Cumulative Effects Analysis Groundwater Modeling Study

Grant Creek-Mullan Road Area,
Missoula, Montana

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1.0 INTRODUCTION

This report presents the results of a groundwater modeling study of the Grant Creek area of Missoula completed by NewFields Companies LLC (NewFields) for the City of Missoula. NewFields developed a numerical groundwater flow model and used it to evaluate potential cumulative effects using sumps to manage storm water within the Study Area.

A number of recent subdivisions in the study area have proposed sumps to manage storm water. In addition, the City is evaluating storm water management for areas of future development as part of the Mullan BUILID Project. The City is interested in the cumulative effects of using sumps to manage stormwater for future development areas within the Study Area.

The Study Area includes the Grant Creek drainage from Interstate 90 south to the Clark Fork River (**Figure 1-1**). The area extends from just west of Grant Creek to east of Reserve Street. The Study Area includes Grant Creek, the Flynn-Lowney Ditch system, and areas of existing and proposed land development and subdivisions.

1.1 BACKGROUND

Flooding in 1997 near the Mullan Trails Estates subdivision prompted Missoula County and others to re-examine Grant Creek area flood risk. Groundwater flow models were developed by RLK Hydro, Inc. (RLK, 1999) and Land and Water Consulting, Inc. (Land and Water, 1999b) to evaluate the causes of the flooding and identify potential mitigation measures. In 2001, a dewatering system to control seasonal high groundwater levels was installed at the Mullan Trails Estates subdivision (RLK, 2000, 2001) and remains in operation.

In 2005, a study was completed to support an environmental restoration and flood control project for Grant Creek (HDR/Maxim 2005a). The study included a hydrogeologic investigation and the development of a numerical groundwater flow model of the shallow aquifer in the Grant Creek Area.

A flood control design report was also completed in 2005 (HDR/Maxim 2005b) that detailed measures that were ultimately adopted to mitigate flooding along Grant Creek. These measures included installation of a peak flow bypass for the lower portion of the creek, creek realignment, bank stabilization, and the development of an engineered floodplain within the flood prone area.

Subsequent groundwater modeling efforts have been completed in the Grant Creek area for proposed subdivisions. Studies for 44 Ranch (Geomatrix, 2006), Valley (Geomatrix, 2008) subdivisions evaluated the potential for basement flooding associated with seasonal high-water conditions and Grant Creek flooding. Studies for Heron's Landing (NewFields, 2019a and 2020a), Remington Flats (NewFields 2019b), and McNett Flats (NewFields, 2020b) subdivisions evaluated the effects of stormwater sumps on groundwater elevations. These studies did not evaluate the cumulative effect of using sumps for storm water management in the Grant Creek- Mullan Road area.

1.2 Project Objectives

The objectives of this modeling study consist of the following:

- Develop a groundwater flow model of the Grant Creek area that includes newer data and incorporates greater detail than previous modeling efforts;
- Calibrate the model to 2020 groundwater conditions and complete a sensitivity analysis;
- Use the groundwater flow model to simulate cumulative effects use of sumps to manage stormwater for existing and future (full buildout) development;
- Complete simulations pairing 2-year and 100-year Grant Creek flooding events with 2-year and 100-year storm discharge into the sumps; and
- Evaluate the potential impacts of removing the Flynn-Lowney Ditch system on groundwater levels.

1.3 Report Organization

This report is organized into the following sections:

- Hydrogeologic Setting
- Groundwater Model Construction and Calibration
- Predictive Simulations
- Conclusions

2.0 CONCEPTUAL MODEL

HDR/Maxim (2005a) described the conceptual model of the shallow groundwater system within the Study Area. **Figure 2-1** is a block model illustrating the conceptual model. Elements of the conceptual model are described below.

2.1 Precipitation and Areal Recharge

The climate of the Study Area is classified as semi-arid. Data from a weather station at the Missoula International Airport indicates that the average annual precipitation for 2007 to 2019 is 14.13 inches (**Appendix A**, **Figure A-1**). May and June typically see the greatest amount of rainfall. Average maximum temperatures of about 85°F occur in July and August.

Areal recharge from precipitation in the Study Area is a function of the amount of rainfall and land use. To estimate areal recharge for this study, land use was simplified into four categories: densely developed, lightly developed, undeveloped, and irrigated based on aerial imagery interpretation. Calculations of the amount of infiltration for each of these categories for the model stress periods in 2020 is summarized in **Appendix A** (**Table A-1**), and maps of the areas covered by each category are presented in the modeling section (**Appendix E**). Infiltration for densely developed, lightly developed, and undeveloped assume a percent of precipitation of 2%, 5%, and 8%, respectively.

To calculate infiltration from irrigation, alfalfa was used as the typical crop and monthly irrigation water requirements (IWR) were obtained for the Missoula airport. The monthly IWR was used to develop the table of monthly groundwater recharge values for irrigated land presented in **Appendix A**. The calculated groundwater recharge assumes a consumptive use percentage of the applied water that varies based on temperature.

2.2 Surface Water

2.2.1 Grant Creek

Grant Creek is a tributary of the Clark Fork River with a drainage area of approximately 25 square miles (HDR/Maxim, 2005c). Grant Creek drains the southern portion of the Rattlesnake mountains and Rattlesnake Wilderness. As Grant Creek flows out of the Grant Creek Valley into the Missoula Valley South of Interstate 90 it flows over coarse alluvial fan sediments. During beginning in late summer, the reach between I-90 and West Broadway dries up as streamflow infiltrates to shallow groundwater. During typical summer conditions, flow resumes in the streambed near the Hiawatha Road crossing and ultimately drains to the Clark Fork River. In addition to groundwater natural baseflow to the creek, waste flow from the Fynn-Lowney discharges to the creek immediately upstream of the Hiawatha Trestle bridge crossing.

Grant Creek flow and stage measurements have been recorded sporadically since the 1997 flooding. Stage and flow measurements were reported by Land and Water (1999a) a few of which were summarized by HDR/Maxim (2005c) and are included in **Appendix A** (**Table A-2**). HDR/Maxim (2005a) installed several staff gages and reported measured stage values, but these were not presented as elevations and no flow measurements were reported.

HDR/Maxim conducted surface water modeling to predict Grant Creek flows (HDR/Maxim, 2005c). Results of the surface water modeling are included in **Appendix A** (**Table A-3 and A-4**). HDR/Maxim predicted 2-year recurrence interval flows at I-90 and the confluence with the Clark Fork River of 213 and 255 cfs respectively, and 100-year recurrence interval flows at those two locations of 738 and 884 cfs. The maximum measured flow in 2020 (June 2) at the Highlander station (location shown on **Figure A-2**) is 163 cfs or approximately equal to the 2-year peak flow reported by HDR/Maxim, although 2020 flows could have been higher prior to the June 2 measurement.

Grant Creek stage measurements in most cases have not been translated to elevations, which limits the usefulness of the data, but for years where multiple measurements are available a typical creek rise can be inferred from the data. In 2004 HDR/Maxim (2005a) recorded a series of stage readings at 10 locations (**Appendix A**, **Table A-5**). For that year the total seasonal increase in stage for stations within the Study Area ranged from 0.6 to 1.9 feet. Also, in 2004, HDR/Maxim (2005c) conducted an evaluation of high-water marks along Grant Creek and found high water marks were typically 2-3 ft above baseflow stage.

The Missoula County Water Quality District (WQD) monitored flow and stage at four monitoring locations along Grant Creek between June and August 2020 (**Appendix A**, **Figure A-2**). Between the Highlander Brewery and West Broadway stations, Grant Creek lost between 3.3 and 19 cfs, with an average loss of 8.6 cfs (**Appendix A**, **Table A-6 and A-7**). In Early June, Grant Creek lost between 15.3 and 51.3 cfs from West Broadway to Mullan Trail, although only two comparable measurements are available. The creek loss from West Broadway to Mullan Trails is likely even greater because it does not take into account water entering the creek from the waste ditch along Hiawatha and the ditch laterals upstream from there.

2.2.2 Flynn-Lowney Ditch

The Flynn-Lowney Ditch system consists of a main ditch with laterals and waste ditches that route water to Grant Creek. The ditch rider has indicated the headgates are typically opened by May 1 and closed in late October. He noted that this year (2020) there was already water in the ditch when the headgates were opened.

There are no known flow or seepage measurements for the ditch system, which makes it difficult to estimate the seepage into the groundwater system. Data from irrigation ditches in and around the West Side Ditch along the upper Clark Fork River (**Appendix A**, **Table A-8**) suggest an average seepage rate of 1.34 cfs/mi, with a range of 0.6 to 2.1 cfs/mi (NewFields, 2016), which in the absence of other data is a reasonable estimate for Flynn-Lowney.

2.3 Hydrogeologic Setting

The Study Area is underlain by a shallow groundwater system that is hydrologically isolated from the deeper regional flow system as shown on **Figure 2-1** (HDR/Maxim 2005a). The Missoula Aquifer is a highly conductive, unconfined, shallow sand and gravel aquifer. Municipal supply wells completed in the Missoula Aquifer commonly produce several thousand gallons of water per minute. The primary Missoula Aquifer delineated by Clark (1986) is within the Quaternary-age valley fill and possibly the Sixmile Creek

Equivalent. The saturated aquifer thickness commonly ranges from 50 to 120 feet (Woessner 1988). Morgan (1986) describes three hydrostratigraphic units of the Missoula Aquifer:

- Unit I: upper coarse-grained unit comprised of boulders, cobbles, gravels, sand, and some clay, ranging from I0 to 30 feet thick;
- Unit 2: silty sandy clay with coarse sand and gravel averaging 40 feet thick in the center of the valley; and
- Unit 3: lower unit, consisting of interbedded gravel, sand, silt, and clay; coarsens toward the bottom; thickness varies from 50 to 100 feet.

HDR/Maxim (2005a) divided the groundwater system into two major water-bearing zones: shallow local aquifer and deeper regional Missoula Aquifer. The regional Missoula Aquifer underlies the shallow aquifer, with the two being separated by a thick sequence of fine-grained sediments.

The hydrostratigraphy encountered in the Study Area generally agrees with the sequences described above, with the exception that the material corresponding to the shallowest unit (upper portion of Unit 1) in places is comprised of clay with very little sand and no gravel (see **Section 2.4**). The unit separating the shallow aquifer from the Missoula Aquifer (Unit 2) appears a competent confining unit within the Study Area except in a portion of the area near West Broadway.

Leakage to the regional aquifer appears to occur in a small area immediately south of Broadway Avenue. HDR/Maxim (2005a) describe the reasoning for this leakage as follows:

> *[leakage occurs at] this location for two reasons fine-grained materials were not encountered while drilling MMW-8 to a depth of 50 feet bgs, and selected potentiometric maps indicate a conspicuously flat hydraulic gradient in this area, relative to other portions of the model domain. These observations suggest that the fine-grained material which acts as the base of the shallow sand and gravel aquifer elsewhere in the area may be absent in this location*

2.3.1 Groundwater Flow

Groundwater flow within the Study Area in the shallow aquifer is from Northeast to Southwest. **Figure 2-2** and **Figure 2-3** are potentiometric surface maps for the shallow groundwater system based on March 2004 and March 2020 data, respectively. Groundwater levels measured from 2003-2005 (HDR/Maxim 2005c) provide the greatest spatial coverage of groundwater elevation data. The March 2020 data includes a mix of measurements from March 2020 and from March 2004 that were adjusted to represent 2020 conditions (see **Section 3.2.1** for a description of the adjusted measurements). **Figure 2-4** is a potentiometric surface map based on June 2005 data.

March 2004 and March 2020 data are representative of seasonal low groundwater levels. Groundwater levels in March 2020 were about 1.2 feet higher than in March 2004, but the pattern of flow for the two time periods is similar. June 2005 data are considered to be representative of a typical seasonal high groundwater condition.

Groundwater enters the local shallow aquifer as underflow from the Grant Creek Valley alluvium and bedrock north of the Study Area. Groundwater in the shallow aquifer eventually discharges to alluvium associated with the Clark Fork River and then into the river south and southwest of the Site (HDR/Maxim 2005a). Groundwater in the deeper regional aquifer generally flows east to west beneath the Site.

2.3.2 Monitoring Wells and Hydrographs

Groundwater levels have been measured intermittently within the Study Area, with the greatest number of wells being measured during 2004. The majority of wells measured in 2004 have since been abandoned or cannot be located.

A summary of monitoring wells within the Study Area and available water level data is included in **Appendix B** (**Table B-1**). In 2020 the WQD installed pressure transducers in several wells (WQD-3, WQD-44, MMW-1, MMW-3, MMW-4, MMW-8, MMW-11, and MMW-12). A hydrograph of the 2020 data for these wells is included in **Appendix B** (**Figure B-1**).

Wells WQD-3, WQD-4, WQD-9, and WQD-22 have the longest period of record of measurements, with most having data from 1996 to 2020, except for WQD-4, which was abandoned in 2008. Combined annual hydrographs from these wells are included in **Appendix B** (**Figure B-2** through **Figure B-4**). WQD-22 is at the same location as WQD-9 but is screened at slightly different depth and has an identical hydrograph that is not included.

The combined annual hydrographs for the WQD wells show that the lowest groundwater levels occur between January and March annually. Groundwater elevations begin to increase with the onset of spring runoff in April and peak in May-June before slow declining throughout the summer and fall. Peak groundwater levels for wells WQD-3 and WQD-9 for in 2020 are within the upper third of the period of record. Peak groundwater elevation in wells WQD-3, WQD-4, and WQD-9 in 2004 (the year previous models were calibrated to) tends to fall in the lower third. These data suggest that peak 2020 groundwater elevations are representative of at least a 2-year hydrologic event.

2.4 Shallow Soil and Aquifer Characteristics

2.4.1 Upper Soil

Previous modeling efforts (HDR/Maxim, 2005a; Geomatrix, 2006 and 2008; NewFields, 2019a, 2019b, 2020a, and 2020b) characterized the upper 10 to 14 feet of subsurface material as uniform fine-grained sediment, with localized adjustment of hydraulic properties to coarser grained material based on site-specific test pit data, where available. A more thorough evaluation was conducted within the Study Area to characterize the spatial nature of the shallow soils for this study.

Soil description data from a total of 88 borings, well logs, and test pits, many of which were completed since the 2005 studies, were compiled and are presented in **Appendix C** (**Table C-1**). Soil descriptions varied amongst the data points, but the soil types were able classified into four simplified groups for the upper 8-10 feet and for 10-14 feet. The four classifications range from mostly fine-grained material to mostly coarse-grained material, with assumed hydraulic conductivity (K) estimates based on material described by Morris and Johnson (1967).

Maps of the shallow soil K classifications and assumed K zones for the upper 8-10 feet and 10-14 feet depths are shown on **Figure C-1** and **Figure C-2**, respectively (**Appendix C**). The maps show that the upper

14 feet of material is mostly coarse- to medium-grained material in the southern portion of the Study Area (estimated K of 15 to 200 feet/day), with finer-grained material (K of 0.1 to 1 feet/day) mostly in the north west portion of the Study Area (Note the maps shown are from the groundwater flow model which is rotated slightly).

2.4.2 Shallow Aquifer

Table C-2 (**Appendix** C) lists estimates of hydraulic properties (K, T, and Storativity) in different portions of the Study Area based on available data and **Figure C-3** shows the location of wells used to provide the estimates. Estimates were derived from pumping tests at three wells, and T calculated from specific capacity derived from well log information. Aquifer properties derived from pumping tests are more accurate than those based on specific capacity; however, estimates based on specific capacity provide estimates of spatial variability in T.

Figure C-3 (**Appendix C**) show zones of generalized K based on average T data in **Table C-2**. Wells in **Table C-2** are organized by model hydraulic conductivity zones and are generally ordered from north to south. T of the shallow aquifer generally increases from north to south. In the northernmost part of the Study Area T is estimated to be 547 ft^2/d based on specific capacity data from five wells. South of the northernmost zone are two areas where T is estimated to be 3,609 ft^2/d (pumping test data) and further east T is estimated at 2,659 ft^2/d. Moving southward T increases to 6,595 ft^2/d (specific capacity data from six wells), and in the southernmost part of the Study Area the highest transmissivities occur averaging 24,942 ft^2/d.

2.5 Sumps and Stormwater Discharge Basins

Appendix D presents and evaluation of existing and future stormwater management in the Study Area and provides estimates of stormwater drainage for inputs to the numerical model. **Figure 1** in **Appendix D** shows the location sumps (dry wells), gravity mains, outfalls and detention basins currently used to manage stormwater in the Study Area. Stormwater management for future development is expected to include a combination of these features. **Figure 2** shows the assumed volume of water discharged through stormwater sumps within the Study Area under both a 2-year and 100-year storm event was estimated using available data from the City of Missoula. These calculations are summarized in a Technical Memorandum included as **Appendix D** and are summarized below.

The Master Plan Drainage Memo (IMEG, October 2020) identifies planned zoning areas with corresponding lot coverage (impervious areas) throughout the entire study area. The Master Plan Drainage Memo also provides estimated runoff values for all areas to be developed as part of the Mullan BUILD plan. While the estimates are not as detailed as the runoff rates provided for each of the planned developments discussed above, NewFields plans to use the results provided in the Memo because each area was assessed using a consistent hydrologic methodology (TR-55 – SCS Curve Number Method). The estimated runoff volumes used to provide model inputs are provided in **Table 1** of **Appendix D**, and **t**he planned development basin locations are shown in **Figure 2** of **Appendix D**. Within each basin the total discharge to groundwater was estimated for a 2-year and 100-year stormwater discharge event. These estimated discharges are used in the groundwater flow model predictive scenarios discussed in **Section 4**.

2.6 Groundwater Balance

A groundwater balance summarizing water inputs and outputs was developed for the conceptual model of the site. Estimates were made using the best available information, with maximum and minimum values included to allow for uncertainty. The groundwater budget was developed for peak seasonal flow conditions.

The groundwater balance can be expressed by the following equation, based on significant sources of groundwater recharge and groundwater discharge at the site:

$$GW_{in} + GCS + DS + INF + IR = GW_{out} + LKG + MTD$$

Where:

GW_{in}	=	*groundwater underflow from upgradient of the Study Area*
GCS	=	*Grant Creek seepage*
DS	=	*Flynn-Lowney ditch seepage*
INF	=	*infiltrating recharge from precipitation*
IR	=	*recharge from irrigation*
GW_{out}	=	*groundwater underflow leaving the Study Area to the south*
LKG	=	*groundwater leakage to the regional Missoula Aquifer*
MTD	=	*groundwater removed by drains at Mullan Trails Estates*

In order to quantify the water balance, a domain must be established, which is shown on **Figure 1-1**. The domain was established in order meet requirements of the groundwater flow model (as described below). In general, the model domain margins are designed to run either perpendicular or parallel to groundwater flow. Ranges of estimated flow rates for each component of the groundwater budget are presented in **Table 2-1**. Note that because ranges are calculated and presented for each component, and there is some degree of uncertainty for each the total inflows do not match the total outflows for each column. The following subsections described how the estimates were developed using available data.

Table 2-1. Groundwater Balance – Peak Flow Conditions

Component	Two-Year Seasonal High Water Level (2020) Flow (ft3/d)		
	Min	Max	Estimate
Inflow			
Underflow In	50,686	102,369	76,796
Upper Grant Creek	649,440	1,692,480	979,364
Lower Grant Creek	105,600	212,800	160,000
Flynn-Lowney Ditch	208,538	752,858	473,629
Recharge from Precipitation	5,354	10,790	8,113
Recharge from Irrigation	15,282	30,796	23,155
Total In	1,034,900	2,802,094	1,721,057
Outflow			
Underflow Out	173,835	386,204	289,725
Leakage to Regional Aquifer	246,840	498,542	374,000
Mullan Trails Drains	0	656,640	43,200
Total Out	420,675	1,541,386	706,925

2.6.1 Inflows

Underflow In

Underflow was calculated using Darcy's Law.

$$Q = KiA$$

Where: Q = *flux*
K = *Hydraulic Conductivity*
i = *Hydraulic Gradient*
A = *Cross Sectional Area*

The cross-sectional area used lies in the northern portion of the Study area. Groundwater enters the Study Area along a line about 5,800 feet in length, and the thickness of the shallow aquifer in this part of the Study Area is estimated to be 55 feet. Hydraulic conductivity of the shallow aquifer in the northern part of the Study Area is estimated to be 10 ft/d based on previous model calibration efforts. The average hydraulic gradient is estimated at 0.024 (**Figure 2-3**).

The estimated underflow in is calculated to be 76,796 ft^3/d. Minimum and maximum rates are assumed to be 50,686 ft^3/d (66% of the estimated value) and 102,369 ft^3/d (133% of the estimated value).

Upper Grant Creek Seepage

Seepage in upper Grant Creek portion of the creek adjacent to and upstream of West Broadway) was calculated using the following formula:

$$Q = L * CL$$

Where:	*Q*	=	*flux*
	L	=	*Creek Length*
	CL	=	*Creek Loss (rate per unit length)*

Creek Loss is estimated based on creek loss measurements from 2020 (see **Appendix A**, **Table A-7**). The minimum measured loss of 3.3 cfs equates to 4.8 cfs/mi. Total length of upper Grant Creek in the Study Area is 1.55 mi, which results in a minimum seepage rate of 649,440 ft^3/d.

The two highest measured steam flow losses of 19 and 12.8 cfs represent high-flow conditions only. Average measured creek losses (8.6 cfs or 12.6 cfs/mi) were used to calculate the maximum value which results in a maximum seepage rate of 1,692,480 ft^3/d.

For the estimated seepage rate, the average measured loss (8.6 cfs or 12.6 cfs/mi) was used for the measured stretch of the creek. Above that stretch creek loss appears to be lower so a rate 25% of the measured section was used, resulting in an estimated creek loss of 979,364 ft^3/d.

Lower Grant Creek Seepage

Seepage from the lower portion of Grant Creek (downstream of West Broadway) was calculated by using Darcy's Law (see Undeflow In). Total length of the creek is 20,000 feet, and assuming a width of 2 ft this equates to an area of 40,000 ft^2. Assuming a riverbed K of 4 ft/d and gradient of 1, the estimated seepage for lower Grant Creek is calculated to be 160,000 ft^3/d. Minimum and maximum rates are assumed to be 105,600 ft^3/d (66% of the estimated value) and 212,800 ft^3/d (133% of the estimated value).

Flynn-Lowney Ditch Seepage

Seepage from the Flynn-Lowney ditch system was calculated using the same formula used for Upper Grant Creek Seepage. No measured seepage rates for the ditch were found so rates from other ditches were used (see **Appendix A**, **Table A-8**).

The length of the Flynn-Lowney Ditch system in the Study Area is 4.09 miles. Using the average seepage rate per mile from **Table A-8** (1.34 cfs/mi) an estimated seepage rate of 473,629 ft^3/d is calculated. The minimum seepage rate from **Table A-8** (0.59 cfs/mi) results in a minimum seepage rate of 208,538 ft^3/d. The maximum seepage rate from **Table A-8** (2.13 cfs/mi) leads to a maximum seepage rate of 752,858 ft^3/d.

Areal Recharge

Recharge from precipitation was calculated using the information presented in **Appendix A**, **Table A-1** for the first week in June and a total of 192,960,000 ft^2 for the Study Area. The area was simplified into four land use categories consisting of densely developed, lightly developed, undeveloped, and irrigated. Because these are simplified categories that represent large areas the percent of recharge from precipitation is a rough approximation. The three land use categories, other than irrigation, were calculated as follows:

- Densely developed land is estimated to occupy about 42% of the Study Area, and recharge is assumed to be 2% of precipitation, which results in an infiltration of 1,737 ft^3/d;
- Lightly developed land is estimated to occupy about 8% of the Study Area, and recharge is assumed to be 5% of precipitation, which results in an infiltration of 827 ft^3/d; and
- Undeveloped land is estimated to occupy about 39% of the Study Area, and recharge is assumed to be 8% of precipitation, which results in an infiltration of 6,450 ft^3/d.

The total estimated recharge from the three land use categories is 8,113 ft^3/d. Minimum and maximum rates are assumed to be 5,354 ft^3/d (66% of the estimated value) and 10,790 ft^3/d (133% of the estimated value).

Recharge from Irrigation

Recharge from irrigation was calculated in a similar manner to that for recharge from precipitation. Irrigated land is estimated to occupy 8% of the Study Area. A return rate of 1.5E-3 ft/d (**Appendix A**, **Table A-1**) was calculated for the first week in June, which equates to an estimated recharge rate from irrigation of 23,155 ft^3/d. Minimum and maximum rates are assumed to be 15,282 ft^3/d (66% of the estimated value) and 30,796 ft^3/d (133% of the estimated value).

2.6.2 Outflows

Underflow Out

Underflow was calculated using Darcy's Law (see Underflow In). The cross-sectional area used lies in the southern portion of the Study area. Groundwater enters the Study Area along a line about 4,400 feet in length, and the thickness of the shallow aquifer in this part of the Study Area is estimated to be 28 feet. Hydraulic conductivity of the shallow aquifer in the southern part of the Study Area is estimated to be 900 ft/d based on previous model calibration efforts. The average hydraulic gradient is estimated at 0.0026 (**Figure 2-3**).

The estimated underflow in is calculated to be 289,725 ft^3/d. Minimum and maximum rates are assumed to be 173,835 ft^3/d (60% of the estimated value) and 386,204 ft^3/d (133% of the estimated value).

Leakage to Regional Aquifer

Leakage from the shallow aquifer to the regional Missoula aquifer is assumed to occur in a small area south of West Broadway (see **Section 2.3**). Leakage was also calculated using the following formula:

$$Q = Cond * i$$

Where: Q = *flux*

i = *Hydraulic Gradient*

$Cond$ = *Conductance Term (Area * K / Thickness)*

The area of leakage is roughly 440,000 ft^2. Hydraulic conductivity of the area of leakage is estimated to be 0.5 ft/d, or similar to a silty-sand. Thickness is assumed to be 10 feet. This results in a conductance term of 22,000 ft^2/d.

The hydraulic gradient is estimated at 14.5 feet. This represents the difference between groundwater elevation (from **Figure 2-2**) and the elevation of the fine-grained material through which the water seeps into the regional aquifer. The fine-grained material elevation is based on the material described on the log for well MMW-8 at a depth of 45 feet (3,128 ft MSL).

The estimated leakage to the regional aquifer is calculated to be 374,000 ft^3/d. Minimum and maximum rates are assumed to be 246,840 ft^3/d (66% of the estimated value) and 498,542 ft^3/d (133% of the estimated value).

Mullan Trails Estates Drains

In 2001, a dewatering system to control seasonal high groundwater levels was installed at the Mullan Trails Estates subdivision (RLK, 2000, 2001). Groundwater removed by the drains at Mullan Trails Estates likely varies depending on seasonal maximum water table elevations in the area.

It appears the drain system operates during spring runoff in most years, based on anecdotal evidence, but the rates are unknown. Years when the water table remains below the drains the flow is 0 ft^3/d so that can be considered the minimum rate. The system is designed with a capacity of 7.6 cfs (656,640 ft^3/d) which would be the maximum. An estimated rate of 0.5 cfs was assumed (43,200 ft^3/d). The estimated flow out the drains represents only about 5% of all of the outflows so potential error in the estimated rate has a small impact on the overall groundwater budget.

3.0 GROUNDWATER MODEL CONSTRUCTION AND CALIBRATION

3.1 Construction

The groundwater flow model developed for this project is based on previous models including the one used for the evaluation of flood control measures (HDR/Maxim 2005a) and those used in the analysis of potential basement flooding for other nearby subdivisions (Geomatrix 2005 and 2008, NewFields 2019a, 2019b, 2020a, and 2020b). The conceptual hydrogeologic model presented in **Section 2** formed the basis for the numerical flow model. Generally, model construction was completed following procedures described by HDR/Maxim (2005a) and NewFields (2019a). However additional new data were incorporated, and the model contains greater site-specific detail in places than the previous models.

The model was constructed using the finite-difference code MODFLOW USG (Panday et. Al, 2013) and the graphical user interface Groundwater Vistas (ESI, 2017).

3.1.1 Model Domain and Grid

The model domain covers the Grant Creek drainage from Interstate 90 in the north to the confluence of Grant Creek with the Clark Fork River (**Figure 3-1**). The west margin of the domain follows what is considered to be the western extent of the shallow aquifer. The east edge of the domain is parallel to flow and is placed far enough east to minimize boundary effects upon the predictive scenarios. The model grid consists of 93 rows and 68 columns uniformly spaced at 200 feet, covering an area of 18,600 feet by 13,600 feet. The grid is rotated 34 degrees to align with the groundwater flow direction in the shallow groundwater system.

The model includes three layers:

- Layer 1: upper 10 feet of fine- to coarse-grained material described in **Section 2.4**;
- Layer 2: Lower 4 feet of coarse-grained material described in **Section 2.4** and
- Shallow aquifer material described in **Section 2.3.**

The deeper regional Missoula Aquifer is not included in the model because it is generally isolated from the shallow Grant Creek sediments represented in the model by a fine-grained aquitard.

The top of Layer 1 is defined by the elevation of land surface derived from Lidar data obtained from the Montana Department of Natural Resources and Conservation combined with final grade maps for the proposed subdivisions at Heron's Landing, Remington Flats, and McNett Flats. Layer 1 was assigned a thickness of 10 feet and Layer 2 was given a thickness of 4 feet. Layer 1 and 2 thicknesses were specified to match the depth of potential sumps at 10 and 14 feet below ground surface (bgs). Layer 3 thickness ranges from about 50 feet to the north to about 30 feet in the south based on information from monitoring wells, piezometers, and domestic wells (HDR/Maxim 2005a).

3.1.2 Boundary Conditions

A combination of specified flux (Recharge Package) and head-dependent (General-Head Boundary [GHB]) Package, Drain Package, and River Package boundary conditions were used to simulate groundwater sources and sinks. Locations of boundary conditions and inputs are shown on **Figure 3-1** and locations and inputs are included in **Appendix E**.

Recharge

The Recharge Package is used to simulate seepage from upper Grant Creek and the Flynn-Lowney Ditch system, including laterals. Recharge Package cells representing these surface water bodies were divided into reaches with varying flux rates (**Appendix E**, **Figure E-1**). Flux rates for these boundary conditions were based on groundwater balance calculations (**Section 2.6**) for peak flow conditions and adjusted for the periods before and after. Flux rates were adjusted during calibration, and the final flux rates used for the creek and ditch are summarized in **Appendix E** (**Table E-1**).

The Recharge Package was also used to simulate infiltration from precipitation and irrigation. The methodology used to identify land use categories and estimate infiltration rates are described in **Section 2.1**, the rates used in the model are presented in **Appendix A** (**Table A-1**), and a map of the land use categories specified in the model is included in **Appendix E** (**Figure E-1**).

River Package Cells

The lower portion of Grant Creek in the model is represented with River Package cells. The River Package cells are included for the predictive scenario because anticipated stage values under normal spring rises and under flood conditions can be estimated; whereas flux values (if the cells were recharge cells) are more uncertain. The location, conductance terms, and stage specifications for model River Package cells are included in **Appendix E** (**Figure E-2**, **Table E-2,** and **Table E-3**).

General Head Boundary Package Cells

General Head Boundary (GHB) Package cells are used to simulate flux into the model from the Grant Creek alluvial fan in the northeast, and discharge from groundwater to Clark Fork River alluvium to the south (**Figure 3-1**). Head values of the GHB cells were assigned based on extrapolation of groundwater contour elevations developed from measured water levels in wells (**Figure 2-2** through **Figure 2-4**) and were varied during the simulation to represent seasonal rise and fall of groundwater levels entering and leaving the model domain. GHB conductance values were calculated based on cell dimensions and model hydraulic conductivity values at the GHB locations. Head and conductance values are summarized in (**Appendix E, Table E-4** and **Table E-5**).

A plot of the seasonal changes in River and GHB cells stage and upper Grant Creek and ditch seepage is provided in **Appendix E** (**Figure E-3**). The pattern of changes for each component were initially specified based on best estimates of seasonal conditions and varied during calibration.

Drain Package Cells

Drain Package (head-dependent boundary) cells simulate flux from the shallow aquifer in the model domain to the regional Missoula Aquifer, and represent the drain system installed at Mullan Trails Estates (**Figure 3-1**). Specifications of the drain cells are included in **Appendix E** (**Table E-6**).

Drain cells representing leakage to the Missoula aquifer are located immediately downgradient of monitoring well MMW-8. As noted in the conceptual model it is believed groundwater travels from the shallow aquifer in this area because fine-grained material was not noted on the log for well MMW-8 drilled to 50 feet bgs, and potentiometric maps depict a conspicuously flat hydraulic gradient in the area relative to other portions of the model domain. The addition of these cells was also crucial to achieve adequate model calibration.

The location and depth of drain package cells representing the drain system installed at Mullan Trails Estates are based on design information presented by RLK (2000, 2001). The drains are located in a ring around the subdivisions with the depth of the drains set at 8 ft below ground surface.

3.1.3 Hydraulic Properties

Hydraulic properties specified in the model include hydraulic conductivity (K) and storage. The distribution and inputs for K and storage are included in **Appendix E**.

K for Layer 1 and 2 were specified based on an evaluation of a number of borings, well logs, and test pits. These were described in **Section 2.4.1** and summarized in **Table C-1** and **Figure C-1** and **Figure C-2** (**Appendix C**). The field data were used to classify K in the upper two layers into four categories. K of 0.1, 1, 20, and 200 ft/d were assigned to these categories based on the material descriptions and literature reference values (Morris and Johnson, 1967). Maps of the model K distribution for the upper two layers are presented on **Figure E-4** and **Figure E-5** (**Appendix E**).

Layer 3 K values range from 10 feet/day in the north to 900 feet/day in the south. Values were initially assigned based on transmissivity or T (K times thickness) data from pumping tests and boring logs (see **Section 2.4.2**) and adjusted during calibration.

The model converts K to T based on thickness, so T is a better way to compare model values to observed data. Final model K values for Layer 3 are shown on **Figure E-6** (**Appendix E**). A comparison of the equivalent transmissivity in these zones at observed data points is summarized in **Table C-2**. In general, the model T values compare reasonably well to the observed data:

- In the north (model K zone 5) the average T from five data points is 547 ft^2/d, which compares very close to the model T at these locations of 527 ft^2/d;
- For model K zone 6 (north-central part of the model) observed data is from a pumping test with T values ranging from 1,353 to 6,424 ft^2/d. The model T value at that location in zone 6 is 2,370 ft^2/d, which is in the range of the observed data;
- Model K zone 8 is a small area in the east-central part of the model. Estimated T data for three data points based on specific capacity data ranges from 1,459 to 4,011 ft^2/d, with an average of 2,659 ft^2/d. Model values at these data locations ranges from 13,090 to 16,660 ft^2/d, with an average of 14,933 ft^2/d. The model values are roughly five time the observed T values. The

discrepancy may be due to potential error in calculating T from specific capacity data, but the difference is not significant (calculation accuracy is often considered to be an order of magnitude), the area of the zone in the model is of less focus than elsewhere, and the model values used were necessary for adequate calibration.

- For model K zone 9 the estimated observed T from specific capacity data at six data points ranges from 5,942 to 8,022 ft^2/d, with an average of 6,595 ft^2/d. The model data at these points ranges from 6,800 to 12,000 ft^2/d, with an average of 8,900 ft^2/d, which are slightly higher than the observed data but within a reasonable range considering the limitations of calculating T from specific capacity data.
- Observed T for model K zone 10, the southernmost zone, comes from three pumping tests completed at two wells. T from the pumping tests ranges from 8,692 to 50,581 ft^2/d, with an average of 24,942 ft^2/d. The model T at those two locations ranges from 17,100 to 23,670 ft^2/d, with an average of 20,385 ft^2/d which compares very closely to the observed data.

Specific yield (Sy) and storativity (S) are used in the transient stress periods of the model. A uniform Sy value of 0.1 was assigned to model layers 1 and 2, and 0.02 was assigned for layer 3. Although low for typical Sy, the value for layer 3 was necessary for proper calibration. S is entered in the model as specific storage (Ss), which is S divided by thickness. A uniform Ss value of 5×10^{-5} was used based on a typical Ss range for sand (Batu 1998).

3.1.4 Stress Period Setup

The model is constructed to run with 20 stress periods, as summarized in **Table 3-1**. The stress periods are representative of 2020 and cover the period from early spring base flow conditions, through the spring rise in water levels and the fall decline back to base flow. Stress period setup was designed to be used both for calibration and for predictive scenarios. For the predictive scenarios, boundary conditions were varied but the stress periods were not changed.

Stress period 1 is steady-state, which was used for the steady-state calibration, and the rest are transient. Stress periods 1-8 represent the rise in boundary condition heads and the start of seepage from the irrigation ditch. Stress periods 9-20 represent the decline in boundary condition heads, although ditch seepage continues through this period. Although boundary condition heads decline starting in stress period 9 groundwater elevations do not peak until stress period 12. Stress period durations range from 14-21 days at the beginning and end of the simulation to mostly 7 days for periods in the middle. Stress period 12 has a one-day duration to accommodate 24-hour sump discharge and the peak of groundwater levels for the predictive scenarios.

Table 3-1. Transient Stress Period Setup

Stress Period	Days	Cum Days	Dates	Simulated Condition	Grant Creek Lower-Stage[2]	Grant Creek Upper-Recharge	Flynn-Lowney Seepage	GHB Boundary[1] North	GHB Boundary[1] South[2]
1	14	14	3/8 - 3/22	Steady State	Base	Steady Rise	Off	Base Elev	Base Elev
2	14	28	3/22 - 4/5	Normal Spring Rise	+0.5			2.5 Ft Rise	10 / 12 Ft Rise
3	14	42	4/5 - 4/19		+1.0 / +1.25				
4	7	49	4/19 - 4/26		+1.25 / +1.75				
5	7	56	4/26 - 5/3		+1.5 / +2.25		On		
6	7	63	5/3 - 5/10		+1.75 / +2.75			Steady Decline Back to Base	
7	7	70	5/10 - 5/17		+2.0 / +3.5				
8	7	77	5/17 - 5/24		+2.5 / +4				
9	7	84	5/24 - 5/31	Begin Decline of Boundary Conditions	+2.25 / +3.5	Steady Decline Back to Base			Steady Decline Back to Base
10	7	91	5/31 - 6/7		+2.0 / +2.75				
11	6	97	6/7 - 6/13		+1.75 / +2.25				
12	1	98	6/13 - 6/14	Sump-Discharge[3]	+1.5 / +2.0				
13	7	105	6/14 - 6/21	Continue Decline of Boundary Conditions	+1.25 / +1.5				
14	7	112	6/21 - 6/28		+1.0 / +1.25				
15	7	119	6/28 - 7/5		+0.75 / +1.0				
16	14	133	7/5 - 7/19		+0.5 / +0.75				
17	14	147	7/19 - 8/2		+0.5 / +0.75				
18	14	161	8/2 - 8/16		+0.25				
19	21	182	8/16 - 9/6		Base				
20	21	203	9/6 - 9/27		Base				

1: General Head Boundary cells, described in Section 3.1.2
2: Numbers represent Base Model (2-year) and 100-year model
3: Sump Discharge corresponds to peak groundwater levels in most locations

3.2 Calibration

The model was calibrated to observed groundwater elevations and groundwater balance fluxes described in **Section 2.6**. During calibration, input parameters were varied iteratively within a plausible range of values to minimize residuals, which are the difference between simulated and target values. Results of each calibration simulation were then evaluated to determine if the input parameter(s) adjusted during that model run achieved a better or worse match to calibration targets. Calibration results were evaluated using both quantitative and qualitative methods and completed iteratively between the transient and steady-state models. Residuals and residual statistics were calculated after each model run and used as a measure of the overall match between simulated and observed conditions.

3.2.1 Targets

Calibration targets and criteria included the following:

Steady-State

Water levels measured in 23 wells were used as steady-state calibration targets to represent March 2020 conditions. Three wells (WQD-3, WQD-9, and WQD-22) had data from both March 2004 and March 2020. Groundwater elevation in 20 of the target wells were not measured in March 2020 but were measured in March 2004. To generate Mach 2020 groundwater elevation targets for these wells, the average difference between the March 2004 and March 2020 water level data was added to the March 2004 measured water levels. Locations of the target wells are shown on **Figure F-1, (Appendix F)**.

Transient

Hydrographs generated from pressure transducers in several monitoring wells and hand measured groundwater elevations from one other well were used as transient groundwater elevation calibration targets. Estimated water balance flows discussed in **Section 2.6** were used as flux targets.

3.2.2 Calibration Process

For the steady-state calibration model parameters were adjusted using manual and automated processes, and the predicted groundwater elevation at the target wells were compared to the measured levels at those locations. Parameter adjustment proceeded until the predicted groundwater elevations met calibration established for the project.

The following goals were established for the steady-state calibration

The residual standard deviation divided by the head range of calibration targets. Adequately calibrated is <10%, well calibrated is <5%;

- The residual mean divided by the head range of the calibrated targets. Adequately calibrated is <5%, well calibrated is <1%;
- The absolute residual mean divided by the head range of the calibration targets. Adequately calibrated is <10%, well calibrated is <5%;
- Residual mean is less than 2 feet; and
- No bias, that is, no clustering of positive and negative residuals unless residuals are small; and
- Comparison of model groundwater elevation contours with those drawn from observed data indicate similar groundwater flow direction and gradients.

Once the steady-state calibration was completed, a transient calibration of the model was performed using groundwater elevations measured in 8 target wells between April and September of 2020 (locations are shown on **Figure F-3** in **Appendix F**).

During the transient calibration, model inputs were adjusted interactively for each stress period to improve the match between hydrographs of observed and simulated groundwater elevations until the best match between the timing and magnitude of simulated and observed hydrographs (charts showing groundwater elevation over time) was achieved. The adequacy of calibration results was evaluated qualitatively.

The following are goals established for the transient calibration.

- Water Levels: Adequate visual match of observed and simulated hydrographs with an emphasis on matching the peak groundwater elevation and the timing of the rise and fall.
- Fluxes: Model predicted fluxes for groundwater budget components are within the estimated ranges.

3.2.3 Results

Steady-State

The model steady-state simulation was calibrated to water levels measured in 23 wells throughout the model domain representative of low water conditions. Locations of the wells are shown on **Figure F-1**, (**Appendix F**) and results of the calibration are included in **Table F-1** and on **Figure F-2** (**Appendix F**).

Figure F-1 (**Appendix F**) is a map showing simulated heads, water table elevations, and residuals resulting from the steady-state simulation for March 2020. Residuals (measured water level minus simulated water level) and calibration statistics are summarized in **Table F-1** (**Appendix F**). Comparison of **Figure F-1** to **Figure 2-5** indicates that the model is able to match flow directions and gradient reasonably well throughout the model domain.

Residual is the difference between simulated groundwater elevation and target values. Residuals in the steady-state calibration range from -4.0 to 1.7 feet, with a residual mean of -1.03 feet and absolute residual mean of 1.28 feet. The residual standard deviation divided by the head range is 1.2%, the residual mean divided by the head range is -0.9%, and the absolute residual mean divided by the head range is 1.1%. All of these measures meet the calibration goals for the model.

A plot of observed versus simulated water levels (**Figure F-2, Appendix F**) indicates the model is well calibrated with minimal spatial bias. Points on the plot all fall along a 1:1 line with no areas being consistently above or below the line.

A map showing contours of simulated groundwater elevation for March 2020 is provided on **Figure 3-2**. Comparison of **Figure 3-2** to the groundwater contours from measured groundwater levels (**Figure 2-3**) shows that there is a good match between simulated and observed groundwater flow directions and gradients.

Transient

Figures F-4 through **Figure F-11** (**Appendix F**) are hydrographs of simulated and observed groundwater elevations over time resulting from the transient simulation and are grouped by location from south to north. The overall quality of the transient calibration is good. The timing and magnitude of simulated changes in water levels matched observed changes in seven of the eight wells:

- WQD-3: The timing and magnitude of simulated water changes matches observed changes well (**Figure F-4, Appendix F**);
- MMW11: The simulated increase in water level matches the pattern of the observed data, although the model peak level is about 2 feet less than the observed, and the water level drops at a slower rate after mid July (**Figure F-5, Appendix F**);
- MMW4: The simulated water level rise and peak matches favorably to the observed data with peak levels being about the same (**Figure F-8, Appendix F**). The model predicts a slower post-peak decline;

- MMW12: The model hydrograph shows an earlier but similar rise to the observed data and the peak level is about the same (**Figure F-9, Appendix F**). The observed data shows a small, short rise following the initial peak likely due to a short-term rain event that is not represented in the model;
- MMW8: The model predicted rise and fall in water levels occur earlier than the observed data, but the peak level matches the observed in both magnitude and timing (**Figure F-10, Appendix F**);
- WQD-9: The model hydrograph matches the observed data favorably. The observed data only consists of five points and it appears the peak level was missed and based on the pattern it appears the model peak level is representative of the 2020 peak in this well (**Figure F-11, Appendix F**); and
- MMW-1: The timing and magnitude of the seasonal water level increase on the simulated and observed hydrographs are similar; however, the simulated rate of decline from July through September is less than observed (**Figure F-6, Appendix F**).

The timing and magnitude of simulated and observed water level increase for well MMW3 (**Figure F-7, Appendix F**) does not match as well. Observed increases in this well increase rapidly in early May and then increase and decrease through spring runoff and early summer, whereas simulated elevations increase and decrease more slowly and steadily. This well is located adjacent to Grant Creek and observed water elves are likely controlled by Grant Creek stage. Daily stage data for the creek are not available, so the stage in the boundary condition representing Grant Creek is more generalized, accounting of the lack of variability in the simulated hydrograph.

A comparison of model simulated fluxes to calculated values for the conceptual model discussed in **Section 6** is shown in **Table F-2** (**Appendix F**). Simulated fluxes for all the components of the groundwater balance fall within the calculated values.

The calibrated model was also used to develop a depth to groundwater map for June (**Figure 3-3**). This represents the minimum depth to water for a 2-year hydrologic event and provides a base case for the predictive scenarios that evaluate the potential impact from sumps.

3.3 Sensitivity Analysis

A sensitivity analysis was completed to evaluate the effect of uncertainty in key model input parameters on model calibration. A selected set of parameters were varied from the calibrated model value and the resulting change in model results were tabulated. Parameters selected for the sensitivity simulation include K values for the major geologic units in Layer 3, ditch and creek recharge, stage, of the creek, and GHB cells. A summary of the sensitivity parameters and simulated variations is provided in **Appendix G** (**Table G-1**).

Peak water levels for the wells used in the transient calibration were used to calculate residual statistics for the sensitivity simulations. Peak water levels were used to evaluate the model sensitivity at high water conditions, which is the time of year of most interest for the predictive scenarios. The eight wells used for the statistical analysis are evenly spread throughout the model which helps to minimize spatial bias.

The statistics were then used to evaluate model sensitivity. Sensitivity simulation results are summarized **Table G-2** and on **Figure G-1** in **Appendix G**.

Results indicate that the model is most sensitive to changes in:

- Hydraulic conductivity for Zone 10 (the southernmost model zone, see **Figure E-6**);
- Hydraulic conductivity for Zone 9 (the mid-model zone, see **Figure E-6**); and
- Recharge from Upper Grant Creek.

The model is least sensitive to changes in:

- Hydraulic conductivity for Zone 8 (zone to the northeast, see **Figure E-6**);
- Recharge from the ditch;
- Stage of Grant Creek; and
- Stage of the southern GHB.

4.0 PREDICTIVE SIMULATIONS

This section describes predictive modeling completed to evaluate the depth to groundwater under different stormwater management scenarios. The intent of these simulations is to provide the City of Missoula a tool to aid in decision making regarding the potential location and depths of sumps.

Simulations included a mix of hydrologic conditions and stormwater discharge events. Hydrologic events include an approximately 2-year flood event for Grant Creek (the model calibrated to 2020 data) and a predicted 100-year flood creek event for Grant Creek. Storm events include stormwater discharge for 2-year and 100-year storm events.

Previous work (HR/Maxim 2005c) indicated that groundwater levels in some portion of the model domain are greatly influenced by the Flynn-Lowney Ditch. At the City's request, a series of simulations were completed evaluating the effect of removing the Flynn-Lowney Ditch system on area groundwater elevations in general and related to the use of sumps to manage stormwater in the area.

4.1 Simulation Design

Simulations were developed to evaluate changes in groundwater elevations in the Study Area due to stormwater discharge via sumps under current conditions, estimated full build-out and with the Flynn-Lowney Ditch removed. Simulations include conditions during a typical 2-year high flow event in Gant Creek (based on 2020 data) and during a predicted 100-year flood event in Grant Creek and included 2-year and 100-year storm events based on inputs developed in **Appendix D**. The following simulations were developed and run.

- **Scenario 1: 2-Year Creek Event, 2-Year Storm Discharge Event, Existing Sumps.**
- **Scenario 2: 2-Year Creek Event, 2-Year Storm Discharge Event, Full-Buildout Sumps.**
- **Scenario 3: 2-Year Creek Event, 100-Year Storm Discharge Event, Existing Sumps**
- **Scenario 4: 2-Year Creek Event, 100-Year Storm Discharge Event, Full-Buildout Sumps**
- **Scenario 5: 100-Year Creek Event, 2-Year Storm Discharge Event, Existing Sumps.**
- **Scenario 6: 100-Year Creek Event, 2-Year Storm Discharge Event, Full-Buildout Sumps.**
- **Scenario 7: Flynn-Lowney Ditch Removed.**
- **Scenario 8: 2-Year Creek Event, 2-Year Storm Discharge Event, Existing Sumps, Flynn-Lowney Ditch removed.**
- **Scenario 9: 2-Year Creek Event, 2-Year Storm Discharge Event, Full-Buildout Sumps, Flynn-Lowney Ditch removed.**
- **Scenario 10: 2-Year Creek Event, 100-Year Storm Discharge Event, Existing Sumps, Flynn-Lowney Ditch removed.**
- **Scenario 11: 2-Year Creek Event, 100-Year Storm Discharge Event, Full-Buildout Sumps, Flynn-Lowney Ditch removed.**

- **Scenario 12: 100-Year Creek Event, 2-Year Storm Discharge Event, Existing Sumps, Flynn-Lowney Ditch removed.**
- **Scenario 13: 100-Year Creek Event, 2-Year Storm Discharge Event, Full-Buildout Sumps, Flynn-Lowney Ditch removed.**

4.1.1 Stormwater Sump Discharge

Infiltration from stormwater sumps during 2-year and 100-year storm events under existing conditions and full buildout are described in **Section 2.5** and **Appendix D** for existing and future (full-buildout) conditions were represented in the model using specified flux (Well Package) boundary conditions. For each stormwater basin described in **Appendix D** Well Package cells were added to model Layer 2 (depth of 10-14 ft bgs) to represent the stormwater sumps, and the number of sumps in each model well cell was identified. Infiltration rates were assigned based on the total calculated basin discharge divided by the number Well Package cells in each basin. The number of wells and associated discharge rates are summarized in **Appendix H** (**Table H-1**). Unique reaches were assigned to wells in each basin to identify which well belonged to which basin. The location of Well Package cells for the existing and future basins are shown on **Figure H-1** (**Appendix H**).

4.1.2 Typical 2-year Seasonal High Water in Grant Creek

The calibrated transient model was used to represent typical 2-year seasonal high-water conditions in Grant Creek. As noted in **Section 2.3.2**, the combined hydrographs for wells WQD-3, WQD-4, and WQD-9 suggest that 2020 is representative of a 2-year hydrologic event. The City has agreed with that assessment.

The calibrated model for a 2-year hydrologic event has a 2.5-foot rise in stage from steady-state conditions. Under the calibrated 2-year hydrologic event the rise in stage from base conditions is specified as 2.5 feet for the north GHB boundary and 10-feet for the south GHB boundary.

4.1.3 100-Year Grant Creek Flood

Surface water elevations in River Package cells and groundwater elevations in the GHB cells representing underflow of the model were adjusted to simulate a 100-year flood event in Grant Creek. The River Package (used to simulate Grant Creek) and GHB Package) are head-dependent boundary conditions that calculate flow into and out of the model based on stage or groundwater elevations and a conductance term.

HDR/Maxim (2005c) modeled flows during a 100-year flood in Grant Creek, but did not provide creek stage information from their modeling for this study. The best available information is from a Federal Emergency Management Agency (FEMA) map from 2015, map 30063C1190E effective 7/6/2015 (FEMA, 2015) which provides creek elevations for a 100-year flood event. The FEMA map indicates that for a 100-year flood event the creek stage would be roughly 1.5 feet higher than the 2-year (June 2020) event and 4 feet above baseflow elevations (March 2020). Peak stage values for River Package Cells were therefore increased by 4 feet above March 2020 elevation to represent a 100-year flood event in Grant Creek. Stage inputs for River Package cells representing Grant Creek in the 100-year flood simulations ae presented in **Table E-7** (**Appendix E**).

Groundwater elevations at the downgradient (south) model boundary were assumed to be 12-feet higher than during baseflow (steady-state) conditions and 2-feet higher than during the 2-year event for the calibrated model. This was estimated based on the combined hydrograph for well WQD-3 (**Figure B-2**, **Appendix B**), which is located near the downgradient boundary. The highest water level measured in WQD-3 is about one foot above the highest level in 2020. It was assumed that groundwater elevation at this boundary would be another foot higher than that for a 100-year event.

4.2 SIMULATION RESULTS

Figures 4-1 through **Figure 4-13** are maps showing predicted minimum depth to groundwater for Scenarios 1 through 13 (listed in **Section 4.1**). These were created by exporting predicted groundwater elevations from each scenario to GIS and then subtracting the groundwater elevation from ground surface elevations based on LIDAR data (**Section 3.1.1**).

Hydrographs of simulated groundwater elevations for each scenario at selected observation points throughout the model domain (shown on **Figure I-1** in **Appendix I**) are presented in **Figures I-2** through **I-15** (Appendix **I**). **Figures 4-14** through **4-16** present contour maps showing the maximum predicted increase in groundwater elevation (mounding) due to stormwater infiltration through sumps for each scenario.

Figure 4-1 indicates that under current conditions during a 2 -year storm event and typical seasonal high groundwater conditions (Scenarios 1) depth to groundwater varies across the study area with depths greater than 20 feet occurring in the northeast and east portion of the model domain, and depths less than 10 feet occurring to the south and west along Grant Creek. Depth to groundwater ranges from 10 to 20 feet in the central portion of the Study Area along the Flynn-Lowney ditch and west of George Elmer Drive, where the proposed Heron's Landing subdivision is planned. South of England Boulevard where two other subdivisions are planned (Remington Flats and McNett Flats) the depth to groundwater ranges from 10 to 16 feet. Predicted depth to groundwater is less than 10 feet along Grant Creek and in low lying areas between 700 and 1,400 feet east of Grant Creek as wells as south of Mullan Road beneath the flood Clark Fork River floodway.

Review of **Figures 4-1** through **4-6** and **I-2** through **I-15** (**Appendix I**) indicates the 100-year storm event occurring at the peak 2-year surface water elevations in Grant Creek with full-buildout (Scenario 4) results in the highest groundwater conditions in most portions of the model domain. The exception is that **Figure I-7** indicates that groundwater elevation at well WQD3 is predicted to be highest in 100-Year Creek Event, 2-Year Storm during the 100-year Grant Creek flood under full-buildout (Scenario 6). This is because WQD-3 is located near Grant Creek in an area with limited sumps where high Grant Creek stage has the greatest influence on groundwater elevations.

Figure 4-7 shows predicted depth to groundwater when the Flynn-Lowney ditch is removed during a 2-year event in Grant Creek. Hydrographs in **Appendix I** and comparison of **Figure 4-1** to **Figure 4-8** indicate that removing the Flynn Lowney Ditch result in seasonal groundwater elevations during a typical 2-year Grant Creek flood event with current storm sumps that are from 1 to 4 feet lower under many portions of the model domain with the greatest affect in areas neath the ditch. Groundwater elevations in the northwest portion of the model domain north of a line about 2,000 feet south west of West Broadway would not be affected appreciably by remove of the ditch. The six additional simulations with the ditch removed (Scenarios 8-13 on **Figure 4-8** through **Figure 4-13**) show that depth to water is slightly less than without the sump discharge (Scenario 7), but all show deeper groundwater than with the ditch in operation (Scenarios 1 through 6).

Figures 4-14, through **4-16** compare groundwater mounding under current sump and full buildout conditions as summarized below.

- **Figure 4-14**: 2-year creek event, 2-year stormwater discharge event with existing (Scenario 1) and full-buildout (Scenario 2) sumps;
- **Figure 4-15**: 2-year creek event, 100-year stormwater discharge event with existing (Scenario 3) and full-buildout (Scenario 4) sumps; and
- **Figure 4-16**: 100-year creek event, 2-year stormwater discharge event with existing (Scenario 5) and full-buildout (Scenario 6) sumps.

Results show under current sump conditions sumps the mounding occurs in the eastern and northern portions of the Study Area where existing sumps are located (see **Figure H-1** in **Appendix H**), with maximum mounding of 1-2 feet from the 2-year storm discharge event (**Figure 4-14** and **Figure 4-16**) to 5-7 feet (**Figure 4-15**) from the 100-year stormwater discharge event.

Full-buildout simulations result in similar mounding in areas with existing sumps, but additional mounding appears in portions of the Study Area where additional stormwater sumps are being considered (see **Figure H-1** in **Appendix H**). The magnitude of additional mounding in the west and south where the future sumps are located ranges from 1-2 feet for the 2-year stormwater discharge event (**Figure 4-14** and **Figure 4-16**) to 3-5 feet (**Figure 4-15**) for the 100-year stormwater discharge event.

