BY-LAW NUMBER 2015/48

BY-LAW NO. 2015/48 is a by-law of the County of Wetaskiwin No. 10 in the Province of Alberta, for the purpose of amending the "J-V Estates" Area Structure Plan.

WHEREAS: Section 191 of the Municipal Government Act, 2000, Chapter M-26 allows for the amendment of by-laws;

AND WHEREAS: Notification and procedural requirements outlined in Section 230 and 606 of the Municipal Government Act, 2000, Chapter M-26 have been met;

NOW THEREFORE: The Council of the County of Wetaskiwin No.10, hereby enacts as follows:

1. By-law 2015/48 is a By-law within the County of Wetaskiwin No.10 for the purpose of an amendment to Area Structure Plan By-law 2009/17 within SW 28-47-24-W4M known as the "J-V Estates" Area Structure Plan.

2. This by-law comes into effect on the date of third and final reading.

READ: A First time this 17th day of September A.D., 2015

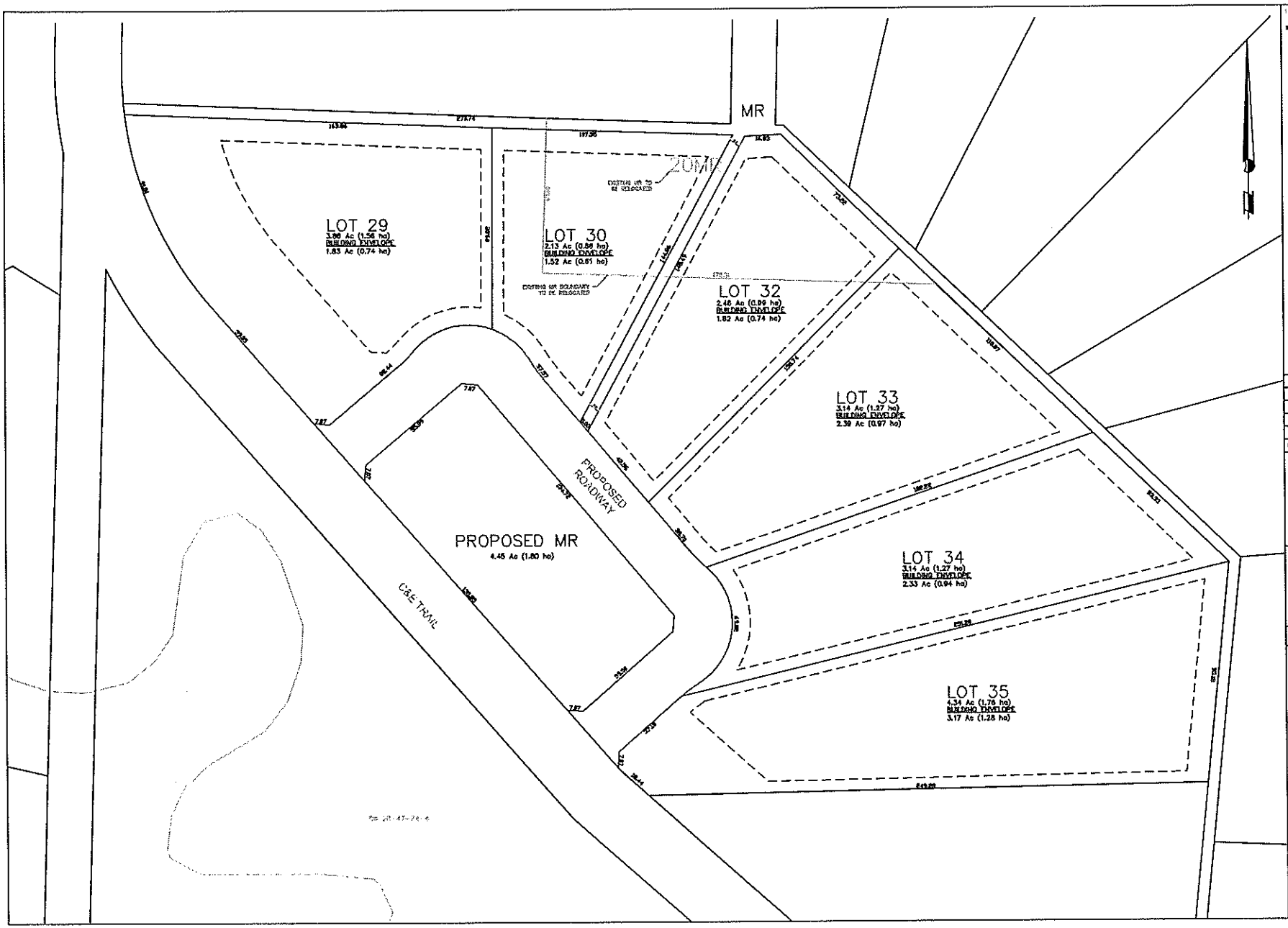
READ: A Second time this 11th day of February A.D., 2016

READ: A Third time and finally passed this 11th day of February A.D., 2016

REEVE

for CHIEF ADMINISTRATIVE OFFICER

APPENDIX A – J.V. ESTATES DEVELOPMENT SITE PLAN



PRELIMINARY

SENON ENGINEERING INC.
APEGGA PERMIT TO PRACTICE NO. P12108

SENON ENGINEERING IN

PROJECT

J.V. ESTATES
COUNTY OF WETASKIWIN
SW 28-47-24-4

DRAWING
PROPOSED LOT CONFIGURATION AND BUILDING ENVELOPES

DESIGN | DATE | SCALE
DRAWN | PROJECT NO.
CHECKED
APPROVED | DRAWING NO.
BE

Appendix "B"

Groundwater Availability – 2014 Addendum

SW 28-047-24 W4M
Millet Area
Big Timbers Sales Inc.

