Pacific Gas and Electric Company®

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July 15, 2005

Mr. Norman Shopay
Project Manager/Senior Engineering Geologist
California Department of Toxic Substances Control
Permitting and Corrective Action Branch
700 Heinz Avenue, Suite 200
Berkeley, California 94710-2721

Subject: Numerical Groundwater Flow Model Simulation of Current and Proposed Interim Measures Extraction, PG&E Topock Compressor Station, Needles, California

Dear Mr. Shopay:

This letter transmits a technical memorandum describing modeled future pumping scenarios, including the modeled capture of extraction well TW-2D, as well as the effects of adding extraction well PE-1.

If you have any questions, please do not hesitate to call me.

Sincerely,

Julie Eakins for Yvonne Meeks

Enclosure

cc: Karen Baker/DTSC
Aaron Yue/DTSC
Alfredo Zanoria/DTSC
Kate Burger/DTSC

Numerical Groundwater Flow Model Simulation of Current and Proposed Interim Measures Extraction, PG&E Topock Facility

DATE: July 15, 2005

Introduction

In February 2005, the California Department of Toxic Substances Control (DTSC) required PG&E to install an additional extraction well, PE-1, in the floodplain near MW-34-100. The purpose of this additional extraction well is to enhance the capture and eventual cleanup of Cr(VI) that had been detected in MW-34-100 after installation. The location of PE-1, along with nearby monitoring and extraction wells, is shown on Figure 1. DTSC is currently considering alternatives for connection of extraction well PE-1 to the IM-3 pump and treat system and operation of this well in conjunction with the current extraction well, TW-2D. DTSC has requested PG&E to provide an assessment of the current capture zone of active extraction well TW-2D, along with an assessment of the potential effects of bringing PE-1 online.

The purpose of this technical memorandum is to address DTSC's request by using the model to simulate pumping of TW-2D under anticipated future conditions, with and without the pumping of PE-1. An assessment will be made of the benefits and drawbacks of activating PE-1, and recommendations for future pumping rates will be provided.

In addition, a brief update of model agreement with recent TW-2D shutdown data is provided in Attachment A.

TW-2D Capture Zone

The capture zone for well TW-2D was simulated for projected future river levels and pumping rates in December 2005. Based on current (June 2005) Davis Dam release projections from the Bureau of Reclamation, December will be the month with the lowest river levels within the next year. A pumping rate of 90 gpm, the current maximum pumping rate from TW-2D, was used in the simulations provided in this memorandum. The IM-3 treatment plant and injection well system is expected to be operational within the next month. Anticipating the use of the injection wells, injection was assigned to IW-2 for the December 2005 simulation. An injection rate of 67.5 gpm, which is 75% of the 90 gpm pumping rate assigned to TW-2D, was assumed to account for water loss in the treatment and RO process.

The predicted river level for December was loaded into the model, and the model was used to simulate a steady-state flow field with the pumping and injection rates described above. Reverse particle tracking was then conducted within the steady state flow field to define the capture zone of the TW-2D well. Flowlines were tracked backwards from the TW-2D model node to illustrate the area from which the well would draw groundwater (i.e. the capture zone). Flowlines were started from various levels of model layers 3 and 4, over which TW-2D is screened, and a total of 50 flowlines were run from each starting point, running radially around the well node.

Figure 2 shows the areal extent of the simulated capture zone. According to the model, groundwater in the Alluvial Aquifer beneath the riverbed is captured from the mouth of Bat Cave Wash downstream to the I-40 bridge in model Layers 3 and 4 (which represent the deeper portions of the alluvial aquifer). The capture zone for the shallower groundwater covers a smaller reach of the river, but still encompasses the area offshore of the leading edge of the plume. Because chromium has only been detected the deeper groundwater at the MW-34 well cluster, emphasis has been placed on examining effects in model layers 3 and 4 in this technical memorandum. The model also predicts greater than 0.001 ft/ft landward gradient between the three key well pairs designated as an IM performance metric by DTSC. Table 1 provides the well pairs and gradient values.

Though not included in this report, simulation of the most current conditions (June 2005 river level with TW-2D pumping at 70 gpm) results in a slightly larger capture zone than that shown on Figure 2. Even though the extraction rate is currently lower, the higher level of the river in June contributes to a landward gradient that tends to increase the capture zone size.

Transducer data from floodplain wells support the model predictions, as landward gradients have been demonstrated since extraction reached targeted levels in the fall of 2004.

Simulation of PE-1 Pumping

Simulation of pumping at PE-1 results in an increase the magnitude of the landward gradient in the vicinity of well MW-34-100. Testing at PE-1 has indicated a maximum sustainable pumping rate of around 40 gpm. The well is screened in the deeper part of the aquifer, corresponding to model layers 3 and 4. It is anticipated that PE-1 would augment pumping at TW-2D, and not replace it.

Two pumping scenarios involving both wells TW-2D and PE-1 were simulated. In order to compare effects of pumping PE-1 to the December 2005 TW-2D scenario described above, a total pumping rate of 90 gpm was maintained. Scenario 1 consisted of pumping PE-1 at its maximum rate of 40 gpm, with a rate of 50 gpm assigned to TW-2D. The pumping rate for PE-1 was cut in half to 20 gpm in Scenario 2, and TW-2D was increased to 70 gpm, its current rate. In each scenario, all plume groundwater was captured and the capture zone was similar to that shown in Figure 2.

Vector plots were constructed on the basis of simulated head distributions in the vicinity of the two pumping wells. These plots show the direction of inferred groundwater flow and allow identification of each well’s capture zone.

Figure 3 shows the vector plot for model layer 3 under pumping Scenario 1. The vector arrows indicate inferred direction of groundwater flow from each vector point. The stagnation zone is indicated by the area of diverging arrows between TW-2D and PE-1. At this level, simulations indicate that PE-1 would pull groundwater from the MW-34, MW-36, MW-30, and MW-39 clusters if pumped at 40 gpm. The remainder of the wells within the plume area would be under the influence of TW-2D. A similar distribution is shown for layer 4 in Figure 4.

Scenario 2 vector plots are provided in Figures 5 and 6, which show inferred groundwater flow directions for layers 3 and 4, respectively. With pumping rate lowered in PE-1 and raised in TW-2D, the stagnation zone is shifted to the east. In this scenario, only well clusters MW-34 and MW-36 are influenced by PE-1.

Pumping at PE-1 is anticipated to increase the velocity of landward groundwater movement at both the MW-34 cluster and further east beneath the river. The calculated velocity from MW-34-100 (in model layer 4) is compared in Table 1 between the base case (90 gpm in TW-2D alone) and Scenarios 1 and 2. As shown, PE-1 pumping does increase the simulated landward velocity around this well.

Table 1 shows that velocities increase close to PE-1, as anticipated. Note that key well pair gradients decrease compared to the base case, and for Scenario 1 the MW-42-65/MW-20-130 gradient falls below 0.001. The stagnation zones shown on Figures 3-6 suggest velocities in other areas may be slower than in the base case. To illustrate this further, the simulated travel time from every model node in the plume area to one of the extraction wells was saved for each scenario. Figure 7 shows the ratio between the base case travel times and the Scenario 1 travel times for model layer 3. Ratios greater than one indicate that the presence of PE-1 results in faster capture than in the base case. Slower capture (ratios less than one) is actually dominant over most of the plume area, since the pumping rate at TW-2D is lower than in the base case, and that PE-1 pumping creates a stagnation zone in the floodplain. Figure 8 shows the floodplain area detail of the same scenario. Figures 9 and 10 provide the same ratio maps for model layer 4. For Scenario 1, capture is quickened in the MW-34 cluster area and on the southeastern edge of the plume, and is slowed in all other areas.

Figures 11 through 14 constitute a similar set of ratio maps for Scenario 2 pumping. In this case, the area of enhanced capture speed is more limited, due to the lower pumping rate at PE-1 and higher rate at TW-2D. There is a significant increase in capture speed only around MW-34 and MW-36. The remainder is either unchanged or slower. These figures indicate that pumping from PE-1 will increase flushing from the MW-34 area and also in groundwater beneath the river in that area, but will result in increased flushing time in large areas of the plume.

Assessment of Potential Extraction Well Locations

Given the model prediction of the wide capture zone shown in Figure 2, the need for additional extraction wells beyond PE-1 for the purpose of plume containment does not appear to be significant. If it is deemed necessary to further increase the magnitude of the landward gradient in the eastern portion of the floodplain, the most logical locations for additional extraction wells would be west of the floodplain and to the north and/or south of TW-2D. In this way, sensitive habitat will not be disturbed, rig access will not be an issue, and extraction conveyance systems will be more easily designed and implemented. As already demonstrated by transducer data, pumping at this distance from the river still has a measurable and significant effect on groundwater gradient. Additional extraction wells would not be recommended at locations significantly outside of the existing plume (for examples, in the eastern portion of the floodplain) because such pumping would tend to draw plume groundwater toward the clean extraction well locations, potentially spreading the lateral extent of the plume. Potential extraction well locations PE-2 and PE-3 (shown on the figures) meet the above criteria very well. Locations north of PE-3 are outside of the plume, and the Alluvial Aquifer becomes very thin to the south of PE-2, making effective extraction difficult.

Assessment of Monitoring Network

Two of the three key well pairs currently used to gauge success of IM extraction, MW-33-150/MW-31-135 and MW-42-65/MW-20-130, would still be useful if PE-1 were activated. The third well pair, MW-34-80/MW-20-130, would not, as PE-1 is located between the two wells. Over the past several months, the MW-34-80/MW-20-130 pair has shown the highest gradient of the three well pairs. Model output indicates that activation of PE-1 will only increase the landward flux from the MW-34 cluster, as demonstrated in Table 1. Given the relationship of the well pair gradients, it would follow that as long as the other two well pairs show favorable gradients, then the gradient along the path between MW-34 and MW-20 clusters will also meet the criterion. In this way, no direct gradient measurement from MW-34-80 would be necessary.

If a direct gradient from MW-34-80 were deemed necessary to gauge IM success with PE-1 active, then a piezometer cluster would be required between that well and PE-1. The cluster would be outfitted with transducers and would screen the middle and deep depths of the aquifer.

The remainder of the monitoring well network is considered sufficient to examine effects of both extraction wells at various depths of the aquifer beneath the floodplain.

Conclusions and Recommendations

The current model predicts a December 2005 capture zone that extends well beyond the plume area and throughout the adjacent area beneath the river, based on projected December river levels and an assumed TW-2D pumping rate of 90 gpm. Model simulations indicate that extraction from PE-1, if implemented, would increase aquifer flushing rates in the vicinity of the MW-34 cluster, including the area beneath the Colorado River. However, the majority of the plume area would experience slower flushing rates, compared to pumping TW-2D at the same total rate by itself.

If PE-1 is activated, it is recommended to maintain the lower extraction rate (i.e., 20 gpm) in order to minimize drawing groundwater from the plume to the east, yet providing an increased landward flushing rate in the vicinity of MW-34-100.

Tables

Table 1. Simulated groundwater flux rates and estimated velocities from MW-34-100.

Pumping Scenario	Gallons per Minute			Specific Discharge at MW-34-100 (ft/d)	Calculated Groundwater Velocity at MW-34-100 (ft/d)[1]	Key Well Gradients		
	TW-2D	PE-1	IW-2			MW-34-80/ MW-20-130	MW-42-65/ MW-20-130	MW-33-150/ MW-31-135
Base Case	90	0	67.5	0.013	0.13	0.0021	0.0023	0.0015
Scenario 1	50	40	67.5	0.068	0.68	0.0003[2]	0.0008	0.0009
Scenario 2	70	20	67.5	0.041	0.41	0.0012[2]	0.0016	0.0012

Notes:

[1]Assumed effective porosity of 0.1

[2]Well pair is split by PE-1 pumping. Calculated gradient is discontinuous.

