WATER SUPPLY REPORT SERIES I – ATTACHMENT 1
MODELING REPORT

PREPARED FOR:
CLARK FORK RIVER BASIN TASK FORCE
AND
MONTANA DNRC (RFP #145041FSU)

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Introduction

This report provides details on the three water development/water right change theoretical scenarios and mitigation options evaluated in the Clark Fork Basin. The three scenarios are as follows:

1) A new municipal well in the Bitterroot Basin (Bitterroot Valley). This scenario investigates depletions to the Bitterroot River caused by both the new well as well as changing the irrigation water right and evaluates potential mitigation and aquifer recharge options.
2) A new subdivision well in the Middle Clark Fork Basin (Missoula Valley). This scenario investigates depletions to the Clark Fork River from the new well, potential mitigation, and effects on the river.
3) A water right change from irrigation to instream flow for fisheries in the Deer Lodge Valley. This scenario investigates changes to instream flow for fisheries, potential mitigation of changes in return flow, and effects on the river.

The scenarios are modeled using the Colorado State University Alluvial Water Accounting System (AWAS) model (IDS Group, 2013). Modeling assists in understanding the mitigation plan requirements for the new or changed water uses and also gives quantitative results on changes in river flows from the new use. The results of the modeled mitigation plans are used to inform the discussion and evaluation of mitigation options provided in chapter 2 of the Water Supply Report Series I.

Each of the three sections below provides a description of the scenario including a basic description of the theoretical development or instream flow for fisheries change and hydrogeologic properties used in the AWAS model. An analysis of legal availability of surface water is provided for each scenario which highlights when depletions from the new or changed water use must be mitigated. The monthly water use for the historic water right are described for each scenario detailing applied water volume, consumptive use, and return flows. The monthly water balance is developed using methods detailed in Administrative Rules of Montana (ARM) and DNRC guidance documents referenced below. Following the description of the historic water right use, mitigation options specific to each scenario are described and evaluated. Each mitigation option includes development of monthly tables of water use (applied water volume, consumptive use, and return flows) and the proposed monthly mitigation plan. The monthly water balance for each mitigation option is modeled using AWAS and modeled change in river flows (accretions/depletions) for the affected surface water are described in tables for each mitigation option. Each mitigation option is evaluated as to whether it successfully offsets depletions of water during periods when water is not legally available. Only those options which successfully offset depletions can be permitted in a new appropriation or water right change.

Scenario descriptions, parameters, and modeling results

1. New municipal well in the Bitterroot alluvial aquifer

1.1 Scenario description

Basic details of development

This scenario represents a new municipal well needed to expand service to an existing municipality water service area in the Bitterroot Valley. This example evaluates the effects of this new use on the Bitterroot River and five potential mitigation options.

The new service area is a 125 acre residential/commercial development with 100 single family homes, 1 church with design flow rate for 120 persons, 1 school with design flow rate for 80 pupils, 1 store with design flow rate for 2 restrooms, and 30 acres lawn and garden irrigation (1/4 acre lawn and garden per home, plus one 5 acre park).

The development uses a community wastewater system with a drainfield (no lagoon). The drainfield is located 5,300 ft from the Bitterroot River.

The development is on ground which formerly had 100 acres of pasture grass irrigated using wheel-line sprinkler with a full service statement of claim water right with a priority date of 1880. The municipality acquired the irrigation water right from the developer. Wheel line was the practice prior to July 1, 1973 when historic use is evaluated.

The water supply well is 5,300 ft from the Bitterroot River and located 275 ft hydraulically side gradient of the drainfield.

Distance from Bitterroot River to Tertiary geology is 13,700 ft (Tertiary sediments are assumed a no-flow boundary for modeling purposes).

Legal availability of surface water

Legal availability of surface water in the lower Bitterroot River is shown in table 1. Median monthly flows are taken from lower Bitterroot USGS gage 12352500 near Buckhouse Bridge. Water rights used to determine legal availability are evaluated on the Clark Fork River from just downstream of Lolo to the confluence with the Clark Fork River because this is the portion of the river which is potentially depleted by a new well. Table 1 only shows legal availability in the Bitterroot River and does not consider Avista's Noxon Rapids Dam water rights (see section 2.2.2 of the main report); which limit legal availability of water in the Bitterroot and Clark Fork Rivers to periods when flows exceed 50,000 cfs at Noxon Rapids. Considering Avista's water right, water is not legally available during any month, but only during short periods of days or weeks when both the Bitterroot River has sufficient flow to satisfy all legal demands in table 1 and the flow of the Clark Fork River at Noxon Rapids is over 50,000 cfs.

Changing monthly legal water availability in the Bitterroot River presents significant challenges to developing a mitigation plan. Pumping from a well is driven by demand, which is often variable in the amount withdrawn, but these spikes and troughs in demand tend to be dampened by the time those depletions are seen in adjacent rivers. This means mitigation of depletions requires aquifer recharge to be maintained, and not alternating on/off, as the pattern of legal availability in table 1 suggests.

Table 1. Bitterroot River median monthly flows and existing legal demand. Months with legally available water shown in green; months without shown in red. Period of flow record for Bitterroot River is 1898-2011.

Month	Bitterroot River Flow median monthly flow (AF)	Existing water rights other than FWP (AF)	FWP Instream Flow (AF)	Total Existing Legal Demand (AF)	Legal Availability (AF)
Jan	48,643	43	55,339	55,382	-6,739
Feb	45,313	39	49,983	50,022	-4,710
March	68,343	131	55,339	55,470	12,873
April	147,451	3,178	53,554	56,732	90,719
May	389,893	3,406	473,885	477,291	-87,398
June	458,420	3,302	458,598	461,901	-3,481
July	151,075	3,146	36,893	40,038	111,037
Aug	57,171	3,140	36,893	40,033	17,139
Sept	49,978	3,016	35,702	38,719	11,259
Oct	55,013	2,970	55,339	58,309	-3,296
Nov	57,172	108	53,554	53,662	3,510
Dec	53,605	43	55,339	55,382	-1,777

Hydrogeologic properties

Transmissivity (T) value of 2800 ft2/d (20,950 gpd/ft) was used from the aquifer test performed for the Town of Stevensville application for 76H 30043133 using recovery data analysis from the pumping well. Specific yield (Sy) of 0.1 is an estimate for unconfined conditions.

Consumptive use calculations for the new water appropriation

Consumptive use calculation methods are described below. Only new consumptive use is modeled and only new consumptive use is mitigated. Non-consumptive use (treated wastewater from the community drainfield and irrigation loss) is assumed to return to the source aquifer. Total consumptive use used in the AWAS model is shown in table 2.

In-house domestic use: Consumptive use is 5% of flow (Kimsey and Flood 1987). The 5% in-house consumptive use standard is for a community wastewater system with a drainfield (no lagoon).

> 100 homes at 100 gpd/person (HRD 2001). Assume 2.5 persons/household (Census is 2.4 for Ravalli County): 100 x 250 gpd x 365days/yr x AF/325,851 gal x 5% = 0.014 AF/yr per household or 1.40 AF for 100 homes.

Church use: Consumptive use is 5% of flow (D.W. Kimsey and P.K. Flood, 1987. Domestic Consumptive use, Memo to DNRC from Wright Water Engineering, Inc. December 31, 1987).

> 20 gpd/person x 120 persons x 104 days/yr x AF/325,851 gal x 5% = 0.04 AF/yr (DNRC Form 615 Planning Guide for Water Use).

School use: Consumptive use is 5% of flow (D.W. Kimsey and P.K. Flood, 1987. Domestic Consumptive use, Memo to DNRC from Wright Water Engineering, Inc. December 31, 1987).

> 20 gpd/pupil (DNRC Form 615 Planning Guide for Water Use) x 80 pupil x 185 days/yr x AF/325,851 gal x 5% = 0.05 AF/yr

School use: Consumptive use is 5% of flow (D.W. Kimsey and P.K. Flood, 1987. Domestic Consumptive use, Memo to DNRC from Wright Water Engineering, Inc. December 31, 1987).

> 20 gpd/pupil (DNRC Form 615 Planning Guide for Water Use) x 80 pupil x 185 days/yr x AF/325,851 gal x 5% = 0.05 AF/yr

Store use: Consumptive use is 5% of flow (D.W. Kimsey and P.K. Flood, 1987. Domestic Consumptive use, Memo to DNRC from Wright Water Engineering, Inc. December 31, 1987).

> 400 gpd/restroom (DNRC Form 615 Planning Guide for Water Use) x 2 restrooms x 365 days/yr x AF/325,851 gal x 5% = 0.04 AF/yr

Total non-irrigation use = 1.58 AF/yr

Lawn and garden consumptive use rates (in inches of water per month) are calculated using modeled pasture grass requirements for a dry year using NRCS Irrigation Water Requirements (IWR) software and precipitation record for Stevensville weather station (values shown in table 2 below).

Table 2. Consumptive use values of new water appropriation used in the Bitterroot model.

Month	Pasture grass dry year net irrigation required (inches)	Irrigation of 30 acres lawn and garden consumptive use (AF)	Consumptive use 100 homes domestic use, church, school, and store (AF)	Total monthly consumption (AF)	Consumed flow rate (gpm)
January			0.13	0.13	1.0
February			0.12	0.12	1.0
March			0.13	0.13	1.0
April	0.58	1.45	0.13	1.58	11.9
May	2.76	6.90	0.13	7.03	51.3
June	4.14	10.35	0.13	10.48	79.0
July	5.5	13.75	0.13	13.88	101.3
August	4.71	11.78	0.13	11.91	86.9
September	2.54	6.35	0.13	6.48	48.9
October	0.51	1.28	0.13	1.41	10.3
November			0.13	0.13	1.0
December			0.13	0.13	1.0
Annual total:	20.7	51.85	1.58	53.43	

Consumptive use calculations for the historic irrigation water right changed to mitigation

Historic irrigation water consumption is calculated using ARM 36.12.1902, IWR irrigation ET for wheel-line sprinkler for Stevensville weather station (19.19 inches ET) and the associated county management factor of 79.5%, which yields a consumptive use of 1.27 AF/ac per irrigation season. This annual consumptive use is allocated to each month of the irrigation season (April to October) based on the proportional irrigation water requirement for each month as calculated by the NRCS IWR program outputs for that area (net irrigation requirement for month/net annual irrigation water requirement) (Table 3).

In this scenario irrecoverable loss (direct evaporation of applied irrigation water) is not included in our calculation of consumptive use. Irrecoverable loss is included in historic consumptive use per ARM 36.12.1902(17) and thus our calculation is different than the administrative rule method. In our scenario the former irrecoverable loss is used to mitigate changes in return flows instead of a new consumptive use. If instead we had strictly used the administrative rule method then mitigation of changes in return flow would require using of a portion of the historic consumptive use in order to have sufficient mitigation water available for each month. So the net historic consumptive use which could be changed to mitigation is approximately the same.

Field applied volume and on-farm loss (field loss) for the historic irrigation water right changed to mitigation

Historic applied volume and field loss is shown in tables 3 and 4 below for two different mitigation options retiring different acreage of irrigation. Historic applied volume was calculated using DNRC guidelines for historic diverted volume (DNRC 2012) with sprinkler efficiency of 70% (ARM 36.12.115). On-farm loss is calculated as 30% of applied volume. Of the on-farm loss, 10% is considered irrecoverable loss (direct evaporation of applied irrigation water) and 20% is return flow to groundwater (DNRC 2013 and ARM 36.12.1902). Changes in return flow are simulated in the model for retired acreage. Ditch conveyance loss is not considered to change in the model because the ditch will continue to be used by other ditch users and conveyance losses are assumed to remain the same.

1.2 Bitterroot Mitigation Options Evaluated

The following mitigation options are evaluated for the theoretical scenario of a new municipal well in the Bitterroot alluvial aquifer:

Option #1. Aquifer recharge is used to offset depletions from the new well-use and generate extra mitigation marketing water which can be sold or used for additional new uses. The new well is used for both domestic and irrigation purposes. Aquifer recharge uses 100% of the former irrigation consumptive use and a portion of on-farm efficiency losses infiltrated using a large drainfield.
Option #2. Historic irrigation water right, conveyed by a ditch is changed to be used for lawn and garden and mitigation. The new water supply well is used only for indoor domestic use, not lawn and garden. Aquifer recharge is used to mitigate depletions from the new well by infiltrating former irrigation consumptive use using a small drainfield.
Option #3. Aquifer recharge is used to offset depletions from the new well by infiltrating using a large drainfield the minimum amount of water needed to offset adverse effects. The new well is used for both domestic and irrigation purposes.
Option #4. Depletions from the new well use are mitigated by curtailing historic irrigation and leaving all of the former irrigation water instream in the river. The new well is used for both domestic and irrigation purposes.
Option #5. Aquifer recharge is used to mitigate depletions from the new well by infiltrating the minimum amount water needed to offset adverse effects using a constructed wetland. The new well is used for both domestic and irrigation purposes.