The greatest amount of mounding for the existing sumps occurs along Reserve Street south of West Broadway and in a band along Reserve Street to the north of West Broadway. In the area of future full-buildout sumps the greatest mounding occurs around England Boulevard and in an area along Grant Creek to the east of the airport.

4.3 Uncertainty Analysis

In order to help quantify the uncertainty associated with model predictions a limited sensitivity analysis was performed. Hydraulic conductivity for model Zones 9 and 10 (**Figure E-6**, **Appendix E**) were identified as sensitive parameters for the model calibration (**Section 3.3**). For the uncertainty analysis, hydraulic conductivity values in these zones were adjusted within plausible ranges to evaluate the effect in model predictions for Scenario 4 (2-year creek event, 100-yr stormwater discharge).

The model simulation was run with each K zone set at 50% and 150% of the calibrated model value. The potential impact was evaluated by comparing depth to water hydrographs for the original scenario to each sensitivity simulation. Hydrographs were developed for observation points at MMW11, Heron's Landing, Remington Flats, and Hellgate School. The resulting hydrographs are included in **Appendix I** (**Figure I-16** through **Figure I-19**).

The analysis suggest that uncertainty associated with predicted groundwater elevations could be up to a few feet in some portions of the model domain. **Appendix I** hydrographs indicate that with the K for Zone 10, which is mostly beneath the southern-most portion of the model, set at 50% the predicted depth to water may be 2-4 feet less than those simulated for the calibrated model. With the K for Zone 10 set at 150% predicted water levels increase by 1-2 feet from the calibrated model. Predicted water levels are not sensitive to changes in K for Zone 9 (central portion of Study Area) except in a small area near Hell gate School where a lower K decreases the depth to water by 2 feet and a higher K increases the depth to water by 2 feet.

5.0 CONCLUSIONS AND LIMITATIONS

This section presents NewFields conclusions resulting from the Grant Creek Groundwater Modeling Study.

- The model is well calibrated in most areas, and depth to water simulations can be considered reasonable estimates for the hydrologic and discharge conditions simulated. The model is appropriate for evaluating changes in water levels reusing form infiltration of stormwater via sumps.
- Use of sumps in areas of future development are likely to result in short term mounding of up to 2 feet during a 2-year storm event and up to 5 feet during a 100-year storm event in the area near England Blvd. Infiltration of stormwater from 2-year and 100-year storms through sumps in future development areas is not anticipated to greatly impact groundwater elevations in currently developed areas.
- Removal of the Flynn-Lowney ditch would decrease peak seasonal groundwater elevation appreciably beneath much of the area between England Blvd. and Mullan Road.
- Most of the areas where future development is planned (see Basins A-F on **Figure 2** in **Appendix D**) would have sufficient depth to groundwater to allow use of sumps to manage stormwater assuming that a minimum depth to groundwater of 10 to 14 feet would be needed. Sumps would not be feasible in Basin G (**Figure 2** in **Appendix D**).
- Models are simplifications of complex systems. In all modeling exercises, some input parameters are not well quantified due to a lack of data, which leads to uncertainty in model predictions. Predictions should be treated as best estimates given available information and should not be treated as certainties. There are inherent limitations in numerical groundwater modeling that must be considered when evaluating predictive simulations, especially when important planning decisions are to be made based on the results. Some of these limitations include the following:
  - The ability of the model to accurately predict changes in groundwater flow and groundwater-surface water interaction at the scale of tens of feet or less may be limited, especially in areas with complex flow characteristics. For these reasons, model predictions should not be viewed as certainties but as the best interpretation of likely outcomes based on available information and data.
  - The quality and spatial nature of model calibration must be considered when interpreting results. Model predictions in areas where the model does not match observed groundwater levels as well may have greater error.

The amount of data available requires that the model assume uniform conditions within parameter zones, such as for hydraulic conductivity and recharge, when in reality there is likely greater spatial variation than simulated. In the case of the Flynn-Lowney ditch it is likely the degree of seepage varies spatially to a greater degree than simulated, and therefore, there is uncertainty in the predicted depth to groundwater adjacent to the ditch.

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FIGURES

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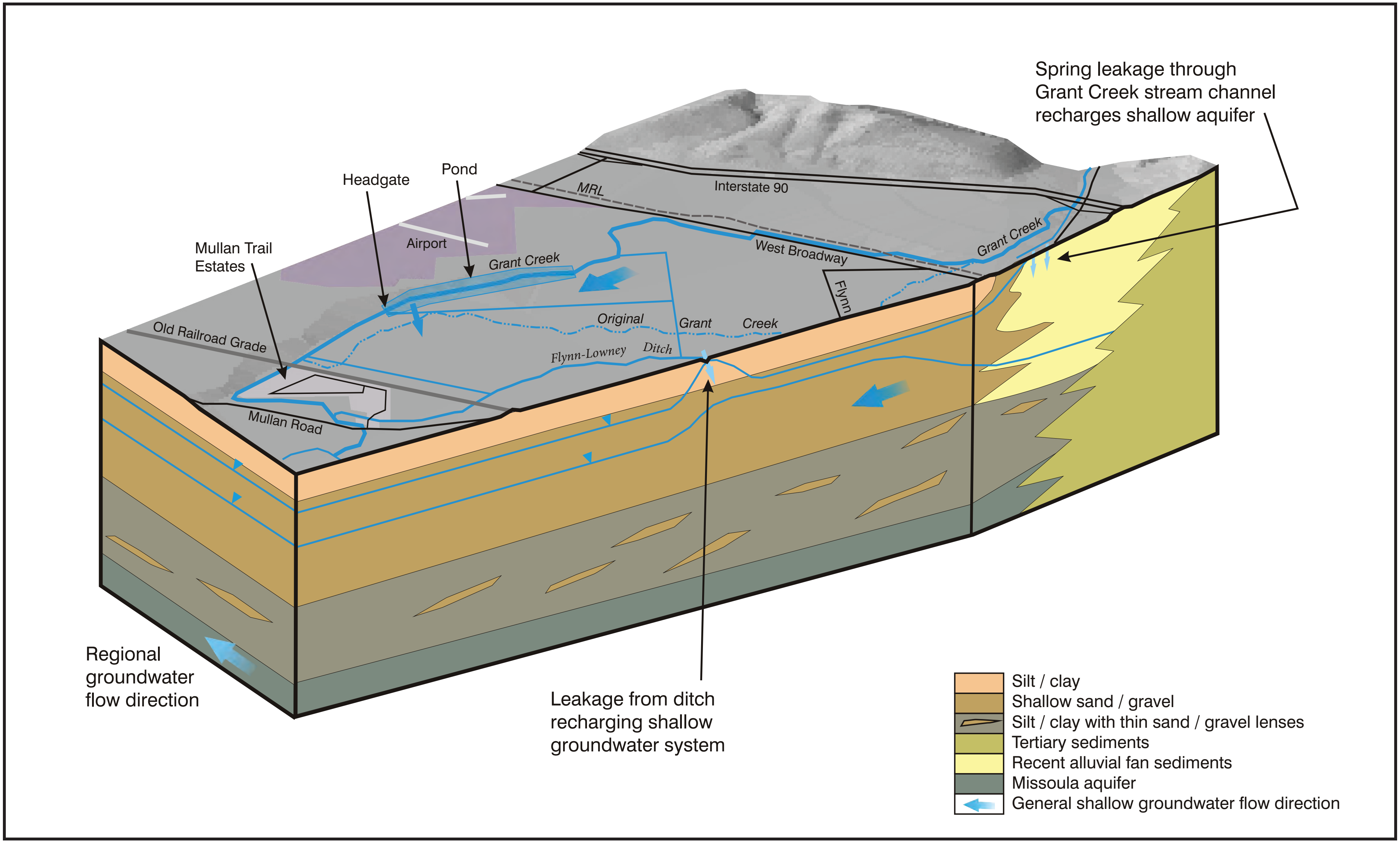
N

0 5,000
Feet

Grant Creek Model Domain

NewFields

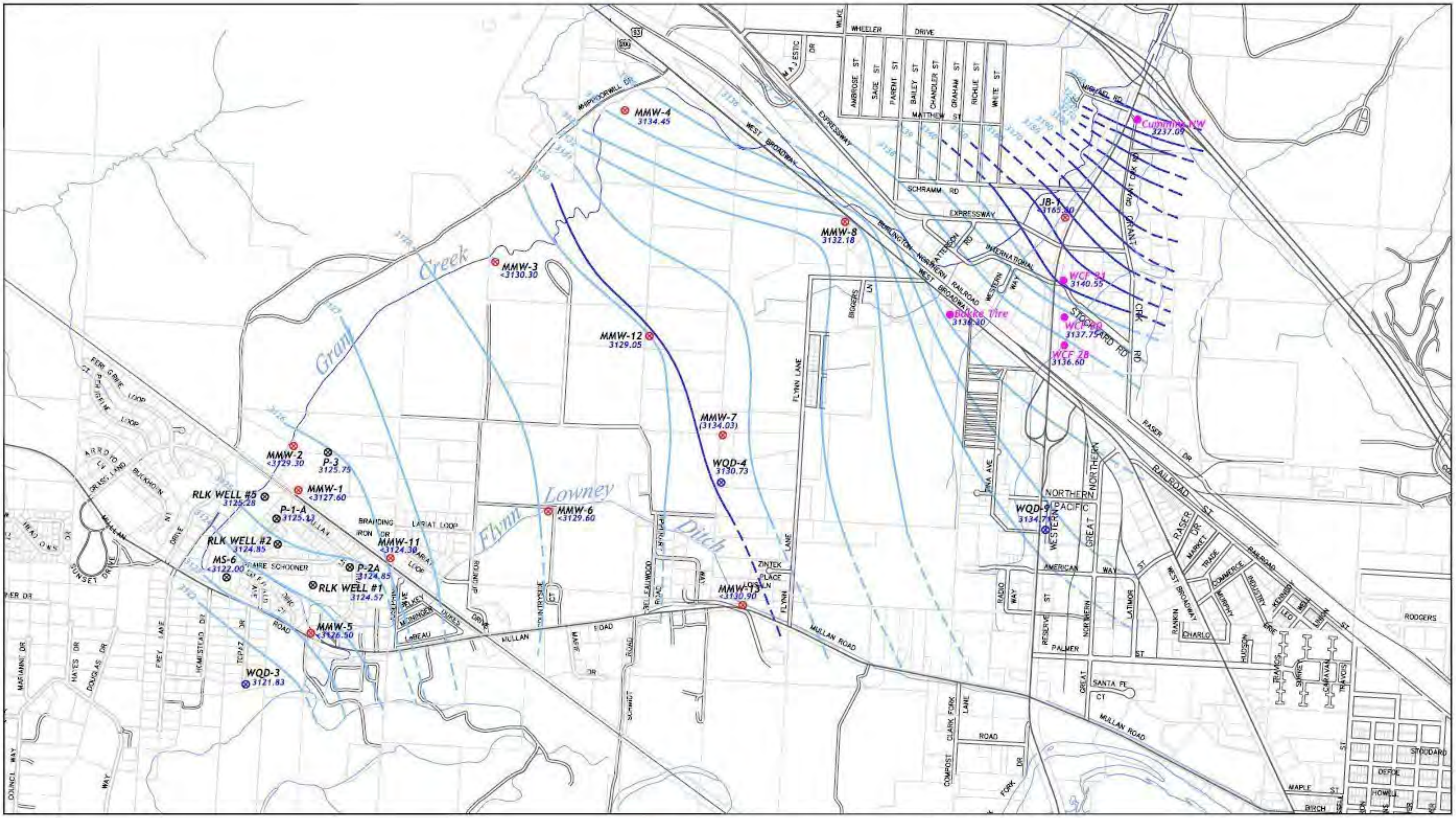
Study Area Map
Groundwater Modeling Study
Grant-Creek-Mullan Road Area
Missoula, Montana
FIGURE 1-1



Source: Maxim/HDR 2005a

Conceptual Model Block Diagram
Groundwater Modeling Study
Grant Creek-Mullan Road Area
Missoula, Montana
FIGURE 2-1

NewFields

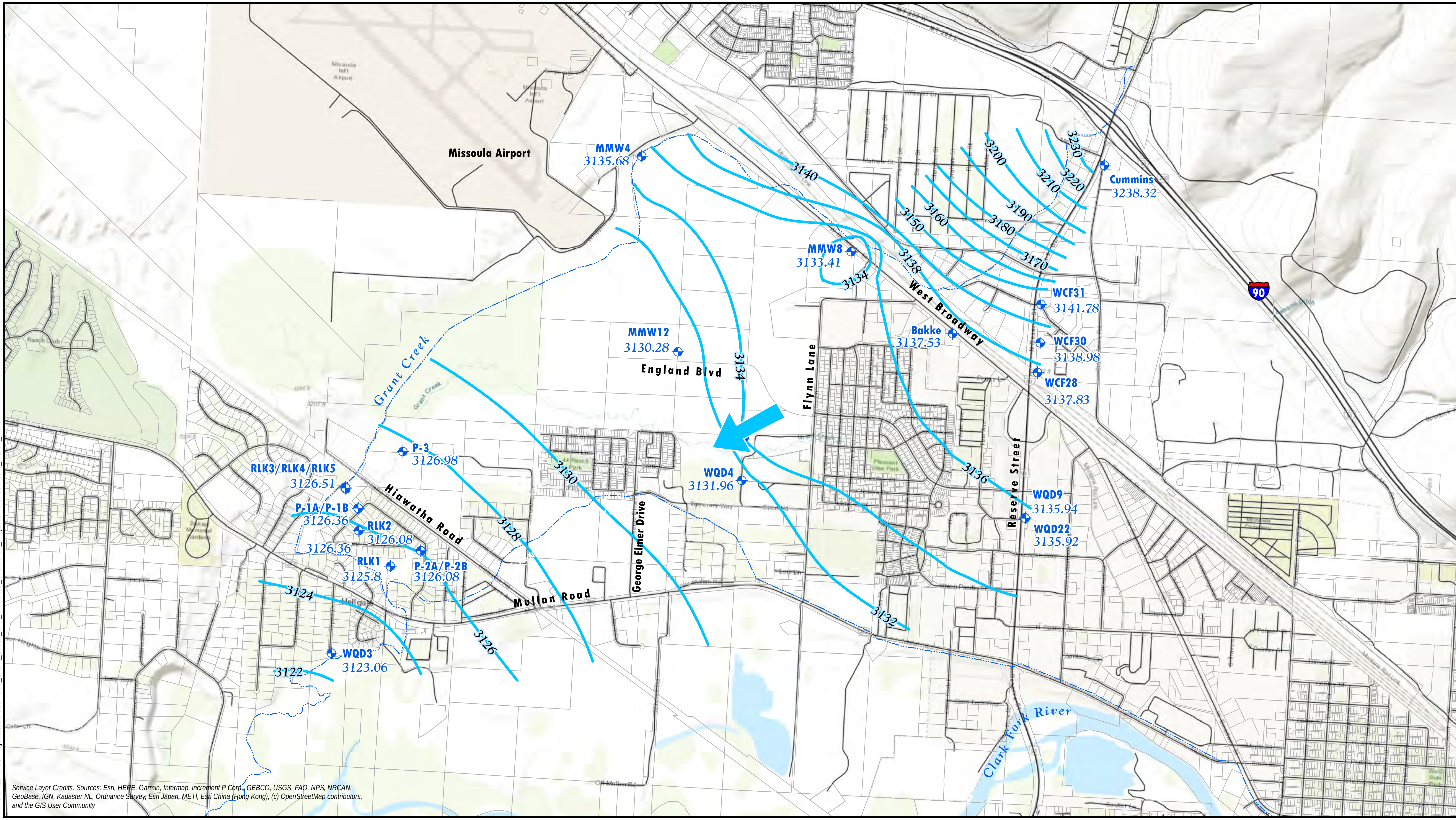


MMW-1	Monitoring Well
P-3	Previous Investigation Well
WQD	Water Quality District Well
WCF30	Water Supply Well
3132.12	Groundwater Elevation (feet msl)
(3134.03)	Groundwater Elevation Not Used (feet msl)
	10 ft Groundwater Contour (Dashed where inferred)
	1 ft Groundwater Contour (Dashed where inferred)

Source: HDR/Maxom 2005a

Groundwater Contour Map - March 23, 2004
Groundwater Modeling Study
Grant Creek-Mullan Road Area
Missoula, Montana
FIGURE 2-2

NewFields



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N

0 Feet 2,000

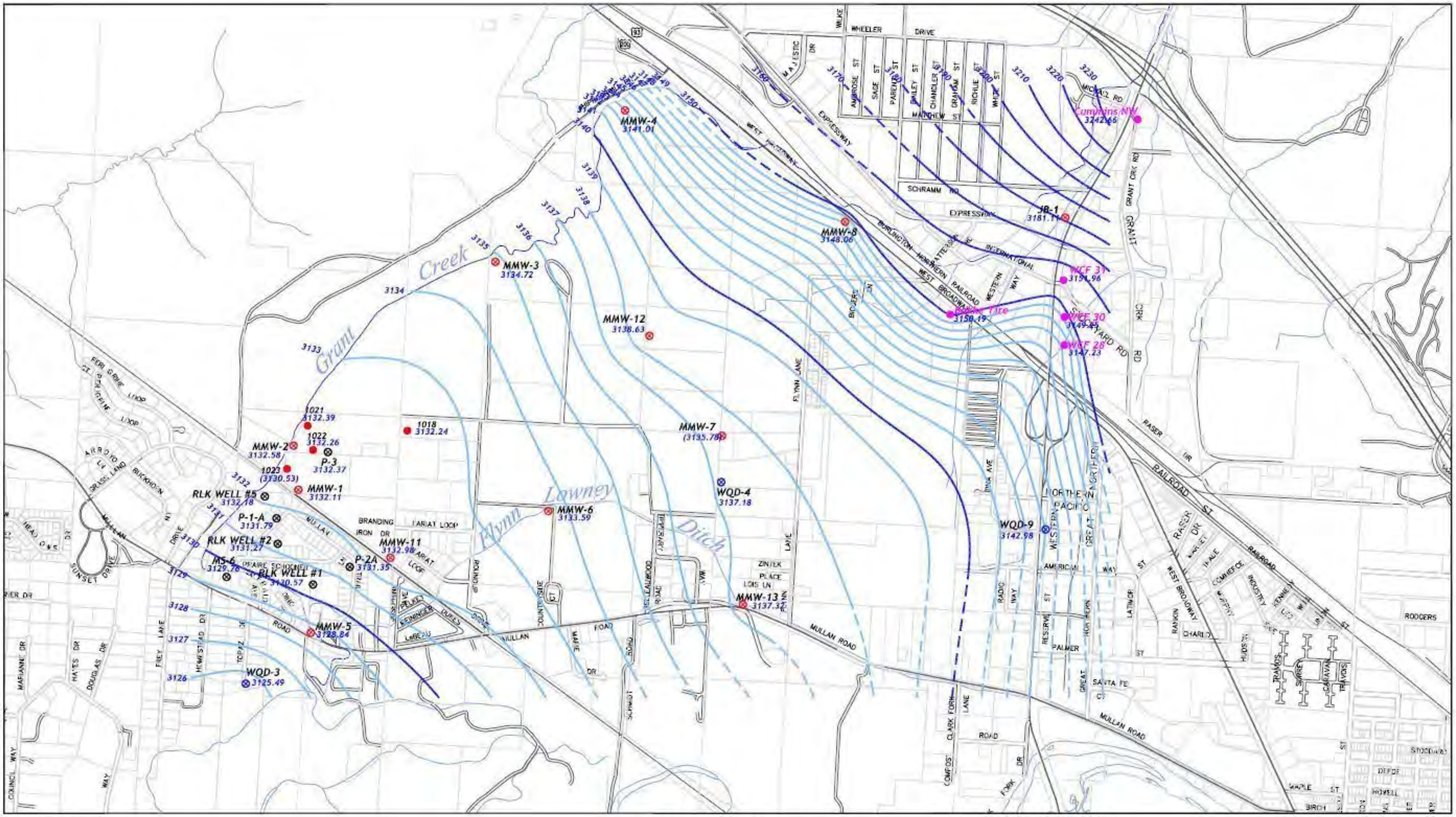
NewFields

MMW4 3135.68 — Groundwater Monitoring Well and Groundwater Elevation (feet)

Groundwater Contours (2 foot interval)

General Groundwater Flow Direction

Water Table Elevation Contour Map
March 2020
Groundwater Modeling Study
Grant Creek-Mullan Road Area
Missoula, Montana
FIGURE 2-3



N

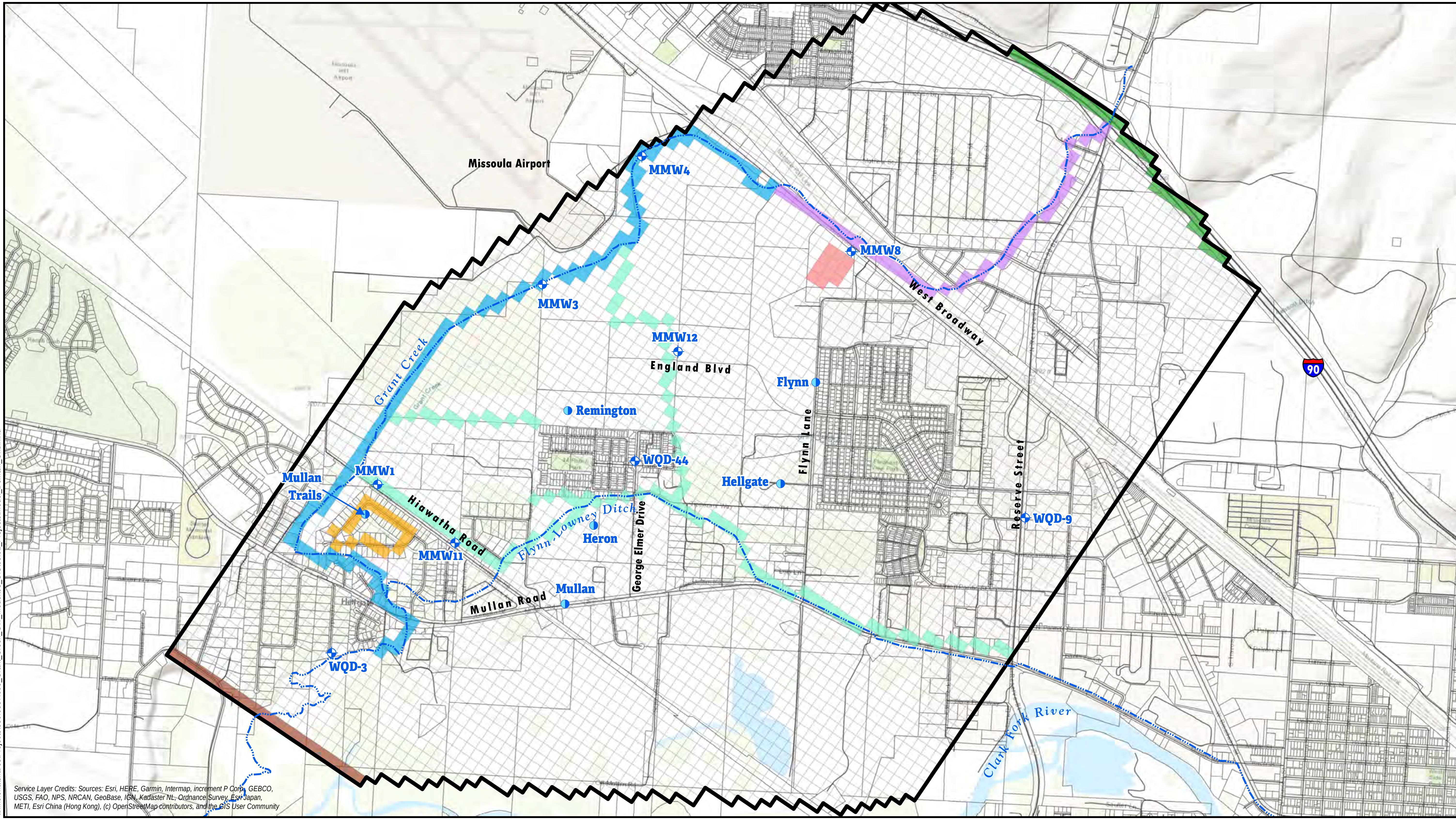
0 Feet 1500

MMW-1	Monitoring Well
P-3	Previous Investigation Well
WQD	Water Quality District Well
WCF30	Private Supply Well
1022	Test Pit Piezometer
3132.12	Groundwater Elevation (feet msl)
(3134.03)	Groundwater Elevation Not Used (feet msl)
	10 ft Groundwater Contour (Dashed where inferred)
	1 ft Groundwater Contour (Dashed where inferred)

Source: HDR/Maxim 2005a

Groundwater Contour Map - June 15, 2005
Groundwater Modeling Study
Grant Creek-Mullan Road Area
Missoula, Montana
FIGURE 2-4

NewFields



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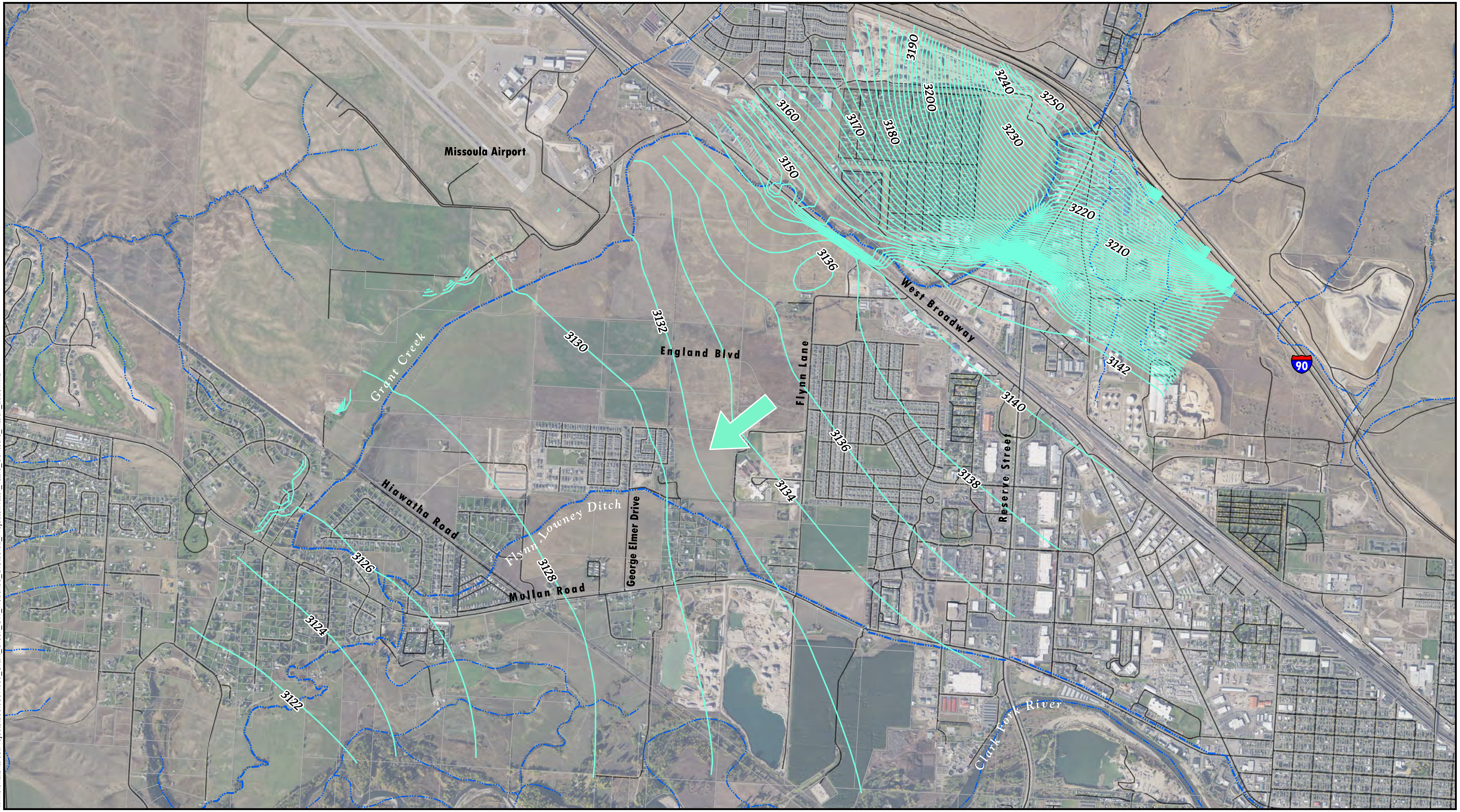
N

0 Feet 2,000

NewFields

- Grant Creek Model Domain and Grid
- River Package Cells Representing Creek
- GHB Package Cells Representing Groundwater Inflow to Model
- GHB Package Cells Representing Groundwater Outflow From Model
- Drain Package Cells Representing Mullan Trails Estates Drainage System
- Drain Package Cells Representing Infiltration to Missoula Valle Aquifer (Layer 3)
- Recharge Package Cells Representing Creek
- Recharge Package Cells Representing Flynn-Lowney Ditch System
- Additional Model Monitoring Points
- Monitoring Wells

Model Domain, Grid, and Boundary Conditions
Groundwater Modeling Study
Grant Creek-Mullan Road Area
Missoula, Montana
FIGURE 3-1



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N

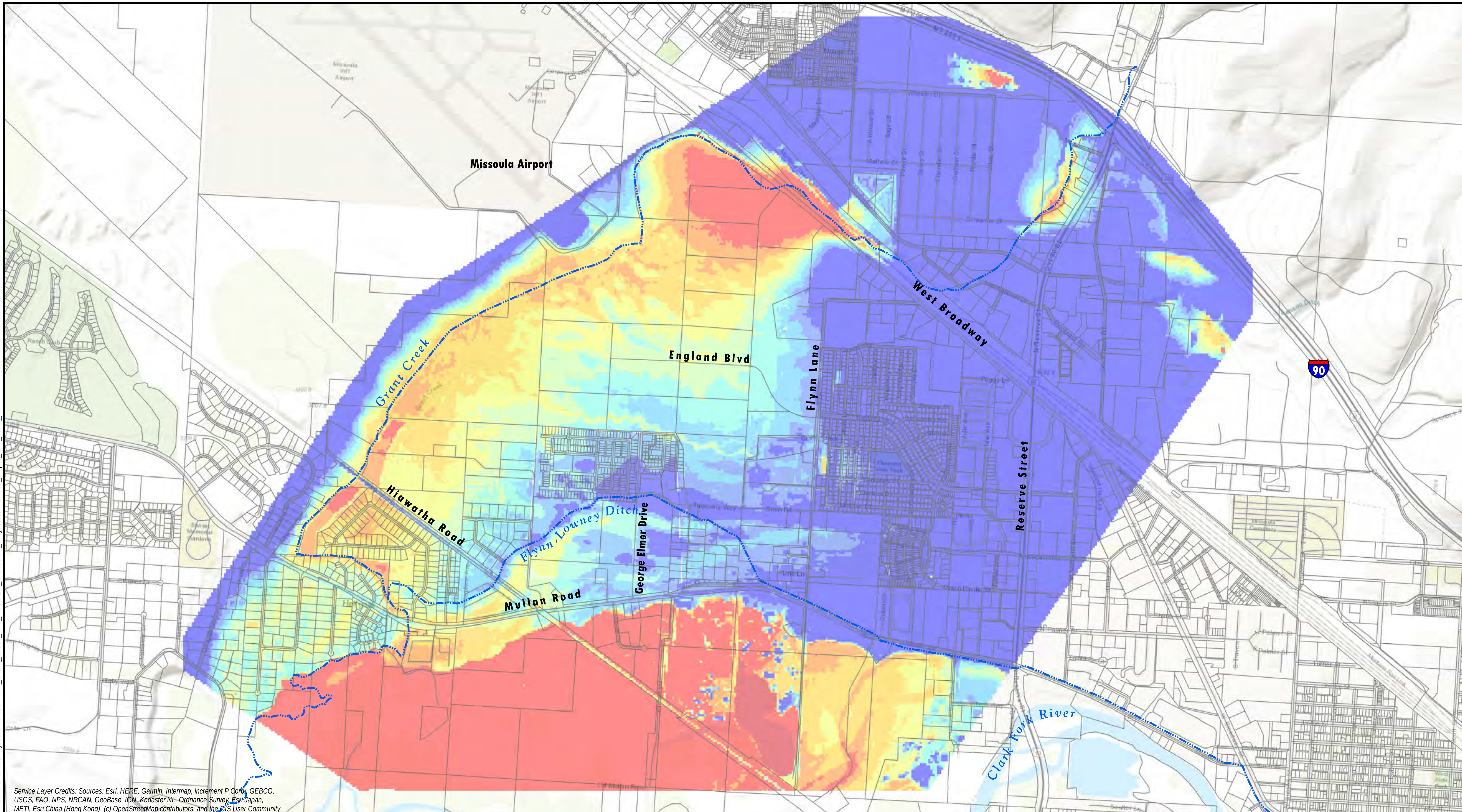
0 Feet 2,000

NewFields

Water Table Elevation Contours (2 foot interval)

General Groundwater Flow Direction

Simulated Water Table Elevation Contour Map: March 2020
Groundwater Modeling Study
Grant Creek-Mullan Road Area
Missoula, Montana
FIGURE 3-2



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N

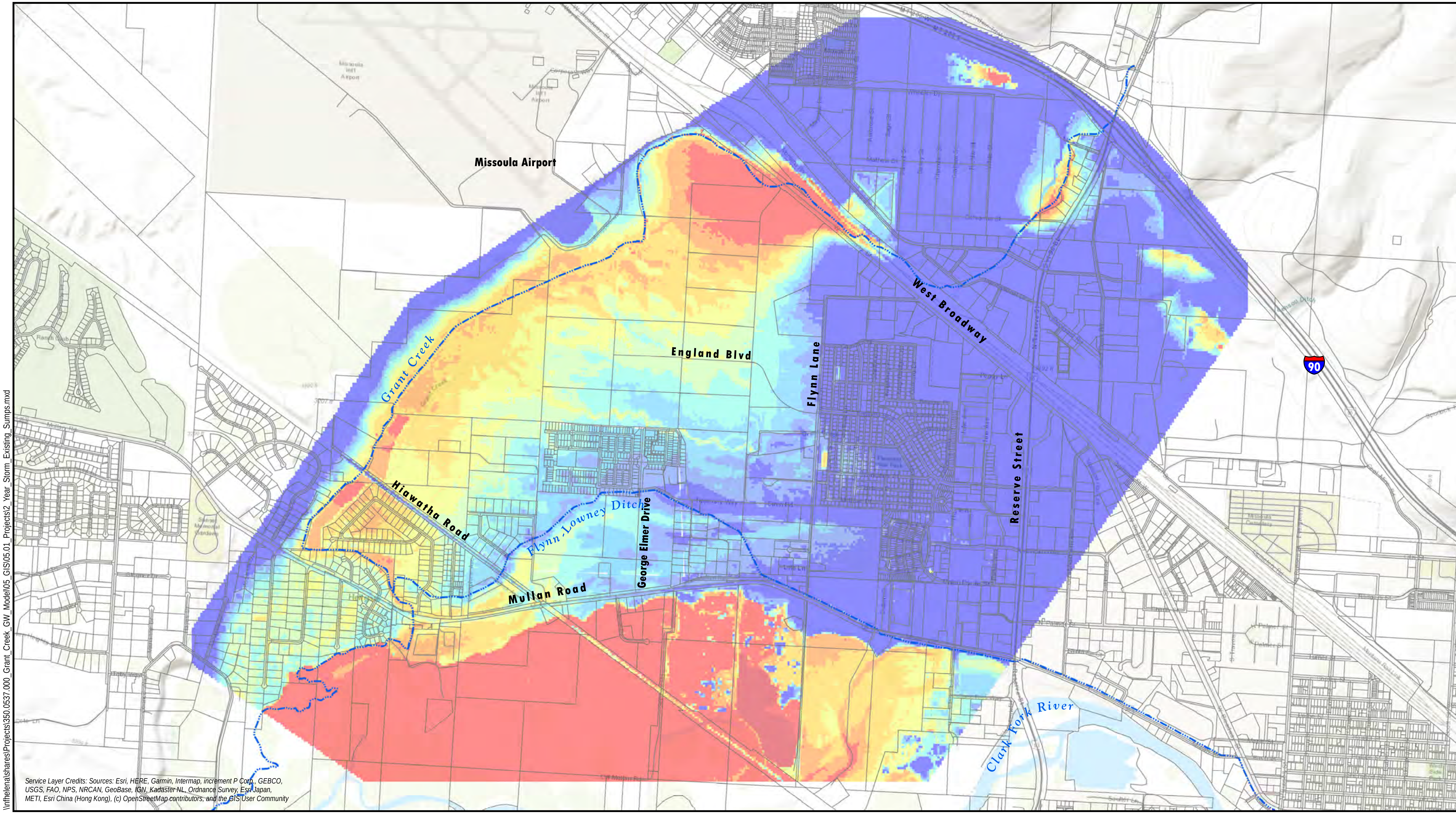
0 2,000
Feet

NewFields

Depth to Groundwater (feet)
Below Existing Ground Surface

- <6
- 6 - 8
- 8 - 10
- 10 - 12
- 12 - 14
- 14 - 16
- 16 - 18
- 18 - 20
- >20

Simulated Depth to Groundwater: June 2020
Groundwater Modeling Study
Grant Creek-Mullan Road Area
Missoula, Montana
FIGURE 3-3

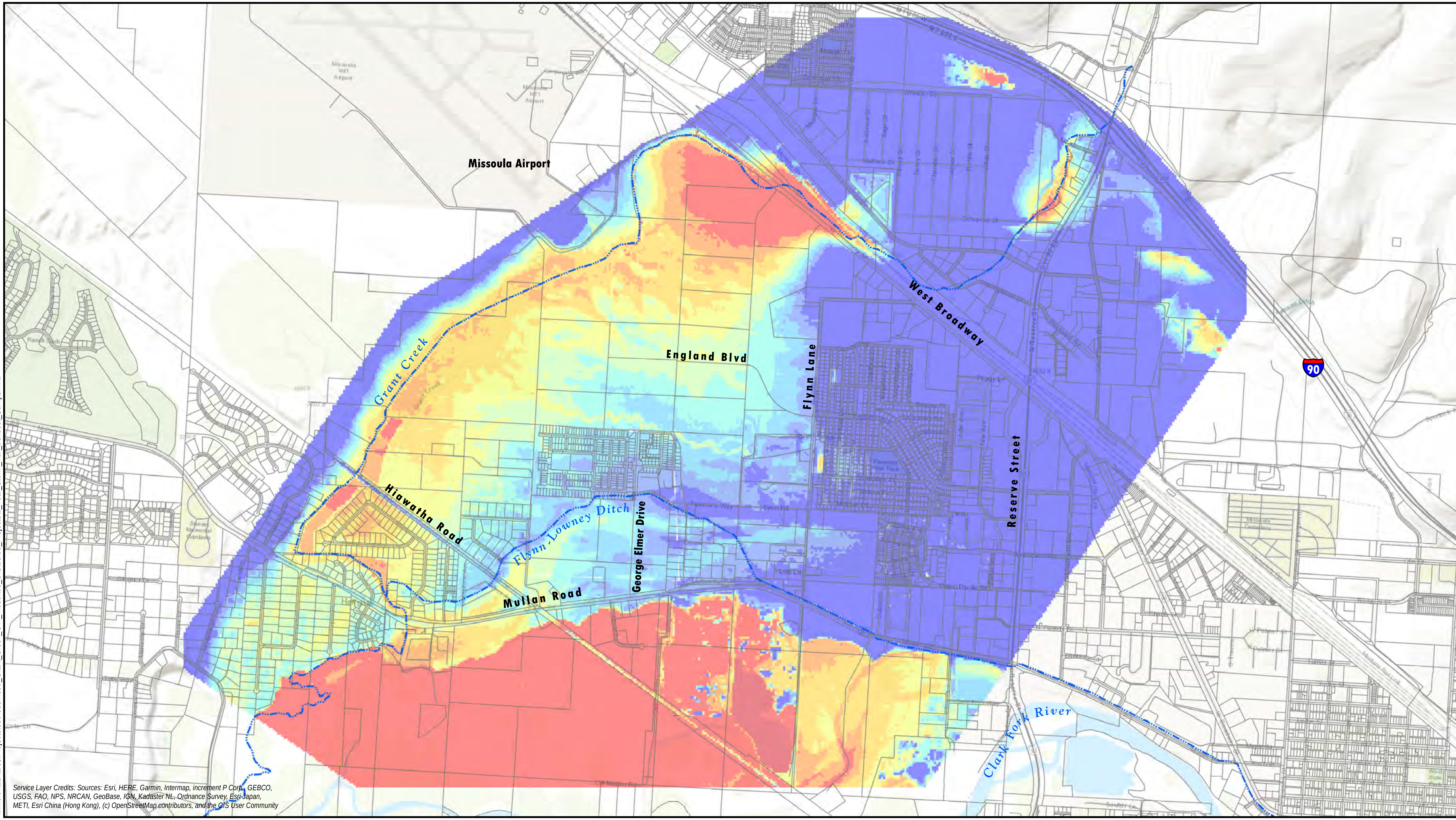


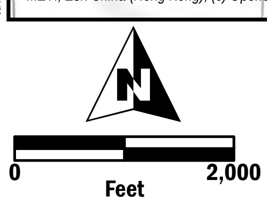
Depth to Groundwater (feet)
Below Existing Ground Surface

<6	10 - 12	16 - 18
6 - 8	12 - 14	18 - 20
8 - 10	14 - 16	>20

NewFields

Simulated Depth to Groundwater: 2-Year Creek Event
2-Year Storm Discharge - Existing Sumps
Groundwater Modeling Study
Grant Creek-Mullan Road Area
Missoula, Montana
FIGURE 4-1



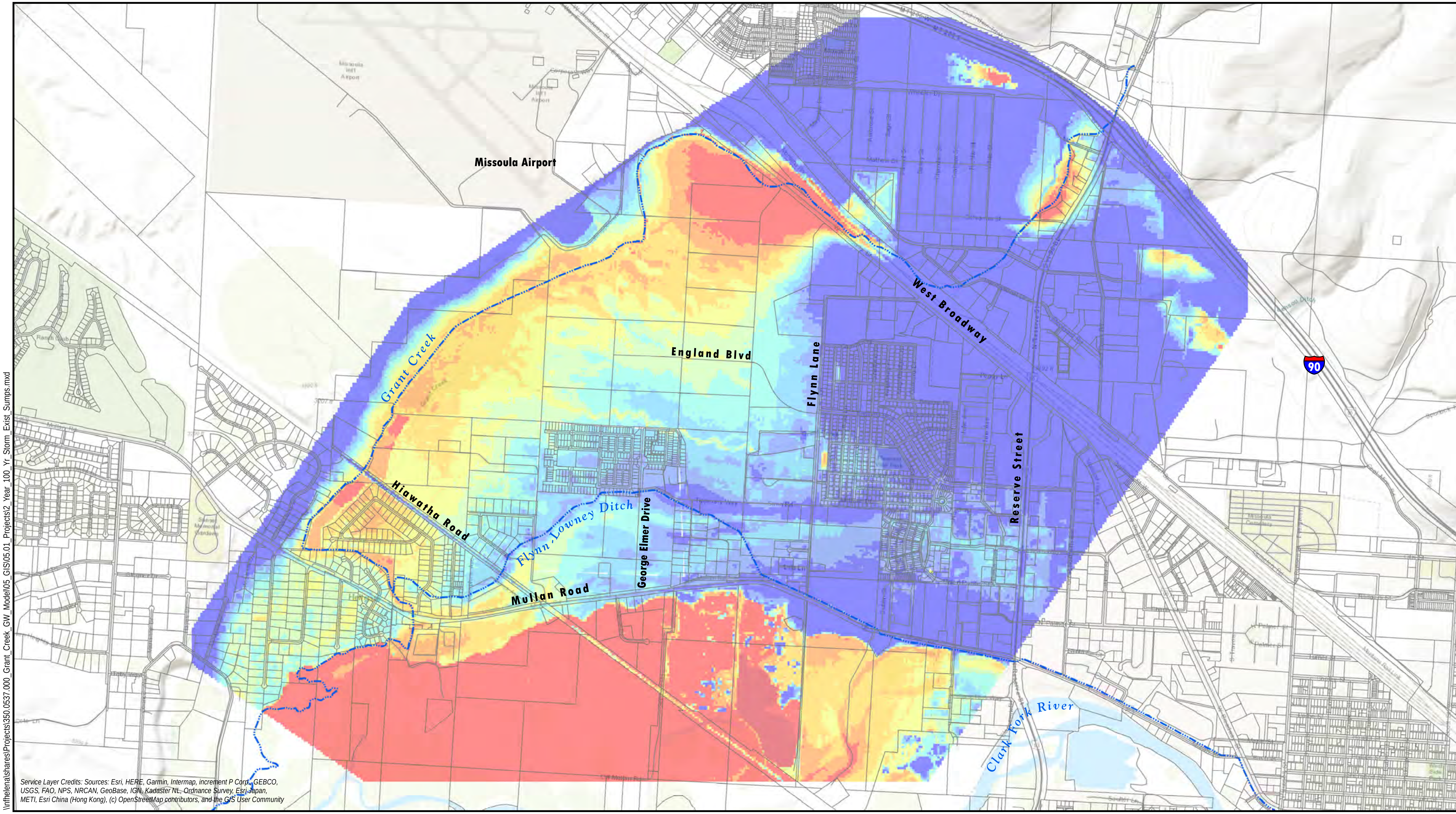


Depth to Groundwater (feet)
Below Existing Ground Surface

<6	10 - 12	16 - 18
6 - 8	12 - 14	18 - 20
8 - 10	14 - 16	<20

NewFields

Simulated Depth to Groundwater: 2-Year Creek Event
2-Year Storm Discharge - Full Buildout Sumps
Groundwater Modeling Study
Grant Creek-Mullan Road Area
Missoula, Montana
FIGURE 4-2

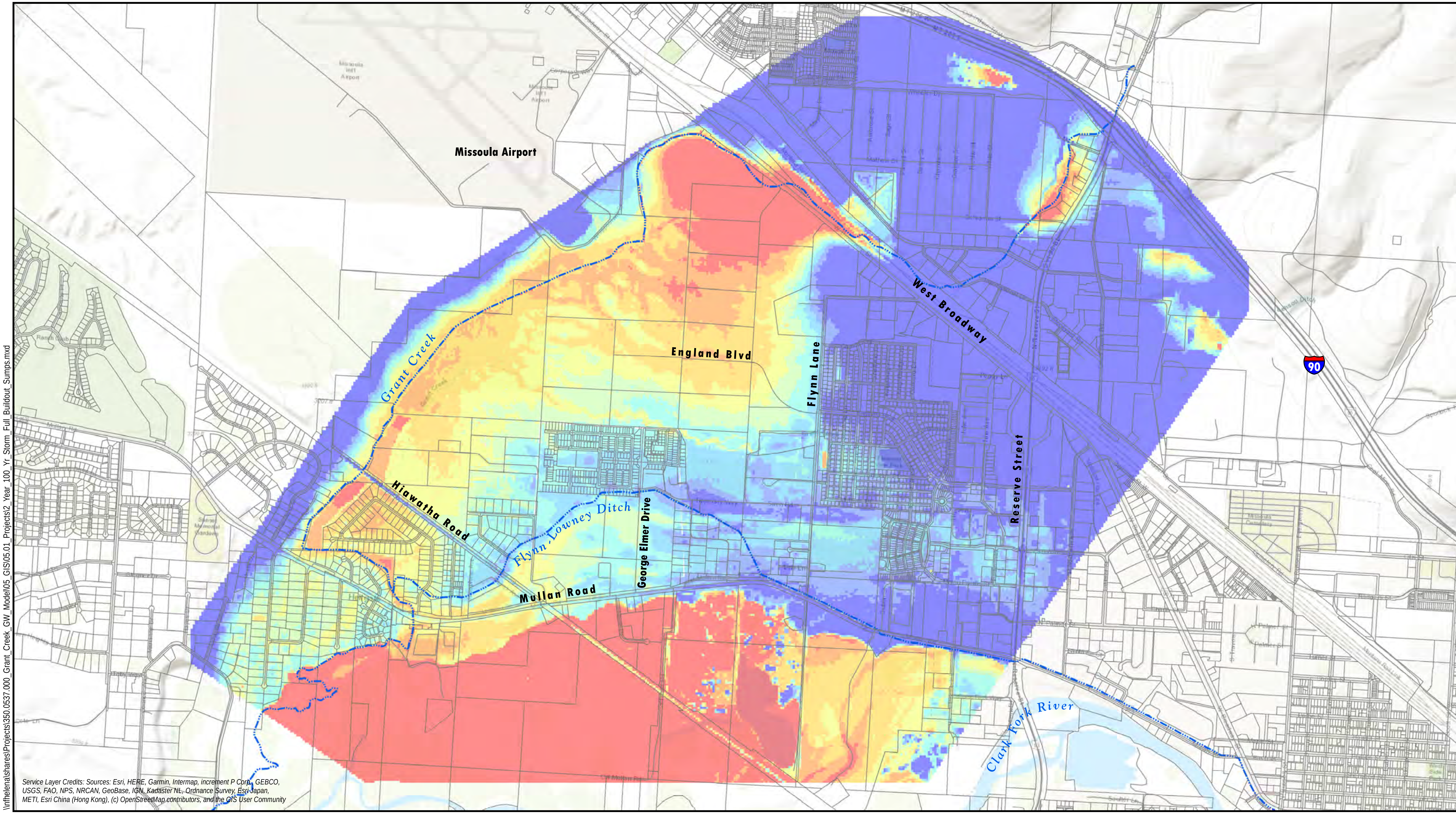


NewFields

Depth to Groundwater (feet)
Below Existing Ground Surface

<6	10 - 12	16 - 18
6 - 8	12 - 14	18 - 20
8 - 10	14 - 16	>20

Simulated Depth to Groundwater: 2-Year Creek Event
100 Year Storm Discharge - Existing Sumps
Groundwater Modeling Study
Grant Creek-Mullan Road Area
Missoula, Montana
FIGURE 4-3

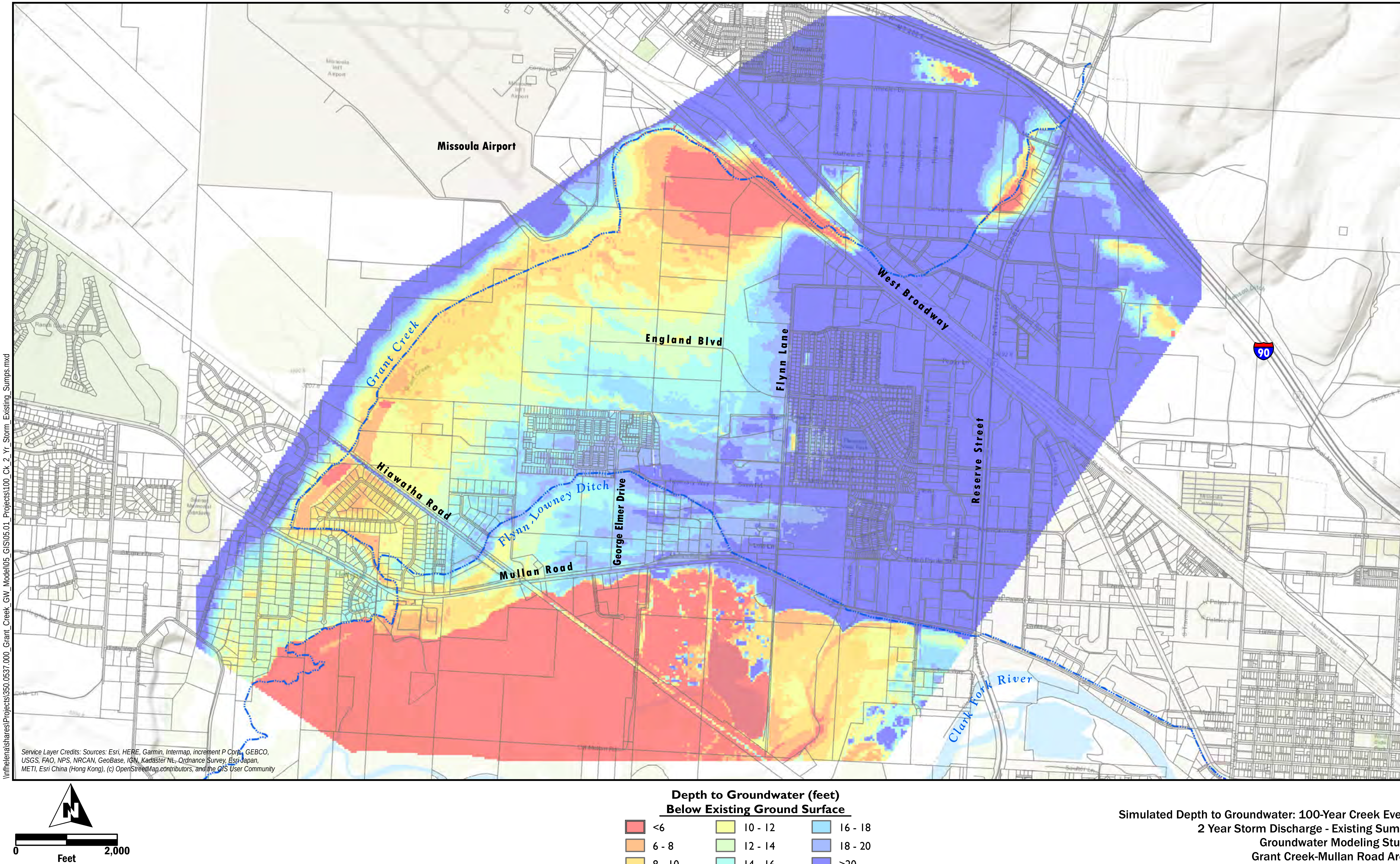


Depth to Groundwater (feet)
Below Existing Ground Surface

<6	10 - 12	16 - 18
6 - 8	12 - 14	18 - 20
8 - 10	14 - 16	>20

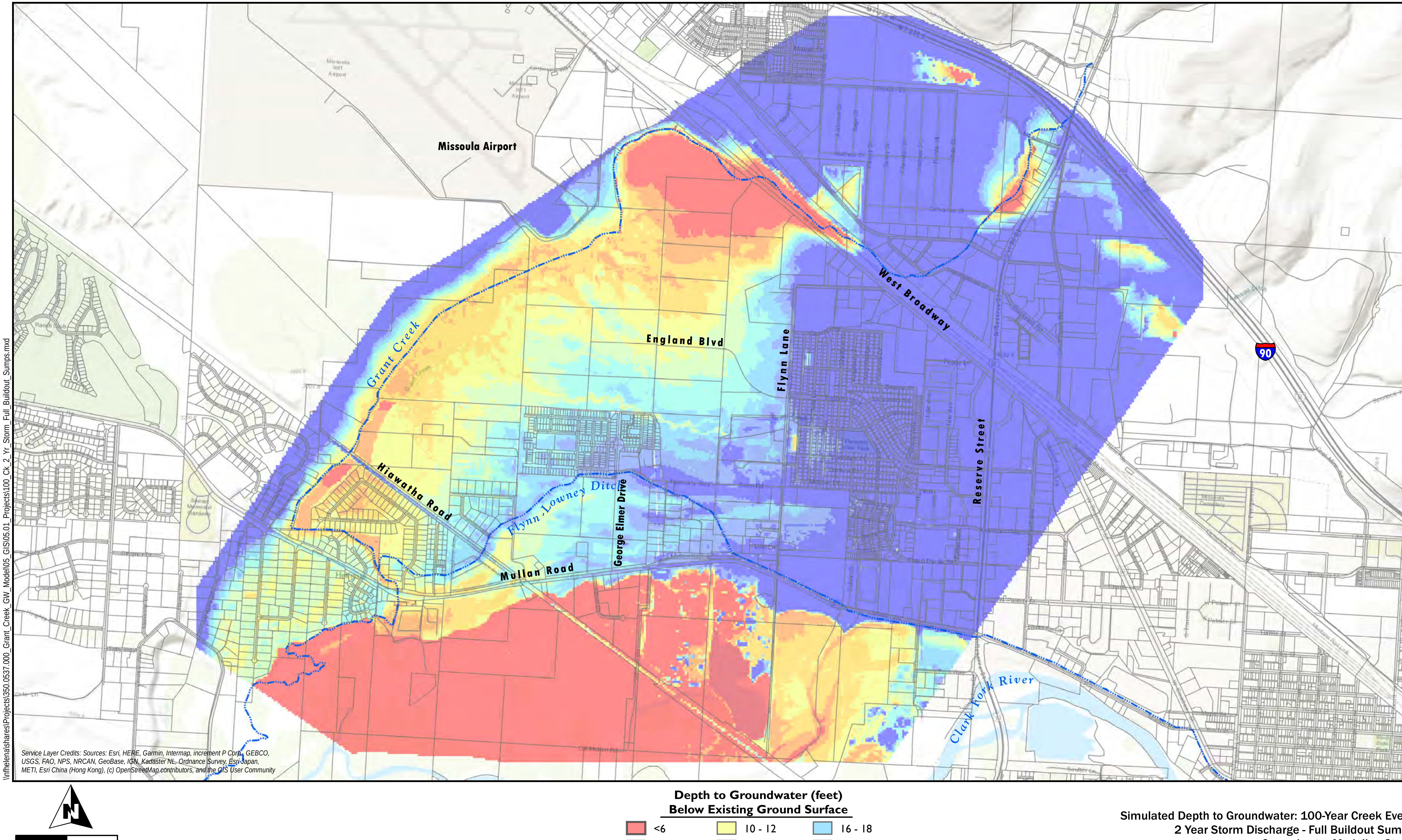
NewFields

Simulated Depth to Groundwater: 2-Year Creek Event
100 Year Storm Discharge - Full Buildout Sumps
Groundwater Modeling Study
Grant Creek-Mullan Road Area
Missoula, Montana
FIGURE 4-4



