APPENDIX G
Layne Hydro Technical Memorandum 2011

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MEMORANDUM

SIMULATED IMPACT OF CHANGES TO IWVWD WELLS

We have completed the execution of the requested model runs based on the model that was previously developed by Brown and Caldwell using Groundwater Vistas (Environmental Simulations). As requested, we have refined the model grid in the local field to improve the quality of the results, particularly the predictions of well interference that will result from additional pumping at proposed new wells. Total withdrawals in the model runs are based on the population estimates and baseline per-capita demand set forth in the Urban Water Management Plan (UWMP) report dated August 1, 2011 by Krieger and Stewart, which was sent by Renee Morquecho of IWVWD on August 17, 2011. This memorandum describes the changes that were made to the model, and presents the model results.

These model runs were executed in response to the telephone conference of August 10, 2011. Additional model runs were executed to assess the variation in water levels that results from seasonally varying pumping rates at the IWVWD wells.

CHANGES TO THE BROWN AND CALDWELL MODEL

Changes to the model may be summarized in the following categories:

1. Changes to the model grid for improved accuracy;
2. Implementation of stress periods for the future predictive scenarios;
3. Implementation of initial conditions for the predictive model;
4. Changes to the solver configuration; and
5. Addition of proposed wells and changes to the distribution of pumping for the existing IWVWD production wells.
6. Modifications to the pumping rates for IWVWD wells to account for future demand projections.

These changes are discussed below.

CHANGES TO THE MODEL GRID

IWVWD requested that the model be refined in the local field to provide increased resolution for well interference and impacts of the proposed pumping changes. The original model has uniform, square cells, $1320 \times 1320\ feet$

on a side. We refined the model in two steps using the grid refinement tool that is built into Groundwater Vistas (Environmental Simulations, 2009). First, the entire local field that contains all four proposed wells was refined into $660 \times 660\ ft$ cells. Then, additional refinement into $330 \times 330\ ft$ cells was performed in the vicinity of each of the proposed wells. The refined grid is shown in Figure 1.

IMPLEMENTATION OF PREDICTIVE STRESS PERIODS

The original model contained 43 stress periods, ending at the end of 2007. For the predictive runs, we have included the years 2008-2010 based on the observed withdrawals for those years. It is understood that the new wells did not begin production in 2011, but practically speaking, the choice of a start date for operation of the new wells is rather arbitrary; the model was configured to predict the impacts after 1 and 10 years as compared to the status quo. The pre-2010 years of the model serve to stabilize the model runs prior to the predictive period.

Three different predictive scenarios were developed by modifying the scenarios used in the previous modeling work performed by Layne Hydro. For each scenario, the model estimates water-level changes in the study region after 1 and 10 years of operation under a pumping distribution configured for the scenario. Thus, the predictive model was configured to have stress periods that end at the end of each year from 2010-2020, with the updated pumping scenarios implemented over 2011-2020 (see Table 1). For consistency with the Brown and Caldwell model, two-month time steps were used throughout the predictive model runs. Table 1 provides a detailed description of the stress periods in the predictive model.

For all predictive scenarios, 2008-2020 projected annual demand was distributed across all wells as described below.

SELECTION OF INITIAL CONDITIONS FOR THE MODEL

After the original model domain was refined as described above, the original model was executed for the purpose of determining the conditions at the end of the simulation. Those conditions correspond to the end of 2007, and they were used to provide initial heads for the predictive simulations. This was done by exporting the final conditions to SURFER-format grid files, one file for each of the four layers in the model. The predictive scenarios were configured to use the SURFER files as initial heads.

It is noted that changes were made to the configuration of the MODFLOW-2000 solver for the refined grid, as discussed below.

CHANGES TO THE SOLVER CONFIGURATION

The Brown and Caldwell model makes use of the “re-saturation” capability of the MODFLOW-2000 groundwater flow model. This feature is not necessary for the predictive runs described here, since it is assumed that water levels are generally declining with time, and therefore any inaccuracies that arise from the lack of re-wetting will be small. It also makes the model more reliable and efficient.

ADDITION OF NEW WELLS AND MODIFIED PUMPING SCHEDULES

In the 2010 modeling performed by Layne Hydro, two wells were added on the Naval Air Station property (NAS-N and NAS-S), one at the Southwest Well Field (SWWF) and one at the Children’s Hospital (CH). Well #17 was removed after the first year of the simulation, as it was to be replaced. However, in the August 10 phone conference it was reported that the NAS-N, NAS-S, and CH wells would not be constructed, however Well #17 can be rehabilitated and it was returned to the model for the predictive runs described here. The “status quo” and three predictive scenarios are described in Table 2. It is noted that for the purpose of possible comparisons with the previous Layne Hydro results, the scenario names (scen4, scen5, and scen6) have been maintained. The other three predictive scenarios in the previous Layne Hydro memo have been eliminated, as they have the NAS wells included.

For each pumping scenario a capacity has been assigned to each well (Table 3). However the model assumes each well will pump continuously throughout the year, so the individual well pumping rates must be scaled down to account for when the wells are not running. For each year the model runs the total annual demand (Table 5) is divided among the wells in the scenario, weighted by their respective specified pumping rate (distribution factor). The scaled pumping rate for each well in each specific year is calculated based on the fraction that the well contributes to the total. The sum of the individual wells pumping continuously at their scaled rates for the year, will meet the annual demand.

For each well pumping scenario, a schedule of annualized withdrawal rates is provided in Table 4. For all “non-status quo” scenarios, the rates are the same as the “status-quo” rates up until 2010. After 2010, the modified rates are used for all the “non-status-quo” scenarios. Values entered into the groundwater flow model were computed by converting the values in Table 4 to units of ft^3/d. In order to account for the entire regional withdrawal rates, the model includes all non-IWVWD wells that were included in the Brown and Caldwell model.

NOTE ABOUT THE “STATUS QUO” SIMULATION

It is important to note that the “Status Quo” simulation does not hold pumping rates constant through time. All simulations are configured to produce sufficient water to meet the demand schedule in each year of the planning period. The design capacities of wells in the various scenarios (including the “Status Quo” scenario) are used to allocate the aggregate pumping rate across the array of District wells. As demand increases, it is assumed that the various wells will be used for longer periods of time, or be pumped for longer periods, in order to meet the demand.

RESULTS

As described above, seven model scenarios were configured and run for the 13-year period 2008-2020. The ultimate objective was to compare the short-term and long-term impact on regional water levels of each proposed configuration to the impacts of the current “Status Quo” configuration. After the seven model runs were complete, grids of the simulated potentiometric head were extracted in SURFER format at the time steps that correspond to the end of 2011 and 2020 (after 1 and 10 years of operation for the new configuration). For each of the three proposed scenarios, SURFER was used to compute grids of the difference in head between the scenario and the “Status Quo” scenario at the end of 2011 and 2020. It is important to note that the resulting grids are not “drawdown” plots of the transient response of the system. Rather, they represent the water-level decline that results from new wells and changes in pumping at existing wells for each proposed scenario, as compared to current operations (Status Quo scenario). The simulated decline or increase includes any interference with other wells in the model.

For each scenario, contour plots of water-level declines are provided in Figures 3-14. In each figure, the contour interval is 2 ft. Color shading is provided to illustrate the magnitude of water-level declines. In regions where the water level increases (arising from reduced pumping at existing wells as compared to the Status Quo), green shading is used. The darker green regions indicate a larger increase in the water level. In regions where the water level increase or decline is smaller than $2\ ft$, no shading is used. In regions where the water level decline exceeds $2\ ft$, shades of red are used, with the darker red colors indicating larger water-level declines.

Annual pumping rates for all wells are reported in Appendix A.

SEASONAL WATER LEVEL VARIABILITY

The water level declines provided in Figures 3-14 are based on annualized pumping. However, in summer it is expected that wells will pump more water than in the cooler seasons of the year. An additional set of model runs for each development scenario were executed for the purpose of identifying the degree of annual variation as compared to the model based on constant pumping at the annualized rate for each year. The annual variability in the aggregate withdrawal rate for all IWVWD wells over the 1997-2009 historical record is presented in Table 6 (IWVWD, personal communication, 2/22/2010). The fractions of annual total withdrawals for each month and the equivalent fraction of the annualized rate for each month are provided. The configuration of stress periods and time steps in the seasonal model is provided in Table 7.

