TECHNICAL MEMORANDUM

DATE:	November 1, 2023	**PROJECT NO.**	350.0537.001
TO:	Andy Schultz – City of Missoula		
CC:			
FROM:	Amelia Tallman, Angela Lucero - NewFields		
SUBJECT:	**Cumulative Effects Analysis Groundwater Model Update**		

1.0 INTRODUCTION

This technical memorandum describes updates made to conceptual and numerical groundwater models of the Grant Creek area created by NewFields in 2021 for the City of Missoula (City). As described by NewFields (2021), the conceptual and numerical groundwater models were originally developed by Geomatrix (2004) and have been updated several times following the collection of additional information to evaluate potential changes in groundwater levels in the local shallow aquifer.

The Study Area is in the western portion of the Missoula Valley and includes the Grant Creek drainage from Interstate 90 south to the Clark Fork River, extending from immediately west of Grant Creek to east of Reserve Street (**Figure 1**). The area includes Grant Creek, the former Flynn-Lowney Ditch system, and areas of existing and proposed land development and subdivisions.

The objectives of the work described in this memorandum were to:

- Update and recalibrate the existing numerical model with recent data, and
- Use the calibrated model to evaluate potential cumulative effects on groundwater levels of 1) a planned realignment of the Horseshoe Bend portion of Grant Creek (Figures 1 and 3) the use of Class V injection wells (referred to below as "sumps") to manage stormwater in areas of future development as part of the Mullan BUILID Project.

The following sections of this memorandum describe:

- Updates made to the conceptual and numerical models based on new boring logs, groundwater elevation data, and creek flow data.
- Incorporation of ancestral Grant Creek channel locations and the proposed Grant Creek realignment design into the model.
- Development and results of predictive simulations designed to evaluate the cumulative effects of realigning Grant Creek and using sumps to manage stormwater for existing and future development after removing the Flynn-Lowney Ditch system, both during average and high Grant Creek flows.

- Conclusions based on the groundwater model focused on guiding future development and stormwater management

2.0 CONCEPTUAL MODEL UPDATE

NewFields (2021) and Maxim/HDR (2005) include detailed descriptions of the conceptual models of the complete hydrologic system and the shallow groundwater system, respectively. The following sections describe updates to the Study Area conceptual model applied to this model update.

2.1. Surface Water

Grant Creek is a tributary of the Clark Fork River that drains the southern portion of the Rattlesnake Mountains and Rattlesnake Wilderness. In late summer, the reach between I-90 and West Broadway dries up as streamflow infiltrates to shallow groundwater; flow resumes in the streambed near the Hiawatha Road crossing and then feeds into the Clark Fork River. As described in NewFields (2021), the Missoula County Water Quality District (WQD) monitored flow and stage at four monitoring stations along Grant Creek between June and August 2020. During this time, average loss of flow from Grant Creek to the shallow aquifer was 8.6 cubic feet per second (cfs) between the Highlander Brewery and West Broadway stations, and 33.3 cfs between the West Broadway and Mullan Trail stations.

The previous conceptual model included seepage from the Flynn-Lowney Ditch system (NewFields, 2021). The City of Missoula acquired the Flynn-Lowney ditch from the Hellgate Valley Irrigation Company in November 2021 and the headgates were not opened after the 2021 irrigation season (personal communication, Andy Schultz, October 2023). Therefore, seepage from this irrigation ditch system is included in the 2020 conceptual model but is not included in predictive simulations.

2.2. Historic Grant Creek Channel Locations

Historic Grant Creek channels deposited coarse-grained sediments to form higher permeability zones within the shallowest portion of the groundwater system. Previous versions of the groundwater model have not considered all locations of previous channel deposits and their potential influence on groundwater flow.

The location of the Grant Creek channel between Interstate 90 and Mullan Road has changed many times over the last few thousand years due to natural and man-made causes. The creek flows out of Grant Creek Valley into the Missoula Valley south of Interstate 90, across a broad alluvial fan, and ultimately drains to the Clark Fork River. Before the development of the Missoula Valley, the creek transported coarse-grained sediments from the mountains and then deposited them as stream velocities decreased upon reaching the alluvial fan in the Missoula Valley. The Grant Creek channel migrated back and forth across the alluvial fan as it deposited sediments blocking flow.

In the last 110 years, farmers and ranchers have moved Grant Creek several times to facilitate agricultural use of the area. **Figure 2** presents previous Grant Creek locations compiled after reviewing historical aerial photographs and topographic maps from 1912 to 2020. The earliest record is a topographic map published in 1912 (USGS, 1912) that indicates Grant Creek was routed northwest along West Broadway for about a half mile before turning west for a half mile, then southwest for ¾ mile, then south about 1 mile before crossing near Mullan Road.

The next visible change is apparent in a 1954 aerial photograph (USGS, 1954) when Grant Creek appeared to be channelized and diverted into two distinct channels (north and south). A new south channel begins when Grant Creek flows out of the Grant Creek Valley, immediately crosses West Broadway near Flynn Lane, and then turns southwest. The creek is then routed around an agricultural land parcel before continuing northwest to where it joins the previous 1912 channel. The north channel coincides with the 1912 path except where it is rerouted along West Broadway around agricultural parcels. This stretch is labeled “Field Dougherty Ditch” in topographic maps from 1964 and 1999 and is unlabeled when it appears in other maps.

An aerial photograph from 1961 (USGS, 1961) shows the same north channel of Grant Creek or Field Dougherty Ditch but a different south path. This south path does not include deliberate routing around an agricultural land parcel, and instead flows west and then southwest until rejoining the original Grant Creek past further downstream than in the 1954 aerial photograph. This south path is labeled “Grant Creek” in 1964, 1999 2011, 2014, 2017, and 2020 topographic maps. However, this south path is not visible beginning in 1976 so we refer to the modern north path as Grant Creek. Historical locations could be indicative of ancestral alluvial deposits which could act as preferential flow paths.

2.3. Grant Creek Realignment Design

The City plans to realign the western portion of Grant Creek near West Broadway to reduce peak groundwater elevations downstream near Mullan Trail Estates during flood events. The City will remove and rehabilitate the horseshoe bend section (about 6,600 feet long) and bypass it with a straighter engineered floodplain and channel about 5,000 feet long (HDR with DJ&D, 2022). The upstream end just south of West Broadway will have a sediment basin and the north and south sides of the floodplain will be bound by riparian areas. **Figure 3** shows the proposed creek realignment location. The 200-foot-wide engineered floodplain will be excavated at least three feet below ground surface. An additional three feet of material will be excavated to form a channel centered within the floodplain. The channel will be 12 feet wide at the top and taper to 8 feet wide at the base. Straightening Grant Creek in this area and constructing a substantial floodplain should allow more water to infiltrate before reaching developed areas downstream during substantial creek flow events.

2.4. Groundwater Flow

The hydrostratigraphy of the Study Area includes a shallow groundwater system that is hydrologically isolated from the deeper regional flow system of the Missoula Aquifer, except in a small area near West Broadway. Hydrographs of wells monitored by WQD from April 2020 to April 2023 are presented in **Figure 4**. **Table 1** describes the construction of select wells in the Study Area and data availability received to date. Maxim monitored additional between 2003 and 2004 (Maxim/HDR, 2005) that were since abandoned and could not be relocated for additional monitoring (NewFields, 2021). Low-water conditions generally occur between January and March, and high-water conditions generally occur between May and July. The hydrograph of well WQD3 indicates higher groundwater elevation later in the season through September 2020 but not in 2021 or 2022. This is likely due to the combined effects of not using the Flynn-Lowney ditch and less precipitation (NOAA, 2023). Prior to 2021, leakage from Flynn Lowney Ditch maintained higher groundwater elevations in this area throughout the irrigation season.

Groundwater in the shallow system flows from northeast to southwest. **Figure 5** is a map showing potentiometric surface contours in June 2020 representing seasonal high-water conditions. The water table elevation is approximately 6.5 to 15 feet higher in high-water conditions than during low-water conditions. The City and NewFields (2021) established that peak 2020 groundwater elevations are representative of seasonal high groundwater conditions with at least a 2-year return period.

Table 1: Current Monitoring Wells Construction and Data Availability

Location	Date Installed	MP Elevation (ft amsl)	Total Depth (ft bgs)	Screen Depth (ft)		Water Level Data		
						Manual		Transducer
				Top	Bottom	Dates	No Pts	Dates
MMW1	8/11/2003	3146.61	18	7	17	8/2003 - 6/2005 4/2020 - 7/2021	23	10/2003 - 6/2004 4/2020 - 9/2020
MMW2	8/11/2003	3146.86	16.5	6.5	16.5	8/2003 – 6/2005	18	--
MMW3	8/13/2003	3152.87	21	11	21	8/2003 - 6/2005 4/2020 - 7/2022	38	10/2003 - 6/2004 4/2020 - 9/2020 5/2021 - 5/2023
MMW4	8/12/2003	3160.55	31	16	31	8/2003 - 6/2005 4/2020 - 8/2022	40	4/2020 - 9/2020 11/2020 - 4/2021 7/2021 - 5/2023
MMW5	8/11/2003	3145.31	18	8	17.5	8/2003 – 6/2005	18	--
MMW6	8/13/2003	3156.67	26.5	11.5	26.5	8/2003 – 6/2005	18	--
MMW8	9/22/2003	3174.14	50	20	50	10/2003 - 6/2005 4/2020 - 2/2023	58	4/2020 - 9/2020 11/2020 - 5/2023
MMW11	8/13/2003	3152.24	27	12	27	10/2003 - 6/2005 4/2020 - 8/2022	48	4/2020 - 9/2020 11/2020 - 5/2023
MMW12	8/13/2003	3158.27	30.5	20.5	30.5	8/2003 - 6/2005 4/2020 - 8/2022	42	10/2003 - 6/2004 4/2020 - 9/2020 11/2020 - 5/2023
MMW13	9/22/2003	3162.49	32	15	32	11/2003 – 6/2005	16	--
WQD3	1/5/1995	3147.13	42	12	42	7/1995 - 4/2023	185	4/2020 - 9/2020 11/2020 - 2/2023
WQD9	2/28/1995	3174.72	50	20	50	7/1995 – 4/2023	158	--
WQD22	1/25/1996	3174.70	100	95	100	6/1996 – 4/2023	154	--
WQD44	5/22/2012	3158.1	112	87	97	2/2020 - 4/2023	64	4/2020 - 8/2020 11/2020 - 2/2023

Notes:
MP = measuring point
ft = feet
amsl = above mean sea level
bgs = below ground surface
No Pts = number of manual water level data points

2.5. Upper Soil and Shallow Aquifer Characteristics

Lithologic logs from percolation test boreholes (locations in **Figure 1**) fill in spatial gaps in shallow soil characteristics within the Site Area. Previously, NewFields (2021) designated the shallow lithology (upper 14 feet) in the Site Area as fine-grained material (silt, clay, and fine sand) to the northwest, and as mostly coarse- to medium-grained material to the south. Lithology beyond 14 feet below ground surface (ft bgs) was designated as gravel. Since then, geologic cross-sections along Flynn Lane and George Elmer Drive were made using the additional borehole data (**Figure 6**). The cross-sections suggest gravel is present at shallow depths to the south beginning near the Flynn-Lowney Ditch.

2.5.1. Percolation Test

Tetra Tech (2020b) performed percolation and infiltration tests on soil within the study area in 2020. Infiltration occurs when water moves from above ground surface to below ground surface whereas percolation is the movement of water through the subsurface. Montana DEQ guidance documents used to inform the tests described below use the terms interchangeably. Tetra Tech performed percolation tests to develop geotechnical recommendations for future development design and construction, and infiltration tests to inform future infiltration facility locations and designs.

In April 2020, percolation tests were conducted in eight exploratory borings within the proposed new roadway extents (Tetra Tech, 2020b). **Figure 1** shows test locations and **Table 2** summarizes results. Borings were advanced using a truck-mounted drill rig with an 8-inch outer diameter hollow stem auger. Soil samples were collected and sent to Tetra Tech's lab for physical and engineering characteristics tests. Appendix A of DEQ Circular 4 describes the methodology for the test hole percolation tests performed. Testing occurred through the open end of a 4-inch PVC pipe installed at depths of 3 to 5 ft bgs and lasted 2 to 30 minutes. The tests indicate shallow subsurface percolation rates range from 4.8 feet per day (ft/day) to 720 ft/day.

Table 2: Percolation and Infiltration Testing Results

Test Location	Soil Type (USCS)	Depth (ft)	Average Rate (ft/day)	K_{fs}[1] (ft/day)
Percolation Test [2]				
MJ-1	SM/GP	3.7	480.0	39
MJ-2	SM	3.7	720.0	58
MJ-3	SM	3	5.4	0.5
MJ-4	GC	3.8	720.0	58
ENG-1	SM	3.4	[3]	--
ENG-2	SC	3.5	4.8	0.4
ENG-3	SP-SC	5	93.3	8
GE-1	CL-ML/GP-GC	3.2	75.8	6
Infiltration Test [4]				
500[5]	ML	5.25	35.5	30
501	GM	9.7	1,603.7	127
502	GM	10	4,191.6	327
503	GM	9.8	57,600.0	4,262

Test Location	Soil Type (USCS)	Depth (ft)	Average Rate (ft/day)	K_{fs}[1] (ft/day)
504	GM	9.78	677.6	55
505	GM	9.53	658.9	53
506	GM	9.8	799.7	64
507	GP	13.1	1,461.5	116
508	GP	10.1	11,520.0	880
509	GP-GM	13.3	3,389.0	265
510	GP-GM	10.3	3,737.4	292
511	GM	9.65	4,126.0	322
512	GM	9.73	543.0	44
513	GP-GM	10.5	43,200.0	3,215
514	GP-GM	10.7	7,434.8	573
515	GP-GM	10.5	2,000.1	158
516	GP-GM	10.3	818.7	66
517	GP-GM	13.6	431.3	35
518	GC	17.45	507.9	41
519	GP-GM	15.9	894.3	72
520	GC	16	787.8	64
521	GC	18.6	514.5	42
522	CL-ML/GP-GM	11.3	4,241.0	331

Notes:
ft = feet
USCS = Unified Soil Classification System
[1] Saturated hydraulic conductivity (K_{fs}) = 3015*$PT^{-0.98}$ where PT is minutes for 25-milimeters of water to infiltrate (Gill et al., 2023).
[2] Percolation tests conducted April 2020 per Appendix A of Montana DEQ Circular 4 (Tetra Tech, 2020b).
[3] Unable to report percolation rate at ENG-1 because there was no change in water level during the duration of the test (Tetra Tech, 2020b).
[4] Infiltration tests conducted in October 2020 per Appendix 6-F of the Missoula Public Works Manual (Tetra Tech, 2020a).
[5] Infiltration tests conducted in October 2020 per Appendix C of Montana DEQ Circular 8, Sections C.2 and C.3 (Tetra Tech, 2020a).

Tetra Tech performed infiltration tests at 23 additional borings in October 2020 (Figure 1). Borings were advanced 5.25 to 18.6 ft bgs. A test duration of 60 minutes was reported for boring 500 but no durations were reported for the other 22 borings. The minimum average infiltration rate was obtained at boring 500 (silts and fine sands) using the test pit infiltration test method described in Appendix A of MT DEQ Circular 4. The infiltration rate at the remaining 22 borings was determined using the encased falling head test described in Sections C.2 and C.3 of MT DEQ Circular 8. This field test evaluates the vertical infiltration rate specifically. The range of subsurface infiltration rates is 35.5 ft/day to 57,600 ft/day.

Gill et al. (2023) relate infiltration rates from falling head percolation tests to field-saturated hydraulic conductivity using the equation:

$$K_{fs} = 3015 * PT^{-0.98}$$

Where K_{fs} is the field saturated hydraulic conductivity in millimeters per day, and PT is the percolation time in minutes per 25-millimeter water level drop. Field-saturated hydraulic conductivity is not interchangeable with saturated hydraulic conductivity used to inform the conceptual model in that field-saturated conditions are not completely saturated. However, the spatial distribution of high and low K_{fs}

from these tests could inform where saturated hydraulic conductivity is likely higher or lower. The infiltration rates and K_{fs} are highest in borings with mostly or all gravel along the Flynn-Lowney Ditch (508, 509, 510, 513, 514, and 522) and near the Grant Creek Ditch (502 and 503), ranging from 3,389 to 57,600 ft/day. These areas would likely have higher saturated hydraulic conductivity (K) than the immediate surrounding area.

3.0 GROUNDWATER MODEL UPDATE

This section describes revisions made to the numerical model based on the updated conceptual model. Refinements include adjustments to model inputs and boundary conditions. The model domain, grid, and layer elevations, as well as Drain and Well Package boundary conditions, remain the same as described in the previous model report (NewFields, 2021). Well Package boundary cells represent sumps, and Drain Package boundary cells simulate the flux between the shallow and deep aquifer and represent the drain system at Mullan Trails Estates.

3.1. Model Setup

The overall model design and construction are the same as previously reported (NewFields, 2021); however, adjustments to model inputs were required to reflect the updated conceptual model. The model was constructed using MODFLOW USG (Panday et al., 2017) and the Groundwater Vistas graphical user interface (Environmental Simulations, Inc, 2020). There are three model layers. Model layer 1 is the first 10 feet below ground surface, layer 2 is the next 4 feet, and layer 3 is the next 20 to 40 feet. The depth and thickness of layer 2 accommodate the potential depth of sumps placed 10 to 14 ft bgs. The layers were parameterized with hydraulic conductivity and storage zones such that layer 1 is fine- to coarse-grained material, layer 2 is coarse-grained material, and layer 3 is shallow aquifer material.

NewFields adjusted hydraulic conductivity (K) in all three model layers and storage (S) in layer 3. Areas along previous Grant Creek channels in layer 1 that had very low K (as for silt or clay) were replaced with higher K zones (as for coarse sand or gravel) since it is unlikely that such barriers to flow would exist in former creek locations. The area south of the Flynn-Lowney Ditch in layers 1 and 2 that had very low K were replaced with higher K zones since borehole logs in that area suggest the gravel aquifer comes up to ground surface. In layer 3, hydraulic conductivity was adjusted to better match early March 2020 steady-state conditions, and specific yield (Sy) was adjusted to better reflect March through September groundwater elevation data. **Table 5** includes the final calibrated hydraulic conductivity and storage parameters, and **Attachment A** (**Figures A-1** through **A-3**) details the final spatial distribution.

3.1.1. Stress Periods

There are 20 stress periods, with the first being steady-state (**Table 3**), that cover the period of March 8th through September 26th. NewFields used hydrologic data from March 8 through September 26, 2020 for model design and calibration described in this section.

Table 3: Stress Period Setup

Stress Period	Duration (days)	Duration (hours)	Cumulative Days	Start Date [1]	End Date [1]	Description
1	14	336	14	March 8	March 21	Steady-State
2	14	336	28	March 22	April 4	Spring rise [2]
3	14	336	42	April 5	April 18	
4	7	168	49	April 19	April 25	
5	7	168	56	April 26	May 2	
6	7	168	63	May 3	May 9	
7	7	168	70	May 10	May 16	
8	7	168	77	May 17	May 23	Peak rise
9	7	168	84	May 24	May 30	Begin summer decline [3]
10	7	168	91	May 31	June 6	
11	6	144	97	June 7	June 12	
12	1	24	98	June 13	June 13	24-hour storm and sump discharge [4]
13	7	168	105	June 14	June 20	Continued summer decline [3]
14	7	168	112	June 21	June 27	
15	7	168	119	June 28	July 4	
16	14	336	133	July 5	July 18	
17	14	336	147	July 19	August 1	
18	14	336	161	August 2	August 15	
19	21	504	182	August 16	September 5	
20	21	504	203	September 6	September 26	

Notes:
[1] Calibration model stress period dates are in 2020. Predictive models use the same stress period setup but do not correspond to a particular year.
[2] Includes increased stage in Grant Creek, recharge from the Flynn-Lowney Ditch, and groundwater underflow-out due to snowmelt.
[3] Includes decreased stage in Grant Creek, recharge from Flynn-Lowney Ditch, and groundwater underflow-out back to steady-state conditions.
[4] Sump discharge corresponds to peak groundwater levels in most locations.

3.1.2. Boundary Conditions

The River Package is used to simulate seepage from the lower portion of Grant Creek south of West Broadway to the underlying shallow aquifer (**Figure 7**). River Package cells use the riverbed conductance to account for the length and width of the creek channel in an individual model cell (Anderson et al., 2015).

$$conductance = \frac{K_r LW}{D}$$

Where K_r is the riverbed conductance, L is the river length, W is the river width, and D is the thickness of the riverbed sediments. The lower portion of Grant Creek is divided into multiple reaches to account for differences in physical characteristics along its path. Groundwater Vistas calculates the length of channel in each model cell, and we set the channel width and sediment thickness to 1 foot. Grant Creek is not an engineered channel with a perfectly square cross-section profile, so we assume the width of the creek increases as the creek stage increases. With the creek width set to 1 ft, we can set the transient K_r term to be the hydraulic conductivity of the sediment material (5 ft/day) multiplied by the actual creek width at that stage. The stage for a 2-year Grant Creek seasonal high-water event peaks at 2.5 ft in Stress Period 8 (by May 23) (**Table 4**). This way, seepage from Grant Creek to the underlying aquifer could be related to the conductance, and variable stage and width.

Table 4: 2-year Grant Creek High-Water Event and 2-year Storm Event Discharge Boundary Condition Setup

Stress Period	Cumulative Days	Change from Steady-State (feet)		Total Well Package Infiltration Rate [3] (cfd)
		River Package [1]	General Head [2]	
1	14	0	0	0
2	28	0.5	2	0
3	42	1.0	4	0
4	49	1.2	5	0
5	56	1.5	6	0
6	63	1.7	7	0
7	70	2.0	8	0
8	77	2.5	10	0
9	84	2.3	9	0
10	91	2.0	8	0
11	97	1.8	7	0
12	98	1.6	6	723,836
13	105	1.4	5	0
14	112	1.1	4	0
15	119	0.9	3	0
16	133	0.7	2	0
17	147	0.5	2	0
18	161	0.2	1	0
19	182	0	0	0
20	203	0	0	0

Notes:
cfd = cubic feet per day
[1] Reach 8 conditions shown here. See **Attachment B** (**Figure B-1** and **Tables B-1** through **B-3**) for reach locations and all reach parameterizations.
[2] Downgradient general head boundaries shown here. Upgradient general head boundaries are described in **Attachment B**, **Table B-4**.
[3] Values representing current sump infrastructure (**Attachment B**, **Figure B-2**). 24-hour sump discharge simulated using well package cells.