Figures

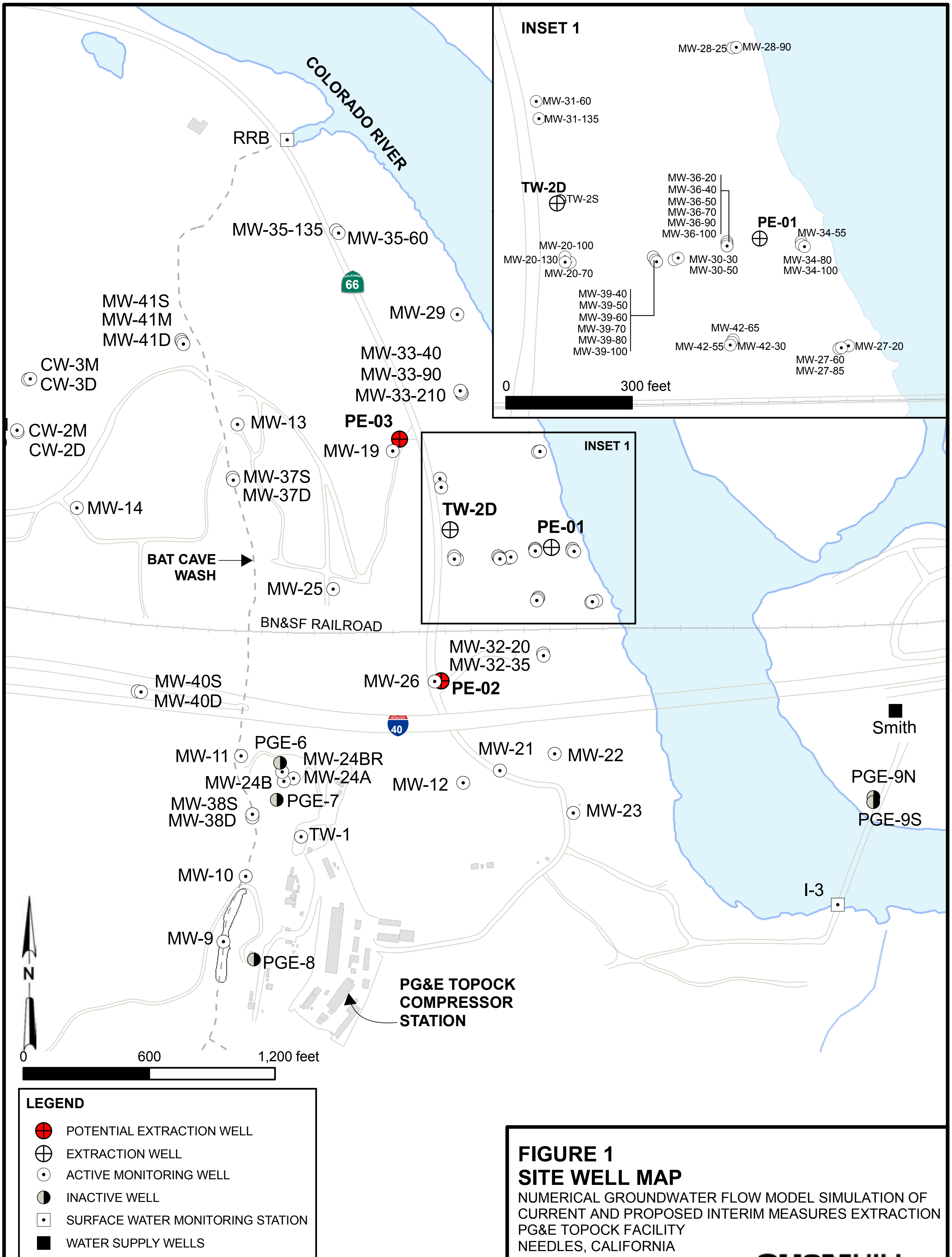
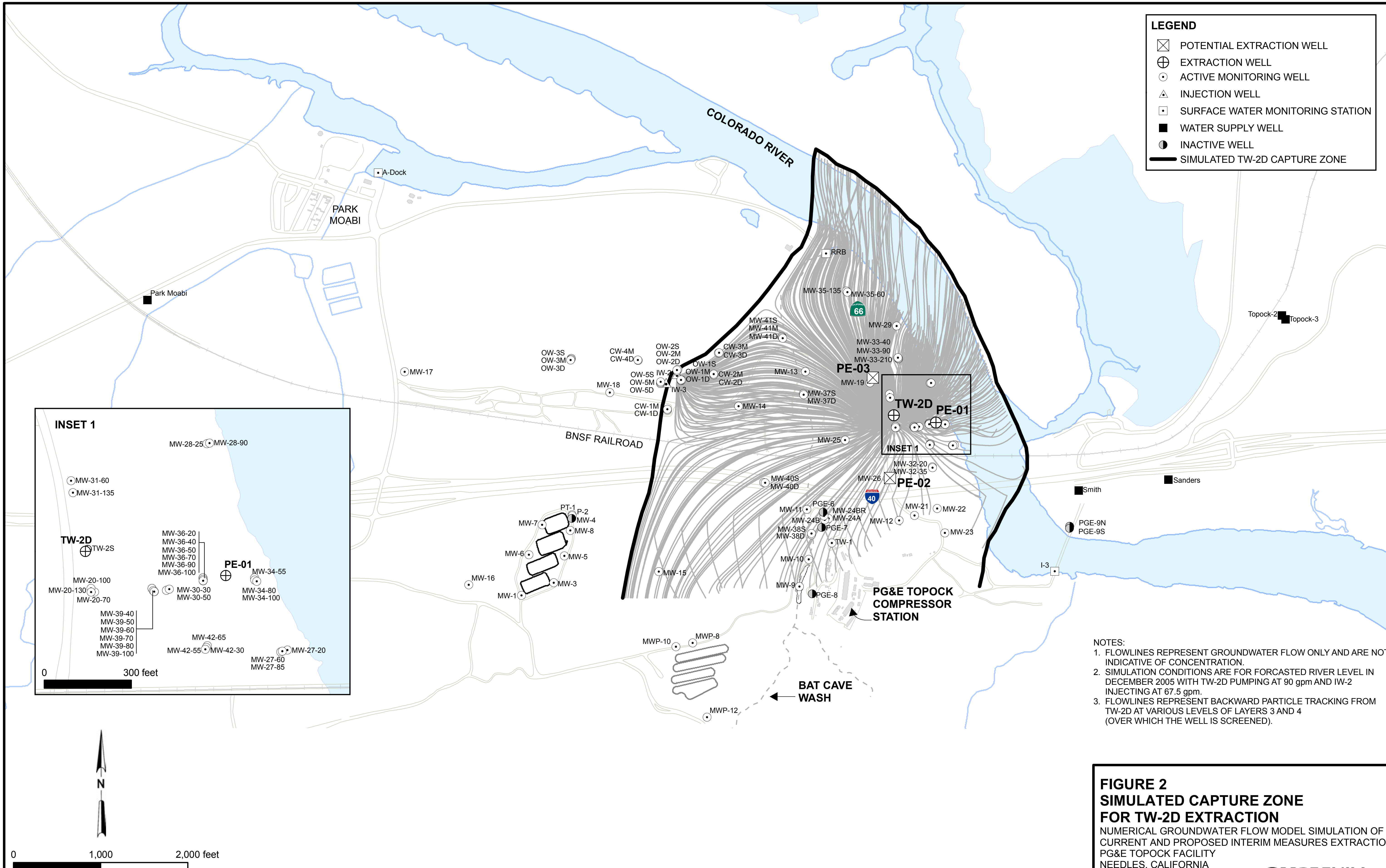


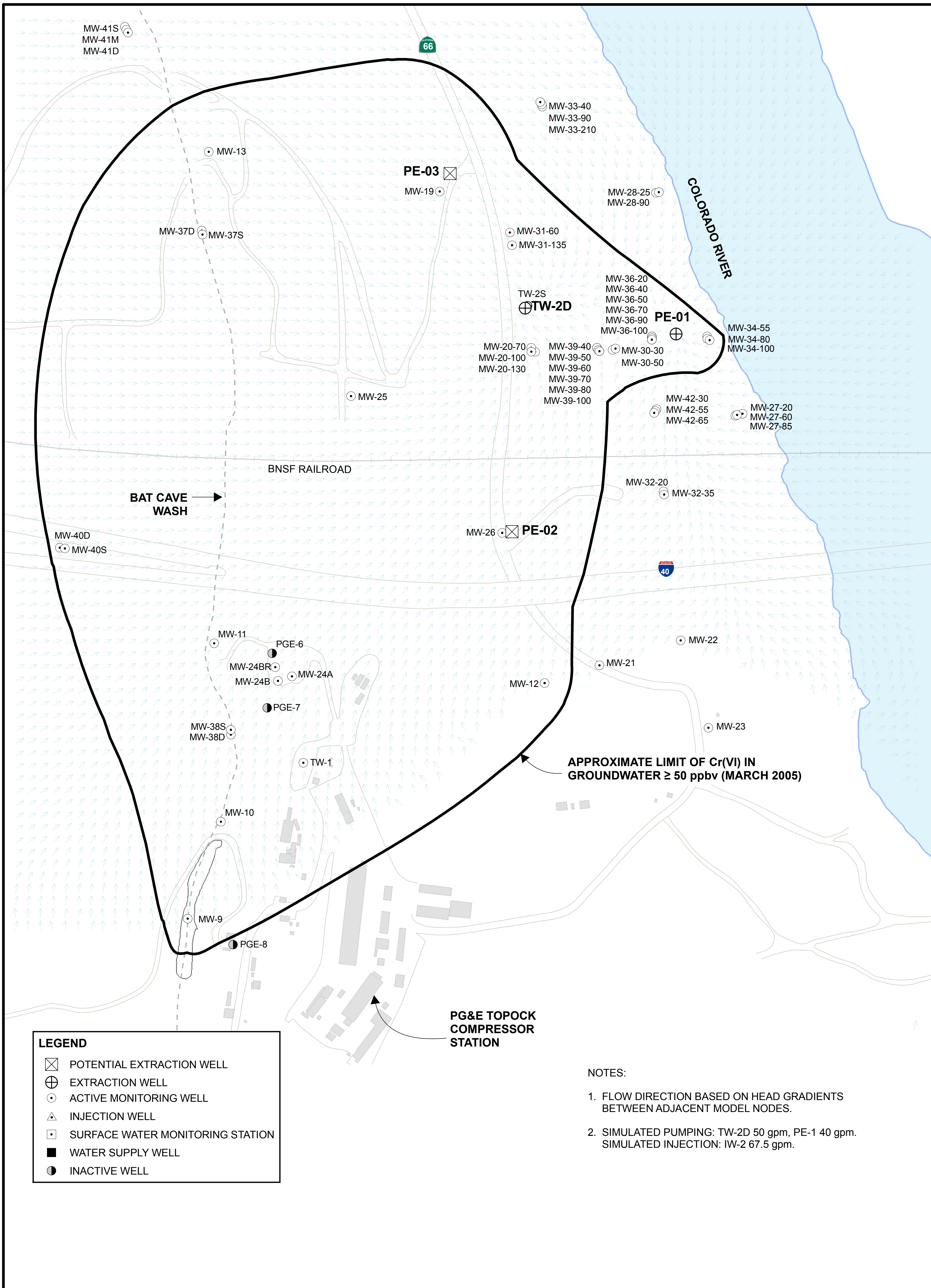
FIGURE 1
SITE WELL MAP
NUMERICAL GROUNDWATER FLOW MODEL SIMULATION OF CURRENT AND PROPOSED INTERIM MEASURES EXTRACTION
PG&E TOPOCK FACILITY
NEEDLES, CALIFORNIA

CH2MHILL



NOTES:
1. FLOWLINES REPRESENT GROUNDWATER FLOW ONLY AND ARE NOT INDICATIVE OF CONCENTRATION.
2. SIMULATION CONDITIONS ARE FOR FORCASTED RIVER LEVEL IN DECEMBER 2005 WITH TW-2D PUMPING AT 90 gpm AND IW-2 INJECTING AT 67.5 gpm.
3. FLOWLINES REPRESENT BACKWARD PARTICLE TRACKING FROM TW-2D AT VARIOUS LEVELS OF LAYERS 3 AND 4 (OVER WHICH THE WELL IS SCREENED).