Mitigation options were evaluated by modeling. The impacts of monthly consumptive volume estimates of the new water appropriation (the new water supply well), changes of historic irrigation return flows, and the effects of mitigation recharge were analyzed to examine net changes to adjacent streamflow. In the model, recharge is simulated and accounted separately for mitigating new consumptive use and mitigating changes in return flow. The separate accounting is necessary to ensure that historically non-consumed water (waste water, ditch loss seepage water, return flow) are not used to mitigate new consumptive use, thereby expanding the water right. Consumptive versus non-consumptive portions of the historic water right (historic return flow & irrecoverable losses) must be estimated for purposes of isolating streamflow depletion components versus what ultimately becomes return flow (Tables 3 and 4).

Table 3. Historic irrigation applied volume, consumptive use, return flow, and irrecoverable losses used in mitigation options 1, 3, 4, and 5.

Month	Pasture grass dry year net irrigation required (inches)	Historic applied volume with on-farm efficiency of 70% (AF)	Historic consumptive use: 100 acres retired (AF)	Historic return flow & irrecoverable evaporative losses: 100 acres retired (AF)	Historic return flow: 100 acres retired (AF)
January					
February					
March					
April	0.58	5.07	3.55	1.52	1.01
May	2.76	24.14	16.90	7.24	4.83
June	4.14	36.22	25.35	10.86	7.24
July	5.5	48.11	33.68	14.43	9.62
August	4.71	41.20	28.84	12.36	8.24
September	2.54	22.22	15.55	6.67	4.44
October	0.51	4.46	3.12	1.34	0.89
November					
December					
Annual total:	20.7	181.43	127.00	54.43	36.29

Individual mitigation options are described in detail below. The streamflow depletion/accretion results given in the monthly water balance for the individual mitigation options are those modeled after 100 years using AWAS. However in the model streamflow depletion/accretion stabilizes at an equilibrium condition after approximately 25 years.

Table 4. Historic irrigation applied volume, consumptive, return flow and irrecoverable losses used in mitigation option 2.

Month	Pasture grass dry year net irrigation required (inches)	Historic applied volume with on-farm efficiency of 70% (AF)	Historic consumptive use: 70 acres retired (AF)	Historic return flow & irrecoverable evaporative losses: 70 acres retired (AF)	Historic return flow: 70 acres retired (AF)
January					
February					
March					
April	0.58	3.55	2.49	1.07	0.71
May	2.76	16.90	11.83	5.07	3.38
June	4.14	25.35	17.75	7.61	5.07
July	5.5	33.68	23.58	10.10	6.74
August	4.71	28.84	20.19	8.65	5.77
September	2.54	15.55	10.89	4.67	3.11
October	0.51	3.12	2.19	0.94	0.62
November					
December					
Annual total:	20.7	127.00	88.90	38.10	25.40

Option #1. Aquifer recharge is used to offset depletions from the new well use and generate extra mitigation marketing water which can be sold or used for additional new uses.

Historic irrigation applied volume, consumptive use, return flow, and irrecoverable losses are shown in table 3 above.

Assumptions:

- The new water supply well supplies 100% of water needs (domestic, lawn and garden, commercial, and institutional) for the development.
- The historic irrigated 100-acre parcel is assumed to be square in shape (2,087 ft x 2,087 ft).
- Loss of historic return flows are simulated as two separate pumping wells at two locations. One is located at the same location as the new water supply well. Another is located 1,043.5 ft closer to the river. This spacing simulates the historic return flow source as two points representing strips 1,043.5 ft width x 2,087 ft long.
- Changed return flow mitigation plan: Mitigation of changes in return flow timing is provided by infiltrating a portion of the historic non-consumptive use (on-farm efficiency losses) using a large drainfield (simulated in the model using a recharge well because the model only includes injection and pumping wells) to replace return flow losses (table 5). The drainfield is simulated with a recharge well located at the top end of the property 261 ft above the new water supply well.

- New appropriation mitigation plan: Recharge mitigation is provided by infiltrating the entire historic consumptive use using this same large drain field (table 5). This mitigation plan mitigates both the new consumptive use from the development and provides extra mitigation marketing water which could be sold to other developers in the Bitterroot Basin. Generating extra mitigation marketing water would require adding mitigation marketing as a purpose during the water right change.
- Long-term infiltration rate of 0.5 inch/hr (7.5 gpd/ft^2) for loamy sand (WA DOE 2005). Drainfield of 1.4 acres in size, maximum average monthly flow rate of 314 gpm.
- The drainfield is constructed below the rooting zone of plants and will not cause a rise in water table which would cause increased evapotranspiration.

Table 5. Bitterroot mitigation option #1 mitigation recharge.

Month	Changed return flow mitigation plan: infiltration of a portion of historic on-farm efficiency losses (AF)	New appropriation mitigation plan: infiltration of entire historic consumed volume (AF)
January		
February		
March		
April	1.52	3.55
May	7.24	16.90
June	7.06	25.35
July	9.38	33.68
August	8.03	28.84
September	4.33	15.55
October	0.87	3.12
November		
December		
Annual total:	38.45	127.00

Option #1 modeling results:

- Mitigation of new appropriation using water historically consumed by hay covers all depletions and generates extra mitigation marketing water in the amount of 73.53 AF annually (table 6).
- Mitigation successfully covers depletions for those months when water is not legally available (table 1).
- The model was used to evaluate the timing and amount of mitigation water infiltrated to compensate for changes in return flow from acreage taken out of production. Mitigation of

return flow changes is provided by infiltrating water which was historically lost to on-farm efficiency losses. Modeling shows that return flow changes were mitigated by infiltration of 100% of the volume historically lost to on-farm efficiency during April and May, and 65% of the volume historically lost during June through October (table 5 and 6).

- Mitigation of return flow changes requires additional 2.17 AF annually (table 6) to offset changes in return flow timing resulting in additional 2.17 AF accreted to the Bitterroot River (this water was historically an irrecoverable direct evaporative loss from irrigation inefficiency).
- Infiltration of former consumptively used irrigation water in excess of that needed for this new appropriation generates extra mitigation marketing water in the amount of 73.53 AF annually. This mitigation marketing water is available each month of the year. The availability of mitigation marketing water outside of the irrigation season could be used to offset depletions from other groundwater development, something that cannot be mitigated by changing existing irrigation water to mitigation by leaving that water instream.

Table 6. Bitterroot mitigation option #1 monthly water balance.

Month	Depletions from change in return flows (AF)	Accretions from changed return flow mitigation plan (AF)	Depletions from new appropriation (AF)	Accretions from new appropriation mitigation plan (AF)	Extra mitigation marketing water generated (AF)	Net change to river with all mitigation water used (AF)
Jan	-3.31	3.46	-4.85	11.48	6.63	0.15
Feb	-2.88	3.08	-4.3	10.22	5.92	0.2
March	-3.06	3.33	-4.63	11.07	6.44	0.27
April	-2.84	3.14	-4.34	10.42	6.08	0.3
May	-2.82	3.15	-4.34	10.45	6.11	0.33
June	-2.67	2.97	-4.09	9.85	5.76	0.3
July	-2.78	3.04	-4.18	10.03	5.85	0.26
Aug	-2.9	3.08	-4.24	10.1	5.86	0.18
Sept	-3	3.08	-4.27	10.07	5.8	0.08
Oct	-3.29	3.3	-4.63	10.85	6.22	0.01
Nov	-3.29	3.31	-4.65	10.9	6.25	0.02
Dec	-3.4	3.47	-4.88	11.49	6.61	0.07
Annual total	-36.24	38.41	-53.4	126.93	73.53	2.17

Option #2. The historic irrigation water right from a ditch is used for lawn and garden and the new water supply well is used only for indoor use. Aquifer recharge is used to mitigate depletions from the new well by infiltrating former irrigation consumptive use using a small drainfield.

Historic irrigation applied volume, consumptive use, return flow, and irrecoverable losses are shown in table 3 above.

Assumptions:

- Seventy historically irrigated acres are retired, while 30 acres remain in irrigation, repurposed for lawn and garden using the same historic ditch for conveyance. The lawn and garden acreage is evenly dispersed throughout 125-acre development.
- The new water supply well is exclusively dedicated to indoor use for the development, which after use, drains to the community septic system.
- The historic irrigated 100-acre parcel is assumed to be square in shape (2,087 x 2,087 ft).
- Return flows associated with the historic 70 acres of irrigation, that no longer occur, were simulated in the modeling as two pumping wells. One is located at the site of the new water supply well, while the other is located 1,043.5 ft closer to the river. This modeling input is designed to simulate the historic return flow source, representing a two-point strip, equating to a 1,043.5 ft width x 2,087 ft area.
- The mitigation plan for changes in return flow is provided by infiltrating into groundwater, a portion of the historic non-consumptive use (on-farm efficiency losses) using a large drain field (simulated in the modeling using a recharge well because the model only includes injection and pumping wells) to replace return flow losses (Table 7). The drainfield is designated as a recharge well in the model, located at the top end of the property 261 ft above the new water supply well.
- New appropriation mitigation plan: Recharge mitigation is provided by infiltrating a portion of historic consumptive use using this same drainfield (table 7). The mitigation water source is a portion of the former consumptive use from the 70 acres retired from irrigation in the development. This mitigation plan is the minimum amount of infiltrated water which mitigates depletions to the Bitterroot River when water is not legally available for new appropriation.
- Long term infiltration rate of 0.5 inch/hr (7.5 gpd/ft^2) for loamy sand (WA DOE 2005). Drainfield of 0.2 acres in size, maximum average monthly flow rate of 50 gpm.
- The drainfield is constructed below the rooting zone of plants and will not cause a rise in water table which would cause increased evapotranspiration.

Option #2 modeling results:

- Mitigation of return flow changes requires additional 1.49 AF of formerly non-consumed water annually to offset changes in return flow timing (table 8).
- Mitigation of new appropriation using water historically consumed by hay covers all depletions (table 8).
- Mitigation successfully covers depletions for those months when water is not legally available (table 1).
- Mitigation generates 1.54 AF of additional water accreted to the Bitterroot River. These accretions are because it is not possible to develop a mitigation plan which perfectly times the depletions to the river and a small amount of extra mitigation recharge is required to offset depletions during all months when water is not legally available.
- Priority date of historic irrigation water right is maintained for lawn and garden irrigation.
- This mitigation option requires the least water to be recharged to the aquifer and smallest infiltration system.

Table 7. Bitterroot mitigation option #2 mitigation recharge.

Month	Changed return flow mitigation plan: infiltration of a portion of historic on-farm efficiency losses (AF)	New appropriation mitigation plan: infiltration of 1.60 AF historic consumed volume (AF)
January		
February		
March		
April	1.07	0.23
May	5.07	0.23
June	4.94	0.23
July	6.57	0.23
August	5.62	0.23
September	3.03	0.23
October	0.61	0.22
November		
December		
Annual total:	26.91	1.60

Table 8. Bitterroot mitigation option #2 monthly water balance.

Month	Depletions from change in return flows (AF)	Accretions from changed return flow mitigation plan (AF)	Depletions from new appropriation (AF)	Accretions from new appropriation mitigation plan (AF)	Net change to river (AF)
Jan	-2.32	2.43	-0.13	0.14	0.12
Feb	-2.02	2.16	-0.12	0.13	0.15
March	-2.15	2.33	-0.13	0.14	0.19
April	-1.99	2.2	-0.13	0.13	0.21
May	-1.98	2.2	-0.13	0.13	0.22
June	-1.87	2.08	-0.13	0.13	0.21
July	-1.94	2.13	-0.13	0.13	0.19
Aug	-2.04	2.16	-0.13	0.13	0.12
Sept	-2.1	2.15	-0.13	0.13	0.05
Oct	-2.31	2.31	-0.13	0.14	0.01
Nov	-2.31	2.32	-0.13	0.13	0.01
Dec	-2.38	2.43	-0.13	0.14	0.06
Annual total	-25.41	26.9	-1.55	1.6	1.54

Option #3. Aquifer recharge is used to offset depletions from the new well by infiltrating using a large drainfield the minimum amount of water needed to offset adverse effects. The new well is used for both domestic and irrigation purposes.

Historic irrigation applied volume, consumptive use, return flow, and irrecoverable losses are shown in table 4 above.