For each development scenario, two model runs were required: a 24-month transient MODFLOW model based on annualized 2020 pumping rates and a 24-month transient MODFLOW model based on the seasonally varying rate multipliers in Table 6. The model was configured with 24, one-month stress periods, each with 4 time steps. The first 12 months of the model were used to “wind up” the transient model, eliminating the influence of the initial condition at the start of the transient simulation. We present the results as plots of the difference between the variable-rate and constant-rate runs at the end of April and at the end of October (stress period 16 and 22). The April and October dates were selected because they represent the largest extent of relative increase or decrease over the course of the year. Figures 15-26 show the maximum extent of water level divergence from the annualized pumping rates; red colors in the figures represent seasonal declines relative to the annualized rate and the green colors represent seasonal increases.

Table 1. Stress period configuration for the predictive model runs.

Stress Period	Year	Number of Time Steps
1	2008	6
2	2009	6
3	2010	6
4	2011	6
5	2012	6
6	2013	6
7	2014	6
8	2015	6
9	2016	6
10	2017	6
11	2018	6
12	2019	6
13	2020	6

Table 2. Scenarios as developed from the provided pumping schedules.

Scen0	Status Quo
Scen4	SWWF / 30 / 34
Scen5	SWWF / 30 / 31
Scen6	SWWF / 18 / 34

Table 3. Specific well capacities for each scenario. Note: recent rehabilitation work at Well #31 suggests that its capacity will more likely be smaller, 1200 gpm (*). However, the model was configured based on the prior 1400 gpm capacity. The difference is small, and since it overstates pumping at Well 31, is conservative for this analysis.

Well	Status Quo (pred0)	SWWF/30/34 (pred4)	SWWF/30/31 (pred5)	SWWF/18/34 (pred6)
9A	1000	1000	1000	1000
10	1100	1100	1100	1100
11	1000	1000	1000	1000
13	1100	1100	1100	1100
18	1200	1200	1200	2200
33	1200	1200	1200	1200
34	1200	2200	1200	2200
30	1400	2300	2300	1400
31	1400 (*)	1400 (*)	2300	1400 (*)
17	1200	1200	1200	1200
SWWF	0	2200	2200	2200

Table 4. Specific well pumping rates for each scenario in year 10. These rates were derived by allocating the annual total withdrawals to each well according to its fraction of the total available capacity.

Well	Status Quo (pred0)	SWWF/30/34 (pred4)	SWWF/30/31 (pred5)	SWWF/18/34 (pred6)
9A	530	393	396	391
10	583	433	435	430
11	530	393	396	391
13	583	433	435	430
18	636	472	475	860
33	636	472	475	469
34	742	865	475	860
30	742	904	910	547
31	742	550	910	547
17	636	472	475	469
SWWF	0	865	871	860

Table 5. Forecasted total annual pumping demand.

Year	Demand (ac-ft/yr)	Demand (gpm)
2008	8,496	5,267
2009	8,401	5,208
2010	7,570	4,693
2011	8,910	5,524
2012	9,380	5,815
2013	9,468	5,870
2014	9.557	5.925
2015	9.646	5,980
2016	9,734	6,035
2017	9,823	6,090
2018	9,912	6,145
2019	10,001	6,200
2020	10,089	6,255

Table 6. Monthly fraction (in percent) of annual pumpage for IWVWD wells.

Month	Monthly fraction of annual withdrawals, 1997-2009 (%)	Monthly fraction of the annualized rate (%)
January	4.5	5.42
February	4.1	4.94
March	5.7	6.87
April	7.4	8.92
May	9.4	11.33
June	11.9	14.34
July	13.2	15.91
August	12.8	15.42
September	11.8	13.47
October	8.6	10.36
November	5.9	7.11
December	4.9	5.90

Table 7. Stress period configuration for the seasonally-varying models. Water levels at the end of the shaded time steps were used to generate the seasonally-varying maps in Figures 14-25.

Stress Period	Month	Number of time steps
1	January (wind-up)	4
2	February (wind-up)	4
3	March (wind-up)	4
4	April (wind-up)	4
5	May (wind-up)	4
6	June (wind-up)	4
7	July (wind-up)	4
8	August (wind-up)	4
9	September (wind-up)	4
10	October (wind-up)	4
11	November (wind-up)	4
12	December (wind-up)	4
13	January	4
14	February	4
15	March	4
16	April	4
17	May	4
18	June	4
19	July	4
20	August	4
21	September	4
22	October	4
23	November	4
24	December	4

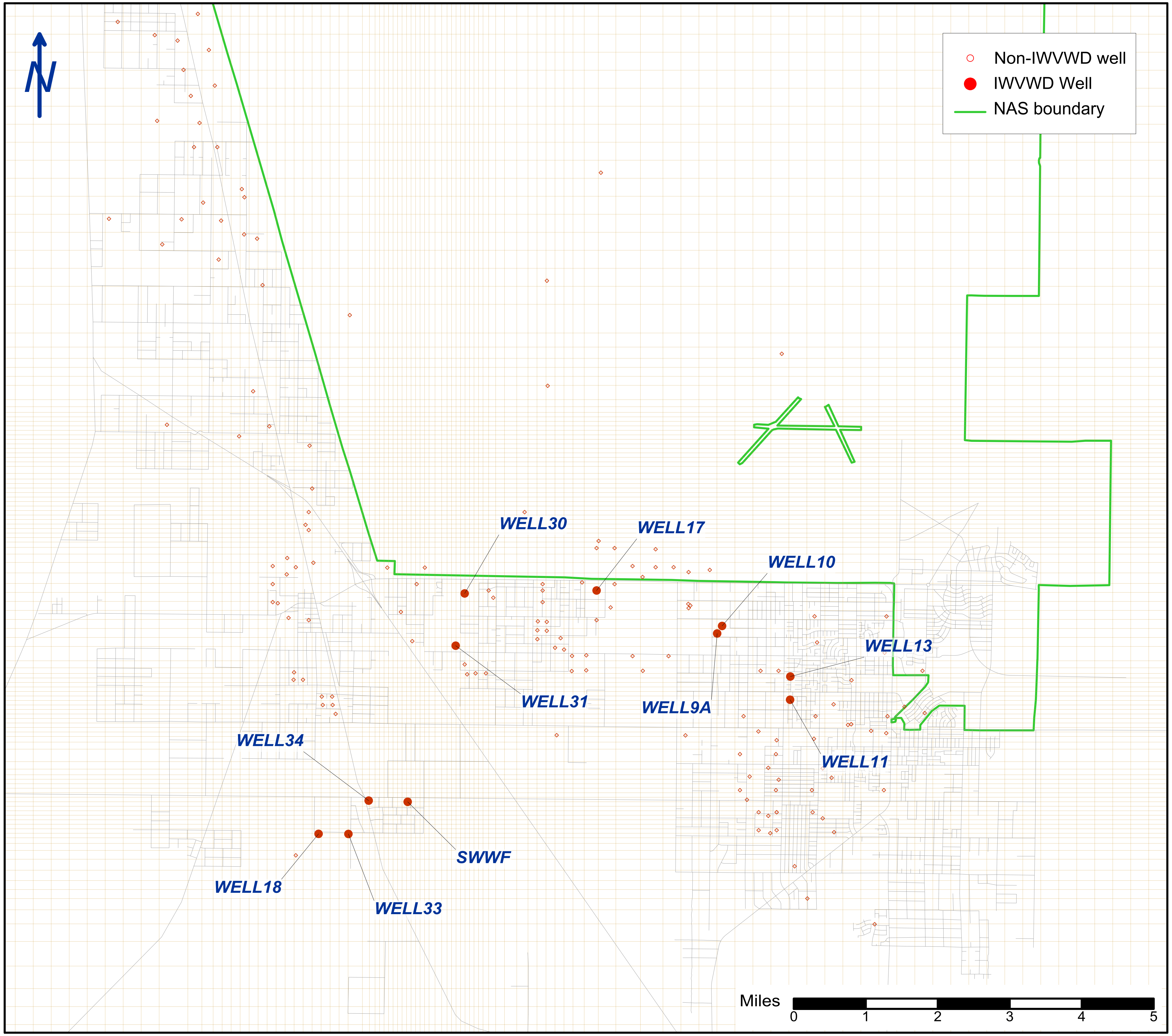

Figure 1. Layout of IWVWD wells and revised grid spacing for the predictive model.