FIGURE 2
SIMULATED CAPTURE ZONE FOR TW-2D EXTRACTION
NUMERICAL GROUNDWATER FLOW MODEL SIMULATION OF CURRENT AND PROPOSED INTERIM MEASURES EXTRACTION
PG&E TOPOCK FACILITY
NEEDLES, CALIFORNIA



LEGEND

- POTENTIAL EXTRACTION WELL
- EXTRACTION WELL
- ACTIVE MONITORING WELL
- INJECTION WELL
- SURFACE WATER MONITORING STATION
- WATER SUPPLY WELL
- INACTIVE WELL

NOTES:

1. FLOW DIRECTION BASED ON HEAD GRADIENTS BETWEEN ADJACENT MODEL NODES.
2. SIMULATED PUMPING: TW-2D 50 gpm, PE-1 40 gpm. SIMULATED INJECTION: IW-2 67.5 gpm.

FIGURE 3
PUMPING SCENARIO 1: SIMULATED GROUNDWATER FLOW VECTORS FOR MODEL LAYER 3

NUMERICAL GROUNDWATER FLOW MODEL SIMULATION OF CURRENT AND PROPOSED INTERIM MEASURES EXTRACTION
PG&E TOPOCK FACILITY
NEEDLES, CALIFORNIA

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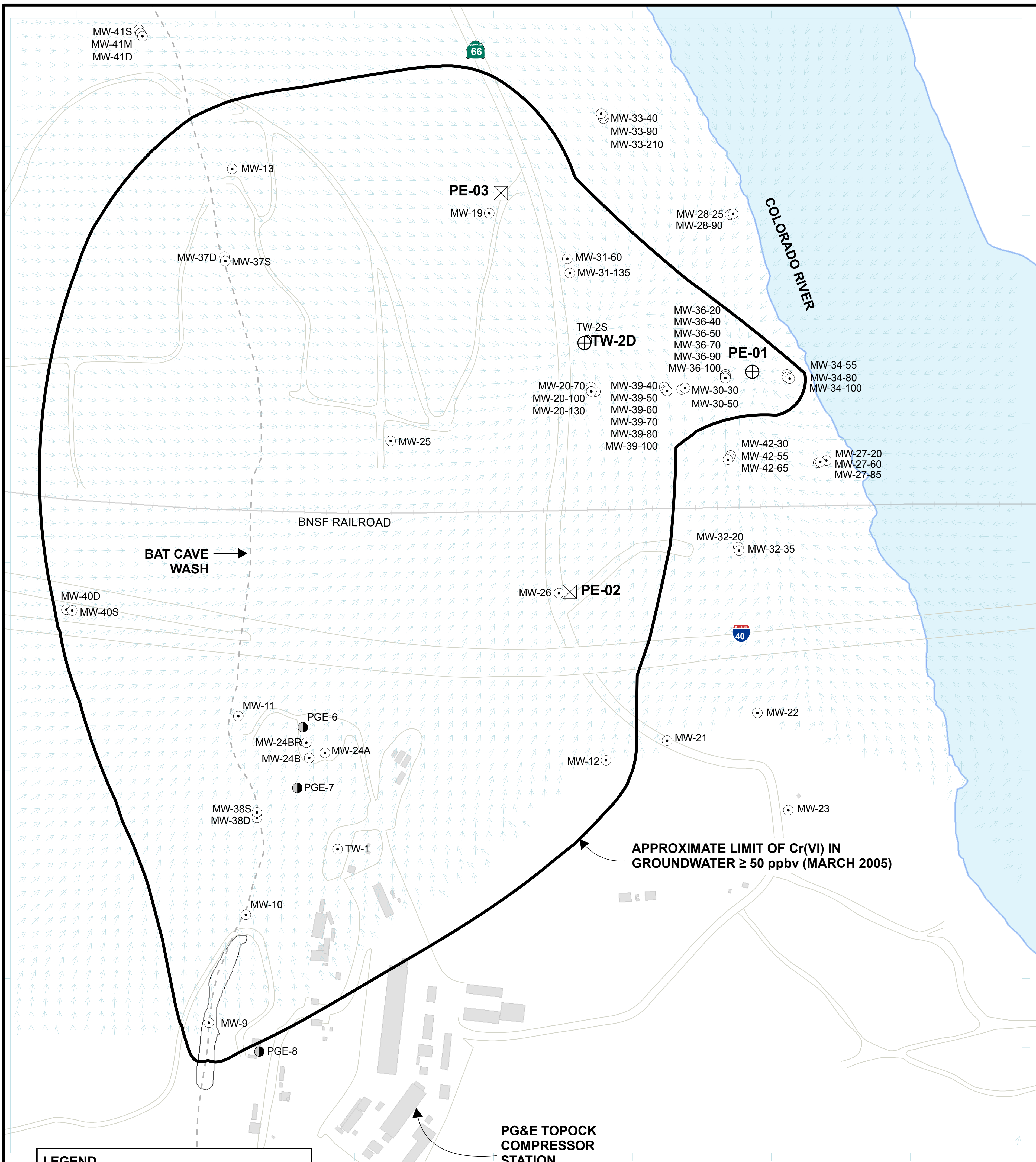

LEGEND

- POTENTIAL EXTRACTION WELL
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2. SIMULATED PUMPING: TW-2D 50 gpm, PE-1 40 gpm. SIMULATED INJECTION: IW-2 67.5 gpm.

N

0 300 600 feet

FIGURE 4
PUMPING SCENARIO 1: SIMULATED GROUNDWATER FLOW VECTORS FOR MODEL LAYER 4
NUMERICAL GROUNDWATER FLOW MODEL SIMULATION OF CURRENT AND PROPOSED INTERIM MEASURES EXTRACTION
PG&E TOPOCK FACILITY
NEEDLES, CALIFORNIA

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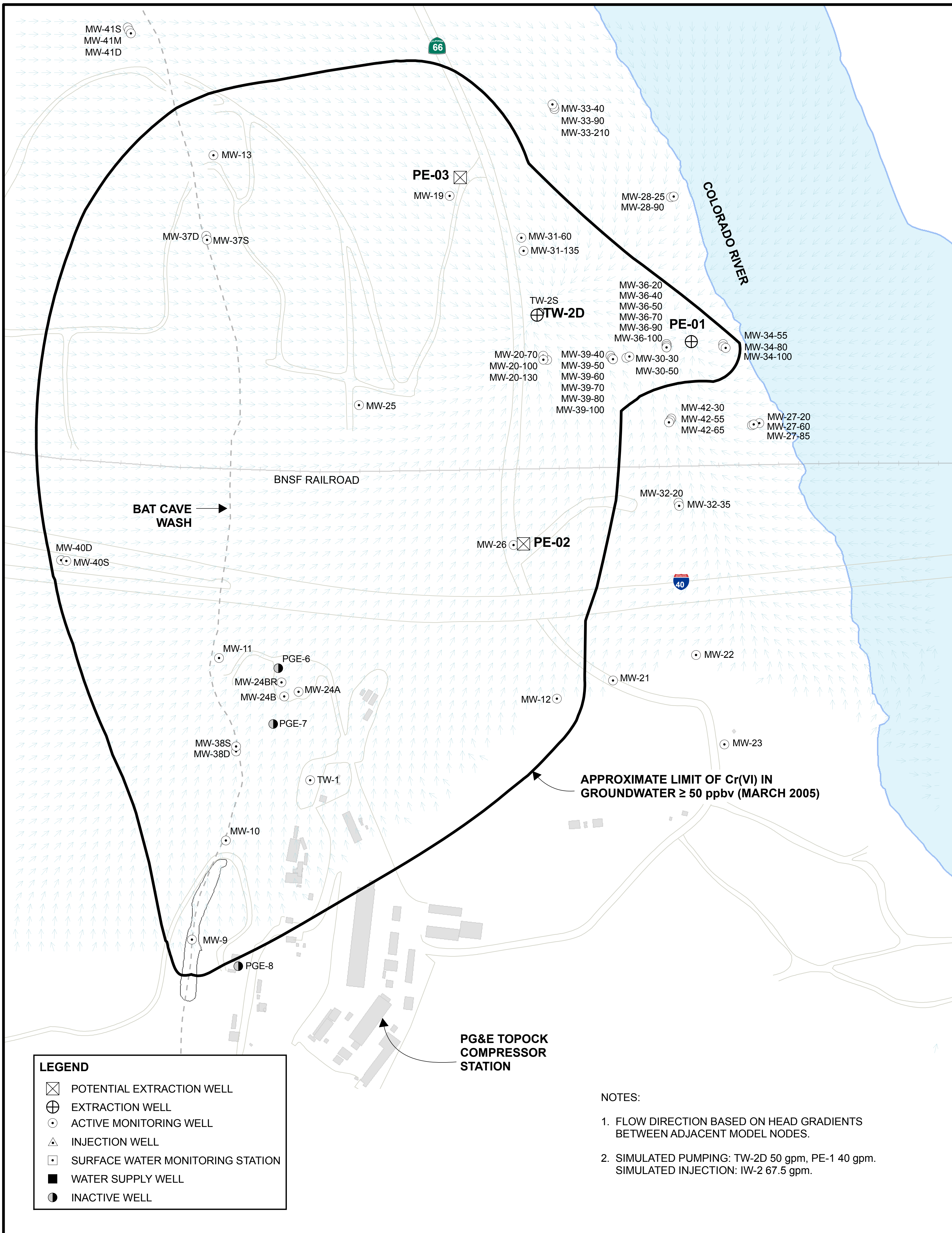

NOTES:

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2. SIMULATED PUMPING: TW-2D 50 gpm, PE-1 40 gpm. SIMULATED INJECTION: IW-2 67.5 gpm.

FIGURE 5
PUMPING SCENARIO 2: SIMULATED GROUNDWATER FLOW VECTORS FOR MODEL LAYER 3
NUMERICAL GROUNDWATER FLOW MODEL SIMULATION OF CURRENT AND PROPOSED INTERIM MEASURES EXTRACTION
PG&E TOPOCK FACILITY
NEEDLES, CALIFORNIA

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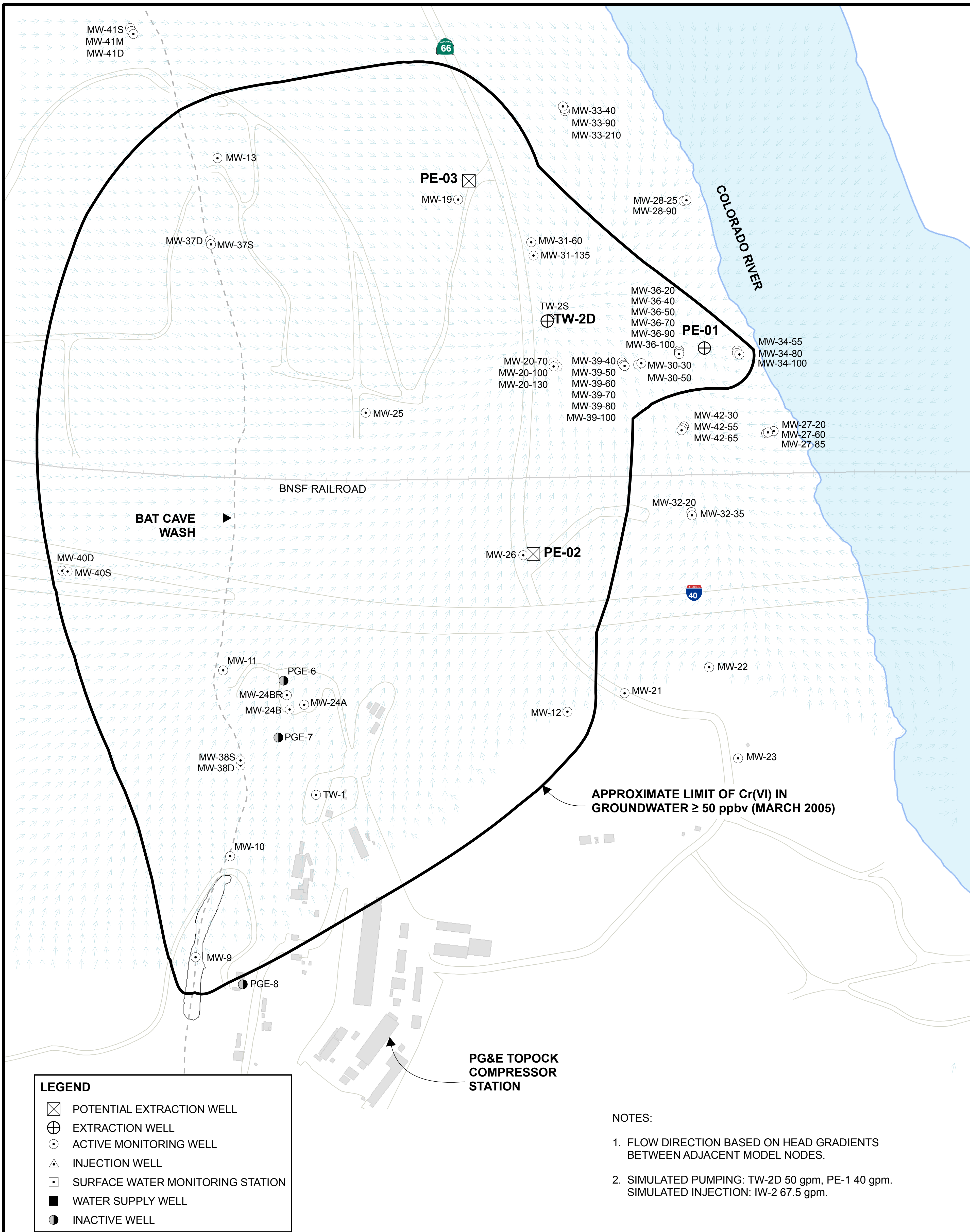