Prepared by
hydrogeological consultants ltd.
1-800-661-7972
Our File No.: 14-0351.01

November 2014

PERMIT TO PRACTICE
HYDROGEOLOGICAL CONSULTANTS LTD.
Signature _____
Date _____
PERMIT NUMBER P 385
The Association of Professional Engineers,
Geologists and Geophysicists of Alberta

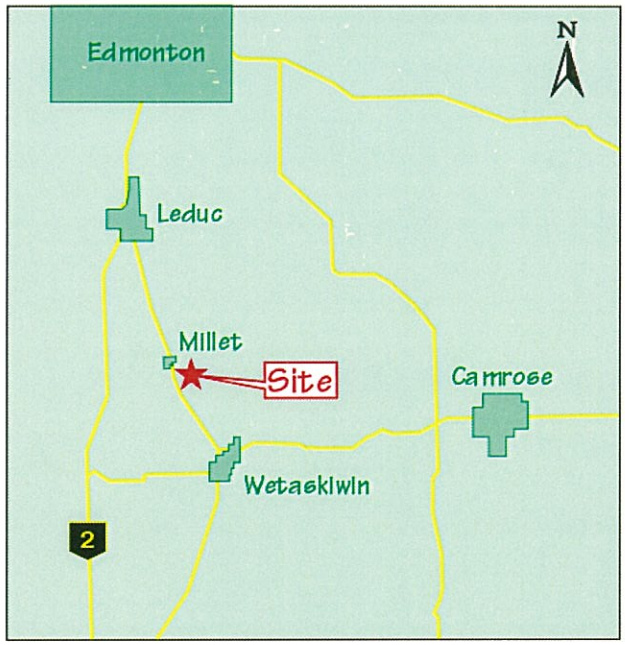
Table of Contents

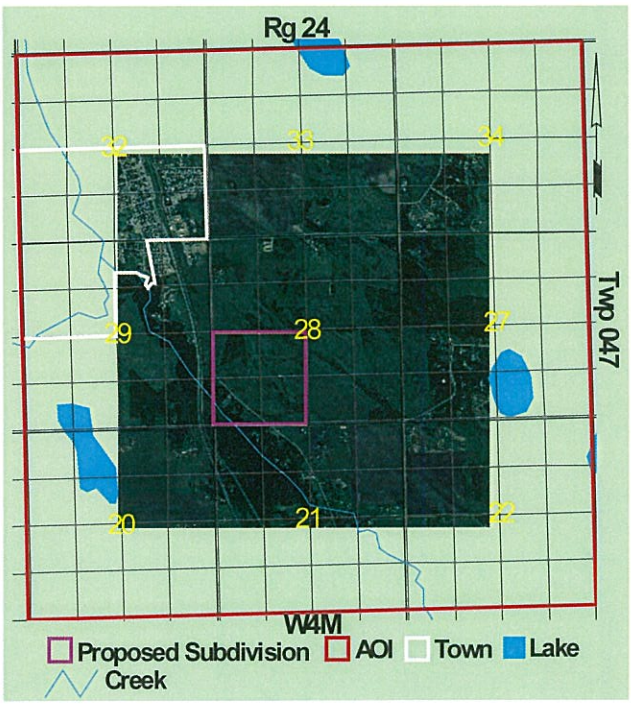
1. INTRODUCTION

1.1. Purpose

Big Timbers Sales Inc. plans to subdivide part of SW 28-047-24 W4M in the Millet area. As part of the application for subdivision, a review of existing hydrogeological data is required to determine if a sufficient quantity of groundwater is available for the proposed subdivision.

Section 23(3) of the Alberta *Water Act*[1] stipulates that a report certified by a professional engineer or professional geoscientist is required to be submitted to the subdivision authority as part of the application for the subdivision under the Municipal Government Act, in order for each of the households within the subdivision to continue to use up to 1,250 cubic metres per year (m³/year) of groundwater for household purposes. Section 9.1 of the Water (Ministerial) Regulation[2] stipulates that where a proposed subdivision will result in six or more parcels of land within a quarter section, a professional engineer, geologist or geophysicist must submit a report to the local subdivision approving authority. The report must advise whether there is a sufficient quantity of groundwater available for each of the parcels to divert 1,250 m³/year of groundwater, while not interfering with other groundwater users in the area. Hydrogeological Consultants Ltd. (HCL) satisfies the conditions required to prepare the report.





Index Maps

[1] Water Act – http://www.aer.ca/rules-and-regulations/acts-and-rules
[2] Water (Ministerial) Regulation – http://www.aer.ca/rules-and-regulations/acts-and-rules

1.2. Scope

A detailed groundwater availability study was completed in 2006 for a 21-lot subdivision in SW 28 (HCL, October 2006); an addendum was completed in 2009 for an additional five lots to the subdivision (HCL, February 2009)[3].

The proposed subdivision, to be located to the southeast of the Town of Millet, will include the developing of six additional rural residential lots in SW 28. This letter-report has been completed as a second addendum to the original report.

Although the 1,250 m^3/year, which is an average of 3.4 cubic metres per day (m^3/day), of groundwater per household is protected under the *Water Act*, the quantity is more than the 1.1 m^3/day that is typically used by a single family.

The area of study (AOS) of the present program is defined as 28-047-24 W4M and the surrounding eight sections. The area of interest (AOI) is defined as the area within 1,000 metres of the quarter section of the residential subdivision (SW 28-047-24 W4M).

The present study includes a review of the groundwater database for any new water wells completed in the AOS, an updated non-pumping water level (NPWL) from the 2006 Robinson Domestic Water Well (Dom WW), and the predicted impact of diverting groundwater from six new lots using aquifer parameters determined from the 2006 investigation.