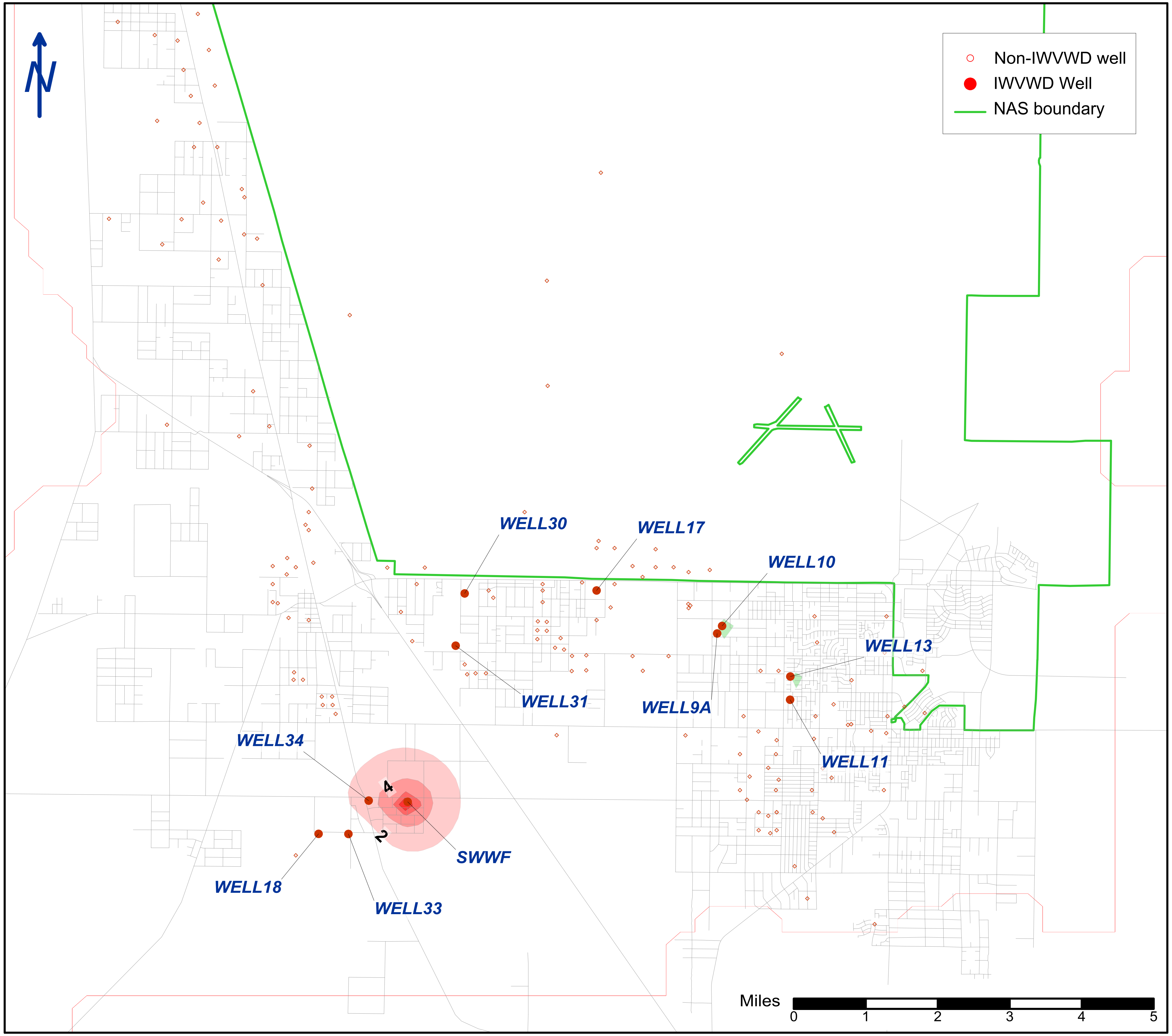

Figure 2. Simulated water-level difference after one year for scenario SWWF/30/34 (pred4). Contour interval 2 ft.

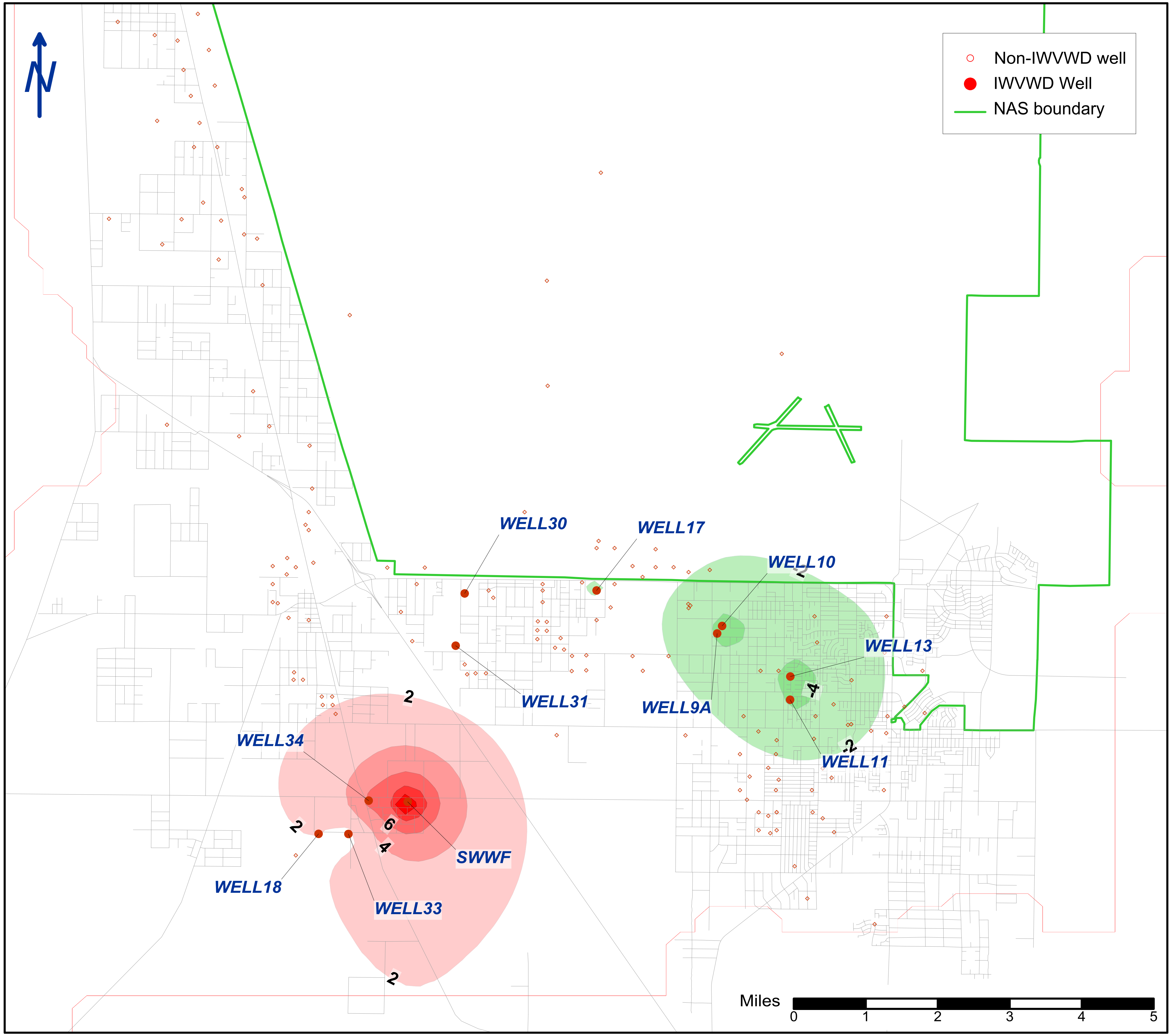

Figure 3. Simulated water-level difference after ten years for scenario SWWF/30/34 (pred4). Contour interval 2 ft.