Minor changes were made to the Recharge and General Head Boundaries (GHB) boundaries. Multiple recharge zones were established throughout the model domain to simulate net recharge from precipitation and irrigation, and to simulate seepage from upper Grant Creek (North of West Broadway) and the Flynn-Lowney Ditch system. We decreased recharge from the Flynn-Lowney Ditch system and laterals beginning in August (Stress Period 17) to reflect the drop in groundwater elevation at nearby monitoring wells (MMW1, MMW11, and WQD44). GHB conditions are used to simulate groundwater underflow into and out of the model domain, and assigned head varies during the simulation to represent the seasonal rise and fall of groundwater. Transient head values in the upgradient GHB cells are decreased by 4 ft to better simulate steady-state conditions (Stress Period 1). Transient head values assigned to the downgradient GHB cells are the same as in NewFields (2021), with groundwater rising to 10 ft during a 2-year Grant Creek seasonal high-water event (Table 4). Well Package (specified flux) boundary cells representing the current configuration of sumps in the Study Area (Attachment B, Figure B-2) are assigned infiltration rates based on the total calculated basin discharge divided by the number of Well Package cells in each basin. Sump discharge occurs during a 24-hour, 2-year storm event in Stress Period 12 (June 13) (Table 4).

3.2. Model Calibration

This section describes calibration of the numerical flow model. Model calibration involves finding a combination of model inputs and model boundary conditions that generate head values that match available observed head values and achieve the calibration goals. NewFields designed and calibrated the groundwater model in general accordance with standard industry practices (Anderson et al., 2015). Achieving calibration does not guarantee the set of input parameters selected is unique and that other plausible inputs would not achieve similar calibration results. However, calibration and verification of the model to independent data sets, including both steady-state and transient target data, increases confidence in the model's capability to simulate groundwater flow under a variety of conditions.

3.2.1. Calibration Targets

NewFields developed both qualitative and quantitative targets as part of the calibration process. Qualitative targets include the March 2020 potentiometric surface map that was developed based on measured and estimated groundwater elevations and hydrographs of groundwater elevations from March 22, 2020 through September 26, 2020 (Stress Periods 2 through 20). Head values from March 8 through 21, 2020 (Stress Period 1) were used as quantitative steady-state targets. Only four wells had measured groundwater elevations in March 2020, namely WQD3, WQD9, WQD22, and WQD44. As discussed by NewFields (2021), the average increase in groundwater elevation at WQD3, WQD9, and WQD22 between March 2004 and March 2020 was 1.24 feet. WQD44 was installed in 2012 and therefore could not be included when determining this correction factor. Adding 1.24 ft to March 2004 groundwater elevations at the remaining monitoring wells provides additional estimated March 2020 targets. This method is not applicable for MMW1, MMW2, MMW3, MMW5, MMW6, MMW11, and MMW13, as they were dry in March 2004, so these wells were not used as steady-state targets. While estimated March 2020 water levels may introduce some uncertainty in the calibration they provide additional spatial coverage. Hydrographs of 10 wells (MMW1, MMW3, MMW4, MMW8, MMW11, MMW12, WQD3, WQD9, WQD22, and WQD44) were used as transient targets when calibrating storage properties.

3.2.2. Calibration Process

The calibration process involved manually varying different input parameters and then evaluating the results of each calibration simulation to determine if the input parameter adjusted during that run achieved a better or worse match to calibration targets. Calibration results for steady-state (Stress Period 1) and transient (Stress Periods 2 through 20) conditions were evaluated using both quantitative and qualitative methods. March 2020 steady-state targets that were estimated by adding a correction factor to March 2004 data are weighted at 50 percent. The following comprise the calibration goals:

- The residual (difference between simulated and target head values) mean (average) for head targets should be close to zero feet.

- The absolute residual mean for head targets (average absolute value of the difference between simulated and target head values) should be less than 2.5 feet.

- The scaled absolute mean (mean absolute residual divided by the range in observed head values) should be less than 10 percent.

- The scaled root mean square error (root mean squared residual divided by the range in observed head values) should be less than 10 percent.

- For the steady-state calibration, the simulated and observed potentiometric maps should be a close fit.

- For the transient calibration, hydrographs of simulated groundwater elevations vs. time should match those based on field-measured values in timing and magnitude of groundwater level changes.

NewFields then judged the quality of the match through application of these comparisons (Anderson et al., 2015).

Input parameters were adjusted during calibration. If the changes improved calibration statistics in the model, then the changes were retained, and the calibration process continued. Changes made to non-transient inputs that improved calibration statistics in the steady-state simulation were also applied to the remaining transient stress periods. Changes made to storage parameters that improved the fit between simulated and observed hydrographs were also retained. The final calibrated parameters were used in the predictive models described in the next section (**Table 5**).

3.2.3. Calibration Results

The final steady-state and transient calibrations meet the previously defined calibration requirements, and therefore the model adequately simulates Site Area conditions. Estimated March 2020 steady-state targets are weighted differently than targets with actual March 2020 data. For that reason, weighted steady-state calibration statistics will be discussed in this section.

Quantitative evaluation of the steady-state calibration was accomplished through the calculation of residual statistics. The residual mean is -0.29 ft, meeting the calibration goal of near zero. The absolute residual mean is 0.50 ft (less than the 2.5 ft calibration goal). The scaled absolute mean is 0.4 percent and the scaled root mean square error is 0.5 percent (both meeting the calibration goal of less than 10 percent). **Figure 8** shows the simulated steady-state potentiometric surface and residuals, with the minimum and maximum residuals of -1.36 ft and 1.17 ft, respectively. The minimum and maximum residuals are under the calibration criteria of 2.5 ft.

Figure 9 is a map showing hydrographs of simulated versus observed groundwater elevations from the transient calibration at target locations. The transient calibration generally matches the timing and magnitude of groundwater level changes at target locations. However, the transient simulation overpredicts peak 2020 groundwater elevations at wells MMW4, WQD3, and WQD44 by approximately 2.5 to 8.5 feet.

Table 5: Final Calibrated Hydraulic Conductivity and Storage Values

Zone	Horizontal Hydraulic Conductivity (ft/d)	Vertical Hydraulic Conductivity (ft/d)	Specific Yield	Lithologic Description	Model Layer
1	0.1	0.01	0.1	Silt and clay	1, 2
2	1	0.1	0.1	Fine sand	1, 2
3	15	1.5	0.1	Medium sand	1, 2
4	200	20	0.1	Coarse sand and fine gravel	1, 2
5	7.7	0.77	0.01	Clay gravel	3
6	99.3	9.93	0.1	Fine sand and gravel	3
8	793.4	79.3	0.1	Sand and gravel, with cobbles	3
9	512.7	54.2	0.05	Sand and gravel	3
10	1440.6	144	0.3	Gravel	3

Notes:
ft/d = feet per day

4.0 PREDICTIVE SIMULATIONS

This section describes predictive modeling completed to evaluate the depth to groundwater under different stormwater management scenarios, both with and without the proposed Grant Creek realignment.

4.1. Setup

Simulations include a mix of hydrologic conditions and stormwater discharge events. Hydrologic events include a 2-year high-flow event and a 100-year high-flow event in Grant Creek. Storm events include stormwater discharge for 2-year and 100-year 24-hour storm events. The probability that both a 100-year high creek flow and a 100-year storm event occur concurrently is less than one percent so it would be overly conservative to develop such a predictive model (Appendix D; NewFields, 2021). The model calibration includes a 2-year high flow event in Grant Creek, stormwater discharge for a 2-year storm event with the current sump configuration, the effects of the Flynn-Lowney Ditch system, and the current Grant Creek alignment. Predictive models do not include boundary conditions simulating the effects of the Flynn-Lowney Ditch system as it was not used after the 2021 irrigation season. Predictive simulations use the same stress period setup as the calibration to represent the period of March 8 through September 22 of a hypothetical future year.

The following simulations were developed and run both with and without the proposed Grant Creek realignment:

- 2-year high-flow creek event in Grant Creek, stormwater discharge for a 100-year storm event, and the estimated full build-out sump configuration
- 100-year high-flow creek event in Grant Creek, stormwater discharge for a 2-year storm event, and the current sump configuration

- 100-year high-flow creek event in Grant Creek, stormwater discharge for a 2-year storm event, and the estimated full build-out sump configuration

The predictive models are set up in the same way as in the previous model version (NewFields, 2021), except for the Grant Creek realignment. Recharge zones that had represented the Flynn-Lowney ditch system (zones 5, 7, and 8) (**Attachment A**; **Figures A-4** and **A-5**, **Table A-1**) were replaced with a single zone (zone 11) that was assigned values equivalent to undeveloped areal recharge (Appendix A; NewFields, 2021), which reduces recharge from former ditch locations by two to three orders of magnitude.

Similar River Package, GHB, and Well Package boundaries representing Grant Creek, underflow, and infiltration from sumps, respectively that were used in predictive simulations by NewFields (2021) were used in this predictive model. **Section 3.1.2** and **Table 4** describe the boundary condition setup simulating the increase in creek stage due to snowmelt and the existing sump configuration during a 2-year storm event. To simulate a 100-year high-flow creek event in Grant Creek, the peak stage values of River Package cells in June (Stress Period 8) were increased by 4 ft from baseflow (Stress Period 1), and head values for downgradient GHB cells were increased by 12 ft above baseflow (**Table 6**). Future full sump build-out is simulated by adding more Well Package cells (**Attachment B**, **Figure B-2**) and subsequently increasing the discharge rate during a 2-year or 100-year storm for 24 hours on June 13 (Stress Period 12) (**Table 6**).

Predictive simulations were run with and without realignment of the Horseshoe Bend section of Grant Creek. River Package cells in the pre-realignment simulation were replaced with River Package cells along the Horseshoe Bend Realignment. During a 2-year or 100-year creek flow event, the transient riverbed conductance term (K_r) is set to the hydraulic conductivity of the sediment material (5 ft/day) multiplied by the average engineered channel width (10 ft) when the creek stage is below the 3-foot channel depth. The transient K_r term is set to the hydraulic conductivity of the sediment material multiplied by the floodplain width (200 ft) when the creek stage is above 3 ft. It is assumed that water will flow through the engineered floodplain from May 10 through June 6 (Stress Periods 7 through 10) during a 2-year creek flow event and from May 3 through June 14 (Stress Periods 6 through 12) during a 100-year flow event.

4.2. Results

Predictive results indicate that realignment of the Horseshoe Bend will have minimal effect on peak water table elevations in the shallow groundwater system. **Figures 10** through **12** are maps showing the predicted minimum depth to groundwater (June 13, Stress Period 12) for all predictive scenarios (including all combinations of seasonal high creek flow and storm events, both with and without Grant Creek realignment). These figures were constructed by subtracting the simulated groundwater elevation from the 2019 LiDAR ground surface elevation (Quantum Spatial, Inc, 2019). Under all scenarios, predicted depth to water is generally:

- Less than 10 ft bgs within approximately 1,000 to 2,000 feet of Grant Creek and south of Mullan Road and Hiawatha Road.
- 10 to 20 ft bgs west of George Elmer Drive along the Flynn-Lowney Ditch (closed headgates).
- Greater than 20 ft bgs in the area bounded by England Boulevard, Flynn Lane, West Broadway, and Reserve Street.

Figures 13 through **15** show predicted peak groundwater elevation contours (June 13, Stress Period 12) with Grant Creek realignment under all predictive scenarios in the area bounded by England Boulevard, Flynn Lane, West Broadway, and Reserve Street. Groundwater elevations in the area between Flynn Lane and Grant Creek are 1 ft higher during a 2-year high-flow creek event with a 100-year storm discharge than during a 100-year high-flow creek event with a 2-year storm discharge, regardless of sump configuration.

Table 6: Predictive Transient Boundary Condition Setup

Stress Period	Cumulative Days	100-year Grant Creek Event Change from Steady-State (feet)		Future Sump Full Buildout Total Well Package Infiltration Rate [3] (cfd)	
		River Package [1]	General Head [2]	2-year Storm Event	100-year Storm Event
1	14	0	0	0	0
2	28	0.6	2.5	0	0
3	42	1.1	4.5	0	0
4	49	1.7	6	0	0
5	56	2.3	7.25	0	0
6	63	2.9	8.5	0	0
7	70	3.4	10	0	0
8	77	4.0	12	0	0
9	84	3.6	11	0	0
10	91	3.3	9.5	0	0
11	97	2.9	8	0	0
12	98	2.5	7	1,422,051	6,586,218
13	105	2.2	6	0	0
14	112	1.8	5	0	0
15	119	1.5	4	0	0
16	133	1.1	3	0	0
17	147	0.7	2	0	0
18	161	0.4	1	0	0
19	182	0	0	0	0
20	203	0	0	0	0

Notes:
cfd = cubic feet per day
[1] Reach 8 conditions shown here. See **Attachment B** (**Figure B-1** and **Tables B-1** through **B-3**) for reach locations and all reach parameterizations.
[2] Downgradient general head boundaries shown here. Upgradient general head boundaries are described in **Attachment B**, **Table B-4**
[3] 24-hour sump discharge simulated using well package cells.

5.0 SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Model calibration described in this report demonstrates this model is capable of simulating groundwater flow in the Study Area under a variety of conditions. The numerical model is appropriate for use in making stormwater management decisions in areas of future development as part of the Mullan BUILID Project.

The model matches all steady-state calibration targets (March 2020) within ±1.4 ft. The transient calibration matches the general timing and magnitude of seasonal water level changes at target locations.

Under all scenarios, predicted depth to water is generally:

- Less than 10 ft bgs along Grant Creek and south of Mullan Road and Hiawatha Road.
- Less than 10 ft bgs within approximately 1,000 to 2,000 feet of Grant Creek and south of Mullan Road and Hiawatha Road.
- Greater than 20 ft bgs in the area bounded by England Boulevard, Flynn Lane, West Broadway, and Reserve Street.

NewFields offers the following conclusion:

- Model results indicate that realignment of the Horseshoe Bend reach of Grant Creek will have minimal effect on water table elevations within the Study Area under any of the scenarios evaluated.
- Peak seasonal groundwater elevations near wells MMW4, WQD3, and WQD44 are likely overpredicted under all scenarios described in **Section 3.2.3** and should be considered conservative.

NewFields recommends that the model be updated in the future with additional groundwater elevation data and infiltration sump designs as they become available. Keeping the model current will increase its effectiveness as a tool for assessing future groundwater conditions and development plans.

6.0 REFERENCES

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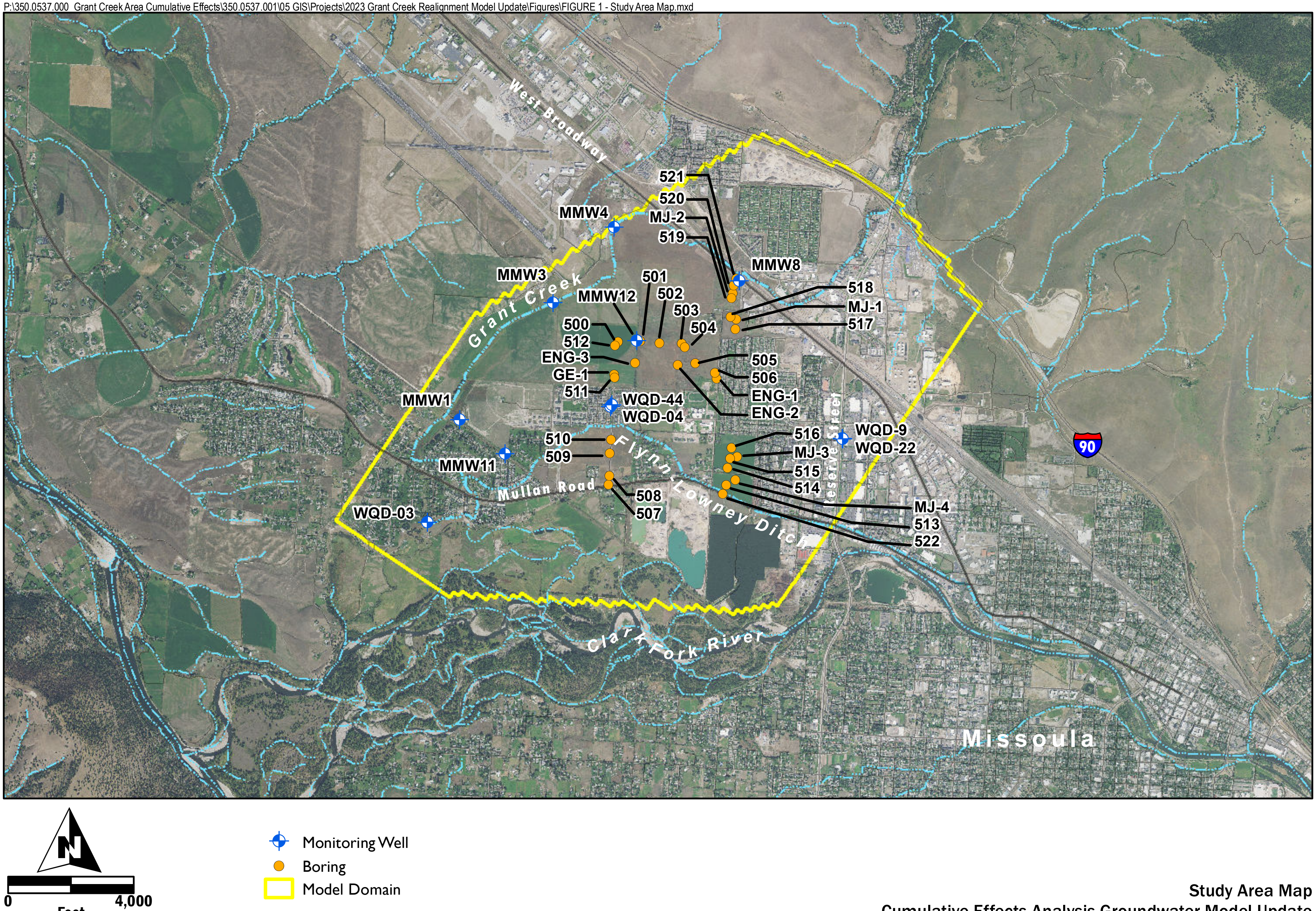
FIGURES

P:\350.0537.000 Grant Creek Area Cumulative Effects\350.0537.001\05 GIS\Projects\2023 Grant Creek Realignment Model Update\Figures\FIGURE 1 - Study Area Map.mxd

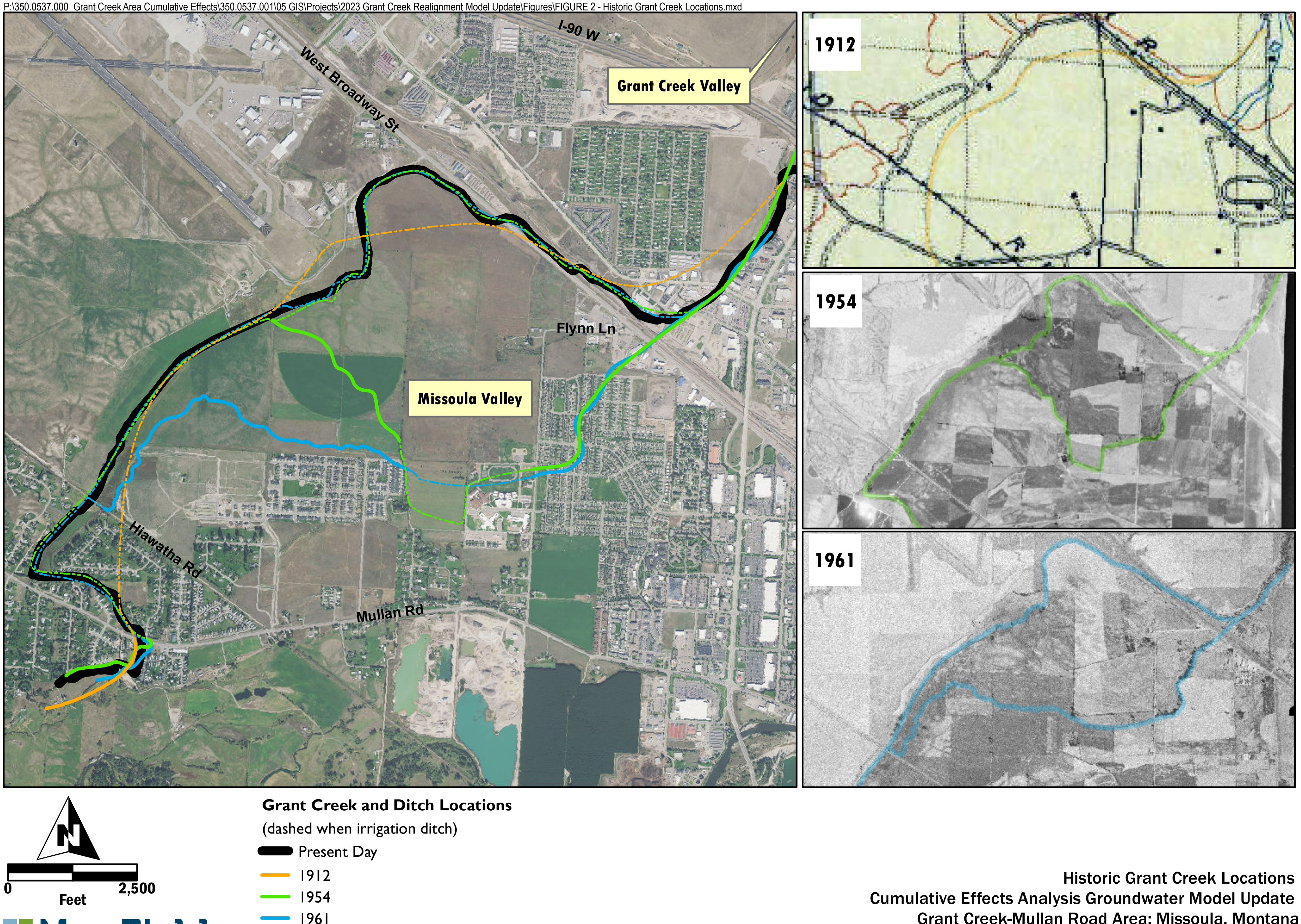


Monitoring Well
Boring
Model Domain

NewFields

Study Area Map
Cumulative Effects Analysis Groundwater Model Update
Grant Creek-Mullan Road Area; Missoula, Montana
FIGURE 1