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FIGURE 6
PUMPING SCENARIO 2: SIMULATED GROUNDWATER FLOW VECTORS FOR MODEL LAYER 4

NUMERICAL GROUNDWATER FLOW MODEL SIMULATION OF CURRENT AND PROPOSED INTERIM MEASURES EXTRACTION
PG&E TOPOCK FACILITY
NEEDLES, CALIFORNIA

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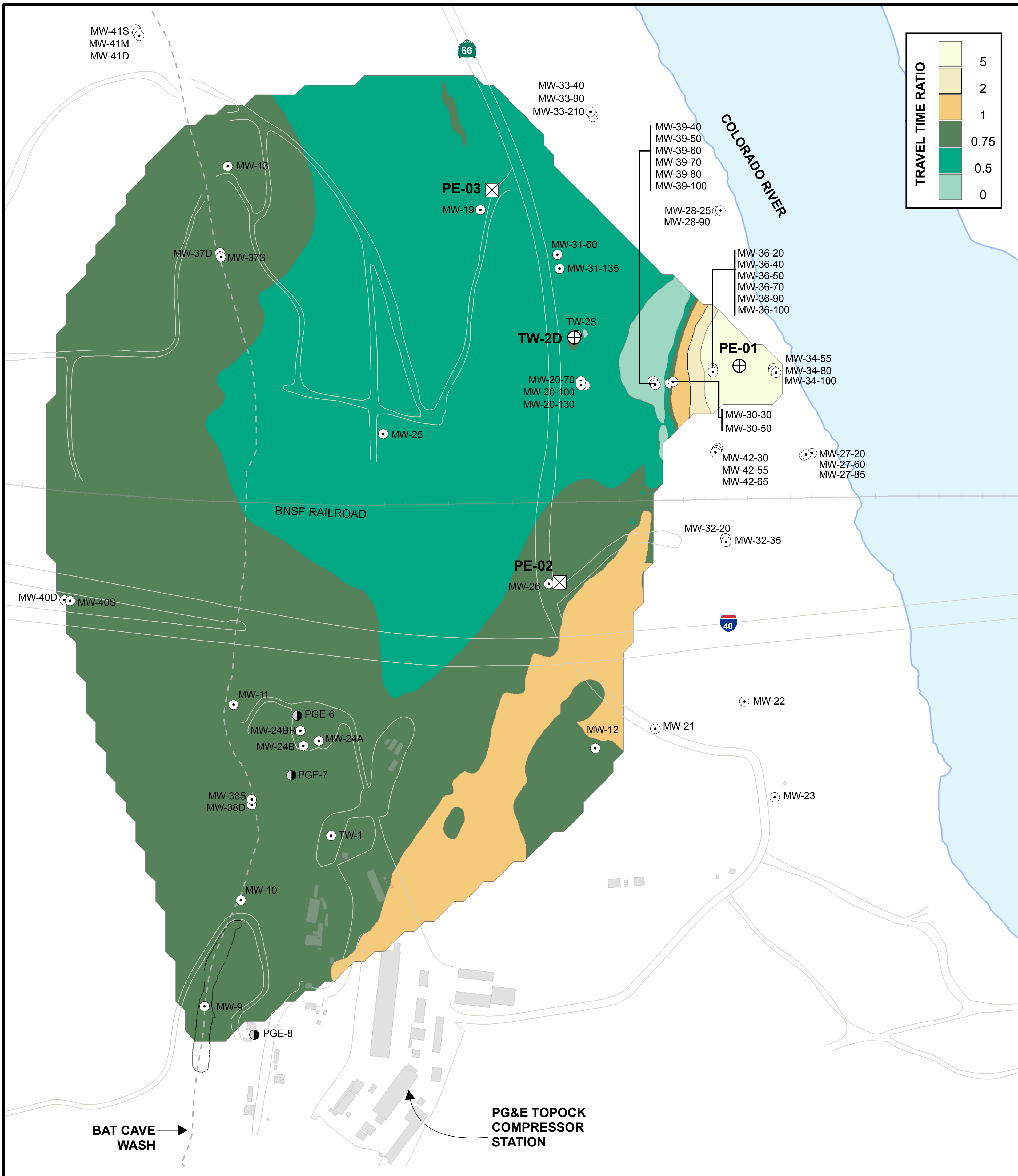

LEGEND

- POTENTIAL EXTRACTION WELL
- EXTRACTION WELL
- ACTIVE MONITORING WELL
- INJECTION WELL
- SURFACE WATER MONITORING STATION
- WATER SUPPLY WELL
- INACTIVE WELL

NOTES:

1. RATIOS COMPARE TRAVEL TIMES TO A WELL UNDER TWO SIMULATED CONDITIONS:
   (A) TW-2D PUMPING AT 90 gpm ALONE AND
   (B) TW-2D PUMPING AT 50 gpm AND PE-1 PUMPING AT 40 gpm.
2. IN EACH SCENARIO, IW-2 SIMULATED INJECTION WAS 67.5 gpm.
3. RATIO VALUES GREATER THAN 1 INDICATE AREAS WHERE PE-1 PUMPING ACCELERATES CAPTURE; VALUES LESS THAN 1 INDICATE SLOWED CAPTURE COMPARED TO TW-2D PUMPING ALONE.

N

0 300 600 feet

FIGURE 7
PUMPING SCENARIO 1:
TRAVEL TIME RATIOS – MODEL LAYER 3
NUMERICAL GROUNDWATER FLOW MODEL SIMULATION OF CURRENT AND PROPOSED INTERIM MEASURES EXTRACTION
PG&E TOPOCK FACILITY
NEEDLES, CALIFORNIA

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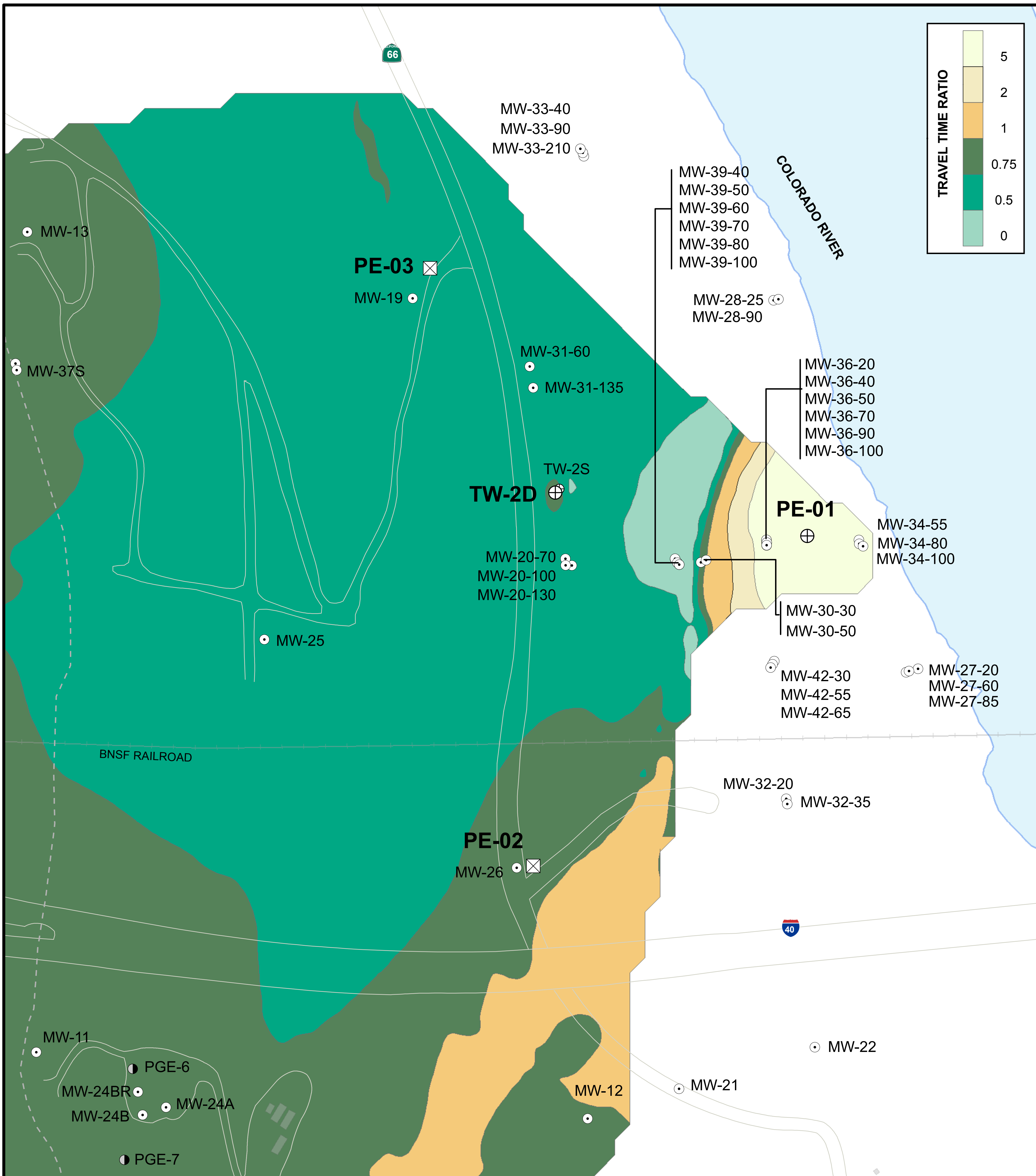

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0 200 400 feet

FIGURE 8
PUMPING SCENARIO 1:
TRAVEL TIME RATIOS – MODEL LAYER 3
DETAILED AREA

NUMERICAL GROUNDWATER FLOW MODEL SIMULATION OF CURRENT AND PROPOSED INTERIM MEASURES EXTRACTION
PG&E TOPOCK FACILITY
NEEDLES, CALIFORNIA