NewFields

Simulated Depth to Groundwater: 100-Year Creek Event
2 Year Storm Discharge - Existing Sumps
Groundwater Modeling Study
Grant Creek-Mullan Road Area
Missoula, Montana
FIGURE 4-5

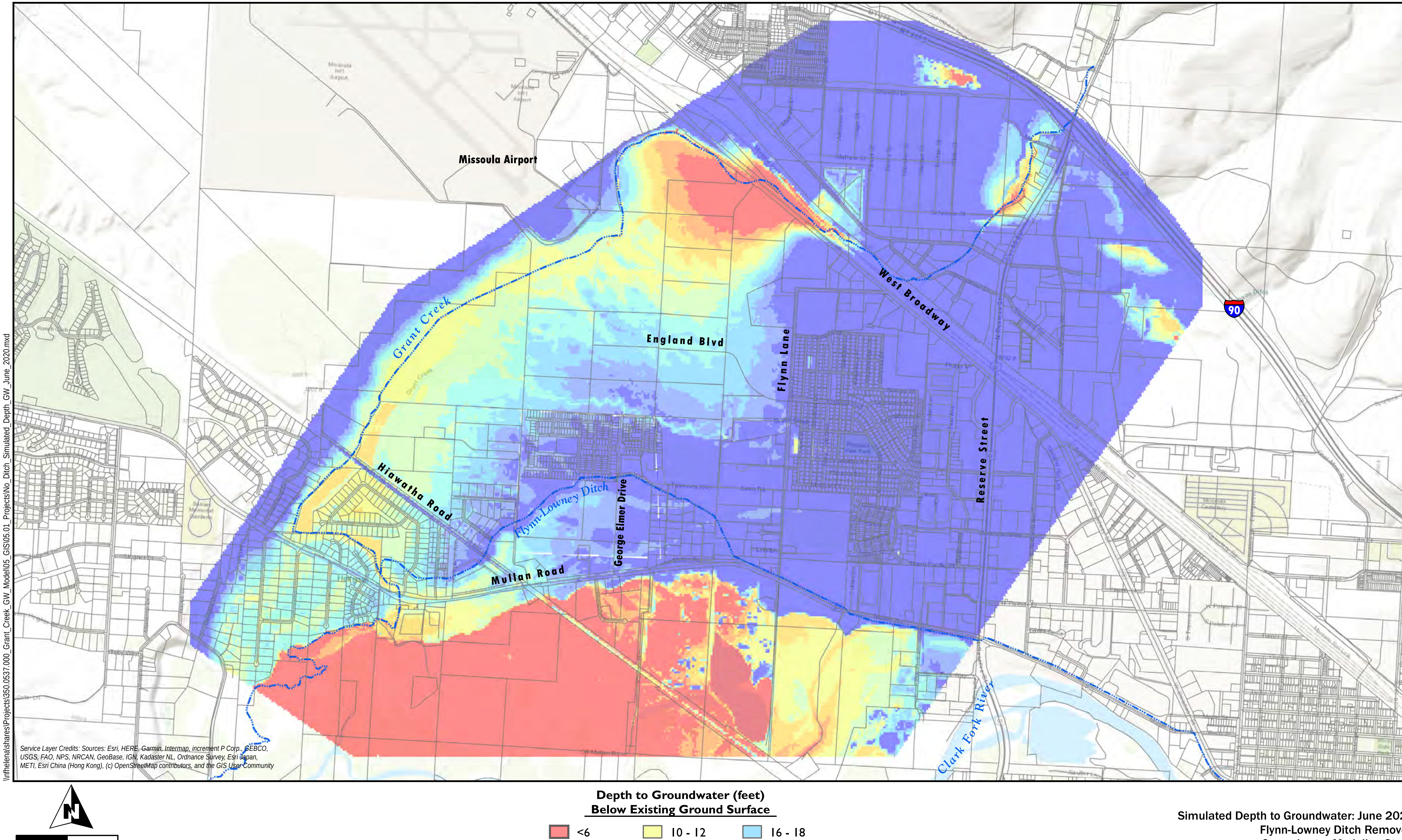


Depth to Groundwater (feet)
Below Existing Ground Surface

- <6
- 6 - 8
- 8 - 10
- 10 - 12
- 12 - 14
- 14 - 16
- 16 - 18
- 18 - 20
- >20

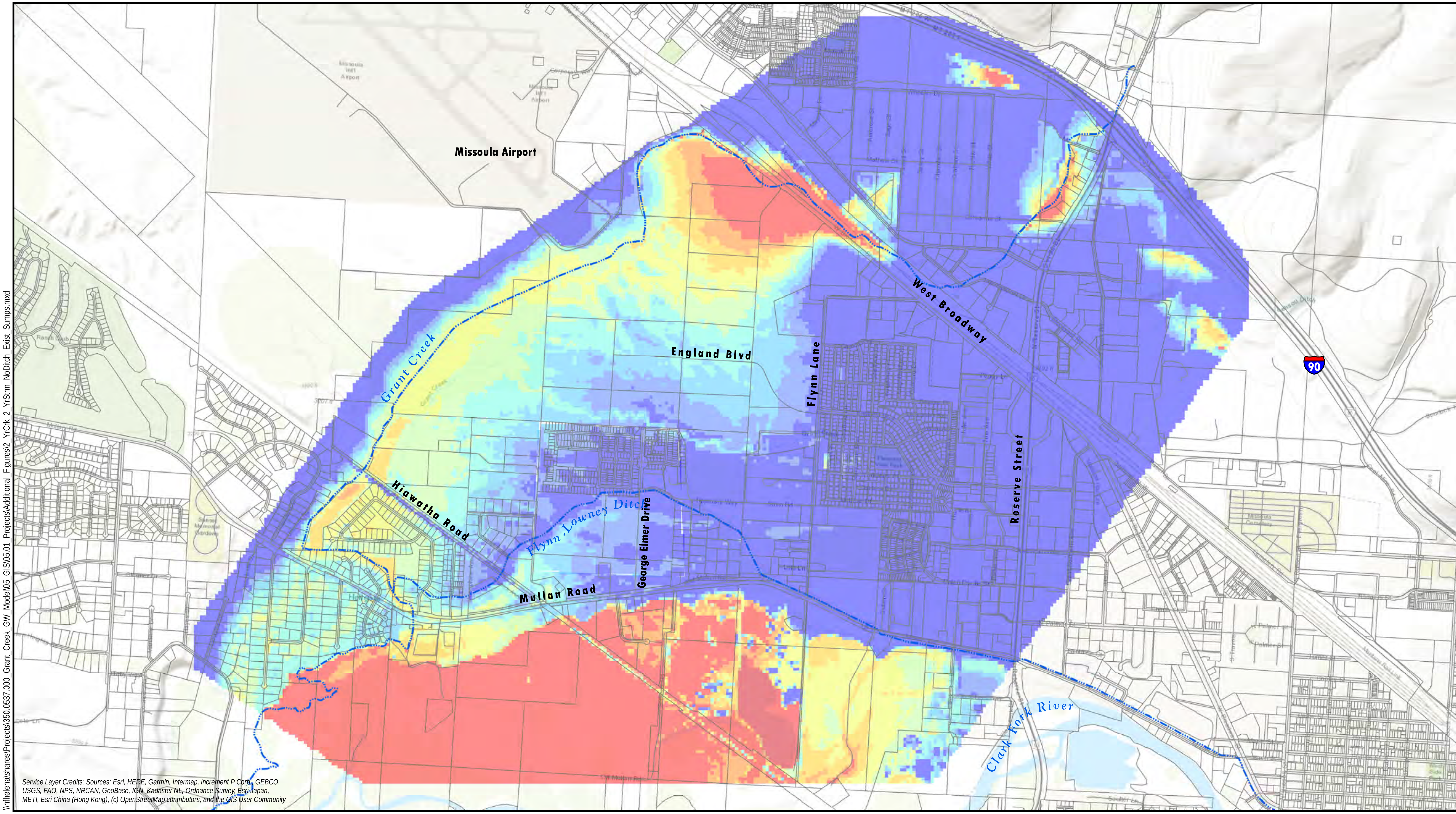
NewFields

Simulated Depth to Groundwater: 100-Year Creek Event
2 Year Storm Discharge - Full Buildout Sumps
Groundwater Modeling Study
Grant Creek-Mullan Road Area
Missoula, Montana
FIGURE 4-6



NewFields

Simulated Depth to Groundwater: June 2020
Flynn-Lowney Ditch Removed
Groundwater Modeling Study
Grant Creek-Mullan Road Area
Missoula, Montana
FIGURE 4-7

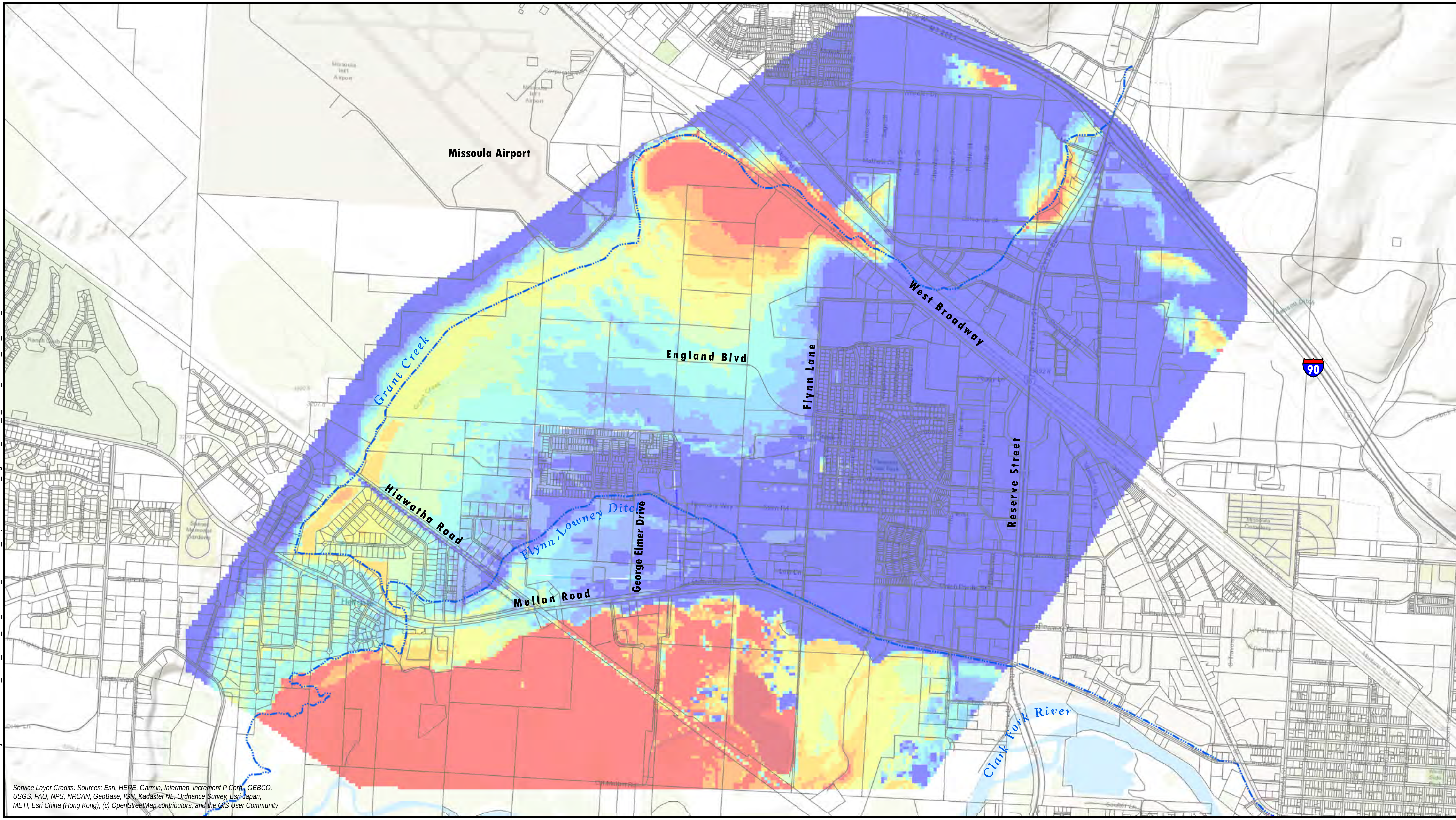


Depth to Groundwater (feet) Below Existing Ground Surface

<6	10 - 12	16 - 18
6 - 8	12 - 14	18 - 20
8 - 10	14 - 16	>20

NewFields

Simulated Depth to Groundwater: 2-Year Creek Event
2 Year Storm Discharge - Flynn-Lowney Ditch Removed
Existing Sumps
Groundwater Modeling Study
Grant Creek-Mullan Road Area
Missoula, Montana
FIGURE 4-8



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N

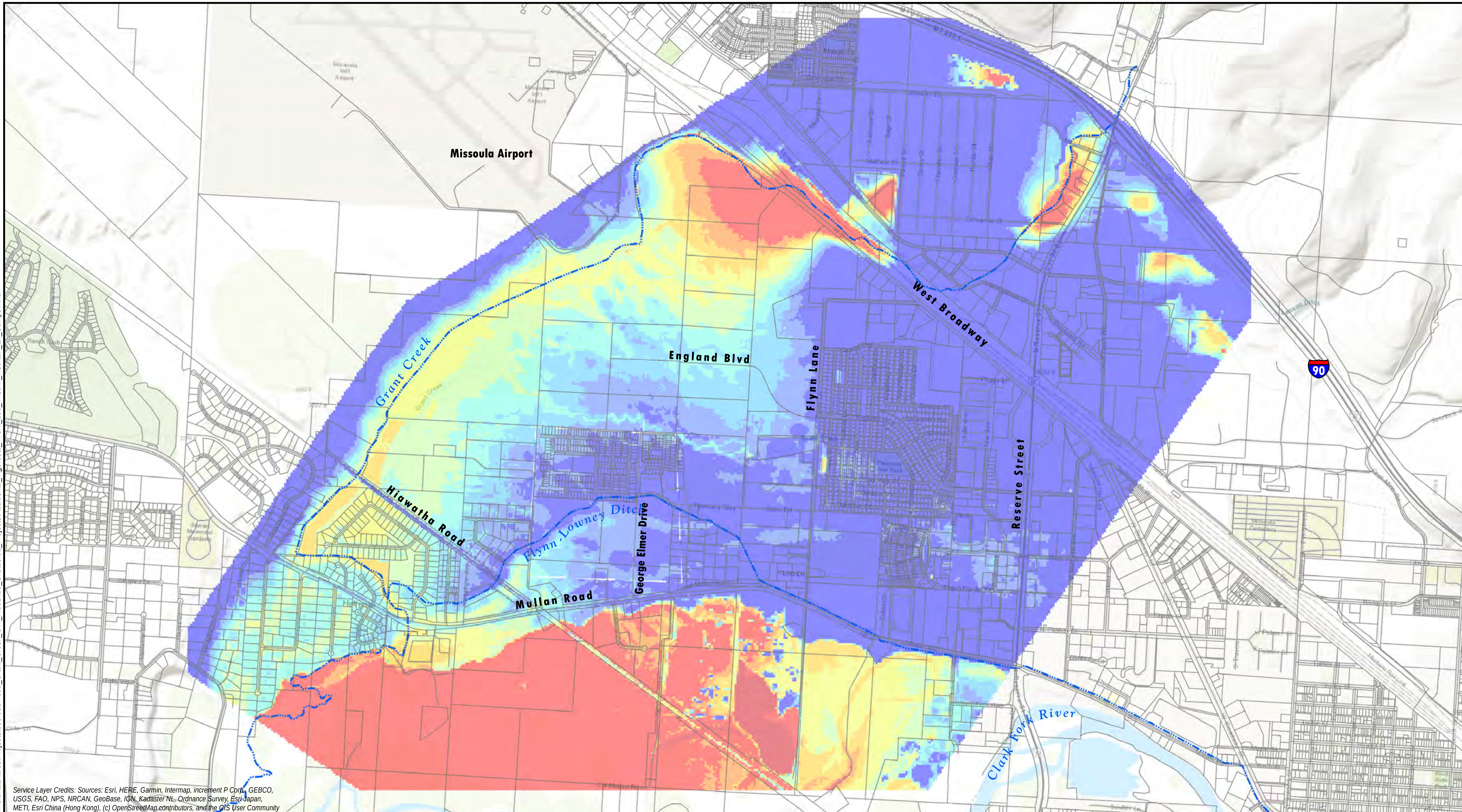
0 Feet 2,000

NewFields

Depth to Groundwater (feet)
Below Existing Ground Surface

<6	10 - 12	16 - 18
6 - 8	12 - 14	18 - 20
8 - 10	14 - 16	>20

Simulated Depth to Groundwater: 2-Year Creek Event
2 Year Storm Discharge - Flynn-Lowney Ditch Removed
Full-Buildout Sumps
Groundwater Modeling Study
Grant Creek-Mullan Road Area
Missoula, Montana
FIGURE 4-9



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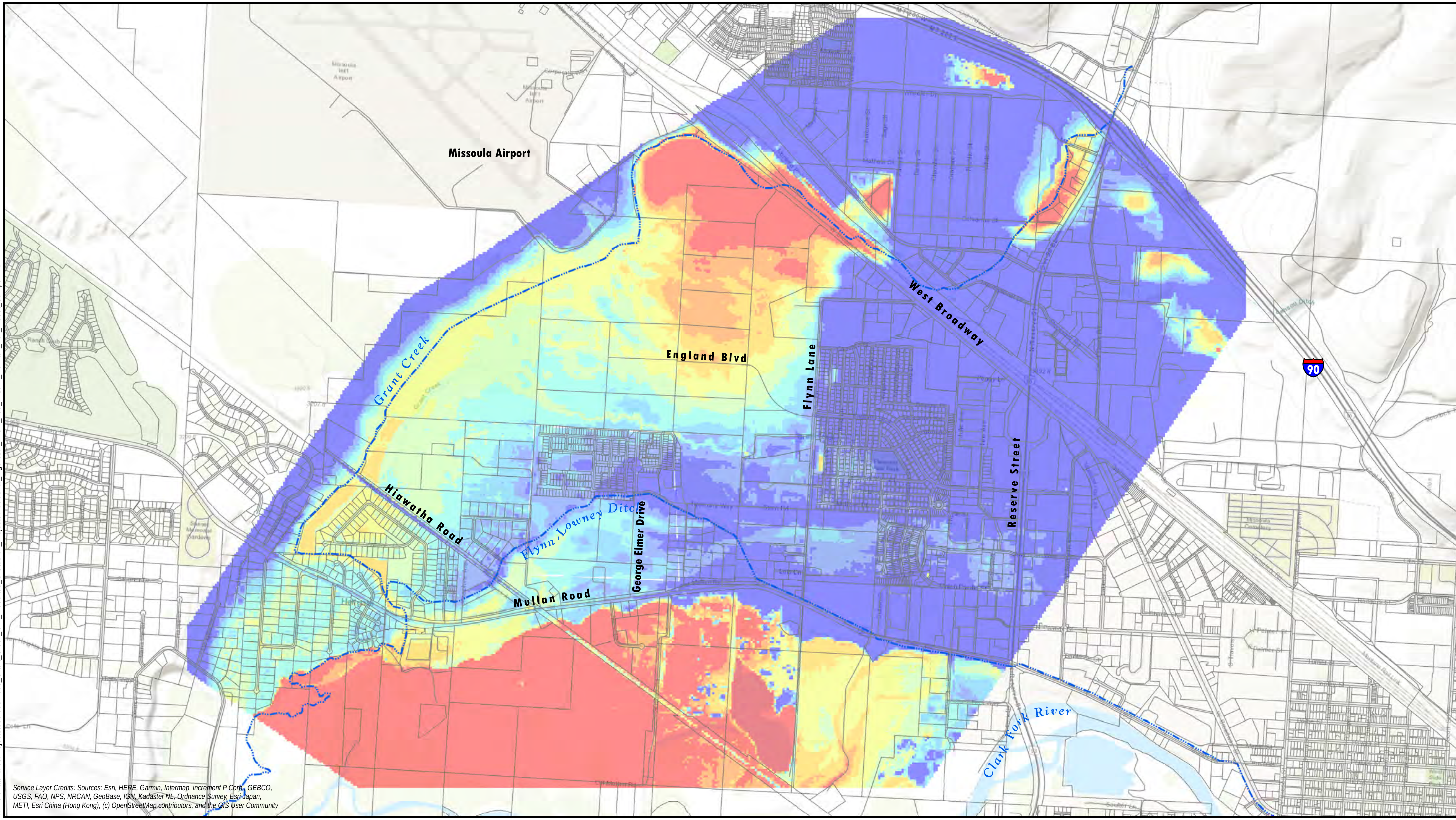
0 Feet 2,000

NewFields

Depth to Groundwater (feet)
Below Existing Ground Surface

<6	10 - 12	16 - 18
6 - 8	12 - 14	18 - 20
8 - 10	14 - 16	>20

Simulated Depth to Groundwater: 2-Year Creek Event
100 Year Storm Discharge - Flynn-Lowney Ditch Removed
Existing Sumps
Groundwater Modeling Study
Grant Creek-Mullan Road Area
Missoula, Montana
FIGURE 4-10



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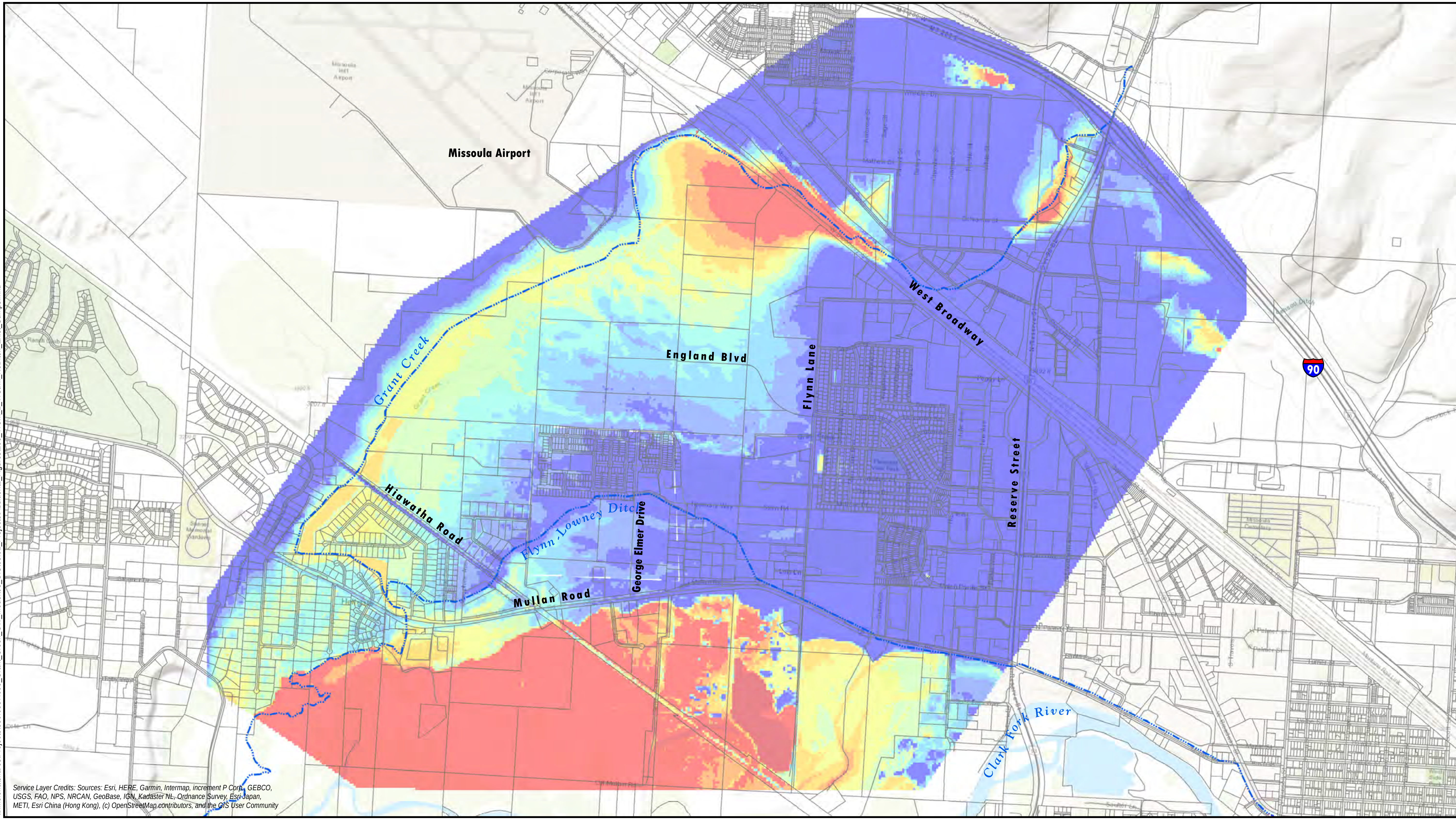
Depth to Groundwater (feet)
Below Existing Ground Surface

<6	10 - 12	16 - 18
6 - 8	12 - 14	18 - 20
8 - 10	14 - 16	>20

NewFields

Simulated Depth to Groundwater: 2-Year Creek Event
100 Year Storm Discharge - Flynn-Lowney Ditch Removed
Full-Buildout Sumps
Groundwater Modeling Study
Grant Creek-Mullan Road Area
Missoula, Montana
FIGURE 4-11



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N

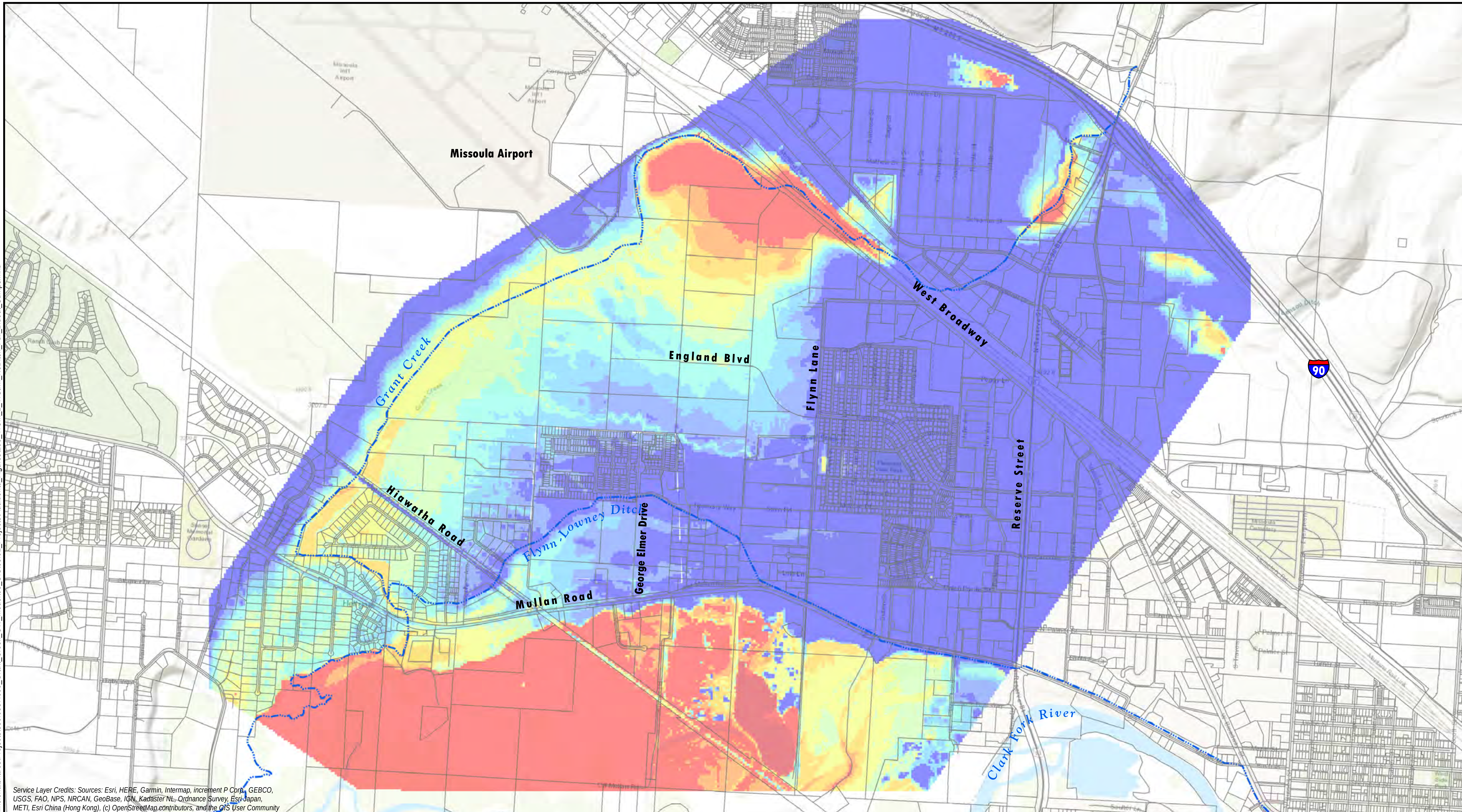
0 Feet 2,000

Depth to Groundwater (feet)
Below Existing Ground Surface

- <6
- 6 - 8
- 8 - 10
- 10 - 12
- 12 - 14
- 14 - 16
- 16 - 18
- 18 - 20
- >20

NewFields

Simulated Depth to Groundwater: 100-Year Creek Event
2 Year Storm Discharge - Flynn-Lowney Ditch Removed
Existing Sumps
Groundwater Modeling Study
Grant Creek-Mullan Road Area
Missoula, Montana
FIGURE 4-12



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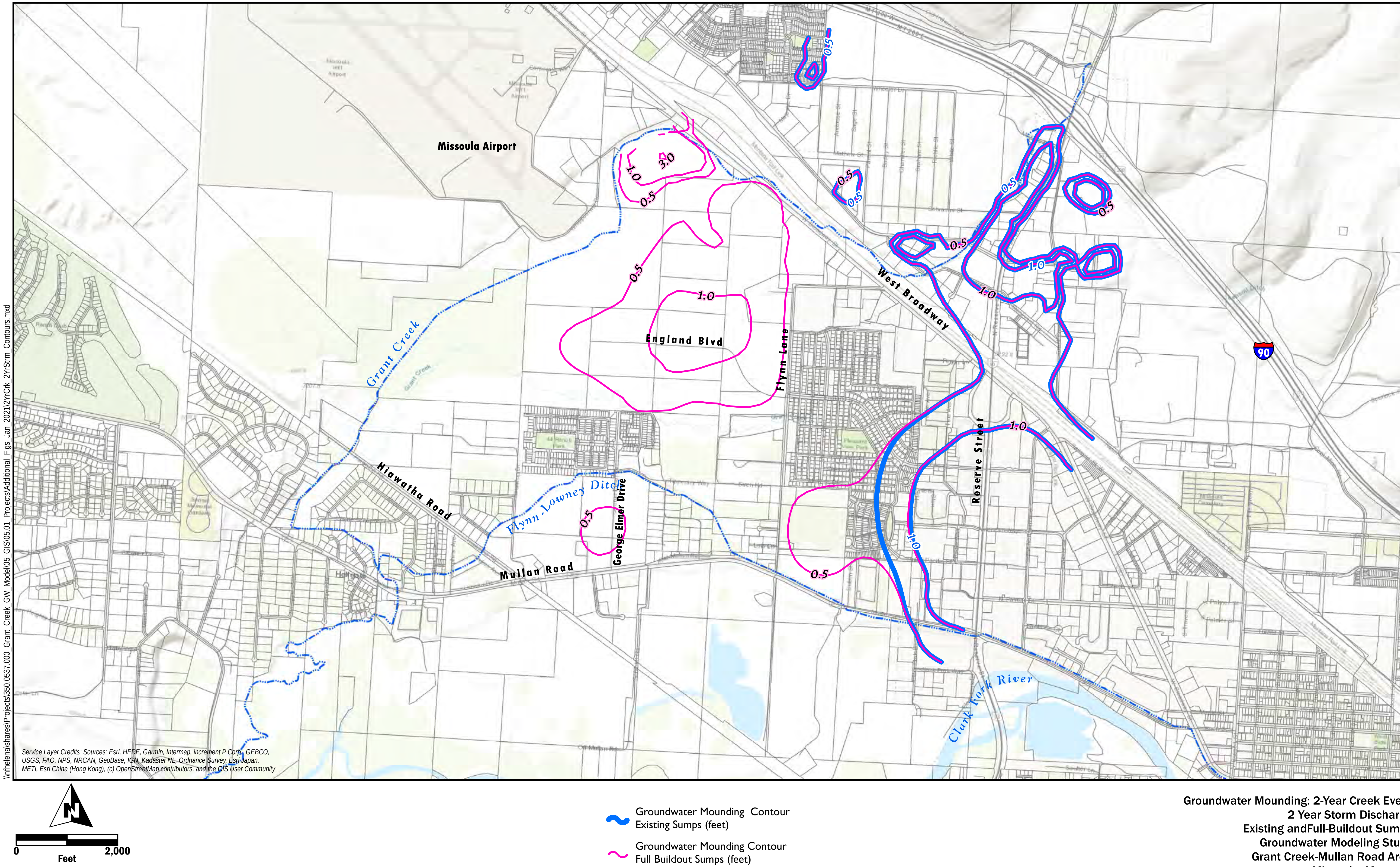
0 Feet 2,000

NewFields

Depth to Groundwater (feet) Below Existing Ground Surface

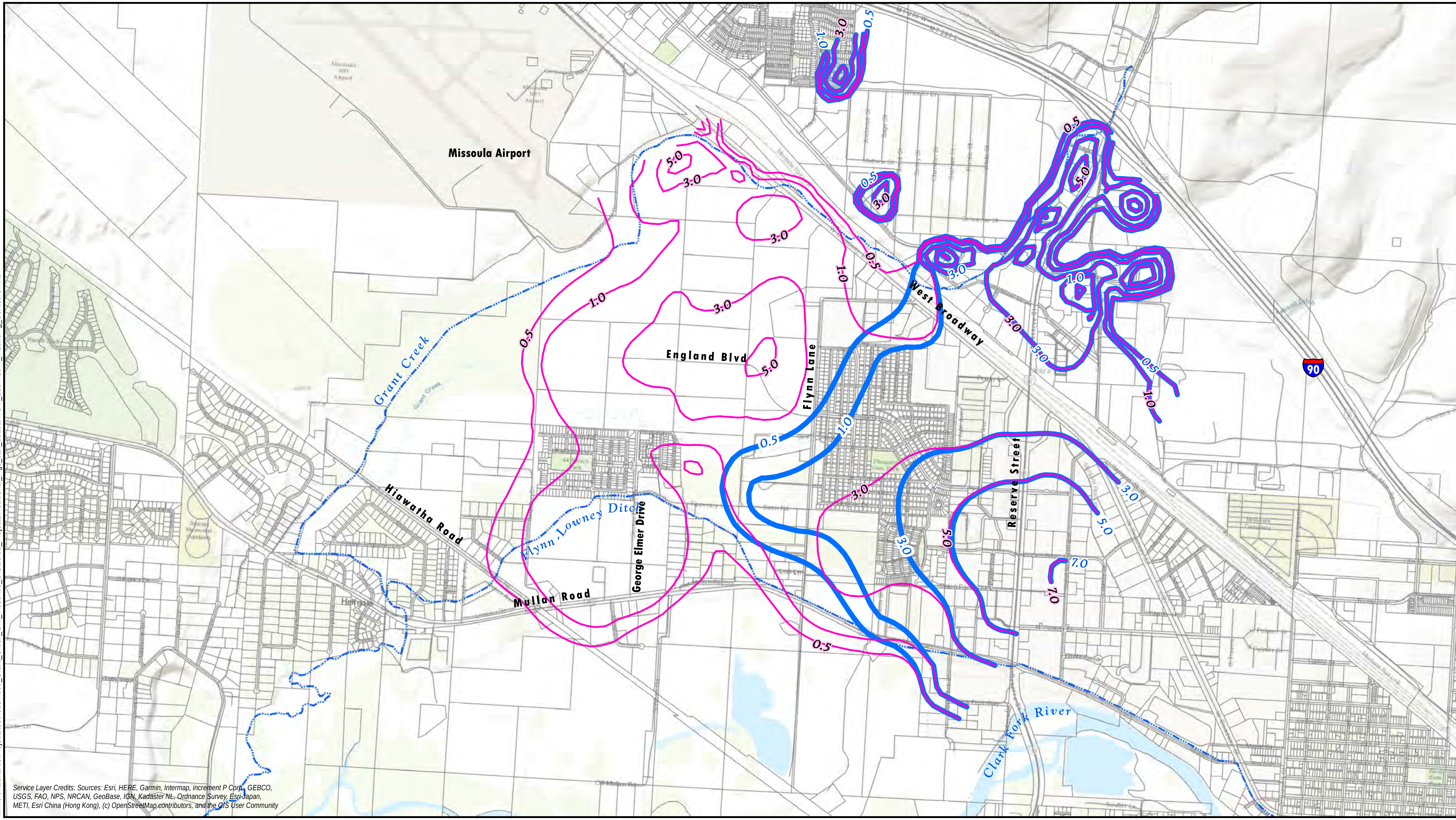
<6	10 - 12	16 - 18
6 - 8	12 - 14	18 - 20
8 - 10	14 - 16	>20

Simulated Depth to Groundwater: 100-Year Creek Event
2 Year Storm Discharge - Flynn-Lowney Ditch Removed
Full-Buildout Sumps
Groundwater Modeling Study
Grant Creek-Mullan Road Area
Missoula, Montana
FIGURE 4-13



NewFields

Groundwater Mounding: 2-Year Creek Event
2 Year Storm Discharge
Existing andFull-Buildout Sumps
Groundwater Modeling Study
Grant Creek-Mullan Road Area
Missoula, Montana
FIGURE 4-14



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N

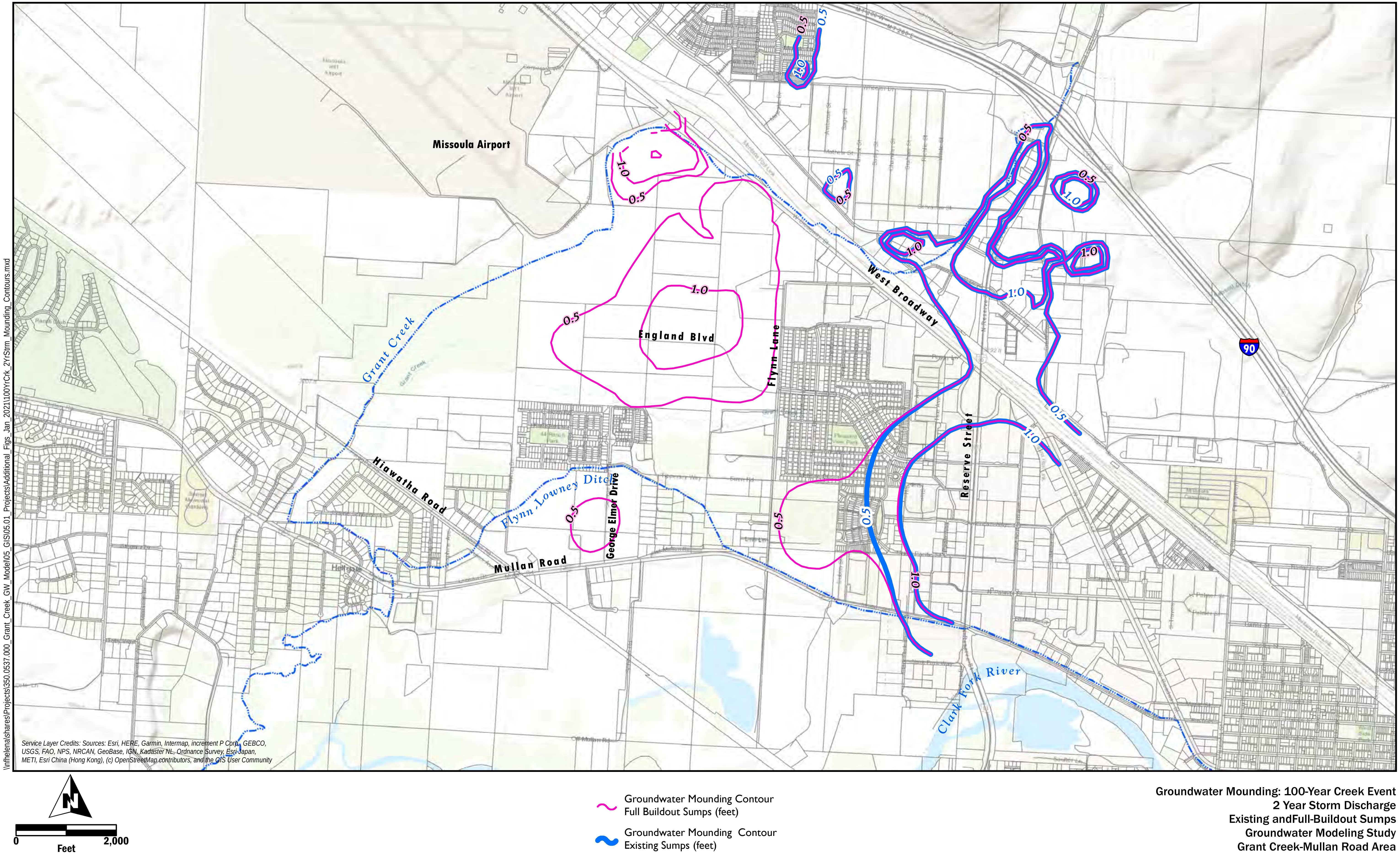
0 Feet 2,000

NewFields

Groundwater Mounding Contour Existing Sumps (feet)

Groundwater Mounding Contour Full Buildout Sumps (feet)

Groundwater Mounding: 2-Year Creek Event
100 Year Storm Discharge
Existing andFull-Buildout Sumps
Groundwater Modeling Study
Grant Creek-Mullan Road Area
Missoula, Montana
FIGURE 4-15



NewFields

Groundwater Mounding: 100-Year Creek Event
2 Year Storm Discharge
Existing andFull-Buildout Sumps
Groundwater Modeling Study
Grant Creek-Mullan Road Area
Missoula, Montana
FIGURE 4-16

APPENDICES

Appendix A
Precipitation and Creek Flow Data

Precipitation and Infiltration

	Jan	Feb	Mar	Apr	May	Jun
Average high in °F	33	39	50	58	67	75
Average low in °F	18	21	28	33	40	47
Av. precipitation in inch	0.85	0.70	1.00	1.22	2.01	2.07
Av. snowfall in inch	8	6	5	1	0	0

	Jul	Aug	Sep	Oct	Nov	Dec
Average high in °F	86	85	73	58	42	31
Average low in °F	51	50	42	32	25	17
Av. precipitation in inch	0.99	1.19	1.17	0.88	1.01	1.04
Av. snowfall in inch	0	0	0	1	5	11

Missoula Climate Graph - Montana Climate Chart

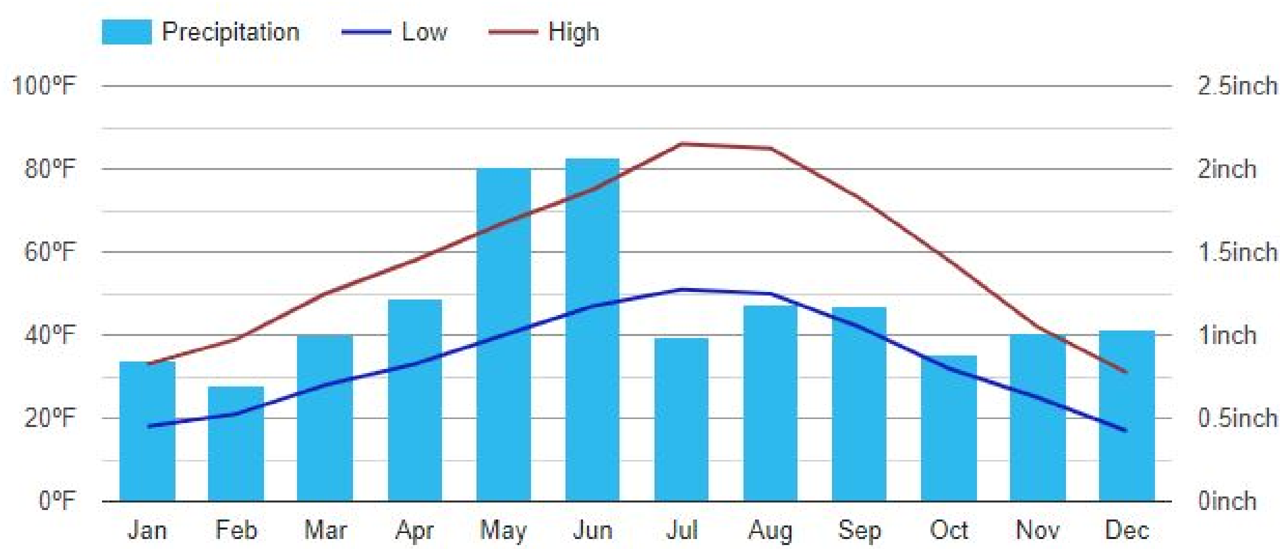


Figure A-1. Climate Data From Missoula Airport: 2007-2019

Table A-1. 2020 Monthly Precipitation and Infiltration by Land Use

				Daily Avg			2020			Densely Developed Recharge			Lightly Developed Recharge			Undeveloped Recharge			Irrigation Recharge		
Stress Period	Days	Cum Days	Dates	Ttl Ppt (in)	Dly Ppt (in/dy)	Temp (F)	Ttl Ppt (in)	Dly Ppt (in/dy)	Temp (F)	2% (ft/d)	Temp Adj Factor	Temp Adj (ft/d)	5% (ft/d)	Temp Adj Factor	Temp Adj (ft/d)	8% (ft/d)	Temp Adj Factor	Temp Adj (ft/d)	Net Irrig Req (in/mo)	Net Irrig Req (ft/d)	Return (ft/d)
1	14	14	3/8 - 3/22	0.43	0.031	38.5	0.03	0.002	34.2	3.6E-06	1	3.6E-06	8.9E-06	1	8.9E-06	1.4E-05	1	1.4E-05			1.3E-05
2	14	28	3/22 - 4/5	0.51	0.036	42.2	0.35	0.025	37.4	4.2E-05	1	4.2E-05	1.0E-04	1	1.0E-04	1.7E-04	1	1.7E-04			1.5E-04
3	14	42	4/5 - 4/19	0.55	0.039	44.8	1.37	0.098	40.6	1.6E-04	1	1.6E-04	4.1E-04	1	4.1E-04	6.5E-04	1	6.5E-04			5.9E-04
4	7	49	4/19 - 4/26	0.31	0.044	46.8	0.24	0.034	49.0	5.7E-05	1	5.7E-05	1.4E-04	1	1.4E-04	2.3E-04	1	2.3E-04			2.1E-04
5	7	56	4/26 - 5/3	0.28	0.040	48.7	0.06	0.009	53.8	1.4E-05	0.9	1.3E-05	3.6E-05	0.9	3.2E-05	5.7E-05	0.9	5.1E-05			4.6E-05
6	7	63	5/3 - 5/10	0.35	0.050	50.7	0.02	0.003	49.4	4.8E-06	1	4.8E-06	1.2E-05	1	1.2E-05	1.9E-05	1	1.9E-05	7.4E-01	2.0E-03	7.9E-04
7	7	70	5/10 - 5/17	0.4	0.057	52.8	1.03	0.147	49.9	2.5E-04	1	2.5E-04	6.1E-04	1	6.1E-04	9.8E-04	1	9.8E-04	7.4E-01	2.0E-03	7.9E-04
8	7	77	5/17 - 5/24	0.51	0.073	54.8	1.44	0.206	52.3	3.4E-04	0.9	3.1E-04	8.6E-04	0.9	7.7E-04	1.4E-03	0.9	1.2E-03	7.4E-01	2.0E-03	7.9E-04
9	7	84	5/24 - 5/31	0.59	0.084	56.5	0.04	0.006	60.1	9.5E-06	0.8	7.6E-06	2.4E-05	0.8	1.9E-05	3.8E-05	0.8	3.0E-05	7.4E-01	2.0E-03	7.9E-04
10	7	91	5/31 - 6/7	0.59	0.084	58.0	0.09	0.013	58.8	2.1E-05	0.9	1.9E-05	5.4E-05	0.9	4.8E-05	8.6E-05	0.9	7.7E-05	4.4E+00	1.2E-02	1.5E-03
11	6	97	6/7 - 6/13	0.47	0.078	59.5	0.3	0.050	58.8	8.3E-05	0.9	7.5E-05	2.1E-04	0.9	1.9E-04	3.3E-04	0.9	3.0E-04	4.4E+00	1.2E-02	3.2E-03
12	1	98	6/13 - 6/14	0.08	0.080	61.1	0.01	0.010	55.5	1.7E-05	0.9	1.5E-05	4.2E-05	0.9	3.8E-05	6.7E-05	0.9	6.0E-05	4.4E+00	1.2E-02	3.2E-03
13	7	105	6/14 - 6/21	0.48	0.069	62.8	0.09	0.013	69.5	2.1E-05	0.8	1.7E-05	5.4E-05	0.8	4.3E-05	8.6E-05	0.8	6.9E-05	4.4E+00	1.2E-02	3.2E-03
14	7	112	6/21 - 6/28	0.39	0.056	63.9	0.06	0.009	69.0	1.4E-05	0.8	1.1E-05	3.6E-05	0.8	2.9E-05	5.7E-05	0.8	4.6E-05	4.4E+00	1.2E-02	3.2E-03
15	7	119	6/28 - 7/5	0.32	0.046	65.1	2.04	0.291	57.6	4.9E-04	0.9	4.4E-04	1.2E-03	0.9	1.1E-03	1.9E-03	0.9	1.7E-03	6.4E+00	1.7E-02	4.6E-03
16	14	133	7/5 - 7/19	0.47	0.034	67.2	0.27	0.019	64.3	3.2E-05	0.8	2.6E-05	8.0E-05	0.8	6.4E-05	1.3E-04	0.8	1.0E-04	6.4E+00	1.7E-02	4.6E-03
17	14	147	7/19 - 8/2	0.39	0.028	69.5	0	0.000	68.6	0.0E+00	0.8	0.0E+00	0.0E+00	0.8	0.0E+00	0.0E+00	0.8	0.0E+00	6.4E+00	1.7E-02	4.6E-03
18	14	161	8/2 - 8/16	0.51	0.036	70.2	0	0.000	73.1	0.0E+00	0.8	0.0E+00	0.0E+00	0.8	0.0E+00	0.0E+00	0.8	0.0E+00	5.4E+00	1.4E-02	3.8E-03
19	21	182	8/16 - 9/6	0.83	0.040	67.9	0.38	0.018	69.2	3.0E-05	0.8	2.4E-05	7.5E-05	0.8	6.0E-05	1.2E-04	0.8	9.7E-05	5.4E+00	1.4E-02	3.8E-03
20	21	203	9/6 - 9/27	0.82	0.039	63.8	0.28	0.013	66.0	2.2E-05	0.8	1.8E-05	5.6E-05	0.8	4.4E-05	8.9E-05	0.8	7.1E-05	1.3E+00	3.5E-03	9.3E-04

Grant Creek Flows and Stage

Table A-2. Summary of Grant Creek Flow Measurements, from HDR (2005c)

Location	Du Breuil (1983)	Land & Water (1999)
I-90	--	158.5 cfs [5/28/99]
International Road	112 cfs [6/26/82]	--
Pepsi Plant	--	126.1 cfs [5/28/99]
Hwy 10	--	(175 cfs) [5/28/99]
MRL Bridge	--	205.1 cfs [5/26/99]
C M St. P& P Trestle	--	--
Mullan Road	--	173.7 cfs [5/26/99]

Table A-3. Summary of Grant Creek Return Period Discharge Estimates-Method 2, from HDR (2005c)

Location	Area (sq-mi)	Avg. Unit Discharge (cfs/sq-mi)					Discharge (cfs)				
		2-yr	10-yr	50-yr	100-yr	500-yr	2-yr	10-yr	50-yr	100-yr	500-yr
I-90	24.7	8.64	16.77	25.65	29.86	40.97	213	414	634	738	1012
@ West Broadway	27.5						238	461	705	822	1127
Confluence with Clark Fork River	29.6						255	496	759	884	1213

Note: Method 2 utilizes a comparison of Grant Creek to other basins

Table A-4. Summary of Grant Creek Peak Flow Intensities, from HDR (2005c)

Return Period	Peak Flow (HEC-HMS)	Peak Flow (Method 2)
2-YR	166	213
10-yr	302	414
50-yr	637	634
100-yr	835	738
500-yr	1684	1012

Table A-5. Summary of 2004 Grant Creek Staff Gage Measurements, from HDR/Maxim (2005a)

Station ID	Coordinates		Staff Gage Measurement (ft)											Min.	Max.	Change
	X	Y	04/21/04	04/30/04	05/03/04	05/05/04	05/10/04	05/18/04	05/25/04	06/01/04	06/08/04	06/14/04	06/22/04			
SG-1	838583	991826	0	0.5	0.54	0	0	0	1.25	1.41	2.23	2.04	1.9	0	2.23	2.23
SG-2	823313	994145	1.1	1.28	2	2.4	1.8	1.4	1.84	1.8	2	2	1.45	1.1	2.4	1.3
SG-4	822316	997142	0.9	0.9	2.1	2.8	1.75	1.1	1.8	1.7	2.05	2.1	1	0.9	2.8	1.9
SG-5a	826690	996457	0	0	0	0	0	0	0	0.96	1.46	1.5	1.27	0	1.5	1.5
SG-5b	828395	997793	0	0	0	0	0	0	0	0.45	1.2	0	0.75	0	1.2	1.2
SG-5c	829901	995112	0	0	0	0	0	0	0	0.95	1.54	1.04	0.88	0	1.54	1.5
SG-6	830331	1002507	0.65	0.76	1.1	1.2	1	0.75	0.98	0.95	0.97	0.95	0.7	0.65	1.2	0.6
SG-7	831753	1001531	1.18	1.7	1.95	1.95	1.7	1.45	1.7	1.7	1.7	1.67	1.35	1.18	1.95	0.8
SG-8	836785	1004216	1	1.15	1.6	1.9	1.5	1.3	1.5	1.35	1.45	1.4	1.15	1	1.9	0.9
SG-9	?	?	1.58	1.7	2	2.2	1.9	1.7	1.9	1.85	1.85	1.85	1.65	1.58	2.2	0.62
SG-10	?	?	N/A	0.85	1.05	1.25	0.95	0.85	0.95	0.8	1	0.96	0.88	0.8	1.25	0.45

Figure A-2. 2020 Grant Creek Surface Water Monitoring Locations

Table A-6. 2020 Grant Creek Flow and Stage

Station:	Old Grant Creek Rd.			Highlander Brewery			West Broadway			Mullan Trail		
Lat/Long:	46.94755, -114.01457			46.90452, -114.04483			46.90907, -114.05833			46.88608, -114.08560		
Date	Time	Discharge (cfs)	Stage (ft)	Time	Discharge (cfs)	Stage (ft)	Time	Discharge (cfs)	Stage (ft)	Time	Discharge (cfs)	Stage (ft)
2-Jun	12:20	140.9	2.46	14:00	163	NA	17:40	144	NA	16:30	92.66	3.40
9-Jun	-----	-----	-----	12:15	97.5	NA	9:45	89.8	NA	14:30	74.53	3.12
18-Jun	12:41	69	1.86	11:25	77	NA	9:54	67.7	NA	-----	-----	-----
26-Jun	-----	-----	-----	10:30	62.9	1.2	12:00	58.3	NA	-----	-----	-----
1-Jul	-----	-----	-----	13:35	101.8	1.39	14:35	89.0	NA	-----	-----	-----
10-Jul	-----	-----	-----	11:00	40.5	1.06	10:00	37.3	NA	-----	-----	-----
23-Jul	-----	-----	-----	9:45	17.0	NA	13:20	11.2	NA	-----	-----	-----
3-Aug	-----	-----	-----	13:44	10	NA	12:40	4.1	NA	-----	-----	-----

Table A-7. 2020 Grant Creek Flow Loss

Date	Flow Loss (cfs) Highlander to W. Broadway	Flow Loss (cfs) W. Broadway to Mullan Trail
2-Jun	19.0	51.3
9-Jun	7.7	15.3
18-Jun	9.3	-----
26-Jun	4.6	-----
1-Jul	12.8	-----
10-Jul	3.3	-----
23-Jul	5.8	-----
3-Aug	5.9	-----
Avg:	8.6	33.3