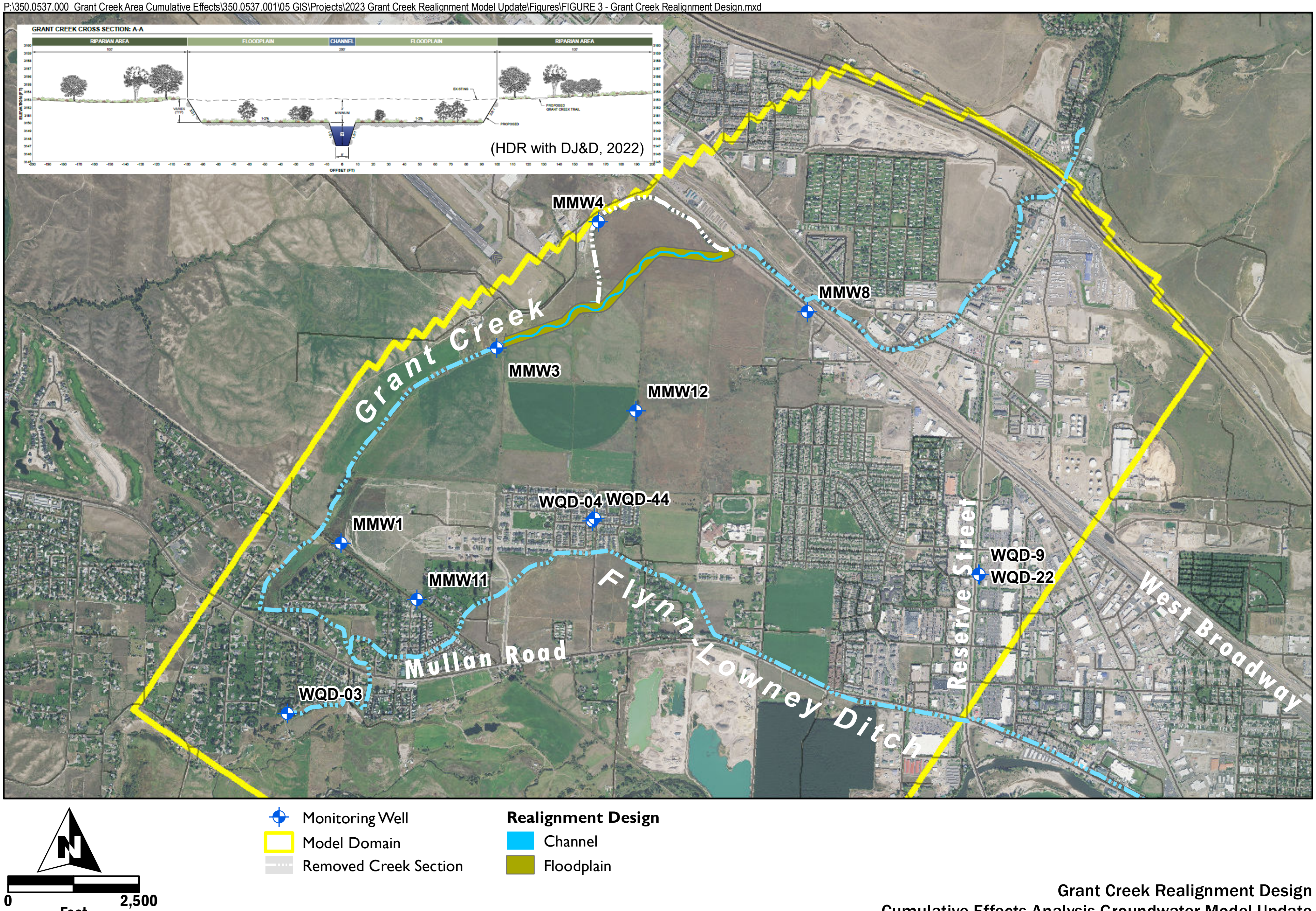
P:\350.0537.000 Grant Creek Area Cumulative Effects\350.0537.001\05 GIS\Projects\2023 Grant Creek Realignment Model Update\Figures\FIGURE 2 - Historic Grant Creek Locations.mxd



NewFields

Historic Grant Creek Locations
Cumulative Effects Analysis Groundwater Model Update
Grant Creek-Mullan Road Area; Missoula, Montana
FIGURE 2

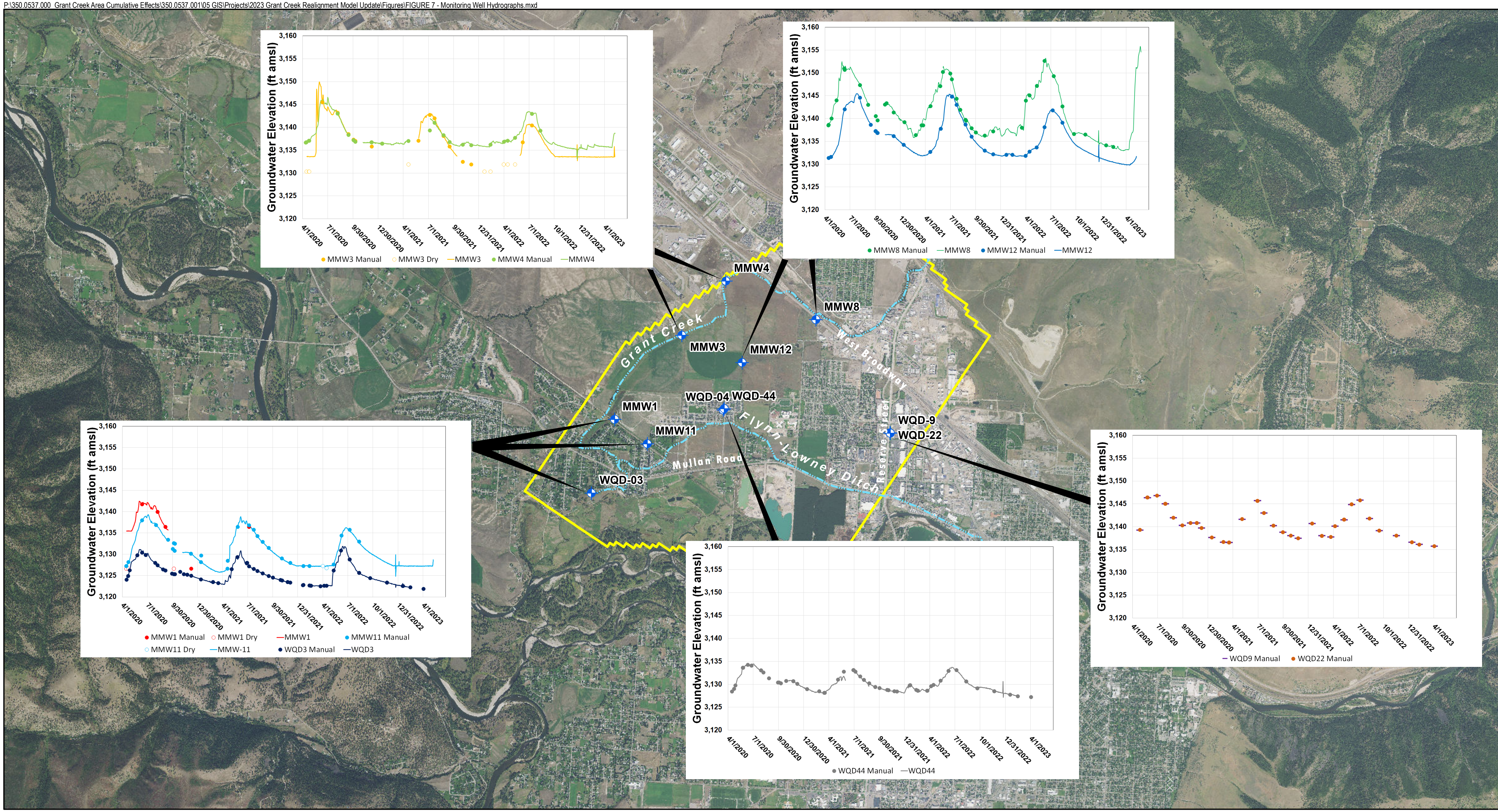
P:\350.0537.000 Grant Creek Area Cumulative Effects\350.0537.001\05 GIS\Projects\2023 Grant Creek Realignment Model Update\Figures\FIGURE 3 - Grant Creek Realignment Design.mxd



NewFields

Grant Creek Realignment Design
Cumulative Effects Analysis Groundwater Model Update
Grant Creek-Mullan Road Area; Missoula, Montana
FIGURE 3

P:\350.0537.000 Grant Creek Area Cumulative Effects\350.0537.001\05 GIS\Projects\2023 Grant Creek Realignment Model Update\Figures\FIGURE 7 - Monitoring Well Hydrographs.mxd



0 Feet 4,000

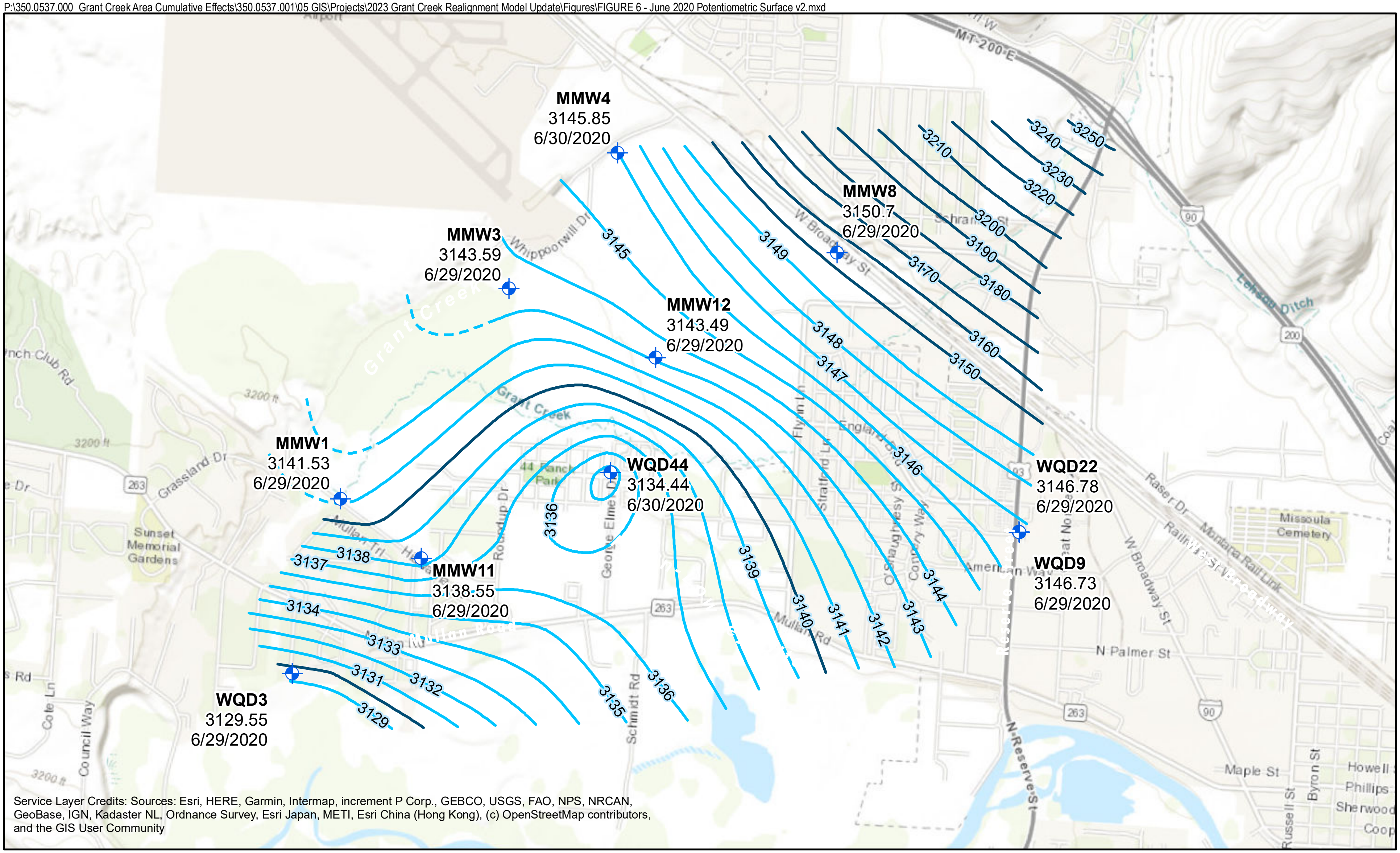
Monitoring Wells

Grant Creek Model Domain

NewFields

Monitoring Well Hydrographs
Cumulative Effects Analysis Groundwater Model Update
Grant Creek-Mullan Road Area; Missoula, Montana
FIGURE 4

P:\350.0537.000_Grant Creek Area Cumulative Effects\350.0537.001\05 GIS\Projects\2023 Grant Creek Realignment Model Update\Figures\FIGURE 6 - June 2020 Potentiometric Surface v2.mxd



Monitoring well, groundwater elevation (ft amsl), and measurement date

Groundwater Elevation Contours (ft amsl)

- 10 foot interval
- 1 foot interval (dashed where inferred)

N

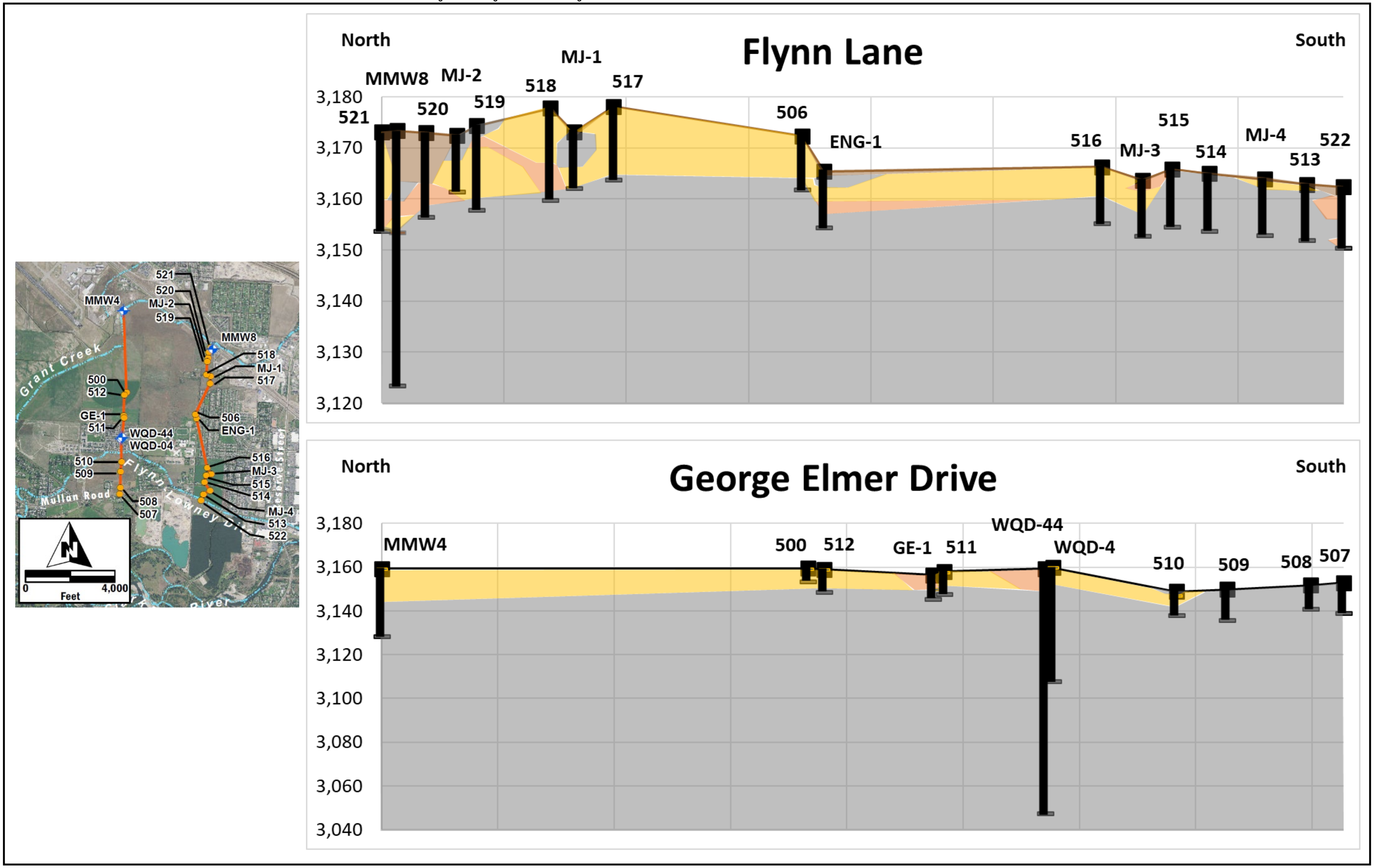
0 — 2,500 Feet

NewFields

Note: ft amsl = feet above mean sea level

June 2020 Potentiometric Surface
Cumulative Effects Analysis Groundwater Model Update
Grant Creek-Mullan Road Area; Missoula, Montana
FIGURE 5

P:\350.0537.000 Grant Creek Area Cumulative Effects\350.0537.001\03 REPORTS\2023 Grant Creek\Figures\Working\FIGURE 6 - Geologic Cross-Sections.docx

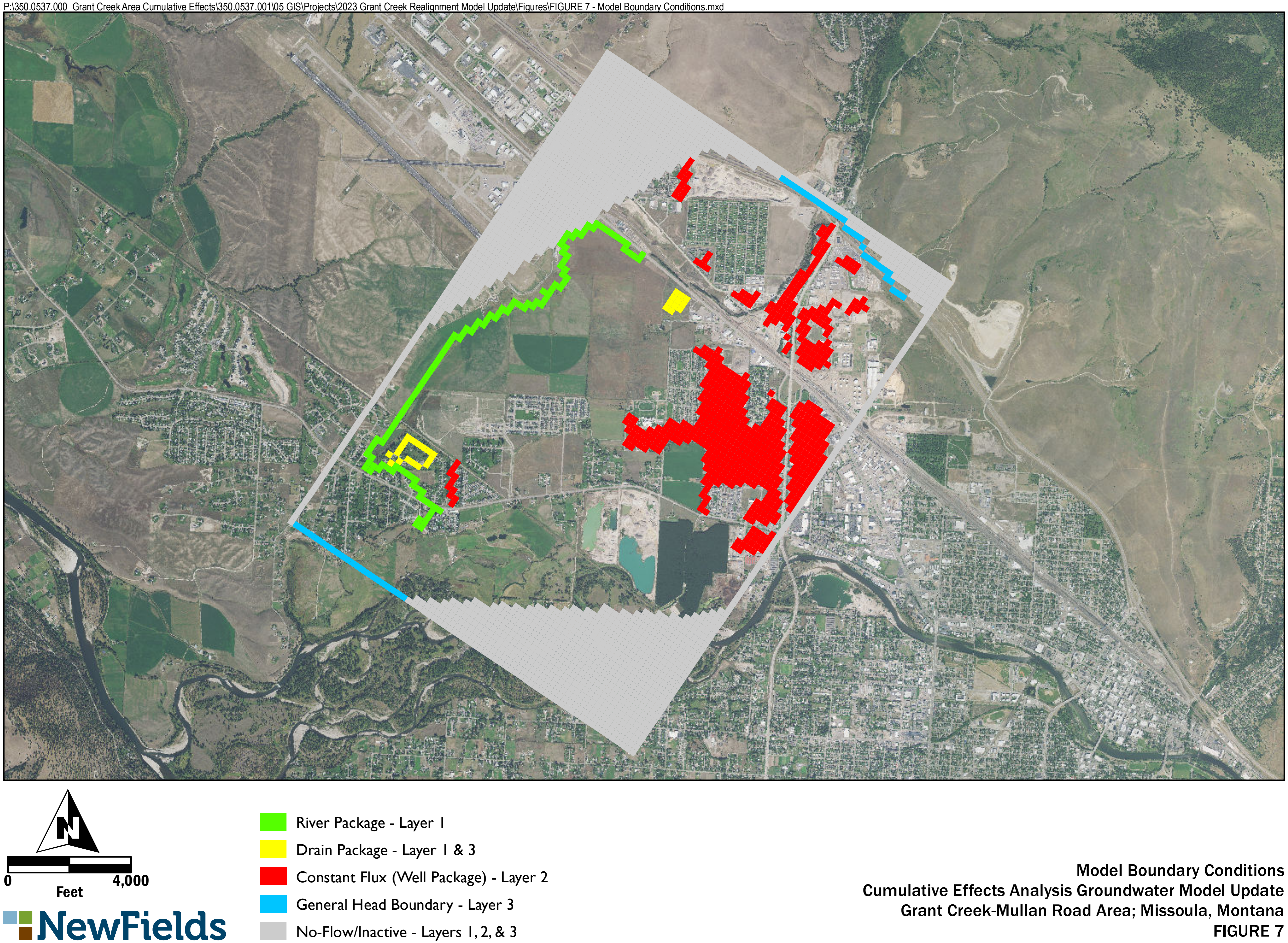


Topsoil/fill
Clay
Sand/silt
Gravel

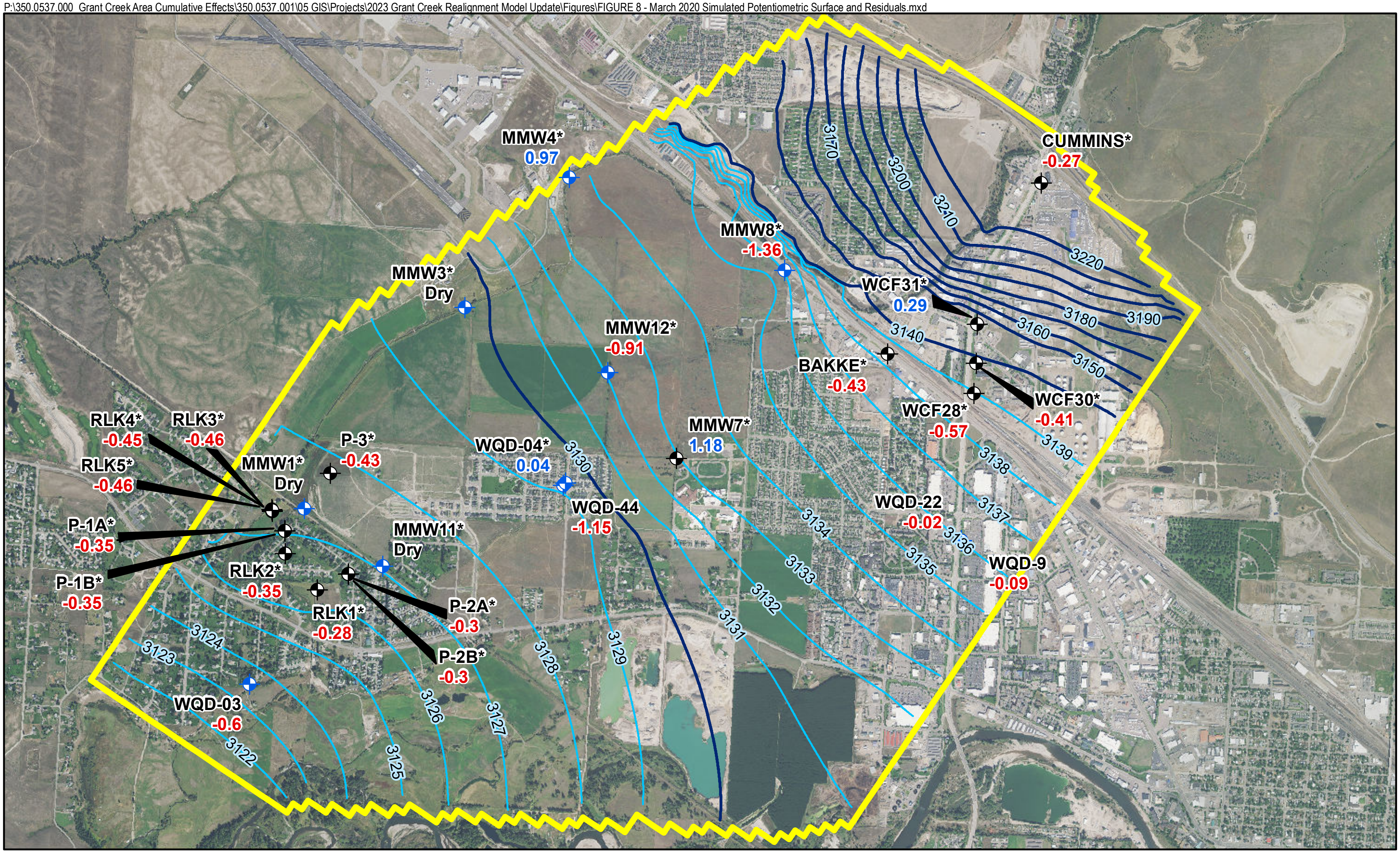
NewFields

Geologic Cross-Sections
Cumulative Effects Analysis Groundwater Model Update
Grant Creek-Mullan Road Area; Missoula, Montana
FIGURE 6

