was used to define initial heads in the model and to compare modeled water level

elevations.

The model included several boundary conditions to represent the alluvial aquifer (head dependent cells), the bedrock (no flow cells), the alluvial underflow (constant heads), the South Platte River, Big Dry Creek and Little Dry Creek (river package) and pit dewatering (constant heads).

A hydraulic conductivity of 770 feet per day was used for the alluvial aquifer in the model based on SPDSS data points located within 2 miles of the Morton-Lakes mine boundary. A specific yield of 0.20 was assumed for the alluvial aquifer in the model.

The model was first run under steady state conditions without consideration of any mine dewatering to determine pre-mining ground water conditions. Then, model scenarios including dewatering of Stage 6A only and Stages 6A and 6B combined were also run under steady state conditions. Final water levels from each of the dewatering scenarios were compared with the pre-mining conditions to estimate changes in water level.

Sufficient data was not available for the area to allow for a full calibration of the model. The model was refined to match measured saturated thicknesses indicated by the limited available data. The saturated thicknesses prepared for the modeling efforts are presented in Figure 2. Current saturated thickness at the A&W well is projected using the monitoring well data to be approximately 28.5 to 25.3 feet. Pre-dewatering saturated thickness conditions in the model were 33 feet, Actual pre-dewatering saturated thickness conditions at the A&W well location were likely closer to the modelled conditions before the dewatering commenced.

The modeling indicates that the dewatering of Stages 6A and 6B will cause drawdown and reduce ground water level elevations near the mine stages. The modeling indicated drawdowns as high as approximately 31.6 feet at the location of Stages 6A and 6B with drawdowns greater than one foot extending up to approximately 7,700 feet from these mine stages as presented in Figures 3 and 4.

The modeling indicates drawdowns at the location of the A&W well of approximately 7.3 feet with only Stage 6A dewatering modeled (Figure 3) and approximately 11.6 feet with Stage 6A and 6B dewatering modeled (Figure 4).

The MODFLOW model was also prepared to analyze potential change in water level in the alluvial aquifer as a result of the lining of Stages 6A and 6B with a slurry wall upon reclamation. The model indicates that lining of the gravel pits after completion would result in approximately 0.2 feet of water level change (decrease) due to a shadowing effect at the location of the A&W well as presented in Figure 5.

**A&W Well Operation**

No operational information has been provided by the operators of the A&W well in response to requests by BBA and RMCC. Potential operations and maximum pumping rates and periods can be estimated based on the well permit, which limits production to 252 acre-feet per year, 8.5 acre-feet per week or 500 gpm (i.e., permitted yield). Producing the annual limit of 252 acre-feet per

year evenly throughout the year would result in an average pumping rate of approximately 157 gpm. Producing the weekly volume of 8.5 acre-feet evenly throughout the week would result in an average pumping rate of 275 gpm, but would only allow the well to pump for up to 207 days before reaching the annual volumetric limit. Operating the well at 500 gpm would allow the well to operate for 3.8 days before reaching the weekly volumetric limit.

The permitted operations are projected to result in the following drawdowns in the well.

| Scenario | Average Annual Limit Operation (252 af/yr) | Average Weekly Limit Operation (8.5 af/week) | Permitted Rate Operation (500 gpm) |
|---|---|---|---|
| Pumping Rate and Period | 157 gpm for 1 year | 275 gpm for 207 days | 500 gpm for 3.8 days |
| Projected Drawdown (ft) | 2.5 | 4.9 | 10.5 |

The drawdowns are projected based on the Theis equation, the rates and pumping periods presented above and the following information:

T = 210,000 gallons per day per foot (determined from modeling efforts)
S = 0.20 (assumed)
Radius = 1.5 feet (36-inch borehole as indicated on the Log and History of Well form for the well)

Transmissivity and drawdowns were adjusted to account for the dewatering of the aquifer based on a starting saturated thickness of 28.5 feet, the 11.6 feet of drawdown resulting from the gravel pit dewatering and the pumping of the production well.
Drawdowns also account for 40% well losses.

The drawdowns presented above are conservative in that they assume the full additional drawdown for the gravel pit dewatering, a corresponding reduction in aquifer transmissivity and well losses of 40% to account for potential well structure inefficiencies. The drawdowns presented above represent a reasonable possible estimate of potential drawdown conditions for this effort.

**A&W Well Available Drawdown Requirements**

As presented above, it is assumed that the A&W well operates with a maximum projected 10.5 feet of drawdown. It is estimated that the dewatering of Stages 6A and 6B may result in up to an additional 11.6 feet of drawdown in the A&W well. The pump also will require an additional 1.6 feet of saturation above the pump to allow for efficient pump operation (non-cavitating operation) based on American National Standards Institute estimations. Accordingly, the A&W well may require a minimum of approximately 23.7 feet of available drawdown above the pump equipment to allow the well to operate at its maximum permitted yield. Less aggressive well operation (i.e. less than 500 gpm for 3.8 days) will result in lower head requirements over the pumping equipment.