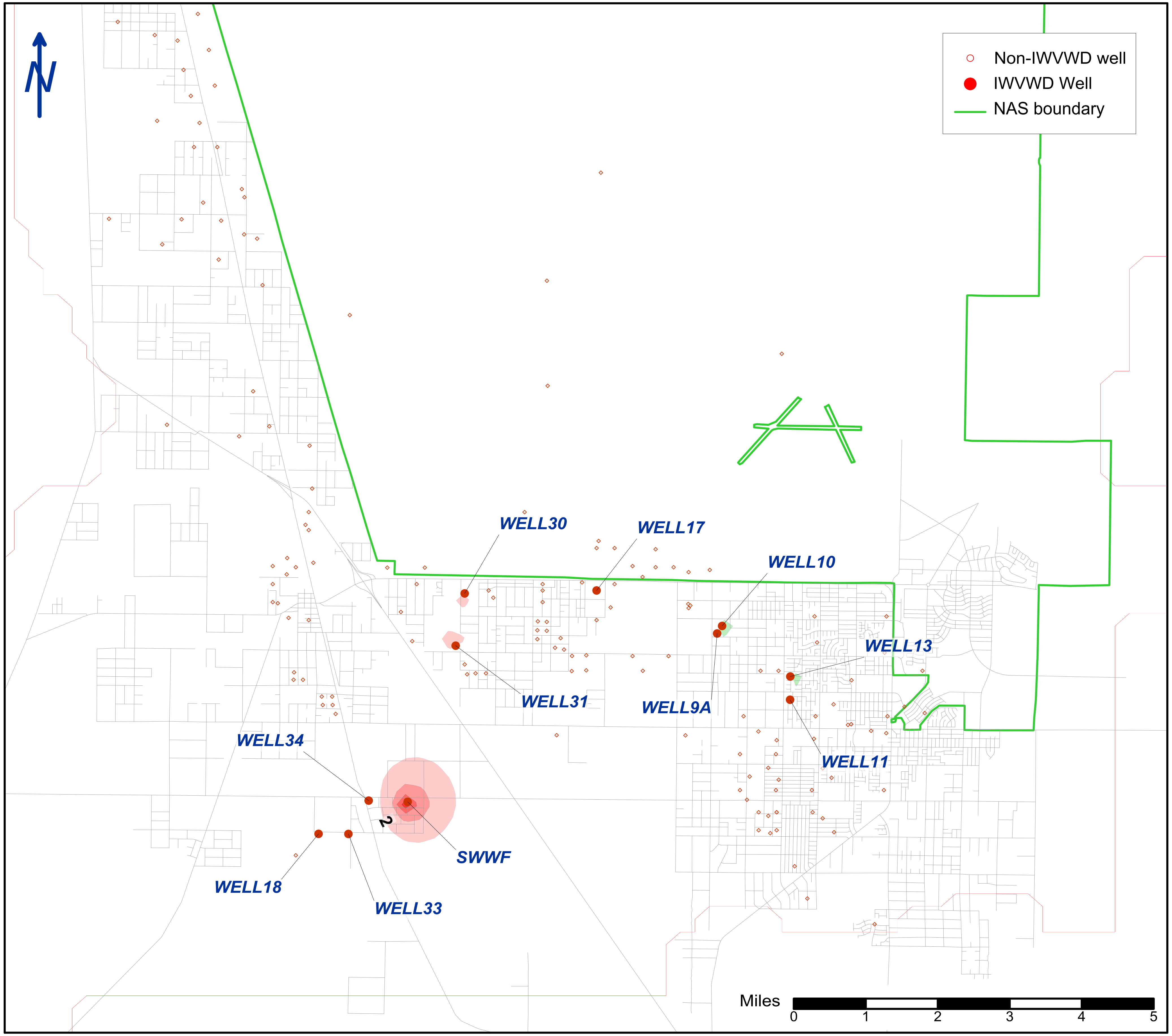

Figure 4. Simulated water-level difference after one year for scenario SWWF/30/31 (pred5). Contour interval 2 ft.

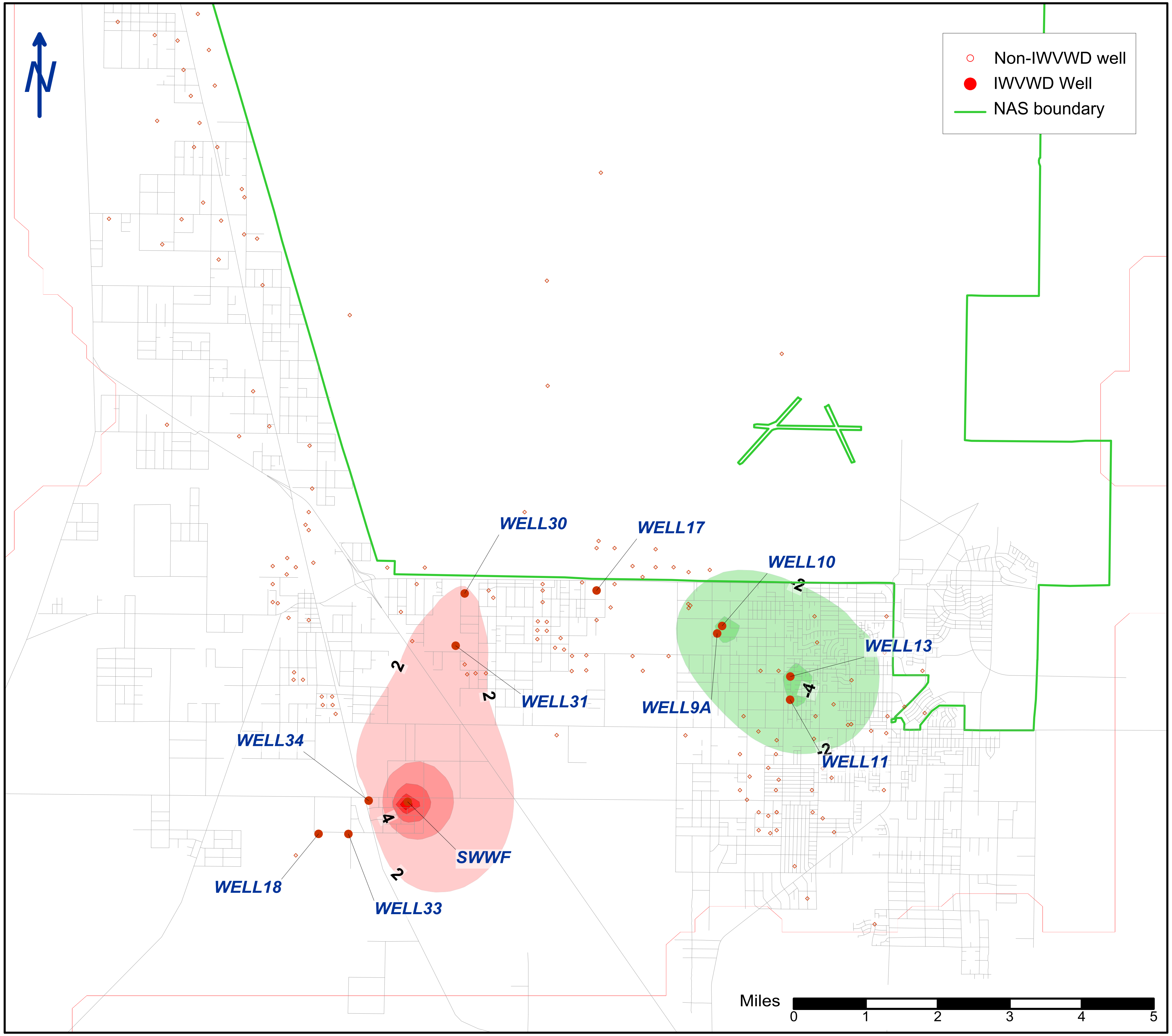

Figure 5. Simulated water-level difference after ten years for scenario SWWF/30/31 (pred5). Contour interval 2 ft.