P:\350.0537.000 Grant Creek Area Cumulative Effects\350.0537.001\05 GIS\Projects\2023 Grant Creek Realignment Model Update\Figures\FIGURE 7 - Model Boundary Conditions.mxd



Model Boundary Conditions
Cumulative Effects Analysis Groundwater Model Update
Grant Creek-Mullan Road Area; Missoula, Montana
FIGURE 7



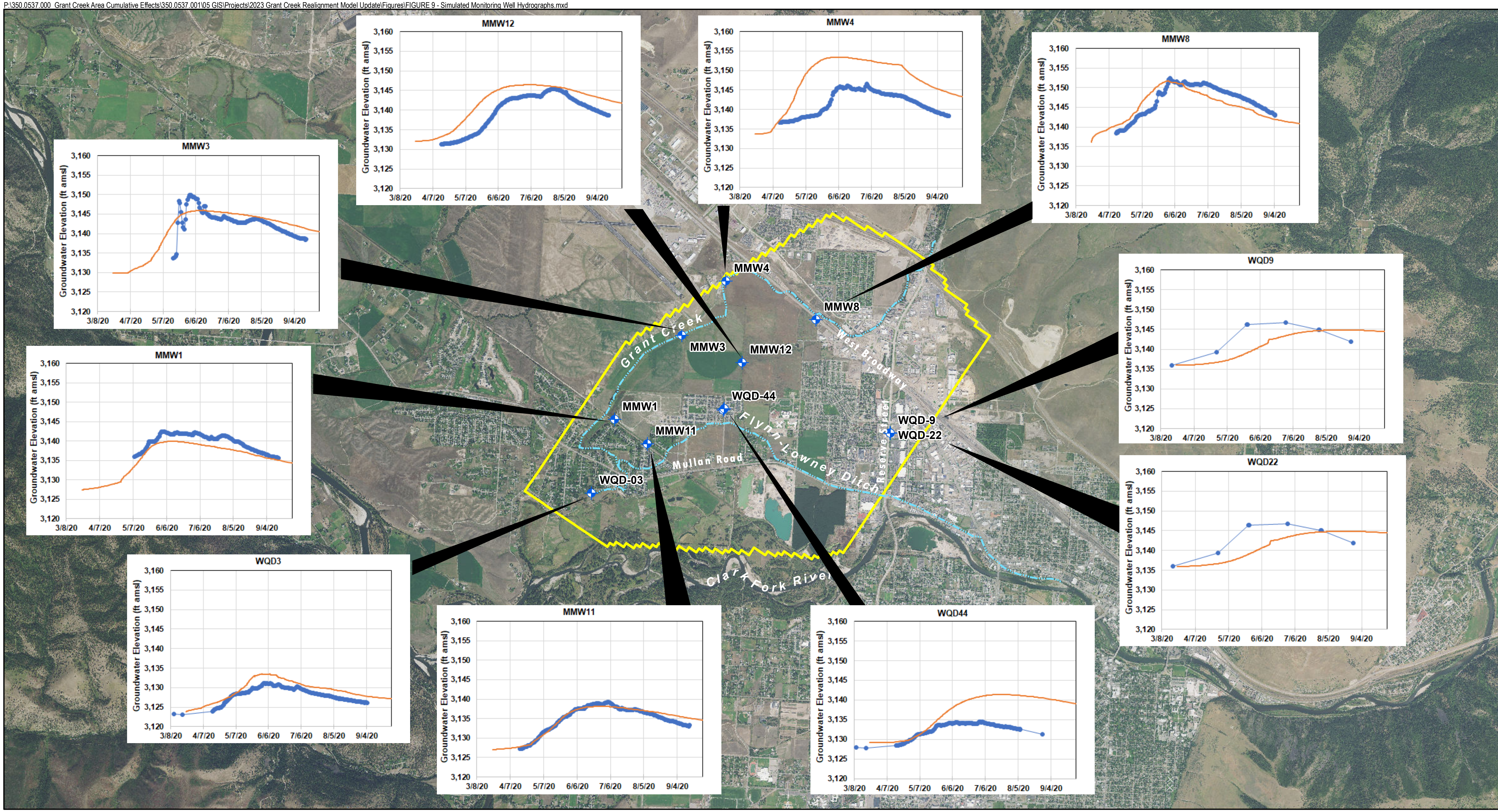
* March 2020 target data estimated by adding 1.24 feet to the March 2003 groundwater elevation. Wells are assumed to be dry in March 2020 if they were dry in March 2003.

- Monitoring well, residual (feet)
- Steady-state target, residual (feet)
- Model Domain
- Simulated groundwater elevation contour (10 foot interval)
- Simulated groundwater elevation contour (1 foot interval)

NewFields

March 2020 Simulated Potentiometric Surface and Residuals
Cumulative Effects Analysis Groundwater Model Update
Grant Creek-Mullan Road Area; Missoula, Montana
FIGURE 8

P:\350.0537.000_Grant Creek Area Cumulative Effects\350.0537.001\05 GIS\Projects\2023 Grant Creek Realignment Model Update\Figures\FIGURE 9 - Simulated Monitoring Well Hydrographs.mxd



Monitoring Wells

Grant Creek Model Domain

Observed Groundwater Elevation

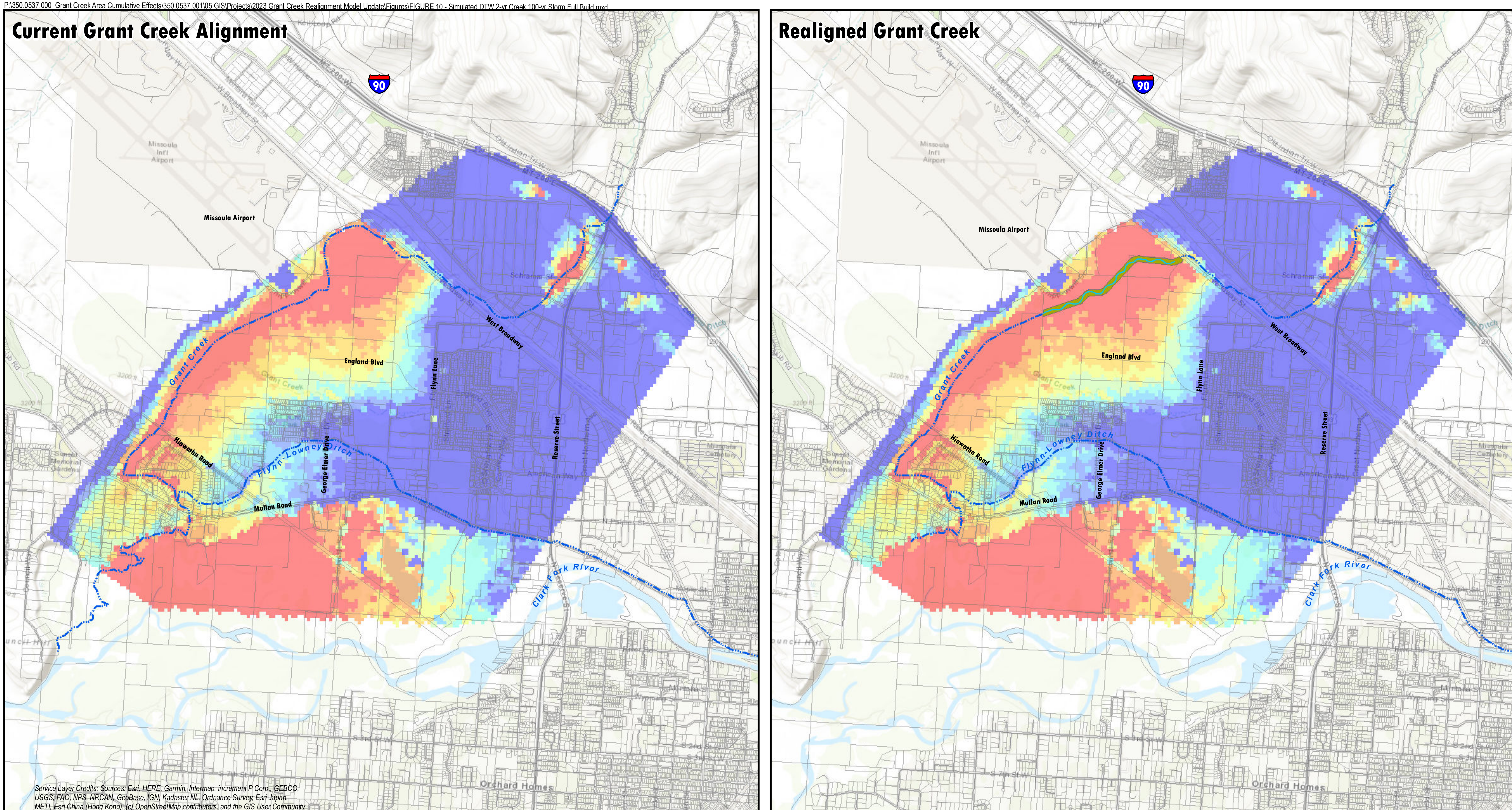
Simulated Groundwater Elevation

0 Feet 4,000

NewFields

Simulated Monitoring Well Hydrographs
Cumulative Effects Analysis Groundwater Model Update
Grant Creek-Mullan Road Area; Missoula, Montana
FIGURE 9

P:\350.0537.000 Grant Creek Area Cumulative Effects\350.0537.001\05 GIS\Projects\2023 Grant Creek Realignment Model Update\Figures\FIGURE 10 - Simulated DTW 2-yr Creek 100-yr Storm Full Build.mxd



N

0 Feet 3,000

NewFields

Depth to Groundwater (feet) Below Existing Ground Surface

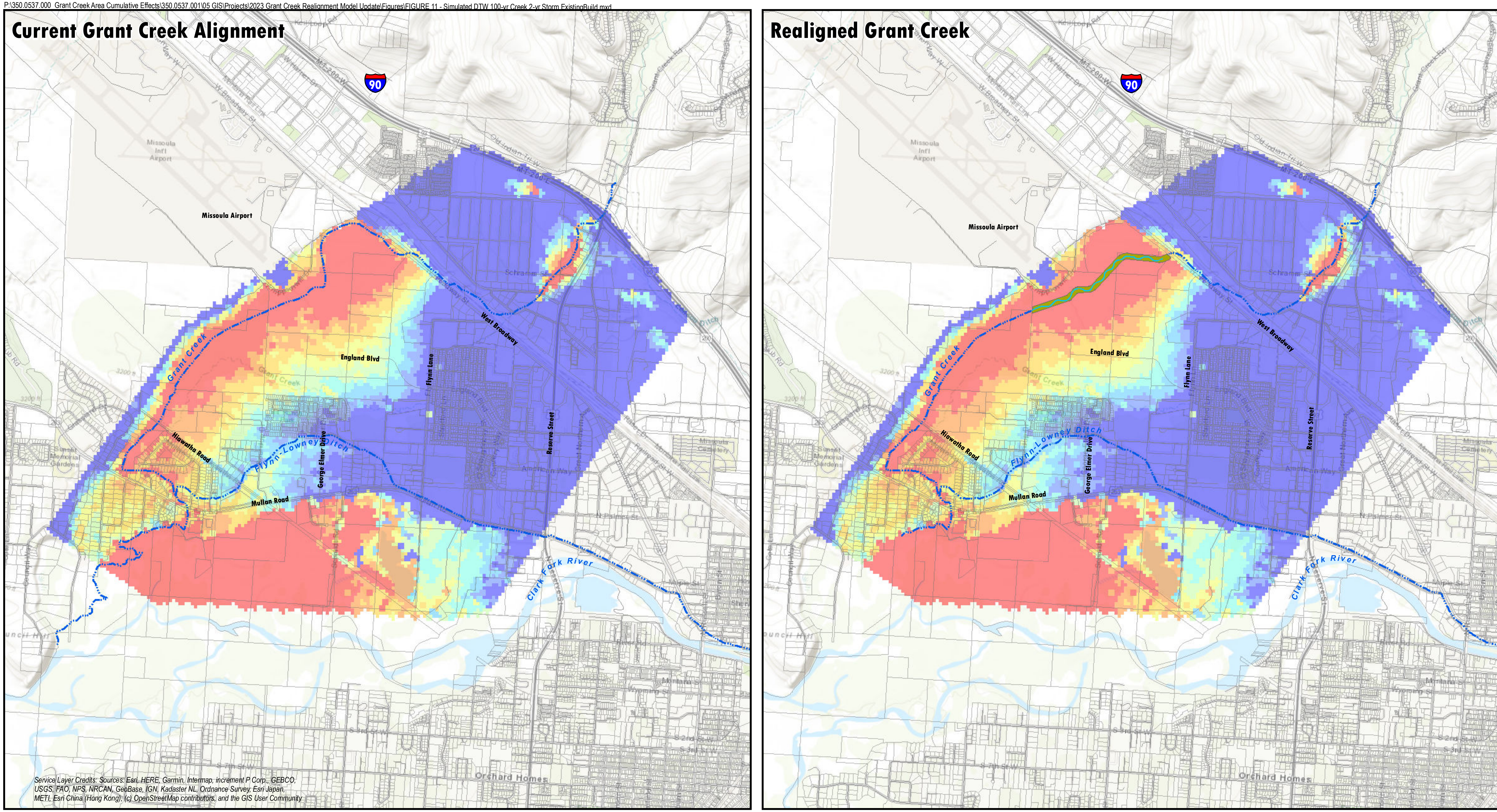
- <6
- 6 - 8
- 8 - 10
- 10 - 12
- 12 - 14
- 14 - 16
- 16 - 18
- 18 - 20
- >20

Realignment Design

- Channel
- Floodplain

Simulated Depth to Groundwater: 2-Year Creek Flow Event, 100-Year Storm Discharge, Full Build-out Sumps
Groundwater Modeling Study
Grant Creek-Mullan Road Area
Missoula, Montana
FIGURE 4-10

P:\350.0537.000 Grant Creek Area Cumulative Effects\350.0537.001\05 GIS\Projects\2023 Grant Creek Realignment Model Update\Figures\FIGURE 11 - Simulated DTW 100-yr Creek 2-yr Storm ExistingBuild.mxd



N
0 3,000
Feet

NewFields

Depth to Groundwater (feet) Below Existing Ground Surface

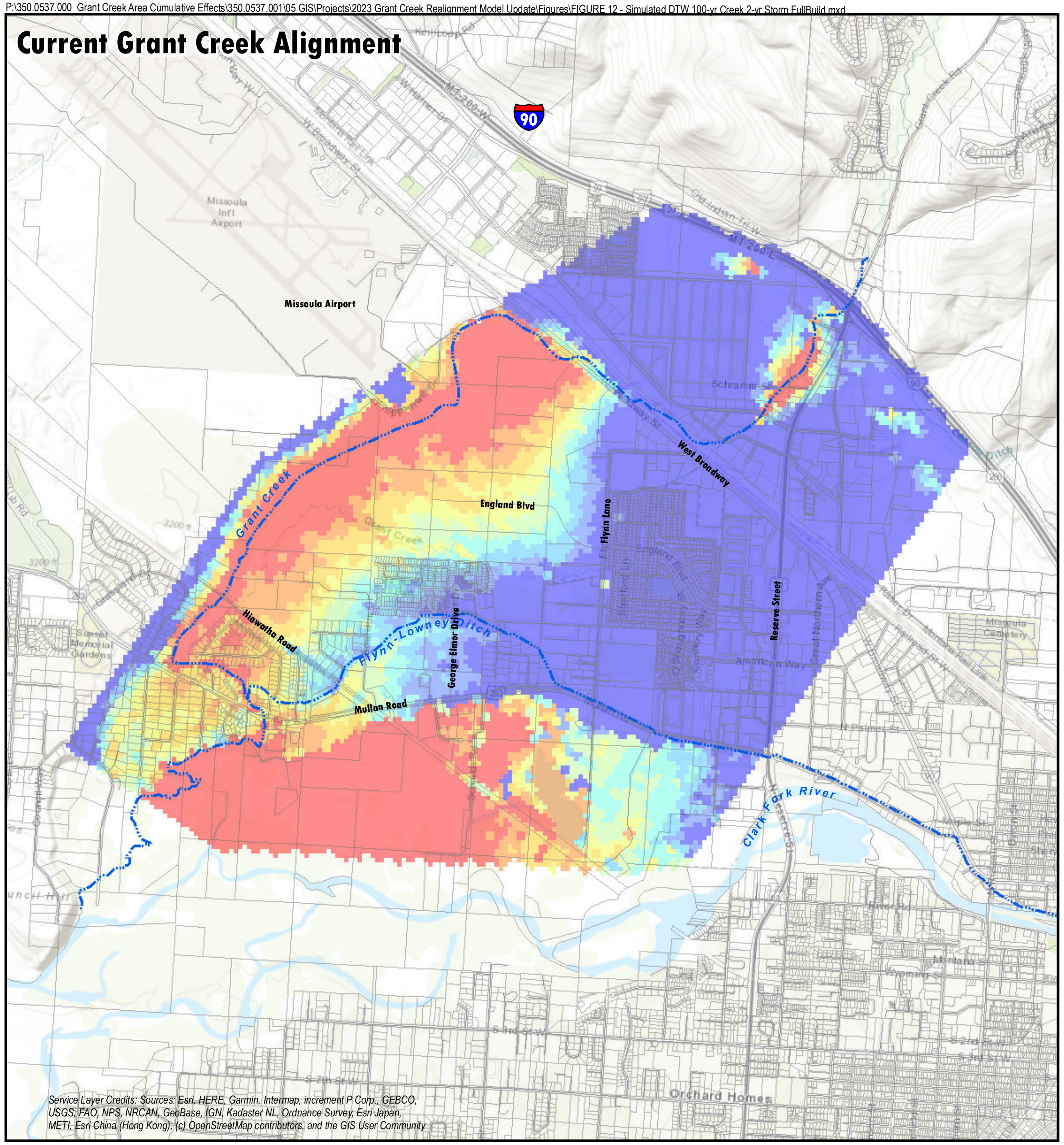
<6	10 - 12	16 - 18
6 - 8	12 - 14	18 - 20
8 - 10	14 - 16	>20