Assumptions:

- The new water supply well supplies 100% of water needs (domestic, lawn and garden, commercial, and institutional) for the development.
- The historic irrigated 100-acre parcel is assumed to be square in shape (2,087 x 2,087 ft).
- Loss of historic return flows are simulated as two separate pumping wells at two locations. One is located at the same location as the new water supply well. Another is located 1,043.5 ft closer to the river. This spacing simulates the historic return flow source as two points representing strips 1,043.5 ft width x 2,087 ft long.
- Changed return flow mitigation plan: Mitigation of changes in return flow timing is provided by infiltrating a portion of the historic non-consumptive use (on-farm efficiency losses) using a large drainfield (simulated in the model using a recharge well because the model only includes injection and pumping wells) to replace return flow losses (table 9). The drainfield is simulated with a recharge well located at the top end of the property 261 ft above the new water supply well.
- New appropriation mitigation plan: Recharge mitigation is provided by infiltrating a portion of the historic consumptive use using this same large drain field (table 9). The mitigation water source is a portion of the former consumptive use from the 100 acres retired from irrigation in the development. This mitigation plan is the minimum volume which mitigates Bitterroot River depletions when water is not legally available in the river.
- Long-term infiltration rate of 0.5 inch/hr (7.5 gpd/ft^2) for loamy sand (WA DOE 2005). Drainfield of 0.8 acres in size, maximum average monthly flow rate of 172 gpm.
- The drainfield is constructed below the rooting zone of plants and will not cause a rise in water table which would cause increased evapotranspiration.

Option #3 modeling results:

- Mitigation of return flow changes requires additional 2.17 AF annually (table 10). Mitigation of new appropriation using water historically consumed covers all depletions (table 10).
- Mitigation successfully covers depletions for those months when water is not legally available (table 1).
- Mitigation of new appropriation requires an additional 0.72 AF of mitigation water annually than is consumed by the new development (table 10). This additional mitigation water is necessary to cover the timing of depletions because the new use is year-round while the mitigation water is only available for infiltration from April through October.
- Mitigation generates 2.89 AF of additional water accreted to the Bitterroot River (table 10). These accretions are because it is not possible to develop a mitigation plan which perfectly times the depletions to the river and a small amount of extra mitigation recharge is required to offset depletions during all months when water is not legally available.

- This mitigation option requires a significantly larger drainfield and higher mitigation flow rate than option #2 using the existing irrigation water right and ditch water for lawn and garden.

Table 9. Bitterroot mitigation option #3 mitigation recharge.

Month	Changed return flow mitigation plan: infiltration of a portion of historic on-farm efficiency losses (AF)	New appropriation mitigation plan: infiltration of a portion of historic consumed volume (AF)
January		
February		
March		
April	1.52	1.70
May	7.24	7.22
June	7.06	10.71
July	9.38	14.16
August	8.03	12.16
September	4.33	6.66
October	0.87	1.53
November		
December		
Annual total:	38.45	54.13

Table 10. Bitterroot mitigation option #3 monthly water balance.

Month	Depletions from change in return flows (AF)	Accretions from changed return flow mitigation plan (AF)	Depletions from new appropriation (AF)	Accretions from new appropriation mitigation plan (AF)	Net change to river (AF)
Jan	-3.31	3.46	-4.85	4.89	0.19
Feb	-2.88	3.08	-4.3	4.36	0.26
March	-3.06	3.33	-4.63	4.72	0.36
April	-2.84	3.14	-4.34	4.44	0.4
May	-2.82	3.15	-4.34	4.46	0.45
June	-2.67	2.97	-4.09	4.2	0.41
July	-2.78	3.04	-4.18	4.28	0.36
Aug	-2.9	3.08	-4.24	4.31	0.25
Sept	-3	3.08	-4.27	4.3	0.11
Oct	-3.29	3.3	-4.63	4.63	0.01
Nov	-3.29	3.31	-4.65	4.64	0.01
Dec	-3.4	3.47	-4.88	4.89	0.08
Annual total	-36.24	38.41	-53.40	54.12	2.89

Option #4. Depletions from the new well use are mitigated by leaving the former irrigation water instream in the river.

Historic irrigation applied volume, consumptive use, return flow, and irrecoverable losses are shown in table 2 above.

Assumptions:

- The new water supply well supplies 100% of water needs (domestic, lawn and garden, commercial, and institutional) for the development.
- The historic irrigated 100-acre parcel is assumed to be square in shape (2,087 x 2,087 ft).
- Loss of historic return flows are simulated as two separate pumping wells at two locations. One is located at the same location as the new water supply well. Another is located 1,043.5 ft closer to the river. This spacing simulates the historic return flow source as two points representing strips 1,043.5 ft width x 2,087 ft long.
- Changed return flow mitigation plan: irrigation water is no longer diverted at ditch headgate and water is left instream (table 11).
- New appropriation mitigation plan: irrigation water is no longer diverted at ditch headgate and water is left instream (table 11).

Table 11. Bitterroot mitigation option #4 mitigation recharge.

Month	Changed return flow mitigation plan: irrigation water is no longer diverted at ditch headgate and water is left instream (AF)	New appropriation mitigation plan: irrigation water is no longer diverted at ditch headgate and water is left instream (AF)
January		
February		
March		
April	1.52	3.55
May	7.24	16.90
June	10.86	25.35
July	14.43	33.68
August	12.36	28.84
September	6.67	15.55
October	1.34	3.12
November		
December		
Annual total:	54.43	127.00

Option #4 modeling results:

- Mitigation plan is insufficient to prevent adverse effects to other water right holders due to changes in return flow timing. Table 12 shows the Bitterroot River is depleted from October through March. Water is not legally available for new use in the river Jan, Feb, Oct, or Dec (table 1).
- Bitterroot River flow is augmented from May-Sept because formerly diverted water is left instream.
- This scenario shows how it is impossible to mitigate year-round depletions from a new well without storing the water and releasing during winter. Options for storage and release of water include either using a reservoir or through mitigation recharge as shown in options 1, 2, 3, and 5.

Table 12. Bitterroot mitigation option #4 monthly water balance.

Month	Depletions from change in return flows (AF)	Accretions from changed return flow mitigation plan (AF)	Depletions from new appropriation (AF)	Accretions from new appropriation mitigation plan (AF)	Net change to river (AF)
Jan	-3.31		-4.85		-8.16
Feb	-2.88		-4.3		-7.18
March	-3.06		-4.63		-7.69
April	-2.84	1.52	-4.34	3.55	-2.11
May	-2.82	7.24	-4.34	16.90	16.98
June	-2.67	10.86	-4.09	25.35	29.46
July	-2.78	14.43	-4.18	33.68	41.15
Aug	-2.9	12.36	-4.24	28.84	34.06
Sept	-3	6.67	-4.27	15.55	14.95
Oct	-3.29	1.34	-4.63	3.12	-3.46
Nov	-3.29		-4.65		-7.94
Dec	-3.4		-4.88		-8.28
Annual total	-36.24	54.43	-53.40	127.00	91.79

Option #5. Aquifer recharge is used to mitigate depletions from the new well by infiltrating using a constructed wetland the minimum amount water needed to offset adverse effects.

Historic irrigation applied volume, consumptive use, return flow, and irrecoverable losses are shown in table 2 above.

Assumptions:

- The new water supply well supplies 100% of water needs (domestic, lawn and garden, commercial, and institutional) for the development.
- The historic irrigated 100-acre parcel is assumed to be square in shape (2,087 x 2,087 ft).
- Loss of historic return flows are simulated as two separate pumping wells at two locations. One is located at the same location as the new water supply well. Another is located 1,043.5 ft closer to the river. This spacing simulates the historic return flow source as two points representing strips 1,043.5 ft width x 2,087 ft long.
- Changed return flow mitigation plan: Mitigation of changes in return flow timing is provided by recharging the alluvial aquifer with a portion of the historic non-consumptive use (on-farm efficiency losses) using a constructed wetland (simulated using a recharge well because the model only includes injection and pumping wells) to replace return flow losses (table 13). The wetland recharge is simulated with a recharge well located at the top end of the property 261 ft above the new water supply well.
- New appropriation mitigation plan: Recharge mitigation is provided by recharging the alluvial aquifer with a portion of the historic consumptive use using this same constructed wetland (table 13). This mitigation plan is the minimum volume which mitigates Bitterroot River depletions when water is not legally available in the river.

- The mitigation plan assumes the wetland is engineered to provide infiltration the maximum required mitigation recharge rate of 172 gpm. Mitigation recharge will be ensured by requiring minimum monthly volume of water in excess of wetland ET be delivered to the wetland each month (table 13).
- The wetland will be an aesthetic feature at the residential community and can also be used for filtering/treatment of storm water.
- The wetland will also be eligible for compensatory mitigation credits under Section 404 of the Clean Water Act (33 U.S. Code § 1344). Mitigation credits can be sold to private or government development projects which eliminate wetlands protected under Section 404.
- Wetland is 1.39 acres is size and assumed to be approximately square. The wetland has a pool volume of 0.70 AF. Wetland has 25% open water. Wetland consumptive use (evapotranspiration) is shown in table 13 and is calculated using methods in Allen et al. (1994) and Potts (1988). Wetland consumptive use requires 3.14 AF of annual consumptive use. The wetland consumptive use will be changed from irrigation to wetland use in the water right change. This amount of water is available for the new wetland use as significantly more consumptively used water remains after mitigation of the new appropriation (table 14).
- The wetland will require additional water beyond that applied in the mitigation plan in table 13. Annual filling of the wetland pool volume will require 0.70 AF. Additionally if the wetland is leakier than the minimum monthly volumes required in the mitigation plan then additional water will be required to maintain the wetland water level. Significant additional water is available from former consumptive use of irrigation water as shown in table 14. Any additional water required for the wetland would be included in the water right change in addition to the change to mitigation recharge.
- If additional water is required and provides recharge above that needed for mitigation, the additional recharge of historically consumptively used water can be changed to mitigation marketing water. Mitigation marketing water could be sold to other new water users generating value for the wetland. Our assumption is that the wetland in this scenario will recharge the minimum amount of water required in the mitigation plan in table 13.
- It is more challenging to guarantee that recharge is correctly timed using a wetland vs a drainfield as in options #1-3. The wetland will need to be engineered to hold enough water to allow ponding and survival of wetland vegetation (phreatophytes and/or hydrophytes) but leaky enough to allow groundwater recharge. To achieve this it may be necessary to have the bulk of the wetland lined with an impermeable liner which is non-leaky and have the wetland drain into an infiltration system. The infiltration system could be either a drainfield, a permeable basin, or a permeable sump/drywell. Our assumptions is any evaporation from the infiltration portion of the wetland is included in the wetland total consumptive use in table 13; if an infiltration basin is used it would be included in the wetland open water evaporation. Potential for plugging of the infiltration system by vegetation, fine sediment and decaying organic matter, or biofouling will have to be accounted for in wetland engineering. This may require filtering of recharge water prior to delivery to the infiltration portion of the wetland.

Table 13. Bitterroot mitigation option #5 mitigation recharge and wetland evapotranspiration (consumptive use).

Month	Changed return flow mitigation plan: infiltration of a portion of historic on-farm efficiency losses (AF)	New appropriation mitigation plan: infiltration of a portion of historic consumed volume (AF)	Wetland total consumptive use (AF)	Minimum volume of water added to wetland (AF)
January				
February				
March				
April	1.52	1.70		3.22
May	7.24	7.22	0.23	14.69
June	7.06	10.71	0.81	18.58
July	9.38	14.16	1.07	24.61
August	8.03	12.16	0.89	21.08
September	4.33	6.66	0.15	11.14
October	0.87	1.53		2.40
November				
December				
Annual total:	38.45	54.13	3.14	95.72

Table 14. Consumptive use surplus after mitigation (historic consumptive use – mitigation).

Month	Consumptive use volume available after mitigation (AF)
January	
February	
March	
April	1.9
May	9.7
June	14.6
July	19.5
August	16.7
September	8.9
October	1.6
November	
December	
Annual total:	72.9

Option #5 modeling results:

- Mitigation of return flow changes requires additional 2.17 AF annually (table 15). Mitigation of new appropriation using water historically consumed covers all depletions (table 15).
- Mitigation successfully covers depletions for those months when water is not legally available (table 15).
- Mitigation of new appropriation requires an additional 0.72 AF of mitigation water annually than is consumed by the new development (table 15). This additional mitigation water is necessary to cover the timing of depletions because the new use is year-round while the mitigation water is only available for infiltration from April through October.
- Mitigation generates 2.89 AF of additional water accreted to the Bitterroot River (table 15). These accretions are because it is not possible to develop a mitigation plan which perfectly times the depletions to the river and a small amount of extra mitigation recharge is required to offset depletions during all months when water is not legally available.

Table 15. Bitterroot mitigation option #5 monthly water balance.