Table A-8. Irrigation Ditch Seepage Rates-West Side Ditch and Environs

Ditch Name	Ditch Length (Miles)	Seepage Quantity (CFS)	Seepage Rate (%)	Data Source	Rate per Mi. (cfs)	Rate per cell (cfs)	Rate per cell (cfd)
Whalen Ditch	3.5	4.2	52.5	Pioneer	1.20	0.045455	3927.3
West Side Ditch	11.4	19.1	54.6	Pioneer	1.68	0.063464	5483.3
Gardiner Ditch	8.12	9.92	40.03	CFC	1.22	0.046276	3998.2
Helen Johnson Ditch	2.7	5.75	48.09	CFC	2.13	0.080668	6969.7
Cement Ditch	4.3	4.59	13.42	CFC	1.07	0.040433	3493.4
Morrison Ditch	7.5	12	38	DNRC	1.60	0.060606	5236.4
Valiton Ditch	4.5	6	25.15	DNRC	1.33	0.050505	4363.6
MSP Tin Cup Joe	2.9	3.15	24	CFC	1.09	0.041144	3554.9
Upper Peterson	1.7	1	20.48	DNRC	0.59	0.022282	1925.1
Total:	46.62	65.71	35.14		1.41	0.053389	4612.8
Total (w/o WSD & Whalen):	31.72	42.41	29.88		1.34	0.050644	4375.7

Appendix B
Monitoring Wells and Hydrographs

Table B-1. Summary of Monitoring Wells Within the Study Area

Well/Piezo.	Alternate	GWIC ID			WL Data - Manual		WL Data	Date	Meas Pt	Coordinates-SP ft			Ttl Depth	Screen Depth (ft)	
ID	ID		Area	Log	Dates	No. Pts	Transducer	Installed	Elev.	X	Y	TRS	(ft bgs)	Top	Bottom
CUMMINS		68339	North	X	03/04 - 06/05	12	--------	11/13/1977	3268.94	836442.0	1002892.5	13N 19W 5	98	52	55
BAKKE		68356	North	X	03/04 - 08/04	11	--------	8/5/1985	3193.75	833584.8	999721.6	13N 19W 7	78.5	79	open @ 78.5
WCF28		?	North	----	03/04 - 08/04	11	--------		3201.56	835186.6	998987.8	13N 19W 8	75		open @ 75
WCF30		?	North	----	03/04 - 06/05	12	--------		3206.9	835234.4	999547.5	13N 19W 8	78		open @ 78
WCF31		?	North	----	03/04 - 08/04	7	--------		3214.63	835250.0	1000272.5	13N 19W 8	112		open @ 112
MMW8	W. Broadway	-----	North	X	10/03 - 06/05	17	04/20 - 09/20	9/22/2003	3174.14	831680.6	1001265.7	13N 19W 7	50	20	50
MMW4	Whippoorwill Dr	-----	North	X	08/03 - 06/05	18	04/20 - 09/20	8/12/2003	3160.55	827739.7	1003058.2	13N 20W 1	31	16	31
WQD22		157211	North	X	06/96 - 07/20	111	--------	1/25/1996	3174.7	834953.3	996252.9	13N 19W 8	100	95	100
WQD9		151061	North	X	07/95 - 07/20	111	--------	2/28/1995	3174.72	834951.9	996258.0	13N 19W 8	50	20	50
MMW12	Pius	-----	Middle	X	08/03 - 06/05	17	10/03 - 06/04 04/20 - 09/20	8/13/2003	3158.27	828419.7	999381.4	13N 20W 12	30.5	20.5	30.5
MMW3	Airport	-----	Middle	X	08/03 - 06/05	18	10/03 - 06/04 04/20 - 09/20	8/13/2003	3152.87	825868.0	1000647.1	13N 20W 12	21	11	21
WQD4		151186	Middle	X	07/95 - 06/08	63	--------	9/2/2008	3162.38	829620.4	996963.1	13N 19W 7	50	20	50
WQD44	44 Ranch Park	267856	Middle	X	04/20 - 07/20	4	04/20 - 08/20	5/22/2012	3158.1	827609.283	997325.6	13N 20W 12	112	87	97
MMW6		-----	Middle	X	08/03 - 06/05	18	--------	8/13/2003	3156.67	826780.5	996512.4	13N 20W 13	26.5	11.5	26.5
MMW7		-----	Middle	X	08/03 - 06/05	18	--------	8/12/2003	3161.28	829674.4	997779.7	13N 19W 7	31	15	31
MMW13		-----	Middle	X	11/03 - 06/05	16	--------	9/22/2003	3162.49	830011.4	995022.8	13N 19W 7	32	12	32
WQD3	Topaz Dr	151179	South	X	07/95 - 07/20	115	04/20 - 09/20	1/5/1995	3147.13	821901.5	993715.6	13N 20W 14	42	12	42
MMW1	Hiawatha II	-----	South	X	08/03 - 06/05	18	10/03 - 06/04 04/20 - 09/20	8/11/2003	3146.61	822766.0	996884.0	13N 20W 11	18	7	17
MMW11	Hiawatha I	-----	South	X	10/03 - 06/05	17	04/20 - 09/20	8/13/2003	3152.24	824222.2	995784.5	13N 20W 14	27	12	27
RLK1		-----	South	----	08/03 - 06/05	18	--------		3145.52	823009.3	995347.5	13N 20W 14		30	35
RLK2		-----	South	----	08/03 - 06/05	18	--------		3144.66	822414.6	996019.1	13N 20W 14		30	35
RLK3		-----	South	----	08/03 - 06/05	18	--------		3146.84	822160.6	996836.7	13N 20W 14		25.2	30.2
P-1B		-----	South	----	08/03 - 08/04	17	--------		3144.9	822399.2	996440.8	13N 20W 14		20	30
P-2B		-----	South	----	08/03 - 06/05	18	--------		3148	823580.4	995639.5	13N 20W 14		20	30
P-3		-----	South	----	08/03 - 06/05	18	--------		3146.37	823245.5	997504.1	13N 20W 14		20	30
MMW2		-----	South	X	08/03 - 06/05	18	--------	8/11/2003	3146.86	822647.9	997570.9	13N 20W 11	16.5	6.5	16.5
MMW5		-----	South	X	08/03 - 06/05	18	--------	8/11/2003	3145.31	823321.2	994484.4	13N 20W 14	18	8	17.5
PWS-1		227593	South	X	--------	----	--------	3/24/2006		823613.0	996223.2	13N 20W 14	120	95	110
PWS-2		227602	South	X	--------	----	--------	3/23/2006		823613.0	996223.2	13N 20W 14	120	97	112

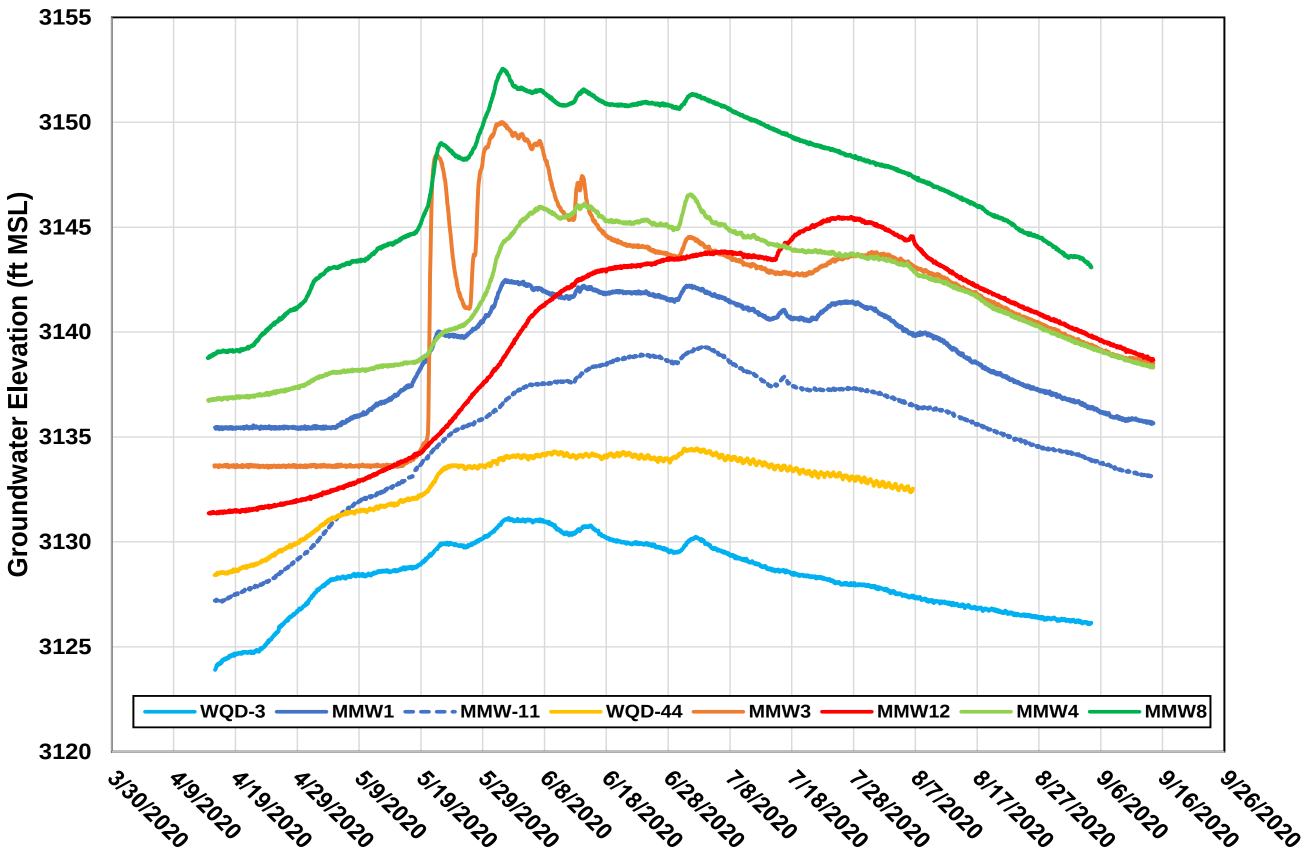


Figure B-1. 2020 Transducer Data: WQD Instrumented Wells

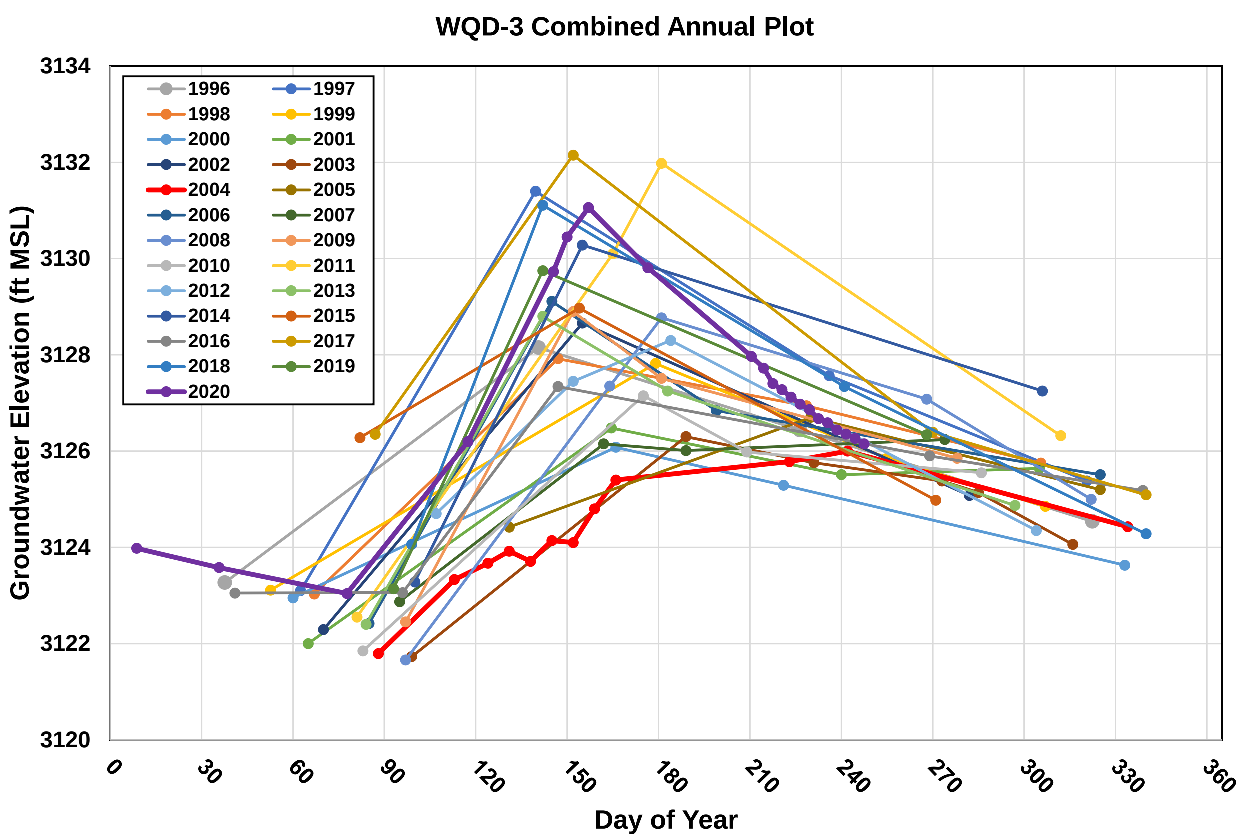


Figure B-2. WQD-3 Combined Hydrographs: 1996 to 2020

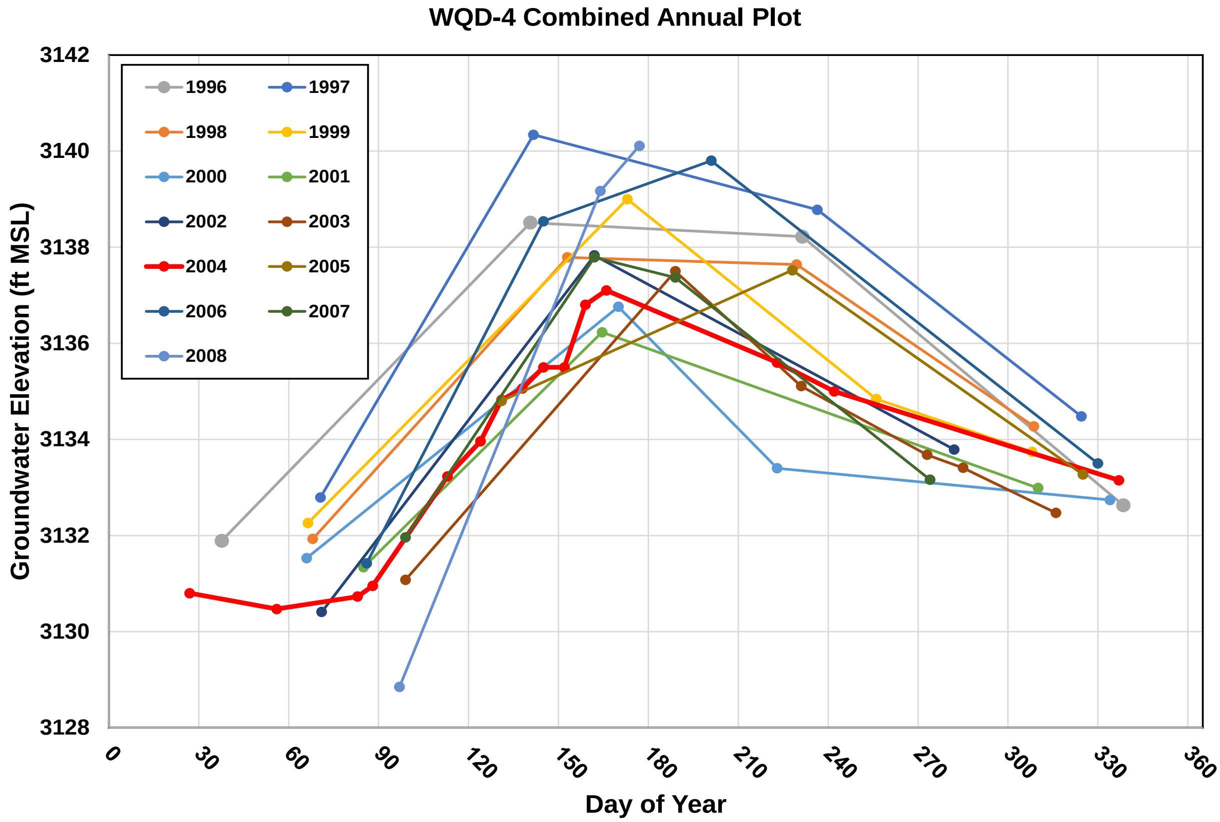


Figure B-3. WQD-4 Combined Hydrographs: 1996 to 2008

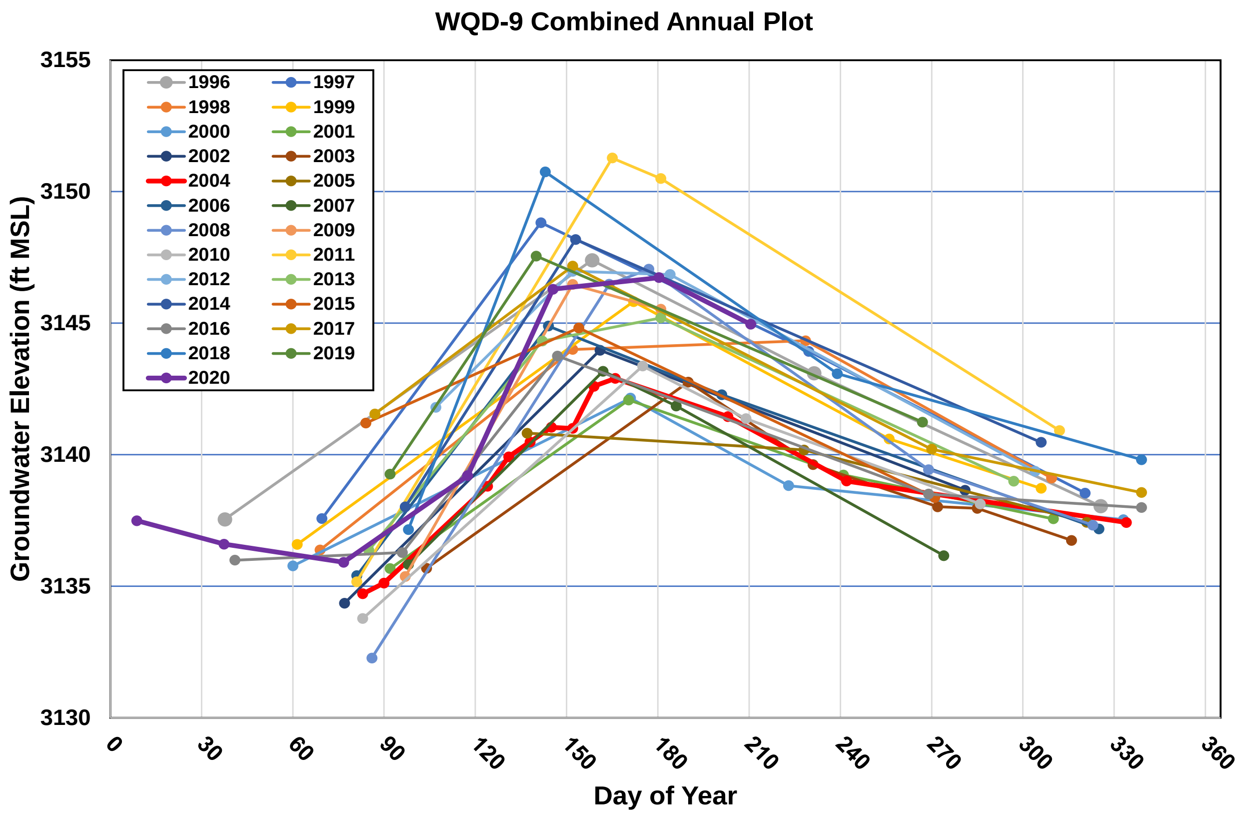


Figure B-4. WQD-9 Combined Hydrographs: 1996 to 2020

Appendix C
Upper Soil and Shallow Aquifer Conditions

Table C-1
Summary of Upper Soil Data Points

Point	GWIC	Coordinates (SP ft)		TD	Upper 10 ft (8-10 ft)		Lower 10-14 ft	
		X	Y		Description	Zone	Description	Zone
HV-TP1		831628	996327	12	loamy sand-some silt	2	Crs loamy sand	3
HV-TP2		831579	996194	12	40% cobbles and gravels	4	60% cobbles and gravels	4
HV-TP3		831881	996143	12	cobbles/gvl, sandy loam	3	cobbles/gvl, crs loamy sand	3
HV-TP4		832044	996217	12	sandy loam	3	cobbles/gvl, crs loamy sand	3
HL-TP1		825690	995573	10	gravely loamy sand	3	---------	
HL-TP2		825752	996315	10	gravely loamy sand	3	---------	
HL-TP3		826246	996500	10	loamy sand	3	---------	
HL-TP4		826794	996304	10	gravely silty clay	2	---------	
HL-TP5		826190	995836	10	extrem gravely loamy sand	4	---------	
HL-TP6		826712	995593	10	crs gravely loamy sand	4	---------	
HL-TP7		827283	995790	10	extrem gravely loamy sand	4	---------	
HL-TP8		827304	996266	10	gravely loamy sand	4	---------	
HL-TP9		827604	996035	10	extrem gravely loamy sand	4	---------	
HL-TP10		827944	996353	10	loamy sand	3	---------	
HL-TP11		828075	995538	10	extrem gravely loamy sand	4	---------	
REM-TP-01		825929	998544	10	GW - gravel with sand	4	---------	
REM-TP-02		826363	998521	10	GW - gravel with sand	4	---------	
REM-TP-03		826864	998459	10	Silt; SP-SM poorly graded sand	2	---------	
REM-TP-04		826082	998342	9	GW - Well graded gravel	4	---------	
REM-TP-05		826600	998292	10	GW - Well graded gravel	4	---------	
REM-TP-06		825887	998153	10	Silt; GW-Well graded gravel	3	---------	
REM-TP-07		826335	998104	10	GW - Well graded gravel	4	---------	
REM-TP-08		826844	998947	10	SM silty sand; SP poorly graded sand	2	---------	
MF-TP1		827075	998173	11.5	GW-GM Well Graded Gravel	4	GW-GM Well Graded Gravel	4
MF-TP2		827675	998205	10.5	GW-GM Well Graded Gravel	4	---------	
MF-TP3		827642	998381	11	GP-GM Poorly Graded Gravel	3	GP-GM Poorly Graded Gravel	3
MF-TP4		828208	998386	11.5	GP-GM Poorly Graded Gravel	3	GP-GM Poorly Graded Gravel	3
MF-TP5		828158	998179	11.8	SP-SM Poorly graded sand with silt	2	SP-SM Poorly graded sand with silt	2
MF-TP6		827685	997930	11.5	GP-GM Poorly graded gravel	3	GP-GM Poorly graded gravel	3
VS-PWS1		823613.0	996223.2	120	SM silty sand, sand with silt	3	GW Well graded gravel	4
VS-PWS2		823613.0	996223.2	120	SM silty sand, sand with silt	3	GW Well graded gravel	4
Bakke	68356	833584.8	999721.6	78.5	Clay, gravel, and ccobblestones	2	Clay, gravel, and ccobblestones	2
Cummins	68339	836442.0	1002892.5	140	Clay, gravel, and ccobblestones	2	Clay, gravel, and ccobblestones	2
MMW-1		822766.0	996884.0	18	silty fine to very fine sand	3	medium sand with gravel	4
MMW-2		822647.9	997570.9	17	silt with some sand	2	silty sand; sand	3
MMW-3		825868.0	1000647.1	22	silt with some sand	2	sand and gravel	3
MMW-4		827739.7	1003058.2	31	silt	1	silt	1
MMW-5		823321.2	994484.4	18	sand; silty sand and gravel	3	silty sand and gravel	3
MMW-6		826780.5	996512.4	26.5	silty sand	3	silty sand and gravel	3
MMW-7		829674.4	997779.7	32	silt; fine sand	2	gravely cobbles	4
MMW-8		831680.6	1001265.7	50	silt with gravel	2	silt with gravel	2
MMW-11		824222.2	995784.5	27	silty very fine sand	2	silty sand and gravel	3
MMW-12		828419.7	999381.4	33	sand and gravel	4	sand gravel and cobbles	4
MMW-13		830011.4	995022.8	34	sand gravel and cobbles	3	medium sand and cobbles	3
MP3		821501.7	995631.5	10	fine to coarse sand	3	gravel	4
MP8		831682.6	1001268.5	19.6	sand and fine gravel	3	sand and gravel, some silt	3
MP10		824222.8	995785.9	10	silty fine sand	2	---------	
MP12		828420.3	999383.8	23.5	fine to coarse sand and gravel	3	sand, gravel, and cobbles	3
WQD-3	151179	821901.5	993715.6	60	silt	1	silt; gravel/sand	3
WQD-4	151186	829620.4	996963.1	52	gravel	4	gravel	4
WQD-9	151061	834951.9	996258.0	50	sand and gravel	4	sand and gravel	4
WQD-22	157211	834953.3	996252.9	100	sandy gravel, some silt	3	sandy gravel, some silt	3
WQD-44	267856	827609.28	997325.57	112	clay	1	gravel, cobbles and sand	4
507		827518	994784	13.5	GP-GM	3	GP	4
508		827504	994937	10.5	GP	4	---------	
509		827520	995095	13.6	GP-GM	3	GP-GM with silt	3
510		827526	995220	10.7	GP-GM	3	---------	
511		827678	998054	10	GM	3	---------	
512		827773	999580	10	GM	3	---------	
513		831226	994865	10.6	GP-GM	3	---------	
514		831243	995338	11	GP-GM	3	---------	
515		831236	995559	11	GP-GM	3	---------	
516		831258	995951	10.7	GP-GM	3	---------	
517		831557	999753	14	ML	1	ML; GP-GM	2
518		831348	1000110	17.8	ML-CL	1	ML-CL	1

Table C-1
Summary of Upper Soil Data Points

Point	GWIC	Coordinates (SP ft)		TD	Upper 10 ft (8-10 ft)		Lower 10-14 ft	
		X	Y		Description	Zone	Description	Zone
519		831444	1000728	16.2	ML	1	ML	1
520		831505	1001266	16.2	CL-ML	1	ML	1
521		831578	1001425	19	ML	1	ML-CL	1
522		831166	994482	11.6	GC	3	ML-CL; GP-GM	2
Knife River	265765	829105	993336		Sand, Gravel, Cobbles	4	Sand, Gravel	4
TwoGood, Marvin	69601	827018	993772		Sand and Gravel	4	Sand and Gravel	4
OHV Well 1	69604	823950	993509		Sand and Gravel	4	Sand and Gravel	4
Overbaugh	187502	822251	992250		clay	1	clay	1
Hinker Const.	203759	819296	992445		clay	1	clay	1
Katoonah Well 1	134807	824598	994506		sandy clay	1	clay, gravel and sand	2
Mt Vw Baptist Ch	78974	819978	996625		clay	1	clay	1
Myers	269141	823662	1000214		sandy soil	3	sandy soil	3
Fisher	280363	821218	998535		clay	1	clay	1
Hegel	191757	831028	993521		Sand and Gravel	4	Sand and Gravel	4
N&E Vent Well 1	199006	832408	995603		Sand and Gravel	4	Sand and Gravel	4
Koble	68381	833960	996500		Sand and Gravel	4	Sand and Gravel	4
Roark	68375	833955	998544		Sand, gravel, cobblestones	3	Sand, gravel, cobblestones	3
Osellame	207991	831557	998339		Sand and Gravel	4	Sand and Gravel	4
Wilson	163046	830409	1001206		silty sand and gravel	3	clay	1
M&S Const.	68344	831809	1002567		clay	1	clay with gravel	1
Wstvw MHP Well 2	68346	834113	1004147		Silt with sand and gravel	2	Silt with sand and gravel	2
N Res Bus Ctr	223926	835729	999267		Gravel	4	Gravel	4
Cons Dir Off Bldg	288768	836920	1000455		Sand and Gravel	4	Sand and Gravel	4

HV	Hellgate Village		Zone	Ref K (Morris & Johnson)	K
HL	Heron's Landing	Silt and Clay; ML	1	Silt - 0.62	0.1
Rem	Remington Flats	Sandy Silt; Silt with Sand, mix; SC; SP	2	Fine Sand - 8.2	1
MF	McNett Flats	Silty Sand; Sand with Silt; GM; GC; SM	3	Med Sand - 40	20
VS	Valley Subdivision	Gravel, Gravel with Sand; GP; GW	4	Crs Sand/Fine Gravel - 150-490	200

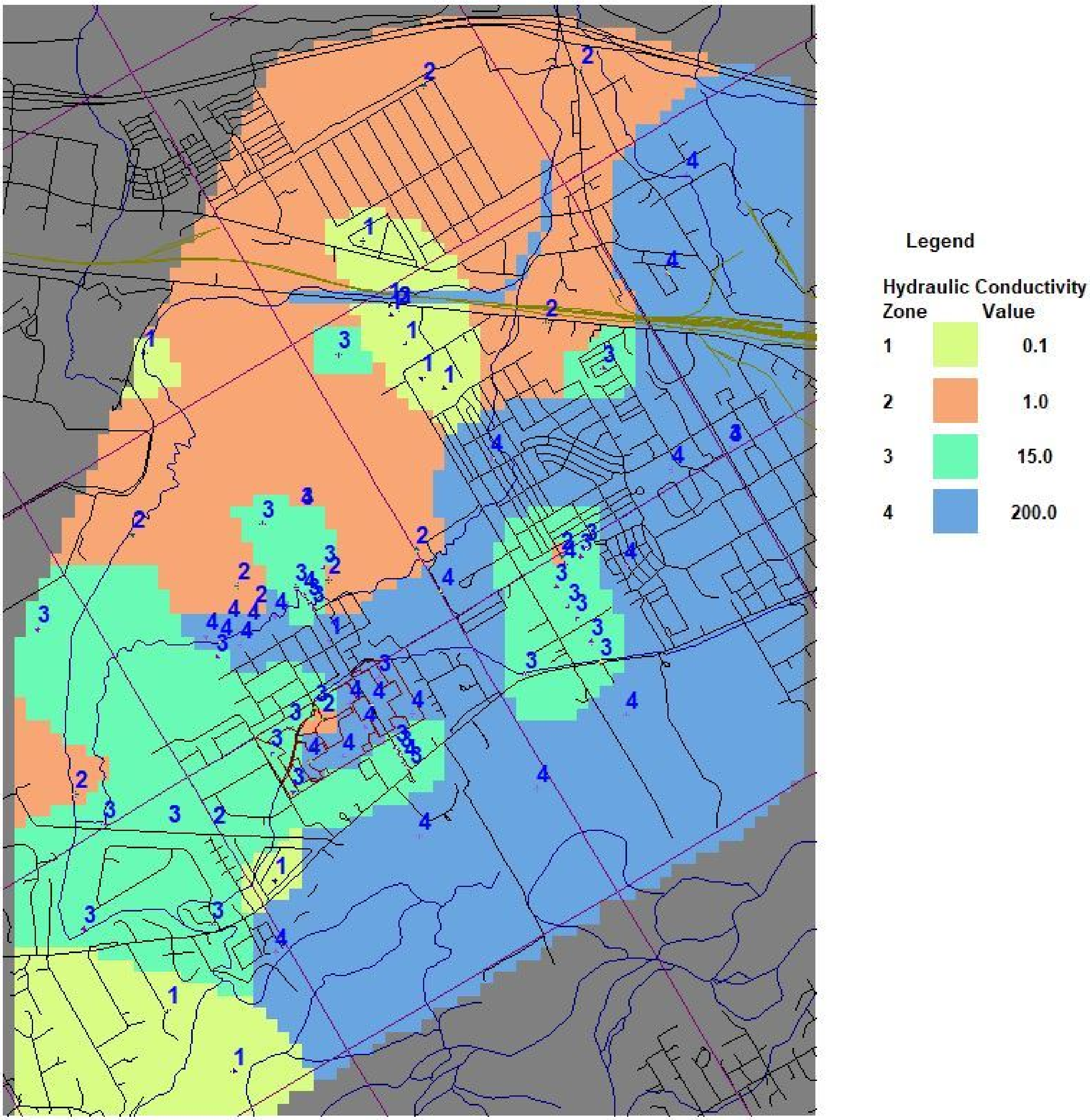


Figure C-1. Upper 10 Feet Soil Categories

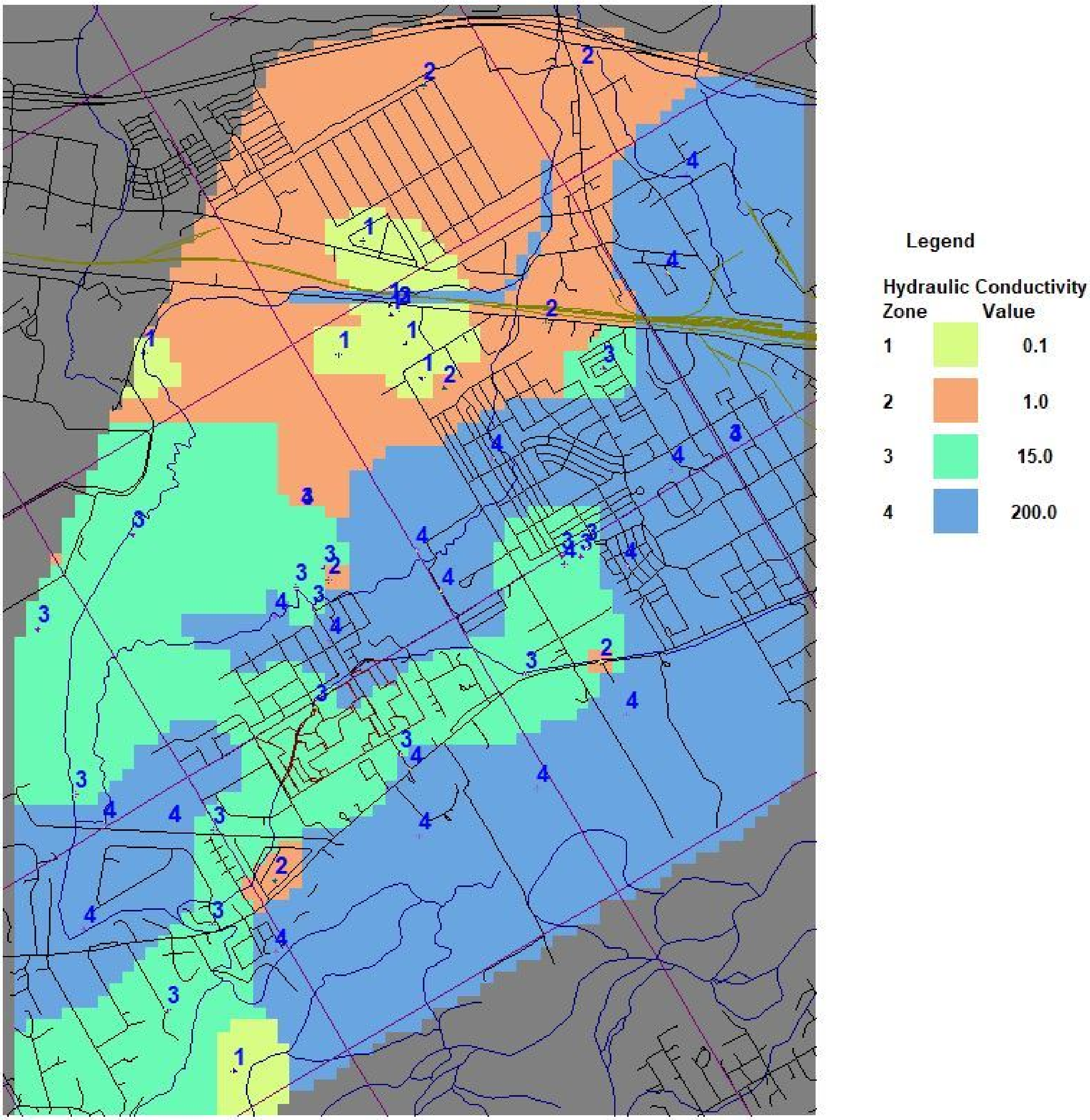


Figure C-2. 10-14 Feet Soil Categories

Table C-2. Calculated and Model Shallow Aquifer Transmissivity Comparison by Model K Zone

Model K Zone	Date	Source	PW	Obs	Method	T (ft2/d)	b (ft)	K (ft/d)	Storativity	Model K (ft/d)	Model b (ft)	Model T (ft2/d)
Zone 5	11/13/1977	GWIC	68339	-----	Specific Capacity	196	121	2	NA	10	48.5	485
	8/10/1979	GWIC	68332	-----	Specific Capacity	455	45	10	NA	10	46.1	461
	6/26/1970	GWIC	68395	-----	Specific Capacity	1,604	40	40	NA	10	91.8	918
	3/2/1979	GWIC	68337	-----	Specific Capacity	214	25	9	NA	10	49.1	491
	10/14/1994	GWIC	144639	-----	Specific Capacity	267	34	8	NA	10	28	280
					Avg:	**547.2**						**527**
Zone 6	9/16/2003	Maxim	MW-12	MP-12	Hantush	3,050	8.79	347	0.2208	100	23.7	2,370
				MP-12	Neuman	1,353		154	0.1221			
				MMW-12	Cooper-Jacob	6,424		731	NA			
					Avg:	**3,609**						
Zone 8	8/5/1985	GWIC	68356	-----	Specific Capacity	1,459	40	36	NA	700	18.7	13,090
	6/16/1969	GWIC	68370	-----	Specific Capacity	2,507	42	60	NA	700	23.8	16,660
	5/30/1969	GWIC	68377	-----	Specific Capacity	4,011	44	91	NA	700	21.5	15,050
					Avg:	**2,659**						**14,933**
Zone 9	8/26/1997	GWIC	163174	-----	Specific Capacity	6,685	39	171	NA	500	13.6	6,800
	8/14/1971	GWIC	68624	-----	Specific Capacity	5,014	41	122	NA	500	14.9	7,450
	6/23/1977	GWIC	68632	-----	Specific Capacity	6,685	30.5	219	NA	500	19.6	9,800
	5/14/1992	GWIC	68634	-----	Specific Capacity	5,942	53.5	111	NA	500	17.8	8,900
	7/1/1972	GWIC	68349	-----	Specific Capacity	7,220	35	206	NA	500	24	12,000
	1/1/1973	GWIC	68620	-----	Specific Capacity	8,022	41	196	NA	500	16.9	8,450
					Avg:	**6,595**						**8,900**
Zone 10	8/20/1998	L&W 1998	P-1A	P-1B	Theis	27,585	17.25	1,567	0.1153	900	26.3	23,670
					Walton-Recov.	8,692		494	0.14903			
	5/2/1999	RLK 1999	P-1A	P-1B	Neuman	50,581	17.63	2,869	0.00062			
	4/30/1999	RLK 1999	P-2A	P-2B	Neuman	12,908	13.97	924	0.00008	900	19	17,100
					Avg:	**24,942**						**20,385**

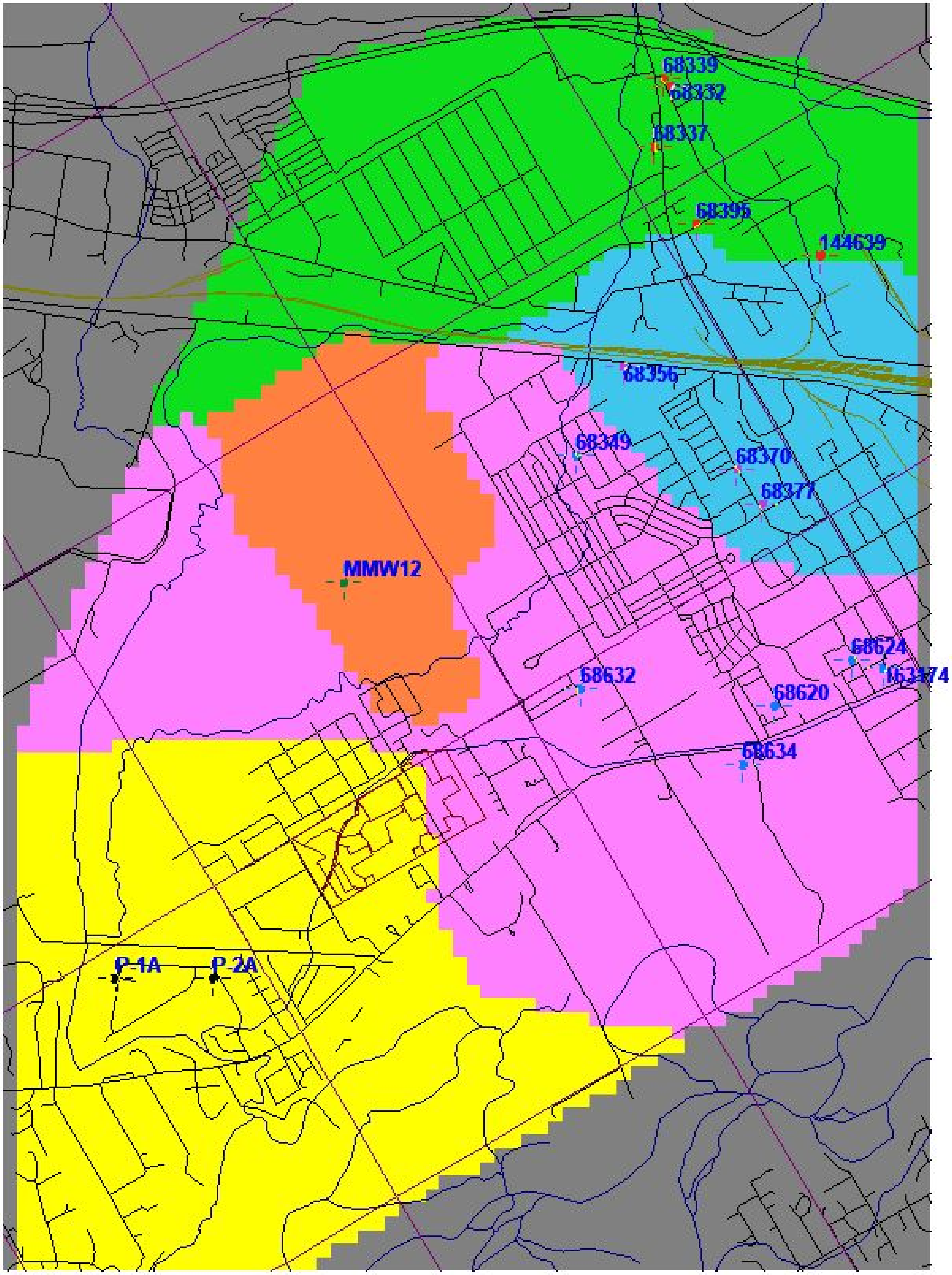


Figure C-3. Shallow Aquifer Transmissivity Data Points

Appendix D
Estimated Stormwater Inputs Technical Memorandum

TECHNICAL MEMORANDUM

DATE:	October 21, 2020	**PROJECT NO.**	350.0537
TO:	Logan McInnis, PE – City of Missoula Public Works; Elena Evans – Missoula Valley Water Quality District		
FROM:	Matt Peterson, PE; Cam Stringer, PG – NewFields		
SUBJECT:	Estimated Stormwater Sump Inputs for Predictive Groundwater Modeling Groundwater Modeling Study in the Mullan BUILD Grant Area		

1.0 BACKGROUND

1.1 OBJECTIVES

NewFields is developing a groundwater flow model that will be used to simulate cumulative effects to the shallow aquifer resulting from development in the Grant Creek watershed. More specifically, the City of Missoula (City) would like to understand the effects that using dry wells (commonly referred to as 'sumps') to manage storm water in the study area would have on the aquifer. This technical memorandum (TM) presents an outline of proposed modeling methodology and approach to simulate inflows to the aquifer from storm water management sumps.

2.0 MODELING SCENARIOS

2.1 COINCIDENT EVENT CONSIDERATIONS

Groundwater levels in the study area are primarily influenced by leakage from Grant Creek and leakage from the Flynn-Lowney Ditch. Other much smaller sources of recharge to the shallow groundwater system include deep percolation of infiltrating precipitation, irrigation return flow, and storm water sumps. Seasonally high groundwater levels generally occur between May and July when the stage in Grant Creek is elevated due to seasonal runoff and the Flynn-Lowney Ditch is active; therefore, predictive model scenarios will be set to occur at the peak of the seasonal hydrograph for Grant Creek. Leakage from the Flynn-Lowney ditch will remain consistent through the predictive modeling period because the ditch operates with a relatively consistent flow through the study area. The volume of recharge to groundwater from Grant Creek varies from year to year based on the volume of snowmelt in the Grant Creek drainage basin. Inflows from storm water sumps will also vary with the volume of runoff from rainfall events occurring in the study area.

The City's goal is to evaluate the cumulative effect of using sumps to manage stormwater as the study area is developed. This will allow evaluation of risk to existing or future structures that might be caused by infiltration of stormwater runoff through sumps increasing water table elevations. The City has selected the Grant Creek 100-year flood event as the baseline for which to develop this analysis; however, it is difficult to estimate flood event probabilities when two or more independent factors contribute to flooding (or in this case, high groundwater levels). For instance, the probability of experiencing a 100-year flood event on Grant Creek through the study area and a 100-year local rainfall event simultaneously is less than 1-percent and it would be overly conservative to develop a model that predicts groundwater levels for these two scenarios occurring simultaneously.

NewFields and the City have agreed to assess the two scenarios presented below; the scenario that results in higher groundwater elevations in the study area will be considered the controlling scenario.

- **Hydrologic Scenario 1 – Grant Creek Control:** This scenario represents the case of a 100-year water surface elevation (WSE) in Grant Creek through the project area coupled with a 2-year, 24-hour rainfall event in the study area.
- **Hydrologic Scenario 2 – Local Rainfall Control:** This scenario represents the case of a 2-year WSE on Grant Creek through the project area coupled with a 100-year, 24-hour rainfall event in the study area.

2.2 Study Area Development Considerations

As discussed in Section 1.1, the objective of this analysis is to assess the cumulative effects of using sumps to manage storm water runoff within the study area. NewFields is planning to develop the following two scenarios to achieve this objective.

- **Base Case (Existing Conditions):** The base case will represent the calibrated existing condition model; run with both of the hydrologic scenarios identified above. Under this scenario, the storm water sump inflows will be limited to existing sumps identified on the City's storm water infrastructure inventory.
- **Predictive Analysis:** The objective of the Predictive Analysis is to provide information for the City so they can determine the optimal locations of future sumps throughout the study area. This case will assess the projected ground water elevations resulting from use of sumps throughout the area to be developed based on the Mullan Area Master Plan. For comparison to the Base Case, the Predictive Analysis will be run with both of the hydrologic scenarios identified above.

3.0 SURFACE WATER INPUTS

3.1 Sump Modeling Approach

Sumps will be simulated using MODFLOW's Well Package (a specified flux boundary).The volume of runoff that will report to each sump will be estimated as described in the following subsections. The volume of water reporting to sumps will be distributed to appropriate well package cells. Well Package cells will be added at the end of the of the 2020 high water and 100-year flood transient simulations followed by a 9-day period with no sump infiltration.

3.2 Base Case Surface Water Inputs

As discussed in Section 2.2, the Base Case will assess the degree of water table mounding for both of the hydrologic scenarios, based on the City's existing drainage infrastructure within the model domain (Figure 1). The groundwater model will not include individual sumps, but rather applies infiltration within the model grids for areas where sumps exist. In order to maintain consistency between the base case and predictive simulations, we plan to use the same hydrologic methodology, the SCS Curve Number Method, for both scenarios. For simplicity and due to lack of detailed design information for existing facilities, the analysis will assume 100 percent infiltration of all runoff within areas that contain sumps (e.g., portions of the Pleasant View Subdivision) and zero runoff infiltration for areas that do not contain sumps (e.g., 44 Ranch Subdivision).

3.3 Predictive Analysis Surface Water Inputs

The surface water inputs for the Predictive Analysis will rely on analyses that have already been conducted for the planned infrastructure throughout the study area. Preliminary designs have been developed for the following subdivisions and associated and facilities within the study area.

- RMB Subdivision
- Remington Flats Subdivision
- McNett Flats Subdivision
- Heron's Landing Subdivision
- BUILD Grant Collector Roads

Use of sumps is being planned for each of the developments identified above, and the preliminary design documentation provides estimates for the anticipated volume of infiltration associated with the 100-year, 24-hour rainfall event. Unfortunately, consistent methodology was not implemented when conducting the hydrology and hydraulics analyses for these developments and the preliminary designs do not contain anticipated runoff values for the 2-year, 24-hour rainfall event. NewFields believes a consistent hydrologic analysis methodology should be used for developing inputs to the groundwater model.

The Drainage and Infrastructure Recommendation Memo for Mullan Area Master Plan (Master Plan Drainage Memo) (Territorial Landworks, Inc. now IMEG, October 2020) identifies planned zoning areas with corresponding lot coverage (impervious areas) throughout the entire study area. The Master Plan Drainage Memo also provides estimated runoff values for all areas to be developed as part of the Mullan BUILD plan. While the estimates are not as detailed as the runoff rates provided for each of the planned developments discussed above, NewFields plans to use the results provided in the Memo because each area was assessed using a consistent hydrologic methodology (TR-55 – SCS Curve Number Method). The runoff volumes to be used are provided in **Table 1** (the planned development basin locations are shown in Figure 2).

Table 1. Estimated Post-Development Runoff Volumes

Basin Name	Basin Area (Acres)	2-Year, 24-Hour Runoff Volume (Cubic Feet)	100-Year, 24-Hour Runoff Volume (Cubic Feet)
Basin A	203	202,645	1,047,858
Basin B	112	111,804	578,128
Basin C	49	59,806	276,271
Basin D	58	58,318	301,556
Basin E	152	150,685	781,472
Basin F	93	93,336	482,634
Basin G	59	97,940	385,132
RMB Subdivision	20	17,018	108,260

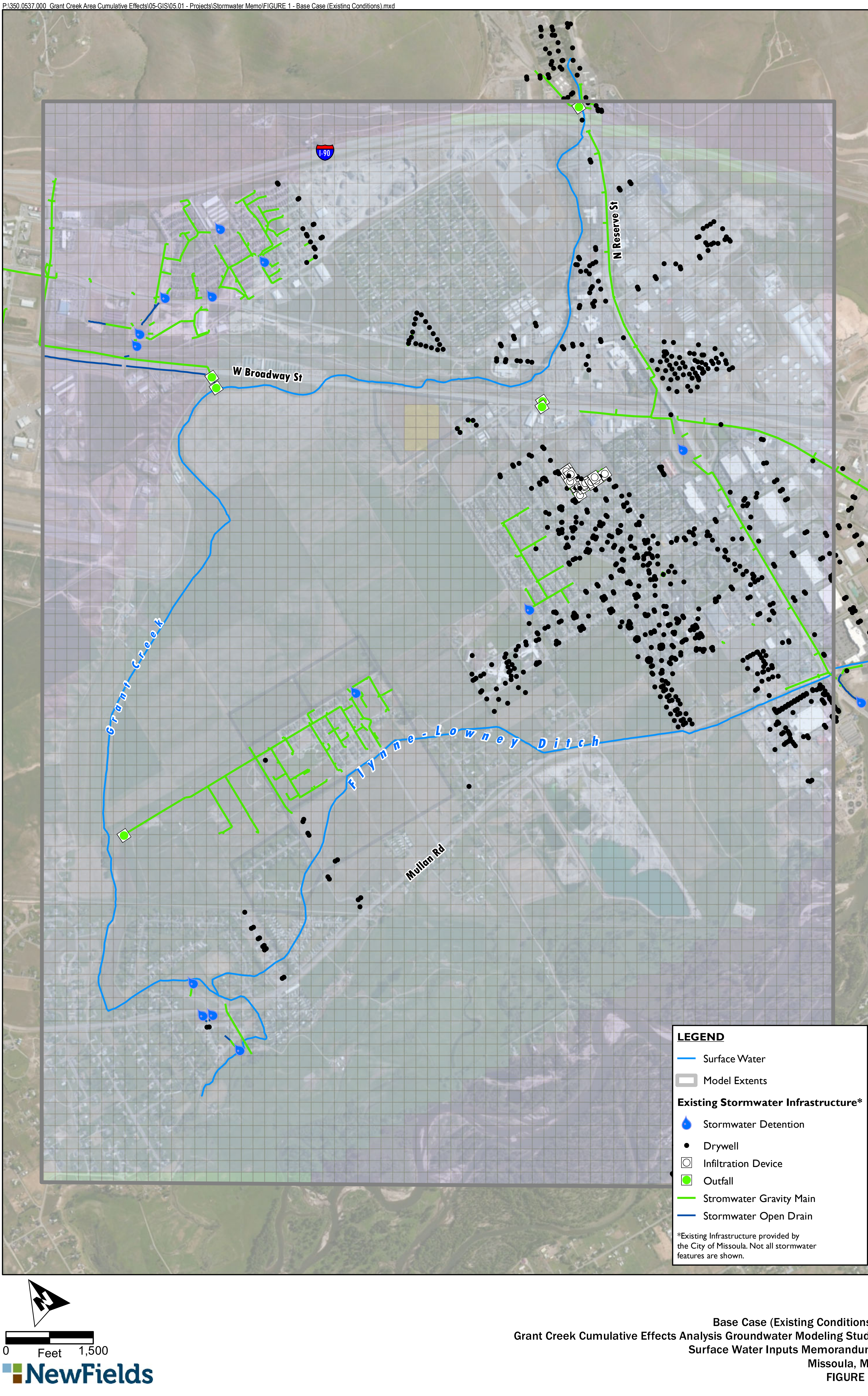
Detailed designs for a large portion of the study area have not been developed, and it has yet to be determined where sumps will be placed. The predictive analysis will assume 100-percent infiltration for all developed areas, using the runoff volumes shown in Table 1. It is important to note that the basins identified in Table 1 do not cover the entire study area, but rather only the areas currently planned for development. Infiltration via sumps will not be assumed for areas were development is not planned.

4.0 REFERENCES

Territorial Landworks, Inc. now IMEG. (October 2020). *Drainage and Infrastructure Recommendation Memo for Mullan Area Master Plan.* Missoula, MT.