Figure 6 presents a schematic diagram of the A&W well which shows estimated potential pre-mining, current and projected water level conditions, including maximum projected operational and recommended pumping water levels. As presented in Figure 6, the dewatering of Stages 6A and 6B may result in a "projected static level during dewatering" of approximately 17.6 feet in the well. Accounting for the conservatively estimated maximum 10.5 feet of drawdown associated with the potential operation of the A&W well, projected operational pumping water levels may be as deep as 28.1 feet below the ground surface.

The projected operational pumping water level indicates that there would still be approximately 10.9 feet of saturated thickness remaining in the well and more than 1/3 of the available drawdown in the aquifer after accounting for the effects of dewatering Stages 6A and 6B. A pumping level of 31.9 feet below the ground surface would maintain 1/3 of the alluvial aquifer drawdown. Maintenance of 1/3 of the aquifer thickness is a rule of thumb for alluvial well operations and is a reasonable maximum pumping water level target allowing the well to operate efficiently in regard to the dewatering of the aquifer.

**Potential Trigger Levels**

Based on the analysis presented above, the A&W well should be capable of pumping rates consistent with its well permit with a projected static water level in the well of 17.6 feet below the ground surface and a maximum static water level as deep as 21.4 feet below the ground surface. Accordingly, a conservative trigger level of 20.0 feet below the ground surface is recommended for the A&W well (representative of static conditions in the well). Mitigation measures may need to be considered at the trigger level to avoid any potential impacts to the permitted yield of the well.

The water level data for the monitoring well from December 4, 2017 indicate a water level of 13.7 feet below the ground surface. Accordingly, the current static water level in the area of the A&W well is approximately 6.3 feet above the identified trigger level of 20.0 feet below the ground surface.

The monitoring well is currently used to project static water level conditions in the A&W well and to determine how current conditions compare to the suggested trigger level. Water level conditions in the A&W well may differ from conditions in the monitoring well. The monitoring well is located further away from Stages 6A and 6B and may experience less drawdown associated with the dewatering than the pumping well. The monitoring well is also impacted by pumping operations in the A&W well. Water levels collected in the A&W well would provide a more direct measurement of the conditions in the production well. At a minimum, production from the A&W well should be monitored to confirm whether there is any observed change in operation.

**Conclusions and Recommendations**

- Based on the assumptions presented in the text above, which were required due to the identified lack of physical and operational data from A&W, a conservative trigger level of 20.0 feet below ground surface has been identified for static water level conditions in the A&W well. The ability to operate the A&W well up to the permitted pumping rate should

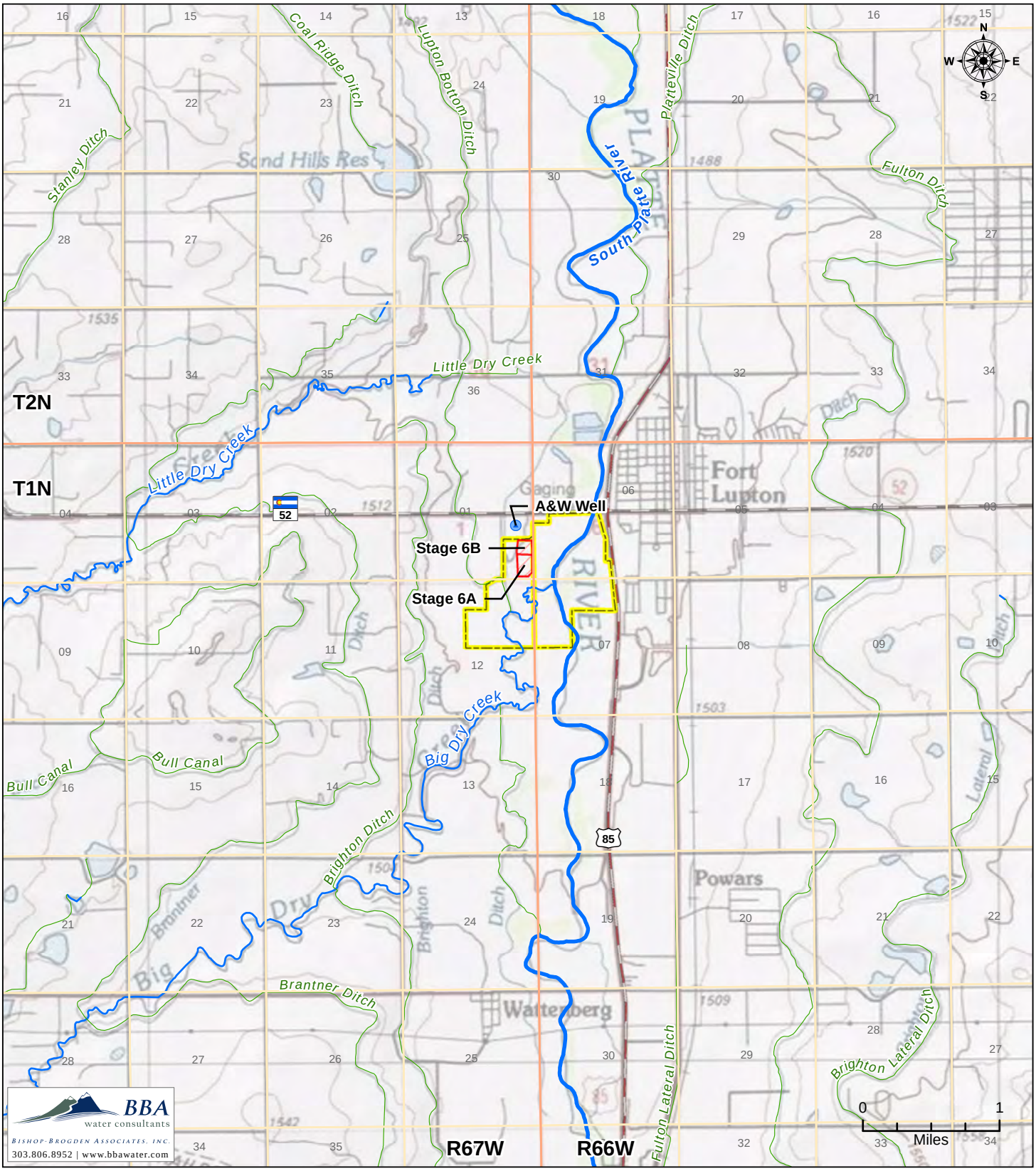
not be affected unless static water level conditions drop to below this level. Mitigation actions may be required when the trigger level is reached.

