APPENDIX B

Responses to NRC Requests for Additional Information (RAI)
RAI-56

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RAI 56

Description of Deficiency

The information provided in TR Section 3.1.6 does not meet the applicable requirements of 10 CFR Part 40 using review procedures in Section 3.1.2 and acceptance criteria outlined in Section 3.1.3 of the SRP.

Basis for Request

TR Section 3.1.6.1 provides the ROI for the 90 sand, 80 sand, and 70 sand as 550 ft, 500 ft, and 750 ft, respectively, based on the aquifer pumping tests. The TR also states there would be no impact to groundwater levels outside the project boundaries based on these estimates for the proposed bleed rate (15-45 gpm). These ROI were derived based on observations during the aquifer testing of these sands but the TR provided no calculations to support these numbers. Staff does not agree with Uranium One's definition of ROI. In practice, the ROI is defined by a function of transmissivity (T), time (t) and storage coefficient (S) in consistent units (Bear, 1979).

ROI=1.5*sqrt (Tt/S)

Staff requires the ROI and drawdown which will be realized at each satellite to assess the impacts of consumptive use on surrounding private wells and to provide reasonable assurance of the safe operation of the satellites.

Formulation of RAI

Uranium One should provide: (a) the ROI using the estimated T, S and the time of production and restoration for each satellite wellfield; and (b) a prediction of the drawdown for each satellite wellfield within 2 km for each phase of operation using the appropriate consumptive use (e.g. 15-45 gpm).

<u>RAI-56 Response</u>

A Theis-based analytical drawdown model for the 70, 80 and 90 Sand units at the proposed project was completed using site-specific aquifer parameters. The production sands of the Ludeman Project satisfy the assumptions required by the Theis model to the extent generally accepted for this type of hydrogeologic evaluation. Project-specific assumptions and limitations have been noted and discussed in this Memorandum. Model inputs were entered into AQTESOLV software, and graphs were produced showing the predicted time-drawdown behavior of the proposed project wellfields. Drawdown contour

maps showing the estimated location of the five and 25 foot drawdown contours (at maximum drawdown) were produced using ArcGIS software. The maximum radii of typical 25 foot drawdown contours ranged from approximately seven to 16 miles, and the maximum radii of five foot drawdown contours ranged from about 14 to 29 miles. Non-ideal aquifer conditions in the vicinity of the site could potentially alter the magnitude and extent of actual versus modeled drawdowns.

<u>Methods and Limitations</u>

Project background information and data for model input were provided to HydroSolutions by TREC. Specifically, TREC provided a project operational schedule, a project summary, versions of *Appendix D6 Hydrology* (Uranium One, 2010) and *Appendix A-1 Pump Test Report* (Uranium One, 2010), a digital ArcGIS shapefile showing wellfield locations, and other documents and figures associated with the Ludeman Project. Project-specific model input data were determined from these documents and through communication with TREC. Additionally, data available on the hydrogeologic properties of Eocene and Paleocene confining units in the Powder River Basin, as summarized in the Powder River Basin Oil and Gas EIS Technical Report on Groundwater Modeling (Applied Hydrology Associates, Inc. and Greystone Environmental Consultants, Inc., 2002), were reviewed.

<u>Analytical Model and Assumptions</u>

The Hantush-Jacob (1955) analytical model for non-equilibrium radial flow to a well in a leaky confined aquifer was selected for estimation of cumulative groundwater drawdown associated with the Ludeman Project. The Hantush-Jacob equation provides a solution for determining groundwater flow and drawdown in time and space around a pumping well completed in a leaky confined aquifer.

In most natural settings, aquifer “confinement” tends to be imperfect, and typical confined aquifers receive some recharge by vertical leakage through confining units. The Hantush-Jacob leaky confined aquifer model allows for a more realistic prediction of groundwater drawdown in these leaky-confined hydrogeologic settings than the Theis model by accounting for this vertical leakage phenomenon. Furthermore, implementation of the Hantush-Jacob model with computer software lends itself to superposition of results through time and space, which allows the model to more accurately represent the

interaction between different wellfields throughout the project area over the full duration of the project.

The 70, 80 and 90 Sand aquifers satisfy the requisite assumptions for application of the Hantush-Jacob model to the extent generally accepted in this type of hydrogeologic evaluation. General assumptions associated with application of the Hantush-Jacob model include those associated with the Theis (1935) model for confined aquifers, as well as several additional assumptions. The following list presents a summary of these assumptions:

- The aquifer is leaky-confined;
- The aquifer and leaky confining unit have an apparent infinite extent;
- The aquifer and leaky confining unit are homogeneous, isotropic, and of uniform thickness over the area influenced by pumping;
- The aquifer is compressible, and water is instantaneously released from storage as head is lowered;
- Groundwater storage is negligible in the leaky confining unit;
- The potentiometric surface of the aquifer is horizontal prior to pumping;
- The well is pumped at a constant rate;
- Flow to the pumping well is horizontal, and flow through the leaky confining unit is vertical;
- The well diameter is small, such that well storage is negligible, and the well is 100 percent efficient; and
- The leaky confining unit is overlain or underlain by an aquifer that maintains constant head at all times.

Further assumptions related specifically to this Ludeman Project model include:

- The modeled aquifers are not in hydraulic communication with the North Platte River; and
- The groundwater drawdown pattern associated with each wellfield can be approximated by utilizing a single hypothetical pumping well located at the center of each wellfield.

Analytical Model Limitations

Boundary conditions present a common challenge to the prediction of groundwater behavior using analytical models. Geologic data indicated that each of the production

sands at the Ludeman project is bounded on top and bottom by low permeability confining units. The use of the Hantush-Jacob leaky confined aquifer model accounts for vertical recharge through confining units, and is therefore expected to improve the accuracy of drawdown predictions over the Theis model in this situation. The most limiting of the remaining model assumptions relate to the horizontal continuity of the aquifers and the potential for lateral boundary conditions. The production sands are not everywhere laterally continuous; however the analytical model assumes continuity, which could have the effect of altering observed drawdown patterns compared to modeled drawdown patterns. The possible effects of these lateral boundary conditions are discussed further below.

The project area is located near the southern edge or the Powder River Basin, and the targeted aquifer units crop out between the project area and uplifted basement rocks of the Laramie Mountains to the south (Love & Christiansen, 1985). Hydrologic studies of the Ludeman site found that the 70 Sand is continuous beneath the area, but that the 80 and 90 Sand aquifers are not everywhere continuous, and crop out in the southeastern portion of the site (Uranium One, 2010). Discontinuous aquifers will not respond ideally to drawdown, and may show locally greater drawdown near pumping wells and less drawdown at greater distances.