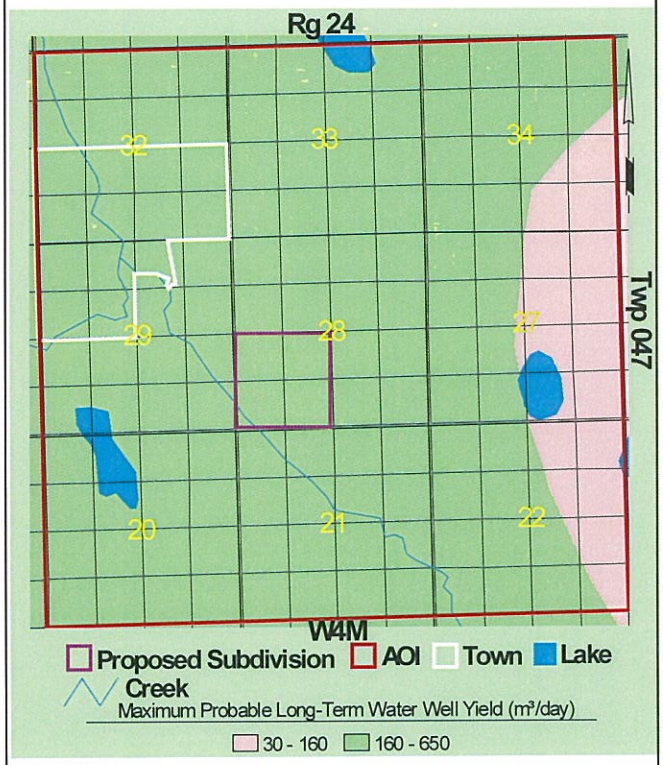
[3] Because of subsequent changes to the development plan, the current development consists of 24 lots; with the proposed development of six additional lots, the total development will consist of 30 rural residential lots.

2. BACKGROUND

2.1. General Hydrogeology

The upper bedrock in the AOS is the Horseshoe Canyon Formation, composed of sandstone, bentonite mudstone, shale, coal and ironstone beds (Ceroici, 1979). The top of the Horseshoe Canyon Formation at the location of the proposed subdivision is at an elevation of approximately 750 metres above mean sea level; the total thickness of the Horseshoe Canyon Formation at the location of the proposed subdivision is greater than 200 metres.

The hydrogeological map (Ceroici, 1979) for the proposed subdivision indicates that water wells completed in aquifers within 90 metres of the ground surface are expected to have long-term yields of 160 to 650 m³/day, as shown on the adjacent map. Ceroici (1979) states that "the Horseshoe Canyon Formation is noticeably more permeable in both the Millet area and north of Devon than in other parts of the map area".



***Hydrogeological Map** (Ceroici, 1979)*

Groundwaters in the nine-section AOS are expected to be sodium-bicarbonate-type waters with a fluoride concentration that is between 0 and 1.5 milligrams per litre (mg/L).

The surficial deposits in the AOS are composed primarily of till; groundwaters from these surficial deposits are expected to be calcium-plus-magnesium-bicarbonate-type waters.

The groundwater query for Wetaskiwin County No. 10, which is based on regional data, indicates that the upper bedrock below the proposed development is the Upper Horseshoe Canyon Formation.

The underlying Middle Horseshoe Canyon Formation is expected in the depth interval from 63 to 113 metres below ground level (BGL), which in turn overlies the Lower Horseshoe Canyon Formation in the depth interval from 113 to 259 metres BGL. The geological units are outlined in the adjacent table.

Wetaskiwin County No. 10
SW 28-047-24 W4M

General Results Depth(s)	Top metre	Yield* m³/day	NPWL metre	TDS mg/L	Sulfate mg/L	Chloride mg/L	Fluid Expected
gwQuery Determined Minimum	20	82[2]	12	651	396	7	--
gwQuery Determined Maximum	57	82[2]	12	651	396	7	--

Detailed Results Geologic Unit Encountered	Top metre	Yield* m³/day	NPWL metre	TDS mg/L	Sulfate mg/L	Chloride mg/L	Fluid Expected
Upper Surficial Deposits	--	--	2	400	24	10	--
Lower Surficial Deposits	0	--	-23	400	24	10	--
Bedrock Surface	16						
Upper Horseshoe Canyon Formation	16	82[2]	12	651	396	7	--
Middle Horseshoe Canyon Formation	63	2[2]	-11	941	78	15	--
Lower Horseshoe Canyon Formation	113	8[3]	--	--	--	--	--
Bearpaw Formation	259	32[3]	--	--	--	--	--

Parameter	metre
Base of Groundwater Protection [Depth]	351
Ground Elevation [AMSL]	746

Legend/Notes

'--' indicates information not available.

Base of Groundwater Protection (BGP: TDS > 4,000 mg/L).

* Yield based on the 'Fluid Encountered' being water.

[2] Results are based on a regional groundwater study by hydrogeological consultants ltd. (HCL)

[3] Results are based on a summary of Drill Stem Test (DST) results.

Contact at least three local licensed water well drillers to get estimates of drilling and water well completion costs in your area. Consult the 'Water Wells that Last for Generations' booklet for advice on hiring a water well driller, and for a check list of items that you and the driller should discuss and agree to before starting the work.

The information calculated with the MOW-TECH LTD. gwQuery is meant only as a guide. Actual drilling conditions may vary. MOW-TECH LTD. is not liable for drilling or groundwater problems as a result of using these data.

Groundwater Query

The groundwater query indicates that expected groundwater yields from water wells completed in the Upper Horseshoe Canyon Formation aquifers are approximately 80 m³/day; in the Middle Horseshoe Canyon Formation and Lower Horseshoe Canyon Formation aquifers, expected groundwater yields from water wells are in the order of 2 m³/day and 8 m³/day, respectively.

Groundwaters from both the Upper and Middle Horseshoe Canyon formations would be expected to have a total dissolved solids concentration that is between 650 and 950 mg/L. Because the groundwater query is based on regional data, local conditions may vary.