- Water levels should continue to be monitored in the existing monitoring well to confirm whether water level conditions indicate changes in A&W well performance and the possible need for mitigation measures.

- The operation of the A&W well should be monitored to confirm whether there is any change in static or pumping water level conditions in the well or if there are any changes in the operation of the well.

- A monitoring tube should be installed in the A&W well. Water levels collected in the well will be more indicative of the conditions in the pumping well than from the existing monitoring well.

- The total depth and the pump equipment depth in the A&W well need to be determined. A pump contractor needs to be engaged to determine the total depth of the well or, at a minimum, the pump setting depth of the well. A pumping test should be performed on the A&W well to determine current performance and efficiency relative to its permitted yield.




BBA water consultants
Bishop-Brogden Associates, Inc.
303.806.8952 | www.bbawater.com

# Figure 1
# Holton-Morton Lakes Site
# General Location Map

Date: 9/25/2017 | Job No. 0430.10

***Legend***

- A&W Well (Permit No. 61793-F)
- Mining Stage 6A and 6B
- Morton Lakes Mine

Data Source: DWR, RMCC, CDOT, USGS, BLM

**Colorado**

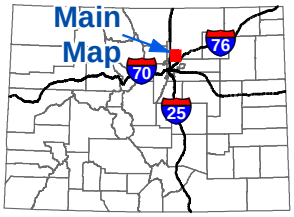


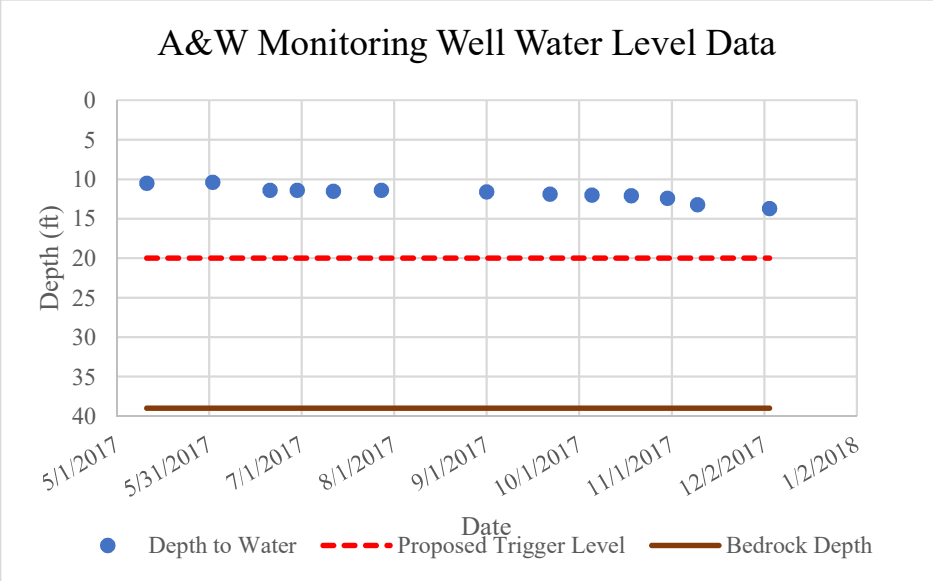
**Table 1**

**Ready Mixed Concrete Company**

**Holton-Morton Lakes Site**

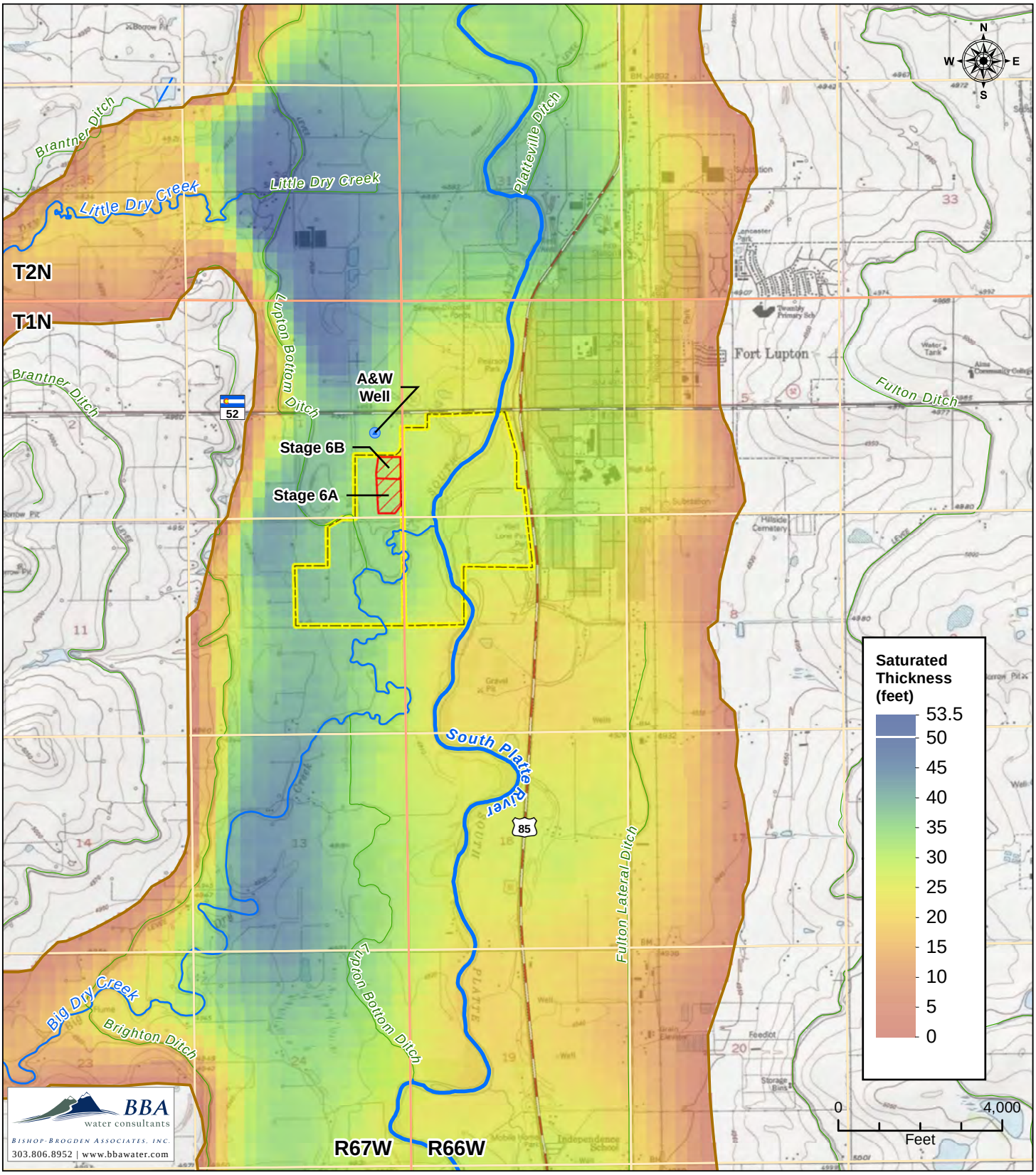
**A&W Monitoring Well Data**

| Date | Depth Below Ground Surface (ft) |
|---|---|
| 5/11/2017 | 10.5 |
| 6/2/2017 | 10.4 |
| 6/21/2017 | 11.4 |
| 6/30/2017 | 11.4 |
| 7/12/2017 | 11.5 |
| 7/28/2017 | 11.4 |
| 9/1/2017 | 11.6 |
| 9/22/2017 | 11.9 |
| 10/6/2017 | 12 |
| 10/19/2017 | 12.1 |
| 10/31/2017 | 12.4 |
| 11/10/2017 | 13.2 |
| 12/4/2017 | 13.7 |




Notes:

Data provided by Ready Mixed Concrete Company.