Specifically, the outcropping of the 80 Sand and 90 Sand aquifers suggest the possibility of a recharge boundary. Potential lateral recharge from an outcrop is not accounted for in this implementation of the Hantush-Jacob model. However, the existence of such a boundary could serve to restrict the extent and magnitude of drawdown. The site studies, however, found that all three production sand units were well confined on top and bottom by shale units within the proposed area of injection and recovery.

This model assumes that groundwater withdrawals are made from a single hypothetical point at the center of each wellfield. This point has been represented by a single well in the analytical model. This single well approximation results in near-well drawdowns that may at times exceed the available drawdown of the aquifer, and are thus unrealistic. However, based on a limited sensitivity analysis conducted prior to full-scale modeling, these effects are most pronounced in the near field and decrease dramatically with distance from the pumping center. At the scale of interest for this model, the single pumping center approach produces a close approximation of the geometry and magnitude of groundwater drawdown from an actual wellfield. Therefore, use of a single pumping

center per wellfield is acceptable for the purpose of estimating cumulative drawdown for the Ludeman Project.

Analytical Modeling Methods

The Hantush-Jacob (1955) model was implemented using AQTESOLV software (Duffield, 2007) to calculate the predicted magnitude and extent of drawdown in each aquifer. ESRI ArcGIS software was utilized to aid with the input of spatial data and to contour and present the estimated groundwater drawdown produced by the model. This sub-section discusses the methods used to determine model input parameters, and the modeling methods. Specific model input parameters are presented in detail in the next section, *Model Inputs*.

Wellfield locations and groundwater consumption rates and schedules were based on information provided by TREC. Groundwater withdrawal rates were estimated by using wastewater production as a proxy for net consumptive use rates of the wellfields. Wastewater production rates are expected to approximate the difference between the rate of groundwater withdrawal and the rate of injection during operations. Separate model runs were conducted for the 70, 80 and 90 Sands.

The Hantush-Jacob analytical model equates the tendency of a confining layer to leak with a parameter called the *leakage factor* (B), which is related to the thickness and hydraulic conductivity of both the pumped aquifer and the confining layer (Neuman & Witherspoon, 1969) (Fetter, 2001). Small leakage factors correspond to highly leaky confining layers, whereas large leakage factors correspond to minimal leakage through confining units. The reciprocal of the leakage factor (1/B) is commonly utilized in practice. When the reciprocal is used, the above relationship is inverted such that large 1/B values correspond to highly leaky confining layers, and small 1/B values correspond to minimal leakage through confining units.

In order to calculate leakage factors, average confining unit thickness was determined by subtracting the thickness of sand units from the total thickness of the stratigraphic section in three locations along Cross-Section C-C’ and three locations along Cross-Section K-K’ (Uranium One, 2010). Vertical hydraulic conductivity for the confining units (K_V) was estimated based on values of K_V reported for Eocene and Paleocene confining units in the Powder River Basin in the Powder River Basin Oil and Gas EIS Technical Report on Groundwater Modeling (Applied Hydrology Associates, Inc. and Greystone

Environmental Consultants, Inc., 2002). AQTESOLV software utilizes the leakage factor in its reciprocal form (1/B), which was calculated for each aquifer using the above sources of information in addition to site specific data.

The pumping wells representing the withdrawal points in the model were located at the geographic center of each wellfield, using the ArcGIS Spatial Statistics tool package Mean Center tool. Positions of the pumping wells used to represent each wellfield were input into AQTESOLV, along with other aquifer properties (see *Model Inputs* section). The Hantush-Jacob model was then applied to each aquifer to predict the magnitude and distribution of groundwater drawdown around the project area over the duration of the project. The principle of superposition was utilized to account for the effects of multiple active wellfields, pumping rates and pumping periods across the project area (Duffield, 2007) (Reilly, Franke, & Bennett, 1987).

Using the results of the model runs, the time(s) of maximum drawdown during the project duration were identified for each aquifer using time-drawdown plots. Subsequently, the model-predicted drawdown in and around the project area was output to ArcGIS for the production of drawdown contour maps at the time(s) of maximum drawdown in each aquifer.

Model Inputs

With the exception of confining unit hydraulic conductivity, all model input data were based on the hydrologic studies of the site conducted by Uranium One or its predecessors in interest (Uranium One, 2010). Details of the pertinent physical aquifer and confining unit parameters, as well as the consumptive use schedule and rates utilized in the drawdown models, are presented in Tables 1-4. In the model, the beginning of 2013 was selected as time = 0, because this is the point at which the first consumptive use of groundwater is scheduled to begin.

Physical aquifer parameters were determined from the *Pump Test Report* (Uranium One, 2010), and were confirmed with TREC. The parameters utilized for the 70, 80 and 90 sands are summarized on Table 1. Average confining unit thickness was estimated to be 66 feet using geologic data provided by TREC and the method described previously. Confining unit vertical hydraulic conductivity was estimated at 6 x 10^{-5} ft/day using published data (Applied Hydrology Associates, Inc. and Greystone Environmental Consultants, Inc., 2002). Using these representative confining unit properties, along with

70, 80 and 90 sand hydraulic conductivity and thickness values, reciprocal leakage factors (1/B) were calculated for each sand unit and are also presented on Table 1.

Average wastewater production rates of the satellite facilities were provided to HydroSolutions as a means to estimate consumptive groundwater use. During production, the wastewater production is estimated to range from 15–45 gallons per minute (gpm), and average 30 gpm. During restoration (reverse osmosis treatment), wastewater production is estimated to range from 60–150 gpm. These rates are not necessarily unique to any single wellfield, because satellite facilities each serve multiple wellfields, at times in different production phases. Therefore, precise consumptive use at each wellfield could not be determined at this time. Rather, rates of 30 gpm during production and 105 gpm during restoration were used as estimates of consumptive groundwater use by each wellfield. These rates are expected to produce reasonable estimates of drawdown.

The rates (in gpm), and timing of consumptive use for each aquifer, are presented on Tables 2 through 4. These values, along with pumping center locations, were entered into the analytical model.