2.2. Previous Work

A bibliography that includes maps and documents related to hydrogeology in the study area is included in the Bibliography section of this report[4].

The 2006 groundwater availability report for a 21-lot subdivision in SW 28-047-24 W4M included water test hole drilling, groundwater sampling and aquifer testing of the 2006 Robinson Dom WW. Information included in the original groundwater availability report for the 21-lot subdivision indicated that the 2006 Robinson Dom WW is completed in a bedrock aquifer within the Upper Horseshoe Canyon Formation, with an effective transmissivity of 21.3 metres squared per day (m^2/day) and a corresponding storativity of 0.0001.

Conclusions of the 2009 addendum associated with adding five new lots to the 21-lot subdivision were as follows:

> *Big Timbers Sales Inc. plans to develop a rural residential subdivision consisting of five adjacent residential lots, in addition to 24 existing lots, for a total of 29 residential lots in SW 28-047-24 W4M. The 29 residential lots require a total groundwater supply of 99.3 m^3/day.*
>
> *Water wells completed in the proposed subdivision will likely be completed in an aquifer in the Upper Horseshoe Canyon Formation. The calculated long-term yield of the 2006 Robinson Dom WW is 151 m^3/day, which is more than adequate for the proposed subdivision. An analysis that included the effects of interference from nearby pumping water wells has shown that the proposed diversion of 99.3 m^3/day, in addition to ongoing drawdown from existing water wells, should not adversely affect any water well users or the aquifer in which the water wells are completed.*
>
> *The chemical quality of the groundwater sample collected from the 2006 Robinson Dom WW is not suitable for human consumption without treatment because the concentration of fluoride exceeds the maximum acceptable concentration (MAC) for health objectives.*

[4] Alberta Environment (AENV) has recently changed its name to Alberta Environment and Sustainable Resource Development (ESRD). Several reference documents are under the AENV designation. In this document, both ESRD and AENV are used to identify the same department of the Alberta Government.

3. PRESENT PROGRAM

3.1. Groundwater Database

The enhanced groundwater database maintained by The Groundwater Centre shows that in the nine-section AOS, there are currently 413 groundwater records. The tables to the right provide a breakdown of the feature type making up the database records. Of the 413 groundwater records currently in the database, 408 are classified as being records that are for water wells, as shown in the upper table to the right. In most cases, spatial information on groundwater records is limited to the quarter section. Unless more detailed information is available, the coordinates assigned to groundwater records are the centre of their legal location.

Feature	No. of Records
Water Well	408
Reclaimed Water Well	2
Spring	1
Structure Test Hole	2
Total:	***413***

Groundwater Database Records (2014)

Feature	No. of Records
Water Well	370
Reclaimed Water Well	1
Spring	1
Structure Test Hole	2
Unknown	5
Total:	***379***

Groundwater Database Records (2009)

Feature	No. of Records
Water Well	349
Reclaimed Water Well	1
Spring	1
Structure Test Hole	2
Unknown	5
Total:	***358***

Groundwater Database Records (Oct 2006)

The information in the groundwater database has been used to determine the number of new water well records in the study area since the 2006 groundwater investigation and the 2009 addendum to the 2006 investigation. The middle table to the right summarizes the groundwater records in the AOS at the time of the 2009 addendum, and the lower table to the right summarizes the groundwater records in the study area at the time of the original groundwater availability report in October 2006. A comparison between the three tables shows that the current database has 38 additional water wells since 2009, and 59 additional water wells since 2006.

3.1. Data Processing

The horizontal coordinates in this report are based on a 10-degree Transverse Mercator projection, referenced to 115 degrees west longitude and using the NAD83 datum (North American Datum of 1983). Coordinates were determined for features identified in the field using a consumer-grade hand-held GPS (global positioning system receiver). Water well records with a reported lot, block and plan were repositioned as part of the present program using the Government of Alberta SPIN2 website[5].

Calculation of Transmissivity Values

Transmissivity values from the aquifer test data from pumped water wells were calculated using the Cooper-Jacob approximation of the Theis non-equilibrium equation:

$$T = \frac{2.3 \cdot Q}{4 \cdot \pi \cdot \Delta s}$$

Where:

T	= transmissivity in m^2/day
Q	= discharge in m^3/day
Δs	= metres of drawdown per log cycle

[5] https://alta.registries.gov.ab.ca/spinii/logon.aspx

Transmissivity from specific capacity was calculated based on the following equation:

$$\frac{Q}{s} = \frac{4 \cdot \pi \cdot T}{2.3 \cdot \log_{10}\left(\frac{2.25 \cdot T \cdot t}{S \cdot r^2}\right)}$$

Where:

Q	= discharge in m^3/day
s	= drawdown in metres
T	= transmissivity in m^2/day
S	= storativity, assumed to be 0.0001, dimensionless
t	= time since discharge started in days
r	= effective radius of the water well in metres

Calculation of Drawdown

Drawdowns at various times and distances from the groundwater discharge point were calculated using the Theis non-equilibrium equation based on approximations of W(u):

$$s = \frac{Q \cdot W(u)}{4 \cdot \pi \cdot T}$$

Where:

s	= drawdown in metres
Q	= discharge in m^3/day
W(u)	= well function for non-leaky artesian aquifers
T	= transmissivity in m^2/day

And

$$u = \frac{r^2 \cdot S}{4 \cdot T \cdot t}$$

Where:

r	= effective radius of the water well in metres
S	= aquifer storativity, dimensionless
T	= transmissivity in m^2/day
t	= time since discharge started in days

For approximations of W(u) for values of u greater than zero and less than one, the following approximation was used:

$W(u) = - \ln u + (-0.57721556) + (0.99999193)*u + (-0.24991055)*u^2 + (0.05519968)*u^3 + (-0.000976004)*u^4 + (0.00107857)*u^5$

Where:

ln	= natural logarithm

For values of 1 < u < infinity, the following approximation was used:

$$W(u) = \frac{1}{u \cdot e^u} \cdot \frac{0.250621 + 2.334733 \cdot u + u^2}{1.681534 + 3.330657 \cdot u + u^2}$$

Where:

e = the base of the natural logarithm

When multiple groundwater discharge points were involved, the principle of superposition was used. The multiple discharge points could be at various locations or at one location.