# Figure 2
# Holton-Morton Lakes Site
# Modeled Saturated Thickness Map

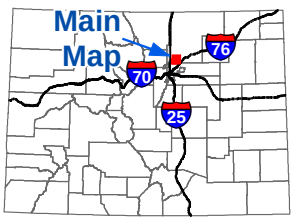
Date: 9/25/2017 | Job No. 0430.10

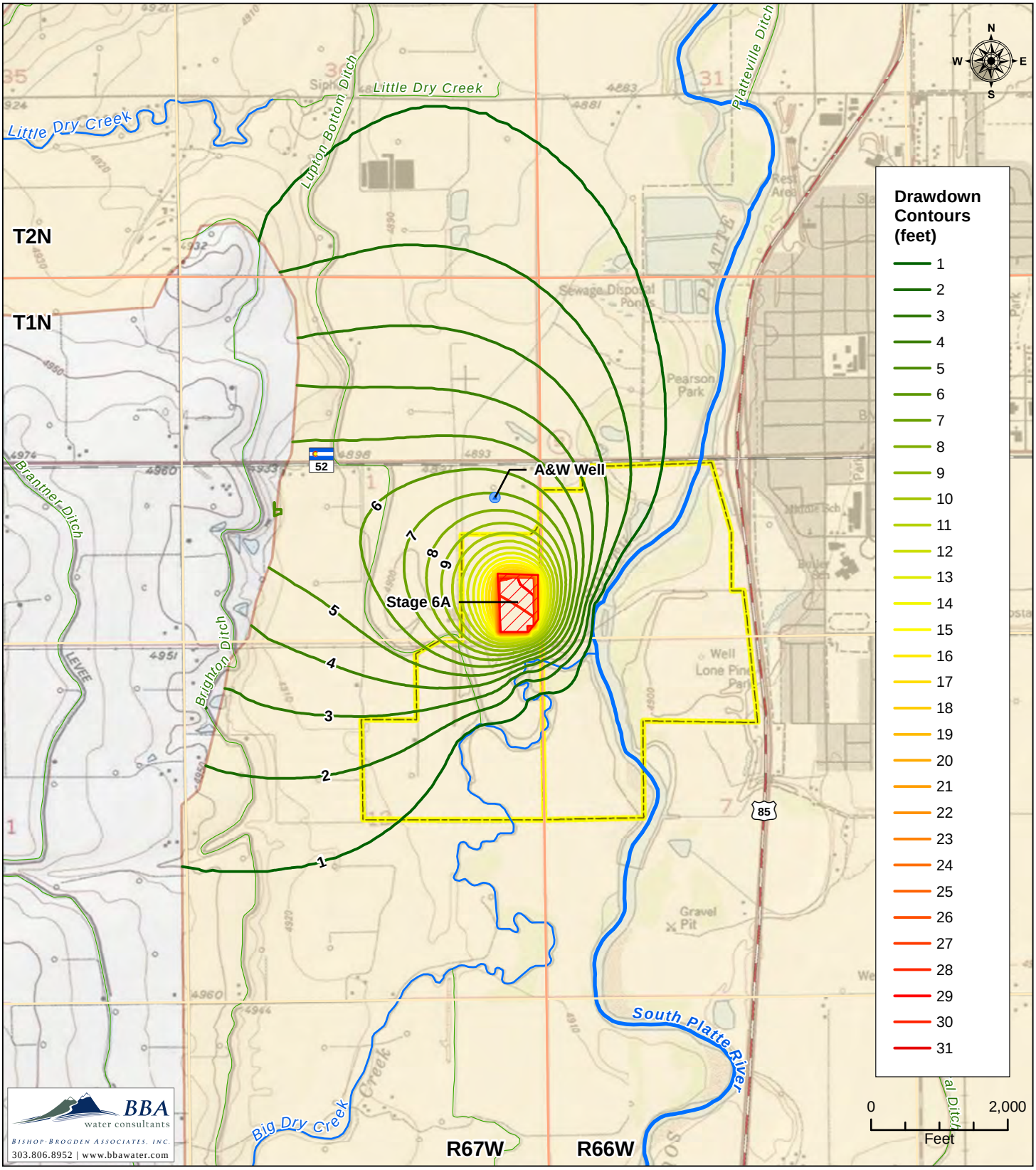
***Legend***

- A&W Well (Permit No. 61793-F)
- Mining Stage 6A & 6B
- Morton Lakes Mine
- Modeled Saturated Alluvium (Approx.)