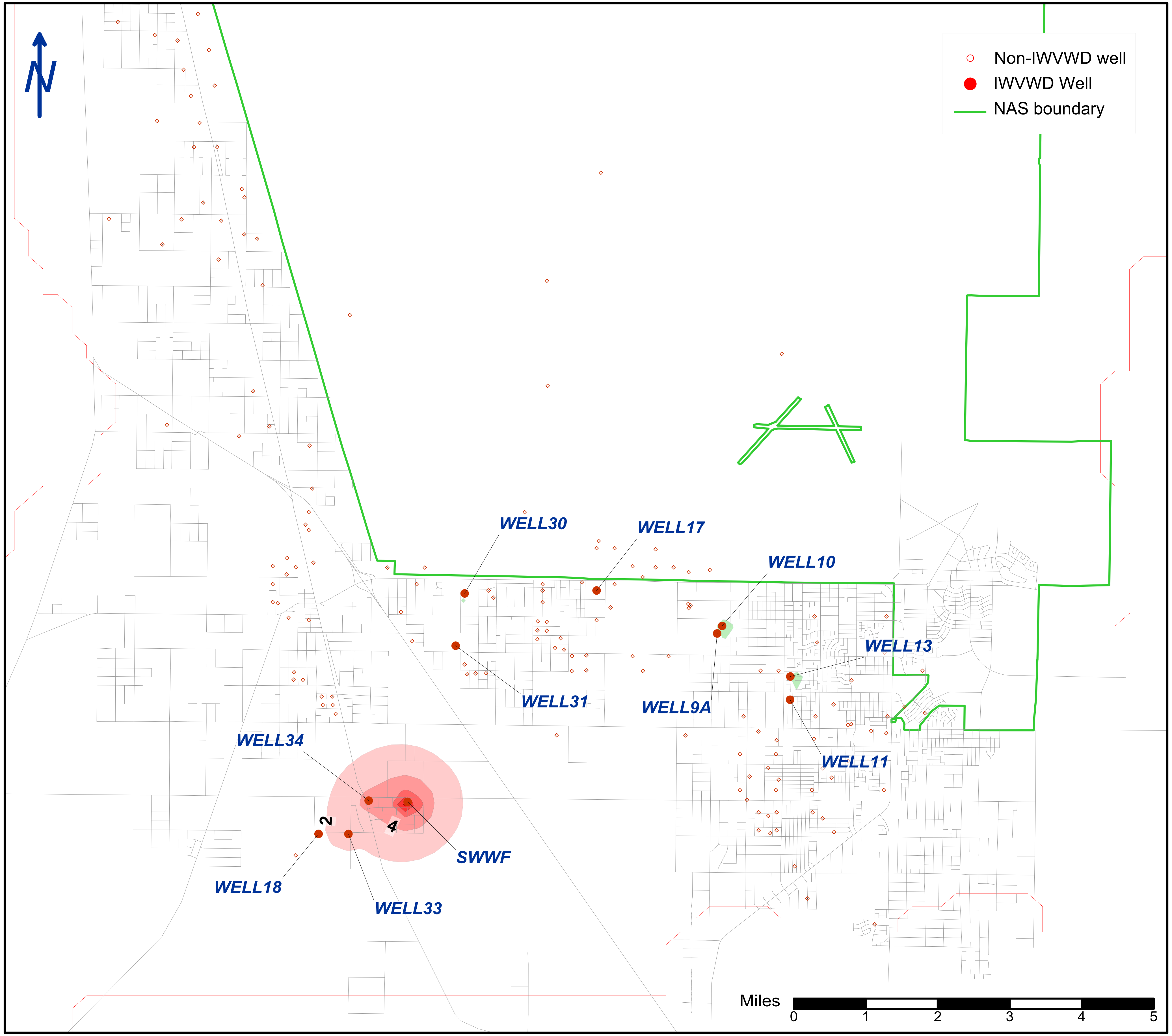

Figure 6. Simulated water-level difference after one year for scenario SWWF/18/34 (pred6). Contour interval 2 ft.

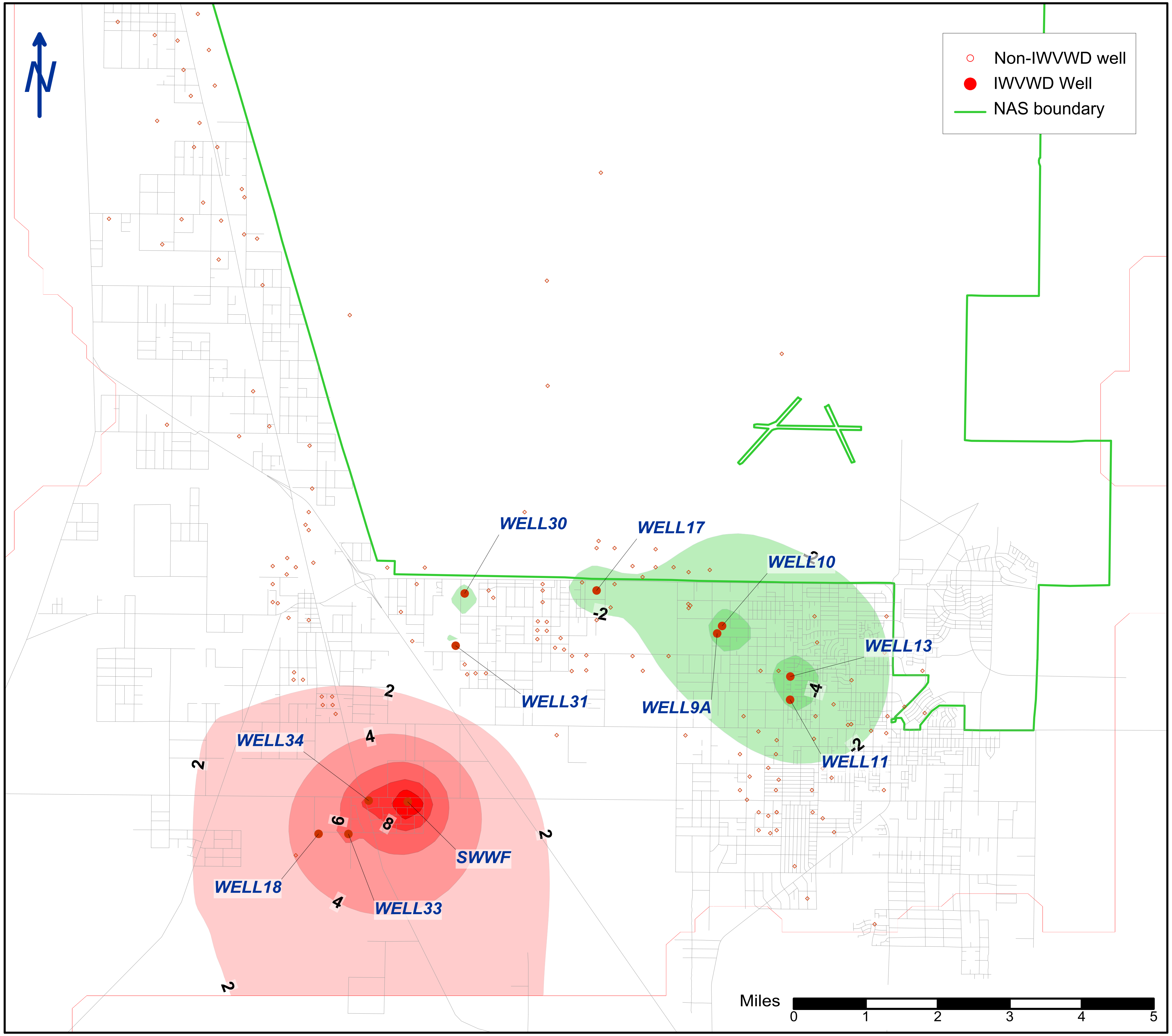

Figure 7. Simulated water-level difference after ten years for scenario SWWF/18/34 (pred6). Contour interval 2 ft.