Figures

P:\350.0537.000_Grant Creek Area Cumulative Effects\05-GIS\05.01 - Projects\Stormwater Memo\FIGURE 1 - Base Case (Existing Conditions).mxd



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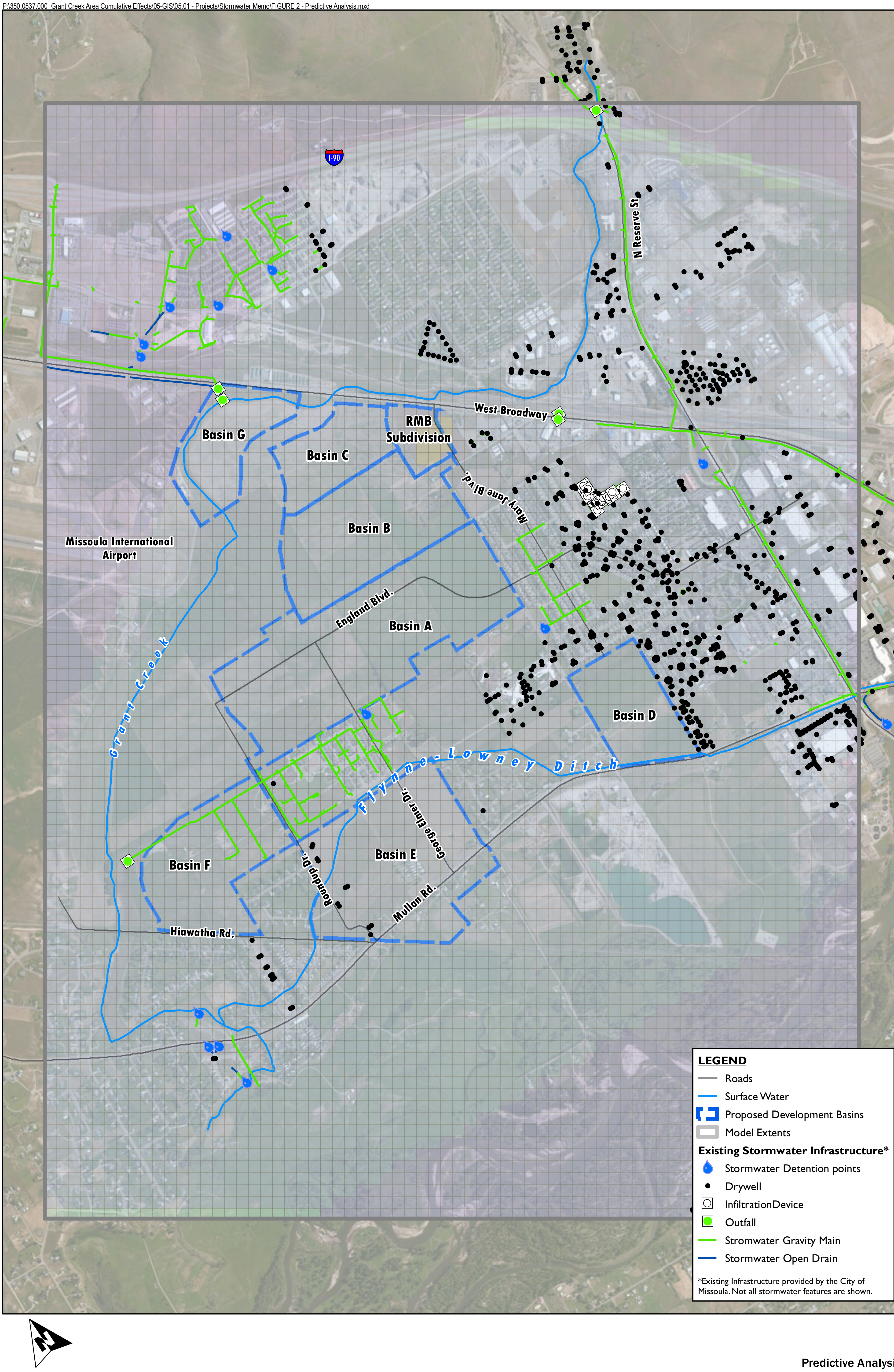
Base Case (Existing Conditions)
Grant Creek Cumulative Effects Analysis Groundwater Modeling Study
Surface Water Inputs Memorandum
Missoula, MT
FIGURE 1

P:\350.0537.000 Grant Creek Area Cumulative Effects\05-GIS\05.01 - Projects\Stormwater Memo\FIGURE 2 - Predictive Analysis.mxd



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Predictive Analysis
Grant Creek Cumulative Effects Analysis Groundwater Modeling Study
Surface Water Inputs Memorandum
Missoula, MT
FIGURE 2

Appendix E
Groundwater Flow Model Boundary Conditions, Recharge, and Hydraulic Conductivity

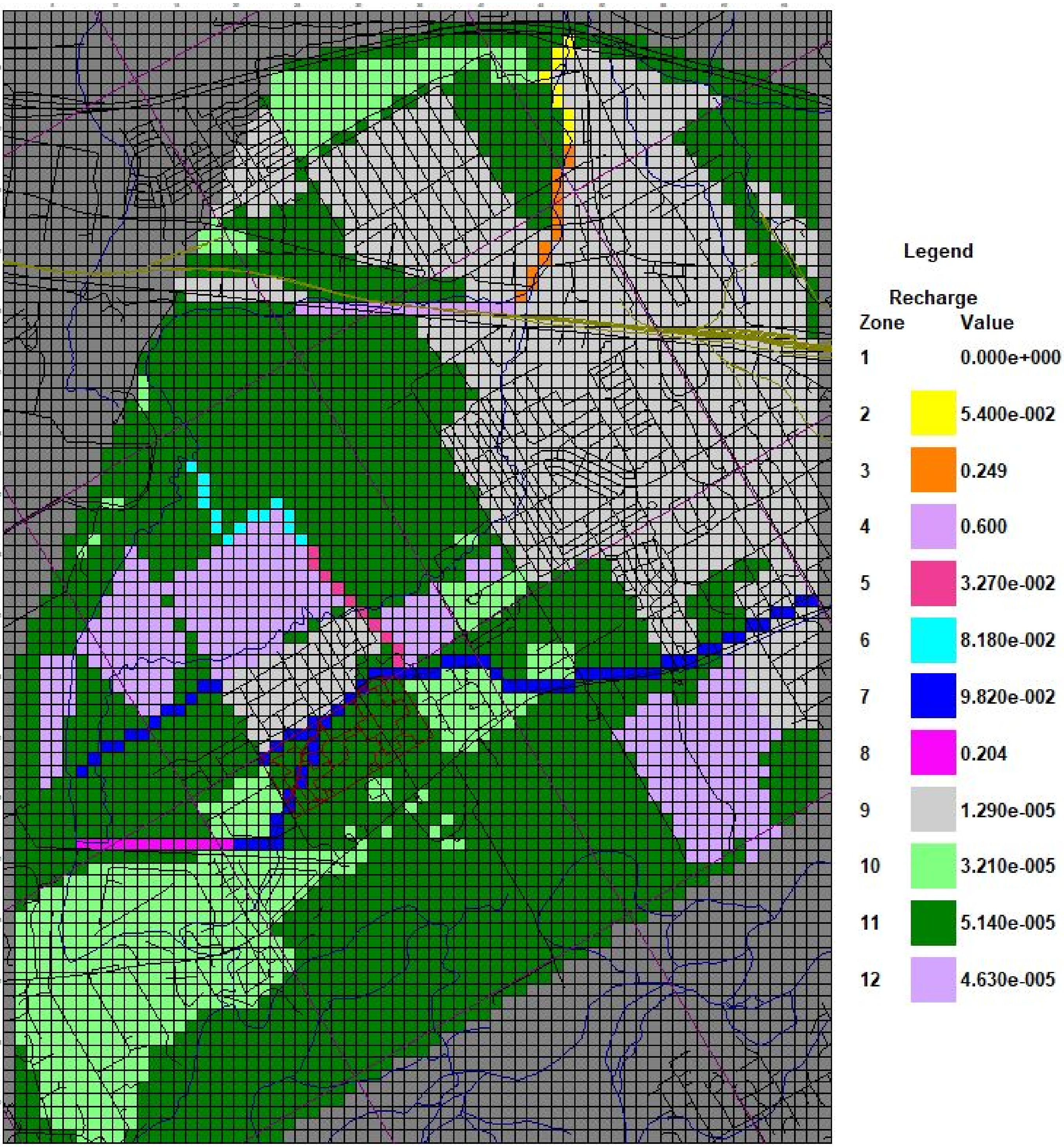


Figure E-1. Model Recharge Zones

Table E-1. Model Specified Creek and Ditch Seepage Rates

SP	Days	Cum Days	Dates	Grant Creek Recharge Zones 2 ft/d	2 cfs	3 ft/d	3 cfs	4 ft/d	4 cfs	Flynn-Lowney Recharge Zones 5 (Upper Lateral) ft/d	5 (Upper Lateral) cfs	6 (Laterals) ft/d	6 (Laterals) cfs	7 (Main) ft/d	7 (Main) cfs	8 (lower Main) ft/d	8 (lower Main) cfs
1	14	14	3/8 - 3/22	0.015	0.07	0.067	0.41	0.162	1.35	0	0	0	0	0	0	0	0
2	14	28	3/22 - 4/5	0.034	0.16	0.157	0.95	0.378	3.15	0	0	0	0	0	0	0	0
3	14	42	4/5 - 4/19	0.038	0.18	0.174	1.05	0.420	3.5	0	0	0	0	0	0	0	0
4	7	49	4/19 - 4/26	0.043	0.20	0.199	1.20	0.480	4	0	0	0	0	0	0	0	0
5	7	56	4/26 - 5/3	0.054	0.25	0.249	1.50	0.600	5	0.0327	0.015	0.0818	0.038	0.0982	0.045	0.2045	0.095
6	7	63	5/3 - 5/10	0.070	0.33	0.324	1.95	0.780	6.5	0.0295	0.014	0.0736	0.034	0.0884	0.041	0.1841	0.085
7	7	70	5/10 - 5/17	0.072	0.34	0.334	2.01	0.804	6.7	0.0295	0.014	0.0736	0.034	0.0884	0.041	0.1841	0.085
8	7	77	5/17 - 5/24	0.078	0.36	0.361	2.18	0.870	7.25	0.0262	0.012	0.0655	0.030	0.0785	0.036	0.1636	0.076
9	7	84	5/24 - 5/31	0.065	0.30	0.299	1.80	0.870	7.25	0.0262	0.012	0.0655	0.030	0.0785	0.036	0.1636	0.076
10	7	91	5/31 - 6/7	0.058	0.27	0.267	1.61	0.719	5.99	0.0229	0.011	0.0573	0.027	0.0687	0.032	0.1432	0.066
11	6	97	6/7 - 6/13	0.044	0.21	0.204	1.23	0.643	5.36	0.0213	0.010	0.0532	0.025	0.0638	0.030	0.1330	0.062
12	1	98	6/13 - 6/14	0.039	0.18	0.182	1.10	0.492	4.1	0.0213	0.010	0.0532	0.025	0.0638	0.030	0.1330	0.062
13	7	105	6/14 - 6/21	0.037	0.17	0.173	1.04	0.438	3.65	0.0196	0.009	0.0491	0.023	0.0589	0.027	0.1227	0.057
14	7	112	6/21 - 6/28	0.031	0.14	0.142	0.85	0.416	3.47	0.0180	0.008	0.0450	0.021	0.0540	0.025	0.1125	0.052
15	7	119	6/28 - 7/5	0.024	0.11	0.110	0.66	0.341	2.84	0.0180	0.008	0.0450	0.021	0.0540	0.025	0.1125	0.052
16	14	133	7/5 - 7/19	0.017	0.08	0.079	0.47	0.265	2.21	0.0164	0.008	0.0409	0.019	0.0491	0.023	0.1023	0.047
17	14	147	7/19 - 8/2	0.017	0.08	0.079	0.47	0.190	1.58	0.0164	0.008	0.0409	0.019	0.0491	0.023	0.1023	0.047
18	14	161	8/2 - 8/16	0.010	0.05	0.047	0.29	0.190	1.58	0.0131	0.006	0.0327	0.015	0.0393	0.018	0.0818	0.038
19	21	182	8/16 - 9/6	0.010	0.05	0.047	0.29	0.114	0.95	0.0115	0.005	0.0286	0.013	0.0344	0.016	0.0716	0.033
20	21	203	9/6 - 9/27	0.010	0.05	0.047	0.29	0.114	0.95	0.0098	0.005	0.0245	0.011	0.0295	0.014	0.0614	0.028

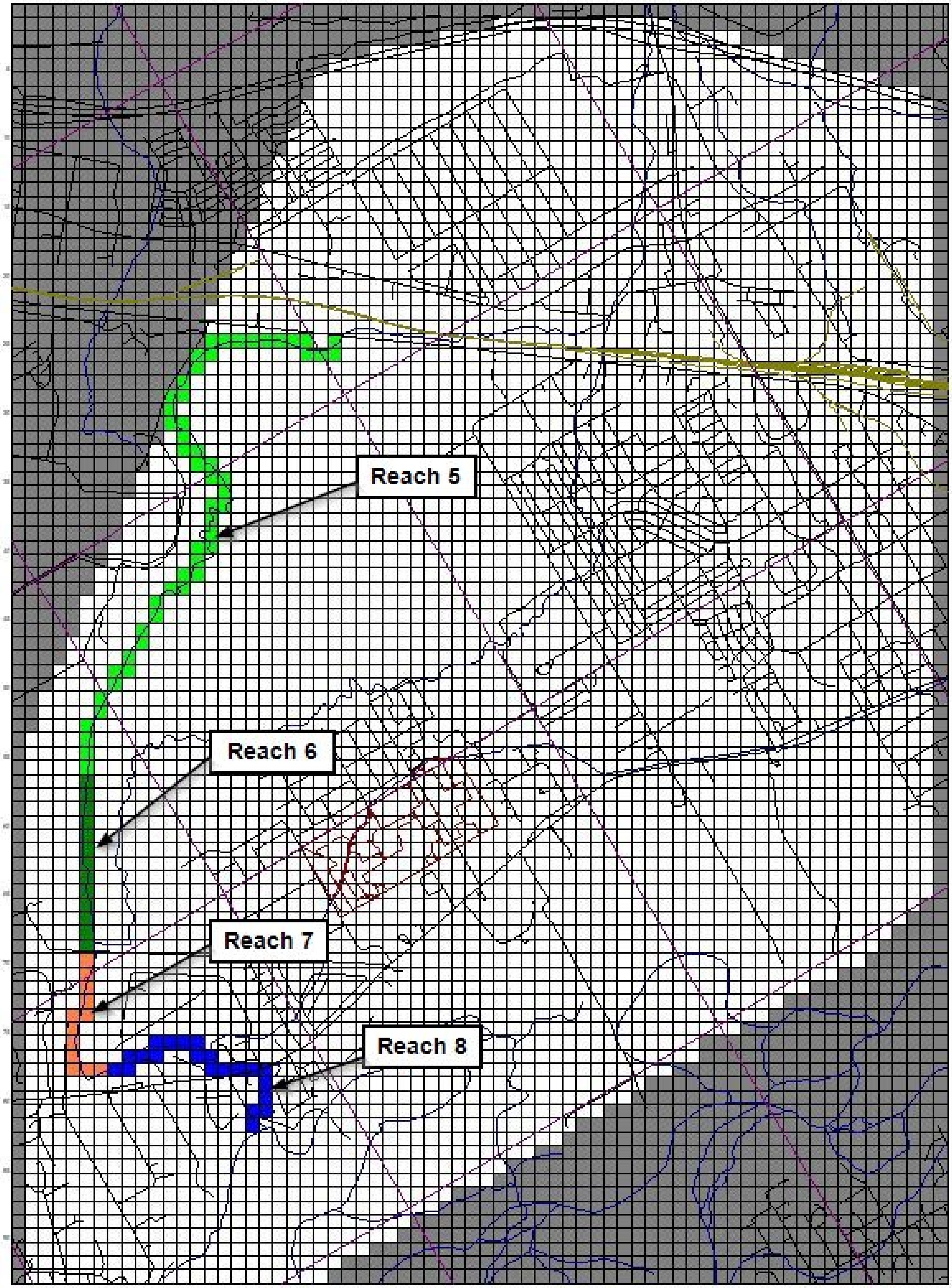


Figure E-2. Model Creek Reaches

Table E-2. Specified Creek Conductance Values

Row	Col	Layer	Reach	Bottom Elev.	Length (ft)	Width (ft)	Thkns (ft)	K (Ft/d)	Conductance
25	24	1	5	3159.00	1	1	1	20.0	20.0
26	24	1	5	3158.25	1	1	1	20.0	20.0
26	23	1	5	3157.50	1	1	1	20.0	20.0
26	22	1	5	3156.75	1	1	1	20.0	20.0
25	22	1	5	3156.00	1	1	1	20.0	20.0
25	21	1	5	3155.25	1	1	1	20.0	20.0
25	20	1	5	3154.50	1	1	1	20.0	20.0
25	19	1	5	3153.75	1	1	1	20.0	20.0
25	18	1	5	3153.00	1	1	1	20.0	20.0
25	17	1	5	3152.67	1	1	1	20.0	20.0
25	16	1	5	3152.33	1	1	1	20.0	20.0
25	15	1	5	3152.00	1	1	1	20.0	20.0
26	15	1	5	3151.67	1	1	1	20.0	20.0
26	14	1	5	3151.33	1	1	1	20.0	20.0
27	14	1	5	3151.00	1	1	1	20.0	20.0
28	13	1	5	3150.67	1	1	1	20.0	20.0
29	13	1	5	3150.33	1	1	1	20.0	20.0
29	12	1	5	3150.00	1	1	1	20.0	20.0
30	12	1	5	3149.80	1	1	1	20.0	20.0
31	12	1	5	3149.60	1	1	1	20.0	20.0
31	13	1	5	3149.40	1	1	1	20.0	20.0
32	13	1	5	3149.20	1	1	1	20.0	20.0
33	13	1	5	3149.00	1	1	1	20.0	20.0
33	14	1	5	3148.80	1	1	1	70.0	70.0
34	14	1	5	3148.60	1	1	1	70.0	70.0
34	15	1	5	3148.40	1	1	1	70.0	70.0
35	15	1	5	3148.20	1	1	1	70.0	70.0
35	16	1	5	3148.00	1	1	1	70.0	70.0
36	16	1	5	3147.75	1	1	1	70.0	70.0
37	16	1	5	3147.50	1	1	1	70.0	70.0
37	15	1	5	3147.25	1	1	1	70.0	70.0
38	15	1	5	3147.00	1	1	1	70.0	70.0
39	15	1	5	3146.75	1	1	1	70.0	70.0
40	15	1	5	3146.50	1	1	1	70.0	70.0
40	14	1	5	3146.25	1	1	1	70.0	70.0
41	14	1	5	3146.00	1	1	1	70.0	70.0
42	14	1	5	3145.75	1	1	1	70.0	70.0
42	13	1	5	3145.50	1	1	1	70.0	70.0
43	13	1	5	3145.25	1	1	1	70.0	70.0
43	12	1	5	3145.00	1	1	1	70.0	70.0
44	11	1	5	3144.88	1	1	1	70.0	70.0
45	11	1	5	3144.75	1	1	1	70.0	70.0
46	10	1	5	3144.63	1	1	1	70.0	70.0
47	10	1	5	3144.50	1	1	1	70.0	70.0
48	9	1	5	3144.38	1	1	1	70.0	70.0
49	9	1	5	3144.25	1	1	1	70.0	70.0
49	8	1	5	3144.13	1	1	1	70.0	70.0
50	8	1	5	3144.00	1	1	1	70.0	70.0
51	7	1	5	3143.86	1	1	1	70.0	70.0
52	7	1	5	3143.71	1	1	1	70.0	70.0

Table E-2. Specified Creek Conductance Values

Row	Col	Layer	Reach	Bottom Elev.	Length (ft)	Width (ft)	Thkns (ft)	K (Ft/d)	Conductance
53	6	1	5	3143.57	1	1	1	70.0	70.0
54	6	1	5	3143.43	1	1	1	70.0	70.0
55	6	1	5	3143.29	1	1	1	70.0	70.0
56	6	1	5	3143.14	1	1	1	70.0	70.0
57	6	1	6	3143.00	1	1	1	100.0	100.0
58	6	1	6	3142.92	1	1	1	100.0	100.0
59	6	1	6	3142.83	1	1	1	100.0	100.0
60	6	1	6	3142.75	1	1	1	100.0	100.0
61	6	1	6	3142.67	1	1	1	100.0	100.0
62	6	1	6	3142.58	1	1	1	100.0	100.0
63	6	1	6	3142.50	1	1	1	100.0	100.0
64	6	1	6	3142.42	1	1	1	100.0	100.0
65	6	1	6	3142.33	1	1	1	100.0	100.0
66	6	1	6	3142.25	1	1	1	100.0	100.0
67	6	1	6	3142.17	1	1	1	100.0	100.0
68	6	1	6	3142.08	1	1	1	100.0	100.0
69	6	1	6	3142.00	1	1	1	100.0	100.0
70	6	1	7	3141.50	1	1	1	100.0	100.0
71	6	1	7	3141.00	1	1	1	100.0	100.0
72	6	1	7	3140.50	1	1	1	100.0	100.0
73	6	1	7	3140.00	1	1	1	100.0	100.0
74	6	1	7	3139.88	1	1	1	100.0	100.0
74	5	1	7	3139.75	1	1	1	100.0	100.0
75	5	1	7	3139.63	1	1	1	100.0	100.0
76	5	1	7	3139.50	1	1	1	100.0	100.0
77	5	1	7	3139.38	1	1	1	100.0	100.0
78	5	1	7	3139.25	1	1	1	100.0	100.0
78	6	1	7	3139.13	1	1	1	100.0	100.0
78	7	1	7	3139.00	1	1	1	100.0	100.0
78	8	1	8	3138.89	1	1	1	100.0	100.0
78	9	1	8	3138.78	1	1	1	100.0	100.0
77	9	1	8	3138.67	1	1	1	100.0	100.0
77	10	1	8	3138.56	1	1	1	100.0	100.0
77	11	1	8	3138.44	1	1	1	100.0	100.0
76	11	1	8	3138.33	1	1	1	100.0	100.0
76	12	1	8	3138.22	1	1	1	100.0	100.0
76	13	1	8	3138.11	1	1	1	100.0	100.0
76	14	1	8	3138.00	1	1	1	100.0	100.0
77	14	1	8	3137.64	1	1	1	100.0	100.0
77	15	1	8	3137.27	1	1	1	100.0	100.0
78	15	1	8	3136.91	1	1	1	100.0	100.0
78	16	1	8	3136.55	1	1	1	100.0	100.0
78	17	1	8	3136.18	1	1	1	100.0	100.0
78	18	1	8	3135.82	1	1	1	100.0	100.0
78	19	1	8	3135.45	1	1	1	100.0	100.0
79	19	1	8	3135.09	1	1	1	100.0	100.0
80	19	1	8	3134.73	1	1	1	100.0	100.0
81	19	1	8	3134.36	1	1	1	100.0	100.0
81	18	1	8	3134.00	1	1	1	100.0	100.0
82	18	1	8	3133.00	1	1	1	100.0	100.0

Table E-3. Specified Creek Stage Values

				Change:	0	0.5	1	1.25	1.5	1.75	2	2.5	2.25	2	1.75	1.5	1.25	1	0.75	0.5	0.5	0.25	0	0
				SP:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Row	Col	Layer	Reach	Date:	22-Mar	5-Apr	19-Apr	26-Apr	3-May	10-May	17-May	24-May	31-May	7-Jun	13-Jun	14-Jun	21-Jun	28-Jun	5-Jul	19-Jul	2-Aug	16-Aug	6-Sep	27-Sep
25	24	1	5		3160.00	3160.50	3161.00	3161.25	3161.50	3161.75	3162.00	3162.50	3162.25	3162.00	3161.75	3161.50	3161.25	3161.00	3160.75	3160.50	3160.50	3160.25	3160.00	3160.00
26	24	1	5		3159.25	3159.75	3160.25	3160.50	3160.75	3161.00	3161.25	3161.75	3161.50	3161.25	3161.00	3160.75	3160.50	3160.25	3160.00	3159.75	3159.75	3159.50	3159.25	3159.25
26	23	1	5		3158.50	3159.00	3159.50	3159.75	3160.00	3160.25	3160.50	3161.00	3160.75	3160.50	3160.25	3160.00	3159.75	3159.50	3159.25	3159.00	3159.00	3158.75	3158.50	3158.50
26	22	1	5		3157.75	3158.25	3158.75	3159.00	3159.25	3159.50	3159.75	3160.25	3160.00	3159.75	3159.50	3159.25	3159.00	3158.75	3158.50	3158.25	3158.25	3158.00	3157.75	3157.75
25	22	1	5		3157.00	3157.50	3158.00	3158.25	3158.50	3158.75	3159.00	3159.50	3159.25	3159.00	3158.75	3158.50	3158.25	3158.00	3157.75	3157.50	3157.50	3157.25	3157.00	3157.00
25	21	1	5		3156.25	3156.75	3157.25	3157.50	3157.75	3158.00	3158.25	3158.75	3158.50	3158.25	3158.00	3157.75	3157.50	3157.25	3157.00	3156.75	3156.75	3156.50	3156.25	3156.25
25	20	1	5		3155.50	3156.00	3156.50	3156.75	3157.00	3157.25	3157.50	3158.00	3157.75	3157.50	3157.25	3157.00	3156.75	3156.50	3156.25	3156.00	3156.00	3155.75	3155.50	3155.50
25	19	1	5		3154.75	3155.25	3155.75	3156.00	3156.25	3156.50	3156.75	3157.25	3157.00	3156.75	3156.50	3156.25	3156.00	3155.75	3155.50	3155.25	3155.25	3155.00	3154.75	3154.75
25	18	1	5		3154.00	3154.50	3155.00	3155.25	3155.50	3155.75	3156.00	3156.50	3156.25	3156.00	3155.75	3155.50	3155.25	3155.00	3154.75	3154.50	3154.50	3154.25	3154.00	3154.00
25	17	1	5		3153.67	3154.17	3154.67	3154.92	3155.17	3155.42	3155.67	3156.17	3155.92	3155.67	3155.42	3155.17	3154.92	3154.67	3154.42	3154.17	3154.17	3153.92	3153.67	3153.67
25	16	1	5		3153.33	3153.83	3154.33	3154.58	3154.83	3155.08	3155.33	3155.83	3155.58	3155.33	3155.08	3154.83	3154.58	3154.33	3154.08	3153.83	3153.83	3153.58	3153.33	3153.33
25	15	1	5		3153.00	3153.50	3154.00	3154.25	3154.50	3154.75	3155.00	3155.50	3155.25	3155.00	3154.75	3154.50	3154.25	3154.00	3153.75	3153.50	3153.50	3153.25	3153.00	3153.00
26	15	1	5		3152.67	3153.17	3153.67	3153.92	3154.17	3154.42	3154.67	3155.17	3154.92	3154.67	3154.42	3154.17	3153.92	3153.67	3153.42	3153.17	3153.17	3152.92	3152.67	3152.67
26	14	1	5		3152.33	3152.83	3153.33	3153.58	3153.83	3154.08	3154.33	3154.83	3154.58	3154.33	3154.08	3153.83	3153.58	3153.33	3153.08	3152.83	3152.83	3152.58	3152.33	3152.33
27	14	1	5		3152.00	3152.50	3153.00	3153.25	3153.50	3153.75	3154.00	3154.50	3154.25	3154.00	3153.75	3153.50	3153.25	3153.00	3152.75	3152.50	3152.50	3152.25	3152.00	3152.00
28	13	1	5		3151.67	3152.17	3152.67	3152.92	3153.17	3153.42	3153.67	3154.17	3153.92	3153.67	3153.42	3153.17	3152.92	3152.67	3152.42	3152.17	3152.17	3151.92	3151.67	3151.67
29	13	1	5		3151.33	3151.83	3152.33	3152.58	3152.83	3153.08	3153.33	3153.83	3153.58	3153.33	3153.08	3152.83	3152.58	3152.33	3152.08	3151.83	3151.83	3151.58	3151.33	3151.33
29	12	1	5		3151.00	3151.50	3152.00	3152.25	3152.50	3152.75	3153.00	3153.50	3153.25	3153.00	3152.75	3152.50	3152.25	3152.00	3151.75	3151.50	3151.50	3151.25	3151.00	3151.00
30	12	1	5		3150.80	3151.30	3151.80	3152.05	3152.30	3152.55	3152.80	3153.30	3153.05	3152.80	3152.55	3152.30	3152.05	3151.80	3151.55	3151.30	3151.30	3151.05	3150.80	3150.80
31	12	1	5		3150.60	3151.10	3151.60	3151.85	3152.10	3152.35	3152.60	3153.10	3152.85	3152.60	3152.35	3152.10	3151.85	3151.60	3151.35	3151.10	3151.10	3150.85	3150.60	3150.60
31	13	1	5		3150.40	3150.90	3151.40	3151.65	3151.90	3152.15	3152.40	3152.90	3152.65	3152.40	3152.15	3151.90	3151.65	3151.40	3151.15	3150.90	3150.90	3150.65	3150.40	3150.40
32	13	1	5		3150.20	3150.70	3151.20	3151.45	3151.70	3151.95	3152.20	3152.70	3152.45	3152.20	3151.95	3151.70	3151.45	3151.20	3150.95	3150.70	3150.70	3150.45	3150.20	3150.20
33	13	1	5		3150.00	3150.50	3151.00	3151.25	3151.50	3151.75	3152.00	3152.50	3152.25	3152.00	3151.75	3151.50	3151.25	3151.00	3150.75	3150.50	3150.50	3150.25	3150.00	3150.00
33	14	1	5		3149.80	3150.30	3150.80	3151.05	3151.30	3151.55	3151.80	3152.30	3152.05	3151.80	3151.55	3151.30	3151.05	3150.80	3150.55	3150.30	3150.30	3150.05	3149.80	3149.80
34	14	1	5		3149.60	3150.10	3150.60	3150.85	3151.10	3151.35	3151.60	3152.10	3151.85	3151.60	3151.35	3151.10	3150.85	3150.60	3150.35	3150.10	3150.10	3149.85	3149.60	3149.60
34	15	1	5		3149.40	3149.90	3150.40	3150.65	3150.90	3151.15	3151.40	3151.90	3151.65	3151.40	3151.15	3150.90	3150.65	3150.40	3150.15	3149.90	3149.90	3149.65	3149.40	3149.40
35	15	1	5		3149.20	3149.70	3150.20	3150.45	3150.70	3150.95	3151.20	3151.70	3151.45	3151.20	3150.95	3150.70	3150.45	3150.20	3149.95	3149.70	3149.70	3149.45	3149.20	3149.20
35	16	1	5		3149.00	3149.50	3150.00	3150.25	3150.50	3150.75	3151.00	3151.50	3151.25	3151.00	3150.75	3150.50	3150.25	3150.00	3149.75	3149.50	3149.50	3149.25	3149.00	3149.00
36	16	1	5		3148.75	3149.25	3149.75	3150.00	3150.25	3150.50	3150.75	3151.25	3151.00	3150.75	3150.50	3150.25	3150.00	3149.75	3149.50	3149.25	3149.25	3149.00	3148.75	3148.75
37	16	1	5		3148.50	3149.00	3149.50	3149.75	3150.00	3150.25	3150.50	3151.00	3150.75	3150.50	3150.25	3150.00	3149.75	3149.50	3149.25	3149.00	3149.00	3148.75	3148.50	3148.50
37	15	1	5		3148.25	3148.75	3149.25	3149.50	3149.75	3150.00	3150.25	3150.75	3150.50	3150.25	3150.00	3149.75	3149.50	3149.25	3149.00	3148.75	3148.75	3148.50	3148.25	3148.25
38	15	1	5		3148.00	3148.50	3149.00	3149.25	3149.50	3149.75	3150.00	3150.50	3150.25	3150.00	3149.75	3149.50	3149.25	3149.00	3148.75	3148.50	3148.50	3148.25	3148.00	3148.00
39	15	1	5		3147.75	3148.25	3148.75	3149.00	3149.25	3149.50	3149.75	3150.25	3150.00	3149.75	3149.50	3149.25	3149.00	3148.75	3148.50	3148.25	3148.25	3148.00	3147.75	3147.75
40	15	1	5		3147.50	3148.00	3148.50	3148.75	3149.00	3149.25	3149.50	3150.00	3149.75	3149.50	3149.25	3149.00	3148.75	3148.50	3148.25	3148.00	3148.00	3147.75	3147.50	3147.50
40	14	1	5		3147.25	3147.75	3148.25	3148.50	3148.75	3149.00	3149.25	3149.75	3149.50	3149.25	3149.00	3148.75	3148.50	3148.25	3148.00	3147.75	3147.75	3147.50	3147.25	3147.25
41	14	1	5		3147.00	3147.50	3148.00	3148.25	3148.50	3148.75	3149.00	3149.50	3149.25	3149.00	3148.75	3148.50	3148.25	3148.00	3147.75	3147.50	3147.50	3147.25	3147.00	3147.00
42	14	1	5		3146.75	3147.25	3147.75	3148.00	3148.25	3148.50	3148.75	3149.25	3149.00	3148.75	3148.50	3148.25	3148.00	3147.75	3147.50	3147.25	3147.25	3147.00	3146.75	3146.75
42	13	1	5		3146.50	3147.00	3147.50	3147.75	3148.00	3148.25	3148.50	3149.00	3148.75	3148.50	3148.25	3148.00	3147.75	3147.50	3147.25	3147.00	3147.00	3146.75	3146.50	3146.50
43	13	1	5		3146.25	3146.75	3147.25	3147.50	3147.75	3148.00	3148.25	3148.75	3148.50	3148.25	3148.00	3147.75	3147.50	3147.25	3147.00	3146.75	3146.75	3146.50	3146.25	3146.25
43	12	1	5		3146.00	3146.50	3147.00	3147.25	3147.50	3147.75	3148.00	3148.50	3148.25	3148.00	3147.75	3147.50	3147.25	3147.00	3146.75	3146.50	3146.50	3146.25	3146.00	3146.00
44	11	1	5		3145.88	3146.38	3146.88	3147.13	3147.38	3147.63	3147.88	3148.38	3148.13	3147.88	3147.63	3147.38	3147.13	3146.88	3146.63	3146.38	3146.38	3146.13	3145.88	3145.88
45	11	1	5		3145.75	3146.25	3146.75	3147.00	3147.25	3147.50	3147.75	3148.25	3148.00	3147.75	3147.50	3147.25	3147.00	3146.75	3146.50	3146.25	3146.25	3146.00	3145.75	3145.75
46	10	1	5		3145.63	3146.13	3146.63	3146.88	3147.13	3147.38	3147.63	3148.13	3147.88	3147.63	3147.38	3147.13	3146.88	3146.63	3146.38	3146.13	3146.13	3145.88	3145.63	3145.63
47	10	1	5		3145.50	3146.00	3146.50	3146.75	3147.00	3147.25	3147.50	3148.00	3147.75	3147.50	3147.25	3147.00	3146.75	3146.50	3146.25	3146.00	3146.00	3145.75	3145.50	3145.50
48	9	1	5		3145.38	3145.88	3146.38	3146.63	3146.88	3147.13	3147.38	3147.88	3147.63	3147.38	3147.13	3146.88	3146.63	3146.38	3146.13	3145.88	3145.88	3145.63	3145.38	3145.38
49	9	1	5		3145.25	3145.75	3146.25	3146.50	3146.75	3147.00	3147.25	3147.75	3147.50	3147.25	3147.00	3146.75	3146.50	3146.25	3146.00	3145.75	3145.75	3145.50	3145.25	3145.25
49	8	1	5		3145.13	3145.63	3146.13	3146.38	3146.63	3146.88	3147.13	3147.63	3147.38	3147.13	3146.88	3146.63	3146.38	3146.13	3145.88	3145.63	3145.63	3145.38	3145.13	3145.13
50	8	1	5		3145.00	3145.50	3146.00	3146.25	3146.50	3146.75	3147.00	3147.50	3147.25	3147.00	3146.75	3146.50	3146.25	3146.00	3145.75	3145.50	3145.50	3145.25	3145.00	3145.00
51	7	1	5		3144.86	3145.36	3145.86	3146.11	3146.36	3146.61	3146.86	3147.36	3147.11	3146.86	3146.61	3146.36	3146.11	3145.86	3145.61	3145.36	3145.36	3145.11	3144.86	3144.86
52	7	1	5		3144.71	3145.21	3145.71	3145.96	3146.21	3146.46	3146.71	3147.21	3146.96	3146.71	3146.46	3146.21	3145.96	3145.71	3145.46	3145.21	3145.21	3144.96	3144.71	3144.71
53	6	1	5		3144.57	3145.07	3145.57	3145.82	3146.07	3146.32	3146.57	3147.07	3146.82	3146.57	3146.32	3146.07	3145.82	3145.57	3145.32	3145.07	3145.07	3144.82	3144.57	3144.57
54	6	1	5		3144.43	3144.93	3145.43	3145.68	3145.93	3146.18	3146.43	3146.93	3146.68	3146.43	3146.18	3145.93	3145.68	3145.43	3145.18	3144.93	3144.93	3144.68	3144.43	3144.43
55	6	1	5		3144.29	3144.79	3145.29	3145.54	3145.79	3146.04	3146.29	3146.79	3146.54	3146.29	3146.04	3145.79	3145.54	3145.29	3145.04	3144.79	3144.79	3144.54	3144.29	3144.29
56	6	1	5		3144.14	3144.64	3145.14	3145.39	3145.64	3145.89	3146.14	3146.64	3146.39	3146.14	3145.89	3145.64	3145.39	3145.14	3144.89	3144.64	3144.64	3144.39	3144.14	3144.14
57	6	1	6		3144.00	3144.50	3145.00	3145.25	3145.50	3145.75	3146.00	3146.50	3146.25	3146.00	3145.75	3145.50	3145.25	3145.00	3144.75	3144.50	3144.50	3144.25	3144.00	3144.00

Table E-3. Specified Creek Stage Values

				Change:	0	0.5	1	1.25	1.5	1.75	2	2.5	2.25	2	1.75	1.5	1.25	1	0.75	0.5	0.5	0.25	0	0
				SP:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Row	Col	Layer	Reach	Date:	22-Mar	5-Apr	19-Apr	26-Apr	3-May	10-May	17-May	24-May	31-May	7-Jun	13-Jun	14-Jun	21-Jun	28-Jun	5-Jul	19-Jul	2-Aug	16-Aug	6-Sep	27-Sep
58	6	1	6		3143.92	3144.42	3144.92	3145.17	3145.42	3145.67	3145.92	3146.42	3146.17	3145.92	3145.67	3145.42	3145.17	3144.92	3144.67	3144.42	3144.42	3144.17	3143.92	3143.92
59	6	1	6		3143.83	3144.33	3144.83	3145.08	3145.33	3145.58	3145.83	3146.33	3146.08	3145.83	3145.58	3145.33	3145.08	3144.83	3144.58	3144.33	3144.33	3144.08	3143.83	3143.83
60	6	1	6		3143.75	3144.25	3144.75	3145.00	3145.25	3145.50	3145.75	3146.25	3146.00	3145.75	3145.50	3145.25	3145.00	3144.75	3144.50	3144.25	3144.25	3144.00	3143.75	3143.75
61	6	1	6		3143.67	3144.17	3144.67	3144.92	3145.17	3145.42	3145.67	3146.17	3145.92	3145.67	3145.42	3145.17	3144.92	3144.67	3144.42	3144.17	3144.17	3143.92	3143.67	3143.67
62	6	1	6		3143.58	3144.08	3144.58	3144.83	3145.08	3145.33	3145.58	3146.08	3145.83	3145.58	3145.33	3145.08	3144.83	3144.58	3144.33	3144.08	3144.08	3143.83	3143.58	3143.58
63	6	1	6		3143.50	3144.00	3144.50	3144.75	3145.00	3145.25	3145.50	3146.00	3145.75	3145.50	3145.25	3145.00	3144.75	3144.50	3144.25	3144.00	3144.00	3143.75	3143.50	3143.50
64	6	1	6		3143.42	3143.92	3144.42	3144.67	3144.92	3145.17	3145.42	3145.92	3145.67	3145.42	3145.17	3144.92	3144.67	3144.42	3144.17	3143.92	3143.92	3143.67	3143.42	3143.42
65	6	1	6		3143.33	3143.83	3144.33	3144.58	3144.83	3145.08	3145.33	3145.83	3145.58	3145.33	3145.08	3144.83	3144.58	3144.33	3144.08	3143.83	3143.83	3143.58	3143.33	3143.33
66	6	1	6		3143.25	3143.75	3144.25	3144.50	3144.75	3145.00	3145.25	3145.75	3145.50	3145.25	3145.00	3144.75	3144.50	3144.25	3144.00	3143.75	3143.75	3143.50	3143.25	3143.25
67	6	1	6		3143.17	3143.67	3144.17	3144.42	3144.67	3144.92	3145.17	3145.67	3145.42	3145.17	3144.92	3144.67	3144.42	3144.17	3143.92	3143.67	3143.67	3143.42	3143.17	3143.17
68	6	1	6		3143.08	3143.58	3144.08	3144.33	3144.58	3144.83	3145.08	3145.58	3145.33	3145.08	3144.83	3144.58	3144.33	3144.08	3143.83	3143.58	3143.58	3143.33	3143.08	3143.08
69	6	1	6		3143.00	3143.50	3144.00	3144.25	3144.50	3144.75	3145.00	3145.50	3145.25	3145.00	3144.75	3144.50	3144.25	3144.00	3143.75	3143.50	3143.50	3143.25	3143.00	3143.00
70	6	1	7		3142.70	3143.20	3143.70	3143.95	3144.20	3144.45	3144.70	3145.20	3144.95	3144.70	3144.45	3144.20	3143.95	3143.70	3143.45	3143.20	3143.20	3142.95	3142.50	3142.50
71	6	1	7		3142.20	3142.70	3143.20	3143.45	3143.70	3143.95	3144.20	3144.70	3144.45	3144.20	3143.95	3143.70	3143.45	3143.20	3142.95	3142.70	3142.70	3142.45	3142.00	3142.00
72	6	1	7		3141.80	3142.30	3142.80	3143.05	3143.30	3143.55	3143.80	3144.30	3144.05	3143.80	3143.55	3143.30	3143.05	3142.80	3142.55	3142.30	3142.30	3142.05	3141.50	3141.50
73	6	1	7		3141.30	3141.80	3142.30	3142.55	3142.80	3143.05	3143.30	3143.80	3143.55	3143.30	3143.05	3142.80	3142.55	3142.30	3142.05	3141.80	3141.80	3141.55	3141.00	3141.00
74	6	1	7		3141.28	3141.78	3142.28	3142.53	3142.78	3143.03	3143.28	3143.78	3143.53	3143.28	3143.03	3142.78	3142.53	3142.28	3142.03	3141.78	3141.78	3141.53	3140.88	3140.88
74	5	1	7		3141.15	3141.65	3142.15	3142.40	3142.65	3142.90	3143.15	3143.65	3143.40	3143.15	3142.90	3142.65	3142.40	3142.15	3141.90	3141.65	3141.65	3141.40	3140.75	3140.75
75	5	1	7		3141.13	3141.63	3142.13	3142.38	3142.63	3142.88	3143.13	3143.63	3143.38	3143.13	3142.88	3142.63	3142.38	3142.13	3141.88	3141.63	3141.63	3141.38	3140.63	3140.63
76	5	1	7		3141.00	3141.50	3142.00	3142.25	3142.50	3142.75	3143.00	3143.50	3143.25	3143.00	3142.75	3142.50	3142.25	3142.00	3141.75	3141.50	3141.50	3141.25	3140.50	3140.50
77	5	1	7		3140.88	3141.38	3141.88	3142.13	3142.38	3142.63	3142.88	3143.38	3143.13	3142.88	3142.63	3142.38	3142.13	3141.88	3141.63	3141.38	3141.38	3141.13	3140.38	3140.38
78	5	1	7		3140.85	3141.35	3141.85	3142.10	3142.35	3142.60	3142.85	3143.35	3143.10	3142.85	3142.60	3142.35	3142.10	3141.85	3141.60	3141.35	3141.35	3141.10	3140.25	3140.25
78	6	1	7		3140.73	3141.23	3141.73	3141.98	3142.23	3142.48	3142.73	3143.23	3142.98	3142.73	3142.48	3142.23	3141.98	3141.73	3141.48	3141.23	3141.23	3140.98	3140.13	3140.13
78	7	1	7		3140.60	3141.10	3141.60	3141.85	3142.10	3142.35	3142.60	3143.10	3142.85	3142.60	3142.35	3142.10	3141.85	3141.60	3141.35	3141.10	3141.10	3140.85	3140.00	3140.00
78	8	1	8		3140.59	3141.09	3141.59	3141.84	3142.09	3142.34	3142.59	3143.09	3142.84	3142.59	3142.34	3142.09	3141.84	3141.59	3141.34	3141.09	3141.09	3140.84	3139.89	3139.89
78	9	1	8		3140.48	3140.98	3141.48	3141.73	3141.98	3142.23	3142.48	3142.98	3142.73	3142.48	3142.23	3141.98	3141.73	3141.48	3141.23	3140.98	3140.98	3140.73	3139.78	3139.78
77	9	1	8		3140.37	3140.87	3141.37	3141.62	3141.87	3142.12	3142.37	3142.87	3142.62	3142.37	3142.12	3141.87	3141.62	3141.37	3141.12	3140.87	3140.87	3140.62	3139.67	3139.67
77	10	1	8		3140.36	3140.86	3141.36	3141.61	3141.86	3142.11	3142.36	3142.86	3142.61	3142.36	3142.11	3141.86	3141.61	3141.36	3141.11	3140.86	3140.86	3140.61	3139.56	3139.56
77	11	1	8		3140.24	3140.74	3141.24	3141.49	3141.74	3141.99	3142.24	3142.74	3142.49	3142.24	3141.99	3141.74	3141.49	3141.24	3140.99	3140.74	3140.74	3140.49	3139.44	3139.44
76	11	1	8		3140.13	3140.63	3141.13	3141.38	3141.63	3141.88	3142.13	3142.63	3142.38	3142.13	3141.88	3141.63	3141.38	3141.13	3140.88	3140.63	3140.63	3140.38	3139.33	3139.33
76	12	1	8		3140.02	3140.52	3141.02	3141.27	3141.52	3141.77	3142.02	3142.52	3142.27	3142.02	3141.77	3141.52	3141.27	3141.02	3140.77	3140.52	3140.52	3140.27	3139.22	3139.22
76	13	1	8		3140.01	3140.51	3141.01	3141.26	3141.51	3141.76	3142.01	3142.51	3142.26	3142.01	3141.76	3141.51	3141.26	3141.01	3140.76	3140.51	3140.51	3140.26	3139.11	3139.11
76	14	1	8		3139.90	3140.40	3140.90	3141.15	3141.40	3141.65	3141.90	3142.40	3142.15	3141.90	3141.65	3141.40	3141.15	3140.90	3140.65	3140.40	3140.40	3140.15	3139.00	3139.00
77	14	1	8		3139.54	3140.04	3140.54	3140.79	3141.04	3141.29	3141.54	3142.04	3141.79	3141.54	3141.29	3141.04	3140.79	3140.54	3140.29	3140.04	3140.04	3139.79	3138.64	3138.64
77	15	1	8		3139.17	3139.67	3140.17	3140.42	3140.67	3140.92	3141.17	3141.67	3141.42	3141.17	3140.92	3140.67	3140.42	3140.17	3139.92	3139.67	3139.67	3139.42	3138.27	3138.27
78	15	1	8		3138.81	3139.31	3139.81	3140.06	3140.31	3140.56	3140.81	3141.31	3141.06	3140.81	3140.56	3140.31	3140.06	3139.81	3139.56	3139.31	3139.31	3139.06	3137.91	3137.91
78	16	1	8		3138.45	3138.95	3139.45	3139.70	3139.95	3140.20	3140.45	3140.95	3140.70	3140.45	3140.20	3139.95	3139.70	3139.45	3139.20	3138.95	3138.95	3138.70	3137.55	3137.55
78	17	1	8		3138.08	3138.58	3139.08	3139.33	3139.58	3139.83	3140.08	3140.58	3140.33	3140.08	3139.83	3139.58	3139.33	3139.08	3138.83	3138.58	3138.58	3138.33	3137.18	3137.18
78	18	1	8		3137.82	3138.32	3138.82	3139.07	3139.32	3139.57	3139.82	3140.32	3140.07	3139.82	3139.57	3139.32	3139.07	3138.82	3138.57	3138.32	3138.32	3138.07	3136.82	3136.82
78	19	1	8		3137.45	3137.95	3138.45	3138.70	3138.95	3139.20	3139.45	3139.95	3139.70	3139.45	3139.20	3138.95	3138.70	3138.45	3138.20	3137.95	3137.95	3137.70	3136.45	3136.45
79	19	1	8		3137.09	3137.59	3138.09	3138.34	3138.59	3138.84	3139.09	3139.59	3139.34	3139.09	3138.84	3138.59	3138.34	3138.09	3137.84	3137.59	3137.59	3137.34	3136.09	3136.09
80	19	1	8		3136.73	3137.23	3137.73	3137.98	3138.23	3138.48	3138.73	3139.23	3138.98	3138.73	3138.48	3138.23	3137.98	3137.73	3137.48	3137.23	3137.23	3136.98	3135.73	3135.73
81	19	1	8		3136.36	3136.86	3137.36	3137.61	3137.86	3138.11	3138.36	3138.86	3138.61	3138.36	3138.11	3137.86	3137.61	3137.36	3137.11	3136.86	3136.86	3136.61	3135.36	3135.36
81	18	1	8		3136.00	3136.50	3137.00	3137.25	3137.50	3137.75	3138.00	3138.50	3138.25	3138.00	3137.75	3137.50	3137.25	3137.00	3136.75	3136.50	3136.50	3136.25	3135.00	3135.00
82	18	1	8		3135.00	3135.50	3136.00	3136.25	3136.50	3136.75	3137.00	3137.50	3137.25	3137.00	3136.75	3136.50	3136.25	3136.00	3135.75	3135.50	3135.50	3135.25	3134.00	3134.00

Table E-4 GHB Cell-North

					Change:	0	1.5	1.75	2	2.5	2.25	2	1.75	1.5	1.25	1	0.75	0.5	0.5	0.25	0	0	0	0	0
					Date:	22-Mar	5-Apr	19-Apr	26-Apr	3-May	10-May	17-May	24-May	31-May	7-Jun	13-Jun	14-Jun	21-Jun	28-Jun	5-Jul	19-Jul	2-Aug	16-Aug	6-Sep	27-Sep
Row	Col	Layer	Reach	K	SP:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2	36	3	1	10		3255	3256.5	3256.75	3257	3257.5	3257.25	3257	3256.75	3256.5	3256.25	3256	3255.75	3255.5	3255.5	3255.25	3255	3255	3255	3255	3255
2	37	3	1	10		3255	3256.5	3256.75	3257	3257.5	3257.25	3257	3256.75	3256.5	3256.25	3256	3255.75	3255.5	3255.5	3255.25	3255	3255	3255	3255	3255
2	38	3	1	10		3255	3256.5	3256.75	3257	3257.5	3257.25	3257	3256.75	3256.5	3256.25	3256	3255.75	3255.5	3255.5	3255.25	3255	3255	3255	3255	3255
2	39	3	1	10		3255	3256.5	3256.75	3257	3257.5	3257.25	3257	3256.75	3256.5	3256.25	3256	3255.75	3255.5	3255.5	3255.25	3255	3255	3255	3255	3255
2	40	3	1	10		3255	3256.5	3256.75	3257	3257.5	3257.25	3257	3256.75	3256.5	3256.25	3256	3255.75	3255.5	3255.5	3255.25	3255	3255	3255	3255	3255
2	41	3	1	10		3255	3256.5	3256.75	3257	3257.5	3257.25	3257	3256.75	3256.5	3256.25	3256	3255.75	3255.5	3255.5	3255.25	3255	3255	3255	3255	3255
2	42	3	1	10		3255	3256.5	3256.75	3257	3257.5	3257.25	3257	3256.75	3256.5	3256.25	3256	3255.75	3255.5	3255.5	3255.25	3255	3255	3255	3255	3255
2	43	3	1	10		3255	3256.5	3256.75	3257	3257.5	3257.25	3257	3256.75	3256.5	3256.25	3256	3255.75	3255.5	3255.5	3255.25	3255	3255	3255	3255	3255
2	44	3	1	10		3255	3256.5	3256.75	3257	3257.5	3257.25	3257	3256.75	3256.5	3256.25	3256	3255.75	3255.5	3255.5	3255.25	3255	3255	3255	3255	3255
2	45	3	1	10		3255	3256.5	3256.75	3257	3257.5	3257.25	3257	3256.75	3256.5	3256.25	3256	3255.75	3255.5	3255.5	3255.25	3255	3255	3255	3255	3255
2	46	3	1	10		3255	3256.5	3256.75	3257	3257.5	3257.25	3257	3256.75	3256.5	3256.25	3256	3255.75	3255.5	3255.5	3255.25	3255	3255	3255	3255	3255
2	47	3	1	10		3255	3256.5	3256.75	3257	3257.5	3257.25	3257	3256.75	3256.5	3256.25	3256	3255.75	3255.5	3255.5	3255.25	3255	3255	3255	3255	3255
2	48	3	1	10		3255	3256.5	3256.75	3257	3257.5	3257.25	3257	3256.75	3256.5	3256.25	3256	3255.75	3255.5	3255.5	3255.25	3255	3255	3255	3255	3255
3	49	3	1	10		3255	3256.5	3256.75	3257	3257.5	3257.25	3257	3256.75	3256.5	3256.25	3256	3255.75	3255.5	3255.5	3255.25	3255	3255	3255	3255	3255
3	50	3	1	10		3255	3256.5	3256.75	3257	3257.5	3257.25	3257	3256.75	3256.5	3256.25	3256	3255.75	3255.5	3255.5	3255.25	3255	3255	3255	3255	3255
3	51	3	1	10		3255	3256.5	3256.75	3257	3257.5	3257.25	3257	3256.75	3256.5	3256.25	3256	3255.75	3255.5	3255.5	3255.25	3255	3255	3255	3255	3255
3	52	3	1	10		3255	3256.5	3256.75	3257	3257.5	3257.25	3257	3256.75	3256.5	3256.25	3256	3255.75	3255.5	3255.5	3255.25	3255	3255	3255	3255	3255
4	53	3	1	10		3255	3256.5	3256.75	3257	3257.5	3257.25	3257	3256.75	3256.5	3256.25	3256	3255.75	3255.5	3255.5	3255.25	3255	3255	3255	3255	3255
5	54	3	1	10		3255	3256.5	3256.75	3257	3257.5	3257.25	3257	3256.75	3256.5	3256.25	3256	3255.75	3255.5	3255.5	3255.25	3255	3255	3255	3255	3255
5	55	3	1	10		3255	3256.5	3256.75	3257	3257.5	3257.25	3257	3256.75	3256.5	3256.25	3256	3255.75	3255.5	3255.5	3255.25	3255	3255	3255	3255	3255
5	56	3	1	10		3255	3256.5	3256.75	3257	3257.5	3257.25	3257	3256.75	3256.5	3256.25	3256	3255.75	3255.5	3255.5	3255.25	3255	3255	3255	3255	3255
5	57	3	1	10		3255	3256.5	3256.75	3257	3257.5	3257.25	3257	3256.75	3256.5	3256.25	3256	3255.75	3255.5	3255.5	3255.25	3255	3255	3255	3255	3255
5	58	3	1	10		3255	3256.5	3256.75	3257	3257.5	3257.25	3257	3256.75	3256.5	3256.25	3256	3255.75	3255.5	3255.5	3255.25	3255	3255	3255	3255	3255
5	59	3	1	10		3255	3256.5	3256.75	3257	3257.5	3257.25	3257	3256.75	3256.5	3256.25	3256	3255.75	3255.5	3255.5	3255.25	3255	3255	3255	3255	3255
6	59	3	1	10		3255	3256.5	3256.75	3257	3257.5	3257.25	3257	3256.75	3256.5	3256.25	3256	3255.75	3255.5	3255.5	3255.25	3255	3255	3255	3255	3255
6	60	3	1	10		3255	3256.5	3256.75	3257	3257.5	3257.25	3257	3256.75	3256.5	3256.25	3256	3255.75	3255.5	3255.5	3255.25	3255	3255	3255	3255	3255
7	61	3	1	10		3255	3256.5	3256.75	3257	3257.5	3257.25	3257	3256.75	3256.5	3256.25	3256	3255.75	3255.5	3255.5	3255.25	3255	3255	3255	3255	3255
7	62	3	1	10		3255	3256.5	3256.75	3257	3257.5	3257.25	3257	3256.75	3256.5	3256.25	3256	3255.75	3255.5	3255.5	3255.25	3255	3255	3255	3255	3255
7	63	3	1	10		3255	3256.5	3256.75	3257	3257.5	3257.25	3257	3256.75	3256.5	3256.25	3256	3255.75	3255.5	3255.5	3255.25	3255	3255	3255	3255	3255

Table E-5. GHB Cells - South

					Change:	0	2	4	5	6	7	8	10	9	8	7	6	5	4	3	2	2	1	0	0
					Date:	22-Mar	5-Apr	19-Apr	26-Apr	3-May	10-May	17-May	24-May	31-May	7-Jun	13-Jun	14-Jun	21-Jun	28-Jun	5-Jul	19-Jul	2-Aug	16-Aug	6-Sep	27-Sep
Row	Col	Layer	Reach	K	SP:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
93	1	3	2	900		3121	3123	3125	3126	3127	3128	3129	3131	3130.00	3129	3128.00	3127	3126.00	3125	3124.00	3123	3123	3122.00	3121	3121
93	2	3	2	900		3121	3123	3125	3126	3127	3128	3129	3131	3130.00	3129	3128.00	3127	3126.00	3125	3124.00	3123	3123	3122.00	3121	3121
93	3	3	2	900		3121	3123	3125	3126	3127	3128	3129	3131	3130.00	3129	3128.00	3127	3126.00	3125	3124.00	3123	3123	3122.00	3121	3121
93	4	3	2	900		3121	3123	3125	3126	3127	3128	3129	3131	3130.00	3129	3128.00	3127	3126.00	3125	3124.00	3123	3123	3122.00	3121	3121
93	5	3	2	900		3121	3123	3125	3126	3127	3128	3129	3131	3130.00	3129	3128.00	3127	3126.00	3125	3124.00	3123	3123	3122.00	3121	3121
93	6	3	2	900		3121	3123	3125	3126	3127	3128	3129	3131	3130.00	3129	3128.00	3127	3126.00	3125	3124.00	3123	3123	3122.00	3121	3121
93	7	3	2	900		3121	3123	3125	3126	3127	3128	3129	3131	3130.00	3129	3128.00	3127	3126.00	3125	3124.00	3123	3123	3122.00	3121	3121
93	8	3	2	900		3121	3123	3125	3126	3127	3128	3129	3131	3130.00	3129	3128.00	3127	3126.00	3125	3124.00	3123	3123	3122.00	3121	3121
93	9	3	2	900		3121	3123	3125	3126	3127	3128	3129	3131	3130.00	3129	3128.00	3127	3126.00	3125	3124.00	3123	3123	3122.00	3121	3121
93	10	3	2	900		3121	3123	3125	3126	3127	3128	3129	3131	3130.00	3129	3128.00	3127	3126.00	3125	3124.00	3123	3123	3122.00	3121	3121
93	11	3	2	900		3121	3123	3125	3126	3127	3128	3129	3131	3130.00	3129	3128.00	3127	3126.00	3125	3124.00	3123	3123	3122.00	3121	3121
93	12	3	2	900		3121	3123	3125	3126	3127	3128	3129	3131	3130.00	3129	3128.00	3127	3126.00	3125	3124.00	3123	3123	3122.00	3121	3121
93	13	3	2	900		3121	3123	3125	3126	3127	3128	3129	3131	3130.00	3129	3128.00	3127	3126.00	3125	3124.00	3123	3123	3122.00	3121	3121
93	14	3	2	900		3121	3123	3125	3126	3127	3128	3129	3131	3130.00	3129	3128.00	3127	3126.00	3125	3124.00	3123	3123	3122.00	3121	3121
93	15	3	2	900		3121	3123	3125	3126	3127	3128	3129	3131	3130.00	3129	3128.00	3127	3126.00	3125	3124.00	3123	3123	3122.00	3121	3121
93	16	3	2	900		3121	3123	3125	3126	3127	3128	3129	3131	3130.00	3129	3128.00	3127	3126.00	3125	3124.00	3123	3123	3122.00	3121	3121
93	17	3	2	900		3121	3123	3125	3126	3127	3128	3129	3131	3130.00	3129	3128.00	3127	3126.00	3125	3124.00	3123	3123	3122.00	3121	3121
93	18	3	2	900		3121	3123	3125	3126	3127	3128	3129	3131	3130.00	3129	3128.00	3127	3126.00	3125	3124.00	3123	3123	3122.00	3121	3121
93	19	3	2	900		3121	3123	3125	3126	3127	3128	3129	3131	3130.00	3129	3128.00	3127	3126.00	3125	3124.00	3123	3123	3122.00	3121	3121
93	20	3	2	900		3121	3123	3125	3126	3127	3128	3129	3131	3130.00	3129	3128.00	3127	3126.00	3125	3124.00	3123	3123	3122.00	3121	3121
93	21	3	2	900		3121	3123	3125	3126	3127	3128	3129	3131	3130.00	3129	3128.00	3127	3126.00	3125	3124.00	3123	3123	3122.00	3121	3121
93	22	3	2	900		3121	3123	3125	3126	3127	3128	3129	3131	3130.00	3129	3128.00	3127	3126.00	3125	3124.00	3123	3123	3122.00	3121	3121
93	23	3	2	900		3121	3123	3125	3126	3127	3128	3129	3131	3130.00	3129	3128.00	3127	3126.00	3125	3124.00	3123	3123	3122.00	3121	3121