Calculation of Theoretical Long-Term Yield

Theoretical long-term yield was calculated from the Modified Moell Method (Alberta Government, March 2011), using the following equation:

$$Q_{20} = \frac{(Q)(H_a)0.7}{s_{100\,\mathrm{min}} + (s_{20\,yrs} - s_{100\,\mathrm{min}})_{Theor}}$$

Where:

Q_{20} = sustainable yield for 20 years in m³/day
Q = pumping rate during the aquifer tests in m³/day
H_a = available drawdown in metres
s_{100min} = measured drawdown in metres after 100 minutes of pumping
$s_{100min\ Theor}$ = calculated theoretical drawdown in metres after 100 minutes of pumping Q using effective transmissivity
$s_{20yrs\ Theor}$ = calculated theoretical drawdown in metres after 20 years of pumping Q using effective transmissivity
0.7 = safety factor

When the aquifer is fully confined, the available drawdown (H_a) is the linear distance from the NPWL to the top of the aquifer. When the aquifer is not fully confined, the available drawdown (H_a) is two thirds of the linear distance from the NPWL to the bottom of the aquifer.

For confined aquifers only, the theoretical long-term yield can also be calculated from the Farvolden Method (Alberta Government, March 2011), using the following equation:

$$Q_{20} = 0.68(T)(H_a)0.7$$

Where:

H_a = available drawdown in metres
Q_{20} = sustainable yield for 20 years in m³/day
0.7 = safety factor
T = transmissivity in m²/day

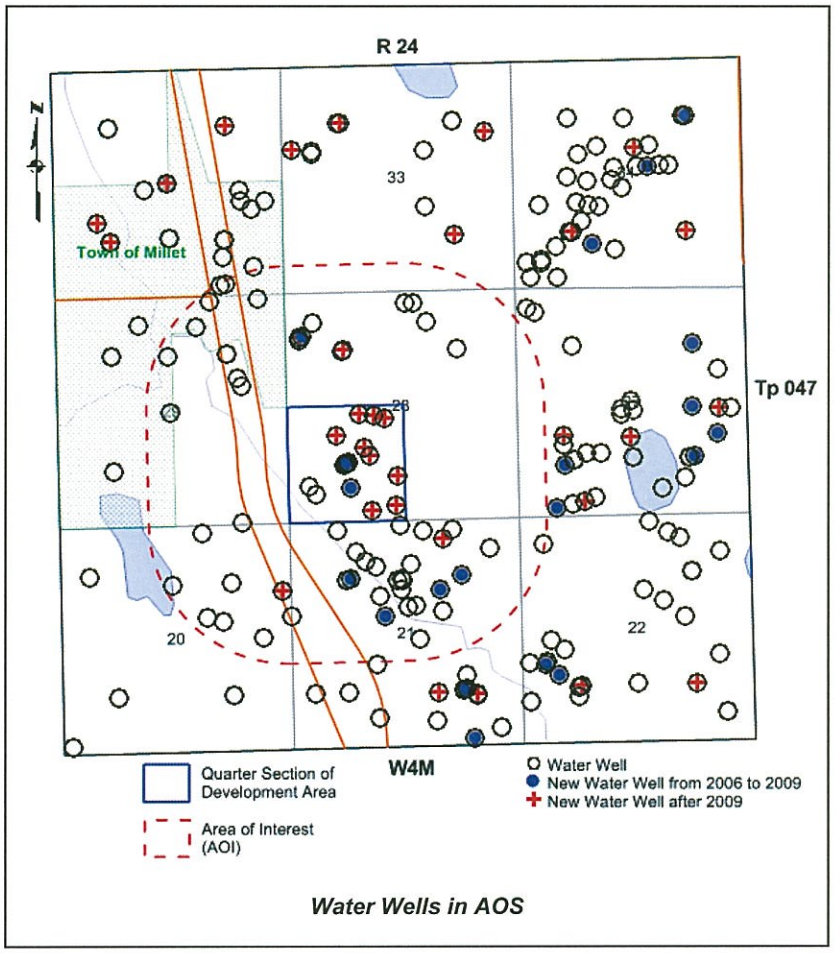
Calculation of Predicted Impact

A mathematical model was used to calculate the water levels in the aquifer at various locations within the AOI when pumping from specific water wells within the AOI. The model, developed by Mow-Tech Ltd., is called the Infinite Artesian Aquifer Model and is used to calculate water levels at specific locations in the aquifer. The aquifer is considered to be homogeneous and isotropic, and to behave as an aquifer of infinite areal extent; the calculations do not account for direct recharge to the aquifer.

4. RESULTS

4.1. Water Well Records

The adjacent map shows the locations of the 408 water wells[6] within the AOS, and includes the 59 new water well records that are in the current groundwater database, compared to the October 2006 version of the database; of these 59 new water wells, 38 have been added after the time of the 2009 addendum. These 59 new water well records, and the diversion from the six proposed lots in SW 28, have been used to update the interpretation of the original groundwater availability calculations, as discussed in the Interpretation section of this report.