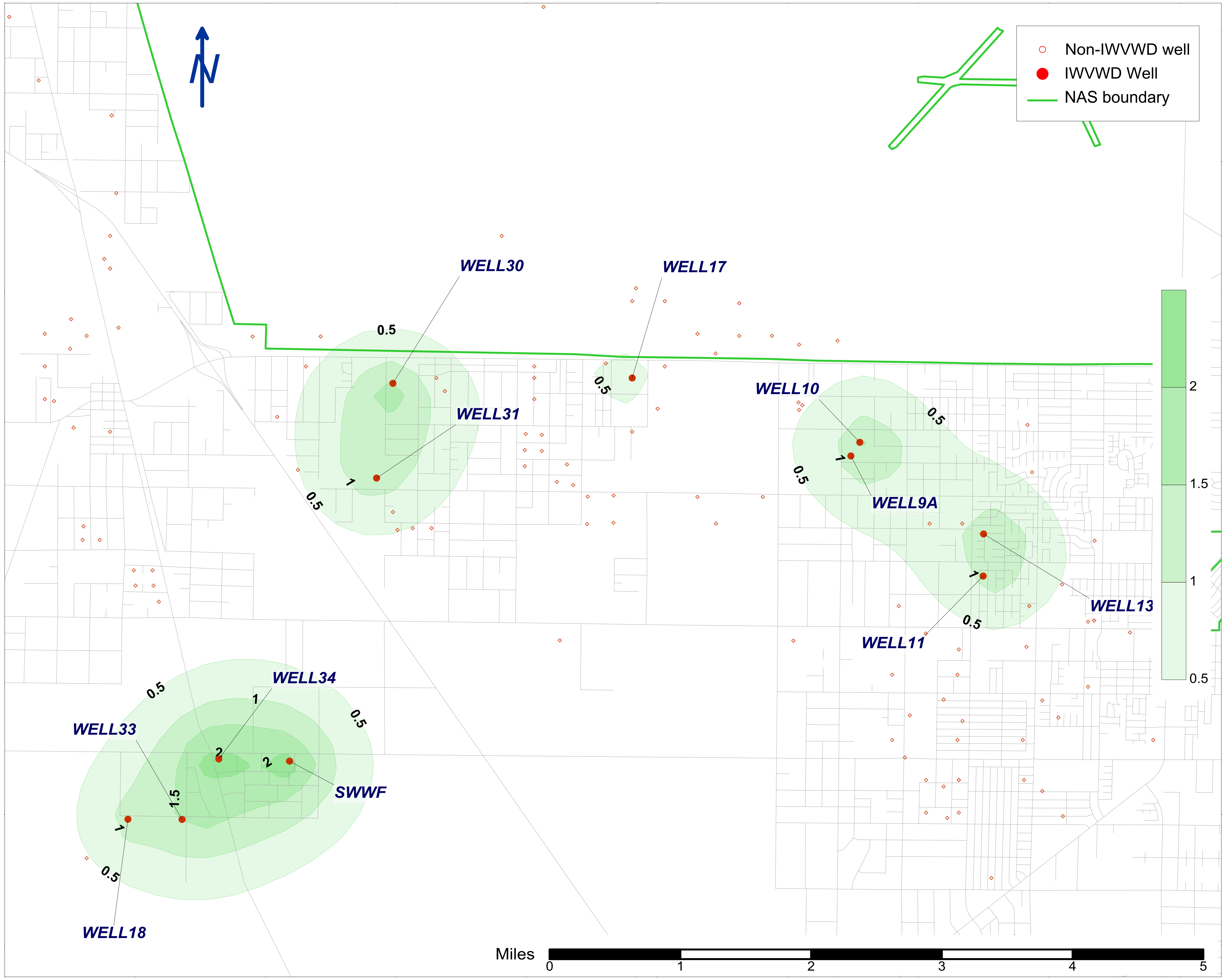

Figure 8. April 2020 water-level increases, as compared to water levels at the steady annualized pumping rate for scenario SWWF/30/34 (pred4). Contour interval 0.5 ft.

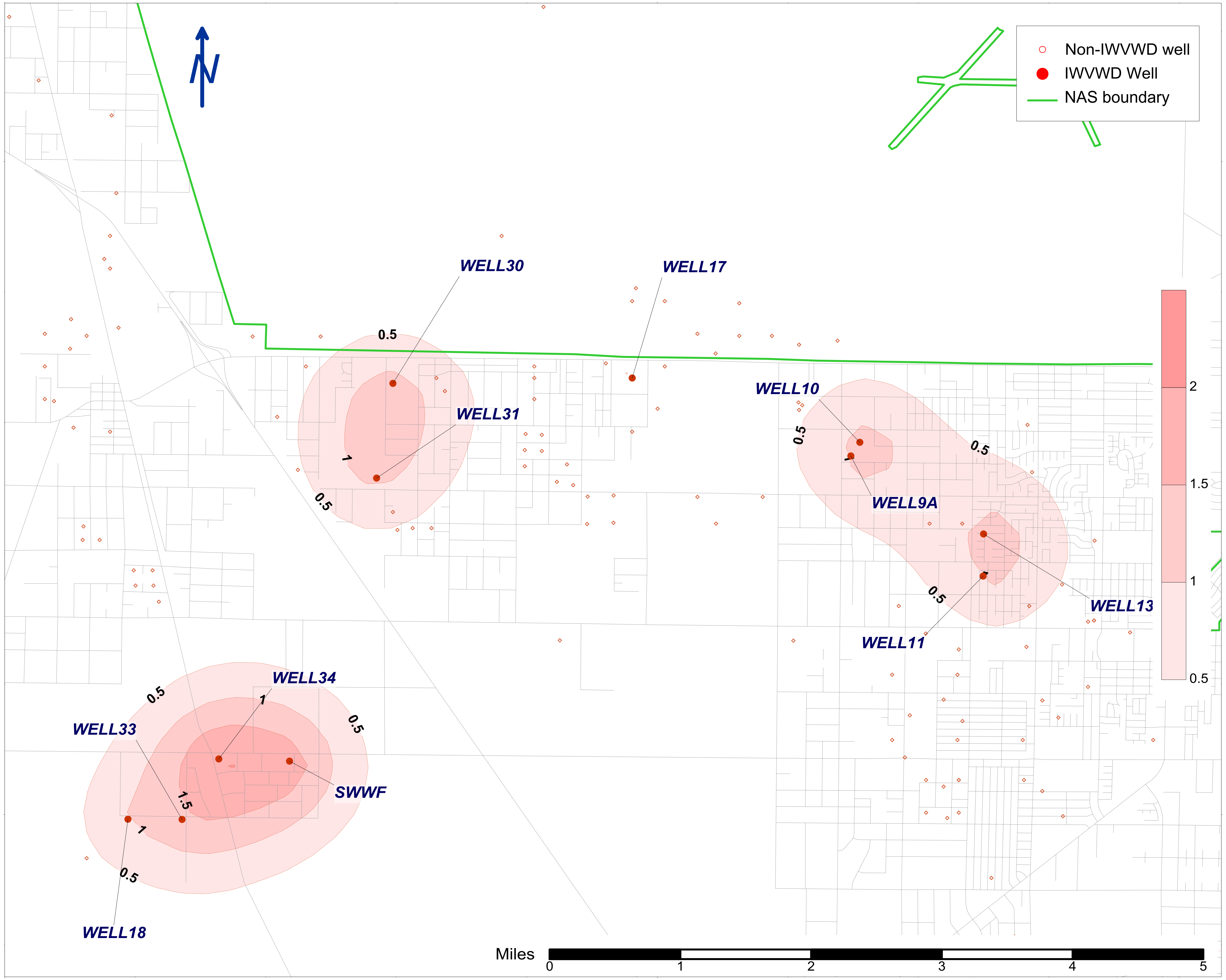

Figure 9. October 2020 water-level declines, as compared to water levels at the steady annualized pumping rate for scenario SWWF/30/34 (pred4). Contour interval 0.5 ft

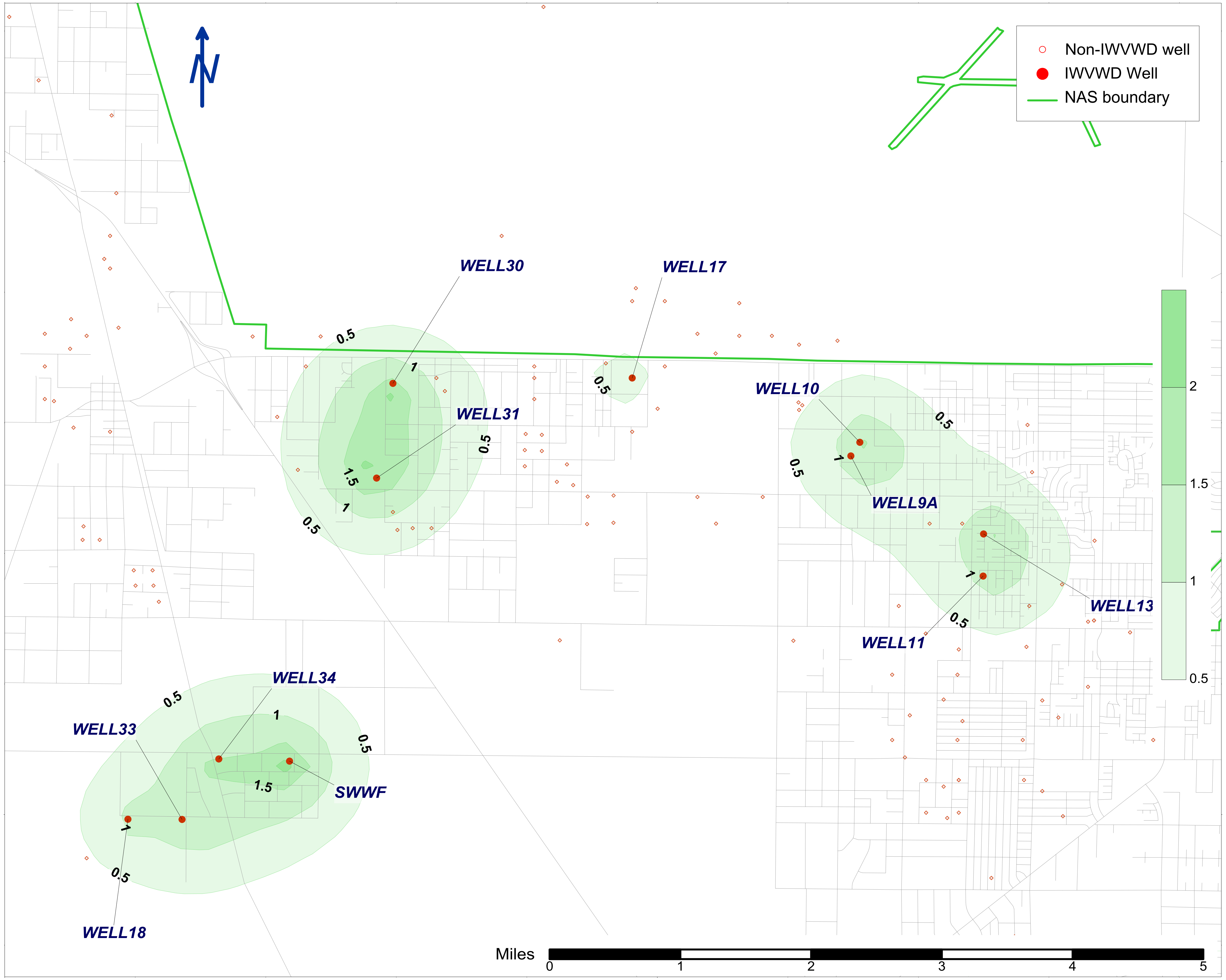

Figure 10. April 2020 water-level increases, as compared to water levels at the steady annualized pumping rate for scenario SWWF/30/31 (pred5). Contour interval 0.5 ft