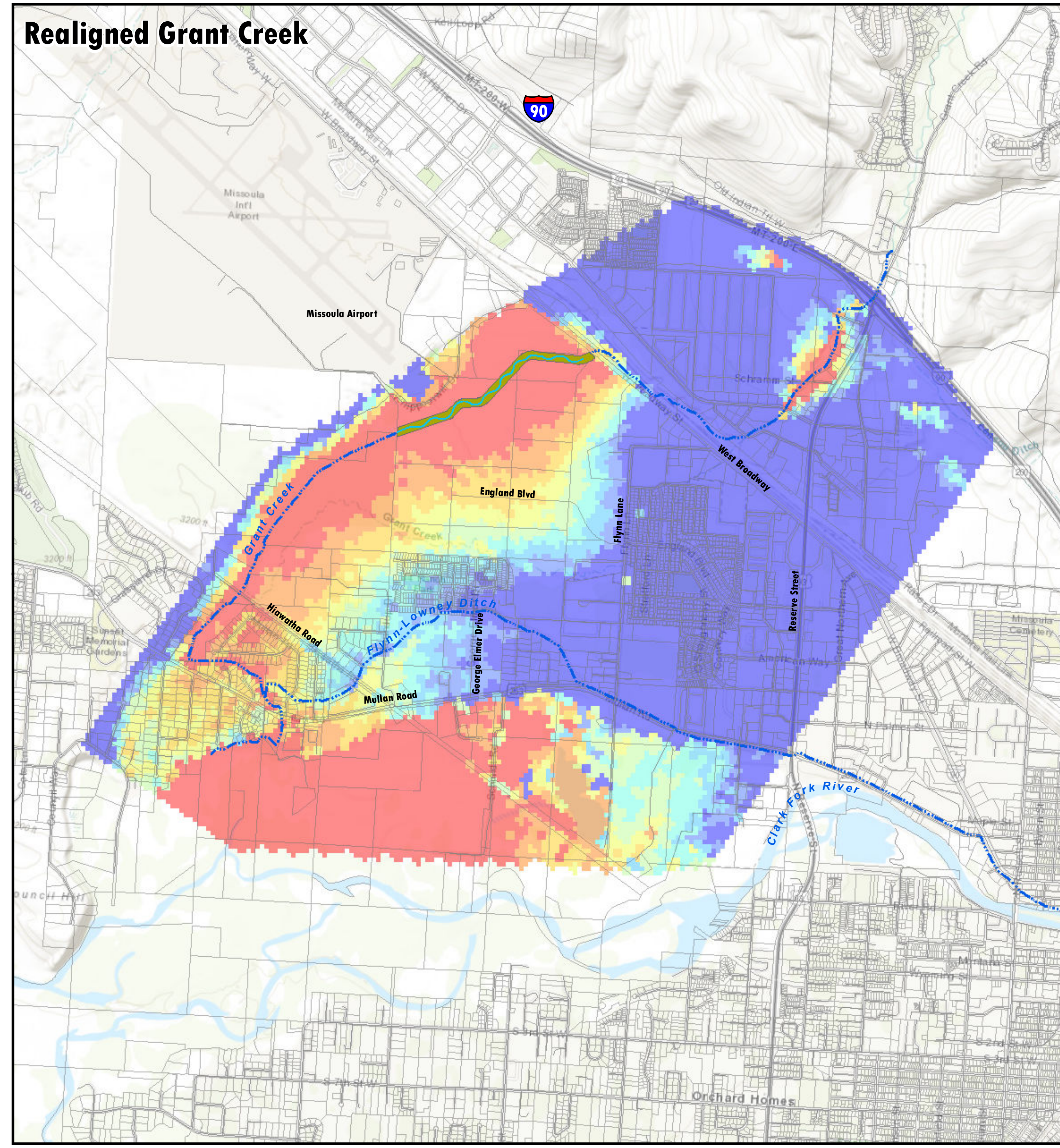
Realignment Design

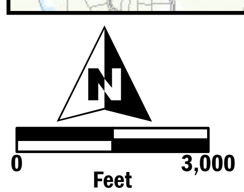
Channel
Floodplain

Simulated Depth to Groundwater: 100-Year Creek Flow Event, 2-Year Storm Discharge, Existing Sumps
Groundwater Modeling Study
Grant Creek-Mullan Road Area
Missoula, Montana
FIGURE 4-11

P:\350.0537.000 Grant Creek Area Cumulative Effects\350.0537.001\05 GIS\Projects\2023 Grant Creek Realignment Model Update\Figures\FIGURE 12 - Simulated DTW 100-yr Creek 2-yr Storm FullBuild.mxd







Depth to Groundwater (feet)
Below Existing Ground Surface

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

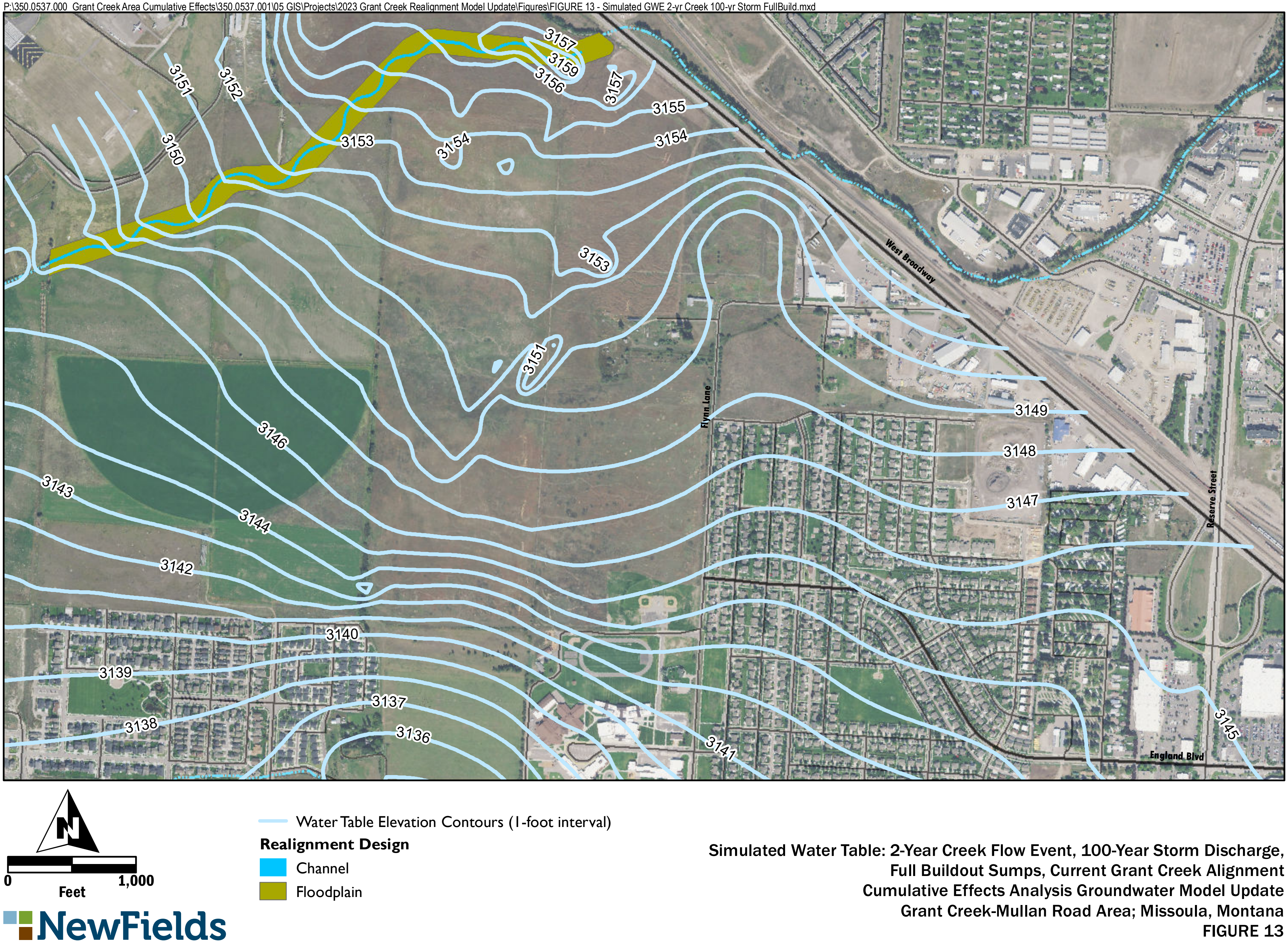
Realignment Design

- Channel
- Floodplain

NewFields

Simulated Depth to Groundwater: 100-Year Creek Flow Event, 2-Year Storm Discharge, Full Build-out Sumps
Groundwater Modeling Study
Grant Creek-Mullan Road Area
Missoula, Montana
FIGURE 4-12

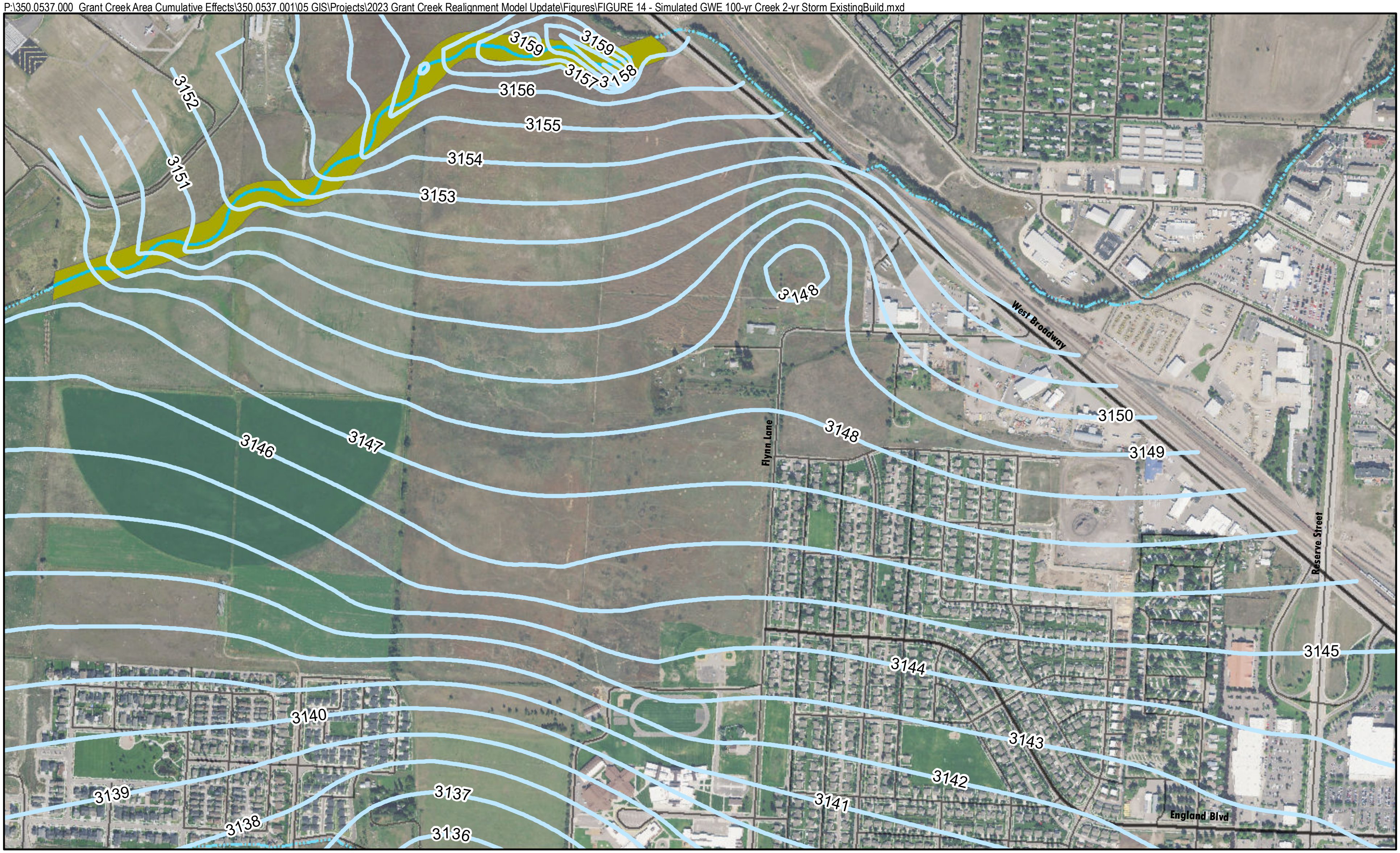
P:\350.0537.000 Grant Creek Area Cumulative Effects\350.0537.001\05 GIS\Projects\2023 Grant Creek Realignment Model Update\Figures\FIGURE 13 - Simulated GWE 2-yr Creek 100-yr Storm FullBuild.mxd

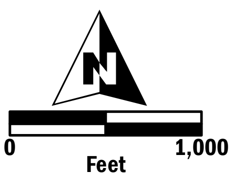


NewFields

Simulated Water Table: 2-Year Creek Flow Event, 100-Year Storm Discharge, Full Buildout Sumps, Current Grant Creek Alignment
Cumulative Effects Analysis Groundwater Model Update
Grant Creek-Mullan Road Area; Missoula, Montana
FIGURE 13

P:\350.0537.000 Grant Creek Area Cumulative Effects\350.0537.001\05 GIS\Projects\2023 Grant Creek Realignment Model Update\Figures\FIGURE 14 - Simulated GWE 100-yr Creek 2-yr Storm ExistingBuild.mxd





Water Table Elevation Contours (1-foot interval)

Realignment Design

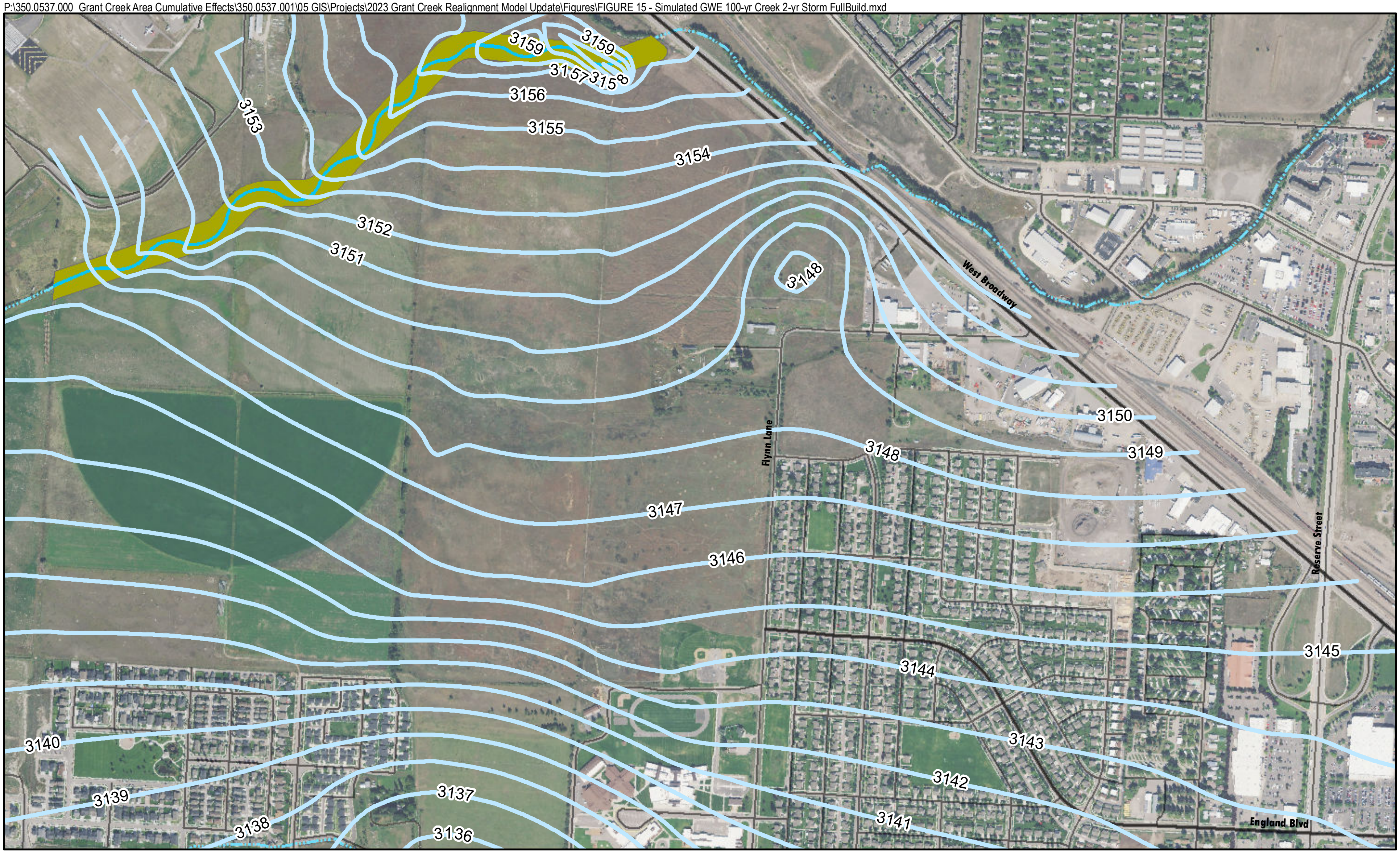
Channel

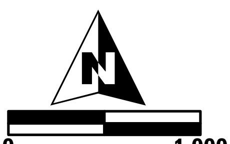
Floodplain

NewFields

Simulated Water Table: 100-Year Creek Flow Event, 2-Year Storm Discharge, Existing Sumps, Grant Creek Realignment
Cumulative Effects Analysis Groundwater Model Update
Grant Creek-Mullan Road Area; Missoula, Montana
FIGURE 14

P:\350.0537.000 Grant Creek Area Cumulative Effects\350.0537.001\05 GIS\Projects\2023 Grant Creek Realignment Model Update\Figures\FIGURE 15 - Simulated GWE 100-yr Creek 2-yr Storm FullBuild.mxd





Water Table Elevation Contours (1-foot interval)

Realignment Design

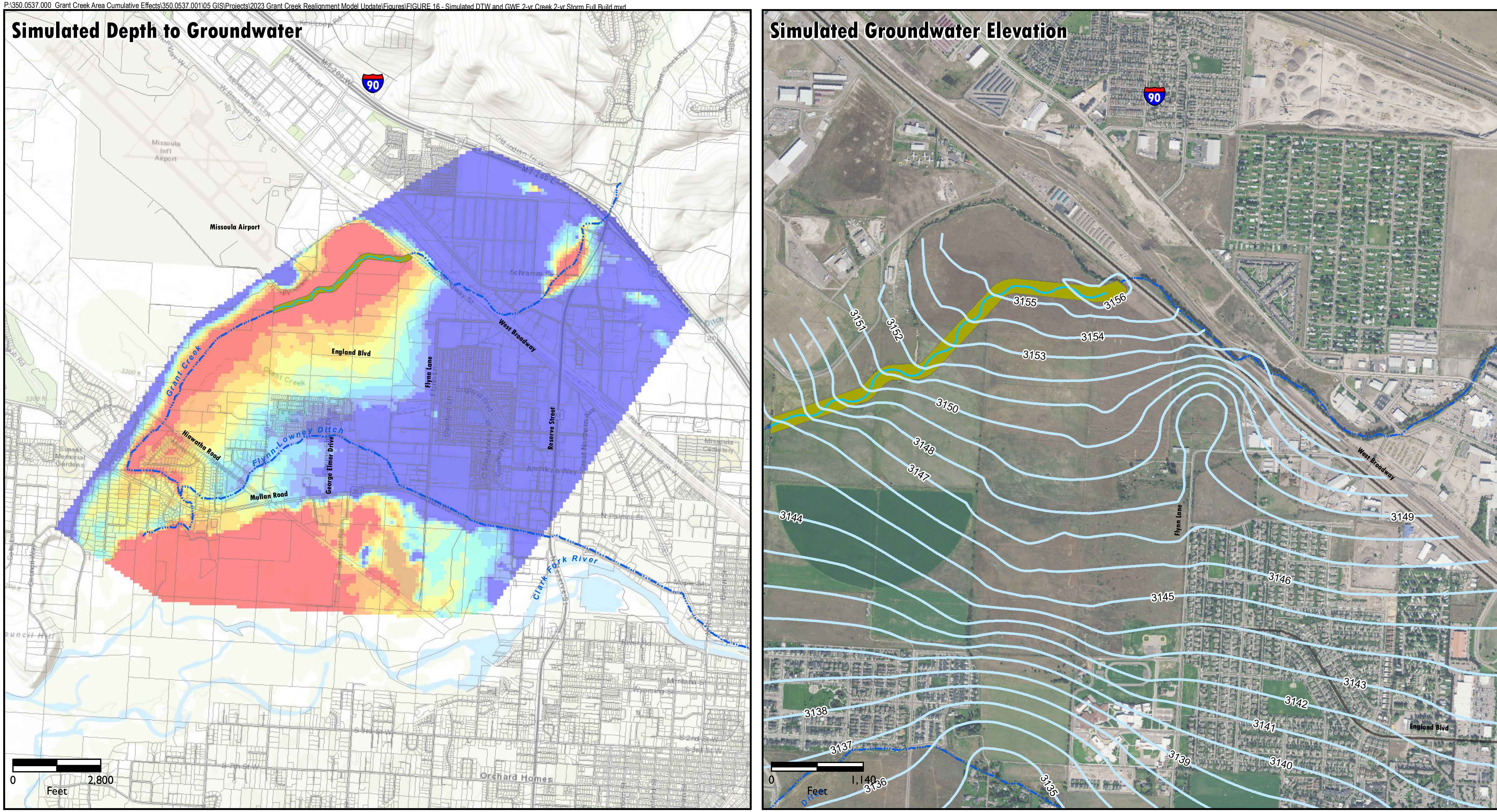
Channel

Floodplain

NewFields

Simulated Water Table: 100-Year Creek Flow Event, 2-Year Storm Discharge, Full Build-out Sumps, Grant Creek Realignment
Cumulative Effects Analysis Groundwater Model Update
Grant Creek-Mullan Road Area; Missoula, Montana
FIGURE 15

P:\350.0537.000 Grant Creek Area Cumulative Effects\350.0537.001\05 GIS\Projects\2023 Grant Creek Realignment Model Update\Figures\FIGURE 16 - Simulated DTW and GWE 2-yr Creek 2-yr Storm Full Build.mxd



Depth to Groundwater (feet)
Below Existing Ground Surface

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

Water Table Elevation Contours (1-foot interval)