Water Wells in AOS

Within the AOI, there are 97 water well records. Of these 97 water wells, three existed in SW 28 prior to the original Big Timbers Sales Inc. development, and 32 have water well completion information and/or a reported NPWL that indicate they could be completed in the same aquifer as the 2006 Robinson Dom WW. An additional 19 water wells have insufficient information to identify the aquifer of completion; an interpretation of predicted impact on the aquifer in which the 2006 Robinson Dom WW is completed is based on pumping from these 51 water wells.

4.2. 2006 Robinson Dom WW

On November 8, 2014, personnel from Warnke Drilling Ltd. measured a depth to water in the 2006 Robinson Dom WW of 2.53 metres below top of casing (BTOC), which is 0.25 metres higher than the 2.78 metres BTOC measured prior to Aquifer Test III (AT III) on September 9, 2006.

[6] Unless there is more detailed information, water wells are plotted in the centre of their reported legal location; therefore, some locations may represent multiple records.

5. INTERPRETATION

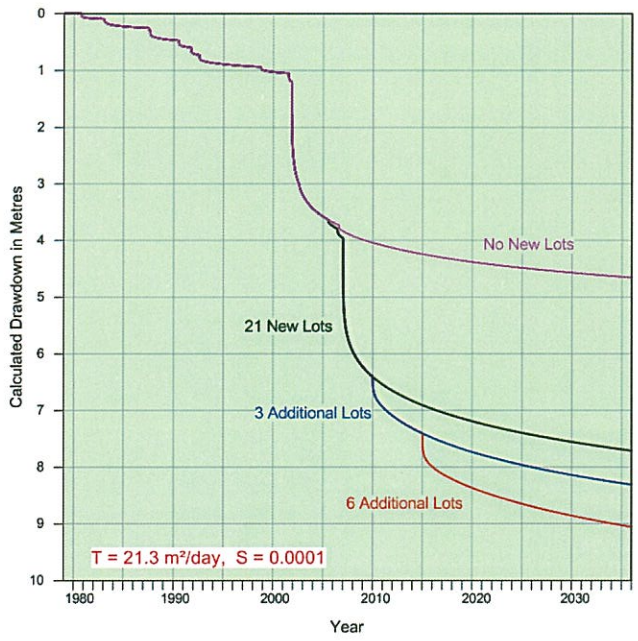
5.1. Long-Term Yield

Analysis of the results of an extended aquifer test indicated that the 2006 Robinson Dom WW has a calculated long-term yield of 151 m³/day (HCL, October 2006). Based on a protected diversion of 3.4 m³/day per lot, the 2006 Robinson Dom WW could supply up to 44 lots, which is in excess of the 30 lots of the proposed development[7]. However, an analysis of predicted impact is required to determine the cumulative effects of pumping from the development in SW 28 and other water wells in the AOI.

5.2. Predicted Impact

The adjacent graph shows the calculated drawdowns at the eastern perimeter of the SW 28 quarter section, based on pumping 3.4 m³/day from each water well identified in the four calculations below:

1. The 37 water wells in the AOI that existed in 2006 that are identified as being completed in the same aquifer in which the 2006 Robinson Dom WW is completed (represented by the pink line)
2. The 37 water wells referred to in No. 1 above, plus the four new water wells in the AOI that were completed between 2006 and 2009, plus the 21 new water wells proposed in the 2006 analysis (represented by the black line)
3. The 62 water wells identified in Nos. 1 and 2 above, plus the two new water wells in the AOI that were completed between 2009 and 2014, plus the three new water wells proposed in the 2009 analysis[8] (represented by the blue line)
4. The 67 water wells identified in Nos. 1, 2 and 3 above, plus the six new water wells proposed as part of the current application (represented by the red line)



Calculated Drawdown at Eastern Perimeter of Subdivision

Each water well is assumed to begin pumping the day that it was completed; the 23 water wells without a completion date are assumed to begin pumping on the average completion date of October 27, 2001. The 21 water wells of the originally proposed subdivision are assumed to begin pumping on January 1, 2007. The three water wells for the 2009 expansion of the subdivision are assumed to begin pumping on January 1, 2010. The six water wells to be completed as part of the proposed expansion are assumed to begin pumping on January 1, 2015. The drawdown calculations use an apparent transmissivity of 21.3 m²/day[9] and a corresponding estimated

7 The 30 lots consist of the current 24 lots plus the six new lots for the proposed expansion.

8 Although five new lots were proposed in the 2009 analysis, changes to the development plan resulted in a total of 24 lots being developed prior to the current application; the number of water wells assumed to begin pumping in 2010 was therefore reduced to three in order to have a combined 24 new lots since 2006.

9 Based on the drawdown and recovery of the 2006 Robinson Dom WW during AT III.

storativity of 0.0001. The analysis is based on an isotropic and homogeneous aquifer; the model does not consider aquifer recharge.

The graph shows that after 20 years of pumping, the water-level drawdown at the eastern perimeter of the proposed subdivision will be 9.1 metres by the end of 2036. A calculated drawdown of 9.1 metres represents 37% of the average available drawdown of 24.6 metres in the aquifer, which is not considered to represent an adverse effect.

The calculated drawdowns are considered to be conservative for the following reasons:

- The calculations assume 3.4 m^3/day will be pumped from each of the water wells, which is approximately three times the volume that is typically used by a single-family household.
- The calculations assume that each new water well in the proposed subdivision will be completed in the same aquifer in which the 2006 Robinson Dom WW is completed.
- The analysis shows drawdown that has occurred between 2006 and 2009; because no drawdown has occurred in the 2006 Robinson Dom WW during this interval, aquifer recharge is currently making up for all groundwater diversion from the aquifer in which the 2006 Robinson Dom WW is completed.

6. CONCLUSIONS

Big Timbers Sales Inc. plans to develop a rural residential subdivision consisting of six additional residential lots in SW 28-047-24 W4M. The six new lots would result in 30 lots in the quarter section, requiring a total groundwater supply of 103 m³/day.