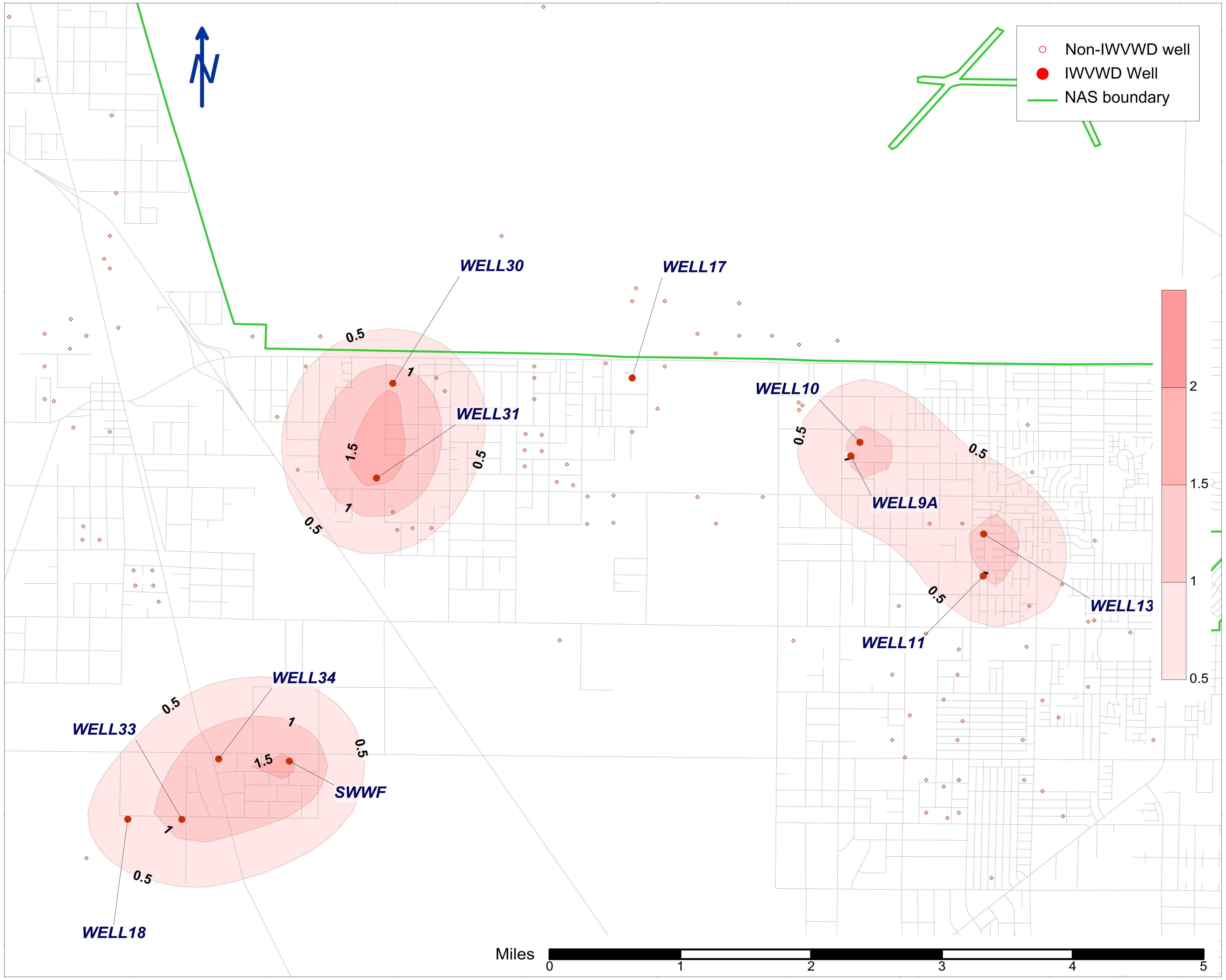

Figure 11. October 2020 water-level declines, as compared to water levels at the steady annualized pumping rate for scenario SWWF/30/31 (pred5). Contour interval 0.5 ft

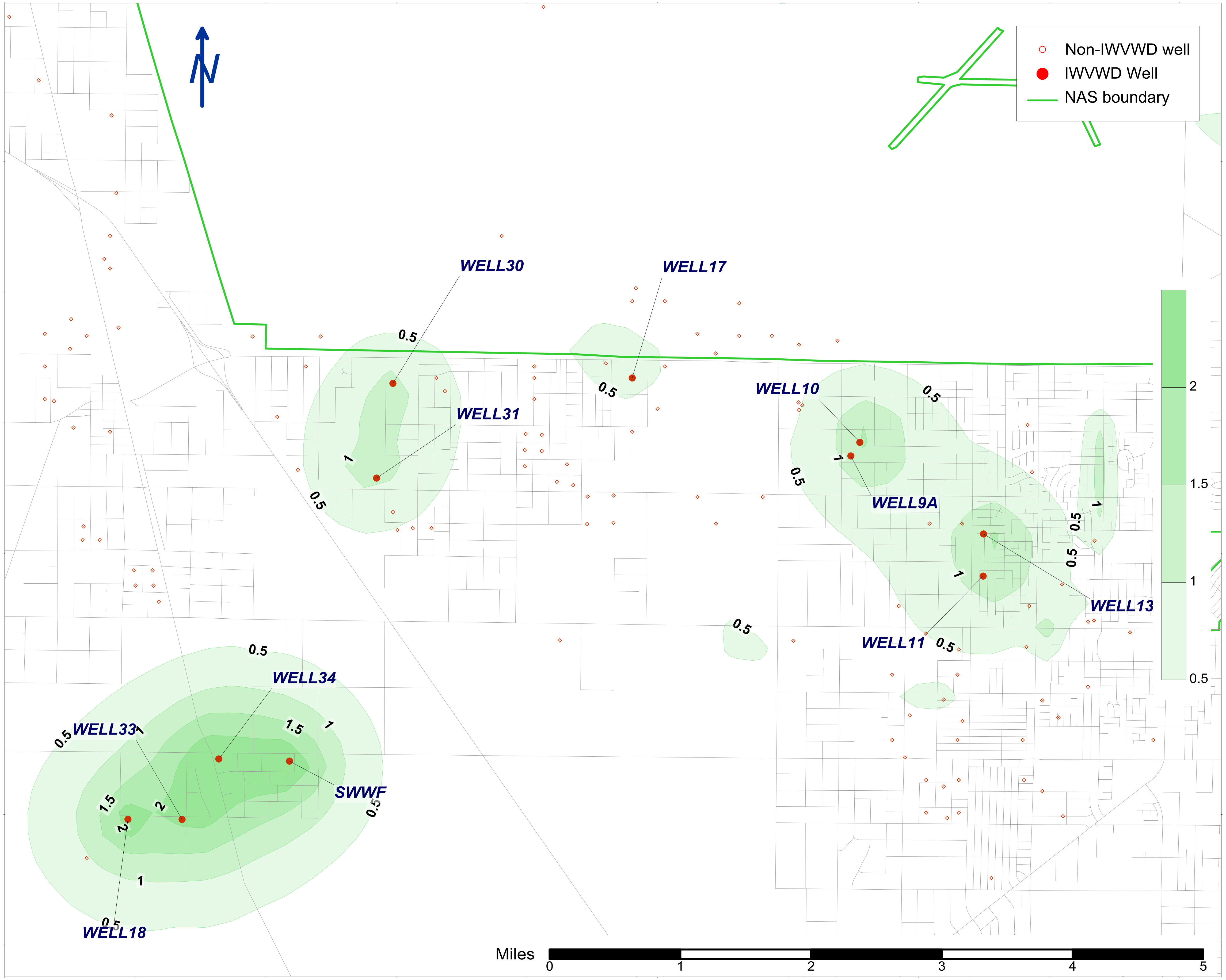

Figure 12. April 2020 water-level increases, as compared to water levels at the steady annualized pumping rate for scenario SWWF/18/34 (pred6). Contour interval 0.5 ft