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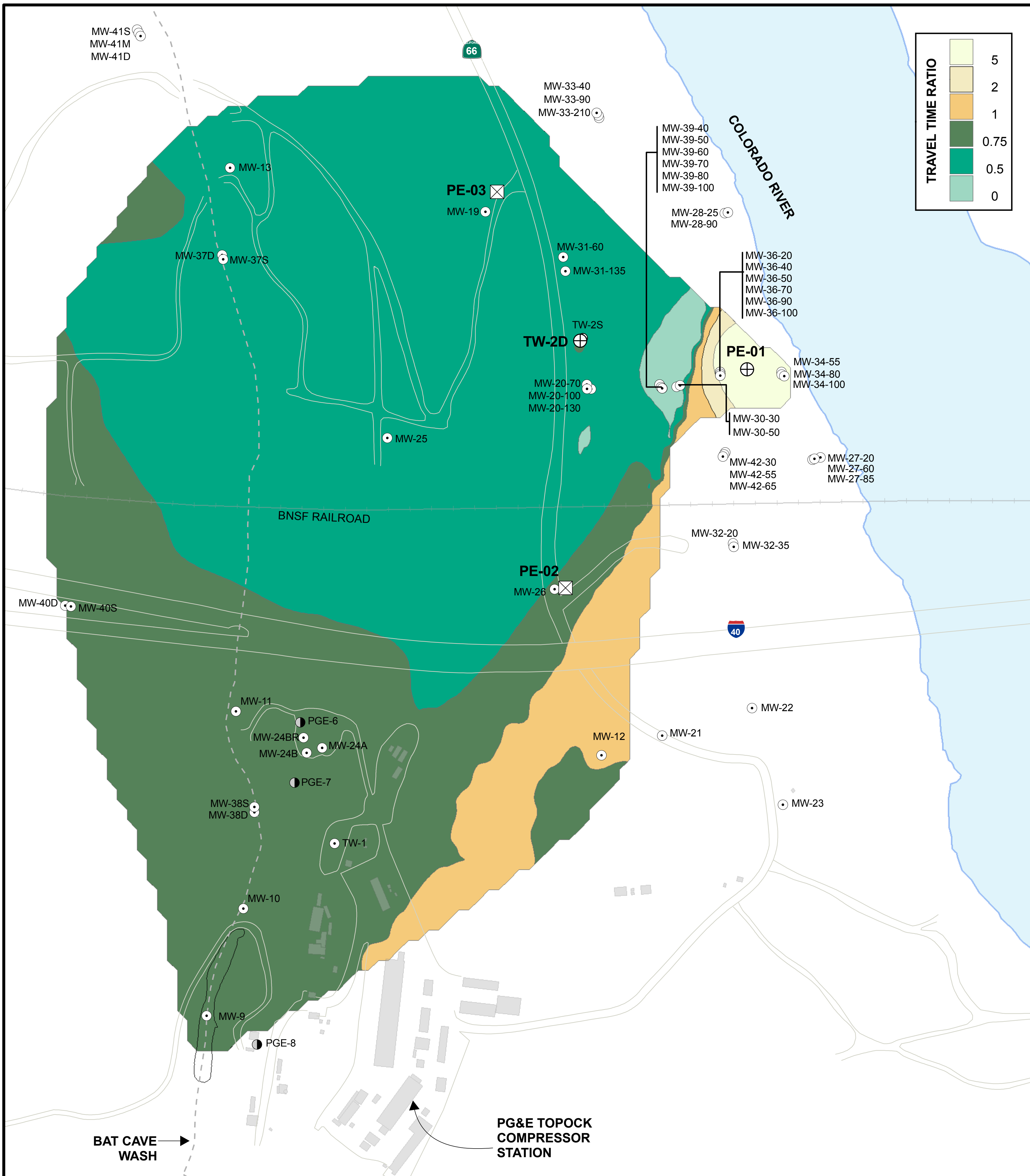

LEGEND

- ☒ POTENTIAL EXTRACTION WELL
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FIGURE 9
PUMPING SCENARIO 1:
TRAVEL TIME RATIOS – MODEL LAYER 4
NUMERICAL GROUNDWATER FLOW MODEL SIMULATION OF CURRENT AND PROPOSED INTERIM MEASURES EXTRACTION
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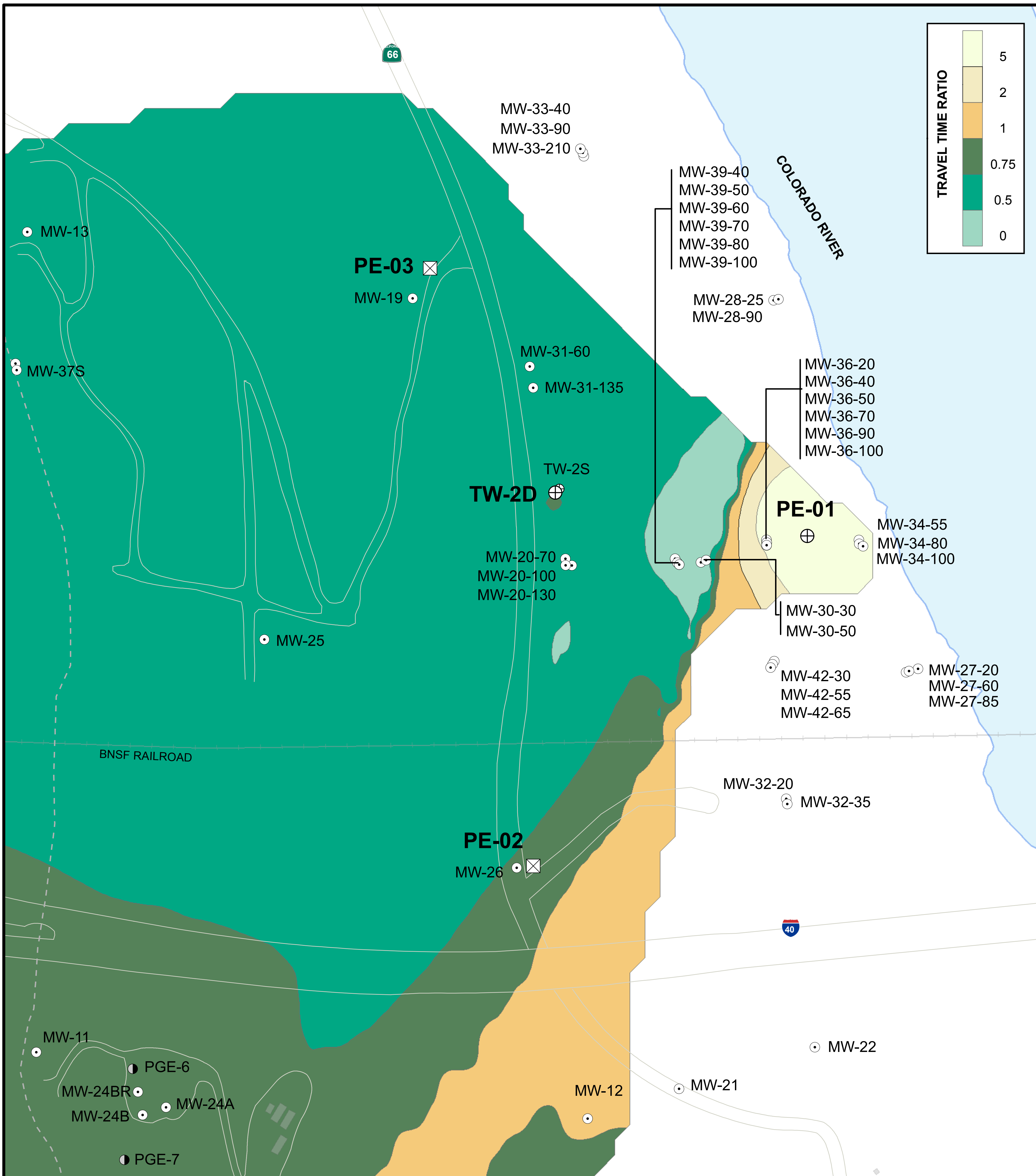

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N

0 200 400 feet

FIGURE 10
PUMPING SCENARIO 1:
TRAVEL TIME RATIOS – MODEL LAYER 4
DETAILED AREA

NUMERICAL GROUNDWATER FLOW MODEL SIMULATION OF CURRENT AND PROPOSED INTERIM MEASURES EXTRACTION
PG&E TOPOCK FACILITY
NEEDLES, CALIFORNIA

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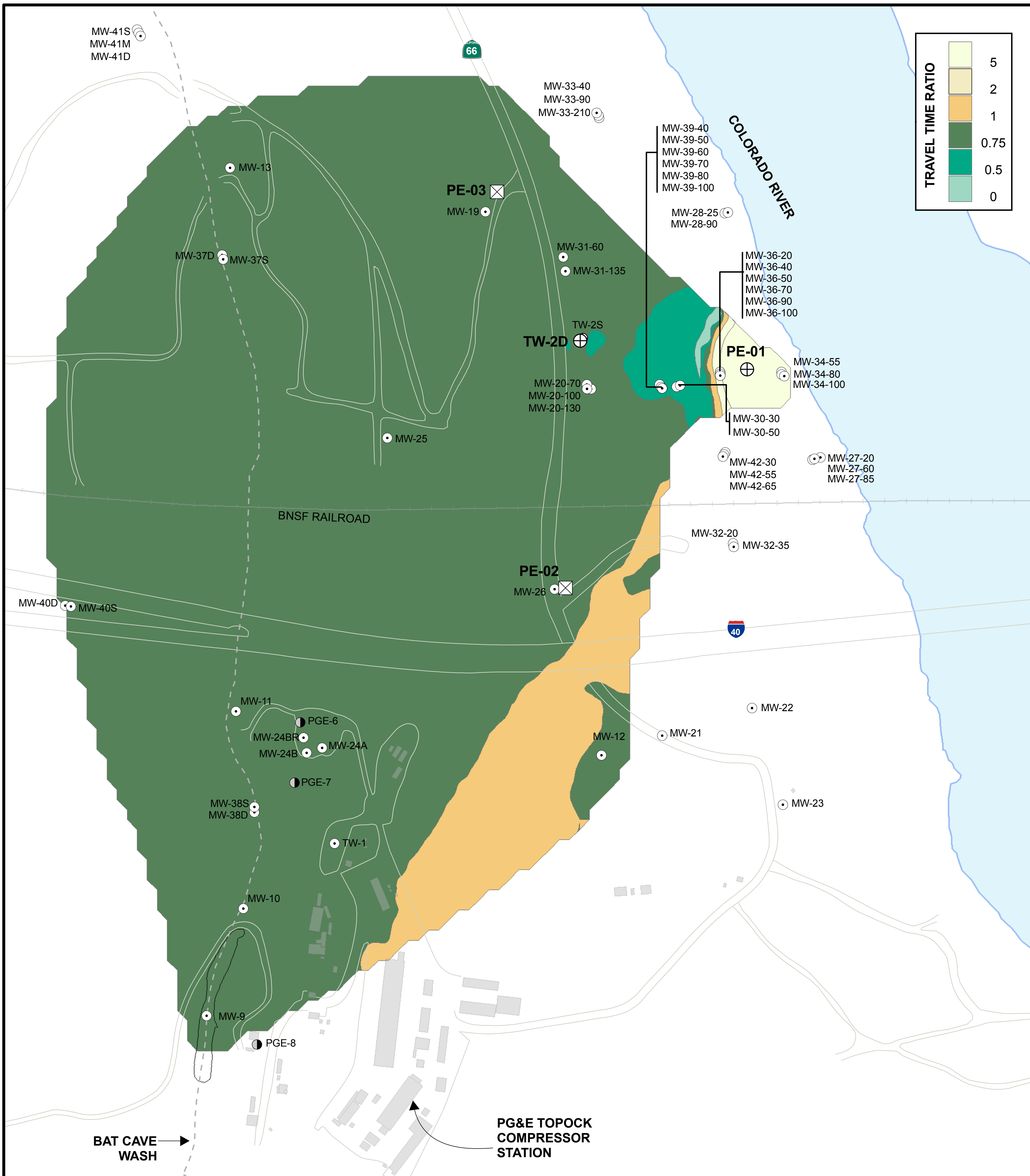

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N

0 300 600 feet

FIGURE 11
PUMPING SCENARIO 2:
TRAVEL TIME RATIOS – MODEL LAYER 3
NUMERICAL GROUNDWATER FLOW MODEL SIMULATION OF CURRENT AND PROPOSED INTERIM MEASURES EXTRACTION
PG&E TOPOCK FACILITY
NEEDLES, CALIFORNIA