Results and Discussions

Drawdown contours produced by the model were typically circular to somewhat elliptical in shape, depending on the distribution of active pumping centers in a given aquifer. At the time(s) of maximum drawdown, 25 foot drawdown contours for the 70, 80 and 90 Sand units had maximum radii that ranged between about 1.2 to 2.4 miles from their approximate pumping centers (wellfields) at the Ludeman site. Five foot drawdown contours for the 70, 80 and 90 sands typically had radii of approximately 3.4 to 4.8 miles from the pumping centers. A summary of approximate radial distances to the five and 25 foot drawdown contours for each aquifer is presented on Table 5.

Graphs showing the modeled time-drawdown characteristics of the pumping centers in each aquifer over the duration of the project are presented on Figures 1–3. Results of the analytical drawdown modeling are also presented as drawdown contour maps on Figures 4–8. Due to the operational schedules of the 80 and 90 Sand units, two distinct drawdown peaks were noted in the model output, which correspond to unique areal drawdown patterns. Thus, individual contour maps were prepared for both the first and second peaks in these cases.

Due to the low vertical hydraulic conductivity of the confining units, leakage across the confining units is expected to occur slowly in response to pumping. Therefore, the effects of this leakage on the observed drawdowns may not be evident in data collected during short-duration pumping tests at the site. However, on the scale of many years, over which the Ludeman Project will take place, it is reasonable to expect that the relatively slow leakage through the confining layers will make a substantial recharge contribution to the pumped aquifers. This vertical recharge contribution is expected to limit the geographic extent of drawdown to a degree, as predicted by these modeling results.

The physical properties of the confining units used in this model are expected to represent reasonable estimates for an average confining unit in the general project area. Note, however, that the results are sensitive to changes in these parameters. Specifically, as a confining unit thins, and/or its K_V increases, the modeled zone of influence (drawdown) contracts to smaller and smaller radii. Conversely, as a confining unit thickens or its K_V decreases, the modeled zone of influence will expand until it eventually converges with the Theis solution at large thicknesses or very small values of K_V.

By accounting for recharge from slow vertical leakage across confining units, the Hantush-Jacob model presents a more realistic estimate of drawdown for the Ludeman project setting compared to a Theis-based model that ignores recharge. Still, as indicated in the Methods and Limitations section, other non-ideal aquifer conditions would, to some extent, alter actual drawdown patterns compared to those predicted by this model. Small-scale boundary conditions, such as those that may exist between discontinuous segments of the 80 Sand and 90 Sand, would likely cause localized areas of increased drawdown immediately surrounding active wellfields. However such conditions would also limit the more distant extent and magnitude of drawdown.
Lateral boundary conditions due to outcropping of the 80 and 90 Sand units could result in offsetting effects. For instance, such boundaries could cause an increase in observed drawdown between the site and the outcrop and expansion of the drawdown elsewhere. However, periodic recharge at these outcrops would also be likely to have a limiting effect on the zones of influence.

Summary

A Hantush-Jacob based analytical drawdown model for the 70, 80 and 90 Sand units at Uranium One's Ludeman Project was completed using site-specific aquifer parameters, and estimates of confining unit characteristics. This model is expected to produce more accurate long term drawdown predictions than a Theis model, because it accounts for aquifer recharge from small amounts of leakage through confining units. The production sands of the Ludeman Project satisfy the assumptions required by the Hantush-Jacob model to the extent generally accepted for this type of hydrogeologic evaluation. Project-specific assumptions and limitations have been noted and discussed in this Memorandum.

Model inputs were entered into AQTESOLV software, and graphs were produced showing the predicted time-drawdown behavior of the Ludeman Project wellfields. Drawdown contour maps showing the estimated location of the five and 25 foot drawdown contours (at maximum drawdown) were produced using ArcGIS software. The maximum radii of typical 25 foot drawdown contours ranged from approximately 1.2 to 2.4 miles, and the maximum radii of five foot drawdown contours ranged from about 3.4 to 4.8 miles. Non-ideal aquifer conditions in the vicinity of the site could potentially alter the magnitude and extent of actual versus modeled drawdown, and the model is also sensitive to changes in the thickness and vertical hydraulic conductivity of the confining units.

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Theis, C. V. (1935). The relation between the lowering of the piezometric surface and the rate and duration of discharge of a well using groundwater storage. *Transactions of the American Geophysical Union, 2*, 519-524.

Uranium One. (2010, January). Ludeman Project Appendix D6: Hydrology for Wyoming Department of Environmental Quality Class III Underground Injection Control Permit Application.

Uranium One. (2010). *Ludeman Project, Addendum D5: Geology for Wyoming Department of Environmental Quality Class III Underground Injection Control Permit Application.*

Uranium One. (2010). Ludeman Project, Addendum D6-G Appendix A-1: Pump Test Report, for Wyoming Department of Environmental Quality Class III Underground Injection Control Permit Application.

Table 1: Aquifer Parameters Used in Analytical Drawdown Model.

Parameter	Aquifer		
	70 Sand	80 Sand	90 Sand
Transmissivity (ft^2/day)	96.4	70.0	94.6
Storativity (unitless)	5.08×10^{-5}	7.75×10^{-5}	5.57×10^{-5}
Average Saturated Thickness (ft)	42.75	66.25	48.75
Hydraulic Conductivity (ft/day)	2.25	1.06	1.94
1/B (ft^{-1})	9.7×10^{-5}	1.1×10^{-4}	9.8×10^{-5}

Table 2: 70 Sand consumptive use schedule showing estimated gallons per minute of consumptive use by year and wellfield.

70 Sand Wellfield	Elapsed Time in Years (Calendar Year)										
	1	2	3	4	5	6	7	8	9	10	11
2	0	30	30	105	105	105 (1/2 yr)	0	0	0	0	0
3	0	0	0	30	30	105	105	105	0	0	0
4	0	0	0	0	30	30	105	105	105	0	0
5a	0	0	0	0	0	30	30	30	105	105	105

Production periods are shown in blue, restoration periods are shown in green, and periods of no groundwater withdrawals are white.

Table 3: 80 Sand consumptive use schedule showing estimated gallons per minute of consumptive use by year and wellfield.

80 Sand Wellfield	Elapsed Time in Years (Calendar Year)										
	1	2	3	4	5	6	7	8	9	10	11
1b	30	30	105	105	105	105 (1/2 yr)	0	0	0	0	0
5b	0	0	0	0	0	30	30	30	105	105	105

Production periods are shown in blue, restoration periods are shown in green, and periods of no groundwater withdrawals are white.