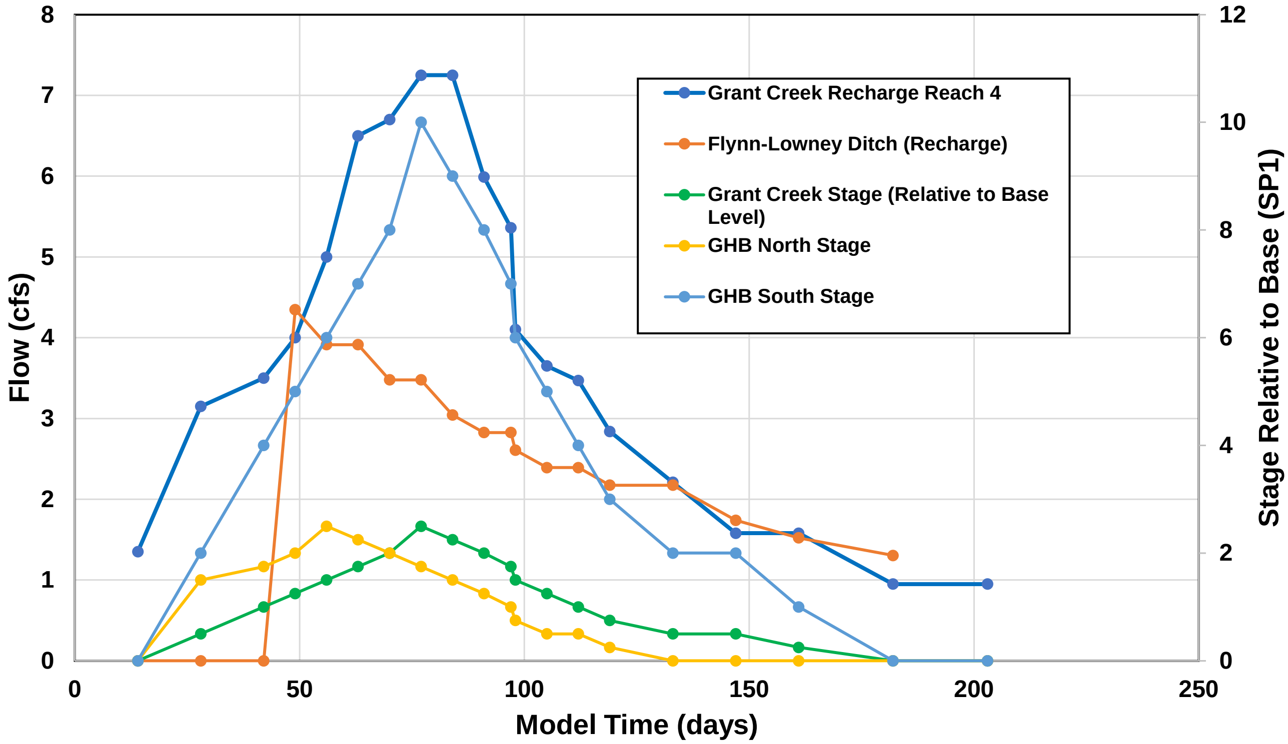


Figure E-3. River and GHB Stage and Creek and Ditch Recharge Seasonal Fluctuations

Table E-6. Drain Package Cells

Drain Cells - Leakage to Missoula Aquifer

Row	Col	Layer	Reach	Drain Elev.	Length (ft)	Width (ft)	Thkns (ft)	K (ft/d)	Conductance
27	32	3	0	3132	200	200	10	0.5	2000
27	33	3	0	3132	200	200	10	0.5	2000
27	34	3	0	3132	200	200	10	0.5	2000
28	32	3	0	3131.2	200	200	10	0.5	2000
28	33	3	0	3131.2	200	200	10	0.5	2000
28	34	3	0	3131.2	200	200	10	0.5	2000
29	32	3	0	3131	200	200	10	0.5	2000
29	33	3	0	3131	200	200	10	0.5	2000
29	34	3	0	3131	200	200	10	0.5	2000
30	32	3	0	3130.8	200	200	10	0.5	2000
30	33	3	0	3130.8	200	200	10	0.5	2000

Drain Cells - Mullan Trails Estates

Row	Col	Layer	Reach	Drain Elev.	Length (ft)	Width (ft)	Thkns (ft)	K (ft/d)	Conductance
75	10	1	1	3137	200	1	1	900	180000
76	9	1	1	3135.3	200	1	1	900	180000
75	8	1	1	3136.9	200	1	1	900	180000
74	9	1	1	3134.7	200	1	1	900	180000
73	9	1	1	3135.1	200	1	1	900	180000
72	9	1	1	3135.9	200	1	1	900	180000
71	9	1	1	3135.6	200	1	1	900	180000
71	10	1	1	3136.8	200	1	1	900	180000
71	11	1	1	3137	200	1	1	900	180000
71	12	1	1	3137.3	200	1	1	900	180000
71	13	1	1	3138.6	200	1	1	900	180000
71	14	1	1	3137.4	200	1	1	900	180000
72	14	1	1	3138.3	200	1	1	900	180000
73	14	1	1	3137.7	200	1	1	900	180000
74	13	1	1	3138.6	200	1	1	900	180000
74	12	1	1	3137.7	200	1	1	900	180000
74	11	1	1	3137.1	200	1	1	900	180000

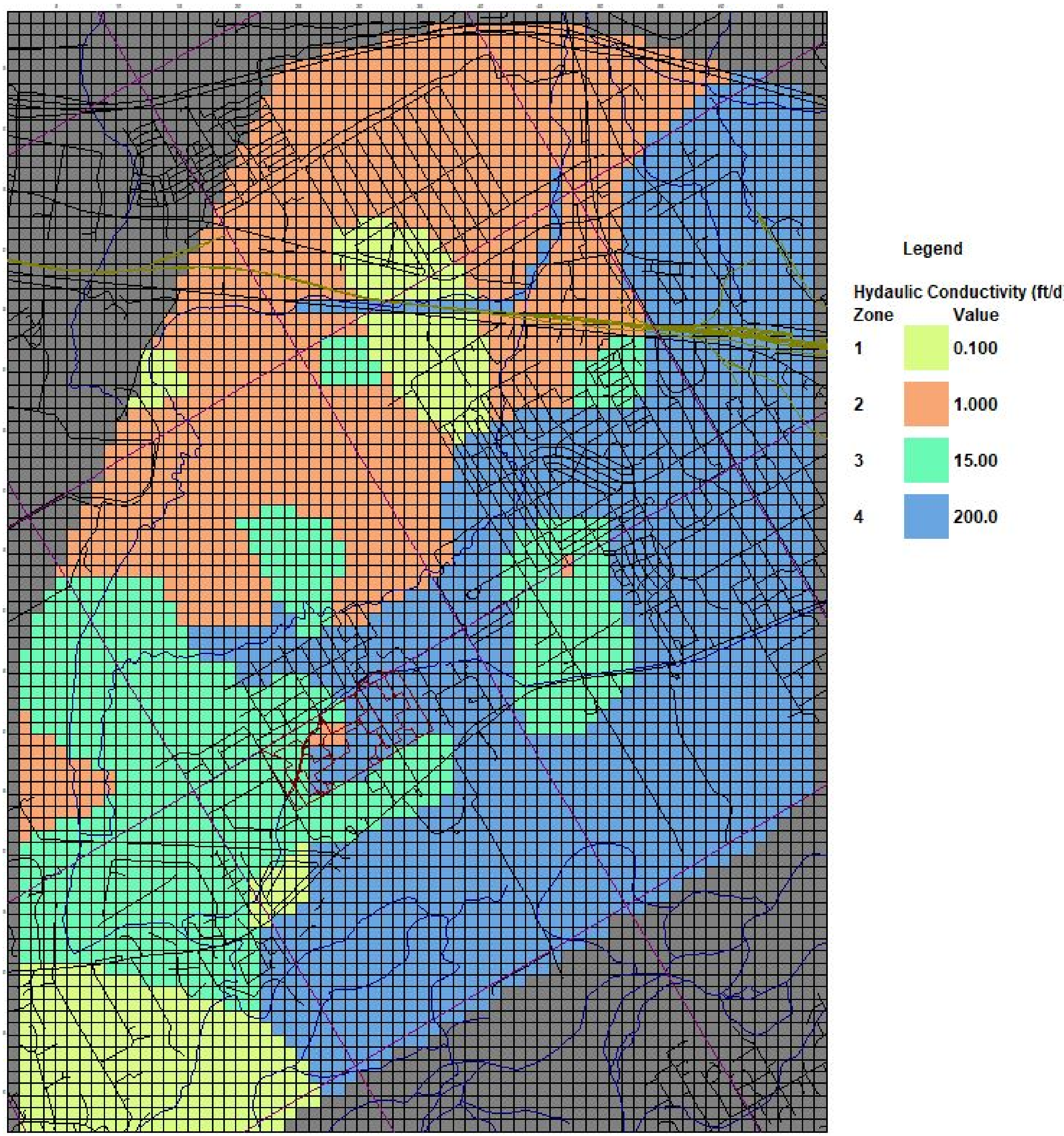


Figure E-4. Model Hydraulic Conductivity – Layer 1

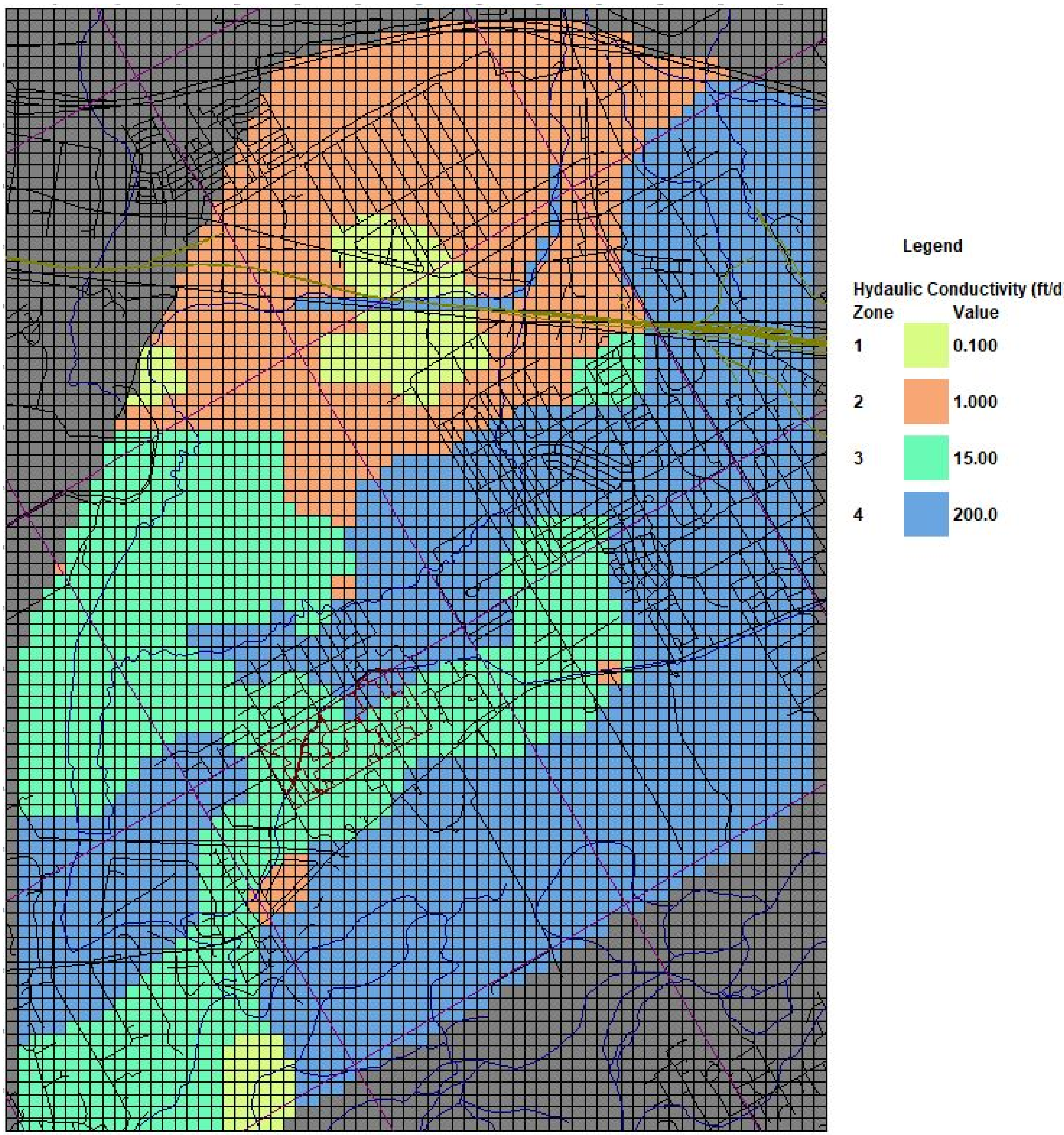


Figure E-5. Model Hydraulic Conductivity – Layer 2

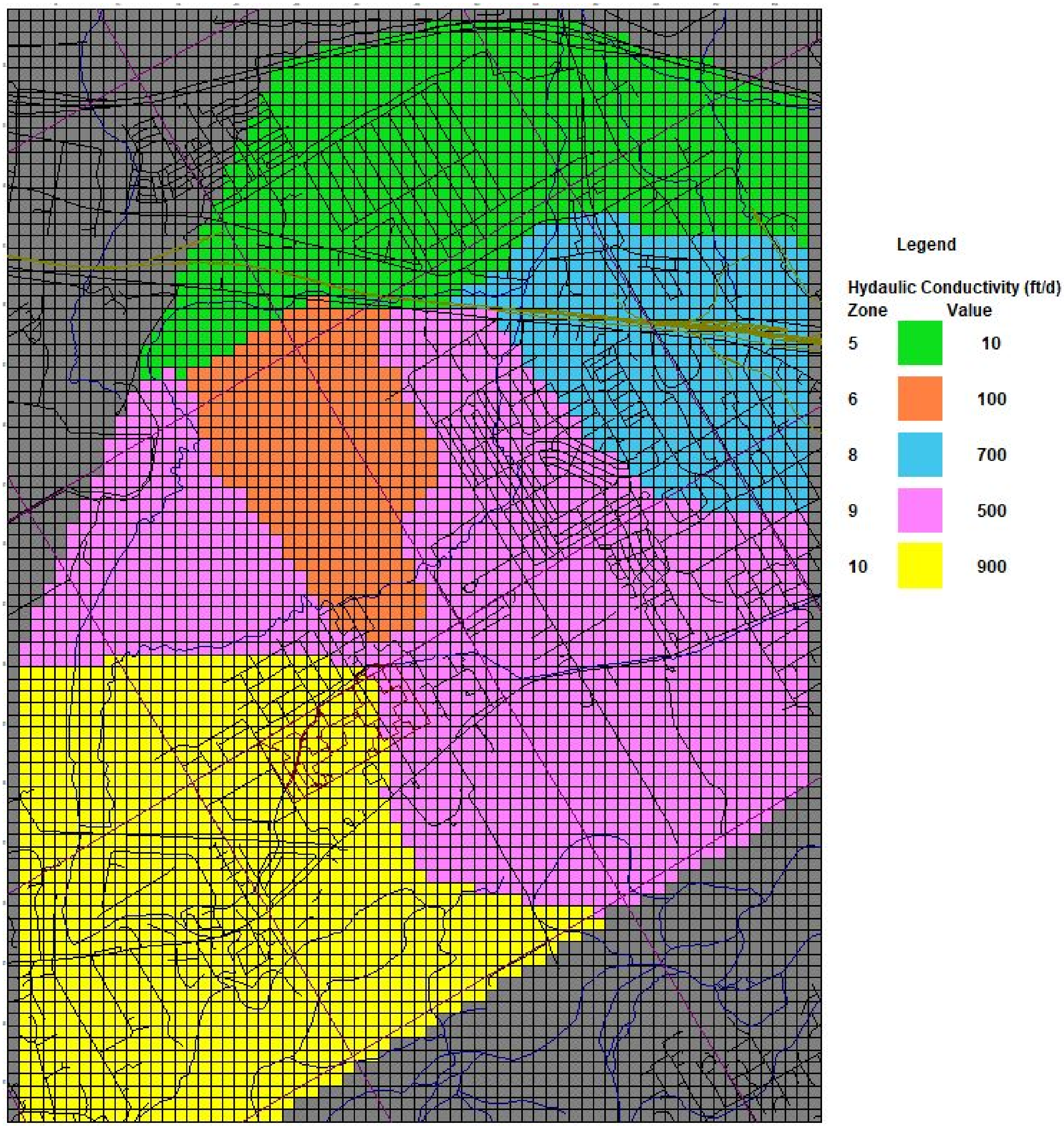


Figure E-6. Model Hydraulic Conductivity – Layer 3

Table E-7. Specified Creek Stage Values - 100-Year Hydrologic Event

				Change:	0	0.5	1.25	1.75	2.25	2.75	3.5	4	3.5	2.75	2.25	2	1.5	1.25	1	0.75	0.75	0.25	0	0
				SP:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Row	Col	Layer	Reach	Date:	22-Mar	5-Apr	19-Apr	26-Apr	3-May	10-May	17-May	24-May	31-May	7-Jun	13-Jun	14-Jun	21-Jun	28-Jun	5-Jul	19-Jul	2-Aug	16-Aug	6-Sep	27-Sep
25	24	1	5		3160.00	3160.50	3161.25	3161.75	3162.25	3162.75	3163.50	3164.00	3163.50	3162.75	3162.25	3162.00	3161.50	3161.25	3161.00	3160.75	3160.75	3160.25	3160.00	3160.00
26	24	1	5		3159.25	3159.75	3160.50	3161.00	3161.50	3162.00	3162.75	3163.25	3162.75	3162.00	3161.50	3161.25	3160.75	3160.50	3160.25	3160.00	3160.00	3159.50	3159.25	3159.25
26	23	1	5		3158.50	3159.00	3159.75	3160.25	3160.75	3161.25	3162.00	3162.50	3162.00	3161.25	3160.75	3160.50	3160.00	3159.75	3159.50	3159.25	3159.25	3158.75	3158.50	3158.50
26	22	1	5		3157.75	3158.25	3159.00	3159.50	3160.00	3160.50	3161.25	3161.75	3161.25	3160.50	3160.00	3159.75	3159.25	3159.00	3158.75	3158.50	3158.50	3158.00	3157.75	3157.75
25	22	1	5		3157.00	3157.50	3158.25	3158.75	3159.25	3159.75	3160.50	3161.00	3160.50	3159.75	3159.25	3159.00	3158.50	3158.25	3158.00	3157.75	3157.75	3157.25	3157.00	3157.00
25	21	1	5		3156.25	3156.75	3157.50	3158.00	3158.50	3159.00	3159.75	3160.25	3159.75	3159.00	3158.50	3158.25	3157.75	3157.50	3157.25	3157.00	3157.00	3156.50	3156.25	3156.25
25	20	1	5		3155.50	3156.00	3156.75	3157.25	3157.75	3158.25	3159.00	3159.50	3159.00	3158.25	3157.75	3157.50	3157.00	3156.75	3156.50	3156.25	3156.25	3155.75	3155.50	3155.50
25	19	1	5		3154.75	3155.25	3156.00	3156.50	3157.00	3157.50	3158.25	3158.75	3158.25	3157.50	3157.00	3156.75	3156.25	3156.00	3155.75	3155.50	3155.50	3155.00	3154.75	3154.75
25	18	1	5		3154.00	3154.50	3155.25	3155.75	3156.25	3156.75	3157.50	3158.00	3157.50	3156.75	3156.25	3156.00	3155.50	3155.25	3155.00	3154.75	3154.75	3154.25	3154.00	3154.00
25	17	1	5		3153.67	3154.17	3154.92	3155.42	3155.92	3156.42	3157.17	3157.67	3157.17	3156.42	3155.92	3155.67	3155.17	3154.92	3154.67	3154.42	3154.42	3153.92	3153.67	3153.67
25	16	1	5		3153.33	3153.83	3154.58	3155.08	3155.58	3156.08	3156.83	3157.33	3156.83	3156.08	3155.58	3155.33	3154.83	3154.58	3154.33	3154.08	3154.08	3153.58	3153.33	3153.33
25	15	1	5		3153.00	3153.50	3154.25	3154.75	3155.25	3155.75	3156.50	3157.00	3156.50	3155.75	3155.25	3155.00	3154.50	3154.25	3154.00	3153.75	3153.75	3153.25	3153.00	3153.00
26	15	1	5		3152.67	3153.17	3153.92	3154.42	3154.92	3155.42	3156.17	3156.67	3156.17	3155.42	3154.92	3154.67	3154.17	3153.92	3153.67	3153.42	3153.42	3152.92	3152.67	3152.67
26	14	1	5		3152.33	3152.83	3153.58	3154.08	3154.58	3155.08	3155.83	3156.33	3155.83	3155.08	3154.58	3154.33	3153.83	3153.58	3153.33	3153.08	3153.08	3152.58	3152.33	3152.33
27	14	1	5		3152.00	3152.50	3153.25	3153.75	3154.25	3154.75	3155.50	3156.00	3155.50	3154.75	3154.25	3154.00	3153.50	3153.25	3153.00	3152.75	3152.75	3152.25	3152.00	3152.00
28	13	1	5		3151.67	3152.17	3152.92	3153.42	3153.92	3154.42	3155.17	3155.67	3155.17	3154.42	3153.92	3153.67	3153.17	3152.92	3152.67	3152.42	3152.42	3151.92	3151.67	3151.67
29	13	1	5		3151.33	3151.83	3152.58	3153.08	3153.58	3154.08	3154.83	3155.33	3154.83	3154.08	3153.58	3153.33	3152.83	3152.58	3152.33	3152.08	3152.08	3151.58	3151.33	3151.33
29	12	1	5		3151.00	3151.50	3152.25	3152.75	3153.25	3153.75	3154.50	3155.00	3154.50	3153.75	3153.25	3153.00	3152.50	3152.25	3152.00	3151.75	3151.75	3151.25	3151.00	3151.00
30	12	1	5		3150.80	3151.30	3152.05	3152.55	3153.05	3153.55	3154.30	3154.80	3154.30	3153.55	3153.05	3152.80	3152.30	3152.05	3151.80	3151.55	3151.55	3151.05	3150.80	3150.80
31	12	1	5		3150.60	3151.10	3151.85	3152.35	3152.85	3153.35	3154.10	3154.60	3154.10	3153.35	3152.85	3152.60	3152.10	3151.85	3151.60	3151.35	3151.35	3150.85	3150.60	3150.60
31	13	1	5		3150.40	3150.90	3151.65	3152.15	3152.65	3153.15	3153.90	3154.40	3153.90	3153.15	3152.65	3152.40	3151.90	3151.65	3151.40	3151.15	3151.15	3150.65	3150.40	3150.40
32	13	1	5		3150.20	3150.70	3151.45	3151.95	3152.45	3152.95	3153.70	3154.20	3153.70	3152.95	3152.45	3152.20	3151.70	3151.45	3151.20	3150.95	3150.95	3150.45	3150.20	3150.20
33	13	1	5		3150.00	3150.50	3151.25	3151.75	3152.25	3152.75	3153.50	3154.00	3153.50	3152.75	3152.25	3152.00	3151.50	3151.25	3151.00	3150.75	3150.75	3150.25	3150.00	3150.00
33	14	1	5		3149.80	3150.30	3151.05	3151.55	3152.05	3152.55	3153.30	3153.80	3153.30	3152.55	3152.05	3151.80	3151.30	3151.05	3150.80	3150.55	3150.55	3150.05	3149.80	3149.80
34	14	1	5		3149.60	3150.10	3150.85	3151.35	3151.85	3152.35	3153.10	3153.60	3153.10	3152.35	3151.85	3151.60	3151.10	3150.85	3150.60	3150.35	3150.35	3149.85	3149.60	3149.60
34	15	1	5		3149.40	3149.90	3150.65	3151.15	3151.65	3152.15	3152.90	3153.40	3152.90	3152.15	3151.65	3151.40	3150.90	3150.65	3150.40	3150.15	3150.15	3149.65	3149.40	3149.40
35	15	1	5		3149.20	3149.70	3150.45	3150.95	3151.45	3151.95	3152.70	3153.20	3152.70	3151.95	3151.45	3151.20	3150.70	3150.45	3150.20	3149.95	3149.95	3149.45	3149.20	3149.20
35	16	1	5		3149.00	3149.50	3150.25	3150.75	3151.25	3151.75	3152.50	3153.00	3152.50	3151.75	3151.25	3151.00	3150.50	3150.25	3150.00	3149.75	3149.75	3149.25	3149.00	3149.00
36	16	1	5		3148.75	3149.25	3150.00	3150.50	3151.00	3151.50	3152.25	3152.75	3152.25	3151.50	3151.00	3150.75	3150.25	3150.00	3149.75	3149.50	3149.50	3149.00	3148.75	3148.75
37	16	1	5		3148.50	3149.00	3149.75	3150.25	3150.75	3151.25	3152.00	3152.50	3152.00	3151.25	3150.75	3150.50	3150.00	3149.75	3149.50	3149.25	3149.25	3148.75	3148.50	3148.50
37	15	1	5		3148.25	3148.75	3149.50	3150.00	3150.50	3151.00	3151.75	3152.25	3151.75	3151.00	3150.50	3150.25	3149.75	3149.50	3149.25	3149.00	3149.00	3148.50	3148.25	3148.25
38	15	1	5		3148.00	3148.50	3149.25	3149.75	3150.25	3150.75	3151.50	3152.00	3151.50	3150.75	3150.25	3150.00	3149.50	3149.25	3149.00	3148.75	3148.75	3148.25	3148.00	3148.00
39	15	1	5		3147.75	3148.25	3149.00	3149.50	3150.00	3150.50	3151.25	3151.75	3151.25	3150.50	3150.00	3149.75	3149.25	3149.00	3148.75	3148.50	3148.50	3148.00	3147.75	3147.75
40	15	1	5		3147.50	3148.00	3148.75	3149.25	3149.75	3150.25	3151.00	3151.50	3151.00	3150.25	3149.75	3149.50	3149.00	3148.75	3148.50	3148.25	3148.25	3147.75	3147.50	3147.50
40	14	1	5		3147.25	3147.75	3148.50	3149.00	3149.50	3150.00	3150.75	3151.25	3150.75	3150.00	3149.50	3149.25	3148.75	3148.50	3148.25	3148.00	3148.00	3147.50	3147.25	3147.25
41	14	1	5		3147.00	3147.50	3148.25	3148.75	3149.25	3149.75	3150.50	3151.00	3150.50	3149.75	3149.25	3149.00	3148.50	3148.25	3148.00	3147.75	3147.75	3147.25	3147.00	3147.00
42	14	1	5		3146.75	3147.25	3148.00	3148.50	3149.00	3149.50	3150.25	3150.75	3150.25	3149.50	3149.00	3148.75	3148.25	3148.00	3147.75	3147.50	3147.50	3147.00	3146.75	3146.75
42	13	1	5		3146.50	3147.00	3147.75	3148.25	3148.75	3149.25	3150.00	3150.50	3150.00	3149.25	3148.75	3148.50	3148.00	3147.75	3147.50	3147.25	3147.25	3146.75	3146.50	3146.50
43	13	1	5		3146.25	3146.75	3147.50	3148.00	3148.50	3149.00	3149.75	3150.25	3149.75	3149.00	3148.50	3148.25	3147.75	3147.50	3147.25	3147.00	3147.00	3146.50	3146.25	3146.25
43	12	1	5		3146.00	3146.50	3147.25	3147.75	3148.25	3148.75	3149.50	3150.00	3149.50	3148.75	3148.25	3148.00	3147.50	3147.25	3147.00	3146.75	3146.75	3146.25	3146.00	3146.00
44	11	1	5		3145.88	3146.38	3147.13	3147.63	3148.13	3148.63	3149.38	3149.88	3149.38	3148.63	3148.13	3147.88	3147.38	3147.13	3146.88	3146.63	3146.63	3146.13	3145.88	3145.88
45	11	1	5		3145.75	3146.25	3147.00	3147.50	3148.00	3148.50	3149.25	3149.75	3149.25	3148.50	3148.00	3147.75	3147.25	3147.00	3146.75	3146.50	3146.50	3146.00	3145.75	3145.75
46	10	1	5		3145.63	3146.13	3146.88	3147.38	3147.88	3148.38	3149.13	3149.63	3149.13	3148.38	3147.88	3147.63	3147.13	3146.88	3146.63	3146.38	3146.38	3145.88	3145.63	3145.63
47	10	1	5		3145.50	3146.00	3146.75	3147.25	3147.75	3148.25	3149.00	3149.50	3149.00	3148.25	3147.75	3147.50	3147.00	3146.75	3146.50	3146.25	3146.25	3145.75	3145.50	3145.50
48	9	1	5		3145.38	3145.88	3146.63	3147.13	3147.63	3148.13	3148.88	3149.38	3148.88	3148.13	3147.63	3147.38	3146.88	3146.63	3146.38	3146.13	3146.13	3145.63	3145.38	3145.38
49	9	1	5		3145.25	3145.75	3146.50	3147.00	3147.50	3148.00	3148.75	3149.25	3148.75	3148.00	3147.50	3147.25	3146.75	3146.50	3146.25	3146.00	3146.00	3145.50	3145.25	3145.25
49	8	1	5		3145.13	3145.63	3146.38	3146.88	3147.38	3147.88	3148.63	3149.13	3148.63	3147.88	3147.38	3147.13	3146.63	3146.38	3146.13	3145.88	3145.88	3145.38	3145.13	3145.13
50	8	1	5		3145.00	3145.50	3146.25	3146.75	3147.25	3147.75	3148.50	3149.00	3148.50	3147.75	3147.25	3147.00	3146.50	3146.25	3146.00	3145.75	3145.75	3145.25	3145.00	3145.00
51	7	1	5		3144.86	3145.36	3146.11	3146.61	3147.11	3147.61	3148.36	3148.86	3148.36	3147.61	3147.11	3146.86	3146.36	3146.11	3145.86	3145.61	3145.61	3145.11	3144.86	3144.86
52	7	1	5		3144.71	3145.21	3145.96	3146.46	3146.96	3147.46	3148.21	3148.71	3148.21	3147.46	3146.96	3146.71	3146.21	3145.96	3145.71	3145.46	3145.46	3144.96	3144.71	3144.71
53	6	1	5		3144.57	3145.07	3145.82	3146.32	3146.82	3147.32	3148.07	3148.57	3148.07	3147.32	3146.82	3146.57	3146.07	3145.82	3145.57	3145.32	3145.32	3144.82	3144.57	3144.57
54	6	1	5		3144.43	3144.93	3145.68	3146.18	3146.68	3147.18	3147.93	3148.43	3147.93	3147.18	3146.68	3146.43	3145.93	3145.68	3145.43	3145.18	3145.18	3144.68	3144.43	3144.43
55	6	1	5		3144.29	3144.79	3145.54	3146.04	3146.54	3147.04	3147.79	3148.29	3147.79	3147.04	3146.54	3146.29	3145.79	3145.54	3145.29	3145.04	3145.04	3144.54	3144.29	3144.29
56	6	1	5		3144.14	3144.64	3145.39	3145.89	3146.39	3146.89	3147.64	3148.14	3147.64	3146.89	3146.39	3146.14	3145.64	3145.39	3145.14	3144.89	3144.89	3144.39	3144.14	3144.14
57	6	1	6		3144.00	3144.50	3145.25	3145.75	3146.25	3146.75	3147.50	3148.00	3147.50	3146.75	3146.25	3146.00	3145.50	3145.25	3145.00	3144.75	3144.75	3144.25	3144.00	3144.00

Table E-7. Specified Creek Stage Values - 100-Year Hydrologic Event

				Change:	0	0.5	1.25	1.75	2.25	2.75	3.5	4	3.5	2.75	2.25	2	1.5	1.25	1	0.75	0.75	0.25	0	0
				SP:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Row	Col	Layer	Reach	Date:	22-Mar	5-Apr	19-Apr	26-Apr	3-May	10-May	17-May	24-May	31-May	7-Jun	13-Jun	14-Jun	21-Jun	28-Jun	5-Jul	19-Jul	2-Aug	16-Aug	6-Sep	27-Sep
58	6	1	6		3143.92	3144.42	3145.17	3145.67	3146.17	3146.67	3147.42	3147.92	3147.42	3146.67	3146.17	3145.92	3145.42	3145.17	3144.92	3144.67	3144.67	3144.17	3143.92	3143.92
59	6	1	6		3143.83	3144.33	3145.08	3145.58	3146.08	3146.58	3147.33	3147.83	3147.33	3146.58	3146.08	3145.83	3145.33	3145.08	3144.83	3144.58	3144.58	3144.08	3143.83	3143.83
60	6	1	6		3143.75	3144.25	3145.00	3145.50	3146.00	3146.50	3147.25	3147.75	3147.25	3146.50	3146.00	3145.75	3145.25	3145.00	3144.75	3144.50	3144.50	3144.00	3143.75	3143.75
61	6	1	6		3143.67	3144.17	3144.92	3145.42	3145.92	3146.42	3147.17	3147.67	3147.17	3146.42	3145.92	3145.67	3145.17	3144.92	3144.67	3144.42	3144.42	3143.92	3143.67	3143.67
62	6	1	6		3143.58	3144.08	3144.83	3145.33	3145.83	3146.33	3147.08	3147.58	3147.08	3146.33	3145.83	3145.58	3145.08	3144.83	3144.58	3144.33	3144.33	3143.83	3143.58	3143.58
63	6	1	6		3143.50	3144.00	3144.75	3145.25	3145.75	3146.25	3147.00	3147.50	3147.00	3146.25	3145.75	3145.50	3145.00	3144.75	3144.50	3144.25	3144.25	3143.75	3143.50	3143.50
64	6	1	6		3143.42	3143.92	3144.67	3145.17	3145.67	3146.17	3146.92	3147.42	3146.92	3146.17	3145.67	3145.42	3144.92	3144.67	3144.42	3144.17	3144.17	3143.67	3143.42	3143.42
65	6	1	6		3143.33	3143.83	3144.58	3145.08	3145.58	3146.08	3146.83	3147.33	3146.83	3146.08	3145.58	3145.33	3144.83	3144.58	3144.33	3144.08	3144.08	3143.58	3143.33	3143.33
66	6	1	6		3143.25	3143.75	3144.50	3145.00	3145.50	3146.00	3146.75	3147.25	3146.75	3146.00	3145.50	3145.25	3144.75	3144.50	3144.25	3144.00	3144.00	3143.50	3143.25	3143.25
67	6	1	6		3143.17	3143.67	3144.42	3144.92	3145.42	3145.92	3146.67	3147.17	3146.67	3145.92	3145.42	3145.17	3144.67	3144.42	3144.17	3143.92	3143.92	3143.42	3143.17	3143.17
68	6	1	6		3143.08	3143.58	3144.33	3144.83	3145.33	3145.83	3146.58	3147.08	3146.58	3145.83	3145.33	3145.08	3144.58	3144.33	3144.08	3143.83	3143.83	3143.33	3143.08	3143.08
69	6	1	6		3143.00	3143.50	3144.25	3144.75	3145.25	3145.75	3146.50	3147.00	3146.50	3145.75	3145.25	3145.00	3144.50	3144.25	3144.00	3143.75	3143.75	3143.25	3143.00	3143.00
70	6	1	7		3142.70	3143.20	3143.95	3144.45	3144.95	3145.45	3146.20	3146.70	3146.20	3145.45	3144.95	3144.70	3144.20	3143.95	3143.70	3143.45	3143.45	3142.95	3142.50	3142.50
71	6	1	7		3142.20	3142.70	3143.45	3143.95	3144.45	3144.95	3145.70	3146.20	3145.70	3144.95	3144.45	3144.20	3143.70	3143.45	3143.20	3142.95	3142.95	3142.45	3142.00	3142.00
72	6	1	7		3141.80	3142.30	3143.05	3143.55	3144.05	3144.55	3145.30	3145.80	3145.30	3144.55	3144.05	3143.80	3143.30	3143.05	3142.80	3142.55	3142.55	3142.05	3141.50	3141.50
73	6	1	7		3141.30	3141.80	3142.55	3143.05	3143.55	3144.05	3144.80	3145.30	3144.80	3144.05	3143.55	3143.30	3142.80	3142.55	3142.30	3142.05	3142.05	3141.55	3141.00	3141.00
74	6	1	7		3141.28	3141.78	3142.53	3143.03	3143.53	3144.03	3144.78	3145.28	3144.78	3144.03	3143.53	3143.28	3142.78	3142.53	3142.28	3142.03	3142.03	3141.53	3140.88	3140.88
74	5	1	7		3141.15	3141.65	3142.40	3142.90	3143.40	3143.90	3144.65	3145.15	3144.65	3143.90	3143.40	3143.15	3142.65	3142.40	3142.15	3141.90	3141.90	3141.40	3140.75	3140.75
75	5	1	7		3141.13	3141.63	3142.38	3142.88	3143.38	3143.88	3144.63	3145.13	3144.63	3143.88	3143.38	3143.13	3142.63	3142.38	3142.13	3141.88	3141.88	3141.38	3140.63	3140.63
76	5	1	7		3141.00	3141.50	3142.25	3142.75	3143.25	3143.75	3144.50	3145.00	3144.50	3143.75	3143.25	3143.00	3142.50	3142.25	3142.00	3141.75	3141.75	3141.25	3140.50	3140.50
77	5	1	7		3140.88	3141.38	3142.13	3142.63	3143.13	3143.63	3144.38	3144.88	3144.38	3143.63	3143.13	3142.88	3142.38	3142.13	3141.88	3141.63	3141.63	3141.13	3140.38	3140.38
78	5	1	7		3140.85	3141.35	3142.10	3142.60	3143.10	3143.60	3144.35	3144.85	3144.35	3143.60	3143.10	3142.85	3142.35	3142.10	3141.85	3141.60	3141.60	3141.10	3140.25	3140.25
78	6	1	7		3140.73	3141.23	3141.98	3142.48	3142.98	3143.48	3144.23	3144.73	3144.23	3143.48	3142.98	3142.73	3142.23	3141.98	3141.73	3141.48	3141.48	3140.98	3140.13	3140.13
78	7	1	7		3140.60	3141.10	3141.85	3142.35	3142.85	3143.35	3144.10	3144.60	3144.10	3143.35	3142.85	3142.60	3142.10	3141.85	3141.60	3141.35	3141.35	3140.85	3140.00	3140.00
78	8	1	8		3140.59	3141.09	3141.84	3142.34	3142.84	3143.34	3144.09	3144.59	3144.09	3143.34	3142.84	3142.59	3142.09	3141.84	3141.59	3141.34	3141.34	3140.84	3139.89	3139.89
78	9	1	8		3140.48	3140.98	3141.73	3142.23	3142.73	3143.23	3143.98	3144.48	3143.98	3143.23	3142.73	3142.48	3141.98	3141.73	3141.48	3141.23	3141.23	3140.73	3139.78	3139.78
77	9	1	8		3140.37	3140.87	3141.62	3142.12	3142.62	3143.12	3143.87	3144.37	3143.87	3143.12	3142.62	3142.37	3141.87	3141.62	3141.37	3141.12	3141.12	3140.62	3139.67	3139.67
77	10	1	8		3140.36	3140.86	3141.61	3142.11	3142.61	3143.11	3143.86	3144.36	3143.86	3143.11	3142.61	3142.36	3141.86	3141.61	3141.36	3141.11	3141.11	3140.61	3139.56	3139.56
77	11	1	8		3140.24	3140.74	3141.49	3141.99	3142.49	3142.99	3143.74	3144.24	3143.74	3142.99	3142.49	3142.24	3141.74	3141.49	3141.24	3140.99	3140.99	3140.49	3139.44	3139.44
76	11	1	8		3140.13	3140.63	3141.38	3141.88	3142.38	3142.88	3143.63	3144.13	3143.63	3142.88	3142.38	3142.13	3141.63	3141.38	3141.13	3140.88	3140.88	3140.38	3139.33	3139.33
76	12	1	8		3140.02	3140.52	3141.27	3141.77	3142.27	3142.77	3143.52	3144.02	3143.52	3142.77	3142.27	3142.02	3141.52	3141.27	3141.02	3140.77	3140.77	3140.27	3139.22	3139.22
76	13	1	8		3140.01	3140.51	3141.26	3141.76	3142.26	3142.76	3143.51	3144.01	3143.51	3142.76	3142.26	3142.01	3141.51	3141.26	3141.01	3140.76	3140.76	3140.26	3139.11	3139.11
76	14	1	8		3139.90	3140.40	3141.15	3141.65	3142.15	3142.65	3143.40	3143.90	3143.40	3142.65	3142.15	3141.90	3141.40	3141.15	3140.90	3140.65	3140.65	3140.15	3139.00	3139.00
77	14	1	8		3139.54	3140.04	3140.79	3141.29	3141.79	3142.29	3143.04	3143.54	3143.04	3142.29	3141.79	3141.54	3141.04	3140.79	3140.54	3140.29	3140.29	3139.79	3138.64	3138.64
77	15	1	8		3139.17	3139.67	3140.42	3140.92	3141.42	3141.92	3142.67	3143.17	3142.67	3141.92	3141.42	3141.17	3140.67	3140.42	3140.17	3139.92	3139.92	3139.42	3138.27	3138.27
78	15	1	8		3138.81	3139.31	3140.06	3140.56	3141.06	3141.56	3142.31	3142.81	3142.31	3141.56	3141.06	3140.81	3140.31	3140.06	3139.81	3139.56	3139.56	3139.06	3137.91	3137.91
78	16	1	8		3138.45	3138.95	3139.70	3140.20	3140.70	3141.20	3141.95	3142.45	3141.95	3141.20	3140.70	3140.45	3139.95	3139.70	3139.45	3139.20	3139.20	3138.70	3137.55	3137.55
78	17	1	8		3138.08	3138.58	3139.33	3139.83	3140.33	3140.83	3141.58	3142.08	3141.58	3140.83	3140.33	3140.08	3139.58	3139.33	3139.08	3138.83	3138.83	3138.33	3137.18	3137.18
78	18	1	8		3137.82	3138.32	3139.07	3139.57	3140.07	3140.57	3141.32	3141.82	3141.32	3140.57	3140.07	3139.82	3139.32	3139.07	3138.82	3138.57	3138.57	3138.07	3136.82	3136.82
78	19	1	8		3137.45	3137.95	3138.70	3139.20	3139.70	3140.20	3140.95	3141.45	3140.95	3140.20	3139.70	3139.45	3138.95	3138.70	3138.45	3138.20	3138.20	3137.70	3136.45	3136.45
79	19	1	8		3137.09	3137.59	3138.34	3138.84	3139.34	3139.84	3140.59	3141.09	3140.59	3139.84	3139.34	3139.09	3138.59	3138.34	3138.09	3137.84	3137.84	3137.34	3136.09	3136.09
80	19	1	8		3136.73	3137.23	3137.98	3138.48	3138.98	3139.48	3140.23	3140.73	3140.23	3139.48	3138.98	3138.73	3138.23	3137.98	3137.73	3137.48	3137.48	3136.98	3135.73	3135.73
81	19	1	8		3136.36	3136.86	3137.61	3138.11	3138.61	3139.11	3139.86	3140.36	3139.86	3139.11	3138.61	3138.36	3137.86	3137.61	3137.36	3137.11	3137.11	3136.61	3135.36	3135.36
81	18	1	8		3136.00	3136.50	3137.25	3137.75	3138.25	3138.75	3139.50	3140.00	3139.50	3138.75	3138.25	3138.00	3137.50	3137.25	3137.00	3136.75	3136.75	3136.25	3135.00	3135.00
82	18	1	8		3135.00	3135.50	3136.25	3136.75	3137.25	3137.75	3138.50	3139.00	3138.50	3137.75	3137.25	3137.00	3136.50	3136.25	3136.00	3135.75	3135.75	3135.25	3134.00	3134.00

Appendix F
Groundwater Flow Model Calibration

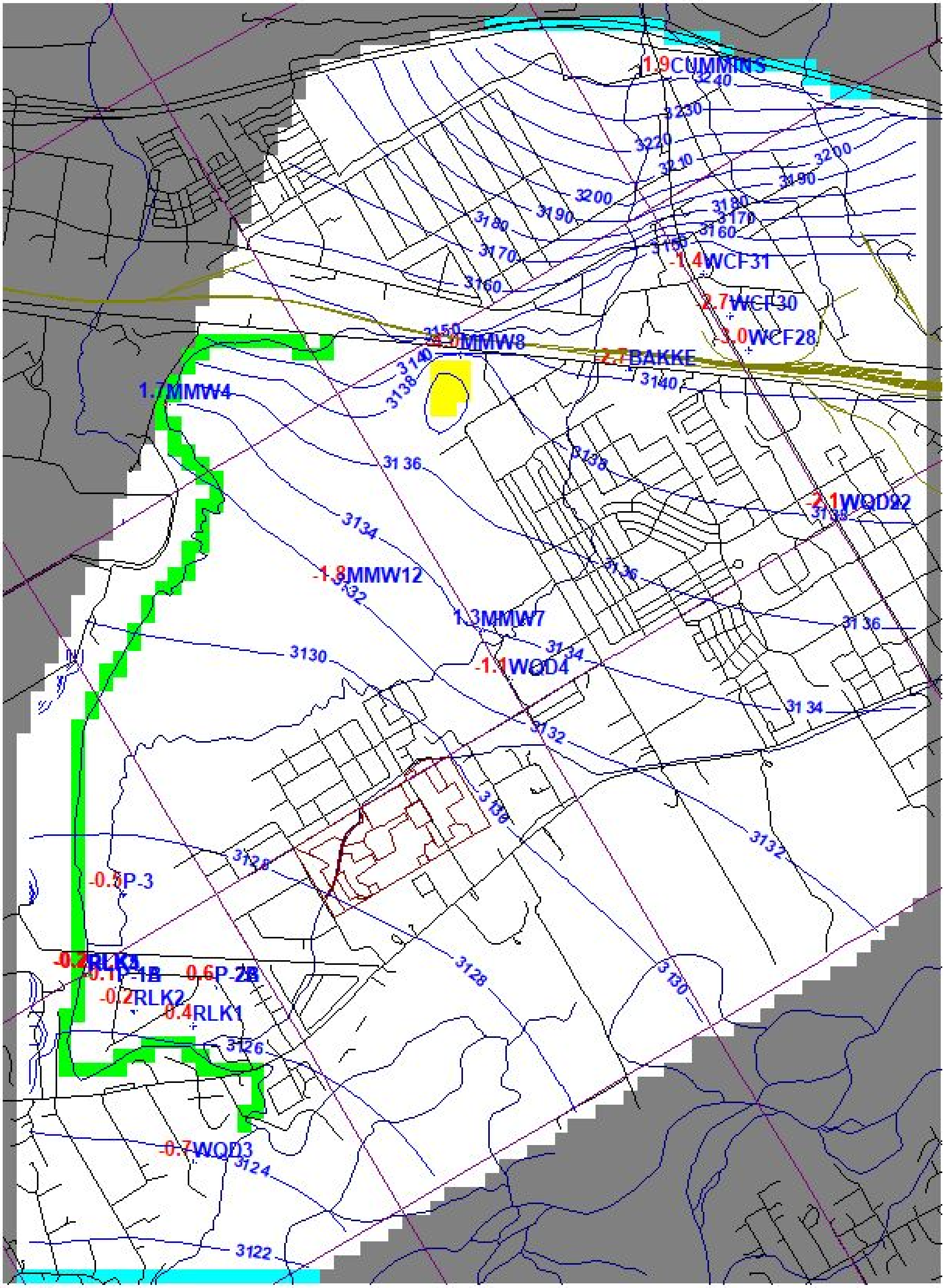


Figure F-1. Steady-State Groundwater Elevation Contours and Residuals

Table F-1. Steady State Head Match Statistics

Name	Time (days)	Coord MT State-Plane ft X	Coord MT State-Plane ft Y	Layer	Observed	Weight	Group	Comp	Residual
MMW4	14	827739.70	1003058.20	3	3135.68	1	1	3134.0	1.7
MMW7	14	829674.40	997779.70	3	3135.26	1	1	3134.0	1.3
MMW8	14	831680.60	1001265.70	3	3133.41	1	1	3137.4	-4.0
MMW12	14	828419.70	999381.40	3	3130.28	1	1	3132.0	-1.8
RLK1	14	823009.30	995347.50	3	3125.8	1	1	3126.2	-0.4
RLK2	14	822414.60	996019.10	3	3126.08	1	1	3126.3	-0.2
RLK3	14	822160.60	996836.71	3	3126.52	1	1	3126.7	-0.2
RLK4	14	822170.70	996802.40	3	3126.5	1	1	3126.7	-0.2
RLK5	14	822165.70	996820.00	3	3126.51	1	1	3126.7	-0.2
P-1A	14	822403.60	996438.11	3	3126.36	1	1	3126.5	-0.1
P-1B	14	822399.20	996440.80	3	3126.36	1	1	3126.5	-0.1
P-2A	14	823584.30	995638.20	3	3126.08	1	1	3126.6	-0.6
P-2B	14	823580.40	995639.50	3	3126.08	1	1	3126.6	-0.6
P-3	14	823245.50	997504.10	3	3126.98	1	1	3127.5	-0.5
WQD3	14	821901.50	993715.60	3	3123.06	1	1	3123.8	-0.7
WQD4	14	829620.40	996963.10	3	3131.96	1	1	3133.1	-1.1
WQD9	14	834951.90	996258.00	3	3135.94	1	1	3138.1	-2.1
WQD22	14	834953.30	996252.90	3	3135.92	1	1	3138.1	-2.1
BAKKE	14	833584.80	999721.60	3	3137.53	1	1	3140.2	-2.7
CUMMINS	14	836442.00	1002892.50	3	3238.32	1	1	3240.3	-1.9
WCF28	14	835186.60	998987.80	3	3137.83	1	1	3140.8	-3.0
WCF30	14	835234.41	999547.50	3	3138.98	1	1	3141.6	-2.7
WCF31	14	835250.00	1000272.50	3	3141.78	1	1	3143.2	-1.4

Residual Mean	-1.02
Absolute Residual Mean	1.28
Residual Std. Deviation	1.33
Sum of Squares	64.58
RMS Error	1.68
Min. Residual	-4.00
Max. Residual	1.68
Number of Observations	23
Range in Observations	115.26
Scaled Residual Std. Deviation	0.01
Scaled Absolute Residual Mean	0.01
Scaled RMS Error	0.01
Scaled Residual Mean	-0.01
Res Std Dev/Head Range (<10%):	1.2%
Res Mean/Head Range (<5%):	-0.9%
ARM/Head Range (<10%):	1.1%