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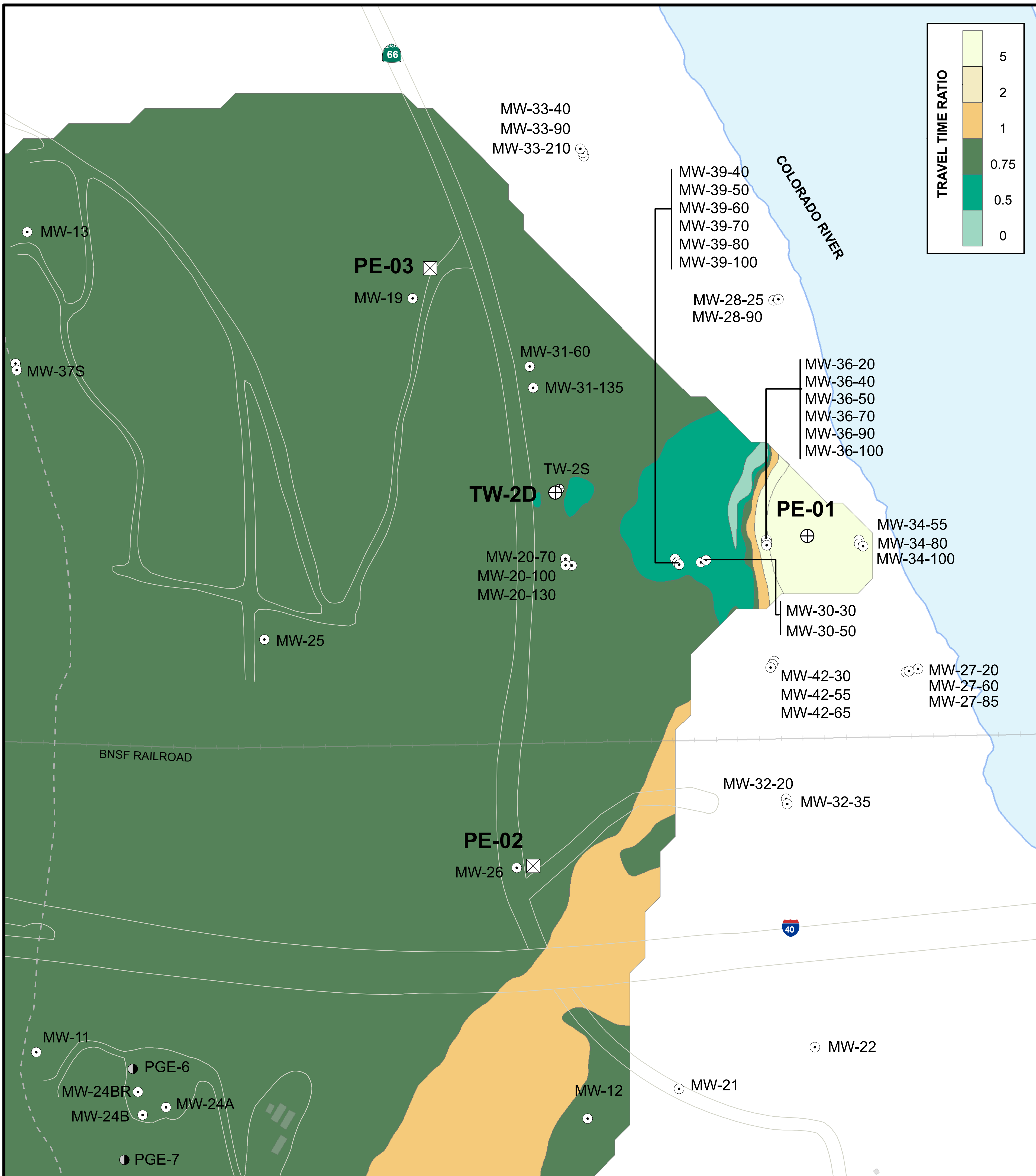

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0 200 400 feet

FIGURE 12
PUMPING SCENARIO 2:
TRAVEL TIME RATIOS – MODEL LAYER 3
DETAILED AREA
NUMERICAL GROUNDWATER FLOW MODEL SIMULATION OF CURRENT AND PROPOSED INTERIM MEASURES EXTRACTION
PG&E TOPOCK FACILITY
NEEDLES, CALIFORNIA

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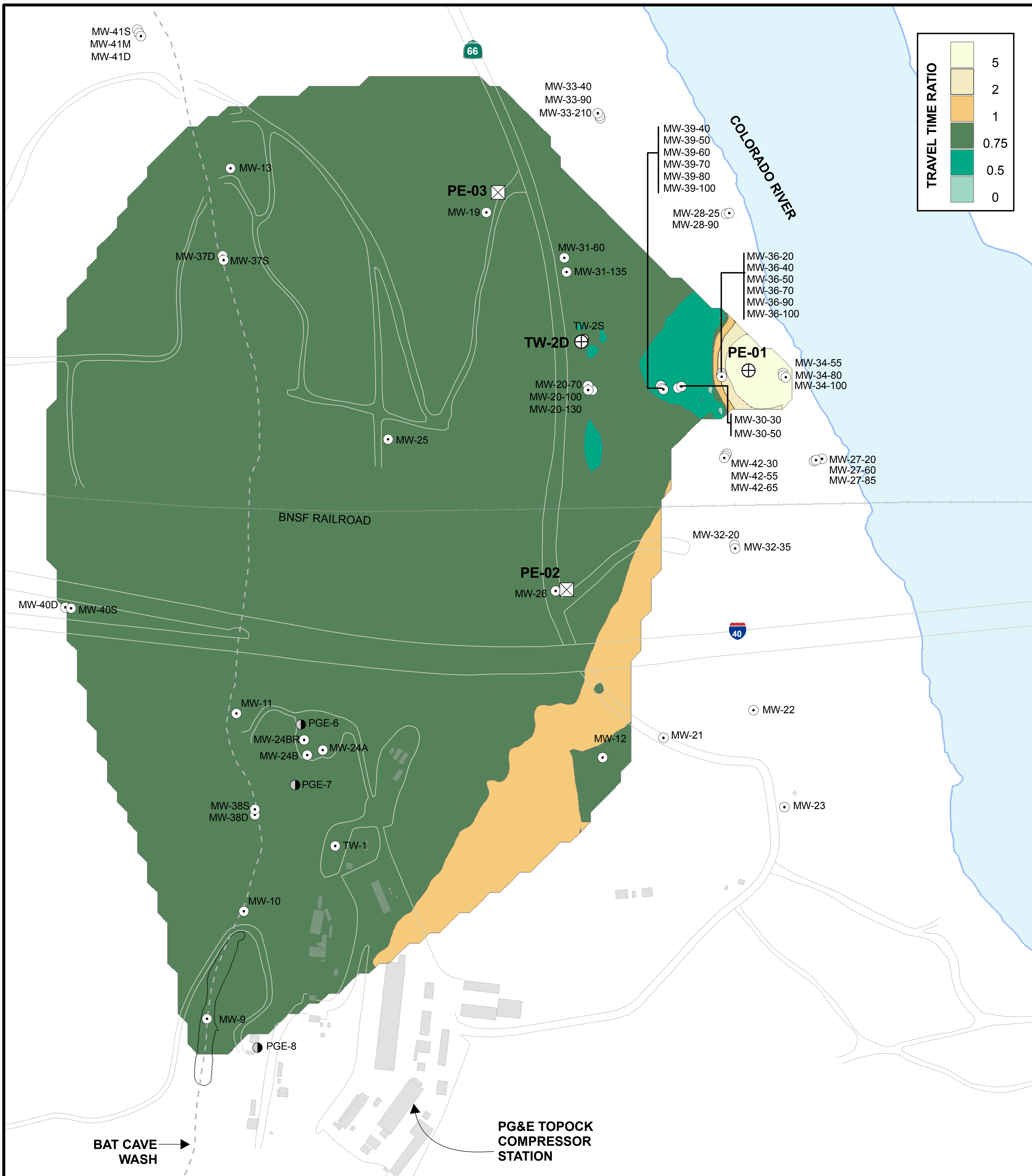

LEGEND

- POTENTIAL EXTRACTION WELL
- EXTRACTION WELL
- ACTIVE MONITORING WELL
- INJECTION WELL
- SURFACE WATER MONITORING STATION
- WATER SUPPLY WELL
- INACTIVE WELL

NOTES:

1. RATIOS COMPARE TRAVEL TIMES TO A WELL UNDER TWO SIMULATED CONDITIONS:
   (A) TW-2D PUMPING AT 90 gpm ALONE AND
   (B) TW-2D PUMPING AT 70 gpm AND PE-1 PUMPING AT 20 gpm.
2. IN EACH SCENARIO, IW-2 SIMULATED INJECTION WAS 67.5 gpm.
3. RATIO VALUES GREATER THAN 1 INDICATE AREAS WHERE PE-1 PUMPING ACCELERATES CAPTURE; VALUES LESS THAN 1 INDICATE SLOWED CAPTURE COMPARED TO TW-2D PUMPING ALONE.

FIGURE 13
PUMPING SCENARIO 2:
TRAVEL TIME RATIOS – MODEL LAYER 4
NUMERICAL GROUNDWATER FLOW MODEL SIMULATION OF CURRENT AND PROPOSED INTERIM MEASURES EXTRACTION
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Attachment A

Attachment A

Modeling of the June 2005 shutdown of TW-2D

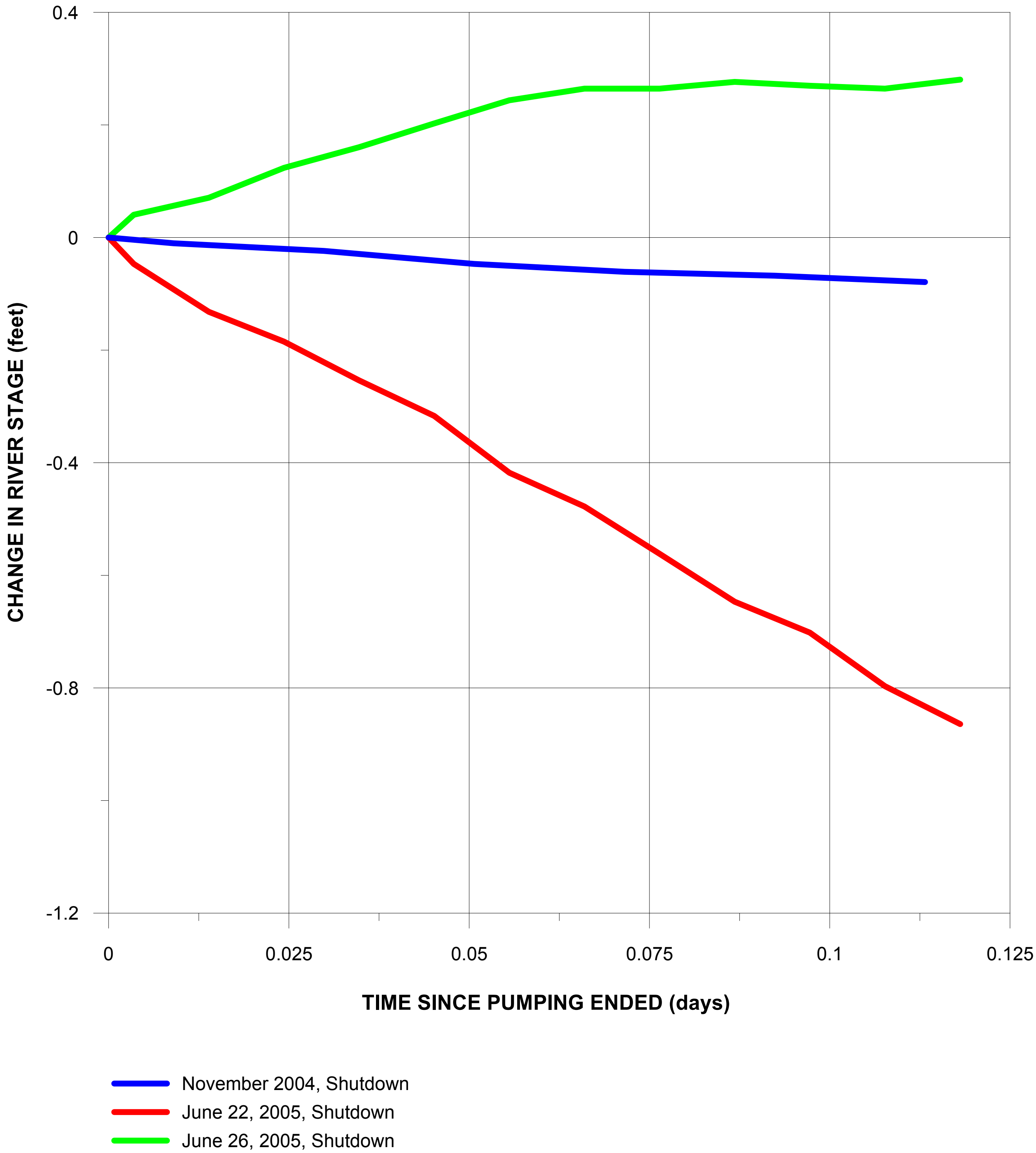
Extraction Well TW-2D was temporarily shut down on June 25, 2005 in order to exchange the existing pump for one of higher capacity. Since several new wells had been installed since the last planned shutdown during November 2004, data from the June 2005 shutdowns were examined to see if a better data set was obtained and also to see if the model could accurately replicate the recovery of groundwater levels caused by cessation of pumping.