Water wells completed in the proposed subdivision will likely be completed in an aquifer in the Upper Horseshoe Canyon Formation. The calculated long-term yield of the 2006 Robinson Dom WW is 151 m³/day, which is more than adequate for the existing and proposed subdivision. An analysis that included the effects of interference from nearby pumping water wells has shown that the proposed diversion, in addition to ongoing drawdown from existing water wells, should not adversely affect any water well users or the aquifer in which the water wells are completed.

A water level in the 2006 Robinson Dom WW measured on November 8, 2014, has shown that there has been no water-level decline in the aquifer in which the 2006 Robinson Dom WW is completed between September 2006 and November 2009.

The chemical quality of the groundwater sample collected from the 2006 Robinson Dom WW is not suitable for human consumption without treatment because the concentration of fluoride exceeds the MAC for health objectives.

The information provided in this report satisfies the intent of Section 23(3) of the *Water Act* and is therefore sufficient for the issuance of a subdivision permit from a hydrogeological perspective.

7. RECOMMENDATIONS

Water wells for new lots should be completed by a journeyman water well driller, and an aquifer test must be conducted with each new water well per the Water (Ministerial) Regulation No. 63 (Alberta Environment, 1998). A groundwater sample from each new water well should be collected and analyzed for microbiological and routine chemical parameters to confirm potability and be reviewed with the local health unit before consumption.

It is also recommended that Big Timbers Sales Inc. establish and maintain a suitable groundwater monitoring site for the collection of water-level and groundwater-quality information from the bedrock aquifer on an ongoing basis. The groundwater monitoring program should include the measuring of annual water levels in the 2006 Robinson Domestic Water Well. The water levels can be entered online by accessing The Groundwater Centre's website at https://www.tgwc.com/. These data would assist in managing the groundwater resource underlying the subdivision and provide information for future developments.

PROFESSIONAL GEOLOGIST ALBERTA
James A. Touw

Jim Touw, P.Geol.
Senior Hydrogeologist

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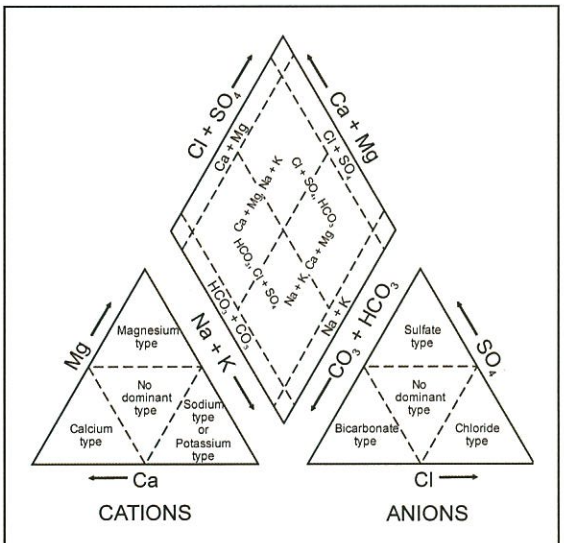
9. SUPPLEMENTARY INFORMATION

9.1. Glossary of Terms

aquifer	a formation, group of formations or part of a formation that contains saturated permeable rocks capable of transmitting groundwater to water wells or springs in economical quantities
available drawdown	in a confined aquifer, the distance between the non-pumping water level and the top of the aquifer in an unconfined aquifer (water table aquifer), two thirds of the saturated thickness of the aquifer and water level within 5 metres of the top of the aquifer
base of groundwater protection	the depth below which groundwater is expected to have a total dissolved solids concentration of more than 4,000 milligrams per litre
geounit	a geologic unit categorized by a similarity in geological feature(s) such as stratigraphic interval, depositional environment or hydrogeological properties
hydraulic conductivity	the rate of flow of water through a unit cross-section under a unit hydraulic gradient; units are length/time
maximum acceptable concentration	the highest level of chemical substances determined by Health Canada to be allowable in drinking water supplies; these substances are generally only a concern if exposure above guideline levels occurs over an extended time
Piper tri-linear diagram	a method to show the composition of water based on major cation and anion composition. This diagram allows groupings or trends in the chemical-quality data to be identified. In Alberta, surface water and shallow groundwater are typically a Ca+Mg-HCO_3-type water, upper bedrock groundwaters are a Na+K-HCO_3-type water and deep groundwaters are a Na+K-Cl-type water.



Piper Tri-Linear Diagram

storativity	the volume of water released from storage by a confined aquifer per unit surface area of aquifer per unit decline in hydraulic head (dimensionless)
surficial deposits	all sediments above the bedrock surface
till	a sediment deposited directly by a glacier that is unsorted and consisting of any grain size ranging from clay to boulders
transmissivity	the rate at which water is transmitted through a unit width of an aquifer under a unit hydraulic gradient; a measure of the ease with which groundwater can move through the aquifer apparent transmissivity: the value determined from a summary of aquifer test data, usually involving only two water-level readings effective transmissivity: the value determined from late pumping and/or late recovery water-level data from an aquifer test aquifer transmissivity: the value determined by multiplying the hydraulic conductivity of an aquifer by the thickness of the aquifer
yield	a regional analysis term referring to the rate at which a properly completed water well could be pumped, if fully penetrating the aquifer apparent yield: based mainly on apparent transmissivity long-term yield: based on effective transmissivity sustainable yield: based on aquifer parameters determined from long-term water-level and groundwater production monitoring