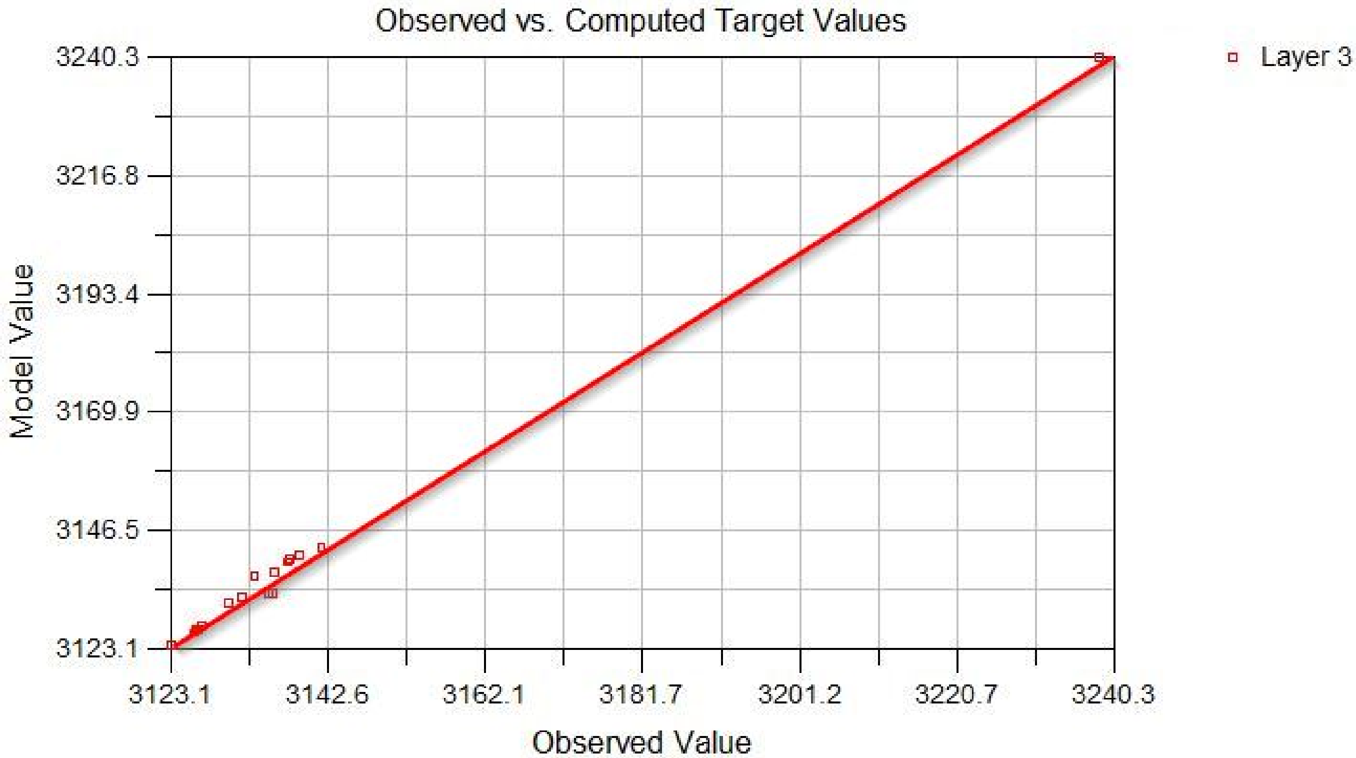


Figure F-2. Steady-State Observed vs Model Heads

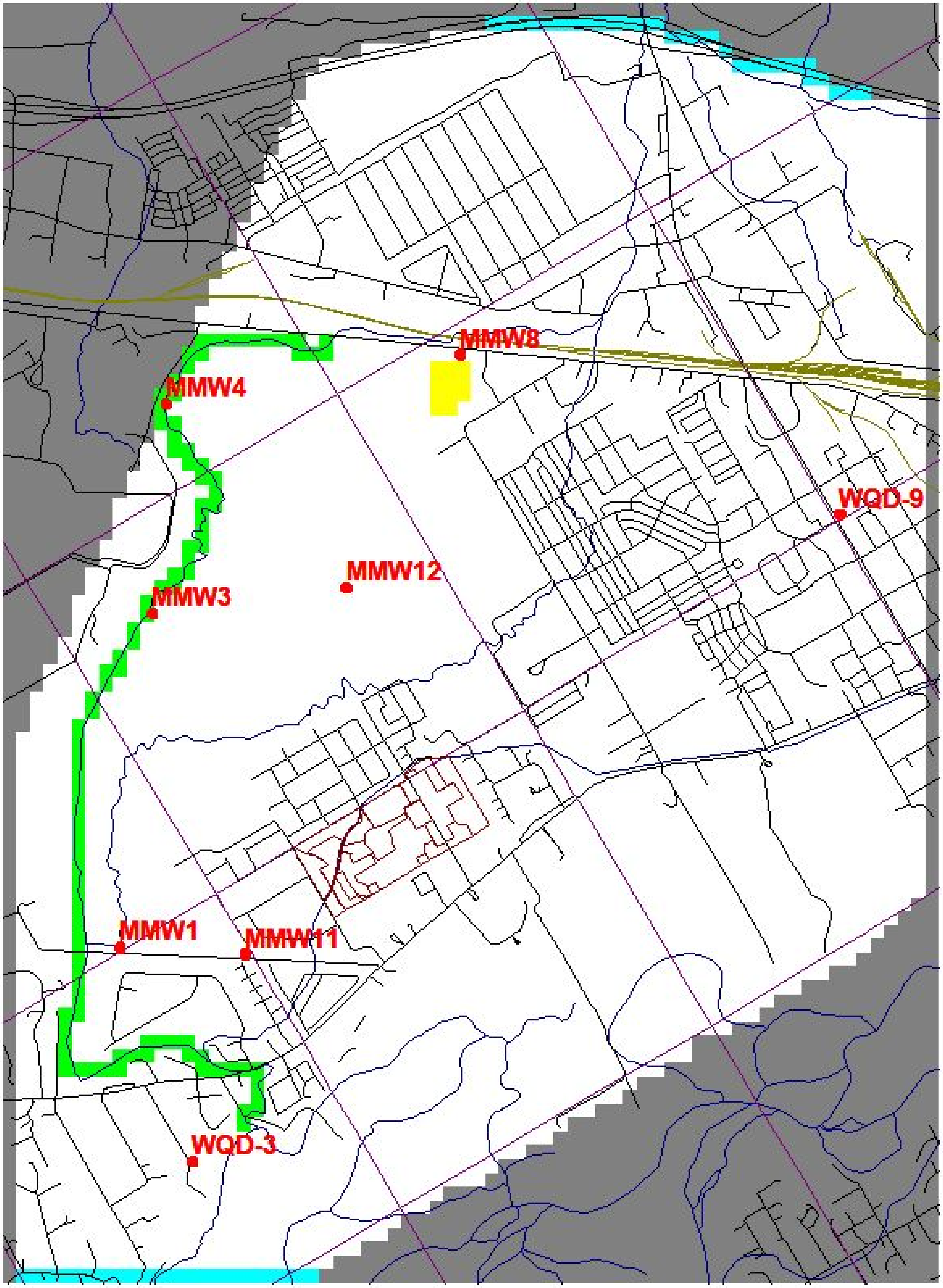


Figure F-3. Transient Calibration Monitoring Wells

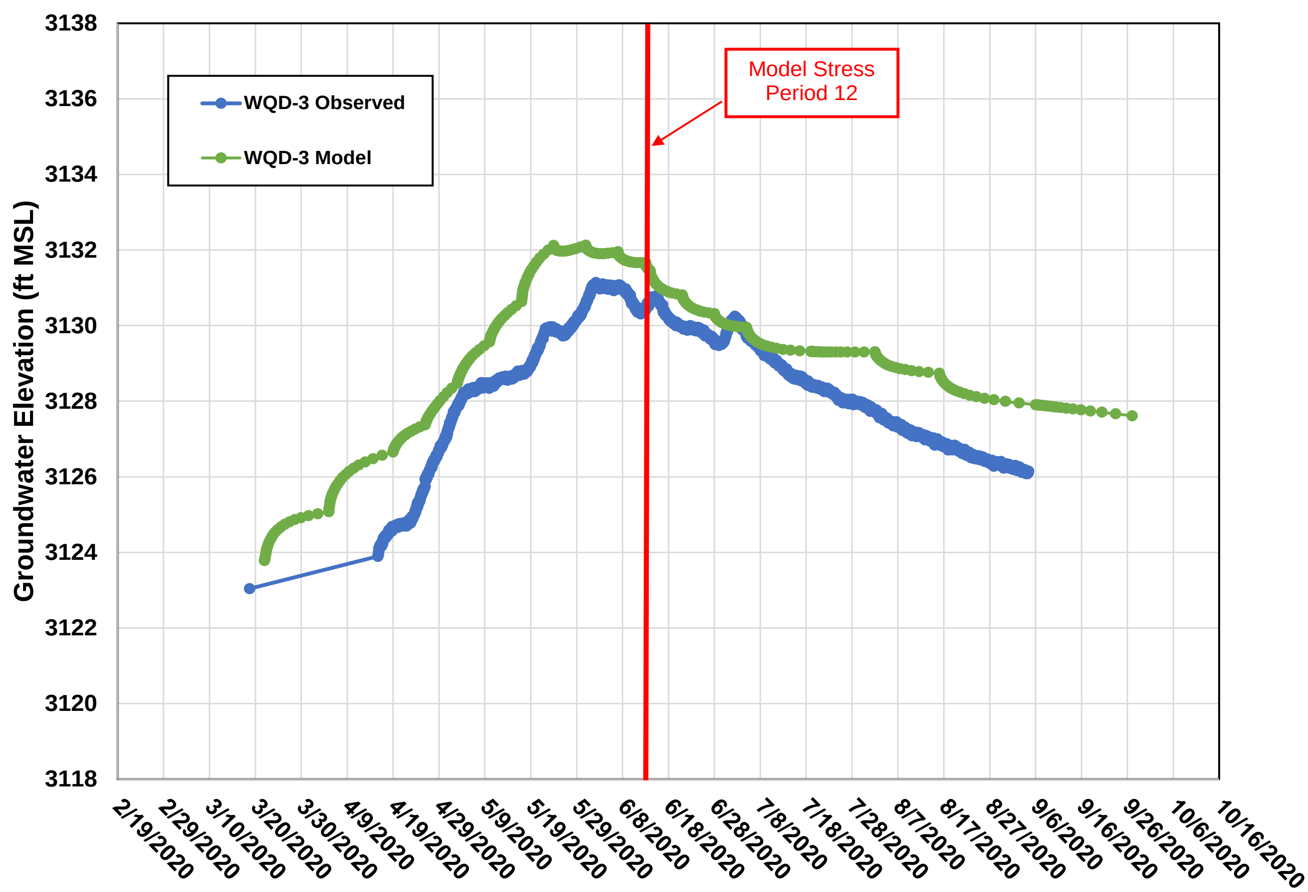


Figure F-4. Observed and Simulated Hydrographs: WQD-3

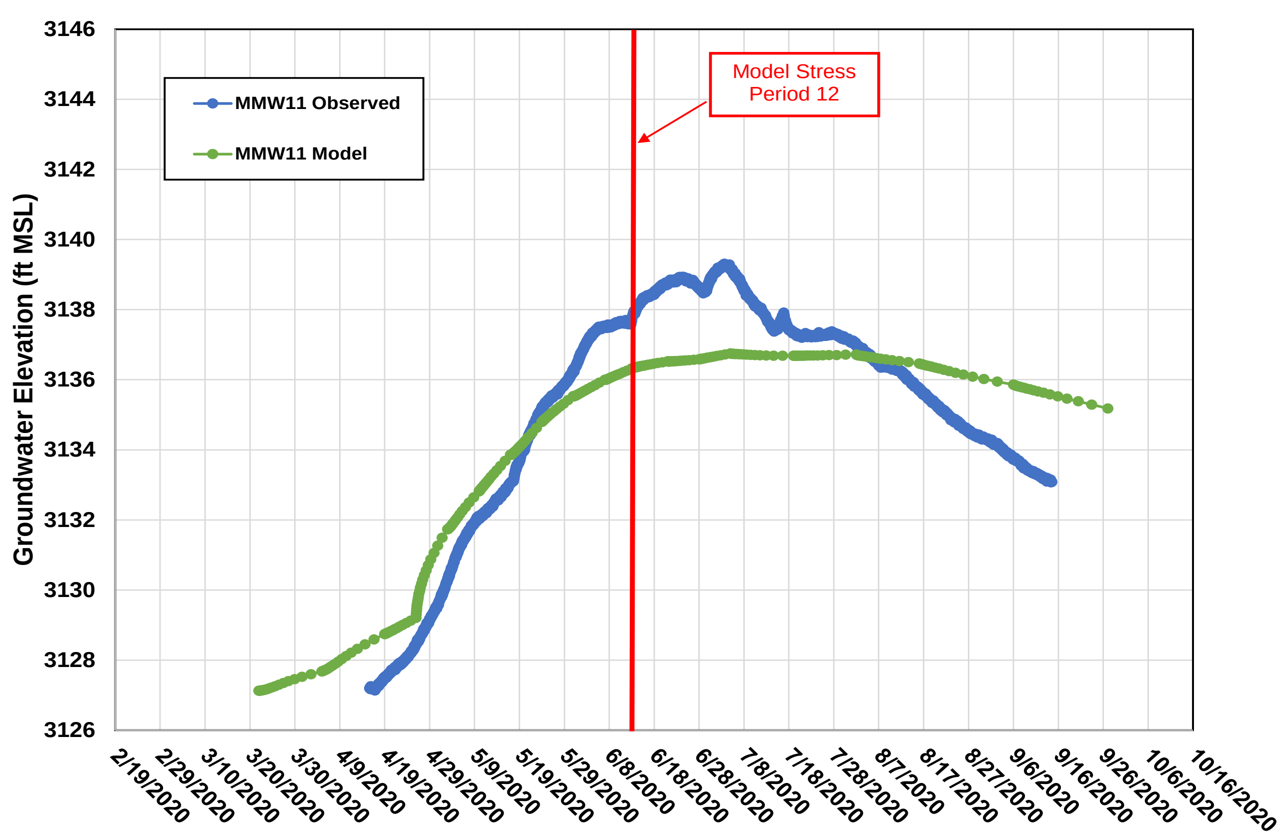


Figure F-5. Observed and Simulated Hydrographs: MMW11

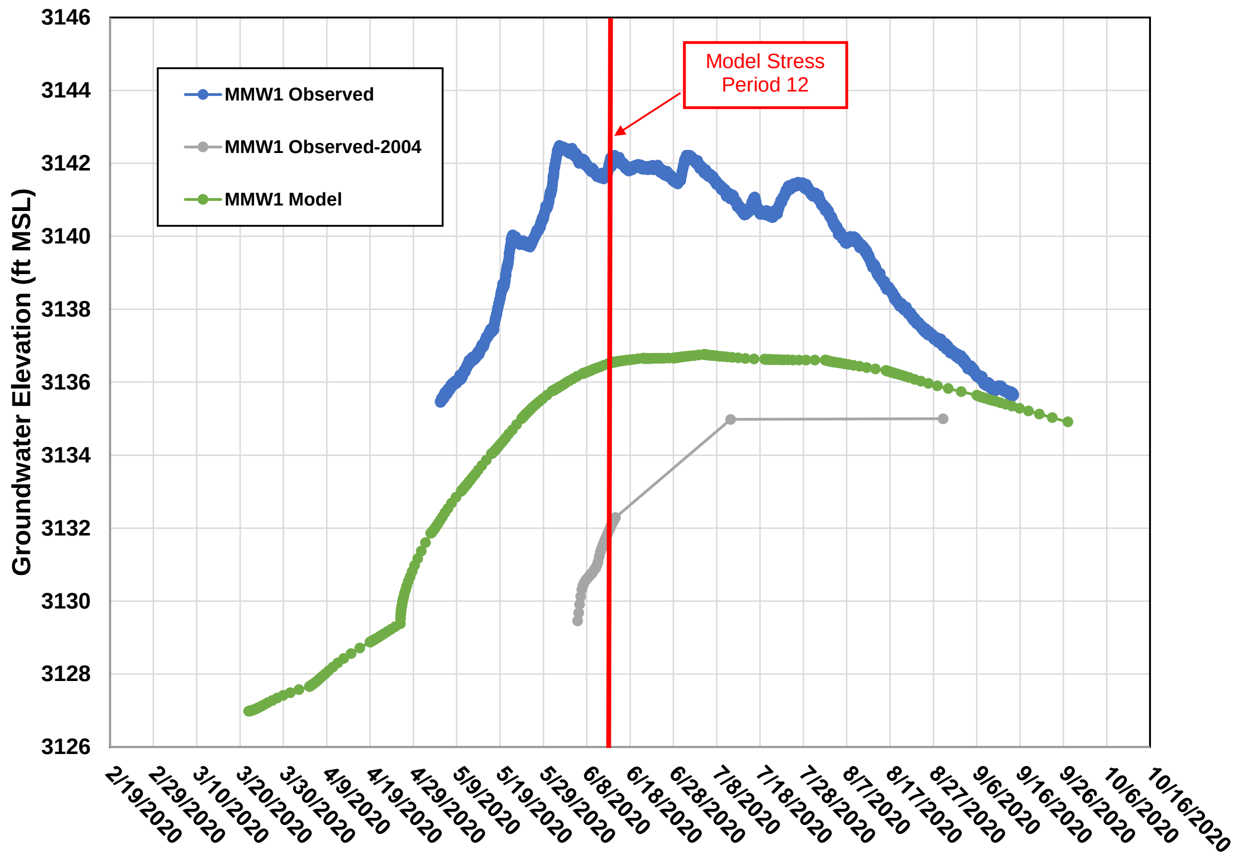


Figure F-6. Observed and Simulated Hydrographs: MMW1

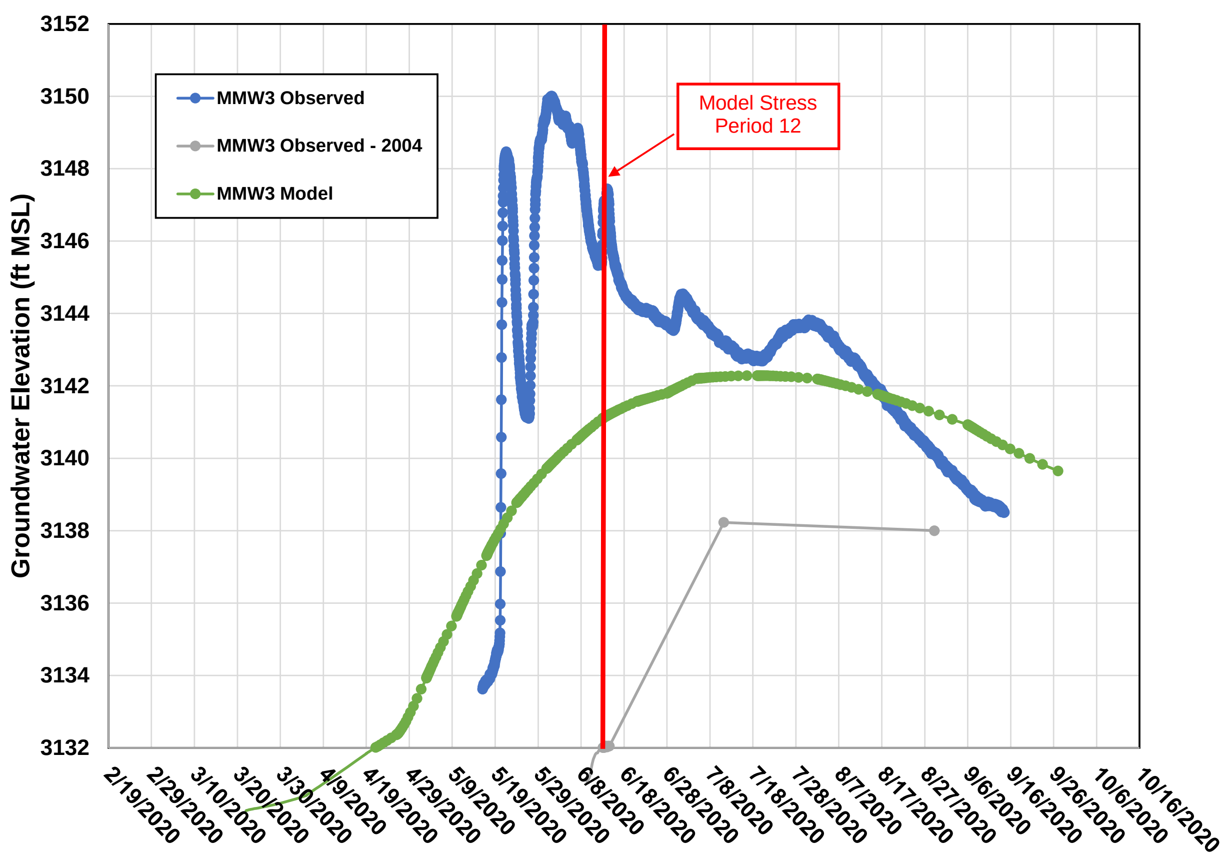


Figure F-7. Observed and Simulated Hydrographs: MMW3

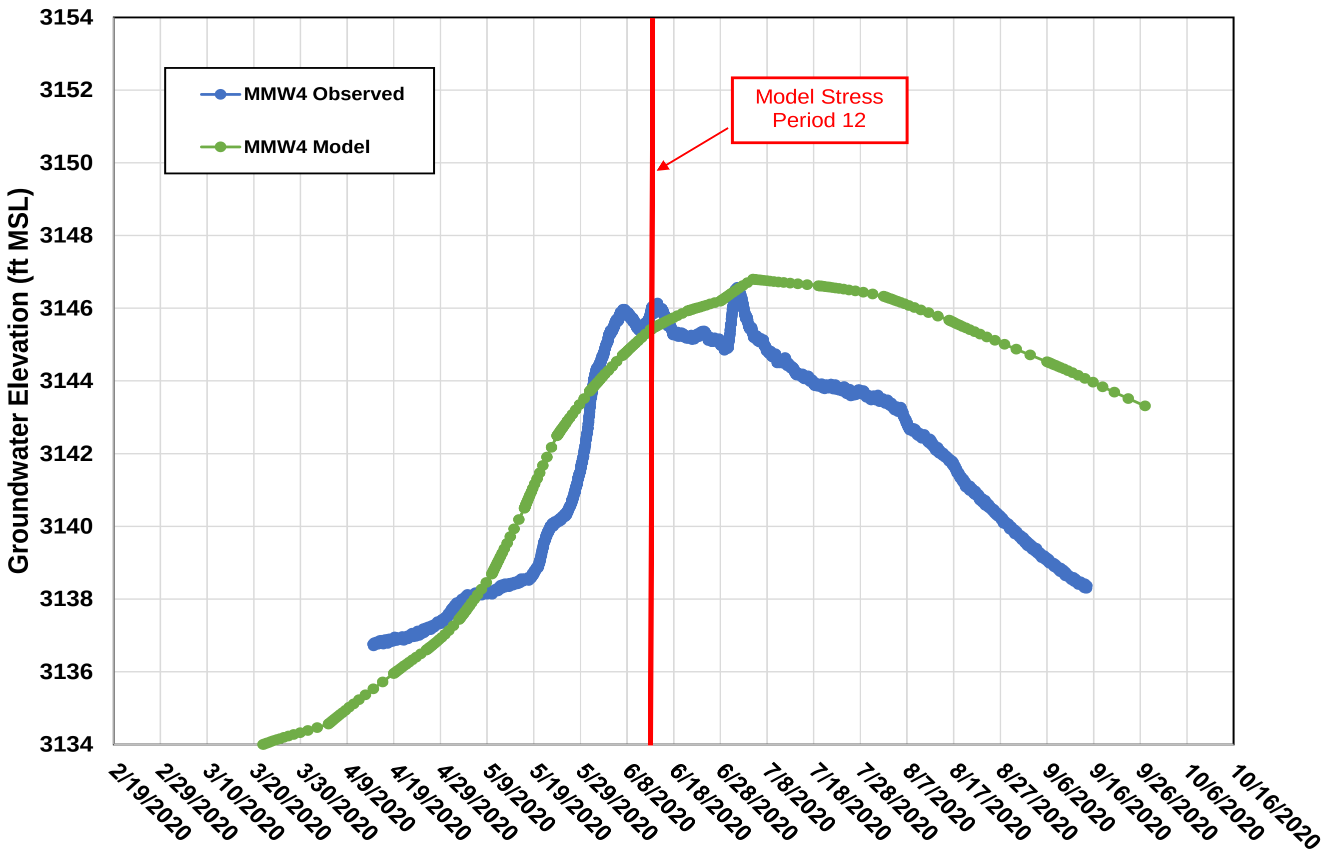


Figure F-8. Observed and Simulated Hydrographs: MMW4

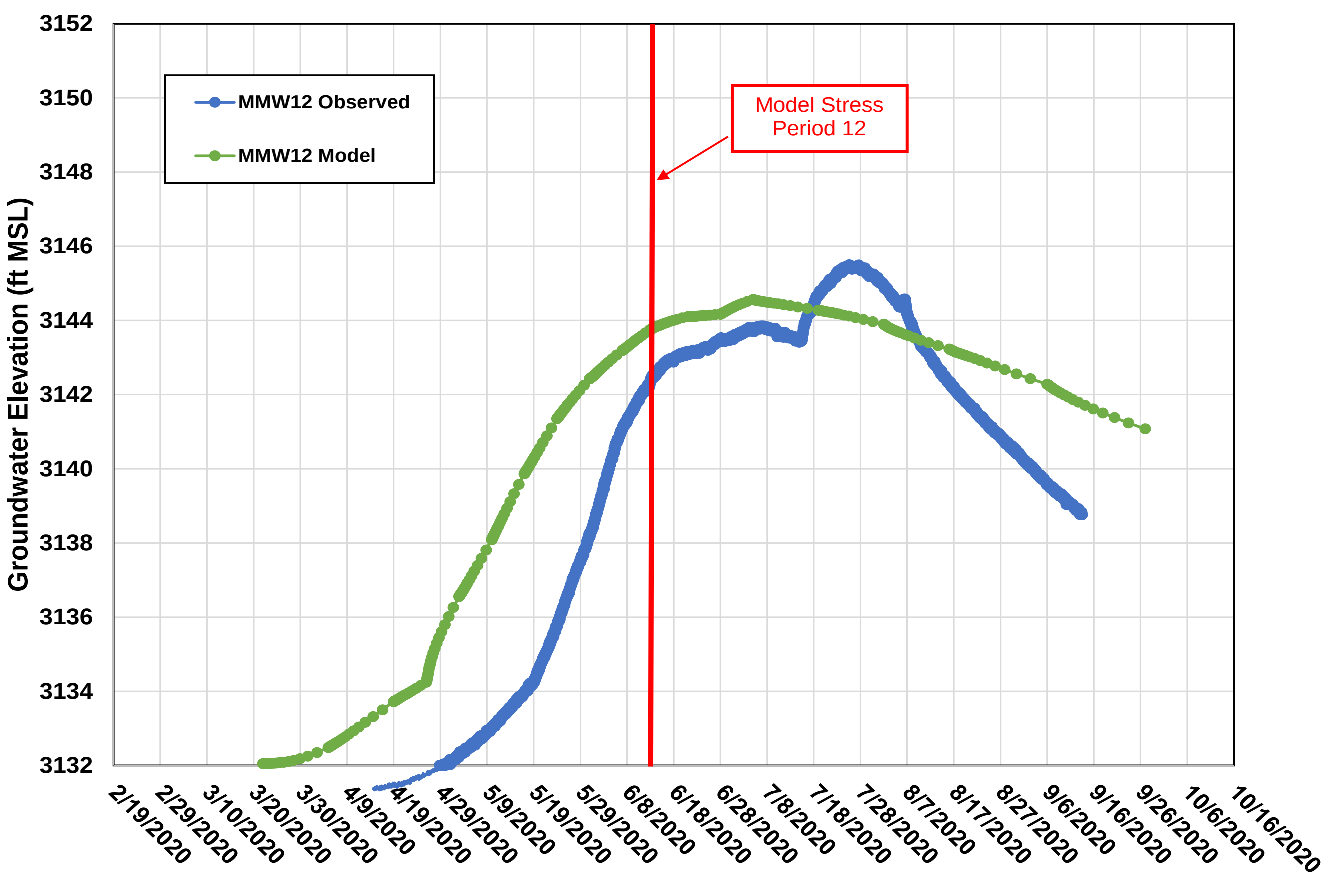


Figure F-9. Observed and Simulated Hydrographs: MMW12

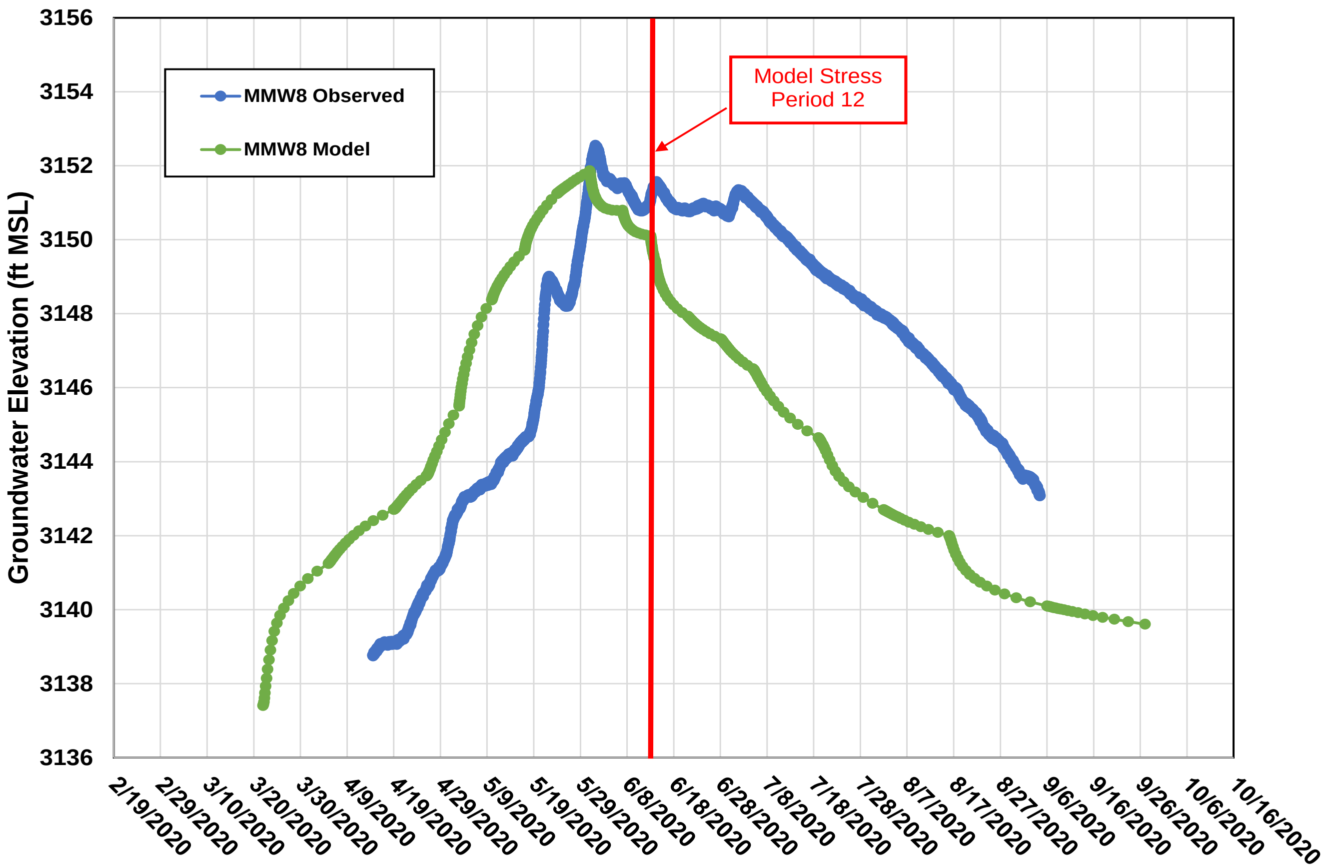


Figure F-10. Observed and Simulated Hydrographs: MMW8

Figure F-11. Observed and Simulated Hydrographs: WQD-9

Table F-2. Calculated and Simulated Fluxes: Model Stress Period 10

Component	Two-Year Seasonal High Water Level (2020) Flow (ft3/d)			Model Flow (ft3/d)
	Min	Max	Estimate	
Inflow				
Underflow In	50,686	102,369	76,796	55,799
Upper Grant Creek	649,440	1,692,480	979,364	679,720
Lower Grant Creek	105,600	212,800	160,000	106,721
Flynn-Lowney Ditch	208,538	752,858	473,629	310,820
Recharge from Precipitation	5,354	10,790	8,113	9,310
Recharge from Irrigation	15,282	30,796	23,155	22,620
Srorage				3,954
Total In	1,034,900	2,802,094	1,721,057	1,188,943
Outflow				
Underflow Out	173,835	386,204	289,725	185,317
Leakage to Regional Aquifer	246,840	498,542	374,000	343,970
Mullan Trails Drains	0	656,640	43,200	2,482
Storage				657,174
Total Out	420,675	1,541,386	706,925	1,188,943

Appendix G
Groundwater Flow Model Sensitivity

Table G-1. Summary of Sensitivity Analysis Simulations

Sensitivity Runs			
Parameter	Area	Zone/Reach	Multipliers*
K	South	10	0.1,1,10
	Central	9	0.1,1,10
	Northeast	8	0.1,1,10
Recharge	Ditch	5,6,7,8	0.5, 1, 1.5
	Creek	2,3,4	0.5, 1, 1.5
Stage	Creek	5,6,7,8	-2 ft, Base, +2 ft
	GHB (South)	2	-2 ft, Base, +2 ft

Table G-2. Sensitivity Analysis Results

Parameter	Zone/Area	Multiplier	Value	Residual Mean	Absolute Residual Mean
K	L3 Zone 10	0.1	90	-4.09	4.09
	L3 Zone 10	1	900	1.56	2.01
	L3 Zone 10	10	9000	5.34	5.34
	L3 Zone 9	0.1	50	-4.15	7.09
	L3 Zone 9	1	500	1.56	2.01
	L3 Zone 9	10	5000	3.79	4.20
	L3 Zone 8	0.1	70	1.51	2.02
	L3 Zone 8	1	700	1.56	2.01
	L3 Zone 8	10	7000	1.42	2.56
Recharge	Ditch (5,6,7,8)	0.5	Variable	2.66	2.75
	Ditch (5,6,7,8)	1	Variable	1.56	2.01
	Ditch (5,6,7,8)	1.5	Variable	0.63	1.85
	Creek (2,3,4)	0.5	Variable	3.59	3.72
	Creek (2,3,4)	1	Variable	1.56	2.01
	Creek (2,3,4)	1.5	Variable	-1.43	3.50
Stage	Creek (5,6,7,8)	-2 ft	Variable	2.30	2.40
	Creek (5,6,7,8)	Base	Variable	1.56	2.01
	Creek (5,6,7,8)	+2 ft	Variable	1.88	2.10
	GHB (2)	-2 ft	Variable	1.90	2.07
	GHB (2)	Base	Variable	1.56	2.01
	GHB (2)	+2 ft	Variable	1.24	2.02

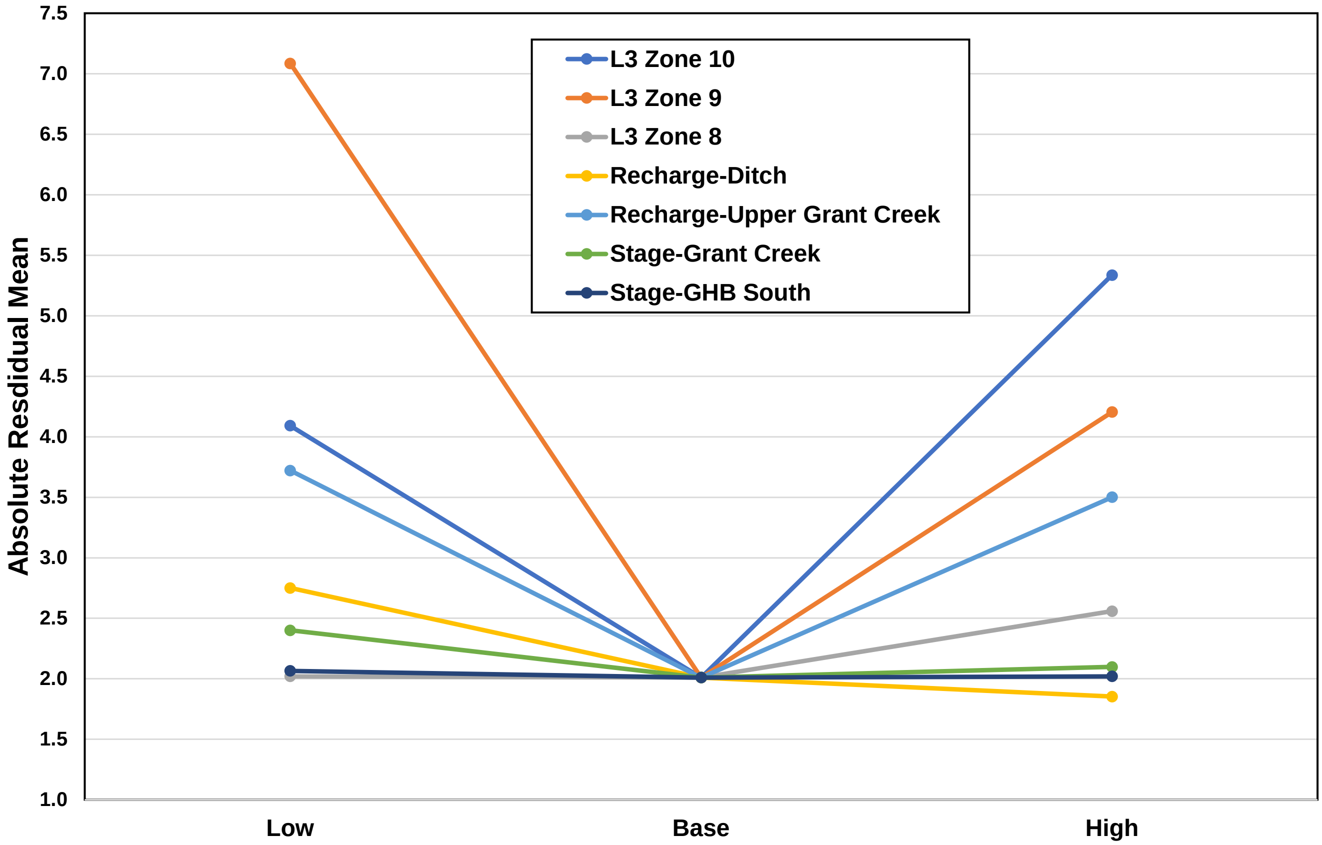


Figure G-1. Sensitivity Analysis Results

Appendix H
Sump Basin Distribution and Calculations

Table H-1. Sump Basins, 2-Year and 100-Year Discharge, and Model Representation

Basin ID	Model Reach	Volume (ft3/d)		Model Cells	Rate per Cell (cfd)	
		2-YR	100-YR		2-YR	100-YR
Existing Basins						
EX 1	1	12,378	63,962	12	1,031.5	5,330.2
EX 2	2	5,809	32,428	5	1,161.8	6,485.6
EX 3	3	13,712	60,091	8	1,714.0	7,511.4
EX 4	4	91,442	378,987	53	1,725.3	7,150.7
EX 5[1]	5	229	3,394	NA	----	----
EX 6	6	31,975	113,818	16	1,998.4	7,113.6
EX 7	7	16,431	58,609	7	2,347.3	8,372.7
EX 8	8	66,886	237,778	31	2,157.6	7,670.3
EX 9	9	183,938	653,890	80	2,299.2	8,173.6
EX 10	10	202,271	719,064	98	2,064.0	7,337.4
EX 11	11	53,563	602,944	203	263.9	2,970.2
EX 12	12	45,128	160,347	19	2,375.2	8,439.3
EX 13	13	296	25,622	10	29.6	2,562.2
Future Basins						
Basin A	21	202,645	1,047,858	213	951.4	4,919.5
Basin B	22	111,804	578,128	119	939.5	4,858.2
Basin C	23	59,806	276,271	53	1,128.4	5,212.7
Basin D	24	58,318	301,556	63	925.7	4,786.6
Basin E	25	150,685	781,472	159	947.7	4,914.9
Basin F[2]	26	93,336	482,634	99	942.8	4,875.1
Basin G	27	97,940	385,132	35	2,798.3	11,003.8
RMB Subd.	28	17,018	108,260	23	739.9	4,707.0