Table 4: 90 Sand consumptive use schedule showing estimated gallons per minute of consumptive use by year and wellfield.

90 Sand Wellfield	Elapsed Time in Years (Calendar Year)										
	1	2	3	4	5	6	7	8	9	10	11
1a	30	30	105	105	105	105 (1/2 yr)	0	0	0	0	0
6	0	0	0	0	0	0	30	30	105	105	105

Production periods are shown in blue, restoration periods are shown in green, and periods of no groundwater withdrawals are white.

Table 5: Approximate maximum radii (in miles) of five and 25 foot drawdown contours from center of maximum drawdown at time(s) of maximum predicted drawdown (n/a indicates not a time of maximum drawdown).

	Time = 5.5 years		Time = 9 years		Time = 11 years	
Drawdown contour →	**5 ft**	**25 ft**	**5 ft**	**25 ft**	**5 ft**	**25 ft**
70 Sand	n/a	n/a	4.8	2.4	n/a	n/a
80 Sand	3.4	1.4	n/a	n/a	3.4	1.4
90 Sand	3.5	1.2	n/a	n/a	3.5	1.2

Figure 1: 70 Sand aquifer time-drawdown graph showing model estimated drawdowns in active 70 Sand wellfields during project lifespan. Based on current schedule; time = 0 corresponds to beginning of year 1. Displacement is shown in meters.

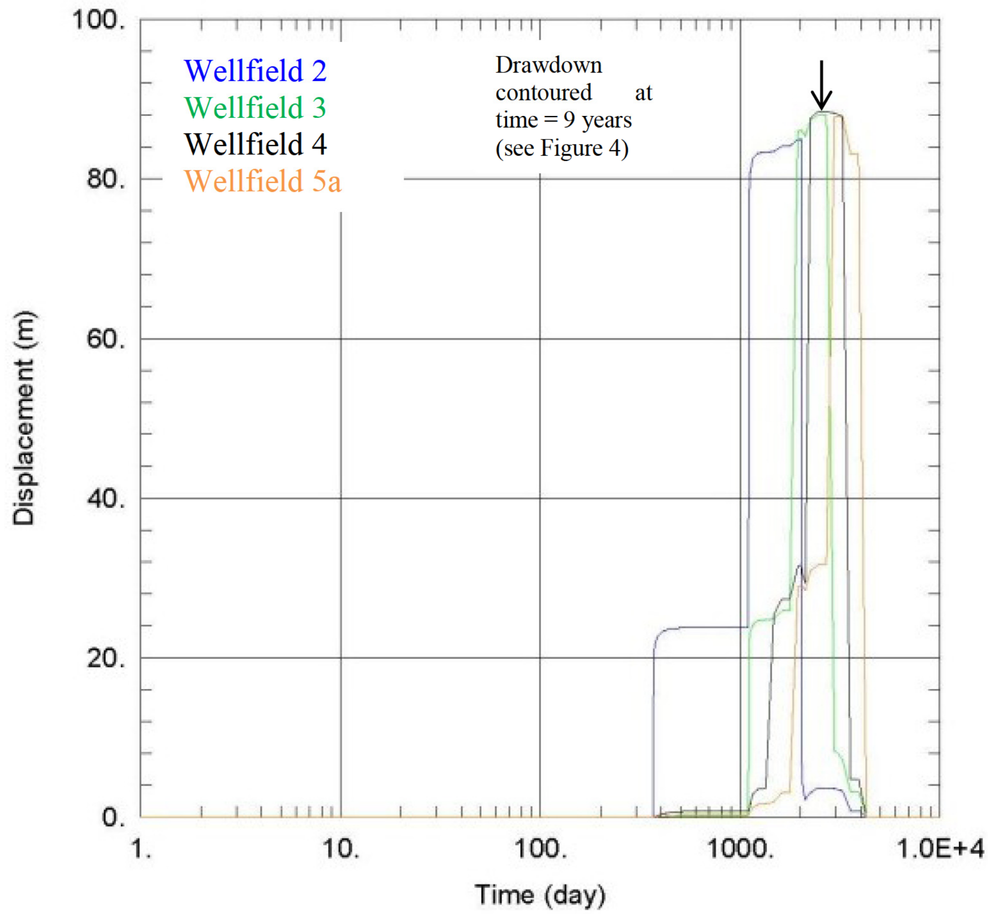


Figure 2: 80 Sand aquifer time-drawdown graph showing model estimated drawdowns in active 80 Sand wellfields during project lifespan. Based on current schedule; time = 0 corresponds to beginning of year 1. Displacement is shown in meters.