Month	Depletions from change in return flows (AF)	Accretions from changed return flow mitigation plan (AF)	Depletions from new appropriation (AF)	Accretions from new appropriation mitigation plan (AF)	Net change to river (AF)
Jan	-3.31	3.46	-4.85	4.89	0.19
Feb	-2.88	3.08	-4.3	4.36	0.26
March	-3.06	3.33	-4.63	4.72	0.36
April	-2.84	3.14	-4.34	4.44	0.4
May	-2.82	3.15	-4.34	4.46	0.45
June	-2.67	2.97	-4.09	4.2	0.41
July	-2.78	3.04	-4.18	4.28	0.36
Aug	-2.9	3.08	-4.24	4.31	0.25
Sept	-3	3.08	-4.27	4.3	0.11
Oct	-3.29	3.3	-4.63	4.63	0.01
Nov	-3.29	3.31	-4.65	4.64	0.01
Dec	-3.4	3.47	-4.88	4.89	0.08
Annual total	-36.24	38.41	-53.40	54.12	2.89

2. New subdivision well in the Missoula Valley Aquifer

2.1 Scenario description

Basic details of development

This scenario represents a new large subdivision development that will require a multiple domestic water right/lawn and garden water right. This example evaluates the effects of this new use on the Clark Fork River and three potential mitigation options.

The development is located in the Missoula Valley in between Missoula and Frenchtown. This is a 250.5-acre development with 300 single family homes, and 100.5 acres lawn and garden irrigation (1/4 acre per home + 25.5 acre park and field common area irrigation).

The development is situated on ground which was not historically irrigated, therefore the developer will need to obtain an existing water right and change its historic purpose to a new purpose of mitigation so that any new depletions during period where water is not legally available can be offset. One alternative to obtaining an existing water right and changing it is to purchase existing mitigation water. Mitigation marketing water is purchased from someone who has already gone through the change process and is marketing that water for sale. In this scenario the purchased marketing water is from the same area of Missoula County as the development.

For the option where an existing water right is changed to mitigation, the existing irrigated field is assumed to be a full service statement of claim water right with a priority date of 1901 for irrigation of pasture grass using wheel-line sprinkler in this same part of Missoula County. The field is 7,500 ft from the Clark Fork River. Historic return flows from the existing water right to be changed are assumed to return to the Clark Fork River and changes in timing of return flows will not adversely affect other water users because the Clark Fork is not water limited below Missoula. Changes in return flows can therefore be adequately mitigated by leaving the water instream.

The development uses a community wastewater system with a drainfield (no lagoon). The drainfield is located 2,600 ft from the Clark Fork River.

The water supply well is 2,600 ft from the Clark Fork River and 500 ft hydraulically side gradient from the drainfield.

Distance from River to Tertiary geology is 21,000 ft (Tertiary sediments are assumed a no-flow boundary for modeling purposes).

Hydrogeologic properties

Transmissivity (T) value of 1,152,000 gpd/ft and specific yield (Sy) value of 0.12 are assumed based on Woessner (1988).

Legal availability of surface water

Legal availability of surface water is shown in table 16. Median monthly flows are taken from lower Clark Fork USGS gage 12353000 below Missoula. Water rights used for the legal availability analysis include surface water rights located between the gage and the confluence of Nine Mile Creek. The legal availability shows that with the exception of Avista's hydropower water right for Noxon Dam, water is legally available during each month of the year. In contrast, when considering Avista's hydroelectric water right, water is not legally available during any month of the year. As described in section 2.2 of the Water Supply Report Series I, water is only legally available above Avista's water right when spring flows exceed 50,000 cfs at Noxon Rapids Dam. Flows exceed 50,000 cfs between zero and several months per year (figure 1) most often during May and June, but also in April and July. Water use outside of periods when flows exceed 50,000 cfs must be mitigated on an annual basis (see DNRC 2008 and 2009 Memos). Therefore, the proposed new consumptive water use for this new subdivision must be mitigated on an annual basis.

Table 16. Clark Fork River median monthly flows and existing legal demand.

Months with legally available water shown in green; months without shown in red. Period of flow record for Clark Fork River is 1929-2013.

Month	Middle Clark Fork River Flow median monthly flow (AF)	Existing water rights other than Avista Noxon Rapids hydropower (AF)	Avista Noxon Rapids hydropower water right (AF)	Total Existing Legal Demand (AF)	Legal Availability (AF)
Jan	144,304	4	3,074,380	3,074,384	-2,930,079
Feb	138,655	4	3,074,380	3,074,384	-2,935,728
March	154,555	20	3,074,380	3,074,400	-2,919,846
April	182,299	9,603	3,074,380	3,083,984	-2,901,685
May	990,673	9,860	3,074,380	3,084,240	-2,093,567
June	1,360,260	10,037	3,074,380	3,084,417	-1,724,157
July	475,572	10,037	3,074,380	3,084,417	-2,608,845
Aug	157,010	10,037	3,074,380	3,084,417	-2,927,407
Sept	151,886	10,021	3,074,380	3,084,401	-2,932,515
Oct	182,360	9,716	3,074,380	3,084,096	-2,901,736
Nov	157,766	14	3,074,380	3,074,394	-2,916,627
Dec	140,683	9	3,074,380	3,074,389	-2,933,706

Consumptive use calculations for the new water appropriation

Consumptive use calculations are described below. Only new consumptive use is modeled and only new consumptive use is mitigated. Non-consumptive use (treated wastewater from the community drainfield and irrigation loss) is assumed to return to the source aquifer. Total consumptive use used in the AWAS model is shown in table 17.

In-house domestic: Consumptive use is 5% of flow (Kimsey and Flood 1987). The 5% in-house consumptive use standard is for a community wastewater system with a drainfield (no lagoon).

> 300 homes at 100 gpd/person (HRD 2001). Assume 2.5 persons/household (Census is 2.36 for Missoula County): 300 x 250 gpd x 365days/yr x AF/325,851 gal x 5% = 0.014 AF/yr per household or 4.20 AF for 300 homes.

Figure 1. Lower Clark Fork River hydrograph and Avista Noxon Rapids Dam water right.

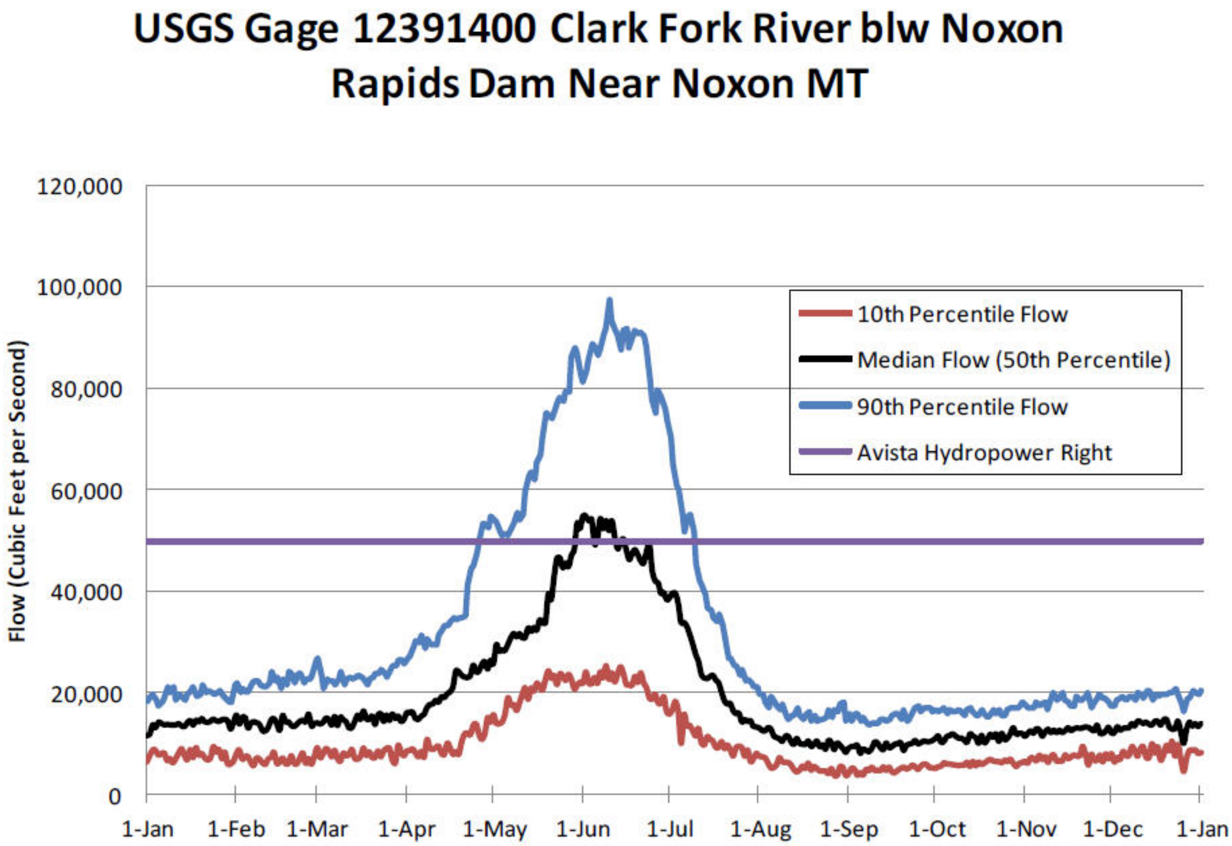


Table 17. Consumptive use values of new water appropriation used in the Missoula Valley model.

Month	Pasture grass dry year net irrigation required (inches)	Irrigation of 100.5 acres lawn and garden consumptive use (AF)	Domestic consumptive use 300 homes (AF)	Total monthly consumption (AF)	Consumed flow rate (gpm)
January			0.36	0.36	2.6
February			0.32	0.32	2.6
March			0.36	0.36	2.6
April	0.44	3.69	0.35	4.03	30.4
May	2.51	21.02	0.36	21.38	156.0
June	3.99	33.42	0.35	33.76	254.7
July	5.61	46.98	0.36	47.34	345.6
August	4.87	40.79	0.36	41.14	300.3
September	2.53	21.19	0.35	21.53	162.4
October	0.43	3.60	0.36	3.96	28.9
November			0.35	0.35	2.6
December			0.36	0.36	2.6
Annual total:	20.4	170.68	4.20	174.88	

Lawn and garden consumptive use rates (in inches of water per month) are calculated using modeled pasture grass requirements for a dry year using NRCS Irrigation Water Requirements (IWR) software and precipitation record for Missoula WSO AP weather station (values shown in table 17 above).

Consumptive use calculations for the historic irrigation water right changed to mitigation

Consumptive water use of the historic irrigation water right to be changed is shown in table 18 below. To calculate the amount of acreage which needs to be taken out of production to mitigate the annual consumptive use of the new residential development, the consumptive use of a generic historic irrigation water right in the Missoula Valley was calculated. Irrigation consumptive use calculations use methods are set forth in ARM 36.12.1902, IWR irrigation ET for wheel-line sprinkler for Missoula WSO AP weather station (19.45 inches ET) and county management factor of 69.5% for a consumptive use of 1.13 AF/ac per irrigation season. This annual consumptive use is allocated to each month of the irrigation season (April to October) based on the irrigation water requirement for the month using IWR (net irrigation requirement for month/net annual irrigation water requirement).

In this scenario irrecoverable loss (direct evaporation of applied irrigation water) is not included in our calculation of consumptive use. Irrecoverable loss is included in historic consumptive use per ARM 36.12.1902(17) and thus our calculation is different than the administrative rule method. In our scenario the former irrecoverable loss is used to mitigate changes in return flows instead of a new consumptive use. If instead we had strictly used the administrative rule method then mitigation of changes in return flow would require using of a portion of the historic consumptive use in order to have sufficient mitigation water available for each month. So the net historic consumptive use which could be changed to mitigation is approximately the same.

As an alternative to changing an existing water right to mitigation, there is existing mitigation marketing water available in the basin at this same rate of 1.13 AF/ac per irrigation season. If the developer can acquire this water from its owners, it is likely that the developer could avoid a change application and instead contract for this water that has already been designated as an option for mitigation of new uses.