Analysis of groundwater level data from the floodplain area is complicated by the changes in river stage of over several feet per day, much greater in magnitude than drawdown caused by pumping at TW-2D. The first shutdown of TW-2D occurred on June 22, 2005. However, this happened during a period of rapid changes in the river stage. The Colorado River stage fell by approximately 1 foot during the first three hours after the pump went off. This dramatic change in river stage caused difficulties in discerning the change in groundwater levels due to recovery from the much larger changes in groundwater levels due to changes in river stage. The second shutdown of TW-2D occurred during the early morning hours of June 26, 2005 when a power surge caused by lightning destroyed the electric motor of the TW-2D pump. After this shutdown, the change in river stage was about 0.3 feet in the first 90 minutes and then the river stage was approximately stable for the next 90 minutes. Although this June 26 shutdown occurred at a time when the river was changing less than during the June 22 shutdown, neither of these shutdowns occurred during a period when the river was as stable as it was during the November shutdown. Comparison of the change in river stage during these three periods is shown on Attachment A-1.

Although the data from the June 2005 shutdowns are not as "clean" as the November data because of the changing river stages, the model was run for the June 26th shutdown to see how well the model replicated the change in groundwater level at key wells throughout the floodplain. Changes in river stage were also input to the model. The results of this model run are presented in Attachment A-2. For many of the wells, the model tends to underestimate the measured change in groundwater levels after the cessation of pumping. This is most likely due to the effects of the changes in river stage that occurred before the beginning of the model run. Changes in groundwater levels due to prior changes in groundwater level were not included in the model. The model significantly under predicts the response in the MW-43 cluster. This cluster did not exist during the November shutdown. The response of this well to pumping may be greater than predicted by the model so it suggests that additional model calibration would be needed in this area.

Conclusions

1. The November 2004 dataset is of higher quality than the June 2005 dataset.
2. The model tends to under predict the effects of pumping, so that the capture zone predicted by the model would be smaller than the actual capture zone. In this sense, the model is conservative.
3. Additional model calibration may be warranted in the vicinity of well MW-43.



ATTACHMENT A-1
CHANGE IN I-3 RIVER STAGE AFTER TW2D TEMPORARILY CEASED PUMPING JUNE 2005 AND NOVEMBER 2004

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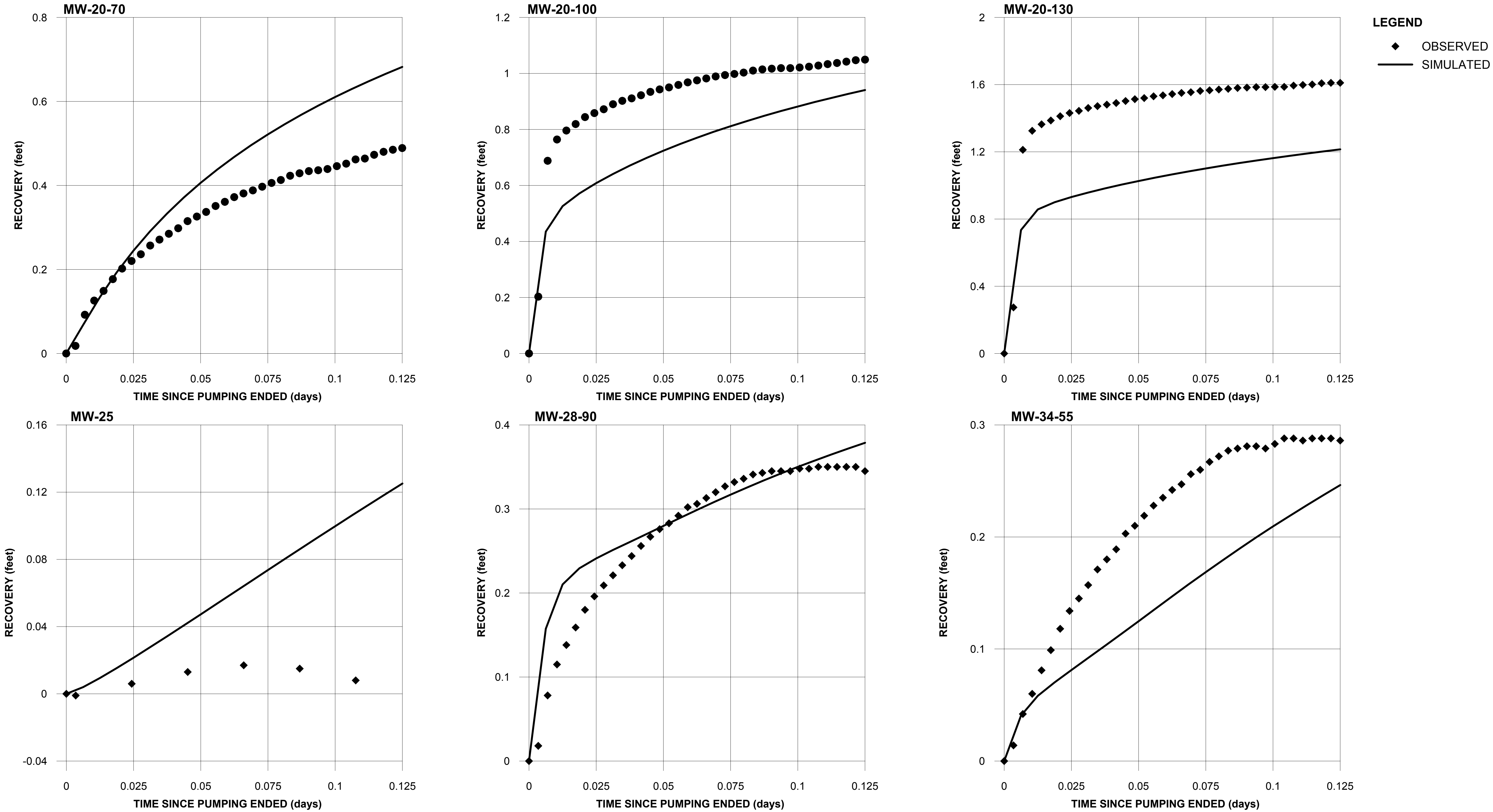

ATTACHMENT A-2 (Page 1 of 5)
COMPARISON OF OBSERVED AND SIMULATED RECOVERY AFTER TW-2D TEMPORARILY CEASED PUMPING, JUNE 2005

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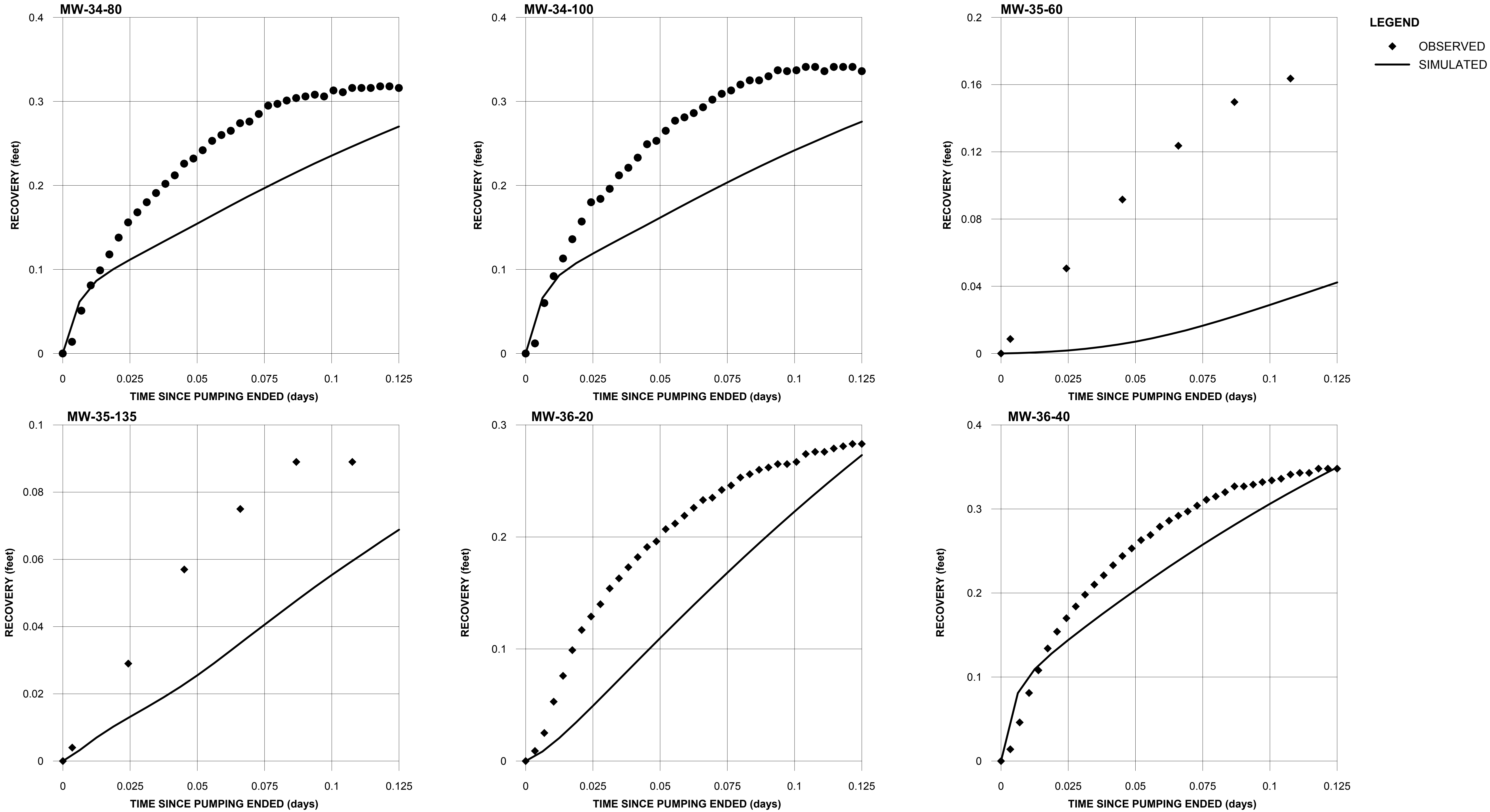

ATTACHMENT A-2 (Page 2 of 5)
COMPARISON OF OBSERVED AND SIMULATED RECOVERY AFTER TW-2D TEMPORARILY CEASED PUMPING, JUNE 2005