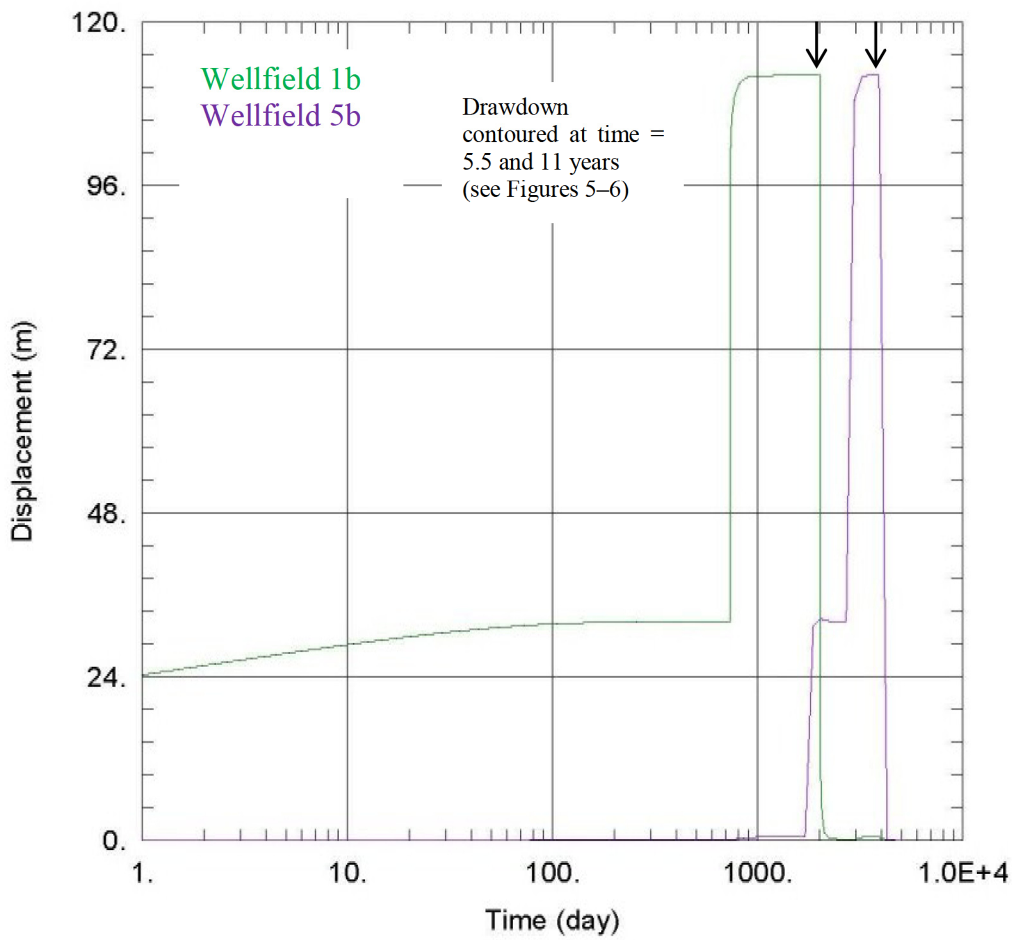
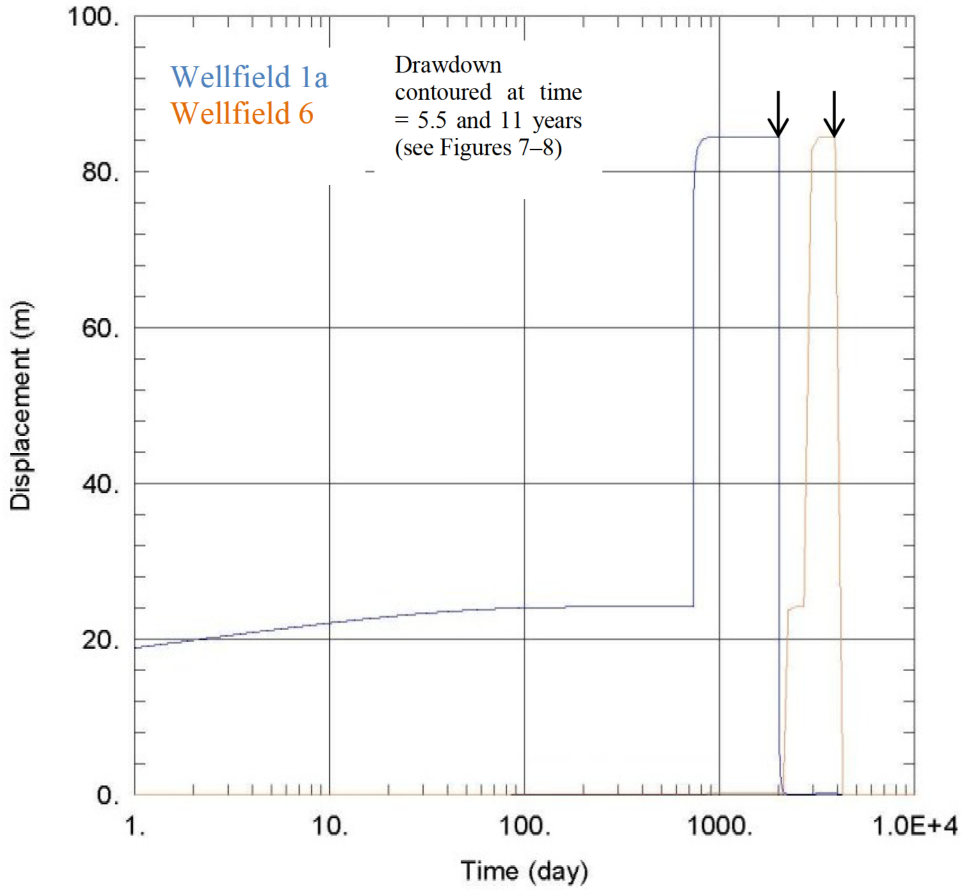