Field applied volume and on-farm loss (field loss) for the historic irrigation water right changed to mitigation

Historic applied irrigation volume and field loss for a generic historic irrigation water right in the Missoula Valley is shown in table 18 below. Historic applied irrigation volume was calculated using DNRC guidelines for historic diverted volume (DNRC 2012) with sprinkler efficiency of 70% (ARM 36.12.115). On-farm loss is calculated as 30% of applied volume. Of the on-farm loss, 10% is considered irrecoverable loss (direct evaporation of applied irrigation water) and 20% is return flow to groundwater (DNRC 2013 and ARM 36.12.1902). Changes in return flow are simulated in the model for the retired irrigation acreage. Ditch conveyance loss (seepage) is not considered to change in the model because the ditch will continue to be used by other ditch users and conveyance losses are assumed to remain the same. In the event conveyance losses change during a water right change, those changes do not need to be mitigated because they are considered “seepage water” which other water users can appropriate, but have no legal right to its continuance (ARM 36.12.101).

Table 18. Historic irrigation applied volume, consumptive, and return flow and irrecoverable losses.

Month	Pasture grass dry year net irrigation required (inches)	Historic applied volume with on-farm efficiency of 70% (AF)	Historic consumptive use: 154.76 acres retired (AF)	Historic return flow & irrecoverable evaporative losses: 154.76 acres retired (AF)	Historic return flow: 154.76 acres retired (AF)
January					
February					
March					
April	0.44	5.39	3.78	1.62	1.08
May	2.51	30.77	21.54	9.23	6.15
June	3.99	48.91	34.24	14.67	9.78
July	5.61	68.77	48.14	20.63	13.75
August	4.87	59.70	41.79	17.91	11.94
September	2.53	31.01	21.71	9.30	6.20
October	0.43	5.27	3.69	1.58	1.05
November					
December					
Annual total:	20.4	249.83	174.88	74.95	49.97

2.2 Missoula Valley Mitigation Options Evaluated

The following mitigation options are evaluated for the theoretical scenario of a new subdivision well in the Missoula Valley Aquifer:

Option #1. Instream mitigation using an existing irrigation water right to be changed to mitigation.
Option #2. Instream mitigation using purchased mitigation credit from an existing mitigation marketing water right.
Option #3. Instream mitigation by storing spring flows in a lined pond and releasing water for mitigation.

Mitigation plan options are evaluated by modeling consumptive use of the new water appropriation (the new water supply well) and modeling any losses of historic irrigation return flow (option #1 only). Mitigation recharge is not modeled because the mitigation options leave the mitigation water instream; because changes in timing of return flows are not an issue, mitigation water is not recharged to the aquifer and the groundwater model is not needed to predict accretion/depletions from mitigation.

The streamflow depletion/accretion results given in the monthly water balance for the individual mitigation options are those modeled after 100 years using AWAS. However in this model streamflow depletion/accretion stabilizes at an equilibrium condition after only 3 years.

Table 19. Missoula mitigation option #1 and 2 mitigation plan instream volumes.

Changed return flow mitigation plan: entire historic non-consumed volume left instream (AF)	New appropriation mitigation plan: entire historic consumed volume left instream
1.62	3.78
9.23	21.54
14.67	34.24
20.63	48.14
17.91	41.79
9.30	21.71
1.58	3.69
74.95	174.88

Option #1. Instream mitigation using an irrigation water right changed to mitigation.

This mitigation option retires the minimum acreage of an existing full service irrigation water right necessary to mitigate the consumptive use of the new water well use. Table 18 shows that retiring 154.76 acres of the existing irrigation will reduce consumptive use by 174.88 AF per year, sufficient to mitigate the new consumptive use shown in table 17. This mitigation option leaves the water formerly applied to these 154.76 acres instream, thereby mitigating, on an annual basis, both new consumptive use and the loss of return historic return flow from the former irrigation.

Assumptions:

- The new water supply well supplies 100% of water needs (domestic, lawn and garden) for the development.
- Changed return flow mitigation plan: Mitigation of changes in return flow is provided by leaving the formerly diverted water instream (table 19). Changes in return flow timing will not adversely affect other appropriators because the Clark Fork is not water limited for non-hydropower uses during any month (table 16 above) and Avista's Noxon Rapid Dam water right can be mitigated on an annual basis.
- New appropriation mitigation plan: Mitigation of new consumptive use is provided by retiring 154.76 acres of an existing irrigation water right and leaving that water instream (table 19).
- Loss of historic return flows are simulated as four separate pumping wells at four locations. The retired acreage is square (approximately one quarter-section). The pumping wells are located at

7,825, 8,474, 9,123, and 9,772 ft distances from the river. This spacing simulates the historic return flow source as four points representing strips 649 ft width x 2,596 ft long.

Option #1 modeling results:

- Depletions from the change in historic return flows and the new well appropriation deplete the Clark Fork River during every month of the year (table 20).
- The mitigation plan replaces the change in return flow and new consumptive use on an annual basis. As shown in table 16 above water is legally available in the Clark Fork below the site, with the exception of Noxon Rapids Dam which must be mitigated on an annual basis. Therefore leaving former return flows instream is sufficient for mitigation.
- The net monthly change to the river is that it is depleted during September through April and gains flow during May through August.
- Mitigation of return flow changes provides an additional 24.98 AF of accretions to the Clark Fork River that was formerly lost to irrecoverable evaporative losses.

Table 20. Missoula mitigation option #1 monthly water balance.

Month	Depletions from change in return flows (AF)	Accretions from changed return flow mitigation plan (AF)	Depletions from new appropriation (AF)	Accretions from new appropriation mitigation plan (AF)	Net change to river (AF)
Jan	-2.64		-3.22		-5.86
Feb	-1.94		-2.41		-4.35
March	-1.73		-2.23		-3.96
April	-1.5	1.62	-4.04	3.78	-0.15
May	-2.37	9.23	-15.19	21.54	13.21
June	-4.08	14.67	-25.85	34.24	18.98
July	-6.39	20.63	-37.78	48.14	24.60
Aug	-7.99	17.91	-37.52	41.79	14.19
Sept	-7.57	9.30	-25.30	21.71	-1.86
Oct	-6.15	1.58	-11.81	3.69	-12.69
Nov	-4.25		-5.52		-9.77
Dec	-3.34		-4.02		-7.36
Annual total	-49.97	74.95	-174.88	174.88	24.98

Option #2. Instream mitigation using purchased mitigation credit from a mitigation marketing water right.

This mitigation option purchases mitigation marketing water in the amount necessary to mitigate the consumptive use of the new water well use. The acreage retired is the same as mitigation option #1 because both are retired sprinkler irrigation in the same area of Missoula County (and consumptive use calculations using administrative rule methods give the same mitigation volume per acre). Historic irrigation applied volume, consumptive, and return flow and irrecoverable losses are shown in table 18 above.

Assumptions:

- The new water supply well supplies 100% of water needs (domestic, lawn and garden) for the development.
- Changed return flow mitigation plan: Mitigation of changes in return flow is provided in the change for mitigation marketing which the individual marketing the water has already provided for. Changes in return flows are not modeled in this option.
- New appropriation mitigation plan: Mitigation of new consumptive use is provided by purchasing mitigation marketing water and leaving it instream (table 19).

Option #2 modeling results:

- Monthly depletions from change in return flows are not modeled because this option purchases mitigation marketing water where the changes in return flow have been approved for the mitigation water. Therefore the water balance is calculated on an annual basis (table 21).
- The mitigation plan replaces the change in new consumptive use on an annual basis. As shown in table 16 above water is legally available in the Clark Fork below the site, with the exception of Noxon Rapids Dam which must be mitigated on an annual basis. Therefore replacing the new consumptive use of 174.88 AF per year with mitigation marketing water is sufficient for mitigation.

Table 21. Missoula mitigation option #2 monthly water balance.

Month	Depletions from change in return flows (AF)	Accretions from changed return flow mitigation plan (AF)	Depletions from new appropriation (AF)	Accretions from new appropriation mitigation plan (AF)	Net change to river (AF)
Jan	included in mitigation marketing change done by individual marketing the mitigation water		-3.22		see annual total
Feb			-2.41		
March			-2.23		
April			-4.04	3.78	
May			-15.19	21.54	
June			-25.85	34.24	
July			-37.78	48.14	
Aug			-37.52	41.79	
Sept			-25.30	21.71	
Oct			-11.81	3.69	
Nov			-5.52		
Dec			-4.02		
Annual total	NA	NA	-174.88	174.88	0.00

Option #3. Instream mitigation by storing spring flows in a lined pond and releasing water for mitigation.
This option evaluates storing spring runoff flow when flows exceed 50,000 cfs at Noxon Rapids Dam and Avista's water right is fully supplied. Legal availability at Noxon Rapids Dam is explained in section 2.1 above.

Water is available for storage in the Clark Fork River during high spring flows of some years. However, the occurrence of flows above 50,000 cfs and surplus water does not happen every year; this presents special challenges to a residential development which will need to be supplied with water every year. Drought in the Clark Fork River Basin may span multiple years, during which water may not be available for storage. Too supply water to a development every year, extra water would have to be stored during years when water is available to cover years when it is not. Storage of multiple years' worth of consumptive use would require a very large reservoir; and the reservoir would need to be lined to prevent seepage. If a reservoir is sized to hold water for residential use for 2 years the reservoir would need to hold twice the 174.88 AF of annual consumptive use and the twice the annual evaporation from the reservoir. A reservoir of 20 acres in size would evaporate approximately 61 AF per year using evaporation methods in Potts (1988). The total capacity of a 20 acre reservoir with 2 years water supply would be 472 AF; and the reservoir would be 23.6 ft deep. The cost of constructing a 20 acre reservoir with a capacity this large combined with the reduction of developable land would be prohibitively expensive. Additionally, the water supply would be insufficient if drought caused Clark Fork River flows below 50,000 cfs for more than two years. Given these considerations, storing spring flows in excess of 50,000 cfs for a large residential development is not considered a realistic option.

Storing spring flows in a lined reservoir for supplying a residential development where there is no irrigation and the development is xeriscaped may be reasonable, as the in-house consumptive demand is very low (0.014 AF per year for a household of 2.5 people as described in section 2.1). However, to our knowledge a xeriscaped development where lawns and gardens are prohibited has not occurred in Montana to date.

3. Change from irrigation to instream flow for fisheries in the Deer Lodge Valley

3.1 Scenario description

Basic details of the water right change
This scenario is a change from irrigation to instream flow for fisheries in the Upper Clark Fork. This example evaluates the effects of this change in water use on the Clark Fork River and three potential water right change options.

Water right changes from irrigation to instream flow for fisheries can be used to change the former consumptive evapotranspiration use by the crop to protectable instream flow below the point of diversion (§85-2-408, MCA). We call these changes "protectable" instream flow because it is backed by a water right and junior appropriators can be called to make sure the water remains instream.

In this scenario, a portion of a center pivot which irrigates a 290 acre field will be taken out of production and the saved water will be changed to an instream flow water right for fisheries. The water right is full service statement of claim with a priority date of 1870. The hay field was historically pasture grass of which 310 acres was flood irrigated prior to July 1, 1973 when historic use is evaluated. Historic flood irrigation used a contour ditch and had a slope of 2%. The historic flood irrigation application used approximately 6 days of application per month; maximum flow rate estimated based on the capacity of the headgate for the diversion for this field is 15 cfs.

The scenario does not include supplemental water rights. Where supplemental water rights exist for an irrigation water right to be changed the entire volume and acreage for each supplemental water right must also be quantified to determine the actual volume and acreage of the water right to be changed.

The irrigation practice was changed to center pivot in the early 1990's and the irrigated area was decreased to 290 acres as the pivot does not reach the lower field corners. The center pivot has a design flow rate of 1,845 gpm/4.1 cfs.

With the water right change a portion of the field will remain irrigated using the pivot sprinkler and a portion will be retired and changed to instream flow for fisheries. The scenario investigates the obstacles to an instream flow for fisheries change where changes to irrigation practices over the years have increased consumptive use of water due to increased irrigation efficiency.

The field which will be taken out of production is 5,401 ft long running parallel to the river. The lower and upper sides of the field are located 2,700 and 5,200 ft from the Clark Fork River.

Distance from the Clark Fork River to Tertiary geology is 9,500 ft (Tertiary sediments are assumed a no-flow boundary for modeling purposes).