9.2. Glossary of Commonly Used Abbreviations, Acronyms and Symbols

AENV	Alberta Environment and Sustainable Resource Development (formerly Alberta Environment, Alberta Environment and Water)
AER	Alberta Energy Regulator (formerly Energy Resources Conservation Board)
AMSL	above mean sea level
AO	aesthetic objective
AOI	area of interest
AOS	area of study
AT	aquifer test
BGL	below ground level
BGWP	base of groundwater protection
BTOC	below top of casing
DEM	digital elevation model
DST	drill-stem test
ERCB	Energy Resources Conservation Board (formerly EUB)
ESRD	Alberta Environment and Sustainable Resource Development (formerly Alberta Environment, Alberta Environment and Water)
GCDWQ–ST	Guidelines for Canadian Drinking Water Quality – Summary Table
GPS	global positioning system receiver
GWUDI	groundwater under the direct influence of surface water
km	kilometre(s)
km^2	square kilometre(s)
Lpm	litre(s) per minute
Lpm/metre	litre(s) per minute per metre
LSD	legal subdivision
m	metre(s)
m^2	metre(s) squared
m^2/day	metre(s) squared per day
m^3	cubic metre(s)
m^3/day	cubic metre(s) per day
m^3/year	cubic metre(s) per year

MAC	maximum acceptable concentration
mg/L	milligram(s) per litre
mm	millimetre(s)
NAD83	North American Datum of 1983
NPWL	non-pumping water level
Obs WW	observation water well
TDS	total dissolved solids
TGWC	The Groundwater Centre www.tgwc.com
VE	vertical exaggeration
WSW	water source well *or* water supply well
WTH	water test hole
WW	water well

9.3. Stratigraphy of the "Undisturbed" Geology of Alberta

(as used by Hydrogeological Consultants Ltd.)

- upper surficial
- lower surficial
- Cypress Hills Fm
- Dalehurst Member
- upper part of Lacombe Member
- lower part of Lacombe Member
- Haynes Member
- upper part of Scollard Fm
- lower part of Scollard Fm
- Battle/Whitemud Fms
- upper part of Horseshoe Canyon Fm
- middle part of Horseshoe Canyon Fm
- lower part of Horseshoe Canyon Fm
- Bearpaw Fm
- Oldman Fm
- Foremost Fm
- Lea Park Fm
- Milk River Fm
- Colorado Shale
- Cardium Fm
- Kaskapau Fm
- Dunvegan Fm
- Shaftesbury Fm
- Viking Fm
- Joli Fou Fm
- upper part of Mannville Grp
- middle part of Mannville Grp
- lower part of Mannville Grp
- Jurassic
- Triassic
- upper part of Paleozoic
- Banff Fm
- Wabamun Group
- Winterburn Group
- Woodbend Group
- Beaverhill Lake Group
- Elk Point Group
- Precambrian

9.4. Guidelines for Canadian Drinking Water Quality – Summary Table

Constituent	AO	MAC
pH (pH units)	6.5 - 8.5	---
Conductivity (µS/cm)	---	---
Total Dissolved Solids	500	---
Sodium	200	---
Potassium	---	---
Calcium	---	---
Magnesium	---	---
Total Hardness	---	---
Manganese	0.05	---
Carbonate	---	---
Bicarbonate	---	---
Total Alkalinity	---	---
Sulfate	500	---
Chloride	250	---
Fluoride	---	1.5
Iron	0.3	---
Nitrate (as N)	---	10
Nitrate	---	45
Nitrite (as N)	---	1
Nitrite	---	3.2
Nitrate + Nitrite (as N)	---	10
Total Coliforms (CFU/100 mL)	---	0*
Fecal Coliforms (CFU/100 mL)	---	0
Escherichia coli (CFU/100 mL)	---	0
Ionic Balance (%)	---	---

Concentrations are in milligrams per litre unless otherwise stated.
Note: Constituents marked with --- do not have a recommended maximum concentration associated with them.

CFU/100 mL - Colony Forming Units per 100 millilitres
AO - Aesthetic Objective
MAC - Maximum Acceptable Concentration

GCDWQ–ST - Guidelines for Canadian Drinking Water Quality – Summary Table, Health Canada. 2012

9.5. Conversions

Multiply	by	To Obtain
Length/Area		
feet	0.304 785	metres
metres	3.281 000	feet
hectares	2.471 054	acres
centimetre	0.032 808	feet
centimetre	0.393 701	inches
acres	0.404 686	hectares
inches	25.400 000	millimetres
miles (statute)	1.609 344	kilometres
kilometres	0.621 370	miles (statute)
square feet (ft^2)	0.092 903	square metres (m^2)
square metres (m^2)	10.763 910	square feet (ft^2)
square metres (m^2)	0.000 001	square kilometres (km^2)
Concentration		
grains/gallon (UK)	14.270 050	parts per million (ppm)
parts per million (ppm)	0.998 859	milligrams per litre (mg/L)
milligrams per litre (mg/L)	1.001 142	parts per million (ppm)
Volume (capacity)		
acre feet	1233.481 838	cubic metres
cubic feet	0.028 317	cubic metres
cubic metres	35.314 667	cubic feet
cubic metres	219.969 248	imperial gallons (UK)
cubic metres	264.172 050	gallons (US liquid)
cubic metres	1000.000 000	litres
cubic metres	6.290 000	Barrels of Oil Equivalent (BOE)
imperial gallons (UK)	0.004 546	cubic metres
imperial gallons (UK)	4.546 000	litres
Rate		
litres per minute	0.219 974	imperial gallons per minute (ipgm)
litres per minute	1.440 000	cubic metres/day (m^3/day)
imperial gallons per minute (igpm)	6.546 300	cubic metres/day (m^3/day)
cubic metres/day (m^3/day)	0.152 759	imperial gallons per minute (ipgm)
Pressure		
pound per square inch (psi)	6.894 757	kilopascal (kpa)
kilopascal (kpa)	0.145 038	pound per square inch (psi)
Miscellaneous		
Celsius	F° = 9/5 (C° + 32)	Fahrenheit
Fahrenheit	C° = (F°- 32) * 5/9	Celsius
degrees	0.017 453	radians