Data Source: DWR, RMCC, CDOT, USGS, BLM

**Colorado**






# Figure 3
# Holton-Morton Lakes Site
# Stage 6A
# Modeled Drawdown Map

Date: 9/25/2017 | Job No. 0430.10

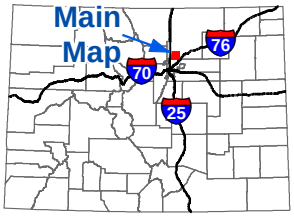
***Legend***

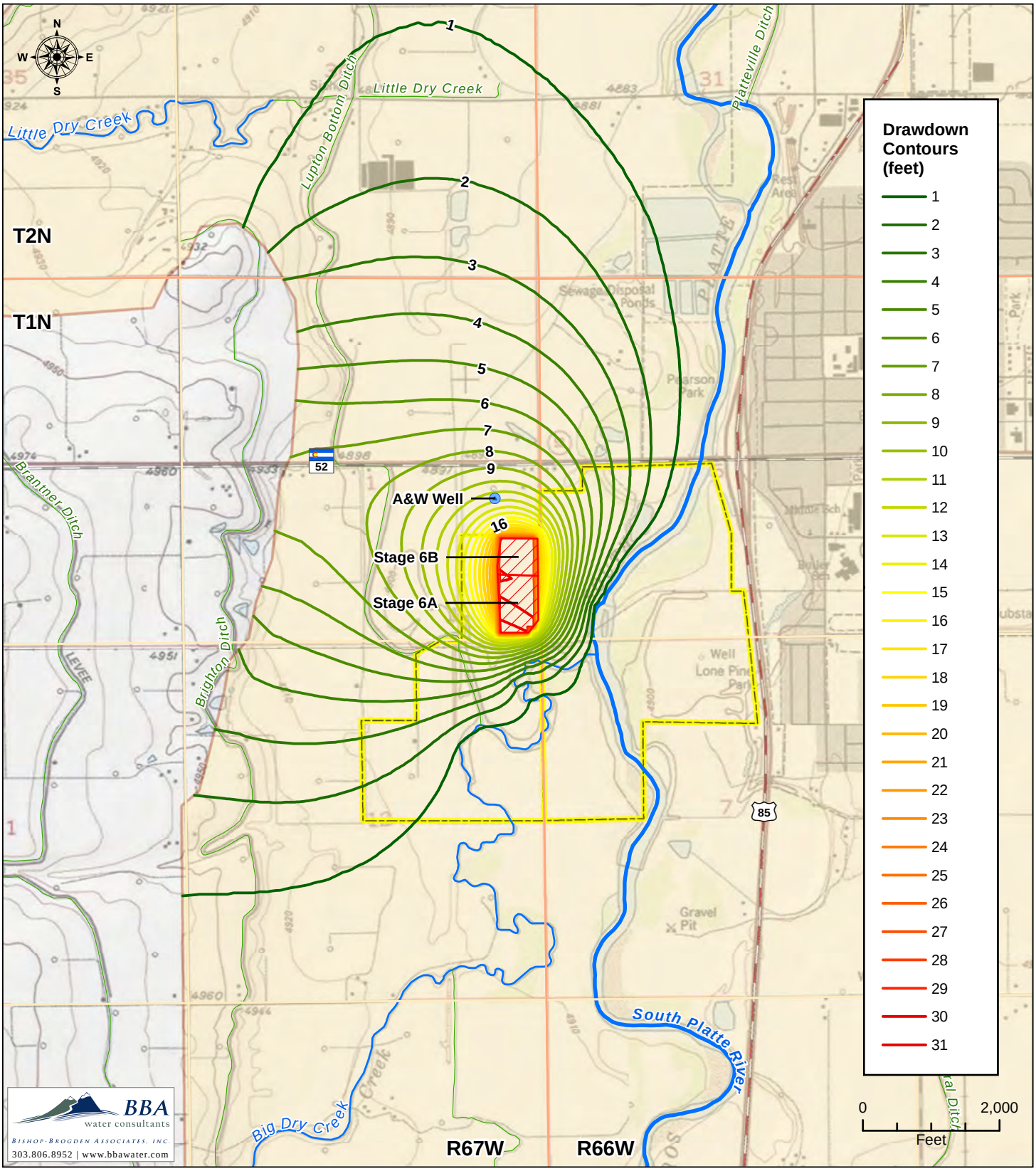
- A&W Well (Permit No. 61793-F)
- Stream / River
- Canal/Ditch
- Mining Stage 6A
- Morton Lakes Mine
- Modeled Saturated Alluvium (Approx.)