Realignment Design

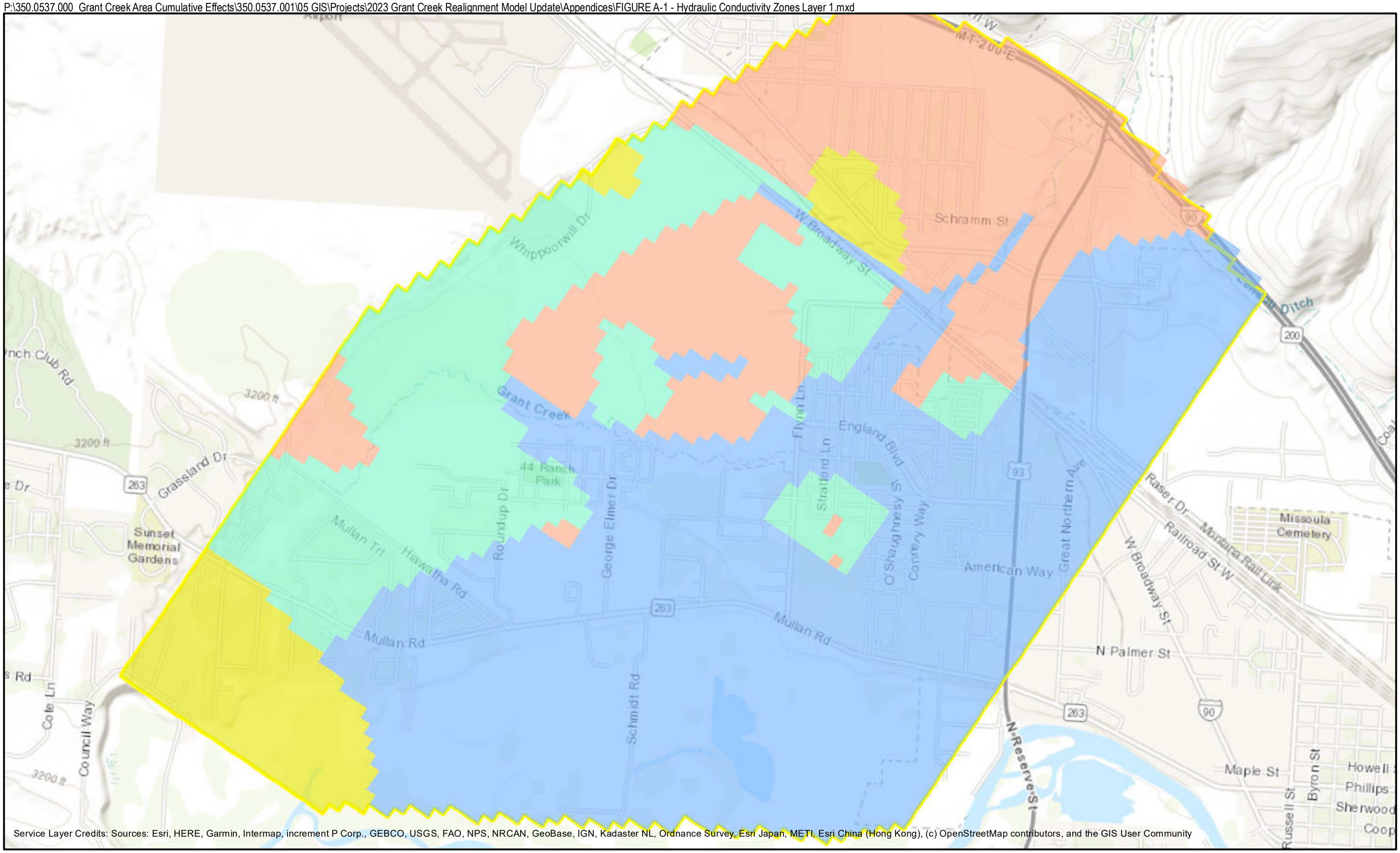
- Channel
- Floodplain

NewFields

Simulated Depth to Groundwater and Groundwater Elevation:
2-Year Creek Flow Event, 2-Year Storm Discharge, Full Build-out Sumps, Grant Creek Realignment
Cumulative Effects Analysis Groundwater Model Update
Grant Creek-Mullan Road Area; Missoula, Montana
FIGURE 16

ATTACHMENTS

P:\350.0537.000 Grant Creek Area Cumulative Effects\350.0537.001\05 GIS\Projects\2023 Grant Creek Realignment Model Update\Appendices\FIGURE A-1 - Hydraulic Conductivity Zones Layer 1.mxd



N

0 2,500
Feet

NewFields

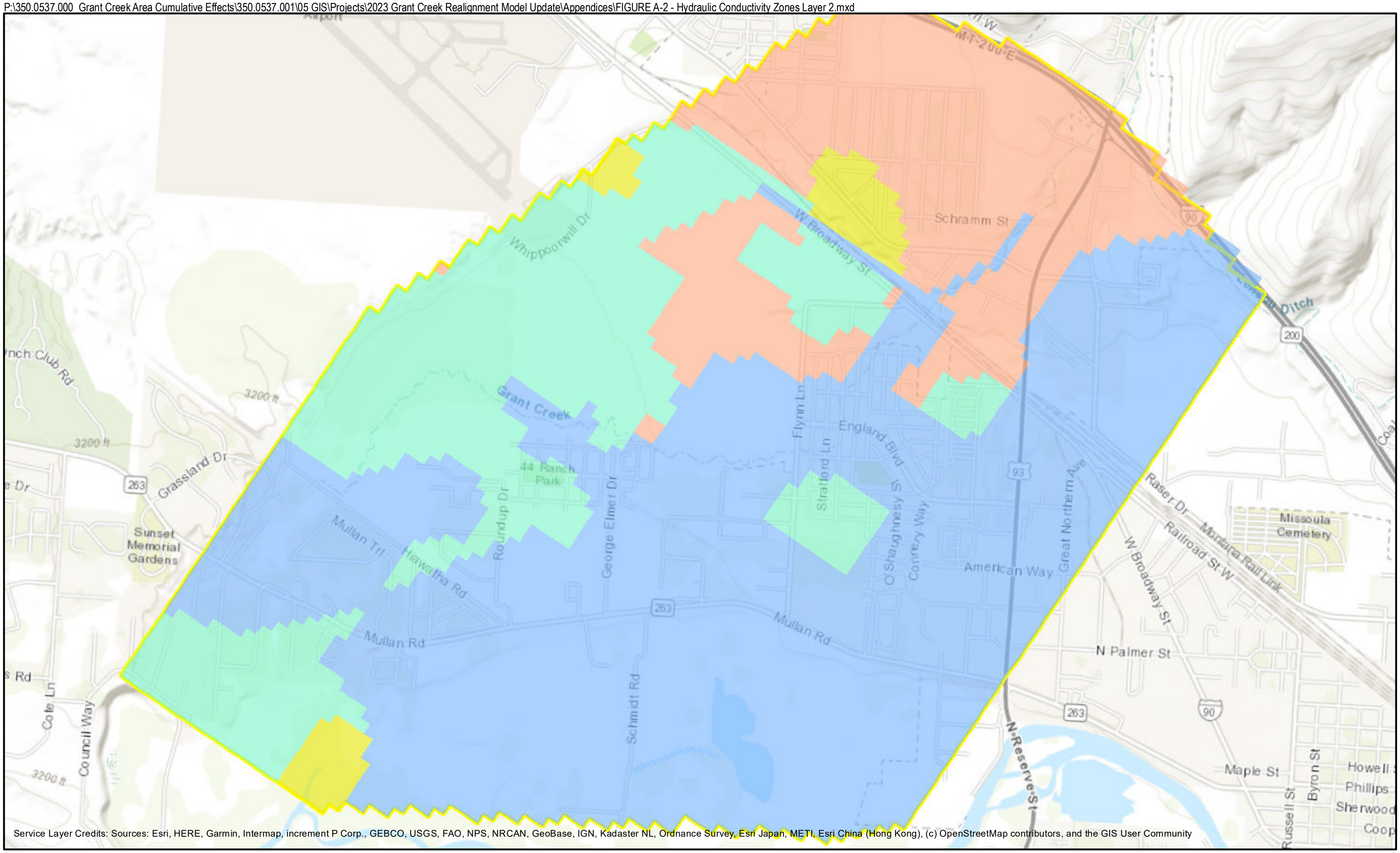
Model Domain

Hydraulic Conductivity Zone

- 1
- 2
- 3
- 4

Hydraulic Conductivity Zones - Layer 1
Cumulative Effects Analysis Groundwater Model Update
Grant Creek-Mullan Road Area; Missoula, Montana
FIGURE A-1

P:\350.0537.000 Grant Creek Area Cumulative Effects\350.0537.001\05 GIS\Projects\2023 Grant Creek Realignment Model Update\Appendices\FIGURE A-2 - Hydraulic Conductivity Zones Layer 2.mxd



Model Domain

Hydraulic Conductivity Zone

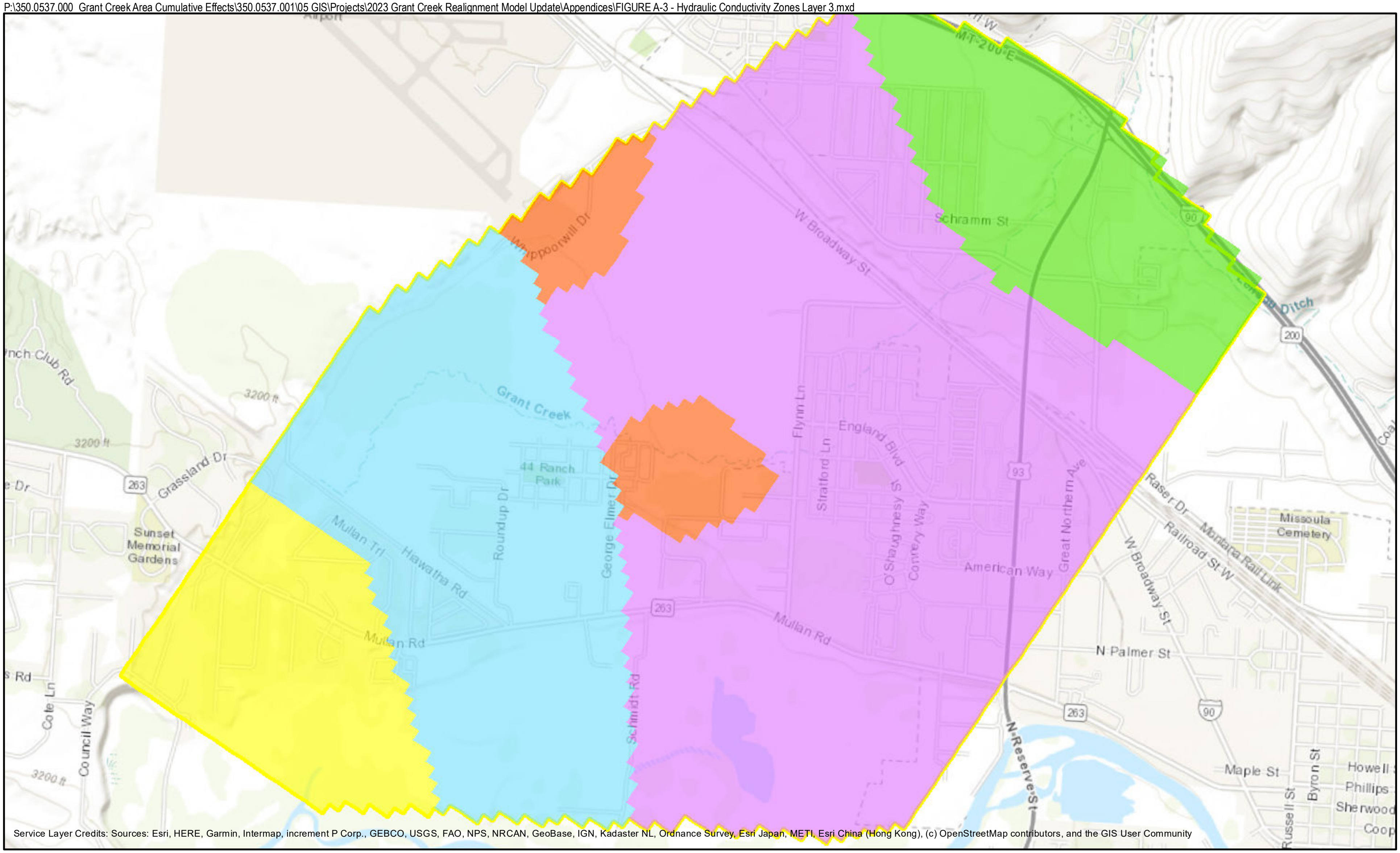
1 2 3 4

0 2,500 Feet

NewFields

Hydraulic Conductivity Zones - Layer 2
Cumulative Effects Analysis Groundwater Model Update
Grant Creek-Mullan Road Area; Missoula, Montana
FIGURE A-2

P:\350.0537.000 Grant Creek Area Cumulative Effects\350.0537.001\05 GIS\Projects\2023 Grant Creek Realignment Model Update\Appendices\FIGURE A-3 - Hydraulic Conductivity Zones Layer 3.mxd



Model Domain

Hydraulic Conductivity Zone

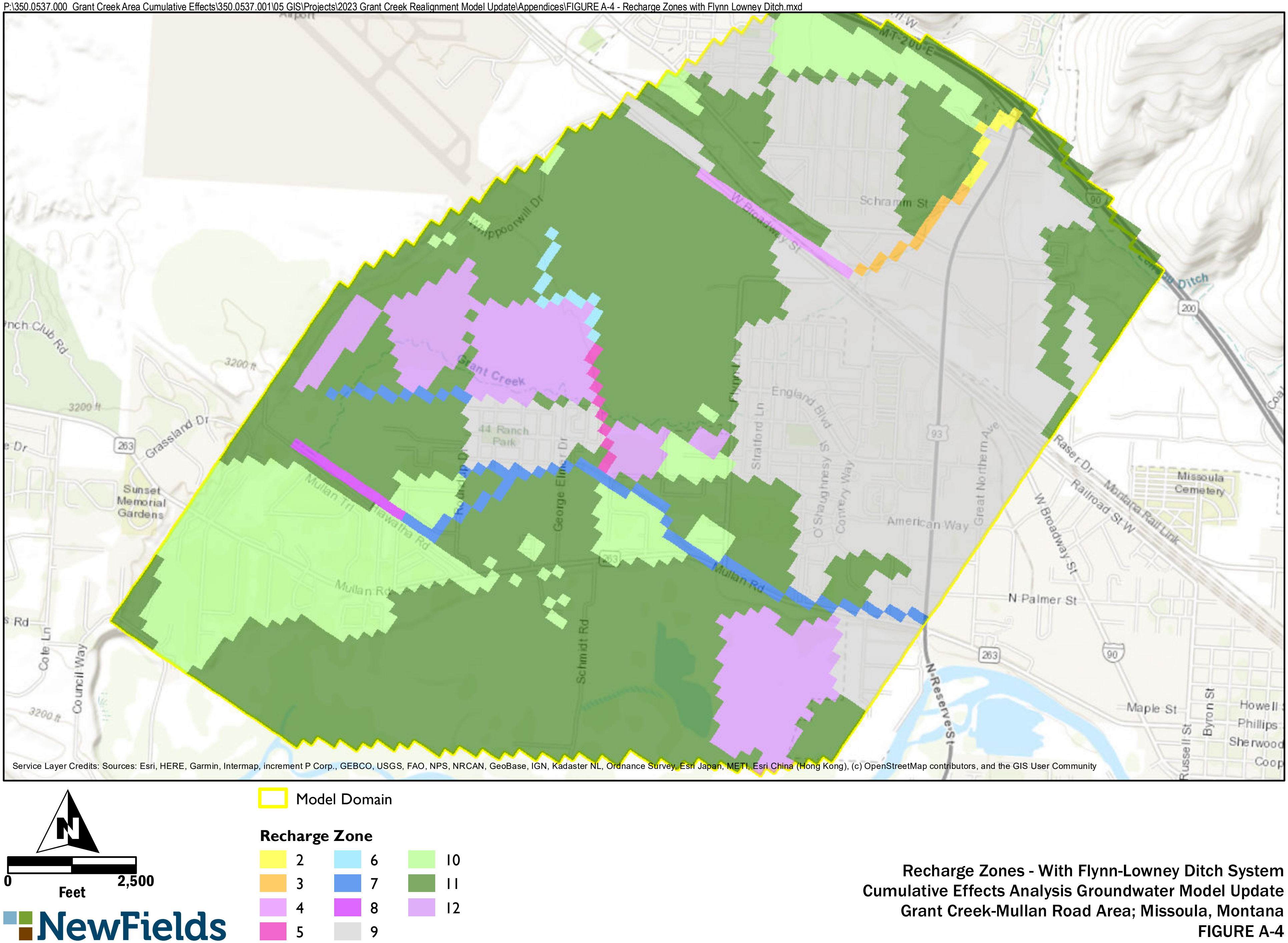
5	8	10
6	9	

0 Feet 2,500

NewFields

Hydraulic Conductivity Zones - Layer 3
Cumulative Effects Analysis Groundwater Model Update
Grant Creek-Mullan Road Area; Missoula, Montana
FIGURE A-3

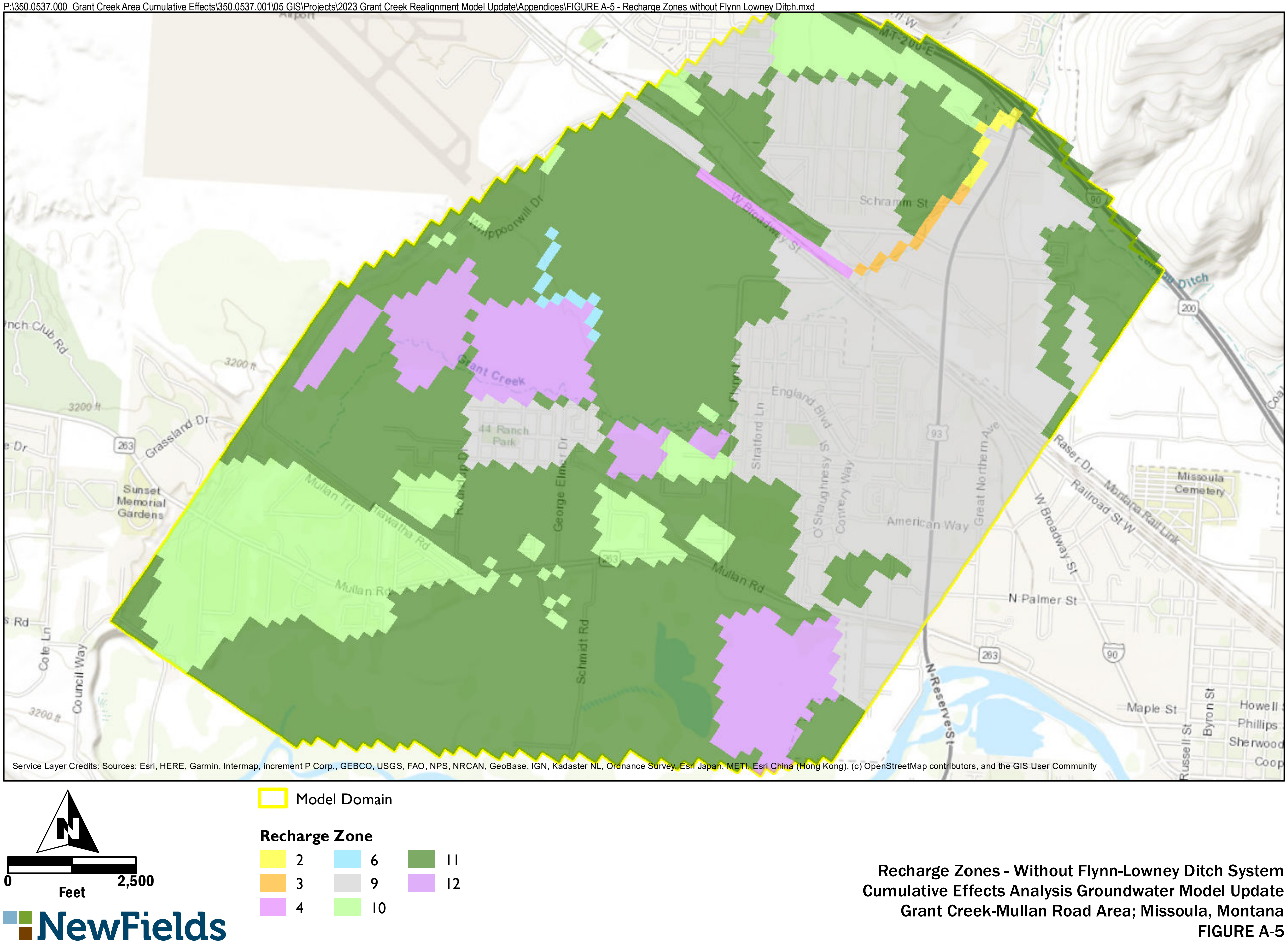
P:\350.0537.000 Grant Creek Area Cumulative Effects\350.0537.001\05 GIS\Projects\2023 Grant Creek Realignment Model Update\Appendices\FIGURE A-4 - Recharge Zones with Flynn Lowney Ditch.mxd



NewFields

Recharge Zones - With Flynn-Lowney Ditch System
Cumulative Effects Analysis Groundwater Model Update
Grant Creek-Mullan Road Area; Missoula, Montana
FIGURE A-4

P:\350.0537.000 Grant Creek Area Cumulative Effects\350.0537.001\05 GIS\Projects\2023 Grant Creek Realignment Model Update\Appendices\FIGURE A-5 - Recharge Zones without Flynn Lowney Ditch.mxd



NewFields

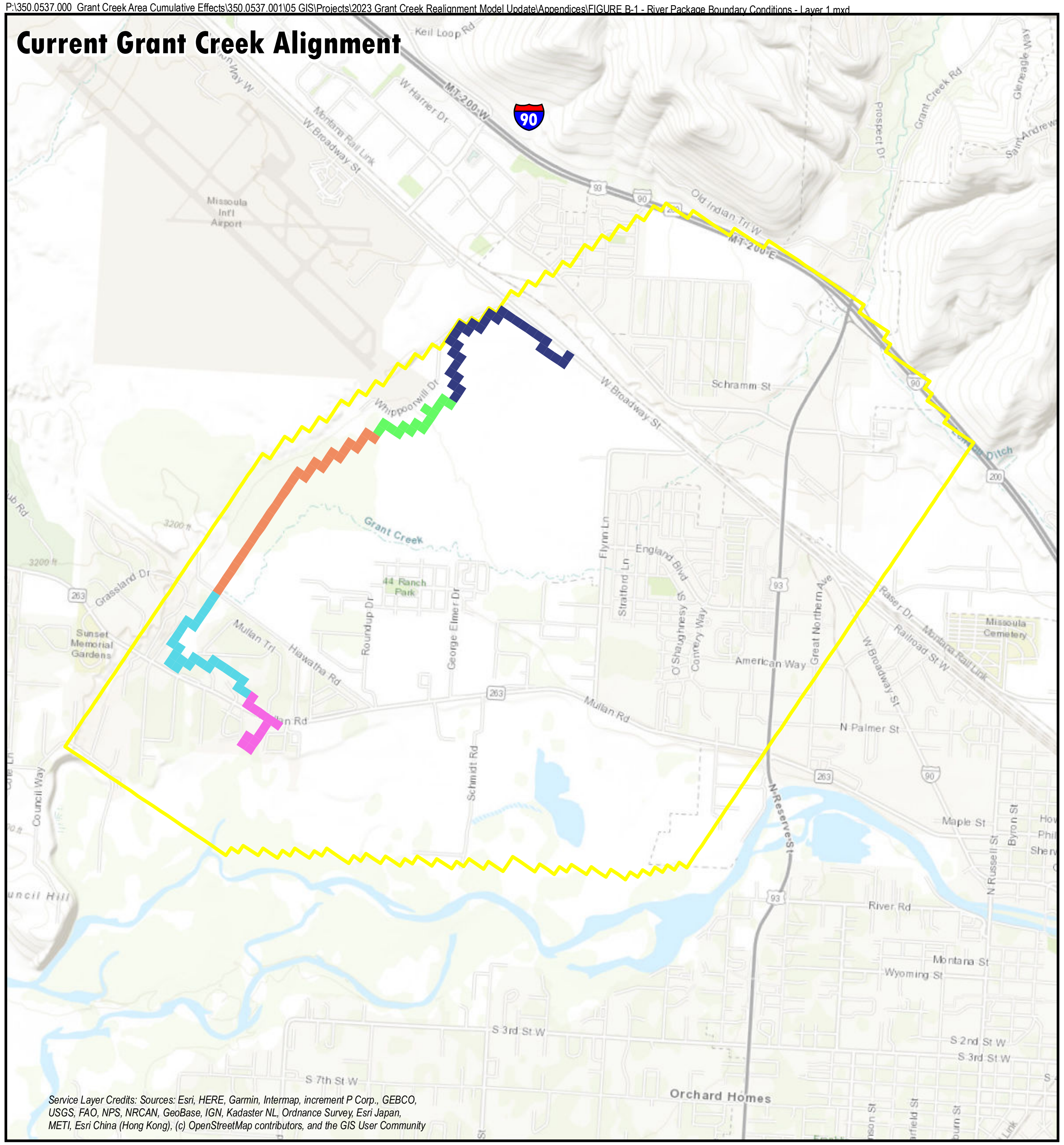
Recharge Zones - Without Flynn-Lowney Ditch System
Cumulative Effects Analysis Groundwater Model Update
Grant Creek-Mullan Road Area; Missoula, Montana
FIGURE A-5