Hydrogeologic properties

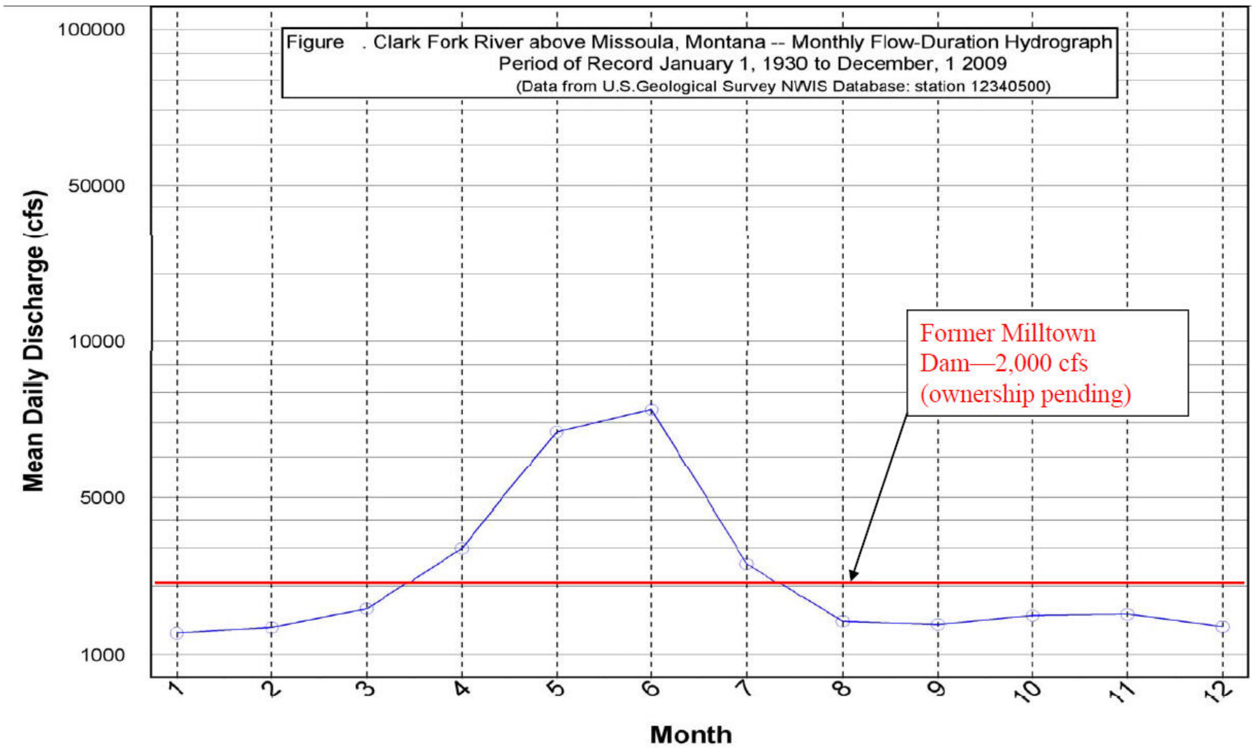
Transmissivity (T) value of 74,800 gpd/ft and specific yield (Sy) value of 0.10 are assumed based on Konizeski et al. (1968)

Legal availability of surface water

New consumptive use water is not legally available in the Clark Fork River with the exception of periods during high spring flows when streamflow exceeds 50,000 cfs at Noxon Rapids Dam; however Avista's Noxon Rapids Dam water right can be mitigated on an annual basis. The existing legal demand for surface water on the Clark Fork River below the center-pivot irrigated field is assumed in this scenario to exceed river flows during July through October and changes in streamflow during those months must be mitigated. Additionally the former Milltown Dam hydropower water right, now owned by the State of Montana, appropriates the entire flow of the Clark Fork River at Milltown and water is not legally available from August through March (figure 2).

This legal availability analysis shows that depletions from new consumptive use must be mitigated any time flows are less than 50,000 cfs at Noxon Rapids Dam and depletions from changes in return flows must be mitigated in all months except April, May, and June.

Figure 2. Milltown Dam water right legal availability.



Consumptive use calculations for the historic flood irrigation practices

Consumptive water use of the historic irrigation water right to be changed is shown in table 22 below. Historic flood irrigation consumptive use is calculated using methods set forth in ARM 36.12.1902, IWR irrigation ET for flood irrigation for Deer Lodge 3W weather station (13.14 inches annual ET) and historic county management factor of 77.6% for a consumptive use of 0.85 AF/ac per irrigation season. This annual consumptive use is allocated to each month of the irrigation season (April to October) based on the irrigation water requirement for the month using IWR (net irrigation requirement for month/net annual irrigation water requirement). Of the irrecoverable losses (explained in DNRC 2012, with values provided in ARM 36.12.1902), 5% of the flood irrigation volume applied to the field is considered an irrecoverable consumptive use and added to total consumptive use.

Field applied volume and on-farm loss (field loss) for the historic flood irrigation practices

Historic applied irrigation volume and field loss is shown in table 22. Historic applied irrigation volume was calculated using DNRC guidelines for historic diverted volume (DNRC 2012) with flood efficiency of 55% (ARM 36.12.115). On-farm loss is calculated as 45% of applied volume. Of the on-farm loss 5% is considered irrecoverable loss (direct evaporation of applied irrigation water) and 40% is return flow to groundwater (DNRC 2013 and ARM 36.12.1902).

Table 22. Historic irrigation applied volume, consumptive, and return flow.

Month	Pasture grass dry year net irrigation required (inches)	Historic flood irrigation applied volume with on-farm efficiency of 55% (AF)	Historic consumptive crop use only: 310 acres (AF)	Historic consumptive use: crop use + irrecoverable evaporation loss: 310 acres (AF)	Historic return flow: 310 acres (AF)
January					
February					
March					
April	0	0.00	0.00	0.00	0.00
May	0.12	4.58	2.52	2.75	1.83
June	3.25	124.07	68.24	74.44	49.63
July	4.28	163.39	89.86	98.03	65.35
August	3.77	143.92	79.15	86.35	57.57
September	1.13	43.14	23.73	25.88	17.25
October	0	0.00	0.00	0.00	0.00
November					
December					
Annual total:	12.55	479.09	263.50	287.45	191.64

3.2 Evaluation of the existing change in water use and consumed volume for the previous flood to center pivot change.

The existing change to center pivot in the 1990's changed irrigation water demand and return flow from that which occurred under flood irrigation. The pivot sprinkler is inherently more efficient leading to greater consumptive use of water by the crop and greatly reduced return flow from field loss. So long as there is no expansion of historic use and irrigation occurs within a water right's specified place of use, Montana's salvage law, §85-2-419, MCA , allows an irrigator to change from flood irrigation to center pivot irrigation without first obtaining a DNRC water right change permit. However, when a water right is changed to a new purpose, such as instream flow for fisheries, Montana law and administrative rules require the water right to be quantified by its historic beneficial use under flood irrigation. This means the increase in consumption associated with the past pivot conversion will need to be factored into the water right change in addition to the actual proposed change of use. We will first look at how the existing center pivot has changed water demand including applied water volume, consumed volume, return flows, and river flow to illustrate the changes in these with the current pivot practice.

Consumptive use calculations for the current center pivot irrigation practices

Consumptive use of the current center pivot is shown in table 23 below. The current center pivot irrigation consumptive use is calculated methods set forth in ARM 36.12.1902, IWR irrigation ET for center pivot for Deer Lodge 3W weather station (15.32 inches annual ET) and modern county management factor of 100% (DNRC 2013 and ARM 36.12.1902) for a consumptive use of 1.28 AF/ac per irrigation season. This annual consumptive use is allocated to each month of the irrigation season (April to October) based on the irrigation water requirement for the month using IWR (net irrigation requirement for month/net annual irrigation water requirement). Of the irrecoverable losses (explained in DNRC 2012, with values provided in ARM 36.12.1902), 10% of the irrigation volume applied to the field is considered an irrecoverable consumptive use and added to total consumptive use.

Field applied volume and on-farm loss (field loss) for the current center pivot irrigation practices

Current applied irrigation volume was calculated using DNRC guidelines for historic diverted volume (DNRC 2012) with center pivot efficiency of 70% for (ARM 36.12.115). On-farm loss is calculated as 30% of applied volume. Of the on-farm loss 10% is considered irrecoverable consumptive use (direct evaporation of applied irrigation water) and 20% is return flow to groundwater (DNRC 2013 and ARM 36.12.1902). Applied volume and return flow for the current center pivot is shown in table 23 below. Changes in return flow are simulated in the model for the change from historic flood to pivot irrigation and reductions in return flows are significant.

Table 23. Current center pivot irrigation applied volume, consumptive, and return flow.

Month	Alfalfa dry year net irrigation required (inches)	Pivot irrigation applied volume with on-farm efficiency of 70% (AF)	Pivot irrigation of alfalfa monthly crop consumptive use only: 290 acres (AF)	Pivot consumptive use: crop use + irrecoverable evaporation loss: 290 acres	Pivot irrigation return flow: 290 acres (AF)
January					
February					
March					
April	0	0.00	0.00	0.00	0.00
May	0.59	20.41	14.29	16.33	4.08
June	4.32	149.43	104.60	119.55	29.89
July	5.48	189.56	132.69	151.65	37.91
August	4.69	162.23	113.56	129.79	32.45
September	0.25	8.65	6.05	6.92	1.73
October	0	0.00	0.00	0.00	0.00
November					
December					
Annual total:	15.33	530.29	371.20	424.23	106.06

The change in monthly consumed and applied water with the change from flood to pivot is shown in table 24. With the current center pivot the existing changes in water use from historic flood are:

- Consumptive use increases in all months except September due to the greater efficiency of center pivot. Center pivot alfalfa consumptive use over the entire irrigation season increases by 141% over flood irrigation of pasture grass. Consumptive use decreases in September because alfalfa the alfalfa is assumed to be harvested in September, while the pasture grass was not harvested.
- The monthly applied volume also increases to provide adequate water to maximize irrigated alfalfa production using the pivot.
- The maximum flow rate is reduced with center pivot (maximum flood flow rate = historic ditch capacity of 15 cfs vs pivot design flow rate of 4.1 cfs). The higher flood flow rate is required to quickly deliver a flood irrigation application. The center pivot has lower peak demand but will be irrigating for a longer duration each month, leading to a slightly higher total monthly applied volume.
- With center pivot the consumptive use of water increases significantly more than the applied volume due to the high efficiency of center pivot irrigation. The increased irrigation efficiency and consumptive use is a factor of three factors: 1) the increased efficiency of center-pivot sprinkler (70%) vs flood (55%) (see ARM 36.12.115), 2) the increase in the county management factor which is the percent of possible attainable hay yield from the historic 1964 – 1973 (77.6%) to modern 1997 – 2006 (100%) periods (ARM 36.12.1902), and 3) the increase in irrecoverable consumptive losses for pivot (10%) vs flood (5%) in ARM 36.12.1902.
- Return flows are significantly reduced in all months but May due to the higher efficiency of the center pivot system. Return flows increase slightly in May due to the higher irrigation water demand in May for alfalfa using a center pivot (modeled with IWR).

Table 24. Change in consumed water, applied water, and return flow with change from flood to pivot.

Month	Change in consumed volume (AF)	Change in applied volume (AF)	Change in return flow (AF)
January			
February			
March			
April			
May	13.58	15.83	2.25
June	45.11	25.37	-19.74
July	53.62	26.17	-27.44
August	43.44	18.32	-25.12
September	-18.96	-34.49	-15.53
October			
November			
December			
Annual total:	136.77	51.19	-85.58

Changes in return flow for the change to center pivot were modeled using AWAS to show depletions to the Clark Fork River.

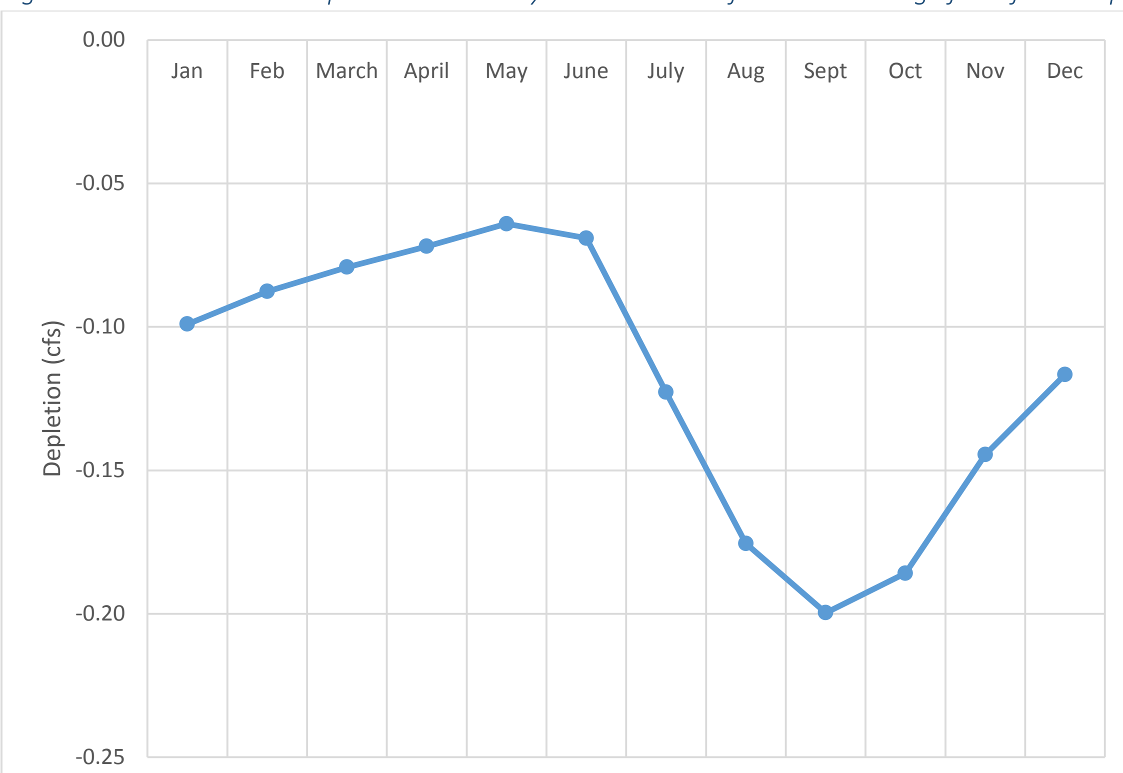
Assumptions:

- Loss of historic return flows are simulated as eight separate pumping wells at eight locations. The rectangular field is divided into eight 38.75-acre strips which are 312.5 ft in width and parallel to the river. This simulates the current return flow source as eight points representing strips 312.5 ft wide x 5053 ft long.
- Return flows are assumed to be reduced evenly across the irrigated area.