Data Source: DWR, RMCC, CDOT, USGS, BLM

**Colorado**

Main Map






# Figure 4
# Holton-Morton Lakes Site
# Stage 6A & 6B
# Modeled Drawdown Map

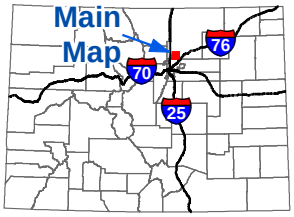
Date: 9/25/2017 | Job No. 0430.10

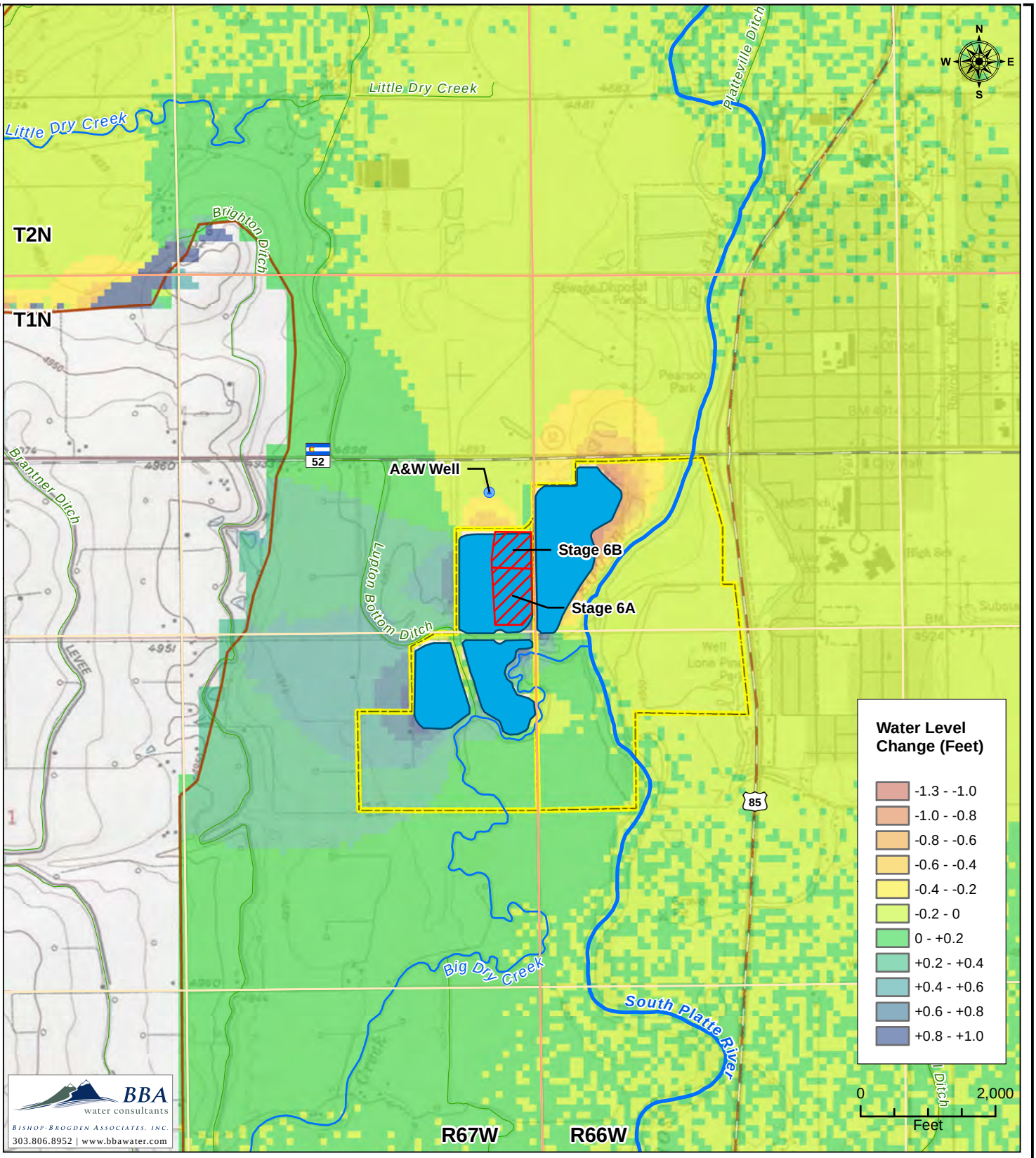
***Legend***

- A&W Well (Permit No. 61793-F)
- Stream / River
- Canal/Ditch
- Mining Stage 6A & 6B
- Morton Lakes Mine
- Modeled Saturated Alluvium (Approx.)