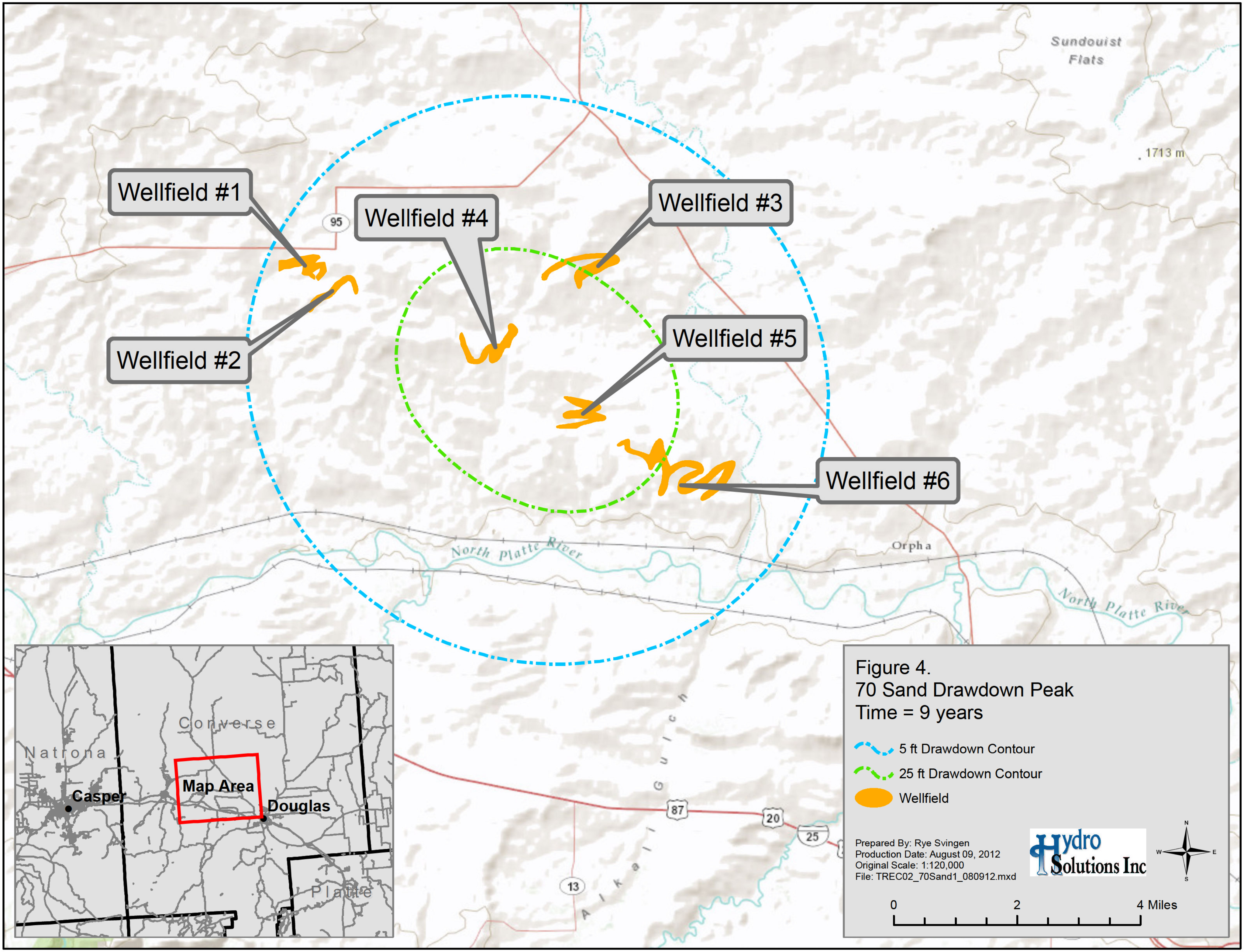
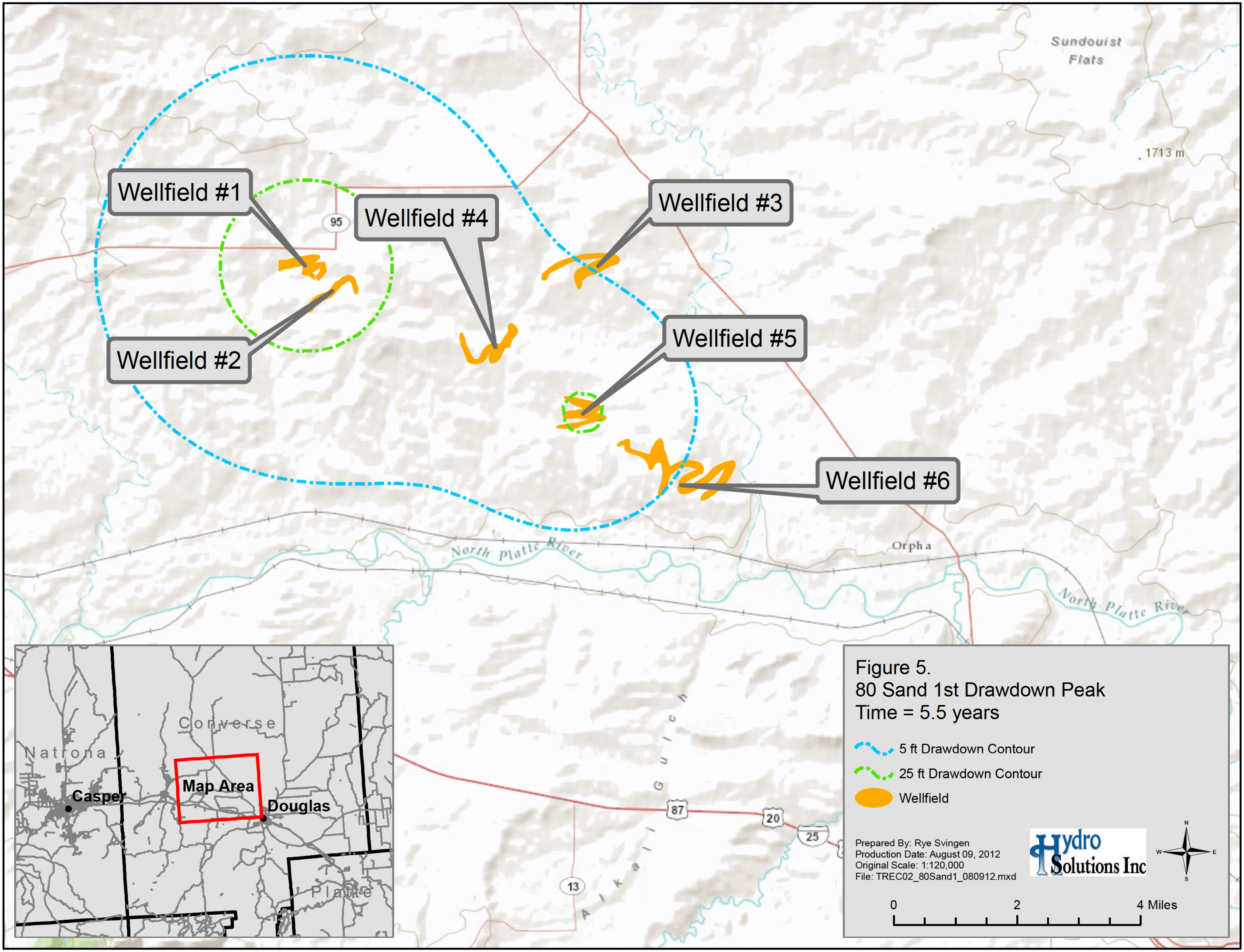