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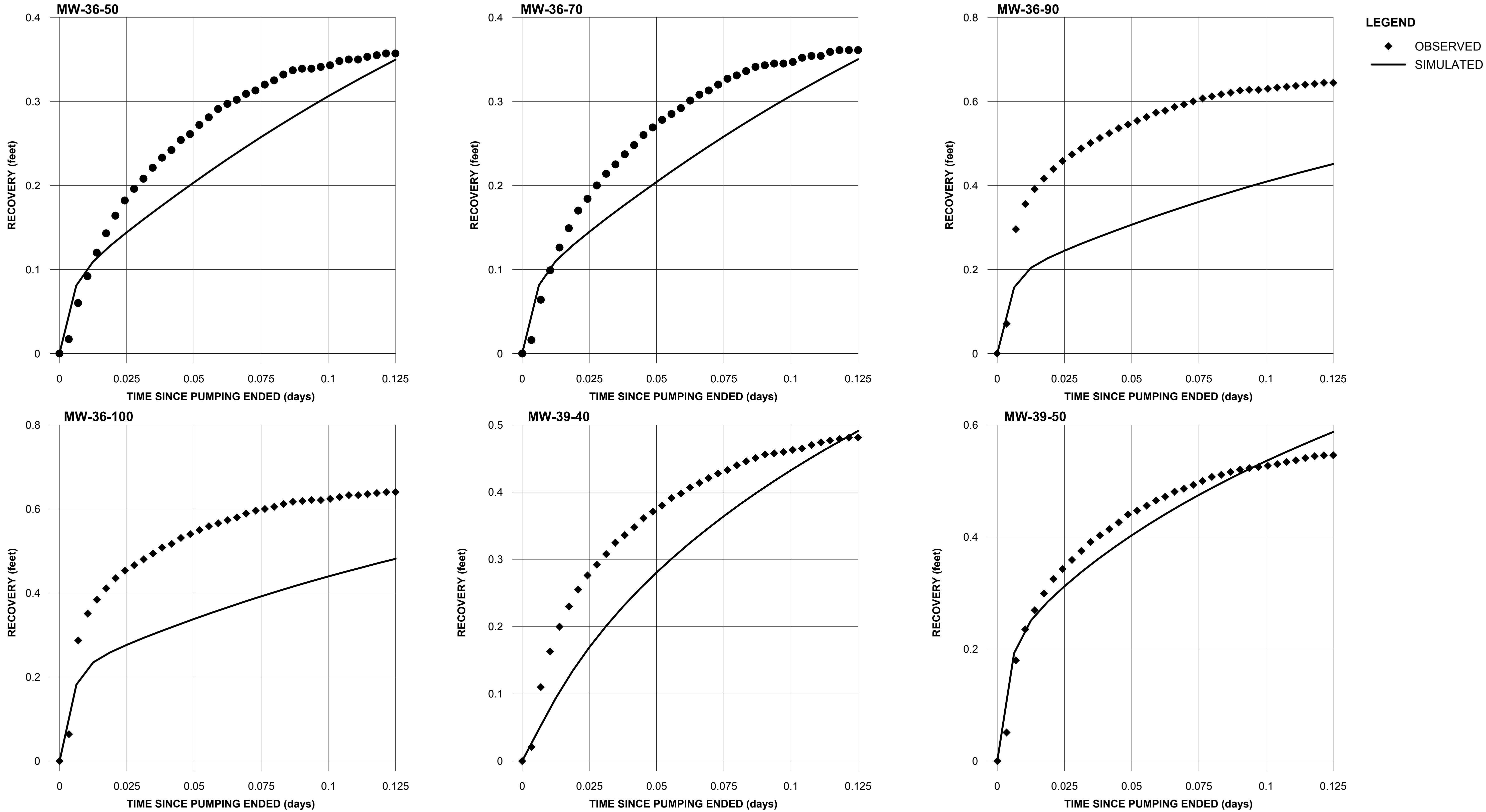

ATTACHMENT A-2 (Page 3 of 5)
COMPARISON OF OBSERVED AND SIMULATED RECOVERY AFTER TW-2D TEMPORARILY CEASED PUMPING, JUNE 2005

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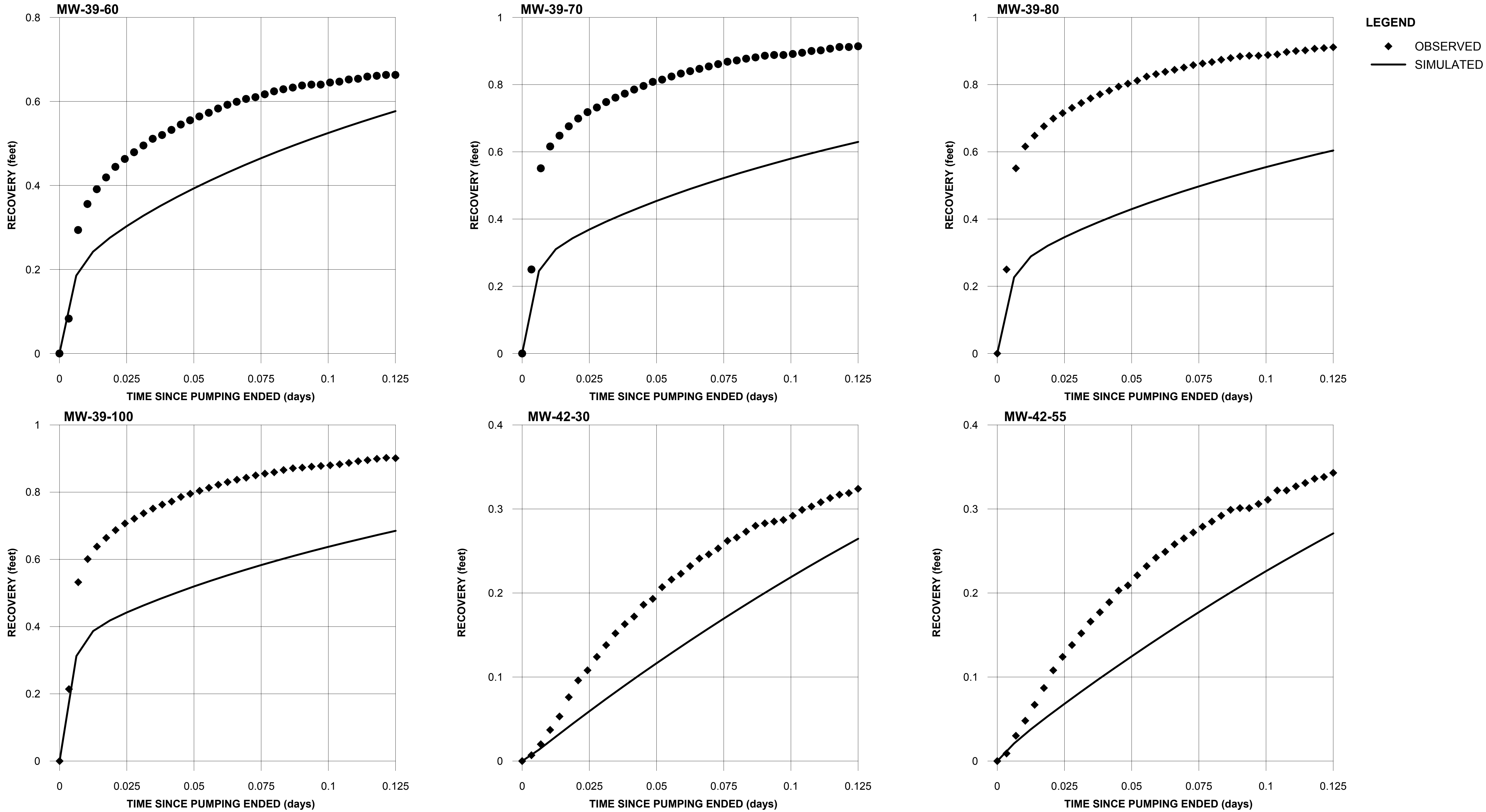

ATTACHMENT A-2 (Page 4 of 5)
COMPARISON OF OBSERVED AND SIMULATED RECOVERY AFTER TW-2D TEMPORARILY CEASED PUMPING, JUNE 2005

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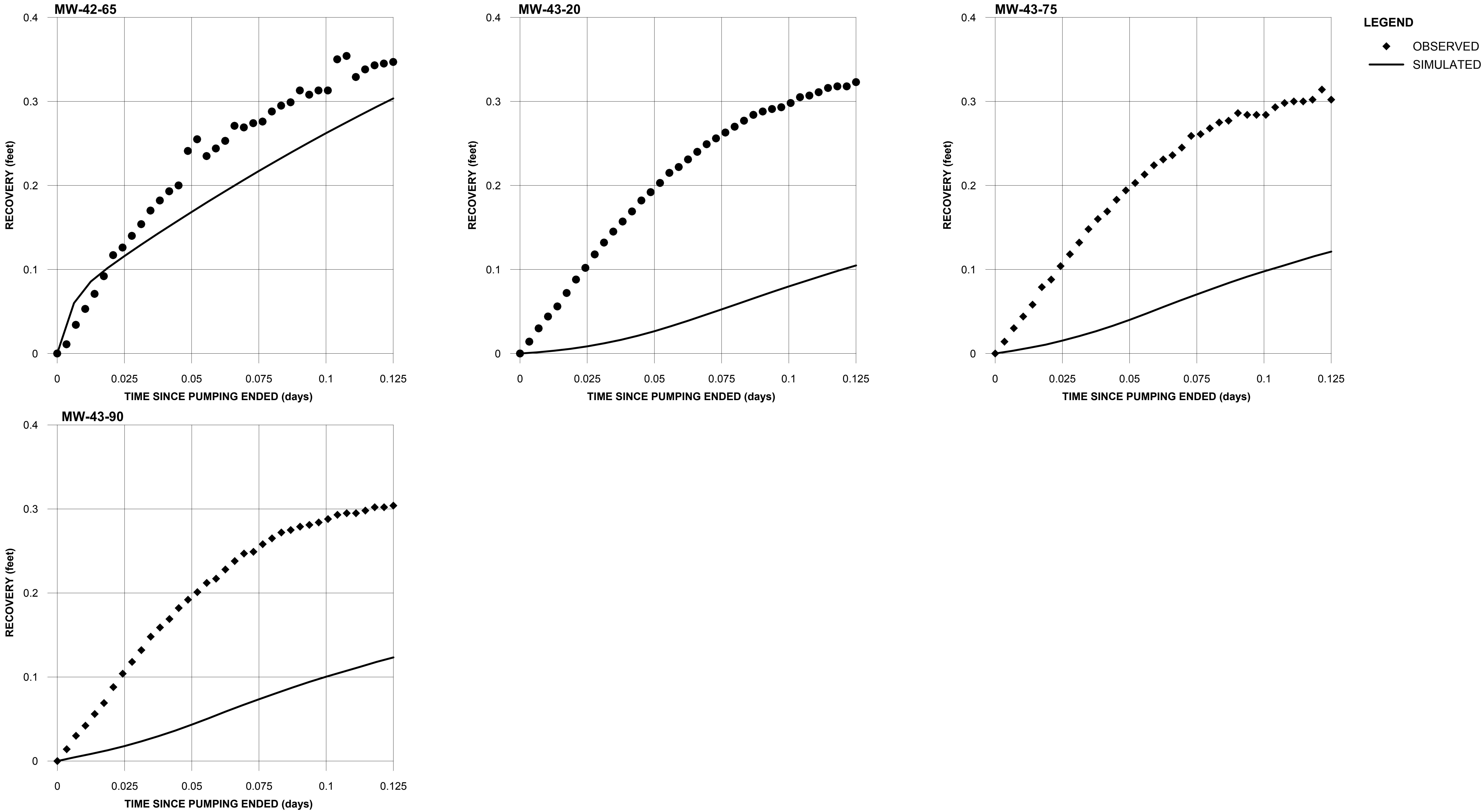

ATTACHMENT A-2 (Page 5 of 5)
COMPARISON OF OBSERVED AND SIMULATED RECOVERY AFTER TW-2D TEMPORARILY CEASED PUMPING, JUNE 2005
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