Current center pivot existing conditions modeling results:

- Modeling shows that the reduced return flows lead to depletions to the Clark Fork River throughout the year (figure 3); depletions range from -0.06 cfs in May to -0.20 cfs in September.
- Depletions from reduced return flow are in addition to depletions from increased applied irrigation water volume during May through August (table 24).

Figure 3. Clark Fork River depletions caused by reduced return flows with change from flood to pivot.



3.3 Deer Lodge Valley Instream flow for fisheries Change and Mitigation Options Evaluated

The following instream flow for fisheries water right change and mitigation options are evaluated:

Option #1. Retire 50-acres of the current pivot acreage (290-acres) and leave the water applied for that 50 acres instream.
Option #2. Retire sufficient acreage from current center pivot (290-acres) to create a minimum of 0.5 cfs of protectable, formerly consumed instream flow for fisheries during August. Offset changes in return flow with instream mitigation.
Option #3. Retire sufficient acreage from current center pivot (290-acres) to create a minimum of 0.5 cfs of protectable, formerly consumed instream flow for fisheries during August. Offset changes in return flows with aquifer recharge using a drainfield.

These three options are evaluated in detail below. Instream flow for fisheries change and mitigation options were evaluated by modeling the impacts of the monthly changes of historic irrigation return flows and the effects of mitigation recharge if included in the option. These were modeled to examine net changes to adjacent streamflow. The streamflow depletion/accretion results given in the monthly water balance for the individual mitigation options are those modeled after 100 years using AWAS. However in the model streamflow depletion/accretion stabilizes at an equilibrium condition after approximately 6 years.

Option #1. Retire 50 acres of the current pivot acreage and leave the water applied for those 50 acres instream.

The irrigation applied volume, consumptive use, and return flows from the proposed 50 acre reduction from 290 to 240-acres of alfalfa is shown in table 25.

Table 25. Instream flow for fisheries change option #1 proposed center pivot irrigation applied volume, consumptive, and return flow.

Month	Alfalfa dry year net irrigation required (inches)	Pivot irrigation applied volume with on-farm efficiency of 70% (AF)	Pivot irrigation of alfalfa monthly crop consumptive use only: 240 acres (AF)	Pivot consumptive use: crop use + irrecoverable evaporation loss: 240 acres	Pivot irrigation return flow: 240 acres (AF)
January					
February					
March					
April	0	0.00	0.00	0.00	0.00
May	0.59	16.89	11.82	13.51	3.38
June	4.32	123.67	86.57	98.94	24.73
July	5.48	156.88	109.81	125.50	31.38
August	4.69	134.26	93.98	107.41	26.85
September	0.25	7.16	5.01	5.73	1.43
October	0	0.00	0.00	0.00	0.00
November					
December					
Annual total:	15.33	438.86	307.20	351.09	87.77

The change in monthly consumed and applied water with the change from flood irrigation of 290-acres pasture grass to pivot irrigation of 240-acres alfalfa is shown in table 26. The monthly water use and return flows show:

- The monthly irrigation applied volume increases in May but is less in all other months.
- The monthly irrigation consumed volume increases in all months except September due to the greater efficiency of center pivot, even though acreage is reduced from 310-acres historic flood to 240-acres pivot. The increase in consumed volume represents an expansion of the water right and would not be approved in a water right change.
- Return flows are reduced significantly from the historic flood irrigation.

Table 26. Change in consumed water, applied water, and return flow with change from flood to 240 acres pivot.

Month	Change in consumed volume (AF)	Change in applied volume (AF)	Change in return flow (AF)
January			
February			
March			
April			
May	10.76	12.31	1.55
June	24.50	-0.40	-24.89
July	27.47	-6.51	-33.98
August	21.06	-9.66	-30.71
September	-20.16	-35.98	-15.82
October			
November			
December			
Annual total:	63.63	-40.23	-103.86

Changes in return flow for proposed reduction to 240-acres of center pivot irrigated alfalfa were modeled using AWAS to calculate depletions to the Clark Fork River.

Assumptions:

- Fifty acres of center pivot irrigated area retired, remaining 240-acres remains in center pivot irrigation using ditch water as done currently.
- Loss of historic return flows are simulated as eight separate pumping wells at eight locations. The rectangular field is divided into eight 38.75-acre strips which are 312.5 ft in width and parallel to the river. This spacing simulates the current return flow source as eight points representing strips 312.5 ft wide x 5053 ft long.
- Return flows are assumed to be reduced evenly across the irrigated area.

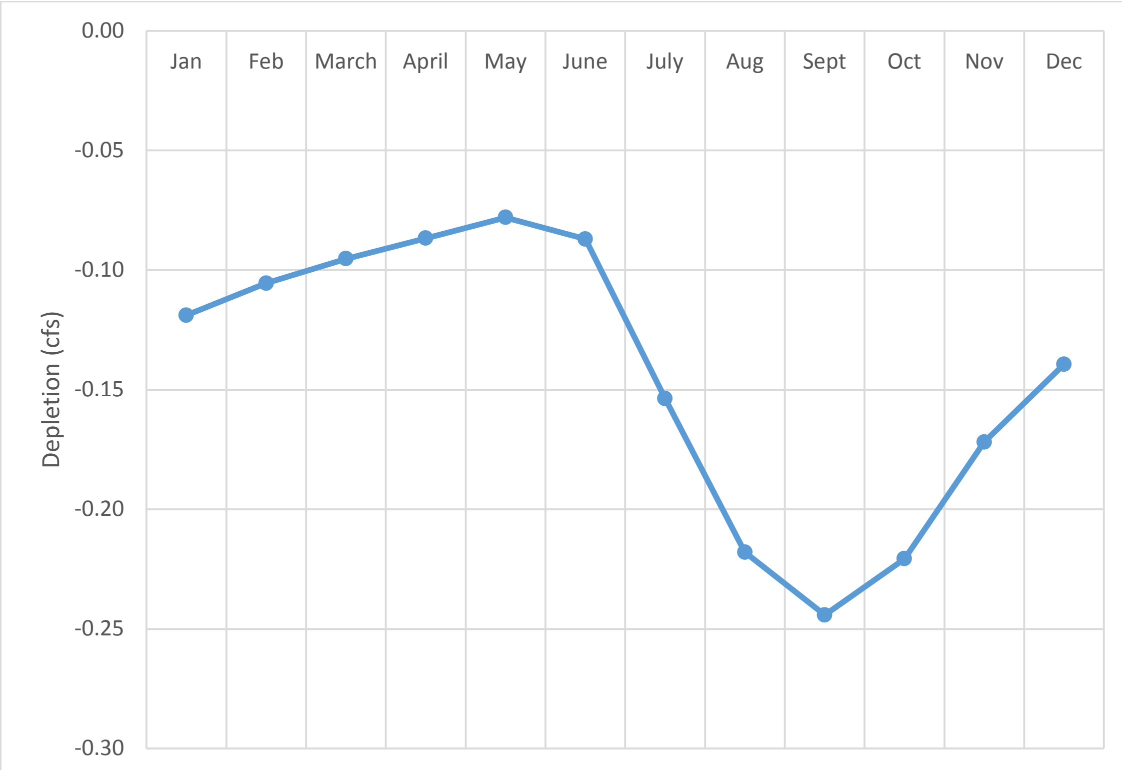
Option #1 modeling results:

- Reduced return flows lead to depletions to the Clark Fork River throughout the year (table 27 and figure 4).
- Depletions from reduced return flow are mitigated during June through September by leaving currently applied irrigation water (return flows + consumptive use) instream (table 27).
- Depletions from net increase in consumed volume and from changes in return flow would cause an adverse effect to other water users in the Upper Clark Fork and to Avista's water right for Noxon Rapids dam because water is not legally available except during springtime when flows exceed 50,000 cfs at Noxon Rapids Dam (legal availability at Noxon Rapids Dam is discussed in section 2.1 above).

Table 27. Accretions/depletions to Clark Fork River from retiring 50 acres of pivot irrigated alfalfa and instream use of water savings.

Month	Depletions from change in return flows (AF)	Accretions from instream use of former return flows (AF)	Accretions from instream use former consumptive use (AF)	Net accretions/ depletion to river
Jan	-7.31			-7.31
Feb	-5.86			-5.86
March	-5.86			-5.86
April	-5.16			-5.16
May	-4.8	0.09	-4.23	-8.95
June	-5.18	36.85	23.32	54.99
July	-9.45	49.14	33.19	72.88
Aug	-13.4	43.69	30.86	61.15
Sept	-14.53	16.52	22.92	24.91
Oct	-13.57			-13.57
Nov	-10.23			-10.23
Dec	-8.57			-8.57

Figure 4. Clark Fork River depletions caused by reduced return flows with change from flood to proposed center pivot irrigation of 240 acres alfalfa.



Option #2. Retire sufficient acreage from current center pivot (290 acres) to create a minimum of 0.5 cfs of protectable, formerly consumed instream flow for fisheries during August. Offset changes in return flow with instream mitigation.

The goal of this option is to change a minimum of 0.5 cfs of the former consumptive use of this irrigation water right to instream flow for fisheries during the months of July and August when Clark Fork streamflow is lowest and water temperature is highest.

To determine the reduction in irrigation required to reduce consumptive use by at least 0.5 cfs we calculate the reduction in acreage need so that the monthly consumed volume is reduced in both July and August by at least 30.74 AF (30.74 AF = 0.5 cfs averaged over 31 days in a month). Reducing pivot irrigated alfalfa acreage to 124.2-acres will reduce monthly consumption by 33.08 AF in July and 30.77 AF in August (table 29). The monthly irrigation water use and return flow for 124.2-acres of alfalfa is shown in table 28.

Table 29 shows that with center pivot acreage reduced to 124.2 acres:

- The monthly irrigation applied volume is reduced in all months except May.
- The monthly irrigation consumed volume is reduced in all months except May.
- Increases in applied and consumed volume in May are due to the higher irrigation requirement for alfalfa in May compared to pasture grass.
- Return flows are reduced significantly from the historic flood irrigation. Return flows are reduced the greatest under this scenario.

Table 28. Instream flow for fisheries change option #2 proposed center pivot irrigation applied volume, consumptive, and return flow.

Month	Alfalfa dry year net irrigation required (inches)	Pivot irrigation applied volume with on-farm efficiency of 70% (AF)	Pivot irrigation of alfalfa monthly crop consumptive use only: 124.2 acres (AF)	Pivot consumptive use: crop use + irrecoverable evaporation loss: 124.2 acres	Pivot irrigation return flow: 124.2 acres (AF)
January					
February					
March					
April	0	0.00	0.00	0.00	0.00
May	0.59	8.74	6.12	6.99	1.75
June	4.32	64.00	44.80	51.20	12.80
July	5.48	81.18	56.83	64.95	16.24
August	4.69	69.48	48.64	55.58	13.90
September	0.25	3.70	2.59	2.96	0.74
October	0	0.00	0.00	0.00	0.00
November					
December					
Annual total:	15.33	227.11	158.98	181.69	45.42

Table 29. Change in consumed water, applied water, and return flow with change from flood to 124.2 acres pivot.