Figure 3: 90 Sand aquifer time-drawdown graph showing model estimated drawdowns in 90 Sand wellfields during project lifespan. Based on current schedule; time = 0 corresponds to beginning of year 1. Displacement is shown in meters.





Sundquist Flats
1713 m
Wellfield #1
Wellfield #2
Wellfield #3
Wellfield #4
Wellfield #5
Wellfield #6
95
North Platte River
Orpha
North Platte River
Alkali Gulch
87
20
25
13
Converse
Natrona
Casper
Map Area
Douglas
Platte
Figure 4.
70 Sand Drawdown Peak
Time = 9 years
5 ft Drawdown Contour
25 ft Drawdown Contour
Wellfield
Prepared By: Rye Svingen
Production Date: August 09, 2012
Original Scale: 1:120,000
File: TREC02_70Sand1_080912.mxd
Hydro Solutions Inc
0
2
4 Miles


Wellfield #1
Wellfield #2
Wellfield #3
Wellfield #4
Wellfield #5
Wellfield #6
Sundquist Flats
1713 m
95
North Platte River
Orpha
North Platte River
Alkali Gulch
13
87
20
25
Converse
Natrona
Map Area
Casper
Douglas
Platte
Figure 5.
80 Sand 1st Drawdown Peak
Time = 5.5 years
5 ft Drawdown Contour
25 ft Drawdown Contour
Wellfield
Prepared By: Rye Svingen
Production Date: August 09, 2012
Original Scale: 1:120,000
File: TREC02_80Sand1_080912.mxd
Hydro Solutions Inc
0
2
4 Miles