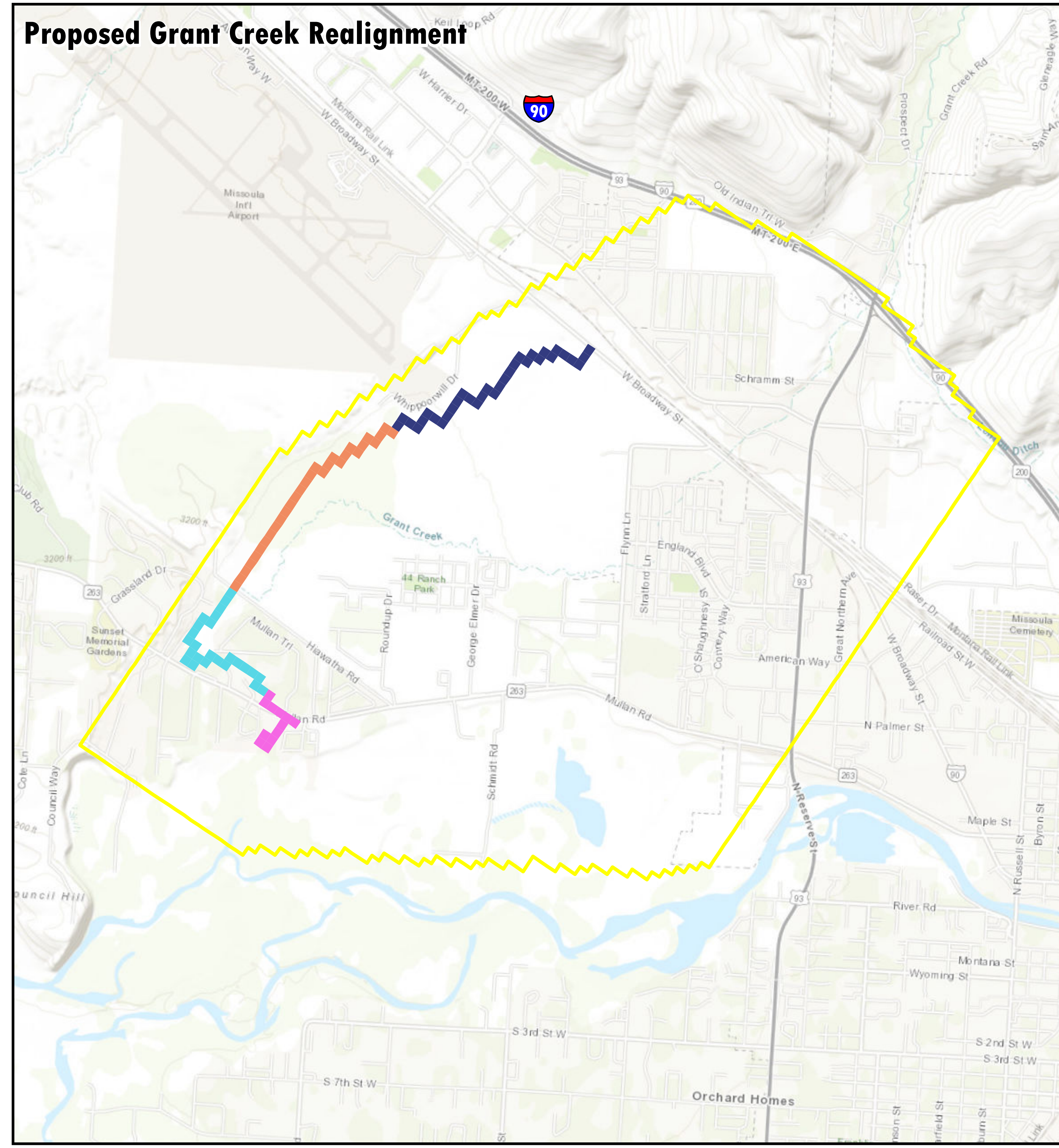
Table A-1. Transient Recharge Zones

		Upper Grant Creek	Upper Grant Creek	Upper Grant Creek	FLD - Upper Lateral	FLD - Laterals	Main FLD	Lower Main FLD	Densely Developed Area	Lightly Developed Area	Undeveloped Area	Irrigated Area
		Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9	Zone 10	Zone 11	Zone 12
		Recharge Rate (ft/d)										
Stress Period	1	1.5E-02	6.7E-02	1.6E-01	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.6E-06	8.9E-06	1.4E-05	1.3E-05
	2	3.4E-02	1.6E-01	3.8E-01	0.0E+00	0.0E+00	0.0E+00	0.0E+00	4.2E-05	1.0E-04	1.7E-04	1.5E-04
	3	3.8E-02	1.7E-01	4.2E-01	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.6E-04	4.1E-04	6.5E-04	5.9E-04
	4	4.3E-02	2.0E-01	4.8E-01	0.0E+00	0.0E+00	0.0E+00	0.0E+00	5.7E-05	1.4E-04	2.3E-04	2.1E-04
	5	5.4E-02	2.5E-01	6.0E-01	3.3E-02	8.2E-02	9.8E-02	2.0E-01	1.3E-05	3.2E-05	5.1E-05	4.6E-05
	6	7.0E-02	3.2E-01	7.8E-01	3.0E-02	7.4E-02	8.8E-02	1.8E-01	4.8E-06	1.2E-05	1.9E-05	7.9E-04
	7	7.2E-02	3.3E-01	8.0E-01	3.0E-02	7.4E-02	8.8E-02	1.8E-01	2.5E-04	6.1E-04	9.8E-04	7.9E-04
	8	7.8E-02	3.6E-01	8.7E-01	2.6E-02	6.6E-02	7.9E-02	1.6E-01	3.1E-04	7.7E-04	1.2E-03	7.9E-04
	9	6.5E-02	3.0E-01	8.7E-01	2.6E-02	6.6E-02	7.9E-02	1.6E-01	7.6E-06	1.9E-05	3.1E-05	7.9E-04
	10	5.8E-02	2.7E-01	7.2E-01	2.3E-02	5.7E-02	6.9E-02	1.4E-01	1.9E-05	4.8E-05	7.7E-05	1.5E-03
	11	4.4E-02	2.0E-01	6.4E-01	2.1E-02	5.3E-02	6.4E-02	1.3E-01	7.5E-05	1.9E-04	3.0E-04	3.2E-03
	12	3.9E-02	1.8E-01	4.9E-01	2.1E-02	5.3E-02	6.4E-02	1.3E-01	1.5E-05	3.8E-05	6.0E-05	3.2E-03
	13	3.7E-02	1.7E-01	4.4E-01	2.0E-02	4.9E-02	5.9E-02	1.2E-01	1.7E-05	4.3E-05	6.9E-05	3.2E-03
	14	3.1E-02	1.4E-01	4.2E-01	1.8E-02	4.5E-02	5.4E-02	1.1E-01	1.1E-05	2.9E-05	4.6E-05	3.2E-03
	15	2.4E-02	1.1E-01	3.4E-01	1.8E-02	4.5E-02	5.4E-02	1.1E-01	4.4E-04	1.1E-03	1.8E-03	4.6E-03
	16	1.7E-02	7.9E-02	2.7E-01	1.6E-02	4.1E-02	4.9E-02	1.0E-01	2.6E-05	6.4E-05	1.0E-04	4.6E-03
	17	1.7E-02	7.9E-02	1.9E-01	1.6E-02	4.1E-02	4.9E-02	1.0E-01	0.0E+00	0.0E+00	0.0E+00	4.6E-03
	18	1.0E-02	4.7E-02	1.9E-01	1.3E-02	3.3E-02	3.9E-02	8.2E-02	0.0E+00	0.0E+00	0.0E+00	3.8E-03
	19	1.0E-02	4.7E-02	1.1E-01	1.2E-02	2.9E-02	3.4E-02	7.2E-02	2.4E-05	6.0E-05	9.7E-05	3.8E-03
	20	1.0E-02	4.7E-02	1.1E-01	9.8E-03	2.5E-02	3.0E-02	6.1E-02	1.8E-05	4.4E-05	7.1E-05	9.3E-04

Note: ft/d = feet per day

P:\350.0537.000 Grant Creek Area Cumulative Effects\350.0537.001\05 GIS\Projects\2023 Grant Creek Realignment Model Update\Appendices\FIGURE B-1 - River Package Boundary Conditions - Layer 1.mxd





0 Feet 3,000

NewFields

Model Domain

River Package Zone

- 5
- 6
- 7
- 8
- 9

River Package Boundary Conditions - Layer 1
Groundwater Modeling Study
Grant Creek-Mullan Road Area
Missoula, Montana
FIGURE B-1

Table B-1. River Package Conductance Values - Current Grant Creek Alignment

Row	Column	Layer	Reach	Channel Bottom Elevation (ft amsl)	Length (ft)	Width (ft)	Thickness (ft)	K_r (ft/d)	Conductance (ft^2/d)
25	15	1	5	3154.3	109	1	1	2.36E+01	2572.4
25	16	1	5	3154.7	207	1	1	2.36E+01	4885.2
25	17	1	5	3155.2	200	1	1	2.36E+01	4720.0
25	18	1	5	3155.6	201	1	1	2.36E+01	4743.6
25	19	1	5	3156.1	201	1	1	2.36E+01	4743.6
25	20	1	5	3156.6	206	1	1	2.36E+01	4861.6
25	21	1	5	3157.1	202	1	1	2.36E+01	4767.2
25	24	1	5	3158.6	181	1	1	2.36E+01	4271.6
26	14	1	5	3153.6	199	1	1	2.36E+01	4696.4
26	15	1	5	3154.0	121	1	1	2.36E+01	2855.6
26	21	1	5	3157.4	12	1	1	2.36E+01	283.2
26	22	1	5	3157.6	204	1	1	2.36E+01	4814.4
26	23	1	5	3158.2	205	1	1	2.36E+01	4838.0
26	24	1	5	3158.5	66	1	1	2.36E+01	1557.6
27	14	1	5	3153.1	203	1	1	2.36E+01	4790.8
28	13	1	5	3152.5	223	1	1	2.36E+01	5262.8
28	14	1	5	3152.8	48	1	1	2.36E+01	1132.8
29	12	1	5	3151.9	158	1	1	2.36E+01	3728.8
29	13	1	5	3152.2	66	1	1	2.36E+01	1557.6
30	12	1	5	3151.5	201	1	1	2.36E+01	4743.6
31	12	1	5	3151.1	133	1	1	2.36E+01	3138.8
31	13	1	5	3150.8	100	1	1	2.36E+01	2360.0
32	13	1	5	3150.5	167	1	1	2.36E+01	3941.2
32	14	1	5	3150.1	129	1	1	2.36E+01	3044.4
33	14	1	5	3149.7	224	1	1	2.36E+01	5286.4
34	14	1	5	3149.3	58	1	1	2.36E+01	1368.8
34	15	1	5	3149.0	230	1	1	2.36E+01	5428.0
35	15	1	5	3148.6	52	1	1	2.36E+01	1227.2
35	16	1	5	3148.3	187	1	1	2.36E+01	4413.2
36	16	1	5	3147.9	147	1	1	2.36E+01	3469.2
37	15	1	6	3147.1	206	1	1	2.07E+01	4264.2
37	16	1	6	3147.3	308	1	1	2.07E+01	6375.6
38	15	1	6	3146.9	229	1	1	2.07E+01	4740.3
39	14	1	6	3146.5	167	1	1	2.07E+01	3456.9
39	15	1	6	3146.7	211	1	1	2.07E+01	4367.7
40	15	1	6	3146.3	230	1	1	2.07E+01	4761.0
41	14	1	6	3145.9	200	1	1	2.07E+01	4140.0
41	15	1	6	3146.1	164	1	1	2.07E+01	3394.8
42	13	1	6	3145.6	90	1	1	2.07E+01	1863.0
42	14	1	6	3145.7	151	1	1	2.07E+01	3125.7
43	11	1	6	3145.1	97	1	1	2.07E+01	2007.9
43	12	1	6	3145.3	214	1	1	2.07E+01	4429.8
43	13	1	6	3145.4	270	1	1	2.07E+01	5589.0

Row	Column	Layer	Reach	Channel Bottom Elevation (ft amsl)	Length (ft)	Width (ft)	Thickness (ft)	K_r (ft/d)	Conductance (ft^2/d)
44	11	1	6	3145.0	154	1	1	2.07E+01	3187.8
45	10	1	7	3144.6	66	1	1	2.59E+01	1709.4
45	11	1	7	3144.7	171	1	1	2.59E+01	4428.9
46	10	1	7	3144.6	221	1	1	2.59E+01	5723.9
47	9	1	7	3144.4	93	1	1	2.59E+01	2408.7
47	10	1	7	3144.5	137	1	1	2.59E+01	3548.3
48	9	1	7	3144.3	226	1	1	2.59E+01	5853.4
49	8	1	7	3144.2	144	1	1	2.59E+01	3729.6
49	9	1	7	3144.2	98	1	1	2.59E+01	2538.2
50	8	1	7	3144.1	217	1	1	2.59E+01	5620.3
51	7	1	7	3143.9	177	1	1	2.59E+01	4584.3
51	8	1	7	3144.0	58	1	1	2.59E+01	1502.2
52	7	1	7	3143.8	212	1	1	2.59E+01	5490.8
53	6	1	7	3143.7	143	1	1	2.59E+01	3703.7
53	7	1	7	3143.8	77	1	1	2.59E+01	1994.3
54	6	1	7	3143.6	201	1	1	2.59E+01	5205.9
55	6	1	7	3143.5	200	1	1	2.59E+01	5180.0
56	6	1	7	3143.4	201	1	1	2.59E+01	5205.9
57	6	1	7	3143.3	200	1	1	2.59E+01	5180.0
58	6	1	7	3143.2	201	1	1	2.59E+01	5205.9
59	6	1	7	3143.1	201	1	1	2.59E+01	5205.9
60	6	1	7	3143.0	201	1	1	2.59E+01	5205.9
61	6	1	7	3142.9	199	1	1	2.59E+01	5154.1
62	6	1	7	3142.8	200	1	1	2.59E+01	5180.0
63	6	1	7	3142.7	230	1	1	2.59E+01	5957.0
64	6	1	7	3142.6	201	1	1	2.59E+01	5205.9
65	6	1	7	3142.5	207	1	1	2.59E+01	5361.3
66	6	1	7	3142.4	206	1	1	2.59E+01	5335.4
67	6	1	7	3142.2	200	1	1	2.59E+01	5180.0
68	6	1	7	3142.1	200	1	1	2.59E+01	5180.0
69	6	1	7	3142.0	167	1	1	2.59E+01	4325.3
70	6	1	8	3141.3	180	1	1	1.81E+01	3258.0
71	6	1	8	3141.2	203	1	1	1.81E+01	3674.3
72	6	1	8	3141.0	203	1	1	1.81E+01	3674.3
73	6	1	8	3140.8	199	1	1	1.81E+01	3601.9
74	5	1	8	3140.5	94	1	1	1.81E+01	1701.4
74	6	1	8	3140.6	138	1	1	1.81E+01	2497.8
75	5	1	8	3140.3	201	1	1	1.81E+01	3638.1
76	5	1	8	3140.1	201	1	1	1.81E+01	3638.1
76	10	1	8	3138.5	137	1	1	1.81E+01	2479.7
76	11	1	8	3138.3	200	1	1	1.81E+01	3620.0
76	12	1	8	3138.1	200	1	1	1.81E+01	3620.0
76	13	1	8	3137.9	200	1	1	1.81E+01	3620.0
76	14	1	8	3137.7	158	1	1	1.81E+01	2859.8

Row	Column	Layer	Reach	Channel Bottom Elevation (ft amsl)	Length (ft)	Width (ft)	Thickness (ft)	K_r (ft/d)	Conductance (ft^2/d)
77	5	1	8	3139.9	145	1	1	1.81E+01	2624.5
77	6	1	8	3139.8	76	1	1	1.81E+01	1375.6
77	8	1	8	3138.9	82	1	1	1.81E+01	1484.2
77	9	1	8	3138.7	219	1	1	1.81E+01	3963.9
77	10	1	8	3138.6	99	1	1	1.81E+01	1791.9
77	14	1	8	3137.6	101	1	1	1.81E+01	1828.1
77	15	1	8	3137.4	197	1	1	1.81E+01	3565.7
78	6	1	8	3139.7	207	1	1	1.81E+01	3746.7
78	7	1	8	3139.2	171	1	1	1.81E+01	3095.1
78	8	1	8	3139.0	183	1	1	1.81E+01	3312.3
79	6	1	8	3139.5	155	1	1	1.81E+01	2805.5
79	7	1	8	3139.4	72	1	1	1.81E+01	1303.2
77	16	1	9	3136.7	88	1	1	1.60E+00	140.8
78	16	1	9	3136.6	148	1	1	1.60E+00	236.8
78	17	1	9	3136.3	206	1	1	1.60E+00	329.6
78	18	1	9	3135.9	202	1	1	1.60E+00	323.2
78	19	1	9	3135.6	234	1	1	1.60E+00	374.4
78	20	1	9	3135.2	276	1	1	1.60E+00	441.6
79	19	1	9	3134.7	223	1	1	1.60E+00	356.8
80	19	1	9	3134.3	206	1	1	1.60E+00	329.6
81	18	1	9	3133.6	141	1	1	1.60E+00	225.6
81	19	1	9	3134.0	265	1	1	1.60E+00	424.0
82	18	1	9	3133.3	126	1	1	1.60E+00	201.6
82	19	1	9	3133.1	134	1	1	1.60E+00	214.4

Notes:

ft = feet

amsl = above mean sea level

ft^2/d = square feet per day

K_r = riverbed conductance (feet per day)

Table B-2.River Package Conductance Values - Reach 5 Proposed Grant Creek Realignment

Row	Column	Layer	Reach	Channel Bottom Elevation (ft amsl)	L (ft)	W (ft)	D (ft)	K_r	Conductance (ft^2/d)
43	11	1	5	3144.2	70	1	1	5.00E+01	3500.0
43	12	1	5	3145.4	213	1	1	5.00E+01	10650.0
43	13	1	5	3146.3	53	1	1	5.00E+01	2650.0
44	11	1	5	3144.0	144	1	1	5.00E+01	7200.0
25	24	1	5	3158.9	67	1	1	5.00E+01	3350.0
26	24	1	5	3158.5	221	1	1	5.00E+01	11050.0
27	21	1	5	3156.9	47	1	1	5.00E+01	2350.0
27	22	1	5	3157.2	204	1	1	5.00E+01	10200.0
27	23	1	5	3157.8	231	1	1	5.00E+01	11550.0
27	24	1	5	3158.2	45	1	1	5.00E+01	2250.0
28	20	1	5	3155.9	114	1	1	5.00E+01	5700.0
28	21	1	5	3156.4	265	1	1	5.00E+01	13250.0
29	19	1	5	3155.2	252	1	1	5.00E+01	12600.0
29	20	1	5	3155.7	93	1	1	5.00E+01	4650.0
30	18	1	5	3154.4	159	1	1	5.00E+01	7950.0
30	19	1	5	3154.7	85	1	1	5.00E+01	4250.0
31	18	1	5	3153.9	203	1	1	5.00E+01	10150.0
32	18	1	5	3153.3	224	1	1	5.00E+01	11200.0
33	18	1	5	3152.8	208	1	1	5.00E+01	10400.0
34	18	1	5	3152.3	204	1	1	5.00E+01	10200.0
35	17	1	5	3151.6	152	1	1	5.00E+01	7600.0
35	18	1	5	3151.9	62	1	1	5.00E+01	3100.0
36	17	1	5	3151.1	205	1	1	5.00E+01	10250.0
37	15	1	5	3149.8	7	1	1	5.00E+01	350.0
37	16	1	5	3150.0	212	1	1	5.00E+01	10600.0
37	17	1	5	3150.6	188	1	1	5.00E+01	9400.0
38	15	1	5	3149.4	229	1	1	5.00E+01	11450.0
39	15	1	5	3148.9	200	1	1	5.00E+01	10000.0
40	15	1	5	3148.3	212	1	1	5.00E+01	10600.0
41	13	1	5	3147.2	92	1	1	5.00E+01	4600.0
41	14	1	5	3147.6	217	1	1	5.00E+01	10850.0
41	15	1	5	3147.9	64	1	1	5.00E+01	3200.0
42	13	1	5	3147.0	195	1	1	5.00E+01	9750.0