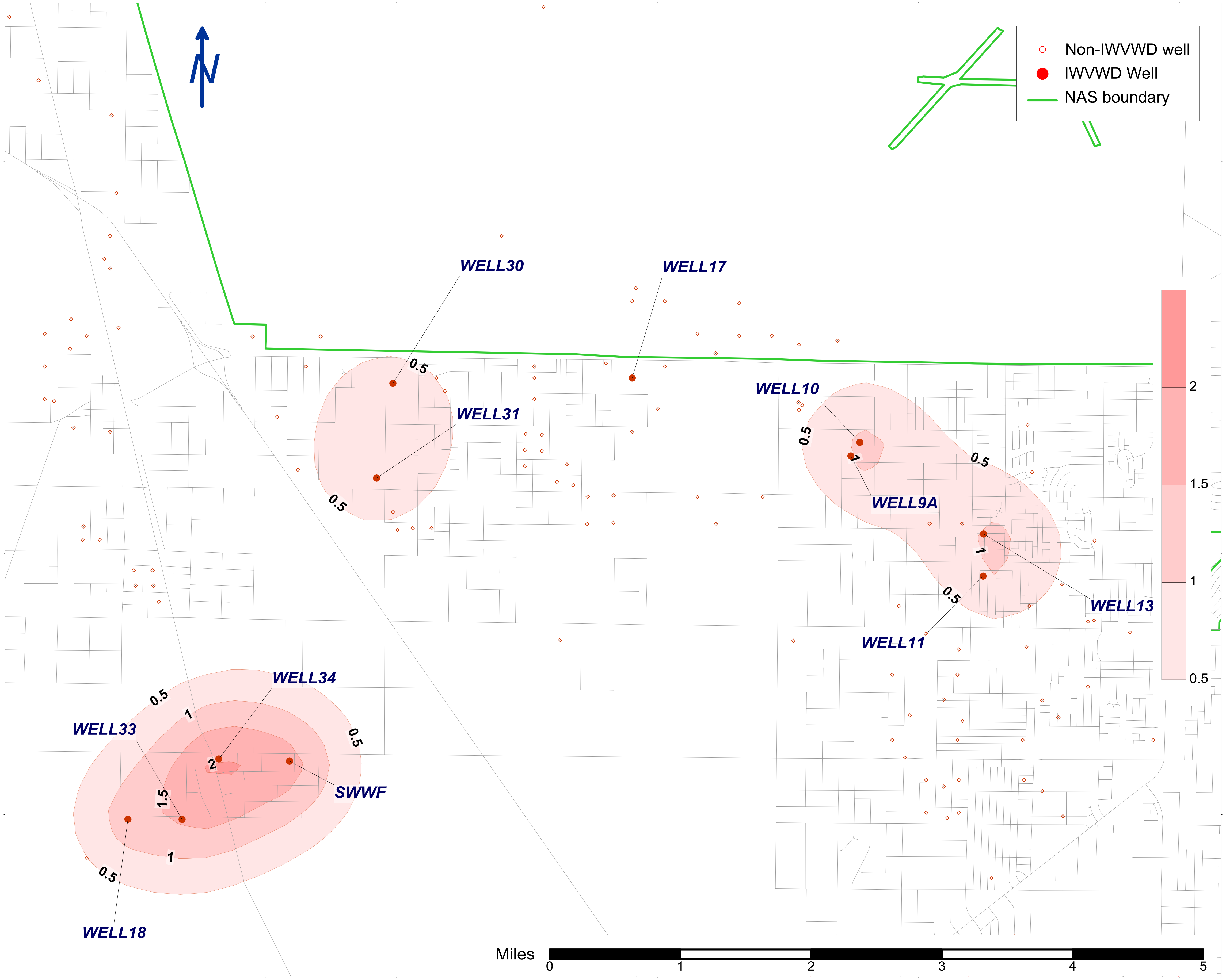

Figure 13. October 2020 water-level declines, as compared to water levels at the steady annualized pumping rate for scenario SWWF/18/34 (pred6). Contour interval 0.5 ft

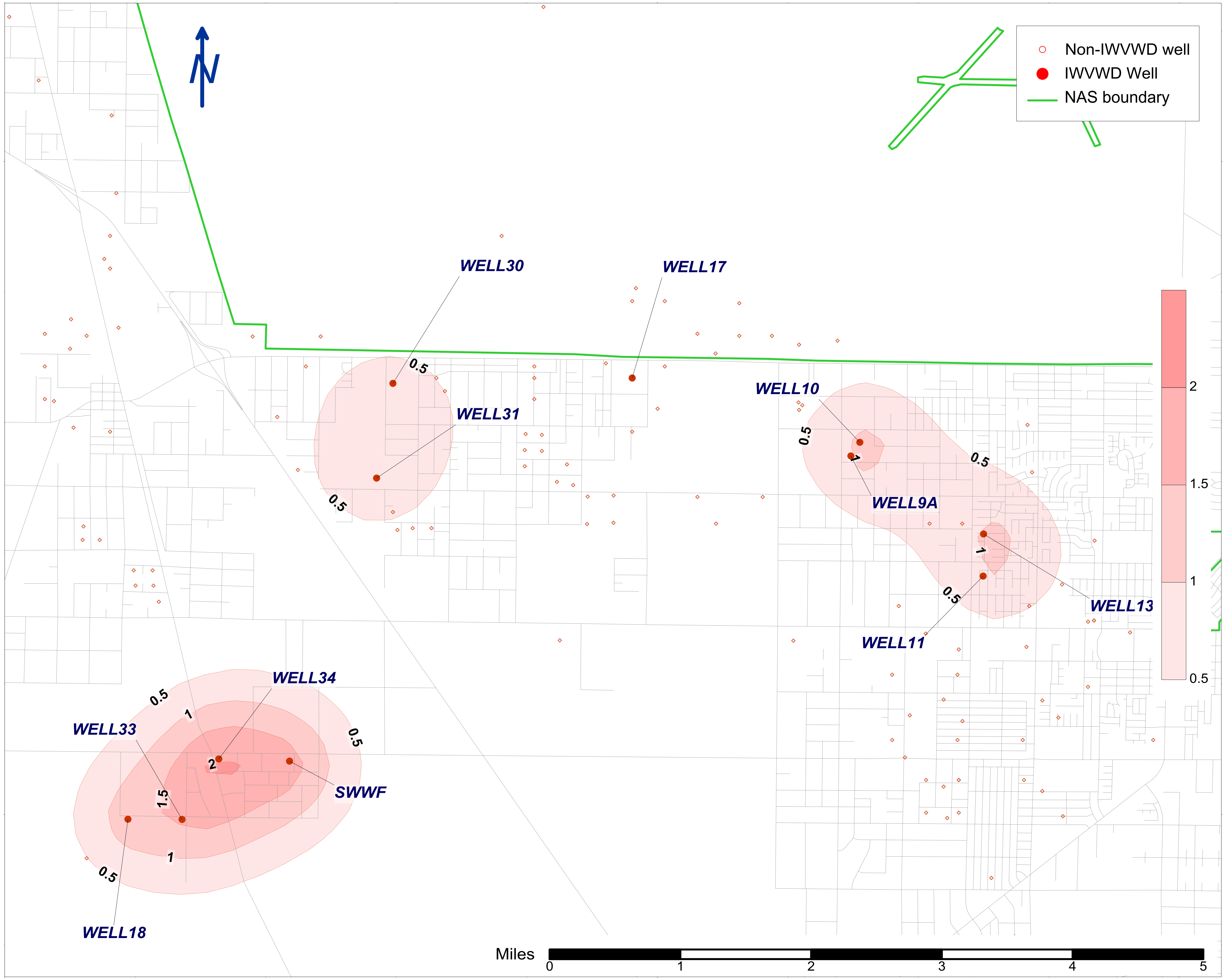

Figure 13. October 2020 water-level declines, as compared to water levels at the steady annualized pumping rate for scenario SWWF/30/34 (pred6). Contour interval 0.5 ft