Data Source: DWR, RMCC, CDOT, USGS, BLM

**Colorado**






# Figure 5
# Holton-Morton Lakes Site
# Modeled Slurry Wall Liner Water Level Change Map

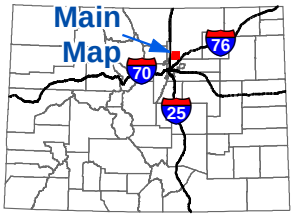
Date: 9/25/2017 | Job No. 0430.10

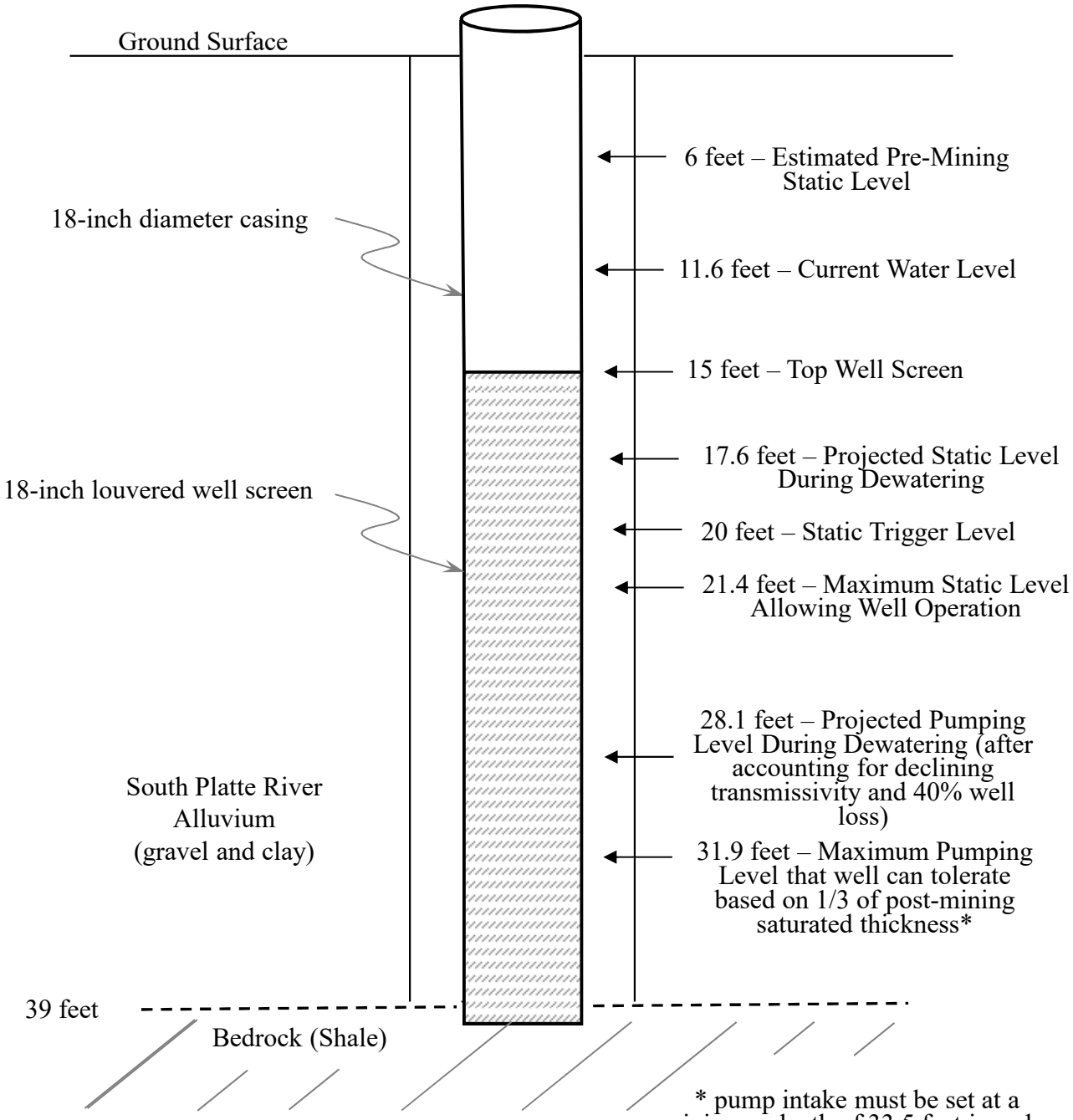
***Legend***

- A&W Well (Permit No. 61793-F)
- Stream / River
- Canal/Ditch
- Mining Stage 6A & 6B
- Slurry Walled Pit
- Morton Lakes Mine
- Modeled Saturated Alluvium (Approx.)

Data Source: DWR, RMCC, CDOT, USGS, BLM

**Colorado**






Note: Schematic not drawn to scale.

| | | |
|---|---|---|
| Date: September 29, 2017 | Figure 6<br>A&W Well Schematic<br>Potential Water Levels | BBA water consultants<br>Bishop-Brogden Associates, Inc.<br>333 W. Hampden Ave., Suite. 1050<br>Englewood, CO 80110<br>(303) 806-8952<br>www.bbawater.com |
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| By: TAC | | |