Month	Change in consumed volume (AF)	Change in applied volume (AF)	Change in return flow (AF)
January			
February			
March			
April			
May	4.24	4.16	-0.08
June	-23.24	-60.07	-36.83
July	-33.08	-82.20	-49.12
August	-30.77	-74.44	-43.67
September	-22.92	-39.43	-16.51
October			
November			
December			
Annual total:	-105.77	-251.98	-146.21

Changes in return flow for the proposed reduction to 124.2-acres of center pivot irrigated alfalfa were modeled using AWAS to calculate depletions to the Clark Fork River.

Assumptions:

- 165.8-acres of center pivot irrigated area retired, remaining 124.4-acres remains in center pivot irrigation using ditch water as done currently.
- Loss of historic return flows are simulated as eight separate pumping wells at eight locations. The rectangular field is divided into eight 38.75-acre strips which are 312.5 ft in width and parallel to the river. This spacing simulates the current return flow source as eight points representing strips 312.5 ft wide x 5053 ft long.
- Return flows are assumed to be reduced evenly across the irrigated area.

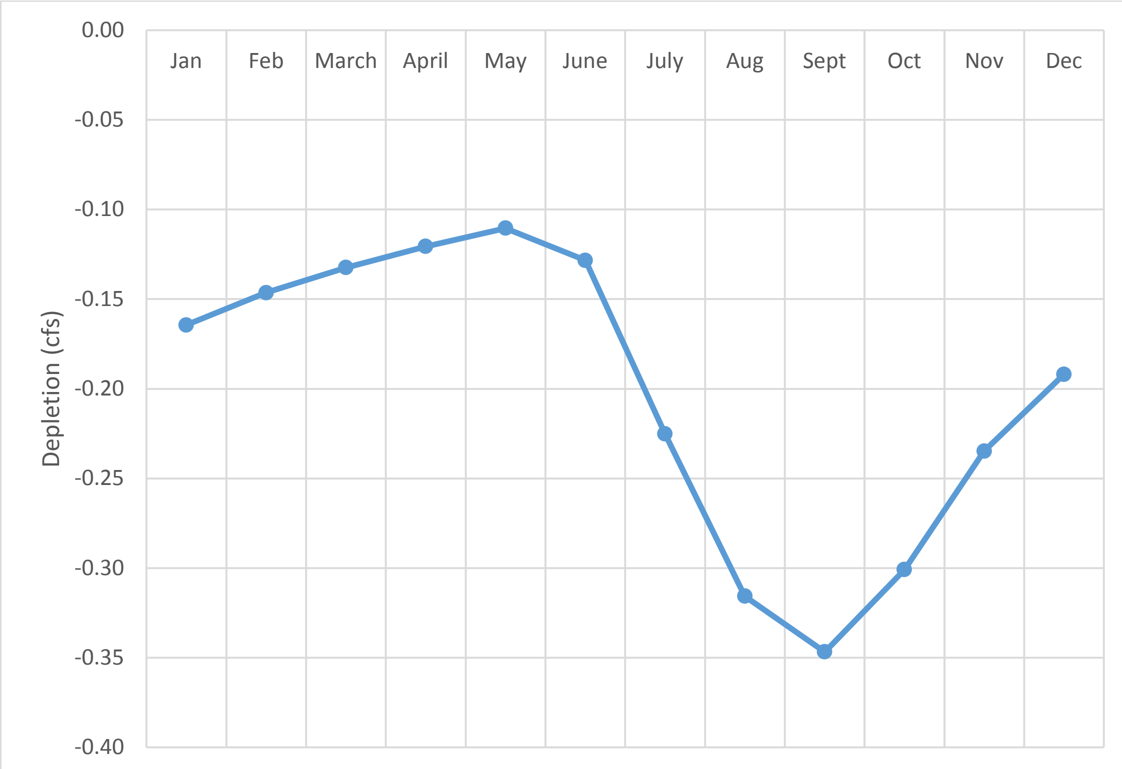
Option #2 modeling results:

- Reduced return flows lead to depletions to the Clark Fork River throughout the year (table 30 and figure 5).
- Depletions from changes in return flow timing are mitigated during June through September by leaving currently applied irrigation water (return flows + consumptive use) instream (table 30).
- Depletions from changes in return flow timing would cause an adverse effect to other water users in the Upper Clark Fork because changes in return flows must be mitigated from July through March (see *Legal availability of surface water* in section 3.1).

Table 30. Accretions/depletions to Clark Fork River from retiring 165.8 acres of pivot irrigated alfalfa and instream use of water savings.

Month	Depletions from change in return flows (AF)	Accretions from instream use of former return flows (AF)	Accretions from instream use of former consumptive use (AF)	Net accretions/ depletion to river
Jan	-10.11			-10.11
Feb	-8.13			-8.13
March	-8.14			-8.14
April	-7.18			-7.18
May	-6.79	0.08	-4.24	-10.95
June	-7.64	36.83	23.24	52.43
July	-13.85	49.12	33.08	68.35
Aug	-19.41	43.67	30.77	55.03
Sept	-20.63	16.51	22.92	18.80
Oct	-18.5			-18.50
Nov	-13.97			-13.97
Dec	-11.8			-11.80

Figure 5. Clark Fork River depletions caused by reduced return flows with change from flood to proposed center pivot irrigation of 124.4 acres alfalfa.



Option #3. Retire sufficient acreage from current center pivot (290 acres) to create a minimum of 0.5 cfs of protectable, formerly consumed instream flow for fisheries during August. Offset changes in return flows with aquifer recharge using a drainfield.

This option is the same as #2 with the exception that changes in return flows are offset with aquifer recharge during October through March when water is not legally available in the Clark Fork River (option #2 is only able to mitigate changes in return flows during May through September by leaving formerly diverted water instream). This option also conditions the change permit so that consumptive use will not increase when irrigating alfalfa in May.

Monthly water use and return flow for 124.2-acres of alfalfa is shown in table 31. Table 32 shows the changes in consumed volume, applied volume, and return flow.

With current practices, consumptive use of water by 124.2-acres of alfalfa is modeled with IWR to increase by 4.24 AF in May (table 29 above) due to the higher irrigation water demand in May for alfalfa using a center pivot. This increase in consumptive use would represent an expansion of the historic water right. To prevent expanding the water right the permit change is conditioned in this mitigation option to reduce center pivot irrigation consumptive use by an additional 4.24 AF during May (compare May consumptive use in table 31 vs table 28). This reduction in consumptive use can be achieved by reducing applied water in May to 3.44 AF (table 31). Reducing applied water in May further reduces return flow, requiring additional water to be infiltrated during May to mitigate changes in return flows.

Reducing applied water may also reduce alfalfa yields; however this is necessary to avoid an increase in consumptive use.

Table 31. Instream flow for fisheries change option #3 proposed center pivot irrigation applied volume, consumptive, and return flow.

Month	Alfalfa dry year net irrigation required (inches)	Pivot irrigation applied volume with on-farm efficiency of 70% (AF)	Pivot irrigation of alfalfa monthly crop consumptive use only: 124.2 acres (AF)	Pivot consumptive use: crop use + irrecoverable evaporation loss: 124.2 acres	Pivot irrigation return flow: 124.2 acres (AF)
January					
February					
March					
April	0	0.00	0.00	0.00	0.00
May	0.59	3.44	2.41	2.75	0.69
June	4.32	64.00	44.80	51.20	12.80
July	5.48	81.18	56.83	64.95	16.24
August	4.69	69.48	48.64	55.58	13.90
September	0.25	3.70	2.59	2.96	0.74
October	0	0.00	0.00	0.00	0.00
November					
December					
Annual total:	15.33	221.81	155.26	177.44	44.36

In order to mitigate the dramatic reduction in return flows (-147.28 AF annually, table 32), caused by the reduced acreage and center pivot irrigation system, former return flows can be recharged at the site using a drainfield. The AWAS model was used to evaluate mitigation recharge rates which will compensate for the reduction in streamflows owing to reduced return flows from irrigation. The mitigation plan is shown in table 33.

Assumptions:

- Same assumptions as option #2 above.
- Mitigation recharge is provided by a large drainfield located in the former irrigated area of the alfalfa field.
- Long-term infiltration rate of 0.5 inch/hr (7.5 gpd/ft^2) for loamy sand (WA DOE 2005). Drainfield of 1.6 acres in size, maximum average monthly flow rate of 359 gpm.
- The drainfield is constructed below the rooting zone of plants and will not cause a rise in water table which would cause increased evapotranspiration.

Table 32. Change in consumed water, applied water, and return flow with change from flood to 124.2 acres pivot.

Month	Change in consumed volume (AF)	Change in applied volume (AF)	Change in return flow (AF)
January			
February			
March			
April			
May	0.00	-1.14	-1.14
June	-23.24	-60.07	-36.83
July	-33.08	-82.20	-49.12
August	-30.77	-74.44	-43.67
September	-22.92	-39.43	-16.51
October			
November			
December			
Annual total:	-110.01	-257.29	-147.28

Option #3 modeling results:

- Infiltration of former return flows alone is inadequate to mitigate changes in return flows because the drainfield provides recharge in a different spatial extent than historic irrigation return flows. 3 AF of former consumptively used irrigation water must be also be infiltrated to fully mitigate changes in return flows (table 33).
- The drainfield location affects how well mitigation works. With the drainfield located at the upper end of the field, mitigation of reduced return flows during summer months is inadequate even when the entire former consumptive use for June is infiltrated during that month. Mitigation with the drainfield at the upper end of the field would require consumptive use from July and August to be infiltrated, reducing water available for instream flow for fisheries and the 0.5 cfs target for August would not be met.
- Locating the drainfield in the middle of the field (3950 ft from river) results in adequate mitigation of return flow changes, minimizes the amount of former consumptive use which needs to be infiltrated, and maximizes water available for instream flow for fisheries.
- The entire historic return flow under flood needs to be infiltrated in the mitigation plan, even though those return flows haven't existed since 1990's. This is necessary to address the fact that the water right change considers pre-1973 use of the water right.
- Accretions and depletion to the Clark Fork River are shown in table 34 (with drainfield located in the middle of the former field). The mitigation infiltration is sufficient to mitigate changes in return flows in all month except June. This depletion in June will also have to be mitigated with former consumptively used water left instream (table 33). The 0.09 AF of water used to mitigate June depletions from changes in return flows will be subtracted from that water which can be legally protected instream during June.

- The resulting savings in consumed and applied irrigation water which is available for instream flow for fisheries is shown in table 35. This option creates 0.54 cfs of protectable instream flow for fisheries during July, 0.5 cfs during August, and 0.39 cfs during September (table 35). Diverted flow is also reduced by over 1 cfs during June through August. Reductions in diverted flow are averaged for the month. Reduced diversions over that which was formerly consumed flow may benefit the river immediately below the point of diversion but could be legally diverted by a downstream irrigator.

Table 33. Deer Lodge instream flow for fisheries mitigation option #3 mitigation plan.

Month	Changed return flow mitigation plan: infiltrate entire former return flow (AF)	Additional mitigation: infiltration of 3 AF formerly consumed volume: (AF)	Additional mitigation: formerly consumed volume left instream: (AF)
January			
February			
March			
April			
May	1.14		
June	36.83	3.00	0.09
July	49.12		
August	43.67		
September	16.51		
October			
November			
December			
Annual total:	147.28	3.00	0.09

Table 34. Accretions/depletions to Clark Fork River from retiring 165.8 acres of pivot irrigated alfalfa and proposed mitigation plan.

Month	Depletions from change in return flows (AF)	Accretions from mitigation plan infiltration (AF)	Net accretions/ depletions to river (AF)	Accretions from instream use of retired consumptive use (AF)	Net change to river (AF)
Jan	-10.16	10.47	0.3		0.30
Feb	-8.17	8.4	0.23		0.23
March	-8.2	8.41	0.22		0.22
April	-7.22	7.41	0.19		0.19
May	-6.89	7.04	0.17	0.00	0.17
June	-7.83	7.75	-0.09	23.24	23.15
July	-14	14.06	0.05	33.08	33.13
Aug	-19.52	19.65	0.12	30.77	30.89
Sept	-20.7	21.09	0.38	22.92	23.30
Oct	-18.59	19.19	0.61		0.61
Nov	-14.05	14.55	0.51		0.51
Dec	-11.87	12.24	0.38		0.38

Table 35. Option #3 changes in consumed and applied water use available for instream flow for fisheries (averaged monthly).

Month	Consumed volume available for instream flow for fisheries (AF)	Consumed volume available for instream flow for fisheries (cfs)	Change in applied flow left instream (cfs)
January			
February			
March			
April			
May	0.00	0.00	0.02
June	20.15	0.34	1.01
July	33.08	0.54	1.34
August	30.77	0.50	1.21
September	22.92	0.39	0.66
October			
November			
December			
Annual total:	106.92		