Notes:

ft = feet

amsl = above mean sea level

ft^2/d = square feet per day

Table B-3. River Stage Values

2-year High-Flow Grant Creek Event

	Stress Period																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	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
Reach	Creek Stage (feet)																			
5	0.0	0.0	1.0	1.5	2.0	2.5	3.0	3.5	3.3	3.0	2.8	2.5	2.3	2.0	1.8	1.5	1.5	0.0	0.0	0.0
6	0.0	0.0	2.0	2.5	3.0	3.5	4.0	4.5	4.1	3.6	3.2	2.7	2.3	1.8	1.4	0.9	0.5	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	2.0	3.0	3.8	4.5	4.1	3.6	3.2	2.7	2.3	1.8	1.4	0.9	0.5	0.0	0.0	0.0
8	1.7	2.2	2.7	2.9	3.2	3.4	3.7	4.2	4.0	3.7	3.5	3.3	3.1	2.8	2.6	2.4	2.2	1.9	1.7	1.7
9	0.0	0.0	0.3	0.8	1.3	1.8	2.3	2.8	2.5	2.2	2.0	1.7	1.4	1.2	0.9	0.6	0.4	0.1	0.0	0.0

100-year High-Flow Grant Creek Event

	Stress Period																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	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
Reach	Creek Stage (feet)																			
5	0.0	0.0	1.0	1.8	2.6	3.4	4.2	5.0	4.6	4.1	3.7	3.3	2.8	2.4	1.9	1.5	1.5	0.0	0.0	0.0
6	0.0	0.0	2.0	2.8	3.6	4.4	5.2	6.0	5.4	4.8	4.2	3.6	2.9	2.3	1.7	1.1	0.5	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	2.0	3.3	4.7	6.0	5.4	4.8	4.2	3.6	2.9	2.3	1.7	1.1	0.5	0.0	0.0	0.0
8	1.7	2.3	2.8	3.4	4.0	4.6	5.1	5.7	5.3	5.0	4.6	4.2	3.9	3.5	3.2	2.8	2.4	2.1	1.7	1.7
9	0.0	0.0	0.3	1.1	1.9	2.7	3.5	4.3	3.8	3.4	3.0	2.6	2.2	1.8	1.3	0.9	0.5	0.1	0.0	0.0

Table B-4. Upgradient General Head Boundary (North)

2-year High-Flow Grant Creek Event

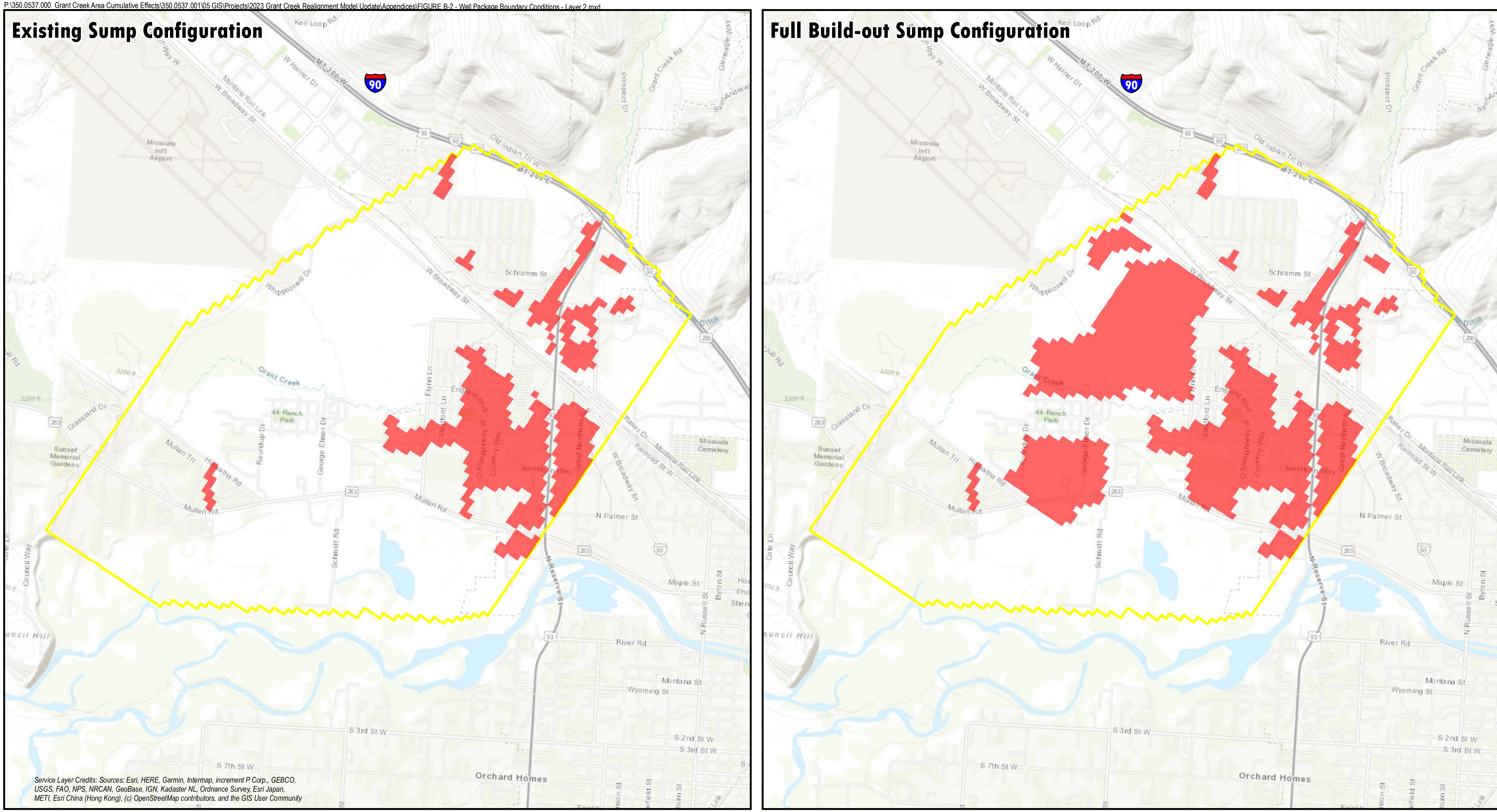
					Stress Period																			
					1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
					22-Mar	5-Apr	19-Apr	26-Apr	3-May	10-May	17-May	24-May	31-May	7-Jun	13-Jun	14-Jun	21-Jun	28-Jun	5-Jul	19-Jul	2-Aug	16-Aug	6-Sep	27-Sep
Row	Column	Layer	Reach	K (ft/d)	Head (feet)																			
2	36	3	1	15	3251.00	3252.50	3252.75	3253.00	3253.50	3253.25	3253.00	3252.75	3252.50	3252.25	3252.00	3251.75	3251.50	3251.50	3251.25	3251.00	3251.00	3251.00	3251.00	3251.00
2	37	3	1	15	3251.00	3252.50	3252.75	3253.00	3253.50	3253.25	3253.00	3252.75	3252.50	3252.25	3252.00	3251.75	3251.50	3251.50	3251.25	3251.00	3251.00	3251.00	3251.00	3251.00
2	38	3	1	15	3251.00	3252.50	3252.75	3253.00	3253.50	3253.25	3253.00	3252.75	3252.50	3252.25	3252.00	3251.75	3251.50	3251.50	3251.25	3251.00	3251.00	3251.00	3251.00	3251.00
2	39	3	1	15	3251.00	3252.50	3252.75	3253.00	3253.50	3253.25	3253.00	3252.75	3252.50	3252.25	3252.00	3251.75	3251.50	3251.50	3251.25	3251.00	3251.00	3251.00	3251.00	3251.00
2	40	3	1	15	3251.00	3252.50	3252.75	3253.00	3253.50	3253.25	3253.00	3252.75	3252.50	3252.25	3252.00	3251.75	3251.50	3251.50	3251.25	3251.00	3251.00	3251.00	3251.00	3251.00
2	41	3	1	15	3251.00	3252.50	3252.75	3253.00	3253.50	3253.25	3253.00	3252.75	3252.50	3252.25	3252.00	3251.75	3251.50	3251.50	3251.25	3251.00	3251.00	3251.00	3251.00	3251.00
2	42	3	1	15	3251.00	3252.50	3252.75	3253.00	3253.50	3253.25	3253.00	3252.75	3252.50	3252.25	3252.00	3251.75	3251.50	3251.50	3251.25	3251.00	3251.00	3251.00	3251.00	3251.00
2	43	3	1	15	3251.00	3252.50	3252.75	3253.00	3253.50	3253.25	3253.00	3252.75	3252.50	3252.25	3252.00	3251.75	3251.50	3251.50	3251.25	3251.00	3251.00	3251.00	3251.00	3251.00
2	44	3	1	15	3251.00	3252.50	3252.75	3253.00	3253.50	3253.25	3253.00	3252.75	3252.50	3252.25	3252.00	3251.75	3251.50	3251.50	3251.25	3251.00	3251.00	3251.00	3251.00	3251.00
2	45	3	1	15	3251.00	3252.50	3252.75	3253.00	3253.50	3253.25	3253.00	3252.75	3252.50	3252.25	3252.00	3251.75	3251.50	3251.50	3251.25	3251.00	3251.00	3251.00	3251.00	3251.00
2	46	3	1	15	3251.00	3252.50	3252.75	3253.00	3253.50	3253.25	3253.00	3252.75	3252.50	3252.25	3252.00	3251.75	3251.50	3251.50	3251.25	3251.00	3251.00	3251.00	3251.00	3251.00
2	47	3	1	15	3251.00	3252.50	3252.75	3253.00	3253.50	3253.25	3253.00	3252.75	3252.50	3252.25	3252.00	3251.75	3251.50	3251.50	3251.25	3251.00	3251.00	3251.00	3251.00	3251.00
2	48	3	1	15	3251.00	3252.50	3252.75	3253.00	3253.50	3253.25	3253.00	3252.75	3252.50	3252.25	3252.00	3251.75	3251.50	3251.50	3251.25	3251.00	3251.00	3251.00	3251.00	3251.00
3	49	3	1	15	3251.00	3252.50	3252.75	3253.00	3253.50	3253.25	3253.00	3252.75	3252.50	3252.25	3252.00	3251.75	3251.50	3251.50	3251.25	3251.00	3251.00	3251.00	3251.00	3251.00
3	50	3	1	15	3251.00	3252.50	3252.75	3253.00	3253.50	3253.25	3253.00	3252.75	3252.50	3252.25	3252.00	3251.75	3251.50	3251.50	3251.25	3251.00	3251.00	3251.00	3251.00	3251.00
3	51	3	1	15	3251.00	3252.50	3252.75	3253.00	3253.50	3253.25	3253.00	3252.75	3252.50	3252.25	3252.00	3251.75	3251.50	3251.50	3251.25	3251.00	3251.00	3251.00	3251.00	3251.00
3	52	3	1	15	3251.00	3252.50	3252.75	3253.00	3253.50	3253.25	3253.00	3252.75	3252.50	3252.25	3252.00	3251.75	3251.50	3251.50	3251.25	3251.00	3251.00	3251.00	3251.00	3251.00
4	53	3	1	15	3251.00	3252.50	3252.75	3253.00	3253.50	3253.25	3253.00	3252.75	3252.50	3252.25	3252.00	3251.75	3251.50	3251.50	3251.25	3251.00	3251.00	3251.00	3251.00	3251.00
5	54	3	1	15	3251.00	3252.50	3252.75	3253.00	3253.50	3253.25	3253.00	3252.75	3252.50	3252.25	3252.00	3251.75	3251.50	3251.50	3251.25	3251.00	3251.00	3251.00	3251.00	3251.00
5	55	3	1	15	3251.00	3252.50	3252.75	3253.00	3253.50	3253.25	3253.00	3252.75	3252.50	3252.25	3252.00	3251.75	3251.50	3251.50	3251.25	3251.00	3251.00	3251.00	3251.00	3251.00
5	56	3	1	15	3251.00	3252.50	3252.75	3253.00	3253.50	3253.25	3253.00	3252.75	3252.50	3252.25	3252.00	3251.75	3251.50	3251.50	3251.25	3251.00	3251.00	3251.00	3251.00	3251.00
5	57	3	1	15	3251.00	3252.50	3252.75	3253.00	3253.50	3253.25	3253.00	3252.75	3252.50	3252.25	3252.00	3251.75	3251.50	3251.50	3251.25	3251.00	3251.00	3251.00	3251.00	3251.00
5	58	3	1	15	3251.00	3252.50	3252.75	3253.00	3253.50	3253.25	3253.00	3252.75	3252.50	3252.25	3252.00	3251.75	3251.50	3251.50	3251.25	3251.00	3251.00	3251.00	3251.00	3251.00
5	59	3	1	15	3251.00	3252.50	3252.75	3253.00	3253.50	3253.25	3253.00	3252.75	3252.50	3252.25	3252.00	3251.75	3251.50	3251.50	3251.25	3251.00	3251.00	3251.00	3251.00	3251.00
6	59	3	1	15	3251.00	3252.50	3252.75	3253.00	3253.50	3253.25	3253.00	3252.75	3252.50	3252.25	3252.00	3251.75	3251.50	3251.50	3251.25	3251.00	3251.00	3251.00	3251.00	3251.00
6	60	3	1	15	3251.00	3252.50	3252.75	3253.00	3253.50	3253.25	3253.00	3252.75	3252.50	3252.25	3252.00	3251.75	3251.50	3251.50	3251.25	3251.00	3251.00	3251.00	3251.00	3251.00
7	61	3	1	15	3251.00	3252.50	3252.75	3253.00	3253.50	3253.25	3253.00	3252.75	3252.50	3252.25	3252.00	3251.75	3251.50	3251.50	3251.25	3251.00	3251.00	3251.00	3251.00	3251.00
7	62	3	1	15	3251.00	3252.50	3252.75	3253.00	3253.50	3253.25	3253.00	3252.75	3252.50	3252.25	3252.00	3251.75	3251.50	3251.50	3251.25	3251.00	3251.00	3251.00	3251.00	3251.00
7	63	3	1	15	3251.00	3252.50	3252.75	3253.00	3253.50	3253.25	3253.00	3252.75	3252.50	3252.25	3252.00	3251.75	3251.50	3251.50	3251.25	3251.00	3251.00	3251.00	3251.00	3251.00

100-year High-Flow Grant Creek Event

					Stress Period																			
					1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
					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	Column	Layer	Reach	K (ft/d)	Head (feet)																			
2	36	3	1	15	3255.00	3256.50	3256.75	3257.00	3257.50	3257.25	3257.00	3256.75	3256.50	3256.25	3256.00	3255.75	3255.50	3255.50	3255.25	3255.00	3255.00	3255.00	3255.00	3255.00
2	37	3	1	15	3255.00	3256.50	3256.75	3257.00	3257.50	3257.25	3257.00	3256.75	3256.50	3256.25	3256.00	3255.75	3255.50	3255.50	3255.25	3255.00	3255.00	3255.00	3255.00	3255.00
2	38	3	1	15	3255.00	3256.50	3256.75	3257.00	3257.50	3257.25	3257.00	3256.75	3256.50	3256.25	3256.00	3255.75	3255.50	3255.50	3255.25	3255.00	3255.00	3255.00	3255.00	3255.00
2	39	3	1	15	3255.00	3256.50	3256.75	3257.00	3257.50	3257.25	3257.00	3256.75	3256.50	3256.25	3256.00	3255.75	3255.50	3255.50	3255.25	3255.00	3255.00	3255.00	3255.00	3255.00
2	40	3	1	15	3255.00	3256.50	3256.75	3257.00	3257.50	3257.25	3257.00	3256.75	3256.50	3256.25	3256.00	3255.75	3255.50	3255.50	3255.25	3255.00	3255.00	3255.00	3255.00	3255.00
2	41	3	1	15	3255.00	3256.50	3256.75	3257.00	3257.50	3257.25	3257.00	3256.75	3256.50	3256.25	3256.00	3255.75	3255.50	3255.50	3255.25	3255.00	3255.00	3255.00	3255.00	3255.00
2	42	3	1	15	3255.00	3256.50	3256.75	3257.00	3257.50	3257.25	3257.00	3256.75	3256.50	3256.25	3256.00	3255.75	3255.50	3255.50	3255.25	3255.00	3255.00	3255.00	3255.00	3255.00
2	43	3	1	15	3255.00	3256.50	3256.75	3257.00	3257.50	3257.25	3257.00	3256.75	3256.50	3256.25	3256.00	3255.75	3255.50	3255.50	3255.25	3255.00	3255.00	3255.00	3255.00	3255.00
2	44	3	1	15	3255.00	3256.50	3256.75	3257.00	3257.50	3257.25	3257.00	3256.75	3256.50	3256.25	3256.00	3255.75	3255.50	3255.50	3255.25	3255.00	3255.00	3255.00	3255.00	3255.00
2	45	3	1	15	3255.00	3256.50	3256.75	3257.00	3257.50	3257.25	3257.00	3256.75	3256.50	3256.25	3256.00	3255.75	3255.50	3255.50	3255.25	3255.00	3255.00	3255.00	3255.00	3255.00
2	46	3	1	15	3255.00	3256.50	3256.75	3257.00	3257.50	3257.25	3257.00	3256.75	3256.50	3256.25	3256.00	3255.75	3255.50	3255.50	3255.25	3255.00	3255.00	3255.00	3255.00	3255.00
2	47	3	1	15	3255.00	3256.50	3256.75	3257.00	3257.50	3257.25	3257.00	3256.75	3256.50	3256.25	3256.00	3255.75	3255.50	3255.50	3255.25	3255.00	3255.00	3255.00	3255.00	3255.00
2	48	3	1	15	3255.00	3256.50	3256.75	3257.00	3257.50	3257.25	3257.00	3256.75	3256.50	3256.25	3256.00	3255.75	3255.50	3255.50	3255.25	3255.00	3255.00	3255.00	3255.00	3255.00
3	49	3	1	15	3255.00	3256.50	3256.75	3257.00	3257.50	3257.25	3257.00	3256.75	3256.50	3256.25	3256.00	3255.75	3255.50	3255.50	3255.25	3255.00	3255.00	3255.00	3255.00	3255.00

					Stress Period																			
					1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
					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	Column	Layer	Reach	K (ft/d)	Head (feet)																			
3	50	3	1	15	3255.00	3256.50	3256.75	3257.00	3257.50	3257.25	3257.00	3256.75	3256.50	3256.25	3256.00	3255.75	3255.50	3255.50	3255.25	3255.00	3255.00	3255.00	3255.00	3255.00
3	51	3	1	15	3255.00	3256.50	3256.75	3257.00	3257.50	3257.25	3257.00	3256.75	3256.50	3256.25	3256.00	3255.75	3255.50	3255.50	3255.25	3255.00	3255.00	3255.00	3255.00	3255.00
3	52	3	1	15	3255.00	3256.50	3256.75	3257.00	3257.50	3257.25	3257.00	3256.75	3256.50	3256.25	3256.00	3255.75	3255.50	3255.50	3255.25	3255.00	3255.00	3255.00	3255.00	3255.00
4	53	3	1	15	3255.00	3256.50	3256.75	3257.00	3257.50	3257.25	3257.00	3256.75	3256.50	3256.25	3256.00	3255.75	3255.50	3255.50	3255.25	3255.00	3255.00	3255.00	3255.00	3255.00
5	54	3	1	15	3255.00	3256.50	3256.75	3257.00	3257.50	3257.25	3257.00	3256.75	3256.50	3256.25	3256.00	3255.75	3255.50	3255.50	3255.25	3255.00	3255.00	3255.00	3255.00	3255.00
5	55	3	1	15	3255.00	3256.50	3256.75	3257.00	3257.50	3257.25	3257.00	3256.75	3256.50	3256.25	3256.00	3255.75	3255.50	3255.50	3255.25	3255.00	3255.00	3255.00	3255.00	3255.00
5	56	3	1	15	3255.00	3256.50	3256.75	3257.00	3257.50	3257.25	3257.00	3256.75	3256.50	3256.25	3256.00	3255.75	3255.50	3255.50	3255.25	3255.00	3255.00	3255.00	3255.00	3255.00
5	57	3	1	15	3255.00	3256.50	3256.75	3257.00	3257.50	3257.25	3257.00	3256.75	3256.50	3256.25	3256.00	3255.75	3255.50	3255.50	3255.25	3255.00	3255.00	3255.00	3255.00	3255.00
5	58	3	1	15	3255.00	3256.50	3256.75	3257.00	3257.50	3257.25	3257.00	3256.75	3256.50	3256.25	3256.00	3255.75	3255.50	3255.50	3255.25	3255.00	3255.00	3255.00	3255.00	3255.00
5	59	3	1	15	3255.00	3256.50	3256.75	3257.00	3257.50	3257.25	3257.00	3256.75	3256.50	3256.25	3256.00	3255.75	3255.50	3255.50	3255.25	3255.00	3255.00	3255.00	3255.00	3255.00
6	59	3	1	15	3255.00	3256.50	3256.75	3257.00	3257.50	3257.25	3257.00	3256.75	3256.50	3256.25	3256.00	3255.75	3255.50	3255.50	3255.25	3255.00	3255.00	3255.00	3255.00	3255.00
6	60	3	1	15	3255.00	3256.50	3256.75	3257.00	3257.50	3257.25	3257.00	3256.75	3256.50	3256.25	3256.00	3255.75	3255.50	3255.50	3255.25	3255.00	3255.00	3255.00	3255.00	3255.00
7	61	3	1	15	3255.00	3256.50	3256.75	3257.00	3257.50	3257.25	3257.00	3256.75	3256.50	3256.25	3256.00	3255.75	3255.50	3255.50	3255.25	3255.00	3255.00	3255.00	3255.00	3255.00
7	62	3	1	15	3255.00	3256.50	3256.75	3257.00	3257.50	3257.25	3257.00	3256.75	3256.50	3256.25	3256.00	3255.75	3255.50	3255.50	3255.25	3255.00	3255.00	3255.00	3255.00	3255.00
7	63	3	1	15	3255.00	3256.50	3256.75	3257.00	3257.50	3257.25	3257.00	3256.75	3256.50	3256.25	3256.00	3255.75	3255.50	3255.50	3255.25	3255.00	3255.00	3255.00	3255.00	3255.00

P:\350.0537.000 Grant Creek Area Cumulative Effects\350.0537.001\05 GIS\Projects\2023 Grant Creek Realignment Model Update\Appendices\FIGURE B-2 - Well Package Boundary Conditions - Layer 2.mxd



0 Feet 3,000

Well Package Cells (specified flux)

Model Domain

NewFields

Well Package Boundary Conditions - Layer 2
Groundwater Modeling Study
Grant Creek-Mullan Road Area
Missoula, Montana
FIGURE B-2