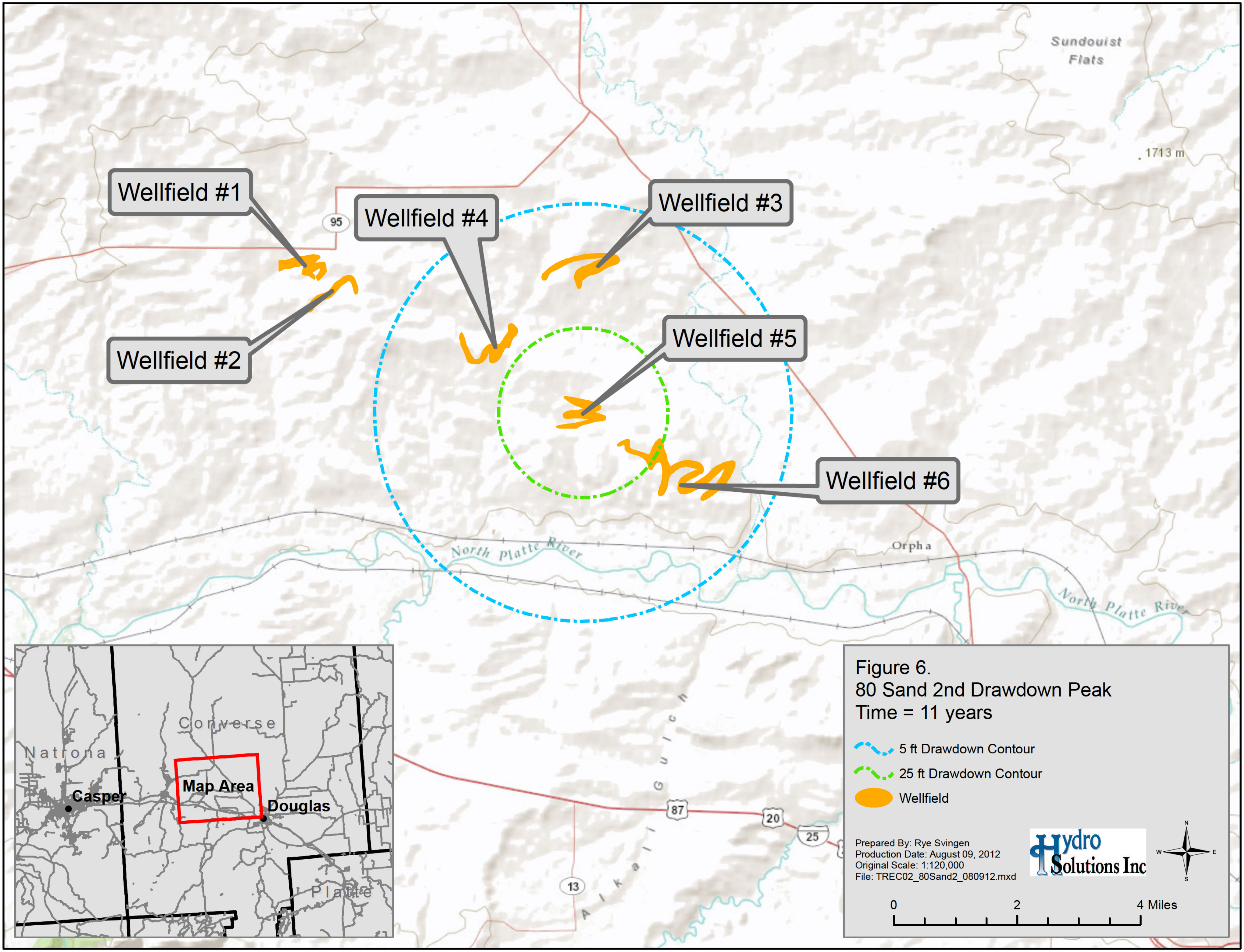


Figure 6.
80 Sand 2nd Drawdown Peak
Time = 11 years

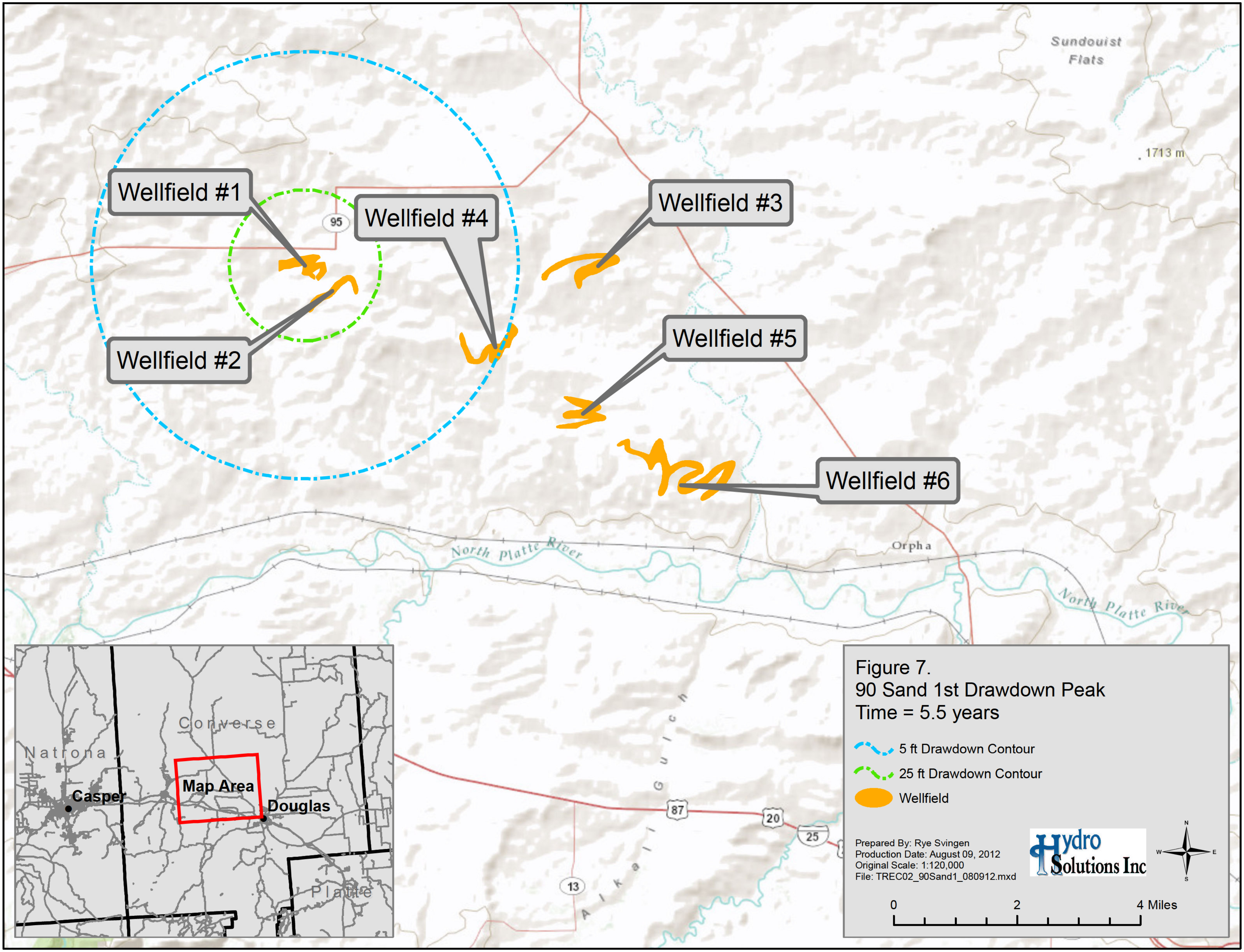
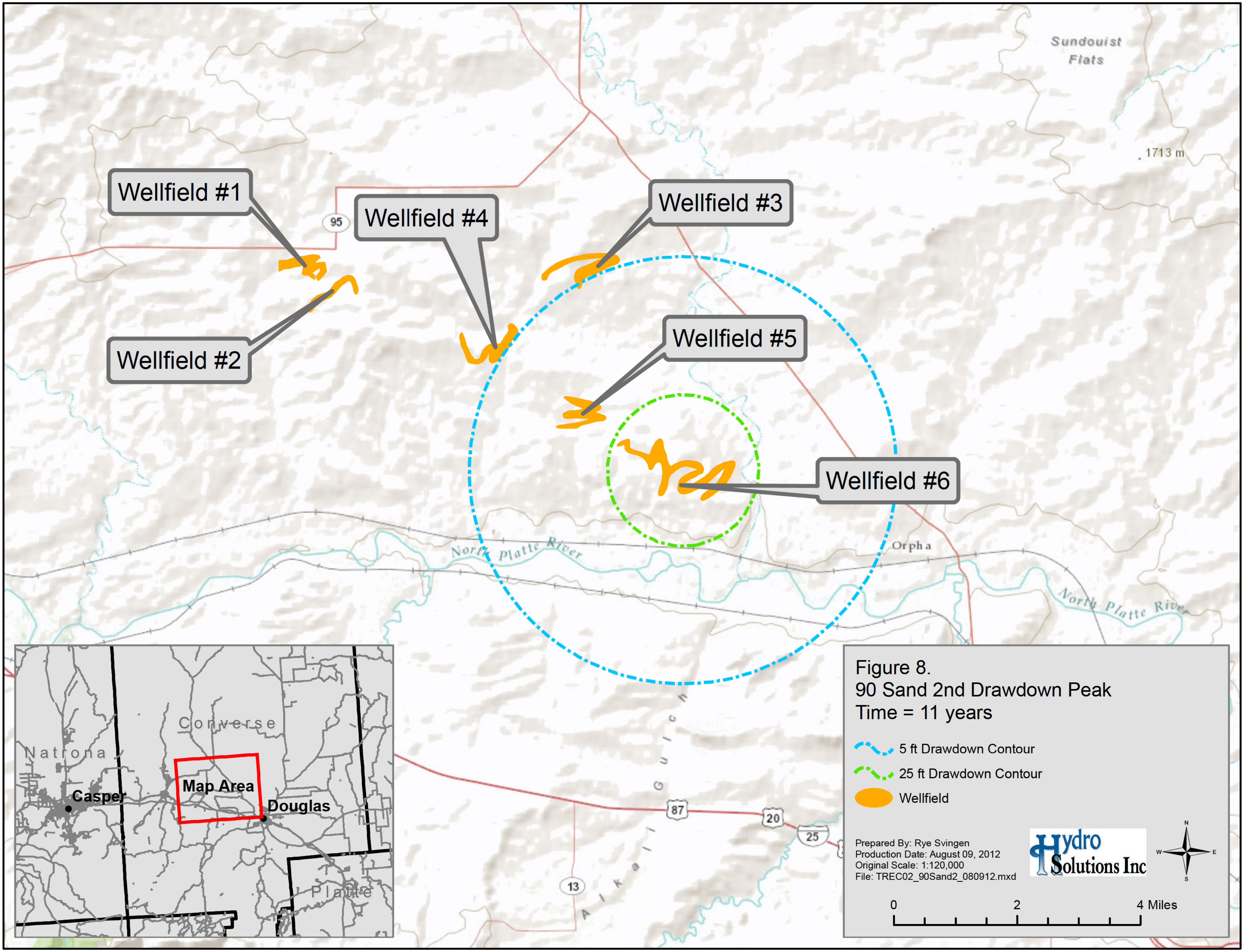


Figure 7.
90 Sand 1st Drawdown Peak
Time = 5.5 years



Sundquist Flats
1713 m
Wellfield #1
Wellfield #2
Wellfield #3
Wellfield #4
Wellfield #5
Wellfield #6
95
North Platte River
Orpha
North Platte River
Alkali Gulch
87
20
25
13
Converse
Natrona
Casper
Map Area
Douglas
Platte
Figure 8.
90 Sand 2nd Drawdown Peak
Time = 11 years
5 ft Drawdown Contour
25 ft Drawdown Contour
Wellfield
Prepared By: Rye Svingen
Production Date: August 09, 2012
Original Scale: 1:120,000
File: TREC02_90Sand2_080912.mxd
Hydro Solutions Inc
0
2
4 Miles