1: Basin outside of model domain

2: Basin in area where sumps will not be allowed

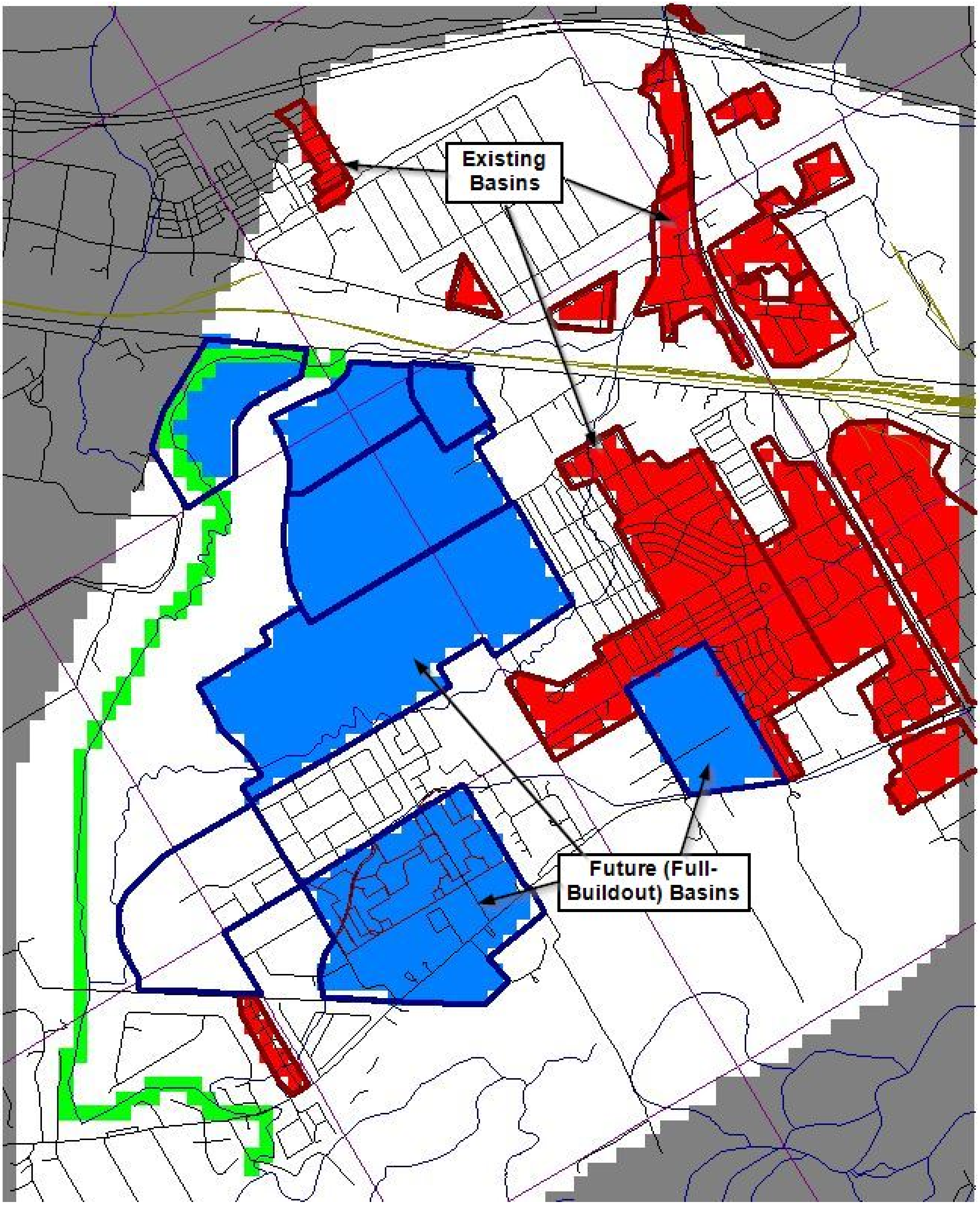


Figure H-1. Model Well Package Cell Locations Representing Sumps

Appendix I
Predictive Simulations and Sensitivity Hydrographs

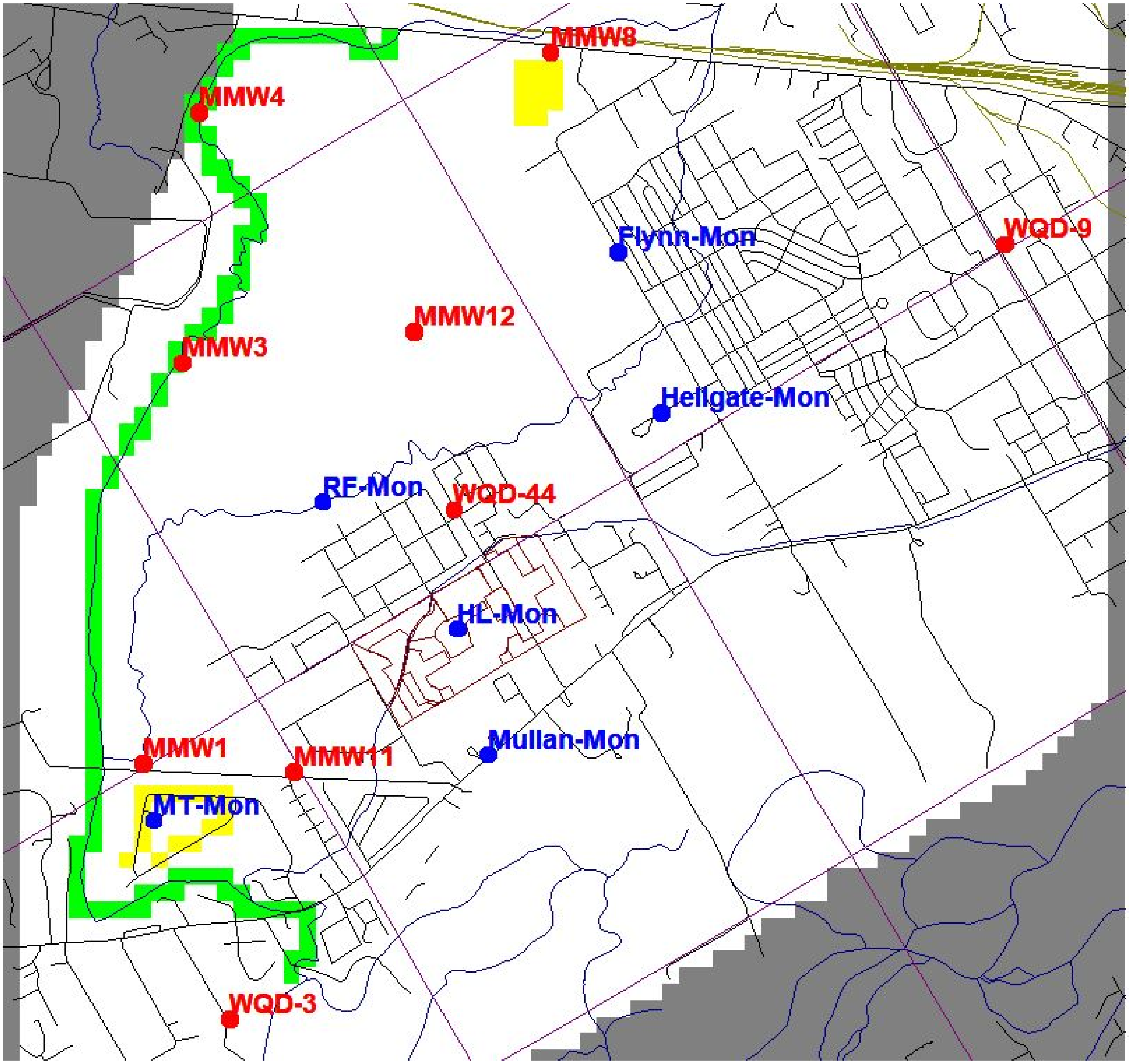


Figure I-1. Map of Monitoring Points for Depth to Water Hydrographs

Predictive Simulations Hydrographs

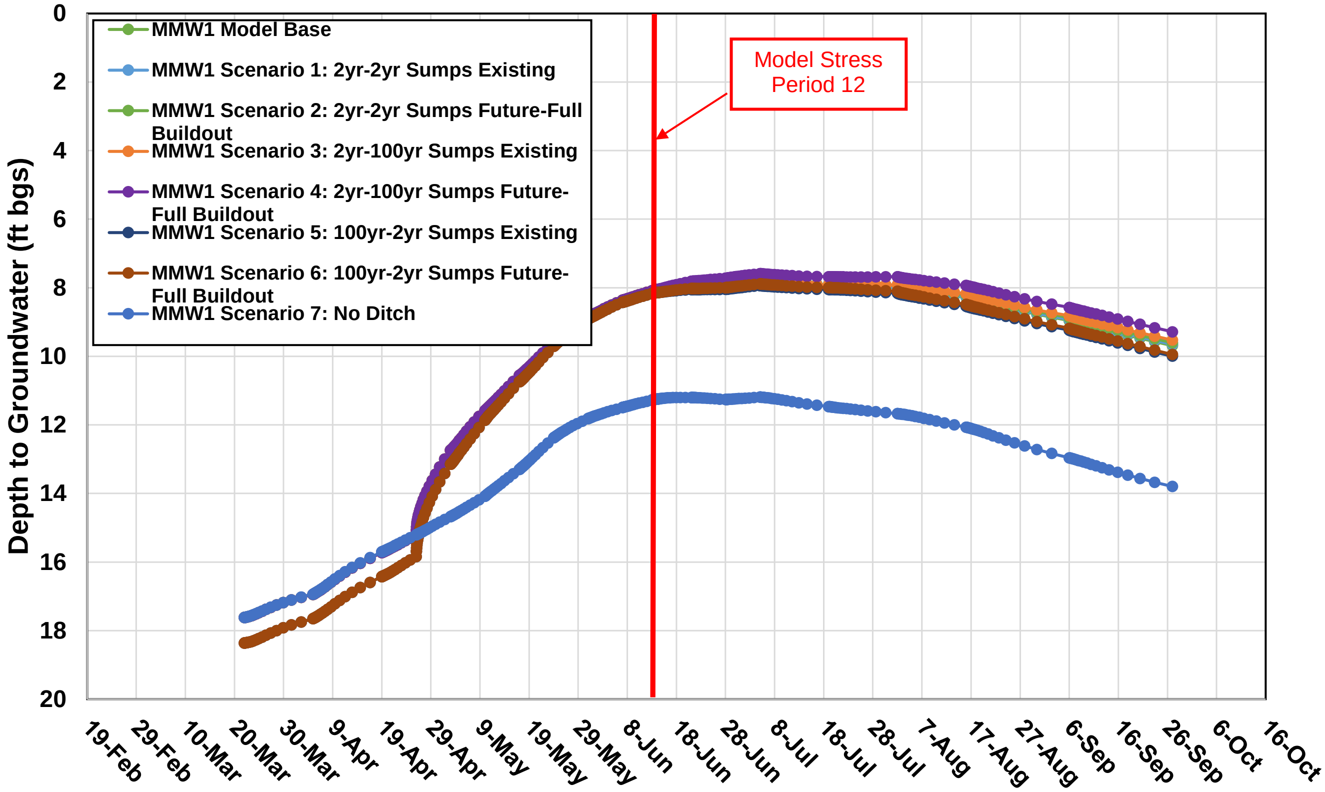


Figure I-1. Depth to Water Hydrographs: MMW1

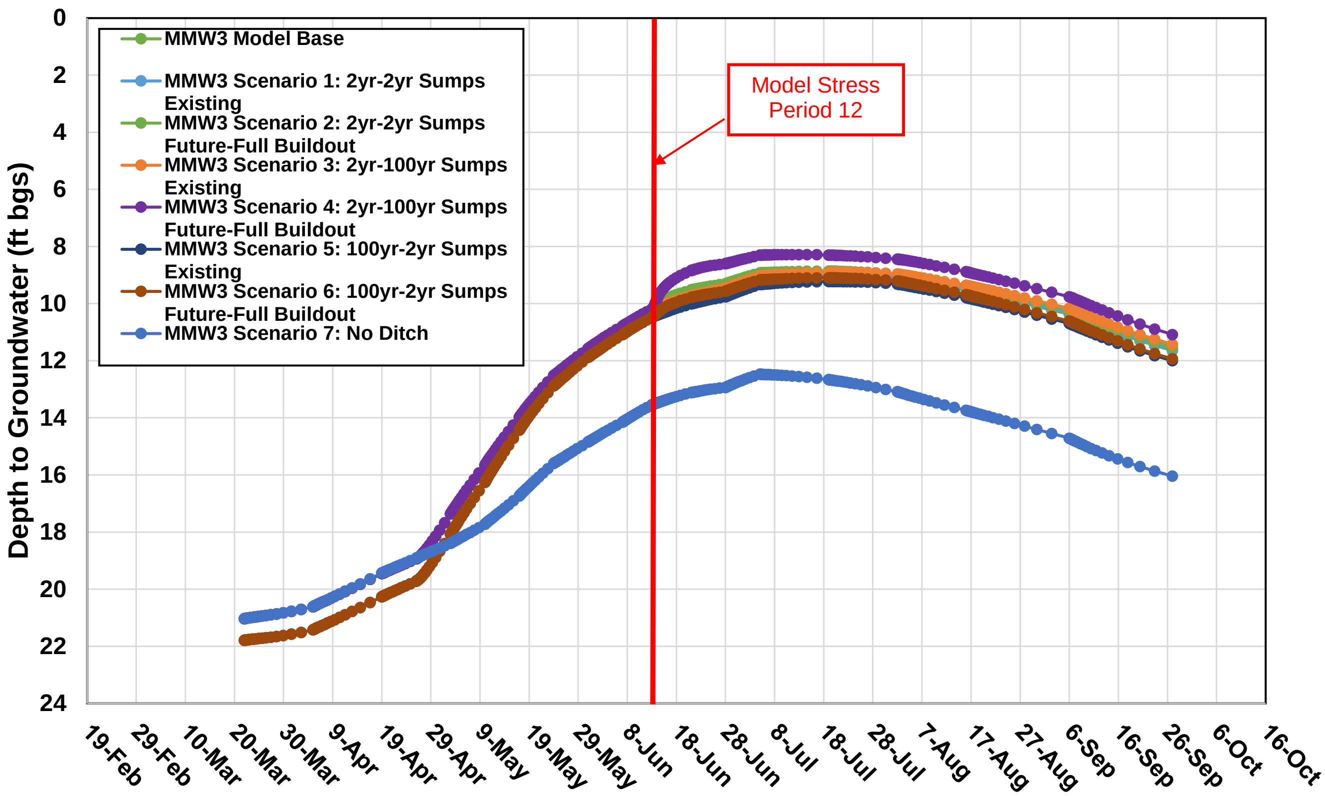


Figure I-2. Depth to Water Hydrographs: MMW3

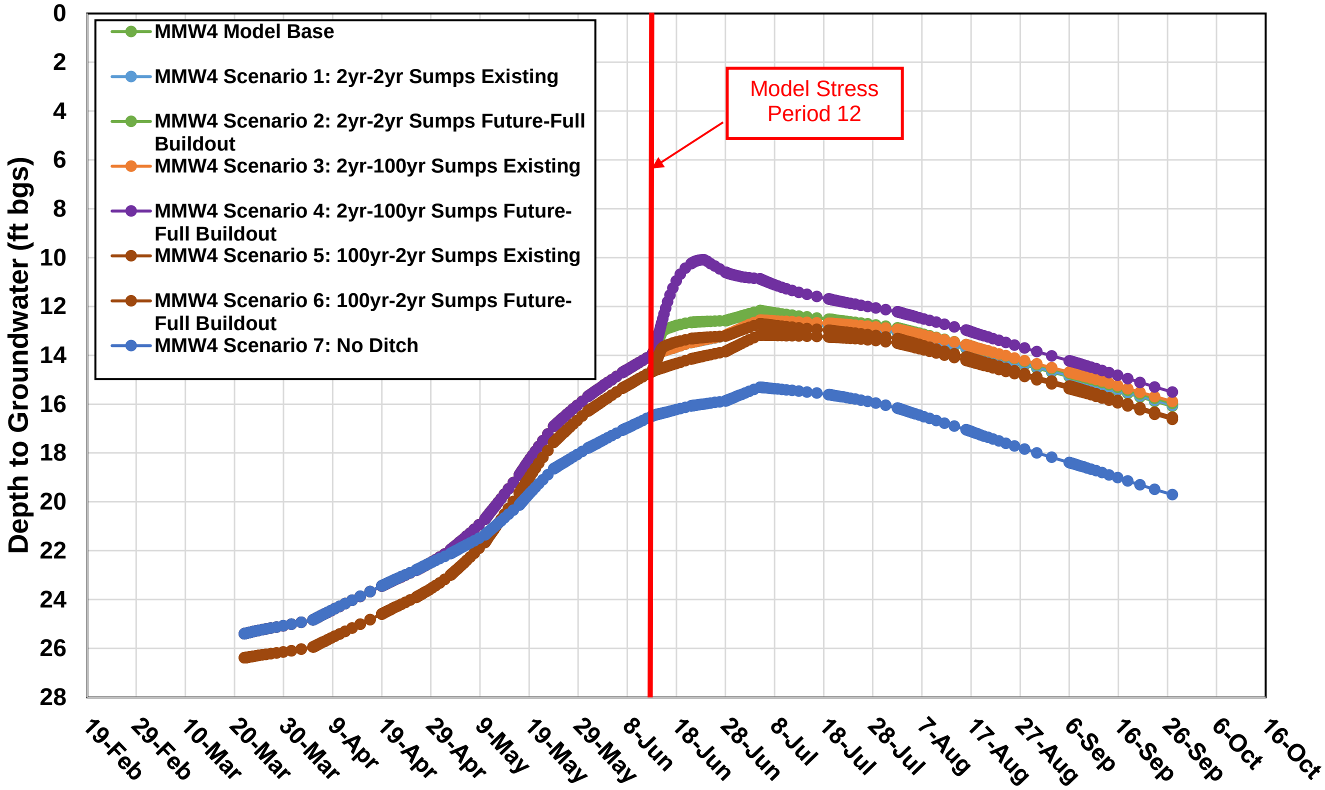


Figure I-3. Depth to Water Hydrographs: MMW4

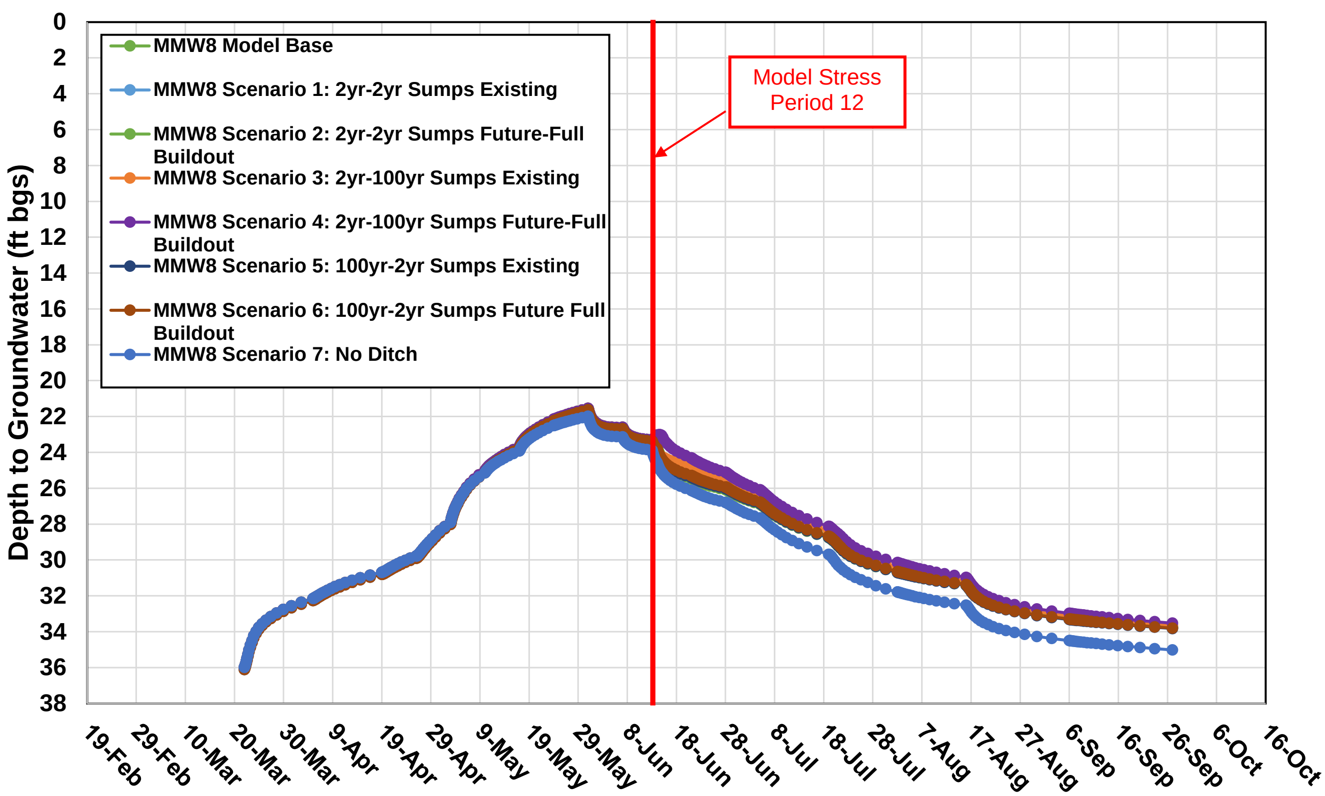


Figure I-4. Depth to Water Hydrographs: MMW8

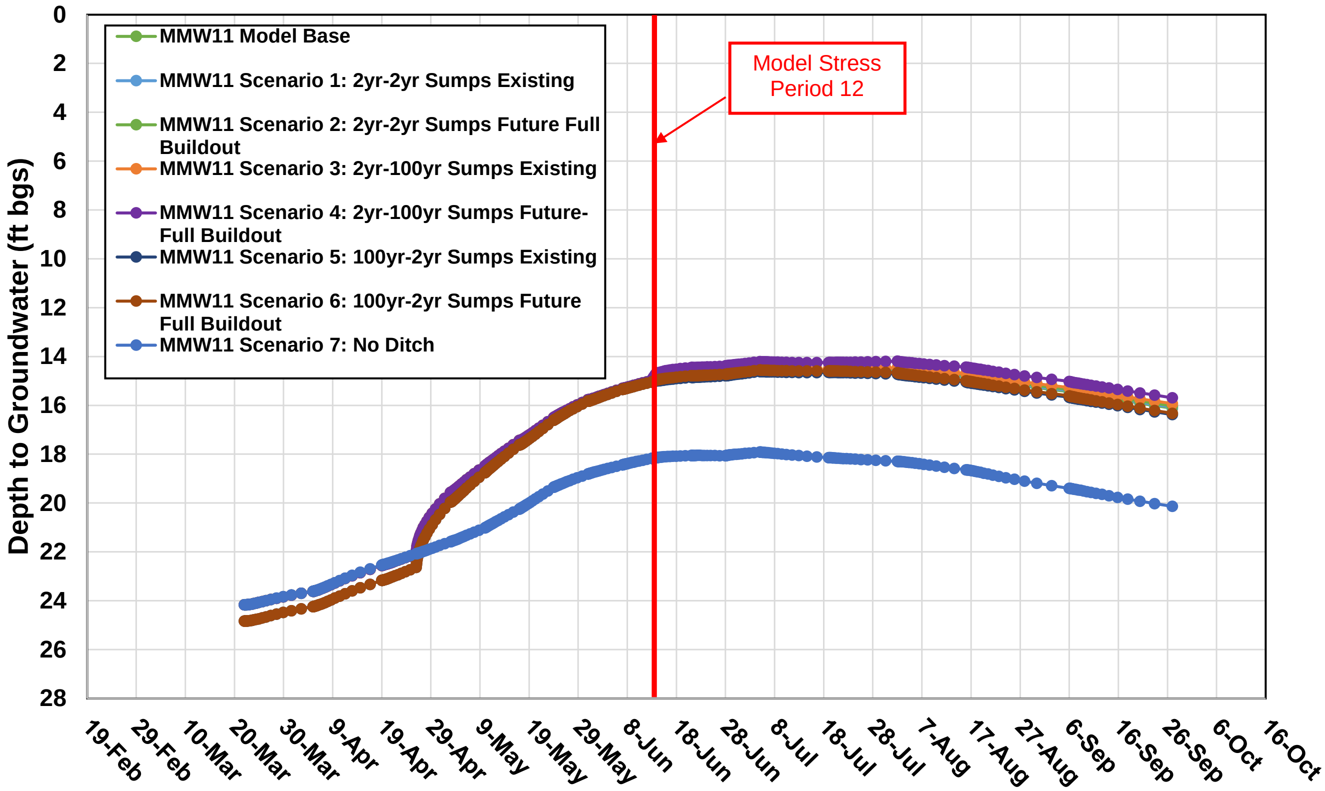


Figure I-5. Depth to Water Hydrographs: MMW11

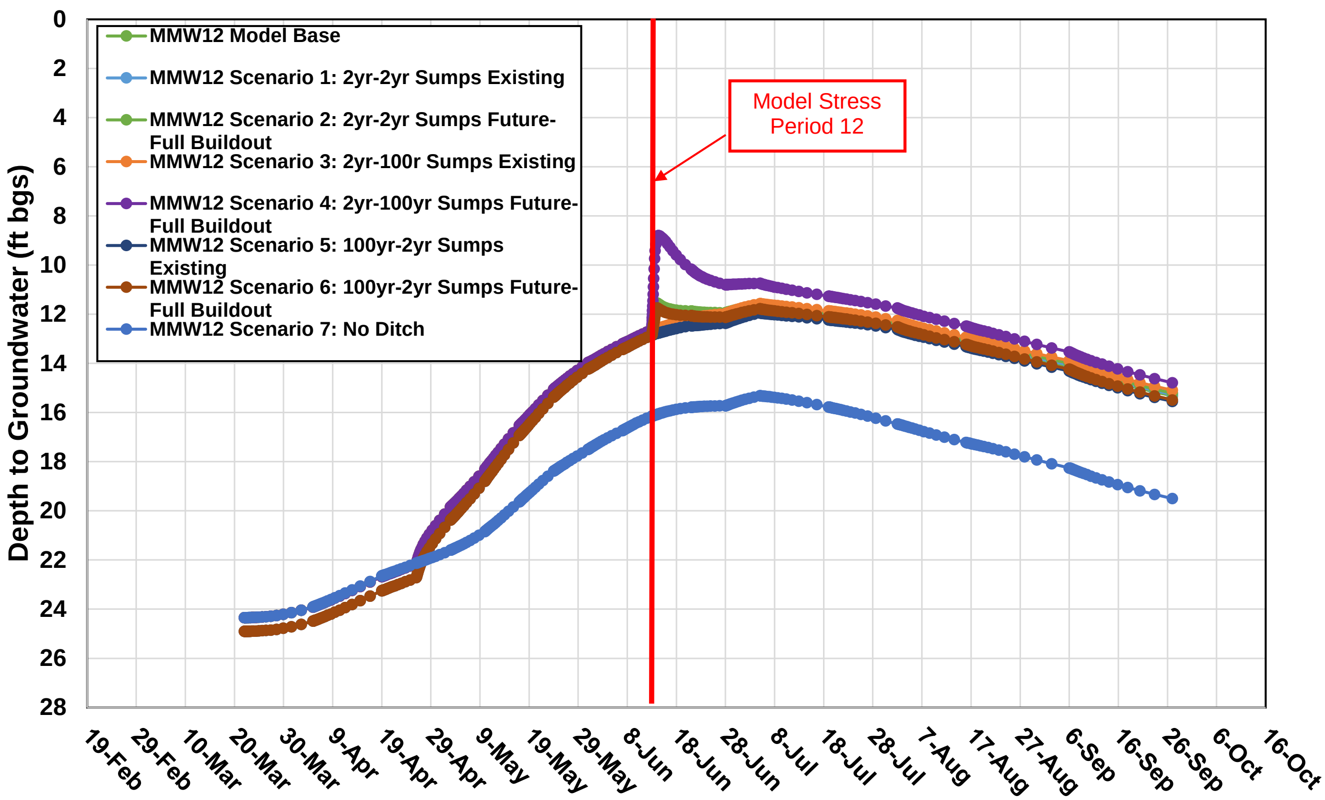


Figure I-6. Depth to Water Hydrographs: MMW12

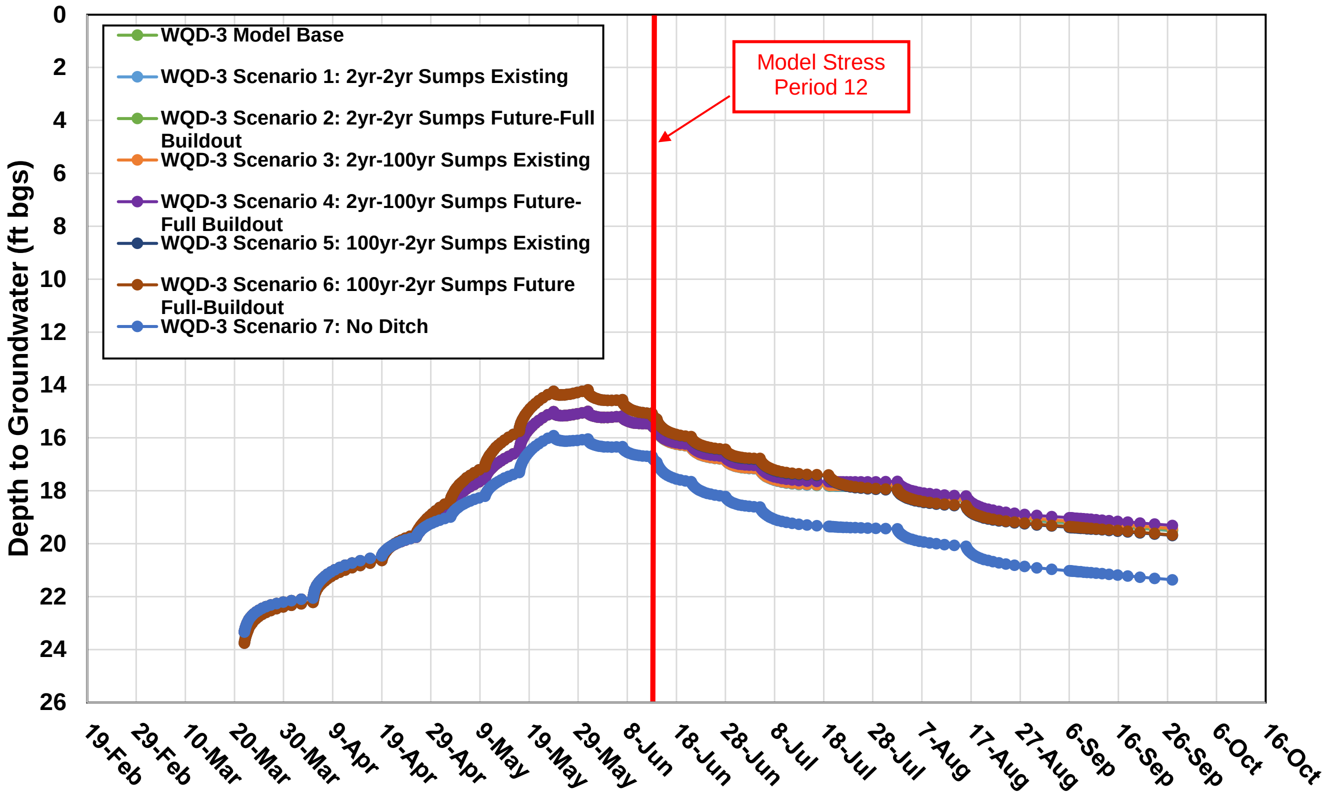


Figure I-7. Depth to Water Hydrographs: WQD-3

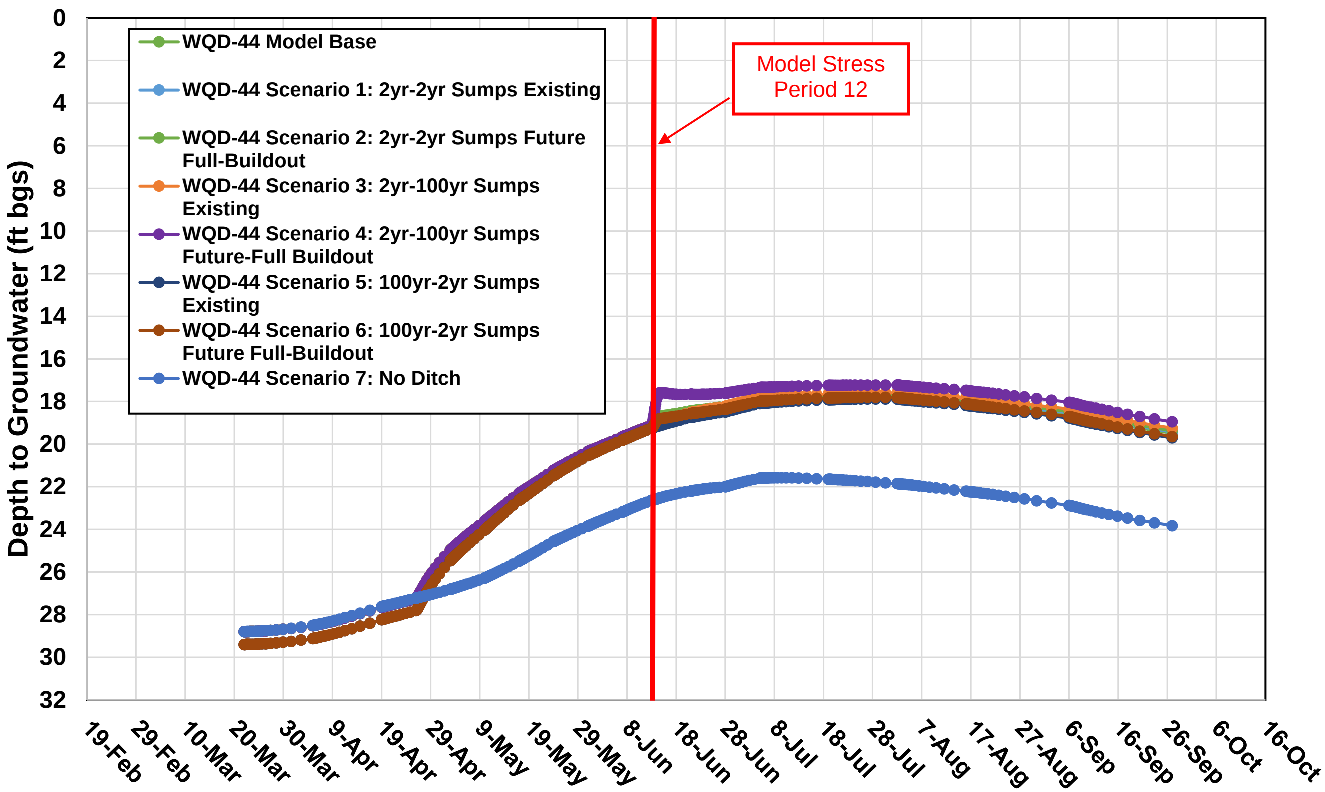


Figure I-8. Depth to Water Hydrographs: WQD-44

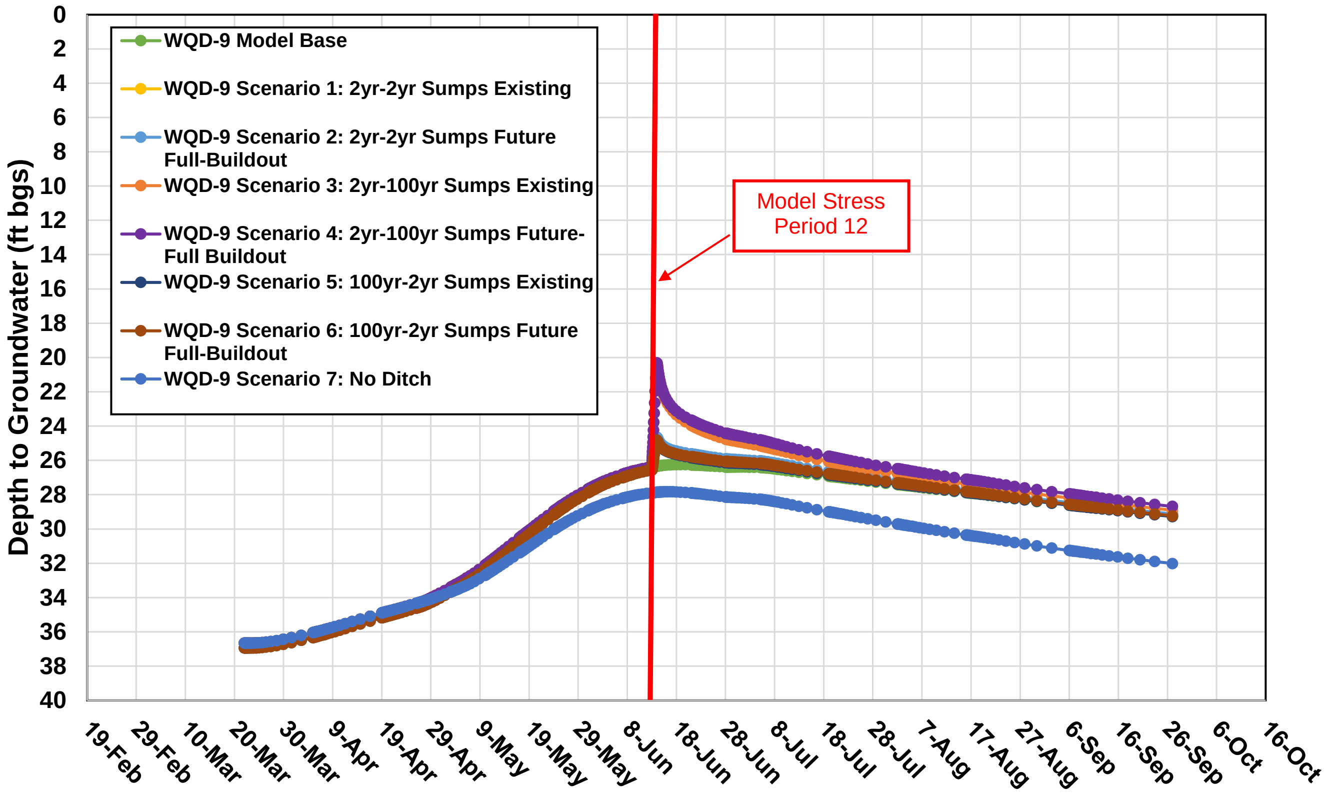


Figure I-9. Depth to Water Hydrographs: WQD-9

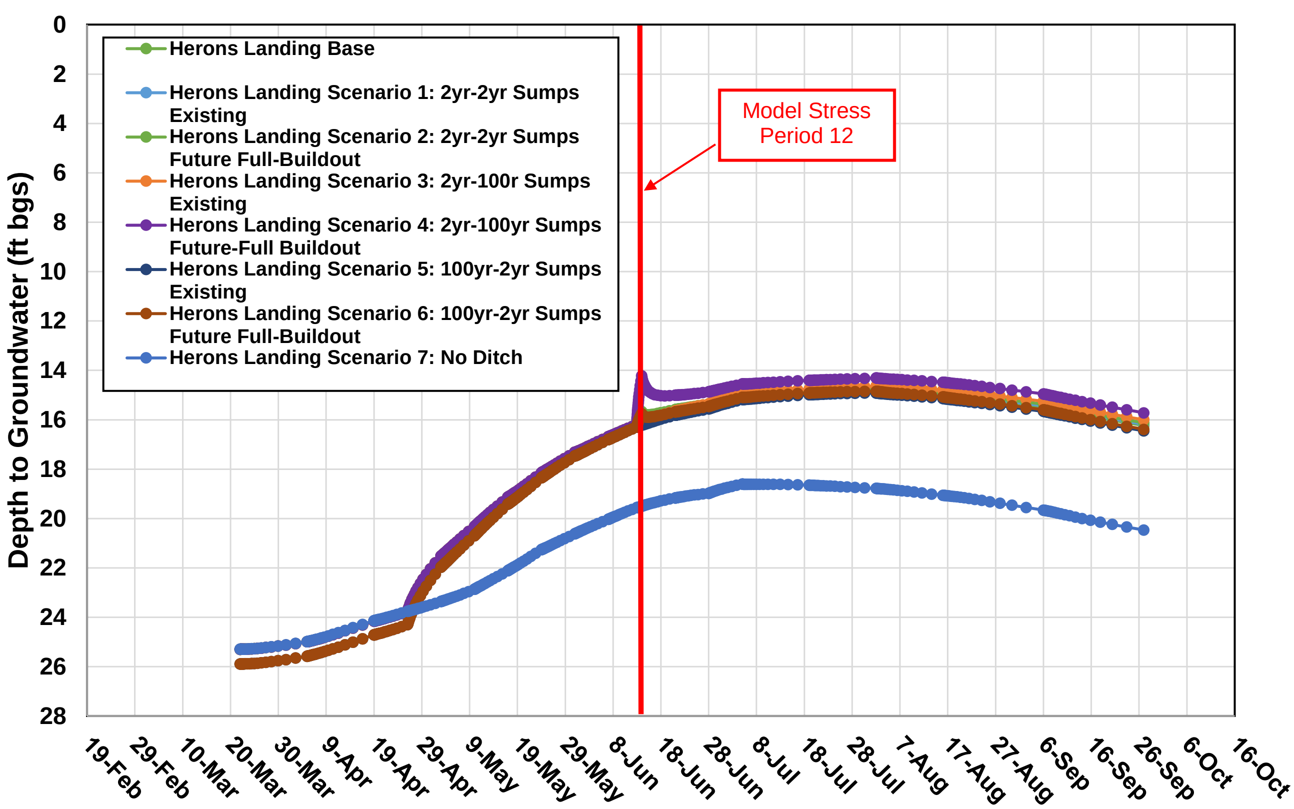


Figure I-10. Depth to Water Hydrographs: Heron's Landing

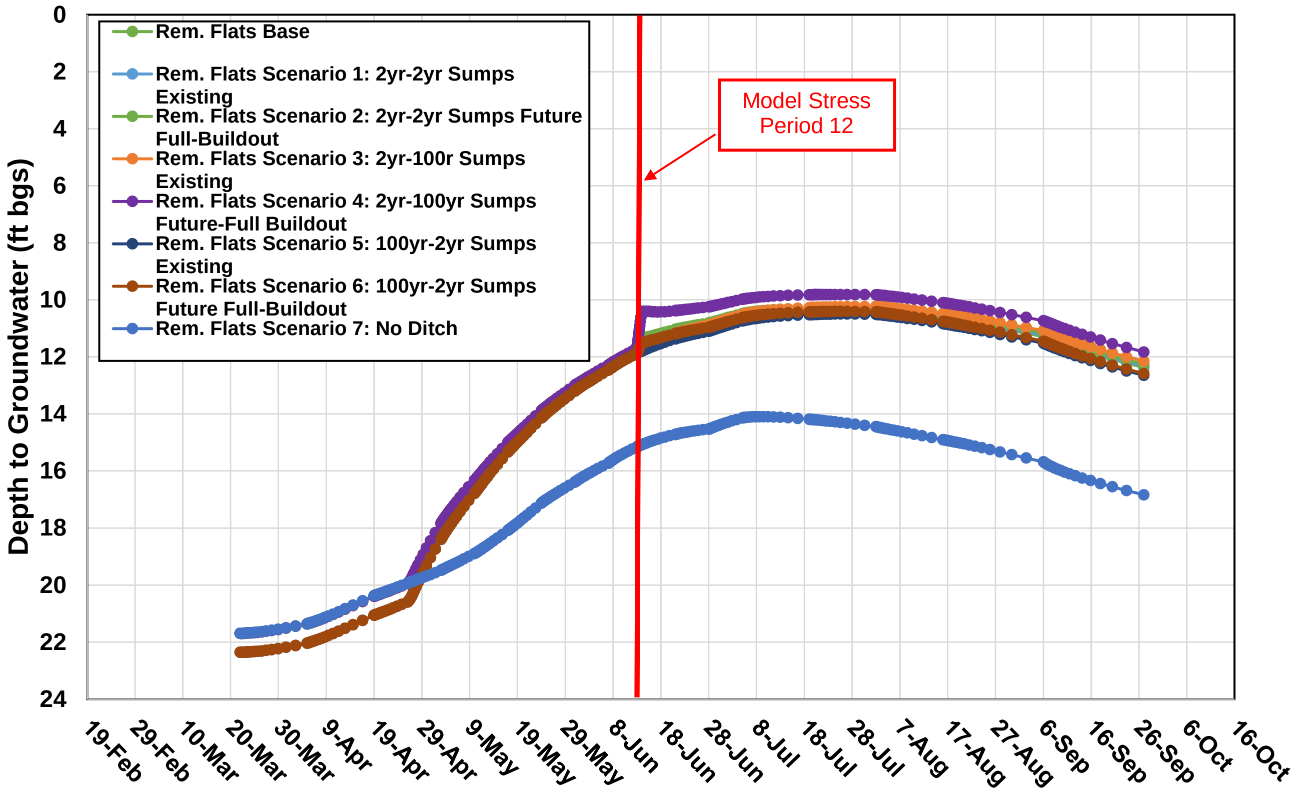


Figure I-11. Depth to Water Hydrographs: Remington Flats

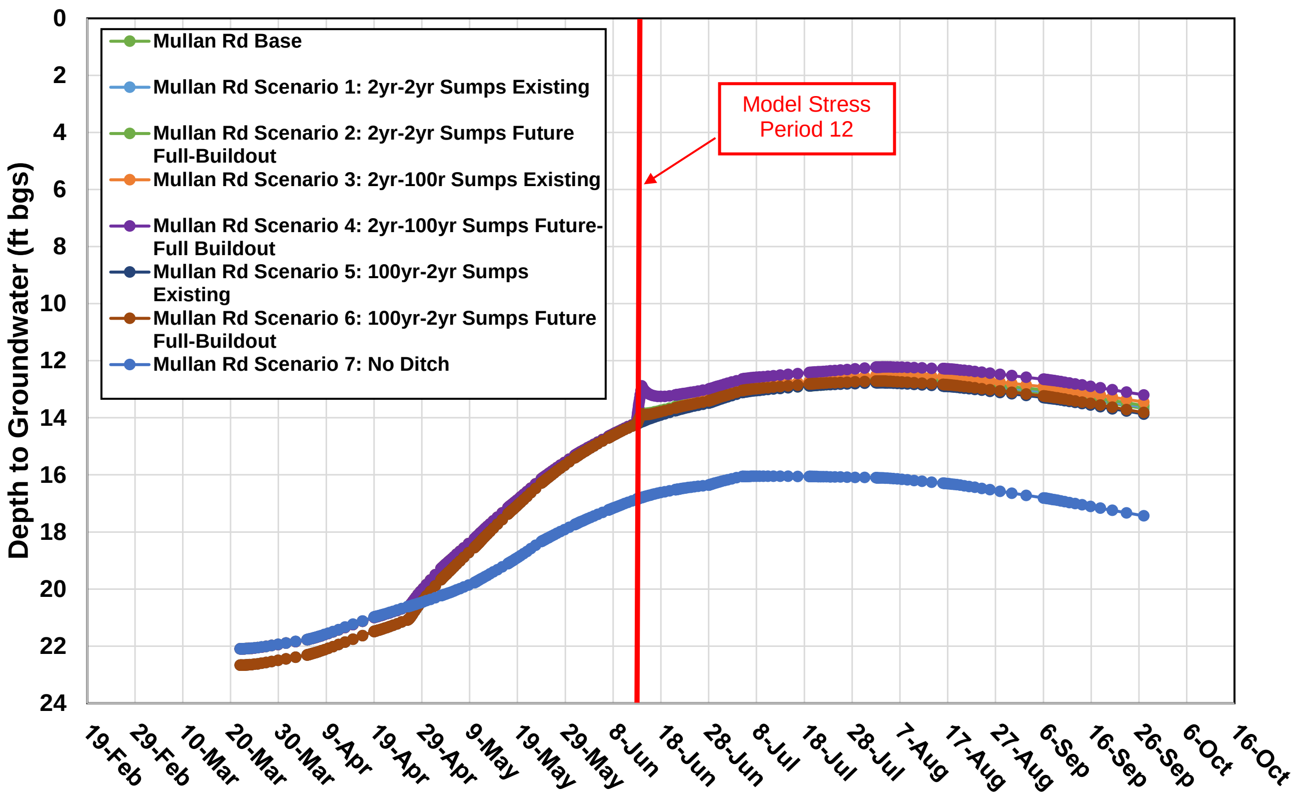


Figure I-12. Depth to Water Hydrographs: Mullan Road

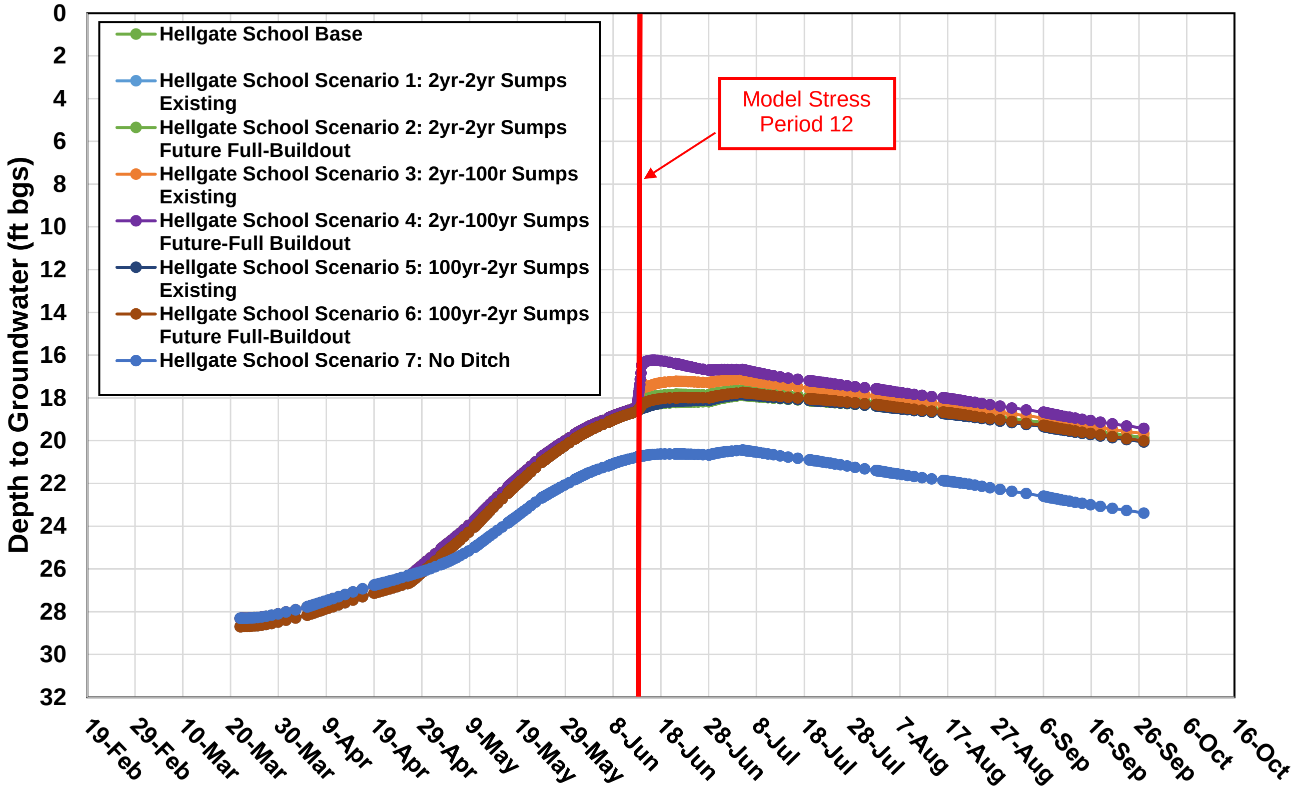


Figure I-13. Depth to Water Hydrographs: Hellgate School

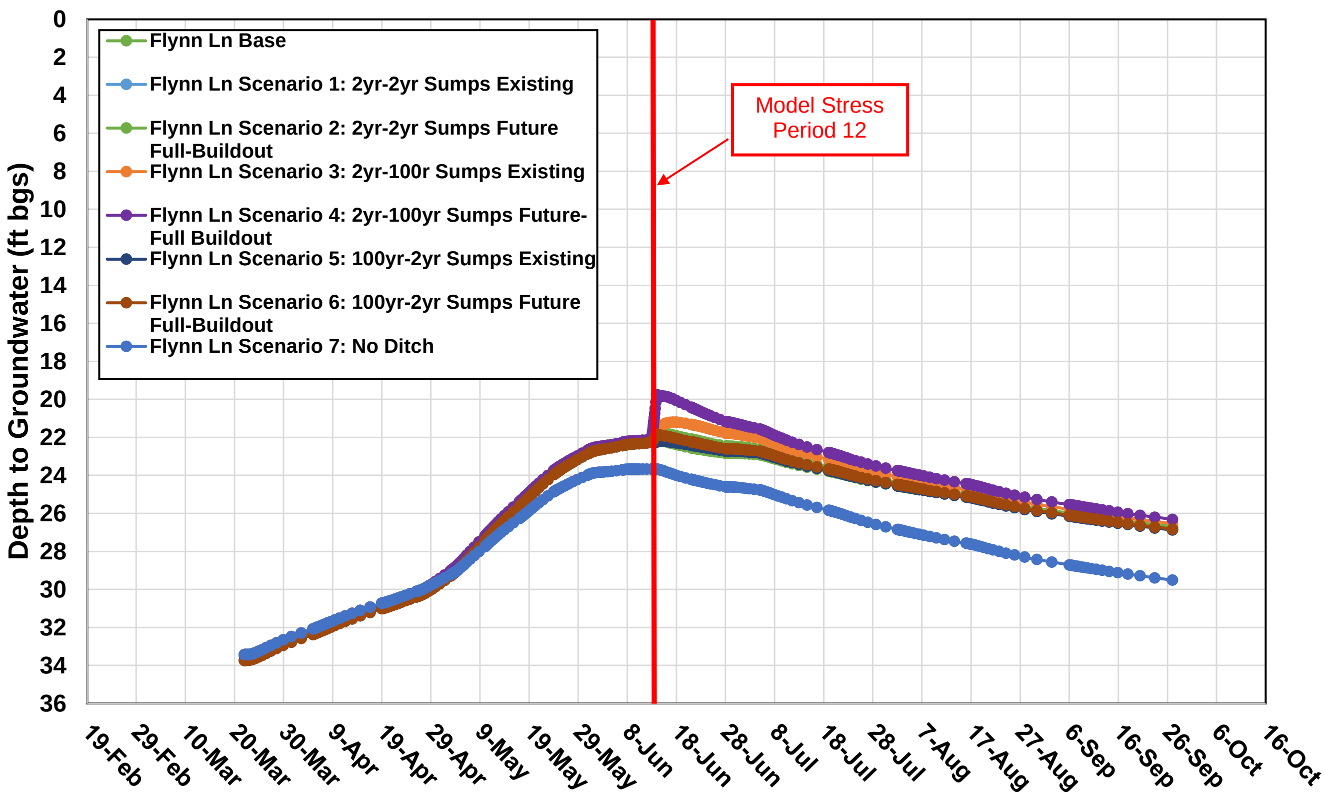


Figure I-14. Depth to Water Hydrographs: Flynn Road

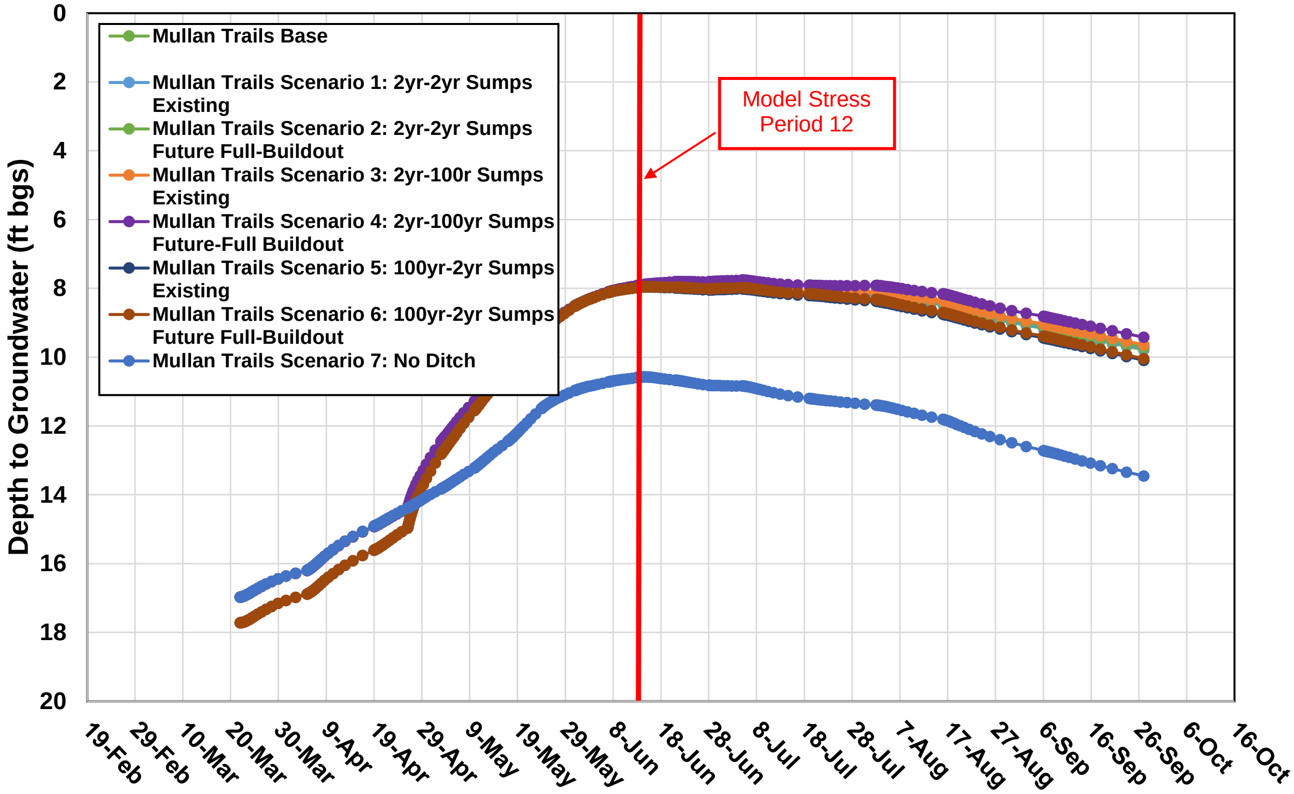


Figure I-15. Depth to Water Hydrographs: Mullan Trails Estates

Sensitivity Hydrographs

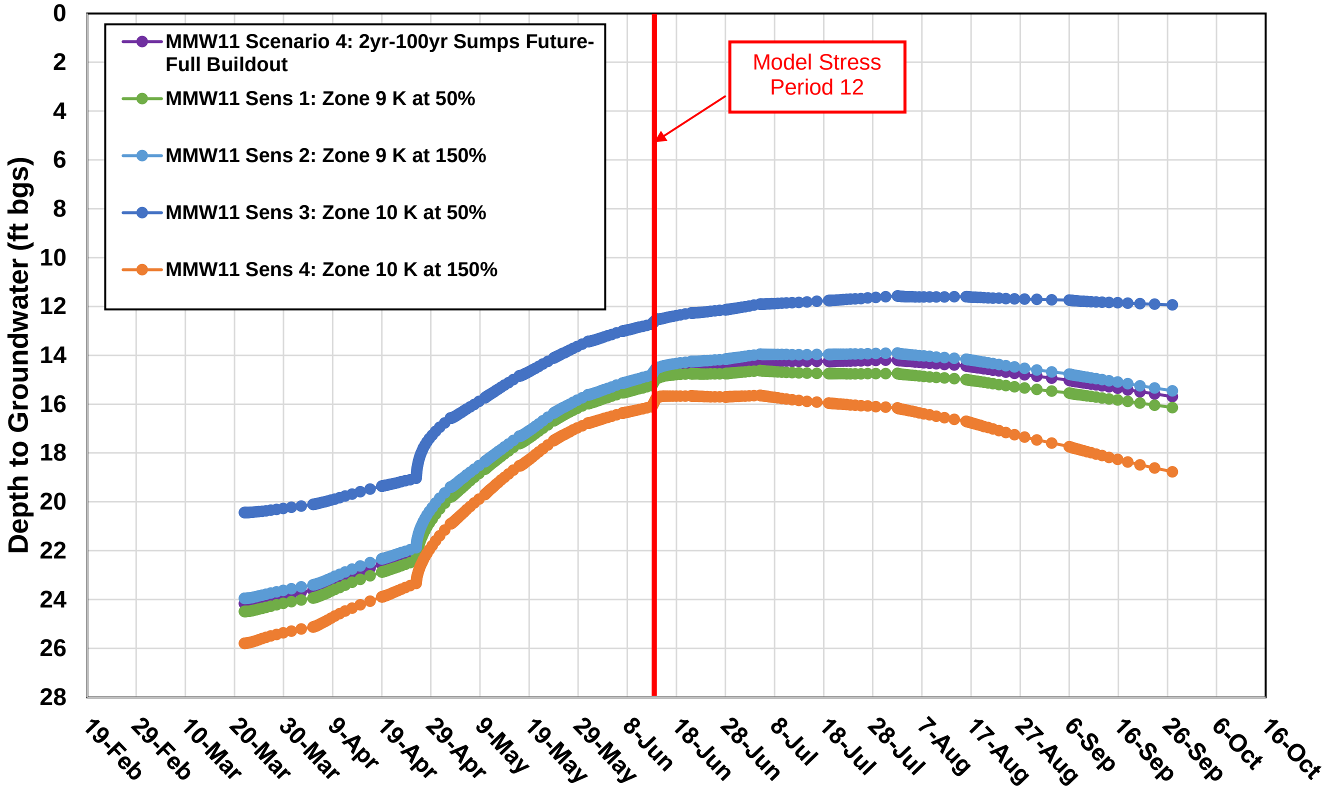


Figure I-16. Scenario 4 Sensitivity: MMW11

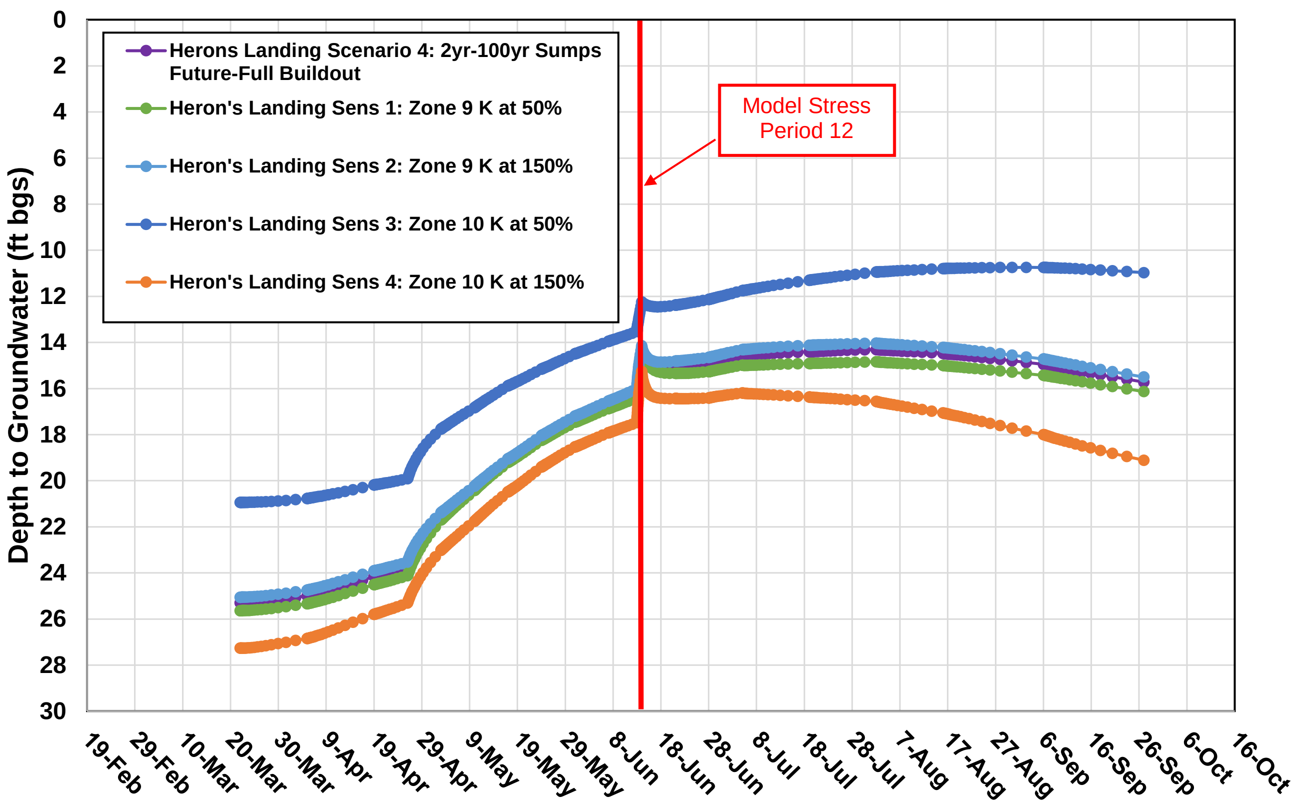


Figure I-17. Scenario 4 Sensitivity: Heron's Landing

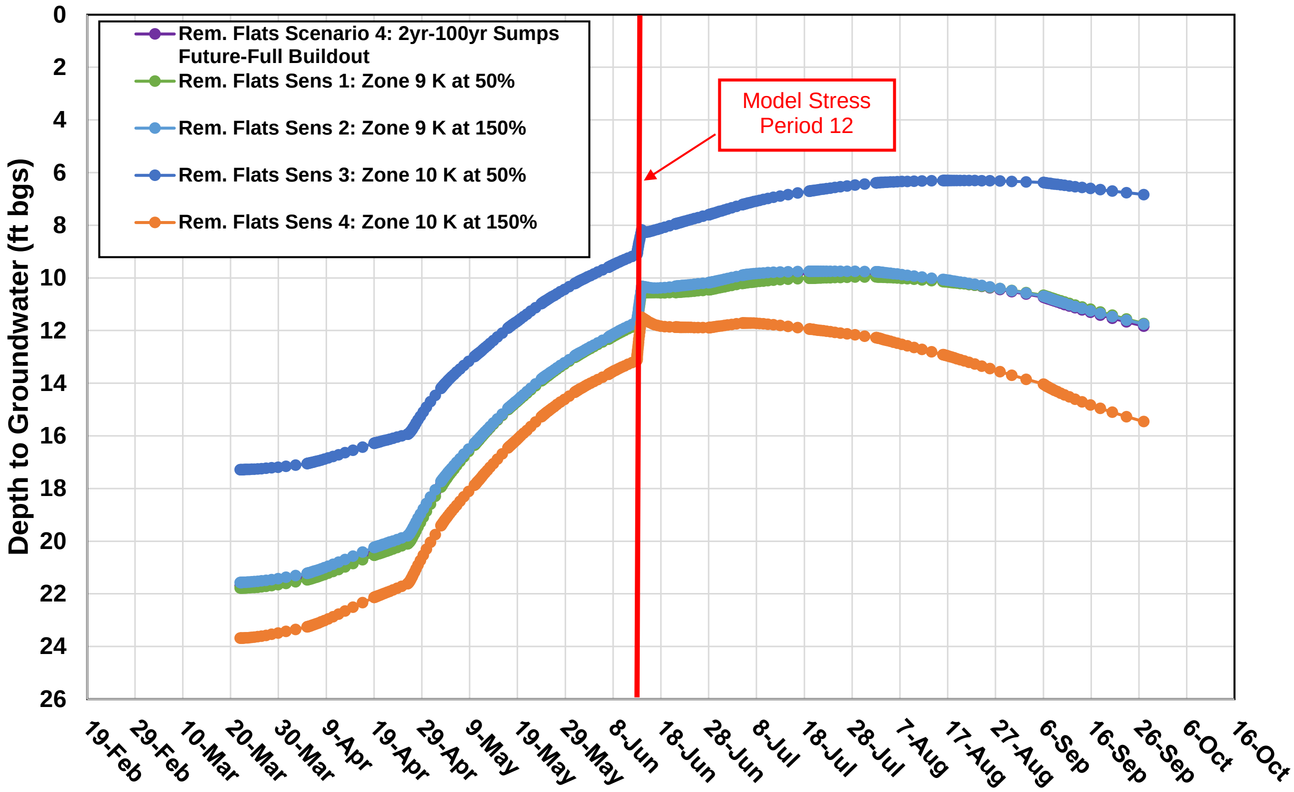


Figure I-18. Scenario 4 Sensitivity: Remington Flats

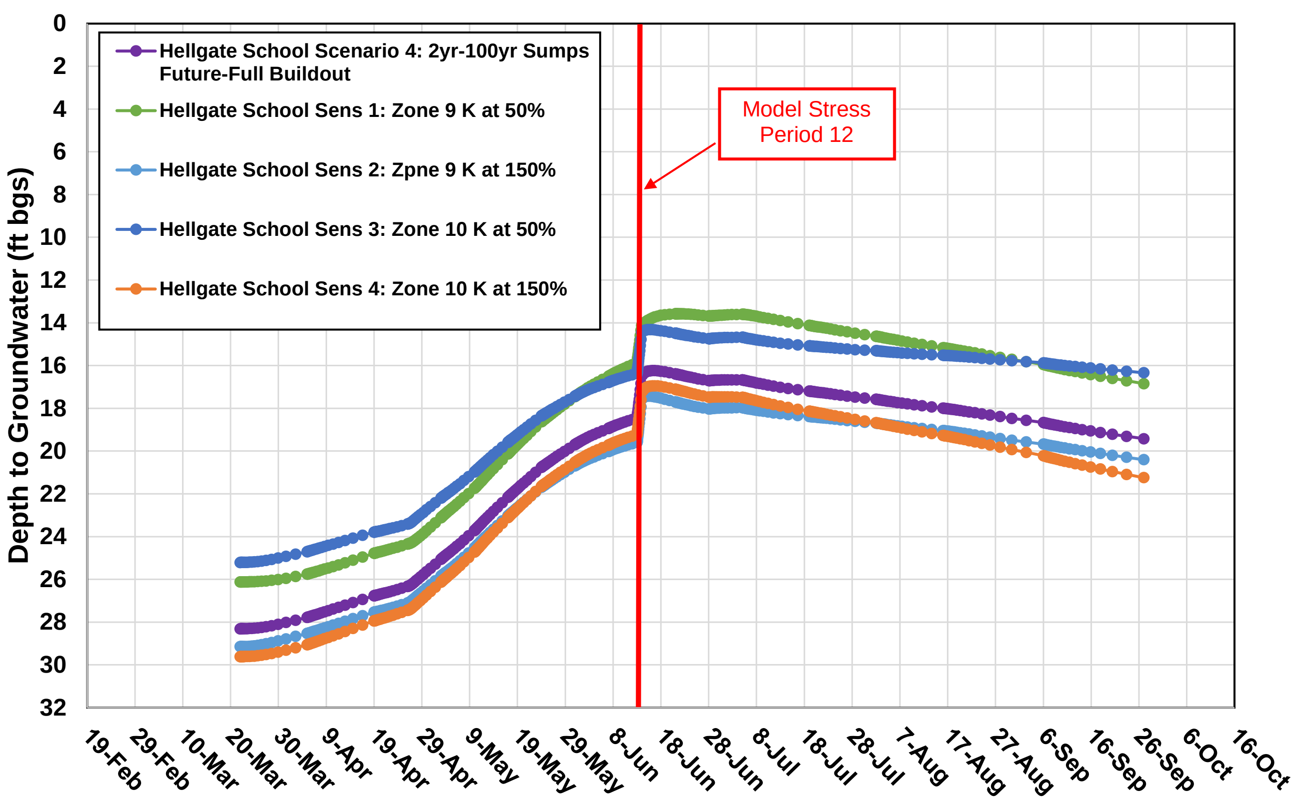
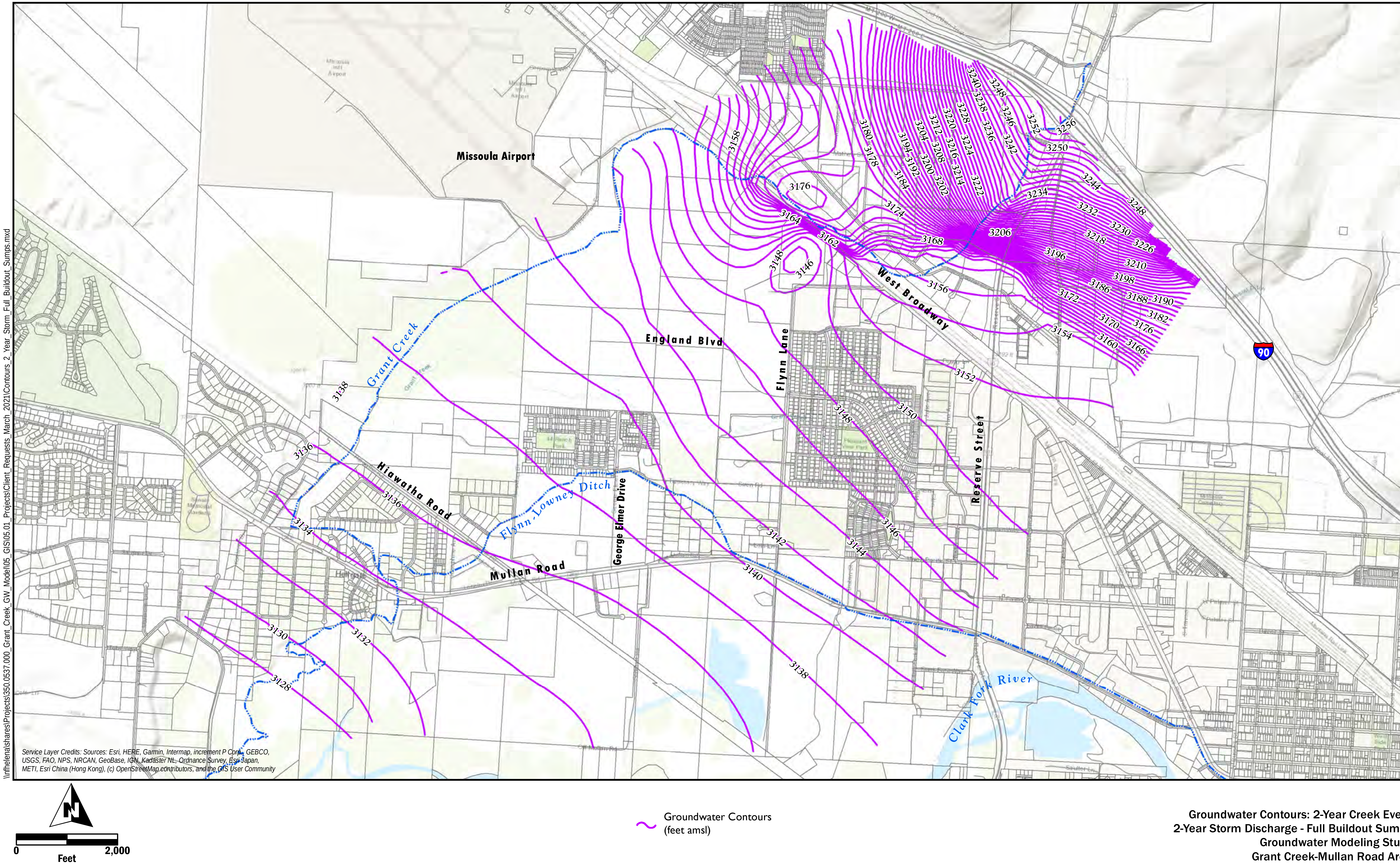


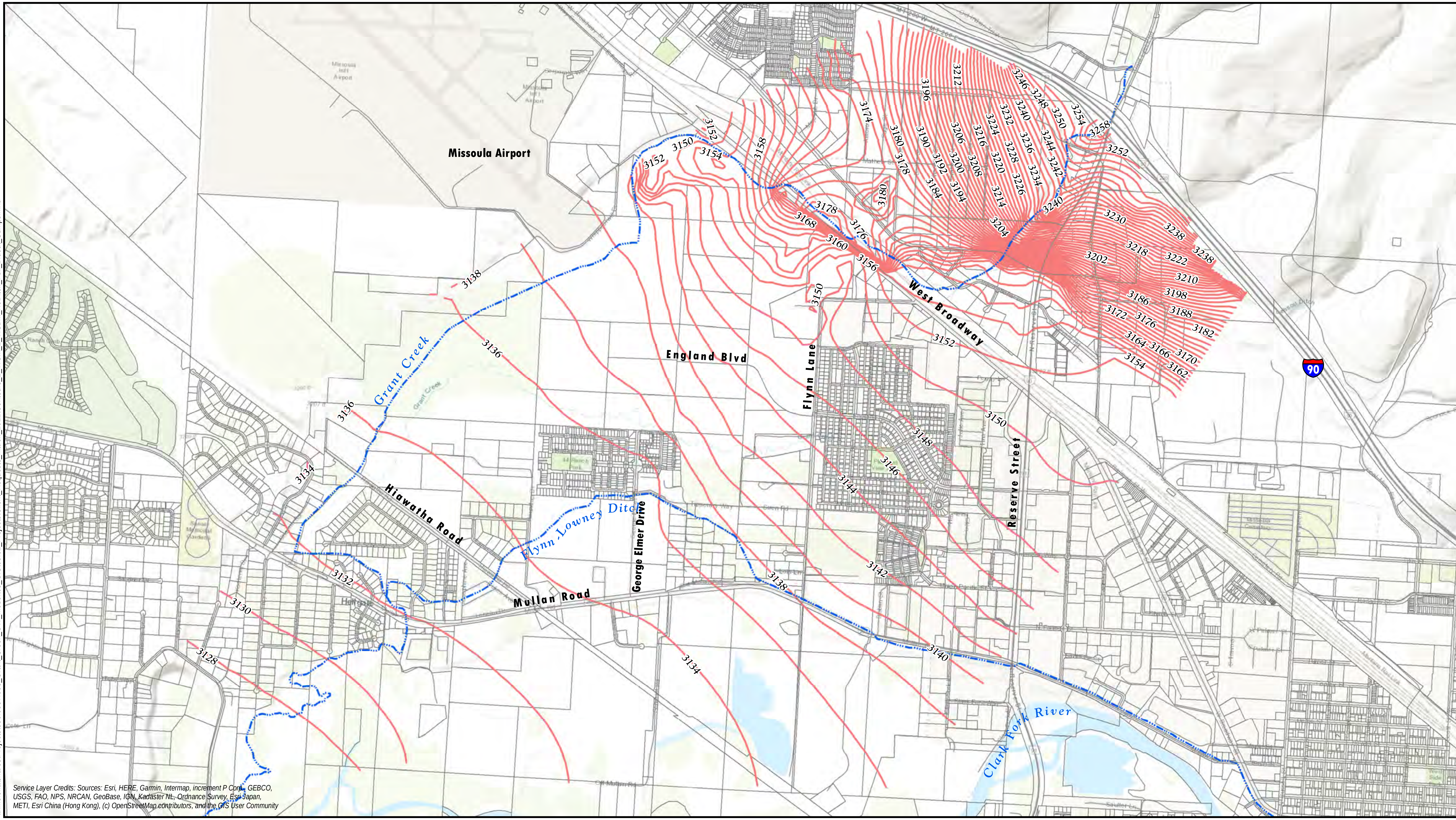
Figure I-19. Scenario 4 Sensitivity: Hellgate School



Groundwater Contours (feet amsl)

NewFields

Groundwater Contours: 2-Year Creek Event
2-Year Storm Discharge - Full Buildout Sumps
Groundwater Modeling Study
Grant Creek-Mullan Road Area
Missoula, Montana
FIGURE 2



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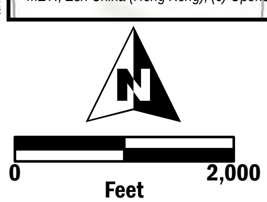

Groundwater Contours (feet amsl)

NewFields

Groundwater Contours: 2-Year Creek Event
2 Year Storm Discharge - Flynn-Lowney Ditch Removed
Full-Buildout Sumps
Groundwater Modeling Study
Grant Creek-Mullan Road Area
Missoula, Montana
FIGURE 1